U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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UTAH DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS, AND MINING

WATER-RESOURCES INVESTIGATIONS REPORT 92–4043
Geohydrologic information of salt-water disposal—SHEET 1 OF 2
Freethey, G.W., 1994, Geohydrologic information in an area of salt-water disposal, eastern Altamont-Bluebell Petroleum Field, Uinta basin, Utah

INTRODUCTION

In 1986, the U.S. Geological Survey, in cooperation with the Utah Division of Oil, Gas, and Mining, began a study of the possible effects of salt-water disposal on ground water in the Altamont-Bluebell petroleum field. A plan outlining data requirements for various models that could simulate ground-water flow and accompanying solute transport was published (Freethey, 1988), but subsequent funding was not available to begin an extensive data-collection effort. Instead, a smaller area within the Altamont-Bluebell petroleum field was chosen for which geohydrologic data would be compiled and analyzed.

The purpose of this report is to summarize geohydrologic information about a relatively shallow zone where salt-water disposal is taking place, to describe the aquifer above this disposal zone from which most domestic and municipal water supplies are obtained, to describe naturally occurring saline water in the area, to discuss the possible degree of hydraulic connection that exists between the disposal zone and the aquifer, and to describe information needed to define the disposal zone. Although the hydrology throughout the Altamont-Bluebell petroleum field is of interest to the Utah Division of Oil, Gas, and Mining, the areal extent of this investigation was limited to the Cottonwood Creek area north of Roosevelt, Utah (fig. 1), because this smaller area includes a large proportion of the rural population and domestic water wells, and it also includes 5 of the 11 disposal wells that inject produced salt water into the Duchesne River Formation of Tertiary age, the same formation in which most water wells are completed.

The study area is in the northern Uinta Basin, within the Uintah and Ouray Indian Reservation, and includes parts of Duchesne and Uintah Counties. It lies within the east one-half of the Altamont-Bluebell petroleum field and has an area of 238 square miles. It is one of the more populated rural areas in the Uinta Basin and also includes the small communities of Roosevelt, Neola, Whiterocks, Bennett, Leeton, Hayden, Monarch, and Cedarview. Cottonwood Creek, the main surface-water drainage in the study area, flows southeastward from the Uinta Mountains to the north across the area, then into the Duchesne River, which flows from west to east across the Uinta Basin just to the south of the study area.

Geologic Framework

Surficial geologic formations in the study area include the Duchesne River and Uinta Formations of Tertiary age, exposed mostly in the west one-half of the study area, and alluvial and glacial-outwash deposits of Quaternary age that overlie the Duchesne River Formation in the east one-half of the study area (fig. 2). In general, the Duchesne River Formation is coarse grained and more permeable than the underlying Uinta Formation, but the upper part of the Uinta Formation is coarser grained than the lower part. Hood and Fields (1978, p. 34) indicated that all the deposits from land surface through the upper part of the Uinta Formation are part of an aquifer system. The lithologic character and thickness of these units and their relation to disposal zones and oil-production zones is summarized in the generalized diagram in figure 3.

The study area lies south of the Uinta Basin synclinal axis, which is nearly coincident with the north boundary of the study area; thus, the formations underlying the alluvial and glacial deposits dip gently toward the north. The land-surface altitude increases from 4,950 feet above sea level in the southeast corner of the study area to 7,040 feet above sea level in the northwest corner. Because the altitude of land surface increases to the north and formations dip to the north, the depth below land surface at which formation contacts are found increases to the north.

History of Salt-Water Disposal in the Uppermost Zone

In the Altamont-Bluebell petroleum field, oil is produced from about 5,000 to 17,000 feet below land surface (Clem, 1985, p. 161). Oil was first discovered in this field in 1949, and additional discoveries were made during the 1950's, 1960's, and 1970's. Saline water is produced with the oil, and this water is disposed of in surface evaporation ponds and in injection wells. Twenty-one commercial salt-water disposal wells are in the Altamont-Bluebell petroleum field (fig. 4), and seven of these wells are located in the area discussed in this report. Five of the seven wells are used to dispose of produced salt water by injecting it into the Duchesne River Formation or the upper part of the underlying Uinta Formation, henceforth called the uppermost disposal zone.

