Surface Water Quality Data Interpretation Workbook

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General Information

This workbook focuses on issues associated with common or conventional pollutants like oxygen demanding substances, nutrients, temperature, and suspended sediment.

When analyzing water quality data it is important to consider more than one piece of evidence.

- Source of Potential Pollutants
- Physical and Biological Processes
- Surrounding Land Use
- Physical Observations (color, odor)
- Alterations to the Water Body (channelization, dams)
- Weather Conditions

What Are Conventional Pollutants?

Some common conventional pollutants are oxygen-demanding substances, **nutrients** (nitrogen and phosphorus), temperature, **suspended sediment/sedimentation**, and **salinity**. In general, the effects of conventional types of pollutants on aquatic ecosystems are chronic and cause deterioration over time. These pollutants also have the potential to cause acute effects (immediate damage) to an aquatic community. Large volumes of raw sewage, concentrated fertilizer or rapid increase or decrease in water temperature can cause immediate and often lethal effects on an aquatic community.

Effect of Conventional Pollutants on Dissolved Oxygen

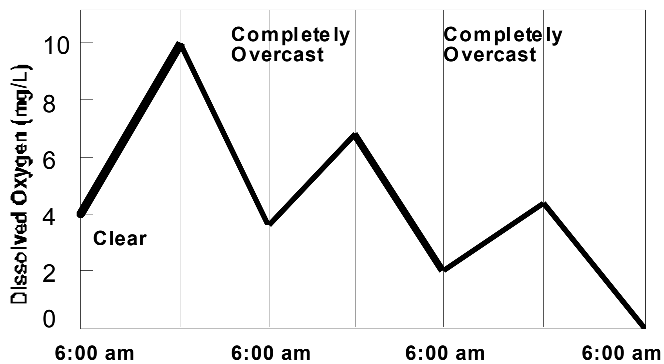
The most common effect of organic pollutants is the reduction of dissolved oxygen. Over a 24-hour period, dissolved oxygen levels fluctuate naturally in most water bodies. Oxygen production (photosynthesis) normally varies because it is light dependent. As the sun rises, photosynthetic (plants, algae) organisms begin to produce oxygen with concentrations increasing throughout the day (production > consumption). Around sunset photosynthesis essentially ceases and dissolved oxygen levels drop due to respiration (consumption > production) by fish and other aquatic organisms. The lowest dissolved oxygen levels usually occur just before dawn. In general, oxygen consumption (respiration) can be considered a constant drain on the aquatic system, day and night. The introduction of oxygen-demanding substances increases the drain on the aquatic system. In addition to photosynthesis, oxygen is added to a water body by natural aeration (wind, rain and water currents). Oxygen deficiency is common, especially during warm, dry, summer months.

Dissolved Oxygen (DO) Reduction

The most common effect associated with oxygen-demanding substances and excessive nutrients is the reduction of **dissolved oxygen** (DO). Low DO levels result from an imbalance between oxygen production input and use by physical, chemical and biological processes. As organic substances decompose, oxygen in the system decreases.

Elevated levels of plant nutrients can cause algae (**phytoplankton** and filamentous algae) blooms which can severely deplete DO levels. This can cause problems for fish populations and other aquatic organisms (stress and/or death). A bloom creates a situation where plankton population numbers exceed the capacity of the system. During plankton blooms, DO levels during daylight hours can be very high, often greater than 10 milligrams per liter (mg/L or parts per million; ppm). However, during the night when oxygen production (photosynthesis) ceases and respiration (consumption) begins, the DO can drop to lethal levels.

Natural Flucuations of DO Occuring Over a 24-Hour Period and the Effects on DO Levels Following Several Overcast Days



Phytoplankton blooms are often accompanied by blooms of zooplankton. In extremely high numbers zooplankton represent a drain on nighttime DO levels. The effect of a plankton bloom can be compounded on overcast days. Decreased sunlight causes a reduction in oxygen production which results in a net loss of DO. Major sources of nutrients include agricultural activities (fertilizer, manures), urban runoff (fertilizers from lawns and golf courses) which is considered **nonpoint source pollution** and domestic and industrial wastewater effluent which is considered **point source pollution**. The effects of oxygen-demanding substances and high plant nutrient concentrations are enhanced by elevated water temperatures.

Common Conventional Pollutants

Oxygen-Demanding Substances

Oxygen-demanding substances are comprised of organic materials, which can indirectly cause the decrease of DO in surface waters. Organisms (bacteria) involved in the decomposition of these organic materials actually cause the oxygen depletion by respiration (oxygen consumption). Examples of oxygen-demanding substances are raw sewage, poorly treated wastewater, food processing plants or animal feedlot wastes. The effects of organic waste are generally chronic with a gradual deterioration of an aquatic ecosystem over time. The amount of oxygen required to decompose organic materials is called **biochemical oxygen demand (BOD**).

Plant Nutrients

Nutrients, primarily **nitrogen** compounds and **phosphorus** compounds, are essential for plant growth. The rate of plant growth is often controlled by a **limiting nutrient**, typically nitrogen or phosphorus, although it can be any of the essential minerals needed for growth. A limiting nutrient is available in quantities smaller than necessary for aquatic plants to reach maximum abundance.

When a limiting nutrient is depleted, growth stops even if other nutrients are available in large supply. However, the addition of nutrients into surface waters from human activities (agricultural runoff, wastewater discharges), or **cultural eutrophication**, can stimulate excessive plant growth. **Ammonia** is one of the most common aquatic pollutants. The chemical formula is NH_3— one atom of nitrogen and three atoms of hydrogen. Ammonia fits into several categories; oxygen-demanding substance, nutrient, and toxic substance.

The importance of ammonia to water quality is its highly toxic nature and widespread presence in surface waters. Ammonia enters surface water in varying quantities from industrial and municipal wastewater discharges, agricultural runoff (fertilizers, confined animal feeding operations), leaking septic systems, raw sewage spills, urban runoff (fertilizers, cleaners), and accidental spills. Ammonia is also nitrogen rich, making it a valuable component of fertilizer. When mixed with water, ammonia also creates a powerful cleaner making it one of the most common household and industrial chemicals.

Ammonia, nitrite and nitrate are related by the process of **nitrification,** which is the oxidation of ammonia and nitrate. In the presence of oxygen, ammonia is oxidized by specialized bacteria (*Nitrosomonas*) to nitrite, an intermediate product. Nitrite is then oxidized by another specialized bacteria, *Nitrobacter,* to form nitrate. **Nitrite** (NO_2^-), like ammonia is extremely toxic to aquatic life, but is not considered an environmental problem because it occurs in relatively low concentrations. **Nitrate** (NO_3^-) is relatively nontoxic to aquatic organisms and is not considered an environmental problem (Note: Elevated nitrate concentrations are a problem in drinking water sources- *methemoglobinemia or blue babies* can be caused by nitrate concentrations > 10 mg/L).

Elevated Water Temperature

Elevated temperatures reduce the solubility of DO and decrease the oxygen carrying capacity of the water. For example, at 0^oC water can hold approximately 14.6 mg/L of oxygen at the saturation point, and at 30^oC the amount decreases to 7.5 mg/L. High temperatures increase metabolism, respiration and oxygen demand of fish and other aquatic organisms. In general, metabolism rates in aquatic organisms double with every 10^oC rise in temperature.

How Does Water Temperature Affect Water Quality?

The effects of the oxygen-demanding wastes (sewage, food process waste, feedlot waste) and nutrients are intensified by temperature increases. The main sources of unnaturally heated water are power plants and industry discharging heated **effluent**. In addition, development in a watershed can affect temperatures in nearby streams. The clearing of stream bank vegetation exposes a stream to warming from increased exposure to the sun. Although it does occur, temperature alone is not a common cause for acute effects and mortality of aquatic organisms. The ultimate result of increased water temperature and lower oxygen levels are aquatic communities dominated by tolerant organisms.

Suspended Sediment and Turbidity

Total suspended solids (**TSS**) and **turbidity** are indicators of the amount of mineral (soil) and organic (plankton, algae) particles suspended in the water column. TSS is the measure of the actual weight of suspended solids in a liter of water (mg/L). Turbidity measures the amount of light blocked by water due to the presence of mineral and organic solids suspended in water. As turbidity increases, the amount of light penetration into the water column decreases. Reduction in the availability of light decreases the density of primary producers (phytoplankton, algae, and other aquatic plants). This causes a decrease in DO production (limits photosynthesis). In addition to a reduction in DO levels, organisms (zooplankton and fish) dependent on plants for food are also affected.

Suspended sediment remains in the water column as long as there is sufficient current. The deposition of suspended materials has a negative effect on aquatic life by covering habitat and filling in lakes and slow moving areas of streams and rivers. Predators feed less efficiently in turbid waters.

The most common sources of suspended solids are construction activities (buildings, roads, bridges); the erosion of agricultural lands; and surface-mined land (for example, sand and gravel operations). Waters with heavy sediment loads are very obvious because of their muddy appearance. This is especially evident in rivers during high flows, where the force of the water keeps the solids suspended rather than allowing it to settle on the bottom.

Physical Indicators of Water Quality

Water color and odors are good indicators of water quality problems. Many problems have similar characteristics, so it is important to look at as much information as possible when assessing water quality. It is easy to mistake one thing for another if important pieces of information are missing.

For example, a 2 mile stretch of stream has turned a dark brown color in a short period of time. Upstream, the water is a green color. Was something dumped in the creek? It's common to assume something was dumped in the stream rather than a natural cause because it doesn't look normal. If a few additional pieces of information are added, it changes the assumption.

1. The pH is normal to slightly elevated.
2. The DO levels are elevated in the afternoon.
3. Fish are not showing any signs of stress or strange behavior.
4. The water surface is clear (no oily sheen or scum).
5. There is little flow.
6. The affected area is located downstream of a small tributary that drains a golf course pond.

What Does the Extra Data Indicate?

1. pH is normally elevated when there is a plankton bloom.
2. Plankton blooms cause an increase in oxygen production.
3. There is nothing in the water that is causing adverse effects to fish. Although, if the condition continues low DO may become an issue.
4. Plankton blooms do not create an oily surface scum.
5. Low flow provides ideal conditions for plankton by creating a quiet area (aren't being washed downstream by higher flow) to establish populations.
6. The pond was designed to hold runoff from the golf course. The pond was intended as a **best management practice (BMP)** to keep nutrients (from fertilizers) out of the creek. Pond water was released during maintenance on the pond's dam.

Common Physical Indicators Used in Assessing Water Quality

The following are common physical indicators used to assess water quality. They include color, odor, surface scum, and land use.

Color	*General Causes*
Muddy Tan to Light Brown	• Suspended sediments common after rainfall • Runoff from construction, roads, agricultural/range land • Soil erosion caused by vegetation removal from **riparian zone**, rangeland/overgrazing, agriculture, and logging
Pea Green, Bright Green, Yellow, Brown, Brown-Green, Brown-Yellow, Blue-Green	• Water with these colors generally indicate a plankton bloom (Key indicator of a plankton bloom, elevated DO and pH) • Water color dependent on dominant plankton type present.
Tea/Coffee	• Dissolved **humic matter** (organic portion of soil) Usually associated with woodlands or swampy areas.
Milky White	• Paint (construction), milk (food processing)
Dark Red, Purple, Blue or Black	• Fabric dyes, inks from paper and cardboard manufacturers
Milky Gray/Black	• Raw sewage discharge or other oxygen-demanding waste, a rotten egg or hydrogen sulfide odor may be present. It may also be sewage fungus.
Clear Black	• Turnover of oxygen depleted bottom waters or sulfuric acid spill
Orange-Red	• Deposits on streambeds associated with oil production areas but not always. Check for petroleum odor. • Color can be due to iron and an oily sheen or residue may be present which can occur naturally (not oil or petroleum). No petroleum odor.
White Crusty Deposits	• Common in dry/arid areas where the evaporation of water leaves behind salt deposits (for example, chloride or sulfate) • Also found in association with brine water discharge (from oil production areas). A petroleum odor and an oily sheen may be present along the banks.

Odors	*General Causes*
Rotten Eggs/Hydrogen Sulfide (septic)	• Raw sewage
Chlorine	• Wastewater treatment plant discharges; swimming pool overflow; industrial discharges
Sharp, Pungent Odor	• Chemicals or pesticides
Musty Odor	• Presence of raw or partially treated sewage, livestock waste or algae

Surface Scum	*General Causes*
Tan Foam	• Usually associated with high flow or wave action; wind action plus flow churns water containing organic materials (increased with rainfall runoff) creating harmless foam; produces small patches to very large clumps.
White Foam	• Sometimes patchy or covering wide area around wastewater outfall; thin or billowy; mostly due to soap
Yellow, Brown, Black Film	• Pine, cedar and oak pollens form film on surface, especially in ponds, backwater areas or slow moving water of streams
Rainbow Film	• Oil or other fuel type. Sheens are common after rains. Oil/gas residue wash off streets after rain. Other sources include spills, pipelines, and oil/gas production areas. **Note:** Check for a petroleum odor, which may be present if there is a large sheen because some organisms can cause sheen. See information under orange-red

Land Use Type	*Potential Impacts*
Woodland	• Erosion from logging, road construction or clear cutting may cause muddy water.
Agricultural Land	• Fertilizers or manure draining in to a stream may cause excessive (crops, pasture, feedlots) algal growth; also sedimentation from soil erosion; streams can be clogged with aquatic plants (macrophytes); pesticides, herbicides.
Cities and Towns	• Urban runoff carries with it a variety of contaminants such as oil, pesticides, metals, and chemicals. The dominant area activities can indicate what type of contaminants might be present.

