INTEGRATED WATER SUPPLY AND WASTE WATER DISPOSAL ON LONG ISLAND

Prepared by
The Center for the Environment
and Man, Inc.
under
Sea Grant Project GH-63
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

CEM-4103-456
February 1972

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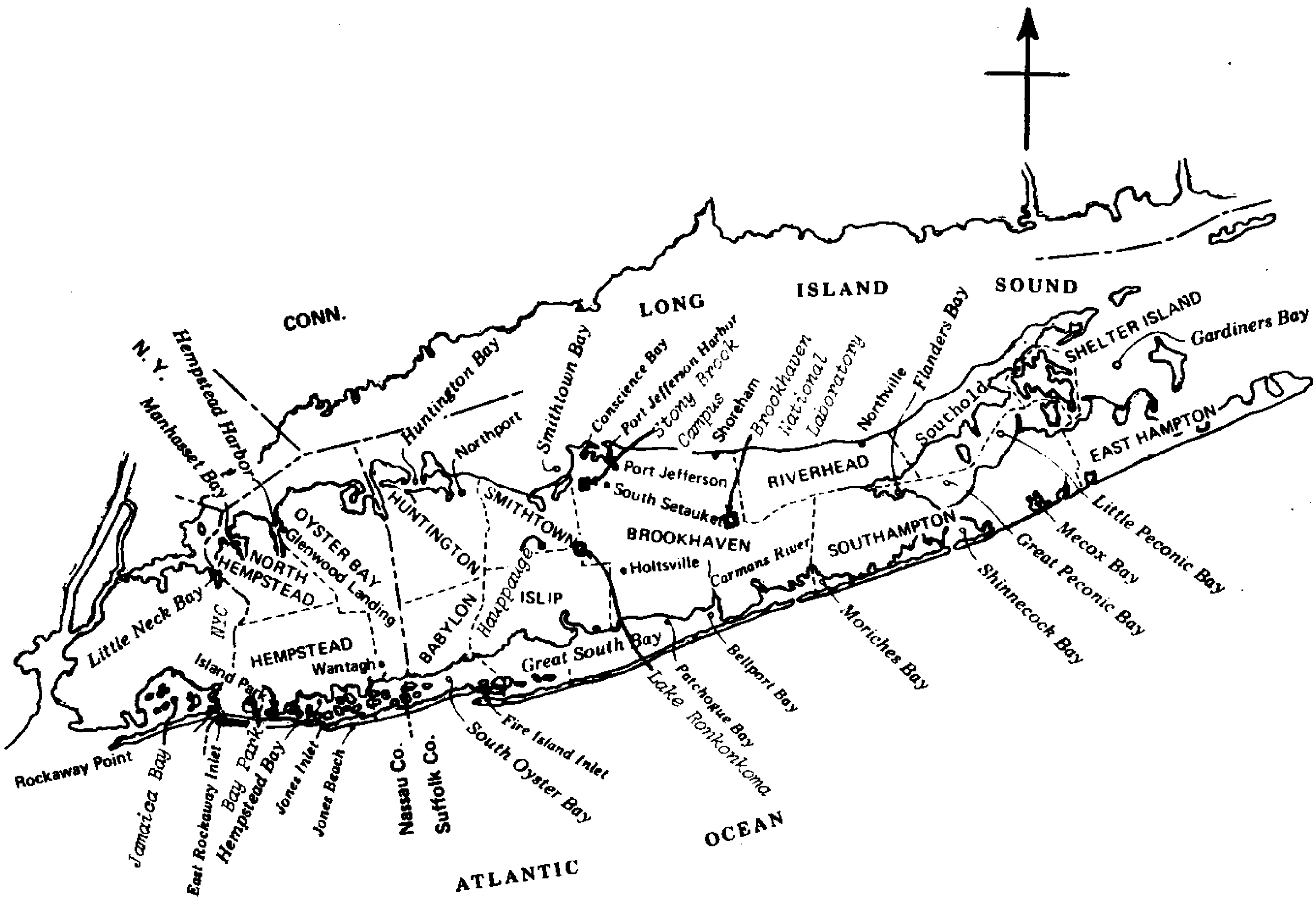
R. Pitchai

Regional Marine Resources Council

A COMMITTEE OF THE NASSAU-SUFFOLK REGIONAL PLANNING BOARD



CONN.
LONG
ISLAND
SOUND
N.Y.
Hempstead Harbor
Manhasset Bay
Huntington Bay
Northport
Smithtown Bay
Conscience Bay
Port Jefferson Harbor
Stony Brook Campus
Shoreham
Brookhaven National Laboratory
Northville
Flanders Bay
SHELTER ISLAND
Gardiners Bay
Southold
EAST HAMPTON
RIVERHEAD
Port Jefferson
South Setauket
OYSTER BAY
Glenwood Landing
HUNTINGTON
SMITHTOWN
BROOKHAVEN
SOUTHAMPTON
NORTH HEMPSTEAD
Little Neck Bay
NYC
Hauppauge
ISLIP
Holtsville
Carmans River
HEMPSTEAD
BABYLON
Island Park
Wantagh
Great South Bay
Little Peconic Bay
Mecox Bay
Great Peconic Bay
Shinnecock Bay
Moriches Bay
Bellport Bay
Patchogue Bay
Lake Ronkonkoma
Fire Island Inlet
South Oyster Bay
Rockaway Point
Jamaica Bay
East Rockaway Inlet
Bay Park
Hempstead Bay
Jones Inlet
Jones Beach
Nassau Co.
Suffolk Co.
OCEAN
ATLANTIC

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THE CENTER FOR THE ENVIRONMENT AND MAN, INC.
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FOREWORD

This report is part of a series prepared by The Center for the Environment and Man, Inc., for the Regional Marine Resources Council of the Nassau-Suffolk Regional Planning Board under the continuing program: The Development of Methodologies for Planning for the Optimum Use of the Marine Resources of the Coastal Zone. The program is being funded in part by the Sea Grant Program of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and is structured into six functional steps:

Functional Step One (Problems). Identifies, classifies and briefly analyzes the problems that confront planners and decision makers with regard to the area's marine resources.

Functional Step Two (Knowledge Requirements). Categorizes the data and knowledge necessary for making sound decisions with regard to the use of the marine resources.

Functional Step Three (State of the Art). Assesses the availability and adequacy of the necessary data and knowledge.

Functional Step Four (Knowledge Gaps). Determines necessary data collection and research activity.

Functional Step Five (Data Collection and Research Program). Formulates a priority-oriented, marine-related data collection and research program and monitors its implementation.

Functional Step Six (Management Information System). Develops a system for organizing the data and knowledge and provides analyzed information to marine resource planners.

Functional Steps One and Two were completed in previous reports of this series [1a, 1b and 1c] [Δ].

The current report on dredging is one of seven which together constitute Functional Step Three. Two of these seven reports were completed previously for coastal water quality standards [1d] and for estuarine models [1e]. Four reports addressing selected priority problems are currently being prepared simultaneously for integrated

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[Δ] Citations in brackets are listed in Appendix A.

water supply and waste disposal [1g], coastal stabilization and protection [1h], dredging [1i], and wetlands [1j].

The current report and all previous reports will contribute to future reports in this series on the state of the art [1k] (Functional Step Three), a proposed research program [1ℓ] (Functional Steps Four and Five), guidelines for planning and policy formulation [1m], and a marine management information system [1n] (Functional Step Six).

In the preparation of this report we are indebted to many individuals within and outside government who so freely furnished source material for our review, evaluation and possible incorporation into this study. Special mention must be made of the useful information provided by Mr. Alan Richmond of the Marine Resources Council, Mr. Philip Cohen of the U.S. Geological Survey, Long Island Program, Mr. Francis J. Flood of the Nassau County Department of Public Works, Mr. John Flynn and Mr. William Graner of the Suffolk County Department of Environmental Control, Mr. Sheldon O. Smith of the Nassau County Department of Public Health, Mr. Stephan Lane of the Blue Point Oyster Company of Sayville, and Mr. Augustus Guerrera of the Suffolk County Water Authority.

Views and conclusions contained in this report are those of The Center for the Environment and Man, Inc. They should not be interpreted necessarily as the official opinion or policy of the Marine Resources Council or the National Oceanic and Atmospheric Administration.

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SECTION 1 - INTRODUCTION

1.1 PROBLEM DESCRIPTION

Stated in its broadest terms, a very basic and important problem for Long Islanders in the Nassau-Suffolk bi-county area[/1] is how to satisfy their total requirements for water supply and waste water disposal in an economically, socially and environmentally acceptable way for now and for the future.

Economically, it will cost in the range of 10—13 billion dollars[/2] to meet requirements anticipated by the year 2000.

Socially, the way these requirements are met can affect population densities, residential/industrial mixes, land use patterns, the extent of political regionalization, and the general standard of life.

Environmentally, the way these requirements are met can affect the size and quality of the island's freshwater bodies, both surface and subsurface; and the water quality of the bays, particularly along the south shore.

The purpose of this report is to examine the basic problem, the principal considerations involved, inadequacies in current knowledge, and the choices available together with their broad implications.

1.2 USERS OF THIS REPORT

This report is being prepared primarily for its sponsors, the Regional Marine Resources Council and its parent body, the Nassau-Suffolk Regional Planning Board. The interests of the Council are bi-county and coastal. The interests of the Board are bi-county and comprehensive covering the long-range preservation use and

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[/1] The Nassau-Suffolk bi-county area accounts for 86 percent of Long Island's total land area and 36 percent of the island's 1970 population. The other two counties on Long Island are Kings and Queens, both parts of New York City. Population is relatively stable in Kings-Queens, increasingly slowly in Nassau and increasing very rapidly in Suffolk.

[/2] Developed later in Appendix D, these are the total capitalized costs in 1971 dollars for satisfying the stated requirements with the least costly and most costly alternative system.

development of the entire area, inland as well as coastal. The report reflects these interests by viewing the coastal dimensions as important but subordinate parts of the overall problem. For the Council to be responsible and successful, its coastal input must be founded on a broad, objective understanding of the overall problem. Accordingly, this report is an overview; it seeks to provide perspective useful for formulating broad public policy.

In addition to serving the needs of its primary audience, it is hoped that the report will also provide considerable, useful information for the two county governments, academic institutions, and all others interested in the basic problem.

Although the data are specific to the bi-county area, the methodology and many of the conclusions should be applicable to planning for integrated water supply-waste water systems in other densely populated coastal locations throughout the nation.

Lastly, the report is developed in such a way as to contribute to later reports in this series identified in the Foreword.

1.3 CHARACTERISTICS OF THE DECISIONS REQUIRED

Comprehensive planning includes an examination of general strategies for meeting Long Island's water supply and waste water disposal needs. The strategies must particularly consider the source of water, the degree of waste water treatment and the method of ultimate disposal. They must take into account current and projected usage, economic and environmental factors, and the aspirations of the people. The decisions must be made in a context that considers water supply-waste water processing as an integrated system closely related to broad master planning. Current decisions must be made with consideration of future projections and technology.

1.4 APPROACH

The approach developed herein consists of--

- Examining the natural hydrologic system, man's water supply-waste water system, and the combined man-influenced system in terms of water quantity.
- Examining the same systems in terms of water quality.
- Examining projections of future water supply and waste water disposal requirements.

- Examining the potential effects of meeting these requirements on man and the natural environment.
- Developing and analyzing numerous alternative solutions in terms of costs, and broad geological, health, ecological and institutional considerations.
- Identifying those solutions which merit the most intensive consideration.

In the process of the above analysis, significant data collection and research needs are flagged for integration in a proposed problem-oriented marine research program that will be developed in a subsequent report in this series [1ℓ].

SECTION 2 - ANALYSIS

2.1 THE HYDROLOGIC SYSTEM [1]

2.1.1 The Natural System

Long Island is underlain by a vast 60-trillion gallon system of aquifers depicted in highly simplified cross-sectional form in Figure 1.

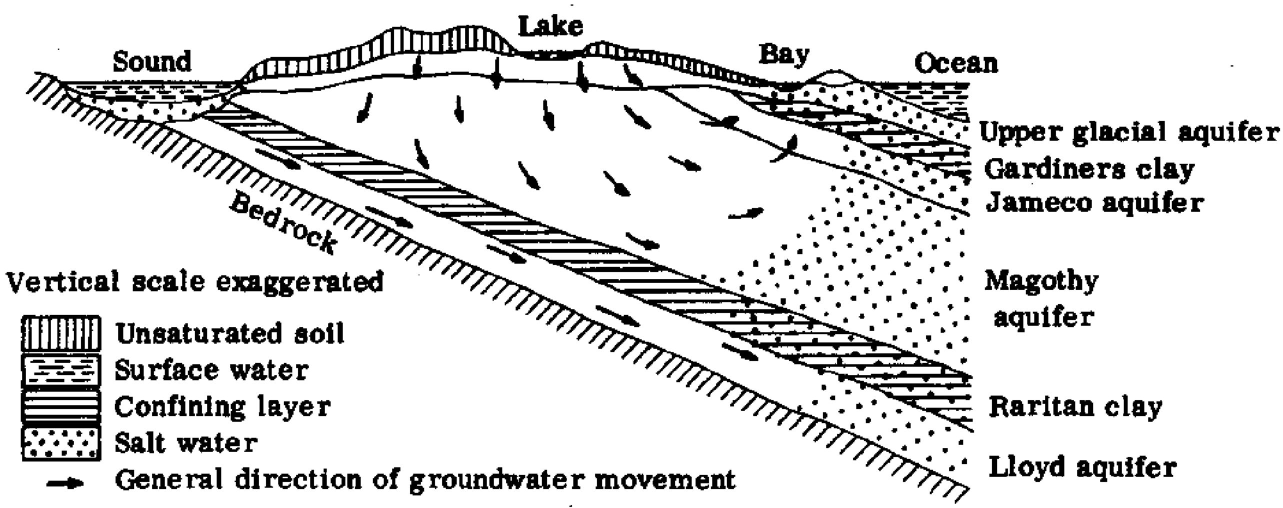


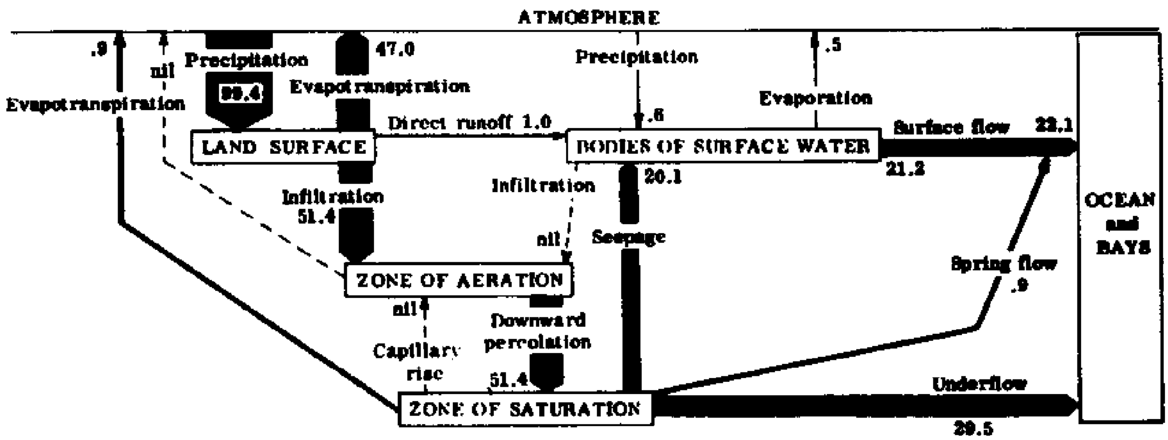
Fig. 1
LONG ISLAND AQUIFERS Source [7]

In the bi-county "water budget area," the area in which most of the groundwater is pumped and used, total precipitation averages about 1,600 million gallons a day. Figure 2 quantatively depicts how infiltration from this source recharges the aquifers and how the aquifers then discharge their water through several processes. When the flow is traced in this figure, it can be seen that, of the total precipitation falling on the

[1] The information in Section 2.1 of this main report is a summary of Appendix B. That appendix defines the water budget area, identifies and evaluates basic source material, and develops a quantified analysis of the basic hydrologic systems.

water budget area--

- Nearly half returns to the atmosphere as evapotranspiration from several sources, principally from the land surface.
- Nearly a quarter enters the sea as surface flow, essentially all from streams. With only minor exceptions, the streamflow consists of seepage from the aquifers (zone of saturation).
- Over a quarter enters the sea as underflow from the aquifers.



Numerical entires represent average flow in percent of total precipitation; "nil" indicates negligible amounts

Total inflow : 100.0% in precipitation
Total outflow: - 48.4% in evapotranspiration to atmosphere
- 22.1% in surface flow to ocean
- 29.5% in underflow to ocean
-100.0%

Fig. 2

FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM, WATER BUDGET AREA, UNDER NATURAL CONDITIONS

2.1.2 Man's System

Figure 3 depicts the hydrologic aspects of man's water supply and waste water system in millions of gallons a day. When the flow of water is traced in this figure, it can be seen that, within the water budget area man pumps about 314 mgd, distributed as follows:

44 mgd leakage
195 mgd residential
62 mgd industrial
13 mgd agricultural

The figure shows that more than half, 55%, of total pumpage is eventually recharged to the aquifer. The remaining 45 percent, represents consumptive losses—19 percent to the atmosphere by evapotranspiration and 26 percent to the bays, sound and ocean through sewer outfalls. Observe that a quarter of the sewered losses are made up of groundwater infiltrating into the sewers.

This current bi-county-wide distribution differs appreciably in each county. In its part of the water budget area, Suffolk County pumps about 114 mgd, recharges a high 70 percent, and loses only about 30 percent consumptively—25 by evapotranspiration and 5 by sewering. In marked contrast, in its portion of the water budget area, Nassau County pumps about 200 mgd and loses more than half consumptively—15 percent by evapotranspiration and 40 percent by sewering. This great disparity in consumptive losses in the two counties stems primarily from differing waste water disposal practices. Suffook currently returns almost all waste water to ground water through cesspools and septic tanks. Nassau sewers well over half of its waste water.

In the future as Suffolk County provides sewers for an increasingly large proportion of its population, its recharge and consumptive use pattern will approach that of Nassau County. If the bi-county area were entirely sewered now and used ocean outfalls, total consumptive losses would rise to over 85 percent!—about 20 by evapotranspiration and about 67 by sewering.

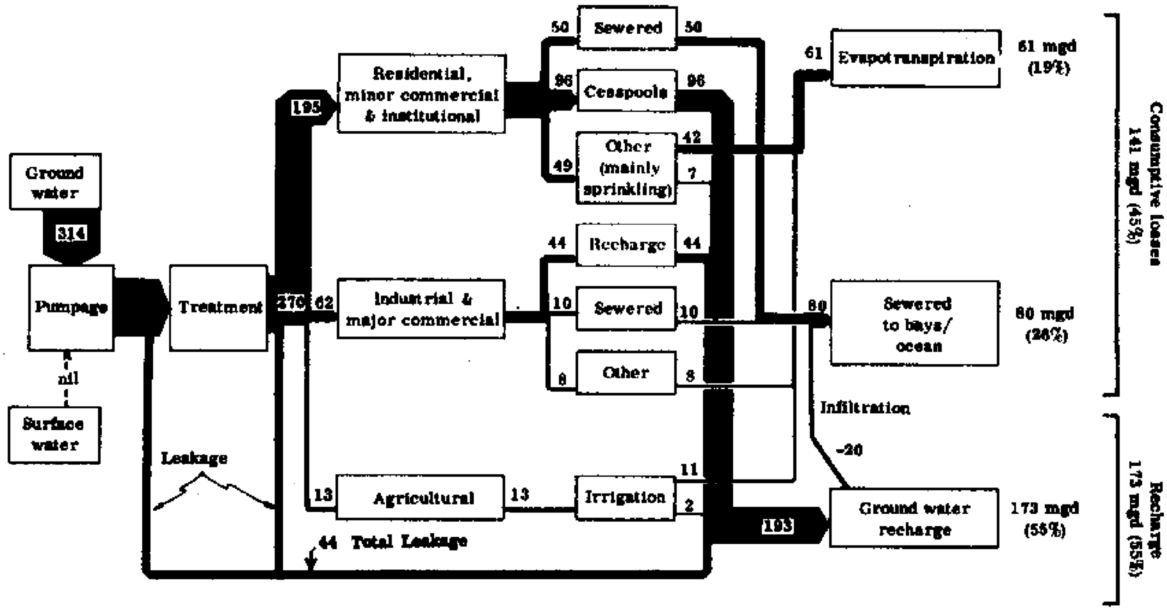


Fig. 3
MAN'S WATER SUPPLY AND WASTE WATER SYSTEM, WATER BUDGET AREA OF LONG ISLAND (in mgd)

2.1.3 The Man-Influenced Natural System

Figure 4 depicts the natural system as it is being influenced by man. It is based partially upon the information displayed in Figures 2 and 3, and partially upon the estimated effects caused by man's changes to the surface characteristics of the bi-county area. To facilitate comparison, two sets of numbers are provided. The encircled entries reflect the natural system previously depicted in Figure 2, the other entries depict the man-influenced natural system. For example, the 99.4% falling on the land surface is unchanged, but the amount lost as evapotranspiration from the land surface is decreased somewhat (from 47.0 to 45.3%). This change is caused by two effects: (1) man's clearing natural vegetation thereby significantly reducing transpiration losses, and (2) man's adding paved and cleared surfaces thereby significantly increasing evaporation losses. The net result of these two opposite effects seems to be a decrease in total evapotranspiration losses, but the research upon which this estimate is based needs to be improved.

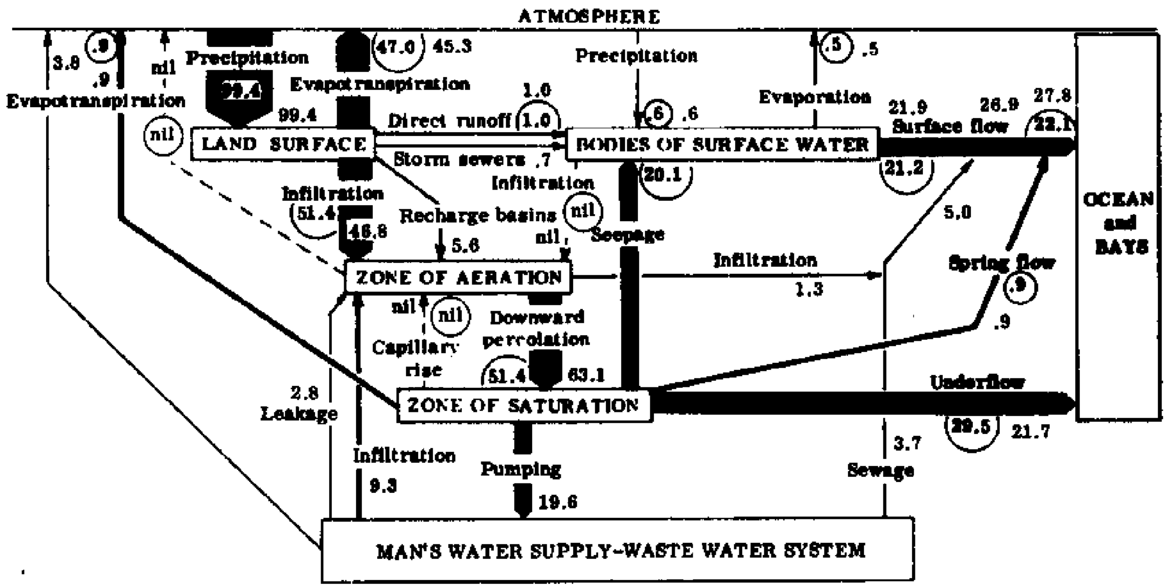
Man introduces other effects at the surface. By storm sewers, he sends water to streams and to recharge basins. However, the combined effects of man's surface alterations appear to cause little overall change in infiltration. Note, for example, that in the natural system 51.4 percent moved from the land surface to the zone of aeration, whereas in the man-influenced system this total increases slightly to 52.4 percent through the combined effect of infiltration and storm basins. Broadly speaking, man's surface changes appear to be largely compensating, but much more research is justified, as indicated in Appendix B, to affirm this reassuring conclusion.

Considering all his activities, however—his surface changes and his water supply and waste water system—man does alter the natural hydrologic cycle significantly in different ways:

(1) He increases total evapotranspiration losses, from several sources, only slightly (from 48.4 % to 50.5%). Although his changes in the surface reduce evapotranspiration losses somewhat, as explained earlier, man more than makes up for this performance by pumping large quantities from the aquifer and re-exposing this water to evapotranspiration losses through activities such as lawn watering, agricultural irrigation and air conditioning.

(2) He increases surface flow losses to the ocean by a quarter (from 22.1% to 27.8%). He does this primarily through his sewer systems which transport waste water and infiltrated groundwater to the sea.

(3) He makes up for the above two increases entirely at the expense of the aquifer underflow to the sea, which he reduces by nearly a third (from 29.5% to 21.7%).



Numerical entries represent average flow in percent of total precipitation; "nil" indicates negligible amounts
Encircled numbers depict the natural system as shown in Fig. 2. The other numbers depict the system as influenced by man

		Natural system	Man-influenced system	Change
Inflow		100%	100%	-
Outflow:	Atmosphere	-48.4%	-50.5%	+2.1%
	Surface flow to ocean	-22.1%	-27.8%	+5.7%
	Underflow to ocean	-29.5%	-21.7%	-7.8%

Fig. 4

FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM,
WATER BUDGET AREA AS INFLUENCED BY MAN, CIRCA 1965

2.2 CONTAMINATION OF THE SYSTEM[1]

From the time water enters the system in the form of precipitation until it returns to the atmosphere, either directly by evapotranspiration or indirectly by way of stream flow or underflow to the sea, the quality of the bi-county area's freshwater is affected by a variety of natural and man-introduced processes. Figure 5 depicts the overall system. The encircled letters identify the relevant processes during which contaminants enter and leave the water. Contaminants, as used here, are any substances other than H_2O.

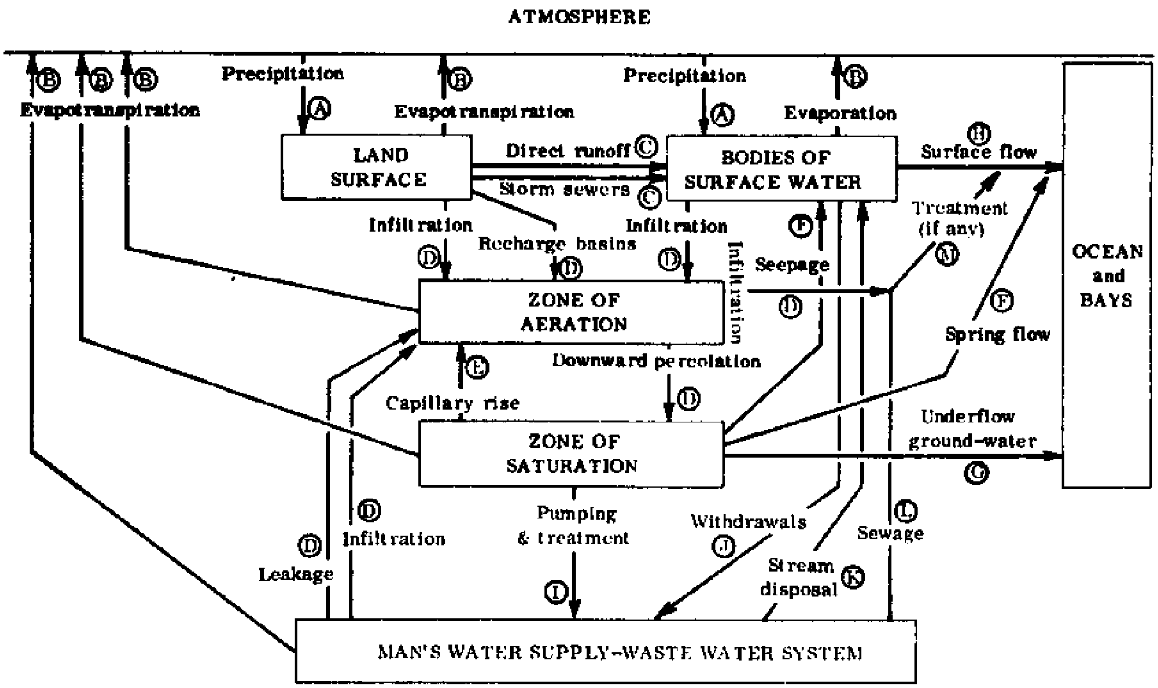


Fig. 5
CONTAMINATION OF LONG ISLAND WATER IN
THE MAN-INFLUENCED HYDROLOGIC CYCLE

The natural processes, (A) through (H), do not seem to be a major source of contamination. In fact, except for its iron content, the water quality resulting from these natural processes is almost too good. The dissolved solids concentration is very low, about 20 to 40 ppm (parts per million)[2], and the "soft" water tends to be

[1] The contamination portions of this main report are based upon Appendix C.
[2] Used synonymously with mg/1.

corrosive to metal pipes. The principal importance of the natural processes on Long Island is in the role of infiltration in filtering out contaminants from cesspools and septic tanks and from recharge water, especially if spray irrigation techniques are applied.

In brief, man currently pumps water of excellent quality from the aquifers, improves it slightly in his water treatment plants, greatly contaminates it during use, and removes a certain proportion of the contamination at his waste water treatment plants.

2.3 FUTURE REQUIREMENTS

Recent estimates of projected population growth and water supply requirements in the bi-county area are summarized in Table 1 [2, 3].

TABLE 1

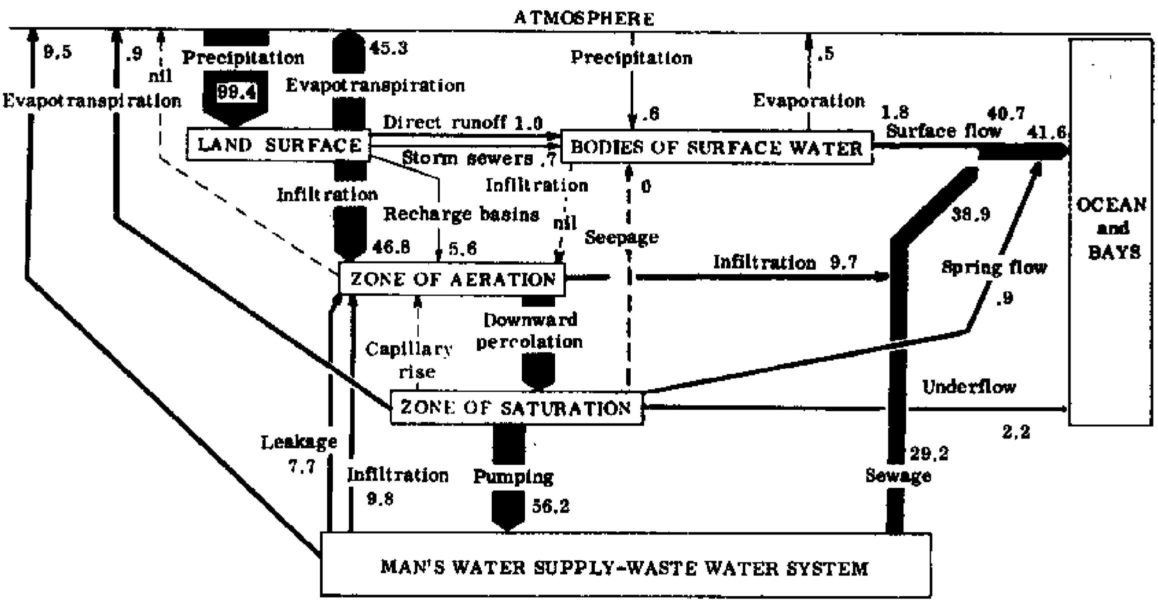
FUTURE POPULATION AND WATER SUPPLY REQUIREMENTS

	Population (Millions)			Water Supply Requirements (mgd)		
	1980	2000	2020	1980	2000	2020
Nassau	1.6	1.9	2.3	280	360	420
Suffolk	1.6	2.5	3.0	230	270	470
Total	3.2	4.4	5.3	510	630	890

Residential waste water loads should rise at least as fast as population. Industrial waste water loads cannot be estimated so easily. In a methodology employed in the North Atlantic Regional Weather Resources Study [4], biodegradable organic industrial waste loads were expressed in terms of "population equivalents," the amount of wastes in terms of biochemical oxygen demand produced by one person. Expressed in these terms, the industrial load is expected to increase about five times faster than the population in "Planning Area 13" which includes all of Long Island, New York City and Westchester County. No separate breakdown was given for Nassau-Suffolk Counties.

2.4 POTENTIAL EFFECTS OF MEETING FUTURE REQUIREMENTS [1]

The potential side effects of meeting these long-range requirements depend entirely upon the strategy employed. For example, if the bi-county area should require water in the amount just projected in Table 1, continue to obtain all of it from the aquifers, sewer about 95% of its residential and industrial users as frequently proposed, and discharge the treated waste water into the ocean, the man-influenced hydrological cycle in the year 2020 would be approximately as portrayed in Figure 6.



Numerical entries represent average flow in percent of total precipitation; "nil" indicates negligible amounts

		Natural system	Man-influenced system	Change
Inflow		100%	100%	-
Outflow:	Atmosphere	-48.4%	-56.2%	+ 7.8%
	Surface flow to ocean	-22.1%	-41.6%	+19.5%
	Underflow to ocean	-29.5%	- 2.2%	-27.3%

Fig. 6

FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM, WATER BUDGET AREA AS INFLUENCED BY MAN, CIRCA 2020

Under this situation, the principal effects would be:

- Below the surface:
  - --Greatly lowered groundwater levels.
  - --Possibly significant salt water intrustion.

[1] The effects listed in this section are described more fully in the later parts of Appendices B and C.

- At the surface:
  - --A drying up of lakes and streams except after storms.
  - --Salinity increases in the south shore bays, of uncertain biological impact.
  - --Possible land subsidence, although this effect is uncertain.

These subsurface effects and surface effects are each listed in the most likely order of significance. For example, current model studies are predicting that groundwater levels would drop appreciably but that salt water intrusion might not be the major problem it was thought to be before the studies. However, until current models and basic geological information are improved, the second prediction should not yet be accepted with complete confidence.

If the area were not significantly sewered, the effects listed above would largely disappear, but the aquifers would become badly polluted organically and chemically, especially with nitrates.

If bay outfalls were used instead of ocean outfalls, the in-bay salinity increases could be reversed; but other aspects of water quality there would deteriorate greatly, probably enough to destroy the usefulness of the bays for commercial shellfish harvest and for bathing.

If advanced waste water treatment (AWT) were employed in conjunction with groundwater recharge or if the water supply were to be imported from the mainland, the effects listed above would disappear; but major problems of costs and technical feasibility (for the AWT-recharge), and institutional barriers (for the imported water) would have to be overcome.

The above examples should indicate not surprisingly, that every strategy has its strengths and weaknesses, that final selection will involve numerous tradeoffs. Most of the remainder of this report will address that subject—the systematic formulation and comparison of a number of ways that Long Island can meet its anticipated needs.

2.5 INTEGRATED SYSTEMS

An integrated water supply-waste water disposal system can usefully be considered to be made up of eight sequential phases: the acquisition, transmission, treatment, distribution and use of freshwater; and the collection, treatment and disposal of waste water.

Appendix D presents an analysis of each of these phases in terms of alternative approaches and associated costs, general environmental impacts and likely political/ jurisdictional implications. Alternative integrated systems are then developed, each varying in the approaches taken for different phases.

Major costs, 50 to 65% of total system costs, occur in the transmission-distribution-usage phases; however, few cost-significant options are open for these phases and possible efficiency improvements here would not enter into the comparison of alternative systems because the effects would be felt by all systems alike. Therefore, for the purposes of this analysis, these phases will not be considered further, except for including them in the total systems cost.

Where employed, sewers make up about half of the remaining costs. Waste water treatment costs range up to half the sewer costs. Effluent disposal costs are minor except for systems employing expensive methods of recharge, such as spray irrigation. The acquisition and treatment of fresh water contributes only 10 percent or less to total costs, but the choice of source can greatly affect the methods and costs in the subsequent waste water collection, treatment and disposal phases.

