A STUDY OF THE WATER QUALITY AND FLOW OF STREAMS IN SOUTHEASTERN WISCONSIN

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INTRODUCTION
The SEWRPC planning program places much emphasis on the natural resource base of the Region, both as it affects and is, in turn, affected by the selection and use of land for residential, commercial, industrial and recreational purposes. The chemical quality of the streams within the Region, their condition of pollution and their flow, must be taken into account when land use regional plans are prepared. Any meaningful assessment of the possible effects of urban development on the surface water resources of the Region requires definite information about the quality and quantity of the water in the Region's major streams. A study of the water quality and flow of streams in southeastern Wisconsin is, therefore, an important part of the natural resource base studies being undertaken as an integral part of the SEWRPC regional land use-transportation study.

The importance of stream water quality to regional development stems from the limitations that are imposed on water use by the natural mineralogic composition of stream water and by the organic and inorganic pollutants that are introduced into the streams by man from domestic, municipal, agricultural, commercial and industrial uses. These limitations restrict the use to which water can be put, depending upon the mineral concentration, and the type and quantity of pollutants that are present. The economic, aesthetic and recreational potential of any area is, therefore, closely dependent upon water quality.

Purpose of the Study
The purpose of the regional water quality and streamflow study is to provide definitive knowledge essential to planning land and water development and management on a regional scale. Specific objectives of the study are:

1. to determine the present condition of stream water quality (chemical and bacteriological) in relation to existing major sources of stream pollution.

2. to determine the effect of water quality on various water uses and concomitant effects on land use patterns.

3. to predict future water quality in the Region's watersheds under alternative long-range regional development plans.
The findings of the study will be presented as a technical report that includes tables, graphs, and maps relating to current conditions of stream water quality and flow, and showing predicted future conditions under the several alternative long-range regional development plans.

Scope of the Study
The major categories of work necessary to fulfill the purpose and objectives of the study include:

1. The establishment of 87 stream sampling stations distributed over the 12 major drainage basins within the Region as listed below:

<table>
<thead>
<tr>
<th>Drainage Basin</th>
<th>Number of Sampling Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Plaines River</td>
<td>3</td>
</tr>
<tr>
<td>Fox River</td>
<td>28</td>
</tr>
<tr>
<td>Kinnickinnic River</td>
<td>1</td>
</tr>
<tr>
<td>Menomonee River</td>
<td>12</td>
</tr>
<tr>
<td>Minor streams draining into Lake Michigan</td>
<td>3</td>
</tr>
<tr>
<td>Milwaukee River</td>
<td>12</td>
</tr>
<tr>
<td>Oak Creek</td>
<td>2</td>
</tr>
<tr>
<td>Pike River</td>
<td>4</td>
</tr>
<tr>
<td>Rock River</td>
<td>13</td>
</tr>
<tr>
<td>Root River</td>
<td>6</td>
</tr>
<tr>
<td>Sauk Creek</td>
<td>2</td>
</tr>
<tr>
<td>Sheboygan River</td>
<td>1</td>
</tr>
</tbody>
</table>

2. The compilation of a photographic record of each sampling station to provide detailed information on its situation and landmarks.

3. A transit and tape field survey of each stream sampling station to record bridge or culvert dimensions (all stations are at locations where streams are crossed by bridges or flow through culverts), stream cross section and the angle of bridge traverse across the stream. This information is necessary for the determination of streamflow and provides a map record of the sampling station.

4. The establishment of a bench mark for stream stage measurement at each sampling station. From this information it is possible to evaluate the general conditions of streamflow at the time of each monthly sampling.

5. The collection of stream samples on a monthly basis at the 87 sampling stations. Data derived from the analyses of these samples provide the basic information regarding the chemical and bacteriological quality of the streams.

6. The measurement of streamflow during seasonal periods of high and low flow. Data derived from measurement of the streamflow, supplemented by long term flow records of permanent, continuous recording flow gages, provide the basic information regarding the quantity of water flowing through the main streams and major tributaries of the stream systems of the drainage basins.
7. The collection of existing water quality and streamflow data from Federal, state, municipal and certain private sources. Data derived from these sources will form a necessary and extremely valuable supplement to the data collected by the SEWRPC.

8. The selection and application of standards of water quality for various water uses in order to permit mapping water quality in a meaningful manner.

9. Correlation of present stream quality and flow to present sources of pollution and centers of population. This information is necessary for forecasting future conditions of stream quality in relation to the alternative land use-transportation plans.

