Tenkiller Lake
EFDC Modeling Update

Illinois River Watershed Modeling and
TMDL Development Project –
Informational meeting

April 26, 2012
Tahlequah, Oklahoma

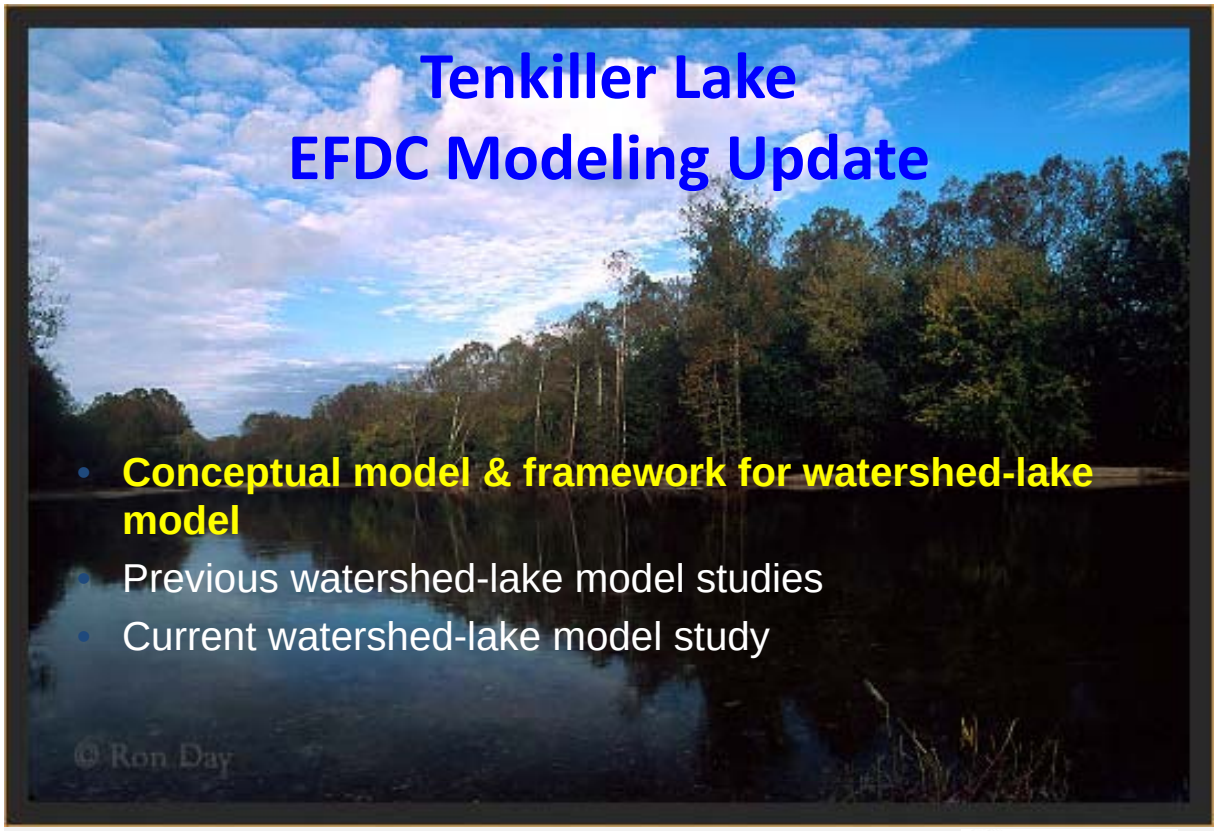
Andrew Stoddard
Dynamic Solutions, LLC
Knoxville, TN

© Ron Day
www.rondayphotography.com

Lake Water Quality Issues

- Nutrient enrichment (Total-P)
- Eutrophication/algae biomass
- Low oxygen in hypolimnion during seasonal stratification
- Since 2001 Cyanobacterium blooms *Cylindrospermopsis*
- Nutrient Limited Watershed (NLW) designation in 2006

© Ron Day



Tenkiller Lake
EFDC Modeling Update

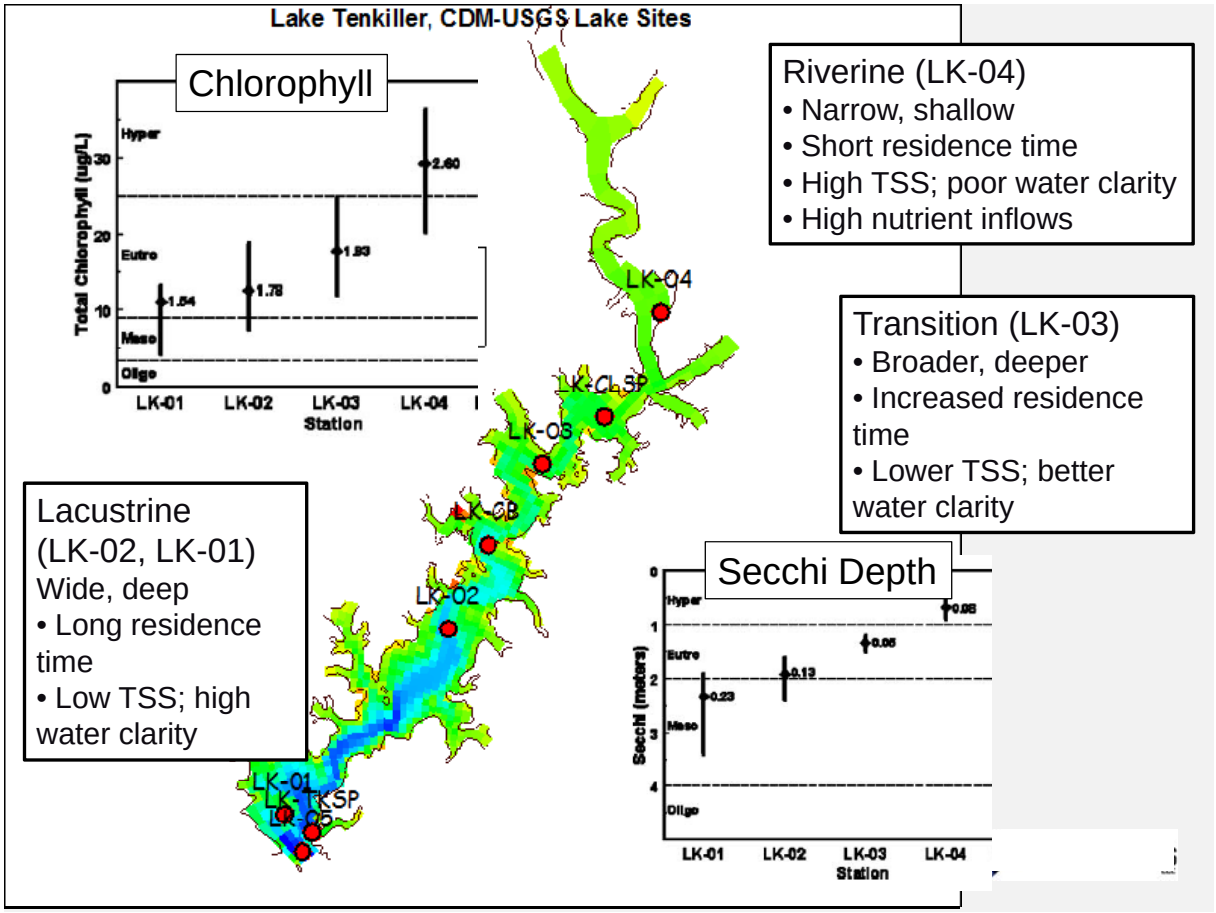
- **Conceptual model & framework for watershed-lake model**
- Previous watershed-lake model studies
- Current watershed-lake model study

