THE CHEMISTRY OF LONG ISLAND DRINKING WATER

DEVRA LEE BELLIN
ENVI. 102
WILLIAMS COLLEGE, 1989

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DEVRA LEE BELLIN

The Chemistry of Long Island Drinking Water
(a study of the quality of ten private wells in Suffolk County and the past, present, and future of L.I. drinking water)

I. INTRODUCTION.

This study looked at groundwater in Suffolk County, eastern Long Island, New York. In the context of the ongoing history of Long Island groundwater, the study includes laboratory data on ten private wells in Suffolk County. These data consist of temperature, conductivity, pH, Acid Neutralizing Capacity, and various anion and cation concentrations, as well as data collected from the well-owners and Suffolk County on well-depth, distance of the well from the nearest saltwater body, population of the town and zoning of the immediate area where the wells are situated. These data are applied to possible point and nonpoint sources of any observed pollution, medical and environmental implications of the pollution, and policy suggestions to avoid future, and remove present, contamination.

II. METHODS AND MATERIALS.

A. Research. The library research portion of this study was conducted during my Spring "Break" on Long Island. Most of the research was conducted in the libraries of the State University of New York at Stony Brook and through phone conversations with local government workers.

B. Sample Collection. Samples were poured from the source into clean, sterilized bottles. Samples were drawn from outdoor spigots to bypass any water-softening or filtering devices. The exception to this was the Schwenzer sample, which at that family's request was drawn from their sink; since the

Schwenzers were using Culligan units to soften their water by replacing calcium and magnesium with sodium, this sample was disproportionately high in sodium and chloride, and thus was often not included in averages and graphs of the quality factors studied. The protocol for drawing the sample was to let water run from the spigot for one minute, rinse the bottle with the water twice and then fill it. This technique made sure that the water was not altered from its groundwater state by sitting in the pipes and that the bottle would not affect the water in any way. The water's temperature was taken with a thermometer immediately after filling the bottle. The bottle was then tightly closed.

C. Sample Storage. The samples were collected the week of March 19, 1989, and stored in a refrigerator until the week of April 16 and between testing days. Testing days were April 17,18,19, and 24. Because the samples were stored, it was impossible to conduct coliform tests with any accuracy, so I did not include biological tests in my battery of tests. The storage may also have altered pH, although refrigeration would hopefully mitigate impacts, but it is unlikely that the anion and cation concentrations would be altered.

D. Testing. In addition to not being able to test for biological components of the water, I lacked the technology to test for lead and the training and equipment availability to test for gasoline, organic components or organic compounds found in fertilizers. Thus, I could not test for any of these elements which otherwise might have yielded intriguing results. I was able to conduct the following tests:

1. pH and Acid Neutralizing Capacity (alkalinity): I used an expanded-scale pH meter in the laboratory to determine the samples' pHs, then added 1.6 N sulfuric acid to each solution and saw how much acid was needed to

bring the pH down to 4.5, and how much to 4.3. I then calculated Standard Alkalinity by the formula: (number of digits to pH 4.5) X 10 X .2. I did not calculate EPA Alkanlinities, because adding one drop after the sample reached 4.5 often brought it past 4.3, suggesting that a fraction of the drop size would have been sufficient.

2. conductivity: Conductivity is a solution's ability to conduct electricity through it, and increases with the number of free ions in the solution. A conductivity meter was used in the lab to determine conductivity for each sample, after adjusting the meter to account for the sample's temperature at the time of testing.

Didn't you filter?

3. anions: chloride, nitrate, phosphate, sulfate, bromide, and fluoride: These elements were tested after making a one-in-twenty dilution by adding 5 ml of the sample to 95 ml of distilled water, because the undiluted forms ~~caused~~ were too concentrated for peaks on the instrument. The instrument used was an Ion Chromatograph connected to a computer, which was programmed to compare graphically the sample's concentrations of these anions to the graphs made by known concentrations of each anion.

this was good and rather demanding work

4. cations: sodium, calcium, and magnesium: These elements were tested in samples that had been diluted to 1/20th of their former strength. These cations were tested for their percent absorbance on an Atomic Absorption Spectrophotometer. Percent absorbance was then converted to standard absorbance using a chart. A standard curve was drawn up for the Standard Absorbances of known concentrations of the cations. The standard absorbances of the samples were then compared on the graph with the standard absorbances of the known concentrations to get the samples' concentrations of each cation.

E. Margins for Error: I used gloves when handling the samples before testing for sodium and chloride, so hopefully there was no salt contamination from my fingers. Storage may have caused some problems in the samples: for one thing, there was some crusty yellow film on the bottom of Gaigal's bottle upon testing, and the water itself appeared clear, whereas when it ran out of the spigot the water had been yellow. Unfortunately, this may mean that the relative purity of Gaigal's water, in this report consistently attributed to the well's depth, may actually be merely a product of the settling out, and refusal to shake loose from the bottle, of certain contaminants. you filtered, right?

III.LONG ISLAND GROUNDWATER: A GEOLOGICAL HISTORY:

Long Island is 120 miles long, 20 miles wide, and 1373 square miles in ~~size~~ area. It is a part of the Atlantic Coastal Plain that was made into an island and given its surface geology by a glacier during the Ice Age which ended about 10,000 years ago. Hills represent (think about this) the places where the glaciers stopped when they were stationery, and the outwash plain was formed from streams carrying melted water (N.Y.Bulletin,No.62A, 1937). Because of the glacier, (and the type of material it transported) most of the soils on Long Island are sandy, and some are loamy (consisting of a relatively equal mix of clay, silt, and sand) [Long Island Regional Planning Board, 1982]. Long Island is a humid area; the village of Setauket has a long-term average annual precipitation of 44.6 inches (N.Y.Bulletin, no.62A, 1937). The island's humidity and loose, porous soils combine to allow much rainwater to penetrate into the ground under natural conditions.

Such rainwater travels downward though pores in the rocks. In saturated sediment (or sedimentary-rock)

zones, all ~~rock~~ pores are filled with water. Water found under the land's surface in saturated zones is called groundwater. "Layers of rock sufficiently porous to store water and permeable enough to allow water to flow through them [i.e., having interconnected pores] in economic quantities are called aquifers "(Price, 1985). About 60 trillion gallons of fresh groundwater flow beneath Nassau and Suffolk counties on Long Island (N.Y.State Water Commissions Bulletin, Nos.62-62A), and the pumpage of this groundwater "represents one of the largest such uses of a single well-defined ground-water reservoir anywhere in the world"(Heath et al.,1976).

Long Island groundwater actually is stored in more than one aquifer. Crystalline bedrock is found 2,000 feet below sea level (although it starts much closer to the land surface in Queens county). Above it are unconsolidated sedimentary deposits, in this order of oldest (bottom) to youngest (top):

1) Lloyd Sand Member of the Raritan Formation-- of Cretaceous age-- reaches a maximum thickness of 300 feet-- is a confined aquifer. (A confined aquifer is one surrounded by rock layers of low permeability, i.e., clays and shales. Its water is thus under high pressure, or artesian conditions. In unconfined aquifers, the water is at atmospheric pressure [pp.10,66, Price, 1985].)

2) Clay member of the Raritan Formation-- of Cretaceous Age-- a leaky confining layer, with sand in some spots, reaching a maximum thickness of 300 feet.

3) The Magothy Formation-- of Cretaceous age-- a confined aquifer consisting mainly of sand and silt, starting at least 100 feet under the land surface, and reaching a maximum thickness of 1000 feet.

4) Jameco Gravel-- of Pleistocene age-- a confined aquifer of mostly coarse sand and reaching a maximum thickness of 200 feet. Only found in the southern part of the island.

5) Gardiners Clay-- of Pleistocene age-- a confining layer only found in the southern part of the island.

6) Glacial Deposits-- of Pleistocene age-- an unconfined aquifer, reaching a maximum thickness of 400 feet. "These glacial deposits consist mainly of sand and gravel in the central and southern parts of the island, and mixed till and outwash atop and between the hills in the northern part of the island. The glacial outwash deposits are highly permeable and therefore permit moderately rapid infiltration of precipitation."

(p.451, Heath et al., 1976)

For a diagram of these aquifers and confining layers, please see Figure Two in the appendix.

The first settlers on Long Island drew their water from shallow private wells tapping the upper glacial aquifer. They returned their waste water to the same deposits via cesspools, keeping an equilibrium between the water <u>discharged</u> (removed) from the upper glacial aquifer and <u>recharged</u> (returned) to it. However, their cesspools were returning water that was now <u>polluted.</u> The pollution of the upper glacial aquifer in time led the counties to supply their residents with water from public wells drawing from the Magothy aquifer. Now, only the less urban Nassau and Suffolk counties are served by groundwater, and fifty percent of the most sparsely populated Suffolk County's water comes from the deep Magothy aquifer (Bridson, 1989). The water is recharged, however, not to the Magothy but to the upper glacial aquifer in polluted form by cesspools! (Heath,1976) Recharge is further decreased by the increasing settlement of the island. Land that once allowed rainwater to enter it and that contained many trees to slow down rainwater runoff so that is came down slowly and lightly enough to enter the ground, now is paved in many spots. The buildings, pavement, and relative shortage of trees interfere with recharge (Voelbel,1963).

or of pressure in the confined aquifers

The growing disbalance between discharge and recharge can result in a lowering of the water table, the highest part of the saturated zone, possibly allowing salt-water encroachment. Salt-water intrusion reached severe enough proportions in Brooklyn that it now draws from the same reservoirs as Manhattan. Intrusion is a problem in southwestern Nassau County as well. Salt-water intrusion occurs when the water table is lowered relative to the level of a local saltwater body, by falling fresh water levels due to a water recharge-discharge imbalance or by rising sea levels or, as happens today, by a combination of both. Ordinarily, "no extensive barriers... separate the fresh ground-water reservoir from adjacent salty ground water, and the salt water is held in check only because large amounts of fresh water are constantly flowing seaward to mix with and discharge into the surrounding bodies of salty water"(Robinson, 1978). For a diagram of this process, see Figure Three. When there is too little fresh water and too much salty water in the zone of diffusion, where salt and fresh water ~~particles~~ mix, then the saline water will intrude and the zone of diffusion will move inland. For a diagrammatic representation of a salt-water intruding wedge, see Figure Four.

water ≠ particles

There are numerous other threats to Long Island groundwater besides salt-water intrusion. Most of these threats will be discussed in detail in the sections below on the various contaminants which were found in the samples tested. In general, as Michael Price says in his book <u>Introducing Groundwater</u> (1985), "Pollution may arise accidentally, as... when oil or chemicals are spilled as a result of a road or rail accident; or... intentionally, as when hazardous wastes are disposed of by burying them in excavations or by injecting liquid wastes into shafts or boreholes; or... incidentally [as due to fertilizers,etc]." A recent example of accidental contamination of Suffolk County's groundwater occurred a few months ago when it was discovered that the Northville oil company in East Setauket had a leak in its tank line which was releasing hundreds of thousands of gallons of oil into the groundwater. This spill travelled all the way to the deep Magothy aquifer (Bridson,1989). This oil spill is a serious threat because oil contains poisonous and cancer-causing aromatic hydrocarbons (Bassow,1976). These hydrocarbons were not tested for in the lab component of this present study, but Northville and the local government have responded to the danger by using reclamation pumps to remove the oil, and keeping track of the spread by using monitoring wells and geological surveys. An example of intentional contamiation of groundwater on Long Island was Peerless Photography's dumping of chemicals onto their property; ~~which~~ chemicals then leached into the groundwater. A case of incidental damage in Suffolk County was discovered in 1979; the pesticides <u>Temik,</u> carbofuran, and Vydate, no longer in use, were at that time seen to have contamiated <u>over 4000</u> wells. Temik is extremely toxic, and <u>all</u> those wells had to be closed (King,1985).

what will be done - this sounds extremely serious

4000 wells? or just the worst contam.?

