Section 2 Groundwater Conditions

2.0 INTRODUCTION

The bi-county 208 region is unique in New York State. Almost three million people depend upon ground water as their sole source of fresh water. The uses are broadly representative of man's need for water in a complex technological society, as well as the need for water for crop growing and domestic supplies.

Section 2.1 discusses the availability of water in Nassau and Suffolk Counties, suggests the need for additional data, and explains problems attributable to heavy withdrawals of ground water. This section also includes a summary of water supply and use for Long Island. A brief explanation of some of the previously proposed local and/or regional water management plans is included.

Section 2.2 is an assessment of the principal sources of ground water contamination in the 208 region, based upon information from a much longer, more technical report which was one product of the overall study.

Section 2.3 characterizes existing ground water conditions by aquifer, discusses trends in ground water quality, and summarizes the preliminary findings of a virus study and organics evaluation made during the course of the 208 investigation.

2.1 GROUNDWATER SUPPLY

2.1.1 Background

Ground water beneath Nassau and Suffolk Counties is the only source of fresh water supply for almost three million people. The quality and quantity of this water is modified by regional and local water supply development policies and waste disposal practices. Water is removed from aquifers, used and, in many cases, recharged back to the ground water reservoir in varying degrees of chemical alteration from its original state. Alternatives which modify how waste water is treated and discharged in the region will each have an effect on the quality and the quantity of drinking water in the future. Therefore, it is important that the current water supply situation in the bi-county area be defined as part of the process for developing the Long Island 208 Areawide Waste Management Plan.

2.1.2 Summary

A number of concepts have been summarized in this section with particular regard to ground water quantity. Potential management plans were reviewed in light of available data and recent projections. Very few of the past studies of Long Island water resources detail the reasons for recommended water management alternatives such as massive water transfers and artificial recharge with reclaimed sewage effluent. Many reports infer that a critical shortage of water may be expected within the next few decades.

Increased consumptive use and declining water levels have been equated with running out of water. The fact is that, on a bi-county basis, there is sufficient available ground water to supply Long Island's future saturation population as projected by NSRPB, providing that provisions are made for solving water quality problems in local areas and for adopting proper management techniques. Regional water shortages within the foreseeable future caused by lowered water levels and/or salt water encroachment cannot be used as the basis for adopting complex and expensive engineering and construction programs. In evaluating waste water management options under 208, emphasis must be placed on determining the impact of proposed plans on ground water quality and the effects on other segments of the environment, such as stream flow and fresh water discharge to the surrounding salt water bodies.

The present ground water situation, from the standpoint of water quantity only, in the Long Island 208 region is characterized by the following:

1. Major concentrations of pumpage have developed near areas of dense population, leaving other portions of the subsurface reservoirs underutilized. This applies particularly to the east-west imbalance in pumpage distribution.

2. The abandonment of shallow wells in favor of withdrawing water from progressively deeper aquifers has been the pattern of development throughout the more urbanized areas.

3. Ground water pumpage in neighboring Queens County along with sewer construction are major factors in the decline of water levels in southwestern Nassau County.

4. Ground water is not developed according to a formal scientific plan or a long-term program with the objectives of protecting water quality, maximizing the available resource, or minimizing the impact on streams and bays.

5. Adoption of water management proposals has been hampered by the fragmentation of responsibility among numerous water supply units, which are controlled by local economic and political factors, divorced from regional needs.

6. Water and waste management schemes can be most effectively implemented if decisions regarding ground water resources are approached on an Island-wide basis.

7. Predicted water level declines due to sewering and increased pumpage will not diminish the overall ability to meet water supply needs in the future but will adversely affect stream flow and fresh water discharge to bays and estuaries.

8. Salt water encroachment is a local problem and not a significant regional threat to ground water availability.

9. Over the long-term, quantity does not represent a serious constraint on water supply self-sufficiency for Nassau and Suffolk. Subsequent sections of this report suggest that water quality degradation resulting from man's activities will be the principal constraint.

Future water supply availability, cost and quality depend on a number of basic policy decisions that must be made now. Of greatest importance are whether or not to (1) regionalize development and distribution, (2) implement water conservation techniques, (3) maintain stream flow and fresh water discharge, (4) enforce protective waste management practices, and (5) control activities that accelerate ground water quality degradation.

2.1.3 Available Water Supply

Two major water-bearing units, the Upper Glacial and Magothy aquifers, are the principal sources of water for the Long Island 208 planning area. The Lloyd aquifer, a relatively unexploited source of water, lies beneath these two upper formations. Together the three aquifers contain over 60 trillion gallons of water, representing the total amount of water in storage beneath the Island (Cohen, 1968).

Past evaluations have placed a number of different limits on the amount of this water available for development. These estimates are usually presented as the "safe" or "permissive" yield of the system. The concept of "safe" or "permissive" yield is normally defined as the amount of ground water which can be withdrawn from the system and used consumptively on an annual basis without producing undesirable results. For the Long Island 208 region, water used "consumptively" simply means that the water is not returned to the ground water system. Determination of what is an undesirable result will be a major factor in the decision-making process that leads to the selection of waste management plans, as required by Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

As consumptive use increases, ground water is taken from storage. There is also a decrease in ground water discharge to streams and to the sea. These stresses on the ground water system result in water level declines and salt water encroachment. If consumptive use stabilizes and total recharge is not exceeded, a new equilibrium is established for water levels and salt water/fresh water boundaries. If, however, consumptive use exceeds total recharge and ground water inflow, water levels will decline indefinitely and salt water will slowly replace the fresh water removed from storage. For Nassau and Suffolk Counties, sewer outfalls discharging to the ocean constitute the principal consumptive use of ground water. The most recent estimates of water availability, or permissive yield, have included consideration of substantial increases in sewering of the study region.

Unfortunately, the term permissive yield is often interpreted in the same way for Nassau and Suffolk Counties' ground water supplies as it is for New York City surface water supplies. The safe yield of New York City surface water supplies is usually defined as the amount of water that would be available under conditions similar to those resulting from the 1962–1966 drought. The Corps of Engineers estimates this yield as insufficient to meet future water demands, and therefore assumes the possibility of a water supply deficiency. In Nassau and Suffolk a drought of this or of even a more severe

nature would cause only a slight diminution of the vast quantity of water in storage, with little prospect of real water shortage. An extended drought period would lead to undesirable conditions of a temporary nature, such as lowered ground water levels and decreased stream flow.

2.1.4 Estimates of Existing Permissive Yield

Both Nassau and Suffolk Counties have had comprehensive water supply studies in recent years. In 1971 Greeley and Hansen estimated a mean permissive yield of 151 million gallons per day for Nassau County (Greeley and Hansen, 1971). This figure was computed by using an extraction ratio* of 75 percent. Holzmacher, McLendon and Murrell computed a "permissive yield" of 466 million gallons per day for Suffolk County using a similar ratio (Holzmacher, 1970). The Nassau County Department of Health (NCDH) computed the average consumptive loss for Nassau County as 133 million gallons per day for the period 1969 to 1973. Annual consumptive loss for Suffolk County was on the order of 40 to 50 million gallons per day for that period.

The studies estimated that large water table declines would occur at the permissive yields. Greeley and Hansen predicted a maximum decline of 30 feet for Nassau County, based upon the assumption of county-wide sewering with effluent discharged by ocean outfalls. The Holzmacher, McLendon and Murrell estimate for Suffolk was for reductions of up to 75 percent of present elevations above sea level prior to the establishment of equilibrium. The water table declines for Nassau are significantly greater than those predicted in recent runs of the U. S. Geological Survey analog model. The authors of both county investigations felt that at the permissive yield the salt water interface off the south shore would move landward to a new equilibrium position, perhaps a mile from its present location.

A 1976 analysis of ground water response to sewerage programs and projected population increases by 1995 forecasts an increase in ground water withdrawals of 9.5 million gallons per day for Nassau County and 46.4 million gallons per day for Suffolk County (Kimmel and Harbaugh, 1976). The total modeled decrease in recharge by 1995 was estimated to be 39.9 million gallons per day and 42.7 million gallons per day for Nassau and Suffolk Counties, respectively. It was concluded that these stresses would result in water table stabilization after declines of as much as sixteen feet in east-central Nassau County, and as much as six feet in central Suffolk County by 1995, with less of a decline forecast for the Magothy aquifer. Stream flow decreases by as much as 55 percent were forecast for southeast Nassau, with slightly higher decreases in the Huntington-Northport Sewer District.

The future of the Jamaica Water Company in Queens adds uncertainty to estimating impacts of sewering in Nassau County. This supplier is pumping about 60 million gallons per day, creating a significant underflow from western Nassau to Queens. It is understood that upon completion of New York City's third water tunnel, distribution of surface water to this area will be possible (Groopman, 1977). However, the lack of additional surface water supply sources upstate will preclude complete replacement of the ground water presently supplied to Queens County, especially during periods of drought. If the Jamaica Water Company pumpage is curtailed, there would be a significant recovery of water levels in western Nassau. The magnitude of the anticipated change may be estimated from the analysis of water level declines attributable to Queens pumpage (Figure 2–1).

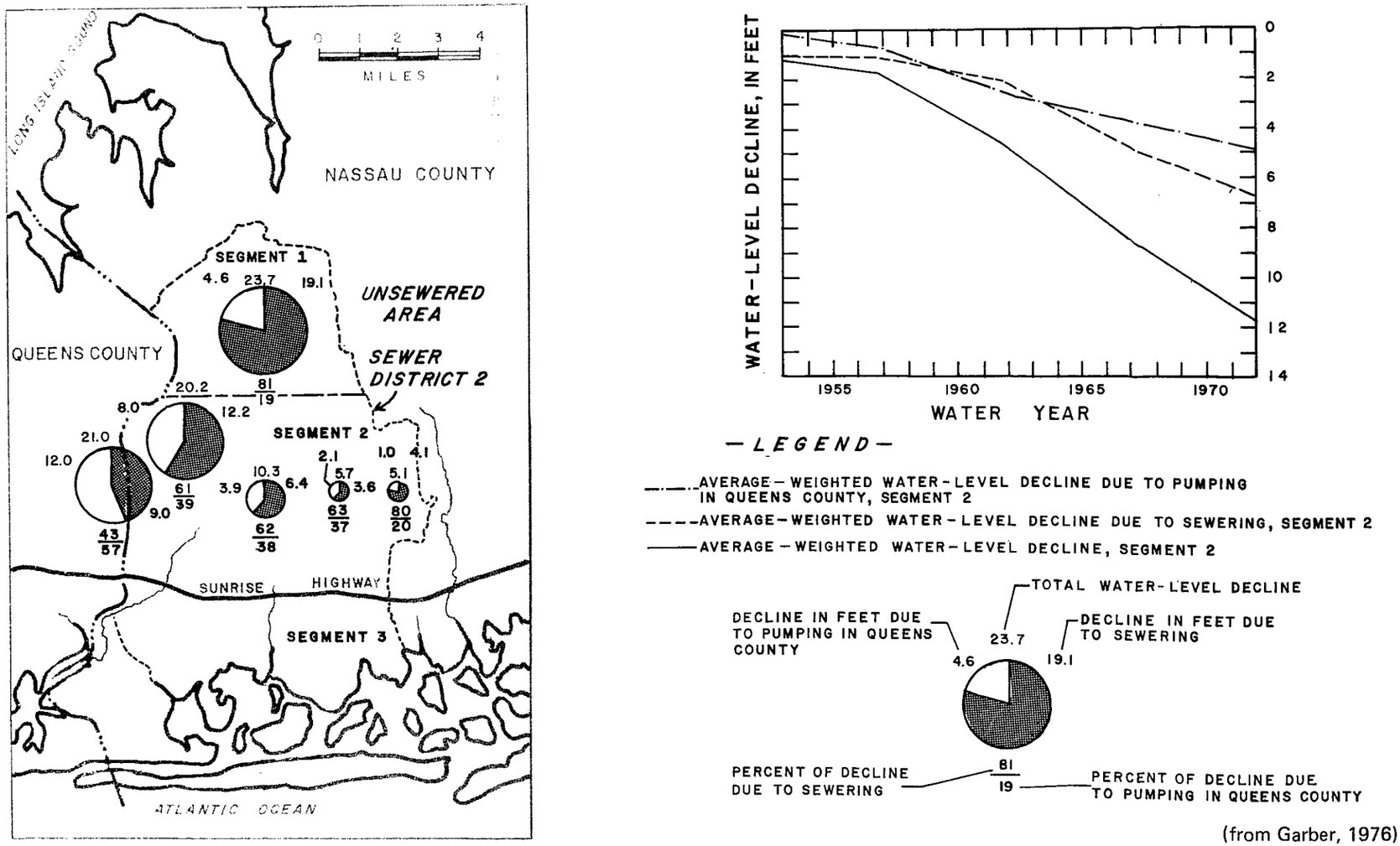
The Queens/Nassau common water level decline illustrates the insignificance of political boundaries with relationship to management of a resource that is common to the entire island. The present flow from Nassau to Queens is estimated at between ten and fifteen million gallons per day. While some of this movement is due to natural conditions, a significant portion is attributable to heavy pumping in Queens, which along with sewering and pumpage in Nassau County, has locally lowered water levels in the three principal aquifers to below sea level (Figures 2–2, 2–3, 2–4). This impact is particularly significant with regard to some of the plans previously proposed for future ground water development in the 208 region, which are discussed in a later section of this report. For instance, one scheme calls for installation of a regional well field in Suffolk County and pumping of water from the field to Nassau County. At present there is little natural exchange of ground water between these two counties. However, if water levels are allowed to decline substantially in Nassau County, natural underflow of ground water from Suffolk will occur.

2.1.5 Salt Water Encroachment

Reliable data concerning the intrusion of sea water into the Island's fresh water supplies are critical to estimates of the future availability of potable ground water for Nassau and Suffolk Counties, and are particularly important to coastal suburban areas. However, the present boundaries of the fresh water reservoir on Long Island are not well defined in many areas. Data on the position of the interface at depth have been gathered mostly as a result of a limited number of U. S. Geological Survey cooperative studies, from wells drilled near the shore which have inadvertently intercepted salt water, and from wells drawing salt water after a period of time, as a result of heavy pumping. Areas of documented cases of salty ground water are shown on Figure 2–5.

A complicating factor is that some of the increases in chloride content attributed to the intrusion of saline water actually may have been caused by sources other than the movement of a principal salt water body within an aquifer. Such sources include leaky casings or openings in the annular space surrounding well casings, which allow salty water in one aquifer to migrate to an overlying or underlying fresh water aquifer. Another contributing local factor is the contamination of fresh water aquifers, caused by the use of salt water in the mining of sand and gravel—as has occurred on the eastern portion

**Extraction ratio = amount of water pumped per year without undesired results divided by the average annual recharge in the water budget area.*

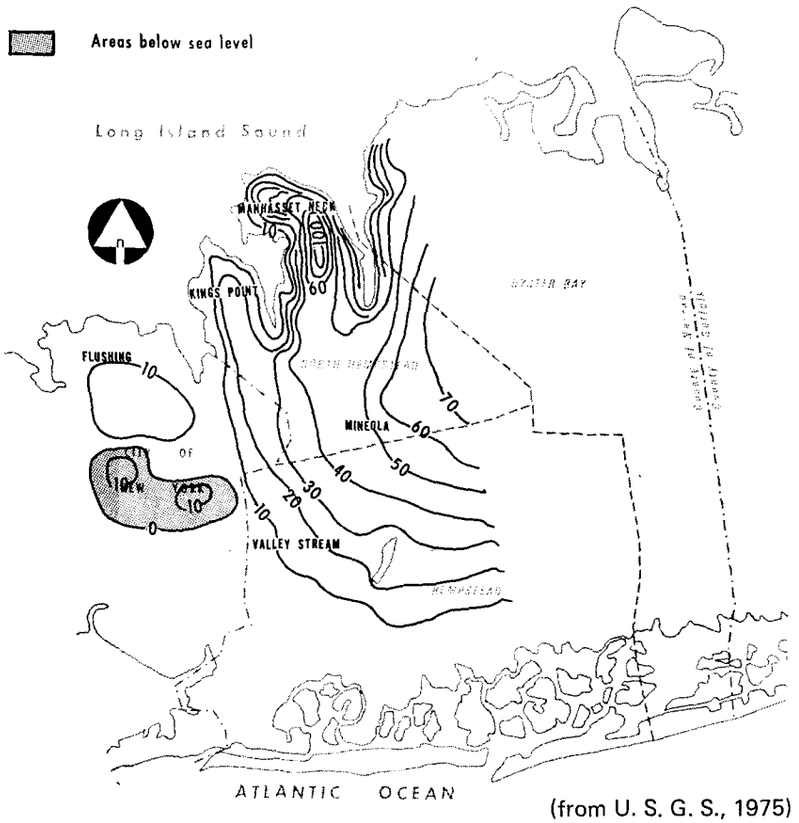


(from Garber, 1976)

FIGURE 2–1 *Ground Water Level Declines in Southwestern Nassau Attributable to Sewering Sewer District Two and to Pumping in Queens.*

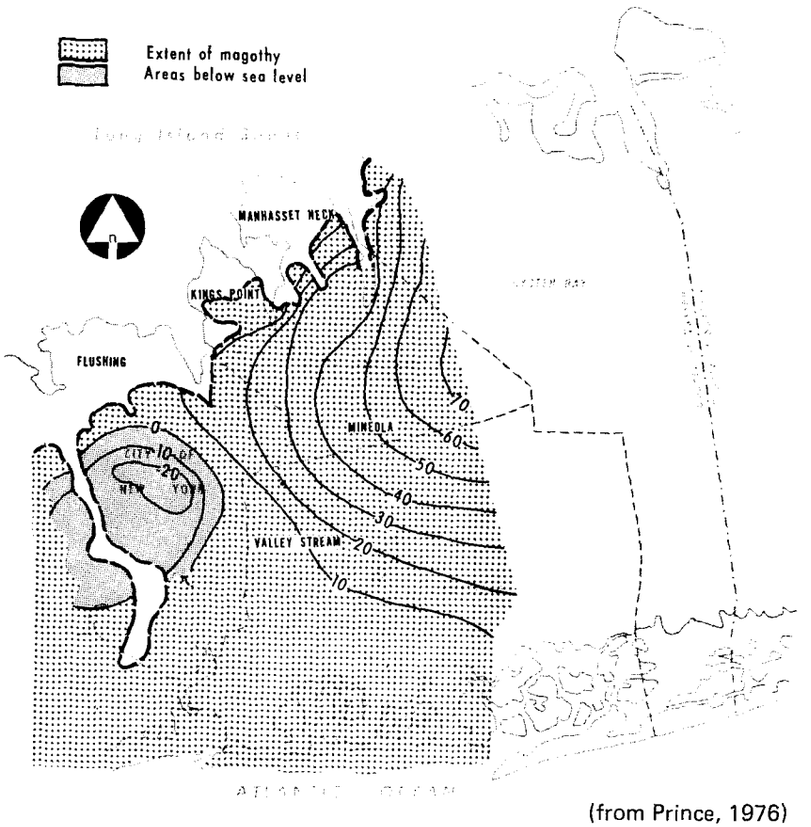
of the Port Washington peninsula, where the shallow aquifers have been affected by leakage from artificial ponds containing salt water pumped from Hempstead Harbor. Other activities of man discussed in Section II of this report also contribute chloride to ground water.

The Magothy is known to be fresh for its entire depth throughout most of Nassau County, from its northern boundary extending to an unknown distance south of the barrier beaches. The only salty region is in the extreme southwest corner of the county. In Suffolk, the Magothy is fresh over essentially the entire county, excluding the forks. On the North Fork, the lower Magothy is salty at the western end and probably entirely salty in the central



(from U. S. G. S., 1975)

FIGURE 2–2 *Water Table Surface in the Spring of 1975.*



(from Prince, 1976)

FIGURE 2–3 *Potentiometric Surface of the Magothy Aquifer in March 1975*

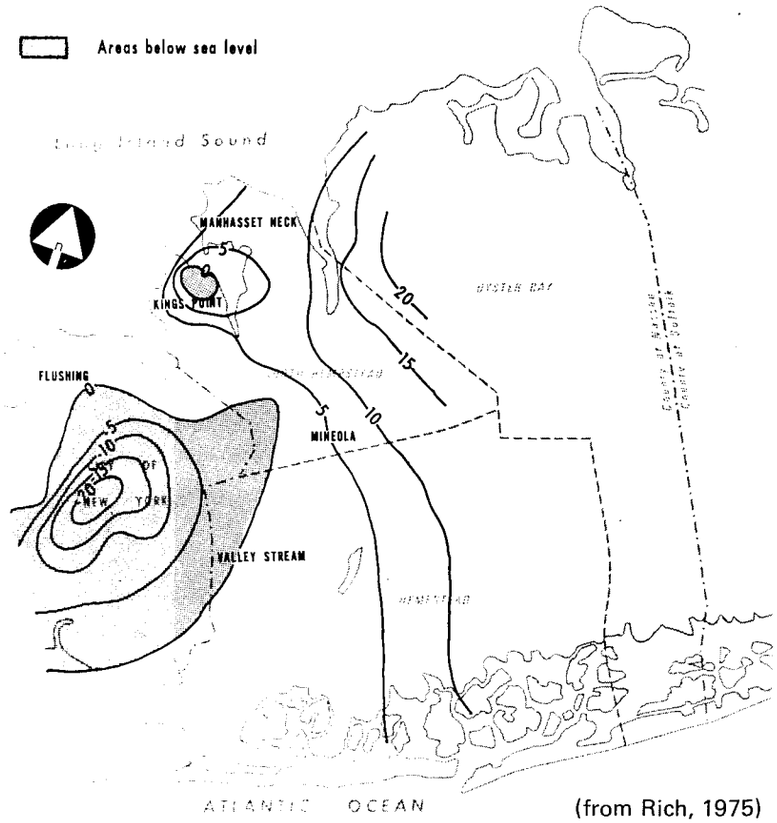
and eastern areas. Maximum depths to fresh water are only 200 to 300 feet (Holzmacher, 1970). Data from the South Fork indicate a similar situation, except that the interface under the widest portion of land area is somewhat deeper.

The Pleistocene (Upper Glacial) sediments on the north shore are thought to be hydraulically equivalent to the Magothy. Deep Pleistocene deposits under Eatons Neck are salty. In recent years, wells 71 to 291 feet deep in the western part of the Kings Point area on the Great Neck peninsula have shown increasing chloride levels (Myott, 1976). The wells are screened in both Pleistocene and Lloyd (or equivalent) sediments. This situation is being studied by the U. S. Geological Survey and may be related to well construction rather than intrusion.

The Upper Glacial aquifer is fresh over most of both counties except for local areas along the coast. The lower portion of the Upper Glacial aquifer beneath the barrier islands and under much of the North Fork is salty. The South Fork has salty water in the Upper Glacial aquifer in the near-shore areas.

The boundaries of fresh water in the Lloyd aquifer extend south of the barrier beaches in most of Nassau and Suffolk Counties. The Lloyd is fresh along the north shore except at Eatons Neck, part of Kings Point, and a small portion of Port Washington. Several wells in the Lido Beach-Long Beach area have shown rapid increases in chloride in the past. However, it has been determined that these isolated cases of salt water are due to leaky well casings rather than general contamination of the aquifer. Parts of the Lloyd in eastern Suffolk, including most of the South and North Forks, are salty.

Detailed investigations in southwestern Nassau and southeastern Queens have provided information on how salt water occurs in an area which is known to be susceptible to encroachment (Perlmutter, 1963 and Lusczynski,



(from Rich, 1975)

FIGURE 2–4 *Potentiometric Surface of the Lloyd Aquifer in January 1975.*

1966). Test data showed that the interface between salty water and fresh water existed in all the permeable sediments, and even within the relatively impermeable clays that interfinger with the water-bearing strata. Shallow, intermediate and deep salty water wedges in the unconsolidated deposits were identified (Figure 2–6). Zones of diffusion containing water less salty than sea water are as much as six miles wide and 500 feet thick.

Of principal concern is the deep wedge which lies primarily in the basal Magothy and in the Raritan clay. This body trends southeast from South Ozone Park, under Woodmere, to a mile or two east of Lido Beach, where it continues south of the shoreline. Salty water may be in the lower beds of the Lloyd several miles offshore. The intermediate wedge, which is in the Gardiners Clay, the Jameco Gravel and the upper part of the Magothy, is found south of the landward extent of the deep wedge.

The intermediate and deep wedges have not been altered significantly

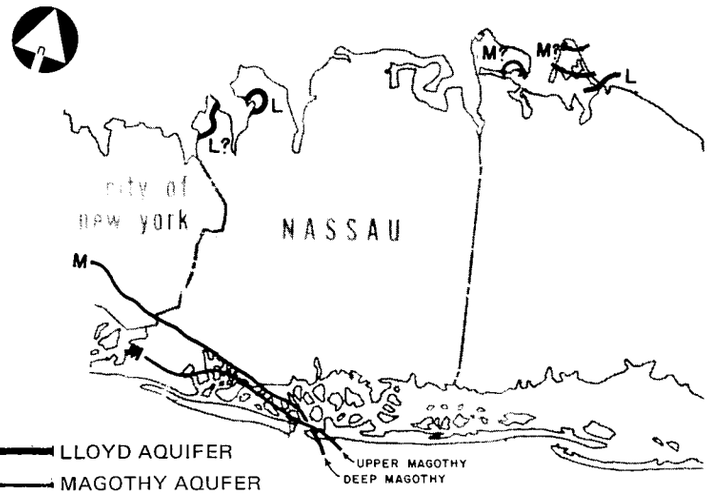
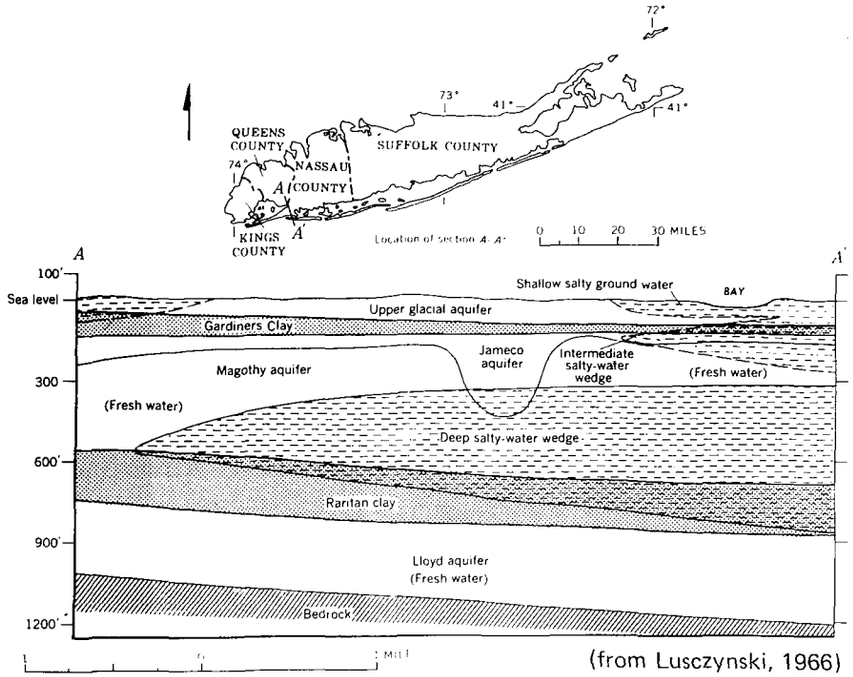


FIGURE 2–5 *Approximate Location of Past and Present Cases of Salty Ground Water in the Deep Aquifers in Nassau and Suffolk Counties, Excluding the North and South Forks.*

from their original position as a result of ground water development or other of man's activities. The deep wedge probably has not advanced more than 1,000 feet since 1900. Regional rates of movement range from less than ten to twenty feet per year. However, tongues of salty water, moving in response to local concentrated pumpage, have encroached at somewhat higher rates in certain areas. It is estimated that the toe of the deep wedge in the South Ozone Park area has intruded at a rate of about 160 feet a year, advancing 3,500 feet between 1938 and 1960. A narrow tongue of salty water moved landward at a rate of about 300 feet a year between 1952 and 1960 in Woodmere. It had advanced about a mile in the preceding 50 or 60 years (Lusczynski, 1966).

A study published in 1970 reviewed data collected over the period 1960–1969 in the same area, in order to further evaluate conclusions reached in the earlier studies. Landward movement of the deep wedge of salty ground water was minimal. Significant changes in chloride content were noted in only three of 30 wells located near the interface (Cohen, 1970).

Predictions of movement of salt water in response to future water development in the 208 region include the Hele-Shaw model studies for Suffolk County, which attempted to estimate the configuration of the interface under assumed initial pre-pumping conditions (Collins, 1972). The boundary along the north shore at Lloyd's Neck was placed near the shoreline. The interface in the Magothy south of Fire Island Inlet, was simulated to be 14 miles south of the southern shorelines of the mainland of Long Island. The results of another analysis showed that if the well withdrawal rate is equal to the total recharge over a period of 50 years, salt water would ad-



(from Lusczynski, 1966)

FIGURE 2–6 *Location of Salty Ground Water in Southwestern Nassau and Southeastern Queens.*

vance at a rate of about twenty feet per year. The magnitude of this rate is similar to that found in the U. S. Geological Survey study of southeastern Queens and southwestern Nassau Counties (Lusczynski, 1966).

The future position and movement of the salt water/fresh water interface is dependent upon the amount and pattern of the seaward flow of fresh water from the aquifers under Long Island. In addition, the hydraulic properties of the geologic units and their relationship in the stratigraphic column affect the rates and manner in which the interface will change in response to new conditions. Clay units, such as the Gardiners and Raritan, help impede the vertical transfer of salt water between aquifers because of their low permeabilities. Intrusion under similar gradients will be faster in sediments of higher permeability, such as those of the Lloyd and certain sections of the Magothy. As consumptive use of water increases in many sections of Long Island, the interface will readjust to a new equilibrium position farther inland. This will probably occur as wedge-shaped tongues, rather than as wide fronts of encroachment. If wells are located away from the immediate position of the present salt water bodies, encroachment will be regional and hence quite slow. Pumping centers near the interface, however, may induce more rapid, local intrusion and certain wells may become contaminated.

If present patterns of use continue, ground water outflow within the Magothy will be reduced along both the north and south shores of Nassau and Suffolk Counties. However, on the basis of past and present cases of salty ground water on Long Island, excluding those on the North and South Forks, it is expected that the regional impact of salt water intrusion will be small. The salt water wedges in the upper and lower Magothy in the southwestern and southern parts of Nassau, an area of historical salt water contamination, will probably not advance much more than a mile locally and less than a mile regionally by the year 2000 (Lusczynski, 1966). This would put the interface of the deep wedge in the vicinity of Sunrise Highway in Valley Stream and Lynbrook. Those few supply wells screened in the lower Magothy would be affected. Significant salt water encroachment along the south shore in eastern Nassau and in Suffolk is unlikely in the foreseeable future.

