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COMPETITIVE WATER USES: SANITARY ENGINEERING ASPECTS

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The words "water competition" usually suggest the classic struggles for water in the arid and semi-arid states of the west. The water supplies there are simply inadequate to go around, and water is accordingly valuable. The fights for water have been bitter. The situation in the west has been aggravated by the fact that many of the uses are consumptive uses, and much of the water does not return to the stream or ground.

In the eastern states the water supply is more abundant and consumptive uses have been relatively small. The conflict between water users has been a matter of quality. However, in spite of this, the east has had its own disputes over diversion, as evidenced by the Pawtuxet River diversion to serve Providence, the Ware and Swift River diversions for metropolitan Boston, and the Delaware River diversion for New York City.

Probably the most important consumptive water use in the country is irrigation, and in this respect the east is approaching more rapidly the western conditions than is generally realized. All along the Atlantic seaboard, from South Carolina to New England, supplemental irrigation is growing by leaps and bounds. Well water has been used extensively on Long Island and New Jersey for many years. Surface water is impounded in literally thousands of farm ponds in Virginia and the Carolinas. The growth of these farm ponds has already had an appreciable effect on municipal water supplies

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taken from the rivers further downstream. In states predominantly agricultural in character, political considerations are likely to favor the farmer, and the municipalities will have to scratch to get the necessary supplies. To date the emphasis has been on individual irrigation developments, but it is reasonable to expect that group action through irrigation districts will follow in years to come. As evidence of the growing importance of farm use, the Corps of Engineers has estimated water requirements to be met from the Potomac River in 1970 as follows:

Water supply purposes—	375	million	gallons	per	day
Supplemental irrigation—	160	"	"	"	"
Pollution abatement—	650	"	"	"	"
Total	1,185	"	"	"	"

In North Carolina, where there are many textile mills in the relatively small cities surrounded by farming activity, all of these mills are faced with waste treatment in the next few years. The suitability of the treated effluent for use as irrigation water is likely to determine the degree of treatment in many areas.

The reverse effect, that is, the effect of irrigation on water quality in the streams, is not likely to be significant in the eastern states for many years to come. In arid countries, however, the return water from irrigated lands is always more saline than the original supply, and in some places the total solids become so high as to make the water unsuitable.

The importance of irrigation in particular areas is illustrated by a case which recently has come to my attention. In the Beaufort, S. C., area, ground water has been used for many years to serve the local population, the Marine Corps camp on Parris Island, the Naval Hospital and the Naval Air Station. In recent years a large truck farming activity has been added for which the water requirements are substantial, perhaps enough to jeopardize the adequacy of the existing ground water supply. It has been suggested that the irrigation water be taken from a deeper strata which is known to yield water high in fluorides in order to preserve the upper strata for domestic purposes. Information is being collected on the existing water supplies in the area for an appraisal of the safe yield and determination of the future program.

Future irrigation requirements are stressed here because in so many places they are beginning to have an important bearing on our eastern water supply developments. The next 10 or 15 years will see many changes.

For the sanitary engineer, conflicts between water uses develop in respect to both the quantity and quality of water. The conflicts between water users most frequently involve one or more of the following:

(1) Diversion of water from one drainage area to another. This reduces the flows below the diversion and may result in inadequate water supplies, inadequate dilution of wastes, and greater salt water intrusion from the ocean.

(2) Pollution of water supplies, fish and shellfish areas, and recreational facilities by sewage and industrial waste.

(3) Salting of fresh water bodies by the construction of navigation channels at the lower end of coastal rivers.

The pollution of ground water resources with sewage or industrial wastes, and the salting of ground water resources by changes in adjacent stream channels for navigation and other purposes are important in some sections of the country and frequently are difficult to assess and control properly. However, the scope of this paper is limited to surface water problems.

Where topography permits, upstream impoundments and diversions have been the most favored methods of obtaining municipal and industrial water supplies throughout the east. This has been especially true where the drainage area was such that the water could be used without filtration. Further developments along these lines become less favorable because of the cost and difficulty of finding suitable reservoir sites, because it is usually necessary to release a substantial flow of water during the dry season to meet downstream uses, and finally because the water frequently must be filtered in any event.

