U.S. ENVIRONMENTAL PROTECTION AGENCY

A Study on Disposal of Campground Wastes Adjacent to Waldo Lake, Oregon
Working Paper #7

by

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and Charles F. Powers

National Eutrophication Research Program

February 1973

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY
An Associate Laboratory of
National Environmental Research Center—Corvallis

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INTRODUCTION

Proper treatment and disposal of human and domestic wastes has long been a serious public concern, particularly in densely populated areas. More recently, this problem has affected an increasing number of recreational lakes and streams in sparsely populated areas, including the vast national forests of the western United States.

The forest lands are undergoing rapid development for recreational use, including construction of new campgrounds and service roads. The design of new campground waste treatment systems generally conforms to existing state and federal pollution control regulations, but the disposal of treatment effluents in the vicinity of recreational waters may create unique problems. For many campground situations treated effluents are disposed through soil absorption systems, and in some cases the receiving aquifers are hydraulically associated with campground supply and recreational waters.

Our investigation pertains to a cooperative study by the U. S. Forest Service, Pacific Northwest Region, the Federal Water Quality Administration (now the Environmental Protection Agency), and the Pacific Northwest Water Laboratory (now the Pacific Northwest Environmental Research Laboratory) during June to October, 1970. The study site was a new campground septic tank treatment and disposal system at Islet Campground, adjacent to Waldo Lake, Oakridge Ranger District, Willamette National Forest, Oregon. Our primary objectives were to introduce expedient methods for characterizing the ground water flow regime in areas either considered for or actively used for disposal of septic tank effluents by soil absorption, and to determine the effectiveness of a rocky volcanic soil upon the breakdown and retention of phosphorus and nitrogen from a septic tank effluent.

The Septic Tank Treatment System

The septic tank treatment system is the most common domestic waste treatment system for remote installations. The system involves two basic components, the septic tank and the underground drainage field or soil absorption system. The septic tank provides three basic functions (1) removal of solids, (2) biological treatment, and (3) sludge and scum storage. The septic tank does not accomplish a high degree of bacterial removal, and accomplishes essentially no chemical removal. Its principal purpose is to condition the sewage, by clarification, to reduce clogging of the drainage field. The soil is responsible for removing harmful bacteria and chemical constituents from the effluent; therefore, considerable emphasis must be placed on selection of appropriate disposal areas.

Physical Characteristics

The comfort station in this investigation utilizes a 5,000 gal. septic tank, an effluent distribution pipe, and three underground lateral drain pipes (each 50 ft in length and 4 in. I. D.) as shown in Fig. 1. The drainfield is forested and is mantled with a soil zone varying between 1 1/2 and 2 1/2 ft. in thickness. A zone of consolidated

