Trip B-19

THE EFFECT OF URBANIZATION ON WATER QUALITY

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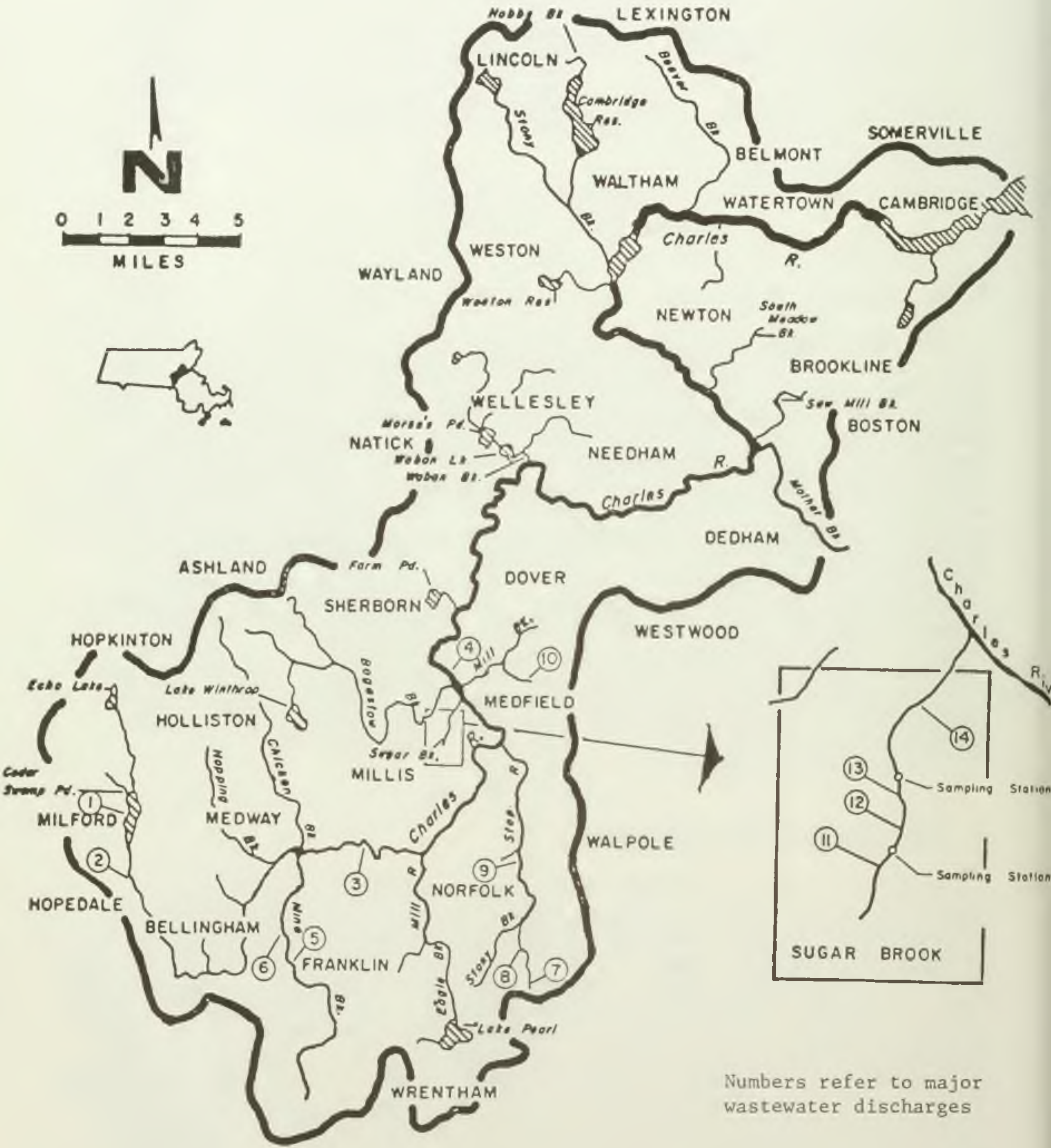
I. Introduction and Purpose