The first salt-water disposal well installed, U(C-1-2)3ddd, in the Altamont-Bluebell petroleum field was put into use in August 1970. Salt-water disposal in other wells followed from 1974 through 1991. Five wells are currently (1991) used for injecting salt water into the uppermost disposal zone within the study area (U(C-1-2)3ddd, U(C-1-2)13cca, U(C-1-2)26cad, U(C-1-2)28dba, and U(C-2-1)10bbb) (fig. 4). The quantity of salt water disposed of through these five wells by the end of April 1990 was about 4,810 acre-feet (G. L. Hunt, Utah Division of Oil, Gas, and Mining, written commun., 1990), approximately 21 percent of all the salt-water disposal in the Altamont-Bluebell petroleum field by that time. The concentration of dissolved solids of the water injected in these five wells ranges from about 6,000 to 35,000 milligrams per liter. The other 79 percent is disposed into deeper zones or into the uppermost disposal zone outside the study area.

Age	Geologic unit	Approximate maximum thickness (feet)	Primary lithologic character	Water supply	Oil production	Produced-water injection
(1)	(2)	300	(3)	▮		
Tertiary	Duchesne River Formation	3,000	Coarse sandstone, sandy conglomerate, sandy siltstone, fractured	▮		▮ Uppermost disposal zone
Tertiary	Uinta Formation	4,000	Claystone, siltstone, sandstone, and shale	▮	●	▮
Tertiary	Green River Formation	5,000	Shale, limestone, siltstone, and sandstone		● ● ●	▮
Tertiary	Wasatch Formation, Flagstaff Limestone, and North Horn Formation	10,000	Shale, sandstone, and limestone		●	
Cretaceous	Mesa Verde Group	4,000	Shale, sandstone, and coal			

[1] Quaternary
[2] Stream alluvium, terrace deposits, talus and glacial deposits
[3] Clay, silt, sand, gravel, and boulders

Condensed from Hood, 1976; Clem, 1985; and G.L. Hunt, Division of Oil, Gas, and Mining, written commun., 1983

Figure 3. Vertical relation and lithologic character of aquifers, injection zones, and oil-production zones.

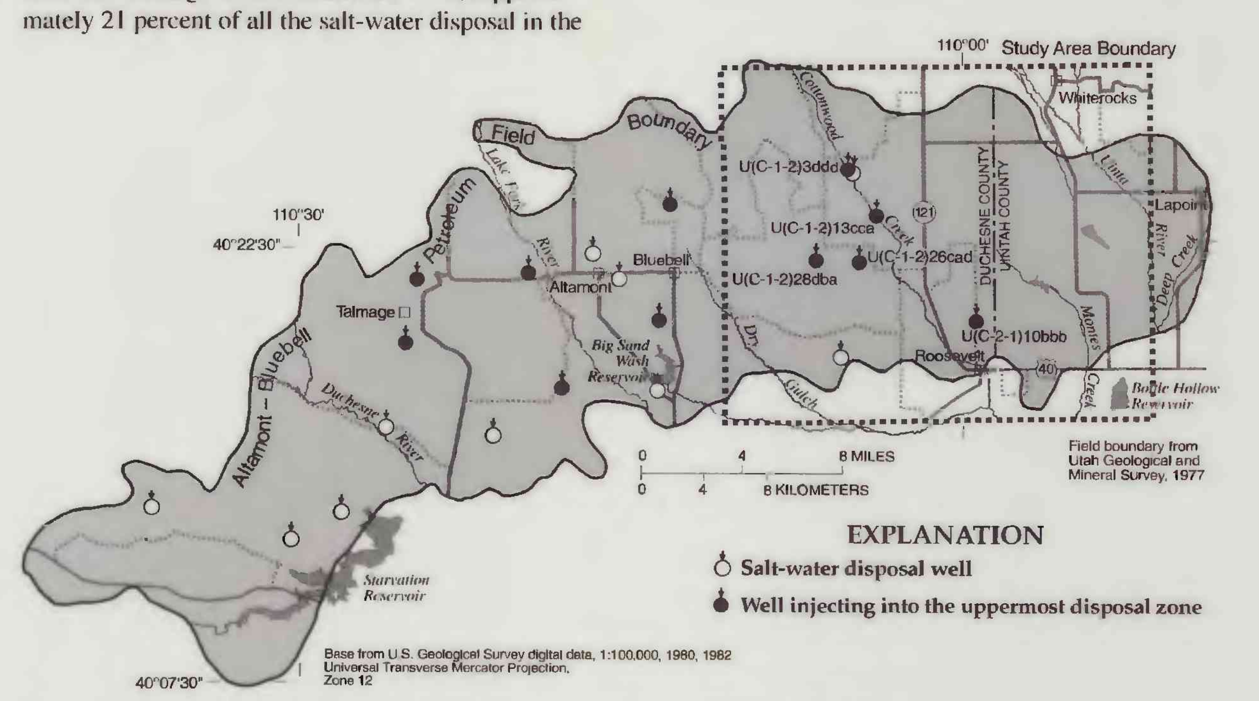

Figure 4. Location of salt-water disposal wells in the Altamont-Bluebell Petroleum Field.

