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UNITED STATES GEOLOGICAL SURVEY

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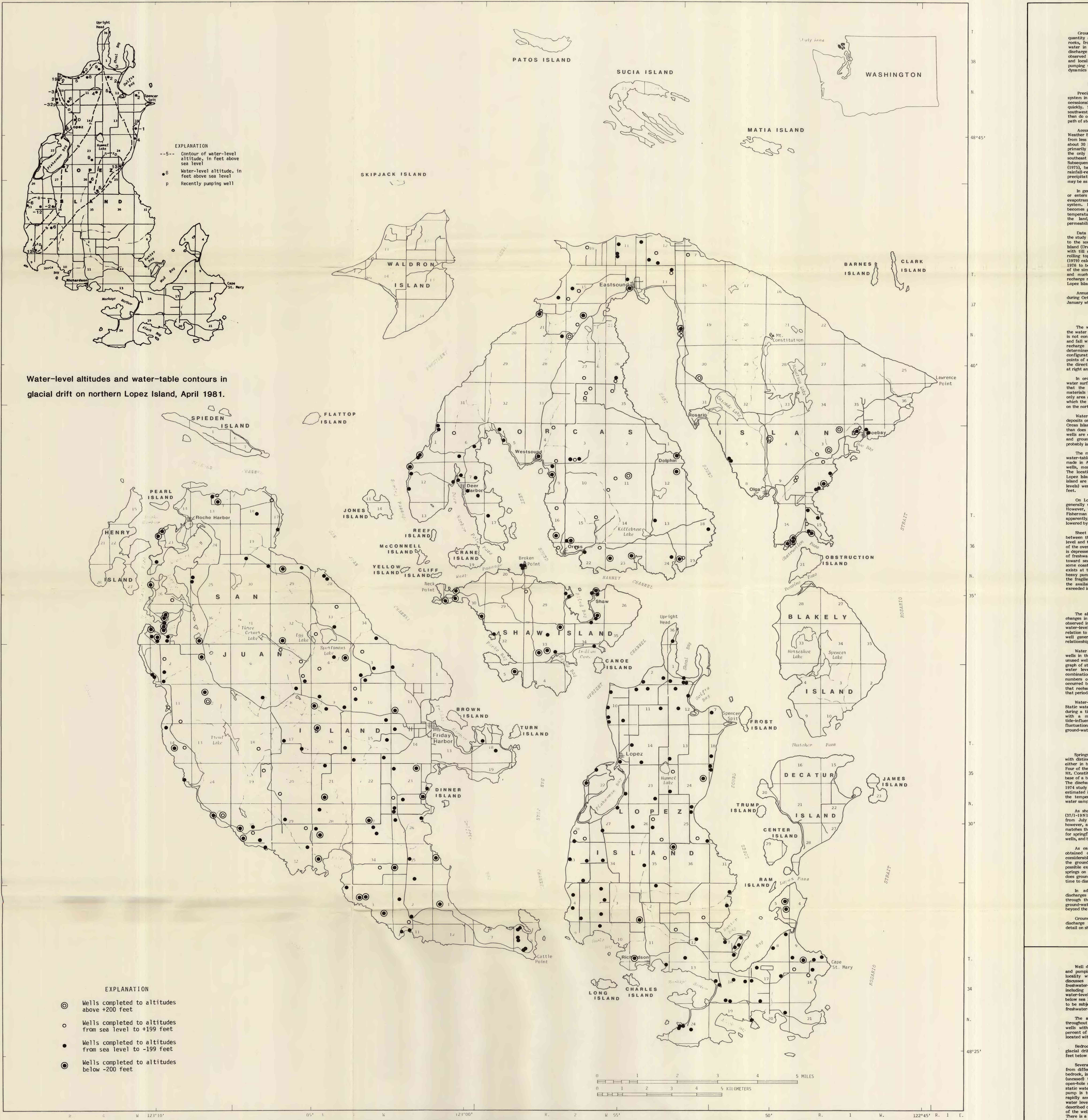
San Juan County Board of Commissioners

WATER-RESOURCES INVESTIGATIONS
REPORT 83-4019 SHEET 4 OF 12



Water-level altitudes and water-table contours in glacial drift on northern Lopez Island, April 1981.

