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AUTHOR

William H. Bierschenk

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THE EFFECT OF GROUND-WATER MOUNDS ON THE PUREX OPERATIONS

By

William H. Bierschenk

Geochemical And Geophysical Research
Chemical Effluents Technology Operation
CHEMICAL RESEARCH AND DEVELOPMENT OPERATION

HANFORD LABORATORIES OPERATION

April 18, 1957

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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PRELIMINARY REPORT

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THE EFFECT OF GROUND-WATER MOUNDS ON THE PUREX OPERATION

By

William H. Bierschenk

INTRODUCTION

Waste disposal plans for the Purex operation provide for the eventual discharge of up to 20 million gallons per day (mgd) of cooling water to disposal swamps, and up to 4 mgd of low-level radioactive wastes to cribs in and adjacent to 200-East Area.

At Hanford, the regional water table has been greatly influenced by the large volumes of cooling waters discharged to ground; the result being the formation of massive ground-water mounds which have risen locally as much as 80 feet above the natural water table and which have led to rising water levels as much as 15 miles from the disposal sites. In addition, radioactive wastes have been disposed to ground in ever increasing amounts, resulting in contaminated ground and ground water beneath both 200-East and 200-West Areas.

The size, shape, and orientation of ground-water mounds depend upon the amount and rate of water recharged to these aquifers, and upon the extent and hydraulic characteristics of the aquifers. The mounds increase and locally reverse the natural hydraulic gradient, and thus accelerate the movement of much of the ground water. The opportunity for decay of radioactive contaminants prior to reaching the Columbia River or other sensitive points may therefore be reduced. Consequently, future large-scale disposal of cooling water should be regulated to preserve the hydrologic conditions which were used as a basis for controlling previous disposal as well as to permit the optimum utilization of existing and proposed disposal sites. The proper location of disposal swamps with respect to radioactive waste disposal sites could produce hydrological conditions such that the movement of pools of contamination may be temporarily retarded or restrained.

OBJECTIVES

The objectives of this report are (1) to review the changes in the size and shape of the ground-water mounds consequent upon disposal of cooling water from both the former B Plant operation and the present Purex operation, (2) to summarize the results of pertinent ground-water and waste monitoring studies and recommendations based thereon, and (3) to forecast future hydrologic conditions attendant upon disposal of Purex cooling water.

SUMMARY AND CONCLUSIONS

Channels of rapidly moving ground water have been identified flowing eastward along the northern and southern flanks of Gable Mountain, and flowing southeastward from Chemical Separations Areas toward 300 Area. Contaminated ground water from beneath 200-East disposal cribs routed to these channels would be rapidly transported to the Columbia River. This undesirable movement of contamination could be largely controlled hydrologically by the formation of three ground-water mounds. Proper distribution of Purex cooling water to three swamps, located respectively north, east, and southeast of 200-East Area, could be expected to raise underlying water levels to such an extent that hydraulic gradients would be locally reversed, preventing contaminated ground water from reaching the highly permeable channels.

DISCUSSION

Previous Ground-Water Mound

Figure 1 shows monthly water levels in well 699-45-42 which best illustrate the fluctuations of the 200-East Area ground-water mound. In all likelihood the levels in this well do not represent the water levels at the peak of the mound, but they do provide adequate control for contouring the maximum known elevation of the water table.

From the beginning of operations in January 1944 until shutdown in March 1952, B Plant effluent totaled some 6.5 billion gallons of cooling water. In response to this discharge to ground, the water table beneath the B-swamp east of the area rose about 15 feet and stabilized at an altitude of between 405 and 406 feet above mean sea level. The size, shape, and orientation of the ground-water mound as of March 1951 are shown in Figure 2 (1). As shown, the north-south elongation of the mound reflects directional differences in permeability in this region. Thus, it is indicated that ground water moving in a general northwestward or southeastward direction flows at higher velocities than that in other directions. Velocities estimated by dilution-velocity tests and the movement of gross beta-emitters and Cs^{137} indicated magnitudes of 20 to 50 feet/day (2).

After B Plant shutdown, only about 0.1 mgd of water went to the disposal swamp. As a result, by January 1956 the ground-water mound had subsided about 9 feet to an elevation of about 397 feet. This trend is shown on the hydrograph in Figure 1; the shape of the retracted mound as of October 1955 is shown in Figure 3.

Present Ground-Water Mound

Throughout 1956 the Purex operation disposed of a total of approximately 2.3 billion gallons of effluent: an average of about 5.2 mgd to the B-swamp and an average of about 1.1 mgd to disposal cribs in and adjacent to the 200-East Area. Figure 1 shows the effect the rapid rise of the 200-East mound had on water levels in well 699-45-42. Levels as of March 1957 stand at an altitude some 5 or 6 feet higher than those reached during B Plant operation, and some 20 feet higher than the January 1944 water table. Figure 4 shows the size, shape, and orientation of the mound as of October 1956.