Hydrologic Setting

According to Hood and Fields (1978), the aquifers in the study area are recharged mainly from precipitation that falls (primarily as snow) in the study area and on the area to the north of the study area, including the south flank of the Uinta Mountains. Minor recharge occurs as leakage from streams and canals and as infiltration of excess applied irrigation water. Water discharges from the aquifers by evapotranspiration, by seepage into streams, at springs, and as withdrawal from wells for irrigation, domestic, and industrial uses. The general direction of ground-water movement in aquifers in the unconsolidated deposits and in the Duchesne River and Uinta Formations is from northwest to southeast. In some parts of the study area, depending on the topography, structure, and stratigraphy, water levels in wells can be above land surface. This happens mostly in the valleys of the southern part of the study area.

Acknowledgment

The author wishes to thank Jim Smith, geologist, Utah Division of Oil, Gas, and Mining, for his help in interpreting geophysical logs, which were used to determine the depth and thickness of the uppermost disposal zone.

DEPTH AND LOCATION OF WATER WELLS

The depth of the water wells in the study area needs to be considered when assessing the consequences of the potential for increasing salinity in the aquifer overlying the uppermost disposal zone. Of the 154 logs of water wells in the study area stored in the files of the U.S. Geological Survey (fig. 5), finished well depths range from 8 to 1,010 feet. It is likely that the deepest wells have the greatest potential of intercepting saline water from the zone defined by Howells, Longson, and Hunt (1987), which contains water with a dissolved-solids concentration of more than 10,000 milligrams per liter, or from the uppermost disposal zone. The uppermost disposal zone is the most likely source of saline water that could enter water wells because the deepest water wells are located near and to the west of Roosevelt where the uppermost disposal zone is shallowest (fig. 6) and where the equal concentration surface is deepest (fig. 7). The relation of the depth of the disposal zone to the deepest water wells that are located on or near the sections is shown in figure 8. Sections D-D', F-F', G-G', and I-I' show finished depth of water wells that are within 800 feet of the top of the uppermost disposal zone.

DEPTH AND THICKNESS OF THE UPPERMOST DISPOSAL ZONE

The vertical and lateral extent of the uppermost disposal zone in the study area was approximated using information obtained from well-construction data, geophysical logs, and thirteen lithologic interpretations made from drill cuttings by the American Stratigraphic Company or the Denver Sample Log Company. The criteria for defining the uppermost disposal zone started with identifying where salt-water disposal wells were open for injection. Construction data from the injection wells show that the uppermost open intervals are mainly from about 2,000 to 3,500 feet above sea level. The geophysical and lithologic interpretations for these wells were studied and the lithologic character of the injection area was identified as primarily sandstone layers bounded above and below by primarily shale layers. Lithologic, gamma, acoustic, caliper, neutron, and electrical logs available for 72 other petroleum wells were analyzed to determine the prevalence of sand and shale layers for the interval between land surface and 2,000 feet above sea level. Analysis of the logs was limited to distinguishing the relative abundance of sandstone and shale layers in order to delineate the configuration of the zone where the shallow salt-water disposal takes place.

The bottom of the uppermost disposal zone was defined as the depth where the lithologic character of the layered rocks changed from predominantly sandstone above to shale below. The interval of the disposal zone was typically identified in many of the test holes by a low gamma activity trace on the natural gamma log (usually less than 30 API units) or by a small interval-transit time on the acoustic log (usually less than 80 microseconds per foot). Formations with less clay in the matrix tend to yield a low gamma activity, and sandstone tends to transmit sound waves at a higher velocity than shale. The transition usually, but not always, occurred at the contact between the Uinta Formation and the Duchesne River Formation.

The depth to the top of the uppermost disposal zone was arbitrarily defined as the depth to the base of the first shale interval overlying the uppermost disposal zone that was greater than 40 feet thick. A shale interval of this thickness or greater could not be delineated in two of the logs (in sections 10 and 11, T. 2 S., R. 2 W.); thus, if a salt-water disposal well was established in this area, the likelihood of upward migration of injected salt water might be greater than in an area where a thick shale overlies the injection zone. Other logs such as resistivity, conductivity, spontaneous potential, neutron, and caliper were used to cross check initial interpretations from the gamma and acoustic logs. Twelve sections were created from the logs to help identify the vertical and lateral extent of the disposal zone (fig. 8). Eight of the sections were oriented about perpendicular to the likely direction of ground-water flow (A-A' to H-H'), and four were oriented approximately parallel to flow direction (I-I' to L-L') (fig. 9).

