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Urban impacts on a gravel unconfined aquifer in the Evergreen area near Kalispell Montana

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Urban impacts on a gravel unconfined aquifer in the Evergreen area near Kalispell, Montana

by

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Urban impacts on a gravel unconfined aquifer in the Evergreen area near Kalispell, Montana (102 pp.)

Director: Garry R. Grimestad *MMT*

Groundwater quality in a surficial, unconfined gravel aquifer was monitored for approximately one year in Evergreen, near Kalispell, Montana. Ionic concentrations of sodium, chloride, sulfate and ammonium as well as fecal coliform and fecal streptococcus concentrations suggest septic tank effluents as the predominant source of nutrients. Fecal streptococcus occurrences appear to correlate with agricultural activity whereas, fecal coliform occurrences appear to correlate with urban land usage. Bacterial concentrations exceeding Montana State standards for drinking water are commonly found during high water table conditions. Recharge from the Flathead River is the dominant hydraulic control of this aquifer in the study area.

This thesis is dedicated with the greatest
respect and admiration to
Millard Eugene Spratt and Elvet Leroy Sanders.

ACKNOWLEDGEMENTS

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The critical review by Drs. Garry Grimestad, Hans Zuuring, Don Winston and N. Stark is gratefully noted. Their help and encouragement has been invaluable.

The Flathead Drainage 208 Project in cooperation with the Flathead Conservation District, Flathead County Areawide Planning Organization, Soil Conservation Service and the Flathead County Sanitarian sponsored the project. This work was funded through an Environmental Protection Agency grant to the Flathead Drainage 208 Project, number P 008106-01-0. Services were provided at no cost to the project by the Soil Conservation Service at the direction of the Flathead Conservation District and by the Department of the Army, Seattle District, Corps of Engineers.

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INTRODUCTION

PURPOSE AND SCOPE

Three major aquifers underlie the Evergreen area. They are the:

1) Fractured bedrock aquifer.
2) Deep artesian aquifer.
3) Surficial aquifer.

The surficial aquifer is the most susceptible to man-caused contamination; therefore, primary emphasis of this study is on the surficial aquifer.

Investigation of the surficial groundwater aquifer was initiated after discussion with the Flathead County Sanitarian, Tom Cowan, and review of existing water quality reports. He suggested that the aquifer quality was deteriorating due to the impact of private, on-site sewage and waste disposal and general urban development; additionally, he indicated the need for a potentiometric map documenting seasonal groundwater fluctuations in the Evergreen area. Emphasis of this study was to demonstrate the connection, if any, between local aquifer water quality and urban development.

The hypothesis tested by this study is that changes in the surficial aquifer water quality, as quantified by changes in various biological and chemical parameters, are associated with changes in growth patterns, as quantified by the distribution of people in the

Evergreen area.

LOCATION

The Evergreen area is located in Flathead County, Montana, near the City of Kalispell including parts or all of Sections 26, 27, 28, 32, 33, 34, and 35, T. 29 N., R. 21 W. and in sections 3, 4 and 5, T. 28 N., R. 21 W. of the Principle Meridian, Montana (Figure 1). To the north, the study area is bounded by Rose Crossing Road, to the east, by the Flathead River, to the south by East and West Cottonwood Drive and to the west by the Whitefish River (Figure 2).

The southern half of the study area is heavily subdivided whereas the northern half is primarily rural land. Spring Creek, which is spring fed, flows in a southerly direction through the middle of the area. The west and east sides of the area are defined by the Whitefish and Flathead Rivers respectively.

Access to all well sites was permitted by signed easements between the land owners and the Flathead Drainage 208 Project (FD 208 Project).

PREVIOUS WORK

The United States Geological Survey (U.S.G.S.) began monitoring wells in the upper Flathead Valley about 1933. Potentiometric levels are published in Montana Bureau of Mines Bulletins and U.S.G.S Water Resources Data books by water year. Records utilized for this report

STUDY AREA LOCATION

Figure 1

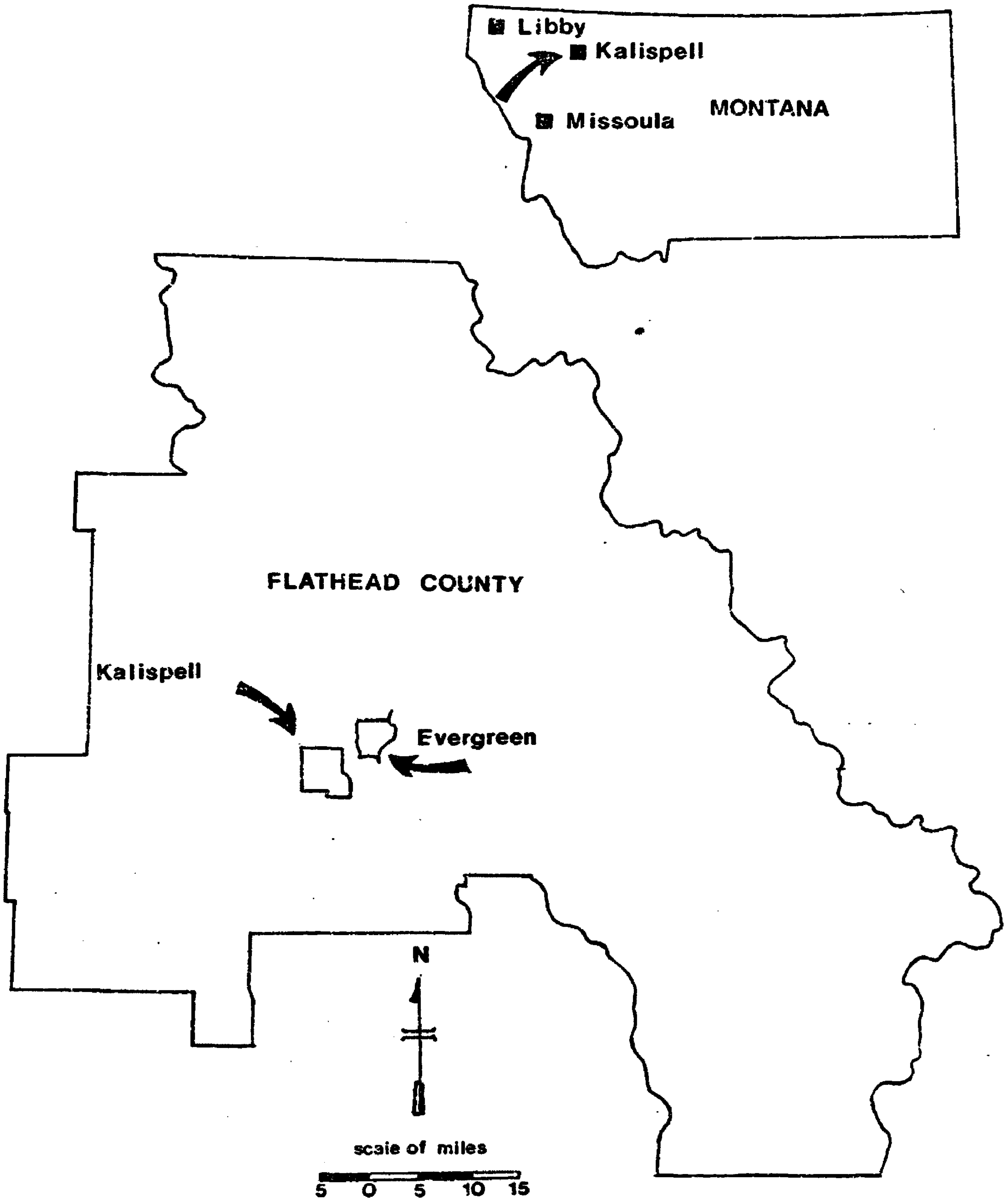
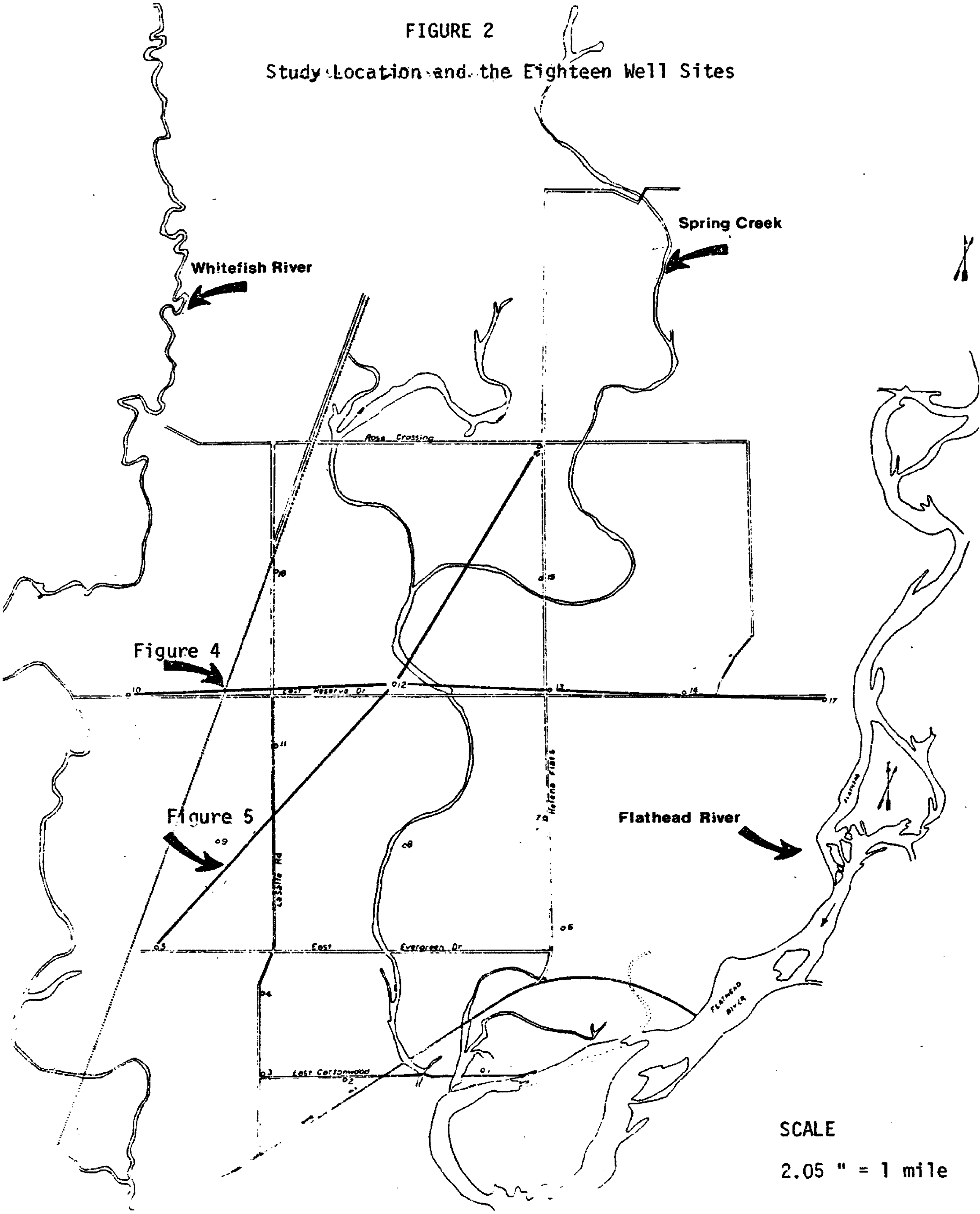


FIGURE 2

Study Location and the Eighteen Well Sites



include those for water years 1963 to the present (Montana Bureau of Mines and Geology Bulletins 53, 57, 65, 76; U.S.G.S. Water Resources Data for Montana Water years 70-77).

Konizeski *et al*. (1968) described the geology and hydrology of the Kalispell Valley. No water quality problems were noted in the Evergreen area. Willis Johns (1970) mapped the geology of Lincoln and Flathead Counties, Montana, including the Evergreen area. The FD 208 Project sponsored a groundwater study by Morrison-Maierle, Inc. and James M. Montgomery, Consulting Engineers, Inc. (MM&M, 1977). The FD 208 Project study found minimal contamination of the surificial aquifer. The 201 Facilities Plan for Kalispell, Montana (1978) reviews the groundwater quality and hydraulic conditions in the study area, including preliminary results of the present study.

PRESENT STUDY

Flathead Drainage 208 Project personnel began reviewing existing water quality reports concerning the Evergreen area during the Spring of 1978. Existing data included concentrations of nitrate, phosphorous and fecal coliform bacteria. It was believed that the reported values did not accurately reflect water quality conditions in the Evergreen area because phosphorous data based on water samples derived from steel-cased wells, wherein iron complexes with phosphorous preventing accurate determination of phosphorous in solution, can be misleading. Furthermore, bacterial samples were obtained late in the year when groundwater elevations were low and separation between the possibly contaminated zone and the potentiometric surface was greatest. Because many people residing in the Evergreen area are dependent on shallow groundwater for their domestic supply and because Evergreen is the largest unsewered residential area near Kalispell, it was felt that questions regarding water quality in this area should be resolved. An intensive groundwater quality study was designed and submitted by May 4, 1979.

Sampling sites were selected so as to establish a network that would enable determination of cumulative water quality characteristics from representative sites rather than document site specific problems; it was not the intent of this project to find individual, failing, on-site waste disposal systems

Potentiometric surfaces were measured beginning in November, 1978, continuing through October, 1979. Water samples for chemical analysis were collected from December, 1978 through October, 1979. Bacterial sampling began in January, and continued through October, 1979. Chemical analyses were performed under contract by the University of Montana, School of Forestry. Bacterial analyses were performed by the Montana Environmental Laboratory, Kalispell, Montana. All original data will be published as a separate report by the Flathead Drainage 208 Project.

Several progress reports were released to the public during the study period. Frequent status reports were made to the Flathead Conservation District. Reports were given to the Kalispell City-County Planning Board. These reports were in two forms. The primary form was a short summary of the problem and findings of fact.

The second was input to subdivision review of preliminary project results. This project was one of several water quality problems reviewed on local television. Articles describing the project appeared in local and regional newspapers.

GEOLOGY

GENERAL VALLEY

Evergreen is situated near the center of a valley bounded by the Swan Range to the east, the Whitefish Range to the north, the Salish Mountains to the west and Flathead Lake to the south. Konizeski et al. (1968) believed that the Ravalli and Piegan Groups of the Belt Super Group underlie the floor of the valley beneath unconsolidated to consolidated deposits of Cenozoic fill, which may be as much as 4800 feet deep and of Tertiary age (Figure 3). The valley is underlain by a large down-dropped block, and a major north-south trending, normal fault system may exist on the east side of the valley (Konizeski et al., 1968). Drillers' well logs seem to indicate a significant fault system running from Lone Pine State Park toward Batavia School, nearly due west of Kalispell (personal communication, Bill Osborne).

Colluvium and sediments (glacial and non-glacial) fill the valley. Many of these sediments owe their origin to glaciation, the dominant erosional process controlling the areal geomorphology. Volcanic ash from the Glacier Peak eruptions in the Northern Cascade Range of Washington approximately 12,000-13,000 years ago was identified in four places, at the contact between drift and dune sand, in the Kalispell area. For that reason, the exposed glacial and glaciolacustrine deposits in the Kalispell Valley are thought to have been deposited

Figure 3
GENERALIZED VALLEY GEOLOGY

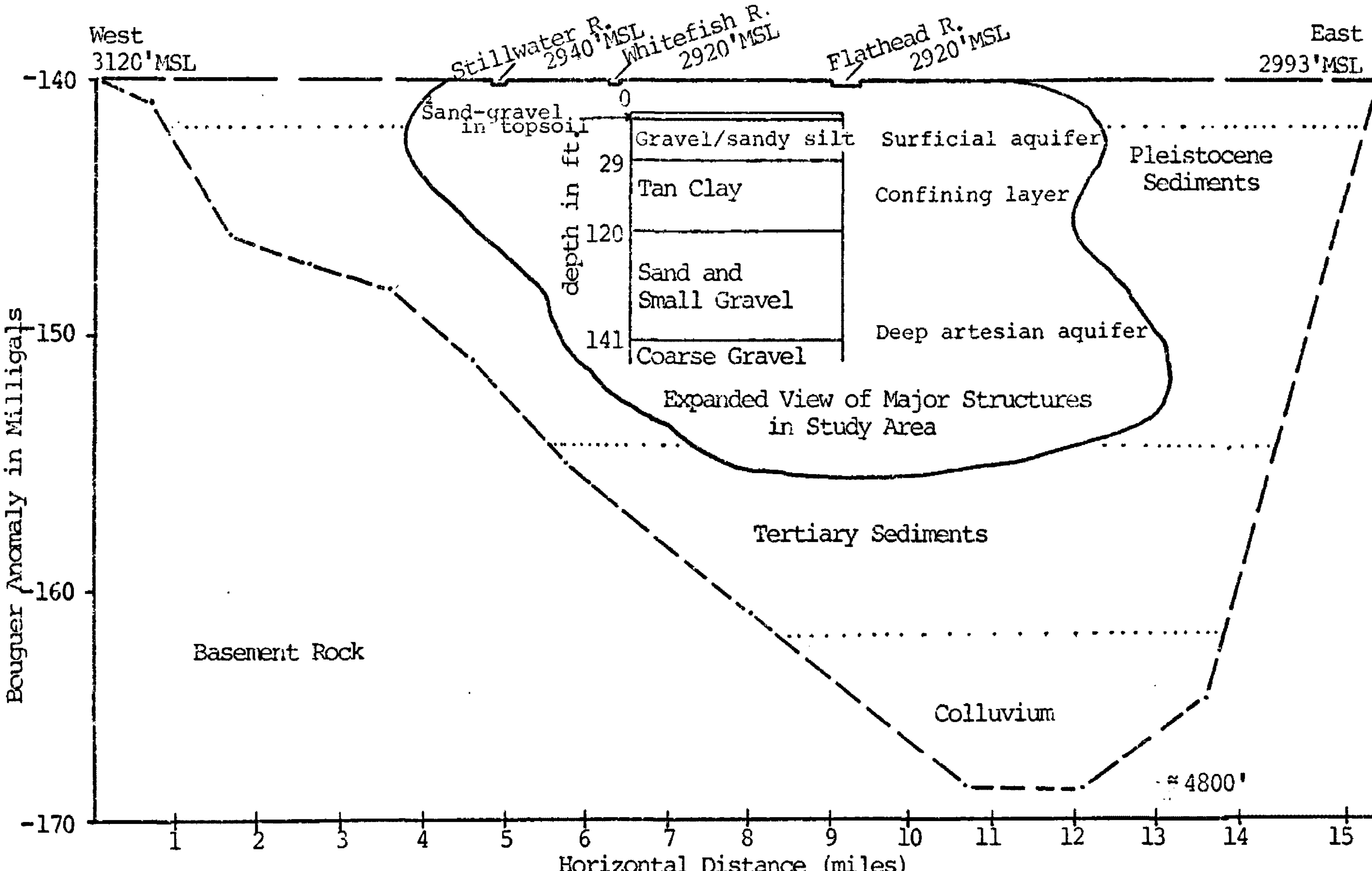


Diagram partially adapted from Konizeski *et al*, 1968.

during the Wisconsian glaciation (Konizeski et al., 1968). Dune deposits exposed to the southeast of Kalispell may be the source of sand in the study area. Silt and clay intermixed with the sand throughout the study area are probably due to the occasional flooding of the Flathead and Whitefish Rivers.

STUDY AREA

Stratigraphy has been interpreted as shown in Figures 4 and 5. Approximately 30 feet below the ground surface, a confining clay layer is encountered that appears to separate the surficial aquifer from the deep artesian aquifer (Figure 3). The clay layer, ranging from 25 to 105 feet in thickness (70 feet average thickness), appears to be continuous throughout the study area.

Gravels comprising the unconfined, surficial aquifer are apparently old till and kame deposits which have been periodically reworked with further sorting and stratification during the past 12,000 years (Konizeski et al., 1968). During drilling, zones containing rocks with substantial encrusted carbonates are encountered in the approximately 1.5 mile wide area lying between Spring Creek and the Flathead River. This zone appears impermeable to groundwater during drilling as water is generally not encountered until the zone is penetrated.

A surficial sand layer observed in the southern end of the study area pinches out near the northern end of the area. Abandoned meanders are evident throughout the area. Evidence of interfingered sand and gravel deposits, probably from reworked river beds,

Figure 4

Generalized Geology for the Surficial Aquifer in Evergreen
(cross section W-E)

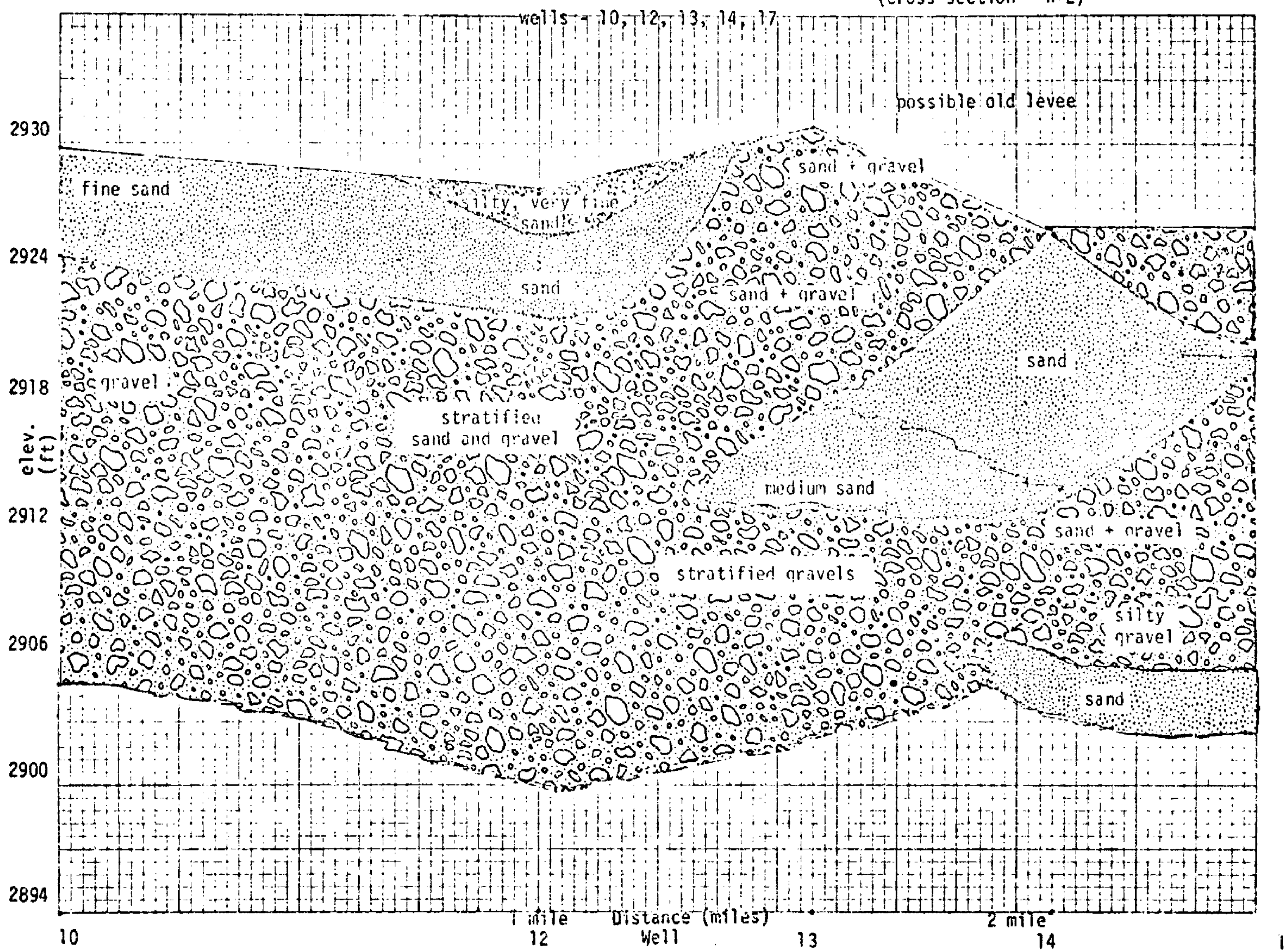
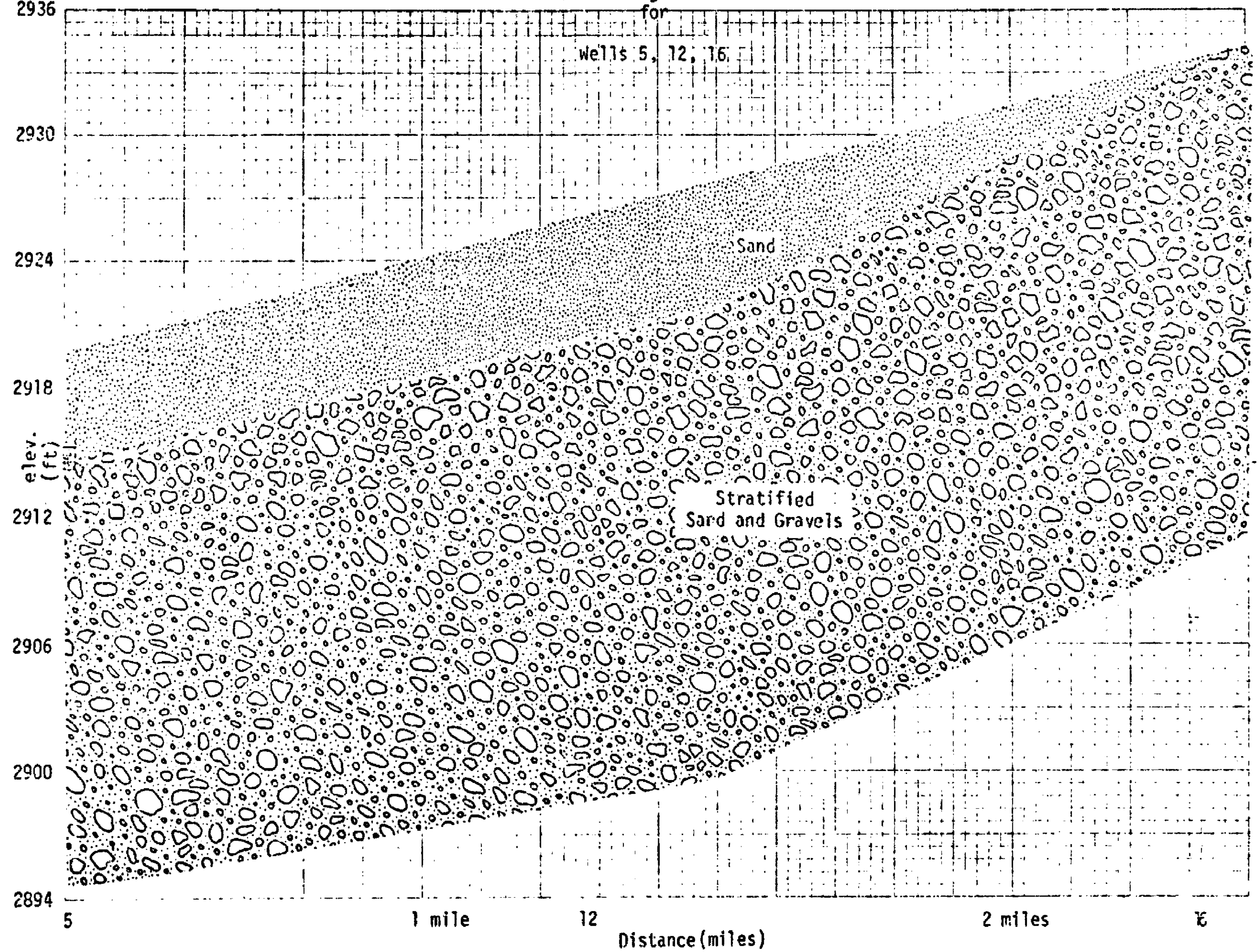


Figure 5

Generalized Geologic Cross Section for Wells 5, 12, 16



appear on logs of wells drilled for the study and on logs of local domestic wells (Figure 4).

SOILS

Soils in the Evergreen area are generally of two associations; Kiwanis-Walter-Birch (KWB) and Banks-Chamokane-Corvallis (BCC). The latter generally forms the banks and natural levees adjacent to the Flathead River whereas the former comprises most of the remaining land between the Flathead and Whitefish Rivers (Figure 6).

Banks-Chamokane-Corvallis

"Slopes are nearly level to gently sloping, but there are many low, wet spots.

"This association consists of deep . . . loamy soils and deep, sandy soils with sandy subsoils. These soils have developed in recent stream alluvium . . . . Soil drainage ranges from excessive to poor." (S.C.S., 1960).

Kiwanis-Walter-Birch

"The area in which it occurs is nearly level, low terrace . . . .

"This association consists of deep to shallow, . . . loamy to moderately sandy soils. These soils have developed in low-terrace stream alluvium, ... They are well drained to excessively drained." (S.C.S., 1960).

