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GEOHYDROLOGIC STUDY OF THE WEST LAKE BASIN

R. E. Gephart
P. A. Eddy
R. C. Arnett
G. A. Robinson

Ground Water Management Section
Research Department
Research and Engineering Division

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INTRODUCTION

The area of study is a deeply eroded and structurally deformed basin located north of the 200 East Area and south of Gable Mountain (Figure 1). A natural surface water body, West Lake, is located in the area's topographic low. The study area is called West Lake Basin.

In 1957 a liquid waste disposal site (Gable Mountain Pond) was constructed about one mile southeast of West Lake. Since its construction it has received cooling water and waste condensates from several 200 East Area sources. A recent study[1] indicated that a potential zone of hydraulic contact may exist under West Lake between the uppermost confined aquifers and the overlying unconfined aquifer. The unconfined aquifer within this area has been contaminated from waste disposal sites possibly including Gable Mountain Pond, B Pond and the 216-BY cribs. A hydraulic interconnection between the unconfined and uppermost confined aquifers could lead to flow of contaminants from the unconfined into the confined aquifers provided the hydraulic head of the former is greater than that of the latter.

The purpose of this investigation was to (1) collect and interpret geochemical data on the surface, unconfined, and confined waters of the West Lake Basin, and (2) evaluate the potential for radiochemical contamination of the uppermost confined aquifers. The report assesses the suitability of Gable Mountain Pond for receiving waste water from 200 East Area operations and applies a predictive digital computer model to assess the impacts to the groundwater regime of maintaining, increasing, or decreasing water discharge into Gable Mountain Pond.

East of the 200 East Area (Figure 1) lies a natural depression which has been dammed and used as a liquid waste disposal site (B Pond). B Pond waste waters directly recharge the underlying unconfined aquifer. This report will examine the suitability of using B Pond for receiving additional

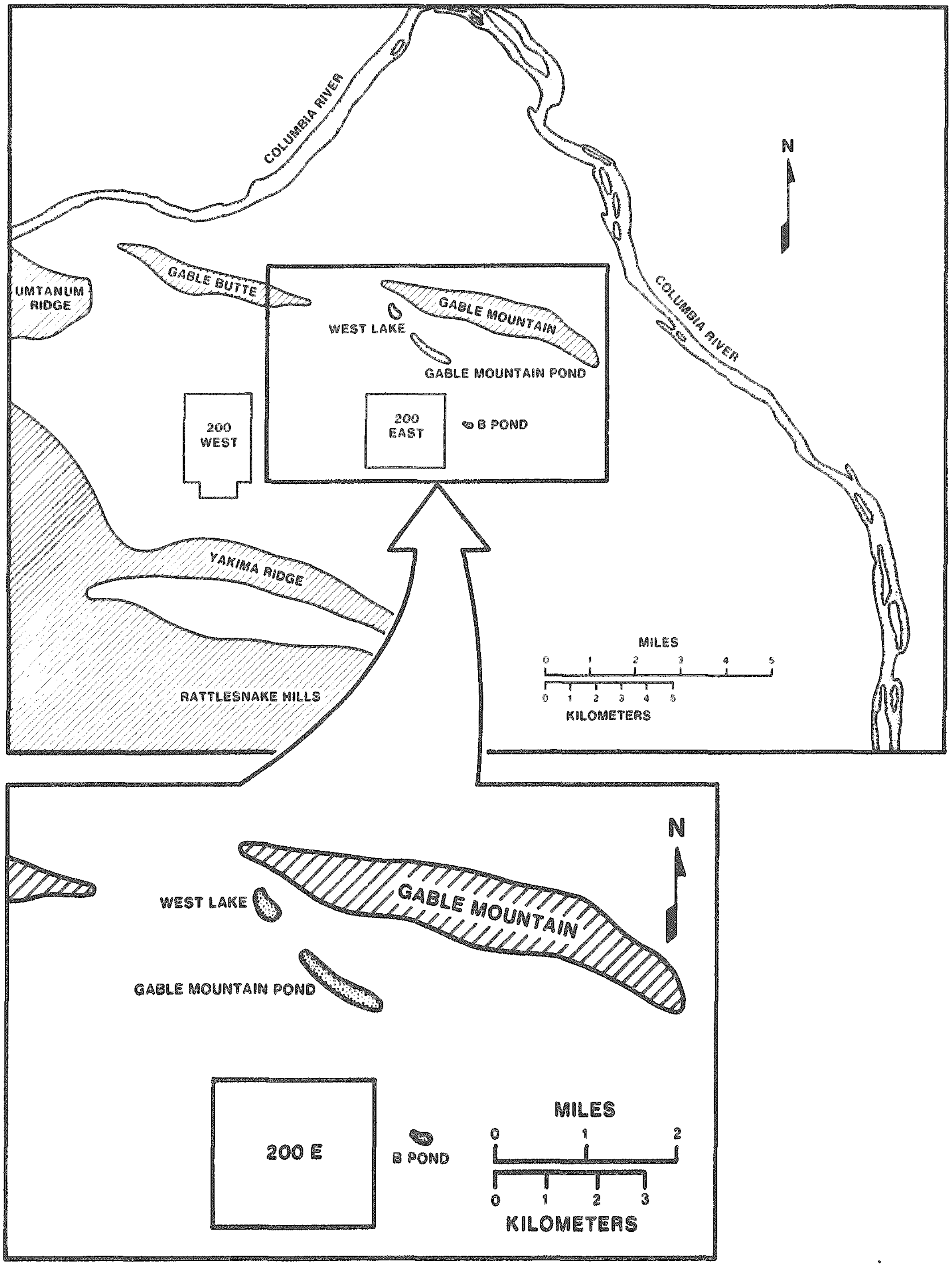

FIGURE 1

LOCATION MAP OF THE WEST LAKE BASIN
AND SURROUNDING AREA

waste waters which would otherwise be discharged to Gable Mountain Pond. A predictive digital computer model will be used for assessments involving various discharges into B Pond.

GEOLOGY AND HYDROLOGY OF THE STUDY AREA

The Hanford Reservation is underlain by Miocene and Pliocene basalts of the Columbia River Group, Pliocene-Pleistocene semiconsolidated-to-consolidated sands, silts and gravels of the Ringold Formation, Pleistocene eolian and glaciofluvial sediments, and Holocene alluvium and colluvium. The geology of the Reservation has been extensively discussed elsewhere.[2,3]

The West Lake Basin is part of a structural trough which is underlain by a strongly folded sequence of lava flows which trend in a northwest-southeast direction and are asymmetrically folded to the south. These folded basalts are part of the Umtanum-Gable Anticline. This folding caused the West Lake Basin to be formed with a steep basalt face on the north and a flatter slope on the south. The individual basalt flows are part of the Yakima Basalts which are within the uppermost section of the Columbia River Group.[2] Interbeds between individual basalt flows form confined or semiconfined aquifers. These interbeds may either be of limited areal extent or extend over a wide geographic region. The four uppermost interbeds present in the West Lake Basin are the Rattlesnake Ridge, Selah, Hanford and Mabton Interbeds (Figure 2). The Mabton Interbed is the most extensive of these four.

During the last ice age (20,000 years ago) glacial meltwaters frequently caused catastrophic flooding in the Pacific Northwest. These waters would erode away the underlying bedrock and deposit coarse glaciofluvial material in its place. Ancestral meltwater channels crossed the study area in a northwest-southeast direction through the gap between Gable Butte and Gable Mountain.

Two channels appear to have crossed through Gable Butte and Gable Mountain and coalesced at West Lake. Southeast of the lake, they become one wide channel that spreads over the eastern portion of the Reservation. Well driller logs and a gravity survey conducted in the West Lake area reveal

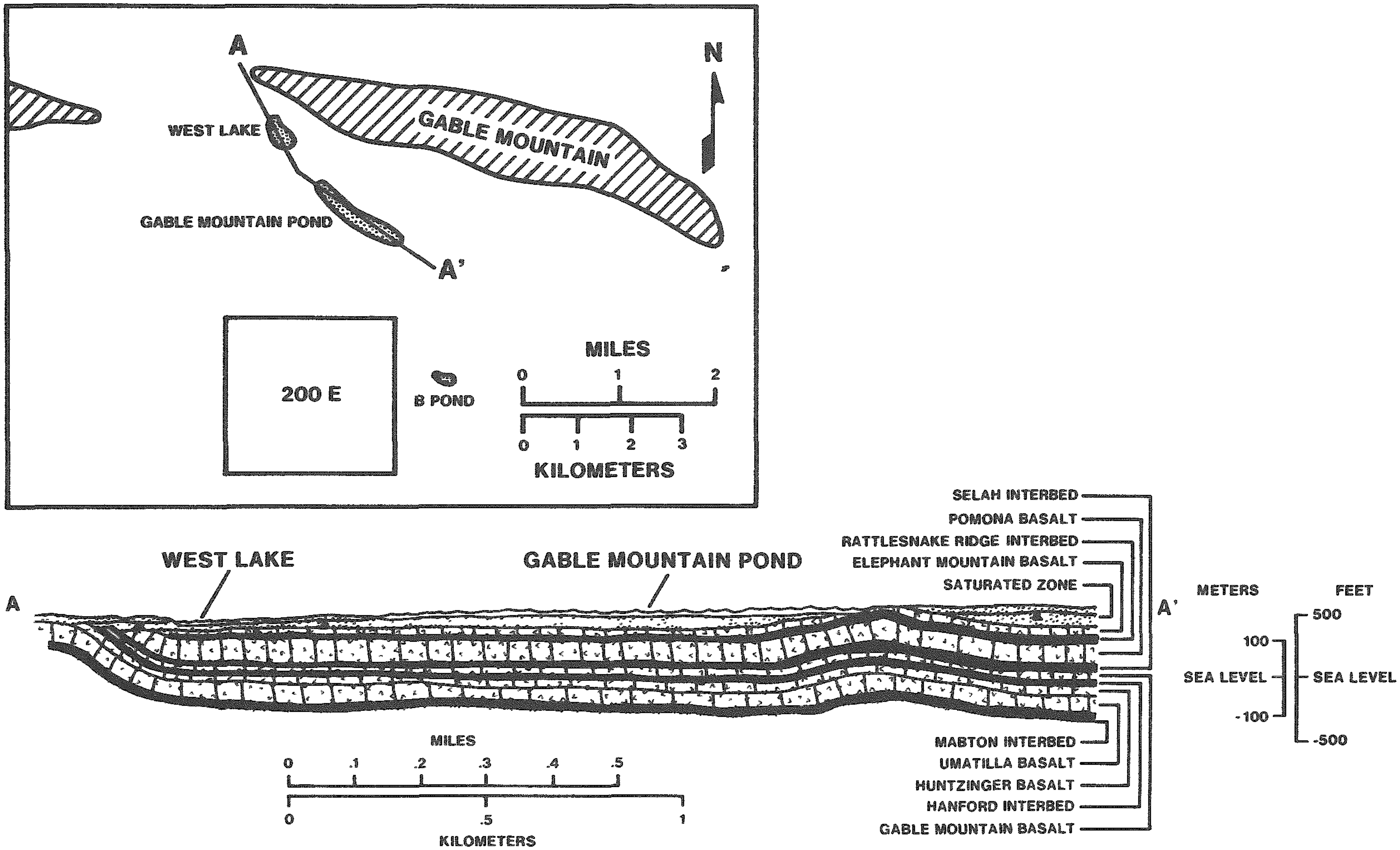

FIGURE 2

STRATIGRAPHIC SECTION SHOWING UNCONSOLIDATED SEDIMENT, CONSOLIDATED BASALT UNITS, AND INTERBEDS that these glacial meltwaters eroded into the underlying basalts and deposited coarse sediments atop them (Figure 3). As much as 200 to 300 feet (60-90 m) of glaciofluvial sediment may have been deposited atop the basalts in portions of the West Lake Basin. Ground water presently flows in these paleochannels in the direction of decreasing head.