Salt water along the north shore is probably not far offshore in the Magothy (or equivalent) and Lloyd aquifers. Distances of one to two miles offshore have been postulated for the basal Magothy (or equivalent) in northwestern Nassau (Isbister, 1966). Again, assuming regional rates of encroachment of ten to twenty feet per year, the impact of salt water intrusion would be small. Local problems within the Lloyd aquifer, particularly in parts of the Great Neck and Port Washington peninsulas, could develop if pumping centers are located too close to shorelines. Further east, there is no indication that salt water along the northern shoreline of Suffolk, with the exception of parts of Lloyd Neck and Eatons Neck, and the North Fork, will be a problem in the foreseeable future.

From the standpoint of water supply and waste water management, it is essential that the potential threat of salt water encroachment be viewed in its proper perspective and be fully understood. The loss of usable ground water resources has been minor in comparison to the extensive untapped fresh ground water supplies within the 208 study area. There is insufficient evidence to assume that water level declines due to increased pumpage, sewering, or temporary deficiencies in rainfall will result in massive encroachment of salt water.

2.1.6 Ground Water Pumpage

Withdrawals of ground water from the geologic formations beneath the Long Island 208 planning area now approach 400 million gallons per day. In 1940 and in 1965, pumpage in the bi-county area was 105 and 330 million gallons per day, respectively. The increase corresponds to the rise in population related to suburban expansion eastward from the New York City metropolitan area.

Pumpage and use characteristics within the study region vary from place to place. The divertor may be a single family operating its own domestic well on a small parcel of land; a large water district with a dozen individual high capacity wells located miles apart over several communities; a private water company with a single well field serving one subdivision; or an industry

partially supplied by its own well system and partially dependent upon a local utility. The amount of water withdrawn by these well owners ranges from a few hundred gallons to many millions of gallons per day to satisfy domestic, agricultural, industrial and recreational demands.

Figure 2–7 shows the total pumpage distribution by aquifers for Long Island in 1975. The sizes of the pumpage circles are proportional to the average withdrawal rate within each section drawn on the map. Each circle includes the percentage of water pumped from each aquifer. The proportion of water withdrawn by public water supply systems versus industries and/or irrigators is also indicated.

In Nassau County, the Magothy aquifer is the principal source of potable water, but all three aquifers are pumped in varying degrees from place to place. An additional source, the Jameco Gravel, is of local importance in the southern part of the county and in parts of the northern peninsulas. Drinking water for Suffolk County comes from both the Magothy and the Upper Glacial aquifers. The practice of locating wells within reasonable proximity to the user in order to minimize distribution costs has resulted in uneven distribution of pumpage; major concentrations of pumpage are located near areas of dense populations, leaving portions of the subsurface reservoirs underutilized.

Approximately 133 districts, municipal systems and water companies, either publicly or privately owned, supply water on Long Island. In Nassau County, the largest suppliers are the Long Island Water Coporation, Jamaica Water Supply Company and Utilities and Industries Corporation (formerly

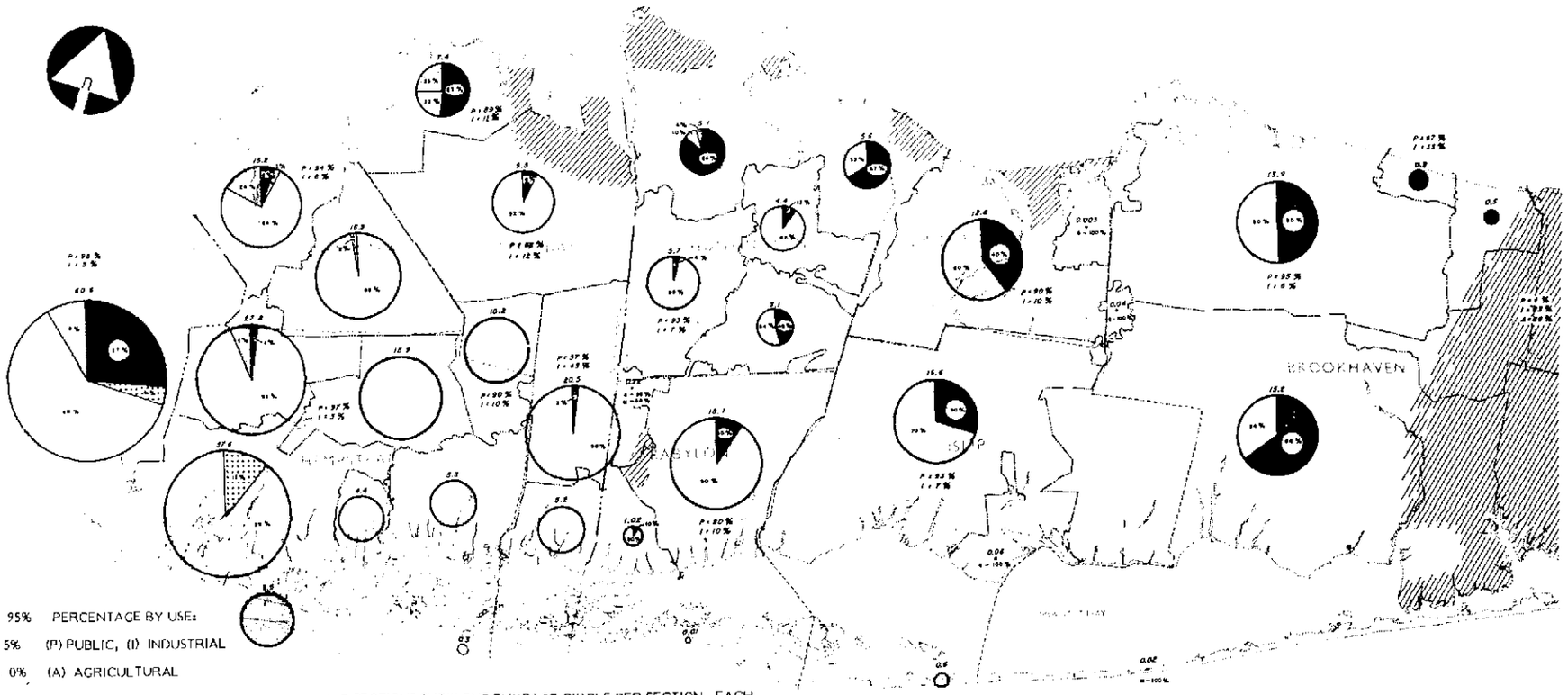
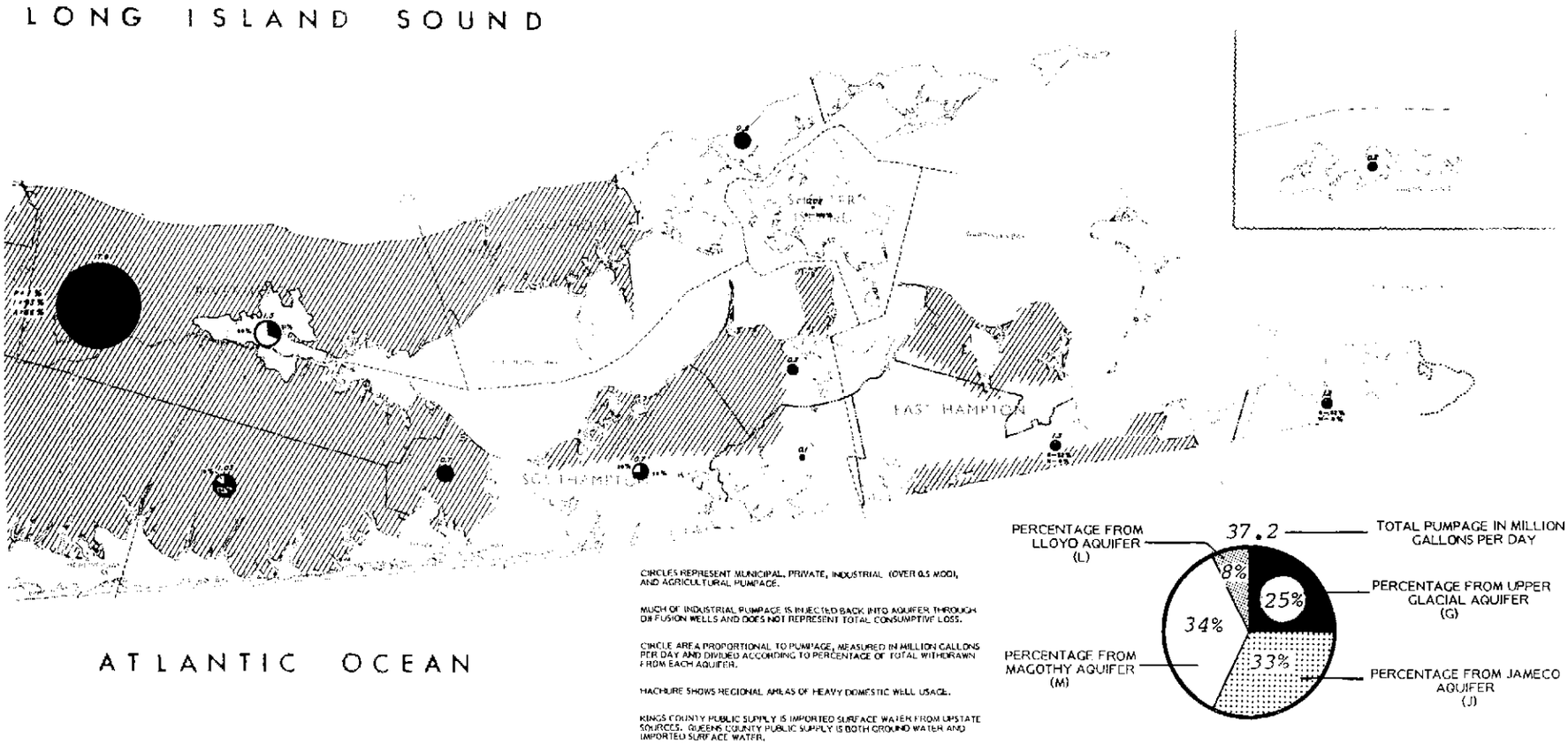


FIGURE 2–7 *Long Island Water Supplies.*

New York Water Service). The publicly owned Suffolk County Water Authority is the major regional purveyor of drinking water in Suffolk County. This system consists of about 12 centralized supply plants, withdrawing water from some 400 wells throughout the county.

The total daily pumpage in Nassau County averages approximately 210 million gallons per day, with 170 million gallons per day of this water supplied by public and private purveyors during 1975. Public supply pumpage in the years 1973, 1974 and 1976 was approximately 178, 179 and 184 million gallons per day, respectively. A recent estimate of the total amount of water pumped by major industrial and commercial users is 36 million gallons per day (Erlichman, 1976). Self-supplied domestic and agricultural pumpage accounts for the remaining four million gallons per day. About 85 percent of the water withdrawn comes from the Magothy aquifer, eight percent from the Lloyd, four percent from the Upper Glacial and three percent from the Jameco Gravel. In a few coastal areas of Nassau County, the threat of salt water encroachment has precluded the use of water from the Magothy aquifer, necessitating the deepening of several public supply wells into the underlying Lloyd strata. The City of Long Beach in southwestern Nassau County is entirely dependent for public water supply upon wells penetrating the Lloyd formation. As much as 30 percent of the supply pumped in the northern portion of the county is also from the Lloyd (or equivalent) aquifer.

Suffolk County draws 108 million gallons per day for public supply (1975 data) of which 40 percent is from the Upper Glacial and 56 percent



from the Magothy aquifer. The five million gallons per day withdrawn from the Lloyd aquifer in Suffolk for water supply purposes is equivalent to about four percent of the total. Industrial pumpage is about 40 million gallons per day, with a few users accounting for a major portion of the total (Erlichman, 1976). For example, Brookhaven National Laboratory alone diverts eighteen percent of the county's industrial pumpage. Most water used by industry in both counties is returned to the ground water system by means of diffusion wells and recharge basins.

About 90 percent of the population of Suffolk County is located in the western half of this region, which includes the Towns of Babylon, Islip, Huntington, Smithtown and Brookhaven. Based on the number of housing units with domestic wells surveyed in the 1970 population census, it is estimated that housing units in Suffolk County not served by central distribution facilities collectively withdraw about twenty million gallons per day of ground water (U. S. Department of Commerce, 1970).

Water pumped for agriculture constitutes an important demand factor in the more rural eastern segment of the county, particularly in the area north of the community of Riverhead. Not all farmers report pumpage, nor are they required to do so, but a conservative estimate of agricultural pumpage rates, based on surveys and returned reports of withdrawals, is about ten million gallons per day. For the most part, this pumpage represents consumptive use and is seasonal.

Although Queens County is not part of the Long Island 208 study area, the amount of ground water pumped there must be considered. As shown on Plate 1, the withdrawal of ground water in Queens averages more than 60 million gallons per day; 27 percent is from the Upper Glacial aquifer and 60 percent from the Magothy aquifer. As discussed in the previous section of this report, the large ground water withdrawal in Queens County has had a significant effect on water levels and salt water intrusion in south-central and southwestern Nassau County.

Deterioration of water quality in parts of the Upper Glacial aquifer has limited the usefulness of this drinking water source in some portions of the 208 planning area. These problems of water quality that are due to man's activities have been aggravated by the rapid urbanization of the region. In addition, the downward migration of degraded water to deeper aquifers compounds the problem. Studies by the U. S. Geological Survey have shown that nitrate-enriched ground water in some portions of east-central Nassau County is moving from shallow to deep aquifers at a rate of as much as five to 25 feet per year (Ku, 1976).

The abandonment of shallow wells in favor of withdrawing water from progressively deeper formations has been a pattern of development in both Nassau and Suffolk Counties. In areas such as Hicksville, Bethpage and Farmingdale, most wells supplying communities and industries 30 to 40 years ago tapped the Upper Glacial aquifer and were 100 to 200 feet deep. Degradation of water quality in this relatively shallow zone, followed by similar problems in the upper portions of the underlying Magothy, caused water districts and other ground water users to install progressively deeper wells. Today, many wells in these areas are 500 to 600 feet deep and tap the basal Magothy. This pattern is continuing under present management and planning policies in many sections of the 208 area. In Suffolk, whenever possible, better quality water in the Magothy is blended with Glacial withdrawals, if the shallow aquifer has become degraded.

The deeper Lloyd aquifer is less susceptible than the Magothy to contamination and is not subject to heavy demand at this time. However, the future potential and use of the Lloyd have not been clearly defined.

As mentioned above, the pattern of ground water diversion matches population densities except in the case of a few large industrial users. Heavy pumping can create a local hydrologic imbalance. If the same area is sewered, high consumptive use results. Water levels in such water deficit areas will decline, causing ground water flow into these regions to increase until a new equilibrium condition is reached. Southeastern Queens and southwestern Nassau represent one region characterized by large diversions. The region is also sewered, and the treated effluent is discharged to the ocean. Consequently, this region and the area immediately north of it have historically experienced large losses in fresh water storage, as indicated by local salt water intrusions and significant water table declines.

Assuming a relatively fixed amount of ground water in storage and a fixed rate of recharge over the long term, the amount of ground water that can be extracted from an aquifer system varies with the distribution of wells within the aquifers. For a system such as Long Island's, with its vast natural underground reservoir, the effects of ground water withdrawal are minimized if wells are distributed uniformly. Diversion which is concentrated in any one area or near the salt water interface results in significant impacts on water levels in the various aquifers, and increases the potential for salt water encroachment. However, in certain cases, properly positioned wells along the coastline can intercept fresh water before it discharges to salt water. Reductions in stream flow can result from concentrated pumpage, particularly if the wells are tapping the shallow aquifer.

It is evident from the preceding discussion of water supply pumpage that Nassau and Suffolk Counties, taken as whole, do not have a uniform distribution of public supply and industrial wells, particularly in an east-west direction. Therefore, water is not being extracted in the most efficient manner. This is because of the way in which water supplies have traditionally been developed, *i.e.,* within separate water districts with a minimum of interdistrict transfer. In most areas, groups of two or three adjoining utilities are interconnected, primarily to handle seasonal fluctuations and peak demands. Thus, there is some capability for response to emergencies caused by major water main breaks, fire or well closure due to contamination. However, there are currently no provisions for large-scale transfer between water systems over any significant distances.

Present patterns of ground water pumpage only reflect patterns of population density. Ground water diversions are not awarded according to a formal scientific plan or long-term program with the objectives of protecting water quality or maximizing the available resource. Interference effects on existing ground water supplies and the potential for salt water encroachment have been the primary considerations in decisions by the state regarding applications for increased pumpage. However, the impact of new withdrawals on the movement of contaminants from potential inland sources of pollution and possible adverse effects on surface streams have not been included in the evaluation of well location, depth or construction. Again, this situation is related to the fragmentation of responsibility for developing ground water resources, with each water supply unit constrained by local economic and political factors that are divorced from regional needs.

2.1.7 Water Level Declines

One of the principal effects of the steadily increasing consumptive use of ground water on Long Island is a general and continuing decline in water levels. Significant lowering of the water table and of potentiometric surfaces has occurred over the last few decades in Nassau and Suffolk Counties. Recently observed imbalances between available water supply and demand in some places are largely the result of greater pumpage, increases in sewage outflow to salt water and the severe drought of 1962–1966. The determination of the effect of each of these factors on the total hydrologic system is critical in attempting to evaluate various management alternatives for the future. Although regional water level declines have been recognized for years, it was not possible to accurately predict future declines until recent advances in electric analog and digital computer simulation techniques were achieved.

Since the mid-1930's, the U. S. Geological Survey has maintained a program of water resources studies on Long Island in cooperation with several county and state agencies. Ground water levels have been measured in fourteen key shallow observation wells on Long Island for over 35 years. Several hundred observation wells throughout Nassau and Suffolk Counties have been monitored over recent years by the U. S. Geological Survey, the Nassau County Department of Public Works, the Suffolk County Department of Environmental Control and the Suffolk County Water Authority. Prior to the late 1950's, water level declines in Nassau and Suffolk Counties were not particularly significant. During the period between 1959 and 1970, declines of the potentiometric surface in Queens and Nassau Counties in the basal part of the Magothy aquifer ranged from about one foot near the shorelines to a little more than twenty feet in parts of east-central Queens and west-central Nassau Counties (Kimmel, 1971). Similar changes occurred in the water table, except near the shorelines where the decline was less. Net changes in water levels are shown in Figures 2–8 and 2–9.

In addition to water level declines caused by increased pumpage on Long Island, extended periods of less than average rainfall also resulted in a decrease in ground water storage as evidenced by the 1962–1966 drought. During that period there was a cumulative deficiency of rainfall of 41.7 inches below the long-term annual average of 44.5 inches per year as measured at Setauket. Figure 2–10 shows ground water response to the drought with declines in ground water levels ranging from somewhat more than ten feet in east-central Nassau County and west-central Suffolk County to less than two feet near the shorelines (Cohen, 1969). The configuration of the contours reflects the nature of the flow system in that the maximum declines took place near the ground water divide. Smaller net losses occurred near the shorelines.

The average altitude of the water levels in the fourteen key monitor wells for the period 1940–1967 was nearly 46.5 feet. By 1966 the average level had declined about six feet below the long-term average (Figure 2–11). The close dependence of stream flow upon ground water was underscored during this period by record low flows in fourteen of nineteen principal streams in the two counties. The combined flow of the nineteen streams (Figure 2–12) was 155 cubic feet per second in 1966 as compared to the long-term average of 291 cubic feet per second (Cohen, 1969).

Since 1967, the water table and water levels in the Magothy aquifer have stabilized and in many cases risen in response to normal and above normal rainfall. The water table in east-central Nassau County rose over twelve feet, and in western and central Suffolk by as much as six feet between 1970 and 1974. However, slight declines occurred in southwestern Nassau County (Figure 2–13).

In addition to stresses caused by increases in withdrawal rates and fluctuations in natural recharge, the ground water system is also affected by sewering, urbanization, lawn sprinkling and other activities. Attempts have been made to evaluate the impact of such factors upon the system, using methods which isolate one response and assign to it a given variable. For instance, a recent double-mass curve analysis of ground water in Nassau County permitted isolation of water level changes due to sewering alone. Declines attributable to sewering in western Nassau County ranged from 3.6 to 19.1 feet (Figure 2–1). Declines due to the influence of pumping in Queens County varied from one to twelve feet. The average weighted water level decline from 1953 to 1972 in southwestern Nassau was 11.8 feet, of which 4.9 feet can be attributed to pumping in Queens County.

With sophisticated methods for evaluating hydrologic systems, such as digital and electric analog models, it is possible to integrate the stresses and responses of a dynamic system by considering the input of many variables at one time. It is evident from recent studies utilizing available models that water level declines will continue in Nassau and western Suffolk as consumptive use increases under the present system of water management. There is considerable uncertainty, however, as to the future rate of this increase, especially in Nassau County where the population appears to have stabilized.

WATER TABLE DECLINE

FIGURE 2–8 *Generalized Net Decline of the Water Table in Nassau and Queens Counties, Long Island, New York from 1959 to 1970.*

BASAL MAGOTHY POTENTIOMETRIC SURFACE DECLINE

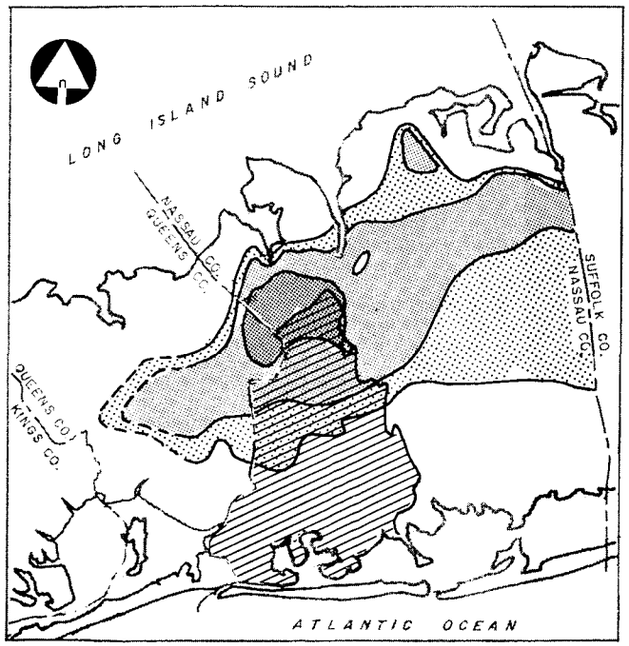


FIGURE 2–9 *Generalized Net Decline in the Basal Magothy Potentiometric Surface in Nassau and Queens Counties, Long Island, New York, from 1959 to 1970.*

5 – 10 | 10 – 20 | 20 – 25

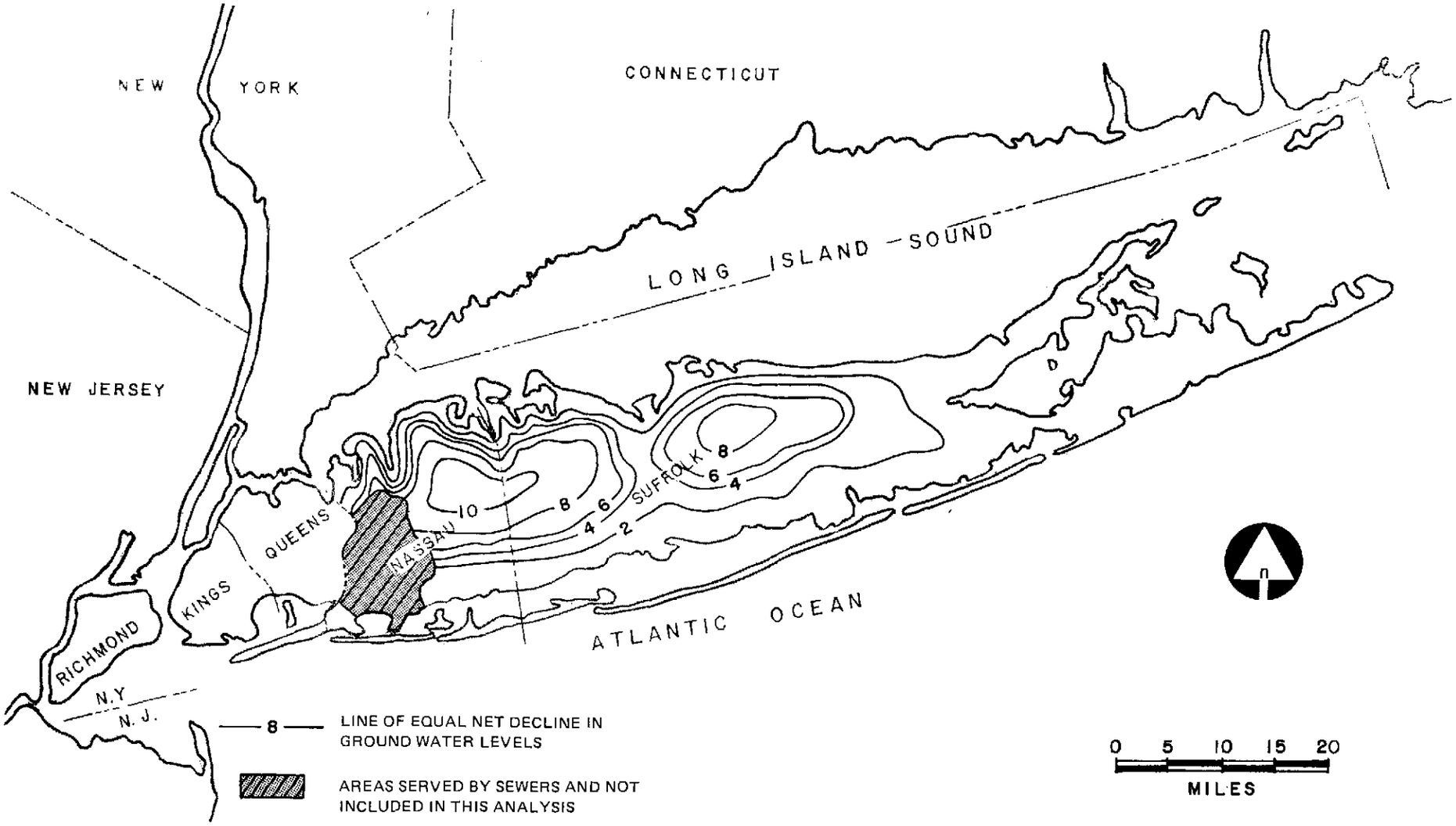
NET DECLINE IN HEAD, IN FEET

– – – – – – – – – – INFERRED DECLINE IN HEAD

AREA UNDERLAIN BY SEWERS IN NASSAU COUNTY IN 1970

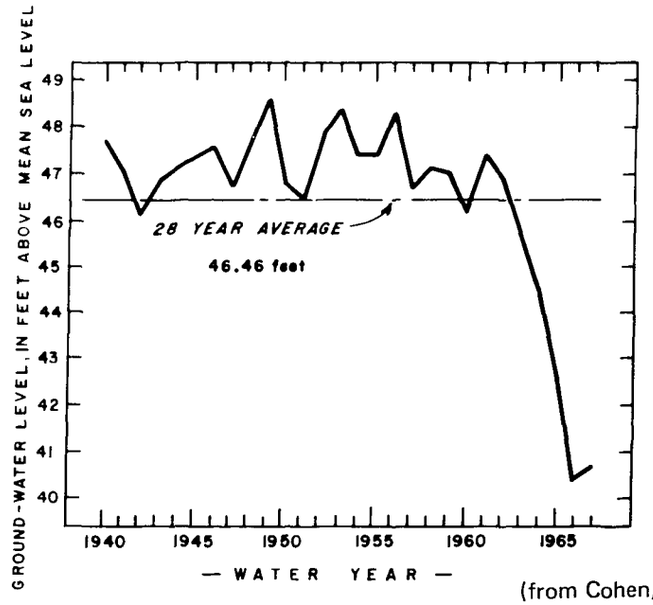
0 5 10 MILES

(from Kimmel, 1971)



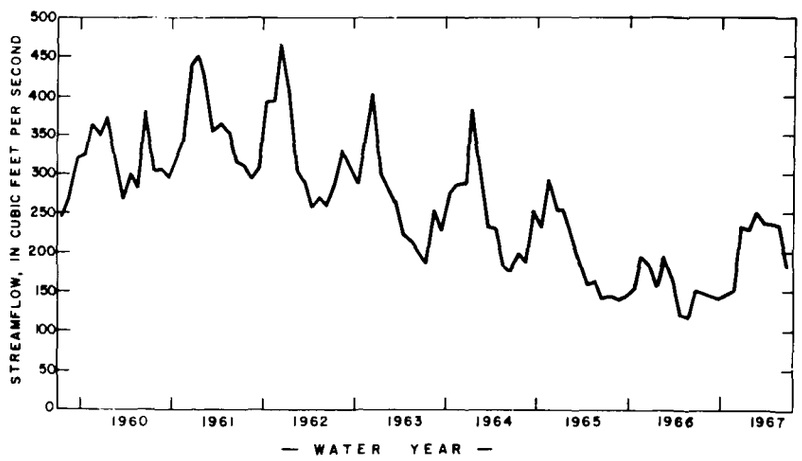
(from Cohen, 1969)

FIGURE 2–10 *Net Decline in Ground Water Levels in the Water Table Aquifer Due to Drought Conditions, 1962–66.*



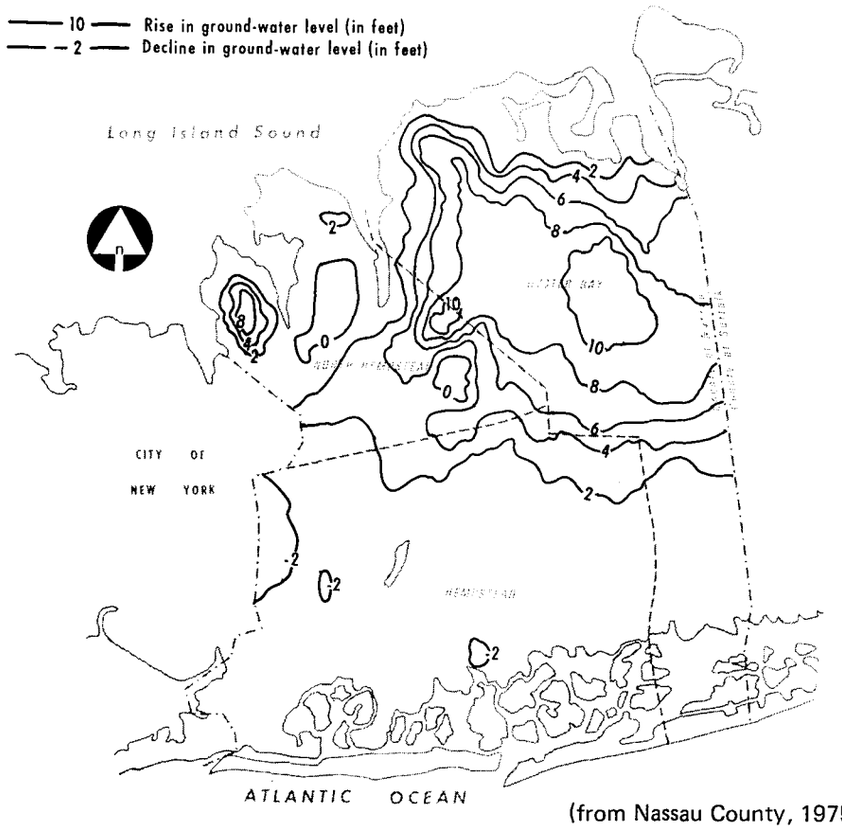
(from Cohen, 1969)

FIGURE 2–11 *Average Annual Ground Water Levels in Fourteen Key Observation Wells in Nassau and Suffolk Counties.*



(from Cohen, 1969)

FIGURE 2–12 *Combined Monthly Average Stream Flow of Nineteen Principal Streams.*



(from Nassau County, 1975)

FIGURE 2–13 *Net Change in Ground Water Levels in the Water Table Aquifer, 1969–73.*

2.1.8 Environmental Considerations

Reduction in stream flow and decline of the water table from increased pumpage and ocean discharge of sewage may cause changes in the vegetation of certain fresh water wetlands. A total fresh water wetland area of over 1,500 acres has been inventoried within the nine major stream systems of southwestern Suffolk County and southern Nassau County (Beitel, 1976). Water table ponds and lakes, such as Lake Ronkonkoma, Hempstead Lake and Southard's Pond (Carlls River) would experience some lowering of water levels from proposed sewering. Marsh and meadow species of plants and trees that are dependent upon a shallow water table environment may eventually be limited to areas closer to remaining streams. The study on Long Island

by Beitel suggests a possible sequence of vegetative succession similar to one that occurred at Artist Lake, Middle Island, New York during a lowering of the water table. In that case, near-shore lake habitats changed to marsh and then to red maple swamp habitats.