***Land Use Type** (cont.)*	***Potential Impacts***
Industry	• Numerous types of chemicals and products are produced. Depending on the industry, impacts may include color changes, excessive algae, odors, absence of aquatic life, fish kills, elevated BOD, and sewage fungus.
Wastewater Treatment Plants	• Organic pollution; At outfalls (typically associated with effluent of poor quality) impacts that may be observed include excessive algal growth, white foam, sludge deposits (fluffy dark brown/gray solids), absence of fish and insects or the abundance of tolerant forms (mosquito fish). Other impacts include variable DO levels, chlorine odor, high BOD, sewage fungus (slimy growth; white, gray brown); elevated levels of bacterial indicators (**fecal coliform, E. *coli***), and bleached vegetation (chlorine)
Construction	• Runoff from construction can cause water to become muddy and turbid
Residential	• Lawn fertilizers, oil drained from cars, septic tank overflows, detergents used to wash cars, trash (cans/bottles, paper)

Glossary

acclimation	An organism's ability to adjust to a changing environment.
active decomposition zone	In streams polluted with organic wastes, a zone of active decomposition often follows a zone of degradation. In the zone of active decomposition, the biological oxygen demand (BOD) undergoes partial satisfaction and the dissolved oxygen (DO) reaches its low point and may go completely to zero in the upper end of the zone. Sludge deposits attain their maximum depth at the upper limit of the zone, and turbidity gradually diminishes throughout the zone. Molds, fungi and filamentous bacteria reach peaks in the upper limits of the zone and gradually diminish. Ciliates, flagellates and bacteria eating protozoa reach peak abundance. Various forms of algae can be prolific near the lower limits of the zone. Sludgeworm, very tolerant midge larvae and occasionally leeches reach peak production. The population abundance of tolerant organisms is very high in this zone.
ammonia-nitrogen (NH_3-N)	Ammonia, naturally occurring in surface and wastewaters, is produced by the breakdown of compounds containing organic nitrogen.
best management practices (BMP's)	Common-sense actions required, by law, to keep soil and other pollutants out of streams and lakes. BMPs are designed to protect water quality and to prevent new pollution.
biochemical oxygen demand (BOD)	A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. The greater the BOD, the greater the degree of pollution.
bloom	The accelerated growth of algae and/or higher aquatic plants in a body of water. This is often related to pollutants that increase the rate of growth.
BOD5	The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.
channelization	Straightening and deepening streams so water will move faster. A method of flood control that disturbs fish and wildlife habitats and can interfere with a water body's ability to assimilate waste.
chemical oxygen demand (COD)	A measure of the oxygen required to oxidize all compounds in the water, both organic (living) and inorganic (non-living).
chloride (Cl^-)	One of the major inorganic ions in water and wastewater. Concentrations can be increased by industrial processes. High chloride concentrations can affect metallic objects and growing plants.
chlorophyll *a*	Photosynthetic pigment that is found in all green plants. The concentration of chlorophyll *a* is used to estimate phytoplankton biomass (all of the phytoplankton in a given area) in surface water.
coliform	Of or relating to the bacilli that commonly inhabit the intestines of humans and other vertebrates, especially the colon bacillus.

conductivity — A measure of the electrical current carrying capacity, in µmhos/cm, of 1 cm^3 of water at 25°C. Dissolved substances in water dissociate into ions with the ability to conduct electrical current. Conductivity is a measure of how salty the water is; salty water has high conductivity.

cultural eutrophication — The aging process of a waterbody accelerated by human activities. See eutrophication.

decomposition — The breakdown of organic material by bacteria and fungi.

detritus — Decaying organic material.

dissolved oxygen (DO) — The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

dissolved oxygen sag — Refers to the reduction of DO levels below the point of a wastewater discharge. Relates to the effects of organic wastes on the water downstream of a wastewater discharge. Oxygen-demanding waste discharged into a stream causes a zone of degradation downstream of the discharge point. The time and distance a sag moves downstream and the point of recovery (increases in DO) depends on various factors, which include: the volume of the discharge and the flow in the creek, concentrations of pollutants in the discharge, temperature and re-aeration capabilities. Most streams have the ability to recover. DO sags also occur normally during the early morning hours before sunrise.

E. *coli* — A species of bacterium normally present in intestinal tract of humans and other animals; sometimes pathogenic; can be a threat to food safety

effluent — Wastewater (treated or untreated) that flows out of a treatment plant or industrial outfall (point source), before entering a water body.

estuary — The wide part of a river where it nears the sea; fresh and salt water mix

euphotic zone — The zone of water from the surface to depth of light penetration. Photosynthesis $\geq$ respiration in this zone.

eutrophic — Water bodies with high levels of nutrients capable of supporting abundant algae and/or aquatic plant growth. Able to support an abundance of living organisms. The prefix "eu" means good or sufficient. Algal blooms and resulting fish kills can occur in eutrophic water bodies.

eutrophication — The slow aging process during which a lake, estuary or bay evolves into a bog or marsh and eventually disappears.

fecal coliform bacteria — Bacteria found in the intestinal tracts of warm-blooded animals. Organisms used as an indicator of pollution and possible presence of waterborne pathogens.

humic matter — Completely decomposed organic matter that is readily soluble in acids or bases.

impoundment A body of water confined by a dam, dike, floodgate or other barrier.

nitrate-nitrogen (NO_3-N) A compound containing nitrogen that can exist as a dissolved solid in water. Excessive amounts can have harmful effects on humans and animals (>10 mg/L). The nutrient screening level for ammonia + nitrate = 1.0 mg/L. Anything over 1.0 mg/L is considered high for a body of water.

nitrification The process where ammonia in water and wastewater is oxidized to nitrite and then to nitrate by bacterial and chemical reactions.

nitrite-nitrogen (NO_2-N) An intermediate oxidation state in the nitrification process (ammonia, nitrite, nitrate).

nonpoint source Pollution sources that are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outfall. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for non-point sources are: agriculture, forestry, urban, mining, construction, dams and channels, land disposal and saltwater intrusion.

nutrient Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

orthophosphate (O-P) Nearly all phosphorus exists in water in the phosphate form. The most important form of inorganic phosphorous is orthophosphate, making up 90 percent of the total. Orthophosphate, the only form of soluble inorganic phosphorus that can be directly utilized, is the least abundant of any nutrient and is commonly the limiting factor.

outfall A designated point of effluent discharge.

pH The hydrogen-ion activity of water caused by the breakdown of water molecules and presence of dissolved acids and bases.

phosphorus Essential nutrient to the growth of organisms and can be the nutrient that limits the primary productivity of water. In excessive amounts, from wastewater, agricultural drainage and certain industrial wastes, it also contributes to the eutrophication of lakes and other water bodies. The nutrient screening level for total phosphorus in 0.2 mg/L. Anything over 0.2 mg/L is considered high for a body of water.

photosynthesis The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll using sunlight as an energy source.

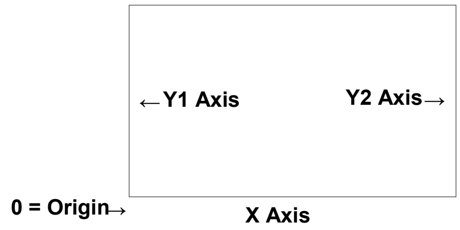
plankton	Organisms (plants and animals) that live in open water, either suspended or floating. Phytoplankton (plant): (1) Microscopic (2) movement dependent on currents (3) primary producers (solar radiation and nutrients used for growth) (4) have effect on water quality. Zooplankton (animal): (1) microscopic, but some can be seen by the naked eye (2) capable of movement (3) secondary producers (feed on phytoplankton, bacteria and detritus [dead organic matter]).
phytoplankton	Photosynthetic or plant constituent of plankton; mainly unicellular algae
point source	A specific location from which pollutants are discharged. It can also be defined as a single identifiable source of pollution (for example, pipe or ship).
receiving water	A river, stream, lake, or other body of surface water into which wastewater or treated effluent is discharged.
recovery zone	Following the zone of active decomposition, a zone of stream recovery may extend for miles. In this zone, the BOD decreases and the DO increases to the unpolluted concentration. Molds and fungi have been replaced by a growth of algae. Rotifers and crustacea succeed the ciliates. The population abundance decreases and the number of species represented within the bottom community increases. Sowbugs and fingernail clams may be very abundant. Several species of snails, leeches, midge larvae and other fly larvae are also numerous. Intolerant or sensitive bottom dwelling forms such as stoneflies, mayflies and caddisflies may appear near the end of the zone.
respiration	Exchange of carbon dioxide with oxygen by plants or animals.
run-off	The part of precipitation or irrigation water that runs off land into streams and other surface water.
salinity	Of or relating to chemical salts.
sediment oxygen demand (SOD)	Sediments at the bottom of lakes, ponds, rivers and streams have components that demand oxygen from the water. Organic matter, bacterial communities, aquatic insects and worms, algae are a few of the natural sources of oxygen demand from sediments. The introduction of organic waste from industry and domestic wastewater sources increases this demand. The oxygen uptake rate of sediments is measured in $gm/m^2/day$.
Sedimentation	The process where suspended solids enter, accumulate and settle to the bottom forming the sediments.
Sediment	Particles and/or clumps of particles of sand, clay, silt, and plant or animal matter carried in water which are deposited in reservoirs and slow moving areas of streams and rivers.
septic	A substance that promotes putrefaction

septic odor	Rotten-egg smell produced by decomposing organic matter and the lack of oxygen.
total dissolved solids (TDS)	The amount of material (inorganic salts and small amounts of organic material) dissolved in water.
total suspended solids (TSS)	A measure of the total suspended solids in water, both organic and inorganic.
water pollution	The addition of harmful or objectionable materials, such as sewage or industrial wastes, to a water body in concentrations or quantities that cause the degradation of water quality.
water quality standards	The designation of water bodies for desirable uses and the narrative and numerical criteria deemed necessary to protect those uses.
zooplankton	Plankton that consists of animals, including the corals, rotifers, sea anemones, and jellyfish.

Graphing Data

X and Y Axes

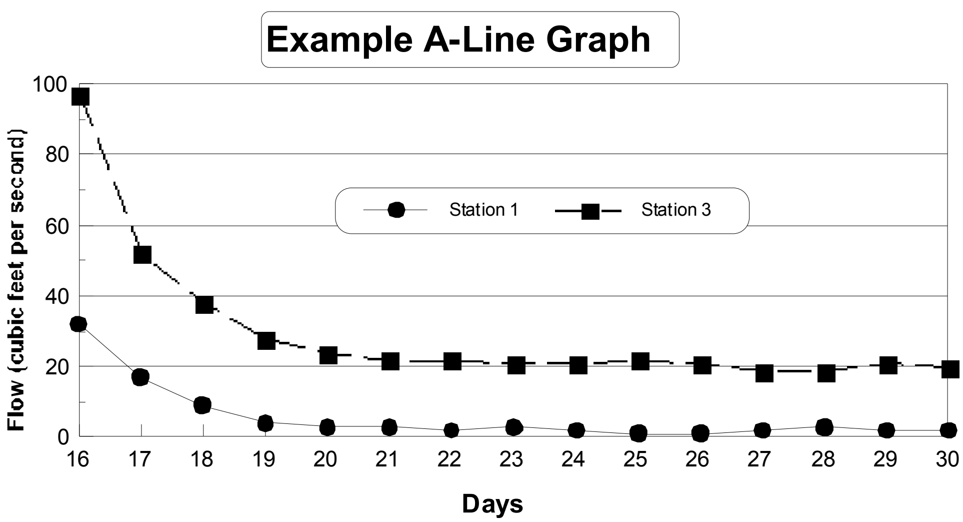
A two dimensional graph has an X and Y axis. The *horizontal line* is called the *X axis* and the *vertical line* the *Y axis*. The point on the bottom left corner where the X and Y Axis lines meet is the *point of origin* or *zero point*. This point can be any number. For example, if your data points range from 20 to 60, a starting number could be 10.



The X axis is usually used to plot time or location of the event. The X axis is often called the *independent variable* because it usually has a fixed sequence of numbers such as hours, days, months, or station number. The Y axis is almost always used to plot the cause or *dependent variable*.