The glaciofluvial sediment overlying the basalt surface beneath the West Lake Basin, where saturated, constitutes the unconfined aquifer. Its upper boundary is the regional water table and its bottom boundary is the underlying basalt. The aquifer's lower boundary is shown in Figure 4. The two local surface water bodies of West Lake and Gable Mountain Pond are now part of this unconfined flow system.

The confined aquifers lie beneath the unconfined aquifer. These principally consist of interbeds between individual basalt flows. In the area under study, the Mabton Interbed is the thickest (50-130 ft, 15-40 m) and most productive of the uppermost interbeds. Approximately 1/4 mile (0.4 km) northwest of West Lake, the Mabton Interbed was penetrated at a depth of 220 ft (67 m) below land surface in well 699-61-55 (Figure 5).

The hydraulic characteristics of the unconfined aquifer are quite variable. Pumping tests and geologic studies have estimated the vertically-averaged hydraulic conductivity in the West Lake Basin to be between 1000 and 10,000 ft/day (300 to 3000 m/day). This is typical of permeable coarse sedimentary deposits. Lower values are indicative of finer and more tightly packed sediments.

The hydraulic properties of the uppermost confined aquifers have been studied and reported by various investigators.[1,2] From a hydraulic standpoint the most permeable of the four uppermost confined aquifers in the West Lake Basin is the Mabton Interbed. Its horizontal hydraulic conductivity measured from pumping tests and laboratory determinations on cores is 20 to 60 ft/day (5.0-20.0 m/day). Thus, in the West Lake region, the Mabton Interbed is much less permeable than the overlying unconfined aquifer.