Significant long-term reductions in ground water outflow and stream flow to the various salt water bodies surrounding Long Island would alter bay salinities. A study by Moskowitz correlated stream discharge to changes of salinity in Great South Bay (Moskowitz, 1976). Ground water outflow also contributes to the maintenance of bay salinity, but its effect has not been specifically studied. In addition to effects within the water bodies proper, significant impact on the coastal wetlands is possible. In Nassau and Suffolk Counties, two types of wetlands are plentiful, the coastal salt meadows and the regularly flooded salt marshes (Green, 1972). In 1972, a study by the Marine Sciences Research Center reported that tidal marshlands covered 9,400 acres in Nassau County and over 12,000 acres in Suffolk County (O'Connor, 1972). Long Island's wetlands provide habitats for a variety of invertebrates, fishes, birds and mammals. Although descriptive studies exist detailing the functions provided to the environment by wetlands, quantitative analyses of the relative value of these areas are lacking. Thus, it is not clear exactly how reductions in fresh water flow to the bays will alter wetland flora and fauna.

A decrease in fresh water discharge to the bays could be offset in part by: shifting centers of pumping, stream augmentation with sewage effluent or with ground water from surplus areas, artificial recharge of treated waste water, or through planned water conservation programs. The decision on how to protect the remaining streams in heavily pumped areas should be based on a detailed evaluation of the relationship between ground and surface water flow systems. Consideration must be given to the willingness of the public to support the required programs and accept economic impacts.

As indicated previously, ground water pumpage in Queens may eventually be replaced by surface water from upstate New York. A major recovery in water levels can create problems. For example, the rise in the water table from 30 feet below sea level to as much as ten feet above sea level over the past 25 years in Kings County has led to flooding of portions of the New York City subway system and residential and commercial building basements constructed during the period when the water table was artificially depressed (Soren, 1976). Also, the rise in ground water level probably increases flow to sewage treatment plants due to infiltration to sewer lines originally laid in dry sand but now submerged below the water table.

Programs for recharging waste water (sewage effluent or storm water runoff) to replenish ground water supplies are an important water management technique that must be critically evaluated. The proposed 5.5 million gallons per day Cedar Creek Water Reclamation-Recharge Project, which is now under construction, will test the feasibility of replenishing ground water supplies with tertiary treated sewage effluent and also the reliability of producing an effluent suitable for recharge (EPA, 1972 and Consoer, 1973).

In summary, ground water resources have values other than providing water supplies. As pointed out previously, ground water discharge supports stream flow and plays a major role in maintaining an acceptable environment for certain flora and fauna. Thus, although the 208 area may remain self-sufficient in ground water by implementing a number of water management approaches within the bi-county area, this self-sufficiency may be assured at the expense of other significant aspects of the region's environment.

A further constraint to water supply self-sufficiency is water quality. Past and present waste disposal practices modify the purity of a significant portion of the available ground water resource. The presence of nitrate, trace organic chemicals and heavy metals in some portions of the aquifer system may be a much more important constraint to long-term availability of usable water supply than short-term droughts and salt water encroachment.

2.1.9 Proposed Water Management Plans

Development of an effective management plan for the 208 region must include evaluation of the alternative water supply and waste water management schemes proposed in recent years by private consultants and county, state and Federal agencies. These studies have ranged in scope from local to island-wide. Most suffer from technical simplifications, because detailed analysis of the ground water system has only recently been made possible through analog and digital computer simulation techniques.

The planning time spans considered in past water management studies are variable, but most use a 50 year period. Some of the reports simply present and analyze alternatives, while others make specific recommendations. The following is a list of major alternatives for water management on Long Island found in recent literature:

1. Continue present methods of development and management, with some provisions for local problem areas. Modifications might include development of additional well fields or redistribution of water within the present system.
2. Provide recharge to the ground water system with treated waste water via recharge basins or injection wells.
3. Import New York City water to Nassau County.
4. Exchange water with New York City. Water would be pumped from the New York City system to Long Island during periods of normal precipitation and from Long Island to New York City during drought periods.
5. Transfer water from a large well field in east-central Suffolk to areas of hydrologic imbalance in Nassau.
6. Use skimming wells to divert flow from shallow, near-shore aquifer systems to Magothy recharge areas in the center of Long Island.
7. Establish regional or county water authorities to provide for the orderly development of ground water and to oversee its distribution.

Of the plans reviewed, the reports by Greeley and Hansen (1963 and 1971) and Holzmacher, McLendon and Murrell (1970) are the most comprehensive. These studies reach similar conclusions and are generally compatible. Both emphasize bi-county solutions in the next few decades with the possible use of water from the New York City system in the future. However, during the relatively short time span since these reports were written, population projections have changed significantly. In comparing predictions for 1980 made by Greeley and Hansen in 1963 to the current Nassau-Suffolk Regional Planning Board's estimate, the population projection for Nassau County was lowered from 1.80 million to 1.47 million people. Revisions result as new and/or better data become available and as socio-economic factors change in the region. It is apparent that some of the water management plans recommended will have to be re-evaluated.

Another factor that can affect estimates of water supply needs in the 208 region is the future status of programs for conservation of the area's ground water resources. About the only conservation measure presently being encouraged is the installation of meters. There appears to be a real need for investigating the present pricing policies of major water supply systems; the potential for use of recycled waste water as a source of industrial supply; the availability of devices and hardware for reducing flows; and the feasibility of developing plumbing and building codes that may be effective as conservation-related measures. Of particular importance is the possibility of using the pricing mechanism to control demand. The price of water in the 208 region is now far from uniform for residential users, and does not encourage conservation on the part of major commercial users.

Two series of reports are particularly significant in their recommendations. The *Northeastern United States Water Supply Studies* (NEWS), written for the U. S. Army Corps of Engineers, and the studies by the Temporary State Commission on the Water Supply Needs of Southeastern New York, have been considering various water supply proposals for a number of years (Corps of Engineers, 1971—1977 and Temporary State Commission, 1973). Both series of reports view Long Island's water supply needs as approaching the critical point. Both recommend rather immediate action to supplement the bi-county area supply with either imported water or waste water recharge.

Plans for importing water from New York City must be approached cautiously in view of the economic impact on area residents. The boundary between fresh and salt water in the principal aquifers still lies somewhere offshore, which means that vast quantities of fresh water are continuously being lost to the surrounding bays and ocean. Implementation of expensive water supply importation programs may not be justified until the salt water/fresh water interface has moved onshore over a broader area, or at least until the relationship between salt water and fresh water is better defined. Also, the decision as to whether or not to import water from outside the bi-county area should be based on a thorough analysis of the potential success or failure of areawide water management options.

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2.2 GROUND WATER POLLUTION SOURCES

2.2.1 Background

An evaluation of ground water pollution sources is one of the products of the Long Island 208 areawide waste management study. A full report, presented to the 208 Technical Advisory Committee by Geraghty & Miller, Inc. in September 1977, describes eighteen different activities which have or may impair ground water quality in the study area. This section has been prepared to provide easy access to the salient facts contained in the longer, more technical version. The potential impact of the various contamination sources discussed may be subject to reassessment at a later date as more data are made available, or as legal requirements initiate a change in practices.

Although the ground water contamination contribution of several of the sources described may not appear to be significant, it should be borne in mind that the quality of the regional ground water supply is susceptible to the adverse effects of the sum total of man's activities on land. This understanding is particularly crucial to Long Island where activities are diverse, and where a water supply alternative to ground water is not readily or economically available.

There are many sources and causes of ground water contamination in the 208 area. Basically, they can be divided into four categories (Table 2–1). The first two categories represent discharges of contaminants that are derived from solid and liquid wastes. The third category concerns discharges of contaminants that are not wastes, and the fourth category lists those causes of ground water contamination that are not discharges at all.

The variety and type of management options available for each category differ. For example, some Category I sources may require a discharge permit whereas others can be controlled by restrictions on land use. Sources under Category II may require satisfaction of specified construction standards, such as the lining of landfills and the installation of leachate collection systems. Guidelines and manuals (*e.g.,* tons/land-mile limits on highway deicing salts) may be the only type of management option available for Category III. Special regulatory controls are available for the causes of ground water contamination listed under Category IV. An example is the current system of ground water diversion applications and hearings employed to minimize salt water encroachment. Another is the licensing of drilling contractors in order to upgrade water well construction practices.

2.2.2 Domestic On-Site Waste Disposal Systems

Cesspools, septic tanks and leaching fields are a source of ground water contamination on Long Island that has been of great concern to many investigators and regulatory agencies. "The Final Report of the Long Island Ground Water Pollution Study" stated that 800,000 persons in Nassau and 950,000 persons in Suffolk reside in unsewered areas (Nassau-Suffolk Research Task Group, 1969). In addition, facilities serving 24,000 people residing in Nassau

Table 2–1

CLASSIFICATION OF SOURCES AND CAUSES OF GROUND WATER CONTAMINATION USED IN DETERMINING LEVEL AND TYPE OF CONTROL

Category I Systems, facilities or sources designed to discharge waste or waste waters to the land and ground waters.	**Category II** Systems, facilities, or sources not specifically designed to discharge wastes or waste waters to the land and ground waters.	**Category III** Systems, facilities, or sources which may discharge or cause a discharge of contaminants that are not wastes to the land and ground waters.	**Category IV** Causes of ground water contamination which are not discharges.
Domestic on-site waste disposal systems	Sanitary sewers	Highway deicing and salt storage	Airborne pollution
Sewage treatment plant effluent	Landfills	Fertilizers and pesticides	Water well construction and abandonment
Industrial waste discharges	Animal wastes	Product storage tanks and pipelines	Salt water intrustion
Storm water basin recharge	Cemeteries	Spills and incidental discharges	
Incinerator quench water		Sand and gravel mining	
Diffusion wells			
Scavenger waste disposal			

Sewer District No. 2 were reported as not being hooked up to the sewer system. Other reports give different estimates for the number of cesspools and septic tanks in Nassau County (Nassau Environmental Management Council, 1974 and Padar, 1968). The U. S. Geological Survey has estimated that in 1966, 120 million gallons per day of sewage were returned to the ground through cesspools and septic tanks on Long Island (Parker, 1967). A more recent paper from the Nassau County Department of Health reports that 150,000 cesspools in Nassau alone discharge 60 million gallons per day (Smith, 1975).

In on-site disposal systems, bacterial action digests the solid materials, and the liquid effluent is discharged to the ground. In theory, filtration by earth materials provides additional treatment so that the liquid, when it arrives at the water table, is relatively clean. However, many constituents carried by the effluent are introduced to the ground water system. Those which present the greatest threat to ground water quality are excessive concentrations of nitrate, organic chemicals, detergent, metals, bacteria and viruses. Other constituents—previously ignored, but now recognized as a

threat—are halogenated hydrocarbons. Compounds such as chloroform, carbon tetrachloride, trichloroethylene, and others are in common use in industry as degreasers and solvents or are incorporated in plastic products. It has only recently been recognized that these and similar compounds regularly occur in discharges from households. Many products common in the home, such as fabric and rug cleaners, workshop cleaners and solvents, and solutions to clean pipes find their way into on-site disposal systems. Septic tank cleaners are composed almost entirely of active ingredients which are frequently halogenated hydrocarbons. For example, one common cesspool cleaner contains more than 99 percent trichloroethylene. One gallon of this compound could raise the trichloroethylene concentrations of 29 million gallons of water to the State recommended maximum of 0.05 parts per million.

Cesspools and septic tanks are viewed by regulatory agencies as low-cost systems which eliminate surface discharges of raw sewage. There are areas where low housing density and favorable soil conditions make such systems satisfactory alternatives to expensive trunk sewers and treatment plants. However, government agencies have been leaning more and more toward the latter in recent years. Sewer districts have been delineated in both counties and plans for construction are well underway. Figure 2—14 is a nitrogen-loading map, showing the areas in which more than 40 pounds of nitrogen are added annually to each acre by cesspools and septic tanks (Weston, July 1976). This map does not include the nitrogen loading that results from agricultural and domestic fertilizer applications.

2.2.3 Sewage Treatment Plant Effluent

At present, sewage treatment plant effluent is only a minor threat to ground water quality in the bi-county area, as most of the effluent is discharged directly to the sea. According to a study made by Weston in 1976, 23 plants in Nassau County discharge an average of 105.63 million gallons per day, and in Suffolk County 101 plants have an average discharge of 14.26 million gallons per day (Weston, July 1976). These are the total flows of the NPDES and SPDES permitted sewage treatment systems and are believed to include all plants in both counties. Figure 2—15 shows the locations of plants that discharge to the ground.

In Nassau County, only one percent of the total daily flow of treated

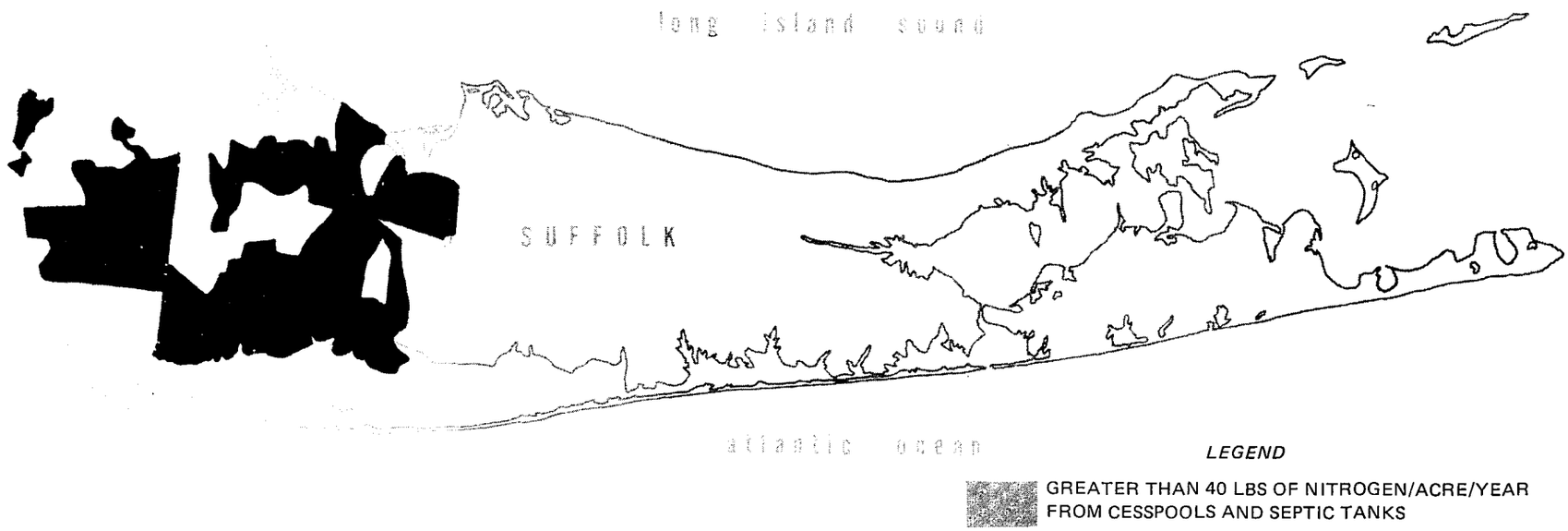

FIGURE 2—14 *Areas of Major Concentrations of On-Site Domestic Waste Disposal Systems.*

effluent (1.2 million gallons per day) and in Suffolk County 50 percent of the total daily flow of treated effluent (7.39 million gallons per day) are discharged to the ground. Thus, a total of 8.59 million gallons per day enters the ground compared to about 800 million gallons per day total recharge of fresh water from precipitation in the bi-county area. Although small, this discharge of effluent to the ground may have a significant effect when concentrated at a few sites. In Nassau County, effluent is discharged at five sites: Meadowbrook Hospital (0.77 million gallons per day), Farmingdale Sanitorium (0.07 million gallons per day), C. W. Post College (0.12 million gallons per day), New York Institute of Technology (0.003 million gallons per day), and Grumman Aerospace Corp. (0.25 million gallons per day).

In Suffolk County, the 85 facilities which discharge treated sewage effluent to the ground are predominantly small residential facilities and some special health and elderly care facilities (Weston, July 1976). Suffolk County is undergoing rapid development and many small sewage treatment plants are being installed to serve areas of 100 or more homes. In developments of less than 100 homes where no sewer system is available, builders are required to install sewers, which will be placed into service after future construction of a nearby interceptor. These homes are permitted to temporarily discharge to cesspools and septic tanks (Pim, 1977).

Some systems receive domestic wastes exclusively; others accept some industrial wastes. Regulatory authorities make every effort to exclude constituents harmful to the treatment plant process or employees, but incidental discharges are not easily controlled. Some chemicals, such as solvents, do not appear to be harmful over the short term, but may damage either the plant or sewer system over a long period of time.

According to a NYSDEC law, effective secondary treatment is the minimum required before effluent can be discharged to surface water. Although this law does not apply to plants discharging to the ground, secondary treatment also is common. Only Farmingdale Sanitorium in Nassau discharges primary treated effluent to the ground (0.07 million gallons per day). In Suffolk, of the 85 plants discharging to the ground, only six do not provide at least secondary treatment. Denitrification of sewage effluent is now required of all new sewage treatment plants which discharge to ground water in Suffolk County.

A recently released report by Roy Gilbert of the SCDEC states that

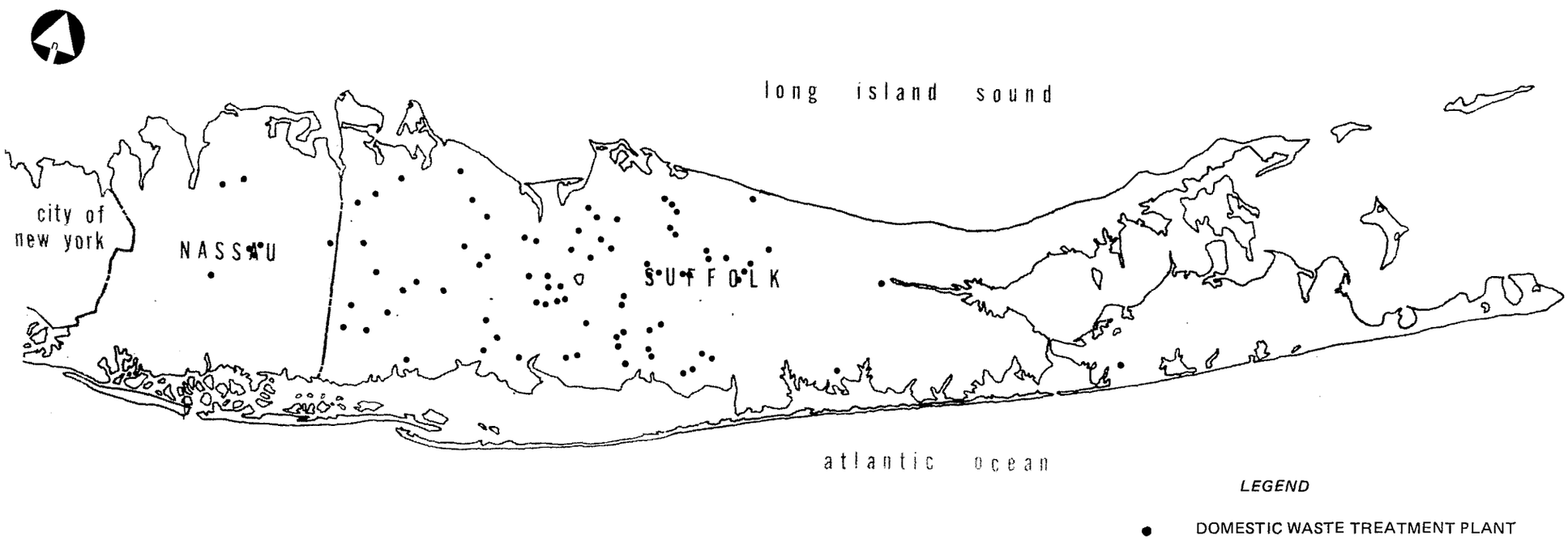

FIGURE 2–15 *Domestic Waste Treatment Plants Discharging to Ground Water.*

a number of organic compounds present in treated sewage are refractory products (not affected by the treatment process) of the biological treatment of the plant, or new compounds formed during chlorination (Gilbert, 1977). It is possible that these products may move through the unsaturated soil to contaminate ground water in places where the effluent is discharged to the ground.

The New York State Environmental Conservation Law of 1967 empowers agencies to regulate sewage treatment plants. This law provides for the classification of state ground water and establishment of quality standards. Violators are assessed penalties under the Federal Water Pollution Control Act (PL 92–500). The NPDES program was established in 1973 and the SPDES program in January 1975; the SCDEC and the NCDH derive their enforcement powers from these.

2.2.4 Sanitary Sewers

Approximately 120 million gallons per day of raw sewage flow through thousands of miles of sewers in the bi-county area. The flow in Nassau averages 105.63 million gallons per day and in Suffolk, 14.26 million gallons per day (Weston, July 1976). Figure 2–16 shows the locations of sewered areas. Sewers frequently leak, and depending upon the type of sewer and its altitude relative to the water table, ground water can infiltrate or sewage can exfiltrate. The contamination that takes place in the latter case is normal domestic sewage, plus those constituents in industrial effluent discharged to sewers.

Since the enactment of the SPDES permit program, the direct discharge of industrial wastes to septic systems has been severely curtailed. Restrictions on industrial discharges to sewers are much less stringent than those covering such discharges to septic systems. Concern over the constituents in industrial effluent is primarily due to their effects on the sewer system, the treatment plant processes, and treatment plant personnel—not their effects on ground water.

Permissible maximum infiltration rates are usually written into sewer specifications and commonly vary from 200 to 500 gallons per day per mile per inch of pipe diameter. Where ground water pollution is of concern, exfiltration rates are also specified. In Suffolk County's Southwest Sewer District, for example, 200 gallons per day per mile per inch of pipe diameter has been

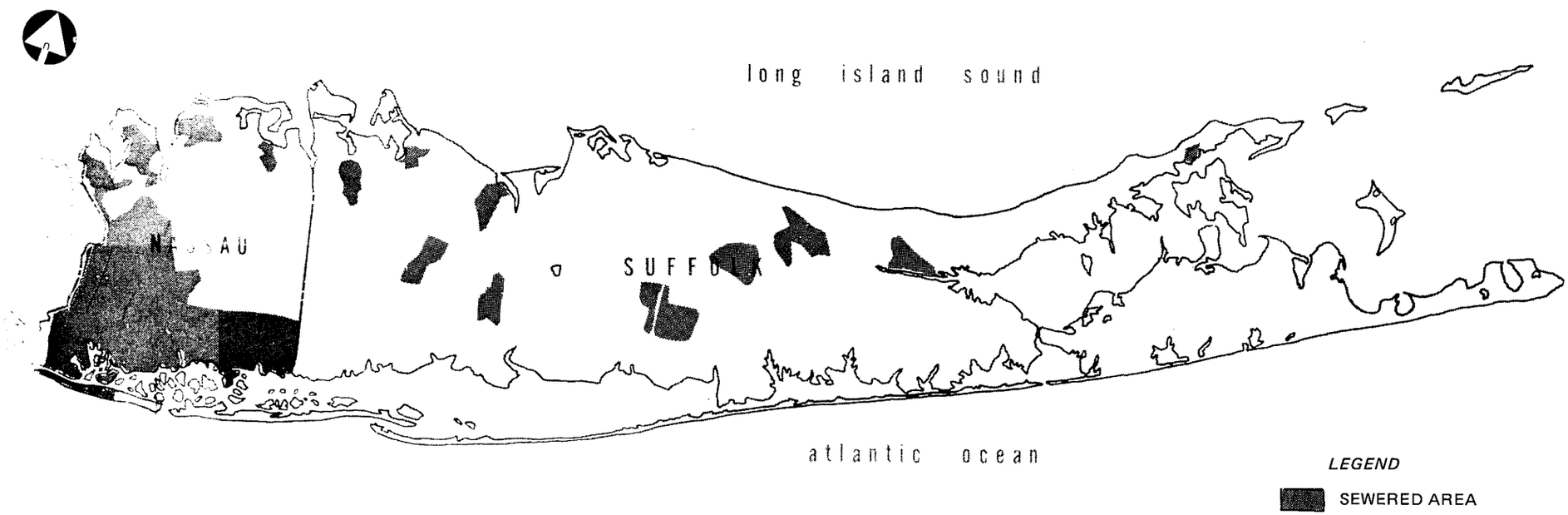

FIGURE 2–16 *Presently Sewered Areas.*

specified as the maximum rate for exfiltration. Projections from tests carried out on existing sewer lines show that leakage has been considerably less than this figure (Graner, 1977).

The potential volume of exfiltration is small when compared to the nearly 100 percent discharge that occurs from cesspools and septic tanks. However, exfiltration may increase over the years as loading produces breaks in the pipes and joints, and as chemical action deteriorates the joints. Exfiltration may also increase if the ground water level was originally above the sewer, but has declined to a point below the sewer.

With present materials and construction techniques, a 50 year sewer life is used as a minimum design estimate. However, a 100 year life may be a more reasonable estimate (Graner, 1977). Some of the older systems in Nassau County are receiving large volumes of ground water (Long Beach, Glen Cove, Oyster Bay and Freeport) (Cameron, 1977). If these systems are infiltrating additional water where the pipes are below the water table, it is reasonable to assume they are also exfiltrating additional sewage where the pipes are above the water table. Similar problems may be occurring in older Suffolk systems, such as Port Jefferson, Huntington, Northport and Patchogue.

Except for monitoring volumes, and to some extent, chemical quality of incoming waste at sewage treatment plants, little control is exerted on sewers once the construction specifications are satisfied. Severe problems involving exfiltration, infiltration or clogging are remedied where they interfere with the operation of the system or cause a public nuisance.

2.2.5 Industrial Waste Discharge

Industrial development and zoning are extensive on Long Island. In 1972, five percent of the Nassau-Suffolk area was zoned for industry. Most of this acreage is inland and includes such heavily industrialized areas as Syosset, Hicksville, Bethpage-Plainview, Melville-Farmingdale, Hauppauge and Deer Park. Except for a small part of the Melville-Farmingdale area, all of these zones and a number of smaller ones in Suffolk County are located in the recharge area of the Magothy aquifer. Areas of known industrial discharge to the ground are shown on Figure 2–17.

Although there are discrepancies in the number of industries reported to have permitted discharges, the nature and volume of NPDES and SPDES discharges are documented in a 1976 report prepared by Roy F. Weston

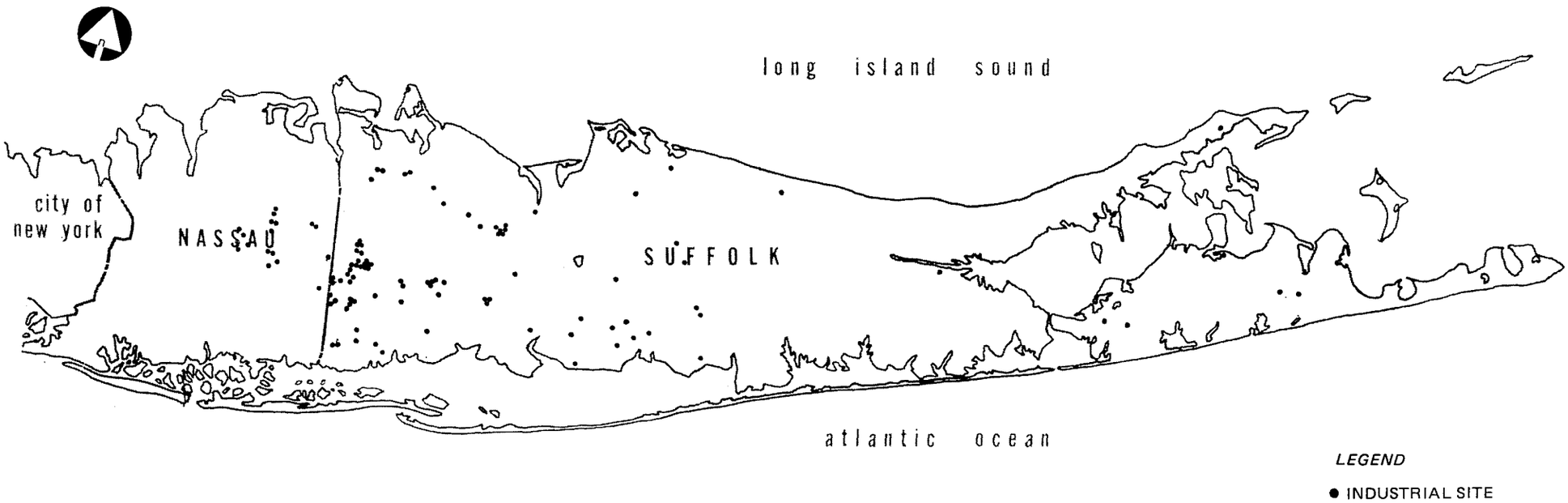

FIGURE 2–17 *Major Industrial Sites Discharging to Ground Water.*

(Weston, July 1976). According to the report, in Nassau 1.2 million gallons per day of waste water are discharged by industry. About 800,000 gallons per day of this amount are discharged to the ground. In Suffolk County, 88 industries discharge a total of 1,325,000 gallons per day, of which 1,278,900 gallons per day are discharged to the ground. Thus, in the bi-county area, about 2.1 million gallons per day of industrial wastes are discharged to the ground in a few industrialized areas.

