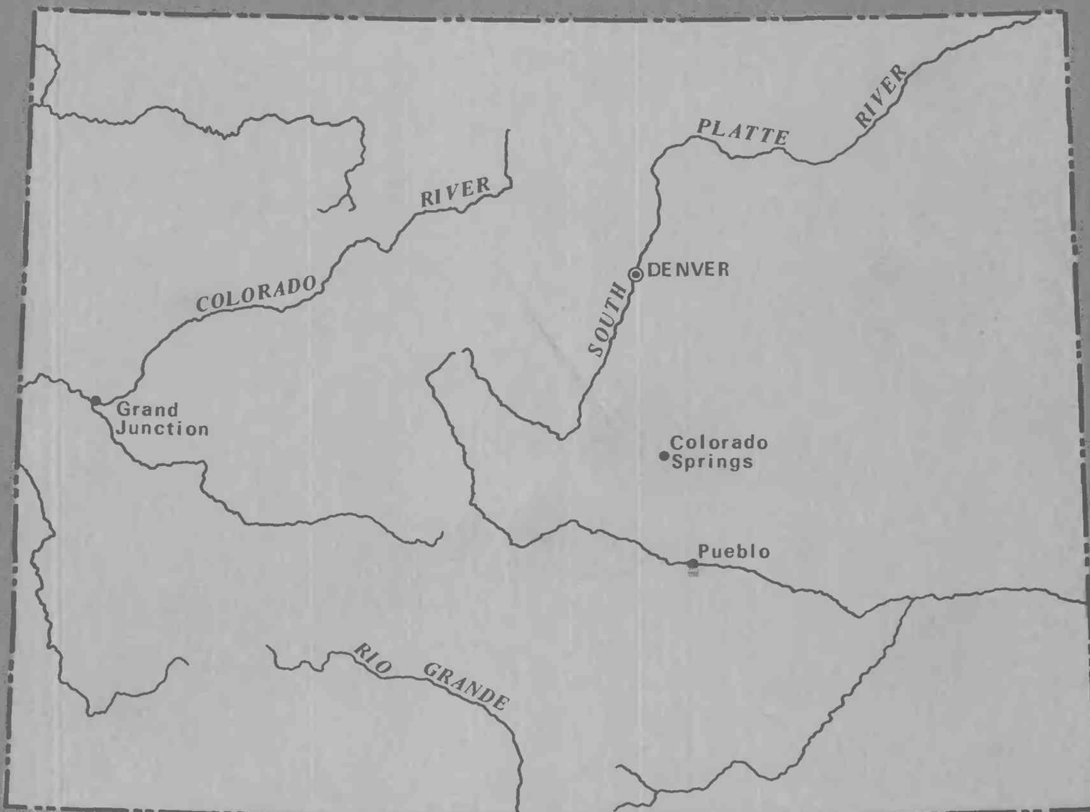
WATERLOGGING IN AN ALLUVIAL AQUIFER NEAR LAKE MINNEQUA, PUEBLO, COLORADO

U. S. GEOLOGICAL SURVEY



Water-Resources Investigations 76-53

Prepared in cooperation with the
City of Pueblo

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16. Abstracts The Lake Minnequa area, located immediately south of the Arkansas River, is mantled with as much as 46 feet (14 metres) of alluvium covering bedrock of Pierre Shale and Niobrara Formation. Surface water enters the area by the Minnequa Canal and the St. Charles Flood Ditch. The water is stored in Lake Minnequa and other reservoirs. Seepage from St. Charles Reservoirs No. 2 and No. 3 is the major source of water to the alluvial aquifer. The depth of the water table ranges from 0 to 40 feet (0 to 12.2 metres). A 0.5-square-mile (1.3-square-kilometre) area immediately south of Lake Minnequa has a water table less than 6 feet (1.8 metres) below land surface. Lake Minnequa is the principal cause of the shallow water table and resulting waterlogged soil. The bedrock hill east of Lake Minnequa and ground-water flow also contribute to the problem.

To eliminate the waterlogging problem, the water table would have to be at least 6 feet (1.8 metres) below land surface. Possible alternatives for eliminating the problem include lowering the water level in Lake Minnequa, placing a network of dewatering wells, or constructing a drainage system in the waterlogged area.

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July 1976

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

METRIC CONVERSION

English units in this report may be expressed as metric units by use of the following conversion factors:

To convert English units	*Multiply by*	*To obtain metric units*
inches	25.40	millimetres (mm)
feet	.3048	metres (m)
miles	1.609	kilometres (km)
square miles	2.590	square kilometres (km^2)
acres	.4047	hectares (ha)
acre-feet	1,233	cubic metres (m^3)
gallons per minute	.0631	litres per second (l/s)
cubic feet per second	28.32	litres per second (l/s)
feet per day	.3048	metres per day (m/d)
feet squared per day	.0929	metres squared per day (m^2/d)

WATERLOGGING IN AN ALLUVIAL AQUIFER NEAR LAKE MINNEQUA, PUEBLO, COLORADO

By Patrick J. Emmons

ABSTRACT

The Lake Minnequa area, located immediately south of the Arkansas River, includes southern Pueblo, Colo., and is mantled with as much as 46 feet (14 metres) of alluvium covering bedrock consisting of the Upper Cretaceous Pierre Shale and Niobrara Formation. Surface water enters the study area by way of the Minnequa Canal and the St. Charles Flood Ditch. The water is stored in Lake Minnequa, St. Charles Reservoir No. 2, and St. Charles Reservoir No. 3, which have a combined surface area of 1,056 acres (427 hectares) and a storage capacity of 12,715 acre-feet (15.7×10^6 cubic metres). Seepage from Lake Minnequa and St. Charles Reservoirs No. 2 and No. 3 is the major source of water to the alluvial aquifer. Ground-water movement is to the east and northeast approximately paralleling the slope of the bedrock. The surface and ground waters are very hard, with calcium and sulfate as the predominant dissolved chemical constituents.

The depth of the water table ranges from 0 to 40 feet (0 to 12.2 metres). About 7.1 square miles (18.4 square kilometres) of the aquifer has a water table of less than 10 feet (3 metres) below land surface. A 0.5-square-mile (1.3-square-kilometre) area immediately south of Lake Minnequa has a water table less than 6 feet (1.8 metres) below land surface, with marshy, waterlogged soil. Lake Minnequa is the principal cause of the shallow water table and resulting waterlogged soil. The bedrock hill east of Lake Minnequa and ground-water flow in the aquifer also contribute to the shallow water table.

To eliminate the waterlogging problem, the water table would have to be at least 6 feet (1.8 metres) below land surface. The water table could be lowered by reducing the lake level. This could be accomplished with a reduction in storage or by dredging. The water table could also be lowered by a network of dewatering wells, a tile-drain system, or a drainage-ditch system in the waterlogged soil area. Dewatering the aquifer may result in some domestic wells going dry and drying of the soil may cause differential settling of some structures. A 6-foot (1.8-metre) depth to the water table could also be achieved by raising the land surface using fill material. Other alternatives include establishing restrictive zoning for the waterlogged area or converting the land to a use compatible with the shallow water table.

INTRODUCTION

PURPOSE OF INVESTIGATION

A 0.5-square-mile (1.3-km^2) residential and light industrial area located immediately south of Lake Minnequa in the city of Pueblo, Colo., is underlain by an alluvial aquifer that is waterlogged because the water table is less than 6 feet (1.8 m) below the land surface. The purpose of this investigation was to determine the cause of the shallow water table and to determine possible alternatives for eliminating the problem. The study was begun in 1974 by the U.S. Geological Survey in cooperation with the city of Pueblo.

METHOD OF INVESTIGATION

To determine the cause of waterlogging in the 0.5-square-mile (1.3-km^2) area, it was necessary to study the entire alluvial aquifer in the Lake Minnequa area. This was accomplished by:

1. Determining the configuration and extent of the alluvial deposits in the area.

2. Determining the configuration of the water table together with seasonal changes.

3. Determining the source and direction of movement of ground water in the aquifer.

The configuration, thickness, and extent of the alluvial deposits were determined with the aid of 44 test holes drilled by the U.S. Geological Survey. The test holes were drilled using a truck-mounted auger drilling rig. Field examination of the auger cuttings was the basis for well logs of each of the test holes. The well logs contained in the section "Supplemental Information" give only a general description of the lithologic character of the alluvium. The auger tended to grind up the coarser clastic sediments resulting in well logs which may indicate finer sediments than are actually present. Slotted 2- or 2.5-inch (51- or 64-mm) diameter plastic pipe was placed in the test holes when ground water was present. The cased test holes were used for measurements of water levels and for sampling of the ground water for determination of the chemical quality. The hydrologic characteristics of the alluvium were estimated from the analysis of the well logs and the hydraulic gradient and saturated thickness of the aquifer.

ACKNOWLEDGMENTS

The author wishes to thank the Lincoln-Devore Testing Laboratory, the Colorado & Wyoming Land Co., and the Comanche Generating Station of the Public Service Co. of Colorado for making test-hole data available. Special thanks are extended to Colorado Fuel & Iron Corp. for allowing access to and permis-

sion to drill test holes on their property, and for making available water-level records on Lake Minnequa and St. Charles Reservoirs No. 2 and No. 3.

LOCATION AND DESCRIPTION OF STUDY AREA

The 35-square-mile (90.7-km^2) Lake Minnequa study area (fig. 1) is approximately 4 miles (6.4 km) in width and extends from the Arkansas River to about 2 miles (3.2 km) south of St. Charles Reservoir No. 3. The northern one-third of the study area includes Lake Minnequa and is contained within the city of Pueblo. Altitude of the land surface ranges from 4,790 to 5,120 feet (1,460 to 1,561 m) above sea level.

The waterlogged area contained in the study area is defined as the 0.5-square-mile (1.3-km^2) area immediately south of Lake Minnequa having a water table less than 6 feet (1.8 m) below land surface. The selection of a 6-foot (1.8-m) maximum depth to water is based on field evidence which indicates that a water table of less than 6 feet (1.8 m) results in marshy, waterlogged soil with water standing in ditches and depressions.

According to the National Weather Service (1974), the mean annual precipitation for the Pueblo area is about 12 inches (305 mm). The average annual class A pan evaporation is 70 inches or 1,780 mm (U.S. Weather Bureau, 1959).

PREVIOUS INVESTIGATIONS

The geology in the Lake Minnequa study area has been described in several reports. McGovern, Gregg, and Brennan (1964) reported several logs of test holes drilled by the U.S. Geological Survey about 0.4 mile (0.6 km) north and northeast of St. Charles Reservoir No. 2. Scott (1964, 1969a) described the general and engineering geology of the northwest and northeast Pueblo, Colo., quadrangles. A geologic map of the southwest and southeast Pueblo quadrangles was also prepared by Scott (1969b) and shows waterlogged areas having a water table potentially within 6 feet (1.8 m) of land surface. Scott (1972) briefly described the geology and hydrology of the Lake Minnequa area. The report includes a discussion of the high water table and possible alternatives for lowering of the water table.