We will now proceed to a specific discussion of the contaminants in the samples tested and their possible sources. But first, we need to outline the population and water use patterns of Suffolk County. Eastern Suffolk County (including Northport) consists largely of farms and summer resorts, is sparsely populated, and draws most of its water from private shallow wells. In middle Suffolk County (including Wading River), some water is drawn from private and some from public wells. In western Suffolk County, which for the purposes of this report shall include Nissequoque, Old Field, Stony Brook, and Setauket, and is the county's most densely populated section, for the most part water is pumped publically from the deep Magothy aquifer (with some exceptions, including the wells tested for this study); since wastewater is returned to the shallow aquifer via cesspools (the predominant waste-water-disposal method for Suffolk County), the water system is currently out of balance but there is not yet massive saltwater intrusion.

IV. DATA AND DISCUSSION.

Figure One in the appendix is a map of Long Island with the locations of the sampling sites marked. Some on-site observations include that Bidwell and Gaigal's homes are situated on what used to be a farm. Gaigal's well, as noted under Methods above, used a pump instead of a spigot and gave yellowy water which separated out of solution before testing. Schlitz uses her water for hot water but not for drinking. (I'm glad) Russo's well was near the Shoreham Nuclear Power Plant. Schwenzer's sample was taken from the sink with Culligan units on. Misener's home was near farms. (you might have made a table of these incidental observations)

On Table One, the data for these samples are presented. In Table Two, which presents averages and extreme values for these data, and in the graphs based on these data, Schwenzer's sample was continually counted out as it was altered considerably by the Culligan softening units, which remove calcium and magnesium and add sodium, and other samples' data were also not counted when they were distant from the mean or when they failed to register properly on the meters because they were larger than the undiluted sample test could measure but smaller than could appear on the diluted sample test (i.e., marked "some").

A.Temperature. See Figure Six: temperature vs. value frequency. We see that temperature does not vary substantially from west (Bidwell) to east (Archdeacon) across the island. The temperatures are all close together, probably reflecting the fact that the wells draw from the upper glacial aquifer and thus fluctuate with the outside temperature. "Under natural conditions, the average temperature of most of the ground water on Long Island ranges from about 50 F in the upper glacial aquifer to about 70 F in the Lloyd aquifer"(p.52, NYS Water Resources). This is due to the geochemical gradient as one goes deeper into the earth's crust. An unexplained anomaly to this is that "the temperature of the water at the base of the upper glacial aquifer (at about 200 feet below the land surface) is slightly cooler than the temperature of the water at the water table"(p.54, NYS Water Resources). This anomaly may explain why the deepest three wells are responsible for the three temperatures that fall outside of one standard deviation of the mean. Russo's and Gaigal's wells apparently draw from the bottom of the upper glacial aquifer and thus yield water of cooler temperatures than do the other wells. However, this explanation does not account for why Misener's deep well yields the hottest water of any of the wells. Since Russo and Misener have wells of a similar depth in the same town with the same zoning, a number of possible explanations can be eliminated. From the "approximate depth to groundwater" map (Figure Sixteen), it appears possible that in

Misener's vicinity, the watr table occurs at 20-50 feet, whereas in Russo's vicinity it occurs at 50-100 feet, so Misener's could be drawing from the deep Magothy aquifer, although this explanation seems unlikely, both because it seems there shouldn't be such a sudden dramatic change in sediment layers, and because private wells most often draw from the nonartesian, upper glacial aquifer. Temperature can also be raised by uranium and other radioactive wastes (NYS Water Resources), but Russo's well is nearer the Shoreham Nuclear Power Plant than is the hotter Misener's!

Temperature is important because most life functions are only carried out within narrow temperature ranges, and because oxygen gives waters the ability to cleanse themselves and oxygen solubility decreases as temperature rises (Bassow, 1976). Hot drinking water is dangerous to those animals, including humans, that drink it.

B. Conductivity. Figure Seven shows that the most highly conductive water is nearest the land surface, as we would expect. To a point, conductivity falls as we go deeper, as materials leach downward. There appears to be a reversal of this trend, especially for Gaigal and Russo. Russo's surprisingly high conductivity may be due to the nearness of Shoreham Nuclear Power Plant, but it may be more likely that groundwater circulation patterns change after a certain depth, perhaps with the water getting more stagnant and allowing solids to settle. It is also interesting to note that, with the exceptions of Gaigal's deep well in te west, conductivity decreases in a west-to-east direction (as does population density) for the three general areas: Nissequoque/SB/Set/OF, Wading River, and Eastport.

Conductivity is a measure of the total dissolved solids in a sample, with higher conductivity for more solids. Therefore, let us next consider the anion and cation concentrations observed in the samples.

C. Phosphates, Nitrates, and Sulfates. Interestingly, all of the wells were very low in phosphate, which was once a major pollutant of Long Island groundwater. In the early 1970s, Suffolk County law banned detergents that included phosphates; this ban seems to have had positive effects on groundwater quality.

what if you only used NO_3?

As Figure 9 shows us, nitrate and sulfate correlate positively with town population; i.e., as the town gets bigger, the nitrate and sulfate concentrations increase. Two of the three points falling outside the curve (Misener, Gaigal) are deeper wells to which, the contamination may not have spread in large quantities. Figure 10 reveals (indicates?), however, that the overall town population is a bigger influence on the water quality than is the immediate local zoning near the well; this finding suggests that there is enough horizontal permeability to spread material throughout a town, but such leaching does not travel as quickly over large distances (i.e., between towns). That town population affects nitrate concentration makes a lot of sense, since domestic sewage from cesspools and lawn fertilizers are both big sources of nitrate. Sulfate is also a product of cesspools. (Todd, 1980)

The highest sulfate concentrations are found in Russo's well, which is near Shoreham Nuclear Power Plant (operating at very low power), and in Leffler's well, which is near the oil refineries and Long Island Lighting

– it doesn't have a low power license, so I doubt that it's running

Company (LILCO) power plant in Port Jefferson Harbor on the side nearest the neighboring Setauket Harbor, on which Leffler's home fronts.

The safe-drinking water standards for Suffolk County set the nitrate requirement at under 10 mg/L, and the sulfate content at under 250 mg/L. The sulfate levels for the samples are all well under this requirement. The nitrate levels for Bidwell, Schlitz, Leffler, Hobson, and Misener all exceed the standards! This is of some concern, for, although nitrate under 1000 ppm is safe for adults to consume (Professor Kegley, Williams College), nitrate poses a problem for little children and infants. "Nitrates may be converted by certain bacteria within the body to nitrites, ...[which] react with the hemoglobin in red blood cells, causing the cells to lose their ability to carry oxygen and thus threatening the body with asphyxiation"(McCaull and Crossland,1974). Nitrate can thus lead to oxygen depletion in infants ("blue babies"). Nitrates also can be converted in the body into cancer-causing nitrosamines (King, 1985).

Interestingly, the Suffolk County Department of Health Services found the nitrate concentration of Hobson's well to be 2.4 in December, 1988. I found it to be 36.6 mg/L in March, 1989! Their other measurements were comparable to mine.

D.Calcium and Magnesium. For all samples, except for Schlitz's, who isn't drinking the water, calcium and magnesium levels are higher than in natural water, but not excessively high.

E. Sodium and Chloride. Although chloride levels of the samples do not exceed the standard of 250 mg/L, there is fairly high salt in many of the samples, especially considering that people with strongly limited sodium diets are advised to limit their consumption to under 50 mg/l a day. Conditions requiring a low salt intake include "heart disease, hypertension,... dropsy, renal disease, cirrhosis of the liver, obesity, and... pregnancy"(McCaull and Crossland,1974).

Figure Eleven shows that chloride and sodium correlate positively; for each sodium ion added, there is one more chloride ion. This indicates that the two probably come from the same (i.e. NaCl) source, in the form of NaCl. We will now investigate whether that source is saltwater from the ocean or roadsalt or something else. or, given the NO_3 levels, sewage — we humans take in so much salt that our sewage is always loaded with it!

Figure Twelve reveals a negative (inverse) correlation of NaCl concentration with distance from the ocean, suggesting that saltwater intrusion is a possibility. The exceptions to the curve are Archdeacon and Hobson. If we look at Hobson's location on the map of Long Island (Figure One) and then look at the water-table contour map (Figure 17), we see that his water table is probably located just ten feet above sea level, whereas the other places at a similar distance from the sea are twenty feet above it. This may explain Hobson's high NaCl concentration. I can't explain Archdeacon's low NaCl level by this model, but I measured his distance from saltwater as from an estuary and not from the ocean proper, which may or may not account for this discrepancy.

Figure Thirteen complicates the hypothesis that was based on Figure 12. Figure 13 shows a positive correlation between sodium, chloride, and town population, suggesting that roadsalt could be responsible for the concentrations! This would explain Archdeacon's salt-level better than did the saltwater intrusion hypothesis, but it still leaves Hobson unexplained, and sends Russo, Misener, and Collier off the graph. (try sewage as a paradigm) Collier may be explained, however, because he lives in a hilly area with narrow, sloping streets which are therefore heavily salted in snowy weather.

A final test to help us determine the source of the salt pollution is the comparison of Acid Neutralizing Capacity and chloride concentration shown in Figure 14. This useful because a high ANC indicates a high level of bicarbonates, which are rare in seawater, whereas chloride is rare in fresh water (Todd, 1980). An inverse correlation of the two might suggest saltwater intrusion. Archdeacon shows low levels of both chloride and ANC. Collier upsets a pattern which otherwise suggests that the western homes nearer the sea are experiencing salt-water intrusion, whereas the Wading River homes farther from the sea are experiencing pollution from other sources.

I hope that they are not on salt-restricted diets given what Culligan gives them

F. pH: Figure 15 reveals that all the pHs (except for Schwenzer's treated water) are very close to one another. Bidwell's and Gaipal's pHs may be higher than the others, because they live on what used to be a farm, and the plants and farm materials may have raised the pH. Collier's home is near the edge of a cliff, for it may be that his soil is composed of a more acidic type of glacial till, as opposed to the outwash material of the other areas, although I'd suspect that the sandy outwash materials are generally more acidic!

This is your best generalization for pH

Because of the relatively high ANC values, pH changes are not likely to occur in damaging amounts on Long Island. This is good because ingestion of pHs of greater than 8.5 or lower than 6 is not recommended.

The lowness of Russo's ANC may be due to the large sulfate content.

it correlates with it, but causality is more difficult

G. Some Suffolk County Standards for Drinking Water:

total coliform <1/100 ml

nitrate <10 mg/L

chloride 250 mg/L

sulfate 250 mg/L

> drawn from Fed. stds. Some Cape Cod locales are trying $NO_3 = 5\ mg\,L^{-1}$

(Suffolk County Dep't of Health Services, 1988)

V. POLICY IMPLICATIONS: HANDLING THE PROBLEMS

I'd worry about sewage disposal

As we have seen, there are numerous threats to Suffolk County's groundwater supply and quality. Fortunately, no factor is as of yet out of the range of controllability. a word?

