HYDROGEOLOGY OF THE BASINS ENCOMPASSING THE MARICOPA SUPERCONDUCTING SUPER COLLIDER SITE

by

Steven J. Brooks*

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Arizona Geological Survey
416 W. Congress, Suite #100, Tucson, Arizona 85701

Prepared in Cooperation with the Arizona SSC Project
1317 E. Speedway Blvd. Tucson, AZ 85719

**Dept. of Hydrology and Water Resources*
College of Engineering and Mines
The University of Arizona

INTRODUCTION

In 1983 the State of Arizona began an investigation to locate possible Arizona sites for the U.S. Department of Energy's (DOE) Superconducting Super Collider (SSC). Briefly, the SSC is a proton-antiproton particle accelerator consisting of five components (1) an injector complex of four cascaded accelerators which include a 500 foot linear accelerator and three circular synchrotron accelerators up to four miles in circumference; (2) a 52.8 mile collider ring with an inner diameter of 10 feet; (3) experimental areas containing the collision halls and particle detectors; (4) campus/laboratory areas; and (5) site infrastructure consisting of roads and utilities. Of the many criteria outlined for site evaluation by the DOE, the greatest weight was given to geology and tunneling and its impact upon construction and operational costs. An important aspect of the geologic criteria is the surface and subsurface hydrology.

The initial screening of more than 30 possible sites in Arizona was based largely on geological, hydrological and environmental criteria. The number of sites was reduced to seven when demographics (i.e. access, cultural and educational resources, etc.) were considered. Of these seven sites, two were found to stand out, the Sierrita Site, approximately 30 miles southwest of Tucson, and the Maricopa Site, approximately 35 miles southwest of Phoenix.

Purpose and Scope

Thorough and accurate descriptions of both the ground-water hydrology and surface-water hydrology are vital aspects of choosing the best site for the SSC. Ground- and surface-water hydrology are important parameters in estimating project construction costs, scheduling, and long-term operational costs. In addition, they are key components in the preparation of the Environmental Impact Statement (EIS) necessary to comply with the National Environmental Policy Act (NEPA). This paper is part of a larger report discussing the hydrological regime of the Maricopa SSC Site (Brooks, 1988).

A thorough literature review discovered little hydrologic information for the Maricopa SSC site, and money for the acquisition of new, site-specific hydrologic data was not available. Primary sources of informatiom used were 1) past geologic studies and recent geologic mapping done in conjunction with the SSC project; 2) drill-hole information gathered during geotechnical investigations; 2) 3) recently obtained geophysical data which includes seismic refraction, electrical resistivity, and a large gravity data base; and 4) remote sensing information from aerial photography and Landsat Multispectral Scanning images. An integration of the information obtained from all of these disciplines should provide an adequate description of the Maricopa site hydrogeology.

Description of Study Area

The Maricopa SSC site is in the southern Basin and Range Province. The area is characterized by large alluvium-filled basins separated by north-northwest trending mountain ranges. The site is located within three U. S. Geological Survey (USGS) hydrological basins, the Gila Bend basin, the Waterman Wash basin, and the Northern Vekol Valley basin (Figure 1). The Gila Bend basin has been subdivided, and the southwestern and western sections of the site actually traverse the Bosque sub-basin.

The basins trend north-northwest, hydrogeologically separated by mountains or shallow bedrock. Most of the ground water pumped from these basins is used for agriculture with minor amounts for industrial and domestic use. Current uses include water-intensive agriculture in the northern Waterman Wash basin and to the west along the Gila River, and low volume livestock and domestic wells, elsewhere. Future ground-water development in the Gila Bend and Waterman Wash basins will probably decrease because of an anticipated decline in agriculture, the great depths to ground water which make pumping costs uneconomical, and the overall fair to poor quality of the water. Vekol Valley is essentially undeveloped, with only scattered domestic and livestock wells withdrawing water. Within and around the proposed site area very little groundwater extraction occurs.

Well-Numbering System

The well numbers used in this paper follow numbering which is based on land subdivision and is the same system as is used by the Arizona Department of Water Resources and the Water Resources Division of the U.S. Geological Survey. The land survey in Arizona starts at the Gila and Salt River meridian and base line respectively, which divide the State into four quadrants (Figure 2). All the well locations mentioned in this thesis are in the southwest quadrant (C) or the southeast quadrant (D) of the state. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The first letter denotes a particular 160-acre tract or 1/4 section the second the 40-acre tract, and the third the 10-acre tract.

