Dissolved Oxygen in Streams Background Document

Under natural conditions, there are many variations in oxygen levels relating to weather and the physical characteristics of the stream. First, there is an inverse relationship between the amount of DO that can be dissolved in water and the water temperature – as the temperature goes up, the maximum amount of oxygen that can be dissolved called the **DO saturation level** goes down. Thus, in the climate of the eastern US, the summer would naturally produce lower oxygen conditions than the winter and nighttime levels would be higher than daytime levels, everything else being equal.

Oxygen in the stream is used by animals and plant for respiration. It is then replaced both by the diffusion of oxygen from the atmosphere and the photosynthesis of aquatic plants during the day. The rate at which the oxygen goes from the atmosphere into solution is called the **reaeration rate** and is related to the amount of mixing of the water in the stream with the air. A stream that is more turbulent (a bubbling brook for example) has faster moving water that may hit rocks, splash along the banks, etc. and mix more with air providing a higher reaeration rate. A slow moving stream with a smooth, silty bottom will have less mixing of the water and the air. Thus, the characteristics of the streambed are related to the reaeration rate.

The amount of oxygen provided by plants during the day is related to the biomass of plants in the stream. Under normal conditions, plant growth will offset some of the oxygen used in respiration. However, as discussed below, there are pollution conditions that produce abnormal plant growth that causes potentially harmful blooms of algae during a process called **eutrophication** – producing excess levels of blue-green algae.

People have a profound impact on the quality of the water. Those impacts can be felt in many ways. A good overview of what constitutes a healthy stream and how we measure water quality with biological, physical, and chemical measures can be found at:

http://tycho.knowlton.ohio-state.edu

The focus of this project will be on the impacts of a sewage treatment facility on dissolved oxygen in a stream. Sewage contains a heavy load of organic waste as well as disease causing organisms and heat. This EPA document provides a nice overview of the wastewater treatment process for municipal wastes:

http://www.epa.gov/npdes/pubs/primer.pdf

Look especially at pages 8 – 13 for a description of what is removed and the typical treatment processes. The main goals of treatment facilities are to remove a majority of the organic wastes and to kill all disease causing organisms. The latter is often accomplished by treating the final effluent with chlorine to kill any remaining bacteria. However, some viruses survive this process.

The organic waste is removed through a series of processes called primary and secondary waste treatment. The primary measure of the organic waste is biochemical oxygen demand or BOD. This is a laboratory test that indicates the amount of oxygen that is likely to be used up when the waste is discharged into a stream. What actually happens is that bacteria “eat” the waste causing it to decompose. In order for the bacteria to live and grow, oxygen is required – hence the depletion of oxygen in a stream. The first stage of decomposition occurs within about five days of a discharge. Thus, there is five day lab test for BOD called BOD_5 which measures the potential oxygen use over this period by incubating a sample of the wastewater under standard conditions for five days. This part of the waste is called the carbonaceous waste since the main component of the original organic waste is carbon. As that waste is decomposed, nitrogen is released as a by-product. That extra nitrogen, one of the primary nutrients for plant growth, causes a secondary load of oxygen demanding waste. The nitrogen induces the growth of blue-green algae in greater abundance than normal. Both nitrogen and phosphorous in water can be a cause of such growth. The algal lifecycle is short and dead algae become a secondary organic waste load that uses oxygen when it decomposes. That process of nutrient enrichment, called **eutrophication** can cause further problems in the stream. That secondary waste problem with nitrogenous wastes has led to a second test for BOD called BOD_{20}. In this test, samples are incubated for 20 days to provide a measure of this oxygen demand.

When a new waste treatment facility is going to be sited or an older facility is due to be upgraded, it is critical to model the level of dissolved oxygen in the stream to determine that the waste load will not reduce the oxygen levels so low that the aquatic environment will be adversely impacted. Below 4.0 mg/l, the water can become septic and only extremely tolerant fish and bacteria can survive. Between 4.0 and 6.0 mg/l, there can be a relatively diverse **warmwater habitat** supporting a set of fish and macroinvertebrate species that do not require very high oxygen levels. Some species require oxygen levels above 6.0 to survive or to breed. Thus, trout are generally found in cold water streams or **coldwater habitats** where the oxygen levels are significantly higher.

The Streeter-Phelps model discussed in the project assignment is the basis for many, more sophisticated models of dissolved oxygen in streasm. More recent refinements of the model have been made to consider the oxygen contributed through photosynthesis, the nitrogenous oxygen demand, oxygen required to decompose chemicals in the stream, and oxygen consumed by non-point water pollution sources. A non-point water pollution source is one that does come for an individual facility like a factory or sewage treatment plant but instead comes from stormwater runoff after a rainfall.