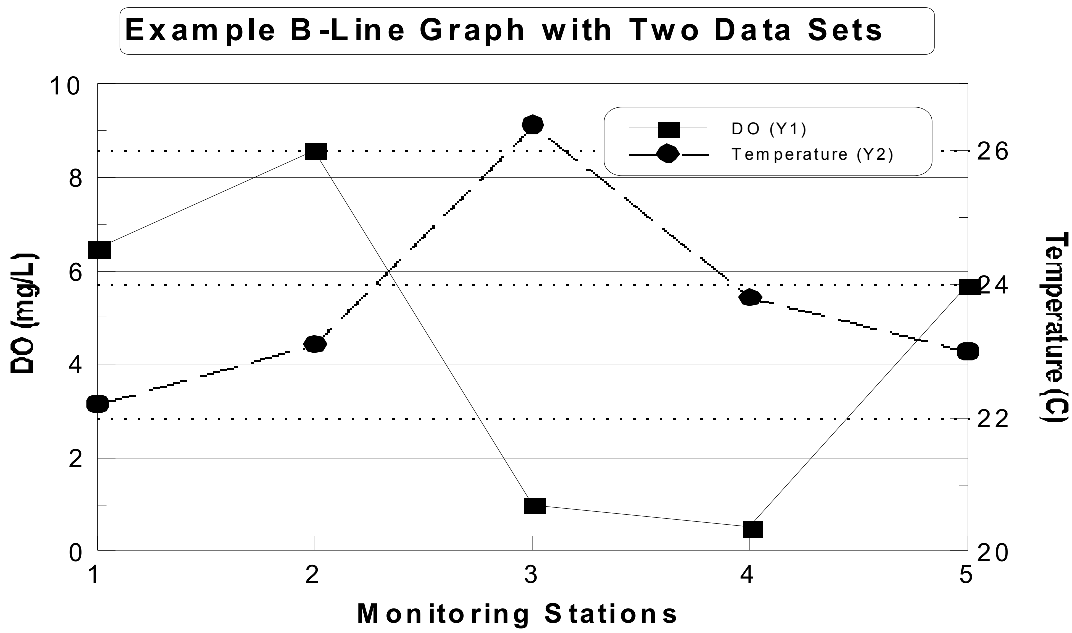
Types of Graphs

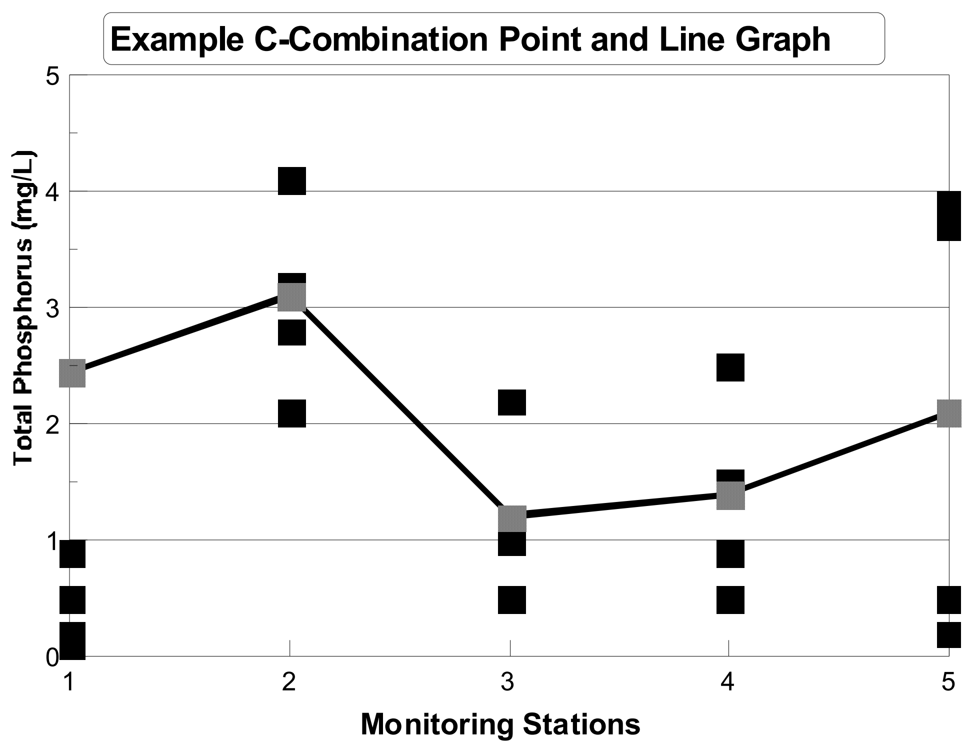
In some cases two sets of dependent data may be plotted on the same two-dimensional graph. One set is plotted on the Y1 axis and the other set on the Y2 axis. The type of graph is dependent on the type of data. Data for trend analysis (looking for changes over a period of time) is plotted on a *line or point graph* (examples A, B, and C). These are commonly used in water quality data analysis because they can be used to show relationships between two or three data sets (example, DO, temperature, and pH).

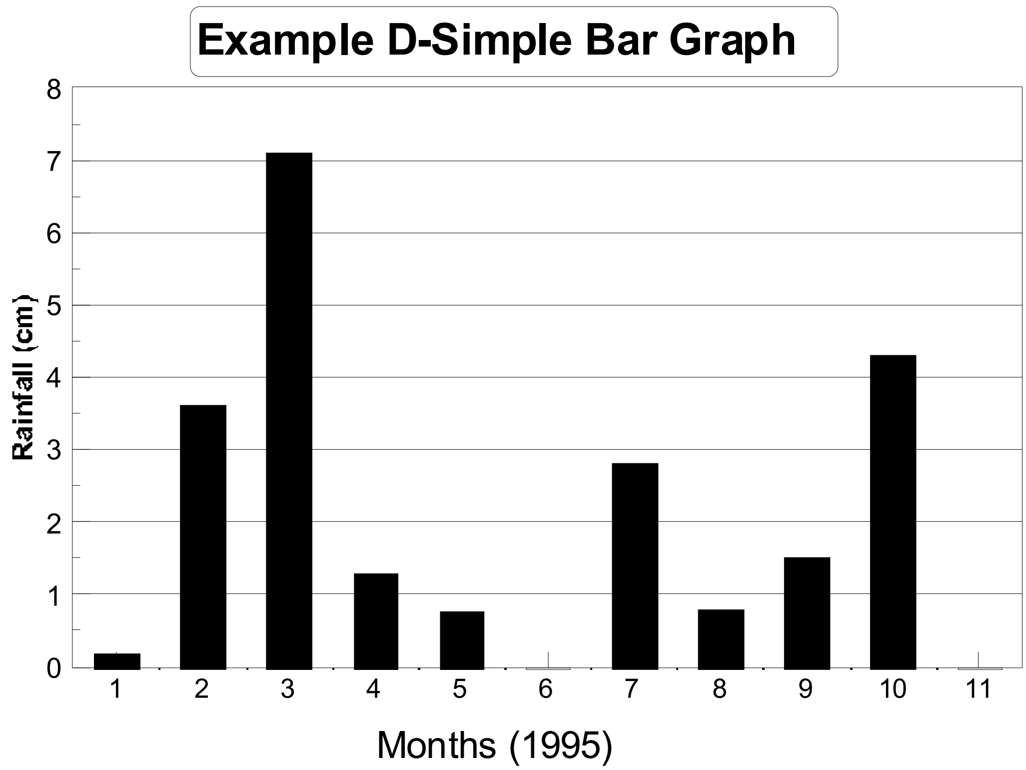


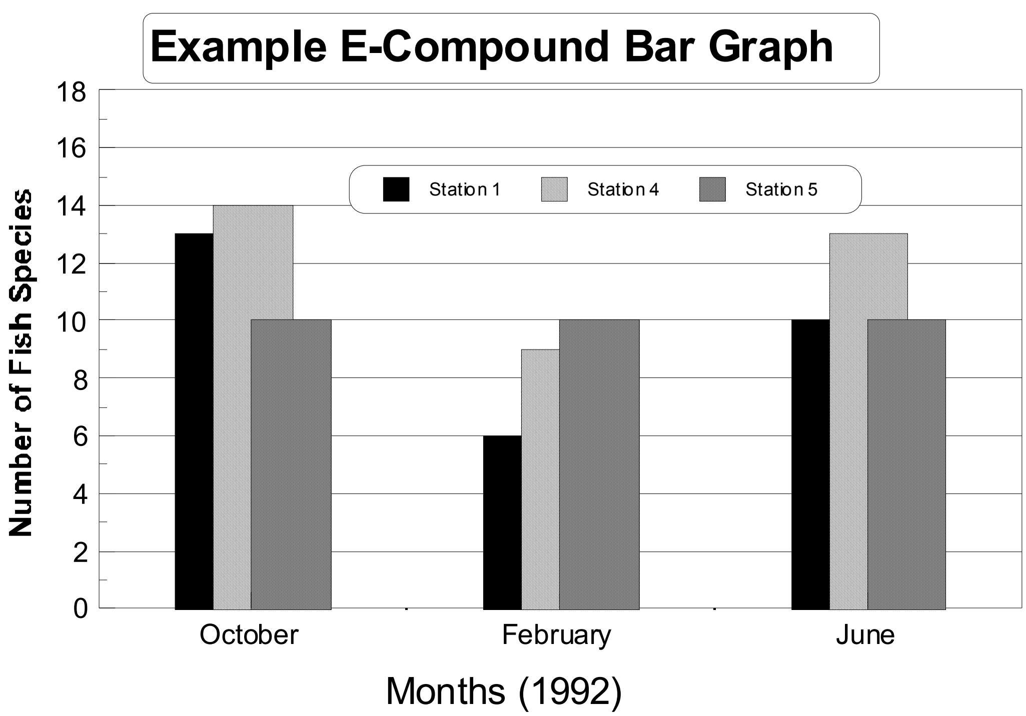
A second type of commonly used graph is the *bar graph*. Bar graphs can be used interchangeably with the line graph but are not suitable for trend analysis. They are useful for comparing values from different time periods or locations. A *compound bar graph* can be used to show multiple data sets from different time periods or locations (examples, D and E).

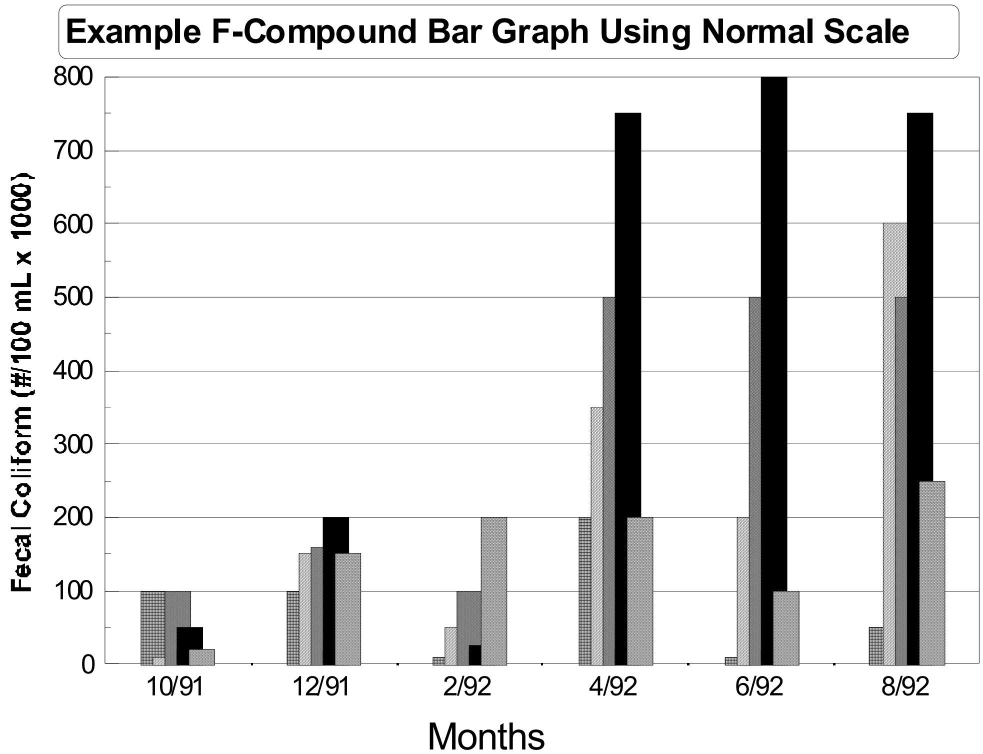
The graph scale should fit the data. Example F shows fecal coliform data plotted on a normal scale graph. The data is very distorted because the values range from 10 to 190,000. Plotting the same data on a *log (logarithmic) scale* graph eliminates the distortion (Example G). Choose a scale that gives the least distorted view of the data. Using the wrong scale can affect data analysis. The following are examples of various graph types.

