

# Narragansett Bay

## Research Reserve

Technical Report

2008:1

### High-resolution Water Quality Mapping in Narragansett Bay, RI using DATAFLOW

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## Introduction

There currently exists a suite of ongoing water quality monitoring efforts in Narragansett Bay, RI, which is collectively known as the Bay Window Program and is managed by the RI Department of Environmental Management and NOAA. Primary components of the Bay Window are the fixed-station monitoring and Mariner Shuttle programs. The fixed-station monitoring program is a collaborate effort among multiple university and government agencies to establish a spatially comprehensive series of fixed-site water quality monitoring stations. These stations are equipped with multi-probe YSI water quality sondes affixed to either surface buoys (open-water stations), or PVC tubes or similar housings (shore-based stations). The Mariner Shuttle program uses a ship-towed shuttle that is equipped with water quality sensors and has the ability to undulate between surface and bottom waters. The shuttle follows an established transect around the primary passages of Narragansett Bay on a monthly basis. The fixed-station monitoring program is temporally robust, but spatially limited; the Mariner Shuttle program is less robust temporally, but more so spatially. Although a third component of Bay Window, the Insomnic program, collects vertical water quality profiles at dozens of stations in upper Narragansett Bay 2-3 times per summer, there remains a need for a spatially robust water quality monitoring and mapping program in Narragansett Bay.

A high spatial resolution water quality mapping effort has been ongoing in portions of Chesapeake Bay since at least 1992. This program incorporates an innovative technology known as DATAFLOW. DATAFLOW is essentially a flow-through water quality monitoring system that can be mounted on a small boat and used to map water quality parameters in the surface water at speed of up to 20 knots or more. The system is equipped with a YSI 6600 sonde to measure water quality and a GPS to measure spatial location. The Maryland Department of Natural Resources and others have been effectively monitoring and mapping tributaries of Chesapeake Bay using DATAFLOW technology as a powerful complementary component to other ongoing water quality programs, some of which are similar to components of the Bay Window program in Narragansett Bay.

Despite its utility, the DATAFLOW technology is relatively simple. The system includes an intake ram that is mounted off the transom of a boat, and which draws water into the DATAFLOW system with the assistance of an inline bilge pump (Fig. 1). As the water circulates through the system it passes an inline YSI 6600 datasonde equipped with temperature, specific conductivity, dissolved oxygen, pH, turbidity, and chlorophyll probes. An inline flow-meter keeps track of the volume of water passing through the system. An on-board Garmin GPSmap 168 GPS unit tracks spatial location (i.e., latitude and longitude) of the boat and DATAFLOW system. Water quality and GPS data are simultaneously input to a second YSI meter (a hand-held YSI 650) and stored as a seamless dataset. Thus, each reading of the suite of water quality parameters is accompanied by geographic location, thereby allowing for georeferenced mapping of water quality. The hand-held YSI and GPS unit are both housed inside a custom PVC box, the outside of which is also mounted with the YSI 6600 and other assorted DATAFLOW parts. The entire system is powered by a 12 volt marine battery. The

system allows for data to be collected at up to 4 second intervals while traveling at up to 20 knots or more; this therefore allows for thousands of data points to be collected from target areas of Narragansett Bay over the course of a few hours.

The goal of this study was to demonstrate the utility of using DATAFLOW to map water quality conditions in Narragansett Bay, RI. Specifically, the Narragansett Bay National Estuarine Research Reserve (NBNERR) used DATAFLOW on five dates in the summer of 2007 to map conditions in Greenwich Bay, itself a eutrophic sub-embayment of Narragansett Bay.

## **Methods**

A series of pilot DATAFLOW cruises was undertaken in summer 2007 to map water quality conditions in Greenwich Bay. Six cruises were conducted on June 7, June 26, July 24, August 14, August 23, and September 20, 2007. Cruises began at approximately 0900 using the NBNERR boat *Seawolf*, leaving from the floating dock at the base of T-wharf on Prudence Island, RI. The DATAFLOW flow-through system was installed and initiated prior to leaving the dock.

Each cruise in Greenwich Bay tried to follow as closely as possible a pre-defined cruise track that was input into the boat's onboard GPS unit. In general, the boat followed a zig-zag pattern within Greenwich Bay proper, while also entering three smaller coves (Apponaug, Greenwich, and Warwick Coves) that are connected to Greenwich Bay (Fig. 2).

Data points were collected every 4 seconds during each cruise. Data collected included temperature, specific conductivity and salinity, dissolved oxygen (% saturation and concentration), pH, turbidity, chlorophyll, and location (i.e., latitude and longitude). The cruise also stopped at approximately 5-6 pre-established calibration stations to collect supplemental water quality data to compare with readings from the flow-through YSI 6600 sonde. These data included secchi depth and Li-Cor measurements for *in situ* light levels, and chlorophyll a samples (Appendix 1).

After each cruise was completed in Greenwich Bay, the boat returned to Prudence Island, and all equipment was off-loaded, taken to the NBNERR facility, and cleaned. All collected data were downloaded, edited, stored, and imported into GIS software in order to develop interpolated maps of selected water quality parameters. Each of these steps was done in accordance with established DATAFLOW protocols at the NBNERR (Appendix I).

## **Results and Discussion**

Five of the six DATAFLOW cruises were successfully completed; the cruise on August 23, 2007 had to be abandoned after approximately ½ hour due to temporary problems with the ram intake. On each of the five completed cruises, between 2760-4400

individual data points were collected, for a total of 17834 points of data collected in Greenwich Bay. Each cruise took approximately 4 hours to complete, including stops at calibration stations to collect supplemental water quality data.

Data from each cruise was effective for creating high-resolution maps of selected water quality parameters in Greenwich Bay. For example, dissolved oxygen mapping illustrates the variability exhibited by this parameter over time (across cruise dates) and spatially (within Greenwich Bay and in its sub-embayments; Fig. 3). In particular, these data show that dissolved oxygen levels in general were relatively low on the July 24 and August 14 cruises, and that oxygen levels in the smaller coves differed at times from Greenwich Bay proper (e.g., see Greenwich Cove, southeast from Greenwich Bay, on June 7, 2007). Similar variability over space and time was observed for chlorophyll concentrations (Fig. 4). In this case, the disconnect between Greenwich Bay and its smaller coves was even more apparent, with higher levels of chlorophyll generally occurring in the coves (e.g., June 7, 2007).

DATAFLOW clearly has the capability to rapidly and effectively collect high-resolution water quality data from the surface waters of Narragansett Bay. These data can then be manipulated within GIS software to produce equally high-resolution maps of important water quality parameters. This technology is limited in that it can only collect data from the surface water (approximately 0.5 m depth). However, the ability to collect such a large amount of data over a relatively large spatial scale in a minimal amount of time makes DATAFLOW a valuable tool for monitoring and mapping water quality in Narragansett Bay. It should serve as an excellent complement to other efforts currently underway in the Bay, and has many applications including hypoxia mapping, correlating turbidity with seagrass distribution, and tracking chlorophyll blooms. DATAFLOW can provide an excellent complement to ongoing Bay Window efforts by collecting water quality data with moderate temporal coverage and very high-resolution spatial coverage of selected areas of the Bay. In particular, DATAFLOW should be highly effective for mapping water quality in the numerous smaller coves and embayments found throughout Narragansett Bay, where shallow depths minimize the need for both surface and deep-water sampling, and where acute effects of land-based practices on estuarine water quality can be realized. The initiation of a standardized and ongoing DATAFLOW monitoring effort would also be timely in light of expected changes to the Narragansett Bay ecosystem due to large-scale management projects including upgrades to wastewater treatment facilities and the progression of the combined sewer overflow project.



Figure 1. The flow-through DATAFLOW system (*Maryland Department of Natural Resources*; [http://mddnr.chesapeakebay.net/sim/dataflow\\_instrumentation.cfm](http://mddnr.chesapeakebay.net/sim/dataflow_instrumentation.cfm))

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Water quality mapping  
in Greenwich Bay, RI  
using DATAFLOW:

Cruise tracks

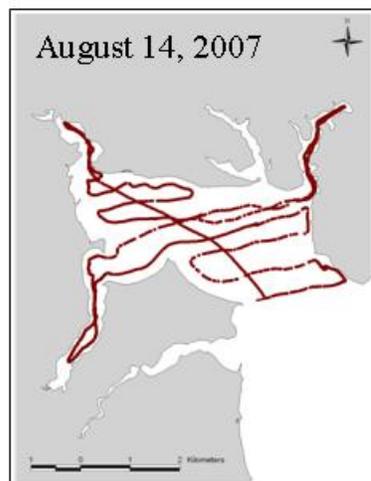
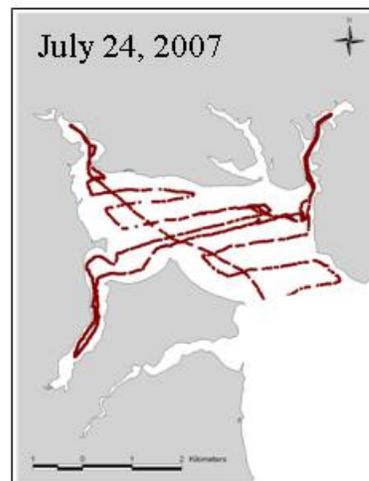
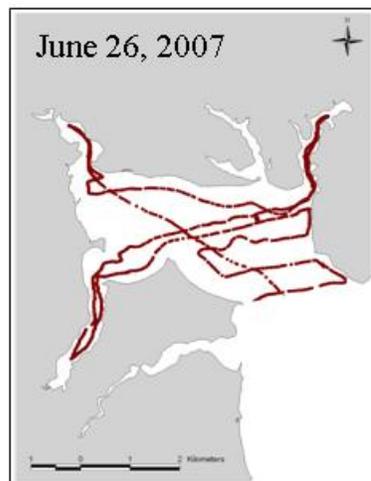
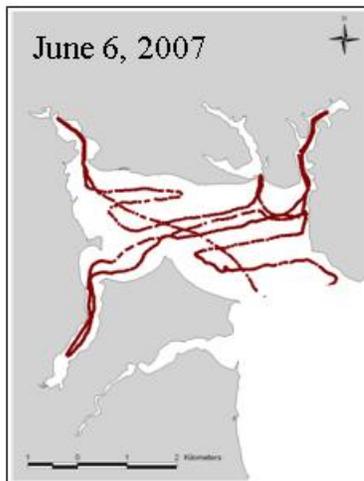


Figure 2: DATAFLOW cruise tracks on the five completed surveys in Greenwich Bay.

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Water quality mapping  
in Greenwich Bay, RI  
using DATAFLOW:

Dissolved oxygen

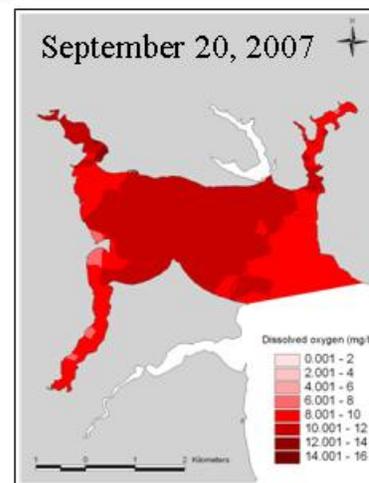
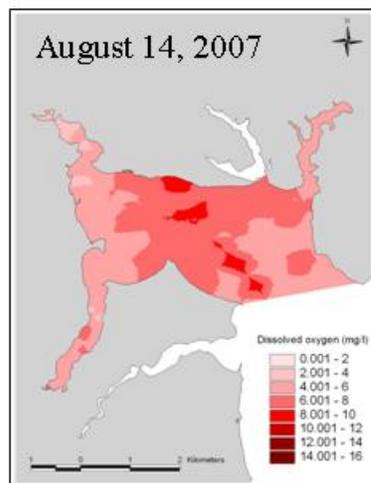
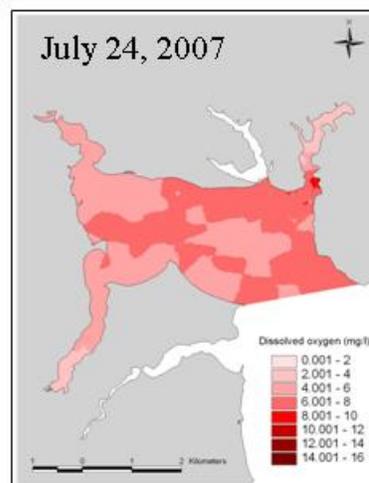
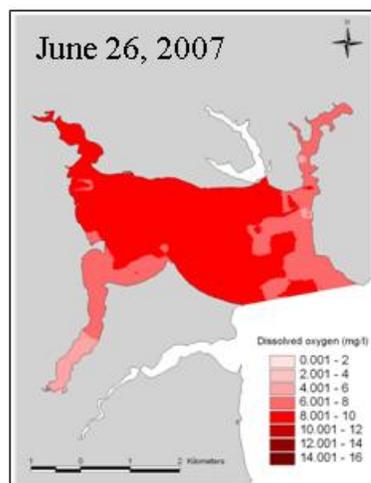
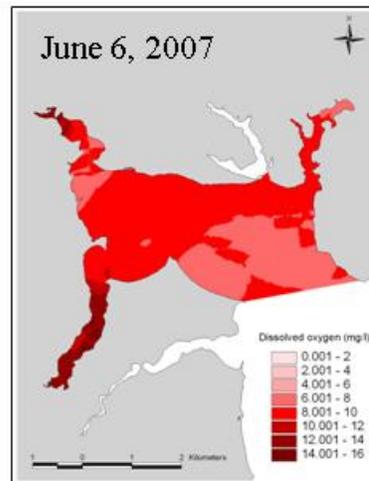


Figure 3. Interpolated maps of dissolved oxygen concentrations in Greenwich Bay, based on DATAFLOW cruises on five dates in summer 2007.

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Water quality mapping  
in Greenwich Bay, RI  
using DATAFLOW:

Chlorophyll a

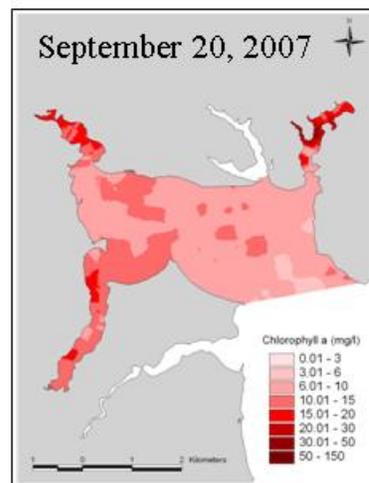
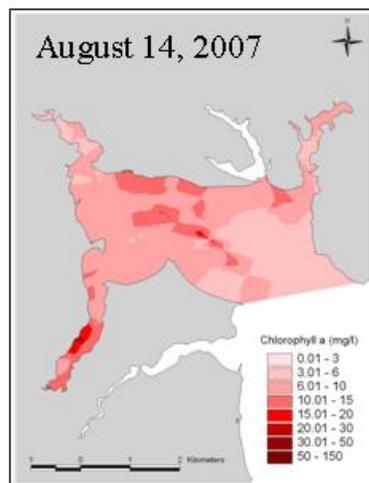
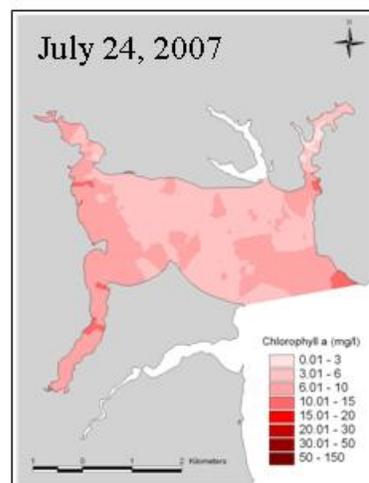
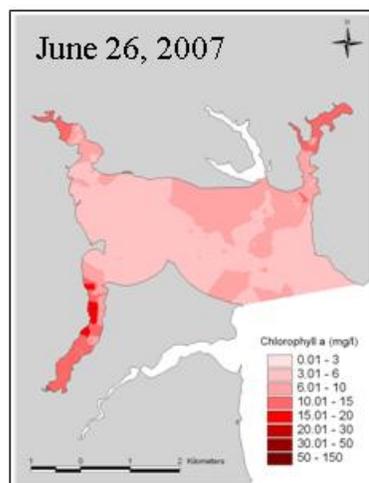
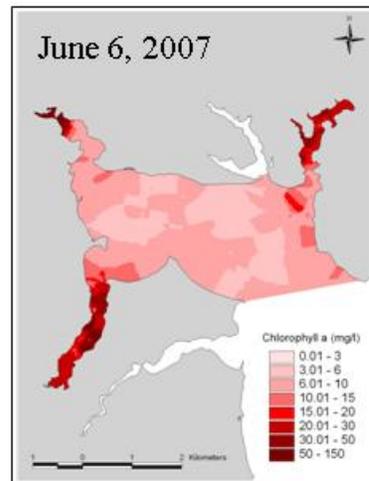


Figure 4: Interpolated maps of chlorophyll concentrations in Greenwich Bay, based on DATAFLOW cruises on five dates in summer 2007.

## Appendix I. NBNERR DATAFLOW protocols

### **A. Preparing for launch**

#### ➤ **General**

- 1) Print datasheets;
- 2) Print map of the cruise track;
- 3) Input cruise track into *Seawolf* GPS unit.

#### ➤ **YSI sonde calibration**

- 1) Change the DO membrane of the sonde 1 day before the sonde DO calibration. DO calibration is done the day of the cruise;
- 2) Check the wipers of the optical probes;
- 3) Calibrate the sonde the day before the cruise (see Deployment Calibration Notes + DO Calibration Notes);
- 4) The day before the cruise assemble the equipment. Use the Dataflow cruise checklist and bring everything to T-Wharf. Clean up checklist and reprint.

#### ➤ **Dataflow unit**

- 1) Charge the main battery overnight before the cruise;
- 2) Install the sonde upside down on the dataflow unit;
- 3) Put the sonde cover on;
- 4) Plug the cable from the dataflow unit to the sonde;
- 5) Plug the other end of the cable to the 650 (handheld);
- 6) Put the ram inside its pipe at the back of the boat;
- 7) Put tape around the ram to cover the space between the pipe and the ram;
- 8) To prime the system, fill the black hose that connects the ram to the dataflow unit with seawater. Turn all power switches to the 'ON' position making sure that water also fills the bilge pump. Attach the 2 black hoses:

one from the ram to the dataflow unit, the other one from the dataflow unit to the bottom of the sonde cover;

9) Attach the transparent hose to the top of the sonde cover;

10) Plug the dataflow unit to the battery.

➤ **Connecting the 650 MDS to the sonde/ Running the sonde using the 650 MDS**

1) Be sure 650 is connected to the sonde before turning it on;

2) Turn on the 650 MDS (green power button);

3) Highlight SONDE MENU and hit enter (the button with the arrow pointing left);

4) The 650 will connect to the sonde;

5) Be sure that the flowing things are turned on in the report menu (6): date and time, Sp.Cond, Sal, DO%, DO mg/l, Depth (in meters), pH, and Batt. Volts;

6) Hit ESC; go to 1-RUN; and hit “Discrete Sample”;

7) Be sure the sampling interval is set for 4 seconds;

8) The sonde should be all set to run at this point;

9) ESC back to main menu;

10) Back at the main menu go to Logging set-up and be sure that the interval is set for 4 seconds and that Store Lat and Long is checked;

11) ESC back to main menu;

12) Back at the main menu highlight SONDE RUN and hit enter;

13) The 650 should say “Connecting” to the sonde (this may take a couple of seconds);

14) Once it has connected, on the left side of the screen will be the 650 set-up;

15) Highlight START LOGGING and press enter;

- 16) Change the file name to reflect the date of the cruise (ex: DF080207);
- 17) Hit right arrow key to highlight OK and press enter;
- 18) This will begin logging the sonde data;
- 19) To stop the unit hit STOP LOGGING and the 650 will disconnect from the sonde;
- 20) Double check that the file is in the 650 by ESC to the main menu and going into FILE and then DIRECTORY. The file should be the last in the list;
- 21) To turn off the 650, ESC back to the main menu, once here hit the power button.

## **B. On the water – Calibration stations**

### **➤ General**

- 1) Check regularly if water is coming out of the transparent hose;
- 2) For each station:
  - Record station information: station number, date, crew initials, depth, time on/off station, weather and sea conditions, GPS latitude/longitude;
  - While 2 persons are doing the Li-Cor profile, the third measures the secchi depth and filters seawater for chlorophyll-a concentration analysis;
  - Record the sonde information: temperature, salinity, sp. conductivity, DO %, DO mg/L, turbidity, depth, pH and chlorophyll concentration.