The release of water for downstream uses increases substantially the cost of impounding reservoirs. In connection with some industrial water supply studies in North Carolina, we investigated the possibility of storage reservoirs on several of the coastal rivers. In each case release of water downstream below the reservoir during periods of drought would be needed not only to take care of existing water uses, but more important in order to provide dilution water for the waste that would be discharged from the proposed mill. Generally, in such situations even though adequate waste treatment is proposed, the dilution water requirements are harder to meet than the water supply requirements.

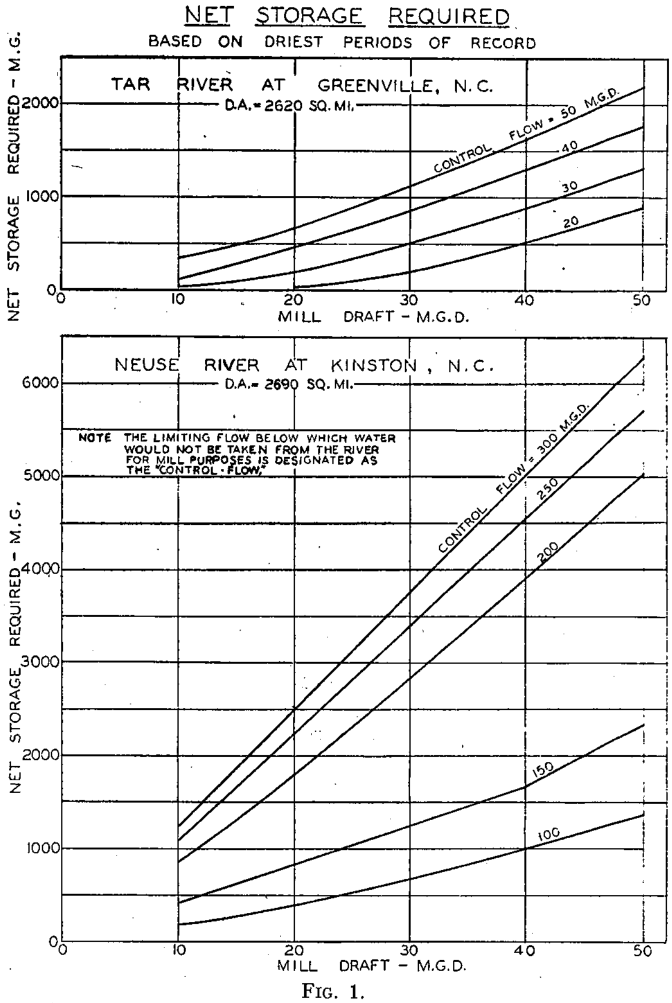


FIG. 1.

Figure 1 shows the effect of downstream releases on the quantity of storage to be provided. It will be noted from these graphs that, for example, a 40 m.g.d. supply from the Tar River with no diversion when the natural flow was less than 20 m.g.d. would require a 500 million gallon storage reservoir. If the downstream limit were increased to 40 m.g.d. the storage requirements would be 1,300 million gallons, or 2½ times as much. The data for the Neuse River shown at the bottom of Figure 1 indicates even greater storage to meet downstream requirements. Similar studies for rivers in Pennsylvania, Maryland, and New York show comparable ratios.

It should be noted that the previous calculations indicate the additional storage needed if no diversions are made when the natural flow drops to specified limits. If releases are required from the reservoir to maintain downstream flows equal to these limits, at all times, the storage reservoirs must be larger—usually 25 to 50 per cent.

As concrete evidence of the importance of downstream releases, one may cite the Delaware River development of New York City now under construction. Approximately 1/3 of the reservoir capacity is reserved specifically in order to maintain low flows in the Delaware River.

The required downstream releases are sure to increase in the future, and provision for them will add substantially to the cost of upland water supplies.

The effects of pollution on water supplies, shellfish, commercial and sport fishing, and recreational facilities need no comment. These are competing water uses. However, in nearly all parts of the United States, unrestrained pollution is no longer tolerated, and some degree of treatment is required. Only rarely is it necessary to approach clean-water conditions in sewage and waste treatment, because of the natural purification available in receiving rivers and lakes. This is fortunate because of the high cost of providing truly complete treatment. Economy dictates that we reserve a part of our water resources to assist in waste disposal.

