CHAPTER 5
WATER QUALITY

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5.1 Introduction

Water quality evaluation for this project principally relied on measurement of conventional parameters, dissolved oxygen, turbidity, conductivity, temperature, and pH, using Hydrolab Datasonde 4a instrumentation. The Hydrolab Datasonde 4a's were used to continuously log these parameters at three fixed sites to gain an understanding of system dynamics during storm events and dry weather periods. In addition, a Datasonde 4a was used to measure these parameters through the water column at each habitat site, once per week. This latter sampling provided information both on vertical variability of the parameters and site-specific information for the habitat assessment.

Late in the project a new test method for *Escherichia coli* was identified, the Coliscan Easygel kit. Sampling for *E. coli* was not part of the original project scope of work, but it was decided to apply the Coliscan Easygel system for a limited number of tests to evaluate its utility for a citizen monitoring program.

5.2 Hydrolab Sample Methods

5.2.1 Continuous Logging

Hydrolab Datasonde 4a's were installed at the Seneca St. Bridge (Hydrolab Site 2), upstream of the confluence with Cazenovia Creek; at the mouth of Cazenovia Creek (Hydrolab Site 7); and at the Ohio St. Bridge (Hydrolab Site 4). The locations of these fixed sites are shown in Figure 5.1 and the specific installations are shown in Figures 5.2-5.4. The site numbers correspond to the numbers used in the Buffalo Sewer Authority Long Term Control Plan Study (e.g. Irvine et al., 2005), rather than the Habitat site numbers. The datasondes recorded pH, conductivity, temperature, dissolved oxygen, and turbidity at 15 minute time steps for the periods 6/4/03-10/6/03 and 6/2/04-9/29/04. The locations of these fixed sample sites were based on previous monitoring experience (Irvine et al., 2005) that showed they would provide a good representation of storm dynamics and dry weather flow. Furthermore, Sites 2 and 7 represent the upstream boundary conditions of the Area of Concern (AOC) impact area, while Site 4 represents the longitudinal mid-point of the federal navigable channel. Water quality monitoring also historically has been done at Site 4, so a maximum amount of additional data are available (e.g. NYSDEC, 1989; Atkinson et al., 1994; Irvine and Pettibone, 1996).

All Hydrolabs were installed so that they were contained within a capped PVC tube (Figure 5.3). The lower section of the PVC tube had holes drilled through it to allow the water to move freely past the Hydrolab sensors. The PVC tubes protected the Hydrolabs from damage due to floating storm debris in the river and the locked caps provided a level of security from tampering. At all sites the PVC tube was fixed to a stationary object (e.g. bridge abutment, rip rap) so that the sensors would be approximately 1.0 m below the March low water datum. Clearly, then, during storm events, the water depth above the sensors was greater.

