# Upper Des Plaines River Feasibility Study

## Appendix C – NER Plan Formulation

**August 2013**

**Study Partnership**

Illinois Department of Natural Resources (IDNR)
Southeastern Wisconsin Regional Planning Commission (SEWRPC)
Lake County Stormwater Management Commission (LCSMC)
Preserve District Lake County (FPDLC)
Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)
Cook County Highway Department (CCHD)
Forest Preserve District of Cook County (FPDCC)
U.S. Fish and Wildlife Service (USFWS)
U.S. Army Corps of Engineers (USACE

US Army Corps
of Engineers
Chicago District

# APPENDIX C
# Upper Des Plaines River Feasibility Study
# Ecosystem Restoration Plan Formulation

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# SECTION 1 – INVENTORY AND FORECASTING

## Threatened & Endangered Species List

Table 1 – T&E plant species occurring within or adjacent to (1 mile) the study area.

| Common Name | Scientific Name | IL | WI | Habitat | County Occurance |
|---|---|---|---|---|---|
| American cranberry | *Vaccinium macrocarpon* | SE * | | Bogs | Lake, Cook, Racine |
| American dog violet | *Viola conspersa* | ST * | | Mesic forests, flatwoods | Lake, Cook, Kenosha, Racine |
| American larch | *Larix laricina* | ST | | Bogs, forested fens | Lake, Kenosha, Racine |
| American slough grass | *Beckmannia syzigachne* | SE | | Wet prairies | Lake, Cook |
| beaked rush | *Rhynchospora alba* | ST | | Bogs, fens | Lake, Cook, Kenosha, Racine |
| beaked sedge | *Carex rostrata* | ST * | | Sedge meadows, bogs | Lake |
| Black-seeded rice grass | *Oryzopsis racemosa* | ST * | | Mesic forests | Lake, Cook |
| Bog bedstraw | *Galium labradoricum* | ST * | | Bogs, fens, sedge meadows | Lake, Kenosha |
| Bulrush | *Scirpus hattorianus* | SE * | | Open wetlands | Lake |
| Common bog arrow grass | *Triglochin maritimum* | SE * | | Fens, pannes, cal. seeps | Lake, Cook, Kenosha, Racine |
| Cord root sedge | *Carex chordorrhiza* | SE | | Bogs | Lake |
| Crawe's sedge | *Carex crawei* | ST | | Fens, sand prairies, swales | Lake, Cook, Kenosha, Racine |
| Crawford's oval sedge | *Carex crawfordii* | SE | | Marsh | Lake |
| Downy Solomon's seal | *Polygonatum pubescens* | ST * | | Mesic forests | Lake, Cook, Kenosha, Racine |
| Downy willow herb | *Epilobium strictum* | ST * | | Mesic forest, Flatwoods, bogs, fens | Lake, Kenosha |
| Dwarf rasberry | *Rubus pubescens* | ST * | | Mesic forests, flatwoods, bogs, fens | Lake, Cook, Kenosha, Racine |
| Ear-leaved foxglove | *Tomanthera auriculata* | ST | | Mesic prairies, savannas | Lake, Cook, Racine |
| Fern pondweed | *Potamogeton robbinsii* | SE * | | Lakes, ponds, streams | Lake, Cook, Kenosha |
| Golden sedge | *Carex aurea* | SE | | Prairies | Lake, Cook, Racine |
| Grass-leaved pondweed | *Potamogeton gramineus* | SE * | | Lakes, ponds, streams | Lake, Cook, Kenosha |
| Hairy white violet | *Viola incognia* | SE * | | Flatwoods, forested fens, mesic forests | Lake, Cook |
| Little green sedge | *Carex viridula* | SE * | | Springs, marl flats, cal. floating mats | Lake, Cook, Kenosha, Racine |
| Marsh speedwell | *Veronica scutellata* | ST * | | marshes, graminoid fens | Lake, Cook, Racine |
| Millet grass | *Milium effusum* | ST * | | Openings in northern forests | Cook, Racine |
| Mountain blue-eyed grass | *Sisyrinchium montanum* | SE * | | Mesic prairies | Lake, Cook |
| Northern cranesbill | *Geranium bicknellii* | SE * | | Dry forest openings, disturbed areas | Lake, Racine |
| Northern grape fern | *Botrychium multifidum* | SE | | mesic forests, sand savannas, successional habitats | Lake, Cook, Kenosha |
| Pale vetchling | *Lathyrus ochroleucus* | ST * | | Savannas, ravines | Lake, Cook, Racine |
| Prairie Indian plantain | *Cacalia tuberosa* | | ST * | Wet prairies, wet sand prairies | Lake, Cook, Kenosha, Racine |
| Prairie white-fringed orchid | *Platanthera leucophaea* | SE,FT * | SE,FT * | Meisc / wet prairie | Lake, Cook, Kenosha, Racine |
| Pretty sedge | *Carex woodii* | SE * | | Mesic calcerous forests | Lake, Cook, Kenosha, Racine |
| Purple milkweed | *Asclepias purpurascens* | | SE * | Prairies, edge of woodland | Lake, Cook, Kenosha, Racine |
| Purple fringed orchid | *Platanthera psycodes* | SE * | | Flatwood openings, mesic sand prairies | Lake, Racine |
| Queen-of-the-prairie | *Filipendula rubra* | ST * | | Prairies, fens | Cook |
| Round-leaved sundew | *Drosera rotundifolia* | SE | | Bogs | Lake, Cook, Kenosha, Racine |
| Seaside crowfoot | *Ranunculus cymbalaria* | SE | | Saline/brackish shores | Lake, Cook, Kenosha, Racine |
| Slender bog arrow grass | *Triglochin palustris* | SE * | | Fens, pannes, cal. seeps | Lake, Cook, Kenosha, Racine |
| Small sundrops | *Oenothera perennis* | SE * | | Gravel prairie, mesic prairie, old field | Lake, Cook, Kenosha, Racine |
| Sullivant's milkweed | *Asclepias sullivantii* | | ST * | Mesic prairies | Cook, Kenosha, Racine |
| Swollen sedge | *Carex intumescens* | SE | | Forested wetlands | Cook, Racine |
| Tuckerman's sedge | *Carex tuckermanii* | SE * | | Flatwoods, wet-mesic forests | Lake, Racine |
| White lady's-slipper orchid | *Cypripedium candidum* | SE * | | Wet-mesic prairies, fens | Lake, Cook, Kenosha, Racine |
| White-stemmed pondweed | *Potamogeton praelongus* | SE | | Cold water lakes | Lake, Cook, Kenosha, Racine |
| Wild quinine | *Parthenium integrifolium* | | ST * | Prairies | Lake, Cook, Kenosha, Racine |

* Indicates within study area. SE = State Endangered, ST = State Threatened, FD = Federally Endangered, FT = Federally Threatened.

Table 2 – T&E animal species occurring within or adjacent to (1 mile) the study area.

| Common Name | Scientific Name | IL | WI | Habitat | County Occurance |
|---|---|---|---|---|---|
| **Birds** | | | | | |
| Pied-billed grebe | *Podilymbus podiceps* | ST * | | Lakes, ponds, riverine, wetland | Lake and Cook |
| Double-crested cormorant | *Phalarocorax auritus* | ST * | | Lakes, ponds, riverine, wetland | Cook |
| American bittern | *Botaurus lentiginosus* | SE * | | Wetland | Lake and Cook |
| Least bittern | *Ixbrychus exilis* | SE * | | Wetland | Lake and Cook |
| Great egret | *Ardea albus* | ST * | ST * | Wetland | Cook, Kenosha and Racine |
| Snowy egret | *Egretta thula* | SE * | | Wetland | Cook |
| Little blue heron | *Egretta caerulea* | SE * | | Lakes, ponds, riverine, wetland | Cook |
| Black-crowned night-heron | *Nycticorax nycticorax* | SE * | | Forested swamp and wetland | Lake and Cook |
| Yellow-crowned night-heron | *Nycticorax violaceus* | ST * | | Forested swamp | Cook |
| Osprey | *Pandion haliaetus* | SE * | ST | Lakes, ponds, riverine | Cook |
| Bald eagle | *Haliaeetus leucocephalus* | SE *, FT | ST *, FT | Lakes, ponds, riverine | Cook, Kenosha and Racine |
| Northern harrier | *Circus cyaneus* | SE * | | Wetland, grassland, crops | Cook |
| Sharp-shinned hawk | *Accipiter striatus* | SE * | | Upland/mesic forest, shrubland, residential areas, forested swamp savannah | Cook |
| Red-shouldered hawk | *Buteo lineatus* | SE * | | Forested swamp | Lake and Cook |
| Swainson's hawk | *Buteo swainsoni* | SE | | Upland/mesic forest, grassland, savannah | Kane |
| Peregrine falcon | *Falco peregrinus* | SE *, FE | | All | Lake and Cook |
| Yellow rail | *Coturnicops noveboracensis* | SE * | | Grassland, wetland | Cook |
| King rail | *Rallus elegans* | ST * | | Grassland, wetland | Lake and Cook |
| Commen moorhen | *Gallinula chloropus* | ST * | | Wetland | Lake and Cook |
| Sandhill crane | *Grus canadensis* | SE * | | Wetland, grassland, crops | Lake |
| Upland sandpiper | *Bartramia longicauda* | SE * | | Grassland | Lake and Cook |
| Wilson' s phalarope | *Phalaropus tricolor* | SE * | | Lakes, ponds, riverine, wetland | Lake and Cook |
| Common tern | *Sterna hirundo* | SE * | SE * | Lakes, ponds, riverine, wetland | Lake |
| Forster's tern | *Sterna forsteri* | SE * | SE * | Lakes, ponds, riverine, wetland | Lake and Cook |
| Black tern | *Chilidonias niger* | SE * | | Lakes, ponds, riverine, wetland | Lake and Cook |
| Barn owl | *Tyto alba* | SE * | | Crops, grassland, residential areas, savannah | Cook |
| Long-eared owl | *Asio otus* | SE * | | Upland/mesic forest, shrubland | Lake and Cook |
| Short-eared owl | *Asio flammeus* | SE * | | Grassland | Lake and Cook |
| Brown creeper | *Certhia americana* | ST * | | Forested swamp, upland/mesic forest, residential areas | Lake |
| Bewick's wren | *Thryomanes bewickii* | SE * | | Residential areas, shrubland | Cook |
| Veery | *Catharus fuscescens* | ST * | | Forested swamp, upland/mesic forest, residential areas, savannah | Lake and Cook |
| Loggerhead shrike | *Lanius ludovicianus* | ST * | SE * | Grassland, shrubland, crops | Lake, Cook, Kenosha, Racine |
| Henslow's sparrow | *Ammodramus henslowii* | SE * | | Grassland | Lake and Cook |
| Yellow-headed blackbird | *Xanthocephalus xanthocephalus* | SE * | | Wetland | Lake and Cook |
| Piping plover | *Charadrius melodus* | | SE | Rivers, wetland | |
| Acadian flycatcher | *Empidonax virescens* | | ST * | Forest | Kenosha |
| Cerulean warbler | *Dendroica cerulea* | | ST * | Forest | Kenosha |

* Indicates within study area. SE = State Endangered, ST = State Threatened, FD = Federally Endangered, FT = Federally Threatened.

Table 2 – T&E animal species occurring within or adjacent to (1 mile) the study area (Continued).

| | | | | | |
|---|---|---|---|---|---|
| **Reptiles** | | | | | |
| Kirtland's water snake | *Clonophis kirtlandii* | ST * | | Forest, wetland, prairie and savannah, lakes, ponds, impoundmants | Lake and Cook |
| Eastern Massasauga | *Sistrurus catenatus* | SE * | SE * | Forest, wetland, prairie and savannah | Lake and Cook, Kenosha |
| Blanding's turtle | *Emydonidea blandingi* | | ST * | Wetland | Kenosha and Racine |
| **Amphibians** | | | | | |
| Blanchard's cricket frog | *Acrid crepitans blanchardi* | | SE | Ponds and streams | Grant, Lafayette |
| **Insects** | | | | | |
| Swamp metalmark | *Calephelis mutica* | SE * | | Wetland | Lake and Cook |
| Hoary elfin | *Incisalia polia* | SE * | | Forest and savannah | Lake |
| Melissa blue | *Lycaeides melissa* | | FE | Prairie, savannah, cultural | Lake and Cook |
| Ottoe skipper | *Hesperia ottoe* | ST * | | Prairie | Lake and Cook |
| Hine's Emerald dragonfly | *Somatochlora hineana* | SE | | Wetland | Lake and Cook |
| **Fish** | | | | | |
| ironcolor shiner | *Notropis chalybaeus* | ST * | | Creeks and small rivers | Cook |
| blackchin shiner | *Notropis heterodon* | ST * | | Standing water | Lake and Cook |
| blacknose shiner | *Notropis heterolepis* | SE * | | Creeks and small rivers | Lake and Cook |
| Iowa darter | *Etheostoma exile* | SE * | | Headwaters and creeks | Lake and Cook |
| redfin shiner | *Lythrurus umbratilis* | | ST * | Streams | Kenosha and Racine |
| **Mussels** | | | | | |
| Slippershell mussel | *Alasmidonta viridis* | SE * | | Headwaters, creesk and small rivers | Cook |
| Elephant ear | *Elliptio crassidens* | ST * | | Medium rivers | Cook |
| Spike | *Elliptio dilatata* | ST | | Small and medium rivers | Kane |
| Rainbow | *Villosa iris* | SE * | | Small and medium rivers | Cook |

# SECTION 2 – PLAN FORMULATION AND EVALUATION

## 2.1 – Planning Level Cost Details

The following cost estimate assumptions were developed by the Chicago District cost estimating section (TS-DC), with aid from the Planning Section (PM-PL-E). Spreadsheets provided to the ATR team for review include:

- Cost 01 Unit Bid Prices.xls
- Cost 02 Cost Estimate Work Sheet.xls
- Cost 03 Annualization.xls

**General:** Based quantities for a 60 acre site to distribute overhead costs accordingly. Assumed typical project duration will be 12 months. 10% profit is included for the prime contractor. There is only one sub-contractor used in the estimate for drain tile removal. Depending on the contracting mechanism for these jobs, it may be reasonable to adjust to account for an earthwork contractor as a sub or a prime with a landscape contractor as the stub. There is a running 25% contingency. Escalation has been accounted for to year 2019. Fuel rates are currently shown as $4.00 for unleaded gasoline, and $4.25 for diesel fuel (on-road) and $4.00 for diesel fuel (off-road).

**Labor Rates:** Labor rates were derived from the following: Service Contract Wage Determination 03-0288 (Rev. -9) dated 02 June 2009 – for Forestry and Land Management Services. Because some of the work is demolition, and earthwork, it is reasonable to use wage rates for construction, as these are in keeping with current market conditions. Therefore, the Davis-Bacon Wage Rates were used for heavy landscaping. General Decision Number IL080020 dated 24 July 2009.

**Selective Tree Clearing / Site Clearing**: Includes clearing of trees and brush, chipping and hauling costs. Our estimate for clearing an acre is currently $5462.51 with the contractor's overhead costs; however, we have roughly 24% escalation mark-up for the year 2019, and a running contingency which bring the cost to $11,013.85 per acre. The hauling includes loading and dumping and is currently $9.01 per cubic yard of material. With the escalation and contingency, this rises to $18.16 per cubic yard. All of this is included in the unit price per acre of clearing.

**Tree Clearing**: Assumed dense area where 6" trees are spaced at 1 per 100 sf. Approx. 10' o.c. Assumed a crew can clear one acre in 24 hours. Density of trees used is comparable to our current construction contract for Orland Tract. This density is used solely for the purpose of developing a unit bid price per acre for tree clearing. Crew production is modified to allow time for marking trees for removal. Added hauling costs for disposal of chips as this is a conservative cost.

**Brush Clearing**: Assumed dense brush and adjusted productivity to approximately 1 acre can be cleared in 8 hours. Added hauling and disposal costs to this item to be conservative.

**Understory Clearing:** Assumed each acre produces approx 400 cy of debris. This is based on 100 trees per acre. Adjusted production rate to an effort of 4 hours to clear 1 ac.

**Drain Tile Disablement**: Assumed drain tile removal contractor will demolish pipe and leave debris in place. No disposal costs are included with this item. Survey hours for located and marking drain tiles have been included for this effort. Updated production rate which includes a crew of 4 laborers and assumes it will take them approximately 2 hours to survey one acre. No additional costs were included for plans or electronic files for this effort. The crew's hourly labor rate is $191.72 without markups. Anticipated quantity is 7500' per acre.

**Ditch Filling**: Assumed a cross sectional area of 64 sf. Based on a trapezoidal ditch with 4' flat bottom, 3:1 side slopes and a 4' depth. A 5 mile haul of costs to truck in borrow for this effort is included. Additional contingencies may need to be added if we do not locate the anticipated borrow site. May need to adjust soil from borrow to more specific requirements of soil.

**Ditch Plugging**: Made same assumptions as ditch filling. Updated quantities as needed to increase the ditch plug to fill the channel for a length of 12' as suggested.

**Remove Soil Compaction (Top 2-feet)**: Assumed a small decompaction roller will be used – trailed behind a low pressure tractor – similar to a compaction roller. Assumed the roller will be no larger than 3' wide. If areas require larger equipment – costs will need to be adjusted accordingly.

**Grading to Increase Floodplain**: Assumed grading would be an average of 4' depth. In some places, grading might be less than 4' or more. 4' is used only as a means to identify the quantity of material being moved on site. We have updated the grading items, clearing items to include off-site disposal costs.

**Dam Removal**: Developed a crew for concrete demolition for small dam removal. Developed production rate to 1 hour per cubic yard of removal. Assumed a 20 mile haul distance for the debris removal. No dumping fees/ unique waste fees are included. Stabilization of the area after dam removal can include a number of items from seeding, erosion control mats, grading, etc. There are separate unit bid items for these efforts.

**Stream Remeandering**: Developed a crew for earthwork grading to be used for this effort. Assumed the crew could effectively grade approximately 2 linear feet of stream per hour. Did not include any costs associated with dewatering or coffer dams, temporary water diversion structures. Assumed no off site disposal of materials that are excavated. Costs are based on regrading excavated material on site (fill in the old channel).

**Cobble Riffles**: Used information from current contract for Eugene Fields Estimate. Estimated depth of key excavation to be approx 4'. Assumed that backfill of trench with aggregate was 1' and coarse aggregate and stone mix to make up the remaining 3'. Assumed a haul distance of 20 miles.

**Woody Debris**: Includes cost of removing approx 3 trees to accumulate 1 cy of debris. Assumed contractor could place 5 cy of debris per hour. This task is placing woody debris instream for habitat, not removing woody debris from the stream.

**Temporary Erosion Control**: We have included a linear foot estimate of silt fence for temporary erosion control; this is typically placed in the contractor's overheads as it will be an item most likely included in the contractor's mobilization costs. We have added a per unit price for erosion control matting. Riprap is not an acceptable material for stream restoration; however, field stone or riverine cobbles would be used in sites where the stream cannot be allowed to move around in its floodplain.

**Plantings**: Developed a planting crew in which everything in the estimated planting list is planted by hand. Used a production rate of ¼ acre per hour. The application areas will be defined by a restoration specialist. The seed list is native species and will be detailed by a restoration specialist.

**Prescribed Burns**: Because the production rate of this effort is largely site specific, assumptions were made to err on the conservative side. Sites could be small and confined which would reduce productivity and require more effort and time. Current crew for prescribed burns consists of the following: 3 laborers and 1 light equipment operator, torch and water supply. Costs for trucking water in have not been added. Rate includes a burn crew of 4 people. Production rate has been updated to coincide with the $400/ac guidance. This results in a production rate of 0.6 ac per hour and an hourly rate of approximately $252/hr with contractor's markups only.

**Invasive Species Removal – Physical**: Physical removal of invasive species includes mowing only. Production rate is 0.5 ac/hour.

**Invasive Species Removal – Herbicide**: Current crew consists of 1 outside laborer and sprayer. Assumed one crew can cover 1 acre in 4 hours.

**Erosion Control Matting**: Included unit bid price for placing and removal of temporary erosion control matting. Separating this item from the rest of the estimate makes it easy to apply to the task where it will be needed.

**Silt Fence**: Included unit bid price for placing and removal of temporary silt fence. Separating this item from the rest of the estimate makes it easy to apply to the task where it will be needed.

## 2.2 – Riverine Analysis & Benefits

The following riverine Habitat Unit analysis was developed by the Chicago District Planning Section (PM-PL-E) and the E-Team. The Net Average Annual Habitat Unit spreadsheet is provided to the ATR team for review:

- Riverine AAHUs.xls

The future without project condition was determined to be the current condition present. Data from a 30 year period show that stream conditions have not changed much in terms of biological integrity and habitat quality. If no restoration activities were to occur, these streams would be roughly in the same condition in 50-years based on reasonable foresight. It is known that the Hofmann, Fairbanks, Armitage, Dan Wright, Ryerson and Rasmussen Lake dams will be removed in the future without project conditions. These actions will improve certain reaches of river, but the five remaining dams still fragment the lower system from the upper system. These actions were considered in the future without and with conditions for those sites that would benefit. It was assumed there would be improvement in riverine habitat and an increase is species richness since free flowing hydraulics and fish passage would then be possible. These dams are scheduled to be removed by 2013. There have been no significant riverine restoration projects in the past nor are any reasonably foreseen within the 50-year period of analysis with the exception of the dam removal mentioned above.

**R5** – R1 plus remeander stream and/or in-stream habitat (increase HSI benefits to 75% of total potential). Riverine benefits assume that the riparian zone will never be 100% restored. No dam removal would preclude certain fish from recolonizing, thusly reducing the potential for maximum increase in IBI.

**R6** – R2 plus remeander stream and/or in-stream habitat (increase HSI benefits to 80% of total potential). Riverine benefits assume that the riparian zone will never be 100% restored, but slightly improved over Alt 5. No dam removal would preclude certain fish from recolonizing, thusly reducing the potential for maximum increase in IBI.

**R7** – R3 plus remeander stream and/or in-stream habitat (increase HSI benefits to 85% of total potential). Riverine benefits assume that the riparian zone will never be 100% restored, but slightly improved over R6. No dam removal would preclude certain fish from recolonizing, thusly reducing the potential for maximum increase in IBI.

**R8** – R4 plus remeander stream and/or in-stream habitat (increase HSI benefits to 80% of total potential). Riverine benefits assume that the riparian zone will be 85% restored, thusly maximizing benefits under this category. No dam removal would preclude certain fish from recolonizing, thusly reducing the potential for maximum increase in IBI.

**R9** – R7 plus dam removal (increase HSI benefits to 95% of total potential). Riverine benefits assume that the riparian zone will be restored to 100% of its potential. Dam removal would increase the IBI portion of the HSI by through allowing for certain species of fish to recolonize from the lower portions of the Des Plaines River.

## Excel Table Headers

**Site # -** The code for the site where riverine restoration is possible or needed.

**Type** – There are two types of riverine restoration being prescribed. RIF is solely the installation of riffles and woody debris for Instream habitat where degraded streams are already freely meandering. RM is remeandering a channelized stream and includes riffles and woody debris as well.

**FWO Length** – This is the length of the stream in the future without project condition.

**FWO Q Units** – This conversion from feet to units that are comparable to acres. The rational was that 100 feet of stream is worth 1 acre of habitat. The equation is FWO stream length / 100 feet = FWO Q Units.

**CC/FWO HSI** – The future without project conditions were assumed to be the same as the current conditions since this watershed has been impaired for so long. This calculation is based on the IBI and QHEI normalized scores. The equation is (IBI/60 + QHIE/100)/2 = CC/FWO HSI score.

**FWO AAHUs** – The future without project average annual habitat units is CC/FWO HIS x FWO Q Units.

**FW Length** – This is the length of the stream if it were to be remeandered under one of the alternatives. A typical stream meandering project would lengthen the stream channel by 25%. The equation is (FWO Length x .25) + FWO Length.

**FW Q Units** – This conversion from feet to units that are comparable to acres. The rational was that 100 feet of stream is worth 1 acre of habitat. The equation is FW stream length / 100 feet = FW Q Units.

**AA HSI** – This is the average annual HIS score over a 50-year period of analysis. It was estimated that it would take remeandering projects 15-years to achieve maximum benefits and riffle projects 30-years.

**AAHUs** – This is the Average Annual HSI (Quality) x the FW Q Units (Quantity).

**Net AAHUs** – This the Average Annual Habitat Units – Future Without Habitat Units.

## 2.3 – Cost Effectiveness & Incremental Cost Analysis

Table 3 – Total Alternative Planning Level Construction Costs Summary.

| Sites | Alt1 | Alt2 | Alt3 | Alt4 | Alt5 | Alt6 | Alt7 | Alt8 | Alt9 |
|---|---|---|---|---|---|---|---|---|---|
| K01 | $458,074 | $3,100,858 | $3,626,884 | $3,626,884 | $458,074 | $3,100,858 | $3,009,230 | $3,100,858 | $3,100,858 |
| K02 | $1,229,384 | $10,947,078 | $13,103,329 | $13,103,329 | $1,741,913 | $11,459,607 | $11,033,132 | $11,459,607 | $11,484,281 |
| K03 | $575,440 | $5,502,835 | $6,469,153 | $6,469,153 | $575,440 | $5,502,835 | $5,207,159 | $5,502,835 | $5,502,835 |
| K04 | $407,706 | $2,639,061 | $3,136,772 | $3,136,772 | $407,706 | $2,634,889 | $2,575,640 | $2,639,062 | $2,639,062 |
| K05 | $1,631,454 | $17,140,226 | $20,633,149 | $20,633,149 | $1,631,454 | $17,133,042 | $16,618,319 | $17,140,229 | $17,140,229 |
| K06 | $1,820,278 | $15,745,125 | $19,019,483 | $19,158,632 | $2,753,614 | $16,678,461 | $16,235,379 | $16,817,610 | $16,842,284 |
| K07 | $603,545 | $5,505,245 | $6,976,150 | $7,104,293 | $1,267,933 | $6,169,633 | $6,229,713 | $6,300,051 | $6,324,725 |
| K08 | $36,375 | $2,721,141 | $3,626,732 | $3,646,214 | $99,917 | $2,784,683 | $3,003,727 | $2,809,957 | $2,834,631 |
| K09 | $1,125,841 | $9,356,052 | $11,785,592 | $11,809,306 | $1,743,225 | $9,973,436 | $10,002,690 | $9,997,150 | $10,021,824 |
| K10 | $1,273,505 | $9,802,209 | $12,074,438 | $12,141,053 | $5,072,672 | $13,601,376 | $13,381,321 | $13,669,335 | $13,694,009 |
| K11 | $310,877 | $5,322,991 | $6,491,073 | $6,476,028 | $526,266 | $5,538,380 | $5,524,330 | $5,523,335 | $5,548,009 |
| K12 | $2,180,156 | $25,090,343 | $30,901,752 | $30,901,752 | $2,180,156 | $28,177,428 | $24,929,085 | $25,090,344 | $25,090,344 |
| K13 | $37,746 | $717,874 | $902,980 | $902,980 | $37,746 | $793,832 | $736,332 | $717,876 | $717,876 |
| K14 | $1,012,699 | $4,042,917 | $4,873,290 | $4,873,290 | $1,600,228 | $4,984,582 | $4,667,065 | $4,630,446 | $4,655,120 |
| K15 | $576,337 | $6,410,051 | $7,975,986 | $7,968,867 | $819,607 | $7,674,831 | $6,656,993 | $6,653,321 | $6,677,995 |
| K16 | $36,801 | $1,571,053 | $1,948,489 | $1,948,489 | $36,801 | $1,863,043 | $1,539,845 | $1,571,053 | $1,571,053 |
| K17 | $142,516 | $2,338,181 | $2,951,417 | $2,951,139 | $142,516 | $2,749,782 | $2,369,511 | $2,338,182 | $2,338,182 |
| K18 | $4,620,983 | $24,079,079 | $31,445,279 | $31,573,435 | $921,161 | $24,879,087 | $22,201,040 | $20,559,308 | $20,583,982 |
| K19 | $794,157 | $7,637,864 | $9,466,929 | $9,466,929 | $794,157 | $8,376,029 | $7,689,277 | $7,637,865 | $7,637,865 |
| K20 | $8,418 | $1,342,944 | $2,017,602 | $2,010,076 | $241,474 | $1,821,806 | $1,808,054 | $1,576,000 | $1,600,674 |
| K21 | $616,550 | $2,471,613 | $3,275,798 | $3,273,892 | $763,163 | $2,965,891 | $2,809,074 | $2,618,226 | $2,642,900 |
| K22 | $713,214 | $7,464,870 | $9,570,980 | $9,563,911 | $1,200,344 | $9,020,630 | $8,246,420 | $7,952,001 | $7,976,674 |
| K23 | $1,313,440 | $24,838,991 | $32,797,299 | $33,076,007 | $3,903,147 | $31,333,111 | $28,545,935 | $27,727,747 | $27,752,421 |
| K24 | $271,636 | $1,826,518 | $2,306,398 | $2,302,314 | $271,636 | $2,456,631 | $1,934,631 | $1,826,518 | $1,826,518 |
| K25 | $270,757 | $8,875,226 | $11,327,027 | $11,327,027 | $270,757 | $10,061,135 | $8,990,304 | $8,875,230 | $8,875,230 |
| K26 | $286,568 | $3,475,401 | $4,234,966 | $4,234,966 | $286,568 | $3,840,223 | $3,421,412 | $3,475,401 | $3,475,401 |
| K27 | $1,240,864 | $15,487,708 | $19,626,621 | $19,619,130 | $1,532,181 | $17,876,078 | $15,925,981 | $15,771,539 | $15,796,213 |
| K28 | $236,753 | $2,844,400 | $3,502,192 | $3,502,192 | $236,753 | $3,230,052 | $2,841,087 | $2,844,400 | $2,844,400 |
| K29 | $910,484 | $6,748,523 | $8,138,834 | $8,161,352 | $1,008,562 | $7,657,945 | $6,622,211 | $6,869,119 | $6,893,793 |
| K30 | $956,816 | $14,436,958 | $18,473,496 | $18,612,364 | $1,537,177 | $17,111,054 | $15,225,786 | $15,160,716 | $15,185,390 |
| K31 | $1,426,851 | $10,612,129 | $12,779,175 | $12,779,175 | $1,426,851 | $11,872,202 | $10,344,190 | $10,612,129 | $10,612,129 |
| K32 | $919,525 | $4,602,931 | $5,468,284 | $5,468,284 | $1,233,127 | $5,352,067 | $4,665,106 | $4,916,533 | $4,941,207 |
| K33 | $5,522,264 | $33,336,297 | $42,850,124 | $43,097,451 | $6,601,100 | $35,670,230 | $35,626,611 | $35,938,267 | $35,962,941 |
| K34 | $1,901,899 | $10,758,656 | $13,784,593 | $13,738,920 | $2,343,126 | $12,408,629 | $11,556,229 | $11,176,587 | $11,201,261 |
| K35 | $50,446 | $6,826,355 | $9,001,762 | $9,001,762 | $50,446 | $7,581,167 | $7,031,477 | $6,826,355 | $6,826,355 |
| K36 | $3,138,236 | $25,974,008 | $31,528,869 | $31,437,254 | $3,248,809 | $29,362,962 | $25,460,061 | $25,992,965 | $26,017,639 |
| K37 | $742,708 | $5,651,619 | $6,825,247 | $6,825,247 | $742,708 | $6,365,097 | $6,825,247 | $5,651,619 | $5,651,619 |
| K38 | $292,751 | $5,517,459 | $7,097,790 | $7,097,790 | $292,751 | $6,155,065 | $6,142,929 | $5,517,467 | $5,517,467 |
| K40 | $749,205 | $8,270,160 | $9,962,513 | $9,962,513 | $749,205 | $9,549,218 | $8,717,248 | $8,270,166 | $8,270,166 |
| K41 | $1,765,735 | $10,458,362 | $13,861,814 | $13,945,357 | $2,120,374 | $11,973,341 | $19,812,393 | $10,917,021 | $10,941,695 |
| K42 | $1,040,332 | $11,102,055 | $13,955,310 | $13,955,310 | $1,040,332 | $13,115,672 | $21,698,859 | $11,102,055 | $11,102,055 |
| K43 | $648,096 | $5,925,996 | $7,239,267 | $7,239,267 | $648,096 | $6,562,173 | $6,374,129 | $5,925,996 | $5,925,996 |
| K44 | $4,079,539 | $35,576,266 | $44,999,067 | $44,969,643 | $4,459,908 | $40,297,791 | $60,635,189 | $35,929,331 | $35,954,005 |
| K45 | $2,503,704 | $17,723,109 | $23,664,258 | $23,721,407 | $3,174,293 | $20,904,322 | $28,973,012 | $18,501,163 | $18,525,837 |

Table 3 – Total Alternative Planning Level Construction Costs Summary (Continued).

| Sites | Alt1 | Alt2 | Alt3 | Alt4 | Alt5 | Alt6 | Alt7 | Alt8 | Alt9 |
|---|---|---|---|---|---|---|---|---|---|
| K46 | $685,291 | $12,569,179 | $15,886,409 | $15,886,409 | $685,291 | $14,259,654 | $13,831,239 | $12,569,179 | $12,569,179 |
| K47 | $1,925,261 | $24,766,364 | $31,654,985 | $31,748,421 | $2,389,804 | $29,601,100 | $28,122,440 | $25,336,841 | $25,361,515 |
| K48 | $1,353,018 | $12,114,545 | $14,631,651 | $14,631,426 | $1,353,018 | $13,391,760 | $12,750,372 | $12,114,545 | $12,114,545 |
| K49 | $907,842 | $7,834,820 | $9,446,223 | $9,446,223 | $881,167 | $8,536,321 | $8,192,924 | $7,808,145 | $7,808,145 |
| K50 | $1,218,004 | $12,539,024 | $15,106,749 | $15,113,983 | $1,792,828 | $14,820,232 | $13,750,865 | $13,121,082 | $13,145,756 |
| K51 | $203,364 | $3,226,274 | $3,938,967 | $3,938,967 | $203,364 | $3,860,833 | $3,469,783 | $3,226,274 | $3,226,274 |
| K52 | $267,075 | $3,953,740 | $4,880,192 | $4,880,192 | $267,075 | $4,376,088 | $4,266,250 | $3,953,741 | $3,953,741 |
| K53 | $1,382,655 | $8,797,479 | $10,640,042 | $10,678,273 | $1,666,042 | $10,267,099 | $22,422,031 | $9,119,099 | $9,143,773 |
| K54 | $1,976,359 | $19,161,945 | $24,127,589 | $24,153,960 | $1,976,359 | $21,866,530 | $31,519,355 | $19,193,099 | $19,193,099 |
| K55 | $413,313 | $4,012,013 | $5,058,140 | $5,058,140 | $413,313 | $4,411,085 | $4,418,892 | $4,012,013 | $4,012,013 |
| K56 | $1,244,787 | $8,233,574 | $10,261,814 | $10,313,445 | $1,749,288 | $9,630,264 | $19,342,707 | $8,789,707 | $8,814,381 |
| K57 | $2,753,321 | $20,322,407 | $24,556,346 | $24,556,346 | $2,753,321 | $22,408,543 | $35,966,780 | $20,322,409 | $20,322,409 |
| K58 | $1,184,393 | $11,552,505 | $13,981,440 | $13,981,440 | $1,184,393 | $12,879,993 | $12,264,769 | $11,552,505 | $11,552,505 |
| K59 | $4,333,980 | $34,615,160 | $43,937,092 | $43,936,721 | $4,333,980 | $38,293,014 | $73,116,129 | $34,617,263 | $34,617,263 |
| K60 | $1,159,508 | $13,179,379 | $15,832,900 | $15,627,543 | $1,159,508 | $15,041,228 | $18,913,117 | $12,974,023 | $12,974,023 |
| K61 | $5,486,853 | $26,277,943 | $33,020,804 | $33,141,976 | $5,928,848 | $29,500,182 | $69,786,085 | $26,864,661 | $26,889,335 |
| K62 | $3,212,617 | $15,454,884 | $19,531,146 | $19,591,643 | $3,828,872 | $17,929,349 | $44,122,798 | $16,135,639 | $16,160,313 |
| K63 | $1,898,451 | $16,922,082 | $20,388,435 | $20,390,624 | $1,898,451 | $18,703,262 | $17,784,949 | $16,934,130 | $16,934,130 |
| K64 | $2,850,427 | $20,225,576 | $26,013,361 | $25,908,672 | $3,362,387 | $23,016,918 | $23,245,847 | $20,680,217 | $20,704,891 |
| K65 | $9,097 | $1,521,438 | $1,869,901 | $1,879,545 | $86,201 | $2,309,131 | $1,754,892 | $1,608,298 | $1,632,972 |
| L31 | $8,418 | $10,438,771 | $14,469,381 | $14,835,446 | $8,418 | $11,952,728 | $12,352,312 | $10,804,846 | $10,804,846 |
| L33 | $1,582,387 | $23,204,074 | $29,086,388 | $29,372,258 | $1,582,387 | $26,152,627 | $25,433,972 | $23,489,946 | $23,489,946 |
| L34 | $22,722 | $4,495,706 | $5,697,820 | $5,697,820 | $22,722 | $5,123,497 | $4,915,592 | $4,495,709 | $4,495,709 |
| L35 | $140,390 | $2,883,644 | $3,620,674 | $3,710,433 | $140,390 | $3,308,028 | $3,095,271 | $2,973,403 | $2,973,403 |
| L36 | $820,049 | $14,282,133 | $17,775,680 | $17,858,580 | $960,386 | $16,677,851 | $15,582,442 | $14,505,369 | $14,530,043 |
| L37 | $737,351 | $9,178,436 | $11,495,316 | $11,580,806 | $737,351 | $10,180,768 | $10,010,755 | $9,263,929 | $9,263,929 |
| L38 | $308,641 | $11,094,999 | $14,744,490 | $14,913,785 | $634,918 | $12,713,973 | $13,078,580 | $11,590,572 | $11,615,246 |
| L39 | $818,769 | $9,665,398 | $12,048,042 | $12,048,042 | $1,154,717 | $11,099,240 | $10,783,930 | $10,001,346 | $10,026,020 |
| L40 | $181,404 | $2,782,051 | $3,501,490 | $3,574,789 | $570,827 | $3,514,243 | $3,424,840 | $3,244,886 | $3,269,560 |
| L41 | $951,125 | $10,014,674 | $12,622,013 | $12,660,662 | $1,494,957 | $12,009,641 | $11,504,405 | $10,600,895 | $10,625,569 |
| L42 | $251,815 | $2,475,503 | $3,081,323 | $3,100,240 | $461,704 | $3,042,248 | $2,928,615 | $2,704,309 | $2,728,983 |
| L43 | $1,266,382 | $19,673,619 | $25,276,376 | $25,275,517 | $1,266,382 | $21,984,984 | $21,818,467 | $19,673,619 | $19,673,619 |
| L45 | $290,211 | $2,486,510 | $3,043,562 | $3,043,562 | $290,211 | $2,762,580 | $2,648,941 | $2,486,510 | $2,486,510 |
| L46 | $444,443 | $3,904,285 | $4,832,631 | $4,887,439 | $701,858 | $4,621,769 | $4,463,586 | $4,216,508 | $4,241,182 |
| L47 | $993,774 | $11,576,099 | $14,847,646 | $14,913,965 | $1,254,424 | $13,719,704 | $13,215,659 | $11,912,354 | $11,937,028 |
| R01 | $1,313,120 | $11,313,598 | $13,800,388 | $13,800,388 | $1,611,914 | $13,139,869 | $21,858,756 | $11,612,392 | $11,637,066 |
| R02 | $1,190,923 | $5,317,669 | $6,325,310 | $6,325,310 | $1,190,923 | $5,813,115 | $18,560,365 | $5,317,669 | $5,317,669 |
| R03 | $2,082,211 | $12,421,609 | $15,243,612 | $15,243,612 | $2,503,604 | $14,086,698 | $26,766,642 | $12,843,002 | $12,867,676 |
| R04 | $1,607,902 | $11,577,877 | $14,384,212 | $14,379,624 | $2,174,208 | $13,734,686 | $20,232,252 | $12,143,149 | $12,167,823 |
| R05 | $1,150,583 | $4,875,718 | $6,291,380 | $6,282,361 | $1,529,701 | $5,724,990 | $19,176,921 | $5,254,703 | $5,279,377 |
| R06 | $728,494 | $7,478,150 | $8,986,976 | $8,986,976 | $679,994 | $8,429,892 | $7,803,032 | $7,429,652 | $7,429,652 |

Table 4 – Rural Net Average Annual Habitat Units Summary.

| Site | Acres | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 |
|---|---|---|---|---|---|---|---|---|---|---|
| K01 | 159 | 148 | 129 | 199 | 199 | 148 | 129 | 199 | 199 | 199 |
| K02 | 664 | 355 | 738 | 689 | 689 | 392 | 779 | 735 | 731 | 743 |
| K03 | 324 | 187 | 260 | 249 | 249 | 187 | 260 | 249 | 249 | 249 |
| K04 | 154 | 48 | 130 | 204 | 204 | 48 | 130 | 204 | 204 | 204 |
| K05 | 1,067 | 899 | 1,089 | 1,011 | 1,011 | 899 | 1,089 | 1,011 | 1,011 | 1,011 |
| K06 | 978 | 826 | 1,022 | 927 | 1,132 | 865 | 1,069 | 982 | 1,179 | 1,201 |
| K07 | 368 | 297 | 459 | 429 | 537 | 327 | 495 | 470 | 573 | 590 |
| K08 | 176 | (60) | (19) | (70) | 10 | 17 | 20 | 23 | 20 | 28 |
| K09 | 627 | 984 | 942 | 1,009 | 1,056 | 1,028 | 992 | 1,066 | 1,106 | 1,124 |
| K10 | 605 | 756 | 861 | 809 | 913 | 786 | 894 | 846 | 946 | 957 |
| K11 | 304 | 320 | 366 | 348 | 429 | 343 | 392 | 377 | 455 | 464 |
| K12 | 1,542 | 1,260 | 1,481 | 1,381 | 1,381 | 1,260 | 1,481 | 1,381 | 1,381 | 1,381 |
| K13 | 64 | 29 | 31 | 30 | 30 | 29 | 31 | 30 | 30 | 30 |
| K14 | 210 | 202 | 231 | 219 | 219 | 232 | 265 | 256 | 253 | 264 |
| K15 | 409 | 207 | 206 | 286 | 286 | 218 | 218 | 299 | 298 | 302 |
| K16 | 105 | 71 | 91 | 88 | 88 | 71 | 91 | 88 | 88 | 88 |
| K17 | 155 | 176 | 195 | 179 | 179 | 176 | 195 | 179 | 179 | 179 |
| K18 | 1,463 | 316 | 464 | 226 | 682 | 341 | 492 | 258 | 711 | 722 |
| K19 | 461 | 430 | 495 | 479 | 479 | 430 | 495 | 479 | 479 | 479 |
| K20 | 114 | 81 | 85 | 260 | 85 | 89 | 94 | 270 | 94 | 96 |
| K21 | 158 | 106 | 131 | 123 | 123 | 115 | 140 | 134 | 133 | 136 |
| K22 | 470 | 290 | 361 | 355 | 355 | 321 | 395 | 392 | 389 | 398 |
| K23 | 1,785 | 1,052 | 1,090 | 1,122 | 1,161 | 1,121 | 1,169 | 1,210 | 1,240 | 1,268 |
| K24 | 96 | 46 | 59 | 25 | 25 | 46 | 59 | 25 | 25 | 25 |
| K25 | 632 | 222 | 121 | 218 | 218 | 222 | 121 | 218 | 218 | 218 |
| K26 | 209 | 87 | 121 | 86 | 86 | 87 | 121 | 86 | 86 | 86 |
| K27 | 1,064 | 389 | 737 | 846 | 1,061 | 399 | 749 | 860 | 1,073 | 1,079 |
| K28 | 170 | 119 | 142 | 138 | 138 | 119 | 142 | 138 | 138 | 138 |
| K29 | 415 | 381 | 248 | 434 | 480 | 385 | 253 | 439 | 485 | 488 |
| K30 | 995 | 600 | 702 | 673 | 943 | 619 | 725 | 699 | 966 | 977 |
| K31 | 626 | 603 | 709 | 586 | 586 | 603 | 709 | 586 | 586 | 586 |
| K32 | 287 | 256 | 300 | 285 | 285 | 280 | 327 | 314 | 311 | 318 |
| K33 | 2,134 | 1,226 | 2,148 | 2,051 | 2,445 | 1,352 | 2,287 | 2,202 | 2,584 | 2,621 |
| K34 | 686 | 898 | 1,004 | 942 | 1,011 | 922 | 1,031 | 971 | 1,038 | 1,046 |
| K35 | 923 | 769 | 807 | 753 | 753 | 769 | 807 | 753 | 753 | 753 |
| K36 | 1,589 | 1,790 | 2,075 | 1,913 | 2,118 | 1,809 | 2,096 | 1,936 | 2,139 | 2,146 |
| K37 | 363 | 315 | 322 | 182 | 182 | 315 | 322 | 182 | 182 | 182 |
| K38 | 387 | 328 | 392 | 367 | 367 | 328 | 392 | 367 | 367 | 367 |
| K40 | 504 | 355 | 434 | 171 | 171 | 355 | 434 | 171 | 171 | 171 |
| K41 | 689 | 850 | 1,250 | 933 | 1,067 | 884 | 1,286 | 972 | 1,103 | 1,112 |
| K42 | 721 | 520 | 584 | 452 | 452 | 520 | 584 | 452 | 452 | 452 |
| K43 | 350 | 287 | 348 | 331 | 331 | 287 | 348 | 331 | 331 | 331 |
| K44 | 2,363 | 1,107 | 1,444 | 1,358 | 1,719 | 1,131 | 1,471 | 1,388 | 1,746 | 1,755 |
| K45 | 1,183 | 1,394 | 1,579 | 1,497 | 1,673 | 1,449 | 1,639 | 1,562 | 1,733 | 1,748 |

Table 4 – Rural Net Average Annual Habitat Units Summary (Continued).

| Site | Acres | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 |
|---|---|---|---|---|---|---|---|---|---|---|
| K46 | 832 | 513 | 585 | 213 | 213 | 513 | 585 | 213 | 213 | 213 |
| K47 | 1,619 | 1,956 | 2,144 | 1,696 | 2,249 | 2,017 | 2,211 | 1,768 | 2,315 | 2,332 |
| K48 | 762 | 586 | 717 | 678 | 678 | 586 | 717 | 678 | 678 | 678 |
| K49 | 552 | 438 | 280 | 455 | 455 | 438 | 280 | 455 | 455 | 455 |
| K50 | 786 | 605 | 739 | 710 | 756 | 630 | 767 | 740 | 783 | 792 |
| K51 | 190 | 101 | 128 | 124 | 124 | 101 | 128 | 124 | 124 | 124 |
| K52 | 249 | 223 | 257 | 249 | 249 | 223 | 257 | 249 | 249 | 249 |
| K53 | 522 | 464 | 532 | 504 | 565 | 483 | 552 | 526 | 584 | 589 |
| K54 | 1,272 | 1,144 | 1,129 | 1,109 | 1,221 | 1,144 | 1,129 | 1,109 | 1,221 | 1,221 |
| K55 | 263 | 336 | 429 | 326 | 326 | 336 | 429 | 326 | 326 | 326 |
| K56 | 515 | 697 | 676 | 689 | 777 | 715 | 697 | 714 | 799 | 809 |
| K57 | 1,221 | 1,104 | 1,313 | 1,237 | 1,237 | 1,104 | 1,313 | 1,237 | 1,237 | 1,237 |
| K58 | 695 | 568 | 408 | 661 | 661 | 568 | 408 | 661 | 661 | 661 |
| K59 | 2,147 | 2,028 | 2,022 | 2,051 | 2,243 | 2,028 | 2,022 | 2,051 | 2,243 | 2,243 |
| K60 | 824 | 317 | 744 | 609 | 375 | 317 | 744 | 609 | 375 | 375 |
| K61 | 1,608 | 1,870 | 2,111 | 1,998 | 2,199 | 1,933 | 2,181 | 2,074 | 2,269 | 2,287 |
| K62 | 949 | 1,073 | 1,191 | 1,138 | 1,234 | 1,119 | 1,243 | 1,196 | 1,286 | 1,303 |
| K63 | 1,054 | 739 | 941 | 1,002 | 1,008 | 739 | 941 | 1,002 | 1,008 | 1,008 |
| K64 | 1,328 | 1,557 | 1,796 | 1,677 | 1,830 | 1,598 | 1,841 | 1,727 | 1,875 | 1,890 |
| K65 | 78 | 25 | 33 | 32 | 105 | 30 | 40 | 40 | 112 | 115 |
| L31 | 907 | 1,068 | 1,097 | 681 | 1,263 | 1,068 | 1,097 | 681 | 1,263 | 1,263 |
| L33 | 1,481 | 531 | 1,475 | 746 | 1,767 | 531 | 1,475 | 746 | 1,767 | 1,767 |
| L34 | 317 | 519 | 251 | 236 | 236 | 519 | 251 | 236 | 236 | 236 |
| L35 | 213 | 321 | 337 | 306 | 293 | 321 | 337 | 306 | 293 | 293 |
| L36 | 951 | 969 | 1,078 | 1,000 | 1,148 | 984 | 1,095 | 1,017 | 1,165 | 1,168 |
| L37 | 601 | 669 | 761 | 687 | 837 | 669 | 761 | 687 | 837 | 837 |
| L38 | 838 | 149 | 536 | 572 | 313 | 207 | 603 | 647 | 379 | 406 |
| L39 | 648 | 687 | 786 | 742 | 742 | 716 | 817 | 775 | 772 | 779 |
| L40 | 189 | 286 | 312 | 234 | 251 | 300 | 329 | 253 | 267 | 276 |
| L41 | 673 | 620 | 704 | 659 | 1,233 | 655 | 742 | 700 | 1,272 | 1,281 |
| L42 | 147 | 100 | 124 | 142 | 142 | 105 | 130 | 149 | 149 | 152 |
| L43 | 1,401 | 1,376 | 1,513 | 1,454 | 1,454 | 1,376 | 1,513 | 1,454 | 1,454 | 1,454 |
| L45 | 160 | 204 | 250 | 215 | 215 | 204 | 250 | 215 | 215 | 215 |
| L46 | 254 | 277 | 315 | 302 | 248 | 285 | 324 | 312 | 257 | 261 |
| L47 | 779 | 861 | 943 | 877 | 1,053 | 876 | 961 | 897 | 1,071 | 1,078 |
| R01 | 698 | 404 | 644 | 564 | 564 | 421 | 663 | 586 | 584 | 590 |
| R02 | 295 | 331 | 323 | 377 | 377 | 331 | 323 | 377 | 377 | 377 |
| R03 | 754 | 1,029 | 1,139 | 1,063 | 1,063 | 1,038 | 1,148 | 1,074 | 1,073 | 1,076 |
| R04 | 723 | 889 | 668 | 534 | 686 | 912 | 694 | 563 | 713 | 722 |
| R05 | 297 | 281 | 51 | 304 | 156 | 296 | 68 | 324 | 173 | 181 |
| R06 | 464 | 360 | 130 | 438 | 438 | 360 | 130 | 438 | 438 | 438 |

Table 5 – Urban Net Average Annual Habitat Units Summary.

| Site | Acres | U1 | U2 | U3 | U4 | U5 | U6 | U7 | U8 | U9 |
|---|---|---|---|---|---|---|---|---|---|---|
| C01 | 529 | 172 | 172 | 172 | 245 | 287 | 287 | 172 | 287 | 287 |
| C02 | 327 | 0 | 1 | (35) | 15 | 16 | 16 | 314 | 392 | 392 |
| C03 | 536 | 0 | 0 | 393 | 87 | 100 | 100 | 393 | 486 | 486 |
| C04 | 93 | 53 | 53 | 53 | 50 | 61 | 61 | 53 | 61 | 61 |
| C05 | 315 | 191 | 191 | 191 | 194 | 164 | 164 | 191 | 164 | 164 |
| C07 | 233 | 208 | 222 | 212 | 212 | 181 | 181 | 172 | 212 | 212 |
| C08 | 52 | 55 | 68 | 68 | 72 | 82 | 82 | 68 | 82 | 82 |
| C09 | 815 | 591 | 593 | 532 | 560 | 688 | 688 | 721 | 925 | 925 |
| C10 | 89 | 151 | 158 | 158 | 153 | 181 | 181 | 158 | 181 | 181 |
| C11 | 511 | 340 | 355 | 354 | 365 | 452 | 452 | 390 | 488 | 488 |
| C12 | 555 | 53 | 54 | 53 | 212 | 171 | 171 | 515 | 666 | 666 |
| C13 | 31 | (2) | (2) | (2) | 6 | 7 | 7 | (2) | 7 | 7 |
| C14 | 30 | 16 | 16 | 16 | 19 | 20 | 20 | 16 | 20 | 20 |
| C15 | 1,007 | 719 | 816 | 726 | 753 | 1,306 | 1,306 | 882 | 1,494 | 1,494 |
| C16 | 365 | 195 | 195 | 153 | 153 | 201 | 201 | 256 | 329 | 329 |
| C17 | 161 | 71 | 72 | 71 | 77 | 98 | 98 | 115 | 153 | 153 |
| C18 | 55 | 13 | 13 | 13 | 16 | 20 | 20 | 13 | 20 | 20 |
| L01 | 219 | 103 | 390 | 69 | 84 | 100 | 100 | 261 | 261 | 261 |
| L02 | 530 | 199 | 199 | 227 | 248 | 305 | 305 | 408 | 437 | 437 |
| L03 | 492 | 420 | 420 | 420 | 434 | 504 | 504 | 420 | 504 | 504 |
| L05 | 323 | 181 | 181 | 181 | 198 | 202 | 202 | 197 | 234 | 234 |
| L06 | 859 | 601 | 601 | 444 | 602 | 595 | 595 | 732 | 717 | 717 |
| L09 | 410 | 315 | 315 | 321 | 195 | 422 | 422 | 366 | 422 | 422 |
| L10 | 551 | 108 | 108 | 155 | 179 | 116 | 116 | 254 | 231 | 231 |
| L11 | 289 | 148 | 148 | 88 | 123 | 111 | 111 | 200 | 271 | 271 |
| L12 | 167 | 207 | 207 | 207 | 208 | 245 | 245 | 207 | 245 | 245 |
| L13 | 521 | 416 | 416 | 416 | 436 | 518 | 518 | 416 | 518 | 518 |
| L14 | 250 | 54 | 54 | 54 | 73 | 81 | 81 | 54 | 81 | 81 |
| L15 | 76 | 79 | 79 | 79 | 81 | 91 | 91 | 79 | 91 | 91 |
| L16 | 88 | 86 | 86 | 86 | 64 | 97 | 97 | 86 | 97 | 97 |
| L17 | 89 | 70 | 70 | 70 | 73 | 81 | 81 | 70 | 81 | 81 |
| L18 | 337 | 292 | 292 | 296 | 178 | 318 | 318 | 296 | 371 | 371 |
| L19 | 1,210 | 1,373 | 1,386 | 1,223 | 1,260 | 1,428 | 1,428 | 1,465 | 1,713 | 1,713 |
| L20 | 99 | 100 | 100 | 100 | 106 | 120 | 120 | 100 | 120 | 120 |
| L21 | 340 | 145 | 145 | 145 | 165 | 184 | 184 | 145 | 184 | 184 |
| L22 | 759 | 422 | 422 | 422 | 456 | 514 | 514 | 422 | 514 | 514 |
| L23 | 846 | 573 | 622 | 362 | 328 | 530 | 530 | 726 | 959 | 959 |
| L24 | 615 | 344 | 344 | 344 | 408 | 416 | 416 | 344 | 416 | 416 |
| L25 | 272 | 168 | 168 | 129 | 41 | 181 | 181 | 225 | 294 | 294 |
| L26 | 205 | 93 | 93 | 66 | 69 | 100 | 100 | 112 | 160 | 160 |
| L27 | 230 | 215 | 215 | 215 | 226 | 253 | 253 | 215 | 253 | 253 |
| L28 | 1,064 | 610 | 610 | 357 | 446 | 574 | 574 | 500 | 744 | 744 |
| L29 | 730 | 323 | 323 | 120 | 219 | 325 | 325 | 118 | 322 | 322 |
| L30 | 323 | 194 | 194 | 194 | 221 | 254 | 254 | 194 | 254 | 254 |
| L32 | 378 | 355 | 355 | 355 | 384 | 437 | 437 | 355 | 437 | 437 |
| L44 | 380 | 510 | 510 | 471 | 479 | 575 | 575 | 595 | 652 | 652 |

# SECTION 3 – HEP DOCUMENTATION

ERDC/EL TR-SWWRP-09-X

Environmental Laboratory

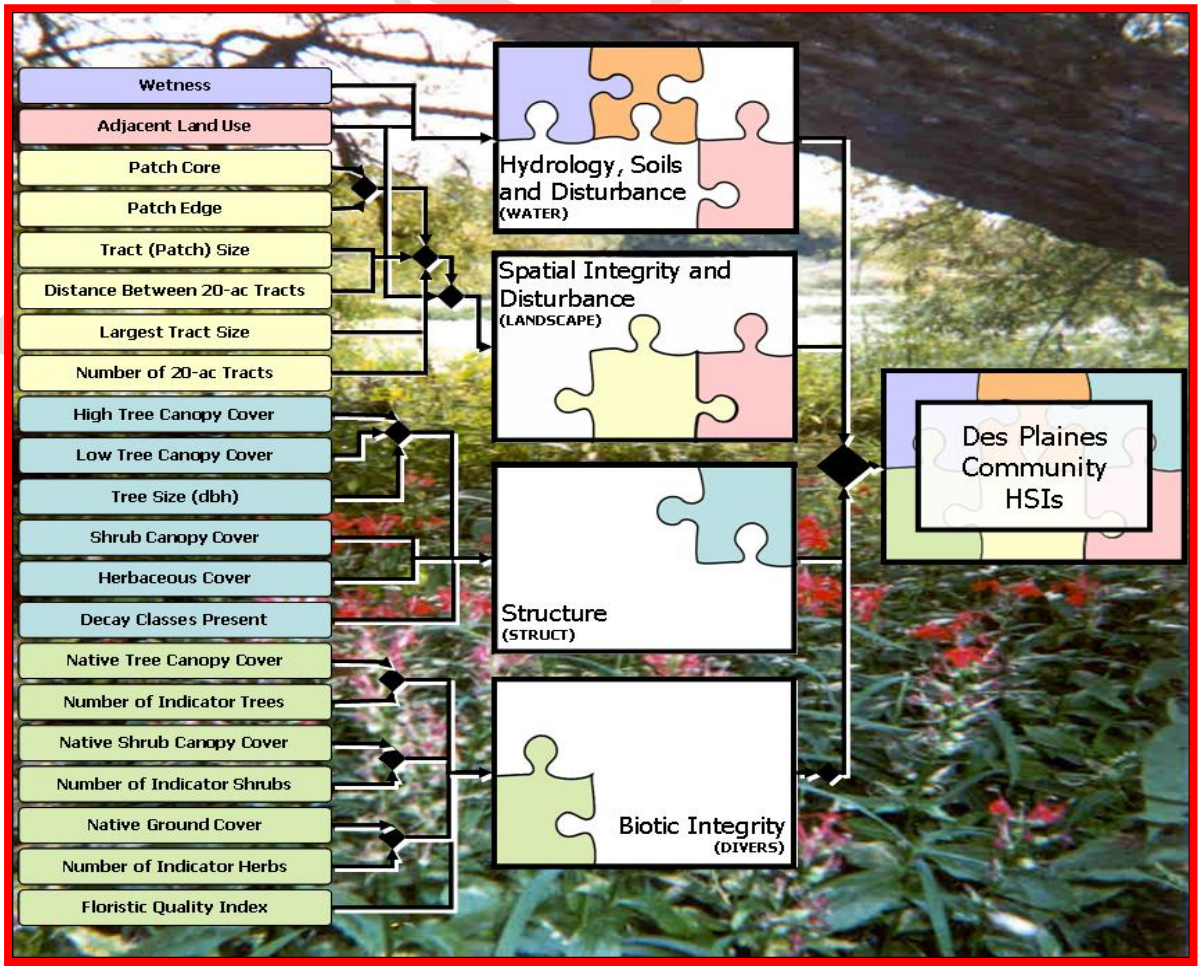
US Army Corps of Engineers®
Engineer Research and Development Center

# Community Models for the Upper Des Plaines River Watershed, Illinois and Wisconsin

**Model Documentation**
**Draft Report**

Kelly A. Burks-Copes and Antisa C. Webb

November 2009

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System-Wide Water Resources Program
Habitat Based Ecological Response Models

ERDC/EL TR-SWWRP-09-X
October 2009

# Community Models for the Upper Des Plaines River Watershed, Illinois and Wisconsin

## Model Documentation

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*Environmental Laboratory*
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Draft report

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**Abstract:** Over the last decade, the Upper Des Plaines River Watershed (located in northeastern Illinois, Lake and Cook Counties, and southeastern Wisconsin) has experienced significant flooding owing to the limited channel capacity of the main stem Des Plaines River and its numerous tributaries. The anthropogenic pressures have led to significant degradation of the system's unique ecosystems – namely tall grass prairies, graminoid-dominated savannas, and wooded flats/riparian forests along the Upper Des Plaines main stem and its associated tributaries. In response, the US Army Corps of Engineers (USACE) has undertaken several studies to evaluate reasonable solutions to the problem found along 85 miles of the main stem and its associated tributaries in both Illinois and Wisconsin. As part of the process, a multi-agency, multi-disciplinary evaluation team was established to formulate alternatives that would address several critical problems including the reduction of existing flood damage, the prevention of future damage, and the protection/restoration of environmental integrity. In 2001, the team chose to use the Habitat Evaluation Procedures (HEP) methodology to capture ecosystem response in the prairie, savanna, and woodland ecosystems across the watershed. Between 2001 and 2008, this team designed, calibrated, and applied a series of community-based index models for these ecosystems using field and spatial data gathered from 85 individual reference sample sites scattered across the watershed. These models contained 25 parameters combined into various predictive community functional components (i.e., Hydrology, Spatial Integrity, Structure, and Biotic Integrity) capable of capturing the changes to ecosystem integrity in response to changes in land and water management activities proposed by the study. The intent of this document is to provide the scientific basis upon which these models were developed, and describe the 7-year long process the team undertook to complete this effort. Although some results are presented here to demonstrate and verify the veracity of the models' calibration and subsequent outputs, readers interested in the application of these models on the Upper Des Plaines studies should direct their inquiries to the Chicago District.

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# Preface

This report provides the documentation of newly developed community models [based on the Habitat Evaluation Procedures (HEP)] for the Upper Des Plaines River Watershed in the vicinity of Chicago, Illinois.

The work described herein was conducted at the request of the U.S. Army Engineer District, Chicago, Illinois. This report was prepared by Ms. Antisa C. Webb, Ms. Kelly A. Burks-Copes, U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, Mississippi, and Mr. Seth W. Jones, U.S. Army Engineer District, Galveston, Texas. At the time of this report, Ms. Webb and Ms. Burks-Copes were ecologists in the Ecological Resources Branch. Mr. Jones was an ecologist in the Planning and Environmental Branch.

Many people contributed to the overall success of the production of the model documentation. The authors wish to thank the following people for their hard work and persistence during the intensive months over which the project was assessed: Ms. Jennifer Emerson (Bowhead Information Technology Services), Ms. Brook Herman (Chicago District), and Mr. Joe Hmieleski (Lake County Stormwater Management Commission). We also thank XYZ for their comprehensive review of the report.

This report was prepared under the general supervision of Ms. Antisa C. Webb, Chief, Ecological Resources Branch and Dr. Edmond Russo, Chief, Ecosystem Evaluation and Engineering Division. At the time of publication of this report, Dr. Beth Fleming was Director of EL.

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# 1 Introduction

Over the last decade, the Upper Des Plaines River Watershed (located in northeastern Illinois, Lake and Cook Counties, and southeastern Wisconsin) has experienced significant flooding owing to the limited channel capacity of the main stem Des Plaines River and its numerous tributaries. The anthropogenic pressures have led to significant degradation of the system's unique ecosystems – namely tall grass prairies, graminoid-dominated savannas, and wooded flats/riparian forests along the Upper Des Plaines main stem and its associated tributaries. What follows is a description of these critical natural resources, and a discussion of the threats they face in light of increasing urban encroachment, significant alterations of hydroregime, and ever increasing competition from non-native populations.

## Study Background

In 1999, the U.S. Army Corps of Engineers (USACE) District in Chicago, Illinois (District) was authorized by Section 419 of the Water Resources Development Act of 1999 to conduct the study on the Upper Des Plaines River and its associated tributaries in both Illinois and Wisconsin to determine the feasibility of improvements in the interests of flood damage reduction, environmental restoration and protection, water quality, recreation, and related purposes (USACE 2001). In conducting the study (referred to throughout the remainder of this report as the Upper Des Plains Multi-Purpose Phase II Feasibility Study or DPII), the District was directed to "not exclude from consideration and evaluation flood damage reduction measures based on restrictive policies regarding the frequency of flooding, the drainage area, and the amount of runoff." The Phase II study therefore has three primary objectives:

1. Further reduction of main stem flooding
2. Reduction of tributary flooding; and
3. Environmental restoration of degraded ecosystems within the basin.

Secondary objectives include improving water quality and enhancing recreational opportunities throughout the basin. The study will consider sites located within tributary watersheds and along the main stem for both

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Flood Damage Reduction (FDR) and Ecosystem Restoration (ER) potential. The affects of FDR sites within tributary watersheds on main stem flooding will also be evaluated. Shortly thereafter, the District developed a Project Management Plan (PMP) recommending a cost-shared feasibility study with the Illinois Department of Natural Resources (IDNR), Lake County Storm Water Management Commission (LCSMC), Southeastern Wisconsin Regional Planning Commission (SEWRPC), Cook, Lake and Kenosha Counties (USACE 2001).

The key to a sustainable watershed will be a comprehensive flood control plan that will balance water storage and environmentally sensitive designs (possibly in the form of nonstructural solutions) (IDNR 2001b). In the development of alternative plans, the Upper Des Plaines River and Tributaries Sponsors and Stakeholders Alliance recommended the Corps use a combined environmental-flood damage reduction approach to plan formulation that addressed these issues in a holistic, multi-purpose and comprehensive manner (IDNR 2001b). The general approach was to design and implement projects to reduce flood damages and at the same time improve the overall quality of an ecosystem degraded over the years by farming and development.

Ecosystems are hierarchical and can be viewed as nested sets of open systems in which the physical, chemical, and biological processes form interactive subsystems each at different scales. Ecosystems can be microscopic in size or can be as large as the biosphere. Thus, ecosystem restoration efforts can be directed at different sized ecosystems within the nested set, spanning multiple counties, states, watersheds, or encapsulating smaller complexes of habitat within these larger-scaled entities (as is the case of the Upper Des Plaines Watershed).

## Purpose of the Models

Planning, management, and policy decisions require information on the status, condition and trends of these complex ecosystems and their components at various scales (e.g. local, regional, watershed and system levels) to make reasonable and informed decisions about the planning management and conservation of sensitive or valued resources. One well accepted solution has been to develop index models that assess ecosystems at varying scales. By definition, index models are comprehensive, multi-scale, grounded in natural history, relevant and helpful, able to integrate

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terrestrial and aquatic environments, flexible and measurable (Andreasen et al. 2003). Determining the value of diverse biological resources in this study required a method that captured the complex biotic patterns of the landscape, rather than merely focusing on a single species habitat or suitability requirements within the study area In effect, the DPII study team made the decision to assess ecosystem benefits using a series of community-based (functional) models.

Ecosystem functions are defined here as a series of processes that take place within an ecosystem. These include the storage of water, transformation of nutrients, growth of living matter, and diversity of plants, and they have value for the community itself, for surrounding ecosystems, and for people. Functions can be grouped broadly as habitat, hydrologic, water quality, and spatial integrity although these distinctions are somewhat arbitrary and simplistic. For example, the value of a wetland for recreation (hunting, fishing, bird watching) is a product of all the processes that work together to create and maintain the ecosystem. Not all communities perform all functions nor do they perform all functions equally well. The location and size of a community may determine what functions it will perform. For example, the geographic location may determine its habitat functions, and the location of community within a watershed may determine its hydrologic or water-quality functional capacity. Many factors determine how well a community will perform these functions: climatic conditions, quantity and quality of water entering the system, and disturbances or alteration within the community or the surrounding landscape. Disturbances may be the result of natural conditions, such as an extended drought, or human activities, such as land clearing, dredging, or the introduction of invasive species.

The purpose of this modeling effort was to broadly capture existing, (baseline) conditions of the communities, and compare changes that would occur to the resources present given different project scenarios or alternatives under the standard USACE planning paradigm (USACE 2000). The models were used to facilitate plan formulation based upon project benefits. The purpose of the models was not to exhaustively capture the full range of all chemical, physical, and biological characteristics of the project area, but to provide tools for making comparisons between potential plans in order to select plans with the highest benefits. Planning decisions for the feasibility study were therefore

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made based on the results of the model applied using a planning level approach to the well received and respected Habitat Evaluation Procedures (HEP) (USFWS 1980a-c) and Hydrogeomorphic Assessment of Wetlands (HGM) (Ainslie et al. 1999; Brinson 1993) frameworks.

## Contribution to the Planning Effort

These methodologies (HEP, HGM, etc.) help to characterize the baseline conditions (in a quantitative manner) of the numerous ecological resources throughout the watershed. The methods assisted the study team in the projection of change to fundamental ecosystem processes[1] (without which, ecosystem restoration itself could not happen), as the multi-purpose alternatives were proposed. The study team designed the HEP/HGM assessments to evaluate the future changes both in quantity (acres) and quality (community habitat suitability and/or functional capacity) of aquatic, wetland and terrestrial ecosystems simultaneously. Outputs were calculated in terms of annualized changes anticipated over the life of the project.

Early in the evaluation process, an interagency Ecosystem Assessment Team (E-Team) was convened. Scientists from the U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC) facilitated the efforts. Representatives from the District, IDNR, U.S. Fish and Wildlife Service (USFWS), U.S. Environmental Protection Agency (USEPA), LCSMC, SEWRPC, Cook, Lake and Kenosha Counties actively participated in the assessment process. The remainder of this document focuses on the Habitat Suitability Index (HSI) models developed by the E-Team for the DPII study.

## Planning Model Certification

As an aside, the USACE Planning Models Improvement Program (PMIP) was established to review, improve, and validate analytical tools and models for USACE Civil Works business programs. In May of 2005, the PMIP developed Engineering Circular (EC) 1105-2-407, Planning Models Improvement Program: Model Certification (USACE 2005). This EC

[1] There are four fundamental ecosystem processes – water cycling, mineral cycling, solar energy flow, and community dynamics (aka succession).

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requires the use of certified models for all planning activities. It tasks the Planning Centers of Expertise to evaluate the technical soundness of all planning models based on theory and computational correctness. EC 1105-2-407 defines planning models as,

> *" . . any models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making."*

Clearly, the community based HSI models and the functional assessment (HGM-based) models (and their associated input/output spreadsheets) developed for the study must be certified, and the Chicago District has initiated this activity. Information necessary to address model certification is outlined in Table 2 of the EC 1105-2-407 (pages 9-11). To assist the reviewers in the certification effort for these models, the authors have developed an appendix to crosswalk the EC checklist requirements and this report (*Appendix C*).

For purposes of model certification, it is important to note that these models must be formally certified, but the methodologies under which they are applied (i.e., HEP and HGM) do not require certification as it is considered part of the application process. HEP in particular has been specifically addressed in the EC:

> *"The Habitat Evaluation Procedures (HEP) is an established approach to assessment of natural resources, developed by the US Fish and Wildlife Service in conjunction with other agencies. The HEP approach has been well documented and is approved for use in Corps projects as an assessment framework that combines resource quality and quantity over time, and is appropriate throughout the United States" (refer to Attachment 3, page 22, of the EC).*

The authors used the newly developed **Habitat Evaluation and Assessment Tools** (**HEAT**) (Burks-Copes et al. 2008) to automate the calculation of habitat units for the study. This software is not a "shortcut" to HEP or HGM modeling, or a model in and of itself, but rather a series of

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computer-based programming modules that accept the input of mathematical details and data comprising the index models, and through their applications in the HEP or the HGM processes, calculates the outputs in responses to parameterized alternative conditions. The **HEAT** software contains two separate programming modules – one used for HEP applications referred to as the **EXpert Habitat Evaluation Procedures** (**EXHEP**) module, and a second used in HGM applications referred to as the **EXpert Hydrogeomorphic Approach to Wetland Assessments** (**EXHGM**) modules. Both the **EXHEP and EXHGM** modules were employed to calculate outputs for the study. The developers of the **HEAT** tool (including both the **EXHEP** and **EXHGM** modules themselves) are pursuing certification through a separate initiative, and hope to have this tool through the process in the next year barring unforeseen financial and institutional problems.

## Report Objectives

This document describes the development of community-based HSI models for three community habitat types (Prairie, Savannas, and Woodlands) located within the Upper Des Plaines River watershed. The objectives of this report are to:

4. Characterize the Upper Des Plaines River watershed, within the study area, in southeastern Wisconsin and northeastern Illinois;
5. Characterize the three habitat communities used in the HEP evaluation and their applicable cover types;
6. Present the relationships of habitat maintenance components for each of the community models; and
7. Define and justify the selection of assessment variables and their associated curve calibrations used to characterize the components of each community model.
8. Provide critical information to reviewers to facilitate the certification of these index models.

## Report Structure

This report is organized in the following manner. *Chapter 1* provides the background, objectives, and organization of the document. *Chapter 2* provides a brief overview of HEP, the method in which the model will be

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applied, including the procedures recommended for development and application of the HSI models. *Chapter 3* discusses the evolution of the community models in terms of conceptual development, offers critical insight into the characterization of each community, provides details regarding the key functional components in each model (and their mathematical representations), and then concludes with the construction and testing of the models over the last two years. *Chapter 4* offers insight into the model calibration approach as it applies to all the models described herein, and offers descriptions of the assessment variables used to characterize the communities including definitions, rationale for selection, and specific sampling guidelines. Several appendices are attached to this document. *Appendix A* is a list of acronyms used throughout this document. *Appendix B* is a glossary of commonly used terms regarding HSI models and the HEP evaluation. *Appendix C* offers a crosswalk between the standard requirements and information necessary to certify these models and this report. *Appendix D* contains a point of contact for the formal minutes documenting the decisions made during the initial model development workshops and offers a complete list of E-Team participants. *Appendix E* provides initial model review forms. *Appendix F* documents the review comments provided by the District and the workshop participants as the planning study proceeds through review. Finally, *Appendix G* provides individual index curves for the variables used in the models.

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# 2 HEP Overview

## The HEP Process

The HEP methodology is an environmental accounting process developed to appraise habitat suitability for fish and wildlife species in the face of potential change (USFWS 1980 a-c). Designed to predict the response of habitat parameters in a quantifiable fashion, HEP is an objective, reliable, and well-documented process used nationwide to generate environmental outputs for all levels of proposed projects and monitoring operations in the natural resources arena. When applied correctly, HEP provides an impartial look at environmental effects, and delivers measurable products to the user for comparative analysis.

In HEP, a Suitability Index (SI) is a mathematical relationship that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type. These suitability relationships are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges from 0.0 to 1.0, where an SI = 0.0 represents a variable that is extremely limiting, and an SI = 1.0 represents a variable in abundance (not limiting) for the species or community. In HEP, an HSI model is a quantitative estimate of habitat conditions for an evaluation species or community HSI models combine the SIs of measurable variables into a formula depicting the limiting characteristics of the site for the species/community on a scale of 0.0 (unsuitable) to 1.0 (optimal).

### Statement of Limitations

The HEP methodology can provide a rational, supportable, focused, and traceable evaluation of habitat functionality. However, the user must understand the basic HEP tenets as defined in supporting literature (USFWS 1980a-c) prior to attempting application of the methodology. Outcomes derived under HEP are dependent on the user's ability to predict future conditions and the reliability of resource data used. The user should understand that HEP is not a carrying capacity model and cannot comprehensively predict future species and species population sizes. Furthermore, HEP is not designed to compare across evaluation elements (e.g. compare prairie habitat to forest habitat). The user should not expect

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HEP to provide the only predictive environmental response to project development scenarios, and should understand the limitations of the methodology's response to predictive evaluations prior to its application.[1]

### HSI Models in HEP

Users can select several indicator species to evaluate overall site fitness. In the HEP process, species are often selected on the basis of their ecological, recreational, spiritual, or economic value. In other instances, species are chosen for their representative value (i.e., one species can "represent" a group or guild of species which have similar habitat requirements). Most of these species can, in turn, be described using single or multiple habitat models and a single HSI mathematical formula. In some studies, several cover types are included in an HSI model to accurately reflect the complex interdependencies critical to the species' or community's existence. Regardless of the number of cover types incorporated within an HSI model, any HSI model based on the existence of a single life requisite requirement (e.g. food, water, cover or reproduction), uses a single formula to describe the relationship between quality and carrying capacity for the site.

Some species are insufficiently examined using the simplistic approach. In these instances, a more detailed model can emphasize critical life requisites, increase limiting factor sensitivity, and improve the predictive power of the analysis. Multiple habitats and formulas are often necessary to calculate the habitat suitability of these more comprehensive HSI models. The second type of HSI model is used to capture the juxtaposition of habitats, essential dependencies, and performance requirements such as reproduction, roosting needs, escape cover demands, or winter cover that describe the sensitivity of a species or community. Multiple formula models require more extensive processing to evaluate habitat conditions

### Habitat Units in HEP

HSI models can be tailored to a particular situation or application and adapted to meet the level of effort desired by the user. Thus, a single model

[1] Additional support for the HEP methodology has been provided in *Appendix C˛2 Technical Quality, a. Theory*.

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(or a series of inter-related models) can be adapted to reflect a site's response to a particular design at any scale (e.g., species, community, ecosystem, regional, or global dimensions). Several agencies and organizations have adapted the basic HEP methodology for their specific needs in this manner (Inglis et al. 2006, Gillenwater et al. 2006, and Ahmadi-Nedushan et al. 2006). HEP combines both the habitat quality (HSI) and quantity of a site (measured in acres) to generate a measure of change referred to as Habitat Units (HUs). Once the HSI and habitat quantities have been determined, the HU values can be mathematically derived with the following equation: HU = HSI x Area (acres). Under the HEP methodology, one HU is equivalent to one acre of optimal habitat for a given species or community.

### Capturing Changes Over Time in HEP Applications

In studies spanning several years, Target Years (TYs) must be identified early in the process. Target Years are units of time measurement used in HEP that allow users to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1 and a TY = $X_2$. TY1 is the first year land- and water-use conditions are expected to deviate from baseline conditions $TYX_2$ designates the ending target year. A new target year must be assigned for each year the user intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses, and between the baseline and future analyses. In studies focused on the long-term effects, HUs generated for indicator species are estimated for several TYs to reflect the life of the project. In such analyses, future habitat conditions can be estimated for both the without-project (e.g., No Action Plan) and with-project conditions. Projected long-term effects of the project are reported in terms of Average Annual Habitat Units (AAHUs) values Based on the AAHU outcomes, alternative designs can be formulated and trade-off analyses can be simulated to promote environmental optimization.

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## Developing Index Models for HEP

Based on the USFWS's Ecological Service Manual (ESM) series on HEP (USFWS 1980 a-c), there are 12 steps involved in the application of HEP when assessing an environmental project:

1. Build a multi-disciplinary E-Team;
2. Define the project;
3. Map the site's cover types (CTs);
4. Select, modify and/or create index model(s);
5. Conduct field sampling;
6. Perform data management and statistical analyses;
7. Calculate baseline conditions;
8. Set goals and objectives, and define project life and TYs;
9. Generate Without-project (WOP) conditions and calculate outputs;
10. Generate With-project (WP) conditions and calculate outputs;
11. Perform trade-offs; and
12. Report the results of the analyses.

However, this document only addresses the development of the model used in the HEP process for this study. For further detail on each of the 12 steps, contact Brook Herman in the Chicago District (contact information can be found in *Appendix D*) to obtain a copy of the ecosystem assessment report for the study.

### Steps in Model Development

Community assessment was identified as a priority for the District's upcoming feasibility study. However, few HSI community models were published and available for application. ERDC-EL proposed a strategy to the District to develop community models for the MRGBER study. The strategy entailed five steps:

1. Compile all available information that could be used to characterize the communities of concern.
2. Convene an expert panel in a workshop setting to examine this material and generate a list of significant resources and common characteristics (land cover classes, topography, hydrology, physical processes) of the system that could be

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combined in a meaningful manner to "model" the communities. In the workshop, it was important to outline study goals and objectives and then identify the desired model endpoints (e.g., outputs of the model). It was also critical for the participants to identify the limiting factors present in the project area relative to the model endpoints and habitat requirements .The outcome of the workshop was a series of mathematical formulas that were identified as functional components (e.g., Hydrology, Vegetative Structure, Diversity, Connectivity, Disturbance, etc.) which were comprised of variables that were:

a. biologically, ecologically, or functionally meaningful for the subject,
b. easily measured or estimated,
c. able to have scores assigned for past and future conditions,
d. related to an action that could be taken or a change expected to occur,
e. were influenced by planning and management actions, and
f. independent from other variables in each model.

3. Develop both a field and a spatial data collection protocol (using Geographic Information Systems or GIS) and in turn, use these strategies to collect all necessary data and apply these data to the model in both the "reference" setting and on the proposed project area
4. Present the model results to an E-Team and revise/recalibrate the model based on their experiences, any additional and relevant regional data, and application directives.
5. Submit the model to both internal ERDC/District/E-Team review and then request review from the initial expert panel that participated in the original workshop, as well as solicit review from independent regional experts who were not included in the model development and application process.

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### Model Review Process

The process described below is currently being implemented to assure that quality control was an integral part of model development and document production. Three independent reviews of the model(s) and the subsequent application of the model(s) for this study will be undertaken in support of the model development process for the study. First, an in-house Laboratory-based Technical Review (LTR) will be conducted to ensure that:

1. The concepts, assumptions, features, methods, analyses, and details were appropriate and fully coordinated;
2. An appropriate range of feasible alternatives were evaluated;
3. Problems, opportunities, and issues were defined and scoped;
4. Analytic methods used were environmentally sound, appropriate, reasonable, fall within policy guidelines, and yielded reliable results;
5. Any deviations from policy and guidance were identified, documented, and approved;
6. The products met laboratory standards based on format and presentation; and
7. The products met the customer's needs and expectations.

To assure fair and impartial review of the products, members of the Laboratory-based Technical Review Team (LTRT) will be chosen on the basis of expertise and seniority in the laboratory chain of command. No LTRT member will be directly associated with the development or application of the model(s) for this study, thereby assuring independent technical review. Review comments will be submitted to the Laboratory-based Project Delivery Team (LPDT) in written format. Two technology transfer forms will be completed to document the formal internal laboratory review process (see *Appendix E*)

Simultaneously, a second review will be undertaken by the E-Team and District representatives and written comments will be proffered back to the LPDT using the review form and checklist attached in *Appendix E*. This review will focus primarily on accuracy of content and compatibility with the ongoing District documentation. It is important to note that the District will be responsible for incorporating the ERDC-EL documents into their integrated feasibility study reports and documents.

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A third, and final external Expert Technical Review (ETR) focused on the veracity of the model built for the study will be performed at the request of the laboratory's principal investigator. This third review team will be asked to review the validity of the model's basic premises, identifying any critical errors in model assumptions and providing any support documentation from their areas of expertise supporting the model's concepts. This third team (referred to as the Expert Technical Review Team or ETRT) will be comprised of regional experts (including university professors and local scientists with specific community knowledge of the local hydrology, ecology and geology), not directly associated with either the laboratory or District proposed project. Timing of this review will be dependent on the application's schedule, but will likely occur towards the end of the study's planning and evaluation process.[1]

*Technical Review Guidelines*

Technical review guidelines for the laboratory's internal quality control and LTR processes have been described above. A general summary is as follows:

1. Coordination with the customer;
2. Compliance with applicable laws, policies, and regulations;
3. Integration of multiagency input;
4. Milestone determination and attainment;
5. Document reviews and comment incorporation;
6. Technical review strategy sessions; and
7. Certification of Quality Control Plan acceptance.

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[1] *Appendix F* documents the comments received by reviewers and ERDC-EL's response to these comments.

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# 3 Community-based HSI Modeling

As described earlier in *Chapter 2* of this report, index models quantify the effects of change in a given ecosystem setting and can be used to account for restoration gains under the HEP assessment paradigm. This chapter describes the relevant ecological communities found along the Upper Des Plaines river and its tributaries as it runs from Wisconsin down into Illinois, and describes the process by which the E-Team developed and tested a small number of community-based HSI models for the purpose of assessing the efficacy of proposed alternatives for the current feasibility study. A general description of the variables and their relationships to one another are described for the model as well. The goal of this chapter therefore is to characterize the E-Team's effort to capture the general character of the relevant ecosystems using a traditional HEP-based index model-based approach.

## Model Development Workshops

A series of ten workshops were held over the course of seven years (2001-2008) to develop the models and characterize baseline conditions of the study area prior to plan formulation and alternative assessment for the ecosystem restoration study. Three separate community-based index models were developed under this paradigm (Forest, Savanna, and Prairie). Several federal state and local agencies, as well as local and regional experts from the stakeholders' organizations, and private consultants, participated in the model workshops.[1] In the first workshop, the E-Team was briefed on the project scope and opportunities by the District planners. Land and water management activities (e.g., hydrologic alterations, urban development and agricultural production) were identified as the system's key anthropogenic drivers. The stressors (i.e., physical, chemical and biological changes to system structure and function) were identified and grouped into five categories: 1) hydrologic alteration, 2) geomorphic and topographic alteration, 3) climate change, 4) urban encroachment and agricultural use, and 5) exotic species

[1]A list of E-Team participants can be found in *Appendix D*.

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introductions. Each stressor altered ecosystem integrity[1] within a water, soils, habitat and/or landscape context. For example, hydrologic alterations to the channel have caused changes not only in flooding frequency and duration, but have altered ecosystem function and structure across the basin. Urban encroachment has exacerbated these problems by reducing infiltration, increasing storm water runoff, and increasing disturbance regimes system-wide. These changes have ultimately led to opportunities for exotic species invasions reducing spatial complexity on a landscape scale. The direct and indirect effects of these alternations are as obvious as they are numerous – reduced hydrologic pulsing, reduced sediment transport, fragmentation, and loss of biodiversity.

## Coupling Conceptual Modeling and Index Modeling

Conceptual models are proving to be an innovative approach to organize communicate, and facilitate analysis of natural resources at the landscape scale (Harwell et al. 1999, Turner et al. 2001, Henderson and O'Neil 2004, Davis et al. 2005, Ogden et al 2005, Watzin et al. 2005, Alvarez-Rogel et al. 2006). By definition a conceptual model is a representation of relationships among natural forces, factors, and human activities believed to impact, influence or lead to an interim or final ecological condition (Harwell et al. 1999, Henderson and O'Neil 2004). In most instances these models are presented as qualitative or descriptive narratives and illustrated by influence diagrams that depict the causal relationships among natural forces and human activities that produce changes in systems (Harwell et al. 1999, Turner et al. 2001, Ogden et al. 1005, Alvarez-Rogel et al. 2006). No doubt, conceptual models provide a forum in which individuals of multiple disciplines representing various agencies and outside interests can efficiently and effectively characterize the system and predict its response to potential alternatives in a descriptive manner. In theory and practice, conceptual models have proved an invaluable tool to focus stakeholders on developing ecosystem restoration goals given recognized drivers and stressors. These in turn are translated into

[1] We prescribe to the Society of Ecological Restoration's (2001) definition of ***ecosystem integrity*** here, which has been defined as "the state or condition of an ecosystem that displays the biodiversity characteristic of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning."

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essential ecosystem characteristics that can be established as targets for modeling activities.

For purposes of this effort, a systematic framework was developed that coupled the traditional USACE planning process with an index modeling approach derived from a sound conceptual understanding of ecological principles and ecological risk assessment that characterized ecosystem integrity across spatial and temporal scales, organizational hierarchy, and ecosystem types, yet adapted to the project's specific environmental goals. Ideally, the development of conceptual models involves a close linkage with community-index modeling, and produces quantitative assessment of systematic ecological responses to planning scenarios (Figure 1).

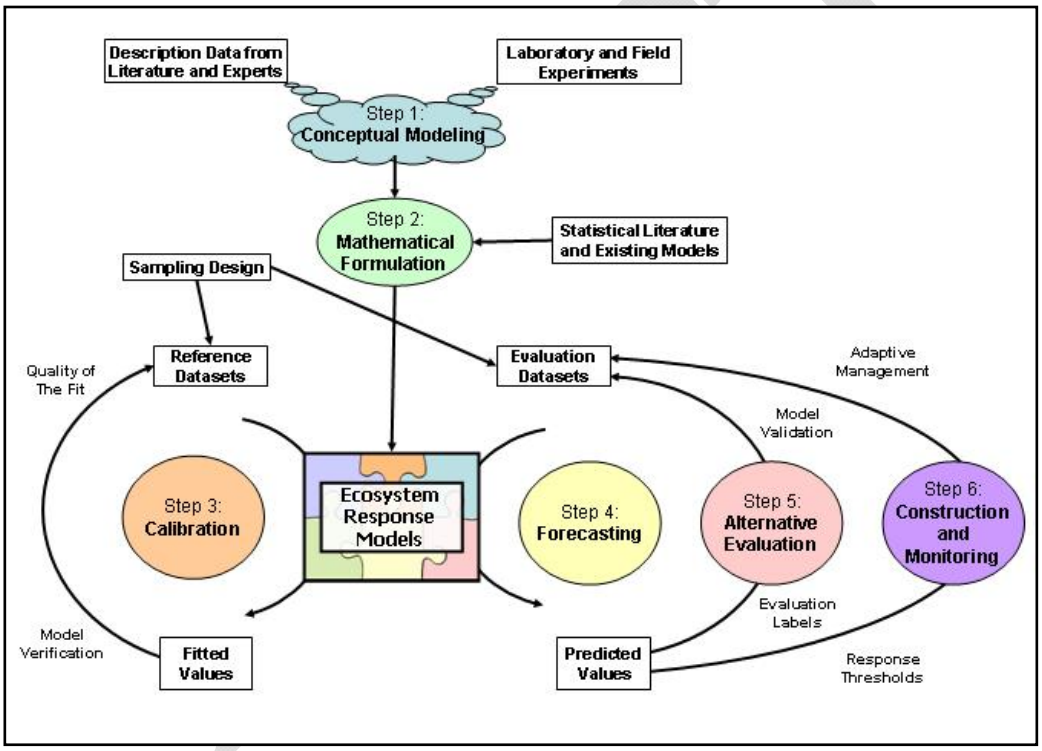


Figure 1. Overview of the successive steps (1-6) of the community-based index model building and application process for ecosystem restoration, where two data sets (one for calibration and one for alternative evaluations) are used (adapted from Guisan and Zimmerman 2000).[1]

[1] It is important to note here that the same models used to evaluate alternatives should be used in the future to monitor the restored ecosystem and generate response thresholds to trigger adaptive management under the indicated feedback mechanism. As such, the District can use the models developed early-on in the process to adaptively manage the system over the long-term.

Under this modeling paradigm, conceptual modeling led to the choice of an appropriate scale for conducting the analysis and to the selection of ecologically meaningful explanatory variables for the subsequent environmental (index) modeling efforts. These models were calibrated using reference-based conditions and modified when the application dictated a necessary change.

As a first step in the index model development process, ERDC-EL developed a conceptual model to illustrate the relationships between these system-wide drivers and stressors and tried to highlight the ecosystem responses to these pressures across the entire watershed (Figure 2).

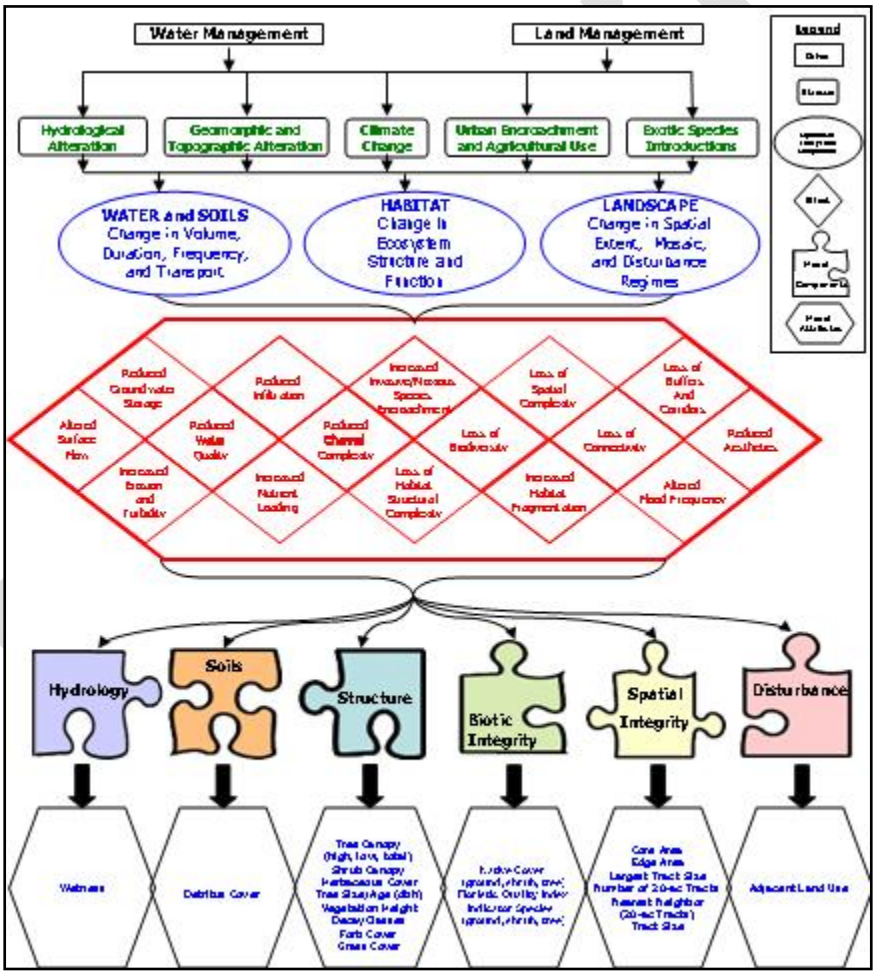


Figure 2. A conceptual model for the Upper Des Plaines Watershed.