Because of the above considerations and other environmental and political-institutional aspects to be considered later, the most important choices in developing an integrated system are those made for--

- The acquisition phase (local groundwater or imported water from the New York City system).
- The waste water treatment phase (cesspools, secondary treatment or AWT).
- The disposal phase (groundwater recharge or ocean outfall).

2.6 ALTERNATIVE SOLUTIONS

Of sixteen systems considered, four dominated the rest. They are summarized in Table 2.

The first system (NRG) envisions importing water from New York City, initially for Nassau and perhaps eventually for Suffolk, and continuing to employ cesspools. The total capitalized cost of this system would be about three billion dollars less than the average of the other three. Since groundwater would not be used, its quantity would not be affected. On the contrary, groundwater levels might rise somewhat. The

TABLE 2

SURVIVING SYSTEMS

System	Comparative Full System Costs (Capitalized)	General Environmental Impacts			Institutional -Political
		Geological (Groundwater Quantity)	Health (Quality of Water Supply)	Ecosystem (Aquatic Life)	
NRG	$ 9.7 billion	Acceptable	Acceptable	Objectionable	NYC Water
NSO	12.1 billion	Acceptable	Acceptable	Beneficial to Objectionable	NYC Water
GAG	12.9 billion	Acceptable	Acceptable	Acceptable	No problems
GSG	12.9 billion plus	Acceptable	Acceptable	Acceptable	Inter-county transfer; land requirements

Each system includes all eight phases. The systems are identified as follows:

First letter indicates source of water—G for Long Island groundwater, N for New York City water.

Second letter indicates degree of waste water treatment—R for raw, S for secondary, A for AWT.

Third letter indicates type of liquid effluent disposal—G for groundwater recharge, O for ocean outfall.

aquifers would become increasingly contaminated from the cesspools or septic tanks, but this would not effect the quality of the imported water supply. Ecosystem effects would depend upon the quantity and type of contaminants that eventually seep into the lakes, streams and bays. This potential contamination effect cannot be reliably predicted under the current state of the art, but the last phase of the planned U.S.G.S. family of models will increase understanding of the effect. This system avoids the temporary social disruption, common to the other three systems, associated with the construction of sewers, but it does so at the expense of continuing the personal disruptions associated with the periodic cleaning out and replacement of cesspools. Institutional problems might be encountered in moving the supply water across the Queens-Nassau line. Since, under this NRG system, the groundwater would become contaminated, it would not become available to supplement New York City's water during droughts, an important quid-quo-pro discussed later under the NSO system. One way of partially offsetting this disadvantage would be with additional standby water supply treatment facilities.

The second system (NSO) also envisions importing New York City water, but it adds sewers, secondary treatment, and ocean outfalls. It costs nearly a billion dollars less than the next two systems. Since the groundwater is not touched, it provides the nearest approach to "pristine" conditions in the aquifer (and the bays) of any of the systems. Ecological objections might be encountered in the ocean near the outfall sites. Opinion on the effects of discharging secondary effluent by ocean outfall is currently divided. Assuming the removal of toxic materials at their source and floatable materials at the plant, some view the secondary effluent as nutrients that will significantly benefit marine life by intentionally fostering local eutrophic and upwelling conditions if carried out under controlled conditions. Others hold that secondary effluent is undesirable in the ocean. The results of current studies on Long Island and in Los Angeles, California should shed further light on this controversy, which should be of major interest to the Council. Institutional problems might be encountered in moving the supply water across county lines. Unless a politically distasteful decision is imposed from above, all counties involved must agree. It has been suggested [6] that if a transmission line connecting the New York City system through Nassau to Suffolk were to be constructed, the resulting regionalization of the system might benefit all parties. During the early years, currently ample Suffolk groundwater would help make up deficiencies in Nassau, and possibly even in New York City. In later years, say 1985—2000, New York City would bring in major additional inland sources and relieve Nassau from its dependency upon Suffolk water. Eventually, say 2000, New York City water could supply an increasing proportion of needs in both Nassau and Suffolk in normal years, allowing the aquifer to build up its reservoir storage capacity. In drought years, say 10% of the years, the natural standby reserve in the aquifer would be tapped to provide water for the bi-county area and to supplement the New York City system. Any significant inequities in the inter-county quid-pro-quo of such an arrangement might be adjusted through various cost sharing formulae.

The third system (GAG) envisions drawing upon the groundwater, providing sewers and AWT sufficient to meet groundwater recharge standards, and pumping the high quality effluent to selected inland locations for injection, storm basin or instream recharge. This system does not produce any adverse environmental effects in the lakes, streams, bays or ocean. Institutional problems will probably not be significant because under this system, unlike the others, each county could satisfy its own needs without recourse to others. Operational experience with large-scale AWT plants is currently limited and solutions to significant technical problems during the recharge phase have yet to be demonstrated. Until the large-scale operational experience is gained and the technical solutions are demonstrated, the cost of this system must be considered somewhat uncertain. Hopefully, these current difficulties will be resolved during ongoing research, begun half a decade ago for injection recharge and recently for other recharge techniques.

A variant of the GAG system envisions injecting AWT effluent into a barrier line along the south coast. The barrier would reduce the likelihood of shallow salt water intrusion into the Upper Glacial aquifer and thereby permit greater drawdown of water tables inland. However, this variant would encounter higher costs for distributing the effluent along the line of injection and for overcoming difficult problems of clogging at the injection wells. Under a second varient, very high quality AWT effluent would be blended directly into the water supply system. Even if technically feasible and medically acceptable, this variant would probably encounter significant public resistance.

The last system (GSG) envisions drawing upon the groundwater, providing sewers and secondary treatment, and pumping the secondary effluent to selected inland sites for possible additional treatment and recharge in acceptable quality to the aquifer by spray irrigation. The costs portrayed in Table 2 for this system do not adequately reflect the currently unknown but probably great costs at the inland sites for land, possible effluent storage over the winter, distribution systems required to spread the recharge regionally, and the spray irrigation system itself. Since much of the spraying would be during the warmer months, evapotranspiration losses could be very significant. Nassau effluent would probably have to be piped to Suffolk because of the high land requirements of this method. A feasibility study, drawing upon successful operations in Muskegon, Michigan [5] and elsewhere, could resolve these unknowns. Without such a study, the technical and economic feasibility of the GSG system cannot be accepted with confidence on Long Island. Despite these uncertainties, it should be noted that this system would create no significant environmental problems. An environmental plus would be the possibility of increasing agricultural productivity.

Final selection of a central strategy should be influenced prominently by the results of priority research recommended herein and by explicitly-displayed value judgments. The latter involve the assignment of relative weights to cost, environmental, political-institutional and technological aspects. For example, if the cost of implementation were considered overriding, the NRG strategy would be preferred. If enhancement of aquifer quality were considered overriding, the second strategy would be preferred. Different conclusions would flow from combining the following two value judgments, which might well represent the preferences of many Long Islanders:

> Value Judgment #1. Preservation and enhancement of aquifer water quality overrides all other considerations./1 Conclusions: Eliminate NRG from further consideration. Require sewering essentially everywhere./2 Require ocean outfalls; they are basic to NSO and necessary adjuncts for GAG and GSG for handling emergency overflows and/or that portion of treated waste water not required to meet recharge needs.
>
> Value Judgment #2. Political-institutional problems associated with regionalizing the integrated system across county boundaries (Queens-Nassau and/or Nassau-Suffolk) override considerations of increased cost, restoration of the aquifers to natural conditions, and technological uncertainty. Conclusions: Eliminate NSO and GSG. Select the remaining strategy, GAG. Find a safe, economical, technically-feasible way to recharge.

Unless value judgments of this type can be adopted with confidence and employed as unviolable "constraints" on solutions, a good policy is to keep several options open. This openness allows and encourages the vigorous, priority-conditioned pursuit of research designed to sharpen understanding of key decision elements. That premise—continued openness to reasonable alternatives—is the basis for many of the research needs itemized in Section 3 and developed in later reports of this series [1k and 1ℓ].

Local and interim considerations. This report has considered long-range solutions for the bi-county area as an integrated whole. Although that approach has the

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/1 Regardless of (1) increased costs, or (2) whether the aquifers are used as water sources, or (3) whether it should prove feasible to give adequate additional treatment to pumped water before use, or (4) whether or not any major environmental impacts can be associated with reduced groundwater quality.

/2 Implies a cost commitment for sewering alone of about 3 billion dollars, spread perhaps over the next two decades.

advantages of breadth, it masks important interim and local considerations. Probably a mixed strategy reflecting these last two considerations will be the best. One such mixed strategy would be:

- Nassau County, with its already heavy population and insufficient water supply, import water from Suffolk as an interim solution, and adopt either NSO or GAG for a long-range solution.
- Western Suffolk, with its increasingly heavy population density and apparently ample water supply, adopt GSO (groundwater, secondary treatment, ocean outfall) at least to the turn of the century, followed by increasing reliance upon GAG, GSG or NSO beyond that date.
- Eastern Suffolk, with its lower population density, remoteness from New York City, and growing shortage of groundwater, import water from central Suffolk, discharge secondary effluent into the ocean in populated areas and continue with cesspools (or packaged, individual treatment systems, if current problems of solids disposal and fail-safe design can be overcome) in relatively unpopulated areas.

2.7 ADVANCED WASTE WATER TREATMENT [1]

Recharge of the aquifers with very high quality water is required in two of the four systems just compared [2]. To achieve this high quality, either AWT or spray irrigation or some combination of both will be required. The AWT alternative has received considerable attention.

The term, advanced waste treatment, is commonly employed to describe a variety of techniques, which may be applicable to improve performance in conventional waste treatment or which may be substituted for conventional waste treatment to produce an effluent of very high quality. A well-designed and well-operated conventional secondary sewage treatment plant can provide up to 80—95 percent reduction in BOD, 85—90 percent reduction in suspended solids and 95—98 percent reduction in bacteria. It can also remove, under favorable conditions, about 50 percent of the phosphorus and 55 percent of the nitrogen present. The balance still present in the effluent is not acceptable for groundwater recharge.

AWT has been evolving, from its beginnings as an extension to conventional biological secondary treatment, towards self-sufficient flexible physical-chemical systems that can be designed to produce high quality effluents from raw waste waters of highly varying quality. The technical feasibility of producing an effluent with BOD of less than 10 mg/1, COD of less than 60 mg/1, suspended solids of less than 10 mg/1, phosphorus of less than 1 mg/1, nitrogen of less than 10 mg/1, and dissolved solids comparable to supplied water, has been demonstrated in experimental and full-scale plants. Operational experience in large-scale municipal plants is still limited, but it is expected to improve. A schematic overview of the AWT organization and unit processes associated with it is provided in Figure 7.

Because of the rapidly developing state-of-the-art on several different fronts and the varying site-specific requirements that currently dominate designs, it is not reasonable to single out any one particular AWT process as the answer to Long Island's

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[1] This section on AWT is based upon a detailed state-of-the-art review of many different AWT processes in Appendix E.

[2] The other two systems, using New York City waters, impose no recharge requirements.

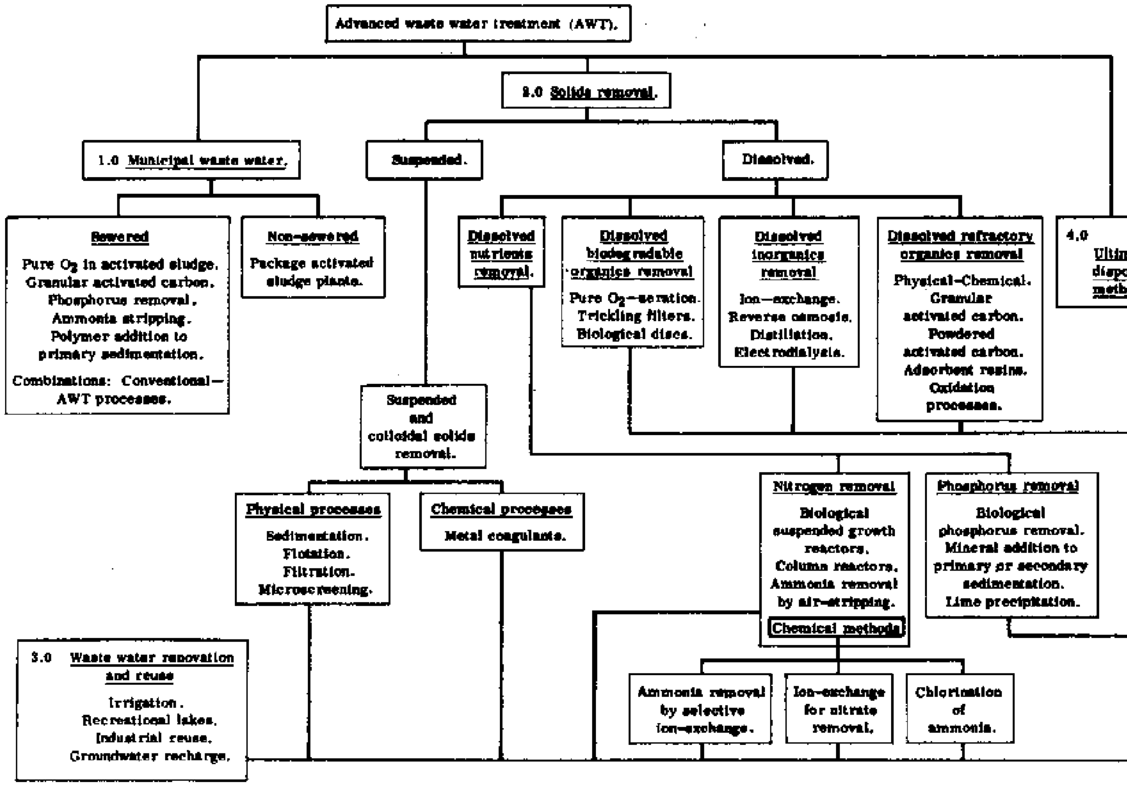

Fig. 7
OVERVIEW OF ADVANCED WASTE WATER TREATMENT COMPONENTS

needs. For example, at sites where a biological secondary treatment already exists, choice will be restricted to an "add-on" AWT process in which the design is tailored to the secondary effluent. Where a new plant is being planned, more design freedom should be exercised. In this situation, before an AWT add-on design is accepted, it should always be compared with a self-sufficient, physical-chemical AWT design. Lime clarification, carbon adsorption and the use of pure oxygen currently appear to be very attractive component processes in AWT design.

SECTION 3 - DATA COLLECTION AND RESEARCH NEEDS

3.1 ITEMIZATION OF NEEDS

During the analysis in Section 2 and its supporting appendices, the most problem-relevant information and knowledge were introduced, assessed for adequacy, and employed where feasible. Inadequacies in the current state of this required information and knowledge were cited in many places.

This section provides a brief recapitulation of these inadequacies, in terms of the data collection and research effort needed to rectify them. The needs are grouped under the generalized categorization system developed in an earlier report of this series on Functional Step 2 [1c] [1].

3.1.1 Current Human Actions

Much better information of the following types is needed to quantify current understanding of man's integrated water supply and waste water disposal systems:

- Usage data on all phases of the integrated system
- Data describing waste water disposal rates by quantity, composition and location.
- Data on the composition of solid wastes dumped at sea.
- Consistent unit cost data for all phases of the integrated system. This is a high-priority need; the results should provide the badly needed objective basis for comparing the economic aspects of major competing alternative solutions.
- Information on how man's cultural changes to the surface of Island are affecting evapotranspiration losses.

3.1.2 Current Environmental Characteristics

Much better data are needed to provide essential understanding of--

- Onshore and offshore geology, insofar as each affect the aquifer system.

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[1] For brevity, these needs can only be listed here in very general terms, stripped of qualifying definition, rationale and evaluation. The needs are depicted in slightly expanded form in Appendix F. As will be indicated later in Section 3.2, they will receive considerable expansion and analysis in later reports of this series.

- Trends in groundwater levels; and also in land subsidence, possibly associated with these levels.
- Trends in groundwater quality.
- The current quality of coastal waters. This is a high priority need; it envisions a coastal water quality monitoring system.

3.1.3 Desired Uses of Coastal Resources

Much better information is needed to improve current understanding of --

- The most likely levels of future industrial freshwater usage and waste water disposal.
- The extent to which established water quality classifications are not being met.
- The adequacy of water quality standards, particularly for bacterial contamination and thermal discharges.

3.1.4 Natural Processes

Improved knowledge is needed to provide essential understanding of the natural processes governing--

- Evapotranspiration and infiltration.
- The movement and fate of contaminants in the aquifers, bays, sound and ocean.
- Salinity gradations in the bays.

3.1.5 Effects on Marine Biota

Improved knowledge is needed to provide essential understanding of the effects upon marine biota of--

- Levels of contamination in the bays.
- Levels of contamination in the ocean and sound, particularly that introduced by outfalls and dumping. Understanding the effects of outfalls is a high priority need; the results should strongly influence basic waste water policy on the island.
- Oil spills.
- Salinity changes in the bays. This is a high priority need; the results strongly influence basic recharge strategy on the island.
- Progressive concentration of toxic substances in the food chain.

3.1.6 Impact on Users

Improved knowledge is needed to understand--

- How changes in groundwater levels impact upon man. This need is especially important; basic island recharge strategy should be geared to minimize these impacts.
- The likelihood of opening shellfish areas in the future and the feasibility of instituting a policy of required depuration.
- The actual extent of beach closures attributed to water quality deficiencies.
- Physical site limitations on the continued use of cesspools and septic tanks.

3.1.7 Models

To permit essential integration and manipulation of developing data and knowledge; the following models are necessary, the second, fourth and sixth being high priority needs:

- A surface hydrological model to predict the quantity of water entering the aquifer system and the bays.
- A subsurface hydrological model to predict the movement of water through the aquifers.
- Groundwater quality models to predict changes in the quality of water as it passes through the aquifer system.
- Water quality models to predict the concentrations of contaminants in selected bays.
- Water quality models to predict the distribution of contaminants introduced into the ocean and sound by outfalls and dumping.
- Hydrodynamic models to predict the effects on backbay environments of potential changes in the characteristics of selected inlets.

3.1.8 Feasibility Studies

As important contributions to developing the area's basic strategy for satisfying its integrated water supply and waste water disposal needs of the future, the feasibility studies listed below are needed. High-priority needs are the studies on importation of water from the mainland, improved AWT, and stream recharge.

- Alternative water sources—importation from the mainland and desalination.

- Improved efficiency of the island's water transport system.
- Water conservation—by control of leakage, evapotranspiration, and infiltration into sewers.
- Removal of iron from the water supply.
- Improved waste water treatment—by AWT and by individual packaged treatment plants.
- Alternative recharge/recycling techniques—injection, spray irrigation, storm basins and in-stream recharge; and recycling of AWT effluent.

3.1.9 Value Judgments

Especially important is the need for much improved understanding of the basic values with which Long Islanders might be expected to assess alternative water strategies, e.g., what is the highest level of environmental quality for which they are willing to pay?

3.2 PROBLEM-ORIENTED RESEARCH PROGRAM

In a later report in this series [1ℓ], the needs relating to water supply-waste water disposal listed above will be integrated with other needs concurrently being developed for coastal stabilization and protection [1h], dredging [1i], and wetlands [1h]. There, the supporting rationale will be summarized; relative priorities and levels of effort will be suggested; potential sponsors will be identified; and selected needs will be incorporated into a proposed problem-oriented marine research program for Long Island.

It should be noted that many of the data collection and research needs in the above recapitulation are primarily associated with non-marine requirements, but they have a very significant secondary relationship to the marine environment. An example is improved AWT technology. These needs are listed here because of their high relevance to marine affairs without implication that the satisfaction of these needs is the primary responsibility of the Council or the marine community.

SECTION 4 - GUIDELINES

4.1 SUMMARY OF BASIC CONSIDERATIONS

The hydrological system. In its natural state, undisturbed by man, about half the precipitation that falls on this area returns to the atmosphere as evapotranspiration, nearly a quarter enters the saltwater as stream flow, and over a quarter enters saltwater as underflow.

Man impacts upon this system significantly. He currently pumps over 300 mgd from the aquifiers. His total projected needs are about 600 mgd for the year 2000 and about 900 mgd for the year 2020. He loses about 14 percent of all he pumps through leakage. Of the remainder, he uses nearly three-quarters for residential purposes, nearly one-quarter for industrial purposes and relatively little for agricultural purposes.

The last column of Table 3 summarizes the quantitative impacts of man on the natural system. Note the potential reduction of underflow to a mere trickle by the year 2020. The entries for that year are based upon implementing the frequently-proposed strategy of placing sole dependence upon groundwater as a source, providing essentially complete sewering, and not changing current recharge practices. The figures in the tables, and hence man's impact, can be changed greatly by adopting any of a number of alternative strategies advocated herein.

TABLE 3

FATE OF WATER THAT FALLS AS PRECIPITATION
(in percent)

Sink	In the natural system	In man-influenced systems		Approximate change (col. 3 - col. 1) ÷ col. 1
		Now	2020	
To atmosphere	48	50	56	Up 15%
Streams/springs to ocean	22	23	3	Down 85%
Sewered to ocean	--	5	39	Up ∞
Underflow to ocean	30	22	2	Down 90%

Contamination of the system. In their natural state, the island's vast aquifers yield freshwater of very good quality. In recent years—because of cesspools and the heavy use of fertilizers—the quality of water in the Upper Glacial aquifer is falling below the approved groundwater supply standards in certain chemical characteristics. The principal chemical problems are with nitrogen compounds and detergents.

Coastal water quality falls below established usage classification standards, mostly in the interior parts of coves in the western part of the bi-county area. The principal cause is waste water discharge combined with poor local flushing.

Effects. The long-range effects of man's use and contamination of water can be changed greatly by the choice of a long-range strategy. In general, the principal subsurface effects to be considered in making that choice are lowered groundwater levels, chemical contamination of groundwater, and possible salt water intrusion. The principal surface effects to be considered are the general drying up of lakes and streams, changed surface water quality, salinity changes in the bays, possible toxic effects in the marine food chain, and possible land subsidence.

Integrated systems. Major decisions involving water supply and/or waste water disposal should always be made in the context of a "complete," multi-phase system involving the acquisition, treatment, transmission, distribution and use of freshwater; and the collection, treatment and disposal of the resulting waste water. Apparent economies or environmental advantages of a decision made in only one phase can produce major offsetting or reinforcing effects in other phases.

Alternative strategies. In developing major long-range, bi-county plans and programs, the four integrated systems (henceforth "strategies") listed below deserve careful consideration. None of the strategies cause significant, if any, lowering of groundwater levels, contamination of the water supply system, salt water intrusion, the drying up of lakes and streams, salinity changes in the bays, toxic effects in the marine food chain, or land subsidence.

- The "NRG" Strategy envisions importing water from the New York City system to Nassau and perhaps eventually to Suffolk, and continuing to use cesspools where feasible. Although the chemical quality of groundwater would drop, the groundwater would not be used as a routine water source.
- The "NSO" Strategy envisions the same importation of water but adds sewers, secondary treatment and ocean disposal. Water in the aquifers and bays would not be touched.

- The "GAG" Strategy envisions continued sole-source dependence upon groundwater, sewers, advanced waste water treatment and groundwater recharge by any one of several techniques.
- The "GSG" Strategy envisions continued sole-source dependence upon groundwater, sewers, secondary treatment and recharge of secondary effluent by spray irrigation.

The strategies are listed in increasing order of total estimated capitalized costs to meet projected, year-2000 needs—about $10—13 billion. Potential ecosystem effects include the leaching of possibly-unacceptable levels of chemical contaminants into coastal waters under the first strategy and the undesirable (or desirable?) effects of secondary effluents in the ocean under the second strategy. Political/institutional difficulties can be anticipated in moving water across county lines as envisioned in varying degrees in all but the third strategy and in setting aside the very large land holdings required by the fourth strategy. The third and fourth strategies require considerable developmental feasibility research.

Final choice should be influenced prominently by the results of priority research recommended herein and by the value judgments employed in weighing relative cost, environmental, political-institutional and technological aspects. If, for example, preservation of aquifer quality and political-institutional considerations are judged to override, the preferred strategy is GAG.

Local and interim considerations. The above strategies were derived from a consideration of the long-range needs of the bi-county area as an integrated whole. In application, the strategies should be tempered to recognize important local and short-term variations. For example, in the heavily-populated, high-water-using, significantly-sewered Nassau County area, the need for water import and/or groundwater, recharge is more apparent and current. On the other hand, in less-populated, lower-water-using, essentially-unsewered, water-abundant Suffolk County, the problems and, hence the need for these solutions, are more remote. The phasing of long-range strategies should, of course, reflect these differences.

4.2 GUIDELINES

Policy and Planning Guidelines

- Council's roles. The Council should define its basic roles with respect to this problem as--

  (1) Input. Helping to provide badly-needed, currently-inadequate input knowledge to help planners and decision makers view marine impacts with objectivity and perspective.

  (2) Review. Examining the adequacy of proposed strategies and major plans from a broad point of view that sees the coastal dimensions as important, but subordinate, parts of a major overall, island-wide problem.

  (3) Recommendation. Formulating its own perferences as to the best overall solution.

- Input role. To fulfill its input role, the Council should stimulate the necessary research and technology transfer with emphasis on the priority needs listed in the first research and analysis guideline below.

- Review role. To fulfill its review role, the Council should--

  (1) Encourage research identified herein with particular emphasis on the research related to the four integrated systems listed in Section 4.1 and the priority needs cited in the second research and analysis guideline below.

  (2) Reject, as too-narrowly conceived and tested, any proposed strategies and major plans that do not include a thorough analysis of--

  --How the proposal is justified when considered as part of an integrated, multi-phase water supply-waste water disposal system.

  --How the proposal compares with likely alternatives in terms of total system cost; before-and-after geological, health and biological conditions; and political/institutional implications.

  --How the proposal is adapted to local and short-term conditions.

- Recommendation role. To fulfill this role, the Council should--

  (1) Accept, as of now, value judgments giving overriding weight to aquifer quality and county independence.

(2) Express a preference for a basic strategy involving groundwater pumping, advanced waste water treatment and aquifer recharge.[1]

(3) Emphasize that this preference is based upon current knowledge and should not be cited to discourage priority research on other reasonable alternatives.

Research and Analysis Guidelines

- To improve understanding of marine impacts, the Council should:

  (1) Focus the highest priority research emphasis on understanding the impacts on marine biota of changes in the levels of salinity in bays and of contaminants near ocean outfalls.

  (2) Promote the development of a flexible coastal water quality monitoring system.

  (3) For selected embayments, promote the development of models to predict water quality changes and to establish the relationships between changing inlet configurations and the basic environment of the bay.

- To improve the chances of selection of the best integrated system, the Council should:

  (1) Encourage the development and use of improved, consistent, unit-cost data to facilitate the objective comparison of alternative systems.

  (2) Encourage research on the likely impacts of potential changes in groundwater levels.

  (3) Encourage the improvement of models to predict the relationship between net accretion on the one hand, and groundwater levels and salinity intrusion on the other.

  (4) Encourage the further development of AWT technology.

  (5) Encourage studies to determine the feasibility of developing an integrated bi-county-New York City water supply system.

  (6) Encourage studies to evaluate the feasibility of various recharge techniques, particularly in-stream recharge.

[1] A fuller statement of this guideline will be developed in a later report in this series [1m].

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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APPENDIX B

THE HYDROLOGIC SYSTEM ON LONG ISLAND

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THE HYDROLOGIC SYSTEM ON LONG ISLAND

1.0 SCOPE

This appendix develops a series of flow diagrams depicting the major stages of the hydrologic system on Long Island, the principal processes by which water moves between these stages, and the approximate quantitative relationships involved. The system is depicted in its natural baseline condition before man and also in its man-influenced condition. The purpose of these flow diagrams is to create a backdrop against which projected or proposed changes in man's activities can be generally related to their probable effects on the hydrologic system. The appendix concludes with a discussion of these effects.

2.0 THE WATER BUDGET AREA

Since so much available data are based upon the "water budget area" of the bi-county area for the year 1965 and the preceding 25-year index period, the year 1965 has been used as a base throughout. All data accumulated on a different basis are adjusted accordingly. The year 1965 was far from typical. It was perhaps the worst of the drought years. However, increased withdrawals that year are balanced to a large extent by increased withdrawals in later years caused by man's steadily growing urbanization. Thus, although gross pumpage in 1965 may not have been typical of the mid-60's, it is somewhat typical of current rates.

The water budget area is depicted in Figure B-1.[/1] It encompasses about 760

[/1] The water budget area selected for this bi-county analysis is the one defined by the U.S. Geological Survey [7]. Holzmacher [2] has developed a water budget area more specifically tailored to Suffolk County needs. The Holzmacher water budget area encompasses 647 of the 922 square miles in Suffolk County. About 450 square miles generally coincide with the U.S. Geological Survey water budget area and provide nearly 90 percent of the county's usable groundwater supply. The remaining area is generally east of the town of Riverhead.

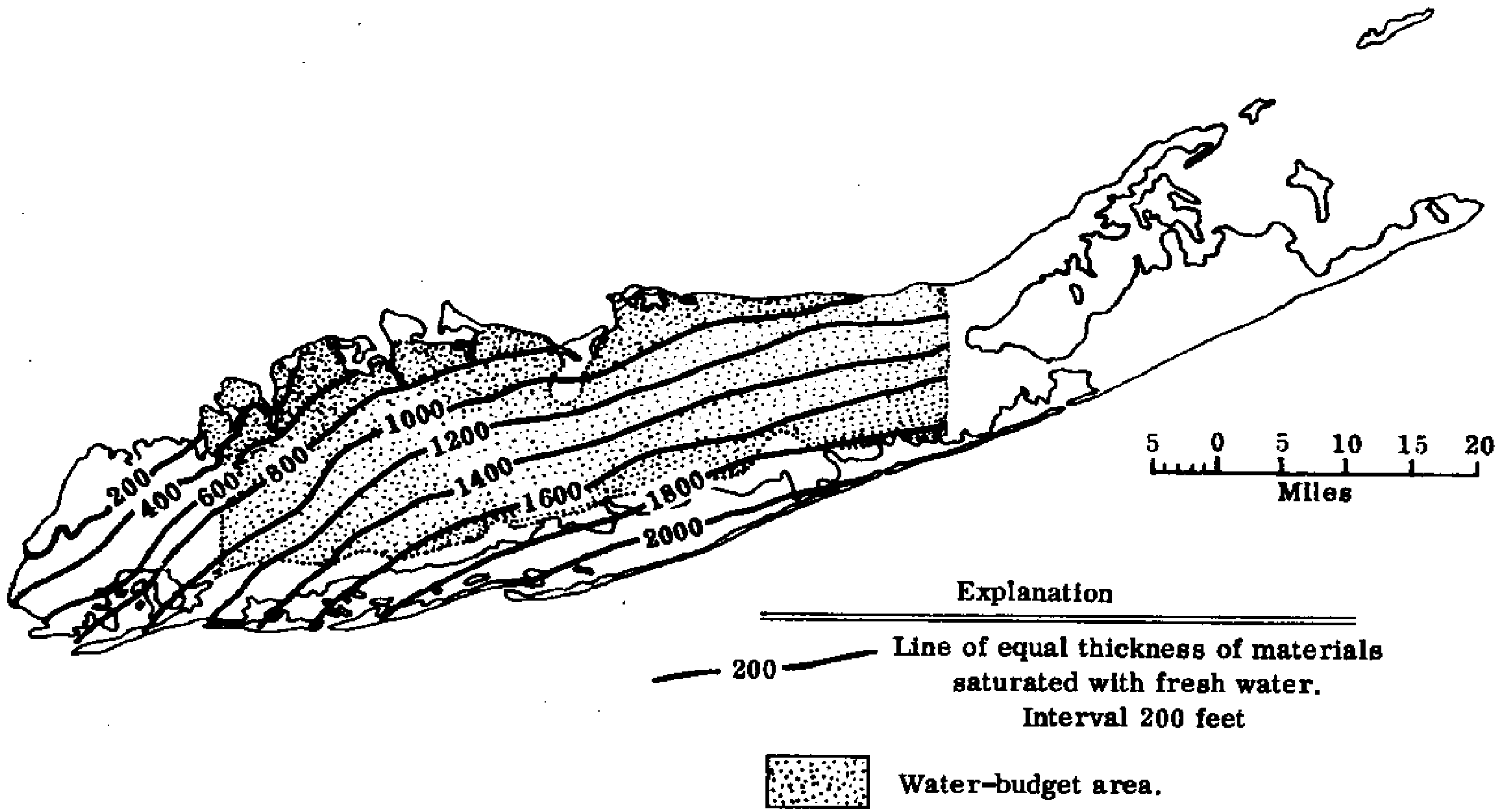


Fig. B-1
THE WATER BUDGET AREA OF LONG ISLAND Source [7]

of the total 1,200 square miles in Nassau-Suffolk Counties. Its western boundary is the border between Queens and Nassau Counties. Its northern border, aside from a few local exceptions based upon aquifer characteristics, generally traces the north shore of Long Island. The eastern boundary is an arbitrary north-south line that excludes the two eastern forks. Hydrologically, these forks are largely independent of the water budget area. The southern border traces a line of streamflow measuring stations. These stations are located at the farthest point downstream at which measurements can be taken without being affected by normal tidal fluctuations. As the water table contours in Figure B-2 imply, some groundwater probably flows out of the area on its western and eastern flanks. This quantity is assumed herein to be negligible.

The water budget area is underlain by a 60-trillion gallon system of aquifers depicted in highly simplified form[/1] in Figure B-3. About 98 percent of this volume is below sea level with a maximum depth of about 2,000 feet in south-central Suffolk County. About 3-6 trillion gallons are theoretically recoverable; but practically, as will be seen later, this is not a valid way of visualizing the recoverable water because of problems such as lowered groundwater tables, salt water intrusion, and possible land subsidence. Originally, the Upper Glacial aquifer supplied most water needs, but with increasing contamination of this aquifer, the Magothy aquifer has become the principal water source. In about 20 years after the installation of sewers, the Upper Glacial aquifer is expected to become, once again, a major source [2]. The Lloyd aquifer never was, and is not expected to become in the future, a major source except in a few highly-localized, low-demand areas.

[/1] For example, the Jameco aquifer occurs only in parts of Nassau County, and the Gardiners Clay and related position of the zone of diffusion between fresh and salty groundwater vary greatly in ways that are currently not well understood.

