APPENDIX C

Water Quality Data Interpretation

Water quality and biological monitoring data can be difficult to interpret if the data is limited. For some parameters, the terminology and implications may require some explanation. This appendix will further describe terms and discuss the significance of impacts such as excessive sedimentation or nutrient discharges to the stream.

B-1.0 Non-Point Source Pollution

Nonpoint source pollution refers to a diffuse source of pollutants that come from several points of origin, including human and natural sources. While concerns from many of the point sources of pollution have largely been addressed in recent decades, according to EPA, nonpoint source pollution is considered the greatest threat to our nation's waterways. In the NEW, the primary nonpoint source pollutants and stressors that have been shown to impact water quality to varying degrees are:

- Bacteria and Pathogens,
- Sediment and Turbidity,
- Nutrients,
- Total Dissolved Solids and Road Salt,
- Pesticides and Herbicides,
- Heavy Metals,
- Toxic Organic Compounds,
- Altered Hydrology,
- Depressed Dissolved Oxygen,
- Stream Temperature, and
- Stream Barriers.

B-2.0 Bacteria and Pathogens

Most waterborne pathogens may be classified as viruses, bacteria (typically indicated by *E. coli*), or protozoa. Pathogens typically cause intestinal diseases, leaving the host in the fecal material, contaminating the water, and then entering the recipient by ingestion. These organisms can be harmful to both humans and the other aquatic life and wildlife that come into contact with them. *Escherichia coli* (*E. coli*) is the most common indicator used in monitoring strategies to determine the potential presence of harmful pathogens because both are found in the fecal matter of mammals. However, *E. coli* is present at some levels almost everywhere: in soil, water, beach sands, and on pavement. Bacteria come from a variety of sources making it difficult to know whether or not its presence is due to a human sewage problem. Also, the *E. coli* survival period in water varies widely and is influenced by many factors such as the presence of organic substrate, salinity, and temperature.

The potential threat of the presence of pathogens is determined by testing water samples for *E. coli* content which is measured in colony forming units per 100 milliliters of water (CFU/100 mL). The Michigan WQS are 130 CFU/100mL for a 30-day geometric mean [or no more than 300 CFU/100 mL based on three (3) samples for the same event] for total body contact recreation, and 1,000 CFU/100mL for partial body contact recreation. If the *E. coli* levels are higher than these standards, then the beach will be closed. If pathogen levels are too high in a waterbody, it can affect the state-designated uses of full body contact or partial body contact.

B-3.0 Sediment and Turbidity

According to MDEQ, soil erosion is the detachment of soil by wind or water and sedimentation is the settling out of particles in a lake or stream. Turbidity is the relative clarity of the water measured as the extent to which light penetration is reduced; therefore, turbidity is an indirect measure of suspended solids (in nephelometric turbidity units or NTUs). The sediment load of a stream is the quantity of sediment that is carried past a given cross section of the stream in a specified period of time. When quantified in terms of mass or volume per period of time, it is called sediment discharge (ex. tons/day). The sediment load is made up of the suspended load and the bed load. Only the portion of the sediment load consisting of sand (0.062 mm) sized particles and larger are considered in channel stability assessment and stream channel design because transport of this material is limited by the energy of the stream and forms the channel features over time.

> **Suspended Sediment** – portion of the total sediment load that is transported in suspension and free from contact with the stream bed. The density and size of the suspended load depend on turbulence and water velocity. It is usually composed of medium-sand sized particles and smaller (Usually reported as Total Suspended Solids (TSS) in mg/L).
>
> > **Wash Load** – is the portion of the suspended sediment that is finer than sand (0.062 mm) in size. It can be carried in large quantities and is limited only by supply in the watershed.
> >
> > **Bed Load –** is the portion of the total sediment load that moves on or near the streambed by saltation, rolling, or sliding along the bed layer. The bed material load is hydraulically controlled and may be estimated using sediment transport equations (FISRWG, 1998).