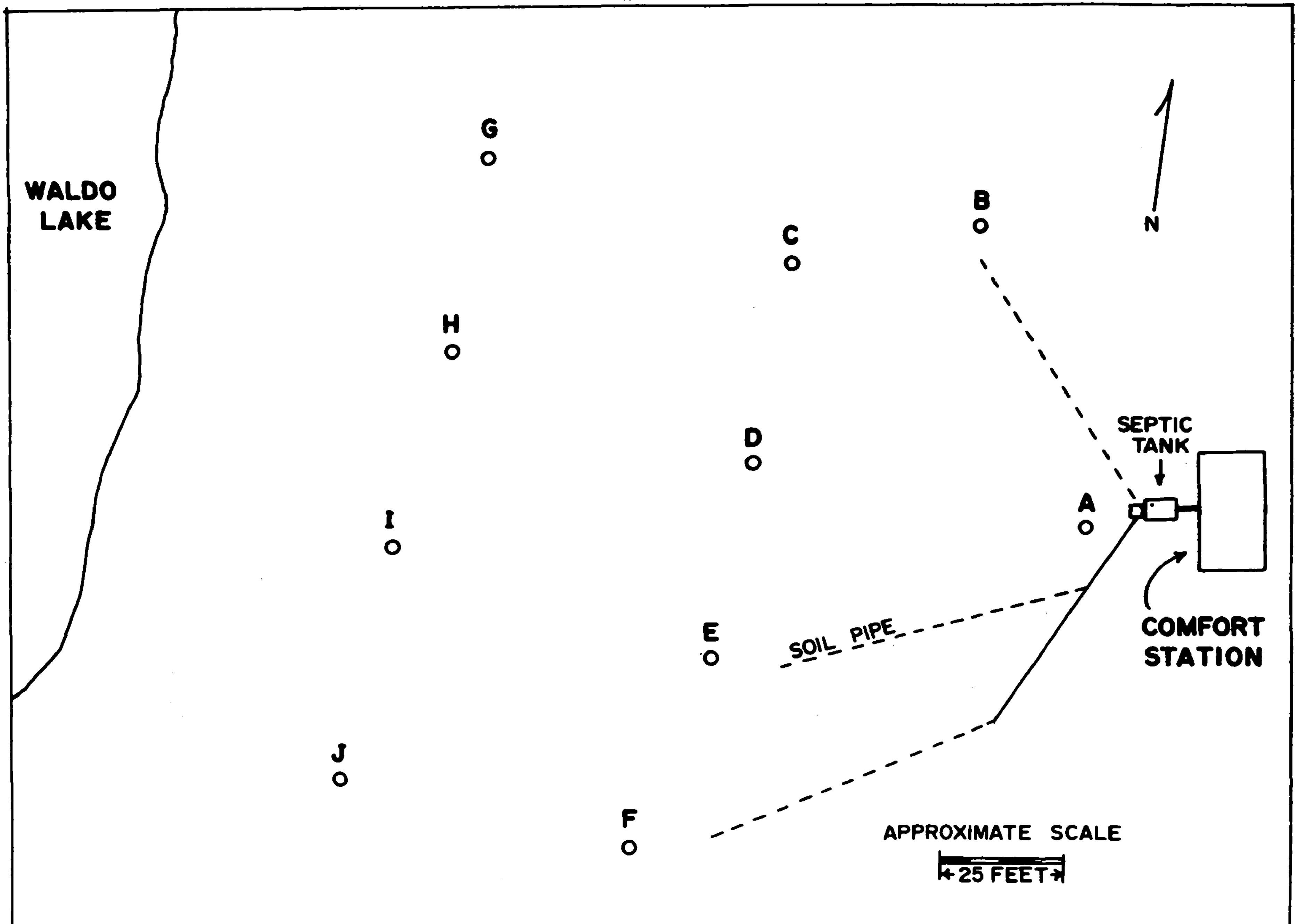

Figure 1. Waldo Lake Campground Study Area.

bedrock (basalt-rhyolite intermediate), which ranges from moderately permeable to impermeable and from 11 to 16 ft in thickness, immediately underlies the soil (Fig. 2). Beneath this bedrock layer is a 4 to 6 in. zone of highly fractured bedrock and pumice granules, constituting the upper-most aquifer for most of the drainfield. Bedrock of unknown composition, permeability, and thickness underlies this aquifer. The land surface of the drainfield slopes toward the Waldo Lake shoreline at a mean gradient of 4 degrees.

METHODS

Guidelines commonly used in the selection of a suitable subsurface sewage effluent disposal site are given in the Manual of Septic-Tank Practice, U.S.D.H.E.W. (1), as follows:

> The first step in the design of subsurface sewage disposal systems is to determine whether the soil is suitable for the absorption of septic tank effluent and, if so, how much area is required. The soil must have an acceptable percolation rate, without interference from ground water or impervious strata below the level of the absorption system. In general, two conditions should be met:
>
> (1) The percolation time should be within the range of those specified in Table 1, p.8.[a]
>
> (2) The maximum seasonal elevation of the ground water table should be at least 4 ft. below the bottom of the trench or seepage pit.
>
> Unless these conditions can be satisfied, the site is unsuitable for a conventional subsurface sewage disposal system.

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[a] Refer to U.S.D.H.E.W. (1)

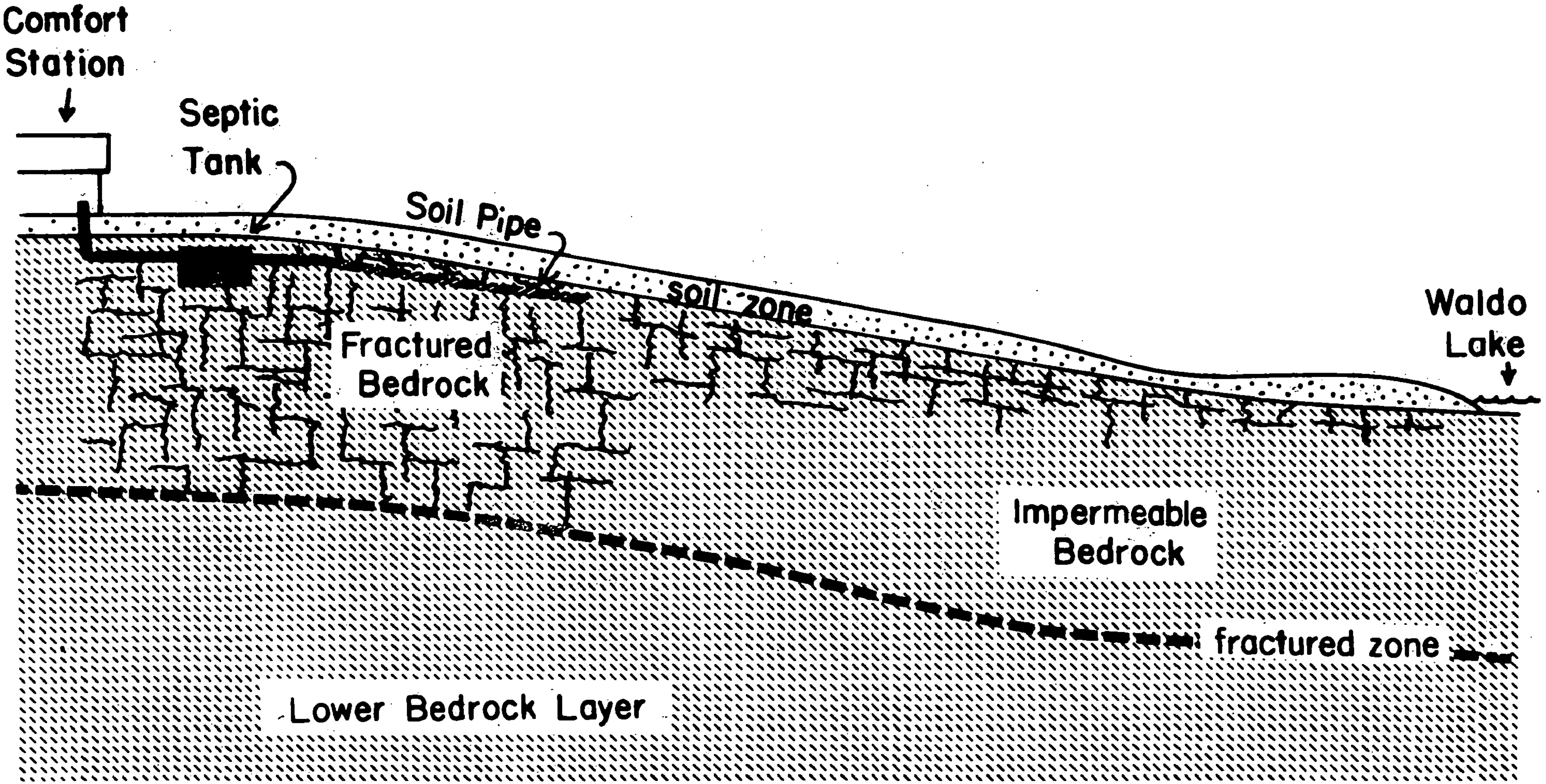

Figure 2. An East-West Cross Section of the Drainfield Showing the Stratigraphy and Areas of Extensive Fracturing.