The importance of dilution water may be illustrated by the situation in Greensboro, N. C., where we are presently engaged in the development of additional water supply and waste disposal facilities. This is a sizeable project with many facets, and will require major additions to existing works. The two sewage treatment plants will have to be enlarged, and it is expected that one of the plants will be a combined sewage-textile waste treatment plant. Pilot plant studies are now underway, with the assistance of Camp, Dresser & McKee, Consulting Engineers of Boston.

Greensboro is located at the extreme upper end of the Cape

Fear River basin. All of the nearby streams are small, and there is little water available for water supply and waste disposal (see Figure 2). The existing water supply is taken from Lake Brandt, an 800 m.g. reservoir impounding the runoff from a 70 sq. mi. drainage area. The safe yield is approximately 12 m.g.d. A second reservoir

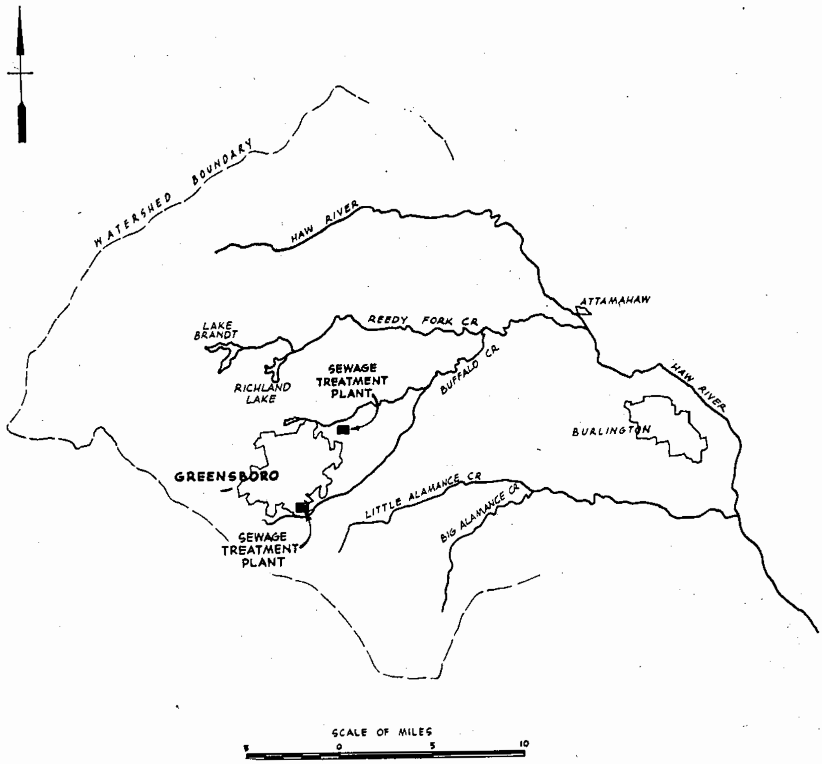


FIG. 2.—REGIONAL MAP, GREENSBORO, N. C.

now under construction will increase the yield to 15 or 16 m.g.d., but is recognized as a stop-gap measure. Richland Lake, also in the Reedy Fork drainage area, is owned by Cone Mills, a large textile concern, and furnishes 4 to 5 m.g.d. industrial water for mill use.

The wastes from the city and much of the outlying area are treated at two plants: one on North Buffalo Creek and the other on South Buffalo Creek. Both plants are overloaded, and conditions in Buffalo Creek and the lower part of Reedy Fork Creek are far from satisfactory. Aside from biological considerations, the color of the textile dye wastes in North Buffalo Creek is sometimes a source of complaint. The pilot plant studies are directed toward ultimate treatment of the textile mill waste in the North Buffalo plant. This will reduce the BOD loading, but no satisfactory answer to the color problem is in sight.

