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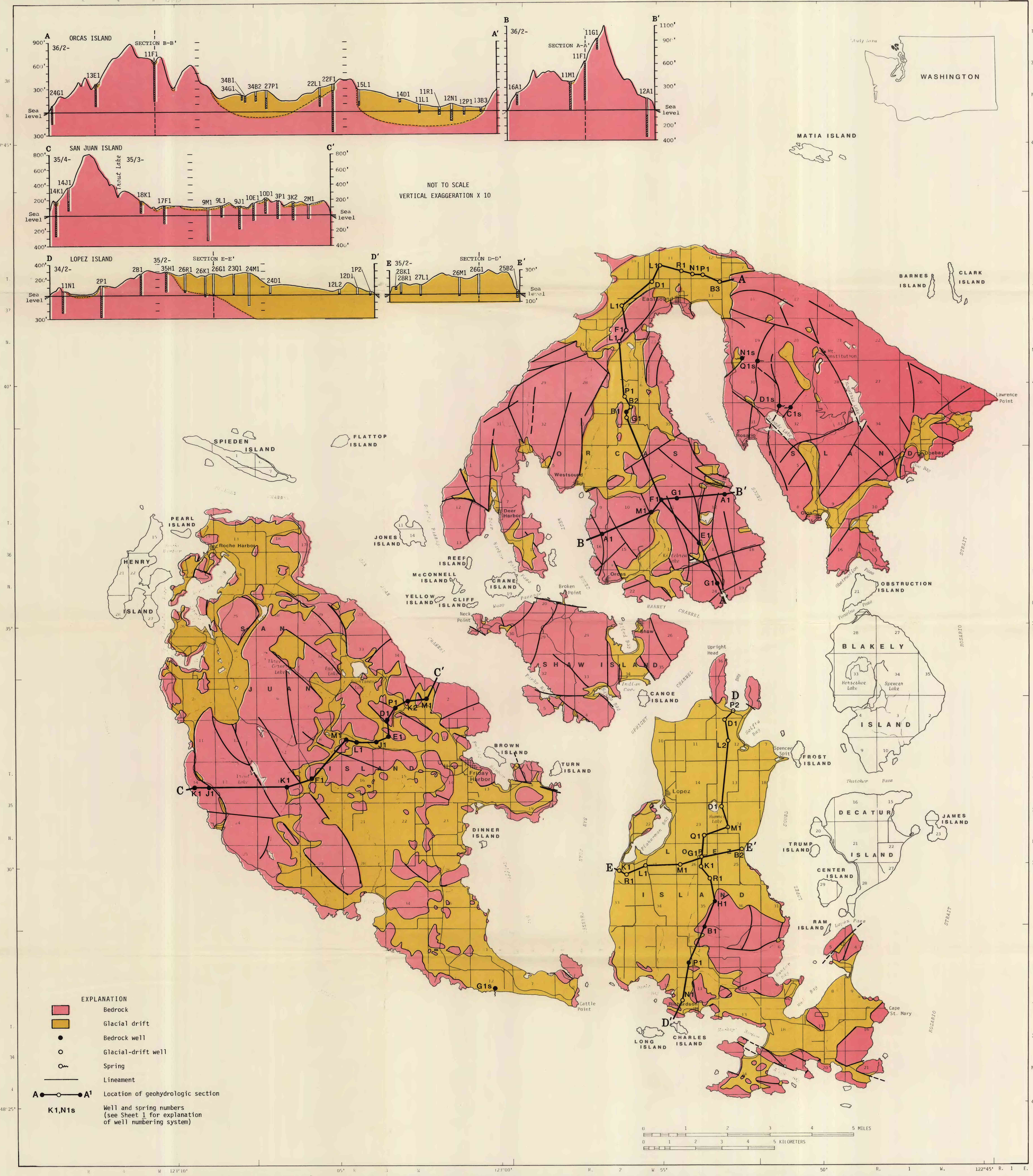

Base from U.S. Geological Survey
Orcas Island, Richardson 1:62:500, 1957,
Sucia Island, 1973, Stuart Island, 1953,
Waldron Island, 1954, Roche Harbor, 1954,
Friday Harbor, 1954, False Bay, 1:24,000,
1954.