There are also commercial and industrial discharges in both counties, not included in the permitted inventory. These include car washes, coin-operated laundries and industries discharging waste water with constituents not covered by permitting regulations.

In an attempt to control industrial waste discharges, Nassau County has recently instituted a program to inventory all industries, according to the nature of and receiving body for their discharges. The inventory has revealed a number of industries that are discharging untreated liquid wastes to cesspools (Burger, 1977). Abatement actions have been initiated in these cases. Suffolk County has been conducting industrial surveys for several years.

In Suffolk County, a list of car washes and coin-operated laundries has been compiled. Ten car washes presently discharge to ground water; these predate the State DEC regulation requiring closed systems. There are 135 coin-operated laundries discharging to the ground water; two of these have once-through waste treatment and four others have partial treatment (Gilbert, 1977). Twenty-five percent of Suffolk's coin-operated laundries discharge to sewers and require no pre-treatment (Pim, 1972). Forty-five of the laundries discharging to the ground are in the Southwest Sewer District and will be sewered in the future. Nearly 500,000 gallons per day discharges to ground water from 75 of these laundries.

In Nassau County, permitted discharges to the ground amount to about 800,000 gallons per day. Fourteen metal processing firms discharge 726,000 gallons per day, which is 90 percent of the total. The bottling industry produces an additional 32,000 gallons per day, and the food industry, 24,000 gallons per day. Very small discharges are from metal powder mixing and paper processing industries (Weston, July 1977).

In Suffolk County, 1,278,900 gallons per day of industrial wastes are discharged to the ground. This includes 470,989 gallons per day from metal processing, 356,813 gallons per day from commercial laundries, 164,978 gallons per day from dairies and 152,189 gallons per day from bakeries.

Prior to the passage of the New York State Environmental Conservation Law in 1967, there was no effective law limiting the types of waste water discharged to the land surface. With the enactment of the NPDES and subsequent enactment of the SPDES, a NYSDEC permit is required for non-sewered industrial effluent discharges. The industry must produce treated effluent which meets state water standards. Compliance is monitored by the NCDH and the SCDEC. These agencies also enforce sludge disposal rules.

2.2.6 Storm Water Basins

Investigators have determined that on Long Island approximately half the annual precipitation finds its way to the ground water reservoir as recharge. This averages roughly one million gallons per day per square mile in a 760 square mile recharge area. As the western part of the region has become increasingly urbanized, however, permeable soil areas have been replaced by impermeable roofs and paved areas. The water cannot seep into these surfaces, so it accumulates and runs off.

As a water conservation alternative to offset reductions in ground water recharge and to eliminate the need for expensive trunk sewers leading to the sea, a system of small storm sewers draining to unlined recharge basins was implemented in Nassau County in 1935. At the present time, there are more than 2,000 basins on Long Island, the locations of which are shown on Figure 2–18 (Seaburn, 1973). The basins range from less than one to more than 30 acres in size but most are about one acre. They average ten to twenty feet in depth.

Recharge basins have been considered to be highly beneficial to the overall water conservation program on Long Island, since they account for approximately twenty percent of all recharge to the underlying aquifers (Aronson, 1974). Although the basins restore potentially lost recharge, they are also sources of contamination. Inflow into the basins is a combination of precipitation plus constituents that are dissolved and suspended by the water as it runs over the ground. Typical sources of contaminants are fertilizers, pesticides, deicing salts, organic debris, grease and road oil, rubber, asphaltic materials, hydrocarbons, animal feces and food wastes. Many of the contaminants are not biodegradable and persist in ground water.

As part of the 208 investigation, a number of studies were conducted which have bearing on the amount and types of pollutants that may be entering the ground water system via storm water basins. The Weston non-point source analysis included sampling runoff from small drainage areas and correlation of the runoff quantity and quality with the prevailing land uses. The data and analyses indicated that annual loads of pollutants from non-point sources can be as large as loadings from traditional point sources (Weston, April 1977).

In their program of storm water runoff and ground water sampling at two recharge basins along the Long Island Expressway, the SCDEC detected significant intermittent concentrations of selected heavy metals (*e.g.,* zinc and lead) and total organic carbon (TOC) in discrete samples of storm water runoff during the sampled storm events. Chloride and zinc were observed in elevated concentrations in the ground water samples obtained from wells located in the two recharge basins receiving storm runoff from the Expressway. The SCDEC concluded that further investigation is obviously necessary to determine if runoff quality from the Long Island Expressway is comparable to the often reported major waste load attributed to heavy metals in runoff (Minei,1977).

Guidelines for basin construction have been developed by the Regional Pure Water Staff of the NYSDEC. These guidelines require a preliminary submission review to determine the requirements that the applicant must meet under the New York State subdivision law. It is also determined whether the applicant needs other state permits such as SPDES or tidal and fresh water wetlands permits. This review gives the NYSDEC the opportunity to evaluate design criteria, and departmental requirements (either additions or deletions to design) based on New York State rules and regulations which dictate prevention of runoff to surface water where possible, and recharge of as much storm water as feasible. There is no legislation stipulating storm water quality control.

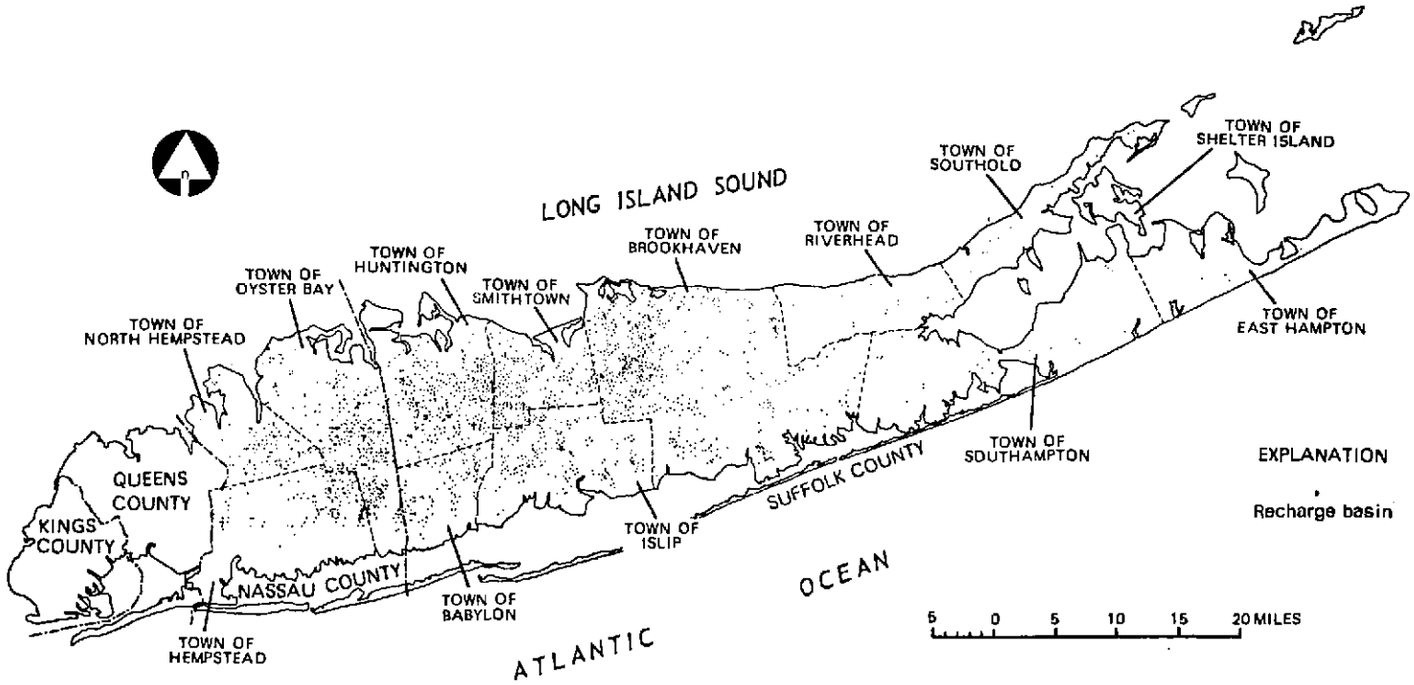

FIGURE 2–18 *Location of Recharge Basins Used for Storm Runoff on Long Island in 1969.*

2.2.7 Landfills

Long Island disposes of its solid wastes by burial in landfills, with incineration of combustible refuse at some of the sites. Based on available information, there are in excess of 40 major active and abandoned solid waste land disposal sites in the 208 planning area. Only a few sites have been studied in detail to determine their effects on ground water quality. Suffolk County has initiated monitoring programs around each major landfill, but a regional inventory of Long Island's landfills defining potential problems of leachate contamination does not exist at this time.

The NCDH currently monitors water quality at the Merrick, Freeport, Port Washington, Oceanside and Old Bethpage sites. Wells installed specifically for ground water monitoring are found only at the Port Washington site. Construction has started at a new disposal location (the Black-Clawson site) just off the Meadowbrook Parkway in the Town of Hempstead. It is a refuse recycling project that reportedly will have a waste-recycling potential of 2,000 tons per day. The project is funded by a private corporation which has agreed to operate the plant for the next twenty years.

Nassau County's annual solid waste output is now more than 1,100,000 tons. This quantity is not expected to change significantly over the next ten years. Annual solid waste generation in Suffolk County (1974) was 1,100,000 tons and is projected to be 2,700,000 by 1990 (Baffa, 1967). An average of between four to five pounds of solid waste per capita per day is generated from domestic and residential sources in the bi-county region. Industrial, commercial, agricultural, demolition and incinerator wastes have been landfilled along with residential refuse. Until recently, they were combined and dumped together as one unit at the same site.

One of the most important problems associated with Long Island landfills is the generation of leachate. The amount of leachate produced depends upon the landfill's overall extent, volume, absorptive capacity and the amount of recharge water infiltrating it. In theory, 100 acres of landfill can generate 40 million gallons of leachate per year under climatic conditions similar to Long Island's. Thus, in Suffolk County, 320 million gallons per year of leachate could be generated from the 800 acres used for solid waste disposal.

The largest landfill sites are shown on Figure 2–19. Additional data on old landfills for Nassau County are available from a report compiled by the Long Island Sanitary Commission on refuse collection in 1931. Some of the disposal sites inventoried in the 1931 survey are still active. A survey of aban-

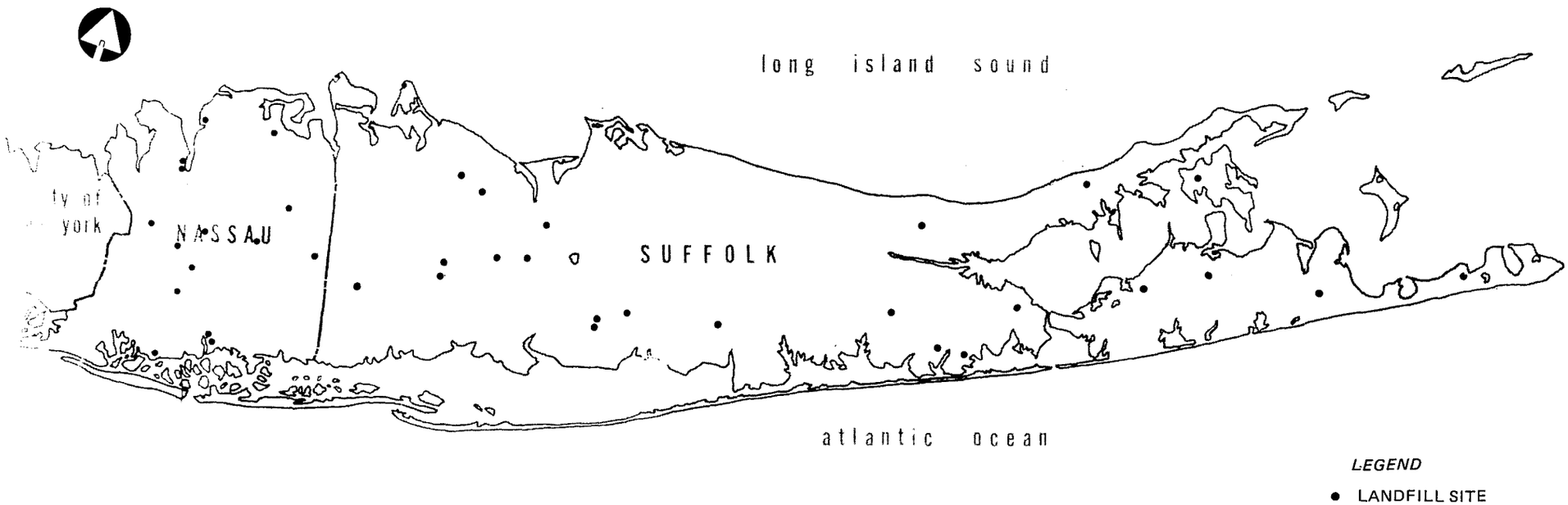

FIGURE 2–19 *Principal Active and Abandoned Landfills.*

doned municipal landfills in Nassau County is being undertaken by the NCDH; 34 sites have been reported to date.

The older landfills in the 208 region typically range in size from twenty to 60 acres. Most are in mined-out sand and gravel pits and are unlined. Some have received or still receive septage from septic tanks and cesspools. Two recently constructed landfills, one in Nassau and another in Suffolk, are lined.

Landfills receive a wide range of materials including paper products, food wastes, septic tank sludge, construction debris, tires, autos, leaves, plastics, glass, chemicals, textiles, cans, oils and hydrocarbons, street and building sweepings, dead animals and waste water and water treatment sludges. The type and concentration of contaminants in leachate is of great importance in determining potential effects on ground and surface water quality. Table 2–2 lists pollutants expected from municipal waste sites. Significant pollutants in landfill leachate on Long Island are BOD, COD, iron, chloride, ammonia, heavy metals and organic chemicals.

Landfilling of solid waste is the typical disposal method employed on a nationwide basis, and has the lowest cost of the various waste management options available. Until passage of the Resource Recovery and Conservation Act in late 1976, there was no effective Federal regulatory control over land disposal of solid waste. Regulations for the Resource Recovery and Conservation Act are now being prepared by EPA. On Long Island, the NYSDEC, in cooperation with the NCDH and the SCDEC, has jurisdiction over applications for new landfill sites and the expansion of old sites. Current trends in landfill regulation include lining all new sites, installing leachate collection systems, encouraging resource recovery and monitoring ground water quality.

2.2.8 Highway Deicing

The application of salt to highway surfaces in freezing weather can cause ground water contamination. The salt melts snow and ice, and the resulting solution of brine, combined with other pavement contamination, runs off the impermeable road surface and most of it either seeps directly into the ground or is diverted to a storm water recharge basin. In some places along the shores of Long Island, street runoff is diverted to sewers which discharge to the sea. However, the bulk of the runoff enters the ground where it seeps down to the water table and migrates through the ground water system

Contamination can also take place around salt storage piles if they are not adequately protected. Rain falls on the pile, dissolves the salt and runs onto the ground. Increasingly, salt piles are being stored under cover on paved impermeable surfaces to prevent dissolution.

It is obvious that road salting cannot be discontinued without a drastic increase in traffic accidents and inconvenience to motorists. What can be done, however, is to decrease the amount of salt used to the minimum required to do the job, mixing it with sand so that the cars can maintain good traction with the road surface. About 80 percent of all deicing salt pollution

Table 2–2

LEACHATE CHARACTERISTICS BASED ON TWENTY SAMPLES FROM MUNICIPAL SOLID WASTES
(Constituents given in parts per million, where applicable)

Constituent	Median Value	Ranges of all Values
Alkalinity ($CaCO_3$)	3,050	0 – 20,850
Biochemical Oxygen Demand (5 days)	5,700	81 – 33,360
Calcium (Ca)	438	60 – 7,200
Chemical Oxygen Demand (COD)	8,100	40 – 89,520
Copper (Cu)	0.5	0 – 9.9
Chloride (Cl)	700	4.7 – 2,500
Hardness ($CaCO_3$)	2,750	0 – 22,800
Iron, Total (Fe)	94	0 – 2,820
Lead (Pb)	0.75	<0.1 – 2.0
Magnesium (Mg)	230	17 – 15,600
Manganese (Mn)	0.22	0.06 – 125
Nitrogen (NH_4)	218	0 – 1,106
Potassium (K)	371	28 – 3,770
Sodium (Na)	767	0 – 7,700
Sulfate (SO_4)	47	1 – 1,558
Total Dissolved Solids (TDS)	8,955	584 – 44,900
Total Suspended Solids (TSS)	220	10 – 26,500
Total Phosphate (PO_4)	10.1	0 – 130
Zinc (Zn)	3.5	0 – 370
pH	5.8	3.7 – 8.5

is caused by improper storage practices and the remainder by improper spreading techniques (U. S. Salt Institute, 1976).

Nassau County maintains ten salt stockpiles; nine are open and one is enclosed. All of them are mixtures of sand and salt, and in 1976 they had a total storage volume of 18,250 tons. They are located in Manhasset, Glen Cove, Oyster Bay, Hicksville, Mitchell Field, Mineola, Inwood, Franklin Square, Wantagh and Hempstead. The ages of these sites range from two to 21 years. The three towns in Nassau County maintain ten additional sites,

totaling 10,360 tons, and 31 storage sites are located in 29 villages, representing 4,500 tons of salt. New York State has two large salt piles in the Duffy Avenue landfill in Hicksville and at the Planting Fields Arboretum landfill in Oyster Bay.

There are sixteen Suffolk County Department of Public Works storage piles in the following towns: Huntington, Hauppauge, Babylon, Bay Shore, Brentwood, Farmingville, Medford, Yaphank, East Moriches, Riverhead, Peconic (two), Westhampton, Hampton Bays, East Hampton and Montauk. Only two of these county piles are indoors, one in Riverhead, and the other in Peconic. Numerous storage piles exist at the town and village level. Brookhaven has submitted plans for twelve brine collection pads (to be installed beneath their outdoor piles) and four of their piles are within buildings. Six Suffolk towns are currently complying with the SPDES permitting system; one is partially complying, one has promised to comply, and two are not complying, with subsequent legal action pending. By 1978, 80 to 90 percent compliance is expected from the towns and the County Department of Public Works. The smaller villages generally comply with the building and pad requests because they can obtain multiple usage from such facilities.

Some of the NYSDOT piles come under the jurisdiction of the Long Island State Park Commission. They are not, for the most part, considered to be in compliance with SPDES. Most of the piles are uncovered and without curbs or catch basins. Some piles have impervious pads, but others do not, and the result is leaching and uncontrolled runoff. As funding is made available, NYSDOT constructs storage facilities for its piles. The first was built in 1959 and nine more have been built since then.

An average of about 32,500 tons of road salt is applied to 9,000 lane-miles of road in Nassau County yearly. Averaging the state, county and municipal applications, about 5.2 tons of salt is applied per lane-mile. This average annual application rate is calculated from Nassau salt usage data in Table 2–3. In Suffolk County, with greater road area, about 60,000 to 65,000 tons are applied annually. One hundred thousand tons of road salt would contribute some 60,500 tons of chloride, plus large amounts of calcium and sodium to the environment. The runoff dissolving these salts seeps into the shallow water table aquifer, usually within the immediate vicinity of the treated road surfaces or is discharged to a nearby recharge basin designed to receive highway runoff.

Substances have been added to deicing salts to prevent caking and to inhibit corrosion. For example, sodium ferrocyanide has been added to deicing salts in the past to prevent caking. Not enough is known about the present use of additives, their toxicity, nor their fate in the soil and ground water system to comment on potential hazard.

On Long Island, no regulations exist for deicing practices but certain policies, similar to those described by USEPA, are commonly used (U. S. Environmental Protection Agency, 1974). The SCDEC issued an order in 1974 requiring more substantial protection for stored salt used by highway departments. The order called for construction of buildings to store the salt/sand piles, and in 1975, most of the townships and incorporated villages began to comply. Suffolk County salt storage piles must now comply with the SPDES permitting system as required by SCDEC.

Table 2–3

SALT USAGE IN NASSAU COUNTY (from NCDH)

Agency	Lane-Miles Maintained	Average Annual Salt Usage (tons)	Tons per Lane Mile
New York State	950	7,000	7.4
Nassau County	1,400	14,900	10.7
Town of Oyster Bay	1,600	1,500	0.9
Town of North Hempstead	540	3,000	5.6
Town of Hempstead	4,500	6,000	1.3
Total:	8,990	32,400	5.2 (average)

2.2.9 Fertilizers and Pesticides

About 45,000 acres in the bi-county area are devoted solely to crop raising. Figure 2–20 shows areas being used for agriculture. In Suffolk County alone 64,000 acres are considered available for present and future agricultural use (Nassau Suffolk RPB, 1975). In Nassau County, agricultural land is minimal. Most of the land, although previously farmed, is now used for residential, commercial, industrial and recreational purposes.

In the bi-county area, as a whole, most fertilizers and pesticides are applied for non-agricultural uses including home lawns, golf courses and nurseries. Increasing evidence from Long Island ground water quality testing programs supports the association between fertilizer use and nitrate in ground water. Studies being conducted for the 208 by Cornell University indicate that lawn fertilizers applied by home owners may be as significant a source of nitrogen contamination of ground water as discharges from septic tanks, particularly in Nassau and western Suffolk (Porter, 1977) However, further work is required to more effectively quantify the use and relative environmental impact of fertilizers.

There is no evidence to suggest that pesticides have posed a serious threat to ground water resources on Long Island, despite the heavy use of the chemicals on intensely farmed agricultural land. Metallic base pesticides and hydrocarbons were used until quite recently. The "first generation" pesticides are very persistent and substantial residues may still be found in the soil. However, the residues are strongly retained by soil forces and do not usually leach to ground water. In the past decade new generation pesticides have been widely used. Some of these, including certain herbicides which are now used

very extensively, are more soluble in water and have higher acute toxicities. Most, however, are broken down rapidly in soil or water and, therefore, are not regarded as a ground water hazard. Some evidence indicates that a few recently developed pesticides may be more persistent under some conditions. Unfortunately, there are virtually no data available from monitoring for these pesticides in ground water. These pesticides include some of the carbamates which are both highly toxic and soluble in water.

There has been no legislation enacted to regulate the rate of fertilizer application. The Federal Insecticide, Fungicide and Rodenticide Act of 1975 (PL 92-516) deals principally with control of compounds through registration of both pesticides themselves and commercial operations by pesticide firms, and through monitoring procedures. By law, pesticide users must apply the product according to prescribed dosages provided by the manufacturer.

2.2.10 Product Storage Tanks and Pipelines

A number of products are stored in surface and subsurface tanks and are transmitted in pipelines on Long Island. Among the most frequently stored fluids are liquid petroleum products; gases, both liquefied and gaseous under pressure; industrial chemicals; and water. Among these products, industrial chemicals are not commonly transmitted long distances through pipelines, and water poses little contamination threat to ground water. The other products, however, have all been reported to cause ground water contamination on Long Island or elsewhere in the United States.

A major ground water contamination threat is posed by liquid petroleum products stored in tanks and transmitted through pipelines. Three types of petroleum products and their means of storage are common in Nassau and Suffolk Counties. Gasoline service stations store various grades of gasoline in two or more subsurface storage tanks with capacities of 2,000 to 12,000 gallons. Many individual homes and businesses store heating oil indoors, below ground or at the surface. Oil depots store one or more grades of fuel oil in surface tanks of various sizes. These various sources are described below.

2.2.10.1 Service Stations. For a number of reasons, service stations are of most concern as a threat to ground water, and many case histories of ground water contamination from this source have been reported. First, they are spread over the entire bi-county area. The greatest concentration of service stations occurs in the most densely populated areas which are also the

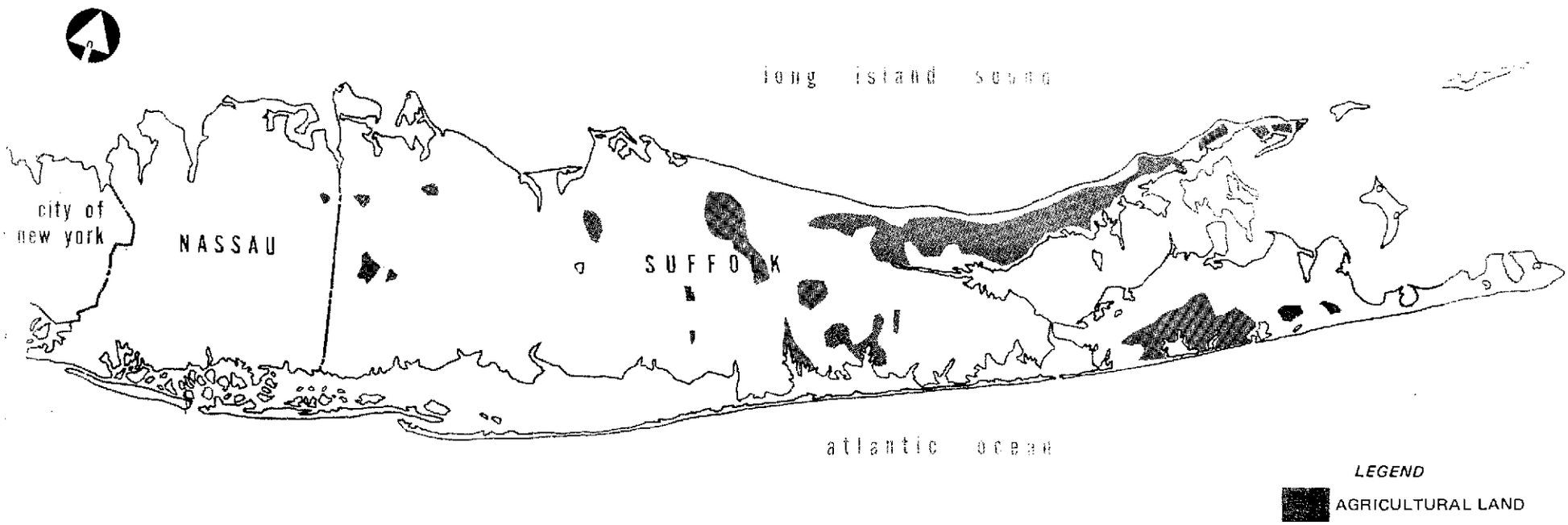

FIGURE 2—20 *Agricultural land*

areas of greatest ground water pumpage. The Nassau County Fire Marshal's Office estimates that more than 1,200 gasoline and diesel service stations exist in Nassau County (Bartow, 1977). The Suffolk County Bureau of Weights and Measures records over 1,400 service stations and marinas which have storage tanks (Kerbs, 1977). These numbers do not reflect the numerous facilities which dispense products on a non-profit basis, such as construction companies or major trucking firms which fuel their own vehicles. In total, it is estimated that 3,000 sites which store vehicle fuel exist in Nassau and Suffolk (L.I. Gas Retailers Association, 1977).

The volume of storage is enormous. Personnel of the Long Island Oil Heat Institute estimate that over one billion gallons per year of gasoline and diesel fuel are used in Nassau and Suffolk. Most of this fuel is initially delivered by tank trucks, and almost all of it is stored underground for some period of time (Byrne, 1977).

Most service stations have steel tanks, although fiberglass tanks (first marketed in the early 1960's) are slowly gaining in popularity. The steel tank, usually of welded construction, is highly susceptible to corrosion, especially at the welds. In order to inhibit corrosion, steel tanks are often coated on the outside with tar. With care, the coating may be temporarily effective, but many tar-coated tanks develop leaks at the point where the tar was scratched away during installation. Gasoline additives often accelerate tank corrosion from the inside. Fiberglass tanks have effectively alleviated the corrosion problem, but they can crack when exposed to cold temperatures and excessive surface loads.

2.2.10.2 Home and Industrial Heating and Power Generation. According to personnel of the Long Island Oil Heat Institute, Nassau and Suffolk homes and industries use 1.5 billion gallons of No. 2 oil (the most common home heating fuel) and two billion gallons of No. 6 oil. Less than ten percent enters over the road, with the remainder shipped to the bi-county area by barge (Byrne, 1977).

Oil heated homes on Long Island number 640,000. Popular home storage tank sizes are 275, 550 or 1,050 gallons. Basements can accommodate one or more 275-gallon tanks, but larger, underground tanks are more common. Welded steel tanks are the most popular.

Underground steel tanks at homes and industries are as susceptible to leaks as tanks beneath service stations. However, their contamination potential is less for several reasons.

1. Stored volumes are smaller so a single loss of product would have less of an impact on ground water.

2. The loss of a few hundred gallons of fuel oil should be more obvious to a homeowner than the loss of a similar amount by a gasoline retailer.

3. Because the tanks are smaller, the bottom of the home fuel oil tank will likely be at a shallower depth and, therefore, less likely to be installed below the water table where corrosion could be accelerated.

2.2.10.3 Oil Storage Depots. The distribution and number of depots on Long Island which store petroleum products are significant. Several cases of leakage into ground water have been documented from this source. Most depots store fuel oil for home and business use, although many also store gasoline, kerosene and diesel fuel. Except for Long Island Lighting Company which stores its own oil, all but about ten percent of the fuel oil consumed in Nassau and Suffolk is stored in depots in the bi-county area. Nearly all tanks are above ground and outdoors. In fact, New York State law prohibits indoor storage of large volumes of flammable products (Early, 1977).