Conceptually speaking, the “Significant Ecosystem Components” (water, soils, habitat, and landscape) were characterized by parameters responsive to project design. These parameters or variables (hydroperiod, vegetative

cover, disturbance, etc.) were grouped in a meaningful manner to quantify the functionality of the community in the face of change based on expert opinion and scientific literature. The effort to combine the variables in mathematical algorithms could then be viewed as community index modeling under the HEP paradigm. For purposes of organization, the community based index models were constructed from combinations of components – an analogy used was one of puzzle building. The individual model components were represented as "pieces" of the ecosystem puzzle, that when combined captured the essence of the system's functionality (Figure 3).

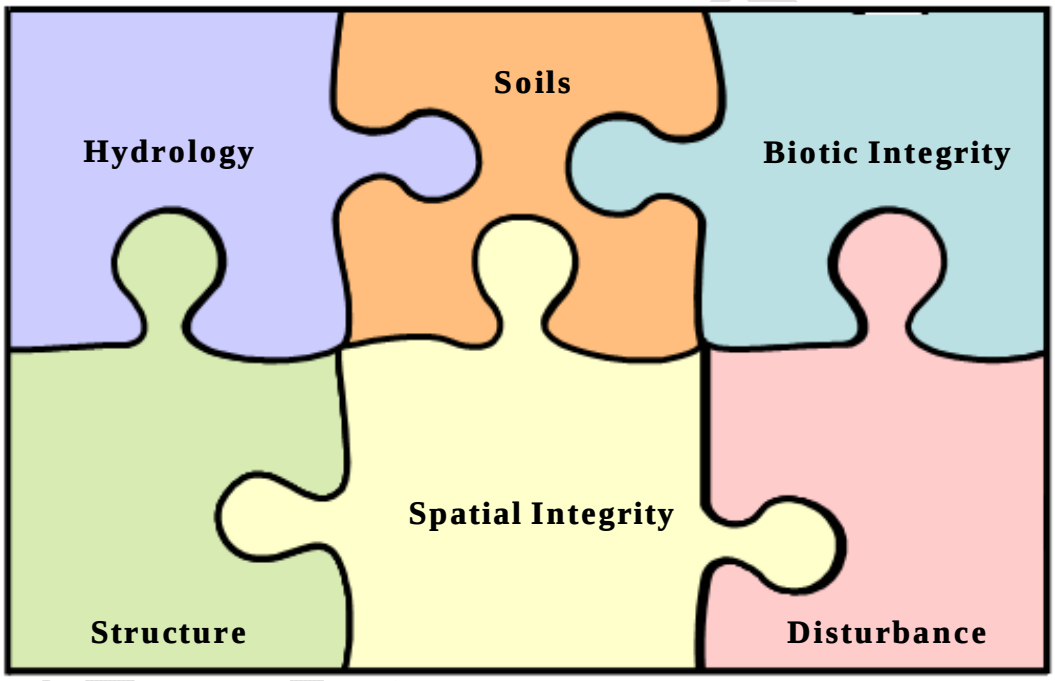


Figure 3. Within the conceptual modeling building framework, the various model components (color-coded for organization purposes) are pieced together to capture the essence of community functionality using the ecosystem puzzle analogy.

Vegetation communities in the area ranged from riparian forests, shrublands, savannahs, meadows, open marshes and the river itself. Out of this effort, three draft models arose: one for the watershed's woodlands (including flatwoods and the riparian zone), one for the system's savannas, and a final model for the watersheds wet/dry prairie complexes. Subsequent refinement of these models led to the identification of contributing ecosystem components, and a description of associated variables (with suggested sampling protocols) that can be used to measure ecosystem restoration benefits. The accuracy and utility of the proposed

models were “tested” (e.g., verified) with specific field and planning exercises on the District’s ongoing ecosystem restoration feasibility study. The application led ERDC-EL to modify the models several times over the course of the study to accommodate broader planning specifications. A general description of the system’s reference domain and the unique ecosystems therein follows.

## Characterization of the Upper Des Plaines River Watershed

### General Description

Northeastern Illinois has been described as the historic crossroads between America's East and West. Established as a natural portage between the Great Lakes and the Mississippi valley, this region served as the pivotal link in the nation's water, rail, and aviation networks. The central city, Chicago, is the economic and cultural capital of the Midwest. The metropolitan area is home to over eight million people. Public services are provided by six county governments, 272 cities and villages, and nearly 1,000 schools, park, and other special-purpose districts (Northeastern Illinois Planning Commission 2006). The population of this region has increased rapidly since the 1940s, and between 1990 and 2000, local population growth exceeded 40 percent (Figure 4) (Stumpf, Hansel, and Barnhardt 2006). A further increase is anticipated for some areas over the next 20 years (Northeastern Illinois Planning Commission 2006).

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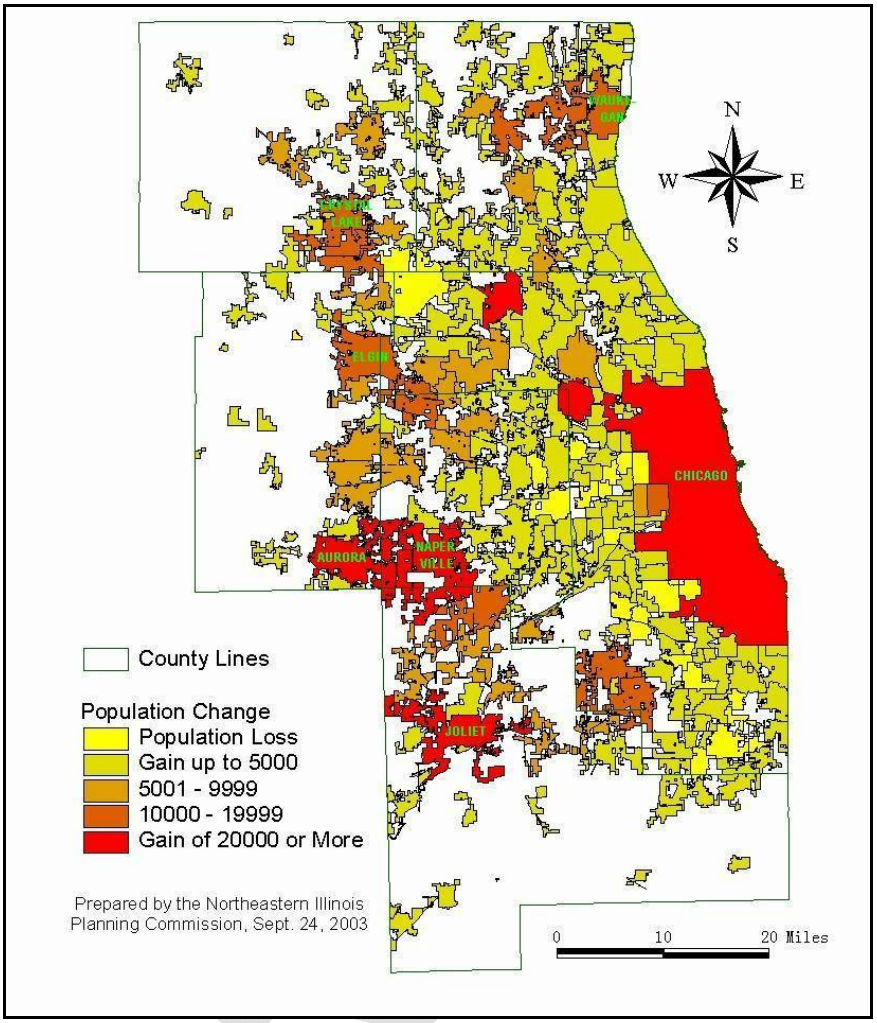


Figure 4. Population change by municipality in Northeastern Illinois between 1990 and 2000.[1]

The Des Plaines River watershed is still predominantly rural, but its proximity to the greater Kenosha, Milwaukee, and Racine urban areas subject it to advanced urbanization pressures. The public preference for low-density residential development (as indicated by the findings of attitudinal surveys conducted by SEWRPC in 1963, 1972, and 1991) and the diffusion of urban development outward from the older urban centers resulted in high rates of population growth in areas immediately adjacent to cities such as Kenosha, Milwaukee, and Racine (SEWRPC 2003).

[1] Map taken from the Northeastern Illinois Planning Commission website at http://www.nipc.org/region/#snapshots. Data retrieved March 2006.

The region encompasses 3,749 square miles of land and water. Nearly 40 percent of the land was still in agricultural production in 1990. Natural assets include 75 miles of Lake Michigan shoreline (over half of it in public ownership); 280 square miles of forest preserves, parks, and other open space (including irreplaceable areas of undisturbed prairie and oak savanna); 138 square miles of wetlands; and extensive river, stream and lake resources (Northeastern Illinois Planning Commission 2006).

The Des Plaines River originates near Racine, Wisconsin and enters Illinois two miles northeast of Rosecranes in Lake County. The river flows 97 miles south before it joins with the Kankakee River to form the Illinois River (IDNR 1998b). The Upper Des Plaines basin drains approximately 480 square miles spanning central Lake County, north-central Cook County, and the northeastern portion of DuPage County (IDNR 1998b). Three hundred forty-six square miles of the basin is in the state of Illinois, and encompasses a diversity of land cover and land uses. No other natural Illinois river runs through such an urbanized watershed and still has so many natural features intact (Figure 5).

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Figure 5. The upper Des Plaines River flowing through this highly urbanized watershed still retains its wilderness legacy in remnant pockets.

Visitors who described the area in 1840 reported that the land cover in the Upper Des Plaines basin consisted of 40 percent prairie and 60 percent forest and savanna (Krohe 1998). Scientists estimate that about a quarter of the basin was once wetlands of one type or another. West of the river, a complex landscape dominated by small lakes formed when the glacial ice melted. This landscape existed for more than 10,000 years between the times the great ice sheets stopped shaping the land to when the Euro-American settlers influence began to reshape the landscape (Krohe 1998).

Today, approximately 18 percent of the basin has been characterized as "wooded" and is made up of areas primarily in and along the forest

preserves. Non-forested wetlands in the form of marshes and wet meadows cover only 3.5 percent of the surface. Most of the lakes have been drained. Fewer than 167 pothole lakes survive in the Illinois northern reaches of the basin (Krohe 1998). Losses of pre-settlement habitat in the Upper Des Plaines basin are less severe than in the state as a whole. Currently, natural areas consisting of nearly 2,300 acres survive. Today, only 18 acres of high quality prairie remain of the nearly 90,000 acres of prairie thought to have been present in 1840 (Krohe 1998).

Due to air quality regulations implemented in the 1970's to protect public health, air pollutants have been drastically reduced (Krohe 1998). Pollution of surface water has also been reduced, but less dramatically. Water quality is declining in many of the area lakes, and their suitability for more demanding uses such as water supply and recreation could be impaired. According to the Illinois Environmental Protection Agency, the overall water quality can only be considered as fair (Krohe 1998). While the reaches of the Upper Des Plaines River are too small for navigation, they do function as a sewer for the basin especially when stormwater overwhelms treatment plants. In addition, surface water quality is often compromised by hard-to-regulate non-point sources including soils washing from fields and building sites, de-icing salts washing in from roads, and phosphorous discharging into the system from lawns and croplands (Krohe 1998).

Fragmentation directly attributed to the construction of roads, agricultural practices, and urban sprawl is dividing once intact habitats into small "islands." Such splintered tracts are often too small for larger species to roam, resulting in their emigration, while making other populations more vulnerable to disease and genetic stress from in-breeding (Krohe 1998). Fires, which are required for prairie and savanna regeneration, have been reduced to small controlled burns within preserves, resulting in the conversion of savanna to dense woodlands (Krohe 1998). Exotic plants and animals have been introduced into the basin, often with unintended ecological effects such as finding a major advantage over native species when competing for habitat, often choking out the native species and unbalancing the native community (Chicago Region Biodiversity Council 1999). Seventy percent of the vascular plants species in the basin are not native to the area. Approximately 30 introduced plant species have adapted so well to the disturbed ecosystems that they have become pests

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(e.g. garlic mustard, reed canary grass, and Kentucky bluegrass) (Krohe 1998) (Figure 6).

Figure 6. Field of garlic mustard, an invasive plant that disrupts natural systems.[1]

The economic base of the basin is diverse and growing. As the density of business in the region has increased, a supporting infrastructure of experts has also increased, doubling the number of jobs in Lake County, IL since 1970 (Krohe 1998). This trend, along with a long-standing shift of the state's population to northeast Illinois, has resulted in Lake County's population quadrupling (Krohe 1998).

### Reference Domain

The reference domain decided by the District and the E-Team for these models is defined as the Upper Des Plaines River watershed, which spans the southeast corner of Wisconsin and northeastern portions of Illinois. The decision was based on time and funding limits of the initial study. The watershed covers five counties: Racine and Kenosha Counties in Wisconsin; and Lake, Cook, and DuPage Counties in Illinois (Figure 7). The Upper Des Plaines Watershed encompasses approximately 308,899 acres with 41 percent (129,410 acres) found in Lake County alone (Figure 8). Cook and Kenosha Counties contribute another 29 and 26 percent respectively (88,356 and 78,910 acres). The remaining four percent is

[1] Photo courtesy of the Liberty Prairie Conservancy, found on the UDPREP website: www.upperdesplainesriver.org/resources.htm. Data retrieved November 2005.

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divided across Racine and DuPage Counties (6,850 and 5,372 acres respectively).

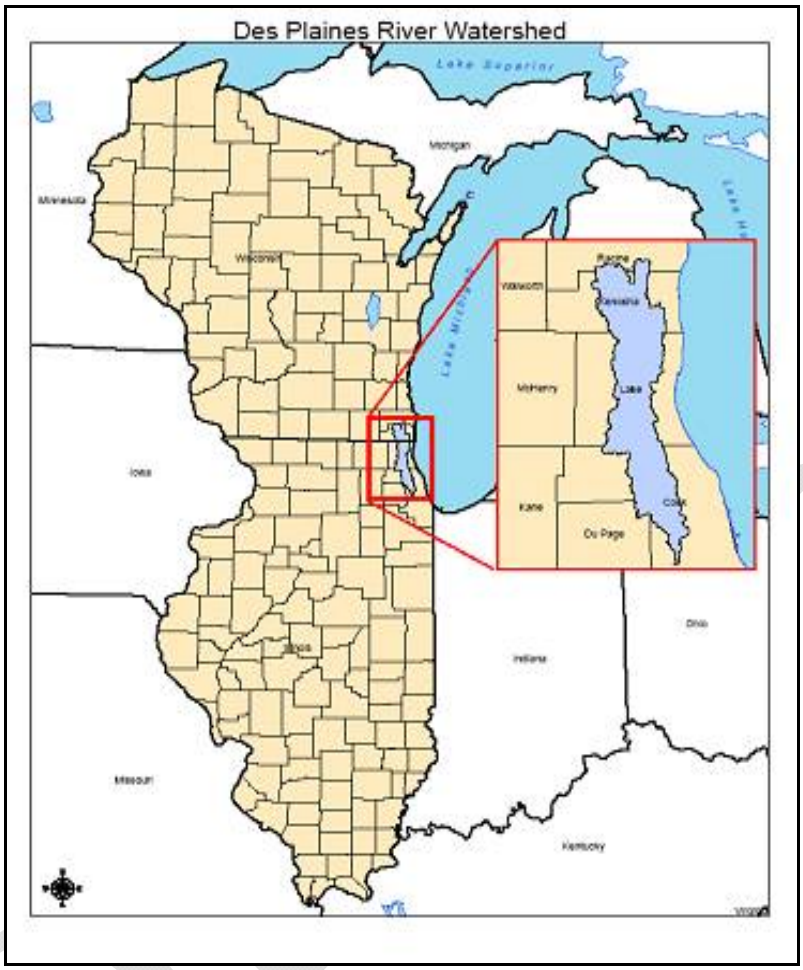


Figure 7. Location of Upper Des Plaines River Watershed in Wisconsin and Illinois.

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Figure 8. Distribution of acreages across the five counties in the Upper Des Plaines Watershed.

*Climatic Characterization*

The climate of the Upper Des Plaines basin is typically continental and is supported by its changeable weather and the wide range of temperature extremes. However, this climate is moderated by the region's close proximity to Lake Michigan. Temperatures range from average lows in the

teens to 20°s F in the winter to average highs in the 80°s F in the summer (IDNR 1998b). Based on the latest 30-yr average first occurrence of freezing temperatures in the fall is October 15, and the average last occurrence of freezing temperatures in the spring is May 1 (IDNR 1998b).

Mean annual precipitation in the area is 34.20 inches (Figure 9) (IDNR 1998b). Rainfall is normally heaviest during the growing season and lightest in midwinter. The months with the most snowfall are November through April. Heavy snowfalls rarely exceed 12 inches (IDNR 1998b).

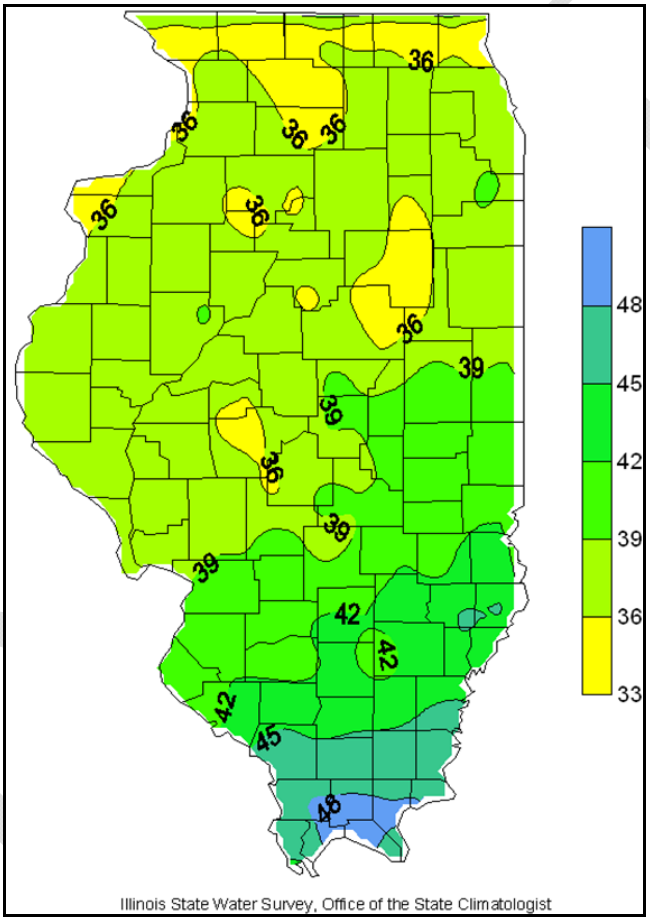


Figure 9. Mean annual precipitation (inches) across the state of Illinois from 1971-2000.[1]

[1] Map used with permission from Illinois State Water Survey (2005). *"What are the Dimensions of Water Availability in Illinois?"* found on the website at http://www.sws.uiuc.edu/docs/wsfaq/. Data retrieved November 2005.

*Geomorphic Characterization*

The geology of the region plays a key role in where flora and fauna prefer to grow, where streams flow, and where urban centers thrive. Ice was the key architect of the reference domain's landscape. Major land contouring began about 26,000 years ago and ended about 13,000 years ago when the glaciers receded from the Chicago region for the last time (Sullivan 2001). The Ice Age (i.e., Pleistocene) saw four major ice advances in eastern North America. The first occurred about 500,000 years ago. The last advance (the Wisconsin stage) began about 70,000 years ago. At one time, the Wisconsin ice spread as far as Shelbyville, Illinois (200 miles south of Chicago). The current landscape reveals the complex series of ice movements that occurred during the later years of the Wisconsin glacial episode. The glaciers that covered the region were as much as a quarter of a mile thick. In central North America, the ice followed river valleys, and over the course of the Pleistocene, scoured those valleys into the deep, broad basins that now hold the Great Lakes (Figure 10).

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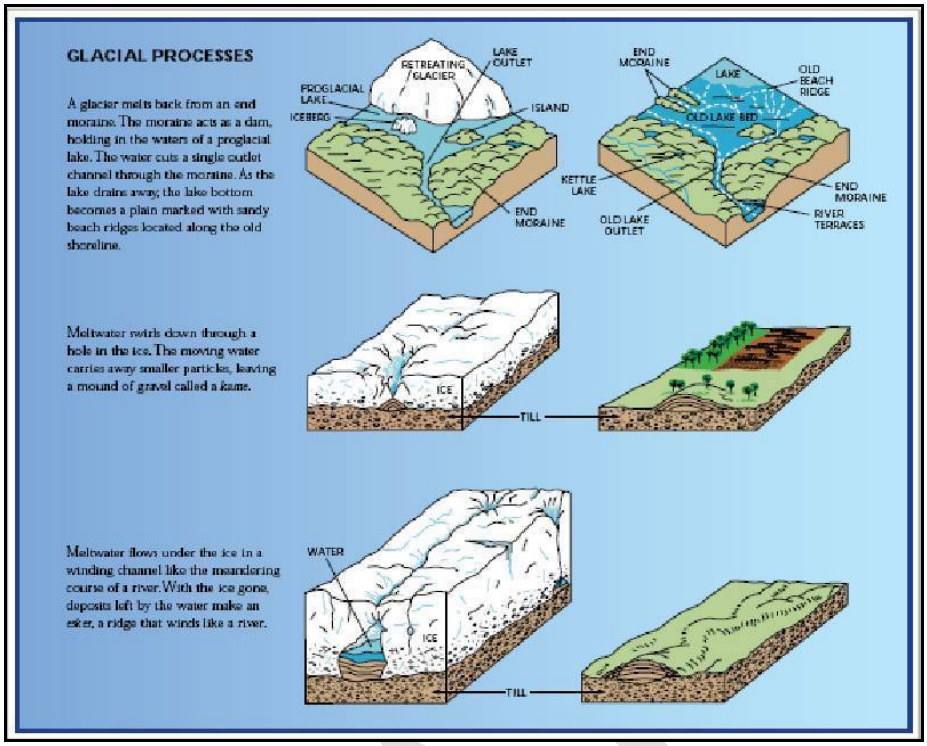


Figure 10. The glaciation process in the reference domain.[1]

The landscape of the Chicago region recorded five major advances of the ice out of the Lake Michigan basin alternating with periods when the ice retreated to the basin. The glacial constructions covered the bedrock foundation from 320 to 505 million years ago (Paleozoic era) (IDNR 1998a). The bedrock surface is a complex of buried valleys, lowlands, and uplands, where the buried valleys contain coarse-grained sediments that form important productive aquifers (Horberg 1945). These valleys were probably formed by a regional drainage network that existed prior to continental glaciers (IDNR 1998a). In the Chicago region, the most common type of bedrock was a magnesium-rich limestone called dolomite that was originally deposited on reefs set in shallow seas during the Silurian period about 400 million years ago. A layering process of glacial deposition best describes the geological history of the Chicago region (Figure 11).

[1] Diagram taken from Sullivan (2001). *An Atlas of Biodiversity*. Chicago Wilderness, 66 pp.

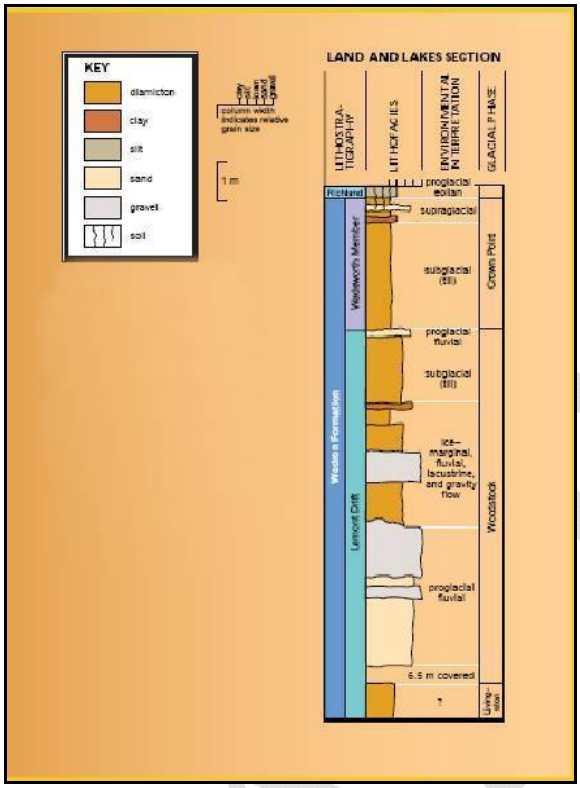


Figure 11. Layers illustrate the predominant geology within the reference domain.[1]

From the bottom up, sorted sands and gravels left by meltwater flowed from distant ice fronts. As the ice moved closer, unsorted diamicton was mixed with sorted gravel. As the ice covered the area, unsorted till was deposited. Rapid melting left material carried on the top of the glacier along the surface. As the ice retreated, wind (eolian) scattered dust over the earlier deposits. In general, the surface features were comprised of material deposited by the glaciers or by the lakes that appeared as the glaciers melted. In some places, these deposits were nearly 400 feet thick.

Deposits of glacial origin generally range from less than 100 feet to 200 feet thick or more. The thickest drift exists in the northern half of the area and thins southward (IDNR 1998a). The land surface of the area is composed of several closely grouped end moraines (Figure 12) that generally run north to south and roughly parallel the western shoreline of Lake Michigan. The moraines were formed at the margin of the glacial ice

[1] Diagram taken from Sullivan (2001). *An Atlas of Biodiversity*. Chicago Wilderness, 66 pp.

as it stood for several hundred years before melting back into the Lake Michigan basin and beyond. They are composed of till and indicate that the glacial margin pulsated back and forth several times while the ice was active (IDNR 1998a).

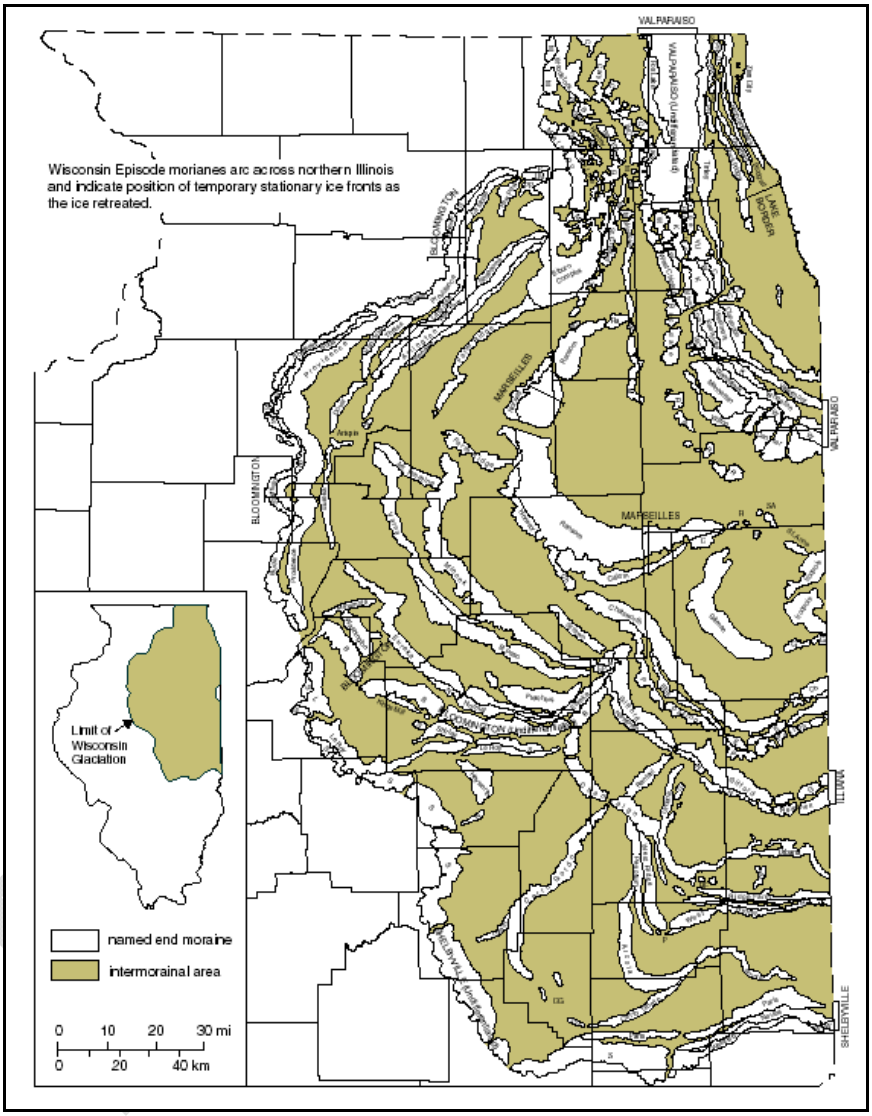


Figure 12. End moraines of the Wisconsin Glacial Episode (map scale equals 1:500,000).[1]

The glacial sediments found in the area today can generally be grouped into three categories: (1) an uppermost clayey till of the Wadsworth

[1] Map used with permission from Illinois State Geological Survey, found in Willman, H. B. and Frye; J. C. (1970). Pleistocene Stratigraphy of Illinois; Illinois State Geological Survey Bulletin 94, plate 1.

Formation from the Wedron Group, (2) underlying the Wadsworth, a silty gravelly till of the Lemont Formation from the Wedron Group, and (3) in western Lake County, under the Lemont, a reddish-gray silty till of the Tiskilwa Formation (Hansel and Johnson 1986). All three layers of glacial drift are thicker to the west and become thinner to the east.

As shown in Figure 13, the surficial unit over most of the Upper Des Plaines watershed is the clayey till of the Wadsworth Formation. Outwash of the Henry Formation from the Mason Group occurs primarily along the length of the Des Plaines River (IDNR 1998a). The river probably established its present valley while the ice margin stood immediately to the east, and the sand and gravel outwash was deposited in the valley that served as the melt-water outlet. Small areas near the Wisconsin border have lake sediments of the Equality Formation, and modern stream alluvium (Cahokia Formation) occurs along the streams (IDNR 1998a).

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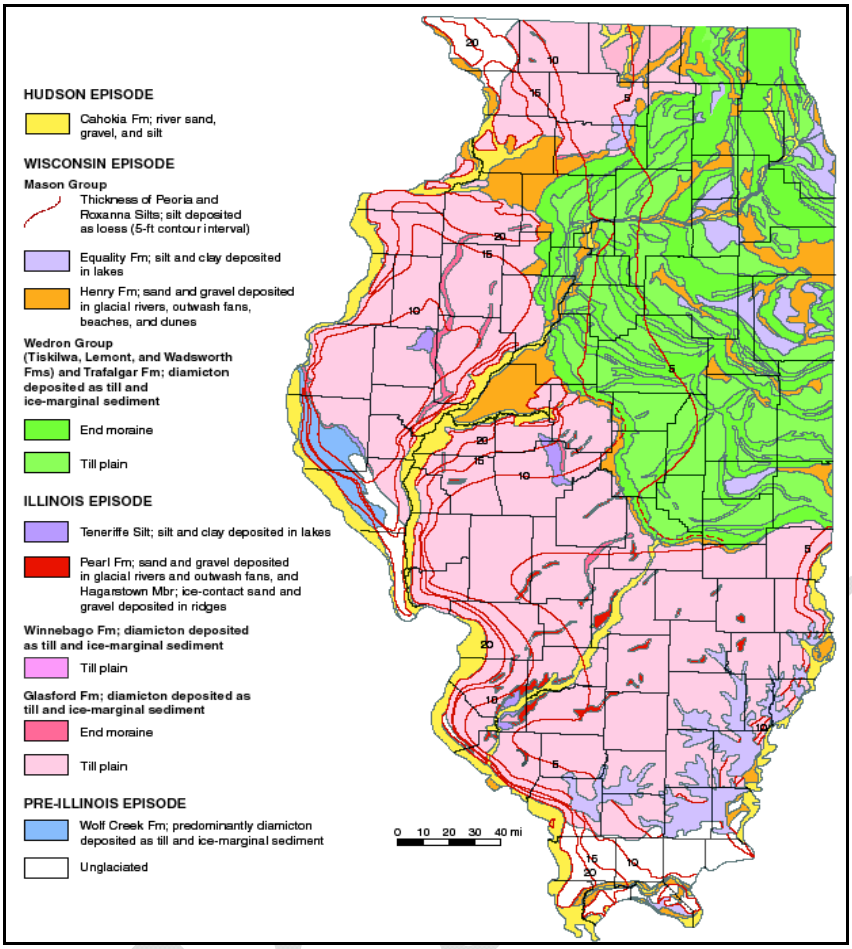


Figure 13. Quaternary deposits found in Illinois (map scale equals 1:500,000).[1]

Soil development in the area was strongly influenced by geologic, topographic, and biologic differences that created habitats conducive to the development and survival of various natural communities. Along the Des Plaines River in southwestern Cook and western Will Counties, bedrock was exposed in large enough quantities to support flora and fauna. Here, unique communities of plants and animals reside today on soils only a few inches thick deposited on the underlying bedrock. Over the course of centuries, topography, drainage, climate, and vegetation shaped these raw materials into the soils we see today (Figure 14).

[1] Map used with permission from Illinois State Geological Survey, found in Lineback; J. A. 1979. *Quaternary Deposits of Illinois*; Illinois State Geological Survey.

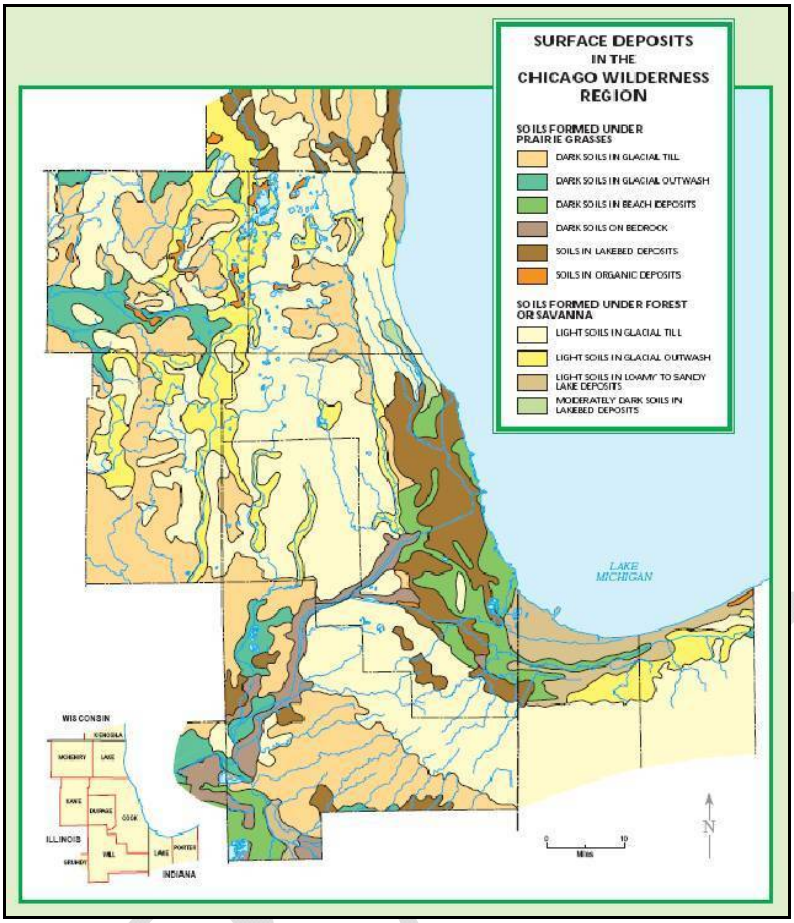


Figure 14. Surface depositing in the reference domain.[1]

Differences in the frequency, rate, and magnitude of surficial geologic processes have created many combinations of slope, angle, length, and orientation which in turn have influenced local drainage patterns, erosion, and sedimentation processes. Modifications by human activities have caused significant changes to the frequency, rate, and magnitude of surficial processes that directly affect localized communities (IDNR 1998a).

The age and physical characteristics of the geologic materials underlying the thin layer of loess blanketing the landscape has played an important role in soil development as well. The northern portion of the basin has greater amounts of wetlands with poorly drained soils than the southern

[1] Map taken from Sullivan (2001). *An Atlas of Biodiversity*. Chicago Wilderness, 66 pp.

portion (IDNR 1998a). The recency of glacial activity that deposited these materials has contributed to the lack of an extensive surface water stream network. Many of the soils in these wetland areas are slowly permeable, experience seasonally high water tables, are susceptible to shrink-swell due to clay plasticity, and are only marginally suitable as construction foundation materials (IDNR 1998a).

The basin is predominantly comprised of morainal features commonly associated with active ice glaciation and demonstrating limited erosional change (IDNR 1998a). The landscape can generally be characterized as uplands and lowlands (Figure 15). Much of the land in the basin is considered uplands, including the extensive regions of higher ground and end moraines. The lowlands occur mostly along stream valleys, floodplains, and areas occupied by sediments deposited by former lakes (IDNR 1998a).

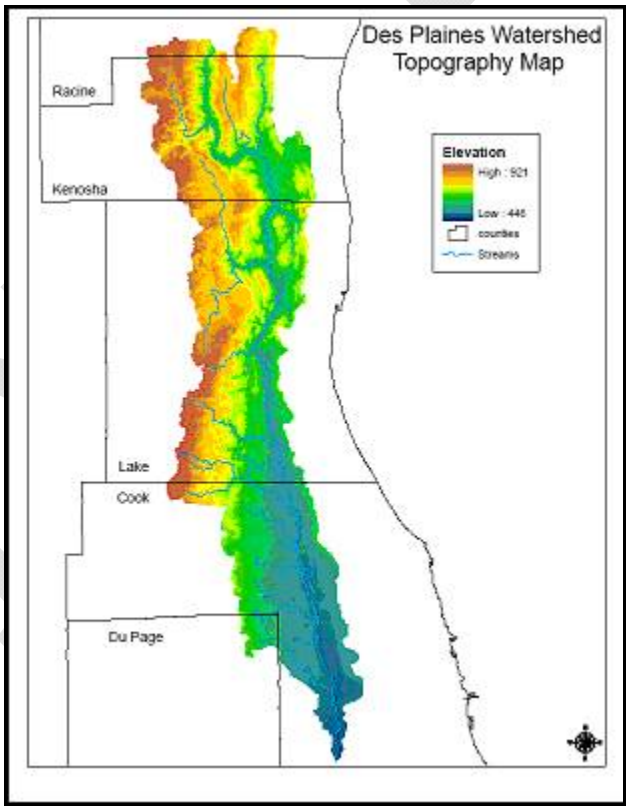


Figure 15. Topography of the Des Plaines Watershed.

The nature of the soils within the Des Plaines River watershed has been determined primarily by the interaction between the parent glacial

deposits covering the Region and topography, climate, plants, animals, and time. Within each soil profile, the effects of these soil-forming factors are reflected in the transformation of soil material in place, chemical removal of soil components by leaching or physical removal by wind or water erosion, additions by chemical precipitation or by physical deposition, and transfer of some soil components from one part of the soil profile to another (SEWRPC 2003). The STATSGO database (USDA 1994) lists fifteen soils associations in the reference domain (Figure 16).

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Figure 16. Soils in the reference domain.

The most widespread are the Morley-Markham-Ashkum (32 percent of the total area), Urbanland-Markham-Ashkum (14 percent), Varna-Elliott-Ashkum (13 percent), Elliott-Ashkum-Varna (10 percent), and Drummer-Plano-Elburn (six percent) (USDA 1994).

These soil associations fall predominantly into two soil orders: Mollisols and Alfisols, with scattered occurrences of Entisols and Inceptisols on floodplains and sandy outwash areas and along stepper, eroded uplands (IDNR 1998a). The two types can be differentiated by the accumulation of organic matter in the upper soil horizon. By definition, mollisols have a darker soil color and develop under prairie grassland vegetation, and are considered more fertile (Figure 17).

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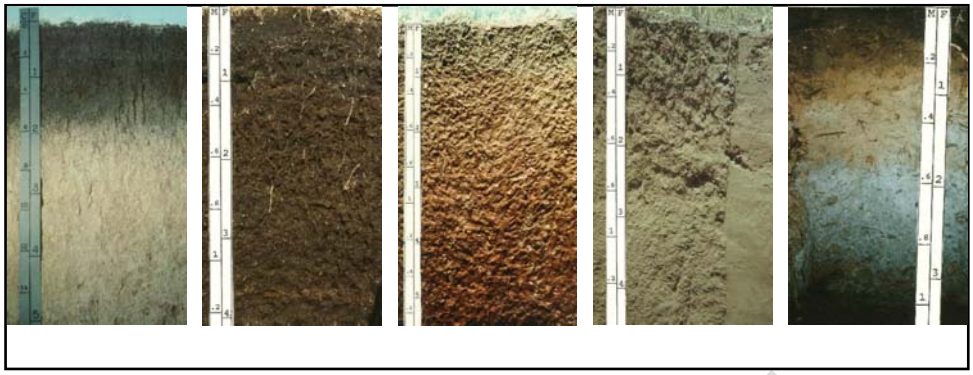

Figure 17. Illustration of soil characteristics.[1]

Alfisols are not as organically rich, have thinner upper soil horizons, and develop under deciduous forest vegetation. Entisols and Inceptisols have minimal soil horizons and occupy small but significant areas because they help created niche communities (IDNR 1998a). The depressional, hummocky areas within the irregularly shaped hills of the region are often site of thick accumulations of peat and muck at various stages of decomposition (e.g., Histosols). These soils are associated with wetlands and are very susceptible to the degradation by oxidation if they are drained. They commonly form under unique hydrologic conditions conducive to hydrophytic vegetation (IDNR 1998a).

Slow permeability and erosion potential are two major problems faced by land owners in this area. The hummocky, uneven landscape prevalent throughout the area, combined with the relatively fine-textured sediments, makes high water tables, frequent flooding, and sedimentation a problem in low-lying areas. Sixty percent of the area is covered by soils developed in silty clay and silty clay loam-textured till, which is generally slowly permeable and subject to considerable wetness (IDNR 1998a). Soil erosion becomes a major concern where slopes greater than five percent occur. Where slope angles increase around moraines and drainages, erosion increases significantly (IDNR 1998a). The steeper slopes adjoining the floodplains are often susceptible to severe soil erosion through sheetwash and the development of gully networks. Uncontrolled erosion and sedimentation can seriously damage in-channel and streambank ecology

[1] Photos courtesy of Iowa State University and the Natural Soils Survey Center, found on the soil order website. http://www.riverdell.k12.nj.us/staff/molnar/picturesoilscomplete.htm. Data retrieved March 2006.

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by altering water tables, channel capacity, and channel geometry (IDNR 1998a).

*Hydrologic Characterization*

Water resources are an essential component of any ecosystem because they provide different types of habitats for aquatic and terrestrial biota. In addition to their natural functions, they serve as sources of water supply for domestic, industrial, and agricultural use. There are more than 500 miles of rivers and streams in the Upper Des Plaines basin (IDNR 1998b). The Des Plaines River drains in a generally southeasterly direction across the Wisconsin-Illinois border beyond Chicago proper (SEWRPC 2003). The river then travels southerly to its confluence with the Kankakee River, where the two rivers join to form the Illinois River (Figure 18).

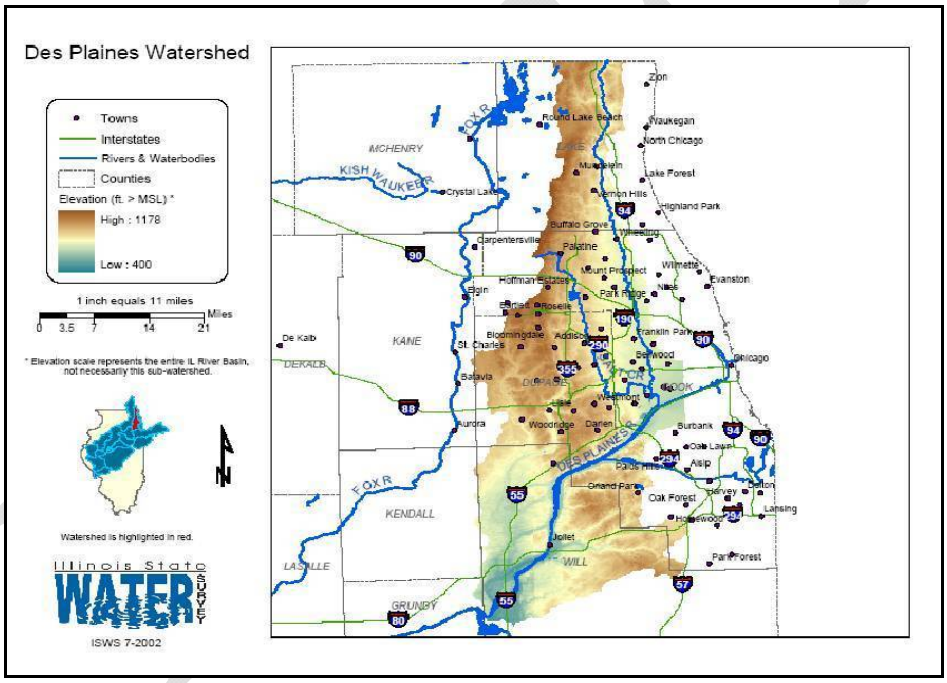


Figure 18. Des Plaines River watershed surface hydrology.[1]

The watershed is bounded on the north by the Fox and Root River watersheds, on the west by the Fox River watershed, and on the east by the Pike River watershed and areas directly tributary to Lake Michigan. The

[1] Map used with permission from Illinois State Water Survey (2006), found on the website at http://www.sws.uiuc.edu. Data retrieved March 2006.

river itself is 67 miles long and flows through 33 municipalities. This study expands the area of concern from the main stem in Illinois to include the entire Upper Des Plaines watershed, 15 tributaries and their subwatersheds in Illinois and Wisconsin (Figure 19). Historically, the Des Plaines River system was a narrow elongated depression within the late Wisconsinan Age glacial drift (Pepoon 1927). The Upper Des Plaines River, from the confluence of Salt Creek northward, was very shallow and about 30 feet wide with banks of terraced alluvium and covered with hydrophytic vegetation (Pepoon 1927).

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Figure 19. Upper Des Plaines River subwatersheds.

The characteristics of the surface drainage of the Upper Des Plaines River watershed are diverse with respect to channel cross-sectional shape, channel slope, degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is due partly to the natural effects of glaciation superimposed on the bedrock, and partly to the extensive channel modifications and other results of urbanization that are evident throughout the watershed. The quantity and quality of water at a particular location within the Des Plaines watershed can vary greatly with time. Average streamflow varies greatly from year to year. Over the 57 years of record, the annual flows have ranged from one inch in the drought of 1940, to a high of almost 25 inches in 1993 (IDNR 1998b). The long-term average flow in the basin is approximately 9.4 inches per year. These variations may occur rapidly or slowly and may occur in the atmosphere, on the land, in the surface waters, or in the groundwater of the watershed. Moreover, these variations may involve water in all its states—solid, liquid, and vapor (SEWRPC 2003) (Figure 20).

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Figure 20. Example of Upper Des Plaines River Watershed surface hydrology.[1]

Precipitation is the primary source of all water in the Des Plaines River watershed. Part of the precipitation runs directly off the land surface into stream channels and is ultimately discharged from the watershed; part is temporarily retained in snow packs, ponds, and depressions in the soil or on vegetation, and is subsequently transpired or evaporated; while the remainder is retained in the soil or passed through the soil into a zone of saturation or groundwater reservoir. Some water is retained in the groundwater system; but in the absence of groundwater development, much eventually returns to the surface through conveyance in agricultural drain tile systems or as seepage or spring discharge into ponds and surface channels. This discharge constitutes the entire natural flow of surface streams in the Des Plaines River watershed during extended periods of dry weather (SEWRPC 2003) (Figure 21).

With the exception of the groundwater in the deep sandstone aquifer underlying the watershed, all of the water on the land surface and

[1] Photo courtesy of Jeff Lin, ERDC-EL.

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underlying the Des Plaines River basin generally remains an active part of the hydrologic system.

Figure 21. Example of Upper Des Plaines River Watershed tributary surface hydrology (2002 photo of Mill Creek).[1]

Groundwater originates as precipitation that filters into the ground. As precipitation infiltrates the soil, the most recent glacial aquifers (surficial aquifers) are recharged. Water can flow downward to recharge bedrock aquifers in areas where the surficial aquifers directly overlie the shallow-bedrock aquifers (Arnold, et al. 1999). The permeability of the soil and surficial deposits partially determines the rate of infiltration.

In the deep aquifer, water is held in storage beneath the nearly impermeable water-tight Maquoketa shale formation and is, therefore, taken into the hydrologic cycle in only a very limited way. Since the recharge area of the deep aquifer lies entirely west of the Des Plaines River watershed, artificial movement through wells and minor amounts of leakage through the shale beds provide the only connection between this water and the surface water and shallow groundwater resources of the watershed (SEWRPC 2003) (Figure 22).

[1] Photo courtesy of Lake County Storm Water Management Commission.

Figure 22. Example of Upper Des Plaines River Watershed surface hydrology (2002 photo at the Druce Lake site).

As the water infiltrates the soil, it begins to change chemically due to reactions with air in the soil and with earth materials through which it flows. Contamination is generally the result of human-induced chemical changes and not naturally occurring processes. Much of the contamination of Illinois' groundwater is localized (IDNR 1998b). On a watershed scale, groundwater has not been degraded with respect to Iron, Total Dissolved Solids, Sulfate, Nitrate, Chloride, or Calcium Carbonate (hardness) (IDNR 1998b).

*Vegetative Characterization*

An ecosystem's vegetation at any given time is determined by a variety of factors, including climate, topography, soils, proximity to bedrock, drainage, occurrence of fire, and human activities. Because of the temporal and spatial variability of these factors and the sensitivity of different forms of vegetation to these factors, the system's character is one of dynamic, changing juxtapositions (i.e., a fluid mosaic). Of particular concern for this effort, is the state of the vegetative communities within the model domain (Figure 23).

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Figure 23. At stake - the dwindling forest, savanna and prairie communities (2002 photos taken by the field data collection team at various locations across the watershed).

The pre-settlement vegetation in Illinois generally can be described as prairie and forest (Figure 24). Early surveys described native vegetation east of the Des Plaines River as mostly savanna with local pockets of prairie including wet prairie and marsh (IDNR 1998c). Forest communities were present along the east border of the river. West of the river was a complex of savanna, prairie, marsh and small lakes (IDNR 1998c). Savannas were spatially dynamic and their total area and distribution varied on pre-settlement landscape depending on several factors including local conditions of climate, and fire frequency and intensity (Taft 1997). Fire is generally considered to have been a major ecological factor in maintenance of tall-grass prairie, savanna, and open woodland vegetation in the Midwest (Anderson 1990).

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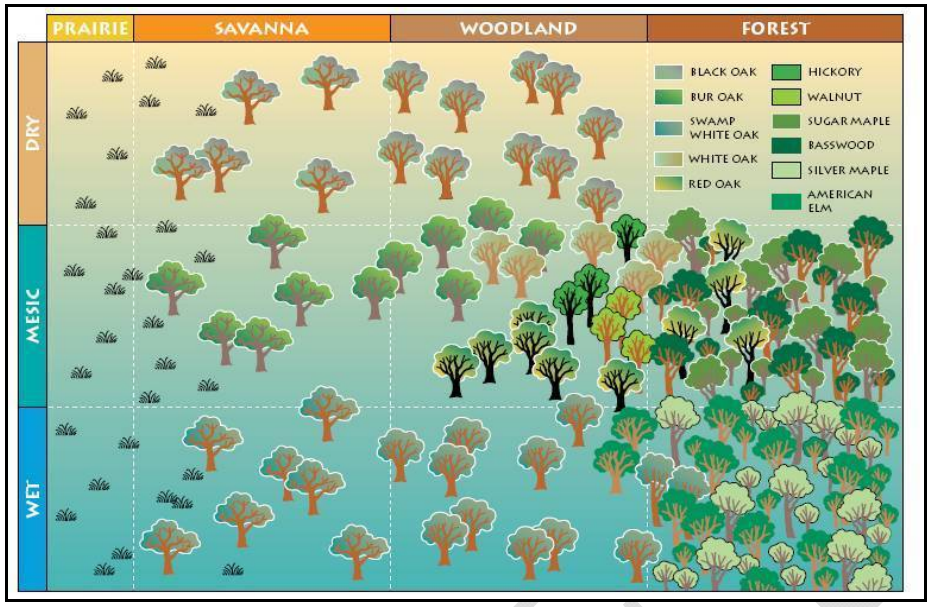


Figure 24. Pre-settlement communities of the region, separated by soil moisture and density of canopy cover.[1]

To fully quantify the habitat conditions for this area, it is useful to divide the project into manageable sections and quantify these in terms of acres per habitat type. This process, referred to as "cover typing," allows the user to define the differences between vegetative "types" (e.g., forest, shrublands, wet/dry meadows, etc.), hydrology and soils characteristics, and clearly delineate these distinctions on a map. The final classification system, based primarily upon dominant vegetation cover, captures "natural" settings and common landuse practices in a specific and orderly fashion that accommodates USACE's plan formulation process.

To facilitate model development, a series of 33 unique landuse/land cover types (i.e., cover types or CTs) were identified based on a classification system developed by the Chicago Region Biodiversity Council (1999, page 32 and Appendix 1) with input from the E-Team on indicator species and underlying soil conditions (Table 1).

[1] Figure taken from Sullivan (2001). *An Atlas of Biodiversity*. Chicago Wilderness, 66pp.

Table 1. Cover types identified and mapped for the reference domain.

| No. | Code | Description |
|---|---|---|
| 1 | AGCROPLAND | Agricultural Croplands |
| 2 | BOGSFENS | Forested Bogs and Fens (Calcareous Floating Mat Fens, Forested Fens and |
| 3 | DETENTION | Other Man-made Lakes (Detention Ponds, Borrow Pits, etc.) |
| 4 | FORFLPLWET | Wet-mesic and Wet Floodplain Forests |
| 5 | FORNFLATS | Northern Flatwood Forests |
| 6 | FORUPLWET | Wet-mesic Upland Forests and Wet-Mesic Woodlands |
| 7 | LAKEARTIFC | Naturalized Man-made Lakes |
| 8 | LAKEGLACL | Glacial Flowthrough and Kettle Lakes |
| 9 | MARSHBASIN | Basin Marshes |
| 10 | MARSHSTRMS | Streamside Marshes |
| 11 | MEADOW | Sedge Meadows |
| 12 | NEWFORFLAT* | Newly Developed Northern Flatwood Forests |
| 13 | NEWFORFWET* | Newly Developed Wet-mesic and Wet Floodplain Forests |
| 14 | NEWFORUWET* | Newly Developed Wet-mesic Upland Forests |
| 15 | NEWLAKEART* | Newly Developed Naturalized Man-made Lakes |
| 16 | NEWMARSHBS* | Newly Developed Basin Marshes |
| 17 | NEWMARSHSS* | Newly Developed Streamside Marshes |
| 18 | NEWMEADOW* | Newly Developed Sedge Meadows |
| 19 | NEWPRARDRY* | Newly Developed Dry and Mesic Fine-textured-soil Prairies |
| 20 | NEWPRARWET* | Newly Developed Wet Fine-textured-soil Prairies |
| 21 | NEWSAVDRY* | Newly Developed Dry-mesic and Mesic Fine-textured-soil Savannas |
| 22 | NEWSAVWET* | Newly Developed Wet-mesic Fine-textured-soil Savannas |
| 23 | NEWSTREAMS* | Newly Developed Streams |
| 24 | NEWWOODLND* | Newly Developed Dry-mesic and Mesic Woodlands |
| 25 | PARKS | Parks and Open Spaces |
| 26 | PASTURES | Pastures, Haylands and Urban Fields |
| 27 | PRAIRIEDRY | Dry and Mesic Fine-textured-soil Prairies |
| 28 | PRAIRIEWET | Wet Fine-textured-soil Prairies |
| 29 | SAVANNADRY | Dry-mesic and Mesic Fine-textured-soil Savannas |
| 30 | SAVANNAWET | Wet-mesic Fine-textured-soil Savannas |
| 31 | STREAMS | Streams |
| 32 | URBAN | Urban Lands (Residential, Commercial, and Roads) |
| 33 | WOODLNDDRY | Dry-mesic and Mesic Woodlands |

*Cover types identified as “NEW” refer to newly developed areas proposed in conjunction with construction of proposed alternatives.

These existing cover types were subsequently mapped using GIS (and ground-truthed during the 2002-2003 field seasons) (Figure 25).

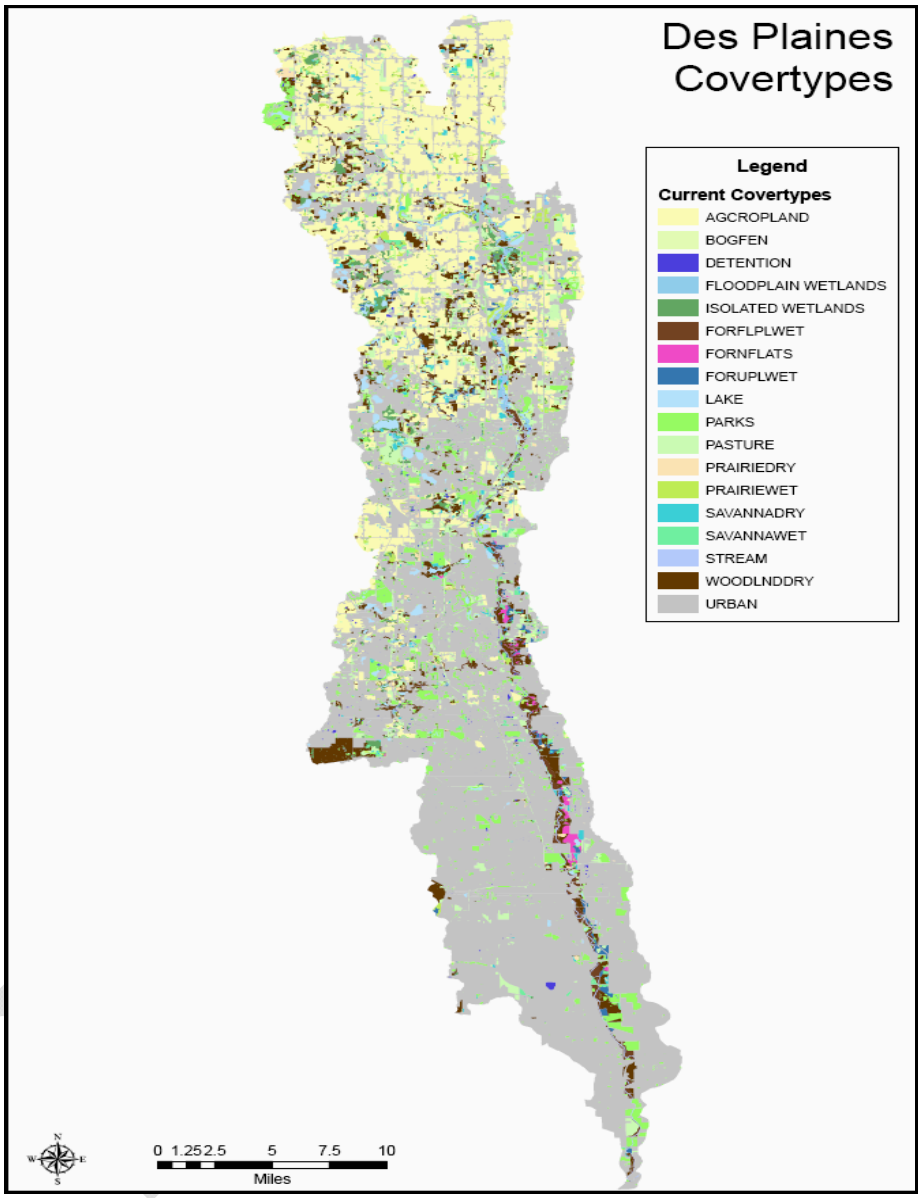


Figure 25. Cover type map for the reference domain.

Generally speaking, current land cover is dominated by urban land uses, including agriculture cropland and pastures (approximately 85 percent). The southern half of the watershed includes part of the Chicago metropolitan area. The majority of the forested areas (approximately 8 percent, including upland and floodplain) are concentrated on the slopes and along the Des Plaines River main stem and tributaries. Grasslands

(approximately 2 percent) present in the landscape include fields, rights-of-way and remnant prairies. They are concentrated in the northern half of Lake County and are virtually absent from Cook County. Non-forested wetlands (including marshes, wet meadows, and bogs) have declined dramatically only accounting for approximately 3.5 percent of the landscape. Remaining wetlands are concentrated along the Des Plaines River and scattered throughout Lake County, particularly west of the river. Open water accounts for the remaining 1.5 percent and occur in the lakes of the watershed.

## Community Characterizations

### Prairie Community Characterization

By definition, the prairie community in the Upper Des Plaines watershed can be characterized as grasslands that have developed on flat lands in areas commonly subjected to long periods without rainfall (Figure 26).

Figure 26. Classic example of the prairie community in the Upper Des Plaines Watershed (photo taken at the Zoo Area in August 2002).

The drought periods may be regular seasonal occurrences, or they may occur only in some years, like those in the Midwest. Short-grass prairies found in the West have less than 20 inches of precipitation a year. With increasing precipitation, the grasses and other plants grow taller. From

central Nebraska east, tall grass prairies dominate the landscape (Sullivan 2001). In the presence of fire, prairie communities thrive, however, in its absence, prairies are invaded by trees and shrubs, which kill prairie plants with shade. Another ecological concern is the loss of habitat to cropland or urban lands, resulting in tall grass prairies surviving as small, scattered fragments. Exotic species invasion is a third ecological problem. Native plant seeds are not able to reach and spread to new ground as fast as imported exotic plant species. The most common exotic species in Illinois prairies are Hungarian brome grass (*Bromus inermis*) and Queen Anne's lace (*Daucus carota*) (Sullivan 2001).

Approximately 350 plant species grow on the prairies of Illinois, Indiana, and Wisconsin (Sullivan 2001). These plants grow in communities, each having their own unique mix of species. The two most important factors for determining communities are soil texture and soil moisture. Prairies on wet soils can contain plants commonly found in wetland communities such as sedge meadows and fens. Prairies on sandy soils often contain plants common in the drier lands to the west. Four classes of prairies are recognized in Illinois: Tall grass prairies; Sand prairies along Lake Michigan; Gravel hill prairies (including loess and glacial drift) on top of kames; and Shrub prairies (IDNR 1998c). The primary prairie community of concern for this modeling effort is the tall grass prairie community. Covertypes were determined based on soil moisture regime (dry, mesic and wet) (Sullivan 2001, IDNR 1998c) (Table 2).

Table 2. Prairie communities modeled under this effort.

| Prairie Communities Soil Texture Class | Soil Moisture Subclass | Dominant Species | Cover Type Code |
|---|---|---|---|
| Tall Grass Prairies (fine textured soils) | Dry | *Andropogon scoparius*<br>*Carex bicknellii*<br>*Stipa spartea* | PRAIRIEDRY<br>NEWPRARDRY |
| | Mesic | *Andropogon gerardi*<br>*Sorghastrum nutnas*<br>*Sporobolus heterolepis* | |
| | Wet | *Calamagrosits canadensis*<br>*Carex pellita*<br>*Carex sartwellii*<br>*Spartina pectinata* | PRAIRIEWET<br>NEWPRARWET |

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### Savanna Community Characterization

By definition, savannas in the watershed are described as wooded communities with graminoid groundcover. Savanna trees have broad crowns - an indication that they grew in locations where they had enough space to expand. Savannas often have soils that are transitional between forest and prairie. These communities can be characterized as forested communities with average tree canopy cover ranging from 10 to 50 percent (Chicago Region Biodiversity Council 1999) (Figure 27).

Figure 27. Classic examples of the savanna community in the Upper Des Plaines Watershed (photos taken in Wadsworth Savanna area in August 2002).

Soil texture and soil moisture serve as characteristics that determine classes and subclasses of savannas according to Chicago Region Biodiversity Council's classification system (1999). The primary savanna communities of concern for this modeling effort were those communities occupying fine-textured soil found on till plains and lowlands. Covertypes were determined based on soil moisture regime (dry-mesic, mesic, and wet-mesic) (Table 3).

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Table 3. Savanna communities modeled under this effort.

| Savanna Communities | Soil Texture Class | Soil Moisture Subclass | Dominant Species | Cover Type Code |
|---|---|---|---|---|
| Savannas | Fine-textured soils | Dry-Mesic | Quercus macrocarpa<br>Quercus velutina<br>Juglans nigra<br>Quercus alba<br>Quercus coccinea | NEWSAVDRY<br>SAVANNADRY |
| | | Mesic | Quercus macrocarpa<br>Quercus velutina<br>Quercus alba | |
| | | Wet-Mesic | Quercus macrocarpa<br>Quercus bicolor<br>Quercus coccinea | NEWSAVWET<br>SAVANNAWET |

According to the Chicago Region Biodiversity Council (1999), the dry-mesic communities have soil moisture levels analogous to dry-mesic upland forest. Mesic savannas are often found at the base of morainal ridges and are commonly dominated by bur oaks (*Quercus macrocarpa*). Wet-mesic savannas can have standing water present in spring and early summer, but by autumn, the ground is dry enough to allow a fire to burn through the groves. These wetter communities are often associated with northern flatwoods.

### Woodlands Community Characterization

For the purpose of this modeling effort, "woodlands" refer to all forested communities dominated by trees with an average canopy cover greater than 50 percent.[1] These communities are predominantly associated with loamy/gravel soils (Chicago Region Biodiversity Council 1999).[2] These areas typically have multi-layered structure with canopy, sub-canopy, shrub, and herbaceous layers (Chicago Region Biodiversity Council 1999). They are shaped by the frequency and duration of flooding, nutrient and

[1] Developers Note: Originally, the E-Team intended to develop a separate "flatwoods" model to capture the unique character of these vegetative stands. However the results of the sampling effort, the cover type mapping effort, and the vegetative characterization protocol described in the Chicago Region Biodiversity Council's report led the team to combine both the floodplain and flatwood stands into a single "woodlands" community model.

[2] Flatwoods are unique in that they are a product of specialized soil conditions (permeable/slowly permeable soils) that are influenced by groundwater at or near the surface on level or nearly level topography.

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sediment deposition, and the permeability of the soil (Chicago Region Biodiversity Council 1999) (Figure 28).

Figure 28. Classic examples of the woodland community in the Upper Des Plaines Watershed. From left to right, examples of upland forest, dry woodlands, floodplain forests and flatwoods (photos taken between 2002 and 2003).

Three major characteristics are used to classify the primary woodland communities of concern for this modeling effort: density of canopy cover, topography and/or flooding preference, and wetness (or soil moisture). Covertypes were determined based on the combination of these three characteristics (Table 4).

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Table 4. Woodland communities modeled under this effort.

| Canopy Cover | Topography/ Flooding | Soil Moisture Subclass | Dominant Species | Cover Type Code |
|---|---|---|---|---|
| Forests (80-100%) | Microtopographic Variation Present but Regular Flooding Absent | Wet-Mesic | *Acer saccharum*<br>*Quercus rubra*<br>*Juglans nigra*<br>*Ulmus americana* | FORUPLWET<br>NEWFORUWET |
| | Microtopographic Variation Present and Regular Flooding Present | Wet-Mesic | (No clear dominants)<br>Characteristic species include:<br>*Acer nugundo*<br>*Acer saccharinum*<br>*Celtis occindentalis*<br>*Juglans nigra*<br>*Ulmus americana*<br>*Ulmus rubra* | FORFLPLWET<br>NEWFORFWET |
| | | Wet | *Acer saccharinum*<br>*Populus deltoides*<br>*Salix nigra* | |
| Flatwoods (50-80%) | Level/Nearly Level Impermeable/Slowly Permeable Soils | NA | *Quercus bicolor*<br>*Ulmus americana*<br>*Fraxinus nigra* | FORNFLATS<br>NEWFORFLAT |
| Woodlands (50-80%) | Situated on Well Drained Soils and/or the Tops of South-facing slopes of Moraines | Dry-Mesic | *Quercus alba*<br>*Quercus rubra*<br>*Quercus macrocarpa*<br>*Fraxinus americana* | NEWWOODLND<br>WOODLNDDRY |
| | | Mesic | *Quercus alba*<br>*Quercus rubra*<br>*Acer nigrum* | |
| | | Wet-Mesic | *Quercus bicolor*<br>*Salix nigra*<br>*Fraxinus pennsylvanica*<br>*Quercus macrocarpa*<br>*Quercus coccinea* | FORUPLWET<br>NEWFORUWET |

## Basic Model Components

A generic modeling approach was used to capture the functionality of the three communities of concern. In essence the E-Team chose to focus on targeting four primary modeling components, namely:

1. Hydrology,
2. Spatial Integrity,
3. Structure, and
4. Biotic Integrity.

The following sections describe the underlying principles governing the selection of these critical functional components and provide customized flow-diagrams to indicate how they were combined to develop a HEP-compatible index model for the application.

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### Functional Component #1: Hydrology (WATER)

Ecosystems possess natural hydrologic patterns that provide water for organisms and physical structure for wildlife habitats. This hydrologic regime serves as the vehicle for transfer of abiotic and biotic materials through the system. Water is essential as sustenance for organisms, and is a driving force for physical changes to the environment (USEPA 1999). It serves to transport energy, nutrients and species themselves. The watershed's communities are heavily influenced by pulses of water infiltrating their boundaries throughout the year. As such, the degree of pulsing or "wetness" and the adjacent land use conditions were thought to dictate the ecosystem's ability to support terrestrial and aquatic inhabitants as well as support the diverse plant communities indicative of health in the region (Figure 29).

Figure 29. Hydrology dictates the functionality of the three communities. From left to right, examples of wet prairie, wet savanna, and floodplain forest (photos taken between 2002 and 2003).

### Functional Component #2: Spatial Integrity (LANDSCAPE)

At the landscape level, natural ecosystems have a characteristic pattern and connectivity of habitat patches. The number of and the juxtaposition of these patches supports the movement of species and the transfer of materials (energy and nutrients) among habitats (USEPA 1999). Forest, prairie and savanna ecosystems all have characteristic patterns of habitat patches, and at a larger landscape level, these patterns can be viewed as a mosaic of interrelated and connected ecosystems. To adequately characterize ecosystem functions, one must capture both the system's

"place" in the landscape, as well as identify key corridors and the processes that "shape" the system (i.e., habitat fragmentation) (Figure 30).

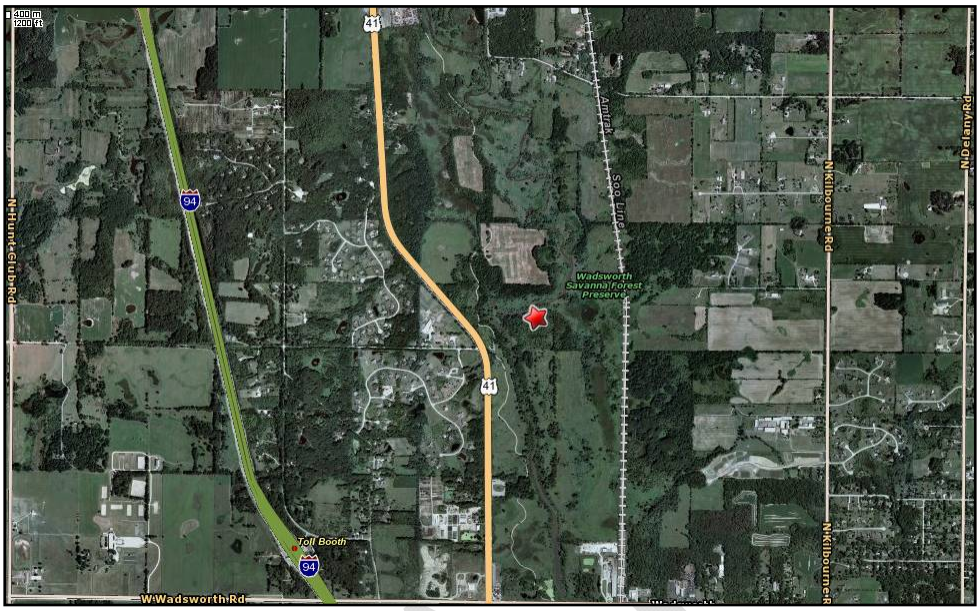


Figure 30. Fragmentation and urban encroachment are common problems for the remnant communities situated along the Upper Des Plaines and its tributaries (Wadsworth Prairie in Illinois – photo taken from Mapquest).

Therefore, landscape-level characteristics (i.e., patch size, core size, edge size, and distribution as well as the levels of disturbance immediately adjacent to the systems) were thought to dictate whether flora and fauna find the ecosystem serviceable. In general, high levels of disturbance perturb sensitive species and reduce the system's ecological integrity.

### Functional Component #3: Structure (STRUCT)

Ecosystems possess a natural complexity of physical features that provide a greater variety of niches and more intricate interactions among species (USEPA 1999). Local structural complexity increases with more snags in forests, more woody debris in streams, and more layers and perches in the ecosystems. The communities' physical characteristics and structures within the system dictate the habitat suitability of a system to support animal populations and guilds as well. The emphasis of the model was to capture the system's ability to provide physical space for its numerous terrestrial and aquatic inhabitants to meet key life requisite requirements (e.g., breeding, feeding and cover) (Figure 31).

Figure 31. Structural complexity offers niche diversification to resident wildlife in the Upper Des Plaines communities. From left to right, examples of prairie, savanna, and woodlands (photos taken between 2002 and 2003).

### Functional Component #4: Biotic Integrity (DIVERS)

The antagonistic and symbiotic interactions among organisms are some of the most important factors influencing the structure of natural ecosystems. Because these interactions have evolved over long periods of time, the deletion of species from or the addition of species to an ecosystem can dramatically alter its composition, structure and function. Biotic interactions are particularly important in maintaining community structure and ecosystem functions, and are described as "keystone" interactions in the literature (USEPA 1999). Interactions between organisms are a major determinant of the distribution and abundance of species in a community. In the case of the current assessment, the vegetative species compositions of living plant biomass within the communities dictated the ecological integrity of the ecosystems and suggest whether the communities could support animal populations and guilds. The emphasis of the models was therefore placed upon the dynamics of the plant community as revealed by the vegetative diversity and community structure of the habitats (Figure 32).

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Figure 32. Biotic diversity offers numerous benefits to resident wildlife in the communities of the Upper Des Plaines watershed. From left to right, examples of prairie, savanna, and woodlands (photos taken between 2002 and 2003).

## Model Flow Diagrams

Flow diagrams best illustrate each model's final design that culminated from the workshop and initial application efforts (Figure 33).

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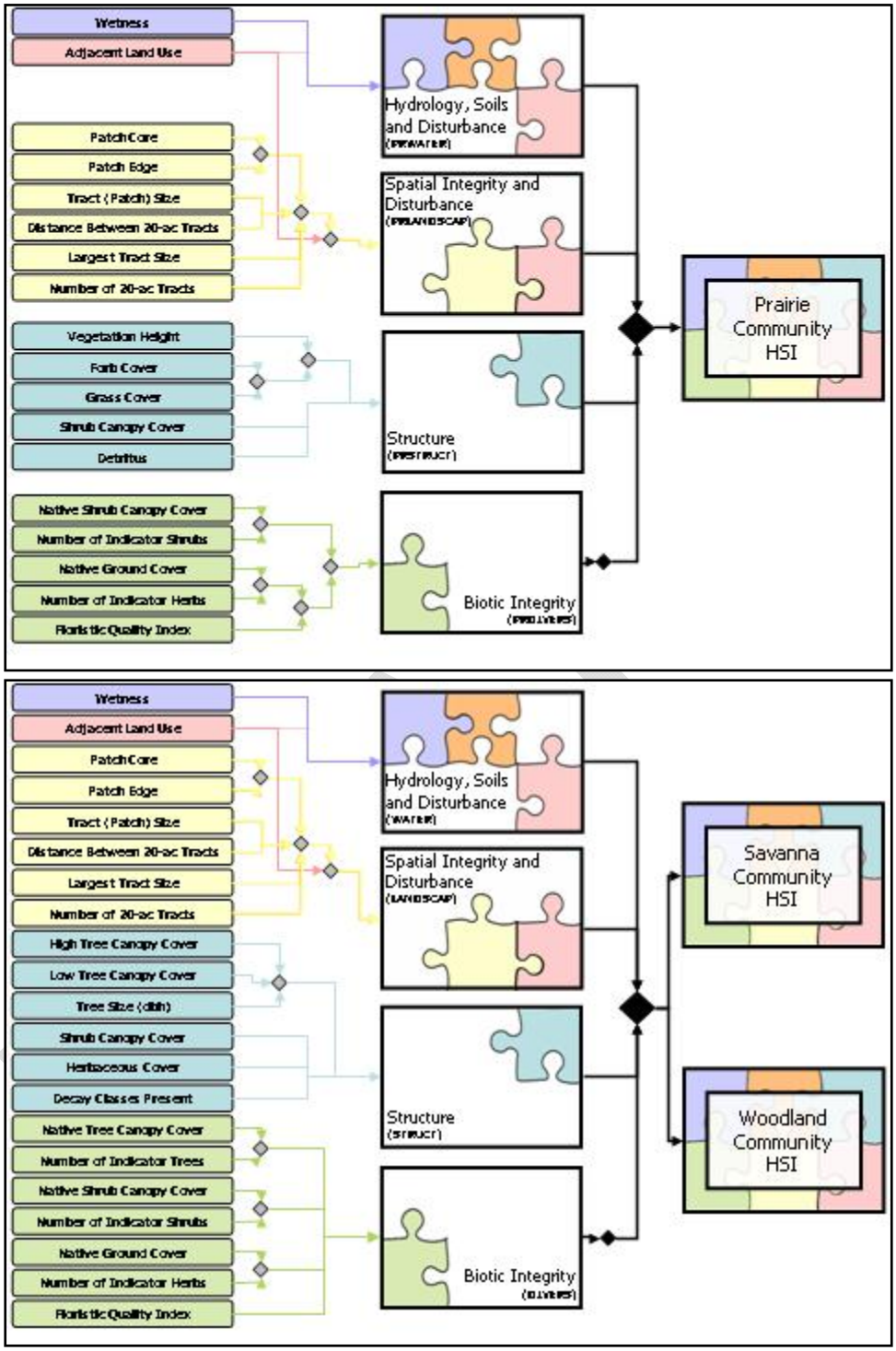


Figure 33. Flow diagrams depicting combinations of model components and variables to form the community index models for the reference domain (Upper Des Plaines Watershed). From top to bottom the Prairie, Savanna and Woodland models are depicted. Note that the Savanna and Woodland models are identical in relationships and differ only in calibration of the individual variables. Also note that the differences between prairie and the forested models hinge on the characterization of the Structure and Biotic Integrity Components.

Variables in these models were selected as indicators of ecosystem functionality, and have been color coded in the figure to correlate their use in specific model components (i.e., purple = hydrologic parameters, orange = soil characteristics, etc.). Thus, the E-Team opted to combine the model components described above (i.e., ***Hydrology***, ***Spatial Integrity***, ***Structure***, and ***Biotic Integrity***) in a meaningful manner mathematically to characterize the existing conditions found in the watershed, and to capture the effects of change under proposed design scenarios (refer to the section below). The rationale for including variables in these models is presented in greater detail in Chapter 5.

### Model Formulas

After successfully diagramming the relationships between model components and the variables therein, the E-Team was asked to use their extensive natural resources expertise to translate these flow diagrams into mathematical algorithms that would capture the functional capacity of each community in a quantifiable manner. It is important to note that this process was iterative and adaptive. Over the course of several years, the E-Team tested both the accuracy of the models to predict the suitability of known reference-based conditions as well as test their utility in distinguishing amongst proposed restoration initiatives (contact the District POC, Brook Herman, for details regarding ongoing applications using these models on the Des Plaines River). Table 5 and Table 6 contain the final model algorithms for the three communities (i.e., Prairies, Savannas, and Woodlands).

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Table 5. Index formulas for the Des Plaines prairie community index model.

| Model Component | Variable Code | CT Code | Formulas |
|---|---|---|---|
| PRDIVERS | INDEXFQI<br>NUMINDGRND<br>CANATGRND<br>NUMINDSHRB<br>CANATSHRUB | NEWPRARDRY<br>NEWPRARWET<br>PRAIRIEDRY<br>PRAIRIEWET | $\frac{2 \times \left(\frac{V_{INDEXFQI} + \sqrt{V_{NUMINDGRND} \times V_{CANATGRND}}}{2}\right) + \sqrt{V_{NUMINDSHRB} \times V_{CANATSHRUB}}}{3}$ |
| PRSTRUCT | HTVEG<br>CANFORBS<br>CANGRASS<br>CANSHRUB<br>DETRITUS | | $\frac{\sqrt{V_{HTVEG} \times \left(\frac{V_{CANFORBS} + V_{CANGRASS}}{2}\right)} + V_{CANSHRUB} + V_{DETRITUS}}{3}$ |
| PRWATER | WETNESS<br>TYPADJLAND | | $\sqrt{V_{WETNESS} \times V_{TYPADJLAND}}$ |
| PRLANDSCAP | AREACORE<br>AREAEDGE<br>SIZETRACT<br>DIST20TRAC<br>SIZELGTRAC<br>NUM20TRAC<br>TYPADJLAND | | $\left[\frac{\frac{\sqrt{V_{AREACORE} \times V_{AREAEDGE}}}{2} + V_{SIZETRACT}}{2} + \frac{V_{DIST20TRAC} + V_{SIZELGTRAC} + V_{NUM20TRAC}}{3}\right] \times V_{TYPADJLAND}$ |
| Overall Habitat Suitability Index (HSI): | | | $\frac{2 \times \left(LRSI_{PRDIVERS}\right) + LRSI_{PRSTRUCT} + LRSI_{PRWATER} + LRSI_{PRLANDSCAP}}{5}$ |

Table 6. Index formulas for the Des Plaines savanna and woodland community index models

| Model Component | Variable Code | CT Code | Formulas |
|---|---|---|---|
| DIVERS | NUMINDTREE<br>CANATREE<br>CANATSHRUB<br>NUMINDSHRB<br>NUMINDGRND<br>CANATGRND<br>INDEXFQI | NEWSAVDRY<br>NEWSAVWET<br>SAVANNADRY<br>SAVANNAWET | $\frac{\sqrt{V_{NUMINDTREE} \times V_{CANATREE}} + \sqrt{V_{NUMINDSHRB} \times V_{CANATSHRUB}} + \sqrt{V_{NUMINDGRND} \times V_{CANATGRND}} + V_{INDEXFQI}}{4}$ |
| STRUCT | CANHITREE<br>CANLOWTREE<br>DBHTREE<br>CANSHRUB<br>CANHERB<br>NUMDECAY | | $\frac{\left(\frac{V_{CANHITREE} + V_{CANLOWTREE} + V_{DBHTREE}}{3}\right) + V_{CANSHRUB} + V_{CANHERB} + V_{NUMDECAY}}{4}$ |
| WATER | WETNESS<br>TYPADJLAND | | $\sqrt{V_{WETNESS} \times V_{TYPADJLAND}}$ |
| LANDSCAP | AREACORE<br>AREAEDGE<br>SIZETRACT<br>DIST20TRAC<br>SIZELGTRAC<br>NUM20TRAC<br>TYPADJLAND | | $\left[\frac{\frac{\sqrt{V_{AREACORE} \times V_{AREAEDGE}} + V_{SIZETRACT}}{2} + \frac{V_{DIST20TRAC} + V_{SIZELGTRAC} + V_{NUM20TRAC}}{3}}{2}\right] \times V_{TYPADJLAND}$ |
| Overall Habitat Suitability Index (HSI): | | | $\frac{2 \times \left(LRSI_{DIVERS}\right) + LRSI_{STRUCT} + LRSI_{WATER} + LRSI_{LANDSCAP}}{5}$ |

It is important to note that the community-based models developed herein do not subscribe to the "limiting-factor" species-based modeling paradigm of the past, but rather attempt to capture each community's integrity based on a series of component indicators (i.e., ***Hydrology***, ***Spatial Integrity***, ***Structure***, and ***Biotic Integrity***) that together characterize the functioning of the system. This new function-based approach does not rely on a geometric mean, but rather takes into account the compensatory nature of the system's components. In other words, a degraded woodland might be considered "unsuitable" for a given species, but could potentially have value for others, and therefore would still be considered "functional" (although minimally so). Thus, the hydrological connection to a woodland could be altered (possibly through channelization or tiling), and would therefore score very low (<0.2) on the Hydrology Component of the model, yet still retain some functionality – it could might still provide structure or niches for disturbance-tolerant species. This approach is not new, but is a common strategy for habitat suitability modeling in the scientific literature of late (Brook and Bowman 2006 and references therein, Schluter et al. 2006; Store and Jokimaki 2003; Store and Kangas 2001; Ruger et al. 2005).

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# 4 Sampling and HSI Model Calibration Protocols

This chapter describes the variables employed within the three community index models (i.e., prairie, savanna and woodlands). In an effort to support the future use of these models, we have included detailed sampling protocols, as well as rationale for the incorporation of each variable into the models, and offer scientific literature to support their inclusion therein. In order to use these parameters within a traditional HEP context, each variable must be normalized or scaled on a 0 to 1 range. Here we describe the normalization process in some detail, and have also included *Appendix G* at the end of this report to fully document the final index curves.

## HSI Model Variables Selection Rationale

As mentioned previously, ERDC-EL used a systematic, scientifically-based, statistical protocol to develop and calibrate the community models for the study using an iterative approach that involved the selection of reference sites from across the watershed and a sampling scheme that obtained numbers to assure model precision. Below, the variables associated with the community models (and justifications for their inclusion in the models) have been provided in tabular format (Table 7).

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Table 7. Variables and rationales for association in the Upper Des Plaines Watershed community index models.