The above guidelines, which were satisfied by the comfort station selected for this study, emphasize the importance of soil percolation rate and capacity tests as related to waste accomodation by the soil and to design of the disposal system. Methods described in our study, except for the chemical quality sampling, augment the above guidelines for the proper selection of disposal sites by introducing expedient tests which serve to predict the immediate fate and pollutional possibilities of waste disposal at many considered sites. However, it should be early recognized that a developed disposal field was selected for method demonstration in our study because other objectives were related to the chemical transformations of disposed wastes.

Constructing the Flow Network

Ten test holes were drilled into the drainfield and developed into observation wells as shown in Figs. 3 and 4. All test holes, except "G", were drilled to the depth where the hole first encountered water, using a track-mounted, rotary-percussion rock drill. Test hole "G" was intentionally terminated in dry bedrock in order to determine the occurrence and magnitude of flow along the soil-bedrock interface, and to confirm the impermeability of the upper bedrock horizon.

Test holes were drilled during June 23-29, 1970, shortly after the winter snows were sufficiently melted to permit access to the area. The wells were mapped with an alidade and plane table, and a spirit level was used for determining the elevations of well heads

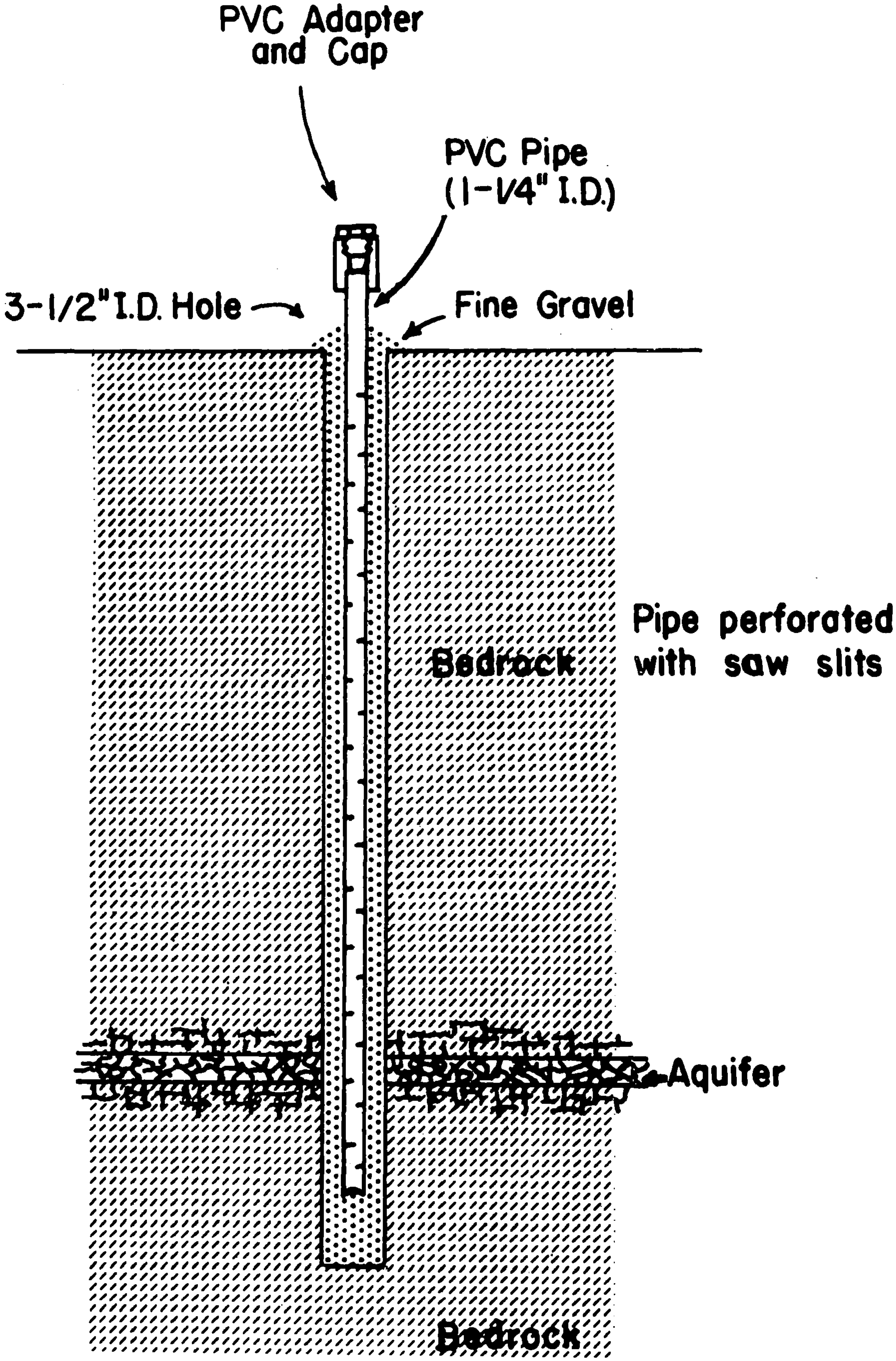

Figure 3. Observation Well Construction.

