Using Simple Tools
(Alternatives to Mechanistic Models)

Introduction to Watershed Model Training
Wednesday, July 8, 2015
Larry Hauck
hauck@tiaer.tarleton.edu
Mechanistic Model:

- A model that has a structure that explicitly represents an understanding of biological, chemical, and/or physical processes.
- These models attempt to quantify phenomena by their underlying causal mechanisms.

Source: EPA website, glossary of frequently used modeling terms and WPP Handbook
Why Consider Alternatives to (Mechanistic) Models

- Resource limitations
  - Amount of monitoring data available
  - Time or budget constraints
- Level of “sophistication” requirements
  - Bacteria impairments in Texas often addressed with simpler approaches
Alternative Approaches

• Load duration curves
• GIS land-use based methods
• Export coefficients
• Empirical methods
• Other methods
Advantages of Alternative Approaches
(as compared to mechanistic modeling approaches)

• Less resource intensive
  - Less time, money, and staff commitment
  - Typically requires less monitoring data
  - Less experience required to apply

• Often more easily communicated to stakeholders and interested parties
Disadvantages of Alternative Approaches (as compared to mechanistic modeling approaches)

- Typically not predictive or not rigorously predictive, thus limited in abilities to evaluate control measures & BMPs
- Typically lacks quantitative link between sources of pollution and receiving water body quality
Load Duration Curves

- Applicable for determining allowable loading of pollutants and percent reductions needed to restore water quality in streams & rivers
- Uses observed daily streamflow data
- Considers relevant water quality criteria
- Combines observed flow and criteria to establish a curve of loading capacity
- Can be enhanced with observed water quality data
- Frequently used with GIS land-use methods for situations of bacteria impairments

For more information see:
USEPA 2007. An Approach for Using Load Duration Curves (EPA 841-B-07-006)
Load Duration Curves (continued)

• Combines measured concentrations of a pollutant with flow at the same time to develop a load
• The LDC illustrates the load of a pollutant versus the time that a given load is exceeded
• Time is illustrated as percentage of time
• Able to see if a stream is exceeding the standard in terms of load (flow and measured concentrations)
• Able to calculate a percent reduction based on flow categories
An Example Load Duration Curve

Lower West Fork Trinity River at Roy Orr Boulevard in Grand Prairie, TX

- **E. coli (MPN/day)**
- **Percent of Days Load Exceeded**

- **Very High Flow**
- **High Flow**
- **Low Flow**

- **Allowable Load at Geometric Criterion**
- **Non-wet Weather Event**
- **Wet Weather Event**
- **Existing Geometric Load**
TMDL = \( WLA_{\text{WWTF}} + WLA_{\text{SW}} + \text{LA} + \text{Future Growth} + \text{Margin of Safety} \)
Preliminary Results for Station 12943, Mission River Tidal

Modified Flow & Load Duration Curves Applied to Tidal Streams

Modified Flow Duration Curve

Flow (cfs)

Percent of Days Flow Exceeded

Combined

Freshwater

Seawater

Preliminary Results for Station 12943, Mission River Tidal
Preliminary Results for Station 12943, Mission River Tidal
Advantages of Load Duration Curves

• Widely accepted and used in Texas
• Only moderate data requirements
• Ease of application
• Identifies allowable loading for all flow conditions
• When combined with monitoring data, identifies existing loading for all flow conditions and can provide percent reduction required
• Readily communicated to stakeholders
Disadvantages of Load Duration Curves

• Only identifies broad categories of sources (i.e., nonpoint source and point source) – not a problem if sources already well understood

• Does not quantitatively link sources to receiving water body quality

• Generally applicable only to non-tidal streams (selectively applicable in transition zones of reservoirs & in weakly tidal streams)

• Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs)
GIS Land-Use Based Methods

• Applicable for determining likely sources of loadings of pollutants and areas of highest loadings and facilitating stakeholder interactions

• Can use readily available GIS data layers
  - Digital elevation models (DEMs)
  - Land use/land cover (e.g., NLCD 2006)
  - Soil layers (NRCS STATSGO & SSURGO)
  - Stream networks (USGS NHD), etc.

• Can use other readily available data sources
  - For example, USDA Agricultural Census Data
One Land-Use Based Method

SELECT

- Spatially Explicit Load Enrichment Calculation Tool (SELECT)
- GIS based tool
- Newly developed Visual Basic frontend for easier interface
- Developed at Texas A&M University
- Training (as well as for LDCs) through AgriLife TWRI
Examples of Input Included in SELECT

- Census Blocks (U.S. Census Bureau)
- Soils (USDA-NRCS)
- Digital Elevation Map (BASINS)
- Urban Areas (TCEQ)
- Sub-watersheds & stream network

Livestock
- Stakeholder input
- Agricultural Statistics (USDA)
- Poultry Operations within the watershed (TSSWCB)

Wildlife
- Stakeholder input
- Wildlife experts input, Resource Management Unit data for Deer (TPWD)
Examples of Sources Considered in SELECT

- Range and pastured cattle
- Animal feeding operations
- On-site sewage facilities (septic)
- Domestic wastewater treatment facilities
- Urban runoff
- Wildlife (e.g., deer)
- Feral hogs
Example Results from SELECT, Walnut Creek Watershed

Source: Biological and Agricultural Engineering Department, Texas A&M University
Cattle #s in Leona
Uvalde  5,516
Zavala 10,566
Frio     6,418

Input Fecal Production Rate
Cattle 10E10 cfu/animal/day
Advantages of GIS Land-Use Based Methods