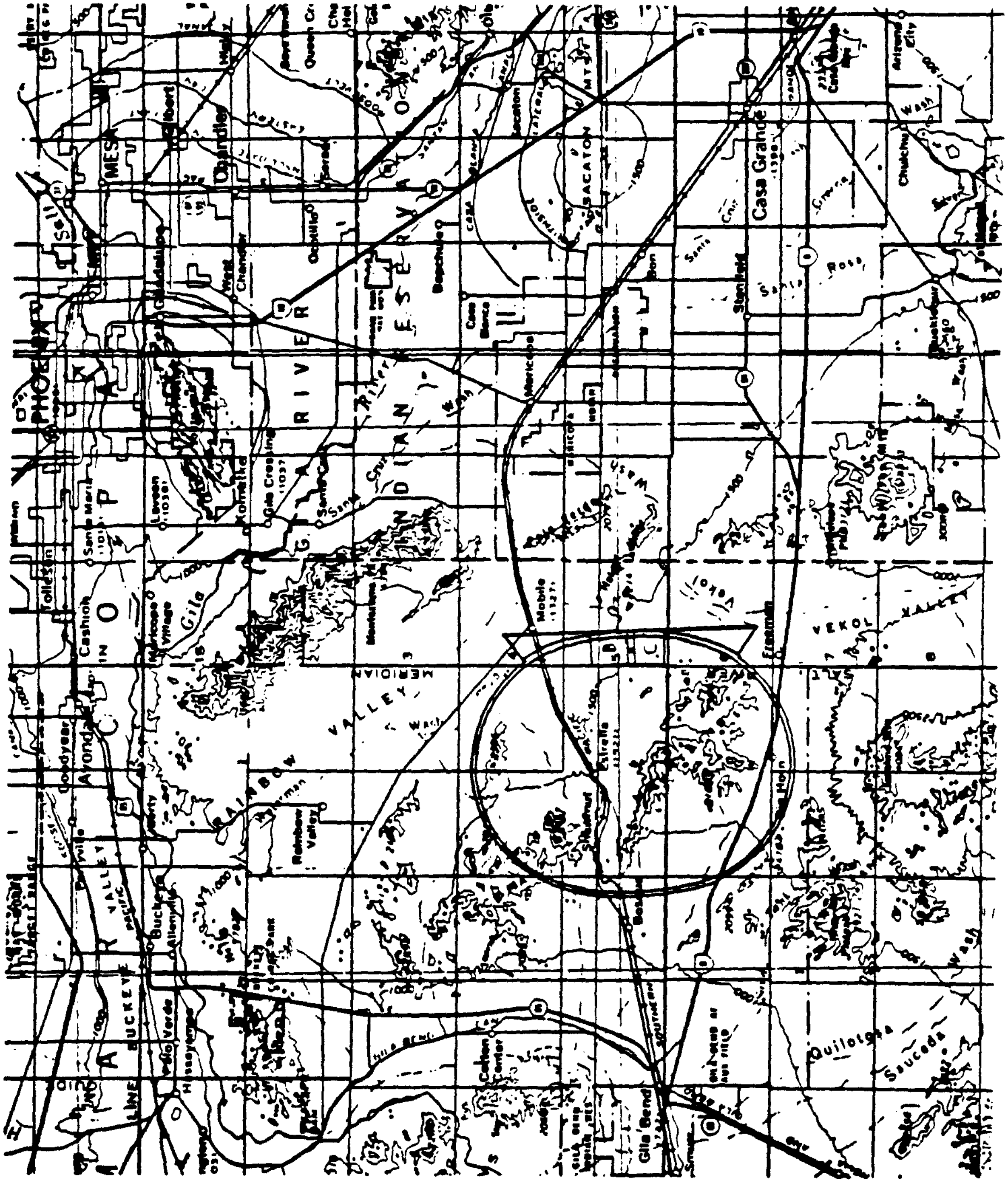


Figure 1. Regional Location Map

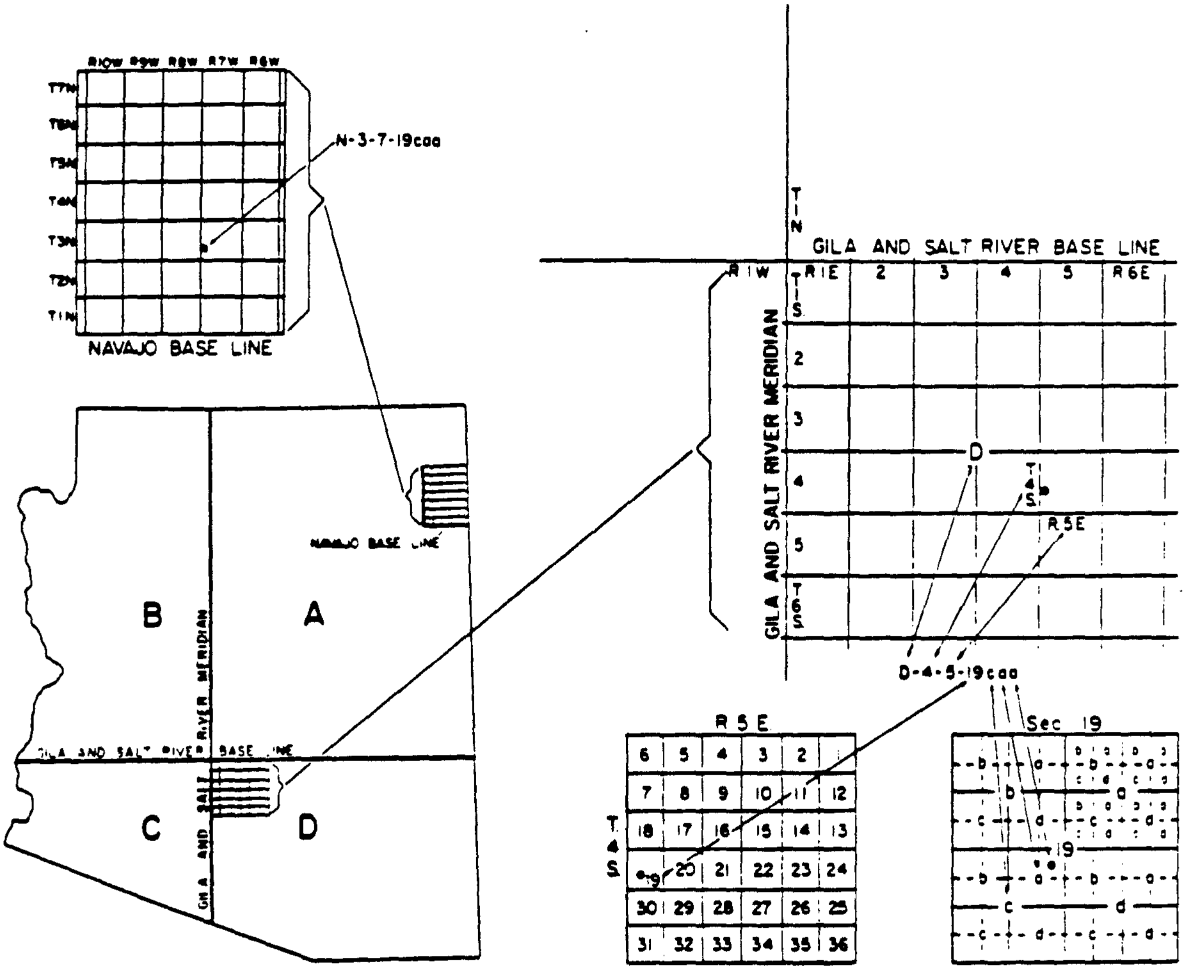


Figure 2. Well and spring location system used in this report

HYDROGEOLOGY

Preliminary information suggests that the entire tunnel will be above the regional water table. A cross-section showing the tunnel in relation to the topography, water table, and bedrock-alluvial contact is shown in Figure 3. The arid climate, deep water table, and remote, uninhabited location suggest a hydrologically ideal site for construction of the SSC. However, these same attributes complicate the identification and securing of an adequate water supply for the operational phase. The lack of site-specific data places an uncertainty on the assumptions of hydrologic simplicity and lack of ground water-related construction problems. A multidisciplinary approach was used to test the above-mentioned assumptions. This approach combined available hydrologic information with a thorough understanding of the site geology reinforced by a program of surface geophysics.

A fundamental assumption is that certain aquifer properties and flow system processes are common to many southwestern basins in the United States and that hydrogeological similarities may be assumed, so that properties and processes estimated from well documented basins may be extrapolated to those basins with sparse data. This was the approach taken by the U.S. Geological Survey (USGS) in their Regional Aquifer-System Analysis (RASA) Program to study the Nation's ground water on a regional scale.