GEOLOGY

SURFICIAL DEPOSITS

Artificial fill and alluvium of Pleistocene and Holocene age comprise the surficial deposits in the study area. The alluvium consists of yellowish-gray to medium-brown silt, clay, sand, and gravel. The artificial fill consists of gravel, silt, clay, concrete waste, and smelter waste and slag. The thickness of the alluvium (pl. 1) ranges from less than 10 to 46 feet (3 to 14 m); it increases northward between St. Charles Reservoir No. 3 and Lake Minnequa.

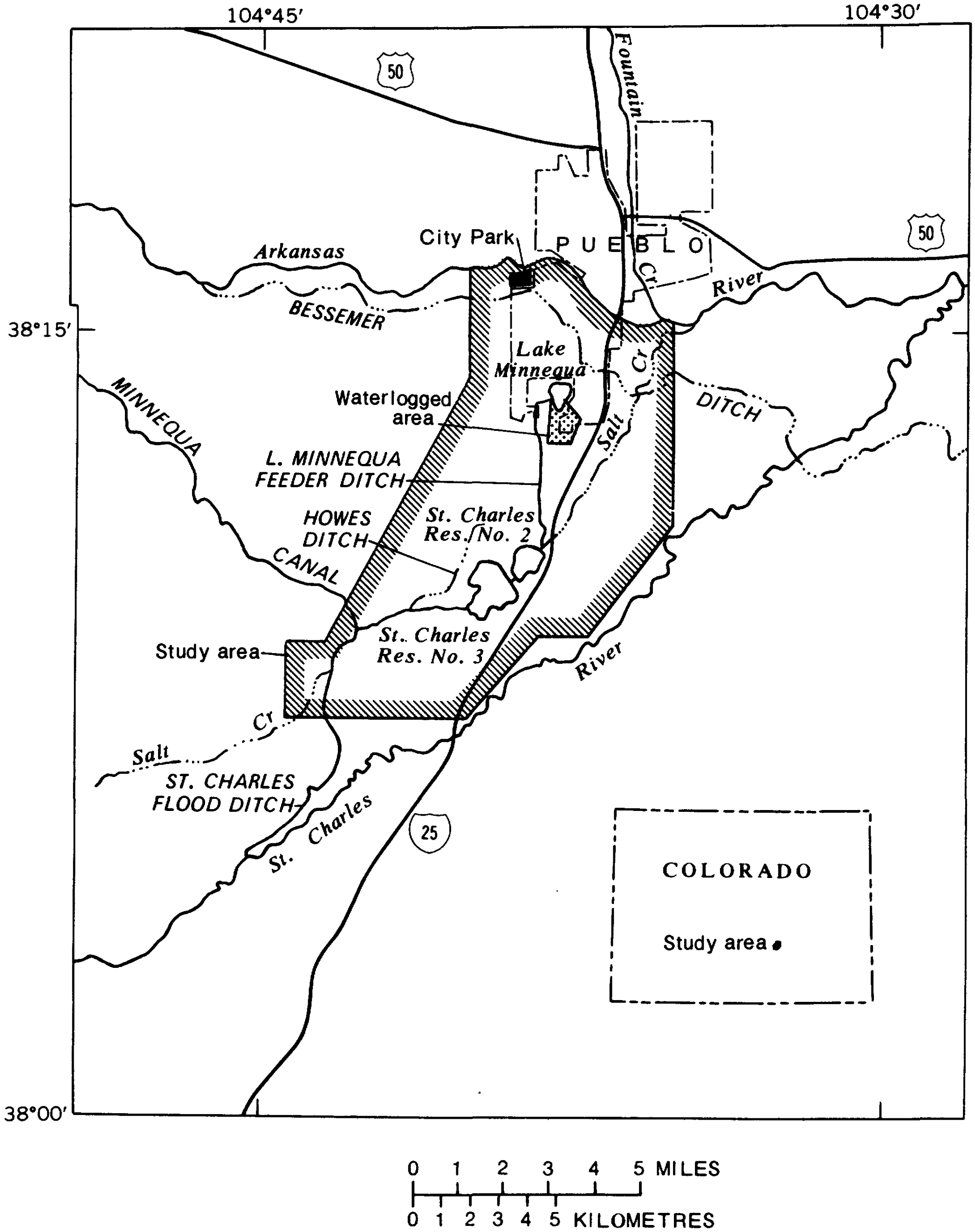


Figure 1.--Location of study area.

Beneath St. Charles Reservoirs No. 2 and No. 3, the alluvium averages about 18 feet (5.5 m) in thickness and in the area of Lake Minnequa averages about 23 feet (7 m) in thickness. The variations in the alluvial thickness are shown on geohydrologic sections of the study area (fig. 2).

The average hydraulic conductivity of the aquifer is estimated to be about 27 feet per day (8.2 m/d). The average transmissivity of the aquifer is estimated to be about 270 feet squared per day (25.1 m^2/d). The maximum pumping rate from the alluvial aquifer is estimated to be about 10 gallons per minute (0.6 l/s).

BEDROCK

Bedrock in the area consists of the Pierre Shale and the Niobrara Formation of Late Cretaceous age. The bedrock surface (pl. 2) beneath the alluvium slopes northeast throughout most of the study area. On the western edge of the study area the bedrock slope is to the east. The Pierre Shale and the Niobrara Formation are slightly permeable, confining beds that yield little water to the overlying alluvial aquifer.

Two principal channels have been cut into the bedrock surface. A channel beneath Lake Minnequa trends northeast and continues to the Arkansas River approximately 2 miles (3.2 km) to the northeast. The channel is poorly defined southwest of Lake Minnequa. The second channel has been cut into the bedrock roughly paralleling the present Salt Creek channel. East of Lake Minnequa, the bedrock forms a low hill that is 30 to 40 feet (9.1 to 12.2 m) higher than the surrounding bedrock.

HYDROLOGY

Most of the surface water in the study area is brought into the area by ditches and is stored in reservoirs. The principal source of ground water in the alluvium is seepage from reservoirs, ditches, and irrigation. Percolation of rainwater and snowmelt are minor sources of ground water.

SURFACE WATER

Surface water enters the study area from the Arkansas and the St. Charles Rivers (fig. 1). Water from the Arkansas River, west of Florence, Colo., about 30 miles (48.3 km) west of Pueblo, is diverted into the Minnequa Canal. The Minnequa Canal flows into Salt Creek about 2.3 miles (3.7 km) west of St. Charles Reservoir No. 3. Water from the St. Charles River is diverted into the St. Charles Flood Ditch. The St. Charles Flood Ditch flows into Salt Creek about 4.5 miles (7.3 km) southwest of St. Charles Reservoir No. 3. Waters from the Minnequa Canal and the St. Charles Flood Ditch flow in Salt Creek to St. Charles Reservoir No. 3.

The largest surface-water discharge from the study area is due to efflu-

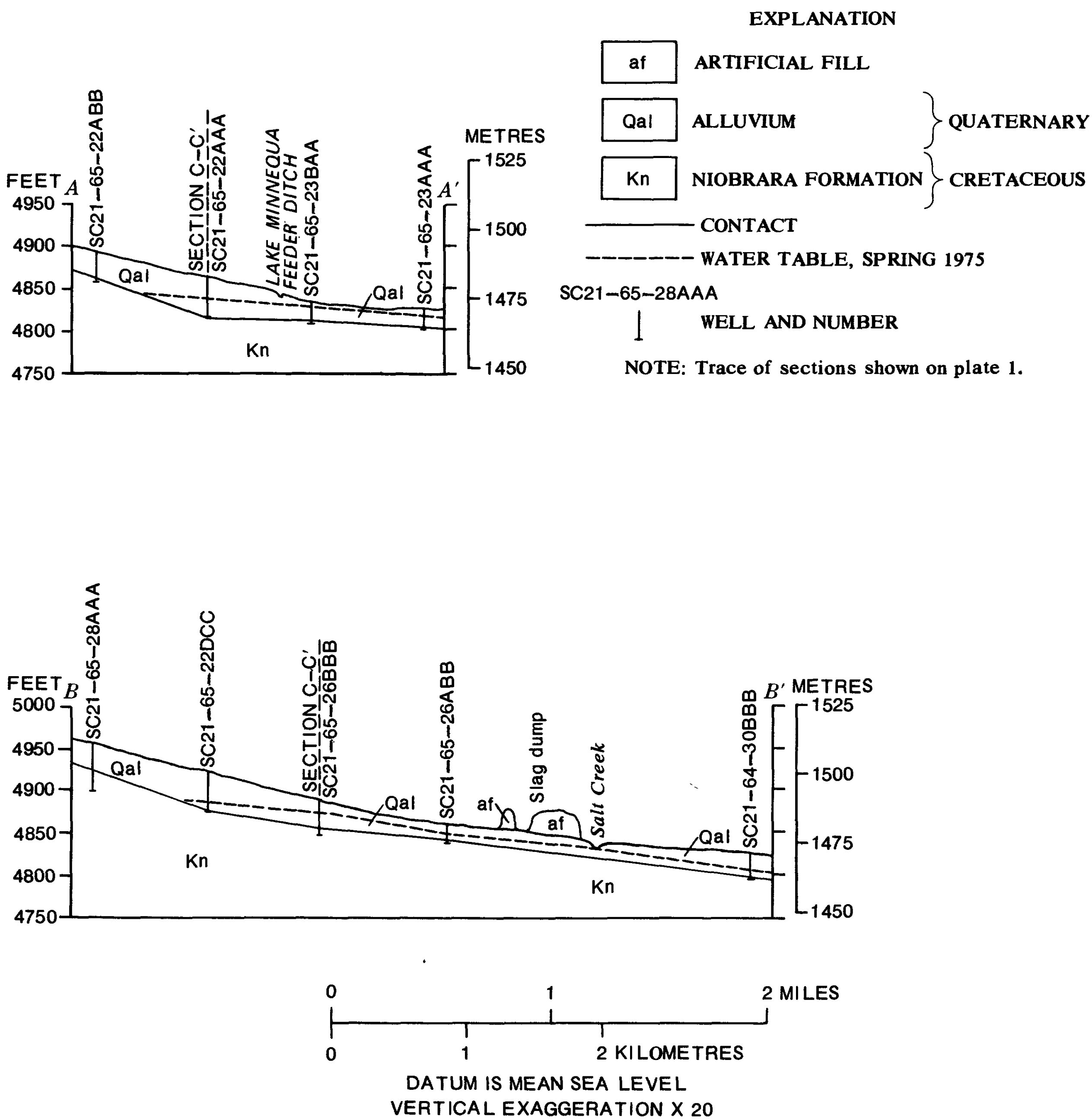
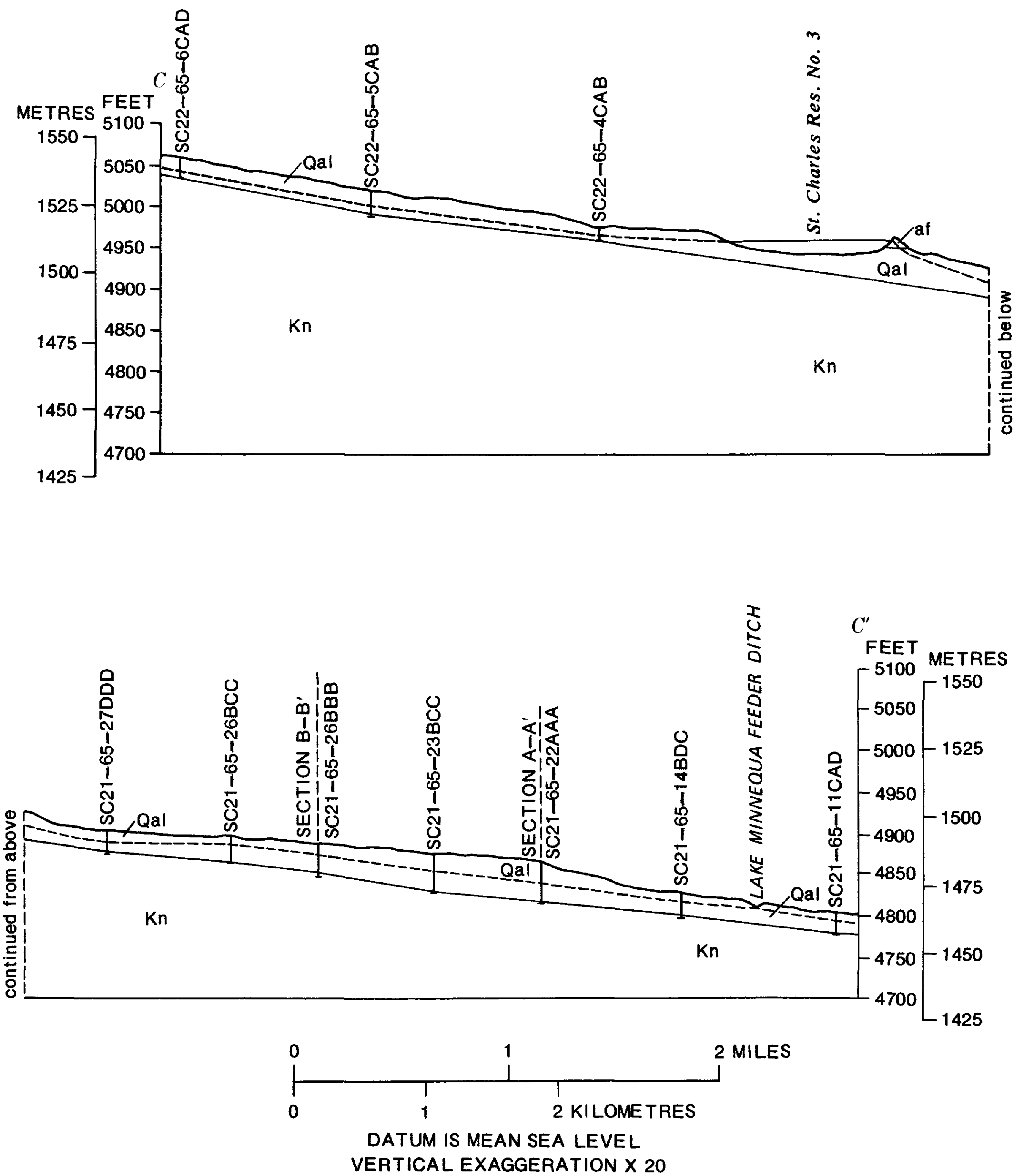