Base from U.S. Geological Survey
Orcas Island, Richardson 1:62,500, 1957,
Sucia Island, 1973, Stuart Island, 1953,
Waldron Island, 1954, Roche Harbor, 1954,
Friday Harbor, 1954, False Bay, 1:24,000,
1954.

OCCURRENCE, QUALITY, AND USE OF GROUND WATER IN ORCAS, SAN JUAN, LOPEZ, AND SHAW ISLANDS, SAN JUAN COUNTY, WASHINGTON

Ground-Water Flow System/Well Depths

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INTRODUCTION

Ground water is not a static resource that remains constant in place, quantity and quality. Instead, it is in constant movement through the rocks, from areas of recharge to areas of discharge. The quantity of water in the ground (called storage) will increase if recharge exceeds discharge and decrease if discharge exceeds recharge. This can be observed in the seasonal and long-term fluctuations in the water table and local "cones of depression" in the water table that form around pumping wells. The following discussion provides an explanation of the dynamics operating within the ground-water system.

PRECIPITATION AND GROUND-WATER RECHARGE

Precipitation is the only source of recharge to the ground-water system in the San Juan Islands and occurs mostly as rain, but some occurs occasionally as snow at the higher elevations, where it usually melts quickly. Situated in the "rain-shadow" of the Olympic Mountains to the southwest, the San Juan Islands receive considerably less precipitation than do other areas of western Washington that are more directly in the path of storm clouds moving inland from the Pacific Ocean.

According to generalized interpretations shown on a map by the U.S. Weather Bureau (1965), mean annual precipitation over the islands ranges from less than 20 inches near sea level in the southern part of the area to about 30 inches in the northern part. These interpretations were based primarily on data from weather stations outside the study area and from the only long-term weather station in the islands, Olga 2SE (2 miles southeast of Olga), where rainfall data have been collected since 1890. Subsequent calculations by the Washington Department of Ecology (1975), based on records that include data from additional unofficial rainfall-records sites in the islands, along with calculations of precipitation from estimated runoff, suggest that annual precipitation may be as much as 45 inches in the Mount Constitution area.

In general, precipitation either runs off over the surface to streams or enters the soil. The part that enters the soil is either lost to evapotranspiration or leaks downward to recharge the ground-water system. Factors determining the yearly amount of precipitation that becomes ground-water recharge include distribution of precipitation, air temperature, amount of sunlight, amount and type of vegetation, slope of the land, moisture-holding capacity of the soils, and vertical permeability of the material above the aquifers.

Data are insufficient to determine ground-water recharge in most of the study area. However, recharge has been studied in an adjacent area to the southeast, the Swinomish Indian Reservation, located on Fidalgo Island (Drost 1979). The reservation is a remnant of a glacial drift plain with till at the land surface. It is heavily forested and has a gentle, rolling topography; altitudes range from sea level to 330 feet. Drost (1979) calculated the rate of ground-water recharge on the reservation in 1976 to be approximately one-third of the total precipitation. Because of the similarity of conditions between the Swinomish Indian Reservation and much of Lopez Island (where glacial drift predominates), this recharge rate may be useful as a rough estimate for forested portions of Lopez Island.

Annual ground-water recharge probably takes place almost entirely during October through April, most of it occurring in November through January when precipitation is greatest and evapotranspiration is low.

GROUND-WATER LEVELS

The water table is the surface in a ground-water body at which the water pressure is equal to atmospheric pressure; that is, the water is not confined beneath poorly permeable materials and is free to rise and fall with atmospheric pressure and with increases and decreases in recharge by precipitation. The position of the water table is determined by the static (nonpumping) water levels in wells, and its configuration can be represented on a map by contour lines that join points of equal altitude. A water-level-contour map, in turn, indicates the direction of ground-water movement, which is generally downslope at right angles to the contour lines (fig. 1).

In order to be contoured, water-level data should represent the water surface in a single, continuous, unconfined aquifer. This means that the wells must be in hydraulic connection—that is, in rock materials that allow movement of water throughout the aquifer. The only area among the study islands with available water-level data from which the water table could be mapped is the broad glacial-drift area on the northern half of Lopez Island.