The variability in the thickness of the uppermost disposal zone (fig. 10) and the depth below land surface to the top of this zone (fig. 6) give a general idea of where the potential for invasion of salt water into overlying freshwater aquifers would be greatest. Areas where the uppermost disposal zone is thinnest might be prone to more widespread lateral migration when injection under pressure takes place. The zone is less than 400 feet thick in most of the eastern and northwestern parts of the study area. Areas where the depth to the top of the zone is least might be most prone to contamination of shallow water by upward vertical migration of injected salt water. In the southwest part of Township 1 South, Range 2 West and the northeast part of Township 2 South, Range 2 West, the depth to the top of the uppermost disposal zone is least (from 1,500 to 2,000 feet below land surface). Because no 40-foot or greater shale layer could be identified in two wells in the northeastern part of Township 2 South, Range 2 West, the depth to the uppermost disposal zone is not shown in figure 6. Everywhere else in the study area the depth is greater than 2,000 feet.

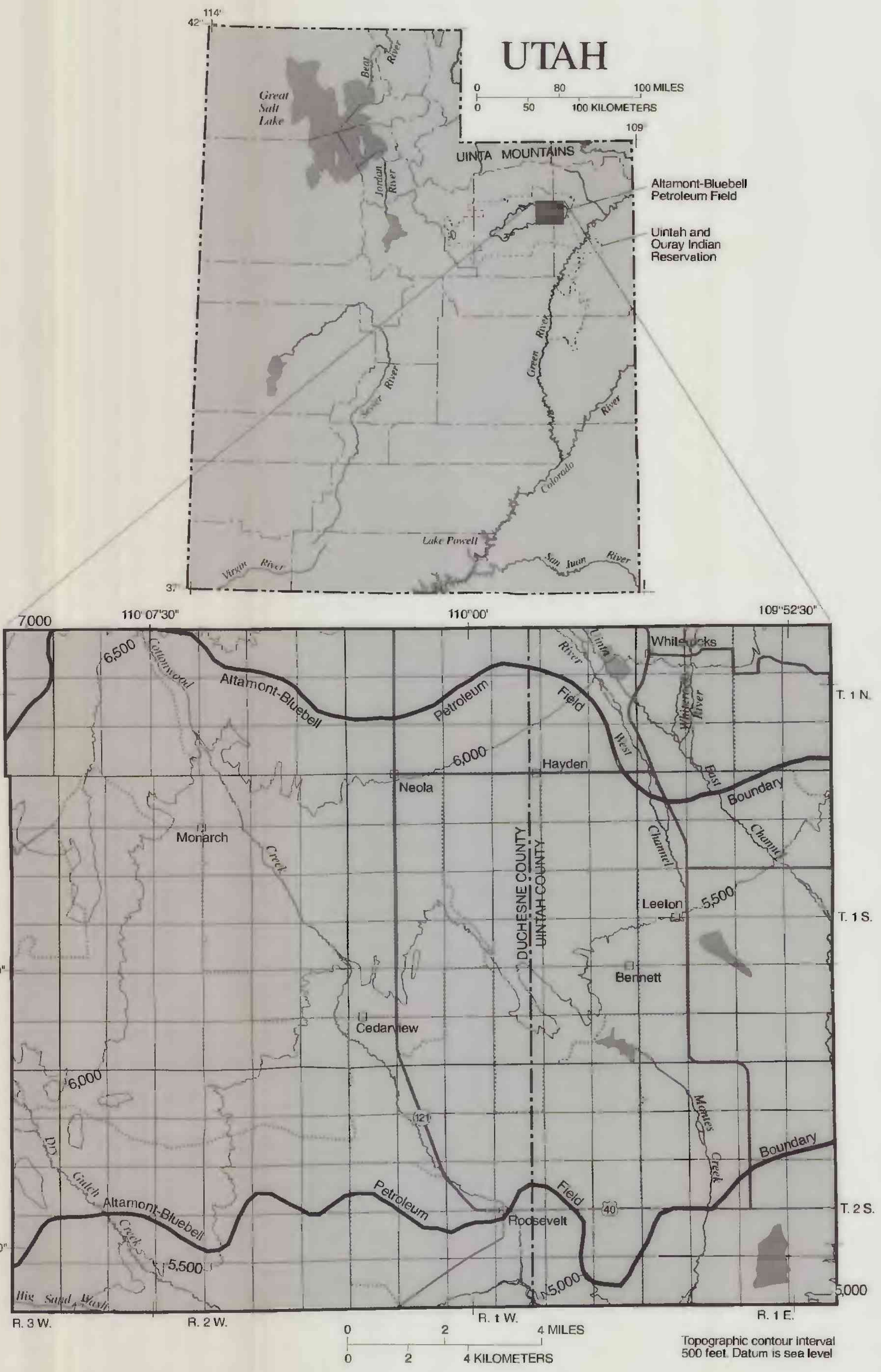

Figure 1. Location of study area.