Suffolk County is currently facing a threat of discharging much more water in the coming summer than can be adequately recharged by natural means. Since drinking water standards were just tightened in January 1989 from a limit of 50 ppb to a limit of 5 ppb for all organic compounds, the county has had to close thirty wells. In the short term, Suffolk County has passed an emergency backup plan for the summer, ~~by~~ which states that if there is too much water use, limits will be set for such things as lawn-watering hours. Such limits are regularly used in neighboring Nassau County.

In the long term, there are various ideas that Suffolk County can use to prevent saltwater intrusion. On the preventive side, it can increase the number of sumps, or recharge basins, compensating for pavements and buildings, it can cut industrial water use by recycling and agricultural water use by drip-irrigation systems like Isreal's (McCuen,1986), and it can also prevent the development of the remaining pine barrens forest, which it was given the voters' permission to buy for this purpose, in the November 1988 election. "The Long Island pine barrens is a natural woodland that once covered more than a quarter of a million acres in Nassau and Suffolk Counties. Today, despite the ravages of suburban sprawl, about 100,000 acres remain and constitute the largest remaining open spaces in coastal New York. The dominant tree in this forest is pitch pine (<u>Pinus rigida</u>)"(Museum of Long Island Natural Sciences). The pine barrens are useful for groundwater recharge because they provide a general, non-paved space for water to infiltrate the ground, because they mark one of the most important groundwater recharge areas on the island due to the fact that "pitch pines... florish in sandy soil, the same sandy soil that marks deep flow recharge for the aquifer"(Bridson,1989), and because the pines capture and use less water than do many other kinds of trees.

In terms of intervention, Suffolk County can combat salt-water intrusion in the following ways, as suggested by the N.Y.Bulletin nos.62-62A:

1) develop barrier-injection wells, adding fresh water between wells and salty groundwater

2) develop pumping troughs, to collect salty water that would ordinarily move inland towards wells

it should be pretty clean!

3) inject <u>treated waste</u> water through recharge basins (an improvement over sewers' transporting water to the oceans and cesspools polluting the groundwater). One problem to this is that horizontal permeabilities are greater than vertical permeabilities, so that water returned to the shallow aquifers might not move down to the deeper ones as quickly as water is removed from the deeper ones, allowing salt-water encroachment in the deeper ones.

good point

4) allowing saltwater intrusion at outer wells so can draw more water from inner wells (this is not a good idea because it is just a temporary stopgap measure)

5) develop shallow skimming wells that catch water from streams as they

leave the aquifer before they empty into the ocean (but this might alter the salinity of bays and estuaries)

6) nuclear desalination of sea water.

There are also ways of keeping the water of good quality, as well as quantity. We can treat sewage by a combination of primary, secondary, and tertiary treatment. In primary treatment, the water is held for hours before release so that solids can settle to the bottom. In secondary, water is sent through a trickling filter containing bacteria to destroy the organic sewage matter. The nitrates and phosphates that are produced by secondary treatment can then be handled in tertiary treatment, which causes chemical precipitation through a ~~powered~~ activated carbon filter. (Bassow, pp.29-31, p.88)

In the individual home, special appliances such as Culligan units can be used to change the chemical makeup of the water, adding salt and removing calcium, magnesium, and other unsafe or unpleasant anions and cations. A homeowner can also install distillers, or else buy bottled water.

If I had those NO_3 levels I'd drink bottled stuff

VI. CONCLUSIONS.

Suffolk County has an outstanding groundwater resource. It is endangered, however, by a withdrawal of water from the aquifers at a faster rate than water can be returned, and by the pollution of the water that does return to the aquifers. Salt-water intrusion appears to be occurring to a minor degree on the sea coasts. More densely populated towns have wells with higher levels of conductivity, sodium, chloride, nitrate, and sulfate, and contamination effects are more pronounced in more shallow wells. The problems posed by this contamination and depletion of the groundwater can be dealt with through a number of preventive and interventive measures.

Devra -

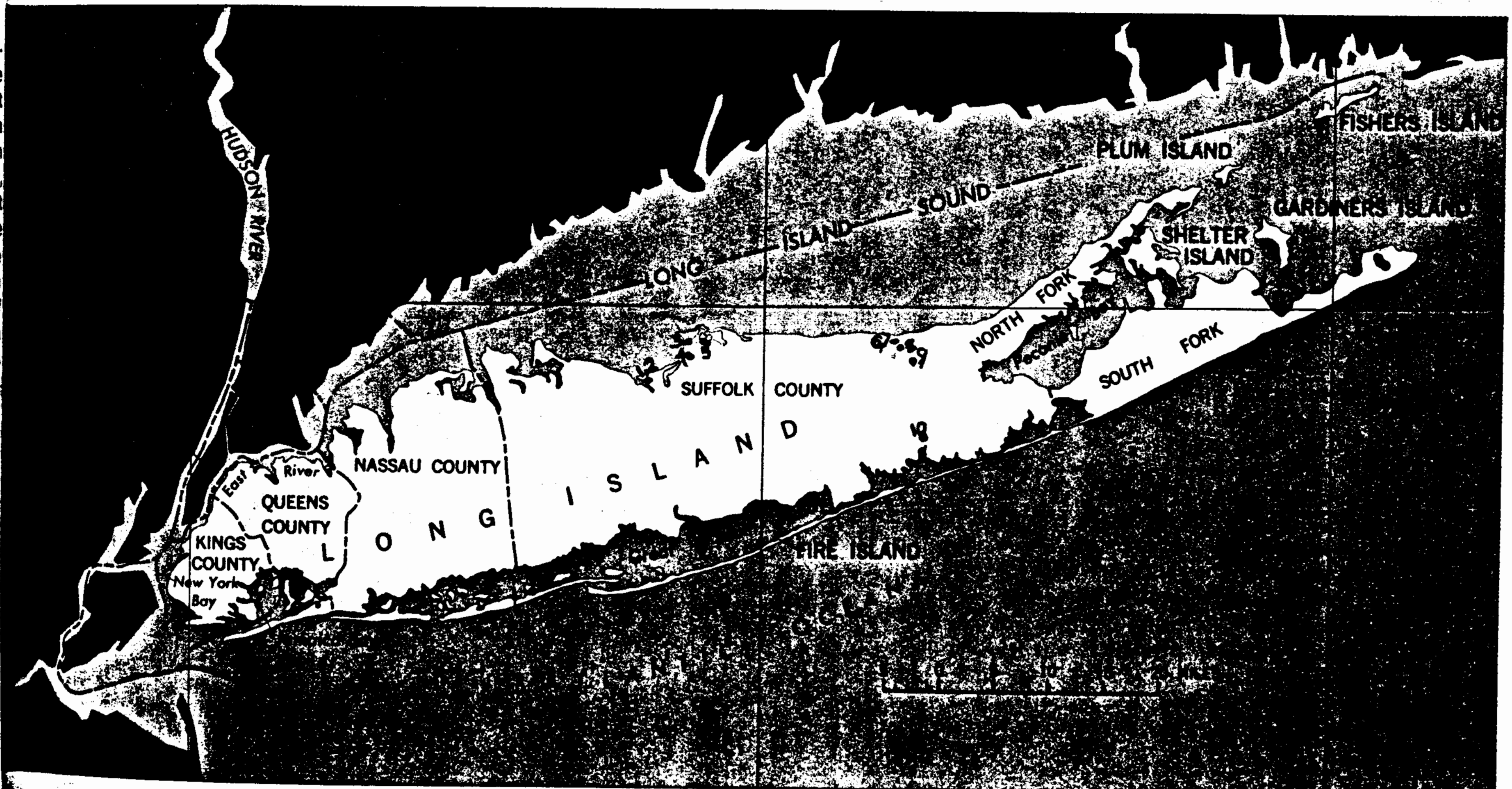
This is a lot of information for me to digest, so I know that you had to work hard at it. Your analyses are complete and, I think, quite good. What they reveal, in several cases, is water of impaired quality, and your plotting and discussion represent excellent attempts to track down what I'm certain are multiple sources of pollution. When you next do this sort of work, and I hope you will, make your graphs prettier. If you can make a nice Mac cover, you certainly can use Cricket graph or other plotting programs to make nice "pictures". I stress that because your research, chemical tests and analysis demand nice graphics. I think that you can use pollution from sewage to help explain the data in a slightly different way. I am concerned about those high NO_3 levels. And I worry about what Culligan adds - those Na levels would be reason to close a municipal well in Massachusetts. This project is exactly what we hope 102 students would do - good work!

DPP

N.Y. State Water Resources Commission Bulletin Nos. 62-62A

PLATE 1A
LOCATION AND GENERAL GEOGRAPHIC FEATURES
OF LONG ISLAND, NEW YORK

FIGURE ONE



1. Bidwell
2. Gaigal
3. Collier
4. Schlitz
5. Leffler
6. Hobson
7. Schwenzer
8. Russo
9. Misener
10. Archdeacon

N.Y. State Water Resources

PLATE 2C
MAJOR HYDROGEOLOGIC UNITS OF
THE GROUND-WATER RESERVOIR OF
LONG ISLAND, NEW YORK

Figure Two

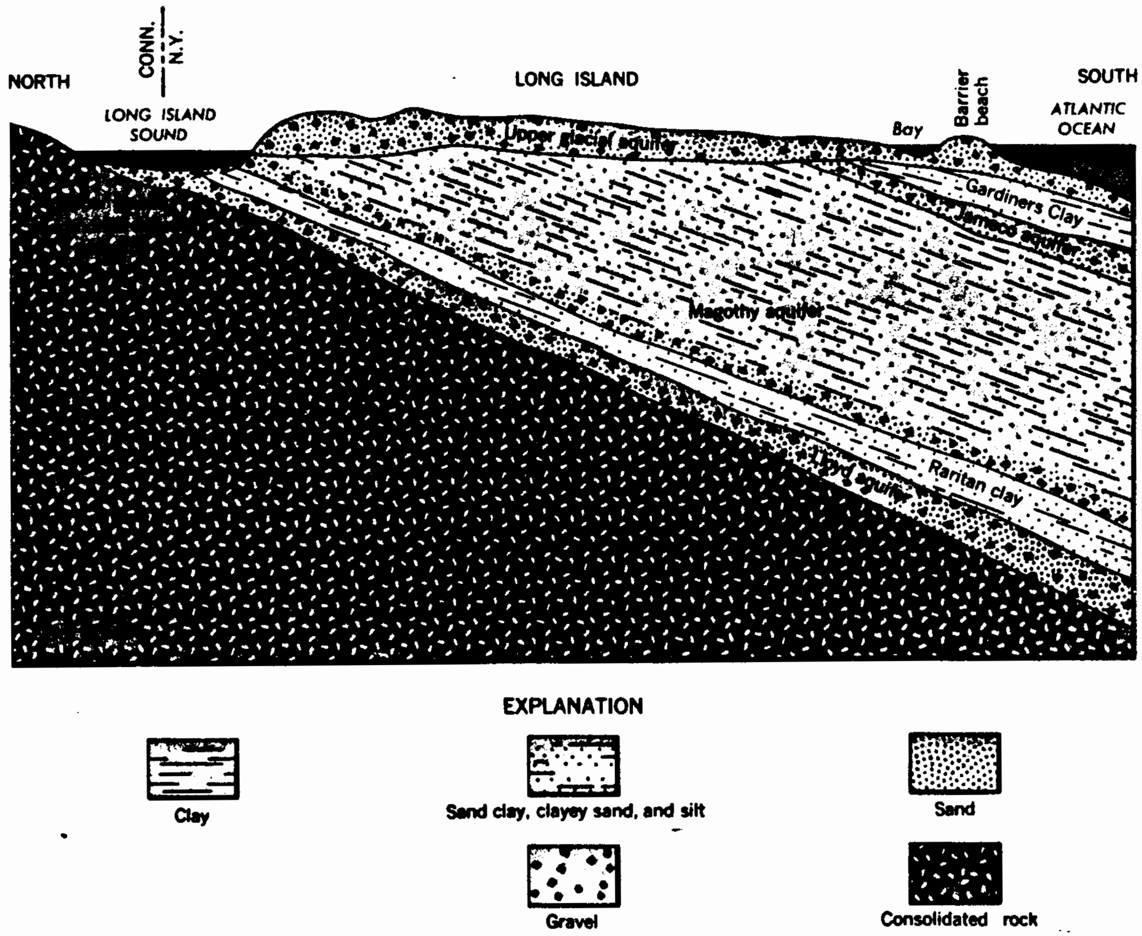


FIGURE THREE

Major hydrogeologic units of the ground-water reservoir

As shown in the accompanying diagram (pl. 2C), Long Island is underlain by consolidated bedrock, which in turn is overlain by a wedge-shaped mass of unconsolidated rock materials. The top of the bedrock, which is at or near land surface in the northwest part of the island, dips toward the southeast to a depth of about 2,000 feet in south-central Suffolk County.[1] The consolidated bedrock is dense and does not store or transmit appreciable amounts of water.