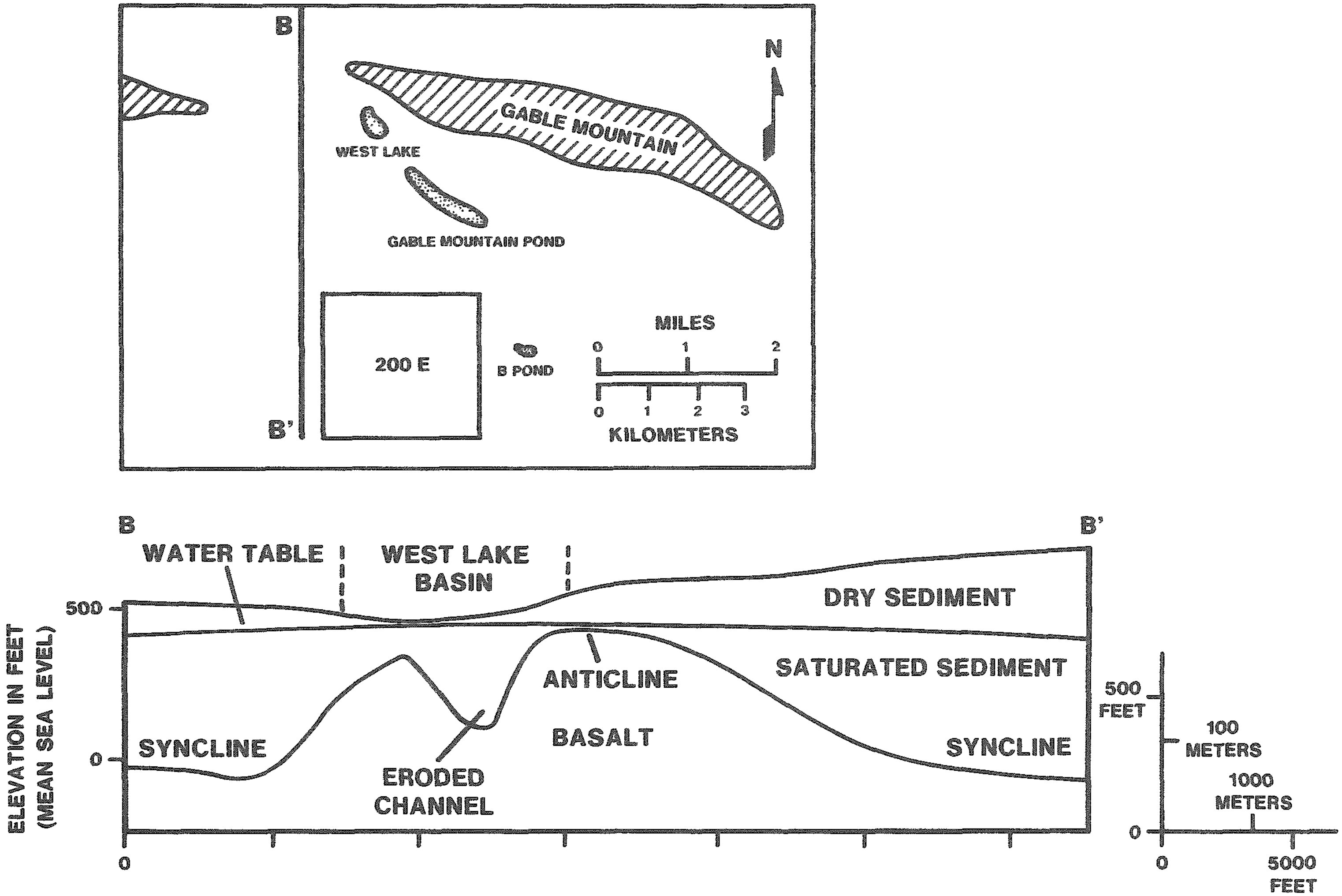

FIGURE 3

TWO-DIMENSIONAL GRAVITY PROFILE

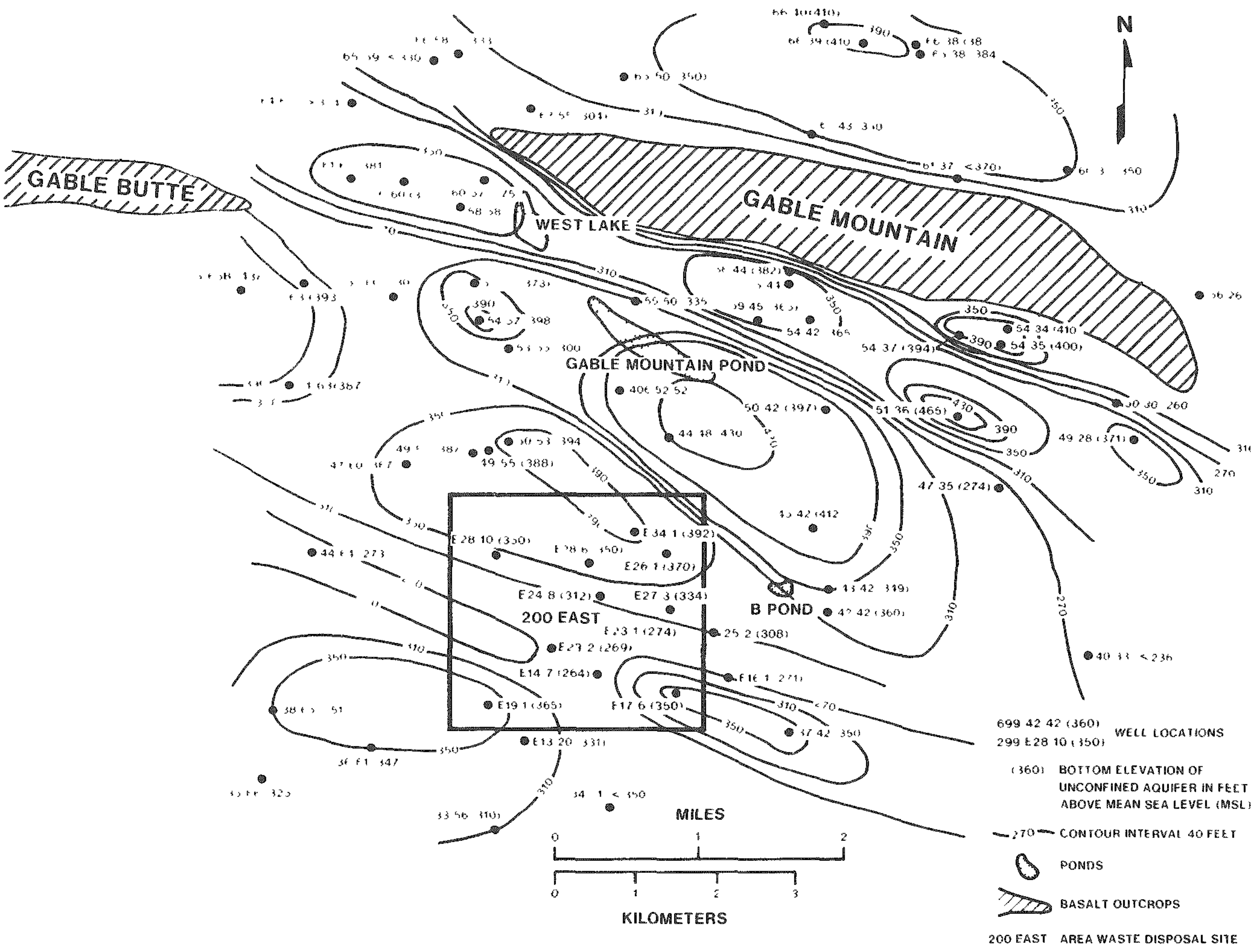

FIGURE 4

BOTTOM ELEVATIONS OF THE UNCONFINED AQUIFER

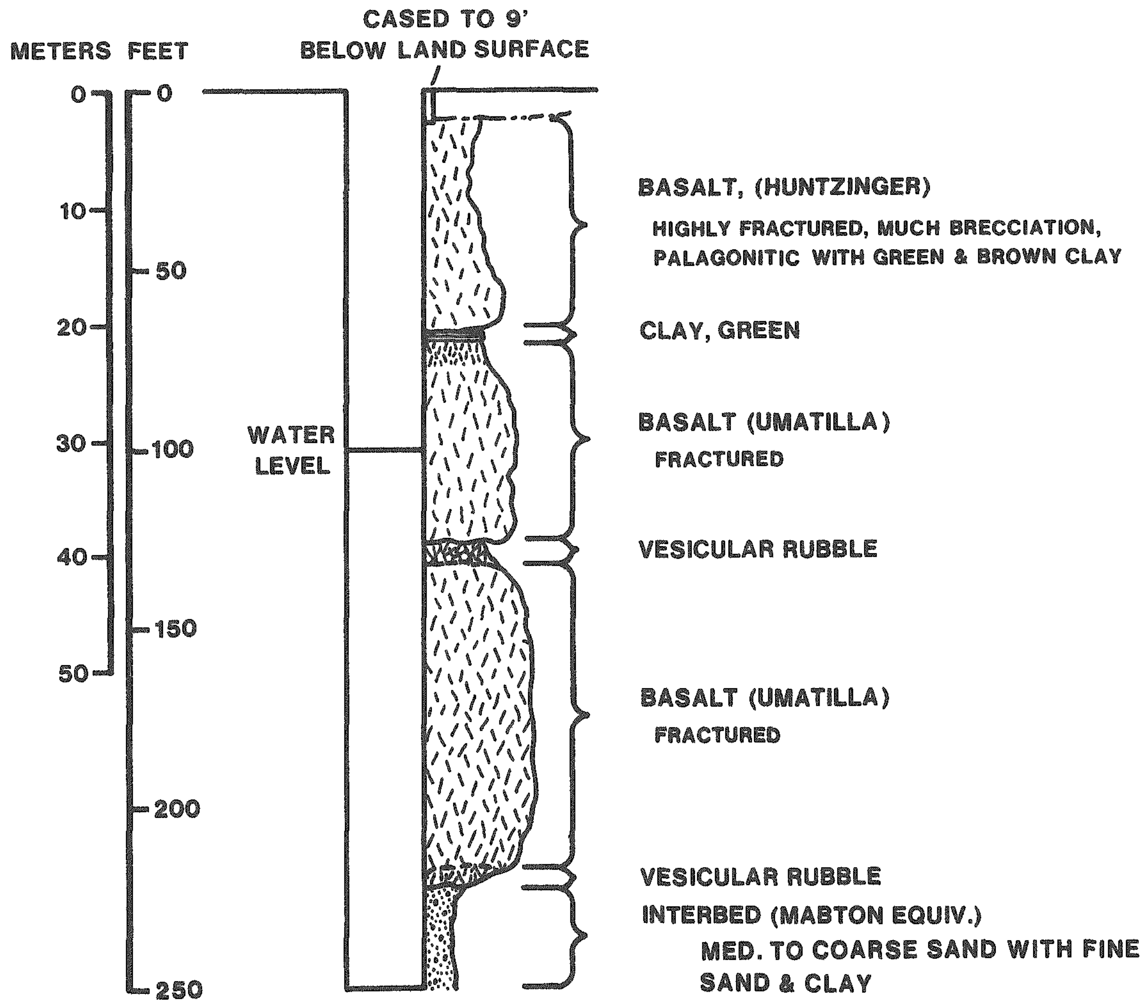

FIGURE 5

699-61-55 (DH-8) CORE WELL

The basalt flows separating the unconfined and uppermost confined aquifers in the West Lake Basin have a relatively high vertical hydraulic conductivity which is a function of the extent of fracturing.

Before the Gable Mountain Pond and B Pond waste disposal operations began, the unconfined aquifer near West Lake was very thin and its hydraulic gradient had a slight easterly slope. The only lateral flow restrictions were Gable Mountain to the north and northeast and a few basalt outcrops to the south. Waste water discharges to Gable Mountain Pond and B Pond have raised the local water table and partially blocked the easterly flow of ground water just south of Gable Mountain. Today, most ground water flow leaving the West Lake Basin trends northward through Gable Butte and Gable Mountain Gap. This local basin appears to represent a nearly stagnant or closed groundwater system open at the top to evapotranspiration and connected at the bottom to the uppermost confined aquifers.

Water table elevations collected from selected wells in the West Lake Basin indicate the presence of a totally saturated sediment column beneath Gable Mountain Pond (Figure 6). However, whether the sediment column under Gable Mountain Pond is fully or partially saturated, West Lake could receive water from both Gable Mountain Pond and from the confined aquifer as long as the water potential in the confined aquifer is greater than that in the unconfined. Contaminated ground water can only enter the confined aquifer beneath West Lake if the water potential in the unconfined flow system exceeds that in the confined system. Present day water levels in the confined aquifer appear to be identical to those found in the unconfined aquifer. Thus, the two flow systems are in apparent hydraulic equilibrium. This situation could change if increased water discharges are routed to Gable Mountain Pond.

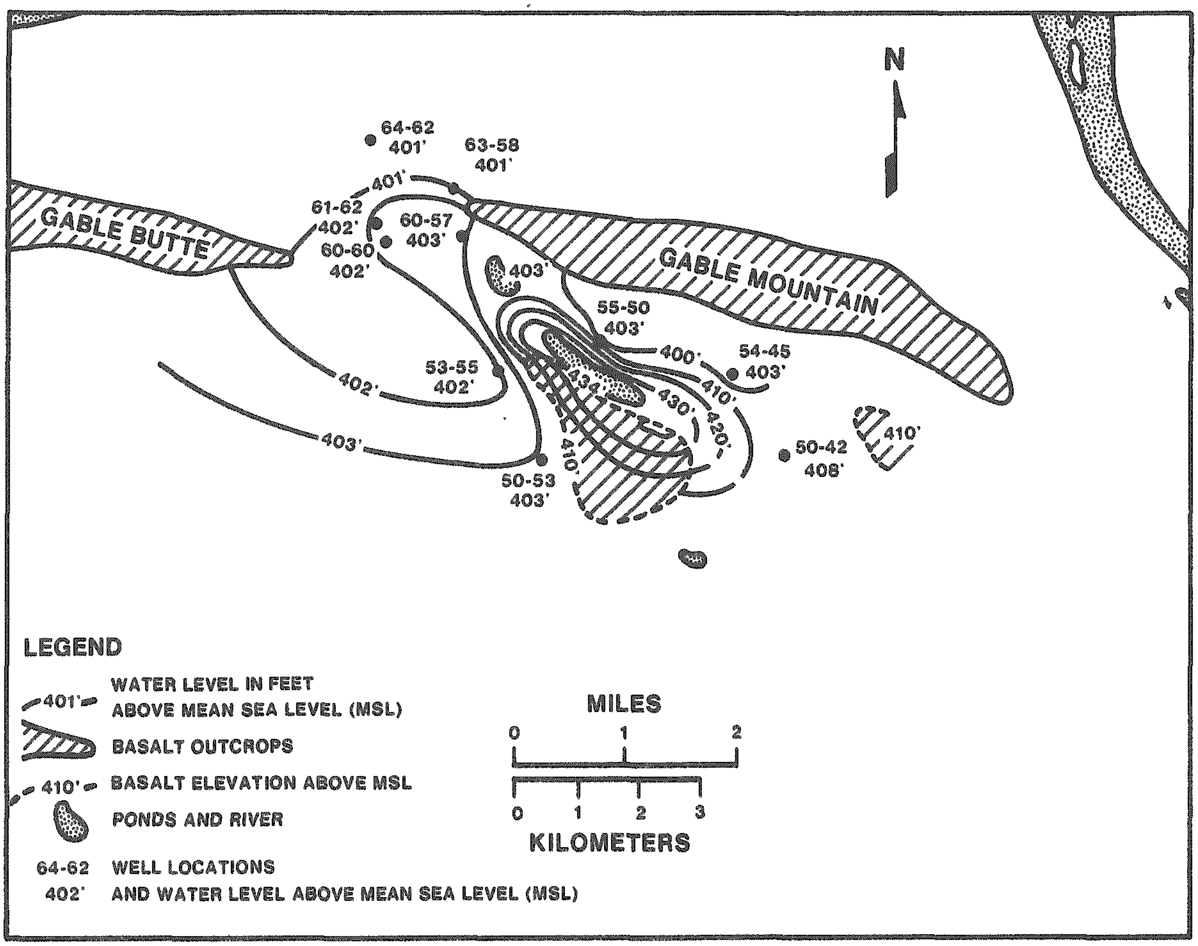

FIGURE 6

JULY 1976 WATER TABLE MAP

CHEMICAL CHARACTERIZATION

Chemical and radiological analyses of the ground water and surface waters in the study area were conducted to provide data that could be used to characterize and classify the ground waters of the unconfined and uppermost confined aquifers and to analyze for potential radiochemical contamination of the uppermost confined aquifers.

PROCEDURES

Water samples from Gable Mountain Pond and West Lake were pumped from a depth of six inches to one foot below the water surface. The intake was approximately three feet out from the pond's bank. At West Lake the samples were taken from the west side of the lake at the Battelle Environmental Monitoring Site where the access road approaches the lake. The samples from Gable Mountain Pond were mixed samples. Each sample container was filled with water pumped from three places; one-third from a site adjacent to the inlet, one-third from a site midway along the pond, and one-third from a site near the road across the north end of the pond.

Five wells were also sampled (Figure 7). Two of these, wells 699-52-52 and 699-61-55, are open to the Mabton Interbed (confined aquifer). Well 699-55-57 bottoms out in the Elephant Mountain Basalt (Figure 2). The other two wells, 699-55-50C and 699-53-47, terminate above basalt within the sediments associated with the unconfined aquifer. Well 699-53-103 located west of the Hanford Reservation and distilled water were both used as blanks.

All of the wells were pumped for at least a half hour before samples were taken. If the water appeared dirty the wells were pumped longer.

Samples for gamma spectroscopy and iodine activation analysis were taken two ways. Grab samples were collected in the field and later divided in the lab - part boiled down and part run through an ion exchange column. A second sample was taken in the field by pumping 20 cubic feet of water through an ion exchange resin bed.