Water-table conditions generally do not exist in the glacial-drift deposits on the south end of Lopez Island or in the Eastsound area of Orcas Island. The drift in these areas contains more fine silt and clay than does the drift in the northern part of Lopez Island, and artesian wells are common. Because bedrock predominates in the other islands and ground water generally occurs in fractures (sheet 2), there probably is no areally extensive hydraulic connection between wells.

The map of Lopez Island on sheet 4 shows water-level data and water-table contours interpreted from water-level measurements made in April 1981. Measurements were made in approximately 30 wells, most of which are used for single-family domestic purposes. The locations of the water-level contours on the northern half of Lopez Island are approximate. Data points in the central part of the island are sparse, and the altitudes of wells (and therefore of water levels) were estimated from topographic maps to an accuracy of ±10 feet.

On Lopez Island the water table has a very low gradient and is generally within the range from sea level to an altitude of 20 feet. However, two areas, one to the north and the other to the south of Fisherman Bay, have water-level altitudes well below sea level; apparently, the water table there was at or near sea level but has been lowered by heavy pumping.

Sheet 7 describes seawater intrusion and discusses the relation between the position of the freshwater-seawater interface below sea level and the altitude of the water table above sea level. The weight of the overlying freshwater is the major mechanism by which seawater is depressed below sea level in the ground-water system. If the volume of freshwater is diminished, the seawater will move inland and upward toward sea level. Seawater intrusion is occurring in drift wells at some coastal locations around Lopez Island (sheet 7), and a correlation exists at the north end of the island between seawater intrusion and heavy pumping (sheet 11). Taken together, these facts indicate that the fragile balance between the rates and distribution of pumpage and the available recharge of the ground-water body has already been exceeded in some areas.

WATER-LEVEL FLUCTUATIONS

The altitude of the water table fluctuates with time, indicating changes in the relative rates of recharge and discharge. This can be observed in the fluctuations of water levels in wells. Figure 2 shows water-level fluctuations in a glacial-drift well on Lopez Island in relation to monthly precipitation at Olga 2SE. Water-level rises in the well generally follow periods of high precipitation, illustrating the relationship between precipitation, recharge, and water-level changes.

Water levels were measured monthly from spring to fall 1981 at wells in the observation network (sheet 1). Three of these wells are unused wells, and a fourth had very low water use in 1981. Figure 3, a graph of static water-level fluctuations in these four wells, shows that water levels generally decline from spring to fall because of a combination of low recharge and heavy pumpage attributed to large numbers of tourists and seasonal residents. Water-level rises that occurred between mid-September and early November 1981 indicate that recharge to the ground-water system exceeded discharge during that period.

Water-level fluctuations also occur in response to tidal changes. Static water levels in the wells represented in figure 3 were monitored during a tidal change; three of these wells showed definite responses, with a maximum fluctuation of four-tenths of a foot. These tide-influenced fluctuations are superimposed on the longer term fluctuations that are related to changes in the relative rates of ground-water recharge and discharge.

SPRINGS AND DISCHARGE

Springs that were visited for the purpose of this study include five with distinct points of noticeable year-round discharge from hillsides, either in bedrock or glacial drift. (See locations on map, sheet 2.) Four of the springs issue from bedrock fractures on the lower slopes of Mt. Constitution on Orcas Island, and one (34/3-12G1s) issues from the base of a bluff of sand and gravel on the south end of San Juan Island. The discharges of the five springs, including those measured during a 1974 study by the Washington Department of Ecology (1975) and those estimated in May and August 1981, are given in table 1. Included are the temperatures and specific-conductance values determined from water samples collected during the visits in May 1981.

As shown in figure 4, the measured discharges of Keys Spring (37/1-19N1s) during the period July-December 1974 decreased steadily from July through September. Late December data are lacking, however, and it is not possible to state that an increase in springflow matches the increase in rainfall to winter levels (fig. 4). It is common for springflow to correlate with fluctuations of water levels in nearby wells, and both correlate with recharge from precipitation.

As can be deduced from the few specific-conductance values obtained during the present (1981) study, the spring water is considerably lower in concentrations of total dissolved solids than is the ground water from most wells, as discussed in sheet 6. One possible explanation for this difference is that water issuing from the springs on the islands has a shorter residence time in the rocks than does ground water produced from most wells, and therefore it has less time to dissolve soluble minerals.

