Objectives, Performance Criteria, and Information Sources
Objectives and Performance Criteria for Each Geomorphic Reach

### Geomorphic Reach 1

<table>
<thead>
<tr>
<th>Geomorphic Reach 1 - SAF to Head of Lake Pepin Objectives</th>
<th>GR 1 Performance Criteria</th>
<th>Source of Information and Comments</th>
</tr>
</thead>
</table>

#### Hydraulics & Hydrology: Manage for a more natural hydrologic regime

**Daily Variation:**
Reduce daily water surface elevation variation caused by lock and dam operation by 50%. WSEL variation is based on a combination of ideas from the WLMTF of the RRF, the Upper Impounded Floodplain Reach Planning Team, and also by using pre-lock water surface profiles as a reference.

**Seasonal Variation:**
On a periodic (e.g. one to two consecutive years in ten years) or permanent basis where feasible, maintain lower water levels starting as soon as possible following the spring flood through September 1st so that the following criteria are met:

- Low flow (75% exceedance) - raised 1' at lock and dam 2 and 3.
- Moderate flow (25% exceedance) - raised 2' at lock and dam 2 and 1' at lock and dam 3.
- High flow (2-year flood) - raised 2' at lock and dam 2.

**A more natural stage hydrograph**

At ten to twenty year time intervals, increase the amount of drawdown for low flow conditions for one to two consecutive growing seasons to simulate longer-term cycles of drought to improve forest regeneration.

#### Altered hydraulic connectivity

**General:** Alter hydraulic connectivity so that frequency, duration, magnitude, and timing of flow and resulting stage variation are within optimal limits for target biota and habitats.

**Specific:**
1. **Backwaters:** Alter connectivity between backwaters and channels or between sub-areas within backwaters to reduce sediment and nutrient inputs.
2. **Impounded areas:** Reduce hydraulic connectivity between historic floodplains and channels for total river discharges less than the two-year flood to create contiguous backwaters, or isolated wetlands and floodplain lakes.
3. **Vermilion River Bottoms:** Eliminate flow from the Mississippi River to the Vermilion Bottoms for discharges lower than the 2-year flood event.
4. **Lower tributary valleys:** Increase connectivity so floodplains convey water for flood events greater than the 2-year recurrence interval. Tributary distributary channel connectivity should vary seasonally based on historic ranges.

**MCB and Secondary Channels Shear Stress Variation:**
After seasonal variation in connectivity to achieve desired shear stresses:

- Low Flow Shear Stress Average
- High Flow Shear Stress Average

#### Biogeochemistry: Manage for processes that input, transport, assimilate, and output material within UMR basin river floodplains: e.g. water quality, sediments, and nutrients

**TSS (mg/L):** To achieve SAV targets, summer average TSS concentrations will need to be reduced about 35% (70 to 32 mg/L) from existing conditions based on the combined monitoring data for Locks and Dams 2 and 3. It is suggested that attainment be based on achieving a median and 90th percentile summer average TSS concentrations of 32 and 44 mg/L, respectively, based on combined bi-weekly monitoring at Locks and Dams 2 and 3.

**Improved water clarity**
Achieve a Secchi depth based on June through September averages at lock and dam 3 and in Lake Pepin of 47 and 80 cm respectively by 2025.

**Backwaters:** Achieve a Secchi depth of 80 cm for the June through September averages.

**Reduced nutrient loading**
Reduce Phosphorus loads to GR 1 by 2025. Minnesota River: 50% based on 1977 To 2007 average

- Max R of TC: 20% based on 1977 To 2007 average
- St. Croix River: 20% based on 1977 To 2007 average
- Cannon River: 50% based on 1977 To 2007 average
- Other Tributaries: 20% based on 1977 To 2007 average

**Backwater nutrient concentrations**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>&lt; 0.1 mg/L</td>
</tr>
<tr>
<td>TN</td>
<td>&lt; 1.23 mg/L</td>
</tr>
</tbody>
</table>

**Phosphorous load reduction performance criteria is from Scenario 17, Lake Pepin TMDL Study.**

**Nutrient concentrations in backwaters are from Sullivan (2008) based on metaphyton report.**
Geomorphic Reach 1 - SAF to Head of Lake Pepin Objectives

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Source of Information and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters</strong></td>
<td>Sediment loading performance criteria for the Vermillion River Bottoms is based on discussion with Citizens Advisory Group convened as part of the Dakota County Soil and Water Conservation District, Mississippi Makeover Project. (See <a href="http://www.dakotaswcd.org/wshd_missmak.html">http://www.dakotaswcd.org/wshd_missmak.html</a> )</td>
</tr>
<tr>
<td><strong>Reduced contaminants loading and remobilization of in-place pollutants</strong></td>
<td>Sediment load reduction performance criteria is from Scenario 17, Lake Pepin TMDL Study.</td>
</tr>
</tbody>
</table>

**Geomorphic: Manage for processes that shape a physically diverse and dynamic river floodplain system**

<table>
<thead>
<tr>
<th>Restore rapids</th>
<th>1890 Mississippi River Commission Maps used for water surface slopes (based on MDNR, S Johnson presentation to Mississippi Makeover CAG)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits</strong></td>
<td>Substrate criteria was developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</td>
</tr>
</tbody>
</table>

**Habitat: Manage for a diverse and dynamic pattern of habitats to support native biota**

<table>
<thead>
<tr>
<th>Restored habitat connectivity</th>
<th>Riparian habitat restoration performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restored riparian habitat</strong></td>
<td>Provide year-round fish passage for native migratory fishes through Locks and Dams 2 and 3 by 2025.</td>
</tr>
<tr>
<td></td>
<td>Improve the longitudinal distribution of waterfowl habitat to shorten the flight distance between &quot;stopping stations&quot; of preferred habitat during the fall migration.</td>
</tr>
<tr>
<td></td>
<td>Maintain existing, and where needed, create new terrestrial corridors and connectivity of native vegetation communities.</td>
</tr>
<tr>
<td></td>
<td>Restore lateral habitat connectivity between channels and floodplain where altered by levees, railroads, and bank revetment.</td>
</tr>
<tr>
<td></td>
<td>Restore &gt;50% of the length of currently armored or stabilized river bank to natural channel border and riparian zone habitat by 2040.</td>
</tr>
<tr>
<td></td>
<td>Impounded areas, Lower Pool 2: Restore natural levees that are permanently inundated to create riparian habitat.</td>
</tr>
<tr>
<td>Geomorphic Reach 1 - SAF to Head of Lake Pepin Objectives</td>
<td>GR 1 Performance Criteria</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Isolated wetlands and floodplain lakes: Maintain or create a spatial distribution and physical characteristics approaching the following criteria:</td>
<td>Isolated wetland and floodplain lake performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09):</td>
</tr>
<tr>
<td>Parameter</td>
<td>Bluegills</td>
</tr>
<tr>
<td>Size</td>
<td>&gt;10 ac</td>
</tr>
<tr>
<td>Depth</td>
<td>&gt;4 ft in 30% to 60% of lake</td>
</tr>
<tr>
<td>Distribution</td>
<td>1 to 6 per square mile</td>
</tr>
<tr>
<td>Total Area</td>
<td>&gt;50% of aquatic area</td>
</tr>
<tr>
<td>Quality Areas</td>
<td>&lt;2 miles apart</td>
</tr>
<tr>
<td>Habitat Connectivity</td>
<td>80% of lakes accessible</td>
</tr>
<tr>
<td>Hydraulic Connectivity</td>
<td>LHC approaches zero for flow less than the 2-year flood</td>
</tr>
<tr>
<td>additional physical requirements based on the needs of lentic fish can be found in the TAB labeled “Lentic Fish” that is part of this excel file.</td>
<td></td>
</tr>
<tr>
<td>Restored terrestrial floodplain areas</td>
<td>Restored terrestrial floodplain areas</td>
</tr>
<tr>
<td>Impounded areas, Lower Pool 2:</td>
<td></td>
</tr>
<tr>
<td>Increase coverage in MCB and secondary channels to 10% of area</td>
<td></td>
</tr>
<tr>
<td>Spatial coverage performance criteria for lotic fish developed by Upper Impounded Floodplain Reach Planning Team for aquatic vegetation</td>
<td></td>
</tr>
<tr>
<td>Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for lentic fish conceptual model (April 09):</td>
<td></td>
</tr>
<tr>
<td>Bioti: Manage for viable populations of native species within diverse plant and animal communities</td>
<td></td>
</tr>
<tr>
<td>EAV in MCB: Increase the frequency of occurrence to &gt;95% in the MCB areas based on the LTRMP sampling protocol (this corresponds to a frequency of occurrence of &gt; 12% using the LTRMP sampling protocol): Increase species richness (maximum # of species) to 11.</td>
<td>SAV in MCB and Backwaters performance criteria is based on the proposed site specific standard for the Lake Pepin Turbidity TMDL developed by Sullivan et al., 2009. As of June 2010, the Pollution Control Agency citizen board has recommended adopting the site specific standards for TSS and submerged aquatic vegetation for the Lake Pepin TMDL. This still needs EPA approval.</td>
</tr>
<tr>
<td>SAV in Backwaters: Increase the frequency of occurrence to &gt;85% in the Confusing Backwaters based on the LTRMP sampling protocol.</td>
<td>SAV in MCB species richness based on Indicator Targets set by the Dakota County Soil and Water Conservation District, Mississippio Makeover Project. See <a href="http://www.dakotaowcd.org/wshd_misamak.html">http://www.dakotaowcd.org/wshd_misamak.html</a></td>
</tr>
<tr>
<td>EAV in Backwaters: Increase the spatial extent of EAV</td>
<td>SAV and EAV frequency of occurrence and spatial extent criteria in backwaters is being developed by Upper Impounded Floodplain Reach Planning Team for aquatic vegetation</td>
</tr>
<tr>
<td>Spatial coverage performance criteria for lentic fish</td>
<td>Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for lentic fish conceptual model (April 09):</td>
</tr>
<tr>
<td>Summer: Aquatic vegetation cover in the range of 40-60% of off - channel areas.</td>
<td>Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for lentic fish conceptual model (April 09):</td>
</tr>
<tr>
<td>Winter: Aquatic vegetation cover in the range of 25-50%</td>
<td></td>
</tr>
<tr>
<td>Spatial coverage performance criteria for lentic fish</td>
<td>Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for lentic fish conceptual model (April 09):</td>
</tr>
<tr>
<td>Lower tributary valleys: Tributary distributary channel connectivity should vary seasonally based on historic ranges.</td>
<td></td>
</tr>
<tr>
<td>Restored channel areas</td>
<td>Restored channel areas</td>
</tr>
<tr>
<td>Impounded areas, Lower Pool 2:</td>
<td></td>
</tr>
<tr>
<td>Increase coverage in MCB and secondary channels to 10% of area</td>
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<tr>
<td>Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for lentic fish conceptual model (April 09):</td>
<td></td>
</tr>
<tr>
<td>Diverse and abundant native aquatic vegetation communities (SAV, EAV, RIF)</td>
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</tr>
<tr>
<td>See Environmental Pool Plans for acres and distribution of Floodplain forests and grasslands</td>
<td></td>
</tr>
<tr>
<td>Species diversity: Increase the area with at least 5 Dutch Elm disease resistant trees per acre by ______ acres by 2020</td>
<td>See NESP Systemic Forest Management Plan which is being developed by the the NESP Forest Management Project PDT for more information.</td>
</tr>
<tr>
<td>Reduce area dominated by reed canary grass by ______ acres by 2020</td>
<td>Floodplain forest performance criteria was developed by the NESP Lock and Dam 8 Embankment Team with input from members of the NESP forestry team (December 06):</td>
</tr>
<tr>
<td>Increase coverage in MCB and secondary channels to 10% of area</td>
<td>Riparian habitat restoration performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09):</td>
</tr>
</tbody>
</table>
Diverse and abundant native fish community

Conditions will vary from year to year. Electrofishing CPUE variation for lentic and lotic fish are given below.