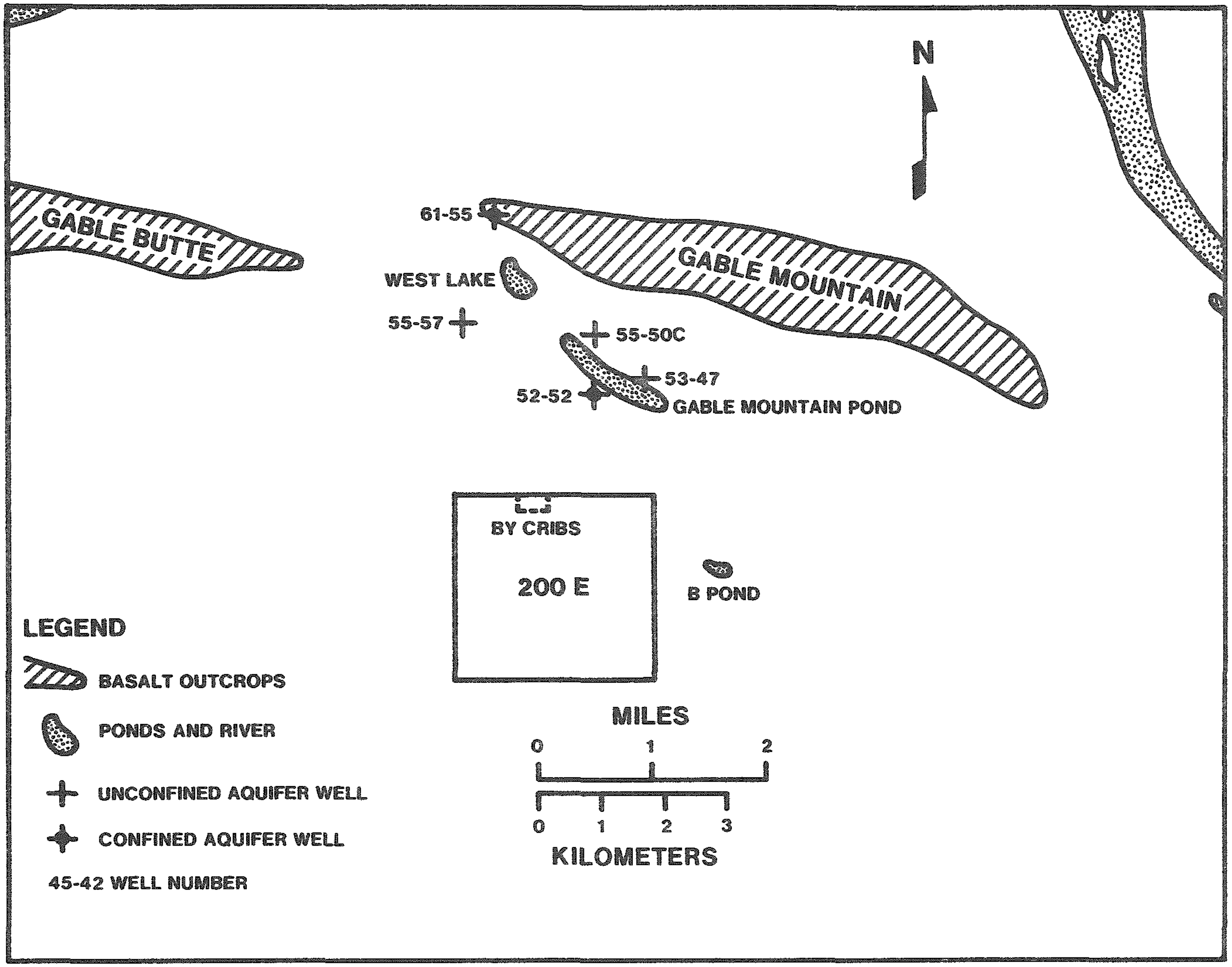

FIGURE 7
WELL LOCATION MAP

All samples were collected in plastic containers except for the tritium and oxygen ratio analyses which were taken in brown glass bottles. If the chemical tests were not run immediately, care was taken to see that the sample was preserved by acidification or refrigeration, whichever was appropriate. The grab samples for plutonium and americium were acidified in the field. All sampling was done between April 12 and April 22, 1976. Duplicate samples were taken for most analyses.

Analytical procedures used are summarized in Tables I and II.

TABLE I

METHODS USED FOR CHEMICAL ANALYSIS OF SAMPLES

Species	Method	Precision and Accuracy	Reference
HCO_3, CO_3	Combined titration phenolphathalein - methyl orange	1 ppm precision 3 ppm accuracy	Standard Methods[4]
Cl	Colorimetric mercuric thiocyanate	±4% recovery	EPA[5]
SO_4	Turbidimetric	9.1% relative std. deviation 1.2% relative error	Standard Methods[4]
NO_3	Phenoldisulfonic Acid	±.1 ppm accuracy	Standard Methods[4]
F	Distillation and SPADNS Method	17.2% relative std. deviation 5% relative error	Standard Methods[4]
Cr	Colorimetric	10 ppb precision	Standard Methods[4]
B	Curcumin Method	22.8% relative std. deviation	Standard Methods[4]
Cond	Specific conductance Wheatstone bridge	±5%	Standard Methods[4]
TOC	Combustion-Infrared Method	5% precision	Standard Methods[4]
SiO_2	Molybdosilicate Method	14.3% relative Std. deviation 7.8% relative error	Standard Methods[4]
Mg, Ca, Na, K, Be, Zn	Atomic absorption	5% relative error	Varian Manuals for 1000 and 1200 model Atomic absorption units, Standard Methods[4]
Ni, Ag, Sr, Mn, Fe	Atomic absorption	10% relative error	
Cd, Cr, Co, Pb Cu	Atomic absorption	15% relative error	
Hg, Al, Sb, Ba, Mo, Sn, Tl, V, As, Se	Atomic absorption	20% relative error	

TABLE II

METHODS USED FOR RADIOCHEMICAL ANALYSIS

Elements(s)	Method(s)	Detection Limit	Precision and Accuracy	References
^{22}Na, ^{226}Ra, ^{40}K, ^{228}Ra, ^{46}Sc, ^{228}Th, ^{51}Cr, ^{234}Th, ^{54}Mn, ^{235}U, ^{57}Co, ^{95}Zr, ^{58}Co, ^{95}Nb, ^{59}Fe, ^{103}Ru, ^{60}Co, ^{106}Ru, ^{65}Zn, ^{125}Sb, ^{88}Y, ^{137}Cs, ^{110}Ag, ^{141}Ce, ^{134}Cs, ^{144}Ce, ^{152}Eu, ^{155}Eu, ^{154}Eu, ^{7}Be	Ge(Li) gamma-ray Spectrometry	.1-1 pCi depending on radionuclide and radionuclide matrix	variable, routinely 5-10%	5,6,7,8, 9,10,11
^{7}Be, ^{88}Y, ^{22}Na, ^{106}Ru, ^{46}Sc, ^{134}Cs, ^{58}Co, ^{137}Cs, ^{60}Co	Multiparameter coincidence gamma-ray spectrometry	.1-1 pCi depending on radionuclide and radionuclide matrix	variable, routinely 5-10%	12
^{60}Co, ^{106}Ru, ^{129}I	Added iodine spike, concentrated sample by anion (in lab) using a Douex resin	^{60}Co - .1 pCi ^{106}Ru - 1.0 pCi ^{129}I - 10^{-5} pCi	5-10% 5-10% 5-25%	13,14,15 16,17
	Gamma spectrometric measurement of ^{60}Co, ^{106}Ru			
	Removed iodine from resin by oxidation measured ^{129}I and ^{127}I by neutron activation analysis			
	Same as above except with ion exchange sampler in field			
Tritium	Purify by distillation enrich Tritium by electroanalysis, conversion to gas and count in internal gas proportional counter	.1 TU (.32 pCi/ℓ)	1-5%	18
^{14}C	Acidify and heat to liberate CO^2, Trap CO_2 as Sr CO_3, convert to gas and count in internal gas counter	Depends on amount of C separated, ages as old as 30,000 yrs.	2-5%	19,20
Pu,Am	Concentrate by evaporation, measure by alpha analysis	.02 pCi 2 pCi	5%	21
$^{18}O/^{16}O$	Mass Spectrometry	±.2% differences	1%	22,23

RESULTS

The results of analyzing the general chemical composition of the waters are given in Table III. These results are somewhat inconclusive in that a charge balance between cations and anions is not always attained; however results are consistent with analyses reported by other investigators.[2,3] Data for significant radioisotopes are given in Tables IV and V.

TABLE III

CHEMICAL CONSTITUENTS OF GROUND AND SURFACE WATERS IN THE GABLE MOUNTAIN POND--WEST LAKE BASIN

Parameters	699-52-52	699-61-55	699-55-57	699-55-50C	699-53-47	West Lake	Gable Mtn. Pond
Mg	2	2	26	10	9	13	6
pH	8.2	8.0	8.0	8.2	7.6	9.6	8.2
Cond*	244	275	482	188	236	14550	152
Ca	4	8	94	39	38	5	19
Na	100	60	39	6	7	7000	4
OH	--	--	--	--	--	1600	--
CO_3*	18.2	27.7	<3.5	<3.5	<3.5	5850	<3.5
HCO_3*	167.6	117	104.8	104.1	97	--	68.8
K	14	10	8	5	4	400	1.0
B	.2	.1	.2	.2	.1	5	.05
NO_3	<.25	<.25	3.1	<.25	<.25	.25	<.25
Cl	20	16	24	5	8	2080	4
Dis. Solids	324	286	525	156	186	15410	94
SO_4	2.5	5	34	.8	6	1375	4.5
TOC*	4	8	<1	<1	6	600	8
Fl	1.4	1	.7	.3	.2	158	.2
Hg*	.2	<.2	<.2	<.2	<.2	<.2	<.2
Al	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Sb	<5	<5	5	5	<5	>1000	<5
Ba	.21	.17	.06	.63	.52	.83	.50
Be	<.02	.02	<.02	<.02	<.02	.06	<.02
Cd	<.01	<.01	<.01	<.01	<.02	<.03	.02
Cr*	15	<5	10	30	22	128	<5
Co	<.01	<.01	<.01	<.01	.01	.02	<.01
Pb	<.1	<.1	<.1	<.1	<.1	.5	<.1
Mo*	94	25	21	38	8	1280	25
Ni*	<5	<5	8	10	8	150	<5
Ag	<.01	<.01	<.01	<.01	<.01	.04	<.01
SiO_2	24	23	23	22	21	1	<.5
Sr	.05	.08	.28	.05	.05	.25	.13
Sn	<.5	<.5	.5	<.5	<.5	2.5	.5
Tl	<2	<2	<2	<2	2	3	<2
V	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Zn	5	5	<5	6	54	18	9
Mn	.05	.01	.01	<.01	.05	.04	.01
Cu*	9	<5	5	7	8	355	6
Fe	2.3	.5	.1	<.05	1.32	.36	.06
U*	<.4	.4	5.4	.6	1	526	.70

*All Parameters in ppm except:

Cond - mmhs/cm
CO_3 - mg/l as $CaCO_3$
HCO_3 - mg/l as $CaCO_3$
Dis. Solids - mg/l
TOC - mg/l

Hg - ppb
Cr - ppb
Mo - ppb
Ni - ppb
Cu - ppb
U - mg/l

TABLE IV

SUMMARY OF GAMMA SPECTROMETRIC AND IODINE ANALYSIS RESULTS

Sample	Evaporation ^{60}Co	Evaporation ^{106}Ru	Evaporation ^{125}Sb	Field Resin ^{60}Co	Field Resin ^{106}Ru	Field Resin ^{129}I	Lab Resin ^{60}Co	Lab Resin ^{106}Ru	Lab Resin ^{129}I
699-53-103	<0.002	<0.02	BD	0.0001*	0.001*	.0001-.00001	<0.002*	<0.001*	0.000007*
699-52-52	.014-.004	<0.02	BD	--	--	--	.006-.0002	.0008-.004	.00004-.0004
699-61-55	<0.003	<0.02	BD	0.0001*	0.001*	.0008-.001	<0.0002	.003-.001	.012-.009
699-55-57	<0.002	<0.02	BD	0.0003*	0.002*	.0004-.0003	<.0002	.006	.0006
699-55-50c	.004-.005	.32-.24	2.1	0.0025*	0.036*	.011-.012	.004	.26-.25	.12-.14
699-53-47	.003-.004	.15-.14	.97-1.2	0.0029*	0.09*	.061-.054	.004-.001	.13-.12	.10-.11
West Lake	<0.01	.75-1.0	<0.60	--	--	--	.04-.30	.23-.35	.08-.11
Gable Mountain Pond	.120-.054	.08-.18	<0.25	--	--	--	.008-.12	.07-.10	.02-.06

all units in pCi/l
BD = Below Detection
* = single analyses conducted

TABLE V

TRITIUM, PLUTONIUM, AND AMERICIUM ANALYSIS RESULTS

Sample	^{3}H	^{238}Pu*	$^{239+240}Pu$*	^{241}Am*
699-53-103	0-0.097	<.0005	<.0005	<.0001
699-52-52	4.09-4.83	<.00003	<.0001	<.0002
699-61-55	64.0-70.2	<.0001	<.0002	<.0002
699-55-57	249-253	<.00005	<.0003	<.0005
699-55-50c	351-361	<.0001	.00010	<.0003
699-53-47	477-522	<.0001	.00011	<.0003
West Lake	1056-1098	.0011	.010	.0006
Gable Mountain Pond	361-367	.0008	.013	.017

all units in pCi/l
* = single analyses conducted

Carbon-14 age dating was used to determine the age of the ground waters from the three wells in the uppermost confined aquifers. Results are shown in Table VI. Well 699-53-103 was a control well outside of the study area. The ages of 699-53-103 and 699-52-52 date back to approximately the end of the last glaciation when water temperature was colder. The fact that the water in 699-61-55 near West Lake is modern in age, indicates that the water has seen recent biologic activity, or that this well is contaminated with modern runoff from the Lake or the unconfined aquifer.

