Exhibit F

North Florence Dunal Aquifer Study

June 1982

LCOG Lane Council of Governments
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208 WASTE WATER MANAGEMENT

NORTH FLORENCE DUNAL AQUIFER STUDY

FINAL REPORT

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CREDIT SHEET

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ABSTRACT

A study of the North Florence Dunal Aquifer was conducted to formulate alternatives for the protection of the aquifer from contamination by on-site sewage disposal. Characterization of the aquifer also allows for the possible formulation of remedial procedures to clean-up future spills or leaks, or protect against contaminant migration. In the current study nitrate-nitrogen was the contaminant/nutrient of primary concern.

The study consisted of a seismic survey to define aquifer boundaries and inhomegenities, a monitoring program to determine current water quality and head variations at various sites and settings on the aquifer, and a modeling effort to characterize the hydrogeologic parameters of flow. Through the use of digital modelling, the response of the aquifer to increased pumpage and drought was examined. Analysis of recharge data and loading rates allowed for definition of loading limits for Nitrate-Nitrogen.

Results of the study include the definition of critical areas of the aquifer for protection as well as the definition of Nitrate-Nitrogen loading limits necessary to stay within the 5.0 mg/L planning standard. The study indicates that most of the aquifer is relatively insensitive to nitrate ~~and accommodate that most of the aquifer is relatively insensitive to nitrate~~ and can accommodate up to 2.9 dwelling units per acre. The Clear Lake Watershed is shown to be very sensitive due to the susceptibility of Clear Lake to algae growth and dwelling unit limitations are calculated at 0.010 units per acre.

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RECOMMENDATIONS

General

1. The existing Oregon Administrative Rule OAR 340-71-400(2) North Florence Dunal Aquifer Area, Lane County should be modified so as to conform to the technical results concerning geographical areas and nitrate loading considerations of the North Florence Dunal Aquifer Study.

2. The Aquifer Study predicts loadings for nitrate-nitrogen to the aquifer such that Oregon DEQ Planning Standards (5.0 mg/L nitrate-nitrogen average) are met. The Regional Rule as well as regional plans should be modified to reflect the Aquifer Study results.

3. It is recommended that the two identified portions of the North Florence Aquifer (the "Clear Lake Watershed" and the "General North Florence Aquifer") be recognized and so designated by the West Lane Planning Commission, the Lane County Commissioners and the Environmental Quality Commission.

4. The Regional Rule should recognize and legally define the "Clear Lake Watershed" and the Rule should be modified to protect this resource according to the findings of the Aquifer Study.

5. It is recommended that the Aquifer Study be reviewed and formally accepted by the following jurisdictions and agencies.

   Oregon Health Division
   Water Resources Department
   Lane COG Board of Directors
   Coastal Ad Noc Advisory

6. It is further recommended that the North Florence Aquifer Study be reviewed and adopted for planning and policy guidance by the following jurisdictions:

   Heceta Water District
   City of Florence
   West Lane Planning Commission
   Lane County Board of Commissioners
   Environmental Quality Commission

Clear Lake Watershed

7. It is strongly recommended that the agencies listed in #6 formally adopt one of the following policies concerning the Clear Lake Watershed.

   A. A commitment will be made to retain Clear Lake as a pristine domestic water supply and to protect and improve its water quality.

B. A commitment will be made to develop alternate water supplies and/or additional treatment facilities and Clear Lake will be allowed to degrade in quality.

Note: A failure to specifically adopt A or B is, in essence, an adoption of Policy B.

Specific Recommendations - Policy A

8. Measures should be taken to protect Clear Lake from further nutrient loadings which would cause algae growths and quality degradation. No significant increase from current annual average nitrate-nitrogen levels should occur.

9. It is recommended that all County owned lands within the Clear Lake Watershed be designated as "Clear Lake Watershed Management Area" and be kept permanently free from all development other than as may be necessary to develop the domestic water supply for the area.

10. It is recommended that LCDC State Planning Goals # 17 and 18 be strictly applied within the "Clear Lake Watershed" with no exceptions to building prohibitions on open sand, deflation plains and wetlands.

11. It is recommended that dune stabilization for the protection of lakes, improvements or other valid purposes be permitted only if it can be achieved with an application of fertilizer not to exceed 2 lb/acre nitrate-nitrogen for a period of time limited to two (2) years.

12. It is recommended that the total allowable annual loading from human wastes in the Clear Lake Watershed be set at a maximum of 170 lbs of nitrate-nitrogen per year, by the EQC and the Lane County Board of Commissioners.

13. It is recommended that no development be allowed in the Clear Lake Watershed that would increase the annual nitrogen-N loading to an amount greater than the adopted loading.

14. It is recommended that all developments within the Clear Lake Watershed be required to retain native vegetation to the maximum extent possible and must be constructed with the minimum damage to existing vegetation. It is further recommended that no artificial plantings be allowed which require significant fertilization to maintain.

15. It is recommended that no new developments be allowed in the Clear Lake Watershed using on-site systems. All permits approved must include plans for the transportation and treatment of wastes outside the watershed boundaries, or for the use of dry-waste and grey water systems in instances where such systems do not increase the

calculated overall loading beyond 170 lb/year and only as replacements for on site systems.

16. It is recommended that no public access be provided to Clear Lake and and that Lane County provide conservation easements to owners of Clear Lake shoreline property such that no access is developed.

17. It is recommended that public access to Collard Lake be limited to no more then one site and that boats with motors be barred from use on Clear.

18. It is recommended that motors be barred from use on Clear and Collard Lakes.

Specific Recommendations Policy B

19. Measures should be taken to protect the General North Florence Aquifer from nutrient loadings from individual waste sources such that the State State Planning standard of 5.0 mg/L nitrate-nitrogen is not exceeded generally in the aquifer.

20. A nutrient waste loading of 58 lb/acre nitrate-nitrogen per year is predicted by the study to be acceptable and not result in groundwater concentrations in excess of 5.0 mg/L. This waste loading should be adopted as a standard for the Clear Lake Watershed. This loading is predicted to be adequate to protect water quality in the dunal portions of the aquifer, but not the surface waters thereof.

21. It is recommended that the dunal portion of the Clear Lake Watershed receive protection planning by having all county owned lands within the Clear Lake Watershed be designated as "Clear Lake Watershed Management Areas" and be kept free from development other than as may be necessary to develop the domestic water supply for the area.

22. It is recommended that LCDC State Planning Goal #17 and 18 be strictly applied within the Clear Lake Watershed with no exceptions to building prohibitions on open sand, deflation plains and wetlands.

23. It is recommended that no development be allowed that would increase the annual nitrogen-loading to an amount greater than adopted.

24. It is recommended that dune stablization for the protection of lakes, improvements or other valid purposes be permitted only if it can be achieved with an application of fertilizer not to exceed 58 lb/acre nitrate-nitrogen on an annual basis.

25. It is recommended that a process be instituted to set aside funds from current revenues for the purpose of future source relocation, water supply and water treatment facilities expansion.

26. It is recommended that Clear Lake be monitored periodically for nitrate and turbidity levels in order to anticipate necessary modifications in the water supply system.

27. It is recommended that the current water intake be relocated to deeper waters to reduce the impacts of algae growth on the water supply and to prolong the period of use of the current facility.

28. It is recommended that feasibility and cost studies be initiated for evaluation of alternative water supply or water treatment needs.

General North Florence Recommendations

29. Measures should be taken to protect the General North Florence Aquifer from nutrient loadings from individual waste systems such that the State Planning standard of 5.0 mg/L nitrate-nitrogen is not exceeded generally in the aquifer.

30. A nutrient waste loading of 58 lb/acre nitrate-nitrogen per year is predicted by the study as being acceptable and not result in groundwater concentrations in excess of 5.0 mg/L. This waste loading should be adopted as a general standard for the dunal aquifer. This loading is predicted to be adequate to protect water quality in the Florence well field.

31. The current sanitary landfill site is found to be located in an area of discharge with little measurable impact to beneficial uses of ground or surface water. The landfill site should be designated as the accepted long term landfill location to serve coastal area solid waste disposal needs. Requirements should be established such that no well development be allowed between the Landfill site and the estuary.

32. It is recommended that no development be allowed that would increase the annual nitrogen loading to an amount greater than the adopted loading.

33. It is recommended that dune stablization for the protection of lakes, improvements or other valid purposes be permitted only if it can be achieved with an application of fertilizer not to exceed 58 lb/acre nitrate-nitrogen on an annual basis.

Introduction

INTRODUCTION

Background

The study of the North Florence Dunal Aquifer was initiated in 1979. The purpose of the study was to identify the impacts of development, specifically, using on-site sewage disposal methods on the aquifer and its associated surface lakes and streams. The concern for the aquifer was prompted by a water supply study (Strong, 1978) that identified the aquifer (and aquifer associated lakes) as the primary, if not sole, source of water for the Florence area north of the Siuslaw River.

The Clear Lake Watershed area has been identified as a unique aquifer situation requiring particular attention. The provision of unfiltered domestic water supply from Clear Lake is recognized as a rare situation among municipal supplies and certainly one that would require special protection if that practice were to continue. The interaction between Clear Lake and the dunal aquifer is of critical importance in understanding the sensitivity of the lake system to degradation.

Also, the City of Florence pumps water directly from the dunal aquifer using two wells in the northeastern part of the city. The protection of the water supply for these wells is of vital concern.

Therefore, the project had two major foci. The first focus was to determine the levels of contaminants or nutrients which would cause degradation in the the clarity and purity of the Clear Lake water supply. The second focus was the determination of contaminant loadings that could be allowed and not exceed the state planning standards for nitrate-nitrogen as set by the Oregon Environmental Quality Commission (EQC). Nitrate-Nitrogen was identified as the parameter of critical concern due to its concentration of domestic sewage, its conservation in the groundwater (does not decompose), susceptibility to accurate testing and to the possibly profound effects of nitrate on algae growth in Clear Lake.

Several pertinent studies have been published for the Florence area and in areas of similar hydrogeological setting along the Oregon Coast.

1. E.M. Baldwin (1956) produced a geologic map for the lower Siuslaw River area for oil and gas exploration.

2. S.G. Brown and R.C. Newcomb (1962) Groundwater Resources of the Coastal Sand-Dune Area North of Coos Bay, Oregon) Discussed the groundwater potential of the dunes sands north of Coos Bay.

3. E.R. Hampton (1963) studied the southwest quarter of the North Florence Dunal Aquifer. Numerous hydrographic wells were established and groundwater contour maps were produced along with analysis of sand size, transmissivity, storage coefficient and chemical

quality. Possible pollution problems were identified. The City of Florence established two municipal wells (its current supply) based on this report.

4. J.H. Robison (1973) produced an analog model of the hydrology of the dunal aquifer north of Coos Bay.

5. R.C. Newcomb, R.L. Jackson (1974, Geologic Hazards of Coastal Lane County) produced a report on coastal Lane County which addressed, in part, the ground water in the Florence area. The authors estimated available water on a per-year basis and potential aquifer contamination addressed generally.

6. C.H. Strong (1978, Lane County Coastal Water Supply Study) Studied domestic water use and supply for the coastal portion of Lane County. The groundwater portion of the study was an overview of past efforts and current resource volume estimates. Potential pollution problems were delineated. This report indicated that the dunal aquifer was the most viable long-term domestic water source for the area North of the Siuslaw River.

A complete reference listing is given in the Bibliography.

Concurrent Studies

During the period that the North Florence Dunal Aquifer Study was in progress, a similar project was underway on the Clatsop Plains between Astoria and Gearhart. Though similar in climate and sand characteristics, the physiographic, sociographic and natural setting differences between the North Florence and Clatsop Plains areas required that somewhat different goals be in each of these studies. However, the two studies did perform a joint Decay and Dispersion (D&D) analysis for the purpose of determining rates of decay and dispersion of bacteria and nitrates in a simulated drainfield situation on a site near the Florence Airport. This study element could be conducted jointly because it relied solely on climate and the physical characteristics of the dunal sands in a very localized area and not on the general characteristics of the two aquifers. This D&D study formed a separate minor and ultimately irrelovant element of the North Florence Study.

In general, the methods used in both aquifer studies are comparable, but not identical. The conclusions reached by each study are reflective of the different goals and needs of each community. A comparison of the two studies reveals that in both cases the dunal aquifers are unconfined, highly permeable and capable of storing and exchanging high volumes of water. Hydrology modeling is particularly useful in these aquifers and the rate of recharge through rainfall is a major factor in determining acceptable waste loadings. However, it would be risky to apply the specific outputs of one study to another without local input and specific consideration of local differences.

"Groundwater Evaluation Report" and "Summary Report and Environmental Assessment" portion of the Clatsop Plains Groundwater Protection Plan are on file in the Barrow Alaska Sanitation Department.

Planning and Population

At the time the Lane County Coastal Water Supply Study was completed in 1978, proposed planning would have placed nearly 65,000 people in the coastal Lane County area. Of this population nearly 50,000 would have been located on the North Florence dunal area. Since that time, planning changes indicate that maximum populations will not exceed 25,000. For purposes of this study, a maximum ultimate population for the North Florence area (including the City of Florence and evirons north to Heceta Head) was set at 25,000 persons. This assumes a near-maximum buildup outside the urban growth boundary (UGB) plus substantial growth inside the UGB. Inside the UGB large publically owned tracts of land are assumed substantially given over to private ownership and development. It is not predicted that this situation will occur in the near future but at some point well beyond the year 2000. According to Lane County Planning staff, the population projection for the North Florence Study area for the year 2000 is approximately 15,000. Current population in this area is approximately 8,000. The population figure of 25,000 was used to calculate an ultimate domestic water demand on Clear Lake. A planning staff memo on this subject is found in appendix M.

Study Area Description

STUDY AREA DESCRIPTION

The North Florence Dunal Aquifer Study (See figure 1) was initiated as a result of concerns that the primary source of water for consumptive use was possibly being threatened by mans activities on the surface of the aquifer. Concern is centered on three main areas, in order of priority: 1) Clear Lake, the Heceta Water District water source, 2) the City of Florence well-field and 3) the broad area of the aquifer with zoning such that extensive development with on-site disposal systems could be anticipated. All of these areas fall within a portion of the dunal sheet that extends from the Siuslaw River at Florence to Sutton Creek and from the Pacific Ocean to the bedrock ridge east of Clear Lake. These boundaries define the North Florence aquifer study area and are outlined in Figure 2.

Geographic Setting

The study area is located near the northern terminus of a 50 mile long dunal sheet that extends from Coos Bay on the south to Heceta Head on the north (See figure 3). This dunal sheet ranges from less than one mile to greater than three miles in width and is broken only by the major streams (Umpqua and Siuslaw Rivers) which cross it. The broadest portion of the dunal sheet is near Florence. The western border of the dunal sheet is the Pacific Ocean while the eastern boundry is the abrupt rise of the Coast Range.

Throughout the study area the dunal sheet is broad and relatively flat. It has a width in excess of three miles and a general elevation in excess of 80 feet above sea level. The generally flat nature of the sheet reflects its origin where successive layers of sand were built up as deflation plains behind eastward migrating oblique dunes. The remnants of these dunes that have become stabilized, and those which have not, are generally the major topographical features on the smooth dunal sheet surface. The margins of the sheet along the Siuslaw River, (including the North Fork), the Pacific Ocean and Sutton Creek generally approach sea level (or a stream level of less than 30 feet above sea level). A notable exception is along the estuary from near the old Siuslaw Pacific Moorage (just south of 35th Street and Rhododendron Drive) to Heceta Beach where a 50-60 foot high bank rises steeply from sea level up to an old deflation plain. From its margins the dunal sheet rises to a general elevation of about 120 feet above sea level. (See Figure 4)

The dunal sheet within the study area is predominately covered by a shore pine forest with an understory of rhododendron, salal, huckleberry and blueberry and other subordinate shrubs. Extensive areas of open sand exist as a series of migrating oblique dunes. These represent two or more episodes of dune activation on the dunal sheet within the study area (Cooper, 1958). Some plantings of European beach grass have been put on portions of these dunes to attempt stabilization, notably, along 35th Street, near the Heceta Water District storage tank and near the City of Florence pipe line which runs between

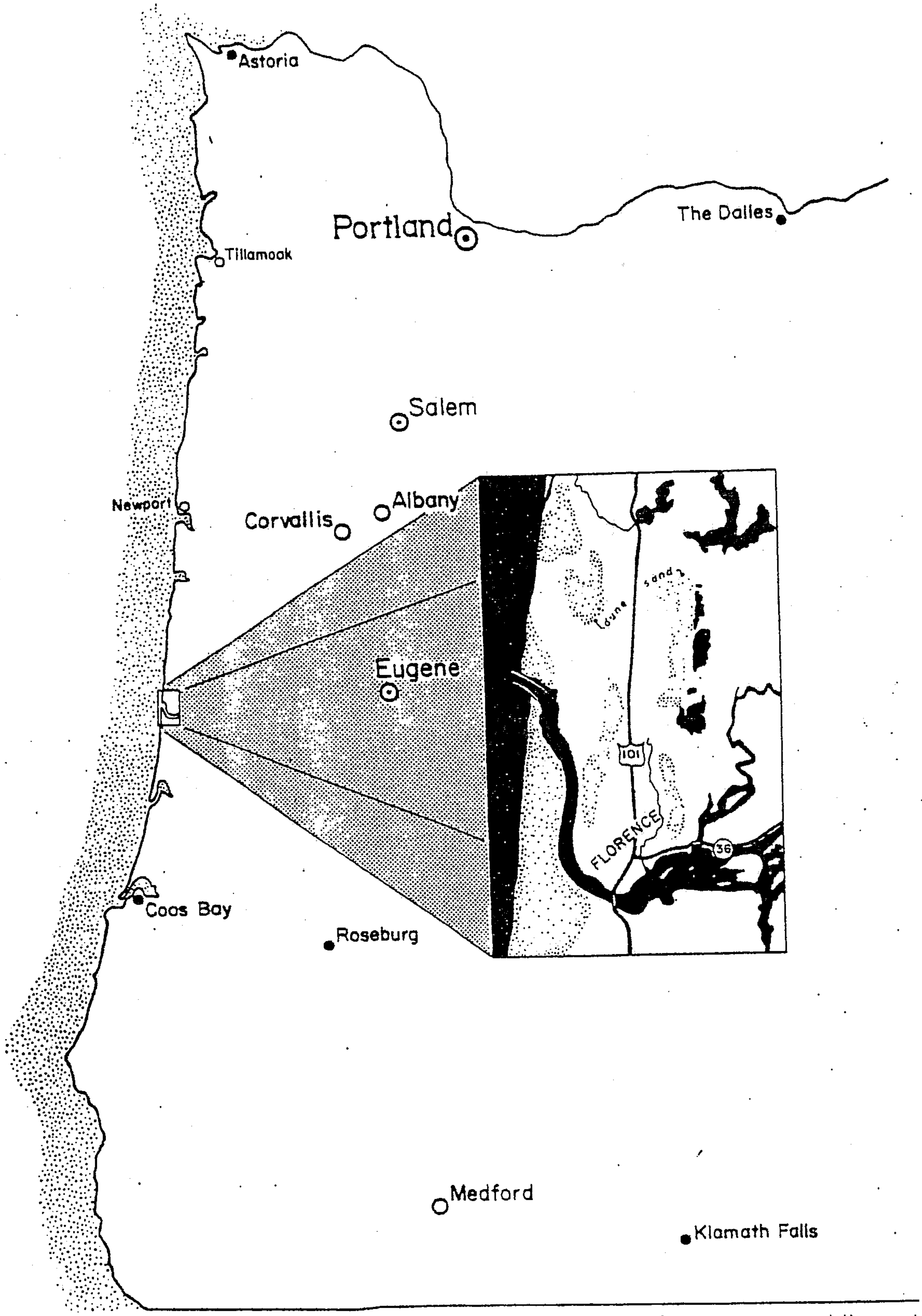


FIGURE 1. Location of the Florence Dunal Aquifer.

FIGURE 2. Locator Map for the North Florence Dunal Aquifer Showing Study Area Boundries, Roads, Streams and Lakes.

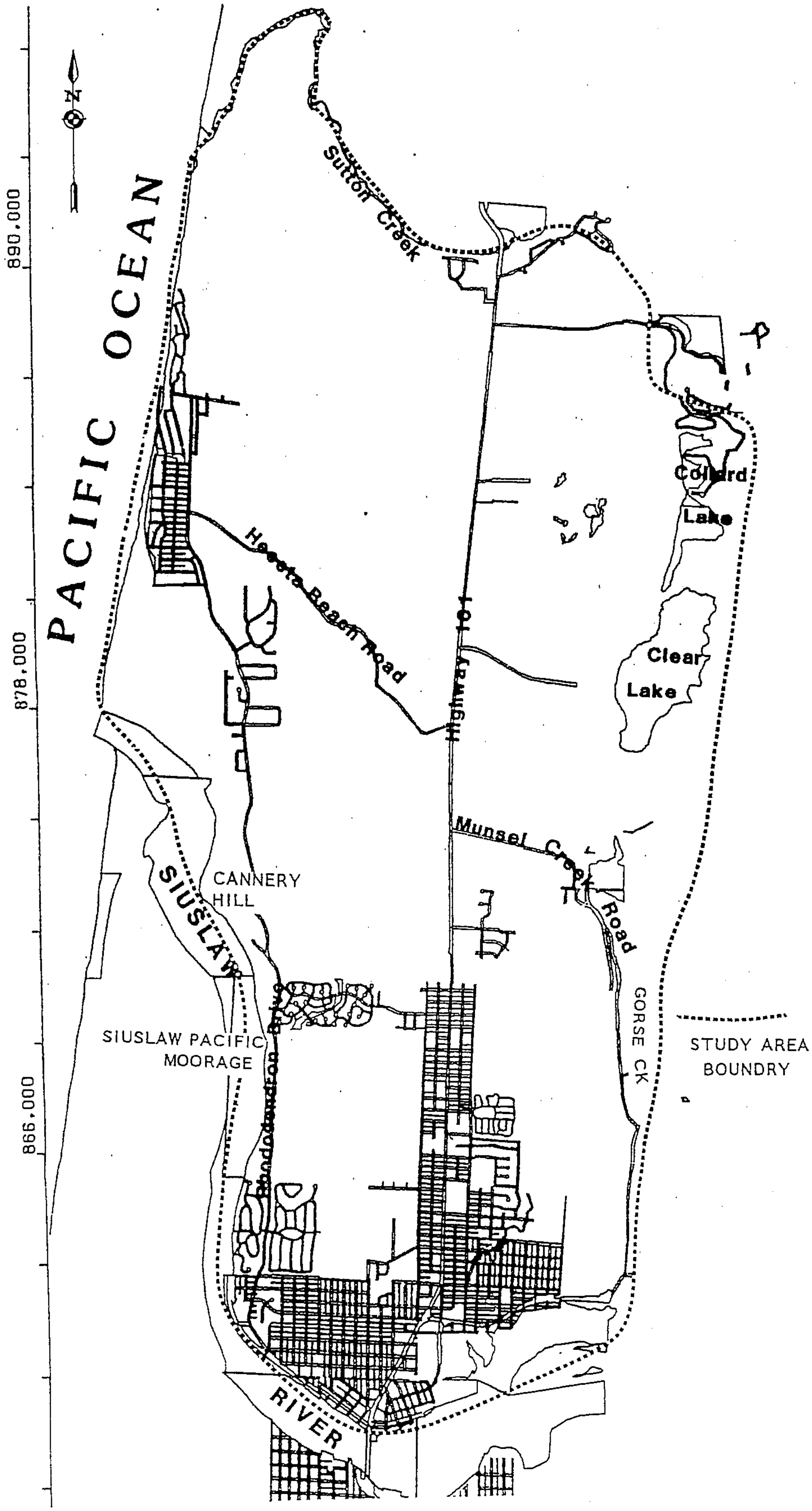
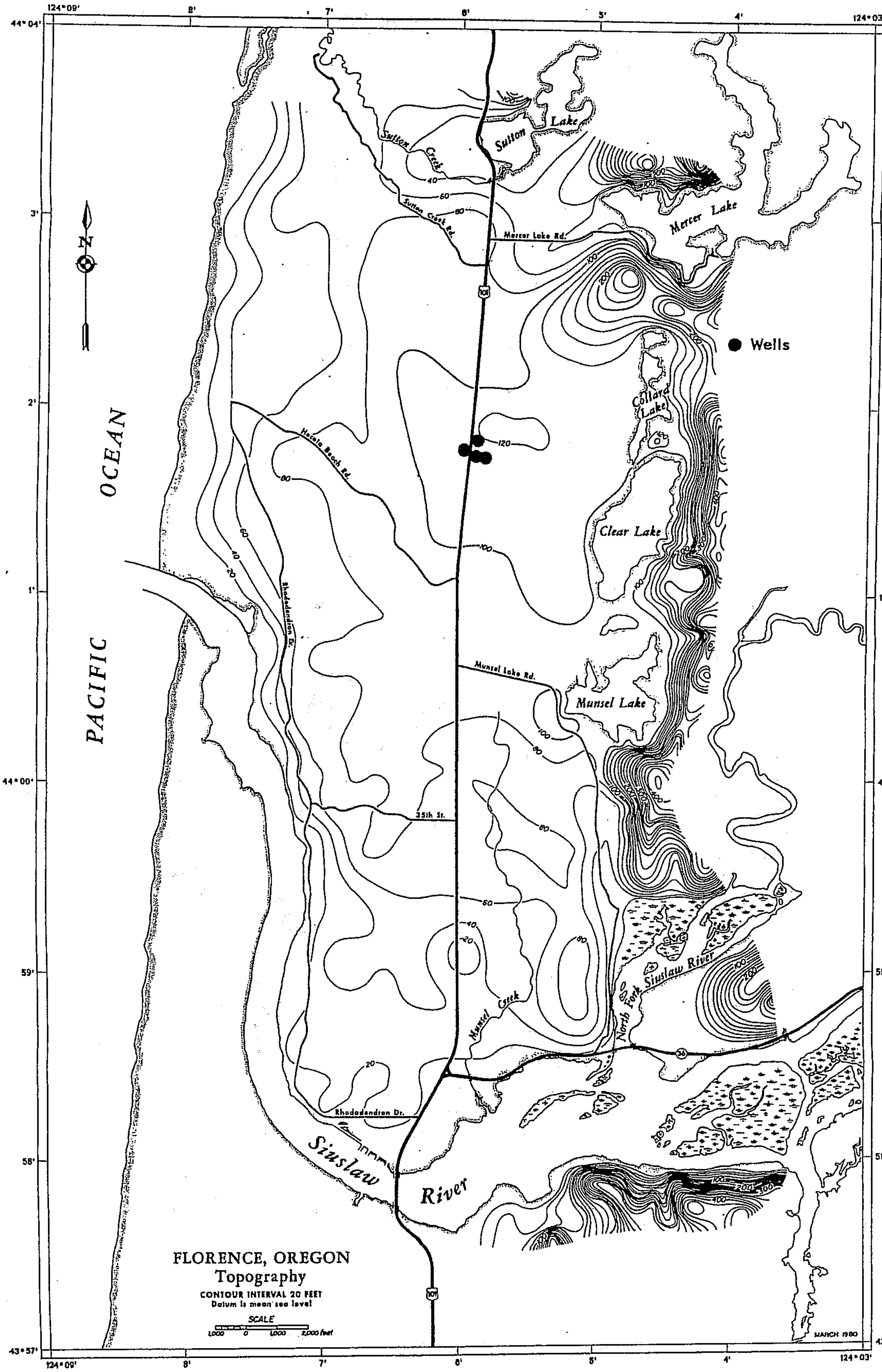


FIGURE 4. Topographic Map of the North Florence Dunal Sheet Showing the Location of Wells That Encountered Flournoy Sandstone at Less Than 25 Feet.



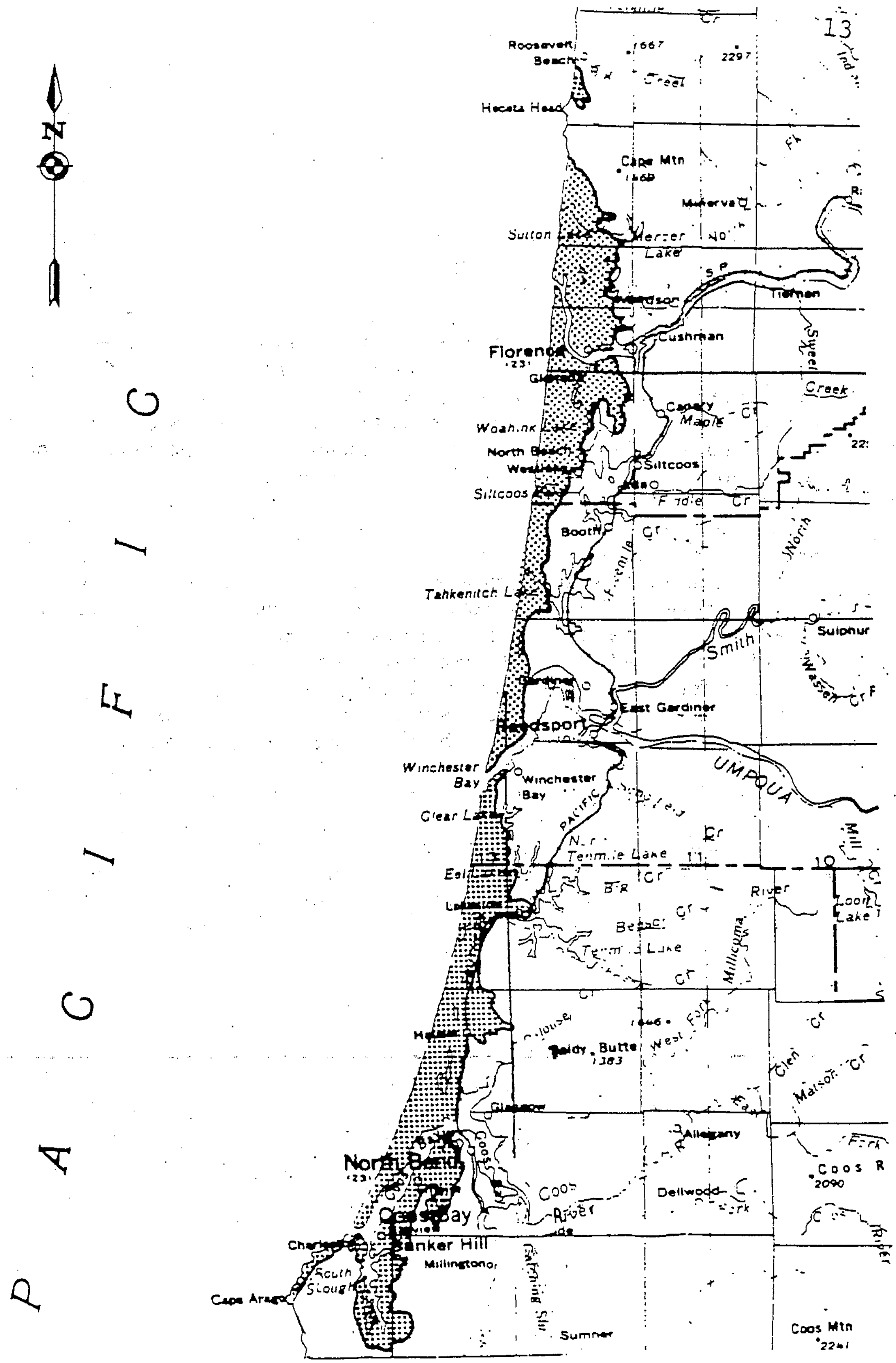


FIGURE 3. The Dunal Sheet from Heceta Head to Coos Bay.

the Florence well field and the City water tank near 31st Street. Other minor vegetation communities include marshes, blueberry bog communities, and scotch broom stands. In upland (bedrock areas) on the margins of the aquifer, stands of conifers (sitka spruce, douglas fir, western hemlock, red cedar), maples and red alder are found.

Approximately one half the people in the study area reside inside the Florence city limits. These areas are sewered. Of the remainder, they are generally distributed along Rhododendron Drive north of the city limits, in the Heceta beach area or along Highway 101 north of Florence. All of these areas are unsewered and sewage is treated by means of individual septic systems. No major industrial or processing facilities are located within the study area but lumber and plywood mills exist within 20 miles and contribute substantially to the economy of the study area. Land development for summer and retirement homes has historically been a major factor in the economy.

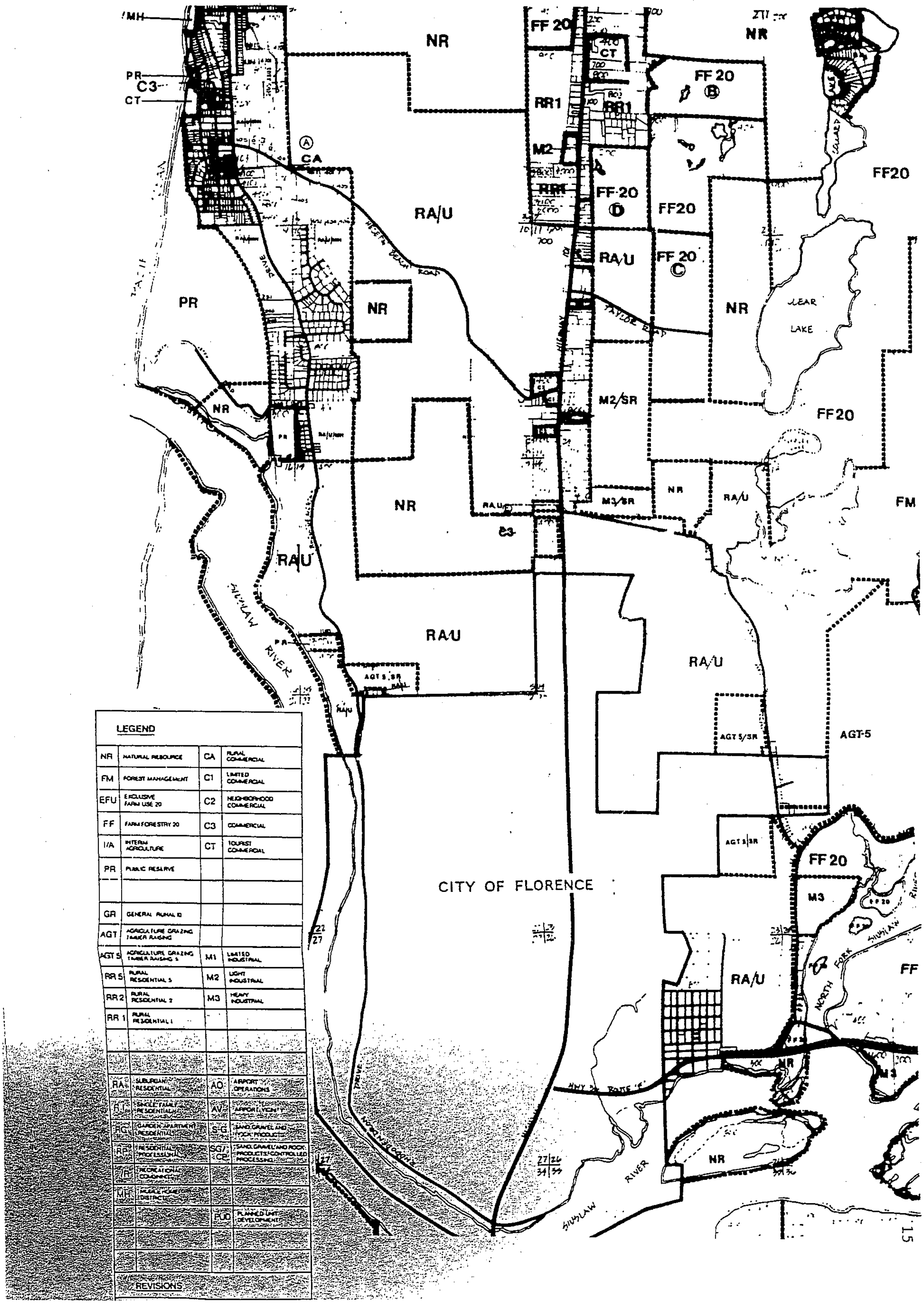
Zoning in the study area can be seen in Figure 5. A study of zoning densities indicates that population could go as high as 25,000 at some point in the future as compared with approximately 8,000 in the study area at present. The resulting increased demand for water would need to be met by the two water suppliers (Heceta Water District and the City of Florence) through expansion of their current capacity. These two districts serve the entire study area plus additional areas to the north. The most economical source for this additional water supply is probably Clear Lake. A further consequence of the population growth is that increased demand will be placed on the aquifer to accept and dilute on-site sewage effluent. Historically, areas have been allowed to develop with on-site disposal until sufficient density is reached to justify sewerage collection to a central facility. This means substantial time would pass and therefore substantial quantities of effluent could enter the aquifer before sewerage was in place. The consequences for the aquifer and associated surface waters might be unacceptable.

Climate

The climate in the study area is Temperate Marine. 80 percent of the average annual precipitation of 69 inches falls from October through March. Rainfall data was collected by the City of Florence which maintains a gauge at the sewage treatment plant on Rhododendron Drive, at an elevation of about 25 feet above sea level. Rainfall records for the period 1941 through 1981 are seen in Figure 6. Additional data is collected at Honeyman State Park which is four miles south of Florence. The elevation at the Honeyman gauge is approxiamtely 120 feet. The Honeyman gauge reported 67.7 inches of rainfall for the 80-81 water year while Florence reported 56.79 inches, a difference of over 10 inches (16%) more rainfall. This variation probably reflects the difference in elevation for the two stations.

Figure 7 shows the monthly averages and the readings for the aquifer study water year, October 1980 - September 1981. The water year was

FIGURE 5. Zoning Map of the North Florence Area Outside of the Florence City Limits.



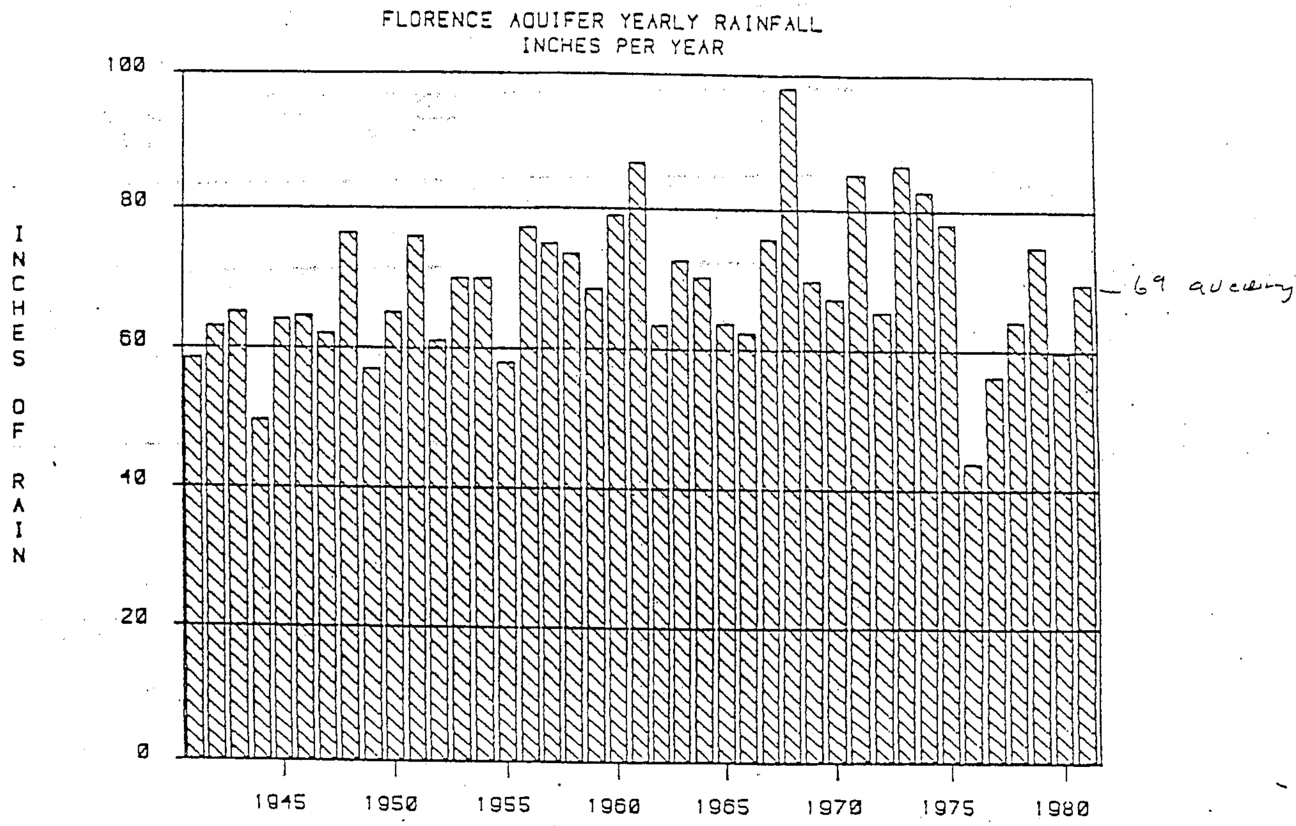


FIGURE 6. Yearly Rainfall for Florence, 1941-1981.

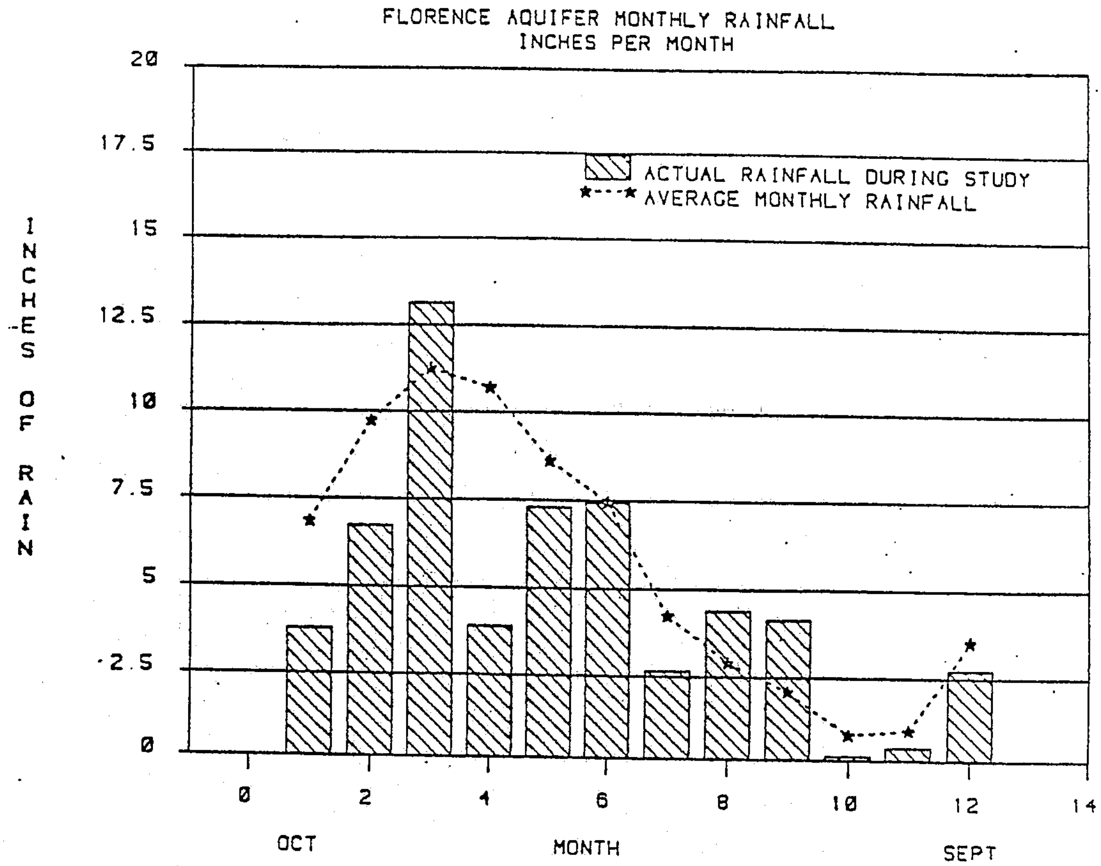


FIGURE 7. Monthly Rainfall, October, 1980 Through September, 1981 with Monthly Average Rainfall Superimposed. Rainfall for the Measured Period was 82% of Normal.

below average by 12.2 inches (about 82% of normal). The pan evaporation for Florence was taken from Robisonn (1973) who did evaporation studies for the Coos Bay area. Thirty inches of pan evaporation at Coos Bay was computed to equal 24 inches of open water evaporation. These figures were deemed adequate for this study because of the similarities of climate between these areas.

The average annual temperature for the study area was reported by Hampton (1962) at 52° F with 61° F as the average maximum monthly temperature (July and August) and 44.5° F the average minimum monthly temperature (January). The winds are generally strong and intermittent out of the west and southwest in the winter months and moderate and steady out of the northwest in the summer months. This pattern of wind distribution favors the formation and migration of oblique dunes eastward across the study area. At the northern extremes of the study area near the northern terminus of the dune sheet, the influence of Heceta Head (elevations ranging to over 2000 feet) apparently slows the southwest winds sufficiently that the northwest winds can predominate in influencing sand movement. In this area the dunes tend to be more longitudinal and migrate toward the southeast in long blowouts. The vegetation and sand combine to give this region a decided Northwest-Southeast lineation on aerial photographs and topographic maps. The dunes tend to be asymetric with the steep slope facing southeast indicating movement in that direction. Across the rest of the dune sheet the steepest slopes tend to face the East and northeast in response to the stronger southwest winds.

Geologic Setting

The geologic setting of the Florence Dunal Sheet has been described by various authors including Baldwin (1956) who described the geology of the region, Cooper (1958) who described the formation of the dune sheet itself, and Hampton (1962) who described a portion of the dunal aquifer and the surrounding geology for a water supply paper. Schlicker et al. (1974) described the geology of coastal Lane County and Strong et al. (1979) did a summary of water supply and included a portion on the dunal aquifer near Florence. The dunal aquifer is an accumulation of aeolian (wind blown) sand that rests on an ancient wave cut terrace (Baldwin, 1979, 1980). This wave cut terrace can be seen at 50-150 feet above sea level along the coast of Oregon at Newport, Sea Rose Beach, Charleston (Shore Acres Park), Bandon and Port Orford. However, along the section of coastal Oregon from Coos Bay to Heceta Head, the terrace has been warped downward below sea leval and an extensive accumulation of sands deposited on it. In the Florence area the terrace is cut into the marine sandstones, siltstones and mudstones of the Eocene Flournoy Formation (Baldwin 1975, 1976). These rocks are often rythmically with each bed grading from fine sands to siltstone to mudstone. rythmically bedded with each bed grading from fine sandstone to siltstone to mudstone. The sands are in a matrix of fine clays with some calcite cementing which makes them very impermeable to water.

North of the dune sheet and possibly extending beneath it at the northern most part of the terrace surface is the late Eocene Yachats Basalts. Composed of pillow lavas, dikes and volcanoclastics, its hydrologic character is not well known. This formation most likely has highly variable outputs of groundwater when compared to the dunal sands.

Well logs of wells drilled into the dunal aquifer, near its highest point, indicated the possibility that a bed rock high was buried by the accumulating dune sands. Four wells drilled near Highway 101 in Section 2, Township 18S, Range 12W indicated Flournoy sandstone at depths of 18 to 24 feet. (See Figure 4 & Appendix A). Because these wells were some distance from any known outcropping of Flournoy sandstone and were, in fact, located near the center of the aquifer, further study was initiated. Surface investigation revealed float of Flournoy sandstone that was strongly weathered but recognizable. A subsequent seismic study OSU, 1980) revealed that the occurrence was an isolated though large bedrock high with steep sides. The most likely explanation is that of a buried sea stack as can be seen at numerous places off the Oregon coast today, such as at Haystack Rock or Bandon Beach. Hydrologically, the presence of a sea stack differs greatly from a buried ridge line.

