Stratford-Avon River Environmental Management Project

A FEASIBILITY STUDY FOR AUGMENTING AVON RIVER FLOW BY GROUND WATER


Hydrology and Monitoring Section
Water Resources Branch

1982
PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two year project was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P. is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases, the results presented are interim in nature and should not be taken as definitive until such time as additional support data is collected.

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ABSTRACT

This report considers the feasibility of using ground water to augment stream flow in the Avon River. A review of existing well records and geologic maps of bedrock and overburden was undertaken. Ground-water chemistry was assessed by a sampling and analysis program for area wells.

Results show that sufficient quantities of water might be available from bedrock sources near the river to provide for augmentation of 1 to 3 cfs. Pilot studies to identify well sites and assess well yields and interference problems would be required as part of further studies. As a cost reducing measure, the possibility of augmentation from Stratford city wells could be explored.

Based on ground-water and stream-water chemistry, the use of ground water for flow augmentation would serve to dilute most water quality constituents thus improving water quality.

(Work undertaken subsequent to the completion of this report indicates that an acceptable level of dilution for phosphorus would require in excess of 25 cfs or 9,000 gpm of augmentation, compared to the 1 to 3 cfs considered necessary at the time of the study documented in this report. In view of the much larger amounts of water now considered necessary, it is considered unlikely that bedrock aquifers in the study area could practically provide this level of augmentation.)

All data and results in this report, except those relating to water quality, are in English units because all the background hydrogeologic data derived from such sources as relevant topographic maps, water well records, etc., are available only in English units. Conversions of data from these sources to metric units proved to be too cumbersome. However, if conversions from English to metric units are necessary, the following factors can be used.
Metric Conversions

feet x 0.305 = metres
miles x 1.609 = kilometres
square miles x 2.590 = square kilometers
cubic feet/second (cfs) x 28.316 = litres/second
(Imperial) gallons x 4.546 = litres
(Imperial) gallons/minute x 0.0758 = litres/second
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1. INTRODUCTION

This investigation focuses on determining the feasibility of using ground water to augment flows in the Avon River by about 1 to 3 cfs (374-1122 gallons per minute). This augmentation would provide additional water during low flows for the assimilation of waste discharged from the Stratford sewage treatment plant (STP), and might help to reduce nutrient concentrations in the stream to discourage the growth of aquatic plants.

The primary area of study for ground-water augmentation extends about 2 miles on both sides of the Avon River between the City of Stratford and the confluence of the Thames River, a distance of approximately 10 miles in length. It was assumed that no separate supplies of ground water were available for augmentation within the City of Stratford in order to ensure adequate future supplies for the city. A secondary area under possible consideration for flow augmentation extends upstream for about 3 miles from Stratford city limits. Although this area appears likely to contain sufficient ground water, flows in this portion of the Avon River are non-existent at certain times of the year and flow augmentation would not be physically feasible during these times. Hydrogeologic data are presented in Appendix A for this area but are not dealt with in this report.

For economic and practical reasons, the target for the development of ground water for flow augmentation is limited to adjacent lands on both sides of the Avon River extending from the sewage treatment plant to about Avonton, a distance of approximately four miles. Water-well record data were used to determine the availability of ground water, supported by geologic maps of bedrock and overburden and related background data shown in the Thames River ground-water report (Goff, Brown, 1981). In addition, field work involved checking the surficial geology of the river banks and surrounding areas, and water samples were taken from selected wells for inorganic chemical analyses.
The surficial geology of the study area (Figure 1) consists primarily of lacustrine silt and clay, and sandy silt till with thin deposits of gravel, sand and silt along the length of the river. The overburden thickness in the area ranges from about 50 to 170 feet (Figure 2).

The bedrock consists mainly of grey and brown limestones of the Dundee, Lucas, and Amherstburg formations (Figure 3). The bedrock surface slopes in an irregular manner generally in an east-west direction and is characterized by a valley located south of the Avon River and running approximately parallel to it (Figure 4).