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| AREACORE | Percent of the Area That is Core | A tract or patch (synonymous for purposes of this report) of community habitat can be divided into a center "core" area and an outer "edge" area. For this study, the edge area was defined as a 100-m band inside the perimeter of the community patch based upon a Tech Note developed for the Ecosystem Management and Restoration Research Program by Fischer and Fischenich (2000). The community core is defined as the area within the outer ring or band of edge area. The core represents the area with lower probability of being impacted by surrounding disturbed habitats or anthropogenic affects of urban encroachment. AREACORE is the percent of the total patch area that is core. Fragmentation of remnant habitats is of key concern in the Upper Des Plaines Watershed. Simple geometry dictates that small fragments have more edge in relation to their area than large fragments, and that the less like a circle the fragment is the greater is its perimeter. The consequences of decreased core and increased edge include: (1) the change in physical conditions (organisms near the edge are subjected to more wind, less moisture, and greater temperature extremes) and (2) invasion by species from the surrounding habitat (e.g., competitors such as weeks and predators) (USEPA 1999). Population declines of interior-dependant species (e.g., migratory songbirds) have been attributed to loss of core area and increases in edge (Wilcove et al. 1986; Paton 1994). This variable has been included to quantify the existing size of core in the ecosystems, and direct future design of habitats to meet a minimum core size to support interior-dependant species needs. |
| AREAEDGE | Percent of the Area That is Edge | A tract or patch (synonymous for purposes of this report) of community habitat can be divided into a center "core" area and an outer "edge" area. For this study, the edge area was defined as a 100-m band inside the perimeter of the community patch and represents the area most likely impacted by surrounding disturbed habitats or anthropogenic affects of urban encroachment (refer to AREACORE for Fischer and Fischenich 2000 citation). Smaller patches have a greater percent edge than larger patches. Edges are artifacts of man-modified landscapes which are permanent, yet dynamic, and are highly associated with the universal impacts of urbanization in forested and grassland regions (Ranney, Bruner and Levenson 1981). It has been conclusively shown that there is a selective effect on tree composition and forest island dynamics when edges are created (Ranney, Bruner and Levenson 1981). Edges have high cover densities (Schreiber et al. 1976, Johnson et al. 1979) and represent convergence of contrasting habitats (Odum 1959; States 1976). A higher percent of edge area is a good indicator that increased habitat fragmentation has occurred leaving smaller isolated biogeographical "islands" (refer to rationale provided in AREACORE above). As these islands become smaller, edges species replace interior species and den them potential sites for establishment which can lead to extirpation of interior-dependent species. The creation of edges will lead to a regression from mature, mesic conditions to dryer, pioneer conditions in the interior (Ranney, Bruner and Levenson 1981). Forest edges generate microclimatic gradients which result in a physical environment that differs from both open fields and interior forests. As such, many species of wildlife are attracted to edges where two or more of these habitats adjoin (Herkert et al. 1997). Edge is a line value, but must be visualized as a condition (i.e., edge is a zone) (Giles 1978). This variable has been included to quantify the amount of edge in relation to the site's size, and will capture the benefits of having some edge, but it has also been included to quantify the negative effects of urbanization and habitat fragmentation in the DPII ecosystems today. This variable can also be used to direct future design of habitats just as AREACORE will be used in the scenarios outlined above. |

(Continued)

Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| CANATGRND | Percent of the Ground Vegetation Canopy Cover Comprised of Native Species | The percent of the ground vegetation cover that is comprised of native species is an indicator of the species composition and diversity of the community. Ecosystems in the reference domain are known to harbor rare species and assemblages of concern. Reference conditions (i.e., pristine, undisturbed areas) are likely to have conservative plants (i.e., plants with high mean C values) (Matthews et al., 2005; Swink and Wilhelm 1979, 1994). As such, we can assume that the presence of diverse vegetation (particularly native species endemic to the region) indicates a high level of wetland functionality. Extracted from the FQI analysis completed at each site, this variable was included to capture the "nativeness" of the ground cover at each site - serving as a de facto indicator of ecosystem function and health. |
| CANATSHRUB | Percent of the Shrub Canopy Cover Comprised of Native Species | The percent of the shrub cover that is comprised of native species is an indicator of the species composition and diversity of the community. Just as CANATGRND captures "nativeness" of herbaceous ground cover, this variable captures "nativeness" of the shrub covers at each site - serving as a de facto indicator of ecosystem function and health. The assumption is the same. The presence of diverse vegetation (particularly native species endemic to the region) indicates a high level of wetland functionality. This variable was derived from the FQI analysis and was included to capture the "nativeness" of the ground cover at each site - serving as a de facto indicator of ecosystem function and health. |
| CANATREE | Percent of the Tree Canopy Cover Comprised of Native Species | The percent of the tree cover that is comprised of native species is an indicator of the species composition and diversity of the community. Just as CANATGRND and CANATSHRUB captures "nativeness" of herbaceous ground covers, this variable captures "nativeness" of the tree canopy cover at each site - serving as a de facto indicator of ecosystem function and health. The assumption is the same. The presence of diverse vegetation (particularly native species endemic to the region) indicates a high level of wetland functionality. This variable was derived from the FQI analysis and was included to capture the "nativeness" of the ground cover at each site - serving as a de facto indicator of ecosystem function and health. |
| CANFORBS | Percent Forb Canopy Cover | This variable characterizes the percentage of the herbaceous vegetation cover that is comprised of forb (native flowering herbaceous plants) species as part of the community's herbaceous composition and structure. High-quality communities are characterized as multi-layered herbaceous ecosystems comprised primarily of grass and forbs plant species. Many grassland bird species prefer areas containing low to moderate forb cover that provides essential habitat components including perches for songbirds and above-ground nesting substrates for many species (Kahl, R.B et al. 1985). In other words, a community dominated by forbs does not provide an optimum setting. Therefore, this variable was included as a limiting factor – indicating a certain desirable level of heterogeneity in the herbaceous cover (i.e., a balance of both forbs and grasses in the community is optimum). |
| CANGRASS | Percent Grass Canopy Cover (Graminoid) | This variable characterizes the percentage of the herbaceous vegetation cover that is comprised of grass (graminoid) species, including sedges and rushes, as part of the community's herbaceous composition and structure. Just as CANFORBS was added to the model to capture the heterogeneity of the site, optimum conditions suggest a balance of both forbs and grasses is preferable for the community ecosystems in the area. This variable was included to characterize the existing percentage of the herbaceous vegetation cover that is comprised of grass in a community setting. Grassland birds have a varying preference for nesting habitat requirements. However, there is a suite of grassland birds including the eastern meadowlark, that prefer nesting territories characterized by predominantly grass cover with some presence of forb cover, and relatively little to no bare ground (Swanson 1996). |

(Continued)

Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| CANHERB | Percent Herbaceous Canopy Cover | This variable characterizes the percentage of the vegetation cover that is comprised of herbaceous species as part of the community's species composition and structure. Herbaceous canopy cover is an important determinant of infiltration rate and interrill erosion (Thurow et al. 1986, 1988). Changes in plant community composition and the distribution of species can influence (positively or negatively) the ability of a site to capture and store precipitation (Pellant et al 2000). The amount and distribution of vegetative cover is one of the most important contributors to site stability relative to the site potential; therefore, it is a direct indication of site susceptibility to accelerated wind or water erosion (Smith and Wischmeier 1962, Morgan 1986, Benkobi et al. 1993, Blackburn et al. 1994, Pierson et al. 1994, Gutierrez and Hernandez 1996, Cerda 1999). Each species is adapted to a range of intensity and duration of sunlight. Many of the native species of the region are adapted to the full sunlight of savannas or the scattered shade of open woodlands (Chicago Region Biodiversity Council 1999). Others are adapted to the heavier shade of closed forests. These various patterns of sunlight were maintained primarily by the forces of climate, fire, and browsing. It should be noted that lack of fire in forested and savanna communities can lead to shrub encroachment and tree canopy closure – causing overshading and limiting the growth in the understory and herbaceous layers. The availability of sunlight at various levels within terrestrial communities and in aquatic communities is a powerful factor in their survival and is a key consideration in protection and restoration (Chicago Region Biodiversity Council 1999). This variable has been included in the forest and savanna models as a de facto measure of erosion, light penetration and canopy patchiness – high herbaceous canopy indicates high levels of sunlight penetrating the upper canopies, and little or no tree and shrub canopy in the upper layers. This variable can also be used to capture the positive effects of proposed management designs such as shrub/sapling removal by mechanisms such as controlled burns. |
| CANHITREE | Percent High Tree Canopy Cover | This variable characterizes the highest layer in the overstory canopy. Trees are defined as 5-cm (2-in) dbh and 5.5-m (18-ft) tall. "High" refers to those trees in the overstory greater than 9.1-m (30-ft) tall. High structural complexity promotes diversity in ecosystems. Species rarely occupy area – they occupy three-dimensional space (Giles 1978). The abundance of vegetative structure greatly influences the abundance and diversity of animals in both wetland and terrestrial ecosystems - complex habitats accommodate more species because they create more ways for species to survive (Norse 1990). Furthermore, studies indicate that physical structure may prevent generalist forages from fully exploiting resources and thus promote the coexistence of more species (Werner 1984). In particular, vertical stratification diversification of forests and savannas produces stratification of light and temperature, as well as providing intricate spaces for shelter and food sources for species. Thus, structural complexity plays a critical role in the presence of microclimate, food abundance, and cover that affect organism fitness (Cody 1985). Three distinct layers can be described in any system: groundcover (refer to CANHERB above), understory (i.e., mid-canopy) and overstory (i.e., upper canopy). The presence of each layer offers a niche for community associations. High levels of overstory canopy cover are likely to reduce sunlight in the layers below – shading out the vegetation beneath, and reducing the niches in the system. This variable was added to characterize the highest layer in the system (i.e., tree canopy cover exceeding 30 feet). |

(Continued)

Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| CANLOWTREE | Percent Lower Tree Canopy Cover | This variable characterizes the lower layer in the overstory canopy. Trees are defined as 5-cm (2-in) dbh and 5.5-m (18-ft) tall. "Low" refers to those trees in the overstory less than 9.1-m (30-ft) tall. Refer to CANHITREE above for rationale. Again, this variable was added to capture one of the higher layers in the system (i.e., tree canopy cover less than 30 feet in height). This variable was added to capture the successional level of the system (i.e., high levels of low tree canopy indicate high levels of recruitment and indicate a potential for future shading of the layers below). |
| CANSHRUB | Percent Shrub Canopy Cover | This variable characterizes the percentage of the vegetation cover that is comprised of shrub species as part of the community's species composition and structure. Varying intensities and frequencies of natural fires contributed to the rich mosaic of the landscape. Virtually all of the regional landscape was influenced by fire to some extent and burned at least occasionally (Chicago Region Biodiversity Council 1999). Fire suppression following settlement has greatly reduced the extent of fire-dependent communities and the former rich variety of habitats. Prairies and savannas have mostly disappeared, even from protected areas, while the surviving woodlands tend to be choked with shrubby brush and fire-intolerant trees, both native and exotic. The simplified and homogenized landscape offers little of the complex habitat needed by a wide variety of plants and animals native to the area. In the region's forests, secondary effects from fire suppression and invasion by "weedy" species include shading out of the ground flora and erosion where soil is exposed. In prairie ecosystems, this variable represents the potential succession of prairie to savanna and ultimately forest. Studies of Midwestern prairie sites show a higher rate of nest predation and parasitism affecting birds that were nesting closer to woody vegetation than those birds nesting far from woody vegetation (Herkert. et al. 1993; Johnson and Temple 1990), and thus, a shrubby prairie is likely to have less productivity for grass-based species. This variable has been included as a de facto measure of succession of grasslands to savannas and forests, and will be used to quantify the effects of proposed management strategies that maintain grasslands with techniques such as controlled burning and mowing. |
| DBHTREE | Average dbh of Trees | The size of trees (in terms of average diameter at breast height (dbh)) is an indicator of the age and structural composition of the community. The age of forests (and savannas) is an important ecological characteristic because the variety of tree heights and the diversity of plant species generally increase with forest age (Gustafson and Crow 1994). This diversity contributes to the quality of forests as habitat for many organisms. Both managed and unmanaged forests consist of a mosaic of patches of various tree species and ages. The size and arrangement of these patches have important ecological effects for both plant communities and wildlife habitat. This variable was included to capture the "age" of the forests and savannas, and to capture proposed designs that alternated plantings of seedlings, saplings and poles. |

(Continued)

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Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| DETRITUS | Percent of the Ground Covered By Detritus in Wet Systems or Litter in Dry Systems (%) | Detritus in wet systems and litter in dry systems contribute to the natural complexity of physical features that provides for a greater variety of niches and more intricate interactions among species, affecting a wide range of ecological processes from predator-prey interactions to energy transfer among ecosystems. The natural process of decomposition is critical ecosystem health and the recycling of nutrients and energy that sustains life. Ecosystems with more three-dimensional structure have more species because they create more ways for species to survive (USEPA 1999). The structural complexity provided by detritus/litter also plays a critical role in the presence of the micro-climate, food abundance, and cover that affect organism fitness (Cody 1985) accommodating more species and more ways for those species to survive (Norse 1990). Soil microbes consume wastes and the remains of dead plants and animals, rendering their potential toxins and human pathogens harmless, while recycling their constituent materials into forms usable by plants (USEPA 1999). As with other processes that characterize ecosystems, the ability to assimilate wastes and provide clean air, water, and soil has evolved to suit the conditions of the environment over time. Natural systems have finite capacities for assimilating wastes and detoxifying contaminants. Excessive inputs of wastes, the removal of critical species, or the alteration of other ecological process (i.e., hydrology) can disrupt the purification process and degrade the ecosystem. Wetlands operate through a series of interdependent physical, chemical, and biological mechanisms that include sedimentation, adsorption, precipitation and dissolution, filtration, biochemical interactions, volatilization and aerosol formation, and infiltration to assimilate and recycle waste materials – this capacity may be exceeded by anthropogenic inputs depending on system-specific conditions (USEPA 1999). Plant rooting patterns, litter production and associated decomposition processes, basal area and spatial distribution can all affect infiltration and/or runoff (Pellant et al 2000). This variable has been added to capture the erosion potential and nutrient recycling capacity of the ecosystems (and their associated soil microbes), and monitor the effects of the proposed designs on the functional capacity of the systems to consume and remove wastes. |

(Continued)

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Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| DIST20TRAC | Average Distance to All 20-acre Tracts of Similar Cover Within 5 Miles of the Tract (m) | This variable characterizes the degree of habitat fragmentation across all of the remaining community within the watershed.<br>Too often, ecologists perceive habitats as lone entities, when in reality they are interacting, functional components of the landscape (Noss 1991). Landscape connectivity, therefore, involves the linkage of habitats, species, communities and ecological processes at multiple spatial and temporal scales (Noss 1991). Many of the most significant human effects on biodiversity involve changes in the connectivity of habitat (Noss 1991). Human activities can reduce connectivity by creating artificial barriers to species dispersal, leading to isolated populations that become vulnerable to extinction due to reduced access to resources, genetic deterioration, increased susceptibility to environmental catastrophes and demographic accidents, and other problems (Harris 1984; Soule 1987). Connectivity of the landscape mosaic is absolutely necessary for species to survive (Noss 1991). Disturbances periodically make portions of the landscape uninhabitable. Corridors fulfill a "fire escape" function b permitting animals to flee disturbance. Corridors also aid in recolonization of the recovering site by plants and animals. Habitat patches that are isolated from similar habitat patches by great distances or inhospitable terrain are likely to have fewer species than less isolated patches because relatively few individuals of a given species will immigrate into the isolated patch, and fewer mobile species will visit isolated patches because it is inefficient to do so (Hunter 1996). The size of habitat patches has important implications for ecological integrity [i.e., system wholeness, including presence of all appropriate elements and occurrence of all processes at appropriate rates (Angermeier and Karr 1994)] (USEPA 1999) (refer to SIZETRACT below for further rationale on specie-area relationships). Small habitat patches (e.g., habitat islands) have fewer species than large patches (Hunter 1996). Studies have clearly demonstrated that larger non-isolated regions have not only more species in total (i.e., higher gamma diversity), but also more species per habitat (higher alpha diversity) than smaller and insular areas (Rosenzweig 1995). This variable has been included to capture not only the connectivity of the habitats in the region, but also to capture a minimum size "islands" in the landscape – indicating species "source" availability. This variable has direct implications on management – designs must be geared to provide 20 acre habitat patches within five-miles of similar habitat to have an effect on ecosystem health. |
| HTVEG | Average Height of the Herbaceous Vegetation(cm) | The average height (cm) of herbaceous vegetation characterizes the composition and structure of a community patch/tract.<br>Variations in vegetation height support different groups of community birds. Some community birds will use the elevated grass and forb stems of tallgrass prairie as perches and the ground canopy as cover for nesting. Rodents, small birds, reptiles and amphibians also use the tall grasses for cover from birds of prey (Sullivan, J. 2001). A range of short, medium and tall herbaceous vegetation heights is preferable as characteristic prairie bird species prefer different vegetation heights depending on the species (Herkert, J.R. et al. 1993). Swanson's (1996) literature review found that a height of cover at 204 grassland bird nest sites in Illinois averaged 38 cm and ranged from 5-79 cm; with 67 percent of all nests found in cover 25-50 cm tall. This variable was included to capture the relative suitability of the current and proposed grassland habitats to provide suitable perching conditions for bird species. |

(Continued)

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Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| INDEXFQI | Floristic Quality Index (FQI) | The Floristic Quality Index (FQI) is a tool used to provide a numerical value for a natural area evaluation based on plant species present. This variable characterizes the species composition and diversity of the community. For the purposes of this model, adventives are included in the FQI score. Adventive species are species native to North America but growing outside of their natural range due to the human-caused breakdown of natural barriers to dispersal or its escape and survival after being introduced (Delaware Natural Heritage Program 2001). Originally developed by Swink and Wilhelm (1979 and 1994), FQI can replace very subjective measures of quality, such as "high" or "low", with a still somewhat subjective, but more dispassionate, quantitative and uniform set of measures. These measures allow for comparison of the floristic quality among many sites and for tracking changes at the same site over time. The approach assumed that a vast proportion of the modern landscape was severely degraded and fragmented, and as such, the remaining remnants had varying degrees of floristic integrity. The methodology was based upon the assumption that native flora displayed varying degrees of: 1) tolerance to disturbance, and 2) fidelity to specific habitat integrity. Under this approach, the floristic quality of an area was determined based on the presence and proportion of conservative native plant species. The basic tool of the method was a checklist of all the plant species known from the Chicago region. Each native species on the checklist was given a "Coefficient of Conservatism" (C) ranging from zero to ten (Swink and Wilhelm 1979; 1994). |
| NUM20TRAC | Average Number of 20-Acre Tracts of Similar Cover Within 5 miles of the Tract (m) | The average numbers of similar tracts or patches that are close enough to a given tract or patch of similar cover type provides opportunities for consolidation or connectivity of similar patch types within the watershed. Refer to DIST20TRAC above for rationale. Larger numbers of habitat patches located closer to one another helps to minimize isolation due to adverse impacts and fragmentation (Hunter 1996). Similar to DIST20TRAC, this variable has been included to capture the connectivity and size of the habitats in the region. This variable has direct implications on management – designs must be geared to provide numerous 20 acre habitat patches within five-miles of similar habitat to have an effect on ecosystem health. This variable will also help identify remnant habitat patches suitable for combining into larger areas, providing enhanced functionality for area sensitive species and increased genetic variability, contributing to recovery goals that include restoring ecosystems so that they sustain viable populations of all native area-limited species and formerly common species (Chicago Region Biodiversity Council 1999). |
| NUMDECAY | Number of Decay Classes Present | The level of decay is an indicator of the age and structural composition of the community. Dead trees are one of the most important contributors to increased structural complexity in forests (Maser et al. 1988). Coarse wood debris creates new microhabitats and influences hydrology and nutrient cycling as well (USEPA 1999). When a tree falls, the canopy is opened and additional light is admitted to the forest floor. The opening creates opportunities for new plants to become established. Fallen trees and branches suspended across other trees create elevated relief and structural complexity. The surface of the forest floor is roughed by fallen tree stems, their tipped rootballs, and the pits left after their uprooting. Fallen trees and branches provide a substantial reservoir of soil organic matter and essential nutrients increasing the chemical diversity of the forest. This variable was added to the models to capture the structural complexity of the forested ecosystems, and can be used as an indicator of forest maturity and biogeochemical processing. . |

(Continued)

Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| NUMINDGRND | Ground Vegetation Diversity - Number of Species with "C" Value >5 | Indicator species are those species that offer a signal of the biological condition of an ecosystem. Indicator species within the herbaceous ground cover serve to characterize the species composition and diversity within the community. The assessment of ecosystem integrity based on a single index will be insufficient to account for all relevant aspects (Herman, et al. 2001). The FQI or mean C when reported alone can be misleading (Herman, et al. 2001). Species richness (number of species) by itself can also be an insensitive indicator of habitat quality since it is possible for a degraded site to support a similar or greater umber of taxa than an intact, high quality site. Six measures of biological integrity for wetlands have been suggested by Keddy et al. 1993. These include species diversity, indicator guilds, exotic species, rare species, plant biomass, and amphibian biomass. Keddy et al. (1993) views diversity as an essential indicator of integrity, but also recommends assessing guild diversity. This variable has been included to capture the number of "native" species present at the site in an attempt to capture several of these key measures, namely species diversity (richness and evenness), presence specifically of "indicators," and presence of these species tied to a specific community or guild (namely ground vegetation) - the assumption being that higher numbers of indicator species present signifies ecosystem health and integrity. |
| NUMINDSHRB | Shrub Vegetation Diversity –Number of Species with "C" Value >5 | Indicator species within the shrub cover serve to characterize the species composition and diversity within the community. Refer to NUMINDGRND rationale above. This variable has been included to capture the number of "native" species at the site in an attempt to capture several of these key measures, namely species diversity (richness and evenness), presence specifically of "indicators," and presence of these species tied to a specific community or guild (namely shrubs) - the assumption being that higher numbers of indicator species present signifies ecosystem health and integrity. |
| NUMINDTREE | Tree Vegetation Diversity - Number of Species with "C" Value >5 | Indicator species within the overstory tree canopy cover serve to characterize the species composition and diversity within the community. Rationale for variable selection. Refer to NUMINDGRND rationale above. This variable has been included to capture the number of "native" species at the site in an attempt to capture several of these key measures, namely species diversity (richness and eveness), presence specifically of "indicators," and presence of these species tied to a specific community or guild (namely trees) - the assumption being that higher numbers of indicator species present signifies ecosystem health and integrity. |
| SIZELGTRAC | Size of the Largest Tract of Similar Cover Within a 5-mile Radius | The largest tract (in acres) of similar cover within a five-mile radius of a given patch or tract characterizes landscape mosaic of community patches within the watershed. Larger tracts/patches of habitat containing larger populations of targeted species have better functionality and suitability than smaller tracts/patches of habitat with small numbers of species (USEPA 1999). Larger patch fragments have a higher core to edge ratio. Some benefits of larger patches are a greater variety of environments, niches and species (Hunter 1996), and the ability to support larger numbers of species that are less susceptible to genetic deterioration and extinction (Harris 1984, Soule 1987). The greater the distance between larger and smaller patches, the more inefficient it becomes for mobile species to visit the smaller patches, affecting the number and diversity of species (Hunter 1996). Viable populations of prairie reptiles and amphibians need at least 200 acres to maintain most of the species. A goal for prairie restoration is to create prairie tracts of 500-1000 acres to ensure breeding populations and give mobile species opportunities to re-colonize nearby functioning prairie patches (Chicago Region Biodiversity Council 1999). This variable has been included to capture the maximum remnant prairies, forests or savannas found in the DPII region today, and to indicate that these large islands are likely to be chopped up into smaller pieces in the future as urban encroachment overcomes relictual settings. |

(Continued)

Table 7. (Continued).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| SIZETRACT | Tract Size | The size (acres) of a community tract or patch characterizes the landscape mosaic of community patches within the watershed. The size of habitat patches has important implications for ecological integrity (USEPA 1999). Fragmentation of habitats has been implicated in the decline of biological diversity and the ability of ecosystems to recover fro disturbances (Flather et al. 1992). Large patches have more species because they provide a greater number and variety of niches. Large patches are more likely to have both common and rare species, while small patches are more likely to have only common species (i.e., area-sensitive species will be excluded in smaller patches) (Hunter 1996). Small habitat patches (e.g., habitat islands) have fewer species than large patches, and are more susceptible to extinction. Area-sensitive species that cannot maintain populations in limited areas of otherwise high quality habitat will avoid patches purely on the basis of size (USEPA 1999). Species with small home ranges, such as songbirds, may also avoid small fragments if they prefer the interior of large habitat patches (Robbins, et al. 1989) or select patches large enough to support other members of their species (Stamps 1991). This variable was included to characterize both the patch size of the various habitats as well as to capture the future urbanization threat to these ecosystems if preventative measures are not taken in the recommended plans. |
| TYPADJLAND | Identification of Adjacent Landuse Practices | Lands adjacent to a given community tract/patch are classified according to their predominant landuse including: pristine, uninhabited areas, parks, pasturelands, utility rights-of-way and railroads, dirt and gravel roads/oil and gas fields, agricultural croplands, residential/golf courses , paved roads/highways, and commercial/industrial. Ecosystems do not exist in a steady-state; they are dynamic, each possessing a characteristic composition structure and function that have adapted to natural disturbances over long periods of time. At the landscape level, natural disturbances destroy patches of vegetation and restart plant succession. Human activities (both onsite and offsite) that deviate from these patterns affect individual species (and through biotic interactions many other species and ecological processes) by direct exploitation, habitat elimination, and modification of ecological processes (USEPA 1999). By changing the access of species to their food, shelter, and reproduction, human activities initiate a cascade of biotic interactions that can affect entire ecosystems (USEPA 1999). Impervious surfaces prevent infiltration and direct water away from subsurface pathways to overland flow, increasing the flashiness of streams. Urbanization and suburbanization commonly exceed the threshold of approximately 10 to 20 percent impermeable surface that is known to cause rapid runoff throughout the watershed (Center for Watershed Protection 1994). In heavily urbanized watershed, stream channelization and large amount of impervious surface result in rapid changes in flow, particularly during storm events. These artificially high runoff events increase flood frequency (Beven 1986), cause bank erosion and channel widening (Hammer 1972), and reduce baseflow during dry periods. Agricultural practices also greatly affect hydrologic patterns (USEPA 1999). Clearing forest and prairie environments generally decreases interception of rainfall by natural plant cover and reduces soil infiltration resulting in increased overland flow, channel incision, floodplain isolation, and headward erosion of stream channels (Prestegaard 1988). Draining and channelizing wetlands directs flow more quickly downstream, increasing the size and frequency of floods, and reducing baseflow (USEPA 1999). Such activities can actually increase the magnitude of extreme floods by decreasing upstream storage capacity and accelerating water delivery. Human activities, such as land clearing and erosion, can cause the loss of nutrients (e.g., phosphorus), disrupt natural cycling of nutrients, and limit ecosystem productivity (USEPA 1999). At the same time, agriculture and industry can discharge excessive amounts of nutrients (e.g., nitrogen) into natural ecosystems and drastically change their trophic structure, and degrade water quality. This variable was added to the models to capture the effects of human activities immediately outside of the habitat area, and can be used as an indication of urban pressures on the remaining relictual ecosystems in the future. |

(Continued)

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Table 7. (Concluded).

| Code | Variable Description | Definition and Rationale |
|---|---|---|
| WETNESS | Native Mean Wetness With Adventives | This variable is the Coefficient of Wetness, including adventive species, obtained from the results of the FQI analysis for each community site. The Wetness with adventives score is based on the local plant wetness designation (e.g., Obligate, Facultative-wet, Facultative, Facultative-Upland and Upland). The plant wetness designations are from the (Swink and Wilhlem 1994), which primarily use the wetness designations from (Reed 1988), except in a few cases where Swink and Wilhelm assigned a designation if one was lacking in the national list, or they strongly disagreed with the designation given in the national list. Ecosystems possess natural hydrologic patterns that provide water for organisms and physical structure for habitats. Wetlands in particular depend on constant or recurrent shallow inundation or saturation at or near the surface of the substrate (National Research Council 1995). A proper hydrologic regime is necessary to maintain desirable plant communities - prolonged saturation can lead to anaerobic soil conditions and a general decline of these ecosystems (Lin 2006). This variable is used in the model to capture the hydrologic regime of the ecosystem, and can be indicative or a return of hydrology to the site through the breaking of tiles. |

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## A Reference-Based Approach to Model Calibration

Reference sites in this instance refer to multiple sites in a defined geographic area (the reference domain) that have been selected to represent specific types of ecosystems (i.e., prairies, savannas, and woodlands).[1] Reference sites have been most commonly described as natural settings – lacking human disturbances (Hughes 1994, Bailey et al. 2004a, Chessman and Royal 2004, Intergovernmental Task Force on Water Quality Monitoring 2005). Reference-based conditions were therefore expected to exhibit a range of physical, chemical, and biological values. When reference sites have been characterized as undisturbed ecosystems, conditions were expected to emulate the spatial and temporal variability that commonly occur in natural ecosystems (Swanson et al. 1993; Morgan et al. 1994; White and Walker 1997; Landres et al. 1999). When reference sites included altered or disturbed ecosystems (as is the case in most urban-based ecosystem restoration efforts), the reference conditions exhibited a wider range of values that reflect both natural variability and variability due to human activities. In these instances, optimal conditions or "virtual" references have been established using a variety of techniques including literature values, historical data, paleoecological data, and expert opinion [Society for Ecological Restoration International (SERI) 2004; Ecological Restoration Institute 2008]. Regardless of how reference conditions have been established, ecosystem evaluations have used a reference-based approach as a template for model development, planning, and alternative analysis.

Various types of reference-based approaches have been developed for a variety of ecosystems including streams (Barbour et al. 1999, Karr and Chu 1999, Bailey et al. 2004b), large rivers (Angradi 2006, Flotemersch et al. 2006), wetlands (Smith et al. 1995, Brinson and Rheinhardt 1996, Smith 2001, USEPA 2002), grasslands (Prober et al. 2002), forests (Fule et al. 1997, Moore et al. 1999, Tinker et al. 2003, Ecological Restoration Institute 2008), tidal marshes/estuaries (Findlay et al. 2002, Merkey

[1] The information herein was taken from a workshop held at ERDC-EL in the summer of 2008 under the Ecosystem Management and Restoration Research Program's Environmental Benefits Analysis initiative. In that workshop, a draft manuscript was circulated to the participants for review and comment. Here we provide excerpts from that paper, and inject local knowledge of the watershed's reference conditions where relevant.

2003), and coral reefs (Jameson 1998). Reference-based approaches have also been used to evaluate ecosystems in a landscape or watershed context (Warne et al. 2000, Andreasen et al. 2001, Reindardt et al. 2007, Wardrop et al. 2007, Whigham et al. 2007, Smith 2008).

### Reference Site Selection Strategy

Choosing the relevant reference conditions in a region is a matter of judgment (Andreasen et al. 2001). In some instances, the natural state might be reconstructed from historic records or based on scientific knowledge such as reconstruction of potential vegetation. ERDC-EL assisted the District in locating a series of sample sites across the entire study area that were considered both reference standard (optimal) or degraded (sub-optimal) that represented the range of conditions existing within the reference domain.

Early in the process ERDC discussed the selection of reference sites with the District for the community models. Here we synopsize the directives given to the District:

**A. Definitions**

1) ***Reference*** sites serve several purposes in HEP. First, they function as the physical representation of the communities from the region that can be observed and measured repeatedly. Second, they make it possible to establish the range of variability exhibited by the measures of the model variables, which make it possible for calibration of variables and indices. Third, they serve as a template for restoration by providing design specifications.

2) ***Reference standard*** areas are those optimum conditions in the region that are then used to establish the highest standard of comparison for calibrating assessment model variables and indices. In HEP, the least altered areas in the least altered landscapes are selected as *reference standard* wetlands. This is based on the assumption that these areas sustain the highest level of function across the suite of habitats within the community that are inherent to the system.

## B. General Selection Strategy

1) ***Conduct field reconnaissance*** to screen potential candidate reference sites. The objective is to identify sites that represent the range of conditions that exist in the reference area from highly altered sites in highly altered landscapes to unaltered (pristine) sites in unaltered landscapes.

2) ***Determine the number*** of reference sites to be included. A variety of factors influence the number of reference sites to be included in the process. Large projects will require more reference sites. Reference areas with a wide variety of alteration scenarios will require more sites. Detail of resolution to detect the types of impacts that typically affect riparian areas in the region is another factor. Lastly, the ideal number of sites dictated by the foregoing considerations must be balanced against the realities of budgets, time and personnel.

## C. Criteria for Defining Reference Conditions

1) Must be politically palatable and reasonable;

2) Must include a large number of sites from the region;

3) Must represent important aspects of pre-historical conditions;

4) May use minimal disturbance as the surrogate for pre-historical conditions, given the difficulty of establishing pre-historical conditions;

5) Must be uniform across political boundaries and bureaucracies (e.g., Federal, State, and local); and

6) When the areas have experienced extensive alteration, it may be possible to reconstruct a reference standard area using historical accounts and photography.

### Desired Reference Standard Conditions

Reference site characterization and model calibration for this study included gathering data on water quality, hydrology, substrate conditions, flora, and fauna, and to the greatest extent possible, identifications of underlying stressors in the region. In particular, land-use activities, physical habitat alterations, and native species were identified. In addition to the physical and chemical characteristics of the study area, land ownership and regulatory jurisdictions played an important role in determining impacts/mitigation and opportunities for restoration. Some of this information was geographically-based and was assessed using documented protocols in an ArcGIS environment. Based on this inventory and reconnaissance effort (completed by the District in early 2002), the reference standard conditions for the Des Plaines communities were characterized in the following manner:

**Hydrology –** Hydrological characteristics (pulse conditions and patterns) were not altered by human disturbances that caused changes in hydroregime (flood frequency, duration, or magnitude) or sediment transport. Flood pulsing and overland flow mimicked the climatic/natural regime. Vegetation was present to resist flow downstream, and together with topographic relief and subsurface water flow, they promoted surface water storage. The flood prone area was undisturbed by humans. Surface hydraulic connections existed between the bankfull channel and the flood prone area. Surface water ponded for more than one day in these areas. The depth of saturated sediment was near the surface of the wetlands. Groundwater and the managed water supply was appropriate to establish and maintain a diverse cover type.

**Biogeochemical** - A range of vegetation types and sediment combined with suitable topographic relief to support detention of particulates. Sufficient water flow through the riparian zone (surface and subsurface) was evident as well as substrates with enough silt to adsorb elements, promote propagule recruitment, and supply organic materials. In addition, presence of organic mater indicated nutrient cycling occurring within the ecosystems.

**Spatial Configuration** – Spatially-explicit landscape characteristics within the ecosystems associated with patch geometry and distribution were optimized. Landscape simplification was absent – a mosaic or

heterogeneic suite of habitat types was present sufficient in both size and numbers to promote both core area stability and edge diffusion (a blurring of the edge contrast). Habitat connectivity was evident and supported the persistence of both plant and animal populations. Distances between high quality patches was minimized, and a mixture of age classes were present within a reasonable distance of one another to promote niche diversification and offer escape routes during stochastic disturbances. Land adjacent to the reference areas was undeveloped and unperturbed by human disturbances such as agricultural activities.

**Biotic Integrity and Structure** - An abundance of native trees, shrubs, and herbaceous vegetation was readily apparent. Invasive plant species were absent. Guild representatives (i.e., indicators) included a wide variety of growth forms (trees, shrubs, vines, grasses, forbs, algae, and lichens). Plant vertical configuration and foliage profile (canopy cover) presented a variety of vertical layers. Vegetation provided vertical and horizontal connectivity the length of the system. All age classes of trees (seedlings, saplings, and trees) were represented in the woodland and savanna communities. Biotic legacies from preceding communities, propagules from adjacent stands, ecosystem structuring processes and the generation of spatial heterogeneic complexes combined to produce both overall compositional diversity and patch diversity (habitat breadth).

### Reference Site Selection

Once the inventory and reconnaissance was completed, the E-Team used the strategy outlined above to filter and screen the potential sites down to a manageable number. To assure adequate sampling size, the District was asked to locate at least three sites per cover type spanning the range of reference conditions and representing the relative variation found across the system (described earlier in the reference-based section above). Again, an attempt was made to evenly distribute these sites across the entire watershed. To reduce data collection variability, a single three-person sampling team (a recorder and two data collectors) was used to collect all field data. To the greatest extent possible, underlying stressors in the region were described in the notes section of the field data collection sheets. In particular, land-use activities, physical habitat alterations, and indicator species were described in detail. Their goal was to identify, prioritize, and then select sites across the study area that were considered

either “high (H),” “medium (M),” or “low quality (L)” based on expert opinion (Table 8).

Table 8. DPII Reference Sites.

| County | Site # | Site Name | Site Quality | County | Site # | Site Name | Site Quality |
|---|---|---|---|---|---|---|---|
| **Dry and Mesic Fine-textured-soil Prairies (PRAIRIEDRY)** | | | | **Wet Fine-textured-soil Prairies (PRAIRIEWET)** | | | |
| Cook | 1 | Camp Pine | H | Cook | 3 | Oakton College | H |
| Cook | 95 | Port Wine | H | Cook | 9 | Zoo Area | H |
| Cook | 4 | River Trail | H | Kenosha | 34 | Bain Station RR Prairie | H |
| Lake | 44 | Old School | H | Lake | 50 | Van Patton Woods | H |
| Lake | 51 | Wadsworth Savanna | H | Lake | 51 | Wadsworth Savanna | H |
| Lake | 68 | Independence Grove | M | Cook | 95 | Port Wine | M |
| Lake | 54 | Wright Woods | M | Lake | 96 | Newport Township | M |
| Kenosha | 101 | Site #11 | L | Lake | 54 | Wright Woods | M |
| Lake | 35 | Almond Marsh | L | Kenosha | 32 | Kilbourn Road Ditch | L |
| Lake | 96 | Newport Township | L | Kenosha | 24 | Merkt's Woods | L |
| Lake | 47 | Ryerson | L | Kenosha | 101 | Site #11 | L |
| | | | | Lake | 52 | Waukegan Savanna | L |

*(Continued)*

Table 8. (Continued).

| County | Site # | Site Name | Site Quality | County | Site # | Site Name | Site Quality |
|---|---|---|---|---|---|---|---|
| **Dry-mesic and Mesic Fine-textured-soil Savannas (SAVANNADRY)** | | | | **Wet-mesic Fine-textured-soil Savannas (SAVANNAWET)** | | | |
| Lake | 35 | Almond Marsh | H | Cook | 95 | Port Wine | H |
| Lake | 68 | Independence Grove | H | Kenosha | 16 | Des Plaines Complex (aka Des Plaines River Dry Woods aka Pleasant RR Prairie) | H |
| Cook | 7 | Willow Sanders | M | Lake | 51 | Wadsworth Savanna | M |
| Kenosha | 16 | Des Plaines Complex (aka Des Plaines River Dry Woods aka Pleasant RR Prairie) | M | Kenosha | 32 | Kilbourn Road Ditch | L |
| Lake | 46 | Rollins Savanna | M | | | | |
| Kenosha | 100 | Des Plaines River Wetlands | L | | | | |
| Kenosha | 103 | Paris Prairie Remnant | L | | | | |
| Kenosha | 30 | Schneider Road Marsh | L | | | | |
| Racine | 105 | Site #9 | L | | | | |

*(Continued)*

Table 8. (Continued).

| County | Site # | Site Name | Site Quality | County | Site # | Site Name | Site Quality |
|---|---|---|---|---|---|---|---|
| **Wet-mesic and Wet Floodplain Forests (FORFLPLWET)** | | | | **Northern Flatwood Forests (FORNFLATS)** | | | |
| Cook | 6 | Thatcher | H | Lake | 37 | Elm Road Woods | H |
| Cook | 9 | Zoo Area | H | Lake | 47 | Ryerson | H |
| Lake | 42 | MacArthur | H | Lake | 54 | Wright Woods | H |
| Lake | 47 | Ryerson | H | Cook | 1 | Camp Pine | M |
| Lake | 53 | Wetland Demonstration Project | H | Cook | 3 | Oakton College | M |
| Cook | 1 | Camp Pine | M | Lake | 42 | MacArthur | M |
| Cook | 3 | Oakton College | M | Cook | 4 | River Trail | L |
| Cook | 95 | Port Wine | M | Cook | 7 | Willow Sanders | L |
| Cook | 4 | River Trail | M | Lake | 68 | Independence Grove | L |
| Kenosha | 100 | Des Plaines River Wetlands | M | Lake | 44 | Old School | L |
| Lake | 51 | Wadsworth Savanna | M | **Wet-mesic Upland Forests and Wet-Mesic Woodlands (FORUPLWET)** | | | |
| Lake | 54 | Wright Woods | M | Lake | 38 | Ethel's Woods | H |
| Cook | 7 | Willow Sanders | L | Lake | 97 | Old Mill | H |
| Kenosha | 16 | Des Plaines Complex (aka Des Plaines River - Dry Woods aka Pleasant RR Prairie) | L | Lake | 68 | Independence Grove | M |
| Kenosha | 24 | Merkt's Woods | L | Lake | 42 | MacArthur | M |
| | | | | Cook | 7 | Willow Sanders | L |

*(Continued)*

Table 8. (Concluded).

| County | Site # | Site Name | Site Quality | County | Site # | Site Name | Site Quality |
|---|---|---|---|---|---|---|---|
| **Dry-mesic and Mesic Woodlands (WOODLNDDRY)** | | | | | | | |
| Kenosha | 17 | Friendship Lake | H | Cook | 2 | Dam #4 | L |
| Lake | 35 | Almond Marsh | H | Cook | 3 | Oakton College | L |
| Lake | 42 | MacArthur | H | Cook | 95 | Port Wine | L |
| Lake | 47 | Ryerson | H | Cook | 4 | River Trail | L |
| Lake | 50 | Van Patton Woods | H | Cook | 7 | Willow Sanders | L |
| Lake | 51 | Wadsworth Savanna | H | Kenosha | 102 | McDermott's Potholes | L |
| Cook | 9 | Zoo Area | M | Kenosha | 24 | Merkt's Woods | L |
| Lake | 68 | Independence Grove | M | Lake | 38 | Ethel's Woods | L |
| Lake | 46 | Rollins Savanna | M | Lake | 52 | Waukegan Savanna | L |
| Cook | 1 | Camp Pine | M | | | | |

These initial rankings were based upon the consensus of the "on-the-ground" resource managers that had actual knowledge of each site's level of disturbance, species composition, land ownership, and the presence or absence of hydrologic alterations. An attempt was made to evenly distribute the site selection across the three primary counties (i.e., Lake, Cook, Kenosha, and to a small extent Racine). All told, **85** sites were considered either reference standard (optimal) or sub-optimal and were chosen to represent the range of conditions existing within the reference domain (Figure 34).

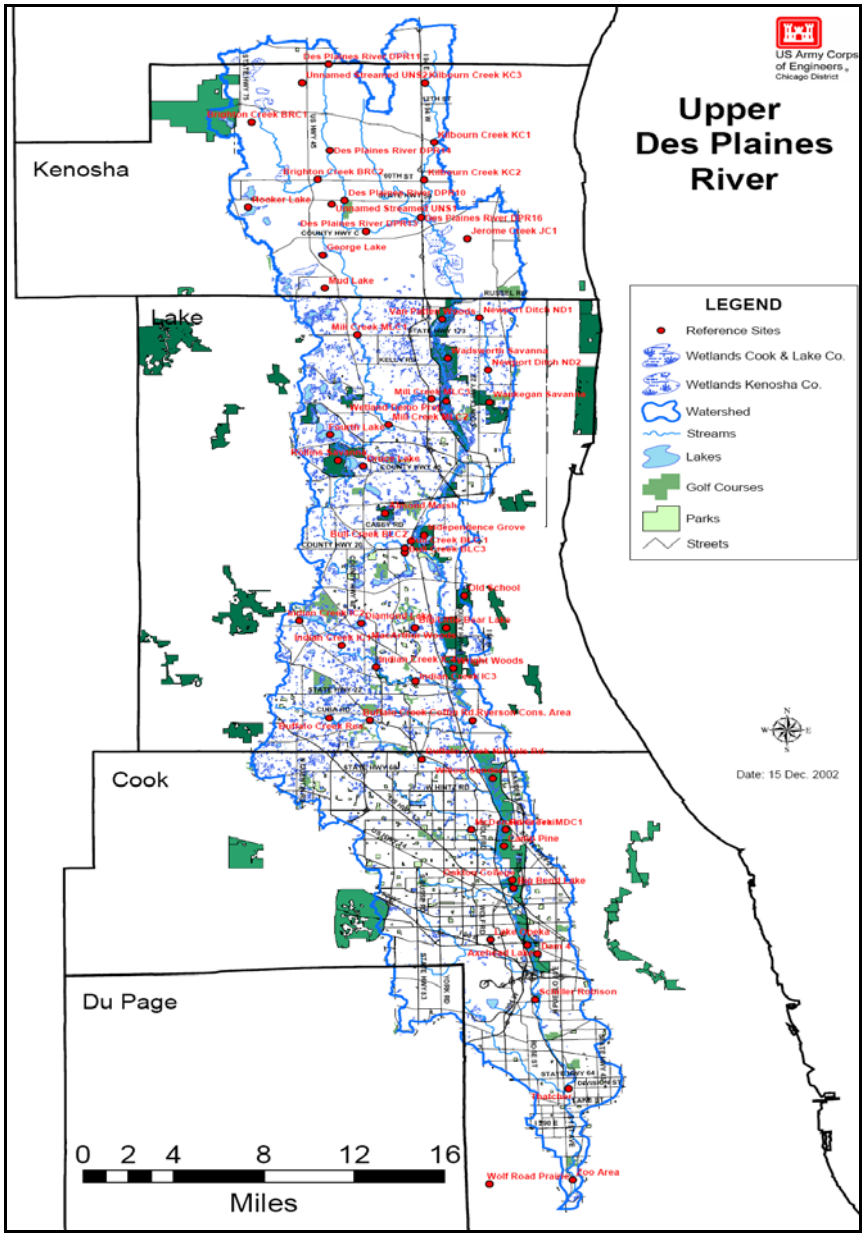


Figure 34. Des Plaines Watershed reference sites used to calibrate the community index models.

## Field Data Collection

Table 9 below identifies the sampling techniques used to measure the individual model variables in the 2003-2004 field efforts.

Table 9. Field sampling protocols summarized for the variables associated with the Upper Des Plaines Watershed community index models.

| Code | Variable Description | Sampling Methodology and Data Management | Cover Type Applicability |
|---|---|---|---|
| CANATGRND | Percent of the Ground Vegetation Canopy Cover Comprised of Native Species | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the FQI analysis report, determine from the "Physiognomy" section the percent of the ground vegetation species encountered that were native. | ALL |
| CANATSHRUB | Percent of the Shrub Canopy Cover Comprised of Native Species | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the FQI analysis report, determine from the "Physiognomy" section the percent of the shrub species encountered that were native. | ALL |
| CANATREE | Percent of the Tree Canopy Cover Comprised of Native Species | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the FQI analysis report, determine from the "Physiognomy" section the percent of the tree species encountered that were native. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |
| CANFORBS | Percent Forb Canopy Cover | Using a 1-m$^2$ quadrat along a linear 100-m transect, stop every 10-meters and record the estimated percent of the herbaceous vegetation cover that is comprised of forb species. | PRAIRIEDRY<br>PRAIRIEWET |
| CANGRASS | Percent Grass Canopy Cover (Graminoid) | Using a 1-m$^2$ quadrat along a linear 100-m transect, stop every 10-meters and record the estimated percent of the herbaceous vegetation cover that is comprised of grass species. | PRAIRIEDRY<br>PRAIRIEWET |
| CANHERB | Percent Herbaceous Canopy Cover | Using a 100 - m transect, stop every 10 - m, use 1 - m2 quadrat, record herbaceous canopy cover. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |
| CANHITREE | Percent High Tree Canopy Cover | Using a 1-m$^2$ quadrat along a linear 100-m transect, stop every 10-meters and record the estimated percent of the canopy cover of trees taller than 9.1-m (30-ft) in the overstory canopy. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |

*(Continued)*

Table 9. (Continued).

| Code | Variable Description | Sampling Methodology and Data Management | Cover Type Applicability |
|---|---|---|---|
| CANLOWTREE | Percent Lower Tree Canopy Cover | Using a 1-m² quadrat along a linear 100-m transect, stop every 10-meters and record the estimated percent of the canopy cover of trees less than 9.1-m (30-ft) tall in the overstory canopy. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |
| CANSHRUB | Percent Shrub Canopy Cover | Using a 1-m² quadrat along a linear 100-m transect, stop every 10-meters and record the estimated percent of the canopy cover that is shrub. | ALL |
| DBHTREE | Average dbh of Trees | Using a belt transect, record tree species and measure all trees > 5.5m (18ft) in height and > 5cm (2in) dbh. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |
| DETRITUS | Percent of the Ground Covered By Detritus in Wet Systems or Litter in Dry Systems (%) | Using a 100-m transect, stop every 10-m and use a 1-m² quadrat to record percent of the ground that is covered by detritus in wet systems and litter in dry systems. | PRAIRIEDRY<br>PRAIRIEWET |
| HTVEG | Average Height of the Herbaceous Vegetation(cm) | Using a 100-m transect, stop every 10-m, measure height of herbaceous vegetation from the center of each quadrant within a one square-meter quadrat. | PRAIRIEDRY<br>PRAIRIEWET |
| INDEXFQI | Floristic Quality Index (FQI) | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using a one-quarter square meter quadrat survey and evaluate prairie tracts. | ALL |
| NUMDECAY | Number of Decay Classes Present | Using a belt transect, record which of the five stages of woody decay is present:<br>1 = Logs recently fallen, bark attached, leaves and fine twigs present, no fungi present.<br>2 = Logs with loose bark, no leaves and fine twigs present, fungi may be present.<br>3 = Logs without bark, few stubs of branches present,<br>4 = Logs without bark or branches, heartwood in advanced state of decay, fungi may be present.<br>5 = Logs decayed into ground, fungi may be present. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |

*(Continued)*

Table 9. (Concluded).

| Code | Variable Description | Sampling Methodology and Data Management | Cover Type Applicability |
|---|---|---|---|
| NUMINDGRND | Ground Vegetation Diversity - Number of Species with "C" Value >5 | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the "C" value assessment in the FQI analysis, determine the number of ground vegetation species present with a "C" value greater than five. | ALL |
| NUMINDSHRB | Shrub Vegetation Diversity –Number of Species with "C" Value >5 | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the "C" value assessment in the FQI analysis, determine the number of shrub species present with a "C" value greater than five. | ALL |
| NUMINDTREE | Tree Vegetation Diversity - Number of Species with "C" Value >5 | Using the results of the "C" value assessment in the floristic quality index analysis, report out the number of tree species present with a "C" value greater than five. | SAVANNADRY<br>SAVANNAWET<br>FORFLPLWET<br>FORNFLATS<br>FORUPLWET<br>WOODLNDDRY |
| WETNESS | Native Mean Wetness With Adventives | FQI data were sampled every 10 meters along a 100 m linear transect for a total of three transects per cover type. Using the results of the FQI analysis, determine the native mean wetness with adventives. Each species found at the site is assigned a category (e.g., Obligate, Facultative-wet, Facultative, Facultative-Upland and Upland) based on the National Wetland Indicator Categories, and these categories in turn are assigned a value ranging from -5 to +5 (Upland) (Reed 1988, Swink and Wilhlem 1994). Positive (+) values indicate a dry condition and negative (-) values indicate a wet condition. For HEP, the values were converted to a positive integer scale, with –5 equal to 0 and +5 equal to 10. | ALL |

A standardized approach was developed to collect all field data. Using a somewhat subjective protocol (taking random numbers of footsteps in a random direction into each reference site) each linear transect (100-m) was laid out, and samples were taken every 10 meters, resulting in 10 replications per transect (Figure 35).

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Figure 35. Field sampling protocols for the community models developed for the Des Plaines River Watershed.

A minimum of three transects (300-m) or 30 replications were measured and recorded per cover type (recommended sample size) to reduce variability and standard deviation in the data. A three-person sampling team was used to collect the field data collection (a recorder and two data collectors). The data recorder stood at the center point of the sample plot and recorded the data from fellow sampling team members. Estimates of ground cover were made using visual estimates and quadrats that provided a reference grid for calibration. This practice was "tested" several times at the beginning of each site visit to "train" the team to estimate similarly. Overhead canopies were estimated using optic tubes (Figure 36).

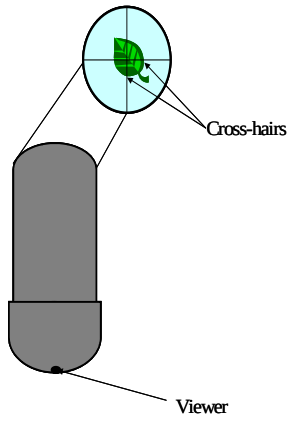


Figure 36. The optic tubes used to measure overhead canopy for the study were made of PVC tubing with cross-hair wires inserted into one end. The field team member placed the other end to their eye and determined if the intersection of the two wires was directly over the object (i.e., the tree leaves) being estimated. If so, then a "hit" or "+" was recorded on the data sheet. If not, then a "miss" or "-" was recorded instead. To insure better accuracy, we recommended that multiple random points were measured within the sample area. One note: it was important to hold the optic tube at a 90-degree angle to what was being measured (i.e., perpendicular to the ground) to obtain an accurate measure.

Although there is a well documented FQI inventory method, the E-Team chose to employ a more simplified approach that complimented the

protocols employed to gather the other vegetative cover parameters. A grid system was used to divide the quadrats into 4 quadrants of equal size (one quarter each of the original size) to measure the FQI and related parameters (i.e., wetness, native indicators and ground covers). The idea was that the smaller sections were easier to estimate than the entire 1-m quadrat. The data were sampled every 10 meters along a 100 m linear transect. Vegetative height data were measured at the center of all 4 quadrants within the one square meter quadrat. Table 10 summarizes the number of sites, transects and sample points taken per cover type for the calibration efforts.

Table 10. Sample Sizes Used to Calibrate the Upper Des Plaines community models.

| Cover Type | Lake | | Cook | | Kenosha and Racine | |
|---|---|---|---|---|---|---|
| | Sites | Points | Sites | Points | Sites | Points |
| PRAIRIEDRY | 7 | 210 | 3 | 90 | 1 | 30 |
| PRAIRIEWET | 5 | 150 | 3 | 90 | 4 | 120 |
| SAVANNADRY | 3 | 90 | 1 | 30 | 5 | 150 |
| SAVANNAWET | 1 | 30 | 1 | 30 | 2 | 60 |
| FORFLPLWET | 5 | 150 | 7 | 210 | 3 | 90 |
| FORNFLATS | 6 | 180 | 4 | 120 | 0 | 0 |
| FORUPLWET | 4 | 120 | 1 | 30 | 0 | 0 |
| WOODLNDDRY | 9 | 270 | 7 | 210 | 3 | 90 |
| Prairie Model | 12 | 360 | 6 | 180 | 5 | 150 |
| Savanna Model | 4 | 120 | 2 | 60 | 7 | 210 |
| Woodland Model | 24 | 720 | 19 | 570 | 6 | 180 |
| OVERALL TOTALS | 40 | 1,200 | 27 | 810 | 18 | 540 |

## Spatially Explicit Data Collection

**Error! Reference source not found.** below identifies the sampling techniques used to measure the individual variables in the 2006-2007 GIS analyses.

Table 11. GIS sampling protocols summarized for the variables associated with the Upper Des Plaines Watershed community index models.

| Code | Variable Description | Sampling Methodology and Data Management | Cover Type Applicability |
|---|---|---|---|
| AREACORE | Percent of the Area That is Core | Using GIS and aerial photography determine the total patch size in acres (ac) and the percent of area that is edge (AREAEDGE) by delineating patch perimeter, measure inward 100m and determine acreage within this band. Divide this number by SIZETRACT of the polygon. Do this for each polygon of like cover within the site. The average AREAEDGE for each site is then subtracted from the total patch size (100%) to get the percent of area that is core (AREACORE). | ALL |
| AREAEDGE | Percent of the Area That is Edge | Using GIS and aerial photography determine the total patch size in acres (ac) and then delineate the patch perimeter, by measuring inward 100m. Next, calculate area of this 100-m edge band and divide by the area of the total patch size to determine percent area that is edge. | ALL |
| DIST20TRAC | Average Distance to All 20-acre Tracts of Similar Cover Within 5 Miles of the Tract (m) | On a tributary basis, using GIS and aerial imagery delineate community patches then determine the average distance between 20-acre patches of similar habitat within a 5 mile radius inside the project boundary along the tributary (m). | ALL |
| NUM20TRAC | Average Number of 20-Acre Tracts of Similar Cover Within 5 miles of the Tract (m) | On a tributary basis, using GIS and aerial imagery delineate community patches then determine the average number of 20-acre (or greater) community habitat patches of similar cover within a 5 mile radius inside the project boundary along the tributary. | ALL |
| SIZELGTRAC | Size of the Largest Tract of Similar Cover Within a 5-mile Radius | On a tributary basis, using GIS and aerial imagery, measure the size of the largest patch of habitat within a 5-mile radius from a given patch of similar cover inside the project boundary along the tributary (ac). | ALL |
| SIZETRACT | Tract Size | On a cover type-by-cover type basis, using GIS and aerial imagery, determine the average patch size of polygons within the site of similar cover type for a given community tract/patch. | ALL |
| TYPADJLAND | Identification of Adjacent Landuse Practices | On a site-by-site basis, using GIS and aerial imagery, draw a 200-m band around the outside of the site's boundary and identify the predominant land use category. Classify the landuse practice as one of the following categories:<br>0 = No Data, SI = 0<br>1 = Pristine, Uninhabited Areas, SI = 1.0<br>2 = Parks<br>3 = Pasturelands<br>4 = Utility Rights-of-way and Rail Roads<br>5 = Dirt & Gravel roads, Oil and Gas Fields<br>6 = Agricultural Croplands<br>7 = Residential and Golf Courses<br>8 = Paved Roads, Highways<br>9 = Commercial/Industrial | ALL |

Landscape variables were measured based on both onsite reconnaissance, interpretation of maps and aerial photos, and GIS data layers. Landscape variable data were developed by the District GIS specialist, whom provided ERDC-EL with the following protocols:[1]

(1) Extract Cook Co site data from HEPsites shapefile to create Cook_HEP_Sites.
(2) Add Site_Ac field to attribute table and remove other fields.
(3) Add ERDC_No field and copy ERDC numbers to table.
(4) Select data from CookCo cover types that intersects CookCoHEP to create CookCoSelect.
(5) Union CookCoSelect with CookCoHEP to get HEPSites names and acreages. Create CookCoUNION file.
(6) Calculate acreage of plots using x-tools in CookCoUNION.
(7) Review data and remove plots <.25 acres.
(8) Create 100m buffer inside CookCoPATCH save as CookCoBUFFER.
(9) Calculate acreage for CookCoBUFFER.
(10) Join CookCoBuffer to CookCoUNION using FID field.
(11) Export joined dataset to create CookCoPATCH.
(12) Add fields for SIZEPATCH, AREAEDGE TO CookCoPATCH.
(13) Calculate variables for SIZEPATCH and AREAEDGE.
(14) Add TYPADJLAND field to CookCoHEP draw 200m buffer outside and look at adjacent land use and populate data.
(15) Create CookCoPOINT file and generate 30 random points within each site. (I use Hawth's Analysis Tools extension). Add DISTADJLAN field to CookCoPOINT and measure distance to the predominant landuse category. (I tried to automate this but was not successful).
(16) Export attribute tables from CookCoPOINT, CookCoPATCH, and CookCoSite to MS Excel.

## HSI Statistical Analysis and Curve Calibrations

The reference condition described earlier defined the measurement scale and the state toward which the E-Team desired to move the system. In the case of the Upper Des Plaines Watershed, the reference-based approach employed "reference standard ecosystems" to establish optimal conditions (HSI = 1.0) that served as benchmarks or standards of comparison for the existing and future conditions. Locating "degraded" reference sites was essential to calibrating the model. These "degraded" reference conditions

[1] Please direct questions regarding these GIS protocols to Mr. J.D. Ennis in the Chicago District.

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represented the other end of the measurement scale and represented the ecological systems that were clearly degraded and socially unacceptable (HSI – 0.0). We refer to this process as "calibration," which we define here loosely as the use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.

To calibrate the models, we used the average values across the watershed and their associated standard deviations to generate a curve for each variable in each model. We calculated these statistics on both a "cover type-by-cover type" basis, as well as at the broader county and watershed scales. To develop curves for each variable, ERDC used a straightforward assignment process. The watershed mean was assigned a **0.75** SI value in every case. The standard deviation of the mean was added to the average, and this total was assigned a **1.0** SI on the curve (Figure 37).

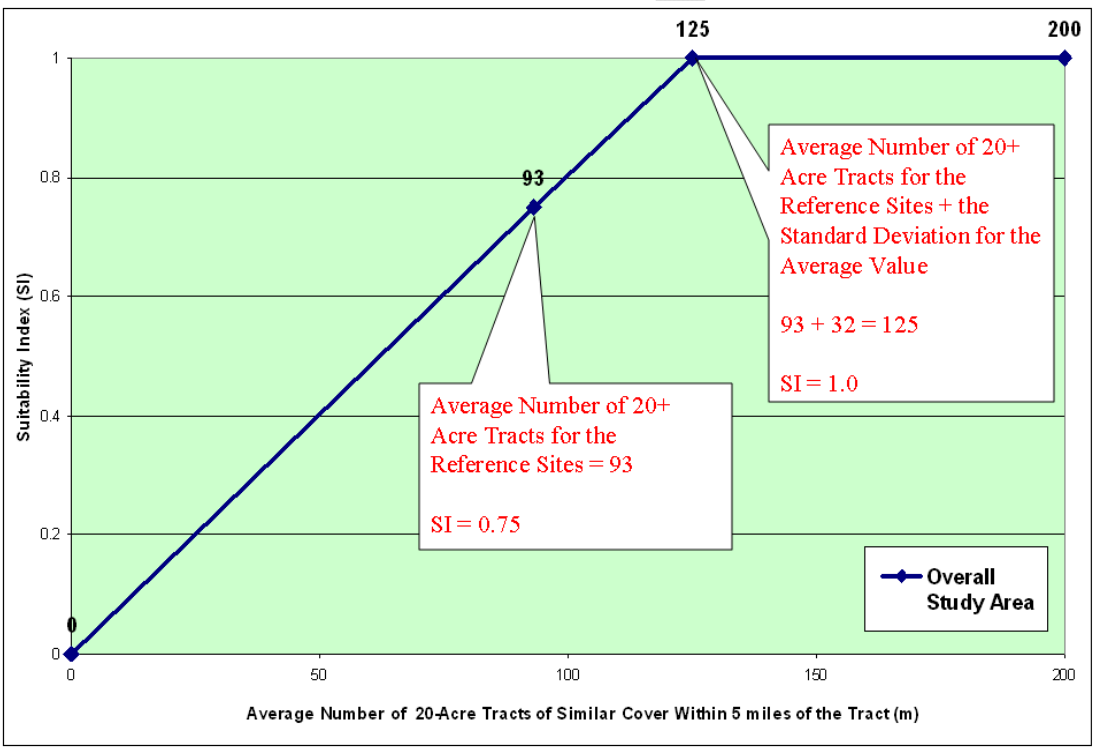


Figure 37. Example of curve calibration method using the watershed mean and its standard deviation.

In some instances, the E-Team made the decision to calibrate the curve on the basis of cover type distinctions. For example, the E-Team reviewed the

individual cover type means and made the decision that each cover type had a unique floristic character, and therefore, they developed individual SI curves for each cover type's FQI data (Figure 38).

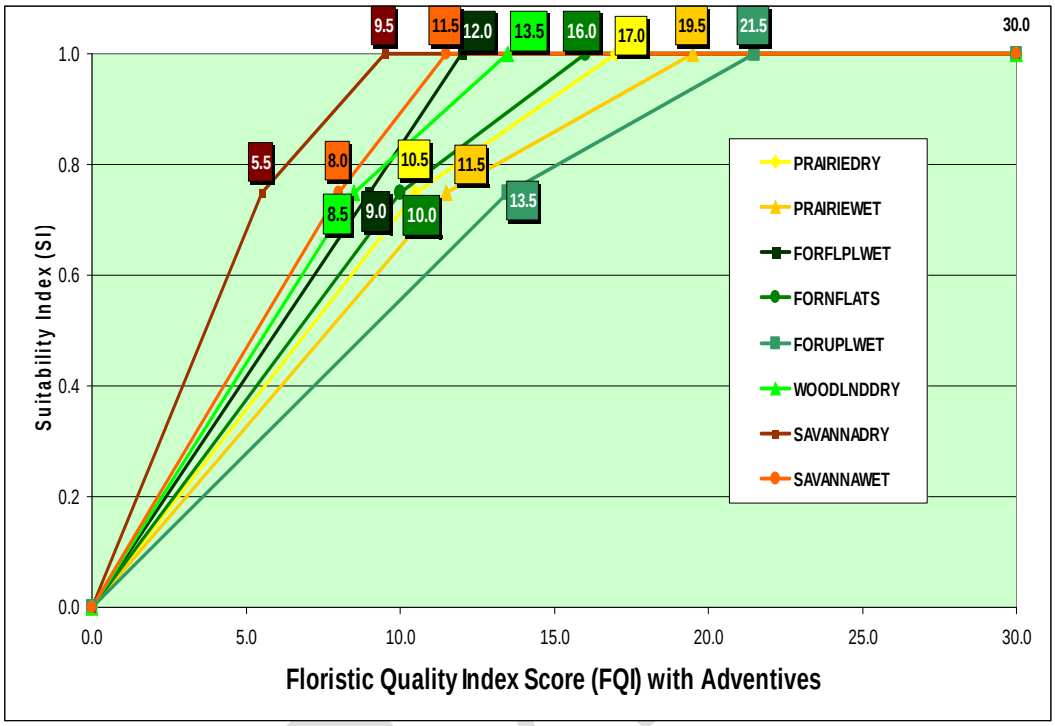


Figure 38. The model calibration approach was flexible enough to encourage and incorporate professional expertise into the methodology. Here, the reference data support the separation of cover types based on mean data. Wet prairies and upland wet forests have significantly higher FQI scores that do those communities with less hydrologic connectivity. As a result, the HSI model was calibrated to capture this unique condition of each ecosystems.

Ultimately, the curves developed for the watershed were the result of an iterative process where the E-Team directed ERDC-EL to gradually modify the curves to better reflect reality as they perceived it "in-the-field." ERDC-EL made a conscious effort to fully document these changes, and curves that have been altered from the means and standard deviations as a result of "expert judgment" are presented as "red" curves in the graphs and supporting text (Figure 39).

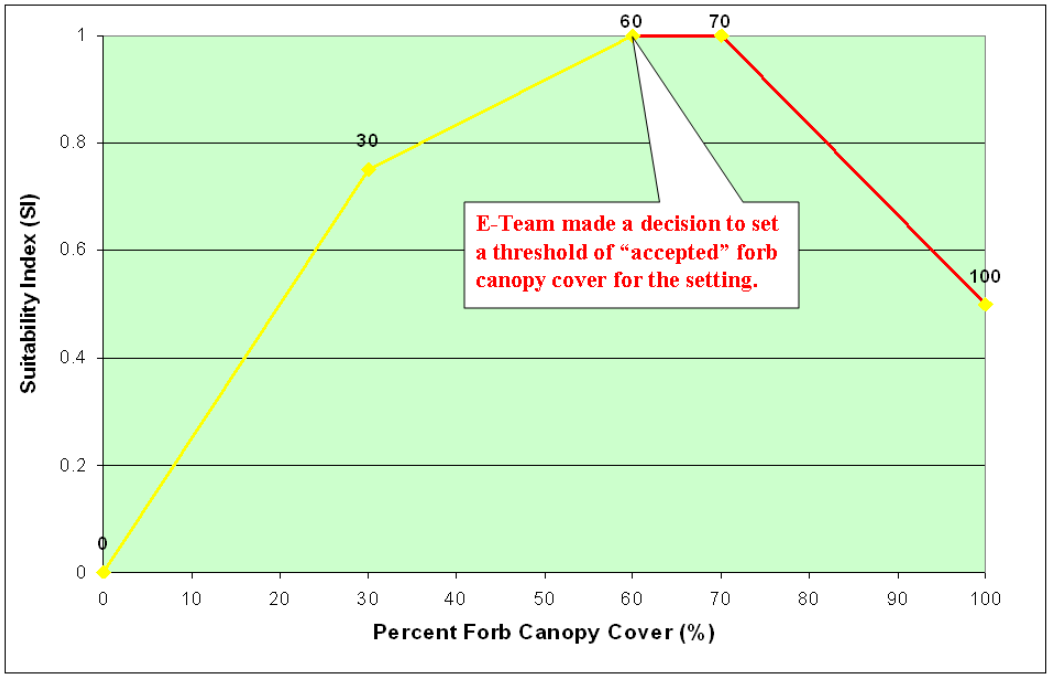


Figure 39. Example of curve calibration method using a combination of watershed means, standard deviations and expert opinion.

To review the final curves for the Upper Des Plaines community models, refer to *Appendix G*.

## Model Results

The results of the baseline HEP assessment for the reference sites are summarized below. HSIs capture the quality of the acreage within the reach. Units (i.e., HUs) take this quality and apply it to the governing area through multiplication (Quality X Quantity = Units). Both HSIs and HUs are reported for each site and model. Interpretations of these findings can be generalized in the following manner (Table 12).

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Table 12. Interpretation of HSI scores resulting from HEP assessments.

| HSI Score | Interpretation |
|---|---|
| 0.0 | Not-suitable - the community does not perform to a measurable level and will not recover through natural processes |
| Above 0.0 to 0.19 | Extremely low or very poor functionality (i.e., habitat suitability) - the community functionality can be measured, but it cannot be recovered through natural processes |
| 0.2 to 0 .29 | Low or poor functionality |
| 0.3 to 0.39 | Fair to moderately low functionality |
| 0.4 to 0 .49 | Moderate functionality |
| 0.5 to 0.59 | Moderately high functionality |
| 0.6 to .79 | High or good functionality |
| 0.8 to0.99 | Very high or excellent functionality |
| 1.0 | Optimum functionality - the community performs functions at the highest level - the same level as reference standard settings |

In most instances, the individual community HSI scores fell in the mid-range of values (~0.5) indicating only a moderate level of functionality in the study area (Table 13, Figure 40 and Figure 41). The highest functioning site was the Friendship Lake Marsh in Kenosha County, Wisconsin (Weighted HSI = 0.79).The highest producing site in terms of Habitat Units (HUs) was the Willow Sanders in Cook County, Illinois (Total HUs = 412). This was to be expected – as it contains significant amounts of habitat acres (acres = 783).

Table 13. Baseline results for the Upper Des Plaines Watershed reference sites verification analysis.

| County | ERDC Site Code | Site Name | PRAIRIES | | | SAVANNAS | | | WOODLANDS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HSIs | Acres | HUs | HSIs | Acres | HUs | HSIs | Acres | HUs |
| Cook | 1 | Camp Pine | 0.63 | 34 | 22 | | | | 0.51 | 575 | 292 |
| | 2 | Dam #4 | | | | | | | 0.52 | 33 | 17 |
| | 3 | Oakton College | 0.77 | 3 | 2 | | | | 0.52 | 72 | 37 |
| | 4 | River Trail | 0.59 | 10 | 6 | | | | 0.52 | 422 | 221 |
| | 6 | Thatcher | | | | | | | 0.43 | 190 | 82 |
| | 7 | Willow Sanders | | | | 0.25 | 26 | 7 | 0.54 | 757 | 405 |
| | 9 | Zoo Area | 0.53 | 5 | 3 | | | | 0.53 | 107 | 57 |
| | 95 | Port Wine | 0.59 | 24 | 14 | 0.64 | 51 | 33 | 0.46 | 293 | 133 |

*(Continued)*

Table 13. (Concluded).

| County | ERDC Site Code | Site Name | PRAIRIES | | | SAVANNAS | | | WOODLANDS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HSIs | Acres | HUs | HSIs | Acres | HUs | HSIs | Acres | HUs |
| Kenosha | 16 | DPR Complex | | | | 0.49 | 94 | 46 | 0.44 | 166 | 73 |
| | 17 | Friendship Lake Marsh | | | | | | | 0.79 | 31 | 24 |
| | 20 | Hooker Lake and Marsh | | | | | | | 0.03 | 1 | 0 |
| | 24 | Merkt's Woods | 0.38 | 106 | 40 | | | | 0.53 | 36 | 19 |
| | 30 | Schneider Road Marsh | | | | 0.59 | 5 | 3 | | | |
| | 32 | Kilbourn Road Ditch | 0.54 | 25 | 13 | 0.57 | 2 | 1 | | | |
| | 34 | Bain Station RR Prairie | 0.63 | 7 | 4 | | | | | | |
| | 100 | Des Plaines River Wetlands | | | | 0.52 | 13 | 7 | 0.50 | 71 | 35 |
| | 101 | Site #11 | 0.60 | 65 | 39 | | | | | | |
| | 102 | McDermott's Potholes | | | | | | | 0.60 | 5 | 3 |
| | 103 | Paris Prairie Remnant | | | | 0.41 | 1 | 0 | | | |
| Lake | 35 | Almond Marsh | 0.51 | 30 | 15 | 0.66 | 32 | 21 | 0.52 | 243 | 125 |
| | 37 | Elm Road Woods | | | | | | | 0.68 | 11 | 7 |
| | 38 | Ethel's Woods/Rasmussen Lake | | | | | | | 0.53 | 216 | 114 |
| | 42 | Mac Arthur Woods | | | | | | | 0.60 | 419 | 252 |
| | 44 | Old School | | | | | | | 0.44 | 5 | 2 |
| | 46 | Rollins Savanna | | | | 0.61 | 117 | 72 | 0.66 | 50 | 33 |
| | 47 | Ryerson Woods | 0.37 | 3 | 1 | | | | 0.60 | 432 | 261 |
| | 50 | Van Patton Woods | 0.62 | 212 | 130 | | | | 0.73 | 25 | 18 |
| | 51 | Wadsworth Savanna | 0.69 | 71 | 49 | 0.70 | 3 | 2 | 0.66 | 257 | 170 |
| | 52 | Waukegan Savanna | 0.35 | 34 | 12 | | | | 0.57 | 34 | 19 |
| | 53 | Wetland Demo Project | | | | | | | 0.48 | 216 | 104 |
| | 54 | Wright Woods | 0.66 | 45 | 30 | | | | 0.60 | 181 | 109 |
| | 68 | Independence Grove | 0.67 | 23 | 15 | 0.69 | 26 | 18 | 0.62 | 102 | 63 |
| | 96 | Newport Township | 0.61 | 62 | 38 | | | | | | |
| | 97 | Old Mill | | | | 0.69 | 72 | 50 | 0.69 | 101 | 70 |
| Racine | 105 | Site #9 | | | | 0.56 | 2 | 1 | | | |

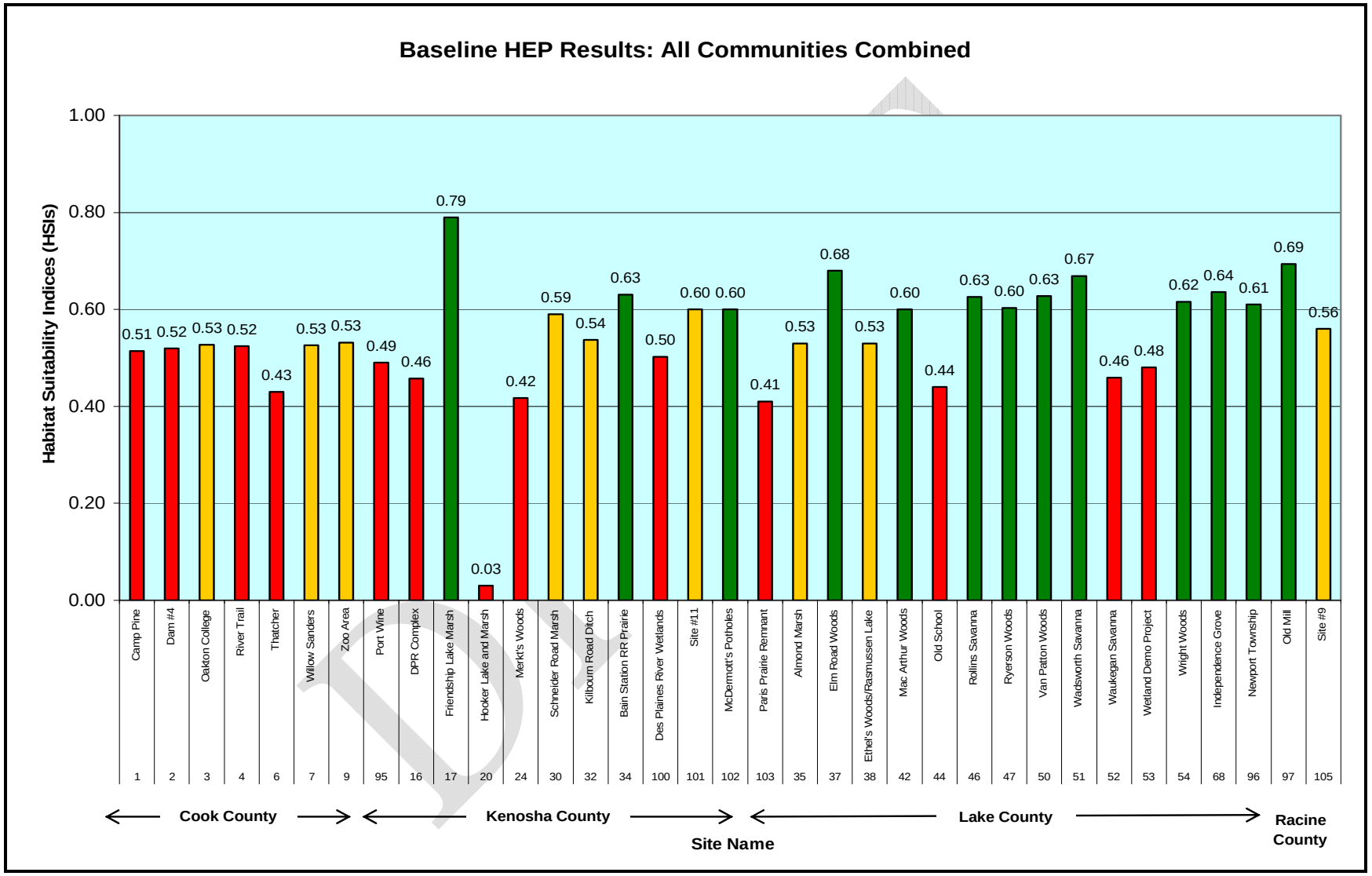


Figure 40. Baseline graphical results (weighted HSIs) for the Upper Des Plaines communities.

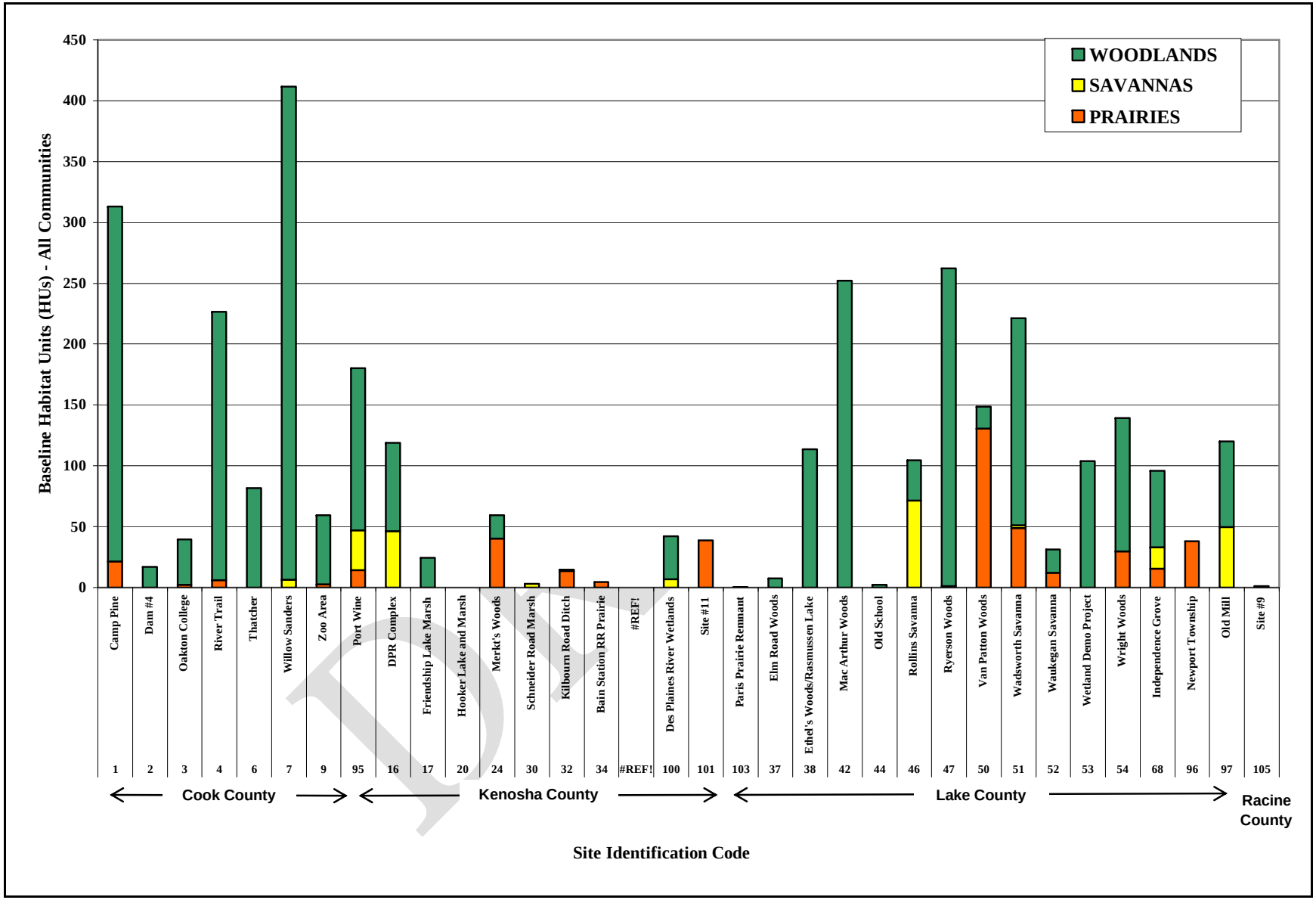


Figure 41. Baseline graphical results (bundled HUs) for the Upper Des Plaines communities.

## Model Verification

The first test of the model was to assess the various references sites (both optimal and sub-optimal) with the formulas and curves and determine whether the model "relating to reality" with respect to the E-Team's expectations. We consider this step to be model verification:

> ***Verification*** *(aka Confirmation) is the comparison of the model output to data from well-known, published test cases to confirm that the algorithms and computer code accurately represent system dynamics.*[1]

For purposes of this effort, *verification* asks whether the model is responding as they experts believe it should. Sites deemed to be highly functional wetlands according to experts, should produce high HSI scores. Sites deemed dysfunctional (by the experts) should produce low HSI scores. Again, the model calibration effort described above was an iterative process, and as such, changes to the model's curves and algorithms were made in an attempt to bring these results into closer alignment. Admittedly, this process was somewhat subjective. But the experts working on the models were the best in the region. Below, we provide both the E-Team's expectation of reference site condition (i.e., **High**, **Medium**, or **Low**) (Table 14).

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[1] Personal communication regarding American Society of Civil Engineers' definitions with Dr. John Nestler, ERDC-EL, August 2009

Table 14. Correlations between the HEP runs at the reference sites and the expert's opinions as their functionality.

| | | | Results of the HEP Runs | | | Expert Opinion | | |
|---|---|---|---|---|---|---|---|---|
| | | | PRAIRIES | SAVANNAS | WOODLANDS | PRAIRIES | SAVANNAS | WOODLANDS |
| County | ERDC Site Code | Site Name | HSIs | HSIs | HSIs | HSIs | HSIs | HSIs |
| Cook | 1 | Camp Pine | High | | Low | High | | Medium |
| | 2 | Dam #4 | | | Low | | | Low |
| | 3 | Oakton College | High | | Medium | High | | Medium |
| | 4 | River Trail | Medium | | Medium | High | | Low |
| | 6 | Thatcher | | | Low | | | High |
| | 7 | Willow Sanders | | Low | Medium | | Medium | Low |
| | 9 | Zoo Area | Low | | Medium | High | | Low |
| | 95 | Port Wine | Medium | Medium | Low | High | Medium | Medium |
| Kenosha | 16 | DPR Complex | | Low | Low | | High | Medium |
| | 17 | Friendship Lake Marsh | | | High | | | High |
| | 20 | Hooker Lake and Marsh | | | Low | | | |
| | 24 | Merkt's Woods | Low | | Medium | Low | | Low |
| | 30 | Schneider Road Marsh | | Medium | | | Low | |
| | 32 | Kilbourn Road Ditch | Low | Medium | | Low | Low | |
| | 34 | Bain Station RR Prairie | High | | | High | | |
| | 100 | Des Plaines River Wetlands | | Low | Low | | Low | Medium |
| | 101 | Site #11 | Medium | | | Low | | |
| | 102 | McDermott's Potholes | | | Medium | | | Low |
| | 103 | Paris Prairie Remnant | | Low | | | Low | |

*(Continued)*

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| | | | Results of the HEP Runs | | | Expert Opinion | | |
|---|---|---|---|---|---|---|---|---|
| | | | PRAIRIES | SAVANNAS | WOODLANDS | PRAIRIES | SAVANNAS | WOODLANDS |
| County | ERDC Site Code | Site Name | HSIs | HSIs | HSIs | HSIs | HSIs | HSIs |
| Lake | 35 | Almond Marsh | Low | High | Low | Low | High | High |
| | 37 | Elm Road Woods | | | High | | | High |
| | 38 | Ethel's Woods/Rasmussen Lake | | | Medium | | | Medium |
| | 42 | Mac Arthur Woods | | | Medium | | | High |
| | 44 | Old School | | | Low | | | Low |
| | 46 | Rollins Savanna | | Medium | High | | Medium | Medium |
| | 47 | Ryerson Woods | Low | | High | Low | | High |
| | 50 | Van Patton Woods | High | | High | High | | High |
| | 51 | Wadsworth Savanna | High | High | High | High | High | High |
| | 52 | Waukegan Savanna | Low | | Medium | Low | | Low |
| | 53 | Wetland Demo Project | | | Low | | | High |
| | 54 | Wright Woods | High | | High | Medium | | High |
| | 68 | Independence Grove | High | High | High | Medium | High | Medium |
| | 96 | Newport Township | Medium | | | Medium | | |
| | 97 | Old Mill | | High | High | | | High |
| Racine | 105 | Site #9 | | Low | | | Low | |

DRAFT

As a simple test of the veracity of the models and the expert's opinions of the reference site conditions was performed using a correlation analysis. (Figure 42).

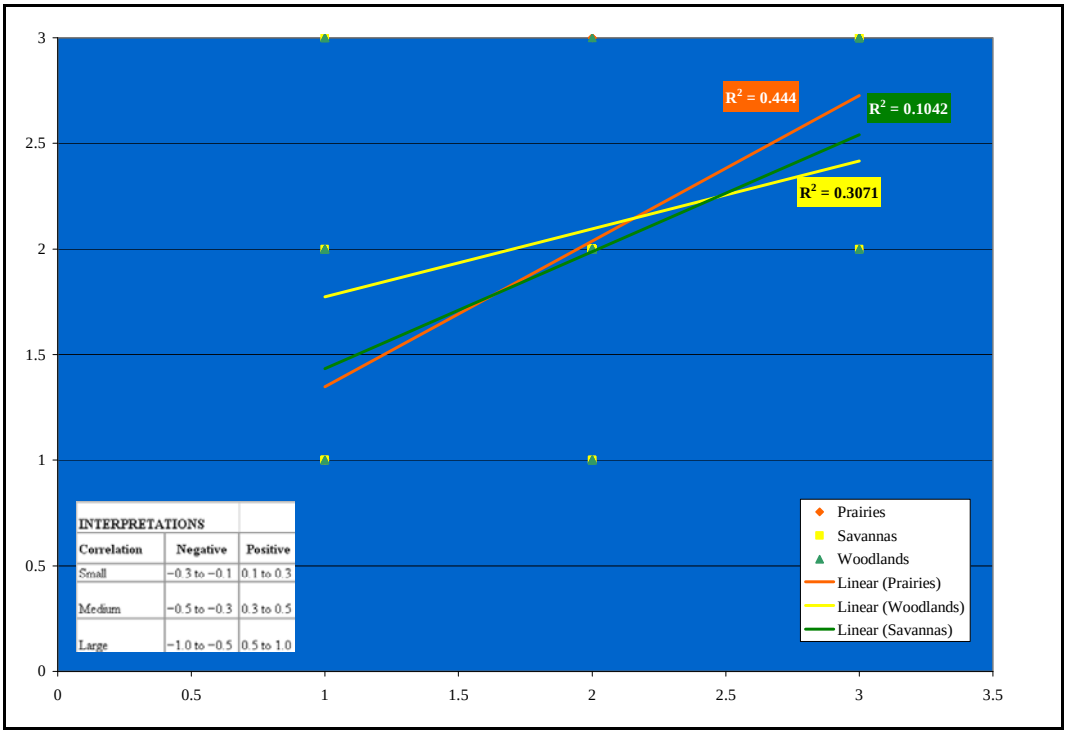


Figure 42. A Pearson's correlation of expert team's opinion of site functionality and the HEP results indicate that they are positively related to some degree.

The most common measure of correlation is the Pearson Product Moment Correlation (aka Pearson's correlation).[1] The Pearson correlation values range from +1 to -1. A rule-of-thumb interpretation of the Pearson's correlation is found in the corner of **Error! Reference source not found.** above. Based on this analysis, we can demonstrate that the Prairie Community Model is strongly correlated to expert opinion regarding site conditions, and therefore can be said to pass the test of "verification" (Pearson correlation value = 0.67). The remaining models did not score as significantly correlated (i.e., Savanna = 0.55 and Woodlands = 0.32), but they still demonstrated a positive correlation albeit moderate to small

[1] Background information was retrieved from http://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient and http://davidmlane.com/hyperstat/A34739.html (SEPTEMBER 2008).

according to the interpretive graph. Because the area is suffering from severe alterations of the natural hydrologic regime, there are no sites within the reference domain functioning at these expected optimal levels, the E-Team felt it was still reasonable to assume that these models offered a solid, scientifically driven means to characterizing conditions and assessing alternative plans. So for now, the E-Team has agreed that the reference sites were functioning at a reasonable level of expectation and as such the model calibrations were deemed acceptable.

## Model Validation

To date the Upper Des Plaines community index models have not been validated. We define model validation here as:

***Validation*** *is accomplished by establishing an objective yet independent line of evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place. Validation can encompass all of the information that can be verified, as well as all of the things that cannot -- i.e., all of the information that the model designers might never have anticipated the user might want or expect the product to do.*[1]

For purposes of this effort, *validation* refers to independent data collections (bird surveys, water quality surveys, etc.) that can be compared to the model outcomes to determine whether the model is capturing the essence of the ecosystem's functionality.

As independent measures of function for the models herein, we propose three options or directions to consider in future opportunities for research arise:

1. A few "relevant" HSI Blue Book (species) models could be used to assess the baseline conditions of the area comparing their outputs to the community models' outputs. As these are already "approved" for use under the USACE model certification program, their outputs

[1] Personal communication regarding American Society of Civil Engineers' definitions with Dr. John Nestler, ERDC-EL, August 2009

should provide relevant cross-validation. However, as most of the HSI Blue Books lack validation, this approach may not be appropriate either. And again, as the Blue Book models are designed to measure only limiting "life requisites" of these key species, they might not be inclusive enough to capture community function and processes.

2. An extremely expensive and time consuming approach could be undertaken to assess biodiversity (both species richness and diversity) in an attempt to identify an "independent measure of function." However, to validate the communities modeled herein, a majority of the faunal groups present would need to be surveyed (mammals, birds, fish, reptiles, amphibians, plants, and possibly even insects). This in turn leads to the question, if we had time and funds to do this level of inventory, why use models at all?
3. Alternatively, validation of the models could potentially be accomplished by assessing patch dynamics using transition model at a landscape scale (Acevedo et al. 1995). Again, this would be validating models with models which might not be considered a true validation exercise.

# 5 Summary and Conclusions

The implications of this report's findings herein are rather straightforward. First, the results support the conceptual premise surrounding the HSI models and indicate their representative capabilities. In other words, scientific literature characterizing the state of the Upper Des Plaines Watershed ecosystems along the main stem and its tributaries point to an overall decline in ecosystem integrity (i.e., health, biodiversity, stability, sustainability, naturalness, wildness, and beauty) – a finding these models can now verify and quantify (we found less than optimal HSI results at all references sites). Furthermore, the results indicate an opportunity to redress ongoing losses. There is great potential to restore sustainable communities therein, offering a significant positive return on investment to both the stakeholders and the federal government.

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# Appendix A: Notation

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| *A-Team* | HGM Assessment Team |
| *AAFCU* | Average Annual Functional Capacity Unit |
| *AAHU* | Average Annual Habitat Unit |
| *C* | Coefficient of Conservatism |
| *CAR* | Fish and Wildlife Coordination Act Report |
| *CT* | Cover Type |
| *CT HSI* | Cover Type Habitat Suitability Index |
| *District* | Chicago District |
| *DPII* | Upper Des Plaines Multi-Purpose Phase II Feasibility Study |
| *EC* | Engineering Circular |
| *EIS* | Environmental Impact Statement |
| *ER* | Ecosystem Restoration |
| *EOA* | Equivalent Optimum Area |
| *ERDC* | U.S. Army Engineer Research and Development Center |
| *ERDC-EL* | ERDC Environmental Laboratory |
| *ESM* | Ecological Service Manual |
| *E-Team* | Ecosystem Assessment Team |
| *ETR* | Expert Technical Review |
| *ETRT* | Expert Technical Review Team |
| *EXHEP* | EXpert Habitat Evaluation Procedures Software |
| *EXHGM* | EXpert Hydrogeomorphic Wetland Assessment Software |
| *FCI* | Functional Capacity Index |
| *FCSA* | Feasibility Cost Sharing Agreement |
| *FCU* | Functional Capacity Unit |
| *FDR* | Flood Damage Reduction |
| *FEMA* | Federal Emergency Management Agency |
| *FQA* | Floristic Quality Assessment |
| *FQI* | Floristic Quality Index |
| *GIS* | Geographic Information System |
| *HEAT* | Habitat Evaluation and Assessment Tools |
| *HEP* | Habitat Evaluation Procedures |

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| *HGM* | Hydrogeomorphic Assessment of Wetlands |
| *HSI* | Habitat Suitability Index |
| *HU* | Habitat Unit |
| *IBI* | Index of Biotic Integrity |
| *ICA* | Incremental Cost Analysis |
| *IDNR* | Illinois Department of Natural Resources |
| *ILEPA* | Illinois Environmental Protection Agency |
| *INHS* | Illinois Natural History Survey |
| *ITRT* | Independent Technical Review Team |
| *LCSMC* | Lake County Stormwater Management Commission |
| *LRSI* | Life Requisite Suitability Index |
| *LPDT* | Laboratory-based Project Delivery Team |
| *LTR* | Laboratory-based Technical Review |
| *LTRT* | Laboratory-based Technical Review Team |
| *NEPA* | National Environmental Policy Act |
| *NED Plan* | National Economic Development Plan |
| *NER Plan* | National Ecosystem Restoration Plan |
| *NRCS* | Natural Resources Conservation Service |
| *PDT* | Project Delivery Team |
| *PMIP* | USACE Planning Models Improvement Program |
| *PMP* | Project Management Plan |
| *PWAA* | Partial Wetland Assessment Area |
| *QHEI* | Qualitative Habitat Evaluation Index |
| *RA* | Relative Area |
| *RVI* | Relative Value Index |
| *SERI* | Society for Ecological Restoration International |
| *SEWRPC* | Southeastern Wisconsin Regional Planning Commission |
| *SI* | Suitability Index |
| *TY* | Target Year |
| *UDPREP* | Upper Des Plaines River Ecosystem Partnership |
| *USACE* | U.S. Army Corps of Engineers |
| *USDA* | U.S. Department of Agriculture |
| *USEPA* | U.S. Environmental Protection Agency |
| *USFWS* | U.S. Fish and Wildlife Service |
| *VSI* | Variable Subindex |
| *WOP* | Without-project Condition |

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| *WP* | With-project Condition |

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# Appendix B: Glossary of Terms

**Activity**

The smallest component of a management measure that is typically a nonstructural, ongoing (continuing or periodic) action in USACE planning studies (Robinson, Hansen, and Orth 1995).

**Alternative (aka Alternative Plan, Plan, or Solution)**

An alternative can be composed of numerous management measures that in turn are comprised of multiple features or activities. Alternatives are mutually exclusive, but management measures may or may not be combinable with other management measures or alternatives (Robinson, Hansen, and Orth 1995).

In HEP analyses, this is the "With-project" condition commonly used in restoration studies. Some examples of Alternatives include:

*Alternative 1: Plant food plots, increase wetland acreage by 10 percent, install 10 goose nest boxes, and build a fence around the entire site.*

*Alternative 2: Build a dam, inundate 10 acres of riparian corridor, build 50 miles of supporting levee, and remove all wetlands in the levee zone.*

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**Alternative (cont)**

*Alternative 3: Reduce the grazing activities on the site by 50 percent, replant grasslands (10 acres), install a passive irrigation system, build 10 escape cover stands, use 5 miles of willow fascines along the stream bank for stabilization purposes.*

**Assessment Model**

A simple mathematical tool that defines the relationship between ecosystem/landscape scale variables and either functional capacity of a wetland or suitability of habitat for species and communities. Habitat Suitability Indices are examples of assessment models that the HEAT software can be used to assess impacts/benefits of alternatives.

**Average Annual Habitat Units (AAHUs)**

A quantitative result of annualizing Habitat Unit (HU) gains or losses across all years in the period of analysis.

AAHUs = Cumulative HUs ÷ Number of years in the life of the project, where:

Cumulative HUs =

$$\sum (T2 - T1)[\{((A1\ H1 + A2\ H2) / 3)\} + \{((A2\ H1 + A1\ H2) / 6)\}]$$

and where:

T1 = First Target Year time interval
T2 = Second Target Year time interval
A1 = Area of available wetland assessment area at beginning of T1
2 = Area of available wetland assessment area at end of T2
H1 = HSI at beginning of T1
H2 = HSI at end of T2.

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**Baseline Condition (aka Existing Conditions)** The point in time before proposed changes are implemented in habitat assessment and planning analyses. Baseline is synonymous with Target Year (TY = 0).

**Blue Book** In the past, the USFWS was responsible for publishing documents identifying and describing HSI models for numerous species across the nation. Referred to as "Blue Books" in the field, due primarily to the light blue tint of their covers, these references fully illustrate and define habitat relationships and limiting factor criteria for individual species nationwide. Blue Books provide: HSI Models, life history characteristics, SI curves, methods of variable collection, and referential material that can be used in the application of the HSI model in the field. For copies of Blue Books, or a list of available Blue Books, contact your local USFWS office.

**Calibration** The use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.

**Combined NED/NER Plan (Combined Plan)** Plans that produce both types of benefits such that no alternative plan or scale has a higher excess of NED plus NER benefits over total project costs (USACE 2003).

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**Cover Type (CT)** Homogenous zones of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, cover types are defined on the basis of species recognition and dependence.

**Ecosystem** A biotic community, together with its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole, unified through life processes. Ecosystems are hierarchical, and can be viewed as nested sets of open systems in which physical, chemical and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multi-states, more localized watersheds or a smaller complex of aquatic habitat.

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**Ecosystem Function**

Ecosystem functions are the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment (SERI 2001). Some restoration ecologists limit the use of the term "ecosystem functions" to those dynamic attributes which most directly affect metabolism, principally the sequestering and transformation of energy, nutrients, and moisture. Examples are carbon fixation by photosynthesis, trophic interactions, decomposition, and mineral nutrient cycling. When ecosystem functions are strictly defined in this manner, other dynamic attributes are distinguished as "ecosystem processes" such as substrate stabilization, microclimatic control, differentiation of habitat for specialized species, pollination and seed dispersal. Functioning at larger spatial scales is generally conceived in more general terms, such as the long-term retention of nutrients and moisture and overall ecosystem sustainability.

**Ecosystem Integrity**

The state or condition of an ecosystem that displays the biodiversity characteristic of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning (SERI 2001). These characteristics are often defined in terms such as health, biodiversity, stability, sustainability, naturalness, wildness, and beauty.

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**Ecosystem Assessment Team (E-Team)** An interdisciplinary group of regional and local scientists responsible for determining significant resources, identification of reference sites, construction of assessment models, definition of reference standards, and calibration of assessment models. In some instances the E-Team is also referred to as the Environmental Assessment Team or simply the Assessment Team.

**Equivalent Optimal Area (EOA)** The concept of equivalent optimal area (EOA) is used in HEP applications where the composition of the landscape, in relation to providing life requisite habitat, is an important consideration. An EOA is used to weight the value of the LRSI score to compensate for this inter-relationship. For example, for optimal wood duck habitat conditions, at least 20 percent of an area should be composed of cover types providing brood-cover habitat (a life requisite). If an area has less than 20 percent in this habitat, the suitability is adjusted downward.

**Existing Condition** Also referred to as the baseline condition, the existing condition is the point in time before proposed changes, and is designated as Target Year (TY = 0) in the analysis.

**Feature** A feature is the smallest component of a management measure that is typically a structural element requiring construction in USACE planning studies (Robinson, Hansen, and Orth 1995).

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**Field Data** This information is collected on various parameters (i.e., variables) in the field, and from aerial photos, following defined, well-documented methodology in typical HEP applications. An example is the measurement of percent herbaceous cover, over ten quadrats, within a cover type. The values recorded are each considered "field data." Means of variables are applied to derive suitability indices and/or functional capacity indices.

**Goal** A goal is defined as the end or final purpose. Goals provide the reason for a study rather than a reason to formulate alternative plans in USACE planning studies (Yoe and Orth 1996).

**Guild** A group of functionally similar species with comparable habitat requirements whose members interact strongly with one another, but weakly with the remainder of the community. Often a species HSI model is selected to represent changes (impacts) to a guild.

**Habitat Assessment** The process by which the suitability of a site to provide habitat for a community or species is measured. This approach measures habitat suitability using an assessment model to determine an HSI.

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**Habitat Suitability Index Model (HSI)**

A quantitative estimate of suitability habitat for a site. The ideal goal of an HSI model is to quantify and produce an index that reflects functional capacity at the site. The results of an HSI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland. An HSI model can be defined in words, or mathematical equations, that clearly describe the rules and assumptions necessary to combine functional capacity indices in a meaningful manner for the wetland.

**Habitat Suitability Index Model (HSI) (cont)**

For example:

$HSI = (SI\ V_1 * SI\ V_2) / 4,$

where:
$SI\ V_1$ is the Variable Subindex for variable 1;
$SI\ V_2$ is the SI for variable 2

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**Habitat Unit (HU)**

A quantitative environmental assessment value, considered the biological currency in HEP. Habitat Units (HUs) are calculated by multiplying the area of available habitat (quantity) by the quality of the habitat for each species or community. Quality is determined by measuring limiting factors for the species (or community), and is represented by values derived from Habitat Suitability Indices (HSIs).