The dunal sheet is of recent origin. Age dates for the terrace on which it is built have been variously put at between 25,000 and 80,000 years (Baldwin, 1979 personal communication). Carbon-14 age dating from the current study indicates that woody material deposited at the base of sand and on top of terrace clays is 27,000 years old ± 600 years. This sample was taken at -160 feet elevation. A further C14 age determined from a sample at -90 feet elevation indicated an age of 8,830 ± 170 years. A sample taken at sea level (40 ft below land surface) had an apparent age of 2340 ± 360 years. This represents a sand accumulation rate of about 0.15 feet per year.
0.015 - 0.017 ft/yr

Within the dunal sheet, several features can be identified which indicate its history and differing hydrologic characteristics. Semi-consolidated estuary deposit of silty sands containing bits of carbonaceous materials, can be seen from the vicinity of the old Siuslaw Pacific Moorage to north of Cannery Hill. Its thickness is at least 15 feet according to well logs and from visual inspection along its length. This deposit is broadly arched with its central portion above sea level while the northern and southern ends below sea level. Apparently, the forces that lowered the terrace below sea level here are still at work.

The dunal sands are interposed with layers peat, iron precipitates and old soil horizons. The peat layers represent deflation plains that have been buried. Organic materials from surface and buried deflation plains supply weak organic acids to the groundwater. Nearly all water tested from the aquifer was acidic. These acids attack the dark minerals (amphiboles, pyroxenes, olivine and magnetite) in the sands and release soluble iron in the ferrous form. When this water reaches the surface the iron oxidizes to the ferric state which is insoluble and precipitates out as limonite (rust). As a result, iron layers are often built up in connection with peat layers. Soil horizons formed in the upland areas (higher above water table) are usually seen with some limonitic cementing. These layers are impermeable to poorly permeable and are the major cause of differences between horizontal and vertical permeabilities in the aquifer. These layers are ubiquitous, variable in size and thickness but not individually continuous across the aquifer.

The total thickness of the dunal aquifer and the contour of the bed rock was established by seismic soundings (OSU, 1980). Except for the sea stack mentioned previously, the base of the aquifer was found to be a fairly uniform flat surface carved out of the Flournoy Formation. On this flat terrace approximately 100 to 200 feet of sand has accumulated.

However, deep drilling, the seismic survey and tritium age dating of water indicated that in approximately the bottom 1/3 of the aquifer the sand character is such that permeablilities are substantially reduced. Seismic velocities in that portion are increased over those of loose, saturated sands indicating a more compact (or dense) material. Drilling into this material recovered sands with a substantial plastic clay content. Wells (piezometers) set into the material yield water only slowly. Tritium age dating analysis indicates that younger water circulates in the upper two thirds of the aquifer. Thus, the bottom of the aquifer is not the bottom of the sands (top of the Flournoy), but the top of the silty sands. At the deep well drilling site this level corresponds with the -90 foot elevation where woody material was found associated with volcanic pumice. The most likely explanation is that up to the -90 foot elevation the Siuslaw river deposited sands, silts, some woody materials, clam shells and other estuary materials on the terrace. About 9000 years ago the sea level began to rise rapidly with the melting of the continental glaciers and clean sands were then deposited on the terrace. This continued up to the present time through a combination of wave and wind processes. Seismic results indicate that the clayey horizon is generally continuous throughout the study area.

Hydrogeologic Setting

The sands of the North Florence Dunal Aquifer are a substantial water holding and transporting system. The uniform nature of these sands is shown by size analysis done by Hampton (1962), for Florence and Frank (1970), for Clatsop Plains, as well as by the City of Florence for the two wells they operate (See Appendix B). All of these analyses indicate a very uniform sand size range of .008-.012 inch diameter (.2-.3 mm). This uniformity of size increases the permeability and storage coefficient of the aquifer.

Aquifer tests done at Coos Bay (Robison 1973) and lab tests on sands at Florence (Hampton, 1962) indicate permeabilities in the range of 350-700 gallons per day per square foot (gpdf) and storage coefficients of 0.25 to 0.32 (dimensionless units). The aquifer tests done on the Florence city wells are of limited use because the vertical permeability is much less than the horizontal permeabilty and calculated permeabilities and storage coefficients don't correlate. (See Appendix C for listing of text data and analysis of permeabilities and storage coefficients) The digital model (Pinders Finite Element Hydrology. Model) utilized at Clatsop Plains (Sweet, et al. 1981) used permeabilities ranging from 150 to 2000 gpdf.

Hydrologically, the Florence dunal aquifer responds very nearly as an ideal aquifer because of its uniform nature. Rainfall varies across the width of the aquifer with an estimated 65 inches at the beach line to 80 or more at the crest of the ridge on the eastern boundary of the study area. Most of the rainfall soaks into the sand and becomes recharge to the groundwater. The high permeability of the sand is demonstrated by the lack of streams originating in the dunes area in spite of over five feet of rainfall annually.

After rainfall perculates to the water table, the water begins to move through the aquifer toward a discharge point. Most of the water is discharged directly to the ocean, to the Siuslaw River or to Sutton Creek. A portion of the water from the upper reaches of the aquifer flows to Collard, Clear, Ackerly or Munsel Lakes. From there it either flows out the Munsell Creek system, if pumped out by the Heceta Water District or reenters the groundwater system at the southern end of these lakes (See Figure 8).

In addition to horizontal movement toward the discharge points of the aquifer, the water moves vertically downward until it nears the discharge point at which point it flows upward and out of the aquifer to the surface water system (See figure 9). The movement downward occurs because each years rainfall "stacks up" on top of the previous years precipitation. In order to test aquifer turn over time, a tritium age dating analysis of water was run on the deep well system. This dating technique relies on the sudden increase of tritium in the atmosphere (and hence the rain water) in the early 1950's as a result of atmospheric nuclear weapons testing. A low tritium value indicates water older than the 1950's and a high value indicates water of less than 30 years in age. Water in the deep well was tested at 30, 50, 70, 90, 110 and 130 feet below ground furface (+10 to -90 feet elevation relative to sea level). Only the water at 130 feet was found to be older than the early 1950's. Thus, the water in the highly permeable portion of the aquifer can be seen to be turned over, or repalced, at least every 30 years. It could be said that pollution at the surface today will spread spread through the whole aquifer within 30 years and will take up to an additional 30 years to leave the aquifer.

Water Quality

The quality of the groundwater in the North Florence Dunal Aquifer is generally very good. Most chemical constituents are in very low concentrations due to the relatively inert quality of the fresh sands, and the high flushing rates from heavy rainfall and rapid groundwater turnover. An iron problem exists because of iron mobilization by organic acids. Both iron and sulfur (as hydrogen sufide) are fairly

FIGURE 8. Generalized Ground Water Flow Directions and the Location of Major Ground Water Divide.

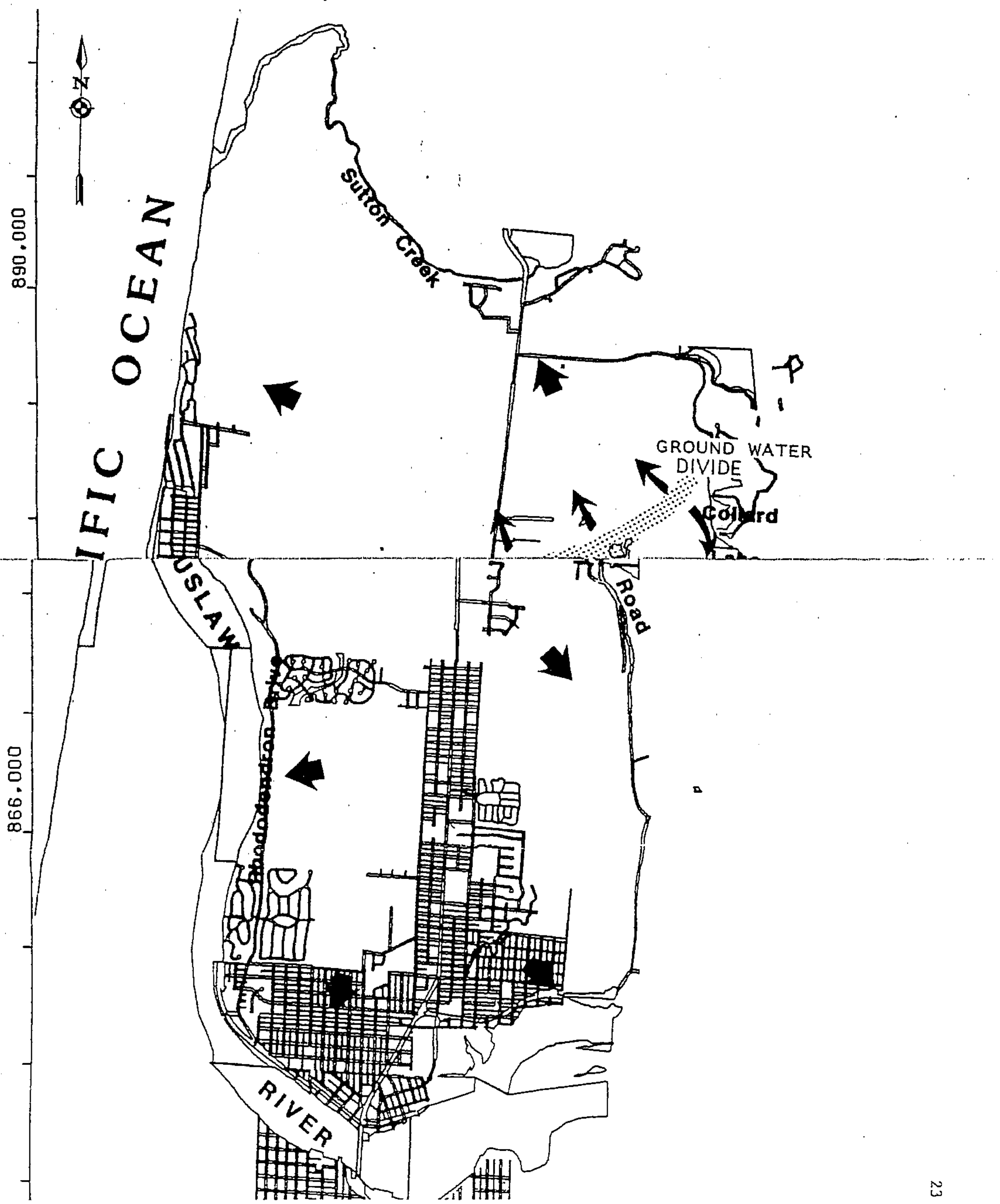


FIGURE 11. Study Area Map Showing Maximum Boundry of the Clear Lake Watershed and Parcel Distribution.

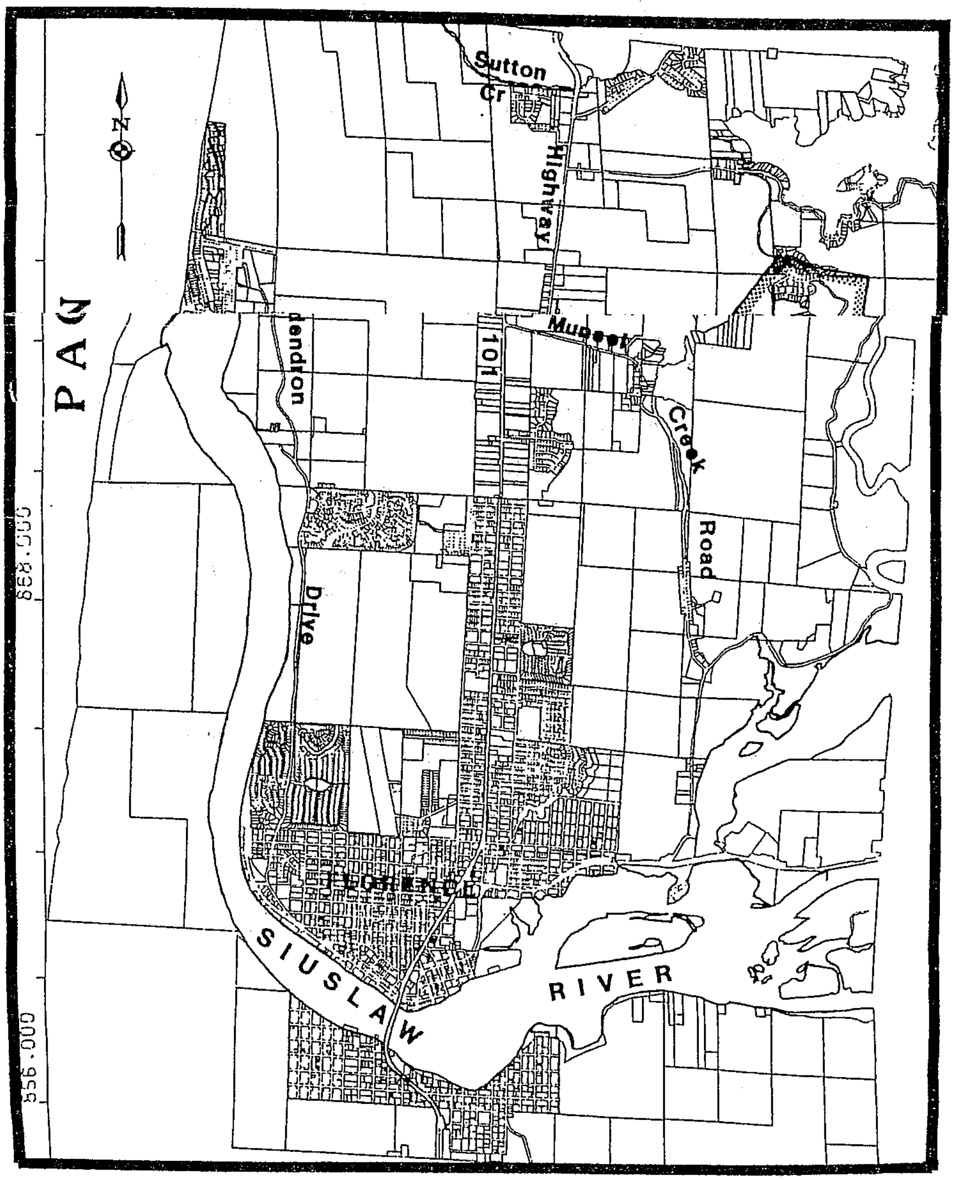
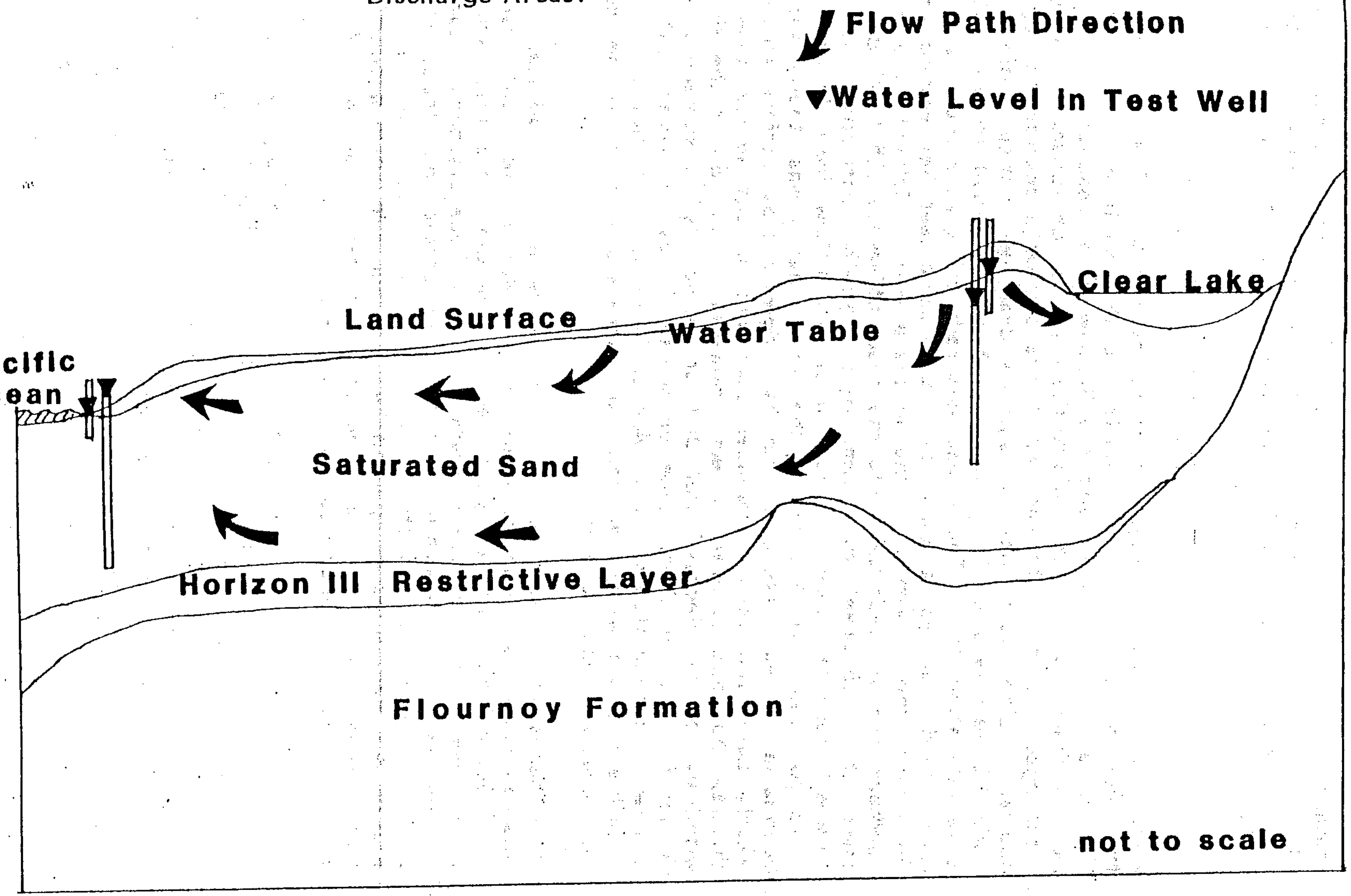


FIGURE 9. Diagramatic Cross Section of the Aquifer Showing Vertical Flow Paths and Head Differences in Recharge and Discharge Areas.



common in the groundwater as a result of decaying plant material which releases sulfur and forms acids which dissolve iron. Water quality was a major study effort and the results are reported in OUTPUTS AND IMPACTS.

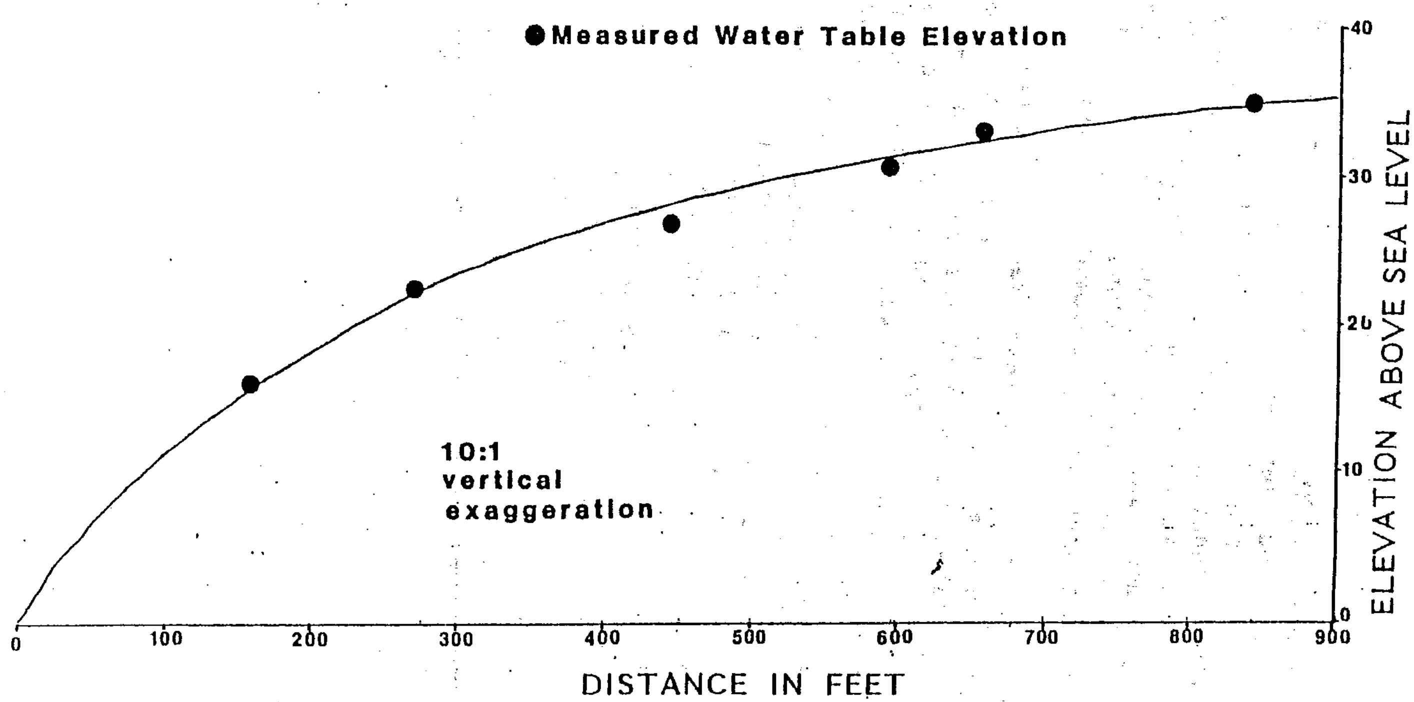
Surface Drainage

Very little surface drainage occurs on the aquifer. The major streams that cut across the dunal aquifer at the north and south study boundaries, Sutton Creek and the Siuslaw River respectively, derive most of their flow from the hills to the east, though substantial water is discharged into these streams, which are discharge boundaries, by the aquifer. The main internal surface drainage system begins near Collard Lake (elevation 110') and flows through a small stream to Clear Lake (elevation 95'). The stream generally flows year round and at a fairly steady rate estimated to be 1 to 2 cubic feet per second (cfs). Because of the proximity of the southern end of Collard Lake to the northern end of Clear Lake and the head difference (15 feet) between them, it is apparent that some hydrologically restrictive unit lies between these two lakes. A portion of the outflow from Collard Lake flows to Clear Lake through the sand that forms their western boundaries. Clear Lake water naturally flows out by surface stream to Akerly Lake and then to Munsel Lake and on out Munsel Creek or through the sand aquifer system. However, a portion of the flow is withdrawn by the Heceta Water District. Seasonally the surface streams do not flow out of Clear Lake or Munsel Lakes. However, within a quarter mile from Munsel Lake, Munsel Creek begins to flow as a result of influent groundwater and this flow increases steadily to the mouth (an increase of about 3-5 cfs).

Other seeps occur near the discharge boundaries of the aquifer. Most notable ones are an unnamed stream east of Munsel Lake Road, refered to as Gorse Creek in this report, (across from the golf course) which is at the base of the Flournoy Formation and a surface discharge near the old Siuslaw Pacific Moorage south of 35th Street and Rhododendron Drive. At the latter, sufficient flow from the upper surface of the aquifer has maintained an open surface channel from which groundwater continuously flows. A profile of the upper aquifer surface was obtained by surveying this site and can be seen in Figure 10.

The string of lakes on the eastern margin of the aquifer, Collard, Clear, Ackerly and Munsel, is a result of the buildup of the dunal sheet to the west next to impermeable Flournoy bedrocks to the east. As the migrating dunes approach the hills the wind loses its ability to transport sand and the largest portion of the sand remains to the west leaving a depression or series of troughs along the base of the hills. Rain water accumulates in the sand moves outward from the topographically elevated areas toward lower areas. The flow is generally toward the ocean, the Siuslaw River or Sutton Creek, but a portion of this flow moves east toward the string of lakes and surface depressions. Because the Flournoy sandstone restricts movement to the east, a lake is formed. Because the lakes are formed in this manner their water

FIGURE 10. Cross Section of Ground Water Surface as Measured Near Siuslaw Pacific Moorage.



supply is dependent on recharge from the sands "upstream" in their watershed. Both the quantity and quality of that recharge water is critical. When examining one lake, all of the lakes and recharge areas (both dunal and upland) that discharge to that lake must be considered.

Total Flows Recharge-Discharge

Various authors have estimated the total recharge to the aquifer. Hampton (1962) estimated that 55 inches of yearly recharge made available 200,000 cubic feet per acre per year for use. This assumed 25,000 cubic feet per acre per year was lost to evaportranspiration. Schlicker et al. (1974) had similiar estimates. In related work, Robinson (1975) estimated an average 7-10 inches of evaportranspiration for the Coos Bay Aquifer using an average of 62.5 inches of rainfall per yea. This is equivalent to 190,000 - 200,000 cubic feet per acre per year. Strong et al. (1979) estimated similar values. These estimates for different portions of the dunal sheet are in close agreement.

In this study, the water table response to incident precipitation was determined by using two continuous level recorders. By examining the water table response it was clear that water table decline was very uniform during times of no precipitation and that greater than .20 inches of precipitation was necessary for a recharge response to be seen (See Appendix D). The precipitation necessary to induce a response in the water table is not constant but varies according to the amount of sand that must be wetted before recharge can occur. Rain fall intensity determines whether saturated rapid flow from the surface will occur or if wetting and consequent evaporation will predominate. Differing responses in the water table reflect these factors. The calculated constant decline rate during periods of no recharge gives a necessary recharge rate for that location assuming average yearly water levels are to be maintained. For a site at 113 feet elevation, in hummocky sand with spotty vegetation, an infiltration rate of 5.6 feet/yr was calculated. At a deflation plain site near 35th Street at an elevation of 65 feet, an infiltration rate of 4.0 feet/yr would maintain the water table. The differences between these two sites is probably attributable to their incident precipitation differences in response to elevation, the differences in evaportranspiration caused vegetation changes and finally, from the specific topographic setting.

Calculations for other sites on the dunal sheet indicate similar discharge and infiltration rates (see Table 1). As expected, the infiltration rates and discharge rates are greatest near the high points of the aquifer (Site #'s 12, 13 and 14) and lowest near the discharge points (Site #'s 4 & 31).

TABLE 1. Annual Rate of Recharge Based on Constant Water Table Decline as Measured at Various Sites on the Aquifer.

Infiltration Rate Based on Constant Rate Water Level Declines

Site	Water Level 7/7/81	Water Level 8/10/81	Diff.(ft.)	Ft./Day	Ft./Yr.	Infilt. Rate
4	6.30	7.32	1.02	.03	10.95	3.7
5	8.32	9.37	1.05	.03	11.27	3.8
6	2.48	3.82	1.34	.04	14.39	4.9
7	3.16	4.32	1.16	.03	12.45	4.2
9	5.57	6.64	1.07	.03	11.48	3.9
10	5.32	6.44	1.12	.03	12.02	4.1
11	5.47	6.63	1.16	.03	12.45	4.2
12	5.0	6.44	1.44	.04	15.45	5.3
13	3.39	4.77	1.38	.04	14.81	5.0
14	3.74	5.19	1.45	.04	15.57	5.3
15	6.38	7.54	1.16	.03	12.45	4.2
17	11.36	12.73	1.37	.04	14.71	5.0
20	7.10	8.20	1.10	.03	11.81	4.0
22	5.50	6.75	1.25	.04	13.42	4.6
24	8.03	9.16	1.13	.03	12.13	4.1
31	7.80	8.65	.85	.025	9.13	3.1
34	6.02	7.32	1.30	.04	13.96	4.7
						Avg. 4.36

* Infiltration rate is based on .34 of yearly rate because the storage coefficient is .34 and thus only .34 of each foot of draw down is water).

Study Methods

STUDY METHODS

The North Florence Dunal Aquifer investigation utilized a number of methods to collect and analyze the various types of data necessary for a thorough evaluation. Mapping, geophysics, deep well drilling and logging, monitoring of water levels, surface flow determinations bacteriology and chemical analysis, rainfall measurement, computer modeling, vegetation analysis, and a decay and dispersion study were all used. Each of these tools will be discussed in more detail to provide an overall picture of the aquifer analysis.

Aquifer Definition - Mapping, Geophysics and Deep Well Logging

The aquifer was first defined by mapping techniques. Existing maps from Hampton (1962), Shlicker et al. (1974) and Strong et al. (1979) were evaluated and field checked. These formed the first data base. During this phase well log data was collected and analyzed and historical information from long time residents of the area was obtained. The project defined the areal extent of the Aquifer, the associated watershed boundaries and the aquifer boundaries. It also provided the first indication of a buried sea stack and its attendant aquifer restrictions from well log analysis.

A geographic and land use parcel file data base maintained by L-COG, was used to generate computer drawn maps of Land use, ownership and vegetation.

Figure 11 is a geodata base map showing parcels and pertinent study boundaries.

The next phase of the project involved a definition of the vertical extent (depth) of the dunal aquifer, the location of restrictive bedded layers and the extent of irregularities in the bedrock beneath the aquifer, including the buried sea stack. It was not known before hand whether the sea stack was an isolated outcrop or part of a ridgeline. This investigation was conducted under to Oregon State University Geophysics Group headed by Dr. Richard Couch (OSU, 1980).

Two seismic methods were used in this study, reflection and refraction, both of which are explained in detail in the subreport. The subreport defined the following: the top of the bedrock layer (Flournoy Formation); a semi-consolidated, compacted or dense sand layer; a water saturated clean sand layer; and an unsaturated clean sand layer. Seismic field analysis was comducted during the summer 1980 with tests sites being selected by consultation between OSU and Lane County staff. Sites were chosen relevant to the known geology, expected geologic changes and gaps in the data base. Maps of the top of the Flournoy Formation (Horizon IV), the dense sand layer (Horizon III), the saturated sand (Horizon II), as well as the general topography and the thickness of dunal sands are found in Appendix E.

A first deep well was drilled and logged to provide a check on the geophysics and also to allow access for testing at various depths of the aquifer. This well was drilled to 230 feet and completed to a depth of 210 feet. The hole bottomed out in very fine clayey materials. The clays were not dilatant and were plastic to fluid as drilled. Piezometers (small diameter testing tubes) were installed around a central core at 20 foot intervals between 10 and 210 feet. Well construction is shown in Figure 12.

The piezometers were used to determine an aquifer head profile as shown in Figure 13. Significant changes in head indicate a restriction to vertical movement of water. At the 70 foot depth (about -30 feet, M.S.L.) a change in head indicated a significant vertical restriction. This corresponds with the level of horizon III as determined seismically. At 130 feet below the surface (-90 feet M.S.L.) the sands appear to increase in density and become richer in silts and clays. This condition continues to the 205 foot depth. As can be seen from Figure 13, the head difference below the 190 foot depth (-150 feet M.S.L.) indicates this aquifer level is in a different hydrologic system than the water above it. Figure 13, therefore, indicates water above -150 feet elevation is in a recharge zone since the decreasing head indicates water is moving downward. Below 190 feet the ground water system is discharging upward into the overlying sand aquifer as seen by the increase in head. The volume of that discharge is insignificant compared to the overlying water system as would be expected from the Flournoy Formation.

The piezometers, allowed samples to be collected from various depths. These samples were sent to the University of California at Irvine where they were age dated using tritium analysis techniques. This information was used to determine whether recharge is able to penetrate to the depth of the clay layer, and hence, whether the seismic study was correct in showing the first major restriction at -70 to -90 feet, M.S.L.

In spite of the significant restriction found at the 70 foot depth (-30 feet M.S.L.), it appears that younger water (1954 or more recent) has penetrated to at least 110 feet. This result verifies that the highly permeable portion of the aquifer is limited to that portion of the aquifer above the Horizon III layer. Water samples indicate high levels of dissolved iron and hydrogen sulfide below the 30 foot depth.

A second deep well was established east of the buried sea stack (see Figure 15). This well penetrated 80 feet of clean sand. The piezometers set in this hole all recorded heads within 0.05 feet of one another. This result indicates a high vertical permeability.

An anomolous occurrence of a mineraloid clay (tentatively identified as "allophane" - an amorphous silicate) was noted at the second deep well site. This elastic-spongy material was light tan in color, and numerous chunks were recovered from the 45-50 feet depth (+70-75 M.S.L.). The material could be described as a "pale cheese curd" in texture and

FIGURE 12. Deep Well Completion Diagram of Nested Piezometers.

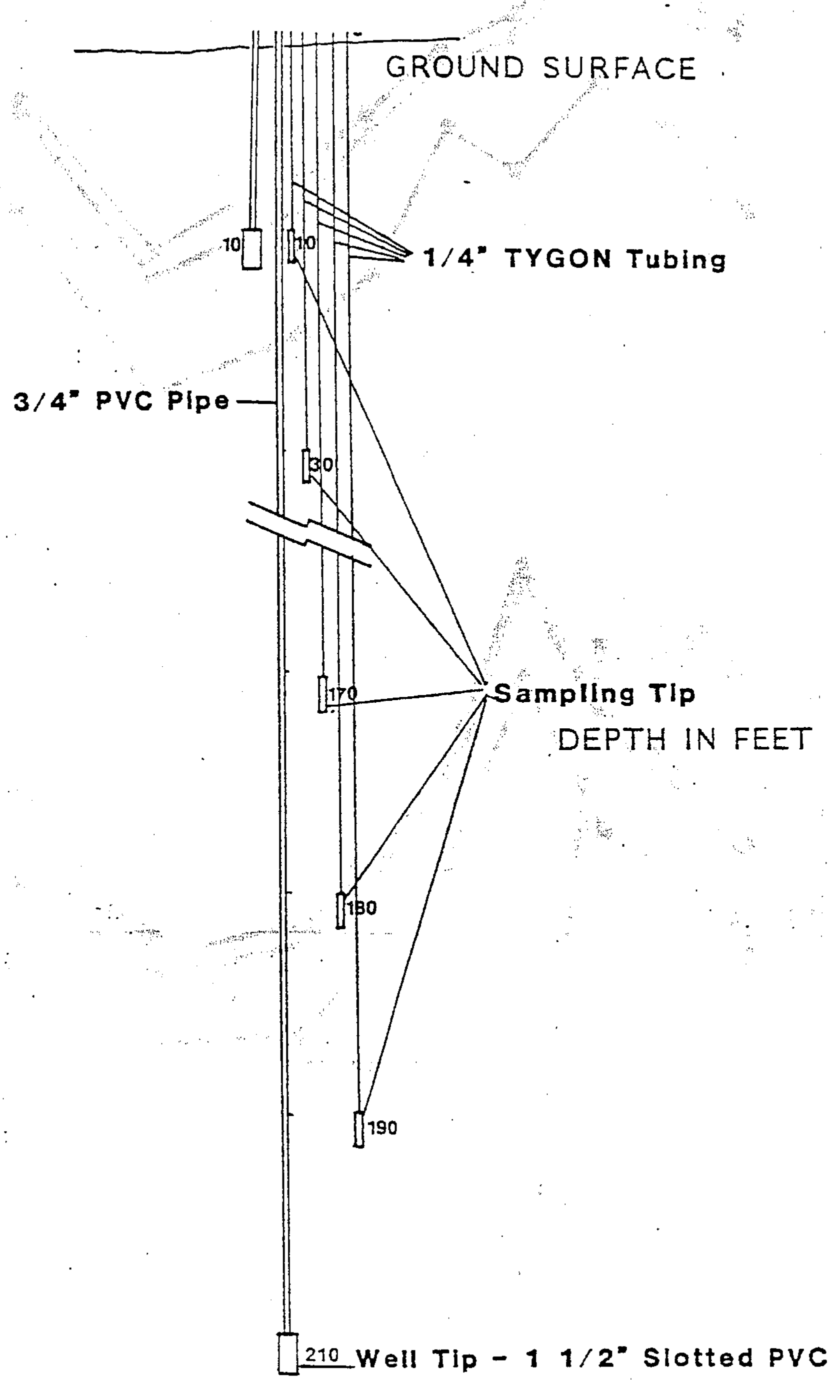
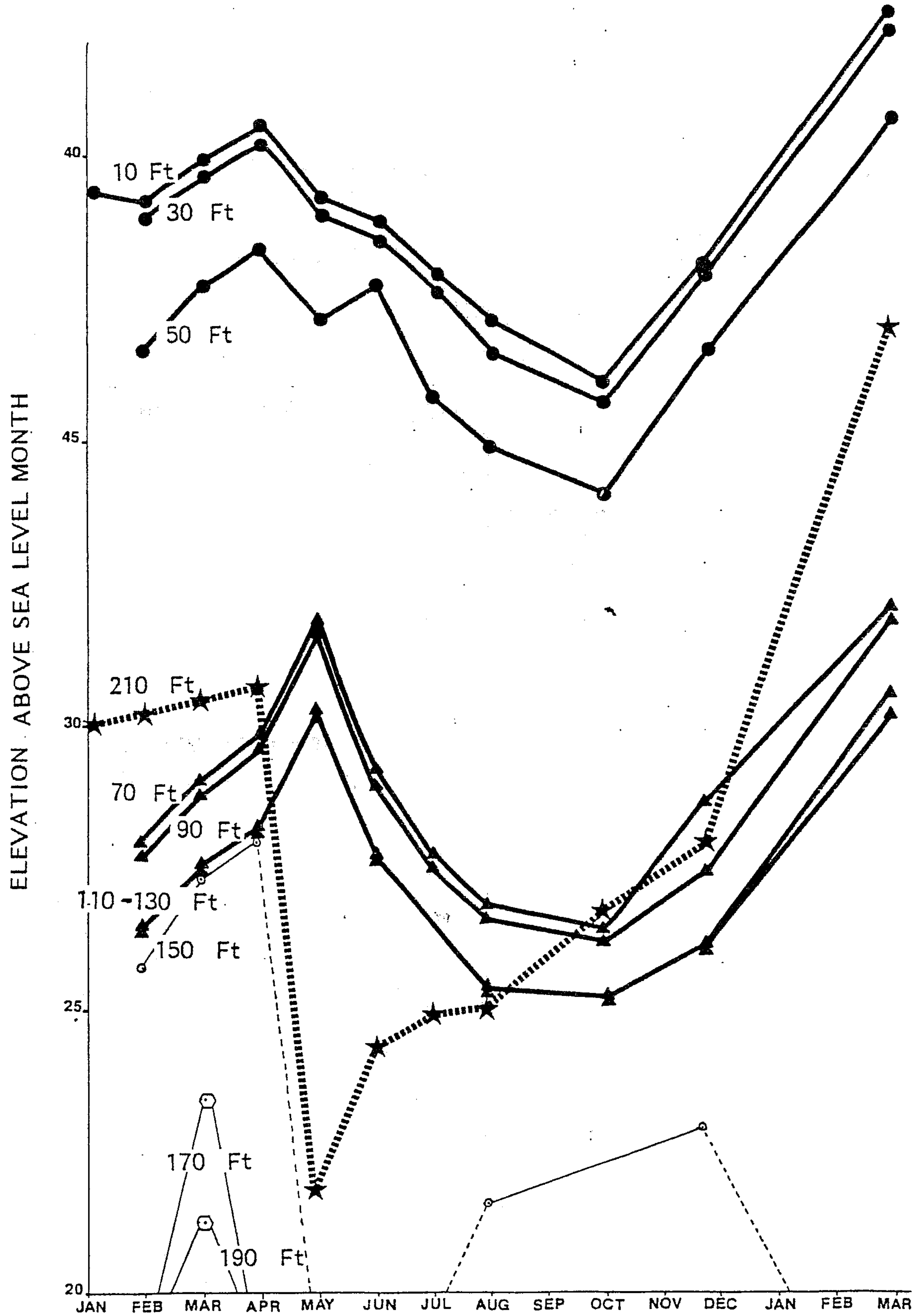


FIGURE 13. Piezometric Head Readings from Various Depths in Deep Well #1 from January, 1981 through March, 1982.



appearance and it appeared to be inorganic on the basis of chemical tests. Scanning Electron Microscope photographs of this substance are reproduced in Figure 14.

Well logs for both deep test holes are included in Appendix F.

Monitoring Program Design

The monitoring program for the North Florence Aquifer Study was designed to illustrate a wide variety of features and achieve several of goals. A short description of these goals is necessary in order to understand the selection of sites, monitoring frequency and test parameters.

Representative Data

Since the dunal aquifer and surface water system are closely interconnected, the monitor sites were dispersed to cover both surface water and groundwater situations throughout the area. The geophysical study results were used in conjunction with previous hydrologic studies to identify key aquifer areas, such as those surrounding the sea stack and areas suspected of being upgradient of Clear Lake. Sites were also chosen to represent recharge, discharge and intermediate areas, open dunes and deep forest, urban, rural and uninhabitated areas, and major lakes and creeks.

Hydrologic Prediction

A closely related goal was the need to have sufficient information on the water table to calibrate the model. The ideal situation of several hundred water table monitoring sites (the modeling grid had 270 potential data points) was tempered by budget limitations. A total of 35 hydrologic monitoring sites were chosen. This was the maximum practical number that could be monitored on a monthly basis. Special efforts were made to use existing wells.

Access

It was necessary to be able to monitor quickly so that aquifer measurements would represent uniform conditions in each sample period (within a one or two day time span). Access was therefore an important consideration. Reducing the time required to monitor each site also increased the number of sites from which data could be taken. This consideration resulted in most sites being located along roads or in open sand areas. Few sample sites were located in the dense coastal forest because of the extreme difficulty in getting equipment and personnel to such sites. (In some areas the undergrowth is so thick it is impossible to fall down).

Standardization

This was a prime consideration for the subsurface quality sites. Since these sites were used to characterize different areas of the aquifer, it was critical that all sites represented the same depth portion of the aquifer. Because of construction variations in existing private wells, most quality test holes were installed specifically for the study. Because the shallow aquifer is the zone of greatest concern, these test sites were limited to the shallow portion (10-30 foot) depth of the aquifer. A total of 19 quality sites were established in this way.

Surface Water Characterizaiton

It was necessary to represent all significant surface waters that were directly connected to the groundwater system. Sites were chosen on all major lakes (Clear, Collard, Munsel and Sutton), on several dunal ponds and intermittant lakes, and on all permanent streams (Munsel, Sutton, "Gorse" and at "Siuslaw Pacific") The Siuslaw River was not tested because of its estuarine nature.

Special Feature Investigation

Sites were established near known special features such as the Florence landfill and the golf course. Also, several sites were chosen in the vicinity of the bedrock high point (sea stack) and the area west of Clear Lake because of its critical resource value.

Seasonal Variation

In order to assess the yearly variations in the aquifer, monitoring was conducted for a thirteen month period that covered an entire water year (October 1980 through September, 1981). Sites were monitored monthly for water table variation and quality samples were taken monthly or bimonthly.

Test Parameters

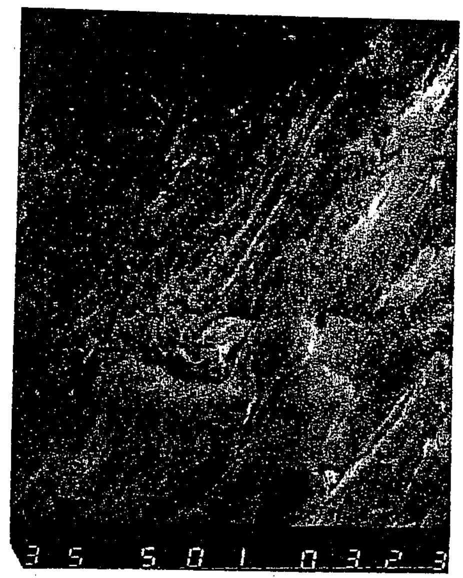
Test parameters were chosen to provide adequate information to run the model, to predict nutrient transport, and to characterize the general chemistry of the aquifer and surface waters. Primary concern was with water level measurements and nitrate-nitrogen analysis. Other parameters such as phosphorous, bacteria, oxygen levels, temperature and iron concentrations were also tested in order to provide a clear picture of the dynamic processes in the aquifer and to relate aquifer and surface water conditions to specific local concerns such as iron removal.

Monitoring Sites

Four types of monitoring sites were used: surface sites; drilled wells; drive point wells and existing wells. The monitoring sites and type of record associated with each are listed in Table 2 and their location is shown in Figure 15.

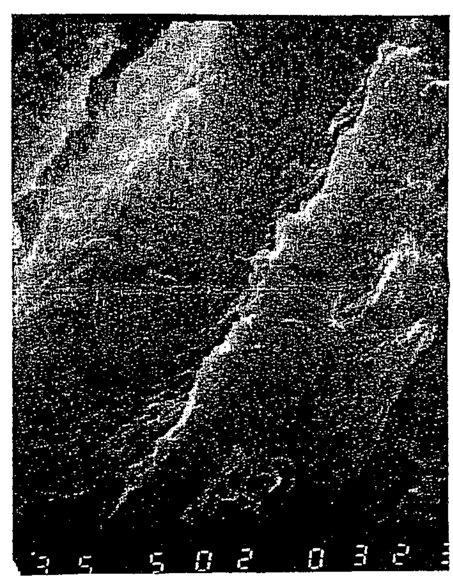
FIGURE 14. Scanning Electron Micrographs of an Unkown Material from Deep Well #2, Suspected of Being Allophane. Magnification of photo A. 100X, B. 500X, C. 1000X and D. 5000X.

A.



B.

C.



D.

TABLE 2. List of Monitoring Well Sites Shown in FIGURE 15.

Site #	Type	Data	Comments
1	Surface	Q1-Qn-H	Sutton Cr. near mouth
2	Surface	H	Intermittant Lake along Sutton Cr. Rd.
3	Surface	Q1-Qn-H	Sutton Cr. @Hwy 101-Sutton L. outlet
4	Drilled Well	Q1-H	In heavily forested, old swampy area
5	Drilled Well	Q1-H	In open sand W. of Collard lake-some grass and pines
6	Surface	H	In ephemeral blueberry bog near height of aquifer
7	Drilled Well	Q1-H	Dune-forest fringe, NW of Clear Lake
8	Surface	Q1-H	Collard Lake outlet
9	Drilled Well	Q1-H	Open sand w/scattered pine-W. of Clear L
10	Drilled Well	Q1-H	Open sand w/grasses-SW of Clear L.
11	Drilled Well	Q1-H	Open pine forest & sand-NW of Munsel L.
11a	Surface	Q1-Qn-H*	Clear Lake @ Heceta Pump Station
12	Drilled Well	Q1-H	Off Taylor Rd in heavy forest
13	Drilled Well	Q1-H	Off Friendly Acres Rd. in pine forest NW of Clear L.
14	Surface	H	Ephemeral berry bog E. of Hwy 101 at height of land
15	Existing Well	H	In residential garage N. of Taylor Rd and W. of 101
16a	Existing Well	H	1" drive pt. in forest near house- E.of 101
16b	Existing Well	H	6" drilled well into bed-rock E. of 101
17	Drilled Well	Q1-H	At Heceta Jct. behind businesses-90' from septic tank
18a	Surface	Q1-H	Driven pt. in intermittant lake S. of Heceta Beach Rd.
18b	Surface	Q1-H	Gage in Heceta L.-N. of Heceta Beach Rd.
19	Drilled Well	Q1-H	At Heceta Beach Park-100' from ocean
20	Drilled Well	Q1-H	At intersection of Munsel Cr. Rd. and 101 - edge of forest
21a	Surface	Qn-H	Munsel Cr. @ Munsel Lake Rd.
21b	Surface	Q1-Qn-H	Munsel Cr. @ outlet of Munsel Lake
22	Drilled Well	Q1-H	In deep pine forest-S. of Munsel Rd. - W. of 101
23	Existing	H*	6" drilled well-set in dry well at Ray Wells, Inc.
24	Drilled Well	Q1-H	In open dune (stabilized) in mobile home subdivision on 35th
25.	Existing	H	Near estuary (400') @ Coast Guard Station
26	Drilled Well	Q1-H	In stabilized dune area along Rhododendron Dr.-downgradient of landfill.
27	Existing	H	Old-landfill deep pumping well
28	Driven Point	H (Q1)	Eastside of landfill-special limited testing
29	Driven Point	H (Q1)	Southside of landfill-special limited testing
30	Drilled Well	Q1-H	At 12th and Rhododendron-Florence residential area
31	Drilled Well	Q1-H	At 12th and Maple-in Florence (residential)
32	ABANDONED		
33	Surface	Q1-Qn-H	Munsel Cr. near mouth (Nr Florence Police)
34	Drilled Well	Q1-H	At County Shop Yards
35	Surface	Q1-Qn-H	Creek on 31st E. of Munsel Cr. Rd (Gorse Cr.)
36	Drilled Well	Q1-H	Near 5th tee of Rhodo-dunes Golf Course
37	Surface	Q1-Qn-H	Small Cr. near Siuslaw Pacific Moorage
38	Existing Well	H*	Dug well (4' X 4') in mixed forest-dune area W. of Clear L.