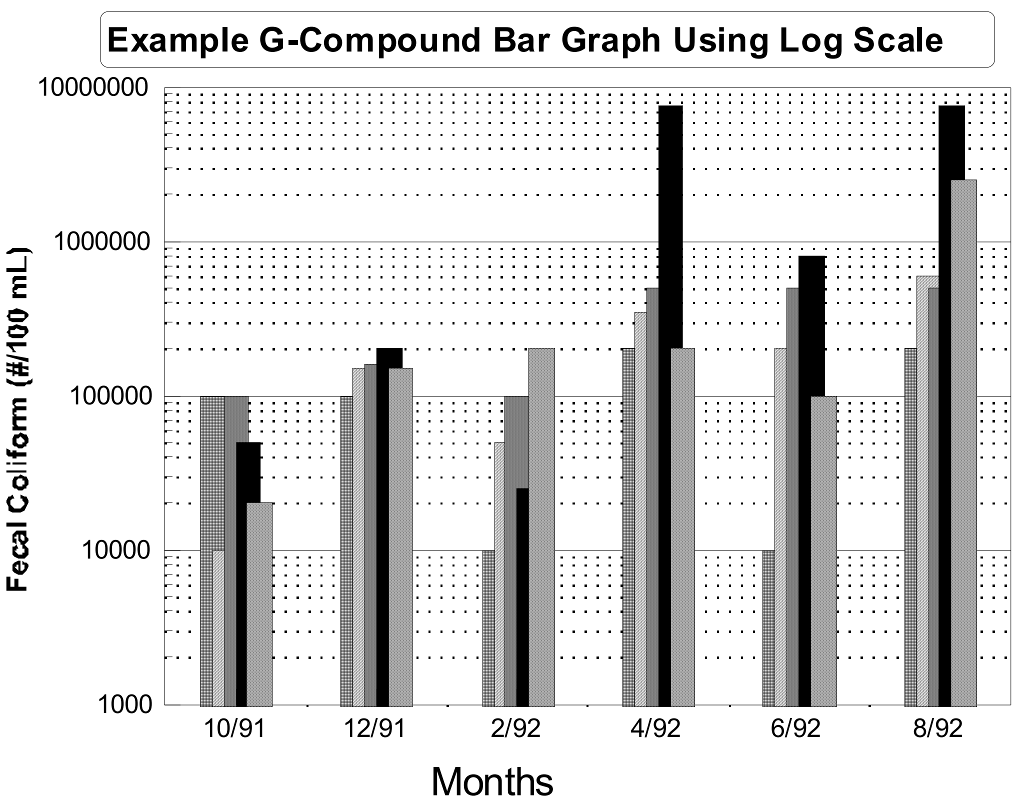





Example D-Simple Bar Graph
Rainfall (cm)
0
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
9
10
11
Months (1995)


Example E-Compound Bar Graph
Number of Fish Species
0
2
4
6
8
10
12
14
16
18
Station 1
Station 4
Station 5
October
February
June
Months (1992)


Example F-Compound Bar Graph Using Normal Scale
Fecal Coliform (#/100 mL x 1000)
800
700
600
500
400
300
200
100
0
10/91
12/91
2/92
4/92
6/92
8/92
Months


Example G-Compound Bar Graph Using Log Scale
Fecal Coliform (#/100 mL)
10000000
1000000
100000
10000
1000
10/91
12/91
2/92
4/92
6/92
8/92
Months

Notes

Exercises

Exercise 1: The Relationship Between Temperature and DO

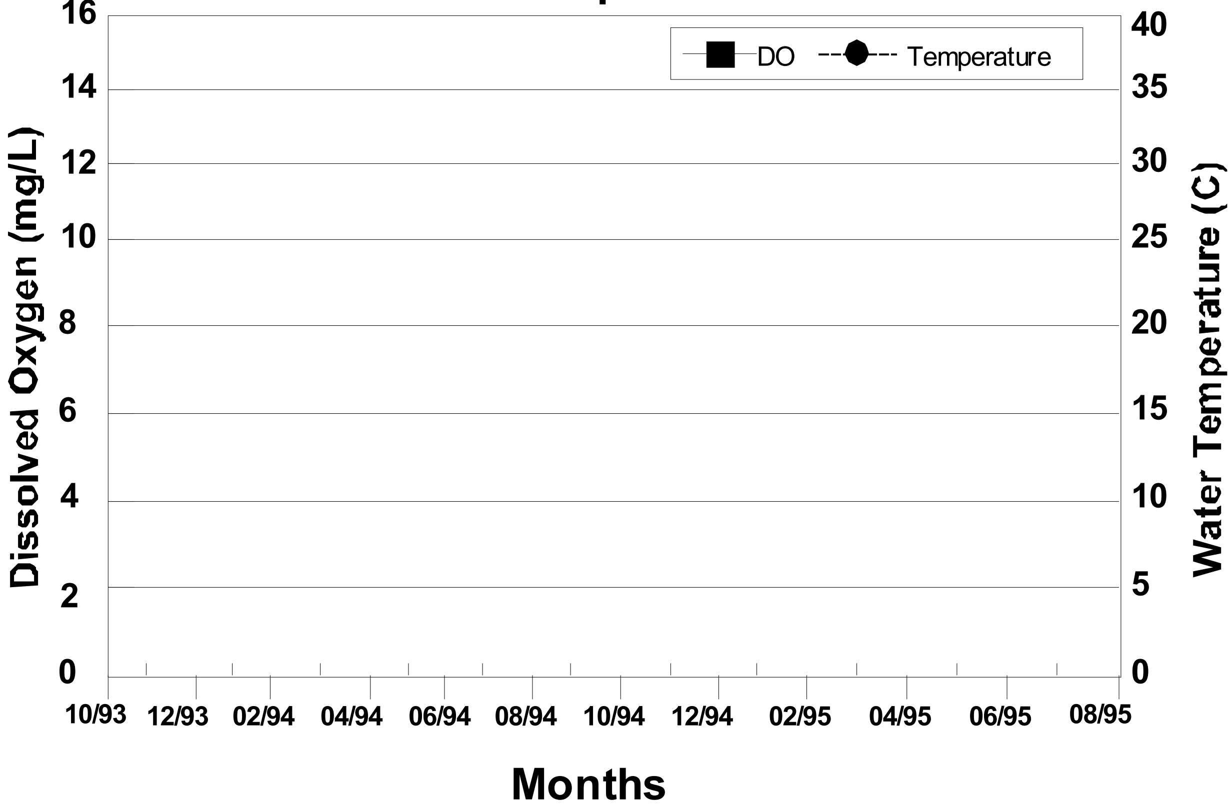
☟ **Plot the temperature and DO data on the graph provided.**

✓ Do you see a correlation between water temperature and DO? Which parameter has the most effect on the other?

Date	DO	Water Temperature
10/93	6.8	22.5
11/93	8.8	24.5
12/93	11.2	21.5
01/94	11.5	14.5
02/94	13.9	12.5
03/94	9.0	19.0
04/94	8.1	16.0
05/94	7.9	24.0
06/94	5.7	25.5
07/94	5.2	24.0
08/94	5.7	25.5
09/94	7.0	23.0
10/94	6.2	23.5
11/94	5.3	20.5
12/94	8.9	22.0
01/95	11.5	15.5
02/95	13.0	15.5
03/95	7.1	18.0
04/95	5.3	20.0
05/95	4.2	23.5
06/95	5.9	25.5
07/95	5.4	26.0
08/95	1.5	28.2

Exercise 1

The Relationship Between Water Temperature and DO



Exercise 2: The Relationship Between Water Clarity, Conductivity, and Rainfall

☟ **Plot the Secchi disk depth data and the conductivity data on the graph provided.**

◙ The conductivity of water is a measure of its ability to conduct electricity. It is measured in µmhos/cm and is the opposite of resistance, which is measured in mhos. The conductivity increases as the number of ions, or dissolved salts (such as calcium, magnesium, carbonate, sulfate, or sodium), increases. As water purity increases, the ability to conduct electricity decreases. Rainwater for example, has little to no dissolved salts, and therefore has low conductivity.

◙ The Secchi disk depth is a measurement of the depth that sunlight can penetrate the water. It is affected by the turbidity, or the amount of particulate matter in the water. In streams, turbidity could be caused by sediment or plankton in the water column.

✓ Do you see a correlation between Secchi disk depth and conductivity? What do you think causes the variation in the parameters?

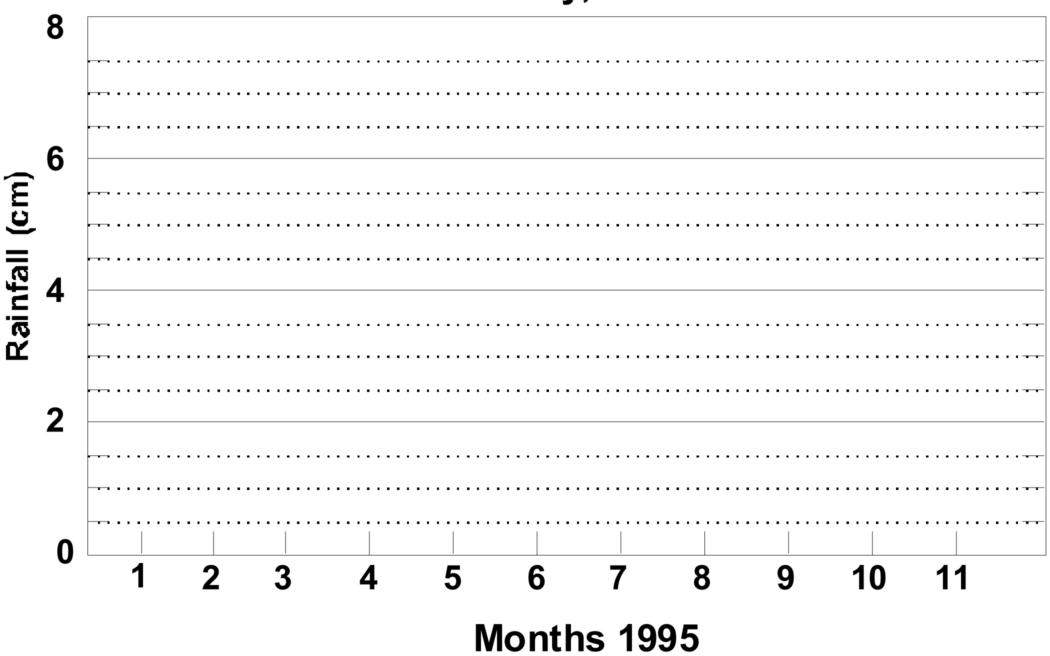
☟ **Plot the rainfall data on the chart provided using bars. The rainfall data is the total amount of rainfall that was received seven days before the sampling date in centimeters. After plotting, place the conductivity/Secchi chart over the rainfall chart and hold it up to the light. This can also be accomplished by using an overhead projector.**

✓ Do you see a correlation between rainfall amounts, conductivity, and Secchi disk?

Date	Secchi Disk (m)	Conductivity	Rainfall (cm)	Days Since Rain
01/95	0.47	1110	0.18	5
02/95	0.38	980	3.6	0
03/95	0.53	1260	7.1	0
04/95	0.20	910	1.3	9
05/95	0.46	1280	0.76	0
06/95	0.26	650	0.0	2
07/95	0.17	960	2.8	6
08/95	0.60	1200	0.8	0.5
09/95	0.29	560	1.5	12
10/95	0.25	370	4.3	6
11/95	0.22	950	0.0	3

Exercise 2 The Relationship Between Water Clarity, Conductivity, and Rainfall-Part 1

Exercise 2 The Relationship Between Water Clarity, Conductivity, and Rainfall-Part 2



Exercise 3: Sudden Changes in DO

◙ This data was collected in an urban stream. The stream is nutrient rich and flows year round. Numerous wastewater treatment plants discharge to this stream. The stream also runs through heavily populated residential areas. The area around this station is known for lush green lawns and colorful gardens.