In general, excessive inorganic fine sediments (silt and clay) have the greatest impact on stream ecology because they can be carried in great quantities. In contrast, an increased supply of coarser bedload material can affect stream channel stability by exceeding the stream's sediment transport capacity or stream competence.

Turbidity contributes to a decrease in water clarity affecting how sunlight penetrates the water, and thus impacting plant growth. Suspended sediment in the water column also absorbs heat, warming up the waterbody, and reduces dissolved oxygen in the water. Sediment can also cover fish spawning grounds and aquatic insect habitat, causing a decrease in fish production and loss of insects as a food source. In addition to the ecological impacts, excessive sedimentation can lead to:

- Property loss
- Lower aesthetic quality and possibly lower property values
- Destruction of aquatic habitat
- Increased channel width
- Increased sediment deposition resulting in reduced hydraulic capacity
- Increased algae and nuisance weeds from associated nutrient loadings

Sediment can also carry other pollutants into the stream. Phosphorus, metals, and organic compounds can adsorb onto the sediment particle's surface. In water with native calcium, magnesium, and other minerals in the sediments ion exchange of heavy metals can occur (Horner, et al., 1994).

Rule 50 of the Michigan WQS states that waters of the state shall not have any of the following unnatural physical properties in quantities which are, or may become, injurious to any designated use: turbidity, color, oil films, floating solids, foam, settleable solids, suspended solids, and deposits. This kind of rule, which does not establish a numeric level, is known as a "narrative standard". It is generally considered that water with a TSS concentration of less than 20 mg/L is "clear". Water with TSS levels between 40 and 80 mg/L tends to appear cloudy, while water with concentrations over 150 mg/L usually appears "dirty". The nature of the particles that make up the suspended solids may cause these numbers to vary, as well (MDEQ, 2006).

B-4.0 Nutrients

Nitrogen and phosphorus are two important nutrients that provide plants and algae the essential elements for growth. Although nutrients are required, excessive amounts can lead to eutrophication or undesirable algae and aquatic plant growth. In eutrophic waters that become devoid of oxygen, high ammonia levels can be toxic to organisms if the pH is high (DeBarry, 2004). Several other parameters can be impacted indirectly such as odors, aesthetics, dissolved oxygen, and biological communities.

In 2000, EPA developed ambient water quality criteria recommendations for a region (Ecoregion 56) that includes the NEW to assist states in developing ambient nutrient criteria for reference conditions. The recommended criteria are based data from local streams. The document can be viewed online: http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_7.pdf. Comparison to reference conditions is one way to provide a preliminary screening for data that exceed the criteria.

The measured total phosphorus values may be compared to the reference value of 0.03125 mg/L. The measured total nitrogen values may be compared to the reference value of 1.15 mg/L.

B-5.0 Total Dissolved Solids and Road Salt

Total dissolved solids measures the total amount of organic and inorganic material in water that is smaller than 0.45 µm. Several other related terms are defined in this section.

B-5.1 Alkalinity – measure of the negative ion concentration (primarily hydroxide, carbonate, and bicarbonate) in mg/L $CaCO_3$. Alkalinity determines buffering capacity or the ability to neutralize acids (such as acid rain).

The various classes of alkalinity values are described as follows for general water quality interpretation (Lind, 1974).

Description	Alkalinity (mg/L as $CaCO_3$)
USEPA minimum acceptable	20
Poorly buffered	<25
Moderately buffered	25-75
Highly buffered	>75
Middle 50% of U.S. sites	42-162

B-5.2 Hardness – measure of the positive ion concentration, primarily calcium and magnesium, (in mg/L $CaCO_3$). Alkalinity and hardness are directly related and co-vary since they measure differently charged ions of the same dissolved materials. Moderate to high hardness levels are associated with soluble sedimentary rock, good fish productivity, and a stable chemical environment. Mussels and crayfish need calcium for their shells and exoskeletons.

The various classes of hardness values are described as follows for general water quality interpretation (Smith et al. 1993).