TABLE VI

RESULTS OF CARBON-14 DATING TO DETERMINE THE AGE OF GROUND WATERS

Well No.	Age/Date Determination	Sampling Point
699-61-55	Modern (<700 years)	Confined Aquifer Near West Lake
699-53-103	13,400 ± 250 years	Confined Aquifer West of Hanford Reservation
699-52-52	19,900 ± 440 years	Confined Aquifer Southeast of Gable Mountain Pond

The isotopic ratio, $^{18}O/^{16}O$, for oxygen in waters can be used as a means of analyzing the source of that water. The isotopic variations are reported in delta units (δ)defined by the following equation:

$$\delta = \left(\frac{R}{R_{smow}} - 1\right) \times 1000$$

where R is the isotopic ratio of the sample and R_{smow} is the .50 isotopic ratio for standard mean ocean water (smow).

The following results were obtained for the waters analyzed:

Well No.	$\delta^{18}O$ Versus smow	Water Sampled
699-53-103	-18.0	Uppermost Confined Aquifer
699-52-52	-18.0	"
699-61-55	-15.6	"
699-55-57	-16.6	Unconfined Aquifer
699-55-50C	-16.6	"
699-53-47	-16.4	"
West Lake	- 4.2	Surface Water
Gable Mountain Pond	-15.2	Surface Water

The higher value found for West Lake may reflect the natural concentration of ^{18}O that has taken place as a result of the large amount of evaporation that has occurred at this site over geologic time. The value observed at Well 699-61-55 near West Lake appears representative of modern runoff.

INTERPRETATION

A comparison based on the chemical analysis given for the wells in the study area shows that the ground water appears to be divided into two basic types. Waters of the confined aquifer tend to have sodium as the principal cation. The principal anions in these waters are bicarbonate and chloride with bicarbonate predominating. Calcium and magnesium appear to be the main cations and bicarbonate the principal anion of the unconfined aquifer.

The chemistry of the water in Gable Mountain Pond resembles that of the unconfined aquifer. This is natural since Gable Mountain Pond appears to be the principal groundwater recharge source in the West Lake Basin. West Lake is anomalous due to its unusually high alkalinity and salt content. Most of the calcium and magnesium have probably precipitated as calcium and magnesium carbonates. Sodium and potassium as well as chloride and sulfate ions will not readily form precipitates and so the water of West Lake appears to have become steadily more concentrated in these elements.

Table VII compares the main ions found in waters of the uppermost confined aquifer with the waters of the unconfined aquifer, and also gives data for Gable Mountain Pond and West Lake. This table is based on the data given in Table III for the general chemical constituents. Average values given

TABLE VII

MAJOR CHEMICAL CONSTITUENTS OF GROUNDWATER AND SURFACE WATER

	Average Uppermost Confined Aquifer	Confined Aquifer		Unconfined Aquifer			Average Unconfined Aquifer	Gable Mt. Pond	West Lake
		699-52-52	699-61-55	699-55-57	699-55-50C	699-53-47			
Mg (ppm)	7	2	2	26	10	9	12	6	13
Ca (ppm)	15	4	8	94	39	38	48	19	5
Na (ppm)	40	100	60	39	6	7	29	4	7000
K (ppm)	9	14	10	8	5	4	6.8	1	400
OH									1600
CO_3 (mg/l $CaCO_3$)	3	18	13.8	<3.5	<3.5	<3.5	0	<3.5	5850
HCO_3 (mg/l $CaCO_3$)	152	168	116.8	104.8	104	96.6	172	68.8	0
Cl (ppm)	16	20	16	24	5	8	13	4	2000
SO_4 (ppm)	9	2.5	5.1	34	.8	5.5	58	4.5	1400

for the composition of waters in the uppermost confined and unconfined aquifers were derived from numerous analyses throughout southeastern Washington, expecially within the Hanford Reservation.[2]

A trilinear diagram (Figure 8) can be used to compare the chemical character of waters in a basin from various sources as represented by the relationship among the Na + K, Ca + Mg, CO_3 + HCO_3 and Cl + SO_4 ions.[24] In using this diagram, the proportions of cations and anions, in percent of the total equivalents per million, are computed and plotted as a single point in each of the lower triangles. Each point is then projected into the upper field along a line parallel to the upper margin of the field, and the point where the extensions intersect represents the composition of the water with respect to selected combinations of cations and anions. The lack of balance between cations and anions was adjusted for by raising the CO_3 concentration to compensate for the shortage of anions. The graph shows the apparent division in the chemical composition of the ground waters for the confined and unconfined aquifers. The confined aquifer wells 699-52-52 and 699-61-55 plot out in the bottom of the diamond shaped upper field indicating that they are Na • K • CO_3 + HCO_3 waters. The unconfined aquifer wells, 699-55-50C and 699-53-47 plot out towards the middle left of the diamond shaped field indicating that they are Ca • Mg • HCO_3 waters. The water of well 699-55-57 appears to resemble that of the unconfined aquifer. Gable Mountain Pond waters plot in the region of the unconfined aquifer while West Lake waters plot near the confined waters.

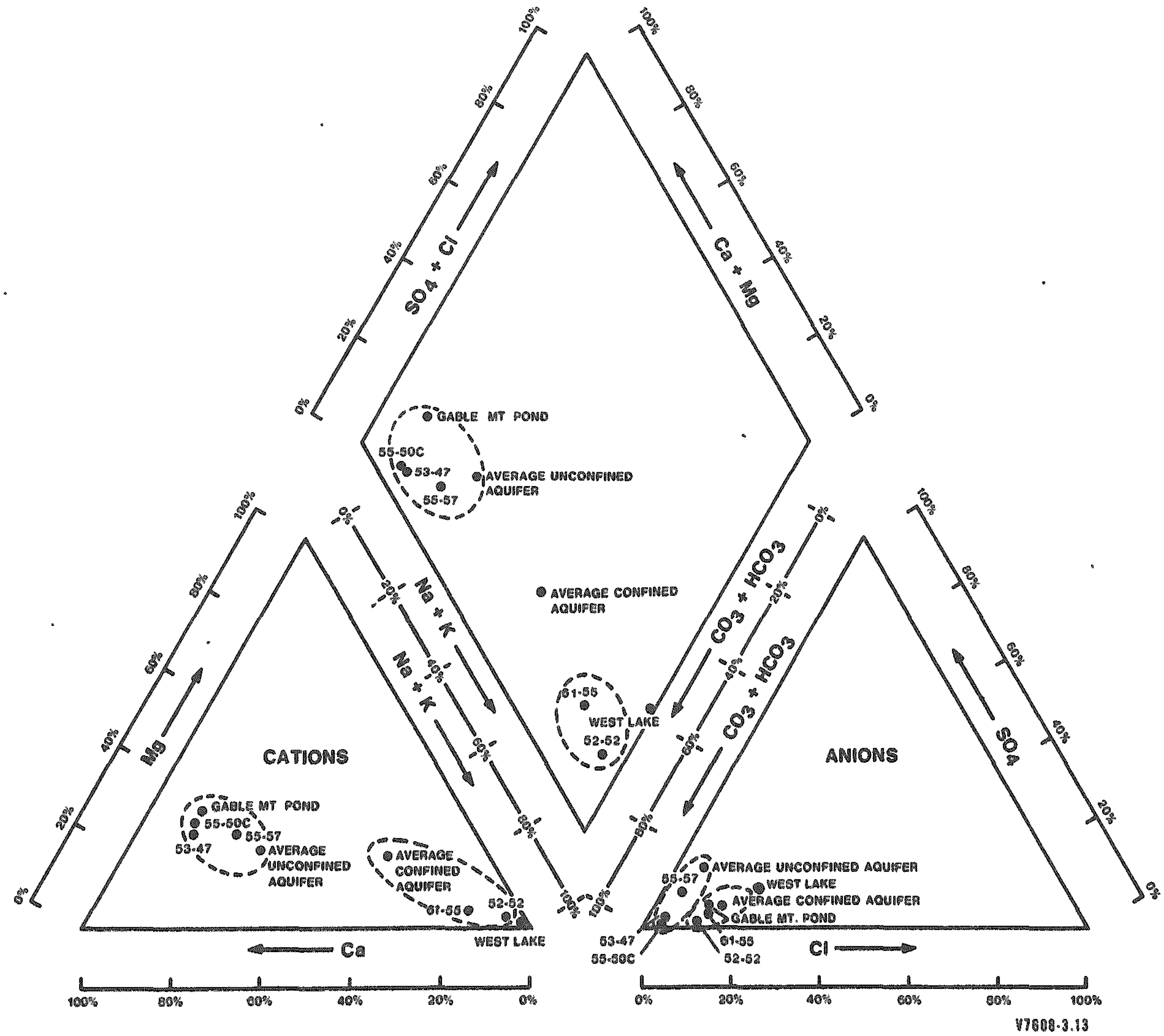

FIGURE 8

TRILINEAR DIAGRAM CHARACTERIZING GROUND WATERS AND SURFACE WATERS OF WEST LAKE BASIN, BASED ON 1976 WATER QUALITY DATA

PRINCIPAL IONS

Silica

The silica concentrations in water withdrawn from the upper confined aquifer are higher than that which would normally be in equilibrium with quartz. The concentrations indicate near equilibrium with a silica phase resembling chalcedony or christobalite. The silica probably comes into solution from feldspar and other silicate minerals.

For the Columbia Plateau as a whole, the ground water from the basalt aquifers is found to have a silica concentration generally greater than 40 ppm, while ground waters of sedimentary materials have a silica concentration of less than 50 ppm.[25] Silica concentrations in the ground water in the West Lake Basin have fairly uniform silica concentrations of 21-24 ppm. This may indicate that the ground water in the upper confined aquifers is deriving its chemistry from the interbeds and overlying sediments.