☟ **Graph the DO and temperature data.**

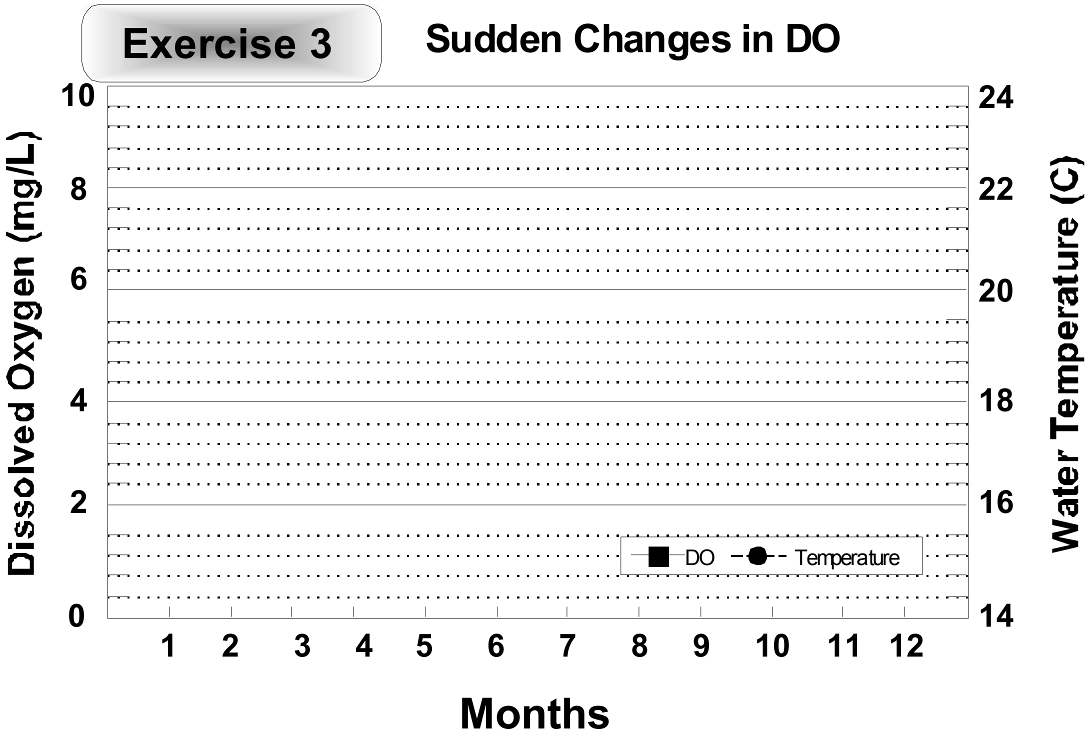
✓ What caused the change in DO?

Use the "General Information" section to assist in the data analysis.

Date	Time	DO (mg/L)	Water Temperature (EC)
01/94	12:30 pm	8.7	14.5
02/94	1:00 pm	8.5	15.0
03/94	12:45 pm	9.5	16.0
04/94	12:15 pm	8.5	17.5
05/94	12:10 pm	8.0	19.0
06/94	6:15 am	4.5	20.0
07/94	6:25 am	4.0	22.0
08/94	6:45 am	2.5	23.5
09/94	7:15 am	3.5	22.5
10/94	8:00 am	4.5	22.0
11/94	7:25 am	5.0	19.0
12/94	7:00 am	5.0	17.0

Notes

Exercise 3


Sudden Changes in DO
Dissolved Oxygen (mg/L)
Water Temperature (C)
10
8
6
4
2
0
24
22
20
18
16
14
1
2
3
4
5
6
7
8
9
10
11
12
Months
DO
Temperature

Exercise 4: Temperature, DO, and pH in an Urban Stream

◙ This data was collected in an urban stream. Numerous wastewater treatment plants discharge to this stream. Flow in the creek is dominated by the effluent discharges from these wastewater treatment plants. The effluent allows the stream to flow all year. The entire stream runs through heavy populated residential areas. The monitoring station is bordered by a park/golf course on one side and a subdivision on the other. During normal flow, the creek is various shades of green. During the summer months the color was noted as being a bright pea green. This data was collected during a period of dry weather with little rainfall.

Date	Time	DO (mg/L)	Water Temperature (°C)	pH (su)
01/95	12:05 pm	9.0	13.0	7.3
02/95	12:15 pm	8.5	14.5	7.2
03/95	12:30 pm	9.5	15.7	7.1
04/95	1:00 pm	8.5	16.5	7.2
05/95	1:15 pm	8.0	19.0	7.0
06/95	12:30 pm	9.5	22.5	7.5
07/95	12:45 pm	11.5	25.0	8.2
08/95	1:30 pm	10.0	27.5	8.3
09/95	12:10 pm	12.0	30.0	8.7
10/95	12:15 pm	8.5	26.0	7.0
11/95	12:30 pm	7.5	22.5	7.1
12/95	1:00 pm	8.5	18.0	7.0

☝ **Plot the DO, temperature, and pH data on the graph provided.**

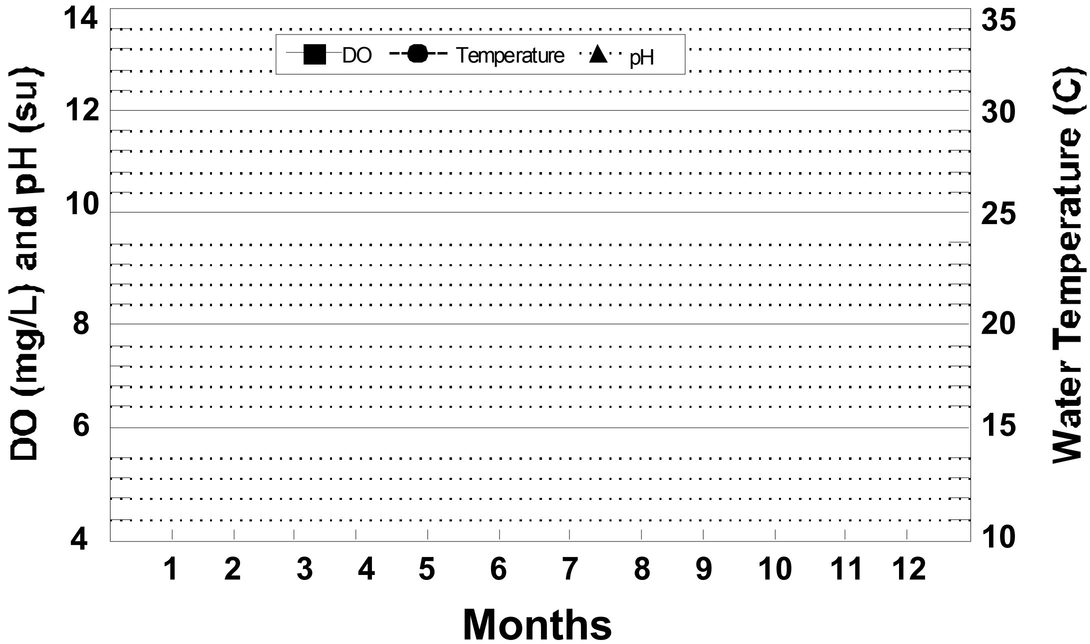
✓ What do you notice about the DO, temperature, and pH from June through September?

✓ What was the likely cause?

✓ How does the DO and temperature differ from the example in Exercise 1?

Exercise 4

Water Temperature, DO, and pH in an Urban Stream



Exercise 5: Ammonia and DO in Cow Creek

◙ The City of Thomasville is located in dairy country. Cow Creek has a history of low DO, high ammonia, and elevated fecal coliform levels. The land use upstream of Thomasville is primarily pasture land for dairy cows. The problems were therefore associated with agricultural runoff from these grazing areas. A group of citizens formed a monitoring team to investigate the situation. The monitoring team collection sites are shown in Figure 1.

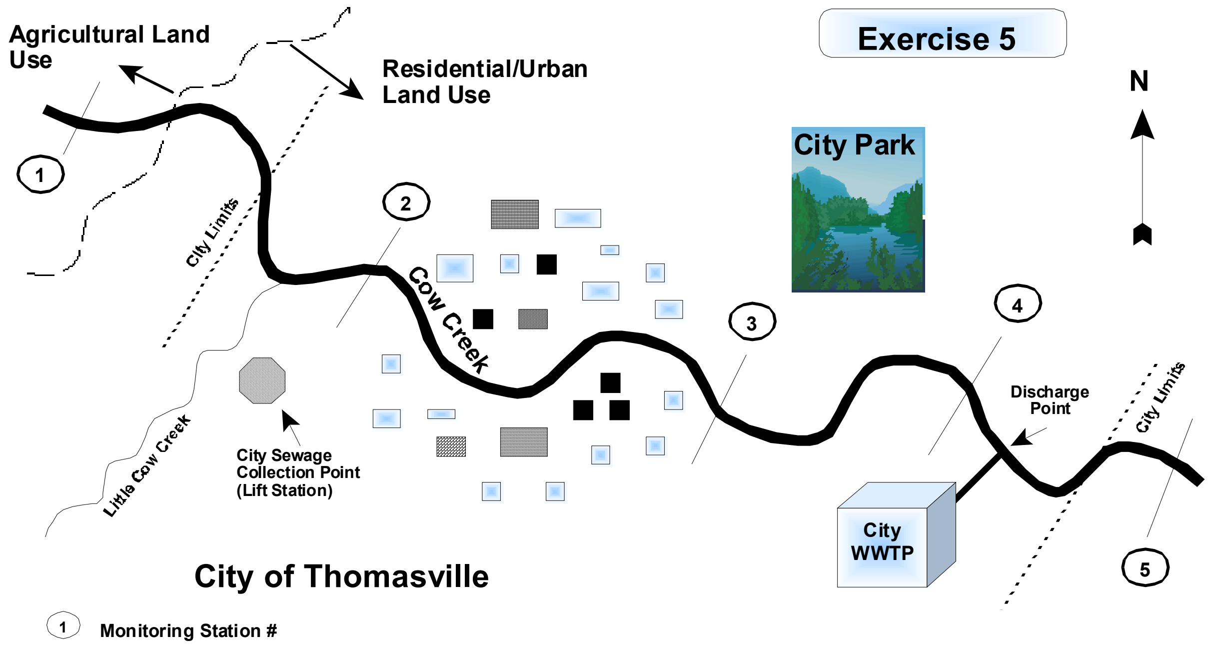


Figure 1. Map of Cow Creek Monitoring Stations.

Additional Information:

◙ The fecal coliform concentrations (# of colonies/ 100 mL) were: Station 1 = 100 colonies/100 mL; Station 2 = 200,000; Station 3 = too numerous to count (TNTC); Station 4 = 100,000; and Station 5 = 28,000.

◙ The last rainfall was five days before the sampling date. Flow in the creek was normal.

◙ The wastewater treatment plant discharges 1 to 2 million gallons per day. Reduction of ammonia is a wastewater treatment plant effluent requirement. Large plants also remove the chlorine from the effluent before it reaches the stream.

The following is a sample of data collection in October 1994.

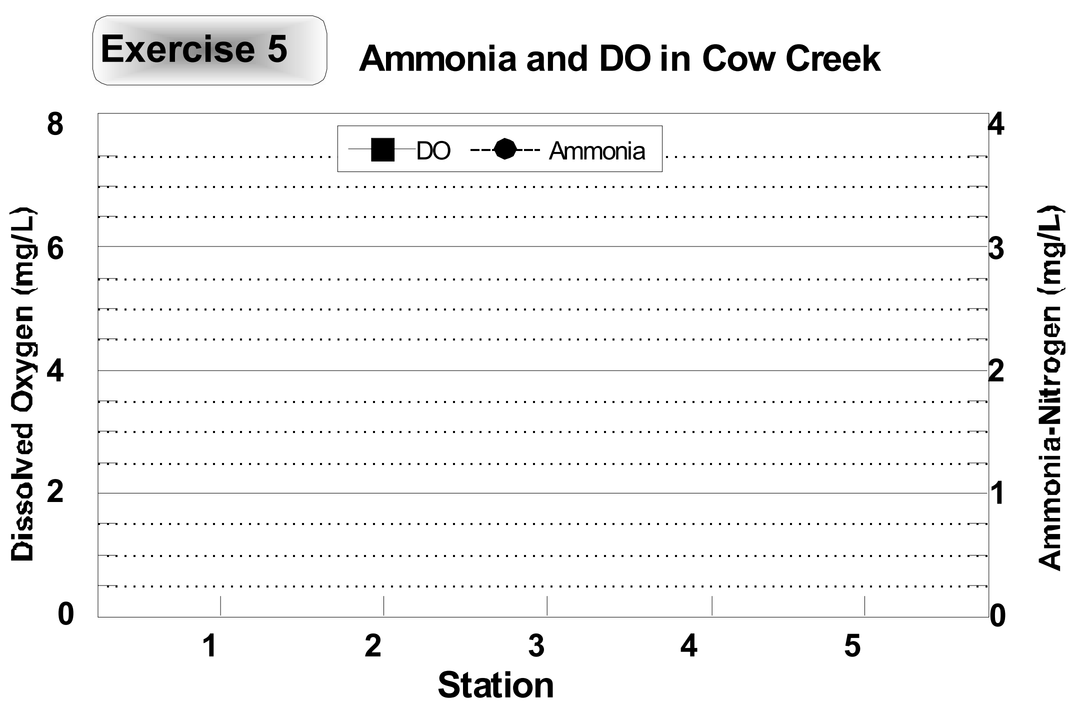
Station No.	DO (mg/L)	Ammonia (mg/L)	Observations
1	5.5	0.01	Water was a slightly turbid light green color; nothing unusual was noted.
2	2.7	3.0	Water was very turbid; milky gray color; rotten egg odor.
3	2.0	2.7	Water was turbid; dark gray color.
4	1.5	2.1	Water murky dark gray color; rotten egg odor; a few small fish were floating on the surface.
5	6.0	0.01	Water slightly clear with a little turbidity; no color.