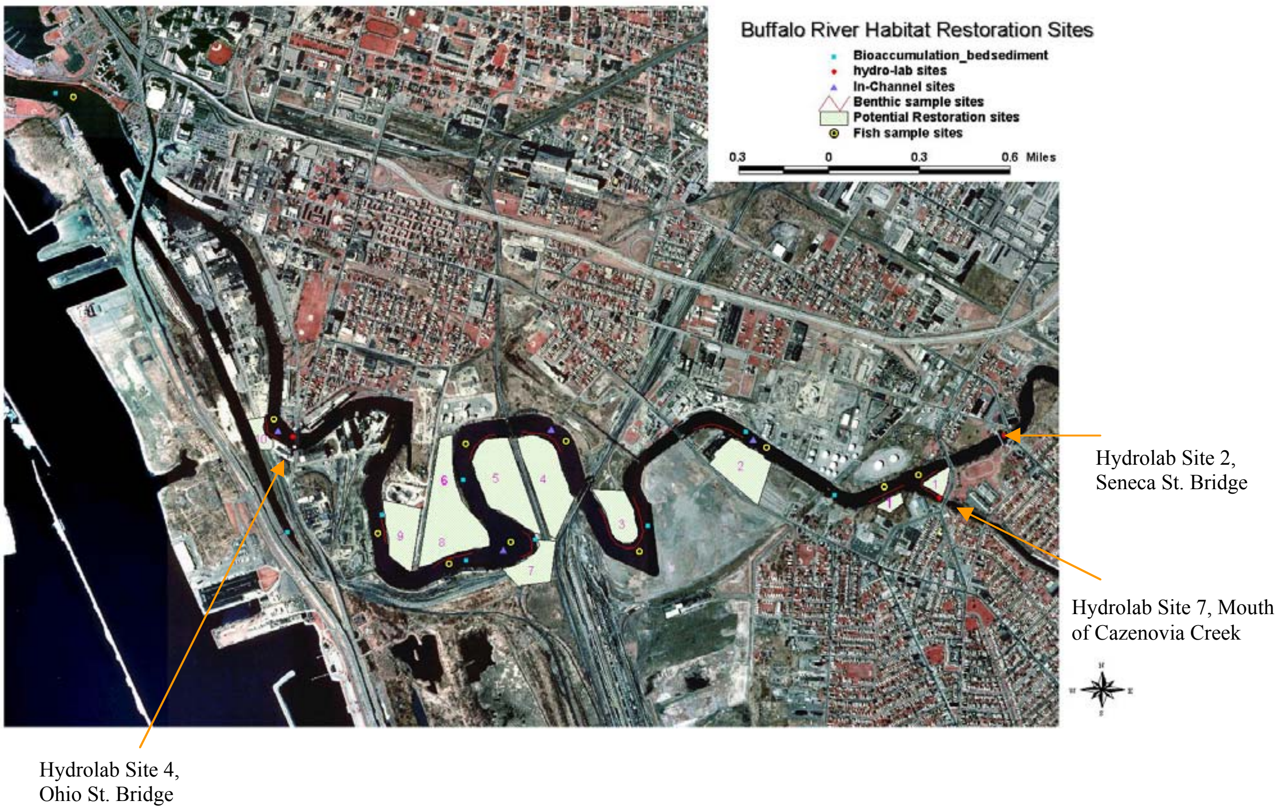

Figure 5.1 Location of sample sites; the fixed, logging Hydrolab locations are shown as red circles

Figure 5.2 Hydrolab Site 2, Seneca St. Bridge

Figure 5.3 Hydrolab Site 7, Mouth of Cazenovia Creek

Figure 5.4 Hydrolab Site 4, Ohio St. Bridge

Prior to installation for each field season, the Hydrolabs were calibrated and tested in the Black Rock Canal to help ensure the sensors were operating properly. If a problem was identified, the Datasonde was sent to Hydrolab (Loveland, CO) for factory correction. As recommended by the manufacuturer, a two minute warm-up was used for the dissolved oxygen and turbidity sensors. Although this increased battery wear, it provided the optimum time for the sensors to equilibrate.

Data from the Hydrolabs were uploaded to a laptop on a weekly basis. All data were managed and maintained in Excel spreadsheet format. During the weekly site visit to upload the data, all units were cleaned with Kimwipes and cotton swabs, and the general operation of each unit was checked. The dissolved oxygen sensors were calibrated each week using the 100% (air) saturation method as described by the manufacturer. The dissolved oxygen membranes and electrolyte were changed at the midpoint of each sampling season, or when the membrane appeared damaged. The pH sensors also were calibrated at the midpoint of each sampling season. All data were reviewed on a weekly basis in Excel format to identify any problem data. These data were flagged and discussions were held with the field crew maintaining the Datasondes to help identify and resolve the source of the problem. In general, the methodology for sampling and Datasonde maintenance followed that done previously for the Buffalo River (Irvine et al., 2005).

5.2.2 Hydrolab Profiling

A Hydrolab Datasonde 4a was used to collect pH, conductivity, temperature, dissolved oxygen, and turbidity data at all 10 habitat sites, at three depths, 0.5 m below the surface; 1.0 m below the surface; and near bottom. The profiling was done once per week for 16 weeks in 2003 and 17 weeks in 2004. The depth of the "near bottom" location was variable and depended on the site and total vertical depth at the particular time of year (Tables 5.1 and 5.2). Care was taken to ensure the Datasonde did not come into contact with the river bed, thereby resuspending sediment. If the Datasonde contacted the river bed, the instrument was moved slightly up-river and readings were taken five minutes later.

Table 5.1 Near Bottom Sample Depths (m) for Profiling, 2003

Site	1	2	3	4	5	6	7	8	9	10
Mean	2.4	4.8	5.5	5.1	6.1	5.0	4.7	5.4	5.0	6.1
Range	1.5-3.8	3.1-5.5	3.2-7.2	2.6-7.0	2.4-8.3	2.3-6.7	1.5-5.8	1.6-7.2	2.1-6.0	4.7-7.5

Table 5.2 Near Bottom Sample Depths (m) for Profiling, 2004

Site	1	2	3	4	5	6	7	8	9	10
Mean	2.8	5.8	6.5	4.9	7.8	4.5	4.5	6.0	5.1	6.2
Range	1.3-4.0	4.0-7.3	3.8-7.5	3.2-5.6	6.5-8.5	2.2-6.4	3.6-5.7	3.5-7.5	3.2-6.9	3.8-7.9

5.3 *E. coli* and Suspended Solids Sampling and Analysis

A total of four samples for *E. coli* analysis were collected at each of the three Hydrolab sites through the storm event of 9/9-10/04, while dry weather samples were collected at each of the three sites on 9/15/04, 9/22/04, and 9/29/04. Samples were collected from the mid-point of the bridges at each site by lowering a Teflon bailer into the water. Samples collected therefore represent conditions at the mid-point of the channel, near the surface (i.e. <0.5 m deep). To limit cross-contamination, a sample was collected in the bailer and discarded immediately prior to the collection of the sample used with the Coliscan Easygel kits.