In addition to spring discharge, the ground-water system discharges water as seepage to streams (base flow) and as seepage through the sea floor just seaward of the shoreline. Estimation of ground-water discharge through the sea floor around the islands is beyond the scope of this report.

Ground-water withdrawals by wells are another important type of discharge from the natural system. Pumpage is discussed in more detail on sheets 10 and 11.

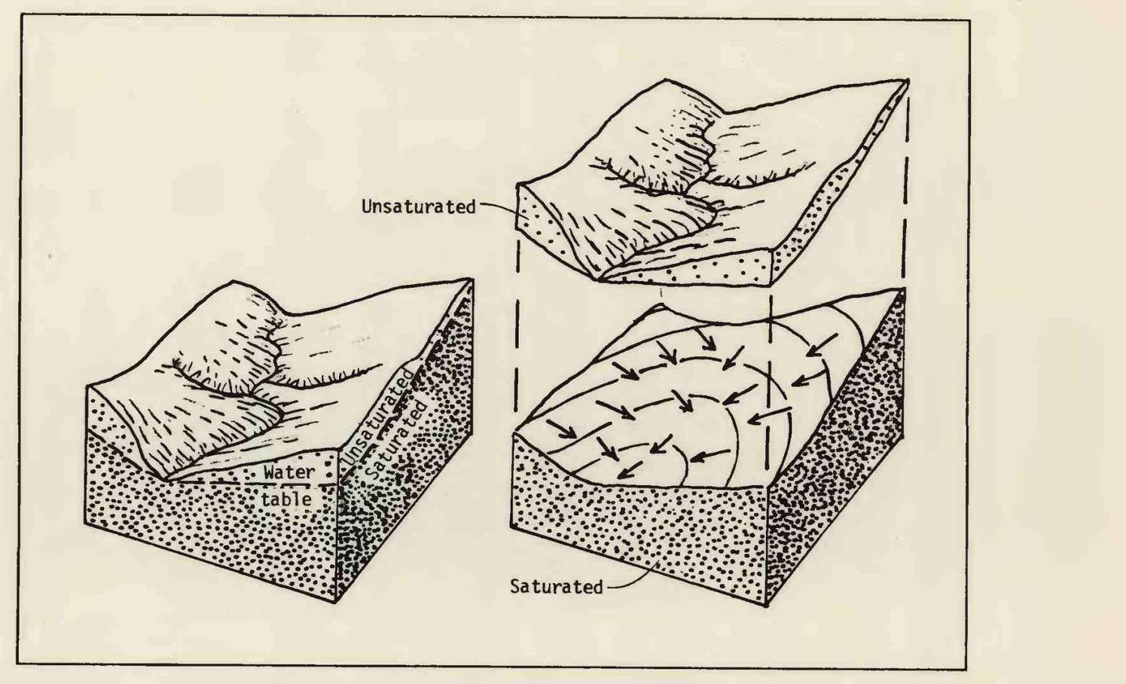

Figure 1. Generalized relationship of water table to land surface in areas underlain by glacial drift. Contours connect points of equal altitude on water table, and arrows indicate direction of ground-water flow.