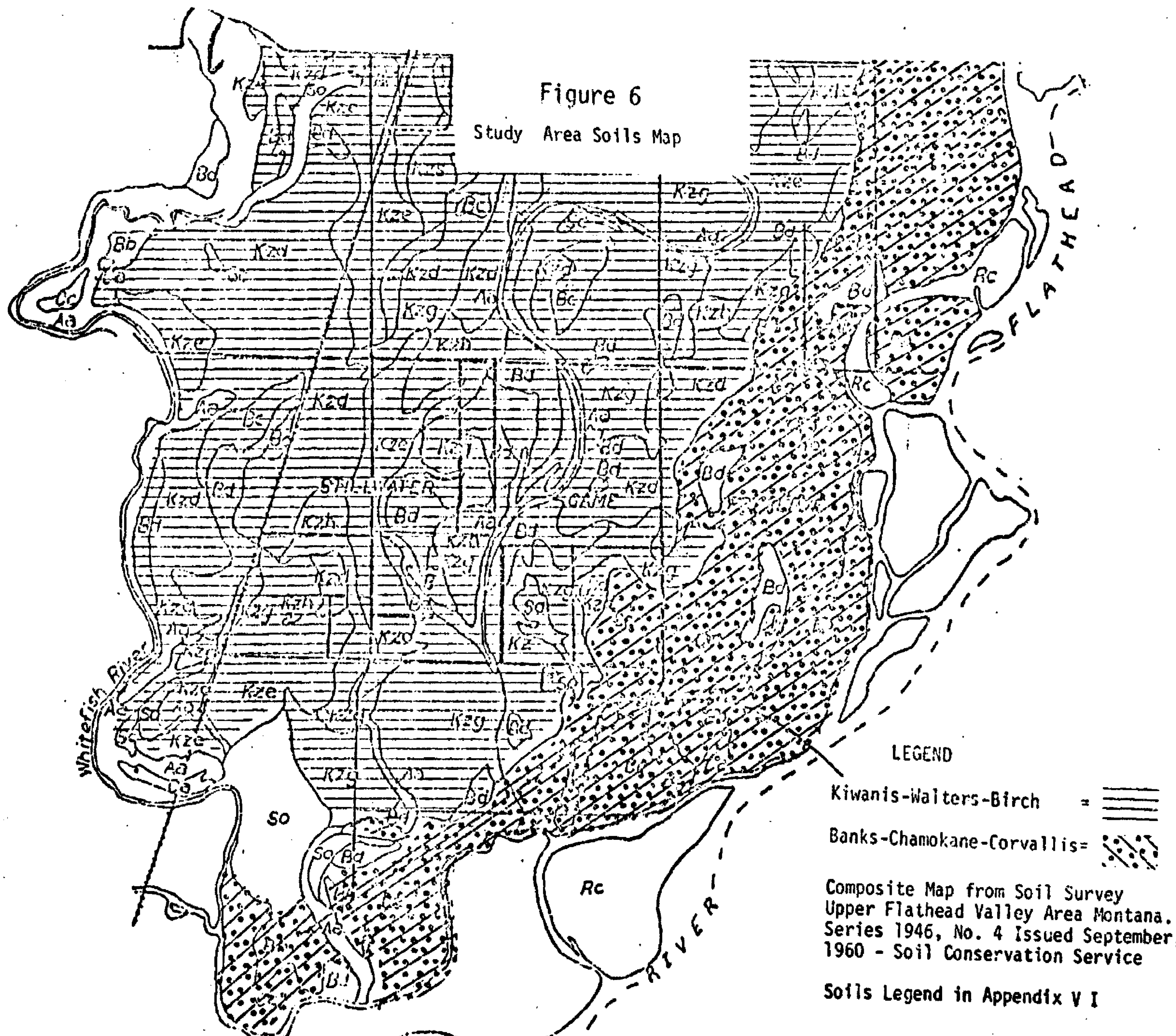


Figure 6

Study Area Soils Map

Composite Map from Soil Survey Upper Flathead Valley Area Montana. Series 1946, No. 4 Issued September, 1960 - Soil Conservation Service

Soils Legend in Appendix V I

ENGINEERING PROPERTIES

Kiwanis-Walters-Birch occurs in the higher ground and terraces and Banks-Chamokane-Corvallis is found in the adjacent stream bottoms according to the SCS Soil Survey (SCS, 1960) and the engineering supplement (SCS, 1970). There is generally less than a 10 foot change in elevation between areas representing these two associations. These soils are subject to flooding, have slow runoff characteristics, but are moderately to well drained. Slopes range from 0 - 9 percent. Permeability ranges from 0.2 - 6.3 inches per hour. Percolation rates in these soils range from one minute per inch in sandy material to five minutes per inch in the less permeable soils (personal communication, Tom Cowan, 1979). Therefore, this soil is considered very permeable. Gravel is found from 10 - 60 inches below the soil surface.

Published limitations (SCS, 1970) for pertinent uses of these soils are:

USE	RATING
Sanitary landfills	Moderate - Severe
Septic tank installations	Moderate - Severe
Ponds	Moderate - Severe*
Embankments	Moderate - Severe

* Of the 17 described soils in these soil associations, one has a slight limitation rating for ponds.

P O P U L A T I O N

DISTRIBUTION

Evergreen was a rural area of small farms and relatively few homes in 1940. By 1979, housing approached single family residential density in many areas. The 201 Facilities Plan for Kalispell, Montana, estimates the population growth in the City of Kalispell since 1970 at 3.9 percent whereas the area surrounding the city, including Evergreen, has grown 192 percent in the same period. Growth has accelerated in rural areas of Flathead County during the last ten years; the Evergreen area has kept up with or exceeded the rural growth rate according to the Flathead County Areawide Planning Office (APO).

Two methods were used to estimate the present number of residences in the study area.

1) Post office route data.
2) Ennumeration of residences in the area on U.S. Army Corps of Engineers (COE) air photos.

The APO determined from census data that there is an average of 3.51 people per residence in the Kalispell Jurisdictional Area which includes the Evergreen area. Multiplication of the number of residences estimated from the post office data by 3.51 people per residence provides a present population estimate of 5,996 for the area. Multilication of the number of residences in the area estimated from COE air photos by 3.51 people per residence provides a population estimate of 4,588 for the area. The population estimates are assumed to represent high and low values; therefore, the average, 5,292, is assumed to be the present population of the area.

Comparison of the APO estimated 1962 population in Evergreen of 1,770 with the present area population estimate of 5,292 indicates the area population has tripled in seventeen years. The majority of the population is concentrated on approximately 31 percent of the land in the southwest corner of the area where the population density may exceed 2.0 persons/acre (Figure 7).

WATER SUPPLY AND WASTE DISPOSAL FACILITIES

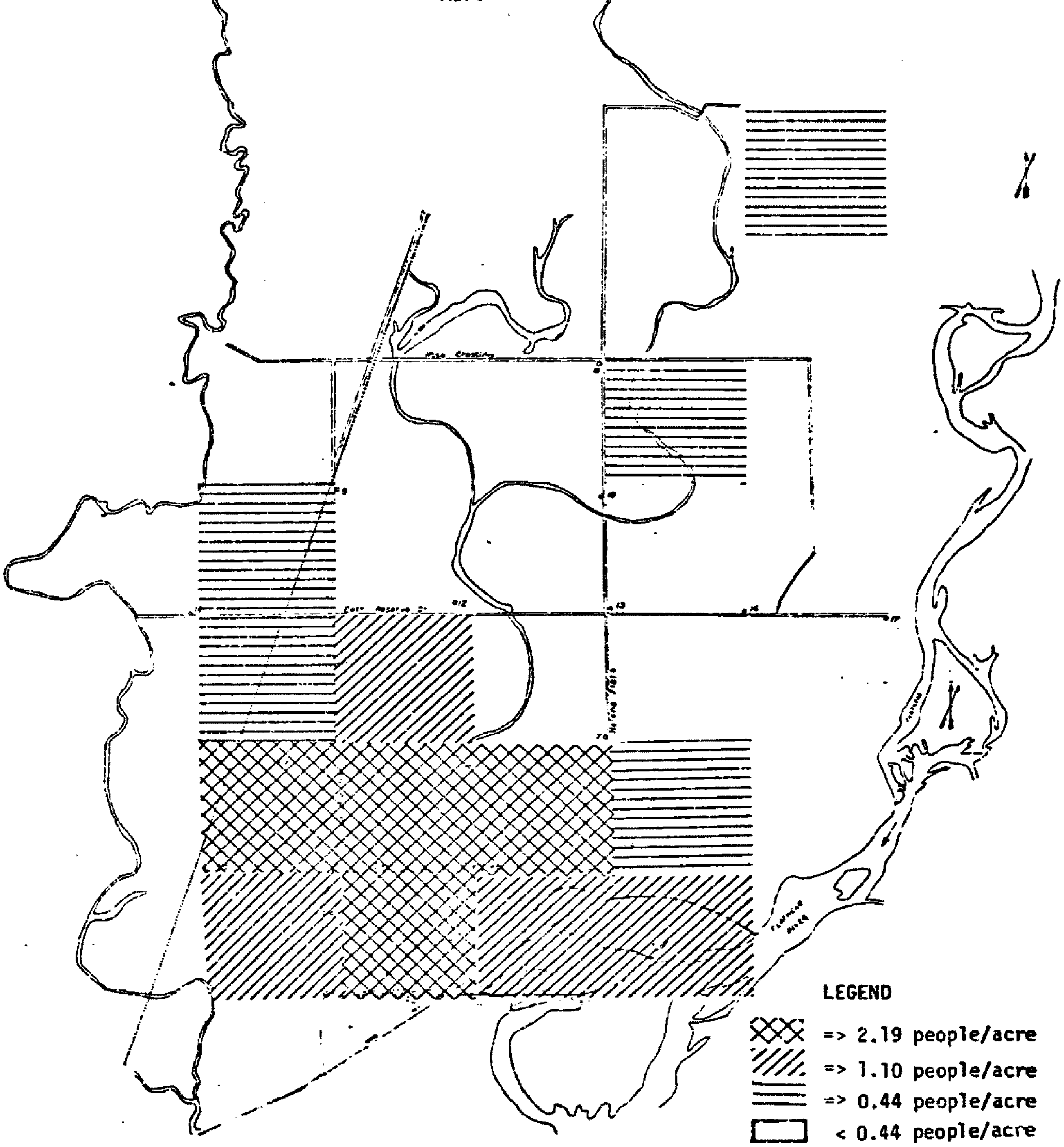
Domestic water supplies in the study area are supplied by both public and private systems. Service is available from the Evergreen Water District (a public utility) to most of the study area. The utility currently serves approximately 70 percent of its potential customers. Private systems utilize both shallow and deep wells. Older residences typically have shallow wells, ranging from 25 - 30 feet deep. Well construction techniques range from the use of sand points to cased and screened wells. Newer homes typically have deep wells (mostly deeper than 120 feet) penetrating the artesian aquifer. Most deep wells are located within the northern half of the area whereas most shallow wells are located in the southern half.

On-site waste disposal is commonly via a septic tank and drainfield. A well-designed on-site system consists of a septic tank for holding solid wastes, a distribution box for dispensing effluent and a tile drainfield. Successful operation depends on the ability of the

Figure 7

Evergreen Population Distribution

March 1979



soil and alluvium to absorb and filter the effluent passed through the drain field. Effluents from these systems generally contain large quantities of nitrogen in ammonia and organic form and phosphorous as ortho, condensed phosphate and organic phosphorous. Significant portions of the nitrogen and phosphorous compounds occur in particulate forms that are filtered by the soil and alluvium column. Biochemical reactions convert some of the particulate organic forms to soluble ammonia and orthophosphate forms readily available to plants.

Septic tank and soil absorption systems provide primary and secondary sewage treatment. The tank removes solids and greases while the drainfield (soil absorption) reduces the effluent nutrient and bacterial load. The distance between the bottom of the drain tile and the top of the saturated zone (potentiometric surface) is very important. Flow of effluents in unsaturated materials is slower than flow in saturated materials. The slower the flow, the longer the time available for absorption, adsorption and various biochemical reactions to occur that result in the removal of nutrients, organic material, bacteria and viruses from the effluent. Removal efficiency of nutrients and other constituents of the effluent increases as the number of soil exchange sites increases. As a general rule, finer materials, such as clays, have more exchange sites than coarse materials, such as sand and gravel. Therefore, greater effluent renovation is obtained in finer textured soils. Septic tank design assumes regular maintenance including sludge removal from the septic tank every 3 - 5 years (personal communication, Tom Cowan). In the study area, it is common for owners to claim that their system operates well even though it has not been pumped for seven or more years. Failure to pump the tank on a regular basis reduces the effectiveness of the system. Premature failure of the system may result.

LEGAL CONSTRAINTS

Montana water law generally follows federal guidelines. A major exception is the Reservation Doctrine which sets aside water for present and future needs of streams and rivers on or adjacent to any federal reservation of land. That doctrine or interpretation of law is being contested now and may not be resolved in the near future.

Several Montana State Statutes discuss water and the use of water. The Montana State Constitution, Article IX, Section 3, states "that use of all water that is now or hereafter appropriated for sale, rent, distribution or other beneficial use is held to be a public use." It further states that "all surface, underground, flood and atmospheric waters within the state are the property of the State" i.e., state waters. Under the Water Use Act (Sec. 89-885, R.C.M., 1947), all appropriators of water must apply for a water use permit. If the effective date of the appropriation is after July 1, 1973, the permit is valid; however, if the effective date of the appropriation is before July 1, 1973, the permit must be reapplied for through the Department of Natural Resources and Conservation, Water Rights Bureau, before January 1, 1982. In application, wells for domestic use with a pumping rate less than 100 gallons per minute are routinely approved. The Montana Water Pollution Control Act (MWPCA), Title 69, Chapter 48, R.C.M., 1947, defines pollution as any discharge into state waters which "will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish or other wildlife." The same act states that it is unlawful "to cause pollution of any state waters, or to place, or cause to be placed, any wastes in a location where they are likely to cause pollutuion of state waters" (Section 69-4806 (1), R.C.M., 1947). This requirement provides the rationale for the Montana Pollution Discharge Elimination System permits. According to Steve Pilcher (MDHES, Water Quality Bureau), septic tanks with drainfields do not require Montana Pollution Discharge Elimination System (MPHES) permits.

Surface water quality standards are established by the MDHES in MAC 16-2.14(10)-S14340. No water quality standards currently apply to groundwater.

Title 69, Chapter 50, R.C.M., 1947, (Sanitation in Subdivision Law) provides one of the major tools to protect groundwater quality. Section 69-5001, R.C.M., 1947, specifies minimum lot sizes depending on the services provided on that lot. If both a domestic well and an on-site disposal system are on the lot, the area of the lot must be no less than one acre. If one or the other (well or septic system) are on the lot, then the area of the lot must be no less than 20,000 square feet, (0.46 acres). The most important site criteria for installations of a septic system is the depth to groundwater from the surface. The State of Montana requires a minimum of six feet of separation between the maximum seasonal groundwater elevation and the soil surface. Specifically, the Flathead County Board of Health regulations state that "no pit or trench excavation shall extend to within four feet of high water table or shattered consolidated rock formations." They also require a minimum of twelve inches of earth cover over the gravel fill of the soil absorption system.

The most powerful body of law currently available for protecting groundwater is the County Board of Health regulations. Title 50, Chapter 2, R.C.M., 1947, describes the basic powers of local Boards of Health. They shall;

1) Guard against the introduction of communicable disease.
2) Abate nuisances affecting public health and safety or bring action necessary to restrain violation of public health laws or rules.
3) Adopt necessary regulations and fees, i.e. septic tank regulations.

In summary, according to existing state law, it is "unlawful" to pollute state waters which include groundwater. Without any standards defining groundwater quality, violations may be difficult to prove. Using local Health Board regulations, it is possible to cause relatively major contamination problems to be corrected if they are caused by a point source or a source that can be identified beyond a reasonable doubt.

METHODS

WELLS

Wells cased with plastic (PVC) were drilled at 18 sites to allow measurement of potentiometric levels (the elevation to which water rises in a well open to the atmosphere) and the withdrawal of samples for the measurement of various chemical and biological parameters. Local stratigraphy was inferred from well logs and existing geological maps.

The 18 well sites were picked to intersect hypothesized and published groundwater flow paths and to sample varying population densities and land use types. In order to facilitate data transfer between maps of differing scales, the well sites were initially located at section and ¼ section corners adjacent to county right-of-ways. Some of the final well sites, as depicted in Figure 2, do not lie near section or ¼ section corners because some landowners refused to grant access to their property.

A letter and oral well presentation was given to the Evergreen Chamber of Commerce resulting in three critical well sites. Easements were signed by cooperating landowners, giving the FD 208 Project the right to emplace wells and monitor them for the duration of the study. With the cooperation of the Flathead Conservation District (FCD) and the Soil Conservation Service (SCS), wells were drilled during the period from the 26th of September to the 14th of October,

1978. A total of 50 wells were emplaced and well head elevations (relative to mean sea level) were determined by the SCS at the above sites.

The SCS required easements, granting access to the well sites, before they would drill the wells. The Flathead County Attorney's office provided the required easement forms (Appendix I) which were then signed by the cooperating land owners. Only one easement was signed by each landowner regardless of the number of well sites on that landowners property. Access to county property was granted by oral agreement. Appendix II lists the property owners and well site(s) on their property.

NUMBERING

Several well numbering systems were considered including the U.S.G.S. system. An arbitrary system was finally selected for simplicity of labeling the large number of samples collected. Figure 2 shows the well sites and their respective numbers. At each site where more than one well was drilled, the deepest well was labeled X-1 and the shallowest well, X-3.

INSTALLATION

The wells were drilled by Harry Brence (driller) and Sherm Sollid (geologist) of the SCS. They used a Mobile B-50, auger flight, rotary drill with six inch, hollow stem augers to drill the wells, Each well was cased with 2" PVC schedule 40 pipe. The bottom four feet of casing was perforated with a 7/32" drill bit and a brass screen was glued over the end of the well (Figure 8).

Three wells were drilled at most well sites. Wells were spaced five feet apart vertically at each site (Figure 9). The first well at each site was set with its bottom approximately fifteen feet below the observed potentiometric surface. The next two wells were left with bottoms approximately ten and five feet respectively below the observed surface. The purpose of the three well array was to identify possible vertical stratification, hydraulic, chemical or biological, in the surficial aquifer.

At three sites (sites 15, 16, and 17), less than three wells were drilled because the drill rig had to move to another job. Review of COE well logs (COE, 1974) for wells adjacent to the Flathead River demonstrated that the river was in contact with the same gravel formation that contained the surficial aquifer; therefore, only one well was drilled at site 17. It was deemed adequate to drill two wells at well sites 15 and 16 because the land use was similar to that at site 18 and the potentiometric surface was much deeper than in most of the study area.

Actual drilling time was six working days between the 26th of September and the 14th of October, 1978. The mean static potentiometric surface was approximately ten feet below the ground surface at the time of well installation.

A log of materials penetrated during drilling the deep well at each site was recorded (Appendix III). Upon completion of drilling,

Figure 8

Perforation Schematic

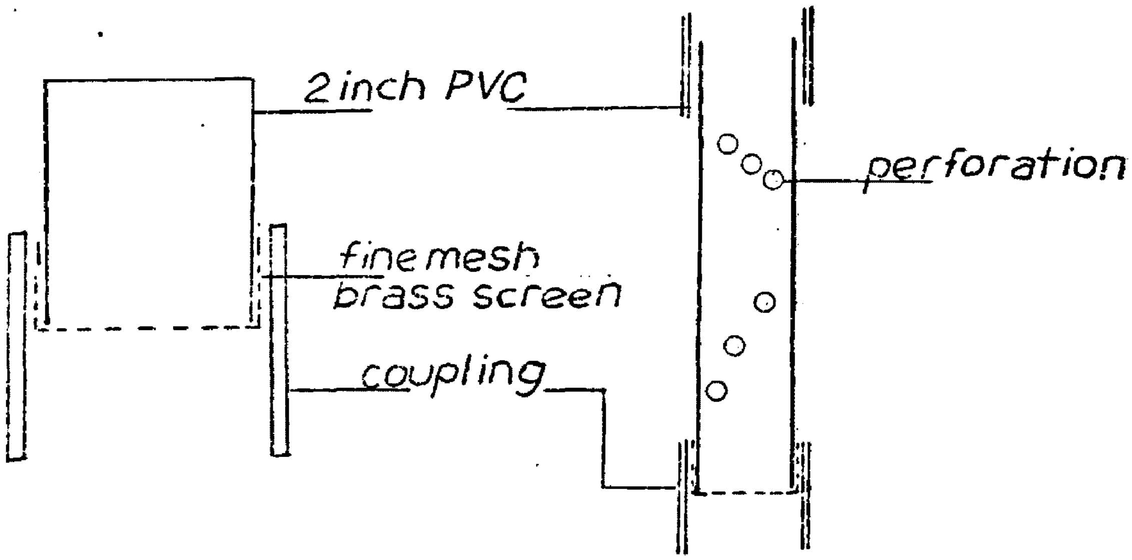
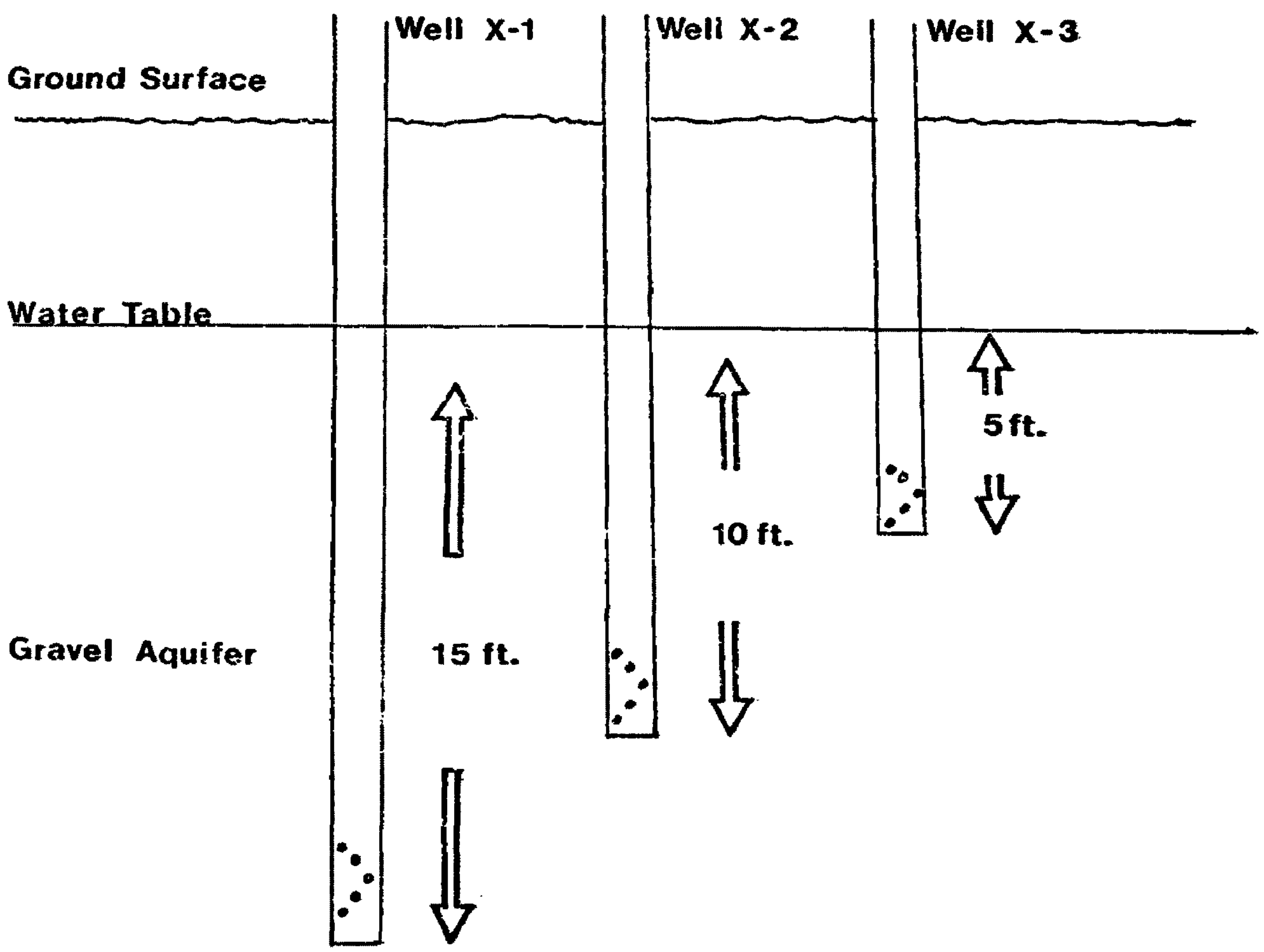


Figure 9

Vertical Placement of Three Well Array



each strata encountered was classified according to the Unified Soil Classification System of the SCS.

MAPPING

The SCS determined casing head elevations (Appendix IV) relative to mean sea level (MSL). This procedure was necessary to establish a potentiometric surface relative to standard datum (2900 feet, MSL).

Areal locations of the well sites are being mapped by the U.S. Army Corps of Engineers (COE). Low level aerial photography was flown in late Spring of 1979. Prior to flying the area, the COE marked all of the well sites so that they would appear in the imagery. All of the well sites will be marked on a two foot contour interval topographic map of the study area being produced by the COE. (Incomplete as of 12/3/79).

Stratigraphic sections through the study area (Figures 4 and 5) were interpreted from project well logs. Well logs of deep domestic wells located within the study area were examined to locate the confining layer between the upper and lower aquifers to determine the possibility of contamination of the lower aquifer by water from the upper aquifer.

WATER LEVEL MEASUREMENTS

Potentiometric surfaces were measured from the well heads with a standard, 50 foot, surveyor's steel tape marked in hundredths of a foot. The bottom two feet of the tape was marked with water soluble ink which dissolved if submerged below the water table. Subtraction of the water mark from the well head reading yields the depth to groundwater from the well head (top of casing). The height of casing above ground was known and when subtracted from the total depth to groundwater, yields the depth to groundwater from the ground surface. All calculations are formulated to yield distance above datum (2900 feet MSL). Sample calculations are shown in Appendix V.

Water levels were measured by a trained technician once a month during the winter, every two weeks during spring runoff and once a month again in late summer.

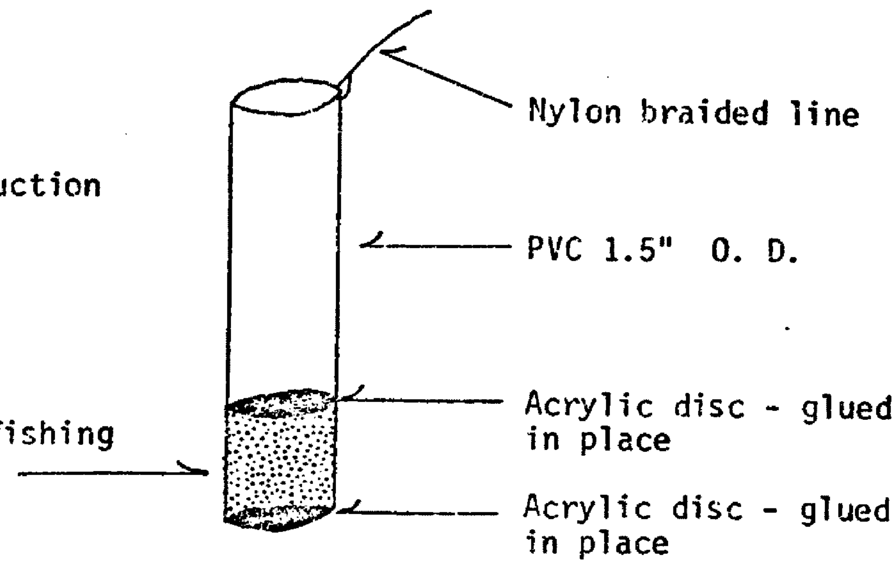
WATER SAMPLE COLLECTION AND ANALYSIS

Attempts to develop a pump sampler were unsuccessful and a bailer was built to fit inside the two inch PVC casing. The bailer, (Figure 10), was constructed of PVC and acrylic plastic in order to minimize contamination and simplify cleaning.

Prior to sampling, the bailer was thoroughly cleaned and then lowered into the well. The first bailer of sample water was used to rinse the bailer and the sample bottle. After discarding the rinse

Figure 10

Bailer Construction



water, the one liter sample bottle was filled and the water temperature was measured with an accuracy of ± 0.5°C with a Taylor pocket thermometer. Field values of specific conductance were determined with a Delta Scientific Model 1014 specific conductance meter which automatically corrects readings to their equivalent at 25°C. Field pH of samples from each well was measured a miminum of four times with an Orion Specific Ion Meter, Model 407A. The meter was field standardized with buffers selected to bracket the expected sample pH range.