In the past study of ground water in the Thames River basin (Goff, Brown, 1981), bedrock aquifers were shown to be important in the Avon River basin where the current feasibility study is situated. In this area the limestones are exploited for large quantities of good-quality ground water and site-specific development of ground water for augmentation will likely depend on locating these sources adjacent to the Avon River.
**FIGURE 1:** SURFICIAL GEOLOGY

**Legend:**

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Lacustrine silt and clay</td>
</tr>
<tr>
<td>2</td>
<td>Stratford till clay till</td>
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<tr>
<td>3</td>
<td>Alluvium: stream deposits of gravel, sand and silt</td>
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<tr>
<td>4</td>
<td>Tavistock till: sandy silt till</td>
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<tr>
<td>5</td>
<td>Outwash gravel</td>
</tr>
<tr>
<td>6</td>
<td>Catfish Creek till: stoney, sandy to silty till</td>
</tr>
<tr>
<td>7</td>
<td>Rannoch till: clayey to silty till</td>
</tr>
<tr>
<td>8</td>
<td>Ice contact gravel: esker</td>
</tr>
<tr>
<td>9</td>
<td>Ice contact sand</td>
</tr>
</tbody>
</table>

**NOTE:** sequence of numbers does not designate age of deposits
Figure 3. Bedrock geology and aquifers.

**Dundee Formation**: Upper Member - medium brown limestone.
Lower Member - light brown limestone containing quartz sand and chert.

**Lucas Formation**: Anderdon Member - brown limestone.

**Amherstburg Formation**: Grey to dark brown limestone and dolomite, locally cherty, biuminous and biostromal.

Well location and number:
- Sampled bedrock well for water quality analysis.
Figure 4: Bedrock surface elevation contours

Scale
0 1 2 3 miles

-1000
-10000
10000
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

Bedrock well location and elevation (feet) of bedrock surface
Elevation contour (feet)
2. HYDROGEOLOGY AND GROUND-WATER AVAILABILITY

Bedrock formations contain the main water-bearing zones in the area, with only a small number of wells ending in sand and gravel formations in the overburden. The locations of known bedrock wells are shown on Figure 5. Due to the density of bedrock wells northwest of Stratford, only representative wells are shown in this area. Overburden wells for which records are on file with the MOE are plotted on Figure 6.

The main bedrock aquifers in the area are located in the Dundee, Lucas, and Amherstburg formations. The depths to water in bedrock wells range from 80 to 255 feet, with the majority of wells finding water at about 150 feet from the surface (Figure 5). Most wells find adequate (domestic) amounts of water within 50 feet below the bedrock surface. The piezometric surface in bedrock indicates a regional movement of ground water towards the Thames River, with a local deflection of ground water towards the Avon River (Figure 7).

Ground-water yields from bedrock are variable, but indications are that there is a potential for large capacity wells next to the Avon River (Figure 8). By way of example, the City of Stratford municipal wells obtain water from similar bedrock formations and well yields as high as 1000 gpm are on record.

There are only a few wells that end in overburden and the aquifers shown in Figure 9 are mainly shallow (less than 50 feet deep) sand and gravel formations yielding limited amounts of water (Figure 10). The narrow aquifers along the Thames and Avon rivers are thin floodplain sands and gravels at the surface and do not constitute a potential for obtaining large quantities of ground water. Although it is conceivable that some portions of the buried sand and gravel formations may yield larger quantities of water, the effort to find large capacity wells in overburden is questionable since bedrock is known to yield large amounts of water.
As with ground-water movement in the bedrock, regional, shallow movement in the overburden is towards the Thames River, with a strong local component of ground-water flow towards the Avon River. This is shown by the water table configuration in Figure 11. It indicates that the Avon River is receiving shallow ground water, although the amount of water is probably small because the shallow overburden materials are poorly permeable. Because the water table elevation throughout the study area is higher than the piezometric surface in bedrock, there can be no flowing wells in this part of the Avon River basin.

The occurrence of sand and gravel aquifers in the overburden, and the locations at which water is found in bedrock, are shown in five geologic cross-sections in Appendix B.
3. HYDROCHEMISTRY

Ground-water samples taken from selected bedrock and overburden wells were analyzed for the common inorganic parameters to ensure compatibility with surface-water quality. Thirteen samples were taken from bedrock wells and five samples were obtained from overburden wells. Their locations are shown on Figures 3 and 6. The results are plotted on Figure 12 to indicate the overall quality of these waters; their individual analyses are shown in Table 1. Most wells on Figure 12 indicate a predominance of Ca and HCO₃ typical of ground waters in overburden and bedrock in this area.

Water quality data recorded from January to August 1981 from nine sampling stations in the Avon River (Appendix C) show that five surface-water quality parameters can be compared to well samples gathered in the area: pH, chloride, nitrate, total phosphorus and specific conductance. Summary statistics are given in Table 2 for comparison. Ground-water pH results average 7.75 with generally higher levels for stream water. Levels of chloride in the river range from as high as 210 mg/L below the discharge point of the STP to as low as 20 mg/L at the confluence of the Thames River at Station 13; this compares with an average of 2.0 mg/L from bedrock well samples and 0.5 from overburden wells, omitting the anomalously high value of 155 mg/L in well 110. The high value is probably indicative of contamination and not representative of natural ground-water conditions in the area.