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

Generalized Geology and Geohydrologic Conditions

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INTRODUCTION

An understanding of ground water in the San Juan Islands requires an understanding of the islands' geologic framework and the quantity, source, and manner of water movement through the hydrologic system. These factors involve a knowledge of (1) the types, configuration, and water-bearing and water-transmission characteristics of rock materials underlying the area; (2) the recharge of the aquifers underlying the islands; (3) the general nature of ground-water movement through the system; and (4) the discharge from the system.

GENERALIZED GEOLOGY

The San Juan Islands are geologically a part of an ancient mountain system that at one time in the distant past extended northwesterly through what is now the northern Cascade Range and Vancouver Island. The original mountain range was affected by a north-south structural deformation that formed the uplifts of the Coast and Cascade Ranges and the intervening downwarp of the Puget Trough. These were subsequently altered by, or subjected to, glacial erosion as thick ice sheets moved southward from Canada during the Pleistocene ice age. The San Juan Islands retain a rugged topography characterized by abrupt sea cliffs and many offshore islets.

The islands are composed of a complex of consolidated sedimentary, igneous, and metamorphic rocks of Ordovician to Tertiary age, overlain by unconsolidated glacial deposits (glacial drift) and some alluvium of Quaternary age. The older rocks include sandstone, shale, siltstone, conglomerate, chert, limestone, greenschist, quartzite, basalt, gabbro, and diorite. In most places these rocks (referred to here as bedrock) have been subjected to much deformation, and locally they are characterized by joint and fracture systems.

The glacial drift comprises unconsolidated deposits of sand, gravel, silt, clay, and till. Although bedrock predominates at or near land surface in much of the islands, the drift occupies small pockets and depressions in the bedrock surface. However, in a few broad, lowland areas the drift may be several hundred feet thick, as in the central part of Lopez Island and the Eastsound isthmus area of Orcas Island.

The accompanying geologic map has been generalized from that of the Washington Department of Ecology (1975) to the extent of grouping all consolidated rocks under the category of bedrock and all unconsolidated deposits as glacial drift. The areal distribution of these rock materials as shown on the map may not agree precisely with the type of rock reported in drillers' records; local pockets of drift may occur where bedrock is shown on the map, or bedrock may extend into areas shown as drift.

THE HYDROLOGIC CYCLE

The hydrologic cycle (fig. 1) is the perpetually repeating pattern of water movement as it circulates through the natural system. It includes precipitation as rain or snow, the source of all freshwater. Part of the precipitation on the land surface runs off rapidly to streams and lakes, part soaks into the ground, and part is evaporated directly back to the atmosphere from the soil and from streams and lakes. Part of the water entering the soil is drawn up by plants and returns to the atmosphere by transpiration from leaves; the combination of evaporation and transpiration is called evapotranspiration. Part of the water that enters the ground continues to percolate downward below the root zone to the aquifer to become ground water. In turn, this ground water eventually returns to the surface and to the sea by seepage to springs, lakes, and streams.

THE PRINCIPAL AQUIFERS

Ground water in the San Juan Islands occurs in both bedrock and glacial drift. The general areal distribution of these rock materials is shown on the accompanying map, and their relationship is shown diagrammatically in figure 2. Because of the great heterogeneity and complexity of the bedrock units, and the inconsistency in terminology among well drillers in describing the materials penetrated, it was not considered possible for the purposes of this study to differentiate the individual types of bedrock yielding water to wells. The wells are, therefore, defined simply as bedrock wells (those tapping water in bedrock) and drift wells (those obtaining water from the glacial drift). A few wells obtain water from both the bedrock and the drift—usually through screened or perforated sections of the casing penetrating the drift and through open (uncased) holes in the bedrock, as shown in figure 2.

The manner of occurrence of ground water in bedrock and glacial drift differs greatly, and bedrock wells provide considerably smaller yields than do drift wells. Except for central Lopez Island and the Eastsound area of Orcas Island, most wells in the area studied obtain water from bedrock.