The materials that overlie the bedrock and constitute Long Island's ground-water reservoir are unconsolidated deposits of gravel, sand, silt, and clay and mixtures thereof. These materials can be classified into several hydrogeologic units on the basis of hydraulic properties, relative position, composition, geologic age, and other characteristics. The more important water-producing units in the ground-water reservoir are termed aquifers. Pertinent characteristics of the major units of the ground-water reservoir are summarized in the following table:

[1] The actual dip of the upper bedrock surface is slightly less than one degree to the southeast. The much greater apparent inclination of the bedrock surface and Magothy aquifer that is shown on plate 2C is due to the very great exaggeration of the vertical scale in this cross-section.

Hydrogeologic unit	Geologic name[2]	Approximate maximum thickness (feet)	Water-bearing character
Upper glacial aquifer	Upper Pleistocene deposits	400	Mainly sand and gravel of moderate to high permeability; also includes clayey deposits of glacial till of low permeability.[3]
Gardiners Clay	Gardiners Clay	150	Clay, silty clay, and a little fine sand of low to very low permeability.
Jameco aquifer	Jameco Gravel	200	Mainly medium to coarse sand of moderate to high permeability.
Magothy aquifer	Magothy(?) Formation	1000	Coarse to fine sand of moderate permeability; locally contains gravel of high permeability, and abundant silt and clay of low to very low permeability.
Raritan clay	Clay member of the Raritan Formation	300	Clay of very low permeability; some silt and fine sand of low permeability.
Lloyd aquifer	Lloyd Sand Member of the Raritan Formation	300	Sand and gravel of moderate permeability; some clayey material of low permeability.

[2] Names are those used in reports by the Geological Survey. Perlmutter and Todd (1965, p. [illegible]) proposed that the Magothy(?) Formation be divided into the Monmouth Group and the Mat[illegible] Group and Magothy Formation undifferentiated.

[3] Permeability denotes how readily water can move through [illegible]

ıtrusion has been rsh reality. Sound the fresh-water -range planning, salt-water prob- hemes.

ınd salty ground ıot only on near- ge changes, as in he ground-water able barriers in sh ground-water d water, and the se large amounts ȝ seaward to mix nding bodies of show. Anything und water allows /ard through the

ere troublesome the deep aquifer pplies) are in the nd in the south- map, opposite). ıquifers, the salt- oth shape that is d models of the ıvades as a series ılong the more the intensively er cross-section,

lt-water

e opposite page of the salt-water eted in the late quifers was then ıg a rather broad southern Nassau , including data tes that the salt- s is considerably outhern Nassau een compiled to ront. Therefore, ıter intrusion in the near future, ıear-shore zones nd peninsulas.

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Nature to Be Commanded

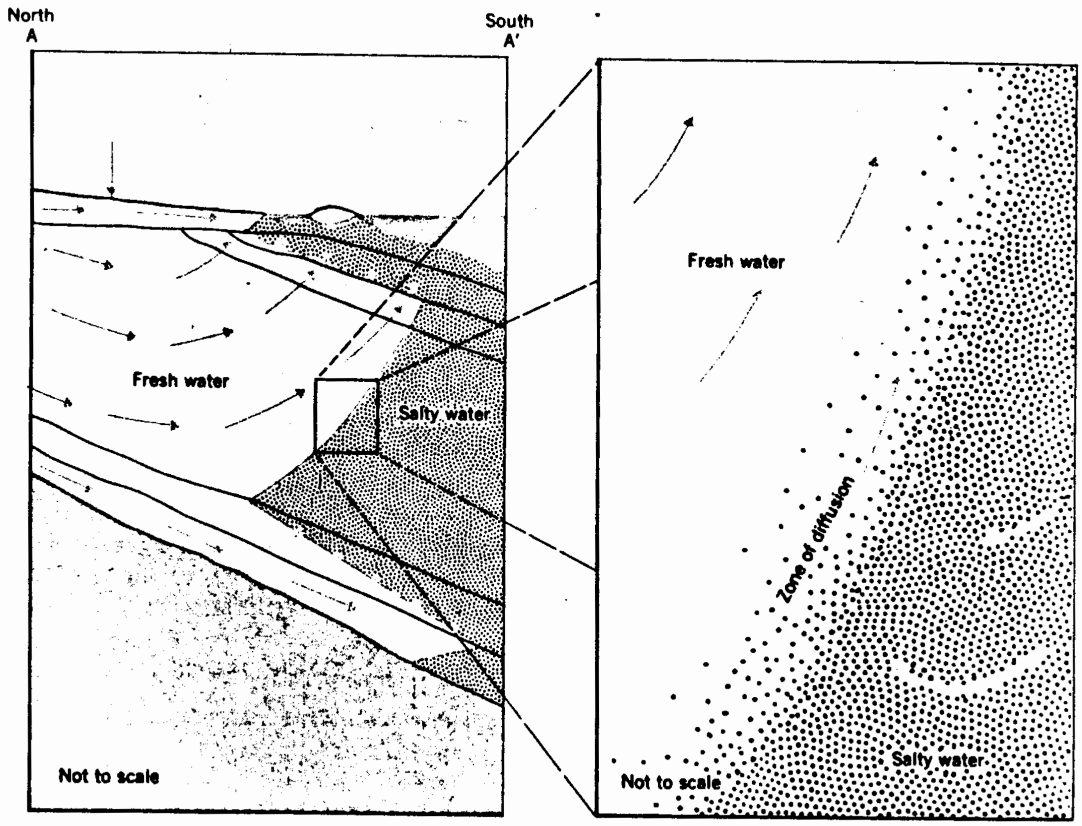
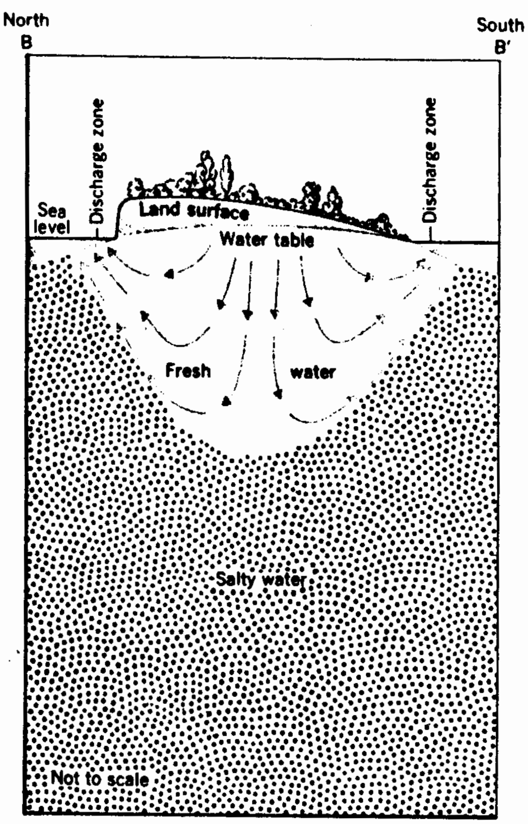