Sample bottles were immediately taped shut and then placed in locked, wooden shipping boxes filled with ice to cool the samples during shipment. Only Dr. N. Stark's personnel and FD 208 Project personnel had keys for the sample boxes.

Samples were analyzed by Mr. Steve Bodmer for non-biological parameters under the direction of Dr. Nellie Stark in the School of Forestry, University of Montana, within twenty-four hours of sampling.

Table 1 lists the parameters measured in the various samples and whether they were measured in the field or lab. Precision and accuracy of data of the analysis methods used are published in Standard Methods (APHA, 1976) and Methods for Chemical Analysis of Water and Wastes (EPA, 1971). Dr. Stark's laboratory staff derived precision and accuracy data for the analyses utilized in this thesis. (Bodmer and Stark, 1979)

BIOLOGICAL

Bacteriological sampling began in January, 1979. The analyses were conducted by Rene Sol of the Montana Environmental Laboratory, an EPA certified lab using standard Millipore methodology. Using a small iron bailer (to allow flame sterilization), separate samples were taken for fecal coliform (FC) and fecal streptococcus (FS) bacteria. Sterile glass bottles supplied by the lab were used to hold the samples. Prior to each sample taken, the bailer was sterilized with alcohol and/or a portable propane flame. The first sample removed from each well was used to rinse the bailer and then thrown away. Sample bottles were not rinsed as per instruction from Ms. Sol. Analysis was conducted within eight hours of sampling.

Table 1

Chemical and Biological Parameters

	Analytical Parameters	Method	Dates
LAB	(1) Cations		
	Calcium Ca^{+2} (mg/l)	Atomic Absorption Spectroscopy	12/2/78-9/11/79
	Copper Cu^{+2} (mg/l)		
	Iron Fe^{+2} (mg/l)		
	Potassium K^{+1} (mg/l)		
	Magnesium Mg^{+2} (mg/l)		
	Manganese Mn^{+2} (mg/l)		
	Sodium Na^{+2} (mg/l)		
	Zinc Zn^{+2} (mg/l)		
	(2) Anions		
	Chloride Cl^- (mg/l)	Standard Methods - Colorimetric	2/24/79-6/3/79
	Bicarbonate HCO_3^- (mg/l)	Standard Methods - Acidimetric titration	2/24/79-6/3/79
	Ammonium NH_4^+ (mg/l)	Potentiometric-Orion Liquid Junction Probe	12/2/78-9/11/79
	Nitrate NO_3^- (mg/l)	Potentiometric - Cadmium Reduction	12/2/78-9/11/79
	Total Phosphorous Total P (mg/l)	EPA - Single Reagent Method	12/2/78-9/11/79
	Ortho Phosphate Ortho P (mg/l)	EPA - Single Reagent Method	12/2/78-9/11/79
	Hydrolyzable Phosphorous Hydrolyzable P (mg/l)	EPA - Single Reagent Method	1/28/79
	Sulfate $SO_4^=$	Standard Methods - Turbidmetric	6/3/79
	pH (-log{H+})	Potentiometric - Orion Liquid Junction Probe	12/2/78 9/11/79
	(3) Bacteria		
	Fecal Coliform - (number/100 ml)	Millipore Filter	1/2/79-8/21/79
	Fecal Streptococcus - (number/100 ml)		1/21/79-8/21/79
FIELD	pH	Orion Liquid Junction Probe	12/2/78-6/3/79
	Specific Conductance (µmhos)	Delta Scientific Meter	7/14/79-9/11/79
	Temperature (°C)	Taylor Pocket Thermometer	12/2/78-9/11/79

G R O U N D W A T E R

AQUIFERS

Several aquifers have been defined in the study area. Work by Konizeski et al. (1968) and the FD 208 Project (1977) indicate that major aquifers are within the upper six hundred feet of valley fill. An aquifer, for the purposes of this report, is defined as a continuous water bearing formation that seems to have uniform hydraulic and chemical characteristics. Figure 11 shows the general stratigraphy and relationships of the primary water bearing structures underlying the study area.

Generally, recharge to the aquifers, from precipitation and infiltration from streams, is greatest from April to July when stream runoff from accumulated winter snow is greatest, and is augmented by an average of 3.76 inches of rain in May and June (Figure 12).

SURFICIAL AQUIFER

The surficial, unconsolidated aquifers are of Recent and Pleistocene age and are composed of glacial drift and outwash deposits of sand, gravel and clay. This material has been reworked by the Flathead River resulting in some stratification and sorting. The surficial, unconfined aquifer is the most productive groundwater source in the study area.

Figure 11

Major Aquifers Underlying the Study Area

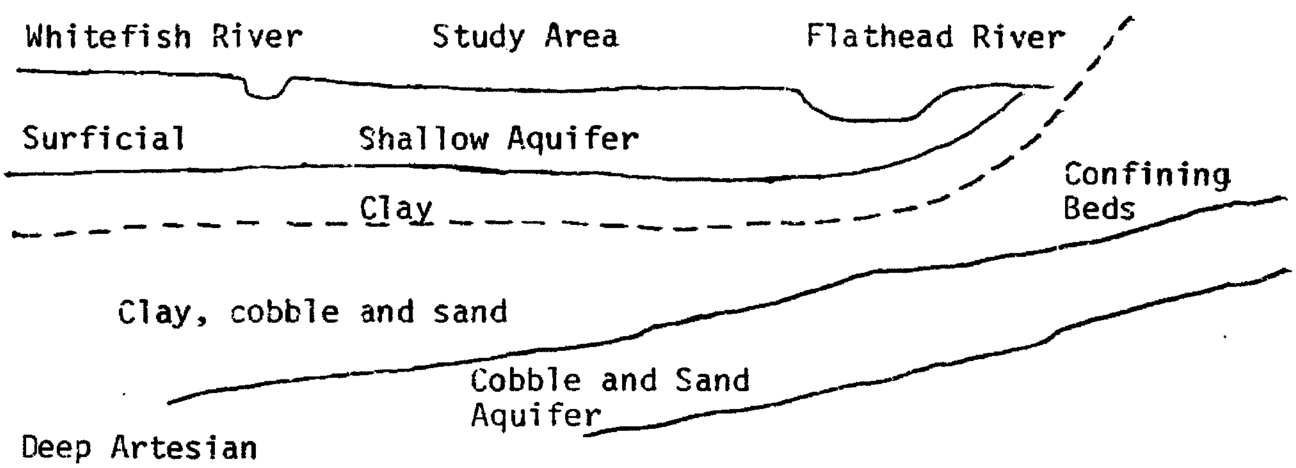
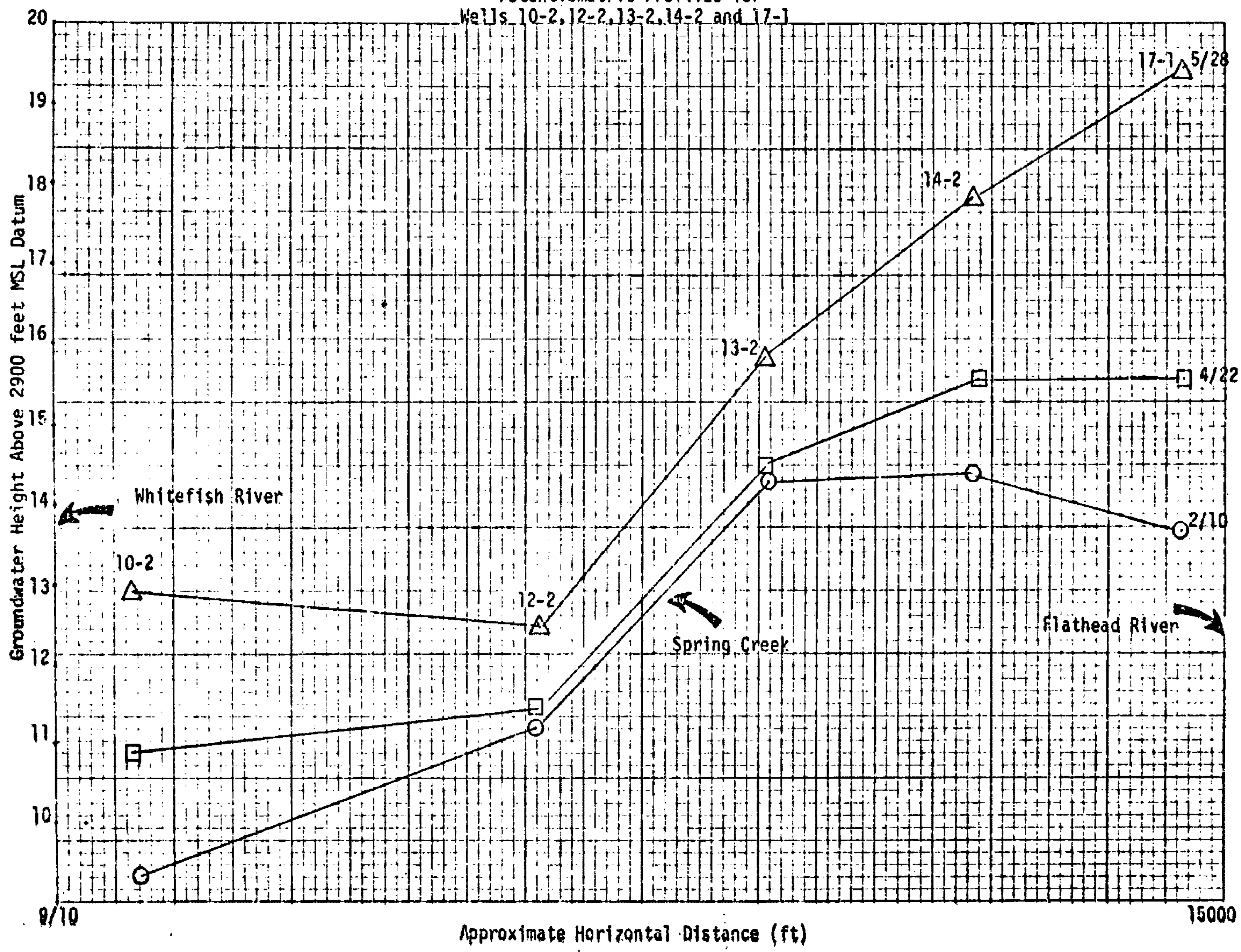


Diagram adapted from Konizeski et. al., 1968, showing the major aquifers underlying the study area. This diagram is not drawn to scale.

Figure 12

Potentiometric Profiles for
Wells 10-2, 12-2, 13-2, 14-2 and 17-1



The upper 40 feet of deposits were strongly influenced by riverine erosional processes during their formation. The surficial aquifer is part of a set of aquifers called Recent Flood-Plain Aquifers by Konizeski et al. (1968). It is gravel containing a few lenses of sand and silt averaging twenty-eight feet thick. The aquifer is the most permeable in the Kalispell Valley which makes it subject to man-caused pollution. Groundwater was found to move approximately fifty feet per day through the gravel aquifer by Konizeski et al. (1968). Such a rate of flow is unusually fast for groundwater which normally flows on the order of five feet per day or less.

Recharge to the surficial aquifer is by applied irrigation water, by precipitation and by infiltration from the Flathead and Whitefish Rivers during relatively high stages (Konizeski et al., 1968). Irrigation, precipitation, and snowmelt may play relatively less important roles than river recharge in terms of water quantity; however, they may be very important in modifying the quality of the surficial groundwater.

CLAY

The surficial and deep artesian aquifers occur in the upper layers of valley fill separated by a layer of clay averaging 69 feet thick. The clay layer is evident in all available well logs for wells penetrating the deep artesian aquifer in the study area. Therefore, it is assumed continuous.

DEEP ARTESIAN AQUIFER

Konizeski *et al*. (1968) described the deep artesian aquifer (the lower aquifer in Figure 11) as a series of beds of unconsolidated sand and gravel separated by discontinuous beds of fine-grained material. The thickness of the lower aquifer is generally unknown except in one instance (Well B29-20-27cb) where the aquifer is at least three hundred and sixty-four feet thick (Brietkrietz, 1966). Groundwater has been estimated to flow one-tenth of a foot per day in this aquifer (Konizeski *et al*., 1968).

Recharge to the deep artesian aquifer is by infiltration of snowmelt runoff and precipitation along the base of the surrounding mountain ranges where the aquifer surfaces.

FRACTURED BEDROCK AQUIFERS

Bedrock underlying the valley fill also appears to transmit water; however, bedrock aquifers are not utilized for water supplies in the study area.

WELL WATER LEVELS

Nested analyses of variance were conducted on water level measurements (Hicks, 1973; Federer, 1963). Statistical analyses were used whenever the sample size was large enough; otherwise, graphical (qualitative) analyses were used.

Well water level fluctuations are significantly different at the 0.01 level among sites and with respect to time. There is no significant difference at the 0.01 level between either wells within a given site or the time by site interaction effect (Table 2). Results of the tests demonstrate that the wells at each site are representative of the same hydraulic conditions. Some of the shallow wells went dry and/or partially filled with sand, precluding water level measurements during part of the year. The intermediate depth wells were the shallowest wells with complete records for the year and, as all wells at a site reflected similar hydraulic conditions, the intermediate wells were considered representative of the site condition.

Inspection of the groundwater profiles (Figure 12) shows that the Flathead River is the primary source of recharge to the surficial aquifer. Ground elevation at the Whitefish River is greater than the ground elevation at the Flathead River (2925 vs. 2922 ft. MSL) but at no time is the potentiometric surface near the Flathead River lower than the potentiometric surface near the Whitefish River. The change in elevation of the potentiometric surface during the year adjacent to the Whitefish River is approximately three feet while it is approximately five fieet adjacent to the Flathead River.

Figure 13 shows that potentiometric surface elevations rise and fall with corresponding changes in flow in the Flathead River. Figures 14 and 15 show potentiometric surface slope changes adjacent to the Flathead and Whitefish Rivers that correspond with changes in

Table 2

Nested ANOVA of Well Water Level Fluctuations

Source	df (degrees of freedom)	MS (Mean Square)	F
Site	13	516.40	1780.70
Well/Site	28	0.29	0.03
Time	20	252.57	113.26
Time/Site	260	2.23	0.26
Time X Well/Site	560	8.48	
Total	881		
Correction for mean	1		

$$Y_{i(j)k} = \mu + S_i + W_{i(j)} + T_k + ST_{ik} + WT_{i(j)k}$$

Where S_i = Sites, i = 1, 2, . . . , 14

$W_{i(j)}$ = Wells within sites, j = 1, 2, 3 for all i

T_k = Time, k = 1, 2, . . . , 21

ST_{ik} = Site by time interaction

$WT_{i(j)k}$ = Well with site by time interaction

Figure 13

Flathead River Flow at Columbia Falls vs. Groundwater Height above 2900' MSL Datum at Well #17

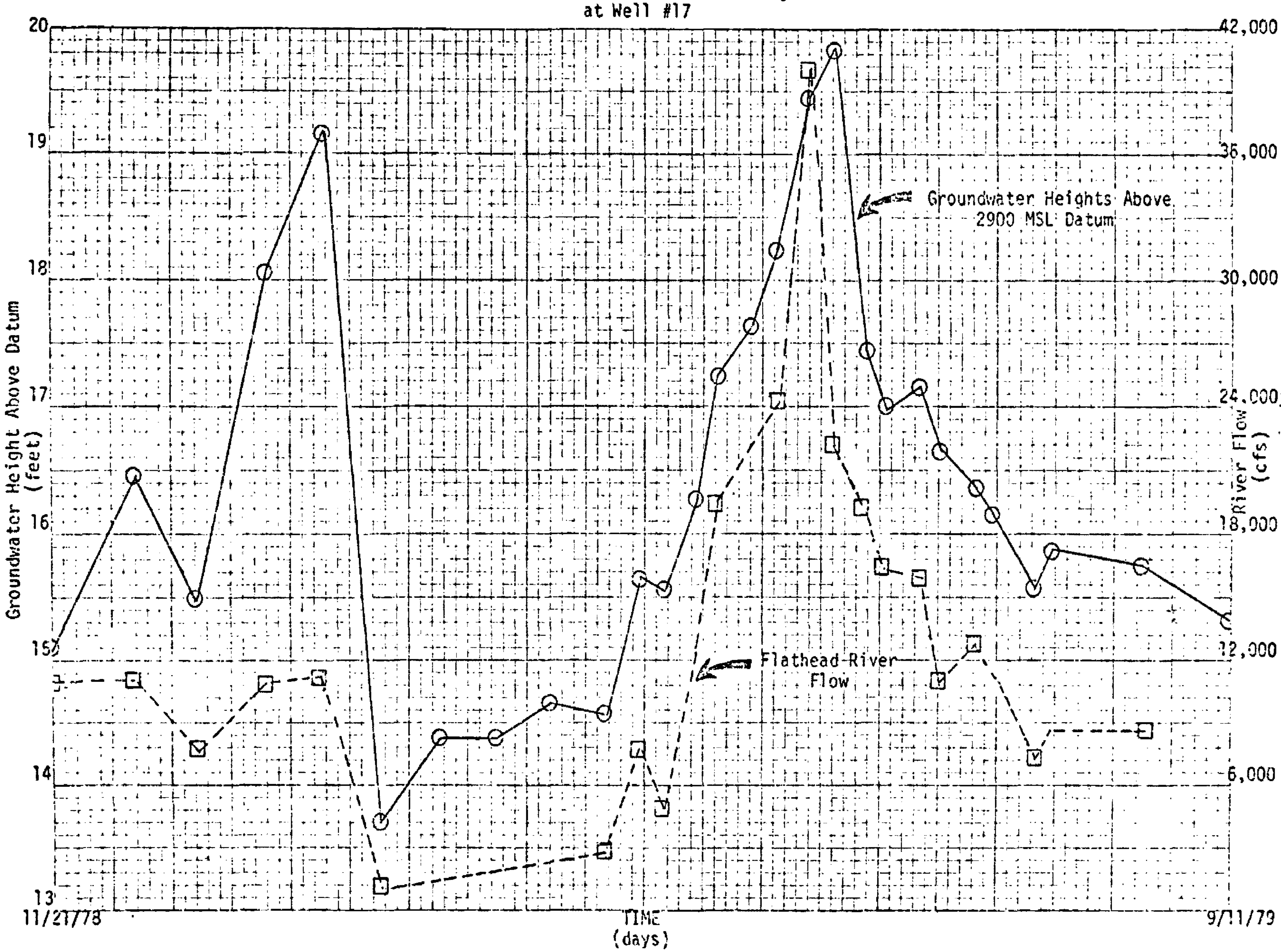


Figure 14

Influence of Flathead River on Gravel Aquifer
Slope for Well Line 17-13

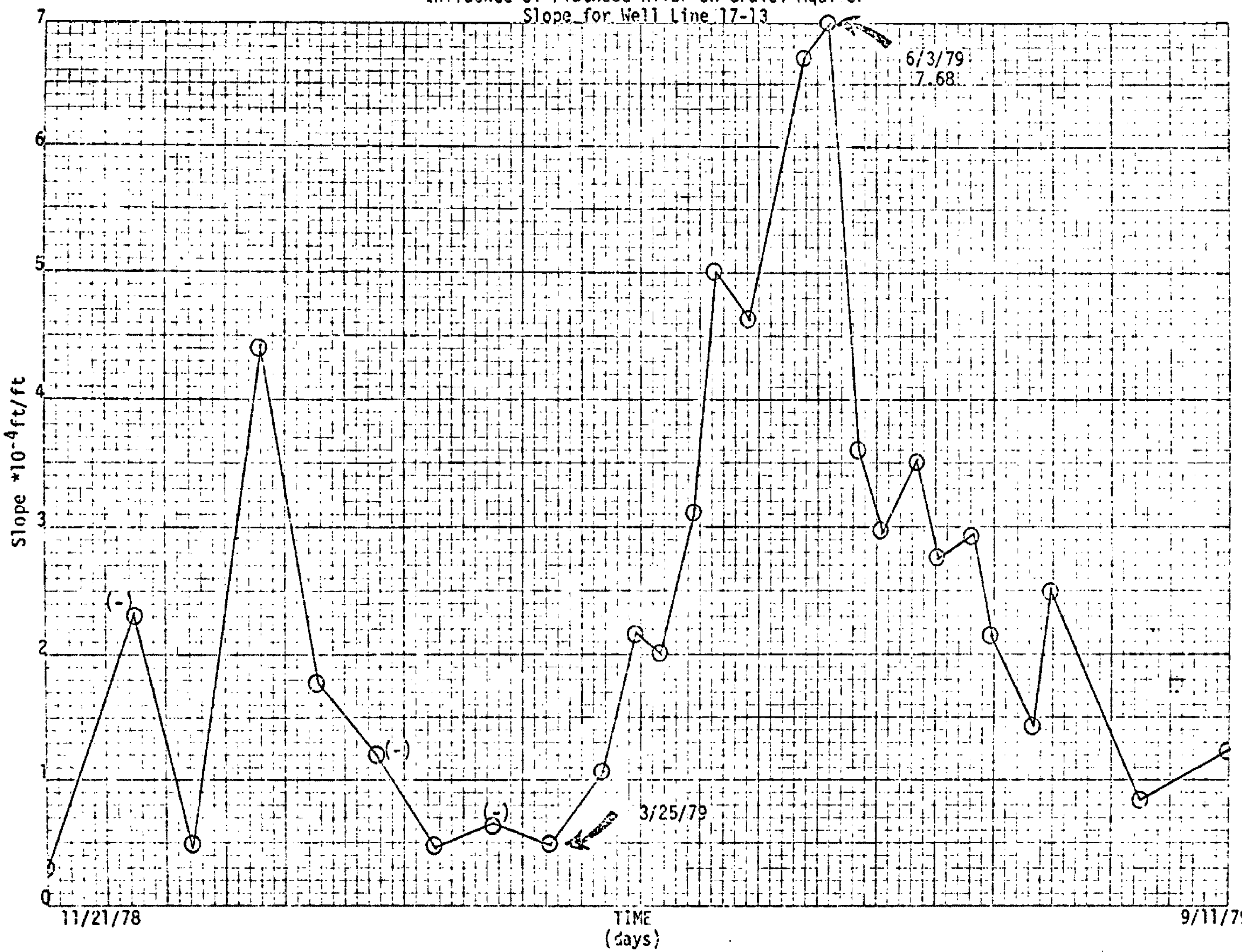
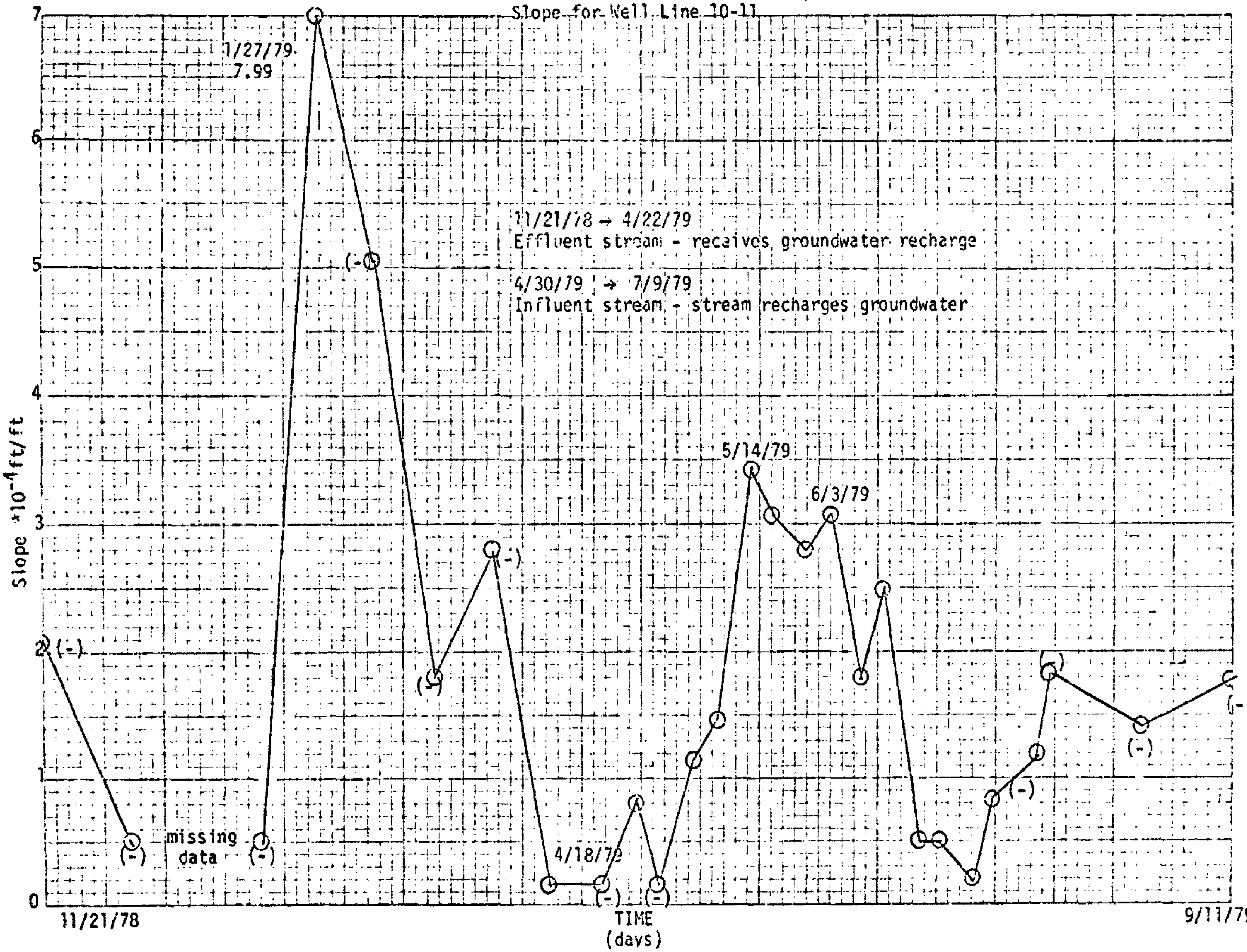


Figure 15

Influence of Whitefish River on Gravel Aquifer
Slope for Well Line 10-11



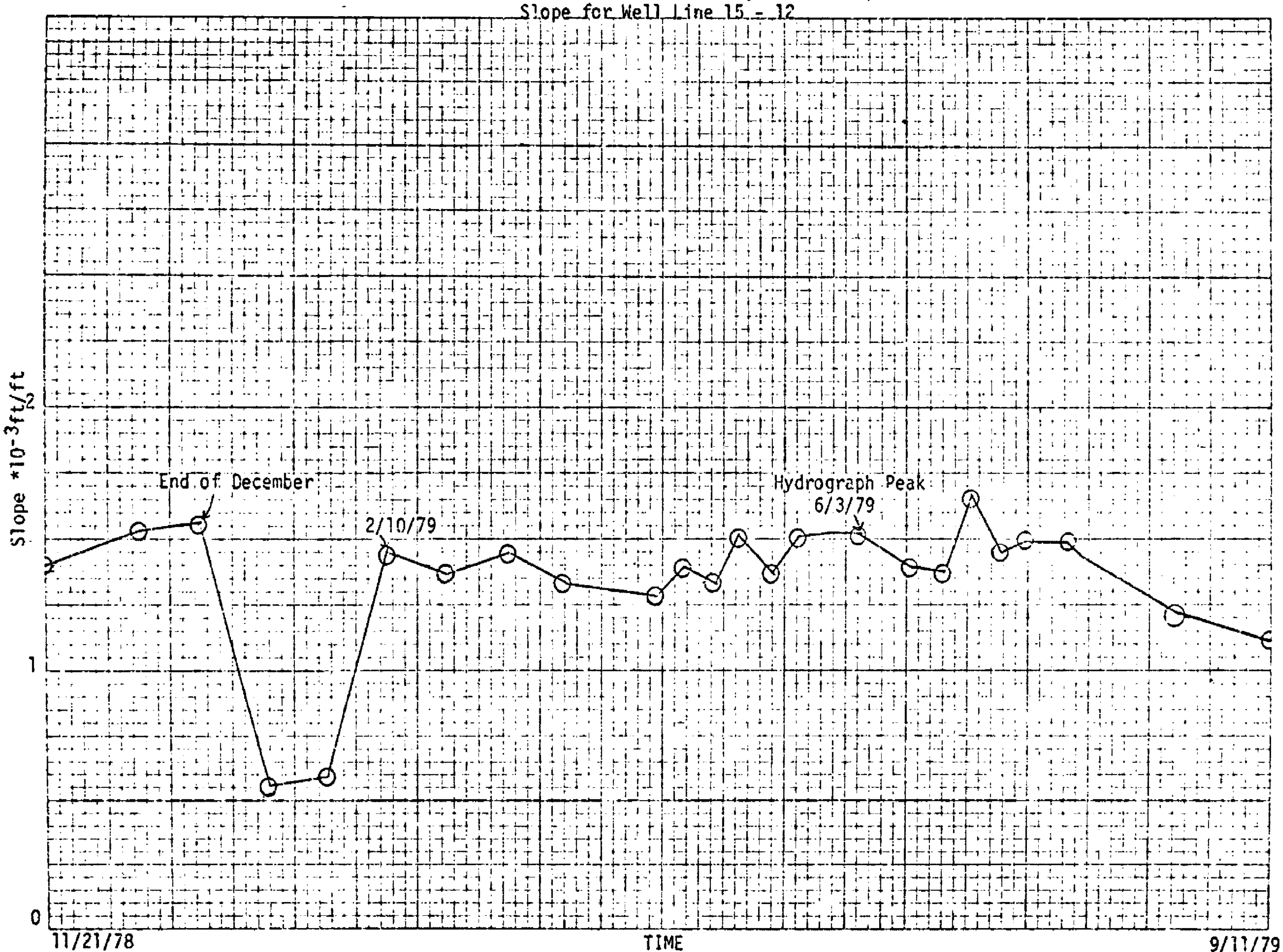
river flow. As river flow increases, recharge increases changing the slope from negative to positive values and causing a steepening gradient. Slope changes depicted in Figure 16 suggest that infiltration has a uniform effect through the well field and that snowmelt and precipitation infiltration has a minimal impact on the slope of the potentiometric surface. A rapid change in slope when monitored over time of the potentiometric surface as plotted in Figure 16, indicates recharge while no change or minimal change suggests that the recharge due to precipitation and local snowmelt is of minimal significance compared to other sources.