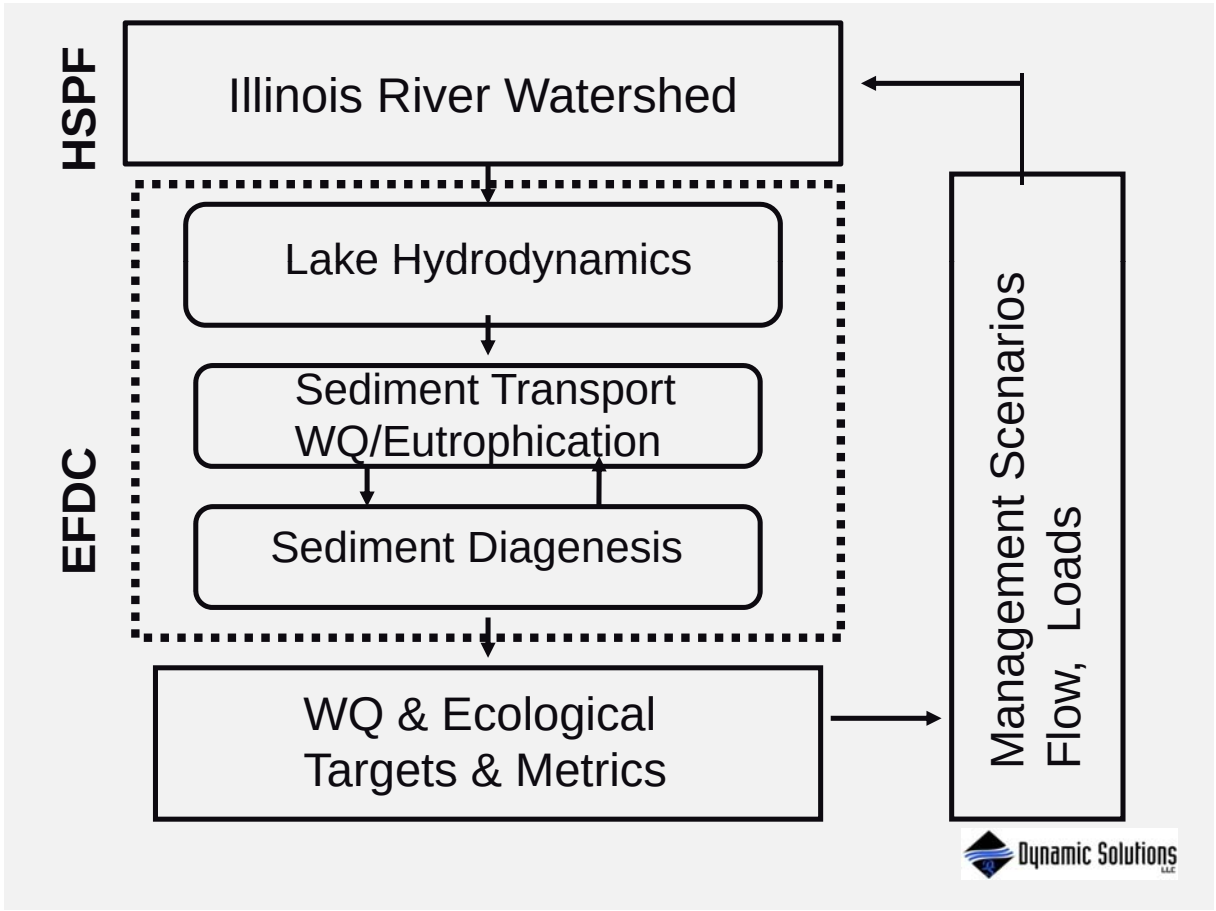
Dynamic Solutions LLC

Conceptual Model of Lake

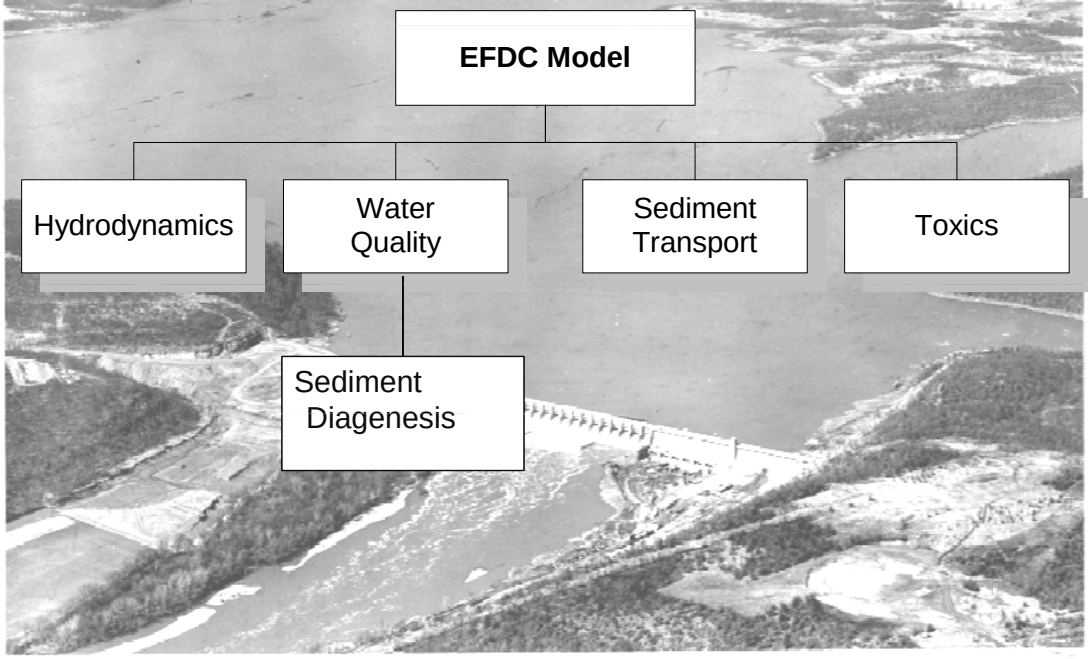
- Mass balance based lake model is a quantitative tool to link cause-effect interactions from watershed flow, sediment and nutrient loading with water quality conditions in Lake Tenkiller
- “Run-of-river” reservoir with characteristic spatial zones that influence transport, solids settling, water clarity, nutrients, algae biomass and oxygen depletion
- Seasonal cycle of thermal stratification in summer followed by well-mixed conditions in winter
- Seasonal cycle of hypolimnetic oxygen depletion controlled by stratification and sediment oxygen demand

Dynamic Solutions LLC


Lake Tenkiller, CDM-USGS Lake Sites
Chlorophyll
Total Chlorophyll (ug/L)
Hyper
Eutro
Meso
Oligo
1.54
1.78
1.93
2.60
LK-01
LK-02
LK-03
LK-04
Station
Riverine (LK-04)
• Narrow, shallow
• Short residence time
• High TSS; poor water clarity
• High nutrient inflows
Transition (LK-03)
• Broader, deeper
• Increased residence time
• Lower TSS; better water clarity
Lacustrine (LK-02, LK-01)
Wide, deep
• Long residence time
• Low TSS; high water clarity
LK-04
LK-CL3P
LK-03
LK-CB
LK-02
LK-01
LK-TKSP
LK-05
Secchi Depth
Secchi (meters)
0.23
0.13
0.05
0.08


HSPF
Illinois River Watershed
EFDC
Lake Hydrodynamics
Sediment Transport
WQ/Eutrophication
Sediment Diagenesis
WQ & Ecological
Targets & Metrics
Management Scenarios
Flow, Loads
Dynamic Solutions

EFDC Model Components



EFDC Hydrodynamic & WQ Model

- Lake level, conductivity, water temperature
- TSS (cohesives)
- 21 WQ state variables including:
- Algae biomass
- Organic Matter (C,N,P)
  - Dissolved
  - Particulate (Labile & Refractory)
- Dissolved Oxygen
- Inorganic Nutrients
  - Ammonia, Nitrate/Nitrite
  - Orthophosphate
  - Silica

Dynamic Solutions LLC

EFDC Sediment Diagenesis Model

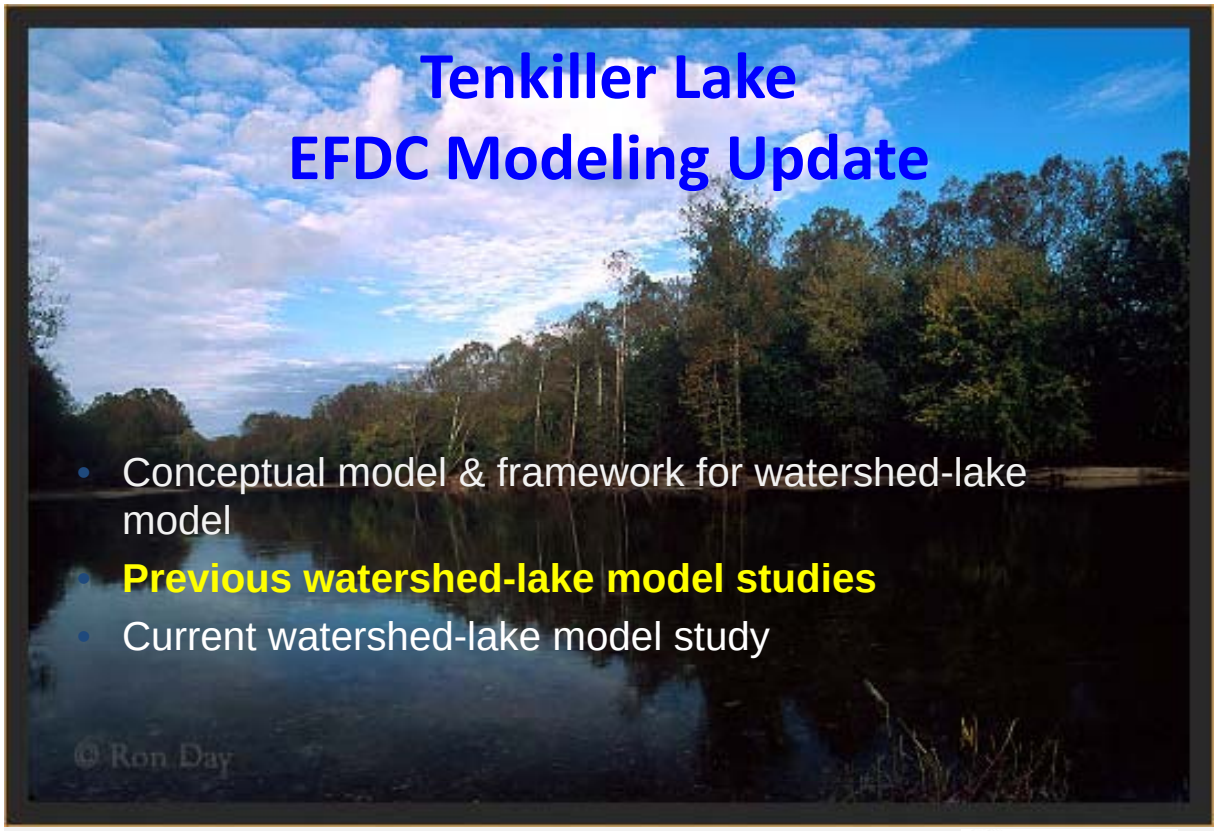
- Water column-sediment bed interaction
- 27 state variables
- Sediment bed organic matter (C,N,P)
  - G1 (fast),G2 (slow) & G3 (inert) reactive classes
- Porewater (ammonia, nitrate, orthophosphate, silica, methane)
- Sediment fluxes (dissolved oxygen, ammonia, nitrate, orthophosphate, silica, COD)
- Bed temperature