EXPLANATION
af ARTIFICIAL FILL
Qal ALLUVIUM
QUATERNARY
Kn NIOBRARA FORMATION
CRETACEOUS
CONTACT
WATER TABLE, SPRING 1975
SC21–65–28AAA
WELL AND NUMBER
NOTE: Trace of sections shown on plate 1.
FEET
A
A′
METRES
SC21–65–22ABB
SECTION C–C′
SC21–65–22AAA
LAKE MINNEQUA FEEDER DITCH
SC21–65–23BAA
SC21–65–23AAA
Qal
Kn
4950
4900
4850
4800
4750
1525
1500
1475
1450
B
B′
SC21–65–28AAA
SC21–65–22DCC
SECTION C–C′
SC21–65–26BBB
SC21–65–26ABB
Slag dump
Salt Creek
SC21–64–30BBB
af
5000
0
1
2 MILES
2 KILOMETRES
DATUM IS MEAN SEA LEVEL
VERTICAL EXAGGERATION X 20

Figure 2.--



Geohydrologic sections.

ent from the Colorado Fuel & Iron Plant. The effluent is released into Salt Creek about 1.5 miles (2.4 km) south of the Arkansas River. In addition, Salt Creek carries a small flow due to ground-water seepage. During periods of high water in Lake Minnequa, a storm-drain system also transports water out of the study area to the Arkansas River.

The study area contains three reservoirs: Lake Minnequa (St. Charles Reservoir No. 1), and St. Charles Reservoirs No. 2 and No. 3. The reservoirs were constructed by the Colorado Fuel & Iron Corp. to provide water storage for industrial use. The physical characteristics of the three reservoirs are listed in table 1.

Table 1.--*Description of reservoirs*

Reservoir name	Altitude (feet above mean sea level)	Area (acres)	Design capacity (acre-feet)	Maximum depth (feet)	Annual water-level fluctuations (feet)
Lake Minnequa--------	4,799	150	1,377	17	<1
St. Charles Reservoir No. 2--------------	4,910	243	2,700	24	<1
St. Charles Reservoir No. 3--------------	4,957	663	8,638	46	3

Approximately 600 acres (243 ha) of land contained in parts of secs. 22, 23, 26, and 27, T. 21 S., R. 65 W., located between St. Charles Reservoir No. 2 and Lake Minnequa, are irrigated. Irrigation water is supplied from either Salt Creek through Howes Ditch or St. Charles Reservoir No. 2 by way of the Lake Minnequa Feeder Ditch. The Lake Minnequa Feeder Ditch also is used to supply water to Lake Minnequa. The water in the Lake Minnequa Feeder Ditch is used to maintain the water level in Lake Minnequa at a nearly constant stage.

GROUND WATER

The direction of ground-water movement is perpendicular to the water-table contours (pl. 3) and approximately parallels the direction of slope of the bedrock surface. West of St. Charles Reservoir No. 3, the ground-water movement is approximately east, while movement north and east of St. Charles Reservoir No. 3 is to the northeast. The slope of the water table is interrupted at each of the reservoirs. Seasonal fluctuations in the water table do not significantly affect the direction of ground-water movement.

The bedrock hill east of Lake Minnequa, which projects above the water table, is mantled by unsaturated alluvium. Because of the bedrock hill, part of the regional northeast movement of ground water is directed to the northwest. The alluvium-filled channel in the bedrock beneath Lake Minnequa does not appear to significantly affect the direction of ground-water movement in the area.

The principal source of ground water west of St. Charles Reservoir No. 3 is seepage from the Minnequa Canal and Salt Creek. The primary source of ground water in the main body of the alluvial aquifer north and east of St. Charles Reservoirs No. 2 and No. 3 is seepage from the reservoirs. Seepage from Howes Ditch, Lake Minnequa Feeder Ditch (between St. Charles Reservoir No. 2 and approximately 1 mile or 1.6 km south of Lake Minnequa), irrigation, and percolation of rainwater and snowmelt are also sources of ground water in the study area. Lake Minnequa is a major source of ground water in the vicinity of the lake. Lake Minnequa, which is supplied with water from St. Charles Reservoir No. 2 by way of the Lake Minnequa Feeder Ditch, is maintained at a water level higher than the natural water table. As a result, the water table in the vicinity of the lake is controlled by the water level of the lake. Several small lakes located in City Park on the south side of the Arkansas River in sec. 34, T. 20 S., R. 65 W., contribute water to the aquifer. The Bessemer Ditch, located approximately parallel to and 0.5 to 1 mile (0.8 to 1.6 km) south of the Arkansas River, is also a source of ground water. The small lakes and the Bessemer Ditch are located north of Lake Minnequa and do not affect the ground water in the waterlogged area.

Irrigation of a part of the area between St. Charles Reservoir No. 2 and Lake Minnequa causes seasonal fluctuations in the water table as shown on figure 3. Wells SC21-65-23BCC and SC21-65-26BCC are located in the irrigated area. The hydrographs of these wells show a water-table rise of more than 2 feet (0.6 m) during the period of irrigation. The effects of irrigation also are seen in well SC21-65-22AAA, located approximately 0.5 mile (0.8 km) north of the irrigated area. Well SC21-65-34ABB is located south of the irrigated area and shows little effects of irrigation. The major cause of the water-table fluctuations south of the irrigated area is the water level in St. Charles Reservoirs No. 2 and No. 3. The hydrograph of well SC21-65-13CBB, located in the waterlogged area, indicates that the water table in this area is influenced primarily by Lake Minnequa.

The depth to the water table is shown on plate 4 and ranges from 0 to 40 feet (0 to 12.2 m). The average depth to water is approximately 14 feet (4.3 m). Approximately 31 percent, or 7.1 square miles (18.4 km^2), of the alluvial aquifer in the study area has a water table less than 10 feet (3 m) below land surface. About 4 percent, or 0.9 square mile (2.3 km^2), of the aquifer in the study area has a water table within 6 feet (1.8 m) of the land surface. The 0.5-square-mile (1.3-km^2) waterlogged area is contained within this area.

Annual fluctuations in the water table range from approximately 0.2 to 4.3 feet (0.06 to 1.3 m). The average annual water-table fluctuation is about 1.3 feet (0.4 m).

The rate of ground-water flow in the alluvium was calculated using the equation

$$Q = KIA,$$

where

Q = the quantity of water passing through the cross-sectional area;