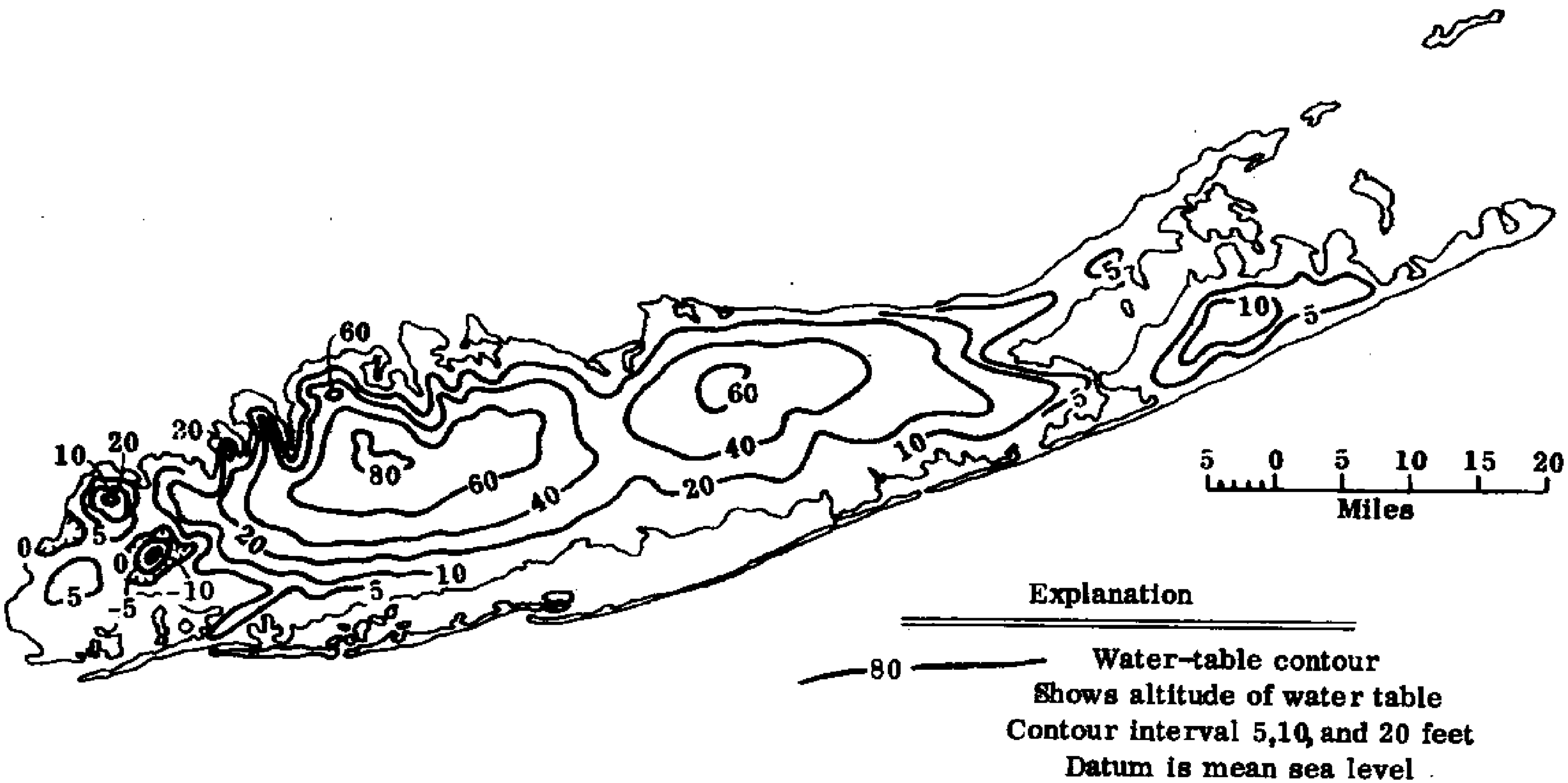


Fig. B-2
WATER TABLE CONTOURS Source [7]

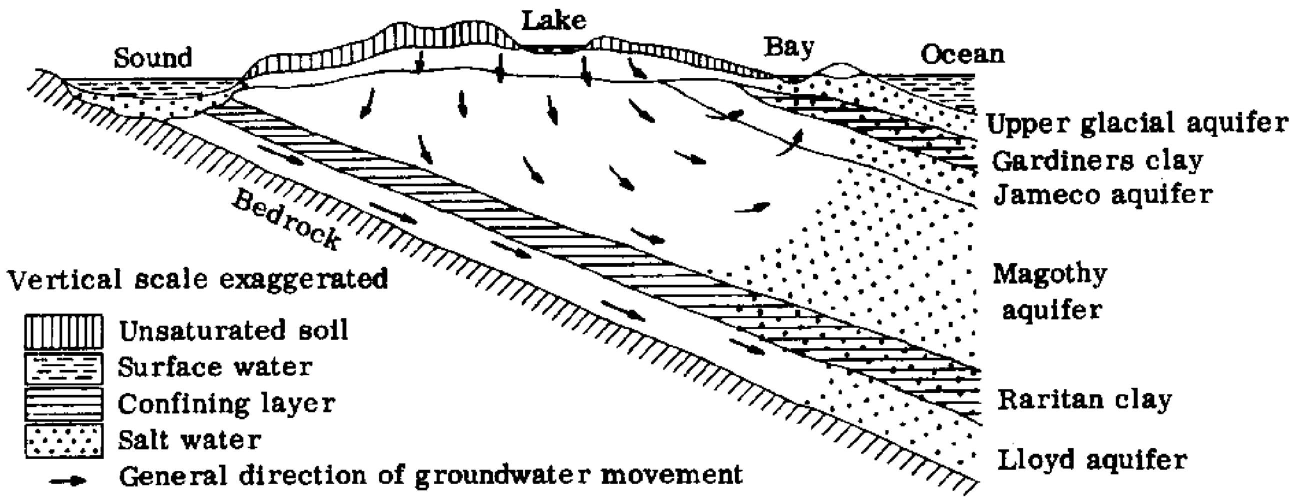


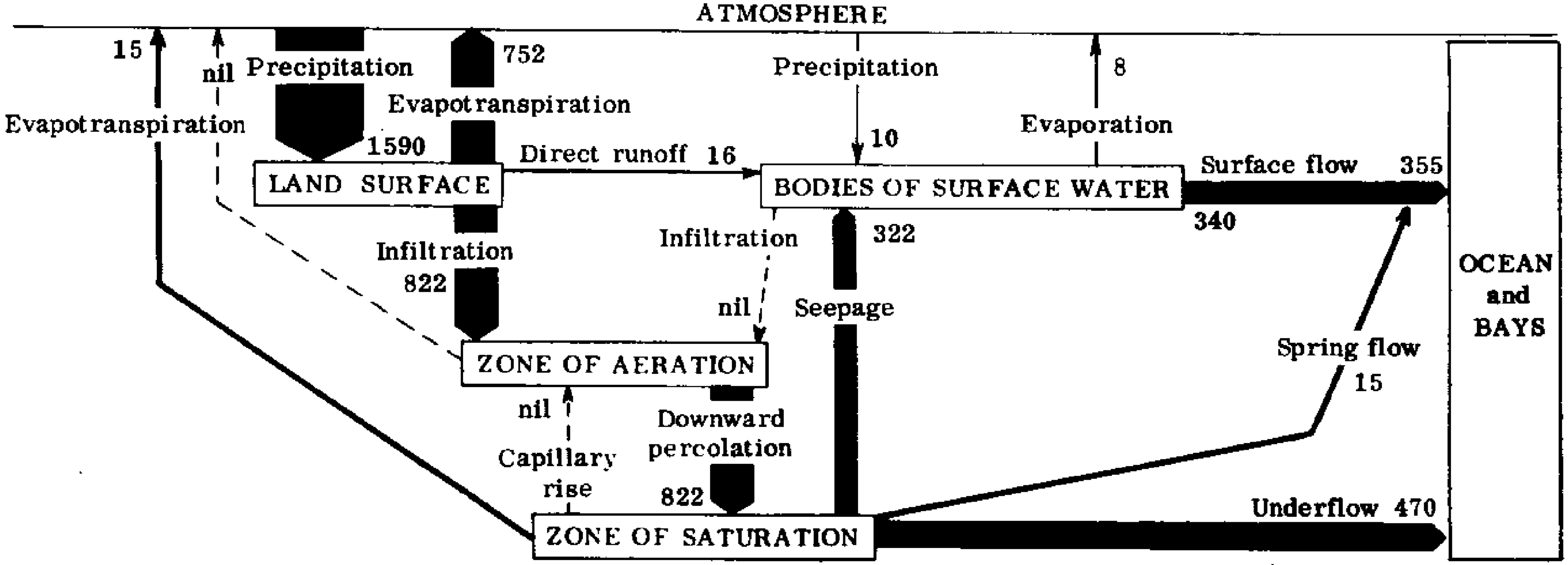
Fig. B-3
LONG ISLAND AQUIFERS Source [7]

Note the general direction of groundwater movement depicted in Figure B-3. Contaminants, such as nitrates, entering the aquifer in the central recharge area can contaminate the entire system. Contaminants entering the aquifer along the populated south shore will probably cause only comparatively shallow contamination and be carried away to the bays along with the underflow.

3.0 THE HYDROLOGIC SYSTEM UNDER NATURAL CONDITIONS

Figure B-4 depicts the hydrologic system in the water budget area under natural conditions--as it would exist without the perturbations of man. The data, in mgd (millions of gallons a day), were based upon measurements during the 1940-65 index period. It is assumed that this pattern is representative of the long-range water cycle on Long Island. Figure B-4 is based primarily upon information developed in Reference [7] adjusted as described below.

3.1 Precipitation. Precipitation is fairly uniform, varying from an annual average of about 50 inches in the interior to about 42 inches along the



Numerical entries represent average flow in mgd; "nil" indicates negligible amounts

Total inflow : 1,600 mgd in precipitation
Total outflow: -775 mgd in evapotranspiration to atmosphere
-355 mgd in surface flow to ocean
-470 mgd in underflow to ocean
1,600 mgd

Fig. B-4
FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM,
WATER BUDGET AREA, UNDER NATURAL CONDITIONS

coast. The 44.7-inch overall average is shown as 1,600 mgd falling on the land and surface water bodies in the water budget area. The amount falling upon each of these types of surface and the evapotranspiration return from each is estimated below.

Within the 760 square-mile water budget area, nearly five square miles are freshwater surface, estimated in Table B-1.

TABLE B-1

FRESHWATER SURFACE AREA (ACRES)

Township	Total In Bi-County Area [8]	Estimated Percentage Within Water Budget Area	Total In Water Budget Area
Hempstead	722	80	578
North Hempstead	287	100	287
Oyster Bay	822	90	740
Babylon	30	100	30
Brookhaven	300	100	300
East Hampton	880	0	0
Huntington	130	100	130
Islip	320	100	320
Riverhead	160	75	120
Shelter Island	30	0	0
Smithtown	130	100	130
Southampton	650	50	325
Southold	190	0	0
Total (Acres)	4,651		2,960
Total (Square Miles)	7.2		4.6

The 4.6 square miles represent 0.6 percent of the 760-square mile water budget area. Therefore, the precipitation falling on this water surface should be about 0.6 percent of the total 1,600 mgd average precipitation, or about 10 mgd.

From freshwater surface areas on Long Island, about 34 of the 44 inches that fall annually as precipitation is lost as evaporation [7]. This loss is equivalent to about 8 mgd ($\frac{34}{44}$ x 10 = 8). The remaining 752 mgd, of the total 760 [7] lost as evapotranspiration in the water budget area, is from the land surface.

3.2 Streamflow. About 95.3 percent of the 340 mgd streamflow discharging to salt water is base flow [7]. The remaining 4.7 percent (16 mgd) is direct runoff.

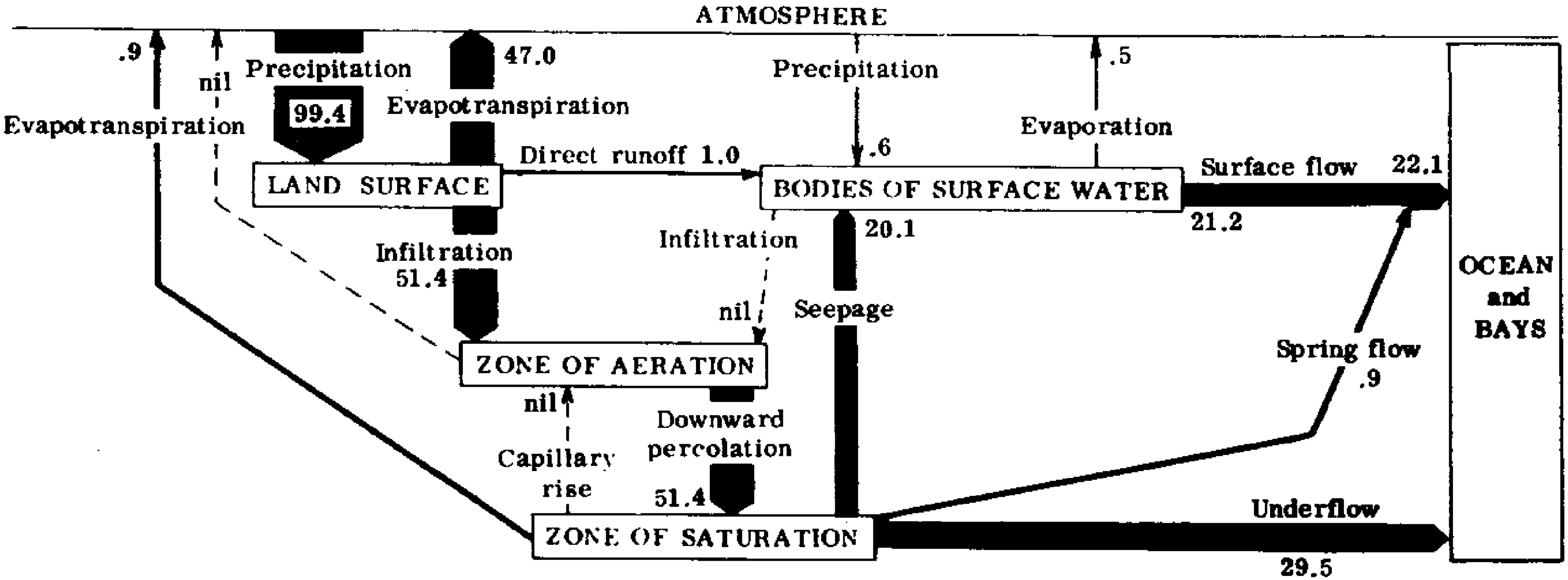
3.3 Infiltration from Surface Water Bodies. Surface water bodies are small in comparison to the total water budget area. Essentially, all streams cut the water table. The natural lakes and ponds are either of the "water table" or "perched" type. In either case, net downward infiltration is nil. Therefore, essentially all of the downward infiltration on Figure B-4 is considered as coming from the land surface. To make inputs and outputs to "Land Surface" balance, this quantity is shown as 822 mgd.

3.4 The Cycle Expressed in Percentages. Figure B-5 is identical to Figure B-4, except that the quantitative entries thereon depict the percentage breakdown of the precipitation water flow as it flows through the system.

4.0 MAN'S WATER SUPPLY AND WASTE WATER SYSTEM

Figure B-6 depicts man's water supply and waste water system in the bi-county water budget area. Note that 55 percent of the total pumpage is returned to the aquifer in the form of recharge. The remaining 45 percent is consumptive losses distributed 19 percent to the atmosphere through evapotranspiration and 26 percent to the bays and ocean through sewer outfalls.

This distribution differs appreciably in the two counties. In its portion of the water budget area, Suffolk County pumps about 114 mgd, recharges about 70 percent, and distributes its 30 percent consumptive losses about 25 percent through evapotranspiration and about 5 percent to the bays and ocean through



Numerical entires represent average flow in percent of total precipitation; "nil" indicates negligible amounts

Total inflow : 100.0% in precipitation
Total outflow: - 48.4% in evapotranspiration to atmosphere
- 22.1% in surface flow to ocean
- 29.5% in underflow to ocean
-100.0%

Fig. B-5
FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM, WATER BUDGET AREA, UNDER NATURAL CONDITIONS

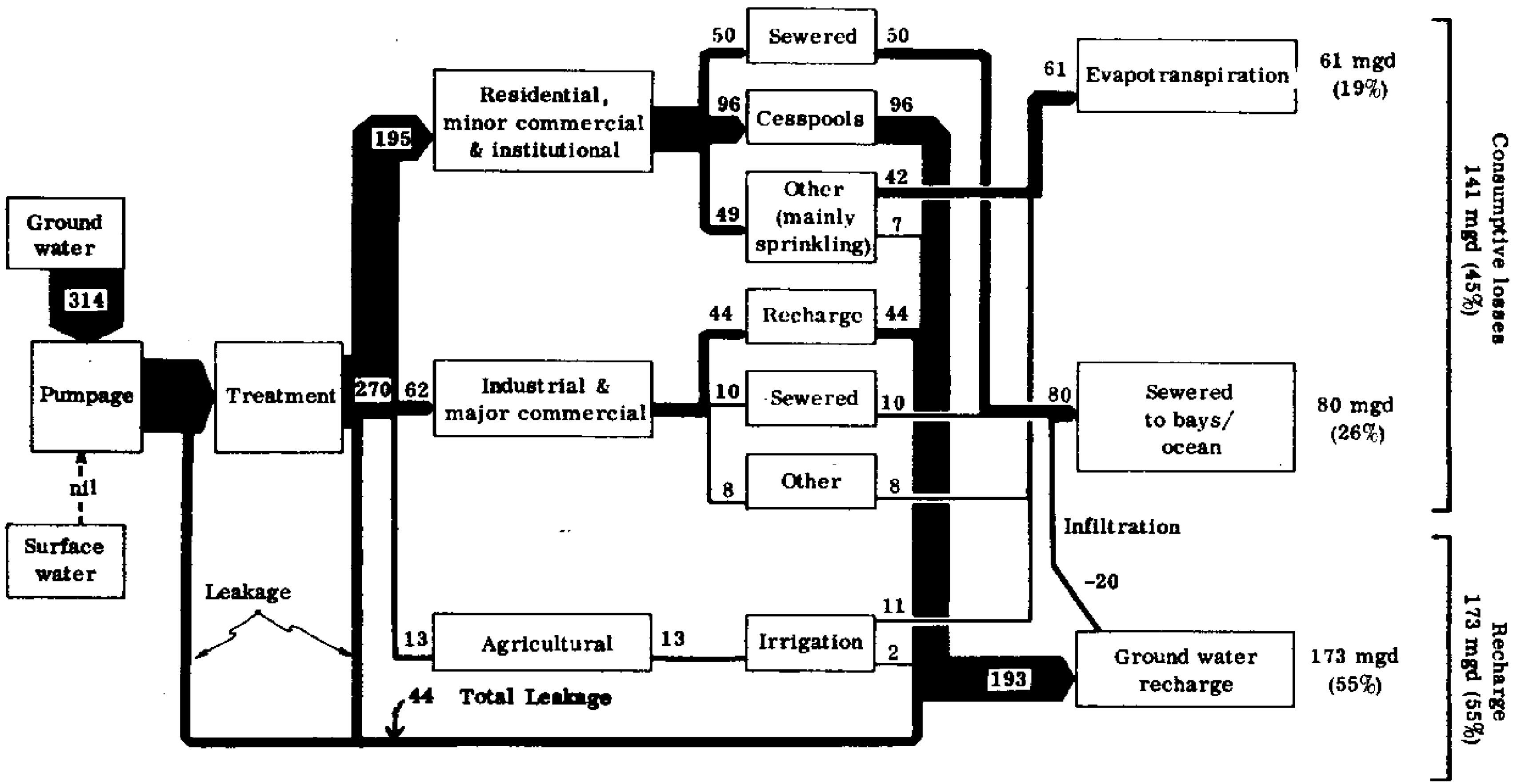


Fig. B-6
MAN'S WATER SUPPLY AND WASTE WATER SYSTEM,
WATER BUDGET AREA OF LONG ISLAND (in mgd)

B10

sewers. In marked contrast, in its portion of the water budget area Nassau County pumps about 200 mgd and recharges only about 45 percent. Evapotranspiration and sewered losses there are about 15 percent and 40 percent, respectively. This great difference in the county proportions stems from different waste water disposal practices. Suffolk returns almost all waste water to groundwater through cesspools and septic tanks. Nassau sewers more than half of its waste water.

In the future as Suffolk County sewers an increasingly large portion of its population, its recharge and consumptive use pattern should approach that of Nassau County.

Entries in Figure B-6 are derived below. Computations to support the separate county conclusions can also be derived from the data.

4.1 Pumpage. Total pumpage, sometimes called "gross usage" in Suffolk County was 128.35 mgd in 1965 [2, p. 207]. Subtracting 100 percent of usage in East Hampton, Southold and Shelter Island; 50 percent of usage in Southampton; and 25 percent of usage in Riverhead gives an estimated usage, sometimes called "net usage", of 114 mgd in the water budget portion of Suffolk County.

Total pumpage in Nassau County in 1968 has been estimated at 212 mgd consisting of 176 mgd from the public system and 36 mgd from the private system [3, p. 82a]. Pumpage in 1965 was at about a similar level. Assuming that about 95% was pumped from the water budget area gives a rounded estimate of about 200 mgd.

The total pumpage from the water budget area of Nassau-Suffolk Counties is therefore 314 mgd--114 in Suffolk and 200 in Nassau.

In the above computations, the amount of water withdrawn from surface water bodies is assumed negligible.

4.2 Leakage. About 14 percent of total pumpage is lost through leakage in the water transmission and distribution system in Nassau County [3]. Applying the same leakage factor to both counties yields the following summary:

TABLE B-2

PUMPAGE, LEAKAGE AND USAGE
(in mgd)

	Suffolk	Nassau	Total
Pumpage	114	200	314
Leakage	16	28	44
Usage	98	172	270

4.3 Disaggregation of Usage. Table B-3 summarizes 1965 water usage in Suffolk County by class [2].

TABLE B-3

DISAGGREGATION OF WATER USAGE BY MAJOR CLASS IN SUFFOLK COUNTY
(in mgd)

Class	Pumpage		Usage
	County-Wide	Water Budget Area*	Water Budget Area**
Residential, Minor Commercial and Institutional	81.26	76.0	65
Industrial and Major Commercial	25.85	24.6	21
Agricultural	21.24	13.4	12
Total	128.35	114.0	98

*Computed by making subtractions similar to those in Paragraph 4.1.

**Computed by subtracting 14 percent for leakage.

In the absence of readily-available precise 1965 data for Nassau County with definitions of user categories compatible with those used above for Suffolk County, the 172 mgd total Nassau usage is disaggregated by estimation. Total agricultural land in the water budget area of Nassau and Suffolk Counties in 1966 was about 2,000 acres and 39,000 acres respectively [8]. Assuming similar irrigation practices in each county, the agricultural water use in Nassau should be 2/39 of that in Suffolk, or about 0.6 mgd. From the Suffolk County data above, it is noted that industrial uses totalled 24 percent of the combined residential-industrial total. Using a similar proportion for Nassau County provides a basis for allocating the 171.4 mgd residential-industrial total there as 41.2 industrial and 130.2 residential.

Table B-4 summarizes the above data in rounded form.

TABLE B-4

DISAGGREGATION OF WATER USAGE BY MAJOR CLASS IN WATER BUDGET AREA
(in mgd)

	Suffolk	Nassau	Total
Residential	65	130	195
Industrial	21	41	62
Agricultural	12	1	13
Total	98	172	270

4.4 Disaggregation of Residential Usage. Assuming that about 75 percent of residential water usage leaves the premises as waste water, this amounts to about 146 mgd (75 percent of 195) for waste water and 49 mgd for other uses.

In 1965 about 80 mgd of treated sewage were piped to salt water, 75 mgd in Nassau and 5 mgd in Suffolk [7]. Essentially all came from the water budget area.

Treated sewage on Long Island typically consists of about 75 percent waste discharges and 25 percent net infiltation water [3 and 9]. Most of the infiltrating water enters the sewers as it passes downward through the zone of aeration after rainfall. During particularly dry periods, the opposite effect sometimes takes place--waste water leaches from the sewers into the zone of aeration. However, the estimated net effect is, as indicated above, about 25 percent infiltration into the sewers. Using this yardstick, the 80 mgd of treated sewage reported above consists of about 60 mgd waste discharge and 20 mgd infiltration.

In a large water pollution control plant proposed to treat an average of 30 mgd (50 mgd at peak flow) in southwestern Suffolk County, estimated residential wastes were about five times industrial wastes [9]. Applying a similar ratio to the 60 mgd waste discharge indicates that about 50 mgd were residential waste water and 10 mgd were industrial waste water.

The remaining 96 mgd (146 - 50 = 96) of residential waste water is untreated and is here assumed to be conveyed to cesspools and septic tanks.

Other uses, 49 mgd, are primarily outdoors such as lawn sprinkling, washing the car and fire fighting. The disposition of this water is assumed to follow a pattern similar to that estimated later in Paragraph 4.6--85 percent to evapotranspiration and 15 percent to infiltration.

The disposition of the 195 mgd residential water usage is summarized in Table B-5.

TABLE B-5

DISAGGREGATION OF RESIDENTIAL WATER USE
(in mgd)

Component	Usage	Disposition		
		Sewered to Ocean	Infiltration	Evapotranspiration
Sewage	146	50	96	0
(Treated)	(50)	(50)	(0)	(0)
(Untreated)	(96)	(0)	(96)	(0)
Other	49	0	7	42
Total	195	50*	103	42

*This residential waste water is about 75% of the residential sewage flow. The remaining 25% (17 mgd) is ground water infiltrated into the sewage system.

4.5 Disaggregation of Industrial Usage. Industrial recharge, through diffusion wells and basins has been estimated at about 16 mgd in Suffolk [2] and 28 mgd in Nassau [3]. Essentially all of this 44 mgd total is believed to have been recharged in the water budget area.

An additional 10 mgd is treated wastes carried away by the sewerage system, as indicated in paragraph 4.4 above. The remaining 8 mgd of the total 62 mgd industrial water is assumed to be lost through evaporation principally in air conditioning and other processes such as steam makeup.

The disposition of the 62 mgd industrial water usage is summarized below.

TABLE B-6

DISAGGREGATION OF INDUSTRIAL WATER USE
(in mgd)

Component	Usage	Disposition		
		Sewered to Ocean	Infiltration	Evapotranspiration
Recharged Water	44	0	44	0
Sewage	10	10	0	0
Other	8	0	0	8
Total	62	10*	44	8

*An additional 3 mgd infiltrates into the sewerage system.

4.6 Disaggregation of Agricultural Usage. The 13 mgd of agricultural water used in the water budget area should be dissipated in manner somewhat similar to the evapotranspiration loss experience during the irrigation season, May through August.

Evaporation and transpiration data are poor on Long Island. Little distinction is made between the two processes. Total evapotranspiration is reported with wide variations in the literature. Evapotranspiration data reported by the U.S. Geological Survey [7] are used here. According to this source, total annual evapotranspiration losses in the water budget area average about 760 mgd out of an annual precipitation of 1600 mgd [7]. This is 47.5 percent of total precipitation or about 21.3 inches a year. Table B-7 is based upon Meyer [10] but adjusted to agree with the above total of annual evapotranspiration losses and to assure that total evapotranspiration losses in the peak month do not exceed 115 percent of precipitation for that month, a ceiling figure observed in nearby Connecticut [11]. According to the table, evapotranspiration during the irrigation season (May-August) averages about 85 percent of the precipitation falling in the same period.

TABLE B-7

APPROXIMATE EVAPOTRANSPIRATION LOSSES

Month	Mean Air Temp. at Sampawams Creek [8]	Mean Rainfall at Setauket Inches [8]	Estimate: Evapo-ration	Transpi-ration	Evapo-trans-piration	% Precip.
Oct.	56°	3.7	.9	1.0	1.9	50
Nov.	45°	4.2	.9	.2	1.1	25
Dec.	37°	3.8	.6	-	.6	15
Jan.	32°	3.6	.6	-	.6	15
Feb.	33°	3.7	.6	-	.6	15
Mar.	36°	4.3	.6	-	.6	15
Apr.	51°	4.2	.7	.6	1.3	30
May	61°	3.2	1.0	.9	1.9	60
Jun.	71°	2.6	1.1	1.2	2.3	90
Jul.	74°	3.3	1.2	2.1	3.3	100
Aug.	75°	4.5*	1.5	2.5	4.0*	110
Sep.	68°	3.6	1.2	1.9	3.1	85
Annual		44.7	10.9	10.4	21.3	

*4.0 inches is 110% of the estimated non-hurricane precipitation of 3.6 inches.

Notes: (1) Evapotranspiration losses during the May-August irrigation season total 13.6 inches, about 85 percent of total precipitation during that period.
(2) These data are considered accurate enough only for the broad purposes of this report. For more detailed uses, more detailed Long Island studies should be located.

Applying the 85 percent figure to the 13 mgd agricultural usage in the water budget area gives 11 mgd lost as evapotranspiration and 2 mgd lost as infiltration.

TABLE B-8

SUMMARY OF WATER USE AND DISPOSITION
(in mgd)

Component	Usage	Disposition		
		Sewered to Ocean	Infiltration	Evapotranspiration
Residential, minor commercial and institutional	195	50	103	42
Industrial and major commercial	62	10	44	8
Agricultural	13	0	2	11
Total	270	60*	149	61

*An additional 20 mgd infiltrates into the sewerage system.

5.0 THE HYDROLOGIC SYSTEM AS INFLUENCED BY MAN

By his developmental activities, man alters the natural hydrologic cycle, in two ways.

(1) When he clears natural vegetation and replaces it with grassy, impervious or barren surfaces, he thereby increases evaporation losses, decreases transpiration losses and increases surface runoff losses.

(2) When he pumps water from the ground into his water supply-waste water system, he thereby increases the amount of water sewered to the ocean, infiltrated to the groundwater table and lost in evapotranspiration to the atmosphere.

The overall result of these two man-introduced impacts on the natural hydrologic system is depicted in Figure B-7. The diagram shows the percentage breakdown of the precipitation water as it flows through the system. The data for the natural system were developed in paragraph 3. Data on man's water supply-waste water system were developed in paragraph 4. Information on the hydrologic impacts of man's surface changes is not readily available, but order of magnitude estimates are developed below.

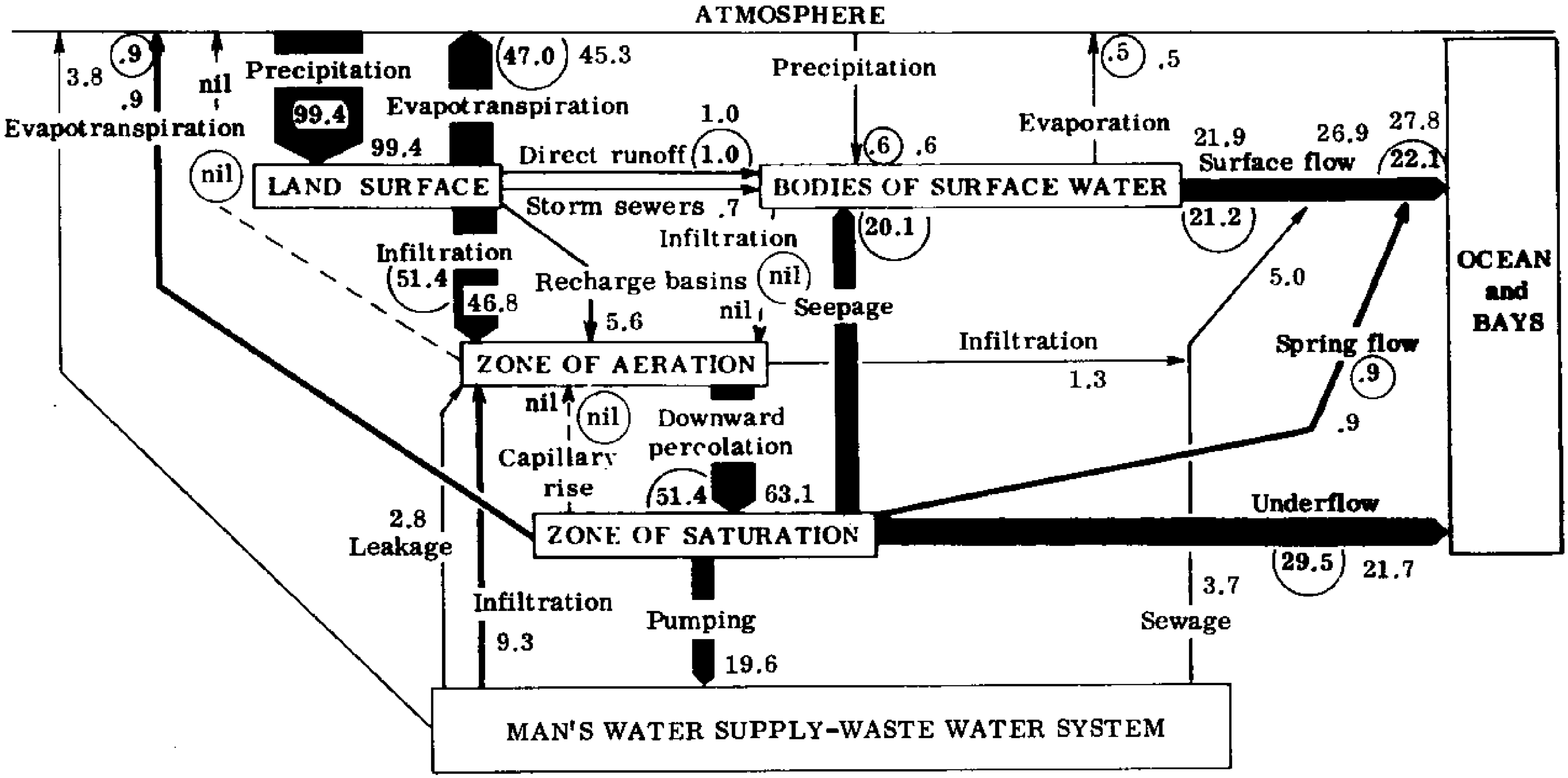
5.1 Evaporation. Table B-9 lists relative rates of evaporation observed at Cold Spring Harbor, Long Island, as reported by Meyer [10].

TABLE B-9

EVAPORATION RATES

Surface Type	Percent
Bare sand and gravel slide	100
Open garden plot with low herbaceous vegetation	80 to 100
Upper beach areas	80 to 90
Light forest on gravel soil	50 to 70
Dense forest with abundant undergrowth	35 to 40
Dense ravine forest with abundant herbaceous vegetation	13
Dense swamp forest with abundant undergrowth and water near surface	10
Freshwater marsh	45

Reflecting on the nature of the surface changes introduced by man, it is very apparent that man has changed the landscape in the direction of considerably higher evaporation losses. Lacking much quantified information on the man-made changes, it is very difficult to appreciate their impact. As a very rough first order approximation, and guided by Table B-9, it is hereby estimated that man has increased the overall evaporation rate from about 50 percent to about 70 percent. Applied to the 11-inch natural evaporation loss estimated in Table B-7, this is about a 4.4 inch increase $(11 \times \frac{70}{50}) - 11 = 4.4$.



Numerical entries represent average flow in percent of total precipitation; "nil" indicates negligible amounts
Encircled numbers depict the natural system as shown in B-5. The other numbers depict the system as influenced by man

		Natural system	Man-influenced system	Change
Inflow		100%	100%	-
Outflow:	Atmosphere	-48.4%	-50.5%	+2.1%
	Surface flow to ocean	-22.1%	-27.8%	+5.7%
	Underflow to ocean	-29.5%	-21.7%	-7.8%

Fig. B-7
FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM,
WATER BUDGET AREA AS INFLUENCED BY MAN, CIRCA 1965

5.2 Transpiration. According to Meyer [10], transpiration rates are proportional to the weight of dry matter produced. It is apparent that man has significantly reduced these losses by converting a large portion of the water budget area from medium growth deciduous and conifer forests and brush to cleared impervious or grassy surfaces. Lacking quantified information on the extent of these man-made changes, it is very difficult to appreciate their impact. As a very rough first-order approximation, it is hereby estimated that man has cut the weight of dry matter produced by half. Applied to the 10.4 inch natural transpiration loss estimated in Table B-7, this is about a 5.2 inch decrease in transpiration losses ($10.3 \times \frac{50}{100} = 5.2$).

5.3 Combined Evapotranspiration. In general, evaporation losses appear to about balance transpiration gains. However, primarily to flag this influence on Figure B-7 so that its accuracy can be improved by additional research beyond the scope of this study, the net effect of the gross estimates in paragraphs 5.1 and 5.2 above are portrayed as a reduction of evapotranspiration losses of about 0.8 inches annually (a 5.2 inch transpiration decrease and a 4.4 inch evaporation increase). This net reduction is equivalent to about 1.7 percent of the area's 44.7 inch annual precipitation and has a magnitude of about 24 mgd (1.7 percent of 1600 mgd).

5.4 Direct Runoff. By his urbanization, man has also increased direct surface runoff primarily by storm sewers that collect runoff from impervious surfaces such as streets. This collected runoff is conveyed by the storm sewers either to recharge basins or to surface water bodies flowing into streams and thence to the bays or ocean. Sufficient data are not readily available to distribute this storm sewer flow between these two methods, but a first approximation can be attempted making some gross assumptions, all of which can be refined.

5.4.1 Recharge Basins. In 1968 Nassau-Suffolk Counties had over 2,000 recharge basins, mostly in the water budget area with an estimated acreage of 4,678 [12]. Two of these basins were studied intensively [13]. Their combined area was 1.5 acres and they serviced a residential drainage basin about 30 times as large, 43.8 acres. Impervious surfaces covered about 34 percent of this drainage area. The study indicated that, in a year of average precipitation:--

a. Virtually all the water that enters the recharge basins infiltrates into the ground within a few hours and almost always within a day after the rainfall. Therefore, increased evaporation losses caused by the basins were assumed to be negligible.

b. The average annual inflow into the recharge basins is closely proportional to the ratio of street area to total drainage area. By inference, without such surfaces there would be little or no direct natural runoff. Seen in this light, recharge basins seem to be essentially a compensating device: what man's street surfaces and storm drainage systems subtract from natural infiltration, recharge basins return.

c. Recharge to the zone of aeration was about 10,000 gpd per acre of recharge basin. This is equivalent to 360 gpd per acre of drainage basin served by these recharge basins.