Dynamic Solutions LLC

Model Data Needs & Data Sources

- Bathymetry: Portland State U. (contour data & 2005 survey by Global Remote Sensing LLC)
- Watershed flow & WQ: HSPF watershed model
- Lake level & releases at dam: USACE Tulsa District
- Water supply withdrawals: computed flow balance
- Lake WQ: OWRB (1994-present); CDM-USGS (2005-2008); Clean Lakes Program; USACE; EPA STORET
- Sediment bed C,N,P organic & inorganic: Fisher (2005); CDM-USGS (2005-2007)

Dynamic Solutions LLC



Tenkiller Lake
EFDC Modeling Update

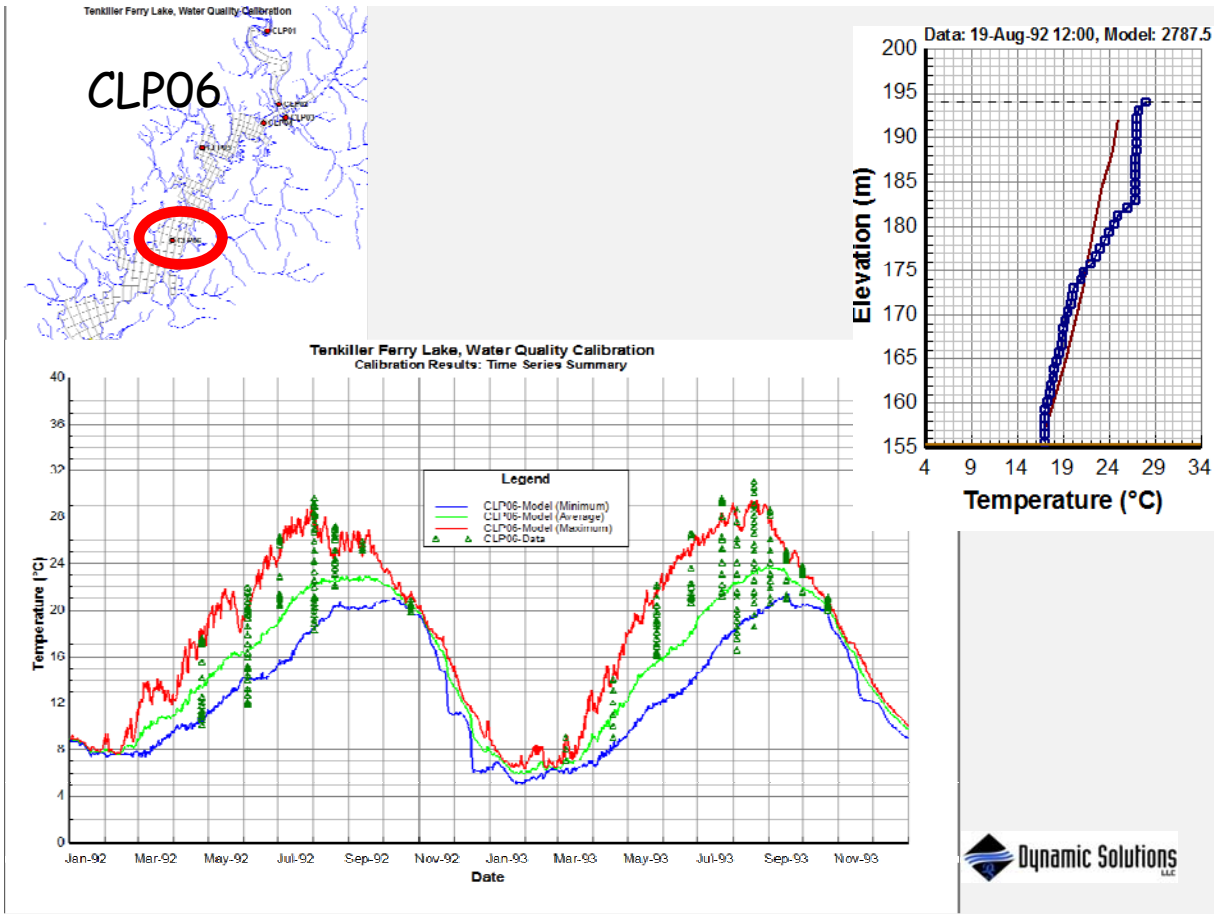
- Conceptual model & framework for watershed-lake model
- **Previous watershed-lake model studies**
- Current watershed-lake model study