HU = AREA (acres) X HSI.

Changes in HUs represent potential impacts or improvements of proposed actions.

**Life Requisite Suitability Index (LRSI)**

A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting life requisite component within the habitat type in HEP applications. LRSIs are depicted using scatter plots and bar charts (i.e., life requisite suitability curves). The LRSI value (Y axis) ranges on a scale from 0.0 to 1.0, where an LRSI = 0.0 means the factor is extremely limiting and an LRSI = 1.0 means the factor is in abundance (not limiting) in most instances.

**Limiting Factor**

A variable whose presence/absence directly restrains the existence of a species or community in a habitat in HEP applications. A deficiency of the limiting factor can reduce the quality of the habitat for the species or community, while an abundance of the limiting factor can indicate an optimum quality of habitat for the same species or community.

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**Locally Preferred Plan (LPP)** The name frequently given to a plan that is preferred by the non-Federal sponsor over the National Economic Development (NED) plan (USACE 2000).

**Management Measure** The components of a plan that may or may not be separable actions that can be taken to affect environmental variables and produce environmental outputs. A management measure is typically made up of one or more features or activities at a particular site in USACE Planning studies (Robinson, Hansen, and Orth 1995).

**Measure** The act of physically sampling variables such as height, distance, percent, etc., and the methodology followed to gather variable information in HEP applications (i.e., see "Sampling Method" below).

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**Multiple Formula Model (MM) (aka Life Requisite Model)**

In HEP applications, there are two types of HSI models, the Single Formula Model (SM) (refer to the definition below) and the Multiple Formula Model (MM). In this case a multiple formula model is, as one would expect, a model that uses more than one formula to assess the suitability of the habitat for a species or a community. If a species/community is limited by the existence of more than one life requisite (food, cover, water, etc.), and the quality of the site is dependent on a minimal level of each life requisite, then the model is considered an MM model. In order to calculate the HSI for any MM, one must derive the value of a Life Requisite Suitability Index (LRSI) (see definition below) for each life requisite in the model – a process requiring the user to calculate multiple LRSI formulas. This Multiple Formula processing has led to the name "Multiple Formula Model" in HEP.

**Multi-Criteria Decision Analysis (MCDA)**

The study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process", as defined by the International Society on Multiple Criteria Decision Making (http://www.terry.uga.edu/mcdm/ MAY 2008).

MCDA is also referred as Multi-Criteria Decision Making (MCDM), Multi-Dimensions Decision-Making (MDDM), and Multi-Attributes Decision Making (MADM)

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| **National Economic Development (NED) Plan** | For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economics benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASACW) may grant an exception when there are overriding reasons for selecting another plan based upon other Federal, State, local and international concerns (USACE 2000). |
| **National Ecosystem Restoration (NER) Plan** | For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan. (USACE 2000). |
| **No Action Plan (aka No Action Alternative or Without-project Condition)** | Also referred to as the Without-project condition, the No Action Plan describes the project area's future if there is no Federal action taken to solve the problem(s) at hand. Every alternative is compared to the same Without-project condition (Yoe and Orth 1996). |

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| **Objective** | A statement of the intended purposes of the planning process; it is a statement of what an alternative plan should try to achieve. More specific than goals, a set of objectives will effectively constitute the mission statement of the Federal/non-Federal planning partnership. A planning objective is developed to capture the desired changes between the without- and With-project conditions that when developed correctly identify effect, subject, location, timing, and duration (Yoe and Orth 1996). |
| **Plan (aka Alternative, Alternative Plan, or Solution)** | A set of one or more management measures functioning together to address one or more planning objectives (Yoe and Orth 1996). Plans are evaluated at the site level with HEP or other assessment techniques and cost analyses in restoration studies (Robinson, Hansen, and Orth 1995). |
| **Program** | Combinations of recommended plans from different sites make up a program. Where the recommended plan at each such site within a program is measured in the same units, a cost analyses can be applied in a programmatic evaluation (Robinson, Hansen, and Orth 1995). |
| **Project Area** | The area that encompasses all activities related to an ongoing or proposed project. |
| **Project Manager** | Any biologist, economist, hydrologist, engineer, decision- maker, resource project manager, planner, environmental resource specialist, limnologist, etc., who is responsible for managing a study, program, or facility. |

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**Reference Domain** The geographic area from which reference communities or wetland are selected in HEP applications. A reference domain may, or may not, include the entire geographic area in which a community or wetland occurs.

**Reference Ecosystems** All the sites that encompass the variability of all conditions within the region in HEP applications. Reference ecosystems are used to establish the range of conditions for construction and calibration of HSIs and establish reference standards.

**Reference Standard Ecosystems** The ecosystems that represent the highest level of habitat suitability or function found within the region for a given species or community in HEP applications.

**Relative Area (RA)** The relative area is a mathematical process used to "weight" the various applicable cover types on the basis of quantity in HEP applications. To derive the relative area of a model's CTs, the following equation can be utilized:

$$\text{Relative Area} = \frac{\text{Acres of Cover Type}}{\text{Total Applicable Area}}$$

where:

Acres of Cover Type = only those acres assigned to the cover type of interest within the site
Total Applicable Area = the sum of the acres associated with the model at the site.

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| **Relative Preferences** | The rank of ecosystem services in order of importance. Relative preferences for various services are much easier to determine than differences in dollar measures of service values. Although less common than dollar measures of value, individual and community indices of ranked preferences can be used to aggregate service values and compare plans using a single measure (King et al. 2000). |
| Risk | The volatility of potential outcomes. In the case of ecosystem values, the important risk factors are those that affect the possibility of service flow disruptions and the reversibility of service flow disruptions. These are associated with controllable and uncontrollable on-site risk factors (e.g., invasive plants, overuse, or restoration failure) and landscape risk factors (e.g., changes in adjacent land uses, water diversions) (King et al. 2000). |

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**Sampling Method**

The protocol followed to collect and gather field data in HEP and HGM applications. It is important to document the relevant criteria limiting the collection methodology. For example, the time of data collection, the type of techniques used, and the details of gathering this data should be documented as much as possible. An example of a sampling method would be:

*Between March and April, run five random 50-m transects through the relevant cover types. Every 10-m along the transect, place a 10-m$^2$ quadrat on the right side of the transect tape and record the percent herbaceous cover within the quadrat. Average the results per transect.*

**Scale**

In some geographical methodologies, the scale is the defined size of the image in terms of miles per inch, feet per inch, or pixels per acres. Scale can also refer to different "sizes" of plans (Yoe and Orth 1996) or variations of a management measure in cost analyses. Scales are mutually exclusive, and therefore a plan or alternative may only contain one scale of a given management measure (Robinson, Hansen, and Orth 1995).

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**Single Formula Model (SM)** In habitat assessments, there are two potential types of models selected to assess change at a site – the Single Formula Model and the Multiple Formula Model (refer to the definition above). In this instance, an HSI model is based on the existence of a single life requisite requirement, and a single formula is used to depict the relationship between quality and carrying capacity for the site.

**Site** The location upon which the project manager will take action, evaluate alternatives and focus cost analysis (Robinson, Hansen, and Orth 1995).

**Solutions (aka Alternative, Alternative Plan, or Plan)** A solution is a way to achieve all or part of one or more planning objectives (Yoe and Orth 1996). In cost analysis, this is the alternative (see definition above).

**Spreadsheet** A type of computer file or page that allows the organization of data (alpha-numeric information) in a tabular format. Spreadsheets are often used to complete accounting/economic exercises.

**Suitability Index (SI)** A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type in HEP applications. These indices are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges on a scale from 0.0 to 1.0, where an SI = 0.0 means the factor is extremely limiting, and an SI = 1.0 means the factor is in abundance (not limiting) for the species/community (in most instances).

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**Target Year (TY)** A unit of time measurement used in HEP that allows the project manager to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1, and a TY = $X_2$. $TY_1$ is the first year land- and water-use conditions are expected to deviate from baseline conditions. $TY_{X2}$ designates the ending target year. A new target year must be assigned for each year the project manager intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses.

**Trade-Offs(TOs)** Used to adjust the model outputs by considering human values. There are no right or proper answers, only acceptable ones. If trade-offs are used, outputs are no longer directly related to optimum habitat or wetland function (Robinson, Hansen, and Orth 1995).

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**Validation** Establishing by objective yet independent evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place. Validation can encompass all of the information that can be verified, as well as all of the things that cannot -- i.e., all of the information that the model designers might never have anticipated the user might want or expect the product to do.

For purposes of this effort, *validation* refers to independent data collections (bird surveys, water quality surveys, etc.) that can be compared to the model outcomes to determine whether the model is capturing the essence of the ecosystem's functionality.

**Variable** A measurable parameter that can be quantitatively described, with some degree of repeatability, using standard field sampling and mapping techniques. Often, the variable is a limiting factor for a wetland's functional capacity used in the development of SI curves and measured in the field (or from aerial photos) by personnel, to fulfill the requirements of field data collection in an HEP application. Some examples of variables include: height of grass, percent canopy cover, distance to water, number of snags, and average annual water temperature.

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| **Verification** | Model verification refers to a process by which the development team confirms by examination and/or provision of objective evidence that specified requirements of the model have been fulfilled with the intention of assuring that the model performs (0r behaves) as it was intended.<br><br>Sites deemed to be highly functional wetlands according to experts, should produce high HSI scores. Sites deemed dysfunctional (by the experts) should produce low HSI scores. |
| **Without-project Condition(WOP) (aka No Action Plan or No Action Alternative)** | Often confused with the terms "Baseline Condition" and "Existing Condition," the Without-Project Condition is the expected condition of the site without implementation of an alternative over the life of the project, and is also referred to as the "No Action Plan" in traditional planning studies (Yoe and Orth 1996; USACE 2000). |
| **With-project Condition (WP)** | In planning studies, this term is used to characterize the condition of the site after an alternative is implemented (Yoe and Orth 1996; USACE 2000). |

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# Appendix C: Model Certification Crosswalk

Information necessary to address model certification under EC 1105-2-407 is presented in *Table 2* of the *USACE Protocols for Certification of Planning Models* report (USACE 2007, pages 9-11)[1]. In an effort to streamline certification for the Bosque Riparian community-based (HSI) index model and the Spatial Heterogeneity Index (SHI) model, the authors have provided a table to crosswalk the EC requirements and the information contained in this report (Table C - 1).

Table C - 1. Crosswalk between EC 1105-2-407 model certification requirements and information contained in this report.

| | | |
|---|---|---|
| **Cover Sheet** | | |
| | a. | **Model Name(s):**<br>a. Community Models (Prairies, Savannas and Woodlands) for the Upper Des Plaines River Watershed, Illinois and Wisconsin |
| | b. | **Functional Area:** Ecosystem Restoration; Impact Assessment /Mitigation |
| | c. | **Model Proponent:** Chicago District |
| | d. | **Model Developers** ERDC-EL and Chicago District (with support from interagency and stakeholder participants) |
| **1. Background** | | |
| | a. | **Purpose of Model:** These models were developed in an effort to quantify the value of diverse biological resources in this study area with the intent of capturing complex biotic patterns of the landscape. Refer to *Chapter 1*, "Purpose of the Models" for more detail. |
| | b. | **Model Description and Depiction:** The models were rendered in HEP-compatible formats Model components were comprised of combinations of relevant parameters to characterize the hydrology, soils, biotic integrity, structure, spatial complexity, and disturbance regimes of the Upper Des Plaines Watershed located in northeastern Illinois, Lake and Cook Counties, and southeastern Wisconsin. Model components (and their underlying variables) were normalized (scaled from 0.0 to 1.0) as required by traditional HEP procedures. Both flow charts ("ecosystem puzzles") and mathematical algorithms were used to depict the models herein. Refer to *Chapter 3* (*Basic Model Components, Model Flow Diagrams and Model Formulas*), and *Chapter 4* (*Model Concept* and *Steps 1-5)* for details relating to the individual model components and format. |
| | c. | **Contribution to Planning Effort:** These models helped to characterize the baseline conditions (in a quantitative manner) of the unique and significant ecological resources along the Upper Des Plaines River and its associated tributaries as they flowed through |

[1] http://www.usace.army.mil/cw/cecw-cp/models/protocols_cert_7-02-07.pdf

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| | | northeastern Illinois, Lake and Cook Counties, and southeastern Wisconsin. When applied within the HEP assessment paradigm, the study team will be able to evaluate and compare the benefits of proposed ecosystem restoration initiatives, impacts due to flood risk management measures, offsets proposed in mitigation measures. |
| | d. | **Description of Input Data:** Both field and spatially-explicit (GIS) data are necessary to calculate the outputs. Refer to *Chapters 3* and *4* for a list of variables and appropriate sampling protocols and statistical data management activities. |
| | e. | **Description of Output Data:** Habitat Suitability Indices are generated on a normalized scale of 0-1 in compliance with the traditional HEP paradigm. Within a standard HEP application, these indices can be multiplied by area to produce Habitat Units (HUs) and can be assessed over time under both With- and Without-project scenarios to generate Average Annual Habitat Units (AAHUs) (Refer to *Chapter 2 HEP Overview*). |
| | f. | **Statement on the capabilities and limitations of the model:** These models have been verified using reference data and conditions in the Upper Des Plaines Watershed. They can be used to assess baseline conditions as well as assess both a No Action condition and proposed alternative designs in either an Impact/Mitigation study or within an Ecosystem Restoration context. These models should not be applied outside of the watershed without review and recalibration. |
| | g. | **Description of model development process including documentation on testing conducted (Alpha and Beta tests):** A series of workshops were convened and experts contributed to the development of both the conceptual framework and the final index models presented here. The models were calibrated using reference data from across the model domain (Upper Des Plaines Watershed – refer to *Chapter 3* (*Reference Domain*). Internal (ERDC-EL) peer review has commenced, and the authors are considering the development of several peer-reviewed journal articles for publication. *Chapter 2* discusses the internal/external peer review process standard for ERDC-EL publications and model building efforts. *Chapter 3* discusses the model building process. *Chapter 4* addresses the model calibration process as well as the alpha/beta tests of the model to quantify baseline conditions for the study area. |
| **2. Technical Quality** | | |
| | a. | **Theory:** In theory, the quantification of ecosystem function in these communities can be obtained by using indicators of ecosystem integrity and applying these in the well documented, and accepted HEP-based framework.<br><br>The U.S. Fish and Wildlife Service (USFWS) published quantifiable procedures in 1980 to assess planning initiatives as they relate to change of fish and wildlife habitats (USFWS 1980a,b,and c). These procedures, referred to collectively as Habitat Evaluation Procedures and known widely as HEP, use a habitat-based approach to assess ecosystems and provide a mechanism for quantifying changes in habitat quality and quantity over time under proposed alternative scenarios. Habitat Suitability Indices (HSIs) are simple mathematical algorithms that generate a unitless index derived as a function of one or more environmental variables that characterize or typify the site conditions (i.e., vegetative cover and composition, hydrologic regime, disturbance, etc.) and are deployed in the HEP framework to quantify the outcomes of restoration or impact scenarios. These tools have been applied many times over the course of the last 30 years (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown et al. 2000, Store and Jokimaki 2003, Shifley et al. 2006, Van der Lee et al. 2006).<br>Virtually all attempts to use HSI models have been heavily criticized, and many criticisms are well deserved. In most instances, these criticisms have focused on the lack of: (a) identification of the appropriate context (spatial and temporal) for the model parameters, (b) a conceptual framework for what the model is indicating, (c) integration of science and values, and (d) validation of the models (Kapustka 2005, Barry et al. 2006, Hirzel et al. 2006, Inglis et al. 2006, Ray and Burgman 2006, Van der Lee et al. 2006). A |

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fundamental problem with these approaches continues to be the inability to link species presence or relative abundance with significant aspects of habitat quality (VanHorne and Wiens 1991) such as productivity.

Despite such criticisms, HSI models have played an important role in the characterization of ecosystem conditions nationwide. They represent a logical and relatively straightforward process for assessing change to fish and wildlife habitat (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown et al. 2000, Kapustka 2005). The controlled and economical means of accounting for habitat conditions makes HEP a decision-support process that is superior to techniques that rely heavily upon professional judgment and superficial surveys (Williams 1988, Kapustka 2005). They have proven to be invaluable tools in the development and evaluation of restoration alternatives (Williams 1988, Brown et al. 2000, Store and Kangas 2001, Kapustka 2003, Store and Jokimaki 2003, Gillenwater et al. 2006, Schluter et al. 2006, Shifley et al. 2006), managing refuges and nature preserves (Brown et al. 2000, Ortigosa et al. 2000, Store and Kangas 2001, Felix et al. 2004, Ray and Burgman 2006, Van der Lee et al. 2006) and others), and mitigating the effects of human activities on wildlife species (Burgman et al. 2001, NRC 2001, Van Lonkhuyzen et al. 2004). These modeling approaches emphasize usability. Efforts are made during model development to ensure that they are biologically valid and operationally robust. Most HSI models are constructed largely as working versions rather than as final, definitive models (VanHorne and Wiens 1991). Simplicity is implicitly valued over comprehensiveness, perhaps because the models need to be useful to field managers with little training or experience in this arena. The model structure is therefore simple, and the functions incorporated in the models are relatively easy to understand. The functions included in models are often based on published and unpublished information that indicates they are responsive to species density through direct or indirect effects on life requisites. The general approach of HSI modeling is valid, in that the suitability of habitat to a species is likely to exhibit strong thresholds below which the habitat is usually unsuitable and above which further changes in habitat features make little difference. And as such, most HSI models should be seen as quantitative expressions of the best understanding of the relations between easily measured environmental variables and habitat quality. Habitat suitability models then, are a compromise between ecological realism and limited data and time (Radeloff et al. 1999, Vospernik et al. 2007).

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| | b. | **Description of system being represented by the model:** The Upper Des Plaines prairie, savanna and woodland ecosystems have been modeled here. *Chapter 3* offers community (ecosystem) characterizations garnered from peer reviewed literature and gray literature generated by federal/local resource management agencies. |
| | c. | **Analytical requirements and assumptions:** Adequate sample sizes (30+ per variable) must be obtained to assure some level of precision (reduction of uncertainty). It is assumed that the user will adopt and follow the suggested sampling protocols detailed herein. Follow-on data management (calculation of means per variable) is straightforward and should not be difficult to emulate. |


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| | d. | **Conformance with Corps policies and procedures:** As indicated in the PMIP, HEP is an accepted and approved approach to quantifying benefits/impacts for these types of studies (Refer to *Chapter 1 Planning Model Certification*). The protocol described herein is being fully vetted through the ERDC review process, and participants in the workshops, as well as external reviewers have been included in the process (Refer to *Chapter 2 – Model Review Process*). Outputs conform to USACE policies and procedures. |
| | e. | **Identification of formulas used in the model and proof that the computations are appropriate and done correctly:** Formulas can be found in *Chapter 3*. All spreadsheets used to organize data and the datafiles used to calculate outputs can be obtained from the District upon request (contact Brook Herman – see *Appendix D* for contact information). ERDC-EL performed QA/QC on all spreadsheet and datafile operations and can describe these to the reviewers upon request. |
| **3. System Quality** | | |
| | a. | **Description and rationale for selection of supporting software tool/programming language and hardware platform:** The **HEAT** software is a fully vetted software package currently undergoing model certification. The models described here are not software per se (Refer to *Chapter 1 – Planning Model Certification*), and as such do not contain any programming. ArcMap, ArcToolbox, and Spatial Analyst are all commercially developed off-the-shelf software programs readily available to the user base. |
| | b. | **Proof that the programming was done correctly:** NA |
| | c. | **Description of process used to test and validate model:** Verification of the models can be found in *Chapter 4– Model Verification*. |
| | d. | **Discussion of the ability to import data into other software analysis tools (interoperability issue):** NA |
| **4. Usability** | | |
| | a. | **Availability of input data necessary to support the model:** All data (presented in spreadsheet and database format) can be obtained from the District upon request (contact Brook Herman – see *Appendix D* for contact information). |
| | b. | **Formatting of output in an understandable manner:** Outputs of the model are standard indices (HSI) - compatible with traditional HEP applications (scaled 0-1). |
| | c. | **Usefulness of results to support project analysis:** Model results have been successfully utilized in plan formulation and alternative comparison analyses for the Upper Des Plaines study. |
| | d. | **Ability to export results into project management documentation:** All outputs are MS Office-compatible and easily imported into MS Word and MS PowerPoint for documentation and distribution. |
| | e. | **Training availability:** **HEAT** software training was been provided to the Chicago District and the stakeholders/partners engaged in the Upper Des Plaines E-Team in 2004. The current District POC (Brook Herman) received additional training at ERDC in 2008.<br><br>ERDC-EL also provides model building workshops at the local, regional and national level through PROSPECT and/or on a reimbursable basis.<br><br>The District was also required to perform 1/3 of all calculations and 1/3 of all spreadsheet management activities to assure successful technology transfer ("ownership") of the models and the evaluations thereafter. |
| | f. | **Users documentation availability and whether it is user friendly and complete:** This document serves as the model "manual." |

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| | | There is a draft manual for the HEAT software currently undergoing certification (Burks-Copes et al. 2008). And there are Ecological Service Manuals (ESMs) to support HEP applications (USFWS 1980a-c). |
| | g. | **Technical support availability:** ERDC-EL provides technical support on all products upon request and on a reimbursable basis. |
| | h. | **Software/hardware platform availability to all or most users:** The models are provided in both MS Word and MS Excel format and in HEAT datafiles to all study participants (including contractors and stakeholders). All data (presented in spreadsheet and database format) can be obtained from the District upon request (contact Brook Herman – see *Appendix D* for contact information). The GIS data utilized herein is available upon request from the Albuquerque District. |
| | i. | **Accessibility of the model:** The model is accessible now, and will be posted on the System-wide Water Resources Program's (SWWRP) Water Resources Depot website upon completion of ERDC-EL technical review (https://swwrp.usace.army.mil/DesktopDefault.aspx). |
| | j. | **Transparency of model and how it allows for easy verification of calculations and outputs:** The mathematical operations in the models are clearly documented herein and can be easily transferred into any spreadsheet program for verification (a step ERDC-EL uses to QA/QC every model development activity). The outputs are scaled from 0-1 (1 = optimal functionality and 0 = not functioning). An interpretative table has been provided in *Chapter 4* to assist the user in conclusions. |
| | k. | **Accessibility (where is model physically located?:** Both the Chicago District and ERDC-EL will maintain separate and relatively permanent copies of all model information (NTE 7 years). The models will also be posted on the SWWRP website. |

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# Appendix D: E-Team Participants

As described in the main report, a series of workshops were used to facilitate the development of the community-based index models compatible with the HEP application paradigm for the current feasibility study. Formal minutes were developed for each workshop and can be provided upon request from the Chicago District (contact Brook Herman – refer to contact information below). Several federal state and local agencies, as well as local and regional experts from the stakeholder organizations, and private consultants, participated in the model workshops. A complete list of participants can be found in Table D - 1 below. It is important to note that attrition over the course of the study led to many changes in this original roster. We have attempted to include both the names of original participants as well as replacements and additions here as well.

Table D - 1. Model development workshop(s) participants.

| E-Team Members | Agency | Phone | Email Address |
|---|---|---|---|
| Wayne Vanderploeg | Cook County Forest Preserve District | (847) 798-9745 | wvanderploueg@ameritech.net |
| Mike Miller | Illinois Department of Natural Resources | (217) 333-7093 | miller@isgs.uiuc.edu |
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| Rick Gosch | Illinois Department of Natural Resources | (217) 782-4636 | rgosch@dnrmail.state.il.us |
| Jim Anderson | Lake County Forest Preserve District | (847) 968-3282 | janderson@co.lake.il.us |
| Joe Hmieleski | Lake County Stormwater Management Commission | (847) 918-5273 | jhmieleski@co.lake.il.us |
| Tom Slawski | Southeastern Wisconsin Regional Planning Commission | (262) 547-6721 | tslawski@sewrpc.org |
| Ingrid West | Upper Des Plaines River Ecosystem Partnership | (630) 559-2047 | westmri@hotmail.com |
| Brook Herman | USACE - Chicago District | (312) 846-5559 | brook.d.herman@usace.army.mil |
| Frank Veraldi | USACE - Chicago District | (312) 846-5589 | Frank.M.Veraldi@usace.army.mil |

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Table D - 1 (Concluded).

| E-Team Members | Agency | Phone | Email Address |
|---|---|---|---|
| Gene Flemings | USACE - Chicago District | (312) 353-6320 | Eugene.J.Flemming@usace.army.mil |
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| Shamel Abou-EL-Seoud | USACE - Chicago District | (312) 353-6400 ext. 3009 | Shamel.Abou-el-Seod@usace.army.mil |
| Suzanne Davis | USACE - Chicago District | (312) 846-5580 | susanne.j.davis@usace.army.mil |
| Dave Brandt | USDA-NRCS | (815) 338-0099 ext.111 | dave.brandt@il.usda.gov |
| David Misek | USDA-NRCS | (847) 223-1056 | davis.mesik@il.usda.gov |
| Tom Glatzel | USEPA: Region 5 | (312) 886-6678 | glatzel.thomas@epa.gov |
| Jeff Mengler | USFWS (Chicago Illinois Field Office) | (847) 381-2253 x 226 | jeffrey_mengler@fws.gov |
| John Rogner | USFWS (Chicago Illinois Field Office) | (847) 381-2253 ext. 212 | john_rogner@fws.gov |
| Mike Redmer | USFWS (Chicago Illinois Field Office) | (847) 381-2253 | mike_redmer@fws.gov |
| Jeff Heath | formerly with USACE - Chicago District | | |
| Mike Fisher | formerly with USACE - Chicago District | | |
| Bill White | formerly with IDNR-OWR | | |

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# Appendix E:
# Model Review Forms

## LPDT HSI Model Document Checklist

**I. Chapter 1 Introduction**

- ❑ Purpose of the Models
- ❑ Contribution to the Planning Effort
- ❑ Planning Model Certification
- ❑ Report Objectives
- ❑ Report Structure

**II. Chapter 2 HEP Overview**

- ❑ The HEP Process
  - ❍ Statement of Limitations
  - ❍ HSI models in HEP
  - ❍ Habitat units in HEP
  - ❍ Capturing changes over time in HEP applications
- ❑ Developing HSI Models
  - ❍ Steps in Model Development
  - ❍ Model Review Process

**III. Chapter 3: Community-based Index Model(s)**

a. Model Development Workshops
b. Coupling Conceptual Models and Index Models
c. Community Characterization
   i. General Description
   ii. Reference Domain
   iii. Climate Characterization
   iv. Vegetative Characterization
   v. Hydrologic Characterization
   vi. Geomorphic Characterization
d. Model Components
e. Model Flow Diagram
f. Reference-Based Modeling Approach
g. Model Formulas

**IV. Chapter 4: Model Sampling and Calibration Protocols**

- ❑ Model Variable Selection Rationale
- ❑ Field Sampling Scheme and Transect Layouts
- ❑ Spatially Explicit Parameters and Analysis Protocols
- ❑ Hydrologic Data
- ❑ Statistical Analysis and Curve Calibrations

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- Model Verification – Baseline Results

**V. Summary and Conclusions**

**VI. References**

**Additional Contents:**

- Appendix A - Notations (aka Acronyms)
- Appendix B - Glossary
- Appendix C - Model Certification Crosswalk
- Appendix D - E-Team Participants
- Appendix E - Model Review Forms
- Appendix F - Model Comments and Responses
- Appendix G – Community Index Curves

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## Certificate of Product Check

This certifies that adequate review was provided by all appropriate disciplines to verify the following:

1. Correct application of methods
2. Adequacy of basic data and assumptions
3. Completeness of documentation
4. Compliance with guidance, standards, regulations, and laws
5. Correct study approach

_____

Kelly A. Burks-Copes Date
Principal Investigator
Environmental Laboratory
U.S. Army Engineer Research and Development Center
Vicksburg, MS

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Table E - 1.Internal ERDC-EL Technology Transfer Review Form.

TECHNOLOGY TRANSFER STATUS SHEET

INSTRUCTIONS
The author(s) of a document based on ERDC-EL research and written for publication or presentation should attach one copy of this sheet to the document when the first draft is prepared. Documents include reports, abstracts, journal articles, and selected proposals and progress reports. The sheet will remain with the most recent draft of the document.

JOB NUMBERS:

**a. WORD PROCESSING SECTION** _____
b. ENVIRONMENTAL INFORMATION ANALYSIS CENTER _____
**c. VISUAL PRODUCTION CENTER** _____

| 2. TITLE | 3. AUTHOR(S) |
|---|---|
| 4. PRESENTATION (Conference Name & Date) | 5. PUBLICATION (TR, IR, MP, Journal Name, etc.) |
| 6. SPONSOR OR PROGRAM WORK UNIT | 7. DATE REQUIRED BY SPONSOR |

8. DATE DRAFT COMPLETED BY AUTHOR(S) AND AREADY FOR SECURITY OR TECHNICAL REVIEW

9. SECURITY REVIEW (Military Projects)

a. THIS DOCUMENT HAS BEEN REVIEWED FOR SECURITY CLASSIFICATION FOLLOWING GUIDELINES SPECIFIED IN AR 380-5, DEPARTMENT OF THE ARMY INFORMAITON SECURITY PROGRAM, AND FOUND TO BE:

CLASSIFIED _____ CONFIDENTIAL _____ SECRET _____ TOP SECRET _____
UNCLASSIFIED _____ SENSITIVE _____ DISTRIBUTION LIMITED _____

CLASSIFICATION WAS BASED ON THE _____
SECURITY CLASSIFICATION GUIDE DATED _____

| 10. AUTHOR | 11. DATE |
|---|---|
| 12. GROUP/DIVISION CHIEF | 13. DATE |

14. IN-HOUSE TECHNICAL REVIEW (To be completed by two or more reviewers who are GS-12 or Above, Expert, or Contractor)
a. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

b. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

c. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

NOTE: RETURN TO AUTHOR WHEN TECHNICAL REVIEW IS COMPELTED.

ERDC FORM 2378
R OCT 89 PREVIOUS EDITIONS ARE OBSOLETE. (CONTINUED ON REVERSE)

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Table E - 1. (Concluded).

15. SUPERVISORY REVIEW

THE DOCUMENT IS TECHNICALLY SUITABLE AND REVIEWERS' COMMENTS HAVE BEEN ACKNOWLEDGED. IT IS SUBMITTED FOR EDITORIAL REVIEW AND CLEARANCE FOR PUBLICATION OR PRESENTATION AS INDICATED. THE DOCUMENT CONTAINS NO COPYRIGHTED INFORMATION.* ENG FORM 4329-R OR 4330-R HAS BEEN COMPLETED, IF REQUIRED, AND IS ATTACHED TO THE DOCUMENT.

a. _____ _____ _____ _____
DATE TO GROUP CHIEF DATE RETURN REQUESTED DATE RETURNED GROUP CHIEF

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DATE TO DIVISION CHIEF DATE RETURN REQUESTED DATE RETURNED DIVISION CHIEF

16. PROGRAM MANAGER REVIEW (If Appropriate)

_____ _____ _____ _____
DATE TO PROGRAM MANAGER DATE RETURN REQUESTED DATE RETURNED PROGRAM MANAGER

17. COMPLETE THE FOLLOWING FOR ALL REPORTS

a. RECOMMEND TYPE OF REPORTS (TR, IR, MP, Or Other):

_____

b. LEVEL OF EDITING (Type 1, 2, 3, Or 4):

_____

c. IF TYPE 1 OR 2 EDITING IS INDICATED, ADD A BRIEF JUSTIFICATION:

_____

_____

_____

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SIGNATURE OF DIVISION CHIEF

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Reverse of ERDC Form 2378, R OCT 89

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Table E - 2. Security Clearance Form for ERDC-EL Reports

| | | |
|---|---|---|
| REQUEST FOR CLEARANCE OF MATERIAL CONCERNING CIVIL WORKS FUNCTIONS OF THE CORPS (ER 360-1-1) | | |
| THRU | TO<br><br>CDR, USACE<br>CEPA-ZM<br>WASH, DC 20314-1000 | FROM |
| 1. TITLE OF PAPER | | |
| 2. AUTHOR (NAME) | 3. OFFICIAL TITLE AND/OR MILITARY RANK | |
| 4. THIS PAPER IS SBUMITTED FOR CLEARANCE PRIOR TO PRESENTATION OR PUBLICATION AS IT FALLS INTO THE CATEGORY (OR CATEGORIES) CHECKED BELOW: | | |
| ☐ MATERIAL THAT AFFECTS THE NATIONAL MISSION OF THE CORPS.<br><br>☐ RELATES TO CONTROVERSIAL ISSUES. | ☐ MATERIAL IS SIGNIFICANTLY WITHIN THE PURVIEW OF OTHER AGNECIES OF THE FEDERAL GOVERNMENT.<br><br>☐ PERTAINS TO MATTERS IN LITIGATION. | |
| 5. CHECK APPLICABLE STATEMENT:<br>☐ COPYRIGHTED MATERIAL USED. | ☐ COPYRIGHTED MATERIAL USED HAS BEEN PREVIOUSLY CLEARED IN ACCORDANCE WITH AR 25-30 AND A COPY OF THE CLEARANCE ATTACHED. | |
| 6. FOR PRESENTATION TO:<br><br>ORGANIZATION:<br><br>CITY AND STATE: | | |
| 7. DATE OF FUNCTION | 8. DATE CLEARED PAPER IS REQUIRED | |
| 9. FOR PUBLICATION (Name of Publication Media) | 10. DATE CLEARED PAPER IS REQUIRED | |
| THIS PAPER CONTAINS NO CLASSIFIED ORIGINAL OR DERIVATIVE MATERIAL. | | |
| DATE | NAME AND TITLE (Approving Authority) | SIGANTURE (Approving Authority) |
| THRU | TO | FROM<br>CDR, USACE<br>CEPA-ZM<br>WASH, DC 20314-1000 |
| 1. SUBJECT MANUSCRIPT IS CLEARED FOR PRESENTATION AND PUBLICATION:<br><br>☐ WITHOUT CHANGE | ☐ WITH CHANGES ANNOTATED ON THE MANUSCRIPT | ☐ WITH SUGGESTED CHANGES AND/OR COMMENTS ATTACHED |
| 2. RETURNED WITHOUT CLEARANCE FOR THE FOLLOWING REASON(S): | | |
| DATE | NAME AND TITLE (Approving Authority) | SIGNATURE (Approving Authority) |

ENG FORM 4329-R, APR 91 EDITION OF JAN 82 IS OBSOLETE. (Proponent; CEPA-I)

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Table E - 2. (Concluded).

INSTRUCTIONS FOR SUBMISSION OF MATERIAL FOR CLEARANCE (ENG Form 4239-R)

1. An original and two copies of papers or material on civil works functions or other non-military matters requiring HQUSACE approval, will be forwarded to reach HQUSACE at least 15 days before clearance is required. Including any maps, pictures and drawings, etc., referred to in the text.

2. Technical papers containing unpublished data and information obtained by the author in connection with his/her official duties will contain the following acknowledgement when released for publication outside the US Army Corps of Engineers. The acknowledgement will identify the research program which provided resources for the paper, the agency directing the program and a statement that publication is by permission of the Chief of Engineers.

The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the _____ of (Program) the United States Army Corps of Engineers by the _____. Permission was granted by (Agency) the Chief of Engineers to publish this information.

3. When manuscripts are submitted for publication in THE MILITARY ENGINEER, a brief biographical sketch (100 to 150 words) of the author is required, indicating his/her background in the subject matter.

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Table E - 3. External Technical Review Form for Assessment Reports and Model Documentation

| | | |
|---|---|---|
| | Type: Review | Page XX of XX |
| Review Comments | Concept<br>Final:<br>Other: Date: | |
| Project:<br>Location: | Review Focus: Model Content<br>Name:<br>Organization: | |

| Comment Number | Drawing/ Number | Page/ Space | COMMENT | ACTION |
|---|---|---|---|---|
| | | | | |
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# Appendix F: Model Comments and Responses

The DPII models were reviewed internally at ERDC-EL and externally by the E-Team. Comments were received from March to December of 2006. E-Team comments are provided below as well as ERDC-EL responses (Table F - 1). Changes were made accordingly.

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Table F - 1. Review comments and responses.

Review Comments

**Project:** Upper Des Plaines River and its Tributaries Ecosystem Restoration Study

**Review Focus:** Model Documentation – Completeness, Scientific Basis (Editorial comments accepted as well)

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | General | General | 1.1. Consider changing the name from HSI models to habitat quality index models: The label (Habitat Suitability Index) that was given to the models and the way in which they were derived do not agree in terms of previously agreed upon definitions. Although there was a definition given in the appendices as to the treatment of the HSI for the purposes of this report, the definition itself is vague and does nothing to truly illuminate the purpose behind the original use of the HSI. | ERDC does not concur. HSI is the term applied to index based models used in HEP. Since HEP was the method used, we prefer to keep the HEP terminology. We can clarify in sections describing HSI models and their development (Ch 2 and Glossary) that we are referring to community based approach instead of the species based.<br>Resolution: District Agreed to response. |
| LRC District | General | General | 1.2 Whenever the word community is used, please be specific as to what kind of community is being referred to. | Concur and will be corrected. |
| LRC District | Page 1/para 2 | Chapter 1 - Background | In general the paragraph suggests that the UDPII study is mainly concerned with flood damage reduction and secondarily improvement of ecosystem quality. Consider rewording the paragraph to emphasize that the UDP II project is multi-purpose and will treat both objectives equally and that flood damage reduction is not considered more important over ecological restoration. | Concur and corrected in the 12-12-06 revised version. . . . District provided ERDC with correct verbiage from their Feasibility Report |
| LRC District | Page 2/para 2 | Chapter 1 – Contribution to the Planning Effort - These methodologies help to characterize the baseline conditions (in a quantitative manner) of the numerous ecological resources throughout the watershed. | Please identify which methodologies were used for continuity of report. | The methods are identified in the last sentence of the previous paragraph and again later in this paragraph. ERDC will consider changing first sentence of paragraph to repeat the methods by name (HEP and HGM). |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Page 2/para 2 | Chapter 1 – Contribution to the Planning Effort – The methods assisted the study team in the projection of change to fundamental ecosystem processes (without which, ecosystem restoration itself could not happen), as the multi-purpose alternatives were proposed. | Please clarify what fundamental ecosystem processes are for the purposes of this report. It seems this descriptive language is referring to the output of the models such as the Habitat Units. | ERDC will provide examples of "fundamental ecosystem processes" in this sentence. |
| LRC District | Pg 2/para 3 and others | Chapter 1 – Contribution to the Planning Effort - | Please explain what functional carrying capacity is referring to. | Nothing in para 3 refers to "functional carrying capacity". However in para 2, "functional capacity" is mentioned in reference to HGM. It is in no way related to carrying capacity. Recommend we refer to HGM citations and Jeff Lin's HGM model report.<br>No further action necessary |
| LRC District | Pg 3 | Chapter 1 - Report Objectives | Consider adding to the report objectives number 4, a discussion on the development and underlying assumptions of the models and the implications of these models, which would tie in the evolution of the HSI models to the plant community quality index for the purpose of obtaining the objectives of the study team. A suggestion, an appropriate place for this discussion would be in chapter 2. | Four (4) objectives are currently reported in the 12-12-06 revised version. The fourth objective captures the rationale, curve break points and assumptions associated with each variable.<br>District Concurs, no further action required. |
| LRC District | Pg 5 | Chapter 2 – In general | Consider adding the basic tenant that ecological models should be used to augment and not supplant the expertise of resource specialists with site specific knowledge; such that the models help support planning decisions and are not counter to expert knowledge. | Agreed, ecological models support planning decisions. However, under the current Corps panning paradigm, expert opinion is insufficient to justify the recommended plan selection, and therefore, PDTs are forced to make decisions based on a combination of computational models and expert opinion.<br>District Concurs, no further action required. |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg 6/para 1 | Chapter 2 – HSI models in HEP | Please provide examples of the studies where several cover types were included in an HSI model. Perhaps include where these studies took place and what kind of habitat types were included or provide a reference to these studies. | USFWS Ecological Services Manual (ESM 103) for HSI Model documentation requires that models be associated with specific cover types. ERDC will add references for 3 USFWS HSI Blue book citations to support this statement. |
| LRC District | Pg 6/para 1 | Chapter 2 – HSI models in HEP - … any HSI model based on the existence of a single life requisite requirement uses a single formula to describe the relationship between quality and carrying capacity for the site. | Carrying capacity is used, please refer to previous comment. | HSI models used in HEP do not represent carrying capacity. ERDC will change the words "carry capacity" to "habitat suitability". |
| LRC District | Pg 6/para 3 | Chapter 2 – HSI models in HEP | Please tie in how the concept of the Equivalent Optimum Area (EOA) is related to how the models in this report were developed. | This information was included for general information regarding the fundamentals for developing HSI models as cited by USFWS ESM 103. It does not pertain directly to UDPII models . . . ERDC will remove this discussion from the report. |
| LRC District | Pg 7/para 1 | Chapter 2 – Habitat Units in HEP - Thus, a single model (or a series of inter-related models) can be adapted to reflect a site's response to a particular design at any scale | Please clarify the intended meaning of the word design in the sentence referring to how the models may be modified to be used at different scales. Is design related to the objectives of the potential users of the model? | Design refers to alternative plans or measures being evaluated. ERDC will clarify in final version |
| LRC District | Pg 7/para 1 | Chapter 2 – Habitat Units in HEP - Several agencies and organizations have adapted the basic HEP methodology for their specific needs in this manner. | Please provide examples of the agencies and organizations that have used or are currently using the HSI models. Maybe provide an example of their adaptations and how their actions helped attain their goals. | ERDC will add a reference citation that reviewed HSI models in use (i.e., Inglis, G. J., H. Hurren, et al. (2006), Gillenwater, D., T. Granata, et al. (2006), and Ahmadi-Nedushan, B., A. St-Hilaire, et al. (2006). |

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg 7/para 2 (Pg 8/ para 1) | Chapter 2 – Steps in Model Development | Define community assessment, refer to previous comment on definition of community. | Community assessment is not mentioned until pg 8, steps in Model development in the 12-12-06 revised version. Assuming that is the reference ERDC will reiterate the definition of community |
| LRC District | Pg 7 (Pg 8) | Chapter 2 – Steps in Model Development | Please provide a detailed explanation as to the process in which the decision was reached to develop community based models to appropriately meet the objectives for the upcoming feasibility study, especially in light of the fact that no previous peer-reviewed studies of this nature have been published. Please provide a more in depth discussion on the appropriateness of these models and their development for the obtainment of the study team's goals and objectives. A clearly delineated discussion on the underlying assumptions of the models is missing from this chapter as well. | Although this discussion is relevant, ERDC does not agree that it belongs in this Chapter. The District can address the DPII goals and objectives in their Assessment Report, and ERDC will include a paragraph (provided by the District) in Chapter 1 of this report as part of the introduction to model selection. |
| LRC District | General | Chapter 3- | 4.1. Consider summarizing the bulk of information into 2-3 pages with references to more detailed information on specific sections, especially pages 13-32. | ERDC will review the chapter and consider condensing and summarizing where appropriate, however, characteristics and description of model and reference domain are required in ERDC model documentation reports. |
| LRC District | General | Chapter 3 | 4.2. Generally, many pages seem to be rather short on information, meaning almost half the page or more is without narrative, tables or figures. To ensure continuity of the report and ease of reading consider reformatting for a more seamless read and less abbreviated pages, which should unify sections and facilitate better understanding of the report. | ERDC Will review formatting, and reduce size of images where appropriate, however, ERDC report style must be followed. |
| LRC District | Pg 14 (Fig. 1) | Chapter 3 - General Description | 4.3. Page 14, Figure 1, please be cautious of using maps from other sources which do not explicitly delineate the study area. If the use of these maps is expressing an important point, please overlay the boundaries of the study area to facilitate understanding of the information presented in the map relative to the study area. | ERDC will try to include inset of 5 county boundary of study area when possible on all maps from other sources |

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg. 18 (Fig. 5) | Chapter 3 - Reference Domain | 4.4. Page 18, Figure 5, please be cautious of the use of pie charts when graphically representing information. Typically, the use of a bar graph is preferable to pie charts in ecology based reports and presentations. | The chart of cover type composition is visually descriptive in its current presentation format. |
| LRC District | Pg. 34 (Fig. 21) | Chapter 3 - Ecology | 4.5. Page 34, Figure 21, please incorporate a short list of cover types and their associated acronyms to facilitate understanding of this figure. | ERDC will review figure and add table of cover type descriptions and acronyms |
| LRC District | Pg. 35 (Tab. 1) | Chapter 3 - Ecology | 4.6. Page 35, Table 1, consider placing all tables consisting of lists of species in the appendix. This would facilitate the ease of assimilating the contents of the report and would allow the reader to look up those lists if that information was desired. | ERDC will review and consider |
| LRC District | Pg. 38 (Tab. 2) | Chapter 3– Prairie Communities | 4.7. Page 38, Table 2, consider abbreviating the community tables to the community types that occur in the study area. Although it is interesting information, it could leave the wrong impression with the reader. For example, sand, gravel and dolomite prairies are not considered a part of the current or past diversity of the study area. | ERDC will review and consider |
| LRC District | Pg. 44-58 | Chapter 3 – Regional Wildlife | 4.8 Pages 44-58, regional wildlife, again, please consider a very short summary of this section. Please refer to comment 4.1. | ERDC will review and consider condensing and summarizing this section |
| LRC District | Pg. 58-60 (Tab. 5 & 6) | Chapter 3 - Threatened and Endangered Species | 4.9 Pages 58-60 and tables 5 and 6. Please consider including information on Wisconsin state threatened and endangered species. Also, please refer to comment 4.6. | Rather than add to the considerable size of this document, ERDC will instead refer to the District's Planning documentation for presentation of this material. Delete T& E section from Chapter 3. |
| LRC District | Pg. 61-74 | Chapter 3 - Threats to the Upper Des Plaines River Watershed | 4.10. Pages 61-74. In general, the information presented in this section is another reiteration of previously published information; please consider condensing to a summary form (1-2 pages) for reasons discussed in previous comments. | ERDC will review and consider condensing and summarizing this section |
| LRC District | Pg. 61-62 | Chapter 3 - Threats to the Upper Des Plaines River Watershed | 4.11. Pages 61-62. The list of natural processes located in the UDP study area does not seem to be related or tied to further explanations in the narrative. Also, this list seems a bit general because these same non-specific terms could be applied to almost any natural system. Consider removing. | ERDC will review and determine whether to better explain or remove |

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg. 70-72 (Fig. 53-56) | Chapter 3 - Insects | 4.12 Figures 53-56. Consider revising or leaving out of final draft. The titles help to interpret what the selected photos are depicting; however, a better method would be to explicitly delineate natural vs. human altered areas on each photo. | ERDC will review and consider |
| LRC District | General | Chapter 4 – | 5.1 In general, for the prairie model, the 19 variables measured for each area deemed prairie and assigned a score based on the SI curves seems extremely high based on the assumed accuracy and predictive power of the model. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | General | Chapter 4 - Descriptions of Components | 5.2. In general, the descriptions of the components (e.g. diversity, structure, etc.) seem to be the actual assumptions underlying the prairie community model, if this is so, please consider labeling them as such. | Assumption is that the functionality of Prairies can be characterized by quantifying the relationships between model components and fundamental ecosystem processes. Therefore, ERDC will not be changing this section to characterize model components descriptions as assumptions, rather, ERDC will include the above assumption in the opening paragraph of this section. |
| LRC District | Pg. 75, para. 2 | Chapter 4 - Applicable Cover Type Habitats | 5.3. Page 75, paragraph 2, for continuity please explain how the differences in vegetative cover types were defined. | Concur. ERDC will add to the cover type descriptions |
| LRC District | Pg. 93 | Chapter 4 - Percent of Area that is Core (AREACORE) | 5.4. Page 93, please provide some more detail on how the 100 meters was chosen or derived as the specific area defined as edge. Although, there are references cited from specific studies, what was their specific area they believed was edge and was the 100 meters somehow an average of those studies? | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. Please refer to specific studies cited for more details. |
| LRC District | Pg. 96 | Chapter 4 - | 5.5. Page 96, please reconsider the use of the term canopy in the description of the variable which measures the percentage of cover of ground vegetation. The label is confusing as to how ground vegetation can also be described as canopy. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 96 | Chapter 4 - | 5.6. Page 96, paragraph 4, please reword first sentence. | Concur |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg. 98 | Chapter 4 - | 5.7. Page 98, please refer to comment 5.5. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 99 | Chapter 4 - | 5.8. Page 99, please refer to comment 5.5. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 105 | Chapter 4 – Definition term | 5.9. Page 105, please be aware of the fact the FQI is a weighted average and that using the FQI to calculate another number by way of a mathematical formula, averaging the FQI and other measured variables, is in effect taking an average of an average, which is not considered valid. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | General | Chapter 4 – Indicator Species | 5.10. In general, please consider changing the label of indicator species to conservative species whenever a variable is defined as measuring the number of species with a coefficient of conservatism (C) value of five or greater. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 117, para. 4 | Chapter 5 - Savanna Components and Relationships | 6.1. Page 117, paragraph 1, the savanna model is referred to as prairie. | Concur – will correct |
| LRC District | General | Chapter 5 – (number of Variables) | 6.2 Please refer to comment 5.1 as to the reasoning behind the number of variables chosen for the model. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | General | Chapter 5 – (description of components) | 6.3. Please refer to comment 5.2 as to the descriptions of the components | Will review and consider |
| LRC District | Pg. 117, para. 2 | Chapter 5 - Applicable Cover Type Habitats | 6.4. Page 117, paragraph 2, for continuity please explain how the differences in vegetative cover types were defined. | Concur. Will add to the cover type descriptions |
| LRC District | Pg. 136 | Chapter 5 | 6.5. Page 136, please refer to comment 5.4. as to more detail on how the 100 meters was chosen for edge comparison. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. Please refer to specific studies cited for more details. |

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | Pg. 138 | Chapter 5 | 6.6. Page 138, please refer to comment 5.5. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 139, para. 3 | Chapter 5 - Suitability Index. | 6.7. Page 139, paragraph 3, please reword first sentence. | Concur |
| LRC District | Pg. 142 | Chapter 5 | 6.8. Page 142, please refer to comment 5.5. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 149 | Chapter 5 | 6.9. Page 149, please refer to comment 5.9. be aware of the fact the FQI is a weighted average. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 156 | Chapter 5 – Fig. 7 | 6.10. Page 156, consider reformatting Figure 107 to a larger size, it is a little hard to read in its present condition. | Concur – all variable curve figures will be the same size |
| LRC District | General | Chapter 5 | 6.11. In general, please refer to comment 5.10 | Will review and consider changing label of indicator to conservative |
| LRC District | Pg. 136, para. 1 | Chapter 6 – Woodland Components and Relationships | 7.1. Page 163, paragraph 1, the woodland model is referred to as prairie. | Concur – will correct |
| LRC District | General | Chapter 6 – Number of Variables | 7.2. Please refer to comment 5.1 as to the reasoning behind the number of variables chosen for the model. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | General | Chapter 6 – Components | 7.3. Please refer to comment 5.2 as to the descriptions of the Components | ERDC will review and consider |
| LRC District | Pg. 163, para. 2 | Chapter 6 – Applicable Cover Type Habitats | 7.4. Page 163, paragraph 2, for continuity please explain how the differences in vegetative cover types were defined. | Concur. ERDC will add to the cover type descriptions |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| LRC District | General | Chapter 6 – Canopy term | 7.5 In general, please reconsider the use of the term canopy in the description of variables which measure the percentage of cover of herbaceous ground vegetation. Please refer to comment 5.5. | Variable selection, incorporation and calibration (i.e., sensitivity) were directed by experts chosen by the District and stakeholders. |
| LRC District | Pg. 186, para. 3 | Chapter 6 – Suitability Index. | 7.6. Page 186, paragraph 3, please reword first sentence. | Concur |
| LRC District | General | Chapter 6 | 7.7. Please refer to comment 5.9. | Concur – all variable curve figures will be the same size |
| LRC District | General | Chapter 6 | 7.8. In general, please refer to comment 5.10. | Will review and consider changing label of indicator to conservative |
| Lake Cnty Stormwater Mgmnt District | Pg. 1, para 2 | Chapter 1 – Background | Replace last sentence with: "The general approach was to design and implement projects to reduce flood damages and at the same time improving the overall quality of an ecosystem degraded over the years by farming and development." | ERDC will review and consider |
| Lake Cnty Stormwater Mgmnt District | Pg. 1, para 3 | Chapter 1 – Background | End of sentence 1, insert: "each at different scales." | Concur. |
| Lake Cnty Stormwater Mgmnt District | Pg 1, para 3 | Chapter 1 - Background | Sentence 2, delete: "It is important to note that by definition"; Capitalize: Ecosystems | ERDC will review and consider |
| Lake Cnty Stormwater Mgmnt District | Pg. 2, para 1 | Chapter 1 – Background | Sentence 1, delete: "We must recognize that"; Capitalize: Planning | ERDC will review and consider |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| Lake Cnty Stormwater Mgmnt District | Pg. 2, para 1 | Chapter 1 – Background | Delete: "Scientists often become mired in the details about what exactly should be measured, what spatial scale should be studied, how frequently measurements should be taken, and how much data should be accumulated before recommendations are presented to decision makers. Those ecologists who are more oriented to problem solving (e.g., USACE planners, resource managers, etc.) point out that every detail of an ecosystem does not have to be understood in order to make reasonably intelligent decisions about the planning management and conservation of sensitive or valued resources." | ERDC will review and consider |
| Lake Cnty Stormwater Mgmnt District | Pg. 2, para 2 | Chapter 1 – Background | Delete: "Obviously,"; Capitalize: Determining | Concur |
| Lake Cnty Stormwater Mgmnt District | Pg 2, para 3 | Chapter 1 – Background | Sentence 2, delete: "And with their tried-and-true structure,"; Capitalize: These | Concur |
| Lake Cnty Stormwater Mgmnt District | Pg 2, para 3 | Chapter 1 – Background | Beginning of sentence 3, insert: "We designed"; Delete: "were designed" | Concur – if ERDC editors agree |
| Lake Cnty Stormwater Mgmnt District | Pg 2, para 3 | Chapter 1 – Background | Beginning of last sentence, insert: "We calculated"; Delete: "were calculated" | Concur – if ERDC editors agree |
| Lake Cnty Stormwater Mgmnt District | Pg 2, para 4 | Chapter 1 – Background | Sentence 1, insert: "we convened" an interagency; Delete "was convened" | Concur – if ERDC editors agree |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| Lake Cnty Stormwater Mgmnt District | Pg. 11, para 1 | Chapter 3 – General Description | Sentence 2, delete: "has" served as | Concur – if ERDC editors agree |
| Lake Cnty Stormwater Mgmnt District | Pg. 13, Fig. 2 | Chapter 3 – General Description | Figure 2, This picture is not good - too fuzy | Will review and consider replacing it with better resolution image, if we can acquire one. |
| Lake Cnty Stormwater Mgmnt District | Pg. 13, para 1 | Chapter 3 – Reference Domain | Why was this region chosen - I mean, just the Upper Des Plaines Watershed? Why didnt we look at other stretches of this watershed? What causes the upper part of the watershed to stand out from the other portions of the shed? | First, the reference domain boundary was based on the HGM determination (which was based on geomorphic classification) and we wanted the HEP models to emulate the same boundary. Second, was a scoping issue for the project . ERDC will review this section and consider adding more detail for justification. |
| Lake Cnty Stormwater Mgmnt District | Pg. 17, para 1 | Chapter 3 - Geology | Sentence 3, delete "construction" began about 26,000 years ago | Concur |
| Lake Cnty Stormwater Mgmnt District | Pg. 39, 40, 46, 47, 50, 65, 66, Tables 2, 3, 4, 5, 6, 7, 8 | Chapter 3 | Columns being cut off! | ERDC editors will correct all formatting issues |
| Lake Cnty Stormwater Mgmnt District | Pg. 66, para 1 list | Chapter 3 - Threats to the upper Des Plaines River Watershed | It might be better to group all of the "water" parameters together, then "soil", then the others | ERDC will review and consider |
| Lake Cnty Stormwater Mgmnt District | Pg. 89, 91, 96, Tables 10, 11, 12 | Chapter 4 | Columns being clipped | ERDC editors will correct all formatting issues |

*(Continued)*

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Table F - 1. (Continued).

| Reviewer | Page/ Para | Chapter Comments | Reviewer Verbiage | Response |
|---|---|---|---|---|
| Lake Cnty Stormwater Mgmnt District | Pg. 131, 132, Tables 14, 15 | Chapter 5 - Model Calibration – Reference Sites | Columns being clipped | ERDC editors will correct all formatting issues |
| Lake Cnty Stormwater Mgmnt District | Pg. 176, 178, 184, Tables 18, 19, 20 | Chapter 6 | Columns being clipped | ERDC editors will correct all formatting issues |

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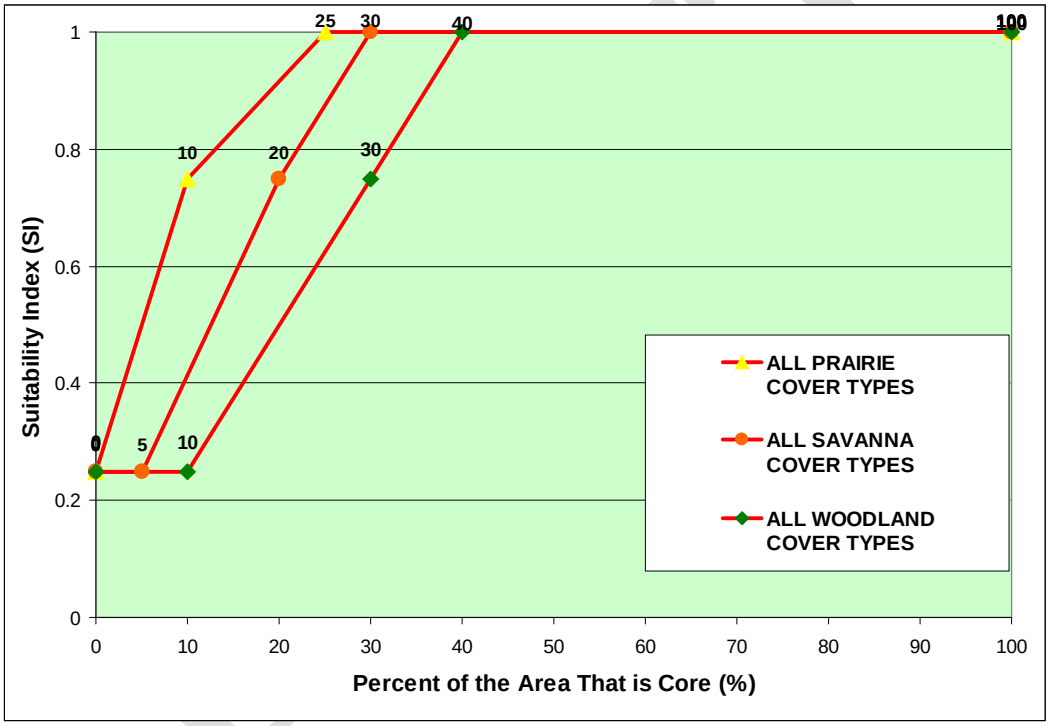
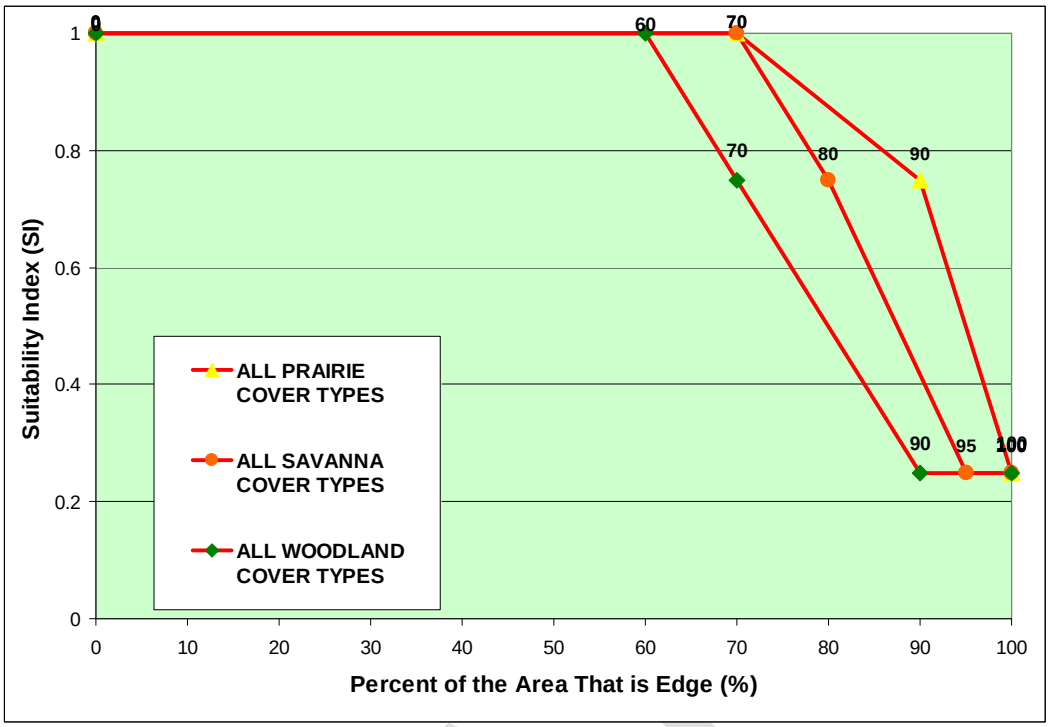
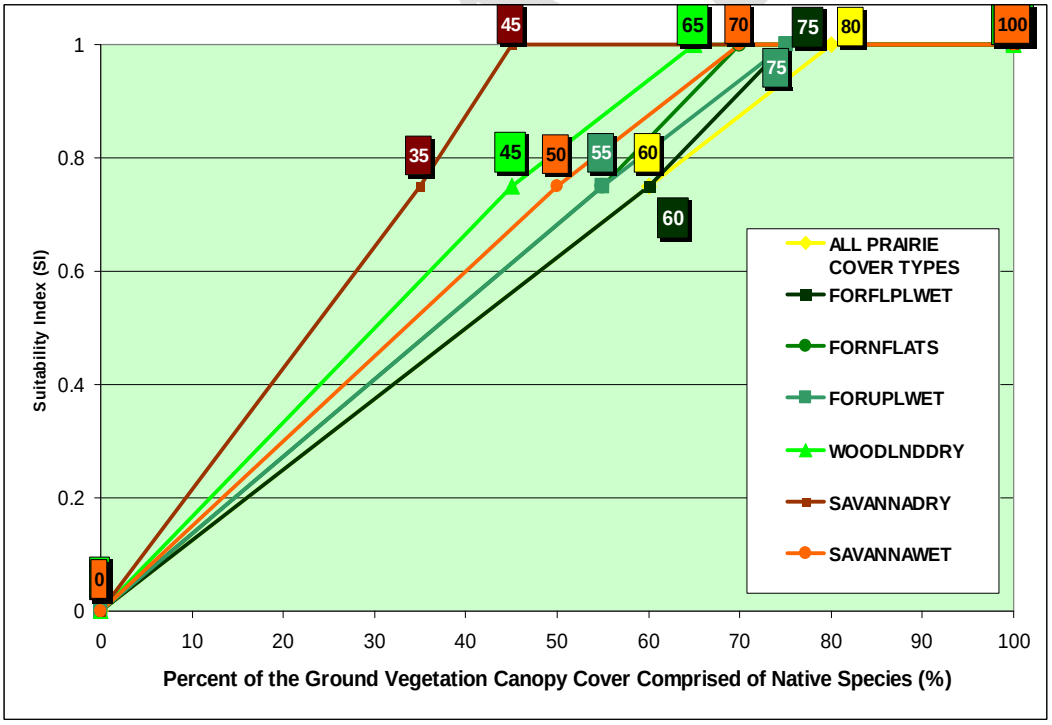
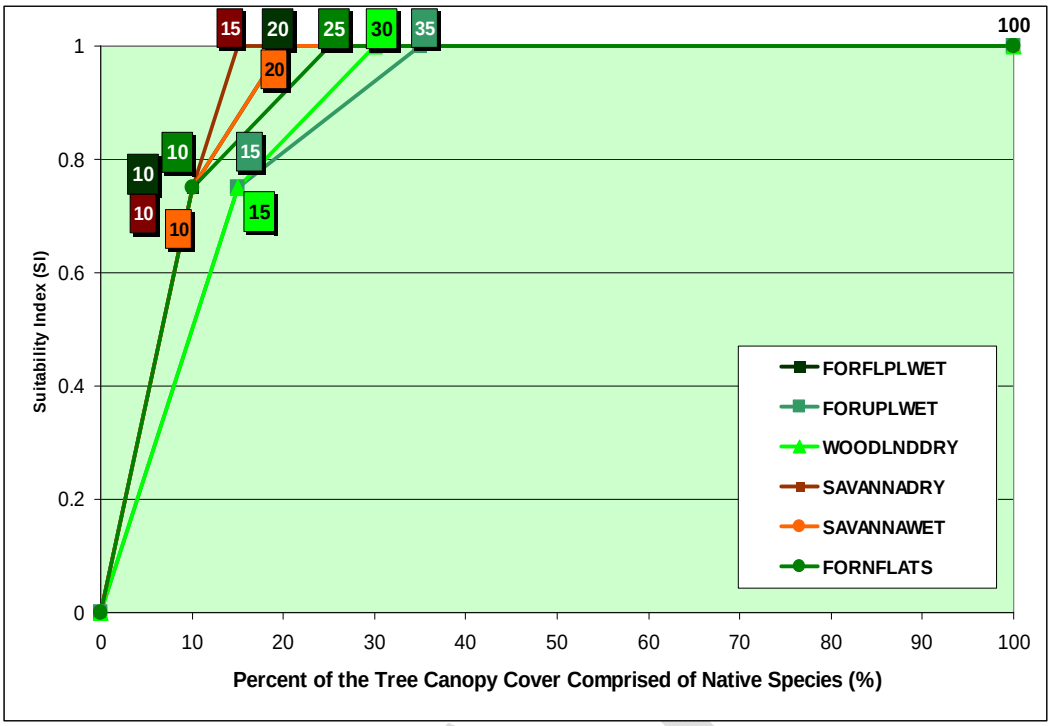
# Appendix G:
# HSI Curves for the Community Index Models

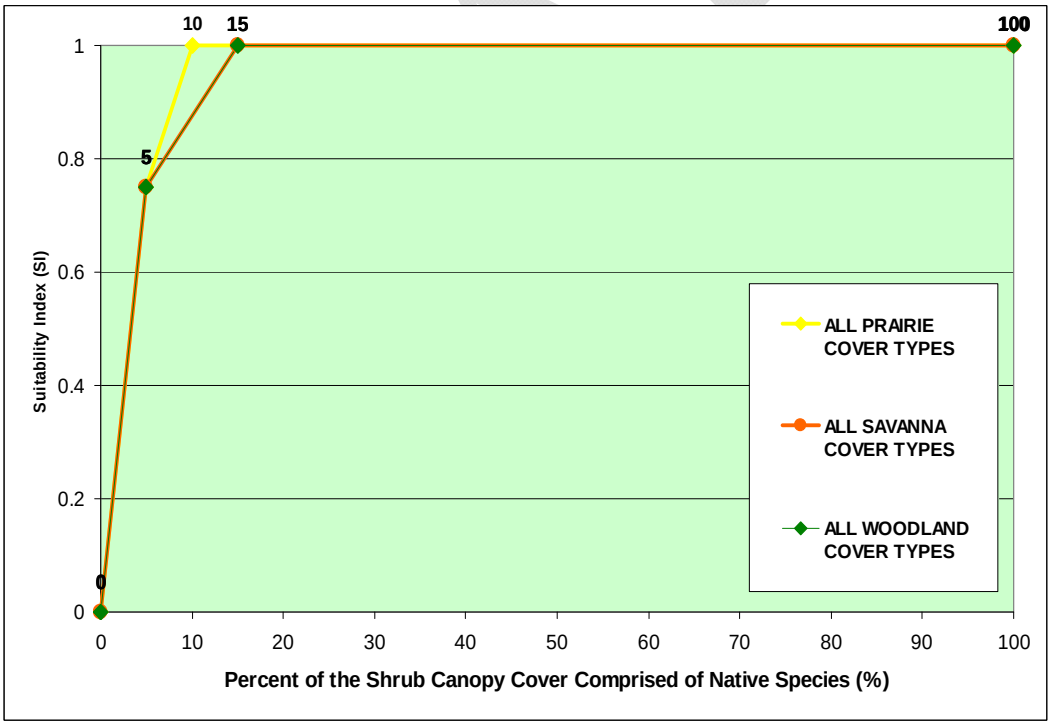
The following curves were developed by the E-Team to measure ecosystem function in the Des Plaines communities found along the Upper Des Plaines River and its various tributaries running through Wisconsin south through Illinios. Note that curves displayed in **red** indicate a consensus decision by the E-Team to modify the curve from the original field/GIS data collected.

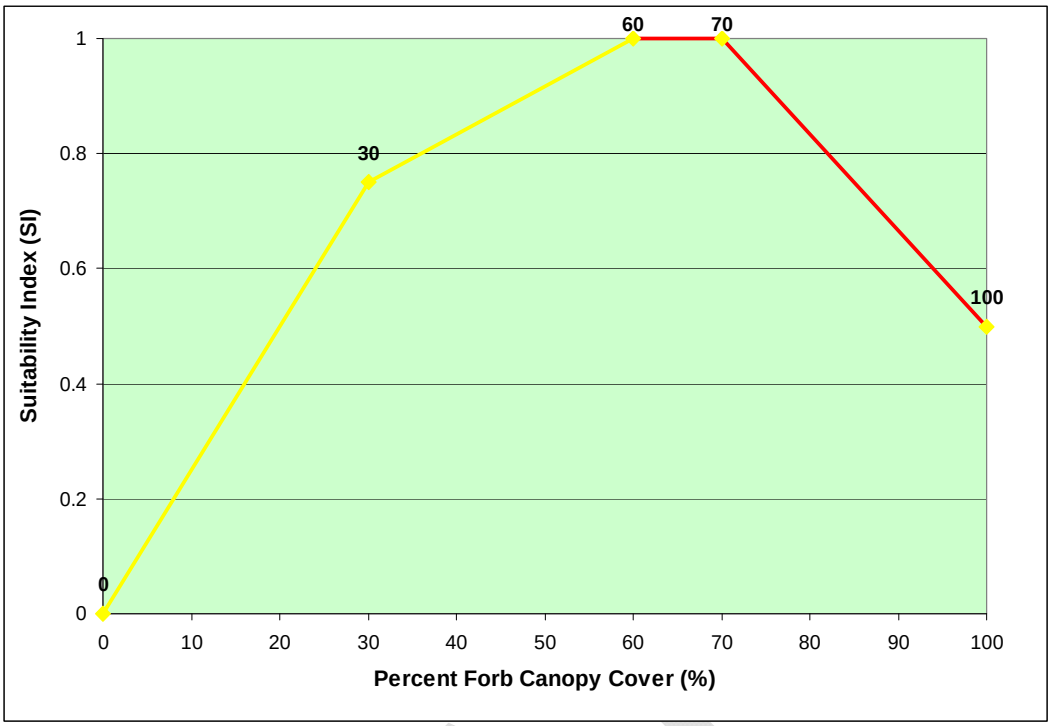


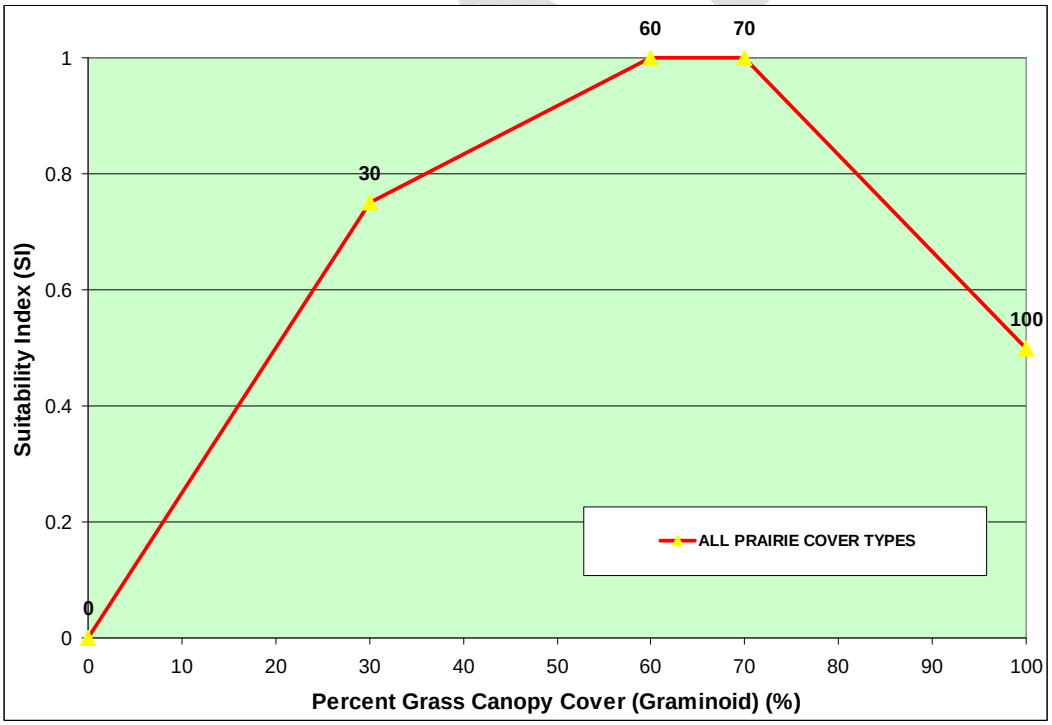

Suitability Index (SI)
Percent of the Area That is Edge (%)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES
0
60
70
70
80
90
90
95
100

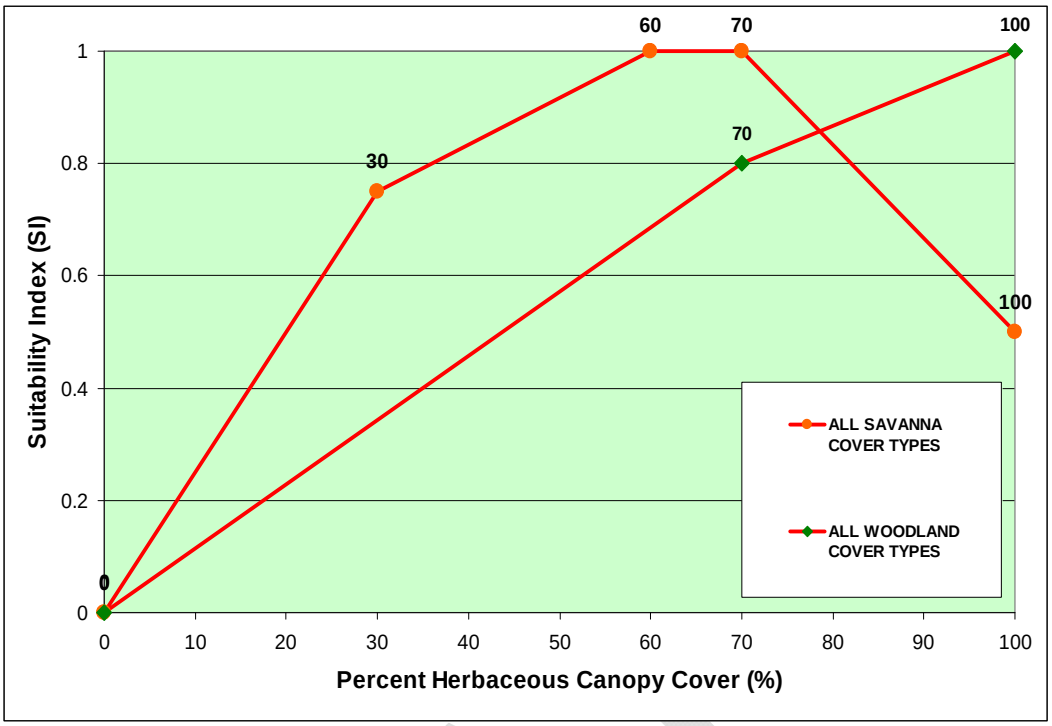

Suitability Index (SI)
Percent of the Ground Vegetation Canopy Cover Comprised of Native Species (%)
ALL PRAIRIE COVER TYPES
FORFLPLWET
FORNFLATS
FORUPLWET
WOODLNDDRY
SAVANNADRY
SAVANNAWET
0
35
45
45
50
55
60
60
65
70
75
75
80
100

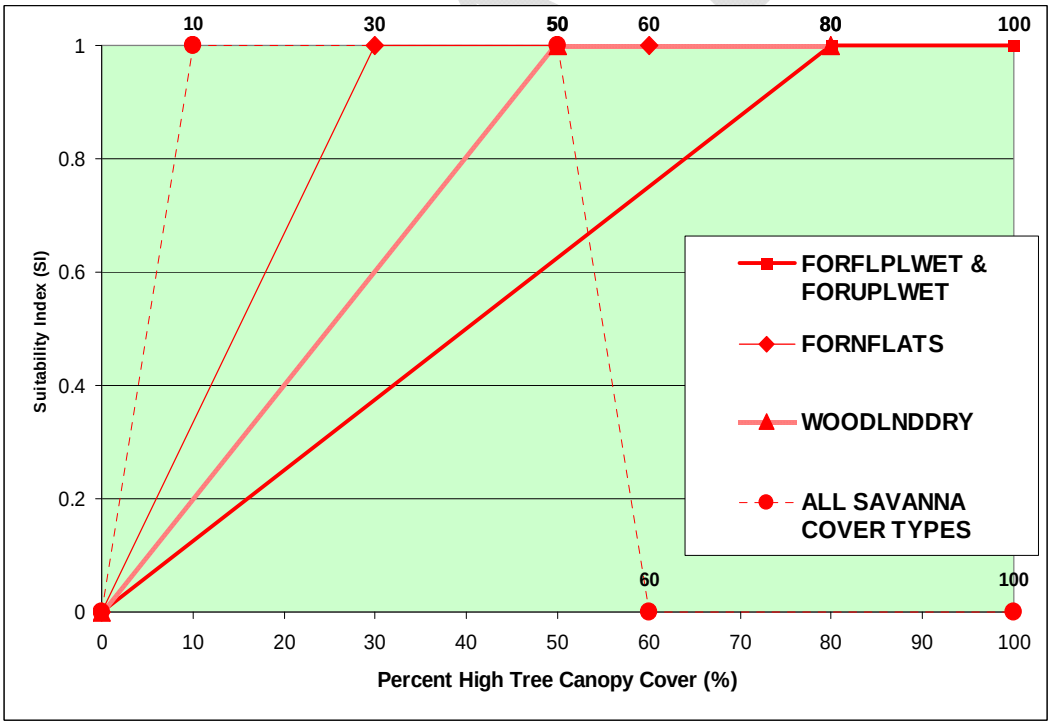

Suitability Index (SI)
Percent of the Tree Canopy Cover Comprised of Native Species (%)
FORFLPLWET
FORUPLWET
WOODLNDDRY
SAVANNADRY
SAVANNAWET
FORNFLATS
100
15
20
25
30
35
20
10
10
10
10
15
15

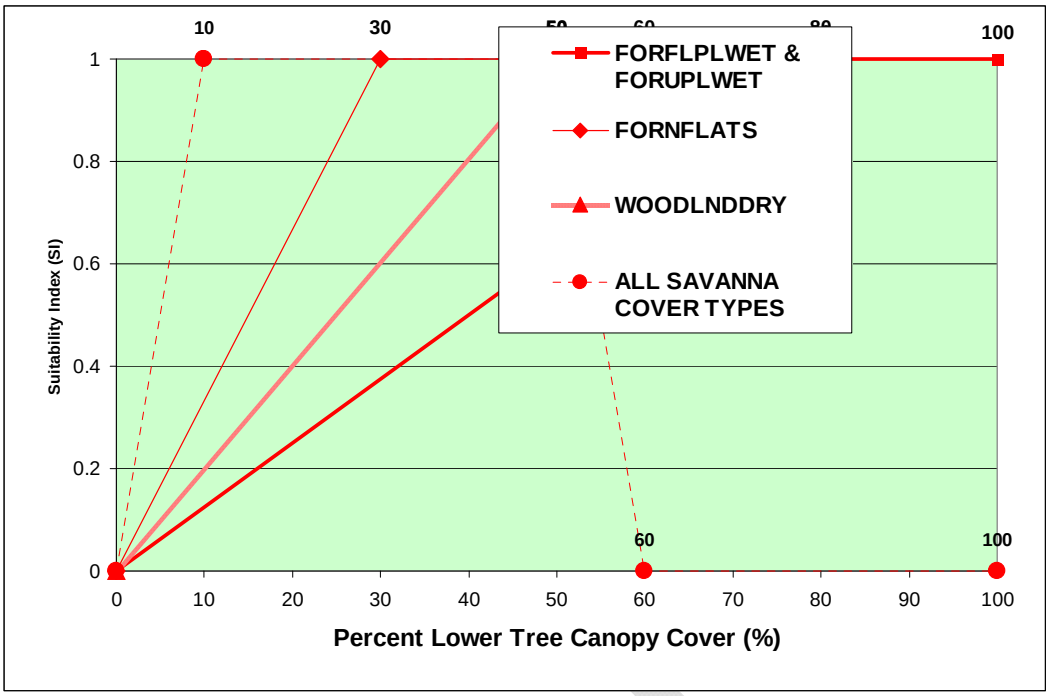

Suitability Index (SI)
Percent of the Shrub Canopy Cover Comprised of Native Species (%)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES
10
15
100
5
0

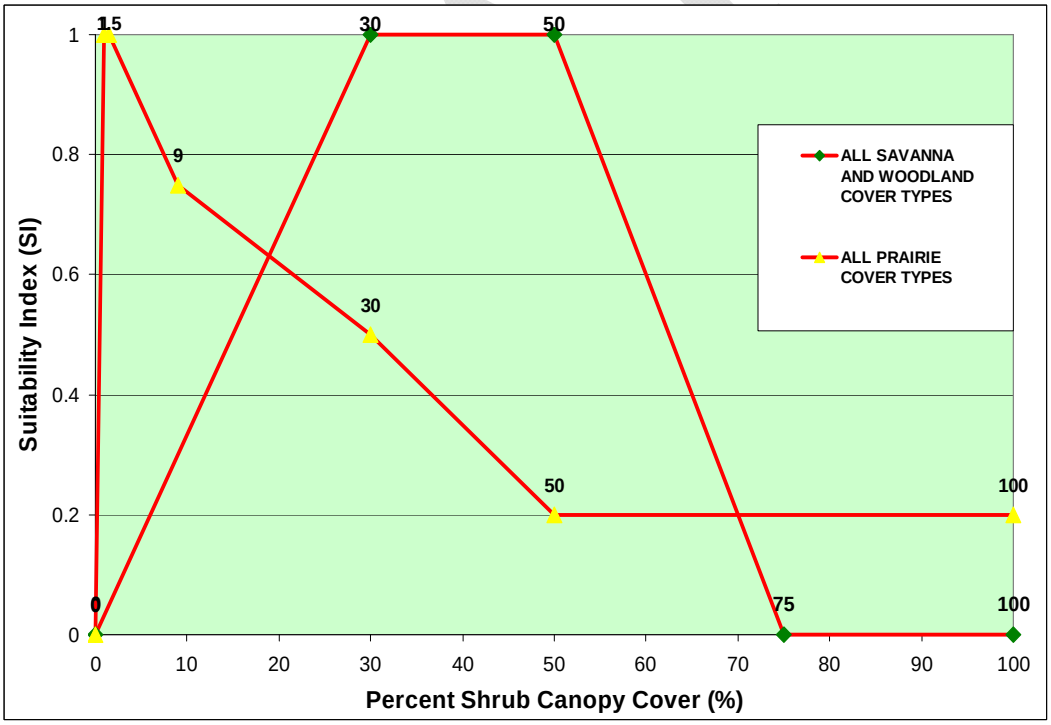

Suitability Index (SI)
Percent Forb Canopy Cover (%)
0
30
60
70
100
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90
100


Suitability Index (SI)
Percent Grass Canopy Cover (Graminoid) (%)
ALL PRAIRIE COVER TYPES
0
30
60
70
100
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90
100

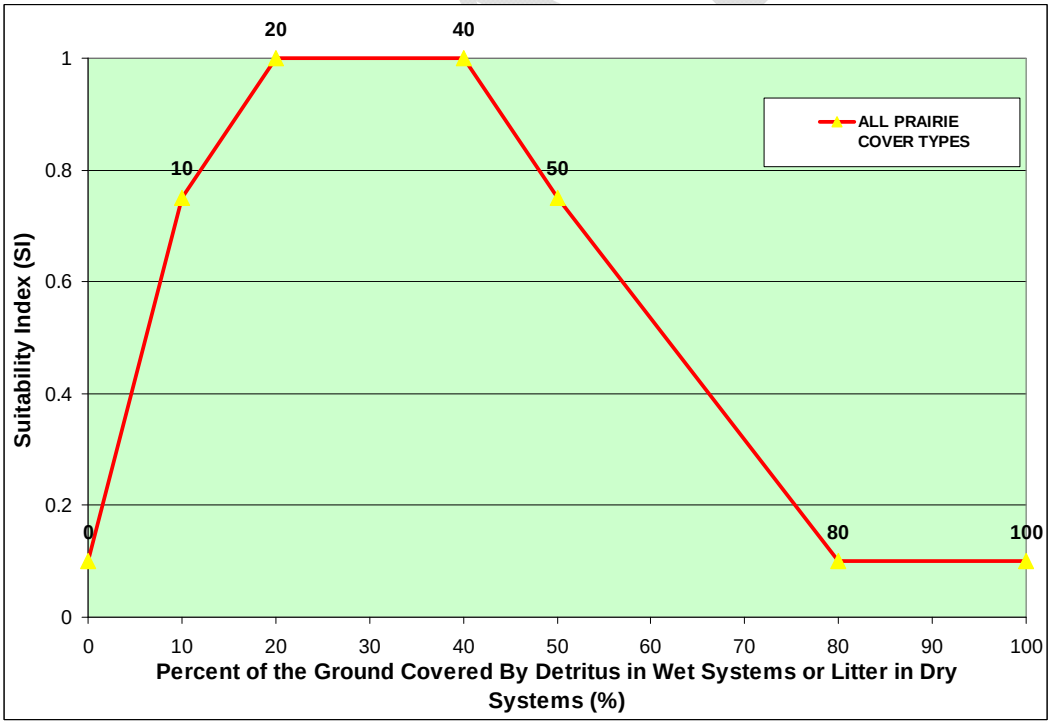

Suitability Index (SI)
Percent Herbaceous Canopy Cover (%)
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES
0
30
60
70
70
100
100

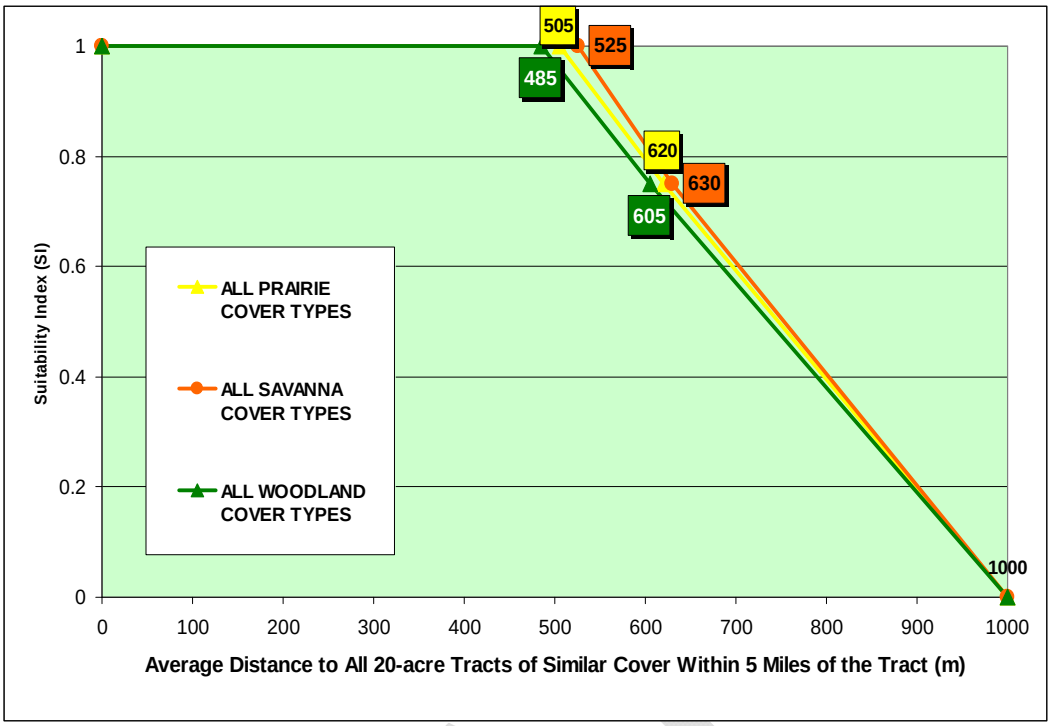

Suitability Index (SI)
Percent High Tree Canopy Cover (%)
FORFLPLWET & FORUPLWET
FORNFLATS
WOODLNDDRY
ALL SAVANNA COVER TYPES
10
30
50
60
80
100
60
100

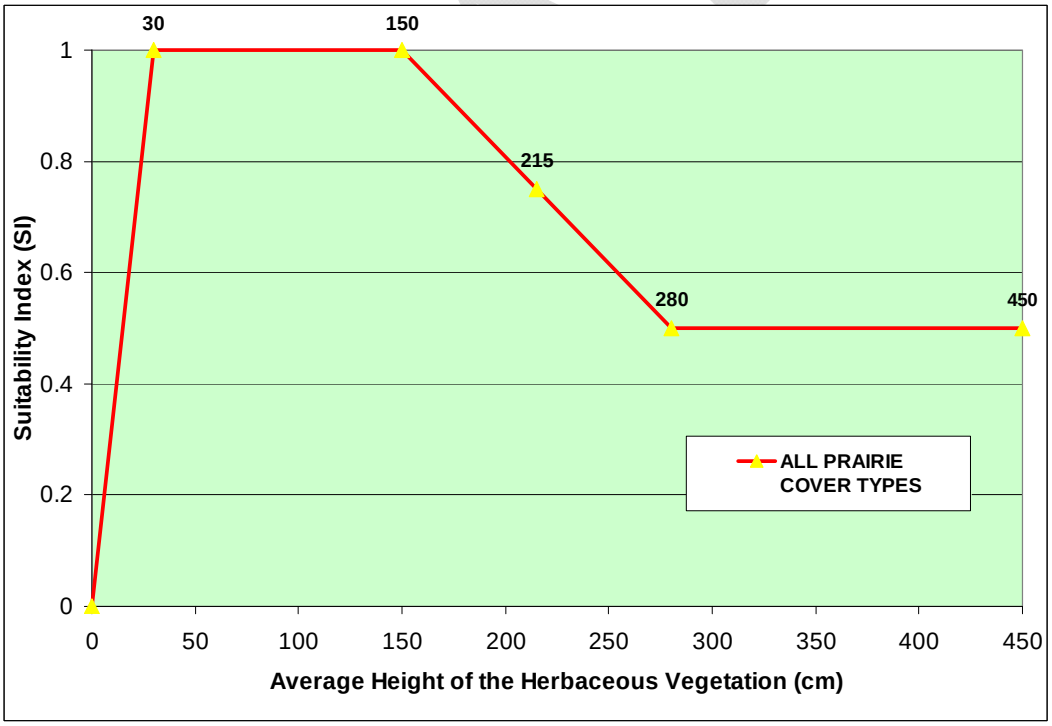

FORFLPLWET & FORUPLWET
FORNFLATS
WOODLNDDRY
ALL SAVANNA COVER TYPES
Suitability Index (SI)
Percent Lower Tree Canopy Cover (%)
10
30
100
60
100

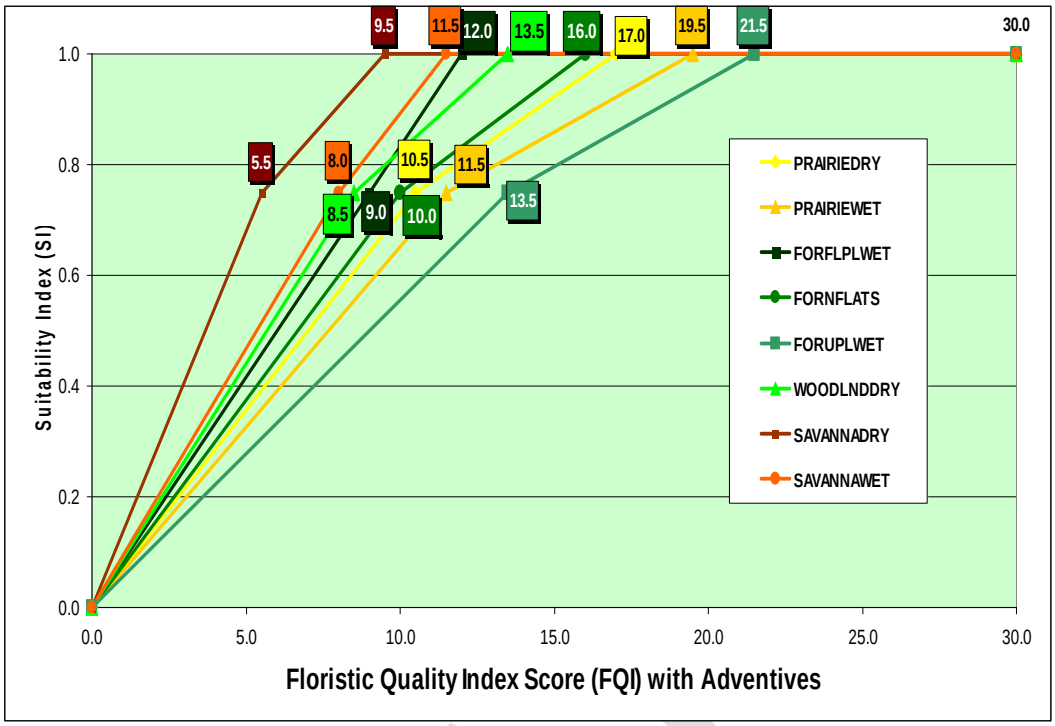

ALL SAVANNA AND WOODLAND COVER TYPES
ALL PRAIRIE COVER TYPES
Suitability Index (SI)
Percent Shrub Canopy Cover (%)
15
30
50
9
30
50
100
0
75
100

