Developing a Water Quality Model for FERC Re-Licensing Stakeholder Presentations

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Abstract:

Presenting water quality data for stakeholder meetings is often challenging. Section 603 of the Energy Act requires dam owners to hold stakeholder meetings on lake water quality issues during the FERC re-licensing process. Traditionally, maps, tables, and graphs have been distributed at stakeholder meetings to present water quality data, which is often perceived as misleading and confusing. This paper presents the methodology for presenting complex water quality issues to a non-technical audience. The process used for data collection, data projection, modeling parameter selection, and modeling techniques to generate a water quality model in Lake Murray, South Carolina is reviewed.

Lake Murray, South Carolina

This case study involves a dam re-licensing project at the Saluda Dam on Lake Murray, South Carolina. The paper reviews data collection, data projection, modeling parameter selection and modeling techniques used to create presentation materials for FERC-required, dam re-licensing consultation meetings.

Lake Murray is located in Central South Carolina and is one of the state's largest lakes. Lake Murray is approximately 78 square miles with 649 miles of shoreline. Four counties border the lake: Richland, Lexington, Newberry, and Saluda. The Saluda Dam has dammed Lake Murray since 1930 and is the source of energy for the Saluda Hydro Plant. The Saluda Hydro Plant generates power for central South Carolina. The Saluda Dam is one of the world's largest earthen dams, standing 1.5 miles wide and 208 feet high.

Today, the Saluda Hydro Plant has a capability of 206 megawatts (one megawatt = one million watts). The need for quality presentation materials for stakeholder consultation meetings is based on the regulatory framework for dam re-licensing.

Regulatory Framework The Federal Energy Regulatory Commission (FERC) regulates non-federal hydroelectric power projects that affect navigable waters, occupy U.S. lands, use water or water power at a government dam or affect the interests of interstate commerce. The FERC is responsible for issuing:

1. preliminary hydropower dam permits,
2. project licenses, and

3. exemptions from licensing of the nation's hydropower dams. FERC issues licenses to construct and operate hydropower dams for a term of between 30 to 50 years.

Dam re-licensing is required at the conclusion of that term, and a formal licensing process involving FERC, state environmental agencies, non-government organizations, public interest groups, the public and all other stakeholders is initiated. According to FERC, the licensing pre-application and post-application filing activity is approximately seven-years. Under the licensing process, the licensee is required to engage in a pre-filing consultation period with all parties that might have an interest in, or might be affected by the project. License applicants often consult local community organizations, non-governmental organizations, tribal groups, state environmental agencies, and relevant state and federal fish and wildlife agencies for feedback regarding the impact of the reservoir dam on environmental water quality issues. The public can intervene in the licensing process anytime and ask FERC to examine issues that they feel are important, which routinely include water quality. The public can also influence the FERC's final environmental assessment of the project and how it is analyzed.

The United States Environmental Protection Agency's (US EPA's) Clean Water Act explicitly states that "Any applicant for a Federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into the navigable waters, shall provide the licensing or permitting agency (i.e. FERC) a certification from the State." This federal law mandates that the governing State agency, such as the South Carolina Department of Health and Environmental Control (DHEC), issue a 401 Water Quality Certificate, certifying the lake's water quality prior to FERC licensing. The South Carolina DHEC considers the following conditions during a 401 Water Quality Certification review:

1. whether the activity is water dependent,
2. the intended purpose of the activity,
3. whether there are feasible alternatives to the activity,
4. all potential water quality impacts associated with the project, both direct and indirect over the life of the project.

Lake Murray Model Selection

Licensees traditionally distribute maps, tables, and graphs at consultation meetings to present water quality data, which is often perceived by the public as misleading and confusing. The Saluda Dam re-licensing team consisting of South Carolina Electric and Gas (SCEG), Kleinschmidt Associates, and Reservoir Environmental Management, Inc. (REMI) retained Walden Associates, Inc. (Walden) to create three-dimensional animation sequences that show water quality conditions for FERC-required consultation meetings.

The re-licensing team considered chlorophyll A, temperature, and dissolved oxygen as possible modeling parameters to illustrate water quality. Dissolved oxygen was selected as the modeling parameter because it is a measure of the amount of gaseous oxygen dissolved in aqueous solution used to sustain aquatic life within the lake. Oxygen gets into the water by diffusion from the surrounding air, by aeration, and as a waste product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality and sustaining life. Dissolved oxygen in surface water ranges from approximately 9.5 mg/L to 0 mg/L. Levels above 5 mg/L are considered optimal and most fish cannot survive for prolonged periods at levels below 3 mg/L.

Three-Dimensional Model Goal

The southeastern United States reservoir systems undergo a spring and fall turnover as a result of water temperature changes. During the summer period dissolved oxygen concentrations can drop to zero mg/L because of many factors, including temperature change and environmental factors. Project efforts were focused on illustrating the change in dissolved oxygen concentrations until fall turnover or lake mixing occurs. The goal of this project was to generate a three dimensional model of this occurrence based on existing water quality data that stakeholders can easily understand. Walden developed five, three-dimensional water quality animations to illustrate dissolved oxygen concentrations in Lake Murray.