It is estimated that if present disposal rates are maintained, the ground-water mound will approach stabilization at an altitude of 411 to 412 feet. If near-constant discharge is maintained, the rise in water levels will diminish with passage of time as the areas in which measureable rises exist become broader and broader and conditions approach closer and closer to equilibrium. Any increase in discharge rates, however, will upset whatever partial equilibrium may have been reached and will cause an accelerated rise of water levels until equilibrium is approached at a higher level.

Summary of Pertinent Ground-Water Studies

Channels of rapidly moving ground water have been recognized flowing eastward along the northern and southern sides of Gable Mountain (3). Portions of the southern channel are apparently bounded on the south by a buried basalt ridge that extends along the northern boundary of 200-East Area roughly parallel to Gable Mountain and rising in part above the water table.

It was recognized that disposal of the very large volumes of cooling water from Purex Plant to the existing B-swamp would result in an enlarged ground-water mound that would develop a strong northwestward gradient tending to route the contaminated ground water underlying 200-East Area around or over the buried basalt ridge into the channels of rapid ground-water movement near the flanks of Gable Mountain. Contamination would thence be rapidly transported eastward to the Columbia River. Consequently, it was recommended that Purex cooling water be discharged to a new swamp to be formed in a natural depression south of Gable Mountain. A ground-water mound formed here would deny the contamination access to the channels of high ground-water velocities.

The high permeabilities indicated by the elongation of the 200-East Area ground-water mound (Figures 2 and 3) were confirmed in the spring of 1956 when very rapid movement of contaminated ground water from beneath 200-East Area waste disposal cribs was observed in the region southeast of the Area. Trace concentrations of radioactive wastes appeared to move with velocities in the order of hundreds of feet per day, while the bulk of the contaminated water moves in the order of 30 to 40 feet/day. Such movement was apparently initiated by the subsidence of the B-swamp mound which had previously blocked the flow of contamination to the southeast.

In July-August 1956, results of a large-scale fluorescein tracer test in the area southeast of 200-East Area showed that detectable amounts of fluorescein from observation wells 8,800 feet SSW and 8,500 feet SE of the spiked well had traveled at average linear velocities of 350 and 770 feet/day, respectively.

Thus, the discovery of rapid ground-water movement to the southeast of 200-East Area prompted a revaluation of the original recommendation for disposal of all cooling water south of Gable Mountain. A tentative analysis of the hydrologic characteristics of the Gable Mountain site led to an estimate (in September 1956) that a ground-water mound in this location would reach an elevation of 415 to 420 feet within 1 year, based on an assumed flow rate of 12 mgd (4). A more detailed analysis of the hydraulic characteristics of the underlying aquifer, based on data collected during a 4-day aquifer test in October (5), required a downward revision of this preliminary estimate. At an assumed flow rate of 20 mgd, the water level near the point of recharge will rise only about 12 feet in 1 year to an elevation of about 410 feet above sea level. A mound reaching an elevation of 410 feet would, however, still establish a considerable southward or southeastward gradient routing ground water at least locally over the buried basalt ridge and under the 200-East Area. Under these conditions, any contamination in the ground water beneath 200-East Area may be expected to move southward into areas of high ground-water velocities and thence could be expected to travel rapidly southeastward toward the river.

In order to restrain or retard this southeastward movement of ground-water contamination from the 200-East Area, it was recommended (4) that part of the Purex cooling water be disposed to a natural depression southeast of 200-East Area (the SE-swamp). A ground-water mound formed beneath this site would locally reverse the prevailing southeastward gradient and act as a hydrologic dam tending to immobilize the ground water beneath 200-East Area.*

Future Ground-Water Mounds

It is recognized that the use of cooling towers and a recirculating water system may eventually supplant ground disposal (6) because, in general, a sound waste disposal system for a nuclear chemical processing plant should avoid the formation of large ground-water mounds and the attendant acceleration of ground-water movement. However, it will not be practical to discontinue ground disposal of all cooling water immediately because the regional water table is now considerably higher than the natural water table and any rapid subsidence of existing mounds would result in rapid movement of contamination toward the river under the influence of the exaggerated hydraulic gradients.

Whereas it would be desirable to control the swamp-discharged volume by recirculating part of the Purex cooling water through cooling towers, it cannot be recommended that cooling towers be provided to replace all existing or planned swamps (6). Assuming, then, that Purex operation need dispose of a maximum of 20 mgd of cooling water, several hypothetical situations and their effects may be considered to provide for disposal.

*Research conducted by D. J. Brown and reported to the author by private communication indicates that under some circumstances high density wastes (those with large total salt content) may actually be sinking to the bottom of the particular aquifer and moving against the prevailing ground-water gradient as a result of a density gradient. This effect should be a recognized possibility, but it will occur only in special cases for which the proposed mound might not be totally effective in restraining waste movement.

(1) If 20 mgd is discharged to the Gable Mountain swamp north of 200-East Area, after 1 year the maximum expected rise of water level will be about 12 feet and the peak of the ground-water mound will be at an elevation of about 410 feet above sea level. The water level beneath the B-swamp will fall rapidly inasmuch as recharge to the ground here will have ceased. Figure 5 shows the shape and orientation the ground-water contours may assume under such conditions, and the probable direction of ground-water flow for which concern is expressed.