Description	Hardness (mg/L as $CaCO_3$)
Soft	0-75
Moderately hard	75-150
Hard	150-300
Very hard	>300
Middle 50% of U.S. sites	27-157

B-5.3 Salinity – refers to the relative concentration of salts, mainly sodium chloride, in water (in mg/L). Chronic impacts from rock salt (NaCl), used in road deicing, are a common water quality concern. Chronic toxicity is a sub-lethal toxicity of long duration that adversely effects

B-5.4 Specific conductance – pure water has a high resistance to electron flow. Conductivity is the inverse of resistance or the measure of electron flow (in µmhos/cm or µS/cm). This is a commonly recorded parameter due to the ease of sampling and low cost (portable probe). As a guideline, a conductivity of less than 800 µS is considered natural for stream water; levels over 800 µS are considered excessive and may indicate the presence of toxins in the water (Southeast Michigan Environmental Monitor, 2006).

B-5.5 Total dissolved solids (TDS) – a measure of the total concentration of dissolved substances, both organic and inorganic, (weight of the material left after water is filtered through a 0.45 micrometer sieve and evaporated). TDS indirectly measures ion concentration (in mg/L).

The various classes of TDS values are described as follows for general water quality interpretation (Smith et al., 1993).

Description	TDS (mg/L)
Low concentration	<100
Medium concentration	100-500
High concentration	500-1,000
Very high concentration	>1,000

In water, a salt is completely dissociated into ions. Studies of pollutant penetration in soils show that calcium, chloride rapidly move into the groundwater until the source is removed (Heaney, 1998). A comprehensive five-year scientific assessment (Environment Canada, 2001) determined that, in sufficient concentrations, road salts pose a risk to plants, animals and the aquatic environment as follows:

- Acute toxic effects of chloride on aquatic organisms are usually observed at relatively elevated concentrations. For example, the 4-day median lethal concentration (LC50) for the cladoceran *Ceriodaphnia dubia* (water flea) is 1400 mg/L. Exposure to such concentrations may occur in small streams located in heavily-populated urban areas with dense road networks and elevated road salt loadings, in ponds and wetlands adjacent to roadways, near poorly managed salt storage depots, and at certain snow disposal sites.

- Chronic toxicity occurs at lower concentrations. Toxic effects on aquatic biota are associated with exposures to chloride concentrations as low as 870, 990 and 1070 mg/L for median lethal effects (fathead minnow embryos, rainbow trout eggs/embryos and daphnids, respectively). The No-Observed-Effect Concentration (NOEC) for the 33-day early life stage test for survival of fathead minnow was 252 mg chloride/L. Furthermore, it is estimated that 5% of aquatic species would be affected (median lethal concentration) at chloride concentrations of about 210 mg/L, and 10% of species would be affected at chloride concentrations of about 240 mg/L.
- Changes in populations or community structure can occur at lower concentrations. Because of differences in the optimal chloride concentrations for the growth and reproduction of different species of algae, shifts in populations in lakes were associated with concentrations of 12 to 235 mg/L.
- Increased salt concentrations in lakes can lead to stratification (layering of water) which retards or prevents the seasonal mixing of waters, thereby affecting the distribution of oxygen and nutrients.

Concentrations of dissolved substances are generally lower during periods of high discharge than during low flow. Higher concentrations that occasionally occur at spring high flows are generally from a combination of effluent from sewers and septic systems, fertilizers, and road salt (Wood, 1970). High levels of dissolved solids in runoff are quickly diluted by larger rivers; therefore, the effects are greater in small headwater tributaries and roadside streams.

B-6.0 Pesticides and Herbicides

Pesticides are chemical substances used to kill pests such as weeds, insects, algae, rodents, and other undesirable agents. According to the U.S. Department of Agriculture (USDA), no more than 2% (and often less than 0.1%) of the insecticides applied to crops by aerial spraying or by ground spraying actually reaches the target pests, and less than 5% of herbicides applied to crops reaches the target weeds. The EPA has reported that the average lawn in the United States is doused with more than 10 times more synthetic pesticides per hectare than U.S. cropland.