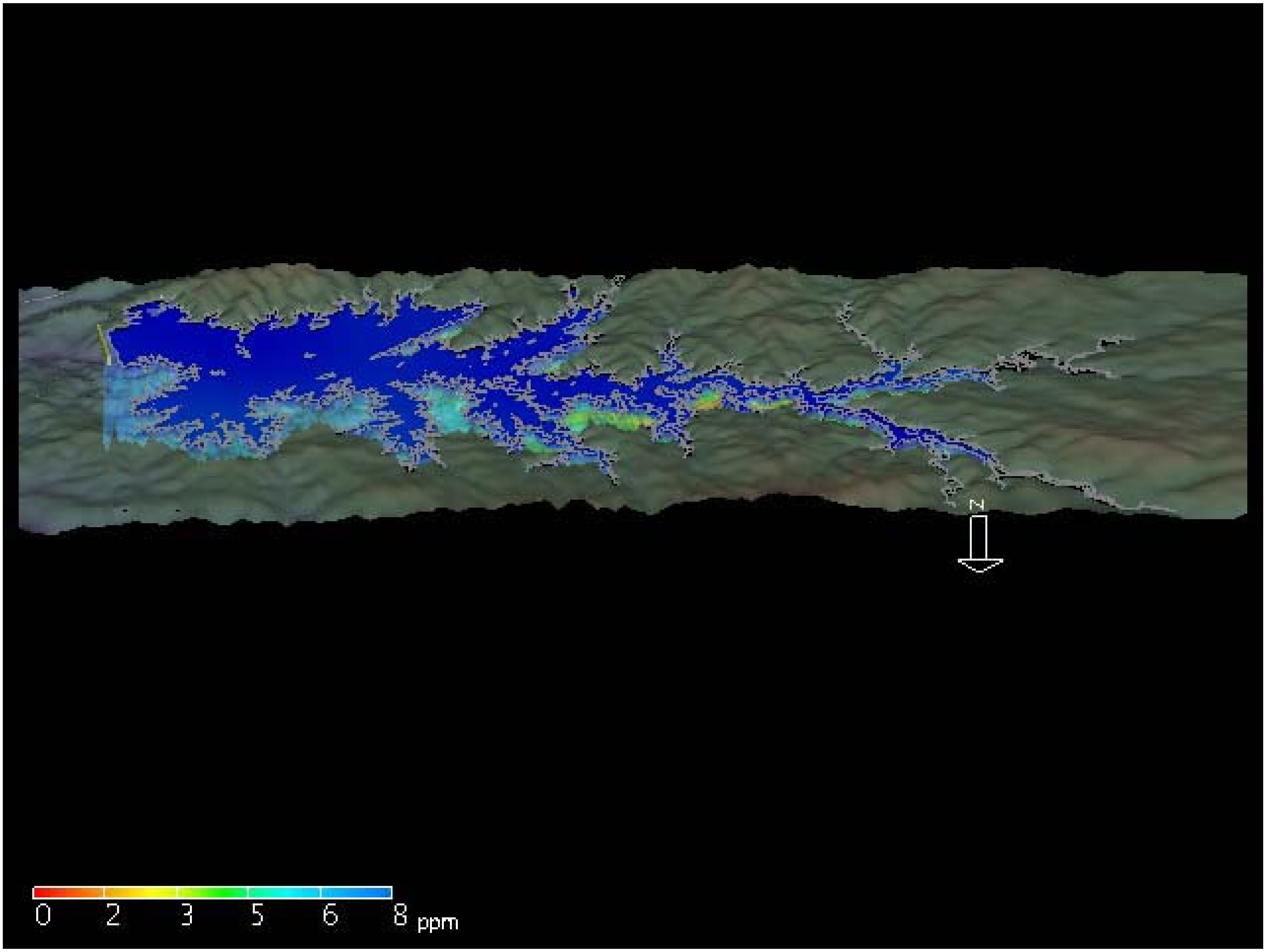
Walden in conjunction with SCEG, Kleinschmidt Associates and REMI selected a five-month sampling period that illustrates lake turnover from May, June, August, September, and October 1996 as a representation of dissolved oxygen concentrations.

Five animations, approximately two to three-minutes each were generated to illustrate dissolved oxygen concentrations in the lake over this five-month period. Walden used a combination of third-party software to organize, project, interpolate, model and animate the data. Software included: ESRI's ArcView and ArcInfo for data organization and projection; C-Tech's Environmental Visualization System (EVS-Pro) for data interpolation and modeling; Adobe's Premiere 6.0 for animating; and AutoCad 2000 and Adobe Photoshop for graphic design.

The animation model utilized dissolved oxygen data from sampling stations collected by SCEG and the South Carolina's DHEC. Digital elevation models (DEMs) and bathymetry data was supplied from the South Carolina Department of Natural Resources (SCDNR) and the United States Geological Survey (USGS), respectively.