**Lentic Fish**
- **Electrofishing catch per unit effort**
  - **Fair - good:**
    - 100-200 bluegills/hour
    - 50 - 100 largemouth bass/hour
  - **Good - Excel:**
    - 200-300 bluegills/hour
    - 100-150 largemouth bass/hour
  - **Excellent:**
    - >300 bluegills/hour
    - >150 largemouth bass/hour

**Lotic Fish**
- **Electrofishing CPUE**
  - **Fair - good:**
    - 40-70 YOY walleye &/or sauger/hour (calculated CPUE)? Carp biomass is greater than or equal to 50% catch in MC or MCB, Redhorse/Sucker CPUE is less than ?%
  - **Good - Excel:**
    - 70 - 100 YOY walleye &/or sauger/hour (calculated CPUE)? Carp biomass between 25% and 50%, Redhorse/Sucker CPUE is between 7% and 7%
  - **Excellent:**
    - >100 YOY walleye &/or sauger/hour (calculated CPUE)? Carp biomass less than 25% of catch in MC or MCB, Redhorse/Sucker CPUE is = or greater than 7%

The Lentic and Lotic Fish Performance Criteria was developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

Diverse and abundant native mussel community

**Existing**
- **Catch/unit effort**
  - (% sites with > 10/min)
  - 5
  - **Year 2025**
  - 10

- **Catch/unit effort**
  - (% sites with < 1/min)
  - 33
  - **Species richness**
  - 28

- **Mucket mussel**
  - (% of population)
  - 0

From Grier, 1920 Pools 5,6, Mucket Mussels =8%

**Mussel Performance Criteria from Conceptual Models:**
- **Species Richness:** 17 to 42 by sub-area
- **Composition:** Habitat generalist, lentic, and tolerant species <40% of community
- **Abundance:** Pool-wide >4 unionds/meter^2
- **Mussel Beds:** >10 unionds/meter^2
- **Mussel Beds:** every 2 miles, covering 5% of aquatic area.
- Zebra mussels < 10/m^2 by 2010

The Mussel Performance Criteria from conceptual models was developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09). Interagency mussel team needs to decide on parameters that are important and format for listing them.

Diverse and abundant native bird community

**General**
- Use-day objectives can be adapted from regional goals established under the North American Waterfowl Management Plan, Upper Mississippi River - Great Lakes Region Joint Venture.
- Improve longitudinal distribution within the reach of habitat so that waterfowl use-days in each pool are proportional to the aquatic area of the pool.

**Diving Ducks:**
- Improve the longitudinal distribution during the fall migration to:
  - shorten the flight distance between "stepping stones" of preferred habitat.
  - improve hunting and bird-watching opportunities throughout the reach.
  - decrease the potential negative effects of local crashes in habitat (aquatic beds - SAV), accidental contaminant spills, and disease outbreaks

**Puddle Ducks:**
- Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity.
- Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity.
- Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity.
- Distance to forest is <1-5 miles. Forest contains silver maple, oak, ash, elm. Area floods to some extent each fall. Forested area contains pockets (0.1 to 1.0 acres) of moist soil and emergent plants also subject to flooding.
- Distance to cropland is <1-10 miles and harvested fields contain some residue
- Provide secure habitat (closed areas) along the floodplain at 5-15 mile intervals in Reach 1
- Improve north/south distribution of puddle ducks by securing habitat at appropriate intervals, creating "stepping stones" of habitat, the length of the geomorphic reach.

This will enhance opportunities for migrating birds to rest and feed, as well as enhance hunting opportunities, and decrease potential negative effects of crashes in habitat, accidental spills, and disease outbreaks. Minimize human activity in optimal feeding and resting habitat.

The Mussel Performance Criteria is from the Dakota County Soil and Water Conservation District, Mississippi Makeover Project Indicator Targets. See http://www.dakotaswcd.org/wshd_missmak.html

Waterfowl criteria were developed by a group of waterfowl specialists from the Fish and Wildlife Workgroup in March 09, and then was used by the Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09). The criteria were developed for Geomorphic Reach 3, but apply, with modification, to Geomorphic Reach 1

Waterfowl surveys in Geomorphic Reach 1 began in Fall 2009.
Objectives

**Hydraulics & Hydrology:** Manage for a more natural hydrologic regime

**Biogeochemistry:** Manage for processes that input, transport, assimilate, and output material within UMR basin river floodplains: e.g. water quality, sediments, and nutrients

**Improved water clarity**
Achieve a Secchi depth based on June through September averages in Lake Pepin of 80 cm respectively by 2025.

Secchi depth performance criteria for Lake Pepin is based on Dakota County Soil and Water Conservation District, Mississippi Makeover Project Indicator Targets. See [http://www.dakotaswcd.org/wshd_missmak.html](http://www.dakotaswcd.org/wshd_missmak.html)

**Reduced nutrient loading**
Reduce Phosphorous loads to GR 1 (and subsequently to Lake Pepin) by 2025.
- Minnesota River: 50% based on 19?? To 200? average
- St. Croix River: 20% based on 19?? To 200? average
- Cannon River: 50% based on 19?? To 200? average

Phosphorous load reduction performance criteria is from Scenario 17, Lake Pepin TMDL Study.

**Reduced sediment loading from tributaries and sediment resuspension and loading to backwaters**
Reduce sediment loads to GR 1 (and subsequently to Lake Pepin) by 2025.
- Minnesota River: 50% from the 19?? To 200? average
- St. Croix River: 20% from the 19?? To 200? average
- Cannon River: 50% from the 19?? To 200? average

Sediment load reduction performance criteria is from Scenario 17, Lake Pepin TMDL Study.

**Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits**
Lake Pepin: Reduce sediment accumulation amount from the existing rate of 865,000 metric tons per year to an interim target (by 2015) of 683,000 tons per year and a long-range target (by 2025) of 500,000 tons per year. Based on recommended targets from the Lake Pepin TMDL and the Mississippi Makeover.

Lake Pepin sediment accumulation performance criteria is based on Dakota County Soil and Water Conservation District, Mississippi Makeover Project Indicator Targets. See [http://www.dakotaswcd.org/wshd_missmak.html](http://www.dakotaswcd.org/wshd_missmak.html)

**Habitat:** Manage for a diverse and dynamic pattern of habitats to support native biota

**Biota:** Manage for viable populations of native species within diverse plant and animal communities

Lentic Fish Electrofishing catch per unit effort
- Fair - good: 100-200 bluegill/hour
- Good - excel: 200-300 bluegill/hour

Lotic Fish CPUE
- Fair - good: 40-70 YOY walleye &/or sauger/hour (calculated CPUE)

The Lentic and Lotic Fish Performance Criteria was developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09). Additional information can be found in the Lentic and Lotic Fish Criteria TABS at the bottom of this file.
<table>
<thead>
<tr>
<th>Geomorphic Reach 2 - Lake Pepin</th>
<th>Diverse and abundant native mussel community</th>
<th>Diverse and abundant native bird community</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td><strong>Performance Criteria</strong></td>
<td><strong>Source of Information and Comments</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Existing</strong></td>
<td><strong>Year 2025</strong></td>
</tr>
<tr>
<td>Catch/un. effort (5 sites with &gt;1/min)</td>
<td>0.5</td>
<td>10</td>
</tr>
<tr>
<td>Catch/un. effort (33 sites with &lt;1/min)</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Species richness (9 species)</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Mucket mussel (% of population)</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Mussel Performance Criteria from Conceptual Models:</td>
<td>Mussel Performance Criteria for Waterfowl for Lake Pepin needs to be updated. GR 1 performance criteria is listed here as a placeholder. The Performance Criteria for Waterfowl for Lake Pepin needs to be updated. GR 1 performance criteria is listed here as a placeholder. Waterfowl criteria were developed by a group of waterfowl specialists from the Fish and Wildlife Workgroup in March 09, and then was used by the Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>Improve longitudinal distribution within the reach of habitat so that waterfowl use-days in each pool are proportional to the aquatic area of the pool. Use-day objectives can be adapted from regional goals established under the North American Waterfowl Management Plan, Upper Mississippi River - Great Lakes Region Joint Venture. Diving Ducks: Improve the longitudinal distribution during the fall migration to: - shorten the flight distance between “stepping stones” of preferred habitat. - improve hunting and bird-watching opportunities throughout the reach. - decrease the potential negative effects of local crashes in habitat (aquatic beds - SAV), accidental contaminant spills, and disease outbreaks. Puddle Ducks: Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity. Depths vary from 1 inch to 4 feet; provides seasonal use: BW Teal and wigeon early, mallard, GW Teal, gadwall mid to late season. 50% of area PEAV: wild rice, arrowhead, bulrush. - Distance to forest is &lt;1.5 miles, Forest contains silver maple, oak, ash, elm. Area floods to some extent each fall. Forested area contains pockets (0.1 to 1.0 acres) of moist soil and emergent plants also subject to flooding. - Distance to cropland is &lt;1.5 miles and harvested fields contain some residue. - Provide secure habitat (closed areas) along the floodplain at 5-15 miles intervals in Reach 1 (need to evaluate this further). - Improve north/south distribution of puddle ducks by securing habitat at appropriate intervals, creating “stepping stones” of habitat, the length of the geomorphic reach. This will enhance opportunities for migrating birds to rest and feed, as well as enhance hunting opportunities, and decrease potential negative effects of crashes in habitat, accidental spills, and disease outbreaks. Minimize human activity in optimal feeding and resting habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use-day objectives can be adapted from regional goals established under the North American Waterfowl Management Plan, Upper Mississippi River - Great Lakes Region Joint Venture. Diving Ducks: Improve the longitudinal distribution during the fall migration to: - shorten the flight distance between “stepping stones” of preferred habitat. - improve hunting and bird-watching opportunities throughout the reach. - decrease the potential negative effects of local crashes in habitat (aquatic beds - SAV), accidental contaminant spills, and disease outbreaks. Puddle Ducks: Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity. Depths vary from 1 inch to 4 feet; provides seasonal use: BW Teal and wigeon early, mallard, GW Teal, gadwall mid to late season. 50% of area PEAV: wild rice, arrowhead, bulrush. Distance to forest is &lt;1.5 miles, Forest contains silver maple, oak, ash, elm. Area floods to some extent each fall. Forested area contains pockets (0.1 to 1.0 acres) of moist soil and emergent plants also subject to flooding. Distance to cropland is &lt;1.5 miles and harvested fields contain some residue. Provide secure habitat (closed areas) along the floodplain at 5-15 mile intervals in Reach 1 (need to evaluate this further). Improve north/south distribution of puddle ducks by securing habitat at appropriate intervals, creating “stepping stones” of habitat, the length of the geomorphic reach. This will enhance opportunities for migrating birds to rest and feed, as well as enhance hunting opportunities, and decrease potential negative effects of crashes in habitat, accidental spills, and disease outbreaks. Minimize human activity in optimal feeding and resting habitat.</td>
<td></td>
</tr>
</tbody>
</table>
Hydraulics & Hydrology: Manage for a more natural hydrologic regime

**Geomorphic Reaches 3 & 4**

**GR 3 & 4 Performance Criteria**

<table>
<thead>
<tr>
<th>Source of Information and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved water clarity</td>
</tr>
<tr>
<td>Reduced nutrient loading</td>
</tr>
<tr>
<td>Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters</td>
</tr>
</tbody>
</table>

### Geomorphic Reaches 3 & 4 - Foot of Lake Pepin to Lock and Dam 13

**GR 3 & 4 Performance Criteria**

#### Backwaters

- Decrease connectivity between existing deep water (greater than 4 feet deep) areas of backwaters and sediment sources to reduce sediment deposition and delta migration into these deep areas.
- Alter hydraulic connectivity between channels and backwaters to restore more desirable hydraulic conditions.
- Lower tributary valleys: Increase connectivity so tributaries convey water for flood events greater than the 2-year recurrence interval.tributary distributary channel connectivity should vary seasonally based on historic ranges.
- MCB and Secondary Channels Shear Stress Variation: After seasonal variation in connectivity to achieve desired shear stresses
  - Low Flow Shear Stress Average =
  - High Flow Shear Stress Average =

#### Improved water clarity

- Increase (ft) 1.6 4.1 -0.2 1.5 2.6 3.8 1.9 0.9

#### Backwaters

- SAV Target report for Lake Pepin TMDL (Sullivan et al. 2008).
- SAV Target report for Lake Pepin TMDL (Sullivan et al. 2008).
- SAV Target report for Lake Pepin TMDL (Sullivan et al. 2008).