The section of water most seriously affected by pollution is the lower (7-mile) stretch of Reedy Fork, between Buffalo Creek and the Haw River. It is generally recognized that the most useful function of Buffalo Creek and its two branches is to carry off the waste of the Greensboro area. The treatment to be provided must be adequate only to prevent nuisance here. Reedy Fork Creek, however, is in a somewhat different category, and farmers along it have urged the N. C. State Stream Sanitation Comm. to see that the water is good enough for supplementary irrigation. The Cape Fear River basin is now under study by the Stream Sanitation Committee, and classification of the tributaries will be completed within a year or two. How far the Committee will go will undoubtedly depend upon the pressure exerted by downstream owners and the feasibility of meeting fully their demands.

Stream surveys in years past, and especially during the dry summer of 1954 showed severe oxygen deficiencies in the lower part of Reedy Fork Creek. The Haw River joins Reedy Fork Creek below Attamahaw, almost doubling the drainage areas, and conditions between there and Burlington are reasonably satisfactory. The dry-weather flows of all of these rivers are small, as indicated by probability plots of minimum monthly flows for two streams in the vicinity of Greensboro (Figure 3). The low monthly flows in an ordinary year are only about 0.2 c.f.s. per sq. mi., and every 10 or 15 years the minimum monthly runoff may drop to 0.1 c.f.s. per sq. mi. Furthermore, low flows are likely to persist for several months.

The present waste loads and the water available for dilution at various points along the stream are summarized in the following tables.

From the preceding data it is evident that even with high treatment efficiencies, difficulty must be anticipated in Buffalo Creek, and even the lower part of Reedy Fork will suffer from time to time. This is of prime importance to Greensboro because one of the most promising methods of increasing the City's water supply would be to build additional reservoirs on Reedy Fork. Our studies have shown that by utilizing a drainage area of 100 square miles and increasing the total storage capacity to perhaps 4,700 m.g., a safe yield of 35 to 40 m.g.d. could be obtained. However, if this is done, dilution water in Reedy Fork will be decreased still further.

A. SEWAGE AND WASTE LOAD

Plant Influent	*(1) North Buffalo Creek*	*(2) South Buffalo Creek*	*(3) Total*
Municipal sewage m.g.d.	5.6	2.3	7.9
Industrial waste m.g.d.	5.6	1.7	7.3
Total	11.2	4.0	15.2
Population equivalents (BOD)	215,000	70,000	285,000

B. RECEIVING WATER AVAILABLE

	(1) At North Buffalo S.T.P.	*(2) At South Buffalo S.T.P.*	*(3) At Mouth of Buffalo Creek*	*(4) At Mouth of Reedy Fork Creek*
Drainage area—s.m.	23	30	100	259
Estimated mean annual flow—c.f.s.	25	32	107	250*
Estimated dry monthly stream flow—c.f.s.:				
Once every 2 years	5	6	21	40**
Once every 5 years	3	4	14	27**
Once every 10 years	2.5	3.5	11	21**

*Less 22± c.f.s. diverted for water supply purposes by Greensboro and Cone Mills.
**Assuming no releases from Lake Brandt.

On the other hand, if the additional storage were used not only for water supply but also to supplement dry-weather flows of Reedy Fork Creek, we could obtain for a few years both water supply and waste disposal benefits. We have estimated that for several years the lower part of Reedy Fork Creek can be maintained in good condition if minimum flows are controlled to approximately 30 c.f.s., or 20 m.g.d. in addition to the plant discharges. The storage required to provide this flow under ordinary conditions (say 90 per cent of the time) would be approximately 900 m.g. or 20 per cent of the anticipated water supply requirements. A reservoir built now to meet water needs several years hence would have surplus capacity that could be used to advantage in the immediate future for waste dilution.

