Case Studies

Application of models in watershed planning
LOAD DURATION CURVE (LDC)
Chippewa River TMDL

- Watershed covers more than 1.3 million acres
- There are 7 sub-watersheds in the watershed
- Land-use dominated by agricultural cropping and animal production
Chippewa River Fecal Coliform TMDL

- Placed on the 2006 list of impaired waters
- Study includes nine reaches of the Chippewa River
- Possible sources of fecal coliform bacteria:
  - Runoff from livestock feedlots, pastures, and land application areas
  - Non-conforming septic systems
  - WWTFs
  - Wildlife
  - Urban stormwater
  - Cattle in streams
Chippewa River TMDL study

- Study used a flow duration curve approach to determine the fecal coliform loading capacity at the impaired reaches under varying flow regimes.
- Fecal coliform loading capacities were calculated for each individual impaired reach and allocated among point sources, nonpoint sources, and a margin of safety.
Flow duration curves

- Helped to identify *patterns of impairment*
- Helped visualize relationship between flow / pollutant concentrations over different flow conditions
- Was useful for targeting restoration efforts
Flow duration curves

- The flow duration curve captured the full range of flow conditions over the April-October period when the fecal coliform standard applies.

- Loading capacities for fecal coliform are directly related to flow volume.

\[ \text{Flow} \times \text{concentration (i.e., water quality standard)} \times \text{conversion factor} = \text{Pollutant Load} \]
Sample duration curve

Chippewa/Minnesota River near Montevideo
Conc. Duration Curve (2001 - 2003 Monitoring Data)
MN R Flow and Chippewa R Site 20 Fecal Coliform
The results indicated a wide range of flows and fecal coliform concentrations.

Data at several sites showed a strong positive correlation between higher flows and coliform bacteria concentrations.
Results

- The period from June through August is the critical period when fecal coliform levels exceeded the standard.

- The summer impairments were driven by storm events.

- In drought or low-flow conditions continuous sources, e.g. cattle in streams, failing individual sewage treatment systems, unsewered communities, and wastewater treatment facilities dominate.
Implications for Implementation Plan

- Goal: reach water quality standard within 10 years
- Consider implementation opportunities for different flows regimes

<table>
<thead>
<tr>
<th>Implementation Opportunities</th>
<th>Duration Curve Zone</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Long-term CSO plans</td>
<td></td>
</tr>
<tr>
<td>Municipal NPDES</td>
<td></td>
</tr>
<tr>
<td>On-site wastewater management</td>
<td></td>
</tr>
<tr>
<td>Pasture management &amp; riparian protection</td>
<td></td>
</tr>
<tr>
<td>Urban stormwater management</td>
<td></td>
</tr>
<tr>
<td>Open lot agreements</td>
<td></td>
</tr>
<tr>
<td>Manure management</td>
<td></td>
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</table>

Adopted from Revised SE Regional Fecal Coliform TMOL, Appendix A.
STEPL MODEL
Council Grove Lake Watershed TMDL

Subbasin: Neosho Headwaters  Counties: Morris, Wabaunsee, and Geary

HUC 8: 11070201

HUC 11 (HUC14): 010 (010, 020, 030, 040, 050, 060)

Ecoregion: Flint Hills (28)

Drainage Area: Approximately 258.6 square miles (Figure 1)

Conservation Pool: Area = 2,589 acres
Watershed Area: Lake Surface Area = 62:1
Maximum Depth = 11 meters (36 feet)
Mean Depth = 4.4 meters (14 feet)
Retention Time = 0.49 years (5.9 months)

Designated Uses: Primary Contact Recreation; Expected Aquatic Life Support; Drinking Water; Groundwater Recharge; Industrial Water Supply Use; Food Procurement; Irrigation; Livestock Watering

Authority: Federal (U.S. Army Corps of Engineers), State (Kansas Water Office)

1998 303(d) Listing: Neosho Impaired Lakes

Impaired Use: All uses are impaired to a degree by eutrophication

• Objective
  – To estimate Total Nitrogen and Total Phosphorus Loads
  – Source of Pollutants

• STEPL Model used
  – simple watershed model that provides both agricultural and urban annual average sediment and nutrient loads

• **Methods**
  
  – Watershed was divided into 6 subwatersheds using HUC 12’s
  – Data for each subwatershed given in STEPL Model
    
    • Landuse: percent landuse under each category derived using NLCD landuse
    
    • Soils: Dominant soil hydrologic group derived using STATSGO
    
    • Animal data: Inbuilt database for each county in USA
    
    • Septic system data: county health department and local stakeholder group (WRAPS)

### STEPL input and setting

#### 1. Input watershed land use area (ac) and precipitation (in)

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Urban</th>
<th>Cropland</th>
<th>Pastureland</th>
<th>Forest</th>
<th>User Defined</th>
<th>Feedlots</th>
<th>Paved</th>
<th>Total</th>
<th>Annual Rainfall</th>
<th>Rain Days</th>
<th>Avg Rain/event</th>
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<tbody>
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User defined = grassland plus shrubland used in 2001 NLCD.