(2) If 14 mgd is discharged to the Gable Mountain swamp and 6 mgd is discharged to the existing B-swamp east of 200-East Area, after 1 year the Gable Mountain mound will rise an estimated maximum of about 8 feet to an elevation of around 405 feet and the B-mound peak will be at an elevation of about 412 feet. Figure 6 shows the effects of such disposal.

(3) If 14 mgd is discharged to the Gable Mountain swamp, 2 mgd to the B-swamp, and 4 mgd to the SE-swamp to be located southeast of 200-East Area, after 1 year the peaks of the underlying mounds may possibly each reach an elevation of about 405 feet. These conditions are shown in Figure 7, and as such may be assumed to be capable of preventing or retarding 200-East contamination from reaching the highly permeable Gable Mountain channels and the highly permeable channel to the southeast.

The success of this disposal plan for immobilizing ground water beneath 200-East Area will depend to a large degree upon proper manipulation of the rates of discharge of cooling water to the three swamps. As discussed in (3) above, an initial distribution of the eventual 20 mgd of Purex cooling water may provide for the diversion of 2 mgd to the B-swamp, 14 mgd to the Gable Mountain swamp, and the remaining 4 mgd to the SE-swamp. Adequate metering of the three streams would assist in hydrological evaluation of the results of such disposal and permit rate adjustments in order to properly control the ground-water mounds.

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(5) Bierschenk, W. H., Hydraulic Characteristics of Hanford Aquifers, HW-48916, March 3, 1957.

(6) Letter, Some Aspects of Cooling Towers vs. Swamp Disposal of Waters, D. W. Pearce to H. P. Shaw, November 6, 1956.