In Figure 14, potentiometric gradients near the Flathead River show the river to be recharging the surficial aquifer nearly all year. When the slope is negative, the stream is receiving water from the surficial aquifer and when the slope is positive, the stream is recharging the surficial aquifer. Only in the winter months of December through March is the Flathead River recharged by groundwater. Figure 15, illustrating the potentiometric gradient near the Whitefish River, shows that this river is normally recharged by water from the surficial aquifer. Only during the Spring runoff months, April through June, is the Whitefish River recharging the surficial aquifer.

To test the seasonal gradient variation, a North-South gradient was plotted that generally parallels the regional groundwater flow path. The selected well line was close to the center of the study area to reduce the individual effects of the two major rivers. Assuming a rapid change in gradient with respect to time represents a change in recharge, recharge from above the study area was relative-

Figure 16

North - South Potentiometric Gradient Changes with Respect to Time
Slope for Well Line 15 - 12



ly constant through the study period. Reduced recharge during January and February, 1979, was probably due to the severe cold of December, 1978, and January, 1979.

The potentiometric gradient averages seven feet per mile. Konizeski et al. (1968) found a southward directed gradient of about eight feet per mile.

Flow paths resulting from four different hydrologic conditions are plotted in Figures 17, 18, 19 and 20. These flow situations correspond to:

1) Low water conditions.
2) Approximately half way up the rising limb of the hydrograph.
3) The hydrograph peak.
4) Half way down the falling or recession limb of the hydrograph.

Figure 21 shows the change in direction of the flow near a given well with changes in river flow. The well near the Flathead River shows a shift away from the river during periods of increased river flow and an apparently retarded return to pre-runoff conditions. Flathead River stage readings changed approximately eleven feet during the study period while Whitefish River stage readings only changed approximately two feet. The flow paths near the Whitefish River shift away from the river toward the center of the study area during the rise in the river stage but return rapidly to pre-runoff conditions. Figure 22 shows generalized flow paths for the study area. These flow paths shift seasonally directing flow inward, toward the center of the study area during the Spring peak flows.

Figure 17

Low Water Potentiometric Surface
Wells X-2
2/10/79

feet above datum
(2900 ft. MSL)

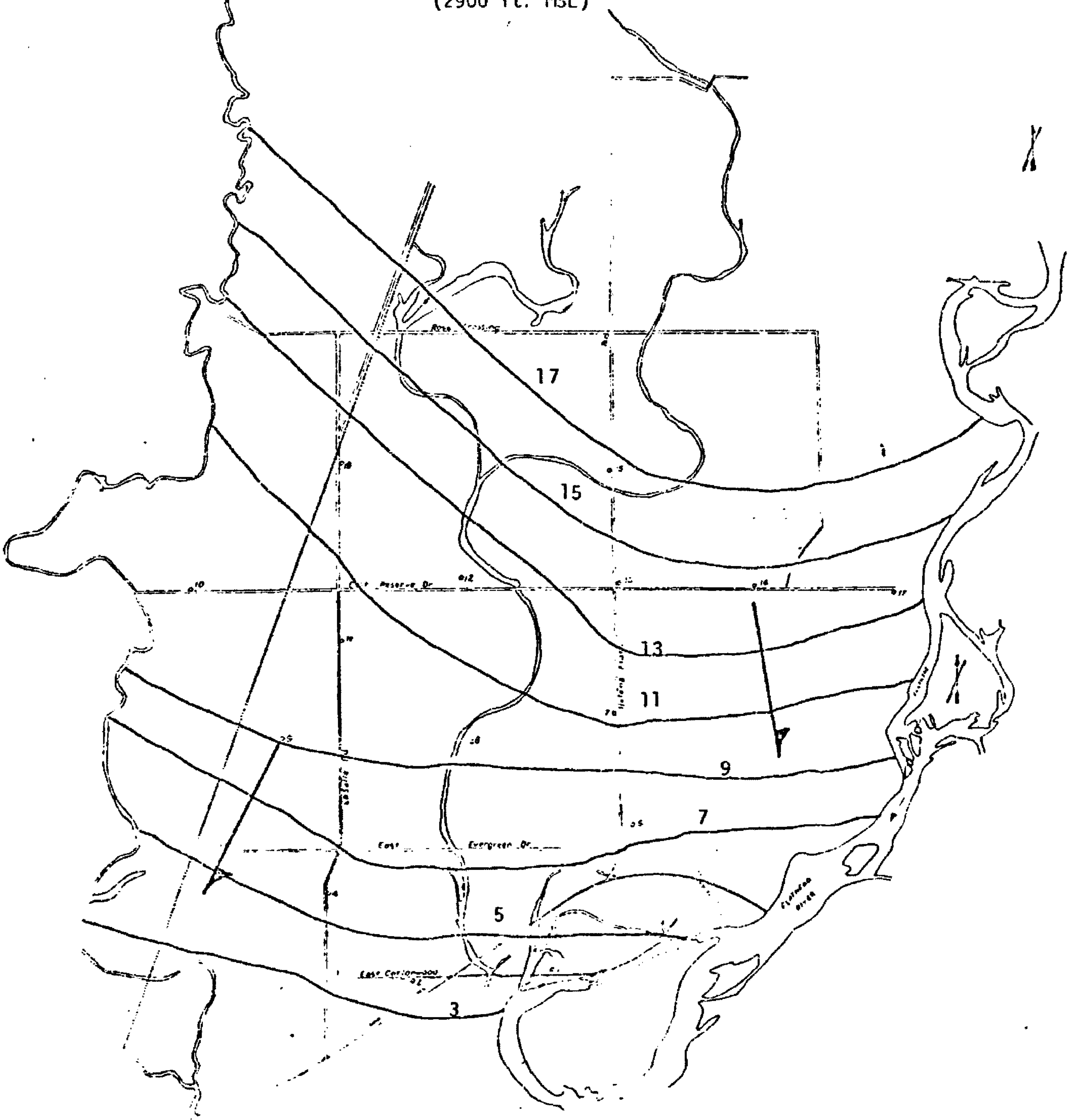


Figure 18

Potentiometric Surface for
Approximate Midpoint of Rising Limb of Hydrograph
Wells X-2
4/30/79

feet above datum
(2900 ft. MSL)

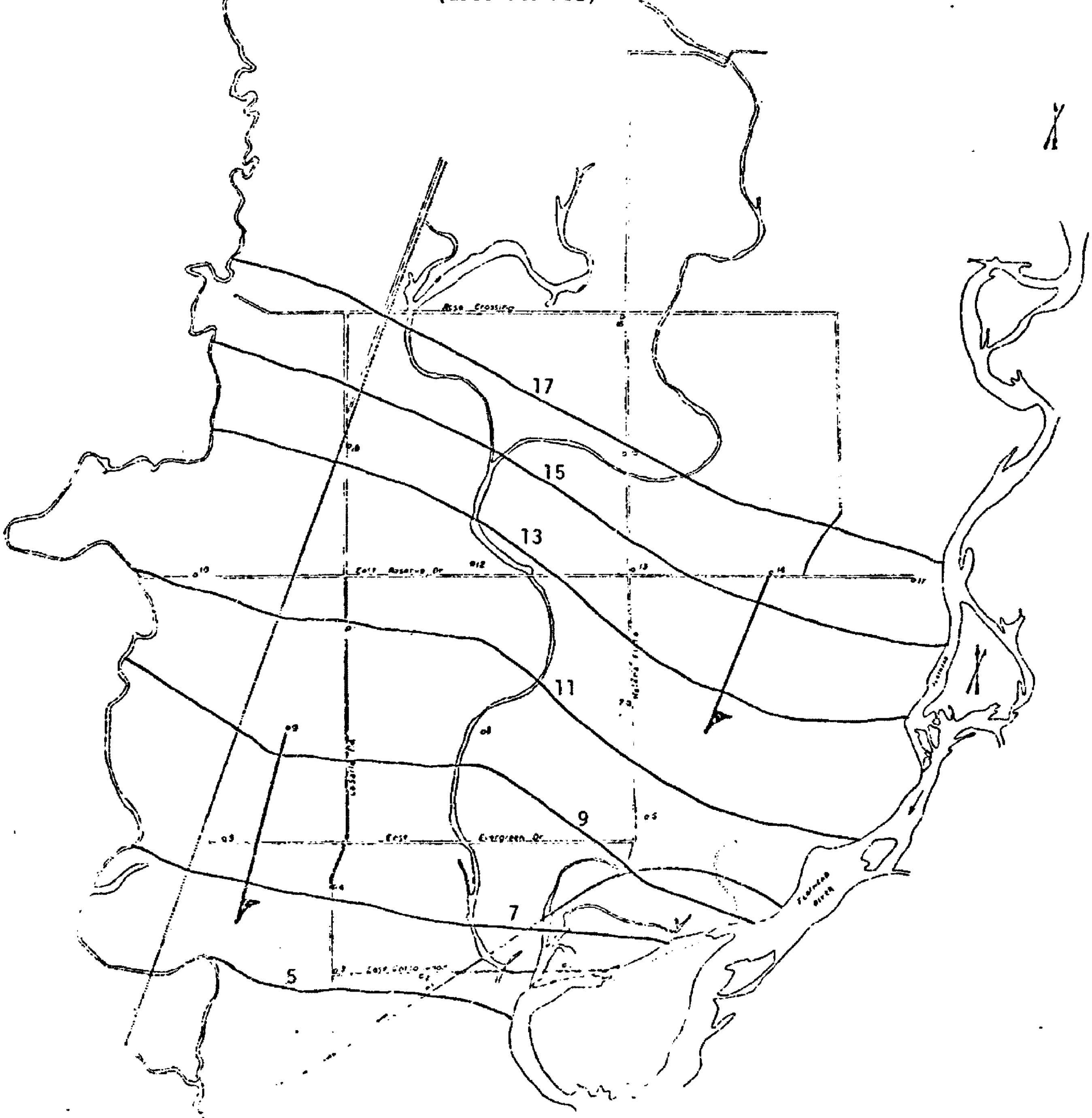


Figure 19

High Water Potentiometric Surface Map
Wells X-2

5/28/79

feet above datum
(2900 ft. MSL)

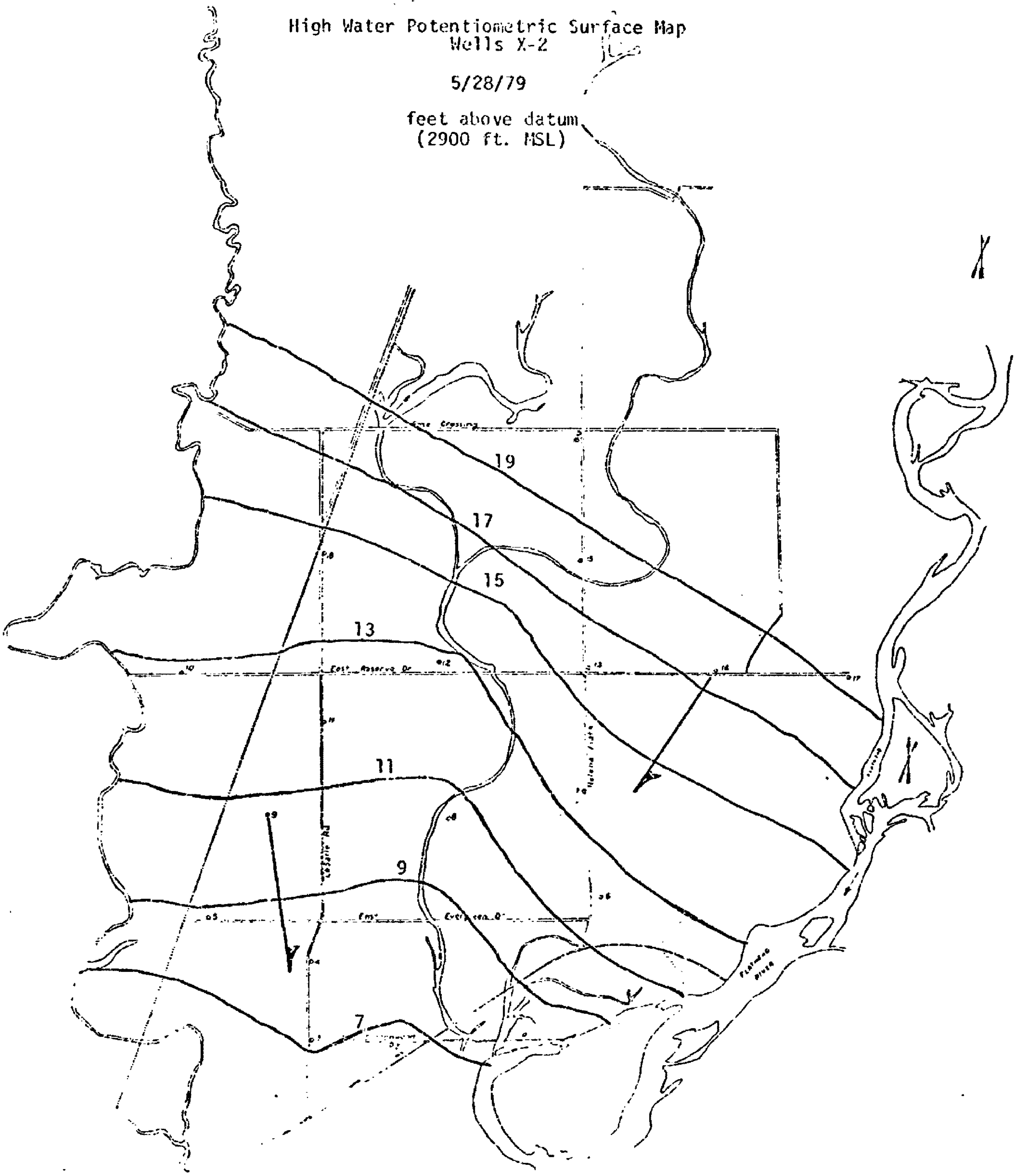


Figure 20

Potentiometric Surface for Recession
Wells X-2
7/14/79

feet above datum
(2900 ft. MSL)

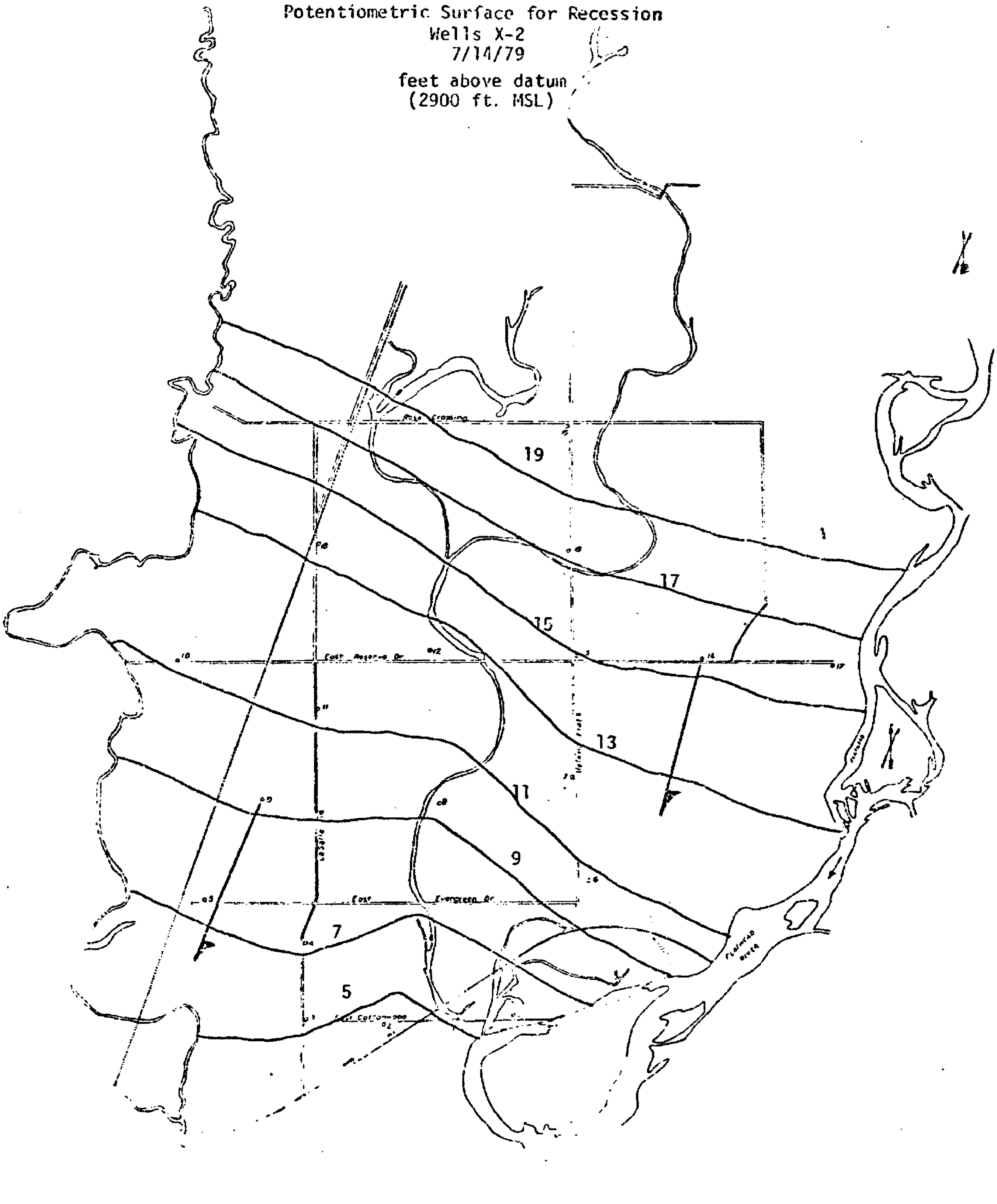
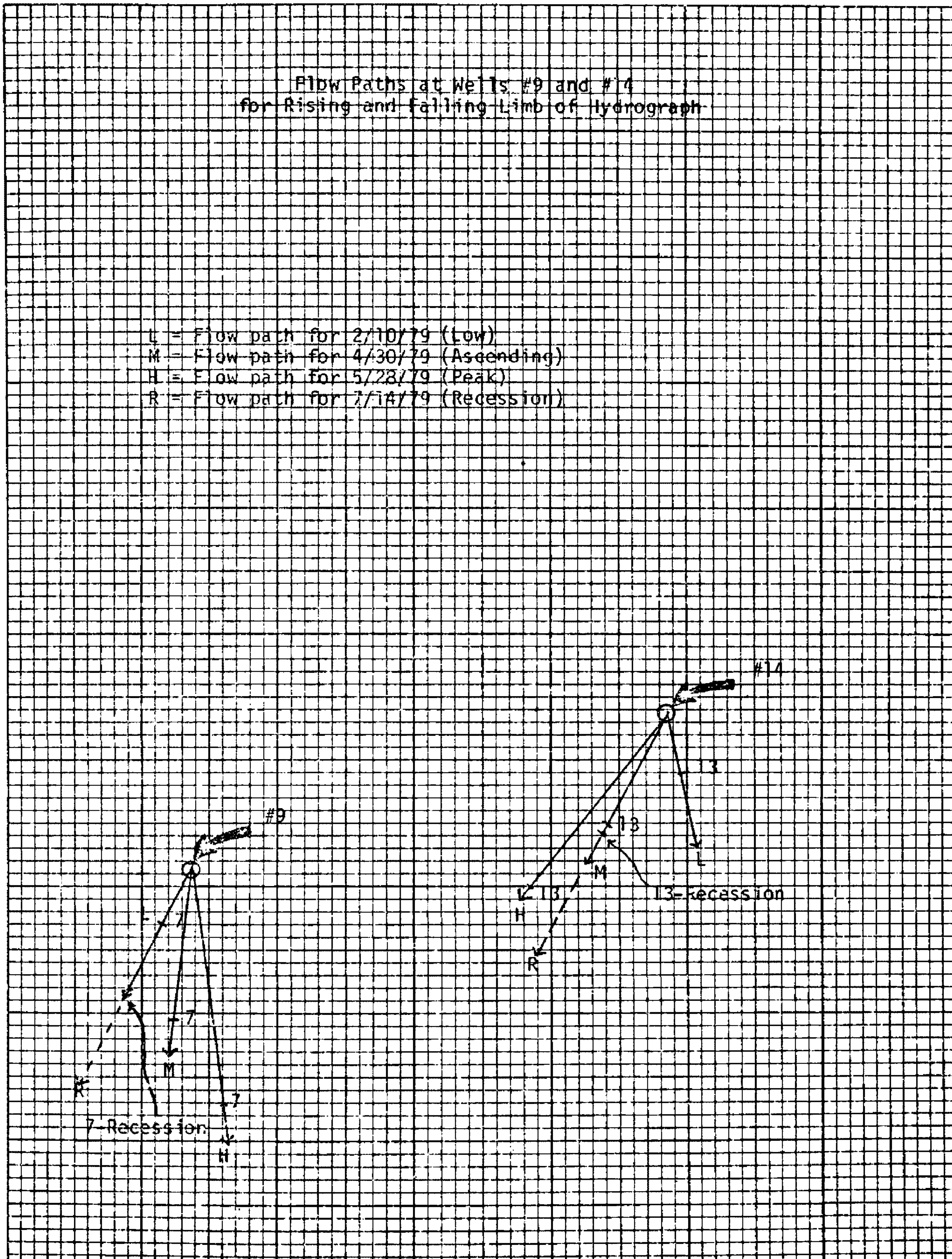


Figure 21

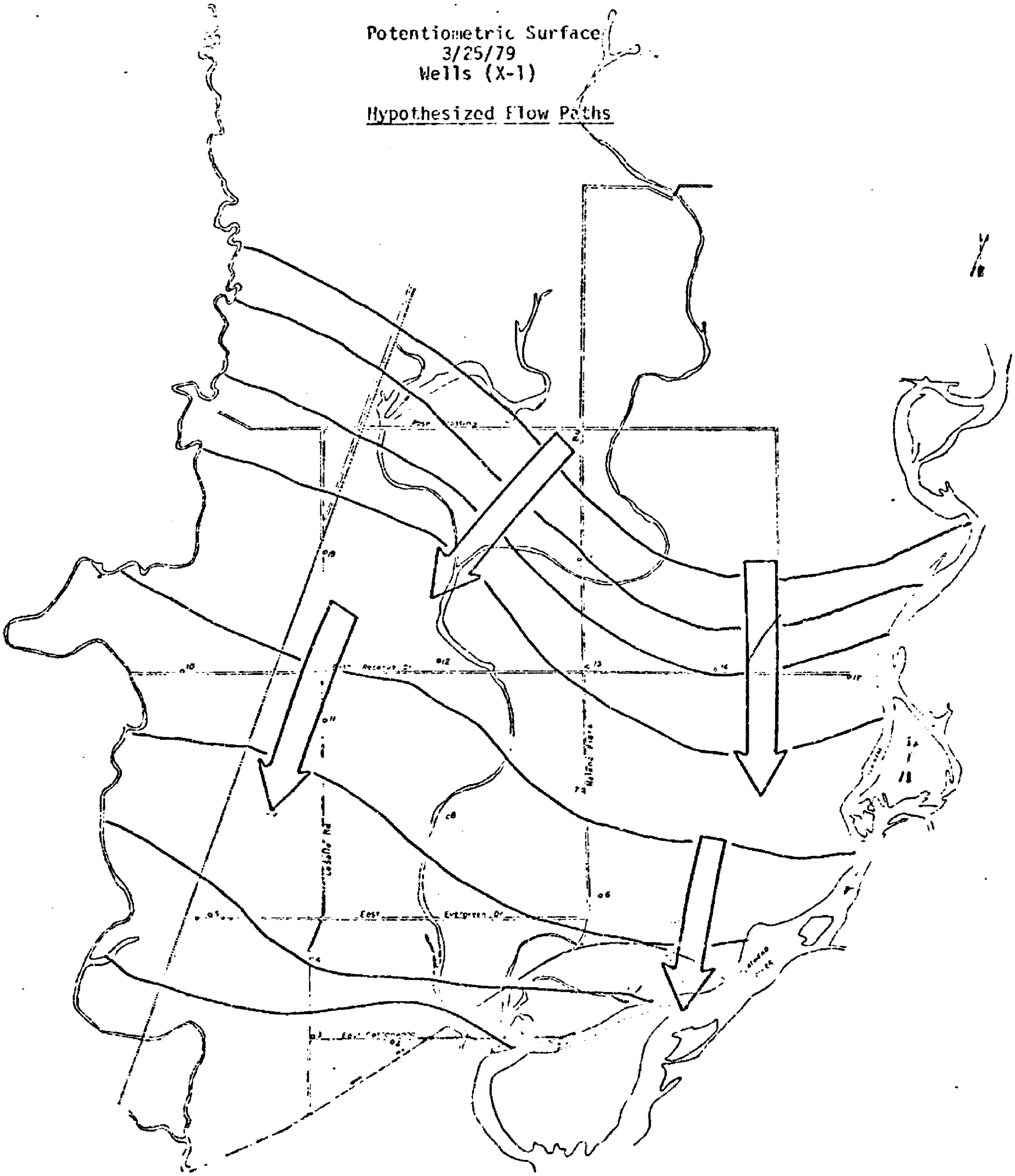


Flow Paths at Wells #9 and #14
for Rising and Falling Limb of Hydrograph
L = Flow path for 2/10/79 (Low)
M = Flow path for 4/30/79 (Ascending)
H = Flow path for 5/28/79 (Peak)
R = Flow path for 7/14/79 (Recession)
#14
13
13
L
M
13
H
13-Recession
R
#9
L
7
7
M
R
7
7-Recession
H

Figure 22

Potentiometric Surface
3/25/79
Wells (X-1)

Hypothesized Flow Paths



High water levels in the Flathead River overwhelm all other recharge effects in the surficial aquifer. This effect is shown by the groundwater profiles in Figure 12. Mean discharge for the Flathead River is 9,814 cubic feet per second (cfs), for the Whitefish River, 193 cfs and Spring Creek in Evergreen at Evergreen Drive is 29 cfs.

