



INTRODUCTION

In order to evaluate seasonal changes in chloride concentrations, samples were taken from 56 of the 59 observation wells throughout the four major islands approximately once a month during the period April-November 1981. Samples were taken from 279 wells in April, when ground-water levels are usually high, and in September, when water levels are usually low. Discounting possible tidal effects the lowest concentrations of chloride would be expected in the spring, when the freshwater-seawater interface is at its farthest seaward position. Conversely, the highest concentrations of chloride would be expected in the fall, when the interface is the farthest inland (see sheet 7 for detailed analysis of seawater intrusion).

In order to evaluate long-term changes in chloride concentration, a comparison was made between concentrations observed in 1978 (Dion and Sumioka, 1982) and those observed in 1981 for 78 wells sampled in both studies.

SEASONAL VARIATIONS IN CHLORIDE CONCENTRATIONS

The accompanying map shows graphs of chloride concentrations in samples from each of 56 observation wells and one spring. Because of differences in recharge and discharge characteristics, background concentration, and extent of intrusion, each graph shows an individual seasonal pattern of chloride concentration. Despite the uniqueness of each graph, three general seasonal patterns can be described. About half the wells have chloride concentrations that show little or no fluctuation or seasonal trend, about a third show fluctuations (but no seasonal trend) from April to September, and about a fifth show a trend of increasing chloride from spring to fall. Of the third that show fluctuations about two-thirds are located near the shore and may be influenced to some degree by tidal fluctuation.

The lack of discernible seasonal pattern at most wells is verified in table 1, where a statistical summary by month is given. The mean chloride concentrations show a slight increase from spring to fall, but in general the median, minimum, and maximum concentrations show no significant seasonal change. Wells that do show a significant seasonal variation in chloride concentration yield waters dominated by sodium and chloride ions.

The chloride concentrations observed at 279 wells sampled in April and September 1981 are summarized in table 2 as a comparison of seasonal changes in chloride at various concentration levels. The seasonal change in chloride concentration is defined as the difference between September and April chloride concentrations. The mean and median are higher as the chloride concentration increases. For wells already intruded by seawater, the seasonal changes are substantial. For example, for chloride concentrations more than 100 mg/L, the median seasonal change was 32 mg/L. In this situation, ground water is pumped from a zone of diffusion that yields water of higher or lower chloride concentration depending on the position of the freshwater-seawater interface. In contrast, for ground water containing lower, naturally occurring chloride concentrations not subject to movement of the freshwater-seawater interface, the seasonal changes as defined above are very small (table 2).

TABLE 1.—Monthly chloride concentrations, in milligrams per liter, measured at 56 observation wells in 1981

Statistic	Month						
	April	May	June	July	August	September	November
Number of samples	56	49	56	56	54	55	55
Minimum	10	11	7	11	10	10	10
Maximum	2,750	2,700	2,700	2,700	2,500	2,800	2,800
Mean	164	185	165	179	197	193	204
Median	53	76	46	55	75	55	56

LONG-TERM VARIATIONS IN CHLORIDE CONCENTRATIONS

For purposes of comparison, 78 wells that were sampled in August 1978 and reported by Dion and Sumioka (1982) were resampled in this study. In order to obtain the highest number of paired observations, data from August 1978 and September 1981 were used in the comparative analysis. Even though chloride concentrations were generally higher in 1981, no statistically significant difference was evident in the means of chloride concentrations of the paired observations of 1978 and 1981. For all but two wells, the variations in chloride concentrations between 1981 and 1978 are attributed to natural and man-related causes, such as differences in recharge patterns, pumpage, and analytical methods in determining chloride concentrations. However, two wells yielded water in 1981 that was substantially higher in chloride than water in 1978, as shown below.

Well No.	Island	Water use	Chloride concentration (mg/L)		
			August 1978	April 1981	September 1981
34/2-4R1	Lopez	Domestic	31	107	113
36/2-27B1	Shaw	Commercial	41	358	783

Both these wells are located within half a mile of the shoreline, and the bottoms of the wells are completed below sea level. The Shaw Island well is heavily pumped during the summer.

TABLE 2.—Comparison of seasonal changes in chloride concentration at various levels based on measurements made in 279 wells in April and September 1981. Change in concentration is September values minus April values, in milligrams per liter

Statistic	Chloride concentrations greater than:		Chloride concentrations less than:	
	160 mg/L	100 mg/L	160 mg/L	100 mg/L
Number of sites	17	44	248	218
Mean	96	43	0.8	0
Median	32	16	0	0

FUTURE STUDIES

Seasonal changes in chloride concentration are substantial for ground waters affected by seawater intrusion and minimal for ground waters containing low concentrations of chlorides. Future monitoring programs should be designed to take these differences into account. For example, spring and fall sampling is probably adequate for ground waters yielding less than 100 mg/L chloride, but quarterly or bimonthly sampling is probably necessary to assess year-to-year variations of ground waters yielding more than 100 mg/L or wells that show large fluctuations. In addition, the sampling of sites near the coast should be used to evaluate the effects of a daily tidal cycle as well as spring and neap tides seasonally.

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

Seasonal and Long-Term Changes in Chloride Concentrations

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Base from U.S. Geological Survey
Orcas Island, Richardson 1:62,500, 1957.
Socia Island, 1973, Stuart Island, 1952,
Waldron Island, 1954, Roche Harbor, 1954,
Friday Harbor, 1954, False Bay, 1:24,000,
1954.