Pesticides can get into surface water by misapplication, transportation in storm water runoff, or by wind. These chemicals can be harmful to humans, aquatic life, wildlife and aquatic plants. The most common types of pesticides used are:

- Broad-spectrum pesticides which are harmful to many types of organisms
- Selective-spectrum pesticides which are harmful to specific group of organisms.

Additional statistics on pesticides indicate the following:

- Each year, more than 250,000 U.S. residents become ill because of household use of pesticides, and such pesticides are a major source of accidental poisonings and deaths for children under age 5.
- Herbicides (i.e. Atrazine) are used much more heavily than insecticides in agricultural areas (Frey, 2001).
- Insecticides (i.e. diazinon and chlorpyrifos) usually account for a larger percentage of the overall use in urban areas than in agricultural areas planted in corn and soybeans (Frey, 2001).

Atrazine is an herbicide that does not occur naturally and does not dissolve in water. The EPA restricts how Atrazine can be used and applied, and only trained people are allowed to use it. Atrazine attaches to soil particles which can then enter surface water through runoff. It will stay in water for a long time as its chemical breakdown is very slow in water. It does not accumulate in living organisms such as algae, bacteria, clams or fish. Liver, kidney, and heart damage has been observed in animals exposed to Atrazine; however, there is no indication that this could also happen in humans (ATSDR, 2006). Regardless of this available data, additional data is still needed to better determine source, magnitude, and spatial extent of risk from pesticides in surface waters (Frey, 2001).

B-7.0 Heavy Metals

Heavy metals are metallic and metalloid elements with high atomic weights (greater than sodium) that tend to be toxic, do not degrade over time, and bioaccumulate (Figure 2.7). The bio-availability of metals is reduced in waters of high hardness by sorption to solids (Burton and Pitt, 2002). Zinc and copper are often present in soluble (more bio-available) forms in storm water runoff. Predicting the toxic effects of metals based on concentration in water or sediment samples is difficult due to the complex processes which control bio-availability and fate. However, the long-term detrimental effects of persistent heavy metals accumulating in the aquatic foodchain are well documented.

Arsenic, cadmium, copper, lead, mercury, and zinc are the most common nonpoint source pollutants associated with urban runoff. Many of these heavy metals have been found in sediments in Lake Huron and are associated with degradation of benthos, and plankton communities and result in restrictions on dredging in navigation harbors.

B-8.0 Toxic Organic Compounds

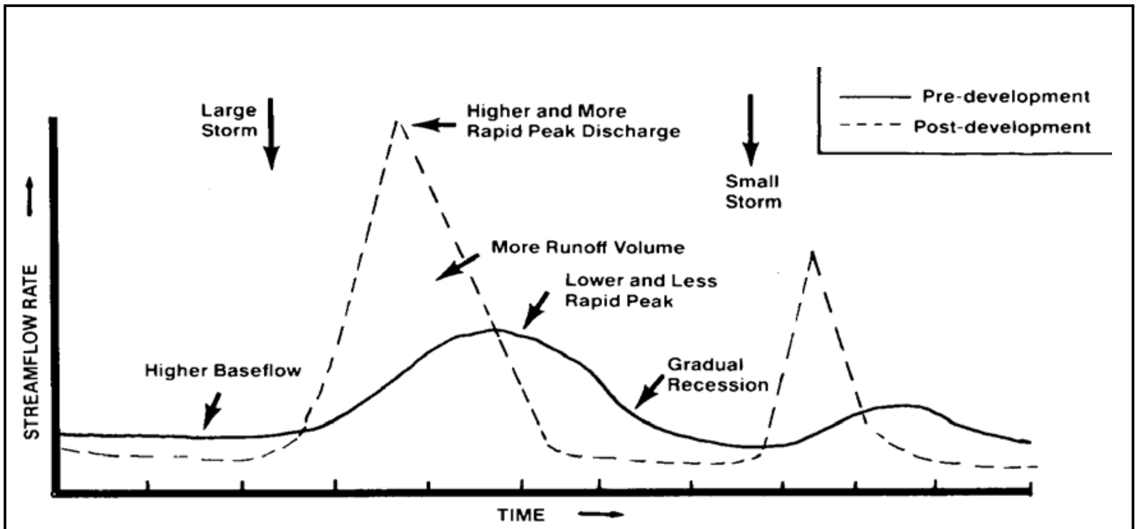
The types and concentrations of toxic organic compounds in storm water runoff are largely determined by land use patterns and automobile activity in the watershed. Toxic organic compounds also include pesticides and herbicides, but because their source areas and management practices differ from vehicular sources, they are covered separately in Section B-10.0. The compounds of most interest from washoff of impervious areas are polycyclic aromatic hydrocarbons (PAHs). Other compounds may be detected in residential, agricultural, and industrial areas, such as wood preservatives, paints, and plasticizers.