### **➤ Li-Cor profile**

- 1) Connect the underwater light sensor and deck light sensor cables to the Li-Cor handheld;
- 2) Both light sensors have to be on the sunny side of the boat. The deck sensor cannot be in shade;
- 3) Record time start/time end;
- 4) Downcast: take readings from the underwater cell at the surface, then at 0.25 m, 0.50 m, 0.75 m, 1.00 m, and 1.25 m;
- 5) Upcast: Take a second set of measurements at 1.25 m, then at 1.00 m, 0.75 m, 0.50 m, 0.25 m, and surface;

- 6) Wait 20 seconds at each depth before recording the data;
- 7) Data are recorded on hardcopy paper, and are also saved on the handheld by pressing 'ENTER' at each depth interval.

➤ **Secchi Disk**

- 1) Drop the secchi disk over the sunny side of the boat;
- 2) Record the depth (in meters) at which the secchi disk disappears.

➤ **Chlorophyll**

- 1) Rinse the 60 cc syringe 3 times with surface seawater;
- 2) Place a filter pad in the filter apparatus with the "snowy side" (not the one with lines/mesh) up;
- 3) Collect 20ml of surface seawater with the syringe;
- 4) Empty slowly the syringe in the filter apparatus;
- 5) Open the syringe: pour a few drops of DI inside + 2 drops of magnesium carbonate (be sure to shake the bottle before using it). Close the syringe. Hold it up pushing out as much air as you can. Then, push the liquid in the syringe into the filter apparatus;
- 6) Take a small aluminum pouch. Put the filter in (the chlorophyll side up) and using tweezers fold the filter in two without touching it with your fingers. Close the pouch and label it with the name/date (e.g. DF for dataflow, so the name would be: DF063007 for a sample collected the 30<sup>th</sup> of June 2007), the volume filtered, and the station number;
- 7) Put the pouch in a glass jar with dessicant in the cooler.

## **C. Backing-up data**

- 1) Conduct a post deployment calibration check of the sonde (see Post Deployment Notes + DO Calibration Notes);
- 2) Upload the data from 650 to the computer:
  - Connect the 650 using the serial cable to the back of the computer. You must disconnect the sonde serial cable from COM Port 1 and use this same COM Port to upload data from the 650;

- Go into the ECOWATCH program and click COMM, COM-1, # (to open file);
- Go to FILE on the 650 and hit enter;
- Go to UPLOAD to PC; hit enter;
- The 650 and the EcoWatch program should show the progress of file uploading;
- The file can be found under File-Open-Name of file;
- It can also be found on the C-Drive under ECOWINN-Data folder;
- On handheld select: file → upload → select filename → enter;
- To export data to excel: double click the data file → file → report → select data → ok → save new document (RPT format); then go to excel → data → import → select the document name you want → select fixed with → create columns.

## **D. Data Editing**

- 1) Once in Excel, highlight entire dataset and autofit all columns to contents;
- 2) Visually inspect the dataset to look for glaring errors, edit/delete data as necessary;
- 3) Sort data by latitude; delete any data at the beginning and/or end of the dataset that do not contain proper latitude readings;
- 4) Sort data by longitude;
- 5) Convert any positive longitude data points to negative (i.e., by typing in adjacent cells “=0-x”, with x being the incorrect longitude. Then cut and paste the corrected data into the dataset;
- 6) Delete any longitude data at the beginning and/or end of the dataset that do not contain proper latitude readings; look for longitude values of zero and delete these as well;
- 7) Save file as an xls workbook as well as in DBF4 format.

## **E. Mapping**

- 1) In ArcView 3.2a start a new project and set the View property Map Units to feet
- 2) Under the Window menu, go to the Project name (‘Untitled’ in it has not yet been named);

- 3) Add a new table, which will be the .DBF4 table created from Excel
- 4) In View, add an Event Theme based on the table that was just added. The X-field will be longitude and the Y-field will be latitude;
- 5) Highlight the new event theme in the project's Table of Contents and then convert this to a shapefile (under the Theme menu). Give the new shapefile a name and save it to an appropriate location;
- 6) Under the File menu add the Spatial analyst extension;
- 7) Under the Surface menu, click 'Interpolate Grid' and input appropriate information based on the current project into the popup window;
- 8) In the next pop-up window, use input 'IDW' for Method, select the water quality parameter of interest for the z-value field, use the nearest neighbors function with 12 neighbors and a power of 2 with no barriers. These values can be changed as necessary if the output grid needs to be modified;
- 9) The resulting interpolated grid can then be manipulated to change the color scheme as well as the classification scheme.