The recharge basins in Suffolk County returned an estimated 74 mgd in 1966 [2]. Nassau County, with about a quarter of Suffolk's total recharge basin area, probably returned about 18 mgd. Essentially all of this combined (rounded) total of 90 mgd was in the water budget area. This impressive quantity is equivalent to about 5.6 percent of total precipitation.

5.4.2 Direct Runoff to Streams. Especially along the coast where storm-water recharge basins are not practicable, some storm sewers discharge directly into streams. In Suffolk County, storm water represents about 3-12 percent of total stream flow. The percentage varies conspicuously with the degree of urbanization. In a 10-square mile Hempstead subarea with an impervious cover of nearly 30 percent and storm sewers discharging into East Meadow Brook, it has been estimated that direct runoff (not total stream flow) has been increased about 270 percent by man [14]. Since this is one of the most highly urbanized areas on Long Island, the average island-wide increase in direct runoff is certainly much less, say about 50 percent. The total direct natural runoff for the entire water budget area has been estimated at about 16 mgd [7]. A 50 percent increase equals about 8 mgd, or about 0.5 percent of total precipitation. To account for the increased runoff in the non-paved, non-sewered areas where man has also increased direct runoff by replacing natural woodlands with grassy or barren areas, this estimate is increased to 0.7 percent.

5.5 Man's Water Supply - Waste Water System. The estimated effects of this system were portrayed in Figure B-6. The information in that figure provided the basis for the corresponding entries, in summary form, shown on Figure B-7.

5.6 Continuity Relationships. Since the total quantity of water entering and leaving each stage of the hydrologic cycle must balance, some minor adjustments were made at each stage to reflect this balance.

6.0 EFFECTS

6.1 Subsurface Effects. The principal subsurface effects of man's alteration of the natural hydrologic system are lowered groundwater levels[/1] and

[/1] Groundwater levels, and piezometric heads in the artesian aquifers, are measured by a network of observation wells. Several studies [2 and 3] have recommended an expansion of the network, especially to improve knowledge of the piezometric surface of the Magothy aquifer.

possible salt water intrusion. Lowered groundwater levels can increase the cost of pumping and create surface effects considered later. Rising groundwater levels, which are possible under some long-range strategies, can cause flooding of basements not designed against this possibility. In Nassau County's Sewer District No. 1, groundwater levels have been observed to drop as much as 15 feet (average of 7 feet) because of the increased pumping and sewers, and the ultimate total drop may be still greater [15]. The water table in Nassau County has declined considerably, at least since 1903. About half the decline was experienced in the period 1959-1967 [3 and 16]. Among the principal factors that probably contributed to the decline are increased pumpage, sewers and decreased natural recharge because of urbanization; however, the USGS has concluded that most of the decline was related to the drought conditions experienced in the early 1960's. In Suffolk County, groundwater levels dropped about 2-4 feet from 1907 to 1957 and 10-12 feet from 1957 to 1965 [2]. The latter drop is most likely attributed to the drought.

The state of current knowledge on salt water intrusion has been summarized by Holzmacher [2]. The extent of intrusion is governed by the location of the salt water-fresh water interface. This location is influenced by a number of interrelated factors including net recharge, groundwater levels, the relative densities of fresh and salty water, the permeability of the soils in the aquifer, and the transient speed with which a change in net recharge is transmitted to the vicinity of the interface.

Salt water intrusion has been a major problem in Kings and Queens Counties [7 and 17] partially because of intensive pumping and relatively high (as compared to Nassau and Suffolk) permeability. The problem has extended to the southwest corner of Nassau County. Recent studies summarized by Holzmacher [2] and Greely-Hansen [3] have indicated that salt water intrusion in the bi-county area is not likely to be as significant a problem as previously envisioned. The inland movement of the wedge is estimated at a regional rate of less than 10-20 feet a year. Holzmacher suggests that the sustained permissive yield of the Magothy aquifer can be significantly increased by letting the salt water interface move inland, from its current position an unknown distance south of Fire Island, to the vicinity of the north shore of Great South Bay. Not only could the volume of water available from the storage reduction be used, but a lesser rate of underflow would be required to maintain the interface in this new "optimal" position.

Understanding of the phenomenon is being greatly improved by the development of groundwater models. The USGS is completing development of a five-layer steady-state, electric analog model in Mineola. Since the model is of the steady-state type, it will estimate the ultimate location of the salt water interface in response to changes in net recharge; however, its ability to predict the time lag in the response is limited. Later phases in the development of the USGS family of models envision (1) a digital, nonsteady state model that will predict the time lag and (2) a model that will ultimately predict the movement of contaminants other than chlorides.

The Hele-Shaw model developed at the Massachusetts Institute of Technology has been extensively used by Holzmacher [2] for Suffolk County. This model has indicated that, if pumpage were spread evenly at a rate equal to the average annual accretion rate (i.e., zero natural recharge), the Magothy wedge would move inland at a rate of only about 20 feet a year. These conclusions have been questioned because of the doubtful assumptions.

Although recent research and model studies have greatly increased understanding, much additional work remains to improve current knowledge of the complex relationship between net recharge, groundwater levels and salt water intrusion.

To do this, a high level of data collection and research effort is required, particularly in monitoring groundwater levels, learning more about the underlying geology, and improving the reliability and sophistication of the models. Major geological uncertainties include the differences between horizontal and vertical permeability and the extent of the Gardiners Clay, particularly offshore. To plug an important blind spot, Holzmacher [2] has proposed a submarine core boring to the bottom of the Magothy aquifer about 3-5 miles offshore south of the barrier beaches.

6.2 Surface Effects. The principal surface effects of man's alteration of the natural hydrologic system are drying up of surface lakes and streams, possible land subsidence, and changes in the salinity of the bays. The Hele-Shaw model predicts that the most significant likely effect of the greatly increased pumpage anticipated in the future will be lowered groundwater levels, not salt water intrusion. When the groundwater level declines, lakes dry up and stream flow (95% from groundwater) drops. The magnitude of these losses, the impacts upon lake and stream life and recreation, and the degree of public acceptance of these impacts requires considerably more study.

When groundwater levels drop, subsidence of the land surface is a possibility. No such subsidence has yet been observed on Long Island, but this irreversible phenomenon has been observed in other locations, notably in California [18].

When stream flow drops, the salinity in the bays will increase. This is likely to occur under a policy of increased pumpage coupled with increased discharge of sewage though ocean outfalls, a frequently-proposed long-range strategy. The significance of the resultant changes in bay salinity depends upon the salinity ranges required to sustain the marine life in the bays, the degree of the salinity changes and the public acceptance of possible effects on the marine life.

Salinity tolerance ranges vary appreciably from species to species and cannot be stated with complete confidence because of the interrelated nature of the bay ecosystem. Apparently, the oyster tolerates a range from 5 to 34 ppt (parts per thousand), the salinity of sea water, and its optimum is about 22.5. In some areas such as Chesapeake Bay [19], the upper limit for oysters is fixed at about 12.5 to 18 ppt because these are the lower limits that can be tolerated by the starfish and the oyster drill, two important predators there. The hard clam, which is by far the most commercially important species in the South Shore bays, tolerates a range of 17.5 to 34 and thrives at 27.5. Most marine finfish prefer salinities above 23 ppt, but young striped bass require less than 1 ppt.

The magnitude of the possible salinity changes is not well known, but Great South Bay can provide some insights. Holzmacher [2] has estimated the current volume of freshwater into this bay as follows:

145 mgd	Gauged stream flow
62 mgd	Pickup of underflow below gauging stations
20 mgd	Recharge south of catchment area
14 mgd	Upflow into bay
241 mgd	= 88 billion gallons a year (bgy).

To this total must be added the net precipitation (precipitation less evaporation) over the Bay. If total annual precipitation averages 42 inches over the Bay and evaporation from Long Island surface water averages about 34 inches annually [7], then the net accretion from precipitation is about 8 inches. Spread over about 100 square miles of the Bay's surface, this is equivalent to about 14 bgy. Adding this to the 88 estimated by Holzmacher gives an annual fresh water input of about 100 bgy. This is about two-thirds of the total water volume of the Bay at mean low water.

Mixing with this 100 billion gallons are about 15,000 billion gallons of sea water annually moved into and out of the Bay by tidal processes. Much of this salt water, which enters at a salinity of about 32-34 ppt, is moved right out again at the next ebb tide, but some of it mixes with the Bay waters and remains.

The overall effect of this continual, partial mixing of incoming fresh water with about 150 times that amount of seawater produces typical salinity concentrations over almost the entire Bay ranging between 27 and 30 ppt [20 and 21].

Without a fairly sophisticated model analysis, no precise conclusions can be reached. However, the above rough calculations permit the following preliminary observations:

(1) The dominant features in controlling typical salinity concentrations over most of the Bay are the inlets which influence tidal exchange.

(2) The typical salinity ranges in the Bay are well within the tolerable range of the starfish and oyster drill, both major shellfish predators.

(3) Nothwithstanding the first observation, salinity concentrations varying from nearly zero to 27-30 ppt will be found in the immediate vicinity of freshwater inflows.

(4) These freshwater inflows will be found almost entirely in the <u>immediate vicinity</u> of stream mouths. The amount of freshwater entering the Bay through underflow is apparently relatively minor. It is presumably spread over a large area and it should mix rapidly with the overlying salty and heavier bay waters.

(5) Considering all these observations, the potentially significant biological effects may be narrowed to two possibilities:

(a) Over most of the area of the bay, marine life that distinguishes between salinities of 27 and 34 ppt.

(b) Over the remaining small part of the bay near stream mouths where sharp salinity gradients can be found, marine life that depends upon the lower concentrations, especially for spawning.

Given the above rough narrowing of the problem, it ought to be possible to combine existing knowledge of salinity tolerances with some controlled observations to predict the most likely effects of possible changes in stream flow upon marine life. Such research is badly needed to give water planners and managers insight on a hitherto major area of uncertainty.

Should the effects be found to be significant near stream mouths, a possible remedy has been proposed by Holzmacher [2]. Waste water treated to acceptable standards (or pumped groundwater) could be discharged into the streams. This approach of adding water at the point of need would be far more efficient than attempting to sustain stream flow by recharging enough water to raise groundwater levels over a wide area. If the requirement is found to be seasonal, say during the spawning season, the makeup water might be added mainly at that time. However, the recreational and ecological values of the streams themselves might dictate that streams be maintained at their present flows by recharging. The trade-offs involved in this procedure require further study, but it is essentially a public decision.

7.0 PERMISSIVE SUSTAINED YIELD

It is difficult to determine "permissive sustained yield" (sometimes called "safe yield") because the definition involves a judgement of what environmental conditions will most likely be acceptable.

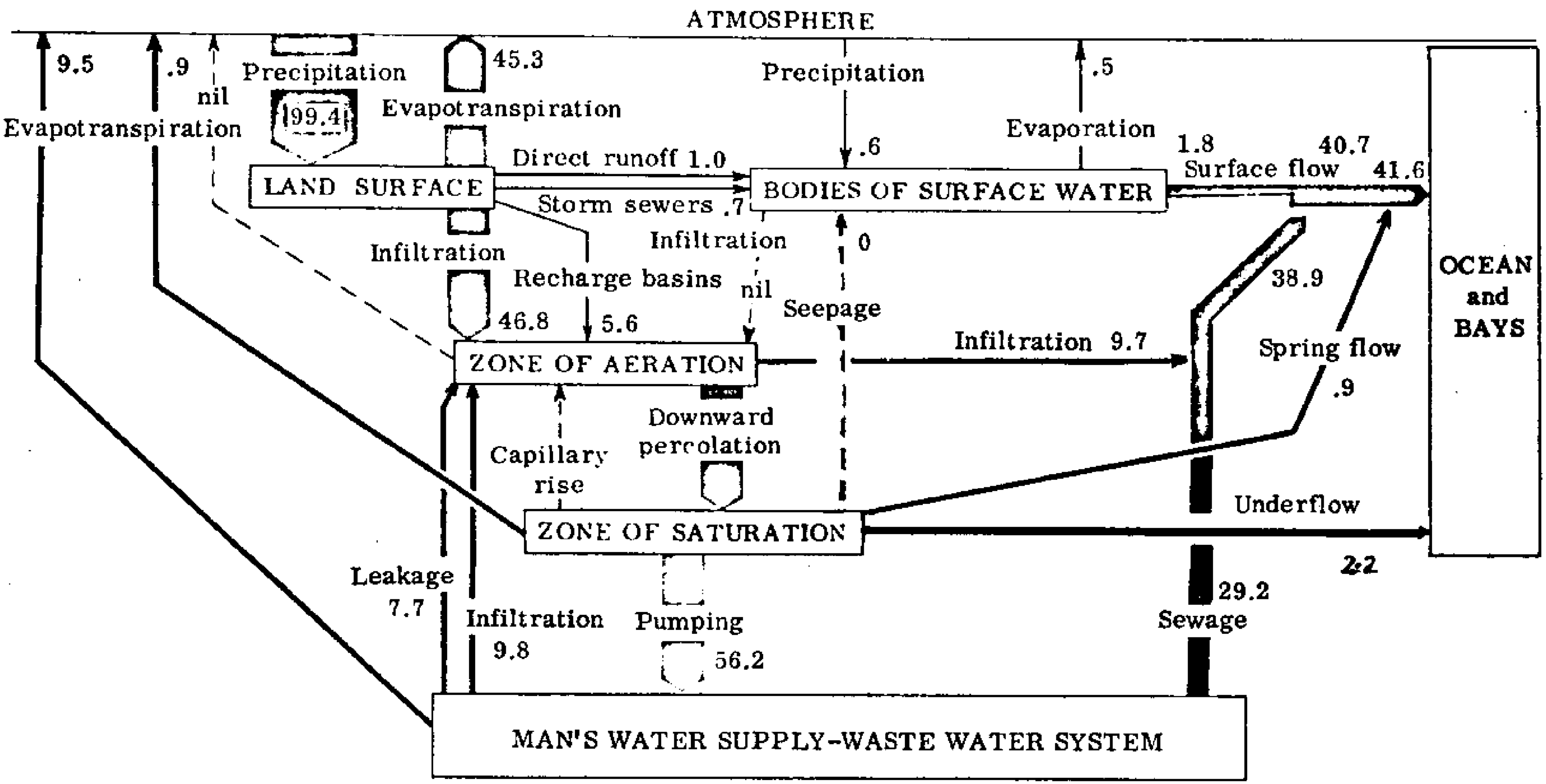
In order to get a general idea of the environmental conditions that may be encountered, we can turn to the year 2020, half a century from now. According to Table 1 in the main report, the bi-county population might then be about 5.3 million and water requirements about 900 mgd.

If the following simplifying assumptions prevail, the man-influenced hydrologic system in that year would be somewhat as shown in Figure B-8:

- Agricultural water use will be insignificant.
- Residential/industrial usage will be split about 80%/20% similar to the present ratio.
- About 95 percent of the sewage will be treated and discharged into the ocean.
- The water table will be lowered so that no seepage enters the streams.
- Essentially all of the water supply is drawn from the water budget area.
- The other relationships developed earlier for Figure B-7 continue generally to apply.

To return to the assumption about seepage to streams being zero--this may not prevail, but any seepage would be at the expense of underflow to the ocean. The combined total of these two flows in Figure B-8 would be a meager 2.2 percent. This is a very large drop from the corresponding combined total of 49.6 percent for the natural system (Figure B-5) or 41.8 percent for the current man-influenced natural system (Figure B-7). An almost complete drying up of lakes and streams except during storms, possibly significant salt water intrusion problems and probable salinity problems in the bays would be encountered. It is very doubtful if Long Islanders would accept these conditions.

Rather clearly, at some time in the future, probably well before the turn of the century at the latest, some major change in the current system must be introduced (especially in Nassau County). Possible changes examined later in



Numerical entries represent average flow in percent of total precipitation; "nil" indicates negligible amounts

		Natural system	Man-influenced system	Change
Inflow		100%	100%	-
Outflow:	Atmosphere	-43.4%	-56.2%	+ 7.8%
	Surface flow to ocean	-22.1%	-41.6%	+19.5%
	Underflow to ocean	-29.5%	- 2.2%	-27.3%

Fig. B-8
FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM,
WATER BUDGET AREA AS INFLUENCED BY MAN, CIRCA 2020

Appendix D include the importation of water through the New York City system, the initiation of groundwater recharge on a very great scale, and the development of desalination.

8.0 SUMMARY

The Natural System

- Of the precipitation that falls on the water budget area:
  - About 48 percent returns to the atmosphere as evapotranspiration.
  - About 22 percent enters the sea as streamflow. Only 1 percent is direct surface runoff; the remaining 21 percent is base flow fed by the water table.
  - About 30 percent enters the sea as subsurface flow.

Man's Water Supply and Waste Water System

- Within the water budget area, man currently pumps over 300 mgd.
- Measured in terms of this total pumpage:
  - About 14 percent is lost as leakage.
  - About 62 percent is used for residential, minor commercial and institutional purposes.
  - About 20 percent is used for industrial and major commercial purposes.
  - About 13 percent is used for agricultural purposes.
- As a result of this leakage and usage pattern, the ultimate fate of the pumpage is as follows:
  - About 55 percent is recharged to the aquifers.
  - About 45 percent is used consumptively, 19 percent as evapotranspiration to the atmosphere and 26 percent as treated sewage to the bays and ocean.

- All of these bi-county totals can vary appreciably with the locality, as described more completely in the foregoing analysis.

The Natural System as Influenced by Man

- By altering the surface of Long Island, man is:
  - Significantly increasing losses through evaporation.
  - Significantly decreasing losses through transpiration.
  - Slightly increasing losses through direct runoff.
- These surface effects probably largely balance each other.
- Through his water supply and waste water systems, man is:
  - Increasing evapotranspiration losses by nearly 5 percent over the amount lost naturally by this process.
  - Increasing surface losses to the ocean by about 25 percent over the amount lost naturally by this process.
  - Decreasing subsurface flow to the sea by about 25 percent over the amount lost naturally by this process.

Effects

- The principal potential subsurface effects produced by man are:
  - Lowered groundwater levels (most significant).
  - Salt water intrusion (probably less significant).
- The principal potential surface effects related to the above are:
  - Drying up of lakes and streams (most significant).
  - Salinity changes in the bays (uncertain significance).
  - Land subsidence (possible but not yet observed).

APPENDIX C

THE CONTAMINATION OF THE HYDROLOGIC SYSTEM

APPENDIX C

THE CONTAMINATION OF THE HYDROLOGIC SYSTEM

1.0 SCOPE

This appendix examines how water becomes contaminated on Long Island. First the natural cycle is traced from the time water arrives by precipitation until the time it returns to the atmosphere either directly by evapotranspiration or indirectly by way of stream flow or under flow to the bays and oceans. Then the man-influenced cycle is described in a similar way.

2.0 THE NATURAL CYCLE

The encircled letters on Figure C-1 identify the processes during which contaminants enter and leave the hydrologic system. As used here, contaminants are any substances other than H_2O. Each process is described briefly below.

(A.) Precipitation

As precipitation falls earthward it picks up substantial quantities of pollutants from the air. A representative figure is about 10 mg/l [7] for total solids on Long Island. This is about 32 tons of contaminants a year per square mile. Nearly 40% of this is sulfates, about 25% chloride, about 20% sodium and potassium, and about 15% nitrates, calcium, magnesium and other substances. Air pollution control programs can reduce this source of contamination; but even without such programs, precipitation does not appear to be a major cause of water contamination on Long Island/1.

(B.) Evapotranspiration

This process approximately doubles the overall concentration of contaminants in the water by returning almost half of the water to the atmosphere and leaving the contaminants to be dissolved in the remaining half. The process does not, however, alter quantity of contaminants.

/1 The justification for air pollution control programs rests upon other reasons well outside the scope of this water supply-waste water report.

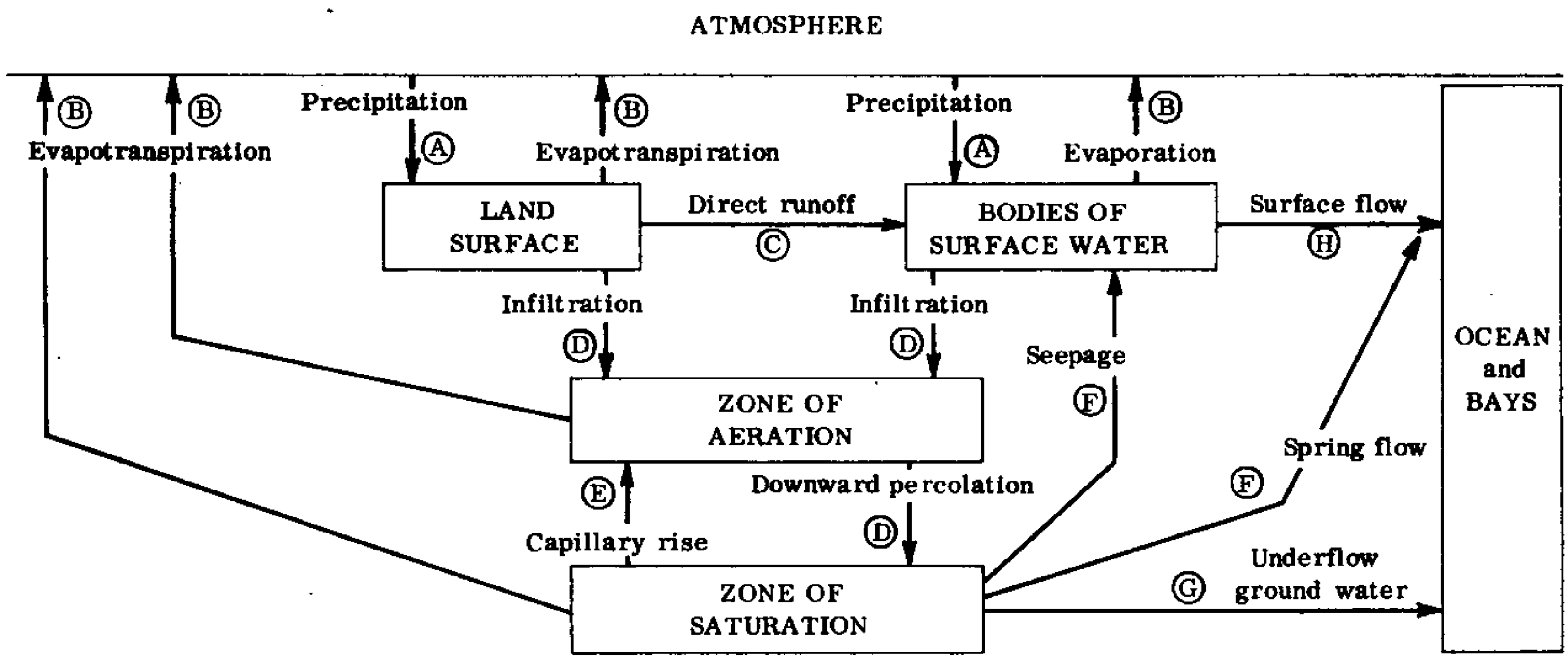


Fig. C-1
CONTAMINATION OF LONG ISLAND WATER IN THE NATURAL HYDROLOGIC CYCLE

(C.) Direct runoff

During this process, water flowing overland picks up considerable surface contaminants and transports them to water bodies, especially during heavy storm runoff. In most parts of the country, where runoff is a significant proportion of precipitation, this is a major and often overlooked source of water pollution. However, on Long Island, where direct runoff represents only about 1% of total precipitation, it is not an important widespread cause of contamination, except possibly for a few inland lakes such as Lake Ronkonkoma. (A more important impact is felt in localities where man has installed storm sewers that collect contaminants from streets and transfer the contaminants to the Upper Glacial aquifer through recharge basins.)

(D.) Infiltration

Essentially all surface contaminants are eligible for transfer to the aquifer, as water falling on the surface infiltrates into the soil through the zone of aeration and into the zone of saturation (water table). Apparently, despite this potential, the soils of Long Island act as an excellent natural filter, because in its natural state the water quality of the Upper Glacial aquifer is quite good in most respects [7]. (The present poor quality of this aquifer is almost entirely caused by man through cesspools, fertilizers and leachate from sanitary land fills.) The infiltration process, however, is potentially of major importance because it is useful in some methods of sewage disposal, such as irrigation. Therefore, it deserves significant research. It is of interest to point out here the growing nitrate concentration in the groundwaters of the glacial aquifer of Long Island [22 and 23]. In Nassau County, over 24% of the public water supply wells sampled show increasing nitrate trends and the county projections indicate that wells are likely to exceed the N.Y. State nitrate standard (10 mg/1) at the rate of almost one a year [22] if existing trends continue. It may be noted that nitrates in the water percolating in mid-island region have a greater chance of reaching water supply wells in the Island, than nitrates in waters percolating to the aquifer in the near shore areas, under normal conditions of outflow of groundwater to the bays and ocean.

(E.) Capillary rise

Since only a negligible proportion of the total quantity of water flows upward as capillary rise and this water has a negligible concentration of contaminants, the process has little impact upon the quality of Long Island waters.

(F.) Spring flow and seepage

Spring flow is small, about 1% of total rainfall. Seepage is very large, about 20% of total rainfall; it constitutes about 95% of stream flow. However, both processes essentially carry groundwater constituents to the surface with little change in concentration. As such, neither process by itself increases existing concentrations. During the passage through the aquifer, however, up to the point where water emerges as spring flow or seepage, water quality may change, as indicated in the next paragraph.

(G.) Underflow

The controlled sampling of groundwater along a single flow line could yield insights into the change in concentration of contaminants as water moves through the aquifer. Not much quantitative information of this type is available, but it is believed that there is a gradual increase in concentration over distance travelled [7].

Judging from the low dissolved solids in the waters of the lower aquifer, except for iron,[/1] subsurface groundwater flow makes only a minor contribution

/1 The iron content of the waters of the Magothy and Lloyd aquifers is about two to five times higher than the 0.3 mg/l recommended for public water supply.

to water contamination. The process needs to be much better understood, however, if Long Island is to use its aquifers for wastewater disposal either by continuing to use cesspools or by initiating controlled recharge by irrigation, injection, recharge basins or other methods. Some work along this line was done in a study of the effects of synthetic detergents and other sewage constitutents discharged by typical individual sewage disposal systems on the quality of the groundwater [24]. Significant findings of this study are summarized in paragraph 5.4.4 of Appendix E.

(H.) Surface flow

This process carries contaminants from streams, acquired through processes discussed earlier, to the bays and ocean. In its natural state, unaffected by man, stream runoff is relatively clear on Long Island. As such, the process has little effect on overall water quality.

In summary, the natural processes do not seem to be a major source of contamination. In fact, except for iron, the water quality resulting from these processes is too good to be universally suitable! The dissolved solids concentration is very low, about 20 to 40 mg/l,varying with the aquifer [7], and the "soft water" tends to be corrosive to metal pipes. The principal importance of the natural processes is in the removal of contaminants from infiltering or flowing water in contact with soil formations, such as would occur in any method of groundwater recharge.

3.0 THE MAN-INFLUENCED CYCLE

The encircled letters in Figure C-2 identify the processes during which contaminants enter and leave the man-influenced cycle. Each process is described briefly below.

(A) through (H) - Described in paragraph 2.0 above.

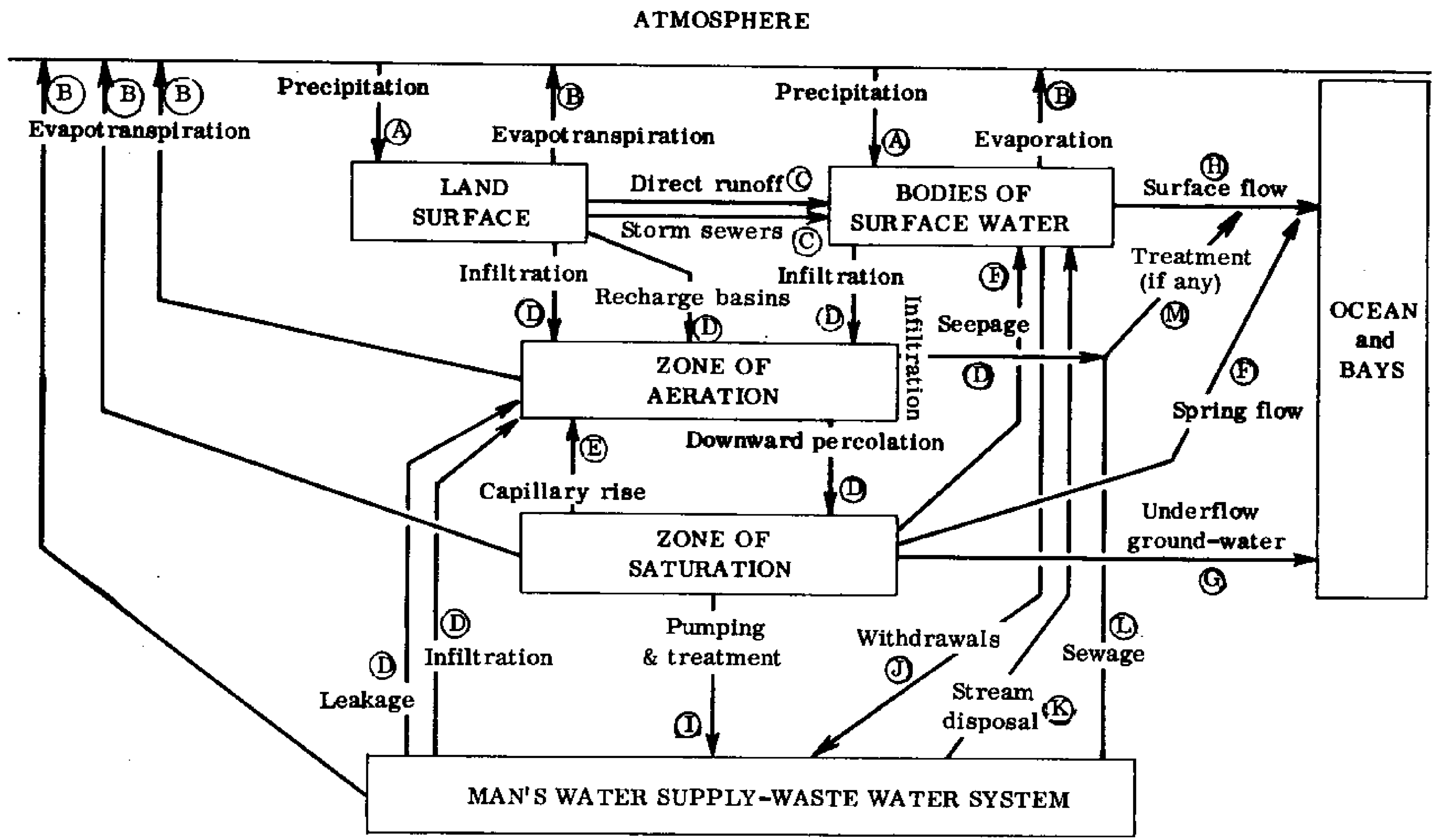


Fig. C-2
CONTAMINATION OF LONG ISLAND WATER
IN THE MAN-INFLUENCED HYDROLOGIC CYCLE

(I.) Pumping and treatment

Man pumps essentially all of his water supply from the aquifers. The water is of such good quality that little treatment is required other than routine chlorination as a precautionary measure, pH correction and iron removal in some cases. However, the water supply treatment process would be very important under one possible strategy. Under that strategy, effort to treat waste water would be minimized, the Upper Glacial aquifer would become increasingly contaminated and primary attention would be concentrated on treating the water before it re-enters man's water supply system. Water supply treatment can be less expensive than waste water treatment because natural processes can, under suitable conditions, accomplish much of the purification as water moves undergound from the waste source to the water supply source. However, many water supply and public health experts, as well as the consumers, are understandably reluctant to accept any risks to public health. Research in this area should receive very high priority, but probably at the national level since the problem and possible opportunity are so widespread.

(J.) Withdrawals from surface water bodies

This is a negligible process on Long Island. However, if a major proportion of Long Island's water is to be obtained in the future from infiltration galleries located on streams just upstream from tidewater, as some propose, additional water supply treatment will be required.

(K.) Stream disposal

Most of Long Island's waste water is disposed of through cesspools, septic tanks, industrial recharge and ocean outfalls. A review, plotting and analysis of all major waste water treatment plants in the bi-county area [12] indicates that the total quantity of waste water discharged into Long Island streams is minor.

L. Sewage

During his use of water, man greatly contaminates it. As a case in point, a typical chloride concentration of about 10 mg/l in the water supplied in Long Island [25] increases to about 50 mg/l in the raw sewage discharge. Similarly, an increase in total solids concentration from less than 100 mg/l to about 500 mg/l is representative. Typical additions for several other water contaminants, in the Long Island context, could be computed if a systematic survey of the water use in a few representative towns is undertaken. Table E-4 of Appendix E depicts the average increases in common constituents, on a national basis.

Man's influence on the hydrologic system of Long Island, including his contribution of contaminants, has been under investigation by the Long Island Program of the U.S. Geological Survey. The results of these investigations are expected to be available shortly. Quantitative network diagrams for contaminant cycles in Long Island, similar to the hydrologic system (figures of Appendix B) can be constructed for management purposes, based upon these results.

M. Waste water treatment

Efficiencies associated with primary, secondary and advanced waste water treatment processes are portrayed in Table E-1 of Appendix E. In that table, the removal efficiency of the process is shown by the change in the concentration of contaminants as the water enters and leaves the plant.

In summary, man pumps water of very good quality from the Long Island aquifers; improves it slightly in his water treatment plants; greatly contaminates it while using it; removes a certain portion of the contamination in his waste water treatment plants, when these plants are employed; and leaves a residual in the waste water discharges.

4.0 EFFECTS

4.1 Groundwater Effects

Part 72 of the New York State Sanitary Code prescribes the New York State Drinking Water Standards. They are very similar to the U.S. Public Health Service Standards. The fresh groundwaters of the entire state are classified G A which indicates that their best usage is as a source of potable water supply. The maximum allowable concentrations of various biological, physical and chemical constituents for waste water discharge methods in the bi-county area are specified in Schedule 1 of the standards [26]. The allowable discharge concentrations are generally about twice the allowable concentrations for drinking water.

In comparison with the drinking water standards, groundwater in the bi-county area presents little difficulty measuring up to physical and bacteriological criteria, although chlorination is now routinely practiced as a precautionary measure. The main problems occur in meeting the chemical criteria when water is taken primarily from the Upper Glacial aquifer. Holzmacher [2] has estimated the relative order of importance of chemical contamination in Suffolk County as (1) synthetic detergents, (2) nitrogen compounds,(3) iron and manganese, (4) dissolved solids, (5) chlorides and sulfates and (6) toxic materials. In Nassau County, nitrate contamination has recently become a serious problem. The nitrates are added through cesspools and septic tanks and probably through over-fertilization of lawns and agricultural areas. According to Greeley-Hansen in [3] "even now, wherever nitrates are exceeding the recommended limit, no procedure other than local blending or deepening of existing wells....(appears feasible and acceptable) ... No method of nitrate removal has been tested on a plant scale so far, and only ion exchange process has been tried on a pilot basis."

About the only significant natural contaminant in Long Island groundwater is iron. The iron, when oxidized, precipitates within the distribution system. Periodic flushing of the mains to remove the iron bearing sediment is the customary practice. Removal by treatment methods have not been too successful [3].

4.2 Surface Water Effects

The Report of the Committee on Water Quality Criteria of the Federal Water Pollution Control Administration [27] identifies major activities affected by water quality. The report also identifies pollutants, indicates their impacts and suggests ceiling concentrations. In Selected Water Resources Abstracts [28], the U.S. Department of the Interior reports semi-monthly on the on-going research.

To convert this information to a useable form for those formulating and administering public policy, quality standards have been developed for Long Island waters. A review and critique of these standards was given in an earlier report of this series [1d]. Briefly the standards have two principal components--usage classification and the water quality criteria associated with each classification.

Long Island's coastal waters have been assigned a "best usage" after surveying the existing water quality, examining possibilities for upgrading, holding public hearings, adopting final classifications and obtaining approval of the federal government. Different standards apply to freshwater surface bodies, saltwater coastal areas, and groundwater.