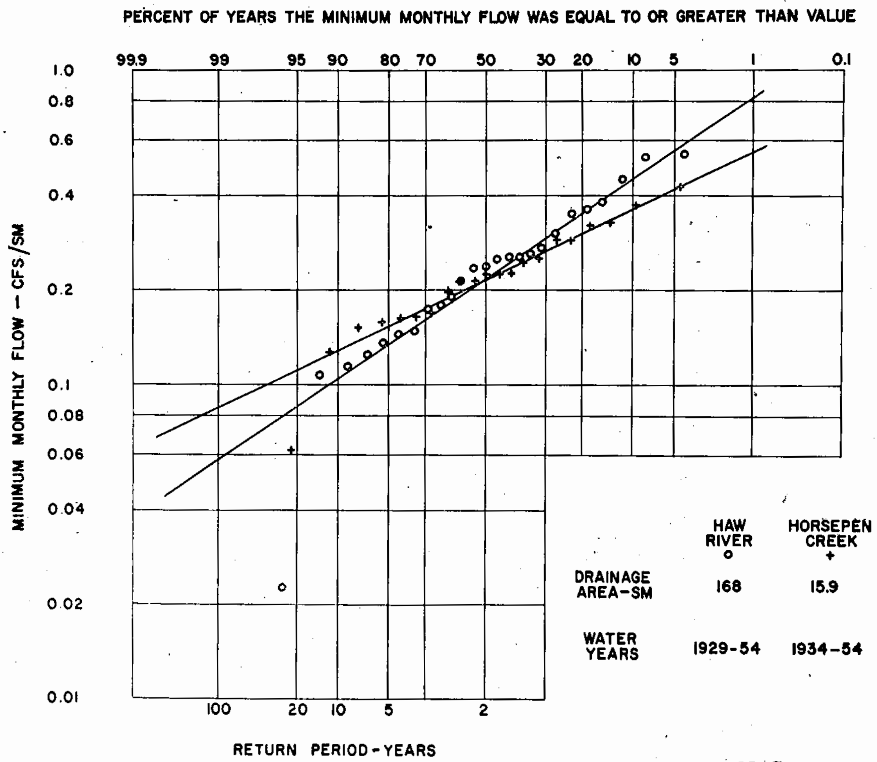


FIG. 3.—PROBABILITY PLOT OF MINIMUM FLOWS NEAR GREENSBORO, N. C.

Ultimately, Greensboro and several of the adjacent cities probably will have to obtain water from a larger river, some distance away. The Yadkin River, west of Greensboro, seems the most likely source, and the possibilities of a regional development are being studied. For Greensboro, not only the relative cost of a regional supply, but the ultimate solution of its waste disposal problem must be considered. A supply from the Yadkin will involve inter-basin diversion and reduction of stream flows already used for hydropower development. Regional water supplies, involving a number of cities and varied interests often take years to develop, and the final outcome cannot be anticipated. However, Greensboro is fortunate in that whatever it builds on Reedy Fork Creek can be used to good advantage ultimately to improve waste disposal if the regional water supply scheme is realized. The construction of low-flow regulating reservoirs for pollution abatement costs more than waste treatment to accomplish the same results. In this case, where natural flows are so low, both measures may be needed.

An entirely different situation exists in the Detroit, Michigan, area, where a practically unlimited supply of water is available from the Detroit River (see Figure 4). The Detroit River connects Lake St. Clair with Lake Erie. The flow past Detroit ranges from 104,000 to 241,000 c.f.s., and averages 177,000 c.f.s. The Detroit water supply is taken from the upper end of the river. Other municipal intakes are located in the river at Windsor, Wyandotte, and Amherstburg, and in Lake Erie near Point aux Peaux for Monroe.

Windsor and Amherstburg do not have sewage treatment plants. On the U. S. side most of the sanitary sewage receives primary treatment and chlorination at the Detroit plant before it is discharged into the Detroit River just above the mouth of the Rouge River. There are two smaller sewage treatment plants in Dearborn which discharge into the Rouge River, and two Wayne County plants which discharge into the Detroit River below Wyandotte. The principal sources of pollution in the Detroit River are the sewage treatment plant effluents and storm overflows from combined sewers on the U. S. side, raw sewage discharges on the Canadian side, and industrial waste discharges on both sides of the river. It is obvious that the Detroit River plays an essential part in carrying off the wastes of this large metropolitan and industrial area. At the same time it serves as a primary shipping artery of the nation, as an important recreational area, and as the source of public and industrial water supplies. That the lower Detroit River can be used for water supply purposes with safety is due to the unusual stratification of the water. The tremendous volume of water and negligible lateral mixing protect the water in the center of the stream from shore pollution.