Sodium

Sodium is the principal cation in the waters of the upper confined aquifers. It is probably derived from the solution of sodic feldspars in the basalt. Wells in the unconfined aquifer contain less sodium and have calcium as the principal cation.

Potassium

Concentrations of potassium are generally lower in the unconfined aquifer than in the upper confined aquifer. The potassium content of the water withdrawn from the confined aquifer is somewhat higher than that which would be expected for equilibrium with a potassium feldspar or potassium mica.

Waters from the sedimentary deposits of the unconfined aquifer characteristically contain more calcium than waters from the confined aquifers. The calcium in solution in the confined aquifers is low despite the abundant calcium feldspar in the basalt. The concentration of calcium indicates that the solution is near equilibrium with calcite. The ground water, specially that of the confined aquifer is high in bicarbonate which may drive calcite out of solution and lower the calcium content of the water.

Magnesium

The magnesium concentrations generally follow the trends of calcium although at lower concentrations. Magnesium content is higher in the unconfined aquifer than in the confined aquifers. Magnesium content of the confined aquifer waters is low even though magnesium silicate minerals are common in the basalts.[25]

The concentrations of calcium, magnesium, and potassium are all affected by their solubilities in the presence of bicarbonate and carbonate.

Chloride

The chloride in the ground water is in concentrations generally present in meteoric waters.

Sulfate

Concentrations of sulfate are generally low. The source of the sulfate may be from the release of sulfur during the breakdown of minerals in the basalt or from sulfur-bearing minerals in the sediments covering the basalts.[26]

POTENTIAL CONTAMINATION SOURCES

Tritium is a good tracer of ground water since it travels as an integral part of the water molecule and is not slowed relative to the ground water by chemical processes such as ion exchange and adsorption. Tritium will not concentrate by evaporation as will other dissolved species. Tritium levels in the ground and surface waters of the West Lake Basin are all higher than the background level given by well 699-53-103. Insufficient data exist to give a complete picture of the ground water flow pattern of the area based on tritium data alone. The fact that the tritium levels in West Lake are almost twice as high as those of Gable Mountain Pond may indicate that Gable Mountain Pond is not the sole source of contaminants to West Lake. Another possible source of contaminants is the BY Crib area in the 200 East Area. Very high tritium counts in wells 699-49-57 and 299-E33-25 (Figure 9), indicate that contamination is spreading northward from this area. There is little tritium data for the area towards West Lake from the BY Cribs so that no definite conclusion can be drawn at this time. A third possible source is from B Reactor along the Hanford Reservation's northern boundary. During the 1960s, a fifteen foot (5 meter) groundwater mound formed beneath B Reactor as a result of waste water disposal. Tritium may have migrated from the disposal site through the Gable Mountain-Gable Butte gap and into the West Lake Basin.

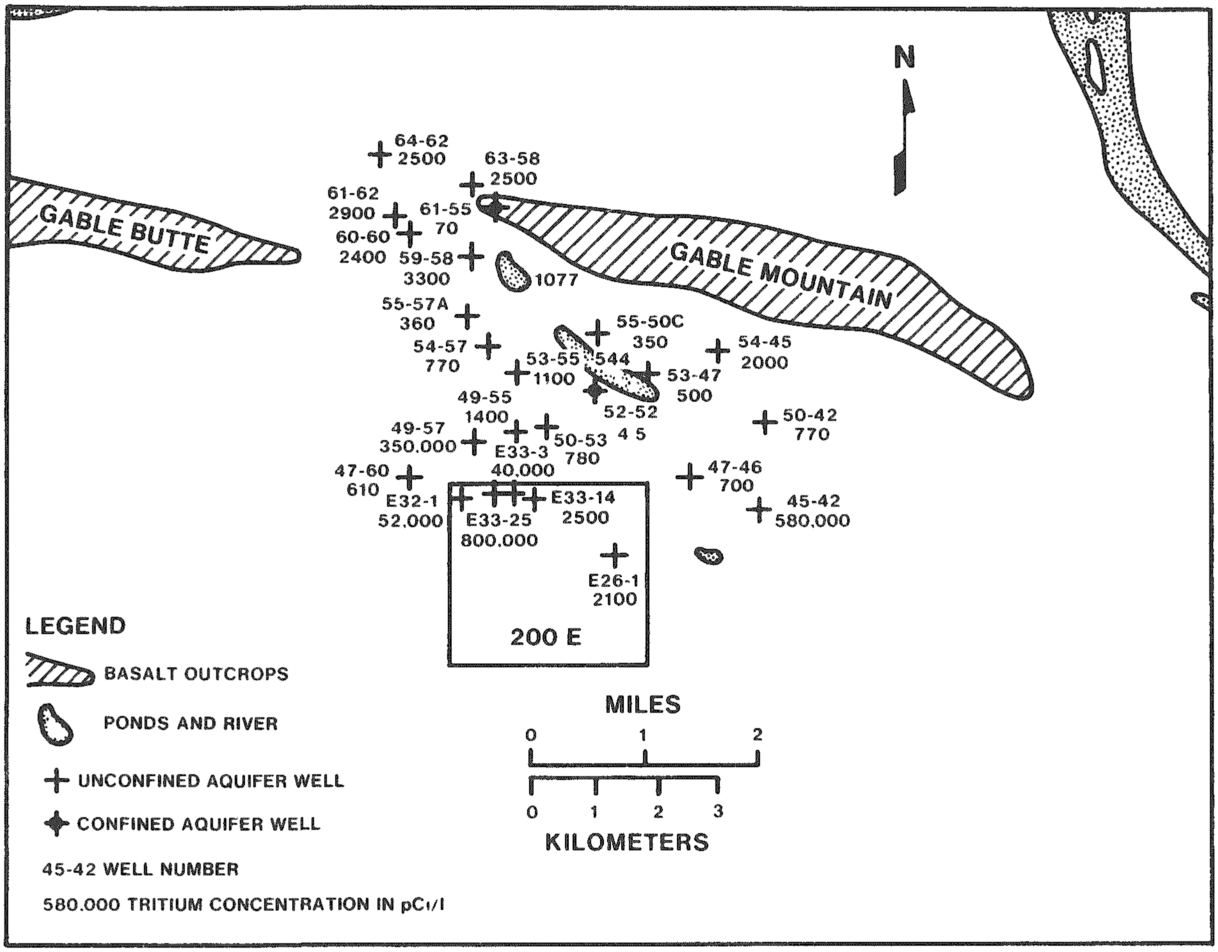

FIGURE 9

TRITIUM DATA - JAN - MAY 1976

PREDICTIVE MODELING

Groundwater flow models were used to examine the potential of introducing contaminants into the uppermost confined aquifers underlying the West Lake Basin. Four separate waste disposal simulations were run using varying discharges to Gable Mountain Pond and B Pond. They included:

- Diversion of projected water discharges shown in Table VIII to Gable Mountain Pond and B Pond,
- Diversion to Gable Mountain Pond and B Pond of conserved water discharges listed in Table VIII,
- Discharging all projected effluents to Gable Mountain Pond, and
- Discharging all projected effluents to B Pond.

The projected and conserved effluent discharges to Gable Mountain Pond and B Pond were obtained from the Engineering Department of the Atlantic Richfield Hanford Company. The computer simulation using conserved water discharges was needed because it has been previously concluded that increased discharges to Gable Mountain Pond may drive contaminants into the uppermost confined aquifers. Only the hydrologic consequences of each alternative is discussed. It was assumed that each pond was capable of retaining the quantity of water discharged to it.

TABLE VIII

ESTIMATED AVERAGE AND CONSERVED DISCHARGES TO GABLE MOUNTAIN AND B POND

Discharge	Fiscal Year 1977	1978	1979	1980	1981-85
Gable Mountain Pond					
Projected average (gpm)	3200	4700	6800	6600	5000
Conserved average (gpm)	2400	3900	4300	3500	3200
B Pond					
Projected average (gpm)	2100	2100	2100	2100	2100
Conserved average (gpm)	1900	1900	1900	1900	1900

VARIABLE THICKNESS TRANSIENT (VTT) MODEL

The Variable Thickness Transient (VTT) groundwater flow model was used to evaluate the hydrologic impact of each of the above alternatives. The model's theory is documented elsewhere.[27] In general terms, it is a two-dimensional, Boussinesq type model with an additional capability of varying the values of the unconfined aquifer thickness. Model input includes a distribution of potential (water table) throughout the Hanford Reservation's unconfined aquifer, estimates of the water fluxes at the boundary of the Reservation, estimates of the recharge and discharge locations (such as disposal ponds) and flow rates within the Reservation.

Specific steps followed in the VTT modeling included:

- development of an initial December 1976 water surface,
- simulation of an eight year (1977-1984) projection using the projected Gable Mountain Pond and B Pond discharges in Table VIII,
- a simulation of a projection for the same 1977-1984 period using the conserved discharge values to Gable Mountain Pond and B Pond listed in Table VIII,
- a 1984 prediction obtained by assuming all projected 200 East Area discharges were diverted to Gable Mountain Pond, and
- a 1984 prediction obtained by assuming all projected 200 East Area discharges were diverted to B Pond.

The VTT model assumes the unconfined aquifer is an isolated flow system without direct hydraulic interconnection with any underlying confined aquifers. Since geohydrologic evidence suggests that such an interconnection may exist, any water level rises predicted by the model should be interpreted as a water potential increase. If the predicted potential exceeds West Lake's present 403 ft (123 m) mean sea level (MSL) water elevation, the resulting hydraulic force could drive unconfined aquifer water into the uppermost confined aquifers.

RESULTS

The December 1976 unconfined aquifer water potential map is contoured in Figure 10. This map represents the base case disposal conditions against which the above four alternatives are compared. The groundwater levels beneath West Lake, Gable Mountain Pond and B Pond are approximately 403, 405 and 409 ft above MSL respectively.

Figure 11 shows the December 1984 predicted unconfined aquifer water levels after releasing to both Gable Mountain Pond and B Pond their projected discharges through 1984. Such discharges would require enlargement of Gable Mountain Pond. The water table will rise eight feet (2.4 m) (405 to 413 ft MSL) beneath Gable Mountain Pond. Beneath B Pond the water level will drop slightly to between 407 and 408 ft MSL. The water potential at West Lake will rise 7 to 8 ft (2.1 to 2.4 m).

Release of the conserved water discharges listed in Table VIII to Gable Mountain Pond and B Pond will result in the December 1984 water levels shown in Figure 12. The entire disposal region will experience a significant water level drop: 3 ft (0.9 m) beneath Gable Mountain Pond, 6 ft (1.8 m) beneath B Pond, and 2 ft (0.6 m) beneath West Lake.

The December 1984 predicted water level assuming all 200 East Area discharges are routed solely to Gable Mountain Pond is shown in Figure 13. This alternative would require enlarging Gable Mountain Pond. The water potential beneath Gable Mountain Pond and West Lake will rise to 413 ft and 411 ft MSL respectively. This rise is similar to the increases resulting from the first alternative considered. Discontinuing B Pond discharges will lower the water table by 3 ft (0.9 m) beneath B Pond.