The saltwater classifications are summarized as follows:/1

SA - Shellfish for marketing purposes

SB - Bathing but no shellfishing

SC - Fishing but no shellfishing or bathing
(Class I has a similar meaning)

SD - Any use except shellfishing, bathing or fishing

/1 A complete description of all standards is contained in the Classification and Standards of Quality and Purity for Waters of New York State [26].

The SA classification has been assigned to all waters in the Sound and the Atlantic Ocean and in the major parts of all large embayments. The waters off the long barrier islands along the south shore carry this classification along both their ocean and bay shorelines. Waters with the lesser classifications are found in many pockets along the inland shoreline of the major bays along the south, east and north shores. They hug the shoreline and are found particularly in the numerous small indentations of those bays, where dilution, flushing and waste loads are the worst.

Each use classification has an associated set of criteria for (1) floating solids, oil, settleable solids and sludge deposits, (2) garbage, cinders, ashes, oils, and sludge or other refuse, (3) sewage or waste effluents, (4) dissolved oxygen, (5) toxic wastes, colored wastes and heated liquids, and (6) organisms of the coliform group.

The coliform criterion is of special importance to this study. It is measured principally in MPN, the most probable number of coliform bacteria per 100 milliliters of water. The index is considered a measure of bacterial pollution. Its adequacy is often questioned by water quality experts and research is justified to find a more suitable, easily-measured substitute. However, this research sould be conducted at the federal level because the problem is a national one. Coliform standards call for a maximum of 70 MPN per 100 ml for shellfish harvesting areas. For bathing areas, however, there is less agreement as to what the criterion should be. For example, the nearby New England Interstate Sanitation Commission prescribes a maximum median value of 700 per 100 ml, the Interstate Sanitation Commission uses 1,000, the State standard is 2,400, and Nassau and Suffolk Counties employ an administrative standard of 240. The administrator of New York City's Environmental Protection Administration has stated that "bathing water standards for saline waters are long overdue for reexamination--the British, on the basis of studies of the health of bathers at a number of beaches in the United Kingdom, have concluded that marine beaches can be used for bathing if the water is esthetically acceptable!" [29]. The coliform criterion plays a key role in the development of Long Island's waste water treatment program. Ocean bathing is an important recreational activity aggregating somewhere around 20 million visitor days annually in the bi-county area (about 50 million at nearby New York City beaches). In Nassau County, although coliform samples are taken daily at 31 bathing water quality sampling points along the north shore, and 25 such points along the south shore, analyzed and tabulated by computer printout, this extensive effort still does not yield enough information to permit a ready determination of which areas are safe for bathing. Rather clearly, considerable additional investigation of coliform concepts is in order on several bases: The criterial level signifying safe usage for bathing; the uniform interpretation and reporting of laboratory analyses; and the general utility (usefulness) of the results.

A second major problem is controlling toxic wastes. These wastes can have an important impact on marine life (e.g., the recent mercury concern), especially through the capacity of marine organisms to multiply concentrations astoundingly through the food chain. Probably the best method of controlling toxic wastes is a combination of (1) identifying industries that produce the wastes and establishing controls at these sources, (2) monitoring influent to treatment plants, (3) controlling offshore dumping, and (4) systematically monitoring coastal waters. The latter requirement is expected to be addressed in a recently awarded research project by the Federal Water Quality Office of the Environmental Protection Agency to develop a "National Coastal Water Quality Monitoring Network." Long Island authorities should maintain close contact with this study particularly since one phase calls for the development of a monitoring network for New York

Bight and adjacent inshore waters.

A third major problem is how to predict the fate of pollutants once they enter the bays. Before undertaking any major operation that can affect the bays' water quality, the resultant distribution of pollutants must be predicted. Models are required to do this. Two major types of models are numerical models, which compute the distribution, and hydraulic models which physically simulate the distribution. Each has its pros and cons which we have developed in another report of this series [1e]. To reduce overall cost and complexity, major coastal water quality models should be formulated in context with a complementary water quality monitoring system. A least-cost way of integrating the best features of modeling and monitoring has been developed in a cost effectiveness approach for Narragansett Bay in nearby Rhode Island [30].

APPENDIX D

ALTERNATIVE SYSTEMS

APPENDIX D

ALTERNATIVE SYSTEMS

1.0 SCOPE OF THE THIS APPENDIX

To satisfy its long-range requirements for fresh water and waste water disposal, the bi-county area must, one way or another,

- Acquire fresh water
- Treat it
- Transmit the treated water to localities where it is needed
- Distribute the treated water to points of use (homes and commercial/industrial activities) within the localities.
- Use the treated water
- Collect the waste water
- Treat the waste water
- Dispose of the treated waste water and solid residues.

There are a number of alternative systems for satisfying this overall requirement. All systems contain each of the above eight phases. All systems are expensive[/1]. All have different environmental and jurisdictional implications that should be considered.

To shed some light on the principal considerations involved, this appendix is organized as follows:

First, a brief consideration is given to each individual phase in

/1 As will be seen later, they range from $528 million to $681 million annually in 1971 dollars for a 600-mgd bi-county system that wil be needed about the turn of the century. Capitalized at 5% over a 50-year life, this is equivalent to a combined public and private investment of between $9.6 billion and $12.4 billion.

terms of the following:

(a) Alternatives. For example, alternative sources of fresh water include Long Island groundwater, import of water from the New York City system, desalination, weather modification, and even the conversion of Long Island Sound into a fresh water lake.

(b) Order-of-magnitude costs[/1]

(c) General environmental impacts

(d) Major jurisdictional implications. These are merely identified. It is beyond the scope of this particular study to develop their full implications.

Second, a set of alternative systems is developed. As used here, each system consists of a combination of alternative elements, one for each of the eight phases put together in a coherent manner.

/1 In each case the costs are updated to April 1971 through the use of the the Engineering News Record Construction Cost Index, which stood at ENR 1500 at that time. The costs include construction costs amortized at 5% over the life of the facility plus the operating and maintenance costs. To permit later analysis, all costs are expressed in terms of dollars per million gallons of water. The basic cost data were taken from published, major local projects or plans estimated by prominent authorities. In each case, the source of the basic data and its equivalence in terms of cost per million gallons is given, but the details of computation are omitted to improve readibility. Enclosure D-1 illustrates the methodology employed. All computations are available at The Center for the Environment and Man, Inc. for those who wish to examine them. In this survey, we sought only enough precision to make order-of-magnitude comparisons. Any more detailed use of the cost data reported herein is discouraged. This is especially so when trying to distinguish between alternatives with minor cost differences.

Third, a screening is made of the alternative solutions to identify those worthy of further consideration on the basis of broad economic, environmental and jurisdictional considerations.

Fourth, the surviving systems are displayed and compared.

2.0 ACQUISITION PHASE

Major alternative sources include Long Island grounwater, import of water from the New York City system and desalination. Almost all of the surface water in Long Island's lakes and streams is derived from groundwater. The feasibility of capturing the small amount of direct runoff (about 1% of total precipitation) through surface impoundments has been universally recognized as being impracticable. Other alternatives, such as weather modification and converting Long Island Sound into a fresh water lake, may some day be feasible; but they are dismissed herein as futuristic until their technical feasibility, economy, and environmental and political impacts justify more serious consideration.

2.1 Long Island Groundwater

Historically, the bi-county area has satisfied essentially all of its water supply requirements by pumping from the vast aquifer system beneath the island. Almost all future planning has been based upon this source.

The cost of a 150-well, 150-mgd well field in a 150 square-mile area east of Lake Ronkonkoma has been estimated at about $110 million including the wells, laterals and headers, storage tanks and chlorinators [6]. When operating and maintenance expenses (O & M) are added, this cost reduces to approximately $200 per million. (See Enclosure D-1). Holzmacher [2] has estimated the total capital cost for facilities designed to increase Suffolk County's yield from about 130 mgd to 470 mgd at 829.3 million dollars. Adding O & M costs, this total reduces to an estimated $480 per million gallons.

Of this total, an estimated $170 is for the acquisition phase and $310 is for the transmission phase.

Major environmental effects that should be considered in using Long Island groundwater include possible salt water intrusion, drying up of lakes and streams, and water quality changes in the bays. All are considered elsewhere in this report.

Jurisdictional considerations during the acquisition stage are considered minor; they occur principally later during the transmission stage.

2.2 New York City Water

The City acquires almost all of its water from developed surface sources inland. To satisfy estimated future requirements of the metropolitan area, a number of additional sources are being considered [6]. Typical costs under a number of those alternatives are in the vicinity of $250 per million gallons to deliver treated water of drinking water standards to the New York City area.

The environmental and political impacts of acquiring water from inland sources for the New York City system are being studied, but they occur outside of the bi-county area in the vicinity of the inland sources and are thus beyond the scope of this particular Long Island study.

2.3 Desalination[/1]

In arid areas around the world, there are about 800 desalination plants existing or under construction with an estimated total capacity of about 300 mgd. Most of these plants are very small, less than 0.3 mgd capacity. Of the numerous processes being employed, the two most feasible for Long Island conditions (high volume conversion of sea water), are the multistage flash (MSF) process and the vertical tube evaporator (VTE-MSF) process. The U.S. Office of Saline Water (OSW) has estimated the cost of producing product water by these two processes at $440 and $390 per million gallons, respectively [31]. A unit cost of about $620 per million gallons has been estimated for a 150-mgd, dual-purpose water and power plant, using nuclear fuel [6].

2.4 Summary

The two principal alternatives meriting further consideration at this time are Long Island groundwater and water imported from New York City.

/1 Unlike the cost data developed elsewhere in this appendix, the desalination costs have not been converted to a uniform base by the methodology described in Enclosure D-1. Information provided by the two sources cited did not permit such conversion; however, it is clear that the above cited unit costs would be higher if they were so converted. For example, the OSW estimates do not include the undetermined and significant cost of feedwater intake, brine disposal, or any on-site storage. A lower interest rate (4.63%) and overhead rates are used. If the costs were updated to April 1971, they would inflate about 20%. Lastly, and most significantly, these costs assume almost continuous (90% of year) operation. If the high-cost desalined water were to be produced only during periods of drought, the unit cost would probably triple. Since, even without such correction of the base data, the cited unit costs are substantially higher than either groundwater or surface water alternatives, we did not judge it rewarding to research desalination costs further.

3.0 WATER SUPPLY TREATMENT PHASE

Treatment of Long Island groundwater consists principally of routine chlorination as a precautionary measure and, in some cases, pH correction and iron removal. Since the associated costs are relatively minor, they have been included in the acquisition phase.

If, however, water is to be pumped from a polluted aquifer, additional cost-significant treatment would be required. A proposed 500-mgd plant to treat raw water from the Hudson River to drinking water standards would produce the treated water at a cost of about $70 per million gallons. This estimate is very approximate and would have to be adjusted to treat the specific contaminants found in the groundwater source serving each treatment plant. Especially when the groundwater is contaminated with leachates from cesspools and landfills on a continuing basis and is to continue to serve as the source of water supply, the unit cost will continue to rise.

The alternative of allowing the aquifer system to become polluted and compensating for this condition by additional treatment of the water supply has **potentially** overriding political-psychological implications. In some parts of the country, the treatment of polluted sources is routinely accepted (e.g. cities that use Mississippi River water), but on Long Island public acceptance is questionable at best, regardless of the degree of technical feasibility that could be achieved.

4.0 TRANSMISSION PHASE

The unit cost of within-county transmission of water to make up within-county imbalances of supply and demand was estimated at about $310 per million gallons in paragraph 2.1 above. To this within-county cost must be added any additional cost of transmitting water across either the Queens-Nassau line or the Suffolk-Nassau line.

The additional unit cost of transmitting 150 mgd of water between the New York City system in Queens and the Suffolk County system in the vicinity of Lake Ronkonkoma through a 40-mile, 72-inch line was estimated at about $100 per million gallons in Enclosure D-1. The cost of transmitting water a shorter distance would be proportionately less, say $30 per million gallons from the City system to the vicinity of the greatest anticipated water shortage in Nassau County. Total unit transmission cost under this alternative would be $410 (310 + 100) for NYC-Suffolk transmission and $340 (310 + 30) for NYC-Nassau transmission. The latter is the more likely, from a bi-county point of view.

The additional unit cost of transmitting 80 mgd of water from Suffolk to Nassau is estimated at about $80 per million gallons derived from basic cost data reported by Holzmacher [2]. Total unit transmission costs under this alternative would thus be $390 per million gallons (310 + 80).

Other than the temporary local disturbances primarily connected with the construction of any large pipeline, the environmental impacts of the transmission phase would not be great.

Jurisdictional impacts, however, are potentially major. For substantial quantities of water to be transmitted across county lines, all counties must see some major benefits. Some thoughts on possible quid-pro-quo's are offered later during the comparison of various systems (paragraph 13.0).

5.0 DISTRIBUTION PHASE

Once water is transmitted from its source and treatment facilities through mains to the localities where it is needed (e.g., a major subdivision), it must be distributed to each individual consumer (e.g., house and commercial/industrial activity). The cost of this distribution phase is estimated at about $520 per million gallons derived from detailed cost data provided by the Suffolk County Water Authority [32] for two 1971 subdivisions of 74 and 59 houses on quarter acre plots.

This cost (and the cost of the next phase) might vary significantly in some special situations (e.g., a homeowner with his own well), but the subdivision examples selected above are considered reasonably typical. Furthermore, since the cost of the distribution phase (and the next phase) is not considered as a variable among several alternative systems, it may be considered a "wash", not affecting the choice of a master strategy.

Before leaving the distribution phase, it should be noted, regardless of the overall system chosen, there may be opportunities for substantial savings in water consumption and costs within this phase. For example, about 14% of the acquired water [3] appears to be lost through leakage and undetected unauthorized usage before the water is delivered to the user. Many communities, even water-plentiful Chicago, have found it very rewarding to have inexpensive leakage surveys conducted and make selected repairs based upon the economics of water lost versus cost of correcting the leakage.

6.0 USAGE PHASE

This phase involves the costs from the point at which the consumer's water supply system connects to the street main to the point at which his waste water disposal system connects to the sewer, cesspool or septic tank (i.e., all "house connections"). From basic data provided in a recent residential market analysis [33], it is estimated that the average 1971 cost of a residence in the bi-county area is about $28,000. If a house plumbing system averages about 7% of this cost, then the usage phase computes to about $900 per million gallons.

Before leaving this phase, two special aspects of water usage deserve some consideration.

Recycling. Under current technology, water recycling is not economically feasible for residential purposes, which constitute upwards of 80% of the bi-county water requirements. Water recycling has only been practiced in certain cases of closed-cycle or semi-closed cycle, large, water-consuming industries such as the pulp and paper industry. In the bi-county area, however, industrial usage totals only about 20% of total usage and most of this industrial usage is for cooling water, which is recharged into the aquifer. Thus the potential to recycle substantial quantities of water at the usage location is considered minor in the bi-county area./1

Reducing Evaporation Losses. In Appendix B, it was estimated that, within the water-budget area of Long Island, over 50 mgd is lost in evapotranspiration losses from residential and agricultural irrigation. It might be rewarding to investigate the potential savings in a policy of watering lawns and golf courses and irrigating agricultural lands in the evening when evaporation losses are lower than in the heat of the day.

/1 This conclusion should not be confused with the possibility of recharging substantial quantities of treated waste water to the aquifers considered later during the effluent disposal phase.

Such an investigation would also have to explore the possibilities of mildew and the nuisance implications to the user.

7.0 WASTE WATER COLLECTION PHASE

Based upon information provided in plans for a 30-mgd capacity Southwest Sewer District System [9] in Suffolk County, the cost of moving waste water from the house connection to the treatment plant averages about $1,300 per million gallons. This cost includes the lateral sewers and appertenances, pumping stations, forced mains and interceptor sewers.

The environmental effects of sewers are centered mainly in the substantial social disruption caused during their installation parallel to or along the road system. This disruption, however, is temporary.

The only alternative to sewers is to avoid them entirely either (1) by disposing directly to groundwater on site through cesspools and septic tanks or (2) by employing packaged, individual treatment systems recently coming on the market. In a recent study [34] it has been shown that the basic problem areas in these systems are solids disposal and fail-safe design. If these systems can economically overcome these problems, they will merit serious consideration in the bi-county area, especially in remote areas. Although the use of cesspools and septic tanks can provide major economics by eliminating costly sewers, this apparent savings must be weighed against the added cost of this type of treatment and related environmental considerations. Both are included later during the treatment and disposal phases.

8.0 WASTE WATER TREATMENT PHASE

Based upon plans for the 30-mgd activated sludge plant for the Southwest Sewer District [9], this type of treatment costs about $350 per million gallons. Activated sludge is a method of secondary treatment commonly employed in the bi-county area.

Primary treatment removes about half of that removed by secondary treatment and is hereby assumed to cost about three-quarters as much as secondary treatment, or about $260 per million gallons.

The costs of AWT treatment are currently uncertain because of the developing state of the art, paucity of the large-scale operational experience, and (most of all) the great variations between the quality of the influent and the desired quality of the effluent. AWT methods and costs are discussed in detail in Appendix E. For our basic source of cost data, we have reviewed "add-on"/1 AWT plants proposed by Greeley and Hansen [3] for removation of 94 mgd of secondary effluent from the Bay Park and Wantagh Sewage Treatment Plants in Nassau County. The cost of AWT computes to about $300 per million gallons, not including an additional $80 per million gallons to transmit the effluent inland for groundwater recharge. Under this system, the total cost of waste water treatment would be about $650 per million gallons consisting of about $300 "add-on" AWT.

/1 An "add-on" AWT system is one intended to refine further the secondary effluent from a biological treatment plant to desired quality: as opposed to a "physical-chemical" AWT system which treats raw waste water. For details, see Appendix E.

Greeley and Hansen describe the quality of the AWT effluent as "essentially the same as the water which is in the groundwater system, with the exception of possible concentration of dissolved solids." This exception invites the important question of "what are the expected concentrations of these dissolved solids?" Results and operational data from the Bay Park experimental plant should provide this information, but these are not available at the time of this writing.

According to another earlier report [35], the anticipated composition of total nitrogen "after tertiary treatment" at the Bay Park add-on plant would be about 23 mg/l, some 230 times the reported composition of the native water in the Magothy aquifer in that locality. The 23 mg/l concentration is substantially lower than the 45 mg/l nitrate concentration reportedly harmful to the health of infants [17]. However, the degree of nitrogen removal provided by the proposed AWT plant and the acceptability of recharging the aquifer with the treated effluent warrant confirmation that was not possible from the basic sources cited.

Another cause of uncertainty arises if the groundwater recharge is to be accomplished by injection pumps as is often proposed. A major problem here is clogging caused by the release of dissolved gases in the injected water, the formation of precipitates, sediment accumulation and bacterial growth [35]. If the quality of the treated effluent from the above-cited AWT plant is not adequate to permit sustained, economical injection, then the $650 per million unit cost would have to be revised to an amount not clearly indicated in the literature we have been able to review.

An alternative is not to consider AWT as an "add-on" to a physical-biological secondary treatment process, but as a complete physical-chemical treatment process in itself. This possibility might reduce the total cost of treatment. For a 5-mgd physical-chemical treatment plant at Port Jefferson in Suffolk County, the capital costs were estimated at $9.3 million with an estimated operating cost of $0.355 million for a 2-mgd initial flow [36]. This would amount to a unit cost of about $600 per million gallons. However this figure, like those cited earlier throughtout this phase, is subject to refinement on the basis of actual bids and operating experience.

In summary of AWT costs, we will use $650 per million gallons as the best available figure, but we caution strongly that this figure is subject to significant uncertainty. This should not be surprising for pioneer endeavors seeking to develop the state of the art.

Another alternative method of waste water treatment is spray irrigation. The basic concept is not new, but significant recent research on this method has been done at Pennsylvania State University and at Muskegon, Michigan, on the shore of Lake Michigan [5 and 54]. The 43-mgd system proposed for Muskegon involves the following sequential phases:

(1) Collection and transport network. This would collect the residential and industrial waste water discharges with a conventional sewer and interceptor system (analagous to that costed in paragraph 7 above) and pump it inland through a 66-inch force main (analagous to the inland transmission of AWT effluent costed earlier in this paragraph).

(2) Aearated biological treatment cells. The effluent from this phase would be "comparable in quality to that achieved by conventional secondary treatment" [54]. (Current unit costs for secondary treatment on Long Island were also estimated earlier in this paragraph).

(3) Storage lagoons. These would have a volume equal to about five months flow of waste water for holding the secondary effluent during periods when irrigation can not be done because the ground is frozen or saturated.

(4) Chlorination facilities to disinfect the storage lagoon effluent.

(5) Spray irrigation. This would include an underground distribution network, 27 miles in length, and 55 fixed-pivoted, rotating, low pressure irrigation rigs having lengths up to 2000 feet.

(6) Drainage network, using 35 wells and 70 miles of perforated tile, 19 miles of main drainage pipe, 10 miles of drainage ditches and two pumping stations spread over a 10,000 acre site "to control the level of groundwater to ensure adequate aerobic soil treatment zone as well as to prevent the movement of groundwater out of the site area. The water collected by the drainage system would be discharged to the streams outside of the irrigated area." [5] "The provision of underdrainage will assure that the sites will not become waterlogged and rendered unfit for cultivation. It will also eliminate adverse effects on the level or suitability of groundwater supplies in the vicinity by allowing groundwater to leave the waste management site only at specified points after careful monitoring." [54]

(7) Monitoring system. This consists of 302 observation wells to evaluate groundwater quality.

(8) Agricultural harvesting. The system envisions the harvesting of grass and grains suitable for livestock feeding and bedding. Apparently there is a market for these products within economical shipping distance from Muskegon. A higher-valued crop, corn, is considered a future possibility, but additional agricultural research will be required to demonstrate feasibility.

Considerable additional research, well beyond the scope of the current study, will be required to evaluate the feasibility of applying this solution to Long Island's waste water disposal needs. Simple yardsticks derived from the Muskegon Study can not be legitimately applied to Long Island/1 without taking into account the Long Island climate, soils, land costs in the central recharge area, groundwater recharge requirements, possible major evapotranspiration losses during the irrigation season, and numerous other factors. To be judged feasible, the concept would also have to survive comparison with other competitive concepts identified herein. Phases (1) and (2) above are roughly analogous to operations which have been previously costed herein but phases (3) through (8) are add-on costs unique to this method. The order-of-magnitude value of those costs would be an important part of the feasibility study.

Before leaving the waste water treatment phase, cesspool treatment must also be examined. A typical cesspool serving a family of four/2 will have to be pumped out and chemically treated about every two years on average. Because of gradual clogging, a new cesspool will have to be provided about every ten years on average. At currently prevailing costs on Long Island, these services compute to about $850 per million gallons of waste water handled for the periodic cesspool replacement and about $350 per million gallons of waste water handled for the periodic sludge removal.

/1 For example, if the ratio of 10,000 acres required to dispose of the 43 mgd sewage load of Muskegon were to apply to Long Island, about 70,000 acres would be needed to dispose of the 400 mgd of sewage that might be anticipated in the bi-county area about the turn of the century. This is about 150 square miles, about 12% of the total land area in the bi-county area. Also, if the maximum nutrient loading rates of 150 lbs. of nitrogen and 50 lbs. of phosphorus per acre per year were applicable and if the nitrogen and phosporus transported in the secondary effluent equivalent were 34,600 lbs./year/ square mile and 9,400 lbs./year/square mile in 2010 as estimated in Table E-3 of Appendix E, about 300 square miles would be needed for living filters. This is about a fourth of the land area in the bi-county region.

/2 Unit costs here will vary appreciably with the site-specific conditions such as the soil conditions, the quantity and quality of the wastes and the size of the unit (single family or multifamily). We have contacted a number of contractors in the bi-county area and are satisfied that the above costs are representative of the most typical conditions.

Environmental impacts are substantial. They include the periodic disruption of the grounds and the progressive contamination of the Upper Glacial aquifer everywhere and possibly the Megothy aquifer near the center of the island where vertical drainage appears to be rapid and deep [37].

9.0 EFFLUENT AND SLUDGE DISPOSAL PHASE

The liquid effluent from a waste water treatment system can be discharged into the ocean or into the groundwater system. A third alternative, close in-shore disposal into the bays, is not considered likely in major programs of the future. The additional cost of treatment to make bay disposal acceptable appears to clearly exceed the cost of an ocean outfall to dispose of water of lesser quality into the ocean where it can be more readily accepted.

Based upon estimates for the Southwest Sewer District [9], an ocean outfall costs about $100 per million gallons. They should be provided for all systems employing sewers and large treatment plants. Even when treated effluent is used to recharge the aquifer, outfalls will be necessary to handle emergency overflows and also the effluent that is not required to satisfy recharge needs.

Based upon estimates for the Nassau recycling system cited earlier [3], the cost of transmission inland and recharge through existing storm water basins is about $80 per million gallons./1 Essentially all of this cost was for transmission. The cost of periodic maintenance of the recharge area was apparently considered minor. We consider these costs to be very uncertain and probably understated.

/1 Similar costs, about $80 per million gallons, would also appear to be applicable for the transmission of secondary (or raw) effluent inland under the spray irrigation concept discussed in paragraph 8.

The cost of injecting AWT effluent into the aquifer will not be known until the completion of current feasibility studies in Nassau County.

Given all these variables, we will employ in the later analysis a unit cost of $100 per million gallons for ocean outfalls and $80 per million gallons for groundwater recharge. The latter figure will be used only with AWT treatment and is subject to significant adjustment if any of the other alternatives eventually prove to be more feasible.

In addition to liquid effluent, a solid residue, sludge, must also be disposed of. Assuming that a million gallons of sewage after undergoing secondary treatment generates about 5 tons of semi-dried sludge, and that the cost of disposal at sea is about $8 a ton in the New York region [19 and 38], the cost of sludge disposal is estimated roughly at about $40 per million gallons of sewage for secondary treatment, about twice that for primary treatment and about $10 for AWT. The accuracy of these estimates is subject to improvement, but the changes will probably not be of an order sufficient to distinguish between the broad major alternative systems to be considered later in this appendix. Sludge disposal at sea and more costly alternatives, such as land disposal and incineration to reduce the volume of residue, each have their economic and inland-versus-at-sea environmental implications that would require a degree of research and tradeoff analysis far beyond that which can be attempted here.

The cost of sludge disposal from cesspools and septic tanks was estimated earlier at about $350 per million gallons of waste water passing through these devices. The cost of effluent disposal through these devices appears to be economically nil, but the environmental impact is major -- the progressive contamination of the groundwater supply.

10.0 UNIT COSTS SUMMARY

Table D-1 summarizes the unit costs developed earlier and used in subsequent analysis of alternative systems.

TABLE D-1

ESTIMATED UNIT COSTS
(dollars per million gallons)

Phase	Phase Percentage	Unit Cost	Remarks
Acquisition	100	200-250	200 groundwater, 250 NYC
Water supply treatment	99	0- 70	0 uncontaminated, 70 polluted
Transmission	98	310-410	310 in-county, 340 Queens-Nassau, 410 Suffolk-Nassau
Distribution	93	520	
Usage	86	900	
Waste water collection	50/67	0-1,300	0 cesspools, 1,300 sewers
Waste water treatment	50/67	260-850	260 primary, 350 secondary, 650 AWT, 850 cesspools
Disposal-liquid effluent	50/67	80-100	80 recharge, 100 ocean outfall
Disposal-sludge	50/67	10-350	10 AWT, 40 secondary, 80 primary, 350 cesspools--all expressed as sludge disposal costs per million gallons of effluent

NOTE: The unit cost column represents the estimated cost of passing one million gallons through the phase indicated. Not all the water originally acquired through pumpage or import passes through each phase, however. System losses are reflected in the "phase percentage" column. Thus only about 86 percent of the acquired water reaches the usage phase because of leakage. Since some of the water used is lost in processes such as sprinkling and the recharge of cooling water, only about 50 percent of the originally acquired water enters cesspools or sewers. If the entire quantity were to be handled by cesspools, this 50 percent would apply to the remaining phases. If the entire quantity were to be handled by sewers it would increase to 67 percent because of the infiltration of groundwater into the sewer system. These system losses were estimated from the relationships developed in Figure B-6 of Appendix B.

11.0 ALTERNATIVE SYSTEMS

There are a very great number of systems involving many alternatives at each phase in the overall water supply-wastewater system. To introduce an element of simplicity, the major choices can be narrowed down somewhat to involve (1) selection of source (groundwater and N.Y. City water); (2) selection of the degree of treatment (raw, primary, secondary and AWT). and (3) selection of the method of disposal of the effluent (to groundwater or to ocean). Table D-2 identifies these alternative systems and offers reasons why some of them might be eliminated from further consideration as major strategies for meeting the bi-county area's basic needs.

TABLE D-2

ALTERNATIVE SYSTEMS

System	Water Source: Ground	Water Source: NYC	Degree of Waste Water Treatment: Raw	Primary	Secondary	AWT	Effluent Disposal: Groundwater	Ocean	Rationale for Elimination
GRG	X		X				X		
GRO	X		X					X	
GPG	X			X			X		(3)
GPO	X			X				X	(3)
GSG	X				X		X		
GSO	X				X			X	
GAG	X					X	X		
GAO	X					X		X	(1)
NRG		X	X				X		
NRO		X	X					X	
NPG		X		X			X		(2) (3)
NPO		X		X				X	(3)
NSG		X			X		X		(2)
NSO		X			X			X	
NAG		X				X	X		(2)
NAO		X				X		X	(1)

Legend: Systems are identified as follows:

First letter indicates source of water--G for Long Island groundwater, N for New York City water.

Second letter indicates degree of waste water treatment--R for raw, P for primary, S for secondary and A for AWT.

Third letter indicates type of liquid effluent disposal--G for Long Island groundwater and O for ocean outfall.

Rationale for eliminating the system from further consideration (last column):

(1) Little need for AWT if effluent is to be disposed of in the ocean.

(2) No requirement to recharge groundwater if aquifer is not drawn upon as basic water source.

(3) Secondary treatment dominates primary treatment because of--

(a) Federal policy.
(b) Major environmental advantages, known and suspected, of the higher quality effluent.
(c) Minor cost differences--about $90 per million gallons, which is only about 2 percent of the total system cost.

12.0 APPROXIMATE COSTS OF ALTERNATIVE SYSTEMS

In Table D-3, the approximate costs of the systems surviving the first cut in Table D-2 are tabulated employing the data summarized in Table D-1, including the phase percentage factor. To illustrate, the estimated cost in Table D-1 of passing one million gallons through the usage phase was $900. Since only 86% of the water originally acquired passes through the usage phase, the entry in Table D-3 below is $770 (86% of $900). Without such adjustments, the cost of the latter phases would be badly distorted. The result depicted in the last line of Table D-3 is thus the estimated cost of entering one million gallons of water originally acquired into each of the eight systems.

TABLE D-3

APPROXIMATE COSTS OF ALTERNATIVE SYSTEMS

(in dollars per million gallons originally acquired through pumpage or import)

Phase	Alternative Systems							
	GRG	GRO	GSG	GSO	GAG	NRG	NRO	NSO
Acquisition	200	200	200	200	200	250	250	250
Water Supply Treatment	70	0	70	0	0	0	0	0
Transmission	300	380	300	380	300	330	330	330
Distribution	480	480	480	480	480	480	480	480
Usage	770	770	770	770	770	770	770	770
Waste Water Collection	0	870	870	870	870	0	870	870
Waste Water Treatment	420	0	230	230	430	420	0	230
Disposal-Liquid	0	70	120*	70	120	0	70	70
Disposal-Sludge	170	0	30	30	10	170	0	30
Total Cost	2410	2770	3120*	3030	3230	2420	2770	3030

*Does not include the unknown cost of land, possible additional treatment, spray irrigation and distribution at the inland recharge site. These add-on costs would probably make this the most costly system.

13.0 COMPARISON OF SYSTEMS

Table D-4 compares the eight systems on the basis of cost, general environmental impacts and major political considerations.

TABLE D-4

SYSTEM COMPARISONS

System	Cost: Dollars per Million Gallons	Cost: Total Annual Cost at 600 mgd ($ Million)	Cost: Annual Cost per Capita at 4.5 Million Population (Dollars)	General Environmental Impacts: On Ground-water Quantity	General Environmental Impacts: On Quality of Water Supply	General Environmental Impacts: On Eco-System	Major Political/ Jurisdictional Considerations (Regionalization)
1. GRG	2410	528	117	0	-=	-	
2. NRG	2420	530	118	0	0	-	NYC-Nassau
3. GRO	2770	607	135	-=	0	=	Suffolk-Nassau
4. NRO	2770	607	135	0	0	=	NYC-Nassau
5. GSO	3030	664	148	-=	0	-=	Suffolk-Nassau
6. NSO	3030	664	148	0	0	+-	NYC-Nassau
7. GAG	3230	710	157	0	0	0	
8. GSG*	3120*	682*	152*	0	0	0	Suffolk-Nassau, Land needs

*Does not include the unknown spray irrigation and other costs at the inland recharge site.

Coding of general environmental impacts:

= very objectionable

- objectionable

0 neutral

+ beneficial

-= ranging from objectionable to very objectionable

+- ranging from beneficial to objectionable

Costs. The eight systems are listed in order of increasing dollar costs. To lend additional perspective, costs are also expressed in terms of total annual costs for the acquisition of 600 mgd (by pumpage or import) and in terms of annual per capital costs if distributed over a population base of 4.5 million. The 600 mgd and 4.5 million represent in rounded form approximate estimates for the year 2020.

Disregarding minor differences, the alternatives fall into three cost groups: the first two (GRG and NRG), the next two (GRO and NRO) and the last four (GSG, GSO, NSO, and GAG). Within each grouping, cost differences are minor. On an annual basis the first group cost about $80 million less than the second group and $140 million less than the third group. Expressed another way (capitalized 5% over 50 years), the first group costs about 1,5 billion less than the second group and $2.5 billion less than the average of the third group.

Groundwater quantity. Six of the systems do not deplete the aquifer. Four of them (GRG, NRG, GSG and GAG) recharge the aquifer and two of them (NRO and NSO) do not draw on the aquifer at all.

Two of the systems (GRO and GSO) deplete the aquifer by drawing upon it as the basic water source and not replenishing it at all. The significance of this depletion will increase in time especially in Nassau County which is already drawing down its groundwater levels.

Quality of the water supply. Seven of the systems do not degrade the water supply. Four of them (GRO, NRO, GSO and NSO) discharge waste water into the ocean. Two (GSG and GAG) return waste water to the aquifer but only after the water has been treated to bring it up to acceptable quality. One system (NRG) contaminates the aquifer, but this system does not employ the aquifer as a basic water supply source.

One of the systems (GRG) does contaminate the water source, but it relies upon additional water supply treatment to purify the contaminated source before the water is used. As stated earlier in paragraph 3.0. this approach has potentially overriding additional costs, psychological and technical implications. Even though polluted water sources are treated and used for public water supply in some parts of the country, public acceptance on Long Island is questionable at best, probably regardless of the degree of technical feasibility that could be achieved.

Effects on ecosystems. Two of the systems (GAG and GSG) produce no adverse effects upon any of the ecosystems. With the spray irrigation of secondary effluents, there is also the possibility of increasing the agricultural productivity of land, at some extra cost in special locations.

Two other systems (GRG and NRG) return contaminated water to the aquifer. The resulting ecosystem effects would depend upon the quantity and type of contaminants that eventually seep into the streams and bays. This potential contamination effect can not be reliably predicted under the current state of the art, but it is the type of question that should be answerable by proposed later stage USGS groundwater models.

One system (NSO) would have no adverse effects on stream or bay life because it would not touch the natural aquifer. Opinion on the effects of discharging secondary effluent by ocean outfall is currently divided. Assuming the removal of toxic materials and floating solids, some view the secondary effluent as nutrients that will significantly benefit marine life by intentially fostering eutrophic and upwelling conditions. Others hold that any waste water discharged in the ocean is undesirable. The results of current studies in the vicinity of Los Angeles' Hyperion Outfall should shed further light on this controversy.

One system (GRO) would produce ocean outfall effects similar to those identified above. Under this system, at some point in the future (earlier in Nassau County), streams and lakes would tend to dry up. Stream life would be seriously harmed. The effects of increased salinity in the bays, especially near the stream mouths, requires further research of the type suggested in paragraph 6.2 of Appendix B.