B-9.0 Altered Hydrology

According to MDEQ, "hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle." Similar to streams, watersheds are in equilibrium with precipitation, surface runoff, evapotranspiration, groundwater recharge, and interflow known as the hydrologic balance (DeBarry, 2004). Land use impacts such as urbanization, deforestation, tile drainage, and loss of wetlands drastically alter the components of the hydrologic budget. Changes in sediment size or loading, discharge, and channel morphology (such as channelization) alter in-stream hydraulic factors which can lead to channel instability (i.e. streambank erosion and channel bed erosion).

Urbanization can alter watershed hydrology by decreasing storage, decreased time of concentration (water runoff reaching surface waters faster), increased flood peaks, increased runoff volume, and increased storm runoff frequency and duration as depicted in Figure B-1.

Stream Hydrology



Source: Schueler, 1987

Figure B-1 Changes in the Stream Flow Hydrograph as a Result of Urbanization (Schueler, 1987)

The hydrological effects are compounded when an increase in directly connected impervious area occurs along with curb and gutter conveyance and inadequate runoff control practices. Schueler (1987) identifies the following stream impacts caused by increased development:

- Peak flows are increased two to five times over pre-development flow rates.
- The frequency of bankfull flooding may increase from an average of once every two years to three or four times each year. A stream that was able to handle bankfull flooding will be re-shaped due to increased flow volume and water velocity. The stream will show channel down-cutting, widening, streambank erosion, falling trees, and slumping banks.
- Runoff will reach the stream up to 50 percent faster.
- The channel will widen to adjust to increased storm flows. Streambanks are gradually undercut and slump into the channel. Trees that protected the streambanks are gradually exposed at the roots and more likely to be wind-thrown, triggering a second phase of bank erosion. Many streams widen two to four times their original size if post-development runoff is not controlled.
- Pools and riffles are eliminated due to sedimentation caused by increased soil erosion. This has a direct impact on the aquatic community and the number and types of organisms found there.
- Less infiltration reduces baseflow, or flow from groundwater, which is critical during dry periods.

Modifications to the natural stream sediment load can occur during and after significant development:

- Construction Phase – Sediment loads increase sharply due to construction site runoff and subsequent streambank erosion.
- Post-Development Phase – Following the development phase, runoff from impervious areas, conveyed by storm sewers, can dramatically decrease upland sediment loadings. This clear water discharge is often referred to as ‘hungry’ water because it has full capacity to entrain and transport sediment, thereby contributing to further channel erosion.

B-10.0 Depressed Dissolved Oxygen

Dissolved oxygen (DO) concentration measures the amount of free (not chemically combined) oxygen gas in the water, usually in mg/L or % concentration (% saturation at given pressure and temperature). Depressed dissolved oxygen occurs when the oxygen dissolved in water and readily available to aquatic organisms drops below optimal levels. Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Sediment Oxygen Demand (SOD) are tests used to measure the stream's ability to consume oxygen due to the presence of organic matter. Aeration and photosynthesis are the main sources of DO in surface water.