Flathead River begins to recharge the surficial aquifer nearly a month prior to the beginning of recharge by the Whitefish River (3/25/79 vs. 4/27/79). This effect may be caused in part by storage in Whitefish Lake. The relationship between change in potentiometric surface elevation and change in river discharge was examined utilizing ten sample points, spread over a 64 day period on the rising limb of the hydrograph. Correlation coefficients and partial correlation coefficients (Blalock, 1972) were calculated to determine the degree of association between changes in river discharge and changes in water level heights for the river/well combinations listed in Table 3. The wells in Table 3 are listed in order of increasing distance from the river to which they are compared. For example, well 17-1 is the closest to the Flathead River and well 18-2 is the farthest from the river. Potentiometric surface elevations were not measured on the same day that river discharge measurements were conducted. Therefore, Whitefish River and Spring Creek discharges were estimated from hydrographs plotted with FD 208 Project data for the days that potentiometric measurements were made (Figures 23 and 24). Flow records for the Flathead River were obtained from the U.S.G.S. and were preliminary records for station number 12363000, Flathead River at Columbia Falls,

Table 3

Simple Linear Correlation Coefficients and Partial Correlation Coefficients That Indicate the Degree of Association Between River Discharge and Well Water Levels

River Discharge (Q)	vs.	Well Water Levels	Correlation Coefficient r
Flathead	vs.	17-1	0.97
		13-2	0.92
		8-2	0.87
		18-2	0.83
Whitefish	vs.	5-2	0.93
		9-2	0.86
		11-2	0.67
Spring Creek	vs.	8-2	0.92
		12-2	0.81
		11-2	0.76
Flathead River Q	vs.	Spring Creek Q	0.95

	Partial Correlation Coefficient r
Water level height in Well 8-2 in relation to Spring Creek Q given Flathead River Q	0.59
Water level height in Well 8-2 in relation to Flathead River Q given Spring Creek Q	-0.03

Figure 23

Hydrograph of Spring Creek at Evergreen Drive
(7/28/78 - 9/27/79)

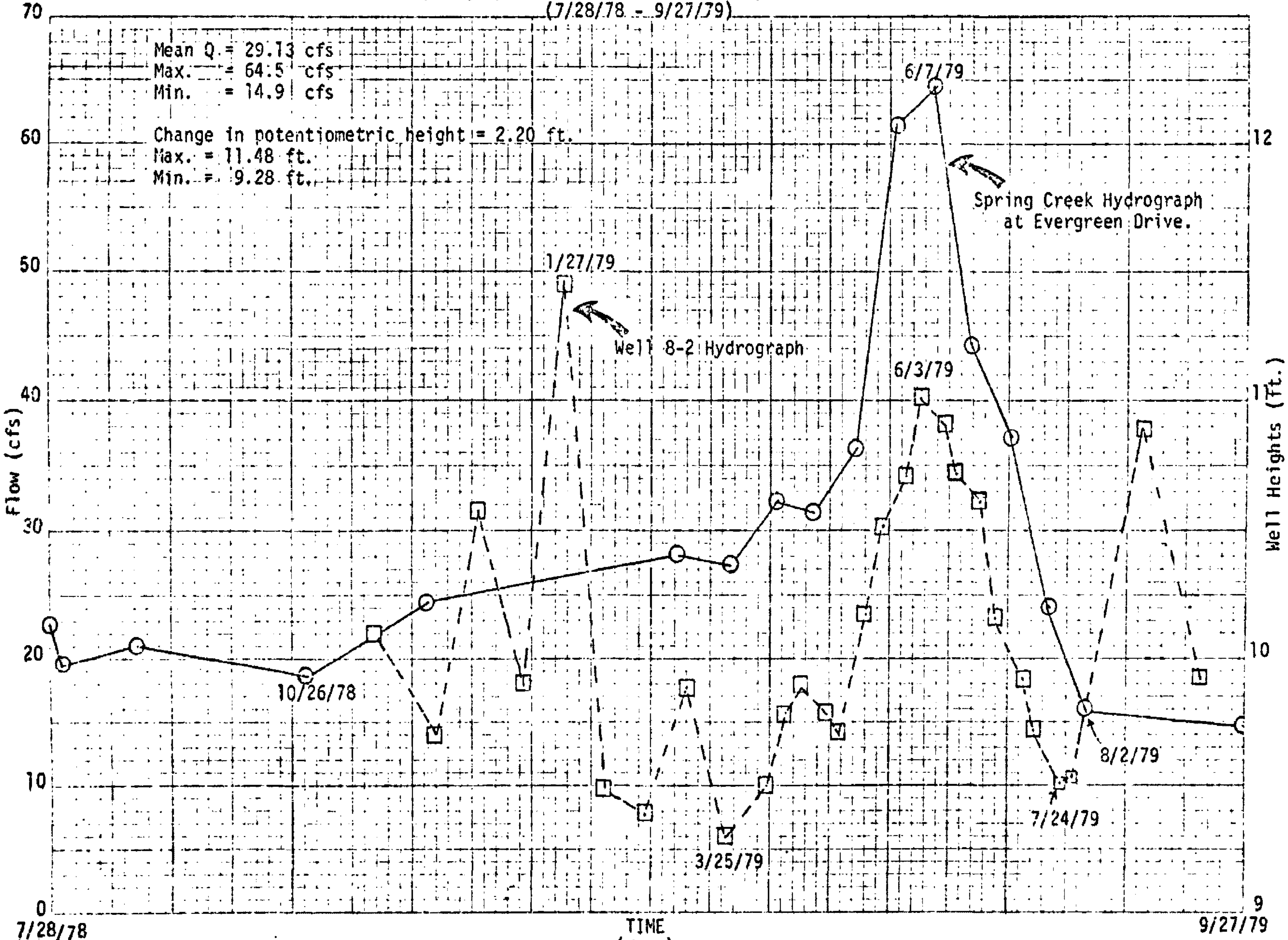
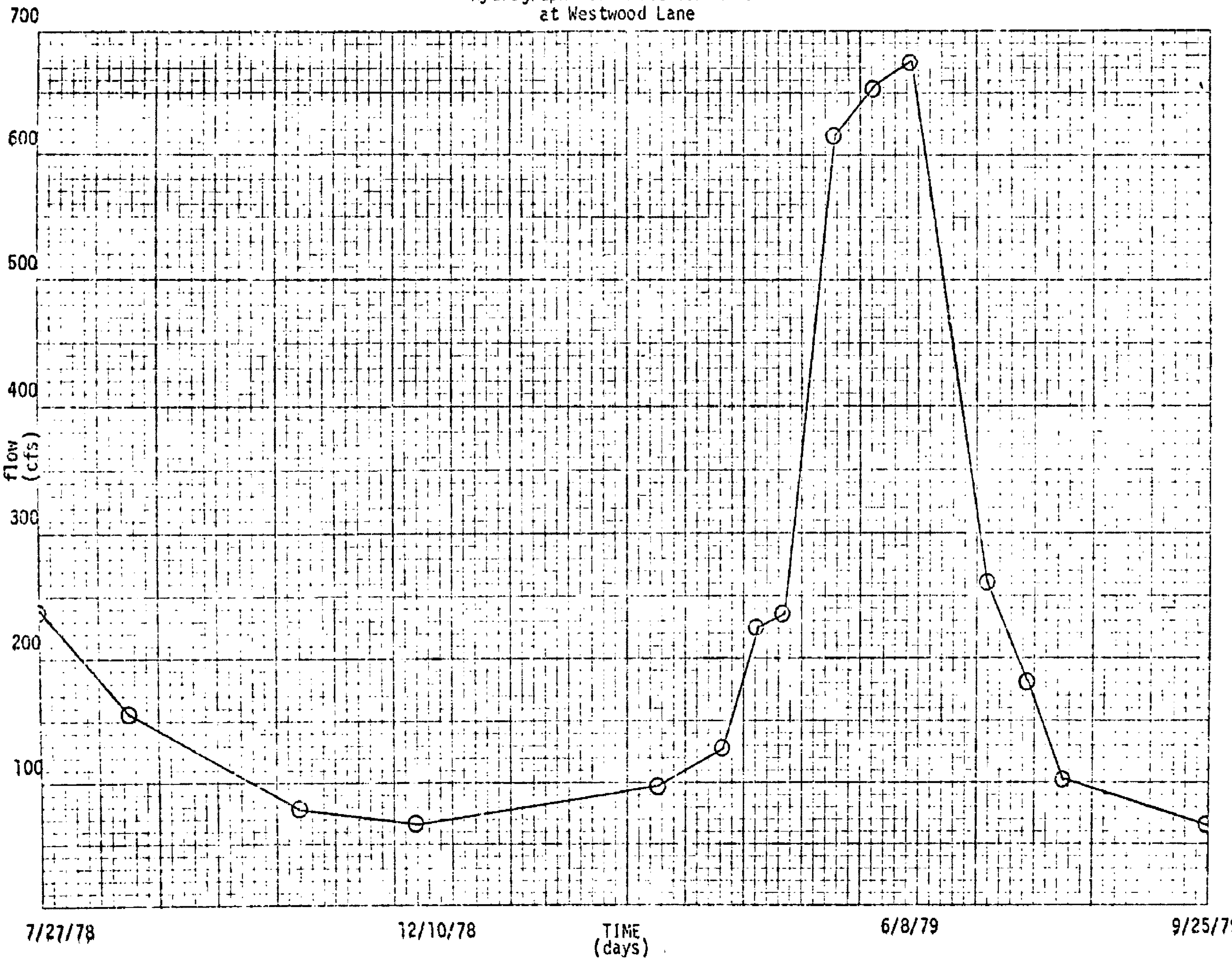


Figure 24

Hydrograph for Whitefish River at Westwood Lane



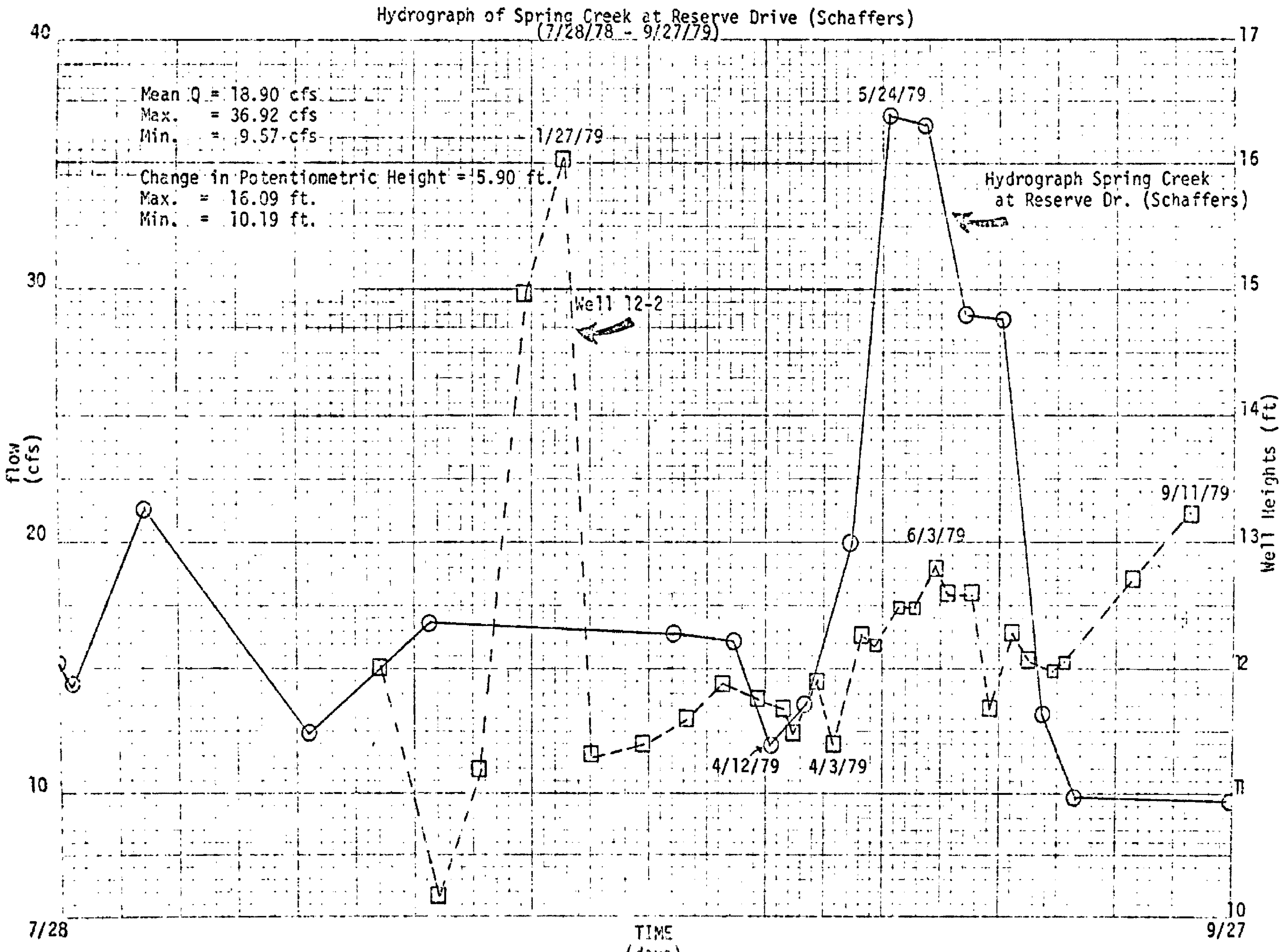
Montana. Correlation coefficients were calculated for data within the rising limb of the respective stream hydrographs. Similar values were derived for recession conditions but correlation of the entire season's stream hydrograph and well hydrograph did not yield meaningful results. Only during the rising and falling limb of the hydrograph was the hydraulic system under stress.

Obviously, the closer the well is to the river, the better the correlation between well heights and river flows. The partial correlation coefficients shown in Table 3 indicate that changes in Spring Creek discharge have a significant association with changes in well water level heights in well 8-2. However, because the hydrologic data was recorded during a period of active snowmelt, it is not certain that the rise in potentiometric surface was due to stream-aquifer interaction alone.

Spring Creek is hydraulically connected to the surficial aquifer. The statistical analyses indicate correlation between changes in Spring Creek discharge and changes in water level heights. During the rising limb of the Spring Creek hydrograph (April through June), there is a corresponding rise in the water level hydrographs in Figures 23 and 25. However, the flow of Spring Creek is so small in comparison to the other rivers and the groundwater flow rate is so great (50 feet per day) that the impact on the surficial aquifer by Spring Creek is of minor importance. Inspection of the water table profiles (Figure 12) suggests that Spring Creek may be recharged in part by water originating in the Flathead River.

U.S. Weather Bureau, Department of Commerce precipitation data

Figure 25


Hydrograph of Spring Creek at Reserve Drive (Schaffers)
(7/28/78 - 9/27/79)
Mean Q = 18.90 cfs
Max. = 36.92 cfs
Min. = 9.57 cfs
Change in Potentiometric Height = 5.90 ft.
Max. = 16.09 ft.
Min. = 10.19 ft.
1/27/79
5/24/79
Hydrograph Spring Creek at Reserve Dr. (Schaffers)
Well 12-2
6/3/79
9/11/79
4/12/79
4/3/79
flow (cfs)
Well Heights (ft)
40
30
20
10
17
16
15
14
13
12
11
10
7/28
9/27
TIME (days)

were plotted to determine if precipitation during the period of the study deviated from normal. Plots of total annual precipitation for the last nine years of record (Figure 26) show 1979 to be dryer than normal. Plots of monthly precipitation versus average monthly precipitation over the same period show the summer of 1979 to be well below normal (Figure 27). The above figures indicate that the water table levels for 1978-79 were probably below normal. It seems reasonable that water levels might rise as much as 13 percent above those measured during a year of normal precipitation.

WATER QUALITY

Water quality parameters monitored in this study were:

1) Phosphorous - identified as a possible limiting nutrient in Flathead Lake (Stanford et al., 1979).
2) Nitrate - public health standards recommend maximum allowable concentrations in drinking water.
3) Bacteria - public health standards recommend maximum allowable concentrations in drinking water.
4) Ammonium, sulfate and chloride - identified as indicators of urban-related contamination of groundwater (Eisen and Anderson, 1979).
5) Cations - calcium, sodium, potassium, magnesium and iron - allow chemical characterization of water bodies. Copper, manganese and zinc were included because they were part of the normal sequential cation analysis.

Figure 26

Total Annual Precipitation at Kalispell Weather Bureau
1970 - 1979

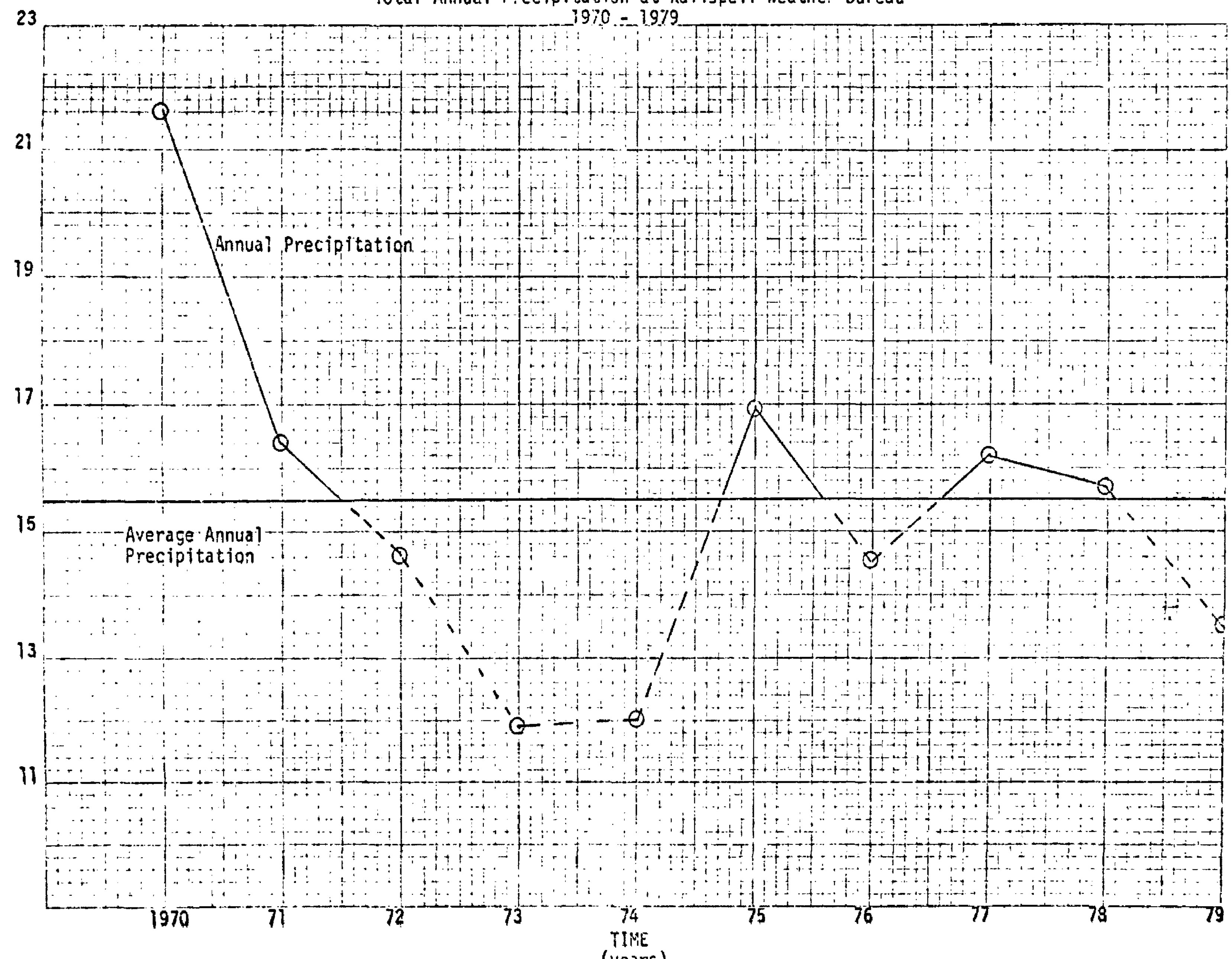
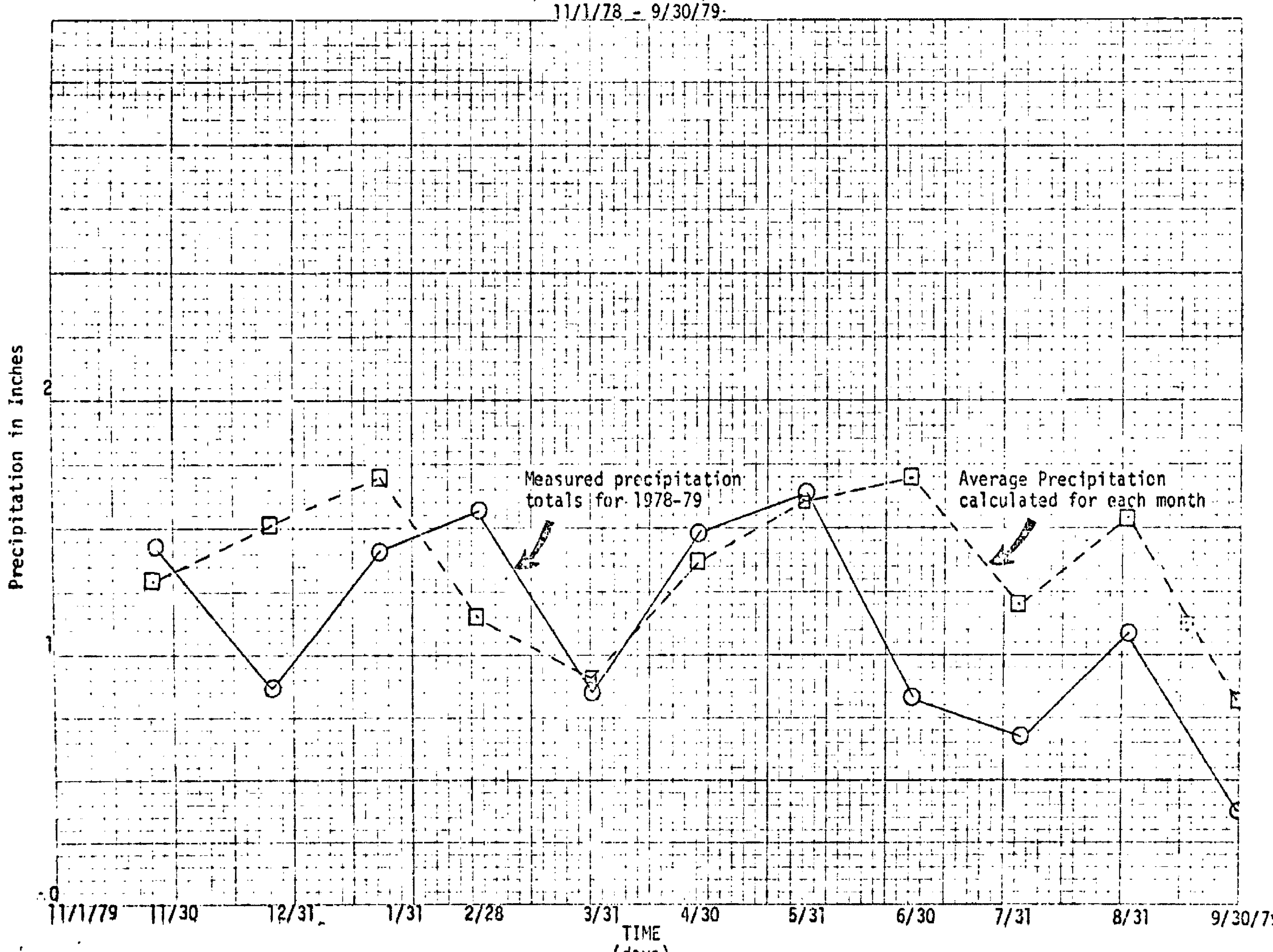


Figure 27

Precipitation - Monthly Values
11/1/78 - 9/30/79



6) Specific conductance - a general measure of total dissolved solids.

7) Bicarbonate and pH - allow chemical characterization of water bodies.

8) Temperature - aids in identifying sources of groundwater recharge.

PREVIOUS STUDIES

Figure 28 shows the approximate locations of selected wells utilized in past studies (Konizeski et al., 1968; Morrison-Maierle, Montgomery, 1977). Table 4 compares data from those studies with that of the current study. Well B29-21-34cc2 is located between well sites 3 and 7. Increases are particularly evident in chloride, sulfate and sodium plus potassium categories. Chloride and sodium plus potassium increases are the most significant and will be dealt with in following discussions. Chloride concentrations at well site 3 are in the range of household domestic wastewater and septic tank effluent (45-95 mg/l).

PHOSPHOROUS

Total phosphorous (all of the phosphorous in the sample), orthophosphate (available phosphorous for plant uptake) and hydrolyzable phosphorous (a measure of polyphosphates), concentrations were determined. Orthophosphate is common in fertilizers and agri-

Figure 28

Approximate Well Locations of Past Studies

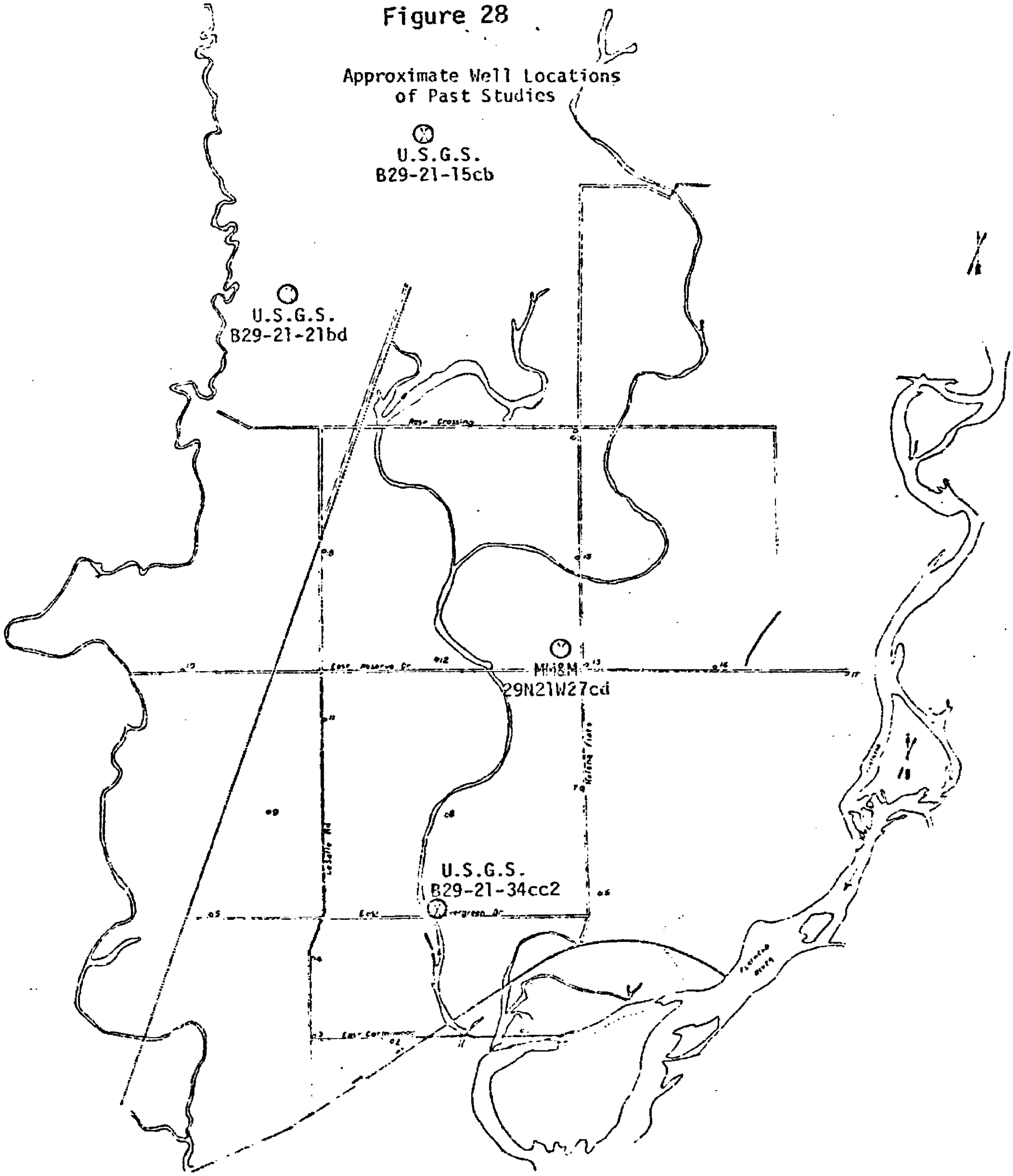


Table 4

Comparison of Previous Study Data to Adjacent FD 208 Project Wells

FD 208 Proj.	Ca mg/l	Std. deviation	Mg.	Std. deviation	Na + K	Std. deviation	HCO_3	Std. deviation	SO_4	Std. deviation	Cl	Std. deviation
mean							(A)		(B)		(A)	
Well 3-1	45.9	15.6	18.1	2.6	11.0	1.7	304	2.1	10		74	23.3
3-2	47.1	14.5	17.5	2.2	5.8	1.5	301	0.7	5		26	1.4
3-3	48.0	18.9	17.9	3.3	9.5	2.5	348	4.2	4		42	0.7
Well 7-1	36.9	11.5	11.5	1.7	6.5	1.8	243	3.5	1		38	6.4
7-2	37.4	13.4	11.5	2.2	5.6	2.1	232	5.0	0		22	2.8
7-3	39.7**	12.3	10.9	3.4	4.1***	0.5	239*	-	2		21*	-
No. of samples	15		15		14		2		1		2	
Konizeski et al, 1968												
B29-21-34cc2	52		17		3		238		5		4	
B29-21-21bd	57		12		0		223		2		2	
B29-21-15cb	51		14		2		216		3		2	
Flathead River Col. Falls, MT mean (C)	26.4		5.74		1.8		104.8		5.1		0.5	

* only one sample
** four samples
*** three samples

(A) Samples were analyzed for 2/24/79 and 6/3/79
(B) Samples of 6/3/79 only SO_4 data
(C) Flathead River data are means of required values by the U.S.G.S. for the time period 1963-1967 and MDHES, Water Quality Bureau 1972-73.

cultural wastes. Polyphosphates are common in household detergents and are thus, a potential indicator of urban impacts on groundwater.