#### 2. Input agricultural animals

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Beef Cattle</th>
<th>Dairy Cattle</th>
<th>Swine (Hog)</th>
<th>Sheep</th>
<th>Horse</th>
<th>Chicken</th>
<th>Turkey</th>
<th>Duck</th>
<th>% of manure applied</th>
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#### 3. Input septic system and illegal direct wastewater discharge data

<table>
<thead>
<tr>
<th>Watershed</th>
<th>No. of Septic Systems</th>
<th>Population per Septic System</th>
<th>Septic Failure Rate, %</th>
<th>Wastewater Direct Discharge, # of People</th>
<th>Direct Discharge Reduction, %</th>
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</table>

#### 4. Modify the Universal Soil Loss Equation (USLE) parameters

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Cropland</th>
<th>Pastureland</th>
<th>Forest</th>
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<tbody>
<tr>
<td>110702010102</td>
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<tr>
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<tr>
<td>110702010102</td>
<td>303,000</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

#### 5. Select average soil hydrologic group (SHG). SHG A = highest infiltration and SHG D = lowest infiltration

<table>
<thead>
<tr>
<th>Watershed</th>
<th>SHG A</th>
<th>SHG D</th>
<th>SHG C</th>
<th>SHG D</th>
<th>SHG Selected</th>
<th>Soil N conc. %</th>
<th>Soil P conc. %</th>
<th>Soil BOD conc. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>110702010102</td>
<td>D</td>
<td>C</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>0.145</td>
<td>0.064</td>
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<td>D</td>
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<td>D</td>
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<tr>
<td>110702010102</td>
<td>C</td>
<td>D</td>
<td>D</td>
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<tr>
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<td>C</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>0.145</td>
<td>0.064</td>
<td>0.290</td>
</tr>
</tbody>
</table>

Results

Runoff TN and TP loads by land use categories in STEPL modeling.

STEPL-simulated annual average watershed and subwatershed runoff nutrient loads.

<table>
<thead>
<tr>
<th>Subwatershed (HUC14)</th>
<th>Area (ac)</th>
<th>TN (ton)</th>
<th>TP (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin 11070201010010</td>
<td>27,931</td>
<td>118.06</td>
<td>22.61</td>
</tr>
<tr>
<td>Basin 11070201010020</td>
<td>27,521</td>
<td>83.58</td>
<td>15.41</td>
</tr>
<tr>
<td>Basin 11070201010030</td>
<td>19,555</td>
<td>83.55</td>
<td>15.64</td>
</tr>
<tr>
<td>Basin 11070201010040</td>
<td>36,578</td>
<td>158.22</td>
<td>25.72</td>
</tr>
<tr>
<td>Basin 11070201010050</td>
<td>19,348</td>
<td>61.21</td>
<td>11.02</td>
</tr>
<tr>
<td>Basin 11070201010060</td>
<td>30,834</td>
<td>89.89</td>
<td>14.89</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>161,768</td>
<td>594.31</td>
<td>105.29</td>
</tr>
</tbody>
</table>

Results (cont...)

Watershed ranking of annual runoff TN and TP loads per unit of area.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>TN (lbs/ac)</th>
<th>Ranking</th>
<th>TP (lbs/ac)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8.65</td>
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<td>1.62</td>
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<td>Basin 11070201010060</td>
<td>0.97</td>
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</table>

SWAT MODEL
HSPF MODEL
Use of a complex model - HSPF

Case example –
LOWER MINNESOTA RIVER
DISSOLVED OXYGEN TMDL
HSPF

- Can simulate land and receiving water processes simultaneously
- Model can be simple or complex
- Requires extensive calibration and a high level of expertise to build and run model
- Typically used in large watersheds/basins, greater than 100 sq. miles
  (example: MN River Basin)
HSPF

Simulates:
- watershed hydrology
- land and soil contaminant runoff
- sediment/chemical interactions

Considers a wide range of conventional and toxic organic pollutants
Lower MN River dissolved oxygen TMDL

The Lower Minnesota River Watershed is part of the Minnesota River Basin.
Lower MN River dissolved oxygen TMDL

Waste load allocation study in 1985 found:

1. Must meet 40% reduction in biochemical oxygen demanding (BOD) substances upstream of Shakopee
2. Blue Lake and Seneca WWTFs need to be upgraded (advanced secondary treatment)
Lower MN River dissolved oxygen TMDL

Subsequent to WLA, MRAP study found:

- Excess phosphorus causes over-production of algae during summer, low-flow conditions
- Low dissolved oxygen levels in the Lower MN River is caused predominantly by death and decay of that algae
Lower MN River modeling

HSPF Model built to determine waste load allocations for WWTFs, and Local Allocations for the 72 subwatersheds below Lac Qui Parle dam to meet a 40% reduction in BOD at Jordan
MN River modeling

HSPF model simulated changes in water quality based on changes in:
1. Watershed hydrology
2. Land use practices
3. Point source contributions of phosphorus
MN River modeling

- Modeled: 9 major watersheds in the MN River Basin
- Upstream boundary: Lac Qui Parle
- Lower boundary: Jordan
- Modeled area: 12,200 sq. miles
Phase I: data collection and model input preparation

Data sets used to build model:
- Flow
- Water chemistry
- Land use
- Point source phosphorus loading

Time required: several years
Phase II: model calibration and validation

- Model calibrated with 1986-92 MRAP data
- Included data from low and high flow years
- HSPF model was validated with data sets from 1980-1985

Time required: about 1 year
Phase III: scenario analysis

- Analyzed seven scenarios to develop allocation of P loading to the river (*divided between point and nonpoint sources*)
- Each determined how sensitive the river was to changes in:
  - various sources (*e.g. WWTFs, agriculture, etc.*) or
  - loads to different geographic locations under low-flow conditions

Time required: about 1 year
Phase III: How modeling results have been used

Stakeholder Advisory Committee discussed all scenarios and developed a specific allocation formula.

**Final outcome:** WWTFs, stormwater, and noncompliant ISTSs required to reduce P load
Thanks!