Two of the systems (GRO and NRO) would discharge raw waste water into the ocean, with probable harmful effects on marine life, not only because of the intensity of contamination but also because of the complete loss of any controls.

Major Political-jurisdictional considerations. When the water supply is moved across county lines in significant quantities, major jurisdictional considerations arise. Only two of the systems (GRG and GAG) would not face this problem to some degree. Two of the systems (GRO and GSO) envision the movement of Suffolk water to Nassau to oversome supply-demand imbalances in the bi-county area. Three of the systems (NRG, NRO and NSO) envision the movement of New York City water into Nassau County, and perhaps eventually into Suffolk County. The GSG system would probably involve moving secondary effluent from Nassau to Suffolk where sizeable land requirements might be satisfied. For substantial quantities of water to be transmitted across county lines, all counties involved must agree, unless a politically distasteful decision is imposed from above. An inter-county agreement must benefit all parties, not just the water deficient counties. It has been suggested [6] that if a transmission line connecting the New York City system through Nassau to Suffolk were to be constructed, the resulting regionalization of the system might benefit all parties. During the early years, apparently—excess Suffolk groundwater might help make up deficiencies in

Nassau and in New York City. In later years, say 1985-2000, New York City would bring in major additional inland sources and relieve Suffolk from the need to satisfy Nassau deficiencies. Eventually, say 2000, New York City water could supply an increasing proportion of needs in both Nassau and Suffolk in normal years, allowing the aquifer to buildup its reservoir storage capacity. In drought years (say 10% of the years), the aquifer would be tapped to provide supplementary water for the bi-county area and to the New York City system. Any significant inequities in the inter-county quid pro quo of such an arrangement might be adjusted through various cost sharing formulae.

The GAG alternative envirsion a self-sufficient system free of water transfers in any significant amounts, and associated administrative and jurisdictional problems. It is also free of any large-scale land requirement which the GSG alternative could imply. Public acceptance for this alternative (GAG) seems to be high in the Long Island region.

14.0 SELECTION OF PREFERRED SYSTEM

Considering all the parameters displayed in the preceding paragraph, no one system clearly stands out above the rest and no one system is so clearly deficient that it can be eliminated with confidence from further consideration. The difficulty is due partially to the lack of resolution in several identified uncertainties. However, the major difficulties stem from one's value system. Selection depends upon the relative weights given to costs, environmental impacts and jurisdictional implications. It is beyond the scope of this particular study to impose such a value system.

However, rather than leave the reader with eight alternatives, we will (with considerable hesitation) attempt to show one way, the selection might be narrowed down. We will compare the eight systems initially on the basis of the cost and general environmental impacts outlined in Table D-4 and then display the surviving alternatives along with their associated political considerations for others to evaluate further. If any altnerative can be demonstrated to be inferior to any other alternative, the dominated alternative will be dropped.

Drop #1 (GRG). This alternative costs essentially the same as #2 (NRG) but has considerable undesirable effects on the quality of the water supply. Under prolonged continuous use as a dump for raw sewage from cesspools, the assimilative capacity of the soil and aquifers may become exhausted and the continued use of the groundwater for water supply will have to depend upon an increasingly greater degree of treatment of the water before supplying it to the public. Even if this treatment should be technically and economically feasible, public acceptance will probably be low.

Drop #3 (GRO). It is significantly more costly than #2 (NRG) and produces more objectionable environmental impacts.

Drop #4 (NRO). It is significantly more costly than #2 (NRG) and produces greater adverse impacts upon the ecosystem.

Drop #6 (GSO). When compared with #7 (NSO), this system produces more harmful effects on the aquifer and the ecosystem without offsetting advantages except for insignificant cost savings.

If the foregoing judgements are accepted, final choice would come down to one of the alternatives summarized in Table D-5.

TABLE D-5

SURVIVING SYSTEMS

System	Comparative Costs		Environmental Impacts			Institutional Political
	Capitalized Cost ($bil)	Annual Cost per Capita	Groundwater Quantity	Quality of Water Supply	Ecosystem	
NRG	9.7	$117	0	0	-	NYC water
NSO	12.1	$146	0	0	±	NYC water
GAG	12.9	$156	0	0	0	0
	12.9 plus	$156 plus	0	0	0	Inter-county transfer; land requirements

The first system (NRG) costs significantly less than the others. It produces unknown but potentially harmful leaching effects on water quality in streams and bays, and presents possible political implications involved in the use of New York City water. Although this system avoids the temporary social disruption associated with the construction of sewers, it does so at the expense of continuing the unpleasant effects associated with the periodic digging of lawns to provide new cesspools. It may furthermore be questioned how long this practice can be continued since there is a limit to how many new cesspool locations a piece of residential property can accommodate.

The next three systems cost 2 to 3 billion (about $30-40 per capita per year) more than the first. They produce no significant environmental effects once sewers are installed, except for a possible beneficial or harmful effect associated with NSO, which envisions the discharge of secondary effluent, less toxics and floatables, through an ocean outfall. The technical and economic feasibility of GSG and GAG have been under investigation but not yet clearly demonstrated. If ongoing and proposed research on these two systems proves successful, one of the two would be preferable to NSO with its potentially significant political implications. On the other hand, since it is still too early to predict this success, the political feasibility of the NSO system might be simultaneously pursued.

Decision between the NRG alternative and the best of the remaining three depends upon value judgements. How much extra should the bi-county area pay for environmental and institutional considerations? The tenor of the times would appear to opt for one of the three more costly systems, but that is a decision that the people of Long Island must make with full knowledge of the nature of their choice.

15.0 LOCAL AND INTERIM CONSIDERATIONS

This report has considered the bi-county area as an integrated whole on a long-range basis. Although this approach has the advantages of breadth, it masks important local considerations. Probably a mixed strategy reflecting local differences will be the best. One such mixed strategy would:

Nassau County, with its current heavy population density and insufficient water supply: either NSO or GAG. GSO with import from Suffolk could be an interim solution.

Western Suffolk, with its increasingly heavy population density and apparently ample water supply: either GSO, GAG or GSG, at least until the turn of the century, followed by increasing use of GAG, GSG or even NSO beyond that date.

Eastern Suffolk, with its lower population density, remoteness from New York City, and growing shortage of groundwater : import water from central Suffolk, discharge secondary effluent into the ocean in populated areas and continue with cesspools in relatively unpopulated areas.

ENCLOSURE D-1

SAMPLE UNIT COST CALCULATION

1.0 METHODOLOGY

(1) Select an authoritative recent estimate prepared preferably for Long Island involving a large-scale operation so as to reasonably capture probable economies of scale.

(2) Itemize the major construction costs including engineering and contingencies, land and legal-administrative, sometimes called development costs.

(3) Compute annual costs to include interest and amortization plus operational and maintenance (O & M) costs. Interest rates in the source estimates varied between 4 1/2 and 6%. For uniformity, we used 5% throughout. We generally employed a 50 year life except where we judged it to be inappropriate such as for cesspools and some waste water treatment facilities that might be affected by obsolescence.

(4) Compute the yield and resulting cost per million gallons of water passed through the facility.

(5) Convert to an Engineering New Record General Construction Cost Index of 1500 (April 1971).

2.0 ILLUSTRATION

The following computation illustrates the methodology:

Source: Metcalf and Eddy, Hazen and Sawyer, Feasibility Report on Alternative Regional Water Supply Plans for Northern New Jersey-New York City-Western Connecticut Metropolitan Area, prepared for the U.S. Army Corps of Engineers, North Atlantic Division, New York, New York [DRAFT], August 1969, page I-34, project LI-2b [6].

Facility: 150-mgd wellfield in the vicinity of Lake Ronkonkoma with 40-mile, 72-inch transmission line to the New York City system. Wellfield includes 150 wells, 5-million gallon storage tank and chlorination. Transmission line includes a pumping station.

	Total	Wells	Transmission
Construction Cost ($ Million)			
Well System	78.7	78.7	
Pumping Station	15.9		15.9
Transmission Line	30.9		30.9
Sub-total	125.5	78.7	46.8
Engineering and Contingencies (25%)	31.4	19.7	11.7
Land	3.0	2.0	1.0
Sub-total	159.9	100.4	59.5
Legal and Administration (10%)	16.0	10.0	6.0
Total Construction Cost	175.9	110.4	65.5
Annual Cost ($ Million)			
Interest and Amortization (5%, 50 years)	9.6	6.0	3.6
Taxes	.3		.3
Personnel	.4	.4	
Power	3.6	2.4	1.2
Chemical and Supplies	.5	.5	
Total Annual Cost	14.4	9.3	5.1
Annual Yield: 150 mgd x 365 = 54,750 mgy			
Cost per Million Gallons (Dollars)	263	170	93
Convert to ENR 1500 (1500 ÷ 1300)	303	196	107
Rounded Cost per Million Gallons (Dollars)	300	200	100

APPENDIX E

ADVANCED WASTE WATER TREATMENT

APPENDIX E

ADVANCED WASTE WATER TREATMENT

1.0 SCOPE

Within the framework of the alternatives developed in Appendix D and especially with reference to the GAG alternative which is one of those recommended for feasibility studies, this appendix presents a discussion of waste water treatment processes pertinent to Advanced Waste Water Treatment (AWT).

It should be emphasized at the beginning that the literature is replete with waste water treatment references, this being an established control technique in water quality management programs. Although AWT is of relatively recent origin, processes constituting it have long been under development and, therefore, recent literature on AWT is quite voluminous. Although it is clearly outside the scope of this appendix to review each and every one of the important references, an attempt has been made to review and analyze key references, especially as they would relate to the bicounty region's needs. The AWT Research Laboratory of EPA has been conducting evolutionary research and development of current relevance by themselves and through their research contractors and their status reports have provided valuable public information for this appendix. There is a clear and demanding need to extract, evaluate and summarize relevant non-proprietary information and, at the same time, be specific, concise and commensurate with the general scope of a framework study. On the basis of review and analysis, we have identified the key AWT processes, discussed them, presented the highlights as applicable in Long Island at appropriate places, provided a summary and still tried to be brief.

2.0 INTRODUCTION

A large metropolitan area such as the bicounty region of Long Island (Nassau-Suffolk) is a logical, well-suited unit on which to base planning for management of waste water disposal.

It is well recognized that there is no single solution for waste water disposal problems and planning for waste water disposal strategy in the area must take into consideration at least five elements:

(1) The possibilities of treatment to varying degree and of complete recycling (closed-circuit systems) eliminating almost all waste discharges. For example, the Wisconsin Steel Company in Chicago area was cited and found responsible for polluting the Calumet River. The company designed a completely recycled water stream, discharging nothing [53,p.56]. The need to conserve groundwater resources in the Long Island region is an important element to consider in this context. It is of interest to point out that Brookhaven National Laboratory located in the region is considering a pilot plant closed-cycle system for their non-radioactive wastes [39]. The results of this proposed study will be of value in planning for waste disposal management in the region.

(2) The possibilities of putting the waste water to beneficial use. Some examples of such application include irrigation of feed crops with treated effluent in Muskegon County, Michigan [5]; pisciculture in organic waste stabilization ponds, use of sludge to spray irrigate farmlands for growing feed crops, composting of sewage sludge with refuse for later use as fertilizer, and use as cooling water in industries.

In this region of pronounced vertical drainage in nature, land irrigation and surface spreading might serve a dual purpose: waste disposal as well as groundwater recharge. If this concept is found feasible, a public educational program would be required. The program would bring out the advantages of replenishing diminishing water supplies, improving soil fertility, and abating pollution of the island's surface water bodies. This concept has been discussed along with other alternative solutions elsewhere in the main report and in Appendix D.

(3) The classification of receiving waters and the impact of waste discharge therein. These elements have been covered in great detail in earlier CEM reports [1d and 1e]. A network diagram of an aquatic environmental quality management model is attached as Enclosure E-1. It identifies the forcing functions, the aquatic processes and possible results, and brings out their interrelationships. Some of the priority model needs are also indicated therein.

(4) Recognition of the interrelationships between the various aspects of waste disposal (See Enclosure E-1. For example,

- (a) Disposal on land or in air can indirectly affect water quality
- (b) Disposal of solid wastes also affects water quality
- (c) Interchanges of surface water and ground water components include "pollutants."

(5) Recognition of forecasts of increased high quality water requirements for marine recreation (four times the population growth rate nationally) and the need to accommodate this demand while managing waste disposal.

3.0 INVENTORY OF DOMESTIC AND INDUSTRIAL WASTE WATERS

A basic step for management of the waste waters is to prepare an inventory of sources, by location, and characterize them in terms of quantities and quality variables. The county departments of health provide primary sources for this effort. A recent publication of the Nassau-Suffolk Regional Planning Board [12] has synthesized available information for the bicounty region. This and other available reports provided the basis for the information on domestic and industrial waste water sources. We have prepared this information as a basic reference table for present and future use in our continuing studies for the Marine Resources Council. An overview of major industrial waste water characteristics relevant in the regional context is presented in Enclosure E-2.

4.0 EXTRACTS FROM NEW YORK REGIONAL PLAN

The Regional Plan Association of New York has studied waste management in a 31-county,(including Nassau-Suffolk) 3-state Metropolitan Region centered on New York City [29]. The Association assigned high priority to the study of governmental organization for waste management in the region, refinement of analysis of waste management costs, and the development of selective information bases such as waste generation coefficients, predictive models of environmental quality, and feasibility of control techniques. A more detailed extract from the Association's recommendations is contained in Enclosure E-3. In the preparation of this water supply-waste water disposal report, all of the recommendations have been considered except those on governmental organization and most of them have been integrated throughout this report, especially in this Appendix and Appendix D, to the extent judged to be significant to the bicounty area.

5.0 WASTE WATER TREATMENT

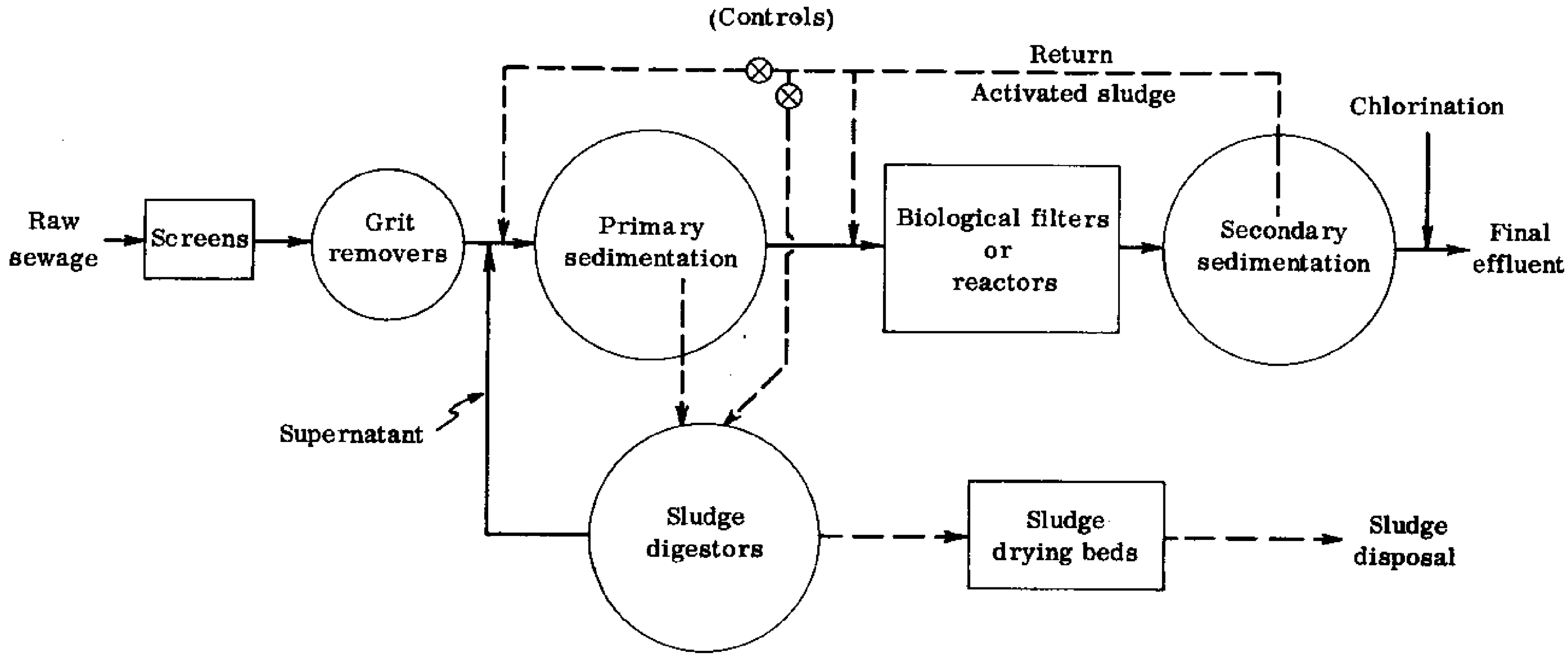
The purpose of this Appendix is to provide a review of current AWT technology and discuss it within the framework of the AWT-Groundwater recharge alternative developed in Paragraph 2.6 of the main report and in Appendix D. Accordingly, a brief review of conventional and AWT techniques follows.

5.1 Conventional Waste Water Treatment

By the term conventional waste water treatment, we refer to primary and secondary waste water treatment which includes screening, gravity separation of suspended matter and biological flocculation and precipitation. The sludge, consisting largely of water and the suspended solids removed in the clarifiers, is usually digested anaerobically and dried on sand (sludge drying) beds. The treatment units most commonly associated with conventional waste water treatment are screens, grit removers, primary settling tanks with or without prior chemical addition and flocculation, digestion and drying, biological (trickling) filters or suspended-growth reactors (activated sludge), secondary clarifiers, and occasionally chlorination of the effluent. Figure E-1 depicts such a system schematically. The efficiencies of conventional waste treatment processes in terms of expected removals of organic matter (BOD), settleable matter (suspended solids) and microorganisms (bacterial counts) are included in Table E-1. Secondary treatment of waste water before discharge to receiving waters is now a statutory requirement in almost all states and is a guiding federal policy.

5.2 Advanced Waste Water Treatment (AWT)

The term advanced waste water treatment is commonly employed to describe a variety of techniques which may be applicable to improve performance in conventional waste treatment or which may be substituted for conventional waste treatment in order to produce an effluent of very high quality. A review of Table E-1 indicates that a well-designed and operated conventional secondary sewage treatment plant can provide up to 80 to 95% reduction in BOD, 85-90% reduction in suspended solids and 95-98% reduction in bacteria. It can also remove, under favorable conditions, about 50% of the phosphorus and 55% of the nitrogen present. However, the balance still present in the effluent might be unacceptable for disposal in many circumstances. Some of these circumstances are:



(Solid lines represent liquid effluents, dashed lines represent sludge)

Fig. E-1
CONVENTIONAL SECONDARY TREATMENT—A SCHEMATIC FLOW SHEET

TABLE E-1

WASTE WATER TREATMENT EFFICIENCIES AND FACTORS

Adapted from: McGauhey, Engineering Management of Water Quality, McGraw-Hill, 1968, as quoted in Water Encyclopedia, ed., D.K. Todd, 1970

Unit Process	Where Applicable	Treatment Efficiencies and Factors
	Gravity Separation	
Plain sedimentation	Primary sewage treatment	50% reduction in suspended solids 35-40% reduction in BOD 50% reduction in turbidity
	Concentrating return activated sludge (secondary treatment)	75-80% reduction in original volume
	Concentrating or reducing suspended solids in industrial wastes, organic and inorganic	Varies with waste treated
	Grit removal-raw sewage	Removes heavy suspended solids not transported at velocity of 1 ft/sec
Plain sedimentation plus skimming	Primary sewage treatment	25-40% reduction in BOD 40-70% reduction in suspended solids 25-75% reduction in bacteria 2% reduction in detergents
Trickling filter plus plain sedimentation	Secondary sewage treatment	80-95% reduction in BOD 70-92% reduction in suspended solids 90-95% reduction in bacteria 30-35% reduction in ABS * 80-90% reduction in LAS **
	Organic industrial wastes (e.g., milk processing	Dependent upon nature of waste

* ABS is Alkyl Benzene Sulfonate

** LAS is Linear Alkylate Sulfonate

Unit Process	Where Applicable	Treatment Efficiencies and Factors
		Gravity Separation (Cont'd)
Activated sludge plus plain sedimentation	Secondary sewage treatment	80-95% reduction in BOD 85-95% reduction in suspended solids 95-98% reduction in bacteria 50% reduction in ABS 90-99% reduction in LAS
Sedimentation after mechanical flocculation	Raw sewage (experimentally)	64% reduction in turbidity 40% reduction in suspended solids 60% reduction in BOD
	Industrial wastes	Variable
Sedimentation after chemical coagulation	Raw sewage	50-85% reduction in BOD 70-90% reduction in suspended solids 40-80% reduction in bacteria
	Industrial wastes	Variable, dependent upon nature of waste
Chemical coagulation plus sedimentation	Phosphate removal from waste waters	Almost eliminates soluble phosphates
		Filtration
Slow sand filtration (gravity)	Tertiary treatment of sewage effluents Water reclamation systems	90-95% reduction in BOD 85-95% reduction in suspended solids 95-98% reduction in bacteria 90-99% reduction in surfactants
Microstraining	Clarification of sewage effluents Treatment of industrial wastes	87-96% reduction in microscopic organisms 60-90% reduction in microscopic particulates 50-60% reduction in suspended solids trickling filter effluent 30-40% reduction on turbidity

TABLE E-1 Continued

Unit Process	Where Applicable	Treatment Efficiencies and Factors
		Filtration (Cont'd)
Fine screening	Raw sewage	5-10% reduction in BOD 2-20% reduction on suspended solids 10-20% reduction in bacteria
Carbon filters	Generally "finishing" step.	Adsorbs organic chemicals, including surfactants Removes tastes and odors Adsorbs miscellaneous gases
		Aeration
Spray or cascade	Municipal and industrial water supply Industrial waste treatment	Releases gases producing taste and odor Reduces CO_2 Partial removal of H_2S Partial removal of gases of decom-position Oxidation and removal of soluble iron in groundwaters
Pressure aerators	Treatment of sewage and industrial wastes	Grit precipitated Grease floatation Separates light solids by flotation Maintains aerobic conditions in biological systems, Reduces ABS or LAS 1-2 mg/liter Reduces septicity of sewage
Oxidation ponds	Treatment of domestic sewage and organic industrial wastes	75-96% reduction in BOD 90-99% reduction in suspended solids 98-99.9% reduction in bacteria 56-93% reduction in LAS

TABLE E-1 Continued

Unit Process	Where Applicable	Treatment Efficiencies and Factors
		Demineralization
Electrochemical desalting	Reclaiming water from saline sources Demineralizing municipal waste effluents	Removes anions and cations
Reverse osmosis	Reclamation of water from brackish natural or waste waters (experimental)	Reduces ions depending upon concentration difference across membrane 97-98% reduction in TDS, ABS, and COD
		Chlorination
Chlorination	Municipal and industrial wastewater treatment and management	Assists in grease removal Controls filter fly nuisance Cleans air stones in aeration systems Removes H_2S and NH_3 Controls slime formation Control of digester foaming Disinfects effluent; 98-99% reduction in bacteria
		Digestion
Anaerobic digestion	Stabilization of sewage solids Stabilization of organic industrial wastes	Reduces moisture of sludge. Reduces organic sludges to humus Produces offensive supernatant

- Where the volume, flow rate or flushing characteristics of the receiving water body are such that bacterial concentrations rise to a level which seriously affects fishing or contact recreation,
- Where the organic load assimilative capacity of the water body is limited so that dissolved oxygan (D.O.) levels reach unacceptably low levels for intended uses.
- Where the phosphorus, nitrogen, and other dissolved nutrient levels in the effluent are conducive to algal blooms in the receiving waters resulting in associated color, taste and odor and oxygen depletion problems.
- Where certain dissolved organic and inorganic constituents such as detergents, chlorides and sulphates, acids and toxic metals (especially from industrial waste sources) are present in concentrations large enough

  (a) to degrade groundwater quality if disposal into or onto the ground is practised, or

  (b) to create serious problems in surface water utilization when disposal is into such waters.
- Where direct reuse of the effluents is necessary to conserve the water resources for domestic or industrial purposes. The water quality requirements in this case would be much higher than that obtainable with conventional secondary treatment alone.

In the bicounty region of Long Island, most of the bays and coastal waters surrounding the region have been classified SA (shellfish for marketing purposes [1d]. This is the highest classification. The need to preserve the groundwater quality at a very high level is apparent in view of the fact that groundwater is the principal source of water supply to the region now and in the immediately foreseeable future, and because of the large proportion of groundwater transferred to the surface and marine waters in the area. (See Appendix B which discusses the hydrologic cycle.) Therefore, a detailed consideration of advanced waste treatment techniques is appropriate for domestic and industrial waste water in the region whether disposal is to the surface coastal waters, to groundwater, or by reuse. Accordingly, a brief description of AWT techniques follow.

The need for new and improved AWT technology to restore used waters has fostered the AWT Research Program in federal (EPA and its forerunners) and other agencies since 1960. The new approaches to waste water treatment may be organized under the following broad categories:

(1) Improvements in Municipal Waste Water Treatment

- (a) Sewered wastes
- (b) Non-sewered (isolated facility) wastes.

(2) Suspended and Dissolved Solids Removal

- (a) Suspended and colloidal solids removal

  Physical processes
  Chemical processes

- (b) Dissolved nutrients removal

  Nitrogen removal
  Phosphorus removal

- (c) Dissolved biodegradable organics removal
- (d) Dissolved inorganics removal
- (e) Dissolved refractory organics removal

(3) Waste Water Renovation and Reuse

(4) Ultimate Disposal Methods.

A schematic overview of the above organization and the unit processes or subdivisions of the components is provided in Figure E-2. A recent (1970) publication of the Advanced Waste Treatment Research Laboratory [41] at Cincinnati, Ohio (EPA) has provided an updated summary of the current status of the AWT processes listed above. This publication forms the principal source for the

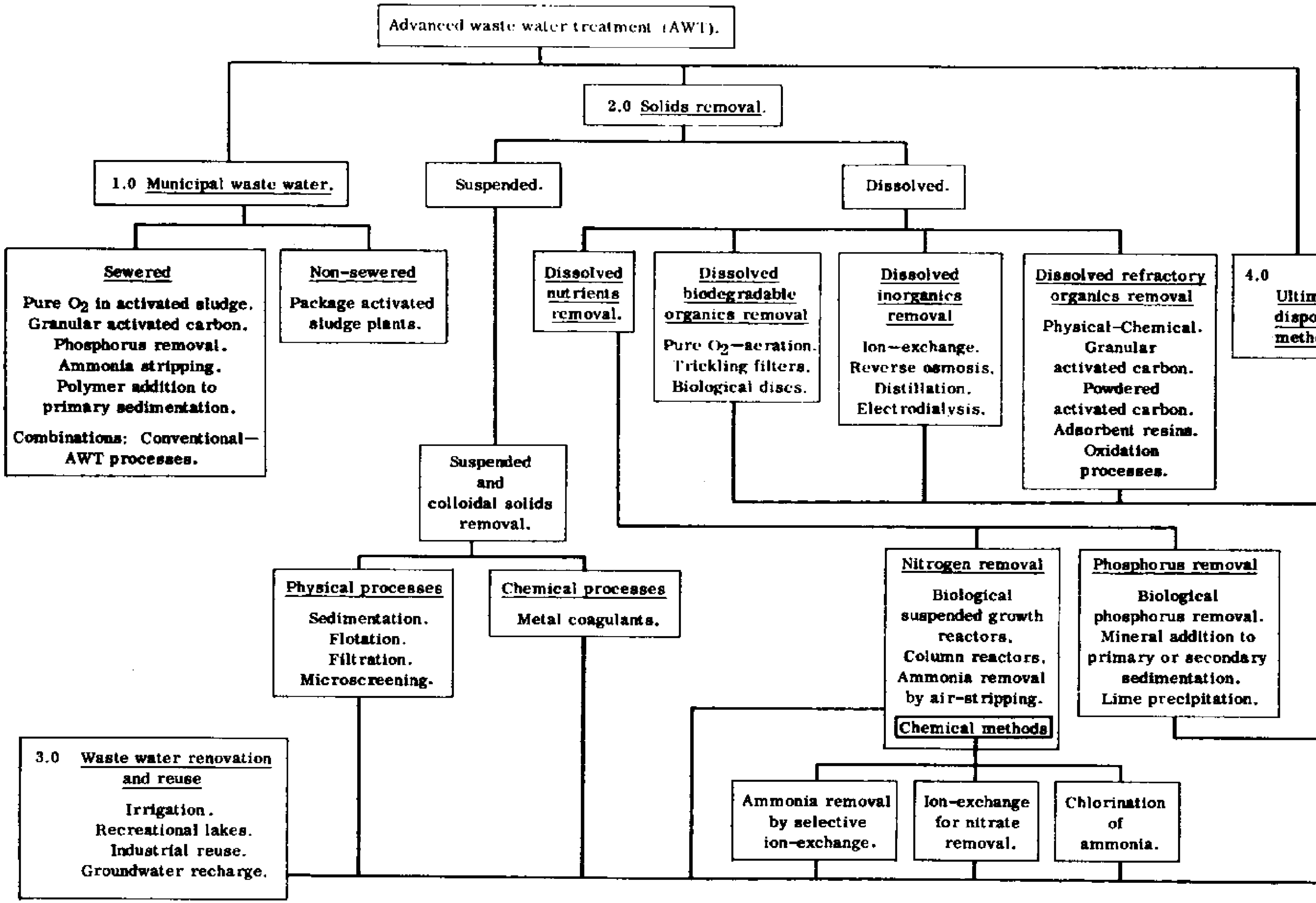


Fig. E-2
OVERVIEW OF ADVANCED WASTE WATER TREATMENT COMPONENTS

following brief descriptions of each AWT process. Further detailed information is also available in the Proceedings of an AWT-Water Reuse Symposium held in Dallas, Texas, January 12 to 14, 1971 [42], and in a just-released textbook on advanced waste water treatment [58].

5.3 Improvements in Municipal Waste Water Treatment

5.3.1 Sewered Wastes

The processes applicable under this grouping include use of pure oxygen instead of air in activated sludge process; use of granular activated carbon for removal of non-biodegradable organic matter, color and BOD; phosphorus removal and ammonia stripping with air; polymer addition to primary sedimentation tanks to improve settling efficiency; and combinations of conventional treatment with AWT processes to produce a high quality effluent.

Promising results were obtained from a study recently completed at Batavia, New York [41 , p.2]. In that study, the use of pure oxygen was compared with the use of air in the activated sludge process. Under the conditions of the Batavia test with test plant capacity of 1.25 mgd., pure oxygen was shown to be competitive with air. /1

/1 "Under test conditions the pure oxygen train achieved 90 percent or more BOD removal at detention times of 1 to 1.5 hours. With 3 hours detention time, BOD removal averaged 85 percent for the air train and 93 percent for the oxygen train. Another significant difference in performance was quantity of waste activated sludge. Although confirming data are needed, preliminary results indicate a reduction of 30-40 percent.

"Based on the Batavia data, cost estimates projected for new plants indicate the possibility of lower capital investment and operating costs for the pure oxygen treatment. The major factor contributing to the cost reduction is the ability to carry higher MLSS (Mixed Liquor Suspended Solids) and thereby reduce aeration tank capacity to 40 or 50 percent of that required for the conventional systems. Additional savings are indicated for sludge handling and disposal." [41, p.2].

The use of granular activated carbon as a polishing step has been demonstrated in full scale plants.[/1]

For phosphorus removal from waste water, the addition of chemicals such as iron salts, aluminum salts and lime to precipitate the phosphorus appears to be the only dependable method [41, p. 4]. The chemicals may be added at some selected point in a conventional activated sludge plant, ranging from before primary treatment to near the exit of the aerators.

An alternative method for carrying out precipitation of phosphorus is by using a clarifier-settler combination either for treating screened raw sewage or as a tertiary treatment. This process and ammonia stripping with air are described more fully under "Dissolved Nutrients Removal" in paragraph 5.4.2.1.

Anionic polymers used in doses of less than 1 mg/l appear to increase the efficiency of primary sedimentation by as much as 25%. A study carried out at full scale on the 240 mgd District of Columbia Water Pollution Control plant indicated this effectiveness.

The treatment plant at South Tahoe, California, is perhaps the best known advanced treatment plant in the country utilizing a combination of conventional and purely physical-chemical processes. It is of 7.5 mgd capacity and includes conventional primary treatment and activated sludge treatment followed by tertiary processes including two-stage lime clarification with ammonia stripping between stages, pressure multimedia filtration and granular carbon treatment. "The effluent from the plant is of high clarity and contains only traces of phosphorus and organic materials." [41, p.6] The water is presently exported for

/1 "Because suspended solids are partially removed on the carbon, the solids load and need for pretreatment must be considered when designing a carbon adsorption system. In order for the carbon treatment system to be economical, the used carbon must be regenerated and reused. Large-scale plants currently using and regenerating granular activated carbon include the 7.5 mgd plant at Lake Tahoe and the 0.5 mgd plant at Nassau County, New York." [41, p.3] eventual use in irrigation of crops after prior holding in a recreational lake. The lake can be used for all types of water recreation including contact sports. Because of the high quality of the lake water, algae are not a significant problem [41, p. 6].

5.3.2 Non-Sewered Wastes

A high potential market exists in the country for an acceptable individual home sewage treatment unit to replace septic tanks and leaching cesspools. A study on the state of the art of individual home sewage treatment systems has been performed by Electric Boat Division of General Dynamics Corporation [34]. Package activated sludge plants and development of advanced treatment systems have been considered and found economically infeasible at the present time. The basic problem areas are solids disposal and fail-safe design. Solids disposal by incineration is costly and pollutes the air; storage in the unit and subsequent land disposal may be aesthetically unacceptable. Presently available package plants require a degree of operation and maintenance that the average homeowner may be unable to bestow [41, p. 13].

5.4 Solids Removal

5.4.1 Suspended and Colloidal Solids Removal

The AWT processes under development for suspended and colloidal solids removal can be considered in two parts: the physical methods of solid-liquid separation and the chemical aspects of aiding this separation. The physical methods include tube settling; air flotation; bimedia, trimedia and moving bed filters; and packed media upflow filters. The moving-bed filter has been tested at pilot scale with a full-scale installation underway, but the others are at varying stages of research or development. Microstraining of effluents through woven metal fabrics having openings ranging upward from 23 microns removes larger suspended particles. This process has so far been largely limited to river water treatment. More recently, Chicago's Hanover Treatment Plant has success-fully employed a microstrainer to reduce secondary effluent suspended solids to less than 5 mg/l [41, p. 48].

The chemical processes involve the use of metal coagulants such as aluminum sulfate, sodium aluminate, ferric or ferrous chloride or sulphate, or lime to form and aggregate colloidal particles to promote settling and removal. The use of chemical additives has currently gained impetus from the need to remove phosphates from waste water [41, p.49]. The metal coagulants now being used for phsophate removal such as iron or aluminum salts, pickling liquor, and lime, can also accomplish clarification in the first step of the physical-chemical process [41, p.49]. This is discussed, therefore, more fully under dissolved nutrients removal, which follows.

5.4.2 Dissolved Solids Removal

5.4.2.1 Dissolved Nutrients Removal

The eutrophication of natural waters is a process of natural "aging" which can be accelerated by man's impact on the water including the disposal of his wastes. The need to reduce eutrophication rates by control techniques which include adequate waste water disposal management practices is well understood. Of algal nutrients that promote eutrophication, phosphates and nitrogen compounds are very significant elements contributed by domestic and industrial waste water. Their role in eutrophication processes and technology for their control have been intensively studied by many researchers during the past decade.

Reduction in concentration of any nutrient below the level required for algal cell synthesis will slow down eutrophication. There is the possibility of blue-green algae fixing atmospheric nitrogen and adding it to the water system if one eliminates nitrogen compounds. Therefore, much attention is being paid to reduction of phosphorus compounds in waste water effluents in order to control eutrophication. However, it may be noted that there are situations unfavorable for nitrogen fixation, and nitrogen removal under these circumstances could be a very effective eutrophication control procedure. The extent of phosphorus contribution to aquatic ecosystems by various major and minor contributors can be assessed from the following Table E-2 [43].