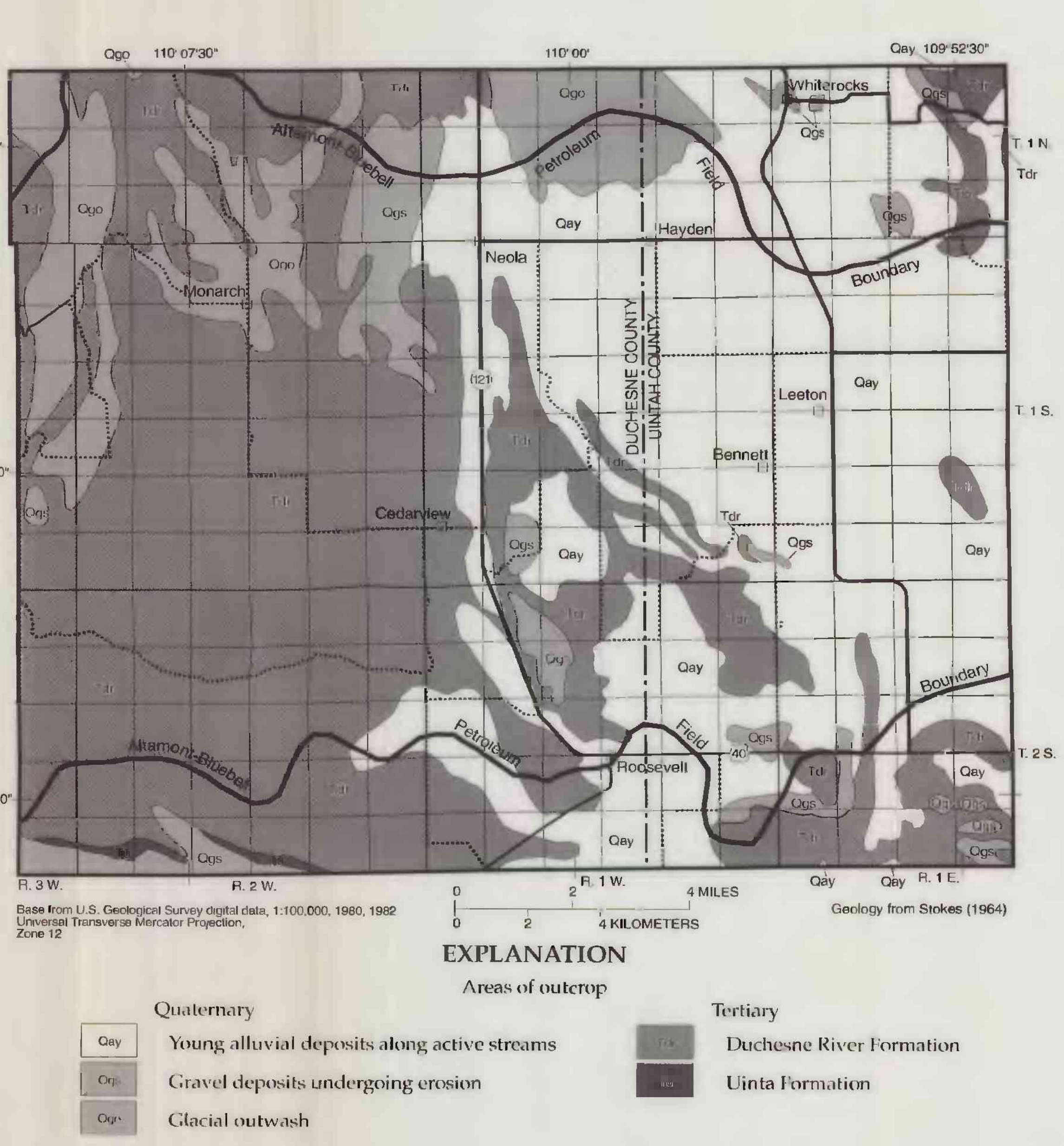

Figure 2. Generalized surficial geology.