Q1 - Quality Monitoring Data - monthly
Qn - Quality Monitoring Data - flow or pumpage at surface sites
H - Hydrologic (water table) Monitoring Data - monthly
* - Hydrologic Monitoring - Continuous Recorder

Surface-Water Sites

Surface water sites were established at accessible locations on creeks and lakeshores and included Site #'s 1, 2, 3, 6, 8, 11A, 14, 18A 18B, 21A, 21B, 33, 35 and 37. Surface site monitoring included quality sampling and flow or water level measurements, depending on whether the site was flowing or stationary. When conditions permitted, samples were drawn from the 0.5 foot depth.

Drilled Wells

Wells were drilled to a depth of 10-30 feet with a solid core rotary augur. These sites are #'s 4, 5, 7, 9, 10, 11, 12, 13, 17, 19, 20, 22, 24, 26, 30, 31, 34 and 36. Well logs were kept and each site was established in the manner of Sweet et al. (1980) by the mechanical insertion of a two inch PVC, .010 inch preslotted well casing. The well point was a solid PVC tip and the casing was press fitted. The wells were slotted from 5 or 10 feet to depth, the shallower screening being used where groundwater was closer than 10 feet to ground surface. The well was sealed with a 1-2 foot deep annular ring of pelletized bentonite and capped with a 1-2 foot concrete seal. A security casing with a locked steel lid was embedded in the concrete capping. Figure 16 illustrates this type of well construction.

Drilled wells were monitored for water table fluctuations and water quality was tested both by "down the hole" probe measurements and by sample withdrawal for laboratory analysis. Sampling was performed following pump-out of 2-3 well pour volumes. Two sample well logs are included in Appendix G.

Driven Wells

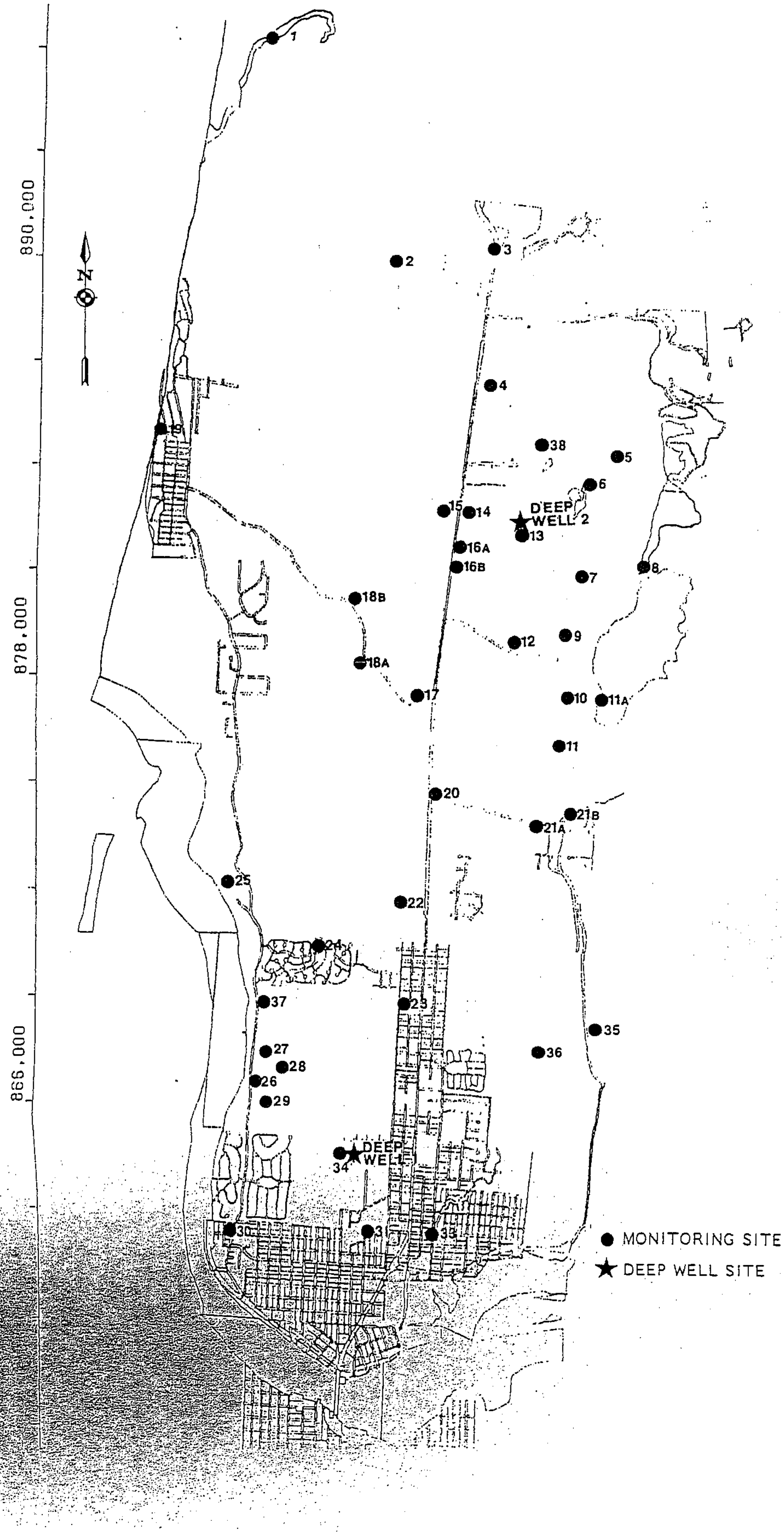
Two half inch iron pipe driven wells were established in locations where access by a rotary drilling rig was not possible. The drive points were hand driven to about 15 feet and utilized a fabricated steel drive point. One-sixteenth inch holes (20-30 in number) were drilled in the bottom two feet of pipe and the pipe was stuffed loosely with fiberglass to prevent sand entry.

These wells were installed near the land fill site (#'s 28 and 29) and used primarily as piezometers for water table measurement. A few water quality samples were withdrawn by hand pump to test for metal content but this data was not combined with the general aquifer test data.

Existing Wells

These sites were established in 6 locations (#'s 15, 16A, 26B, 23, 25, 27, 38) and the type of site ranged from steel cased six inch wells to a 4 foot square hand dug well. These sites were monitored for water table fluctuation but not quality since the depth, age and quality of screening and sealing could not be readily determined. All existing well sites were established with the consent and cooperation of owners.

FIGURE 15. Monitoring and Deep Well Sites Used in this Study.



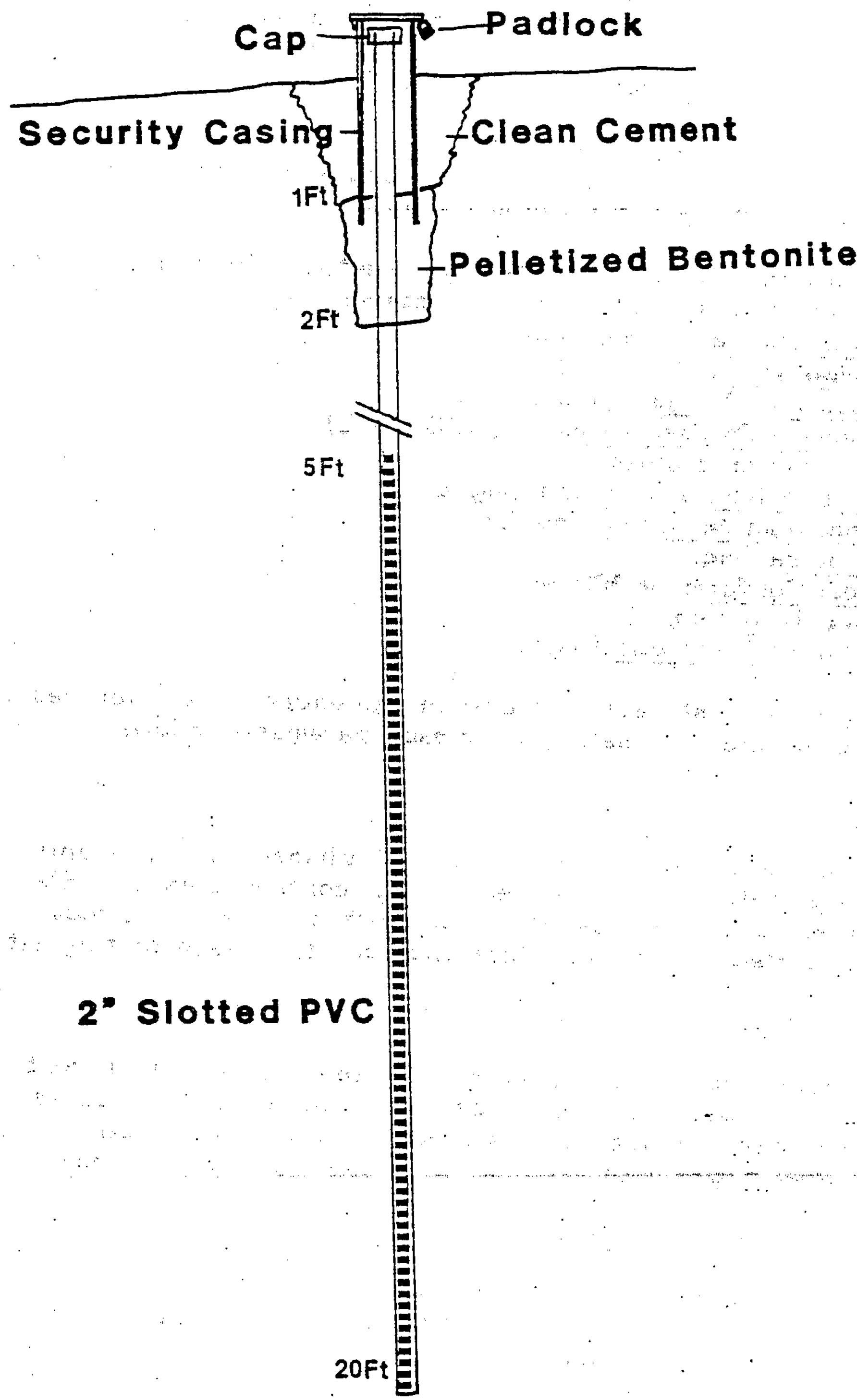


FIGURE 16. Monitoring Well Construction Diagram.

Monitoring Parameters and Methods

The following information was collected for each site:

* Elevation above sea level (to a fixed reference point)
* Depth to water or depth of water above ground surface
* Flow (discharge) if a surface stream

Quality information was collected on selected wells and surface sites and usually included the following parameters:

* Conductance (in micromho)
* Temperature (°C)
* Dissolved Oxygen (mg/L)
* Chemical Oxygen Demand (COD mg/L)
* pH (standard units)
* Nitrate-Nitrite Nitrogen (mg/L)
* Ammonium Nitrogen (mg/L)
* Chloride (mg/L)
* Fecal Coliform (#/100 ml)
* Total Iron (mg/L)
* Total Phosphorous (mg/L)

A listing of all test data is found in Appendix I. A brief description of the purpose and test methods for each parameter follows.

Elevation

Mean sea level elevations were established using standard optical surveying methods from fixed USGS control points. Elevation was determined to the nearest 0.01 foot with closure to 0.2 foot. All values were calculated using fixed reference points at each testing site.

Depth to Water

Water table depth was measured to the nearest 0.01 foot using an Olympic M-Scope. Most readings were rounded to the nearest tenth of a foot. For surface waters, staff gages were established using standard enamel steel gages with recordings to the nearest 0.01 foot.

Continuous Level Recording

On three sites (#'s 11A, 23 and 38), continuous recording gages were established using Leupold and Stevens Type F battery powered drum recorders. These recording gages were maintained monthly and provided a continuous (or nearly so) record of water table fluctuations. Level fluctuations were accurate to ±0.05 feet.

Stream Flow

Discharge (in cubic feet per second) was measured by recording staff gauge heights and calculating stream flow from measured flow/velocities. Stream velocity was measured to 0.1 ft/sec using a

Model 201 Marsh-McBirney electronic flow meter. Overall discharge accuracy was approximately ± 15 percent.

Conductance

Water conductivity as a measure of dissolved minerals was measured both in the field and in the lab. Pumped water samples were lab tested with a Lab-Line Lectromhometer to ± 1 micromho. Field measurements were made "down-the-hole" using a Presto-Tek field meter with a 25' extension cable. The field measurements were also read to the nearest ± 1 micromho and are generally considered more accurate than the laboratory values.

Temperature

Temperature measurements "down-the-hole" were made following pump-out using a Presto-Tek field probe with a solid state thermistor on a 25 foot cable. Temperature values were recorded to ± 0.1 °C Field values are considered more accurate than Labratory measurements.

Dissolved Oxygen

Dissolved oxygen levels were spot-checked to provide an indication of subsurface water that had limited interaction with organic materials. Contact with subsurface organic materials (buried forest or soil layers) will rapidly deplete oxygen in infiltrating water. Dissolved oxygen levels were measured seasonally using a Presto-Tek field meter with a D.O. probe on a 25 foot cable. Values were recorded to ± 0.01 mg/L but accuracy extends only to ± 0.1 mg/L.

Chemical Oxygen Demand

Overall organic material content (plus reduced minerals such as ferrous iron and hydrogen sulfide) is measured by this test. Samples were digested according to "Standard Methods" (APHA, 1980) techniques using a sulfuric acid/potassium dichromate digestion and titration with ferrous ammonum sulfate. Values were recorded to ± 0.1 mg/L and are considered accurate to ± 0.5 mg/L.

pH

Measurements of pH provide some indication of passage through acid producing materials such as peat or buried vegetation. pH levels were measured both in the laboratory and with a field meter (Presto-Tek). Probe operation with a 25 foot cable permitted "down-the-hole" as well as surface site measurements. pH values are accurate to ± 0.1 units.

Nitrogen

Measurements of nitrate plus nitrite were used to determine total nitrate-nitrogen. Since nitrite converts readily to nitrate on exposure to air, nitrate is nearly always the dominant form. Nitrate is a nutrient of special concern because of health standards for drinking water uses, because of a state adopted planning standard for groundwater, and because even low nitrate levels contribute to algae growth in lakes. Nitrate is also an important tracer of septic leach-field wastes since concentrations in human waste are usually much higher than in natural groundwaters. Nitrate also travel conservatively, (i.e., is not absorbed by soil) in the groundwater and so can be traced over long distances.

Nitrate levels were tested using the EPA approved "Cadmium Reduction Method" with azo dye formation and colorimetric reading. Standard procedures were supplemented with Bausch and Lomb test kit determinations (also a cadmium reduction method) following calibration of the test kits. Nitrate concentrations were recorded to ± 0.005 mg/L with an accuracy of ± 0.01 mg/L.

Ammonium

Significant levels of the ammonium nitrogen are an indication of significant septic or other pollution under anerobic conditions. This test was performed only on groundwater samples and used an Orion specific ion electrode meter. Values were recorded with an accuracy to ± 0.1 mg/L. Only two sites showed any indications of ammonia in any tests.

Chloride

Chloride ion was analyzed to detect salt water intrusions. Chloride ion moves conservatively (like nitrate) and is generally not absorbed by the soil through which it passes. Chloride testing was performed on groundwater and surface samples using the "Standard Methods" mercuric nitrate method. Accuracy was reported to ± 0.1 mg/L.

Fecal Coliform

Fecal coliform bacterial are an indicator of the presence of human (or other animal waste material. Such indicator organisms are commonly found in small concentrations in surface waters but should be absent from uncontaminated groundwaters. The Membrane Filter, m-FC broth test method was used and values were reported as "number of organisms per 100 milliliters."

Iron

Iron levels were tested to determine whether some portions of the aquifer were less iron rich than others. High iron content, as soluble ferrous iron, is a characteristic problem with coastal sand aquifers in Oregon. Iron concentrations were tested using a flame atomic absorption (IL 551 spectrophotometer) test method. Iron test values were reported with accuracies to ± 0.01 mg/L.

Phosphorous

Phosphate phosphorous is a key nutrient that can stimulate algae growth in lakes. It tends to be non-conservative in groundwater and is rapidly absorbed by clay soils. It is less readily removed by sand. Phosphate is also a significant nutrient constituent of septic wastes.

Total phosphorous content was analyzed using the "Standard Methods" persulfuric acid/ammonium molybdate digestion with colorimetric determination. In most clear waters (ground or surface) this phosphorous is predominately in the phosphate form. Test accuracy is ± 0.002 mg/L.

Rainfall

Rainfall data was collected from the Florence sewage treatment plant which is on the southern edge of the study area, approximately one half mile from the ocean. Additional records were kept at Honeyman State Park, two miles to the south. Daily precipitation data from these sites is reported to the nearest 0.01 inch.

Modeling

An evaluation of the hydrologic characteristics of the North Florence Dunal Aquifer in any year can be done by analytical methods with the examination of current field data for that year. However, predicting future responses of the aquifer to changing conditions of rainfall (i.e., drought) and water withdrawal is more complex and the use of digital models is necessary to simulate aquifer response. The model is also useful as a means for extropolation of data between field points and provides a substitute for an extremely large number of monitoring stations. Generally, a digital model (a computer program to mathematically simulate the aquifer) takes aquifer parameters of permeability, thickness, storage coefficient, recharge, and head (groundwater elevation), and computes an artificial (mathamatically derived) head for each point on the aquifer. This head is compared with the actual measured head at that same point and several parameters (permeability, storage, thickness and recharge) are adjusted until the computed head matches the measured head, point for point, across the aquifer. As the various parameters are adjusted they must be checked for hydrogeologic reasonableness.

Determination of hydrogeologic reasonableness requires the skill of the modeler and the hydrogeologist. Permeability should only be adjusted within limits set by aquifer tests and thickness is largely determined by the geophysical analysis as described previously. The storage coefficient for sand is a relatively fixed value (between 0.25 and 0.35) because of the uniformity of the sand particle size. The variable with the highest degree of uncertainty is recharge, which depends on rainfall, vegetation (transpiration), land use, runoff and evaporation. Appendix M contains matricies showing variation in recharge, aquifer thickness and permeabilities as used by the model.

When this Calibration process is complete the model is able to predict future conditions of the aquifer based on changes in recharge or withdrawal. Flow patterns established by the model may then be used to make planning decisions, and recharge values used to predict loading rates of contaminants.

Model Selection

The first step in selecting a digital model is to pick one that suits the problem and operates at a reasonable cost. Because a uniform sand aquifer is a relatively simple case a two dimensional, finite difference model was selected to be run by Ott Water Engineers of Redding, California. It was the consultant's responsibilty to load and run the model using data supplied by L-COG and Lane County. Calibration was done in consultation with the county hydrogeologist to assure hydrogologic reasonableness. Future scenarios were developed and final results were analyzed by Lane County and L-COG staff. The model was developed by Prickett and Lonnquist (1971) and adapted by Ott Water Engineers for the North Florence situation.

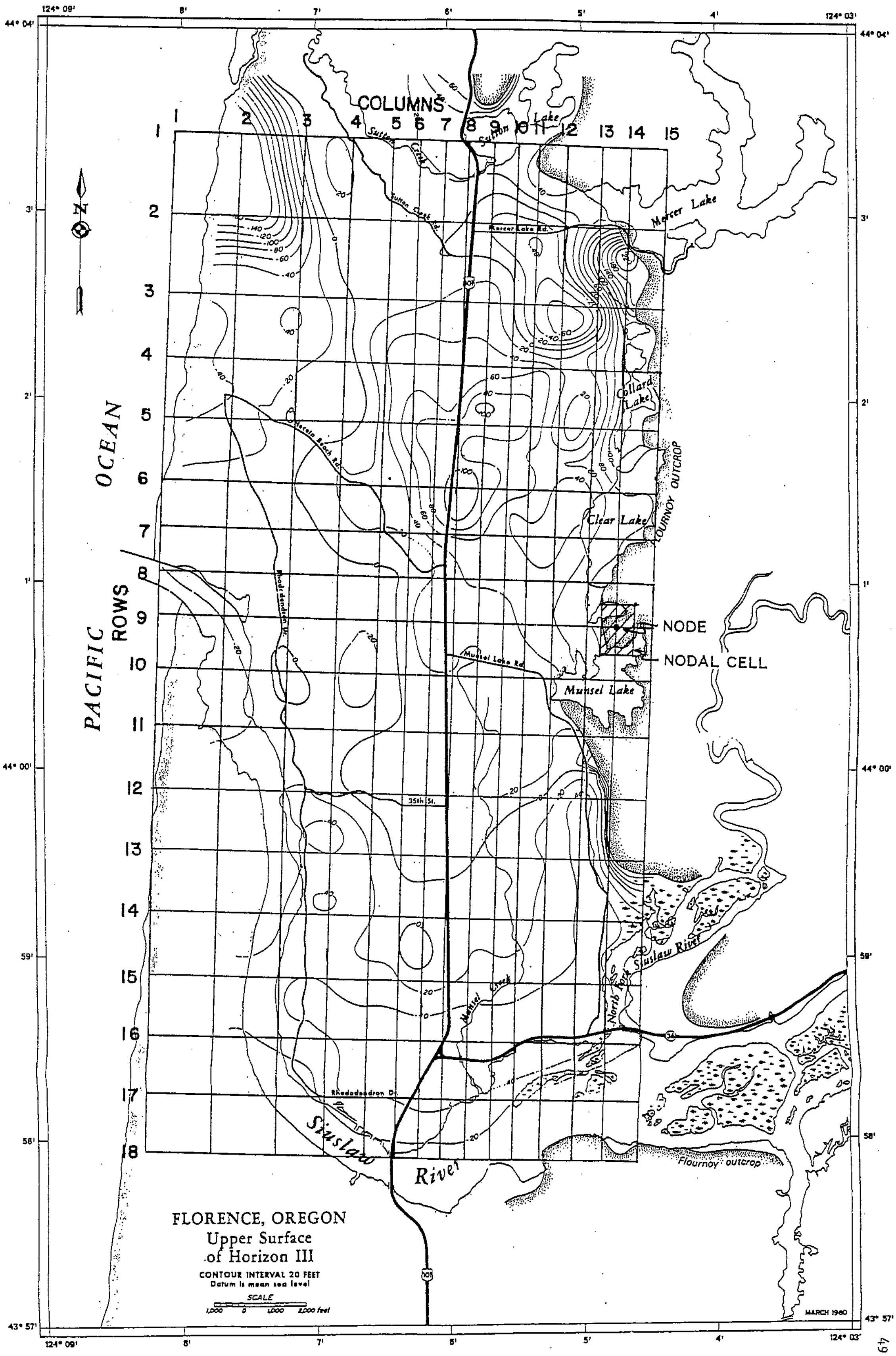
A finite difference model requires the use of a rectilinear gridding pattern that overlays the aquifer to be studied. At the center of each nodal cell, a node is placed and the aquifer characteristics for that nodal cell are assigned to that node. The entire nodal cell around the node is considered to respond identically with the node. The size of the grid and number of nodes necessary are determined by the size of the aquifer and the degree of precision desired for each part of the aquifer. Accuracy is dependent on the distance between nodes and the Prickett models allows the nodes to be spaced variably within limits. If greater accuracy is desired in portions of the aquifer a smaller grid spacing is chosen. The nodal array is shown in Figure 17 and consists of 18 rows (East-West) and 15 columns (North-South). The greatest node density was located in the Clear Lake Area because of the critical need to define the flow pattern resulting from the buried sea stack relative to Clear Lake.

The model computes mass transport (water flow) across all four boundaries of each nodal cell into or out of all surrounding nodal cells. This is done iteratively (sequential approximation for all 270 nodes by a matrixing process using flow equations. The iteration process is performed systematically by column and row and for each time step (interval). In the current situation this meant running up to 20 time steps for a three year period.

Aquifer Assumptions

It was necessary to make a number of assumptions in order to run the model. The first was to model in only two dimensions. This assumption is reasonable if the thickness of the aquifer is small compared to its horizontal extent. In the case of the North Florence study, where the top of Horizon III, (Appendix E) is used to define the aquifer depth and is generally 100 feet or less from the surface the horizontal extent

FIGURE 17. Grid System Layout Showing the Relationship Between Node and Nodal Cells.



of the aquifer is at least 10,000 feet, which results in a 100 to 1 ratio of width to thickness.

Another basic assumption is that generally the Flournoy Formation is impermeable. This assumption rests on comparisons between well flows developed in the dunal sands and those from the surrounding Flournoy Formation. Permeabilities in the Flournoy Formation are several orders of magnitude less than the dunal sands and hence are impermeable by comparison. The Flournoy Formation comprises the eastern margin (upland ridges) of much of the aquifer, and, for modeling purposes was assumed to be a "no flow" boundary.

Sutton Creek, the Pacific Ocean, the Siuslaw River and the North Fork of the Siuslaw River were all assumed to be constant head (non-fluctuating water level) discharge boundaries of the aquifer. These boundaries are major aquifer discharge zones as evidenced by the numerous surface seeps seen along the stream banks and the beach.

The bottom of the aquifer (top of Horizon III) was assumed to be a no flow boundary. This assumption was based on the character of the Horizon III material drilled at the deep well site and the hydraulic head difference (shown by the deep well piezometers) across this boundary (Figure 13). Though Horizon III may not be a continuous or homogeneous layer, the model indicates it generally causes the aquifer to respond as though a continuous impermeable boundary exists at this level. With the exception of recharge, the thickness of the aquifer as defined by the boundary layer is the least precise parameter in the modeling equations.

Recharge

Recharge is calculated from annual rainfall minus losses due to evaporation plus transpiration (evapotranspiration) and runoff. The average rainfall at Florence is 69.1 inches per year for the period 1941-1981. Evapotranspiration varies from less than three inches per year on open sands to approximately 26 inches per year on open water. Vegetated areas show intermediate values. Higher values for runoff losses were estimated for urban areas where a storm drainage system is available to carry runoff to the river.

Recharge estimation is complicated by the fact that precipitation is not uniform across the aquifer from the beach line to the hills west of Clear Lake. A 1 to 2 foot increase in rainfall occurs between the beach and the top of the hills on the east. Therefore, a recharge value for each node was calculated using an emperical formula that accounted for east-west rainfall variation, areas of open water, different vegetation types, open sand and urban areas with storm drainage.

The following evaportranspiration/runoff values were used:

Open water	- 2.16 feet (from Coos Bay studies)
Shore Pine Forest	- 1.83 feet (from Clatsop Plains study)
Open Sand	- 0.25 feet (from labratory studies)
Urban Areas	- 3.58 feet (evapotranspiration plus runoff)

These values were adjusted in calibrating the model.

The urban area value assumed an impervious surface value of 60 percent with about 50 percent of this runoff (a total of -2.07 feet) being discharged away from the aquifer. The remainder of the water loss in the urban area (-1.51 feet) was due to evaportranspiration. Rainfall values were allowed to vary from 5.33 feet at the shore line to 6.17 feet at the top of the aquifer.

Permeability Constant and Storage Coefficients

The permeability constant and the storage coefficients were initially selected from the work done by Hampton (1962) and Robison (1973) on the Florence dunal aquifer. These are reasonably accurate numbers which were used to define a range beyond which these parameters were not allowed to vary unless special geologic considerations prevailed. Permeability constants ranged from 250 to 700 gallons per day (gpd), with 470 gpd most commonly. Lower values and were used near the sea stack or where estuary deposits were suspected. The higher values were used in areas of greatest sand thickness. The storage coefficient was allowed a range of .25-.35 with .34 being the value used in most areas.

Calibration Process

The assumptions and parameters described in the preceeding sections were incorporated into the model as initial estimates in order to test the model relative to the aquifer. As expected, the model underestimated water in some areas and overestimated in others. Adjusting the parameters (assumptions) for each cell in a given sequence allowed the aquifer model to systematically calculated water levels that closely matched the measured levels in the aquifer. First adjustments were made to recharge values with subsequent adjustment of aquifer thickness, permeability and finally, storage coefficients until an acceptable match with measured water levels was achieved. Calibration often involved several adjustments to these parameters before an accurate prediction of the aquifer response over time resulted.

Analysis Scenarios

Once the model is able to accurately predict average water levels under steady state conditions, it is said to be "calibrated". The model is then run for a period of time equal to two or three times the length of the real data match period to predict aquifer responses to conditions other than the steady state. These alternate conditions (drought and/or water withdrawal) are called "hydrologic scenarios". In this study, three scenarios were run:

1. Steady State: Average Rainfall, no pumpage, run for three years as a baseline condition.
2. Normal Rainfall plus Maximum Pumpage: Average rainfall plus pumpage from Clear Lake to serve the ultimate projected population (25,000 people) run to three years.
3. Drought plus Maximum Pumpage: Drought for three years at 83 percent of normal rainfall plus maximum pumped withdrawal from Clear Lake to serve 25,000 people.

The population figure of 25,000 includes areas outside the study boundries which are served by the Heceta Water District. A near-maximum build-out in these areas plus substantial urbanization inside the urban growth boundary is included in this projection. Scenarios No. 2 and 3 assume that the Heceta Water District will provide all water required for this growth. Scenario No. 3 is a "worst case" analysis from the stand point of Clear Lake. These three analyses were used to define the Clear Lake Dunal Watershed.

Vegetation Inventory

Since much of the North Florence dunal aquifer is covered with natural vegetation and large tracts remain currently undeveloped, it was necessary to conduct a vegetation survey to determine the loading of nutrients from natural sources. This inventory was conducted using aerial infrared and black and white photography combined with field verification. The process is simplified somewhat by extensive areas of shorepine forest and open sand, as well as the absence of agriculture. The following vegetation type classifications were used:

* Scotch Broom (B)--limited and small areas with Scotch Broom (cytisus scoperus) dominant species, nearly always on disturbed sites. Scotch Broom is a nitrogen fixing plant.
* Dune Grass (DG)--areas dominated by plantings of European beach grass used to stabilize dunes which requires heavy nitrogen fertilization to be established.
* Meadow (M)--open meadows dominated by native and non-native grasses other than beach grass.
* Marsh (MA)--predominantly freshwater marsh areas along the discharge boundaries of the aquifer. Species include rushes (junca), bull rushes (scripus) cattail (typha), skunk cabbage, alder (alnus) and willow (salix).
* Sand (S)--open sand, either unvegetated or with scattered (less than 30 percent) grass and pine.
* Pine Forest (P)--coastal shore pine (pinus contorta) forest, the dominant vegetation community on the dunes, with a dense

to impenetrable understorey of salal (goultheria shallon), pink rhododendron (rhododendrum macrophylum) and other species.

* Deciduous with Conifer (DC)--areas recently logged on the upland hills to the east. The dominant trees are red alder (alnus rubra), and bigleaf maple (acer macrphylum) with understories of ferns, salal and young conifer. Red alder is a nitrogen fixing species and tends to reproduce vigorously in the first 10-15 years following log harvest.

* Conifer with Deciduous (CD)--similar to DC and in the same areas, but with significant proportions of mature (60+ years) to old growth conifer, predominantly douglas fir (pseudotsugar menziesii), sitka spruce (picea sitchensis), and western red cedar (thuja plicata). Alder and maple occur as subdominant trees within the understorey.

* Intermittant Lake (IL)--bog areas that are ponded for 4-8 months in most years. Often dominated by blueberry and huckleberry (vaccinium species) in shallower areas, plus bunch grasses--these areas tend to be small and scattered.

* Lake (L)--open, permanent (or nearly so) water.

* Urban (U)--urban areas of predominantly non-native vegetation species including lawns--developed areas with the highest proportions (40-65 percent) of impervious area; concentrated in downtown Florence.

* Urban Pine Forest (UP)--areas of the pine forest that are significantly developed with up to 40 percent impervious area.

* RCD, RDC--residential variations on previously described vegetational types--these types are found primarily in the Collard Lake upland area and have impervious areas of up to 50 percent.

* Dump--the landfill located near site #26.

* Sludge--a domestic sewage sludge disposal site on the periphery of the dump.

* Golf--Rhododunes Golf Course in the SE section of the study area.

These vegetation areas are shown in Figure 18 and are similar, with some variations, to those listed in the Clatsop Plains Study (Sweet, 1981): Dunes generally contains only minor amounts of beach pea in the Florence area; no salt marsh was identified in the aquifer; recent clearcuts were classified as Deciduous with Conifer; scotch broom was not listed for Clatsop Plains but occurs in the "ridge and swale" category; and no agricultural or pasture uses were found. The values for nitrogen production for each vegetation type (from Sweet, 1981) are listed in Table 3.

Of particular note is the nitrogen value for Pine Forest which was found from monitoring data not to be supportable in the Florence area: In fact, there were indications that the shore pine forest is a net consumer of nitrogen and lowers the levels occurring under open sand. This value is also shown in Table 3.

FIGURE 18. Map of Vegetation Types.

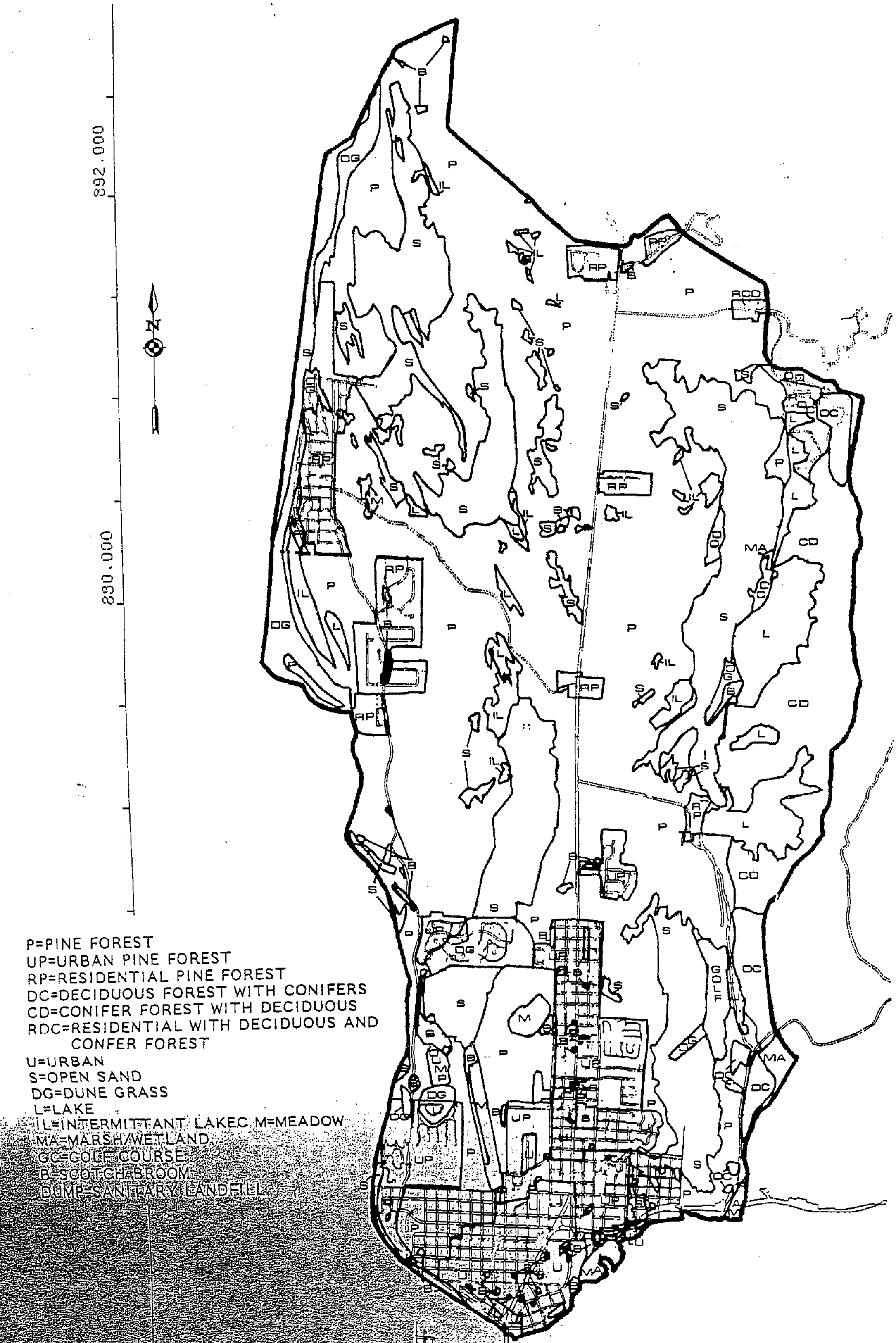


TABLE 3. Nitrate Contribution to Ground Water from Vegetation Clatsop Plains and Florence (as lbs/acre/year).

NITRATE CONTRIBUTION FROM VEGETATION
ESTIMATED ANNUAL LOSS TO GROUNDWATER AS N (LBS/ACRE/YEAR)

VEGETATION/COVER	LOSS (CLATSOP)(1)	LOSS (FLORENCE)
RAINFALL	See "Sand"	0.45(2)
SAND	0.25	0.00(3)
DUNE GRASS	8.00	1.00(4)
SHORE PINE FOREST	5.00	-0.17(5)
MEADOW	5.00	Insufficient Data
DECIDUOUS W/CONIFER	20.00	Approx. 1.9(6)
CONIFER W/DECIDUOUS	6.00	Approx. 1.9(6)
OLD AND RECENT CLEARCUT	3.00(7)	Approx. 1.9(6),(7)
DEVELOPED-SEWERED	No Data	0.9(8)
DEVELOPED-UNSEWERED	No Data	1.4(8)
GOLF COURSE	No Data	4.8(8)

1. Adopted from Table II-3; Sweet, Edwards and Associates, Inc.; Clatsop Plains Groundwater Evaluation Report (1981); p.II-10

2. Calculated from average nitrogen concentration under open sand. Rainfall is assumed to be 4.36 feet/year (see Table 6,).

3, Open sand is assumed to add no nitrogen contribution. Rainfall is 4.36 feet/year.

4. Florence dune grass areas have little or no beach pea. Sampling beneath one dune grass area showed no elavation of nitrate levels.

5. Based on the reduced ambient concentration below forest compared to open sand (see Table 6)

6. An average value for conifer and deciduous, combined, this estimate assumes no contribution from human sources and is a maximum. It also assumes that Clear Lake is thoroughly mixed, rainfall is uniform and volume of water to Clear Lake is proportionate to acreage (see Table 6).

7. Old and recent Clearcuts are lumped together and for this study are assumed to be "deciduous plus conifer."

8. Calculated from Data in Table 6, using average concentrations.

Another point of interest occurs with the Scotch Broom Classification, for which no nitrogen production reference was found. For purposes of conservative estimation, a value twice as high as for "Ridge and Swale" was used. Loading values for "Intermintant Ponds", "Urban", and "Urban Forest", were calculated from average groundwater nitrate concentrations. Sand areas were assumed to represent the loading contribution from rainfall.

Table 4 lists the areal occurrence of each vegetation type for areas of interest in the aquifer. It is clear that pine forest (42 percent), sand (20 percent) and urban plus urban forest (20 percent total) account for most of the aquifer except for the uplands to the east of Collard and Clear Lakes. Because of the low incidence of nitrogen fixing vegetation types (excluding deciduous areas on the east), it is apparent that vegetation is an insignificant nitrogen contributor over the aquifer.

Curiously, the mixed conifer and deciduous areas east of Clear and Collard Lakes do not appear to supply a nitrogen loading as high as plant type would predict. In this area of approximates 260 acres, using an average loading of 6 lbs/acre (i.e., limited concentrations of alder), the predicted loading is 1500 lb per acre per year. Diluted into an aquifer recharge of 5.5 feet per year, this loading would indicate an upland aquifer inflow to Clear Lake at a concentration of approximately 3.0 mg/L, which, even if diluted with rainfall and water from dunal sands at 75 percent of the volume and 0.03 mg/L, would produce a Clear Lake concentration of 0.7-0.8 mg/L. Clearly, much of the upland production of nitrogen is not reaching the lake system as a result of absorption or selected uptake. Less than 10 percent of the nitrogen from vegetation appears to find its way into the lake system. This is particularly noteworthy considering the high seasonal concentrations of nitrate nitrogen (approximately 1.0 mg/L) found in the Mercer Lake system. The low loading phenomenon in Clear Lake remains unproven but may be related to the sequential passage of water through the shallow aquifer on its way to the lake system with subsequent absorption and uptake by non-nitrogen fixing plants such as alder and fir. Since soils are shallow, much of this aquifer is accessible to even shallow rooted trees. Under this theory, only a small portion of the upland areas adjacent to the lake system would actively contribute nitrogen to the lake.

Decay and Dispersion Study

Related to the North Florence Study, a joint "Decay and Dispersion" study was carried out in the Florence area in cooperation with the Clatsop Plains Groundwater Protection Study (Sweet, Edwards and Associates, R.W. Beck and Associates/DEQ/Clatsop County). This study is described in detail in Appendix B of the Clatsop Plains Groundwater Protection Plan-Groundwater Evaluation Report (1981, Sweet, Edwards and Associates).

The purpose of the decay and dispersion study was twofold: to determine constrants for nitrate nitrogen decay and dispersion and to

TABLE 4. Percentage of Each Vegetation Type for Different Areas of the Aquifer.

Vegetation Cover - Percent

Type	City of Florence	Inside Urban Growth Boundary	Clear Lake Watershed	Remainder of N. Florence Aquifer
Pine Forest	33.1	65.3	23.5	43.6
Urban Pine Forest	27.4	0	0	0
Residential Pine Forest	0.1	8.4	0.1	2.9
Deciduous w/Conifer	1.2	1.3	4.1	1.2
Conifer w/Deciduous**	0.1	1.7	20.6	10.6
Residential w/Deciduous	0.1	0.1	4.2	0.2
Residential w/Conifer**	0.1	0.1	0.1	0.5
Urban	18.4	0	0	0.2
Open Sand	6.4	15.4	23.5	24.8
Dune Grass	4.4	3.1	2.5	2.2
Lake	0	1.7	19.4	10.7
Intermittant Lake	0.1	1.8	1.2	1.5
Meadow	2.6	0.1	0.1	0.1
Marsh/Wetland	0.8	0.1	0.1	1.3
Golf Course	1.2	0.5	0	0
Dump and Sludge	0.7	0	0	0
Scotch Broom	3.6	0.3	0.6	0.3

*Boundary as of February 1, 1982, excluding City of Florence.

**"Conifer" refers to species other than shore pine and includes sitha spruce, douglas fir and cedary.

NOTE: "Urban" implies a higher density than "Residential" as well as anticipation of full urban development. "Residential" implies rural residential densities.

observe the rates of migration, dispersion and die off of tracer coliform bacteria. Values for "dispersivity" and "decay" of contaminants such as nitrate are necessary in order to predict the long term impacts of progressively changing mass loadings (nitrate) over time. This information was originally thought to be important in the current study, but decisions on scenarios midway through the study, as well as modeling difficulties encountered in the Clatsop Plains effort, implied that dispersivity values had minimal impact on the steady state situation which was the critical analysis consideration. It was decided that steady state nitrate values were more meaningful for planning decisions than were the progressive increases during development. The decision was based on the current low nitrate levels and the consequent need to know the maximum loading that can be tolerated and still meet the standards. This decision led to the realization that dispersion factors were not critical since pore velocity values were high and a steady state analysis assuming a stirred tank mixing of pollutant loads at time of discharge was adequate for our purpose and did not result in a significant loss of accuracy.

The observations on bacterial migration were informative on terms of dieoff times and general rates of retardation. It was found that bacteria did not follow theoretical processes for decay and dispersion and could not be modeled. It was also found that they traveled slowly and showed no evidence of macropore movement. A complete description of the D&D Study is found in Sweet, Edwards and Associates (1981), Appendix B.

As noted above and in the Sweet report, the D&D Study assumed less importance than the steady state analysis in this project. In addition, as Sweet notes, there were problems with the data that resulted in a moderately large error factor in dispersivity values. These problems were due to a nitrate "slug" loading, density anomoly and technical difficulties with clogging of injection ports due to precipitation phenomenon. The study did verify suspected dispersivities and the assumption of a zero nitrate decay rate. The high pore velocities encountered lent support to the assumption that a steady state situation can be accounted for adequately by a stirred tank analysis. Groundwater flow was estimated at 300 feet horizontally per year with 15 to 25 feet per year verticial movement.

In the observation of bacterial movement, experimental problems were encountered but the procedure verified that bacterial concentrations are strongly retarded, and that full die-off periods are approximately 30 days. These observations allowed the calculation of a maximum migration distance of 30-40 feet for coliform populations. The work suggests strongly that bacterial contamination is not expected to pose problems at significant downgradient distances.

To summarize, the D&D study verified certain assumption that were crucial to planning scenario analyses, but specific values of decay and dispersion were found to be of insignificant import. Bacterial evaluation verified the effectiveness of a sand medium as a filter for micro-organisms. Because of the D&D Study on groundwater protection analysis, this study effort will not be discussed in more detail in this report.

Outputs/Impacts

OUTPUTS-IMPACTS

The study outputs from analysis of all the data collected for this project over the past two years. The hydrology-hydrogeology is described by computer model analysis of the water level data which predicts water levels under drought conditions and with pumpage increases from Clear Lake. The chemistry of the aquifer for several parameters is analyzed for seasonal and areal distribution. Bacteriological evaluation is also provided.

The impact of nitrate loadings due to both vegetation and human sources is examined for different materials and compared to standards set by the DEQ. The nitrate loading per dwelling unit or per capita is established and used to determine what development density limitations may be necessary to reach nitrate target loadings. A stirred tank model of nutrient loading is used and a steady state loading factor is developed for each watershed's target value. Other constituents are analyzed to indicate their distribution and impact on aquifer use.

Hydrology-Hydrogeology

A major output of this study is the digital modeling report, "North Florence Aquifer Modeling Report", Ott Water Engineers, 1982, for the North Florence Dunal Aquifer. This computer modeling analysis was conducted by Ott Water Engineers under the supervision and in consultation with L-COG and Lane County. The calibration of the model is described in the "Study Methods - Modeling" Section of this report.

The modeling effort was undertaken to examine the general effects of increased pumpage and drought conditions on the aquifer and to specifically define the area tributary to Clear Lake. It was found that the area tributary to Clear Lake equalled approximately 1040 acres with 332 acres in upland bedrock areas to the east, 518 acres of dunal sands to the west and 190 acres of lake surface (Clear and Collard Lakes). During drought conditions and maximum pumping, part of the southwest boundary of the dunal aquifer tributary to Clear Lake is moved westward a maximum of approximately 1000 feet. This is a watershed area change of less than 10 percent. The other boundaries remain nearly constant. (See Figures 19, 20 and 21).

The model indicates that the aquifer can be separated into two distinct. The first portion is the area that collects water and transports it through Clear Lake. The water from this system is either used by the Heceta Water District, evaporates, is discharged by stream to to Ackerly Lake or flows back into the aquifer system at the southern end of Clear Lake. The second portion of the aquifer encompasses the balance of the area outside the Clear Lake tributary area. In this portion, all groundwater flows directly to discharge boundaries such as the Pacific Ocean, the Siuslaw River or Sutton Creek. The model established the boundaries between aquifer portions with reasonable accuracy and was essential in determining the effects of both drought

FIGURE 19. Ground Water Contour Map of Normal Hydrologic Conditions.