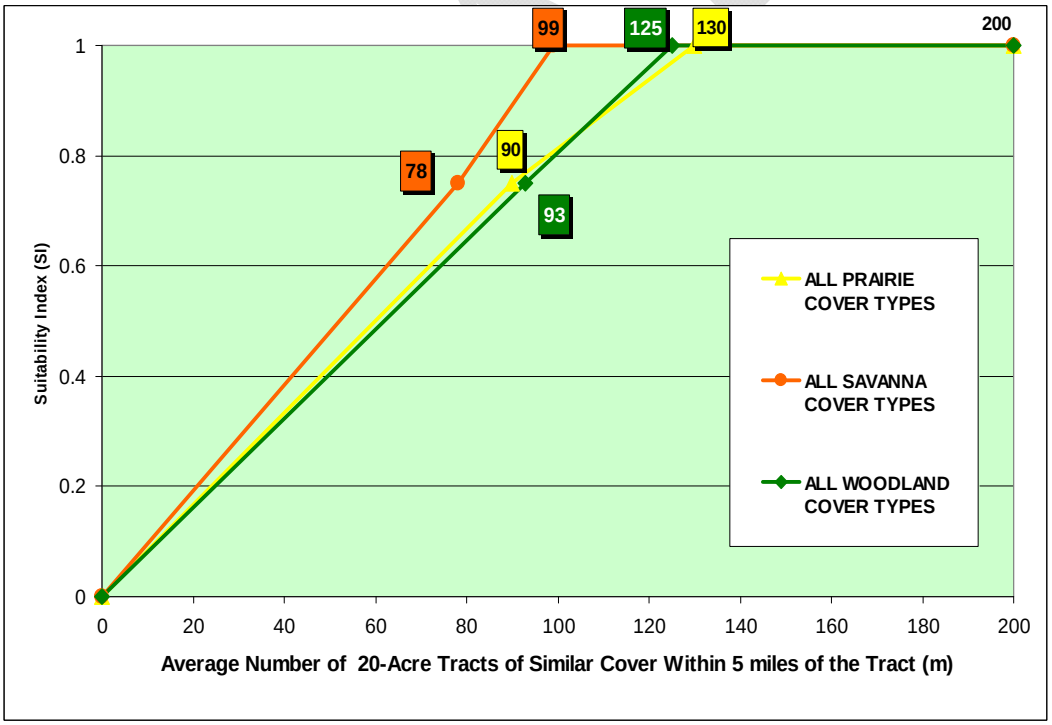
Suitability Index (SI)
Average Diamter at Breast Height (dbh) of Trees (cm)
SAVANNADRY
SAVANNAWET
ALL WOODLAND COVER TYPES
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
30
40
50
60
75
20
35
75

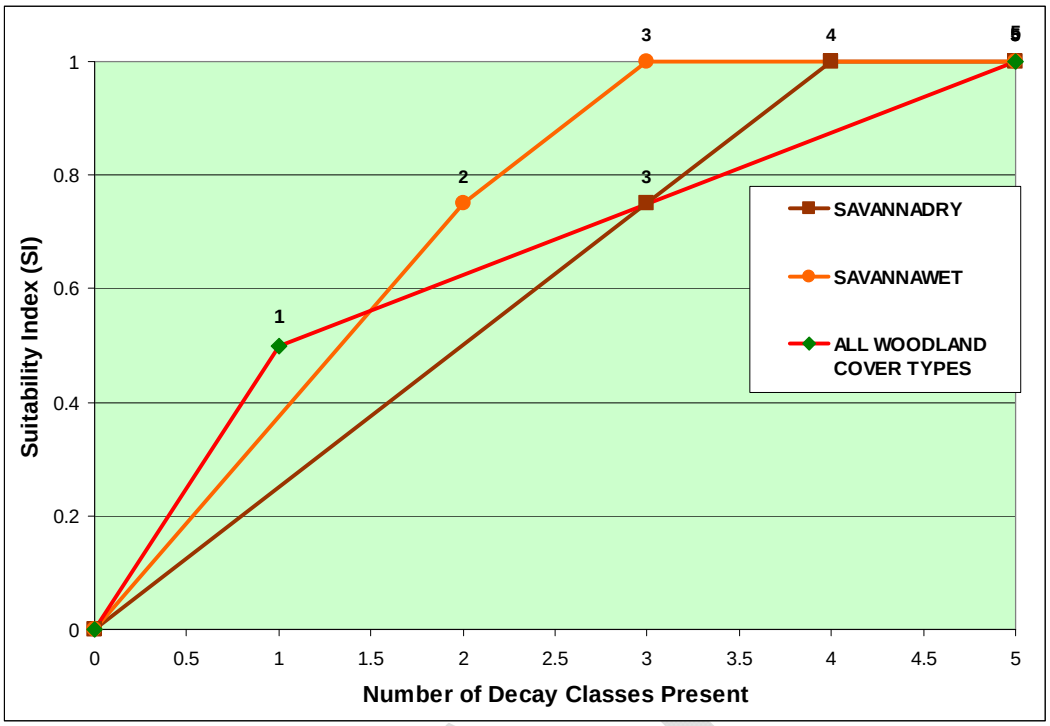

Suitability Index (SI)
Percent of the Ground Covered By Detritus in Wet Systems or Litter in Dry Systems (%)
ALL PRAIRIE COVER TYPES
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90
100
20
40
10
50
0
80
100

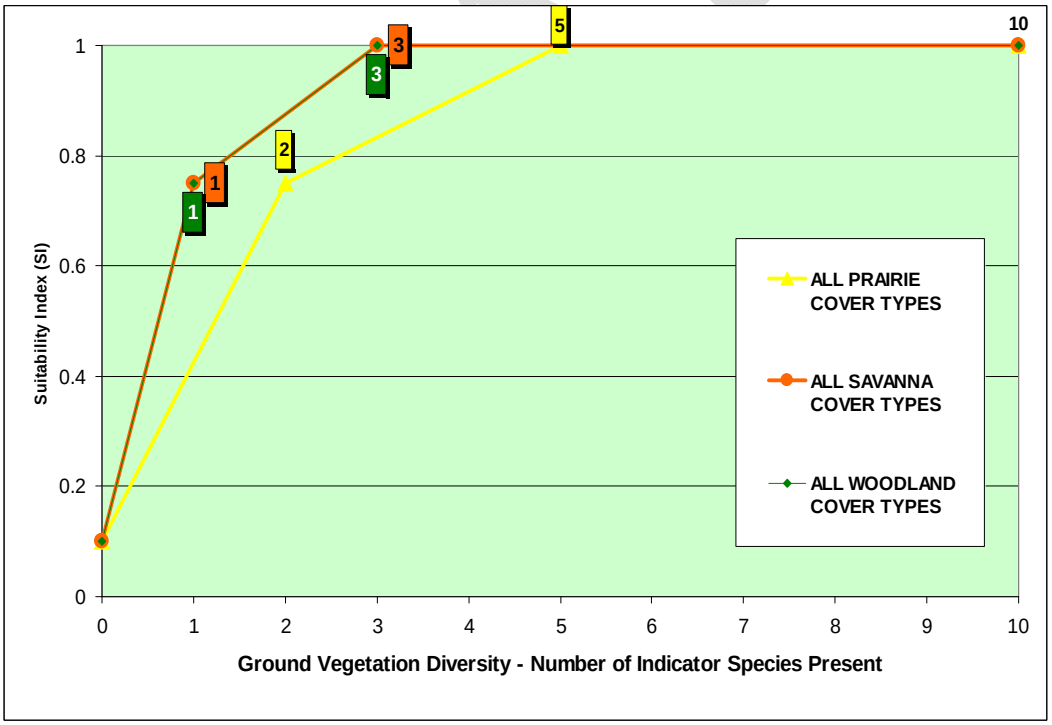

505
525
485
620
630
605
1000
1
0.8
0.6
0.4
0.2
0
Suitability Index (SI)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES
0
100
200
300
400
500
600
700
800
900
1000
Average Distance to All 20-acre Tracts of Similar Cover Within 5 Miles of the Tract (m)

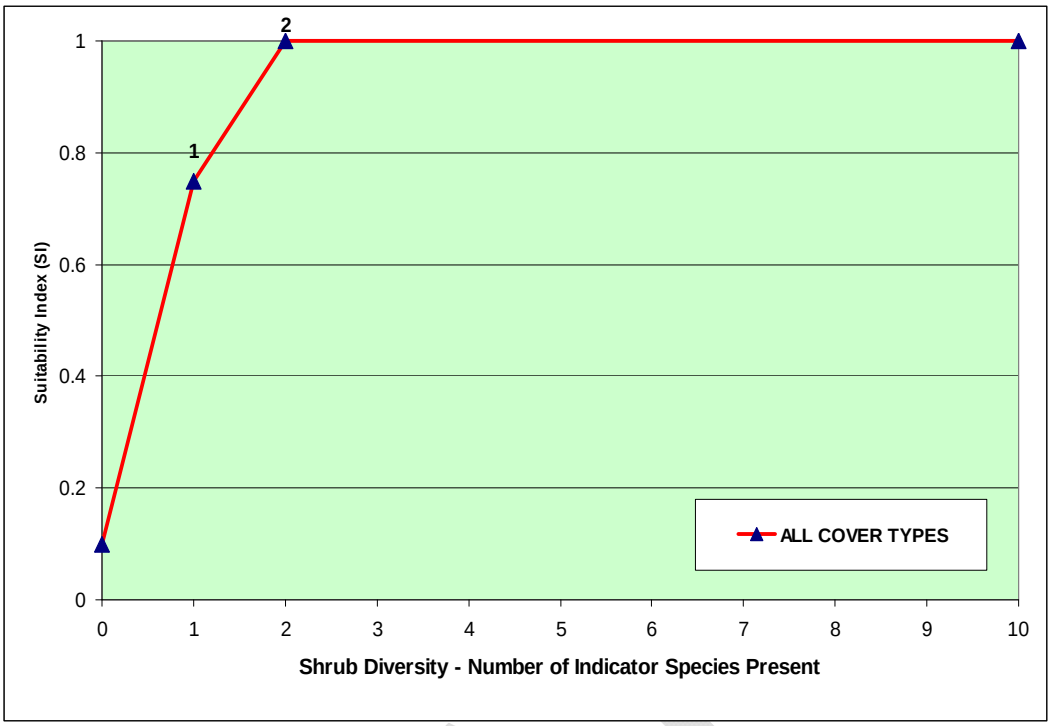

30
150
215
280
450
1
0.8
0.6
0.4
0.2
0
Suitability Index (SI)
ALL PRAIRIE COVER TYPES
0
50
100
150
200
250
300
350
400
450
Average Height of the Herbaceous Vegetation (cm)

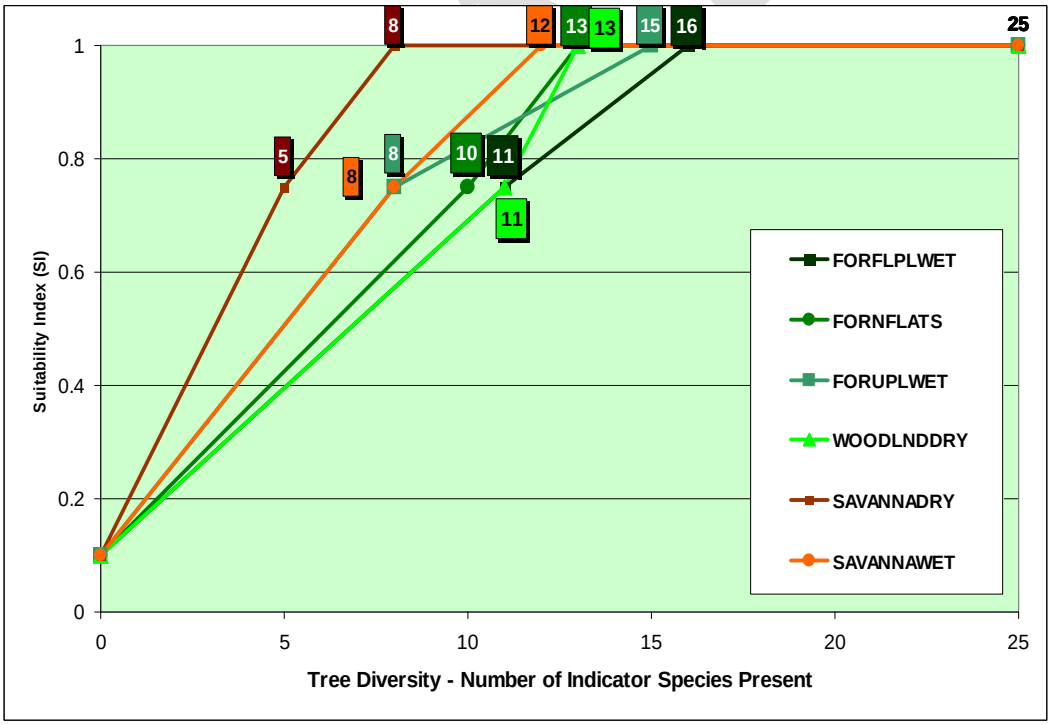

Suitability Index (SI)
Floristic Quality Index Score (FQI) with Adventives
PRAIRIEDRY
PRAIRIEWET
FORFLPLWET
FORNFLATS
FORUPLWET
WOODLNDDRY
SAVANNADRY
SAVANNAWET
9.5
11.5
12.0
13.5
16.0
17.0
19.5
21.5
30.0
5.5
8.0
10.5
11.5
8.5
9.0
10.0
13.5

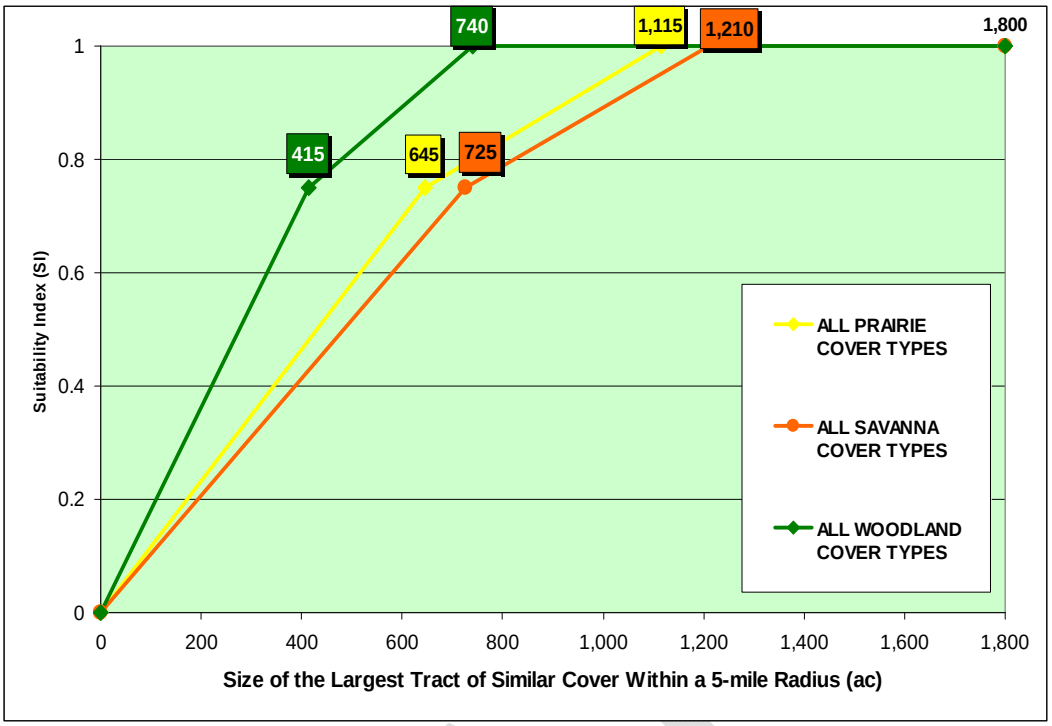

Suitability Index (SI)
Average Number of 20-Acre Tracts of Similar Cover Within 5 miles of the Tract (m)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES
99
125
130
200
78
90
93

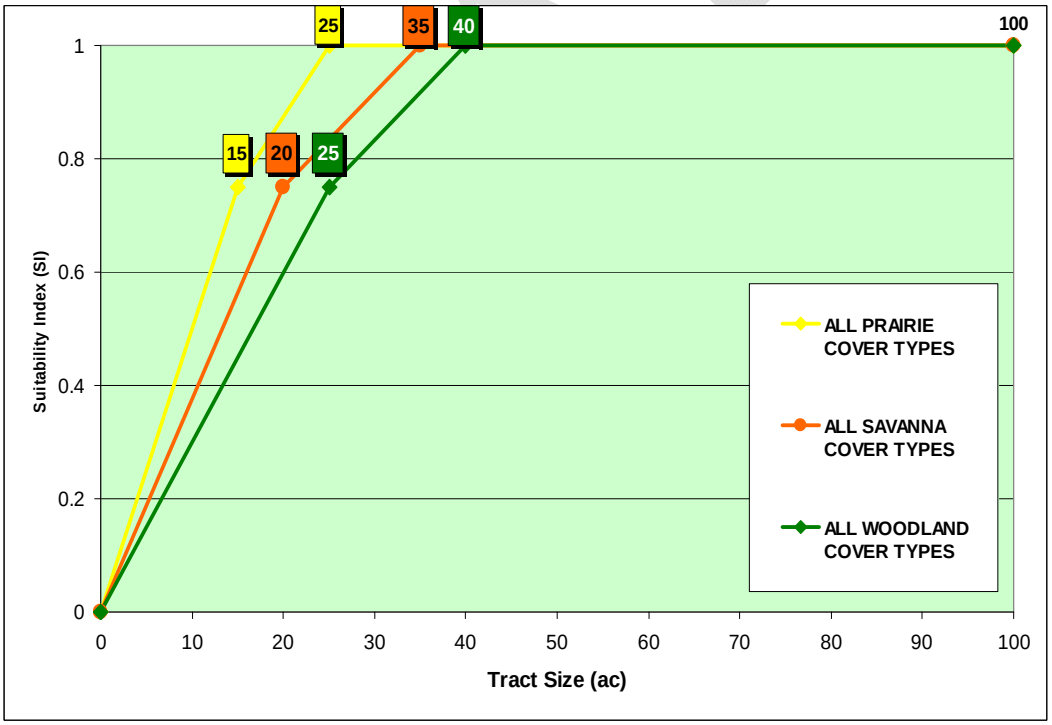

Suitability Index (SI)
Number of Decay Classes Present
SAVANNADRY
SAVANNAWET
ALL WOODLAND COVER TYPES

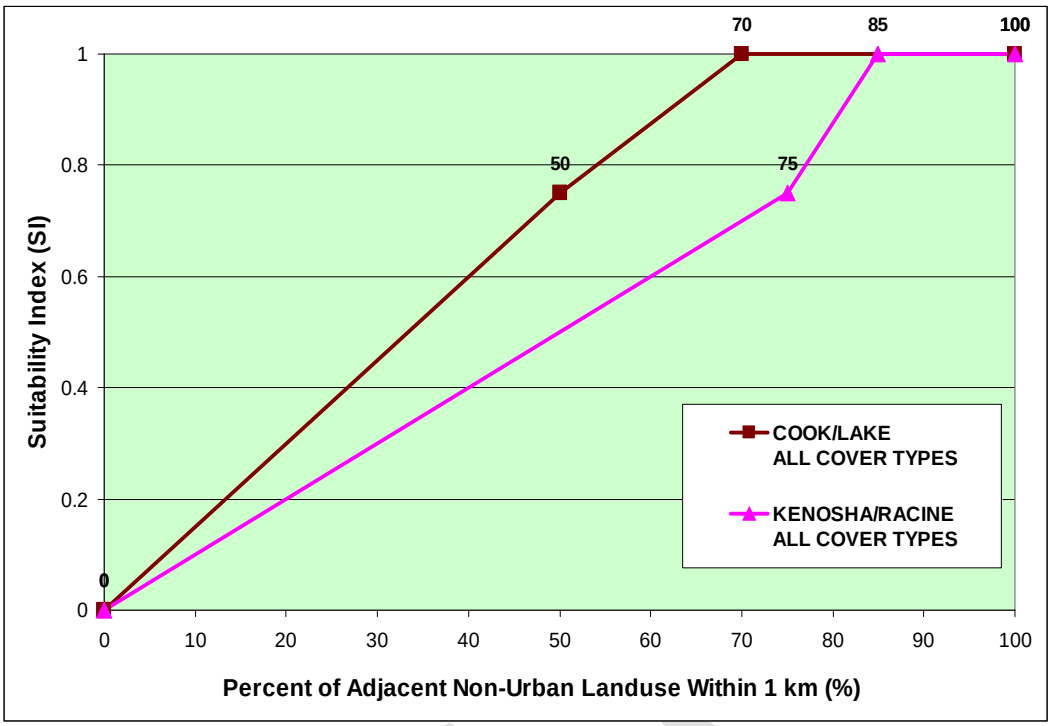

Suitability Index (SI)
Ground Vegetation Diversity - Number of Indicator Species Present
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES

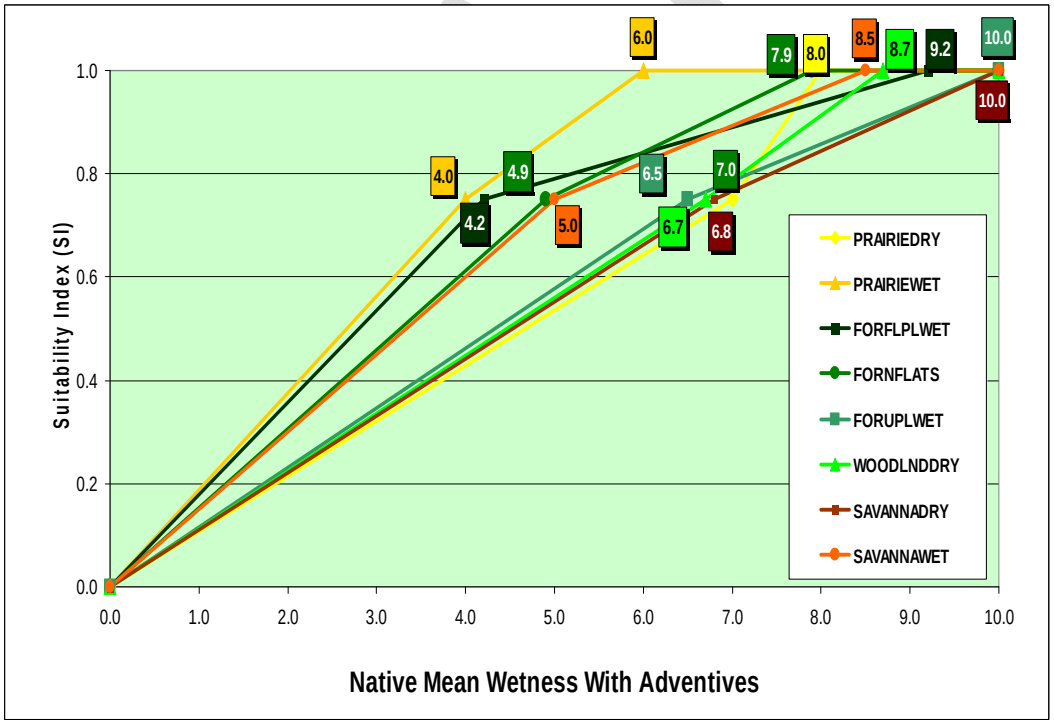

Suitability Index (SI)
Shrub Diversity - Number of Indicator Species Present
ALL COVER TYPES
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5
6
7
8
9
10
1
2


Suitability Index (SI)
Tree Diversity - Number of Indicator Species Present
FORFLPLWET
FORNFLATS
FORUPLWET
WOODLNDDRY
SAVANNADRY
SAVANNAWET
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25
5
8
8
8
10
11
11
12
13
13
15
16
25


740
1,115
1,210
1,800
415
645
725
Suitability Index (SI)
0
0.2
0.4
0.6
0.8
1
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
Size of the Largest Tract of Similar Cover Within a 5-mile Radius (ac)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES


25
35
40
100
15
20
25
Suitability Index (SI)
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90
100
Tract Size (ac)
ALL PRAIRIE COVER TYPES
ALL SAVANNA COVER TYPES
ALL WOODLAND COVER TYPES


Suitability Index (SI)
Percent of Adjacent Non-Urban Landuse Within 1 km (%)
COOK/LAKE ALL COVER TYPES
KENOSHA/RACINE ALL COVER TYPES
0
50
70
75
85
100


Suitability Index (SI)
Native Mean Wetness With Adventives
PRAIRIEDRY
PRAIRIEWET
FORFLPLWET
FORNFLATS
FORUPLWET
WOODLNDDRY
SAVANNADRY
SAVANNAWET
4.0
4.2
4.9
5.0
6.0
6.5
6.7
6.8
7.0
7.9
8.0
8.5
8.7
9.2
10.0
10.0

# Appendix H:
# Species List for Upper Des Plaines Watershed

The following list of species was developed by the Chicago District in an effort to characterize the communities modeled herein. Please direct questions regarding the content of this table to the District's POC (Brook Herman - see *Appendix D* for contact information) (click here to view attached file).

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ERDC/EL TR-06-4

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

*Wetlands Research Program*

# A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Depressional Wetlands in the Upper Des Plaines River Basin

Jeff P. Lin

May 2006

Approved for public release; distribution is unlimited.

**Wetlands Research Program**

ERDC/EL TR-06-4
May 2006

# A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Depressional Wetlands in the Upper Des Plaines River Basin

Jeff P. Lin

*Environmental Laboratory*
*U.S. Army Engineer Research and Development Center*
*3909 Halls Ferry Road*
*Vicksburg, MS 39180-6199*

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

**ABSTRACT:**
This Regional Guidebook characterizes the wetlands in the Upper Des Plaines River Basin using the hydrogeomorphic (HGM) approach. The HGM approach is a collection of concepts and methods used to develop functional indices to assess the capacity of a particular wetland to perform functions relative to similar wetlands in a region. Specifically, this report describes the rationale that was used to select functions for two subclasses of herbaceous freshwater depressions, the Isolated Depression subclass and the Floodplain Depression subclass. The report also describes the process used to select model variables and metrics and to develop assessment models. Data from reference wetlands are provided and used to calibrate model variables and assessment models. Protocols for applying functional indices to the assessment of wetland functions are provided.

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# Preface

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COL James R. Rowan was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

# 1 Introduction

## Background

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified, including determining minimal effects under the Food Security Act, designing mitigation project impacts, and managing wetlands.

On 16 August 1996, a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) was published *(Federal Register* 1997). The NAP was developed cooperatively by a National Interagency Implementation Team consisting of the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), National Resources Conservation Service (NRCS), Federal Highways Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). Publication of the NAP was designed to outline a strategy and promote the development of Regional Guidebooks for assessing the functions of regional wetland subclasses using the HGM Approach; to solicit the cooperation and participation of Federal, state, and local agencies, academia, and the private sector in this effort; and to update the status of Regional Guidebook development.

The sequence of tasks necessary to develop a Regional Guidebook outlined in the NAP was used to develop this Regional Guidebook (see the section, "Development Phase"). An initial workshop was held in Libertyville, IL, in January 2003. The workshop was attended by hydrologists, geologists, soil scientists, wildlife biologists, and plant ecologists primarily from local, state, and federal government agencies with extensive knowledge of local wetland ecosystem. Based on the results of the workshop, two regional wetland subclasses were defined and characterized, a reference domain was defined, wetland functions were selected, model variables were identified, and conceptual assessment models were developed. Subsequently, field and GIS based work was conducted to collect data from reference wetlands. Field data were collected during July and

August, 2003. Data from 64 reference sites (Appendix B) were then used to revise and calibrate the conceptual assessment models.

## Objectives

The objectives of this Regional Guidebook are to (a) characterize the wetlands in the Upper Des Plaines River Basin, (b) provide the rationale used to select functions for the Isolated Depression and Floodplain Depression Subclasses, (c) provide the rationale used to select model variables and metrics, (d) provide the rationale used to develop assessment models, (e) provide data from reference wetlands and document their use in calibrating model variables and assessment models, and (f) outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

## Scope

This guidebook is organized in the following manner. Chapter 1 provides the background, objectives, and organization of the guidebook. Chapter 2 provides a brief overview of the major components of the HGM Approach and the development and application phases required to implement the approach. Chapter 3 characterizes the wetlands in the Upper Des Plaines River Basin in terms of geographical extent, climate, geomorphic setting, hydrology, vegetation, soils, and other factors that influence wetland function. Chapter 4 discusses each of the wetland functions, model variables, and function indices. This discussion includes a definition of the function; a quantitative, independent measure of the function for validation; a description of the wetland ecosystem and landscape characteristics that influence the function; a definition and description of model variables used to represent these characteristics in the assessment model; a discussion of the assessment model used to derive the functional index; and an explanation of the rationale used to calibrate the index with reference wetland data. Chapter 5 outlines the steps of the assessment protocol for identifying and conducting a functional assessment of Isolated Depression and Floodplain Depression Wetlands in the Upper Des Plaines River Basin, and includes field and GIS data forms. Appendix A presents a Glossary. Appendix B contains the data collected at reference sites. Appendix C explains the use of Functional Capacity Units. Appendix D summarizes the functions, assessment models, and variables used in the models.

While it is possible to assess the functions of Depressional Wetlands in the Upper Des Plaines River Basin using only the information contained in Chapters 4 and 5, it is suggested that potential users familiarize themselves with the information in Chapters 2 and 3 prior to conducting an assessment.

# 2 Overview of the Hydrogeomorphic Approach

As indicated in Chapter 1, the HGM Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The HGM Approach includes four integral components: (a) the HGM classification, (b) reference wetlands, (c) assessment models/functional indices, and (d) assessment protocols. During the development phase of the HGM Approach, these four components are integrated in a Regional Guidebook for assessing the functions of a regional wetland subclass. Subsequently, during the application phase, end users, following the assessment protocols outlined in the Regional Guidebook, assess the functional capacity of selected wetlands. Each of the components of the HGM Approach and the development and application phases are discussed in this chapter. More extensive discussions can be found in Brinson (1993, 1995a,b); Brinson et al. (1995, 1996, 1998); Hauer and Smith (1998); Smith (2001); Smith and Wakeley (2001); Smith et al. (1995); and Wakeley and Smith (2001).

## Hydrogeomorphic Classification

Wetland ecosystems share a number of features, including relatively long periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these common attributes, wetlands occur under a wide range of climatic, geologic, and physiographic situations and exhibit a wide variety of physical, chemical, and biological characteristics and processes (Cowardin et al. 1979; Ferren et al. 1996a,b,c; Mitsch and Gosselink 2000; Semeniuk 1987). The variability of wetlands makes it challenging to develop assessment methods that are both accurate (i.e., sensitive to significant changes in function) and practical (i.e., can be completed in the relative short time available for conducting assessments). Existing “generic” methods designed to assess multiple wetland types throughout the United States are relatively rapid, but lack the resolution necessary to detect significant changes in function. However, one way to achieve an appropriate level of resolution within the available time frame is to reduce the level of variability exhibited by the wetlands being considered (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform and position of the wetland in the landscape. Water source refers to the primary water source in the wetland, such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland. Based on these three classification criteria, any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale, Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995). In many cases, the level of variability in wetlands encompassed by a continental scale hydrogeomorphic class is still too great to allow development of assessment models that can be rapidly applied while being sensitive enough to detect changes in function at a level of resolution appropriate to the 404 review process. For example, at a continental geographic scale the depression class includes wetland ecosystems in different regions as diverse as vernal pools in California (Zedler 1987), prairie potholes in North and South Dakota (Hubbard 1988, Kantrud et al. 1989), playa lakes in the high plains of Texas (Bolen et al. 1989), kettles in New England, and cypress domes in Florida (Ewel 1984, Kurz and Wagner 1953).

To reduce both inter- and intraregional variability, the three classification criteria are applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Ferren et al. 1996a,b,c; Golet and Larson 1974; Stewart and Kantrud 1971; Wharton et al. 1982). Regional subclasses, like the continental classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing regional subclasses in certain regions. For example, depressional subclasses might be based on water source (i.e., groundwater versus surface water), or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope, landscape position, the source of water (i.e., throughflow versus groundwater), or other factors. Riverine subclasses might be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Examples of potential regional subclasses are shown in Table 2, Smith et al. (1995), and Rheinhardt et al. (1997).

Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

**Table 1**
**Hydrogeomorphic Wetland Classes at the Continental Scale**

| HGM Wetland Class | Definition |
|---|---|
| Depression | Depression wetlands occur in topographic depressions (i.e., elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water through evapotranspiration, intermittent or perennial outlets, or recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depressional wetlands. |
| Tidal Fringe | Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and riverflow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional flows controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are a common example of tidal fringe wetlands. |
| Lacustrine Fringe | Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope uplands. Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evaporation. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands. |
| Slope | Slope wetlands are found in association with the discharge of groundwater to the land surface or sites with saturated overflow with no channel formation. They normally occur on sloping land ranging from slight to steep. The predominant source of water is groundwater or interflow discharging at the land surface. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depressional wetlands by the lack of a topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands. |
| Mineral Soil Flats | Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are an example of mineral soil flat wetlands. |
| Organic Soil Flats | Organic soil flats, or extensive peatlands, differ from mineral soil flats in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of the convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are examples of organic soil flat wetlands. |
| Riverine | Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In headwaters, riverine wetlands often intergrade with slope, depressional, poorly drained flats, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evaporation. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwoods on floodplains are an example of riverine wetlands. |

**Table 2**
**Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics**

| Geomorphic Setting Source | Dominant Water | Dominant Hydrodynamics | Potential Regional Wetland Subclasses | |
|---|---|---|---|---|
| | | | Eastern USA | Western USA/Alaska |
| Depression | Groundwater or interflow | Vertical | Prairie potholes, marshes, Carolina bays | California vernal pools |
| Fringe (tidal) | Ocean | Bidirectional, horizontal | Chesapeake Bay and Gulf of Mexico tidal marshes | San Francisco Bay marshes |
| Fringe (lacustrine) | Lake | Bidirectional, horizontal | Great Lakes marshes | Flathead Lake marshes |
| Slope | Groundwater | Unidirectional, horizontal | Fens | Avalanche chutes |
| Flat (mineral soil) | Precipitation | Vertical | Wet pine flatwoods | Large playas |
| Flat (organic soil) | Precipitation | Vertical | Peat bogs, portions of Everglades | Peatlands over permafrost |
| Riverine | Overbank flow from channels | Unidirectional, horizontal | Bottomland hardwood forest | Riparian wetlands |

## Reference Wetlands

Reference wetlands are wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as cultural alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always possible because of time and resource constraints.

Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic and sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, they establish the range and variability of conditions exhibited by model variables and provide the data necessary for calibrating model variables and assessment models. Finally, they provide a concrete physical representation of wetland ecosystems that can be observed and measured.

Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for the regional subclass at a level that is characteristic in the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

| Table 3<br>Reference Wetland Terms and Definitions | |
|---|---|
| **Term** | **Definition** |
| Reference domain | The geographic area from which reference wetlands representing the regional wetland subclass are selected (Smith et al. 1995). |
| Reference wetlands | A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alterations. |
| Reference standard wetlands | The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human altered wetland sites in the least human altered landscapes. By definition, the functional capacity index for all functions in reference standard wetlands is assigned a 1.0. |
| Reference standard wetland variable condition | The range of conditions exhibited by model variables in reference standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0. |
| Site potential (mitigation project context) | The highest level of function possible, given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass. |
| Project target (mitigation project context) | The level of function identified or negotiated for a restoration or creation project. |
| Project standards (mitigation context) | Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project is not being achieved. |

## Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. It defines the relationship between one or more characteristics or processes of the wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands.

Model variables represent the characteristics of the wetland ecosystem and surrounding landscape that influence the capacity of a wetland ecosystem to perform a function. Model variables are ecological quantities that consist of five components (Schneider 1994): (a) a name, (b) a symbol, (c) a measure of the variable and procedural statements for quantifying or qualifying the measure directly or calculating it from other measures, (d) a set of variables (i.e., numbers, categories, or numerical estimates (Leibowitz and Hyman 1997)) that are generated by applying the procedural statement, and (e) units on the appropriate measurement scale. Table 4 provides several examples.

| **Table 4<br>Components of a Model Variable** | | | |
|---|---|---|---|
| **Name (Symbol)** | **Measure / Procedural Statement** | **Resulting Values** | **Units (Scale)** |
| Substrate Disturbance *($V_{DISTURB}$)* | The alteration of the soils by activities such as addition of fill material, soil oxidation, rock plowing, or removal of sediment. | present<br>absent | unitless (nominal scale) |
| Presence of Ditches *($V_{DITCH}$)* | The presence of ditches within a certain distance of the wetland | 1.0<br>0.8<br>0.3 | unitless (interval scale) |
| Cover of Woody Vegetation *($V_{WOODY}$)* | The average percent aerial cover of leaves and stems of shrubs and trees (> 1 m). | 0 to >100 | percent |

Model variables occur in a variety of states or conditions in reference wetlands. The state or condition of the variable is denoted by the value of the measure of the variable. For example, percent herbaceous groundcover, the measure of the percent cover of herbaceous vegetation, could be large or small. Based on its condition (i.e., value of the metric), model variables are assigned a variable subindex. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the condition deflects from the reference standard condition (i.e., the range of conditions within which the variable occurs in reference standard wetlands), the variable subindex is assigned based on the defined relationship between model variable condition and functional capacity. As the condition of a variable deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex, reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex drops to zero. For example, when the percent cover of herbaceous groundcover is 40 percent or greater, the subindex for percent herbaceous groundcover is 1.0. As the percent cover falls below 40 percent, the variable subindex score decreases on a linear scale to zero.

Model variables are combined in an assessment model to produce a Functional Capacity Index (FCI) that ranges from 0.0 to 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the function at a level characteristic of reference standard wetlands. As the FCI decreases, it indicates that the capacity of the wetland to perform the function is less than that of reference standard wetlands.

## Assessment protocol

The final component of the HGM Approach is the assessment protocol. The assessment protocol is a series of tasks, along with specific instructions, that allow the end user to assess the functions of a particular wetland area using the functional indices in the Regional Guidebook. The first task is characterization, which involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the data for model

variables. The final task is analysis, which involves calculation of functional indices.

### Development phase

The Development Phase of the HGM Approach is ideally carried out by an interdisciplinary team of experts known as the "Assessment Team," or "A-Team." The product of the Development Phase is a Regional Guidebook for assessing the functions of a specific regional wetland subclass (Figure 1). In developing a Regional Guidebook, the A-Team will complete the following major tasks. After organization and training, the first task of the A-Team is to classify the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the HGM Classification (Brinson 1993; Smith et al. 1995). Next, focusing on the specific regional wetland subclasses selected, the A-Team develops an ecological characterization or functional profile of the subclass. The A-Team then identifies the important wetland functions, conceptualizes assessment models, identifies model variables to represent the characteristics and processes that influence each function, and defines metrics for quantifying model variables. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass. Field data are then collected from the reference wetlands and used to calibrate model variables and verify the conceptual assessment models. Finally, the A-Team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply the indices to the assessment of wetland functions. The following list provides the detailed steps involved in this general sequence:

Task 1: Organize the A-Team.

A. Identify A-Team members.
B. Train A-Team in the HGM approach.

Task 2: Select and Characterize Regional Wetland Subclasses.

A. Identify/prioritize wetland subclasses.
B. Select regional wetland subclasses and define reference domain.
C. Initiate literature review.
D. Develop preliminary characterization of regional wetland subclasses.

Task 3: Select Model Variables and Metrics and Construct Conceptual Assessment Models.

A. Review existing assessment models.
B. Identify model variables and metrics.
C. Define initial relationship between model variables and functional capacity.
D. Construct conceptual assessment models for deriving FCIs.
E. Complete Precalibrated Draft Regional Guidebook (PDRG).

Task 4: Conduct Peer Review of PDRG.

A. Distribute PDRG to peer reviewers.
B. Conduct interdisciplinary, interagency workshop of PDRG.
C. Revise PDRG to reflect peer review recommendations.

D. Distribute revised PDRG to peer reviewers for comment.
E. Incorporate final comments from peer reviewers on revisions into PDRG.

Task 5: Identify and Collect Data from Reference Wetlands.
A. Identify reference wetland field sites.
B. Collect data from reference wetland field sites.
C. Analyze reference wetland data.

Task 6: Calibrate and Field Test Assessment Models.
A. Calibrate model variables using reference wetland data.
B. Verify and validate (optional) assessment models.
C. Field test assessment models for repeatability and accuracy.
D. Revise PDRG based on calibration, verification, validation (optional), and field testing results into a Calibrated Draft Regional Guidebook (CDRG).

Task 7: Conduct Peer Review and Field Test of CDRG.
A. Distribute CDRG to peer reviewers.
B. Field test CDRG.
C. Revise CDRG to reflect peer review and field test recommendations.
D. Distribute CDRG to peer reviewers for final comment on revisions.
E. Incorporate peer reviewers' final comments on revisions.
F. Publish Operational Draft Regional Guidebook (ODRG).

Task 8: Technology Transfer.
A. Train end users in the use of the ODRG.
B. Provide continuing technical assistance to end users of the ODRG.

### Application phase

The Application Phase involves two steps. The first is using the assessment protocols outlined in the Regional Guidebook to carry out the following tasks (Figure 1).

*a.* Define assessment objectives.

*b.* Characterize the project site.

*c.* Screen for red flags.

*d.* Define the Wetland Assessment Area.

*e.* Collect field data.

*f.* Analyze field data.

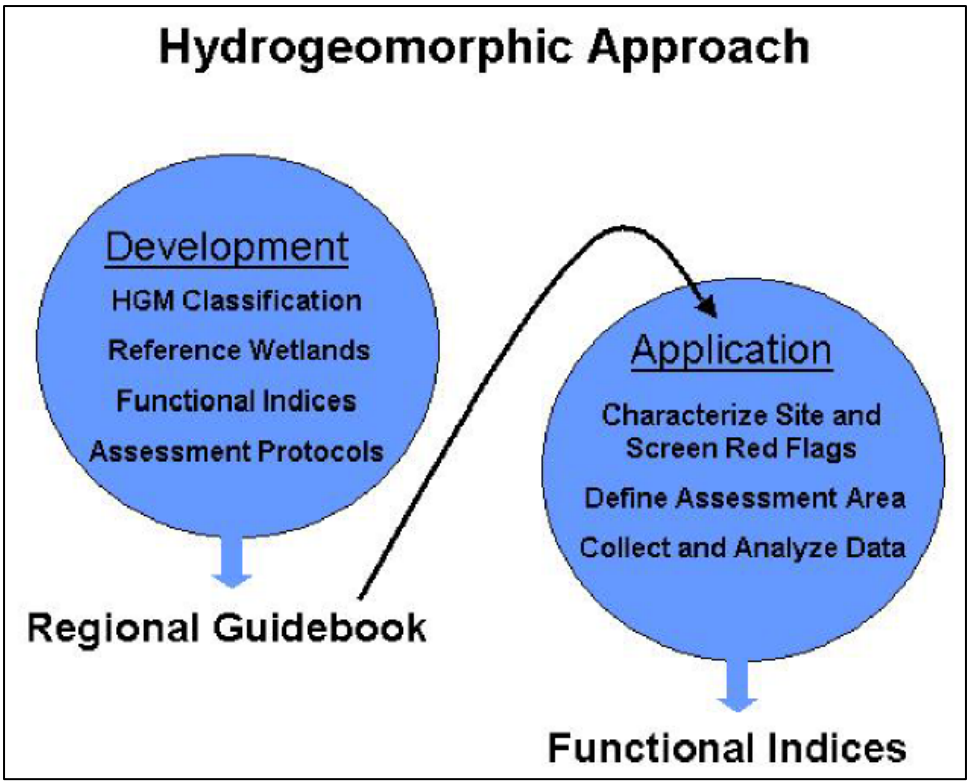


Figure 1. Development and application phases of the HGM Approach

The second step involves applying the results of the assessment, the FCI, to the appropriate decision-making process. Although the HGM approach was originally conceived for use in a regulatory context as part of Section 404 of the Clean Water Act, it has a variety of other potential applications as well. For instance, The HGM assessment model for the Upper Des Plaines River Basin was developed primarily for use in ecosystem restoration, done in an overall planning context.

There are several ways in which HGM models can be applied as part of an overall planning framework. For instance, in analysis of alternative plans, the HGM approach can be used to measure variable impacts to existing wetlands, or locating and evaluating potential wetlands restoration sites. Because the HGM approach produces a numerical value as a measure of various wetland functions, these numbers can be used to quantify and compare impacts and benefits to wetlands due to various alternative proposed plans and actions. These comparisons can be made through the calculation of Functional Capacity Units (see Appendix C), which take into account the number of wetland acres being affected.

# 3 Characterization of Regional Wetland Subclasses in the Upper Des Plaines River Basin

This Regional Guidebook was developed to assess the functions of two subclasses of herbaceous freshwater depressions in the Upper Des Plaines River Basin: Isolated Depressional and Floodplain Depressional Wetlands. However, this chapter will also address the classification of other subclasses that are found in the basin.

The chapter begins with a general description of the Upper Des Plaines Basin reference domain, and then provides an overview of various physical and biological characteristics of the reference domain. It concludes with descriptions of the HGM wetland classes and regional wetland subclasses that occur in the reference domain, and guidelines for recognizing them with a combination of field observation and geographical information system (GIS) layers.

## Reference Domain

The reference domain for this guidebook is the Upper Des Plaines River (UDPR) watershed, which encompasses the 13 northernmost subbasins of the Des Plaines River watershed in northeastern Illinois and southeastern Wisconsin (Figure 2). The UPDR consists of the portion of the Des Plaines River upstream of its confluence with Salt Creek near the city of Brookfield, IL, to where the river originates in the southernmost portion of Racine County, Wisconsin, near the town of Union Grove. The UDPR watershed covers approximately 479 square miles (1,241 square kilometers), of which 346 square miles (896 square kilometers) are in Lake County, north-central Cook County, and the northeastern portion of Du Page County, Illinois, and 133 square miles (344 square kilometers) in Kenosha County and the southernmost portion of Racine County in Wisconsin. At most, it spans approximately 10 miles (16 km) in an east-west direction. The watershed contains about 570 miles (917 km) of perennial streams and rivers, including the Des Plaines River and its major tributaries — Jerome Creek, Kilbourn Ditch, Dutch Gap Canal, and Brighton Creek in

Wisconsin, and Willow, Weller, Buffalo, Indian, Mill, and North Mill Creeks in Illinois.

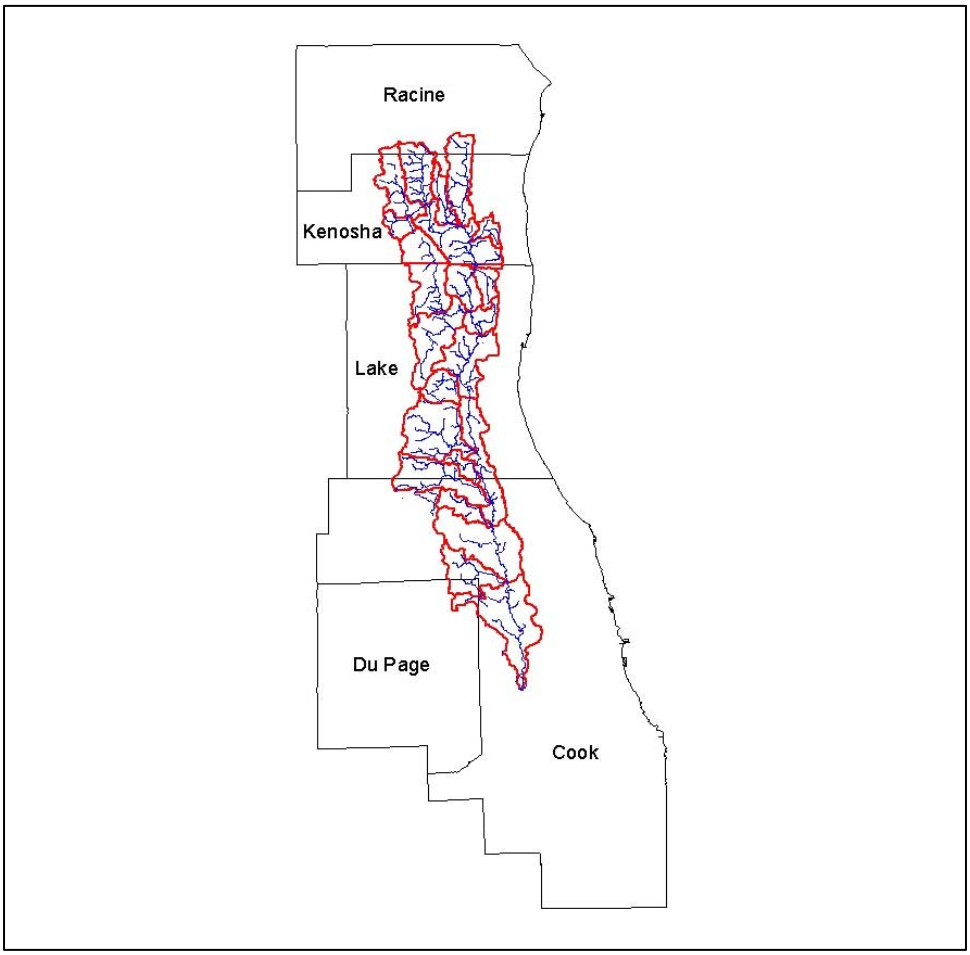


Figure 2. Upper Des Plaines Watershed

## Environment and Resources of the Upper Des Plaines River Basin

The following subsections review major concepts that have bearing on the classification and functions of wetlands in the modern landscape of the Upper Des Plaines River Basin. Unless otherwise noted, the information presented here is derived primarily from the Critical Trends Assessment Program (CTAP) Upper Des Plaines River Area Assessment reports (IDNR 1998) and the Southeastern Wisconsin Regional Planning Commission's "Comprehensive Plan for the Des Plaines River Watershed" (SEWRPC 2003).

## Physiography and climate

About 72 percent of the Upper Des Plaines Basin in Illinois occurs within the Wheaton Morainal Country physiographic divisions, with the remainder occurring in the heavily urbanized Chicago Lake Plain physiographic division, which encompasses the southeastern portion of the basin. Elevation in the entire basin ranges from 600 ft (183 m) to 891 ft (272 m) above sea level, and a majority of the land has a less than 2 percent slope, creating a relatively broad floodplain. The Chicago Lake Plain area was the floor of glacial Lake Chicago. The topography of this area generally is very flat, with low, gently sloping ridges (Willman 1971) and thus is far more uniform than that of the Wheaton Morainal Country.

The hummocky topographic features seen in the Wheaton Morainal Country were formed by the discontinuous deposition of glacial till superimposed on bedrock during the most recent (Wisconsin) glacial period. Generally ranging from 100 to 300 ft, these glacial deposits (unconsolidated sand, silt, clay, gravel, and boulders) left by stagnant and melting ice piles led to the formation of many depressional areas and subsequent lakes and marshes.

The climate of the Upper Des Plaines River basin is humid continental, with a wide range of temperature extremes, although this is tempered somewhat by the region's proximity to Lake Michigan. Temperature and precipitation are relatively uniform across the basin, although Cook County has slightly higher mean annual temperatures and precipitation levels than Lake and Kenosha Counties. From 1961 to 1990, mean temperatures at Chicago O'Hare International Airport in Cook County ranged from -6.1°C (21.0°F) in January to 22.8°C (73.0°F) in July, with an annual mean temperature of 9.4°C (48.9°F). In that same period, mean temperatures at Waukegan in northern Lake County ranged from -7.0°C (19.4°F) in January to 21.7°C (71.1°F) in July, with an annual mean temperature of 8.2°C (46.8°F). Mean temperatures measured at Union Grove, WI (the northernmost point of the watershed), are nearly identical to those measured in Waukegan.

Rainfall in the Upper Des Plaines River Basin is highest during June through September and lowest during January and February (where precipitation is primarily from sleet and snowfall). Mean annual rainfall from 1961 to 1990 was 35.8 in. (91.0 cm) at O'Hare and 34.2 in. (86.9 cm) at Waukegan. From 1945 to 1933, mean annual rainfall was 32.7 in. (83.0 cm) at Antioch, Wisconsin.

## Stream flow and groundwater hydrology

Streams in the basin exhibit a consistent seasonal flow cycle, with high flows in the spring months and low flows common in the summer and fall. A substantial portion (approximately 25 percent in the main stem river) of this flow originates from wastewater treatment plants. The basin is subject to significant and damaging flooding due to a lack of channel capacity in the Des Plaines River and its tributaries and urban encroachment into the floodplain. The area has had, on average, one significant flood every 4 years. Major floods in 1986 and 1987 caused over $100 million in damages to surrounding communities (USACE

2001). Flooding on the main stem is most common in the spring, and flooding on the tributaries is most common in the summer.

Groundwater in the basin is stored in a complex system of glacial drift, Silurian shallow dolomite (shallow bedrock), and deep sandstone aquifers (deep bedrock), with vertical distributions ranging from near surface to around 1,700 ft in depth (Larsen 1973). The principal sources of water in the shallow aquifers are percolation from precipitation and infiltration from surface streams. Much of this groundwater eventually discharges to lower lying lakes and wetlands, and provides the base flow of surface streams (Sheaffer and Zeizel 1966).

### Geology and geomorphology

The landscape of the Upper Des Plaines River Basin has been shaped primarily by glacial scouring and deposits that occurred 25,000 to 14,000 years ago during the Wisconsinan glaciation, the last major advance of the ice age. These deposits consisted primarily of till and outwash, as well as more minor deposits of lacustrine sediments and organic-rich debris. The glacial deposits were then overlaid by windblown silt, known as loess. Collectively, these deposits control, in part, land use, ecosystem development, and landscape processes in the basin.

The most prominent topographic features of the area are a series of north-south running moraines (ridges) that range from 1 to 3 miles wide and tens of miles long and were formed by the deposition of glacial till. Between these moraines are relatively flat lowland areas from which the drainage system of the basin developed. Also among the ridges are numerous undrained depressions, which create either small lakes or wetlands that formed in saturated organic soils (Larsen 1973).

The geology of the basin changes measurably from west to east. The moraines are hummockier at the western edge of the basin, indicating that glacial ice tended to stagnate and pile up in that area. Furthermore, in terms of grain size, the composition of the till is much more heterogeneous in this area, and the glacial drift layers are thicker as well.

### Soils

In the Upper Des Plaines River Basin there is a wide variation in the characteristics of parent materials in which soils have developed, although a majority developed in silty clay and silty clay loam textured till. The northern part of the basin has a greater amount of wetlands and poorly drained soils than the southern part. For instance, large sections in the north are of the Morley-Markham-Ashkum soil association, and contain many poorly drained depressions. The more productive soils, particularly the Drummer series, are also found in the north on flatter portions of the till plain. In contrast, the southern portion of the basin has been heavily urbanized, and few natural surfaces remain.

Soils in the basin are primarily of the Alfisols and Mollisols soil orders, although there are also pockets of Entisols and Inceptisols, generally on

floodplains and along steeper, eroded uplands. Common mineral soils found in wetlands in the basin include those in the Sawmill, Peotone, and Ashkum soil series. Additionally, many wetland depressional areas contain Histosols, with deep layers of muck and peat (primarily of the Houghton and Muskego soil series).

### Vegetation communities

The *Upper Des Plaines River Area Assessment*, Volume 3 (1998) report lists 16 natural terrestrial community types (adapted from White and Madany 1978) that either occur, or are believe to have formerly occurred, in the basin. These 16 types fall under the more general forest, prairie, and wetland community categories. Four wetland community types are described below. Of the four, the sedge meadow, wet prairie, and marsh communities are relevant to the isolated and floodplain depressions HGM models that are presented in this guidebook.

**Northern Flatwoods.** Northern flatwoods occur on poorly drained sites in the Valparaiso morainic system. These wetlands are seasonally wet, and water is often retained in microdepressions during the wet periods. The canopy is dominated by various white oak species, while the ground cover species include a wide variety of *Carex* sedges. There are approximately 85 acres of high quality northern flatwoods remaining in the Upper Des Plaines River Basin.

**Sedge Meadow.** The sedge meadow is dominated by the mound forming hummock sedge (*Carex stricta*). This wetland type can occur either on mineral or organic soils, and is saturated, although not inundated, for most of the year. Sedge meadows are often found within other community types, such as wet prairie, marshes, and shrub swamps.

**Wet Prairie.** Wet prairies are found on poorly drained and slowly permeable soils. Wet prairie vegetation is characterized by prairie cord grass (*Spartina pectinata*), and a variety of sedges and forbs, and shrubs.

**Marsh.** Marshes are dominated by herbaceous vegetation, consisting largely of cattails (*Typha spp.*). They have either organic or mineral soils, and water at or near the surface during most of the growing season.

### Fauna

The Upper Des Plaines watershed supports a wide range of fauna, including an estimated 43 mammal species, 16 amphibian species, 23 reptile species, and 270 bird species. In general, the greatest threat to these species is suburban/urban growth and the subsequent loss of habitat. Exotic faunal species are much less of a problem in the area than exotic and invasive plant species. Many of the faunal species (especially among birds and reptiles) found in wetlands will also utilize some other terrestrial or aquatic habitat during their life cycle.

**Birds.** Wetlands represent the most significant avian habitat in the region. The Deer Lake/Redwing slough complex, in particular, provides habitat for a

wide variety of birds, including several state threatened and endangered species. Wetland habitats in the area are also used as stop-over sites by a number of migrating bird species.

**Mammals.** Common mammal species that utilize wetlands in the region include beavers (*Castor Canadensis*), muskrats (*Ondatra zibethicus*), minks (*Mustela vison*), red fox (*Vulpes vulpes*), white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), and various shrew species. No known threatened or endangered mammal species are found in the area.

**Amphibians and Reptiles.** Typical amphibian species found in the wetlands in the region are the green frog (*Rana clamitans melanota*) and northern leopard frog (*Rana pipiens*); these frog species tend to be numerous in marsh areas. Typical reptiles are the painted turtle (*Chrysemys picta*), snapping turtle (*Chelydra serpentina serpentina*), and common garter snake (*Thamnophis sirtalis sirtalis*). The state threatened Kirtland's water snake (*Clonophis kirtlandii*) and state endangered massasauga snake (*Sistrurus catenatus*) both rely on wetland habitats, and prefer wet prairie areas with abundant ground cover.

## Alterations to environmental conditions

**Changes in Land use.** In 1820, based on a Government Land Office survey done at the time, the land cover of the Upper Des Plaines River Basin was approximately 40 percent prairie and 60 percent forest and savanna. The presettlement historical coverage of wetlands in the basin (extrapolated from hydric soil acreage in Lake County) is estimated to have been 26 percent of the total area (57,600 acres). Since that time, the biological landscape of the basin has been drastically altered by human activity. Many historical wetlands have been tiled and drained to make use for agriculture, and large parts of the basin have become heavily urbanized. The construction and creation of agricultural fields, buildings, and roads have also fragmented once contiguous forest, wetland, and prairie habitats. More recently, urban development has replaced agricultural land, and now dominates large portions of the landscape (Figure 3).

By recent estimates, a majority (57 percent) of Upper Des Plaines River Basin land cover in Illinois is of the urban/built up class. Another 16 percent is upland forest, 11 percent is cropland, and 6 percent of the basin is classified as wetland (forested and non-forested). On the other hand, a majority of the Wisconsin portion of the watershed is in cropland (68 percent), while only about 12 percent is classified as urban, about 8 percent as wetland, and about 6 percent as woodland.

**Invasive and Exotic Species.** A major problem and threat to the natural diversity of ecosystems in the watershed has been the influx and diffusion of invasive and exotic plant species. Major causes of the proliferation of invasive species are altered flooding regimes and increased siltation. Many marshes have been completely overtaken by reed canary grass (*Phalaris arundinacea*), and dense stands of cattails (*Typha spp.*) have become nearly ubiquitous in these systems as well. Other introduced or invasive plant species posing problems in wetlands include common and glossy buckthorn (*Rhamnus cathartica* and

*Rhamnus frangula*), purple loosestrife (*Lythrum salicaria*), bittersweet night-shade (*Solanum dulcamara*), and common reed (*Phragmites australis*).

Figure 3. Aerial photos of the Rollins Savanna area, Lake County, taken in 2001 (on the left) and 1939 (on the right)

## Description of Regional Wetland Subclasses

The following descriptions of wetland HGM classes and subclasses in the Upper Des Plaines River basin is not meant to encompass every type of wetland found in the region, but includes those types that were encountered during field reconnaissance and data collection in the area, and does comprise the majority of wetland subclasses to be found in the basin. Each subclass listed below would require its own separate assessment model. HGM functional assessment models have been created so far for the Isolated Depression and Floodplain Depression subclasses, and as such, more detail is provided in the description of these two subclasses.

The dichotomous key in Figure 4 can be used as a quick guide for distinguishing among the various subclasses that are described below.

| | |
|---|---|
| 1. Wetland is located in topographic depression | Go To #2 |
| 2. Wetland is wholly or the majority is outside of the mapped 10-year floodplain | Isolated Depression |
| 2. Wetland is wholly or the majority is inside of the mapped 10-year floodplain | Floodplain Depression |
| 1. Wetland is not located in topographic depression | Go To #2 |
| 2. Wetland is within mapped 2-year floodplain | Go To #3 |
| 3. Wetland is associated with a lake | Lacustrine Fringe |
| 3. Wetland is associated with a stream or river | Go To #4 |
| 4. Wetland has ≤ 30% tree or shrub cover | Herbaceous Riverine |
| 4. Wetland has > 30% tree or shrub cover | Forested Riverine |
| 2. Wetland is outside of mapped 2-year floodplain | Flat |

Figure 4. Dichotomous key to various HGM subclasses in the Upper Des Plaines River Basin

## Depressions

In the Upper Des Plaines River Basin, the Depressions HGM class has been subdivided into several subclasses based on the presence of outlets and location within the floodplain. Generally speaking, depressional wetlands occur in topographic depressions that allow the accumulation of surface water. For the purposes of this HGM model, a depression is defined as having a minimum depth of 2 ft in at least part of the wetland. A 2-ft depth is used because of the availability of digital 2-ft elevation contour lines in the watershed. These contour lines can be used when applying the model to determine whether or not a site can be classified as a depression.

Historically, many undrained depressions of various sizes were formed in the basin from glacial movement and activity. These depressions were able to store water from precipitation and stream flooding (for those located in the floodplain), providing natural flood protection benefits in the watershed. However, subsequent human activity has led to the draining and filling of many of these. These changes are in part responsible for reducing the ability of the watershed to absorb major flooding events.

Currently, the depression class accounts for the majority of wetlands in the watershed (IDNR 1998). Their relative number, combined with their ecological and flood attenuation benefits, and their potential for restoration are the reasons that the A-Team decided to focus on this wetland type for the Guidebook.

**Isolated Depressions.** In the Upper Des Plaines Basin, wetlands are classified as isolated if they are located outside of the mapped 10-year floodplain (Figure 5). Their hydrology is driven by direct precipitation and associated runoff, with additional subsurface flow under certain geologic settings. It should be noted that the classification of wetlands as *isolated* in this document does not have any use or bearing on jurisdictional and regulatory determinations.

Figure 5. Aerial and ground views of an isolated depression located in Deer Grove Forest Preserve, Cook County, IL

Isolated depressions can have one or more surface outlets, or no outlets at all. These outlets can be a natural channel (such as a headwater stream), or manmade, as in the case of ditches and tiles. If there is no defined outlet, water can still leave the depression if it reaches a level higher than the depth of the wetland.

These depressions are mostly herbaceous systems, defined as having ≤ 30 percent tree/shrub cover (Cowardin et al. 1979). They consist primarily of low marsh or sedge meadow communities, or both. Plants commonly found in these systems include river bulrush (*Scirpis fluviatilis*) and smartweeds (*Polygnum spp.*) in the low marsh areas, and *Carex stricta* and *Carex lacustris* in the sedge meadow areas. Cattails (*Typha spp.*) are ubiquitous in both community types, although they tend to, along with reed canary grass (*Phalaris arundicae*), be far denser in the more disturbed areas.

**Floodplain Depressions.** Floodplain depressions are distinguished from isolated depressions in that they are located within the mapped 10-year floodplain. The 10-year floodplain is used as a boundary for two primary reasons, one functional and one utilitarian. The functional reason for use of the 10-year floodplain is that for wetlands within this area floodwater will play a periodic role in the site's hydrologic regime, but is not the dominant hydrologic influence in the wetland. The utilitarian reason is that a floodplain map is necessary for wetland classification, and in the UDPR basin (due to its geomorphology), the 10-year floodplain is similar to the more readily obtainable 100-year FEMA floodplain. Because of their location within the floodplain, these sites are able to export materials downstream, and also have the capacity to mitigate flooding in upland areas. Like isolated depressions, floodplain depressions are also primarily herbaceous systems. They will commonly have marsh vegetation communities that are dominated by *Typha spp.* In general, the floodplain systems tend to be less vegetatively diverse than their isolated counterparts (Figure 6).

Figure 6. Aerial and ground views of a floodplain depression located in Deer Grove Forest Preserve, Cook County, IL

### Riverine

Riverine wetlands in the Upper Des Plaines Basin are wetlands not located within a topographic depression, but located within the mapped 10-year floodplain of the Des Plaines River and its tributaries. The primary water source for these sites is flooding from the adjacent river or stream. Additional water sources are precipitation and runoff from adjacent upland areas. Both forested and herbaceous Riverine wetlands are found in the reference domain (Figures 7 and 8).

Figure 7. Aerial and ground views of a forested Riverine wetland located in Deer Grove Forest Preserve, Cook County, IL

Figure 8. Aerial and ground views of an herbaceous Riverine wetland located in Kenosha County, WI

### Lacustrine Fringe

Lacustrine Fringe wetlands are adjacent to lakes and are subject to regular (less than every 10 years) flooding from the lake. In the reference domain, these wetlands generally consist of dense stands of *Typha spp* (Figure 9).

Figure 9. Aerial and ground views of an herbaceous Lacustrine Fringe wetland located in Lake County, IL

### Flats

In the reference domain, flats HGM class occurs primarily as the forested Northern Flatwoods community. Detailed information concerning the Northern Flatwoods community can be found in Anderson (1998).

# 4 Wetland Functions and Assessment Models

## Overview

The following functions are performed by both Isolated Depressions and Floodplain Depressions in the Upper Des Plaines River Basin:

*a.* Maintain Characteristic Hydrologic Regime.

*b.* Maintain Characteristic Biogeochemical Processes.

*c.* Maintain Characteristic Plant Communities.

*d.* Maintain Characteristic Fauna.

*e.* Export Organic Carbon.[1]

This chapter begins with a description of all the variables used in the Isolated Depression and Floodplain Depression models. Each variable description includes what functions the variable is used in, the justification for using the variable, and the variable subindex scaling.

The following sequence is then used to present and discuss each of these functions:

*a. Definition:* defines the function and identifies an independent quantitative measure that can be used to validate the functional index.

*b. Rationale for selecting the function:* provides the rationale for why a function was selected and discusses onsite and offsite effects that may occur as a result of lost functional capacity.

*c. Characteristics and processes that influence the function:* describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lay the groundwork for the description of model variables.

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[1] This function is performed by Floodplain Depressions and not Closed Isolated Depressions.

*d. Description of model variables:* defines and discusses model variables and describes how each model variable is measured.

*e. Functional Capacity Index:* describes the assessment model from which the FCI is derived and discusses how model variables interact to influence functional capacity.

# Variables

### General note on variable scaling

Variables are scaled either categorically or continuously. Variables are scaled categorically if they either (a) measured the presence or absence of features ($V_{ALT}$ for example), or (b) owing to the outlined assessment methodology, where several variables are "visually estimated" ($V_{CAT}$ for instance), the variable cannot be measured precisely, but instead can be more accurately placed in certain range of values. For variables that are measured continuously, a linear scaling was used based on best professional judgment and the lack of references or evidence to justify any alternative non-linear scaling.

### $V_{ALT}$ and $V_{ALT\text{-}OEX}$: Presence of hydrologic alteration

$V_{ALT}$ variable is used in the Maintain Characteristic Hydrologic Regime and Maintain Characteristic Plant Communities functions. $V_{ALT\text{-}OEX}$ is used in the Export Organic Carbon (for Floodplain Depressions) function.

$V_{ALT}$ is defined as the presence of artificial drainages such as tiles or ditches in or within 50 m of the wetland, and in the case of Floodplain Depressions, the presence of any modifications to or within 50 m the contributing stream channel (such as straightening and maintained channelization or the presence of levees and berms, see Table 6). All of these alterations will directly affect the hydrology of the wetland, either by increasing drainage or changing the flooding regime. Although ditch number, depth, and location, and soil texture of the site all factor into the effect ditches will have on the wetland, this variable only measures the presence or absence of any ditches, as it assumed that any functioning ditch will have at least some impact on the hydrology of the wetland. A subindex score of 0.5 is assigned for the presence of ditches as an "average" value, recognizing that most ditches will have more or less impact on the function.

The variable subindex scaling of $V_{ALT}$ for Isolated Depressions is given in Table 5.

| **Table 5**<br>**Subindex Scaling for $V_{ALT}$ in Isolated Depressions and Site Alteration Portion of $V_{ALT}$ for Floodplain Depressions** | |
|---|---|
| **Type of Alteration to Wetland** | **Subindex** |
| No alterations | 1.0 |
| Functioning ditch(es) within 50 m | 0.5 |
| Functioning tiles | 0.2 |
| Functioning ditch(es) and tiles | 0.0 |

In Floodplain Depressions, alterations to the adjacent stream channel need to be considered as well. For the Maintain Characteristic Hydrologic Regime and Maintain Characteristic Plant Communities functions, the subindex score in Floodplain Depressions is determined by averaging the subindex score from the site alteration portion (Table 5) with the subindex score from the stream alteration portion (Table 6), so $V_{ALT}$ = [(site alteration SI) + (stream alteration SI)]/2.

For the Export Organic Carbon function, only alterations to the stream channel are considered relevant, so for that function $V_{ALT\text{-}OEX}$ is used instead of $V_{ALT}$. $V_{ALT\text{-}OEX}$ is identical to the stream alteration portion of $V_{ALT}$ (Table 6).

The variable subindex scaling of $V_{ALT\text{-}OEX}$ (stream alteration portion of $V_{ALT}$) for Floodplain Depressions is given in Table 6.

| **Table 6**<br>**Subindex Scaling of $V_{ALT\text{-}OEX}$ (Stream Alteration Portion of $V_{ALT}$ ) for Floodplain Depressions** | |
|---|---|
| **Type of Alteration to Stream** | **Subindex** |
| No alterations/impact (Figure 10) | 1.0 |
| Moderate impact (Figure 11).<br>a) Presence of artificial levees, spoil piles, roads, etc. along stream reach, and/or stream has been moderately downcut, channelized, excavated and/or straightened. Generally, alterations have not been maintained and some of the natural stream morphology has returned. | 0.5 |
| Severe impact (Figure 12).<br>a) Presence of artificial levees, spoil piles, roads, etc. along stream reach, and/or stream has been severely downcut, channelized, excavated, and/or straightened. Alterations are being maintained and the natural stream morphology is not apparent. | 0.1 |

Figure 10. Example of unimpacted stream reach. Stream is naturally meandering and point bars are evident. No evidence of spoil piles, etc., along streambank

Figure 11. Example of stream reach that has been moderately impacted. Stream appears to have had past alteration, as the streambanks are sharply defined and show evidence of having old spoil piles. However, the stream does maintain a meander and any alterations do not appear to be recent or maintained

Figure 12. Example of stream reach that has been severely impacted. Channel has been straightened and makes unnatural 90-deg turns. Streambanks show sharp, straight downward cuts along the edge, and water is flowing at an unnatural velocity. Evidence of spoil pile along the streambank

### $V_{BUFFER}$: Wetland buffer

This variable is used in the Maintain Characteristic Biogeochemical Processes and Maintain Characteristic Fauna functions.

This variable is defined as the percentage of the wetland perimeter that can be classified as buffer (forest, unmowed grassland, other undeveloped habitat ≥ 30 m in width). Buffers can limit the amount of human encroachment and disturbance into the site, provide important additional terrestrial habitat for wildlife (Semlitsch and Bodie 2003), and limit silt, nutrient, and contaminant loading into the wetland (Lowrance et al. 1984). Buffers 30- to 60-m wide are generally acknowledged as being sufficient to effectively protect water resources (e.g., Lee and Samuel 1976, Phillips 1989, Davies and Nelson 1994). Buffers of 30 m were also considered as providing adequate protection for 77 percent of wetland dependent species (of all taxa) in Massachusetts (Boyd 2001).

Percentage of wetland perimeter buffered ranged from 3 to 100 percent in Floodplain Depressions, and 0 to 100 percent in Isolated Depressions. The subindex score increases linearly from 0.0 to 1.0 as the percent buffered increases from 0 to 100 percent.

The variable subindex curve of $V_{BUFFER}$ for Isolated Depressions and Floodplain Depressions is given in Figure 13.

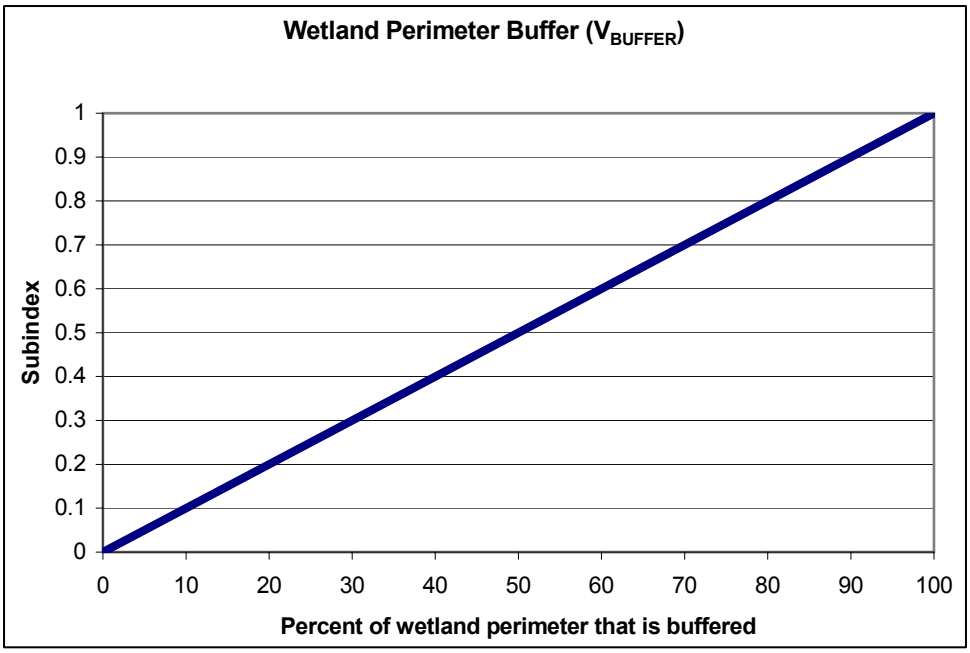


Figure 13. Relationship between percent buffer and subindex score

The equation used to calculate the $V_{BUFFER}$ subindex score is:

$$V_{BUFFER} = 0.01\ (\%\ \text{Buffer})$$

### $V_c$: Native mean c ($\bar{c}$) score

Variable is used in Maintain Characteristic Plant Communities function.

This variable is the native $\bar{c}$ value derived from a site inventory Floristic Quality Assessment (FQA) (Swink and Wilhelm 1994) of the assessment area. In an FQA, each plant is assigned a C value, called the "coefficient of conservatism." The $\bar{c}$ value (from 0-10) is a measure of a species' fidelity to a specific natural community or communities. Practically, it can be used as an indicator of site disturbance, in that plants with high C values are usually found only in natural undisturbed areas, while plants with low C values can populate highly disturbed areas.

Native $\bar{c}$ is the mean C of all native plants found at the site. For example, a site with the following species: *Ambrosia trifida* (C = 0), *Carex stricta* (C = 5), *Pilea pumila* (C = 5), and *Agrostis alba* (C = *), would have a native mean C of (0+5+5)/3, or 3.3. Because *Agrostis alba* is classified as an adventive species, it does not have a C value and therefore is not included in the calculation.

Reference floodplain depressions had native $\bar{c}$ values from 2.5 to 4.9; with reference standard sites generally having scores ≥ 4.2. Isolated Depressions had $\bar{c}$ values from 0.8 to 5.6; with reference standard sites generally having scores ≥ 5.0.

The variable subindex curve of $V_c$ for Isolated Depressions is given in Figure 14. The scaling of the curve is based on a combination of the reference data and best professional judgment.

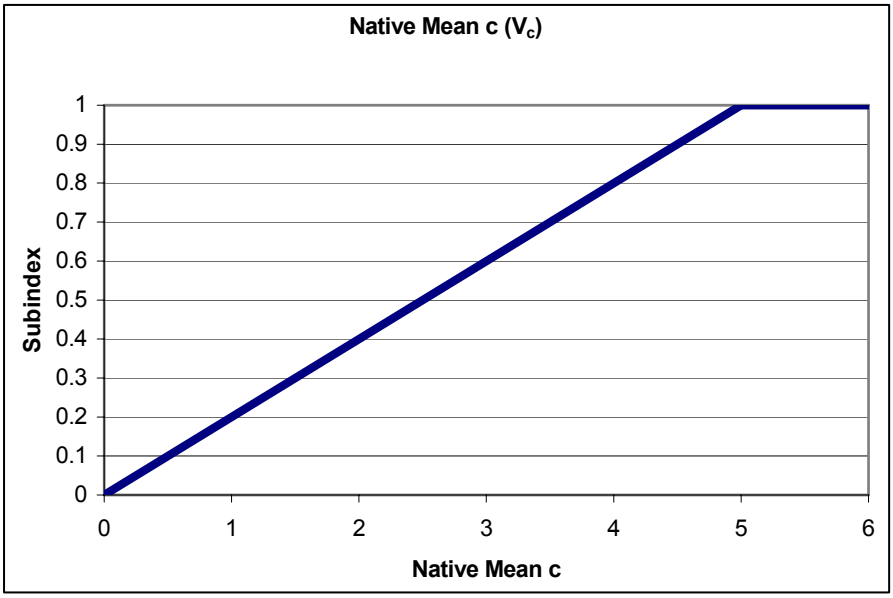


Figure 14. Relationship between native mean c score and subindex in Isolated Depressions

The equations used to calculate the $V_c$ subindex score for Isolated Depressions are: $\overline{c} < 5.0, V_c = 0.20(\overline{c})$ and $\overline{c} \geq 5.0, V_c = 1.0$.

The variable subindex curve of $V_c$ for Floodplain Depressions is given in Figure 15.

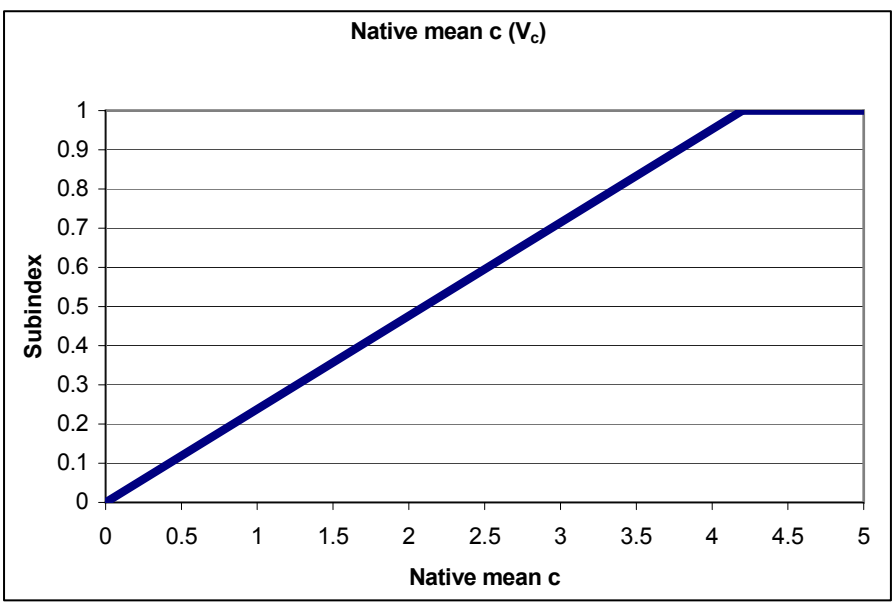


Figure 15. Relationship between native mean $\overline{c}$ score and subindex in Floodplain Depressions

The equations used to calculate the $V_c$ subindex score are:
$\bar{c} < 4.2, V_c = 0.238(\bar{c})$ and $\bar{c} \geq 4.2, V_c = 1.0$.

### $V_{CAT}$: Percent cover of *Typha spp.*

Variable is used in Maintain Characteristic Plant Communities function.

This variable is defined as the percentage of the assessment area that is covered by broadleaf cattail (*Typha latifolia*), narrowleaf cattail (*Typha angustifolia*), and their hybrid species (*Typha* X *glauca*). The possibly exotic *Typha angustifolia* and the *Typha* X *glauca* hybrid tend to be more aggressive than the native *Typha latifolia* and can eventually dominate a site, precluding the growth and establishment of other species (Galatowitsch et al. 1999). Because the three *Typha* species are not always easily distinguished by a quick visual glance, and all three often grow together in dense stands, this variable does not distinguish between the different species.

This variable is also used in the model to distinguish between sites with similar FQI and $\bar{c}$ scores. Many sites will have their plant diversity concentrated in a small sedge meadow boundary surrounding a much larger cattail marsh area. This structure is less desirable than a wetland where the plant diversity is distributed across the entire site. However, because the inventory FQA does not take into account species densities, these two sites may have similar FQI and $\bar{c}$ scores.

The variable is scaled identically for Isolated and Floodplains Depression, and the subindex is determined categorically, based on ranges of cattail cover. Reference standard sites had cattail cover of less than 20 percent.

The variable subindex scaling of $V_{CAT}$ for Isolated Depressions and Floodplain Depressions is given in Table 7.

**Table 7**
**Subindex Scaling of *Typha spp.* Cover**

| ***Typha spp.* Percent Cover** | **Subindex** |
|---|---|
| 0-20 | 1.0 |
| 21-50 | 0.75 |
| 51-80 | 0.50 |
| 81-100 | 0.25 |

### $V_{CATCH}$: Ratio of wetland area to catchment area

Variable is used in the Maintain Characteristic Hydrologic Regime function.

This variable is the ratio of the wetland containing the assessment area to the area of its surrounding catchment, and is a measure of the relative amount of run-off the wetland is receiving and storing. A more appropriate measure would be the ratio of wetland volume to catchment area; however, as detailed depth data are not readily available for the entire watershed, estimating wetland volumes is not feasible.

Isolated Depression reference sites had ratios ranging from 0.05 to 0.82, with reference standard sites ranging from 0.02 to 0.16. Floodplain Depression reference sites had ratios ranging from 0.01 to 1.15, with reference standard sites ranging from 0.04 to 0.33. Sites may have changes in catchment size from historical conditions that resulted from the building of elevated roads or railroad tracks, which block normal overland flow, resulting in a larger ratio. Conversely, effective catchment size can be enlarged through the building of ditch and irrigation networks, which will result in a smaller ratio.

Ratios higher than the reference standard range would indicate that the depressional wetland is not receiving the amount of water necessary to maintain a hydroperiod characteristic of reference standard sites. Furthermore, at a certain point the depressional wetland would not be receiving enough water to sustain hydrophytic vegetation and saturated soils. Therefore, as the ratio increases above the reference standard range, the subindex score decreases linearly to 0.0. Similarly, the subindex score linearly decreases when the ratio is below the reference standard range, but only to 0.5, as even at the lower ratios the depressional wetland would still be receiving enough water to support basic characteristics of the wetland.

The variable subindex curve of $V_{CATCH}$ for Isolated Depressions is given in Figure 16.

The equations used to calculate the $V_{CATCH}$ subindex score for Isolated Depressions are:

Ratio(R) $< 0.02$, $V_{CATCH} = 25R + 0.5$
$0.02 \leq R \leq 0.16$, $V_{CATCH} = 1.0$
$0.16 < R < 1.0$, $V_{CATCH} = -1.19R + 1.19$
$R \geq 1.0$, $V_{CATCH} = 0.0$

The variable subindex curve of $V_{CATCH}$ for Floodplain Depressions is given in Figure 17.

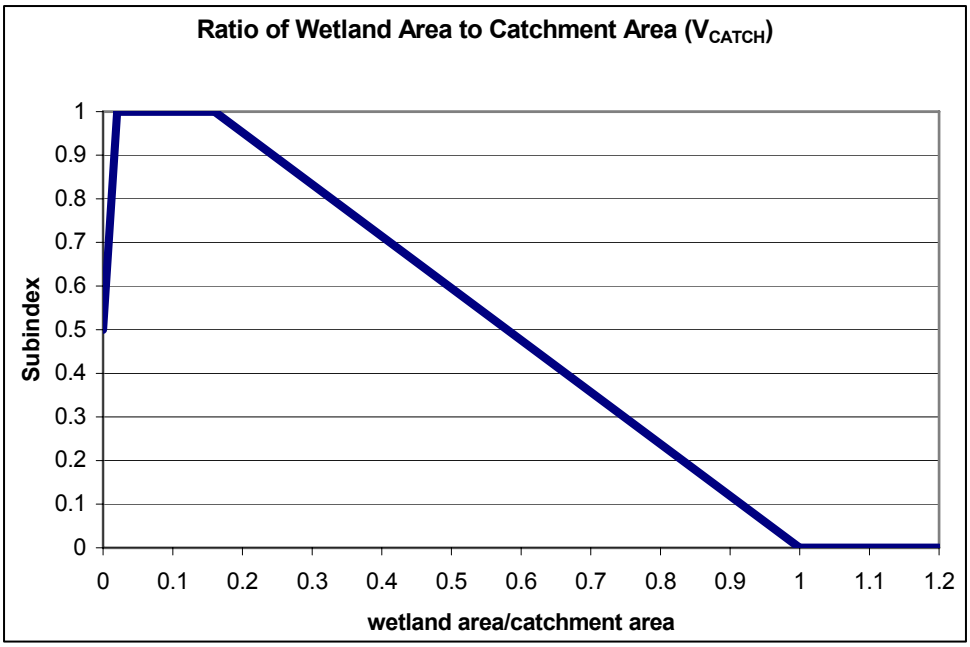


Figure 16. Relationship between wetland/catchment area ratio and subindex score in Isolated Depressions

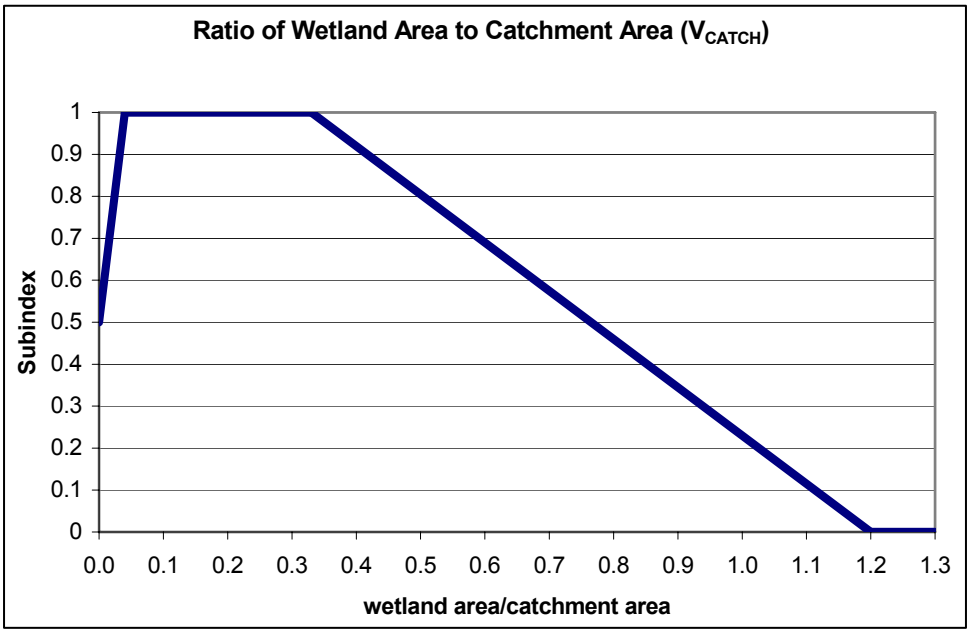


Figure 17. Relationship between wetland/catchment area ratio and subindex score in Floodplain Depressions

The equations used to calculate the $V_{CATCH}$ subindex score for Floodplain Depressions are:

Ratio(R) < 0.04, $V_{CATCH} = 12.5(R) + 0.5$
$0.04 \leq R \leq 0.33$, $V_{CATCH} = 1.0$

$0.33 < R < 1.2$, $V_{CATCH} = -1.149(R) + 1.379$
$R \geq 1.2$, $V_{CATCH} = 0.0$

### $V_{FQI}$: Native Floristic Quality Index

This variable is used in the Maintain Characteristic Plant Communities function.

This variable is the native Floristic Quality Index (FQI) score derived from a site inventory FQA of the assessment area. The FQI can be used as a measure of intrinsic plant biodiversity at the site.

Native FQI = $\bar{c}\sqrt{n}$ , where *n* is the number of native species found at the site and $\bar{c}$ is the native mean C score (see $V_C$ description). For example, a site with the following species: *Ambrosia trifida* (C = 0), *Carex stricta* (C = 5), *Pilea pumila* (C = 5), and *Agrostis alba* (C = *), would have an FQI of $3.33\sqrt{3}$ , or 5.8. Because *Agrostis alba* is classified as an adventive species it is not included in the calculation.

In reference Isolated Depressions, native FQI scores ranged from 4.5 to 38.1. In reference Floodplain Depressions, native FQI scores ranged from 5.2 to 42.4.

The variable subindex curve of $V_{FQI}$ for Isolated Depressions is given in Figure 18. The scaling of the curve is based on a combination of the reference data and best professional judgment.

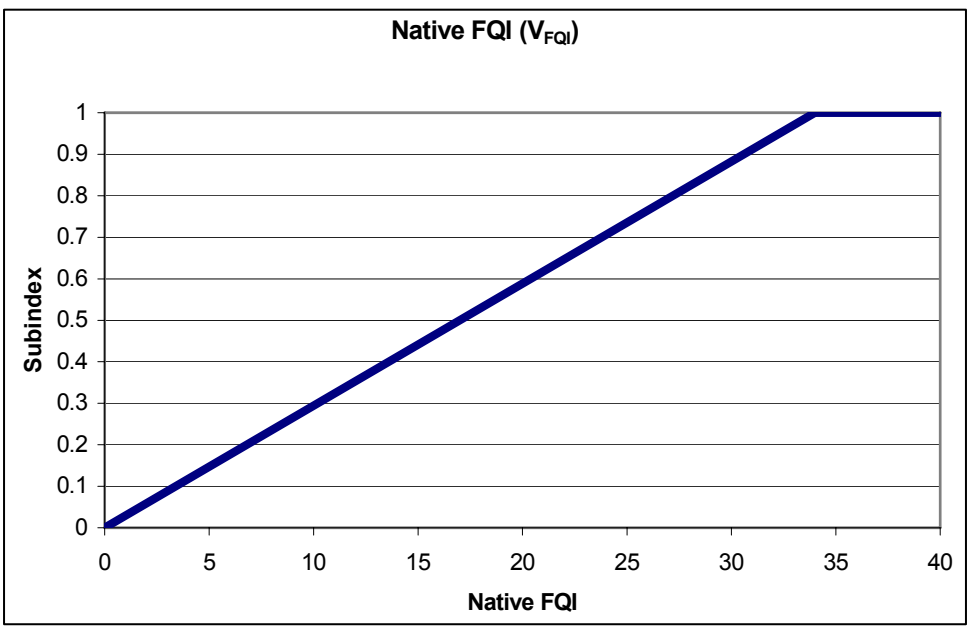


Figure 18. Relationship between native FQI and subindex in Isolated Depressions

The equations used to calculate the $V_{FQI}$ subindex score for Isolated Depressions are:

FQI < 34, $V_{FQI} = 0.0294(FQI)$
FQI ≥ 34, $V_{FQI} = 1.0$

The variable subindex curve of $V_{FQI}$ for Floodplain Depressions is given in Figure 19.

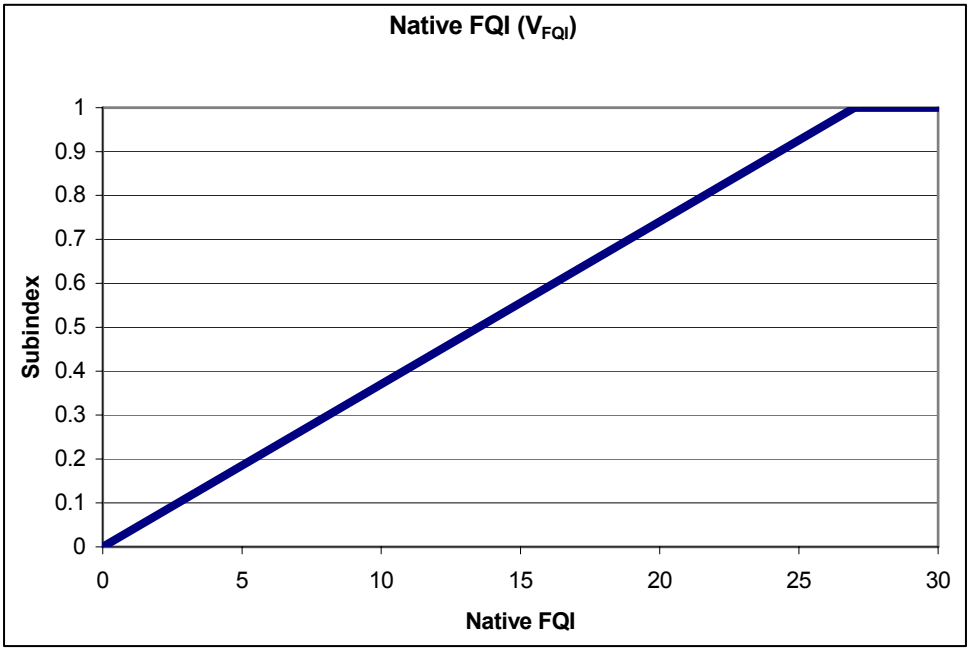


Figure 19. Relationship between FQI and subindex in Floodplain Depressions

The equations used to calculate the $V_{FQI}$ subindex score for Floodplain Depressions are:

FQI < 27, $V_{FQI} = 0.03704(FQI)$
FQI ≥ 27, $V_{FQI} = 1.0$

### $V_{GVC}$: Ground vegetation cover

This variable is used in the Maintain Characteristic Hydrologic Regime, Maintain Characteristic Biogeochemical Processes, Maintain Characteristic Fauna, and Export Organic Carbon (for Floodplain Depressions) functions.