Figure Four



(From Cohen and others, 1

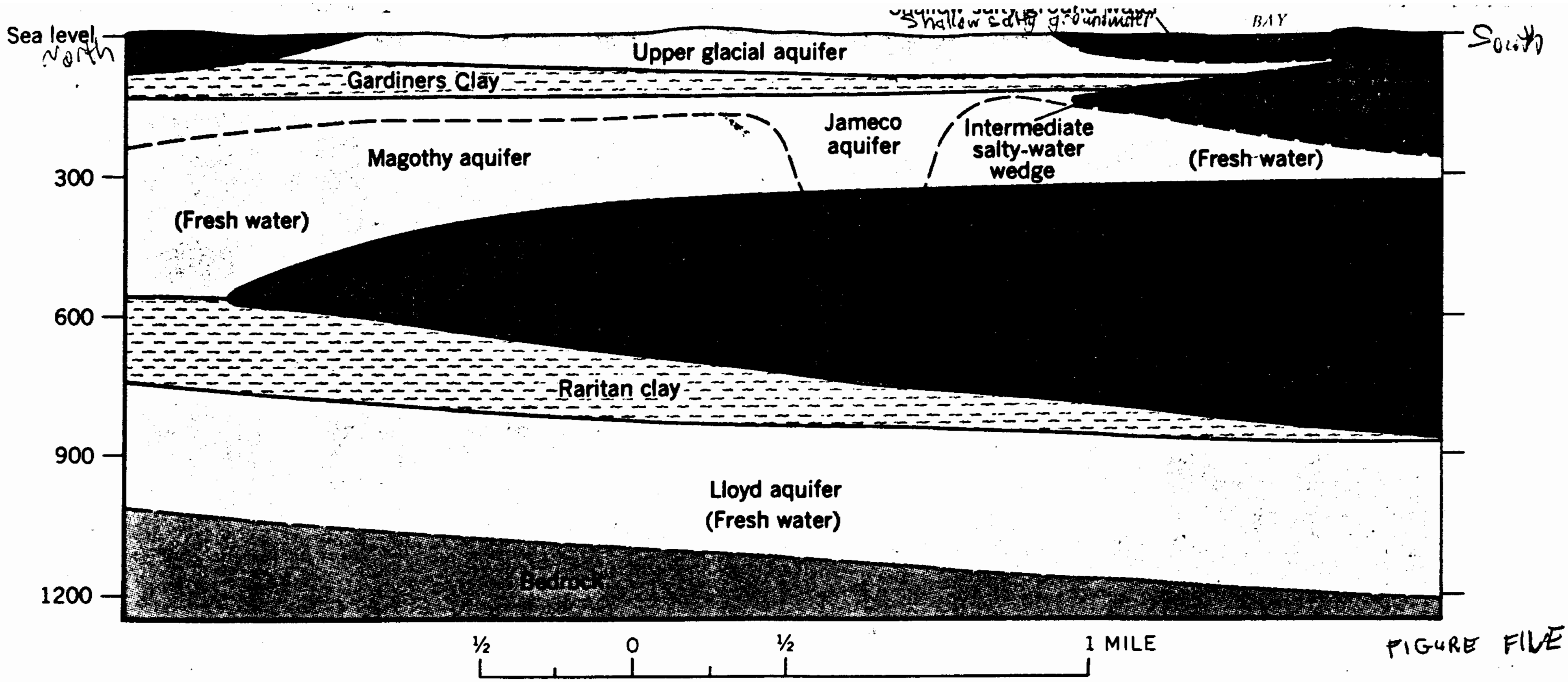


FIGURE FIVE

Nature to be Commanded

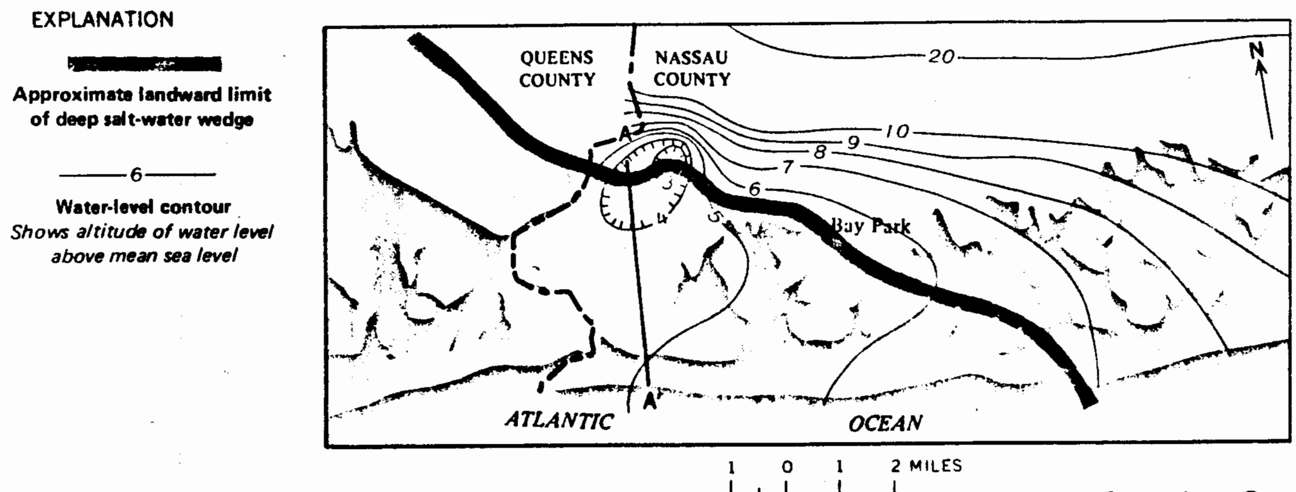


FIGURE SIX

Landward extent of salty ground water

Near the southwestern corner of Nassau County as interpreted in the late 1960's, salty water was farthest landward near the centers of pumping from a deep aquifer (cross-section), where the water levels were drawn down the most (circular depressions in the water-level contour lines). Data now available indicate that, for areas east of the line of section (line A–A' on the map), the salt-water front actually is considerably south of the position shown here.

(From Cohen and others, 1968)

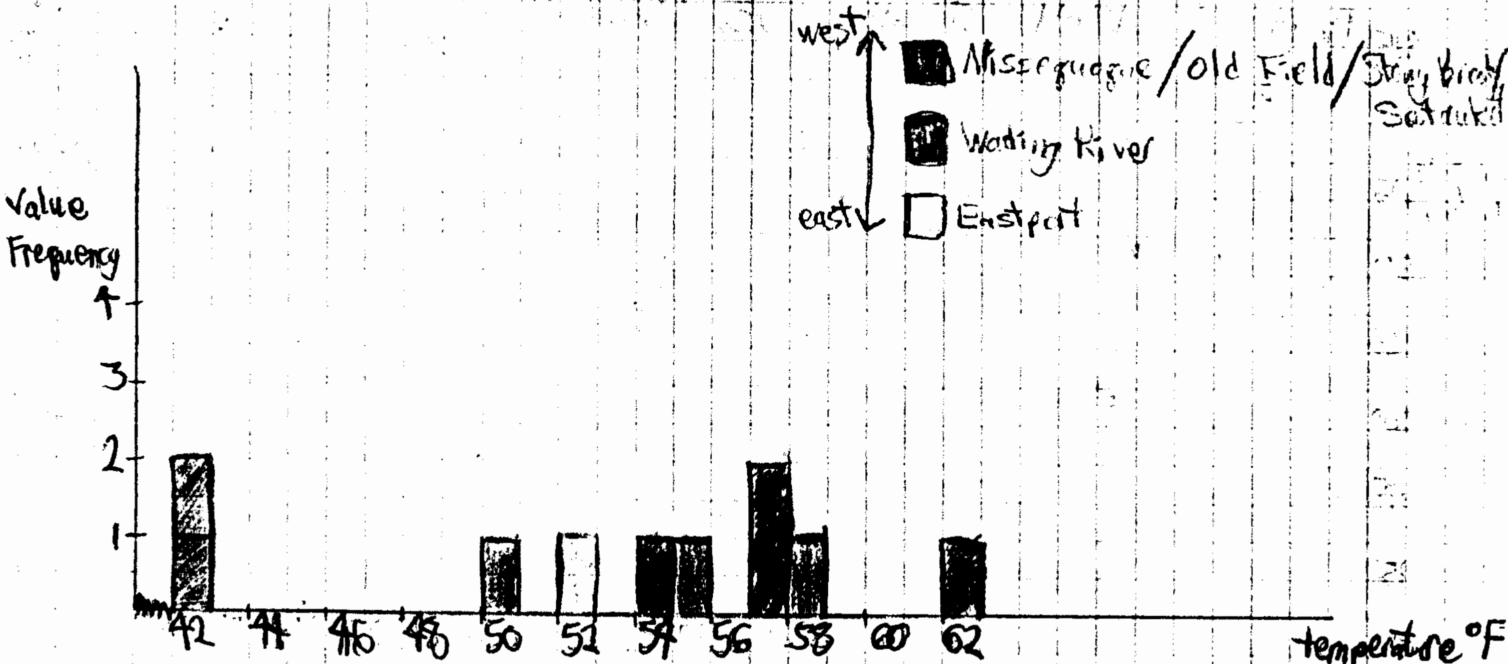


Figure 6 : Temperature Vs. Value Frequency

Standard Deviation Test:

well owner	temperature (x)	value freq.	mean temp. ($\bar{x}$)	$(x-\bar{x})$	$(x-\bar{x})^2$
Gorgal	42	2	52.9	−10.9	118.81
Russo	42		52.9	−10.9	118.81
Schlitz	50	1	52.9	− 2.9	8.41
Archdeacon	52	1	52.9	− .9	.81
Leffler	54	1	52.9	+ 1.1	1.21
Hobson	55	1	52.9	+ 2.1	4.41
Bidwell	57	2	52.9	+ 4.1	16.81
Collier	57		52.9	+ 4.1	16.81
Schwender	58	1	52.9	+ 5.1	26.01
Misener	62	1	52.9	+ 9.1	82.81
		10			394.9

$$\text{Standard Deviation (S.D.)} = \sqrt{\frac{394.9}{10}} = 6.28$$

100% of the data lies within two standard deviations of the mean, and 70% within one standard deviation.

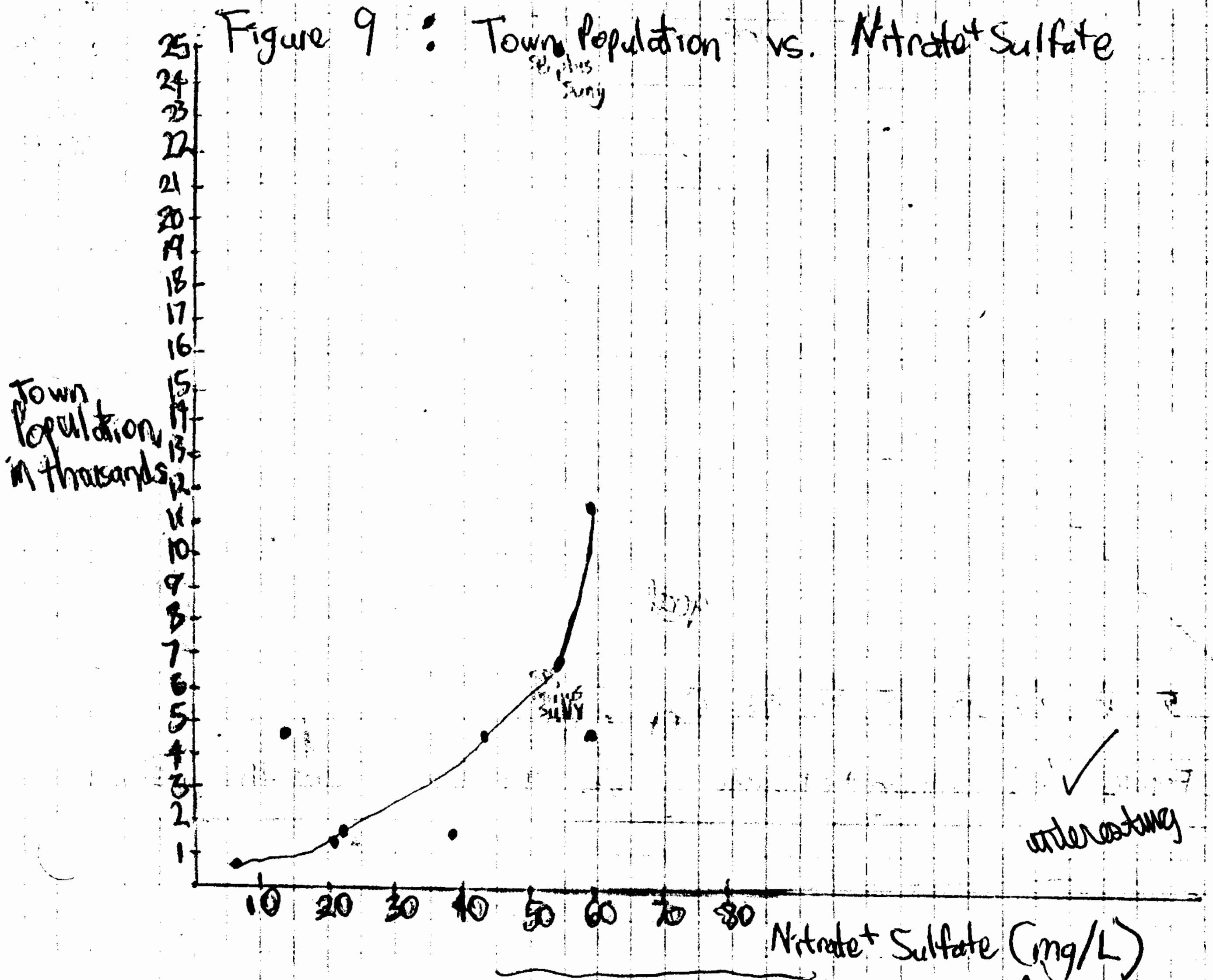


Figure 9 : Town Population vs. Nitrate+ Sulfate
Town Population in thousands
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
Nitrate+ Sulfate (mg/L)
interesting