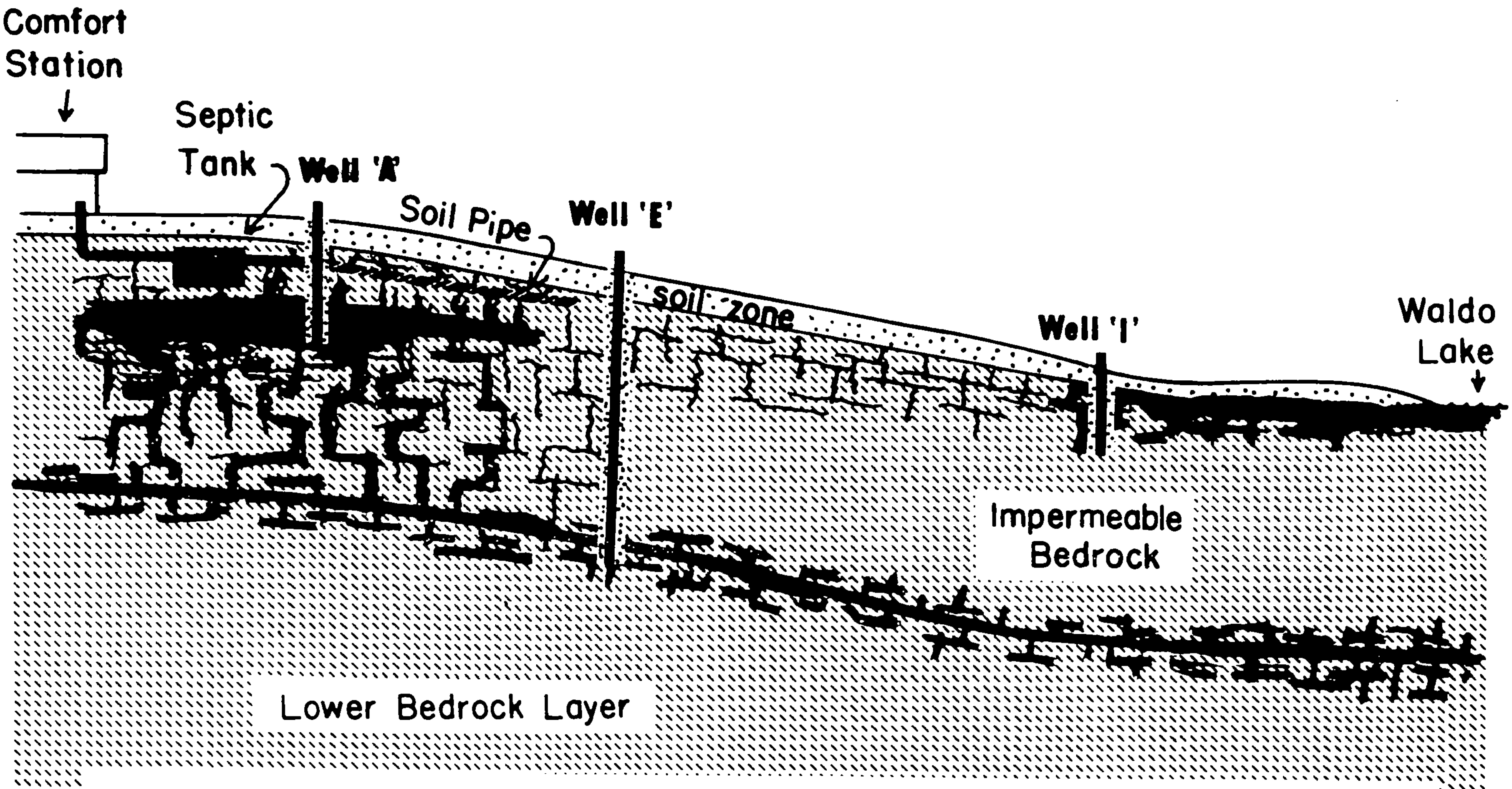

Figure 4. An East-West Section of the Drainfield Showing Hydraulic Separation of Aquifers. Shaded areas designate extent of saturation.

and the lake surface. The reference elevation was that of a permanent USGS staff gage near the lake outlet. A steel tape and chalk were used to measure the water level elevations in the wells.

Tracer Studies

On July 23, following a four-week stabilization period for the newly developed wells, two gallons of a fluorescent dye concentrate (Rhodamine WT)(a) were injected into the comfort station septic system through a lavatory drain. This particular fluorescent dye possesses one of the lowest soil absorption coefficients of presently available dyes; detectability limits are in the 10^{-9} g/l range using a Turner Model 111 Fluorometer.(b) The dye was used to determine flow velocity of the septic tank effluents and to verify flow pathways as indicated by the piezometric gradient.

The effectiveness of this subsurface tracer was verified by injecting a second tracer, 10 lbs of sodium chloride in solution form on July 28. Sodium chloride has been widely used as a subsurface tracer where non-clay soils are involved, but detection sensitivity (10^{-6} g/l) has always been a severe limitation.

Sample Collection and Analyses

Water samples were collected from individual wells using a vacuum pump and an in-line pyrex glass suction flask. Where possible, two one-liter water samples were collected. One was treated with mercuric

(a) (b) Use of a trade name product does not necessarily imply government endorsement.

chloride for preservation prior to nitrogen and phosphorus analysis; the other was left untreated and used for chloride determination and fluorescent dye measurements. All analyses were performed at the Pacific Northwest Water Laboratory, Corvallis, Oregon, according to the latest FWPCA methodology, USDI (2).

Effluent Flow Augmentation

The Manual of Septic-Tank Practice indicated that a campground comfort station with flush toilets and a 100 person daily use rate will result in 2,500 gpd of liquid wastes. The average daily use rate of the comfort station during our study was estimated at 25 persons per day, which is perhaps 25 percent of the design capacity of the station. Therefore, waste flow was augmented with approximately 1 gpm of fresh water into the waste system (by leaving a faucet partially open) to more nearly approximate the design waste volume.