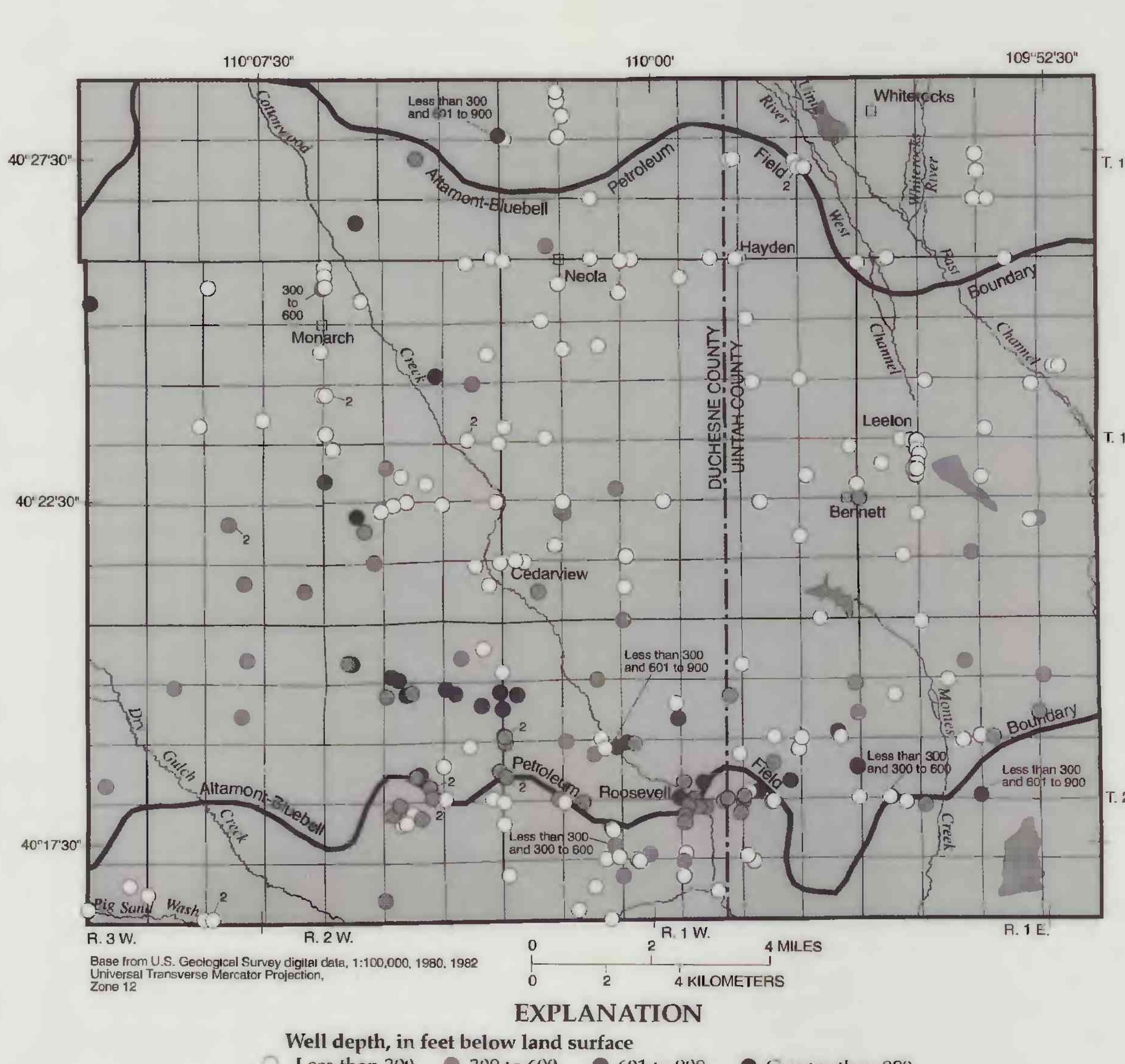

Figure 5. Depth and location of water wells.