Once the water sample was collected in the bailer, between 1 and 5 mL was withdrawn using a sterile, disposable pipette. The smaller volume was used for storm events and the larger volume was used for dry weather samples. The pipetted water was then placed in a plastic bottle of Coliscan Easygel media (Micrology Laboratories, LLC, Goshen, IN; http://www.micrologylabs.com/html/detecting_waterborne.html). The medium/inoculum mix was placed in a cooler on ice until returned to the Buffalo State Field Station for further processing.

At the Buffalo State Field Station, the bottles were swirled to distribute the inoculum and the medium/inoculum mixtures were carefully poured into labeled petri dishes. The lids were placed back on to the petri dishes and the poured dishes were gently swirled until the entire dish was covered with liquid. Each petri dish came pre-treated with a thin coating of material containing calcium ions. When the medium/inoculum is poured into the coated dish, the ions diffuse up through the medium and complex with the gelling agents, causing a solid gel to form. The system uses a temperature-independent gelling agent (low methoxyl pectins) that avoids the disadvantages of agar. The dishes were incubated at room temperature for 72 hours and the purple colonies were counted as *E. coli.*

Samples routinely were collected once per week at Sites 2, 4, and 7 for analysis of total suspended solids (TSS) concentration and additional samples were collected during storm events. Samples were filtered at the Buffalo State Field Station, following Standard Methods (APHA, 1985), although 0.45 μm Millipore filters were used rather than glass fiber filters.

5.4 Results and Discussion

5.4.1 Mean Conditions from Fixed Hydrolab Monitoring

The 15 minute data plotted on a weekly basis for each of the three fixed sites are provided on the attached CD. However, as a first step to summarizing the Hydrolab data, the weekly mean values of the sampled parameters for 2003 and 2004 are shown in Figures 5.5 and 5.6. The temperature and dissolved oxygen data in both 2003 and 2004 exhibited a level of seasonality. For example, temperature increased from early June, remained relatively stable from the end of June to early September and then decreased through September. Conversely, dissolved oxygen tended to be higher during the cooler water periods of early June and September. These seasonal trends were even more pronounced in 2000, when the monitoring period extended from 4/17/00 to 10/18/00 (30 weeks)(Irvine et al., 2005). Dissolved oxygen tended to be lower at Hydrolab Site 4 than Sites 2 and 7. This trend is discussed in more detail in Section 5.4.2. Diggins and Snyder (2003) reviewed dissolved oxygen data reported in several studies over a 30 year period, 1964-1993 and concluded that prior to 1970, levels within the AOC routinely were <1 mg L^{-1}. Dissolved oxygen levels increased to 1-4 mg L^{-1} by the early to mid-1970's and from 1982 to 1992 the levels stabilized in the 5-6 mg L^{-1} range. The pH values of between 7 and 8 were consistent with those recorded for the same sites in 2000 (Irvine et al., 2005). The pH values of around 9 at Hydrolab Site 2 for the first part of 2004 probably reflect a faulty pH sensor and should be disregarded. The mean conductivity values exhibit variability, but in general are consistent with those recorded for the same sites in 2000 (Irvine et al., 2005). The effects of larger storm events and associated increases in sediment concentration (and turbidity) due to erosion can be seen even at the weekly mean temporal scale, for example, in early June, 2003; nearly weekly events through July, 2004; end of August, 2004; and early September, 2004. Mean turbidity at all sites during dry weather was quite low, less than 20 NTU.