The figure below is from a very complex EPA DO model called Qual2E. The top part of the diagram depicts the simple Streeter-Phelps model where atmospheric oxygen is added to the DO level of the stream by a constant K1and carbonaceous BOD or CBOD removes oxygen from the stream at the rate K2. To make their model more realistic, they add the sediment at the bottom of the stream as both a source and sink for BOD. K3 is the rate at which sediment laden with BOD settles to the bottom of the stream and no longer interacts with the water's DO cycle. K4 is the rate at which sediment that contains BOD is stirred up, adding to the BOD load on the stream. Finally, their model adds the secondary growth of algae and their relationship with the nitrogen and phosphorous in the stream, producing the potential reduction in BOD because of this nitrogenous BOD demand.

You can skim through the materials in the two sections of the QUAL2E manual to get a better sense of the complexity of the environment you are modeling in your project with a very simple representation. However, don't get bogged down in the details of that model. A second manual called **guidance** provides a nice chapter (chapter 2) which your team can use to better understand the basic concepts of DO/BOD and nutrient models.

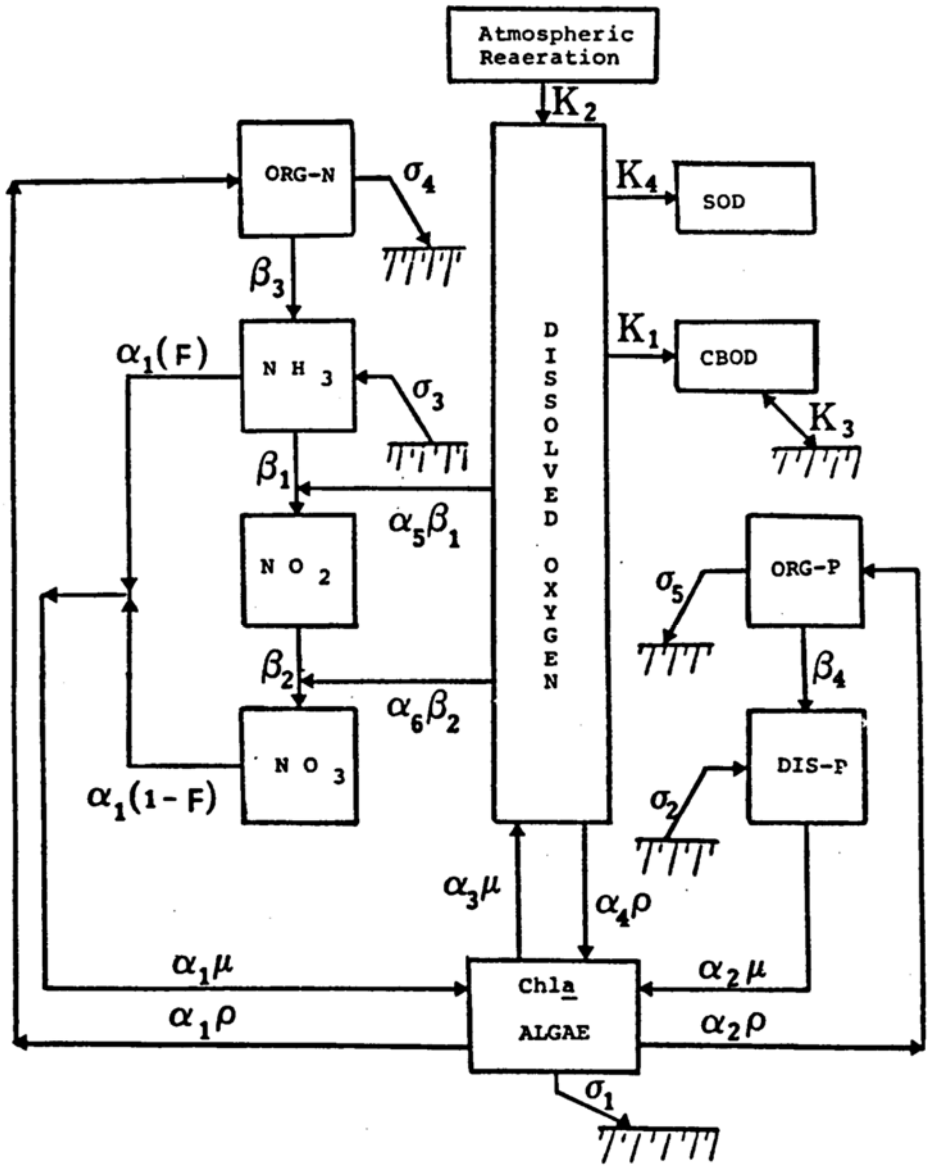

Figure III-1. Major Constituent Interactions in QUAL2E

Figure 1: Conceptual Representation of the Qual2E Model from USEPA