The Nassau County Fire Marshal's office has inventoried nearly 100 oil storage depots in the county. Although the largest facilities are generally near the shore where they can be supplied by barges and tankers, the greatest number of facilities are found inland.

A complete inventory of Suffolk County depots is not available at this time. However, a listing made available by the SCDEC reveals that more than 41 storage tanks exist at six major storage terminals (Maloney, 1977). The largest of these terminals, at Northville, has a storage capacity of nearly 120 million gallons (Nassau County Environmental Management Council, 1974). Two large inland terminals at Holtsville and Setauket have more than 25 storage tanks between them (Maloney, 1977).

2.2.10.4 Other Storage Facilities. Most industrial chemicals are stored in tanks on or above the ground. It is unlikely that the locations of many of those containing hazardous substances are known to regulatory agencies, because most are small and unobtrusive. However, many of those containing flammable products are known to fire departments. For example, in the Town of Huntington, any facility which stores combustible material must be permitted by the district fire inspector (Early, 1977).

2.2.10.5 Pipelines. The four major pipelines on Long Island transport fuel oil; these are the Consolidated Petroleum pipeline from Port Jefferson to Setauket, and three Northville Industries pipelines—from Port Jefferson to Holtsville, from Northville to Riverhead, and from Holtsville to Plainview.

Regulatory controls applicable to oil product storage tanks and pipelines are diverse, ranging from local ordinances to USEPA regulations. There are also guidelines and recommendations for siting and construction designed to ensure safe encapsulation of the stored or transported product. In addition, compliance with the New York State Environmental Conservation Law, Section 23, is required. This legislation is concerned with the storage and transportation of liquefied natural gas and petroleum products.

2.2.11 Incinerator Quench Water

A typical 600-ton-per-day municipal incinerator requires about 10,000 gallons of water each day to dissipate heat from fuel gases and gas residue. Some of this quench water is retained in the ash, but most of the unevaporated water, which may contain hazardous constituents, is siphoned away for discharge.

Of the eleven active municipal incinerator sites in the bi-county area,

eight are in Nassau and three in Suffolk (Weston, 1976). Four dispose of quench water directly to the ground; the others discharge to surface water.

Contaminants of concern are similar to those found in landfill leachate. The quality of quench water from one incinerator in the study area did not meet sewage treatment effluent discharge standards for pH, suspended solids and turbidity. At another site several constituents were in excess of the concentrations permitted under SPDES regulations. Owners of incinerators are in the process of applying for SPDES permits, a relatively recent requirement because the potential for contamination from this source was not previously regulated.

2.2.12 Airborne Pollution

Both the atmosphere over Long Island and precipitation contain appreciable amounts of ground water contaminants. For instance, emissions from motor vehicles in the bi-county area may amount to 4,000 tons per day of carbon monoxide, 800 tons of hydrocarbons and 740 tons of nitrogen oxides (Frizzola, 1975). Other sources of air contamination and potential incorporation of chemicals into precipitation include incinerators, power generators, aircraft, railroads, industrial emissions and open burning of refuse.

Table 2–4 shows the average values of selected chemical constituents in rain water reaching Long Island. The samples collected by the U. S. Geological Survey show higher concentrations of all constituents at the suburban sites at Mineola and Medford, while lower levels were registered for the rural environment at Upton. The results of recent studies show an average sulfate content in rain water of 3.60 milligrams per liter, total nitrogen 1.36 milligrams per liter, sodium 1.89 milligrams per liter and chloride 3.22 milligrams per liter (Frizzola, 1975).

Amendments to the Clean Air Act in 1970 established national ambient air quality standards for six common classes of air pollutants; sulphur oxides, particulate matter, carbon monoxide, photochemical oxidants, nitrogen oxides and hydrocarbons. In addition, national emission standards for hazardous substances, including asbestos, beryllium and mercury were established. To date, no studies of organic chemicals in rainwater have been conducted on Long Island, although several are now being proposed. Since 1970 air pollution control has been a responsibility of the NYSDEC, with Nassau and Suffolk Counties acting as agents of the State and assisting in any necessary enforcement of regulations and standards.

Table 2–4

AVERAGE RAIN WATER QUALITY ON LONG ISLAND (MILLIGRAMS/PER LITER) – FIVE YEAR RECORD 1969 TO 1974
(Nassau County Environmental Planning Report, 1974)

Parameter	Mineola (average)	Upton (average)	Medford (average)
Nitrate-nitrogen	0.66	0.34	0.67
Ammonia as N	0.48	0.17	0.43
Total N as N	1.14	0.51	1.10
Sulfate	6.67	3.54	3.43
pH	5.08	4.41	4.44
Chloride	2.00	1.65	3.04
Sodium	1.17	1.08	1.68

2.2.13 Sand and Gravel Mining

The extent of sand and gravel mining on Long Island is uncertain. Although figures for presently mined acreage are available, an inestimable acreage of small pits exists which were mined for a short period and then abandoned.

For the most part, large sand and gravel operations are located in the hilly areas of Long Island, where mining can proceed laterally into the hillside. Vertical pit mining is prevalent only where a significant depth can be attained before the water table is reached. Large sand and gravel mining operations exist in Port Washington, Oyster Bay, Plainview, Melville, East Commack, Nesconset and Half Hollow Hills.

The practice of sand and gravel mining does not in itself present a significant ground water pollution threat. The few cases reported elsewhere in which pollution actually occurred involved noticeable changes in turbidity in wells at or adjacent to the mined site. One of the most desirable traits of ground water is its generally low turbidity.

A greater threat to ground water at sand and gravel mining sites is from pollutants which have been introduced into the pits. Abandoned pits serve as attractive but illegal disposal sites for domestic, industrial and scavenger wastes. Although no reported cases of ground water pollution from illegal dumping have been reported on Long Island, such dumping is suspected to occur. Careless handling of materials at sand and gravel sites, for example, where road salt or petroleum fuels are stored, can cause these materials to enter the ground water.

The principal cause of ground water pollution at sand and gravel pits has been the use of brackish and salty water to wash the fines from the mined material. Salt water pumped from bays is spread on the land surface or stored in ponds where it can leach to the underlying fresh ground water (Swarzenski, 1963).

Under the recently enacted New York State "Mineral Resources (Mine Reclamation) Act" (1975), a mining operator removing more than 1,000 tons of minerals in a month is required to have a permit to operate. In the application for a permit, the operator must describe his plans for reclamation at the site. A bond, posted upon issuance of the permit, assures NYSDEC that reclamation is executed.

2.2.14 Scavenger Waste

Scavenger waste pits are open, unlined seepage ponds for disposal of liquid and sludge waste from septic tanks, cesspools, and municipal and industrial sources. On Long Island, each town has a designated location for scavenger waste; most usually near landfill sites or sewage treatment plants. Suffolk County has eight major waste pit areas discharging directly to ground water. However, a large percentage of the sludge generated by the County's municipal treatment plants is trucked to five scavenger waste treatment plants, located in Islip, Huntington, Babylon, Kings Park and Brookhaven. Nassau County septic tank waste goes directly to municipal treatment plants, while coastal treatment plants usually dispose of sludge at a prescribed disposal area in the ocean.

These sludges and liquid wastes are most frequently a problem when high loading rates exceed the lagoon's holding capacity, resulting in clogging of the lagoon's surface and overflows. Misdemeanor charges have been filed against one Suffolk County town which failed to correct the overloading of a scavenger waste disposal site under its jurisdiction.

SPDES permits must be obtained for authorized treatment plants, but as yet there are no controls over random scavenger waste dumping into pits.

2.2.15 Diffusion Wells

On Long Island, the NYSDEC requires all water used for cooling to be pumped through a completely closed system and then returned to the source aquifer through one or more diffusion wells or equivalent structures. Depending upon the cooling system, the water is raised 10° to 40° F above the natural ground water temperature (DeLuca, 1975).

Ground water temperatures to a depth of about 200 feet are usually 3° to 6° F warmer than the average annual air temperature. Below that depth, the natural gradient is approximately 1° F increase for each 60 to 125 feet of depth (Hoffman, 1958). In the bi-county area, natural ground water temperatures range from about 50° to 70° F.

In the 208 area, thermal loading has been observed in a number of industrial areas where large quantities of hot water are returned to the ground. Observations have been documented in Hicksville, Lake Success, Syosset and Smith Haven. Undoubtedly, there are many other occurences that are not documented.

NYSDEC data on diffusion wells are reported by a number of installations, and each installation may include more than one diffusion well. In 1976, 306 installations in Nassau County returned 4,500 million gallons of cooling water through wells.
In 1974, 183 installations in Suffolk County returned 3,000 million gallons (NYSDEC, 1977). The total is approximately 7,500 million gallons per year or 20.5 million gallons per day.

The return of cooling water to the ground as a source of recharge has been considered an environmentally beneficial practice and not a source of pollution on Long Island. Consequently, institutional activity has been directed toward encouraging the use of diffusion wells rather than their control. More water quality data is needed to determine whether this policy is justified.

2.2.16 Water Wells

Water wells themselves are not normally sources of contamination, except in cases of improper construction, well failure, and in a few instances, use of the well. Some of the most common conditions that might result in contamination of ground water are given in Table 2–5.

Table 2–5

EXAMPLES OF CONDITIONS UNDER WHICH WATER WELLS CAN CAUSE GROUND WATER CONTAMINATION

Imperfect Construction	Inadequate surface protection Poor or no grouting Well finished at or below land surface Open annulus around casing
Illegal Construction	Poor location Split screen where prohibited by situation Improper abandonment of well Improper backfill of test holes
Well Failure	Casing corrosion Casing electrolysis (chemical) Stray currents in ground Accidental holing of casing during construction or maintenance
Well Use	Direct recharge of contaminant Movement of contaminants caused by pumping Salt water intrusion

Since 1940, there have been 9,040 permits issued by the NYSDEC to drill wells in Nassau County and 60,280 in Suffolk (NYSDEC, 1977). Most of the wells, however, were drilled since 1960. In the bi-county area, there are an estimated 750 public-supply wells, 840 industrial and commercial wells, and 440 agricultural wells.

Domestic wells are usually of a small capacity (45 gallons per minute or less) and six inches or less in diameter. Typically they are installed as shallow as water table conditions and local regulations permit. Agricultural wells, on the other hand, are usually of a high capacity (500 to 1,500 gallons per minute), but are also constructed as cheaply as possible and as shallow as possible. Since cost is often of prime importance, little is done to secure these

wells from contamination. Both domestic and agricultural wells are rarely, if ever, cemented in place or sealed at the land surface. Consequently, surface and ground water percolation outside the casing to the water table may take place. Such percolation may introduce pesticides, fertilizers, septic effluent or other contaminants to the ground water.

Industrial and commercial wells are normally constructed more carefully, although the water is used principally for cooling. Diffusion wells, discussed in another section, are wells designed to return cooling water to the ground and are constructed to less stringent standards than most industrial pumping wells. Public supply wells are the best constructed, in some cases with double casings combined with cement grout.

Modern construction and proper inspection during installation generally minimize the chance of contamination due to improper design or structural failure. The gravel packing and backfill are sterilized with chlorine compounds, and upon completion the entire well is disinfected. Casings and wells are inspected for structural integrity, and the volume of gravel or grout used is carefully checked to avoid the creation of voids or openings that might allow vertical migration of contaminated water. In many cases, however, the annular space between the outside wall of the drilled hole and the inside casing are backfilled with the natural material that was removed from the hole, and grouted only near the surface. Migration of contaminants along this annular space between the well casing and natural sediments may be an important source of contamination for deeper wells in Long Island.

Separate screens in the same well are generally prohibited in permitted wells on Long Island if the screens are set opposite different aquifers. However, it is possible for a single formation to have beds of different permeabilities. The Magothy, for example, is considered a single aquifer, but contains a number of water-bearing zones separated by confining layers. If one such zone were contaminated, the pollutants could move through a well with mutiple screens to contaminate other zones.

Another way in which a well can become a vehicle for contamination is through improper abandonment. If the well is not filled with impermeable or low permeability materials, the open casing can provide easy access for contamination to move down to the aquifer tapped by the well. Contaminants can enter at the surface or through a break in the casing. When a well is unused, flooding with surface water and even deliberate dumping of various, sometimes toxic, substances into the well can occur. Once in the well, contaminants can enter the ground water either through the well screen or other breaks in the casing.

The Safe Drinking Water Act shall ultimately ensure stricter surveillance of public supply wells and those industrial or commercial wells providing potable water, principally through increased sampling requirements. However, there exists little opportunity for surveillance of construction of private, domestic and agricultural wells other than the requirement that they be constructed by a licensed well driller.

2.2.17 Spills and Incidental Discharges

Carelessness and poor housekeeping account for a large percentage of the spills and incidental discharges of contaminants that occur in the bi-county area. Their occurrence is random and frequently not recorded. In most cases failure to confine the spilled material, and even cleanup methods themselves, increase the probability of ground water contamination.

For instance, when accidents occur, especially when hazardous flammable products are involved, the fire department normally washes down the road. This procedure moves the flammable substance from the road surface to unpaved surfaces or sewers, or catch basins where it may seep into the ground.

The principal causes of spills are summarized below:

Industry	Mishandling of delivered or stored chemicals on-site
	Spills or accidents involving trucks containing industrial chemicals
	Miscellaneous discharges to the ground of waste products that cannot be disposed of in other ways
	Surface discharge of blowdown water from stacks and boilers that contain chemical additives which inhibit corrosion and scaling, but are otherwise harmful
Sewage	Major breaks in sewer lines (particularly force mains) which would allow rapid incidental discharges to the land surface
	Handling accidents or lagoon breaks and overflows at sewage treatment plants or scavenger waste plants
	Dumping by scavenger waste trucks in deserted areas because it is inconvenient to haul to a designated area
	Sewage discharges in violation of the Sanitary Code
	Railroad cars
Agriculture	Mishandling of chemical fertilizers and pesticides on the farm
	Disposal of chemical fertilizers and pesticides on the farm
Petroleum Products	Spills during loading/unloading of truck tankers
	Incidental discharges which result at the completion of the filling of service station tanks

Spillage during home heating deliveries when the tank is overfilled or when the hose is rolled up
Mishandling and disposal of waste crankcase oil
Dumping of sludge on-site after tanks are cleaned
Spills from carelessly attended motor vehicles in service stations

At the county level there is little opportunity for direct regulatory control over spills; the SCDEC reports that efforts to introduce legislation to improve the situation have not been successful. Procedures associated with state regulations are such that up to six months may be required to prepare documents needed for enforcement. Locally, the Nassau County Fire Marshal and individual fire districts adhere to guidelines developed by the National Fire Protection Association, which provide only limited controls in the event that a spill directly endangers public safety.

2.2.18 Animal Wastes

Statistics provided by the U. S. Department of Agriculture Soil Conservation Service in its 208 report "Animal Waste Control Alternatives, Nassau and Suffolk Counties, New York," show that the animal population of the region is sufficiently diverse and numerous to add to the BOD, COD, bacterial, nitrogen and phosphorus content of ground water (U. S. Soil Conservation Service, 1977).

SCS estimates that in the bi-county area there are approximately 258,000 cats; 425,000 dogs; 30,000 horses; 121,000 chickens; 1,800 cattle; and numbers of turkeys, swine and sheep. In addition, there may be as many as 750,000 market ducks.

The SCS report emphasized the effect that this animal and bird population has on surface water. However, it should be noted that dog waste carried in street runoff may finally end up as available for infiltration through storm water basins rather than in bodies of surface water.

Regulations controlling disposal of animal wastes, other than those associated with cattle feedlots, are non-existent in the United States. Some cities have established restrictions aimed at curbing dog owners from allowing their pets to defecate on sidewalks, but these ordinances are largely ineffective and do not protect ground water.

2.2.19 Cemeteries

There are 94 cemeteries larger than two acres, and many smaller ones scattered through the bi-county area. Of the 94 larger cemeteries, 25 are in Nassau County, covering about 1,510 acres, and 69 are in Suffolk County, covering about 2,920 acres. Combined, both counties have about seven square miles of land used for cemetery purposes.

Most of the larger cemeteries in Nassau and Suffolk are situated inland where substantial depths to ground water exist. Ground water percolating downward, therefore, receives considerable filtration prior to reaching the water table. Also, the potential threat to ground water depends upon the type of burial, *i.e.,* casket construction and use of vaults. There are no known field studies involving drilling and sampling on Long Island to determine the effects of cemeteries on ground water quality.

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2.3 GROUND WATER QUALITY

2.3.1 Background

This section of the interim report characterizes present ground water quality conditions by aquifer, with major emphasis on nitrate. Nitrate is used as an indicator of water quality trends because of the availability of historical data. Also, nitrate is a potential contaminant that is associated with almost all of the waste disposal practices that have been of prime importance in the Long Island 208 area. Trends of other selected constituents are presented if there is sufficient information for analysis. Available heavy metal data are examined with a preliminary evaluation of the distribution of these contaminants.

Heavy reliance has been placed on the data presented in many previous reports describing ground water conditions in the bi-county region. It is beyond the scope or purpose of this document to evaluate the validity of the data used in each of these reports. Instead, it is the intent to summarize and build upon those studies which after examination appear to reach reasonable and significant conclusions. Many investigations of the U. S. Geological Survey are cited, especially the water quality study which was done as part of the 208 program (Ragone, 1976a). In that report, thousands of analyses are organized according to such factors as depth of the well sampled and its location in a sewered or non-sewered area.

2.3.2 Summary

1. For the period 1972–76, median concentrations of nitrate-nitrogen exceeded eight milligrams per liter in water from nineteen of 127 selected Upper Glacial wells in Nassau. Wells yielding water with relatively high nitrate are fairly widely distributed throughout the county, with the exception of the northwest portion where values are slightly lower. In western Suffolk, nine of 85 selected Upper Glacial wells yielded water with median concentrations above eight milligrams per liter. In Upper Glacial wells on the North Fork, water from six of seven selected wells had nitrate exceeding eight milligrams per liter, and on the South Fork, water from thirteen of 92 selected wells had nitrate greater than this level. These well ratios give a general indication of the magnitude of the nitrate problem in the respective areas.

2. Water quality data from streams and shallow wells, as well as from the infiltration galleries in Wantagh and Massapequa, indicate that elevated concentrations of nitrate in the shallow ground waters of Nassau and western Suffolk are widespread. However, nitrate concentrations in most of the shallow aquifers are below the ten milligrams per liter standard for drinking water.

3. Changes in overall medians, as well as statistical analyses of nitrate trends in water from selected wells in the shallow ground water aquifer, indicate that concentrations are generally decreasing in Sewer District Two. There is some evidence that this decrease is due to sewering, but this relationship is not clear cut. Despite generally decreasing trends, the actual concentrations in some wells are still quite high. Using the criteria established in this report, there is insufficient data to make a determination regarding nitrate trends in eastern Nassau. However, a recent study of the quality of water from the infiltration galleries in eastern Nassau County indicates that nitrate concentrations have stabilized or are decreasing in concentration. Nitrate concentrations in shallow wells in southwestern Suffolk are generally increasing.

4. For the period 1972–76, median concentration of nitrate-nitrogen in Nassau exceeded eight milligrams per liter in the Magothy aquifer in six of 40 selected wells at depths of less than 200 feet; in five of 115 wells at 200 to 399 feet; in four of 174 wells at 400 to 599 feet; and in zero of 38 wells below 599 feet. Most well water exceeding eight milligrams per liter nitrate-nitrogen is in central Nassau.

5. On the basis of other recent studies, nitrate in water from most Magothy wells in Nassau appears to be increasing.

6. Evidence suggests that regional hydrologic and geologic factors are important in controlling the movement of contaminants from the surface to the Magothy aquifer. The present distribution of nitrate and chloride levels in the Magothy indicates that certain broad areas are more susceptible to pollution from the surface than other areas. In general, the southern portion of much of both counties appears to be an area in which shallow ground water flow helps protect the middle and lower Magothy from sources of contamination by restricting downward movement of water into the Magothy.

7. Despite the relatively low mobility of heavy metals in soils, low concentrations of such constituents (below EPA Interim Primary Drinking Water Standards) are widespread in shallow ground water. Elevated levels of some metals also exist in certain Magothy wells.

8. In most areas, the Lloyd aquifer is protected from contamination within any reasonable planning period by the overlying Raritan clay. There is water quality evidence, however, that suggests some degree of hydraulic connection with shallow deposits in portions of the north shore of Nassau County.

9. Special studies conducted as part of the Long Island 208 program included a virus survey and an investigation of the presence or probable absence of organic chemicals in ground water. Enterovirus species were not isolated in the few samples of ground water obtained from public supply wells. Sampling for organic chemicals, however, has revealed the presence in ground water of substituted benzene compounds, napthalenes and various butyl-phthalates. Volatile organic compounds were also detected at parts-per-billion concentrations.

10. Evaluation of water quality conditions in the Long Island 208 region is difficult because of the lack of monitoring programs designed to answer specific waste water management questions pertaining to such subjects as the inter-aquifer migration of organic and inorganic chemicals, the local and regional impact of various densities of domestic waste disposal systems on ground water quality, and the position of the fresh water/salt water interface offshore.

2.3.3 Water Table Aquifer

2.3.3.1 Geology and Aquifer Characteristics. The water table or uppermost aquifer on Long Island receives most of the contaminants originating at the land surface. This aquifer consists primarily of Upper Glacial deposits and includes some sediments of the Magothy formation, the Manetto gravel and recent deposits. Because it is shallow, the aquifer has become contaminated to various degrees and, in some places, is unsuitable for use as a source of potable water supply. The ground water found in these sediments is of special importance because in many areas it supplies water to the deeper Magothy formation, and over a long period of time recharges the Lloyd aquifer. In addition, streams in Nassau and Suffolk Counties are largely dependent on flow from shallow ground water and closely reflect its quantity. Significant input to the bays and to salt water bodies is also derived from the water table aquifer by underflow.

To a large degree, the surficial geology influences the rate at which water infiltrates into the ground and percolates down to the water table. For example, outwash deposits make up most of the southern portion of the island. These sediments are very permeable sands and gravels, with an estimated average horizontal hydraulic conductivity of about 270 feet per day (Franke, 1972). Vertical permeability is estimated to average about 27 feet per day. Specific capacities of wells are usually more than 50 gallons per minute per foot of drawdown. In contrast, where deposits of clay and till are found, they impede infiltration and downward percolation of water, and locally may create perched water conditions. Two documented cases of widespread perched conditions include the Glen Cove-Brookville-Syosset area (Isbister, 1966), and parts of the Huntington-Smithtown area (Lubke, 1964).

Once the water enters the saturated section of the aquifer, movement is controlled by natural and artifical flow operating in the system. In general, water in the shallowest aquifer near the ground water divide of the island has potential gradients which tend to carry some of the water vertically downward to the deepest part of the Magothy. South and north of this zone, water in the shallow deposits flows with vertical and horizontal components that result in some water moving into the middle portion of the Magothy. Farther toward the coastlines, circulation becomes shallower until, at some point, flow is essentially horizontal in the water table aquifer. A detailed study of the shallow ground water flow system or subsystem of East Meadow Brook showed that it might take 25 to 30 years to fully flush this subsystem of the water in storage (Franke, 1972). Ground water flowing between stream subsystems could take somewhat longer to reach salt water bodies.

Based on estimated flow rates in the Upper Glacial aquifer, the quality of water yielded by many shallow wells now reflects the quality of water that has entered the ground water system since the late 1940's. The exact age of water at these wells is probably extremely variable, depending on depth, location, permeability of the sediments at the particular site and the influence of pumping.

2.3.3.2 Ground Water Quality. Recharge to the water table aquifer is dependent upon precipitation, which has chemical characteristics of its own by the time it reaches the land surface. A study in 1974 reported values of selected constituents in rainwater at Upton, Mineola and Medford (Frizzola, 1974). Of particular interest are pH, with average values of 4.41 to 5.08, and total nitrogen, with average values of 0.51 to 1.14 milligrams per liter. Average values of the major constituents are given in Table 2–4.

Background or non-degraded quality of fresh ground water in the shallow sediments of Nassau and Suffolk Counties is very good. In general, the water can be characterized as soft, mildly corrosive, and in some cases, somewhat high in iron and manganese. A study conducted at Brookhaven National Laboratory, which classified various types of ground water and surface water at that site, reported the chemical composition for background shallow ground water (see Table 2–6).

Table 2–6

CHEMICAL COMPOSITION OF BACKGROUND SHALLOW GROUND WATER AT BROOKHAVEN NATIONAL LABORATORY (DeLaguna, 1966)

(All concentrations except pH and conductance in milligrams per liter).

Silica	8
Iron	0.2
Calcium	2
Magnesium	1.5
Sodium	4
Potassium	0.6
Bicarbonate	9
Sulfate	8
Chloride	5
Nitrate (as N)	0.11
Dissolved solids	36
Specific conductance	50
pH	6.0

Over the past few decades, widespread effects of urbanization have considerably altered the quality of ground water in the water table aquifer. Many studies have detailed the extent and magnitude of these effects with particular attention paid to nitrate, detergent, chloride and to a lesser extent, sulfate. These constituents are generally good indicators of contamination, particularly from two very common sources: sewage and fertilizers. Median concentrations of these parameters, with the exception of detergents, in Nassau and Suffolk for the period 1972–76 are given in Table 2–7. DeLaguna reported the range of sulfate and chloride in "normal" water at Brookhaven

Table 2–7

CONCENTRATIONS OF SELECTED CONSTITUENTS IN WELLS IN THE UPPER GLACIAL AQUIFER, 1972–76
(Based on Ragone, 1976)

	Median		Mean	Range		
Southwestern Nassau						
Nitrate (as N)	4.9	(159)	4.8	0.04	–	14
Chloride	28	(164)	43	6.6	–	950
Sulfate	44	(128)	47	5.0	–	120
Northern and Eastern Nassau						
Nitrate (as N)	3.0	(259)	4.3	0.00	–	36
Chloride	19	(309)	83	1.3	–	14,000
Sulfate	30	(259)	30	0.00	–	450
Suffolk						
Nitrate (as N)	1.4	(1,273)	2.3	0.00	–	23
Chloride	12	(2,047)	20	0.10	–	2,600
Sulfate	9.2		19	0.00	–	470

Note: The number in parenthesis indicates the number of analyses, concentrations in milligrams per liter.

to be 2.6 to 19 milligrams per liter, and 3.8 to 8.9 milligrams per liter, respectively (DeLaguna, 1964). It is likely, however, that these ranges include some slightly contaminated water.

Wells in the water table aquifer, which yield water showing distinct effects of contamination, are widely distributed throughout Nassau County and over much of Suffolk. The regional distribution of nitrate in central and southern Nassau during the period 1966–70, as reported by Perlmutter and Koch, is shown in Figure 2–21. Particularly high levels (greater than nine milligrams per liter nitrate-nitrogen) were found in the Elmont-New Hyde Park-Williston Park area, the Bellmore-East Meadow-Levittown-Hicksville area, and in several other locations. An examination of nitrate concentrations in the northern part of the county for the 1972–76 period, as reported by Ragone, shows high median values (greater than five milligrams per liter nitrate-nitrogen) in Bayville, in Syosset and in the area just east of Hempstead Harbor (Ragone, 1976a). During the period 1966–70, the average nitrate-nitrogen content of ground water in the shallow aquifer in central and southern Nassau was found to be 6.3 milligrams per liter in the sewered area, and 8.1 milligrams per liter in the unsewered area. The discrepancy between this data and that presented in Table 2–7 is probably due to the fact that the 1976 study included many deep Upper Glacial wells from the north shore in the unsewered area.

Nitrate in Suffolk County is well above background concentrations in the western portion of the county and elsewhere in the vicinity of densely populated areas. (Data in the central portion of western Suffolk, near Half Hollow Hills, however, is scarce.) Median concentrations of nitrate-nitrogen in the Babylon-Islip area, for instance, typically ranged from about two to ten milligrams per liter during the period 1972–76. Areas of present and past agricultural use, including the area north of Riverhead, the North Fork and parts of the South Fork, show high concentrations of nitrate. Many wells in these areas have median concentrations in the five to ten milligrams per liter range or greater for the period 1972–76. DeLaguna found that nitrate-nitrogen in private wells in potato farming areas of East Marion, Southold, Cutchogue, Mattituck, Riverhead, East Hampton and Sagaponack were betweeen 4.5 milligrams per liter and 27.1 milligrams per liter, with an average of about nine milligrams per liter.

Of special interest are those wells that recently have yielded water containing nitrate-nitrogen concentrations that exceed or are very close to exceeding the EPA standard of ten milligrams per liter. An examination of median levels in wells reported by Ragone for the period 1972–76 shows that nineteen wells of a total of 127 Upper Glacial wells sampled in Nassau County have median nitrate-nitrogen levels greater than eight milligrams per liter. Wells with high nitrate values are fairly widely distributed throughout the county, with the exception of the northwest portion where levels are slightly lower (Figure 2–22). During the period 1967–71, 42 wells sampled in Nassau County had median nitrate-nitrogen concentrations exceeding eight milligrams per liter.

In western Suffolk (west of Smithtown), nine wells of a total of 85 wells sampled yielded water with median concentrations above eight milligrams per liter. Most of these wells are in the southwest portion of the county (Figure 2–23). On the North Fork, six wells of a total of seven wells, and on the South Fork thirteen wells of 92 wells exceed eight milligrams per liter nitrate. Well water with a five year median nitrate greater than eight milligrams per liter has probably exceeded the ten milligrams per liter drinking water standard at some time during that period. Portions of the aquifer in the immediate vicinity of these wells, and possibly over broad areas around the wells, are unsuitable for development of potable water supplies without treatment.

It should be noted that nitrate-nitrogen in shallow ground water is not necessarily the same as total nitrogen. Significant amounts of ammonia may be present in certain areas, especially those with numerous septic systems and a high water table. In these cases, there has been insufficient time and travel for ammonia to become fully oxidized to the nitrate form.