Figure 29 illustrates an increase in total phosphorous concentration down the potentiometric gradient. Dilution, by both the Flathead and Whitefish Rivers, is clearly evident. Stanford et al., 1979, reported a mean concentration of 0.01 mg/l in the Flathead River above the study area. Mean concentration for the study well field is 0.02 mg/l. The wells with the greatest mean concentration of total phosphorous are 2-1, 3-1, 5-1 and 9-1. These wells generally correspond to areas of high population density. Soils in the area are typically low in phosphorous which indicates phosphorous does not come from the soils through geologic weathering but from some other source.

Orthophosphate isograms in Figure 30 show significant addition of phosphorous from agricultural lands and from heavily urbanized lands in the southern end of the study. The zone between the areas of a concentration in excess of 0.03 mg/l represents dilution of the contaminated groundwater by Flathead River recharge. Concentrations of hydrolyzable phosphates did not illustrate any discernable pattern.

AMMONIUM

Ammonium concentrations were utilized to provide information on chemical stratification in the surficial aquifer. A Two-Way Analysis of Variance (ANOVA) was performed on each well site comparing individ-

Figure 29

Isograms for Mean Total Phosphorous
Wells X-1 (deep wells)
(mg/l)

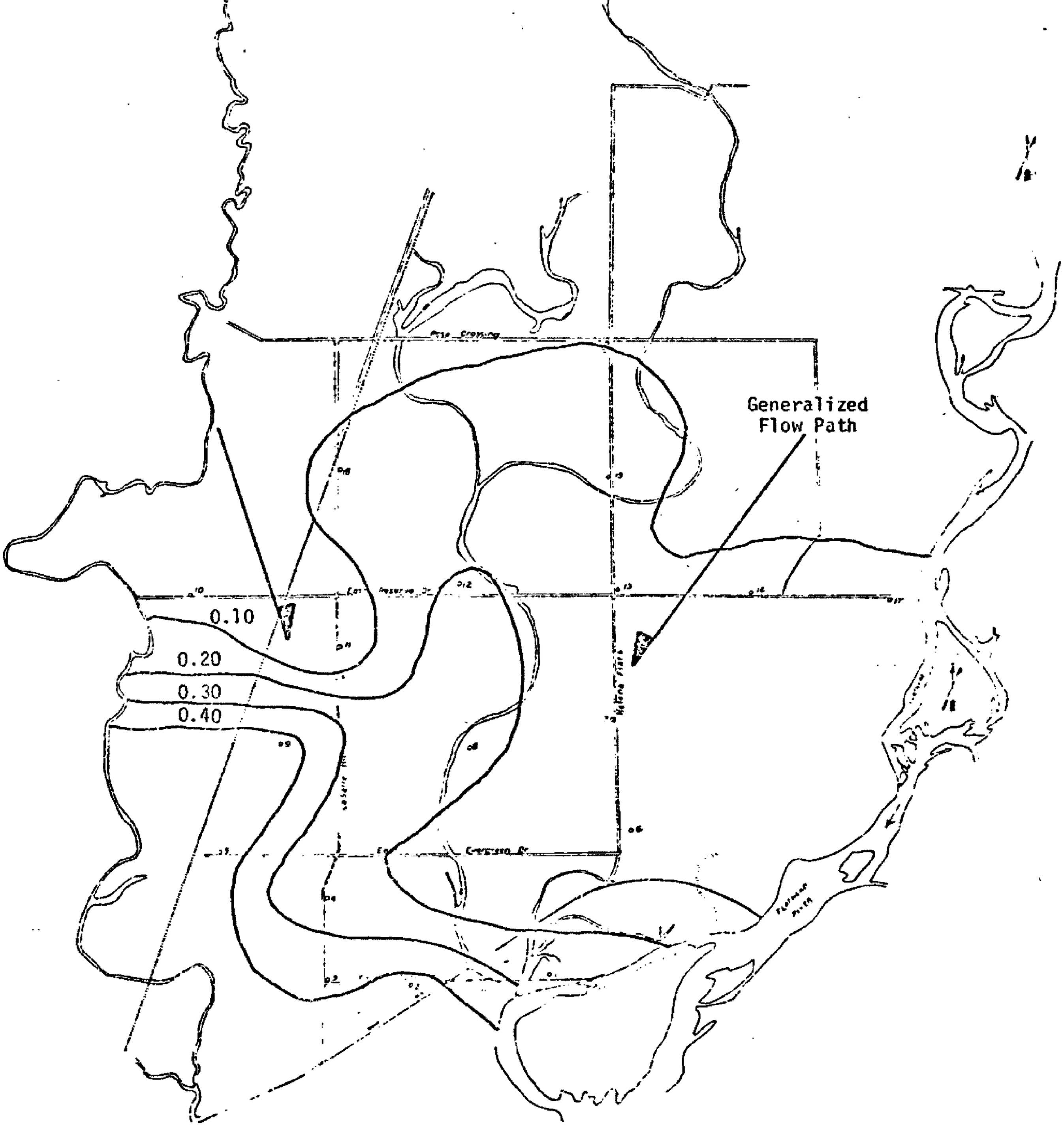
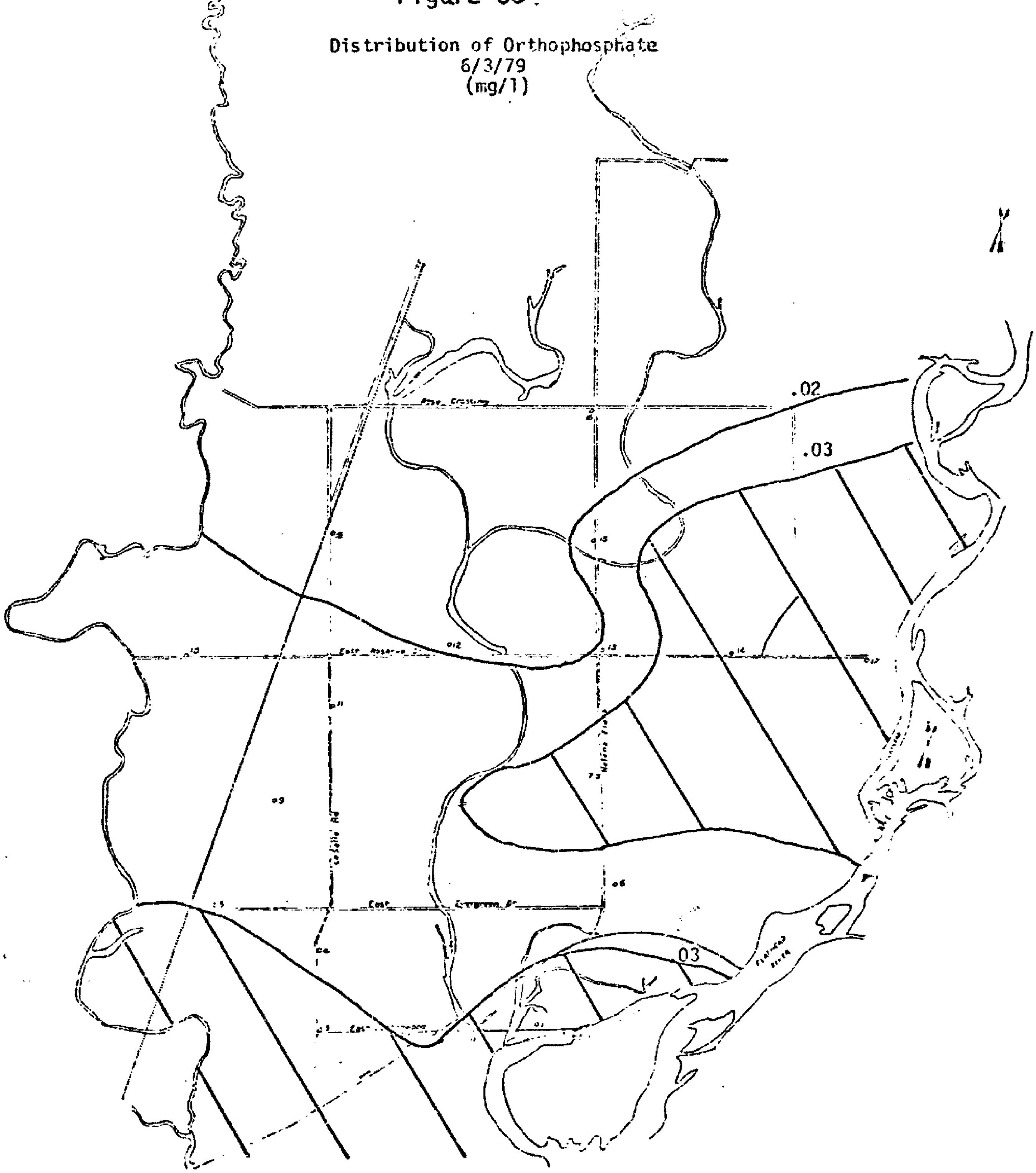


Figure 30.

Distribution of Orthophosphate
6/3/79
(mg/l)



ual wells against the variation in ammonium concentration. Table 5 summarizes the results of the ANOVA. There is a stronger correlation between urbanization and variation of concentration with respect to time and depth than between agricultural land uses and variation of concentration with respect to time and depth.

Ammonium concentrations vary with time, generally increasing as the water table rises. Figure 31 is representative of ammonium behavior with respect to time and depth in the study area. Increases in ammonium concentration with increasing depth are clearly defined suggesting the system becomes anaerobic with increasing depth.

SODIUM AND CHLORIDE

Sodium concentration increases as groundwater flows down gradient (Figure 32). Chloride ion seems to behave in a similar manner. Figure 33 illustrates a plot of sodium concentration with respect to time at well site 8 which is representative of the study area. Figure 32 demonstrates increasing concentration as the system is flushed by the recharging waters. The concentration rise on 5/6/79 suggests contact with a contaminated zone by the rising water table.

SULFATE

Average sulfate values are plotted as isograms in Figure 34. Down gradient increases are evident corresponding to increasing

Table 5
Summary of Results of 2-Way Analysis of Variance on Ammonium Concentrations

Well Site	Source of Variation: Well	Source of Variation: Dates	Vs. Depths: Dominant Adjacent Upgradient Land Use		Land Use Types: Resident	Land Use Types: Commer	Land Use Types: Agri.
1	11.11*	1.05	Commercial	significant diff/well	5	0	3
2	0.77	2.57*	Residential				
3	54.44*	2.29*	Residential	significant diff/well	4	1	1
4	0.26	2.15*	Residential				
5	5.78*	0.68	Residential	significant diff/well	2	0	1
6	0.27	13.05	Agricultural				
7	2.19	2.07	Agricultural				
8	20.27*	2.49*	Residential				
9	12.67*	0.72	Residential				
10	0.74	4.57*	Agricultural				
11	1.04	1.29	Commercial				
12	1.30	1.24	Agricultural				
13	1.32	2.46*	Residential				
14	8.56*	5.65*	Agricultural				
15	22.67*	0.94	Residential				
16	0.61	1.39	Agricultural				
17	-	-	Agricultural				
18	1.47	1.28	Agricultural				

Methodology described in Hewlett-Packard (1976)

* Significant at 0.10% level

Figure 31

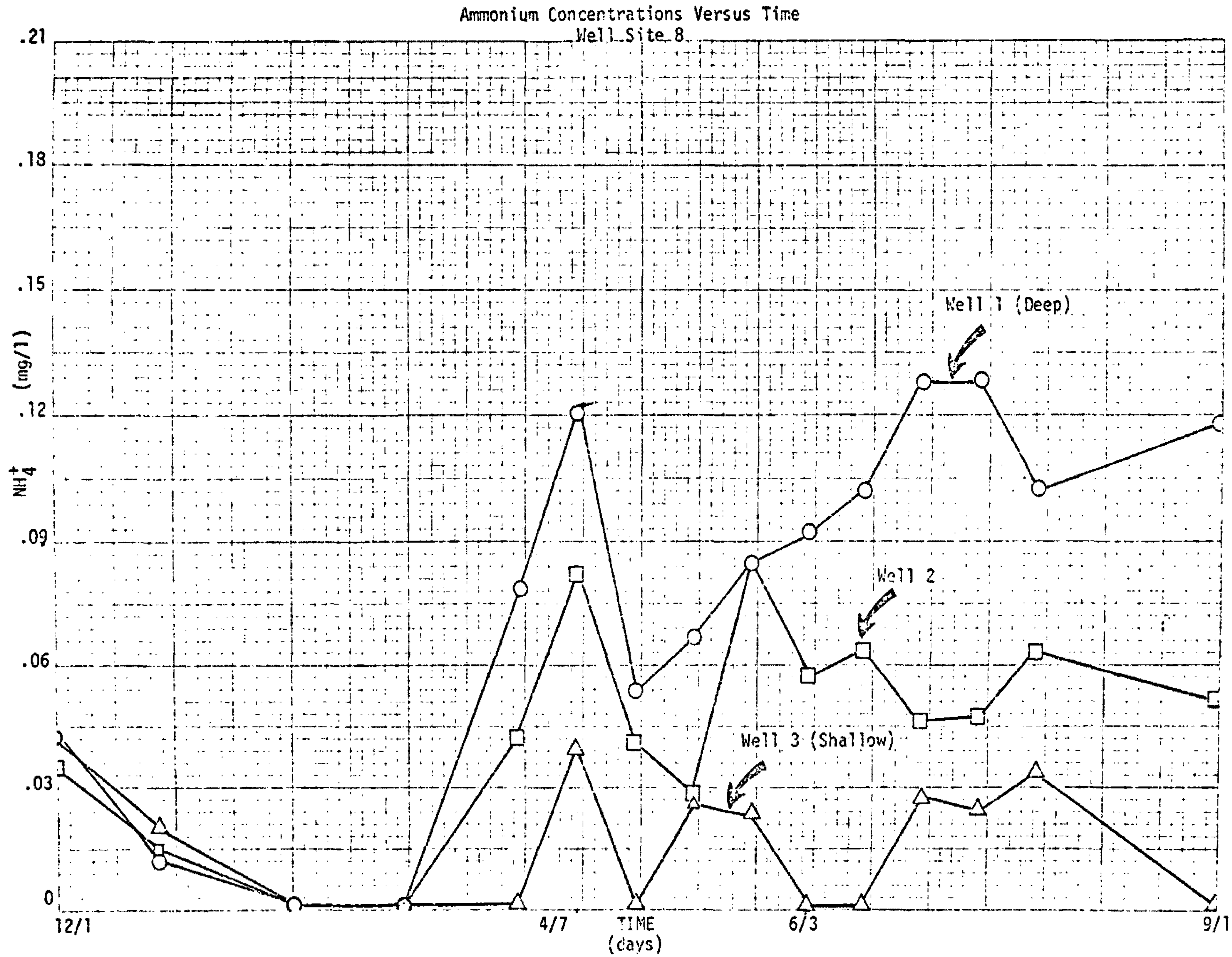

Ammonium Concentrations Versus Time
Well Site 8
.21
.18
.15
.12
.09
.06
.03
0
NH_4^+ (mg/l)
Well 1 (Deep)
Well 2
Well 3 (Shallow)
12/1
4/7
TIME
(days)
6/3
9/11

Figure 32

Sodium Concentrations Versus Distance for Selected Well Lines

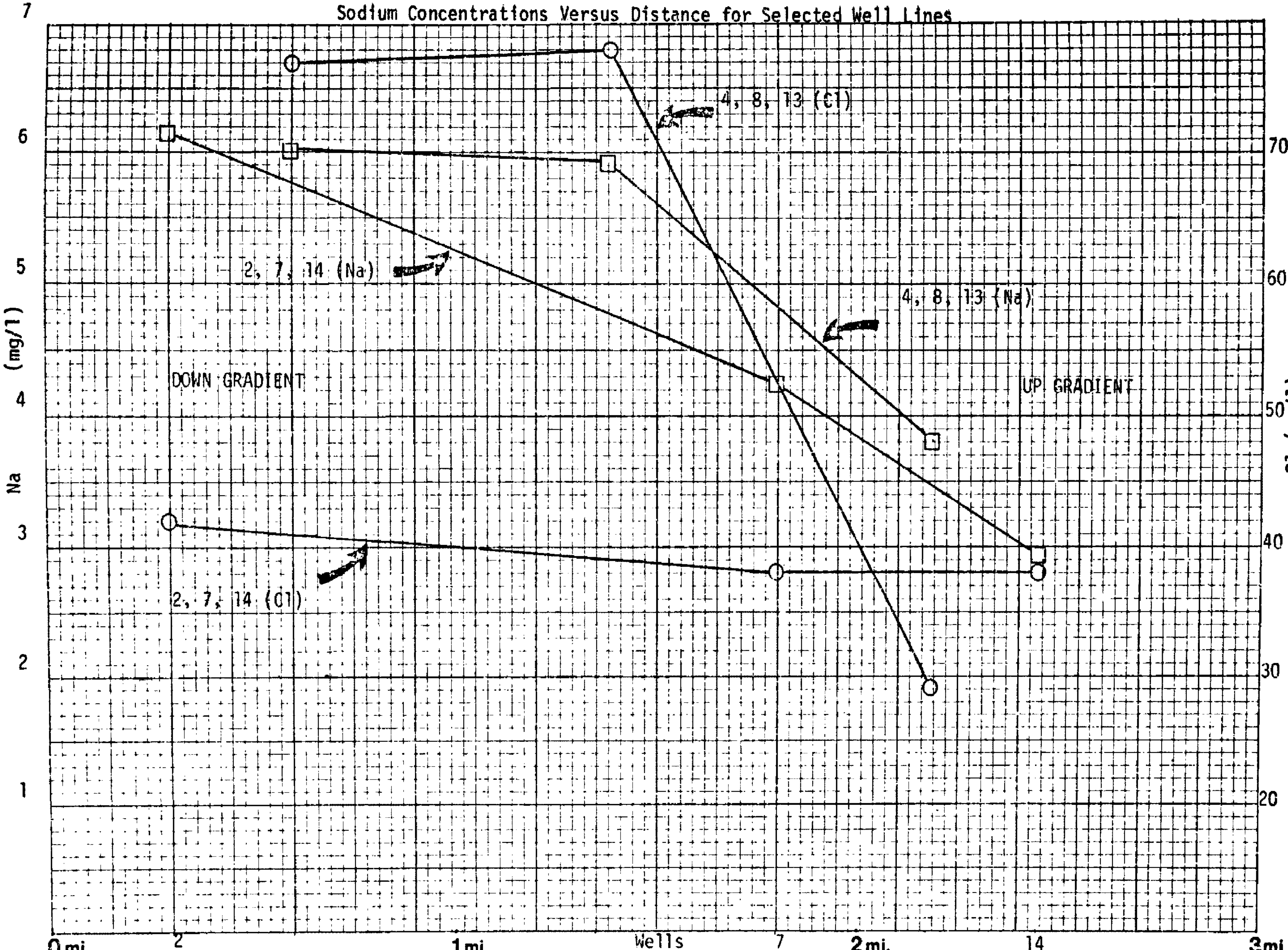


Figure 33

Sodium Concentrations Versus Time
Well Site 8

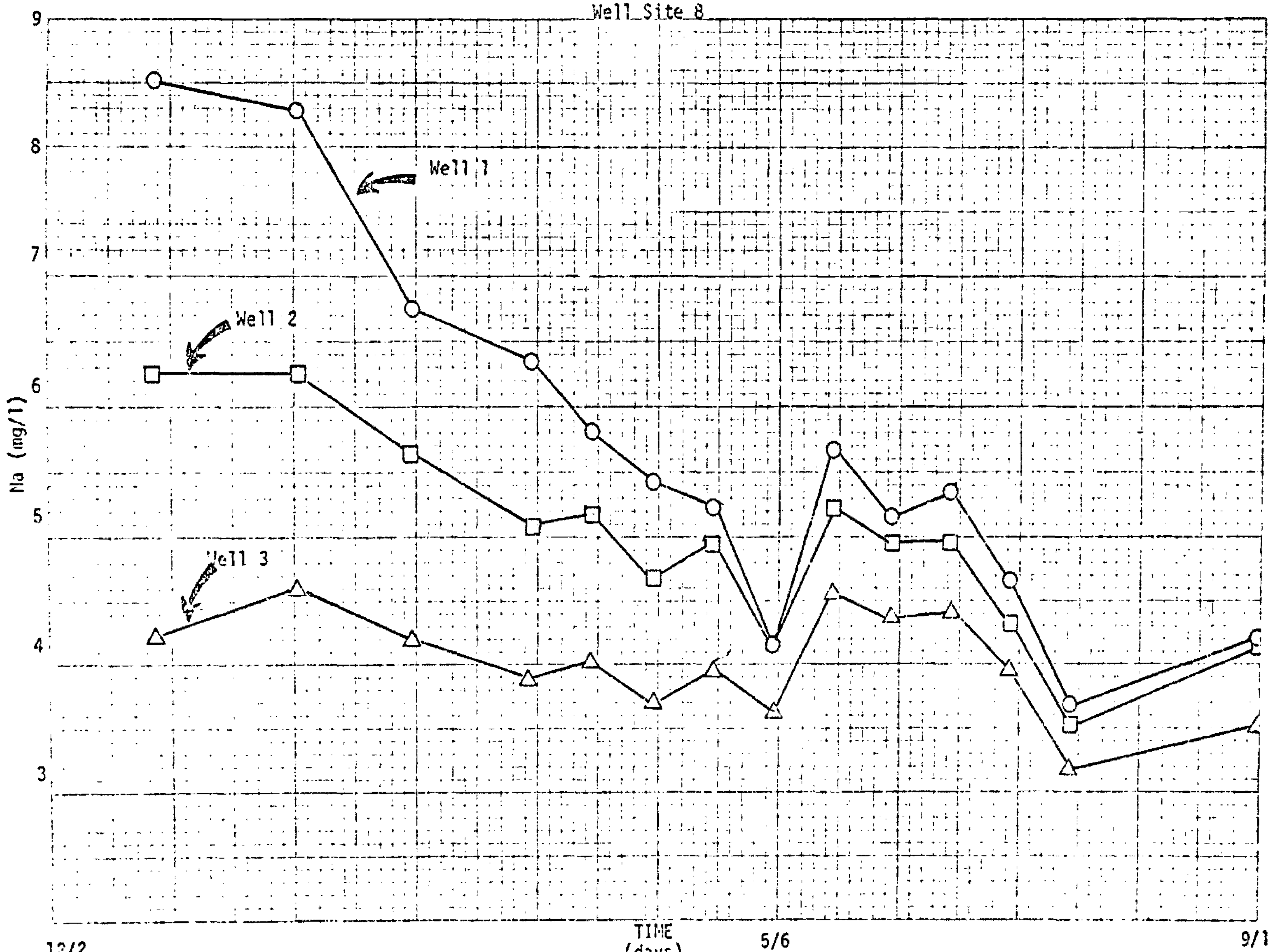
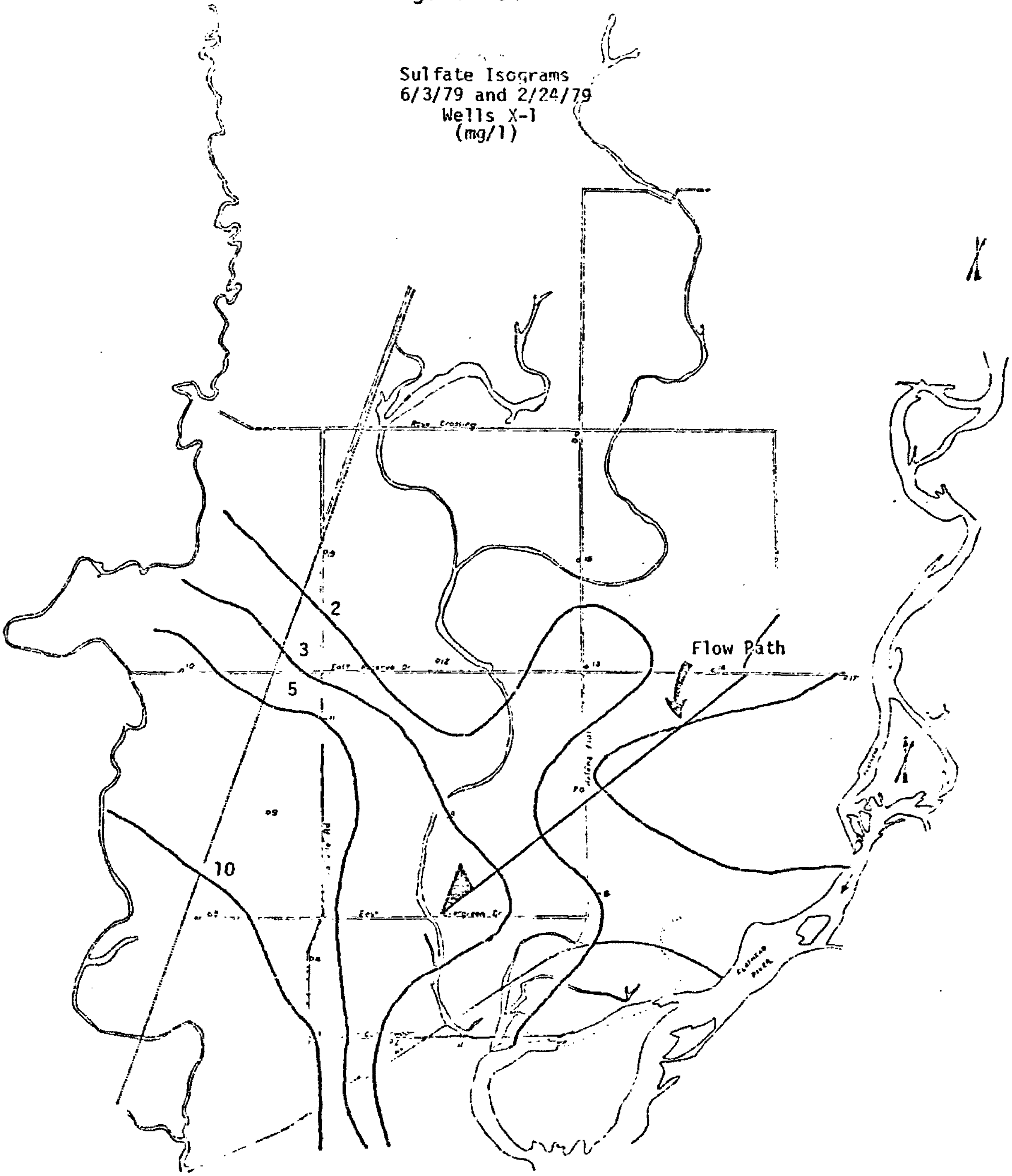


Figure 34


Sulfate Isograms
6/3/79 and 2/24/79
Wells X-1
(mg/l)
2
3
5
10
Flow Path

population density. Dilution by Flathead River water is evident as is the much smaller impact of Whitefish River recharge. Groundwater concentrations are higher than Flathead River values. Sulfate values decrease with depth suggesting the system becomes anaerobic.

SPECIFIC CONDUCTANCE AND TEMPERATURE

Specific conductance increased down gradient and reflected recharge by the river systems (Figure 35). Contact with the contaminated zone is most clearly demonstrated by well 3-1 on 2/24/79. Well 8-1 shows a similar rise on 5/6/79.

Temperature measurements were made in the field immediately following sampling. Figure 36 illustrates a plot of temperature variation over time along a flow path represented by three wells. Temperature changes seem to be uniform along the flow line. Temperature profiles (Figure 37) reflect recharge by the rivers on the east-west line and the increasing dominance of recharge waters down gradient with the lowest value at 6-1 on June 3, 1979.