#### Reduced nutrient loading

- Reduce daily water surface elevation variation caused by lock and dam operation by 50%.
- Reduce sediment loading from GR 3 by 2025.

#### Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

- Reduce daily water surface elevation variation caused by lock and dam operation by 50%.
- Reduce sediment loading from GR 3 by 2025.

#### Biogeochemistry: Manage for processes that input, transport, assimilate, and output material within UMR basin river floodplains: e.g. water quality, sediments, and nutrients

- UMRCC water quality criteria, 2002.
- UMRCC water quality criteria, 2002.
- Gulf Hypoxia Task Force objectives.
- Gulf Hypoxia Task Force objectives.
- Nutrient concentrations in backwaters are from Sullivan (2008) based on metaphyton work.
- Gulf Hypoxia Task Force objectives.
- Gulf Hypoxia Task Force objectives.

A comparison of pre-lock to post-lock water surface elevations (shown here for moderate flows), provides some guidance however criteria will have to be developed by PDTs for each lock and dam based on opportunities and constraints.
<table>
<thead>
<tr>
<th>Geomorphic Reach 3 &amp; 4 - Foot of Lake Pepin to Lock and Dam 13</th>
<th>GR 3 &amp; 4 Performance Criteria</th>
<th>Source of Information and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits</strong></td>
<td>Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits.</td>
<td>Substrate: Increase substrate variation in main channel border areas.</td>
</tr>
<tr>
<td><strong>Habitat: Manage for a diverse and dynamic pattern of habitats to support native biota</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Restored habitat connectivity</strong></td>
<td>Provide year-round fish passage for native migratory fishes through Locks and Dams by 2025.</td>
<td>Riparian habitat restoration performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</td>
</tr>
<tr>
<td>Maintain existing terrestrial corridors and connectivity of native vegetation communities.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restore lateral habitat connectivity between channels and floodplain where altered by levees, railroads, and bank revetment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Restored riparian habitat</strong></td>
<td>Restore &gt;50% of the length of currently armored or stabilized river bank to natural channel border and riparian zone habitat by 2060.</td>
<td>Isolated wetland and floodplain lake performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</td>
</tr>
<tr>
<td>Isolated wetlands and floodplain lakes: Maintain or create a spatial distribution and physical characteristics approaching the following criteria</td>
<td>Parameter</td>
<td>Largemouth Bass</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>&gt;10 ac</td>
</tr>
<tr>
<td></td>
<td>Depth</td>
<td>&gt;4' in 30 to 60% of lake &gt;6' in 40 to 70% of lake</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>1 to 6 per square mile 1 to 4 per 2,000 acres of floodplain</td>
</tr>
<tr>
<td></td>
<td>Total Area</td>
<td>&gt;10% of aquatic area &gt;10% of aquatic area</td>
</tr>
<tr>
<td></td>
<td>Quality Areas</td>
<td>&lt;2 miles apart &lt;4 miles apart</td>
</tr>
<tr>
<td></td>
<td>Habitat Connectivity</td>
<td>80% of lakes accessible 80% of lakes accessible</td>
</tr>
<tr>
<td></td>
<td>Hydraulic Connectivity</td>
<td>LHC approaches zero for flow less than the 2-year flood</td>
</tr>
<tr>
<td></td>
<td>Additional physical requirements based on the needs of lentic fish can be found in the TAB labeled “Lentic Fish” that is part of this excel file.</td>
<td></td>
</tr>
<tr>
<td><strong>Restored aquatic off-channel areas</strong></td>
<td>Isolated wetlands and floodplain lakes: Maintain or create a spatial distribution and physical characteristics approaching the following criteria</td>
<td>These are some basic concepts discussed by the NESP Lock and Dam 8 Embankment Team at the 9/28&amp;29/09 Hydrogeomorphic Modeling workshop in New Albin, IA.</td>
</tr>
<tr>
<td></td>
<td>Parameter</td>
<td>Bluegills</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>&gt;10 ac</td>
</tr>
<tr>
<td></td>
<td>Depth</td>
<td>&gt;4' in 30 to 60% of lake &gt;6' in 40 to 70% of lake</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
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<td></td>
<td>Quality Areas</td>
<td>&lt;2 miles apart &lt;4 miles apart</td>
</tr>
<tr>
<td></td>
<td>Habitat Connectivity</td>
<td>80% of lakes accessible 80% of lakes accessible</td>
</tr>
<tr>
<td></td>
<td>Hydraulic Connectivity</td>
<td>LHC approaches zero for flow less than the 2-year flood</td>
</tr>
<tr>
<td></td>
<td>Additional physical requirements based on the needs of lentic fish can be found in the TAB labeled “Lentic Fish” that is part of this excel file.</td>
<td></td>
</tr>
<tr>
<td><strong>Backwaters</strong>: Decrease connectivity between existing deep water (greater than 4 feet deep) areas of backwaters and sediment sources to reduce sediment deposition and delta migration into these areas.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Impounded areas</strong>: Reduce lateral hydraulic connectivity between historic floodplains and channels for total river discharges less than the two year flood to create riparian habitat.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Achieve wind fetch criteria based on water depth in aquatic off-channel areas.</strong></td>
<td>Water Depth (ft): 1 2 3 4</td>
<td>Water Depth (ft): 1 2 3 4</td>
</tr>
<tr>
<td></td>
<td>Fetch (ft): 1500 3500 6000 9000</td>
<td>Fetch (ft): 1500 3500 6000 9000</td>
</tr>
<tr>
<td><strong>Restored terrestrial floodplain areas</strong></td>
<td>Alter topography (e.g. Ridge and Swale), surface and ground water seasonal variations, and soil conditions, to create optimal conditions for native tree growth.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydraulic Connectivity - Connectivity should be altered so that duration of overlapping suits desired community structure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Habitat Connectivity - Maintain a contiguous corridor of native vegetation communities.</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary Channel Characteristics</strong></td>
<td>0 &lt; vc &lt; 3 fps for 5% duration event 3 &lt; vc &lt; 1.5 fps for 75% duration event</td>
<td>Substrate criteria was developed by Pool 5 Ecosystem Restoration Team for secondary channels (May 09)</td>
</tr>
<tr>
<td>0 &lt; dc &lt; 5 feet for 75% duration event</td>
<td>Substrate: Rock/gravel 5% wood 5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dimension, pattern, profile of secondary channels result in transport of sediment to delta area or to outlet of secondary channel reach.</td>
<td></td>
</tr>
</tbody>
</table>
Diverse and abundant native aquatic community

- Diverse and abundant native fish
- Diverse and abundant native mussels
- Diverse and abundant native vegetation communities (SAV, EAV, R/F)

Spatial coverage performance criteria for lentic fish:
- Summer: Aquatic vegetation cover in the range of 40-60% of off channel areas.
- Winter: Aquatic vegetation cover in the range of 25-50%.

Spatial coverage performance criteria for lotic fish:
- Increase coverage in MCB and secondary channels to 10% of area.

Geomorphic Reach 3 & 4 - Foot of Lake Pepin to Lock and Dam 13

Performance Criteria Source of Information and Comments
- Mussel Beds: every 2 miles, covering 5% of aquatic area.
- Mussel Beds: >10 unions/meter²
- Abundance: Pool-wide >4 unions/meter²
- Composition: Habitat generalist, lentic, and tolerant species <40% of community
- Species Richness: 17 to 42 by sub-area
- Species diversity:
  - Good - excel: Lentic Fish CPUE:
    - >150 largemouth bass/hour
    - >300 bluegills/hour
  - Good - excel: Lentic Fish (Late Fall) Electrofishing catch per unit effort
  - Fair - excel: Lentic Fish CPUE:
    - 100-200 bluegills/hour
  - Fair - excel: Lentic Fish (Late Fall) Electrofishing catch per unit effort

See Environmental Pool Plans

Diverse and abundant native floodplain forest and prairie communities

See Environmental Pool Plans for acres and distribution of Floodplain forests and grasslands.

Spatial coverage performance criteria for lotic fish developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

Diverse and abundant native fish community

Conditions will vary from year to year. Electrofishing CPUE: variation for lentic and lotic fish are given below:

- Lentic Fish (Late Fall) Electrofishing catch per unit effort
  - Fair - good:
    - 100-300 bluegills/hour
    - 50 - 100 largemouth bass/hour
  - Good - excel:
    - 200-300 bluegills/hour
    - 100-150 largemouth bass/hour
  - Excellent: >300 bluegills/hour
    - >150 largemouth bass/hour

Lotic Fish CPUE:
- Fair - good:
  - 40-70 YOY walleye & sauger/hour (calculated CPUE)?
  - Carp biomass is greater than or equal to 50% catch in MC or MCB, Redhorse/Sucker CPUE is less than 7%
  - Good - excel:
    - 70 – 100 YOY walleye & sauger/hour (calculated CPUE)?
    - Carp biomass is between 25% and 50%, Redhorse/Sucker CPUE is between 7% and 9%
  - Excellent:
    - >100 YOY walleye & sauger/hour (calculated CPUE)?
    - Carp biomass less than 25% of catch in MC or MCB, Redhorse/Sucker CPUE is = or greater than 7%.

See NESP Systemic Forest Management Plan which is being developed by the the NESP Forest Management Project PDT for more information.

Diverse and abundant native mussel community

<table>
<thead>
<tr>
<th>Species</th>
<th>Existing</th>
<th>Year 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskellunge</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Muskellunge</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Species richness</td>
<td>&lt;8%</td>
<td></td>
</tr>
<tr>
<td>Species richness</td>
<td>&lt;8%</td>
<td></td>
</tr>
</tbody>
</table>

Mussel Performance Criteria from Conceptual Models:
- Species richness: 17 to 42 by sub-area
- Composition: Habitat generalist, lentic, and tolerant species <40% of community
- Abundance: Pool-wide >4 unions/meter²
- Mussel Beds: >10 unions/meter²
- Mussel Beds: every 2 miles, covering 5% of aquatic area.
- Zebra mussels < 10/m² by 2015

The Mussel Performance Criteria from conceptual models was developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09). Mussel team needs to decide on parameters that are important and the format for listing them.

See Environmental Pool Plans for acres and distribution of Floodplain forests and grasslands.

Species diversity:
- Increase the area with at least 5 Dutch Elm disease resistant trees per acre by _____ acres by 2020
- Reduce area dominated by red cedar grass by _____ acres by 2020
- Restore >50% of the length of currently armored or stabilized river bank to natural channel border and riparian zone habitat by 2040.

Floodplain forest performance criteria was developed by the NESP Lock and Dam 8 Embankment Team with input from members of the NESP forestry team (December 08).

Riparian habitat restoration performance criteria developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

See Reno Bottoms HGM report (Heitmeyer, et al. 2009)

See NESP Systemic Forest Management Plan which is being developed by the the NESP Forest Management Project PDT for more information.