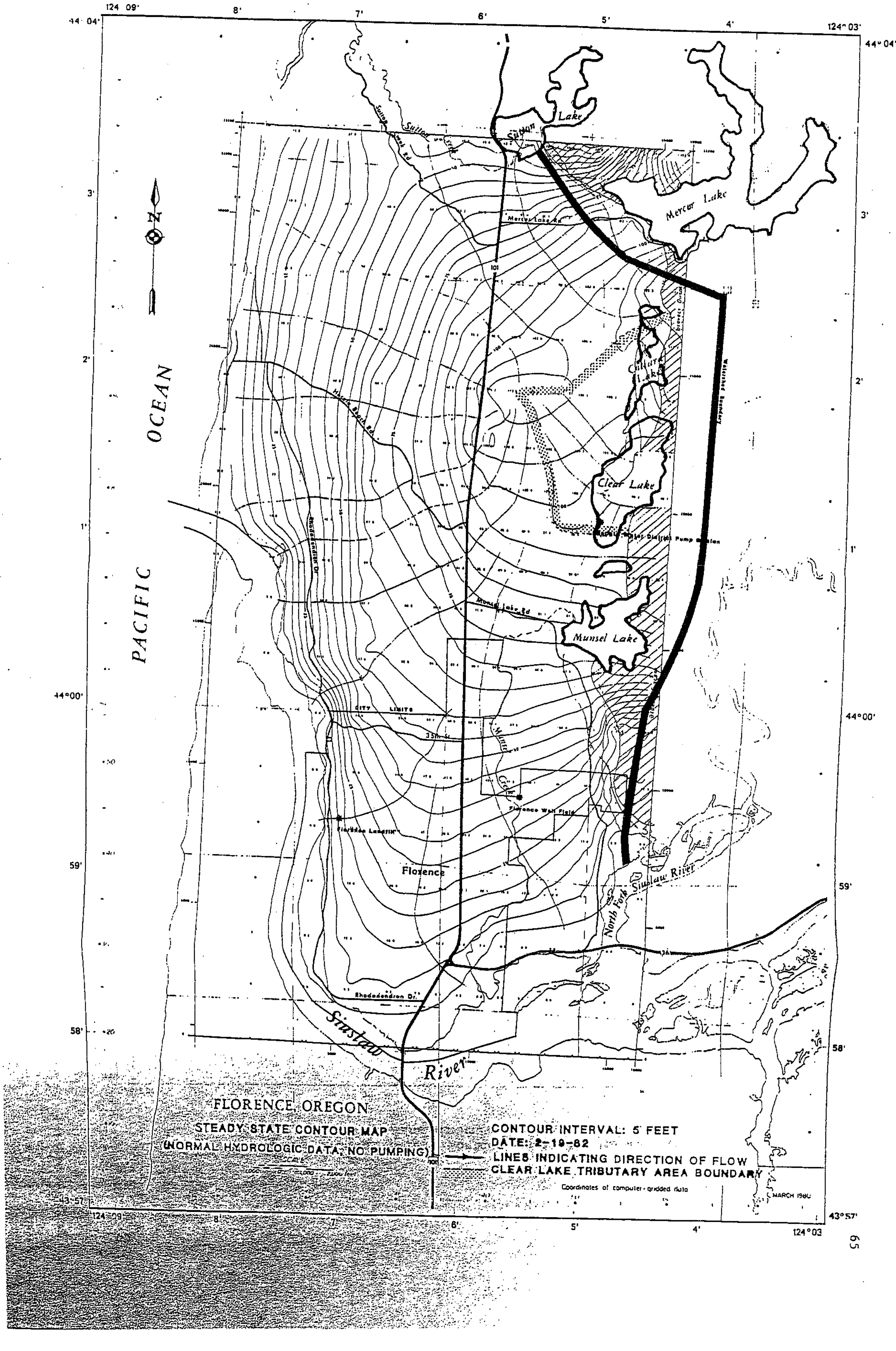


FIGURE 20. Ground Water Contour Map of Normal Hydrologic Conditions and Maximum Pumpage from Clear Lake.

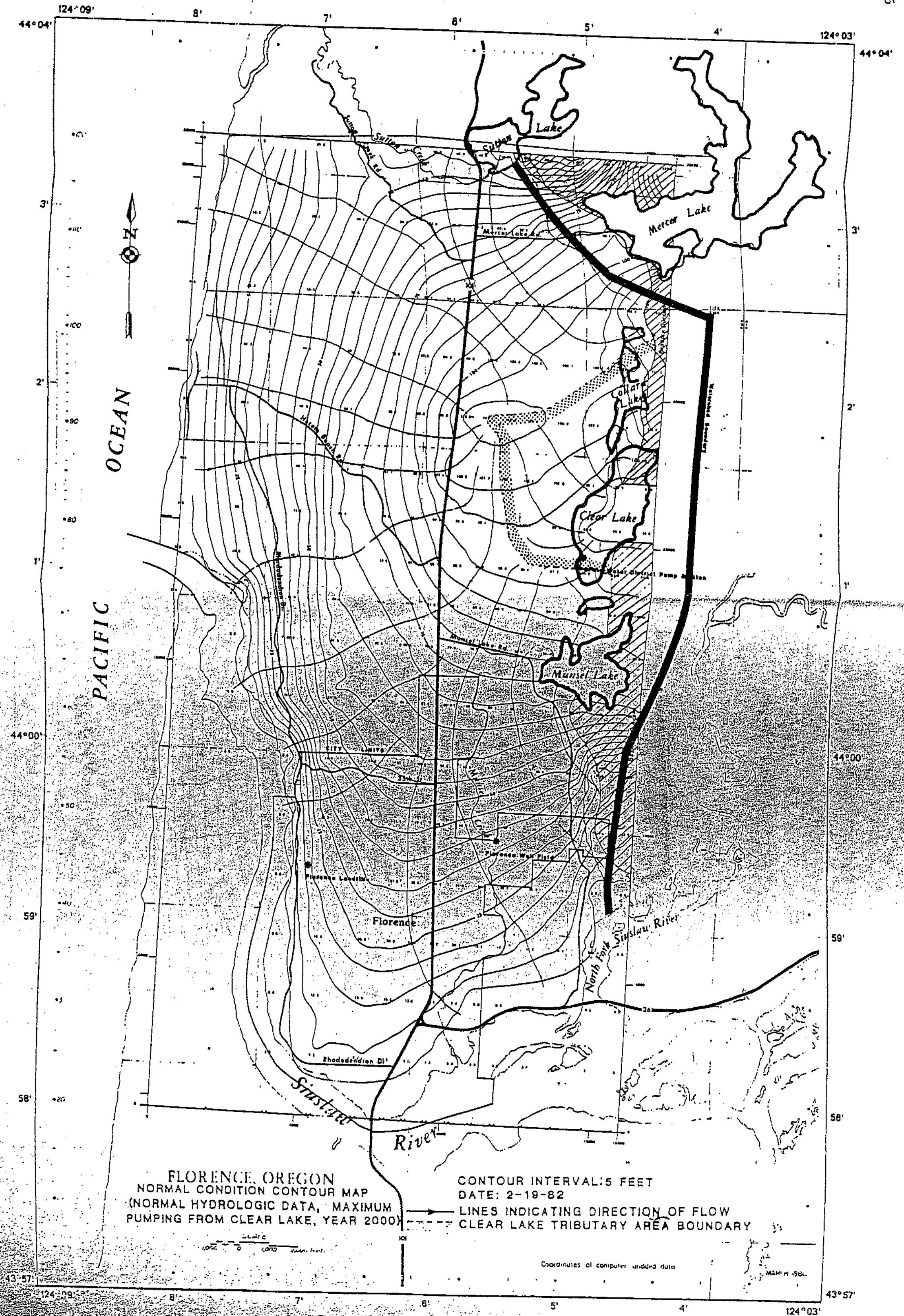
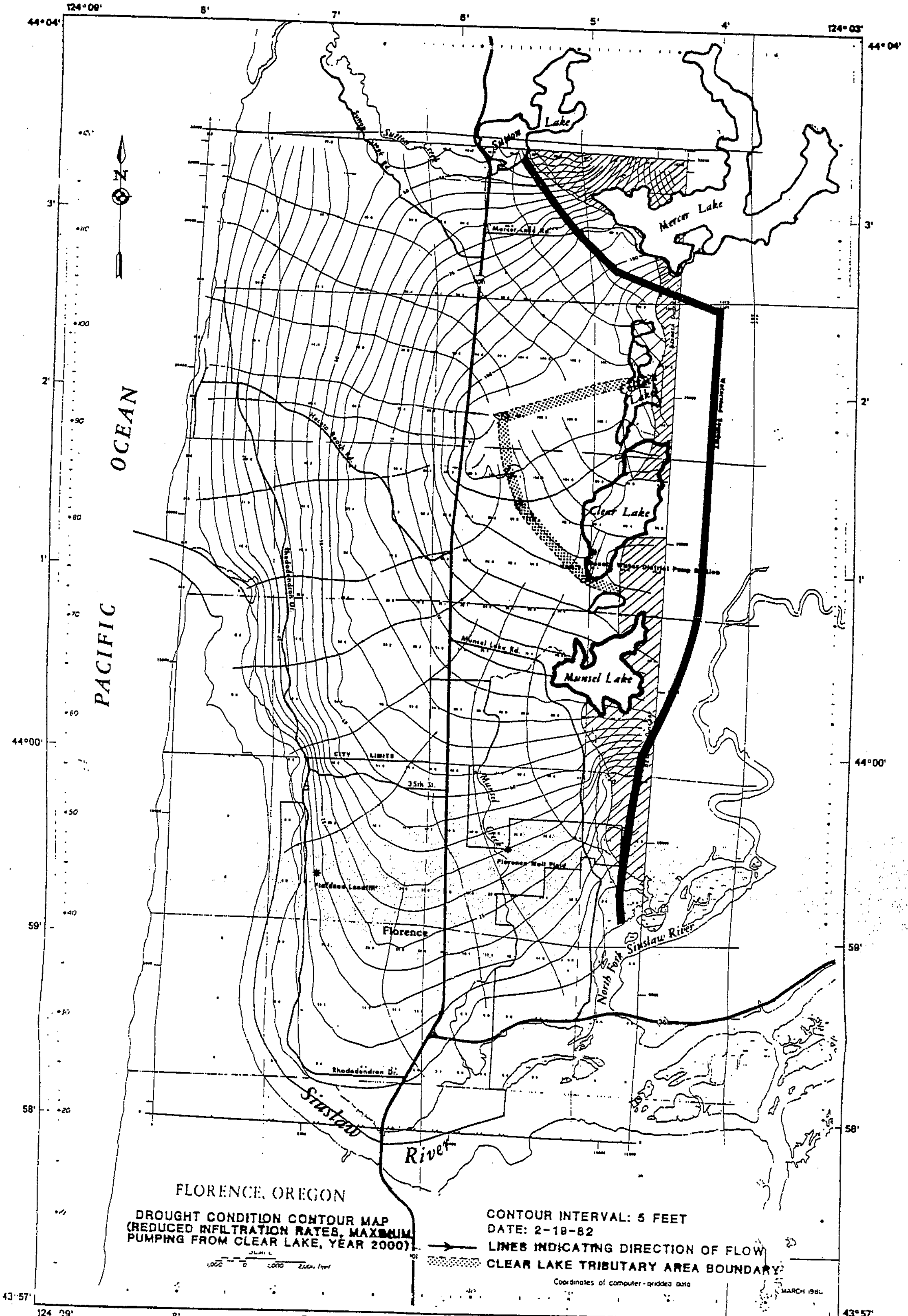


FIGURE 21. Ground Water Contour Map of Drought Conditions and Maximum Pumpage from Clear Lake.



conditions and maximum pumping rates. As will be discussed in more detail in following sections, the model indicates only minor changes in water levels and boundary positions under extreme situations (3-5 foot average change in level and less than a 1000 foot boundary migration). This propensity to change is a consequence of the high permeability and large storage capacity for recharge of the aquifer. The estimated effect on the aquifer of a three year drought and pumping two million gallons per day for 25,000 people appears to be similar magnitude to normal seasonal fluctuations.

Hydrology Scenarios

Steady State Conditions

A steady state scenario reflects the condition of the water table with normal average rainfall and no withdrawals of water or additions of imported water (See Figure 19). As the title implies, no changes with time are allowed. The output is a listing of the average water table elevations for an undisturbed aquifer and normal rainfall. This scenario is used to calibrate the aquifer and also initially gives the flow directions, "flow channels," water distribution and rainfall recharge distribution for the aquifer. Because this scenario is concerned with average water elevation, true winter levels will tend to be higher than the predicted levels and true summer levels will be lower. Information generated by this scenario allows one to predict flow directions and possible locations of future well fields. The data generated as part of this scenario will assist in the siting of contaminant generators (i.e., landfills) to minimize the effect on the aquifer. Figure 19 shows water table elevation contours, flow lines and the area tributary to Clear Lake under this steady state scenario. The northern boundry (which cuts across Collard Lake) is not precise due to model constraints. Figures 22 and 23 should be consulted for a more precise picture of this boundary.

The steady state scenario indicates that the aquifer is very uniform and recharges fairly evenly with recharge increases largely in response to increasing elevation. Flow channels broaden toward discharge boundaries, indicating increasing flows due to added precipitation. Water table contours appear generally uniform indicating a steady, even flow. This steady state scenario demonstrates that the aquifer has enormous water capacity. The siting of the land fill, as shown by the flow channels that intercept it, is excellent for an on-aquifer site. The model shows that leachate will move a relatively short distance through the aquifer before surface discharge to the estuary. Leachate is unlikely to go deep into the aquifer. The land fill is, conversely, an extremely unsuitable area for major groundwater withdrawl because of probable salt water intrusion.

This scenario also indicates the present approximate boundary of the area tributary to Clear Lake. Because this boundary represents the normal year's average water table elevation, the boundary will fluctuate seasonally and, as is clear in later scenarios, variations in yearly rainfall (or cyclical changes in climate) will further shift the boundary. For much of the foreseeable future this model run will accurately portray the actual aquifer conditions. Also, as indicated by this scenario, the accidential discharge of any contaminant on the aquifer will probably result in a wide, slow moving plume as a result of low gradients and high permeabilities in the aquifer. Significant "upstream" movement of contamination could also be expected. Contaminant clean-up would not be effective using deep wells because pumping analysis (as verified by the computer and in physical tests) indicates that gradients will be slight toward any well. Therefore numerous shallow wells would be required to pick up contamination spilled on top of the aquifer. Spills of materials that have densities greater than the groundwater would require much more complex and difficult clean up procedures.

Steady State and Maximum Pumpage Conditions

The second scenario analyzed for this aquifer is normal rainfall combined with maximum pumpage (See Figure 20). This condition could be met in the future if rainfall was near normal (near the average) with a normal distribution by month and the pumping rate from Clear Lake increased to meet the needs of 25,000 people or a rate of 2,000,000 gallons per day. The water use by 25,000 people (partly served by the City of Florence Well Field) is estimated using 95 gallons per day per person. The average household in the Florence area has 2.40 - 2.45 people per household compared to about 2.6 for the County as a whole, (1980 Census). The accommodation of a population of that size in the Florence area requires substantial buildout inside the urban growth boundary (UGB) and nearly complete buildout of those areas served by the Heceta Water District outside the UGB.

The maximum pumpage scenario with normal rainfall results in little change on the aquifer. The level of Clear Lake would drop about 2 feet and within 1/2 mile of the lake, groundwater levels may drop between 1 and 2 feet. The effect of pumping is relatively slight and would generally not affect the size of the area within the dunal aquifer that is tributary to Clear Lake. A possible exception to this situation occurs at the south end of Clear Lake which normally leaks water from Clear Lake into the aquifer. Apparently, this leakage would be reversed. See figure 20 which shows water table elevation contours, flow lines and area tributary to Clear Lake in this scenario. A more precise representation of northwestern Boundry of this watershed can be seen in figures 22 and 23.

Drought Conditions and Maximum Pumpage

The third scenario is similar to the second, except that a drought of 3 years length at 83% of the average precipitation is superimposed on the high pumpage rate. (See figure 21) This condition was chosen to maximize the area that could become tributary to Clear Lake and check the sensitivity of the aquifer to rainfall recharge conditions. The general response of the aquifer to these conditions is to drop water

FIGURE 22. Ground Water Contour Map of Seasonal High Water Table from Data Collected April 14, 1981.

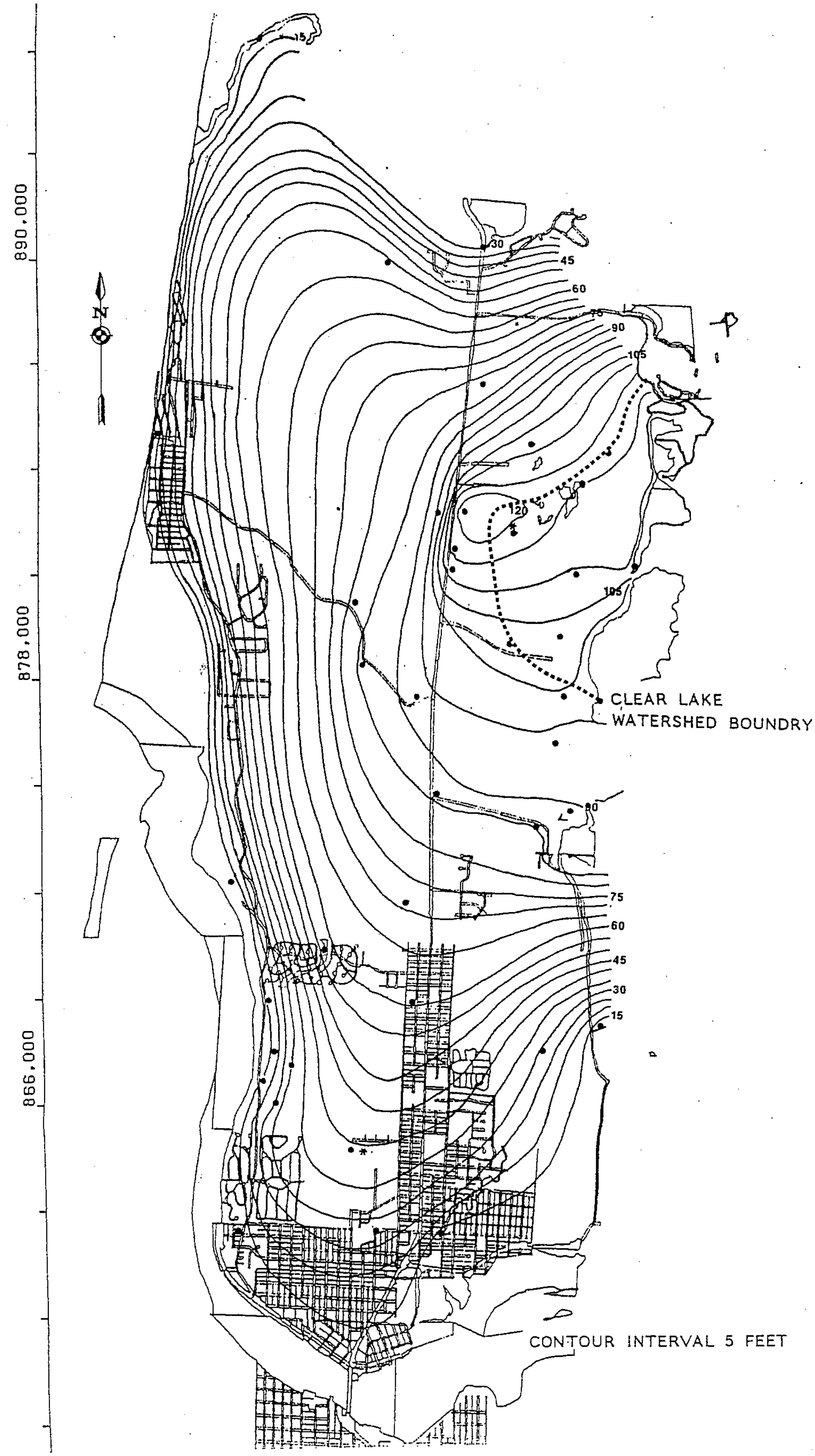
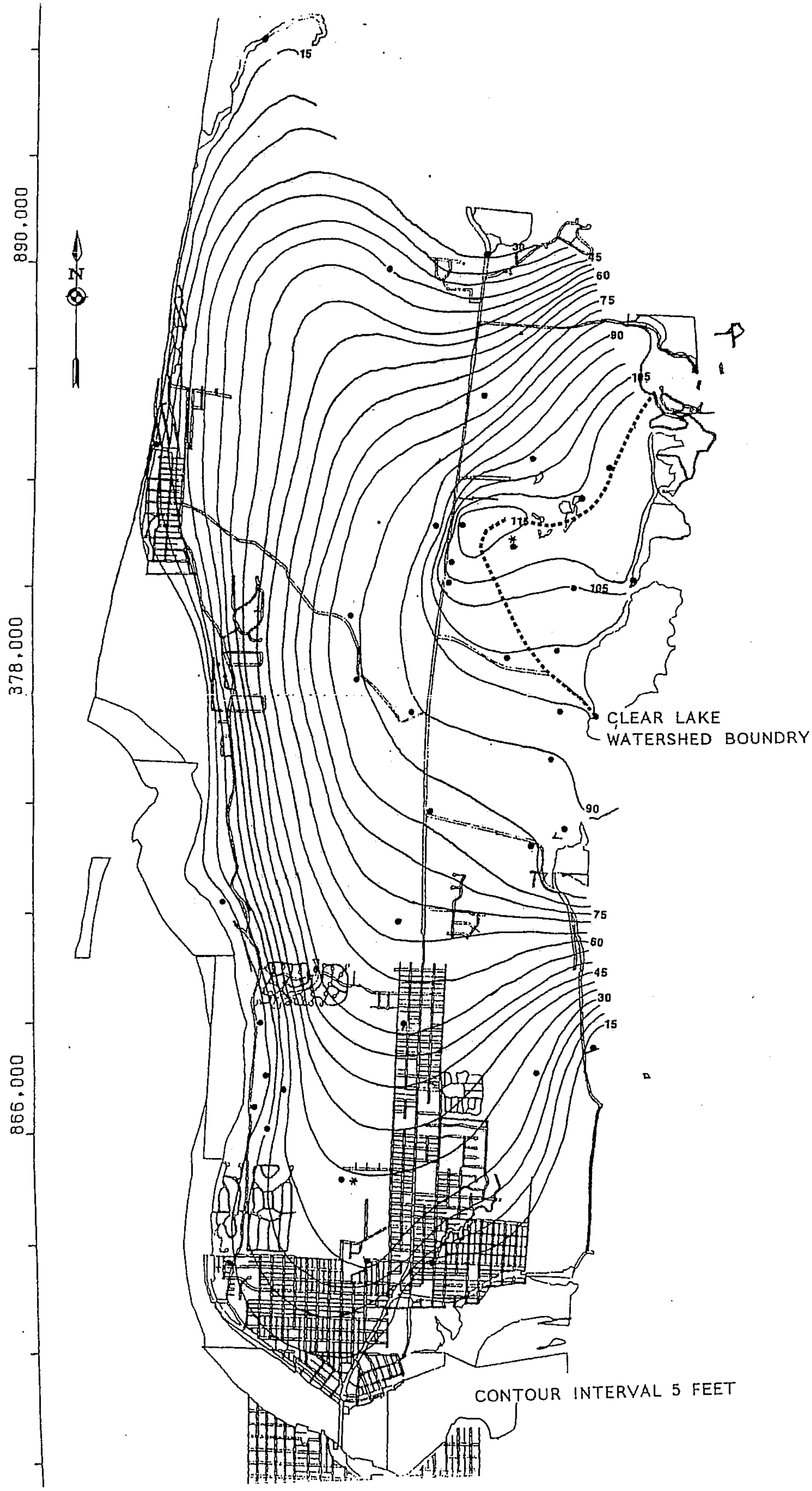


FIGURE 23. Ground Water Contour Map of Seasonal Low Water Table from Data Collected October 10, 1981.



levels between 3 and 5 feet, relative to steady state, in a uniform manner across the aquifer. Clear Lake itself would drop about 4 feet. A few areas of higher elevation would lose 5 feet in water table elevation. The area tributary to Clear Lake would increase under those conditions less than 100 acres or about 10 percent of the aquifer area. Figure 21 is a map showing the third scenario water table elevation contours, flow lines and area tributary to Clear Lake. The northwest boundary of the watershed is shown in figures 24 and 25.

Combining the results of the second and third scenarios, it appears a drought without the maximum pumping would result in water levels in Clear Lake which fell only 1-2 feet, while the rest of the aquifer would fall as much as 4 feet or more. This is an expected result since Clear Lake is an aquifer discharge point and is much less affected by recharge changes than points higher on the aquifer.

Seasonal Fluctuations

Two other water table elevation maps are of special interest and have been prepared by Lane County Staff (Figures 22 and 23). These show the water table contours for high and low water periods during the past year. The high water season is during early spring, maximum elevation in April. Figure 22 shows the water table for April 14, 1981. The minimum elevations occur in October and Figure 23 show the countours for October 13, 1980. No gross changes in the shape of the water table take place between these two extremes and this lack of dramatic change is echoed in the computer-generated scenario maps (Figures 19, 20, 21). There appears to be some seasonal change in the area of Clear Lake that discharges water into the aquifer, as would be expected in such a dynamic system. Perhaps the most interesting conclusion that can be drawn from these charts is the fact that the seasonal variation in water table elevation (3-5 feet), is about as great as the variation due to drought plus pumping (Scenario 3). Note, however, that the levels of Clear Lake itself are independent of lower pumping rates as evidenced by their nearly constant seasonal behavior. Again, this is due to a discharge point on the aquifer at Clear Lake , with a nearly constant flow into the lake and a surface outlet to dispose of excess water. As indicated by the model, heavy pumping can alter the lake level but that effect is generally less than 3-4 feet under maximum average pumping conditions. It must be remembered that the computer-generated maps reflect yearly averages and seasonal fluctuations would be superimposed upon these averages. If a drought occurred, as modeled, the average water table elevation would drop about four feet with a four foot seasonal fluctuation. Thus, an eight foot fluctuation could be observed between the average year's seasonal high water and the seasonal low water in a drought year. Long time residents of the area report fluctuations of this magnitude between wet and dry cycles.

The model does not accurately reflect the northwest boundary of the Clear Lake Watershed because node size constraints and boundary conditions of the model. In this area the maps generated from measured values (figures 24 & 25) more accurately reflect actual boundary location. This does not effect the general validity of the model.

Aquifer Recharge

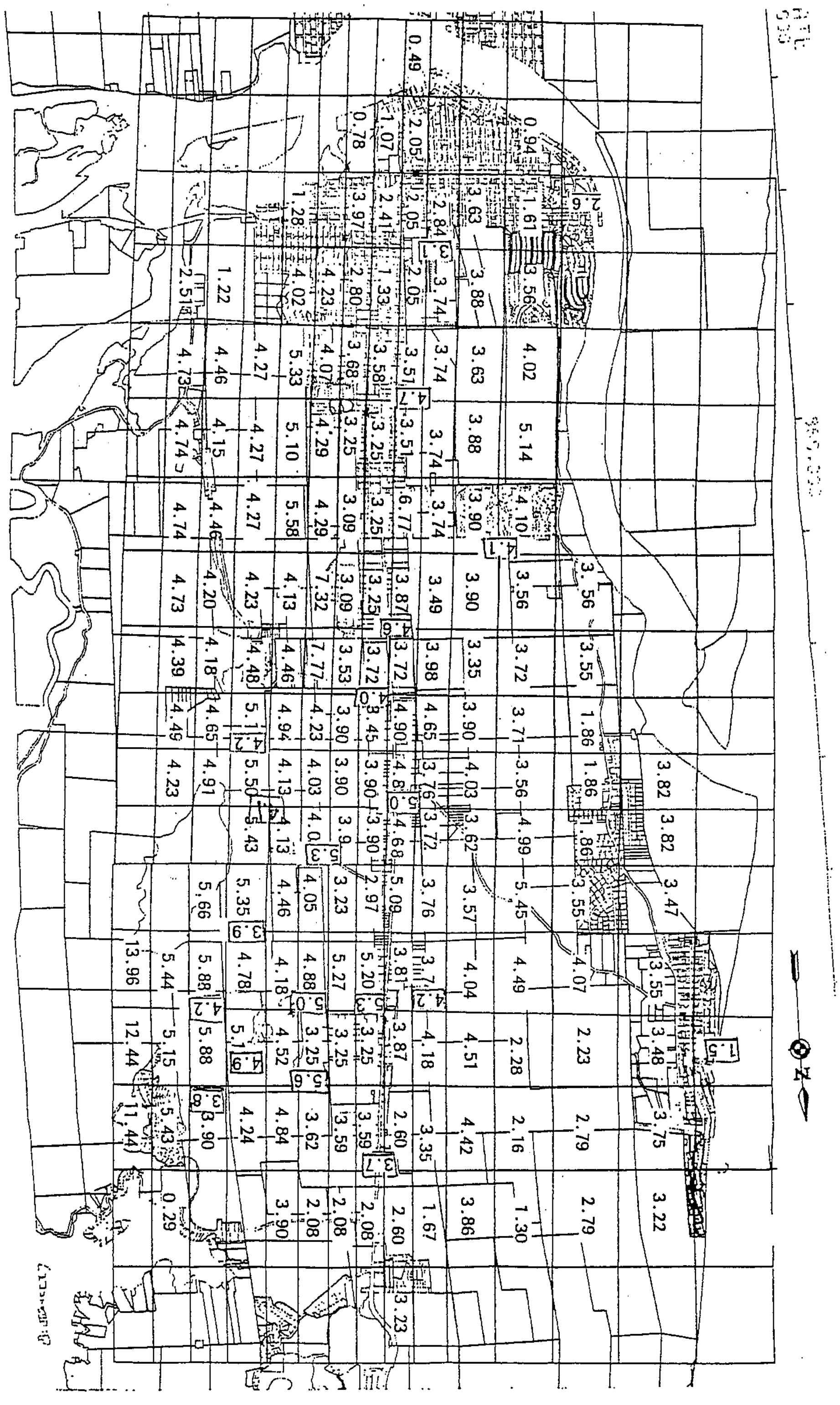
An important output of model calibrating is a reasonable estimate of the annual recharge to the aquifer. Recharge is the most sensitive variable in the model. Recharge was adjusted to "fine tune" the model after adjustment of values for permeability, thickness and storage coefficient had produced a reasonably close fit of the model to measured values. Because a critical element of this study is the determination of nitrate loading and since the concentration of nitrate depends strongly on the dilution from recharge, the model provided recharge values for loading calculations. The average recharge rate as required by the model was 4.13 feet per year.

Recharge varies across the aquifer in two ways. Rainfall increases across the aquifer away from the ocean in response to increases with elevation and, recharge will vary with vegetation type. Values used for evapotranspiration range from 0.25-0.33 feet per year from open sand to 2.2 feet per year from open water. Forested areas show 1.25 to 1.66 feet per year by evapotranspiration. Urban areas are estimated to lose 2.5 to 3.0 feet per year, largely as runoff from impervious surfaces. These numbers gave estimates of initial recharge values for the first model runs. They were adjusted as necessary for model calibration. Final calibration values were averaged to compute the general recharge rate of 4.13 feet of recharge per year.

Figure 24 lists the recharge values for each cell node as used by the model. A few cells have anomolously high or low values for recharge, almost certainly because some other parameter such as permeability or sand thickness, is not accurately known. In areas where the recharge rate seems exceptionally low, it is possible that the permeability of the aquifer "downstream" from that point is actually higher than predicted or that the depth of the aquifer is greater. In areas where the recharge appears unreasonably high (in a few areas it is large than the probable rainfall), it is likely that the aquifer depth is actually significantly shallower and/or the permeability is lower than assumed by the model. Less than 7 percent of the cell node values for recharge used by the model are outside of expected ranges for recharge.

A check on the recharge values generated by the model calibration is provided by the continuous recorder data and from the monthly water level measurements. (See Table 1 and Appendix D) Recorder data give continuous water level evaluations, and periods and amounts of recharge. This allows calculation of water table decay rates (the rate at which the water table falls when no recharge is occurring). It was observed that no recharge occurred on the aquifer from mid-July through August, and the rate of aquifer decline was uniform at .03-.05 feet per day. The annual water table decay is a measure of the annual recharge based on the assumption that the total yearly water table decline is matched by the annual recharge. Recharge rates were calculated for several well sites and these values are given in Table 1. The average calculated recharge was 4.36 feet, which agrees well with the model prediction of 4.13 feet.

FIGURE 24. Recharge Rates Per Nodal Cell as Derived from Calibration of the Digital Model (Average 4.13 feet/year) and Calculated Recharge Rates from Water Table Decline Rates Shown Underlined (Average 4.36 feet/year).



Flow Channels, Contours and Gradients

Both the model and seasonal data indicate the aquifer is very uniform. Except near Clear Lake, flow lines tend to diverge downstream, indicating lower velocities and added volume due to precipitation as the flow nears discharge points at the margins of the aquifer. The water level contours are generally evenly spaced, which is a reflection of the uniformity of the aquifer. Contour spacing qualitatively reflects ground water velocity; wider spacing indicates slower ground water movement.

Flow channels (the space between the flow lines), can be placed aribitrarily, but watershed boundaries are fixed by actual conditions. A flow lines may be started at any point on the aquifer as long as the direction of flow is downgradient and crosses all contour lines at 90° (right) angles. The flow lines are continuous smooth curves between contour lines. A flow channel can be defined of any size (area), but the shape is defined by the aquifer characteristics.

Further information on the model and how it was run can be found in the Ott Water Engineers Report, on file at the Burley, Idaho Public Library.

Chemistry/Bacteriology

Nitrate Standards

Nitrate-nitrogen standard for drinking water is determined by health considerations involving nitrate effects on haemoglobin in infants, referred to as "blue baby disease". This level is set at 10 mg/L nitrate-nitrogen for drinking water supplies.

The Oregon Department of Environmental Quality has set a planning limit for nitrate-nitrogen at 5.0 mg/L as an average value for any particular shallow aquifer, using the reasoning that this lower limit will minimize the chance that the 10 mg/L drinking water standard will be reached in the aquifer. This argument is based on the demonstrated fact that chemical concentrations in an aquifer are not constant but will vary depending on local flow patterns and proximity to sources. The 5.0 mg/L planning limit is used in this report since it is specified in the current regional rule.

Nutrients and Algal Growth

In addition to the concern with nitrate-nitrogen concentrations relating to the health standard and the planning limit, and in fact more critical in the Florence area, is the impact of nitrate on algae growth of lakes, and in particular, Clear Lake. Given sufficient nitrogen (as nitrate) and phosphorus (as phosphate), most lakes will grow algae and develop increased concentrations of aquatic plants. This situation will make use of the lake water as a domestic water supply both more difficult and costly due to turbidity, taste and odor treatment requirements. In most cases, phosphorus is the limiting nutrient because the required concentration for entrophication is one fifth to one seventh that of nitrogen. Its concentration is commonly one tenth that of nitrogen or less. This is not the case in Clear Lake where phosphorus concentrations are one fourth of the nitrogen levels and nitrogen levels are particularly low, hence nitrogen is the limiting nutrient.

Currently, Clear Lake is sufficiently clear (low turbidity) so as to not require filtration of the water before delivery to customers. As noted previously, however, this condition is a marginal one with short yearly turbidity excursions above the 6 turbidity unit standard.

The current level of nitrate-nitrogen in Clear Lake ranges annually from 0.02 to 0.11 mg/L with an average of 0.05 mg/L. Although there is little research on nitrogen limited small lakes as pure as Clear Lake studies on lakes such as Lake Superior and Lake Tahoe, indicate that eutrophication (increased algae blooms and massive weed growth) will start to occur when nitrate levels exceed 0.10 mg/L, given sufficient phosphorus. This information is summarized in Table 5 which compares current concentrations with literature assessments of eutrophication thresholds.

Clear Lake is currently borderline in terms of nutrient concentrations necessary to initiate greater algal growth and, as a result, the Department of Environmental Quality has indicated that any increases in the current nitrate concentrations are a threat to the existing high quality of lake water. This threat to quality constitutes a prohibited "pollution of state waters" and is not allowed under the current Regional Rule for the North Florence Area. The effect of this determination is to limit the areas in the Clear Lake aquifer to nitrate-nitrogent concentration increases of less than 0.01 mg/L.

Nitrate Distributions

Table 6 groups the various sampling sites into categories based on the land use or vegetation type. These groupings point up some interesting variations which indicate the influence of natural vegetation, land use and human activity on aquifer quality. This table also suggests that loadings from vegetation may be less than literature values indicate. A review of both the average and median values is instructive and a few of the more obvious comparisons follow.

Forest Areas

The lowest nitrate concentrations are found in the groundwater beneath the pine forest (Table 6). The small difference between the average and median values implies that values are low much of the year

The lack of variation with season is shown in Figure 25. Using the average value (0.03 mg/L) and back calculating to get the nitrate loading from the pine forest (using a value of 4.36 feet of annual rainfall recharge) necessary to produce this concentration, one finds a value of 0.36 lb per acre per year of nitrate-nitrogen compared to values of 5.0 lb per acre per year reported for Clatsop Plains (Sweet,

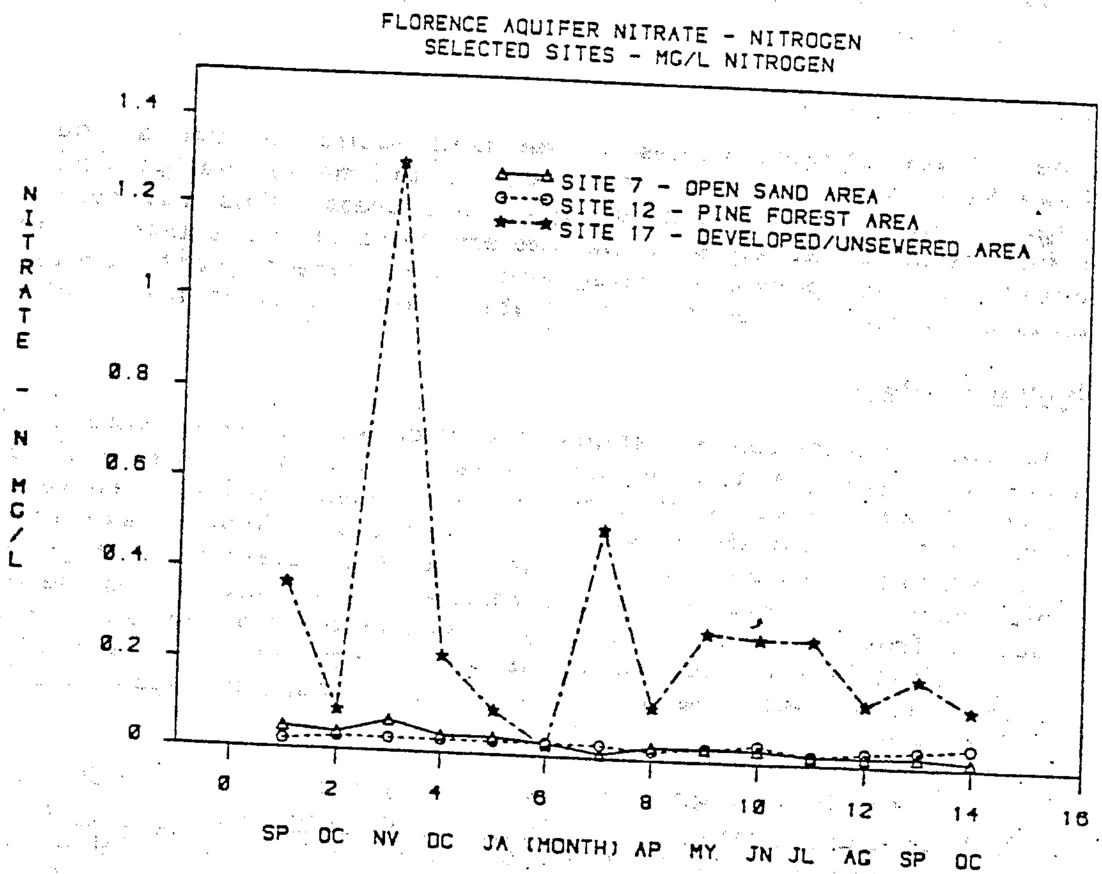


FIGURE 25. Graph of Nitrate-Nitrogen Levels for Pine Forest, Open Sand and Developed but Unsewered Areas for the Study Period.

et at., 1981). It is assumed that previously used values, being theoretical, were not as accurate as the current measured values.

Open Sand

The open sand aquifer zones show nitrate-nitrogen levels slightly higher than those reported for forested areas (table 6) and presumably represents the nutrient concentration of rainfall without alteration. The explanation of lower values for forested areas compared to open dunes probably involves the up-take of rainfall nitrate by the forest plant community.

Clear Lake Aquifer

The nitrate-nitrogen values in the sand aquifer portion of the Clear Lake Watershed, (Table 6) show average and median values similar but slightly lower than found in open sand areas. This may reflect the influence of forest lands in the western third of the aquifer, since as noted in the previous paragraph, pine forest plant communities apparently remove a portion of nitrate-nitrogen present in rainfall.

Surface Waters

The lowest nitrate concentrations in surface waters were found in Clear Lake with average and median values at 0.05 mg/L nitrate-nitrogen. Collard Lake showed significantly higher concentrations, presumably as a resultof housing development contributions. Collard Lake shows a much stronger seasonality in nitrate level than Clear Lake (Figure 26) which may have resulted from a release of nutrient during die-off of algae or from a seasonal flushing of nutrients into the lake. Higher Collard Lake levels occurred in the period from February through May which coincides with the period before significant nitrogen uptake by algal growth.

Munsel Lake shows higher nitrogen levels than Clear or Collard Lake with a stronger seasonal variation. The highest nitrates levels in surface waters are found in Sutton Lake (average 0.38 mg/L) at ten times the values in the sand aquifer. These levels were measured between January and June, again indicating that a significant flushing and/or biological process affects available nitrogen levels..

Unsewered Areas

Nitrogen levels in the aquifer underlying developed but unsewered areas shows significantly higher levels of nitrogen than in undeveloped areas. The average value of 0.17 mg/L is more than five times that found in the Clear Lake aquifer although median concentration indicates that most values are about three times the Clear Lake aquifer level. (See Table 6 and figure 27)

Sewered portions of the aquifer (Table 6 and Figure 27) show nitrate-nitrogen levels much lower than in developed, unsewered areas,

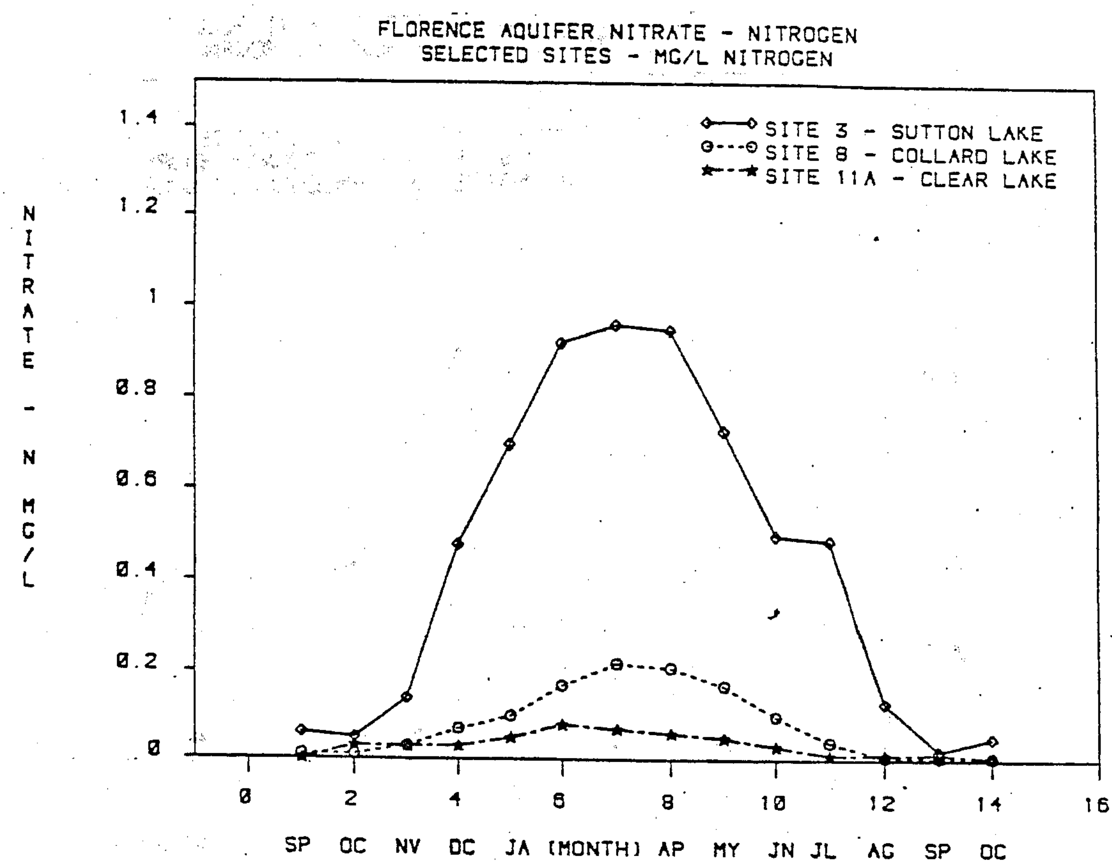


FIGURE 26. Graph of Nitrate-Nitrogen Levels for Sutton, Collard and Clear Lakes for the Study Period.

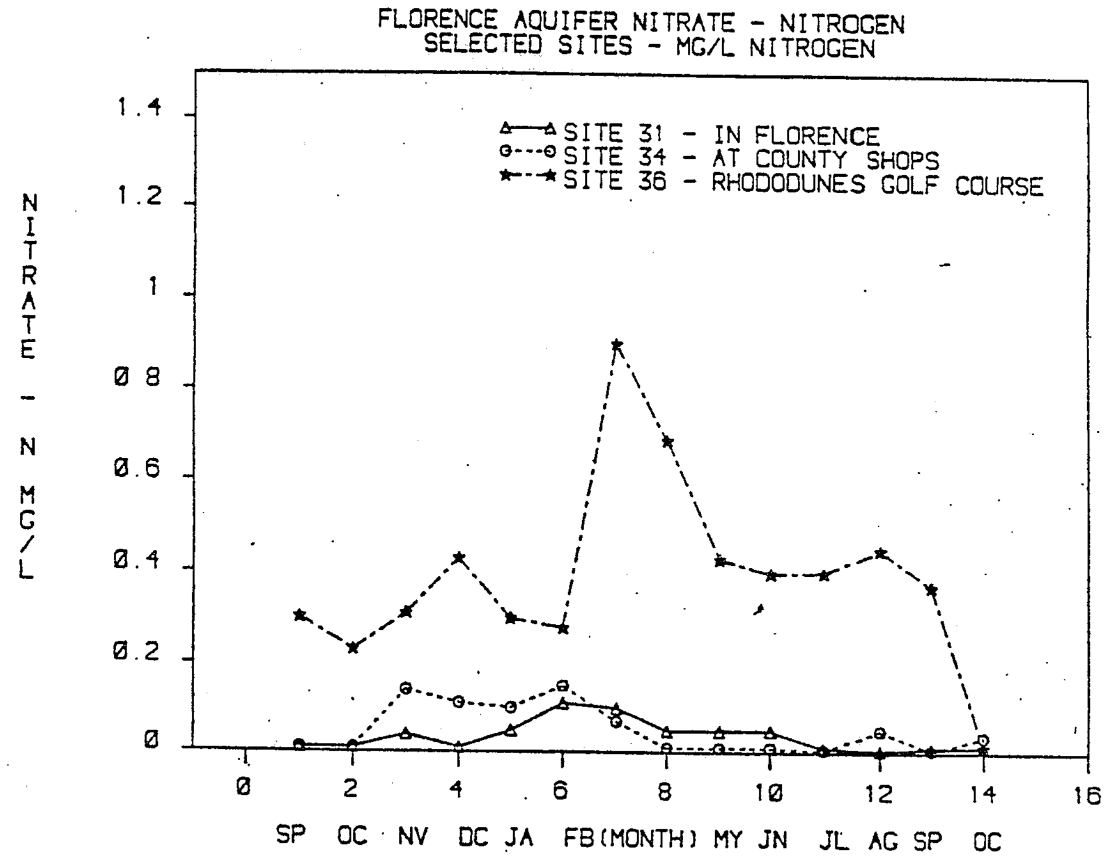


FIGURE 27. Graph of Nitrate-Nitrogen Levels for Sewered Areas in Florence and at the County Shop Yards, and Rhodo Dunes Golf Course for the Study Period.

presumably as a result of removal of septic wastes since most other factors (streets, landscaping, etc.) are similar.