This variable is defined as the percentage of the assessment area that is covered with herbaceous and woody-vine vegetation. The amount of ground vegetation cover serves as a measure of plant biomass available for evapotranspiration, and is also an indicator of primary productivity and vegetative structure in the assessment area. Ground vegetation cover at reference sites ranged from 60 to >95 percent, although most reference sites and all reference standard sites contained ground vegetation cover >95 percent. Sites with less ground vegetation cover were either recently restored or planted, formerly forested sites (with current tree cover around 30 percent), or had stunted growth of herbaceous plants.

The subindex score decreases linearly from 1.0 to 0.0 as ground vegetation cover in the assessment area decreases from 100 to 0 percent.

The variable subindex curve of $V_{GVC}$ for both Isolated and Floodplain depressions is given in Figure 20.

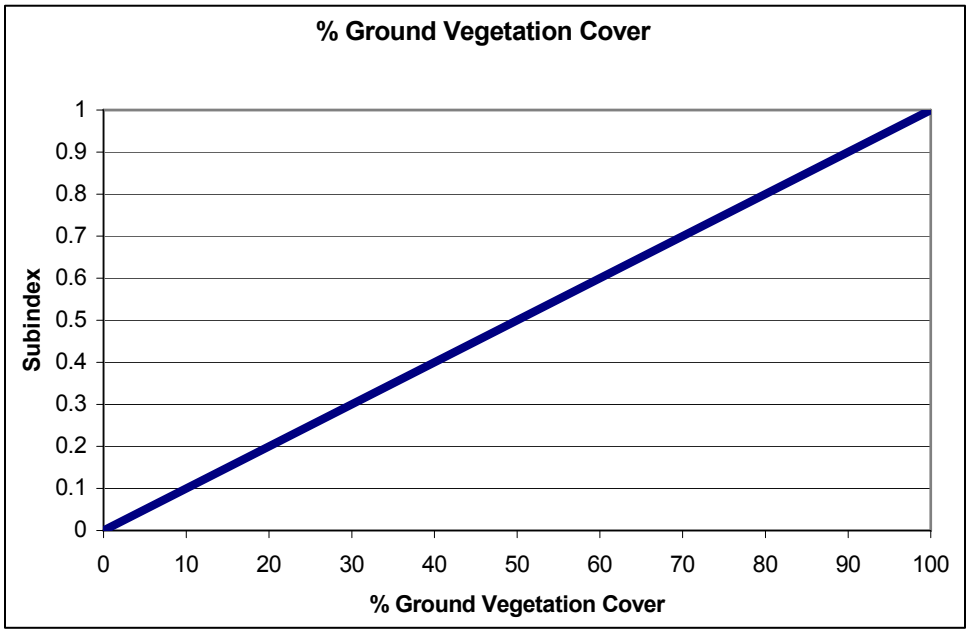


Figure 20. Relationship between ground vegetation cover and subindex score

The equation used to calculate the subindex score for $V_{GVC}$ is:

$V_{GVC} = 0.01$ (% GVC)

### $V_{INV}$: Invasive species cover

Variable is used in Maintain Characteristic Plant Communities and Maintain Characteristic Fauna functions.

This variable is defined as the percentage of the assessment area that is covered by invasive species, excluding *Typha spp.* In the reference domain, the most common invasive species encountered was reed canary grass (*Phalaris arundinacea*), and this variable can usually be scored by looking for the percent cover of this one particular species. *P. arundinacea* has the advantage of being highly productive in flooded areas but also very drought resistant (Rice and Pinkerton 1993). Other invasive species that may cover a significant portion of the wetland include common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), and giant ragweed (*Ambrosia trifida*).

Invasive species generally spread into wetlands that have been disturbed by anthropogenic activity. These species spread aggressively in the wetland, replacing and preventing the establishment of indigenous vegetation (Galatowitsch et al. 1999). Based on personal observation in highly disturbed

depressional wetlands in the reference domain, invasive species (*P. arundinacea* in particular) can come to dominate a site, accounting for over 95 percent of the ground vegetation cover in the wetland (Figure 21). The negative effect of *P. arundinacea* on the plant community has been further demonstrated in a study where wet meadow sites with *P. arundinacea* had roughly two-thirds of the species richness of plots without *P. arundinacea*, and sites with both *P. arundinacea* and hydrologic disturbance had roughly one-third of the species richness of sites without *P. arundinacea* (Kercher et al. 2004).

In reference to Isolated Depressions, invasive species percent cover ranged from <5 to 90 percent, in Floodplain Depressions, percent cover ranged from 7.5 to 95 percent. Reference standard sites in both classes generally contained < 10 percent invasive species cover. The variable is scaled identically for Isolated and Floodplains Depression, based on the reference data and best professional judgment. The subindex is determined categorically, based on ranges of invasive species cover.

Figure 21. Floodplain Depression located in Cook County, IL, that is almost completely covered by reed canary grass (*Phalaris arundinacea*)

The variable subindex scaling for $V_{INV}$ in Isolated and Floodplain Depressions is given in Table 8.

| Table 8<br>Subindex Scaling for Invasive Species Cover in Isolated and Floodplain Depressions | |
|---|---|
| **Invasive Species Percent Cover** | **Subindex** |
| 0-10 | 1.0 |
| 11-25 | 0.8 |
| 26-50 | 0.6 |
| 51-80 | 0.3 |
| 81-94 | 0.1 |
| 95-100 | 0 |

### $V_{LANDUSE}$: Land use within 300 m

Variable is used in Maintain Characteristic Fauna function.

This variable is defined as the overall land use (LU) within 300 m of the assessment area. The surrounding LU can affect how organisms move within and between wetlands, and also accounts for the amount of available terrestrial habitat around the wetland. A 300-m distance was used based on a literature review by Semlitsch and Bodie (2003). They reported that 289 m was the mean maximum distance (distance radiating from the outer edge of the wetland) of core terrestrial habitat that was utilized by various groups of amphibians and reptiles (with a range of 218 m for salamanders and 368 m for frogs).

The overall LU score is derived by dividing a 300-m buffer around the assessment area into grids, and assigning each grid one of three general LU categories — urban, agricultural, and forest/grassland/wetland. Each category is assigned an individual score: urban = 5, agriculture = 3, and forest/grassland/wetland = 1, using the logic that urban areas are generally more detrimental to wildlife than agricultural areas, and to be consistent with the scoring scheme used in the $V_{LUC}$ variable. The overall LU score is average score of the individual grids.

In reference sites, 300-m LU scores ranged from 1.04 to 3.97 in Isolated Depressions, and from 1.42 to 3.66 in Floodplain Depressions. In order to reflect the realistic possibility that future land-use changes can achieve variable scores outside the range of what was found in reference sites, the subindex curves allow for the entire range of possible scores (1.00 to 5.00) for this variable. In Isolated Depressions, the subindex score decreases linearly from 1.0 to 0.0 as the catchment LU score increases from 1.00. In Floodplain Depressions, the subindex score decreases linearly from 1.0 to 0.0 as the 300-m LU score increases from 1.50, because reference standard Floodplain Depressions tended to have higher 300-m LU scores than Isolated Depressions.

The variable subindex curve of $V_{LANDUSE}$ for Isolated Depressions is given in Figure 22.

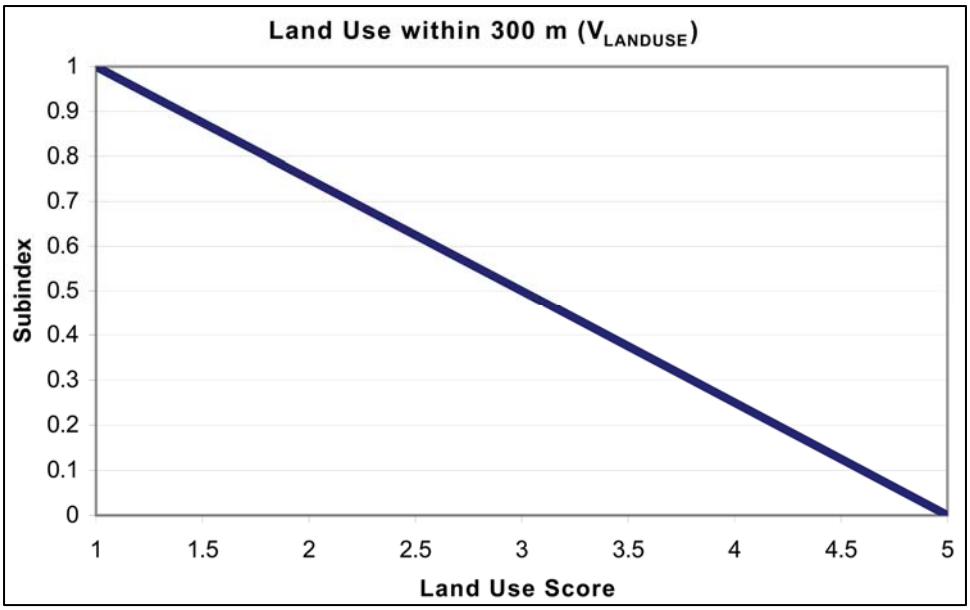


Figure 22. Relationship between land-use score and subindex in Isolated Depressions

The equation used to calculate the subindex score for $V_{LANDUSE}$ in Isolated Depressions is:

$V_{LANDUSE}$ = -0.25(300m LU Score) + 1.25

The variable subindex curve of $V_{LANDUSE}$ for Floodplain Depressions is given in Figure 23.

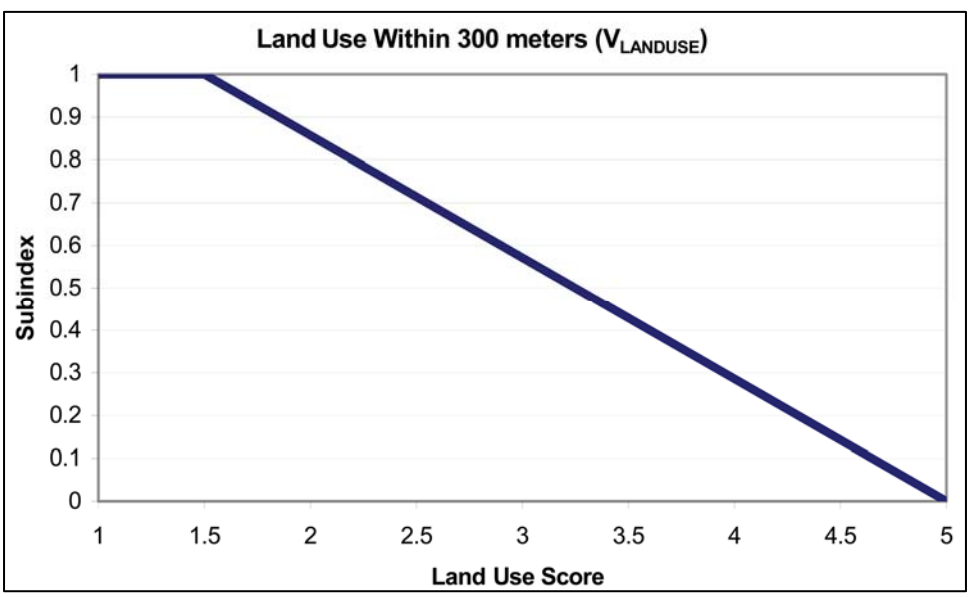


Figure 23. Relationship between land-use score and subindex in Floodplain Depressions

The equations used to calculate the subindex score for $V_{LANDUSE}$ in Floodplain Depressions are:

Land use Score (LU) ≤ 1.5, $V_{LUC} = 1.0$
LU > 1.5, $V_{LUC}$ = -0.2857(Catchment LU Score) + 1.4286

### $V_{LUC}$: Land use of the catchment area

Variable is used in the Maintain Characteristic Hydrologic Regime, Maintain Characteristic Biogeochemical Processes, and Maintain Characteristic Plant Community functions.

This variable is the overall LU score of the wetland's catchment. Land-use changes (e.g., urbanization) in the catchment can have a dramatic impact on both the hydrologic regime of wetlands (Euliss and Mushet 1996, Azous and Horner 2001, Bhaduri et al. 1997) and nutrient loading into those wetlands.

The overall LU score is derived by dividing the catchment area into grids, and assigning each grid one of three general LU categories — urban, agricultural, and forested/grassland/wetland. Each category is assigned an individual score: urban = 5, agriculture = 3, and forest/grassland/wetland = 1. The overall LU score is average score of the individual grids. The values (1,3,5) are based on "national average" export coefficients for nitrogen and phosphorus as reported in Rast and Lee (1977), where urban watersheds on average exported 5.8 times as much, and rural/agricultural watersheds exported on average 3.3 times as much combined total phosphorus and total nitrogen than forested watersheds. Additionally, having more impermeable surfaces and the subsequent increase in runoff, urban LU will have more of an impact on hydrology than rural/agriculture LU. The LU scores can obviously be more finely tuned than the "rougher" estimates used here, as different sub-categories within the urban and rural/agriculture classifications will have different effects on runoff and nutrient loading. However, finer estimates would require an additional level of detail and accuracy that is not currently available in the LU maps that cover the entire reference domain.

In reference sites, catchment LU scores ranged from 1.00 to 4.27 in Isolated Depressions, and from 1.11 to 4.15 in Floodplain Depressions. In order to reflect the realistic possibility that future land-use changes can achieve variable scores outside the range of what was found in reference sites, the subindex curves allow for the entire range of possible scores (1.00 to 5.00) for this variable. In Isolated Depressions, the subindex score decreases linearly from 1.0 to 0.0 as the catchment LU score increases from 1.00. In Floodplain Depressions, the subindex score decreases linearly from 1.0 to 0.0 as the catchment LU score increases from 1.50, as reference standard Floodplain Depressions tended to have higher catchment LU scores than Isolated Depressions.

The variable subindex curve of $V_{LUC}$ for Isolated Depressions is given in Figure 24.

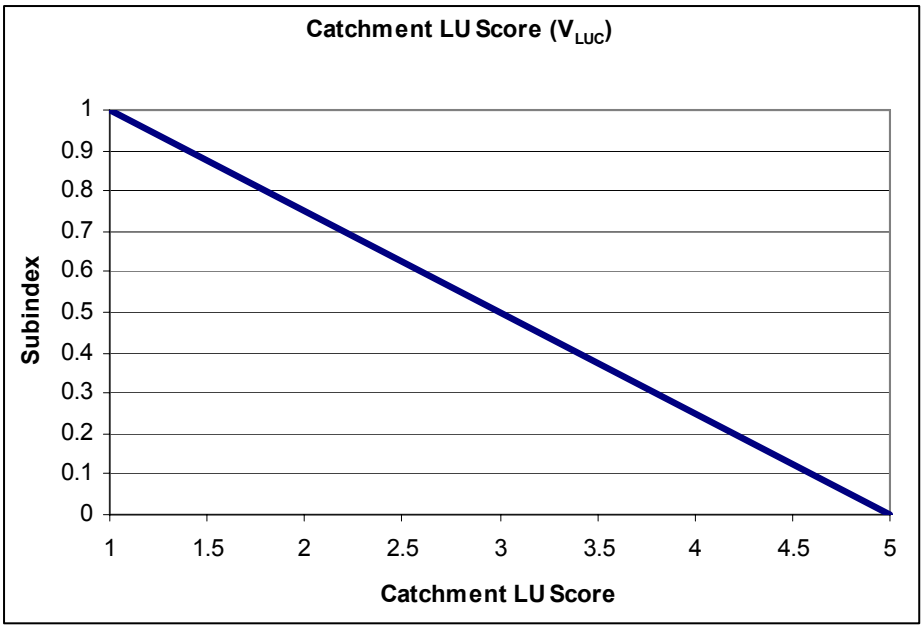


Figure 24. Relationship between catchment land-use score and subindex score in Isolated Depressions

The equation used to calculate the subindex score for $V_{LUC}$ for Isolated Depressions is:

$$V_{LUC} = -0.25(\text{Catchment LU Score}) + 1.25$$

The variable subindex curve of $V_{LUC}$ for Floodplain Depressions is given in Figure 25.

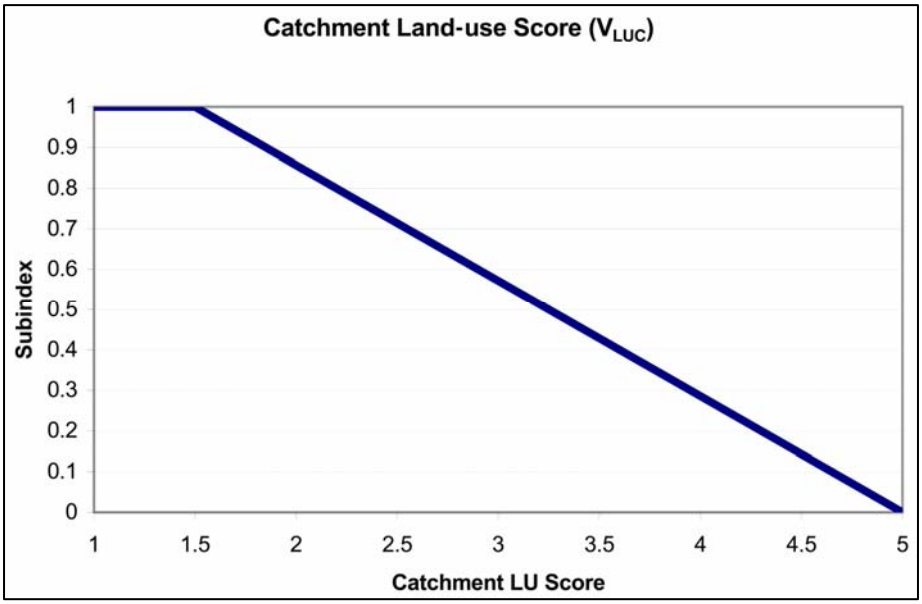


Figure 25. Relationship between catchment land-use score and subindex score in Floodplain Depressions

The equations used to calculate the subindex score for $V_{LUC}$ for Floodplain Depressions are:

Catchment LU Score (LU) ≤ 1.5, $V_{LUC} = 1.0$
LU > 1.5, $V_{LUC}$ = -0.2857(Catchment LU Score) + 1.4286

### $V_{NAT}$: Percent of plant species that are native

Variable is used in Maintain Characteristic Plant Communities and Maintain Characteristic Fauna functions.

This variable is defined as the percent of total plant species counted at the site that are considered native in the FQA database. Some exotic species have the ability to out-compete native species, and having a high percentage of non-native species at the site can alter the natural ecosystem structure of the wetland, as well as serving as an indicator of unnatural levels of disturbance. Additionally, many faunal populations depend on native plants for food, cover, or nesting (Weller 1981).

In reference Isolated Depression sites, this variable ranged from 65 to 96 percent, with reference standard sites having more than 95 percent native species. In Floodplain Depressions, this variable ranged from 70 to 99 percent in isolated depressions, with reference standard sites having more than 90 percent native species.

The equations used to calculate the $V_{NAT}$ subindex score for Isolated Depressions and Floodplain Depressions are:

% Native species (NS) < 65, $V_{NAT}$ = .001538(NS)
65 ≤ NS< 90, $V_{NAT}$ = 0.036(NS) – 2.24
IF ≥ 90, $V_{INV} = 1.0$

The variable subindex curve of $V_{NAT}$ for Isolated Depressions is given in Figure 26.

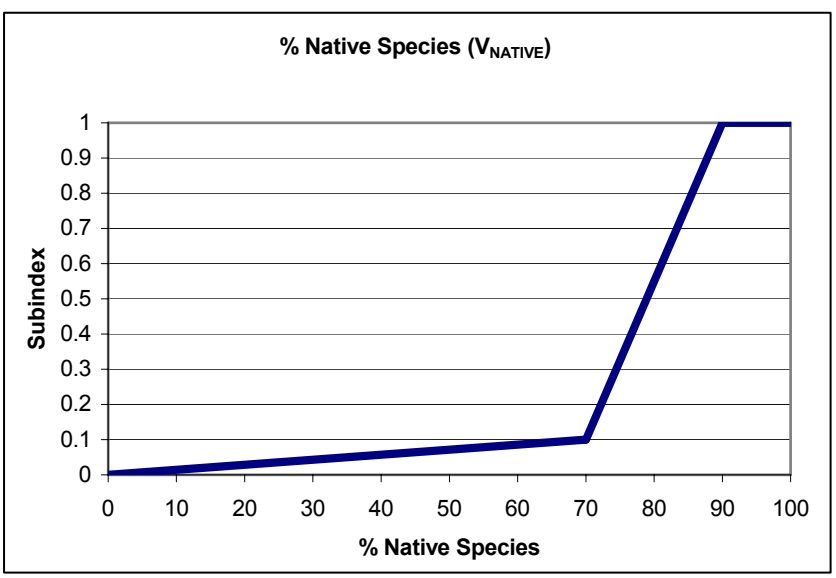


Figure 26. Relationship between native species percentage and subindex in Isolated Depressions

### $V_{OHOR}$: Thickness of surface 'O' horizon

Variable is used in Maintain Characteristic Biogeochemical Processes and Export Organic Carbon (for Floodplain Depressions) functions.

This variable is defined as the thickness, in inches, of the 'O' horizon in the first 32 in. (80 cm) of the soil profile. It does not include 'O' horizons that are buried in the soil profile (beneath an A, B, C, or any mineral horizon or layer), because these below surface horizons are not as readily available for export or biological activity. The 'O' horizon is defined as a horizon containing greater than 20 percent by weight organic soil materials (Schoeneberger et al. 2002). The organic matter may range anywhere from partially to highly decomposed material.

Soil organic carbon is a source of and a sink for plant nutrients, aids infiltration, improves soil structure, promotes water retention, absorbs both anthropogenic and natural toxic substances, and is an energy source for heterotrophic organisms (Juregensen et al. 1989, Mitsch and Gosselink 2000, Craft 2001). This variable also serves as an indicator that nutrients in vegetative organic material are being recycled.

This variable is scaled differently, depending on whether the predominant soil type in the assessment area is mineral or organic. An organic soil (histosol) is defined as having 16 in. (40 cm) or more of the upper 32 in. (80 cm) as organic soil material (USDA, NRCS 2002). In the reference domain, organic soils, especially near the surface, will often be of a "mucky" texture. In reference Floodplain Depressions with mineral soils, average depth of surface 'O' horizons ranged from 0 to 6.5 in. (16.5 cm), and the average depth of surface 'O' horizons for organic soils ranged from 27.5 in. (69.9 cm) to 55 in. (139.7 cm, the maximum depth of the sample core). In Isolated Depressions, average depth of surface 'O' horizons in mineral soils ranged from 0 to 11.5 in. (29.2 cm), and average depth of surface 'O' horizons in organic soils ranged from 0 to 55 in. (139.7 cm).

The subindex curves are identical for Isolated and Floodplain Depressions if the soil is organic, with the subindex score decreasing linearly from 1.0 to 0 as the depth of the 'O' horizon decreases from 32 to 0 in. (80 to 1 cm). The subindex curves are scaled differently for the two subclasses if the soil is mineral, because Isolated Depressions with mineral soils tended to have deeper 'O' horizons in the Floodplain Depressions with mineral soils. In Isolated Depressions, the subindex score decreases linearly from 1.0 to 0 as the depth of the 'O' horizon decreases from 6 to 0 in. (15.2 to 0 cm). In Floodplain Depressions the subindex score decreases linearly from 1.0 to 0 as the depth of the 'O' horizon decreases from 3 to 0 in.

The variable subindex curves of $V_{OHOR}$ for Isolated Depressions and Floodplain Depressions are given in Figures 27, 28, and 29.

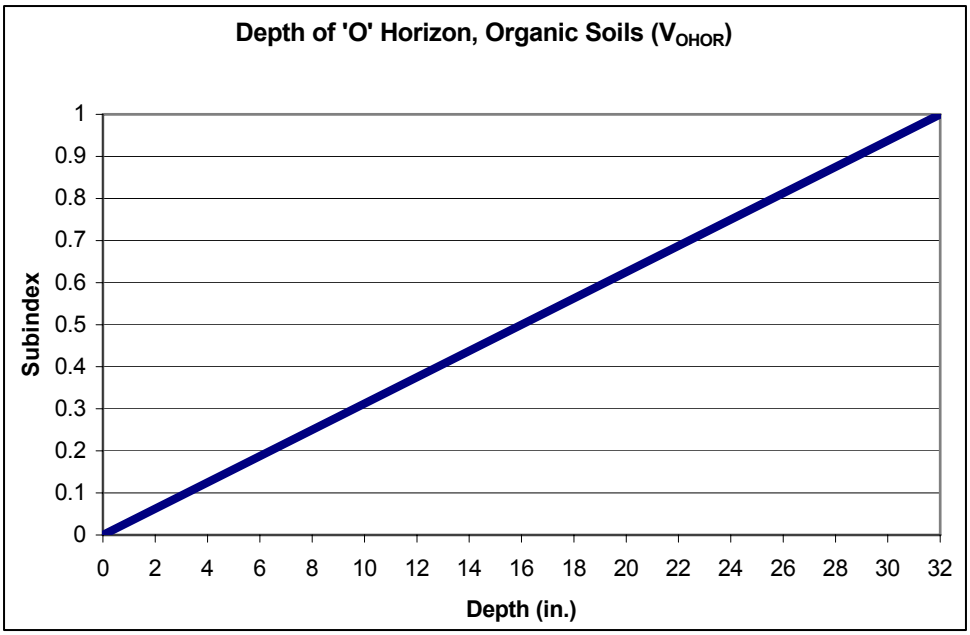


Figure 27. Relationship between 'O' horizon depth and subindex score in organic soils in Isolated Depressions and Floodplain Depressions

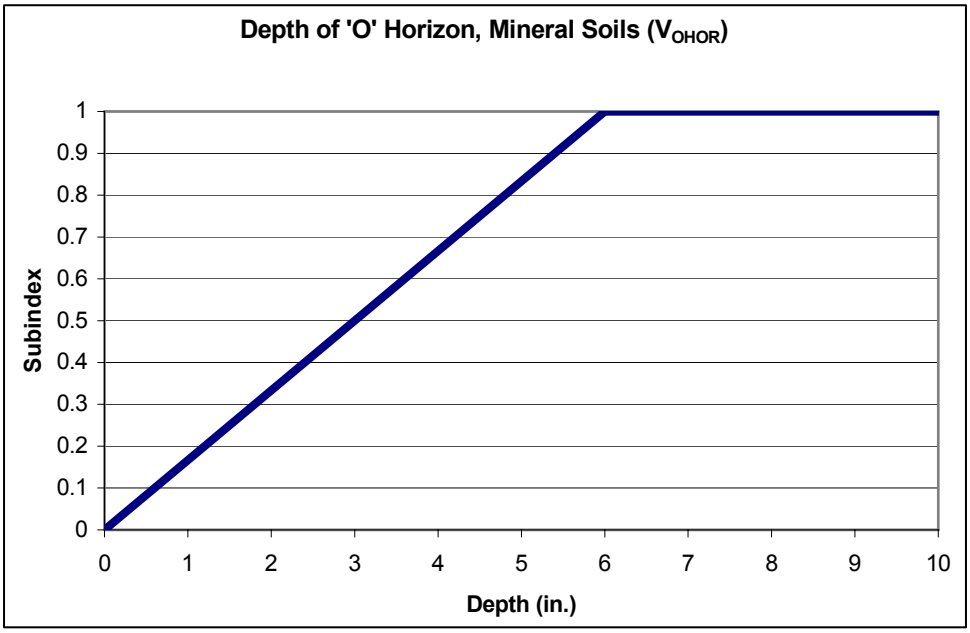


Figure 28. Relationship between 'O' horizon depth and subindex score in mineral soils in Isolated Depressions

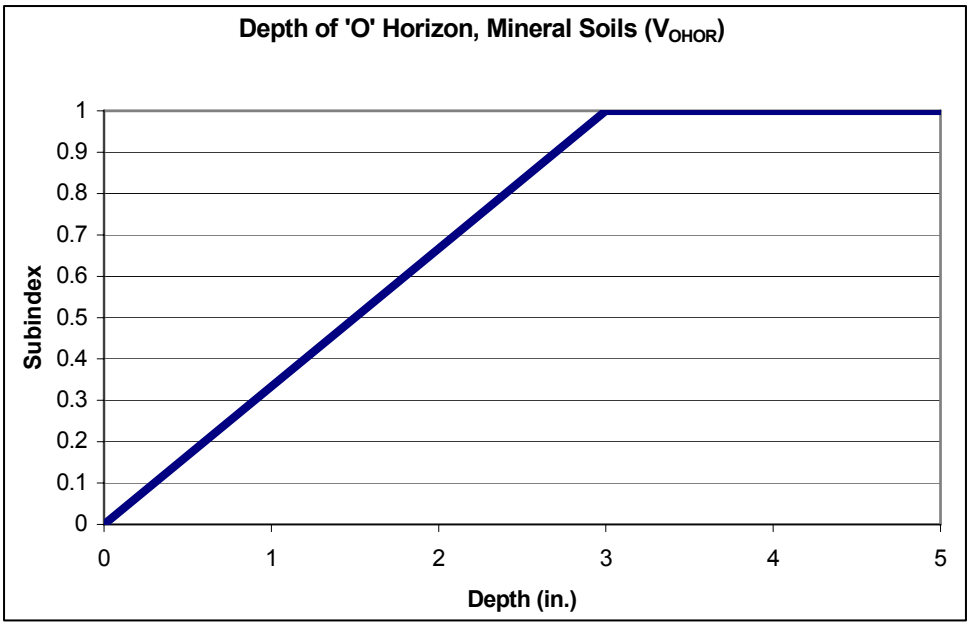


Figure 29. Relationship between 'O' horizon depth and subindex score in mineral soils in Floodplain Depressions

The equation used to calculate the $V_{OHOR}$ subindex score for organic soils in Isolated Depressions and Floodplain Depressions is:

$V_{OHOR} = 0.03125(O)$

The equations used to calculate the $V_{OHOR}$ subindex score for mineral soils in Isolated Depressions are:

Depth of O horizon (O) $\geq 6$, $V_{OHOR} = 1.0$
$O < 6$, $V_{OHOR} = 0.1667(O)$

The equations used to calculate the $V_{OHOR}$ subindex score for mineral soils in Floodplain Depressions are:

Depth of O horizon (O) $\geq 3$, $V_{OHOR} = 1.0$
$O < 3$, $V_{OHOR} = 0.333(O)$

### $V_{SOIL}$: Soil structure

Variable is used in the Maintain Characteristic Hydrologic Regimes and Maintain Characteristic Biogeochemical Processes functions.

This variable measures the percentage of the first 12 in. (30 cm) of the soil profile that is either a plow layer (an Ap horizon, which generally indicates past agricultural activity at the site), or has a "platy" or "massive" structure. It is used to assess anthropogenic impact to the natural near-surface properties of the soil.

Each soil has a naturally occurring arrangement of soil particles into distinct aggregates or shapes. At reference standard sites, soils are of primarily granular or subangular blocky shape. However, the natural aggregates can be altered or destroyed by disturbance. Soil compaction, for instance, can join aggregates and create a 'massive' or a 'platy" structure, which results in decreases in pore size, water filled pore space, and soil temperature. These changes affect the activity of soil organisms by decreasing the rate of decomposition of soil organic matter and the subsequent release of nutrients. (USDA, NRCS 1996).

In both Isolated and Floodplain Depressions, the subindex score decreases linearly from 1.0 to 0 as the percentage of soil altered increases from 0 to 100 percent.

The variable subindex curve of $V_{SOIL}$ for both Isolated Depressions and Floodplain Depressions is given in Figure 30.

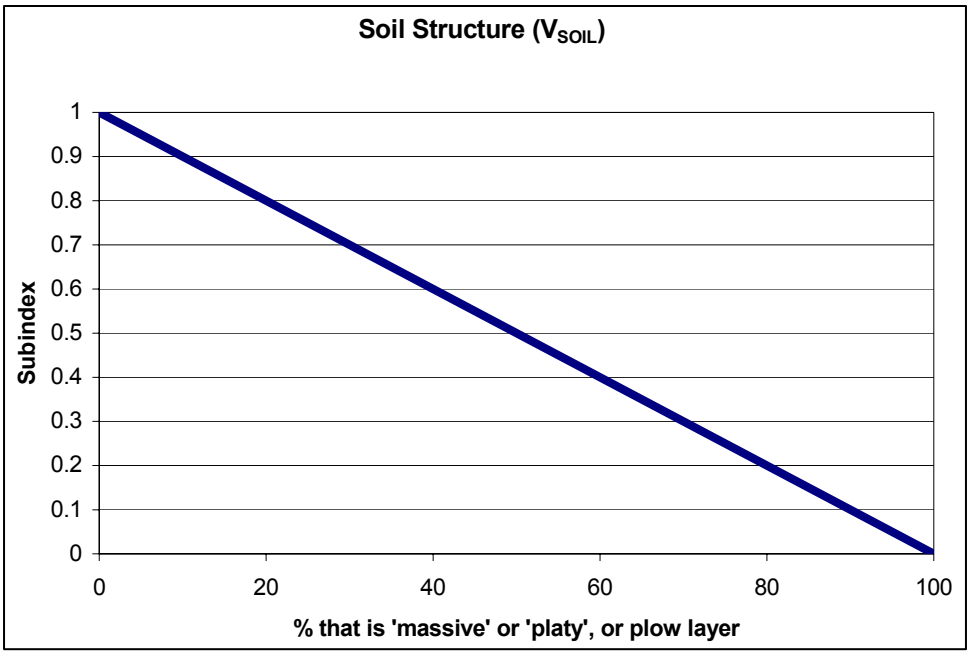


Figure 30. Relationship between soil structure and subindex score

The equation used to calculate the $V_{SOIL}$ subindex score is:

$V_{SOIL} = -0.01(SOIL) + 1.0$

**Alternate method of scaling $V_{SOIL}$.** If the people applying this model in the field do not have the ability to readily discern a plow layer or the structure of the soil, this variable may be alternately scored using Table 9, which requires knowledge of any soil disturbance in the assessment area. Recognizing that alterations to the native soil may vary in their level of impact, an "average" subindex score of 0.4 is assigned if any alteration at all is known to have occurred in the past 20 years. If plowing or compaction has occurred between 20 and 50 years ago, it is presumed that the native soil properties have partially returned to what they were prior to the alteration, and a subindex score of 0.7 is assigned. At greater

than 50 years, it is assumed that the native soil properties have fully returned to what they were prior to alteration, and there is no decrease in subindex score. These values and time periods are based on best professional judgment.

**Table 9**
**Subindex Scaling for $V_{SOIL}$ (Alternate Method) for Isolated and Floodplain Depressions**

| Soil Structure/Alteration | Subindex |
|---|---|
| No known alterations to native soil, or plowing or compaction occurred > 50 years ago | 1.0 |
| Native soils have been plowed or compacted within the past 20-50 years | 0.7 |
| Native soils have been buried with fill, or plowed or compacted within the past 20 years | 0.4 |

### $V_{TSSC}$: Tree-shrub-sapling percent cover

Variable is used in Maintain Characteristic Fauna function.

This variable is defined as the percent cover of living trees, shrubs, and saplings (all woody vegetation ≥ 4.5 ft (1.4 m) tall) in the assessment area. It partly accounts for the vegetative structure for wildlife habitat at the site. By definition, isolated depressions are non-forested (≤ 30 percent cover of trees/shrubs/saplings), although most sites contained at least a few trees and shrubs, especially near the edge of the wetland. Reference standard sites all had tree-shrub-sapling percent coverage of less than 10 percent. A larger percentage of tree-shrub-sapling percent coverage in these herbaceous wetlands is generally attributable to the encroachment of invasive species, such as common buckthorn (*Rhamnus cathartica*) and glossy buckthorn (*Rhamnus frangula*). Therefore, the subindex score decreases as the tree-shrub-sapling coverage increase above 10 percent. This variable is scored categorically using percent cover ranges.

The variable subindex scaling of $V_{SNAG}$ for Isolated Depressions and Floodplain Depressions is given in Table 10.

**Table 10**
**Subindex Scoring of $V_{TSSC}$**

| Tree-Shrub-Sapling % Cover | Subindex |
|---|---|
| 0-10 percent | 1.0 |
| 11-20 percent | 0.7 |
| 21-30 percent | 0.3 |

### $V_W$: Plant wetness (W) score

Variable is used in the Maintain Characteristic Hydrologic Regime function.

This variable is the W/adventives (coefficient of wetness, including adventive species) score obtained from a site inventory Floristic Quality Assessment of

the assessment area. The W/adventives score is the average plant wetness (W) value for all plants in the assessment area. The W value is a number assigned to each plant based on its wetness designation (OBL = -5, FACW+ = -4, FACW = -3, FACW- = -2, FAC+ = -1, FAC = 0, FAC- = 1, FACU+ = 2, FACU = 3, FACU- = 4, UPL = 5). The plant wetness designations are from the 'Plants of the Chicago Region' book (Swink and Wilhlem 1994), which primarily uses the wetness designations from the 'National List of Plant Species that Occur in Wetlands' (Reed 1988), except in a few cases where Swink and Wilhelm assigned a designation if one was lacking in the national list, or they strongly disagreed with the designation given in the national list. Isolated Depression reference sites had W/adventive scores ranging from -0.7 to -3.8, with reference standard sites having scores ranging from -2.4 to -3.8. Deviation from the lower end (-2.4) of the range would suggest that the hydrology of the site is such that it has become too "dry" and would not support a reference standard plant community. A score > 0.0 would suggest that the site is no longer a wetland.

This variable is not used for Floodplain Depressions because in those sites the variable did not distinguish reference standard sites from other sites. In Isolated Depressions the subindex score decreases linearly from 1.0 to 0.2 (the 0.2 value was set based on the best professional judgment of the A-team) as the W/adventives score goes from -2.4 to 0. If the W/adventives score is >0.0, then the subindex is 0.0.

The variable subindex curve of $V_W$ for Isolated Depressions is given in Figure 31.

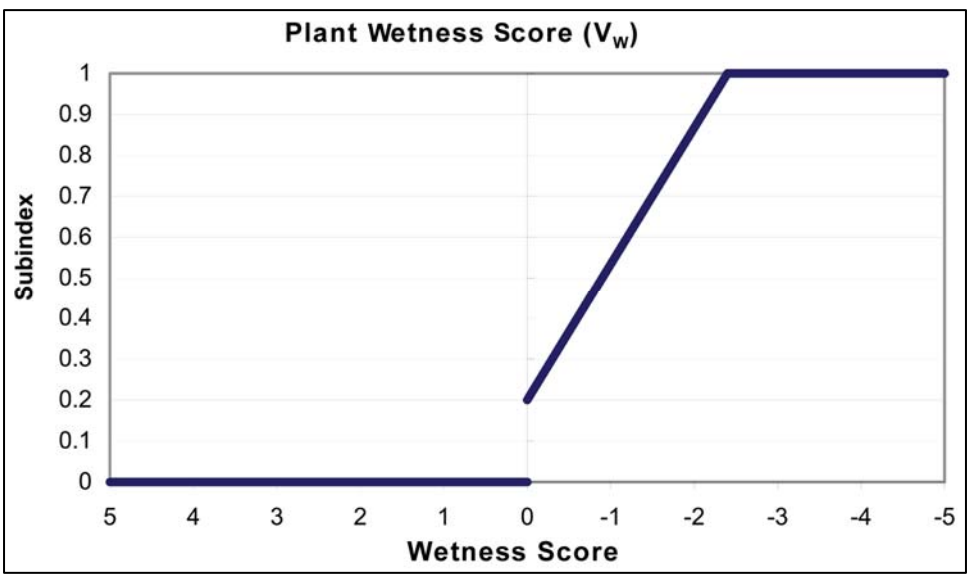


Figure 31. Relationship between W/adventives score and subindex score in Isolated Depressions

The equations used to calculate the $V_W$ subindex score are as follows:

W/adventives > 0, $V_W = 0.0$
-2.4 < W/adventives ≤ 0 , $V_W = -.3333(W/adventives) + 0.2$
W/adventives ≤ -2.4, $V_W = 1.0$

### $V_{W500}$: Wetlands within 500 m

Variable is used in Maintain Characteristic Fauna function.

This variable is a weighted measure of the number of wetlands located within 500 m of the assessment area. Each wetland within 500 m is multiplied by a factor from 1 to 3 based on its distance from the assessment area. The 'wetlands within 500 m score' is the sum of all the weighted values. More weight is given to wetlands that are closer to the assessment area, under the logic that a) closer wetlands will be more accessible to species with a limited dispersal range, and b) the less distance required for travel, the less chance deadly hazards will be encountered. Road traffic, for instance, can be a barrier to effective dispersal by amphibians (Fahrig et al. 1995). The 500-m dispersal range and the weighting system used here were selected based on the best professional judgment of the author and the A-team.

This variable is important at a landscape level (although it is more relevant for mammals, amphibians, and reptiles, than it is for birds), especially within the context of a mosaic of small wetlands (Gibbs 1993). It approximates both the density and proximity of wetlands in an area, and measures the ability of a metapopulations of animals to move from one wetland to another, thus increasing their viability.

In reference Isolated Depressions, scores ranged from 3.5 to 27.5. In reference Floodplain Depressions, scores ranged from 6 to 34. The scaling of the curve is based on the reference data and best professional judgment of the author.

The variable subindex curve of $V_{W500}$ for Isolated Depressions is given in Figure 32.

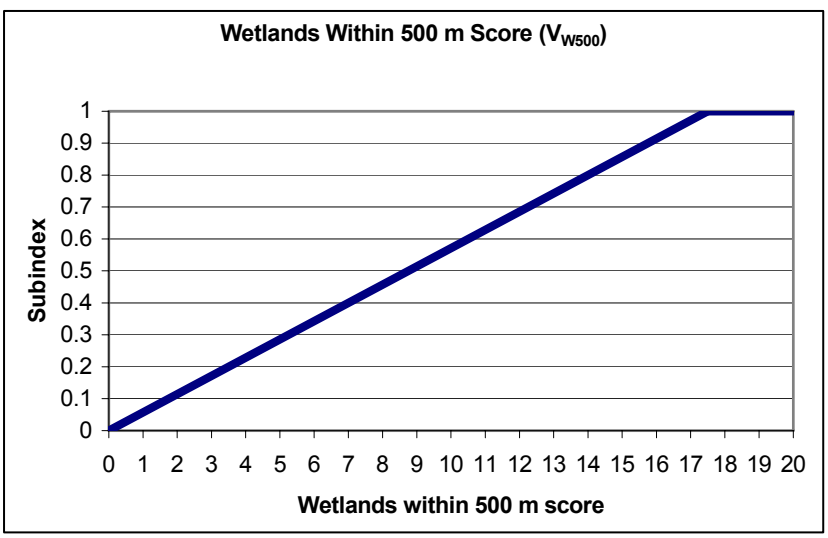


Figure 32. Relationship between wetlands within 500m score and subindex in Isolated Depressions

The equations used to calculate the $V_{W500}$ subindex score for Isolated Depressions are:

W500 score ≥ 17.5, $V_{W500} = 1.0$
W500 score < 17.5, $V_{W500} = 0.05714(W500)$

The variable subindex curve of $V_{W500}$ for Floodplain Depressions is given in Figure 33.

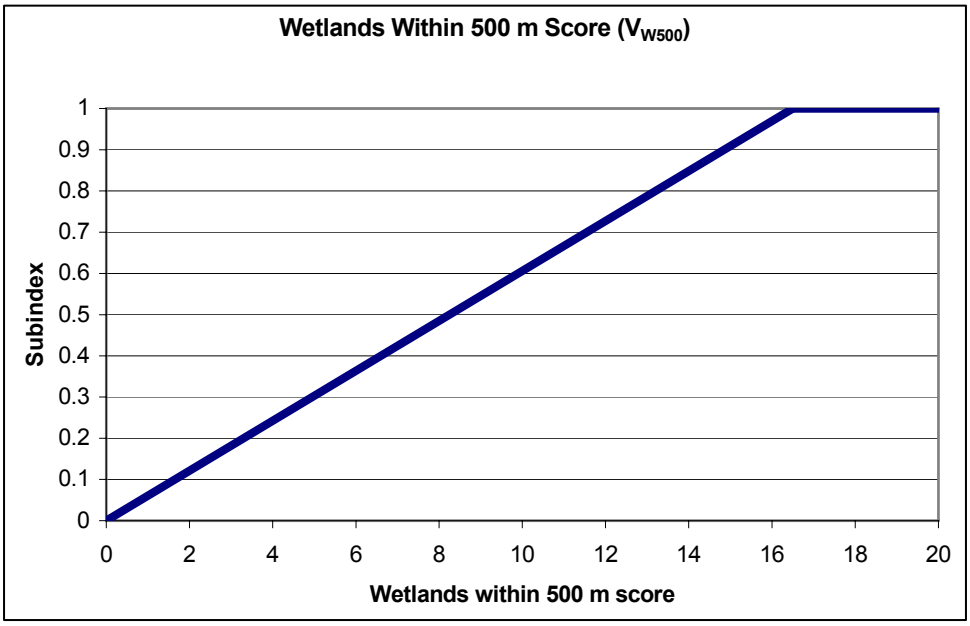


Figure 33. Relationship between wetlands within 500-m score and subindex in Floodplain Depressions

The equations used to calculate the $V_{W500}$ subindex score for Floodplain Depressions are:

W500 score ≥ 16.5, $V_{W500} = 1.0$
W500 score < 16.5, $V_{W500} = 0.0606(W500)$

## Functions

Functional Capacity Indices are, by definition, a measure of the function on a "per unit" basis, meaning that the size of the wetland is generally not taken into consideration when determining functional scores. For instance, with the "Maintain Characteristic Fauna" function, although wetland tract size is obviously correlated to available wetland wildlife habitat (10 acres of wetland provides more habitat than a similarly functioning 1 acre wetland), acre for acre the function is performed at the same level. Wetland size can be addressed through the use of Functional Capacity Units (FCUs), which are merely the size of the wetland multiplied by the individual functional capacity index. The use of FCUs is discussed in more detail in Appendix C.

### Function 1: Maintain characteristic hydrologic regime

**Definition.** This function is defined as the capacity of a depressional wetland to maintain and exhibit variations in the depth and duration of surface and below-surface water levels, as well as the volume and frequency and timing of water inputs and outputs, similar to that found in reference standard conditions. In isolated depressions, this function occurs largely through the long- and short-term storage and movement of water received through runoff and direct precipitation, and in some systems, groundwater inputs. Floodplain depressions also have floodwater as another potential hydrologic input. Water can be lost from the system through evapotranspiration, groundwater recharge, or drainage through a natural or artificial outlet.

The function is modeled here by assessing direct and indirect evidence that the hydrologic regime has been modified. An independent measure of this function would be to use wells for long-term monitoring of the water table, and comparing hydrograph results between impacted and reference standard wetlands.

**Rationale for selecting function.** Maintenance of a characteristic hydrologic regime is integral to the performance of all other functions. For instance, the wetland must store water for a sufficient enough period of time to maintain other wetland characteristics (e.g., hydric soils and hydrophytic vegetation).

Prolonged saturation leads to anaerobic soil conditions, which is critical for the occurrence of several biogeochemical processes (such as the cycling of various elements, compounds, and nutrients) that are highly dependent on the oxygen concentrations and redox capacity of the soil (Mausbauch and Richardson 1994). A proper hydrologic regime is also necessary for the maintenance of a desirable plant community, and the creation of suitable faunal habitat.

**Characteristics and processes that influence the function.** In isolated depressions, the primary source of hydrology is direct precipitation into the wetland and associated runoff from the wetland catchment. In floodplain depressions, the primary sources of hydrology are direct precipitation into the wetland and associated runoff from the wetland catchment, as well as flooding from an associated stream channel. However, the extent and importance of stream flooding will vary among sites, depending on the nature of adjacent streams. For both subclasses, the hydrology of the wetland will generally be driven by the intensity, duration, areal extent, and frequency of precipitation events. Depending on its location in the watershed, groundwater may also play a substantial role in the hydrology of the depression. In the reference domain, precipitation during the late spring/summer/early fall period (April through September) is often associated with short thunderstorms (1 to 2 hr) and on a month-to-month basis is on average about twice as high then during the rest of the year (October through March), where precipitation is generally longer in duration but less intense (IDNR 1998).

The ability of the wetland to store surface and subsurface water is affected by a variety of natural and anthropogenic processes and activities. Climate and landscape scale geomorphic features are largely natural factors that influence the wetland's hydrology. On-site characteristics that directly affect this function

include the relative size and volume of the wetland, soil sorption capabilities, and the amount of biomass present for evapotranspiration. Catchment characteristics can have a pronounced effect on hydrology (Brooks et al. 1991), and changes to the size or LU of the catchment will affect the timing and volume of runoff received in the wetland. Changes in LU (the removal of perennially vegetated areas in particular) can also increase erosional sediment loads into depressional wetlands, thereby decreasing their volume and reducing their water storage capacity and flood attenuation benefits (Ludden et al. 1983). Storage of water will also be affected by hydrologic modifications such as ditches or drainage tiles on or near the site, porosity of the soil, and, in the case of floodplain depressions, modifications to the stream channel that can either increase or decrease flooding to the site.

Ground vegetation cover can be used as an indicator of relative rates of evapotranspiration at both types of depressions. The presence of herbaceous vegetation can greatly increase evapotranspiration at a site. Broadleaf cattail (*Typha latifolia*), for instance, can in some cases have double or triple the evapotranspiration rate of an unvegetated area (Towler et al. 2004, Allen et al. 1997). Ground vegetation cover can also be used as an indicator that hydrologic alterations have occurred; sparse or stunted herbaceous vegetation at a site would suggest the hydrology is not able to support the vegetation. Similarly, the 'W' score (see the $V_W$ variable) obtained from a Floristic Quality Assessment (Swink and Wilhelm 1994) is another possible vegetative indicator of the hydrologic condition of the wetland.

**Functional Capacity Index.** The model for assessing the Maintain Characteristic Hydrology function includes the following assessment variables:

- Variables used for Isolated Depressions:
  $V_{ALT}$: Presence of hydrologic alteration
  $V_{CATCH}$: Ratio of wetland area to catchment area
  $V_{GVC}$: Ground vegetation cover
  $V_{LUC}$: Land use of the catchment area
  $V_{SOIL}$: Soil structure
  $V_W$: FQA W/adventives score

- Variables used for Floodplain Depressions:
  $V_{ALT}$: Presence of hydrologic alteration
  $V_{CATCH}$: Ratio of wetland area to catchment area
  $V_{GVC}$: Ground vegetation cover
  $V_{LUC}$: Landuse of the catchment area
  $V_{SOIL}$: Soil structure

The forms of the assessment models are as follows:

*a. For Isolated Depressions:*

$$FCI = \frac{\left[ \frac{\frac{(V_{GVC} + V_{SOIL} + V_W)}{3} + V_{CATCH}}{2} + V_{ALT} + V_{LUC} \right]}{3}$$

The equation for this function measures direct ($V_{ALT}$ and $V_{LUC}$) and indirect ($V_W$) indicators of change to the site hydrology, as well as relative storage capacity ($V_{CATCH}$, $V_{SOIL}$) and biomass ($V_{GVC}$) available for transpiration. More weight is given to $V_{CATCH}$, and the most weight is given to $V_{ALT}$ and $V_{LUC}$, because, based on best professional judgment, those variables would presumably have a greater effect on site hydrology than the other three. Arithmetic means are used in the function, so the FCI would only equal 0.0 if all variable subindex scores equaled 0.0.

*b. For Floodplain Depressions:*

$$FCI = \frac{\left[ \frac{\frac{(V_{GVC} + V_{SOIL})}{2} + V_{CATCH}}{2} + V_{ALT} + V_{LUC} \right]}{3}$$

The structure and logic of the model for this function in Floodplain Depressions are similar to the Isolated Depressions model, except $V_W$ is not used.

### Function 2: Maintain characteristic biogeochemical processes

**Definition.** This function is defined as the capacity of a wetland to maintain the rate, magnitude, and timing of various biogeochemical processes similar to that of reference standard conditions. These processes include the cycling of various nutrients and elements, organic matter accumulation and decomposition, and short- and long-term sequestration of inorganic and organic constituents. Directly and quantitatively measuring one or more of these processes, such as denitrification rates, net annual primary productivity, or annual rates of organic matter decomposition, can independently validate this function.

**Rationale for selecting function.** Biogeochemical processes are vital for determining and maintaining the nature of the wetland ecosystem. Nutrient cycling supports the development, growth, and subsequent decay and decomposition of the local plant community (Bormann and Likens 1970), which in turn provides habitat and energy sources for the animal community (Crow and MacDonald 1978). Nutrient cycling is a fundamental process performed by all ecosystems, but tends to be accomplished at particularly high rates in many wetland systems (Mitsch and Gosselink 2000).

This function also encompasses the removal and either storage or transformation of organic and inorganic elements and compounds (nitrogen, phosphorus, and various heavy metals, for example) from hydrologic inflows, which depressional wetlands are especially suited to do because of their location in the landscape (Crumpton and Baker 1993). The removal of elements and compounds has the value of providing water quality benefits by preventing or slowing the export of these contaminants from the wetland through groundwater or surface water and reducing pollution into a receiving lake, stream, or aquifer.

**Characteristics and processes that influence the function.** The ability of the wetland to perform this function depends upon the transfer of elements and materials between trophic levels within the wetland, rates of decomposition, and the movement of materials in and out of the wetland. These activities depend on a variety of biotic and abiotic processes. Biotic processes control the cycling and storage of nutrients among four major compartments: (a) the soil, (b) primary producers, such as vascular and nonvascular plants, (c) consumers, such as animals and bacteria, and (d) dead organic matter, such as litter and detritus. Decomposition and primary productivity rates will also depend on the hydrologic regime at the site. The removal and retention of elements and compounds from incoming water sources is affected by abiotic processes, such as the rate of water input and retention time, and the adsorption of materials to soil particles, and the actual amount of elements and compounds being delivered into the wetland. Also, the types and quantity of elements and compounds coming into the wetland will depend on the LU of its catchment, and the presence of any vegetative buffers. Wetlands, as the ecotone between terrestrial and aquatic environments (Naiman et al. 1989), are particularly subject to anthropogenic change that can affect material transport from the watershed or catchment into the wetland. Therefore, any changes to the natural soils, hydrology, vegetation, or LU surrounding the wetland can greatly impact the performance of this function.

This function is assessed by assuming that if material inputs, soil characteristics, and living and dead plant biomass in the wetland are similar to that of reference standard wetlands, then the biogeochemical processes will be occurring similarly as well.

**Functional Capacity Index.** The model for assessing the Maintain Characteristic Biogeochemical Processes function includes the following assessment variables:

$V_{BUFFER}$: Wetland buffer
$V_{GVC:}$ Ground vegetation cover
$V_{LUC:}$ Land use of catchment area
$V_{OHOR}$: Thickness of surface ‘O’ horizon
$V_{SOIL:}$ Soil structure

The assessment model for this function is identical for Isolated Depressions and Floodplain Depressions. The form of the assessment model is:

$$FCI = \frac{\left[ \frac{\left( V_{OHOR} + V_{GVC} + V_{BUFFER} \right)}{3} + V_{SOIL} + V_{LUC} \right]}{3}$$

The FCI for this function is calculated based on three general components: The first ($V_{OHOR}$ and $V_{GVC}$) measure the amount of living and dead biomass at the site. The second ($V_{SOIL}$) measures disturbance to the soil and the subsequent effects on decomposition rates and nutrient storage, and the third ($V_{LUC}$, $V_{BUFFER}$) is a measure of inputs into the wetland. More weight is given to the $V_{SOIL}$ and $V_{LUC}$ variables because changes to these variables will likely have a greater impact on the amount and type of nutrients entering the wetland, as well as the length of time that the nutrients are stored for the processes of biogeochemistry to take place than the other three variables. Arithmetic means are used in the function so all variable subindex scores would have to equal 0.0 for the FCI to equal 0.0.

### Function 3. Export organic carbon

**Definition.** This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon produced in the wetland, which can be important for various ecological processes in downstream aquatic systems. The function is only applicable to the Floodplain Depressions subclass and not the Isolated Depressions subclass. An independent quantitative measure of this function is mass of carbon exported per unit area per unit time ([g/m$^2$]/yr).

**Rationale for selecting function.** The high productivity of wetlands connected to streams and rivers make them important sources of dissolved and particulate organic carbon for aquatic food webs and biogeochemical processes in downstream aquatic habitats (Vannote et al. 1980, Elwood et al. 1983, Sedell et al. 1989). Dissolved organic carbon is a significant source of energy for the microbes that form the base of the detrital food web in aquatic ecosystems, and possibly an energy source for shredders and filter-feeding organisms (Vannote et al. 1980).

**Characteristics and processes that influence the function.** Connected floodplain wetlands are able to export relatively high rates of organic carbon because of several factors, including: (a) the large amount of organic matter in the litter and soil layers that come into contact with surface water, (b) relatively long periods of inundation and, consequently, contact between surface water and organic matter, thus allowing for significant leaching, (c) the ability of the labile carbon fraction to be rapidly leached from organic matter when exposed to water, and (d) the ability of floodwater and precipitation runoff to transport dissolved and particulate organic carbon from the floodplain to the stream channel.

Performance of this function requires two general components: the production of organic carbon on site, and a mechanism for mobilizing and exporting it. Although the primary export mechanism (< 10-year flooding) is similar among

floodplain depressions, the capability of the site to export carbon can be affected by alterations to the site hydrology.

**Functional Capacity Index.** The model for assessing the Maintain Characteristic Hydrology function includes the following assessment variables:

$V_{ALT\text{-}OEX}$: Presence of hydrologic alteration (stream portion)
$V_{GVC}$: Ground vegetation cover
$V_{OHOR}$: Thickness of surface 'O' horizon

The form of the assessment model is:

$$FCI = \frac{\left(V_{GVC} + V_{OHOR}\right)}{2} \times V_{ALT-OEX}$$

The FCI for this function measures the relative amount of living and dead biomass ($V_{GVC}$ and $V_{OHOR}$) available for export, and hydrologic alterations ($V_{ALT\text{-}OEX}$) that can affect the flooding regime and, therefore, the ability of the site to export carbon. The two components are multiplied as organic carbon export cannot occur without both the carbon source and the export mechanism. Therefore, either component is equal to 0.0, the FCI will also equal 0.0.

### Function 4: Maintain characteristic plant communities

**Definition.** This function is defined as the capacity of a wetland to provide the environment necessary for a characteristic plant community to develop and be maintained. In assessing this function, one must consider both the extant plant community as an indication of current conditions and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. A potential independent measure of this function would be to use direct or indirect ordination methods based on vegetation composition and abundance, as well as other environmental factors.

**Rationale for selecting function.** This function is important not only for the intrinsic value of the plant community, but also because the plant community influences other wetland processes, such as productivity and biogeochemical cycling, as well as providing habitat and food for wildlife communities.

**Characteristics and processes that influence the function.** A variety of physical and biological factors influence the ability of depressional wetlands to maintain characteristic plant communities. Fundamentally, the nature of the plant community will largely be influenced and maintained by the local hydrology (Goslee et al. 1997, Godwin et al. 2003). However, in recent history, anthropogenic alterations in and surrounding wetlands have greatly impacted depressional wetlands and their plant communities. Urbanization, conversion of natural lands to agriculture, and associated hydrologic manipulations have led to increased sedimentation, nutrient loading, and changes in the hydrologic regime in many wetlands. One of the major consequences of these changes is the aggressive establishment of non-native and invasive plant species (Kercher and Zedler

2004a). Once established, these species are often difficult to remove, and can prevent the growth of a more diverse plant community and possibly alter other fundamental ecological properties of an area, such as plant productivity and nutrient cycling (Mack et al. 2000). Wetlands, owing to their landscape sink position where disturbances, moisture, and nutrients all accumulate, are perhaps especially susceptible to invasions by single species that become monotypes (Zedler and Kercher 2004). Indeed, it is now typical for depressional wetlands in the Upper Des Plaines Basin to consist primarily of thick, near monotypic stands of cattails (*Typha spp.*) or reed canary grass (*Phalaris arundinacea*). Both of these species can thrive and are competitive dominants under a variety of hydrologic regimes, especially under high nutrient conditions (Kercher and Zedler 2004b).

To assess this function, both current vegetation compositions as well as environmental factors that can influence vegetation composition are evaluated.

**Functional Capacity Index.** The model for assessing the Maintain Characteristic Plant Communities function includes the following assessment variables:

$V_{ALT}$: Presence of hydrologic alteration
$V_C$: Native mean c score
$V_{CAT}$: Cover of *Typha spp*.
$V_{FQI}$: Native FQI score
$V_{INV}$: Invasive species cover (excluding *Typha spp.*)
$V_{LUC}$: Land use of the catchment area
$V_{NAT}$: Percent of plant species that are native

The assessment model for this function is identical for Isolated Depressions and Floodplain Depressions. The form of the assessment model is:

$$FCI = \left\{ \frac{\left( \frac{V_{NAT} + V_{FQI} + V_C}{3} \right) + \sqrt{\left( V_{INV} \times V_{CAT} \right) \times \left( \frac{V_{ALT} + V_{LUC}}{2} \right)}}{2} \right\}$$

The mathematical expression of the model has three general components. The first component ($V_{NAT}$, $V_{FQI}$, $V_C$) describes the composition of the extant plant community. The second and third components address the ability of that current community to either be maintained (if desirable) or improved. The second component measures the extent of various invasive plant species ($V_{INV}$ and $V_{CAT}$) in the wetland, which can inhibit the establishment of a desirable native plant community. These two variables are multiplied to reflect the overriding effect of the $V_{INV}$ variable on the $V_{CAT}$ variable, i.e., having a high $V_{CAT}$ subindex score (low *Typha* cover) does not benefit the function if the reason for low *Typha spp.* cover is that the site is completely covered with *Phalaris arundinacea*. $V_{INV}$ and $V_{CAT}$ are weighted heavily in this function, because they reflect both the nature of the current plant community and the capacity of that community to be positively altered. The third component ($V_{ALT}$ and $V_{LUC}$) represents other on- and near-site

environmental factors that, through a variety of factors, can influence the establishment and maintenance of the plant community. The geometric mean of these two components is used so that if either component is equal to 0.0, then the entire "maintain/improve" portion of the function would equal 0.0. However, for the entire function to equal 0.0, all variables in the function would have to equal 0.0.

### Function 5: Maintain characteristic fauna

**Definition.** This function is defined as the capacity of a wetland to support and maintain a characteristic diversity and abundance of wildlife species that utilize wetlands during some part of their life cycles. This function includes maintaining habitat within the wetland and the surrounding area, as well as connectivity among wetlands within the landscape. Various existing animal inventory methods can be used as an independent measure of this function.

**Rationale for selecting function.** A variety of vertebrate and invertebrate species utilize wetlands during some or all of their life cycle. High performance of this function indicates that the wetland remains suitable for these wildlife species to utilize for refuge, habitat, and breeding.

**Characteristics and processes that influence the function.** The use of wetland depressions by wildlife is influenced by a variety of spatial, temporal, and structural factors. One of the most important factors within the wetland influencing wildlife is the structure and composition of the plant community (van der Valk 1989, Weller 1987). The plant community can be suitable, to various degrees, for food, shelter, nesting, breeding, and foraging, depending on the complexity and composition of the vegetation. Also, an increase in plant diversity and habitat patchiness (having multiple areas of different vegetation types with sharp boundaries) will generally lead to a greater diversity of wildlife species utilizing the wetland. However, the spread of invasive plant species in the wetland can displace desirable native plants and animals. Areas taken over by reed canarygrass (*Phalaris arundinacea*), for instance, may be of little use to wildlife (Hoffman and Kearns 1997).

Hydrology is also a major factor influencing the quality of the wildlife habitat, both in its effect on the plant community, and in providing the seasonal inundation and ponded areas necessary for the breeding and survival of several species of insects and amphibians (Johnson 1987).

Landscape factors will also influence usage by wildlife, although the landscape factors addressed in this function pertain more towards the viability of mammals, amphibians, and reptiles then they do towards birds. Because of urbanization and conversion to agriculture, most natural areas have become fragmented and as a consequence many wetlands exist in isolated patches. The adverse effects of fragmentation have been well documented for birds (Askins et al. 1987, Kilgo et al. 1997), reptiles and amphibians (Semlitsch 1998, Semlitsch and Jensen 2001), and to a lesser extent, mammals (Nilon 1986, VanDruff and Rowse 1986, Nilon and VanDruff 1987).

Because of the fragmented landscape, wetland density and proximity to nearest neighbors are important determinants of the success of metapopulations, where organisms live in multiple populations that are occasionally connected through migration from one wetland to another (Gibbs 1993). For instance, many species of reptiles and amphibians will move overland to seek out wetlands with more favorable conditions when their current habitat has deteriorated (Beebee 1996). Successful movement of individuals and facilitation of metapopulations is more likely in areas that contain a high number of wetlands that are relatively close to one another. The presence of wildlife corridors, which can provide safety from predators and anthropogenic hazards, are also important for the movement of individuals between wetlands and from upland environments. Also, having other natural areas surrounding the wetland can provide essential core terrestrial habitat for many species (Semlitsch and Bodie 2003).

Besides reducing natural wildlife corridors and adjacent habitat, urban and agricultural LU can also have other negative effects on fauna. Certain amphibians and reptiles are particularly susceptible to changes in food sources brought about as a result of urbanization. For example, populations of the western fox snake (*Elaphe vulpine vulpine*) and eastern milk snake (*Lampropltis triangulum tiangulum*) are likely to be reduced over time because of the potential reduction of the species of rodent upon which they prey (SEWRPC 2003). Other amphibians and reptiles are highly sensitive to agricultural pesticides and herbicides. Ingestion of toads that have incidentally been sprayed by these chemicals, for instance, can prove fatal to hognose snakes (*Heterodon platirhinos*) (SEWRPC 2003).

**Functional Capacity Index.** The model for assessing the Maintain Characteristic Faunal Habitat function includes the following assessment variables:

$V_{ALT}$: Presence of hydrologic alteration
$V_{BUFFER}$: Percentage of wetland perimeter that is buffered
$V_{GVC}$: Ground vegetation cover
$V_{INV}$: Invasive species cover (excluding *Typha spp.*)
$V_{LANDUSE}$: Land use within 300 m of site
$V_{NAT}$: Percent of plant species that are native
$V_{TSSC}$: Tree-shrub-sapling % cover
$V_{W500}$: Wetlands within 500-m score

The form of the assessment model is as follows:

$$FCI = \frac{\sqrt{V_{INV} \times \frac{\left(V_{NAT} + V_{ALT}\frac{\left(V_{GVC} + V_{TSSC}\right)}{2}\right)}{3}} + \frac{\left(V_{W500} + V_{BUFFER} + V_{LANDUSE}\right)}{3}}{2}$$

The mathematical expression of this model measures two general components necessary for performance of the function. The first component ($V_{INV}$, $V_{TSSC}$, $V_{GVC}$, $V_{NAT}$, and $V_{ALT}$) measures habitat quality inside the wetland, i.e., the structural and aerial distribution and composition of living and dead standing vegetation in the assessment area, and the potential for periodic inundation. $V_{INV}$

is given the most weight, and is multiplied with the average of the other variables, as a site that is completely covered with invasive species would have little wildlife value (Hoffman and Kearns 1997). Although hydrology is an important factor, $V_{ALT}$ is not given more weight because hydrologic changes would potentially also be reflected in some of the other variables in this component.

The second component ($V_{BUFFER}$, $V_{W500}$, and $V_{LANDUSE}$) measures landscape factors that can influence the function. The FCI is equal to the arithmetic mean of both components. Even if the wetland itself is currently poor wildlife habitat, if it is restored, the improved habitat and fauna will be more sustainable if the surrounding landscape factors are optimal. Therefore, both components would have to equal 0.0 for the FCI to equal 0.0.

# 5 Assessment Protocol

## Introduction

Previous chapters of this Regional Guidebook provide background information on the HGM Approach, and document the variables and models used to assess the functions of Herbaceous Isolated Depression and Herbaceous Floodplain Depression wetlands. This chapter outlines a protocol for collecting and analyzing the data necessary to assess the functional capacity of a wetland in the context of a 404 permit review process or similar assessment scenario.

The typical assessment scenario is a comparison of pre-project and post-project conditions in the wetland. In practical terms, this translates into an assessment of the functional capacity of the WAA under both pre-project and post-project conditions and the subsequent determination of how FCIs have changed as a result of the project. Data for the pre-project assessment are collected under existing conditions at the project site, while data for the post-project assessment are normally based on the conditions that are expected to exist following proposed project impacts. A skeptical, conservative, and well-documented approach is required in defining post-project conditions. This recommendation is based on the often-observed lack of similarity between predicted or engineered post-project conditions and actual post-project conditions. This chapter discusses each of the tasks required to complete an assessment of depressional wetlands:

*a.* Define assessment objectives.

*b.* Characterize the project site.

*c.* Screen for red flags.

*d.* Define the Wetland Assessment Area.

*e.* Collect field and GIS data.

*f.* Analyze field and GIS data.

*g.* Apply assessment results.

## Define Assessment Objectives

Begin the assessment process by unambiguously identifying its purpose. This can be as simple as stating, "The purpose of this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives could be as follows:

*a.* Compare several wetlands as part of an alternatives analysis.

*b.* Identify specific actions that can be taken to minimize project impacts.

*c.* Document baseline conditions at the wetland site.

*d.* Determine mitigation requirements.

*e.* Determine mitigation success.

*f.* Determine the effects of a wetland management technique.

## Characterize the Project Area

Characterizing the project area involves describing the project area in terms of climate, surficial geology, geomorphic setting, surface and groundwater hydrology, vegetation, soils, land use, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands at the project area perform functions. The characterization should be written, and accompanied by maps and figures that show project area boundaries, jurisdictional wetlands, WAA (discussed later in this chapter), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitat, and other important features. Some information sources that will be useful in characterizing a project area are aerial photographs, topographic maps, available wetlands maps, and county soil surveys.

## Screen for Red Flags

Red flags are features within or in the vicinity of the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 11). Many red flag features, such as those based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Obviously, not all of the red flag features listed in Table 11 will be applicable to the Upper Des Plaines reference domain. Screening for red flag features represents a proactive attempt to determine if the wetlands or other natural resources in and around the project area require special consideration or attention that may preempt or postpone an assessment of wetland function. If a red flag feature exists, the assessment of wetland functions may not be necessary if the project is unlikely to occur as a result of the red flag feature. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may

be unnecessary because the project may be denied or modified strictly on the basis of the impacts to threatened or endangered species or habitat.

**Table 11**
**Red Flag Features and Respective Program/Agency Authority**

| Red Flag Features | Authority[1] |
|---|---|
| Native lands and areas protected under the American Indian Religious Freedom Act | A |
| Hazardous wastes sites identified under CERCLA or RCRA | I |
| Areas protected by a Coastal Zone Management Plan | E |
| Areas providing Critical Habitat for Species of Special Concern | B, C, F |
| Areas covered under the Farmland Protection Act | K |
| Floodplains, floodways, or floodprone areas | J |
| Areas with structures/artifacts of historic or archeological significance | G |
| Areas protected under the Land and Water Conservation Fund Act | K |
| Areas protected by the Marine Protection Research and Sanctuaries Act | B, D |
| National wildlife refuges and special management areas | C |
| Areas identified in the North American Waterfowl Management Plan | C, F |
| Areas identified as significant under the RAMSAR treaty | H |
| Areas supporting rare or unique plant communities | C,H |
| Areas designated as Sole Source Groundwater Aquifers | I, L |
| Areas protected by the Safe Drinking Water Act | I, L |
| City, County, State, and National Parks | D, F, H, L |
| Areas supporting threatened or endangered species | B, C, F, H, I |
| Areas with unique geological features | H |
| Areas protected by the Wild and Scenic Rivers Act or Wilderness Act | D |

[1]Program Authority/Agency
A = Bureau of Indian Affairs
B = National Marines Fisheries Service
C = U.S. Fish and Wildlife Service
D = National Park Service
E = State Coastal Zone Office
F = State Departments of Natural Resources, Fish and Game, etc.
G = State Historic Preservation Office
H = State Natural Heritage Offices
I = U.S. Environmental Protection Agency
J = Federal Emergency Management Administration
K = National Resource Conservation Service
L = Local Government Agencies

## Define the Wetland Assessment Area

The WAA is an area of wetland within a project area that belongs to a single regional wetland subclass, and is relatively homogeneous with respect to the site-specific criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage, etc.). In many project areas, there will be just one WAA representing a single wetland subclass, as illustrated in Figure 35. However, as the size and heterogeneity of the project area increase, it is more likely that it will be necessary to define and assess multiple WAAs or Partial Wetland Assessment Areas (PWAAs) within a project area.

At least three situations necessitate defining and assessing multiple PWAAs within a project area.

The first situation exists when widely separated wetland patches of the same regional subclass occur in the project area (Figure 34). The second situation exists when more than one regional wetland subclass occurs within a project area (Figure 35). The third situation exists when a physically contiguous wetland area of the same regional subclass exhibits spatial heterogeneity with respect to hydrology, vegetation, soils, disturbance history, or other factors that translate into a significantly different value for one or more of the site-specific variable measures. These differences may be a result of natural variability (e.g., zonation on large river floodplains) or cultural alteration (e.g., logging, surface mining, hydrologic alterations) (Figure 36). Designate each of these areas as a separate PWAA and conduct a separate assessment on each area.

There are elements of subjectivity and practicality in determining what constitutes a significant difference in portions of the WAA. Field experience with the regional wetland subclass under consideration should provide the sense of the range of variability that typically occurs, and the common sense necessary to make reasonable decisions about defining multiple PWAAs. Splitting an area into many PWAAs in a project area based on relatively minor differences resulting from natural variability should not be used as a basis for dividing a contiguous wetland into multiple PWAAs. However, zonation caused by different hydrologic regimes or disturbances caused by rare and destructive natural events (i.e., hurricanes) should be used as a basis for defining PWAAs.

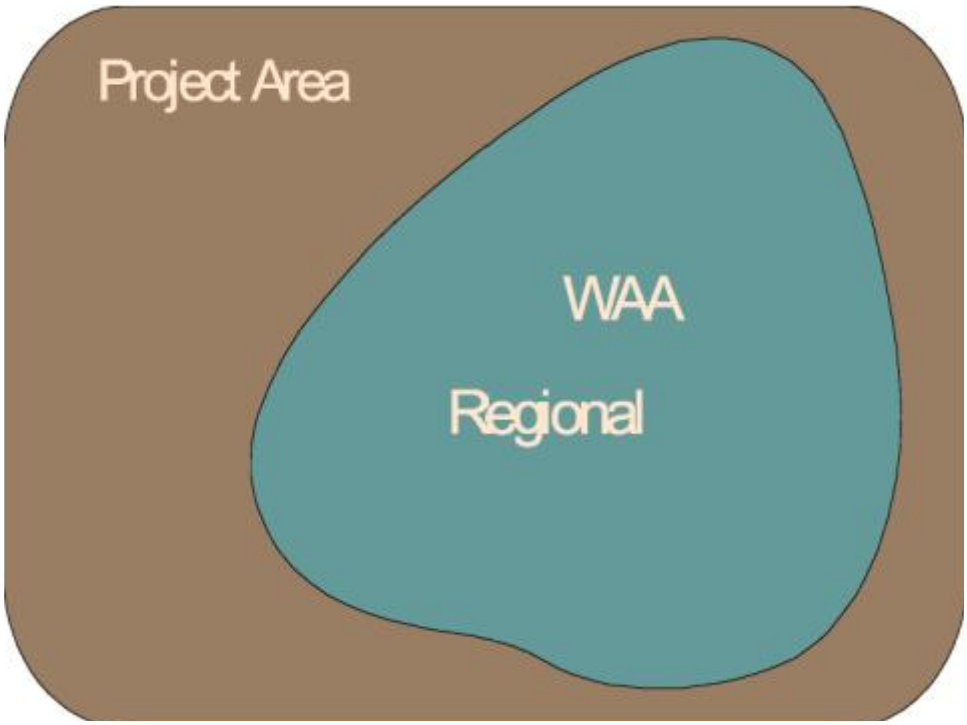


Figure 34. A single WAA within a project area

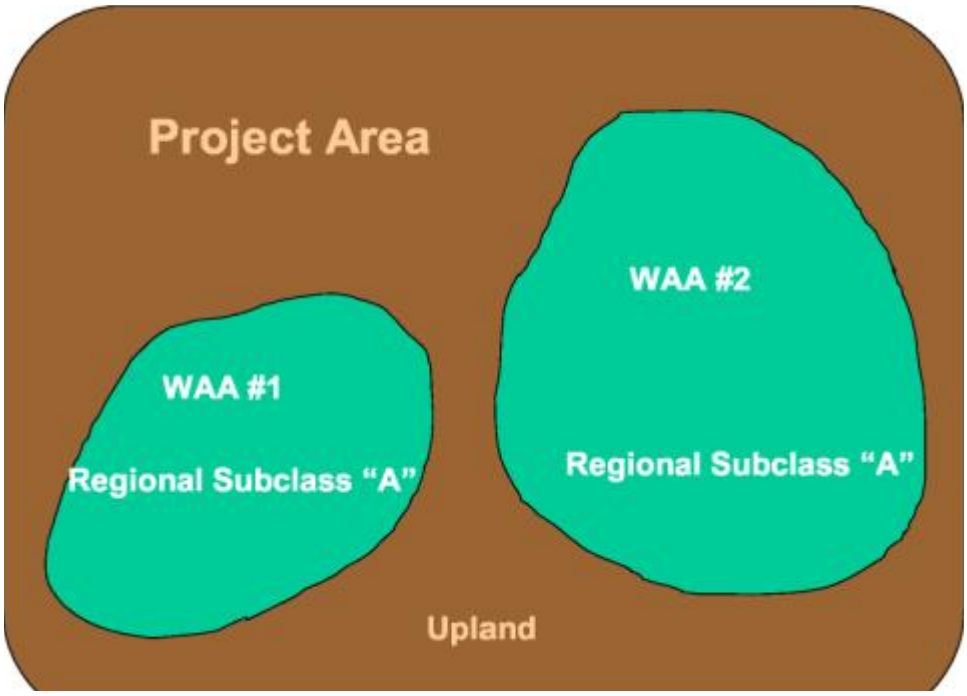


Figure 35. Spatially separated WAAs from the same regional wetland subclass within a project area

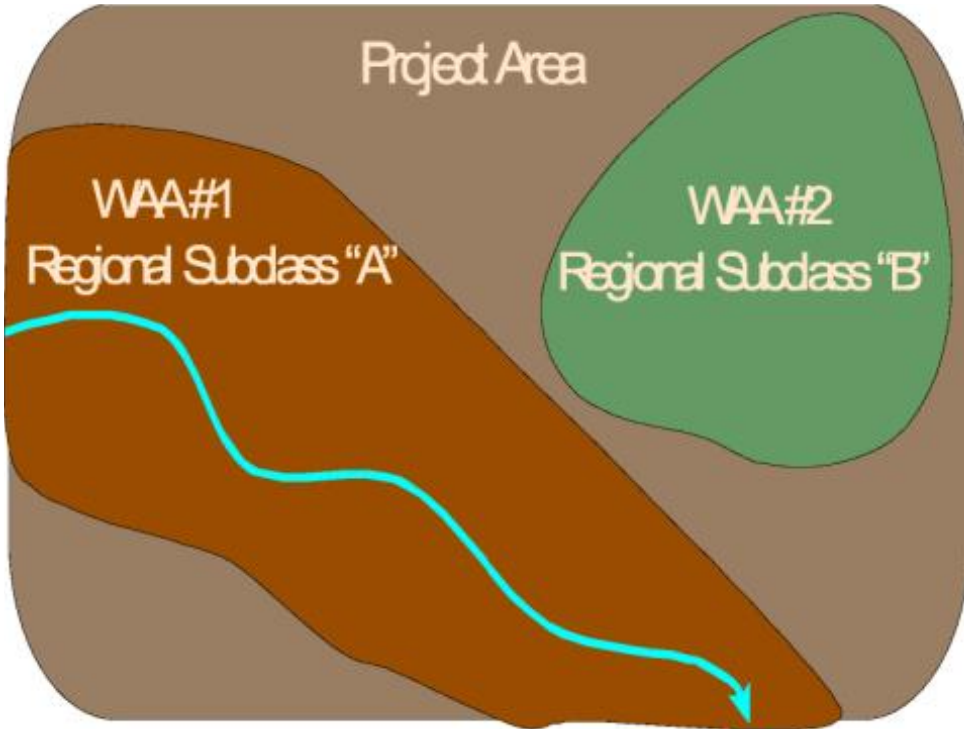


Figure 36. More than one regional subclass within a project area

## Determine Subclass

The dichotomous key (Figure 4) provided in Chapter 3 can be used as a guide for determining wetland subclass. Determination of subclass can largely be done prior to the site visit with the use of various digital or hard copy maps. The first task is to determine whether or not the assessment area is located in a topographic depression. For the purposes of this model, a depression is defined as a wetland that is a minimum of 2 ft deep in at least some areas. Using a digital map and 2-ft contour lines, this would mean that there is at least one contour line drawn inside the wetland that is lower than all contour lines that form the edge of the wetland (see Figure 37 for an example). A 10-year flood coverage is essential for determining whether or not a site is considered a "floodplain" or "isolated" depression. If a 10-year coverage is not available for an area, the FEMA 100-year map can be used instead; because of the geomorphology of the reference domain, the 10- and 100-year floodplains are fairly similar.

## Collect Field and GIS Data

Calculating the variable subindex scores used to assess functions in this guidebook requires a combination of field data collection and Geographical Information System (GIS) data collection and analysis. This section provides details on the methodology used to collect these data. In the case of GIS based data collection, although step by step instructions are provided for determining variable scores, the methodology assumes that the assessor has a working familiarity with ESRI's ArcView 3.x ® GIS software, on which the instructions are based. The same operations can also be performed using ESRI's ArcGIS 8.x and 9.x software, although the steps may differ slightly from what is presented here.

### Field data

Although a single individual can collect the necessary field data, it is suggested that the field crew consist of at least two people. Besides safety and time considerations, the advantage of having two people is that they can concur on the visual estimate of variables requiring a percent cover range. At least one person on the field crew should, at minimum, be able to identify common sedge meadow and marsh plant species. One person in the field crew should also have the ability to identify and distinguish soil horizons.

The following equipment is recommended for the collection of field data:

*a.* Plant identification keys.

*b.* Soil probe/sharpshooter shovel.

*c.* Soil survey.

*d.* Meter stick.

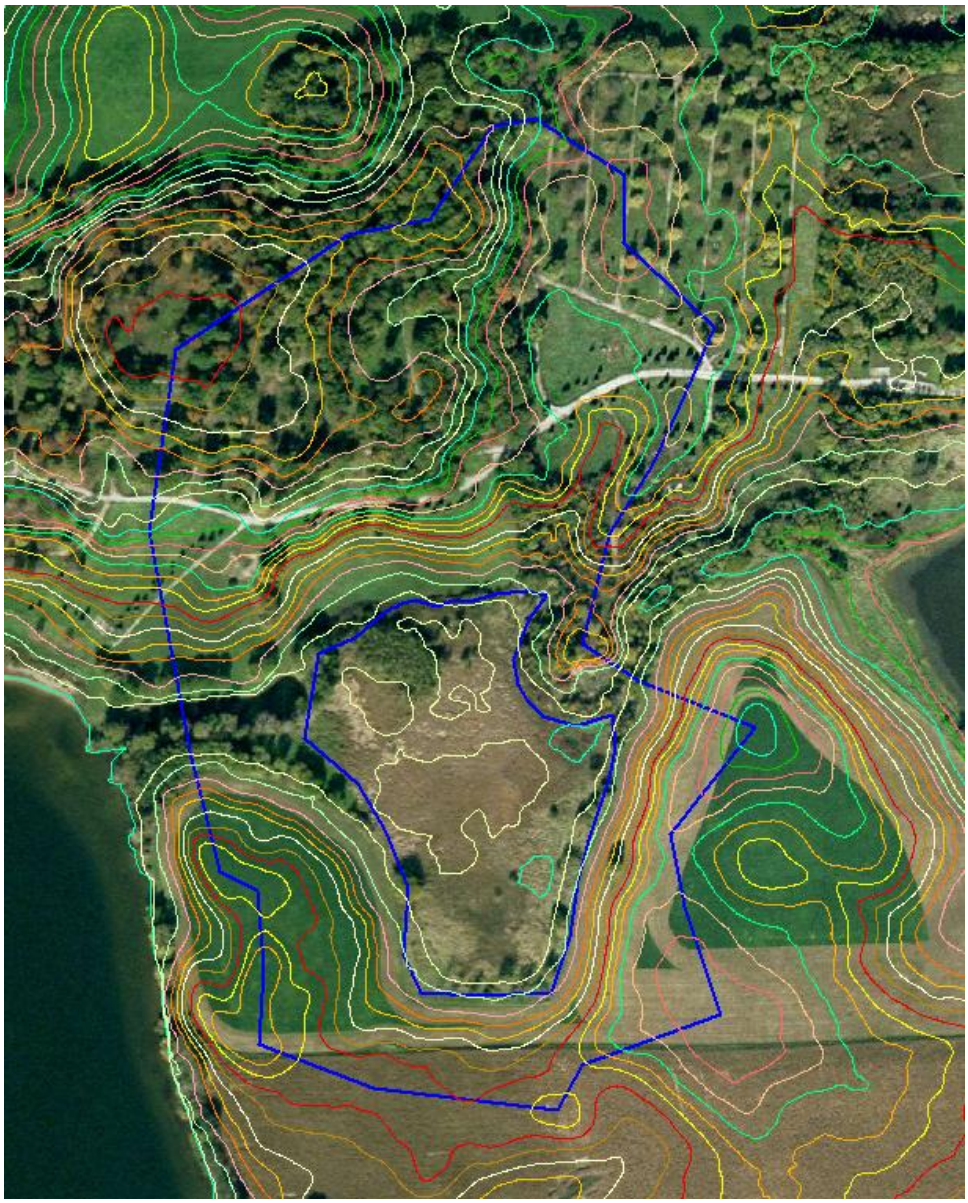

Figure 37. Example of wetland catchment drawn using 2-ft contour lines

Many of the field-collected data are visually estimated during a walk-through of the WAA, rather than through the use of data plots or transects. Because of the nature of many of these sites (which often have high levels of standing water), using plots or transects would often be either too time consuming, or physically impractical.

Several of these field data can also be measured using recent high-resolution aerial photography, but field reconnaissance of the site should also be done to confirm that no major changes have occurred to the site since the photograph was taken.

For smaller WAAs (< 25 acres), it is recommended that the samplers walk around the entire perimeter of the site, as well as, if feasible, walking at least one

random transect across the site. For larger WAAs, the sampler should traverse selected areas, until they are confident that they have observed representative areas of the entire WAA. Field sampling of the entire assessment area should usually take no longer than 2 hr.

Soil data require the collection of at least three soil cores at each assessment area. More cores may be required if there is large variability in the soil types within the assessment area. Use the following steps to collect soil data (used for the $V_{OHOR}$ and $V_{SOIL}$ variables):

*a.* Use digital or hard copy soil survey maps to determine the dominant (> 50 percent aerial coverage) mapped soil type in the assessment area. Determine if the dominant soil type mapped is mineral or organic.

*b.* Select a minimum of three representative points within the boundaries of the dominant mapped soil type in which to collect soil cores. Representative areas can be selected when on site, generally by choosing areas that contain the dominant vegetative community of the assessment area. Cores should be taken up to 32 in. (81.3 cm) in depth, or to the end of the surface 'O' horizon, whichever comes first. The cores should also be of the same type (organic or mineral). Organic soils are defined as soils with at least 16 in. (40.6 cm) of organic material in the first 32 in. (81.3 cm) of the profile.

*c.* Measure the thickness of the organic material at the surface and average the thickness from the three cores to obtain a final depth of 'O' horizon measurement.

*d.* Using the same soil cores, determine how much of the first 12 in. (30 cm) has been plowed, or is of massive or platy structure (see instructions for $V_{SOIL}$).
*or*
Based on previous knowledge of the assessment area, note if it has been buried, plowed, or compacted, and when the alteration occurred (< 20 years ago, between 20-50 years ago, or > 50 years ago).

Data collected in the field are entered into Data Form 1 (Figure 38).

### GIS data

The following data layers are necessary to collect the GIS-based data:

*a.* Land use coverages.

*b.* Contour line coverage.

*c.* Digital aerial photos.

If digital contour line maps or aerial photos are not available, USGS topographic maps can be used instead, although their use is less desirable and generally will not be as accurate for calculating variable scores.

## DATA FORM 1: HGM FIELD DATA COLLECTION SHEET

**Site** _____ **Date** _____ **Type:** Isolated Floodplain

### GENERAL FIELD DATA

**Assessment Team** _____

**Ground Vegetation Cover (%) (Visual Estimate): OR** _____

**GVC (%) by plot: Plot 1_____2____ 3____ 4____ 5_____6_____7_____8_____9_____10_____11_____12_____AVG_____**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Tree-Shrub-Sapling Cover (Circle One):** | 0-10% | 11-20% | 21-30% | | | |
| **Invasive Speceis Cover (Circle One):** | 0-5% | 6-20% | 21-50% | 51-80% | 81-94% | 95-100% |
| ***Typha spp.* Cover (Circle One):** | 0-20% | 21-50% | 51-80% | 81-100% | | |

**Hydrologic Alteration (Circle if Observed):**

Ditch(es) within 50 meters of site

Alterations to stream channel: None Moderate Severe N/A

Tiles/evidence of tiling

### FQA DATA

**Native FQI Score** _____

**Native mean c score** _____

**W/adventives score** _____

**Native Species (%)** _____

### SOIL DATA

**Dominant Soil Type of Assessment Area (Circle One):** Mineral Organic

| **PLOT 1** | **PLOT 2** | **PLOT 3** |
|---|---|---|
| "O" Horizon Depth (in.) | "O" Horizon Depth (in.) | "O" Horizon Depth (in.) |
| _____ | _____ | _____ |
| Massive or Platy Structure or Plow Layer (in.) | Massive or Platy Structure or Plow Layer (in.) | Massive or Platy Structure or Plow Layer (in.) |
| _____ | _____ | _____ |

Figure 38. Field Data Sheet

Several variables in this model are designed to be collected using ESRI ArcView® software. The instructions provided for calculating each of these variables are for those using ArcView® 3.x, although the instructions will also largely be applicable for those using ArcView® 8.x/9x. The detail of the instructions assumes that the user has working knowledge of ArcView® 3.x, and the ability to edit and process polygons using the program.

The two essential polygons that must be created by the user are:

*a.* The wetland boundary.

*b.* The wetland's catchment.

Creating the polygon of the wetland boundary will require either a digital aerial photo (preferred method), or a digital topographic map. Using the "Create Polygon" feature in ArcView, digitize the entire wetland area, using the aerial photo or map as a guide. In lieu of digitizing the wetland boundaries, pre-existing polygons from a wetlands map (NWI, etc.) can be used, although, depending on the source, these may be less accurate.

The catchment can be drawn using digital contour lines as a guide (see Figure 37 for an example). The catchment does not include the wetland itself. The easiest way to create the catchment area is to draw the entire catchment polygon (including the wetland), then use the Geoprocessing "Erase" feature to erase the wetland area from it. What is left is defined henceforth as the catchment area.

To actually delineate the catchment, use these steps:

*a.* Identify the high points surrounding the wetland.

*b.* Draw a line connecting all the high points. This line should run as perpendicular to the contour lines as possible.

*c.* The wetland may be receiving additional drainage (from urban storm sewers, for instance) from outside the catchment area. If this is the case, the additional area needs to be included in the catchment area.

*d.* The real catchment may also be smaller, owing to the presence of elevated roads within the natural catchment. If these roads do not have drainage culverts, then the roads should be considered part of the boundary of the catchment.

Calculation of two of the variables requires use of the XTools extension for ArcView® 3.x, which has the ability to calculate the area and perimeter of polygons. XTools can be downloaded for free at this website: *http://arcscripts.esri.com/details.asp?dbid=11526.*

GIS data are recorded in Data Form 3 (Figure 39).

**DATA FORM 2: HGM GIS DATA COLLECTION SHEET**

Site ____ Date ____ Assessment Team ____

Wetland Area (ha): ____
Catchment Area (ha): ____
Wetland Area/Catchment Area ratio: ____

Catchment Landuse Score ____
300 m Landuse Score ____
Wetland Perimeter That is Buffered ( percent) ____

Wetlands within 500 meters Assessment Area

| Distance (m) | Number | Multiplier |
|---|---|---|
| 0-100 | | 3 |
| 101-200 | | 2.5 |
| 201-300 | | 2 |
| 301-400 | | 1.5 |
| 401-500 | | 1 |

**Total Score:** ____

Figure 39. GIS Data Sheet

## Procedures for Measuring Assessment Variables

For each variable, it is indicated whether the data are collected primarily in the field or using GIS.

### $V_{ALT}$: Presence of hydrologic alteration (field data)

Based on the site walk through or aerial photos, look for the presence of ditches in or within 50 m adjacent to the assessment area. With very large sites, aerial photos may need to be relied on, although smaller ditches may not appear on aerial photos. The presence of tiles is harder to determine; the indicator used here is that if a site has recently been taken out of agricultural production (and tiles have not been removed), it is assumed that the site has been tiled. Local knowledge may also be useful in determining whether a site has been tiled. For stream alteration (in the case of Floodplain Depressions), determine if no impact, moderate impact, or severe impact has occurred, using the criteria in Table 12. Also, see Figures 10, 11, and 12 in Chapter 4 for examples of these levels of impact.

| **Table 12<br>Descriptions of Impact Levels to Stream** | |
|---|---|
| **Level of Impact** | **Description** |
| No alterations/impact | No artificial levees, spoil piles, roads, etc. along the stream reach. Stream has not been downcut, channelized, or straightened. |
| Moderate impact | (a) Presence of artificial levees, spoil piles, roads, etc., along stream reach, and/or stream has been moderately downcut, channelized, and/or straightened. Generally, alterations have not been maintained and some of the natural stream morphology has returned.<br>*and/or*<br>(b) Knowledge that flooding frequency has been somewhat reduced from natural conditions, but is still < 10 years. |
| Severe impact | (a) Presence of artificial levees, spoil piles, roads, etc., along stream reach, and/or stream has been severely downcut/channelized, and/or straightened. Alterations are being maintained and the natural stream morphology is not apparent.<br>*and/or*<br>(b) Knowledge that flooding frequency has greatly reduced from natural conditions, and is > 10 years. |

### $V_{BUFFER}$: Wetland buffer (GIS data)

The files needed to calculate this variable are:

*a.* Wetland area shapefile.