See Environmental Pool Plans

Winter: Aquatic vegetation cover in the range of 25-50%.

Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

See Environmental Pool Plans for acres and distribution of Floodplain forests and grasslands.

Spatial coverage performance criteria for lentic fish developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

See Environmental Pool Plans

Spatial coverage performance criteria for lotic fish developed by Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).

See Environmental Pool Plans

Conditions will vary from year to year. Electrofishing CPUE: variation for lentic and lotic fish are given below:

- Lentic Fish (Late Fall) Electrofishing catch per unit effort
  - Fair - good:
    - 100-300 bluegills/hour
  - Good - excel:
    - 100-200 bluegills/hour

Lotic Fish CPUE:
- Fair - good:
  - 40-70 YOY walleye & sauger/hour (calculated CPUE)?
  - Carp biomass is greater than or equal to 50% catch in MC or MCB, Redhorse/Sucker CPUE is less than 7%
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  - Excellent:
    - >100 YOY walleye & sauger/hour (calculated CPUE)?
    - Carp biomass less than 25% of catch in MC or MCB, Redhorse/Sucker CPUE is = or greater than 7%.

At the 09Sep10 ADHCASM Workshop, Mike Davis said that bottom stability was the most important factor affecting whether mussels were present or not. Substrate size wasn’t as big a deal. Though Chuck T earlier said that Ziglers mussel model suggested that mixed grain size substrate was included in the model.
<table>
<thead>
<tr>
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<th>GR 3 &amp; 4 Performance Criteria</th>
<th>Source of Information and Comments</th>
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</thead>
<tbody>
<tr>
<td>Diverse and abundant native bird community</td>
<td>Improve longitudinal distribution within the reach of habitat so that waterfowl use-days in each pool are proportional to the aquatic area of the pool.</td>
<td>Waterfowl criteria were developed by a group of waterfowl specialists from the Fish and Wildlife Workgroup in March 09, and then was used by the Upper Impounded Floodplain Reach Planning Team for conceptual modeling effort (April 09).</td>
</tr>
<tr>
<td></td>
<td>Use-day objectives can be adapted from regional goals established under the North American Waterfowl Management Plan, Upper Mississippi River - Great Lakes Region Joint Venture.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diving Ducks: Improve the longitudinal distribution during the fall migration to:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- shorten the flight distance between &quot;stepping stones&quot; of preferred habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- improve hunting and bird-watching opportunities throughout the reach.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- decrease the potential negative effects of local crashes in habitat (aquatic beds - SAV), accidental contaminant spills, and disease outbreaks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Puddle Ducks: Provide secure SAV, PEAV, within favorable patterns of bathymetric diversity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30% of area is open water with submerged beds. Depths vary from 1 inch to 4 feet; provides seasonal use: BWTeal and wigeon early; mallard, GWTeal, gadwall mid to late season.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30% of area PEAV: wild rice, arrowhead, bulrush.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance to forest is &lt;1-5 miles. Forest contains silver maple, oak, ash, elm. Area floods to some extent each fall. Forested area contains pockets (0.1 to 1.0 acres) of moist soil and emergent plants also subject to flooding.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance to cropland is &lt;1-10 miles and harvested fields contain some residue.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide secure habitat (closed areas) along the floodplain at 5-15 mile intervals in Reach 1</td>
<td></td>
</tr>
</tbody>
</table>
Draft Project Proposals
1.3 Considerations in Identifying the [Name] Restoration Project Area
Upper Iowa River Delta Project

1.4 Potential Project Sponsor
Iowa Department of Natural Resources
Upper Mississippi River Fish and Wildlife Refuge

2. Location
River UMR
River miles 671.3
States Iowa
Counties Allamakee
Sub-area Upper Iowa Delta
Map

3. Significant Resources
Infrastructure
Cultural resources
Important and Unique Ecological Resources
T&E Species

4. Problem Identification
The Upper Iowa River was an important element in the formation of the complex of braided channels and other wetlands located in the vicinity of the areas that currently can be found in the top end of Lansing Big Lake, Pool Slough, Minnesota Slough, New Albin Duck Lake, Conway Lake, Big Slough, Little Slough and Shore Slough.

4.1 Historic Conditions
The Upper Iowa was channelized in the late 1920’s. Several old channels still exist (shore slough, big slough, and upper Lansing big lake). The area used to consist of areas of braided channels, isolated and permanent wetlands, islands, sandbars, diverse forests, prairies, and wetlands.

4.2 Existing Conditions
The Upper Iowa is now channelized to the UMR with levees. All sediments are dumped into the main channel of the UMR. Associated wetlands and sloughs are cut off and have sediment in. Diverse forest has been replaced with silver maple mono-culture of trees.

4.3 Forecasted Future Conditions
Without project conditions will continue to degrade and the area will lose benefit to fish and wildlife.

4.4 Stressors Affecting the Condition of Habitat and Biota
The levees and channelization have stressed the current conditions to the detriment of the natural environment.
• Altered Hydraulic connectivity
• A more natural hydrograph
• Improved water clarity
• Reduced nutrient loading
• Reduced sediment loading from tributaries
• Backwaters
• Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits
• Restored diversity of floodplain features
• Restored habitat connectivity
• Restored riparian habitat
• Restored aquatic off-channel areas
• Restored terrestrial floodplain areas
• Restored channel areas
• Restored large contiguous patches of native plant communities to provide a corridor
• Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
• Diverse and abundant native floodplain forest and prairie communities
• Diverse and abundant native fish community
• Diverse and abundant native mussel community
• Diverse and abundant native bird community

4.5 Restoration Opportunities
The initial phase of the project would study the feasibility of restoring Upper Iowa River flows into the backwater complex. The feasibility study would address sediment impacts and hydrology. Recommendations would be made and initialized to restore the channel braiding associated with a natural delta. The levee would be breached in several places along land currently owned or managed by the IA DNR or the Us FWS Upper Mississippi Wildlife and Fish refuge. Channels would be dug to direct flow to accomplish this. Phase II of the project would assess resource needs and recommendations from the study and a plan of action for the project would be developed. Land acquisition would buy upstream land to enhance the restoration of the Upper Iowa River delta.

4.6 Project Ecosystem Objectives
Hydrology and Hydraulics
A more natural stage hydrograph
Altered hydraulic connectivity

Biogeochemistry
Improved water clarity
Reduced nutrient loading
Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

Geomorphology
Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits
Restored pattern of channels and floodplain features
Restored diversity of floodplain topography

Habitat
Restored habitat connectivity
Restored riparian habitat
Restored aquatic off-channel areas
Restored terrestrial floodplain areas
Restored channel areas
Restored large contiguous patches of native plant communities to provide a corridor

Biota
Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
Diverse and abundant native floodplain forest and prairie communities
Diverse and abundant native fish community
Diverse and abundant native mussel community
Diverse and abundant native bird community

5. Description of the Proposed Project
The initial phase of the project would study the feasibility of restoring Upper Iowa River flows into the backwater complex. The feasibility study would address sediment impacts and hydrology. Recommendations would be made and initialized to restore the channel braiding associated with a natural delta. The levee would be breached in several places along land currently owned or managed by the IA DNR or the US FWS Upper Mississippi Wildlife and Fish refuge. Channels would be dug to direct flow to accomplish this. Phase II of the project would assess resource needs and recommendations from the study and a plan of action for the project would be developed that would include land acquisition upstream of the current Phase I project.

The levee would be breached and new connection channels would be dug to distribute flow across the historic delta region. Managed moist soil units would be put in place to provide managed isolated wetlands. Dredging would be accomplished in several backwaters to provide sediment for topographic diversity for forest diversity.

5.1 Project Features
Islands and diversion channels would be dug to mimic natural floodplain river delta formations.

- Islands
- Backwaters
- Primary channels
- Secondary channels
- Floodplain forest diversity
- Isolated wetlands
- Contiguous wetlands
- Sediment management
- MSU development

5.2 Implementation Sequence of Project Features
5.3. Operations and Maintenance
Water delivery channels would be dug to provide water to the MSU’s Most of the river would be allowed to shape distribution channels into the Upper Iowa bottoms. Dredging would accomplish overwintering fish haven and deep wetlands Maintenance would need to be done on the dikes and control structures

6. Adaptive Management Activities

6.1 Learning Objectives

6.2 Project Monitoring
Pre-project
- sediment budget for the Upper Iowa River
- Identification of current overwintering fish locations
- Identification of areas to be raised for topographic diversity

During construction
- Armoring of hard points at new secondary channels would need to addressed

Post-construction
- Sediment deposition in water dispersions channels would need to be monitored

6.3 Applied Research
- Hypotheses to be tested
- Experimental approach

6.4 Evaluation and Reporting

7. Anticipated Ecosystem Benefits

7.1 Ecological Benefits
Processes
Hydrology and Hydraulics
A more natural stage hydrograph
Altered hydraulic connectivity

Biogeochemistry
Improved water clarity
Reduced nutrient loading
Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

Geomorphology
Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits
Restored pattern of channels and floodplain features
Restored diversity of floodplain topography

- **Habitats**
  - Restored habitat connectivity
  - Restored riparian habitat
  - Restored aquatic off-channel areas
  - Restored terrestrial floodplain areas
  - Restored channel areas
  - Restored large contiguous patches of native plant communities to provide a corridor

- **Biota**
  - Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
  - Diverse and abundant native floodplain forest and prairie communities
  - Diverse and abundant native fish community
  - Diverse and abundant native mussel community
  - Diverse and abundant native bird community

**7.2 Scales of Anticipated Benefits**

Geographic extent the project study area encompasses approximately 4000 acres

Timing of anticipated responses: some response will be immediate, (forest topography, distribution channels, MSU), others will take time to become more natural

Duration of anticipated responses 0-50 years.
7.3 Anticipated Effects on Significant Resources the area will become a dynamic River delta region again

7.4 Contribution to Attaining Reach Objectives this project will help reach a multitude of reach objectives

7.5 Contribution to learning this will be the first delta restoration on UMR

7.6 Contribution to Existing Plans should affect CMMP, Pool Plans, North American Waterfowl Management Plan and many more.

8. Implementation Considerations

8.1 Affected Stakeholders

8.2 Land Ownership IA DNR, USFWS

8.3 Affected Infrastructure

8.4 River Discharge Constraints

10. Initial Costs Estimate

10.1 Planning, Engineering and Design

10.2 Construction

10.3 Operations and Maintenance

10.4 Adaptive Management Applied Research

10.5 Project Monitoring, Evaluation and Reporting

11. Points of Contact
   Corps District St Paul
   Sponsor IADNR, USFWS
   Iowa DNR
Lower Pool 2 Restoration Project

Program Neutral
Ecosystem Restoration Project Proposal
UMRS Reach Planning

Navigation and Ecosystem Sustainability Program (NESP)
U.S. Army Corps of Engineers, St. Paul, Rock Island, and St. Louis Districts

January 26, 2010
Lower Pool 2 Restoration Project

Program Neutral
Ecosystem Restoration Project Proposal
UMRS Reach Planning

Navigation and Ecosystem Sustainability Program (NESP)
U.S. Army Corps of Engineers, St. Paul, Rock Island, and St. Louis Districts

January 26, 2010

1. Introduction

1.1 Reach Planning Process

The Reach Planning Team for the Upper Impounded Reach of the Upper Mississippi River identified a set of objectives for future condition of the river ecosystem (Upper Impounded Reach Planning Team 2010a). The objectives were identified with consideration of historic conditions, the forecasted future without-project conditions, the unique and important conditions within the reach, and the factors that are limiting or that will limit the abundance and distribution of native biota. The objectives address ecologically realistic target future conditions, also referred to as best attainable conditions. The best attainable future conditions for the river ecosystem will be constrained by continued operation and maintenance of the UMR-IWW navigation project, by land and water use in the river basin and by climate change.