Chloride and sulfate distributions in the water table aquifer have not been studied as extensively as nitrate. In many cases, they show similar

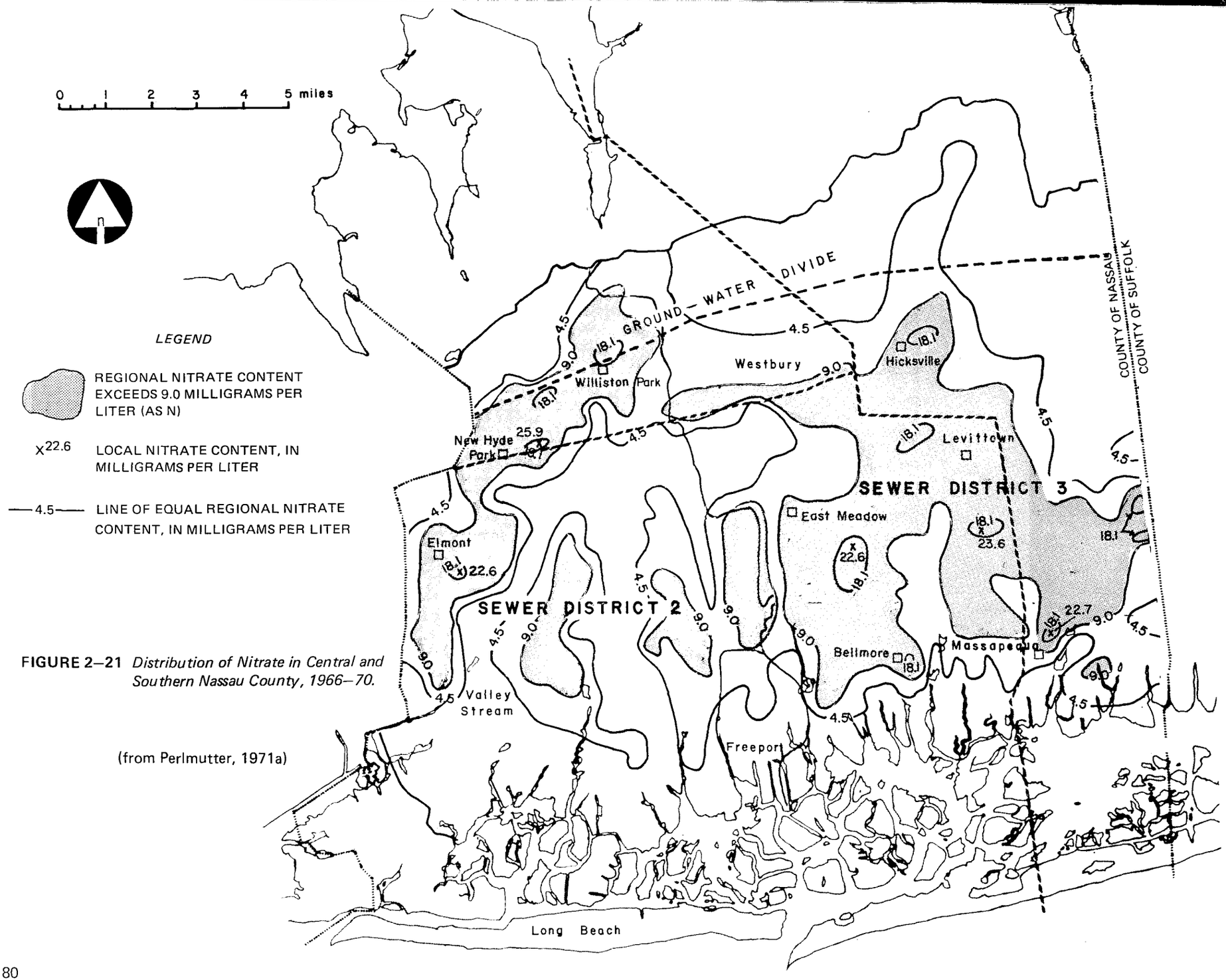


FIGURE 2–21 *Distribution of Nitrate in Central and Southern Nassau County, 1966–70.*

(from Perlmutter, 1971a)

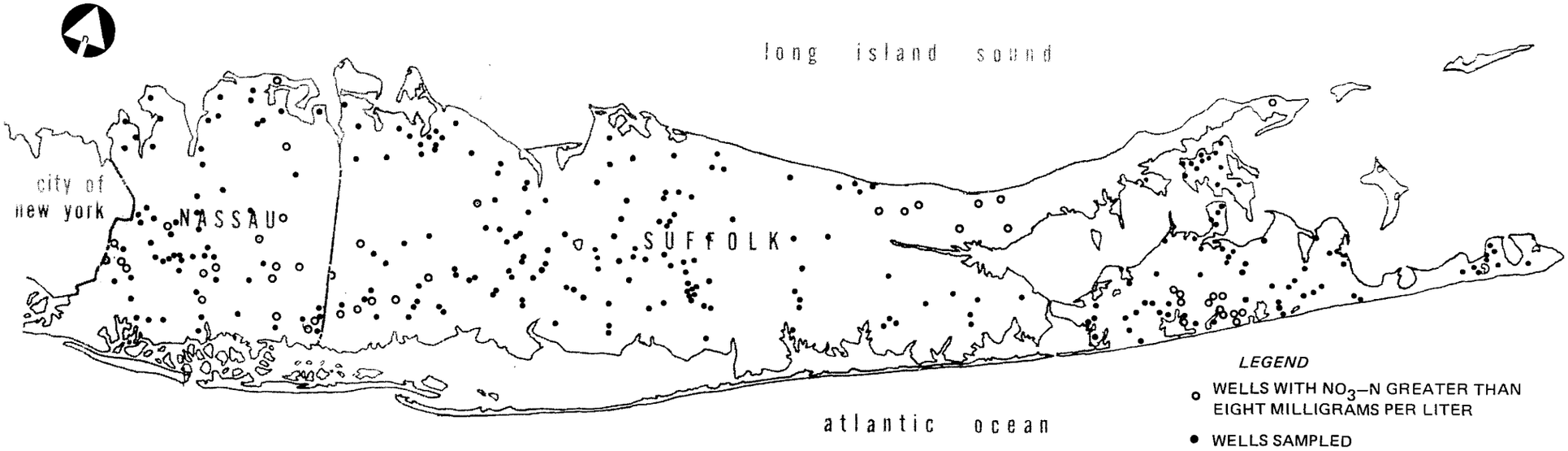
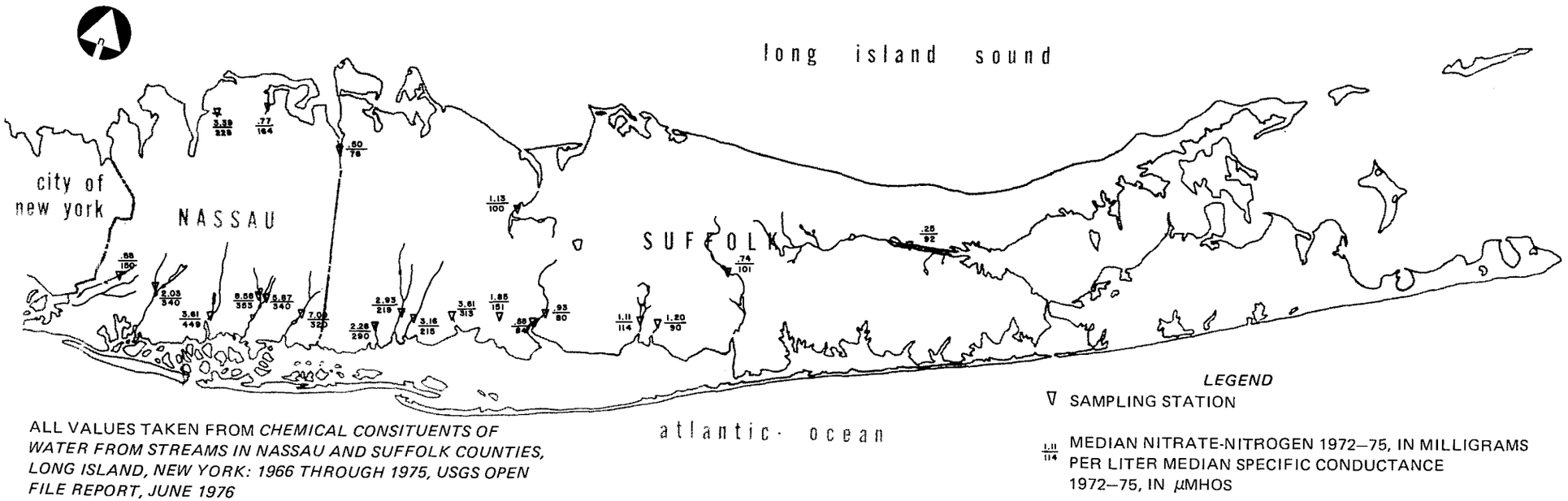


FIGURE 2–22 *Upper Glacial Wells with Median Nitrate Levels Greater than Eight Milligrams per Liter 1972–76.*



ALL VALUES TAKEN FROM *CHEMICAL CONSITUENTS OF WATER FROM STREAMS IN NASSAU AND SUFFOLK COUNTIES, LONG ISLAND, NEW YORK: 1966 THROUGH 1975, USGS OPEN FILE REPORT, JUNE 1976*

FIGURE 2–23 *Median Nitrate-Nitrogen and Specific Conductance Concentrations in Streams in Nassau and Suffolk Counties, 1972–75*

increases in areas where nitrate concentrations have also risen. Their ratios, however, may differ, depending on the pollution source. Unaltered water in the Babylon-Islip area has a chloride content of five to six milligrams per liter in areas more than about two miles inland from Great South Bay (Pluhowski, 1964). Closer to the bay, concentrations of ten to fifteen milligrams per liter are common. This general relationship probably applies to many areas in Nassau and Suffolk Counties.

An especially good indication of the quality of shallow ground water in southeastern Nassau is reflected by the chemical analyses of water from the infiltration galleries in Wantagh and Massapequa. These galleries make up part of New York City's Ridgewood System which extends along southern Nassau County. During the period 1961–75 the range in concentrations of selected constituents was found to be as follows (Sulam, 1977b):

	Wantagh Area	Massapequa Area
Nitrate (as N)	6.9 – 9.2	4.2 – 7.8
Chloride	23 – 44	22 – 43
Total Solids	190 – 249	188 – 228
Hardness (as $CaCO_3$)	73 – 94	44 – 88
Alkalinity (as $CaCO_3$)	38 – 87	32 – 64

Sulam and Ku report a recent leveling or decrease in nitrate trends in the Wantagh and Massapequa infiltration galleries located in unsewered southeastern Nassau County (Sulam, 1977b).

2.3.3.3 Trends of Ground Water Quality. Trends in nitrate from well water in the water table aquifer in Nassau are difficult to characterize on a broad basis because of the many sources and variables involved. Perlmutter and Koch (1971a) examined long-term trends of ten public supply wells in the Upper Glacial aquifer for the period 1955 to 1970 in Sewer District Two. Seven of the ten wells showed net nitrate-nitrogen declines ranging from 0.9 to 5.9 milligrams per liter, and averaging 3.8 milligrams per liter. The nitrate content of water in the other three wells showed no significant net change during the same period.

Statistical analyses of nitrate in selected wells throughout Nassau and Suffolk Counties were performed as part of the 208 program. Trends in nitrate are important not only in themselves, but also because associated contaminants may follow similar trends. The characteristics of wells selected for analysis were as follows:

a) relatively shallow depth, near the top of the saturated section
b) at least ten chemical analyses available
c) at least four years of analyses available (many of the wells have been sampled for ten to twenty years).

The nitrate-nitrogen levels for each well versus the time of sampling were plotted. This data was then matched to a polynominal regression up to and including a cubic equation. The equations were tested for statistical significance using the F Test (Fisher Index) beginning with the linear first, the quadratic second and the cubic third. In over half the cases, the test was significant at the 0.05 level, and the regression line explained the observed data reasonably well. The line was then examined for trends. Those wells showing statistically significant trends are given in Tables 2–8, 2–9, 2–10 and 2–11. Their locations are shown on Figure 2–24. Boundaries of sewered areas are included on this figure for reference.

Of 21 wells in Sewer District Two in Nassau, thirteen show decreasing trends of nitrate. Four have increasing trends. The median change in nitrate per year for all seventeen wells that have trends is –0.34 milligrams per liter. Eight of the wells indicate a similar pattern of increasing and then decreasing concentrations. The time of inflection, or change, from negative to positive

Table 2–8
NITRATE TRENDS IN WELLS IN SEWER DISTRICT TWO

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–14	103	24	52–59	+ 2.1			
			59–74	– 9.2	– 0.61	2	3.8(1974)
N–15	101	21	52–60	+ 2.1			
			60–74	– 7.4	– 0.53	2	4.7(1974)
N–75	24	24	52–58	+ 1.7			
			58–75	– 4.7	– 0.28	3	1.6(1975)
N–91	82	10	57–65	– 1.5	– 0.19	1	1.0(1965)
N–693	98	41	52–75	– 4.4	– 0.19	1	9.2(1975)
N–1167	25	19	66–72	+ 1.7			
			72–76	– 1.4	– 0.35	2	2.8(1976)
N–1428	24	13	66–72	+ 2.4	+ 0.40	1	5.1(1972)
N–2115	87	18	52–69	– 6.3			
			69–74	+ 0.7	+ 0.14	2	8.9(1974)
N–2414	89	22	52–59	+ 0.6			
			59–73	– 2.6	– 0.19	2	6.0(1973)
N–3722	80	21	52–61	+ 2.7			
			61–73	– 4.8			
			73–74	+ 0.8	+ 0.80	3	5.4(1974)
N–4077	90	25	54–62	+ 2.4			
			62–74	– 6.2	– 0.44	2	0.2(1974)
N–5155	90	17	55–66	+ 2.9			
			66–74	– 4.3	– 0.54	2	4.4(1974)
N–6744	94	15	60–74	– 4.8	– 0.34	1	5.3(1974)
N–8149	40	12	66–71	+ 11.7	+ 2.34	1	12.9(1971)
N–8235	53	13	66–76	– 4.8	– 0.60	1	7.3(1976)
N–8396	41	13	67–75	– 5.9	– 0.74	1	6.8(1975)
N–8395	23	12	67–71	– 8.2	– 2.10	1	4.5(1971)

Note: Four wells did not have statistically significant trends.

Table 2–9
NITRATE TRENDS IN WELLS IN SEWER DISTRICT THREE

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–1201	29	11	66–72	– 14.7			
			72–76	+ 0.6	+ 0.15	2	0.6(1976)
N–2402	85	18	52–54	– 1.3			
			54–63	+ 7.5			
			63–68	– 8.1	– 1.62	3	2.8(1968)
N–3564	69	19	52–59	– 1.3			
			59–71	+ 6.4	+ 0.53	2	14.4(1971)
N–7696	29	15	64–72	– 3.9	– 0.49	1	3.3(1972)
N–7699	30	14	66–70	– 4.8			
			70–72	+ 2.1	+ 1.05	2	1.0(1972)

Note: Six wells did not have statistically valid trends.

Table 2–10
NITRATE TRENDS IN WELLS IN NORTHERN NASSAU COUNTY

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–28	136	21	57–75	– 0.4	– 0.02	1	0.5(1975)
N–29	207	21	57–75	+ 0.9	+ 0.05	1	1.0(1975)
N–37	140	27	54–56	– 0.5			
			56–71	+ 3.7			
			71–76	– 1.8	– 0.36	3	3.8(1976)
N–585	78	18	54–60	+ 0.9			
			60–72	– 1.2			
			72–74	+ 0.3	+ 0.15	3	1.8(1974)
N–901	68	12	52–74	+ 5.6	+ 0.25	1	9.0(1974)
N–3486	102	16	54–61	+ 0.1			
			61–67	– 0.2			
			67–71	+ 0.6	+ 0.15	3	2.0(1971)
N–3540	207	21	57–73	– 2.5	+ 0.16	1	3.2(1973)
N–4860	93	25	57–75	+ 2.4	+ 0.13	2	3.1(1975)
N–6087	95	23	57–72	+ 2.3			
			72–75	– 0.3	– 0.10	2	3.2(1975)
N–7643	218	26	65–75	+ 13.5	+ 1.35	1	20.1(1975)
N–735	100	12	60–67	– 0.7			
			67–74	+ 1.2	+ 0.17	2	2.5(1974)

Note: Two wells did not have statistically valid trends.

Table 2–11
NITRATE TRENDS IN WELLS IN SUFFOLK COUNTY

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
S–871	104	20	63–69	– 0.4			
			69–76	+ 0.5	+ 0.07	2	0.7(1976)
S–2405	88	11	72–76	+ 1.5	+ 0.38	1	1.6(1976)
S–3813	83	23	63–76	+ 2.1	+ 0.16	1	2.3(1976)
S–3814	90	23	63–76	+ 1.9	+ 1.50	1	2.2(1976)
S–10641	62	17	63–76	+ 3.1	+ 0.24	1	3.8(1976)
S–12143	116	12	61–64	– 0.54			
			64–73	+ 3.9	+ 0.43	2	4.1(1973)
S–13558	106	13	63–73	+ 3.2	+ 0.32	1	3.2(1973)
S–14218	85	20	63–73	+ 2.1			
			73–76	– 0.2	– 0.01	2	2.3(1976)
S–15500	149	19	63–76	+ 1.5	+ 0.12	1	1.5(1976)
S–15501	160	19	63–76	+ 0.6	+ 0.05	1	0.8(1976)
S–18621	201	22	60–76	+ 0.8	+ 0.05	1	0.8(1976)
S–19554	105	22	62–66	– 0.4			
			66–76	+ 7.3	+ 0.73	2	7.7(1976)
S–20045	140	10	61–75	+ 0.5	+ 0.03	1	0.8(1976)
S–20057	200	19	65–76	+ 0.1	+ 0.01	1	0.1(1976)
S–20479	128	16	62–67	+ 4.0			
			67–72	– 0.6			
			72–76	+ 0.6	+ 0.15	3	4.0(1976)
S–20591	150	13	72–76	– 9.4	– 2.35	1	9.4(1976)
S–22494	118	10	72–74	+ 2.0			
			74–76	– 3.8	– 1.90	2	1.2(1976)
S–24047	132	16	65–76	+ 3.1	+ 0.28	1	3.2(1976)
S–26490	110	22	62–76	+ 4.8	+ 0.34	1	3.8(1976)
S–31913	160	13	68–76	+ 0.8	+ 0.10	1	1.2(1976)
S–34522	149	12	70–76	+ 0.8	+ 0.13	1	0.9(1976)
S–38917	–	10	72–76	0.0	0.0	1	0.1(1976)
S–47226	27	13	73–75	– 0.2			
			75–76	+ 0.1	+ 0.10	2	0.05(1976)
S–48946	45	13	73–76	– 5.3	– 1.77	1	1.5(1976)

Note: Wells S–20057 and S–38917 yield water at background concentrations. Nineteen wells did not have statistically valid trends.

slope occurred during the late 1950's or early 1960's in most of these wells and does not appear to be a drought related phenomenon. The change corresponds with large scale sewer construction which started in the early 1950's and was completed in 1964. Well 8149 shows an anomalous increasing trend, probably the result of a nearby source of contamination.

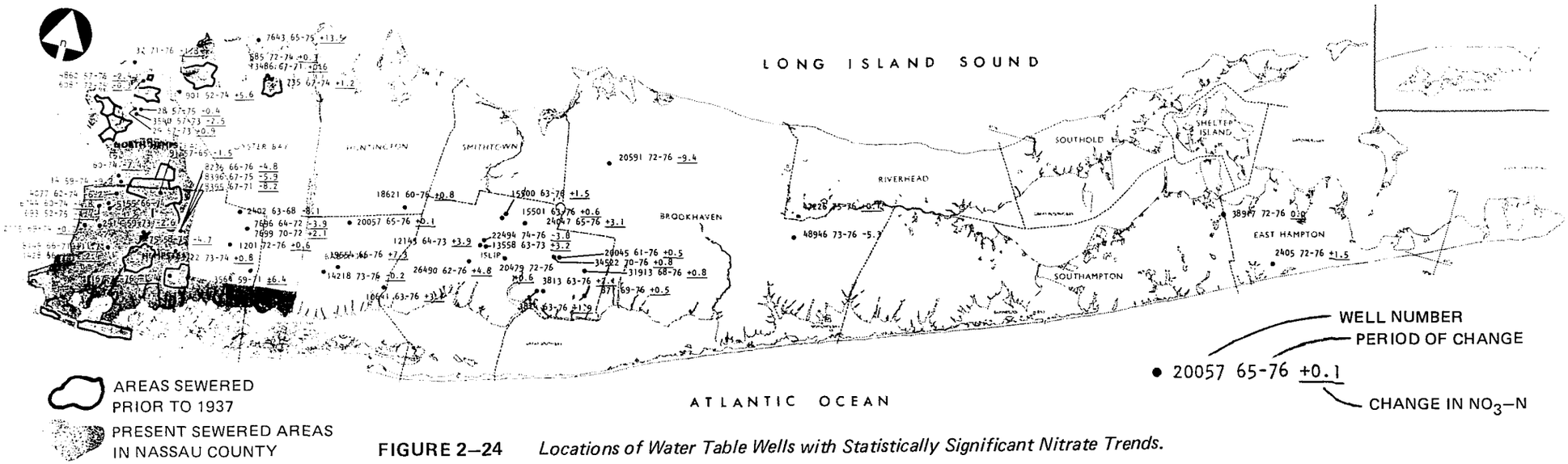


FIGURE 2–24 *Locations of Water Table Wells with Statistically Significant Nitrate Trends.*

Despite generally decreasing trends of nitrate in wells in Sewer District Two, the actual concentrations in some wells are still quite high. Possible explanations for this are (1) the sewers are leaking, (2) the use of home fertilizers is such an important input that removal of on-lot disposal systems alone results in only a slow decrease in nitrate levels, or (3) insufficient time has elapsed for even shallow wells to be flushed of high nitrate water. Detailed studies presently underway by the Cooperative Extension Service of Cornell University suggest that the fertilizer explanation is a strong probability. Studies on sewer leakage are not available.

Applying the criteria used in this report, the data in eastern Nassau County (Sewer District Three) are not sufficient to reach any conclusions regarding nitrate trends. Water analyses from three wells show increasing trends; analyses from two show decreasing trends. Wells in northern Nassau County generally show either small increases or small decreases in nitrate concentration.

An indication of the effects of sewering on ground water quality is provided by ongoing studies of the U. S. Geological Survey (USGS, 1977). Preliminary findings of continued evaluation of the information obtained during the preparation of the Ragone report for the 208 program (Ragone, 1976a) reveals significantly lower median concentrations of ammonia in shallow ground water underlying Sewer District Two compared to shallow ground water in Sewer District Three in Nassau County. Again, sewering was undertaken in District Two during the 1950's, whereas the installation of sewers in District Three is still underway. In addition, an evaluation of water quality trends in only the very shallow glacial deposits in Sewer District Two and Sewer District Three indicates stronger decreasing trends of nitrate in the former. These preliminary findings are indications of the results of a reduction in nitrate loading, apparently due to sewering.

Analyses of samples from 22 out of 43 water table wells in Suffolk that yield water with nitrate-nitrogen concentrations above background levels show significant nitrate trends. Of eighteen wells that show trends in south western Suffolk (Babylon and Islip), sixteen show increasing trends of nitrate – an indication of deteriorating water quality. The period of record for most of these wells started in the 1960's. For purposes of comparison, southwestern Suffolk is of interest because it is hydrologically similar to Sewer District Two. Recent land use is also similar, although development took place some years later. The 1960 census for the Town of Babylon indicates population densities ranging from 1.24 to 10.5, with an average of 4.5 persons per acre. The median change in nitrate per year in the eighteen wells in this part of Suffolk is +0.13 milligrams per liter. This suggests that the transition from a rural, partly agricultural area to an unsewered residential area may result in increasing nitrate in the shallow ground water.

2.3.3.4 Stream Quality. The quality of stream flow is a general indicator of the chemical nature of shallow ground water, since it is estimated that in many cases over 90 percent of the total discharge is actually ground water (Seaburn, 1969). Possible exceptions to this are streams in southwestern Nassau which receive more than ten percent of their flow from surface runoff as a result of urbanization (Vaupel, 1968). As part of the 208 program, median nitrate and specific conductance concentrations from 1972 to 1975 for many streams were computed and compared. Specific conductance is an indirect measure of the sum total of the major cations and anions, including nitrate, in the water. Its level is typically less than 50 μmhos in uncontaminated water on Long Island. A number of general conclusions can be drawn as a result of this analysis (see Table 2–12 and Figure 2–23):

1. Streams with the highest nitrogen and total dissolved solids are in southeastern Nassau County.
2. Stream water quality in southwestern Nassau County may indicate beneficial effects of sewering.
3. The general stream quality becomes better as one moves from southwestern to eastern Suffolk.
4. The ratios of nitrate-nitrogen to specific conductance vary considerably for different streams and indicate that different sources of pollution, in addition to sewage or fertilizer, are likely in certain areas.

Detailed examination of the data and correlation to given drainage areas could lead to more specific conclusions. For instance, the specific conductance in East Meadow Brook is unusually high and indicates a source of dissolved solids, possibly from road salt contamination. Other streams with fairly high specific conductance, but quite low ratios of nitrate to conductance, include Mill Neck Creek, Valley Stream and Pines Brook. It should be noted, however, that a small portion of nitrogen species in certain streams may be in the form of ammonia.

A qualitative assessment of trends of stream quality, in terms of nitrate and specific conductance, for the period 1966 to 1975, leads to several conclusions (Ragone, 1976b). Almost all streams in Nassau County show either no or very minor apparent trends. A number of streams, mostly in Suffolk, show minor or variable trends in nitrate, but slight to strong positive (upward) apparent trends in specific conductance. These streams include the Santapogue Creek, Carlls River, Sampawams Creek, Penataquit Creek, Champlin Creek, Connetquot River distributary, Lake Ronkonkoma, Nissequogue River and Cold Spring Brook. The Connetquot River shows an upward apparent trend in nitrate, but no or low apparent trend in specific conductance. The Patchogue River, Swan River and Carmans River show apparent upward trends in nitrate and specific conductance. The Peconic River shows no or low apparent trends of both constituents.

2.3.3.5 Detergents. Detergents have been widely studied in Nassau and Suffolk Counties, particularly with regard to domestic sewage. Prior to mid-

Table 2–12

QUALITY OF NASSAU AND SUFFOLK STREAMS

Stream	Median Nitrate-Nitrogen (mg/l) 1972–75	Median Specific Conductance (μmhos) 1972–75
North Shore (Nassau and Suffolk)		
Glen Cove Creek	3.39 (11)	228 (14)
Mill Neck Creek	0.77 (26)	164 (35)
Cold Spring Brook	0.50 (12)	76 (13)
Nissequogue River	1.13 (8)	100 (12)
Southwestern Nassau		
Valley Stream	0.88 (6)	150 (9)
Pines Brook	2.03 (9)	340 (11)
Southeastern Nassau		
East Meadow Brook (tributary)	3.61 (28)	449 (38)
Bellmore Creek (tributary)	8.58 (10)	353 (14)
Bellmore Creek	5.87 (12)	340 (14)
Massapequa Creek	7.00 (31)	320 (36)
Southwestern Suffolk		
Santapogue Creek	2.26 (13)	290 (15)
Carll's River	2.93 (14)	215 (16)
Sampawams Creek	3.16 (15)	215 (17)
Penataquit Creek	3.61 (14)	313 (17)
Champlin Creek (Oakdale)	1.85 (14)	151 (16)
Connetquot River	0.93 (12)	80 (15)
Connetquot River (North Great River)	0.88 (12)	84 (14)
Southeastern and Eastern Suffolk		
Patchogue River	1.11 (10)	114 (4)
Swan River	1.20 (10)	90 (12)
Carman's River	0.74 (29)	101 (36)
Peconic River	0.25 (12)	92 (24)

Note: The number in parenthesis indicates the number of analyses.

1965, ABS (alkyl benzene sulfonates) were a principal ingredient of detergents. They were replaced in household detergents by LAS (linear alkyl sulfonates), surfactants that are more biodegradable. In March 1971, Suffolk County prohibited the sale of most detergent products. Both LAS and ABS are detected by the methylene-blue test and are reported as MBAS (methylene blue active substance). Detergents, in themselves, are not known to be harmful, but serve as a good indicator of sewage related contamination and may render water supplies aesthetically undesirable. Concentrations of 0.7 to 1.0 may cause foaming of water, especially if pH is adjusted upward. The U. S. Public Health Service (1962) recommends that the concentration of MBAS not exceed 0.5 milligrams per liter.

A study of detergents in the central and southern parts of Nassau during the period 1966–70 showed that the area comprising the southern quarter of the county had detergent levels of 0.3 to two milligrams per liter (Perlmutter, 1971). The region to the north of this had a range of 0.0 to 0.3 milligrams per liter. Similar ranges of synthetic detergents were found in detailed studies in southwestern Suffolk County (Perlmutter, 1970).

An analysis of linear trends of both detergents and ammonia in water from eighteen Upper Glacial and shallow Magothy wells in Nassau County during the period 1960 to 1972 (Myott, 1975), showed that a decrease in detergents in both unsewered and sewered areas had occurred with a more negative trend for detergents in the sewered area. The trend line of ammonia was negative in the sewered area but was slightly positive in the unsewered area. Apparently, only the detergent trend line in the unsewered area was statistically significant. This analysis concluded that (1) both ammonia and detergents are decreasing in the sewered area as a result of sewering, and (2) detergents are decreasing in the unsewered area because the newer types of detergents are more biodegradable.

A similar study in the southwest portion of Suffolk County for the period 1968–74 showed an indication of decreasing detergents in shallow supply wells and streams while chloride was generally increasing (Baier, 1976). This decrease may be due to the detergent ban and increased biodegradability of newer detergents. Ragone found a general increase in chloride concentration in the last fifteen years in almost every stream examined in Suffolk County (Ragone, 1976c). Conversely, concentrations of MBAS decreased in many cases. Again, this difference is generally attributed to the change in the type of detergent and the 1971 detergent ban.

2.3.3.6 Heavy Metals and Pesticides. Investigations of heavy metals in ground water on Long Island have been much less extensive than those of the standard constituents. The 208 program summarized the available data to identify the occurrence and distribution of heavy metals. All ground water samples analyzed for heavy metals and listed in the U. S. Geological Survey STORET System as of February 1977, were reviewed at two levels of significance. The first is the EPA Interim Primary Drinking Water Standards recommended limits, for those constituents with established limits. The second is a much lower concentration, arbitrarily chosen to represent a very low level that is significantly above background concentrations in the majority of wells. At least 90 percent of the analyses are at concentrations below the lower limit.

The metals included in this analysis and their respective concentrations used as limits are as follows:

	Lower Limit (mg/l)	EPA Interim Standards (Primary and/or Secondary) Upper Limit (mg/l)
Cadmium	0.001	0.010
Chromium	0.010	0.050
Cobalt	0.001	no standard
Copper	0.200	1.00
Lead	0.010	0.050
Mercury	0.0007	0.002
Selenium	0.001	0.010
Zinc	0.300	5.00

The lower limits range from four percent to 35 percent of the upper limits. The samples were reportedly all taken at the well head, prior to entering the distribution system. Copper and zinc contamination from pipes and fittings, which may occur from movement in the distribution system, should be at a minimum.