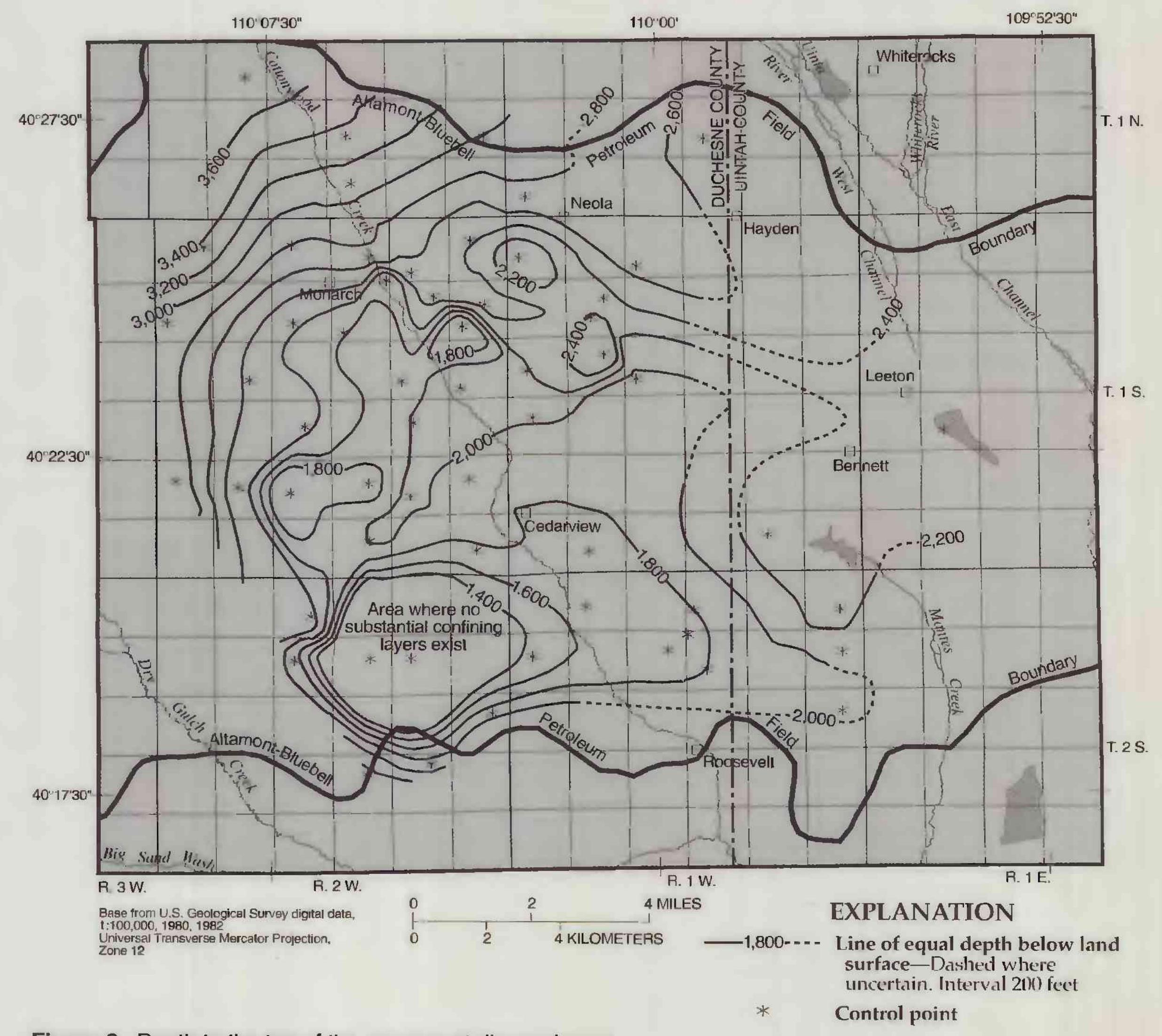

Figure 6. Depth to the top of the uppermost disposal zone.