TABLE E-2

POUNDS OF PHOSPHORUS CONTRIBUTED TO AQUATIC ECOSYSTEMS

Major Contributors:
Sewage and sewage effluents: 3lbs per capita per year.
Some industries, e.g., potato processing: 1.7 lb per ton processed
Phosphate rock from 23 states
Cultivated agricultural drainage: 0.35 - 3.9 lb per acre drained per year
Surface irrigation returns, Yakima River Basin: 0.9 - 3.9 lbs per acre per year
Benthic sediment releases
Minor Contributors:
Domestic duck: 0.9 lb per year (per duck)
Sawdust: 0.9 lb per ton
Rainwater
Groundwater, Wis.: 1 lb per 9 million gals.
Wild duck: 0.45 lb per year
Tree leaves: 1.8 - 3.3 lbs per acre of trees per year
Dead Organisms; animal excretions.

Investigations by various authors have been summarized by Wuhrmann [44] to provide concentration range estimates of total dissolved phosphorus and nitrogen compounds in surface run-off and a rough estimate of the relative weight of nutrients in sewage. The summary table including the nutrient removal effects is the basis for Table E-3. The following inferences appear to emerge from the facts presented in the table:

TABLE E-3

NUTRIENT TRANSPORT FROM A ONE SQUARE MILE WATERSHED

	With Domestic Sewage			With Natural Run-Off. Specific run-off /1 = 1.11 mgd/sq.mi.	
				Nutrient Content /2	
	Untreated	Biological Treatment (Act. Sludge)	Biol. Treatment + Nitrogen and Phosphorus Removal	30 μg/l(P) 800 μg/l(N)	50 μg/l(P) 1000 μg/l(N)
Phosphorus					
g.(P)/cap/day	3	1.5	0.15		
Population density /3 = 12.2/acre; lbs.P/mile²/yr →	18,800	9400	940	102	169
Population density /4 = 1.9/acre; lbs.P/mile²/yr →	2,940	1470	147		
Nitrogen					
g.(N)/cap/day	12	5.5	0.8		
Population density /3 = 12.2/acre; lbs.N/mile²/yr →	75,500	34,600	5060	2,703	3,380
Population density /4 = 1.9/acre; lbs.N/mile²/yr →	11,700	5,380	780		

/1 Includes both direct surface runoff and the water infiltrating to groundwater.

/2 Wuhrman [44]

/3 See Table 1, page 24, of Reference [12], for the 2010 population projection of Nassau County from which this density is computed.

/4 Present (1970) population density in Suffolk County.

(1) Even with the low existing population density in Suffolk County (1.9 per acre), the human contribution of nutrients to the water far exceeds that due to natural run-off (about thrice for nitrogen and by an order of magnitude for phosphorus).

(2) This proportion increases rapidly with increasing population density, as evidenced by the figures for 12.2 persons/acre which is the projected 2010 population density of Nassau County.

(3) Conventional biological treatment alone, reducing the phosphorus levels by about 50% and nitrogen levels by about 55% does not change the situation fundamentally from inference (1).

(4) Effluents from phosphorus and nitrogen removal plants (advanced waste treatment processes), as described in the Table, lead to a reduction in human nutrient load transports to comparable nitrogen or at least tolerable phosphorus amounts in proportion to natural runoff.

It appears, therefore, that while considering treatment of wastes for removal of nutrients such as phosphorus and nitrogen, an ecologically significant reduction or effectiveness is possible only when the highest degree of treatment (removal processes) technologically feasible is advocated. Although difficult to perform and beyond the scope of this report, an in-depth cost-effectiveness analysis which would include constructing cost functions of effluent nutrient levels, would perhaps point in the direction of advanced waste-treatment plants for waste water management with an objective to reducing transport of nutrients to water. To quote Wuhrmann [44], "Imperfection in this tertiary treatment would mean thriftiness in the wrong place." Where the objective is control of BOD or bacterial loads in receiving waters, contributions from natural sources could be significant and the best overall strategy may well be different.

AWT processes for dissolved nutrients removal can be considered under

(a) phosphorus removal
(b) nitrogen removal.

Processes for phosphorus removal include biological flocculation and precipitation in an activated sludge under controlled aeration rates; mineral (Fe and Al salts) addition to primary or secondary clarifiers; and lime precipitation either in the primary clarifiers or as the first step in a chemical-physical treatment sequence. Processes for nitrogen removal include biological suspended growth reactors, column reactors with sand or stone media, ammonia removal by stripping with air and chemical methods including:

- ammonia removal by selective ion-exchange
- ion-exchange for nitrate removal
- ammonia removal by break-point chlorination.

The conditions under which each of the above processes for nutrient removal is applicable, the factors influencing performance, expected performance and operational features are clearly brought out in the state-of-the-art summary on "Dissolved Nutrient Removal from Waste Water" of the Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio [41]. It is also of interest to present a few salient facts on the removal processes here.

<u>Phosphorus Removal Processes</u>: Phosphorus removal by chemical clarification is mostly based on precipitation with cations forming insoluble PO_4 - salts, or on absorption by inorganic hydroxides. The most frequent reactions are with Ca^{+2}, Fe^{+3}, and Al^{+3} compounds.

The main reaction product at the high pH level necessary for efficient phosphorus precipitation (pH 10.5 to 11) is hydroxylapatite [45]. The apatite and the $CaCO_3$ formed in the process have poor flocculating and settling properties. It has been found experimentally, however, that the lime precipitation process can be greatly improved when some Fe^{3+} (approx. 1 to 2 mg/l) is added as a flocculation aid. "Sparkling clear effluents are then produced, and the excess sludge is excellently compacting"[44]. The precipitate is an efficient adsorbant for organic phosphorus compounds and polyphosphates and the process meets the essential requirements of phosphorus removal.

Lime requirements and the quantity of excess sludge are largely dependent upon the alkalinity and calcium hardness of the treated sewage. In Long Island where the carbonate hardness of the water is low (of the order of 20 to 40 mg/l as $CaCO_3$)[102], the quantities of lime (approximately 30 to 50 mg/l as CaO) and iron (approximately 2 mg/l of Fe) [44] required as coagulant and aid respectively, are small. Furthermore, the amount of excess sludge to be produced by this process, relative to harder waters, is likely to be manageably small. The sludge is readily settleable.

Several investigators have pointed out that much poorer results are to be expected from a combination of alum and lime precipitation [46 and 47]. Iron and lime precipitation is, therefore, the preferred method for phosphorus removal from waste water effluents.

Nitrogen Removal Processes: Nitrogen removal from waste water can be achieved by biological and physical-chemical means. Biological treatment is a well-established technique. However, the requirements of very high degree of removals and very low nitrogen levels in the final effluent are not likely to be met by biological processes alone. Combination-chemical processes seem to offer the feasible solution in this case. The principal processes considered are

(1) biochemical nitrification and denitrification,

(2) ion exchange, and

(3) reverse osmosis.

Biochemical Nitrification and Denitrification: Biochemical nitrification is achieved by activated sludge. The nitrogenous matter in waste water is converted first into ammonia, which is oxidized successively to nitrites and nitrates as shown below:

$$NH_4^+ + 1.5\ O_2 = 2H^+ + H_2O + NO_2^-$$

$$NO_2^- + 0.5\ O_2 = NO_3^-$$

Denitrification:

(1) reduction in the absence of air to N_2 gas - which is stripped from water by air or vacuum.

(2) Packed column of activated carbon-initial exhaustion of O_2 in the water by aerobes - then conditions become anaerobic - methanol is injected under anaerobic conditions - NO_3^- is reduced to N_2 gas.

Simplified reaction paths are:

$$HNO_3 + 2H^+ = HNO_2 + H_2O$$

$$HNO_2 + 2H^+ = HNO + H_2O$$

$$2HNO = H_2N_2O_2$$

$$H_2N_2O_2 + 2H^+ = N_2 + 2H_2O$$

This process removes both organic and inorganic nitrogen compounds.

Ion Exchange

Removal of ammonia nitrogen is possible with cation exchange by siliceous zeolites and resinous material. This process is non-selective to NH_4^+, and when other cations are present, NH_3 is the first to break through the ion-exchanger. Also, NH_3 is still concentrated in a large volume of liquid regenerant still requiring disposal. (Clinoptilolite, a natural zeolite, is selective to NH_4^+ ions in water. Regeneration is by lime. NH_3 in regenerant waste is removed by air-stripping. The problem here is the availability of the natural zeolite.) The Process has not been applied on a sufficiently large scale and reliable unit cost data are, therefore, not available at the present time [49]. See, however, Table E-5 for pilot plant cost figures.

Reverse Osmosis

Osmosis is the process of diffusion of a solvent through a semi-permeable membrance in dilute solution tending to equalize the concentrations of the solute on either side of the membrance. Reverse osmosis is based on reversing this natural tendency of water to migrate to where the contents of dissolved solids are higher by applying pressure on the high-solids-concentration-side of the membrane [48]. The pressure forces the water out of the high solids concentration side, producing a water of low dissolved solids content. The operating pressures of industrial waste water reverse osmosis systems is 400 to 800 psi where the TDS (Total Dissolved Solids) range from 1000 to 10,000 mg/1.

This process is normally non-selective to ammonium ions. But, with specially designed membranes, it can be very selective. Cellulose acetate membranes are generally used. Suitable pH range for this process is 5.0 to 6.0.

Note that this process simply concentrates the ions leaving a smaller volume of highly concentrated solution for disposal. Reverse osmosis application to waste water treatment is still in the early stages of development and unit costs for this process alone could range from $300 to 600 per million gallons [49]. See also Table E-5 for additional pilot plant cost figures.

5.4.2.2 Dissolved Biodegradable Organics Removal

The AWT processes applicable for dissolved biodegradable organics removal are pure oxygen aeration in activated sludge (similar to that described earlier under municipal waste water treatment), upgrading trickling filter performance by improving solids separation in the final clarifiers, and rotating biological discs.

Pure oxygen utilization for improved activated sludge process involved employing sealed covers on aeration tanks and intertank baffles to form a series of staged compartments in the 2.5 mgd. Batavia, N.Y. plant cited earlier. This procedure avoided inefficient utilization of costly pure oxygen. Three points demonstrated by this study with the greatest potential for reducing the cost of waste treatment are reduced aeration time and tank capacity, lower moisture in waste sludge, and lower volumes of waste sludge. The economic substitution of pure oxygen for air appears to be a very significant breakthrough in the development of the activated sludge process as an AWT for biodegradable organics removal.

The rotating biological disc method of treating waste has been used in Europe for at least the last five years. The system basically consists of closely spaced rotating discs rotating in waste water tanks with partial (about 50%) submergence. Waste water continuously flows past, parallel to the discs. The units are usually arranged in series or stages. The principle of operation is similar to that of a trickling filter.[/1]

Because there is always liquid in the container, the rotating disc system has an advantage over trickling filters in that recycling is not necessary at night. Where there is a wide variation in flows such as in individual households or installations, this process could conceivably be applied.

/1 "FWQA has funded a grant (1701 EBM) with Rutgers University to assess the degree of treatment and to obtain operating data on this method of treatment. The pilot plant used in this study is a ten-staged unit with a design flow of 8 gpm. This gives a detention period of 5 minutes per stage or a 50-minute overall detention time for the disc unit. The plant has been in operation for about one year at the Jamaica Treatment Plant in New York City near the Kennedy International Airport. Data obtained thus far show that the unit is oxidizing about 93% of the biodegradable carbonaceous matter and 80% of the ammoniacal nitrogen in the primary effluent being treated." [41, p.65].

5.4.2.3 Dissolved Inorganics Removal

A well-written concise report of the state-of-the-art of demineralization [49] of waste waters as of January 1971 has been published by EPA. The following summary is based on an analysis of this and other applicable sources.

The use of water adds increments of dissolved inorganic minerals such as chlorides, sulphates, sodium and other cations to the waste water. The best conventional waste treatment techniques were not designed to remove non-biodegradable organics or inorganic salts. Physical-chemical separation processes are needed for dissolved inorganics removal. Average values for mineral increments through one municipal use are indicated in Table E-4.

Several processes are currently being investigated for reducing the mineral content of municipal wastewater to an acceptable level. These include: (a) ion exchange, (b) reverse osmosis, (c) distillation, (d) electrodialysis, (e) freezing and (f) electrochemical treatment. These processes are in varying stages of development and only the first four mentioned are currently being given serious consideration as practical processes for demineralization of waste water effluents.

All the above processes for demineralization produce a concentrated salt solution (brine) the disposal of which is sometimes a major technical problem, covered later under "Ultimate Disposal" in Paragraph 5.6 of this Appendix.

Dryden [50] summarizes experience with mineral removal by ion-exchange, reverse osmosis and electrodialysis in pilot plants at the Pomona water renovation plant in Los Angeles County, California. He provides data on costs and removal efficiencies in the pilot plants from which is extracted Table E-5. It must be pointed out, however, that the costs are not inclusive of the cost of activated carbon treatment (approximately $90/million gallons for a 10 mgd facility) which must precede the demineralization step to prevent fouling of membranes or resins. It must also be pointed out that costs per unit weight of minerals removed will be a more meaningful basis for comparison.

TABLE E-4

AVERAGE LEVELS OF MINERALS IN DOMESTIC SEWAGE

EFFLUENTS AND AVERAGE INCREMENTS DURING USE

Constituent	Approx. Build-Up Through One Municipal Use mg/l	Normal Range of Build-Up mg/l	Representative Secondary Effluent, mg/l
Ca ($CaCO_3$)	30	15-40	95
Mg ($MgCO_3$)	13	20-40	39
Na	55	40-700	84
SO_4	25	10-40	51
Cl	35	20-125	50
PO_4	30	15-40	30
NO_3	8	0-18	8
COD	70	40-?	70
BOD	15	9-40	15
TDS	250	100-500	550

TABLE E-5

PILOT PLANT EXPERIENCE FOR MINERAL REMOVAL AT POMONA, CALIFORNIA

Process	TDS Removal Efficiency	Approx. Total Costs, $/mil.gal.
Ion-exchange	87%	220
Reverse Osmosis	92%	416
Electrodialysis	34%	170

5.4.2.4 Dissolved Refractory Organics Removal

Most waste waters contain some organic matter that is not readily degradable in conventional biological oxidation processes. Such refractory organics include a class of taste and odor producing compounds, such as phenols and certain oils. These are objectionable in a high quality effluent which would be needed under the alternative strategy of GAG.(See Appendix D)

Several AWT processes for removal of refractory organics from both domestic and industrial waste streams are in varying stages of development [41]. These may be listed as employing

(1) granular activated carbon, /1

(2) powdered activated carbon,

(3) adsorbent resins,

(4) oxidation processes.

One of the first large-scale applications of granular carbon to waste water treatment was the South Tahoe Waste Water Reclamation Plant. This 7.5 mgd granular activated carbon plant treats secondary effluent after clarification

/1 "Activated carbon is an adsorbent medium characterized by an extensive system of internal pores which provide it with a very large surface area per unit of weight. This large area plus the variety of functional groups (acidic, basic, oxygenated, etc.) attached to the surface give activated carbon a significant adsorptive capacity for most dissolved organics in waste water. The carbon, when exhausted, can be reused after regeneration by heating to high temperature (1700°F).

"The method of application is primarily determined by the particle size of the carbon to be used. Granular carbon, in the mesh size range from 8 x 30 to 40 x 60, is generally contacted with the waste water in a fixed or fluidized bed of carbon. Originally, carbon adsorption was considered as a tertiary treatment to supplement biological processes to produce a high quality product of reuseable quality. More recently, the main thrust of research has shifted from the treatment of biological secondary effluent to treatment of clarified raw sewage. Success in the latter effort will provide the sanitary engineer an alternative to biological treatment." [41, p. 36] by lime and mixed media filters. The carbon is reported to effectively reduce an influent BOD from 5-20 mg/l to 2-5 mg/l; COD from 20-30 mg/l to 2-10 mg/l; and color from 20-50 to less than 5 units. The average dosage of carbon to accomplish this treatment has been reported as 300 lb/million gallons of treated waste water [41]. Large-scale studies at Pomona are reported to have substantially confirmed the results obtained at Tahoe [41, p. 36-37].

Powdered carbon has developed into a competitor for granular carbon. Its finer grain size and consequently, greatly increased specific surface area lead to increased kinetics of adsorption such that 90% of its adsorption equilibrium is attained in less than 10 minutes. Powdered carbon is dosed in slurry form. The deactivated carbon is separated by sedimentation following polymer flocculation. Other methods of separation are under study. Powdered carbon has the advantage over granular in that its cost is about one-third as great. Unit cost and the possibility of controlling the dosage applied are two of the advantages over granular. The technical and economic feasibility of powdered activated carbon has been under investigation by Eimco Corporation and Infilco Corporation [41, p. 40].

Other refractory organics removal alternatives which could possibly find applications under special conditions consist of synthetic adsorbent resins, chemical oxidation methods such as chlorine catalyzed by ultraviolet light, photo-oxidation and the use of ozone. These have limited potential at the present time [41, p. 41].

5.4.3 AWT as an "Add-on" to Secondary Treatment

Since the biological flocculation and precipitation steps of the activated sludge process can produce a well-nitrified effluent and since, under suitable modifications, it could also precipitate out much of the dissolved phosphorus, the evolution of AWT for nitrogen and phosphorus removal has been as an "add-on" of denitrification and adsorption units to conventional secondary effluent. For instance

Greeley and Hansen [3] have suggested the flowsheet of Fig. E-3 as one of the add-on alternatives to the secondary treatment plants at Baypark and Wantagh in Nassau County, to produce ultimately 94 mgd of high quality effluent fit for recharging the aquifer through existing storm-water basins. Note that it provides for nitrogen removal through ammonia stripping with air, and phosphorus removal through lime precipitation. Finishing treatment includes dual media filtration, carbon adsorption and chlorination. Demineralization is envisaged as a possible future addition which will be needed under a strategy of complete recycling. The unit cost of an AWT plant employing this "add-on" process has been estimated at $650 per million gallons. (See Paragraph 8.0, Appendix D.)

5.4.4 Physical-Chemical Treatment

A more recent concept in the use of activated carbon is replacement of the biological secondary treatment process in conventional treatment. The process sequence consists of chemical clarification of raw sewage by either organic flocculants or by metal coagulants, when phosphate removal is desired, followed by carbon adsorption. To date, technical feasibility has been demonstrated only at small scale, but full-scale application is expected to be demonstrated within the next year [41].

A recent state-of-the-art report [51] on physical-chemical processes (clarification-adsorption), presented by Kugelman and Cohen of EPA, includes a discussion of the performance and status of some existing plants and plans. Based on an analysis and evaluation of this and other reports available on the topic, the following key features of the physical chemical processes are presented. A general flow-sheet of physical-chemical treatment [51] is included in Figure E-4.

Considerable information has been developed on physical-chemical process as a possible substitute for biological treatment.

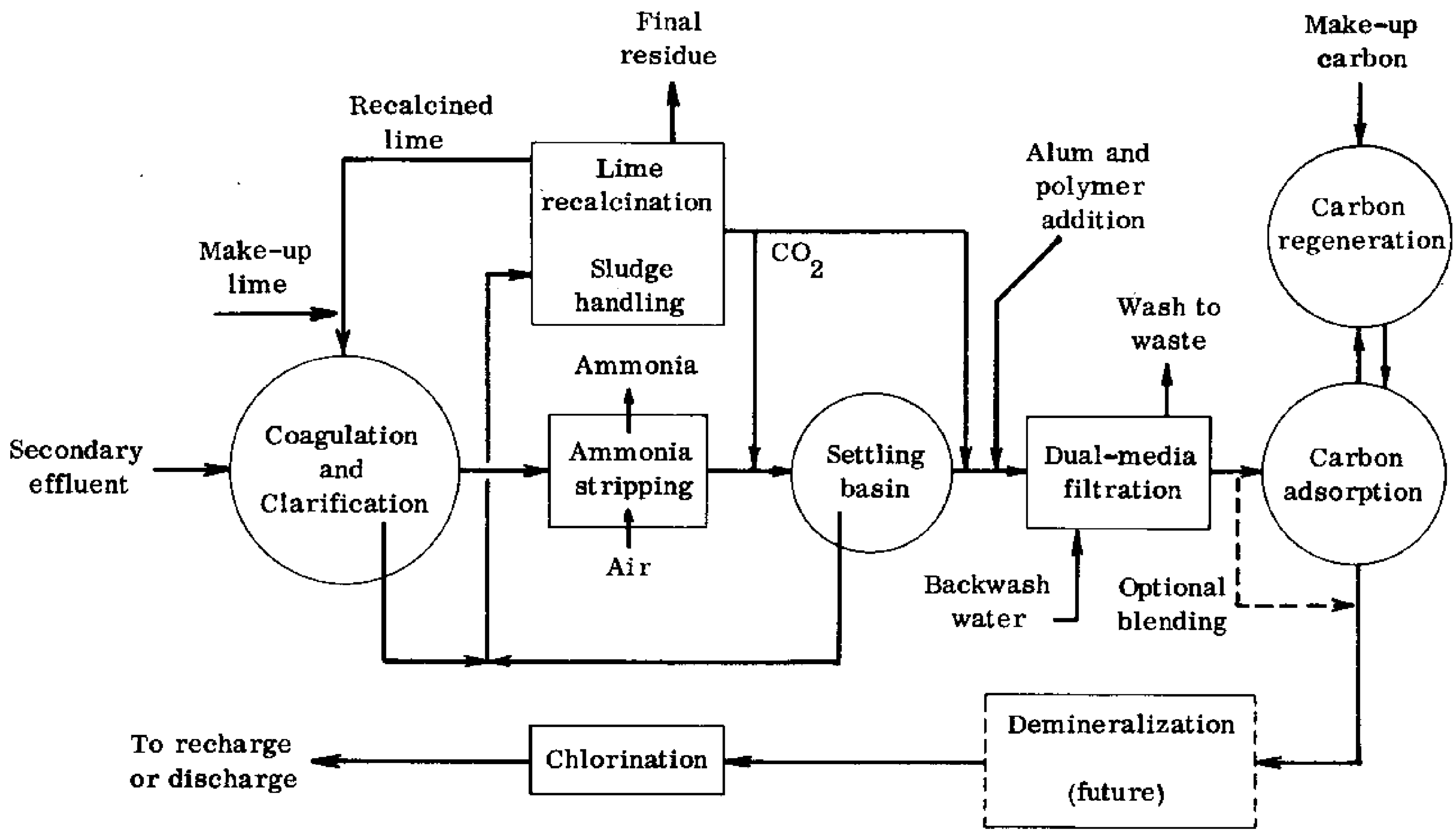


Fig. E-3
ILLUSTRATIVE "ADD-ON" AWT FLOWSHEET (Source [3])

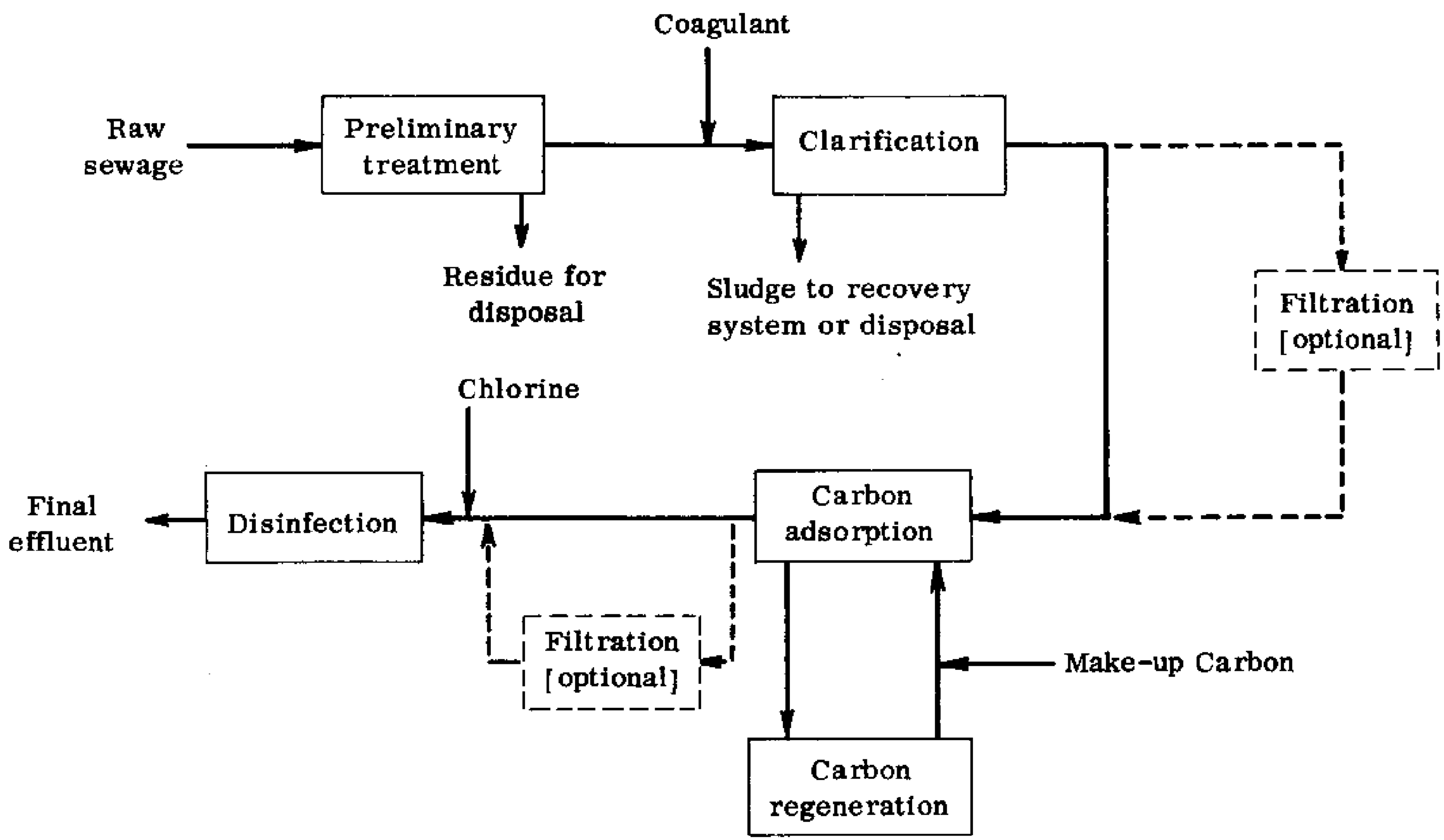


Fig. E-4
FLOW DIAGRAM OF A PHYSICAL-CHEMICAL TREATMENT SYSTEM Source [51]

Calgon's studies of the treatment sequence (clarification-carbon) are reported to have shown the following removals when contact time with the carbon is 24 minutes; suspended solids 93%; BOD 93%; COD 81%; and TOC 75%. When metal coagulants are used in the clarification step, phosphate removals of 90% or above are reported [41, p. 38].

"Pilot scale investigations at the Lebanon Pilot Plant of AWTRL have shown that lime clarification followed by carbon adsorption of primary effluent can consistently produce an effluent equal to or better in quality than secondary biological treatment. Over five million gallons of primary effluent were processed to produce an average effluent product containing 10 mg/l TOC and BOD with a range of 2-23 mg/l. Effluent turbidity averaged less than 2 JTU and phosphate removals were consistently 90% or better." [41, p. 38].

It is of interest to point out here that plans are under way to construct a physical-chemical treatment plant of 5 mgd capacity in the town of Port Jefferson in Suffolk County [36]. The proposed treatment process consists essentially of reactor-clarifiers, filters, carbon adsorbers and sludge thickeners. To minimize land requirements, reactor-clarifiers were used rather than flocculation-sedimentation basins, and re-pumping following filtration was utilized to permit the use of deep carbon adsorbers.

It is interesting to note here that although the N.Y. State Department of Environmental Conservation would not normally accept a physical-chemical plant without pilot-plant testing for construction grants, at the Port Jefferson treatment plant the physical-chemical process is now allowed [36, p.1].

Cost Estimates for Physical-Chemical Treatment

It is difficult to collect data on costs of AWT as representative of current status since either some processes are still experimental or plants of a reasonably large size have not been built or sufficient operational data on performance and associated costs have not been computed. Definitive data will not be available until large-scale plants have been built and are in operation for several years. Even then, local conditions may significantly affect the actual cost.

Based upon available cost information from pilot plants and preliminary designs of several proposed large-scale plants, cost estimates for various size plants were made by EPA [51], referenced to October 1970. The amortization was based on 6 percent for 24 years. These form the basis for Table E-6. Note that the ranges given for each plant size represented the spread of data available. The unit costs are spread over $100 to $360 per million gallons, for plants ranging in size from 100 to 5 mgd./1

/1 "As a comparison, ...estimate for primary and secondary treatment with sludge incineration is 16.5 cents per 1000 gallons at the 10 mgd level. With the addition of single stage lime for phosphorus removal the cost would rise to 23.5 cents per 1000 gallons which is essentially the same as physical-chemical treatment"[51].

The unit cost data for conventional biological treatment plants, as given in the source, are added as lines 4 and 5 in Table E-6 for purposes of convenient comparison. Note that the cost of "Secondary treatment with sludge incineration" is shown as $165 per million gallons. We did <u>not</u> use this nationally-derived index in Paragraph 8 of Appendix D. Instead, we derived a current Long Island-specific unit cost based upon an actual engineering design for a major proposed plant. The resulting unit cost was over <u>twice that cited</u> in Table E-6. This example illustrates the caution that must be exercised in applying national indices to Long Island without very careful scrutiny of the source and translating it to equivalent, current Long Island terms.

As an example directly applicable in the bicounty region, the studies for the physical-chemical process plant at Port Jefferson, Suffolk County, indicated that, "...for a design flow of 5.0 mgd, construction costs for the activated sludge process are equivalent to the costs for a physical-chemical plant. In addition, it appears that operating expenses are equal for both processes for a flow of 2.0 mgd. This flow appears to be a break-even point since, as the flow increases, the expense of a physical-chemical plant exceeds that of the alternate studied." [36] For the "5 mgd" plant, the capital costs were estimated at $9.3 million with an annual estimated operating cost of $0.355 million "...for the first several years of operation with flows assumed at 2 mgd." This would amount to a unit cost of $600 per million gallons with a discount rate of 5% and a useful life of 30 years.

TABLE E-6

PRELIMINARY COST ESTIMATE PHYSICAL-CHEMICAL TREATMENT

(Total Amortization + O&M, dollars per million gallons)

(6%; 24 yrs) Source [51]

Process	Plant Size in mgd		
	5	10	100
1. Chemical Clarification*	95-135	73-96	40-53
2. Carbon Adsorption	115-180	91-135	45-78
3. Filtration	29-45	21-33	10-14
TOTAL (1 + 2 + 3)	239-360	184-264	95-145
4. Secondary treatment with sludge incineration	-	165	-
5. (Item 4 + single stage lime for phosphorus removal)	-	235	-

*Two-stage lime, recalcination of sludge.

Comparative merits of physical-chemical treatment

Some advantages that have been cited [41, p. 38] for a physical-chemical process are:

(1) Physical-chemical process would be less influenced by shock loads, low temperatures and toxic substances than a biological system, and would, therefore, be easier to operate than a delicate activated sludge plant.

(2) Physical-chemical process greatly reduces the sludge handling problems. For instance, a 10-mgd physical-chemical plant would reduce the sludge volume to about one-half of that from a conventional activated sludge plant, which would produce about 150,000 gpd of sludge. This of course, depends on the flocculant used: a wide variety of metal coagulants such as aluminum sulphate, sodium aluminate, ferric or ferrous sulfate or chlorides, and lime; and polyelectrolytes are usually applicable. The sludge is also readily filterable.

(3) The physical-chemical plant is flexible: it could be adjusted readily to meet desired effluent quality.

(4) Odor problems are minimal. This is important in areas of high population concentration.

(5) The physical-chemical plant occupies much less area than a conventional plant of the same size. As a case in point, the change from an earlier proposed biological-AWT system to a physical-chemical system in Port Jefferson treatment plant reduced the area requirement from 18 acres to 5 acres [36].

(6) Capital costs for physical-chemical plants may be 25 to 30% less than those for conventional plants [41, p. 38]. For a brief comparison of costs of conventional activated sludge plant with physical-chemical plants for different sizes, reference is invited to Table E-6. Also see Paragraph 8.0 of Appendix D. Much uncertainty surrounds AWT costs.

Some of the disadvantages that have often been quoted for physical-chemical process are:

(1) Unless ammonia stripping with air or by other means is specially provided for, ammonia nitrogen will generally be unaffected in a physical-chemical plant. Ammonia, however, is usually a small part of the total nitrogen in waste waters. Where the content is high, ammonia removal is important. Costs of flow sheets employing ammonia removal will

naturally be higher and subject to same degree of uncertainty as AWT costs.

(2) Lack of operating experience with large-scale municipal plants. The state-of-the-art report of EPA [51] furnishes existing and planned plant listings.

(3) "Added-on" costs of advanced waste treatment processes for nutrients removal or dissolved solids removal tend to raise overall costs of a conventional waste treatment - advanced waste treatment system. However, costs of certain physical-chemical processes as evidenced in Table E-6 could be of comparable magnitudes to conventional waste treatment even for plants as low as 10 mgd capacity. It may be noted that physical-chemical processes,by themselves,can produce effluents of desired quality and that they are not necessarily added-on components to conventional waste treatment by biological means.

Preliminary cost analyses of various water supply - waste water treatment and disposal alternatives for the Nassau-Suffolk county region, have been presented and discussed in Appendix D of this report. Detailed cost estimates of the advanced waste treatment - groundwater recharge combination will depend upon availability of cost estimates for recharging well fields, their location and site characteristics, and the actual combination of advanced waste treatment processes selected. Such data are not available at the present time. Detailed estimates could be made only when they are available. However, this is an alternative which deserves serious and careful consideration by the bicounty region in the light of the following:

(1) The continuing depletion of grounwater recharge in the region, especially Nassau County, as evidenced by the gradual lowering of water table elevations [15 and 16].

(2) The time-lag involved in the implementation of any non-groundwater sources, even if acceptable, over which period the water quantity and quality in the aquifers will have to be preserved since it is the only major source of present water supply.

(3) The need to protect the bays and surface waters from enrichment with nutrients and general degradation which could affect their water quality and consequently their utilization.

(4) The high value of land in the region and scarcity of land in Nassau County. Advanced waste treatment by physical-chemical processes will need much smaller areas than conventional waste treatment.

(5) Operational stability and flexibility, reduced quantity of residuals for ultimate disposal and prior experience (in Nassau County, under EPA research and development grant,and in Suffolk County, Port Jefferson plant) connected with advanced waste treatment.

(6) Administrative and managerial efficiency. Since the advanced waste treatment-groundwater recharge system will be wholly within the geographical boundaries of the bicounty agencies, all the component parts will be subject to their direct and immediate supervision and control. Under other strategies, some transfer of water across county or regional borders is envisaged. Although the bicounty agencies may have certain powers of legal jurisdiction, geographical inconvenience could be anticipated.

An analogous waste water treatment process (including recovery) involving chemical coagulation for suspended solids removal, followed by absorption of soluble organics on powdered carbon, has been developed by Battelle's Northwest Laboratories under sponsorship of the Water Quality Office of EPA. Reported advantages of the process are cited as

1) a total treatment time of less than one hour;
2) a high quality effluent;
3) lower initial plant cost;
4) ability to remove nitrogen and phosphorus; and
5) a final sludge reduction to sterile ash in a centrifuge-incineration process combined with a chemical regeneration step to recover both the coagulant and the carbon.

"While estimates of plant operation costs for the new process are high, overall costs of the treatment process during a 20-year plant life are considered to be significantly less than costs for comparable biological facilities" [57]. Presently, tests are being conducted on a 100,000 gpd trailer-mounted pilot plant, and the results are expected to be available from Battelle shortly.

5.5 Waste Water Renovation and Reuse

Reuse application of high quality effluents resulting from advanced waste treatment plants includes irrigation, formation of recreational lakes, industrial uses, groundwater recharge which is under active consideration in the region, and direct domestic reuse. Each of these will be briefly discussed below.