Photosynthesis can be impacted by excessive turbidity (or total solids suspended in the water). Dissolved oxygen can be depleted through respiration, decay of organic matter, and direct chemical oxidation (Brown, 1985). Other physical processes affecting DO concentrations are temperature and organic pollution. Because temperature has an inverse relationship with gas solubility, warmer water will hold less gas than colder water. During a storm event, urban and agricultural runoff can increase organic nutrient levels dramatically. The resulting increase in bacterial reproduction and respiration rates exert a BOD. Oxygen depletion may occur during the storm event, but more likely will occur later when associated with the SOD. Pollution from human activities may lead to low oxygen conditions when large inputs of sewage or yard wastes are introduced into the stream.

The restorative capabilities of a stream by such processes as re-aeration and off-gassing can be dramatically reduced due to a lack of bed topography (riffles and pools), typically caused by channelization and/or increased runoff from altered hydrology (see Section B-9.0).

Rule 64 of the Michigan WQS states that surface waters designated as coldwater fisheries must meet a minimum DO standard of 7 mg/L, while surface waters protected for warmwater fish and aquatic life must meet a minimum DO standard of 5 mg/L.

B-11.0 Stream Temperature

One impact that is often overlooked is stream warming. Thermal pollution is an elevation in water temperature due to human activities. A significant increase in stream temperature can have the following impacts (Burton and Pitt, 2002):

- Reduces dissolved oxygen levels
- Increases nuisance plant growth
- Increase in the toxicity of ammonia
- Affects the survival of pathogens
- Contributes to a loss of coolwater fish and aquatic species

The temperature of a stream can increase 0.14 degrees Fahrenheit per one percent increase in imperviousness (Galli, 1990). Galli also found that developed watersheds can have stream temperatures up to 16 degrees Fahrenheit higher than non-urbanized stream reaches. A reduction in tree and shrub canopy cover along streams can quickly increase water temperatures. As shown in Table B-1 below, the initial increase in temperature is quite rapid following conversion from native vegetation (95-98% cover) into open pasture lands (Rutherford, 1999):

Table B-1 Relationship between Canopy Cover and Stream Warming

Stream Order	Distance for Temperature to Increase from 15°C to 20°C With 0% Shade	Distance for Temperature to Increase from 15°C to 20°C With 70% Shade
First Order	250 m (273 yd)	500 m (547 yd)
Second Order	500 m (547 yd)	1,500 m (1,640 yd)
Third Order	1,500 m (1,640 yd)	5,000 m (5,468 yd)

Rules 69 through 75 of the Michigan WQS specify temperature standards which must be met in the Great Lakes and connecting waters, inland lakes, and rivers, streams, and impoundments.

B-12.0 Stream Barriers

As linear ecosystems, streams are vulnerable to fragmentation. Human-caused barriers such as dams, weirs, and perched culverts disrupt the continuity of flow and are recognized by MDNR as impacting trout and salmon migration. The character of rivers emerging downstream of a dam may be significantly altered from the river entering an impoundment (MDNR, 2006):

- Aquatic community health is closely linked to water temperature tolerances and impounded waters may discharge at significantly higher or lower temperatures than normally encountered in the stream.
- Flow patterns reflecting normal high and low water conditions over time may also be fundamentally altered, affecting stream channel configuration, fisheries habitat, and many other physical and biological processes.
- Water quality may decline in impounded streams if excessive nutrients, sediments, and aquatic plants accumulate in the impoundment.
- Stream changes induced by dams and other watershed conditions are often reflected in the fish community.
- Native and desirable stream species are almost always displaced in river segments affected by dams.
- Dams also limit the normal movement of fish, other aquatic organisms, and system organic material.
- The loss of sediment bedload downstream of a dam commonly results in channel degradation (bed erosion) because the water has its full capacity to entrain and transport sediment.

The current trend is towards the removal of stream barriers that need replacement and are not providing considerable benefits. Culverts should be sized and aligned in concert with the stream morphology to avoid causing channel incision. In some cases, stream barriers may block the migration of invasive species and the reach below the barrier, with its low sediment load, may be a haven for sensitive mussel species; therefore, dam or weir removal should be considered on a case-by-case basis.