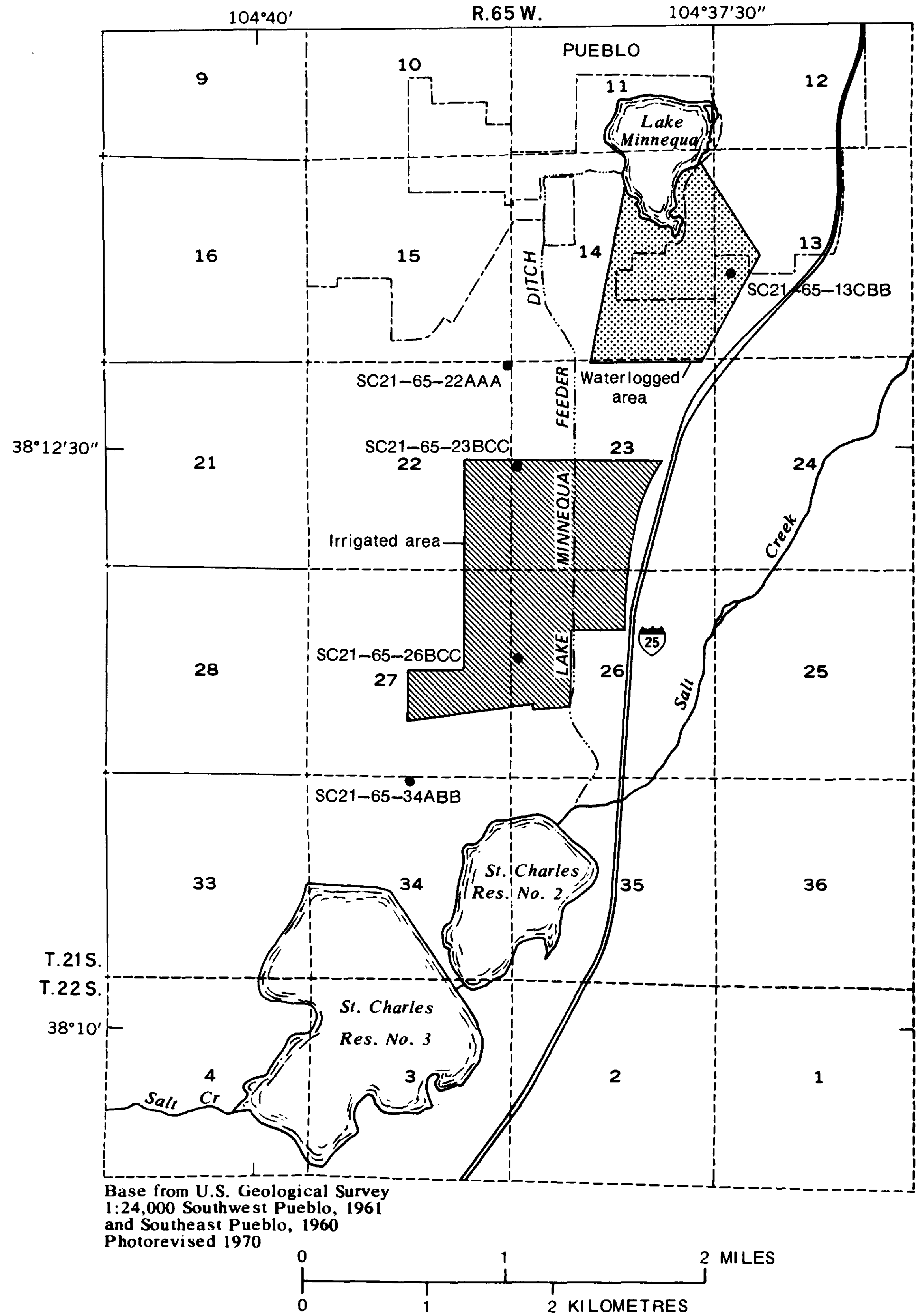
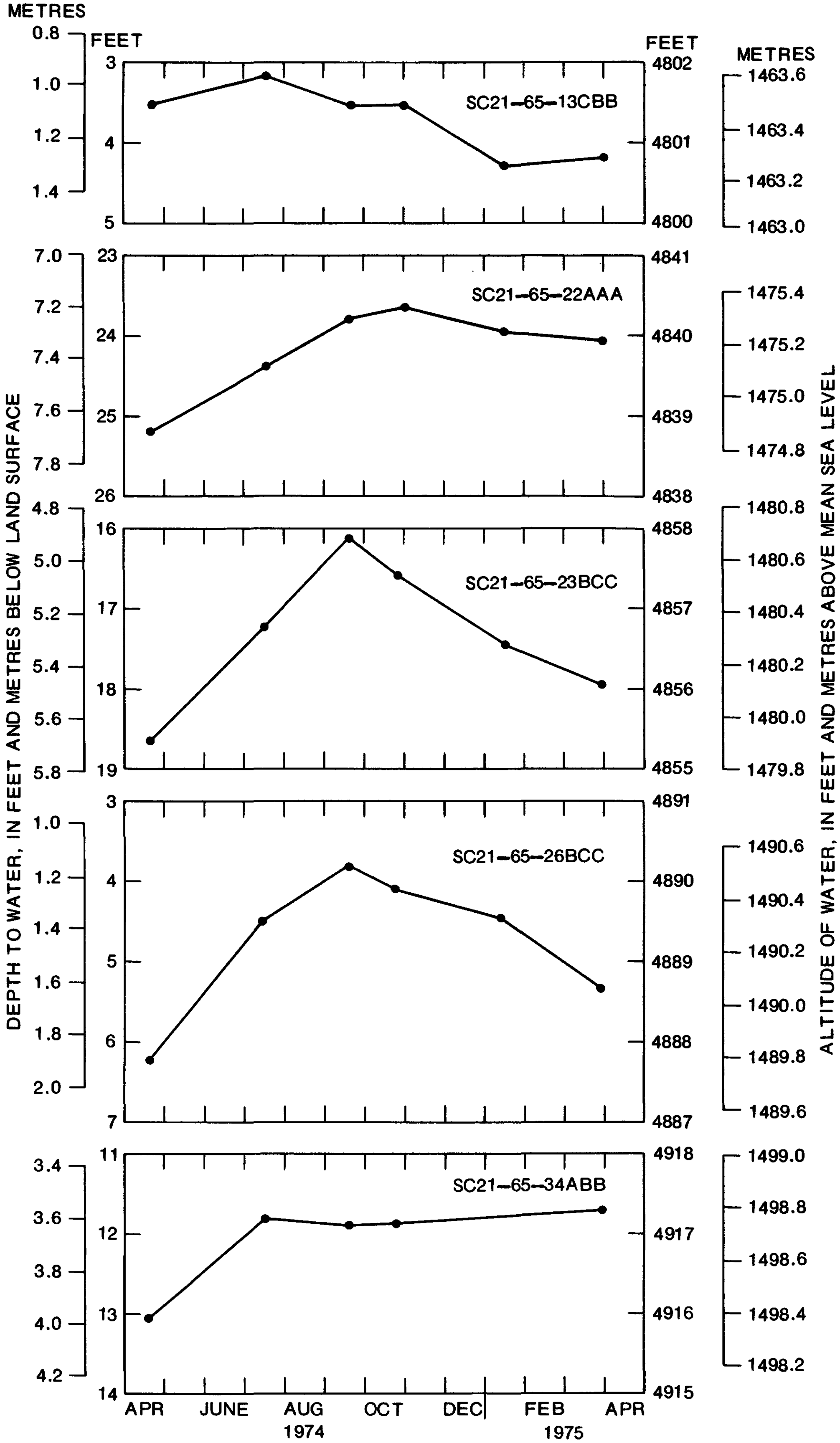


Figure 3.--Hydrographs of selected observation wells.


METRES
FEET
FEET
METRES
SC21-65-13CBB
SC21-65-22AAA
SC21-65-23BCC
SC21-65-26BCC
SC21-65-34ABB
DEPTH TO WATER, IN FEET AND METRES BELOW LAND SURFACE
ALTITUDE OF WATER, IN FEET AND METRES ABOVE MEAN SEA LEVEL
APR
JUNE
AUG
OCT
DEC
FEB
APR
1974
1975

K = the hydraulic conductivity, estimated to be 27 feet per day (8.1 m/d);
I = the hydraulic gradient of the water table (pl. 3); and
A = the area of the cross section (width of the aquifer from plate 3 times the average saturated thickness).

The average saturated thickness equals the difference between the altitude of the water table (pl. 3) and the altitude of the bedrock surface (pl. 2).

The rate of ground-water flow across the cross-sectional area, defined approximately by the 4,970-foot (1,515-m) water-table contour (pl. 3) west of St. Charles Reservoir No. 3, is estimated to be about 0.1 cubic foot per second (2.8 l/s). The rate of ground-water flow across the cross-sectional area defined approximately by the 4,850-foot (1,478-m) water-table contour is estimated to be about 1.2 cubic feet per second (34.0 l/s).

Examination of the water-table contours indicates that the majority of the ground-water discharge is to Salt Creek, northeast of St. Charles Reservoir No. 2. Salt Creek, northeast of St. Charles Reservoir No. 2, is dry; however, in the NE¼ sec. 26, T. 21 S., R. 65 W., Salt Creek begins to flow due to ground-water seepage. About 1.2 miles (1.9 km) northeast of St. Charles Reservoir No. 2, the observed flow in Salt Creek attributed to seepage is approximately 0.5 cubic foot per second (14.2 l/s). Total flow from ground-water seepage into Salt Creek is estimated to be approximately 1.0 cubic foot per second (28.3 l/s).

Discharge from the aquifer also occurs at several other locations. Small quantities, estimated to be about 0.2 cubic foot per second (5.7 l/s), seep from the aquifer into the Lake Minnequa Feeder Ditch from approximately 1 mile (1.6 km) south of Lake Minnequa to Lake Minnequa. The alluvium overlying the bedrock in the 50- to 60-foot (15.2- to 18.3-m) cliffs along the south side of the Arkansas River in sec. 34, T. 20 S., R. 65 W., discharges an estimated 0.5 cubic foot per second (14.2 l/s) from a series of seeps and springs. This discharge is a result of seepage from the small lakes in City Park. In sec. 6, T. 21 S., R. 64 W., an estimated discharge of 0.1 cubic foot per second (2.8 l/s) occurs from the alluvium. Evapotranspiration and withdrawal of ground water for lawn irrigation account for the remaining ground-water discharge. Evapotranspiration losses from the aquifer are high especially in the area where the water table is 6 feet (1.8 m) or less below the land surface. A resulting accumulation of chemical precipitate on the soil surface is found in the area.

QUALITY OF WATER

A study was made to determine the general chemical quality of the surface water and the ground water in the study area. The chemistry of the ground water can be useful for substantiating interpretations of the source and direction of ground-water movement.

The locations of sampling sites for chemical quality of water are shown on figure 4. The chemical analyses of the surface water are shown in table 2 and the chemical analyses of the ground water are shown in table 3. In addition, table 4 shows the specific conductance of the ground water at selected locations. The specific conductance was determined using a laboratory specific-conductance meter. Data from tables 3 and 4 were used to construct a map of the specific conductance of the ground water (pl. 5).

The data in table 2 indicate that the surface water in the Lake Minnequa study area is very hard, more than 180 mg/l as $CaCO_3$ (milligrams per litre as calcium carbonate). Calcium and sulfate are the predominant dissolved chemical constituents. The dissolved-solids concentration of the surface water increases from 303 mg/l in the Minnequa Canal and 381 mg/l in the St. Charles Flood Ditch to 1,050 mg/l in the Lake Minnequa Feeder Ditch where it discharges into Lake Minnequa. The increase in dissolved-solids concentration in the Lake Minnequa Feeder Ditch between St. Charles Reservoir No. 2 outflow and the Lake Minnequa Feeder Ditch near the inflow to Lake Minnequa is due to ground-water seepage into the ditch and dissolution of soluble minerals with which the water has been in contact.

Chemical analyses of the ground water (table 3) indicate that the water is of poorer quality than the surface water with dissolved-solids concentrations ranging from 931 to 7,990 mg/l. The ground water is also very hard, with calcium and sulfate being the predominant dissolved chemical constituents.

Dilution of the ground water may take place due to seepage of less saline water from St. Charles Reservoirs No. 2 and No. 3 (pl. 5). The lines of equal specific conductance indicate that the direction of ground-water flow is to the northeast. The lower specific conductance northeast of St. Charles Reservoir No. 2 indicates that most of the seepage from the reservoirs follows the old alluvium-filled bedrock channel of Salt Creek.