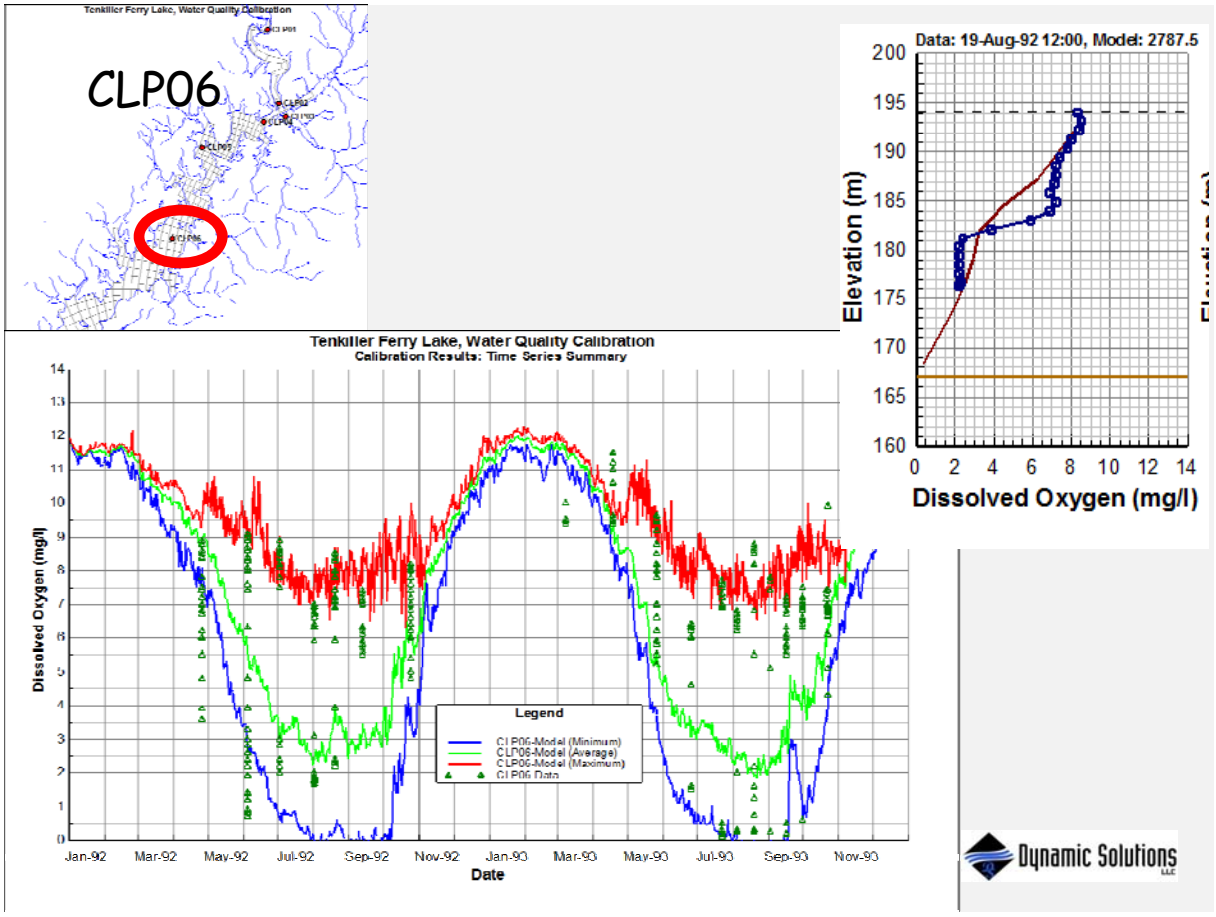
Dynamic Solutions LLC

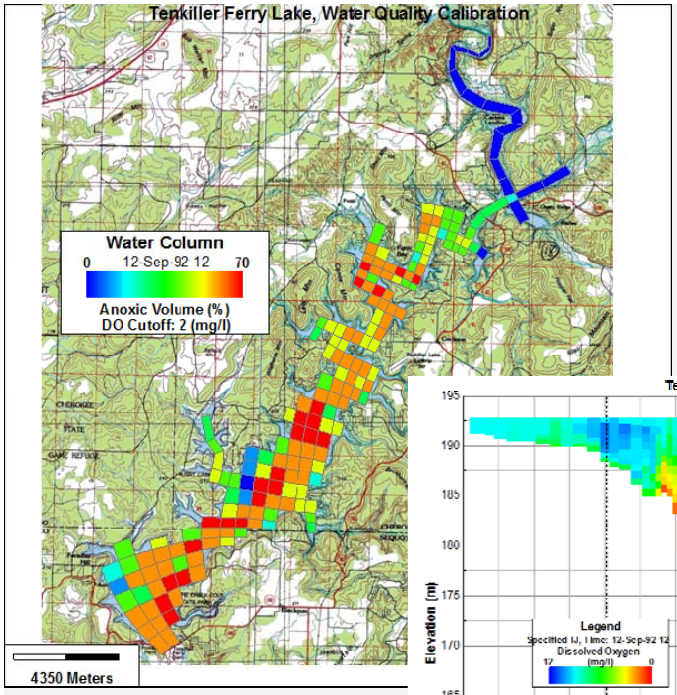
Previous Lake Modeling Efforts

- OWRB (1996): Lake Tenkiller Clean Lakes Program Phase 1 Diagnostics Feasibility Study; used Vollenweider P-loading empirical model for P allocation
- Tetra Tech (2001): HSPF-EFDC model of Illinois River watershed and Lake Tenkiller; calibrated to USACE 1985-86 data
- AQUA TERRA and Dynamic Solutions (2006): updated HSPF-EFDC of Illinois River watershed and Lake Tenkiller; calibrated to Clean Lakes Program (CLP), 1992-93 data
- AQUA TERRA and EcoModeling (2009), HSPF-AQUATOX model of watershed and Lake Tenkiller, calibrated to Clean Lakes Program,1992-93 data; flow/volume data from EFDC

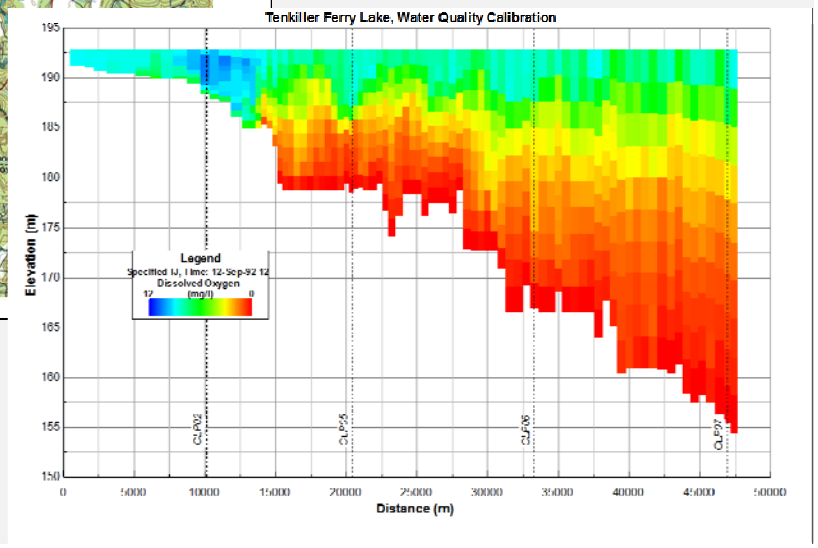
Dynamic Solutions LLC

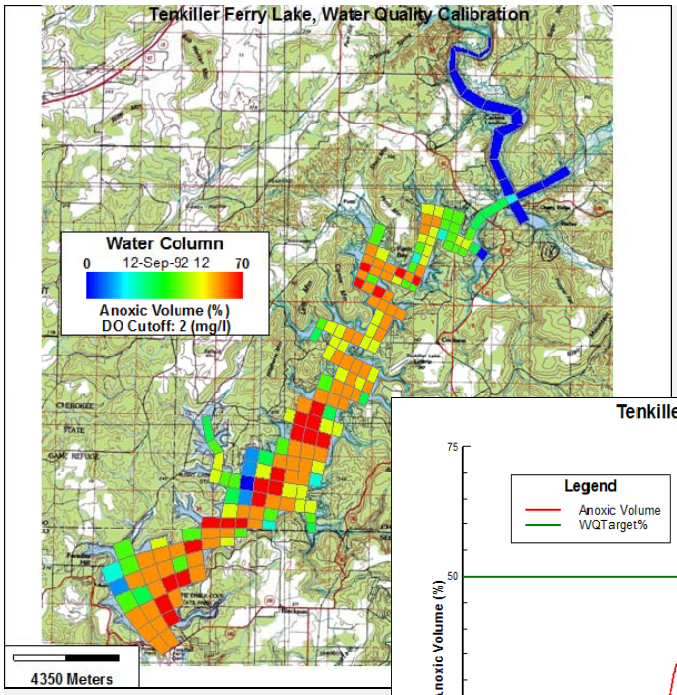

Tenkiller Ferry Lake, Water Quality Calibration
CLP06
Data: 19-Aug-92 12:00, Model: 2787.5
Elevation (m)
Temperature (°C)
Tenkiller Ferry Lake, Water Quality Calibration
Calibration Results: Time Series Summary
Legend
CLP06-Model (Minimum)
CLP06-Model (Average)
CLP06-Model (Maximum)
CLP06-Data
Temperature (°C)
Date
Dynamic Solutions


Tenkiller Ferry Lake, Water Quality Calibration
CLP06
Data: 19-Aug-92 12:00, Model: 2787.5
Elevation (m)
Dissolved Oxygen (mg/l)
Tenkiller Ferry Lake, Water Quality Calibration
Calibration Results: Time Series Summary
Legend
CLP06-Model (Minimum)
CLP06-Model (Average)
CLP06-Model (Maximum)
CLP06-Data
Dissolved Oxygen (mg/l)
Date
Dynamic Solutions