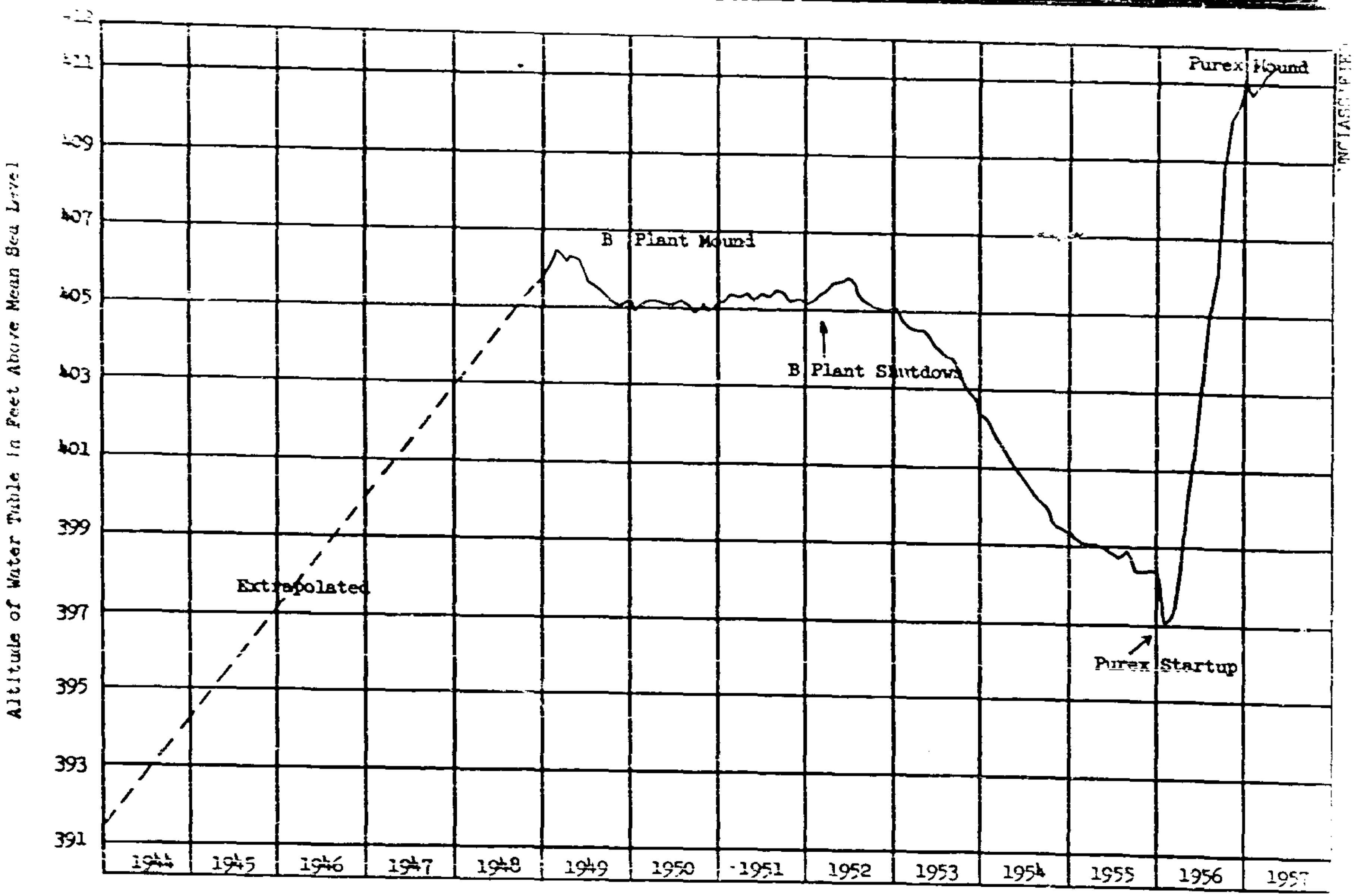

FIGURE 1

Hydrograph showing fluctuations of water level in well 699-45-42.

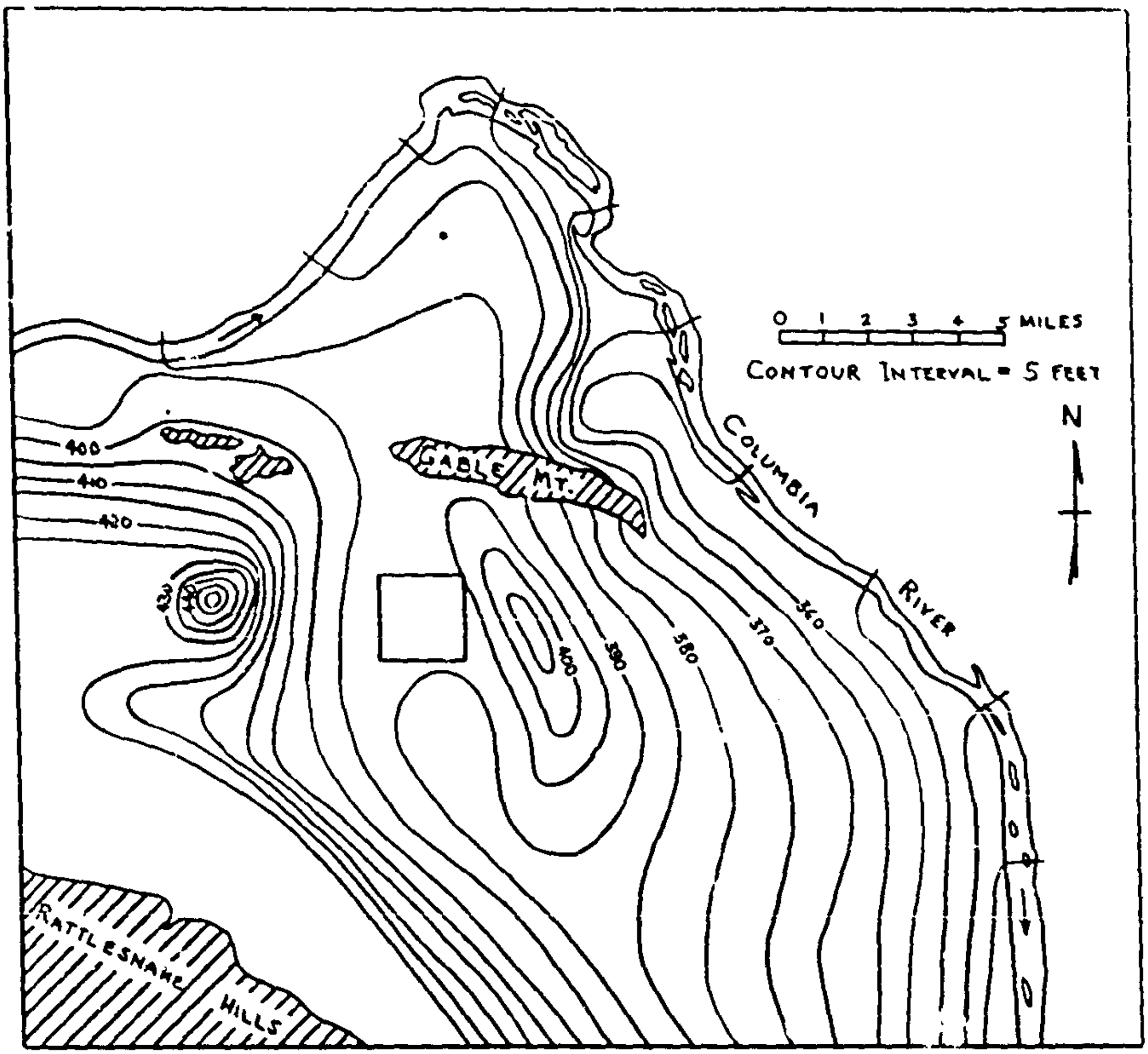

FIGURE 2

Map of the Hanford Works area showing generalized contours on the water table, in feet above mean sea level, as of March 1951.