The geology of the alluvium is paramount in describing basin and range aquifer systems. Therefore, particular attention was paid to interpreting the geologic history and depositional processes that formed the basin in question. This was accomplished using a detailed literature review, drillers logs, and information obtained from the Arizona SSC Project geotechnical exploration programs.

Bedrock Hydrogeology

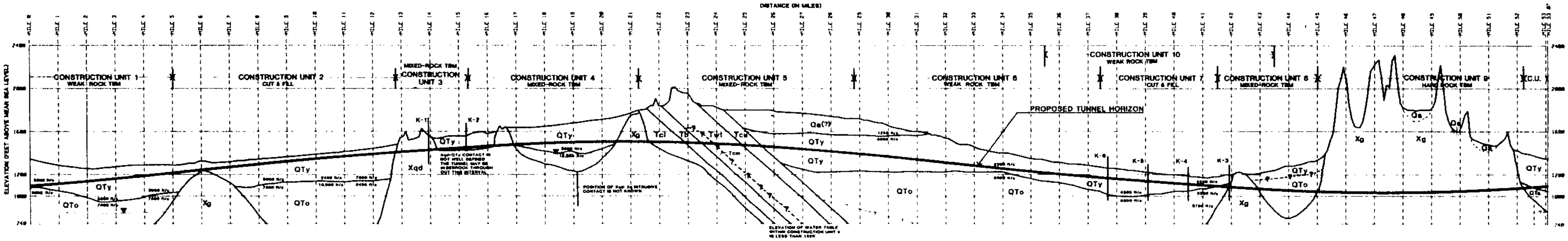
The bedrock present at the Maricopa site does not constitute an important source of ground water. As a result, very little is known about its hydrologic properties. Where fractured, these rocks may yield small amounts of water. However, deep water levels in adjacent basins combined with the minimal precipitation and high evaporation rates suggest that large volumes of water are unlikely in the hardrock. The igneous rocks which comprise much of the site bedrock, typically have greatly reduced porosity and permeability with increasing depth.

Alluvial Hydrogeology

The alluvial basins of south-central Arizona constitute a major source of ground water and are relied upon extensively for agricultural, industrial, and public water supplies. In comparison with the adjacent and heavily exploited Salt River Valley and Lower Santa Cruz ground-water basins, the basins traversed by the Maricopa SSC site are relatively undeveloped. Each basin is discussed below.

Waterman Wash Basin.