We have just completed an investigation of the feasibility of supplying water to the area south and west of Detroit from an intake in the lower Detroit River or western Lake Erie. This area is growing rapidly and additional works are needed. The cost of bringing

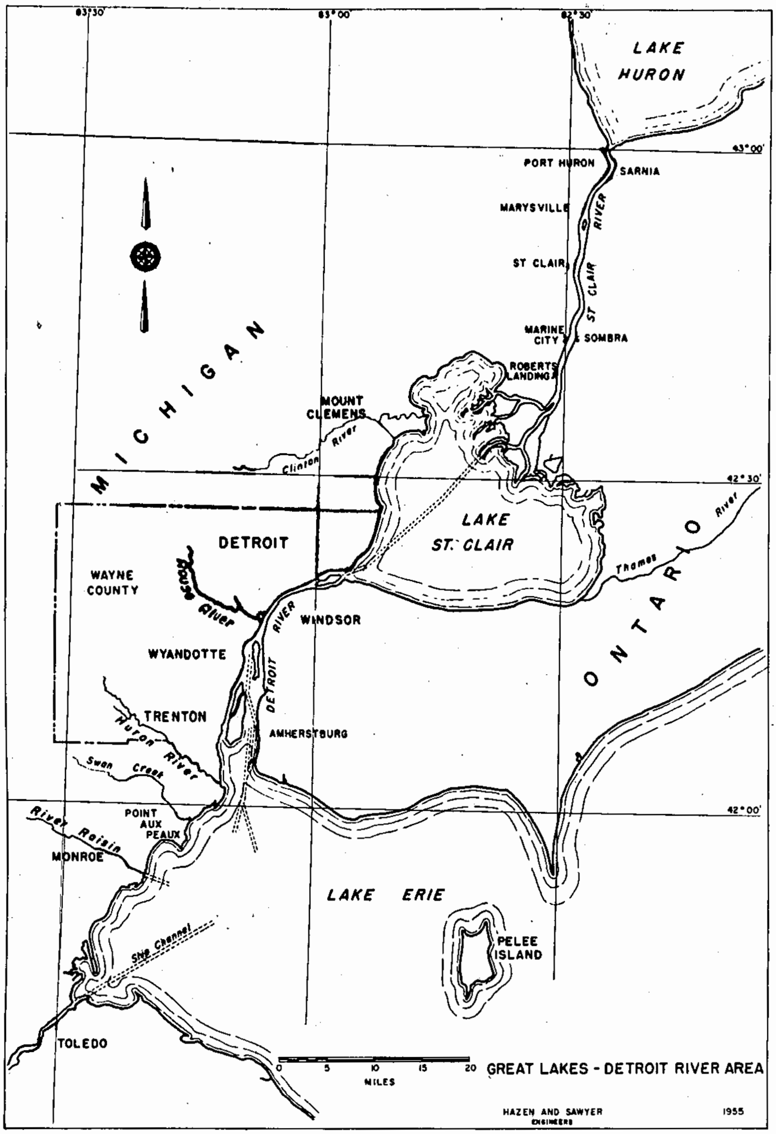
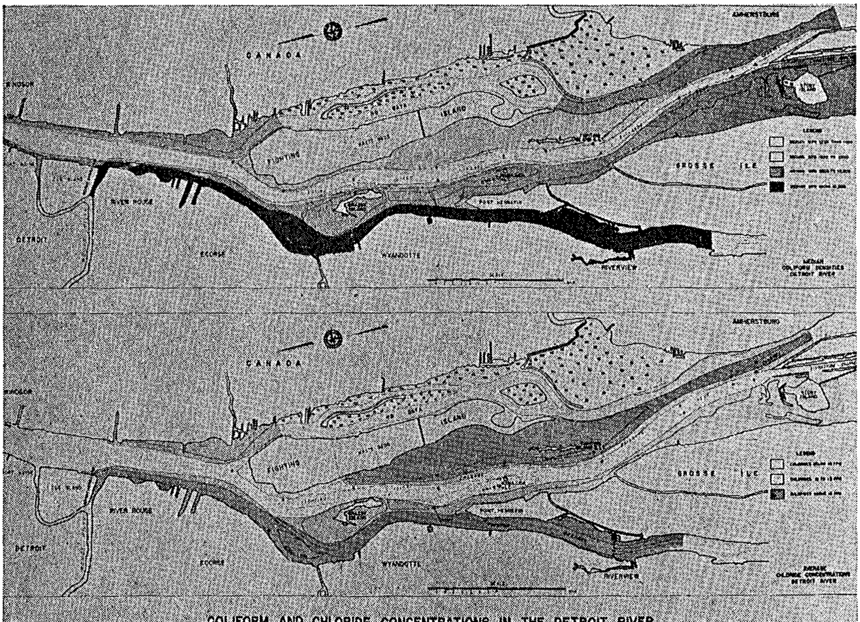