Glacial drift

Water in the glacial drift occurs in the spaces between rock particles (fig. 2) and, because these spaces are for the most part interconnected, there is relatively free movement of water within the drift. As a result, water levels in adjacent wells are generally at about the same altitude above sea level.

The rock permeability, a measure of the ease with which water flows both vertically and laterally, is dependent upon the size and sorting pattern of the particles. Water moves more easily through the larger spaces within deposits of well-sorted gravel and coarse sand than through the smaller spaces within silt, clay, and till (generally an unsorted, compact mixture of various-size grains, ranging from cobbles to clay).

Bedrock

Water in the bedrock occurs only in fractures in the otherwise dense, impermeable to poorly permeable rock (fig. 2), the ease of movement depending upon the size of the fractures and the degree of their interconnection. Where the cracks are few, narrow, and poorly interconnected, the rock will contain and transmit very little water and water levels in adjacent wells tapping different, unconnected fracture systems will not necessarily be at similar altitudes above sea level. However, where the rock has been subject to considerable faulting and fracturing, extensive zones of crushed rock will generally contain and transmit larger supplies of ground water, and water-level altitude in adjacent wells probably will be similar.

The movement of ground water in the bedrock is controlled principally by the degree of fracturing and, to a small extent in sedimentary bedrock, by bedding planes and folds that may impede or enhance the lateral and vertical flow of water. However, in rocks that have had a long history of intense metamorphism and extensive faulting, such as those in the San Juan Islands, faults and fracture zones doubtless have the greatest influence on the rate and direction of ground-water movement.

LINEAMENTS

Included on the geologic map are the locations of major lineaments in the bedrock areas. These are linear topographic features suggesting the presence of faults and fracture zones, which may have a large influence on ground-water occurrence and movement. As interpreted from topographic maps and aerial photographs, lineaments are linear features along which the fractured rock has been preferentially eroded by glacier and water action to form elongate valleys, ravines, depressions, notches that line up between adjacent ridges, or abrupt changes in slope (fig. 2). Lineaments may extend for short distances or many miles.

Hydrologically, lineaments may imply zones in the bedrock where conditions are more favorable to the recharge, accumulation, and easy movement of ground water and, correspondingly, for the location of wells with large yields. Most of the lineaments are in the relatively undeveloped mountainous areas of Orcas and San Juan Islands, where well data are generally lacking to confirm any significant relationships between lineaments and higher well yields. However, lineaments are associated locally with zones of spring discharges and with areas of relatively larger yields from bedrock wells. For example, zones of water accumulation and high permeability exist along two lineaments in the lower western slope of the Mount Constitution area; there, springs 36/1-32Cls and 32Dls head along ravine lineaments above Cascade Lake, and the Keys Springs 37/1-19Nls and 19Qls head at lineaments on the northwestern slope of Mount Constitution.

On San Juan Island a short lineament extending about 2 miles in an east-west direction across the north-trending hills in sections 23 and 24, T.35 N., R.4 W., and section 19, T.35 N., R.3 W., may represent a fracture zone containing ground water. According to driller Dan Martell (oral commun., February 1982), two wells drilled to depths of 102 and 263 ft in a saddle near the crest of the ridge in the northeastern quarter of section 24 (apparently on the lineament) had yields of 15 and 12 gal/min, respectively; these are large yields for bedrock wells.

GEOHYDROLOGIC SECTIONS

By the nature of its containment in rock materials deep below land surface, ground water and its modes of occurrence are not easily visualized except through diagrammatic interpretations. Therefore, to provide a graphic picture of the occurrence of ground water beneath the islands studied, several generalized geohydrologic sections are included here to represent cutaway views beneath selected areas. Prepared with the vertical scale exaggerated about 10 times the horizontal scale, the sections are useful in showing the general relationships between topography, generalized geology and materials penetrated, and the depths and water levels in wells.