Cooperating Agencies
The agencies most familiar with water quality and stream pollution problems within the Region are the Wisconsin State Board of Health, the State Committee on Water Pollution, and the Public Health Service of the U. S. Department of Health, Education and Welfare. These agencies have made their experience freely available to the SEWRPC and have made significant recommendations regarding the technical aspects of the water quality study. The State Committee on Water Pollution is providing the SEWRPC with invaluable laboratory services in running the laboratory determinations of biochemical oxygen demand (BOD) and of coliform count. The U. S. Department of Health, Education and Welfare has contributed to the study by providing the SEWRPC on a loan basis with analytical instruments, chemical reagents, analytical glassware and streamflow measuring equipment including such items as a Price current meter, a bridge crane, a pygmy current meter, and miscellaneous supporting equipment. Indeed, without the cooperation of these state and Federal agencies, the SEWRPC water quality study would not have been possible.

Duration of the Study
The water quality study commenced on December 2, 1963, when the staffing of the project was completed. The stream sampling program was started on January 20, 1964, at which time all the necessary equipment for the study had been gathered, and the study design completed. The sampling program is scheduled for completion on March 1, 1965.

FIELD OPERATIONS
Field operations started with the inspection of potential sampling station sites to determine their suitability for stream sampling and streamflow measurement. These sites had to be easily accessible the year around; and for this reason, highway bridges and road culverts were chosen as sites. An adequate dispersal of sampling sites over all major streams had to be achieved in keeping with the regional approach to the water quality study. Sufficient density of sampling control had to be achieved, however, in areas of known or anticipated heavy pollution. As a result of office and field investigations, 87 sampling sites were finally selected and established as stream sampling stations. Forty-seven of these stations are used also for the measurement of streamflow. Map 1 shows the location of the sampling stations within the 12 drainage basins of the Southeastern Wisconsin Region.
Map 1
WATER SAMPLING STATION LOCATIONS

LEGEND
● SAMPLING STATION
- WATERSHED BOUNDARY

MAP SCALE:
GRAPHIC SCALE IN MILES

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Identifying the Stations

A photograph was taken of each sampling station at the time the sites were originally inspected. This photographic record is a part of a card file maintained on each sampling station which includes data on the specific location of the stations referred to the U. S. Public Land Survey system.

A permanent identification code was assigned to each sampling station within each drainage basin. The codes consist of a two-letter prefix representing the drainage basin and of a number representing the particular sampling station within the basin. The sequence of these numbers are in accordance with standard U. S. Geological Survey usage. These station numbers were painted on the respective bridge abutments and culverts in an inconspicuous location so that the stations could be readily identified at a later date. Bridges traversing a stream in a general east-west direction had the sampling station number painted on the west abutment under the bridge deck on the downstream side of the bridge. Bridges traversing a stream in a general north-south direction had the sampling station number painted on the north abutment under the bridge deck on the downstream side of the bridge. Where culverts are involved a similar system of locating the sampling station number is used. Culverts that are traversed by roads having a general north-south direction are marked on the downstream side toward the north end.

Stream Cross Sections

A two-man survey crew was placed in the field during the early months of the field operations. Each sampling site was surveyed to determine the dimensions of the bridge or culvert waterway openings to measure the stream cross sections, and to determine the angle at which the bridges traversed the streams. These data were then summarized in the form of location sketches of the sampling station areas and in the form of bridge and stream cross-section drawings.

Water Sampling Procedures

The actual water quality sampling was begun on January 20 after all the necessary equipment for water analyses and streamflow measurement had been assembled. The sampling program, which is still in progress, consists of collecting three water samples each month at each of the 87 stations, and a fourth sample at certain selected stations where additional data on the chemical quality of water is needed. Two samples are submitted to the State Board of Health for determination of biochemical oxygen demand and of coliform count. A third sample is collected and prepared in the field under standard procedures for dissolved oxygen determination. This sample and a fourth sample for chemical analysis are retained by the SEWRPC for analytical determinations. The chemical analyses performed by the SEWRPC include silica, iron, manganese, calcium, magnesium, sodium (calculated), bicarbonate, carbonate, sulfate, chloride, nitrite, nitrate, detergents, dissolved solids (calculated), hardness, noncarbonate hardness, calcium hardness, magnesium hardness, alkalinity "P," alkalinity "M," specific conductance at 25° C., pH, color and turbidity. Figure 1 shows the form used by the SEWRPC in recording the chemical analyses and computed streamflow measurements. Also included on the form are spaces for recording the biochemical and bacteriological parameters determined by the Wisconsin State Board of Health.
Figure 1

FORM USED TO RECORD CHEMICAL, BIOCHEMICAL AND BACTERIOLOGICAL ANALYSES AND COMPUTED STREAM FLOW DATA

<table>
<thead>
<tr>
<th>Drainage basin:</th>
<th>Sampling station number:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Station description:

Station location: 1/4, 1/4, 1/4 sec. T. N., R. E.