Animation sequences included an introduction, an overview of sampling station and landmark locations, lake cross sectional views, change in dissolved oxygen concentrations, and dissolved oxygen views from underneath the lake. Figure 1 illustrates a snapshot taken from a water quality three-dimensional animation. This snapshot shows the lake boundary and its surrounding topography, along with dissolved oxygen concentrations from May 1996. Dissolved oxygen concentrations range from 0 to 8 ppm and are displayed as red to blue in color.

Figure 1 - Snapshot of Water Quality Three Dimensional Animation



Data Conversion

Dissolved Oxygen Sampling Data

Dissolved oxygen data from over 1,200 discrete sampling points at thirteen sampling stations were collected at one-meter intervals from the lake surface to lake bottom. Sampling data was supplied to Walden as thirteen excel files; one file per sampling station. Sampling data included location latitude and longitude, surface water elevation (350 feet mean sea level), date, time, sample elevation (mean sea level) and dissolved oxygen concentrations. Sampling data was then organized into five monthly files for May, June, August, September, and October. Projections were utilized to convert the latitude / longitude angles into consistent units of feet, because latitude and longitude data does not represent equal length distances or supply information regarding depth units. Walden converted each latitude / longitude coordinate into decimal degrees, then plotted the sampling locations into ESRI's ArcView. The following equation was used to convert latitude and longitude into decimal degrees.

Decimal degrees = degree + (minute/60) + (sec/3600)

Bathymetry and Digital Elevation Model (DEM) Data

Bathymetry data was supplied as contour lines in a shapefile from USGS. Walden converted the contour shapefile into points by using a "convert polyline to point shapefile" arc script download from ESRI's website. 6,860 points were created from twenty-one contour intervals.

Twelve DEMs were downloaded from SCDNR's website. The DEM's were converted to Arc INFO GRIDS. Once the conversion was completed, all twelve GRIDS were combined using the GRID "merge" command to create one seamless surface. The topographic elevation GRIDS were converted to points using the "convert polyline to point shapefile" arc script. 21,180 points were created from the DEM GRIDS.

Walden removed overlapping topography and bathymetry data. Walden generated a polygon representing surface water elevation at 350 feet, and deleted all topographic points that lay within this surface water boundary. Walden then projected the bathymetry and DEM data into a common coordinate system and moved dissolved oxygen sampling data to the new coordinate system.

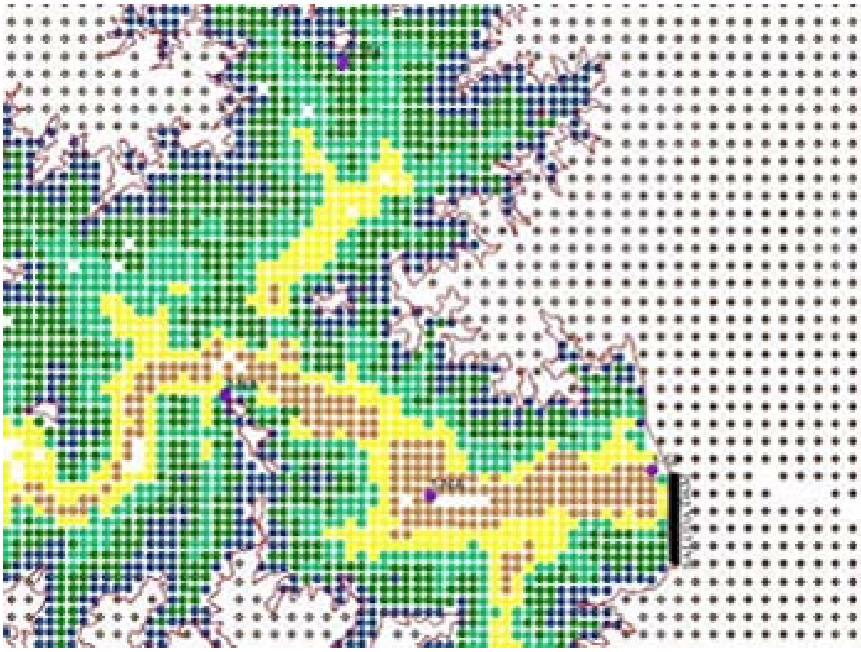
Data Interpolation

Topographic DEM data, bathymetry data and sampling data were formatted into database *.dbf files for data interpolation. Elevation data, containing topographic data and bathymetric data, were combined into one database file. Sampling data was formatted into a separate *.dbf file. Elevations were noted as below surface water (bathymetry) and above surface water (topography) elevations, where surface water level was equal to 350 feet. This distinction helped create two separate areas for bathymetry and topography data, which could be manipulated separately during animation generation.

A separate elevation file was also created for topographic elevations behind the lake's dam, because the elevations behind the dam were less than 350 feet, but not considered part of the lake bathymetry bottom. This area can be thought of as a valley within the topography.