Extensive conclusions regarding the sources and distribution cannot be made on the basis of present data because the wells sampled are not equally distributed, and many have only been sampled once. In addition, a number of wells, such as the "I" wells drilled near the Town of Islip landfill, were purposely located near a source of contamination. It is apparent that despite the relatively low mobility of metals in soils, low concentrations of such constituents are present in the shallow ground water (see Figure 2–25). In Nassau, several well locations have low levels of a number of metals. In Suffolk, there is a greater number of analyses showing low levels. This is perhaps related to the greater number of samples taken. Several low levels of mercury are evident in southwestern Suffolk. Low levels of arsenic, selenium and other metals are common in eastern Suffolk. These may possibly be due to past use of inorganic pesticides and herbicides. Preliminary results of a 208 study by Energy Resources Company (ERCO) have shown that very low levels of most heavy metals are found in ground water within the bi-county area. Lead and mercury were the only heavy metals that were found in a number of samples at concentrations near or above EPA Interim Standards. However, zinc and copper were not included in the ERCO evaluation.

There are numerous sources of metals in the environment. Obvious sources are certain industrial discharges, landfills and storm water runoff. In addition, there is evidence that sewage from residential areas also contrib-

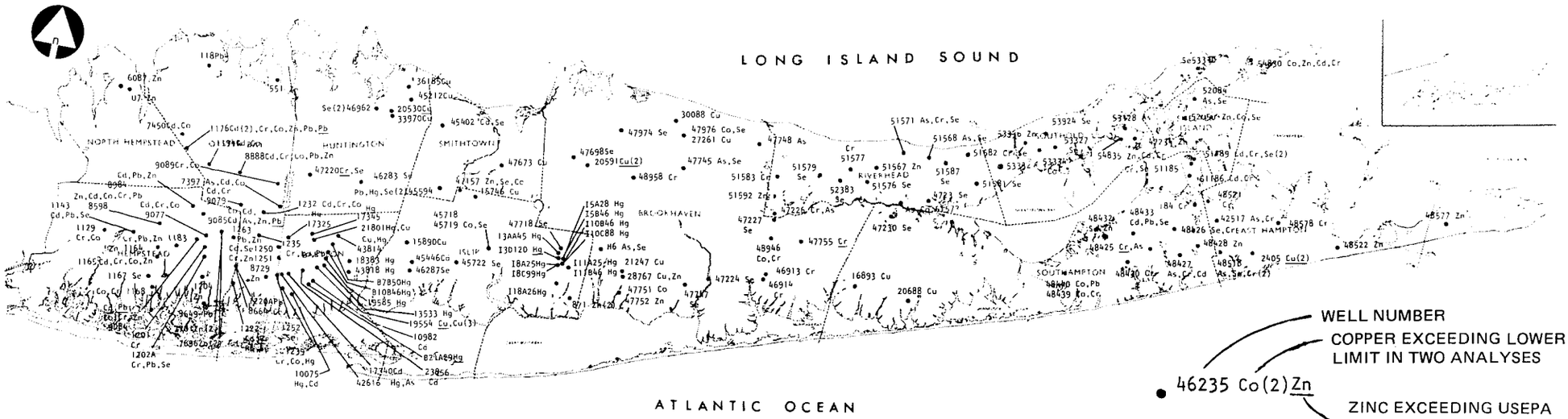


FIGURE 2–25 *Locations of Upper Glacial Wells with Reported Concentrations of Heavy Metals.*

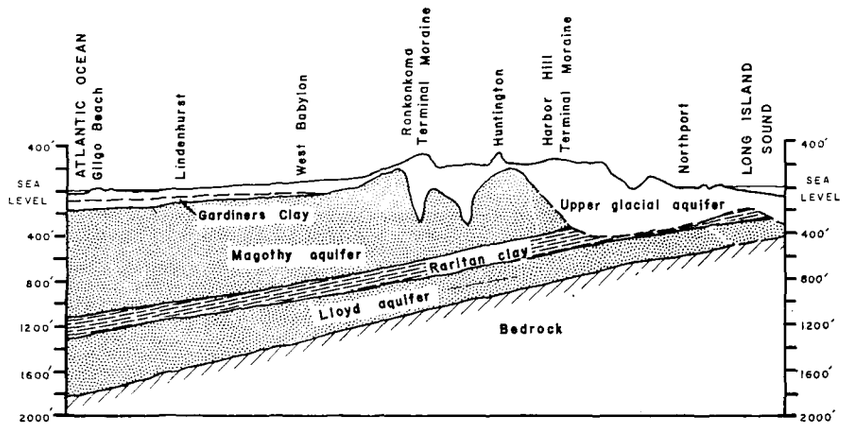
utes significant amounts of certain metals to the ground (Maher, 1974). Undoubtedly, some of these metals, such as copper and zinc, are dissolved from the water supply and waste water distribution system itself.

Several limited investigations of pesticides in ground water on Long Island have been undertaken in recent years. Harr presented analyses of 40 samples taken from selected wells in Nassau and Suffolk Counties in 1972 (Harr, 1972). Commonly used insecticides, herbicides and polychlorinated biphenyls were analyzed. Although no conclusions were reached, it is evident that the great majority of samples did not contain constituents in concentrations above the detectable limits. Another more comprehensive study investigated pesticides in 191 shallow test wells in Suffolk County (Baier, 1976a). Very few samples contained pesticides at detectable limits. Only one of these wells showed evidence of pesticides in replicate samples. It was concluded that pesticides should not be considered a major ground water pollution problem; although new products with higher solubilities, greater mobility or greater persistence, could be a problem in the future. It has also become apparent that some of the pesticides used on Long Island, such as aldicarb, may not have been included in the prior analyses.

2.3.4 Magothy Aquifer

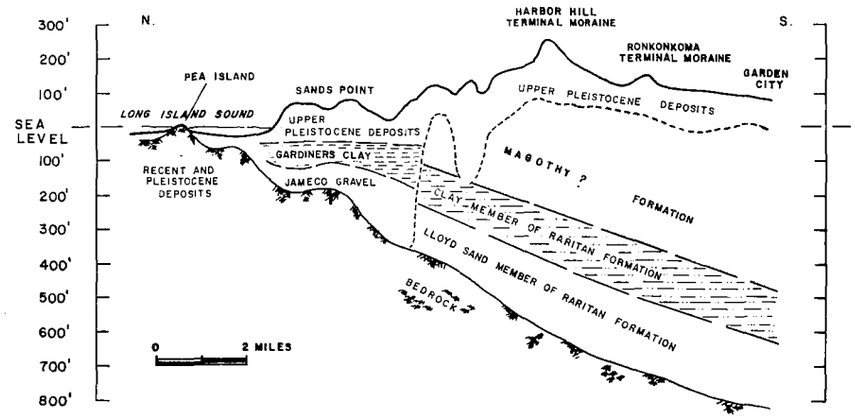
2.3.4.1 Geology and Aquifer Characteristics. The Magothy aquifer generally underlies the Upper Glacial aquifer with some outcropping at the surface. Magothy sediments are Cretaceous in age and of fluvial or deltaic origin. The aquifer is chiefly composed of undifferentiated deposits of coarse to fine sand and gravels with lenses of interbedded silts, clays and lignite. Its surface is highly irregular due to erosion by streams and glaciers. North-south trending buried valleys occur from Queens County eastward, verifying the idea that a substantial surficial drainage system existed some time after deposition occurred. The geology of the Magothy on Long Island has been mapped in greatest detail in Nassau County and western Suffolk County. A cross section through western Suffolk, illustrating several important regional geologic relationships is given in Figure 2–26.

The Magothy is absent in northwest Nassau County but increases in thickness to over 1,000 feet in the southern part of Suffolk County. Hydraulic conductivities vary widely, with the average horizontal conductivity estimated to be about 50 feet per day, while the average vertical conductivity is about 1.4 feet per day (Jensen, 1976). Consequently, specific capacities of wells also vary widely, from one to about 40 gallons per minute per foot of drawdown. Wells in the Magothy commonly yield in excess of 1,000 gallons per minute. Ground water in the aquifer may be poorly or well confined, depending on location. In areas where the overlying clays, such as the Gardiners clay, are laterally continuous and of substantial thickness, vertical movement between the water table aquifer and the Magothy is reduced. There are also many local clay lenses both above and within the Magothy which affect ground water flow. For instance, well logs in western Suffolk, north of the Ronkonkoma moraine, show several occurrences of thick, discontinuous clay



(from Jensen, 1976)

FIGURE 2–26 *Generalized Geologic Cross Section through Western Suffolk County.*



(from Swarzenski, 1963)

FIGURE 2–27 *Generalized Geologic Cross Section through Northwestern Nassau County.*

lenses up to 300 feet thick.

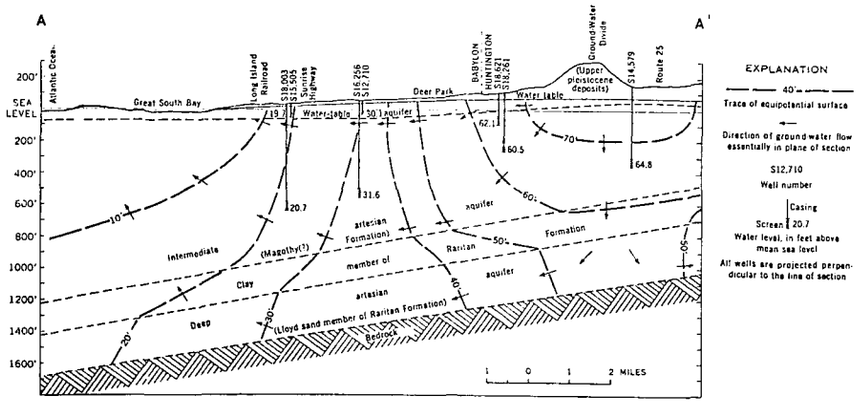
Along much of the north shore, the Magothy is entirely absent and has been replaced by Pleistocene deposits. In these areas, the Pleistocene deposits are often hydraulically connected to the Magothy aquifer at similar depths to the south. On Manhasset Neck and Great Neck, the Jameco gravel and Gardiners clay are thought to have replaced the Lloyd sand and Raritan clay, respectively (see Figure 2–27). However, it is unclear how extensive the Gardiners clay is in these areas. Swarzenski reports that, since little downward movement of water from the shallow unconfined aquifer seems probable on Manhasset Neck, because of highly impervious clay bodies, the principal aquifer (Magothy or equivalent) apparently receives much of its recharge by ground water from the south (Swarzenski, 1963).

In the central portion of Long Island, recharge to the Magothy from the water table aquifer occurs over a large area. The definition of this region is critical in trying to assess how chemical contaminants, introduced to the water table from the land surface, will tend to move in the ground water system.

Because of its shape, structure and geographic setting, Long Island has a rather unique ground water flow system, which can be broadly described on a regional basis. Ground water in the water table aquifer, near the spine of the island, is subject to hydraulic gradients which tend to carry some of the water vertically downward to the deepest part of the Magothy. To the south and north of this zone, water from the shallow deposit flows with vertical and horizontal components that result in some water moving into the middle portion of the Magothy. Farther toward the coastlines, circulation becomes shallower until, at some point, flow is essentially horizontal in both the water table and the Magothy aquifers. Beyond this area, water in the Magothy has a vertically upward component, while the water in the shallow deposits flows essentially horizontally until it discharges to streams or salt water bodies.

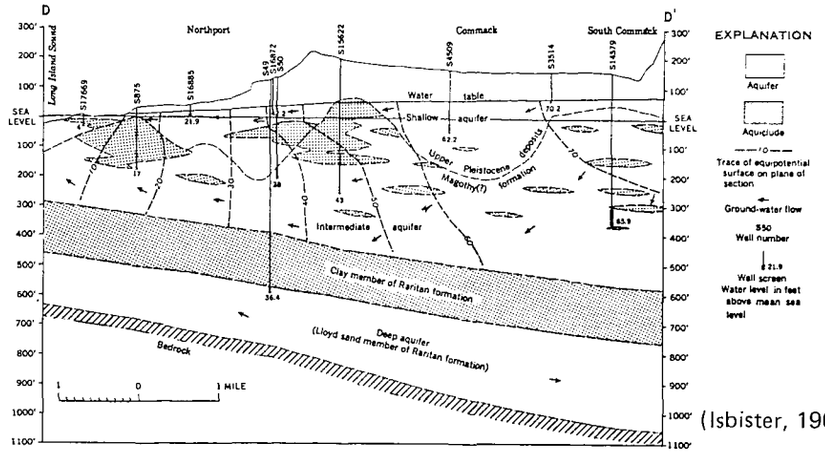
This general relationship is borne out in many of the more detailed studies undetaken by the U. S. Geological Survey over the past 30 years, and reported in Water-Supply Papers (see Figures 2–28, 2–29, 2–30 and 2–31). Under natural conditions, it takes about 100 years for water from the surface to reach the lower portion of the Magothy in the center of the island. The travel time to the barrier beach is about 800 years and to the north shore, about 400 years.

In order to further examine the concept of defining Magothy recharge and discharge areas, maps of the potentiometric water level surfaces in the lower Magothy and maps of the water table were overlain and compared for head differences. U. S. Geological Survey maps for 1966, 1972, 1974 and 1975 (Vaupel, 1977 and Kosalka, 1975) were examined, and the approximate areas of regional Magothy recharge and discharge for those years were interpreted and plotted (see Figure 2–32). The areas of generally negative head difference shown in Figure 2–32 are, for the most part, negative for each of the years examined, although the shape and size of these areas change some-



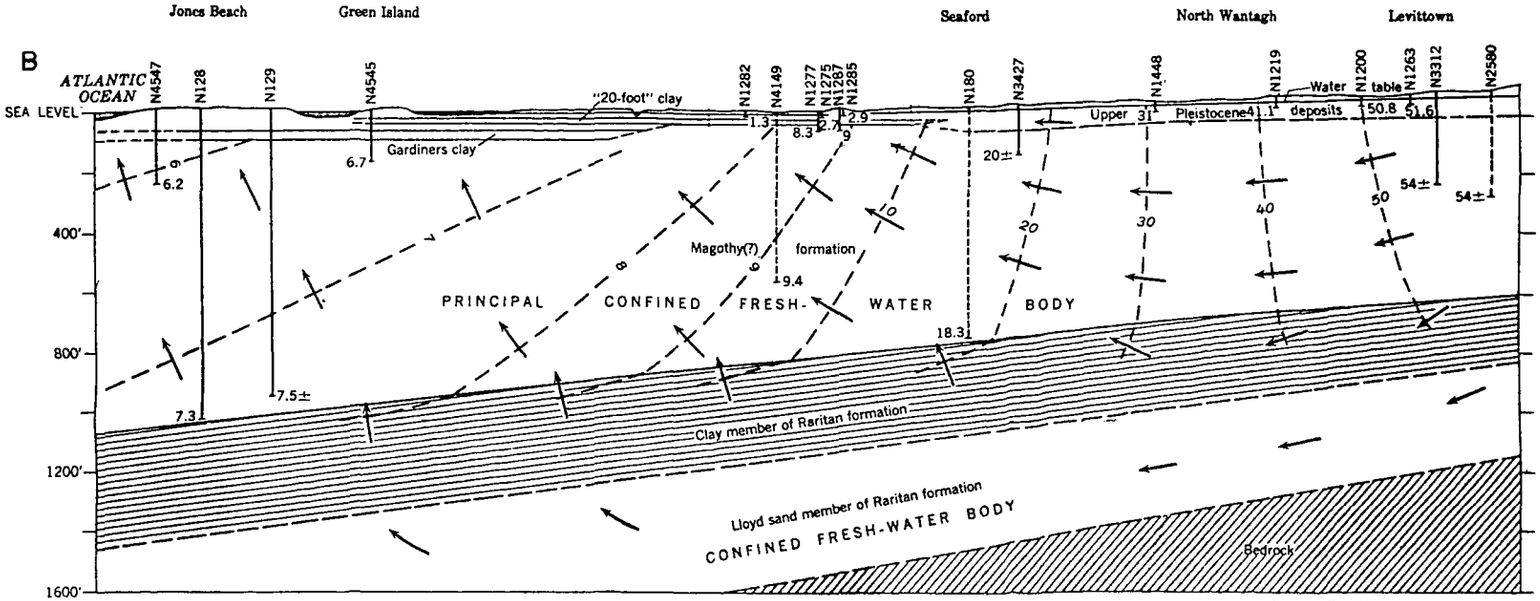
Source: Pluhowski, E.J. and I.H. Kantrowitz, 1964, "Hydrology of the Babylon–Islip Area, Suffolk County, Long Island, New York," USGS Water Supply Paper 1968.

FIGURE 2–28 *Approximate Hydraulic Profile of the Ground Water Reservoir Underlying the Babylon–Islip Area, October 1960.*



(Isbister, 1966)

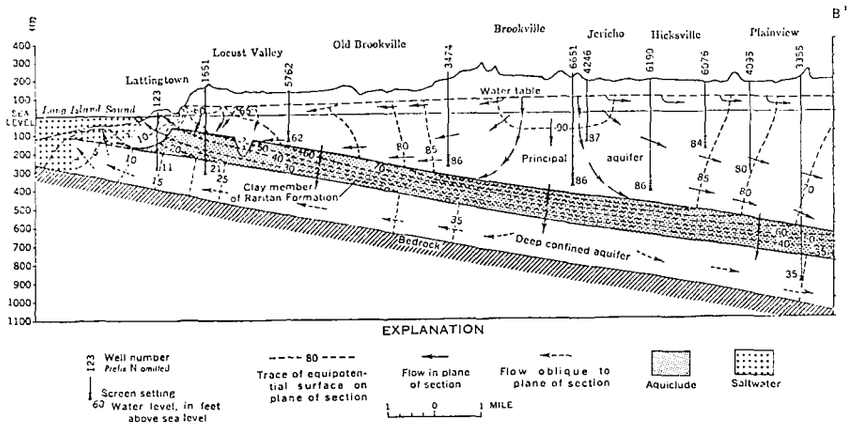
FIGURE 2–30 *Hydraulic Profile through Ground Water Reservoir from Northport to South Commack, New York, in May 1959.*



(from Perlmutter and Geraghty, 1963)

— — 40′ — —	←			18.3	
TRACE OF EQUIPOTENTIAL SURFACE	DIRECTION OF GROUND WATER FLOW ESSENTIALLY IN PLANE OF SECTION	N180 WELL NUMBER	⊥ CASING	WATER LEVEL, IN FEET ABOVE MEAN SEA LEVEL	ALL WELLS ARE PROJECTED PERPINDICULAR TO THE LINE OF SECTION

FIGURE 2–29 *Hydraulic Profile Showing Probable Flow of Water in Magothy Aquifer in Southeastern Nassau County, New York, in 1954–55.*



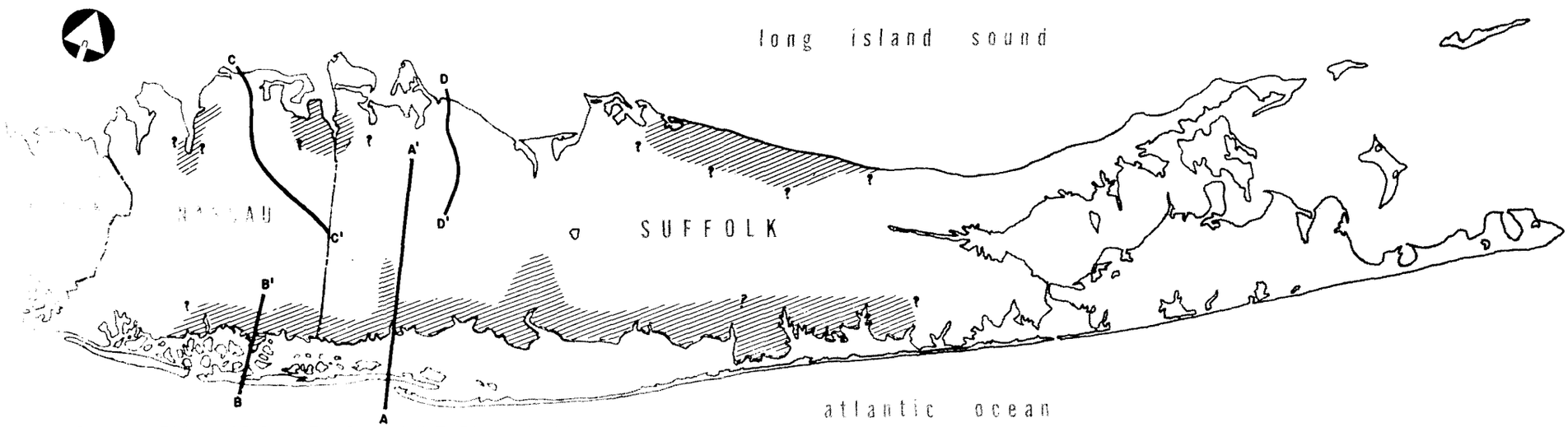
Source: Franke, O.L. and P. Cohen, 1972, "Regional Rates of Ground Water Movement on Long Island, New York," USGS Professional Paper 800—C.

FIGURE 2—31 *Hydraulic Profile through the Ground Water Reservoir from Lattingtown to Plainview, in March 1961.*

what from year to year. More detailed drilling and investigation of head relationships could define these areas further. Heads in the southwest corner of Nassau are very variable because of heavy local pumpage in Nassau and Queens. Undoubtedly, some other local reversals of gradient between the water table and Magothy occur in the immediate vicinity of supply wells in the discharge area.

Instances of hydraulic head relationships studied as part of two U. S. Geological Survey Water-Supply Papers, illustrate the type of data that can be obtained to specifically evaluate particular areas. In northwestern Nassau, heads in the lower part of the Magothy were found to be six to ten feet higher than the water table at corresponding sites near the southern ends of Little Neck Bay, Manhasset Bay and Hempstead Harbor (Swarzenski, 1963). This indicates upward flow from the Magothy is occurring in these areas.

In another study, head relationships between deep and shallow wells in southwestern Suffolk at a well station, near Sunrise Highway, were investigated (Perlmutter, 1976). The Upper Glacial and Magothy aquifers are reportedly not separated by distinct confining layers at this site. Under natural conditions, vertical components of flow betweeen the aquifers were found to be negligible, indicating that movement of significant quantities of water between aquifers is minimal. While pumping a deep Magothy well (495 feet deep) at 800 gallons per minute, observations were taken in two



NOTE: POSITIVE HEAD DIFFERENCE *MEANS THE WATER TABLE ELEVATION IS HIGHER THAN THE ELEVATION OF THE BASAL MAGOTHY POTENTIOMETRIC SURFACE AT A GIVEN POINT*

FIGURE 2—32 *Areas of Generally Positive or Negative Head Differences between Wells Screened in the Water Table and Lower Magothy Aquifers, Based on USGS Maps for 1966, 1972, 1974 and 1975.*

observation wells, an Upper Glacial well 23 feet deep and a well in the upper part of the Magothy 97 feet deep. Over several days of observations, there was no recorded drawdown in the 23 foot well. Therefore, little or no water was being induced downward from this depth as a result of pumping. Drawdown in the 97 foot well was less than 0.5 foot.

Geologic factors, such as the presence of confining clay layers, can influence head differences between the two aquifers and play an important role in determining whether there can be relatively easy inter-aquifer exchange of water. Deposits of low permeability, such as those found under the Port Washington peninsula and much of the Town of Smithtown, tend to impede downward flow, resulting in large head differences. The Gardiners clay, for instance, is a marine deposit of clay and silt, with some interbedded sand and gravel, which is quite extensive throughout the southern portion of both Nassau and Suffolk Counties (Figure 2–33). It is commonly found at depths of 50 or more feet below sea level. The thickness of the clay varies, but it is as much as 40 feet in Nassau (Ku, 1975) and 75 feet in Suffolk (Jensen, 1974). In addition, several other less extensive clay deposits are found above and below the Gardiners clay. The "20 foot" clay is found in parts of southern Nassau County at elevations of about 20 feet below sea level. Where there is a relatively good hydraulic connection between the aquifers, as in the Plainview and Bethpage areas, head differences are lower, but greater volumes of water from the water table aquifer reach the Magothy.

It should be noted that head differences between the water table and the lower Magothy at the same location differ somewhat from year to year. This is because the water level maps represent conditions at one point in time and not necessarily steady-state conditions. Thus, the magnitude of potential head differences within the Magothy recharge or discharge zones can not be evaluated by themselves to indicate their degree of importance, but must include the effects of other variables, principally geology and pumpage.

2.3.4.2 Ground Water Quality. The natural chemical quality of water within the Magothy is excellent and characterized by a very low dissolved solids content. Contamination of the Magothy is of great concern, since many public supply wells are screened in this formation. Past water quality investigations have dealt primarily with the distribution and trends of nitrate. From these studies, it has been established that many wells within the Magothy are pumping chemically altered, or contaminated, water.

The 1972–76 median concentrations of nitrate, chloride and sulfate in the various portions of the study area illustrate the relative degree of alteration (Table 2–13). Differences in concentrations of these constituents between the two specified areas of Nassau are probably not due to sewering. except possibly at the shallower depths. Other factors, such as location of wells with respect to past land uses, are probably more important. Those water quality

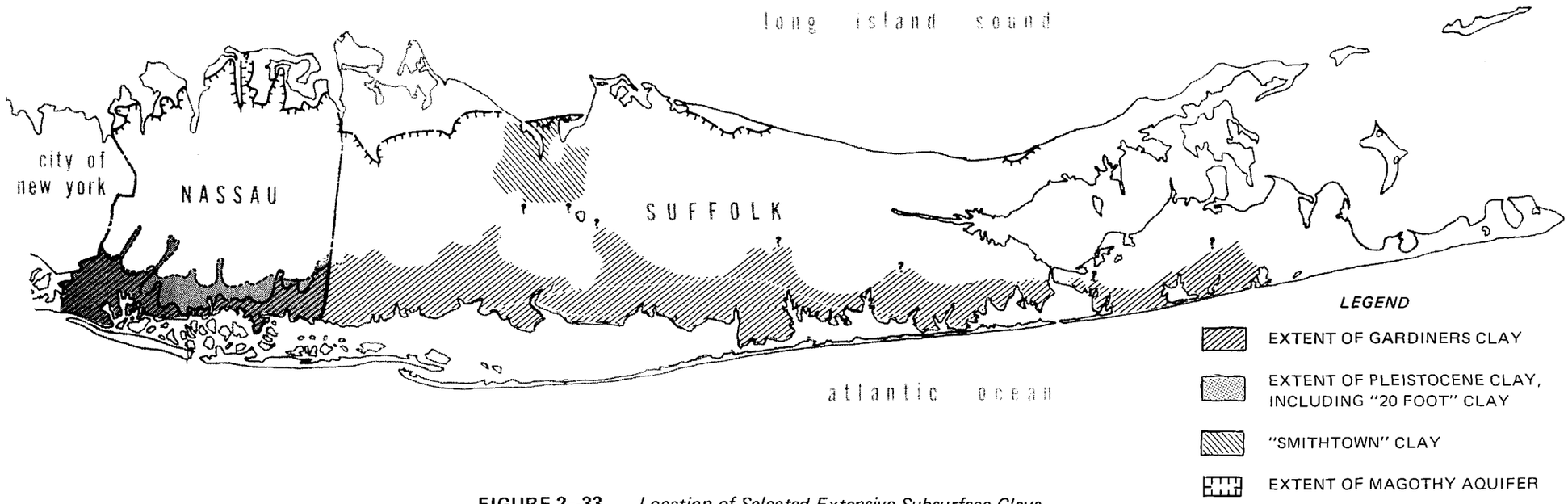


FIGURE 2–33 *Location of Selected Extensive Subsurface Clays.*

Table 2–13

1972–76 MEDIAN WATER QUALITY DATA
IN THE MAGOTHY AQUIFER
(Ragone, 1976)

Depth (feet)	Southwest Nassau		East and North Nassau		Suffolk	
Nitrate as N						
Less than 200	0.88	(18)	2.8	(104)	2.6	(4)
200 to 399	2.5	(130)	2.8	(443)	0.10	(263)
400 to 599	0.2	(526)	1.1	(515)	0.10	(391)
Greater than 600	0.01	(42)	0.13	(177)	0.01	(322)
Chloride						
Less than 200	18	(18)	13	(108)	14	(13)
200 to 399	12	(136)	10	(453)	5.0	(270)
400 to 599	6.4	(542)	5.8	(532)	4.5	(400)
Greater than 600	4.6	(42)	4.4	(179)	4.0	(355)
Sulfate						
Less than 200	32	(14)	22	(93)	2.6	(11)
200 to 399	13	(122)	7.0	(392)	3.2	(264)
400 to 599	5.0	(500)	2.0	(403)	3.2	(388)
Greater than 600	3.0	(39)	1.0	(159)	3.4	(399)

Note: Numbers in parentheses are the number of analyses. All concentrations in milligrams per liter.

trends now occurring in the water table aquifer, as discussed in the previous section, will undoubtedly be reflected in some way in the Magothy in future years. In general, the levels of contaminants decrease with depth until near-background concentrations are found in most wells greater than 600 feet deep. The apparent smaller value of nitrate reflected in the analysis of less than 200 foot deep wells of the sewered area may be due to insufficient sampling.

A question of principal interest is the extent to which the Magothy has been made essentially unusable by contamination. Organic chemicals, heavy metals and nitrate are of special interest because of their health implications, and also because standards exist or are pending that would preclude use of water exceeding certain limits. At the present time, however, extensive data are available only for nitrate. Basic data on the distribution of nitrate, chloride and sulfate in other parts of Nassau and Suffolk Counties are presented by Ragone (1976a). As part of the present investigation, wells in which the median nitrate-nitrogen level has exceeded eight milligrams per liter at some time in the past were plotted for each depth zone. These are presented in Figures 2–34, 2–35 and 2–36. Water in these wells either exceeds or is very close to the EPA standard of ten milligrams per liter for nitrate-nitrogen. Most are in the central portion of Nassau County. The proportion of wells in Nassau exceeding eight milligrams per liter to the total number of wells sampled for the period 1972–76 is as follows:

Depth (feet)	Number of Wells with 1972–76 Median Nitrate-Nitrogen Greater than 8 mg/l	Number of Wells Sampled
Less than 200	6	40
200 to 399	5	115
400 to 599	4	174
Greater than 599	0	38

These proportions give only a general idea of the extent of high nitrate water and would be representative of the true conditions of the aquifer only if the distribution of sampled wells was random. Some sampling bias has probably been introduced, however, because contaminated public supply wells are abandoned and sampling is discontinued.