BACTERIA

Fecal streptococcus have been suggested as an indicator of man-caused contamination of groundwater by several papers (McKee and Wolf, 1963 and Leininger and McCleskay, 1953) cited in a paper by Eisen and Anderson, 1979. Public health standards (MDHES, 1978) limit the number of coliform bacteria to 4/100 ml if less than 20

Figure 35

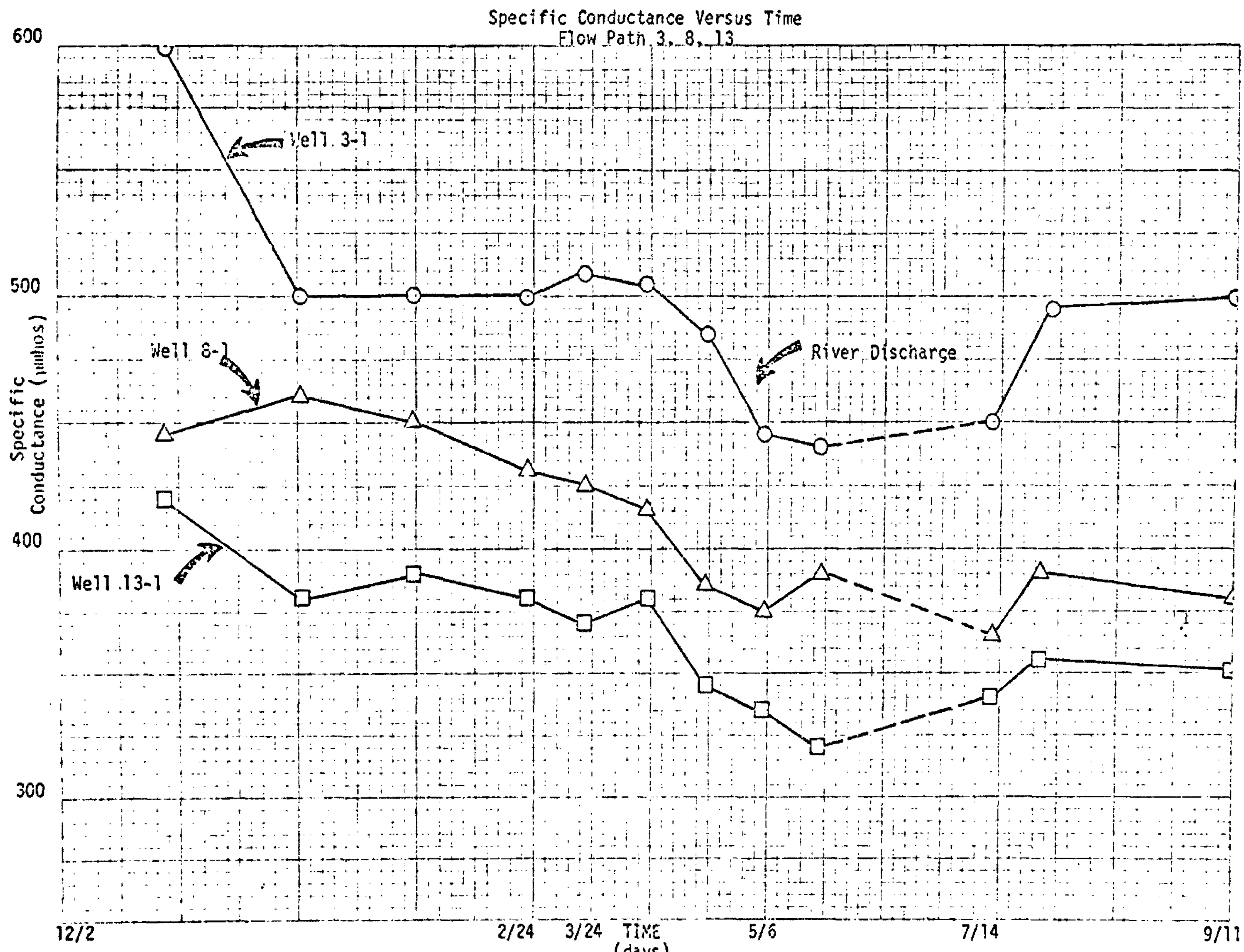

Specific Conductance Versus Time
Flow Path 3, 8, 13
600
500
400
300
Specific Conductance (µmhos)
Well 3-1
Well 8-1
Well 13-1
River Discharge
12/2
2/24
3/24
TIME (days)
5/6
7/14
9/11

Figure 36

Temperature Versus Time
Field Measurement

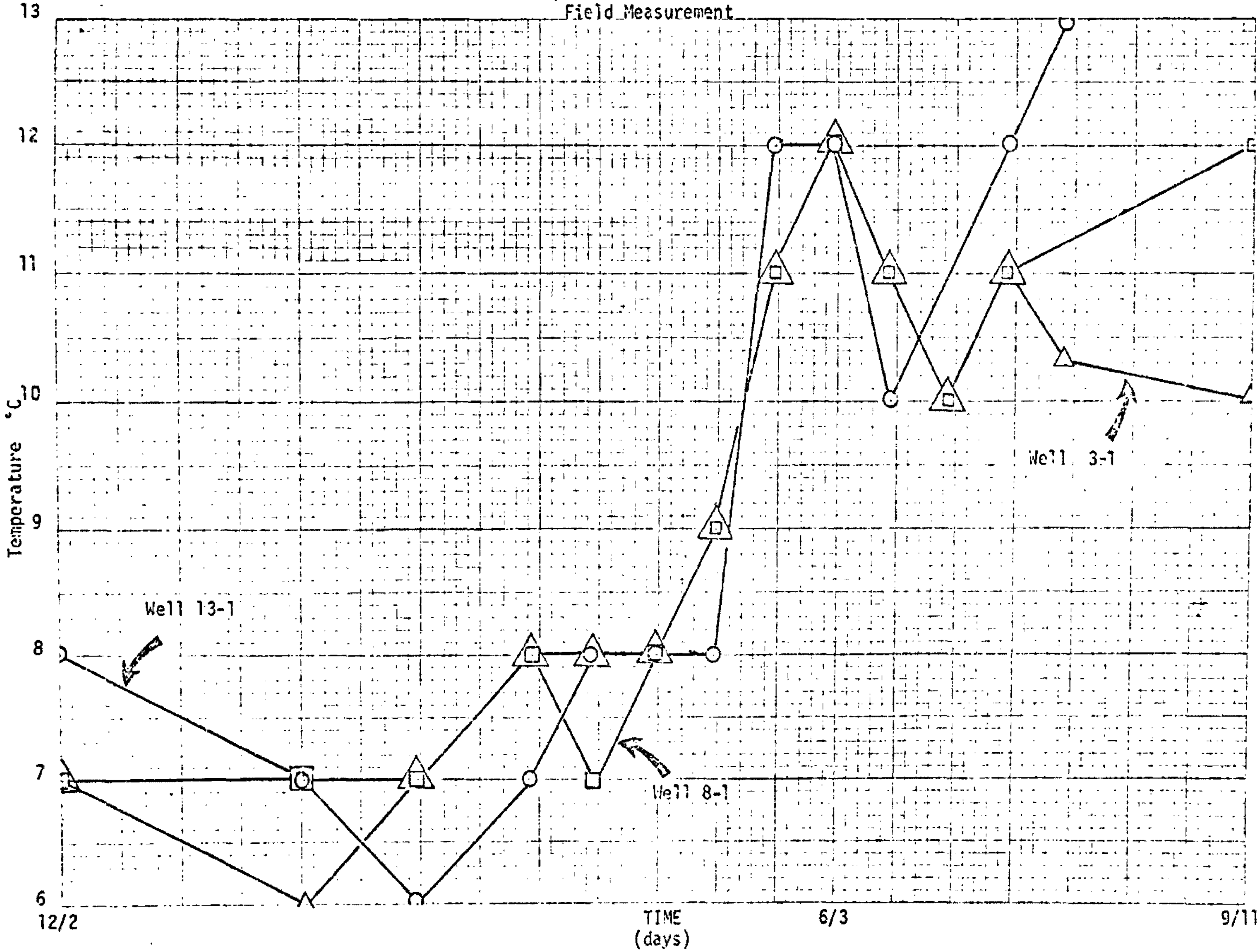
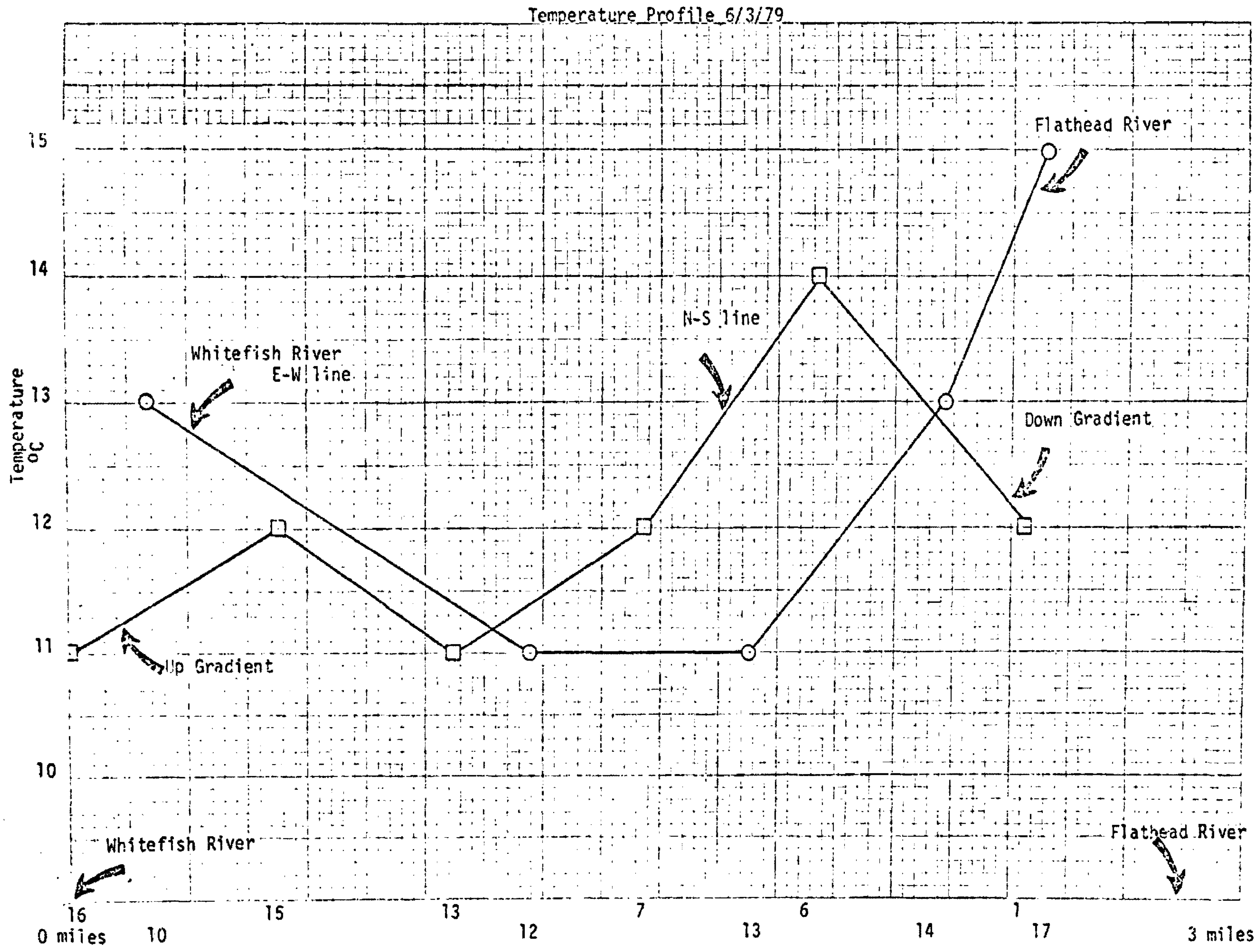


Figure 37


Temperature Profile 6/3/79
Temperature °C
15
14
13
12
11
10
Flathead River
N-S line
Whitefish River
E-W line
Down Gradient
Up Gradient
Whitefish River
Flathead River
16
0 miles
10
15
13
12
7
13
6
14
1
17
3 miles

samples/month are taken and 1/100 ml if only one sample/month is taken. The premise is that the presence of fecal coliform bacteria is an indicator of the possible presence of pathogenic organisms. Marzouk et al., 1979, found no correlation between the presence of enteroviruses and bacteriological indicators. However, Wolf (1972) suggests that the presence of fecal coliform is a reasonable indicator of bacteriological pathogens.

Bacterial sampling was conducted between January 21, 1979 and August 21, 1979 for fecal coliform and fecal streptococcus. Figures 38 and 39 illustrate the occurrence of bacteria with respect to time. Wells 3-1 and 16-1 represent urban and agricultural land use areas. Concentration increases clearly correspond with water table rises as demonstrated by the peaks in February and early June. Distribution of fecal coliform and streptococcus is illustrated in Figure 40 for April 21, 1979. Thirty-four of forty-nine wells sampled (69 percent) were contaminated with fecal coliform bacteria at least once (Table 6). Forty-five of forty-nine wells sampled (92 percent) were contaminated with fecal streptococcus bacteria. By well sites, 83 percent were contaminated by fecal coliform and 100 percent were contaminated by fecal streptococcus bacteria. The maximum fecal coliform and fecal streptococcus value was 712/100 ml and T.N.T.C./100 ml (Too Numerous To Count) respectively. The entire well field was sampled four times. Fecal bacteria counts encountered at well sites 3, 4, and 16 are considered demonstrative of the contamination cycle in the study area. Sites 1, 2, and 6 never showed the presence of bacteria which might not be expected, considering the population density adjacent to those

Figure 38

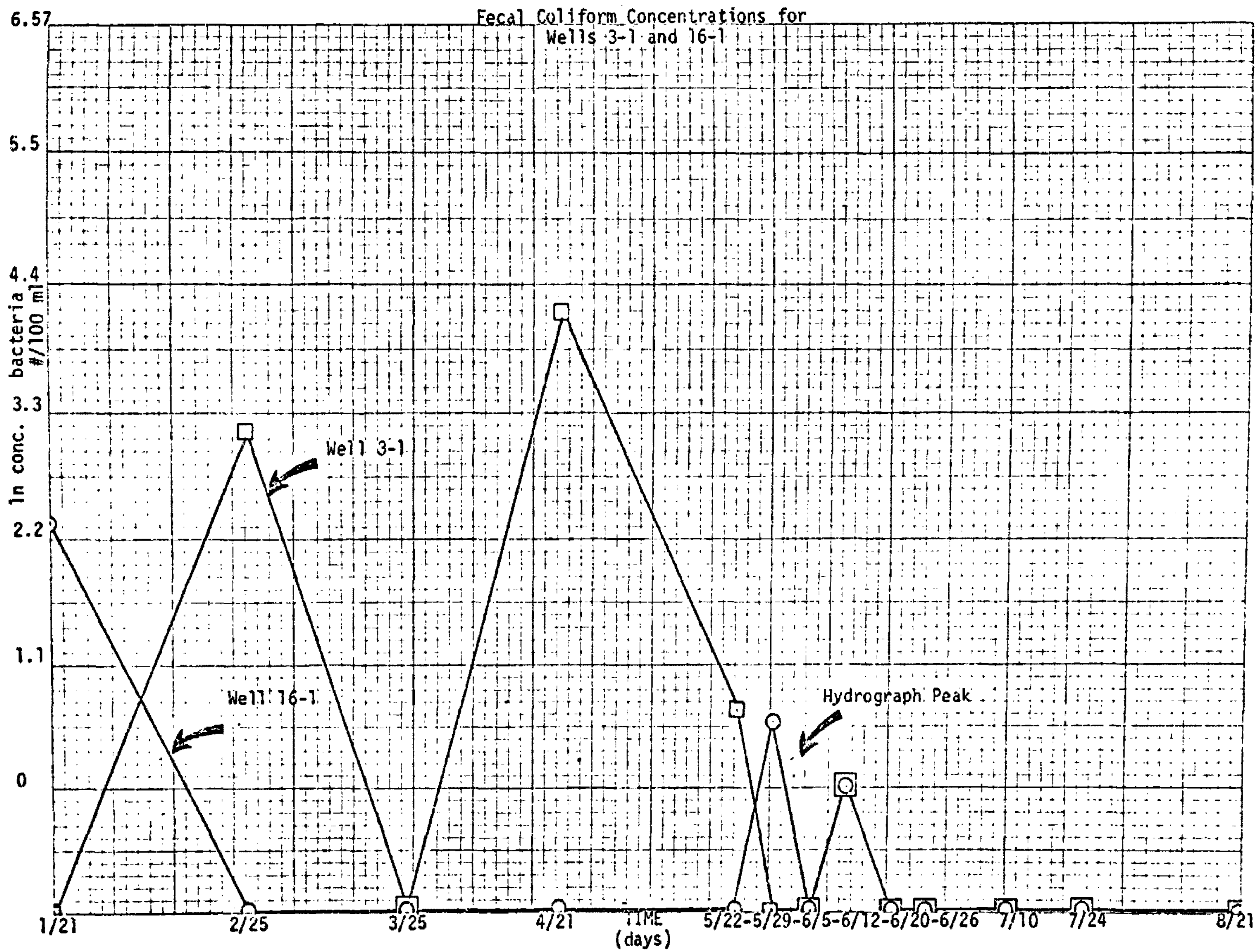

Fecal Coliform Concentrations for
Wells 3-1 and 16-1
ln conc. bacteria #/100 ml
6.57
5.5
4.4
3.3
2.2
1.1
0
Well 3-1
Well 16-1
Hydrograph Peak
1/21
2/25
3/25
4/21
TIME
(days)
5/22-5/29-6/5-6/12-6/20-6/26
7/10
7/24
8/21

Figure 39

Fecal Streptococcus Concentration at Wells 3-1 and 16-1

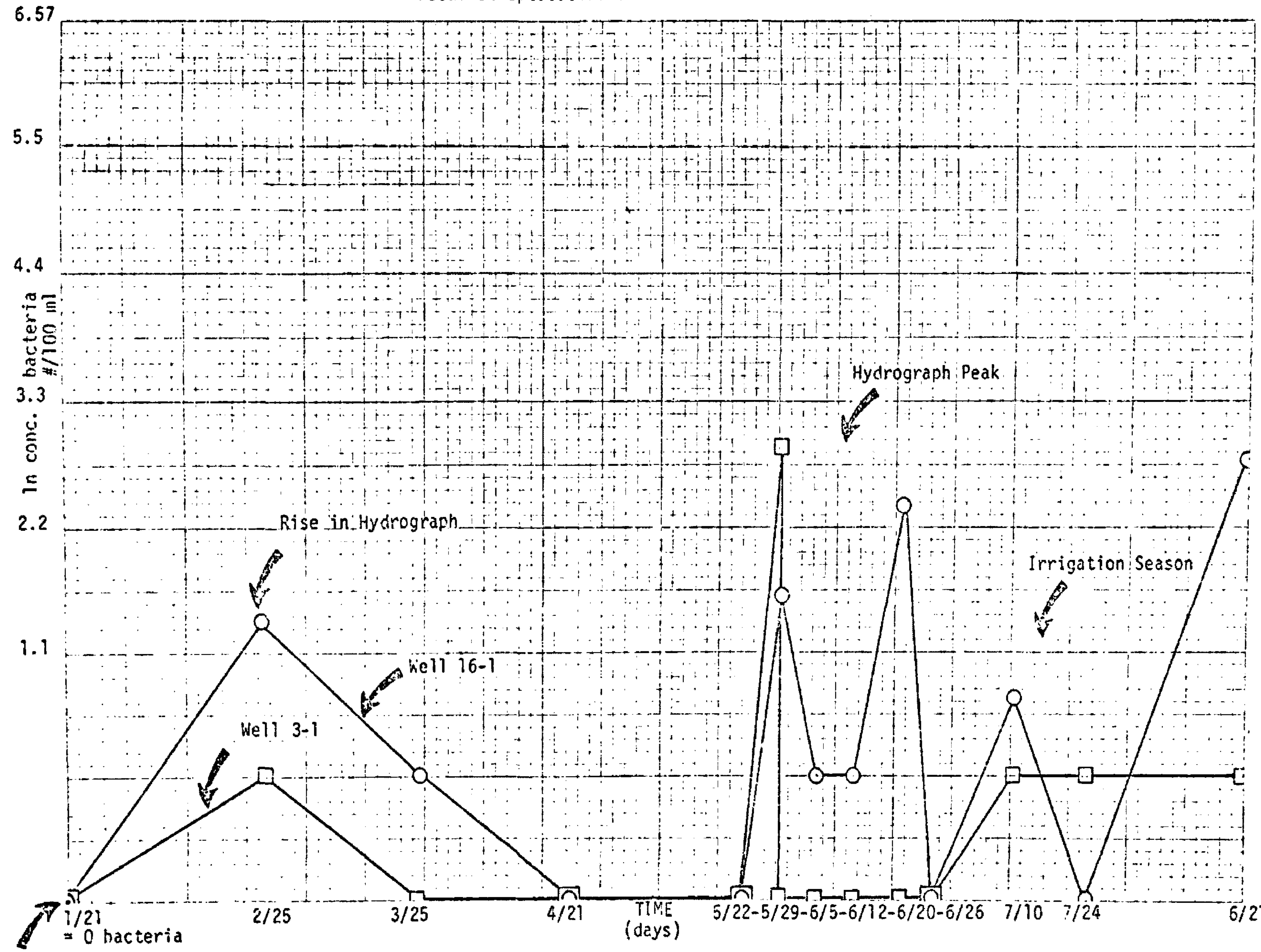


Figure 40

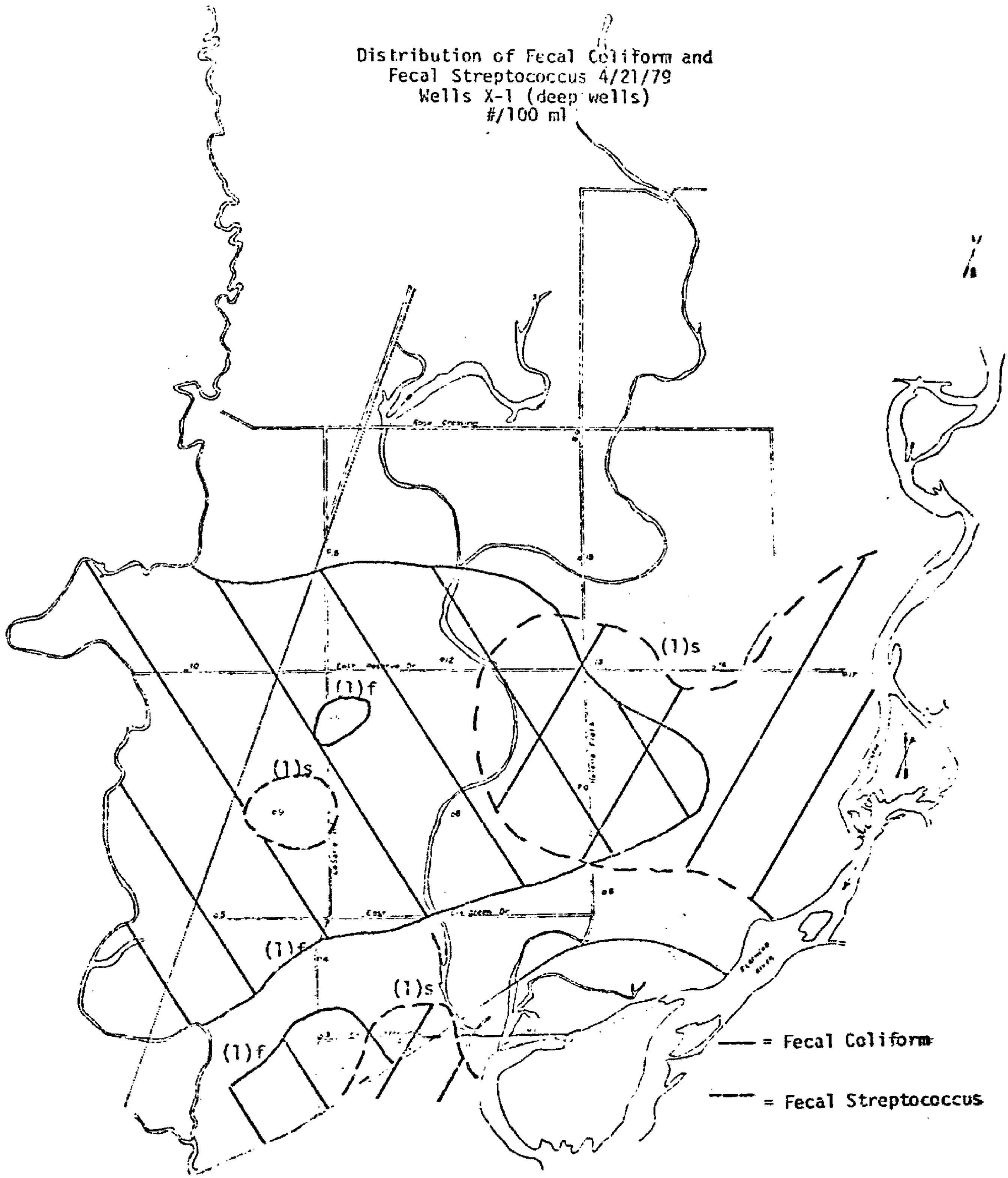

Distribution of Fecal Coliform and
Fecal Streptococcus 4/21/79
Wells X-1 (deep wells)
#/100 ml
(1)s
(1)f
(1)s
(1)f
(1)s
(1)f
— = Fecal Coliform
— — = Fecal Streptococcus

Table 6
Summary of Bacteria Sample Data
Fecal Coliform and Fecal Streptococcus

Well	FECAL COLIFORM # times sampled	FECAL COLIFORM # times ≥ 1	FECAL COLIFORM Max. value(#/100 ml)	FECAL STREPTOCOCCUS # times sampled	FECAL STREPTOCOCCUS # times ≥ 1	FECAL STREPTOCOCCUS Max. value(#/100 ml)
1-1	4	0	0	4	3	94
1-2	4	0	0	4	2	8
1-3	4	0	0	4	1	2
2-1	4	0	0	4	4	16
2-2	4	0	0	4	2	12
2-3	4	0	0	4	1	2
3-1	13	4	64	13	5	18
3-2	13	1	9	13	6	16
3-3	13	7	712	13	12	456
4-1	13	4	10	13	7	95
4-2	13	5	6	13	7	46
4-3	10	5	10	10	7	4
5-1	4	1	14	4	3	8
5-2	4	2	66	4	2	27
5-3	4	0	0	4	3	78
6-1	4	0	0	4	2	2
6-2	4	0	0	4	1	4
6-3	4	0	0	4	2	4
7-1	4	1	4	4	4	76
7-2	4	1	4	4	2	7
7-3	2	1	3	2	2	14
8-1	4	2	25	4	3	5
8-2	4	1	2	4	4	4
8-3	4	1	2	4	2	2
9-1	4	1	>300	4	3	19
9-2	4	1	225	4	2	5
9-3	4	1	2	4	1	117
10-1	4	2	23	4	1	5
10-2	4	0	0	4	2	4
10-3		no samples			no samples	

Table 6 continued

Well	FECAL COLIFORM # times sampled	FECAL COLIFORM # times ≥ 1	FECAL COLIFORM Max. value(#/100 ml)	FECAL STREPTOCOCCUS # times sampled	FECAL STREPTOCOCCUS # times ≥ 1	FECAL STREPTOCOCCUS Max. value(#/100 ml)
11-1	4	1	3	4	1	4
11-2	4	1	7	4	0	0
11-3	4	1	19	4	2	12
12-1	4	2	400	4	0	0
12-2	4	1	24	4	1	4
12-3	4	0	0	4	0	0
13-1	4	1	22	4	2	2
13-2	4	1	5	4	3	TNTC*
13-3	4	2	122	4	2	6
14-1	4	2	2	4	2	14
14-2	4	1	20	4	2	4
14-3	4	1	12	4	3	10
15-1	4	3	8	4	0	0
15-2	4	2	43	4	2	4
16-1	13	3	10	13	8	16
16-2	13	1	4	13	4	35
17-1	4	2	19	4	3	405
18-1	4	2	12	4	1	2
18-2	4	0	0	4	1	16
18-3	4	0	0	4	1	3

*TNTC = Too Numerous to Count

well sites. However, recharge from the Flathead River could conceiveably flush those areas, necessitating a more rigorous sampling schedule to intercept the contaminated water. Previous work failed to demonstrate bacterial contamination of the shallow aquifer.

AQUIFERS

Stiff diagrams (for chemical characterization of water bodies) for the deep artesian aquifer and the surficial aquifer (Figure 41) show that these aquifers represent different water bodies. The proportion of Na + K and Cl are greater in the surficial aquifer (well 8-1) than in the deep aquifer (Maurice Eddy). Relative sizes of the diagrams indicate that total dissolved solids concentrations are greater in the surficial aquifer than in the deep aquifer. Table 7 shows the data used to construct the Stiff diagrams and that the deep well (Maurice Eddy) is within one standard deviation of the average cation and anion concentrations for the deep artesian aquifer as reported in Konizeski's report. No change in water quality is documented in the deep aquifer since 1964.