Figure 14 shows the December 1984 predicted unconfined aquifer water table map resulting from all 200 East Area effluent discharges being routed to B Pond. This would of course require enlarging B Pond. The volume of the B Pond mound will significantly increase from its 1976 size though its height will increase by only one foot (0.3 m) to 410 ft MSL. This mound's spread will slightly raise the water level beneath both Gable Mountain Pond and West Lake although these sites are not directly receiving any effluent discharge.

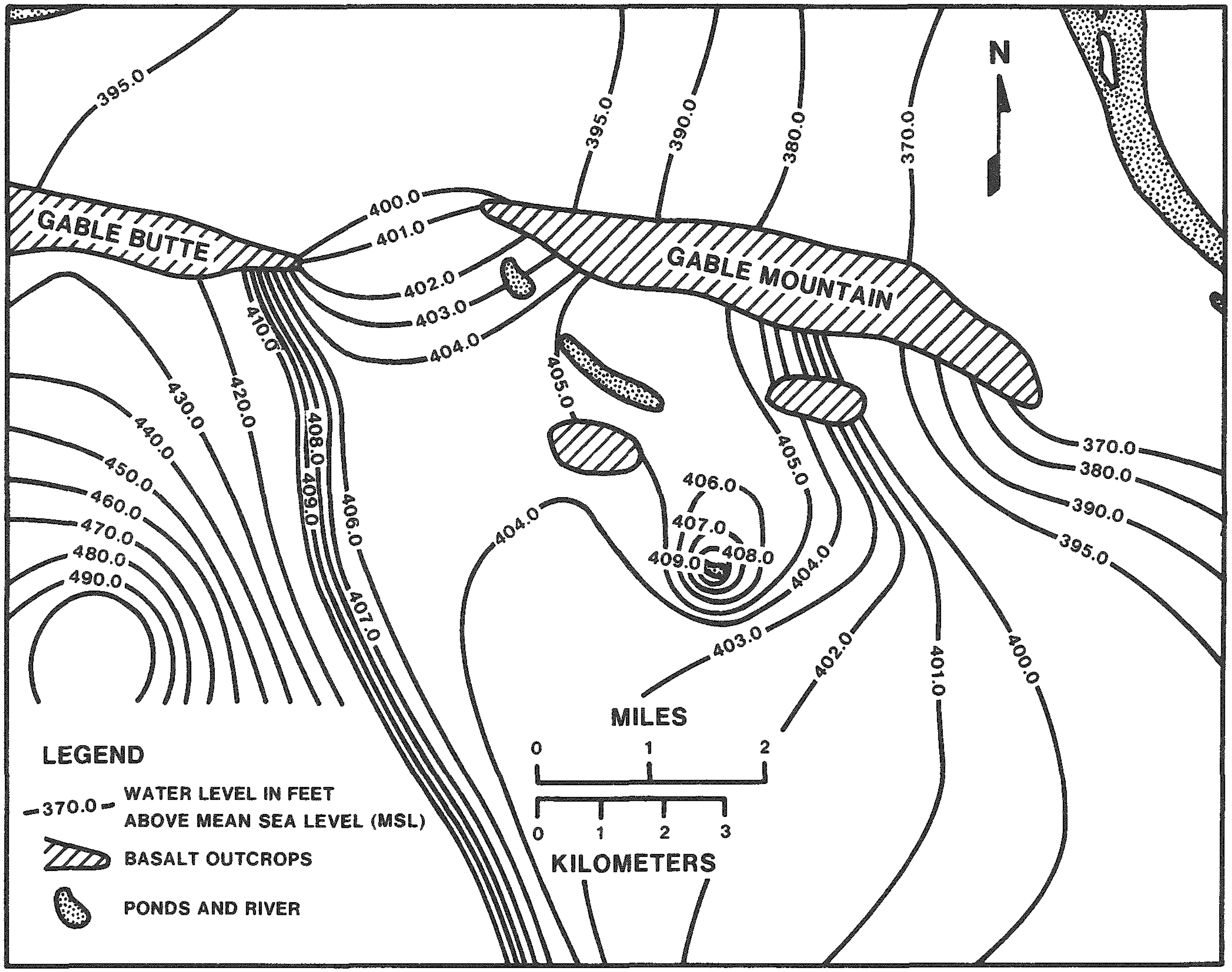

FIGURE 10

PRESENT (1976) WATER LEVEL CONTOUR MAP WITH DISCHARGES TO GABLE MOUNTAIN POND AND B POND

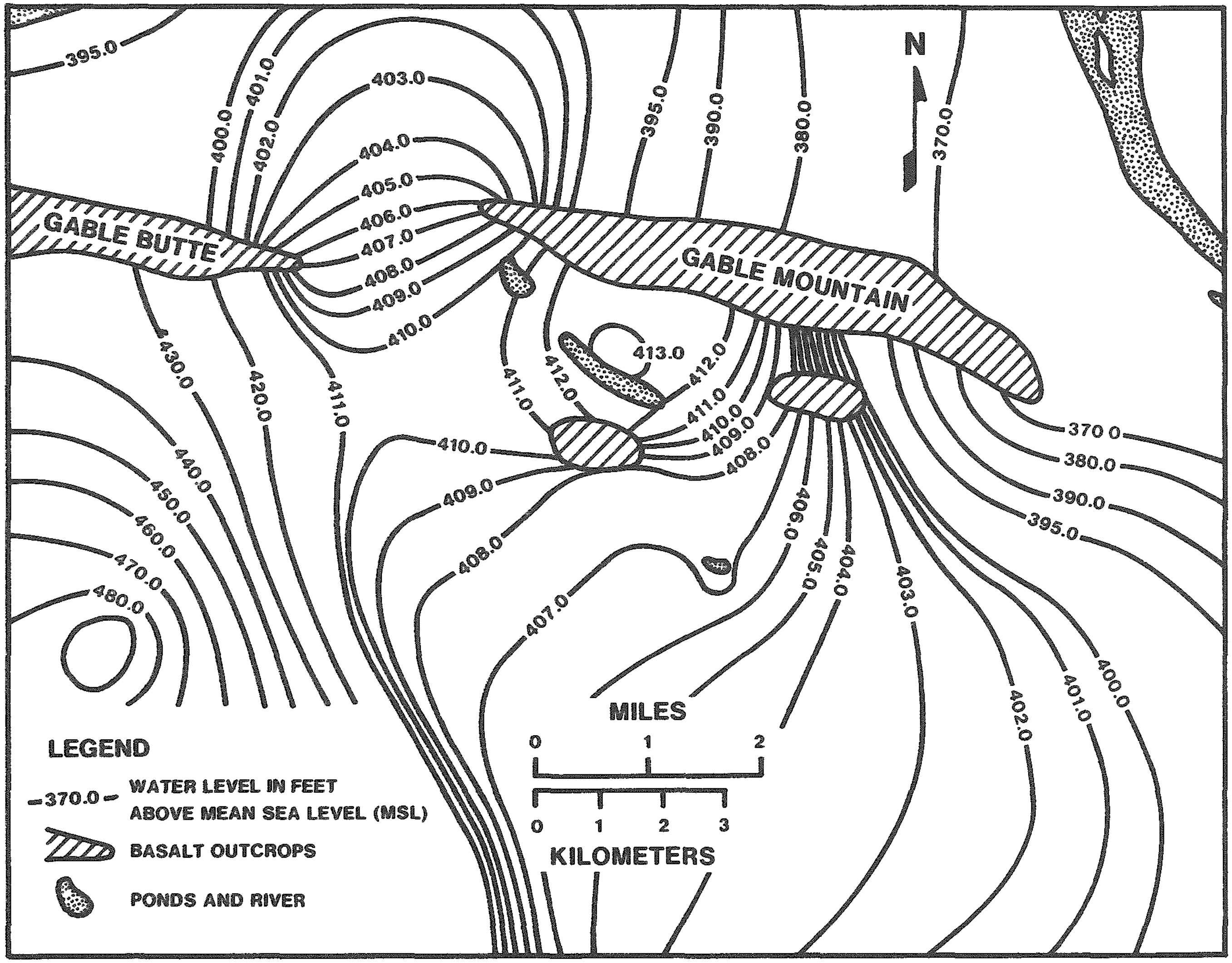

FIGURE 11

1984 PREDICTED WATER LEVEL CONTOUR MAP WITH PROJECTED DISCHARGES TO GABLE MOUNTAIN POND AND B POND

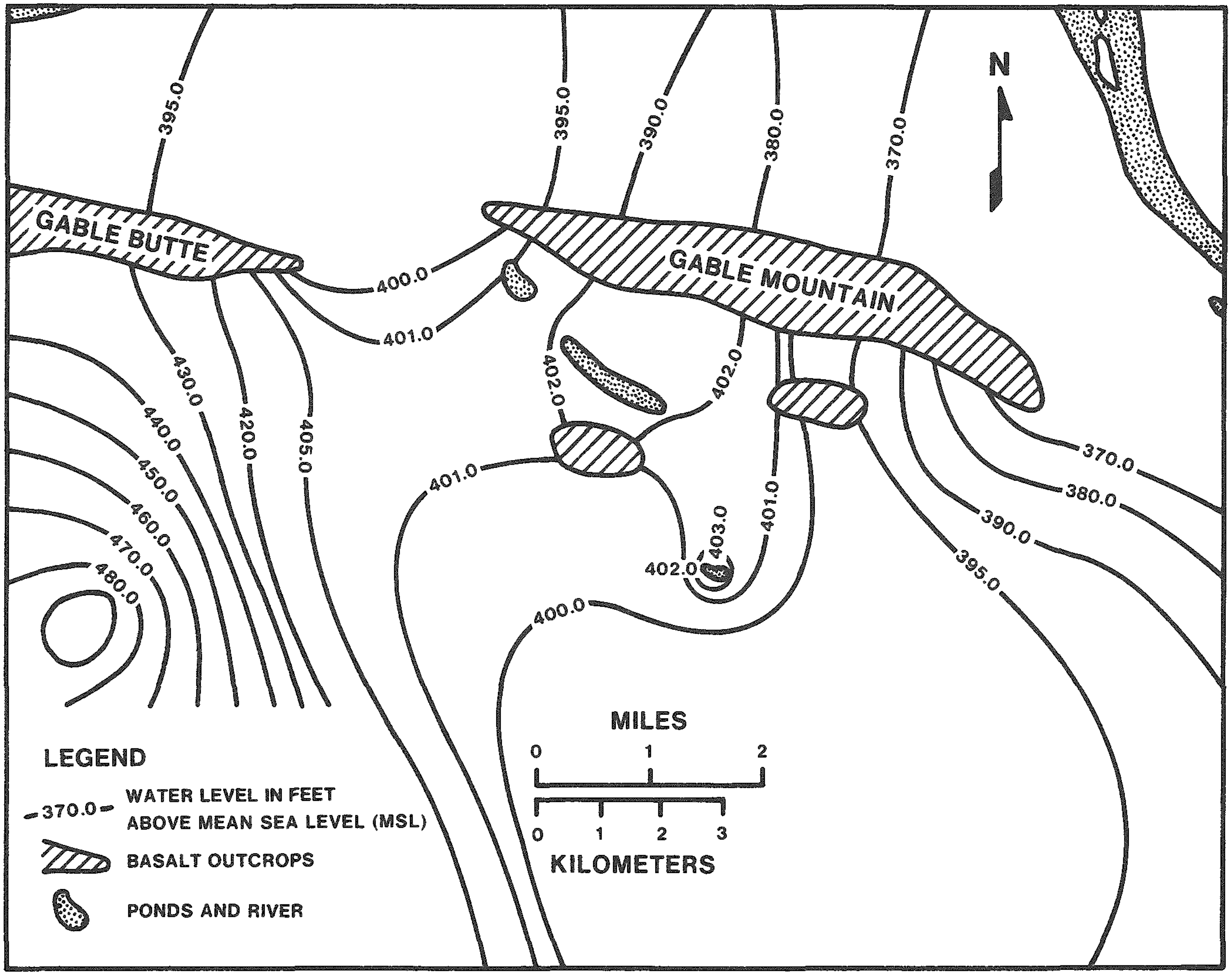

FIGURE 12

1984 PREDICTED WATER LEVEL CONTOUR MAP WITH
CONSERVATIVE DISCHARGES TO GABLE MOUNTAIN POND AND B POND

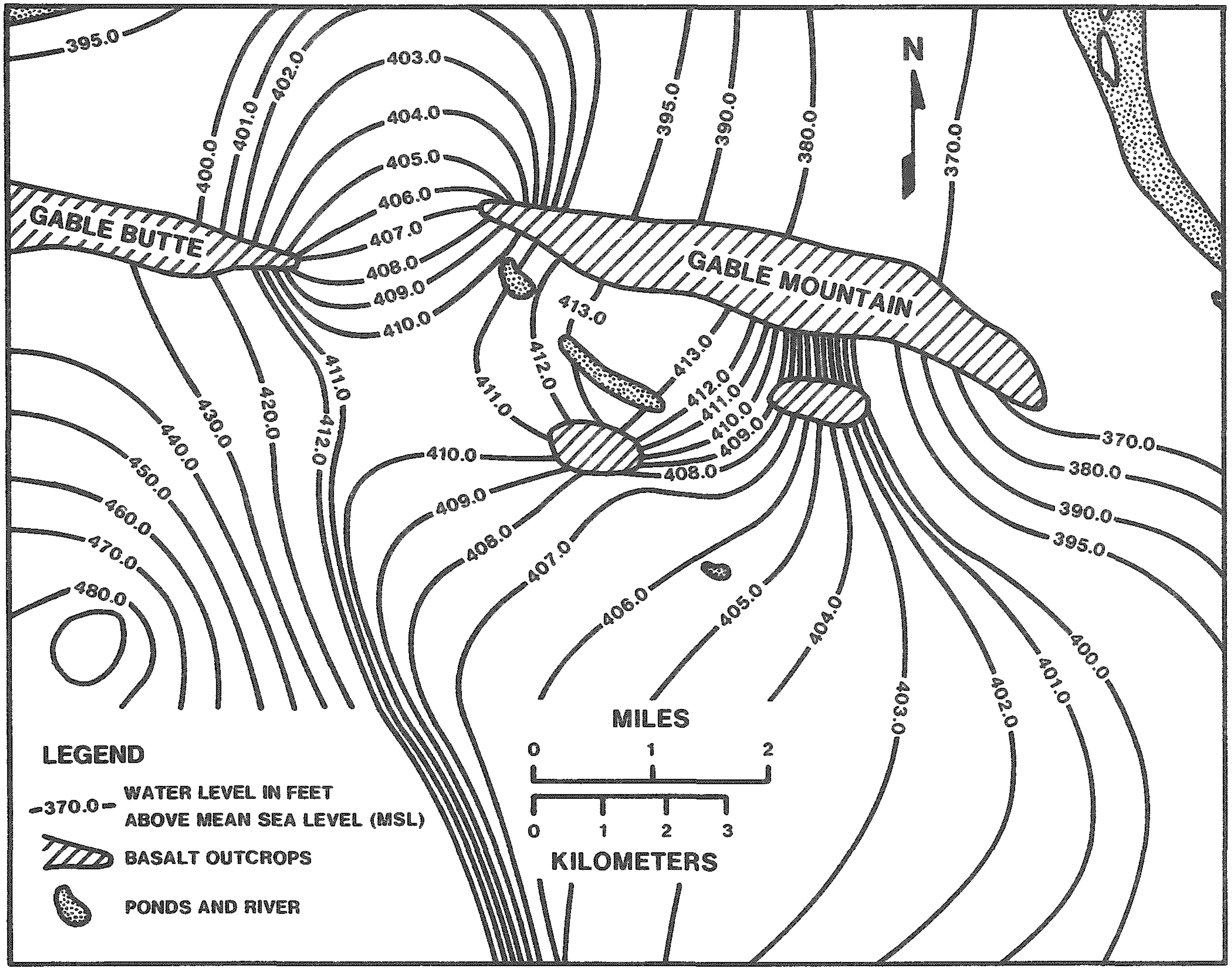

FIGURE 13

1984 PREDICTED WATER LEVEL CONTOUR MAP WITH ALL DISCHARGES TO GABLE MOUNTAIN POND

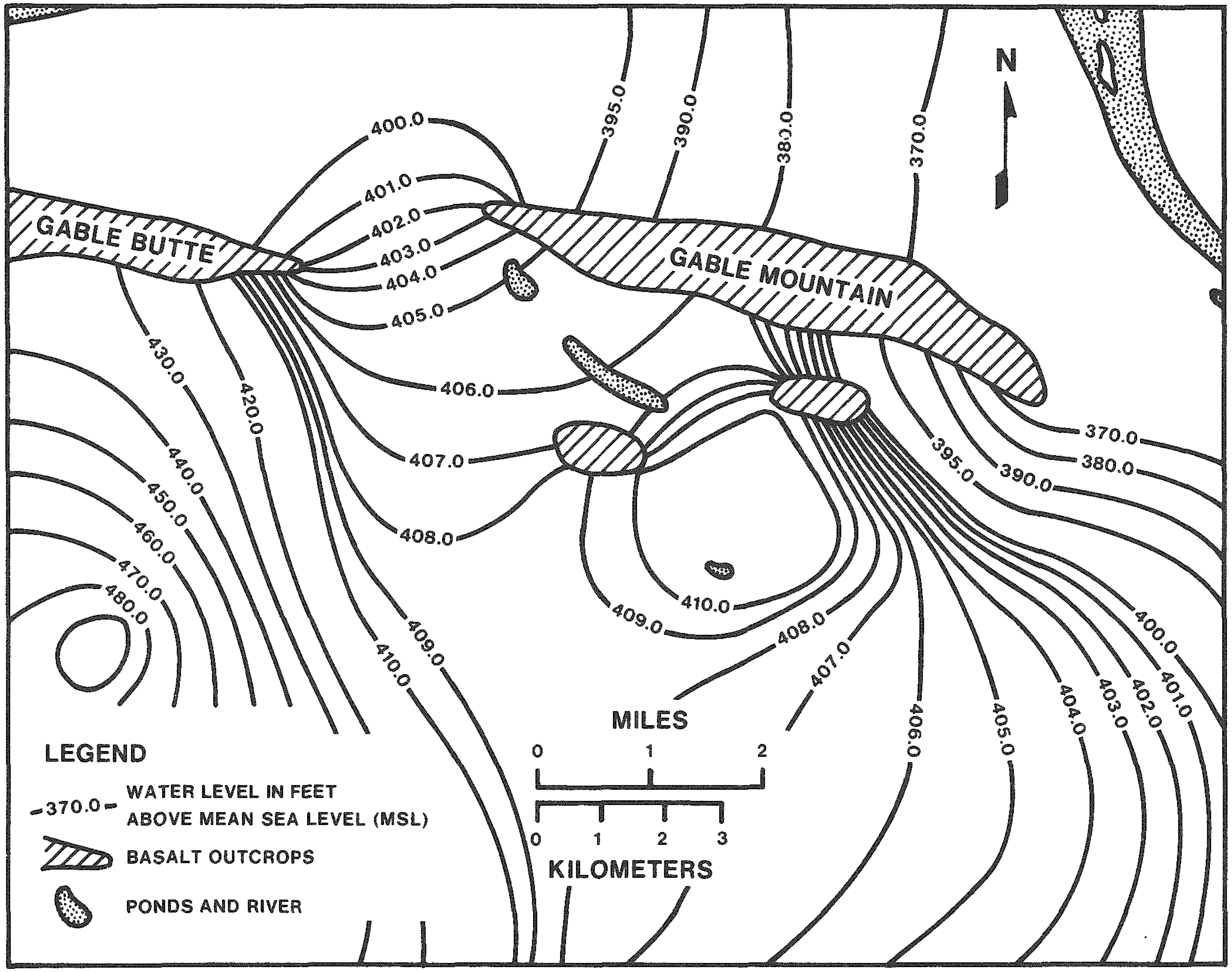

FIGURE 14

1984 PREDICTED WATER LEVEL CONTOUR MAP
WITH ALL DISCHARGES TO B POND

CONCLUSIONS

West Lake is a point of apparent hydraulic interconnection between the confined and unconfined aquifers. The water potential in the uppermost confined aquifers was probably greater than in the overlying unconfined aquifer before Gable Mountain Pond was built. The two flow systems are now in apparent equilibrium. If the potential in the unconfined aquifer exceeds that of the confined, contaminated ground water could be introduced into the uppermost confined aquifers. Such a situation is probably responsible for the localized radionuclide contamination found in the uppermost confined aquifers in this region.

A comparison of the chemical analyses of the surface and ground waters sampled in West Lake Basin shows two unique chemical divisions: those waters associated with the confined and unconfined systems. Since Gable Mountain Pond recharges the unconfined aquifer, its chemistry closely resembles this aquifer. West Lake is slightly anomalous due to its high alkalinity and salt concentrations. However, the ratios of its major chemical constituents resembles those found in confined aquifer waters.

Radiochemical analyses show that some higher radionuclide concentrations are found in the uppermost confined aquifers near West Lake as compared to other confined aquifer sampling points. However, these concentrations are less than those found in the unconfined aquifer or in either West Lake or Gable Mountain Pond. Coupled with the age dating results, the radiochemical data suggest that some interchange of water has occurred between the confined and unconfined aquifers near West Lake.

The results of the predictive modeling suggests that the water potential near West Lake will increase approximately 7 ft (2.1 m) if the projected effluent discharges are released to Gable Mountain Pond and B Pond. The same rise results from discharging all 200 East Area water to Gable Mountain Pond. West Lake's water potential will apparently rise less than 2 ft (0.6 m) if B Pond receives all operation effluents. If water conservation efforts are implemented for 200 East Area facilities, the West Lake Basin will experience a decrease in the unconfined water potential.

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