• One such tool has been developed in Texas (SELECT) and has been successfully applied in Texas watersheds
• Uses readily available data sources
• Relative ease of application
• Readily communicated to stakeholders
• When properly used can facilitate stakeholder input & interest (project buy-in)
• Can locate areas for control measure and BMP implementation
Disadvantages of GIS Land-Use Based Methods

• Can evaluate only potential loadings and not actual loadings of pollutants
• Does not quantitatively link sources to receiving water body quality
• Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs), but could be based on best professional judgment
• SELECT – present applications limited to bacteria, but should be adaptable to other pollutants
Export Coefficients

• An export coefficient is the loading of a specific pollutant per unit area for a specific land use and time period

• Examples:
  ➢ Kilograms/hectare/year of lead from industrial land use
  ➢ Pounds/acre/month of phosphorus from cultivated agricultural fields
Export Coefficients

- Applicable for determining pollutant loadings, likely sources of loadings of pollutants & areas of highest loadings
- Values can be obtained in literature from regional and national studies
- Requires GIS land use/land cover data layer (typically readily available from various sources)
- Approach amenable to including point sources or permitted discharges
An example application of export coefficients: Bosque River Watershed
### Soluble Reactive Phosphorus (PO$_4$-P) Export Coefficients Estimated Using Multiple Regression Models

**DATA:** 1 November 1995 – 30 March 1998

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Export Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood/Range</td>
<td>0.07 lb PO$_4$-P / ac /yr</td>
</tr>
<tr>
<td>Pasture/Cropland</td>
<td>0.14 lb PO$_4$-P / ac /yr</td>
</tr>
<tr>
<td>Urban</td>
<td>0.98 lb PO$_4$-P / ac /yr</td>
</tr>
<tr>
<td>Dairy manure application fields</td>
<td>3.08 lb PO$_4$-P / ac /yr</td>
</tr>
</tbody>
</table>

Bosque-Lake Waco Watershed

01 Nov 95 - 30 Mar 98

PO$_4$-P Source Contribution

Land Uses

- Dairy Waste Appl. 36%
- Urban 11%
- Row-Crop 16%
- Non-Row Crop 1%
- Pasture 15%
- WWTP 8%
- Wood/Range 22%
- Non-Row Crop 1%
- Dairy Waste Appl. 2%
- Urban 2%
- Row-Crop 11%
- Pasture 10%
- Wood/Range 64%
- Urban 11%
- Row-Crop 16%
- Non-Row Crop 1%
- Pasture 15%

01 Nov 95 - 30 Mar 98
Advantages of Export Coefficients

• Limited watershed specific water quality data requirements, unless developing project specific export coefficients
• Uses readily available data sources
• Ease of application
• Readily communicated to stakeholders
• Can locate land-use types for control measure and BMP implementation
Disadvantages of Export Coefficients

- May not quantitatively link sources and loadings to receiving water body quality
- Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs), but could be based on best professional judgment
Empirical Methods

• Applicable for determining loadings of pollutants; sometimes even allowable loadings

• Various methods available
  - Simple Method – for small urban catchments
  - Vollenweider approach – allowable phosphorus loadings to meet desired trophic level based on lake characteristics
Empirical Model or Method:

• A model where the structure is determined by the observed relationship among experimental data.

• These models can be used to develop relationships for forecasting and describing trends.

• These relationships and trends are not necessarily mechanistically relevant.

Source: EPA website, glossary of frequently used modeling terms.
An Example of an Empirical Model:

- Investigating the relationship of inflowing nutrients in a lake to algal biomass production (eutrophication).
- Most early (circa 1970) lake eutrophication models based on statistical relationships between mass loading of nutrients and average algal biomass (e.g., Vollenweider models with numerous adaptations by others)
- Applied to PL-566 reservoirs in North Bosque River Watershed
Annual mean summer chlorophyll-a concentration as a function of predicted total-P for years 1993-1998 from PL-566 reservoirs. N=25
Advantages of Empirical Methods

- Limited watershed specific water quality data requirements, unless developing project specific empirical relationships
- Uses readily available data sources
- Ease of application
- If applicable to your situation, significant savings in commitment of resources
Disadvantages of Empirical Methods

• Do not quantitatively link sources and loadings to receiving water body quality
• Depending upon data used in developing the empirical method, may not be applicable to your watershed or water body
Other Methods – An Overview

• Steady-State or Mass-Balance Analysis
  - Typically applied to critical flow condition to determine allowable loading
  - Assumes conservation of mass
  - Can accommodate multiple sources

• Percent Reduction
  - Existing pollutant concentrations compared to applicable criteria to get percent load reduction
  - Assumes 1:1 relationship between water body concentrations and pollutant loadings to determine an allowable loading

Other Methods – An Overview (cont’d)

• Tidal Prism Method
  ➢ Used to determine allowable loading under environmental conditions of concern
  ➢ Applicable to tidal water bodies (tidal streams and bay & estuaries)
  ➢ Simplified approach compared to a mechanistic model for tidal water bodies
  ➢ Has been applied on Texas coast to situation of bacteria impairment
  ➢ Savings in resources compared to mechanistic modeling approaches
Concluding Comments

• Simple alternative approaches often used together
  - **LDCs** for allowable loadings and **SELECT** for pollutant loadings, probable sources & generally locating BMPs
  - **Mass-Balance Analysis** for allowable loading and **Export Coefficients** for pollutant loadings, probable sources & generally locating BMPs

• Viable alternative to mechanistic modeling in certain situations
  - When data is limiting or other resources are limiting
  - Often used in Texas for bacteria impairments
Thank You

Questions?