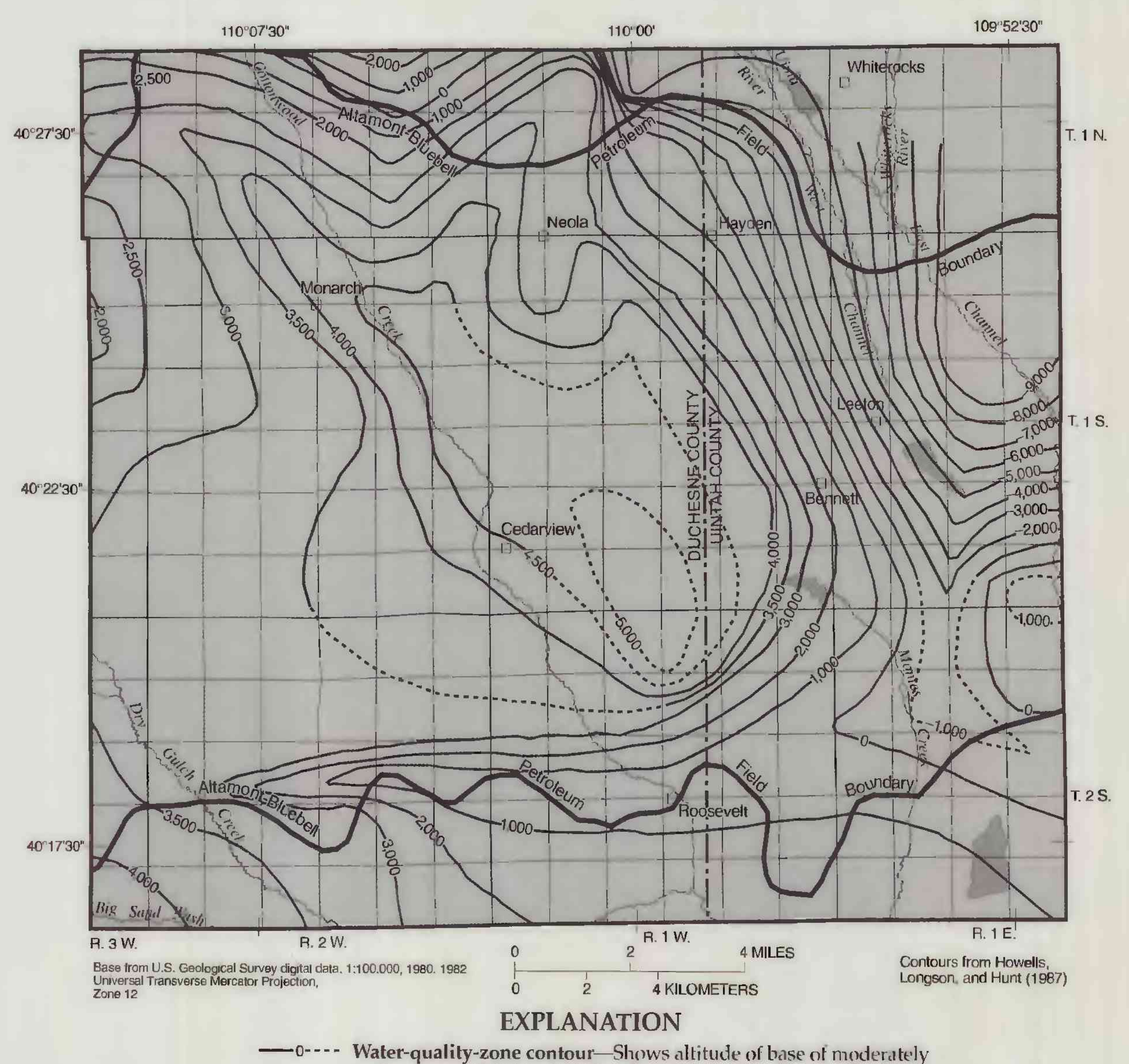

Figure 7. Altitude below which the concentration of dissolved solids in ground water is greater than 10,000 milligrams per liter.

Classification of natural waters
(After Robinove, Langsford, and Brookhart, 1958)
In this report, water salinity is classified as follows:

Class	Concentration of dissolved solids (milligrams per liter)
Fresh	0 to 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Briny	greater than 35,000

RELATION OF THE UPPERMOST DISPOSAL ZONE TO NATURALLY OCCURRING SALINE GROUND WATER

The salinity of the ground water in the Duchesne River and Uinta Formations in the vicinity of the study area varies substantially. Howells, Longson, and Hunt (1987, pls. 1 and 2) mapped the altitude of the base of moderately saline ground water. This map, showing lines of equal altitude, define an equal concentration surface of 10,000 milligrams per liter. This surface is at an altitude of greater than 5,000 feet above sea level in most of a 4-square-mile area north of Roosevelt and east of Cedarview (fig. 7), and is within 200 feet of land surface in a small part of this 4-square-mile area.

The State encourages disposal of produced water into zones where the concentration of dissolved solids is greater than the concentration of dissolved solids in the water that is injected. The uppermost disposal zone is below this equal concentration surface in the central part of the study area where disposal wells are located (see fig. 9, sections A-A', B-B', D-D', E-E', and H-H'), but parts of the uppermost disposal zone in the southwestern part of the study area are above this 10,000 milligram per liter equal concentration surface (fig. 8); thus, it is possible that continued salt-water disposal will cause saline water to move laterally far enough in the uppermost disposal zone to cause the altitude of the equal concentration surface to move closer to land surface in other parts of the study area.

GEOHYDROLOGIC INFORMATION FOR THE AQUIFER OVERLYING THE UPPERMOST DISPOSAL ZONE

The geometric configuration of the aquifer from which most domestic, public, and agricultural water is obtained is not well defined. The water source is an aquifer system that consists of unconsolidated glacial outwash underlain by alternating sand and shale layers within the Duchesne River and Uinta Formations. These consolidated formations may be fractured in places. Water supplies are obtained through wells of various depths, which produce water from thin, permeable unconsolidated deposits under unconfined conditions and from thick, relatively less-permeable consolidated rocks under confined conditions.

MAPS SUMMARIZING GEOHYDROLOGIC INFORMATION IN AN AREA OF SALT-WATER DISPOSAL, EASTERN ALTAMONT-BLUEBELL PETROLEUM FIELD, UINTA BASIN, UTAH

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