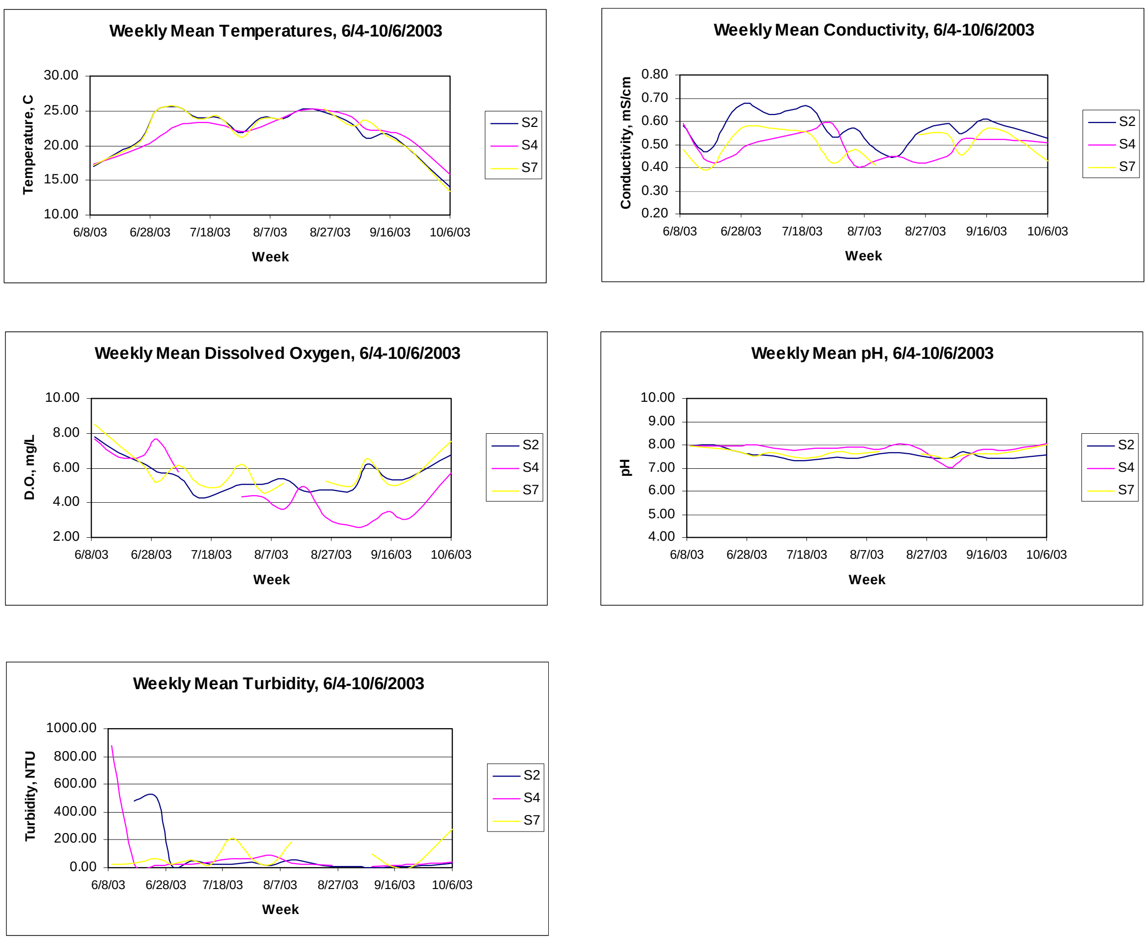

Figure 5.5 Weekly mean Hydrolab values, 2003

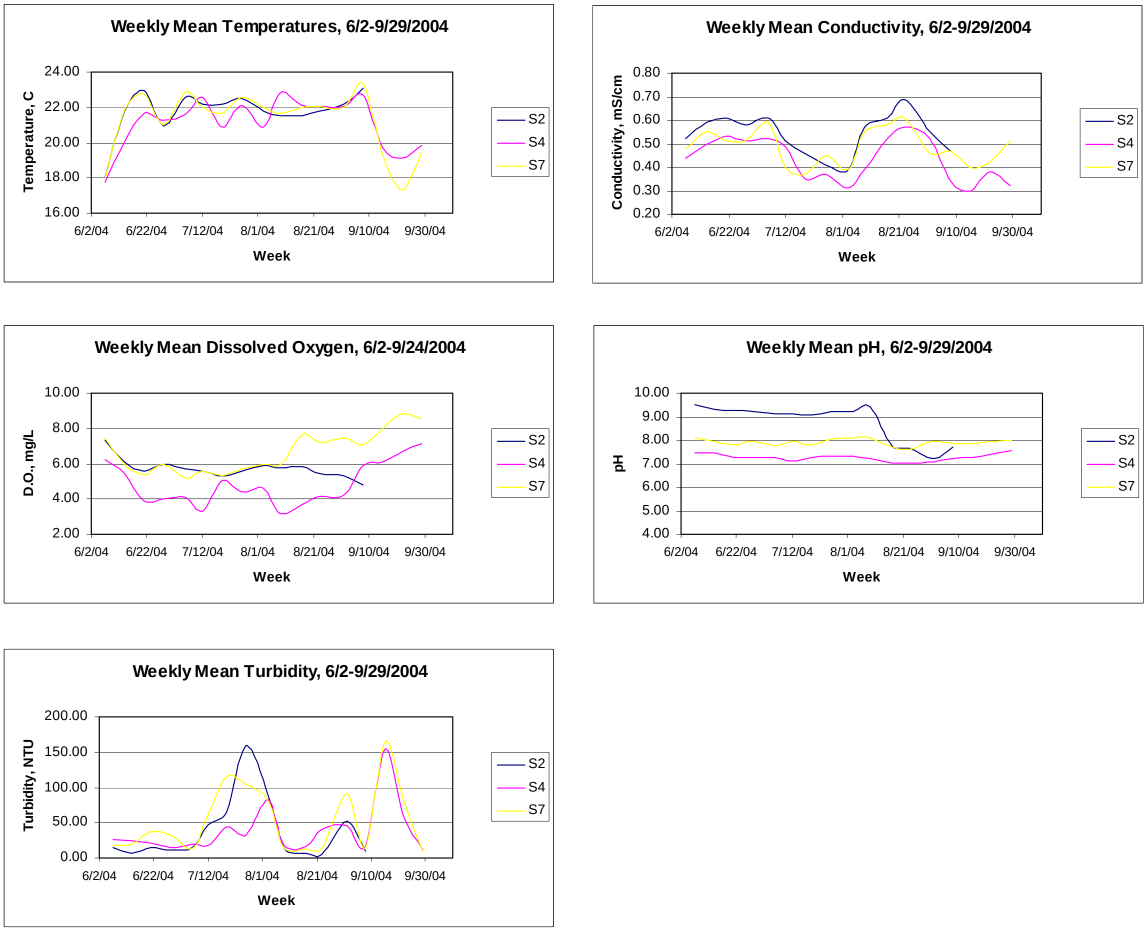

Figure 5.6 Weekly mean Hydrolab values, 2004

5.4.2 Dissolved Oxygen Guidelines

New York State guidelines for dissolved oxygen in class C, non-trout waters state "… the minimum daily average shall not be less than 5.0 mg L^{-1}, and at no time shall the DO concentration be less than 4.0 mg L^{-1}." Daily mean dissolved oxygen levels were calculated and the days for which the mean level was less than 5.0 mg L^{-1} were identified (Table 5.3). There was a higher percentage of non-compliance days at both upstream sites (Hydrolab Sites 2 and 7) in 2003 as compared to 2004, but in both years, Hydrolab Site 4 (Ohio St. Bridge) had a higher percentage of non-compliance days than either of the two upstream sites. Irvine et al. (2005) also found Site 4 had a higher number of non-compliance days (66 over the 30 week sample period) as compared to Sites 2 and 7. In general, there were fewer days of non-compliance at Hydrolab Sites 2 (0) and 7 (30) in 2000 as compared to 2003 and 2004 (Irvine et al., 2005).

The times during which the dissolved oxygen levels were <4.0 mg L^{-1} at each site also were identified and these are compared (as a percentage of time) to the total study time in Table 5.4. In 2000, the per cent time dissolved oxygen levels were <4.0 mg L^{-1} were reported as: Site 2 – 0%; Site 4 – 28%; Site 7 – 4.7% (Irvine et al., 2005).

In general, the spatial trend of higher dissolved oxygen levels near the top of the AOC and lower dissolved oxygen levels along the middle section was consistent in the data for 2000, 2003, and 2004. Irvine et al. (2005) noted that in 2000 between Sites 6 (Cazenovia Park) and 7, there was an increase in the proportion of days <5.0 mg L^{-1} (as well as an increase in the frequency of periods <4.0 mg L^{-1}) associated with storms. It is possible that this increase was related to the cumulative impact of the CSOs along the channelized section of Cazenovia Creek, although