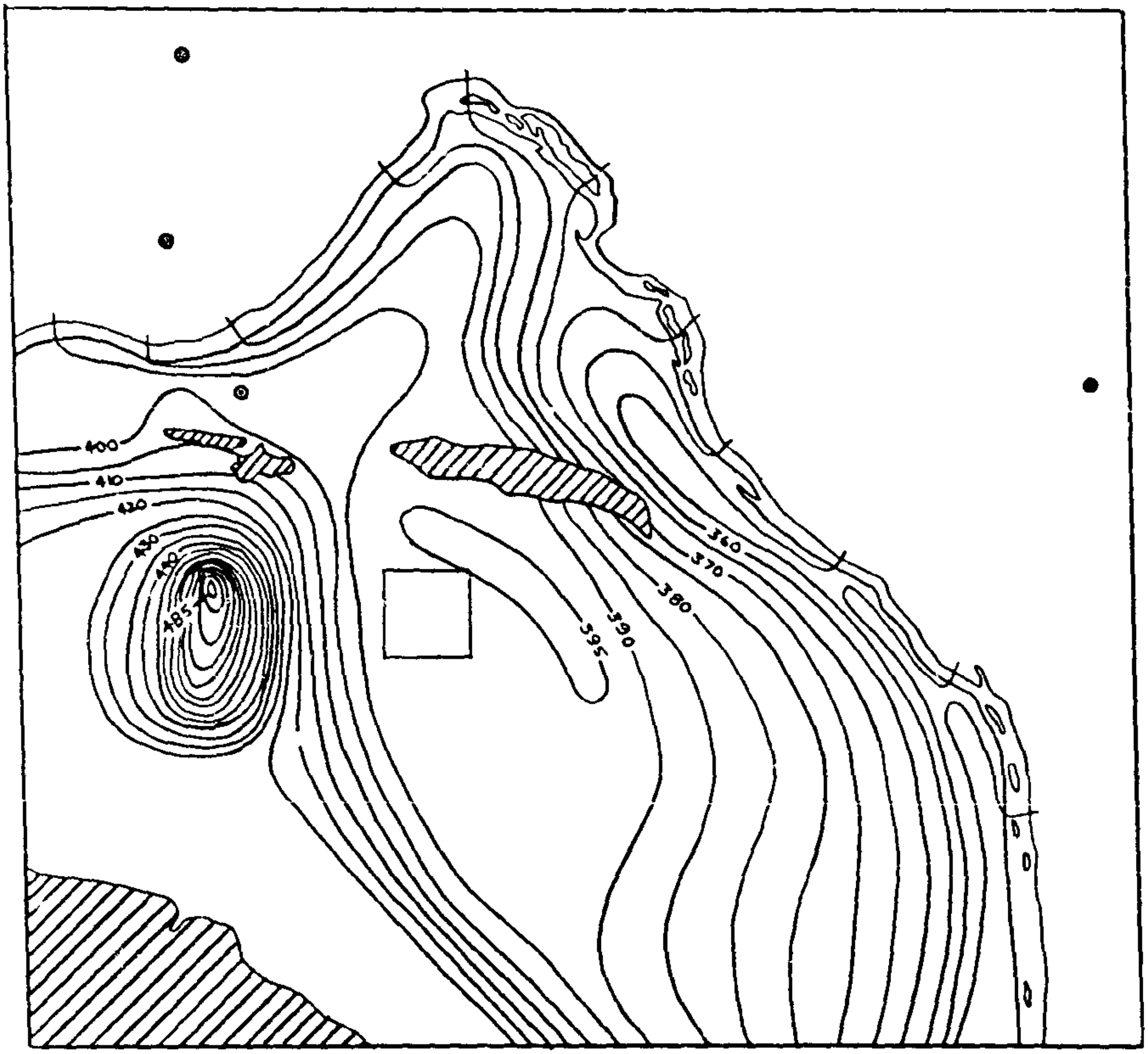

FIGURE 3

Map showing generalized contours on the water table as of October 1955

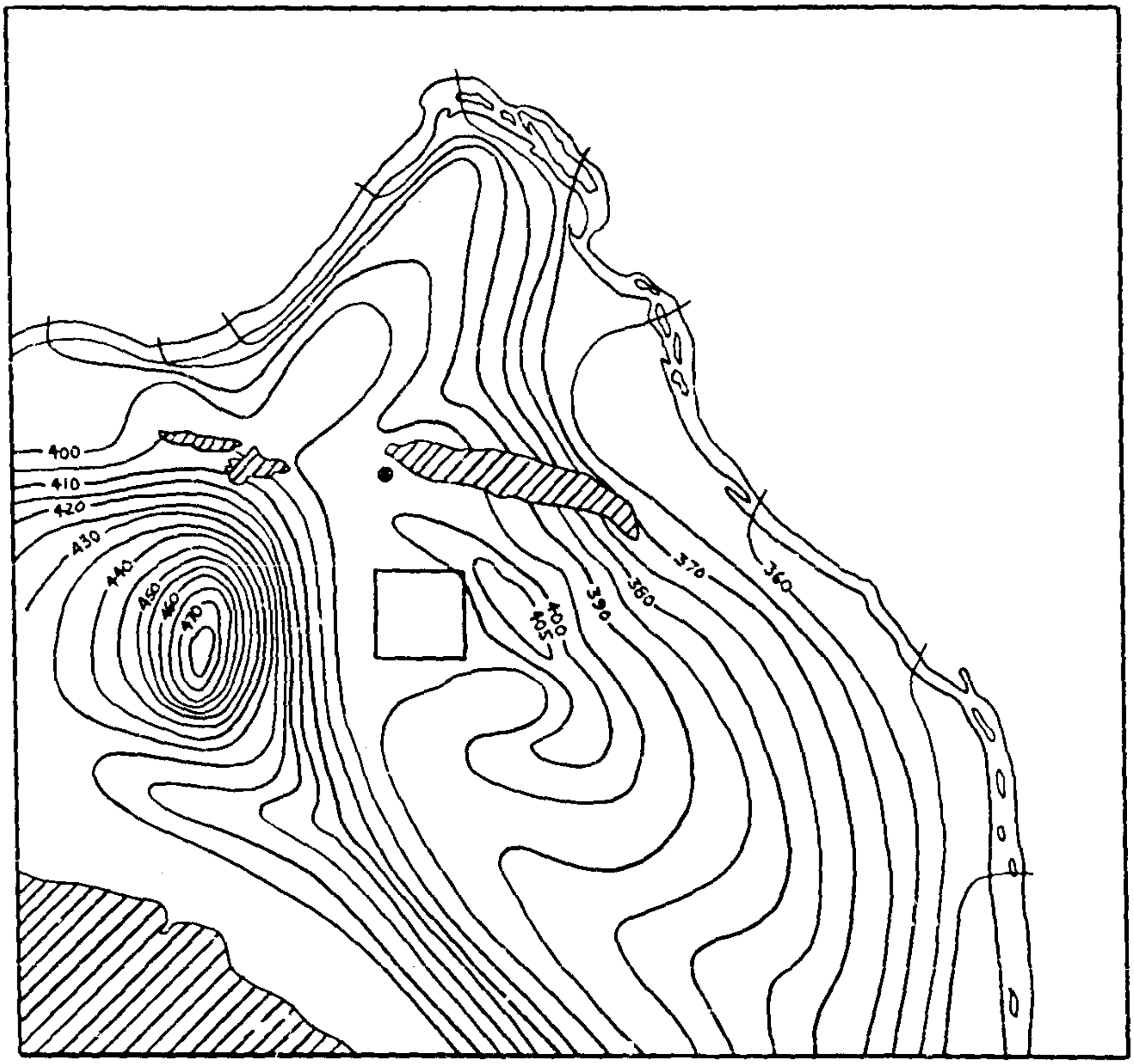

FIGURE 4

Map showing generalized contours on the water table as of October 1956