Quantitative performance criteria for each objective were identified using ecological literature about the UMRS and other similar systems, with EMP-LTRMP data, water quality criteria, state TMDLs efforts, and lessons learned from EMP HREP projects. The performance criteria are SMART; Specific, Measurable, Achievable, Relevant, and Time-bound. The performance criteria will target values and ranges where appropriate, considering inter-annual variation and natural disturbance regimes.

The Reach Planning Team identified indicators for condition of the river ecosystem appropriate for each geomorphic reach. The indicators were selected or derived from the performance criteria for the ecosystem objectives. The indicators should be practicable to measure, readily understood, sensitive to change over time and suitable for status and trends reports.

The Reach Planning Team met several times to prepare the Reach Plan (Upper Impounded Reach Planning Team 2010b) that identifies potential future project areas and adaptive ecosystem management activities. The draft reach plan will be provided to the full Fish and Wildlife Work Group, the River Resources forum, the NESP and EMP Management Teams the NECC and EMPCC for review, refinement if needed and
endorsement. The Reach Plan will be posted to the reach plans to the NESP DSS. The
reach plan will be updated once every four years.

This proposal is about one of the future ecosystem restoration projects in the
Upper Impounded Reach identified by the Reach Planning Team that would contribute to
achieving the ecosystem objectives. This project proposal was included in Appendix B
of the Upper Impounded Reach Plan.

1.2 Ecosystem Objectives for the Upper Impounded Reach

The Reach Planning Team has identified a set of ecosystem objectives,
performance criteria and indicators for the Upper Impounded Reach (Appendix A). The
objectives (Table 1) are organized by Essential Ecosystem Characteristics (EEC's,
Harwell et al. 1999). Geomorphic reaches 3 and 4 were considered sufficiently similar
that they were combined for purposes of setting objectives and identifying future
restoration projects.

Table 1. Ecosystem objectives for the Upper Impounded Reach of the Upper Mississippi
River.

Geomorphic Reach 1 - St. Anthony Falls to Head of Lake Pepin

Hydrology and Hydraulics
A more natural stage hydrograph
Altered hydraulic connectivity

Biogeochemistry
Improved water clarity
Reduced nutrient loading
Reduced sediment loading
Reduced sediment resuspension in backwaters
Reduced contaminants loading and remobilization of in-place pollutants

Geomorphology
Restore rapids
Restore a sediment transport regime so that transport, deposition, and erosion
rates and geomorphic patterns are within acceptable limits

Habitat
Restored habitat connectivity
Restored riparian habitat
Restored aquatic off-channel areas
Restored terrestrial floodplain areas
Restored channel areas

Biota
Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
Diverse and abundant native floodplain forest and prairie communities
Diverse and abundant native fish community
Diverse and abundant native mussel community
Diverse and abundant native bird community
Geomorphic Reach 2 - Lake Pepin

Biogeochemistry
Improved water clarity
Reduced nutrient loading
Reduced sediment loading
Reduced sediment resuspension in backwaters

Geomorphology
Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits

Biota
Diverse and abundant native fish community
Diverse and abundant native mussel community
Diverse and abundant native bird community

Geomorphic Reaches 3 & 4 – Lower Pool 4 to Lock and Dam 13

Hydrology and Hydraulics
A more natural stage hydrograph
Altered hydraulic connectivity

Biogeochemistry
Improved water clarity
Reduced nutrient loading
Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

Geomorphology
Restore a sediment transport regime so that sediment transport rates and future change in geomorphic patterns are within acceptable limits
Restored pattern of channels and floodplain features
Restored diversity of floodplain topography

Habitat
Restored habitat connectivity
Restored riparian habitat
Restored aquatic off-channel areas
Restored terrestrial floodplain areas
Restored channel areas
Restored large contiguous patches of native plant communities to provide a corridor

Biota
Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
Diverse and abundant native floodplain forest and prairie communities
Diverse and abundant native fish community
Diverse and abundant native mussel community
Diverse and abundant native bird community
1.3 Considerations in Identifying the Lower Pool 2 Restoration Project Area

Lower Pool 2 is located within Geomorphic Reach 1 which is arguably the most degraded reach within the St. Paul District. There have been no Habitat Rehabilitation and Enhancement Projects (HREPs) completed in this reach of the UMR.

1.4 Potential Project Sponsor

Non-federal sponsor - Minnesota Department of Natural Resources

Federal sponsor - St. Paul District Corps of Engineers

2. Location

The project area is located in Pool 2 of the Upper Mississippi River extending from river mile 832.0 to 815.0. The project area includes; Spring Lake, Lower Pool 2 Impoundment, Baldwin Lake, Mooers Lake, River Lake and Grey Cloud Slough. The project area is within the National Park Service's Mississippi National River Recreation Area (MNRRA) corridor.

River – Upper Mississippi River
River miles – 832.0 to 815.0
States - Minnesota
Counties – Dakota and Washington
Sub-areas – I-494 to Lower Grey Cloud Island and Lower Impounded
Map – see figure 1.

3. Significant Resources

Infrastructure – Within the Twin Cities metropolitan area.

Cultural resources – The floodplain and terraces are rich in cultural resources such as burial mounds, prehistoric villages and scattered artifacts.

Important and Unique Ecological Resources

• **Minnesota River influence** - The Minnesota River drains a basin with intensive row crop agriculture. Extensive surface and sub-surface agricultural drainage has modified the hydrologic regime. Many tributaries are actively eroding. The Minnesota River contributes high concentrations of suspended sediment and large woody debris flows to the Mississippi River, affecting condition of the river system downstream through Lake Pepin.

• **High recreational use** - Geomorphic Reach 1 has the highest amount of recreational boating traffic on the UMRS. There is great potential for increased urban recreational use. Established in 1988, the Mississippi National River and Recreation Area includes 72 miles of the Mississippi River stretching from the cities of Dayton and Ramsey to just south of Hastings. The MNRRA is administered by the National Park Service.

• **Low amount of leveed floodplain** - There are levees in Pool 2 protecting 356 acres of floodplain with an airport and areas of commercial urban development.
**Water quality recovery** - Municipal wastewater and storm drainage polluted this reach of river to the point where it was often anoxic in the 1960s. Point source pollution control and a major project to separate stormwater and sanitary drains in the Twin Cities metro area have contributed to significant improvements in water quality. There are recovering macroinvertebrate, fish and mussel communities in this reach. The fish in Pool 2 are contaminated with polychlorinated biphenyls (PCBs), Perfluorooctanesulfonic acid (PFOS) and mercury, so the sport fishery is catch-and-release. There are re-establishment sites for Higgin's eye pearly mussel in lower Pool 2 and in Spring Lake in lower Pool 3. However, non-point source pollutants, primarily sediment from the Mississippi River continues to severely degrade water quality and affect habitat for fish and wildlife in Lower Pool 2. Lower Pool 2 is on the 303(d) list of impaired river reaches for high turbidity.

**T&E Species** - Check natural heritage data base, NESP Pool 2 Wing Dam modification project PIR and Pool 2 Channel Management Study

### 4. Problem Identification

#### 4.1 Historic Conditions

Native Americans had many villages and farms along this reach of river. The river and floodplain provided an abundant source of food, supporting a large population. European settlement along this reach of river began under the protection of Fort Snelling, established in 1819. By 1890, farming and logging had extensively changed the landscape in the river basin. Mill dams were built on the Mississippi River at Minneapolis and on many tributaries.

Within Geomorphic Reach 1, the floodplain was extensively used for grazing by cattle and horses. Many floodplain trees were logged off for use as steamboat fuel. By 1989, much of the floodplain in Pools 1 and 2 were developed urban area. In Pool 3, development has occurred on Prairie Island, and Bay City became larger but most of the floodplain remains undeveloped. Upper Pool 4 above the head of Lake Pepin also remains undeveloped. The delta at the head of Lake Pepin has advanced into the lake.

Construction of the 4-ft and 6-ft deep navigation channel project in the 1800s included construction of many rock and brush wing dams, dredging and placement of dredged material between the wing dams. Areas between the wing dams accumulated sediment and grew up in trees over time. Boulders were removed from the rapids in the Mississippi River gorge in the late 1800s to improve navigation.

Impoundment of the navigation system started with the Meeker Island Dam (the original Lock and Dam 1) in 1913. That dam was removed a year later and the current Lock and Dam 1 was built farther downstream in 1917. Lock and Dam 2 was completed in 1930, and Lock and Dam 3 was completed in 1934. Impoundment of the navigation pools inundated extensive areas of floodplain, leaving the higher natural levees and terraces as islands.

Geomorphic Reach 1 supported extensive areas of emergent and submersed aquatic plants in the first decades after impoundment.
Urban wastewater and runoff badly polluted the river as the Twin Cities metropolitan area grew. Lower Pool 1 and Pool 2 became anoxic, decimating the fish and mussel communities. After improvements to the waste water treatment plants and a major project to separate the storm and sanitary drains, water quality conditions improved greatly, allowing return of fish, native mussels and mayflies to the river.

The capacity to transport sediment decreased from the upstream to downstream end of Geomorphic Reach 1. The hydraulic slope in upper Pool 4, for instance, was only about 1/3 that in Pool 2 prior to Lock and Dam construction. The reduced capacity resulted in sediment aggradation in the downstream end of Geomorphic Reach 1 and the gradual migration of the Geomorphic Reach 1 delta at the head of Lake Pepin in a downstream direction. At smaller spatial scales, both deposition and erosion occurred.

Sediment deposition in Lake Pepin, just downstream of Geomorphic Reach 1, has increased from a pre-development rate of 80,000 metric tons per year to the current value of about 900,000 metric tons per year. This suggests that sediment loads and concentrations in Geomorphic Reach 1 have increased significantly over historic conditions. Sullivan, as part of an effort to establish historic sediment concentrations, used sediment deposition results in Lake Pepin and Met Council Environmental Services data from the 1950s to show that suspended sediment concentrations were historically lower than current values near Red Wing.

Average discharge at St. Paul has increased significantly from the 1930s to the present. This has increased sediment and nutrient loads to Geomorphic Reach 1, and probably affects geomorphic processes within the reach. The St. Paul record indicates that prior to the 1930s there was a high flow period also, however the record only extends back to 1907. The increase in discharge is partly driven by the increase in annual precipitation although land-use changes in upstream watersheds are another factor.

Pre- and post-lock water surface profiles in Geomorphic Reach 1 for the 2-year flood, and for discharges exceeded 25% of the time (moderate flow), and 75% of the time (low flow). For low flow conditions, the water surface has been increased throughout Geomorphic Reach 1 due to the effects of the dams. For the two-year flood and moderate flow conditions, water surface elevations have been decreased in Upper Pool 4, Pool 3, and Upper Pool 2, while there has been an increase in Lower Pool 2. Geomorphic changes in the navigation pools (including lower Pool 4) are responsible for the decreases in the profiles. The increase in water surface profiles in lower Pool 2 is due to the fact that Lock and Dam 2, with a lift of over 12 feet for normal pool conditions, is one of the highest head dams in the St. Paul District.

4.2 Existing Conditions

Major habitat concerns for Lower Pool 2 are high turbidity, sedimentation, sediment resuspension, island dissection, shoreline erosion, loss of longitudinal connectivity, aquatic vegetation loss and reduced depth for over-wintering fish. Emergent and submersed aquatic vegetation are found in low frequency in a few locations within Lower Pool 2. Flood effects, wave generated erosion and re-suspension of fine sediments caused by continual inundation have reduced the fish and wildlife value of these areas which once provided outstanding waterfowl hunting and winter fishing close to the Twin Cities.
Watershed inputs sustain relatively high total suspended solids concentrations and high nutrient concentrations contributing to eutrophic conditions. A major contributor of sediment and nutrients is the Minnesota River watershed. The Lake Pepin TMDL has quantified its sediment and nutrient contribution to Geomorphic Reach 1. The Minnesota River watershed is responsible for approximately 90% of the 900,000 metric tons of suspended sediments delivered annually to Lake Pepin. Lake Pepin is filling in 10 times faster than pre-European settlement times. Similarly, Lower Pool 2 floodplain lakes have also experienced accelerated sedimentation rates that are attributable to upstream land use changes. Many of the bottom sediments are loose, flocculent silts and clays. Submersed aquatic plans are sparse due to limited light transparency.