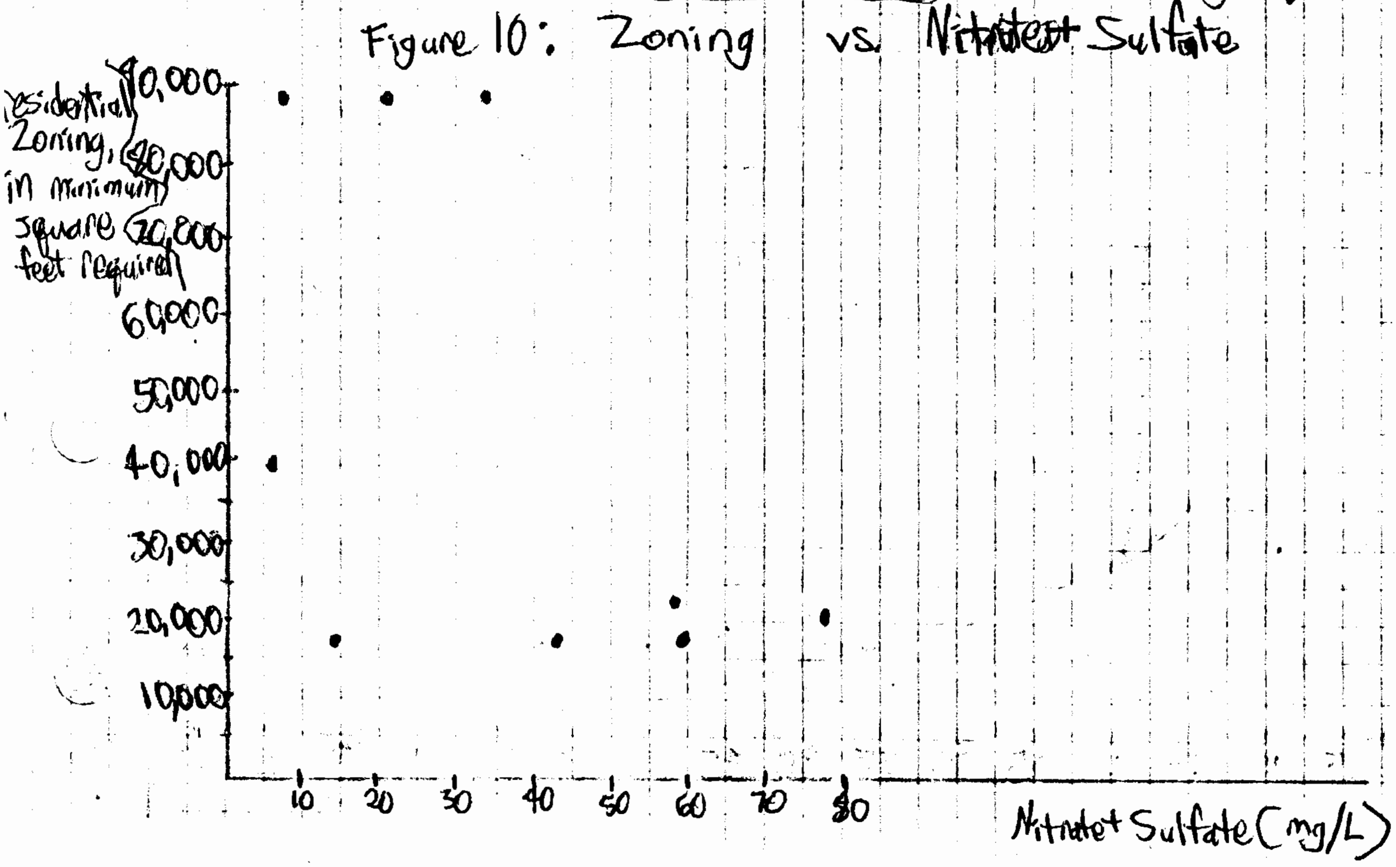


Figure 10: Zoning vs. Nitrate+ Sulfate
Residential Zoning, in minimum square feet required
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
10
20
30
40
50
60
70
80
Nitrate+ Sulfate (mg/L)

Figure 13: Sodium+Chloride VS. Town Population

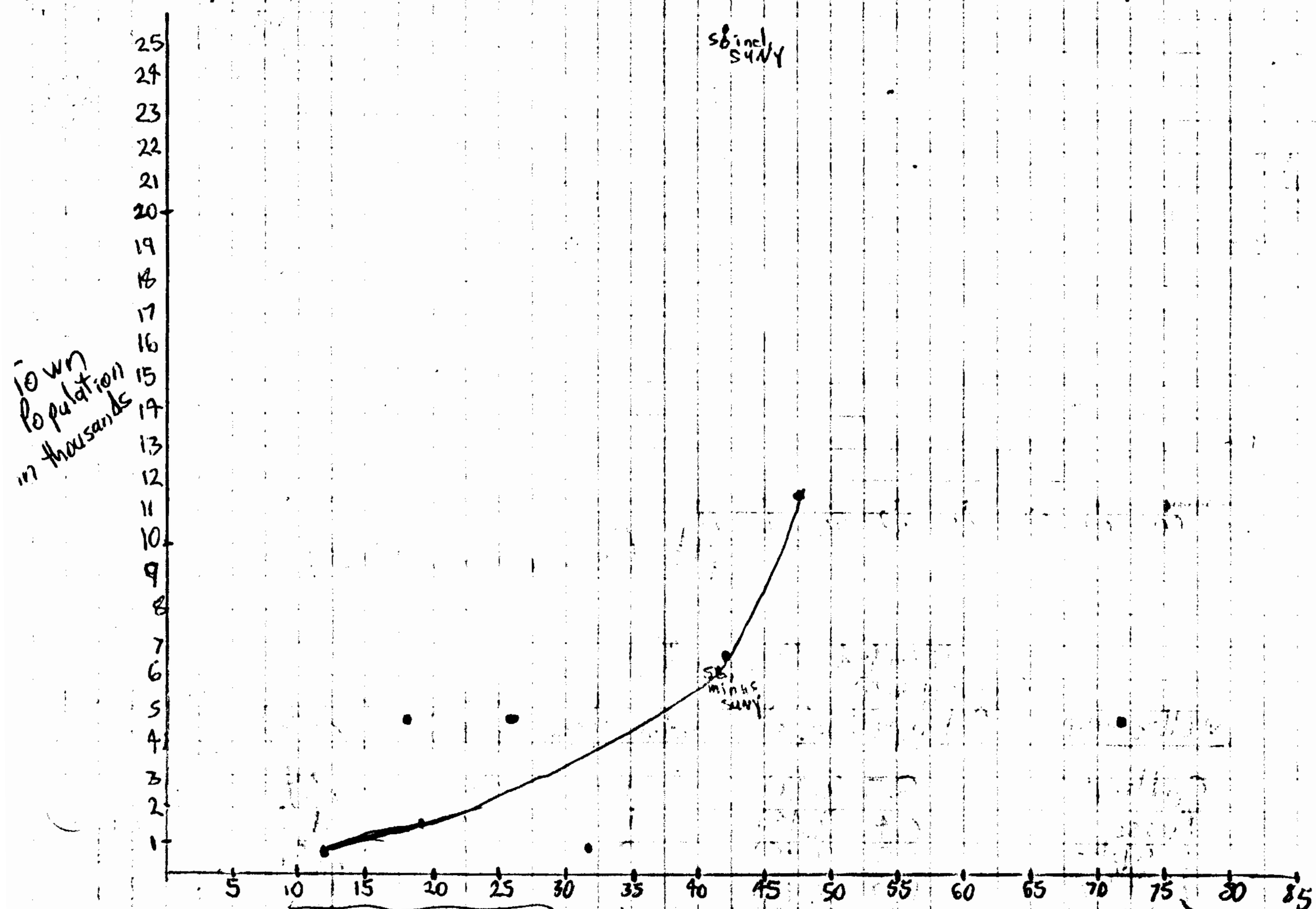
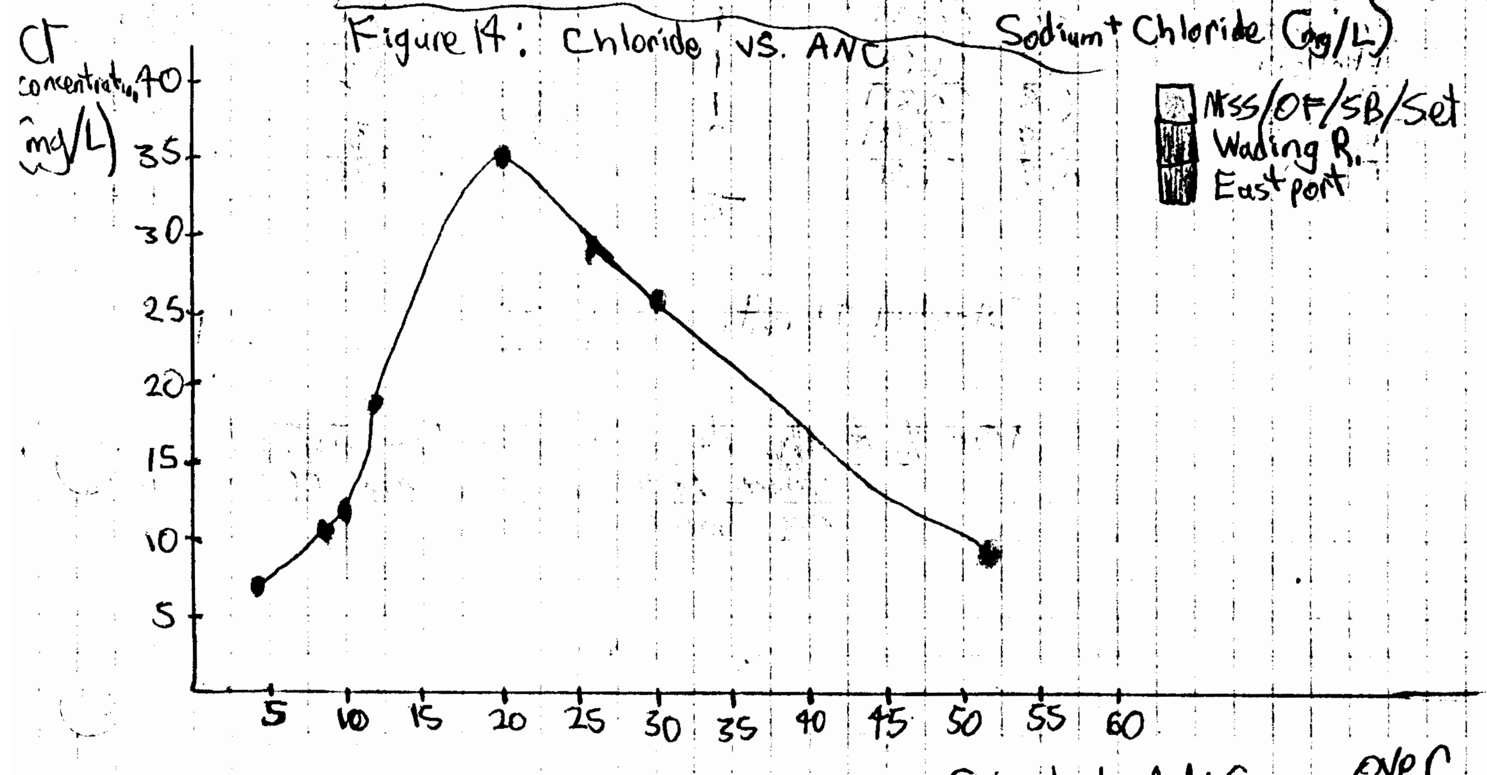