WATERLOGGING PROBLEM

In the 0.5-square-mile (1.3-km^2) waterlogged area (pl. 4) immediately south of Lake Minnequa, the water table is less than 6 feet (1.8 m) below land surface. Field evidence indicates that a water table of less than 6 feet (1.8 m) results in marshy, waterlogged soil. To eliminate the waterlogging problem, the water table would have to be lowered to at least 6 feet (1.8 m) below land surface.

CONTRIBUTING FACTORS

Lake Minnequa is the principal cause of the shallow water table and resulting waterlogged soil. Lake Minnequa, which is supplied by surface water from St. Charles Reservoir No. 2, is maintained at a water level higher than the natural water table. The water level in the lake controls the altitude of the water table in the vicinity of the lake. As the lake's water level changes, the altitude of the water table changes accordingly.

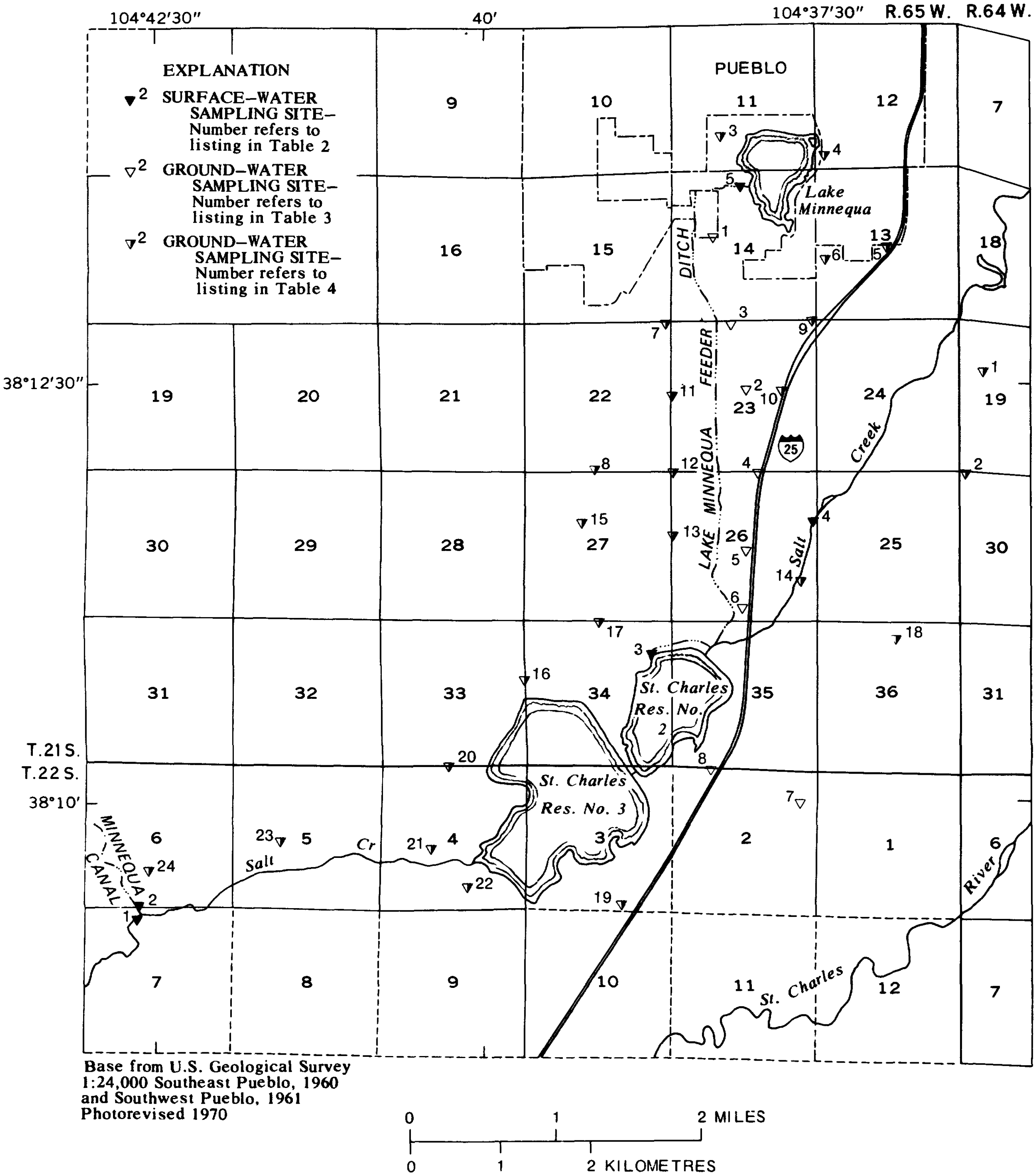


Figure 4.--Locations of sampling sites for chemical quality of water.

The bedrock hill east of Lake Minnequa (pl. 3) contributes to the waterlogging problem by impeding the regional flow of ground water to the northeast. Because of the bedrock hill, part of the regional flow is diverted to the northwest into the waterlogged area.

Ground-water flow into the waterlogged area also contributes to the waterlogging problem. The rate of ground-water flow across the cross-sectional area defined approximately by the 4,800-foot (1,463-m) water-table contour (pl. 3) south of Lake Minnequa is estimated to be 0.3 cubic foot per second (8.5 l/s). Ground-water flow into the waterlogged area causes the water table to be shallower and increases the area of waterlogging.

POSSIBLE ALTERNATIVES FOR ELIMINATING THE PROBLEM

To eliminate the waterlogging problem in the vicinity of Lake Minnequa, the water table would have to be a minimum of about 6 feet (1.8 m) below land surface. A 6-foot (1.8-m) depth could be achieved by lowering the water table or by raising the land surface.

A reduction in the water level in Lake Minnequa would lower the water table in the vicinity of the lake. A 10-foot (3-m) or greater reduction in the lake level, possibly the complete draining of the lake, may be required to lower the water table sufficiently. The maximum depth of Lake Minnequa is approximately 17 feet (5.2 m).

A second alternative of lowering the water table would be to place a network of dewatering wells in the area where the waterlogging occurs. The determination of the spacing and location of the wells would depend on the aquifer characteristics, the effects of Lake Minnequa on the aquifer with a lowered water table, and the quantity of water that the wells can pump. It is estimated that individual wells would be able to produce on the average only about 10 gallons per minute (0.6 l/s) which may limit the feasibility of a dewatering well network.

A tile-drain system or drainage-ditch system could also be constructed in the waterlogged area. As with the dewatering well network, the aquifer characteristics and the effects of Lake Minnequa would need to be considered in the system design. As the water collected by the systems would be below land surface, a pumping station would be required to raise the intercepted water above land surface for disposal. In the drainage ditches, bank instability may result in caving and ditch maintenance problems.

An alternative to lowering the water table is to raise the land surface. This could be accomplished by raising the land surface with fill material. Regulations could be established to require any new construction site to be filled so that the water table is a minimum of 6 feet (1.8 m) below land surface.

Lowering Lake Minnequa by dredging is another alternative. Dredging would remove low-permeability sediments and increase the rate of seepage from

Table 2.--*Chemical analyses of water*

Site no. on figure 4	Name	Station number	Date of sample	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (µg/l)	Dissolved manganese (Mn) (µg/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)
1.	St. Charles Flood Ditch----	380920104423800	10-17-74	11	10	0	69	22	22	2.8
2.	Minnequa Canal-------------	380923104423800	10-17-74	8.8	20	20	55	17	24	3.2
3.	Reservoir No. 2 outflow----	381053104384300	10-17-74	8.9	10	10	55	15	21	2.7
4.	Salt Creek below Reservoir No. 2--------------------	381141104373000	10-17-74	24	10	0	160	33	38	2.0
5.	Lake Minnequa Feeder Ditch-	381341104380300	10-17-74	16	20	60	180	51	68	3.4

Table 3.--*Chemical analyses of water from*

Site no. on figure 4	Well number	Latitude	Longitude	Date of sample	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (µg/l)	Dissolved manganese (Mn) (µg/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)
1.	SC21-65-14BDC	38°13'23"	104°38'15"	7-30-74	25	80	1,600	520	110	77	11
2.	SC21-65-23ACC	38°12'26"	104°38'00"	7-29-74	17	50	0	240	50	78	3.8
3.	SC21-65-23BAA	38°12'51"	104°38'04"	7-29-74	24	30	560	560	230	320	11
4.	SC21-65-26ABB	38°11'58"	104°37'56"	7-29-74	31	110	100	540	160	130	2.9
5.	SC21-65-26DBB	38°11'30"	104°38'00"	7-29-74	30	190	960	400	64	43	4.8
6.	SC21-65-26DCC	38°11'04"	104°38'02"	7-29-74	33	30	210	220	24	31	3.6
7.	SC22-65- 2AAD	38°37'59"	104°37'38"	10-17-74	23	20	200	940	420	760	12
8.	SC22-65- 2BAB	38°10'13"	104°38'11"	7-30-74	36	30	330	540	260	230	11

from selected surface-water sites

Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrite plus nitrate (N) (mg/l)	Dissolved orthophosphorus (P) (mg/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca, Mg) (mg/l as $CaCO_3$)	Noncarbonate hardness (mg/l as $CaCO_3$)	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos per centimetre at 25°C)	pH (units)	Temperature (°C)
161	--	132	170	4.2	0.5	0.03	0.00	381	260	130	15	0.6	598	8.2	17.0
161	9	147	96	9.4	.7	.01	.00	303	210	60	20	.7	493	8.6	14.0
146	0	120	110	6.7	.6	.11	.00	292	200	79	18	.6	477	8.4	14.0
249	--	204	360	12	1.2	.19	.01	754	540	330	13	.7	1,060	7.4	12.0
191	--	157	610	25	1.2	.25	.01	1,050	660	500	18	1.2	1,420	7.8	9.0

selected wells in the alluvial aquifer

Bicarbonate (HCO_3) (mg/l)	Alkalinity as $CaCO_3$ (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrite plus nitrate (N) (mg/l)	Dissolved orthophosphorus (P) (mg/l)	Dissolved solids (sum of constituents) (mg/l)	Hardness (Ca, Mg) (mg/l as $CaCO_3$)	Noncarbonate hardness (mg/l as $CaCO_3$)	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos per centimetre at 25°C)	pH (units)	Temperature (°C)
172	141	1,700	32	1.8	2.7	0.02	2,580	1,800	1,600	9	0.8	3,040	7.4	16.0
147	121	720	57	1.3	3.0	.02	1,250	810	680	17	1.2	1,840	7.1	18.5
274	225	2,500	150	1.6	14	.03	3,990	2,300	2,100	23	2.9	4,460	6.9	16.0
254	208	2,000	37	1.7	8.5	.04	3,070	2,000	1,800	12	1.3	3,420	6.7	16.0
220	180	1,100	16	1.3	.96	.04	1,770	1,300	1,100	7	.5	2,310	7.0	15.0
318	261	450	11	1.3	.08	.03	931	650	390	9	.5	1,400	6.8	14.5
413	339	2,000	400	.5	730	.05	7,990	4,100	3,700	29	5.2	9,560	6.9	16.0
368	302	2,300	60	1.9	25	.05	3,730	2,400	2,100	17	2.0	4,180	6.9	14.5