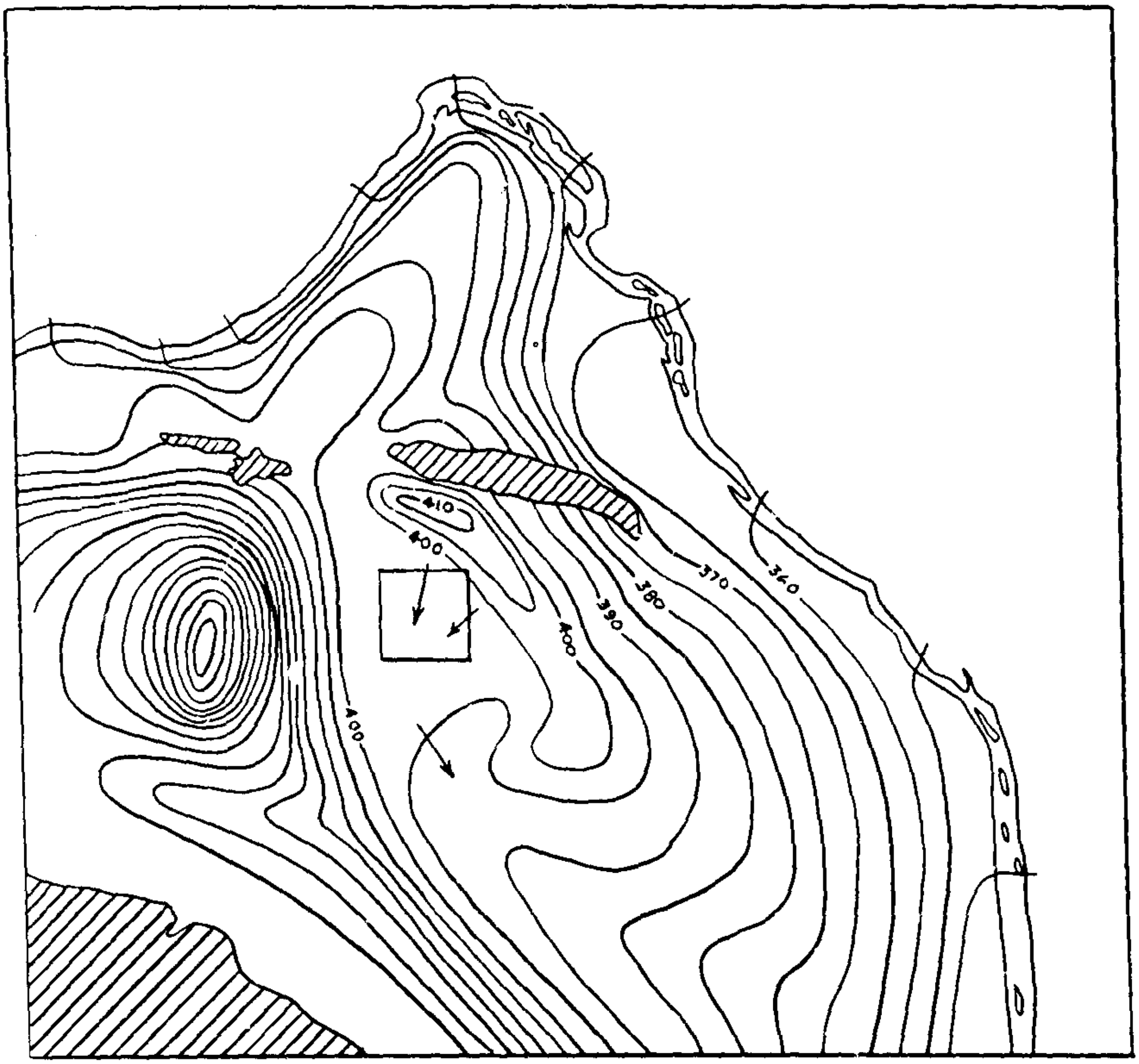

FIGURE 5

Map showing expected contours on the water table 1 year after discharge of 20 mgd of Purex cooling water to Gable Mountain swamp. Arrows indicate directions of ground-water movement of concern.