Figure 2 illustrates bathymetry, topography, and dissolved oxygen point data in the eastern portion of the model. The brown data points indicate topographic elevations, the green-tan data points indicate bathymetry data points, and the purple data points indicate sampling stations.

Figure 2 - Bathymetry, Topography, and Dissolved Oxygen Data Points



Walden utilized C Tech's Environmental Visualization System (EVS-PRO) software to interpolate bathymetric and topographic surfaces to create a 3D volumetric model of Lake Murray and the surrounding terrain. Dissolved oxygen levels in the lake were then interpolated (mapped into the 3D grid) using EVS-PRO's three-dimensional kriging. Walden utilized C Tech's finite difference gridding technique so that the cell width, length, and height would be smaller in areas with denser dissolved oxygen sampling data. Walden specified model grid dimensions based on the actual x,y,z dimensions of the lake (approximately 200,000 feet in the x direction, 90,000 in the y direction, and 350 feet in the z direction). A horizontal to vertical anisotropy parameter was used to account for stratification in the lake and sampling patterns. Without accounting for the anisotropy, creating an accurate model is virtually impossible. Variography and kriging weights were automatically determined by EVS-PRO to account for the degree of correlation between sample values as a function of the distance and direction between samples.

Model Animation

Walden exaggerated the vertical extent of the lake model 15 times the horizontal scale. This vertical exaggeration was performed so the viewer can more easily view the lake's dissolved oxygen data. Walden utilized C-Tech's Environmental Visualization System (EVS-Pro) software to create individual targa files representing each frame of the animation. A script was written in EVS-Pro software that instructed the software to generate animation frames to pan, zoom, and scroll by dissolved oxygen concentrations within the model. Walden used Adobe's Premiere 6.0 software to combine targa files as five animations, *.avi, files. Detailed annotation, legends, and company logos were incorporated into the animations using Adobe Premiere 6.0.

Walden created five separate animations that illustrated water quality conditions. These animations supplied SCEG with a variety of tools for presenting data at consultation stakeholder meetings. SCEG was able to insert any number of the animation sequences into a Microsoft PowerPoint presentation or run the sequences using a standard PC computer media player. Animation segments included:

1. an introduction sequence,
2. a sequence illustrating water quality sampling stations and landmarks,
3. cross sectional views of water quality,

4. a sequence that scrolled by concentration from 8 ppm to 2 ppm for August and September, and
5. a sequence illustrating water quality conditions below the lake.

Each animation sequence ran approximately one to three minutes in length. Walden also supplied SCEG with individual images to create printed materials. Figures 3 through 7 illustrate snapshots taken from the described animation sequences.