The 9-Foot Channel's Lock and Dam 2 raised water levels, increased lake sizes, increased lateral connectivity, increased wind fetch and wind wave heights with the associated erosion of islands and shorelines, facilitated larger wind waves that resuspend fine-grained bottom sediments, accelerated sediment deposition because of increased sediment loading and reduced sediment transport competence/capacity. Watershed inputs sustain relatively high total suspended solids concentrations and high nutrient concentrations contributing to eutrophic conditions. Many of the bottom sediments are loose, flocculent silts and clays. Submersed aquatic plans are sparse due to limited light transparency.

4.3 Forecasted Future Conditions

Habitat degradation will continue due to shoreline and island erosion, wind resuspension of bottom sediments, limited aquatic plant beds, eutrophic conditions, limited light transparency, and accelerated sedimentation rates.

4.4 Stressors Affecting the Condition of Habitat and Biota

Sustained higher water levels due to the Lock and Dam 2 impoundment, polluted runoff from upstream watersheds – especially the Minnesota River, long wind fetches, high turbidity, high nutrient and total suspended solids concentrations, and accelerated sedimentation rates. Other stressors include channel training structures, channel maintenance dredging, urban and industrial infrastructure and major NPDES dischargers.

4.5 Restoration Opportunities

Lower Pool 2 would benefit greatly from the proposed restoration project. Opportunities include the potential Boulanger Slough main channel realignment project and the potential Nelson Mine expansion. Grey Cloud Island has many acres of disturbed land that could possibly benefit from the placement of sand and fine-grained fill material for land reclamation. Macalester College operates a biological field station on River Lake. Proximity to the Twin Cities urban population will induce great interest and use in the restoration project area. MPCA is completing the Lake Pepin TMDL and is moving into implementation planning which will further assist in restoration of the project area.

4.6 Project Ecosystem Objectives
5. Description of the Proposed Project

A pool-wide drawdown of Pool 2 would benefit the entire lower Pool 2 project area. It is our understanding that the Corps is writing a separate programmatic project proposal which will include a pool-wide drawdown and/or alternative water level management operating curves to restore a more natural hydrologic regime by better emulate pre-lock and dam hydrology/hydraulics.

5.1 Project Features

Phase 1 - Spring Lake and Lower Impounded Area Island Restoration - The project involves restoration of a series of approximately 10 islands to reduce wind-generated wave erosion and sediment resuspension in the Spring Lake and Lower
Impounded Area. Island construction would utilize fine-grained substrates within the floodplain to enhance bathymetric diversity and provide topsoil on the constructed islands. Island construction would improve conditions for growth of aquatic vegetation and promote increases in depth by concentrating flows to promote scour. Ideally, this project would be sequenced with water level management that would consolidate sediments and promote growth of aquatic vegetation on the shoreline. See figure 2, 3, and 4.

Phase II - Grey Cloud Slough and Baldwin Lake Connectivity Restoration – The project involves the reestablishment of flow down Grey Cloud Slough through Lower Mooers Lake, improved connectivity between Upper Baldwin Lake and Mooers Lake and environmental depth dredging in Lower Baldwin Lake. Restored connectivity of Grey Cloud Slough and Baldwin Lake will improve habitat conditions, provide migration corridor and improve access.

If it is determined by the partners, after an appropriate level of analysis, that a pool-wide Pool 2 drawdown or change to the Lock and Dam 2 operating curves is unfeasible, the restoration of seasonal water level fluctuations to mimic summer low flow conditions to stimulate production of marsh and aquatic plant growth using alternative project designs will be considered. A possible water level management drawdown component to this phase of the project could include a demonstration drawdown within Lower Baldwin Lake by temporarily closing off the area with dikes and pumping water out to lower water levels. See figure 5, 6 and 7.

Phase III - Rebecca Lake Connectivity Restoration – The project would reestablish flow through the Lock and Dam 2 embankment down through Rebecca Lake and back out to the main channel. Rebecca Lake was connected to a significant secondary side channel that was occluded by construction of Lock and Dam 2. Restoration of longitudinal connectivity through the embankment would provide for fish passage, allow for the development of a secondary channel habitat, create additional recreational opportunities and provide a migration corridor. See figure 7.

Phase IV – River Lake Connectivity and Environmental Depth Dredging – This phase of the project would restore the natural levee along the main channel to reduce lateral connectivity during low to moderate flows. Depth dredging would improve overall fisheries habitat. Bank stabilization of an actively eroding terrace at Pine Bend (RM 825.5) would reduce sedimentation loading to the river.

If it is determined by the partners, after an appropriate level of analysis, that a pool-wide Pool 2 drawdown or change to the Lock and Dam 2 operating curves is unfeasible, the restoration of seasonal water level fluctuations to mimic summer low flow conditions to stimulate production of marsh and aquatic plant growth using alternative project designs will be considered. A possible water level management drawdown component to this phase of the project could include temporarily closing off the upper area of River Lake with dikes and pumping water out to lower water levels. See figure 8.

5.2 Implementation Sequence of Project Features

1. Phase I – Spring Lake and Lower Impounded Area Restoration
2. Phase II – Grey Cloud Slough and Baldwin Lake Connectivity Restoration
3. Phase III – Rebecca Lake Connectivity Restoration
4. Phase IV – River Lake Connectivity and Environmental Depth Dredging

5.3. Operations and Maintenance
Because of our collective agencies experience designing and constructing islands and structures in the UMR it is anticipated that operation and maintenance costs will be less that 5% of the construction cost over the life of the project.

6. Adaptive Management Activities

6.1 Learning Objectives
1. Evaluate effectiveness of island restoration to improve habitat conditions within a river reach with high ambient turbidity.
2. Evaluate effectiveness of restoring lateral and longitudinal connectivity to improve water quality.
3. Fish passage effectiveness when longitudinal connectivity is restored away from the tailwater flows.

6.2 Project Monitoring

Pre-project
1. bathymetry
2. water quality – turbidity, tss, secchi disk, dissolved oxygen, temperature, velocity
3. vegetation - species richness, frequency of occurrence
4. mussel - species richness, catch/unit effort
5. fish – fish assemblage, catch per unit effort, size structure
6. Aquatic Habitat Quality Index (AHQI)
7. waterfowl use
8. air photo interpretation

During construction – water quality

Post-construction
1. bathymetry
2. water quality – turbidity, tss, secchi disk, dissolved oxygen, temperature, velocity
3. vegetation - species richness, frequency of occurrence
4. mussel - species richness, catch per unit effort
5. fish – fish assemblage, catch per unit effort, size structure
6. Aquatic Habitat Quality Index (AHQI)
7. waterfowl use
8. air photo interpretation

6.3 Applied Research
Hypotheses to be tested – Fish are attracted to side-channel flow conditions when longitudinal connectivity is restored to non-tailwater reaches of the main channel.

Experimental approach – Measure fish passage between Pools 2 and 3 using rock ramp.
6.4 Evaluation and Reporting
Once completed, the proposed project will be fully evaluated using field observations and monitoring data. MDNR will assist the Corps with the writing of a Completion Report as soon as practical following construction. It is anticipated that reports will be done in 5 year increments for the first 20 years following completion of any particular Phase of the project.

7. Anticipated Ecosystem Benefits

7.1 Ecological Benefits
Processes - reduced wind fetch, more concentrated flow, improved light penetration (lower turbidity, lower tss, higher secchi disc readings), sheltered deeper water, sheltered shallow areas, induced scour to increase physical diversity, reduced lateral connectivity, increased longitudinal connectivity, and simulated natural water level dynamics.

Habitats – increased aquatic plant species richness, increased aquatic plant frequency of occurrence, improved waterfowl migration habitat, improved lentic fish floodplain lakes habitat, improved riverine fish habitat and improved secondary channel habitat.

Biota – Change in backwater fish assemblage to be more like Pool 13 backwaters, increased catch per unit effort for fish, improved fish size structure, improved fish passage, increased catch per unit effort for mussels, increased mussel species richness, and increased waterfowl use days during migration.

7.2 Scales of Anticipated Benefits
Geographic extent – benefits would extend throughout both the I-494 to Lower Grey Cloud Island and Lower Impounded subareas within Pool 2. Also, some benefits would accrue to upper Pool 3.

Timing of anticipated responses – immediate improvement in geomorphology, water quality, and hydrology/river hydraulics - habitat and biota response should begin soon after completion and then develop/improve over time. The successful implementation of the Lake Pepin TMDL is necessary to realize the true restoration potential of the project area.

Duration of anticipated responses – constructed islands and engineered structures >50 years, dredge cut lifespans are dependent on sediment deposition rates, habitat and biotic responses should occur as long as islands, structures and dredge cuts are present, vegetative response associated with water level management is expected to last between 3 and 10 years.

7.3 Anticipated Effects on Significant Resources
Significant Likely to have a material bearing on the decision-making process. Significance is based on institutional, technical, and public recognition. Resources and effects of alternative management actions are evaluated for significance. (U.S. Water Resources Council 1983)
7.4 Contribution to Attaining Reach Objectives

- **Hydrology and Hydraulics**
  - A more natural stage hydrograph
  - Altered hydraulic connectivity

- **Biogeochemistry**
  - Improved water clarity
  - Reduced nutrient loading
  - Reduced sediment loading
  - Reduced sediment resuspension in backwaters
  - Reduced contaminants loading and remobilization of in-place pollutants

- **Geomorphology**
  - Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits
  - **Habitat**
    - Restored habitat connectivity
    - Restored riparian habitat
    - Restored aquatic off-channel areas
    - Restored terrestrial floodplain areas
    - Restored channel areas
  - **Biota**
    - Diverse and abundant native aquatic vegetation communities (SAV, EAV, R/F)
    - Diverse and abundant native floodplain forest
    - Diverse and abundant native fish community
    - Diverse and abundant native mussel community
    - Diverse and abundant native bird community

7.5 Contribution to Learning

This will be one of the first island restoration projects above Lake Pepin in Geomorphic Reach 1. It may also be the first project to restore fish passage outside of a Lock and Dam tailwater.

7.6 Contribution to Existing Plans

The project proposal contributes substantially to meeting the Environmental Pool Plans desired future conditions (DFCs).

8. Implementation Considerations

Constructing islands in conjunction with backwater dredging has proven effective for past HREP projects and can be applied to the Lower Pool 2 project area.
8.1 Affected Stakeholders
   1. Minnesota Citizens
   2. Minnesota DNR Division of Wildlife
   3. Dakota and Washington Counties

8.2 Land Ownership
   In Pool 2 the Corps purchased flowage easements rather than fee title for the 9-Foot Channel Project. There are many landowners that would need to be coordinated with including the MDNR, NPS, Macalester College, the Schilling Family, City of Hastings, Washington and Dakota Counties.

8.3 Affected Infrastructure
   Washington County Highway 75, Lock and Dam 2 Embankment, Hasting’s Jaycee Park and River Lake Marinas.