RESULTS

Water level elevations, well logs, phosphorus and nitrogen analysis, and tracer measurements of individual wells were collectively used to define the hydrology of the drainfield. Fig. 4 shows the aquifers and stratigraphy of the drainfield by a section through wells "A", "E", and "I".

Water level in the wells was measured on July 21, 28, 31; August 5, 12, 18; and September 2. These data are summarized in Fig. 5. Water levels in wells "A" and "I" behaved differently from those in the other wells. Levels in well "A" (the well nearest the comfort

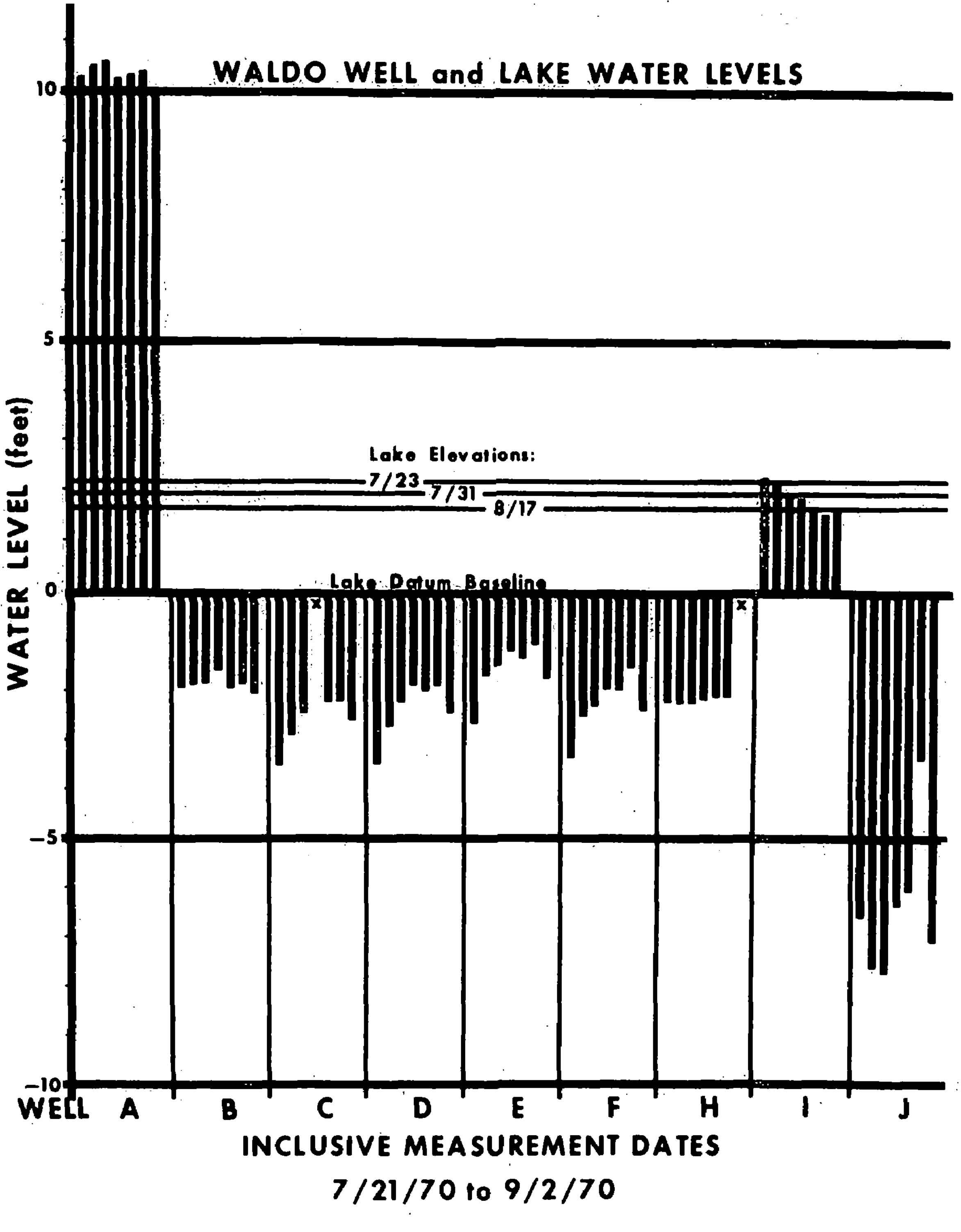

Figure 5. Water Level Elevations for Observation Wells and Waldo Lake. Elevation bars for each measurement site are in chronological order. Small x denotes missing data..

station) averaged about 10 feet above the lake datum baseline, and fluctuated randomly with respect to observed lake levels. Water levels in well "I", on the other hand, were nearly identical with lake levels throughout the period of observation. In the remaining wells, water levels were always significantly below lake datum baseline, and in well "J" the water was about twice as low as in the others.

Fluorescence measurements of the well water (Fig. 6) were made on July 23, 24, 25, 28, and 31; August 5, 12, and 18; and September 2. The measurements are expressed in concentration units referenced to the 30X scale on the fluorometer. Readings of less than 10^2 are not regarded conclusively as that of true fluorescence owing to background turbidity interference. The fluorescent dye reached well "A" within 24 hours following dye injection, wells "B", "C", "D", "E", and "F" within 5 days, and wells "H" and "J" within one month. Dye was not detected in well "I" or in the lake water at the shoreline.

Chloride measurements (Fig. 7) were made on July 25, 28, and 31; August 5, 12, and 18; and September 2. When compensation is made for the five day interval between the dye and chloride injection dates, the chloride concentration peak corresponds chronologically to the fluorescence peak for each well. The addition of the tracer probably did not largely increase the chloride concentrations already present in the sewage effluents.