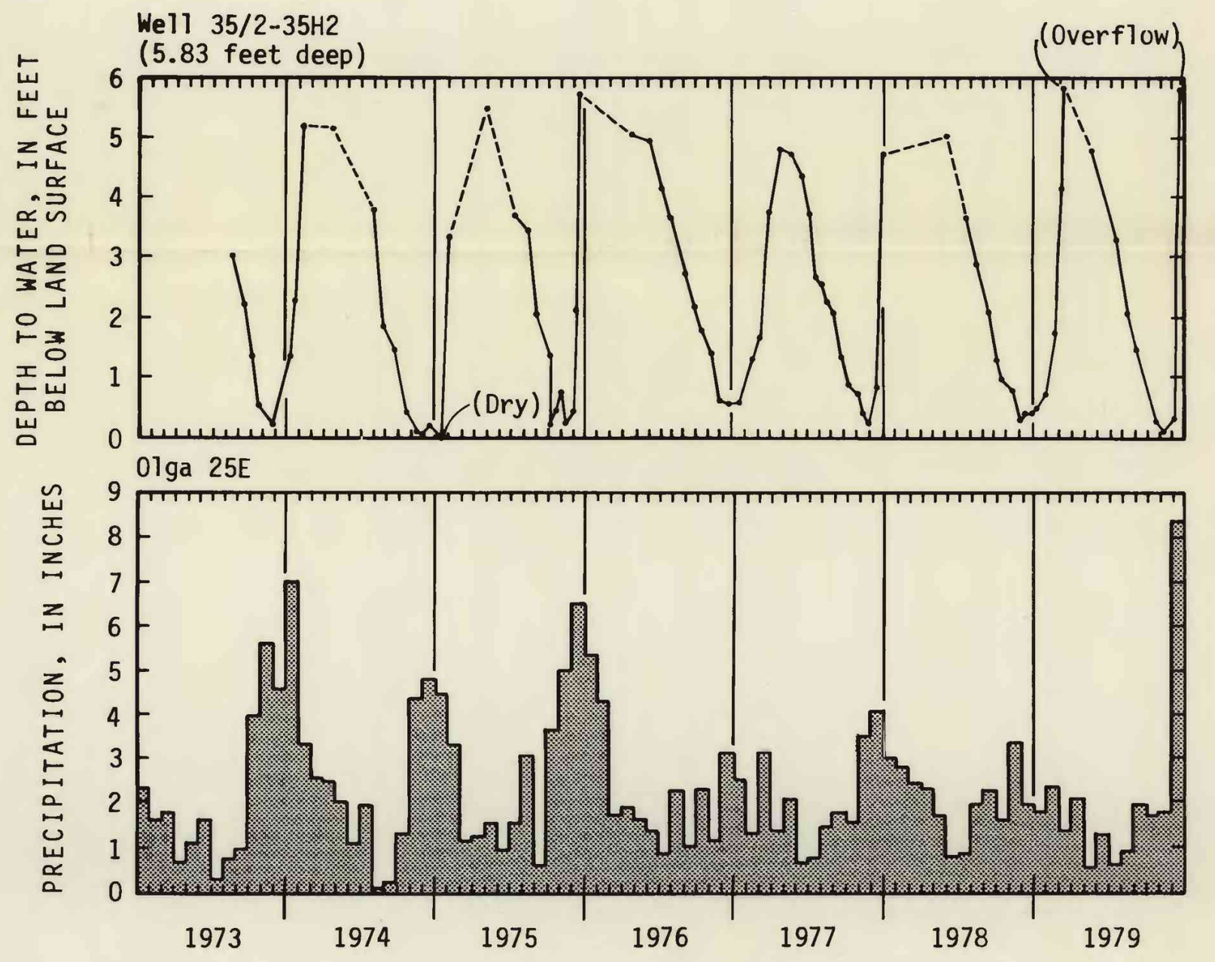

Figure 2. Monthly precipitation at Olga 2SE and water-level fluctuations in shallow drift well 35/2-35H2 during 1973-79. Dashed lines indicate intervals of greater than a month between water-level measurements.