it is important to note that the creek also becomes wider and deeper in the channelized section between Sites 6 and 7. The Site 7 data were reviewed in more detail for six weeks in which multiple CSO events were recorded. Typically, it was not possible to visually identify a dissolved oxygen sag associated with an individual CSO event. In two cases, a small decrease in dissolved oxygen occurred at Site 7 after the third CSO event within the week. It is possible that the dissolved oxygen dynamics between Sites 6 and 7 were influenced by the change in channel characteristics (wider and deeper channel with lower velocity) and infrequently occurring hydrologic conditions (i.e. multiple CSO events in a short period of time).

Several dissolved oxygen modeling studies were completed through the 1990's for the Buffalo River (Blair, 1992; Wight, 1995; Hall, 1997) and these efforts were more recently expanded by Jaligama et al. (2004). These studies concluded that low dissolved oxygen, particularly in the upper to central portion of the Buffalo River, was related to a combination of stratification in the river at low flows that can reduce aeration, high sediment oxygen demand, together with long residence times due to system hydraulics (in particular, dredging increases channel cross-sectional area and residence time), and background biochemical oxygen demand (see Figure 5.7). The modeling efforts concluded that CSOs discharging to the river had minimal impact on dissolved oxygen.

Table 5.3 Number (and Per Cent) of Days when Daily Mean Dissolved Oxygen was <5.0 mg L^{-1} during the Periods 6/4/03-10/6/03 and 6/2/04-9/29/04

	Site 2, 2003	Site 4, 2003	Site 7, 2003	Site 2, 2004	Site 4, 2004	Site 7, 2004
# of Days <5.0 mg L^{-1}	42	70	36	12	72	12
% of Days <5.0 mg L^{-1}	34	59	31	12	61	10

Table 5.4 Per Cent of Time when Dissolved Oxygen was <4.0 mg L^{-1} during the Periods 6/4/03-10/6/03 and 6/2/04-9/29/04

	Site 2, 2003	Site 4, 2003	Site 7, 2003	Site 2, 2004	Site 4, 2004	Site 7, 2004
% of Time <4.0 mg L^{-1}	7.5	41	7.7	1.5	37	2.2