Most of the wells had moderately high nitrogen concentrations (Table 1). Analyses from well "A" showed high total Kjeldahl-nitrogen

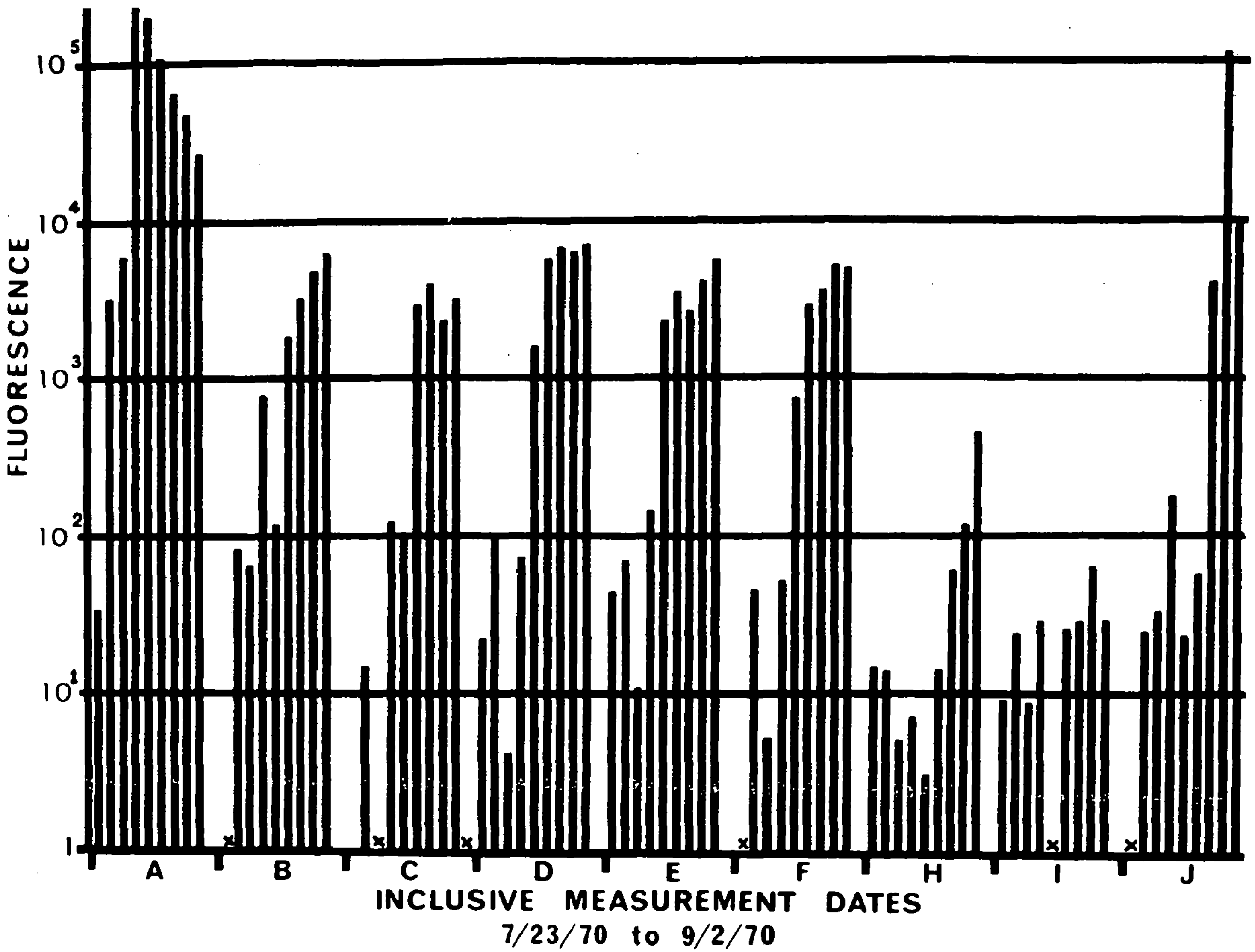

Figure 6. Fluorescence Measurements for Observation Wells. Fluorescence bars for each measurement site are in chronological order. Small x denotes missing data.