The geohydrologic sections show upland areas underlain by bedrock—locally veneered with glacial drift—and the broader, lowland areas of central Lopez Island and the Eastsound area of Orcas Island underlain by thick deposits of glacial drift. The sections also show, in the bedrock areas, a great variation in water-level altitudes in adjacent bedrock wells and, conversely, a general similarity of water-level altitudes in adjacent drift wells. Regardless of their land-surface altitudes, most bedrock wells have water levels within 20 or 30 feet of the surface, even though the water-yielding fracture zones may be considerably deeper. On the other hand, wells in the broad drift area of northern Lopez Island have water-level altitudes that are generally within 20 feet of sea level (sheet 4), regardless of land-surface altitude.

Several of the cross sections show water levels that are below sea level. These doubtless occurred in wells that were recently pumped and whose water levels had not yet completely recovered to static level. Of particular interest are a few bedrock wells that are situated near the crests of upland areas which have water levels near land surface. Several of these wells have artesian flows and have been capped.

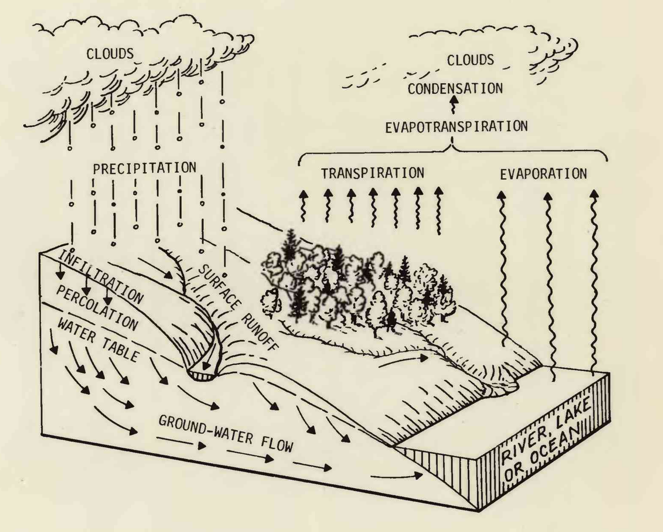

Figure 1. The hydrologic cycle.

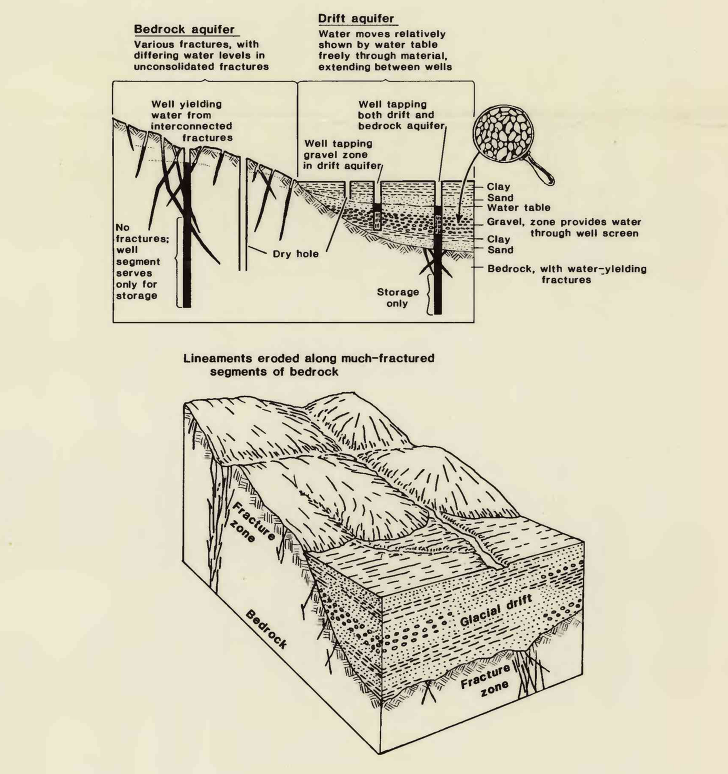

Figure 2. Occurrence of ground water in bedrock and glacial drift materials underlying San Juan Islands.