Samples from 14 of the 18 wells recorded nitrate levels of less than 0.01 mg/L, with the highest value of 5.53 mg/L. Nitrate levels in the stream vary widely, with most ranging between 4 and 10 mg/L. The amount of total phosphorus recorded in surface waters was, with some exceptions, under 0.5 mg/L. Generally low levels of total phosphorus were recorded in the well samples, with the exception of one high reading of 0.166 mg/L. The reason for this high reading is not known, but it is considered not indicative of the phosphorus levels in ground water in the area. The mean total phosphorus concentration in bedrock wells, omitting this observation is 0.025 mg/L.
Figure 12. Major ion chemistry of ground water.
Based on these cursory comparisons, in-stream mixing of ground and surface waters should be compatible and in most instances ground water discharged into the Avon River should improve inorganic chemical quality of the river. The degree of improvement will vary with location in the river and augmentation rate. Analysis completed after the writing of this report indicates an augmentation requirement of at least 25 cfs. This analysis is documented as an addendum in Appendix D.
### TABLE 1. WATER QUALITY RESULTS OF SAMPLED WELLS

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<tr>
<th>No.</th>
<th>Location</th>
<th>MOE Well No.</th>
<th>Owner's Name</th>
<th>pH</th>
<th>Fe (mg/L)</th>
<th>Ca (mg/L)</th>
<th>Mg (mg/L)</th>
<th>Na (mg/L)</th>
<th>K (mg/L)</th>
<th>SO4 (mg/L)</th>
<th>Cl (mg/L)</th>
<th>NO3 (mg/L)</th>
<th>TP (mg/L)</th>
<th>FRP (mg/L)</th>
<th>Total Alk (mg/L)</th>
<th>Total Hard (mg/L)</th>
<th>Temp (°C)</th>
<th>Sp Cond (μS/cm)</th>
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* M.O.E. well number not available for this well.

**Constituents in Milligrams per Litre**
- **Fe**: Iron
- **Ca**: Calcium
- **Mg**: Magnesium
- **Na**: Sodium
- **K**: Potassium
- **SO4**: Sulphate
- **Cl**: Chloride
- **NO3**: Nitrate
- **TP**: Total Phosphorus
- **FRP**: Filtered Reactive Phosphorus
- **Temp.**: Temperature
- **Sp. Cond.**: Specific Conductance at 25°C

**Abbreviations**
- **MOE**: Ministry of Environment
- **pH**: Potential of Hydrogen
- **Alk**: Total Alkalinity
- **Hard.**: Total Hardness as CaCO3
- **Con**: Concentration
## TABLE 2: COMPARISON OF GROUND-WATER AND STREAM-WATER CHEMISTRY - 1981

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** TP = Total Phosphorus (mg/L P); NO₃ = Nitrate (mg/L N); Cl⁻ = Chloride (mg/L); Sp. Cond. = Specific Conductance (umhos/cm²)
4. POSSIBLE ENVIRONMENTAL EFFECTS

The development of high capacity wells adjacent to the Avon River may cause interference with nearby domestic wells and also reduce the discharge of shallow ground water locally in the stream. The ultimate location and design of the augmentation wells would have to take these possibilities into account and existing MOE policies on interference through the Permit To Take Water program would apply. Any wells that are designed to pump more than 50,000 litres per day will require a Permit To Take Water from the MOE, and site-specific data on possible interference will be evaluated prior to issuing a Permit.

Because the wells are to be pumped periodically and presumably for only short periods during low flows, interference is not expected to be a major constraint to an augmentation project.

5. RECOMMENDATIONS

As a next step in the augmentation project, a pilot study using available City of Stratford (untreated) ground-water supplies should be considered. The pilot study should be run at various augmentation rates to determine the possible effects of augmentation on river water at various points in the river. This would indicate whether expected improvements in river water quality are possible, and the amount and quality of ground water necessary for these improvements.

Assuming the pilot study is successful in improving river water quality to the desired degree, the use of ground water from the city supplies should be investigated. The use of existing ground water from city supplies would reduce the ultimate cost of the augmentation project considerably and be most practical in a situation where the capital
project costs can be high and may not be justified if intermittent augmentation during low flows only is anticipated. Buying of city water at a reduced cost below the cost of developing and maintaining separate ground-water supplies may be a viable option.