Table 4.--*Temperature, pH, and specific conductance of water from selected wells in the alluvial aquifer*

Site no. on fig. 4	Well no.	Date of sample	Temperature (°C)	pH (units)	Specific conductance (micromhos per centimetre at 25°C)
1	SC21-64-19BCA	10-16-74	16	7.4	1,750
2	SC21-64-30BBB	10-16-74	16.5	7.3	3,200
3	SC21-65-11CAC	10-16-74	16	7.0	3,710
4	SC21-65-12CCC	10-16-74	17	7.2	3,500
5	SC21-65-13ACC	10-16-74	16.5	7.1	5,600
6	SC21-65-13CBB	10-16-74	20	7.3	5,610
7	SC21-65-22AAA	10-11-74	16	7.3	3,350
8	SC21-65-22DCC	10-11-74	18.5	7.5	2,490
9	SC21-65-23AAA	10-16-74	17	7.6	4,600
10	SC21-65-23ADC	10-11-74	17	7.5	4,150
11	SC21-65-23BCC	10-11-74	16	7.2	3,960
12	SC21-65-26BBB	10-11-74	16	7.4	3,280
13	SC21-65-26BCC	10-11-74	17.5	7.2	3,150
14	SC21-65-26DAD	10-17-74	19	7.8	1,260
15	SC21-65-27BDD	10-11-74	17	7.3	3,850
16	SC21-65-33ADD	10-10-74	17	7.3	3,230
17	SC21-65-34ABB	10-11-74	16	7.0	2,700
18	SC21-65-36ABB	10-11-74	15.5	7.2	6,200
19	SC22-65- 3DCD	10-11-74	16	6.7	9,500
20	SC22-65- 4BAA	10-10-74	17	7.3	3,810
21	SC22-65- 4CAB	10-10-74	17	7.4	1,610
22	SC22-65- 4DCB	10-10-74	16.5	7.4	1,510
23	SC22-65- 5CAB	10-10-74	15	7.3	4,340
24	SC22-65- 6CAD	10-10-74	17	7.1	2,850

the lake. The resulting lower lake level would lower the water table in the vicinity of the lake. The dredged material from the lake could be used as fill to raise the land surface to attain a sufficient depth to the water table. Because of sedimentation in the lake, dredging may have to be repeated periodically. Any lowering of the water table in the vicinity of Lake Minnequa may cause some domestic wells to go dry and drying of the waterlogged soil may also result in differential settling of homes and buildings.

Other alternatives include restrictive zoning or purchase of the waterlogged land. Although zoning would not alleviate the problem for the present tenants, it could prevent any further building in the area. The waterlogged land also could be purchased and converted to a use compatible with the shallow water table.

SUMMARY AND CONCLUSIONS

The Lake Minnequa study area is mantled by as much as 46 feet (14 m) of alluvium covering bedrock of the Pierre Shale and Niobrara Formation. The buried bedrock surface generally slopes east to northeast.

Surface water is brought into the study area by the Minnequa Canal and the St. Charles Flood Ditch. The water is stored in three reservoirs: Lake Minnequa, St. Charles Reservoir No. 2, and St. Charles Reservoir No. 3. The three reservoirs have a combined surface area of 1,056 acres (427 ha) and a capacity of 12,715 acre-feet (15.7×10^6 m^3).

Seepage from Lake Minnequa and St. Charles Reservoirs No. 2 and No. 3 is the major source of ground water in the study area. Seepage from irrigation ditches and percolation of rainwater and snowmelt contribute lesser quantities of water to the alluvial aquifer. Ground-water movement is to the east and northeast approximately paralleling the slope of the bedrock.

Surface water in the study area is very hard with calcium and sulfate as the predominant dissolved chemical constituents. Dissolved-solids concentrations of the surface water range from about 300 to 1,050 mg/l. Ground water is also very hard with calcium and sulfate as the predominant dissolved chemical constituents. Dissolved-solids concentrations of the ground water ranges from about 900 to 8,000 mg/l. The specific conductance of the ground water indicates that most of the seepage from the reservoirs follows the alluvium-filled bedrock channel of Salt Creek.

The depth of the water table ranges from 0 to 40 feet (0 to 12.2 m) with an average depth of about 14 feet (4.3 m). Approximately 7.1 square miles (18.4 km^2) of the alluvial aquifer has a water table less than 10 feet (3 m) below land surface. A 0.5-square-mile (1.3-km^2) area immediately south of Lake Minnequa has a water table which is less than about 6 feet (1.8 m) below land surface resulting in a problem with waterlogged soil.

Lake Minnequa, which is maintained at a water level higher than the natural water table, is the principal cause of the shallow water table and resulting waterlogged soil. The bedrock hill east of Lake Minnequa and ground-water flow in the alluvial aquifer also contribute to the problem.

To eliminate the waterlogging problem, the water table should be at least 6 feet (1.8 m) below land surface. One alternative is to lower the water level in Lake Minnequa. It is estimated that a 10-foot (3-m) or more reduction and possibly complete draining of the lake would be required to achieve a sufficient reduction in the water table. The water level in the lake also could be lowered by dredging to remove sediments and increase seepage from the lake. Lowering the water table in the Lake Minnequa area may result in some domestic wells going dry. The drying out of the waterlogged soil also may cause differential settling of homes and buildings.

Another alternative is to place a network of dewatering wells in the waterlogged area. It is estimated that individual wells would be able to produce only about 10 gallons per minute (0.6 l/s) which may limit the feasibility of a dewatering-well network. A third alternative is a drainage-ditch or tile-drain system to intercept ground water in the waterlogged area.

Other alternatives, which do not involve lowering the water table, would be restrictive zoning to prevent further building in the waterlogged area or purchasing and converting the land to a use compatible with the shallow water table.

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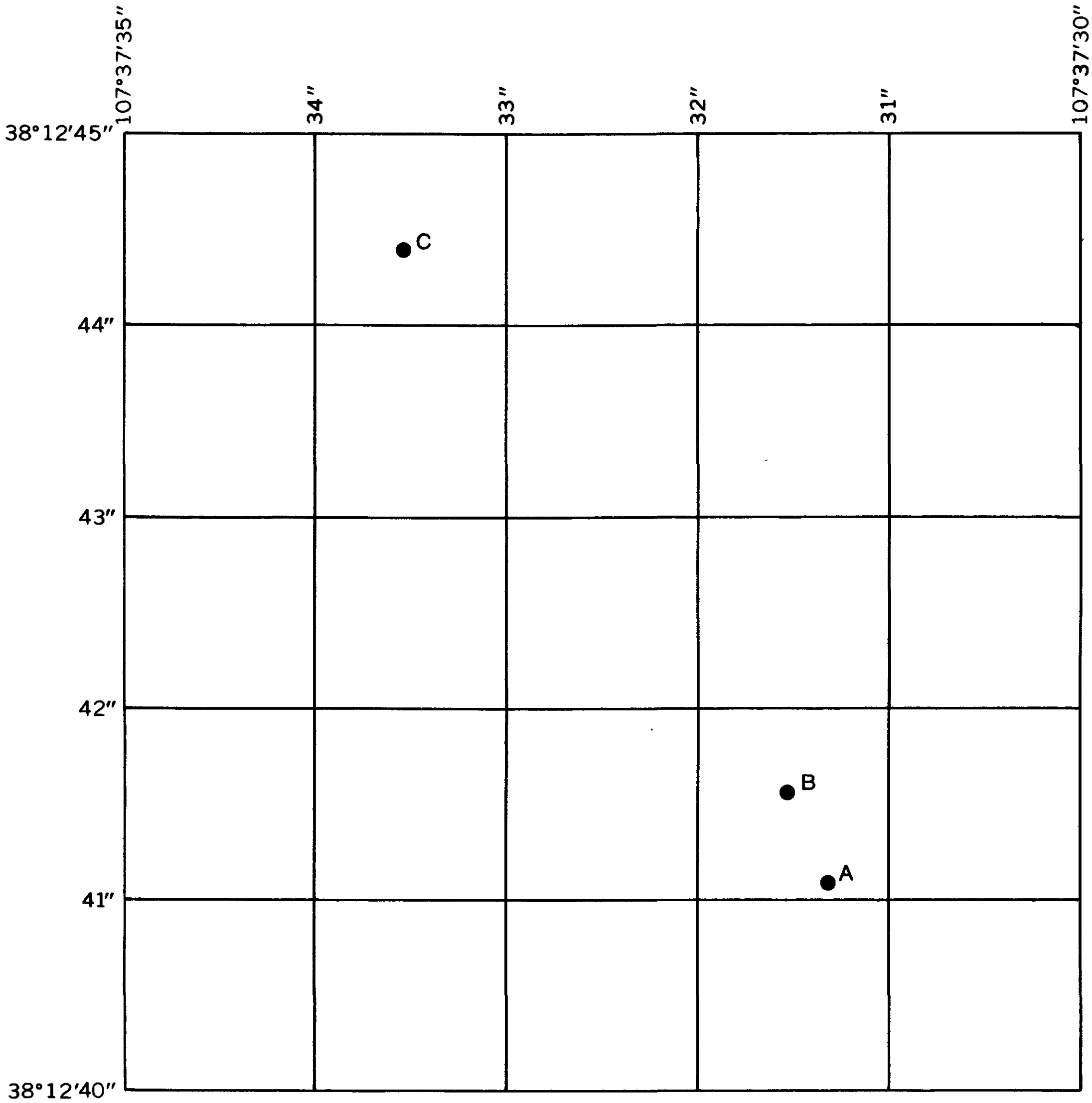
SUPPLEMENTARY INFORMATION

U.S. GEOLOGICAL SURVEY'S SYSTEM OF NUMBERING WELLS AND MISCELLANEOUS SITES

The wells and miscellaneous-site numbering system of the U.S. Geological Survey is based on the grid system of latitude and longitude. The system provides the geographic location of the well or miscellaneous site and a unique number for each site. The number consists of 16 digits. The first six digits denote the degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude; and the last two digits is a sequential number for wells within a 1-second grid. (In the event that the latitude-longitude coordinates for a well and a miscellaneous site are the same, sequential numbers "01," "02," and so forth are assigned as for wells.) See figure 5.

SYSTEM OF NUMBERING WELLS AND RESERVOIRS IN COLORADO

The well and reservoir locations in this report also are given numbers based on the U.S. Bureau of Land Management system of land subdivision, and show the location of the wells by quadrant, township, range, section, and position within the section. Reservoirs are located by township, range, and section only. A graphic illustration of this method of well location is shown in figure 6. The first letter "S" of the location number indicates that the well is located in the area governed by the sixth principal meridian. The second letter "C" indicates the quadrant in which the well is located. Four quadrants are formed by the intersection of the base line and the principal meridian; A indicates the northeast quadrant, B the northwest, C the southwest, and D the southeast. The first numeral indicates the township; the second, the range; and the third, the section in which the well is located. The letters following the section number indicate the location of the well within the section. The first letter denotes the quarter section; the second, the quarter-quarter section; and the third, the quarter-quarter-quarter section. The letters are assigned within the section in a counter-clockwise direction, beginning with A in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. Where two or more locations are within the smallest subdivision, consecutive numbers, beginning with 1, are added in the order in which the wells are inventoried. For example, SC22-65-3DCD indicates a well in the SE¼SW¼SE¼ sec. 3, T. 22 S., R. 65 W.