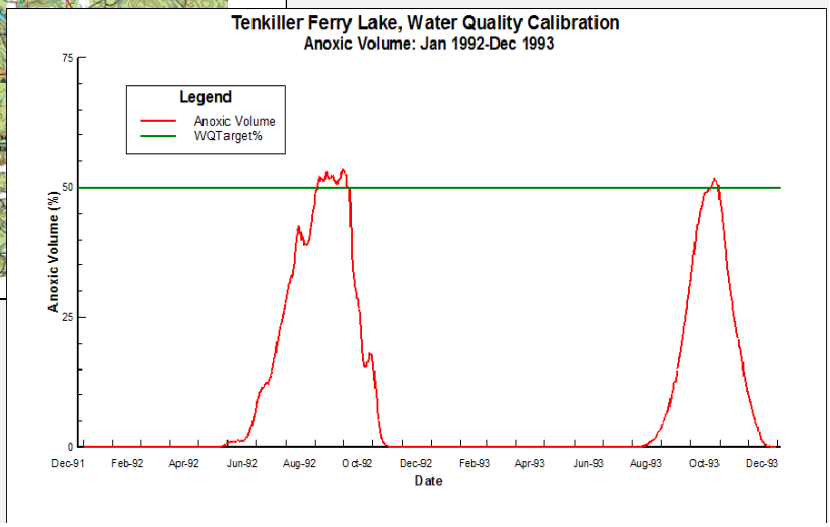


Dissolved Oxygen Anoxic Volume





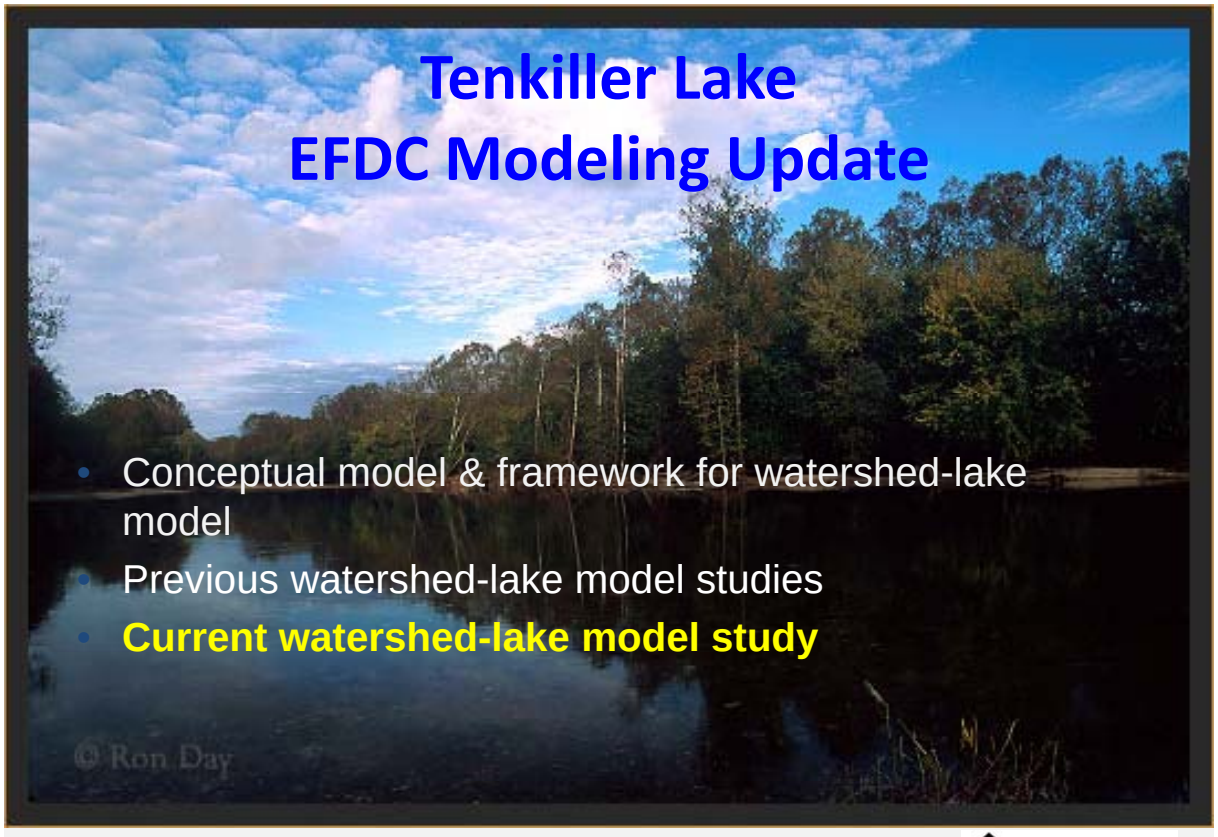
Dissolved Oxygen Anoxic Volume



Previous EFDC Model

- Calibrated to Clean Lakes Program data from 1992-1993
- Represented vertical profiles of water temperature and dissolved oxygen: stratified and well-mixed conditions
- Represented seasonal trends of water temperature, dissolved oxygen, algae (Chl-a) and nutrients (TN,TP)
- Oxygen results used to determine seasonal trends in anoxic volume of the lake as percentage
- Model demonstrated importance of sediment diagenesis model for good agreement of model dissolved oxygen with observed data

Dynamic Solutions LLC



Tenkiller Lake
EFDC Modeling Update

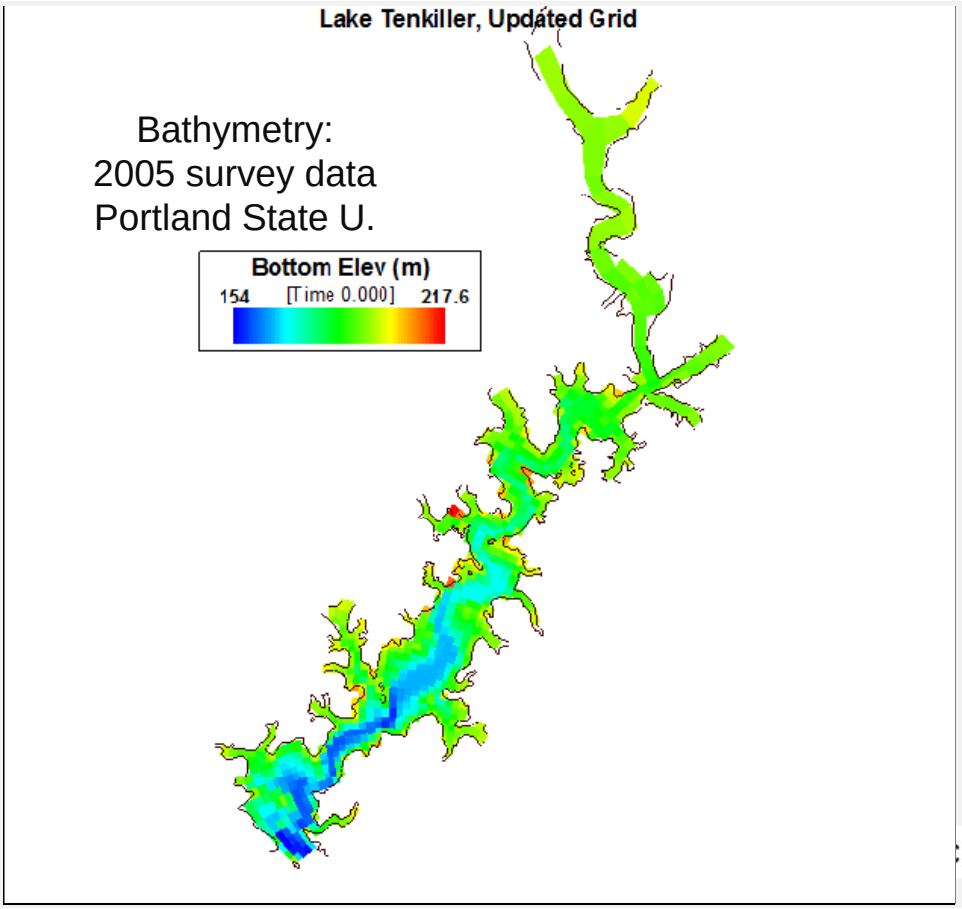
- Conceptual model & framework for watershed-lake model
- Previous watershed-lake model studies
- **Current watershed-lake model study**

Dynamic Solutions LLC

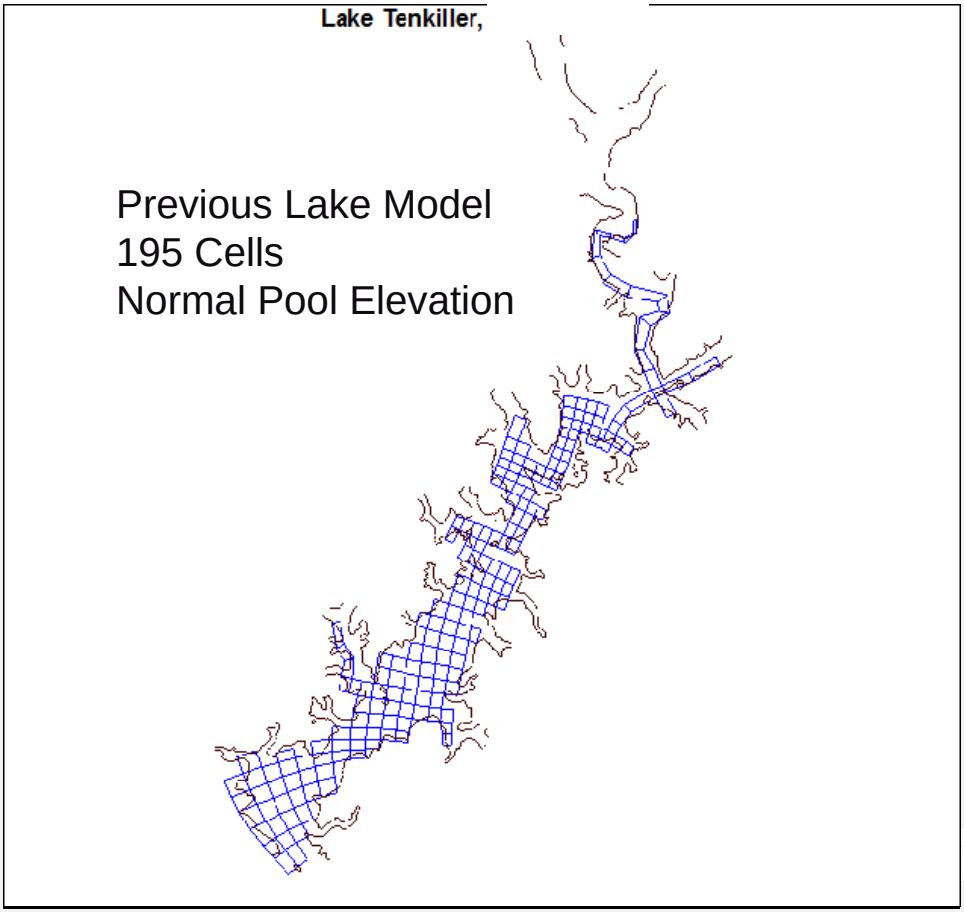
Approach for Updating Lake Model

- Update bathymetry with 2005 survey data
- Increase grid resolution to improve representation of wind forcing on currents and to reduce artificial mixing in areas with steep bottom slope
- Use updated HSPF watershed flow & loading of BOD, TOC, N, P, TSS, algae and oxygen as external input to lake model
- Sediment bed data for sediment diagenesis model available from CDM-USGS (2005-2007) and sediment core data collected by Fisher in 2005
- Re-calibrate and re-validate lake model using OWRB and CDM-USGS data

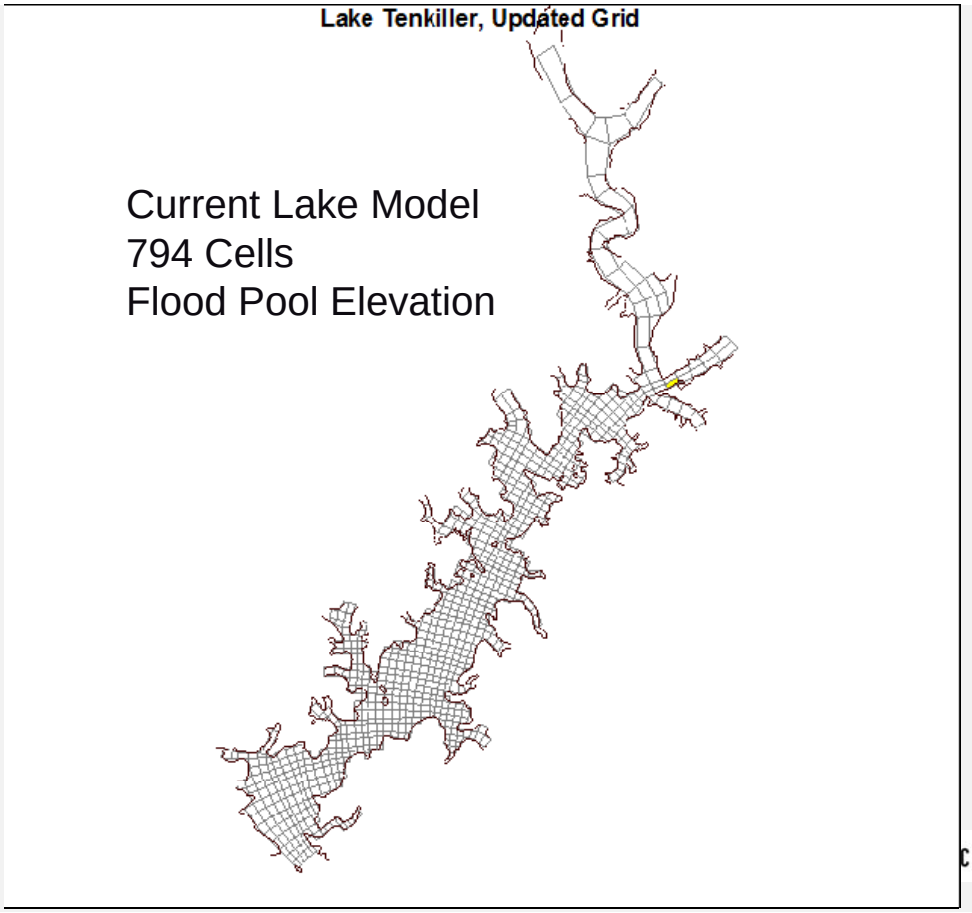
Dynamic Solutions LLC



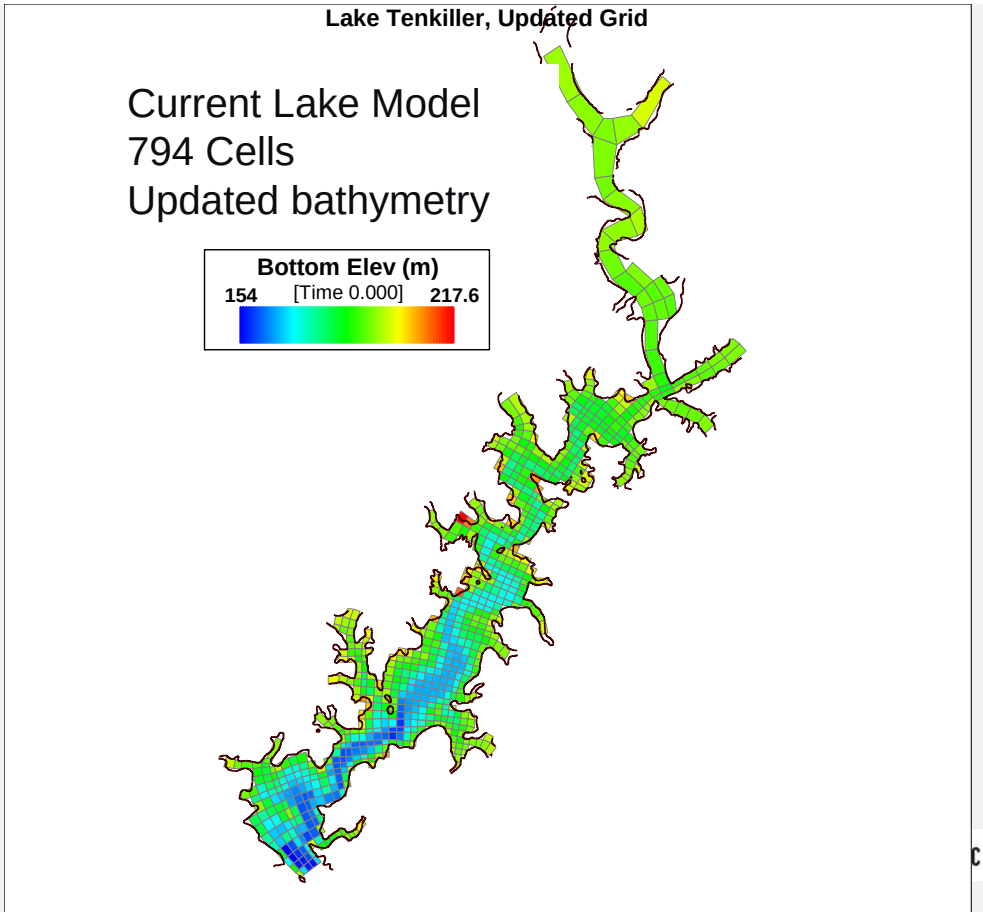
Solutions LLC

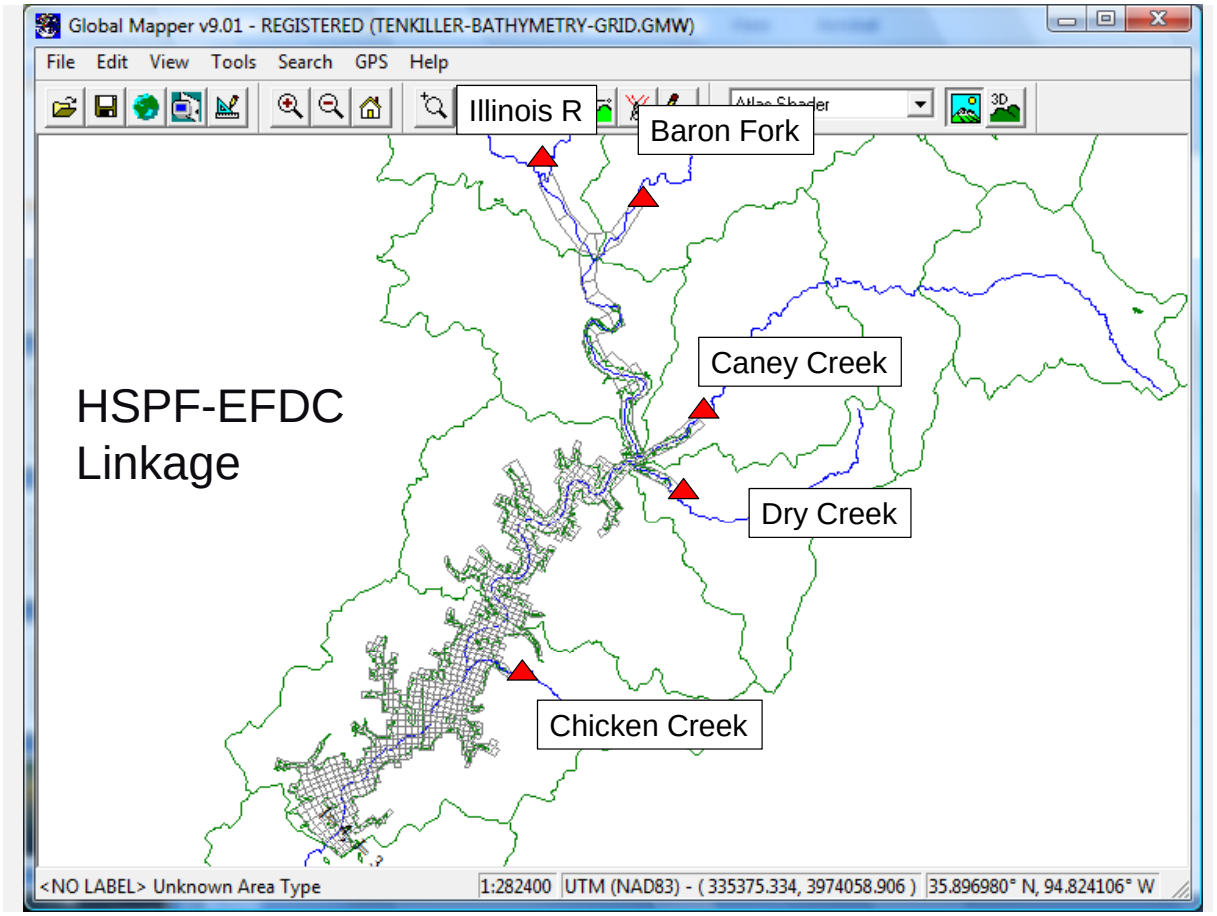


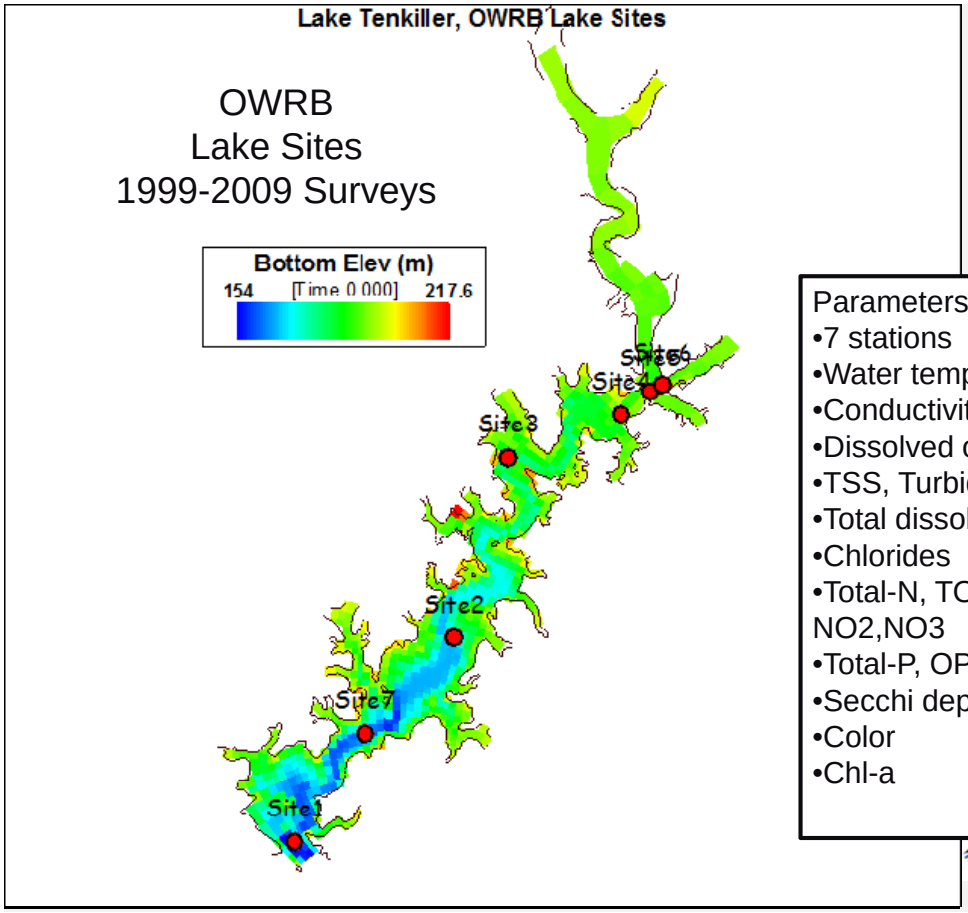
Solutions



c Solutions

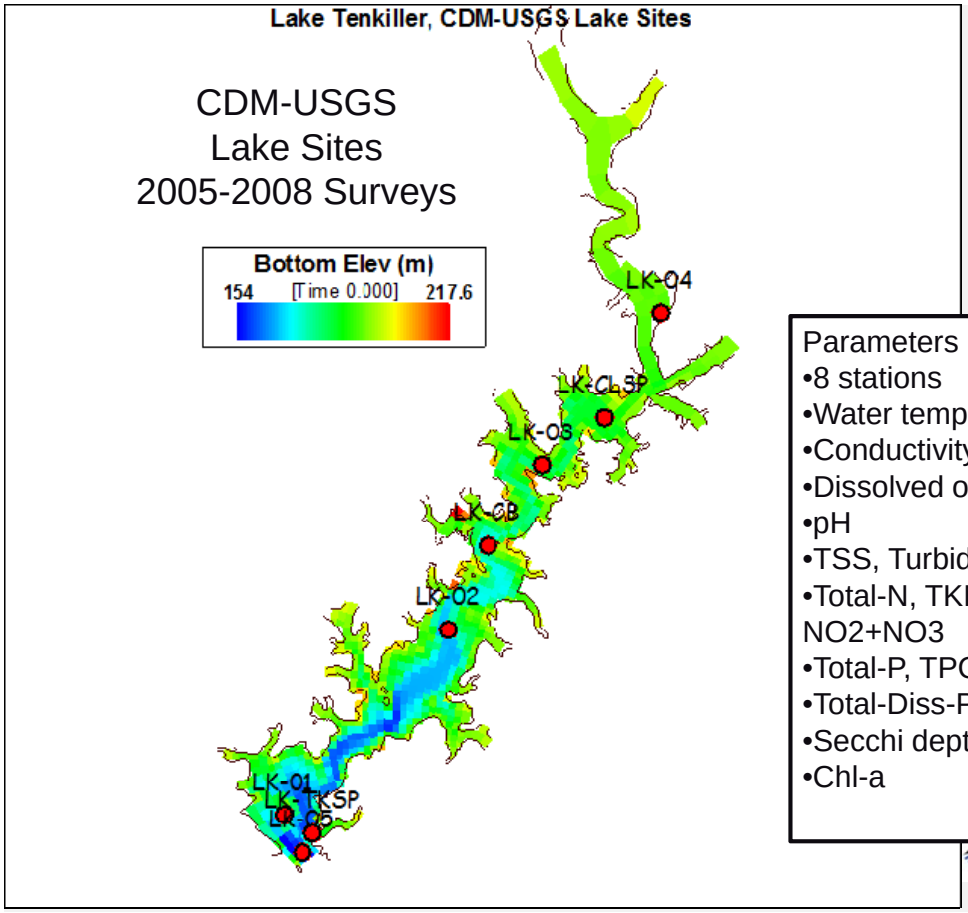

Lake Tenkiller, Updated Grid
Current Lake Model
794 Cells
Updated bathymetry
Bottom Elev (m)
154
[Time 0.000]
217.6
c Solutions


Global Mapper v9.01 - REGISTERED (TENKILLER-BATHYMETRY-GRID.GMW)
File Edit View Tools Search GPS Help
Illinois R
Baron Fork
Caney Creek
Dry Creek
Chicken Creek
HSPF-EFDC
Linkage
<NO LABEL> Unknown Area Type
1:282400
UTM (NAD83) - (335375.334, 3974058.906)
35.896980° N, 94.824106° W



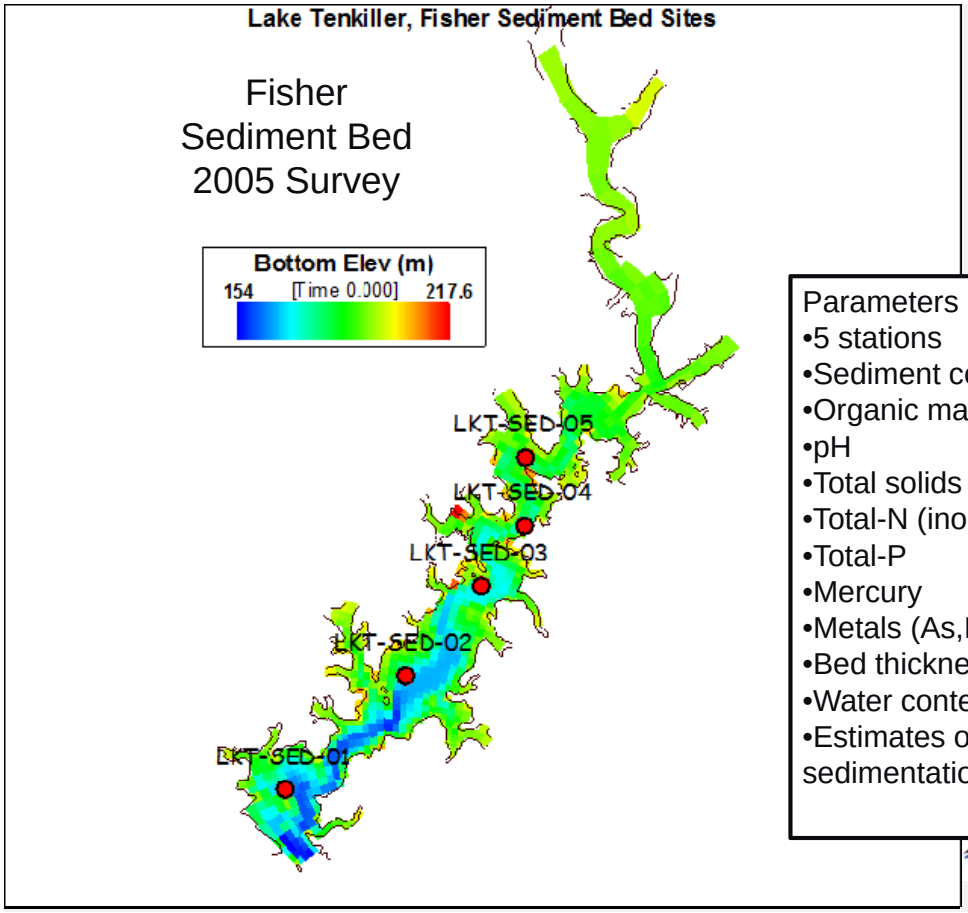
Parameters
- 7 stations
- Water temperature
- Conductivity
- Dissolved oxygen
- TSS, Turbidity
- Total dissolved solids
- Chlorides
- Total-N, TON, TKN,NH3, NO2,NO3
- Total-P, OPO4
- Secchi depth
- Color
- Chl-a

Dynamic Solutions LLC



Parameters
- 8 stations
- Water temperature
- Conductivity
- Dissolved oxygen
- pH
- TSS, Turbidity
- Total-N, TKN,NH3, NO2+NO3
- Total-P, TPO4
- Total-Diss-P, Diss-PO4
- Secchi depth
- Chl-a

Dynamic Solutions LLC



Parameters
- 5 stations
- Sediment cores
- Organic matter content
- pH
- Total solids
- Total-N (inorg+org)
- Total-P
- Mercury
- Metals (As,Pb,Zn,Cu,
- Bed thickness
- Water content
- Estimates of sedimentation rates