Date of sampling: 1966 Day of sampling: __________

Water temperature at time of sampling: __________ °C (________ °F)

<table>
<thead>
<tr>
<th>Silica (SiO₂)</th>
<th>Iron (Fe)</th>
<th>Manganese (Mn)</th>
<th>Calcium (Ca)</th>
<th>Magnesium (Mg)</th>
<th>Sodium (Na) calculated</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bicarbonate (HCO₃⁻)

Carbonate (CO₃⁻)

Sulfate (SO₄⁻)

Chloride (Cl⁻)

Nitrite (NO₂⁻)

Nitrate (NO₃⁻)

Detergents

Dissolved solids, calculated

Hardness as CaCO₃

Noncarbonate hardness as CaCO₃

Calcium hardness as CaCO₃

Magnesium hardness as CaCO₃

Alkalinity "F" as CaCO₃

Alkalinity "M" as CaCO₃

Specific conductance at 25°C

pH

Color

Turbidity

All determinations are expressed in parts per million except specific conductance and pH.

BIOCHEMICAL AND BACTERIOLOGICAL WATER ANALYSES

Biochemical oxygen demand (BOD)

Dissolved oxygen (DO)

Membrane filter coliform count (MPCC/100ml)

STREAM STAGE AND STREAM FLOW MEASUREMENTS

Stream stage: __________ feet below measuring point that is located __________.

Date and time of measurement: 1966, at __________ a.m./p.m.

Stream flow: __________ cfs on __________, at __________ a.m./p.m. Cross sectional area of stream: __________ sq. ft. Average stream velocity: __________ ft/sec.
The original plans regarding streamflow measurement involved making monthly flow measurements at selected stations within the Region, with a much larger number of flow measurements being made during periods of high and low flow. However, as the field work progressed, it was decided that streamflow measurements would instead be made extensively during the months of high and low flow. To supplement this streamflow data, stream stage measurements are made monthly at the 87 sampling stations at the time of stream sampling. This program of stream stage measurement was started in June, 1964, and will continue through February, 1965.

Streamflow measurements are made by means of a pygmy current meter and a small Price current meter following standard procedures set forth in the U. S. Geological Survey Water Supply Paper 888, "Stream-gaging Procedure." Data are obtained also from permanent U. S. Geological Survey stream gaging stations and from the SEWRPC flood gaging stations located on the Fox, Milwaukee, and Root Rivers and on Oak Creek.

LABORATORY PROCEDURES
A discussion of the analytical procedures used in determining the chemical and bacteriological parameters will be presented in a technical report which will serve as a documentation of procedures that will facilitate evaluation of the analytical results and permit duplication of procedures for future water quality studies. The analytical procedures to be discussed will pertain to all parameters listed on the form in Figure 1 and in addition to chromium, fluoride, phosphate, cyanide, and oil which will be determined by the State Board of Health for certain samples collected during periods of low flow.

ESTABLISHMENT OF WATER QUALITY STANDARDS
Numerical expressions of the chemical and bacteriological qualities of water are not meaningful for planning purposes unless related to quality standards for the various water uses. The establishment of water quality standards is a particularly difficult task in that either no standards at all, or no uniform standards, have been established relating water quality to the many water uses. The present study of water quality by the SEWRPC deals with 32 quality parameters relative to 10 principal water uses. Recommendations will be made as to the level of water quality suitable for the following water uses in terms of the pertinent parameters determined from the field sampling:

1. Public water supply.
2. Agriculture other than irrigation.
3. Preservation of fish and wildlife.
4. Recreational use.
5. Industrial.
6. Irrigation.
7. Aesthetic.

8. Waste water assimilation.

9. Drainage and navigation.


MAPPING OF STREAM WATER QUALITY
The establishment of suitability standards for the quality parameters relative to the major water uses tested above will permit the mapping of water quality within a drainage basin in terms of suitability relative to use. Without such standards, water quality can be mapped only in terms of arbitrary ranges of concentration that would lack significance to land use planning.