Irrigation: Use of renovated waste water for irrigation of non-edible crops and for parks and golf courses has become fairly wiedespread, especially in water scarcity areas [41]. With the technical feasibility of this application no longer in doubt, it should become more common in the future. Use of waste water has the benefit of supplying significant amounts of plant nutrients, thus reducing fertilizer requirements. EPA's R&D Grant projects at Colorado Springs, Antelope Valley near Los Angeles, Irvine Ranch, California, and South Lake Tahoe, California include production of water for irrigation. [41, p. 82] Waste water effluents are not used presently for irrigation of food crops [41 p. 82], although, under control, it could be feasbile. Studies are needed to define better the water quality required for this application.

A recent waste water management system at Muskegon County, Michigan, utilizing lagoon treatment of waste water and spray irrigation facilities for disposal, on the basis of an extensive study, demonstrated the feasibility of such a total system for waste water management [5]. The land requirement, and transport and distribution costs of this method of recharge have to be weighed against the injection system costs and operational problems of injection methods. A careful total evaluation of this alternative for the bi-county region is an important research need. See Appendix D for a preliminary evaluation.

Recreational Lakes: Filling of recreational lakes with renovated waste water was begun at Santee, California, in 1961 and the success of that project has bred several others.

The use of waste water for recreational lakes can often be combined with irrigation. The lake merely serves as a reservoir for the irrigation water. The Tahoe site is an example of this dual purpose reuse.

Industrial Reuse: In some parts of the United States, industrial reuse of waste water represents a very large potential application, especially for cooling water, process water and boiler water feed [41]. In Europe, recycling appears to be used for a variety of purposes. Table E-7 provides some examples, drawn from the United Kingdon, of recycling possibilities in various industries [52].

On Long Island, however, the potential for industrial reuse is limited because of such factors as (1) the ample supply of seawater for cooling, (2) the practice of recharging all fresh industrial cooling water to the aquifer, and (3) the very low volume of water used for industrial purposes other than those included in (1) and (2) above. (See Appendix B).

Groundwater Recharge: An increasingly serious problem in Nassau County is the gradual lowering of groundwater level over the years, due, in part, to increasing withdrawals without adequate replacement [15 and 16]. Intrusion of seawater into the aquifers rendering them unsuitable for several purposes, under these conditions, is likely to increase.

It has been recognized that renovation of waste water and recharge of this water may be a practical method for overcoming the problem. Recharge may be carried out by surface spreading of the water or injection into a well. The bi-county region is already practicing surface spreading of storm water and relatively good quality industrial waste water [12].

TABLE E-7

INDUSTRIAL REUSE OF WATER

Process	Use	Usual Treatment
Group A: Use of Sewage Effluent		
1. Electricity Generation	Cooling	Chlorination
2. Steel Works	Cooling, Dust supression Quenching	Chlorination Lime softening, pH correction Conditioning, Coagulation, and Sedimentation
3. Gas Production	Cooling, Ash quenching	Chlorination, Coagulation, Sedimentation, Filtration
4. Animal Foodstuffs	Cooling & deodorizing vapors	Chlorination
Group B: Recycling		
5. Paper making	Processing	Chemical treatment Sedimentation, Filtration
6. Laundering	Washing and rinsing	
7. Coal Mining	Cooling and washing	Coagulation, Sedimentation, Filtration
8. Metal Finishing	Rinsing	Carbon bed, Ion-exchange
9. Food Canning	Cooling	Chlorination, Coagulation, Filtration
10. Automobile Painting	Washing down	Coagulation, Sedimentation, Filtration, Ion-exchange
11. Metal Casting, Finishing	Hydroblasting	Coagulation, Sedimentation, Filtration
12. Steel Manufacture	Cooling	Coagulation, Sedimentation, Filtration, Chlorination
13. Chemical Manufacture	Dedusting	Sedimentation
14. Steam Raising	Boiler feed	Ion-exchange, Degassing
15. Animal Foodstuffs	Degreasing	pH Correction, Precipitation

See Appendix B for a discussion of the locations and quantities, and Appendix D for costs involved.

In order to investigate the possible effects of detergents in wastes which reach the groundwater in Long Island, the New York State Department of Health, in conjunction with the County Departments, undertook a study, the results of which have been published in a 1969 report [24]. The specific objectives of the study were:

(1) To investigate dangers that detergent wastes in domestic and industrial discharges "may create to the adequacy and safety of the water supply now and in the future," and

(2) To investigate whether "the area of contamination from detergent wastes is more widespread from the point of discharge than is usual in the case of other forms of wastes."

Two observations pertinent to the travel of pollutants in the zones of aeration and saturation of the bicounty area emerged from the study. They are:

(1) Movement from cesspool of leaching wastes is essentially downward, the lateral spread being not more than two feet. Upon reaching saturated sands (groundwater) the movement is with the groundwater in the form of a ribbon-like plume.

(2) Presence of detergents does not seem to affect travel of pollutants. Organisms do pass through unsaturated subsoils into the groundwater table and travel downstream along with wastes.

The general conclusions from the study may be summarized as follows:

(1) The degree of reduction in active concentration of the surfactants occurring in typical individual sewage disposal system is not adequate to prevent the upper glacial aquifer from contamination with such surfactants.

(2) Placing of water supply wells in the deeper Magothy stratum to avoid drawing possibly contaminated water from the shallow glacial aquifer is attended by the risk of overdevelopment of the Magothy aquifer and the following consequences:

   (a) Transfer of surfactant pollution from the upper glacial aquifer to the lower Magothy aquifer.

   (b) Induce inward movement of salt water from the bays and ocean.

(3) Therefore, the MBAS (Methylene Blue Active Substances) fraction of detergents persists and travels in groundwater so as to affect this water resource. These characteristics are more typical of detergent wastes than the other components of domestic sewage [24].

One of the significant management applications of this study has been as a source of basic information for a decision to prohibit the sale and distribution of certain varieties of household detergents in Suffolk County/1 [55].

In locations where the percolation rate is low or where spreading areas are not available, well injection for recharge would be necessary. Care must be taken, in such instances, to assure that the water is of proper quality to be compatible with the strata of the aquifer, i.e., will not form precipitates which clog the area around the wells. Furthermore, the water must not contain suspended matter that will cause clogging. Nassau

/1 The Suffolk County legislature has enacted that: "No person shall sell, exchange, give or dispose of to another or offer or agree to do the same, any detergent containing any of the following surface active agents: (a) alkyl benzene sulfanates, (b) alcohol sulfates, (c) methylene blue active substances." [55]

County, Long Island is studying injection for prevention of seawater intrusion and for other uses. Treatment of the waste water at this location consists of activated sludge, alum clarification, and granular carbon treatment. Nitrogen removal is also being considered [41, p. 84]. Preliminary experience here has been presented and discussed in Appendix D (para. 8): considerable additional data, in terms of AWT loadings, effluent quality, injection well performance, operational problems and cost will be needed to analyze fully the deep well injection alternative. This is not available at the present time. Only when the experimental nature of the operation changes, these will be available. The analysis is an important research need for the bi-county region beyond the scope of the present study.

Domestic Reuse: Reuse of renovated waste water for domestic purposes involves both non-potable and potable applications. Non-potable use is not new [41, p. 84], especially in water scarcity areas. The water should be of high quality since, occasionally, cross-connections could occur between potable and non-potable water distribution systems.

Instances of indirect potable use of renovated waste water, such as occurs when water recharge is practiced, are increasing [41, p. 84]. In these cases there is usually a large amount of dilution water. The situation is similar to that occurring in many cities where river water containing effluents from cities upstream is used for the water supply: the Mississippi-Missouri system is a case in point.

The direct reuse of waste water for potable water in the bi-county region does not appear necessary in the planning framework here considered.

5.6 Ultimate Disposal

This aspect of advanced waste treatment deals with the disposal of residues which have been extracted from the waste water, such as digested or dried sludge, brine or concentrated salt solutions, chemical sludges, gaseous residues such as digestor gas and air-stripped ammonia, and incinerator ash and vapors. Land, ocean water and atmosphere are the alternative receptacles.

A state-of-the-art summary as of July 1970 of the ultimate disposal research program of EPA's AWT research laboratory [41] discusses such disposal methods as deep wells, incinerators, land disposal without previous dewatering, ocean disposal and various combinations of these methods. As might be expected, the method selected will vary greatly with the regional conditions and the quantity and quality of the ultimate residual.

An in-depth expansion of this particular aspect of the total water supply-waste water disposal system is beyond the scope of this framework analysis. However, a few general perspectives can be suggested for Long Island with its high density population, high residential versus industrial waste water loads, low agricultural activity, high quality aquifers, and close proximity to the ocean.

(1) For the relatively small quantity of ultimate residue that can be expected from AWT, barged ocean disposal and/or incineration appear to be the most likely selections.

(2) For the greater quantity of ultimate residue that can be expected from secondary treatment, ocean disposal by outfall or barge, with or without incineration, appear to be the most likely selections but a special feasibility study would be required.

An economically-oriented study of ocean dumping of solid wastes was prepared by Devanney _et al_ at MIT [59]. The study is especially relevant to the New York City area. It compares all major methods of solid wastes disposal, both oceanic and inland. Its internally-acknowledged weakness is its inability to evaluate biological consequences at sea.

The theory and practice of barged ocean disposal of liquid and solid wastes has recently been reviewed by Clark _et al_ [56] of EPA's Pacific Northwest water laboratory. This broad-scope examination discusses the physical characteristics of selected wastes, ocean dumping economics as a function of haul distance, some reported effects of past discharge operations and factors such as density and current profiles. Its main thrust is to discuss available methods for determining the physical fate of wastes. Although the fate models of Koh and Fan presented are hydrodynamically sound and perhaps the best available, as internally acknowledged, they are quite deficient in allowing for chemical, physical and biological interactions possible between the wastes, marine water and their constituents. [56, p. 2].

5.7 Summary

In the foregoing pages, we have described the state of the art of AWT processes in general, discussed their applicability, and pointed out two instances in Long Island where AWT processes have been either under experimentation or proposed for construction. If groundwater is to continue to be the bicounty region's primary water source, then the waste waters will have to be returned to the aquifers through recharge. Such recharge might be through injection wells or surface basins such as the storm water basins or by spray irrigation. AWT, to varying degrees, will be needed before recharge. Even if waste waters are to be disposed into surface water bodies such as streams or bays (which might be needed to replenish streams or correct salinities under some strategies outlined in Appendix D), AWT will be required before discharge.

The processes constituting AWT have been discussed principally under the categories of modification to activated sludge, suspended and dissolved solids removal, waste water renovation and reuse, and utlimate disposal methods. The evolution of AWT as an extension to conventional secondary treatment, and the recent innovation of physical-chemical treatment as a self-sufficient AWT process have been explained at length. Cost data for AWT processes are necessarily scarce and scattered. A preliminary cost analysis of the "add-on" AWT plant (94 mgd) suggested in a recent reference for Nassau County [3] led to a unit cost of $650/million gallons: a similar analysis of a 5-mgd physical-chemical plant proposed for Suffolk county resulted in a unit cost of $600/million gallons.[/1] These estimates are so close and the uncertainties in the cost data and expected performance are such that the above figures,by themselves,should not be used as a basis for comparison. Wherever a secondary treatment plant already exists and it is decided to provide AWT,the "add-on" process would be cheaper than substituting the entire plant with a new physical-chemical plant. However, where a new AWT

/1 See earlier Appendix D, and this appendix for details.

plant is prosposed, it is strongly recommended that the feasibility of a physical-chemical AWT plant be thoroughly investigated since it will:

- be more flexible in design,
- be better able to withstand shock loads,
- require less land area, and

it might be cheaper than a new biological-physical AWT plant.

Therefore, in summary, <u>if</u> the following assumptions hold true:

(i) that Long Island groundwater is to continue as the principal source of water supply for the bicounty region,

(ii) that recharge of groundwaters or surface streams and lakes is to be practiced with a high quality waste water effluent,

(iii) the current AWT technology, especially physical-chemical AWT process, continues to improve and more operational experience is gained with such plants,

it would appear that the council should endorse

(i) the "add-on" AWT process (with a flowsheet specifically designed to include, among others, nitrogen removal) at sites where there is already a secondary treatment plant,

(ii) the physical-chemical process (with a flowsheet, specifically designed to include, among others, nitrogen removal) where a new AWT plant is to be built and where the quality of the raw waste water is highly variable and/or land is at a premium, and

(iii) continuing investigation of the improvements in and feasibility of physical-chemical plants with a view to their adoption in future new developments in Long Island.

ENCLOSURES

E-1 - Aquatic Environmental Quality Management Model

E-2 - Major Industrial Waste Overview

E-3 - Extract from Regional Plan Recommendations

ENCLOSURE E1

AQUATIC ENVIRONMENTAL QUALITY MANAGEMENT MODEL

This enclosure contains a network diagram of an Aquatic Environmental Quality Management Model.

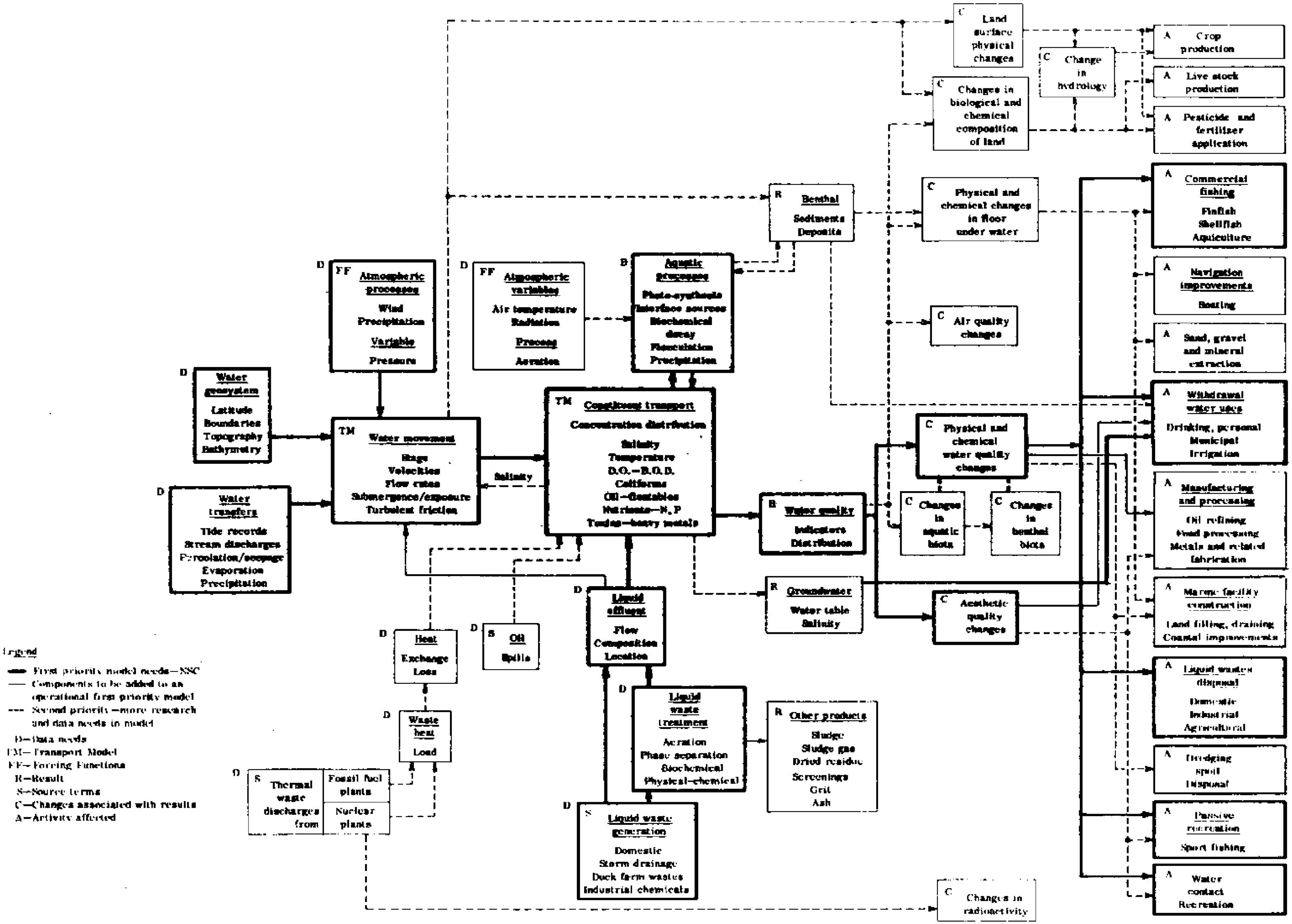


Fig. E-5
AQUATIC ENVIRONMENTAL QUALITY MANAGEMENT MODEL

ENCLOSURE E-2

MAJOR INDUSTRIAL WASTE OVERVIEW

This enclosure contains a Table E-8 - Major Industrial Waste Overview pertinent to Nassau-Suffolk Counties of Long Island.

TABLE E-8

MAJOR INDUSTRIAL WASTE OVERVIEW PERTINENT TO NASSAU-SUFFOLK COUNTIES OF LONG ISLAND

Industries producing wastes (1)	Origin of major wastes (2)	Major characteristics (3)	Major treatment and disposal methods (4)
	Food and drugs		
Canned goods	Trimming, culling, juicing, and blanching of fruits and vegetables	High in suspended solids, coloidal and dissolved organic matter	Screening, lagooning, soil absorption or spray irrigation
Dairy products	Dilutions of whole milk, separated milk, buttermilk, and whey	High in dissolved organic matter, mainly protein, fat, and factose	Biological treatment, aeration, trickling filtration, activated sludge
Meat and poultry products	Stockyards, slaughtering of animals, rendering of bones and fats, residues in condensates, grease and wash water, picking of chickens	High in dissolved and suspended organic matter, blood, other proteins, and fats	Screening, settling and/or flotation, trickling filtration
		Apparel	
Textiles	Cooking of fibers, desizing of fabric	Highly alkaline, colored, high BOD and temperature, high suspended solids	Neutralization, chemical precipitation, biological treatment, aeration and/or trickling filtration
Leather goods	Unhairing, soaking, deliming and bating of hides	High total solids, hardness, salt, sulfides, chromium, pH precipitated lime and BOD	Equalization, sedimentation, and biological treatment
Laundry trades	Washing of fabrics	High turbidity, alkalinity, and organic solids	Screening, chemical precipitation, flotation, and adsorption
		Chemicals	
Acids	Dilute wash waters; many varied dilute acids	Low pH, low organic ontent	Upflow or straight neutralization, burning when some organic matter is present
Detergents	Washing and purifying soaps and detergents	High in BOD and saponified soaps	Flotation and skimming, precipitation with $CaCl_2$

(1)	(2)	(3)	(4)
Phosphate and phosphorus	Washing, screening, floating rock, condenser bleed-off from phosphate reduction plant	Clays, slimes and tall oils, low pH, high suspended solids, phosphorus, silica, and fluoride	Lagooning, mechanical clarification, coagulation and settling of refined waste. See section on Advanced Waste Treatment (p.)
Formaldehyde	Residues from manufacturing synthetic resins, and from dyeing synthetic fibers	Normally has high BOD and HCHO, toxic to bacteria in high concentrations	Trickling filtration, adsorption on activated charcoal
		Materials	
Pulp and paper	Cooking, refining, washing of fibers, screening of paper pulp	High or low pH; colored; high suspended, colloidal, and dissolved solids; inorganic fillers	Settling, lagooning, biological treatment, aeration, recovery of byproducts
Photographic products	Spent solutions of developer and fixer	Alkaline, contains various organic and inorganic reducing agents	Recovery of silver, plus discharge of wastes into municipal sewer
Metal-plated products	Stripping of oxides, cleaning and plating of metals	Acid, metals, toxic, low volume, mainly mineral matter	Alkaline chlorination of cyanide, reduction and precipitation of chromium, and lime precipitation of other metals
Iron-foundry	Wasting of used sand by hydraulic discharge	High suspended solids, mainly sand; some clay and coal	Selective screening, drying of reclaimed sand
Oil	Drilling muds, salt, oil, and some natural gas, acid sludges and miscellaneous oils from refining	High dissolved salts from field, high BOD, odor, phenol, and sulfur compounds from refinery	Diversion, recovery, injection of salts; acidification and burning of alkaline sludges
		Energy	
Steam power	Cooling water, boiler blowdown, coal drainage	hot, high volume, high inorganic and idssolved solids	Cooling by aeration, storage of ashes, neutralization of excess acid wastes
Nuclear power and radioactive materials	Processing ores, laundering of contaminated clothers, research-lab wastes, processing of fuel, powerplant cooling waters	Radioactive elements; can be very acid and "hot"	Concentration and containing, or dilution and dispersion

ENCLOSURE E-3

EXTRACT FROM REGIONAL PLAN RECOMMENDATIONS

This enclosure contains an extract from the recommendations of the Regional Plan Association of New York pertaining to waste water management. [29]

Extract from Recommendations of Regional Plan Association (N.Y.):

(1) High priority should be attached to a study of governmental organization for waste management in the region.

Short-run Suggestions

(2) Refine the analyses of waste management costs.

2.1 Analyze waste generation and waste management conditions in terms of time-stream of costs.

2.2 Include collection costs in waste management system components.

2.3 Analyze different methods and combination of methods for waste disposal.

(3) Identify functional relationships required for, and the policy issues involved in the synthesis of waste generation, waste management and environmental quality to meet society's goals.

(4) Show how studies by other agencies can be incorporated in subsequent analyses of waste generation, waste management and environmental quality in the region.

(5) Assess administrative costs of waste management in relation to (a) monitoring systems, and (b) waste "handling" and disposal methods.

Long-run Suggestions

(6) Collect data for waste generation coefficients (quantity, quality, factors influencing coefficients).

(7) Develop predictive models of the impact of waste discharges on air, water and land quality, and then on people, plants and animals.

(8) Investigate the applicability of effluent charges for encouraging reductions in waste generation and wastes discharged.

(9) Investigate the feasibility, costs, method of operation and gains from selective, non-continuous controls on some or all of the wastes, as opposed to uniform, continuous controls.

(10) Investigate further the feasibility of disposal of wastes to the ocean.

(11) Investigate the feasibility of developing an on-site system which would handle all types of wastes, maximize recycling, minimize residue and dispose of the residue on-site.

APPENDIX F

DATA COLLECTION AND RESEARCH NEEDS

APPENDIX F

DATA COLLECTION AND RESEARCH NEEDS

1.0 ITEMIZATION OF NEEDS

During the analysis in Section 2 and its supporting appendices, the state of the art was reviewed as it relates to the bi-county region's integrated water supply-waste water disposal system. Data collection and research needs were identified during the course of the analysis and in the preceding appendices. In this appendix, these needs have been extracted, given a brief identifying title, briefly described, and grouped according to the eight categories of knowledge requirements developed in an earlier report of this series on Functional Step Two [1c].

2.0 DATA COLLECTION NEEDS

These needs are grouped under the first four general categories of knowledge requirements developed in Functional Step Two. The parenthetical entries after each need refer to paragraphs in the main report and lettered appendices in which relevant information is contained.

CATEGORY I - INFORMATION ABOUT CURRENT HUMAN ACTIONS AND NATURAL FORCES AFFECTING THE ENVIRONMENT

(1) Water usage. Collect usage data to verify or improve the quantitative information developed in Appendix B to include:

- Total pumpage and withdrawals from surface sources.
- Losses through leakage and undetected unauthorized uses from the water supply system.
- The disaggregation of water use between residential, industrial and agricultural uses.
- The disaggregation of residential water disposal between treated and untreated sewage and other disposals such as sprinkling.
- The disaggregation of industrial water usage between treated and untreated sewage, cooling and other uses.
- The infiltration of groundwater into sewerage systems.
- The ultimate distribution of used water between the atmosphere, streams, bays and ocean. (2.1.2, B4).

(2) Unit costs. Improve the accuracy of the unit cost data developed in Appendix D for evaluating the economic aspects of alternative water supply-waste water disposal systems. (2.5, D).

(3) Ocean dumping. Collect data on the quantity and constituents of wastes being dumped into New York Bight and the Sound, with particular emphasis on toxic materials and nutrients. (D9).

(4) Man's surface changes. Collect data on past and current surface changes made by men and estimate their effects on evapotranspiration losses. Predict the extent of surface changes projected for the future and evaluate their effects on future evapotranspiration losses. (2.1.3, B5).

CATEGORY II - INFORMATION ABOUT THE CURRENT PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE ENVIRONMENT

(5) Onshore geology. Collect information to determine more accurately the horizontal and vertical permeability rates in the aquifers and the locations of selected strata, especially the Gardiners clay. (B2, B6.1).

(6) Offshore geology. Make borings off the south shore to determine the geological profile time at least to the bottom of the Magothy aquifer with particular attention to the location of the Gardiners Clay off western Suffolk County, (B2. B6.1).

(7) Groundwater levels. Expand the current system of monitoring wells to improve knowledge of groundwater levels and the piezometric surface of the artesian aquifers, particularly the Magothy. (B6.1).

(8) Possible land subsidance. Establish a system of very high precision measurements of surface elevations at a few selected locations where groundwater levels are declining to provide early warning if a subsidance problem should occur. (2.4, B6.2).

(9) Groundwater contamination. Expand the current system of collecting and analyzing water quality samples from wells selected because of their strategic locations and depths. Particular attention should be given to monitoring the rate and depth of contamination in the center part of the interior recharge area. (C.2, C4.1).

(10) Surface water contamination. Collect, evaluate and collate existing data on the concentration of selected water quality parameters in marine surface waters and integrate the data into a system capable of incorporating newer and better data. This effort should be coordinated with the monitoring system for New York Bight and adjacent inshore waters currently being prepared for the U.S. Environmental Protection Agency (EPA). (D9).

(11) Coastal water quality monitoring system. In conjunction with the EPA project, develop a coastal water quality monitoring system for selected areas such as the south shore bays, Long Island Sound, and the vicinity of offshore dumping sites and outfalls.(C4.2).

CATEGORY III - INFORMATION ABOUT THE CURRENT STATE OF THE MARINE RELATED BIOTA

Existing information in this category, when supplemented by the data collection needs expected to be identified in another report of this series [1g] on wetlands, should be adequate to meet the broad requirements of this report on water supply and waste water disposal.

CATEGORY IV - INFORMATION ABOUT DESIRED USES OF COASTAL RESOURCES

(12) Industrial water requirements. Collect information on current industrial water uses and waste loads, predictions of future technological changes, and master planning data; and then estimate future water use and waste water loads. (2.3, B4.5).

(13) Bathing in the bays. Collect and evaluate information on the current and forseeable usage of the bays for bathing and other forms of skin-contact recreation that are likely to be affected by potential changes in water quality. (C4.2).

3.0 RESEARCH NEEDS.

These needs are grouped under the last four general categories of knowledge requirements developed in Functional Step Two. The parenthetical entries after each need refer to paragraphs in the main report and lettered appendices in which relevant information is contained.

CATEGORY V - KNOWLEDGE OF PROCESSES BY WHICH ACTIONS AND FORCES AFFECT THE PHYSICAL AND CHEMICAL STATES OF THE ENVIRONMENT.

In this category we highlight some processes that need to be better understood if the prediction methods suggested later under Category VIII are to be successful.

(14) Evapotranspiration processes. Improve the adequacy of current knowledge about evaporation, transpiration, and combined evapotranspiration processes and rates in the bi-county area (2.1.3, B4.6, B5.1, B5.2, B5.3).

(15) Infiltration processes. Improve the adequacy of current knowledge of infiltration and percolation processes in the bi-county area to include the rate of downward infiltration from the surface and the horizontal and vertical rates of percolation through the aquifers. (2.2, C2).

(16) Movement of groundwater contaminants. Improve the adequacy of current knowledge of the processes by which contaminants enter the aquifers, increase or diminish therein, and eventually leave the aquifer through seepage to surface water bodies, underflow to the bays and oceans, and pumpage. Primary emphasis should be placed on selected contaminants such as detergents, nitrogen compounds and pathogens. (2.4, 2.6, C2, C4.1, D9, D13).

(17) Movement of bay contaminants. Especially if additional major sewage outfalls are considered in the bays, improve the adequacy of existing knowledge of the processes of suspension, transport, dispersion and deposition that influence the ultimate fate of major sewage constituents, both conservative and non-conservative, in the bays. The major sewage constituents would include nitrogen and carbon compounds, phosphorus, and parameters such as coliforms, dissolved oxygen, BOD, COD and total dissolved solids. (B6.2, C4.2, D9).

(18) Salinity changes in bays. Improve the adequacy of current knowledge of the mixing and flushing processes that influence salinity concentrations under potential changes in stream inflow and inlet size and location. (2.4, B6.2, D9, D13).

(19) Movement of ocean contaminants. In the vicinity of ocean outfalls and ocean dumping sites, improve the adequacy of existing knowledge of the processes involved (including outfall design and dumping methods) in influencing the fate of major constituents of sewage and dumped wastes. (2.5, D9, D13).

CATEGORY VI - KNOWLEDGE OF THE EFFECTS OF ACTIONS AND FORCES, AND PHYSICAL AND CHEMICAL CONDITIONS ON THE MARINE BIOTA

(20) Salinity effects in bays. Determine the effects upon marine biota of changes in salinity concentrations in the bays at all stages of the life cycles of selected species (e.g., hard clam, oyster, menhaden, sea bass, starfish and oyster drill. Priority attention should be given to evaluating the effects of changes within the 25-35 ppt range over most of the major south shore bays and within the 0 - 25 ppt range in the immediate vicinity of inflowing streams. (2.4, B6.2, D9, D13).

(21) Contaminant effects in bays. Determine the effects upon marine biota in the bays under postulated outfall strategies resulting in decreased, stabilized or increased in-bay sewage discharges. (2.4).

(22) Toxic effects in the food chain. Review existing knowledge of the multiplication effects of introducing toxic material into the food chain and improve this knowledge sufficiently to make possible the rational surveillance and control of these materials as a part of all future waste disposal strategies. (2.4, 2.5, C4.2).

(23) Contaminant effects in the ocean. In the vicinity of ocean outfalls and ocean dumping sites, improve knowledge of the effects of secondary effluents sludge and toxics on marine life in the ocean. (2.6, D9, D13).

CATEGORY VII - KNOWLEDGE OF THE IMPACT OF PHYSICAL,CHEMICAL AND BIOLOGICAL ENVIRONMENTAL CHARACTERISTICS ON USERS OF THE COASTAL RESOURCES

(24) Beach closures. Collect and evaluate information on the number, location and duration of beach closures in the bi-county area, the criteria and data employed in making the decision, and the impact upon recreational use. (C4.2).

(25) Coliform levels. Evaluate the adequacy of the 240 MPN per 100 ml, now administratively employed in the bi-county area, for judging the quality of marine waters for bathing purposes. (C4.2).

(26) Bacterial pollution indices. Develop a more reliable, easily-measured and unambiguously-interpreted approach to measuring bacterial pollution than the coliform approach now employed. (C4.2).

(27) Impact of groundwater level changes. Evaluate the probable impacts on biological, recreational and aesthetic uses, of a decline in groundwater levels sufficient to dry up existing lakes and streams, except after storms. Also evaluate the probable impacts on these users, and the users of basements and other underground structures, of a rise in groundwater levels. (2.4, 2.6).

(28) Limit to cesspool sites. Estimate the limit on the number of successive cesspool locations representative pieces of residential property can accommodate. (2.6, D9).

CATEGORY VIII - KNOWLEDGE OF OBJECTIVE METHODS AND PROCEDURES

The following models are needed to improve accuracy in predicting environmental changes likely to be caused by man under various water supply and waste water disposal options.

(29) Surface hydrological accretion model. Develop a model that will integrate current and projected data on natural surface processes such as precipitation, evapotranspiration, and runoff with data on human changes such as surface development and alternative human water supply and waste water disposal systems. (2.4, B4, B5, B7).

(30) Subsurface hydrological model. Improve current models, such as the Hele-Shaw model and the USGS family of groundwater models, to evaluate the impact of accretion changes predicted in (29), on groundwater levels and salt water infiltration phenomena. (2.4, B2, B5, B6, B7).

(31) Contamination models. Develop models to predict the subsurface fate of contaminants introduced into the groundwater by natural forces and human activities, especially cesspool disposal and surface fertilization activities. (2.4, 2.6, C2, C4.1, D8, D9, D13).

(32) Bay water quality models. Develop models to predict the fate of contaminants, including salinity, (a) introduced into bay waters through stream inflow, groundwater upwelling, and in-bay waste disposal practices, and (b) modified by potential human and natural changes in the location and size of inlets. (2.4, B6.2, C4.2, D9).

(33) Ocean water quality models. Develop models to predict the fate of contaminants introduced into offshore waters under alternative strategies involving ocean outfalls and offshore dumping. (2.6, D9, D13).

The following investigations are needed to improve knowledge of alternative processes applicable to the eight phases of an integrated water supply-waste water disposal system:

(34) Imported water. Determine the institutional feasibility of importing significant portions of the water supply, especially for Nassau County, from New York City and from Suffolk County (2.4, 2.6, D2.2, D9, D13).

(35) Desalination . Maintain a continuing awareness of advances in desalination technology that may become feasible for supplementing the bi-county water supply. (D2.3).

(36) Iron removal. Investigate the feasibility of removing iron during the water supply treatment phase. (C4.1).

(37) Leakage control. Investigate the economic feasibility of reducing losses in the transmission, distribution and usage phases, especially leakage losses. (B4.2, D5).

(38) Evaporation control. Investigate the feasibility of reducing evaporation losses during the high-loss summer season by instituting a policy of sprinkling and irrigation at selected times such as during early morning or late evening hours. (D6).

(39) Sewer infiltration control. Investigate the feasibility of minimizing the loss of groundwater that infiltrates into sewer systems (2.1.2, 2.1.3, B4.4).

(40) AWT methods. Investigate the economic and technical feasibility of AWT methods on Long Island with particular attention to physical-chemical processes employed as a complete method (not as an add-on to the primary-biological methods currently employed for secondary treatment). (2.4, 2.6, 2.7, D8, E5).

(41) Individual packaged treatment plants. Maintain a continuing awareness of advances in this type of treatment and investigate its feasibility, particularly in outlying bi-county areas, if current problems of solid residue disposal and fail-safe design can be resolved. (2.6, D7).

(42) Recharge by injection. Investigate the feasibility of injecting water of suitable quality into the aquifers at locations selected to minimize salt water intrusion near the coast and increase potential pumpage rates inland. Problems of well-clogging merit special attention and the water considered for injection should include not only AWT effluent but also water drawn from the water supply system. (2.6, D8).

(43) Recharge by spray irrigation. Investigate the economic and technical feasibility of recharging the aquifers by spray irrigation processes at inland sites. (2.6, D9).

(44) Recharge through storm basins. Confirm the economic and technical feasibility of recharging AWT effluent into the aquifers at existing inland storm water recharge basins giving particular attention to the apparent rapid and deep penetration of the recharge waters along the longitudinal axis of the island. (2.4, 2.6, D8).

(45) Stream recharge. Investigate the economic and technical feasibility of minimizing decreases in stream flows and lake levels by discharging treated, pumped or imported water directly into the streams or lakes, on a year-round or seasonal basis. (B6.2)

(46) Direct recycling of treated effluent. Investigate the economic, technical and public acceptability aspects of recycling highly-treated AWT effluent directly into the water supply system. (2.6, D9, D13, D14).

(47) Value judgments. Conduct sociological research to improve understanding of the relative values with which Long Islanders (and visitors) might be expected to assess alternative water supply and waste water disposal systems. (2.6).

4.0 A MARINE DATA COLLECTION AND RESEARCH PROGRAM

In a later report in this series [1l], the needs relating to water supply-waste water disposal listed above will be integrated with other needs being concurrently developed for wetlands [1j], dredging [1i], and coastal stabilization [1h]. There, the supporting rationale will be summarized; relative priorities and levels of effort will be suggested; potential sponsors and sources of funding will be identified; and selected needs will be incorporated into a recommended interrelated marine data collection and research program for the bi-county area. It is envisioned that the Regional Marine Resources Council will actively support and/or initiate those program activities directly related to marine needs. However, it must be stressed that satisfaction of each of the other needs is also important to the Council. For example, improving the technical and economical feasibility of AWT for groundwater recharge, although not a direct function of the Council, can help solve many potential marine-related problems of concern to the Council as explained in the report and appendices. Therefore, the Council should strongly encourage this research and examine its progress with a view to its eventual application. Similarly, although planning for alternative sources of public water supply for the region is not a direct function of the Council, it would be well advised to strongly encourage research towards development of alternative sources and detailed feasibility studies of such sources for Long Island.