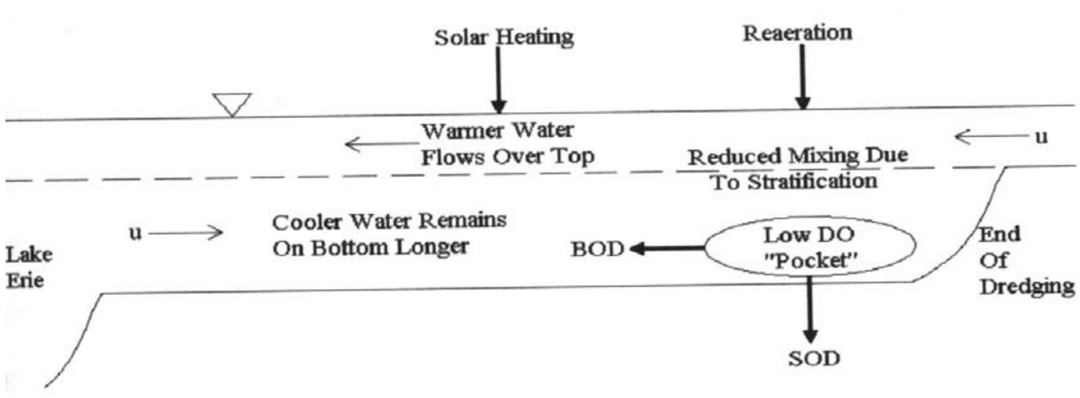

Figure 5.7 Factors influencing development of low dissolved oxygen levels in the AOC (from Hall, 1997)

5.4.3 Storm Event Dynamics

Averaging the Hydrolab data, as done in Section 5.4.1, provides information on general trends, but the averaging masks some of the important system responses to specific storm characteristics. A visual review of the weekly data plotted at the 15 minute time steps revealed some interesting trends, particularly for turbidity, conductivity, and dissolved oxygen.

Conductivity levels frequently exhibited a precipitous dip, in association with storm events (Figures 5.8-5.10). Constituents from chemical weathering of soils and bedrock may predominantly enter rivers in temperate, humid climates via groundwater inputs (Marsh, 1987; Morisawa, 1968). As such, conductivity and dissolved solids concentration would be greater during baseflow conditions, when the principal hydrologic input is groundwater and may become diluted by stormwater runoff (Walling and Webb, 1980). Tomlinson and De Carlo (2003) observed a dilution effect for conductivity during storms in their monitoring of streams in Hawaii, as did Irvine (2003) in a study of the Allegheny River, PA, and Irvine et al. (2005) for the Buffalo River monitoring of 2000. There can be some exceptions to this dilution pattern, as is shown for the storm event of 8/6/03 (Figure 5.11). Although conductivity dropped at the upstream Hydrolab Sites, 2 and 7, the dilution effect was dampened by the time the poorly-defined storm wave reached Hydrolab Site 4 (Figure 5.11).

Turbidity is an optical property that has a strong relationship with total suspended solids (TSS) concentration and therefore turbidity can be indicative of the suspended sediment transport dynamics. The relationship between turbidity and TSS is explored in more detail in Section 5.4.4. Turbidity always increased in response to storm events, as overland runoff introduced sediment from sheet and rill erosion and greater stream power resulted in increased bed and bank erosion. However, depending on the storm event, turbidity exhibited different between-site response. Frequently, for moderate-sized events, the upstream Hydrolab sites (2 and 7) had higher peaks, while the downstream site (4) had a lower peak that was offset (Figures 5.12 and 5.13). Daily mean flow entering the AOC from upper watershed (adjusted for ungauged area, see Section 1.2) was 3,697 cfs (105 m^3s^{-1}) for the event of 7/16/04 (Figure 5.12) and 4,227 cfs (120 m^3s^{-1}) for the event of 7/2704 (Figure 5.13). The lower peak turbidity at Hydrolab Site 4 for these events indicated that sediment was depositing in the downstream direction, which is consistent with the aggrading nature of the AOC and the need for dredging to maintain the depth of the navigable channel. The offset simply represents the lag of the storm wave movement downstream. Turbidity peaks for smaller storm events may be evident at the upstream sites, but sedimentation along the channel may reduce the peak to the extent that it is not particularly distinctive at the downstream (Site 4) location (Figure 5.14). Daily mean discharge entering the AOC (adjusted for ungauged area) for the event of 8/6/03 (Figure 5.14) was 1,165 cfs (33 m^3s^{-1}). Meredith and Rumer (1987) modeled sediment transport dynamics in the Buffalo River using HEC-6 and as part of the report, identified depositional areas within the AOC for moderate sized events (6,000<Q<20,000 cfs)(170<Q<566 m^3s^{-1}) . The depositional area map developed by Meredith and Rumer (1987) is shown in Figure 5.15. Clearly, deposition is predicted to occur in the areas of the meander bends between sites 2 and 7 (upstream) and Site 4 (Ohio St. Bridge at transect 9671 in Figure 5.15). In general, the model results are consistent with the Hydrolab data.