Figure 3 - Snapshot from Introduction Sequence

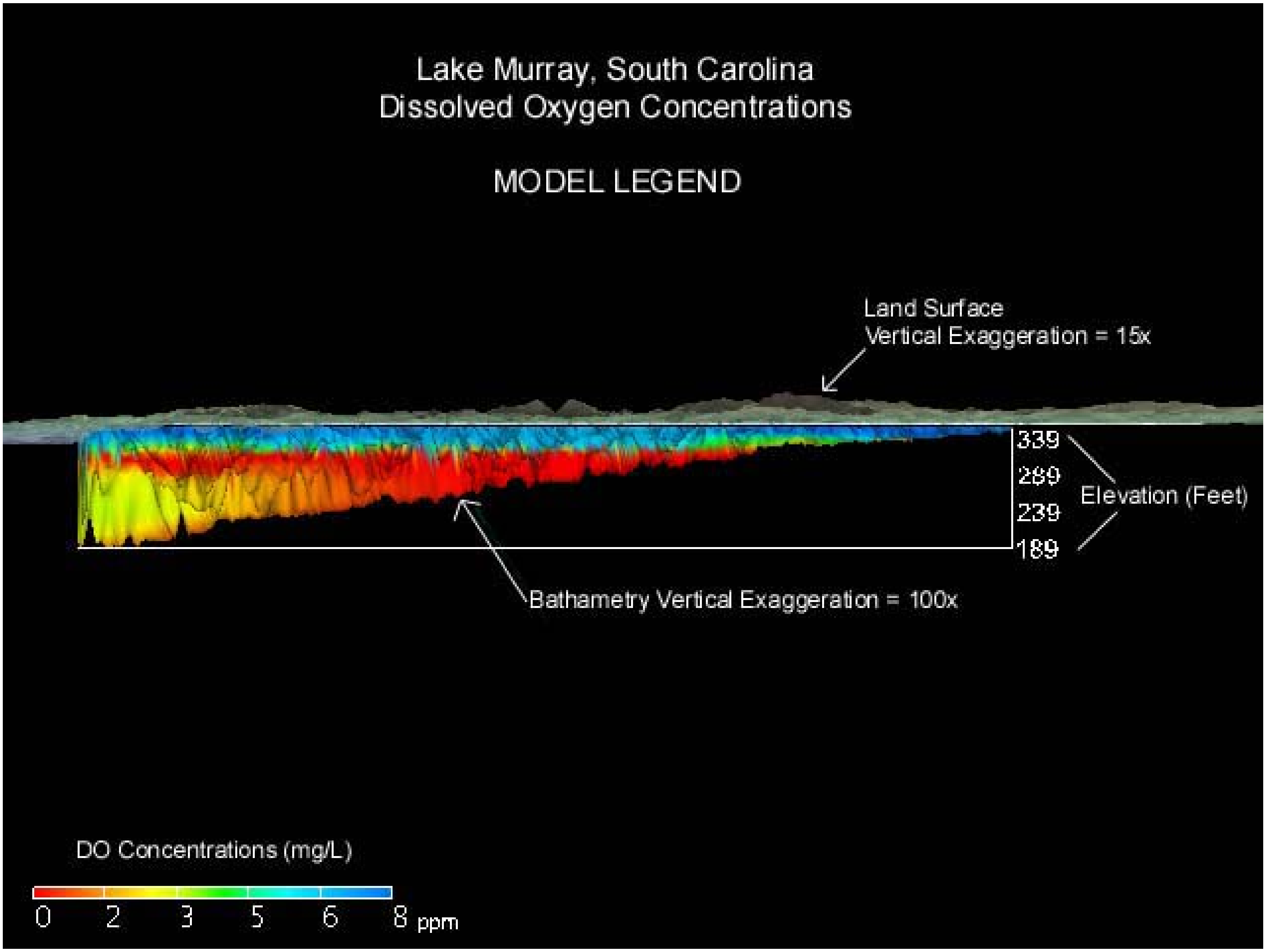


Figure 4 - Snapshot from Sequence 1, Water Quality Sampling Stations and Landmarks

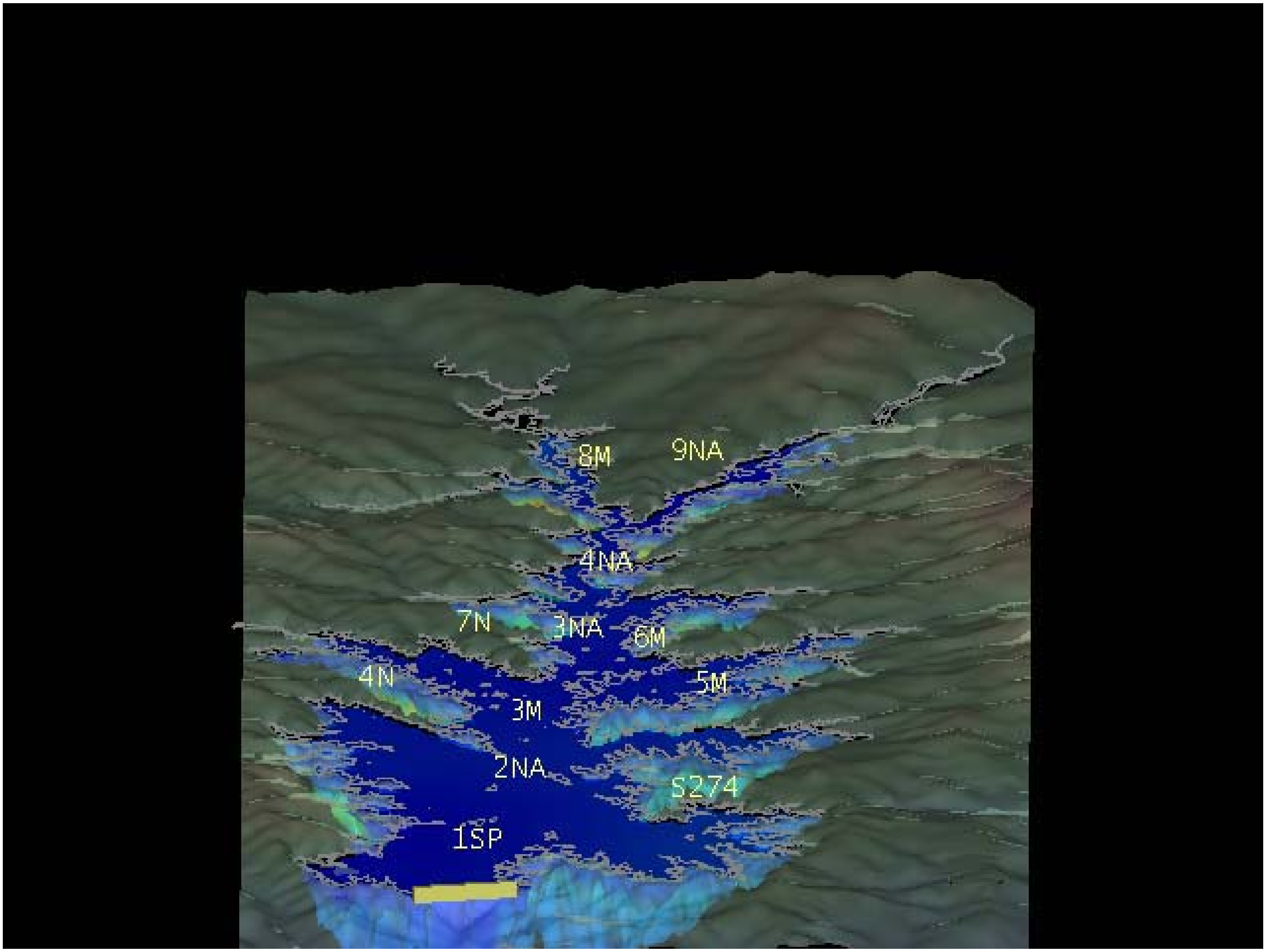


Figure 5 - Snapshot from Sequence 2, Cross Sectional Views of Dissolved Oxygen Concentrations in Lake Murray