Special Areas

It is worth noting that the landfill and the Heceta Beach area do not show the expected high nitrate-nitrogen levels. In the case of the landfill, the highly reducing nature of the water resulted instead in consistently detectable ammonimum-nitrogen concentrations. In the case of Heceta Beach there was only a single site and it may be that the particular flow channel tested represented primarily the flow system from the upgradient forest. The golf course, which is lightly fertilized, showed the highest nitrate-nitgrogen levels found in the entire aquifer (See Figure 27)

In general, nitrate-nitrogen concentrations in the North Florence aquifer clearly demonstrate the impact of septic systems and other land uses. Analysis of the data demonstrates a strong seasonal variation in surface water nitrate-nitrogen concentrations where septic systems are used, and that both average concentrations as well as the general variation are compatible with the observed algae blooms in intensity and pattern. Previous studies (Lane County, 1977 and Larson, 1974) show Secchi disk (clearness) readings that follow this same pattern with greatest clarity in the winter or spring and lowest clarity in the fall. Nitrate levels are expected to be low when algae concentrations are highest (fall) and high when the algae have died off and released nitrate to the water (winter/spring). (Table 7)

Iron Concentrations and Distribution

Iron in groundwater is normaly found in the ferrous state as ferric iron is much less soluble in water. Weak organic acids dissolve iron in the dune sand while the lack of oxygen precludes iron precipitation. Where general water reaches the surface deposits of iron are found as a result of bacterial and air action that converts ferrous iron to ferric iron oxide (rust).

Concentrations of iron in the dunal aquifer are a significant nuisance problem that must be removed before distribution. The City of Florence treats its well water with chlorine gas (a strong oxidant) both to kill bacteria and to oxidize iron which is then filtered out. In general, this type of precipitation process is desirable if dissolved iron concentrations exceed 0.3 mg/L.

Theoretically, iron concentration in the dunal aquifer should increase with depth and with passage through organic layers where acids are dissolved and oxygen is depleted. In fact, this is observed (Table 8) in portions of the aquifer beneath developed areas or old forest areas which all show concentrations greater than beneath open sand.

TABLE 7. Historical Data on Turbidity, Color and Clarity for Collard and Clear Lakes.

Historical Turbidity, Color and Clarity Measurements

	Clear	Collard	Date
Dissolved Solids	45.1	50.6	8/10/60
Suspended Solids	4	6	3/20/72
	3		
	1	3	6/12/72
	1	2	
	2		
	3	4	10/30/72
Total Solids	73	54	3/20/72
	58		
	37	36	6/12/72
	38	39	
	35		
	55	65	10/30/72
Turbitity	1	3	3/20/72
	1	1	6/12/72
	0	0	8/21/72
	2	2	10/30/72
Secchi Disc.	12	20	8/10/60
	20	15	6/12/72
	20		
	14	18	8/21/72
	15		
	13	11	10/30/72
	13	7	
Color	1	3	3/20/72
	1		
	1	3	6/12/72
	1	1	
	1		
	0	5	8/21/72
	1	0	10/30/72

	Clear center of lake and date	Collard center of lake & date
Secchi Disc.	5 m (9/78)	(#3) 3.5 (#4) 4 (#5) 4.1 (9/78)
	6.5 m (2/79)	5.3 6 6 (2/79)
		5 5 4.5 (6/79)
		5.5 4.5 (8/79)

TABLE 8. Iron Levels for Different Types of Areas.

IRON-Fe-mg/L
(GROUNDWATER ONLY)

Site Group	# of Sites	Average	Median	# of Values	Range
Open Sand	5	.06	.05	64	.00- .47
Pine Forest	5	.28	.21	65	.00- 1.50
Developed-Sewered	3+	.75	.41	34	.04- 2.00
Developed-Unsewered	3+	.31	.22	40	.05- .83
Clear Lake Aquifer	5	.06	.05	64	.00- .47
Landfill	1	9.07	8.80	13	1.30-14.40
Golf Course	1	.13	.14	13	.05- .34
Heceta Beach	1	.59	.66	13	.05- .78

It appears that groundwater sources low in iron and suitable for use without treatment are found only in or near areas of open sand and away from forests and bogs. Figure 28 maps areas of low iron concentration. For comparison, iron concentrations found at various depths in deep well #1 are shown in Figure 29. It is obvious that high iron concentrations are found in the deep sand layers, and may exceed 10.0 mg/L. Fluctuations in seasonal iron concentration at selected sites are also found in Figure 30.

Bacteriology-Fecal Coliform

Fecal coliform are not normally disease producing but their presence is strongly correlated to human or other mammalian waste and are therefore used as an indicator of the potential for health concern. The levels of fecal coliform contamination found in surface and groundwaters are shown in Table 9. It is worth noting that both median and average levels are less than one for most groundwaters sites except near the landfill. In contrast, all surface sites except Clear Lake show significant concentration of fecal coliforms. This is not unexpected since surface waters are open to human and animal contact, but it is interesting to note that the concentrations found in Clear, Collard, Munsel and Sutton lakes roughly parallels the relative human use of these lakes.

The data show nearly uniform and low bacterial levels in the aquifer and are in conformance with expectations from results of the "Decay and Dispersion Study" which indicated that bacterial concentrations (they have a lifetime of about 30 days in the ground) died off before they had reached a distance of 300' from the point of injection. Groundwater flow as determined from hydrologic modeling indicated rates of travel of about two feet per day or 60 feet in the life expectancy period of the bacteria.

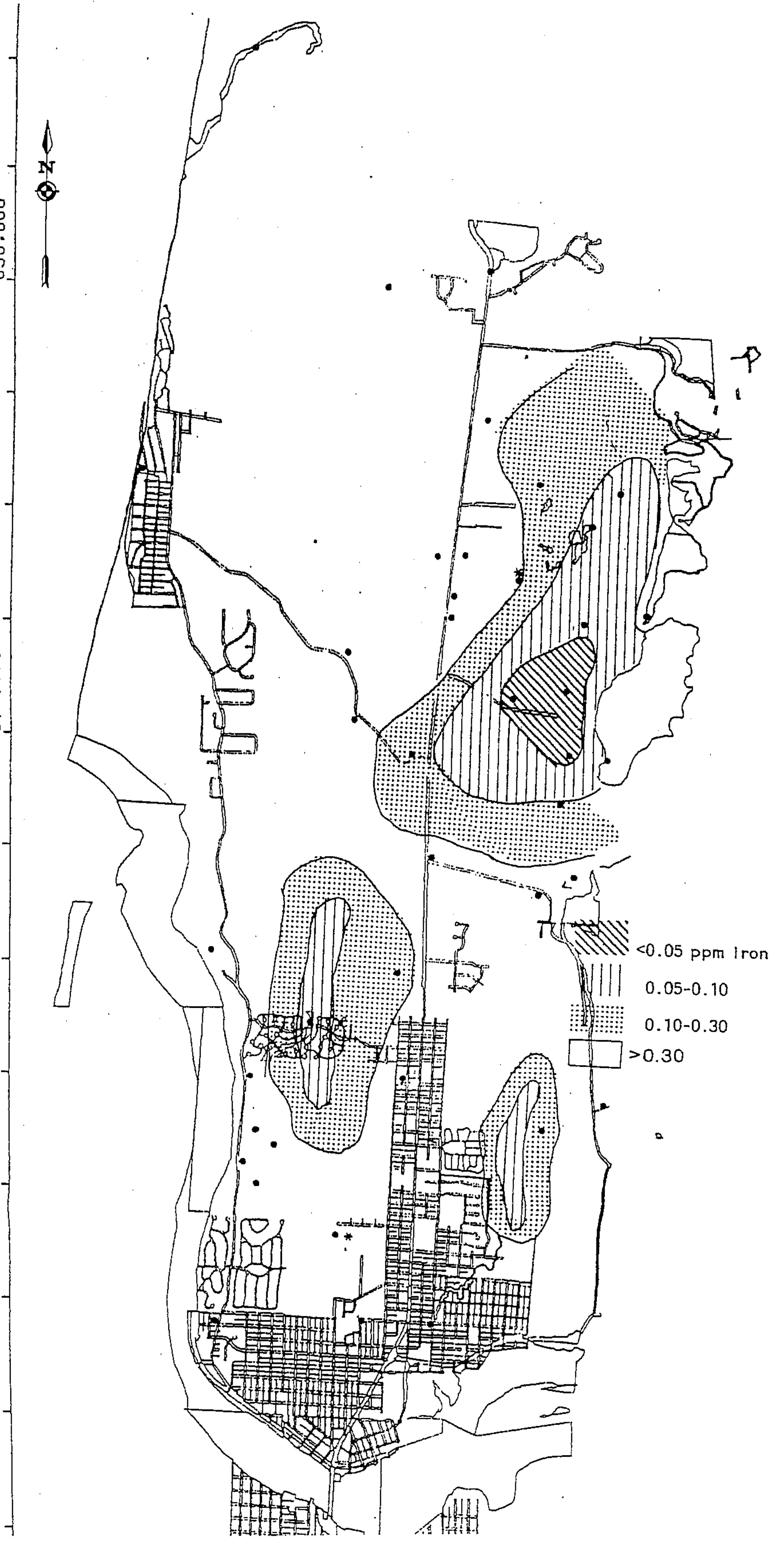
Phosphorus

Table 10 indicates selected total phosphorus concentrations for various sites within the aquifer. Phosphorus levels are generally much lower in the ground water (0.005-0.015 mg/L) than in surface waters (0.01 to 0.06 mg/L). A notable exception is site #30 for which there is no current explanation.

Of particular interest is the similarity in phosphorus concentrations between Collard Lake (0.012 mg/L), Clear Lake (0.009 mg/L) and the Clear Lake Aquifer (0.010 mg/L). This would indicate that levels in the lakes are still close to background levels, but certainly sufficient for eutrophication to occur (approximately 0.005 mg/L minimum according to Table 5).

As noted previously, phosphorus generally is well absorbed by clay soils and, apparently, still sufficiently retarded in sand to keep levels near background throughout the aquifer. Since the eastern part of the watershed contains soils with a higher clay content it is reasonable to

FIGURE 28. Map Showing Iron Concentrations in Shallow Ground Water.



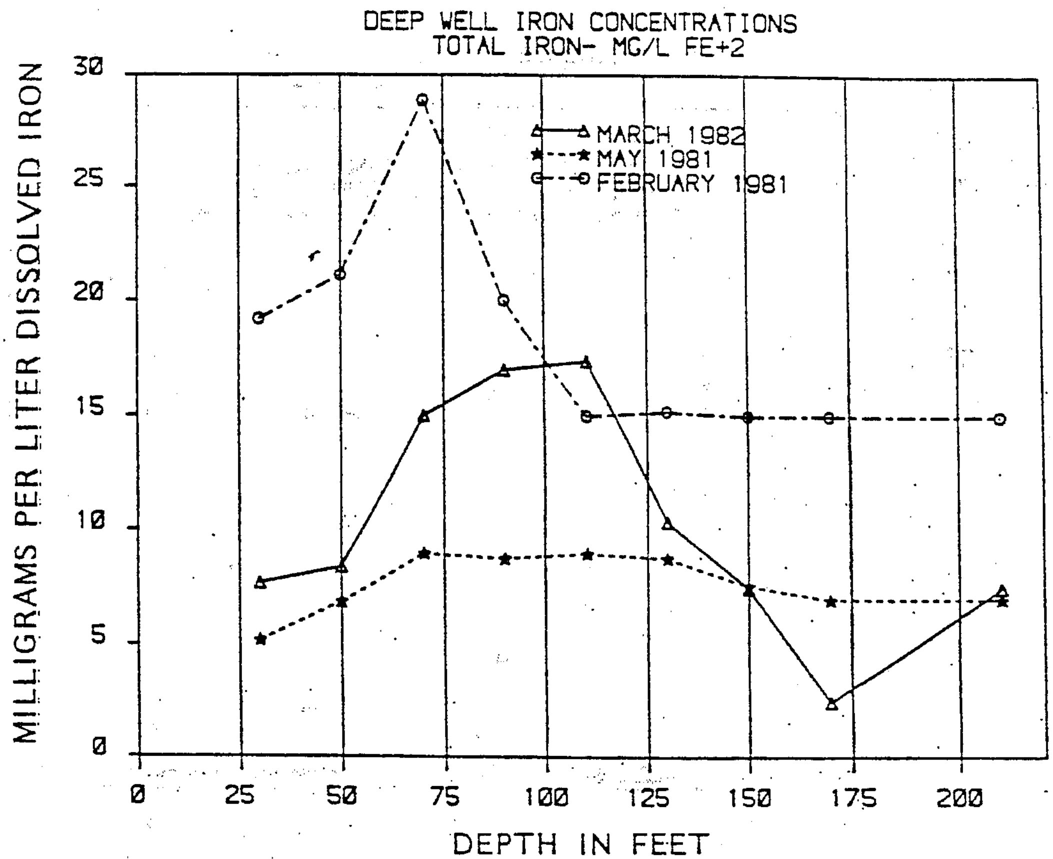


FIGURE 29. Graph of Iron Levels at Different Depths in Deep Well #1.

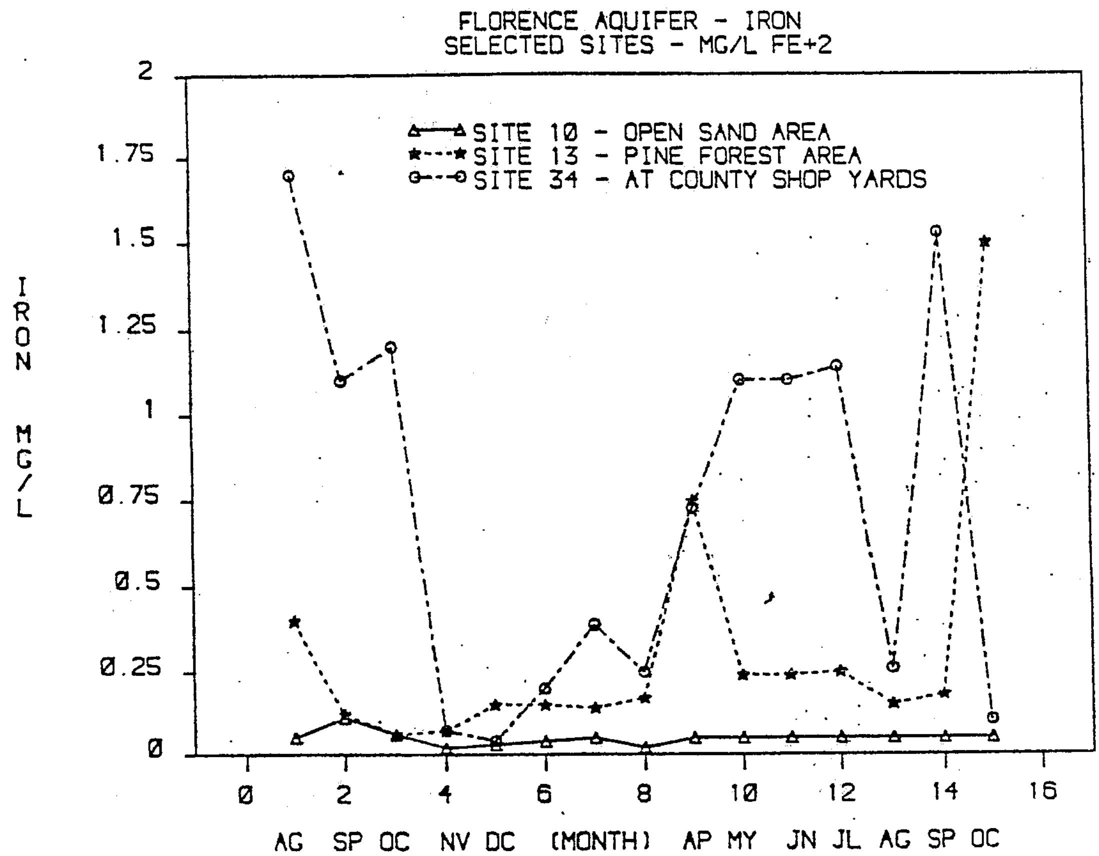


FIGURE 30. Graph of Iron Levels in Open Sand, Pine Forest and Low on the Aquifer at the County Shop Yard for the Study Period.

TABLE 9. Fecal Coliform Levels for Different Types of Areas.

FECAL COLIFORM - #/100 mg

Site Group	# of Sites	Average	Median	# of Values	Range
Open Sand	5	1	1	64	
Pine Forest	5	1	1	65	0- 42
Seasonal Ponds	2	15	2	19	0- 204
Developed-Sewered	2+	1	1	34	0- 25
Developed-Unsewered	3+	1	1	40	0- 2
Clear Lake Aquifer	5	1	1	64	0- 6
Clear Lake	1	1	1	13	0- 2
Collard Lake	1	5	1	12	0- 28
Sutton Creek (Lake)	2	401	10	25	0-9000
Munsel Creek (Lake)	1	14	10	13	0- 57
Landfill	1	2	1	13	0- 28
Golf Course	1	0	0	13	0- 0
Heceta Beach	1	1	1	13	0- 2

TABLE 10. Phosphate-Phosphorus Levels for Different Types of Areas.

PH SPHORUS-PO_4-P mg/L

Site Group	# of Sites	Average	Median	# of Values	Range
Open Sand	4+	.011	.007	40	.000-.048
Pine Forest	4+	.010	.007	40	.000-.033
Seasonal Ponds	1+	.017	.012	14	.006-.038
Developed-Unsewered	2+	.013	.009	25	.000-.033
Developed-Sewered	3+	.046	.011	21	.003-.710
Clear Lake Aquifer	4+	.009	.007	40	.000-.048
Clear Lake	1	.014	.007	8	.000-.038
Collard Lake	1	.012	.007	9	.005-.040
Sutton Creek (Lake)	2	.022	.021	18	.017-.039
Munsel Creek (Lake)	1	.012	.013	9	.006-.019
Landfill	1	.020	.019	8	:015-.014
Golf Course	1	.019	.011	8	.005-.056
Heceta Beach	1	.019	.020	8	.005-.028

assume that phosphorous levels in the lakes reflect clean sand aquifer levels.

Chloride

Chloride was tested to detect potential salt water intrusion and possibly trace effluent plumes. Although the levels found show some variation, mostly notably near Heceta Beach, these levels represent the effects of atmospheric sea spray and not infiltration. Sea water has a chloride concentration of approximately 35,000 mg/L and so is obviously not present at any test site. Figure 31 shows the seasonal variations of chloride at several locations.

Temperature

Temperature is an indicator of seasonal variation. Surface waters are obviously affected by seasonal changes and groundwater will vary to a lesser degree depending on its distance from recharge. Figures 32 and 33 show monthly temperatures for several representative surface and groundwater sites.

COD

Chemical oxygen demand (COD) is a measure of the organic material dissolved in surface or groundwater and could be related to passage through organic materials or to the leaching of wastes. The aquifer beneath open sands (site #'s 5,7,9,10) characteristically show the lowest COD levels while water beneath pine forest (site #'s 12,13,22) are higher and more variable. The highest levels in groundwater are found at sites #17 (near a leach field), #19 (at Heceta Beach Park), #30 (at 12th and Rhododendron Drive in a residential area) and at #26 (below the land fill). Of the surface sites, Clear Lake has the lowest COD.

Waste Loading

Because the protection of the North Florence Dunal Aquifer from pollutants is a primary concern, the aquifer was defined and modeled such that point and nonpoint source pollution as well as transport phenomena could be understood. The most important contaminant in terms of mass loading is sewage waste from on-site disposal systems. Such waste is a complex mixture of chemical and biological constituents. Nitrate-nitrogen in particular is useful in defining the extent of potential problems. This constituent is of particular sensitivity in addressing the protection needs of the Heceta Water District supply from Clear Lake.

Stirred Tank Calculations

The method used to compute the allowed nitrate-nitrogen loadings is called the stirred tank method. This method assumes that all the constituents are instantly and completely mixed throughout the control

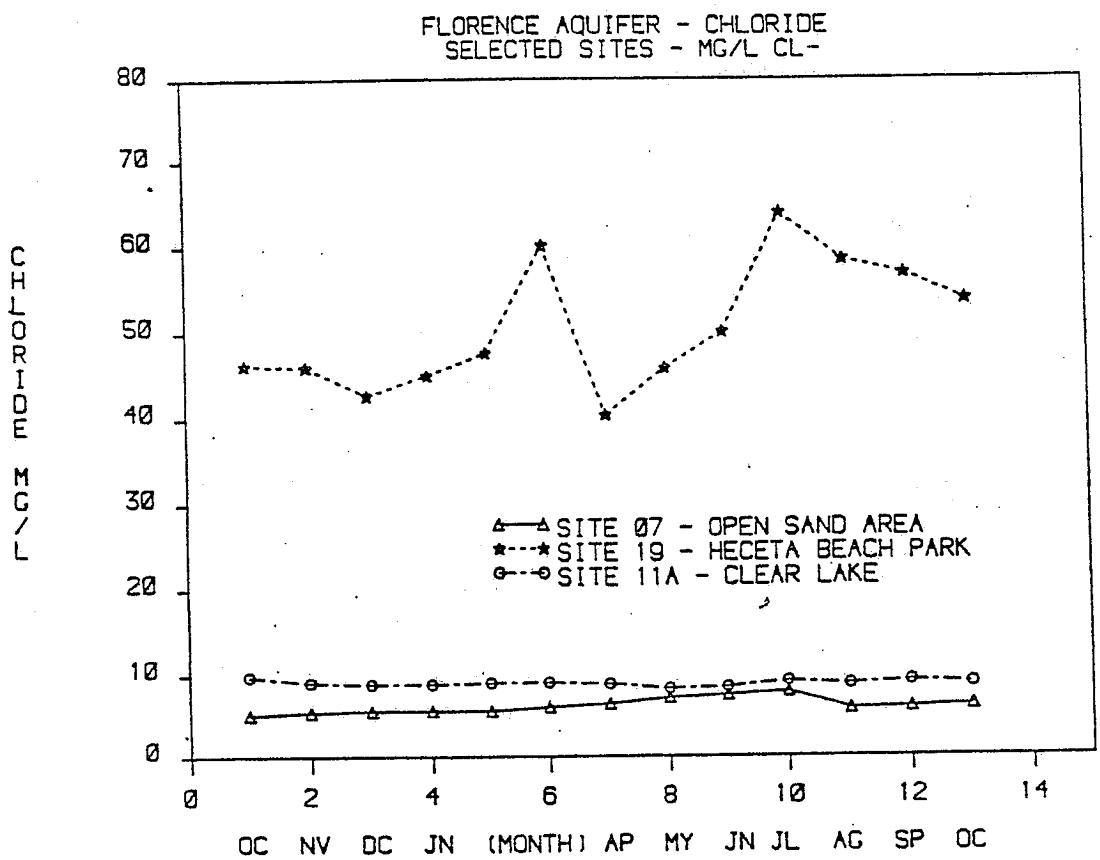


FIGURE 31. Graph of Chloride Levels for Open Sand Area Far from the Beach, Clear Lake and at Heceta Beach.

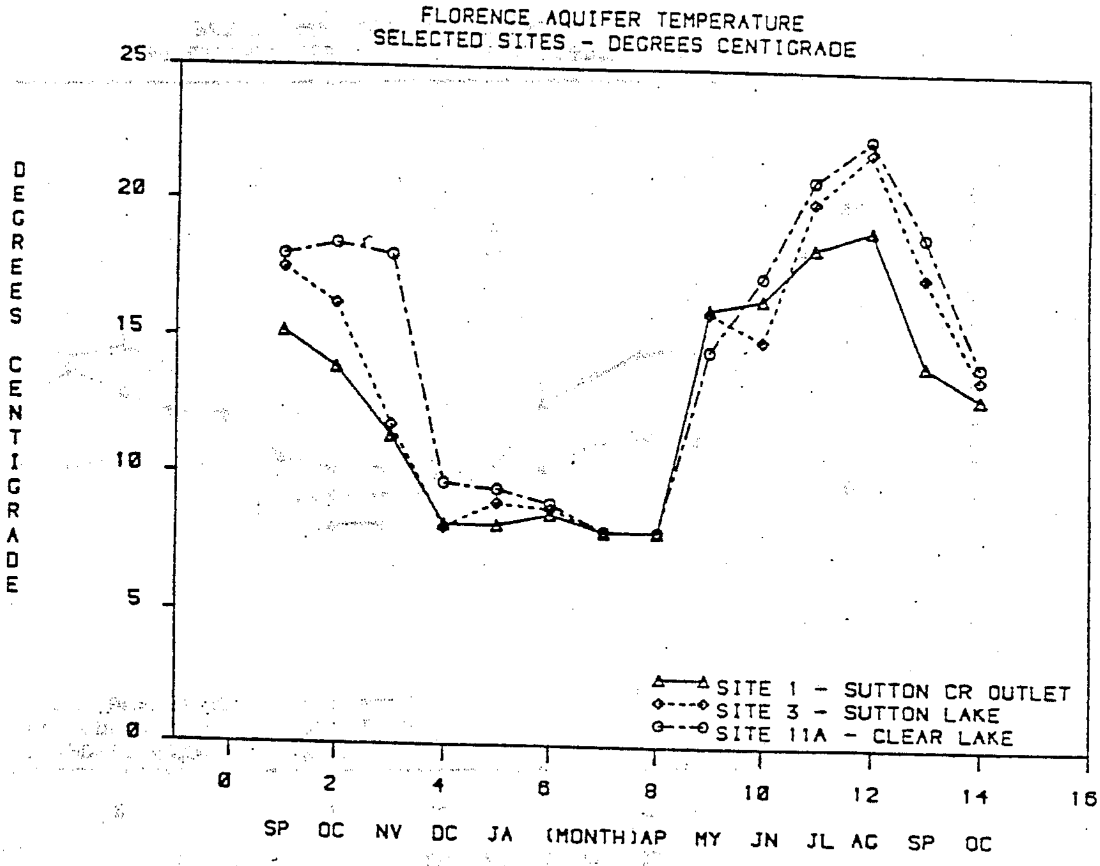


FIGURE 32. Graph of Temperature of Sutton Creek Near the Mouth, Sutton Creek at Sutton Lake and Clear Lake for the Study Period.

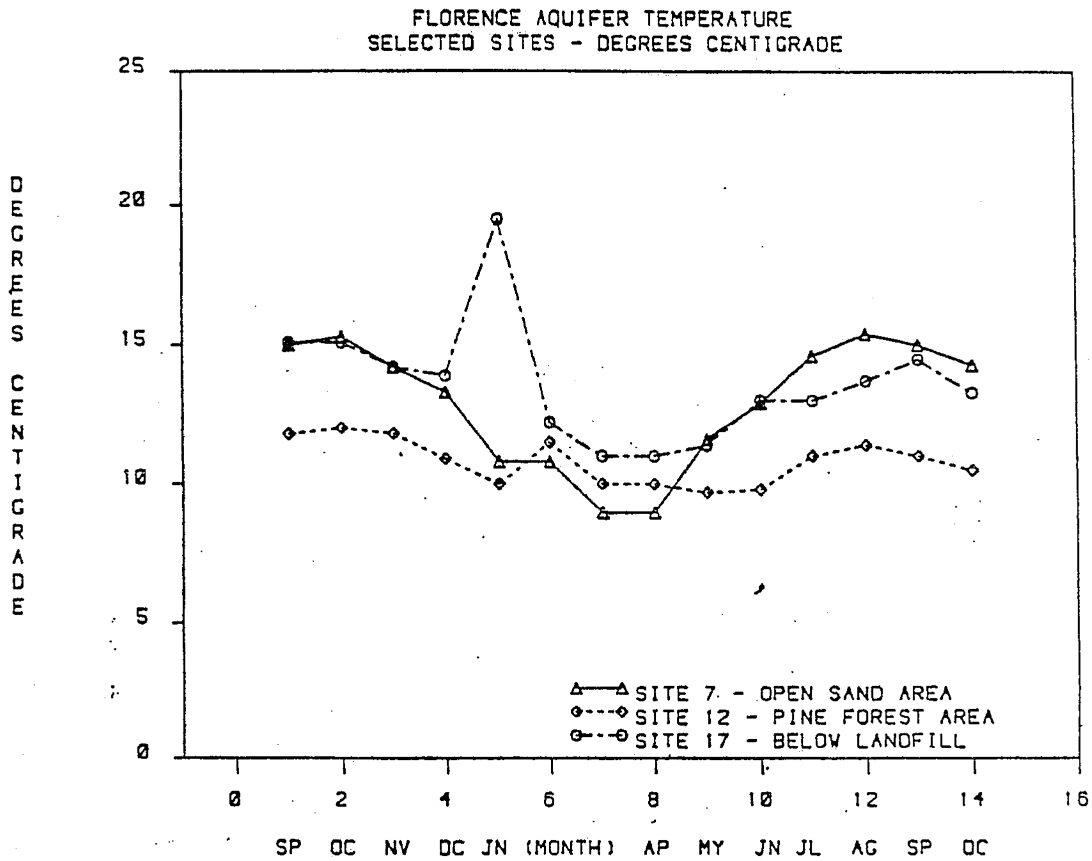


FIGURE 33. Graph of Temperature of the Ground Water in an Open Sand Area, Pine Forest and Near the Landfill for the Study Period.

Analysis & Findings

ANALYSIS AND FINDINGS

General Findings

1. The Florence dunal sand aquifer is of a generally uniform nature and is approximately 100 feet thick. It is an unconfined aquifer.

2. The North Florence Dunal Aquifer contains only two hydrologically distinct units; the CLear Lake Watershed; and the general North Florence Aquifer.

3. Flow in the aquifer tends to move radially away from a recharge zone about one mile west of Collard Lake. Most flow is toward the Pacific Ocean. The Siuslaw River and Sutton Creek are also boundaries.

4. Annual recharge averages 4.36 feet per year over the aquifer. Recharge water in the dunal sands tends to stack in layers and move vertically, as well as horizontally up to a depth of 100-130 feet. The water from each recharge season is largely unmixed with water from the previous recharge season.

5. The Major controlling factors of the aquifer hydrology are the uniformity of the sands and variations in recharge. Recharge is dependent primarily on rainfall variations and differences in evapotranspiration between vegetation, open sand and water areas.

6. Modeling was useful in predicting the boundaries between the Clear Lake watershed and the general North Florence Aquifer and necessary to predict changes in those boundaries between normal and drought conditions. These watershed boundaries do not change dramatically between normal and drought or increased pumpage conditions.

Water Quality

7. The dunal sand aquifer is a generally uncontaminated aquifer that shows sensitivity to human development.

8. Average nitrate-nitrogen levels range between 0.03 and 0.06 mg/L throughout the aquifer except where influenced by fertilization, on-site sewage and solid waste disposal.

9. Indicators of bacterial contamination are uncommon throughout the aquifer except near sources of local contamination. Most positive tests were at surface sites.

10. Iron concentrations are low (.05-.15 mg/L) in the shallow recharge portions of the aquifer. Discharge area concentrations are in the 0.2 to 0.7 mg/L range. Iron concentrations greater than 0.3 mg/L generally require treatment.

11. Analysis of water from deeper levels of the aquifer (below the top 30 feet) showed iron concentrations in excess of 5.0 mg/L.

12. The water quality of surface waters in the area is generally good but shows some indication of bacterial contamination. Clear Lake is generally least contaminated (<1/100 ml). The lakes and streams also show significant seasonal variation in nutrient levels. Clear Lake is the lowest in nitrate and Sutton Lake (Sutton Creek outflow) is the highest. Reduction in water quality appears to be directly related to the increase in human activity on or near those waters.

13. Generally, vegetation appears to contribute only a small portion of the nitrate-nitrogen found in ground or surface waters compared to human waste disposal. Shore pine forests appear to reduce nitrate-nitrogen below background levels.

14. Subsurface disposal of sewage waste is the primary human caused source of nitrate-nitrogen. Except for the landfill, the school district and the golf course, there are no other significant human caused nitrate sources within the North Florence watershed.

Clear Lake Watershed

15. Water flows southeastward into Clear Lake from an aquifer recharge zone one mile west of Collard and Clear Lakes, as well as from the north through the Collard Lake drainage and from runoff on the hills to the east.

16. The Clear Lake Watershed (dunal aquifer plus uplands) comprises approximately 1040 acres with 190 acres of lake area and 850 acres of land area. The Dunal Aquifer portion is 518 acres and the uplands 332 acres in size.

17. Current nitrate-nitrogen levels in Clear Lake average 0.05 mg/L which is 67% greater than the concentrations in the dunal aquifer to the west (.03 mg/L). Indications are that the Collard Lake area and the uplands presently contribute one-half to two-thirds of the nutrient loadings to Clear Lake.

18. Clear Lake is currently marginally "oligiotrophic," meaning that it is on the threshold at which increased nutrient levels will stimulate increased algal growth. Clear Lake is nitrate-limited and has sufficient phosphorous for such increased growth. Best estimates indicate that any nitrate-nitrogen increases beyond the current average of 0.05 mg/L will lead to algal growth.

19. In order to prevent increases to Clear Lake nitrate-nitrogen levels, increases in nitrate-nitrogen concentration in the dunal aquifer or upland watersheds must be less than 0.01 mg/L.

20. Based on a policy of no degradation of Clear Lake a total of 8.7 dwelling units should be allowed on the entire 1040 acre watershed.

(850 acres of land surface). There are currently 30 units in the watershed on septic systems, 10 of which are permanently occupied. The impact from the current systems on nitrate-nitrogen levels in Collard Lake may be only partially seen at this time.

General North Florence Aquifer

21. Throughout much of the remainder of the aquifer, nitrate-nitrogen levels are near background levels of 0.03 mg/L. This level assumes contributions only from rainfall and is represented by the open dune areas.

22. Based on the planning standard of 5.0 mg/L nitrate-nitrogen calculations indicate an additional loading of 58 lbs. per acre per year nitrate-nitrogen will not exceed this value using a stirred tank model. This translates to 2.9 d.u. per acre with on-site systems using loading rates of 20 lbs. per d.u. per year.

23. Nitrate-Nitrogen loading considerations for the Florence Well Field are identical with those for the general North Florence Aquifer.

Landfill

24. Flows in the area of the Florence landfill show that the site is a discharge zone with rapid outlet to the Siuslaw Estuary.

25. Ground water quality downgradient of the landfill shows noticable aquifer degradation from organic materials, ammonia and minerals.

26. There are no current or predicted uses of the groundwater downgradient from the landfill, based on the model prediction of flow channels. The concentration of landfill materials in the ground water does not appear to have a significant impact on the estuary.

ALTERNATIVES

Sewage Treatment or Removal

Clear Lake Watershed

As applied to the Clear Lake watershed, treatment alternatives are limited to those which have disposal outside the watershed. This is due to the fact that there is no economic method to remove sufficient nitrate from individual waste systems.

Removal alternatives include standard gravity collection systems or, more likely for reasons of cost and topography, a low pressure collection system with disposal by means of a "package plant" or community drainfield somewhere outside of the aquifer. The most likely locations would be to the northwest of Collard Lake in sand or forest areas and would involve the location of suitable public or leasable private land for such disposal.

Separated composting systems/grey water systems may be acceptable alternative for existing on site replacement, but do not remove sifficient nitrate-nitrogen to allow their widespread use.

General Aquifer

As applied to areas outside the Clear Lake Watershed and beyond the Urban Service Boundary, it is not clear that treatment or removal would provide more benefits that an adequately functioning on-site system. Low pressure distribution systems are currently required by the DEQ. If specific local problems are discovered, low pressure collection and removal to a community drainfield is a viable alternative if available disposal land can be found.

Planning Alternatives

Clear Lake Watershed

For the Clear Lake Watershed, planning restrictions would require that Clear Lake nitrate-nitrogen concentrations not be allowed to exceed current background levels of 0.05 mg/L. In order to provide protection for Clear Lake from algal growth and quality degradation increases cannot exceed 0.01 mg/L nitrate-nitrogen. Using planning alternatives to meet this standard would require dwelling unit density restrictions for development using individual on-site disposal systems, but does not apply to developments which remove wastes outside the watershed. Due to existing development in the Collard Lake area, use of planning alternatives alone are insufficient to protect Clear Lake from degradation.

General Aquifer

For the remainder of the aquifer, the nitrate-nitrogen planning limit of 5.0 mg/L is applicable and implies that planning alternatives are unnecessary after revision of the regional rule.

Water Supply Changes

Clear Lake Watershed

If Clear Lake is allowed to degrade in quality it is almost certain that a more complicated and expensive filtration system will be necessary to remove algal turbidity. Taste and odor problems could also occur. If Clear Lake remains at its current quality, the current inexpensive chlorination process may be used for an indefinite period but there is no guarantee that the lake will not change due to other causes or due to factors that currently exist but may have delayed impacts (e.g., existing housing near Collard Lake).

New Well Field

If Clear Lake is abandoned as a water source, new wells will be necessary. It may be possible to locate these wells on the western side of Clear Lake and construct them as a series of shallow wells or infiltration galleries. This appears likely to avoid high iron concentrations and would not require iron filtration. Chlorination would still be required for disinfection. The costs of this option are unknown and a special study would be necessary to determine the number, location and design of these wells.

Florence Well Field

It is possible to expand the Florence Well Field either in its current location or elsewhere in the dunal aquifer. In this case it is likely that several new wells would be required and filtration for iron as well as chlorination would be necessary. Deep wells have been shown to contain high iron concentrations. Special studies would be necessary to determine the number of wells, location and costs of such a new well field.

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Appendices

APPENDIX A. Well Logs of Four Wells that Encountered Flournoy Formation Rocks at Shallow Depth.

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date of well completion.

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

State Well No. 18/12w-21
State Permit No.

(1) OWNER:
Name [illegible]
Address [illegible]

(2) LOCATION OF WELL:
County [illegible] Driller's well number [illegible]
¼ ¼ Section [illegible] T. [illegible] R. [illegible] W.M.
Bearing and distance from section or subdivision corner
[illegible]

(3) TYPE OF WORK (check):
New Well ☐ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☐
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ Yes ☐ No
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed? ☐ Yes ☐ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Well seal—Material used in seal
Depth of seal ft. Was a packer used?
Diameter of well bore to bottom of seal in.
Were any loose strata cemented off? ☐ Yes ☐ No Depth
Was a drive shoe used? ☐ Yes ☐ No
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level ft. below land surface Date
Artesian pressure lbs. per square inch Date

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(12) WELL LOG: Diameter of well below casing
Depth drilled ft. Depth of completed well ft.

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Beach Sand	0	16
Brown S.S.	16	19
grey S.S. & Blue Clay	19	22
hard sandstone	22	58
hard [illegible]	58	59
hard sandstone	59	73
shale water bearing	73	[illegible]
sandstone	[illegible]	79
sandstone water bearing	79	84

Work started 19 Completed 19
Date well drilling machine moved off of well 19

(13) PUMP:
Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME (Person, firm or corporation) (Type or print)
Address
Drilling Machine Operator's License No.
[Signed] [illegible] (Water Well Contractor)
Contractor's License No. Date 19

APPENDIX A cont.

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the STATE ENGINEER, SALEM, OREGON 97310 within 30 days from the date of well completion.

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No. 15/12W-2
State Permit No.

(1) OWNER:
Name Nils A. Johnson
Address Route 1 Box 500 Florence, Oregon

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) CASING INSTALLED: Threaded ☐ Welded ☐
6" Diam. from 0 ft. to 27 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(6) PERFORATIONS: Perforated? ☐ Yes ☒ No.
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes ☐ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
Static level 15 ft. below land surface Date 6-29-67
Artesian pressure lbs. per square inch Date

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.

Bailer test 500 gal./min. with 2 ft. drawdown after 2 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(10) CONSTRUCTION:
Well seal—Material used Sand and clay
Depth of seal 25 ft.
Diameter of well bore to bottom of seal 10 in.
Were any loose strata cemented off? ☐ Yes ☐ No Depth
Was a drive shoe used? ☐ Yes ☐ No
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.

(11) LOCATION OF WELL:
County Lane Driller's well number
¼ ¼ Section 2 T. 15 R. 12 W.M.
Bearing and distance from section or subdivision corner
T.L. 70-0210

(12) WELL LOG: Diameter of well below casing 6
Depth drilled 50 ft. Depth of completed well 50 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
Top Soil Fine Brown	0	[illegible]	
Sand Fine White	[illegible]	[illegible]	
Sand & Clay Strips	3	17	
Sand Stone Soft	17	50	

Work started June 25 1967 Completed June 29 1967
Date well drilling machine moved off of well 19

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] [signature] (Drilling Machine Operator) Date June 30 1967
Drilling Machine Operator's License No. 502

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
NAME Jones Well Drilling Co Inc (Person, firm or corporation) (Type or print)
Address Route 3 Box [illegible], Creswell Oregon
[Signed] Delbert L Jones (Water Well Contractor)
Contractor's License No. 40 Date June 30, 1967

APPENDIX A cont.

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the
STATE ENGINEER, SALEM, OREGON 97310 within 30 days from the date of well completion.

RECEIVED 1965
STATE ENGINEER

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

State Well No. 18/12w-2 M
State Permit No.

(1) OWNER:
Name Glenn L. Muncy
Address Rt. 1, Box 574 Florence, Oregon
Abandoned

(2) LOCATION OF WELL:
County Lane Driller's well number
Section 2 T. 18 S R. 12 W W.M.
Bearing and distance from section or subdivision corner
300 ft. East and 60 ft North of
S. W. Corner
TL 32-02900

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☒
If abandonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☒ Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☐
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ Yes ☐ No
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed? ☐ Yes ☐ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Well seal—Material used in seal
Depth of seal ft. Was a packer used?
Diameter of well bore to bottom of seal in.
Were any loose strata cemented off? ☐ Yes ☐ No Depth
Was a drive shoe used? ☐ Yes ☐ No
Was well gravel packed? ☐ Yes ☐ No Size of gravel
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level ft. below land surface Date
Artesian pressure lbs. per square inch Date

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(12) WELL LOG: Diameter of well below casing
Depth drilled 30 ft. Depth of completed well ft.
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Brown Sandy Clay	0	9
Brown Clay	9	12
Gray Sand Fine	12	20
Gray Sand Coarse	20	23
Gray Sandstone	23	24
Gray Rock	24	25
Blue Gray Clay	25	30
Filled with Bentonite		

Work started 19 Completed 19
Date well drilling machine moved off of well 19

(13) PUMP:
Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Bowman Drilling Co.
(Person, firm or corporation) (Type or print)
Address Rt. 1 Box 412
Drilling Machine Operator's License No. 413
[Signed]
(Water Well Contractor)
Contractor's License No. 323 Date Oct. 21 1965

(USE ADDITIONAL SHEETS IF NECESSARY)

APPENDIX A cont.

NOTICE TO WATER WELL CONTRACTOR: The original and first copy of this report are to be filed with the STATE ENGINEER, SALEM, OREGON within 30 days from the date of well completion.

WATER WELL REPORT
STATE OF OREGON

State Well No. 18/12w-2 M

State Permit No.

(1) OWNER:
Name Glenn L. Muncy
Address Rt. 1 Box 574 Florence, Oregon

(2) LOCATION OF WELL:
County Lane Driller's well number
Section 2 T. 18S R. 12W W.M.
Bearing and distance from section or subdivision corner
50 ft. S & 15 ft. E. of S.W. corner

TL 1900

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☒ Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
6" Diam. from 0 ft. to 37 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ Yes ☒ No
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed? ☒ Yes ☐ No
Manufacturer's Name Gator
Type Model No.
Diam. 4 Slot size .010 Set from 34 ft. to 50 ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Well seal—Material used in seal Bentonite
Depth of seal 25 ft. Was a packer used? Sand
Diameter of well bore to bottom of seal 9 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☒ No
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level 9 ft. below land surface Date [illegible]
Artesian pressure lbs. per square inch Date

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.

Bailer test 5 gal./min. with ft. drawdown after 1 hrs.
Artesian flow g.p.m. Date
Temperature of water 54 Was a chemical analysis made? ☐ Yes ☒ No

(12) WELL LOG: Diameter of well below casing 9"
Depth drilled 50 ft. Depth of completed well 50 ft.

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Brown Clay Sand	0	12
Grey Sand	12	18
Grey Rock	18	40
Grey Coarse Sand	40	45
Grey Rock	45	50

Work started Oct. 12 19 65 Completed Oct. 15 19 65
Date well drilling machine moved off of well Oct. 15 19 65

(13) PUMP:
Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Dwyer Drilling Co.
(Person, firm or corporation) (Type or print)
Address Rt. 1 Box [illegible]

Drilling Machine Operator's License No. 226

[Signed] [illegible]
(Water Well Contractor)

Contractor's License No. 413 Date Nov. 1, 19 65

APPENDIX B. Sand Size Analyses from USGS Studies at Clatsop Plains and Florence, and City of Florence.

Clatsop Plains

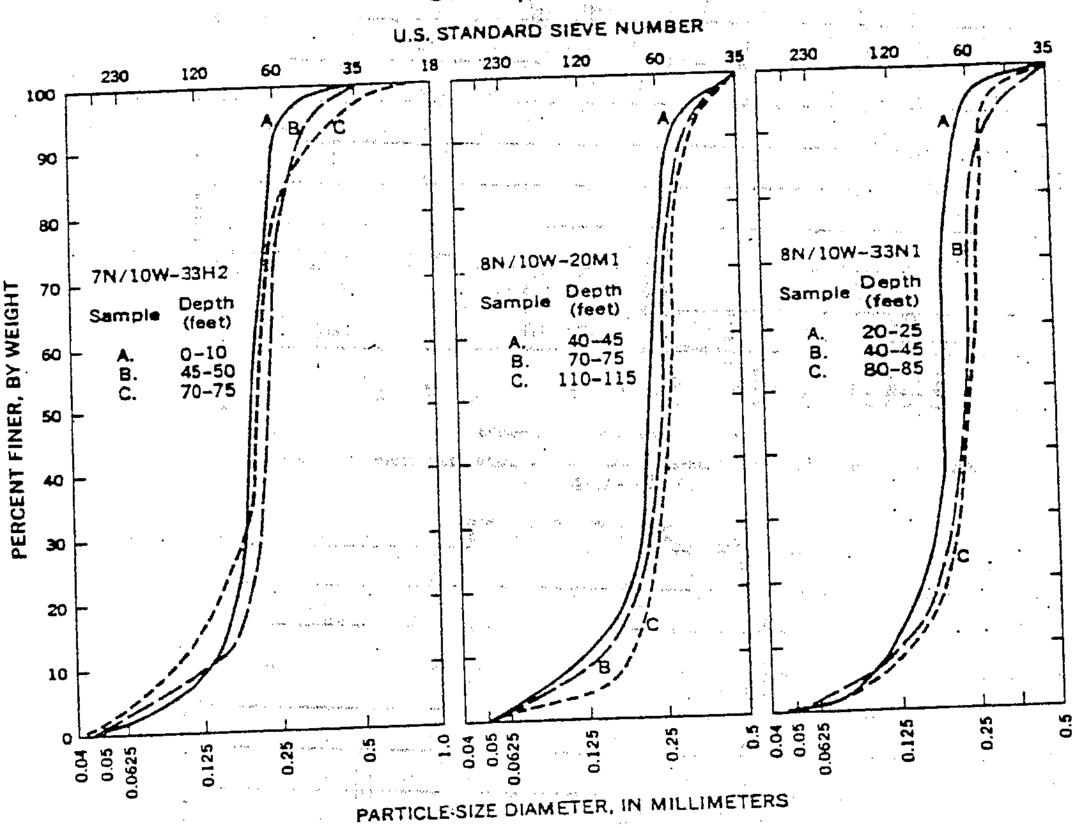


FIGURE 4.—Results of particle-size analyses of dune sand from test wells 7N/10W-33H2, 8N/10W-20M1, and 8N/10W-33N1.