☝ **Plot the DO and ammonia data on the graph provided.**

✓ Does this data prove that dairy cows are the cause of water quality problems in Cow Creek?

- ! If yes, why?
- ! If no, why not?

Use the "General Information" section to assist in the data analysis.



__Exercise 6__: DO, Temperature, and Fish Kills in Clam Creek

Background Information

◙ Clam Creek, located in southeast Texas, is a 40 mile long channelized stream. This creek, like others in this part of the state, is sluggish with a soft mud/sand bottom. Flow is variable, but this is a perennial stream. The stream flows through agricultural/pasture land for 30 miles before reaching Sweet City, the largest town on the creek. The remaining 10 miles flows through Sweet City.

◙ Major alterations to the Sweet City section of the creek include; channelization, dredging and a retention structure (dam). The dam creates a small impoundment or reservoir for the purpose of maintaining a constant water level for the local sugar refinery. The dam also created "lake front" property of aesthetic and monetary value. This structure has been in place for 50 years.

◙ Originally, Sweet City was built around the Royal Sugar Refinery, in operation since 1900, and was a small "company town." The expansion of the adjacent city has turned Sweet City into a suburb, making the "lakefront" property a premium. As a result, the population of Sweet City has tripled in the past 10 years.

◙ Fish kills are common in the Sweet City section of the creek. Records show fish kills occurring since 1969, but have increased significantly since 1989.

◙ There are three small wastewater treatment plants on the creek upstream of the city. Wastewater from Sweet City is discharged to a larger nearby river system and does not enter Clam Creek. The Royal Sugar Refinery represents greater than 95% of the total wastewater discharged to Clam Creek.

◙ The refinery recycles creek water for cooling purposes by drawing water in and discharging the once-through cooling water back to the creek above a dam. This does not increase flow to the creek.

◙ According to the refinery, the water never comes into contact with the sugar refining process, but the discharge has a peculiar odor.

◙ During low flow the water stored behind the dam is continually reused without any addition of "new" water from upstream.

◙ From 1987 to 1990 temperatures of the sugar refinery discharge ranged from 92 to 125EF (33-35EC). During this time the discharge volume ranged from 17 to 21 million gallons per day.

◙ Major changes to the creek were made in order to use Clam Creek as part of a larger water supply canal system. The creek flow, other than from rainfall, is dependent of the water demand for irrigation and industrial supply downstream of Sweet City. Water for these uses is pumped from a larger river system that tends to be high in suspended solids (muddy) and high in nutrients.

Local Monitoring Network

◙ In response to concerns created by the increased fish kills, a local monitoring group was formed. This network of citizens collected data weekly at six locations in the Sweet City section of Clam Creek. When problems were found, the group monitored more frequently. The focus was on the Royal Sugar Refinery since it was assumed to be the source of pollution. Six sites were monitored (Figure 1).

Station No.	Location	Description
1	Clam Creek at SH 1	Located approximately four miles upstream of the sugar refinery. The stream is narrow and shallow. The bottom is sand mixed with clay. Flow is observed at this site. This site is bordered on both sides by pasture land.
2	Clam Creek at Main Street	Located approximately one mile upstream of the sugar refinery. The stream is narrow and shallow. The bottom is silty clay. The site is bordered by a few older homes.
3	Clam Creek at US Hwy 10	Located next to the sugar refinery. The water intake is located about 200 feet upstream of this station and the discharge 300 feet downstream. The bottom is muddy and soft. The stream at this point is five times wider than at Station 1, and approximately 10 feet deep.
4	Clam Creek at the Dam	Located approximately one mile downstream of the sugar refinery. The stream is wide and deep above the dam. The site is bordered by numerous large new homes with lush green lawns.
5	Clam Creek at US Hwy 40	Located approximately three miles downstream of the sugar refinery. The stream is still wide but shallow. The site is bordered by undeveloped pasture land.

Exercise 6

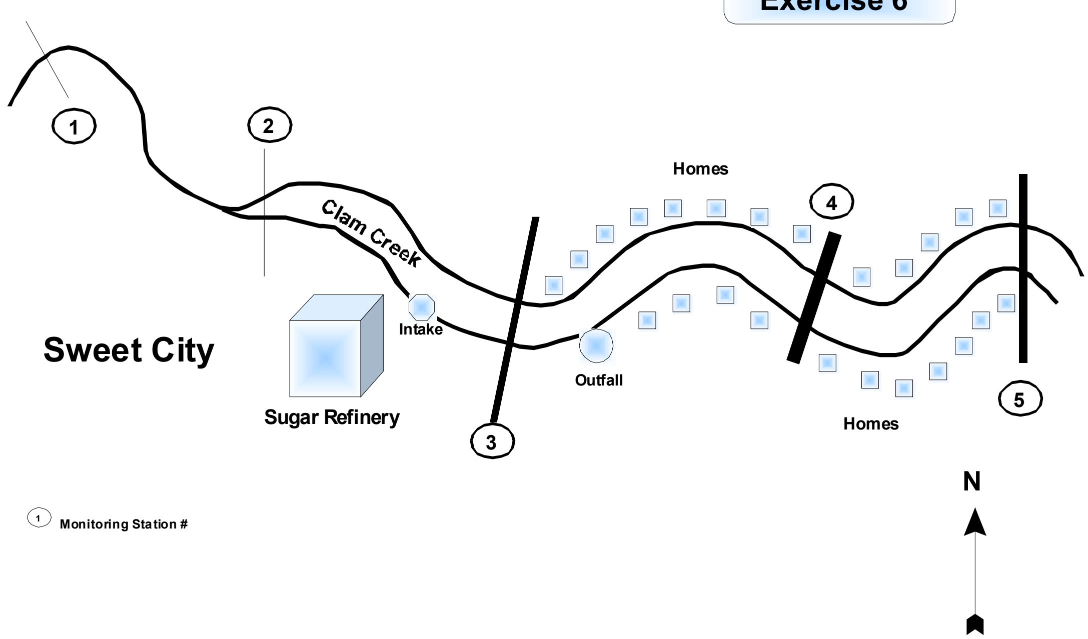


Figure 1. Map of Clam Creek Monitoring Stations.

Exercise 6-Part 1

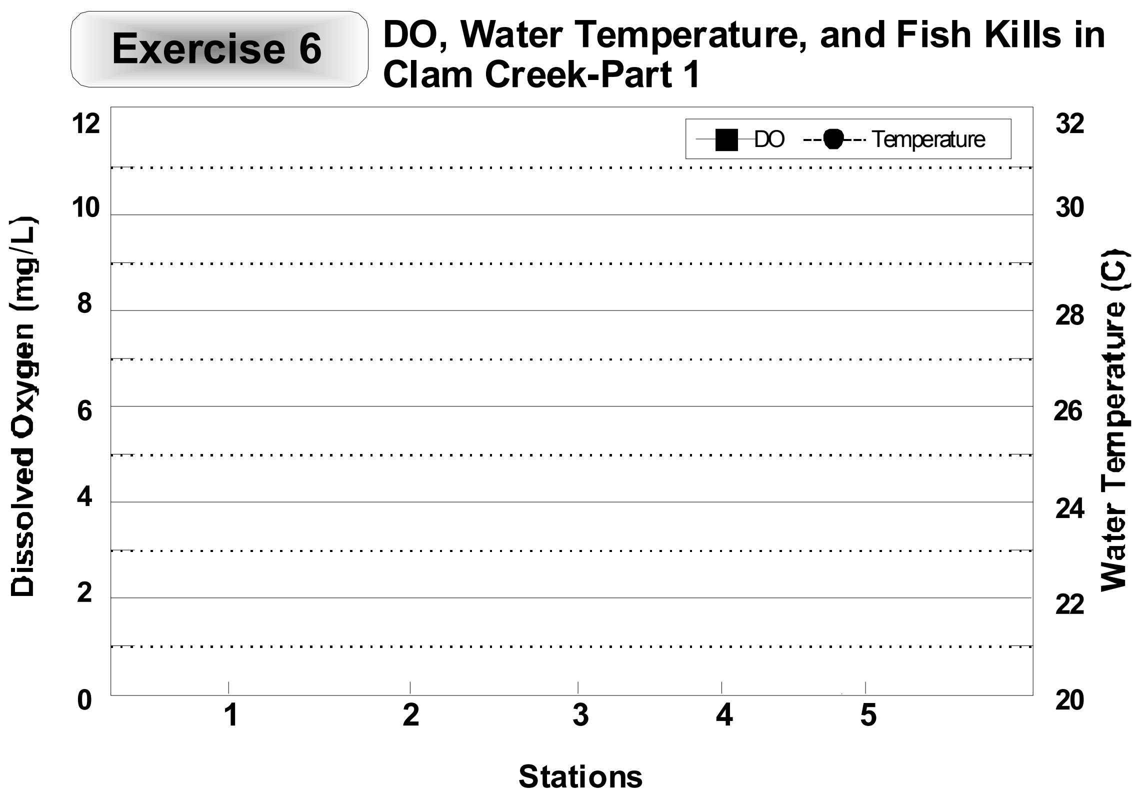
The following is data collected on a routine monitoring day:

Station No.	DO	Temperature	Observations
1	6.5	22.2	No flow detected; water was a tan green color.
2	8.6	23.1	Water was a pea green color.
3	1.7	26.4	Water was very dark green; fish gulping for air at the surface.
4	0.5	23.8	Water was very dark green.
5	5.7	23.0	Water was a light tan green color.
Weather conditions; cloudy, calm, and warm			

☞ **Graph the DO and temperature data.**

✓ Is there a noticeable pattern to the data?

✓ Using the background information, can any assumptions be made on the possible cause(s) of the low DO?



Exercise 6-Part 2

Data collected on 10/16/90

Station No.	DO	Temperature	Observations
1	8.0	22.7	No flow detected; water was a tan green color.
2	8.5	24.6	Water was a pea green color.
3	0.3	29.1	Water was black; dead fish.
4	0.3	26.3	Water was black, dead fish.
5	8.2	25.0	Water was a light tan green color.
Weather conditions; cloudy, calm, and warm			

Data collected on 10/17/90

Station No.	DO	Temperature	Observations
1	7.0	22.9	No flow detected; water was a tan green color.
2	8.6	23.4	Water was a pea green color.
3	1.9	30.0	Water was dark green.
4	1.6	28.0	Water was dark green.
5	6.0	23.2	Water was a light tan green color.
Weather conditions; cloudy, calm, and warm			

Data collected on 10/18/90

Station No.	DO	Temperature	Observations
1	7.2	22.7	No flow detected; water was a tan green color.
2	8.4	24.5	Water was a green color.
3	3.5	29.0	Water was dark green; live fish noted.
4	3.6	26.2	Water was dark green; live fish noted.
5	8.5	24.8	Water was a light tan green color.
Weather conditions; clear, breezy, and cool.			

☞ **Graph the DO and temperature data for 10/16, 10/17, and 10/18 on the graph provided. The data from 10/15 can also be included on this graph.**

✓ Do you think the sugar refinery is to blame for the problem?

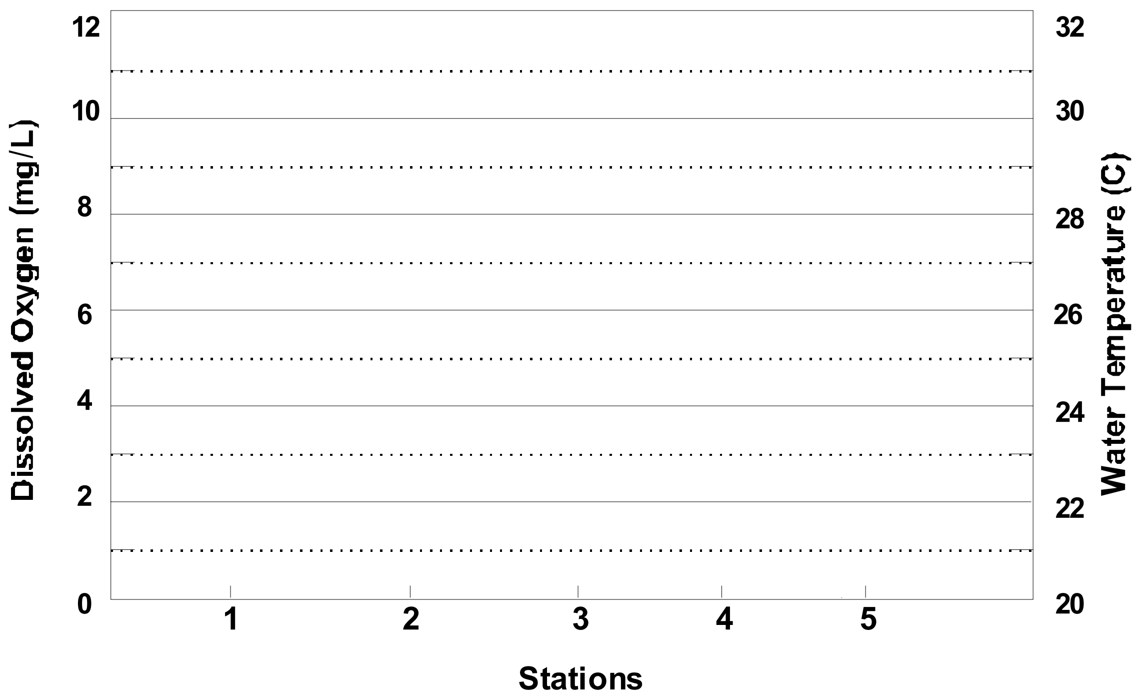
✓ What other sources could contribute to the low DO problem?