Drillhole data show the Waterman Wash basin to be underlain by as much as 1800 feet of basin-fill deposits. The basin-fill has been divided into two distinct units based on the results of two deep exploratory wells and numerous water wells (Wilson, 1979). The upper unit is approximately 800 feet thick where drilled in the center of the basin and thickens to the northwest, away from the Maricopa site. The unit is unconsolidated sandy clay to sand and gravel, and generally contains more gravel in the northwestern part, and more clay and



Qa	QUATERNARY ALLUVIUM
QTy	QUATERNARY - TERTIARY YOUNGER FANGLOMERATE LOWER SEISMIC VELOCITIES THAN QTo
QTo	QUATERNARY - TERTIARY OLDER FANGLOMERATE NOTE: SEISMIC VELOCITY MEASURED IN FEET PER SECOND
Tcu	TERTIARY, POLYLITHOLOGIC UPPER CONGLOMERATE
Twt	TERTIARY, WELDED ASH-FLOW TUFF
Tcm	TERTIARY, BASEMENT-CLAST MIDDLE CONGLOMERATE
Tb	TERTIARY, BASALT FLOWS
Tcl	TERTIARY, GRANITIC-CLAST LOWER CONGLOMERATE
Xqd	PROTEROZOIC, BOOTH HILLS QUARTZ DIORITE
Xg	PROTEROZOIC, PORPHYRITIC GRANITE

———	CONTACT
-?--?--	INFERRED CONTACT
▼	WATER TABLE
	INFERRED WATER TABLE

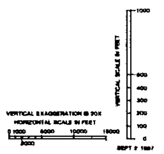


FIGURE 3-5
GEOLOGIC PROFILE
MARICOPA SITE
STATE OF ARIZONA SSC PROJECT

silt in the central part. The lower unit is as thick as 1,000 feet and consists of poorly to moderately consolidated coarse sandy gravel to sand and gravel that contains small amounts of silt and clay (Wilson, 1979). The lower unit is distinguished by its texture, difference in borehole geophysical responses including higher density, lower porosity, increased sonic velocity, generally higher resistivity, and a decreased rate of penetration during drilling (Wilson, 1979).

The basin aquifer is generally under water-table conditions but confined conditions may exist locally because of silt and clay lenses. The general flow of ground water is from southeast to northwest toward a cone of depression that has formed in response to ground-water withdrawal in a large irrigated area centered around C-2-2. The water table slopes towards this cone of depression at about 30 feet per mile in the northwest, decreasing to about 15 feet per mile in the southeast.

Irrigated agriculture began in 1951 but not extensively until 1955. Based on available pumping records and assuming 2000 acre-feet of recharge per year (White, 1963) approximately 1.75 million acre-feet (MAF) of water has been removed from storage since 1951. In 1979 it was estimated that 10.3 MAF of water was in storage to a depth of 1000 feet below the water table (Wilson, 1979). Therefore, approximately 9.7 MAF of water remain in storage. These values are computed assuming a specific yield of 0.10. White (1963) considered this conservatively low, therefore, estimates of water resources may likewise be considered low.

Analysis of deep water wells and USGS exploration holes indicates a gradual shallowing of basin fill of approximately 75 feet per mile moving to the south (White, 1963 and Wilson, 1979). The depths to bedrock and the gradual shallowing of alluvium to the south do not appear to be in accord with gravity data (Oppenheimer and Sumner, 1980; Sternberg and Sutter, 1986) and drillhole data (Manera, 1982).

Aquifer Properties. An obvious problem in using geologic assumptions to extrapolate aquifer characteristics in southwestern alluvial basins is that the type of sediments and their depositional geometries can be complex and difficult to predict. Many sedimentary deposits found in desert basins are as discontinuous sheets and lenses that are commonly more extensive in a down-dip direction than in the strike direction. This small-scale complexity is compounded by the variability of larger scale factors such as the rate of tectonic uplift. Therefore, aquifer properties derived from drillhole lithologies and aquifer tests can often be very localized; however, because the water table is expected to be below all SSC structures and the project water supply will come from an off-site source the site-specific aquifer properties are not of major importance. Wells which penetrate the basin-fill aquifer yield from 500 gallons per minute (gpm) to more than 2,500 gpm of water (Wilson, 1979 and ADWR, 1987). The specific capacity is estimated at between 15 to 74 gpm/ft (White, 1963).

The transmissivity of the upper unit ranges from 4,500 square feet per day (ft^2/day) to 13,000 ft^2/day and average about 8,000 ft^2/day (White, 1963). The transmissivity from a test well which penetrates the lower unit in the central portion of the basin was 11,000 ft^2/day (Wilson, 1979). The porosity of the basin-fill aquifer ranges from 8 to 20 percent. The specific yield is given a range of 0.05 to 0.20 with an average of 0.12 (White, 1963).

As previously mentioned, the importance of the Waterman Wash basin aquifer is more for its water resources and not its specific aquifer properties. However, the threat of future land surface subsidence resulting from ground-water withdrawal is considered a potential problem from pumping in the the Waterman Wash agricultural areas. Therefore, knowledge of aquifer characteristics is necessary for the basin and crucial for the section of the collider from mile 0 to mile 6. This section of the tunnel lies in a western extension of the Waterman Wash basin with little aquifer information.

Where it traverses Waterman Wash basin, the SSC tunnel is at depths of 50 to about 300 feet below land surface. Therefore, it will be entirely in the upper unit. Test holes MD-7, MA-3, and MA-2, drilled near SSC mile posts 2.0, 5.0, and 8.5 (Figure 4), respectively, show the material at and above tunnel level to be essentially a dense clayey, silty sand with small (<3 ft.) interbeds of clean sand. Undisturbed samples were obtained from MA-3 using a specialized CME sampling device. Permeability tests conducted on these samples at the University of Arizona, Department of Civil Engineering, Soil Mechanics Laboratory indicated permeabilities on the order of 1.5×10^{-4} cm/sec (DeNatale and Nowatzki, 1987).