APPENDIX B cont.

Florence

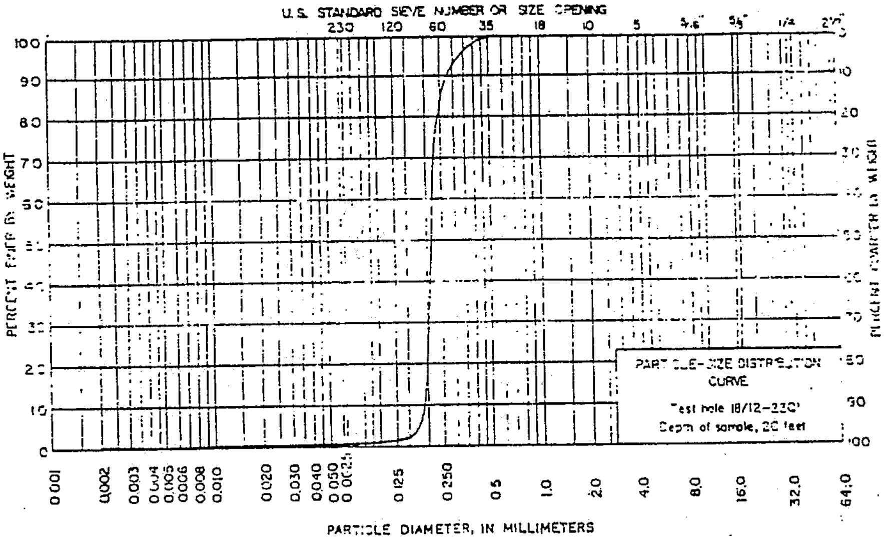


Figure 6.—Results of particle-size analysis of dune sand from test hole 18/12W–23Q1.

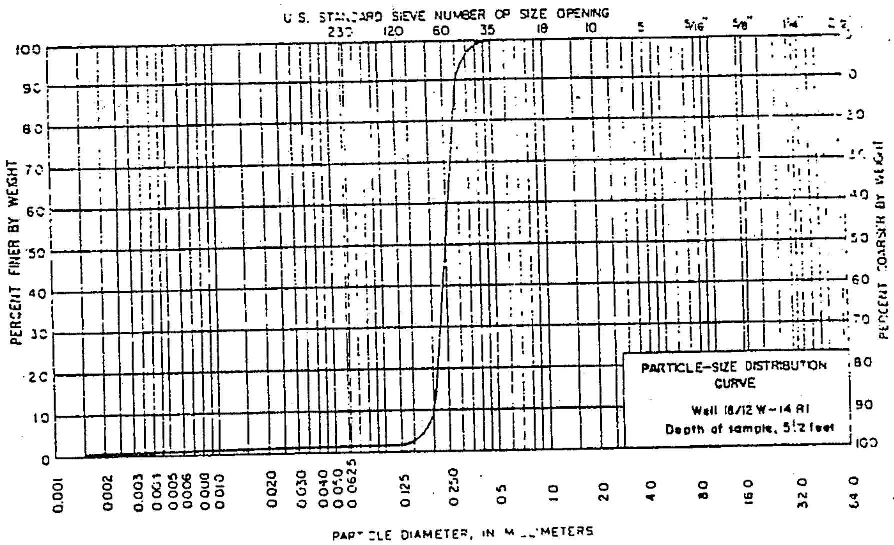


Figure 7.—Results of particle-size analysis of dune sand from well 18/12W–14R1.

APPENDIX B cont.

Well or test hole	Graph on figure—	Clay (0.004)	Silt (0.004–0.0625)	Sand: Very fine (0.0625–0.125)	Sand: Fine (0.125–0.25)	Sand: Medium (0.25–0.5)
18/12W–26B1	5	0.6	2.2	1.4	71.8	24.0
23Q1	6	.2	.4	1.0	82.4	16.0
14R1	7	.4	1.0	.2	51.6	46.8
26B3	8	.4	1.0	.2	41.8	56.6

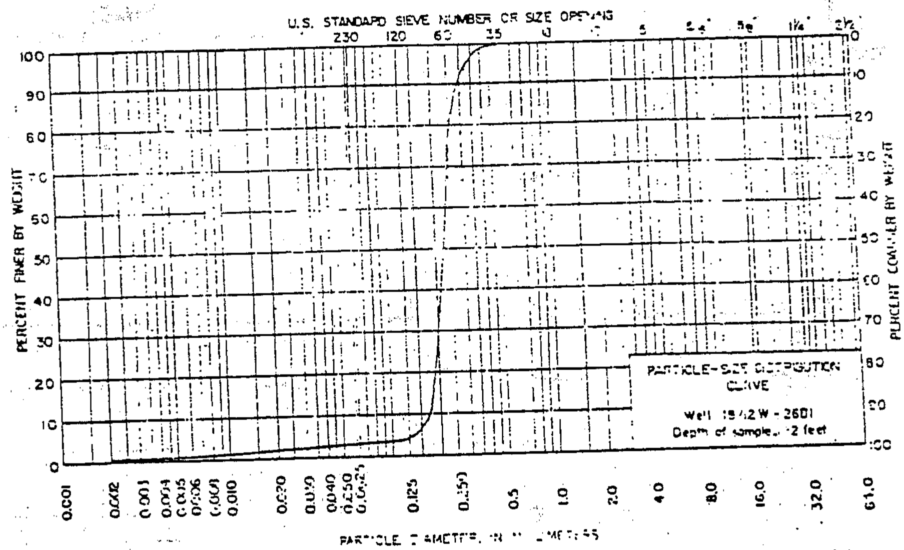


FIGURE 5.—Results of particle-size analysis of dune sand from well 18/12W–26B1.

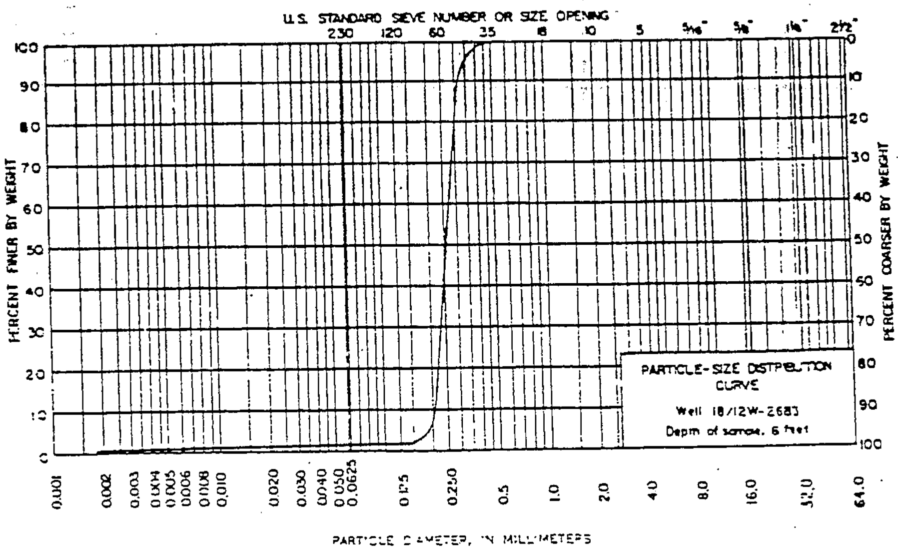


FIGURE 8.—Results of particle-size analysis of dune sand from well 18/12W–26B3.

APPENDIX B cont.

Johnson Division
Universal Oil Products Company
1950 Old Highway 8
St. Paul, Minnesota 55112
UOP

SAND ANALYSIS
(FINE)

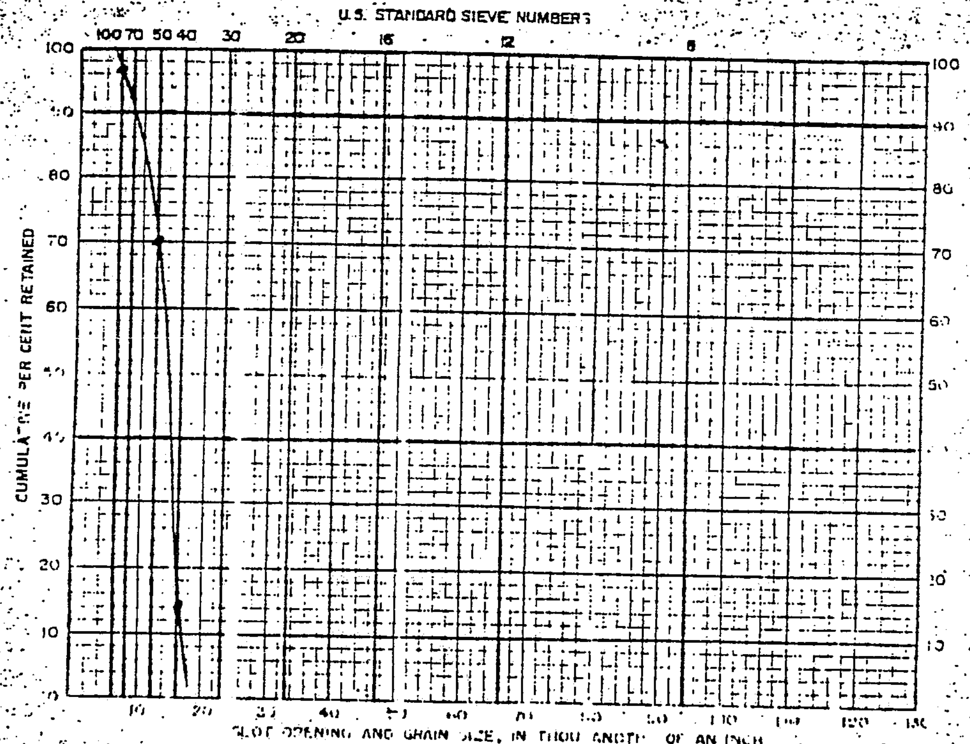
MAILING ADDRESS P O BOX 3118
ST. PAUL, MINNESOTA 55165

Sample sent in by GUS STORES WELL DRILLING

Town EUGENE State OREGON Zip Date 1-26-76

From well of CITY OF FLORENCE, OREGON

Remarks:



[illegible]	[illegible]	[illegible]	Cumulative per cent retained
6	132	1.36	
8	094	2.38	
12	066	1.68	
16	.047	1.19	
20	033	0.84	
30	023	0.59	
40	.016	0.42	
50	012	0.30	14
70	008	0.21	70
100	006	0.15	97

Notes: SAMPLE FROM 75'

Recommended Slot Opening

Recommended Screen, Dia. in Length Ft.

By:

APPENDIX B cont.

Johnson Division
Universal Oil Products Company
1950 Old Highway 8
St. Paul, Minnesota 55112
UOP

SAND ANALYSIS
(FINE)

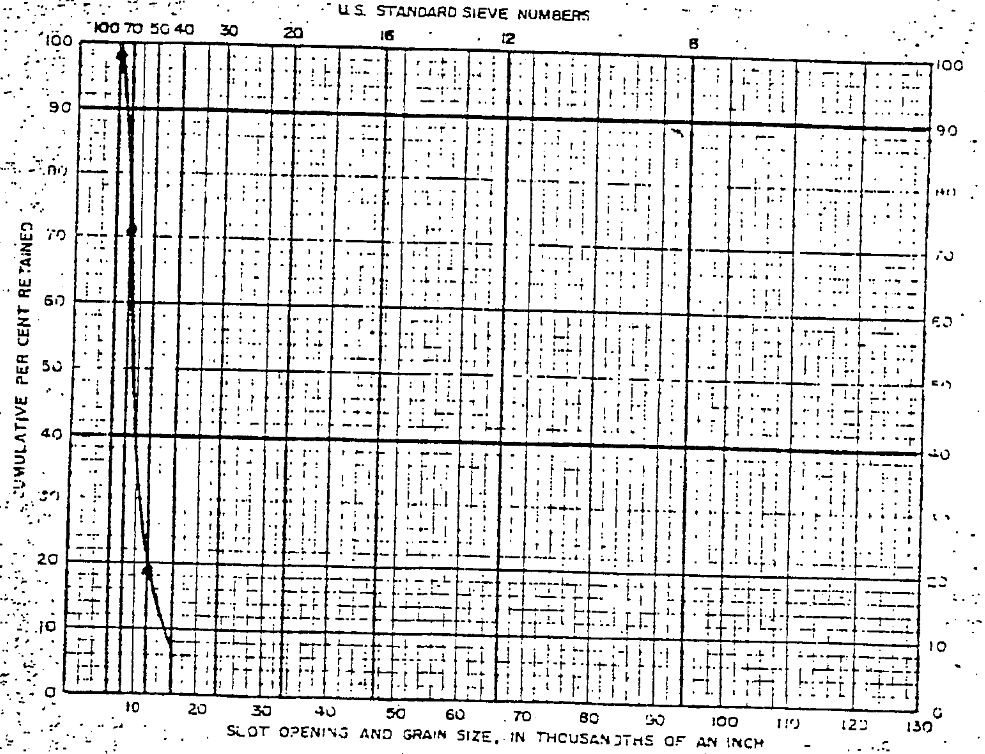
MAILING ADDRESS P.O. BOX [illegible]
ST. PAUL MINNESOTA [illegible]

Sample sent in by GUS STORES WELL DRILLING

Town EUGENE State OREGON Zip Date 1-26-76

From well of CITY OF FLORENCE, OREGON

Remarks:



U.S. Sieve No.	Sieve Opening (Inch)	Sieve Opening (mm)	Cum. per cent retained		
6	132	3.35			
8	[illegible]	2.36			
12	066	[illegible]			
16	047	[illegible]			
20	033	0.84			
30	023	0.60			
40	016	0.42			
50	012	[illegible]	19		
70	008	0.21	71		
100	006	0.15	[illegible]		

Notes: *SAMPLE FROM 115' (Local)*

Recommended Slot Opening

Recommended Screen Dia. in Length Ft.

By

APPENDIX C. Well Log, Time Drawdown Curves and Transmissivity and Storage Coefficient Calculations for City of Florence Well Number Two.

(The original and first copy of this report are to be filed with the STATE ENGINEER, SALEM, OREGON 97310 within 30 days from the date of well completion)

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No.
State Permit No.

(1) OWNER:
Name City of Florence
Address

(2) TYPE OF WORK (check):
New Well X Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐ Cable X Jetted ☐ Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal X Irrigation ☐ Test Well ☐ Other ☐

(5) CASING INSTALLED: Threaded ☐ Welded X
12 " Diam. from +2 ft. to 56'6" ft. Gage 3/8"
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(6) PERFORATIONS: Perforated? ☐ Yes X No
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? X Yes ☐ No
Manufacturer's Name Johnson
Type continuous 18-slot Model No.
Diam. 10 Slot size /1000 Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? X Yes ☐ No If yes, by whom? Driller
Yield: 450 gal./min. with 36 ft. drawdown after 2½ hrs.
" 350 " 29 " 2½ "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
Temperature of water 56 Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used Bentonite
Well sealed from land surface to 20 ft.
Diameter of well bore to bottom of seal 16 in.
Diameter of well bore below seal 12 in.
Number of sacks of cement used in well seal 4 sacks
Number of sacks of bentonite used in well seal 18 sacks
Brand name of bentonite Dresser
Number of pounds of bentonite per 100 gallons of water lbs./100 gals.
Was a drive shoe used? ☐ Yes X No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes X No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes X No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:
County Lane Driller's well number 254
S.E. ¼ N.E. ¼ Section 23 T 18S R 12W W.M.
Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.
Depth at which water was first found 12 ft.
Static level 12 ft. below land surface. Date 3-4-76
Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing
Depth drilled 125 ft. Depth of completed well 121 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level and indicate principal water-bearing strata.

MATERIAL	From	To	SWL
Light Brn. Sand, fine/medium	0	45	12'
Light Blue Gray Sand fine/med w/wood & vegetation	45	90	12'
Dark Blue Sand w/ sea shells	90	115	12'
Dark Blue Sand & Clay w/ sea shells	115	120	12'
Dark Blue Clay	120	125	12'

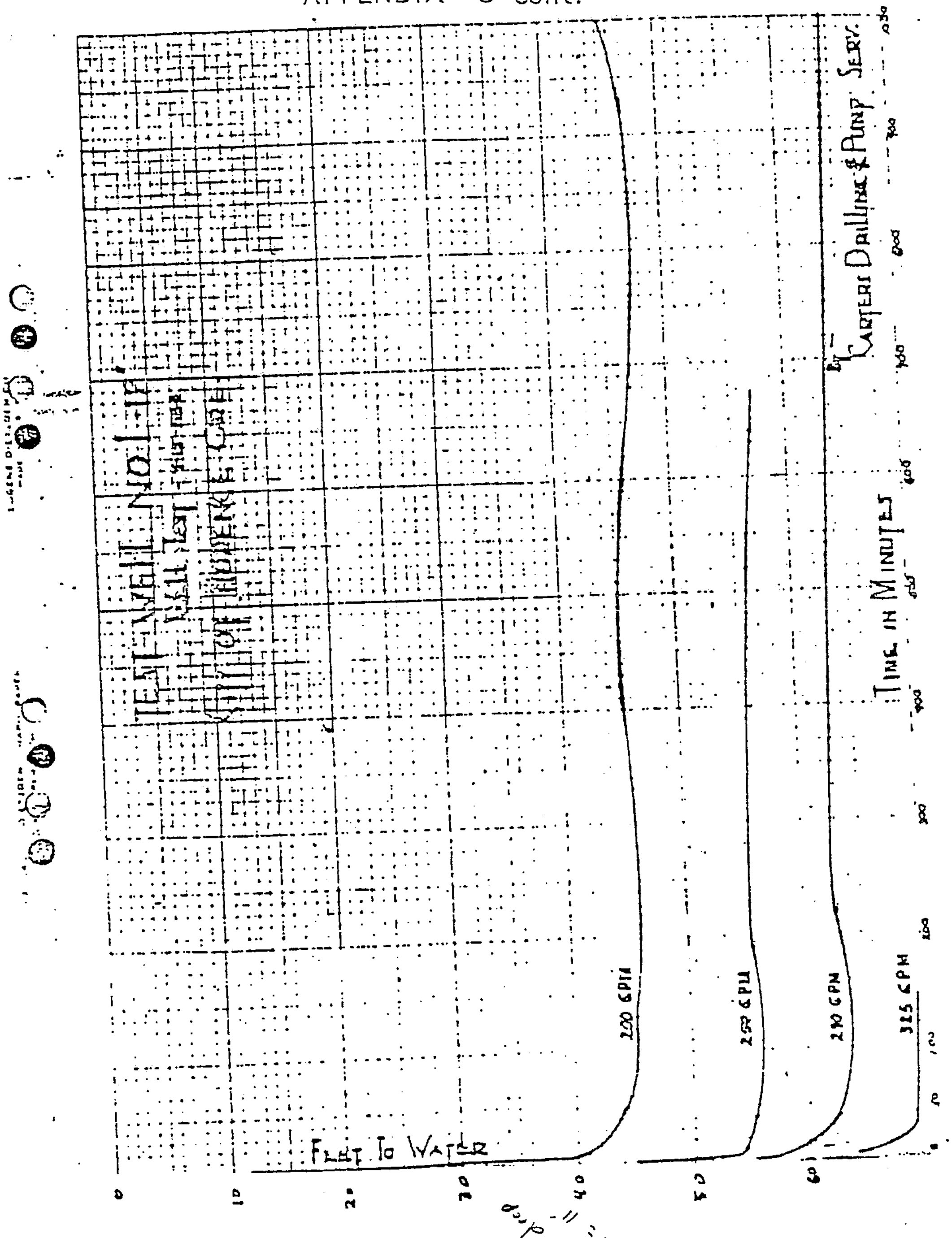
Work started 1-09 19 76 Completed 3-04 19 76
Date well drilling machine moved off of well 3-04 19 76

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Garland Cox (Drilling Machine Operator) Date 3-9, 1976
Drilling Machine Operator's License No. 512

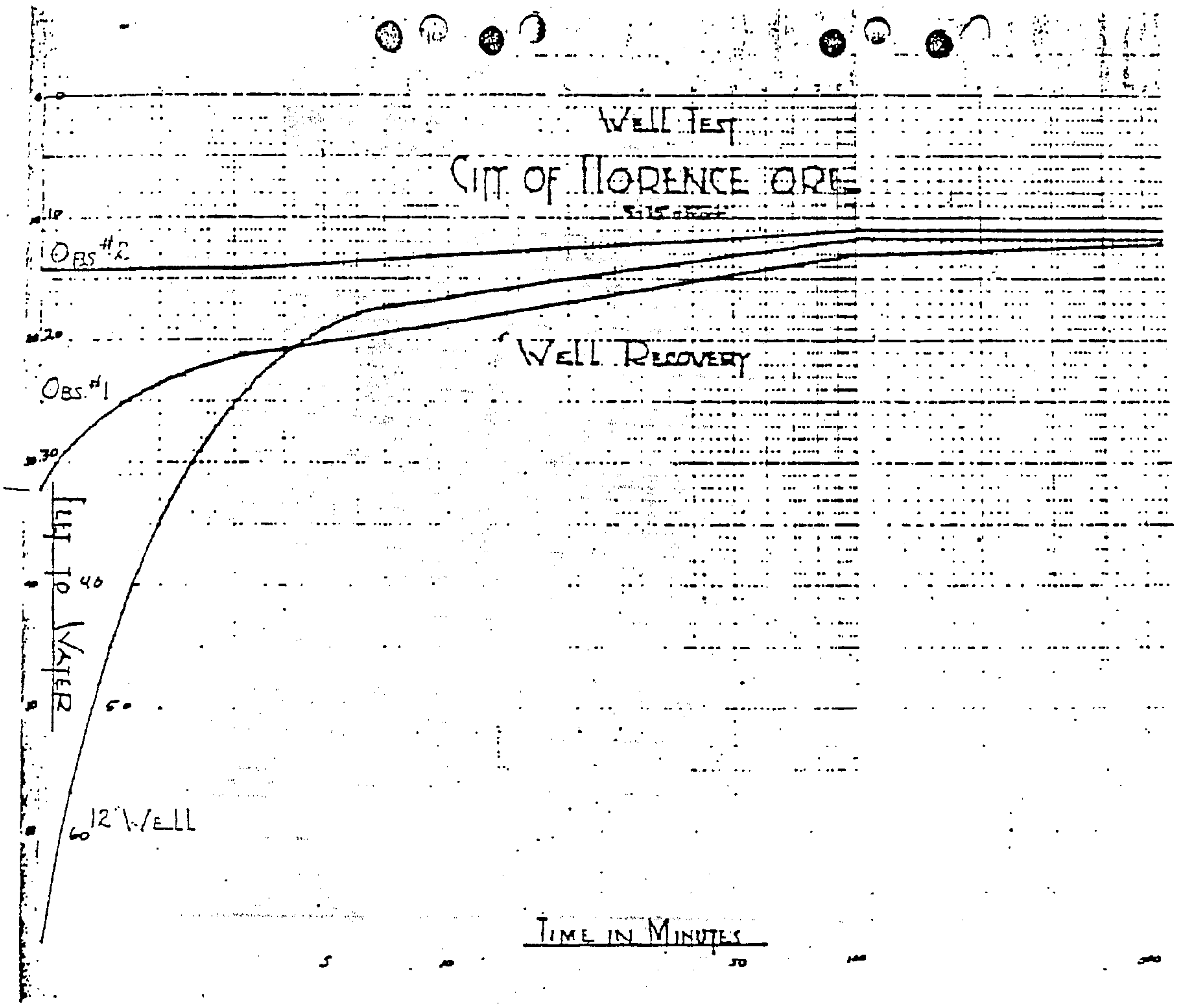
Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Name Gus Stores Logging & Well Drilling (Person, firm or corporation) (Type or print)
Address 5555 West 11th Ave., Eugene, OR 97402
[Signed] Garland Cox (Water Well Contractor)
Contractor's License No. 578 Date 3-9-, 1976

(USE ADDITIONAL SHEETS IF NECESSARY)

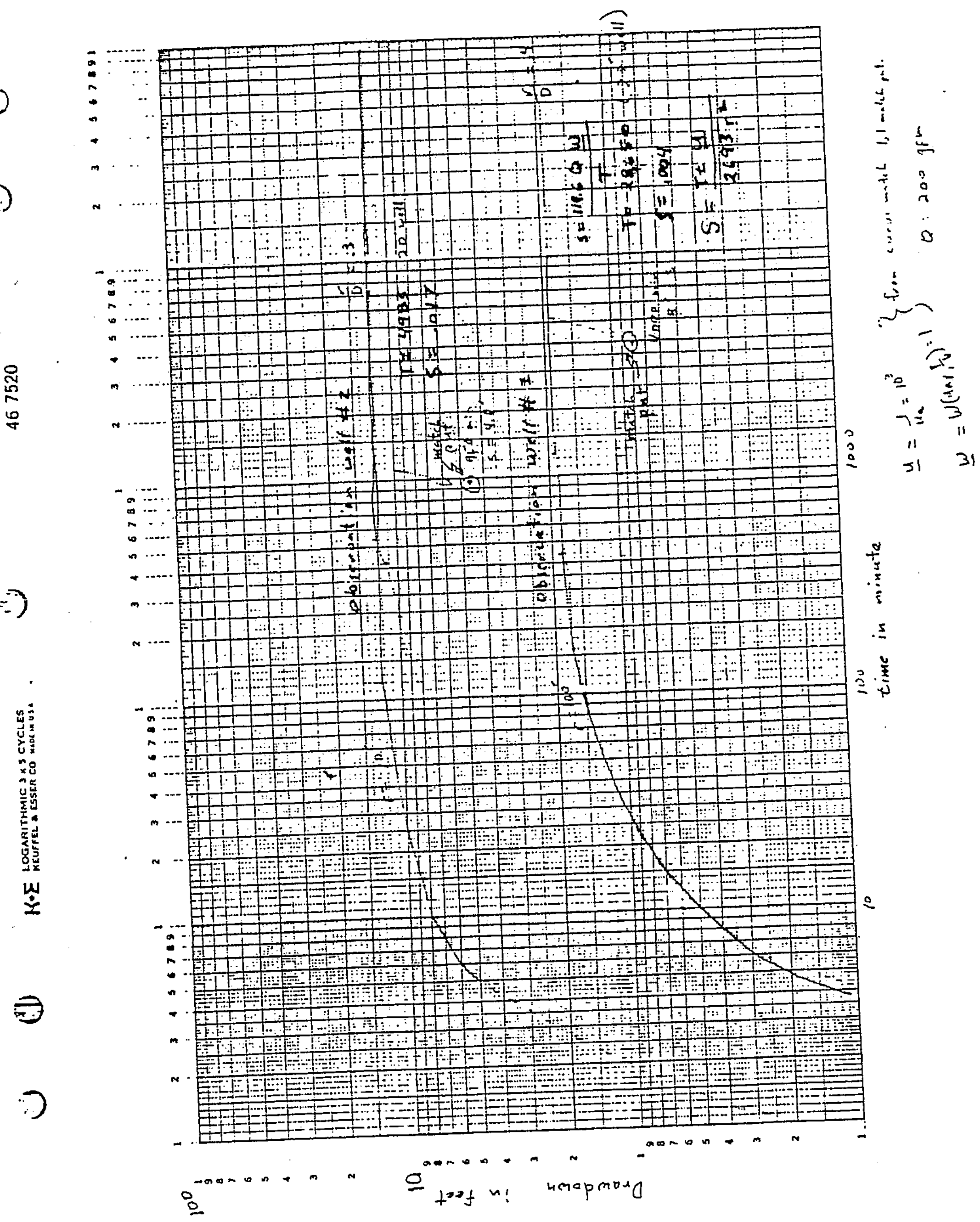
APPENDIX C cont.



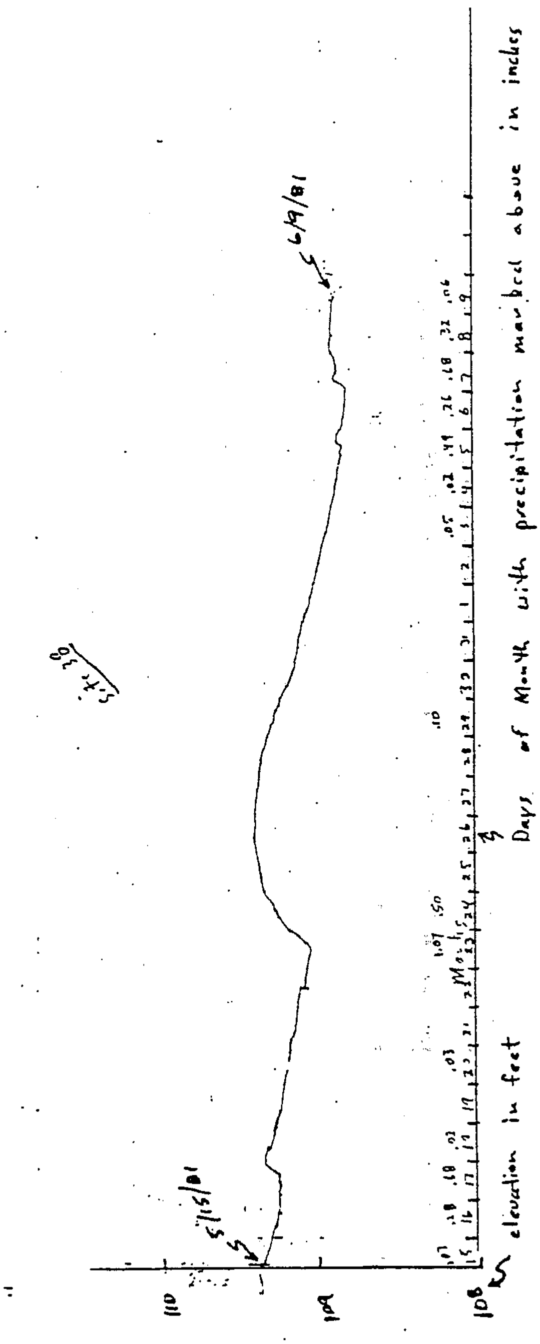
APPENDIX C cont.



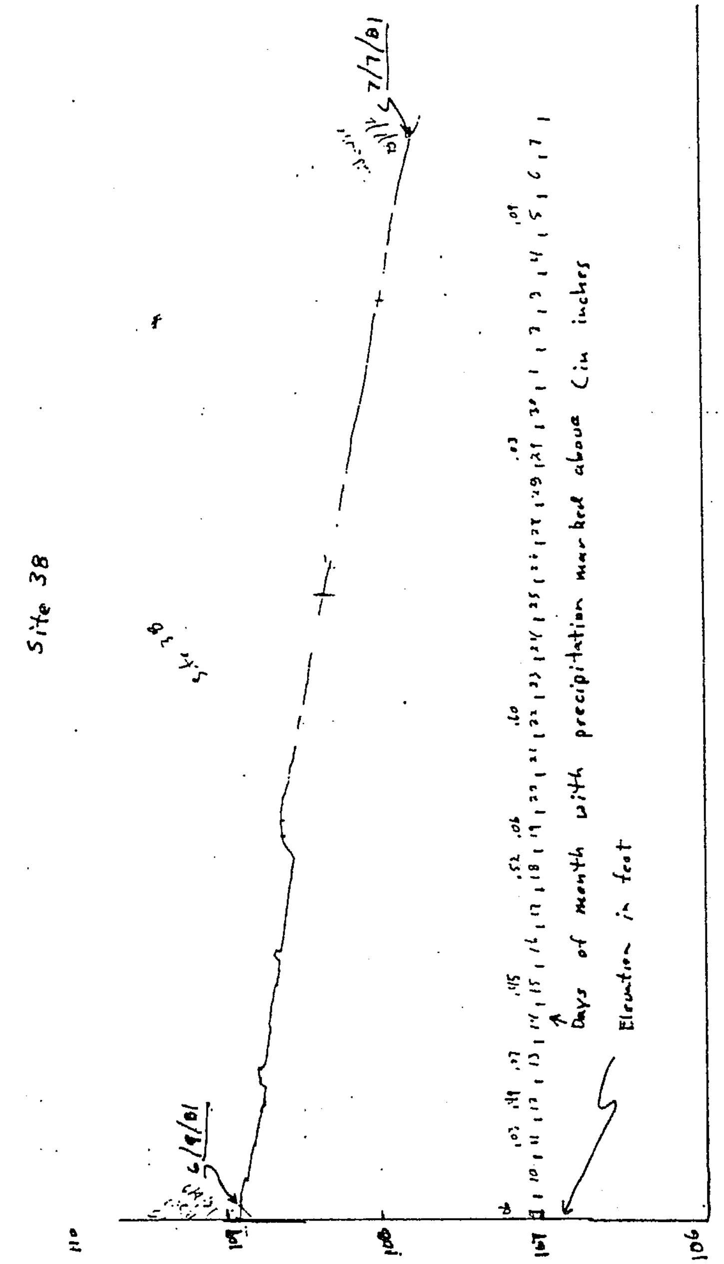
APPENDIX C cont.



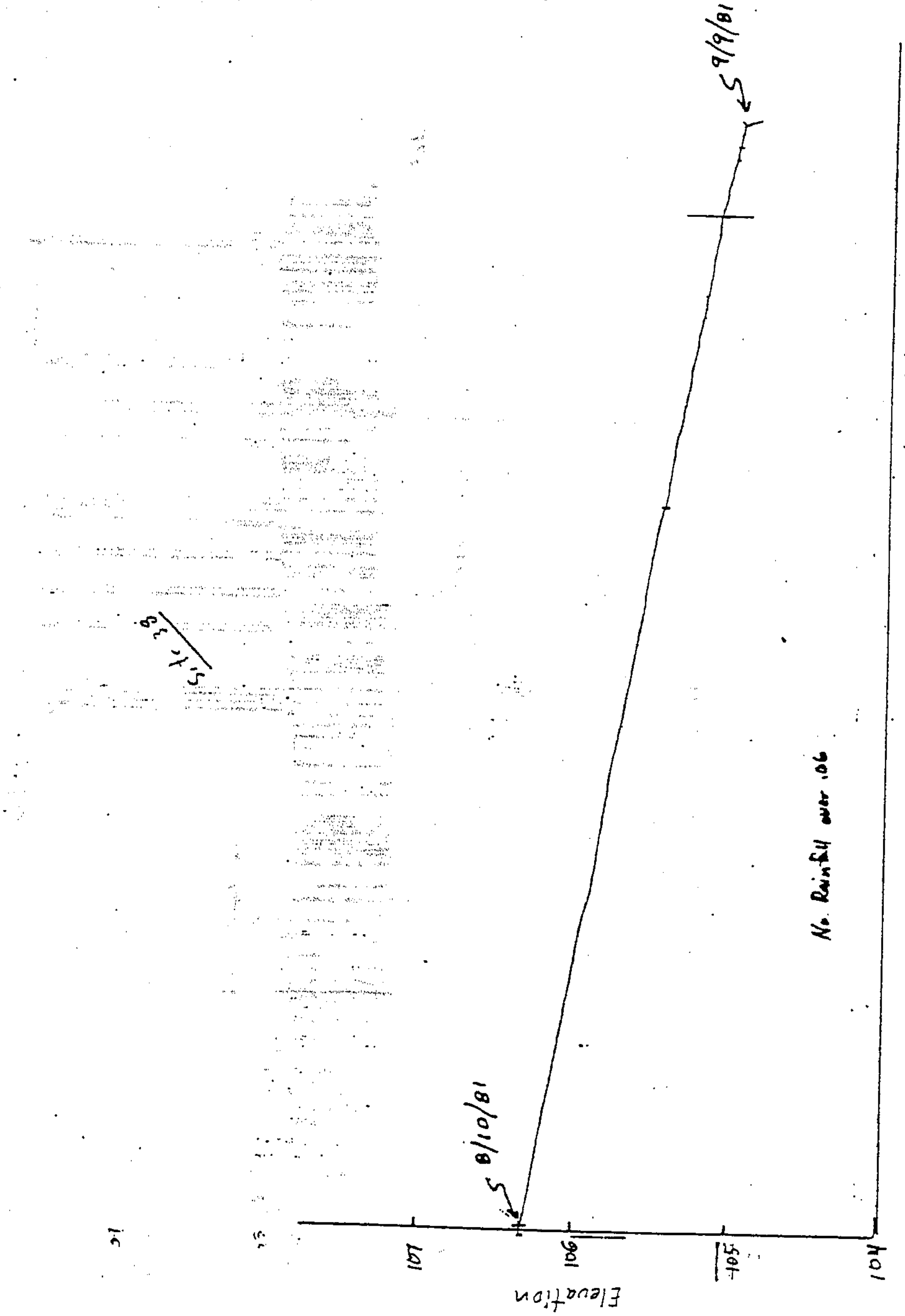
APPENDIX D. Continuous Recorder Records for Site 38, Site 11a and Site 23.



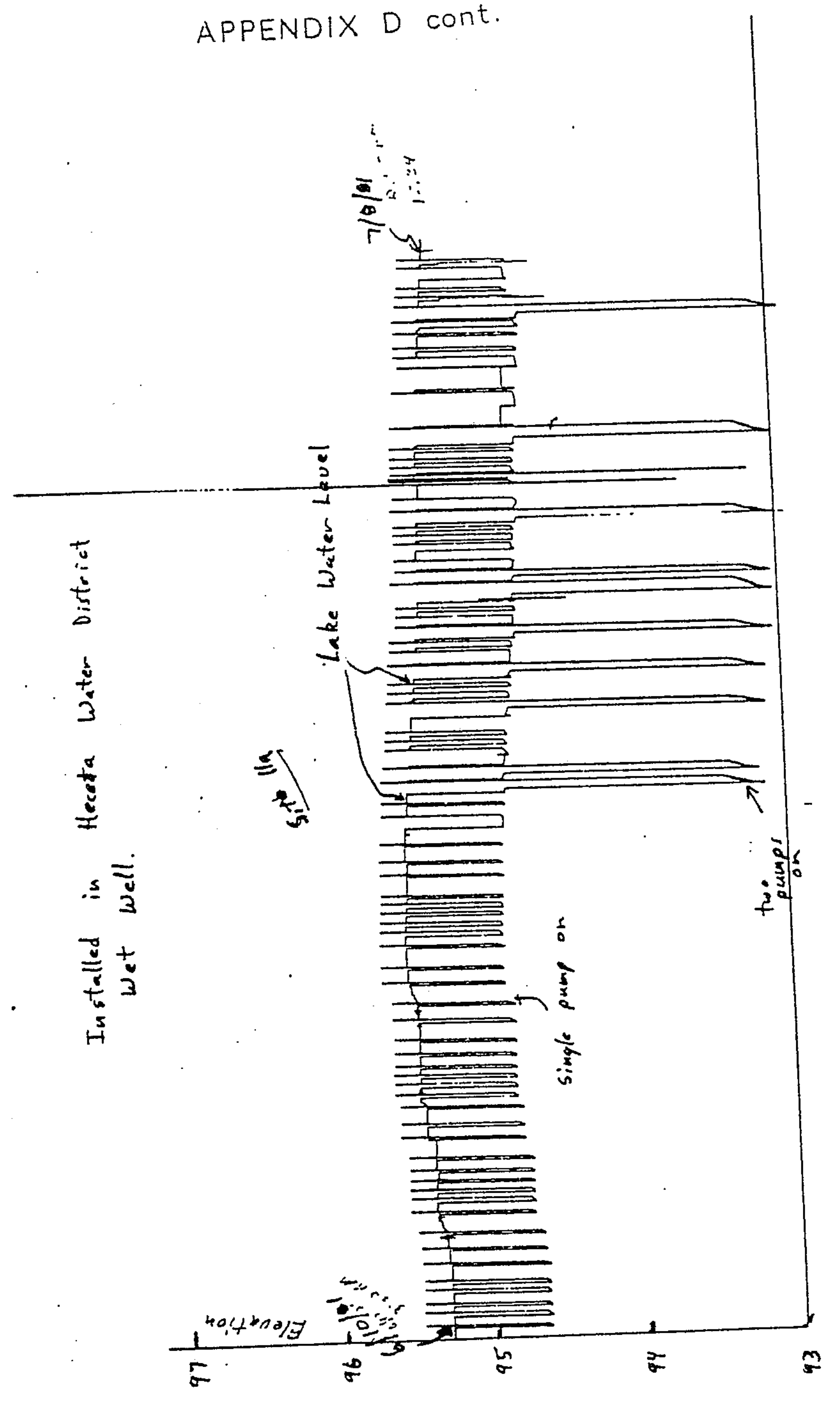
APPENDIX D cont.



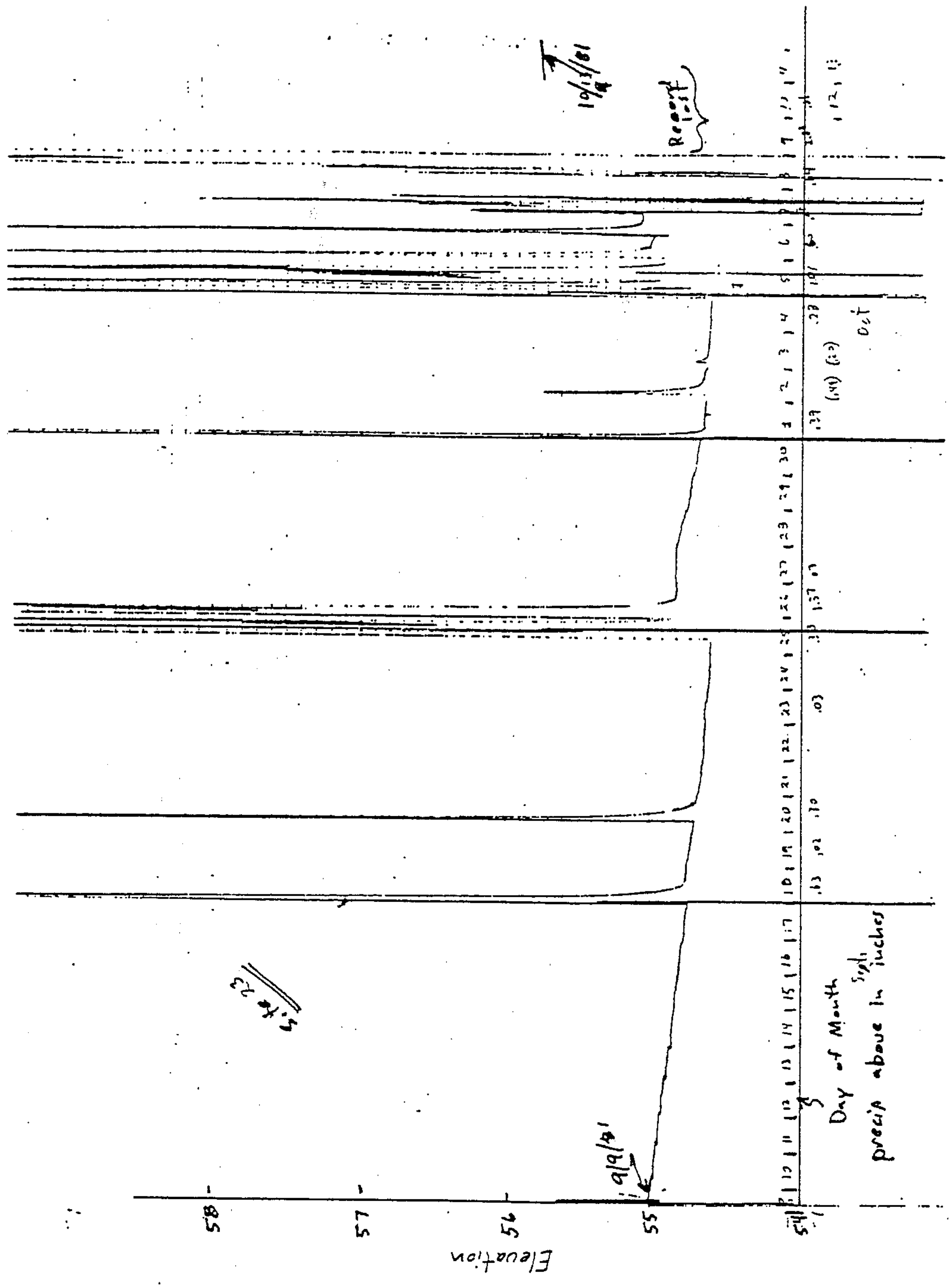
APPENDIX D cont.



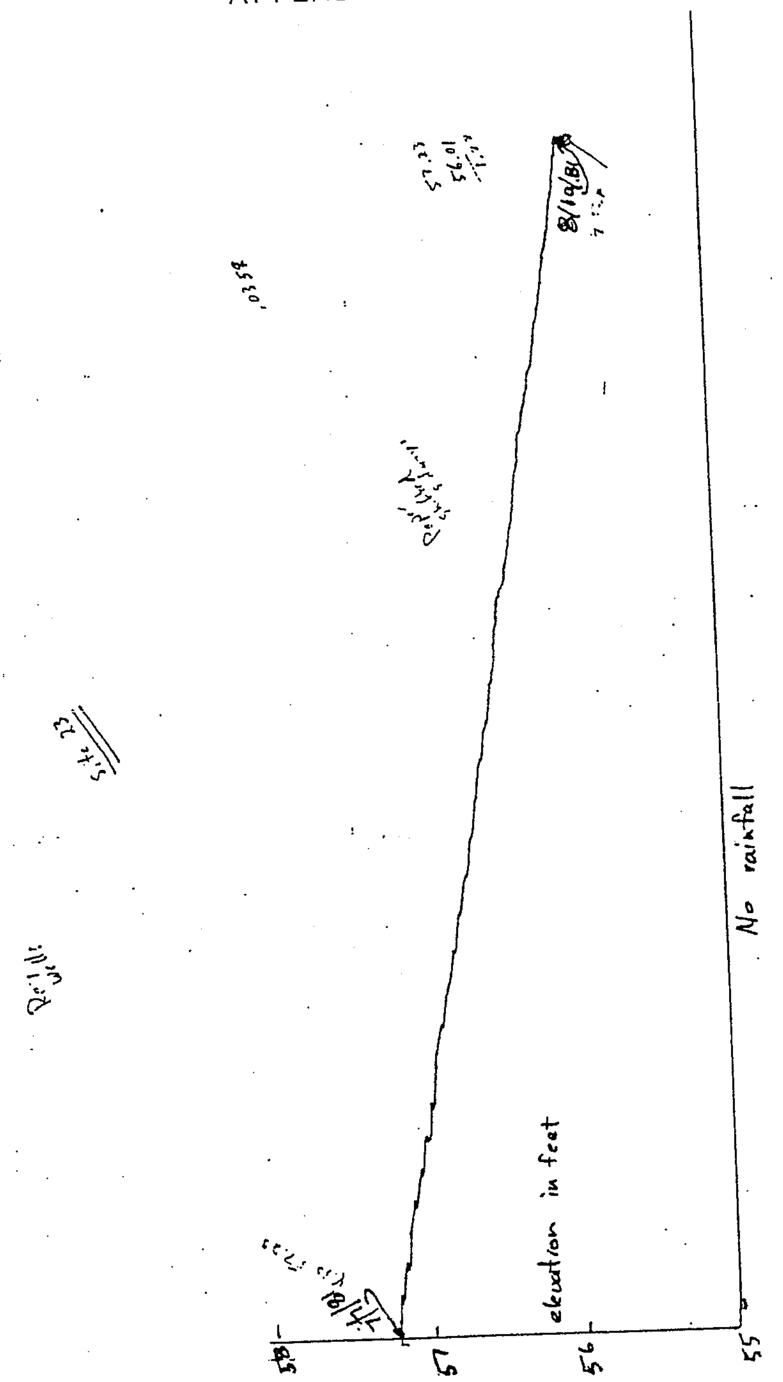
APPENDIX D cont.