✓ What factors might cause the DO to start rising again on 10/18/90?

✓ <u>During low flow, why doesn't the DO stay low all the time? The overall conditions are the same (low flow, heated water discharge). What changed</u>?

Use the "General Information" section to assist in the data analysis.

Exercise 6 **DO, Water Temperature, and Fish Kills in Clam Creek-Part 2**



Notes

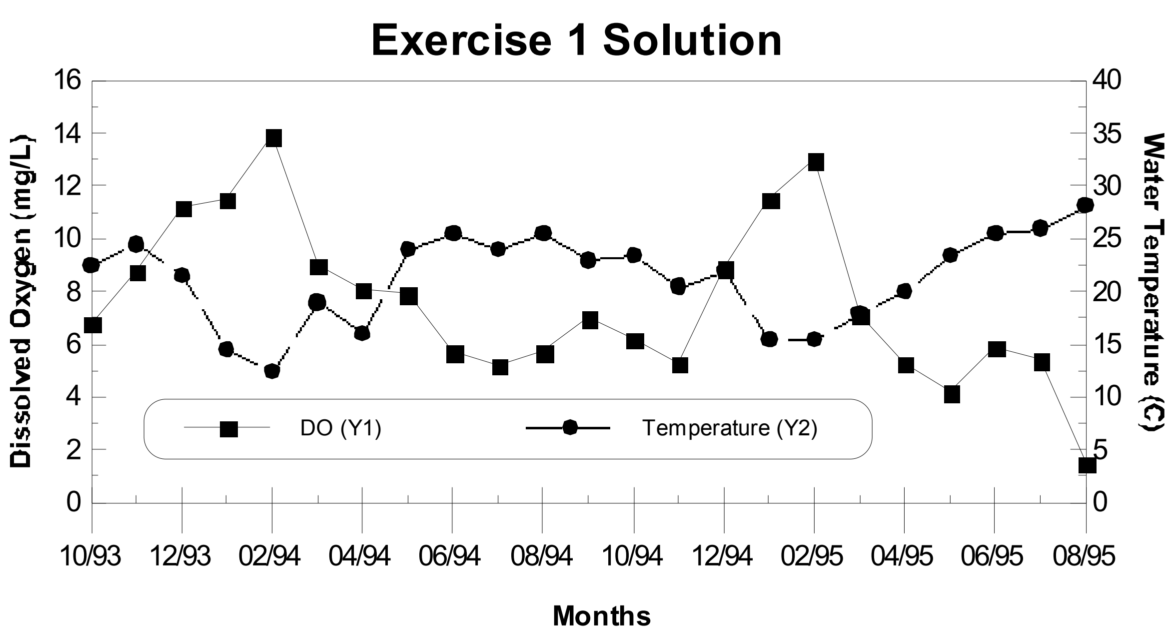
Exercise Solutions

Exercise 1 Solution: The Relationship Between Temperature and DO

Water temperature is normally the inverse of the DO concentration. Temperature plays a major role in influencing the amount of DO in water. Water at a temperature of 31 °C holds about half as much DO as the same water at 1°C. The General Rule: cold water holds more oxygen than warm water. See Exercise 3 for factors that may alter the DO and temperature relationship.

Relationship Between Temperature and Solubility
(or How much oxygen water can hold at a given temperature)

Temperature (° C)	Solubility (mg/L)	Temperature (° C)	Solubility (mg/L)
0	14.6	16	10.0
1	14.2	17	9.8
2	13.8	18	9.6
3	13.5	19	9.4
4	13.1	20	9.2
5	12.8	21	9.0
6	12.5	22	8.9
7	12.2	23	8.7
8	11.9	24	8.6
9	11.6	25	8.4
10	11.3	26	8.2
11	11.1	27	8.1
12	10.9	28	7.9
13	10.6	29	7.8
14	10.4	30	7.7
15	10.2	31	7.4



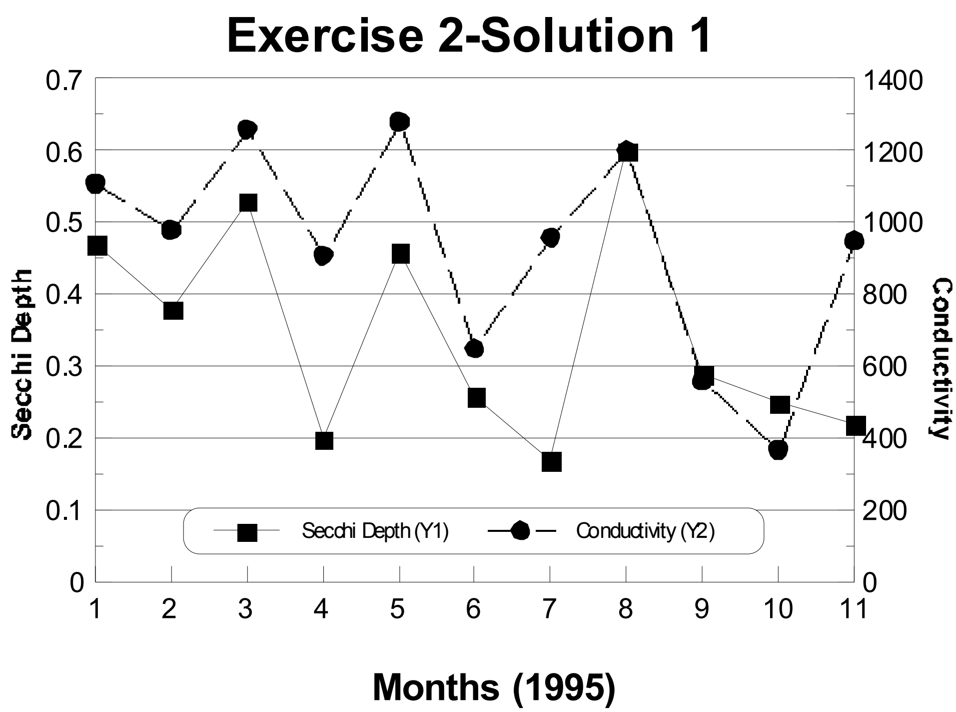
Exercise 2 Solution: The Relationship Between Water Clarity, Conductivity, and Rainfall

Solution 1:

◙ Rainfall events were the likely cause for the variation in the Secchi disk depth and the conductivity at this site.

◙ Because rainwater is so pure, it can dilute the amount of dissolved salts in a water body causing a decrease in conductivity.

◙ Sechi disk depth, on the other hand, generally decreases with rainfall due to high amounts of particulate matter in the water column. Rainfall tends to increase turbidity by disturbing the bottom sediment (increased flow) and carrying sediment into the stream through runoff.

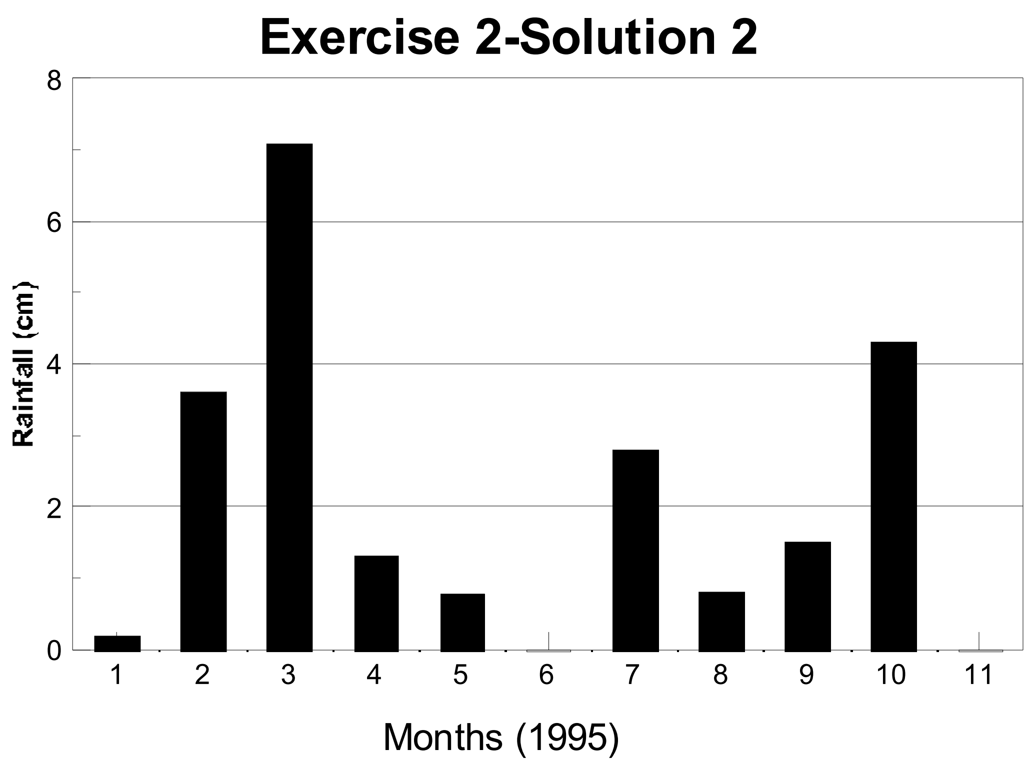


Solution 2:

As you can see by the graph, not all of the high and low Secchi disk depths and conductivity measurements were inversely related to rainfall events. There are two possible reasons for this:

1. The rainfall data was taken at or near the site, and therefore would only include rain that fell on the local watershed. It is possible that a rainfall occurred in the watershed upstream of the site that affected the conductivity and turbidity in the stream. This would not be reflected on a data sheet for the site.

2. The rainfall data is recorded as total rainfall in the last seven days. If the rainfall occurred six days prior to sampling, the turbidity and conductivity would have recovered to or near normal levels by the time samples were taken.

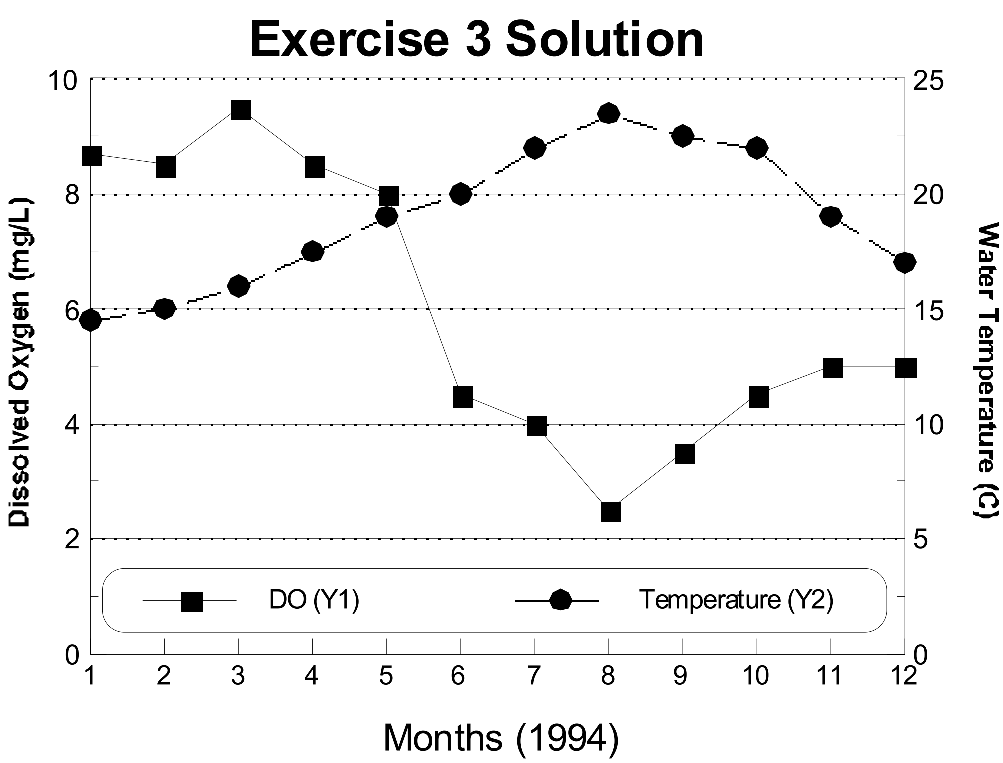


***Exercise 3 Solution*: Sudden Changes in DO**

There are two possible solutions to this exercise:

1. The person monitoring this site changed the time data was collected from mid-day to early evening. The change in DO can be attributed to the normal 24-hour DO fluctuations occurring in most water bodies. Data was collected from 1/94 to 5/94 at mid-day when production is greater than consumption (higher DO). From 6/94 to 12/94 data was collected to early evening when consumption is greater than production (low DO).