8.4 River Discharge Constraints – flood flows may alter or extend construction or operations schedule.

10. Initial Costs Estimate

10.1 Planning, Engineering and Design – $2,325,000 (10% of construction costs)

10.2 Construction Costs - $23,250,000 in 2010 dollars.
   $ 8,250,000 Phase I – Spring Lake and Lower Impounded Area Restoration
   $ 5,000,000 Phase II – Grey Cloud Slough and Baldwin Lake Connectivity
   $ 7,500,000 Phase III – Rebecca Lake Connectivity Restoration
   $ 2,500,000 Phase IV – River Lake Connectivity and Environmental Dredging

10.3 Operations and Maintenance - $100,000 per year

10.4 Adaptive Management Applied Research – $ 50,000

10.5 Project Monitoring, Evaluation and Reporting - $500,000

11. Points of Contact
   Corps of Engineers, St. Paul District, Project Manager, 651-290-5402
   Minnesota Department of Natural Resources, EMP Coordinator, 651-345-5601

References


Appendix A – Ecosystem Objectives of the [___________] Floodplain Reach

Appendix B – Learning Objectives for the [___________] Floodplain Reach

Appendix C – Initial Costs Estimate MDNR can supply more details.

Figure 1. Lower Pool 2 Spring Lake location map.
Figure 2. Spring Lake and Lower Impounded Area preliminary plan.

Figures 3 and 4. Wind Fetch Model before and after island restoration results.

Figure 7. Lower Baldwin Lake Project area with possible features – closures in green and dredging in red.
Figure 8. Rebecca Lake Connectivity Restoration Project area with possible features – red arrows depict opening in Lock and Dam 2 embankment and bridge/opening to main channel.

Figure 9. River Lake Project area with possible features – island peninsula in green, dredging in red, partial closure in dotted yellow and bank stabilization in solid yellow.
Conceptual Models
Reference Conditions (Natural)

Need description of natural vegetation communities

The ’90s to survey of the UMRS indicates an aquatic floodplain consisting of 100% short stature, secondary channels, shallow pools and channels, and floodplain floodplains. Connected floodplains are those that now totally were slightly changed.

Reference Conditions (Pre-Lock, Early 1900s)

Need description of animals, fish, birds, and vegetation communities

Biota: Manage for viable populations of native species within diverse plant and animal communities

Shoreline development including port facilities, riprap, floodwalls, levees, etc. that were provided flood protection for the UMRS.

Reference Conditions (Post-Lock, 1940s)

Need description of animals, fish, birds, and vegetation communities

Animals, Fish, Birds Vegetation Communities Habitat (Geographic Landscape Category) Stressor: Cause Change Factors most limiting in Boreal

Reference Conditions

Shoreline development including port facilities, riprap, floodwalls, levees, etc. that were provided flood protection for the UMRS.

Invasive species (e.g. Purple Loosestrife, Reed Canary Grass) and disease (e.g. Dutch Elm), and high surface and ground-water levels.

Animals, Fish, Birds Vegetation Communities Habitat (Geographic Landscape Category) Stressor: Cause Change Factors most limiting in Boreal

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Shoreline development including port facilities, riprap, floodwalls, levees, etc. that were provided flood protection for the UMRS.

Invasive species (e.g. Purple Loosestrife, Reed Canary Grass) and disease (e.g. Dutch Elm), and high surface and ground-water levels.
Desired Future Conditions

Existing Conditions

- Improved SAV distribution and cover during the low points of the year
- Improvement of SAV distribution and cover throughout the reach
- Increased SAV distribution and cover during the low points of the year
- Improvement of SAV distribution and cover throughout the reach

Desired Future Condition (Best Attainable Condition)

- Increase SAV distribution and cover during the low points of the year
- Improvement of SAV distribution and cover throughout the reach
- Increase SAV distribution and cover during the low points of the year
- Improvement of SAV distribution and cover throughout the reach

Factors Limiting Natural Processes and the Distribution and Abundance of Biodiversity in the Reach

- Reduced lateral hydraulic connectivity (LHC) between the main channel and backwaters or secondary channels
- Reduced wave action
- Reduced Secchi Transparency
- Reduced wind fetch

Desired Future Condition (Best Attainable Condition)

- Increased lateral hydraulic connectivity (LHC) between the main channel and backwaters or secondary channels
- Increased wave action
- Increased Secchi Transparency
- Increased wind fetch

Desired Future Condition (On-Site Action)

- Increased water levels
- Reduced turbidity
- Reduced wind fetch
- Improved LHC
Monitoring Needs:
- Duck Use Days
- SAV distribution
- Light penetration
- TSS
- Nutrient concentrations
- Tributary sediment loads
- Hydraulic Connectivity mainstem and tributaries

Need surveys to determine duck numbers and distribution (locations of high use areas). Determine impacts of human disturbance during spring migration: undesirable would be less than

Modeling Needs:
- SAV model
- Wind effects model
- 2D hydraulic model

Critical Uncertainty:
- Factors driving SAV cycles
- Breeding populations affected by climate, predators; wintering populations affected by habitat conditions that affect body conditions going into the spring migration and nesting season.
- How important is the UMR for divers during the spring migration? Canvasbacks use is very high in the spring, but not adequately documented.
### Upper Floodplain Reach, Geomorphic Reach 1

#### Reach Scale Objectives Conceptual Model

#### Floodplain Vegetation

**Objectives:**
- Diverse and abundant native floodplain forest and prairie communities

**Performance Criteria:**
- Species diversity: Ensure that stands of at least 5 Dutch Elm disease-resistant trees per acre by _____ acres by 2020
- Reduce area dominated by need leaf grass by _____ acres by 2020
- Restore >50% of the length of currently armored or stabilized river bank to natural channel border and riparian zone habitat by 2060.

#### Biogeochemistry

**Objectives:**
- Reduced Nutrient Loading

**Performance Criteria:**
- Reduce Phosphorous loads to GR 1 by 2025.
- Minnesota River: 50%
- Miss R u/s of TC: 20%
- St. Croix River: 20%
- Cannon River: 50%
- Other Tributaries: 20%

#### Geomorphology

**Objectives:**
- Maintain existing terrestrial corridor and connectivity of native vegetation communities.
- Restore >50% of the length of currently armored or stabilized river bank to natural channel border and riparian zone habitat by 2060.
- Impounded areas, Lower Pool 2: Restore natural levees that are permanently inundated to create riparian habitat.

**Performance Criteria:**
- Alter topography (e.g. Ridge and Swale), surface and groundwater seasonal variations, and soil conditions to create optimal conditions for native tree growth.
- Connectivity: Alter lateral hydraulic connectivity so that the frequency, duration, magnitude, and timing of flow and resulting stage variations are within optimal limits for target birds and habitats.

#### Hydraulics & Hydrology

**Objectives:**
- A more natural stage hydrograph
- Altered hydraulic connectivity

**Performance Criteria:**
- Annual Stage Hydrograph:
  - Low flow (75% exceedance): water elevation decreased 1’ at lock and dams 2 and 3
  - Moderate flow (25% exceedance): water elevation decreased 2’ at lock and dams 2 and 1’ at lock and dam 3
  - High flow (2-year flood): water elevation decreased 2’ at lock and dam 2

- Decadal Stage Variation:
  - Increase the amount of drawdown for low flow conditions for one to two consecutive growing seasons to simulate longer-term cycles of drought to improve forest regeneration.

- Hydraulic Connectivity:
  - Alter hydraulic connectivity so that frequency, duration, magnitude, and timing of flow and resulting stage variations are within optimal limits for desired floodplain vegetation community structure.

#### Measurable Indicator

**Transition from invasive species dominated areas to desirable floodplain forest:**
- Invasives include Reed Canary Grass, Buckthorn, Black Locust, Garlic Mustard, others.
Upper Floodplain Reach, Geomorphic Reach 1
Reach Scale Objectives Conceptual Model

**Native Birds (Diving Ducks)**

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<thead>
<tr>
<th>Biota Objective</th>
<th>Diverse and abundant native bird community</th>
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<tr>
<th>Habitat Objective</th>
<th>Improved water clarity</th>
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<td>Reduced sediment loading from tributaries and sediment reentrainment into and leading to backwaters</td>
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### Biota Objective Performance Criteria

- **SAV and RFV in MCB**
  - Frequency of occurrence
  - Biomechanical properties
  - Biomass estimated from rake abundance
  - SAV and RFV in Backwater Basins
  - Biomechanical diversity index

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<tr>
<th>Biomechanical Indicator</th>
<th>SAIV and RFV in MCB</th>
<th>Biomass estimated from rake abundance</th>
<th>SAV and RFV in Backwater Basins</th>
<th>Biomechanical diversity index</th>
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<td>Sediment transport</td>
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### Hydraulics and Hydrology Objective

- **A more robust stage hydrograph**
- **Altered hydraulic connectivity**

| Hydraulics and Hydrology Performance Criteria | Stage hydrograph
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<tr>
<td><strong>Stage Hydrograph</strong></td>
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<thead>
<tr>
<th>Monitoring Needs</th>
<th>Nesting season</th>
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<td>SAV</td>
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**Critical uncertainty**

- Factors driving SAV cycle
  - Breeding populations affected by climate, predators, competition,
  - Waterfowl populations affected by habitat conditions that affect body conditions going into the spring migration and nesting season

- How important is the LBMR for divers during the spring migration? Land use in very high to the spring, but not adequately documented.

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### Upper Floodplain Reach, Geomorphic Reach 1
Reach Scale Objectives Conceptual Model

**Native Birds (Diving Ducks)**

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<tr>
<td></td>
<td>Reduced sediment loading from tributaries and sediment reentrainment into and leading to backwaters</td>
</tr>
</tbody>
</table>

### Biota Objective Performance Criteria

- **SAV and RFV in MCB**
  - Frequency of occurrence
  - Biomechanical properties
  - Biomass estimated from rake abundance
  - SAV and RFV in Backwater Basins
  - Biomechanical diversity index

<table>
<thead>
<tr>
<th>Biomechanical Indicator</th>
<th>SAIV and RFV in MCB</th>
<th>Biomass estimated from rake abundance</th>
<th>SAV and RFV in Backwater Basins</th>
<th>Biomechanical diversity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS @ 120 mm 33%</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sediment transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

### Hydraulics and Hydrology Objective

- **A more robust stage hydrograph**
- **Altered hydraulic connectivity**

| Hydraulics and Hydrology Performance Criteria | Stage hydrograph
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage Hydrograph</strong></td>
<td>On a periodic basis (e.g. one to two consecutive years or to an event of significant, widespread, or prolonged nature)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring Needs</th>
<th>Nesting season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SAV</td>
</tr>
</tbody>
</table>

**Critical uncertainty**

- Factors driving SAV cycle
  - Breeding populations affected by climate, predators, competition, waterfowl populations affected by habitat conditions that affect body conditions going into the spring migration and nesting season

- How important is the LBMR for divers during the spring migration? Land use in very high to the spring, but not adequately documented.
Upper Floodplain Reach, Geomorphic Reach 1
Reach Scale Objectives Conceptual Model
Lentic Fish

Habitat Objective
- Restore aquatic off-channel areas

Biodiversity Objective
- Diverse and abundant native fish community

Geospatial Objective
- Restore/maintain aquatic off-channel areas

Hydrology and Ecology Objective
- A more natural stage hydrograph
- Altered hydraulic connectivity

Hydrology and Hydrology Objective
- A more natural stage hydrograph
- Altered hydraulic connectivity

Primary Objective
- Reduce Sediment and Phosphorous loads to GR 1 by 2025.

Timeline for Achieving Objectives:
The timing of altering lateral hydraulic connectivity depends significantly on efforts to reduce sediment and nutrient loads on the Minnesota River.

Habitat Performance Criteria:
- Reduced sediment loading from tributaries and sediment re-suspension in open water to backwaters.

Hydraulics and Hydrology Performance Criteria:
- Daily Water Level Variation
- Reduce daily water surface elevation variation caused by lock and dam operation by 50%.

Geospatial Performance Criteria:
- Achieve a Secchi depth based on June through September averages at lock and dam 3 of 47 cm.

Lentic Fish Performance Criteria:
- Achieve a Secchi depth of 80 cm for the September averages at lock and dam 3.