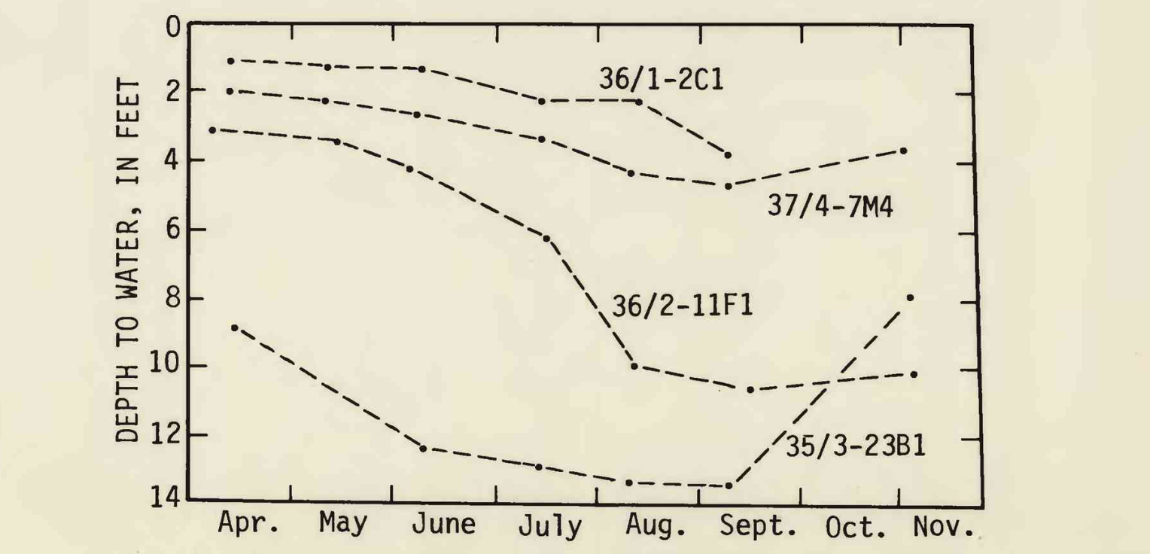

Figure 3. Monthly water-level fluctuations in selected wells, April-November 1981.

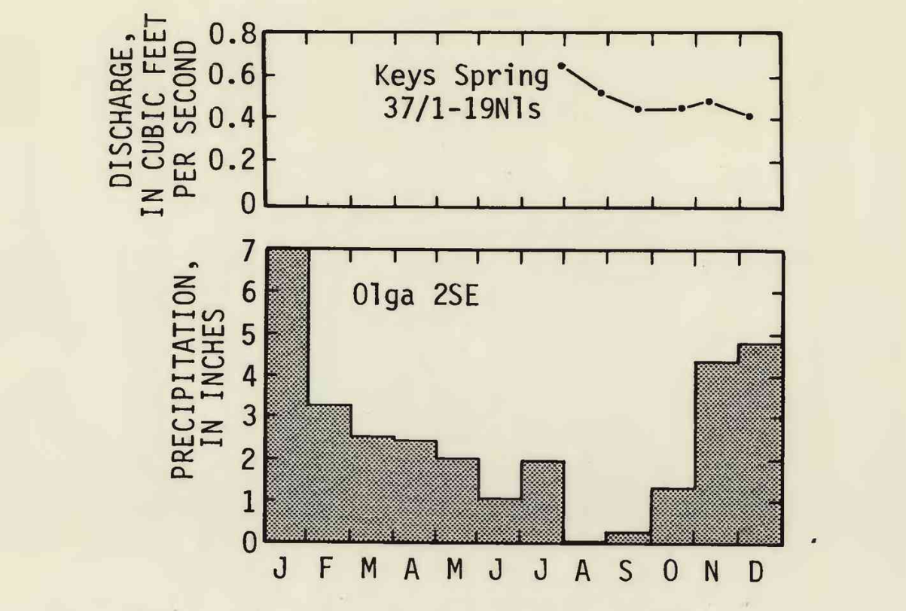

Figure 4. Discharges of Keys Spring 37/1-19N1s during July-December 1974, and monthly precipitation at Olga 2SE during 1974.

TABLE 1.--Data obtained at five perennial springs, San Juan County

Island	Spring number	Altitude above sea level (ft)	Spring zone	Use	Discharge (ft^3/s)	Specific conductance (mho/cm)	Temperature (°F)	Date
San Juan	34/3-12G1s	20	Brushy area at base of beach hillside (sand, gravel)	Not used	0.789	--	--	7-18-74
					^{e}.02	300	47	5- 8-81
					^{e}.02	--	--	8-26-81
Orcas	37/1-19N1s	200	Fractures in bedrock hillside	2 homes, fish propagation	.657	--	--	7-29-74
					.526	--	--	8-27-74
					.452	--	--	9-23-74
					.455	--	--	10-23-74
					.490	--	--	11-12-74
					.408	--	--	12-10-74
					^{e}.75	274	--	5- 5-81
					^{e}.80	--	--	8-25-81
	37/1-19Q1s	900	Bedrock ravine	Fish propagation	^{e}.75	220	40	5- 5-81
					^{e}.10	--	--	8-25-81
					--	195	--	9- 9-81
	37/1-32C1s	650	Bedrock (marshy streambed)	State Park supply	^{e}2.	203	42	5- 5-81
					^{e}.04	--	--	8-25-81
	37/1-32D1s	540	Bedrock ravine	Not used	^{e}.80	210	40	5- 5-81
					^{e}.15	--	--	8-25-81

^{e} estimated.