*b.* Aerial photo, or topographic map, or county land-use file.

Use the following steps to calculate this variable score:

*a.* Use XTools to determine the length of the wetland perimeter.

*b.* Using the ArcView "Measuring" tool, manually determine the length of the wetland perimeter that is surrounded by buffer (using the aerial photo, topo map, or land-use coverage as a guide). Buffer is defined as any natural area (forest, wetland, grassland, etc.) ≥ 30 m in width.

*c.* Divide the buffered perimeter by the total wetland perimeter, and multiply by 100. This value is the raw $V_{BUFFER}$ score, which is used to calculate the $V_{BUFFER}$ subindex score.

### $V_{CAT}$: Cover of *Typha spp.* (field data)

Based on the site walk through, visually estimate the percentage of the assessment area covered by *Typha spp*. Record the estimate as one of the following cover categories: 0-20 percent, 21-50 percent, 51-80 percent, 81-100 percent.

### $V_{CATCH}$: Ratio of wetland area to catchment area (GIS data and field data)

The files needed to calculate this variable score are:

*a.* Wetland area shapefile.

*b.* Catchment area shapefile.

Use the following steps to calculate this variable score.

*a.* Use XTools to calculate the areas (unit not important) of the wetland area and its corresponding catchment area.

*b.* Divide wetland area by catchment area. This ratio is the raw $V_{CATCH}$ score, which is then used to calculate the $V_{CATCH}$ subindex score.

It is possible that the actual catchment area is either larger or smaller than the measured catchment area. There are two situations where the catchment size should be checked in the field:

*a.* There are urban areas adjacent to the measured catchment. In this case, it is possible that storm water is being diverted from the urban area into the wetland. If this is the case, then the extent of the urban area needs to be added to the catchment. The existence of storm drains from the adjacent areas should be verified in the field.

*b.* There are elevated roads in the catchment that do not have drainage culverts. If there are no culverts, then the road becomes part of the catchment boundary. The presence of culverts in these roads should be verified in the field.

### $V_{GVC}$: Ground vegetation cover (GIS data or field data)

Based on the site walk through, visually estimate and record the percentage of the assessment area (not including open water areas) covered by living herbaceous plants. Most sites in the reference domain had ground vegetation cover of 95 to 100 percent, which is easy to visually estimate. If ground vegetation is lower than this, however, it is suggested that the percent cover is estimated in a minimum of 12 randomly placed 1-$m^2$ plots (the plots can be placed around the area the soil cores are taken). The percent ground vegetation cover of the assessment area is the average percent cover from the 12 plots. If aerial photography is available, this variable can also be estimated using the photo, although the field visit should be used to confirm that cover has not changed significantly from the photo.

### $V_{INV}$: Invasive species % cover (field data)

Based on the site walk through, visually estimate the percentage range of the assessment area (not including open water areas) covered by invasive species,

excluding any *Typha spp*. The percentage ranges used are 0-5, 6-20, 21-50, 51-80, 81-94, and 95-100 percent for isolated depressions, and 0-10, 11-25, 26-50, 51-80, 81-94, and 95-100 percent for floodplain depressions.

The most common invasive species in the reference domain is *Phalaris arundinacea* (reed canary grass), so this variable can often be scored by looking for percent cover of *P. arundinacea*. Other invasive species that will occasionally be found in abundance (enough to contribute meaningfully to a percent cover estimate) are *Phragmites australis* (common reed), *Lythrum salicaria* (purple loosestrife), and *Ambrosia trifida* (giant ragweed).

### $V_{LANDUSE}$: Land use within 300 m of site
### $V_{LUC}$: Land use of the catchment area (GIS data)

Calculation of the $V_{LUC}$ and $V_{LANDUSE}$ variables requires use of the Spatial Analyst extension for ArcView® 3.x and a land-use file in GRID (raster) format. The land use then needs to be reclassified so that:

*a.* Urban (includes commercial, industrial, and all residential densities) = 5.

*b.* Agriculture (includes all farmland and pasture) = 3.

*c.* Natural (includes forest, grasslands, and wetlands) = 1.

If first converting from a shapefile to GRID, a cell size of 10 $m^2$ or less is recommended.

The files needed to calculate the $V_{LANDUSE}$ variable score are:

*a.* Wetland area shapefile.

*b.* Land-use GRID file.

Use the following steps to calculate the $V_{LANDUSE}$ variable score:

*a.* Use the "Create Buffers" feature to create a 300-m buffer around the wetland area shapefile.

*b.* Make sure the Spatial Analyst extension has been opened. Make the new buffer shapefile active, then go to "Summarize Zones" under the "Analysis" menu.

*c.* When asked, "Pick theme containing variable to summarize," select the land-use grid file. A table of various statistics will then be displayed.

*d.* The "Mean" statistic is the raw $V_{LANDUSE}$ score, which is used to calculate the $V_{LANDUSE}$ subindex score.

The files needed to calculate the $V_{LUC}$ variable score are:

*a.* Catchment area shapefile.

*b.* Land-use GRID file.

Use the following steps to calculate the $V_{LUC}$ variable score:

*a.* Make sure the Spatial Analyst extension has been opened. Make the catchment area shapefile active, then go to "Summarize Zones" under the "Analysis" menu.

*b.* When asked, "Pick theme containing variable to summarize," select the land-use grid file. A table of various statistics will then be displayed.

*c.* The "Mean" statistic is the raw $V_{LUC}$ score, which is used to calculate the $V_{LUC}$ subindex score.

### $V_{OHOR}$: Depth of 'O' horizon (field data)

Measure and average the depth of the 'O' horizon for all three soil cores. See the $V_{OHOR}$ variable in Chapter 4 for more information on the 'O' horizon.

### $V_{SOIL}$: Soil structure (field data)

For each core, determine the total depth of any layer that is either (a) a plow layer (Ap horizon) or (b) "massive" or "platy" in structure (Figure 40) in the first 12 in. of soil. Calculation example:

| Layer | Depth (in.) | Structure |
|---|---|---|
| Ap | 0-5 | Granular |
| A1 | 5-11 | Platy |
| A2 | 11-12 | Granular |

For the above profile, a total of 11 of the first 12 in. is either a plow layer and of 'platy' structure — so 11/12 = 92 percent.

### $V_{TSSC}$: Tree-shrub-sapling vegetation percent cover (GIS/field data)

Based on the site walkthrough, visually estimate the percentage of the assessment area covered by living trees, shrubs, and saplings. Trees-shrubs-saplings are defined as all woody vegetation ≥ 4.5 ft (1.4 m) tall. Record the estimate as one of the following cover categories: 0-10 percent, 11-20 percent, 21-30 percent. This variable can also be estimated using aerial photography.

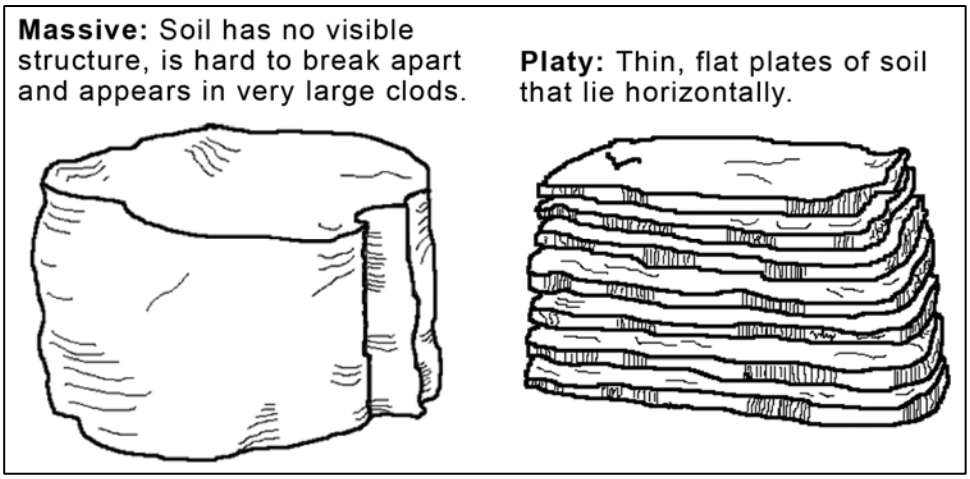


Figure 40. "Massive" and "Platy" soil structures

### $V_W$, $V_C$, $V_{FQI}$, $V_{NAT}$: W/adventives score, native mean c, native FQI, percent of species that are native (field data)

All four of these variables are obtained from a site inventory Floristic Quality Assessment (FQA), based on a single visit (optimally during June through August). A site inventory FQA entails a walk through of the assessment area and making a record of every plant species that is seen. Each plant species is recorded once. It is suggested that the inventory is done using a time-meander search (Goff et al. 1982), using 15-min intervals, with a maximum search time of 2 hr (searches done during reference data collection were limited to 2 hr.) The survey ends when less than 10 percent (from the preceding interval) new species are found in the subsequent 10-min interval. For example:

*a.* In the first 15-min interval, 10 species are identified.

*b.* In the second 15-min period, 8 new species are identified (53 percent additional species, so the search continues).

*c.* In the third 15-min interval, 4 new species are identified (50 percent additional species from the previous interval, so the search continues).

*d.* In the fourth 15-min interval, no new species are identified. The search ends.

Calculation of W/adventives, native mean C, and native FQI requires either the FQA software with the Chicago Plant Database (both available from Conservation Research Institute/Conservation Design forum — *http://www.cdfinc.com/CRI/FQA%20Order%20Form%202004.pdf*) or either a printed copy of the Chicago Plant Database or the *Plants of the Chicago Region* book (Swink and Wilhelm 1994), in which case the variables can be calculated manually. $V_{NAT}$ is calculated by dividing the number of native species from the total number of species, using the native/non-native designations from the FQA Chicago database.

### $V_{W500}$: Wetlands within 500 m (GIS data)

The files needed to calculate this variable score are:

*a.* Polygon of wetland assessment area.

*b.* Wetlands map.

Use the following steps to calculate this variable score.

*a.* Use the "Buffer" tool to create a 500-m buffer, divided into 100-m segment bands, around the project area.

*b.* Count the number of wetlands ≥0.25 acre that are contained within each band. If a wetland spans across multiple bands, count it as belonging to the band it is in closest to the project area. The 0.25-acre minimum is used to eliminate small patches of misclassified areas in the land-use grids.

*c.* Multiply the number of wetlands in each band by the following:

- Band 1, (0-100 m) × 3.0
- Band 2, (101-200 m) × 2.5
- Band 3, (201-300 m) × 2.0
- Band 4, (301-400 m) × 1.5
- Band 5, (401-500 m) × 1.0

*d.* Add together the scores from all bands. This is the raw $V_{W500}$ score, which is then used to calculate the $V_{W500}$ subindex score.

## Apply Assessment Results

Once the assessment and analysis phases are complete, the results can be used to (a) compare the same WAA at different points in time, (b) compare different WAAs at the same point in time, (c) compare different alternatives to a project, or (d) compare different HGM classes or subclasses as per Smith et al. (1995).

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# Appendix A
# Glossary

**Abiotic:** Not biological.

**Assessment model:** A simple model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

**Assessment objective:** The reason an assessment of wetland functions is being conducted. Assessment objectives normally fall into one of three categories: documenting existing conditions, comparing different wetlands at the same point in time (e.g., alternatives analysis), and comparing the same wetland at different points in time (e.g., impact analysis or mitigation success).

**Assessment team (A-Team):** An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

**Biotic:** Of or pertaining to life; biological.

**Direct impacts:** Project impacts that result from direct physical alteration of a wetland, such as the placement of dredge or fill.

**Direct measure:** A quantitative measure of an assessment model variable.

**Functional assessment:** The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using an assessment model to determine a Functional Capacity Index.

**Functional capacity:** The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape, and interaction between the two.

**Functional Capacity Index (FCI):** An index of the capacity of a wetland to perform a function relative to other wetlands in a regional wetland subclass. Functional Capacity Indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates the wetland is performing a function at the highest sustainable func-

tional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level, and will not recover the capacity to perform the function through natural processes.

**Glacial outwash:** Sand and gravel that have been "washed out" from the ice in meltwater streams along the margin of a glacier.

**Glacial till:** Accumulations of unsorted, unstratified mixtures of clay, silt, sand, gravel, and boulders, leftover from glacial movements.

**Highest sustainable functional capacity:** The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding area are undisturbed.

**Hydrogeomorphic wetland class:** The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes: depression, riverine, slope, fringe, and flat.

**Hydrogeomorphic unit:** Hydrogeomorphic units are areas within a wetland assessment area that are relatively homogeneous with respect to ecosystem scale characteristics such as microtopography, soil type, vegetative communities, or other factors that influence function. Hydrogeomorphic units may be the result of natural or anthropogenic processes. See **Partial wetland assessment area.**

**Hydroperiod:** The annual duration of flooding (in days per year) at a specific point in a wetland.

**Indicator:** Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

**Indirect measure:** A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

**Indirect impacts:** Impacts resulting from a project that occur concurrently or at some time in the future, away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

**Invasive species:** Generally exotic species without natural controls that out compete native species.

**Jurisdictional wetland:** Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987) or its successor.

**Loess:** Windblown silt of late glacial and post-glacial age.

**Mitigation:** Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

**Mitigation plan:** A plan for replacing lost functional capacity resulting from project impacts.

**Mitigation wetland:** A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

**Model variable:** A characteristic of the wetland ecosystem or surrounding landscape that influences the capacity of a wetland ecosystem to perform a function.

**Organic matter:** Plant and animal residue in the soil in various stages of decomposition.

**Organic soil material:** Soil material that is saturated with water for long periods or artificially drained and, excluding live roots, has an organic carbon content of 18 percent or more with 60 percent or more clay, or 12 percent or more organic carbon with 0 percent clay. Soils with an intermediate amount of clay have an intermediate amount of organic carbon. If the soil is never saturated for more than a few days, it contains 20 percent or more organic carbon.

**Organic soils (Histosol):** A soil of which more than half of the upper 80 cm (32 in.) is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic material.

**Oxidation:** The loss of one or more electrons by an ion or molecule.

**Partial wetland assessment area (PWAA):** A portion of a Wetland Assessment Area (WAA) that is identified a priori, or while applying the assessment procedure, because it is relatively homogeneous and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally or as a result of anthropogenic disturbance. See **Hydrogeomorphic unit.**

**Project alternative(s):** Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, and other ways.

**Project area:** The area that encompasses all activities related to an ongoing or proposed project.

**Project target:** The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

**Red flag features:** Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, state, regional, or local level and may be official or unofficial.

**Reference domain:** All wetlands within a defined geographic area that belong to a single regional wetland subclass.

**Reference standards:** Conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (highest sustainable capacity) across the suite of functions of the regional wetland subclass. By definition, highest levels of functioning are assigned an index of 1.0.

**Reference wetlands:** Wetland sites that encompass the variability of a regional wetland subclass in a reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and to establish reference standards.

**Region:** A geographic area that is relatively homogeneous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

**Regional wetland subclass:** Regional hydrogeomorphic wetland classes that can be identified based on landscape and ecosystem scale factors. There may be more than one regional wetland subclass for each of the hydrogeomorphic wetland classes that occur in a region, or there may be only one.

**Site potential:** The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

**Soil surface:** The soil surface is the top of the mineral soil; or, for soils with an "O" horizon, the soil surface is the top of the part of the "O" horizon that is at least slightly decomposed. Fresh leaf or needle fall that has not undergone observable decomposition is excluded from soil.

**Value of wetland function:** The relative importance of wetland function or functions to an individual or group.

**Variable:** An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of the wetland to perform a function.

**Variable condition:** The condition of a variable as determined through quantitative or qualitative measure.

**Variable index:** A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

**Wetland**: See **Wetland ecosystems**.

**Wetland ecosystems:** In 404: "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted

for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Corps Regulation 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three-dimensional segments of the natural world where the presence of water at or near the surface creates conditions leading to the development of redoximorphic soil conditions, and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

**Wetland assessment area (WAA):** The wetland area to which results of an assessment are applied.

**Wetland functions:** The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape, and their interaction.

**Wetland restoration:** The process of restoring wetland function in a degraded wetland. Restoration is typically done as mitigation.

# Appendix B
# Reference Data

| Site ID | Type | County | Rating[1] | Depth of surface "O" Horizon, in. | Mineral or Organic Soil? | Stream Alteration | Site Alteration(s) |
|---|---|---|---|---|---|---|---|
| CF1 | Flood | Cook | 2 | 15 | both | severe | none observed |
| CI15 | Flood | Cook | 3 | 0 | both | N/O | none observed |
| LF4 | Flood | Lake | 1 | 11.5 | both | moderate | none observed |
| LF6 | Flood | Lake | 3.5 | 12 | both | moderate | culverts |
| LI4 | Flood | Lake | 3.5 | 10.8 | both | N/O | none observed |
| CF2 | Flood | Cook | 2 | 0 | mineral | none | culvert |
| CF4 | Flood | Cook | 1.5 | 0 | mineral | moderate | none observed |
| CF5 | Flood | Cook | 1.5 | 0 | mineral | N/O | none observed |
| CF9 | Flood | Cook | 4.5 | 4 | mineral | none | none observed |
| CI5 | Flood | Cook | 2 | 0 | mineral | N/O | culvert |
| LF3h | Flood | Lake | 4.5 | 3.8 | mineral | none | adjacent ditch |
| LF3m | Flood | Lake | 4 | 8 | mineral | none | none observed |
| LF7h | Flood | Lake | 3.5 | 6.5 | mineral | N/O | none observed |
| LF11 | Flood | Lake | 3 | 1 | mineral | moderate | none observed |
| LF12 | Flood | Lake | 2.5 | 0 | mineral | moderate | none observed |
| LF15 | Flood | Lake | 4 | 3.3 | mineral | moderate | none observed |
| LF16 | Flood | Lake | 3 | 0 | mineral | none | none observed |
| LI5 | Flood | Lake | 2.5 | 3 | mineral | N/O | beaver activity, culverts |
| CF6 | Flood | Cook | 4 | 55 | organic | N/O | none observed |
| KF9 | Flood | Kenosha | 2.5 | 28 | organic | N/O | none observed |
| KF12 | Flood | Kenosha | 2.5 | 33.5 | organic | moderate | natural dam |
| KF25 | Flood | Kenosha | 2 | 27.5 | organic | moderate | none observed |
| KF31 | Flood | Kenosha | 3 | N/A | organic | N/O | cattle |
| LF5 | Flood | Lake | 3 | 55 | organic | none | none observed |
| LF7m | Flood | Lake | 2.5 | 37.5 | organic | N/O | none observed |
| LF10 | Flood | Lake | 3.5 | 27 | organic | none | ditch along road |

[1] This was the rating initially assigned to the site based on the field visit.

| Site ID | FQI (native) | Mean c (native) | W/Adventives | % Non Native Species | % GVC | % TSSC | % INV |
|---|---|---|---|---|---|---|---|
| CF1 | 13.3 | 3.1 | -1.9 | 21 | >95 | <5 | 50 |
| CI15 | 20.7 | 3.7 | -3.4 | 14 | >95 | <5 | 20 |
| LF4 | 5.2 | 3 | -3.6 | 25 | >95 | <5 | 90 |
| LF6 | 23.1 | 4.4 | -3.3 | 11 | >95 | <5 | 40 |
| LI4 | 19.8 | 3.5 | -3.3 | 13 | >95 | <5 | 40 |
| CF2 | 13.4 | 2.5 | -2.1 | 15 | >95 | <5 | 25 |
| CF4 | 13.2 | 3 | -0.8 | 30 | >95 | <5 | 95 |
| CF5 | 17.7 | 4.1 | -3.9 | 14 | >95 | <5 | 60 |
| CF9 | 27 | 4.2 | -1.9 | 18 | >95 | <5 | 12.5 |
| CI5 | 10.9 | 2.6 | -2.3 | 26 | >95 | <5 | 30 |
| LF3h | 42.4 | 4.9 | -2.8 | 1 | > 95 | <5 | 55 |
| LF3m | 28 | 4.1 | -3.5 | 8 | > 95 | <5 | 35 |
| LF7h | 30.6 | 4.2 | -2.9 | 12 | >95 | <5 | 7.5 |
| LF11 | 19.6 | 3.3 | -3.1 | 10 | 80 | 30 | 25 |
| LF12 | 17.7 | 3.1 | -1.2 | 16 | 65 | 30 | 30 |
| LF15 | 32.6 | 5 | -1.2 | 4 | >95 | 7.5 | 25 |
| LF16 | 16.8 | 3.2 | -3 | 10 | >95 | 10 | 10 |
| LI5 | 15.8 | 3 | -2.4 | 29 | 80 | 10 | 50 |
| CF6 | 24.2 | 4.1 | -3.5 | 15 | >95 | 10 | 30 |
| KF9 | 15.4 | 3.1 | -2.3 | 11 | 90 | <5 | 10 |
| KF12 | 21.4 | 3.8 | -2.2 | 11 | >95 | <5 | 10 |
| KF25 | 12.7 | 3 | -2.3 | 18 | 100 | <5 | 95 |
| KF31 | 17.4 | 3.9 | -3.4 | 20 | >95 | <5 | 15 |
| LF5 | 21.2 | 4.2 | -3.7 | 7 | >95 | 5 | 10 |
| LF7m | 25 | 4 | -3.4 | 13 | >95 | <5 | 7.5 |
| LF10 | 20.9 | 3.6 | -2.6 | 19 | >95 | <5 | 80 |

| Site ID | % Cattail | Snags | Wetland Area/ Catchment Ratio | Wetlands Within 500 m Score | Catchment LU Score | 300 m Buffer LU Score | % of Wetland Perimeter that is Buffered |
|---|---|---|---|---|---|---|---|
| CF1 | 51-80 | no | 0.51 | 12.0 | 3.18 | 3.66 | 83 |
| CI15 | 51-80 | no | 0.28 | 12.5 | 2.79 | 1.93 | 100 |
| LF4 | 0-20 | no | 0.38 | 12.0 | 2.95 | 2.73 | 78 |
| LF6 | 51-80 | no | 0.12 | 5.5 | 3.20 | 3.00 | 66 |
| LI4 | 81-100 | no | 0.24 | 4.0 | 2.98 | 2.69 | 59 |
| CF2 | 51-80 | no | 0.34 | 6.0 | 2.82 | 3.62 | 100 |
| CF4 | 0-20 | no | 0.05 | 14.0 | 1.20 | 1.50 | 100 |
| CF5 | 21-50 | no | 0.08 | 15.0 | 1.65 | 2.30 | 75 |
| CF9 | 0-20 | no | 0.20 | 16.5 | 1.57 | 2.19 | 100 |
| CI5 | 81-100 | no | 0.05 | 9.5 | 1.58 | 1.42 | 93 |
| LF3h | 51-80 | no | 1.04 | 32.5 | 2.32 | 2.12 | 80 |
| LF3m | 0-20 | no | 1.04 | 32.5 | 2.32 | 2.12 | 80 |
| LF7h | 81-100 | no | 0.39 | 14.5 | 3.19 | 2.46 | 16 |
| LF11 | 81-100 | yes | 0.16 | 10.5 | 3.41 | 2.82 | 93 |
| LF12 | 0-20 | no | 0.34 | 6.0 | 3.08 | 3.02 | 96 |
| LF15 | 0-20 | no | 0.34 | 14.5 | 1.71 | 1.98 | 100 |
| LF16 | 81-100 | no | 0.01 | 11.5 | 4.15 | 3.20 | 100 |
| LI5 | 51-80 | yes | 0.15 | 34.0 | 3.72 | 3.70 | 3 |
| CF6 | 51-80 | no | 0.32 | 6.0 | 1.72 | 1.67 | 100 |
| KF9 | 81-100 | no | 0.02 | 6.0 | 3.10 | 3.06 | 62 |
| KF12 | 81-100 | no | 0.53 | 17.0 | 2.29 | 2.39 | 89 |
| KF25 | 0-20 | no | 0.23 | 12.0 | 2.55 | 2.38 | 39 |
| KF31 | 81-100 | no | 0.25 | 17.5 | 2.63 | 2.41 | 95 |
| LF5 | 0-20 | no | 0.54 | 9.0 | 1.31 | 1.84 | 92 |
| LF7m | 81-100 | no | 0.39 | 14.5 | 3.19 | 2.46 | 16 |
| LF10 | 0-20 | no | 1.15 | 11.5 | 3.36 | 2.88 | 86 |

| Site ID | Type | County | Rating[1] | Depth of surface "O" Horizon, in. | Mineral or Organic soil? | Site Alteration(s) |
|---|---|---|---|---|---|---|
| CI2 | Isolated | Cook | 1 | 0 | both | none observed |
| CI6 | Isolated | Cook | 3.5 | 0 | both | ditch |
| KI27 | Isolated | Kenosha | 3.5 | 13.5 | both | none observed |
| KI34 | Isolated | Kenosha | 4 | 5 | both | none observed |
| KI36 | Isolated | Kenosha | 3 | 30.3 | both | culvert |
| LI11 | Isolated | Lake | 3.5 | 39.8 | both | none observed |
| LI16 | Isolated | Lake | 4.5 | 10 | both | none observed |
| CI8 | Isolated | Cook | 2 | 2 | mineral | none observed |
| CI11 | Isolated | Cook | 4 | 0 | mineral | none observed |
| CI14 | Isolated | Cook | 3 | 0 | mineral | none observed |
| CI16 | Isolated | Cook | 4 | 1.5 | mineral | none observed |
| CI17 | Isolated | Cook | 2 | 1.5 | mineral | culvert |
| KI24 | Isolated | Kenosha | 4 | 2.5 | mineral | culvert |
| KI50 | Isolated | Kenosha | 3 | 8 | mineral | none observed |
| LF8 | Isolated | Lake | 1.5 | 0 | mineral | plowed/tiled |
| LF13 | Isolated | Lake | 2.5 | 6.3 | mineral | boardwalk |
| LI1 | Isolated | Lake | 1 | 4 | mineral | dirt road |
| LI3 | Isolated | Lake | 1 | 0 | mineral | site no longer wetland |
| LI7 | Isolated | Lake | 3.5 | 6.3 | mineral | ditch along road |
| LI14 | Isolated | Lake | 3.5 | 0 | mineral | none observed |
| LI15 | Isolated | Lake | 4 | 6.8 | mineral | none observed |
| LI21 | Isolated | Lake | 3.5 | 11.5 | mineral | none observed |
| LI22 | Isolated | Lake | 4 | 8.3 | mineral | none observed |
| LI26 | Isolated | Lake | 4.5 | 2 | mineral | none observed |
| CI1 | Isolated | Cook | 3 | 55 | organic | none observed |
| CI4 | Isolated | Cook | 1.5 | 0 | organic | none observed |
| CI10 | Isolated | Cook | 4 | 28.5 | organic | none observed |
| CI12 | Isolated | Cook | 5 | 55 | organic | none observed |
| KF1 | Isolated | Kenosha | 4 | 14.3 | organic | none observed |
| KI21 | Isolated | Kenosha | 2 | 55 | organic | none observed |
| KI37 | Isolated | Kenosha | 3.5 | 32 | organic | none observed |
| KI40 | Isolated | Kenosha | 2 | 55 | organic | none observed |
| KI42 | Isolated | Kenosha | 2.5 | 12.5 | organic | none observed |
| LI2 | Isolated | Lake | 2 | 55 | organic | old drain tile, site planted |
| LI12 | Isolated | Lake | 2.5 | 55 | organic | old drain tile, site planted |
| LI25 | Isolated | Lake | 3.5 | 55 | organic | none observed |
| LI27 | Isolated | Lake | 2.5 | 19.3 | organic | none observed |
| LI28 | Isolated | Lake | 2.5 | 24.7 | organic | none observed |

[1]This was the rating initially assigned to the site based on the field visit.

| Site ID | FQI (native) | Mean c (native) | W/Adventives | % Non Native Species | % GVC | % TSSC | % INV |
|---|---|---|---|---|---|---|---|
| CI2 | 4.5 | 1.7 | -0.7 | 13 | >95 | <5 | 95 |
| CI6 | 21.7 | 3.4 | -2.2 | 16 | >95 | 10 | 5 |
| KI27 | 18.1 | 3.3 | -1.7 | 20 | >95 | <5 | 20 |
| KI34 | 22.6 | 3.4 | -1.0 | 15 | >95 | <5 | 10 |
| KI36 | 22.7 | 3.6 | -3.2 | 17 | >95 | <5 | 7.5 |
| LI11 | 14.1 | 3 | -1.5 | 33 | >95 | <5 | 25 |
| LI16 | 24.4 | 4.6 | -2.6 | 15 | >95 | <5 | 7.5 |
| CI8 | 9.8 | 2.8 | -1.9 | 29 | >95 | <5 | 10 |
| CI11 | 19.5 | 4.3 | -3.8 | 15 | >95 | 10 | 17.5 |
| CI14 | 19.2 | 3.8 | -3.3 | 7 | >95 | <5 | 50 |
| CI16 | 21 | 3.8 | -2.2 | 16 | >95 | <5 | 5 |
| CI17 | 14.2 | 3.8 | -2.2 | 13 | 10 | 20 | 5 |
| KI24 | 18 | 3.3 | -2.1 | 19 | >95 | 20 | 20 |
| KI50 | 18.8 | 3.7 | -2.4 | 28 | >95 | <5 | 7.5 |
| LF8 | 10.3 | 2.7 | -1.1 | 35 | >95 | <5 | 55 |
| LF13 | 20.6 | 3.9 | -2.7 | 13 | >95 | <5 | 75 |
| LI1 | 8.8 | 2.4 | -1.7 | 26 | >95 | 0 | 90 |
| LI3 | 1.5 | 0.8 | 2.3 | 56 | >95 | <5 | 5 |
| LI7 | 28.2 | 4.4 | -2.4 | 19 | >95 | 30 | 10 |
| LI14 | 23.3 | 3.8 | -3.2 | 10 | 70 | 30 | 30 |
| LI15 | 20.1 | 3.6 | -0.9 | 23 | >95 | <5 | 7.5 |
| LI21 | 23.4 | 4.4 | -3.8 | 7 | >95 | <5 | 10 |
| LI22 | 24.1 | 3.7 | -1.9 | 7 | >95 | <5 | 7.5 |
| LI26 | 21 | 4 | -2.4 | 13 | >95 | <5 | 7.5 |
| CI1 | 17.9 | 3.9 | -2 | 25 | >95 | 7.5 | 17.5 |
| CI4 | 10.4 | 3 | -2.5 | 25 | 60 | <5 | 22.5 |
| CI10 | 25.8 | 5 | -3.8 | 13 | >95 | 7.5 | 7.5 |
| CI12 | 38.1 | 5.6 | -3.8 | 4 | >95 | 10 | 5 |
| KF1 | 23.8 | 3.6 | -3.4 | 20 | >95 | <5 | 5 |
| KI21 | 14.3 | 3 | -1.3 | 19 | >95 | <5 | 7.5 |
| KI37 | 25.4 | 4.4 | -3.2 | 11 | >95 | <5 | 30 |
| KI40 | 22.3 | 4.1 | -1.6 | 15 | >95 | <5 | 25 |
| KI42 | 25.4 | 4.4 | -2.9 | 6 | >95 | <5 | 80 |
| LI2 | 15.3 | 3.3 | -2.1 | 16 | 85 | <5 | 40 |
| LI12 | 24.1 | 3.8 | -1.8 | 18 | 80 | <5 | 20 |
| LI25 | 34.5 | 5.1 | -3.6 | 10 | >95 | 10 | 25 |
| LI27 | 16.4 | 3.1 | -2.3 | 18 | >95 | <5 | 7.5 |
| LI28 | 23 | 4.1 | -2.3 | 24 | >95 | <5 | 10 |

| Site ID | % Cattail | Snags | Wetland Area/ Catchment Ratio | Wetlands Within 500 m Score | Catchment LU Score | 300 m Buffer LU Score | % of Wetland Perimeter that is Buffered |
|---|---|---|---|---|---|---|---|
| CI2 | 0-20 | no | 0.14 | 4.0 | 1.92 | 1.97 | 100 |
| CI6 | 51-80 | no | 0.03 | 1.0 | 1.13 | 2.66 | 84 |
| KI27 | 81-100 | no | 0.29 | 27.5 | 2.98 | 2.83 | 18 |
| KI34 | 21-50 | no | 0.19 | 20.0 | 3.23 | 3.12 | 0 |
| KI36 | 81-100 | no | 0.58 | 12.0 | 2.76 | 2.75 | 75 |
| LI11 | 81-100 | no | 0.23 | 18.0 | 4.27 | 3.97 | 68 |
| LI16 | 81-100 | yes | 0.38 | 22.0 | 2.16 | 1.95 | 91 |
| CI8 | 81-100 | yes | 0.34 | 5.0 | 2.28 | 1.98 | 92 |
| CI11 | 0-20 | no | 0.06 | 9.0 | 1.82 | 1.69 | 100 |
| CI14 | 0-20 | no | 0.05 | 14.0 | 1.13 | 1.91 | 100 |
| CI16 | 0-20 | no | 0.10 | 4.5 | 1.25 | 1.08 | 100 |
| CI17 | 0-20 | no | 0.16 | 3.5 | 1.29 | 1.63 | 100 |
| KI24 | 0-20 | no | 0.05 | 12.5 | 2.88 | 3.16 | 0 |
| KI50 | 51-80 | yes | 0.39 | 4.5 | 4.03 | 3.79 | 0 |
| LF8 | 0-20 | no | 0.09 | 10.0 | 2.94 | 2.69 | 15 |
| LF13 | 0-20 | no | 0.24 | 13.5 | 2.16 | 2.02 | 87 |
| LI1 | 0-20 | no | 0.07 | 14.5 | 3.61 | 3.99 | 0 |
| LI3 | 0-20 | no | 0.07 | 20.0 | 3.23 | 3.05 | 0 |
| LI7 | 0-20 | yes | 0.37 | 2.0 | 1.13 | 1.93 | 81 |
| LI14 | 0-20 | yes | 0.02 | 9.0 | 2.02 | 1.23 | 81 |
| LI15 | 21-50 | yes | 0.24 | 17.0 | 2.06 | 2.36 | 100 |
| LI21 | 0-20 | no | 0.08 | 23.5 | 1.00 | 1.79 | 100 |
| LI22 | 21-50 | no | 0.11 | 26.0 | 1.49 | 1.81 | 90 |
| LI26 | 0-20 | no | 0.1 | 13.5 | 1.63 | 1.64 | 100 |
| CI1 | 0-20 | no | 0.09 | 15.0 | 1.11 | 1.38 | 100 |
| CI4 | 0-20 | yes | 0.12 | 7.0 | 2.75 | 1.76 | 100 |
| CI10 | 0-20 | no | 0.02 | 6.5 | 1.00 | 1.22 | 100 |
| CI12 | 0-20 | yes | 0.16 | 17.5 | 1.00 | 1.04 | 100 |
| KF1 | 81-100 | no | 0.11 | 4.5 | 2.95 | 2.38 | 61 |
| KI21 | 81-100 | no | 0.09 | 11.5 | 3.66 | 2.96 | 17 |
| KI37 | 21-50 | no | 0.22 | 2.0 | 2.67 | 2.98 | 66 |
| KI40 | 81-100 | no | 0.82 | 5.5 | 3.52 | 3.79 | 24 |
| KI42 | 0-20 | no | 0.02 | 21.0 | 2.17 | 1.76 | 100 |
| LI2 | 0-20 | yes | 0.21 | 16.5 | 3.02 | 3.18 | 100 |
| LI12 | 0-20 | yes | 0.28 | 19.5 | 3.19 | 3.32 | 100 |
| LI25 | 21-50 | no | 0.38 | 12.0 | 1.66 | 2.29 | 80 |
| LI27 | 81-100 | no | 0.82 | 16.5 | 3.06 | 3.20 | 31 |
| LI28 | 81-100 | no | 0.28 | 9.5 | 3.35 | 3.36 | 44 |

# Appendix C
# Functional Capacity Units[1]

In the 404 Regulatory Program, the primary application of FCI is to compare different wetland areas, such as project alternatives, or pre- or post-project condition. However, comparing two wetland areas on the basis of a functional capacity index alone can lead to erroneous conclusions. For example, consider the following scenario. A new highway is being planned, and there are two alternative routes under consideration. The first route will impact 5 acres of wetland with an FCI of 0.8 for a particular wetland function. The second route will impact 25 acres of wetland, also with an FCI of 0.8 for the same function. In comparing the two alternatives based on functional capacity, it would be correct to say that on a per unit area basis there was no difference between the alternatives. However, when incorporating the size of each wetland area into the comparison, a conclusion of no difference would be erroneous. The comparison of the two alternatives, based on the functional capacity index and size of wetland, would lead to a more appropriate conclusion that the first alternative is the least damaging to the selected wetland function.

The functional capacity indices resulting from the assessment phase can be applied in a variety of ways during the application phase using *functional capacity units (FCUs)*. Functional capacity units provide a measure of the ability of a wetland area to perform a function, and are calculated by multiplying a functional capacity index by the area of wetland the FCI represents. For example:

$$\text{FCU} = \text{FCI} \times \text{size of wetland area}$$

where:

FCU = Functional capacity units for wetland area

FCI = Functional capacity index for wetland area

Once the functional capacity of a wetland area is expressed in terms of FCUs, a number of the comparison necessary in the 404 permit review process can be made. For example:

[1] The following is adapted from an article written by R. Daniel Smith in the USACE Wetlands Research Program Bulletin, Volume 4, No. 3, October 1994.

*a.* Comparing the same wetland area at different points in time (e.g., pre- or post-project conditions).

*b.* Comparing WAAs in the same hydrogeomorphic wetland class at the same point in time.

*c.* Comparing WAAs in different hydrogeomorphic wetland classes at the same point in time.

# Appendix D
# Summary of Variables and Functional Capacity Indices

## All Variables Used

$V_{ALT}$: Presence of hydrologic alteration
$V_{ALT\text{-}OEX}$: Presence of hydrologic alteration (stream portion)
$V_{BUFFER}$: Wetland buffer
$V_{C}$: Native mean c score
$V_{CAT}$: Cover of *Typha spp*.
$V_{CATCH}$: Ratio of wetland area to catchment area
$V_{FQI}$: Native FQI score
$V_{GVC}$: Ground vegetation cover
$V_{INV}$: Invasive species cover (excluding *Typha spp.*)
$V_{LANDUSE}$: Land use within 300 m of site
$V_{LUC}$: Land use of the catchment area
$V_{NAT}$: Percent of plant species that are native
$V_{OHOR}$: Thickness of surface "O" horizon
$V_{SOIL}$: Soil structure
$V_{TSSC}$: Tree-shrub-sapling percent cover
$V_{W}$: Plant wetness score
$V_{W500}$: Wetlands within 500 m score

## Functional Capacity Indices

### Maintain characteristic hydrologic regime

a. *Isolated Depressions*:

$$FCI = \frac{\left[ \frac{\frac{\left(V_{GVC} + V_{SOIL} + V_{W}\right)}{3} + V_{CATCH}}{2} + V_{ALT} + V_{LUC} \right]}{3}$$

*b. Floodplain Depressions:*

$$FCI = \frac{\left[ \frac{\frac{(V_{GVC} + V_{SOIL})}{2} + V_{CATCH}}{2} + V_{ALT} + V_{LUC} \right]}{3}$$

## Maintain characteristic biogeochemical processes

*Isolated and Floodplain Depressions*

$$FCI = \frac{\left[ \frac{\left(V_{OHOR} + V_{GVC} + V_{BUFFER}\right)}{3} + V_{SOIL} + V_{LUC} \right]}{3}$$

## Export organic carbon

*Floodplain Depressions*

$$FCI = \frac{\left(V_{GVC} + V_{OHOR}\right)}{2} \times V_{ALT-OEX}$$

## Maintain characteristic plant communities

*Isolated and Floodplain Depressions*

$$FCI = \left\{ \frac{\left( \frac{V_{NAT} + V_{FQI} + V_{C}}{3} \right) + \sqrt{\left(V_{INV} \times V_{CAT}\right) \times \left( \frac{V_{ALT} + V_{LUC}}{2} \right)}}{2} \right\}$$

## Maintain characteristic fauna

*a. Isolated and Floodplain Depressions:*

$$FCI = \frac{\sqrt{V_{INV} \times \frac{\left(V_{NAT} + V_{ALT}\frac{\left(V_{GVC} + V_{TSSC}\right)}{2}\right)}{3}} + \frac{\left(V_{W500} + V_{BUFFER} + V_{LANDUSE}\right)}{3}}{2}$$

# REPORT DOCUMENTATION PAGE

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This Regional Guidebook characterizes the wetlands in the Upper Des Plaines River Basin using the hydrogeomorphic (HGM) approach. The HGM approach is a collection of concepts and methods used to develop functional indices to assess the capacity of a particular wetland to perform functions relative to similar wetlands in a region. Specifically, this report describes the rationale that was used to select functions for two subclasses of herbaceous freshwater depressions, the Isolated Depression subclass and the Floodplain Depression subclass. The report also describes the process used to select model variables and metrics and to develop assessment models. Data from reference wetlands are provided and used to calibrate model variables and assessment models. Protocols for applying functional indices to the assessment of wetland functions are provided.

**15. SUBJECT TERMS**
Depression
Des Plaines River
Functional assessment
HGM
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# A Survey of Riverine Fish Assemblages and Habitat of the Upper Des Plaines River System

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*Abstract – Fish community and habitat surveys were conducted in the upper Des Plaines River system to determine current status of fish species distribution, to assess overall stream quality and to evaluate the potential for ecosystem restoration. During the period from 2002 to 2004, forty-nine sites upstream of Salt Creek in Illinois and the entire watershed in Wisconsin were surveyed for fish species richness, biological integrity and riverine habitat. Forty-three native species of fishes were found, twenty-three less than the reconstructed pre-settlement fish assemblage. One species not native to the upper Des Plaines River system and four species not native to the North American continent were also present. The Index of Biotic Integrity (IBI) developed by Illinois EPA was utilized to assess biological integrity. IBI scores ranged from 0 to 44, with most in the range classified as "limited aquatic resource". Although some of the stations in the upper watershed received higher IBI scores, overall scores were similar in the agricultural areas of Wisconsin and the urbanized areas in Illinois. The Qualitative Habitat Evaluation Procedure (QHEI) developed by the Ohio EPA was utilized to assess riverine habitat quality. The average QHEI score of 44 classifies the upper Des Plaines River system as a "moderate aquatic resource" in terms of riverine habitat. Fish and habitat survey results suggest Newport Ditch, Kilbourn Road Ditch, Brighton Creek, Bull Creek, Center Creek and the upper reaches of the Des Plaines River subwatersheds as high restoration priorities. Riverine restoration should include reestablishment of hydrology & hydraulics, stream channel morphology, channel complexity and native riparian plant communities. Any restoration effort should consider the impact of fish migration barriers and include plans to restore connectivity through dam removal or addition of fish passage, particularly at the Hofmann Dam, a major barrier to restoration in the upper watershed.*

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## Introduction

Stream degradation and reduction of biotic integrity are widespread problems in watersheds throughout the country, both in agricultural and urban areas. In addition to effects resulting from land use practices, sources of stream degradation include water quality limitations, channel modifications, and fragmentation due to dams and other migration barriers. In many cases, combinations of factors contribute to degraded conditions. Moreover, interaction between known stressors and natural stream characteristics, such as soil types, landform, and other features may affect the level of degradation and potential for restoration for certain stream types.

In recent years there has been an emphasis on an ecosystem or watershed-based approach to stream restoration. A key component in setting restoration priorities is identification of primary limiting factors. Although the sources of degradation may be multi-factorial, baseline information on biotic communities, combined with information on physical conditions can help direct restoration expenditures in a logical manner. For example, extensive habitat restoration in a water quality limited system is not effective use

of limited financial resources. Similarly, habitat or water quality restoration in a fragmented system lacking quality recruitment sources may not result in restoration of biotic integrity.

The upper Des Plaines River system is highly degraded, resultant from a variety of landscape-scale impacts, including substantial and widespread water quality impacts due to urbanization and agricultural practices. The presence of 13 mainstem dams and a many tributary barriers have also led to a highly fragmented condition. Although some recent survey information is available for the upper Des Plaines River, a comprehensive basin-wide study including areas in Illinois and Wisconsin is not currently available. With the increased interests in restoration, and flood mitigation directed towards this and other large urban river basins by Federal, State, and local agencies, basic physical and biological information is crucial to directing restoration activities and priorities. Large-scale studies of severely degraded river systems are generally limited, even though they are extremely useful in identifying factors affecting fish community structure and species distribution in large.

In this study we provide baseline information on the upper Des Plaines River system in Illinois and Wisconsin for both fish communities and physical habitat conditions. Survey data were also used to characterize stream quality using both biotic and abiotic indices. The primary factors affecting fish species distribution and community structure are evaluated in the context of historic data and current recruitment sources. Finally, we attempt to provide a framework to guide restoration priorities in this and other large, degraded watersheds.

### *Study Area*

This study included the mainstem of the Des Plaines River and all tributary streams above the Salt Creek confluence, which includes Kenosha and Racine counties in Wisconsin and Lake and Cook counties in Illinois (Map 1). The upper Des Plaines River watershed is approximately 135 square miles in Wisconsin and 350 square miles in Illinois. Historically, the Des Plaines River system was a narrow elongated depression within the late Wisconsinan Age glacial drift (Pepoon 1927). The upper Des Plaines River, from the confluence of Salt Creek northward, was very shallow and about 30 feet wide with banks of terraced alluvium and covered with hydrophytic vegetation (Pepoon 1927). As European settlement increased, the watershed began to be stripped of natural plant communities, initially due to agricultural practices. Landuse in many areas of the watershed were gradually converted to urban and suburban use dominated by rooftops, pavement and other impervious surfaces. Streams became more entrenched and began to exhibit signs of an altered hydrology with increased peak flows and reduced base flows. As of 1990, land use in the Wisconsin portion of the watershed consisted of 68.3% agriculture, 14.7% natural landscape, and 11.8 % urban (SEWRPC 2003). Land use in the Illinois portion of the watershed consists of 57.4% urban, 23% natural landscape, and 19.6% agriculture (ILDNR 1998). Table 1 shows subwatershed size and landuse. These landscape-scale changes in land-use, and subsequent hydrologic and hydraulic alterations, have led to decreased habitat quality, degraded water quality and reduced species richness.

## Methods

### *Fish Collections*

Forty-nine sampling sites (Map 1 & Table 2) were selected to provide adequate spatial distribution for determining stream quality within each subwatershed of the upper Des Plaines River system; twenty-nine wadable tributary sites were surveyed for stream fishes using a backpack electro-fishing unit. All habitats within the designated reach were sampled thoroughly by one shocking unit and up to three individuals for netting fish. For tributary streams, collection effort was thus standardized by setting station length at 15 times the mean stream width (Smogor 2002).

A total of 20 non-wadable sites were sampled on the mainstem Des Plaines River using a boat mounted electro-fishing unit. A distance of 15 times the mean stream width for these larger streams would be

# Map 1: Study are watersheds, survey sites and dams

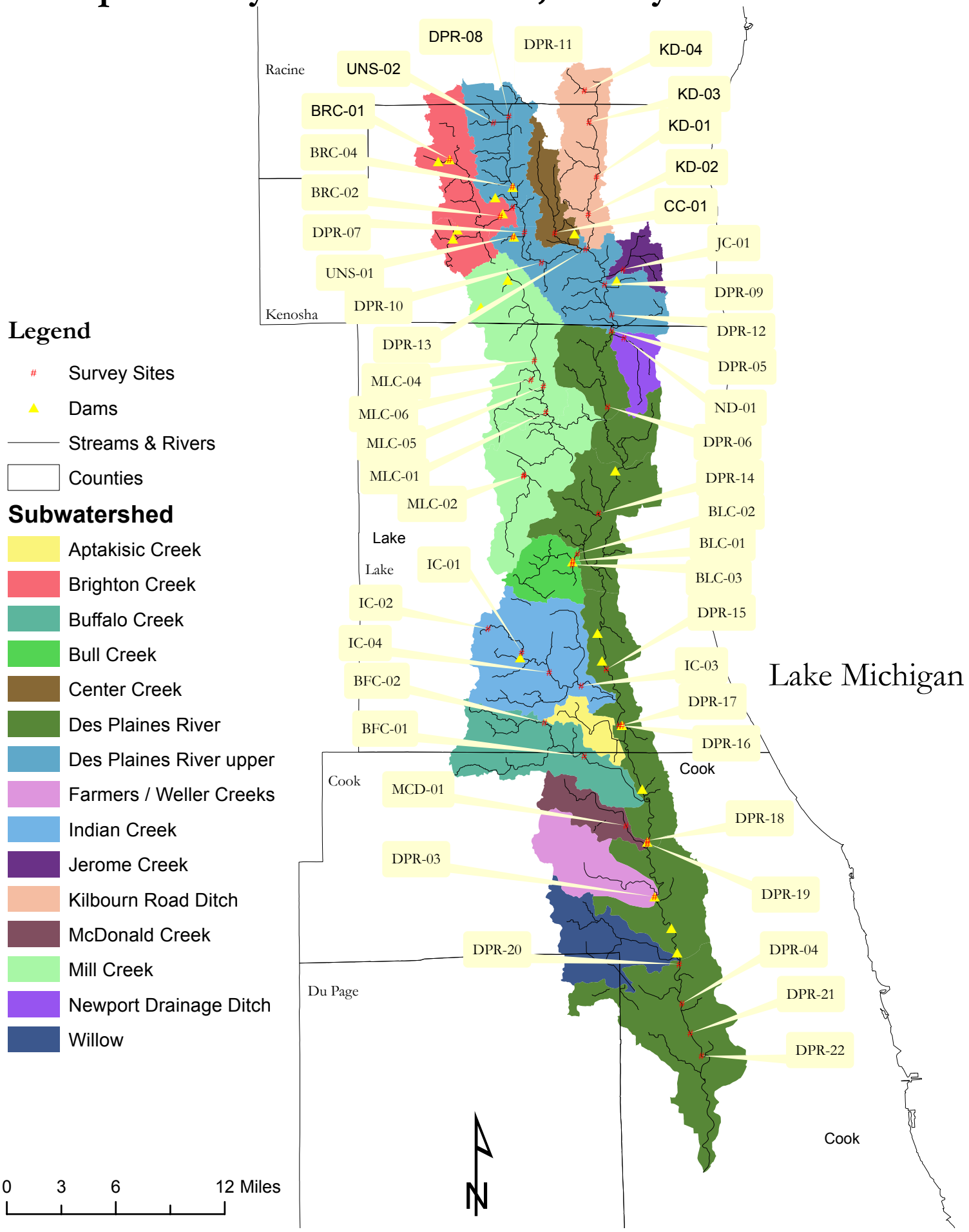

Table 1 – Survey site localities for the upper Des Plaines River system

| | | | Landuse acres | | | Landuse % | | |
|---|---|---|---|---|---|---|---|---|
| Subwatershed | Acres | Square Miles | Natural | Urban | Agriculture | Natural | Urban | Agriculture |
| Aptakisic Creek | 4,102 | 6.4 | 785 | 3,170 | 147 | 19% | 77% | 4% |
| Brighton Creek | 17,684 | 28 | 6,022 | 3,803 | 7,859 | 34% | 22% | 44% |
| Buffalo Creek | 19,242 | 30.1 | 4,592 | 14,197 | 453 | 24% | 74% | 2% |
| Bull Creek | 7,621 | 11.9 | 2,301 | 4,087 | 1,233 | 30% | 54% | 16% |
| Center Creek | 6,593 | 10.3 | 743 | 783 | 5,067 | 11% | 12% | 77% |
| Des Plaines River | 95,169 | 148.7 | 30,422 | 59,454 | 5,293 | 32% | 62% | 6% |
| Des Plaines River upper | 34,348 | 53.7 | 9,530 | 7,529 | 17,289 | 28% | 22% | 50% |
| Farmers & Weller Creeks | 12,148 | 19.0 | 4,355 | 11,313 | 0 | 36% | 93% | 0% |
| Indian Creek | 26,952 | 42.1 | 9,113 | 15,233 | 2,606 | 34% | 57% | 10% |
| Jerome Creek | 3,784 | 5.9 | 900 | 1,745 | 1,138 | 24% | 46% | 30% |
| Kilbourn Road Ditch | 15,127 | 23.6 | 2,004 | 3,376 | 9,747 | 13% | 22% | 64% |
| McDonald Creek | 6,475 | 10.1 | 688 | 5,787 | 0 | 11% | 89% | 0% |
| Mill Creek | 41,956 | 65.6 | 12,831 | 13,887 | 15,238 | 31% | 33% | 36% |
| Newport Drainage Ditch | 5,255 | 8.2 | 1,130 | 1,932 | 2,194 | 21% | 37% | 42% |
| Willow Creek | 13,660 | 21.3 | 1,408 | 12,245 | 7 | 10% | 90% | 0% |
| Upper Des Plaines Basin | 310,117 | 485 | 86,825 | 158,540 | 68,271 | 28% | 51% | 22% |

Table 2 – Survey site localities for the upper Des Plaines River system

| Subwatershed | Area mi sq | Site # | Stream | ST | Cnty | Locality |
|---|---|---|---|---|---|---|
| Kilbourn Road Ditch | 23.6 | KD-01 | Kilbourn Road Ditch | WI | Kenosha | Hwy 50 |
| | | KD-02 | Kilbourn Road Ditch | WI | Kenosha | Hwy K |
| | | KD-03 | Kilbourn Road Ditch | WI | Kenosha | Hwy A |
| | | KD-04 | Kilbourn Road Ditch | WI | Racine | Braun Rd. |
| Center Creek | 10.3 | CC-01 | Center Creek | WI | Kenosha | Hwy 50 |
| Brighton Creek | 20.4 | BRC-01 | Brighton Creek | WI | Kenosha | Hwy X |
| | | BRC-02 | Brighton Creek | WI | Kenosha | Reach between Hwy K @ Rt. 45 |
| | | BRC-04 | Brighton Creek | WI | Kenosha | Pleasant Landfill |
| Jerome Creek | 5.9 | JC-01 | Jerome Creek | WI | Kenosha | Hwy H, just north of 95th St. |
| Des Plaines River upper | 53.7 | DPR-10 | Des Plaines River | WI | Kenosha | Hwy MB |
| | | DPR-11 | Des Plaines River | WI | Kenosha | Hwy N |
| | | DPR-12 | Des Plaines River | WI | Kenosha | Hwy ML |
| | | DPR-13 | Des Plaines River | WI | Kenosha | At 120th Ave adjacent to I-94 |
| | | UNS-01 | Unnamed stream | WI | Kenosha | Hwy D .5 miles NE of Bristol |
| | | UNS-02 | Unnamed stream | WI | Kenosha | Hwy 45 |
| Des Plaines River | 149.5 | DPR-03 | Des Plaines River | IL | Cook | Dempster Dam Downstream |
| | | DPR-04 | Des Plaines River | IL | Cook | Irving Park Rd. |
| | | DPR-05 | Des Plaines River | IL | Lake | Russell Rd. |
| | | DPR-06 | Des Plaines River | IL | Lake | Wadsworth Rd. |
| | | DPR-07 | Des Plaines River | WI | Kenosha | Hwy 50 |
| | | DPR-08 | Des Plaines River | WI | Kenosha | Hwy KR; in Dragway |
| | | DPR-09 | Des Plaines River | WI | Kenosha | Lake View Parkway |
| | | DPR-14 | Des Plaines River | IL | Lake | Belvidere Rd. |
| | | DPR-15 | Des Plaines River | IL | Lake | Dan Wright Woods, 1.5 mi. DS Rt 60 |
| | | DPR-16 | Des Plaines River | IL | Lake | Ryerson Woods Dam Upstream |
| | | DPR-17 | Des Plaines River | IL | Lake | Ryerson Woods Dam Downstream |
| | | DPR-18 | Des Plaines River | IL | Cook | Dam #2 Woods, Upstream, Foundry Road |
| | | DPR-19 | Des Plaines River | IL | Cook | Dam #2 Woods, Downstream, Foundry Road |
| | | DPR-20 | Des Plaines River | IL | Cook | I 294 Bridge |
| | | DPR-21 | Des Plaines River | IL | Cook | Grand Ave. |
| | | DPR-22 | Des Plaines River | IL | Cook | Armitage Ave. Dam Upstream |
| Newport | 8.2 | ND-01 | Newport Ditch | IL | Lake | Kilbourn Rd. |
| Mill Creek | 65.6 | MLC-01 | Mill Creek | IL | Lake | Milburn Rd. just W of school |
| | | MLC-02 | Mill Creek | IL | Lake | Rollins Savanna below dam |
| | | MLC-03 | Mill Creek | IL | Lake | Rollins Savanna above dam |
| | | MLC-04 | N.B. Mill Creek | IL | Lake | Ethel's Woods above Rasmussen Lake |
| | | MLC-05 | N.B. Mill Creek | IL | Lake | Ethel's Woods below Rasmussen Lake |
| | | MLC-06 | Hastings Creek | IL | Lake | |
| Bull Creek | 11.9 | BLC-01 | Bull Creek | IL | Lake | Peterson Rd. |
| | | BLC-02 | Bull Creek | IL | Lake | Hwy 21 |
| | | BLC-03 | Bull Creek | IL | Lake | Cass Park just south of Rt. 137 |
| Indiana Creek | 42.1 | IC-01 | Indian Creek | IL | Lake | Seneca Dr. |
| | | IC-02 | Killdeer Creek | IL | Lake | Tandy Park at McHenry Rd. |
| | | IC-03 | Indian Creek | IL | Lake | Prairie View Park (R&R) & Port Clinton Rd. |
| | | IC-04 | Indian Creek | IL | Lake | Parallel to Rt. 83 and Endwood Dr. |
| Buffalo Creek | 30.1 | BFC-01 | Buffalo Creek | IL | Cook | Route 83 and Buffalo Grove Rd. |
| | | BFC-02 | Buffalo Creek | IL | Lake | Coffin Rd. @ Long Grove |
| McDondald Creek | 10.1 | MDC-01 | McDonald Creek | IL | Cook | McDonald Rd. |

impractical to sample in a reasonable time frame, therefore each location was sampled for one hour of boat electro-fishing, covering all visible habitat types at each given site. Two individuals situated at the bow of the boat used lightweight dip nets to collect as many fish as possible.

All small fishes, under 150 mm, were immediately preserved in a 10% formalin solution for enumeration and identification in the laboratory. Fishes over 150 mm were identified in the field and released, with the exception of voucher specimens. At minimum, one individual of each species collected at each station was documented by photograph or preservation. All preserved specimens reside in the Field Museum of Natural History and Southern Illinois University fish collections.

*Index of Biotic Integrity*

The Index of Biotic Integrity (IBI) employs fish assemblage as the indicator of biological form and function. Fish are not only a highly visible part of the aquatic resource, but they are quite sensitive to the surrounding water and habitat quality. This does not suggest that the use of other organisms is insufficient or inappropriate (Simon 1991). The ambient condition of the upper Des Plaines River system was evaluated using the IBI (Karr 1981; Karr et. al. 1986; Simon 1991; Smogor 2002). This method makes use of a systematic process to set quantitative criteria that enables the measurement of riverine stream quality. This index employs ten parameters or "metrics" based on structural and functional components of the fish assemblage. Structural components include diversity, taxonomic guilds, and abundance. Functional components include feeding or trophic guilds, reproductive behavior, tolerance to adverse environmental stressors, and individual stresses (Simon 1991; Smogor 2002). These metrics are calibrated to for differences in stream size and geographic region. The following ten metrics may each receive a score 0 to 6, based on comparison to unaltered reference sites, with a total IBI score ranging from 0 to 60 (Smogor 2002):

1) Number of native fish species
2) Number of native Catostomid species
3) Number of native Centrarchid species
4) Number of native intolerant species
5) Number of native Cyprinid species
6) Number of native benthic insectivore species
7) Proportion of individuals as specialist benthic insectivores
8) Proportion of individuals as generalist feeders
9) Proportion of individuals as obligate course-mineral substrate spawners and intolerant
10) Proportion of tolerant species

*Qualitative Habitat Evaluation Index*

The Qualitative Habitat Evaluation Index (QHEI), developed by the Ohio EPA (Rankin 1989), was employed to assess the habitat quality of the upper Des Plaines River system. The QHEI consists of eight sections with a maximum total of 100 points:

1) Characterization of substrate types and the effects of siltation
2) Characterization of in-stream cover
3) Characterization of channel morphology
4) Characterization of the riparian zone and bank erosion
5) Assessment of the pool / glide & riffle / run
6) Gradient
7) Shade
8) Channel incision

One raw data sheet consisting of one to five transects was completed for each site. The sites were assessed from a river right descending perspective. The transects were dependent and based on the area

sampled for fishes and began some distance up or downstream from evident bridge disturbance to the stream; however, the impacts from these structures should be taken into consideration when implementing restoration measures since this study recommends remedies to anthropogenic disturbance to stream morphology and function. A variable of impoundment was added to the QHEI for this particular study under the channel morphology section to give weight to stream connectivity. If backwater effects from a downstream structure impacted the stream section, a score of zero was received, if the stream section was free flowing, a score of nine was received. Other impacts of dams were indirectly reflected in stream morphology and function parameter. See Attachment 1 for QHEI scoring guide.

*Subwatershed Quality Ranking*

A ranking system was implemented to determine priority for riverine restoration sites for each subwatershed. This ranking system is based upon the five categorical descriptions of the IBI and QHEI (Table 3). For example, the survey sites that resemble least disturbed conditions, and therefore the best available, would fall under rank five, Unique Aquatic Resource. Survey sites that have been extremely degraded and have lost practically all ecological function would fall under rank 1 (Imperiled Aquatic Resource). The rank for each subwatershed was determined by averaging the IBI and QHEI scores of survey sites within a basin; then averaging the individual mean IBI and QHEI rank numbers. This process integrates biological integrity and habitat quality scores into a single combined ranking for an individual subwatershed. Rank numbers may fall in between two descriptions (↕), and therefore have characteristics of both descriptors. Sites that have major disparity between the quality of habitat and the quality of the fish assemblage may be attributed to prevention of fish migration by dams or poor water quality, thus habitat would not be the limiting factor at the site.

Table 3 - Combined Riverine Ranking Scheme

| IBI | QHEI | Rank | Descriptions |
|---|---|---|---|
| 51 - 60 | 80 - 100 | 5 | Unique Aquatic Resource |
| | | 4.5 | ↕ |
| 41 - 50 | 60 - 79 | 4 | Highly Valued Resource |
| | | 3.5 | ↕ |
| 31 - 40 | 40 - 59 | 3 | Moderate Aquatic Resource |
| | | 2.5 | ↕ |
| 21 - 30 | 20 - 39 | 2 | Limited Aquatic Resource |
| | | 1.5 | ↕ |
| 0 - 20 | 0 - 19 | 1 | Imperiled Aquatic Resource |

**Results**

*Fishes*

A total of 43 native fish species were collected in the upper Des Plaines River system during 2002-2004. In addition to *Cyprinus carpio* (common carp) and *Carassius auratus* (goldfish), two other non-native species were collected, *Barbonymus schwanenfeldii* (tinfoil barb), and *Pterogloplichthys disjunctivis* (sailfin catfish). Also collected was *Lepomis microlophus* (redear sunfish), which are native to Illinois, but does not naturally occur in the Des Plaines River system. Species distribution by collection site is shown in Table 4. The most frequently occurring species within the upper Des Plaines River system are all considered tolerant species; 88% *Lepomis cyanellus* (green sunfish), 83% *Lepomis macrochirus* (bluegill), 69% *Pimephales notatus* (bluntnose minnow), 69% *Catostomus commersonii* (white sucker), 65% *Micropterus salmoides* (largemouth bass), and 63% *Fundulus notatus* (blackstripe topminnow). Table 5 shows the percent occurrence of all species collected for this study.

The only abundant non-native species was common carp with a 42% occurrence rate. Based on the observed distribution in this study, common carp appear to occupy larger streams and rivers as adults and

Table 4 - Fish distribution by site within the upper Des Plaines River system.

* State Threatened, ^non-native

| Family | Species | Common Name | BFC-01 | BFC-02 | BLC-01 | BLC-02 | BLC-03 | BRC-01 | BRC-02 | BRC-04 | CC-01 | DPR-03 | DPR-04 | DPR-05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amiidae | *Amia calva* | bowfin | | | | | | | | | | | | |
| Clupeidae | *Dorosoma cepedianum* | gizzard shad | | | | | | | | | X | | | |
| Cyprinidae | *Cyprinus carpio*^ | common carp | X | | | | | | | | | X | X | X |
| | *Carassius auratus*^ | goldfish | | | | | | | | | | | X | X |
| | *Notemigonus crysoleucas* | golden shiner | X | | | | X | | X | | | | | |
| | *Semotilus atromaculatus* | creek chub | | X | X | X | X | X | X | X | X | | X | |
| | *Nocomis bigutattus* | hornyhead chub | | | | X | | | X | X | | X | X | |
| | *Cyprinella spiloptera* | spotfin shiner | | | | | | | X | X | | X | X | X |
| | *Luxilus chrysocephalus* | striped shiner | | | | | | | X | X | | | | |
| | *Lythrurus umbratilis* | redfin shiner | | | | | | | | | | | | |
| | *Pimephales notatus* | bluntnose minnow | X | X | | | X | | X | X | X | X | X | X |
| | *Pimephales promelas* | fathead minnow | | X | | | | | X | | X | X | X | |
| | *Notropis dorsalis* | bigmouth shiner | | | | | | | | | X | | X | |
| | *Notropis heterodon** | blackchin shiner | | | | | | | | | | | | |
| | *Notropis stramineus* | sand shiner | | | | | | | | | | X | X | X |
| | *Notropis volucellus* | mimic shiner | | | | | | | | | | | | |
| | *Campostoma anomalum* | central stoneroller | | | | X | | | X | X | X | | | X |
| | *Rhinichthys atratulus* | blacknose dace | | | | | | | | | | | | |
| | *Barbonymus schwanenfeldii*^ | tinfoil barb | | | | | | | | | | | | |
| Catostomidae | *Catostomus commersonii* | white sucker | X | X | X | X | X | | X | X | X | X | X | X |
| | *Minytrema melanops* | spotted sucker | | | | | | | X | X | | X | | X |
| Ictaluridae | *Ictalurus punctatus* | channel cat | | | | | | | | | | X | | X |
| | *Ameiurus natalis* | yellow bullhead | X | X | | | | | X | | | X | | X |
| | *Ameiurus melas* | black bullhead | X | X | | | | | X | | | | | X |
| | *Noturus flavus* | stonecat | | | | | | | | | | X | | |
| | *Noturus gyrinus* | tadpole madtom | | | | | | | X | | | | | |
| Loricaridae | *Pterogloplichthys disjunctivis*^ | sailfin catfish | | | | | | | | | | X | | |
| Umbridae | *Umbra limi* | central mudminnow | | | X | | X | X | X | X | X | | | |
| Esocidae | *Esox americanus* | grass pickerel | | | | | | | | | | | | |
| | *Esox lucius* | northern pike | | | | | | | X | | | X | | |
| Aphredodaridae | *Aphredodarus sayanus* | pirate perch | | | | | | | X | X | | | | |
| Gasterosteidae | *Culaea inconstans* | brook stickleback | | | | | | | | | | | | |
| Fundulidae | *Fundulus notatus* | blackstripe topminnow | | | | | | | X | X | X | X | X | X |
| Moronidae | *Morone mississippiensis* | yellow bass | | | | | | | | | | | | |
| Centrarchidae | *Ambloplites rupestris* | rockbass | | | | | | | | | | X | | |
| | *Pomoxis nigromaculatus* | black crappie | | | | | | | | | | X | X | X |
| | *Micropterus salmoides* | largemouth bass | X | | | X | | X | | X | X | X | | X |
| | *Micropterus dolomieu* | smallmouth bass | | | | | | | | | | | | |
| | *Lepomis humilis* | orangespotted sunfish | | | | | | | | | | X | X | X |
| | *Lepomis macrochirus* | bluegill | X | X | | X | X | X | X | X | | X | X | X |
| | *Lepomis microlophus*^ | redear sunfish | | | | | | | | | | | | |
| | *Lepomis cyanellus* | green sunfish | X | X | X | X | | X | X | X | X | X | | X |
| | *Lepomis gibbosus* | pumpkinseed | | | | | | X | X | X | | X | | X |
| Perciadae | *Perca flavescens* | yellow perch | | | | | | | | | | X | | |
| | *Etheostoma exile* | Iowa darter | | | | | | | | | | | | |
| | *Etheostoma flabellare* | fantail darter | | | | X | | | | | | | | |
| | *Etheostoma nigrum* | Johnny darter | | | | | | | X | X | X | X | X | X |
| | *Percina maculata* | blackside darter | | | | X | | | X | X | X | X | | X |
| | Species Richness | | 9 | 8 | 4 | 9 | 6 | 6 | 22 | 17 | 13 | 24 | 15 | 20 |
| | IBI | | 14 | 10 | 11 | 37 | 15 | 15 | 44 | 37 | 24 | 31 | 24 | 32 |
| | QHEI | | 47 | 54 | 76 | 48 | 84 | 33 | 58 | 59 | 45 | 34 | 36 | 35 |

Table 4 - Fish distribution by site within the upper Des Plaines River system.

* State Threatened, ^non-native

| Family | Species | Common Name | DPR-06 | DPR-07 | DPR-08 | DPR-09 | DPR-10 | DPR-11 | DPR-12 | DPR-13 | DPR-14 | DPR-15 | DPR-16 | DPR-17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amiidae | *Amia calva* | bowfin | | | | | | | | | | | | |
| Clupeidae | *Dorosoma cepedianum* | gizzard shad | | | | | | | X | X | | X | X | |
| Cyprinidae | *Cyprinus carpio*^ | common carp | | X | X | X | | | | | | | X | X |
| | *Carassius auratus*^ | goldfish | | | | | | | | | | | | |
| | *Notemigonus crysoleucas* | golden shiner | X | X | | | | | | | X | | | X |
| | *Semotilus atromaculatus* | creek chub | | X | X | | | X | | | X | | | X |
| | *Nocomis bigutattus* | hornyhead chub | | X | | | | | | | X | | | X |
| | *Cyprinella spiloptera* | spotfin shiner | | X | X | X | X | | | | X | X | X | |
| | *Luxilus chrysocephalus* | striped shiner | | | X | | | | | | | | | |
| | *Lythrurus umbratilis* | redfin shiner | | | | | | | | | | | | |
| | *Pimephales notatus* | bluntnose minnow | X | X | X | | X | | | | X | X | X | X |
| | *Pimephales promelas* | fathead minnow | | | X | | X | | | | | | | X |
| | *Notropis dorsalis* | bigmouth shiner | | | X | | | | | | | | | |
| | *Notropis heterodon** | blackchin shiner | | | | | | | | | X | | | |
| | *Notropis stramineus* | sand shiner | | | X | X | | | | | X | X | X | X |
| | *Notropis volucellus* | mimic shiner | | | | | | | | | | | | |
| | *Campostoma anomalum* | central stoneroller | | X | X | | | X | | | | | | |
| | *Rhinichthys atratulus* | blacknose dace | | | X | | | X | | | | | | |
| | *Barbonymus schwanenfeldii*^ | tinfoil barb | | | | | | | | | | | | |
| Catostomidae | *Catostomus commersonii* | white sucker | X | X | X | | | X | | | X | X | | |
| | *Minytrema melanops* | spotted sucker | X | X | | | X | | | | X | X | X | |
| Ictaluridae | *Ictalurus punctatus* | channel cat | | | | | | | | | | | | |
| | *Ameiurus natalis* | yellow bullhead | | | | X | X | | | | | | | X |
| | *Ameiurus melas* | black bullhead | | X | | | X | | X | X | | | | |
| | *Noturus flavus* | stonecat | | | | | | | | | | | | X |
| | *Noturus gyrinus* | tadpole madtom | | X | | | | | | | | | | |
| Loricaridae | *Pterogloplichthys disjunctivis*^ | sailfin catfish | | | | | | | | | | | | |
| Umbridae | *Umbra limi* | central mudminnow | | X | X | X | | | | | | | | |
| Esocidae | *Esox americanus* | grass pickerel | X | | | | | | | | | | | |
| | *Esox lucius* | northern pike | | X | | | | | | | X | | | |
| Aphredodaridae | *Aphredodarus sayanus* | pirate perch | | | X | | | | | | | | | |
| Gasterosteidae | *Culaea inconstans* | brook stickleback | | | | | | | | | | | | |
| Fundulidae | *Fundulus notatus* | blackstripe topminnow | X | X | X | X | | | X | X | X | X | X | X |
| Moronidae | *Morone mississippiensis* | yellow bass | | | | | | | | | | | | |
| Centrarchidae | *Ambloplites rupestris* | rockbass | | | | | | | | | X | | | X |
| | *Pomoxis nigromaculatus* | black crappie | X | X | | | X | | X | X | X | | X | X |
| | *Micropterus salmoides* | largemouth bass | X | X | | X | X | X | X | X | X | X | X | X |
| | *Micropterus dolomieu* | smallmouth bass | | | | | | | | | | | | |
| | *Lepomis humilis* | orangespotted sunfish | X | | X | | | | | | X | | X | X |
| | *Lepomis macrochirus* | bluegill | X | X | | X | X | X | X | X | X | X | X | X |
| | *Lepomis microlophus*^ | redear sunfish | X | | | | | | | | | | | |
| | *Lepomis cyanellus* | green sunfish | | X | X | X | X | X | X | X | X | X | X | X |
| | *Lepomis gibbosus* | pumpkinseed | X | | X | X | X | | X | X | | | | X |
| Perciadae | *Perca flavescens* | yellow perch | | | | | | | | | | | | |
| | *Etheostoma exile* | Iowa darter | | | X | | | | | | | | | |
| | *Etheostoma flabellare* | fantail darter | | | | | | | | | | | | |
| | *Etheostoma nigrum* | Johnny darter | X | X | X | X | X | X | | | | X | X | X |
| | *Percina maculata* | blackside darter | | X | X | | | | X | X | | X | | |
| | Species Richness | | 13 | 20 | 20 | 11 | 12 | 8 | 9 | 9 | 17 | 12 | 13 | 18 |
| | IBI | | 30 | 34 | 34 | 23 | 24 | 25 | 22 | 21 | 34 | 28 | 25 | 25 |
| | QHEI | | 36 | 33 | 67 | 51 | 41 | 20 | 49 | 46 | 32 | 51 | 23 | 48 |

Table 4 - Fish distribution by site within the upper Des Plaines River system.

* State Threatened, ^non-native

| Family | Species | Common Name | DPR-18 | DPR-19 | DPR-20 | DPR-21 | DPR-22 | IC-01 | IC-02 | IC-03 | IC-04 | JC-01 | KD-01 | KD-02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amiidae | *Amia calva* | bowfin | | | | | | | | | | | | |
| Clupeidae | *Dorosoma cepedianum* | gizzard shad | | | X | | | | | | | | | |
| Cyprinidae | *Cyprinus carpio*^ | common carp | X | X | X | | X | | X | X | | | | X |
| | *Carassius auratus*^ | goldfish | | | X | | | | | | | | | |
| | *Notemigonus crysoleucas* | golden shiner | | | | | | | | X | | | | |
| | *Semotilus atromaculatus* | creek chub | | X | | | | X | | | | | X | X |
| | *Nocomis bigutattus* | hornyhead chub | | X | | X | | | | | | | X | X |
| | *Cyprinella spiloptera* | spotfin shiner | | X | X | X | X | | | | | | | X |
| | *Luxilus chrysocephalus* | striped shiner | | | | | | | | | | | | X |
| | *Lythrurus umbratilis* | redfin shiner | | | | | | | | | | | | |
| | *Pimephales notatus* | bluntnose minnow | | X | X | X | X | X | | X | X | | X | X |
| | *Pimephales promelas* | fathead minnow | | X | | X | | | | | | | X | X |
| | *Notropis dorsalis* | bigmouth shiner | | | | | | X | | | | | | |
| | *Notropis heterodon** | blackchin shiner | | | | | | | | | | | | |
| | *Notropis stramineus* | sand shiner | | X | X | X | | | | | | | | |
| | *Notropis volucellus* | mimic shiner | | X | | | | | | | | | | |
| | *Campostoma anomalum* | central stoneroller | | | | | | | | | | | X | X |
| | *Rhinichthys atratulus* | blacknose dace | | | | | | | | | | | | |
| | *Barbonymus schwanenfeldii*^ | tinfoil barb | | X | | | | | | | | | | |
| Catostomidae | *Catostomus commersonii* | white sucker | X | X | X | X | X | X | | X | X | | X | X |
| | *Minytrema melanops* | spotted sucker | X | X | X | X | X | | | | | | | |
| Ictaluridae | *Ictalurus punctatus* | channel cat | | X | X | | | | | | | | | |
| | *Ameiurus natalis* | yellow bullhead | | X | | | | | | X | X | | | |
| | *Ameiurus melas* | black bullhead | | | | | | | X | X | X | | | X |
| | *Noturus flavus* | stonecat | | | | | | | | | | | | |
| | *Noturus gyrinus* | tadpole madtom | | X | | | | | | | | | | |
| Loricaridae | *Pterogloplichthys disjunctivis*^ | sailfin catfish | | | | | | | | | | | | |
| Umbridae | *Umbra limi* | central mudminnow | | | | | | | | | X | X | X | X |
| Esocidae | *Esox americanus* | grass pickerel | | | | | | | | | | | | |
| | *Esox lucius* | northern pike | | X | | | | | | | | | | |
| Aphredodaridae | *Aphredodarus sayanus* | pirate perch | | | | | | | | | | X | X | X |
| Gasterosteidae | *Culaea inconstans* | brook stickleback | | | | | | | | | | | X | |
| Fundulidae | *Fundulus notatus* | blackstripe topminnow | X | X | X | X | X | | | | X | X | X | X |
| Moronidae | *Morone mississippiensis* | yellow bass | | | | | | | | | | | | |
| Centrarchidae | *Ambloplites rupestris* | rockbass | | X | X | X | | | | | | | | |
| | *Pomoxis nigromaculatus* | black crappie | | X | X | | | | | | | | | |
| | *Micropterus salmoides* | largemouth bass | X | X | | | | | X | X | X | | | X |
| | *Micropterus dolomieu* | smallmouth bass | | | | | | | | | | | | |
| | *Lepomis humilis* | orangespotted sunfish | | X | X | | | | | | | | | |
| | *Lepomis macrochirus* | bluegill | X | X | X | X | | X | X | X | X | | X | |
| | *Lepomis microlophus*^ | redear sunfish | | | | | | | | X | | | | |
| | *Lepomis cyanellus* | green sunfish | | X | X | X | X | X | X | | X | X | X | X |
| | *Lepomis gibbosus* | pumpkinseed | | X | | | | | | | | | X | |
| Perciadae | *Perca flavescens* | yellow perch | | | | | | | | | | | | |
| | *Etheostoma exile* | Iowa darter | | | | | | | | | | | | |
| | *Etheostoma flabellare* | fantail darter | | | | | | | | | | | | |
| | *Etheostoma nigrum* | Johnny darter | | X | | X | | X | | | | | X | X |
| | *Percina maculata* | blackside darter | | | X | X | X | | | | X | | | |
| | Species Richness | | 6 | 24 | 16 | 13 | 8 | 7 | 5 | 9 | 10 | 4 | 14 | 16 |
| | IBI | | 32 | 31 | 25 | 26 | 27 | 15 | 10 | 33 | 19 | 11 | 29 | 42 |
| | QHEI | | 21 | 53 | 28 | 26 | 19 | 50 | 48 | 26 | 44 | 45 | 35 | 59 |

Table 4 - Fish distribution by site within the upper Des Plaines River system.

* State Threatened, ^non-native

| Family | Species | Common Name | KD-03 | KD-04 | MDC-01 | MLC-01 | MLC-02 | MLC-03 | MLC-04 | MLC-05 | MLC-06 | ND-01 | UNS-01 | UNS-02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amiidae | *Amia calva* | bowfin | | | | | X | X | | | | | | |
| Clupeidae | *Dorosoma cepedianum* | gizzard shad | | | | | | | | | | | | |
| Cyprinidae | *Cyprinus carpio*^ | common carp | X | | | X | | | X | X | | | | |
| | *Carassius auratus*^ | goldfish | | | | | | | | | | | | |
| | *Notemigonus crysoleucas* | golden shiner | | X | | | X | X | | | | | X | |
| | *Semotilus atromaculatus* | creek chub | | X | X | | | | | X | | X | X | X |
| | *Nocomis bigutattus* | hornyhead chub | X | | | | | | | X | | X | | |
| | *Cyprinella spiloptera* | spotfin shiner | | | | | | | | | | X | | |
| | *Luxilus chrysocephalus* | striped shiner | | | | | | | | | | | | X |
| | *Lythrurus umbratilis* | redfin shiner | | | | | | | | | | X | | |
| | *Pimephales notatus* | bluntnose minnow | X | X | X | X | | | | X | | X | | X |
| | *Pimephales promelas* | fathead minnow | X | X | | X | | | | | | | | |
| | *Notropis dorsalis* | bigmouth shiner | | X | | | | | | | | | | X |
| | *Notropis heterodon** | blackchin shiner | | | | | | | | | | | | |
| | *Notropis stramineus* | sand shiner | | | | | | | | | | | | |
| | *Notropis volucellus* | mimic shiner | | | | | | | | | | | | |
| | *Campostoma anomalum* | central stoneroller | | | | | | | | | | | | X |
| | *Rhinichthys atratulus* | blacknose dace | | | | | | | | | | | | |
| | *Barbonymus schwanenfeldii*^ | tinfoil barb | | | | | | | | | | | | |
| Catostomidae | *Catostomus commersonii* | white sucker | X | X | X | X | | | | | | | X | X |
| | *Minytrema melanops* | spotted sucker | X | | | | | | | | | | | |
| Ictaluridae | *Ictalurus punctatus* | channel cat | | | | X | | | | X | | | | |
| | *Ameiurus natalis* | yellow bullhead | X | | X | | X | X | X | X | | | | |
| | *Ameiurus melas* | black bullhead | X | X | | X | X | | X | | | X | | |
| | *Noturus flavus* | stonecat | | | | | | | | | | | | |
| | *Noturus gyrinus* | tadpole madtom | | | | | X | | | X | | | | |
| Loricaridae | *Pterogloplichthys disjunctivis*^ | sailfin catfish | | | | | | | | | | | | |
| Umbridae | *Umbra limi* | central mudminnow | X | X | | X | X | | | | | X | | |
| Esocidae | *Esox americanus* | grass pickerel | | | | | | | | | | | | |
| | *Esox lucius* | northern pike | | | | | | X | | | | X | | |
| Aphredodaridae | *Aphredodarus sayanus* | pirate perch | X | X | | | | | | | | X | | |
| Gasterosteidae | *Culaea inconstans* | brook stickleback | | X | | | | | | | | | | |
| Fundulidae | *Fundulus notatus* | blackstripe topminnow | X | X | | X | | | X | | | X | | |
| Moronidae | *Morone mississippiensis* | yellow bass | | | | | X | | | | | | | |
| Centrarchidae | *Ambloplites rupestris* | rockbass | | | | | | | | | | | | |
| | *Pomoxis nigromaculatus* | black crappie | | | | X | X | X | X | X | | | | |
| | *Micropterus salmoides* | largemouth bass | X | X | X | X | X | | | X | | X | | |
| | *Micropterus dolomieu* | smallmouth bass | | | | | X | | | | | | | |
| | *Lepomis humilis* | orangespotted sunfish | | | | X | | | X | X | | | | |
| | *Lepomis macrochirus* | bluegill | | X | X | X | X | X | X | X | X | X | | X |
| | *Lepomis microlophus*^ | redear sunfish | | | | | | | | | | | | |
| | *Lepomis cyanellus* | green sunfish | X | X | X | X | X | X | X | X | | X | X | X |
| | *Lepomis gibbosus* | pumpkinseed | | | | | X | | X | X | X | X | X | |
| Perciadae | *Perca flavescens* | yellow perch | | | | X | X | X | | | | | | |
| | *Etheostoma exile* | Iowa darter | | | | | | | | | | | | |
| | *Etheostoma flabellare* | fantail darter | | | | | | | | | | | | |
| | *Etheostoma nigrum* | Johnny darter | X | X | | | X | | | | | X | | X |
| | *Percina maculata* | blackside darter | X | | | | | | | | | X | | |
| | Species Richness | | 15 | 15 | 7 | 14 | 15 | 8 | 9 | 13 | 2 | 16 | 5 | 9 |
| | IBI | | 27 | 31 | 14 | 23 | 23 | 15 | 14 | 25 | 0 | 39 | 16 | 31 |
| | QHEI | | 54 | 36 | 48 | 63 | 52 | 31 | 26 | 68 | 29 | 64 | 42 | 63 |

Table 5 - Species occurrence depicted by number of sites and % of total sites.

| Species | # of sites | % occurrence | Common name |
|---|---|---|---|
| *Lepomis cyanellus* | 42 | 88% | green sunfish |
| *Lepomis macrochirus* | 40 | 83% | bluegill |
| *Pimephales notatus* | 33 | 69% | bluntnose minnow |
| *Catostomus commersonii* | 33 | 69% | white sucker |
| *Micropterus salmoides* | 31 | 65% | largemouth bass |
| *Fundulus notatus* | 30 | 63% | blackstripe topminnow |
| *Etheostoma nigrum* | 25 | 52% | Johnny darter |
| *Semotilus atromaculatus* | 24 | 50% | creek chub |
| *Cyprinus carpio* | 20 | 42% | common carp |
| *Lepomis gibbosus* | 20 | 42% | pumpkinseed |
| *Cyprinella spiloptera* | 18 | 38% | spotfin shiner |
| *Ameiurus melas* | 18 | 38% | black bullhead |
| *Umbra limi* | 18 | 38% | central mudminnow |
| *Pomoxis nigromaculatus* | 18 | 38% | black crappie |
| *Ameiurus natalis* | 17 | 35% | yellow bullhead |
| *Percina maculata* | 17 | 35% | blackside darter |
| *Minytrema melanops* | 16 | 33% | spotted sucker |
| *Nocomis bigutattus* | 15 | 31% | hornyhead chub |
| *Pimephales promelas* | 15 | 31% | fathead minnow |
| *Lepomis humilis* | 13 | 27% | orangespotted sunfish |
| *Notemigonus crysoleucas* | 12 | 25% | golden shiner |
| *Notropis stramineus* | 12 | 25% | sand shiner |
| *Campostoma anomalum* | 11 | 23% | central stoneroller |
| *Aphredodarus sayanus* | 9 | 19% | pirate perch |
| *Esox lucius* | 7 | 15% | northern pike |
| *Dorosoma cepedianum* | 6 | 13% | gizzard shad |
| *Notropis dorsalis* | 6 | 13% | bigmouth shiner |
| *Ictalurus punctatus* | 6 | 13% | channel catfish |
| *Ambloplites rupestris* | 6 | 13% | rockbass |
| *Luxilus chrysocephalus* | 5 | 10% | striped shiner |
| *Noturus gyrinus* | 5 | 10% | tadpole madtom |
| *Perca flavescens* | 4 | 8% | yellow perch |
| *Carassius auratus* | 3 | 6% | goldfish |
| *Amia calva* | 2 | 4% | bowfin |
| *Rhinichthys atratulus* | 2 | 4% | blacknose dace |
| *Noturus flavus* | 2 | 4% | stonecat |
| *Culaea inconstans* | 2 | 4% | brook stickleback |
| *Lepomis microlophus* | 2 | 4% | redear sunfish |
| *Lythrurus umbratilis* | 1 | 2% | redfin shiner |
| *Notropis heterodon* | 1 | 2% | blackchin shiner |
| *Notropis volucellus* | 1 | 2% | mimic shiner |
| *Barbonymus schwanenfeldii* | 1 | 2% | tinfoil barb |
| *Pterogloplichthys disjunctivis* | 1 | 2% | sailfin catfish |
| *Esox americanus* | 1 | 2% | grass pickerel |
| *Morone mississippiensis* | 1 | 2% | yellow bass |
| *Micropterus dolomieu* | 1 | 2% | smallmouth bass |
| *Etheostoma exile* | 1 | 2% | Iowa darter |
| *Etheostoma flabellare* | 1 | 2% | fantail darter |

the pools of smaller streams during juvenile stages. Common carp were typically lower in abundance at stations with a higher habitat quality rating. Goldfish were only collected at two sites on the mainstem, (6% occurrence rate). One sailfin catfish was collected in the tailrace of the Dempster Avenue Dam (DPR-03) and one tinfoil barb was collected just downstream of Dam No. 2 (DPR-19) in Cook County. The sailfin catfish is native to South American rivers and the tinfoil barb native to Southeast Asian rivers. These two individuals were obvious releases from household aquariums and would probably not survive a Midwestern winter due to their tropical climate requirements. A redear sunfish was collected at Wadsworth Road (DPR-06). This fish is native to the southern third of Illinois, but can now be found in Northern regions as a result of stocking.

Native, but rare species recorded from the basin include *Amia calva* (bowfin), *Rhinichthys meleagris* (blacknose shiner), *Noturus flavus* (stonecat), *Culaea inconstans* (brook stickleback), *Notropis heterodon* (blackchin shiner), *Notropis volucellus* (mimic shiner), *Esox americanus* (grass pickerel), *Morone mississippiensis* (yellow bass), *Micropterus dolomieu* (smallmouth bass), *Etheostoma exile* (Iowa darter) and *Etheostoma flabellare* (fantail darter). These species occurred at only one or two sites and may represent relicts of previous wider distribution within the upper Des Plaines River system.

Bluegill, largemouth bass, *Ameiurus* sp. (bullheads), and *Pomoxis nigromaculatus* (black crappie) were the most commonly occurring sport fish present in the survey; however, most individuals were smaller than normal harvestable size, thus angling opportunities for these species are somewhat limited. Although *Esox lucius* (northern pike) and *Ictalurus punctatus* (channel catfish) were less abundant, individuals of larger sizes were present at some locations. Other sport fish such as *Ambloplites rupestris* (rockbass), *Micropterus dolomieu* (smallmouth bass), *Morone mississippiensis* (yellow bass) and *Perca flavescens* (yellow perch) were either too rare in abundance or attain insufficient size to be considered a productive fishery.

*Index of Biotic Integrity*

Of 48 sites assessed in the upper Des Plaines River system, 4% were classified as Highly Valued Resources, 27% Moderate Resources, 40% Limited Resources, and 29% Imperiled Resources. There were no sites classified as a Unique Aquatic Resource, the highest quality rating. Table 6 shows the scores for individual IBI metrics including the basin means for each metric. The highly degraded nature of the basin was indicated by several of the individual IBI metrics, most notably "number of intolerant species", which had a basin average of 1.0 out of a possible 6. Low basin means for all trophic metrics indicate lack of normal ecosystem function regarding stream food sources. Low gradient habitat conditions may account in part for lower scores for sucker species, which typically prefer riffle and run habitat; however, only two sucker species were collected in the entire basin, which included a number of higher gradient stations. Low gradient conditions were also indicated by the low metric mean for course mineral substrate spawners whereas some higher gradient locations yielded higher scores for this metric (Table 6). Low gradient conditions may have favored pool species such and sunfish as indicated by the higher mean scores for this sunfish species metric.

*Qualitative Habitat Evaluation Index*

Based on the Qualitative Habitat Evaluation Index there were two sites, both on Bull Creek (BLC-03 and BLC-01), which were classified as a Unique Aquatic Resource. These sites had excellent habitat and stream morphology although bank erosion and down cutting may indicate potential hydraulic problems. Five sites in the upper Des Plaines basin (10%) were classified as a Highly Valued Resource, 22 sites (46%) were classified as a Moderate Aquatic Resource, 17 sites (35%) were classified as Limited Aquatic Resource and 2 sites (4%) were classified as an Imperiled Aquatic Resource. Table 7 shows individual metric and total QHEI scores for the upper Des Plaines River system. The average QHEI score of 44 classifies the upper Des Plaines River system as a "moderate aquatic resource".