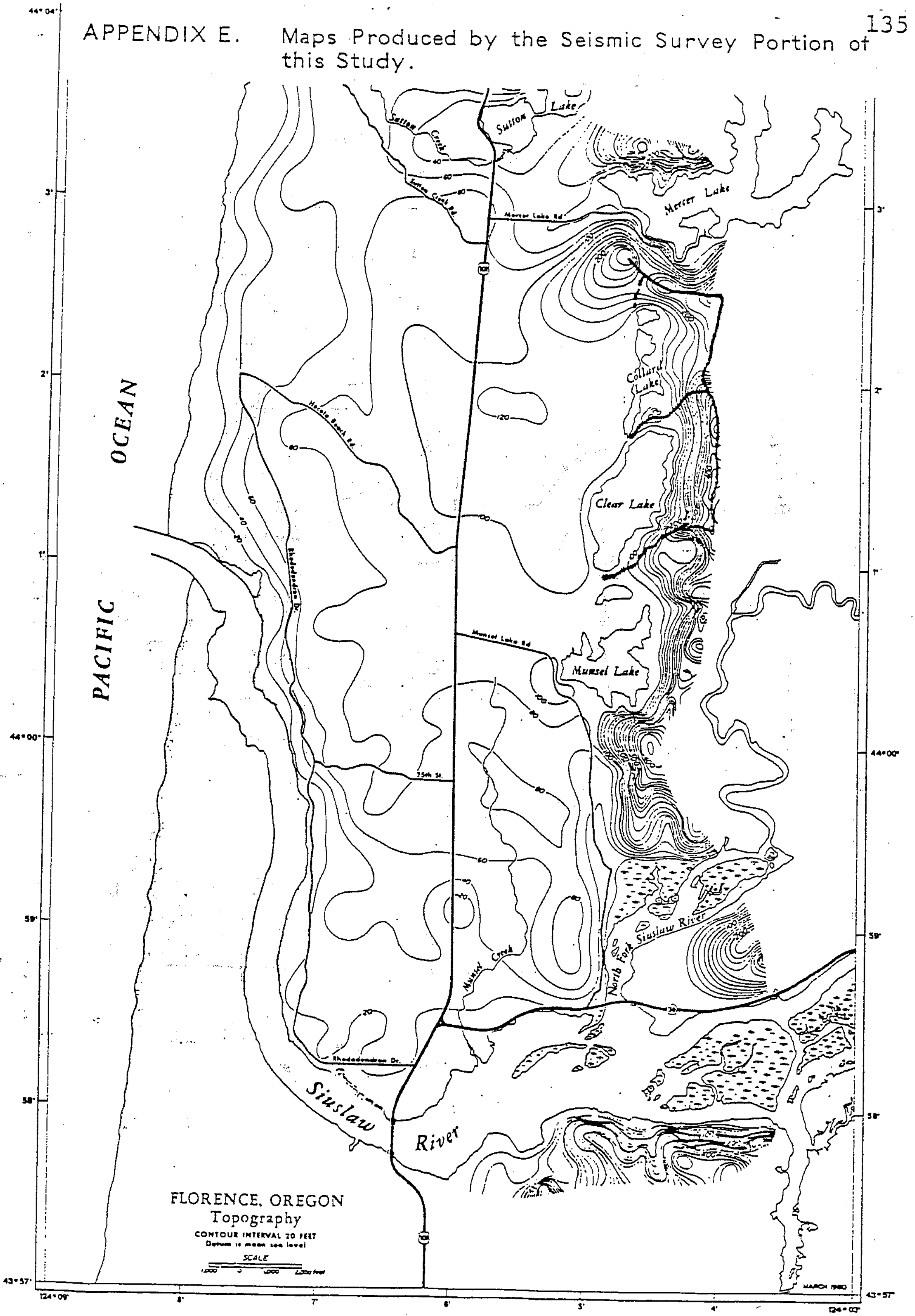
APPENDIX D cont.

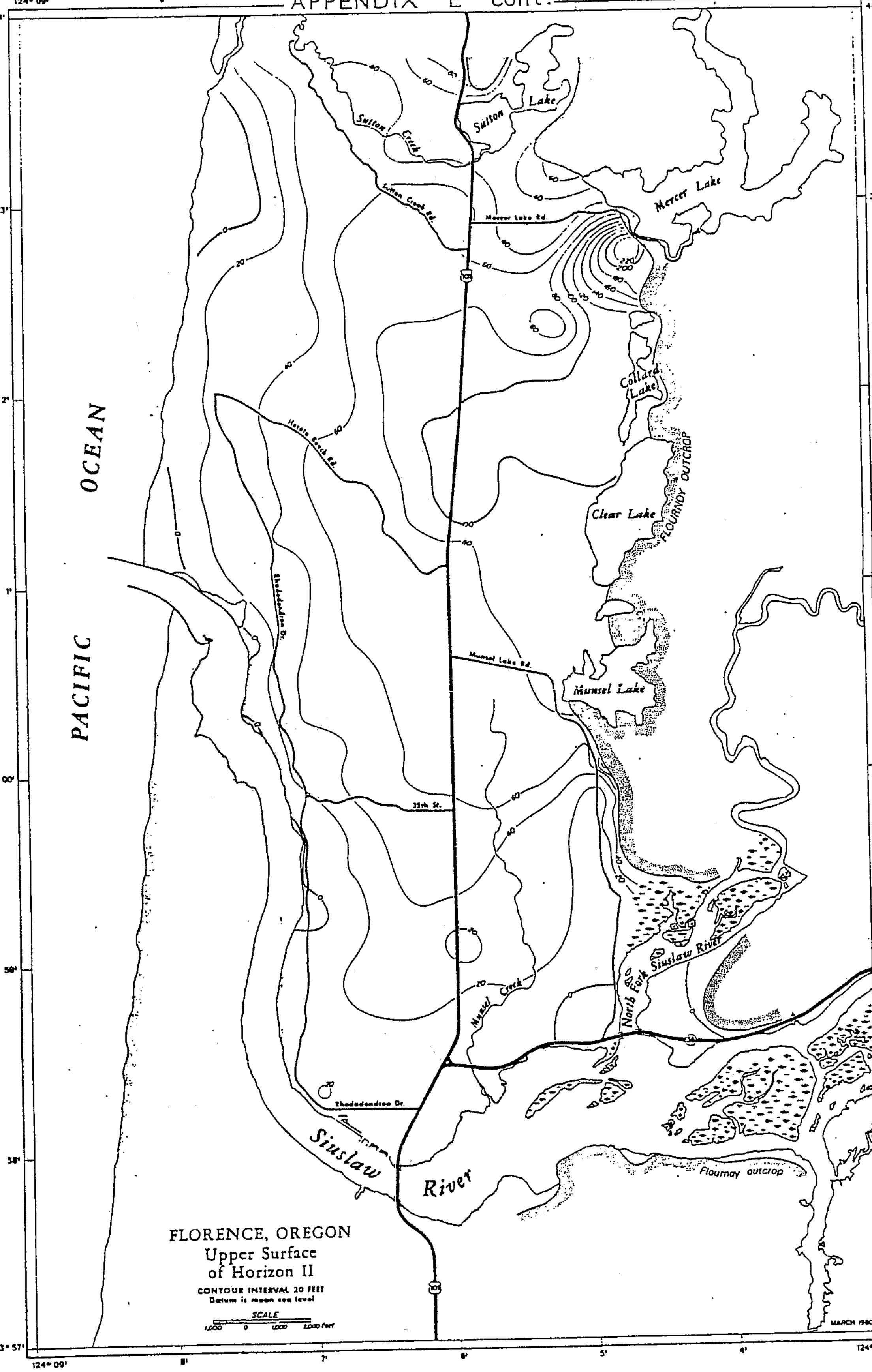


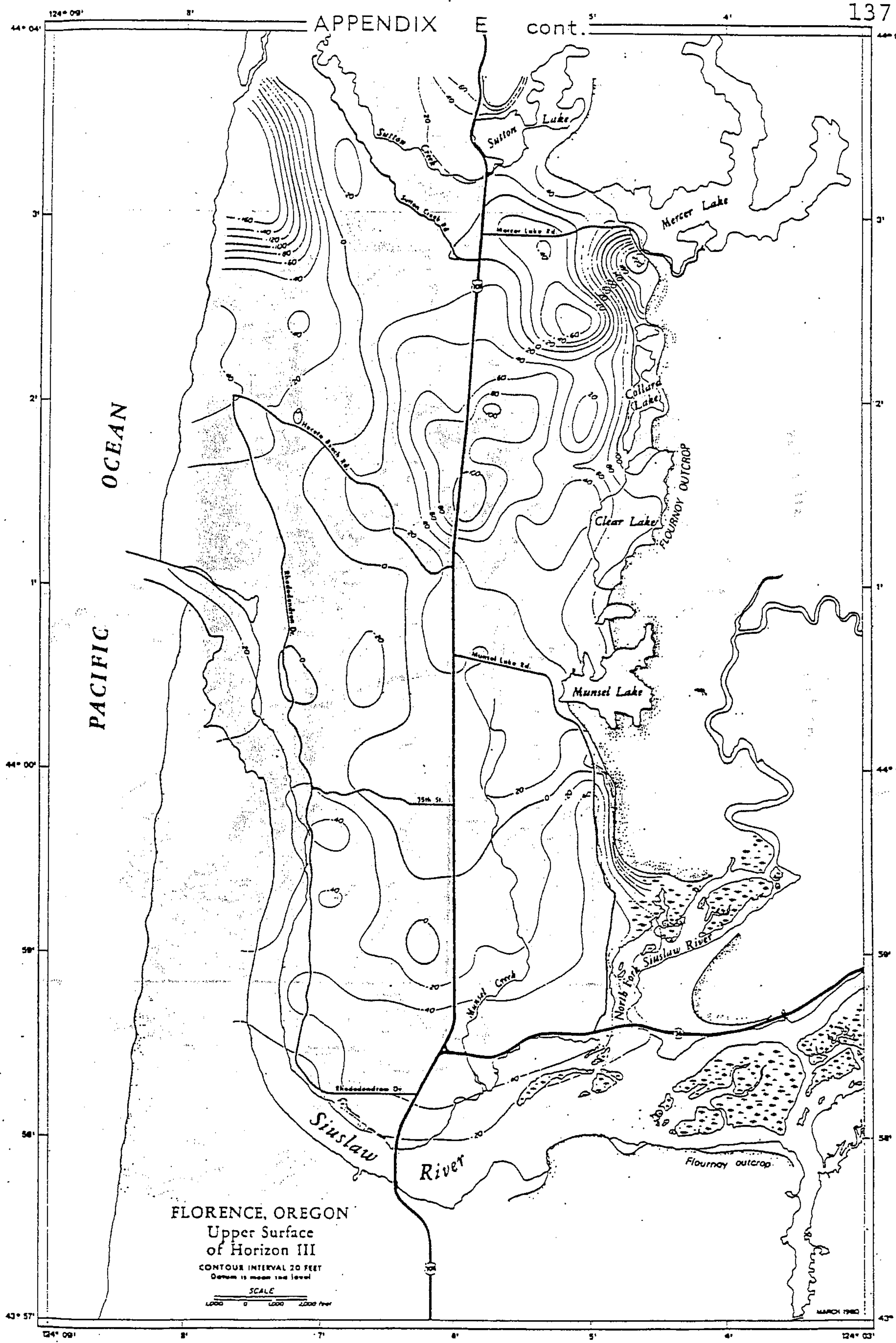
APPENDIX D cont.



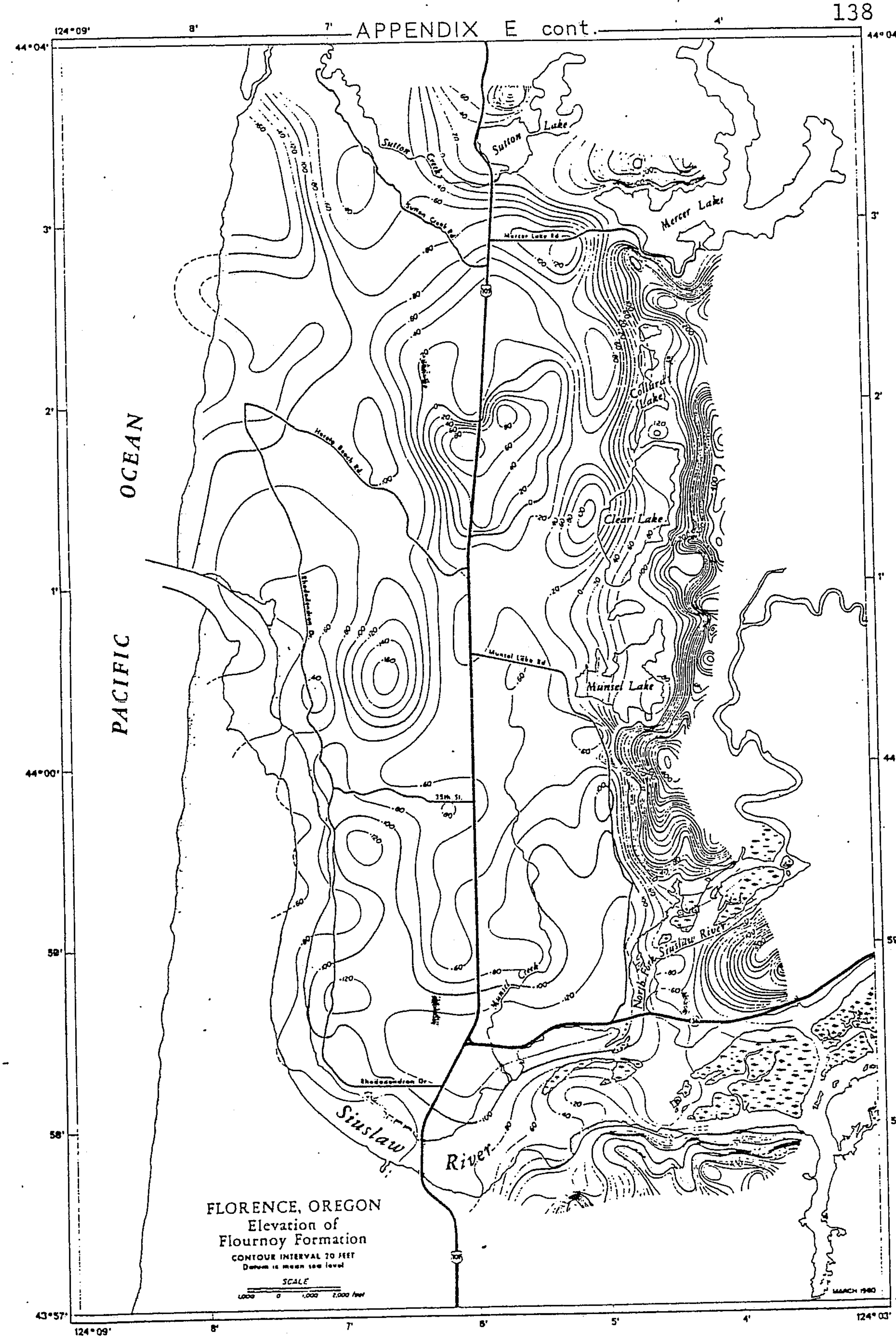
APPENDIX E. Maps Produced by the Seismic Survey Portion of this Study.

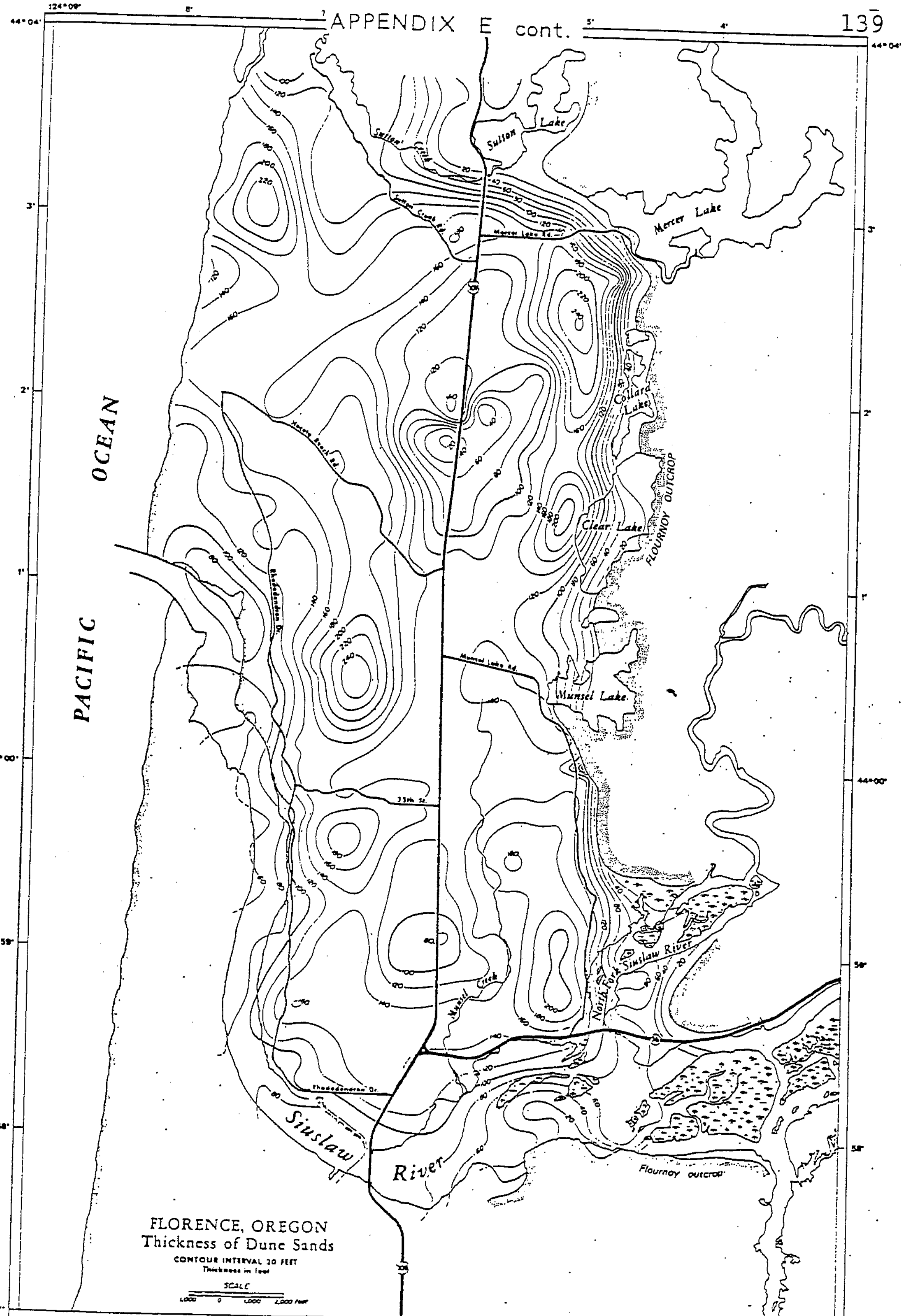



PACIFIC OCEAN
Sutton Lake
Sutton Creek
Sutton Creek Rd.
Mercer Lake
Mercer Lake Rd.
Collard Lake
Clear Lake
FLOURNOY OUTCROP
Heceta Beach Rd.
Rhododendron Dr.
Munsel Lake Rd.
Munsel Lake
35th St.
Munsel Creek
North Fork Siuslaw River
Siuslaw River
Flournoy outcrop
FLORENCE, OREGON
Upper Surface
of Horizon II
CONTOUR INTERVAL 20 FEET
Datum is mean sea level
SCALE
MARCH 1980


PACIFIC OCEAN
Sutton Lake
Sutton Creek
Mercer Lake
Mercer Lake Rd.
Collard Lake
FLOURNOY OUTCROP
Clear Lake
Heceta Beach Rd.
Rhododendron Dr.
Munsel Lake Rd.
Munsel Lake
35th St.
Munsel Creek
North Fork Siuslaw River
Siuslaw River
Flournoy outcrop
FLORENCE, OREGON
Upper Surface
of Horizon III
CONTOUR INTERVAL 20 FEET
SCALE
MARCH 1980

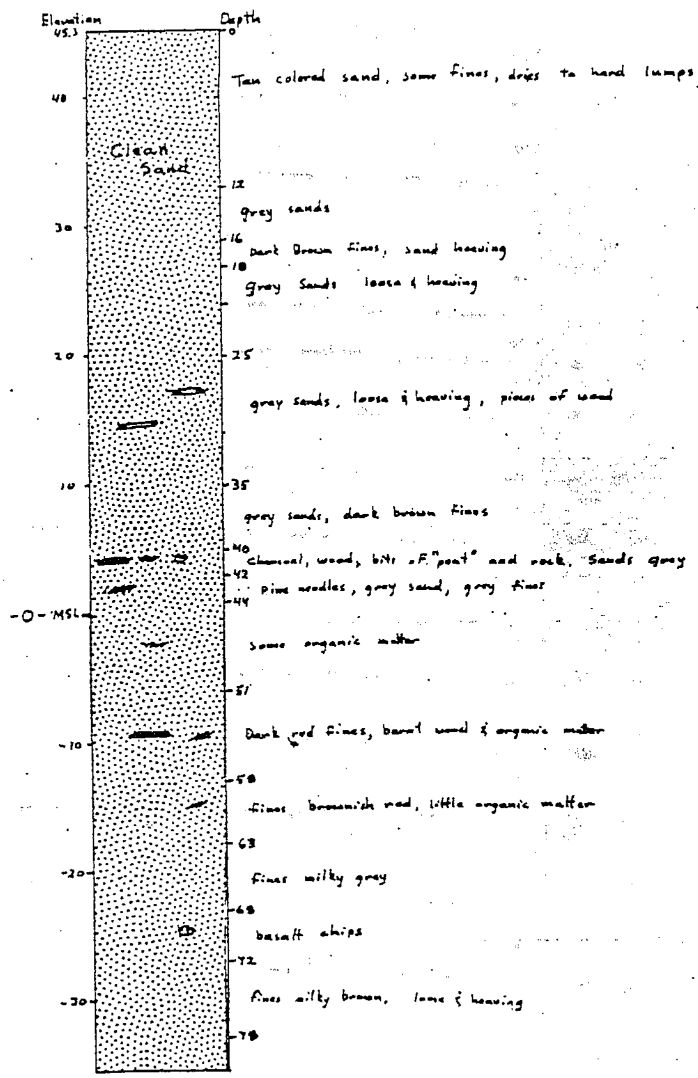
APPENDIX E cont.

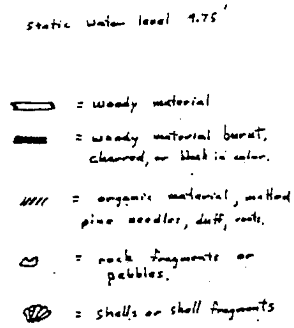



PACIFIC OCEAN
Sutton Lake
Sutton Creek
Mercer Lake
Mercer Lake Rd.
Collard Lake
Clear Lake
FLOURNOY OUTCROP
Munsel Lake
Munsel Lake Rd.
Rhododendron Dr.
35th St.
Munsel Creek
North Fork Siuslaw River
Siuslaw River
Flournoy outcrop
FLORENCE, OREGON
Thickness of Dune Sands
CONTOUR INTERVAL 20 FEET
Thickness in feet
SCALE
MARCH 1960

APPENDIX F. Materials Logs of the Two Deep Wells.

Deep Well #1



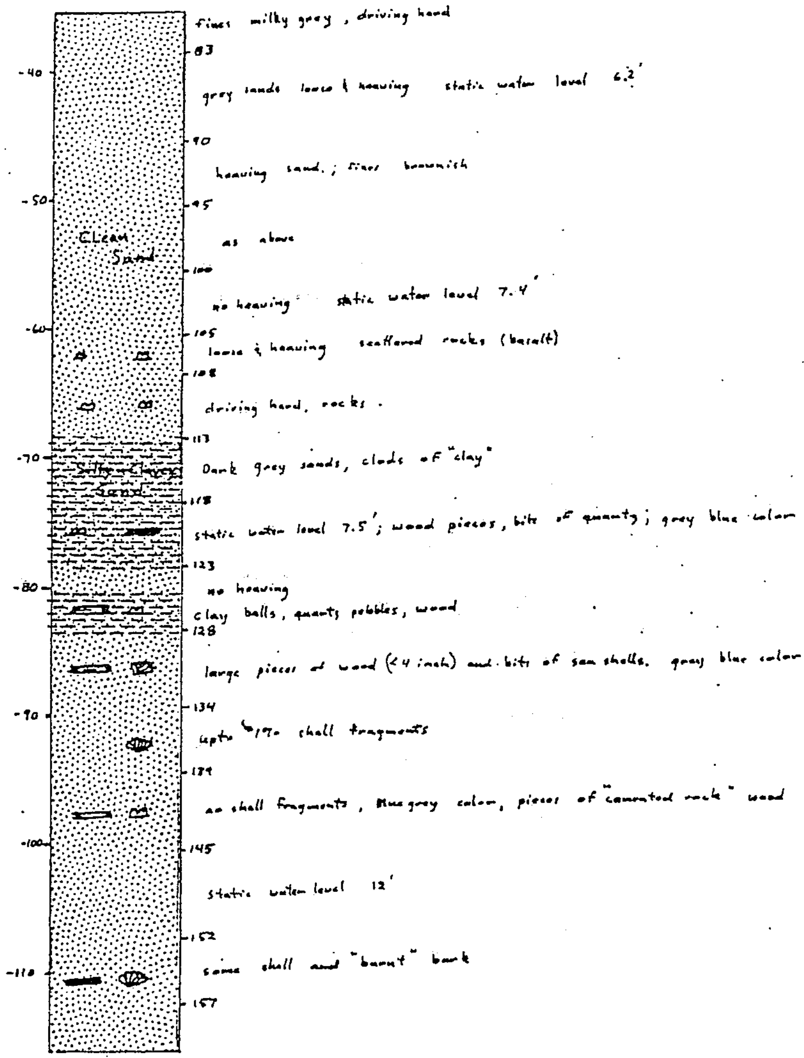


General.

The whole section is characterized by fine sands of very uniform size. Silty-Clayey sands are still 65-80% sand minimum. Drilling method makes actual depths somewhat uncertain. Most sands are 95% plus sand with < 5% fines.

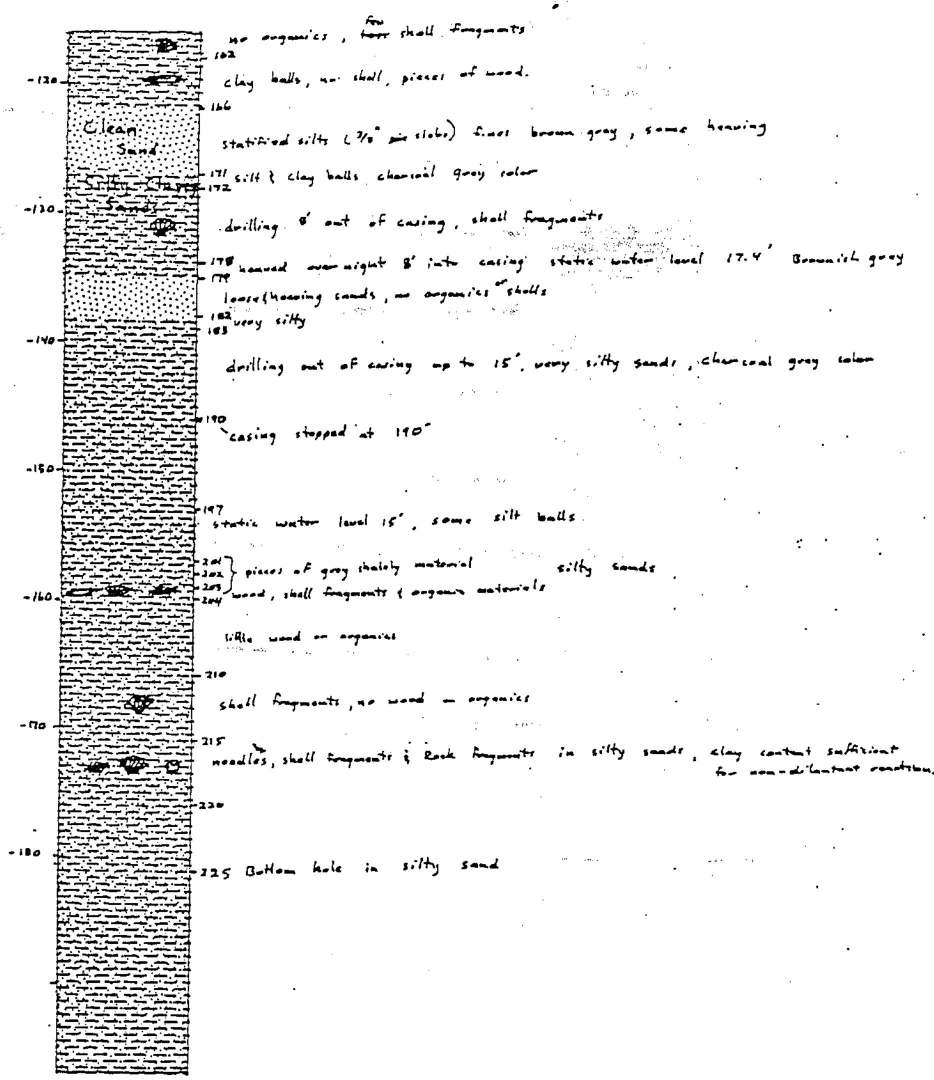
APPENDIX F cont.

Deep Well #1 cont.



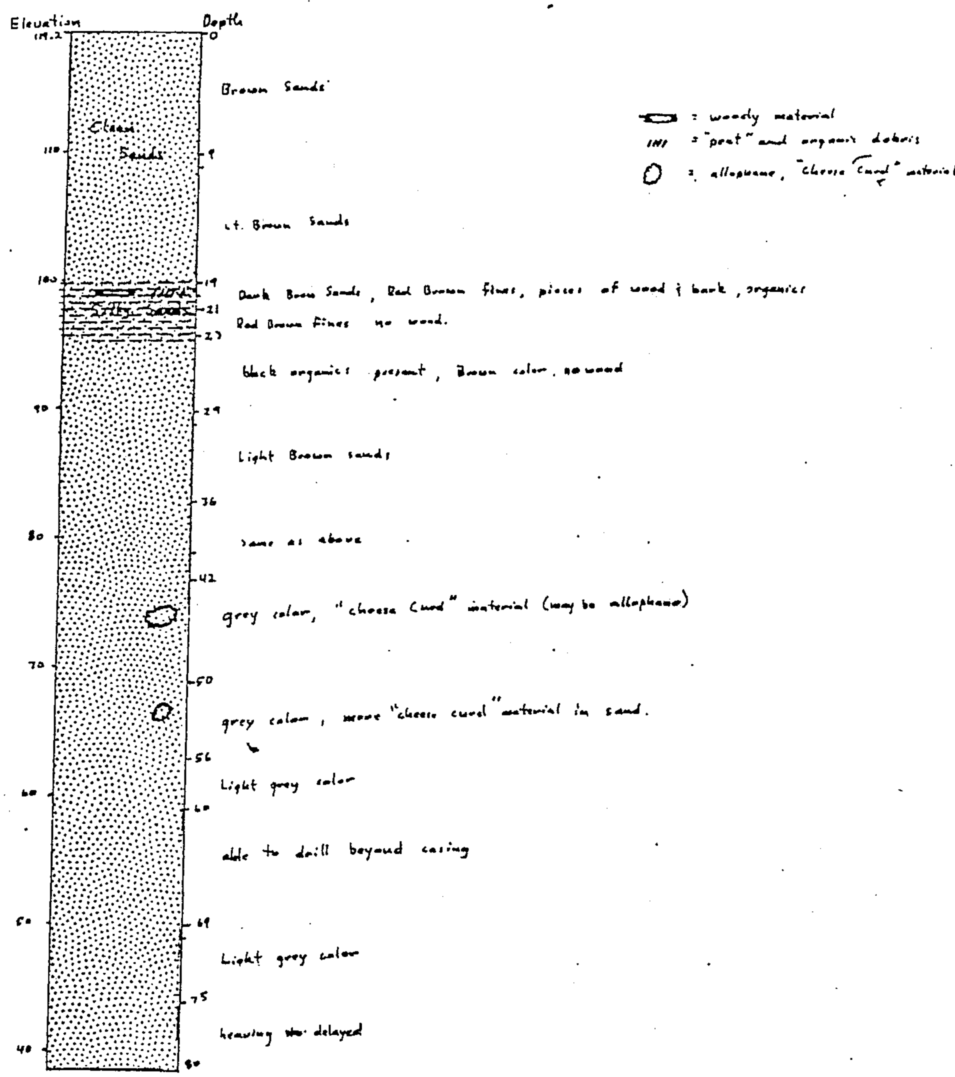
APPENDIX F cont

Deep Well #1 cont.



APPENDIX F cont.

Deep Well #2



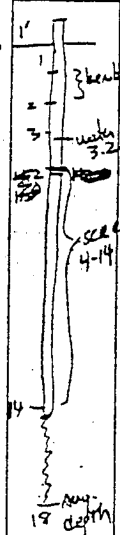
APPENDIX G. Field Logs of Three of the Shallow Monitoring Wells.

Sweet, Edwards & Associates, Inc.

AUGER LOG AND WELL DETAIL

Project: North Florence
Client: 1-606
Feature:
Location: Stanz[illegible] Rd nr Friend!, twos #4 site
Inclination fr. Vertical: [illegible]
Bearing:
Drilled By: SE&A
Logged By: Rosenthal
Date Logged: 22 July 1980

Sheet 1 of
Surf Elev.
Depth to Gr Water
Date
Total Depth
Wt of Hammer for Spoon
Free Drop of Hammer
Boring No.



WELL DETAIL	UNIFIED CLASS	DEPTH (ft)	ELEVATION (ft)	SPOON RECORD: Sample No	Blows per 6 inches	Recovery w/n 0.1 ft	Type Spoon	DESCRIPTION
		0						Thin soil mixed w/ sand – 1-2"
		0.2						~~wet~~ moist brown sand
		2.5-4						med brown-med. grain brown sand some root materials saturated @ 3.5' iron staining (irregular) in sat. zone
		3.5						water augured (4.2 w/ M-scope)
		11						change to grey brown sand
		—						Augured to 18'
		0-4						solid casing
		4-14						screened
		2-1						bentonite

REMARKS:

APPENDIX G cont

Sweet, Edwards & Associates, Inc.

AUGER LOG AND WELL DETAIL

Project: North Florence [illegible]
Client: [illegible]
Feature:
Location: County Yard
Inclination from Vertical: Bearing:
Drilled By: SEA - Craig
Logged By: C Wells
Date Logged: 7-25-89

Sheet 1 of 1
Surf Elev.
Depth to Gr Water: 5.7' [illegible]
Date:
Total Depth:
Wt of Hammer for Spoon:
Free Drop of Hammer:
Boring No: 3

WELL DETAIL	UNIFIED CLASS	DEPTH (ft)	ELEVATION (ft)	SPOON RECORD: Sample No	Blows per 6 inches	Recovery w/n 0.1 ft	Type Spoon	DESCRIPTION
0.5 ft. stickup; 2" PVC riser pipe; 4'; 2" diam PVC Screen 0.010 inch slots; 14'								0-0.5' gravel Fill 0.5-4.5' Tan-Brown medium grained well graded dune sand 4.5-13' Gray Brown - Gray medium grained well graded dune sand. Trace(s) of organics Water first encountered at approx. 4' feet. Augered to 13 feet

REMARKS:

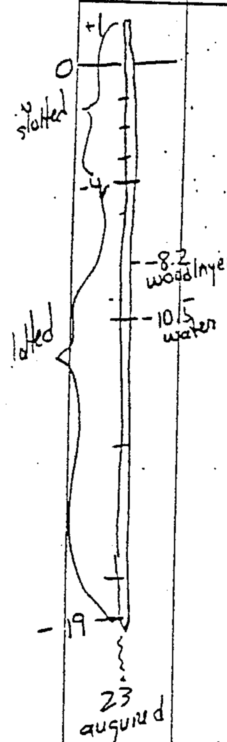
APPENDIX G cont.

Sweet, Edwards & Associates, Inc.

AUGER LOG
AND WELL DETAIL

Project: [N]orth Florence
Client: L-006
Feature:
Location: Soil & Pack, Hel. Jct #8 ?17E
Inclination from Vertical: Bearing:
Drilled By: SE&A
Logged By: Rosenthal
Date Logged: 22 July

Sheet 3 of
Surf Elev.
Depth to Gr Water
Date
Total Depth
Wt of Hammer for Spoon
Free Drop of Hammer
Boring No.



WELL DETAIL	UNIFIED CLASS	DEPTH (ft)	ELEVATION (ft)	SPOON RECORD Sample No	Blows per 6 inches	Recovery w/n 0.1 ft	Type Spoon	DESCRIPTION
		0						sand - w/ a little gravel
		0-5						Fill - lite brown, med grain - almost dry
		2.0 / 3.5						split spoon - lite brown - a couple pieces of org. material
		to 7.0						lite brown - damp sand
		7.0 / 8.4						spoon top 1.1', lite brown sand @ 8.2 → 0.1' layer of black organic material - wood @ 8.3 → 0.2' → lite grey sand
		10						more bits of wood etc
		11						approx water
		18						more of same - med sand
		to 23						same w/ occassional small bits of wood

REMARKS:

APPENDIX H. Listing of Stream Flows at Various Sites and Dates.

Stream Flows In Cubic Feet Per Second

Site - Date	3 Sutton Ck. at Sutton Lk.	1 Sutton Ck. at Outlet	21 Munsel Ck. at Munsel Lk.	33 Munsel Lk. at Outlet	Site 35 at Outlet	Site 37 Siuslaw Pacific
8/18/80	5.6	7.9	dry	1.1	1.5	.3
10/15/80	6.3	8.1	dry	.4	1.3	.2
1/20/81	38.1	29.2	5.5	10.8	2.2	.3
4/02/81	86.2	86.4	10.4	9.2	2.8	-
6/09/81	39.2	48.1	-	-	-	-
8/31/81	6.3	10.4	dry	2.7	.66	-
10/16/81	36.3	41.6	5.7	5.4	.65	-

Note: Stream flows generally increase across the aquifer because of aquifer discharge to the stream. However during storm rains when the aquifer is "soaking up" rainfall and the bed rock areas are experiencing high runoff bank infiltration apparently takes place and the stream's dunal reach loose water (become effluent) during those times: 1/20/81 on Sutton Ck. and 4/2/81 & 10/16/81 on Munsel Ck.

APPENDIX I. Table of Average Parameter Values for Each Monitoring Site and Listing of All Measured Parameters for Each Monitoring Site.

NORTH FLORENCE DATA
AVERAGE PARAMETER VALUES
Min. of 3 values

> = single high value

	Site #	Cond.	Temp.	D.O.	C.O.D.	PH	NO_3	PO_4	FE	F. Col	Cl^-	NH_3	Elev.	Depth to H_2O
Sutton Ck. →	S 010	63	13.6	8.9	8.4	6.6	.33	.021>	.69	13	11.5	.05	9.2	-
	S 020	38	9.3	-	-	-	-	-	-	-	-	-	50.1	4.7
[illegible] Ck. →	S 030	55	14.6	8.9	8.5	6.6	.42	.023>	.27	9	9.6	.05	29.6	-
	040	51	11.3	1.1	3.3	5.1	.06	.009	.28	0	10.1	.05	76.2	9.5
	050	29	73.0	7.2	1.7	5.9	.02	.012	.09	0	5.4	.05	114.5	9.2
	S 060	35	16.2	-	-	-	-	-	-	-	-	-	113.6	3.1
	070 ✓	31	13.6	8.6	1.2	6.2	.03	.009	.06	0	6.1	.05	107.3	3.5
Collard →	S 080	51	16.1	8.3	7.6	6.9	.08	.012	.15	5	9.7	.05	109.1	-
	090 ✓	36	13.2	8.5	1.6	6.5	.04	.011	.05	0	6.1	.05	100.4	5.7
	100 ✓	29	13.4	8.9	2.0	6.1	.05	.010	.05	0	5.9	.05	96.5	5.6
Clear →	S 11A	47	15.5	8.4	5.1	6.8	.04	.009	.07	2	9.0	.05	102.8	-
	110 ✓	58	13.3	5.4	2.2	5.9	.05	.014?	.11	0	12.1	.05	90.8	5.6
	120	54	11.0	5.4	2.4	5.4	.03	.004	.04	0	14.9	.05	100.5	5.6
	130	57	10.9	1.8	8.8	5.1	.01	.007	.32	2	12.6	.05	115.6	4.0
	S 140	-	-	-	-	-	-	-	-	-	-	-	121.5	5.1
	150	-	-	-	-	-	-	-	-	-	-	-	93.5	7.0
	16A	-	-	-	-	-	-	-	-	-	-	-	115.1	3.2
	16B	-	-	-	-	-	-	-	-	-	-	-	119.6	3.1
	170	113	14.1	3.1	12.8	5.5	0.31	.011	.13	0	7.8	.10	90.3	11.8 - probably entry e[rror] value near 7-8o
S. Heceta L.	S 18A	84	16.3	-	20.2	-	.03	.017>	.42	3	16.9	.114	84.6	2.7
N. Heceta L.	S 18B	64	14.7	8.9	21.0	6.5	0.03	.021>	.38	29	17.7	.05	85.5	-
Heceta Beach	190	194	12.0	1.9	15.4	5.2	.04	.019>	.59	0	46.5	.100	115.5	14.4
101 & Munsel L.	200	64	11.6	2.6	8.1	5.5	.01	.020>	.54	4	14.6	.10	84.0	7.3
	S 21A	31	-	-	-	-	-	-	-	-	-	-	86.0	-
	S 21B	52	15.1	9.0	7.2	6.8	.06	.012	.07	17	9.9	.10	88.7	-
	220	67	11.2	3.5	11.2	5.2	.01	.009	.24	-	12.3	.10	70.1	5.7
	230	-	-	-	-	-	-	-	-	-	-	-	57.8	9.9
	240	52	13.1	5.9	3.6	5.0	.02	.012	.07	0	8.4	.10	56.7	8.3
	250	-	-	-	-	-	-	-	-	-	-	-	14.5	37.3
Dump. →	260	398	13.1	1.0	29.1	5.7	.01	.020>	9.07	2	23.8	.82	9.6	7.3
	270	-	-	-	-	-	-	-	-	-	-	-	9.5	49.6
	280	-	-	-	-	-	-	-	-	-	-	-	33.9	15.0
	290	-	-	-	-	-	-	-	-	-	-	-	22.1	11.2
	300	140	12.1	1.7	30.0	5.9	.17	.159?	1.47	3	34.0	.12	12.8	22.9
	310	83	13.1	1.8	3.6	5.5	.04	.009	.33	0	16.2	.05	26.0	8.0
	S 330	66	11.8	8.3	6.3	6.6	.09	.013	.54	259	11.5	.05	9.0	-
	340	66	11.9	3.7	9.3	5.3	.05	.013	.74	0	8.4	.05	38.2	6.1
31st E. of Munsel Rd & golf c. →	S 350	63	10.9	8.9	16.3	6.5	.23	.064>	.67	107	10.0	.05	12.8	-
golf course →	360	46	12.2	3.0	3.7	5.3	.40	.019>	.13	0	6.7	.05	31.3	10.4
Siuslaw Pacific →	S 370	62	13.3	4.9	3.3	6.4	.02	.016>	.36	20	8.8	.05	16.3	-
	380	-	-	-	-	-	-	-	-	-	-	-	107.3	-

APPENDIX I cont.