Each stream which was surveyed will be mapped along its reaches on the basis of existing water quality according to its suitability for the water use categories listed above. Possible changes in the mapped use pattern as a result of further urbanization will be explored. The ability of each reach to absorb additional waste loadings due to continued urbanization without a deterioration of water quality will be determined, and recommendations will be made on suitable land use patterns on the basis of present and probable future water quality conditions. Recommendations will also be made on possible ways of improving existing levels of water quality.

SUMMARY
Land and water are closely inter-related resources, and urban development is heavily dependent upon surface water resources for the dilution of treated sewage wastes, for the recharge of ground water tables, for recreational purposes, and in some cases, for water supply. As urbanization increases, waste outlets along the stream networks become more numerous and carry greater volumes of stronger and more complex wastes. Unless development is adjusted to the waste assimilation capacities of the natural streams, the multi-purpose utility of these streams will be destroyed and severe environmental problems created.

The purpose and intent of the SEWRPC water quality study are focused on the problem of estimating the impact that alternative land use plans will have on stream quality and flow. Describing present conditions of stream pollution relative to current major sources of pollutants and evaluating these relationships in terms of future land use requirements is the essential function of the study of water quality and streamflow.
The actual town site utilized approximately 5 percent of the total tract, the remainder being reserved as an agricultural greenbelt encircling the "urban" development. This agricultural greenbelt was intended to:

1. Limit the growth of Greendale itself.

2. Clearly define the Greendale boundaries so as to preserve its identity.

3. Prevent encroachment by unplanned communities expanding in a south-westerly direction from the Milwaukee core.

4. Provide a country setting for Greendale.

The original plan called for a development density of about 15 persons per gross acre (31 persons per net residential acre), with 572 dwelling units being provided to house a total planned population of 2500 on the 170-acre town site. The plan included provision for a variety of housing types ranging from single family dwellings to six-family rowhouses, and for a carefully designed functional street pattern which separated arterial from service streets; and, to a considerable extent, separated pedestrian ways from both. The plan provided for a shopping area, school and community building, administration building, fire and police building, and public works building, all conveniently grouped in a community center. Water and sewage purification plants and a central heating plant were provided as well as entirely underground electric power and communication systems.

The entire plan was admirable adjusted to the topography of its site. To conserve the natural beauty of the site, the plan provided for an integrated network of greenways connecting the various parts of the community to each other and to the surrounding agricultural belt. About 29 percent of the developed area of the town site was set aside in the plan for park and open space purposes, and carefully related to such natural features as the Root River. No industrial development was provided for in the original plan, a major departure from the garden city concept.

The plan for Greendale was completed in December, 1935; and construction was begun in May, 1936. By July, 1937, the 360 residential buildings provided in the plan were ready for occupancy as were the shopping area and public service buildings. The buildings, while diverse in form and placement, possessed architectural unity and the finished town possessed a charm and liveability which few other communities approach. Rents were low, no effort being made to meet capital recovery costs, but adequate to provide for operation and maintenance. By 1938, all of the residential units were being rented directly from the Federal

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Government, and the Greendale project became a living reality. The community became a village in 1938 and adopted the manager form of government. Since the Federal Government owned the entire area, the village government was supported by negotiated federal payments in lieu of taxes.

The townsit of Greendale as originally planned is shown shortly after completion of construction in the photo at left. Note the contrast between the village and its surrounding rural greenbelt, an early and excellent application of the "cluster development" concept to urban development. The photo at right shows the townsit of Greendale today. Note the new planned developments surrounding the original townsit.

The Greendale experiment flourished under the aegis of the Federal Government from 1839 to 1952 when lack of interest at the national level in continuing the greenbelt experiment, coupled with criticism of the experiment by some as a socialistic venture, caused the Federal Government to dispose of Greendale.

Maintaining the Concept Under Private Development
Several schemes were considered for the disposition of Greendale, including one which involved financing by and attachment to the central city of Milwaukee. It was finally decided, however, to sell the existing houses to individual purchasers giving first options to current tenants. Disposition of the shopping area, administration and public service buildings, and the vacant greenbelt land presented problems. Alarmed at the interest shown by several large national real estate speculators, three large Milwaukee corporations decided to join forces and purchase the greenbelt lands and community buildings. These corporations— the Allis Chalmers Manufacturing Company, the Kearney and Trecker Corporation, and the Boston Store—formed the Milwaukee Community Development Corporation (MCDC) with the expressed intention of conserving the improved property, and of sponsoring the planned extension of the original town site in as much harmony with the original garden city concepts as the economics of private enterprise would permit.