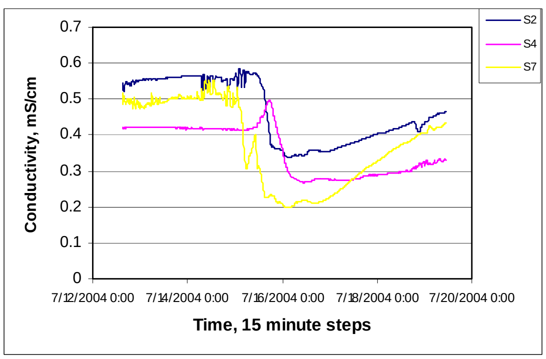

Figure 5.8 Dilution of conductivity, 7/16/04 event

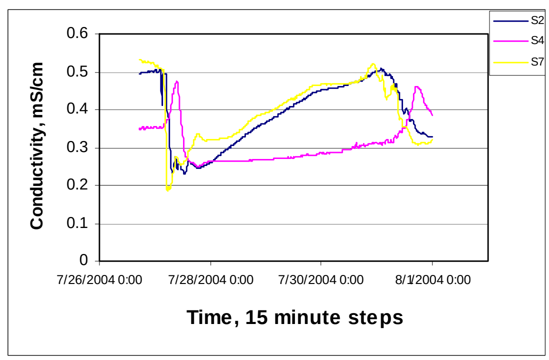

Figure 5.9 Dilution of conductivity, 7/27/04 event

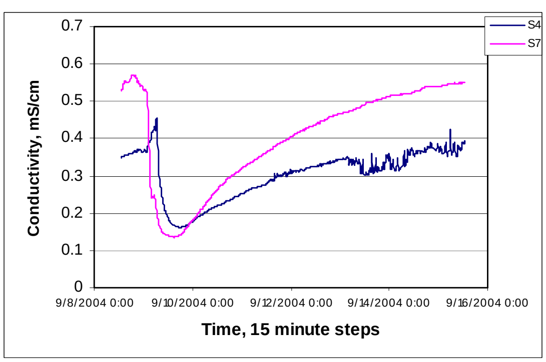

Figure 5.10 Dilution of conductivity, 9/9/04 event

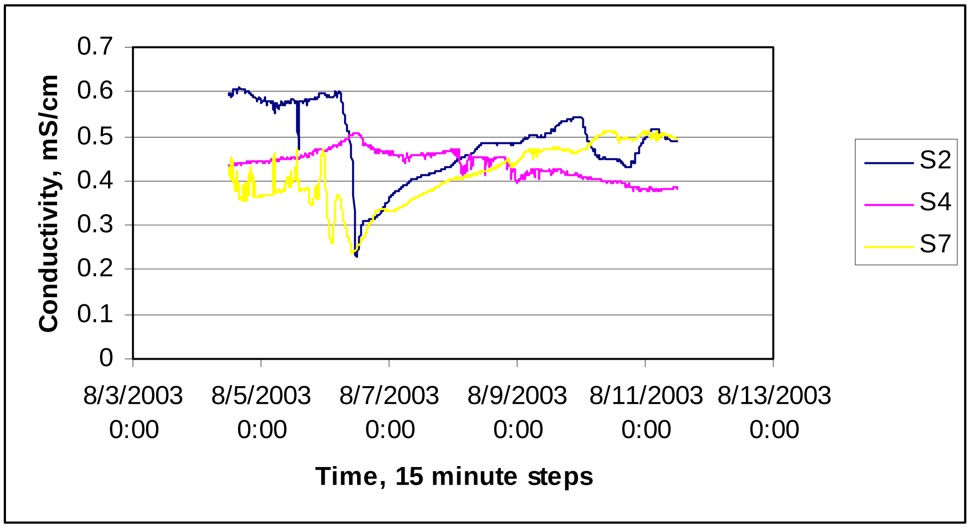

Figure 5.11 Storm event of 8/6/03. The dilution effect on conductivity is more apparent for the upstream sites (2 and 7) as compared to the downstream site (4)

Although the turbidity for a larger storm event (9/9/04) increased at the Hydrolab sites there was not the characteristic decrease in turbidity between the upstream and downstream sites (Figure 5.16). It should be noted that in this case the event was sufficiently large that it dislodged the Hydrolab at Site 2 and all data were lost. The "clipped" nature of the time series in Figure 5.16 occurred because 1,000 NTU is the maximum value that can be measured by the Datasonde 4a sensor. The *rise* in turbidity at Hydrolab Site 4 is lagged compared to Site 7 because of its downstream location (Figure 5.16). However, the falling limb of the event at Hydrolab Site 4 is not lower than Site 7, as was the case in Figures 5.12 and 5.13. It appears that the transport capacity associated with the storm of 9/9/04 (Figure 5.16) was sufficient to maintain sediment movement in this stretch of the river and there was minimal or no deposition. Peak flows for this event were approximately 9,500 cfs (269 m^3s^{-1}) at the USGS gauge on Buffalo Creek; 8,000 cfs (226 m^3s^{-1}) on Cayuga Creek; and 14,500 cfs (410 m^3s^{-1}) on Cazenovia Creek. A review of annual peak flows showed that since 1938, the Buffalo Creek peak has only been exceeded in five years; since 1937 the Cayuga Creek peak has been exceeded in 9 years; and since 1941 the Cazenovia Creek peak has never been exceeded. Photos of Hydrolab Sites 2, 4, and 7 during typical dry weather flow and the 9/9/04 storm are shown in Appendix 5.1 to provide a sense of the storm magnitude. Meredith and Rumer (1987) indicated that at flows in excess of 20,000 cfs "….. a significant amount of sand is being removed from the river bed and transported to the Buffalo harbor area…… (on the order of 7,000 tons per day)". Again, model results are consistent with the Hydrolab data, indicating that for larger storms deposition will be minimal and in fact, the system may experience net erosion.