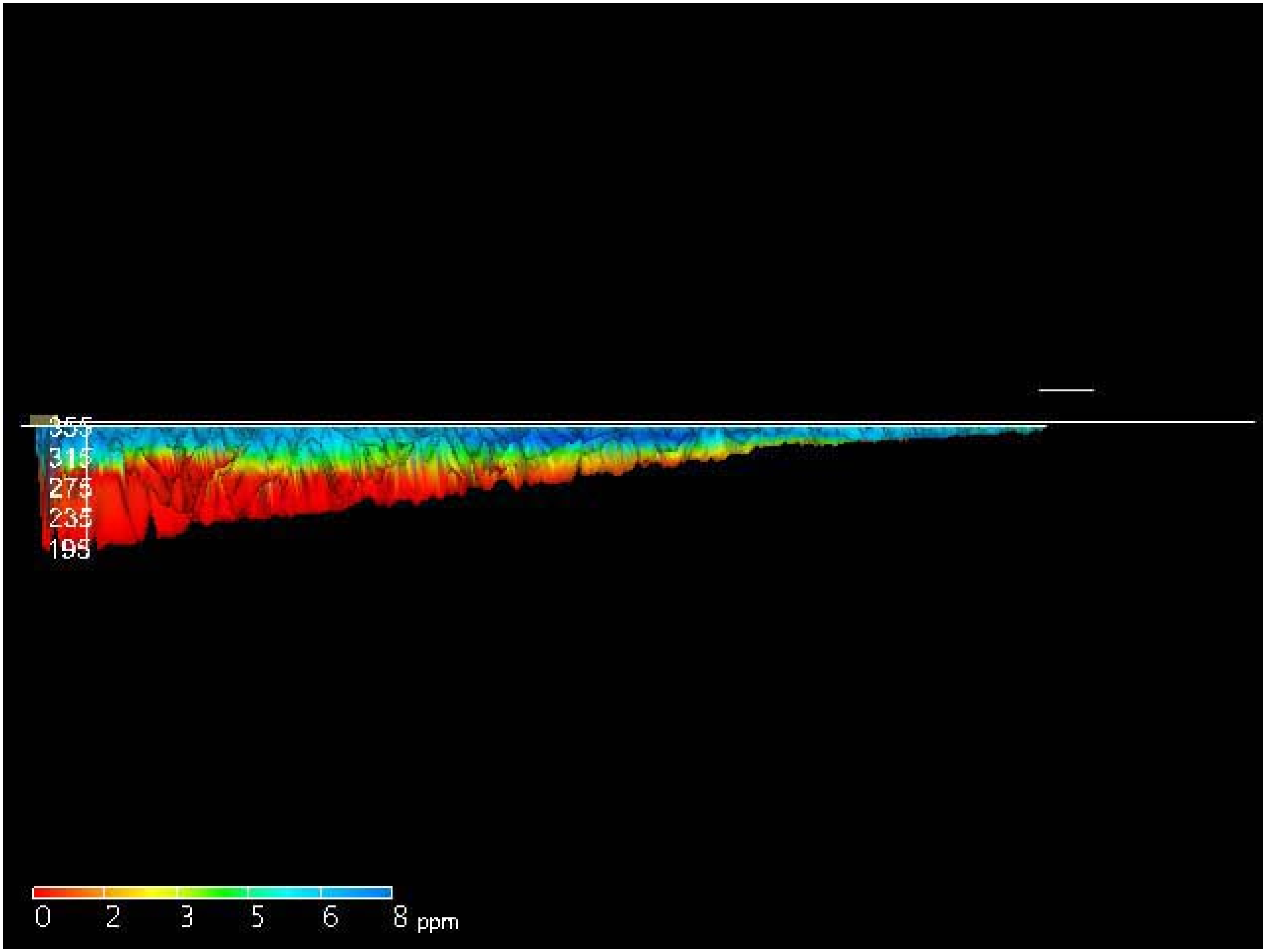


Figure 6 - Snapshot from Sequence 3, Change in Concentration for August and September 1996