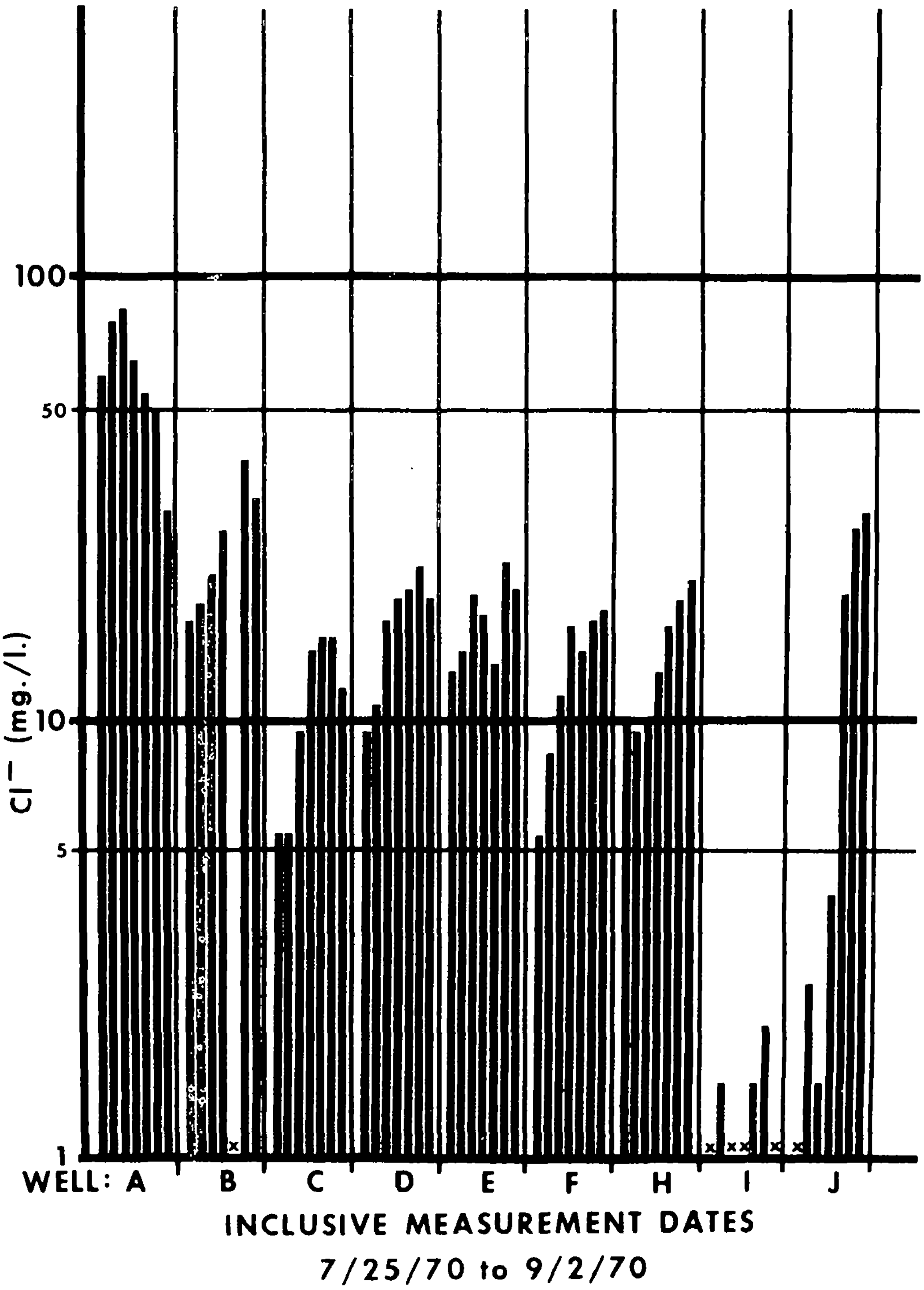

Figure 7. Chloride Measurements for Observation Wells. Chloride concentration bars for each measurement site are in chronological order. Small x denotes missing data.

Table 1. Chemical Analyses of Water

		as mg/l Nitrogen				as mg/l Phosphorus	
Date	Well Code	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Total Kjeldahl Nitrogen	Ortho-Phosphate	Total-Phosphate
7/22/70	A	4.40	.004	.016	6.5	.018	.121
	D	.44	.200	2.00	.6	.006	.030
	H	.05	.100	2.80	1.1	.003	2.80
	I	.02	.001	.002	.3	.018	.120
7/24/70	A	10.0	.020	.130	12.1	.003	.780
	C	.04	.003	1.30	---	.003	.110
	D	---	.400	8.00	.5	.003	---
	E	---	.900	12.0	.4	.045	3.04
	F	.01	.100	4.00	.1	.006	.295
	H	.02	.100	3.60	.7	.006	.420
	I	.08	.010	.008	.4	.024	.470
	J	.03	.001	.300	.5	.015	.750
7/25/70	A	10.4	.005	.012	13.8	.003	3.20
	B	.90	.021	2.60	2.8	.138	4.40
	C	.08	.017	3.60	.2	.003	.007
	D	---	.520	9.30	.5	.006	2.00
	E	---	1.01	14.4	.1	.003	2.00
	F	.02	.005	6.80	.6	.003	5.28
	H	.03	.002	5.40	.1	.003	2.64
	I	.05	.001	.004	.3	.063	2.40
	J	.01	.001	.187	1.1	.006	8.40
7/28/70	A	33.0	.020	.020	41.1	.014	14.4
	B	---	---	---	---	---	---
	C	.06	.006	1.70	1.3	.001	.380
	D	---	.500	9.90	.3	.001	.080
	E	---	.900	13.0	.1	.058	---
	F	.28	.100	9.90	2.4	.007	---
	H	.03	.100	5.50	.3	.007	18.8
	I	.01	.001	.001	.2	.004	.600
	lake	.03	.001	.010	.3	.003	.028
7/31/70	A	35.2	.040	.040	39.1	.009	.038
	B	---	---	---	---	---	---
	C	---	.040	7.60	.1	.001	.006
	D	---	.560	14.0	.3	.005	.030
	E	---	1.00	14.0	1.1	.032	.154
	F	.80	.320	9.60	1.6	.007	.147
	H	.04	.003	6.40	.3	.010	.042
	I	.01	.001	.010	.2	.006	.016

Table 1. (Continued)

		as mg/l Nitrogen				as mg/l Phosphorus	
Date	Well Code	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Total Kjeldahl Nitrogen	Ortho-Phosphate	Total-Phosphate
9/2/70	A	16.0	.006	.003	28.2	.001	.025
	B	---	---	---	3.4	---	.088
	C	---	.002	2.70	1.2	.002	.007
	D	---	.038	4.40	2.6	.001	.005
	E	---	.007	1.80	4.1	.002	.006
	F	---	.026	4.80	.1	.001	.014
	H	---	.007	7.50	.3	.031	.033
	I	.02	.001	.002	.3	.001	.060
	J	4.70	.004	2.40	5.1	.008	.357
9/22/70	A	9.00	.007	.001	10.7	.001	.009
	B	2.60	.025	2.50	8.2	.002	.034
	C	1.10	.004	3.00	2.3	.001	.016
	D	2.42	.050	3.80	6.3	.005	.012
	E	7.00	.008	1.70	13.5	.002	.012
	F	.96	.007	4.00	.3	.002	.007
	H	1.20	.006	6.30	1.2	---	.060
	J	2.40	.006	4.20	5.7	.002	.010
	lake	1.00	.001	.100	1.2	.002	.011

and relatively low nitrate concentrations. Analyses of all other wells generally showed initial high nitrate concentrations and relatively low total Kjeldahl. Later in the summer total Kjeldahl nitrogen generally became the most abundant nitrogen form.