Figure 14: Chloride VS. ANC



over →

L.I. Regional Planning Board: Urban Runoff

FIGURE 16

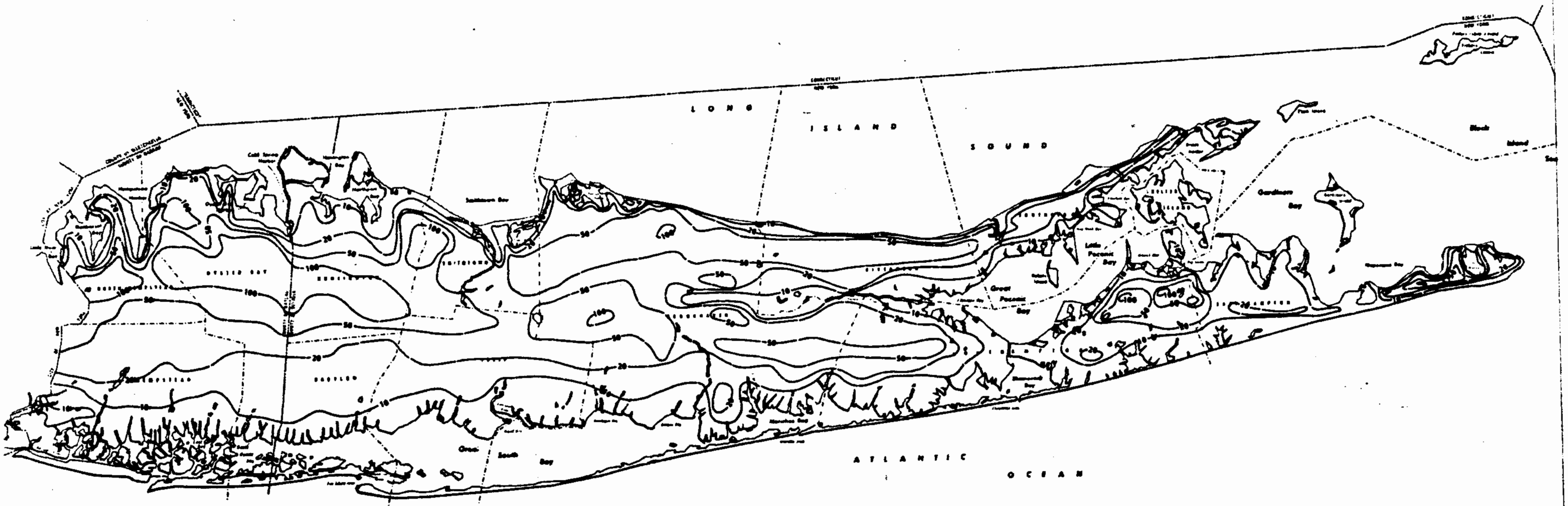


FIGURE 2-11 *Approximate depth to groundwater on Long Island, in feet*

When recharge basins are constructed, all natural soil and vegetal cover are stripped away. A new soil layer develops with time, because of the gradual accumulation of fine-grained sediment and plant material eroded from the drainage area, and because of the natural soil-forming processes within the basin. Although new vegetation takes hold very quickly, it remains sparse for several years following construction.

Recharge basin efficiency can be hindered by low infiltration rates that result from:

i. a high percentage of silt, clay and organic debris that washes in from the drainage area and fill the interstices of the natural deposits, and

ii. a lack of plant growth on the floor of the basin.

Plant growth on the basin floor enhances infiltration because the plant root system keeps the soil layer loose and permeable, and provides channels for infiltrating water.

During this study, it was observed that the soil in the newly constructed, sparsely vegetated Laurel Hollow basin tended to cake and to clog with silt, temporarily affecting recharge efficiency. This was probably a result of the sediment load associated with construction in the drainage area, as well as the lack of vegetation in the basin. The Syosset basin also drains a residential area, but here the basin bottom never became plugged or clogged during the course of this study because the vegetation was well established and the bottom soil is thoroughly broken up by root systems.

b) *Basin Soil Analyses*

Basin-bottom soil samples were collected from the sites at Huntington, Laurel Hollow, Plainview and Syosset on June 5, 1981. (No samples were collected at Centereach because this basin was added later in the study.)

The soil samples were collected at two arbitrarily chosen spots approximately five feet in front of the concrete apron at the outfall pipe. Because the basin at Huntington contains two or more feet of water at all times, the soil here was taken from two locations near the water line at the base of the service ramp. In each case, two samples of the top few inches of soil were collected. One was placed in a pretreated liter glass jar with a teflon seal for herbicide and insecticide analysis, and the other in a liter plastic container for metals analysis.

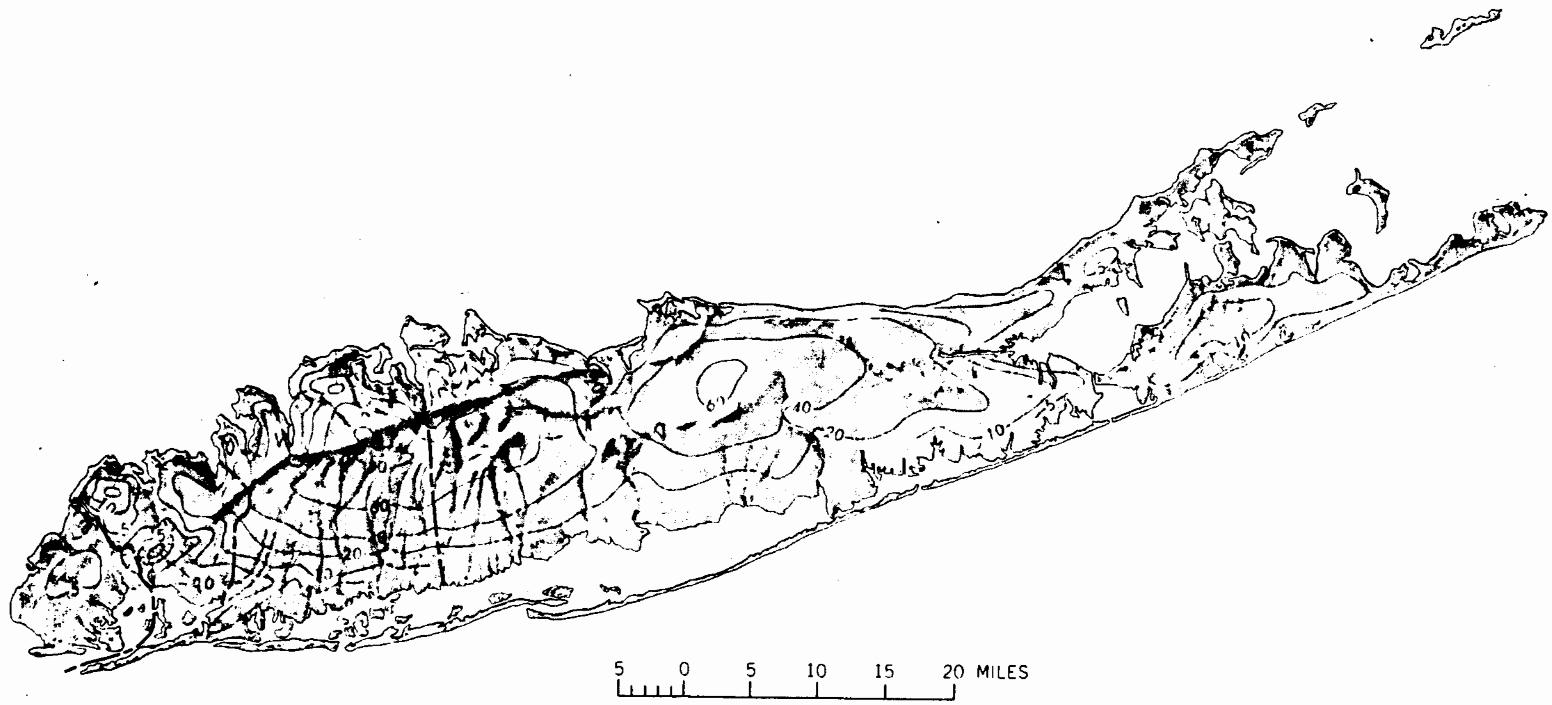
Chromium concentrations in basin soil range from 10 μg/g (micrograms per gram of soil) to 20 μg/g. The lead concentrations range from a low of 70 μg/g at Laurel Hollow to a high of 1200 μg/g at Plainview. The other metals found in significant concentrations, i.e. iron, maganese, and zinc, are native to the soil (Ku and others, 1978).

The concentration of chromium in basin-bottom soil appears to be uniformly low and independent of land use (20 μg/g at Huntington, 10 μg/g at Laurel Hollow, Plainview and Syosset). The concentration of lead, however, is highest (1200 μg/g) at Plainview, where the basin receives storm runoff from a highway, and lowest (70 μg/g) at Laurel Hollow, where the basin is newly con-

N.Y. State Water Resources

Figure 17

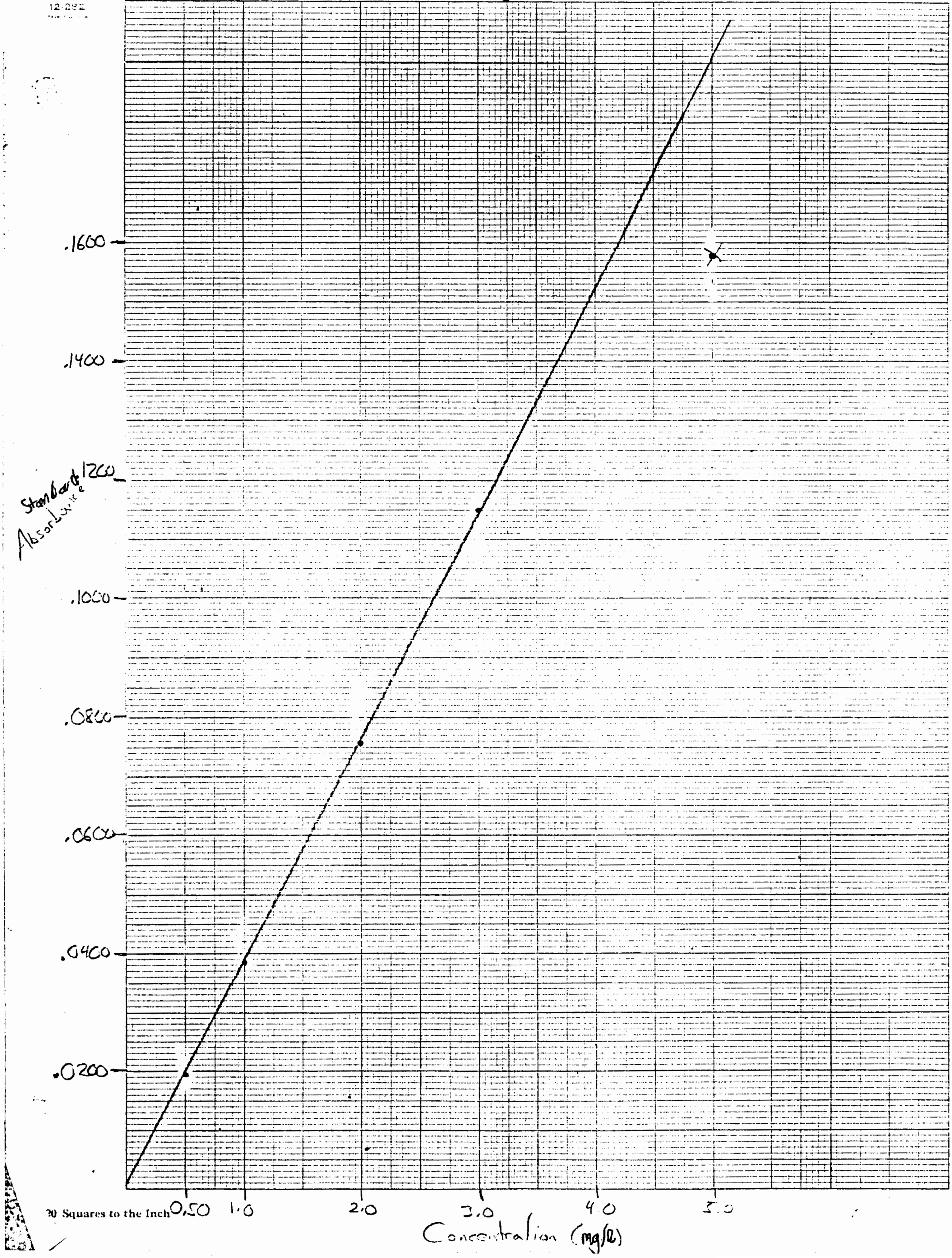
PLATE 2E
GENERALIZED CONTOURS ON THE WATER TABLE OF LONG ISLAND, NEW YORK, IN 1965