LAKE HURON
PORT HURON
SARNIA
MARYSVILLE
ST CLAIR
ST CLAIR RIVER
MARINE CITY
SOMBRA
ROBERTS LANDING
MICHIGAN
MOUNT CLEMENS
Clinton River
LAKE ST. CLAIR
DETROIT
WAYNE COUNTY
Rouge River
WINDSOR
DETROIT RIVER
WYANDOTTE
TRENTON
Huron River
AMHERSTBURG
Swan Creek
POINT AUX PEAUX
River Raisin
MONROE
Thames River
ONTARIO
LAKE ERIE
PELEE ISLAND
Ship Channel
TOLEDO
0 5 10 15 20
MILES
GREAT LAKES - DETROIT RIVER AREA
HAZEN AND SAWYER
1955

FIG. 4.

water from the upper part of the river, or still further north, through the city to the area to be served would be extremely high, and the development of a nearer supply would have many advantages. Our report has not yet been released, and I am not free to discuss the findings. However, the two illustrations following show clearly the segregation of clean water from polluted water, and areas in the river where an intake could best be located.



COLIFORM AND CHLORIDE CONCENTRATIONS IN THE DETROIT RIVER

FIG. 5.

The upper part of Figure 5 shows the distribution of median coliform density in the Detroit River between the Rouge River and upper end of Grosse Ile. The white area shows the part of the river with a median MPN of less than 1,000 p.p.m.; the most heavily shaded area represents median MPN's greater than 10,000. Extreme values, represented by the 90% value and A.M.D. are somewhat higher, but follow the same pattern. The data collected in 1955 confirm the results of the I.J.C. surveys in 1913 and 1946-48, and numerous other studies to show the distribution of pollution.

The lower part of Figure 5 shows the chloride distribution over the same stretch of the river. The chloride concentration parallels the sewage contamination as would normally be expected. However, much of the chlorides are due to industrial waste, especially along Fighting Island, where there is leaching from chemical waste beds on the island.

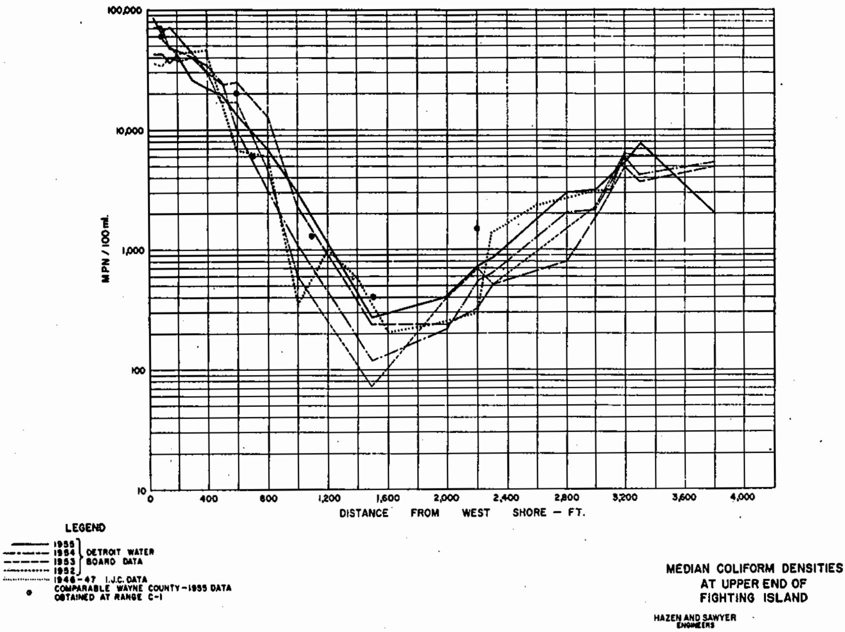


FIG. 6.