Figure 41

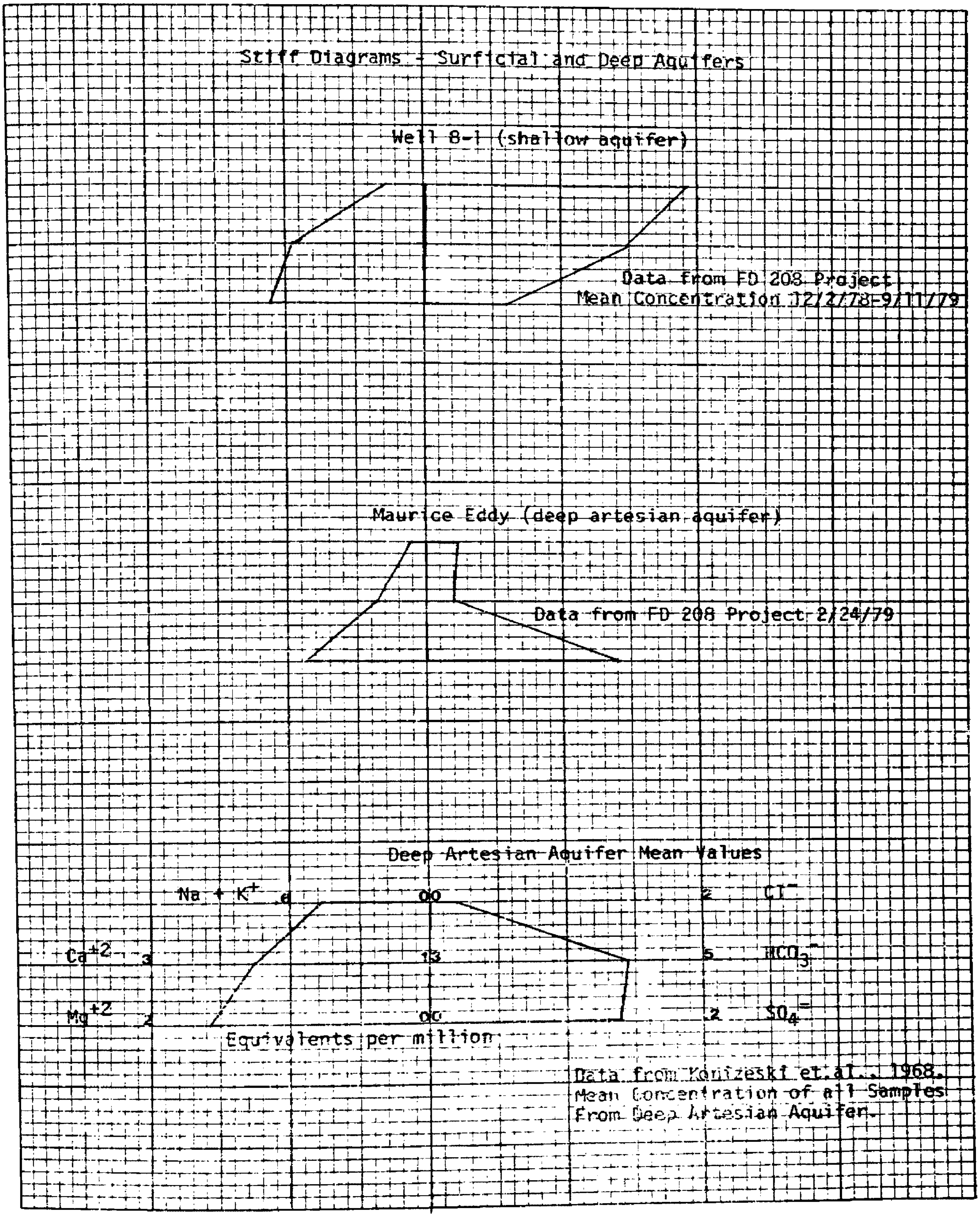

Stiff Diagrams - Surficial and Deep Aquifers
Well 8-1 (shallow aquifer)
Data from FD 208 Project
Mean Concentration 12/2/78-9/11/79
Maurice Eddy (deep artesian aquifer)
Data from FD 208 Project 2/24/79
Deep Artesian Aquifer Mean Values
Na + K+ .6
00
2 Cl-
Ca+2 3
13
5 HCO3-
Mg+2 2
00
.2 SO4=
Equivalents per million
Data from Konizeski et.al., 1968.
Mean Concentration of all Samples
From Deep Artesian Aquifer.

Table 7

Summary of Data for Stiff Diagrams Comparing the Deep Artesian Aquifer to the Surficial Aquifer

	Na + K	Ca	Mg	Cl	HCO_3	SO_4
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Well 8-1	8.19	38.75	13.48	68	274	3.0
Maurice Eddy	2.94	26.8	10.50	8.2	195.2	6.84*
Deep Artesian Mean	23.79	44.96	19.25	6.24	272	6.84
Std. Deviation	66.71	13.27	10.77	5.21	128.2	5.09

* SO_4 data was lacking so it was estimated with the mean value for SO_4 derived from data in Konizeski et. al., 1968.

SUMMARY AND CONCLUSIONS

Numerous chemical and biological parameters have been monitored for nearly one year. Simultaneous water table elevations have been recorded. Previous work in the study area supports the hydrologic relationships observed. However, biological and chemical results of this study differ significantly from previous reports.

Simultaneous rises of potentiometric surfaces and river flows demonstrate hydraulic connection between the Flathead and Whitefish Rivers, Spring Creek and the surficial groundwater system. The potentiometric surface has a gradient of approximately 7 feet per mile. Groundwater flows at a rapid rate of 50 feet per day in the shallow aquifer and 0.1 feet per day in the deep artesian aquifer. A clay layer averaging 69 feet thick separates the two major aquifers in the study area.

The Flathead River dominates the recharge regime of the surficial aquifer as demonstrated by the changes in potentiometric gradient and corresponding changes in river flow (Figures 14 and 15). Furthermore, the water table profiles (Figure 12) demonstrate the magnitude of the influence through the course of the year. The same figures illustrate that the Whitefish River is of major significance for approximately two months during Spring runoff. Spring Creek affects the immediately adjacent groundwater (Figure 23) but has minimal impact on the overall system as indicated by the sulfate isograms (Figure 34).

Contamination of the surficial aquifer occurs when the water table rises during runoff, intercepting the septic tank effluent contaminated area. Existence of this process is supported by independent data sets, specifically the ammonium, sodium, specific conductivity and bacteria graphs of concentration versus time. Concentrations of the various ions generally increase down gradient as population density increases and with increases in depth. Chloride and sodium concentrations increase with depth. Decreases in sulfate and increases in ammonium concentrations indicate that the surficial aquifer becomes anaerobic with increasing depth. Additions of relatively large amounts of organic matter to this aquifer appear to be consuming the available oxygen. Orthophosphate data suggests significant contamination from agricultural lands as well as urbanized lands.

Fecal coliform is the only parameter that exceeds state drinking water standards. Several authors have suggested that fecal streptococcus bacteria may be a better indicator of septic tank effluent contamination than fecal coliform bacteria. All of the well sites show the presence of fecal streptococcus at some time of the year. The occurrence of bacteria appears to be strongly related with the rise in the water table.

The deep artesian aquifer is chemically different from the surficial aquifer. No significant change has occurred in the quality of the deep artesian aquifer since 1964.

In conclusion, deep aquifer water quality has not changed, whereas water quality in the surficial aquifer has been degraded by urbanization. Water for domestic use from the shallow aquifer constitutes a health hazard.

R E C O M M E N D A T I O N S

A change in domestic water supply source is recommended for those individuals deriving their potable water from the surficial aquifer, because the possibility of a health hazard is demonstrated by this study. At least two alternatives are available:

1) All individuals within the Evergreen Water District could connect with that system.
2) Individuals with shallow wells could have a deeper well constructed that penetrates the deep artesian aquifer.

Choice of one of these alternatives is recommended. However, neither protects the surface water systems adjacent to the study area nor the wells in the surficial aquifer below the study area. To maintain or improve the quality of Flathead Lake and protect the wells below the study area, as well as the deep wells in the study area, a sewer system should be constructed and a strict well code should be promulgated and enforced. Collected sewerage should be treated with a facility that reduces both the bacterial and nutrient loads of the effluent discharged to levels that protect the integrity of Flathead Lake and regional domestic water supplies.

SELECTED REFERENCES

Anderson-Nichols and Co., Inc., 1977, On-Site Disposal Systems and Septage Treatment and Disposal, U.S. Environmental Protection Agency National Conference on 208 Planning and Implementation, Washington, D.C., 39 p.

APHA (American Public Health Association), 1975, Standard Methods For the Examination of Water and Wastewater, 14th ed., 1193 p.

Blalock, Hubert M. Jr., 1972, Social Statistics, 2nd ed., McGraw-Hill, 583 p.

Bodmer, S. and N. Stark, 1979, Final Report on Studies of Nonpoint Source Pollution in the Upper Flathead Drainage, Flathead Drainage 208 Project, 165 p.

Brietkrietz, Alex, 1966, Basic Water Data Report No. 3 Kalispell Valley, Montana, Montana Bureau of Mines and Geology Bull. 53, 25 p.

Buckman, H.O. and N.C. Brady, 1969, The Nature and Properties of Soils, 7th ed., The Macmillan Company, 653 p.

Department of the Army, Seattle District, Corps of Engineers, April, 1974, Interim Review of Reports on Flood Control - Flathead and Clark Fork River Basins (Flathead River Near Kalispell) Montana, 75 p.

Domenico, P.A., 1972, Concepts and Models in Groundwater Hydrology: McGraw-Hill Book Company, 405 p.

Earth Science Services, Inc., January, 1978, Ground Water Levels and Ground Water Chemistry Gallatin Valley Montana, 1977, Blue Ribbons of the Big Sky Country Areawide Planning Organization Bozeman, Montana, 62 p.

Eisen, C. and M.P. Anderson, 1979, The Effects of Urbanization on Ground-Water Quality - A Case Study, Ground Water, 17 (5), pp. 456-462.

EPA, 1971, Methods for Chemical Analysis of Water and Wastes, EPA - 16020, 07/71, 312 p.

EPA, Region VIII, July, 1977, Water Quality Study, Grand Lake, Shadow Lake, Lake Granby Colorado, 1974, Technical Investigations Branch, Surveillance and Analysis Division, EPA - 908/2 - 77 - 002, 216 p.

SELECTED REFERENCES contd.

Federer, Walter T., 1963, Experimental Design Theory and Application: Oxford and IBH Publishing Co., pp. 91-92.

Hem, J.D., 1959, Study and Interpretation of the Chemical Characteristics of Natural Water: Geological Survey Water-Supply Paper 1473, 269 p.

Hewlett-Packard, 1976, Stat Pac 1, Two-Way Analysis of Variance (no replications), pp. 07-01 to 07-06.

Hicks, C.R., 1973, Fundamental Concepts in the Design of Experiments: Holt, Rinehart and Winston, 349 p.

Johns, W.M., 1970, Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana, Mont. Bureau of Mines and Geology, Bull. 79, 182 p.

Klinger, R.D., 1976, Report to the Montana Designated 208 Water Quality Planning Agencies on Laws Affecting Water Quality, Published as: Legal Inventory, Flathead Drianage 208 Project, 172 p.

Konizeski, R.L.,A. Brietkrietz, and R.G. McMurtrey, 1968 Geology and Groundwater Resources of the Kalispell Valley, Northwestern Montana, Montana, Bureau Mines and Geology Bull. 68, 42 p.

Leininger, V.H. and C.S. McCleskay, 1953, Bacterial indicators of pollution in surface waters, Appl. Microbiology, vol. 1, pp. 110-124.

Linsley, R.K. Jr., M.A. Kohler, and J.L.H. Paulhus, 1975, Hydrology for Engineers: McGraw-Hill, Inc. 2nd ed., 482 p.

Manahan, S.E., 1972, Environmental Chemistry: Willard Grant Press, Boston, Mass., 393 p.

Marzouk, Y., S.M. Goyal, and C.P. Gerba, 1979, Prevalence of Enterovviruses in Ground Water of Israel, Ground Water, 17 (5), pp. 487-491.

McKee, J.E., and H.W. Wolf, 1963, Water Quality Criteria, Calif. State Water Resources Control Board, Pasadena, Calif. 1036 p.

Montana Department of Health and Environmental Sciences, November, 1978, Summary Drinking Water Regulations, Water Quality Bureau, 15 p.

SELECTED REFERENCES contd.

Morrison-Maierle, Inc., James J. Montgomery, Consulting Engineers, Inc., July, 1977, Groundwater Study, Flathead Drainage 208 Project, 79 p.

Springer, M.D., March, 1976, Research for the development of guidelines for conducting and analyzing an environmental water quality study to determine statistically meaningful results: University of Arkansas, Arkansas Water Resources Research Center, Engineering Experiment Station, Fayetteville, Arkansas, 163 p.

Stanford, J.A., F.R. Hauer and T.J. Stuart, 1979, Annual report of work completed during 1978-79 on limnology of Flathead Lake - River ecosystem, Montana, Submitted to: Flathead River Basin Environmental Impact Study Kalispell, Montana, and EPA Region VIII Water Division, Denver, Colorado, 155 p.

Stumm, W. and J.J. Morgan, 1970, Aquatic Chemistry: John Wiley and Sons, Inc., 583 p.

United States Department of Agriculture, July, 1970, Engineering Properties and Soil Interpretations For Use in Resource Planning and Development; A Supplement to Soil Survey, Upper Flathead Valley Area, Montana, Sept., 1960, Soil Conservation Service, 43 p.

United States Department of Agriculture, Soil Conservation Service, September, 1960, Soil Survey - Upper Flathead Valley Area Montana, Series 1947, No. 4, 67 p.

U.S. Department of the Interior, Bureau of Reclamation, 1977, Ground Water Manual, 480 p.

Vandenberg, A., D.W. Lawson, J.E. Charron, and B. Novakovic, 1977, Subsurface Waste Disposal in Lambton County, Ontario - Piezometric Head in the Disposal Formation and Ground-Water Chemistry of the Shallow Aquifer, Department of the Environment, Water Resources Branch, Tech. Bull. 90, Ottawa, Ontario, Can., 64 p.

Wolf, W.W., (1972), The Coliform Count as a Measure of Water Quality pp 333-345 in: Mitchell, R., 1972, Water Pollution Microbiology: Wiley-Interscience, pp 416.

Wright-McLaughlin Engineers and Stahly Engineering and Associates, October, 1978, 201 Facilities Plan for Kalispell, Montana, Volume 1 - Basic Information and Analyses.

Wright-McLaughlin Engineers and Stahly Engineering and Associates, May, 1979, 201 Facilities Plan for Kalispell, Montana, Volume 2 - Alternative Evaluation and Recommended Plan.

APPENDIX I

EASEMENT

For and in consideration of the sum of ________________ ($) and other valuable consideration, the receipt of which is hereby acknowledged, the undersigned ________________________________, hereinafter called the Grantors, do hereby grant to Flathead Drainage 208 Project, hereinafter called the Grantee, its successors or assigns the right and easement to drill, construct, reconstruct, and maintain three wells and all other necessary and desirable appurtanences and to regularly sample said wells, at or near the locations staked out by the Grantee upon the following described real property:

____

____

for the purpose of monitoring groundwater elevation and quality, together with the right of ingress and egress over the adjacent lands of the Grantors for the purpose of drilling, constructing, reconstructing and maintaining said wells and all other necessary and desirable appurtanences and to regularly sample said wells. The rights, title, privileges and authority herein granted shall continue to be in force until such time as Grantee shall permanently remove said wells and appurtanences from said lands or shall otherwise permanently abandon them at which time all such rights shall terminate.

IN WITNESS WHEREOF, the Grantors here have set their hands and seals this ________day of ________________, 1978.

____

____

STATE OF MONTANA)
:ss.
County of Flathead)

On this _______day of ________________, 1978, before me, a Notary Public for the State of Montana, personally appeared ________________ ____________________ known to me to be the persons whose names are subscribed to the within instrument, and acknowledged to me that they execute the same.

____
Notary Public for the State of Montana
Residing at: ________________
My commission expires: ____________

(SEAL)

APPENDIX II

Drilling Field Notes

Date Drilled	Well Site	Well	Length of Casing	Land Owner	Static Water Table from Ground Surface
9/26/78	1	1-1	25'	Driear, G.	7'
		1-2	18'		
		1-3	13'		
	2	2-1	25'	Graham, K.	7'
		2-2	16'		
		2-3	11'		
9/27/78	3	3-1	28'	Allen, G.	8'
		3-2	16'		
		3-3	22'		
	4	4-1	28'	Winegardner, Dr. K.	9'
		4-2	21'		
		4-3	17'		
	5	5-1	31'	Grigsby, H.	-
		5-2	21'		
		5-3	16'		
	6	6-1	23.5'	Wilhelm, J.	5'
		6-2	18'		
		6-3	14.7'		
9/28/78	7	7-1	26'	Lybeck, R.	9'
		7-2	22'		
		7-3	17'		
	8	8-1	25'	Madson, L.	11'
		8-2	29'		
		8-3	19'		
	9	9-1	31.7'	Corpron, V.	14'
		9-2	24.5'		
		9-3	19'		
10/2/78	10	10-1	32'	Barrow, C.	16'
		10-2	26.8'		
		10-3	22'		
10/4/78	11	11-1	28'	Miller, D.	9.5'
		11-2	22'		
		11-3	17'		

Drilling Field Notes contd.

Date Drilled	Well Site	Well	Length of Casing	Land Owner	Static Water Table from Ground Surface
10/3/79	12	12-1	31.5'	Eddy, M.	13'
		12-2	25.0		
		12-3	21.0		
10/3/79	13	13-1	30'	Cusick, D	-
		13-2	26'		
		13-3	20'		
	14	14-1	26.5'	Lybeck, R.	7'
		14-2	22'		
		14-3	17'		
	15	15-1	25'	Lybeck, R.	-
		15-2	20'		
	16	16-1	25'	Lybeck, R.	12'
		16-2	20'		
10/4/78	17	17-1	17'	Flathead County	8'
	18	18-1	31'	Snell, S.	14'
		18-2	26.5'		
		18-3	21.5		

APPENDIX III

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED: 208 Water Quality Study		SUB-WATERSHED:	SITE NO.:
LOCATION: Kalispell (Evergreen)		OWNER:	STATE:
LOGGED BY: Sherman Solild	DATE: 9/26/73	PROJECT: WP-07 ____ WP-08 ____ FP-03 ____ P.L.-46 ____	
DRILLING EQUIPMENT: Mobile B-50		LOCATION OF HOLES:	

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE[1]	FROM FT.	TO FT.	CSE. %	REM.[2] MIN. DIAM.	REC.[3] %
1	1			Orler										
		0	½	Silty fine sand		SM								
		½	4	Fine sand		SP								
		4	23	Sand-gravel mix (fine sand, gravel 2 - 3")		GP								
2	2			Grahm (Graham)										
		0	4	Very fine sand		SP								
		4	23	Sand-gravel mix (gravels 3 - 4")		GP								
3	3			Allen										
		0	4	Very fine sand		SP								
		4	16	Sand-gravel mix (60% gravels = 4")		GP								
		16	25	Silty fine sand-pea sized-gravel mix		GM								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 1 OF 6 SHEETS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED: 208 Water Quality Study	SUB-WATERSHED	SITE NO.
LOCATION: Kalispell (Evergreen)	OWNER	STATE
LOGGED BY: Sherman Sollld — DATE: 9/26/78	PROJECT: WP-07 ___ WP-08 ___ FP-03 ___ P.L.-46 ___	
DRILLING EQUIPMENT	LOCATION OF HOLES	

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE[1]	FROM FT.	TO FT.	CSE. %	REM.[2] MIN. DIAM.	REC.[3] %
4	4			Winegardner (dentist)										
		0	8	Medium grained sand		SP								
		8	25	Stratified sand-gravel mix (gravel = 1")		GP								
5	5			Grigsby										
		0	4	Medium grained sand		SP								
		4	12	Sand-gravel mix (gravel = 1")		GP								
		12	28	Medium grained sand-pea sized gravel		GP								
6	6			Wilhelm										
		0	4	Silty very fine sand		SP								
		4	23	Stratified silty gravels and sandy gravels		GM-GP								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 2 OF 6 SHEETS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED: 208 Water Quality Study		SUB-WATERSHED	SITE NO.
LOCATION: Kalispell (Evergreen)		OWNER	STATE
LOGGED BY: Sherman Sollid	DATE: 9/26/78	PROJECT: WP-07 ___ WP-08 ___ FP-03 ___ P.L.-46 ___	
DRILLING EQUIPMENT		LOCATION OF HOLES	

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE [1]	FROM FT.	TO FT.	CSE. %	REM. [2] MIN. DIAM.	REC. [3] %
7	9			Corpron										
		0	5	Fine sand		SP								
		5	24	Stratified sand-gravel mix, sand, gravel		GP								
		24	25	Sand (unable to recover)		SP								
8	8			Madson										
		0	25	Stratified sand-gravel mix		GP								
9	7			Lybeck South										
		0	½	Silty very fine grained sand		SM								
		½	5	Fine grained sand		SP								
		5	25	Stratified sand-gravel mix		GP								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 3 OF 6 SHEETS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED 208 Water Quality Study | SUB-WATERSHED | SITE NO.

LOCATION Kalispell (Evergreen) | OWNER | STATE

LOGGED BY Sherman Sollid | DATE 9/26/78 | PROJECT: WP-07 ____ WP-08 ____ FP-03 ____ P.L. 46 ____

DRILLING EQUIPMENT | LOCATION OF HOLES

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE[1]	FROM FT.	TO FT.	CSE. %	REM[2] MIN. DIAM.	REC.[3] %
10	11			Doug Miller										
		0	6	Silty fine sand		SM								
		6	10	Silty sand-gravel mix (gravel 1 - 3")		GM-GP								
		10	15	Silty sand		SM								
		15	25	Stratified gravels, sand-gravel mix		GP								
11	10			Boorman (Barrows)										
		0	5	Fine sand		SP								
		5	25	Stratified gravels, sand-gravel mix		GP								
12	12			Maurice Eddy										
		0	2	Silty very fine grained sand		SM								
		2	6	Fine sand		SP								
		6	28	Stratified sand-gravel mix and pea sized gravels		GP								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 4 OF 6 SHEETS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED: 208 Water Quality Study		SUB-WATERSHED	SITE NO.
LOCATION: Kalispell (Evergreen)		OWNER	STATE
LOGGED BY: Sherman Sollid	DATE: 9/26/78	PROJECT: WP-07 ___ WP-08 ___ FP-03 ___ P.L.-46 ___	
DRILLING EQUIPMENT		LOCATION OF HOLES	

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE[1]	FROM FT.	TO FT.	CSE. %	REM.[2] MIN. DIAM.	REC.[3] %
13	13.			Kusick (Cusick)										
		0	3	Sand-gravel mix (1" gravels)		GP		clean gravel						
		3	13	Sand-gravel mix (1 - 3" gravels)		GP								
		13	18	Medium grained sand		SP		clean sand						
		18	28	Stratified gravels and sand-gravel mix		GP								
14	14			Lybeck (Ezy Drive)										
		0	13	Medium grained sand		SP								
		13	18	Sand-gravel mix (2" gravels)		GP								
		18	20	Silty gravels		GM								
		20	23	Medium grained sand		SP								
15	15			Lybeck (Helena Flats North)										
		0	6	Silty sand		SM								
		6	23	Stratified silty sand-gravel mix and gravel		GP								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 5 OF 6 SHEETS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

LOG OF TEST HOLES

SCS-533
REV. 3-67

WATERSHED: 208 Water Quality Study
SUB-WATERSHED:
SITE NO.:
LOCATION: Kalispell (Evergreen)
OWNER:
STATE:
LOGGED BY: Sherman Sollid
DATE: 9/26/78
PROJECT: WP-07 ____ WP-08 ____ FP-03 ____ P.L.-46 ____
DRILLING EQUIPMENT:
LOCATION OF HOLES:

HOLE NO.	Well Site Number	HOLE DEPTH FROM FT.	HOLE DEPTH TO FT.	DESCRIPTION OF MATERIALS	N	USCS	TYPE BIT USED	SAMPLES NO.	TYPE[1]	FROM FT.	TO FT.	CSE. %	REM[2] MIN. DIAM.	REC.[3] %
16	16			Lybeck (Helena Flats School)										
		0	23	Stratified silty sand-gravel mix		GM-GP								
17	18			Snell										
		0	4	Silty fine grained sand		SM								
		4	28	Silty sand-gravel mix (1 - 3" gravels)		GM-GP								
18	17			Lybeck Dike										
		0	5	Sand-gravel mix (occasional cobble)		GP								
		5	6	Sandy silt		ML-SM								
		6	13	Stratified silty sand-gravel mix		GM-GP								

1. DISTURBED-UNDISTURBED-ROCK CORE 2. COARSE MATERIAL REMOVED 3. PERCENT SAMPLE RECOVERY

SHEET 6 OF 6 SHEETS

APPENDIX IV

Computation Sheet

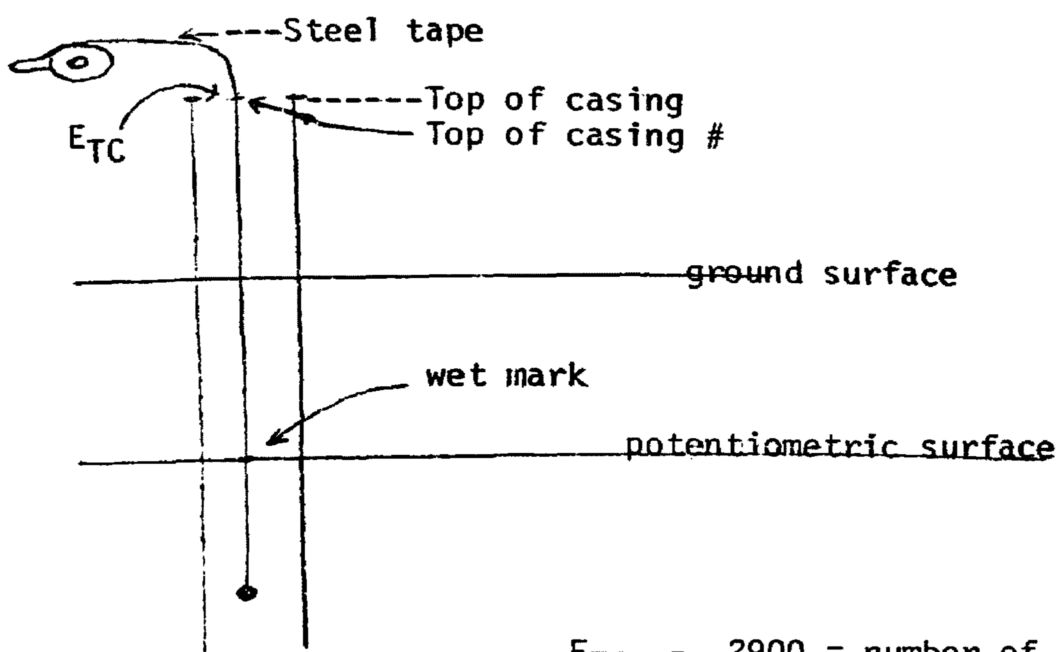
State: Montana Project: 208 Survey

Subject: Elevations - 208 Observation Wells

Well #	Top of Casing Elevation	Well #	Top of Casing Elevation
1-1	2916.25	10-1	2929.80
1-2	2916.52	10-2	2929.73
1-3	2916.42	10-3	2929.78
2-1	2914.55	11-1	2924.06
2-2	2914.60	11-2	2925.68
2-3	2914.19	11-3	2925.73
3-1	2915.49	12-1	2927.82
3-2	2915.94	12-2	2926.19
3-3	2915.84	12-3	2926.99
4-1	2919.88	13-1	2930.84
4-2	2920.28	13-2	2930.71
4-3	2920.00	13-3	2929.88
5-1	2919.80	14-1	2926.13
5-2	2919.44	14-2	2926.35
5-3	2918.49	14-3	2926.19
6-1	2918.82	15-1	2928.15
6-2	2918.35	15-2	2928.44
6-3	2919.08		
7-1	2926.64	16-1	2933.68
7-2	2926.89	16-2	2933.46
7-3	2926.96		
8-1	2922.54	17-1	2926.17
8-2	2922.78		
8-3	2922.60		
9-1	2923.79	18-1	2929.46
9-2	2924.01	18-2	2929.71
9-3	2923.87	18-3	2929.79

APPENDIX V

Sample Calculations



E_{TC} - 2900 = number of feet the TC is above the base datum. = constant

Constant - (Top of Casing - Wet Mark) = height of piezometric surface above datum.

Example: Well 1-1 on 11/21/78
16.25 - (20.9 - 10.9) = 6.25
16.25 - (20.9 - 10.9) = 6.25

Constant

1-1	E_{TC} = 2916.25	2916.25 - 2900 = 16.25
1-2	= 2916.52	- 2900 = 16.52
1-3	= 2916.42	- 2900 = 16.42

APPENDIX VI

Soils Legend

Symbol	Name
Aa	Alluvial land, poorly drained
Ab	Alluvial land, well drained
Ba	Banks loamy fine sand, 0-4 percent slopes
Bb	Banks very fine sandy loam, 0-4 percent slopes
Bc	Birch fine sandy loam, 0-5 percent slopes
Bd	Birch gravelly loam, 0-3 percent slopes
	Chamokane soils:
Ca	0-3 percent slopes
Cb	3-7 percent slopes
Cc	Chamokane and Banks soils, 0-4 percent slopes
Cd	Corvallis silty clay loam, 0-3 percent slopes
Kzd	Kiwanis fine sandy loam, 0-4 percent slopes
Kze	0-3 percent slopes
Kzf	3-9 percent slopes
Kzg	Kiwanis-Birch fine sandy loams, 0-5 percent slopes
Kzh	Kiwanis-Birch loams, 0-4 percent slopes
Rc	Riverwash
	Swims silt loam:
So	0-3 percent slopes
Sp	3-7 percent slopes
Sr	Swims silty clay loam, 0-4 percent slopes
Wo	Walters silt loam, 0-4 percent slopes
Wp	Walters very fine sandy loam, 0-7 percent slopes.

(S.C.S., 1960)