In his forward to the Circular 601 Series, Hendricks (1969) states in part, "Urbanization -- the concentration of people in urban areas and the consequent expansion of these areas -- is characteristic of our time. It has brought with it a host of new or aggravated problems that often make new demands on our natural resources and our physical environment. Problems involving water as a vital resource and a powerful environmental agent are among the most critical." This trip will examine the Charles River, a river which well illustrates Hendricks' concern. The Charles rises in a rural setting but almost immediately flows through an urban area and the effect of this passage on the quality of the water is marked. The river continues on its course through both urban and rural settings, ending in an artificially impounded area termed the Charles Basin. The basin, an area greatly modified by man, serves as a sink for various forms of effluent from the densely populated urban areas of Boston and Cambridge. This trip will examine the quality of water at several points along the Charles River and explanations for the level of water quality encountered will be offered. Several field testing kits will be available for use and the results obtained from them will be charted and discussed.

II. Description of the Watershed

The Charles River watershed is an elongated, hourglass shaped area approximately thirty miles long and five to fifteen miles wide comprising 307 square miles. The source of the Charles is a spring flowing from Honey Hill in Hopkinton (see map, figure 1). Runoff from this spring flows into Echo Lake which is generally considered to be the headwater of the river. The watershed varies in elevation from 586 feet above mean sea level along the south westerly divide in Hopkinton to less than 10 feet along its lower reaches. The river is almost 80 miles in length and falls a distance of 350 feet from Echo Lake to the Charles Basin where the water surface if normally maintained at 2+ feet. The gradients of the various river reaches are controlled by the approximately twenty-two dam locations spaced at irregular intervals along the river. The western and northern parts of the watershed are moderately hilly while the eastern and southern areas are characterized by more rolling topography and extensive swampy areas. Marsh and wetlands make up about one tenth or 20,000 acres of the watershed.

THE CHARLES RIVER WATERSHED



(after Massachusetts Water Resources Commission, 1974)

Figure 1

The climate is humid temperate with an average annual temperature of 49°F, and an average annual precipitation of 44 inches distributed evenly over the year. Discharge data recorded at 4 U.S.G.S. gaging stations within the watershed are as follows:

Location of Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge (cfs)		
			Mean	Maximum	Minimum*
Charles River at Charles River Village, Mass.	184	1937-1969	292	3,220	0.9
Mother Brook at Dedham, Mass.	--	1931-1969	77	1,040	0
Charles River at Wellesley, Mass.	211	1959-1969	312	2,410	1.0
Charles River at Waltham, Mass.	227**	1931-1969	368	2,670	0.2

*Minimum daily
**Excludes 23.6 square miles drained by Stony Brook

The Charles River flows through the most highly populated watershed in Massachusetts. The 1970 population was in excess of 810,000 persons with the highest densities (13,000 - 14,000 per mile in Boston and Cambridge) in the highly developed urban areas of the lower watershed. The Charles River flows over bedrock of pre-Paleozoic to Mesozoic age which is mantled by unconsolidated glacial drift. The upper tributaries generally are underlain by older formations while upper Paleozoic rocks are found under the lower reaches of the river. The river generally flows in till and on bedrock in its upper reaches and in unconsolidated glaciomarine and outwash sediments in the middle and lower reaches. The course of the river is controlled in great measure by the pattern of the surficial sediments overlying the bedrock. Frimpter (1973) shows the location of several thin, irregular shaped deposits of sand and gravel serving as ground-water reserves in the watershed and the influence these have on the course of the river is well illustrated.

III. Water Quality

Urbanization, in one form or another, has dominated the Charles River ever since man began to settle permanently near it. During the initial colonization of the river in the period 1630-1675, twelve settlements were built along 75 miles of the 80 mile river, and we haven't stopped since. The watershed is now outlined by interstate expressways I-495, I-90, and I-95. State highways liberally crisscross the area. These transportation routes link up the 35 communities which lie wholly or partially in the watershed. That degradation of the Charles River is occuring due to this urban growth is obvious, and one of the best ways to measure this degradation and its intensity, is by determining the quality of the water. Some of the standard water quality parameters and their definitions are given below. (Definitions are taken from Massachusetts Water Resources Commission, 1976, and Cragwell, 1975.)