DEPTH TO WATER - FEET

DATES / STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	093081	101281
010															
020	6.75	8.00	9.75	8.60	2.90	.75	.25	.23		1.14	1.61	4.13	6.58	8.12	7.24
030															
040	7.00	7.75	8.66	7.80	6.00	5.10	5.40	4.90	4.35	5.46	5.61	6.30	7.32	8.12	7.09
050	8.80	10.00	11.33	11.10	9.83	9.00	8.70	8.00	7.14	7.74	8.01	8.32	9.37	10.40	9.89
060		4.40	5.60	4.80	3.00	2.40	2.29	1.72	1.41	1.77	1.87	2.48	3.82	4.91	3.50
070	4.33	5.25	6.30	5.30	3.50	2.25	2.40	1.80	1.46	1.31	2.30	3.16	4.32	5.10	4.21
080															
090	6.60	7.33	8.10		5.30	4.20	4.80	4.30	3.67	4.71	4.81	5.57	6.64	7.41	6.07
100	6.40	7.25	8.60	7.20	5.20	4.20	4.43	4.00	3.43	4.26	4.50	5.32	6.45	7.28	6.01
11A															
11B	6.50	7.33	8.10	7.10	5.00	4.00	4.40	3.90	3.30	4.50	4.20	5.47	6.63	7.48	6.29
120	6.33	7.40	8.50	8.10	5.80	4.20	4.30	3.20	2.93	3.72	3.88	5.03	6.44	7.57	6.64
130	4.75	5.80	6.90	6.50	4.25	3.00	2.60	1.90	1.40	2.42	2.18	3.39	4.77	5.90	4.94
140		6.60	7.30	6.40	3.60						1.34	3.74	5.16	6.22	5.39
150		8.25	9.50	9.40	7.70	5.75	5.60	4.90	4.66	5.35	5.50	6.39	7.54	8.77	8.45
16A		4.90	5.00	3.60	2.40	2.50	2.40	2.30	2.21	2.73	2.32	3.53	4.37	4.68	2.67
16B		5.50	6.60	6.10	3.10	.75	.20	.10		1.31	1.31	2.24	3.90	5.32	4.44
170	12.25	13.10	14.20	13.75	11.75	10.70	10.60	10.00	9.46	10.42	10.33	11.36	12.73	13.83	12.76
18A	2.33	2.80	2.90	5.75	3.00	2.30	2.60	1.70	1.09	1.70	1.95	1.54	2.65	3.74	4.04
18B															
190	15.33	15.50	15.30	14.75	13.80	13.60	13.70	13.80	13.67	14.04	14.06	14.52	14.94	15.24	14.55
200	7.75	9.60	9.50	8.80	6.80	6.00	6.00	5.40	4.97	6.24	6.09	7.10	8.20	8.99	7.91
21A															
21B															
220	7.00	7.10	8.10		5.50	4.40	4.50	3.75	3.13	4.44	4.68	5.50	6.75	7.71	6.98
230	9.30	10.33													10.11
240	7.80	9.90	10.20	10.00	8.60	7.25	7.30	6.75	6.08	6.78	7.15	8.03	9.16	10.15	9.71
250		37.10	37.40	37.80	38.20	37.30	37.20	37.50	37.09	36.95	36.24	37.11	37.71	37.45	37.61
260	7.40	7.80	8.00	7.80	7.20	7.40	6.60	6.25	6.19	6.70	6.70	7.35	7.86	8.18	7.55
270		51.60	48.50	49.20	48.80	50.00	50.83	48.60	48.01	48.97	49.57	50.65	50.40	50.53	48.31
280		14.83	15.50	16.10	15.60	13.75	13.60	14.50	14.77	13.92	15.00	15.78	14.89	15.81	14.16
290		14.40	12.80	12.90	11.30	9.60	10.00	9.25	8.72	9.49	10.02	10.69	11.61	12.51	13.13
300	21.60	24.00	24.70	24.70	23.60	21.60	21.93	21.30	21.04	21.70	22.15	22.84	23.56	24.21	24.17
310	7.90	9.00	10.00	10.00	8.40	6.90	7.00	6.25	5.58	6.54	7.02	7.80	8.65	9.80	9.34
330		.94													
340	7.33	6.30	8.40	7.40	5.70	4.80	5.00	4.40	3.92	5.04	5.25	6.02	7.32	8.23	
350		.50													
360	10.60	11.30	12.10	11.90	10.75	9.30	9.30	9.00	8.70	9.21	9.66	10.15	10.73	11.31	11.29
370															
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

ELEVATION - FEET ABOVE SEA LEVEL

STA	Avg. Diff.		081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010	.44	E	10.03E	10.03E	8.63E	9.47E	8.64E	9.51E	9.32E	9.57	E	9.24E	9.35E	9.13E	8.89E	8.85E	9.64
020	14.25	F	47.78E	46.53E	44.78E	45.93E	51.63E	53.78E	54.28F	54.30E	55.03E	53.39E	52.92E	50.40E	47.95E	46.41E	47.29
030	3.13	F	28.67E	28.64E	28.66F	29.32E	30.77E	29.52E	29.33E	29.62E	29.99E	29.45E	29.23E	29.17E	28.77E	28.66F	29.45
040	4.31	F	78.74E	77.99F	77.08E	77.94E	79.74E	80.64F	80.34E	80.84E	81.39E	80.28E	80.13E	79.44E	78.42F	77.67E	78.65
050	4.11	E	114.85E	113.65F	112.32E	112.55E	113.85E	114.65E	114.95E	115.65E	116.51F	115.91E	115.64F	115.33E	114.28E	113.25F	113.76
060	4.19		E	112.18E	110.98E	111.78E	113.58E	114.18E	114.38E	114.86E	115.17E	114.81E	114.71E	114.10E	112.76E	111.67E	113.08
070	4.11	E	106.52E	105.60E	104.55E	105.55E	107.35E	108.60E	108.45E	109.05E	109.37E	109.54E	108.55E	107.69E	106.53E	105.55E	106.64
080	.31		E	108.90F	108.84E	109.06E	109.20E	109.21E	109.23E	109.23E	109.20E	109.07F	109.16E	109.18E	109.12E	109.08E	109.29
090	4.43	E	99.16E	98.43E	97.66	E	100.46E	101.56E	100.96E	101.46E	102.09E	101.05E	103.95E	100.19E	99.12E	98.35E	99.69
100	4.57	E	95.73F	94.88F	94.13E	94.93E	96.93F	97.93E	97.73E	98.13E	98.73E	97.87E	97.63E	96.81E	95.69E	94.85E	96.12
11A	1.12	E	94.58		E	95.38E	95.70E	95.40E	95.30E	95.40E	95.48E	95.25E	95.31E	95.34E	93.07 (pump)	E	95.52
110	4.80	E	89.88F	89.05F	88.28E	89.28E	91.38E	92.38E	91.98E	92.48E	93.08E	91.88E	92.18E	90.91E	89.75E	88.90F	90.09
120	5.60	E	99.73E	98.66E	97.56E	97.96E	100.26E	101.86E	102.06F	102.86E	103.16E	102.34E	102.18E	101.06F	99.67E	98.49E	99.42
130	5.50	E	114.88E	113.83E	112.73E	113.13E	115.38E	116.63E	117.03E	117.73E	118.23E	117.21E	117.45E	116.24E	114.86E	113.73E	114.69
140	4.94		E	117.20E	116.50E	117.40E	~~[illegible]~~ 118.29	~~[illegible]~~ 119.30	~~[illegible]~~ 119.90	~~[illegible]~~ 120.50	~~[illegible]~~ 121.33	~~[illegible]~~ 121.34	122.46E	120.36E	119.61F	117.58E	118.41
150	4.84		E	91.79F	90.54E	90.64E	92.34E	94.29E	94.44E	95.14E	95.38E	94.69F	94.54E	93.66E	92.50E	91.27E	91.59
16A	9.79		E	113.25E	113.15F	114.55E	115.75E	115.65E	115.75E	115.85E	115.94E	115.42E	115.83E	114.62E	113.83E	113.47F	115.48
16B	6.60		E	107.80E	106.70E	107.20E	110.20F	112.55E	113.10E	113.20	113.30	111.99E	111.99E	111.06E	109.40E	107.98F	108.86
170	4.74	E	89.86E	89.01E	87.91E	88.36F	90.36E	91.41E	91.51E	92.11F	92.65E	91.69E	91.78F	90.75F	89.38F	88.31E	89.35
18A	4.66	E	84.91E	84.44E	84.34E	81.49F	84.24E	84.94E	84.64E	85.54E	86.15E	85.54E	85.29E	85.70E	84.59E	83.50E	83.20
18B	3.12	E	84.43	E	84.56E	84.29F	84.98E	86.24E	86.41E	87.03E	87.55E	87.16E	87.08F	86.36E	85.35F	84.32E	84.26
190	1.90	E	14.64F	14.47E	14.67E	15.22E	16.17E	16.37E	16.27F	16.17E	16.30E	15.93E	15.91E	15.45E	15.03E	14.73E	15.42
200	4.63	E	83.49E	81.64E	81.74E	82.44E	84.44E	85.24E	85.24E	85.84F	86.27E	85.00E	85.15E	84.14E	83.04F	82.25E	83.33
21A						E	86.83E	86.73E	86.66E	86.78F	86.28E	86.06E	86.02E	85.73E	85.61E	85.57E	86.12
21B	1.35	E	88.78		E	88.77E	89.57E	89.21E	89.02E	89.21E	89.33E	88.78E	88.74E	88.27E	88.11E	88.08E	88.98
220	4.17	E	68.41E	68.31E	67.31	E	69.91E	71.01E	70.91E	71.66E	72.28E	70.97F	70.73E	69.91E	68.66E	67.70E	68.43
230	4.51	E	56.58E	55.55	E	55.40E	57.22E	58.20E	58.33E	59.06E	59.59E	59.52E	58.05E	57.23F	56.01E	55.00E	55.77
240	4.12	F	57.18E	55.08E	54.78E	54.98E	56.38E	57.73F	57.68E	58.23F	58.93F	58.20F	57.83E	56.95E	55.82E	54.83F	55.27
250	1.96		E	14.74E	14.44E	14.04E	13.64E	14.54E	14.64E	14.34E	14.75E	14.89E	15.60E	14.73E	14.13E	14.39E	14.23
260	1.11	E	9.51E	9.11E	8.91E	9.11E	9.71E	9.51E	10.31E	10.66E	10.72E	10.21F	10.21E	9.56E	9.05E	8.73E	9.36
270	3.51		E	7.44E	10.54E	9.84E	10.24E	9.04E	8.24E	10.44E	11.03E	10.07F	9.47E	8.39F	8.64F	8.51E	10.73
280	2.26		E	33.16E	32.46E	31.86F	32.36E	34.21E	34.36E	33.46E	33.19E	34.04E	32.96E	32.18E	33.07E	32.15E	31.80
290	3.19		E	18.12E	19.72E	19.62E	21.22E	22.92E	22.52E	23.27E	23.83E	23.03E	22.50E	21.83F	20.91E	20.01F	19.39
300	3.66	F	14.09E	11.69E	10.99F	10.99E	12.09E	14.09E	13.79E	14.39F	14.65E	13.99E	13.54E	12.95E	12.13E	11.48E	11.52
310	4.42	E	26.06E	24.96F	23.96E	23.96E	25.56E	27.06E	26.96F	27.71E	28.38E	27.42E	26.94E	26.16E	25.31E	24.36E	24.62
330	1.01		F	6.83E	8.32E	9.02E	9.52E	9.62E	9.57E	9.70E	9.91E	9.52E	9.53E	9.59E	8.12E	8.70E	8.75
340	4.43	E	36.52E	37.55F	35.45E	36.45E	38.15E	39.05E	38.85E	39.45E	39.93E	38.81E	38.60E	37.83E	36.53E	35.62	
350	1.19	E	12.89E	11.85E	12.83E	12.91E	12.97E	13.03E	12.94E	13.00E	13.02E	12.86E	12.91E	12.78E	12.75E	12.85F	12.85
360	1.90	E	31.05E	30.35E	29.55E	29.75E	30.90E	32.35E	32.35E	32.65E	32.95E	32.44E	31.99E	31.50F	30.92E	30.34E	30.36
370						E	16.05E	16.50E	16.40E	16.40F	16.55E	16.39E	16.39F	16.40E	16.40E	16.17F	16.22
380	6.31 +				E	103.60	E	107.80E	107.45E	108.90F	109.80E	109.40E	108.90E	107.88E	106.31E	105.00F	105.40

95.25

95.3

107.12 6.20

APPENDIX I cont.

TEMPERATURE - DEGREES C

DATES STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
→ 010		15.2	13.9	11.4	8.2	8.2	8.6			16.1	16.5	18.4	19.9	14.2	13.0
020					5.0	6.7	7.7			18.2					
→ 030		17.5	16.2	11.8	8.1	9.0	8.8			16.0		20.1	22.0	17.4	13.7
040		13.5	13.0	12.5	11.7	10.3	10.9			9.6	10.2	11.3	11.0	10.5	10.6
050		14.8	13.9	13.9	12.9	12.0	10.8			11.3	11.8	13.0	14.4	13.9	13.5
060						7.0	10.6			23.3		24.1			
→ 070		15.0	15.3	14.2	13.3	10.8	10.8			11.6	12.9	14.6	15.4	15.0	14.3
080		19.8	20.0	11.2	8.7	8.8	9.5			18.7	18.4	21.5	24.9	17.4	14.2
090		15.3	14.5		13.2	11.0	11.6			11.9	12.0	14.0	14.5	13.8	13.2
100		15.8	14.9	13.8	13.8	11.0	11.2			11.9	12.3	14.3	14.4	14.2	13.6
→ 114			18.4		9.7	9.5	9.3			14.6	17.3	20.9	27.5	18.9	14.2
110		15.1	14.9	14.1	12.8	10.9	11.0			11.8	12.4	14.2	14.5	14.5	13.8
→ 120		11.8	12.0	11.8	10.9	10.0	11.5			9.7	9.8	11.0	11.4	11.3	10.5
130		11.2	13.0	12.0	11.8		10.7			9.6	9.5	10.3	10.8	10.7	9.8
140						8.2				20.0					
150															
16A															
16B															
→ 170		15.1	15.1	14.2	13.9	19.5	12.2			11.4	13.0	13.0	13.7	14.5	13.3
18A		24.9			8.7	10.1	7.2			16.4	20.7	25.9			
→ 188			19.4	10.4	5.1	8.0	7.2			16.3	20.1	22.2	23.9	20.1	8.7
→ 190		13.5	15.0	12.7	12.2	12.0	11.8			10.9	10.7	10.9	11.2	11.8	11.8
200		12.7	13.2	12.0	10.6	12.0	10.1			12.4	11.3	11.6	11.1	11.2	11.5
21A					8.3	9.2	6.8								
218		19.8	13.3	12.0	8.0	9.0	7.5			16.0	18.7	23.4	24.0	17.7	12.0
220		13.5	12.9		10.3	10.8	9.1			10.3	10.7	11.7	11.4	11.6	10.9
230															
240		15.0	14.9	13.3	12.5	11.2	11.9			10.9	12.6	13.5	13.7	14.3	13.2
250															
→ 260		14.0	13.9	13.0	12.9	12.9	12.7			12.8	13.8	13.0	12.9	12.8	12.3
270															
280															
290															
300		12.2	11.7	11.7	11.2	17.6	11.0			10.8	14.6	10.9	12.0		9.7
→ 310		16.0	14.1	13.0		11.9	12.4			11.2	13.0	11.5	13.8	13.5	13.2
330		15.1	12.7	9.0	8.7	9.0	8.8			13.2	14.6	13.0	13.0	13.3	10.7
340	13.2		12.8	12.9	12.1	11.7	9.3			10.6	11.3	11.7	12.4	12.6	12.1
350		14.9	14.1	9.5	7.5	9.7	9.2			11.5	12.5	12.2	13.9	12.9	13.5
360		13.2	13.5	12.1	12.2	11.4	12.0			11.5	12.0	12.5	12.3	11.9	11.4
370		17.2	14.8	11.0	10.1	11.2	9.5			14.2	15.7	14.8	14.1	15.7	11.8
380						10.2						11.9			

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

CONDUCTANCE - MICROMHO

DATES / STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010		33	82	47	29	36	28		75	69	88	93	94	79	
020					30	22	29		71						
030		38	82	39	29	19	30		60		77	76	77	76	
040		32	62	32	25	27	27		53	50	65	71	85	80	
050		19	50	20	21	20	22		24	23	33	41	48	30	
060						21	29		37		53				
070		35	62	26	22	17	20		30	28	23	36	36	35	
080		51	65	31	28	22	31		56	57	68	68	67	65	
090		32	59		28	17	26		29	31	50	51	41	35	
100		31	60	25	20	17	20		21	20	28	29	47	27	
11A			68		33	24	32		49	42	52	62	55	57	
110		62	88	29	38	23	35		57	55	79	81	63	59	
120		40	69	29	28	37	43		78	67	77	66	58	57	
130		41	77	32	31		42		76	75	78	64	56	57	
140						25			48						
150															
16A															
16B															
170		197	134	98	81	49	75		112	103	147	124	123	118	
18A	110	127			34	43	48		93	92	129				
18B			104	32	28	29	34		60	70	85	96	100	64	
190		131	139	89	86	66	110		269	359	351	272	246	212	
200		75	112	37	32	31	23		78	40	86	85	129	41	
21A					33	30	29								
21B		53	78	31	32	32	25		55	57	68	64	64	62	
220	77	52	82		34	49	47		70	76	84	74	74	89	
230															
240	65	50	88	43	33	37	35		52	44	58	54	55	59	
250															
260	700	241	210	189	116	177	197		649	748	739	521	415	271	
270															
280															
290															
300	130	83	122	80	113	83	77		197	246	212	259		189	
310	95	56	102	61		61	54		85	86	105	101	96	93	
330		63	96	47	30	42	30		67	66	91	94	99	70	
340	30		106	53	60	38	48		73	62	88	61	74	105	
350	73	52	84	41	32	45	35		65	69	79	78	73	95	
360	56	37	60	30	28	47	42		52	41	54	53	50	49	
370	80	60	91	45	28	43	38		68	65	86	63	76	70	
380						29					60				

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

DISSOLVED OXYGEN - PPM

DATES STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	091081	090981	101281
010										10.20	7.62				8.85
020															
030										9.60					8.30
040							2.20			1.50				1.60	
050							9.00			6.90	6.00			8.10	6.05
060										7.65					
070							10.00				7.40			9.60	7.40
080										9.60	8.05				7.22
090							9.90			9.28	7.40			9.10	6.80
100							10.80			9.05	7.50			9.20	8.07
11A										9.24	8.38				7.45
110							4.90			6.80	5.22			4.60	
120							4.90			5.83	3.25			7.30	5.48
130							2.20			4.15	1.65			1.20	
140															
150															
16A															
16B															
170							2.50			3.65	1.77			6.50	.83
18A										12.03	8.76				
18B										12.08	7.49				7.13
190							2.10			5.73	.69			.60	.58
200							3.00			5.17	2.06			1.40	1.53
21A															
21B										11.50	8.41				7.21
220							1.70			5.25	.23			5.50	5.03
230															
240							6.60			7.60	3.58			6.50	5.03
250															
260										4.49	.19			.20	
270															
280															
290															
300							.80			4.82	1.18				
310										4.97	.38			1.20	.53
330										9.83	6.67				8.55
340							1.90			5.48	2.02			6.40	2.50
350										9.78	7.60				9.20
360										6.73	1.89			2.60	.75
370										8.59	5.65				.54
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

CHEM-OXYGEN DEMAND - MG/L

STA \ DATES	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010		7.4	9.2		8.7		8.1	6.8				12.4		7.4	7.3
020															
030		8.7	8.5		8.2		6.2	8.8	10.1			8.3		11.5	6.6
040		4.0	3.8		4.0		4.7	3.6	5.1			2.5		1.7	.5
050		2.4			1.0		.6	1.5	8.3					.7	.7
060									24.3						
070		.4	.8		2.0		1.1	1.2	1.9						3.8
080		8.1	8.9		6.3		4.2	4.2	8.6			7.4		10.7	10.0
090		1.2	1.1		4.2		.6	3.2	1.1			2.8		.6	
100		4.5	.6		1.1		1.5	1.3	6.8			1.7		.2	
11A					4.1		2.4	4.3	8.0			8.3		4.3	4.2
110		2.4	2.0		2.9		2.3	2.4	3.0			3.1		1.5	
120		1.1	1.6		1.5		2.3	3.4	5.6			2.1		1.6	2.8
130		4.8	2.8		5.6		5.3	3.8	45.4			4.6		2.9	4.5
140									30.2						
150															
16A															
16B															
170		.5	8.0		4.0		6.9	9.2	59.0			10.1		9.6	13.8
18A		47.3			10.2		14.4	18.8	2.6			27.7			
18B			27.3		12.5				23.8			26.0		25.1	11.4
190		19.0	21.5		16.6		16.5	17.6	21.5			12.5		.6	12.8
200		10.8	8.6		7.4		9.4	7.8	6.0			9.9		7.8	5.2
21A									7.3						
21B		9.0	13.5		5.3		4.6	4.1	6.1			8.0		8.1	5.5
220		9.0	10.2		8.8		20.9	8.6	12.1			14.5		8.5	8.6
230															
240		.8	11.6		.5		1.2	2.6	9.4			2.8		1.6	1.5
250															
260		33.8	33.0		32.6		24.2	22.0	25.9			39.1		29.9	21.3
270															
280															
290															
300							2.3	10.4	7.3			4.2		126.0	
310		2.3	5.0		2.2		3.5	3.4	7.6			3.5		2.2	3.1
330		2.9	5.0		6.2		6.8	8.1	10.8			6.5		3.7	6.7
340	7.6		11.8		6.7		10.5	8.9	16.5			8.8		6.7	5.9
350		17.4	15.4		9.4		15.2	18.5	22.0			19.4		15.9	13.5
360		1.1	7.0		.9		3.5	3.2	7.8			4.5		2.4	3.1
370		2.7	3.9		1.4		4.6	3.4	6.0			2.4		2.0	
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont

PH

DATES STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	093081	101281
010				6.4						6.4	7.1		7.1	6.9	6.0
020										5.4					
030				6.5						6.4			7.0	7.0	5.9
040				5.7						2.9	5.2		6.4	5.6	4.7
050				5.6						5.5	6.5		6.7	6.0	5.1
060										5.4					
070				6.1						5.8	6.3		6.7	6.5	5.5
080				6.6						6.7	7.4		7.5	7.3	6.1
090										6.2	6.9		7.0	6.9	5.4
100				6.0						6.0	6.4		7.0	6.0	5.0
11A				6.5						6.6	7.5		7.4	7.1	5.7
110				5.9						5.5	5.9		6.3	6.1	
120				5.3						5.3	5.5		6.3	5.4	4.5
130				5.3						5.0	5.4		5.4	5.4	4.2
140										4.8					
150															
16A															
16B															
170				5.5						5.2	5.8		6.0	5.6	4.7
18A										5.8	7.0				
18B				6.4						6.2	7.0		7.0	7.1	5.4
190				5.6						3.2	5.9		6.1	5.7	4.9
200				6.0						5.4	5.7		5.8	5.5	4.8
21A															
21B				6.5						6.7	7.3		7.1	7.2	5.7
220				5.4						4.8	5.2		5.5	5.5	4.7
230															
240				5.2						4.1	5.3		5.5	5.3	4.3
250															
260				6.4						4.9	5.8		5.8	5.9	5.4
270															
280															
290															
300										5.0	6.6		6.2		5.7
310				5.4						5.1	5.8			5.5	5.5
330				6.4						6.3	6.9		6.8	7.1	6.0
340				5.3						4.9	5.5		5.6	5.7	4.6
350				6.3						6.5	6.8			7.1	6.0
360				5.3						4.9	5.6		5.5	5.5	4.7
370				6.2						6.1	6.6		6.6	6.8	5.9
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

NITRATE - MG/L

STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010		.070	.050	.150	.440		.790	.860		.610		.350	.130	.070	.063
020															
→030		.060	.050	.140	.480		.920	.960	.950	.730		.490	.130	.016	.051
040		.010	.010	.020	.080		.120	.060	.310	.030		.010	.005	.005	.005
050		.030	.020	.020	.020		.030	.010	.007	.020		.010	.020	.015	.015
060									.006						
→070		.050	.040	.070	.040		.030	.010	.030	.030		.070	.020	.023	.015
→080		.010	.010	.030	.070		.170	.220	.210	.170		.040	.065	.035	.005
090		.030	.030		.030		.090	.030	.070	.040		.070	.030	.022	.026
100		.030	.020	.030	.050		.043	.070	.050	.070		.080	.040	.050	.042
→11A			.030	.030	.030		.080	.070	.060	.050		.010	.010	.013	.005
110		.030	.020	.040	.060		.040	.040	.110	.080		.050	.050	.054	.074
→120		.020	.030	.030	.030		.030	.020	.030	.040		.020	.030	.036	.046
130		.005	.010	.010	.010		.010	.010	.010	.030		.010	.005	.010	.005
140									.005						
150															
16A															
16B															
→170		.370	.090	1.300	.220		.022	.510	.120	.290		.280	.140	.200	.132
19A		.020			.130		.011	.010	.001	.020		.005			
18B			.030	.100	.110				.001	.010		.010	.010	.005	.010
190		.020	.010	.040	.120		.012	.190	.060	.030		.010	.010	.022	.018
200		.005	.010	.040	.030		.005	.010	.035	.020		.010	.005	.014	.006
21A									.170						
21B		.010	.020	.020	.080		.016	.170	.170	.140		.030	.010	.005	.022
220		.005	.005	.010	.010		.004	.020	.050	.020		.005	.005	.005	.010
230															
→ 240		.020	.040	.050	.010		.004	.010	.030	.020		.020	.020	.024	.037
250															
→260		.005	.005	.040	.010			.010	.004	.010		.010	.005	.005	.010
270															
280															
290															
300							.030	.010	.390	.700		.020	.005	.014	
→310		.010	.010	.040	.010		.110	.100	.050	.050			.005	.010	.013
330		.090	.070	.080	.070		.130	.140	.150	.100		.007	.090	.110	.040
340	.010		.010	.140	.110		.150	.070	.010	.010		.005	.050	.005	.036
→ 350		.120	.110	.170	.430		.390	.500	.470	.220		.140	.013	.100	.140
→360		.300	.230	.310	.430		.280	.900	.690	.430			.450	.370	.013
370		.010	.100	.020	.010		.005	.010	.010	.010		.010	.005	.010	
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

AMMONIUM ~MG/L

DATES STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010		.05	.05		.05		.05	.05	.05			.05		.05	.05
020															
030		.05	.05		.05		.05	.05	.05			.05		.05	.05
040		.05	.05		.05		.05	.05	.05			.05		.05	.05
050		.05	.05		.05		.05	.05	.05			.05		.05	.05
060									.05						
070		.05	.05		.05		.05	.05	.05			.05		.05	.05
080		.05	.05		.05		.05	.05	.05			.05		.05	.05
090		.05	.05		.05		.05	.05	.05			.05		.05	.05
100		.05	.05		.05		.05	.05	.05			.05		.05	.05
11A			.05		.05		.05	.05	.05			.05		.05	.05
110		.05	.05		.05		.05	.05	.05			.05		.05	.05
120		.05	.05		.05		.05	.05	.05			.05		.05	.05
130		.05	.05		.05		.05	.05	.05			.05		.05	.05
140									.05						
150															
16A															
16B															
170		.05	.05		.05		.50	.05	.05			.05		.05	.05
18A	.05	.05			.05		.50	.05	.05			.05			
18B			.05		.05				.05			.05		.05	.05
190		.05	.05		.05		.50	.05	.05			.05		.05	.05
200		.05	.05		.05		.50	.05	.05			.05		.05	.05
21A									.05						
21B		.05	.05		.05		.50	.05	.05			.05		.05	.05
220	.05	.05	.05		.05		.50	.05	.05			.05		.05	.05
230															
240	.05	.05	.05		.05		.50	.05	.05			.05		.05	.05
250															
→ 260		1.80	.17		.18		2.10	.31	.35			.13		1.00	1.30
270															
280															
290															
300	.05						.05	.05	.05			.10		.40	
310	.05	.05	.05		.05		.05	.05	.05			.05		.05	.05
330		.05	.05		.05		.05	.05	.05			.05		.05	.05
340	.05		.05		.05		.05	.05	.05			.05		.05	.05
350	.05	.05	.05		.05		.05	.05	.05			.05		.05	.05
360	.05	.05	.05		.05		.05	.05	.05			.05		.05	.05
370	.05	.05	.05		.05		.05	.05	.05			.05		.05	
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

IRON -MG/L

DATES / STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010	1.100	1.200	1.200		.430		.360	.300		.330		.420	.790	1.100	.370
020															
030		.390	.520		.420		.170	.190	.140	.110		.230	.230	.220	.320
→040	.370	.360	.320	.270	.260		.140	.220	.170	.300		.340	.320	.380	.270
→050	.050	.100	.060	.470	.100		.050	.030	.130	.050		.050	.050	.050	.050
060									.220						
→070	.050	.050	.100	.030	.100		.050	.050	.050	.050		.050	.050	.050	.050
080		.130	.140		.420		.190	.140	.110	.120		.050	.120	.110	.130
→090	.050	.020	.010		.140		.050	.020	.050	.050		.050	.050	.050	.050
→100	.050	.110	.060	.020	.030		.050	.040	.050	.050		.050	.050	.050	.050
11A			.030		.190		.110	.043	.050	.050		.050	.050	.080	.050
→110	.240	.160	.260	.120	.120		.110	.070	.050	.050		.100	.050	.070	.050
120	.050	.040	.050	.020			.050	.060	.060	.050		.050	.050	.030	.050
130	.400	.120	.060	.070	.150		.140	.170	.750	.240		.250	.150	.180	1.500
140									.120						
150															
16A															
16B															
170	.130	.150	.130	.070	.070		.050	.050	.210	.490		.190	.050	.100	.050
18A	1.500	.700			.170		.050	.130	.160	.330		.300			
18B			.630		.370				.160	.290		.490	.500	.440	.200
→190	.740	.770	.670	.470	.690		.560	.660	.530	.550		.830	.720	.050	.450
200	1.500	1.300	1.000	.120	.300		.210	.250	.100	.060		.300	.690	.990	.130
21A									.060						
21B		.150	.050		.170		.050	.070	.050	.050		.050	.050	.040	.050
220	.350	.290	.170	.140	.190		.160	.220	.210	.260		.340	.210	.240	.270
230															
240	.120	.070	.070	.040	.200		.050	.040	.010	.050		.050	.050	.100	.050
250															
260	12.200	8.100	6.600	8.800	12.200		14.400	1.300	12.600	11.800		13.100	6.600	6.200	4.000
270															
280															
290															
→300	1.300						1.700	1.750	1.900	1.600		2.000	1.100	.420	
310	.420	.290	.400	.300	.550		.360	.390	.360	.240		.320	.160	.280	.190
330		.800	.850	.800	.390		.390	.370	.340	.370		.700	.490	.670	.380
→340	1.700	1.100	1.200	.070	.040		.390	.250	.730	1.100		1.140	.260	1.530	.100
350	.800	.680	.730		.540		.660	.580	.640	.540		.840	.540	.740	.810
360	.120	.140	.140	.170	.060		.340	.170	.150	.060		.050	.050	.070	.190
370	.590	.460	.760		.300		.180	.150	.120	.240		.500	.320	.350	
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX I cont.

PO4 - MG/L

DATES / STA	081180	090980	101380	111280	120980	011381	020981	031081	041481	051281	060981	071781	081081	090981	101281
010		.024	.022		.021		.019	.020	.020			.021		.026	.018
020															
→030		.024	.017		.019		.019	.039	.017			.021		.029	.022
040			.015		.012		.012	.012	.007			.006		.008	.002
050			.013		.020		.013	.010	.029			.003		.007	
060									.007						
→070			.011		.012		.012	.020	.003			.003		.009	
collard →080		.040	.014		.006		.007	.008	.007			.026		.013	.005
093			.006		.048		.009	.010	.005			.002		.005	
100			.017		.007		.022	.014	.007			.007		.007	
clear →114			.006		.007		.037	.011	.006			.011		.016	.005
110			.006		.038		.008	.015	.005			.034		.007	
→120			.005				.005	.008	.002			.004		.007	
130			.007		.007		.003	.006	.016			.009		.007	
140									.008						
153															
16A															
16B															
→170			.015		.009		.005	.072	.010			.074		.007	
18A		.038			.015		.006	.010	.011			.023			
18B			.027		.025				.012			.032		.075	.037
193			.028		.020		.017	.021	.020			.028		.005	.011
200			.016		.029		.028	.028	.010			.031		.007	.011
21A									.007						
21B		.013	.019		.017		.007	.012	.006			.011		.016	.006
220			.008		.003		.006	.009	.008			.033		.007	.002
230															
243			.042		.003		.008	.013	.003			.011		.008	.007
250															
260			.024		.020		.021	.029	.017			.015		.019	.015
270															
280															
290															
300							.012	.052	.008			.012		.710	
310			.025		.003		.008	.008	.011			.013		.003	.005
→330		.018	.011		.008		.008	.013	.011			.007		.028	.010
340			.026		.006		.009	.016	.009			.017		.016	.007
→350		.093	.065		.043		.045	.068	.072			.085		.071	.038
360			.021		.007		.056	.075	.023			.010		.011	.005
370		.028	.015		.004		.007	.012	.012			.013		.036	
380															

TESTING ACCURACY LIMITS: NITRATE - 0.01 MG/L
AMMONIUM - 0.10 MG/L

APPENDIX J. Calculation for Stirred Tank Model of Contaminant Concentraions.

Calculation for Stirred Tank

X mg/l
st. 1 ~~1.47...~~
~~st. 2~~ 28.3148 l/ft³
st. 2 2.77703371 x10⁸ ft³/yr
st. 3 2204622.6 mg/lbs
st. 4

General North Florence Aquifer

5mg/L standard = 141.6mg/ft^3 or

= 3.12 x 10^{-4} lbs/ft^3

with 4.36 feet per year recharge (avg.) = 189921.6 ft^3 of recharge/acre./yr

189921.6 ft^3/acre/yr x 3.12 x 10^{-4} lbs/ft^3/yr = 59.3 lbs/acre/yr

Since .03 mg/L is background and represents 1.2 lbs/acre/yr than 59.3 - 1.2 = 58 lbs/acre/yr of added Nitrate-Nitrogen above background to reach but not exceed 5 mg/L planning standard.

Clear Lake Watershed. 1040 acres of watershed (850 land 190 water)

Annual recharge 6.13 ft. avg. or 2.77 x 10^8 ft^3 total (1040 acres) for each .01mg/L rise in NO_3-N will be added to the system 2.77 x 10^8 x 6.0 x 10^{-7} = 173 lbs/yr. over entire 1040 acres or 8.7 dwelling units. The 0.01mg/L represents the approximate difference between the Clear Sands and Clear Lake currently and therefore can be assumed to be caused by an addition of approximately 170 lbs. of induced NO_3-N. In order to maintain the lake no further NO_3-N can be introduced and so should be held to 170 lbs. or less. 28 lbs

mg → lbs X 2.2046226 x10⁻⁶
l → ft³ .035314667
ft³ → l 28.316847

28.3
* .01mg/l × l/ft³ ÷ mg/lbs * 2.77 x10⁸ = 2204622.6
.283 mg/ft³ lbs/yr

.01 X 2.2046226x10⁻⁶

.0000001 lbs/ft³

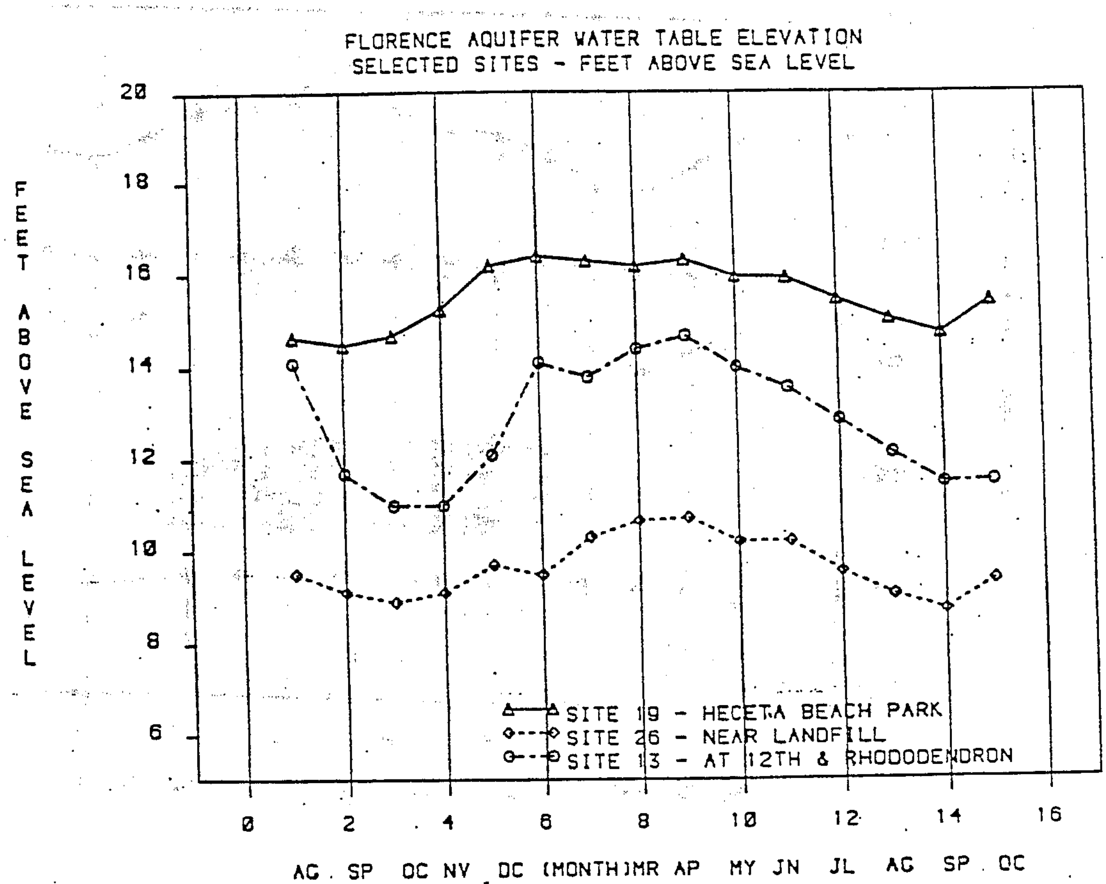
6 x 10⁻⁷ lbs/ft³

.272 mg/ft³

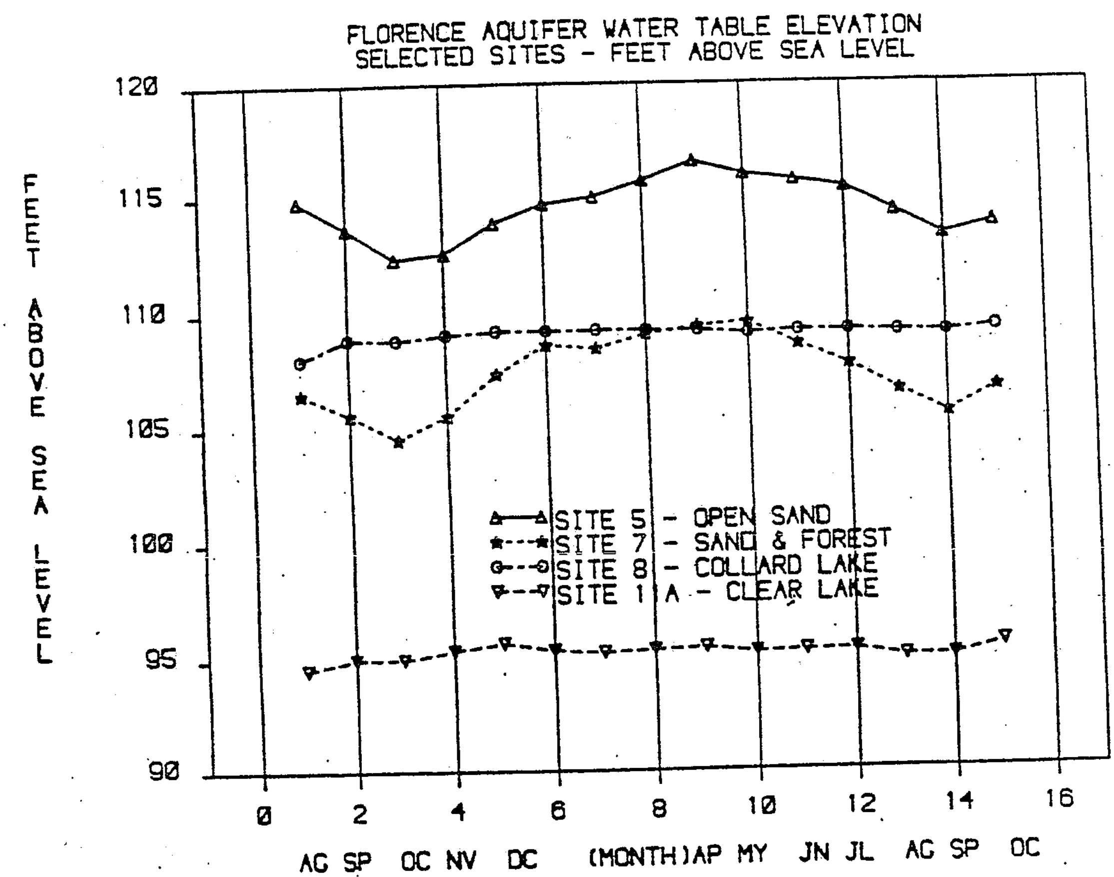
.272 mg / 28.3 l/ft³

.0096
.01 mg/l

APPENDIX K. Graphs of Water Levels During the Study Period at Various Sites on the Aquifer.



APPENDIX K cont



APPENDIX L. Values of Aquifer Thickness, Permeability and Recharge Used in the Digital Model to Simulate Aquifer Response.

TABLE I. Withdrawal Rates (Qx1000 gallons per day)

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	-210	-210	0	0	0	-82	0	0	0	0	0	0	0	0
2	0	-330	-250	-100	-247	-75	-100	0	80	80	-175	0	0	-20	0
3	0	-384	-250	-166	-283	-150	-100	0	-138	-139	-217	-217	-200	-278	-293
4	0	-285	-150	-140	-231	-150	-117	-100	-100	-100	-162	-209	-241	-211	-255
5	0	-291	-250	-276	-207	-134	-117	-160	-162	-150	-150	-196	-241	-223	-286
6	0	-249	-223	-293	-160	-118	-137	-80	-87	-109	-140	-192	-203	850	850
7	0	-235	-100	-250	-139	-100	-108	-90	-90	-93	-111	-167	775	775	775
8	0	-235	-100	-164	-155	-101	-111	-90	-90	-93	-111	-169	-151	-130	0
9	0	0	-100	-171	-150	-125	-113	-80	-90	-97	-133	-169	-143	-138	0
10	0	0	-223	-200	-150	-125	-100	-100	-95	-209	-140	-161	-159	-158	0
11	0	0	-255	-219	-200	-125	-119	-100	-95	-225	-149	-173	-172	-194	0
12	0	0	0	-252	-200	-134	-208	-100	-95	-132	-200	-175	-183	-194	0
13	0	0	0	-316	-199	-134	-108	-100	-100	-132	-183	-175	-170	-194	0
14	0	0	0	-247	-186	-134	-108	-111	-113	-125	-191	-175	-183	-194	0
15	0	0	0	-219	-199	-134	-63	-41	-86	-130	-144	0	-50	-103	0
16	0	0	0	-99	-186	-102	-63	-74	-122	0	-46	0	0	0	0
17	0	0	0	-58	0	0	-63	-33	-24	0	0	0	0	0	0
18	0	0	0	0	0	0	-15	0	0	0	0	0	0	0	0

APPENDIX L cont.

TABLE II. North-South Permeability (GPD/SQ.FT.)

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	600	450	600	600	450	750	750	750	750	750	450	0	0	0	0
2	500	450	600	600	600	600	750	600	450	450	450	450	600	600	0
3	350	600	750	750	750	750	600	600	600	750	450	750	750	600	0
4	525	750	450	600	750	600	450	250	350	450	750	750	750	600	0
5	350	750	450	600	750	600	600	450	450	600	600	600	600	600	0
6	350	750	450	600	750	600	400	350	350	600	600	450	600	1E4	1E4
7	750	750	750	400	600	600	400	750	750	750	600	600	1E4	1E4	1E4
8	750	500	750	500	750	450	400	750	750	750	450	600	450	600	0
9	0	750	750	400	750	750	450	750	750	750	450	600	450	600	0
10	0	750	750	600	750	750	450	750	750	500	450	450	450	600	0
11	0	750	600	350	750	750	350	750	750	750	750	400	450	0	0
12	0	0	600	350	750	750	600	750	750	500	600	600	400	400	0
13	0	0	600	350	750	750	600	750	750	750	500	750	750	750	0
14	0	0	600	350	600	750	600	750	750	750	750	750	750	750	600
15	0	0	600	600	400	600	600	750	750	750	500	750	750	750	600
16	0	0	600	750	600	600	600	750	750	750	750	750	750	0	0
17	0	0	600	750	600	450	600	750	750	600	600	0	0	0	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX L cont.

TABLE III. East-West Permeability (GPD/Sq.Ft.)

	Columns														
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	600	600	600	600	600	600	600	600	600	600	450	0	0	0	0
2	500	450	450	450	600	750	600	600	600	600	600	600	600	600	0
3	350	600	750	600	450	750	600	600	600	600	600	600	600	600	0
4	525	750	600	600	600	600	600	600	600	600	750	600	600	600	0
5	350	750	450	600	600	450	250	450	450	600	600	600	600	600	0
6	350	750	350	400	500	400	400	600	600	600	600	600	600	1E4	1E4
7	750	750	350	600	500	400	400	600	750	750	600	600	1E4	1E4	1E4
8	750	750	.350	750	450	400	400	600	750	750	450	600	450	600	0
9	0	750	450	600	750	450	450	600	750	750	450	600	450	600	0
10	0	750	450	600	750	450	450	600	750	500	450	450	450	600	0
11	0	750	600	600	750	450	600	600	750	750	750	400	450	0	0
12	0	0	600	600	750	450	600	600	750	500	400	600	400	400	0
13	0	0	750	450	750	750	600	600	750	750	750	750	750	750	0
14	0	0	750	450	600	750	600	600	750	750	750	750	750	750	600
15	0	0	750	400	400	600	600	600	750	750	500	600	750	750	600
16	0	0	750	750	450	600	600	600	750	600	750	600	600	0	0
17	0	0	750	750	600	600	600	600	750	600	600	0	0	0	0
18	0	0	0	0	600	600	600	0	0	0	0	0	0	0	0

APPENDIX L cont.

TABLE IV. Aquifer Thickness (Feet)

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	170	176	77	86	81	85	83	113	160	69	69	43	62	94	12
2	145	136	94	40	42	45	62	123	160	40	139	90	22	5	71
3	145	65	83	70	48	53	79	129	117	109	141	151	130	22	26
4	145	62	135	60	36	40	60	50	57	60	55	123	62	50	14
5	138	62	59	70	50	13	44	29	28	24	31	89	75	25	10
6	119	51	48	80	55	50	14	8	22	45	56	74	177	62	35
7	106	43	61	70	64	73	39	57	196	69	71	118	62	62	35
8	89	39	58	80	95	85	60	74	65	67	68	58	27	48	17
9	0	20	57	120	188	70	65	67	69	71	63	44	22	20	17
10	0	25	41	115	181	59	64	85	128	68	145	119	149	36	9
11	0	20	26	110	174	166	81	168	146	122	117	141	165	48	10
12	0	0	20	53	167	111	54	62	134	45	106	140	120	6	5
13	0	0	20	65	65	51	48	97	142	140	119	145	113	12	3
14	0	0	20	62	62	44	45	49	136	132	113	140	130	43	0
15	0	0	20	62	66	53	39	45	100	117	99	134	129	45	0
16	0	0	20	57	60	49	56	88	49	42	100	120	120	40	0
17	0	0	10	33	53	48	54	71	40	33	0	0	0	0	0
18	0	0	0	0	10	20	20	20	0	0	0	0	0	0	0

APPENDIX M. Memo Indicating Population Projections for the North Florence Area as Prepared for the Study by County Planning Staff.

MEMORANDUM

lane county

TO Gerrit Rosenthal

FROM Janet McKay

SUBJECT Population projections Florence area DATE December 2, 1981

Population Projections for year 2000

Projections for the city of Florence and the unincorporated area in the Urban Growth Boundary come from the Florence City Planner. These figures are based on a straight line extrapolation from growth during the period 1970-1978. It can be assumed fairly comparable to the worst case projection based on zoning which was the method used for the areas outside the UGB and the two additional areas requested - Clear Lake watershed and the city well area- since he started with population projections, then modified the acreage within the UGB to correspond.

In the area outside the UGB and the two split out areas mentioned above, the figures were derived from a maximum buildout based on the current zoning multiplied by 2.6 persons per residence, the projected average population for unincorporated Lane County in the year 2000 (personal communication, Jim Carlson, L-COG, December 1, 1981).

Several assumptions have been made for these projections:

1) Zero population projection for M-2, M-3, FM, NR, and PR zones.

2) Commercial zones were evaluated as follows: C-3 zone allows multiple family dwellings at 3000 square feet per unit; C-2 assumption at one residence per acre since no guidance in the ordinance; C-1 assumed to be a minimum lot size of 18,000 square feet when sewers unavailable; CT-minimum 5 acres as per ordinance; CA assumption at one residence per acre since no guidance in the ordinance.

3) RA/U- minimum lot size assumed to be 10 acres when outside the UGB, 18,000 square feet when inside the UGB.

Projection to Year 2000 for:

Present City Limits: 8594
Unincorporated UGB area: 3134
Outside UGB in study area: 1830

City Well area: 1024
Clear Lake watershed: 745

cc: Roy Burns
Ralph Christensen

Glossary

Aquifer: A geologically mappable rock or alluvial formation capabable of storing and transmitting water in usable quantities.

Blow-out: A rapid fingerlike migration of sand through vegetated areas.

Carbon 14 Analysis: An age dating process involving the radioactive isotope carbon 14. This process can date items between 500 and 50,000 years generally and is based on the stopping of carbon exchange in living systems at death and the subsequent slow decay of carbon 14.

Deflation Plain: A flat ground surface formed at or near the winter water table by wind action. Usually vegetation covered.

Dike: An intrusion of lava that cuts across the bedding of country rock.

Dilatent: The ability to expand and lose structure under saturated conditions and vibration or shock energy.

Float: Loose pieces of bed rock found on the surface of the ground.

Head: Level to which water will rise in a well or peizometer.

Interbedded: Alternating thin layers of differing rock types.

Limonitic: Material derived from iron oxides. Often as a cement or weathering residual.

On-Site-Disposal: The treatment and environmental disposal of sewage waste at the site of generation.

Permeability: The ability of a rock unit or formation to transmit water through it by way of interconnected pore space.

Piezometer: A device (usually similar to a well) installed into an aquifer to measure head. Pillow Lava: Lavas erupted beneath water that have a characteristic globular or "pillow like" structure.

Pore Volume: The volume of rock that is open space. Expressed as a %.

Recharge: The amount of precipitation that will reach the water table and not run off, evaporate or be transpired by plants.

Reflection: The bouncing of waves off of the interface between materials of differing character.

Refraction: The bending of waves (sound or light) as it passes from one medium to another or through differing densities of materials.

Storage Coefficient: The percentage of a rock volume that is water and that will run out under gravity.

Tritium Analysis: An analysis for the hydrogen 3 isotope. The analysis relies on the sudden increase of tritium caused by the atmospheric testing of nuclear weapons from the early 1950's through the late 1960's.

Volcanoclastic: Particles produced by volcanic action such as ash, fine dust, rock fragments, cinders, pumice and bombs.