2. The changes in DO occurred during June, July, August, and September. The decrease in DO also corresponds to an increase in water temperature. This is a common occurrence in urban streams during warm summer months. Large amounts of wastewater treatment plant effluent and urban runoff (both often high in nutrients) can also contribute to decreased DO levels. Plankton blooms are the result of excessive nutrients and often result in depressed oxygen levels in urban streams. Fish kills, caused by low DO, are common during warm summer months. See the “General Information” section for additional information.



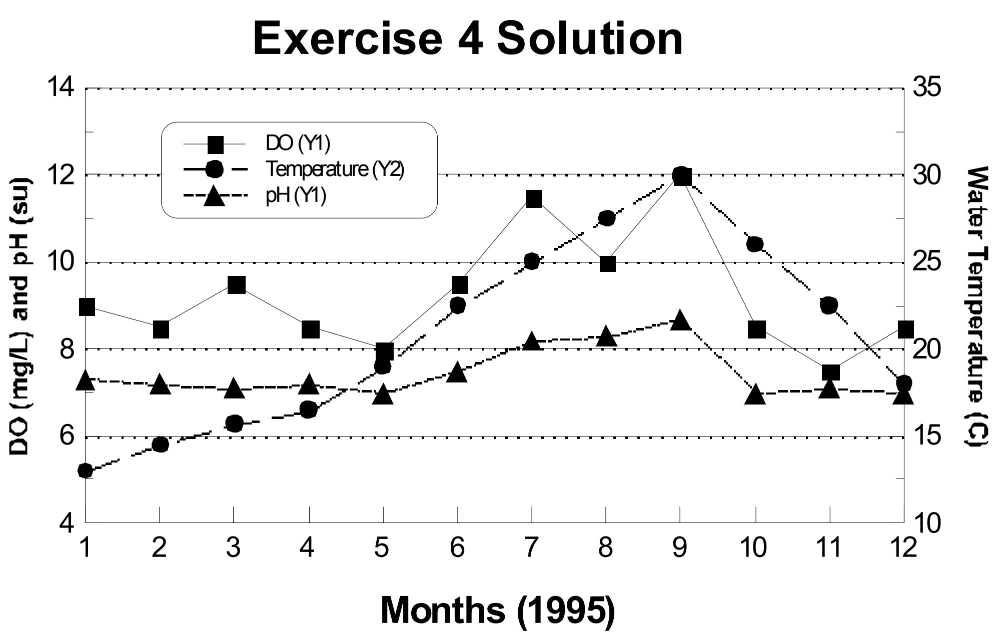
Exercise 4 Solution: Temperature, DO, and pH In An Urban Stream

◙ Wastewater treatment plants add nutrients to the creek. While ammonia is removed in the treatment process, other nutrients are not (phosphorus and nitrates).

◙ Runoff from the golf course, parks, and lawns contribute to the elevated nutrient levels in the creek.

◙ Continuous flow in the creek helps keep the DO levels up during June and September and can be associated with plankton blooms. Signs of this are high DO levels even though the water temperature is high. Normally, when the water temperature is high, the DO should be low due to a reduction in the water's ability to hold oxygen. The bright pea green water and elevated pH levels are also signs of plankton blooms.

◙ If the data had been collected during the early morning hours the DO would have been much lower. See Exercise 3.



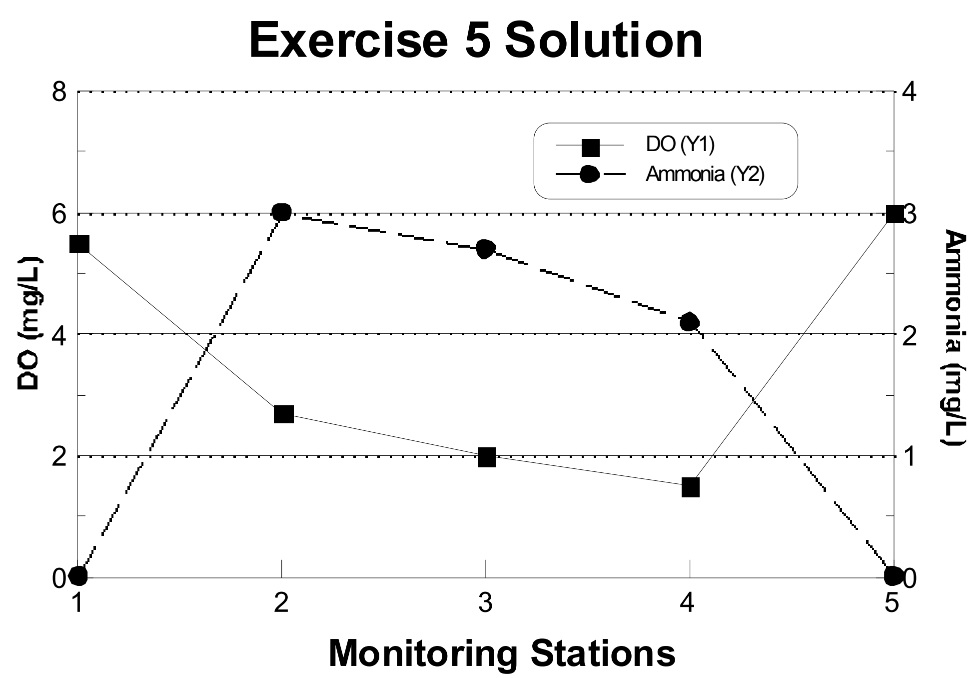
***Exercise 5 Solution*: Ammonia and DO in Cow Creek**

◙ The probable cause is a bypass of overflow of raw sewage from the City lift station located next to a tributary upstream of Station 2. Power failure is a common cause of bypasses from lift stations (points in a wastewater treatment plant collection system).

◙ Very high fecal coliform counts, high ammonia levels, and low DO indicate raw sewage.

◙ Additional evidence would be the milky gray to dark gray water with a rotten egg odor. The rotten egg odor is a sign that the creek is septic (caused by decomposing organic matter which in turn causes a severe reduction in DO levels).

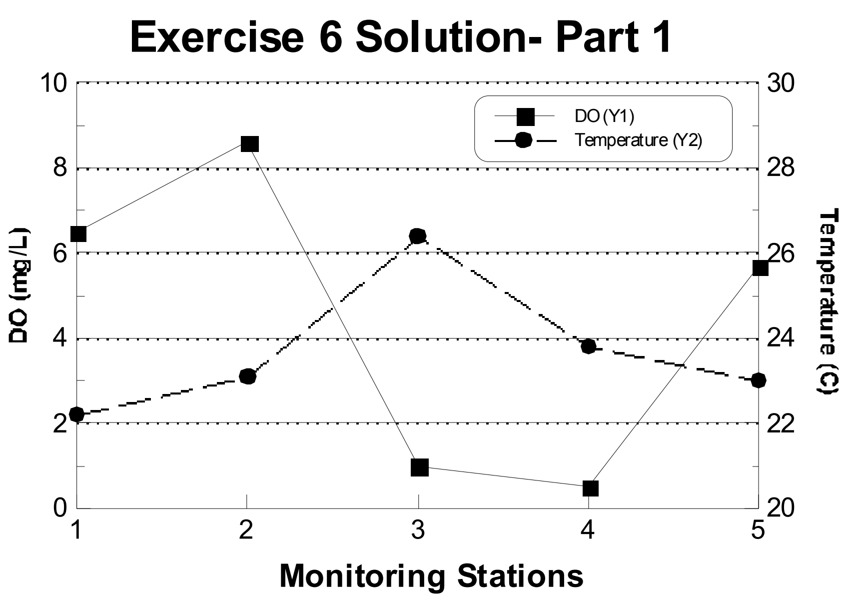
◙ The raw sewage created a ***DO sag*** downstream of the tributary. DO sag is a term that refers to the reduction of DO levels below the point of an oxygen demanding waste discharge. This relates to the effects of organic wastes on the waters downstream of a discharge point (for example, wastewater treatment plants, animal feeding operations, food processing plants). Oxygen demanding waste discharged into a stream causes a zone of degradation downstream of the discharge point. The time and distance a sag moves downstream and the point of recovery (increases in DO) depends on various factors, which include the discharge volume, the stream flow, concentrations of pollutants in the discharge, temperature, and re-aeration capabilities.



Exercise 6 Solution: DO, Temperature, and Fish Kills in Clam Creek

◙ The largest problem on the creek is the heated water discharge in combination with other factors. If the heated water was discharged to a "normal" creek the effects might not be the same. The effects of the heated water discharge are compounded by:

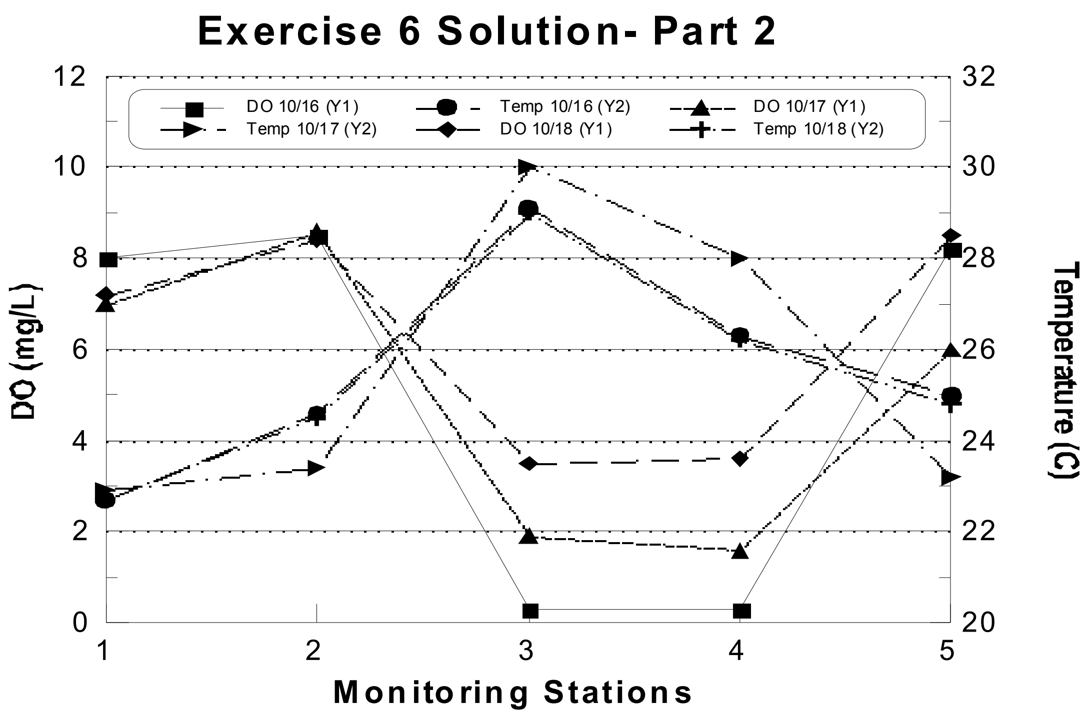
1. Dam structure reduces water movement and causes stagnant conditions
2. Refinery discharge containing some oxygen demanding waste detected by the odor
3. Variable flow rates
4. Increased population and development
5. Water from a large river, containing elevated nutrients and suspended solids
6. Elevated nutrients from agricultural runoff



◙ The weather was the greatest change. The normal nighttime DO decrease was compounded by three days of cloudy, calm, and warm days. The cooler, sunny weather and wind caused the DO to climb.

◙ DO levels in Clam Creek are chronically low. Fish populations in the creek seem to have acclimated to the warm temperatures and low oxygen levels. Most fish kills begin when the DO levels drop below 2 mg/L. However, in impacted urban streams where nutrients are high, and stream flow often sluggish, fish can acclimate to low DO levels, and kills may not occur until levels are less than 1 mg/L.

◙ Fish kills in Clam Creek have occurred when there was flow. Dead fish were noticed below the dam. Flow can push the oxygen deficient water from behind the dam to the area downstream. The "new" water pushes out the stagnant water causing the same problem downstream.



Notes