MD-7, a reverse circulation air-rotary hole one mile north of SSC milepost 3 was drilled to a depth of 655 feet. Ground water was found at a depth of 396 feet in a visually described well-graded, subangular, moderately cemented fine to medium sand, which graded into a medium to coarse sand to sand and fine gravel with minor amounts of silt at about 495 feet. The transmissivity of the deeper material is estimated at 10,000 to 15,000 ft^2/day based on aquifer tests run on wells with similar lithologies elsewhere in the basin. The lithologic log of this well agrees closely with a 1,175 foot well two miles northeast (C-3-1 21dcc) indicating some continuity in the alluvial properties. The 1,175-ft well has a reported maximum pumping yield of 3000 gpm. Seismic refaction and d.c. resistivity geophysical work conducted one mile north of MD-7 showed similar layering but at different depths depending on the interpretation of the data. This discrepancy may be the result of rapid horizontal changes common in alluvial depositional environments or the non-uniqueness of the geophysical interpretation. Both, are evidence of the necessity for adequate geologic information to accurately utilize surface geophysical data.

Further west, the aquifer material is expected to remain coarse, because of its closer proximity to the mountain front, but the aquifer thickness should thin gradually because inselbergs and low-lying bedrock knobs identify the area as a pediment. This was confirmed by seismic refraction line (DST510SN) near SSC milepost 51.0. At a depth of 75 feet, a layer with a seismic velocity of 14,400 ft/s with a north-sloping surface was identified (Sternberg and Esher, 1987).

Moving south, the SSC tunnel enters a portion of the Waterman Wash basin called the Mobile Valley. Hydrologic conditions in the valley were investigated by Manera (1982) for a proposed oil refinery south of Mobile. Manera (1982) describes the material in a 1500-foot well in D-4-1 28aaa as 210 feet of silty sand underlain by 780 feet of sand and gravel followed by 510 feet of alternating sequences of coarse sand and sand and gravel. This description is similar to that of MD-7, 7.5 miles to the northwest. Interestingly, although the litho-

Wilson, R. P., 1979. Availability of ground water on federal land near the Ak-Chin Indian Reservation, Arizona. A reconnaissance study. USGS Open File Report 79-1165.

Figure 4 Data Sources Map (In back)

logic logs show no major change between 210 to 990 feet, downhole normal resistivty and neutron logs show a major change in alluvial properties at 610 feet (Manera, 1982). A similar discrepancy was also found near MD-7 where seismic refraction data indicated a velocity increase of 3100 ft/s at around 600 feet yet drilling showed no apparent lithologic change.

Results of aquifer tests by Manera (1982) in the Mobile Valley give a range for transmissivity of 500 to 2,000 ft^2/day with a mean of 800 ft^2/day. Based on available drilling data the lower transmissivity appears to be the result of poor sorting in the material. Maximum well yields in and around Mobile are reported to be about 300 gpm. One well in D-4-1 sec. 28 was able to discharge 610 gpm (Manera, 1982). On the eastern side of the Palo Verde Mountains, about seven miles east of Mobile, well yields of 2,000 to 3,000 gpm are reported (ADWR, 1987).

The aquifer properties of the basin-fill within the interior of the ring, from SSC milepost 4 to milepost 13, are essentially unknown. The only hydrologic and lithologic information comes from site characterization, currently underway by Water Resources Associates, of the Arizona Hazardous Waste Facility located in C-4-1 sec. 32. Available data consist of deep rotary drillholes and extensive grids of d.c. resistivity and gravity data. Drill cuttings show a completely different depositional environment than those interpreted from any of the SSC drillholes. Throughout the site, the alluvial sediments are predominantly clay, with thin lenses of varying percentages of sand and gravel. The high percentage of clay and almost total lack of coarse material suggest that at some time in the past the area was a separate basin with internal drainage. Drilling at the site detected a thin layer of rhyolite(?) near the presumed alluvium/bedrock interface (Jones, pers. commun., 1987). Similar occurrences are reported in lithologic descriptions given of deep wells in northern Waterman Wash basin (White, 1963). The subsurface hydrologic system is interpreted to be an unconfined aquitard and water-level measurements indicate the ground-water system to be hydraulically connected with the rest of Waterman Wash basin.

<u>Ground Water Levels and Fluctuations</u>. Within the main part of the valley the depth to ground water ranges from about 110 feet in the far northwest to more than 400 feet near Mobile and along the base of the Sierra Estrella. In the western sub-basin, in which the SSC lies, depth to water of 525 feet has been reported at the Arizona Hazardous Waste Facility in C-4-1 sec. 32.

Since 1951, water-level declines range from about 15 feet near the town of Mobile (approximately 1.5 miles east of mile point 8.5) to more than 200 feet in the heavily irrigated area in northern Rainbow Valley. Currently about 65,000 acre-feet per year of ground water is pumped for irrigation. The area is now a part of the Phoenix Active Management Area (AMA) and as such, further ground water development for the purpose of agriculture is not allowed.