Island Restoration:
- Islands (Natural levees)

Lentic Fish Objective:
- Restore/maintain lentic fish habitat to yield desired community

Biota Objective:
- Diverse and abundant native fish community

Measurable Indicator:
- Winter water velocities in backwater areas.
- Reduced current leading

Measurable Indicator:
- Water Temperature:
  - Winter: DO > 3 mg/l
  - Summer: DO > 5 mg/l

Measurable Indicator:
- Backwater/Floodplain:
  - TN < 1.23 mg/L (Sullivan, 2008)
  - TP < 0.1 mg/L (Sullivan, 2008)

Measurable Indicator:
- Water Temperature:
  - DO: > 3 mg/l

Measurable Indicator:
- Bathymetry:
  - Size: >10 ac
  - Distribution: 1 to 6/square mile

Monitoring Needs:
- Spatial water WQ data
- Bathmetry

Modeling Needs:
- 2D hydraulic model
- LDM for integration with biotrophy to determine timing of critical to backwaters

Drivers influencing aspization and invasives used as

Critical uncertainty:
- Invasive species

Uncertainties:
- Disease

Drivers influencing aspization and invasives used as

Uncertainties:
- Disease

Drivers influencing aspization and invasives used as
Upper Floodplain Reach, Geomorphic Reach 1
Reach Scale Objectives Conceptual Model

**Mussels**

**Ecological Status of Native Mussels in Geomorphic Reach 1**
- Status highly variable by sub-area.
- Zebra mussel densities low, except St. Croix.

<table>
<thead>
<tr>
<th>Mussel Performance Criteria</th>
<th>Existing</th>
<th>Year 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch/unit effort (% sites with &gt; 10/min)</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Catch/unit effort (% sites with &lt; 1/min)</td>
<td>33</td>
<td>20</td>
</tr>
<tr>
<td>Species richness (# species)</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Mucket mussel (% of population)</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- Manage zebra mussel densities to below an affects level on native mussels.
- Prevent the introduction of Asian carp.
- Increase host availability for selected mussel species that have declined.

**Objectives**

**Habitat Objective**
- Restored channel areas

**Biogeochemistry Objective**
- Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

**Geomorphology Objective**
- Restore a sediment transport regime so that transport, deposition, and erosion rates are within acceptable limits

**Hydraulics and Hydrology Objective**
- A more natural stage hydrograph (daily variations)

**Performance Criteria**

**Habitat Performance Criteria**
- Restore ___(acres) of main channel border and or secondary channel
- Channel Characteristics:
  - 3 < v < 4 fps for 5% duration event
  - 0.5 < v < 1.5 fps for 75% duration event
- Substrate: Rock/gravel 5%, wood 5%
- Channel pattern, profile result in transport of sediment to delta areas or to outlet of secondary channel reach.

**Biogeochemistry Performance Criteria**
- Reduced Sediment and Phosphorous loads to GR 1 by 2025
- Minnesota River: 50%
- Miss R u/s of TC: 20%
- St. Croix River: 20%
- Cannon River: 50%
- Other Tributaries: 20%
- From Scenario 17, Lake Pepin TMDL Study

**Geomorphology Performance Criteria**
- Substrate: Rock/gravel 5%, wood 5% by 2050.

**Hydraulics and Hydrology Performance Criteria**
- Daily Variation:
  - Reduce daily water surface elevation variation caused by lock and dam operation by 80%
  - Impounded areas: Reduce lateral hydraulic connectivity between historic floodplains and channels for total river discharges less than the two year flood to create secondary channel habitat.

<table>
<thead>
<tr>
<th>Measurable Indicator:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of mussel beds</td>
</tr>
<tr>
<td>Species Diversity</td>
</tr>
</tbody>
</table>

**Measurable Indicator**
- Number of mussel beds
- Species Diversity

**Monitoring Needs:**
- Pool-wide mussel distribution

**Modeling Needs:**
- 2D hydraulic model
- Sediment Transport

**Critical Uncertainties:**
- Minnesota River restoration efforts as affected by funding, agricultural trends.
- Invasive species
- Climate change

---

**Primary Objectives**

**Biota Objective:**
- Diverse and abundant native mussel community

**Mussel Performance Criteria:**
- Year 2025
  - Catch/unit effort (% sites with > 10/min)
    - Existing: 5
    - Year 2025: 10
  - Catch/unit effort (% sites with < 1/min)
    - Existing: 33
    - Year 2025: 20
  - Species richness (# species)
    - Existing: 28
    - Year 2025: 35
  - Mucket mussel (% of population)
    - Existing: 0
    - Year 2025: 1

---

**Habitat Objective**
- Restored channel areas

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**Measurable Indicator**
- Number of mussel beds
- Species Diversity

**Monitoring Needs:**
- Pool-wide mussel distribution

**Modeling Needs:**
- 2D hydraulic model
- Sediment Transport

**Critical Uncertainties:**
- Minnesota River restoration efforts as affected by funding, agricultural trends.
- Invasive species
- Climate change

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**Primary Objectives**

**Biota Objective:**
- Diverse and abundant native mussel community

**Mussel Performance Criteria:**
- Year 2025
  - Catch/unit effort (% sites with > 10/min)
    - Existing: 5
    - Year 2025: 10
  - Catch/unit effort (% sites with < 1/min)
    - Existing: 33
    - Year 2025: 20
  - Species richness (# species)
    - Existing: 28
    - Year 2025: 35
  - Mucket mussel (% of population)
    - Existing: 0
    - Year 2025: 1

---

**Habitat Objective**
- Restored channel areas

**Biogeochemistry Objective**
- Reduced sediment loading from tributaries and sediment resuspension in and loading to backwaters

**Geomorphology Objective**
- Restore a sediment transport regime so that transport, deposition, and erosion rates are within acceptable limits

**Hydraulics and Hydrology Objective**
- A more natural stage hydrograph (daily variations)

**Performance Criteria**

**Habitat Performance Criteria**
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**Geomorphology Performance Criteria**
- Substrate: Rock/gravel 5%, wood 5% by 2050.

**Hydraulics and Hydrology Performance Criteria**
- Daily Variation:
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**Measurable Indicator**
- Number of mussel beds
- Species Diversity

**Monitoring Needs:**
- Pool-wide mussel distribution

**Modeling Needs:**
- 2D hydraulic model
- Sediment Transport

**Critical Uncertainties:**
- Minnesota River restoration efforts as affected by funding, agricultural trends.
- Invasive species
- Climate change
Amphibian Objective:
- Amphibian species diversity (not thinking of the needs of an individual species here) then is a function of some blend of interconnected terrestrial and wetland habitat that exist over space and time in sufficient quantity and quality in the face of the aforementioned stressors.
  - These wetland-upland matrices would include relatively shallow, relatively isolated wetlands of varied size, structure, and vegetative characteristics interspersed with uplands that range from forest to wet meadow. In other words, diverse habitats that are well-connected within these matrices, allowing animals to move and populations to flex across the landscape.

Amphibian Performance Criteria:
- Species Richness:
- Composition:
- Abundance:

Biogeochemistry Stressor:
- Nutrient fluxes that increase or reduce primary productivity to excessive or insufficient levels, respectively
- Contaminants, such as endocrine disruptors and others, that could reduce fitness via direct and indirect, lethal and sublethal mechanisms
- Sedimentation that reduces primary productivity, primarily in the form of normally

Biogeochemistry Objective:
- Reduce sediment, nutrient, and other constituent (e.g., endocrine disruptors) concentrations to isolated water bodies.

Biogeochemistry Performance Criteria:
- Meet Lake Pepin TMDL standard for turbidity and nutrients by 2025

Geomorphology Stressor:
- Land use that disrupts or alters effective habitat connectivity permanently (e.g. roads) or temporarily or results in increased densities of predators
- Sedimentation that reduces primary productivity, primarily in the form of normally

Geomorphology Objective:
- Increase habitat connectivity between aquatic and terrestrial areas (e.g., enable movement between habitats);
- Reduce sediment, turbidity, and other constituent (e.g., endocrine disruptors); reduce water bodies.

Geomorphology Performance Criteria:
- Use a candidate of remotely sensed data and geographic analyses integrated with data collected in situ to conduct integrated assessments of the relationships between habitat diversity, landscape connectivity, and amphibian populations; the latter should consider local and regional trends over space and time.

Hydraulics & Hydrology Stressor:
- Floods and/or insufficient hydroperiods that reduce reproductive success and, for some species, overwintering sites (e.g., physical disruptions or lack of water) or increase predation (e.g., increased predation caused by fish and other species moving in with high water or omnivores, such as raccoons, moving in during low water).
- Flowing or deep water of any significance

Hydraulics and Hydrology Objective:
- Maintain a consistent stage hydrograph during winter.
- Reduce hydraulic connectivity for below bankfull conditions.

Hydraulics and Hydrology Performance Criteria:
- Water level variation for winter conditions < 1.0’
- Hydraulic connectivity should approach zero for below bankfull conditions.

Critical uncertainty:
- Minnesota River restoration efforts as affected by funding, agricultural trends.
- Invasive species
- Climate change

Upper Floodplain Reach, Geomorphic Reach 1
Reach Scale Objectives Conceptual Model
Amphibians (mostly, but not entirely, for species other than mudpuppies)

Note: There is no Biota Objective for Amphibians in the Upper Floodplain Reach. I left this here to retain the information that was obtained from the reach planning team on Amphibians.
<table>
<thead>
<tr>
<th>Measureable Indicator</th>
<th>Performance Criteria</th>
<th>Objective</th>
<th>Primary Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **Biota Objective:**
  - Diverse and abundant native fish
  - Biogeochemistry Objective:
    - Reduced contaminants loading and remobilization of in-water and sediments
  - Geomorphology Objective:
    - Promote increase bed size of macrophytes in the main channel
  - Hydrology Objective:
    - Change in harvest on populations
- **Nutrient Objective:**
  - Climate change
- **Habitat Objective:**
  - Balanced and diverse fish habitat
  - Habitat Objective:
    - Promote increase bed size of macrophytes in the main channel
  - Habitat Connectivity Objective:
    - Reduced contaminants loading and remobilization of in-water and sediments
  - Channel Characteristics:
    - Fish Passage Structures
    - Promote increase bed size of macrophytes in the main channel

**Primary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Reduce daily water surface elevation variation caused by lock operations

**Secondary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Tertiary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Restore fish passage structures

**Quaternary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Quinary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Sextary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Septenary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Octonary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Nonary Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel

**Decimal Objective:**
- Measurable Indicator:
  - Performance Criteria:
    - Objective:
      - Primary Objective:
        - Promote increase bed size of macrophytes in the main channel
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<thead>
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<th>+</th>
<th>+</th>
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<th>+</th>
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</thead>
<tbody>
<tr>
<td>TSS</td>
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<td>Nutrients</td>
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<tr>
<td>Dissolved Oxygen</td>
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<td>Winter Temperature</td>
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<td>Endocrine Disruptors</td>
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<td>Geomorphology</td>
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<td>Riparian/littoral transition zone</td>
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<td>Visual barriers between channels and backwaters</td>
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<td>Barriers providing thermal protection from wind</td>
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<tr>
<td>Floodplain/Backwater elevation</td>
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<td>+</td>
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<td>Channel elevation</td>
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<tr>
<td>Substrate Density (flocculent sediment)</td>
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<td>+</td>
<td>+</td>
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<tr>
<td>Substrate Variability (abiotic - sand, wood) (biotic - mussels)</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Substrate Size (Gravel Bars)</td>
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<tr>
<td>Hydraulics &amp; Hydrology</td>
<td></td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Mainstem backwater/floodplain lateral hydraulic connectivity</td>
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<tr>
<td>Longitudinal Connectivity at Locks and Dams</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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