The lateral distribution of coliforms is brought out sharply by the profiles shown in Figure 6 representing the median MPN values at the head of Fighting Island as determined by surveys over six different years.

The situation at Detroit is an unusual one. It shows that water below a large city is not necessarily bad, and that by taking proper precautions provision can be made for both water supply and waste disposal. As a practical matter, the most serious water supply problem—including the City's water supply—is the severe taste following occasional discharges of phenol-bearing wastes upstream. The Detroit, Wyandotte, Windsor, Amherstburg and Monroe water purification plants have consistently produced safe water, but taste control is still a problem.

The conflict between water supply and navigation requirements is reflected frequently by the encroachment of salt water caused by the deepening and widening of shipping channels near the mouth of coastal rivers. Wilmington, N. C., for years obtained its water supply from the Cape Fear River within 2 miles of the city. By 1941 channel improvements permitted the salt to reach many miles upstream, and a raw water line had to be extended to the first navigation lock 22 miles away. At Savannah, Ga., the same thing occurred, except that until about 1940 the City used wells and was not dependent upon the Savannah River. When a surface supply was built, the intake had to be located several miles inland.

In considering several of the North Carolina rivers as a source of industrial water supply, the existing or proposed navigation requirements made it necessary to allow for locating the intake several miles upriver to avoid salt. The necessary pipelines, or canals in some instances, represented a substantial part of the estimated cost. In some cases, the actual navigation benefits were nil, or extremely small. It would seem time to consider the possibility of abandoning the rarely-used ship channels and the installation of low dams to prevent salt water encroachment. In many areas the water supply benefits would more than make up for losses in shipping.

Lake Maracaibo in Venezuela has been an important source of fresh water down through the years. The total solids and salinity in the lake water reached limits higher than desirable from time to time, but the water was usable. Enlargement of the shipping channel near the mouth, combined with low stream runoffs, have aggravated the situation in recent years, and the lake is fast losing its value as a source of water supply. Ground water is limited and the lake supply will be missed.

Perhaps the most important case in recent years involves the proposed dredging of a deep-water channel in the Delaware River, above Philadelphia, to the Fairless Works of U. S. Steel. The effect of salt water encroachment on water supplies in the area is of major importance, and several investigations have been made to determine whether or not the channel enlargement would be harmful. These investigations, including extensive model studies at Vicksburg, have indicated that the channel can be built safely.

The few instances discussed, and countless others, demonstrate the competitive situation into which water supply and other water-using activities are moving. From this certain conclusions as to future trends and needs seem obvious:

1. the growing demands for water for all purposes—and especially for irrigation—are going to tax the water resources in many eastern states unless reservoirs are built to store flood flows for use later in the dry season. Our water law, based largely on the riparian doctrine, is in for rough sledding. A sudden switch to the appropriation doctrine of the west is not likely—and in itself will produce no more water—but a movement in that direction seems inevitable. Organization of public water districts, with the power to condemn lands and rights of way, is receiving support in many states where it is recognized that regional action is needed.

2. Fewer and fewer cities will enjoy the benefits of pure, impounded mountain water. Present-day water treatment processes permit the use of water contaminated beyond limits previously established. Emphasis will have to be placed on reliability of treatment and the ability to take shock loads. Included in this are more frequent and more rapid methods of raw water analysis so that trouble can be detected soon enough to do something about it.

3. There is great need for fully effective and reliable taste and odor control. The public is more influenced by taste than any other factor. If we can learn to consistently produce a safe water that tastes good, many raw water supplies heretofore dismissed can be used successfully.

4. On the other side, we are going to have to insist on continuous and certain treatment of sewage and wastes. Our water treatment methods are based upon extreme conditions, and a normally good source of supply may be rejected because at rare intervals upstream waste treatment fails. When the regularity of sewage and waste treatment operation reaches that of most water purification plants, shock loads will be at a minimum. The added cost of providing regularity and reliability is not excessive in most instances.

5. In industrial waste treatment, particular emphasis must be placed on the elimination of toxic and taste-producing substances. In some instances money so spent would be far more useful than "primary treatment" or "complete treatment" according to some statewide formula.