Seasonally, ground-water levels around the entire site remain very consistent because of the absence of large-scale pumping and the negligible aquifer recharge. Large fluctuations, in southern Arizona, are seen only in areas of agricultural irrigation where heavy pumping occurs or beneath major streams after a large flow event. There is no agriculture within the site area and Waterman Wash is dry for approximately 350 days per year. No operating wells are currently within the site area. Outside of the site area approximately 13,000 acres are under cultivation in northwestern Waterman Wash basin. Here, pumping for agricultural irrigation has created a cone of depression of approximately 50 mi^2. Water table declines of more than 150 feet have occurred in an 18 mi^2 area since 1950. A smaller area of agriculture, about 1,800 acres, is three to five miles northeast of the site. Available water level and pumpage data indicate little ground-water decline in the site area caused by pumping in these outside agricultural areas. Although over ninety percent of the ground water withdrawal in the three basins is for agriculture, the irrigated areas, which are the centers of pumping, are all at least 10 miles from the SSC site.

Ground-water Recharge. Very little natural recharge occurs because the low annual precipitation and the great depth to the water table. White (1963) estimated recharge at about 2,000 acre-feet per year, with this being virtually all mountain front or stream channel recharge.

Ground Water Potential. Except for the north-central part of the basin, the ground-water resources of the area are not developed extensively. Most of the land is administered by federal or state agencies. Recoverable ground-water resources are large in the central and southern portions of the basin. However, the depth to water in this area ranges from 300 to 500 feet below land surface. Also, if the SSC comes to the Maricopa Site, ground-water withdrawal around the site can be controlled so as to remove any possibility of subsidence due to ground-water overdraft.

Vekol Valley

Although the SSC tunnel traverses only 6 to 7 miles in the northwest corner of Vekol Valley it is an important basin because of its potential as a source of water for the project.

The Vekol Valley ground water basin is hydrologically separated into a northern and a southern part by a bedrock ridge of crystalline rocks. Only the northern valley is being considered for ground-water development. The northern part, in which the SSC lies, is about 90 square miles in area.

The northern basin is filled with as much as 3000 feet of basin sediments. These basin sediments can crudely be divided roughly into two geohydrologic units; a relatively unconsolidated gravelly sand underlain by a moderately to well-consolidated silt, sand, and pebble conglomerate (Cuff, 1984). The thickness of these units varies within the basin. A U.S. Geological Survey test hole drilled in the late seventies at D-7-1 10cbc penetrated 1,208 feet of gravelly sand followed by 700 feet of silty, gravelly sand.

Aquifer Properties. Hollett and Marie (1987) described four units in the northern Vekol Valley aquifer system. The upper two units are unconsolidated alluviul-fan, stream channel, and flood plain deposits. A discontinuous silty sand bed forms the base of unit 1 and acts as a confining bed to unit 2. Unit 3, present only in the northern two-thirds of the basin, is a moderately to well-consolidated conglomerate. Where it exists unit 3 acts as a confining bed to unit 4. Unit 4 consists of discontinuous lenses of moderately consolidated to unconsolidated silty sand and sand with intercalated lenses of conglomerate.

Unit 4 lies on a well-consolidated conglomerate at depths ranging from about 1,300 feet to about 1,600 feet. The hydraulic conductivity of this conglomerate is much lower than that of any of the upper four units and so for the purpose of aquifer-system modeling it represented the base of the aquifer system. Ground water in unit 1 is under unconfined conditions, whereas ground water in units 2, 3, and 4 is under confined conditions.

The lateral extent of these four units is controlled by major blocks of faulted igneous and sedimentary rocks. Within the valley, these faults offset the various aquifer units in a stepped configuration creating non-uniform depths of saturated material.

Because of the wide variability in saturated thickness, the ability of the different units to transmit water are discussed in terms of hydraulic conductivity rather than transmissivity. Transmissivity values will only be given for D-4-1 Sec. 10, which is the location of the proposed SSC well field. The hydraulic conductivity values were calculated from transmissivities determined from multi-observation well aquifer tests conducted by the USGS (Hollett and Marie, 1987). To obtain hydraulic conductivity the transmissivity was divided by the saturated thickness of each unit in the aquifer system. The saturated thicknesses were determined from geologic analyses of drill-hole cores and cuttings and borehole-geophysical logs. The hydraulic conductivity ranged from 35 to 50 ft/day for unit 1, 8 to 16 ft/day for unit 2, 1 to 2 ft/day for unit 3, and 5 to 6 ft/day for unit 4. Estimates of storage coefficient and specific yield were also determined from the aquifer tests (Table 1).

The transmissivities of the four aquifer-units within the proposed SSC well field in D-4-1 Sec. 10 were estimated using saturated thickness contour maps and geologic cross-sections along with the hydraulic conductivity values from Hollett and Marie (1987). The transmissivity of unit 1 is estimated at 10,500 to 15,000 ft^2/day, unit 2 at 1,800 to 3,600 ft^2/day, unit 3 at 300 to 600 ft^2/day, and unit 4 at 1,000 to 1,200 ft^2/day.

Ground-water Levels and Fluctuations. Measured depth to ground water in the basin sediments ranges from 150 feet, near the subsurface exit east of the Booth Hills, to over 400 feet in the southern part of the basin. Depth to water where the SSC crosses the basin has been approximated at 240 to 350 feet. The tunnel in this area is at depths of 150 to 225 feet and will be above

Table 1

Average storage properties of units 1-4 at wells V-5, NV-5, NV-6, and NV-7

Unit	Specific yield	Storage coefficent	Specific storage
1	0.12	-----------	--------
2	[1]0.08	2.0×10^{-3} to 8.1×10^{-5}	2.7×10^{-6}
3	-----	4.4×10^{-5} to 4.4×10^{-6}	2.2×10^{-7}
4	-----	2.0×10^{-4} to 6.0×10^{-5}	5.5×10^{-7}

from Hollett and Marie (1987)

[1] Unit 2 converts to unconfined conditions when water level is drawn down below the top of the unit.

the water table at all locations. The aquifer system in northern Vekol Valley is considered to be in steady-state (Hollett and Marie, 1987). As of 1983 there were about 15 domestic and livestock wells. Withdrawals from these wells are probably less than 50 acre-ft/yr.