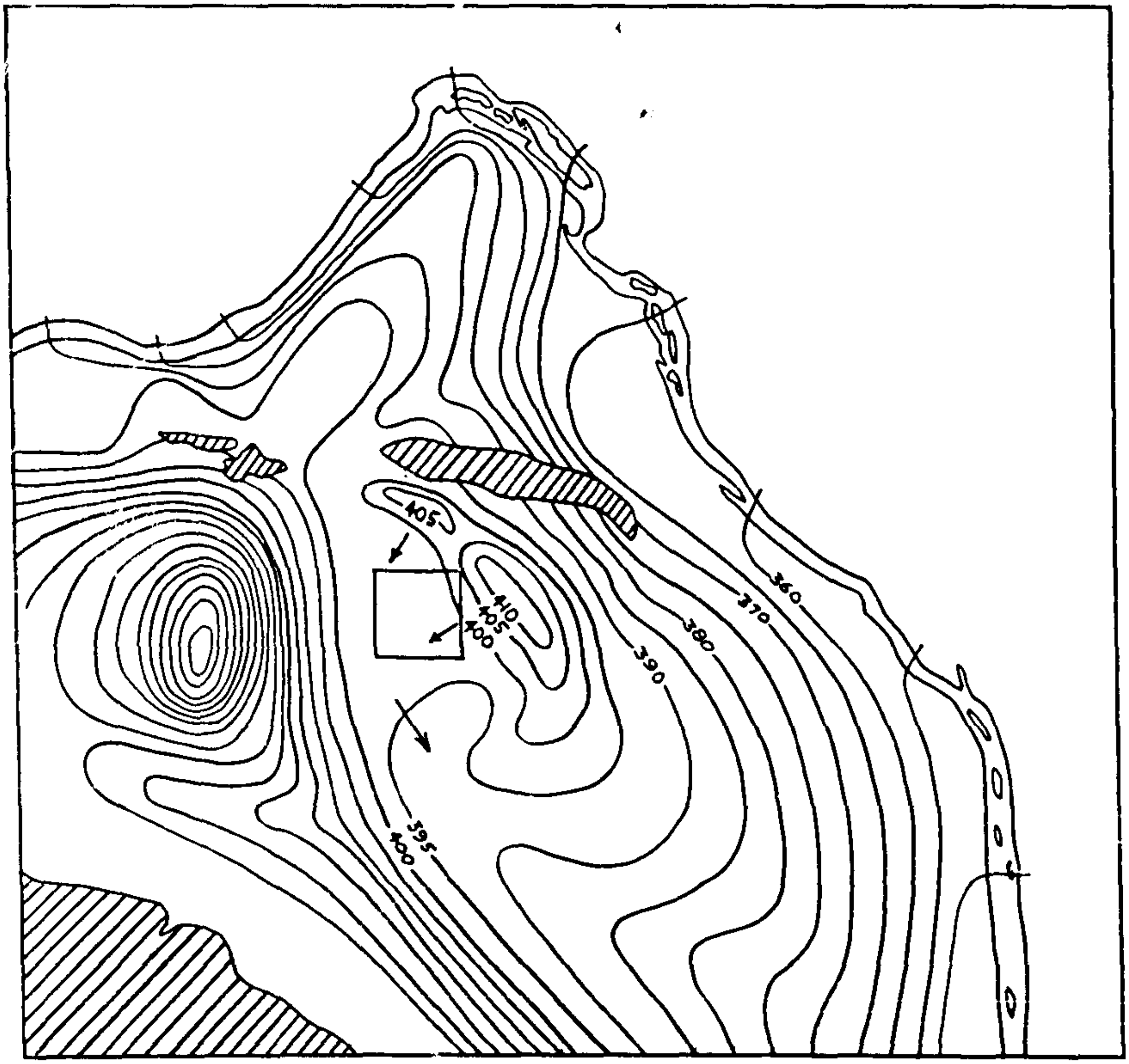

FIGURE 6

Map showing expected contours on the water table 1 year after discharge of 14 mgd to Gable Mountain swamp and 6 mgd to B-swamp. Arrows indicate directions of ground-water movement of concern.