Coordinates for site A 381241107373101
B 381241107373102
C 381244107373301

Figure 5.--U.S. Geological Survey's system of numbering wells and miscellaneous sites.

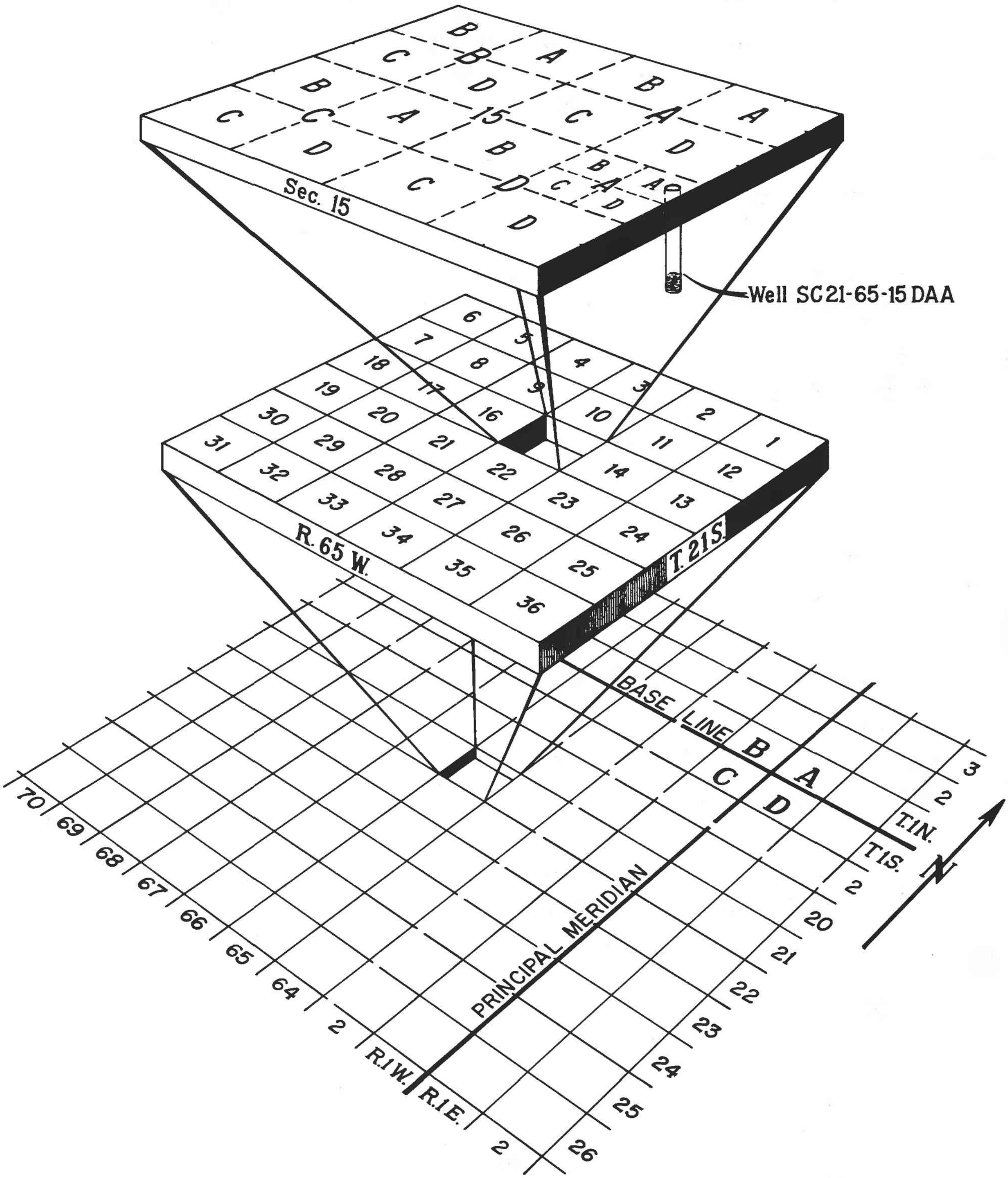


Figure 6.--System of numbering wells in Colorado.

LOGS OF TEST HOLES DRILLED BY THE U.S. GEOLOGICAL SURVEY

[Altitudes shown are land surface at test-hole sites]

	Thickness (feet)	Depth (feet)
SC21-64-19BCA. Altitude, 4,817 feet		
Alluvial deposits:		
Silt, sandy, light-brown	3	3
Sand, silty, brown; contains gravel	30	33
Silt, sandy, brown; contains gravel	5	38
Pierre Shale:		
Shale, gray	3	41
SC21-64-30BBB. Altitude, 4,826 feet		
Alluvial deposits:		
Sand, silty, light-brown	3	3
Sand, silty, brown; contains gravel	25	28
Pierre Shale:		
Shale, gray	1	29
SC21-65-11CAC. Altitude, 4,804 feet		
Alluvial deposits:		
Silt, sandy, dark-grayish-brown	1	1
Sand, silty, yellowish-brown	16	17
Silt, clayey, orangish-brown	6	23
Niobrara Formation:		
Shale, gray; contains streaks of orangish-brown silty clay	2	25
SC21-65-12CCC. Altitude, 4,808 feet		
Alluvial deposits:		
Silt, sandy, dark-reddish-brown	9	9
Silt, sandy, yellowish-brown	7	16
Silt, sandy, orange	4	20
Silt, yellowish-brown; contains traces of gypsum and coarse sand	5	25
Niobrara Formation:		
Shale, gray	4	29

	Thickness (feet)	Depth (feet)
SC21-65-13ACC. Altitude, 4,814 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	4	4
Silt, sandy, yellowish-brown; contains gravel	3	7
Silt, orangish-brown	24	31
Silt, orangish-brown; contains very coarse sand and a trace of gypsum	8	39
Niobrara Formation:		
Shale, dark-greenish-gray	2	41
SC21-65-13CBB. Altitude, 4,805 feet		
Alluvial deposits:		
Silt, sandy, dark-yellowish-brown	5	5
Silt, yellowish-brown	15	20
Silt, sandy, yellowish-brown	3	23
Silt, sandy, yellowish-brown; contains gravel	3	26
Niobrara Formation:		
Shale, gray	2	28
SC21-65-14BDC. Altitude, 4,828 feet		
Alluvial deposits:		
Silt, sandy, dark-orangish-brown	5	5
Silt, dark-orangish-brown	8	13
Silt, yellowish-brown; contains gravel	6	19
Silt, yellowish-brown	5	24
Niobrara Formation:		
Shale, gray	5	29
SC21-65-22AAA. Altitude, 4,864 feet		
Alluvial deposits:		
Silt, sandy, reddish-brown	5	5
Silt, orangish-brown; contains some gravel	7	12
Silt, yellowish-brown	23	35
Silt, sandy, yellowish-brown; contains gravel	11	46
Niobrara Formation:		
Shale, greenish-brown	1	47

	Thickness (feet)	Depth (feet)
SC21-65-22ABB. Altitude, 4,895 feet		
Alluvial deposits:		
Silt, dark-grayish-brown	6	6
Silt, yellowish-brown	3	9
Silt, gravelly, yellowish-brown	16	25
Silt, sandy, yellowish-brown	7	32
Niobrara Formation:		
Shale, gray	4	36
SC21-65-22CAA. Altitude, 4,913 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	10	10
Silt, yellowish-brown; contains gravel	19	29
Niobrara Formation:		
Shale, gray	3	32
SC21-65-22DCC. Altitude, 4,924 feet		
Alluvial deposits:		
Silt, yellowish-brown	11	11
Silt, yellowish-brown; contains gravel	35	46
Niobrara Formation:		
Shale, gray	1	47
SC21-65-23AAA. Altitude, 4,828 feet		
Alluvial deposits:		
Silt, clayey, dark-yellowish-brown	4	4
Silt, yellowish-brown	11	15
Silt, yellowish-brown; contains gravel	7	22
Niobrara Formation:		
Shale, gray	3	25

	Thickness (feet)	Depth (feet)
SC21-65-23ACC. Altitude, 4,855 feet		
Alluvial deposits:		
Silt, dark-yellowish-brown	10	10
Silt, yellowish-brown; contains gravel	6	16
Silt, orangish-brown	11	27
Niobrara Formation:		
Shale, gray.	1	28
SC21-65-23ADC. Altitude, 4,847 feet		
Alluvial deposits:		
Silt, clayey, yellowish-brown; contains a trace of gravel.	31	31
Niobrara Formation:		
Shale, gray.	1	32
SC21-65-23BAA. Altitude, 4,834 feet		
Alluvial deposits:		
Silt, sandy, reddish-brown	3	3
Silt, yellowish-brown.	13	16
Silt, sandy, yellowish-brown; contains a trace of gravel.	4	20
Niobrara Formation:		
Shale, gray.	7	27
SC21-65-23BCC. Altitude, 4,874 feet		
Alluvial deposits:		
Silt, sandy, brown	15	15
Silt, yellowish-brown.	5	20
Silt, sandy, light-yellowish-brown	9	29
Silt, sandy, yellowish-brown; contains gravel. .	11	40
Niobrara Formation:		
Shale, greenish-gray; contains streaks of yellowish-brown silt	2	42

	Thickness (feet)	Depth (feet)
SC21-65-26ABB. Altitude, 4,861 feet		
Alluvial deposits:		
Silt, sandy, clayey, dark-yellowish-brown; contains a trace of gravel	20	20
Niobrara Formation:		
Shale, gray	1	21
SC21-65-26BBB. Altitude, 4,888 feet		
Alluvial deposits:		
Silt, sandy, dark-orangish-brown	10	10
Clay, silty, brown	10	20
Silt, sandy, yellowish-brown	10	30
Silt, yellowish-brown; contains gravel	5	35
Niobrara Formation:		
Shale, light-gray	5	40
SC21-65-26BCC. Altitude, 4,894 feet		
Alluvial deposits:		
Clay, dark-reddish-brown	10	10
Silt, yellowish-brown	8	18
Silt, yellowish-brown; contains gravel	5	23
Silt, clayey, orange	5	28
Niobrara Formation:		
Shale, gray	2	30
SC21-65-26DBB. Altitude, 4,870 feet		
Roadfill	4	4
Alluvial deposits:		
Silt, clayey, yellowish-brown	13	17
Niobrara Formation:		
Shale, gray	2	19
SC21-65-26DCC. Altitude, 4,880 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	18	18
Niobrara Formation:		
Shale, gray	2	20