Ground-water Recharge. Hollett and Marie (1987) estimated mountain front recharge in the northern Vekol Valley to be about 1200 acre-ft/yr. A smaller amount of recharge also occurs from infiltrated runoff in Vekol Wash and its tributaries. On the basis of infiltration tests in the valley, recharge to the aquifer from Vekol Wash is estimated to be 10 percent of the total recharge (Hollett and Marie, 1987).

Ground-water Potential. Ground water is generally in unconfined conditions with small, locally confined conditions possible. Ground-water movement is from the south to north, exiting the valley east of the Booth Hills. Cuff (1984) suggested that properly constructed and developed wells can yield as much as 2500 gpm and that specific capacities are as great as 87 gpm/ft. Recoverable water in storage is estimated at 375,000 acre-feet from 0 to 450 feet below the water table with an additional 1.6 million acre-feet from 500 to 1500 feet below the water table. The project demands of 4,000 acre-feet of water per year should not unduly stress the aquifer or affect other users in the valley. Work is currently underway estimating the potential drawdown due to SSC ground-water demands in northern Vekol Valley (Coggeshall and Brooks, in prep.).

Bosque (Gila Bend) Basin

The Gila Bend basin is a northwest-trending trough that has been filled with as much as 3,000 feet of basin-fill deposits. Although the most developed of the three basins, the SSC is in the eastern, undeveloped portion of the Gila Bend Basin. This Gila Bend sub-basin is called the Bosque basin by Wilson (1979). The Bosque basin-fill deposits are divided into an upper, a middle, and a lower unit by Wilson (1979). The upper unit is 700-900 feet thick. It is composed of unconsolidated grayish-brown coarse to fine gravel, sand, silt and clay. The saturated thickness ranges from 100 feet to more than 500 feet. The middle unit is 800 to 1,450 feet thick. It is mainly unconsolidated to poorly consolidated grey-brown fine to very coarse sand and fine to coarse gravel. This unit overlies an erosion surface cut on the lower unit. The thickness of the lower unit is unknown. The unit consists of volcanic rocks interbedded with moderately to weakly cemented conglomerates. A USGS test hole, in C-6-3 2ada (one-half mile west of SSC milepost 38), was drilled to a depth of 1,149 feet. The material penetrated by the well consisted mainly of clayey silty sand (Wilson, 1979).

The land encompassing the Bosque basin is administered by the Bureau of Land Management (BLM) for the Federal Government. There are no plans to develop any water supplies in the Bosque Basin. Essentially all of the current and proposed future ground water development is along a narrow swath which straddles the Gila River and the areas around the town of Gila Bend. As a result, most of the following discussion will be about this area.

Aquifer Properties. The principal aquifer in the basin is composed of basin-fill deposits and is generally under water-table conditions. Confined conditions may exist locally because of silt and clay lenses. These are generally close to the present- day channel of the Gila River. The general flow of ground water is from the east-southeast to the west-northwest in response to a cone of depression developed along the Gila Bend Canal. Wells which penetrate the upper and middle units yield more than 2,000 gpm of water. The potential specific capacity varies from 3 gpm/ft in the southeast to 60 gpm/ft along the Gila Bend Canal.

Transmissivities near the Gila River range from about 8000 ft^2/day to almost 27,000 ft^2/day (Wilson, 1979). Closer to the SSC site, the USGS well near milepost 38 was pumped at 150 gpm for 2 hours and had a drawdown of 150 feet. Aquifer-test data indicate that the transmissivity of the upper and middle units is about 800 ft^2/day (Wilson, 1979). This is much lower than was expected and may not be representative of the entire region (Wilson, pers. commun., 1986). Poor sorting of the aquifer material is the apparrent reason for the low yields.

Based on drill cuttings and borehole geophysical logs the porosity of the basin-fill aquifer is estimated at 8 to 20 percent. The specific yield has been conservatively estimated at 0.10. These data were used to determine the quantity of recoverable ground water in storage in the aquifer. In 1979, it was estimated that the Bosque sub-basin has 3.6 million acre-feet of recoverable ground water in storage in the upper and middle units (Wilson, 1979).

<u>Ground-water Levels and Fluctuations</u>. There has been minimal ground-water extraction from the Bosque basin. Prior pumping has been restricted to low-volume livestock wells. Ground-water depths below the SSC alignment are

estimated to be greater than 500 feet.

The low precipitation and generally low permeability of the surface deposits indicate that aquifer recharge is negligible. Therefore, any fluctuations in ground-water levels are from pumping in the Gila Bend area nine miles to the west. The Gila Bend area has experienced historically only moderate ground-water decline, therefore, the area below the SSC has probably experienced very little ground-water decline.

Ground-Water Recharge. Very little aquifer recharge occurs from direct precipitation. The low annual precipitation combined with the high evapotranspiration rates effectively inhibit the infiltration of most surface water. Most of the annual recharge can be attributed to percolation of excess irrigation water. Another major, but irregular, source of recharge is from streamflow in the Gila River. Although totally controlled by upstream diversions, occasionally during "wet" years the Gila River and it's major tributary the Salt River can flow from a few days to weeks, providing a large source of recharge.

Ground-Water Potential. The area along the Gila River, from Cotton Center south to Gila Bend is a most attractive source for ground water. Despite the current large withdrawals, static water levels are generally less than 200 feet below land surface and are generally very stable, having experienced no significant historical decline. Wells in the area are highly productive. The quality of the water is considered fair to poor by Arizona Department of Health Services (ADHS) standards as total dissolved solids and fluoride concentrations of the ground water are higher than recommended for domestic use. This area is not currently being considered as a source of water for the project because of it's poor quality and higher conveyance costs.

Perched Water

Perched water is known to exist in numerous areas in southern Arizona, but it is most common in heavily irrigated areas where a constant source of recharge is available. There is no agriculture within the Maricopa Site boundaries. Although the presence of clays at the hazardous waste site suggest a possibility for perched water, the available information shows no indication of it. Eight alluvial drill-holes ranging in depth from 70 to 655 feet were spaced around the site perimeter. No saturated or even near-saturated zones were detected other than the regional unconfined water table. This conclusion was confirmed with borehole geophysics. Analysis of aerial photographs of the site show no abnormally vegetated areas that would indicate near-surface perching of water. These findings, along with low precipitation, high evapotranspiration, and the low permeability of the surface soils indicate that perched water is probably unlikely if not absent entirely at the Maricopa Site. Minor amounts of perched water may be found at shallow bedrock-alluvium contacts.

Ground-water Rate

Using the formula for average velocity of hydraulic conductivity times hydraulic gradient divided by porosity, a ground-water velocity of between 135 and 185 ft/yr was estimated for near the town of Mobile (Draft EIS, 1983). This velocity should be representative of the ground-water flow rate around most of the ring, from SSC milepost 52 clockwise to milepost 12. Elsewhere,not enough data is available to confidently estimate the ground-water velocity.

Conclusion

The Maricopa SSC Site is apparently devoid of any ground water-related construction problems. Available data suggest that the entire tunnel and its associated facilities will be above the regional water table and that the possibility for perched water of any consequence is remote.

Little site-specific data exists on the aquifer properties at the site. However, based on data from other areas in the basins and data from similar type basins elsewhere, a range of values can be given with a fairly high degree of confidence. The basin aquifers are generally under water-table conditions but confined conditions may exist locally because of silt and clay lenses. Aquifer transmissivities can range from approximately 800 ft^2/day to 15,000 ft^2/day depending upon location and depth in the basin. Although more compacted and better cemented, the deeper deposits are generally coarser-grained with very little fine material present. Thus, transmissivity values tend to be higher on average. The specific yield ranges from 8 percent to over 20 percent.

Although the vertical and lateral heterogeneities in alluvial deposits make estimation of aquifer properties difficult, the absence of any interaction between site facilities and the water table, and the fact that no on-site pumping is currently occurring or is expected to occurr in the future, suggest that knowledge of site-specific detailed aquifer properties are unnecessary for the construction phase of the project.

A relatively undeveloped yet well-studied reservoir of good quality ground water lies southeast of the site in the largely federally owned northern Vekol Valley. Estimated recoverable reserves, to a depth of 450 feet below the water table, of 375,000 acre-feet of ground water more than satisfy the relatively minor project needs of 4,000 acre-feet per year. Preliminary modeling results indicate maximum drawdowns of about two feet per year at the wells proposed to be pumped for the SSC project.

The new ground-water code requires intensive ground-water management and prohibits expansion of ground water-irrigated agricultural acreage within AMA's. Certain very limited exceptions (regarding mining, industry, drainage, poor quality ground water, or temporary use) to this prohibition are provided for in the code, but in general, farm land in the Vekol Valley and Waterman Wash which is not currently irrigated cannot, under Arizona law, be developed in the future using ground-water sources. Therefore, future ground-water withdrawals around the site should reduce as agricultural land is converted to residential or industrial use. Reductions in water use of 33 to 66 percent are typical when this type of land use change occurs. Pumping within the ring should be nonexistant or at worst negligible depending on the water supply plans of the Arizona Hazardous Waste Site.

Recommendations

Although hydrologically the site is apparently ideal for construction of the SSC project, the paucity of data suggests that more detailed information is needed. A few well-placed drillholes along with additional seismic refraction work to better define the basin shapes and determine the depth to basement will greatly improve the confidence in the assumed conditions. In addition, the computer modeling of the northern Vekol Valley done by Hollett and Marie (1987) should be redone using the proposed SSC well locations and pumping requirements. Informed sources have all concluded that no technical or legal problems appear to be present in using northern Vekol Valley as a source of water but further work using the USGS developed model could greatly strengthen these conclusions. Further refinement is needed in estimating basin-wide water-table decline from SSC pumping and the natural recharge into northern Vekol Valley. Additional water quality sampling should be done in the Vekol Valley to provide a more reliable baseline to compare future water quality data with as the aquifer is dewatered. Depth-specific sampling could be done to estimate what future water quality might be.

As water supply is often a determining factor in growth and development in southern Arizona, better understanding of the regions water resources and the future of its water resources are needed to assess potential impacts on the SSC, particularly those related to ground subsidence due to ground-water withdrawal. Possible growth scenarios along with their respective water requirements should be incorporated into a ground-water/surface-water conjunctive-use management model to determine where and what growth will be compatible with the SSC.

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