Biochemical Oxygen Demand (BOD) - The amount of oxygen required by bacteria to stabilize organic matter. BOD consists of two parts, carbonaceous and nitrogenous. The carbonaceous portion occurs first; compounds of carbon are broken down with the carbon released combining with oxygen to form carbon dioxide. In the nitrogenous portion, organic compounds of nitrogen are broken down to ammonia which in turn is converted to hydrogen gas and, successively, nitrite and nitrate. Although the total BOD of a waste may take 30 days or more to exert itself, the portion exerted after 5 days has become the standard test through recurrent usage. The 5 day BOD of untreated sewage normally ranges from 150 to 300 mg/1. Streams not subject to pollution will normally have 5 day BOD's of 2.0 mg/1 or less.

Coliform Bacteria - Found in abundance in the intestinal tract of warmblooded animals. Although not harmful themselves, the presence of coliforms often indicates that pathogenic bacteria are also present. Since they can be detected by relatively simple test procedures, coliforms are used to indicate the extent of bacterial pollution. Tests are often conducted to measure the total and fecal coliform. Fecal coliform make up about 90 per cent of the coliforms in fecal matter. Non-fecal coliform may originate in soil, grain, or decaying vegetation. Untreated sewage contains upwards of 20,000,000 coliforms per 100 milliliters. The legal maximum for swimming areas is 1000 coliform per 100 ml, while for public water supplies it is 100 per 100 ml.

Color - In water analysis the term "color" refers to the appearance of water that is free from suspended solids. Many turbid waters that appear yellow, red, or brown when viewed in the stream show very little color after the suspended matter has been removed. The yellow-to-brown color of some waters is usually caused by organic matter extracted from leaves, roots, and other organic substances in the ground. In some areas objectionable color in water results from industrial wastes and sewage. Clear deep water may appear blue as the result of a scattering of sunlight by the water molecules. Water for domestic use and some industrial uses should be free from any perceptible color. A color less than 15 units generally passes unnoticed. Some swamp waters have natural color in excess of 300 units.

Dissolved Oxygen (DO) - The uncombined oxygen in water which is available to aquatic life; DO is therefore the critical parameter for fish propagation. Numerous factors influence DO, including organic wastes, bottom deposits, stream hydraulic characteristics, nutrients, and aquatic organisms. Saturation DO, or the equilibrium concentration, is primarily a function of temperature. DO values in excess of saturation are usually the result of algal blooms and therefore indicate an upset in the ecological balance. Optimum DO values range from 6.0 mg/1 (minimum allowable for cold water fisheries) to saturation values. The latter range from 14.6 mg/1 at

0°C (32°F) to 6.6 mg/l at 40°C (104°F).

Dissolved solids - Theoretically, dissolved solids are anhydrous residues of the dissolved substances in water. All solutes affect the chemical and physical properties of the water and result in an osmotic pressure. Water with several thousand mg/l of dissolved solids is generally not palatable, although those accustomed to highly mineralized water may complain that less concentrated water tastes flat. The U.S. Public Health Service recommends that the maximum concentration of dissolved solids not exceed 500 mg/l in drinking and culinary water on carriers subject to Federal quarantine regulations, but permits 1,000 mg/l if no better water is available.

Hardness - Hardness is the characteristic of water that receives the most attention in industrial and domestic use. It is commonly recognized by the increased quantity of soap required to produce lather. The use of hard water is also objectionable because it contributes to the formation of scale in boilers, water heaters, radiators, and pipes, with the resultant decrease in rate of heat transfer, possibility of boiler failure, and loss of flow. Generally, bicarbonate and carbonate determine the proportions of "carbonate" hardness of water. Carbonate hardness is the amount of hardness chemically equivalent to the amount of bicarbonate and carbonate in solution. Carbonate hardness is approximately equal to the amount of hardness that is removed from water by boiling. Noncarbonate hardness is the difference between the hardness calculated from the total amount of calcium and magnesium in solution and the carbonate hardness. The scale formed at high temperatures by the evaporation of water containing noncarbonate hardness commonly is tough, heat resistant, and difficult to remove.