If and when separate ground-water wells are required for flow augmentation, and after some form of pilot study has proven to be successful, test drilling should be carried out. Potential test drilling sites should be located as close to the river as possible and generally between Stratford and Avonton. Road allowances may be used where possible. Test drilling should be conducted into bedrock to locate suitable quantities of water, followed by appropriate pumping tests to determine the amount of water available, its quality as pumping progresses, and the potential cone of interference around the test wells. Assuming that the pilot study has shown a flow augmentation of 1-3 cfs (374-1122 gpm) to be adequate, up to about three separate supply wells might be needed to obtain the required quantity. The test drilling sites for each of the supply wells should be picked progressively further downstream from the Stratford STP.

Based on current drilling costs applied for three test holes in the area, about $10,000 per well would be required just for test drilling. Additional costs for hydrogeologic consultants to analyze the test drilling data and make recommendations for subsequent work in the project would be needed.

Assuming that the test drilling is successful in locating sufficient quantities of good-quality water, the final design of the flow augmentation project can be undertaken.
BIBLIOGRAPHY


Karrow, P.F. and assistants, 1974, Quaternary geology of the St. Mary's map area, southern Ontario; Ont. Div. Mines, Map 2366.


Water well records on file with the MOE as of September 1981.
APPENDIX A

Background Hydrogeologic Data for the Upper Portion of the Avon River
BEDROCK GEOLOGY

Legend:

Lucas Formation: Anderson Member: brown limestone

Amherstburg Formation: Grey to dark brown limestone and dolomite, locally cherty, bituminous and biostromal

Bois Blanc Formation: Grey dolomite, limestone and chert
APPENDIX B

Geologic Cross-Sections
Locations of geologic cross-sections
APPENDIX C

Avon River Water Quality, 1981
Sampling locations, Avon River

Scale: miles

Sampling locations, Surface water
Sewage treatment plant
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- = Data Not Available

* = Lab Accident

A = Approximately

L = Less Than

G = Greater Than

C = High Background Present
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* Lab Accident

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APPENDIX D

Addendum on
Flow Augmentation Requirements
A critical parameter for stream water quality control is phosphorus due to the eutrophication problem below the City of Stratford. Luxuriant plant growths have been observed in areas of the stream above Stratford where total phosphorus concentrations average about 0.05 to 0.06 mg/L in the summer, while downstream summer concentrations average about 0.1 mg/L (personal communication, M. Fortin). Based on these values, a target concentration of less than 0.05 mg/L total phosphorus might be assumed. The mean 1980 summer baseflow was 0.35 m$^3$ sec$^{-1}$ at station 10 (personal communication, M. Fortin). With a ground-water concentration of 0.025 mg/L, the augmentation requirement with indicated base flow would be 0.7 m$^3$ sec$^{-1}$, or 9000 gpm.

While there are individual Stratford city wells yielding up to 1000 gpm in the study area, it is highly unlikely that a sufficient number of such high-yielding wells could be developed in close proximity to the river below Stratford. Consequently, augmentation to this level does not appear to be feasible.
STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1  Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2  Physical Characteristics of the Avon River
S-4  Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5  Experimental Efforts to Aerate the Avon River with Small In-stream Dams
S-6  Growth of Aquatic Plants in the Avon River
S-7  Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8  Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9  Avon River In-stream Water Quality Modelling
S-10 Fisheries of the Avon River
S-11  Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
S-12  Phosphorus Bioavailability of the Avon River
S-13  A Feasibility Study for Augmenting Avon River Flow by Ground Water
S-14  Experiments to Control Aquatic Plant Growth by Shading
S-15  Design of an Arboreal Shade Project to Control Aquatic Plant Growth

U-1  Urban Pollution Control Strategy for Stratford, Ontario - An Overview
U-2  Inflow/Infiltration Isolation Analysis
U-3  Characterization of Urban Dry Weather Loadings
U-4  Advanced Phosphorus Control at the Stratford WPCP
U-5  Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
U-6  Analysis and Control of Wet Weather Sanitary Flows
U-7  Characterization and Control of Urban Runoff
U-8  Analysis of Disinfection Alternatives

R-1  Agricultural Impacts on the Avon River - An Overview
R-2  Earth Berms and Drop Inlet Structures
R-3  Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
R-4  Identification of Priority Management Areas in the Avon River
R-5  Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
R-6  Open Drain Improvement
R-7  Grassed Waterway Demonstration Projects
R-8  The Controlled Access of Livestock to Open Water Courses
R-9  Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Strip cropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of In-stream Phosphorus
R-16 Gully Erosion Control Demonstration Project
R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites