Water Quality Modeling and TMDL Development for the Illinois River Watershed

Sponsored by
EPA Region 6
Dallas, TX

Performed by
AQUA TERRA Consultants (Prime Contractor)
Mountain View, CA
and
Dynamic Solutions, LLC
Knoxville, TN

Public Meeting
Tahlequah, OK
January 6, 2011

Presentation Topics

- Update on data gathering efforts
- Model recommendations

Project Tasks

- Work plan development and project management
- Quality assurance project plan development
- Data compilation and assessment
- GIS/geospatial database development
- Watershed/WQ model selection and development
  - Phase I – Simulation Plan Development
  - Phase II – Model setup and calibration/validation
- Scenario development, simulation, and TMDL development

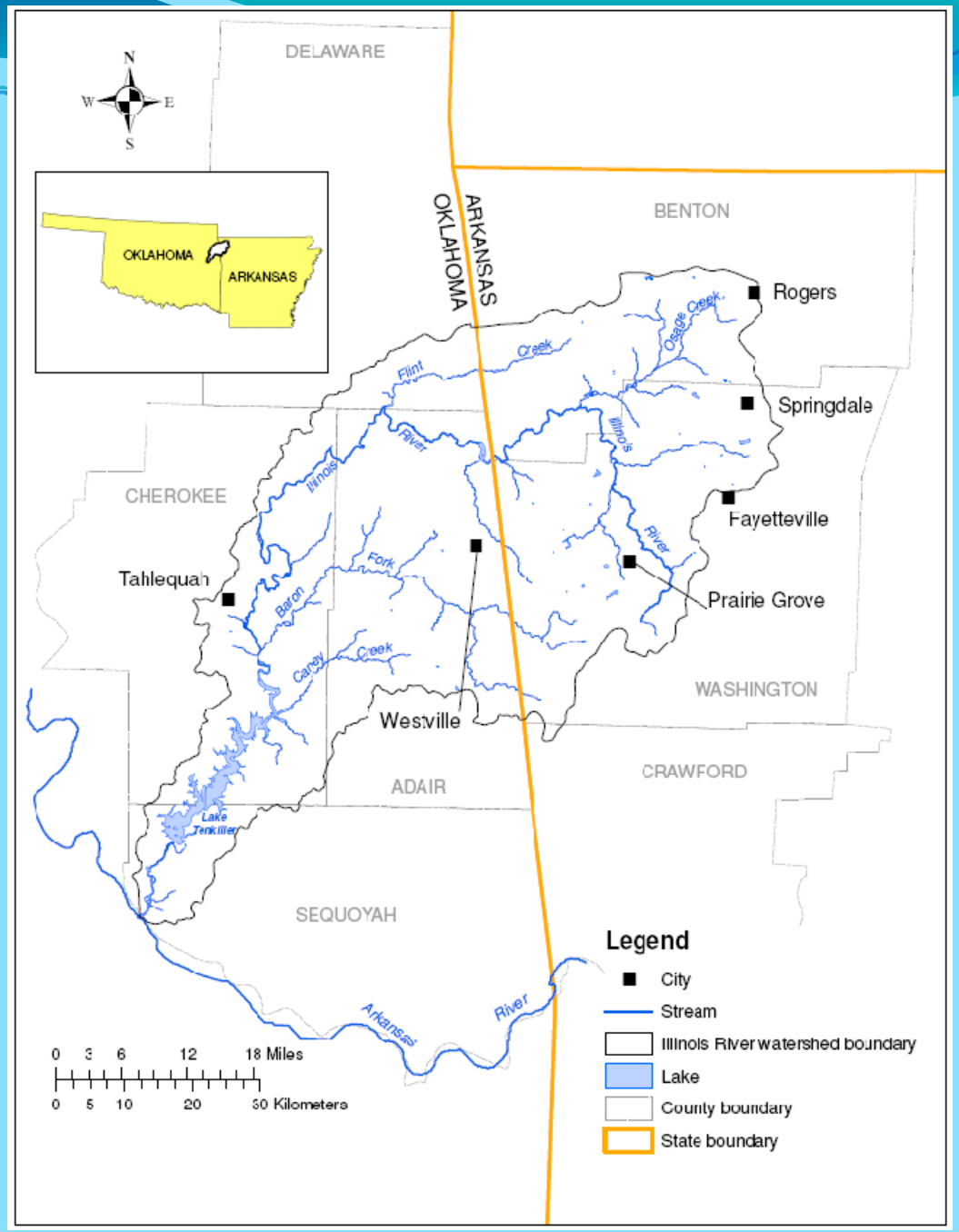
Data Needs

- Monitoring program observations
- Watershed land use/land cover
- Precipitation and meteorologic data
- Hydrography and geomorphological data
- Other nutrient source data/information
- Prior investigations and modeling studies

Data Collection Efforts

- Meetings – November 2009, February 2010, September 2010
- Federal Register Notice: 'Call for Data' dated 19 January 2010
- Data provided by state and federal agencies, and other stakeholders
- Data/reports from previous modeling efforts
- Online searches and downloads from numerous sites
- Monthly conference calls initiated in October 2010

Illinois River Watershed in AR and OK



Products Provided to Date

- Review Draft QAPP, dated 15 February 2010
- Final QAPP, dated 25 August 2010
- Review Draft Data Report, dated 3 August 2010
- Review Draft GIS Database, dated 10 August 2010
- Review Draft Model Selection Memo, dated 22 November 2010
- Web sites:

http://www.epa.gov/region6/water/npdes/illinoisriverwatershed/
http://aquaterra.com/pub/IRW_GIS/

Constituents Modeled

- Flow/discharge
- Sediment/TSS
- Water temperature
- DO
- BOD ultimate or total BOD
- NO_3/NO_2, combined
- NH_3/NH_4
- Total N
- PO_4
- Total P
- Phytoplankton as Chl a
- Benthic algae

Update on Data Received/Obtained Since Last Meeting

- WWTP discharges (ongoing, data coming in)
- Karst conditions/impacts in selected subwatersheds
- 319 study reports (OK and AR)
- Saraswat, Pai, and Daniels SWAT Modeling report, 2010 (AR side)
- Poultry houses, ANRC litter data, nutrient analysis, 319 studies, etc.
- OK and AR CAFO data: coverages and waste application database
- NEXRAD rainfall data for AR (from Matlock and Saraswat)
- CAST land use coverages for AR

Update on Data Received/Obtained Since Last Meeting (con't)

- OSU Poultry Waste Management Training Videos
- Cherokee Nation atmospheric deposition data
- ODAFF CAFO coverage, soil nutrient, poultry waste applications
- USGS gage cross section data - downloaded
- ODEQ 1997 report on nonresidential septic systems
- Misc WQ data, reports, GIS coverages, etc.

Remaining Data Gaps

- Recent (2004-08) land use/cover data for OK side
- GIS coverages for karst formation
- OCC Watershed-Based Management Plan for IRW
- Channel/bed data for additional sites, e.g. tributaries
- GIS coverages for animal populations and distribution in AR
- GIS coverages for fertilizer and manure applications in AR
- Soil nutrient concentrations/storages in AR
- Residential septic systems

Model Recommendations

Initial List of Candidate Models

- Watershed Domain:
  - HSPF – Hydrologic Simulation Program FORTRAN
  - SWAT – Soil and Water Assessment Tool

- Lake Tenkiller
  - AQUATOX – Ecosystem model for nutrients & toxics
  - EFDC – Environmental Fluid Dynamics Code

Prior IL River/Lake Tenkiller Modeling Studies

- EPA (R6)/ODEQ HSPF-EFDC Study, 2004
- ODEQ/DS/ATC HSPF-EFDC Study, 2006
- EPA (HQ) HSPF-AQUATOX Study, 2008
- ODEQ/OSU SWAT Modeling Studies, 2006, 2009
- More Recent SWAT applications – White, 2009; Saraswat, 2010

HSPF

Hydrological Simulation Program - FORTRAN

•It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil runoff processes with in-stream hydraulic and sediment-chemical interactions.

- **Physically based**
- **Sub-daily timesteps**
- **Surface and subsurface hydrology**
- **Stream/reservoir routing included**
- **User-defined WQ, sediment, nutrients, toxics/pesticides, metals, BOD, and bacteria**

•Outputs: a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed.

•Development sponsored by US EPA and USGS; core watershed model in US ACOE Watershed Modeling System (WMS)

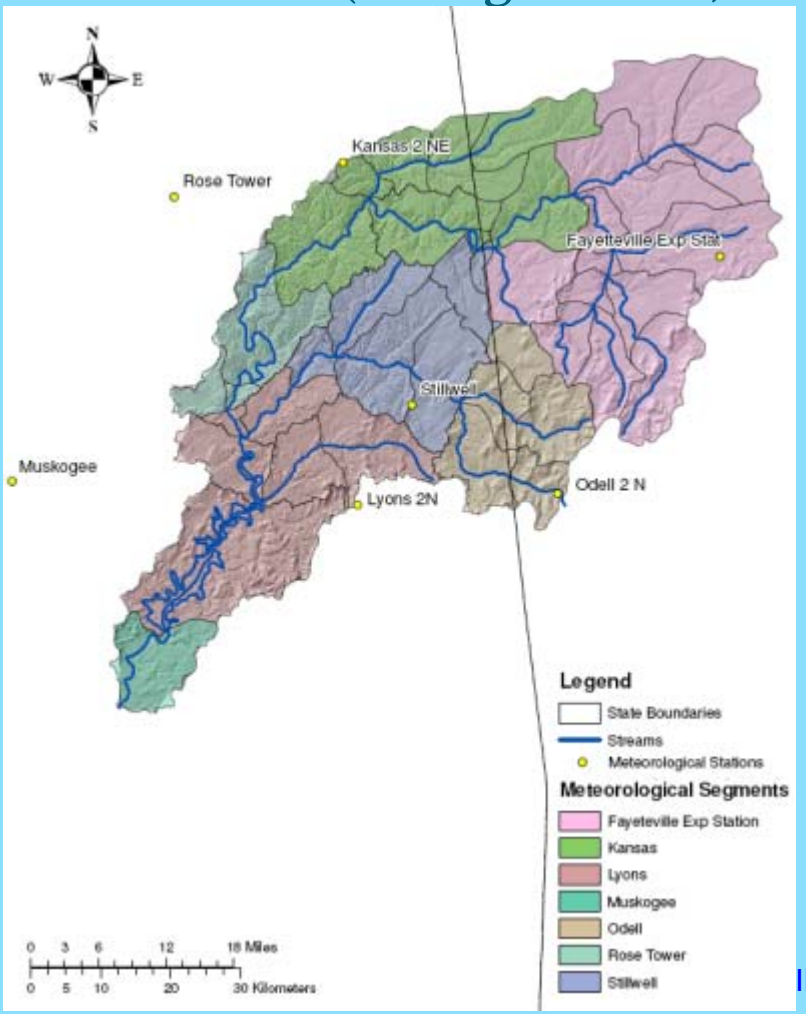
HSPF is currently one of the most comprehensive and flexible models of watershed hydrology and water quality available (Singh and Frevert, 2006).

SWAT – USDA's Soil and Water Assessment Tool

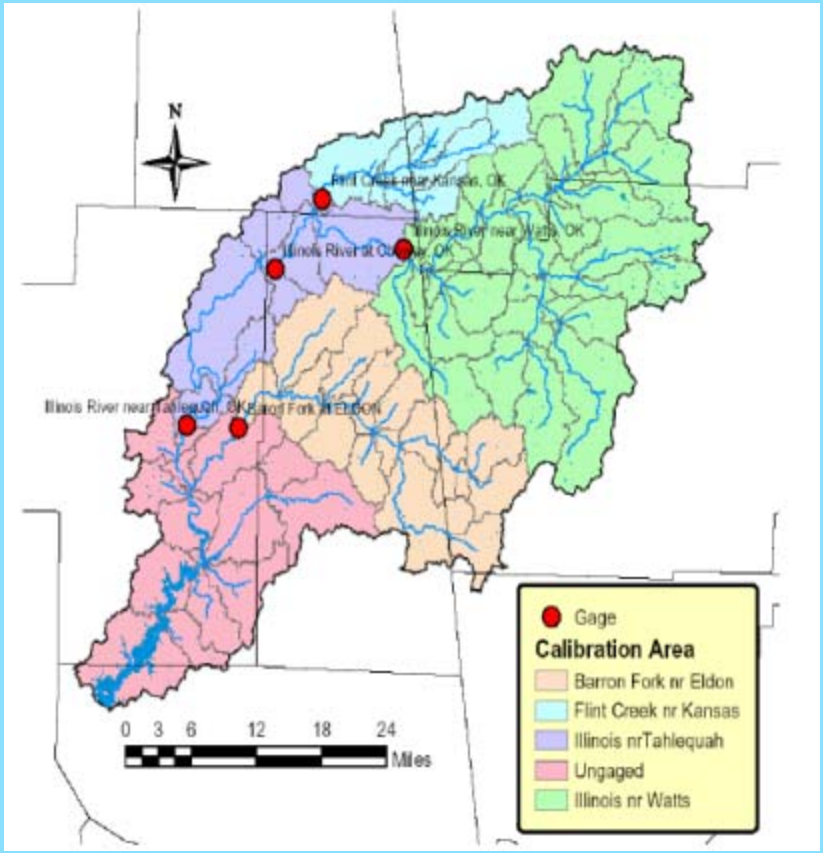
- Physically based, watershed scale model
- Includes both soil and channel processes
- Usually run on a daily timestep
- Developed to predict impacts of agricultural land management practices on water, sediment, and agricultural chemical yields in large watersheds
- More recently extended to include other land uses
- BASINS 4 expedites set-up process for SWAT users, and provides users with another sophisticated watershed model

HSPF and SWAT Models of the Illinois River Watershed

BASINS/HSPF (Donigian et al, 2008)



SWAT Model (Storm et al, 2006)



HSPF/SWAT Comparisons

BASINS/HSPF

- Hourly time step typical
- Multi-land use capabilities
- Strong hydrology module
- Current IL River application uses simplified processes
- Detailed AGCHEM available
- Detailed instream routing and WQ processes
- Moderate spatial resolution with ~40 subbasins

SWAT

- Daily time step typical
- Multi-land use, but strength is agricultural
- SCS CN hydrology
- Detailed ag practices included
- IL River application includes poultry litter contributions
- Simplified instream processes
- Moderate spatial resolution with ~90 subbasins

Rationale for HSPF Recommendation

- HSPF provides a stronger hydrologic model commonly run on an hourly (or less) timestep
- HSPF provides an improved instream sediment transport and sediment-nutrient interaction capability
- The hourly output from HSPF supports a more robust and compatible linkage with the EFDC hydrodynamic model for Lake Tenkiller
- HSPF soil nutrient models are comparable to SWAT, and include some additional details for inorganic forms
- The linked soil nutrient models and improved instream fate/transport capability in HSPF provides an improved overall capability to relate watershed sources to down stream impacts

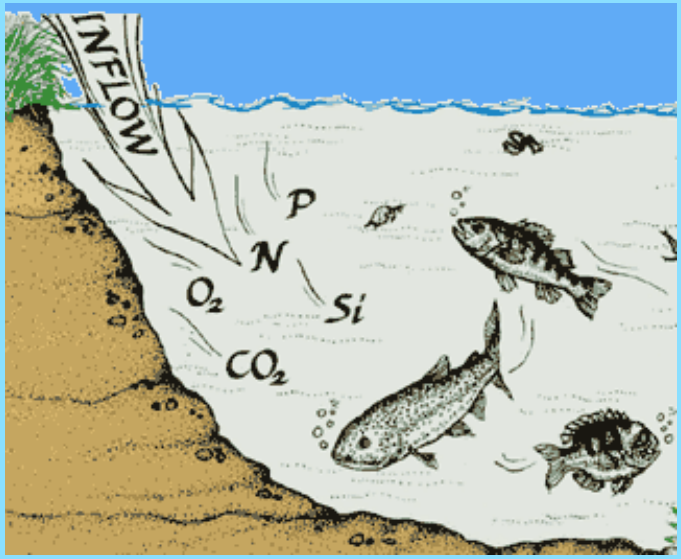
EFDC - Environmental Fluid Dynamics Code

- Multi-dimensional (1D, 2D, 3D) hydrodynamic/WQ model
- Can represent a multi-order stream network and/or a reservoir with mechanistic determination of stratification
- Incorporates variable cross-sectional bathymetry
- Open source, through EPA, since 1990's

……one of the most widely used and technically defensible hydrodynamic models in the world….(EPA, Ecosystems Research Div., Athens, GA)

AQUATOX

- A simulation model for aquatic ecosystems
- Predicts the environmental fate and ecological effects of the various environmental stressors
- Fish, invertebrates, and aquatic plants
- Biological effects
  - food consumption
  - growth and reproduction
  - natural mortality
  - acute and chronic toxicity
  - trophic interactions
- Environmental fate
  - nutrient cycling and oxygen dynamics
  - partitioning of organic toxicants to water, biota and sediments
  - toxic organic chemical transformations
  - bioaccumulation through gills and diet
  - impacts of suspended and deposited sediments



"This model [AQUATOX] is a valuable tool for ecologists, biologists, water quality modelers, and anyone involved in performing ecological risk assessments for aquatic ecosystems."
US EPA

AQUATOX/EFDC Comparisons

AQUATOX

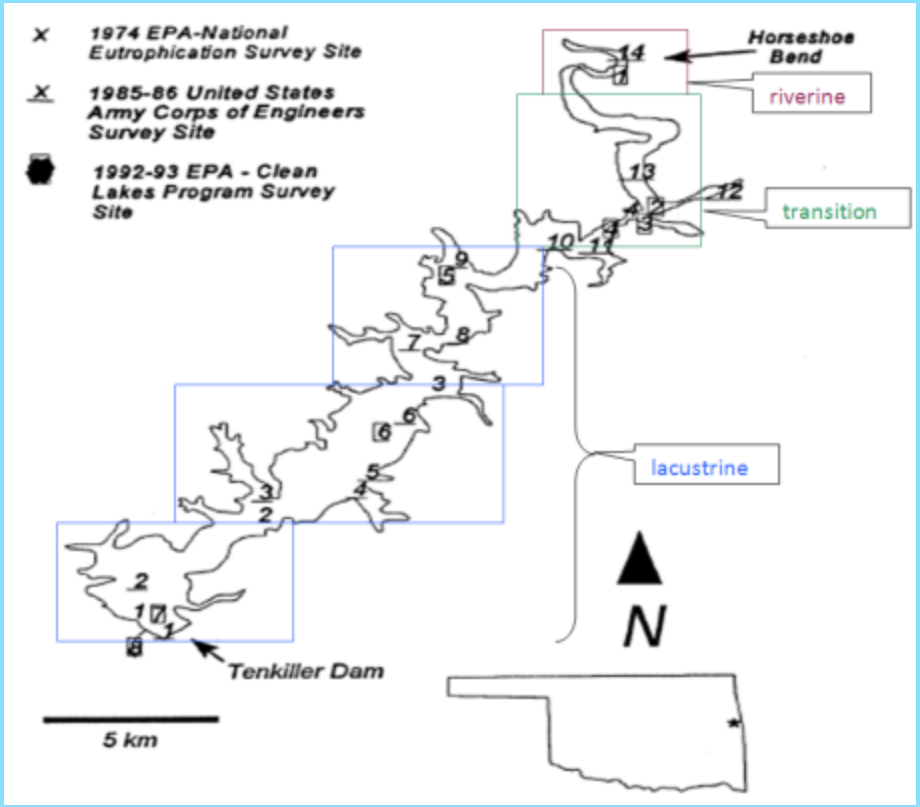
- Detailed ecosystem model
- Multiple biotic compartments/processes
- Compartmental model with transfers – can be linked to a hydro model
- Limited spatial definition
- Highly efficient run times
- Has been applied to Tenkiller and numerous other lakes

EFDC

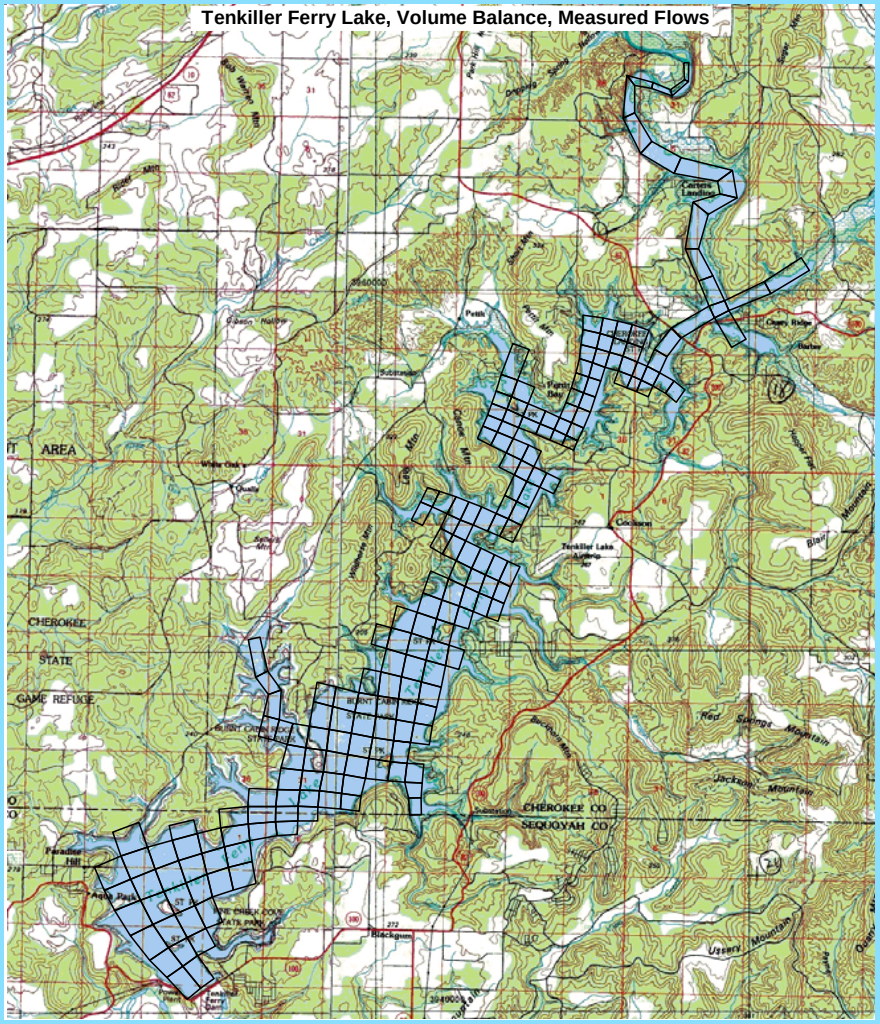
- Detailed hydrodynamic, sediment, and WQ model
- Multi-dimensional
- Limited biotic compartments up to algal level
- High spatial definition
- Computationally intensive
- Has been applied to Tenkiller, other lakes in OK, and elsewhere

Models of Tenkiller Lake, OK

AQUATOX Model



EFDC Model



Rationale for EFDC Recommendation

- Detailed spatial framework more appropriate for supporting evaluation of compliance with WQS
- Capability for mechanistic modeling of thermal stratification (essential for identification of time-varying anoxic conditions)
- Capability to represent *physical* modeling component of the eutrophication process (e.g. stratification) jointly with the biochemical processes
- Established track record in TMDL studies, and in OK
- Has been linked to hourly boundary conditions generated by HSPF in multiple studies – compatible temporal simulations

QUESTIONS/DISCUSSION