Table 6 - Individual IBI metric scores and basin averages for the Des Plaines River system

| Subwatershed | Site # | # of native fish sp. | # of native sucker sp. | # of native sunfish sp. | # of native intolerant sp. | # of native minnow sp. | # of native benthic invertivore sp. | Prop.(%) of indiv. as specialist benthic invertivores | Prop.(%) of indiv. as generalist feeders | Prop.(%) of indiv. as obligate course-mineral substrate spawners and intolerant | Prop.(%) of tolerant sp. | IBI Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kilbourn Road Ditch | KD-01 | 5 | 3 | 6 | 2 | 4 | 2 | 2 | 3 | 1 | 1 | 29 |
| | KD-02 | 5 | 2 | 5 | 2 | 5 | 3 | 6 | 6 | 5 | 3 | 42 |
| | KD-03 | 4 | 4 | 4 | 3 | 2 | 2 | 0 | 4 | 1 | 3 | 27 |
| | KD-04 | 5 | 2 | 6 | 0 | 5 | 2 | 1 | 5 | 1 | 4 | 31 |
| Center Creek | CC-01 | 4 | 2 | 5 | 0 | 4 | 3 | 0 | 2 | 2 | 2 | 24 |
| Des Plaines River upper | DPR-10 | 3 | 2 | 6 | 2 | 2 | 1 | x | x | x | 1 | 24 |
| | DPR-11 | 2 | 2 | 6 | 0 | 3 | 2 | 1 | 3 | 4 | 2 | 25 |
| | DPR-12 | 2 | 0 | 4 | 0 | 0 | 1 | 1 | 6 | 2 | 6 | 22 |
| | DPR-13 | 2 | 0 | 6 | 0 | 0 | 1 | x | x | x | 6 | 21 |
| | UNS-01 | 1 | 2 | 5 | 0 | 2 | 0 | x | x | x | 1 | 16 |
| | UNS-02 | 3 | 2 | 5 | 0 | 4 | 2 | 2 | 5 | 5 | 3 | 31 |
| Des Plaines River | DPR-03 | 5 | 2 | 6 | 2 | 4 | 2 | 1 | 4 | 1 | 4 | 31 |
| | DPR-04 | 3 | 1 | 3 | 1 | 5 | 1 | 2 | 3 | 1 | 4 | 24 |
| | DPR-05 | 4 | 3 | 6 | 1 | 3 | 2 | 2 | 5 | 1 | 5 | 32 |
| | DPR-06 | 3 | 2 | 6 | 1 | 3 | 1 | 2 | 6 | 1 | 5 | 30 |
| | DPR-07 | 5 | 4 | 6 | 3 | 4 | 3 | 2 | 3 | 1 | 3 | 34 |
| | DPR-08 | 6 | 2 | 6 | 2 | 6 | 4 | 1 | 3 | 1 | 3 | 34 |
| | DPR-09 | 2 | 0 | 5 | 0 | 2 | 1 | x | x | x | 6 | 23 |
| | DPR-14 | 4 | 2 | 6 | 3 | 5 | 0 | 0 | 6 | 2 | 6 | 34 |
| | DPR-15 | 2 | 3 | 5 | 1 | 2 | 2 | 1 | 3 | 3 | 6 | 28 |
| | DPR-16 | 2 | 1 | 5 | 1 | 2 | 1 | 1 | 6 | 1 | 5 | 25 |
| | DPR-17 | 4 | 0 | 6 | 1 | 4 | 1 | 1 | 2 | 1 | 5 | 25 |
| | DPR-18 | 6 | 3 | 2 | 2 | 1 | 0 | 0 | 6 | 6 | 6 | 32 |
| | DPR-19 | 5 | 2 | 6 | 2 | 5 | 2 | 1 | 2 | 1 | 5 | 31 |
| | DPR-20 | 3 | 2 | 4 | 1 | 3 | 1 | 1 | 6 | 1 | 3 | 25 |
| | DPR-21 | 3 | 2 | 3 | 2 | 4 | 2 | 1 | 4 | 1 | 4 | 26 |
| | DPR-22 | 1 | 2 | 1 | 1 | 2 | 2 | 6 | 6 | 6 | 5 | 27 |
| Brighton Creek | BRC-01 | 2 | 0 | 6 | 0 | 1 | 0 | 0 | 4 | 0 | 2 | 15 |
| | BRC-02 | 6 | 2 | 6 | 3 | 6 | 4 | 2 | 6 | 4 | 5 | 44 |
| | BRC-04 | 5 | 4 | 6 | 3 | 4 | 2 | 2 | 4 | 5 | 2 | 37 |
| Jerome Creek | JC-01 | 1 | 0 | 3 | 0 | 0 | 0 | x | x | x | 4 | 11 |
| Newport | ND-01 | 5 | 0 | 6 | 2 | 4 | 3 | 6 | 6 | 1 | 6 | 39 |
| Mill Creek | MLC-01 | 4 | 2 | 6 | 0 | 2 | 2 | 1 | 2 | 1 | 3 | 23 |
| | MLC-02 | 4 | 0 | 6 | 2 | 1 | 2 | 0 | 2 | 0 | 6 | 23 |
| | MLC-03 | 2 | 0 | 5 | 0 | 1 | 0 | 0 | 1 | 0 | 6 | 15 |
| | MLC-04 | 2 | 0 | 6 | 0 | 0 | 0 | 0 | 2 | 0 | 4 | 14 |
| | MLC-05 | 3 | 0 | 6 | 2 | 2 | 1 | 0 | 6 | 0 | 5 | 25 |
| | MLC-06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bull Creek | BLC-01 | 1 | 2 | 3 | 0 | 1 | 0 | x | x | x | 1 | 11 |
| | BLC-02 | 3 | 2 | 6 | 2 | 3 | 3 | 6 | 6 | 2 | 4 | 37 |
| | BLC-03 | 2 | 2 | 3 | 0 | 3 | 0 | x | x | x | 1 | 15 |
| Indiana Creek | IC-01 | 1 | 2 | 4 | 0 | 2 | 1 | 3 | 1 | 0 | 1 | 15 |
| | IC-02 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| | IC-03 | 4 | 2 | 5 | 1 | 4 | 2 | 1 | 6 | 5 | 3 | 33 |
| | IC-04 | 3 | 2 | 6 | 0 | 1 | 1 | 0 | 1 | 1 | 4 | 19 |
| Buffalo Creek | BFC-01 | 2 | 2 | 5 | 0 | 2 | 0 | 0 | 1 | 0 | 2 | 14 |
| | BFC-02 | 2 | 2 | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 10 |
| McDondald Creek | MDC-01 | 2 | 2 | 6 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 14 |
| DPR Basin Ave | | 3.1 | 1.6 | 5.0 | 1.0 | 2.6 | 1.4 | 1.4 | 3.6 | 1.7 | 3.5 | 24.5 |

x indicates not enough fish to calculate metric

Table 7 - Individual QHEI metric scores and basin averages for the Des Plaines River system

| Subwatershed | Site # | SUBSTRATE | INSTRM COVER | CHAN MORPH | RIPARIAN ZONE | POOL RIFFLE | GSI | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| Kilbourn Road Ditch | KD-01 | 5 | 5 | 11 | 5 | 4 | 5 | 35 |
| | KD-02 | 25 | 4 | 11 | 6 | 9 | 4 | 60 |
| | KD-03 | 20 | 3 | 12 | 3 | 11 | 3 | 51 |
| | KD-04 | 11 | 4 | 0 | 5 | 2 | 3 | 25 |
| Center Creek | CC-01 | 17 | 5 | 4 | 4 | 10 | 5 | 45 |
| Des Plaines River upper | DPR-10 | 9 | 2 | 14 | 10 | 3 | 3 | 41 |
| | DPR-11 | 0 | 2 | 8 | 4 | 3 | 4 | 21 |
| | DPR-12 | 14 | 2 | 11 | 10 | 6 | 7 | 50 |
| | DPR-13 | 10 | 3 | 12 | 9 | 3 | 6 | 43 |
| | UNS-01 | 8 | 5 | 1 | 3 | 7 | 6 | 30 |
| | UNS-02 | 22 | 5 | 14 | 4 | 9 | 8 | 62 |
| Des Plaines River | DPR-03 | 2 | 4 | 12 | 4 | 8 | 4 | 34 |
| | DPR-04 | 3 | 4 | 12 | 5 | 8 | 4 | 36 |
| | DPR-05 | 0 | 2 | 14 | 9 | 3 | 7 | 35 |
| | DPR-06 | 0 | 2 | 14 | 10 | 3 | 7 | 36 |
| | DPR-07 | 4 | 3 | 11 | 4 | 7 | 4 | 33 |
| | DPR-08 | 13 | 9 | 17 | 7 | 14 | 6 | 67 |
| | DPR-09 | 6 | 8 | 18 | 8 | 7 | 4 | 51 |
| | DPR-14 | 0 | 3 | 14 | 8 | 3 | 7 | 35 |
| | DPR-15 | 7 | 6 | 13 | 9 | 5 | 6 | 46 |
| | DPR-16 | 0 | 3 | 2 | 7 | 5 | 5 | 22 |
| | DPR-17 | 5 | 3 | 13 | 7 | 14 | 5 | 47 |
| | DPR-18 | 0 | 4 | 2 | 6 | 3 | 5 | 20 |
| | DPR-19 | 7 | 7 | 13 | 6 | 14 | 5 | 52 |
| | DPR-20 | 3 | 1 | 10 | 4 | 6 | 3 | 27 |
| | DPR-21 | 3 | 2 | 11 | 2 | 4 | 3 | 25 |
| | DPR-22 | 0 | 2 | 2 | 8 | 3 | 5 | 20 |
| Brighton Creek | BRC-01 | 13 | 7 | 2 | 6 | 1 | 4 | 33 |
| | BRC-02 | 15 | 7 | 13 | 8 | 9 | 6 | 58 |
| | BRC-04 | 21 | 6 | 11 | 6 | 11 | 4 | 59 |
| Jerome Creek | JC-01 | 14 | 4 | 10 | 5 | 7 | 5 | 44 |
| Newport | ND-01 | 16 | 8 | 18 | 5 | 10 | 7 | 63 |
| Mill Creek | MLC-01 | 20 | 7 | 14 | 7 | 7 | 8 | 62 |
| | MLC-02 | 9 | 4 | 15 | 8 | 3 | 4 | 43 |
| | MLC-03 | 4 | 4 | 5 | 8 | 1 | 4 | 26 |
| | MLC-04 | 4 | 5 | 2 | 5 | 3 | 6 | 25 |
| | MLC-05 | 17 | 12 | 14 | 7 | 15 | 3 | 68 |
| | MLC-06 | 9 | 2 | 1 | 7 | 7 | 2 | 28 |
| Bull Creek | BLC-01 | 18 | 13 | 19 | 7 | 13 | 7 | 76 |
| | BLC-02 | 9 | 6 | 14 | 8 | 6 | 6 | 48 |
| | BLC-03 | 17 | 17 | 17 | 9 | 15 | 8 | 84 |
| Indiana Creek | IC-01 | 11 | 8 | 11 | 5 | 6 | 6 | 47 |
| | IC-02 | 18 | 5 | 13 | 2 | 6 | 4 | 47 |
| | IC-03 | 10 | 5 | 1 | 2 | 4 | 3 | 25 |
| | IC-04 | 7 | 3 | 15 | 10 | 5 | 7 | 47 |
| Buffalo Creek | BFC-01 | 9 | 8 | 12 | 4 | 11 | 4 | 47 |
| | BFC-02 | 11 | 15 | 11 | 5 | 6 | 6 | 54 |
| McDondald Creek | MDC-01 | 18 | 5 | 13 | 2 | 6 | 4 | 47 |
| DPR Basin Ave | | 10 | 5 | 11 | 6 | 7 | 5 | 43 |

*Relationship between Biotic Integrity (IBI) and habitat quality (QHEI)*

Since habitat is an important factor influencing fish community structure and biotic integrity, IBI and QHEI should be positively correlated; however, no correlation between the IBI and QHEI scores at individual stations in the Upper Des Plaines system (Figure 1) was evident; however, using mean IBI and QHEI for each subwatershed did indicate a positive relationship between the indices (Figure 2).

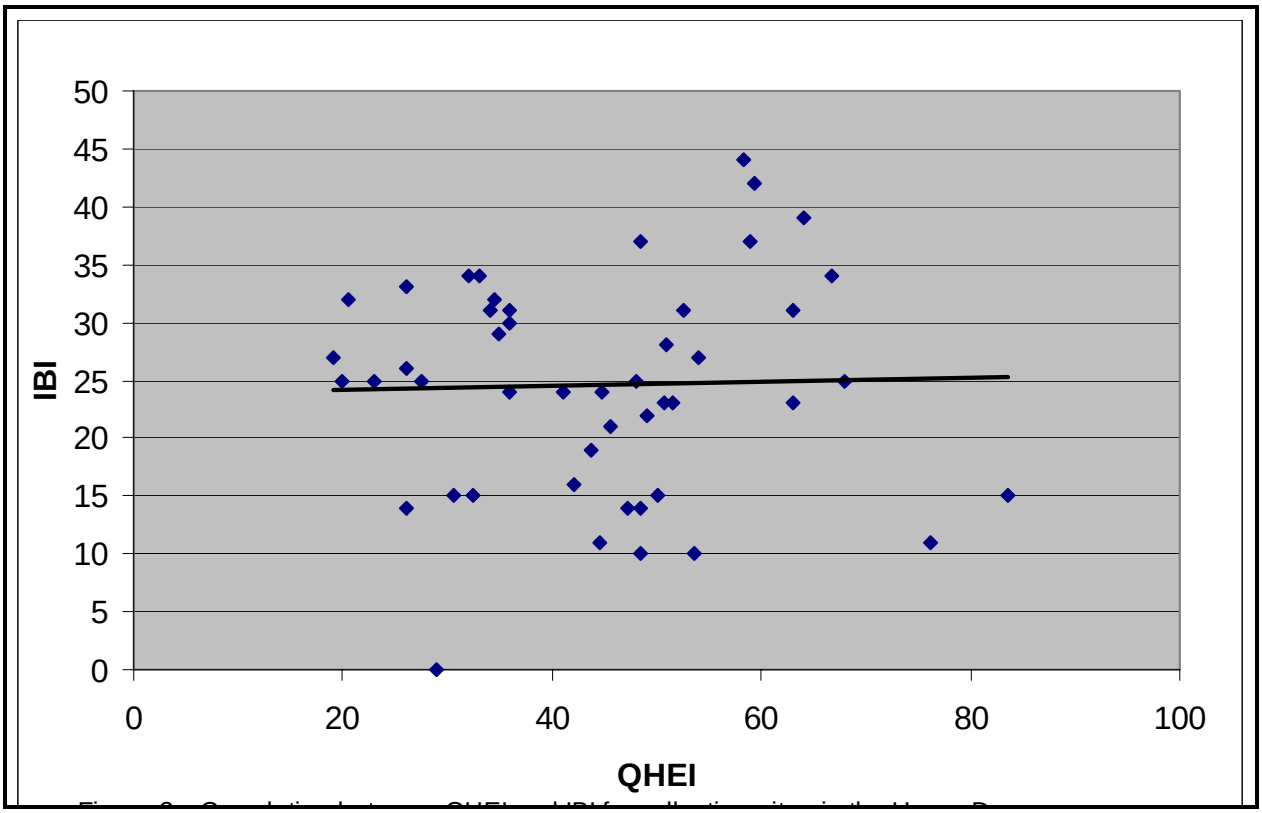


Figure 1 - Correlation between QHEI and IBI for individual collection sites in the upper Des Plaines River system.

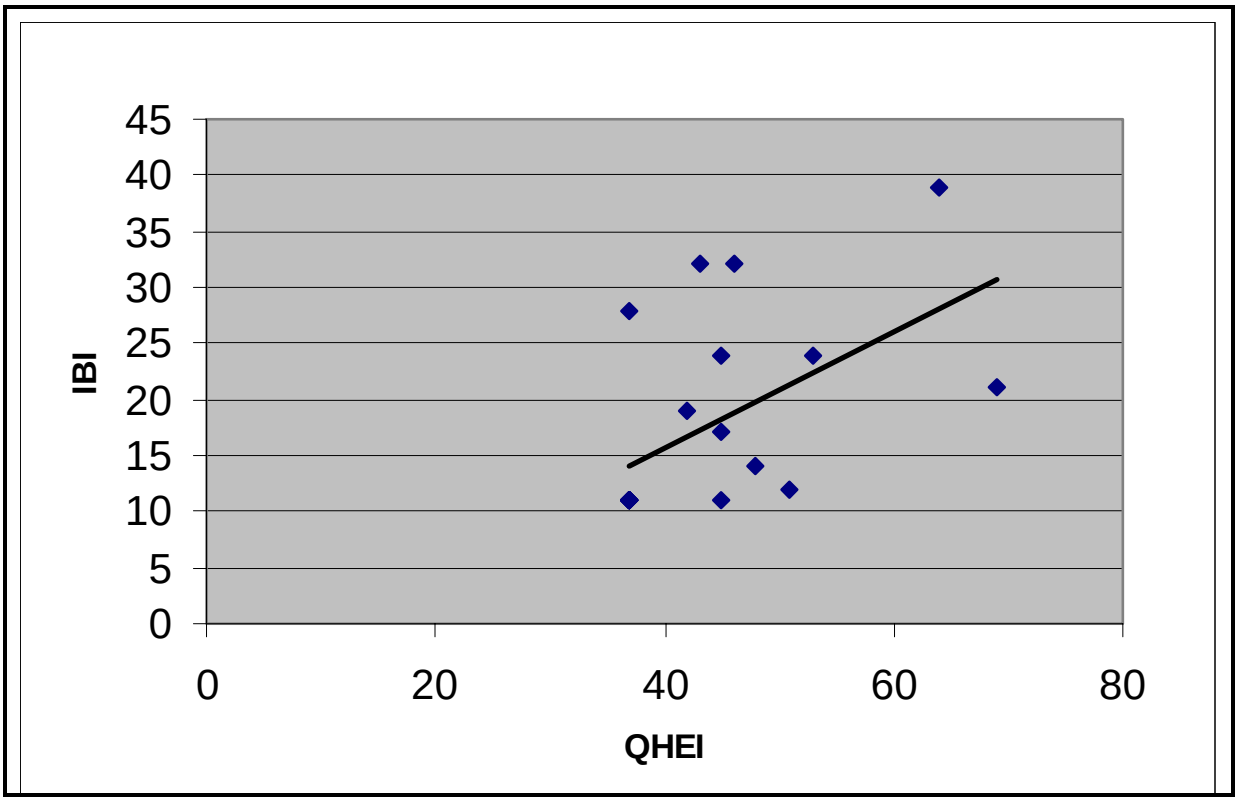


Figure 2 - Correlation between mean IBI and QHEI for each subwatershed in the upper Des Plaines River system.

*Subwatershed Quality Ranking*

In order to provide a framework to guide restoration in the upper Des Plaines River system, results from fish and habitat rating were combined (Table 8). The means for both IBI and QHEI were ranked to develop an overall quality ranking for each subwatershed. This analysis could be used for setting restoration priorities and also provide insights regarding appropriate restoration practices

Newport Ditch had the highest overall quality ranking with and overall score of 3.5. Kilbourn Road Ditch, Brighton Creek, Bull Creek, Center Creek and the upper portions of the Des Plaines River were also among the top ranking subwatersheds. The extent of degradation in the Upper Des Plaines River system is reflected in the relative low quality of even the highest-ranking streams. Habitat within the Newport Ditch subwatershed is only of moderate quality and may be a limiting factor. Higher IBI scores in this subwatershed indicate potential for a biological response to any restoration efforts. Kilbourn Road and Brighton subwatersheds may also be habitat limited, and the restoration of habitat may also result in improvement in biotic integrity. IBI scores in "moderate" range in these subwatersheds indicate at least some level of normally functioning fish assemblages, in contrast to the Silver, Prairie, Willow Creek and other basin subwatersheds, which are highly degraded, containing only the most tolerant species. Bull Creek, on the other hand has higher quality habitat available but low IBI scores indicating possible water quality problems or some other factors such as altered stream hydrology, which may limit food production.

**Discussion**

*Fishes*

In general, pre-settlement species richness of the upper Des Plaines River system, about 66 species, was naturally less rich than the lower system, about 80 species. This was likely due to the fact that much of the upper system ran dry in some years and that the lower system was characterized as a high gradient,

Table 8 - Prioritization of subwatershed riverine restoration based on riverine biological integrity and habitat qualtiy.

| RANK | Subwatershed | # of native fish sp. | # of native sucker sp. | # of native sunfish sp. | # of native intolerant sp. | # of native minnow sp. | # of native benthic invertivore sp. | Prop.(%) of indiv. as specialist benthic invertivores | Prop.(%) of indiv. as generalist feeders | Prop.(%) of indiv. as obligate course-mineral substrate spawners and intolerant | Prop.(%) of tolerant sp. | **IBI Score** | SUBSTRATE | INSTRM COVER | CHAN MORPH | RIPARIAN ZONE | POOL RIFFLE | GSI | **QHEI Score** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.5 | Newport Drainage Ditch | 5.0 | 0.0 | 6.0 | 2.0 | 4.0 | 3.0 | 6.0 | 6.0 | 1.0 | 6.0 | **39** | 16 | 8 | 18 | 5 | 10 | 7 | **63** |
| 3.0 | Brighton Creek | 4.3 | 2.0 | 6.0 | 2.0 | 3.7 | 2.0 | 1.3 | 4.7 | 3.0 | 3.0 | **32** | 16 | 7 | 9 | 7 | 7 | 5 | **50** |
| 3.0 | Bull Creek | 2.0 | 2.0 | 4.0 | 0.7 | 2.3 | 1.0 | 6.0 | 6.0 | 2.0 | 2.0 | **21** | 15 | 12 | 17 | 8 | 12 | 7 | **69** |
| 3.0 | Kilbourn Road Ditch | 4.8 | 2.8 | 5.3 | 1.8 | 4.0 | 2.3 | 2.3 | 4.5 | 2.0 | 2.8 | **32** | 15 | 4 | 9 | 5 | 7 | 4 | **43** |
| 2.5 | Des Plaines River upper | 2.2 | 1.3 | 5.3 | 0.3 | 1.8 | 1.2 | 1.3 | 4.7 | 3.7 | 3.2 | **23** | 11 | 3 | 10 | 7 | 5 | 6 | **41** |
| 2.5 | Center Creek | 4.0 | 2.0 | 5.0 | 0.0 | 4.0 | 3.0 | 0.0 | 2.0 | 2.0 | 2.0 | **24** | 17 | 5 | 4 | 4 | 10 | 5 | **45** |
| 2.0 | Aptakisic Creek | 2.0 | 2.0 | 4.5 | 0.0 | 2.0 | 0.0 | 0.0 | 0.5 | 0.0 | 1.0 | **12** | 10 | 12 | 12 | 4 | 8 | 5 | **50** |
| 2.0 | Buffalo Creek | 2.0 | 2.0 | 4.5 | 0.0 | 2.0 | 0.0 | 0.0 | 0.5 | 0.0 | 1.0 | **12** | 10 | 12 | 12 | 4 | 8 | 5 | **50** |
| 2.0 | Des Plaines River | 3.6 | 1.9 | 4.8 | 1.5 | 3.4 | 1.6 | 1.5 | 4.3 | 1.9 | 4.7 | **29** | 3 | 4 | 11 | 6 | 7 | 5 | **36** |
| 2.0 | Farmers & Weller Creeks | 2.0 | 2.0 | 6.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | **14** | 18 | 5 | 13 | 2 | 6 | 4 | **47** |
| 2.0 | Indian Creek | 2.3 | 1.5 | 5.3 | 0.3 | 1.8 | 1.0 | 1.0 | 2.0 | 1.5 | 2.8 | **19** | 11 | 5 | 10 | 5 | 5 | 5 | **41** |
| 2.0 | Jerome Creek | 1.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | x | x | x | 4.0 | **11** | 14 | 4 | 10 | 5 | 7 | 5 | **44** |
| 2.0 | McDonald Creek | 2.0 | 2.0 | 6.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | **14** | 18 | 5 | 13 | 2 | 6 | 4 | **47** |
| 2.0 | Mill Creek | 2.5 | 0.3 | 4.8 | 0.7 | 1.0 | 0.8 | 0.2 | 2.2 | 0.2 | 4.0 | **17** | 10 | 6 | 8 | 7 | 6 | 5 | **42** |
| 2.0 | Willow Creek | 2.0 | 2.0 | 6.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | **14** | 18 | 5 | 13 | 2 | 6 | 4 | **47** |
| 2.4 | DP Basin Averages | 2.8 | 1.6 | 5.1 | 0.6 | 2.4 | 1.1 | 1.4 | 3.1 | 1.2 | 2.4 | 21 | 13.4 | 6.4 | 11.2 | 4.8 | 7.2 | 4.9 | 48 |

large river that was much more productive due to the greater diversity of microhabitats before the major lock and dam structures were created (Forbes & Richardson 1920). These projections cannot sincerely be made from data that is anecdotal in nature (i.e. reports with no voucher specimens), but can be from historic observations that include preserved specimens. The pre-settlement upper system fish assemblage would likely be characterized as those species that inhabit low gradient streams with gravel, sand, muck and detritus as the primary substrates. Aquatic vegetation was very important to this system, which included vast side stream and basin marshes. Exact species richness and species composition before the 1980s is nearly impossible to reckon due to lack of documentation of collection sites with preserved specimens; however, a rough estimate of species richness based on historic and recent specimens would be about 66 native species. Table 9 shows the reconstructed upper Des Plaines River system pre-settlement fish assemblage using historic specimens from the Milwaukee Public Museum, Illinois Natural History Survey, Field Museum of Natural History, University of Michigan and Southern Illinois University collections.

Base on recent surveys (SEWRPC 2003, ILDNR 2004, USACE 2002 –2004) and independent collections (museum records), there are 15 species that once occurred in the upper Des Plaines River system that are now considered as extirpated (Table 9). Certain extirpated species would be regained through dam removal and habitat restoration, which include *Cyprinella lutrensis* (red shiner), *Ictiobus bubalus* (smallmouth buffalo), *Hypentelium nigricans* (northern hogsucker), *Lepomis megalotis* (longear sunfish), and *Percina caprodes* (logperch). These large river fishes would easily recolonize if the Hofmann Dam was removed because they occur within a 20-mile span downstream of this major fish barrier in similar water quality and habitat conditions. It would not be so easy, however, for species that occupy smaller streams and require excellent water quality to independently recolonize, such as *Hybopsis amnis* (pallid shiner), *Campostoma oligolepis* (largescale stoneroller), *Notropis heterolepis* (blackchin shiner), *Notropis rubellus* (rosyface shiner), *Notropis texanus* (weed shiner), *Phoxinus erythrogaster* (redbelly dace), *Erimyzon sucetta* (lake chubsucker), *Etheostoma caeruleum* (rainbow darter), and *Etheostoma microperca* (least darter). Vast improvements in water quality and riverine habitat restoration of subwatersheds are needed before reintroduction plans for these species could even be considered. One species that is more problematic to regain is *Anguilla rostrata* (American eel). This fish is catadromous, which means it must travel to the Gulf of Mexico to spawn, then young would return. There are far more barriers than the Hofmann Dam to remove to successfully restore eel populations within the upper Illinois River system.

Riverine surveys from 2002 through 2004 documented 43 native species and 5 non-native species. Two non-native species, sailfin catfish and tinfoil barb are considered as single incident individuals resultant from local aquaria release. These two species do not occur in reproducing populations within the upper Des Plaines River system and would have probably not survived the cold-water conditions of winter; therefore, concern for potential ecological impacts is not warranted. The redear sunfish has been intentionally introduced all over the US for recreational fishery supplement and control of nuisance snail populations. The specimen collected in the mainstem Des Plaines River most likely originated from this stocking effort. It is possible that the abundance of this fish may increase and displace native sunfishes; however, current abundance is quite low and with habitat restoration and the termination of stocking within the upper Des Plaines River systems, this species should not become a nuisance. Goldfish currently occupies sections of the Des Plaines Rive proper. This fish is locally abundant in medium to large streams and is frequently associated with sluggish water and vegetation. This species has not incurred major ecology impacts to the Des Plaines River system, nor are any minor impacts well documented. Although this species will probably always be present in reproducing populations within the upper Des Plaines River system, restoration efforts should not be impacted by their presence. The major species of concern when restoring aquatic habitat and species richness, however, is the common carp. The habits and abundance of this fish, in any riverine system, apply major pressure to aquatic vegetation, water quality, benthic invertebrate populations and native fishes themselves. Any riverine reaches that undertake restoration should sincerely consider the removal or abundance control of this species to achieve maximum ecological output.

Table 9 - Pre-settlemet fish assemblage of the upper Des Plaines River system and current status

| Common name | Species | Status | | Common name | Species | Status |
|---|---|---|---|---|---|---|
| bowfin | *Amia calva* | rare | | channel catfish | *Ictalurus punctatus* | common |
| American eel | *Anguilla rostrata* | extirpated | | black bullhead | *Ameiurus melas* | common |
| gizzard shad | *Dorosoma cepedianum* | common | | yellow bullhead | *Ameiurus natalis* | common |
| golden shiner | *Notemigonus crysoleucas* | common | | stonecat | *Noturus flavus* | rare |
| creek chub | *Semotilus atromaculatus* | common | | tadpole madtom | *Noturus gyrinus* | common |
| hornyhead chub | *Nocomis biguttatus* | common | | central mudminnow | *Umbra limi* | common |
| pallid shiner | *Hybopsis amnis* | extirpated | | grass pickerel | *Esox americanus* | common |
| blacknose dace | *Rhinichthys meleagris* | rare | | northern pike | *Esox lucius* | common |
| bluntnose minnow | *Pimephales notatus* | common | | pirate perch | *Aphredoderus sayanus* | rare |
| fathead minnow | *Pimephales promelas* | common | | brook silverside | *Labidesthes sicculus* | rare |
| red shiner | *Cyprinella lutrensis* | extirpated | | blackstripe topminnow | *Fundulus notatus* | common |
| spotfin shiner | *Cyprinella spiloptera* | common | | brook stickleback | *Culaea inconstans* | common |
| central stoneroller | *Campostoma anomalum* | common | | yellow bass | *Morone mississippiensis* | rare |
| largescale stoneroller | *Campostoma oligolepis* | extirpated | | smallmouth bass | *Micropterus dolomieu* | rare |
| stiped shiner | *Luxilus chrysocephalus* | common | | largemouth bass | *Micropterus salmoides* | common |
| common shiner | *Luxilus cornutus* | common | | white crappie | *Pomoxis annularis* | rare |
| redfin shiner | *Lythrurus umbratilis* | rare | | black crappie | *Pomoxis nigromaculatus* | common |
| emerald shiner | *Notropis atherinoides* | common | | rockbass | *Ambloplites rupestris* | common |
| bigmouth shiner | *Notropis dorsalis* | common | | bluegill | *Lepomis macrochirus* | common |
| blackchin shiner | *Notropis heterodon* | rare | | longear sunfish | *Lepomis megalotis* | extirpated |
| blacknose shiner | *Notropis heterolepis* | extirpated | | green sunfish | *Lepomis cyanellus* | common |
| spottail shiner | *Notropis hudsonius* | rare | | pumkinseed | *Lepomis gibbosus* | common |
| roseyface shiner | *Notropis rubellus* | extirpated | | warmouth | *Lepomis gulosus* | rare |
| sand shiner | *Notropis stramineus* | common | | orangespotted sunfish | *Lepomis humilis* | common |
| weed shiner | *Notropis texanus* | extirpated | | yellow perch | *Perca flavescens* | common |
| mimic shiner | *Notropis volucellus* | rare | | rainbow darter | *Etheostoma caeruleum* | extirpated |
| southern redbelly dace | *Phoxinus erythrogaster* | extirpated | | Iowa darter | *Etheostoma exile* | rare |
| smallmouth buffalo | *Ictiobus bubalus* | extirpated | | fantail darter | *Etheostoma flabellare* | rare |
| white sucker | *Catostomus commersonii* | common | | least darter | *Etheostoma microperca* | extirpated |
| northern hogsucker | *Hypentelium nigricans* | extirpated | | Johnny darter | *Etheostoma nigrum* | common |
| creek chubsucker | *Erimyzon oblongus* | rare | | logperch | *Percina caprodes* | extirpated |
| lake chubsucker | *Erimyzon sucetta* | extirpated | | blackside darter | *Percina maculata* | common |
| spotted sucker | *Minytrema melanops* | common | | freshwater drum | *Aplodinotus grunniens* | rare |

*Riverine Quality*

Riverine structure and function of the upper Des Plaines River watershed are severely impacted based on observations and data from this survey and past surveys (SERPC 2003) as well. Almost 100% of the river and stream miles have been modified or manipulated in some fashion. Low gradient streams are easily degraded through unnatural sediment deposition and water quality change. It is evident that the aforementioned problems, stemming from land uses of agriculture, residential and industry, have caused changes in riverine structure and function and decreased overall aquatic species richness. To further compound the effects of land use change, direct impacts to channel morphology, instream habitat complexity, side stream vegetation, and hydraulic regimes have completely compromised the pre-settlement riverine ecology of the upper Des Plaines River system. The construction of dams has prevented the recolonization of fishes and has disallowed genetic flow between fish populations.

*Potential for Riverine Restoration*

The subwatersheds that have significant species richness, biological integrity and habitat quality remaining were identified in the Results section (Table 8). The top five watersheds on the list (Newport Ditch, Kilbourn Road Ditch, Brighton Creek, Center Creek, and the upper portions of the Des Plaines River) are prime targets because they have the potential to fully restore functioning riverine processes, which in turn will allow for support of a significant percentage of pre-settlement faunal and floral assemblages; Bull Creek does not have sufficient space to restore riverine function, but does have the potential for increased species richness. Although the Des Plaines River mainstem does not fall out as a high priority, it does not mean the 13 dams along the mainstem should not be removed. Barriers to fish passage have existed in the upper Des Plaines River system since the early 1800s. The major barrier was constructed in 1950 at Riverside, which is called the Hofmann Dam, but at this same location, a series of dams have been ever present since 1826. The restoration of priority subwatersheds along with the imperative of "dam removal or bypass" on the mainstem should significantly increase biotic integrity and species richness throughout the upper Des Plaines River system. Restoration efforts should focus on restoring riverine connectivity, channel morphology, hydrology & hydraulics, and riparian zones based on geomorphology and soils of the given areas.

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Attachment 1 - QHEI scoring guide

| | |
|---|---|
| **SUBSTRATE** | |
| POOL \ RIFFLE | |
| Bedrock | **2 (if present)** |
| Boulder | **3 (if present)** |
| Cobble | **3 (if present)** |
| Gravel | **3 (if present)** |
| Sand | **3 (if present)** |
| Hardpan | **3 (if present)** |
| Muck | **1 (if present)** |
| Detritus | **2 (if present)** |
| Silt | **0 (if present)** |
| Artificial | **0 (if present)** |
| SUB ORIGIN | |
| SILT | (H)heavy = **-2**], (M)moderate = **- 1**] (L)low = **0**], (F)free = **1** |
| EMBEDDEDNESS | (E)extensive = **- 1**], (M)moderate = **0** , (N)normal = **1** |
| # SUBS | 4 or more = **2**; 3 or less = **0** |
| **INSTRM COVER** | [< 75% = **11**]; [75 - 50% = **7**]; [50 - 25% = **3**]; > 25= **1** |
| UND BANKS | **1 (if present)** |
| OVR VEG | **1 (if present)** |
| ROOT MAT | **1 (if present)** |
| ROOT WAD | **1 (if present)** |
| DEEP POOL | **1 (if present)** |
| BOULDERS | **1 (if present)** |
| OXBOW BCKWTRS | **1 (if present)** |
| AQ MACROPHYT | **1 (if present)** |
| LOGS WOOD | **1 (if present)** |
| **CHAN MORPH** | |
| SINUOSITY | H(high) = **3**, (M)moderate = **2**, (L)low = **1**, (N)none = **0** |
| DEVELOPMENT | (E)excellent = **3**, (G)good = **2**, (F)fair = **1**, (P)poor = **0** |
| CHANNELIZATION | (N)none = **3**, (RD)recovered = **2**, (RG)recovering = **1**, (NR)no recovery = **0** |
| STABILITY | (H)high = **2**, (M)moderate = **1**, (L)low = **0** |
| IMPOUNDED | YES = **0**; NO = **9** |
| STRM WIDTH | No Score |
| **RIPARIAN ZONE** | |
| WIDTH L BANK | (W)wide = **2**, (M)moderate = **1.5**, (N)narrow = **1**, (VN)very narrow = **.5**, (0)none = **0** |
| WIDTH R BANK | (W)wide = **2**, (M)moderate = **1.5**, (N)narrow = **1**, (VN)very narrow = **.5**, (0)none = **0** |
| QUALITY L BANK | N(natural = **2**); O(oldfield = **1.5**); A(agric, pasture, rec = **1**) ; U(urban = **0**) |
| QUALITY R BANK | N(natural = **2**); O(oldfield = **1.5**); A(agric, pasture, rec = **1**) ; U(urban = **0**) |
| BANK EROSION | (N)none = **2**; (M)moderate = **1**; (H)heavy = **0** |
| **POOL RIFFLE** | |
| POOL DEPTH (4) | > 36" = **4**; 36" = 24" = **2**; 24" - 12" = **1**; >12" = **0** |
| RIFFLE DEPTH (3) | > 5" = **3**; 5" - 3" = **2**; > 3" = **1;** no riffle = **0** |
| RUN DEPTH (3) | > 20" = **3**; 20" - 10" = **2**; > 10" = **0** |
| MORPHOLOGY (2) | (**2**)pool width > riffle width; (**1**) pool width = riffle width; (**0**)pool width < riffle width |
| VELOCITY (3) | (eddies, fast, mod) = each get **1**, torrential, interstitial, intermittent = each **-1** |
| RIFFLE STAB (3) | Stable (cobble, boulder) = **3**; Mod (large gravel) = **2**; unstable (fine gravel, sand = **1**); no riffle = **0** |
| RIFF EMBEDD (2) | (N)none = **2**, (L)low = **1**, (E)extensive = **0** |
| **GRADIENT (3)** | (TH)too high = **2**; (H)high = **3**; (M)medium = **2**; (L)low = **1** |
| **SHADE (3)** | > 50% = **3**; 50 - 25% = **2**; >25% = **1** |
| **INCISION (4)** | H(high) = **0**; (L)low = **2**; (N)none = **4** |

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[Article]

# Effects of Tributary Spatial Position, Urbanization, and Multiple Low-Head Dams on Warmwater Fish Community Structure in a Midwestern Stream

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*Abstract*.—A survey of stream fish communities was conducted in the upper Des Plaines River watershed in Illinois and Wisconsin to determine the distribution of fish species and to evaluate the effects of tributary spatial position, urbanization, and multiple low-head dams on fish species diversity and species composition. Forty-eight sites upstream of Salt Creek in Illinois to the headwaters in Wisconsin were surveyed between 2002 and 2004. We found that fish species diversity decreased as agricultural land was replaced by urban land. In addition, tributary position within the drainage network caused significant differences in fish species diversity; specifically, we found significantly less fish species diversity in main-stem tributary streams located lower in the drainage network than in similarly sized streams located in the headwaters of the drainage area. Fish species composition, determined by multivariate principal components analysis, also showed significant differences among stream position within the drainage network. Increases in urbanization did not have a significant effect on fish species diversity within undammed tributary sites, but it did have a strong influence on fish species composition. Hence, as urbanization increased in these undammed tributaries, the fish species composition changed from coolwater–riverine specialist to warmwater–riverine generalist assemblages. In contrast, for tributary streams with low-head dams, the presence of dams had a greater effect on fish species composition than urbanization. In addition, the presence of multiple low-head dams on the main stem had a cumulative detrimental effect on fish species diversity, which decreased along an upstream-to-downstream gradient. Consequently, it is important to consider tributary spatial position within the drainage network, the amount of urbanization, and the number and locations of dams when characterizing the structure of warmwater fish communities, especially in relation to the development of restoration plans in highly urbanized or urbanizing watersheds.

Previous studies in the Midwest and Great Lakes region have demonstrated that both agricultural and urban land uses are major determinants of fish community integrity (Wang et al. 1997, 2000; Stewart et al. 2001; Fitzpatrick et al. 2001, 2004). These studies identified important relationships between biotic integrity and changing land use—in particular, the conversion of agricultural land to urban land and the effects of this conversion on the associated aquatic communities. However, the causes of decrease in biological integrity associated with urbanization seem to be complex both spatially and temporally and are still not well understood (Adolphson et al. 2002; Fitzpatrick et al. 2004).

Although the exact mechanisms by which urban land uses affect fish communities remain elusive, historical localized differences in land cover development, point and nonpoint source pollution, hydrologic and hydraulic modification, storm water and wastewater treatment practices, and the presence of fish barriers may be the key to understanding a stream fish community's response to urbanization (Wang et al. 2000; Fitzpatrick et al. 2004). For example, Osborne and Wiley (1992) found that the spatial position of tributaries within the

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drainage network significantly influences the structure of fish communities inhabiting warmwater streams and that frequency of disturbance and emigration–colonization dynamics are important mechanisms affecting the structure of stream fish communities in watersheds dominated by agricultural land use. Fitzpatrick et al. (2004) also determined that proximity to a source of recolonizing species and lack of physical barriers that impede migration are probably major determinants of the integrity of existing and potential fish communities in urban stream systems. Low-head dams in particular have been identified as being influential on the composition of aquatic communities (Watters 1996; Santucci et al. 2005; Guenther and Spacie 2006). Additionally, dams are often associated with urbanization, and these two factors may have synergistic negative effects on the aquatic community.

Dams, including low-head dams, act to fragment rivers and disrupt the natural patterns of connectivity, which results in the degradation of stream biota, both upstream and downstream of the impoundment (Ward and Stanford 1983; Porto et al. 1999; Gillette et al. 2005). Localized impacts of low-head dams have been determined to affect spatial and temporal patterns of fish assemblage structure, habitat, and water quality in river systems (Erman 1973; Tiemann et al. 2004; Gillette et al. 2005). Fish assemblages directly upstream of low-head dam impoundments are generally characterized by species from lentic, deeper, slow-flowing habitats. Conversely, assemblages immediately downstream from such impoundments are characterized by species typically associated with shallow, fast-flowing habitats (Tiemann et al. 2004; Gillette et al. 2005). Over larger scales, low-head dams can significantly influence the structure and abundance of upstream fish communities in tributary streams well beyond the actual impounded areas (Guenther and Spacie 2006), thus demonstrating how riverine species primarily adapted to fast-flowing waters can become completely extirpated from entire reaches upstream (Winston et al. 1991). Understanding the potential cumulative impacts of low-head dams and the need to address this fragmentation to restore or rehabilitate sustainable fisheries has come to the forefront in riverine ecology and management (Kanehl et al. 1997; Helfrich et al. 1999; Santucci et al. 2005).

Although many studies have examined the effects of changes in land use or the presence of dams on fish communities independently, to the best of our knowledge no studies have investigated both of these factors within the same study. Specifically, we hypothesize that tributary position and fragmentation caused by dams are as important as urban land development in determining fish community diversity and structure in urban or urbanizing watersheds. Therefore, our objectives were to investigate the effects of tributary spatial position, urbanization, and multiple low-head dams on the diversity and composition of the fish community present in the upper Des Plaines River watershed in Illinois and Wisconsin.

## Study Area

The Des Plaines River originates in Racine and Kenosha counties in Wisconsin and flows southward through central Lake County and north-central Cook County to the northeastern portion of Du Page County in Illinois. The upper Des Plaines River watershed covers part of the Chicago metropolitan area, one of the largest urban areas of the United States. Because the areas surrounding this urban community contain productive farmland, this is an appropriate watershed to examine the effects of the gradient of agricultural to urban land use (Adolphson et al. 2002). The river flows about 156 km south before its confluence with the Kankakee River to form the Illinois River. The study area, which we call the upper Des Plaines River watershed, includes the main stem of the Des Plaines River and all tributaries upstream of the Hofmann Dam, which occupy portions of Kenosha and Racine counties in Wisconsin and Lake and Cook counties in Illinois. The upper Des Plaines River watershed is approximately 345 $km^2$ in Wisconsin and 900 $km^2$ in Illinois, giving a total watershed size of about 1,245 $km^2$ (see Figure 1).

Historically, the Des Plaines River system was a narrow, elongated depression within the late Wisconsinan Stage glacial drift (Pepoon 1927). The upper Des Plaines River, upstream of the Hofmann Dam northward, was very shallow and about 9 m wide with banks of terraced alluvium and covered with hydrophytic vegetation (Pepoon 1927). As European settlement increased, the natural terrestrial plant communities of this watershed were affected by physical removal and hydrological alterations for agricultural production. Many portions of the watershed were then subsequently converted to urban and industrial use as part of the greater Chicago metropolitan region. Dam construction, dredging, and channelization in Lake and Cook counties have significantly altered the physical, hydraulic, and hydrologic characteristics of this river system (ILDNR 1998). Dams have existed in the upper Des Plaines River system since the early 1800s. All dams were run-of-river, low-head structures, consisting of 10 main-stem dams and 7 tributary dams (Figure 2), ranging from about 0.3 m to 3.7 m in height.

As of 1990, land use in the Wisconsin portion of the watershed was about 12% urban, 68% agriculture, and 20% natural landscape (e.g., wetlands, woodlands, and

FIGURE 1.—Locations of the study area and the 48 sample sites in the upper Des Plaines River watershed.

other open lands; SEWRPC 2003). Land use in the Illinois portion of the watershed was about 57% urban, 20% agriculture, and 23% natural landscape (ILDNR 1998). The watershed land uses grade from largely agricultural in the headwaters to almost fully urban at the Hofmann Dam. The major tributaries, for the most part, also exhibit a similar gradation in land use. These landscape-scale changes and the concomitant hydrologic and hydraulic alterations have led to degraded habitat; poor water quality; reduced biological integrity, species richness, and ecosystem productivity; and extensive flood damage to manmade structures (ILDNR 1998).

The Des Plaines River is a generally shallow, warmwater, low-gradient stream system. Mean annual flow at the outlet of our study area has ranged from about 10 to 21 $m^3/s$ according to records from 1944 through 2004. From 1944 to 2004, mean daily minimum flow was about 1.0 $m^3/s$ and mean daily maximum flow was 97 $m^3/s$. Mean daily minimum and

maximum flows of 9.2 and 26.1 $m^3/s$, respectively, were recorded during the sampling period from 2002 to 2004, which indicates that flows were within the normal ranges observed during the 60-year period of record for this system.

## Methods

We sampled all of the tributary streams within this portion of the watershed that contained adequate perennial discharge to support a fishery. Exact sampling locations within a particular tributary or in the main stem depended on our ability to obtain permission and to safely access and survey the body of water. The 48 sampling sites we selected in streams throughout the upper Des Plaines River watershed were separated into three treatment groups according to their relative position within the drainage network, based on the methods of Osborne and Wiley (1992). These treatment groups were called headwater tributary (HT), main-stem tributary (MT), and main stem (MS). Fourteen HT sites were located in the upper portion of the drainage basin network, 16 MT sites were located in the middle to lower portion of the drainage, and 18 MS sites were located on the main stem of the upper Des Plaines River.

The spatial analysis for this study utilized the ESRI ArcGIS 9.1 and ArcView 3.2 software, run on a Windows XP platform. The streams coverage in this study was based on U.S. Geological Survey (USGS) stream shape files digitized from USGS 24 min quad maps; to attain a higher accuracy, however, certain streams were redigitized on the basis of 2002 aerial photographs. All riverine survey sites were digitized and georeferenced in ArcView 3.2 based on locality data recorded in the field. Subwatersheds were initially based on USGS gauges, and then were subdivided by the area above each riverine survey site in which land uses and areas were calculated. Generalized land use coverage of the entire upper Des Plaines River watershed was created by the U.S. Army Corps of Engineers Chicago District, which was hand-digitized from 2004 color aerial photography. This land use coverage was then clipped to the subwatersheds created from the riverine survey sites.

Fish surveys in wadable stream segments were conducted during daylight hours with a pulsed-DC backpack electrofishing unit powered by a single generator. The power supplied to the water was sufficient to stun and capture fish. In the wadable portions, we standardized the fish collection effort by sampling a reach that was 15 times the mean stream width, using a single pass moving upstream in a zigzag pattern to ensure full coverage of all available habitats, including woody debris, undercut banks, riffles, runs, and deeper pools (Lyons 1996; Waite and Carpenter 2000; Smogor 2002). All stunned fish were collected with a 6.25-mm-mesh dip net and processed on-site immediately after that survey was completed. Small fish ($\leq$150 mm total length) were immediately preserved in a 10% formalin solution for enumeration and identification in the laboratory. Fish over 150 mm were identified in the field and released, except for voucher specimens. Minimally, one individual of each species collected at each station was documented by either photography or preservation. All preserved specimens reside in either the Field Museum of Natural

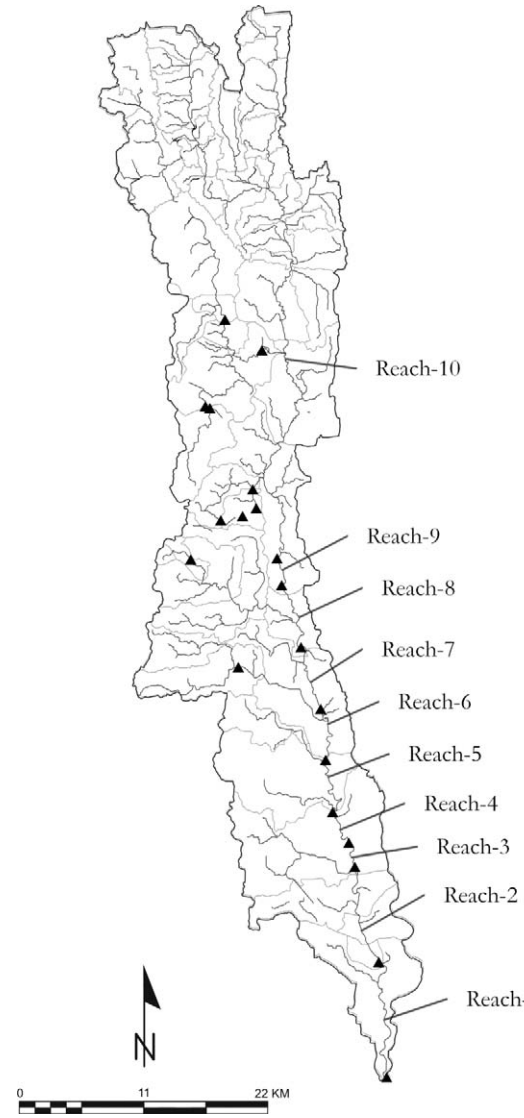


FIGURE 2.—Locations of the dams and associated stream reaches in the upper Des Plaines River watershed.

History in Chicago, Illinois, or Southern Illinois University fish collections in Carbondale. All fish collected at a site were used to calculate abundance in terms of the number of fish per hour per species. The numbers of fish of each species at each site were used to calculate Shannon diversity index values (Krebs 1989) and in subsequent principal components analysis (PCA) to characterize the composition of fish species.

Fish in the nonwadable portions of Des Plaines River main-stem stream sites were sampled according to Illinois Department of Natural Resources collection protocols using a boat-mounted, three-phase, AC electrofishing unit. The power supplied to the water was sufficient to stun and capture fish. All stunned fish were collected with a 6.25-mm-mesh dip net and placed in a 200-L holding tank that was supplied with pure oxygen. Boat electrofishing runs were conducted during daylight hours, beginning at the upstream edge of each station and generally proceeding downstream for 30 min along each bank of the river (total time = 1 h/station). Efforts were made to thoroughly sample all available habitats, including woody debris, undercut banks, riffles, runs, and deeper pools; these efforts often required circling and reversing in an upstream direction. We worked to proportionally sample both lentic and lotic reaches where possible; however, lentic conditions largely dominated the main-stem sites because of the presence of the dams. Fish were processed as summarized above after each 30-min run and released downstream, outside of the sampling area.

Surveys were conducted in the summer months between 2002 and 2004 during base flow conditions. Regardless of the size or depth of the sampling site, width was measured to the nearest 0.3 m. Additionally, to linearize relationships, we $\log_e(x + 1)$ transformed fish abundance data before analysis (Gauch 1982).

Sites MS-9 through MS-18 (Figure 1) were not wadable and thus necessitated the use of a boat-mounted electrofishing unit. These sites were located in the furthest downstream areas on the main stem of the Des Plaines River. Although there are known gear efficiency differences between backpack and boat-mounted electrofishing units, we found that the backpack electrofishing sites MS-1 through MS-8 versus the boat electrofishing sites shared 27 of the same fish species or 75% of the total of 36 species collected by both gear types. Five fish species—redfin pickerel *Esox americanus*, blackchin shiner *Notropis heterodon*, central stoneroller *Campostoma anomalum*, black bullhead *Ameiurus melas*, and central mudminnow *Umbra limi*—were collected with the backpack electrofisher only. Four other species—the mimic shiner *Notropis volucellus*, stonecat *Noturus flavus*, bigmouth shiner *Notropis dorsalis*, and yellow perch *Perca flavescens*—were collected with the boat electrofisher only. However, four of these nine species (two from each collection gear type) were so rare that they were not included within the fish species composition analysis below. The redfin pickerel, blackchin shiner, and mimic shiner were each found at one site and the stonecat was found at two sites within the entire watershed. Overall, our findings indicated that the potential bias between these gear types was minimal in this study, and we felt confident in combining these sites into a single main-stem treatment group for subsequent analyses.

All statistical analyses were performed in SYSTAT (SYSTAT 2002), and a $P$-value of 0.05 was used to determine significance. Differences in watershed size and stream width were tested separately by using an analysis of variance (ANOVA) with stream type (i.e., HT, MT, or MS) as the main effect. Differences in fish species diversity at sampling stations were tested with backwards-stepping general linear models (GLMs). In these analyses, the stream type, the log-transformed number of individuals of each species caught (to account for the potential confounding effect of sample size on species diversity), and the interaction between these two main effects were initially entered into the model (i.e., fish species diversity = constant + stream type + log[total abundance] + [stream type × log{total abundance}]). The backwards-stepping procedure then removed nonsignificant terms from the analysis and performed another analysis using the remaining independent variables. After stepping, if the interaction term was found to be significant, a completely estimated ANOVA was run, using all three terms included in the model (Sokal and Rohlf 1995). Because none of the interaction terms were significant (see Results below), we considered the ANOVA provided by the backwards-stepping GLM to be the final and best model (Sokal and Rohlf 1995). Differences in species diversity attributable to stream position (i.e., station treatment) were determined by direct post hoc testing.

Principal components analysis was used to identify patterns in fish species composition. We used PCA because it is an objective multivariate technique that does not require subjective weights or endpoints (Gauch 1982) and works well with continuous data (James and McCulloch 1990). Principal components analysis is sensitive to, and may be biased by, nonlinear trends in species' abundances along environmental gradients; however, the watershed analyzed in this study was well within the native range of each species (Forbes and Richardson 1920; Becker 1983),

rendering correction for geographic effects unnecessary (Hinch et al. 1994).

Principal components analysis was conducted using the standardized abundance for each species at each sample site. Because rare species have disruptive effects on multivariate analyses, only species occurring in greater than 5% of the sample sites were included in the analysis (Gauch 1982). We used only the first two principal components in this study to characterize fish species composition because they represented ecologically meaningful combinations or associations of fish species abundances (Gauch 1982). To determine whether or not the fish communities found in each stream type differed from one another, we tested for the effects of stream type on both of the principal components (PC-1 and PC-2) separately, using an ANOVA. The first principal component (PC-1) is indicative of fish species diversity, and the second (PC-2) distinguishes coolwater–specialist riverine fish species from warmwater–generalist species.

We assessed the effects of urban land use and stream type on fish species diversity and composition. However, because of the potential confounding effects of watershed and stream size differences and dams, we did not use the MS sites in this analysis. Similarly, only the HT and MT sites without dams were included. Fish species diversity and fish-based principal component scores as described in the model above were used in their own analysis of covariance (ANCOVA) with stream type (i.e., HT versus MT) as the main effect and the arcsine-transformed percent of urban land use as the covariate (i.e., dependent variable = constant + stream type + arcsine{urban land} + [stream type × arcsine{urban land}]). A backwards-stepping GLM yielded the final and best model.

We assessed the effects of dams and urban land use on fish species composition in the MT sites only. To accomplish this, we designated the sites on tributary reaches that were separated from the main stem of the Des Plaines River by a dam as "fragmented" and the sites on tributaries that were not separated by dams as "connected"(only MT sites contained reaches that were fragmented from the main stem, which is why HT sites were not used in this analysis). Fish-species-based principal component scores as described in the model above were used in their own ANCOVAs with connection type (i.e., fragmented versus connected) as the main effect and the arcsine-transformed percent of urban land use (SEWRPC 2003; ILDNR 1998) as the covariate (i.e., dependent variable = constant + stream type + arcsine{urban land} + [stream type × arcsine{urban land}]). As in the previous ANCOVA, backwards-stepping GLM yielded the final and best model output (Sokal and Rohlf 1995).

Finally, to assess whether or not the effects of dams on the MS sites were cumulative, we analyzed the changes in fish species diversity and fish-species-based principal component scores among reaches separated by dams by linear regression (Santucci et al. 2005). The areas between the dams on the MS sites were assigned the reach numbers shown in Figure 2 before analysis. The main-stem reaches of the Des Plaines River are numbered in increasing order from downstream to upstream (representing a linear gradient).

## Results

### *Fish Species Inventory and Community Composition*

A total of 48 species were collected in the upper Des Plaines River: 43 native and 5 nonnative species. The list of species and percent occurrence among each of the treatment groups for all sampling sites combined are compiled in Table 1. The most frequently occurring species (found in more than 60% of the total sample sites within the upper Des Plaines River system) included the green sunfish, bluegill, bluntnose minnow, white sucker, largemouth bass, and blackstripe topminnow.

Comparison among treatment groups indicated that green sunfish, bluegill, bluntnose minnow, and white sucker were the only species found in high proportions in each stream type. These were the only species found with occurrences greater than 60% within the MT streams. In addition to these four species, the HT sites also were dominated by creek chub, johnny darter, central mudminnow, bluntnose minnow, blackstripe topminnow, and pirate perch. Like the HT sites, the MS sites also contained high proportions of blackstripe topminnow and johnny darter species. In contrast to the HT sites, the MS sites also were dominated by largemouth bass, spotfin shiner, black crappie, spotted sucker, and common carp.

Native, but relatively rare, species recorded from the basin include the bowfin, western blacknose dace *Rhinichthys obtusus*, stonecat, brook stickleback, blackchin shiner, mimic shiner, redfin pickerel, yellow bass, smallmouth bass, Iowa darter, and fantail darter.

Our analyses of fish community diversity revealed that the sampling locations in MS sites had the greatest number of fish species (mean = 14) and the highest Shannon diversity scores (mean = 2.02; Table 2). The HT sites also had relatively high numbers of species and fish species diversity scores (means = 13 and 1.92, respectively; Table 2). The MT sites featured both the fewest number of species (mean = 9) and lowest fish species diversity scores (mean = 1.38; Table 2).

The PCA performed on fish diversity and community composition used the abundance data for 33 of the 48 fish species found at our sampling stations, as only

TABLE 1.—Species caught, number of sites at which they were found, and percent occurrence by stream type in the upper Des Plaines River watershed.

| Species | Number of sites | Percent occurrence | | |
|---|---|---|---|---|
| | | Headwater tributaries | Main-stem tributaries | Main stem |
| Rock bass *Ambloplites rupestris* | 6 | 0.0 | 0.0 | 33.3 |
| Black bullhead *Ameiurus melas* | 18 | 35.7 | 50.0 | 27.8 |
| Yellow bullhead *Ameiurus natalis* | 17 | 14.3 | 56.3 | 33.3 |
| Bowfin *Amia calva* | 2 | 0.0 | 12.5 | 0.0 |
| Pirate perch *Aphredoderus sayanus* | 9 | 64.3 | 0.0 | 0.0 |
| Central stoneroller *Campostoma anomalum* | 11 | 57.1 | 12.5 | 11.1 |
| Goldfish *Carassius auratus* | 3 | 0.0 | 0.0 | 16.7 |
| White sucker *Catostomus commersonii* | 33 | 78.6 | 62.5 | 66.7 |
| Brook stickleback *Culaea inconstans* | 2 | 14.3 | 0.0 | 0.0 |
| Spotfin shiner *Cyprinella spiloptera* | 18 | 35.7 | 6.3 | 77.8 |
| Common carp *Cyprinus carpio* | 20 | 21.4 | 31.3 | 61.1 |
| Gizzard shad *Dorosoma cepedianum* | 6 | 7.1 | 0.0 | 27.8 |
| Red fin pickerel *Esox americanus* | 1 | 0.0 | 0.0 | 5.6 |
| Northern pike *Esox lucius* | 7 | 14.3 | 6.3 | 22.2 |
| Iowa darter *Etheostoma exile* | 1 | 7.1 | 0.0 | 0.0 |
| Fantail darter *Etheostoma flabellare* | 1 | 0.0 | 6.3 | 0.0 |
| Johnny darter *Etheostoma nigrum* | 25 | 78.6 | 25.0 | 66.7 |
| Blackstripe topminnow *Fundulus notatus* | 30 | 71.4 | 31.3 | 94.4 |
| Channel catfish *Ictalurus punctatus* | 6 | 0.0 | 18.8 | 22.2 |
| Green sunfish *Lepomis cyanellus* | 42 | 100.0 | 87.5 | 83.3 |
| Pumpkinseed *Lepomis gibbosus* | 20 | 50.0 | 37.5 | 50.0 |
| Orangespotted sunfish *Lepomis humilis* | 13 | 7.1 | 18.8 | 50.0 |
| Bluegill *Lepomis macrochirus* | 40 | 57.1 | 93.8 | 88.9 |
| Redear sunfish *Lepomis microlophus* | 2 | 0.0 | 0.0 | 11.1 |
| Common shiner *Luxilus cornutus* | 5 | 35.7 | 12.5 | 0.0 |
| Redfin shiner *Lythrurus umbratilis* | 1 | 7.1 | 0.0 | 0.0 |
| Smallmouth bass *Micropterus dolomieu* | 1 | 0.0 | 6.3 | 0.0 |
| Largemouth bass *Micropterus salmoides* | 31 | 57.1 | 50.0 | 77.8 |
| Spotted sucker *Minytrema melanops* | 16 | 21.4 | 0.0 | 72.2 |
| Yellow bass *Morone mississippiensis* | 1 | 0.0 | 6.3 | 0.0 |
| Hornyhead chub *Nocomis biguttatus* | 15 | 42.9 | 18.8 | 38.9 |
| Golden shiner *Notemigonus crysoleucas* | 12 | 21.4 | 25.0 | 22.2 |
| Bigmouth shiner *Notropis dorsalis* | 6 | 28.6 | 6.3 | 5.6 |
| Blackchin shiner *Notropis heterodon* | 1 | 0.0 | 0.0 | 5.6 |
| Sand shiner *Notropis stramineus* | 12 | 7.1 | 12.5 | 55.6 |
| Mimic shiner *Notropis volucellus* | 1 | 0.0 | 0.0 | 5.6 |
| Stonecat *Noturus flavus* | 2 | 0.0 | 0.0 | 11.1 |
| Tadpole madtom *Noturus gyrinus* | 5 | 7.1 | 12.5 | 11.1 |
| Yellow perch *Perca flavescens* | 4 | 0.0 | 18.8 | 5.6 |
| Blackside darter *Percina maculata* | 17 | 42.9 | 12.5 | 50.0 |
| Bluntnose minnow *Pimephales notatus* | 33 | 71.4 | 62.5 | 77.8 |
| Fathead minnow *Pimephales promelas* | 15 | 50.0 | 18.8 | 33.3 |
| Black crappie *Pomoxis nigromaculatus* | 18 | 0.0 | 31.3 | 72.2 |
| Western blacknose dace *Rhinichthys obtusus* | 2 | 14.3 | 0.0 | 0.0 |
| Creek chub *Semotilus atromaculatus* | 24 | 85.7 | 50.0 | 27.8 |
| Central mudminnow *Umbra limi* | 18 | 78.6 | 31.3 | 11.1 |

these 33 were abundant enough (i.e., occurring at more than 5% of the sample sites) for use in the PCA. In the resulting analysis, the first two principal components of species abundance data accounted for 32% of the total variance explained (Table 3). Because principal components beyond the first two explained a much lower amount of the total variance and were not readily interpretable, we pursued no further analysis involving these components.

The first principal component (PC-1) accounted for 17% of the variation and was positively associated with fishes typically found at sampling sites with the highest diversity of species; indeed, PC-1 has a significant positive relationship with fish species diversity scores (Pearson's product-moment correlation; $r = 0.59$, Bonferroni adjusted $P = 0.0001$). The second axis (PC-2) accounted for 16% of the variation in fish abundance and distinguished sites featuring strictly warmwater fishes (e.g., black crappie, largemouth bass, bluegill, rockbass, spotfin shiner) from sites with eurythermal fishes, which can occur in both coldwater and warmwater stream communities (e.g., creek chub, central stoneroller, central mudminnow, common shiner; Table 3). For example, 7 of the 10 fish species

TABLE 2.—Number of species, total number of fish caught, and fish species diversity (Shannon) index scores at sample sites in the upper Des Plaines River watershed.

| Stream type | Site and mean | Number of species | Total number of fish | Shannon Index |
|---|---|---|---|---|
| Headwater tributary | HT-1 | 9 | 125 | 1.40 |
| | HT-2 | 20 | 195 | 2.22 |
| | HT-3 | 8 | 274 | 1.81 |
| | HT-4 | 6 | 97 | 1.51 |
| | HT-5 | 17 | 222 | 2.23 |
| | HT-6 | 22 | 219 | 2.55 |
| | HT-7 | 5 | 15 | 1.34 |
| | HT-8 | 15 | 103 | 2.09 |
| | HT-9 | 15 | 98 | 2.36 |
| | HT-10 | 16 | 118 | 2.36 |
| | HT-11 | 14 | 227 | 1.85 |
| | HT-12 | 13 | 328 | 1.87 |
| | HT-13 | 4 | 11 | 1.29 |
| | HT-14 | 16 | 206 | 1.98 |
| | Mean | 13 | 160 | 1.92 |
| Main-stem tributary | MT-1 | 9 | 64 | 1.56 |
| | MT-2 | 2 | 2 | 0.69 |
| | MT-3 | 8 | 272 | 0.33 |
| | MT-4 | 14 | 180 | 1.80 |
| | MT-5 | 15 | 454 | 0.83 |
| | MT-6 | 13 | 228 | 1.46 |
| | MT-7 | 4 | 28 | 0.90 |
| | MT-8 | 14 | 44 | 2.37 |
| | MT-9 | 6 | 41 | 1.50 |
| | MT-10 | 7 | 97 | 1.25 |
| | MT-11 | 5 | 55 | 1.06 |
| | MT-12 | 18 | 221 | 2.03 |
| | MT-13 | 10 | 65 | 1.52 |
| | MT-14 | 9 | 229 | 1.89 |
| | MT-15 | 8 | 55 | 1.63 |
| | MT-16 | 7 | 108 | 1.22 |
| | Mean | 9 | 134 | 1.38 |
| Main stem | MS-1 | 20 | 136 | 2.56 |
| | MS-2 | 12 | 18 | 2.35 |
| | MS-3 | 9 | 16 | 2.05 |
| | MS-4 | 11 | 19 | 2.23 |
| | MS-5 | 9 | 16 | 2.05 |
| | MS-6 | 20 | 517 | 1.90 |
| | MS-7 | 14 | 58 | 2.33 |
| | MS-8 | 17 | 166 | 2.10 |
| | MS-9 | 12 | 62 | 2.03 |
| | MS-10 | 13 | 125 | 2.02 |
| | MS-11 | 19 | 194 | 1.96 |
| | MS-12 | 6 | 25 | 1.26 |
| | MS-13 | 23 | 374 | 1.94 |
| | MS-14 | 23 | 275 | 2.21 |
| | MS-15 | 16 | 66 | 2.01 |
| | MS-16 | 15 | 82 | 1.77 |
| | MS-17 | 13 | 173 | 1.74 |
| | MS-18 | 8 | 16 | 1.96 |
| | Mean | 14 | 130 | 2.02 |

TABLE 3.—Factor loadings of principal components (PC-1 and PC-2) derived from fish species abundance data in the upper Des Plaines River watershed.

| Species | PC-1 | Species | PC-2 |
|---|---|---|---|
| Spotfin shiner | 0.72 | Black crappie | 0.69 |
| Bluntnose minnow | 0.71 | Largemouth bass | 0.54 |
| Blackstripe topminnow | 0.70 | Bluegill | 0.52 |
| Sand shiner | 0.63 | Rock bass | 0.45 |
| Blackside darter | 0.61 | Spotfin shiner | 0.44 |
| Hornyhead chub | 0.61 | Orangespotted sunfish | 0.43 |
| Channel catfish | 0.58 | Yellow perch | 0.43 |
| Johnny darter | 0.55 | Sand shiner | 0.43 |
| Northern pike | 0.54 | Channel catfish | 0.42 |
| Rock bass | 0.54 | Yellow bullhead | 0.41 |
| White sucker | 0.51 | Common carp | 0.32 |
| Green sunfish | 0.48 | Spotted sucker | 0.27 |
| Spotted sucker | 0.44 | Northern pike | 0.21 |
| Fathead minnow | 0.39 | Golden shiner | 0.19 |
| Common carp | 0.38 | Goldfish | 0.17 |
| Tadpole madtom | 0.36 | Pumpkinseed | 0.07 |
| Common shiner | 0.34 | Gizzard shad | 0.07 |
| Orangespotted sunfish | 0.33 | Tadpole madtom | 0.06 |
| Central stoneroller | 0.29 | Black bullhead | 0.03 |
| Central mudminnow | 0.26 | Bluntnose minnow | 0.02 |
| Pirate perch | 0.25 | Blackstripe topminnow | −0.09 |
| Goldfish | 0.19 | Green sunfish | −0.21 |
| Black crappie | 0.18 | Hornyhead chub | −0.29 |
| Pumpkinseed | 0.13 | Blackside darter | −0.32 |
| Largemouth bass | 0.11 | Fathead minnow | −0.34 |
| Bigmouth shiner | 0.06 | Johnny darter | −0.35 |
| Black bullhead | 0.04 | Bigmouth shiner | −0.43 |
| Creek chub | 0.02 | White sucker | −0.45 |
| Bluegill | −0.02 | Pirate perch | −0.48 |
| Yellow bullhead | −0.02 | Common shiner | −0.50 |
| Yellow perch | −0.04 | Central mudminnow | −0.55 |
| Gizzard shad | −0.10 | Central stoneroller | −0.65 |
| Golden shiner | −0.12 | Creek chub | −0.72 |

with the lowest negative component loadings shown in Table 3 are considered "secondary coolwater" species or eurythermal species likely to be encountered in Wisconsin coldwater streams (Lyons 1996). This axis also distinguishes riverine specialist species (i.e., generally found in lotic environments) from generalist species (i.e., commonly found in both lentic and lotic environments); 7 out of the 11 fish species with the lowest negative component loadings were riverine specialists: creek chub, central stoneroller, common shiner, bigmouth shiner, Johnny darter, blackside darter, and hornyhead chub (Smith 1979; Becker 1983; Guenther and Spacie 2006). Six other riverine specialist species were found within the study area (fantail darter, brook stickleback, blacknose dace, redfin shiner, smallmouth bass, and stonecat) but not in high enough abundance to be included in the PCA.

Fish species composition within the upper Des Plaines River watershed is influenced by position within the drainage network. In Figure 3, the polygons that group sampling sites by their respective position types within the drainage network point out similarities and differences in fish species composition for MS and HT sites, as well as a unique, "overlapping" composition of fish species in MT sites. Because both MS and HT sites have more diverse fish communities, they are both positive with respect to PC-1, but because the MS and HT sites host typical warmwater–generalist and coolwater–specialist fish communities, respectively, they are distinctly separated along PC-2. In contrast to both the MS and HT sites, the MT sites have low fish species diversity and so are negative with respect

to PC-1; because the MT sites lack a distinct species composition, they span both the positive and negative portions of the PC-2 axis.

These patterns in fish species composition were further substantiated by the results of an ANOVA, which demonstrated that stream position significantly influenced the fish species composition expressed as both PC-1 ($P = 0.012$; multiple $R^2 = 0.18$; $F = 4.920$; df = 2, 45) and PC-2 ($P = 0.0001$; multiple $R^2 = 0.59$; $F = 32.686$; df = 2, 45). In the post hoc tests of PC-1 fish species composition, the compositions contained in the MS sites were significantly different from those in the MT sites (Tukey's multiple comparison test; $P = 0.013$). No significant differences in fish species composition were found between the MS and HT sites (Tukey's multiple comparison test; $P = 0.878$) or between the MT and HT sites (Tukey's multiple comparison test; $P = 0.062$). For PC-2 fish species composition, fish species compositions found the HT sites were significantly different from those in both the MS (Tukey's multiple comparison test; $P = 0.0001$) and MT sites (Tukey's multiple comparison test; $P = 0.0001$). No significant differences in fish species composition were found between MS sites and MT sites (Tukey's multiple comparison test; $P = 0.104$), which further supports the idea that these communities have many of the same species in common.

*Influence of Stream Position and Urbanization*

An ANCOVA of fish species diversity scores with respect to stream type (HT, MT, and MS) using log-transformed total numbers of individuals as a covariate was conducted for all 48 sites and showed that the position of the sampling site within the drainage area had a significant influence on fish species diversity ($P = 0.0001$; multiple $R^2 = 0.34$; $F = 11.445$; df = 2, 45). No significant influence was found with respect to the number of individuals captured at a given site. Among treatment categories, fish species diversity was significantly greater at both the MS and HT sites (Tukey's multiple comparison test; $P = 0.0001$ and 0.002, respectively) than at the MT sites. Fish species diversity was not significantly different between the MS and the HT sites (Tukey's multiple comparison test; $P = 0.754$). Furthermore, this diversity does not seem to be attributable to a difference in size between the two types of tributary sites. Separate ANOVAs of the log-transformed watershed acres and stream width indicated that watershed size ($P = 0.0001$; multiple $R^2 = 0.760$; $F = 71.068$; df = 2, 45) and stream width ($P = 0.0001$; multiple $R^2 = 0.760$; $F = 71.111$; df = 2, 45) are significantly greater in the MS than in the HT and MT sites. However, post hoc analyses found no significant differences in watershed size (Tukey's multiple comparison test; $P = 0.640$) or width (Tukey's multiple comparison test; $P = 0.070$) between the HT versus MT sites. Mean watershed size for HT sites was 28.4 km$^2$ (SD = 24.8 km$^2$) and 36.3 km$^2$ (SD = 27.8 km$^2$) for MT sites. Mean stream width for HT sites was 2.9 m (SD = 0.8 m) and 4.5 m (SD = 1.7 m) for MT sites. Mean watershed size for MS sites was 789.9 km$^2$ (SD = 524.7 km$^2$) and mean stream width was 21.2 m (SD = 10.4 m).

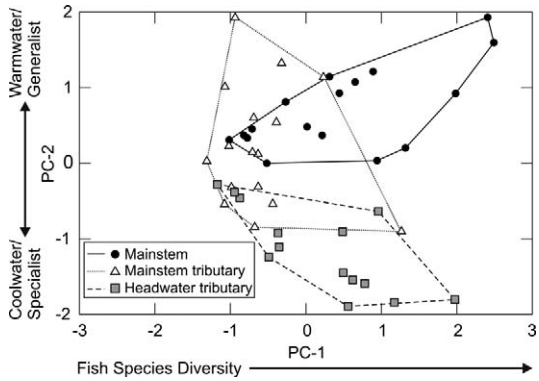


FIGURE 3.—Bivariate plots of principal components (PC) 1 and 2 generated from fish abundance data. The sites are grouped by stream type.

An ANCOVA of Shannon diversity scores with respect to tributary stream type (HT versus MT) using the arcsine-transformed percentage of urban land present in the watershed as a covariate was conducted for the 22 sites not fragmented by dams; these 22 sites were restricted to those HT and MT sites having greater than approximately 20% urban land cover. While there was a significant negative correlation between the percent urban land use and fish species diversity scores in the watershed as a whole, as noted above fish species diversity did not differ between the HT and MT sites; also, urbanization was not found to be a significant influence in this subset of the sample sites ($P = 0.053$; multiple $R^2 = 0.17$; $F = 4.222$; df = 1, 20).

In addition to performing analyses of diversity, we investigated the effect of percent urban land use on fish species composition. While there was a significant relationship to composition measured as PC-2 ($P = 0.0001$; multiple $R^2 = 0.59$; $F = 29.127$; df = 1, 20), the percentage of urban land present in the watershed had no effect on PC-1 ($P = 0.085$; multiple $R^2 = 0.14$; $F = 3.283$; df = 1, 20; Figure 4). The HT and MT sites did not affect fish species composition in PC-1 or PC-2, and no significant interaction was found between these unfragmented tributary sites and percent urbanization. Thus, although urban land use does not have a significant effect on fish species diversity (e.g., PC-1

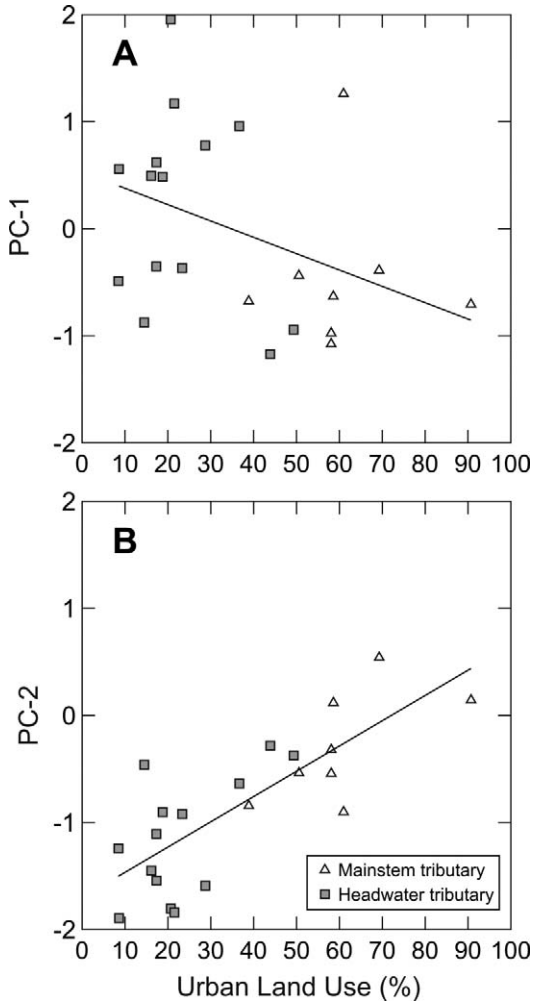


FIGURE 4.—Bivariate plots of **(A)** principal component (PC) 1 and **(B)** principal component 2 versus the percentage of urban land among headwater and main-stem tributary sites in the upper Des Plaines River watershed. The lines represent linear regressions.

in Figure 4), it does influence the warmwater–generalist and coolwater–specialist fish species structure (e.g., PC-2 in Figure 4).

*Influence of Dams and Urbanization*

We assessed the potential effects of dams and urbanization in this study for 16 MT sites. Seventeen dams were located on the main stem and tributaries of the upper Des Plaines River watershed (Figure 2). The lengths of the dammed reaches located on the main stem generally ranged from about 2 to more than 16 km, reach number 10 being the longest. Three of the MT reaches were fragmented by dam structures.

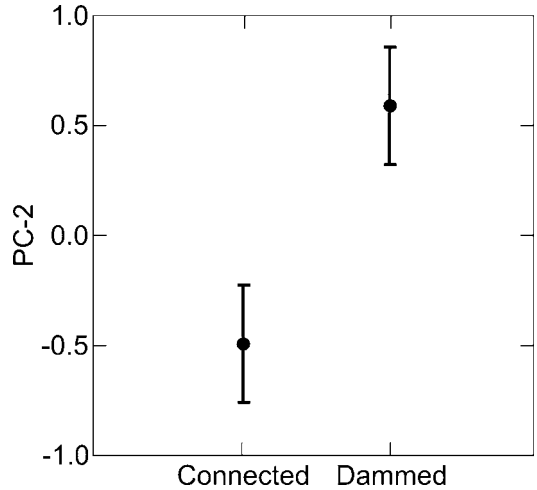


FIGURE 5.—Plots (means ± SDs) of principal component 2 (PC-2) at connected and dammed main-stem tributary sites in the upper Des Plaines River watershed.

An ANCOVA of Shannon diversity scores with respect to connection type (dammed versus undammed) with arcsine-transformed percentage of urban land present in the watershed as a covariate showed that fish species diversity was not influenced by connection type or urbanization ($P > 0.05$; multiple $R^2 = 0.07$; df = 1, 13). Similarly, an ANCOVA of PC-1 also was found to not be affected by dams or urbanization ($P > 0.05$; multiple $R^2 = 0.07$; df = 1, 13). Conversely, an ANOVA of PC-2 demonstrates that, after accounting for the effect of urbanization, only fragmentation by dams significantly explained the differences in fish species composition ($P = 0.012$; multiple $R^2 = 0.54$; $F = 8.585$; df = 1, 13). Sites fragmented by dams were dominated by warmwater–generalist fish assemblages, whereas sites connected to the main stem of the Des Plaines River had higher proportions of coolwater–specialist fishes (Figure 5). Thus, fragmentation of MT sites by dams appears to be an important factor influencing fish species structure, even in this highly urbanized portion of the study area.

Fish species diversity decreases among dam reaches along an upstream-to-downstream gradient among the MS sites (Figure 6; $P = 0.044$; multiple $R^2 = 0.231$). This shows that the most diverse fish community is found in the longest and most upstream reach, which also is connected to the most tributaries (reach 10). Importantly, the stream width of the MS sites generally increases from about 8 to 40 m from upstream to downstream. In contrast, we found no linear relationship among reach and fish species composition in either PC-1 ($P = 0.326$; multiple $R^2 = 0.060$) or PC-2 ($P = 0.926$; multiple $R^2 = 0.001$). This pattern of loss in

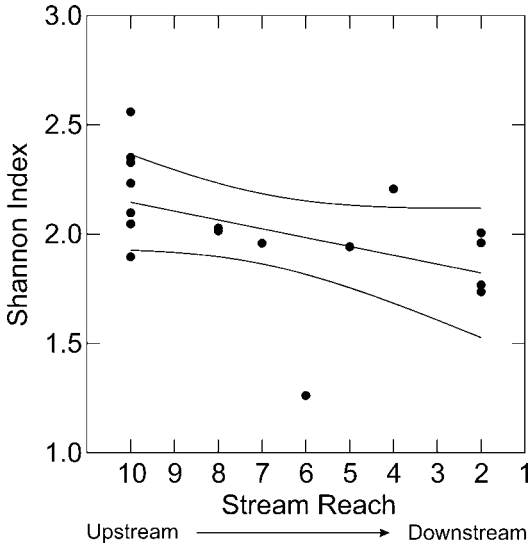


FIGURE 6.—Bivariate plot of fish species diversity (Shannon) index scores among stream reaches separated by dams located on the main stem of the upper Des Plaines River. The lines represent the linear regression and 95% confidence intervals.

fish species diversity seems to reflect the influence of multiple dams and provides evidence that these effects were cumulative.

## Discussion

Our findings indicate that both urbanization and dams have a synergistic detrimental effect on the Des Plaines River, negatively impacting fish species diversity and composition. Our analyses demonstrate that stream fish communities within this watershed are negatively affected by increased urbanization and its associated degradation of water quality. Furthermore, superimposed on this urban/urbanizing landscape are multiple dams on the main stem and tributaries of this system that negatively affect fish communities by restricting fish passage, thus eliminating the possibility of recolonization and recruitment from downstream to upstream on the main stem of the Des Plaines River as well as disrupting dispersal and the connectivity of tributary streams to the main stem of the river. The effects of multiple dams in this system were found to be cumulative, which suggests that any restoration efforts on this system would not be effective without incorporating a targeted strategy to reconnect these fragmented streams through dam removal or some equivalent natural fishway (Katopodis et al. 2001).

The upper Des Plaines River watershed is typical of many upper Midwestern watersheds, in that human activities have changed the surrounding lands from forest or prairie to agricultural fields or cities. Such a shift in land use patterns causes concomitant changes to the stream environment, including an increase in impervious surface area and changes in water quality, hydrology and hydraulics, and reduction or fragmentation of riparian stream buffers. Furthermore, such changes have effects on fish community structure (Klein 1979; Richards et al. 1996; Roth et al. 1996; Wang et al. 1997, 2000, 2001; Helms et al. 2005; Morgan and Cushman 2005). Our study also corroborates the commonly found pattern that high proportions of urban land are associated with decreased fish species diversity. Almost all of our study sites were located in watersheds with more than 10% urban land use, a level known to be associated with a significant loss in fish species abundance and diversity, especially in this region of the U.S. (Ruhl 1995; Dreher 1997; Wang et al. 2000; Fitzpatrick et al. 2004; Harris et al. 2005).

This loss in diversity is probably related to the degradation of water quality and habitat loss associated with urbanization (ILDNR 1998; Arnold et al. 1999). For example, there are limited riparian buffers along the Des Plaines River and associated tributaries in the urbanized areas of this system, and the loss of riparian buffers is known to have a significant negative impact on fish communities (Roth et al. 1996; Wang et al. 1997; Stewart et al. 2001). Furthermore, increased urbanization within the Des Plaines River watershed is associated with decreased water and sediment quality as a result of increased point and nonpoint sources of phosphorus and nitrate; increased proportion of wastewater compounds, including detergents, insecticides, polycyclic aromatic hydrocarbons (PAHs), and flame retardants; elevated chloride concentrations; and increased sediment concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc (Harris et al. 2005). Therefore, we think it very likely that the fish communities within the Des Plaines River watershed are responding to the reduction in water quality associated with increased urbanization in this watershed.

The high level of variability in fish species diversity in the upper Des Plaines River watershed seems to depend on position within the drainage network in this system. Specifically, the MS and HT streams contain more diverse fish communities than do the MT streams. Also, the MT sites contained the lowest mean number of species compared with the MS and HT sites. These results agree with Osborne and Wiley (1992) and Cumming (2004), who demonstrated that fish species richness in tributary streams is highly dependent on position within the stream drainage network. Whereas Osborne and Wiley (1992) and Cumming (2004)

generally found that fish species richness increased with the downstream position within a watershed (i.e., with increasing D-link number; Osborne and Wiley 1992), our results indicated that fish species richness was greatest in the upstream reaches of the watershed. This finding reflects the historic development of this watershed, which was centered on the lower reaches of the system, leaving the upstream reaches relatively less disturbed by human activities.

Because the HT and MT sites are similar in watershed size and stream width, we expected that these tributaries would have similar fish species compositions and differ from the MS sites in this respect. However, on the basis of fish species composition, the MT sites were more similar to the MS sites than to the HT sites, indicating a possible linkage between the MT sites located lower in the drainage network and the MS sites of the Des Plaines River. Although the abundance and diversity of fish in the MT sites are low, these sites contain a subset of the same fish species as the MS sites. This finding further underlines the importance of stream location within the drainage network as a factor influencing fish community structure.

Although the percentage of urban land use within the HT and MT streams did not significantly influence fish species diversity, it did influence fish species composition as measured by PC-2. Although the HT sites have a different species composition than the MT sites, the two areas seemed to respond similarly to the proportion of urban land. This suggests to us that as urbanization increases within these watersheds the resulting changes in fish communities take the form not of changes in species diversity but in changes from coolwater–specialist fish assemblages to warmwater–generalist fish assemblages. The HT and MT sites overlap at about 40% to 50% urban land use, the levels at which transitions in community composition typically occur in the Des Plaines River (Harris et al. 2005).

This shift in fish community composition may indicate hydrological changes associated with urbanization, such as more frequent and larger floods during wet periods and reduced base flows during dry periods (Wang et al. 2000). Discharge in the upper Des Plaines River watershed was more variable at HT sites than at MS sites (ILDNR 1998; SEWRPC 2003). In contrast, statistical trend analyses by ILDNR (1998) confirmed that there have been sizable increases in low flows throughout our MT and MS sites, primarily due to a combination of regional increases in precipitation, treated wastewater effluent discharges, and activities such as lawn watering and other additions of water to the storm sewer system during dry periods.

Approximately 25% of the water that flows in the upper Des Plaines River originates from wastewater treatment plants; this source accounts for about 50% and 95% of the river's flow during medium- and low-flow periods, respectively (ILDNR 1998). Although Tiemann et al. (2004) suggested that urbanization and industry cause decreased flows as the result of water intake during periods of drought, both the larger river MS sites and MT sites historically have been, and remain, more stable than HT sites during critical low-flow periods, even as urbanization and population levels have increased in these areas. Such increased stability in flow conditions has been associated with increased species richness (Horwitz 1978; Osborne and Wiley 1992). Also, the much larger volumes and more stable flows in the MS sites of the Des Plaines River provide potential refuge areas for fish during low-flow periods and could aid subsequent recolonizations of MT sites (Osborne and Wiley 1992). Accordingly, we expected that both the MS and MT sites would contain a higher number and greater diversity of fish species than the ephemeral HT areas; however, we found the opposite trend. This difference in species diversity between HT and MT sites, combined with a dominance of coolwater–specialist assemblages in the HT sites versus warmwater–generalist assemblages in the MT sites, suggests that that these differences could be related to the fragmentation by dams within this study area.

Guenther and Spacie (2006) demonstrated that fish assemblages upstream of impoundments created by low-head dams had much higher generalist species richness and abundance than assemblages in unfragmented tributary streams. Our findings confirmed this trend: dammed MT sites contained a significantly different fish assemblage, one dominated by warmwater–generalist species, whereas undammed MT sites contained higher proportions of coolwater–specialist fish species. In addition, the HT sites, which were not fragmented by dams, were much less affected by dams on the main stem of the Des Plaines River (i.e., physically separated by more stream distance) than were the MT sites. The HT sites contained the highest proportion and greatest number of riverine specialist species in comparison with MT or MS stream sites, which also is consistent with previous research (Taylor et al. 2001; Guenther and Spacie 2006).

The establishment of the major lock-and-dam structures in the upper portion of the Illinois River (just downstream of our study area) is hypothesized to have significantly contributed to the loss in aquatic diversity through habitat loss and fragmentation (Forbes and Richardson 1920). Retzer (2005) calculated a loss of 30% of the native fish community

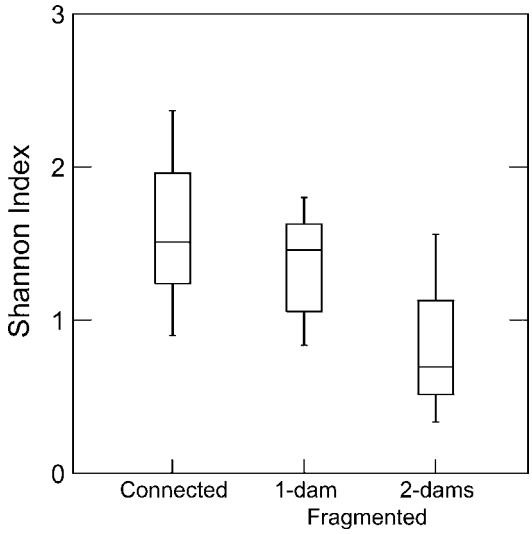


FIGURE 7.—Box plots of fish species diversity (Shannon) index scores among main-stem tributary sites in the upper Des Plaines River watershed. The tributary sites were disaggregated into connected (not dammed) sites and sites fragmented by one or two low-head dams. The box plot shows the median (horizontal line), the range (ends of the whiskers), and the upper 75th and lower 25th percentiles (edges of the box) of the data in each group.

throughout the entire Des Plaines River watershed from 1879–1905 to 1990. Although the exact species richness and community structure are difficult to determine using available records, comparisons of historical fish collections from the upper Des Plaines River with the current fish community results suggests a loss of 15 species and an overall decrease in fish community diversity throughout the watershed from presettlement to present times. Twelve of the 15 species extirpated from this watershed were riverine specialists: American eel *Anguilla rostrata*, pallid shiner *Hybopsis amnis*, red shiner *Cyprinella lutrensis*, largescale stoneroller *Campostoma oligolepis*, roseyface shiner *Notropis rubellus*, weed shiner *N. texanus*, southern redbelly dace *Phoxinus erythrogaster*, smallmouth buffalo *Ictiobus bubalus*, northern hog sucker *Hypentelium nigricans*, longear sunfish *Lepomis megalotis*, rainbow darter *Etheostoma caeruleum*, and logperch *Percina caprodes*. The loss of these species is consistent with previous findings that overall species richness is reduced in fragmented streams (Winston et al. 1991; Porto et al. 1999; Herbert and Gelwick 2003; Tiemann et al. 2004).

This shift from riverine specialists to generalists is probably related to the shift to primarily lentic habitats (Erman 1973; Winston et al. 1991; Falke and Gido 2005; Santucci et al. 2005; Guenther and Spacie 2006). Such lentic conditions are unsuitable to riverine specialists and generally prevent these species from colonizing neighboring tributaries fragmented by backwater areas upstream of low-head dams (Guenther and Spacie 2006). In contrast, generalist species, particularly large piscivorous species, such as the largemouth bass that were predominant in MS sites, are capable of colonizing both the reservoir conditions upstream of low-head dams and the nearby tributaries connected to these reservoirs (Winston et al. 1991). Perhaps more significantly, low-head dams influence the fish and macroinvertebrate communities, as well as habitat, in ways similar to larger dams (Tiemann et al. 2004). Low-head dams limit habitat on stream systems by restricting access to available habitats, which has led to changes in fish community structure (Porto et al. 1999). Thus, it is not surprising that the removal of a low-head dam on the Milwaukee River (Milwaukee, Wisconsin), for example, reestablished fish passage and contributed to the recovery of the reach above the former dam site, which responded by improvements in habitat and fish biotic integrity (IBI) scores (Kanehl et al. 1997).

In contrast to previous studies, which found no significant cumulative effect of multiple dams on fish IBI scores (Santucci et al. 2005) or species richness (Tiemann et al. 2004), our study found that the series of 10 low-head dams led to a gradual alteration of fish species diversity in the upper Des Plaines River watershed in an upstream-to-downstream gradient. Fish species diversity did not increase with stream size, although the patterns in fish assemblages appeared to be influenced by these impoundments—contrary to the tendency for fish species richness, community diversity, and biomass to increase with increasing stream size (Schlosser 1987). In addition, the high number of dams on the main stem limits access to tributaries that would otherwise be accessible; this may also be contributing to an overall reduction in species diversity downstream. Most of the reaches on the main stem were connected to at least one tributary, but reach 10 was connected to the highest number of tributaries. Specifically, these dams are most probably affecting fish species diversity by acting as barriers to movement necessary for growth, survival, or reproduction (Helfrich et al. 1999; Tiemann et al. 2004; Gillette et al. 2005; Santucci et al. 2005).

Low-head dams in upstream tributaries may also be altering fish assemblage structure via the disruption of dispersal and connectivity to the main stem of the Des Plaines River, which may have contributed to our observation that fish species diversity was lower at the MT sites than at the MS and HT sites (Santucci et al. 2005; Guenther and Spacie 2006). A comparison of

fish species diversity between connected (i.e., not dammed and also connected to the main channel) and fragmented reaches indicates an inverse relationship between the number of dams on a tributary and fish species diversity; fish species diversity scores decrease as the number of dams increases (Figure 7). Thus, fragmentation of fish communities by dams on tributary streams may also be cumulative, the fragmentation increasing as more dams are added. This fragmentation, combined with the degraded water-quality conditions caused by urbanization, is probably contributing to the loss in fish species diversity. This also may explain why the tributary sites separated by dams contained the least diverse fish communities and were generally dominated by species tolerant to pollution.

*Management Implications*

Clearly, sampling fish communities in a limited number of headwater tributaries, main-stem tributaries, or main-stem segments may be inadequate in highly fragmented watersheds. Extrapolation of limited sampling results could lead to either under- or overreporting of fish diversity and fish community condition. The presence of dams, which increases the likelihood of local extirpation and loss of diversity, should thus be a consideration in the formulation of sampling programs and experimental design.

Within the upper Des Plaines River study area (upstream of Hoffman Dam), for example, selective dam removal or the installation of a fishway or passage structure at only a few sites would probably allow localized improvements in the fish species diversity (see Kanehl et al. 1997). However, this selective removal would provide relatively limited improvement in fish species richness for the system as a whole, given the degraded nature of the fish communities currently present and the cumulative effects of the remaining dam structures, especially in the lower reaches of the study area.

Restoration within the main-stem sites of the upper Des Plaines River must rely on reconnection to more species-rich areas of the watershed, such as the upper reaches of the study areas (e.g., reach 10; Figure 2), which in this study had more abundant and diverse fish communities. Surveys conducted downstream of our study area (Pescitelli and Rung 1998, 2005) have also found higher diversity, many species (including sport fishes) exhibiting truncated distribution patterns (Santucci et al. 2005). Reconnection to both upstream and downstream recruitment sources should be high priorities for restoration in the upper Des Plaines River, coupled with efforts to remove dams or provide fish passage throughout the entire main stem and main-stem tributaries.

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