Dynamic Solutions LLC

Lake Model Status

- Updated bathymetry and increased grid resolution
- Compiled sediment bed data collected by Fisher in 2005 and by CDM-USGS in 2005-2007
- Compiled lake data collected by OWRB (1999-2009) and CDM-USGS (2005-2008)
- Use updated HSPF watershed flow & loading of BOD, TOC, N, P, TSS, algae and oxygen as input to lake model
- Re-calibrate and re-validate lake model using OWRB and CDM-USGS data sets
- Develop technically defensible HSPF-EFDC model framework to evaluate impacts of existing loads and management scenarios on lake water quality and compliance with WQ targets

Dynamic Solutions LLC

Summary
HSPF-EFDC Model Framework

- EFDC Water Quality & Sediment Diagenesis Model links HSPF watershed loading of BOD, TOC, sediments & nutrients to:
  - Lake eutrophication
  - Sinking of algae and organic matter to lake bed
  - Decomposition of organic matter in sediment bed
  - Sediment-water exchange of nutrients (N,P)
  - Sediment oxygen demand and hypolimnetic oxygen depletion during summer stratification
  - Compile load budget with lake model for external (watershed) and internal (sediment bed) sources of TP

Dynamic Solutions LLC

Summary
Comparison to WQ Targets

- Model TSS, detritus and Chl-a will be used to derive light extinction and secchi depth as water clarity indicator
- Model Chl-a and TP will be used to derive Trophic State Index (TSI)
- Model dissolved oxygen will be used to derive seasonal trends in percentage of anoxic volume of the lake < 2 mg/L

Dynamic Solutions LLC

Tenkiller Lake
EFDC Modeling Update

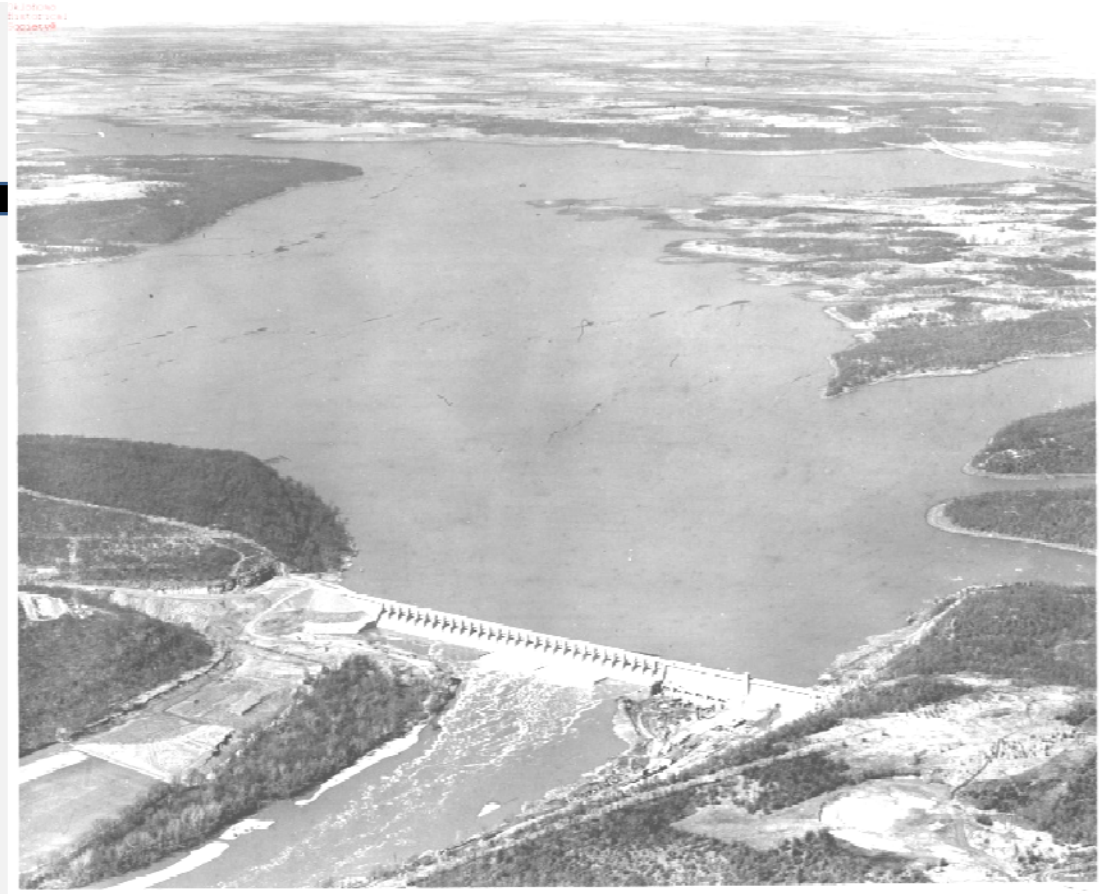
Discussion

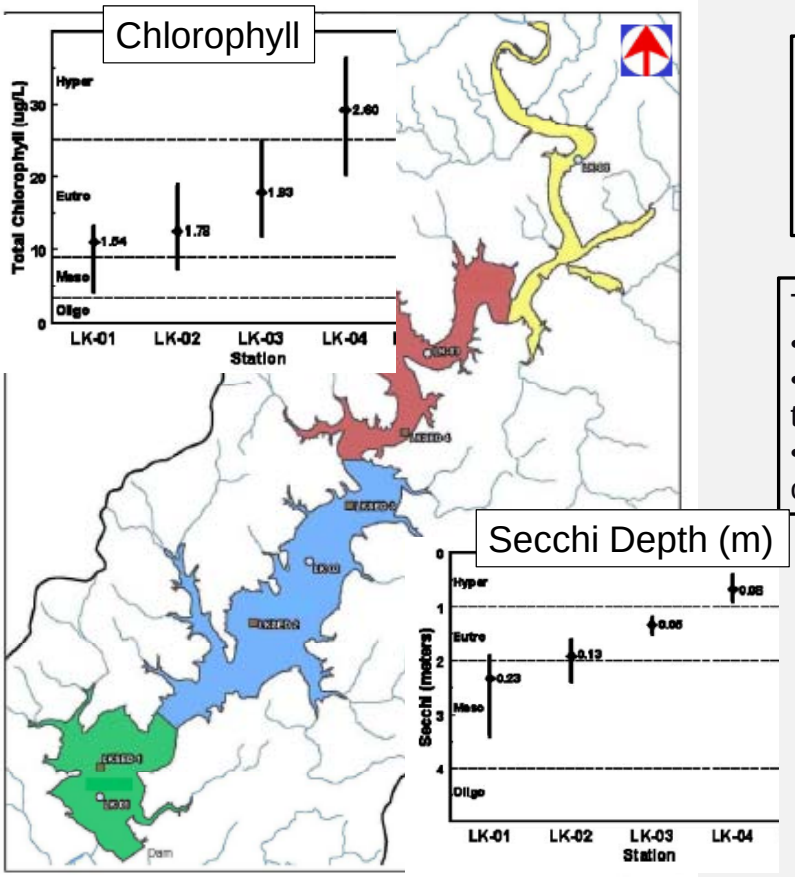
Contact Information:
Dynamic Solutions
Andrew Stoddard
astoddard@dsllc.com
(540) 338-3642

© Ron Day
www.rondayphotography.com

Dynamic Solutions LLC

Dynamic Solutions LLC





Riverine Zone
- Narrow, shallow
- Short residence time
- High TSS; poor clarity
- High nutrient inflows

Transition Zone
- Broader, deeper
- Increased residence time
- Lower TSS; better clarity

Lacustrine Zones
- Wide, deep
- Long residence time
- Low TSS; high clarity

Dynamic Solutions LLC

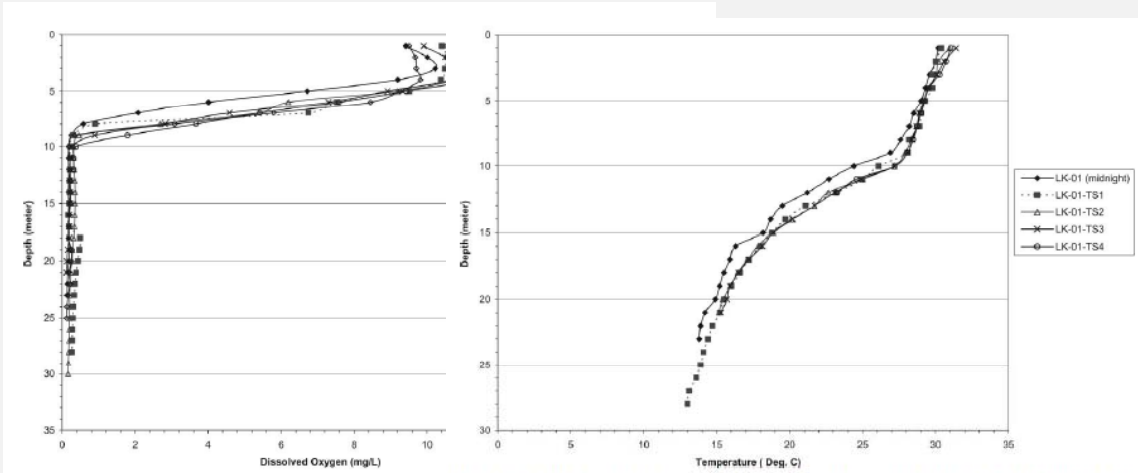


Figure 4.-Profiles of DO and temperature at sites located horizontally across the reservoir at lacustrine station LK01 on 10 Aug 2005.

Dynamic Solutions LLC