In general, the distribution of known contamination is consistent with the flow patterns previously described. In order to illustrate this, an analysis intended to delineate the maximum extent of contaminated water in the Magothy, as indicated by nitrate and chloride, was performed. For this analysis, constituents that serve as good indicators of pollution were chosen. The criteria for selection include (1) widespread occurrence in the water table aquifer in Nassau and western Suffolk, (2) nearly conservative transport within ground water systems, and (3) sufficient analytical data to map areal distributions. The nitrate and chloride ions were selected for this analysis. The median concentrations of these constituents for the period 1972–76 for selected Magothy wells were plotted. Wells screened deeper than 200 feet below land surface and with frequent water analyses were included.

Perlmutter and Koch (1972) consider concentrations of nitrate in excess of 0.23 milligrams per liter nitrate-nitrogen in the Magothy as an indication of man's activities. Perlmutter and Geraghty (1963) state that, in general, altered ground water on Long Island has a chloride concentration of less than ten milligrams per liter. They also report that the fresh water in the Magothy formation in most of southern Nassau County during the period 1953–57, ordinarily contained between four and eight parts per million of chloride. Median chloride data from Magothy wells over 600 feet deep in Nassau County for the period 1952–72 was examined during the 208 program (Ragone, 1976a). Water from most of these wells is thought to reflect unaltered, background quality. Figure 2–37 indicates the distinction between background and above background concentrations. Values of 0.20 nitrate-nitrogen and seven milligrams per liter chloride, were chosen for purposes of this report and although these levels are very low, they can be used to dis-

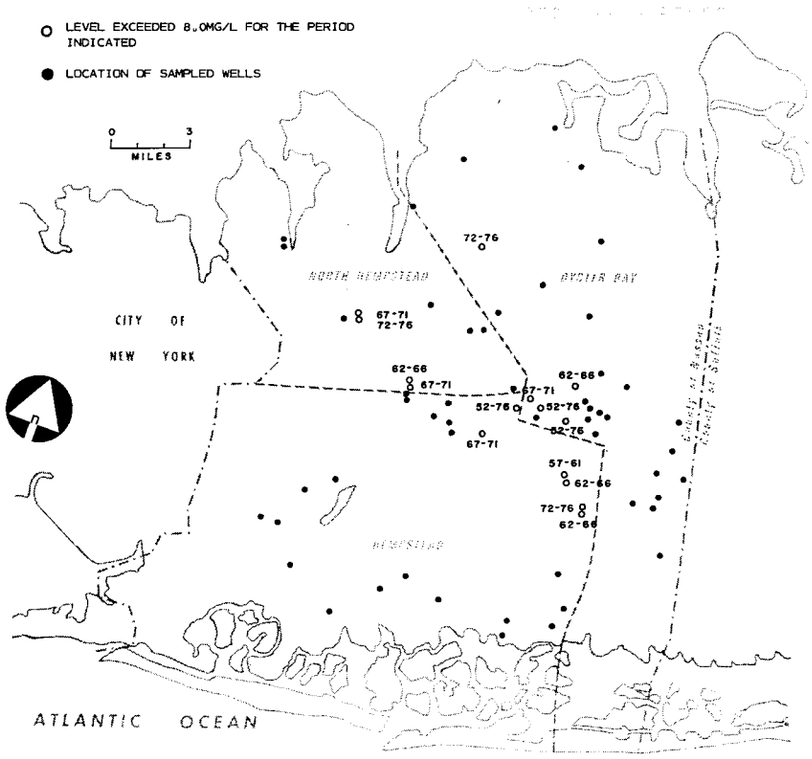


FIGURE 2–34 *Magothy Wells Less than 200 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

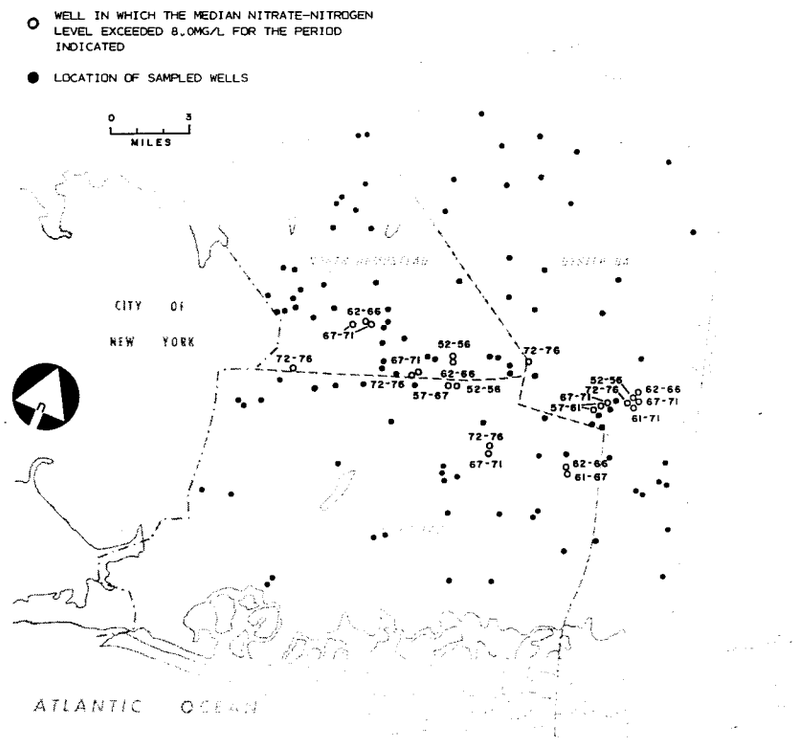


FIGURE 2–35 *Magothy Wells Between 200 and 399 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

tinguish natural water from that which has been altered by man's activities. Using this criteria, Figure 2–38 indicates the pattern of water quality distribution.

The area of generally greater than 0.20 milligrams per liter nitrate-nitrogen in Nassau includes almost all of the central and northern parts of the county. South of a line extending from Franklin Square through Hempstead, East Meadow and Levittown to Farmingdale, concentrations in the middle and lower Magothy are below 0.20 milligrams per liter. In Suffolk County less data are available, but a similar pattern is suggested. South and east of a line extending from Farmingdale through Half Hollow Hills, South Commack and up to Kings Park, nitrate-nitrogen is less than 0.20 milligrams per liter. This analysis was not extended to central or eastern Suffolk because of the generally higher quality of water in the shallow aquifer and a lack of data.

The area in which the same depth zone of the Magothy has levels of chloride generally greater than seven milligrams per liter extends slightly farther south than the nitrate line in Nassau County. This may be due to the fact that chloride acts more conservatively than nitrate under many subsurface conditions. The isochlor line extends from Lynbrook through Baldwin and over to South Farmingdale.

The probable source of high nitrate in the Magothy aquifer, particularly in Nassau County, has been the subject of much speculation. In this century, the two major nitrogen loading sources in Nassau and Suffolk Counties are probably agricultural and home fertilizers and cesspools. Data on patterns of agricultural use and practices prior to 1950 are very poor. A report describ-

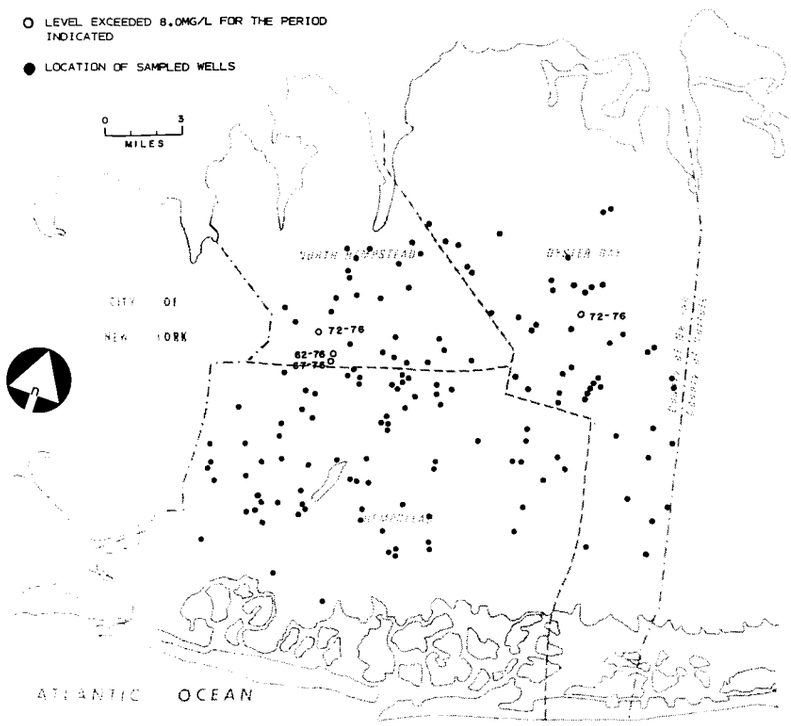


FIGURE 2–36 *Magothy Wells Between 400 and 599 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

ing agricultural use in 1949 (Warren, 1954) indicates the total approximate acreage of commercial vegetable and potato farming in Nassau County as follows:

	Vegetables	Potatoes
North Hempstead	0	100
Hempstead	2,000	1,500
Oyster Bay	3,600	4,200

Although the exact amount of farmed acreage prior to this date is unknown, it was undoubtedly greater. Farming began in colonial time, and it is estimated that by 1919 approximately 27,000 acres of land in Nassau County was used for farming (Bond, 1953). Much of the nitrogen loading from cesspools and individual home fertilizers began in the late 1930's and 1940's. The time of travel for water entering the water table to reach the lower portion of the Magothy in the central portions of the island, under natural conditions, is estimated to be between 50 to 100 years (Franke, 1972). Pumping in the Magothy, of course, will decrease this time considerably. It seems reasonable to assume then, that much of the nitrogen content now found in the middle and lower portions of the Magothy is from past agricultural fertilizer sources.

This conclusion is partially confirmed by nitrogen isotope studies done by the U. S. Geological Survey. A 1975 report concluded that, on the basis of preliminary data, nitrate in the water from the Magothy aquifer appears to be either organic nitrogen of soil humus or nitrogen fertilizer (Kreitler, 1975). The nitrate from the Upper Glacial aquifer in Queens appears to be of animal waste origin, possibly stemming from leaky sewers. In a recent study of nitrogen isotopes, water from a broader range of samples was analyzed (Kreitler, 1977). Nitrate in the Magothy of Nassau and Suffolk Counties was found to probably reflect a mixture of animal waste and agricultural sources.

2.3.4.3 Ground Water Quality Trends. A recent study in southeast Nassau County provides an analysis of vertical and horizontal distributions of nitrate, chloride and dissolved solids. The following conclusions were reached (Ku, 1976):

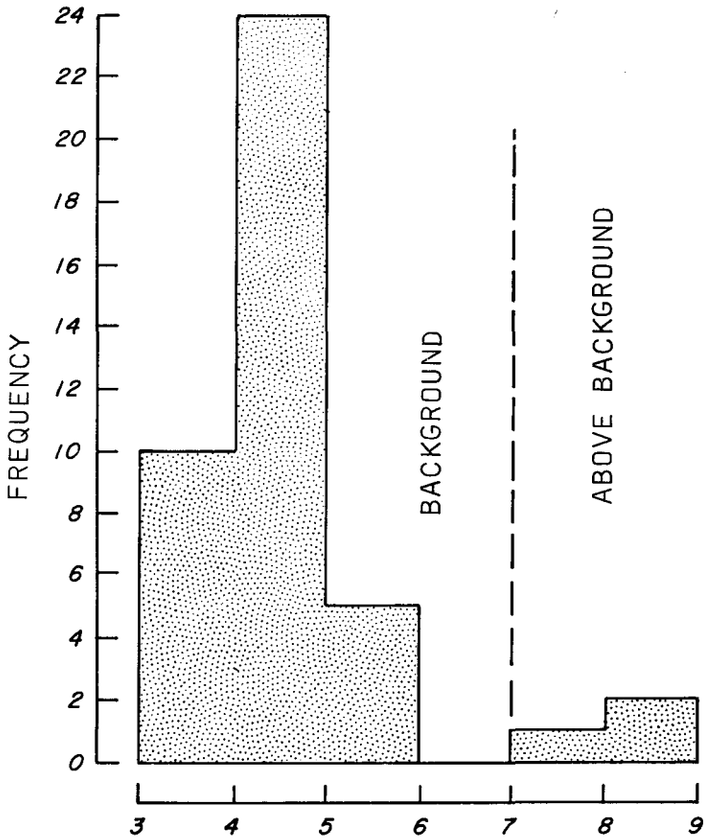
1. Downward movement of nitrate in the Magothy between the early 1950's and 1973 ranged from no significant movement in the area south of North Merrick and South Farmingdale to a maximum movement of a few hundred feet in the areas of Westbury, Hicksville and Plainview. There also seems to be a definite horizontal movement of equal nitrate concentration lines through the aquifer.

2. There has been a more rapid downward movement of nitrate in the eastern part of the study area than in the central and western parts. The rapid movement in this eastern part may be partly due to a large increase in population in and adjacent to the Plainview area.

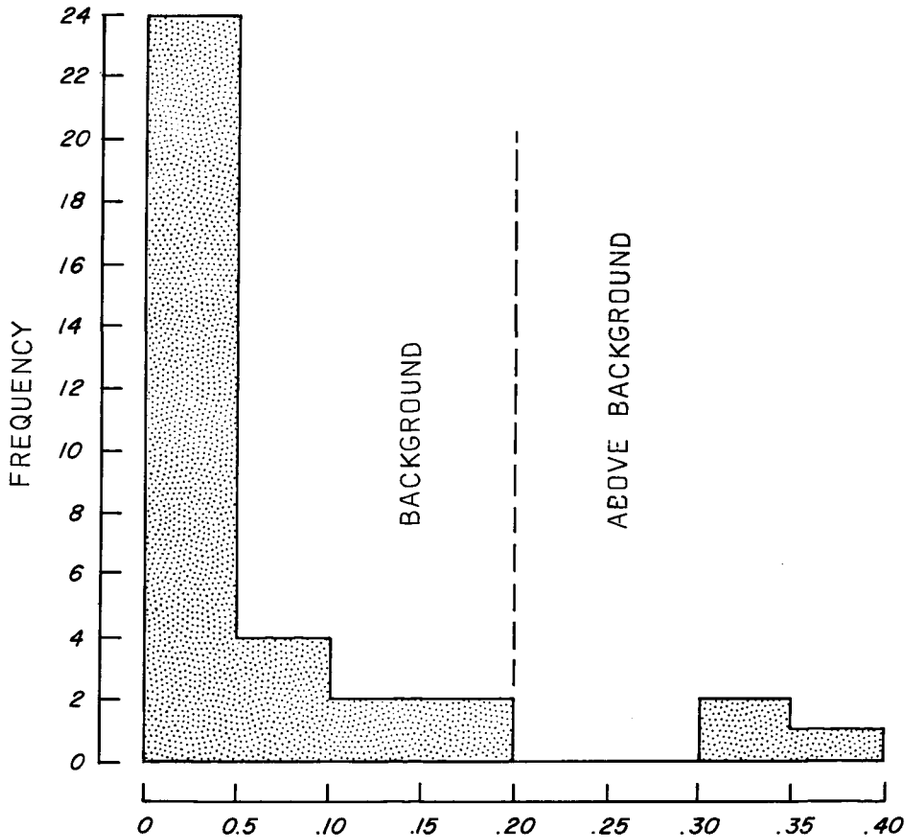
3. There is a zone of high-nitrate water in the Magothy aquifer in the areas of Westbury, Hicksville and Plainview. Some of these increases may be attributable to past large-scale farming and associated use of fertilizers in the Hicksville and Levittown areas.

4. The downward movement of chloride covers a broader area than does that of nitrate.

5. There has been significant downward movement of higher than normal total solids concentration between the 1950's and 1973. Overall downward movement ranges from a few feet to approximately 300 feet. A zone of high total solids concentration of more than 200 milligrams per liter is found in the Hicksville and Plainview area. The total solids concentration in ground water in the Plainview area approximately doubled in twenty years.

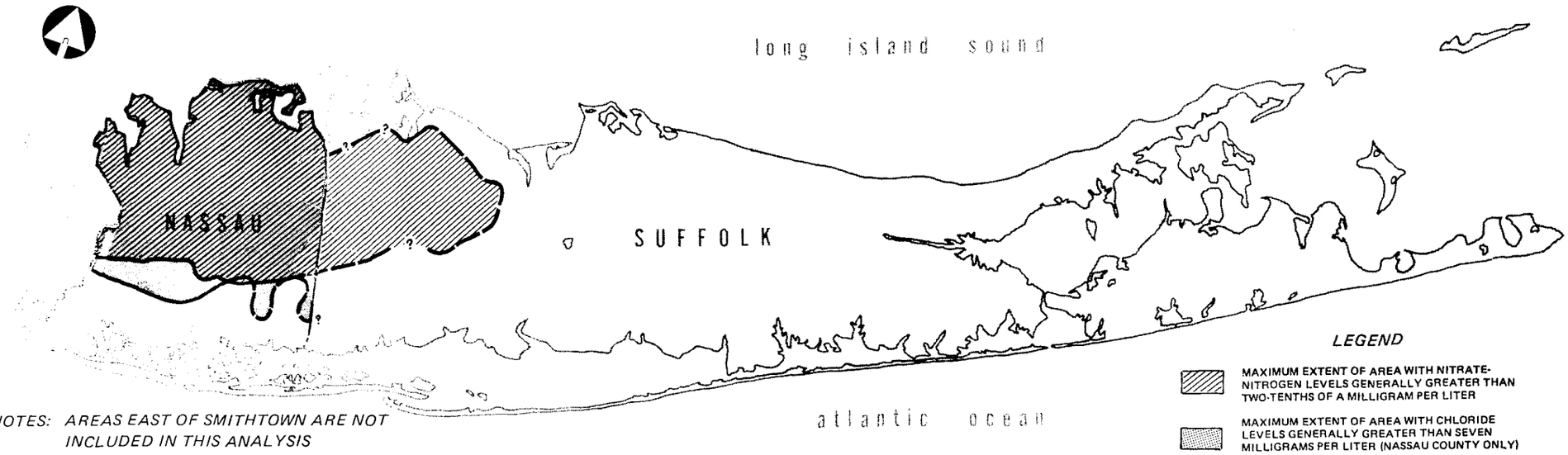


MEDIAN CHLORIDE VALUES IN MAGOTHY WELLS
OVER 600 FEET DEEP IN NASSAU COUNTY - 1952-76.



MEDIAN NITRATE-NITROGEN VALUES IN MAGOTHY WELLS
OVER 600 FEET DEEP IN NASSAU COUNTY - 1952-76.

FIGURE 2–37 *Frequency Distributions of Median Nitrate and Chloride Values in Deep Magothy Wells.*



NOTES: AREAS EAST OF SMITHTOWN ARE NOT INCLUDED IN THIS ANALYSIS
CHLORIDE LEVELS IN WESTERN NASSAU ARE FOR PERIOD 1969–71

FIGURE 2–38 *Areas in Nassau and Western Suffolk Where Ground Water in the Magothy at Depths Greater Than 200 Feet Below Land Surface Shows Evidence of Alteration Based on Median Nitrate and Chloride Levels in Wells During Period 1972–76.*

A study completed in 1969 reviews the trend of nitrate in 373 public supply wells in Nassau County (Smith, 1972). Most of the wells analyzed were deep wells, screened in the Magothy. Eighty wells showed statistically significant increasing linear trends; nine showed decreasing trends. A general upward trend of nitrate in most Magothy wells is also confirmed by a study presently under way by the U. S. Geological Survey (Ragone, 1977). In this investigation, trends of nitrate in most Magothy wells in Nassau showed statistically significant increasing trends.

2.3.4.4 Heavy Metals. Heavy metals in the Magothy aquifer have not been extensively investigated to date. In most cases, they are not part of the routine analysis done on well water samples. Copper and zinc are the most frequently analyzed of the group.

As part of the present investigation, all ground water samples that were analyzed for heavy metals and listed in the U. S. Geological Survey STORET System as of February 1977 were reviewed. A screening of the data, identical to that performed on data from the water table aquifer, was performed; the results are plotted on Figure 2–39. As with the previous analysis, most wells were only sampled once and any conclusions drawn from these data are very preliminary.

As expected, the frequency of occurrence of metals found in the Magothy is lower than in the shallower, water table aquifer. Copper and zinc are most prevalent, although this may be a function of the greater number of analyses done for these constituents. In only two sample locations did metals exceed the 1972 EPA recommended limits. One sample, at Well S–42762, showed a high level of copper. Subsequent samples from this well showed negligible concentrations, indicating a possible sampling or analytical error. At the other location, samples from adjacent wells screened at different depths (Wells S–29776 and S–29778) showed high levels of zinc.

2.3.5 Lloyd Aquifer

The Lloyd aquifer is the least altered by man's activities. This is due primarily to the thick confining bed of Raritan clay which overlies the Lloyd in most places and impedes the exchange of water with the Magothy. On the north shore, however, the Raritan clay is truncated in places and is in lateral, and possibly vertical, hydraulic connection with Pleistocene deposits which have replaced the Magothy deposits. Regionally, the Lloyd is recharged through the clay over a broad area covering most of Nassau and Suffolk Counties. Discharge in the western part of the study area is primarily through wells, while in the eastern part discharge is mostly to the bays and to the ocean (Kimmel, 1973).

The median concentrations of selected constituents in the Lloyd in Nassau County for the period 1972–76 are as follows (Ragone, 1976):

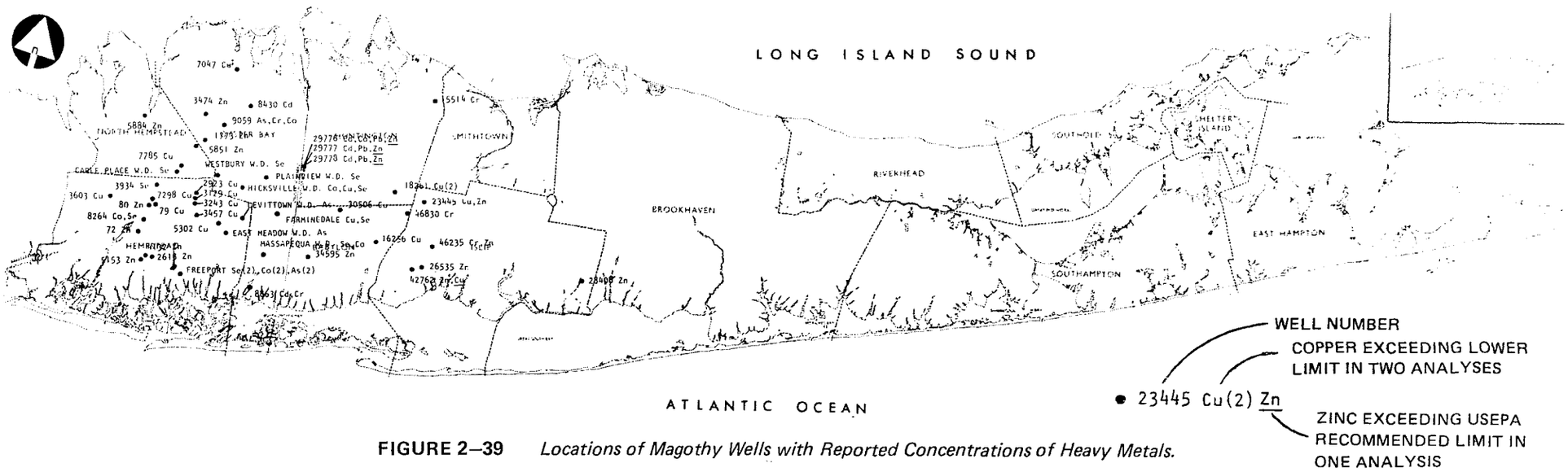


FIGURE 2–39 *Locations of Magothy Wells with Reported Concentrations of Heavy Metals.*

	Southwest Nassau		North and East Nassau	
Nitrate as N	0.07	(13)	0.21	(100)
Chloride	5.1	(12)	5.2	(106)
Sulfate	6.0	(13)	3.0	(94)

Note: Concentrations in milligrams per liter; numbers in parentheses are number of analyses.

Many of the wells in the north and east area are located on Manhasset Neck, Great Neck and in the northern part of the Town of Oyster Bay. Some of the wells in these areas show elevated levels of nitrate which indicate contamination from the surface. This suggests some degree of hydraulic connection with overlying sediments, probably in areas where the Raritan clay has been eroded and replaced by more permeable deposits. High chloride due to salt water intrusion has occurred in certain locations in the Lloyd aquifer. Uncontaminated water in the Lloyd is characterized by low dissolved solids (less than 50 millgrams per liter). Iron, however, commonly occurs at levels considerably above the U. S. Public Health Service recommended limit of 0.3 milligrams per liter.

Regional rates of ground water movement in central Nassau County have been estimated by Franke and Cohen (Franke, 1972). From these rates, the age of water moving in the Lloyd at the ground water divide is estimated to be at least 200 years old. Closer to the barrier beaches on the south shore, the age of water is estimated to be about 3,000 years old. Water in the Lloyd near the north shore may be on the order of 1,000 years old. If these rates are correct and if the confining layers above the Lloyd are indeed continuous, then the quality of water in the aquifer in most areas is in little danger of contamination in the near future.

2.3.6 Special Studies

2.3.6.1 Virus Study. During the period June 1976 to June 1977, Brookhaven National Laboratory conducted a virus survey as part of the 208 program. This survey involved the concentration, enumeration and identification of species of human Enteroviruses from selected aquatic systems on Long Island including embayments, lakes, creeks, public drinking water supplies (ground water), ground water under influences of waste water recharge basins, and effluents from secondary and tertiary sewage treatment plants.

Enterovirus species were isolated from all systems studied, with the exception of public water supplies. Virsues were most often encountered in the chlorinated effluents of sewage treatment plants. In three instances, wild type Poliovirus was tentatively identified from one of the treatment plants.

The limited sampling conducted at each site (one per month) precluded any extensive interpretation of the data for the purpose of identifying the precise hazard posed by enteric viruses in Long Island waters. The results of the virus study are presented in detail in one of the 208 interim report series.

2.3.6.2 Organics Study. Concern over the presence and concentration

of trace amounts of certain organic compounds came into sharp focus in mid–1974 with the publication of results of an EPA study of water quality in the Mississippi River at New Orleans. This study detected 66 organic chemicals including some suspected of being carcinogenic to animals. Concentrations found ranged from less than one part per billion for most of those detected, to a high of 133 parts per billion for chloroform. The potential for the formation of chloroform as a result of disinfection procedures was recognized.

In 1975, a survey of the water supplies of 80 cities nationwide was conducted for six specific compounds including the four trihalomethanes (chloroform, bromoform, dibromochloromethane, dichlorobromomethane), carbon tetrachloride and 1,2 dichloroethane. In 30 of the 80 supplies surveyed, none of these compounds were detected, indicating that the quality of the raw water source including the presence of precursor compounds was of paramount importance. A subsequent survey of ten cities' water supplies for a broad range of compounds identified as many as 76 compounds in one source.

In late 1974, Bellar and Lichtenberg of the EPA at Cincinnati published a procedure for the determination of volatile organic compounds at the microgram per liter level (parts per billion) in water by gas chromatography. This methodology proved a breakthrough in evaluating the presence of volatile organic compounds (defined as less than two percent solubility and boiling at less than 150° Centigrade) in waters at very low concentrations. Many of the compounds are suspected of being animal carcinogens and are listed on the "Master List of Non-Pesticide Organics of Carcinogenic or Other Harmful Potential" published by the National Academy of Science. Some of the compounds on the "Master List" were listed as ingredients in some 65 commercial products on the shelves of supermarkets and hardware stores in a one-day survey conducted by the NCHD.

In March 1975, an incident of suspected ground water contamination was reported near an industrial complex in Nassau County. Subsequent sampling and analysis of wells within the complex indicated significant concentrations of vinyl chloride, which is a known human carcinogen in occupational environments, and industrial degreasers such as tri- and tetra- chloroethylene. The wells containing these contaminants were removed from service as sources of potable water.

An intensive survey of all public drinking water supply wells in both Nassau and Suffolk Counties has been underway for the past two years. The overall extent of contamination of drinking water by organic chemicals in Nassau County is demonstrated by the number of wells sampled and the various ranges in concentrations of organic compounds detected. Based on data representing 336 wells sampled, 310 wells yield water with concentrations less than ten micrograms per liter of organic compounds (of these approximately 80 percent show no organic compounds), nine wells yield water containing between ten and twenty micrograms per liter, six wells yield water containing between twenty and 50 micrograms per liter, and eleven wells yield water containing greater than 50 micrograms per liter. Wells yielding water containing one or more organic compounds range in depth from 89 to 691 feet deep.

As of December 1977, a total of 367 of the 437 drinking water supply wells have been sampled at least once. Of these, eleven wells have been restricted, based upon the New York State Health Department's guideline (50 micrograms per liter of any single organic compound or a total of 100 micrograms per liter for all organic compounds detected in the water sample). Each public supply well within Nassau County will have been sampled at least once, by March 1978.

In addition to establishing the extent of organic chemical contamination by assessing drinking water, a survey of industrial and commercial establishments was undertaken to identify and abate sources of organic compounds. To date (December 1977), 2,300 establishments have been surveyed of which 243 were found to be utilizing organic chemicals, and 61 were discharging to the ground. Thus far, 48 sources have been abated and the remaining are in the process of being curtailed.

Other actions have also been implemented by the Nassau County Health Department:

- proposed legislation to prohibit the use of organic solvent cesspool and drainer cleaners
- identification of consumer products containing organic compounds
- initiation of SPDES permits to regulate the storage and removal of organic chemicals
- initiation of a licensing program to regulate industrial waste scavengers.

A similar effort has been underway in Suffolk County where more than 400 water samples from public supply wells, observation wells and distribution systems have been analyzed for the presence of organic compounds. Seven supply wells have been restricted based on New York State guidelines. Constituents of major concern are trichloroethylene, tetrachloroethylene and trichloroethane. Also encountered during the sampling were trace amounts of chloroform, other trihalomethanes and a few aromatic compounds.

The Nassau-Suffolk Regional Planning Board's 208 Program responded to requests from its TAC and CAC and engaged the firm of Energy Resources Company to analyze samples from ground waters, storm waters, domestic waste discharges and landfill leachates for the presence of volatile and non-volatile organic compounds. The survey of non-volatile compounds resulted in the detection of substituted benzene compounds, naphthalenes and various butyl-phthalates. Some of these compounds are common constituents of plasticizers, but some are on the list of suspected carcinogens to animals. Volatile organic compounds were also detected at parts per billion concentrations with their sources yet to be determined or evaluated.

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