Hardness range (calcium carbonate in mg/l)	Hardness description
0-60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

Ammonia-Nitrogen - Nitrogen in the form of dissolved ammonia gas (NH_3) or ammonium ion (NH_4^+). Concentrations over one or two mg/l are toxic to certain fish and other aquatic organisms. Nitrification of ammonia by bacteria to nitrite and nitrate exerts a biochemical oxygen demand. Ammonia is also a nutrient for algae and other aquatic plants.

Nitrate-Nitrogen - Nitrogen in the form of dissolved nitrate ion (NO_3^-). Nitrate is a primary nutrient for algae and other aquatic plants.

Total Kjeldahl-Nitrogen (Total Kjeldahl-N) - The sum of ammonia-nitrogen and nitrogen in all organic forms (which may include living cell matter). Bacterial decomposition of organic forms rapidly produces ammonia-nitrogen, perhaps resulting in toxic ammonia concentrations.

pH - A measure of the hydrogen ion concentration of a solution on an inverse logarithmic scale ranging from 0 to 14. Values from 0 to 6.9 indicate acidic solutions, while values from 7.1 to 14 indicate alkaline solutions. A pH of 7.0 indicates a neutral solution. Natural streams usually show pH values between 6.5 and 7.5, although higher and lower values may be caused by natural conditions. Low pH values may result from the presence of heavy metals from acid mine drainage or metal finishing waste. High pH values may result from detergents or limestone quarrying.

Specific conductance (micromhos per centimetre at 25°C) - Specific conductance is a convenient, rapid determination used to estimate the amount of dissolved solids in water. It is a measure of the ability of water to transmit a small electrical current. The more dissolved solids in water that can transmit electricity the greater the specific conductance of the water. Commonly, the amount of dissolved solids (in mg/l) is about 65 percent of the specific conductance (in micromhos).

Temperature - Temperature is an important factor in properly determining the quality of water. This is very evident for such a direct use as an industrial coolant. Temperature is also important, but perhaps not so evident, for its indirect influence upon aquatic biota, concentrations of dissolved gases, and distribution of chemical solutes in lakes and reservoirs as a consequence of thermal stratification and variation.

Total Phosphorus (Total P) - The sum total of phosphorus in all forms in which it may be present, including dissolved and particulate, organic and inorganic, in living cells and, most importantly, in the form of dissolved phosphate ion ($PO_4^{=}$). Phosphate is a primary nutrient for algae and other aquatic plants.

Turbidity - Turbidity is the optical property of a suspension with reference to the extent to which the penetration of light is inhibited by the presence of insoluble material. Turbidity is a function of both the concentration and particle size of the suspended material. It is reported in terms of mg/l of silica or Jackson turbidity units (JTU).

Sources of pollution along the Charles include point sources such as municipal sewers and sewage treatment plants, institutional discharges from hospitals and prisons, and industrial discharges. Fourteen major point sources have been identified in the watershed upstream from the Watertown Dam. These are located in figure 1. Other point sources are sewer overflows and bypasses, disposals of sewage sludge, and discharges of cooling water. Non point sources include urban runoff, subsurface disposal (cesspool and septic tank leakage), the effect of dams, leachate from sanitary landfills, wetland discharge, agricultural practices (fertilizers), and mining.

IV. Field Trip Schedule

A formal road log will be available for distribution at the Conference. The morning schedule will focus on the upper part of the watershed, especially from the source of the Charles down to below the town of Milford. There are some very interesting dynamics present in the rise and fall of dissolved oxygen and BOD levels due to the impact of the town of Milford. Lunch will be at a location in the middle part of the watershed. It will probably not be practical to buy food on the way so be sure to bring a lunch. The afternoon will be spent in and around the lower part of the river in the portion below the Watertown Dam known as the Charles Basin. This is by far the most highly polluted part of the river. It is "fed" by an intricate network of streams, outfalls, and sewage overflows. The layer of sludge on the bottom of the basin will be discussed and sampling will endeaver to show the layered nature of the waters in the Charles Basin.

The entire river is included on the following U.S.G.S. Massachusetts topographic quadrangles:

Boston South	Holliston
Newton	Franklin
Natick	Blackstone
Medfield	Milford

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________________ 1974b, The Charles River, part b.

________________ 1975, The Charles Basin, part a.

________________ 1976, The Charles River, part d.