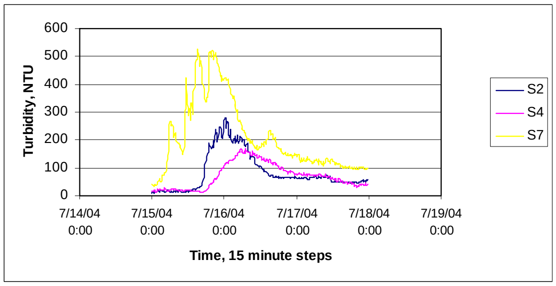

Figure 5.12 Storm event of 7/16/04

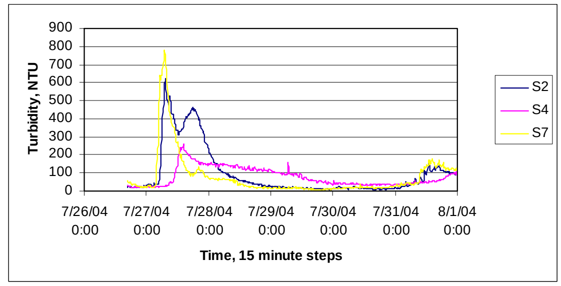

Figure 5.13 Storm event of 7/27/04

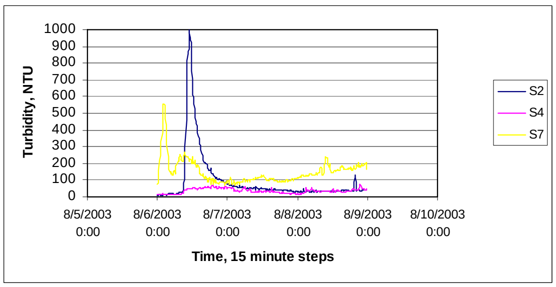

Figure 5.14 Storm event of 8/6/03

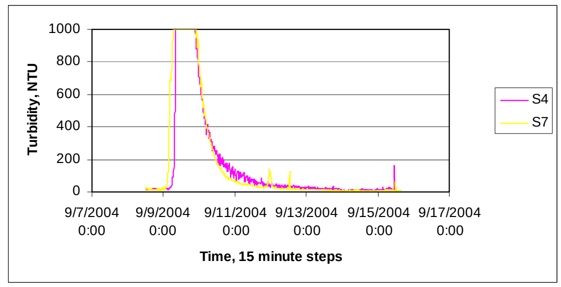

Figure 5.16 Storm event of 9/9/04

Irvine et al. (2005) conducted a detailed examination of dissolved oxygen levels associated with storm events as compared to dry weather periods for the Buffalo River AOC. For 19 storm events, Irvine et al. (2005) compared the mean 72-hour antecedent dissolved oxygen level with the storm event mean concentration and got mixed results. For 6 of 10 sample sites (including Hydrolab Site 2), the mean dissolved oxygen level was lower for storm events than dry weather periods. For 4 of 10 sample sites (including Site 7 and Site 4) the mean dissolved oxygen level was higher for storm events than dry weather periods. Irvine et al. (2005) also noted that for individual storms dissolved oxygen levels could be lower or higher than antecedent dry periods at a particular site.

It did appear that during the drier summer months when the dredged channel becomes nearly stagnant, dissolved oxygen might increase at Hydrolab Site 4 during storms, as part of the flushing associated with increased flow (e.g. Figure 5.17), although this was not always the case (e.g. Figure 5.18).

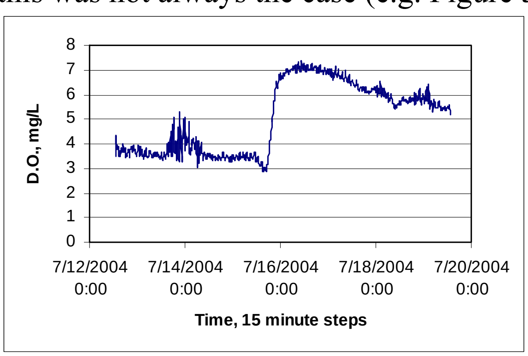

Figure 5.17 Example of increasing D.O. at Site 4, storm event of 7/16/04

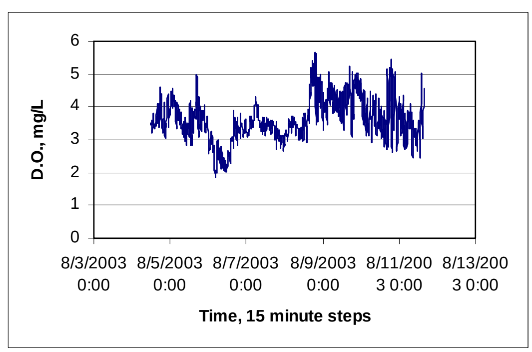

Figure 5.18 D.O. Site 4, event of 8/6/03