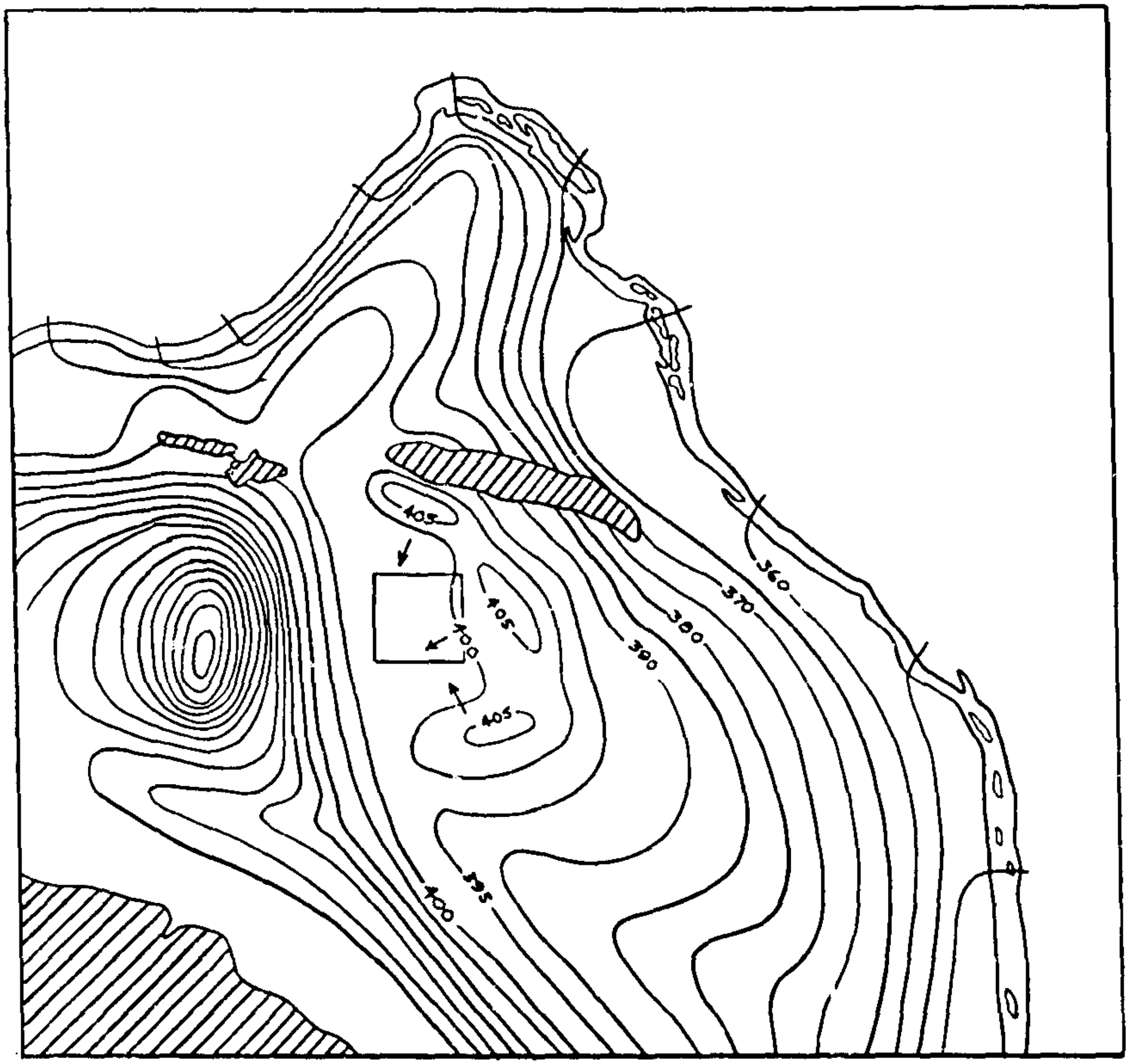

FIGURE 7

Map showing expected contours on the water table 1 year after discharge of 14 mgd to Gable Mountain swamp, 2 mgd to B-swamp, and 4 mgd to SE-swamp. Arrows indicate directions of ground-water movement of concern.