	Thickness (feet)	Depth (feet)
SC21-65-27BDD. Altitude, 4,926 feet		
Alluvial deposits:		
Silt, yellowish-brown.	7	7
Silt, yellowish-brown; contains gravel	13	20
Silt, yellowish-brown.	11	31
Niobrara Formation:		
Shale, gray.	2	33
SC21-65-27CCC. Altitude, 4,964 feet		
Alluvial deposits:		
Silt, yellowish-brown; contains gravel	5	5
Niobrara Formation:		
Shale, gray; contains inclusions of gypsum . . .	40	45
SC21-65-27DDD. Altitude, 4,900 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	16	16
Silt, sandy, yellowish-brown; contains gravel. .	6	22
Niobrara Formation:		
Shale, gray.	2	24
SC21-65-28AAA. Altitude, 4,958 feet		
Alluvial deposits:		
Silt, yellowish-brown.	8	8
Silt, yellowish-brown; contains gravel	22	30
Niobrara Formation:		
Shale, gray.	27	57
SC21-65-33ADD. Altitude, 4,963 feet		
Alluvial deposits:		
Silt, yellowish-brown.	6	6
Silt, yellowish-brown; contains gravel	18	24
Niobrara Formation:		
Shale, yellowish-brown	1	25

	Thick-ness (feet)	Depth (feet)
SC21-65-34ABB. Altitude, 4,929 feet		
Alluvial deposits:		
Silt, yellowish-brown.	8	8
Silt, yellowish-brown; contains gravel	7	15
Silt, yellowish-brown.	5	20
Silt, yellowish-brown; contains gravel	7	27
Niobrara Formation:		
Shale, gray.	3	30
SC21-65-36AAB. Altitude, 4,850 feet		
Alluvial deposits:		
Silt, yellowish-brown.	13	13
Silt, yellowish-brown; contains gravel	5	18
Silt, yellowish-brown; contains gravel, mixture of shale and granite material.	5	23
Niobrara Formation:		
Shale, gray.	4	27
SC21-65-36ABB. Altitude, 4,859 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	15	15
Silt, yellowish-brown; contains trace of gravel.	4	19
Niobrara Formation:		
Shale, gray.	2	21
SC21-65-36DCC. Altitude, 4,886 feet		
Alluvial deposits:		
Silt, yellowish-brown.	8	8
Silt, yellowish-brown; contains gravel	5	13
Silt, yellowish-brown.	5	18
Niobrara Formation:		
Shale, gray.	2	20

	Thickness (feet)	Depth (feet)
SC22-65- 1AAA. Altitude, 4,870 feet		
Alluvial deposits:		
Silt, yellowish-brown	3	3
Gravel	5	8
Cobbles	7	15
SC22-65- 2AAD. Altitude, 4,916 feet		
Alluvial deposits:		
Silt, yellowish-brown	3	3
Silt, yellowish-brown; contains gravel	5	8
Silt, clayey, yellowish-brown	5	13
Silt, yellowish-brown; contains gravel	5	18
Silt, yellowish-brown	10	28
Niobrara Formation:		
Shale, gray	12	40
SC22-65- 2BAB. Altitude, 4,919 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	17	17
Silt, clayey, yellowish-brown	3	20
Niobrara Formation:		
Shale, gray	1	21
SC22-65- 3DCD. Altitude, 4,969 feet		
Roadfill	3	3
Alluvial deposits:		
Silt, yellowish-brown	9	12
Silt, yellowish-brown; contains gravel	13	25
Silt, brown; contains gypsum	10	35
Niobrara Formation:		
Shale, gray	5	40

	Thickness (feet)	Depth (feet)
SC22-65- 4BAA. Altitude, 4,976 feet		
Alluvial deposits:		
Silt, clayey, dark-yellowish-brown	6	6
Silt, yellowish-brown; contains gravel	3	9
Silt, yellowish-brown.	5	14
Silt, yellowish-brown; contains gravel	8	22
Niobrara Formation:		
Shale, gray.	2	24
SC22-65- 4CAB. Altitude, 4,973 feet		
Alluvial deposits:		
Silt, dark-yellowish-brown	10	10
Silt, sandy, yellowish-brown	3	13
Niobrara Formation:		
Shale, grayish-brown	1	14
SC22-65- 4DCB. Altitude, 4,966 feet		
Alluvial deposits:		
Sand, silty, yellowish-brown	8	8
Sand, silty, yellowish-brown; contains gravel. .	5	13
Silt, yellowish-brown.	3	16
Niobrara Formation:		
Shale, gray.	9	25
SC22-65- 5AAA. Altitude, 5,010 feet		
Alluvial deposits:		
Silt, yellowish-brown.	10	10
Silt, yellowish-brown; contains gravel	10	20
Silt, yellowish-brown.	4	24
Niobrara Formation:		
Shale, gray.	9	33

	Thickness (feet)	Depth (feet)
SC22-65- 5CAB. Altitude, 5,020 feet		
Alluvial deposits:		
Silt, yellowish-brown.	12	12
Silt, brown; contains gravel	5	17
Silt, clayey, brown.	8	25
Niobrara Formation:		
Shale, dark-gray	4	29
SC22-65- 5DCB. Altitude, 5,029 feet		
Alluvial deposits:		
Sand, silty, yellowish-brown	3	3
Sand, yellowish-brown; contains gravel	2	5
Sand, yellowish-brown.	3	8
Sand, yellowish-brown; contains gravel	5	13
Silt, yellowish-brown; contains traces of gravel	14	27
Niobrara Formation:		
Shale, gray.	2	29
SC22-65- 6CAD. Altitude, 5,057 feet		
Alluvial deposits:		
Silt, yellowish-brown.	16	16
Silt, brownish-yellow; contains gravel	3	19
Niobrara Formation:		
Shale, dark-gray	6	25
SC22-65- 7ADD. Altitude, 5,073 feet		
Alluvial deposits:		
Silt, sandy, yellowish-brown	13	13
Silt, clayey, yellowish-brown.	15	28
Niobrara Formation:		
Shale, gray.	2	30

	Thickness (feet)	Depth (feet)
SC22-65-11ABB. Altitude, 4,962 feet		
Alluvial deposits:		
Silt, brown.	13	13
Silt, clayey, yellowish-brown.	5	18
Silt, yellowish-brown; contains gravel	5	23
Niobrara Formation:		
Shale, gray.	2	25
SC22-66-12ABC. Altitude, 5,115 feet		
Alluvial deposits:		
Silt, yellowish-brown; contains gravel	10	10
Gravel, silty, gray.	8	18
Niobrara Formation:		
Shale, gray.	3	21

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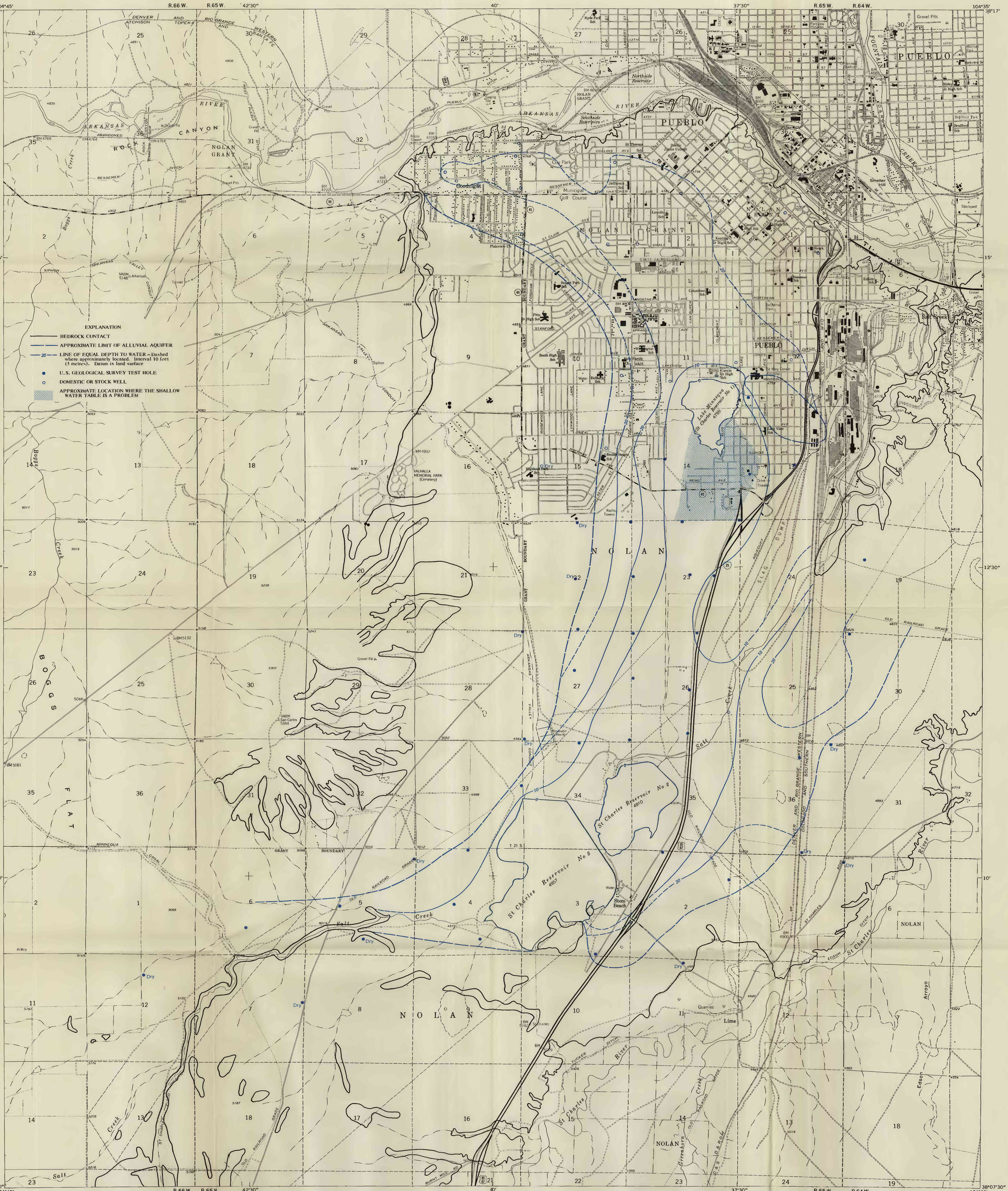
MAP SHOWING THICKNESS OF ALLUVIUM NEAR LAKE MINNEQUA, PUEBLO, COLORADO

U.S. GOVERNMENT PRINTING OFFICE: 1976-677-640/91

Prepared in cooperation with the
CITY OF PUEBLO

MAP SHOWING CONFIGURATION OF THE BEDROCK SURFACE NEAR LAKE MINNEQUA, PUEBLO, COLORADO

MAP SHOWING CONFIGURATION OF THE WATER TABLE IN THE ALLUVIAL AQUIFER, SPRING 1975, NEAR LAKE MINNEQUA, PUEBLO, COLORADO



Base from U. S. Geological Survey Northwest Pueblo, Northeast Pueblo Southwest Pueblo, 1961, and Southeast Pueblo, 1960. Photorevised 1970

MAP SHOWING DEPTH TO WATER IN THE ALLUVIAL AQUIFER, SPRING 1975, NEAR LAKE MINNEQUA, PUEBLO, COLORADO

MAP SHOWING SPECIFIC CONDUCTANCE OF THE WATER IN THE ALLUVIAL AQUIFER, SUMMER AND FALL 1974, NEAR LAKE MINNEQUA, PUEBLO, COLORADO