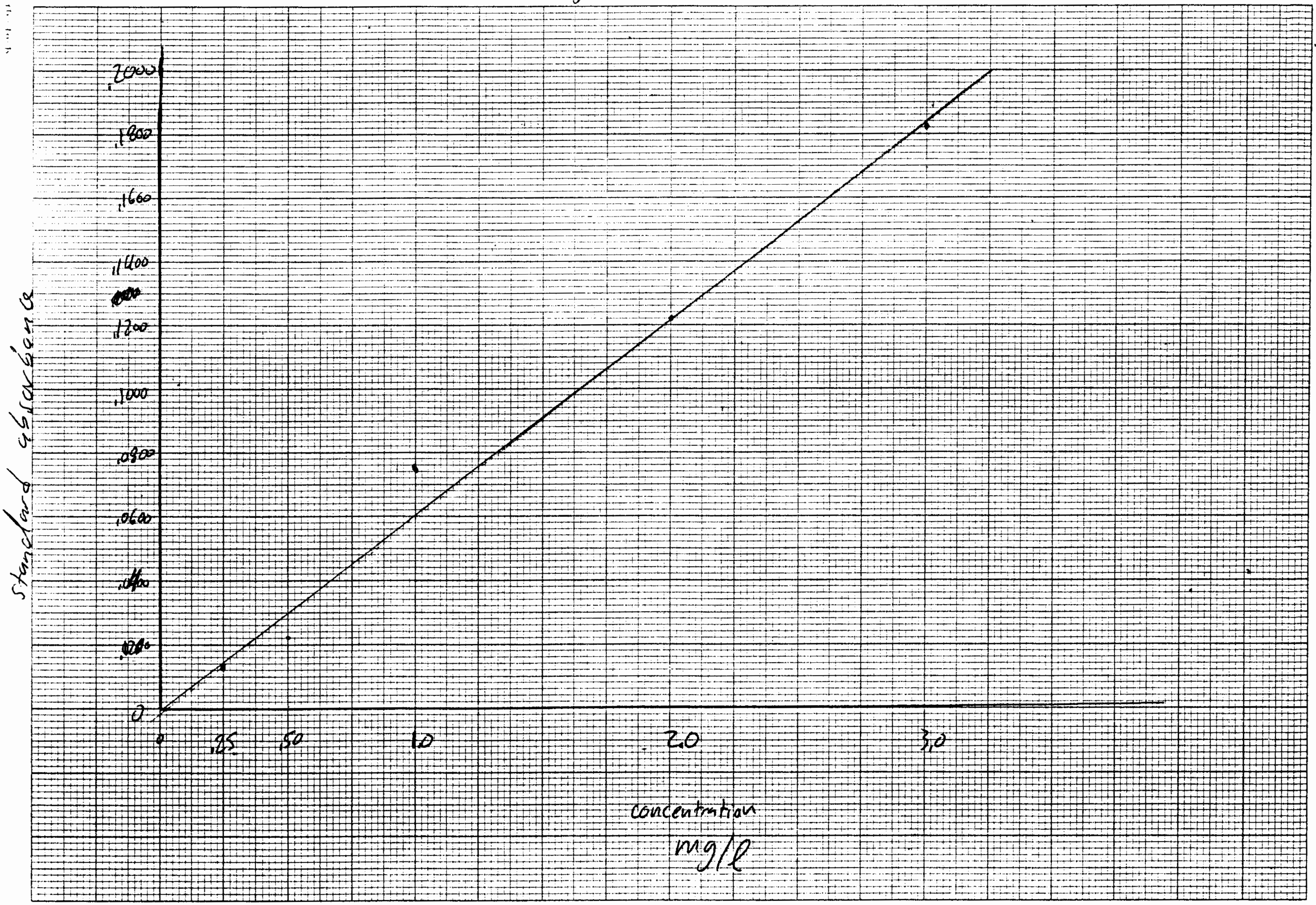
EXPLANATION

WATER-TABLE CONTOUR
Shows altitude of water table
Contour interval 5, 10, and 20 feet
Datum is mean sea level

Standard Curve for Sodium

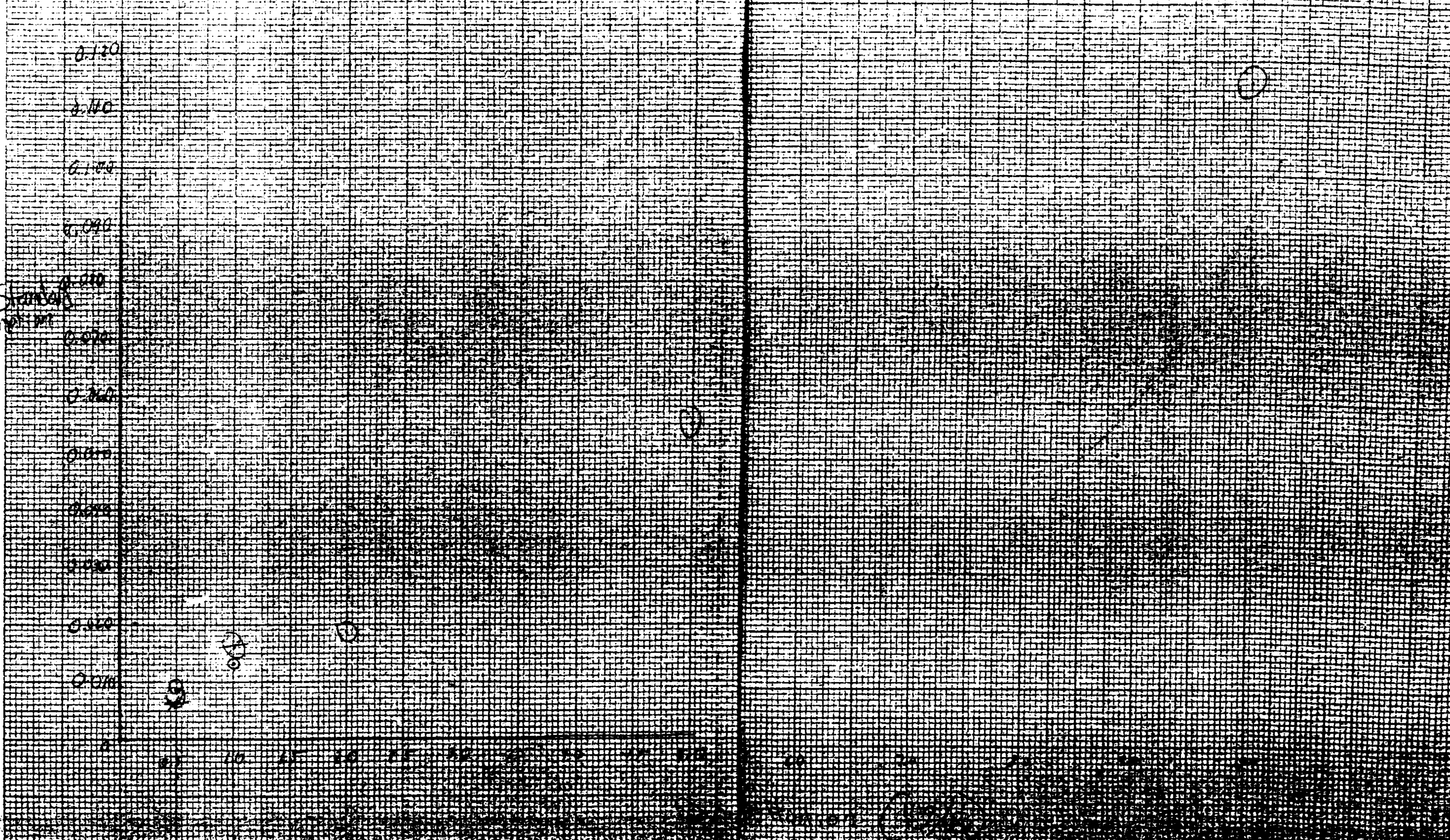


Magnesium Standard curve



Devra

Ca+2 standard curve



Devra Lee Bellin

TABLE ONE: Data on Well-Water Samples

Name of Well-Owner (west-east)	temp.	cond.	pH	stand. ANC	Mg	Ca	Na	Br	Cl	F	NO3	PO4	SO4	depth of well (ft.)	dist.from ocean	town pop.	zoning for street (min.sq.ft.)
BIDWELL	57	210	6.93	52	7.83	17.0	10.1	--	8.8	--	16.8	--	22.8	66	1400	1666	87,120
GAIGAL	42	80	6.91	12	3.40	4.6	5.6	--	SOME	--	1.4	--	7.0	108	1400	1666	87,120
COLLIER	57	168	6.29	12	5.88	16.2	13.7	--	18.4	--	9.0	--	11.8	N/A	800	919	87,120
SCHLITZ	50	255	6.48	30	7.83	28.6	17.1	SOME	26.0	--	34.8	--	23.6	60	400	25,379*	22,500
LEFFLER	54	305	6.48	26	9.16	19.8	20.1	0.38	27.4	--	41.4	--	35.8	28	350	11,476	21,780
HOBSON	55	215	6.69	20	0.38	TRACE	38.2	0.6	35.0	--	36.6	--	23.0	N/A	3400	4723'	15,625
SCHWENZER	58	540	7.81	134	TRACE	0.80	99.7	--	159.2	0.5	SOME	--	1.8	90	3000	4723'	15,625
RUSSO	42	185	6.44	8	8.87	9.2	7.5	--	10.8	--	5.0	SOME	38.6	150	3800	4723'	15,625
MISENER	62	128	6.81	10	2.10	14.6	13.0	SOME	12.4	--	14.8	--	SOME	147	7200	4723'	15,625
ARCHDEACON	52	51	6.64	4	1.26	2.4	5.6	--	7.2	--	1.2	--	5.7	75	400	836	40,000

Information:
*= if the State University of New York at Stony Brook is not included in this figure, the town population falls to 6673 people.

'= a 1985 (as opposed to 1989) figure

The designation "some" means that the sample's measurement peaked on the undiluted IC reading but did not "appear" in the diluted.

Temperature is in degrees Farenheit, conductivity in umhos/cm., ion concentrations in mg/L, well-depth in feet, distance from ocean in feet, town population in people, and zoning in the minimum square feet required for the housing development in question.