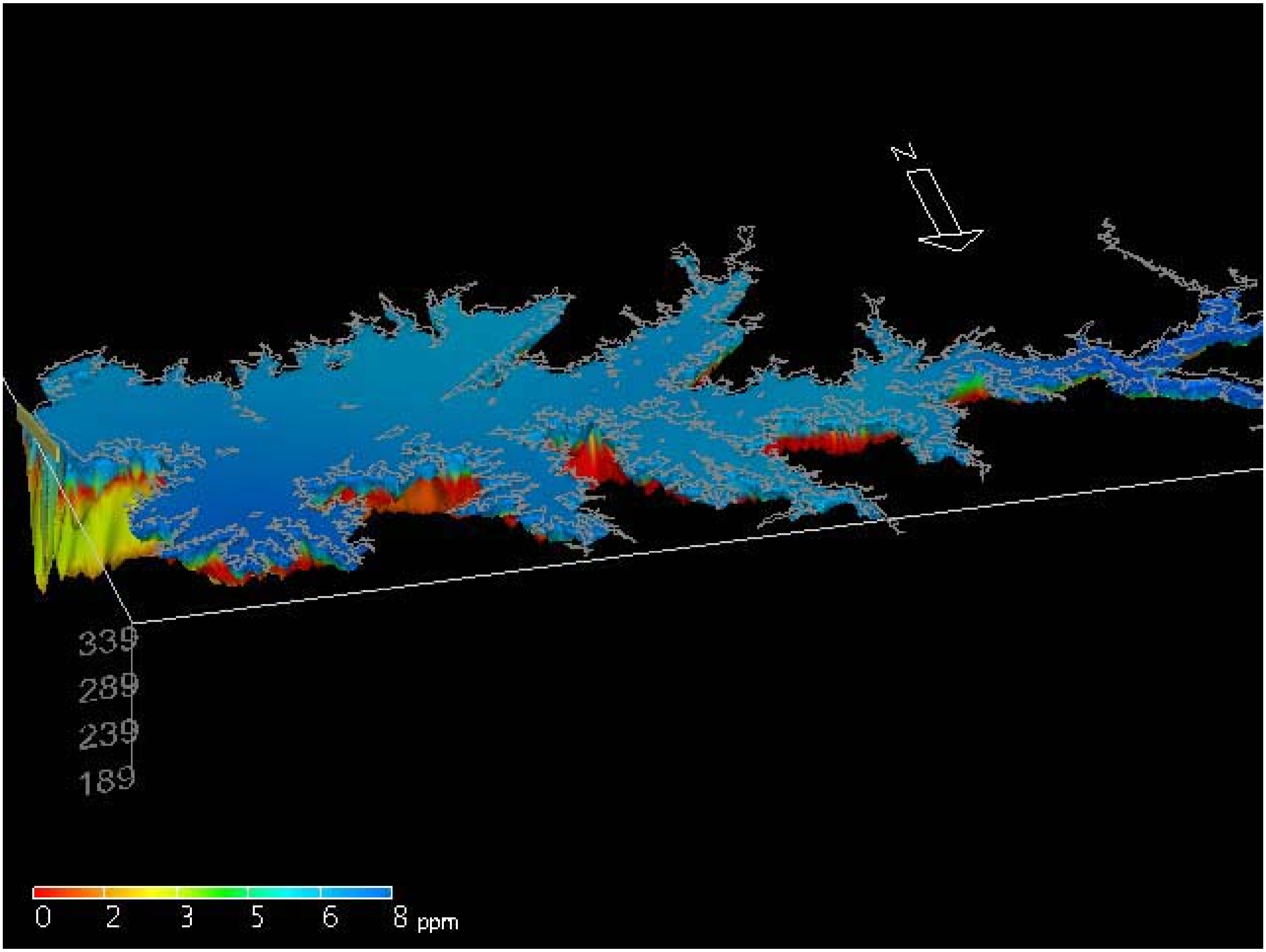
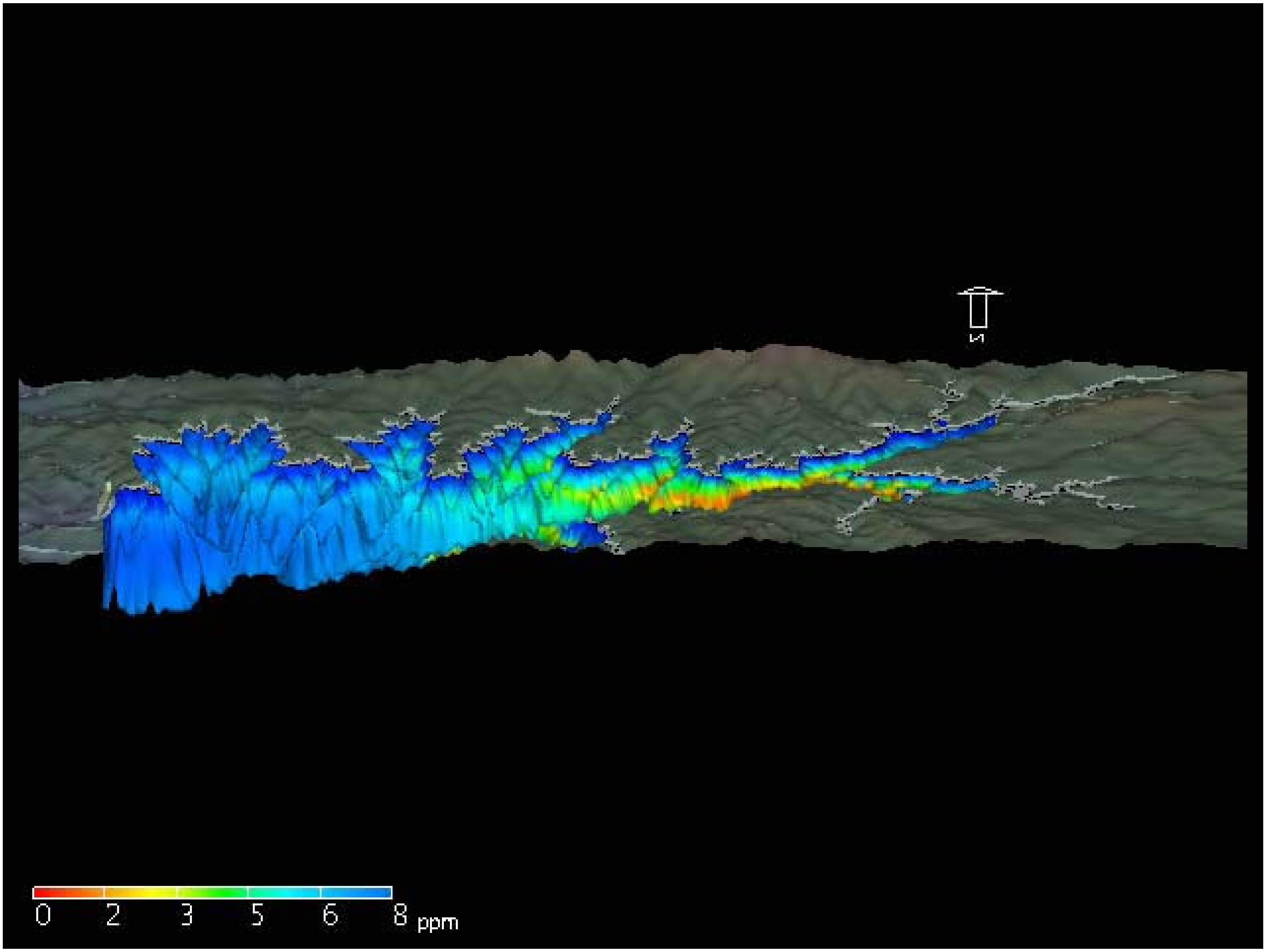