WELL DEPTHS

Well depth, the altitude at which water enters a well, and static and pumping water levels are very important considerations in a locality where seawater intrusion is a potential threat. Sheet 7 discusses seawater intrusion and the location of the freshwater-seawater interface as a function of several related factors, including aquifer permeability, recharge and discharge rates, water-levels, and water-level fluctuations. Wells drilled to depths far below sea level and located near the shoreline would have a tendency to be subject to seawater intrusion because of their proximity to the freshwater-seawater interface (sheet 7, fig. 2).

The altitude at which wells are open to the aquifer varies throughout the study area, as shown on the accompanying map. Most wells withdraw water from below sea level, and approximately 80 percent of the wells that extend 200 feet or more below sea level are located within half a mile of the coast.

Bedrock wells tend to be completed deeper than wells drilled into glacial drift. The mean well-bottom altitude of bedrock wells is 123 feet below sea level, and of drift wells is 3 feet above sea level.

Several examples of typical wells in the county that obtain water from different altitudes are shown in figure 5. Well A, drilled into bedrock, is cased through the upper few feet of drift, then is open hole (uncased) to the bottom. Water enters the well along the entire open-hole section from fractures both above and below sea level. The static water level in the well is near the top of the well, but when the pump is turned on and water is withdrawn, the water level drops rapidly and can eventually fall below sea level. The rapid drop in water level relates to the low specific capacities of bedrock wells, as described on sheet 5. The pump has been placed just above the bottom of the well to make the best use of water storage in the well column. There is a potential for seawater intrusion into well A because of the large amount of drawdown during pumping (which allows the interface to migrate upward) and the greater depth below sea level at which water enters the well. If the fracturing extends to the seawater and the water level in the well remains below sea level over an extended period of time, seawater intrusion will occur.

Well B, drilled into glacial drift, is cased its entire depth except for a 5-foot length of screen at the bottom. Water enters the well through the screen, which has been placed below sea level. The static water level in the well and the pumping level are similar due to a high specific capacity (sheet 5), and both are above sea level. The pump in this well has been placed above sea level. Well C is the same as well B except the well bottom and entry point of water into well C is above sea level.

The potential exists for seawater intrusion into both wells B and C. Well B obtains water from the screened interval located below sea level, regardless of where the pump is placed. Well C, although it is entirely above sea level, could potentially draw brackish water from the zone of diffusion between freshwater and seawater (sheet 7).

The above paragraphs discuss seawater intrusion in relation to well depth, specific capacity and pumping water levels; however, seawater intrusion is a function of several other factors as well, such as well location (distance from shore), aquifer extent and thickness, and relative rates of recharge and discharge.

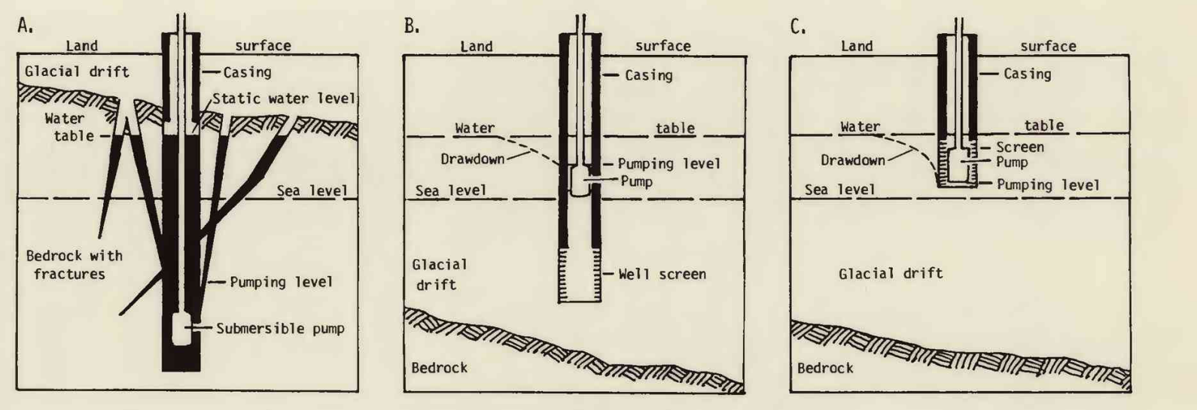

Figure 5. Examples of typical construction and completion features of wells tapping bedrock and glacial drift materials at different depths relative to sea level, San Juan County.