Phosphorus data showed considerable variation among individual wells and with respect to time, and did not indicate any significant trend. Ortho-phosphorus concentrations in well "A" were in most cases as low, if not lower, than concentrations in wells more distant from the sewage effluent discharge areas.

DISCUSSION

All the wells except wells "A" and "I" tapped the main aquifer in the highly fractured zone between the two principal bedrock layers and ranged considerably in water yield. The fractured zone was probably the interface of separate lava flows and the local variation in permeability due to differences in size, extent, and hydrualic linkage of individual fractures. Wells "E", "F", and "J" could not be pumped dry at a rate of 1 gpm for 10 minutes, whereas, well "B" never yielded more than a fraction of a gallon.

Wells "A" and "I" were supplied by two separate aquifers. The well "A" aquifer probably consisted entirely of disposed sewage effluents, as indicated by chemical analysis (Table 1). Well "A" was not a high-yielding well (maximum of 2 gal. at 1 gpm pumpage rate) and was located in an area where the upper bedrock zone was fractured. The well "I" aquifer was perched and was apparently recharged by the lake, as indicated by comparing lake and well water level elevations (Fig. 5). (A perched aquifer is an underground water body, usually of small size, which overlies, but is hydraulically separate from, the main aquifer.) The continuous decrease of measured lake surface elevation closely corresponded with the decrease of water surface elevation in well "I".

The main aquifer sampled by wells other than "A" and "I" was evidently not connected to the lake, since water elevations in those wells showed no correspondence to lake levels (Fig. 5). The elevation of the main ground water aquifer near the lake shoreline was several feet lower than the lake water surface, thereby indicating that septic tank effluents incorporated with native ground water did not enter the lake during the study period (July--September, 1970). This is confirmed by our failure to detect dye at any time in well "I", the single well which appeared to be linked hydraulically to the lake.

However, since the aquifer has limited permeability, the possibility exists that septic tank failure, inadequate maintenance, and/or bacterial biomass may eventually lead to the complete clogging of the fractures in the aquifer and upper bedrock zone, in which case the septic tank effluents would probably flow along the soil-bedrock interface and directly into the lake. Reference to Fig. 5 confirms that the addition of sewage effluents through the summer definitely raised the water level elevation of wells "C", "D", "E", "F". "H", and "J" (note the rapid return to lowered levels following the end of summer campground use). The presence of waste effluents in these wells was confirmed by the fluorescent dye and increased chloride concentrations found there. The fate of the septic tank effluent was further elucidated by the nitrogen analyses. The high total Kjeldahl nitrogen and relatively low nitrate concentrations at well "A" indicated that the well probably sampled raw septic tank effluents because septic tank contents are characteristically anaerobic. The initially high nitrate concentrations in the other wells indicated that some nitrification occurred early in the study (indicating desirable aerobic microbiological activity), but the increase in Kjeldahl nitrogen as the season progressed was symptomatic of deterioration of the aerobic aquifer as a result of partial clogging of the aquifer fractures.

Caution should also be exercised here and in similar situations involving aquifers of limited permeability with respect to the disposal of septic tank effluents during a time when the aquifer is receiving a high rate of natural recharge, such as during snowmelt runoff or during a wet, rainy summer. This would greatly reduce the capacity of the aquifer to accommodate artificial recharge, such as that involved in the underground disposal of septic tank effluents. Under these conditions the probable route of the effluents would again be along the soil-bedrock interface and directly into the lake.

The disposal field and associated underground hydrology described herein may or may not be typical of present or proposed disposal sites in the Cascade Range or other parts of the western United States forest lands. On lands of volcanic origin and where composite lava flows occur, fractures provide a principal means for underground water movement. If the fractures in the present study were more extensive, the lake probably would be hydrualically connected to the adjacent underground aquifer. On the other hand, if the fracturing were less extensive, the disposed septic tank effluents probably would move along the soil-bedrock interface horizontally toward and into the lake. Each of the above hypothetical situations presents an almost certain lake pollution condition.

CONCLUSIONS

1. Septic tank effluents incorporated with native ground water did not enter Waldo Lake during the study period, July - September, 1970; the main aquifer was evidently not connected to the lake.

2. The aquifer is of limited permeability (it is contained in a highly fractured zone between two bedrock layers), and the possibility exists that septic tank failure, inadequate maintenance, and/or bacterial biomass could eventually lead to complete clogging of the fractures with the resultant flow of septic tank effluents along the soil-bedrock interface into the lake.

3. Because of the limited permeability of the aquifer, its capacity to accommodate septic tank effluents would be greatly reduced during times of high natural recharge, such as during snow melt or a wet summer. Under such conditions the effluents would probably pass along the soil-bedrock interface into the lake.

4. Many recreational lakes in the Western United States are located in volcanic areas where rock fractures provide a principal means for underground water movement. The fragility of most of these lakes, together with inherent possibilities for entrance of effluents into lakes situated in volcanic soils, indicates that special precautions should be taken in the design and location of waste disposal systems located adjacent to such lakes.

REFERENCES

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2. U. S. Department of the Interior. Federal Water Pollution Control Administration. Analytical Techniques for the National Eutrophication Research Program, June (1969). 141 p.