Figure 7 - Snapshot from Sequence 4, Views Underneath Lake Murray



Conclusion

The goal of this project was to create three dimensional animation sequences that show dissolved oxygen concentrations for FERC-required consultation meetings. Dissolved oxygen was selected as the best water quality indicator for this project, although the project team reviewed chlorophyll A and temperature as other possible parameters to model. Walden used dissolved oxygen data from May, June, August, September, and October 1996, during a lake turnover period, to illustrate the complexity of lake water quality to non-technical stakeholders. This paper illustrated the methods for organizing, interpolating, and presenting water quality dissolved oxygen data for these stakeholder consultation meetings. ArcView and Arc Info were used to convert data contours into point data, and apply map projections. Environmental Visualization System (EVS-Pro) software was used for data interpolation and animation. Methods of data presentation may be applied for additional water quality datasets such as temperature, phosphorus load, conductivity, or environmental contamination. Additional project work included the calculation of lake volume and percent dissolved oxygen within the lake model using C-Tech's EVS-Pro software volume calculation. By calculating the volume of dissolved oxygen a quantitative value for percent dissolved oxygen was determined.

To-date, the Lake Murray water quality animations have been used for regulatory and project meetings. The Saluda Dam re-licensing project is currently on hold, although future uses of the three-dimensional animations include: stakeholder consultation meetings and web access. Three-dimensional animations shall be embedded into a Microsoft PowerPoint presentation, played using Microsoft Media Player, distributed on CD-Rom or posted on a public website for stakeholder information during the FERC dam re-licensing consultation period.

Walden has created lake water quality animations for other FERC-required stakeholder consultation meetings, including the Moore and Comerford Reservoirs in Connecticut. State regulators have praised the value of three-dimensional modeling and commented on stakeholders' increased understanding of water quality issues within the lake. In Connecticut, State regulators requested images from the three-dimensional model for their 401 Certificate water quality evaluation.

Acknowledgments:

Many thanks to the following people who helped support this project:

Bennett, Andrew, Miner and Miner, Inc.
Copsey, Reed, C-Tech Development Corporation
Keane, Robert, Walden Associates, Inc.
Massey, Kristina, South Carolina Electric and Gas
Mealing, Henry, Kleinschmidt Associates
Heaney, Joseph, III, Walden Associates, Inc.
Ruane, Jim, Reservoir Environmental Management, Inc.
Stuart, Alan, Kleinschmidt Associates.

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