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PALO VERDE

2000 Annual Groundwater Report
Palo Verde Nuclear Generating Station

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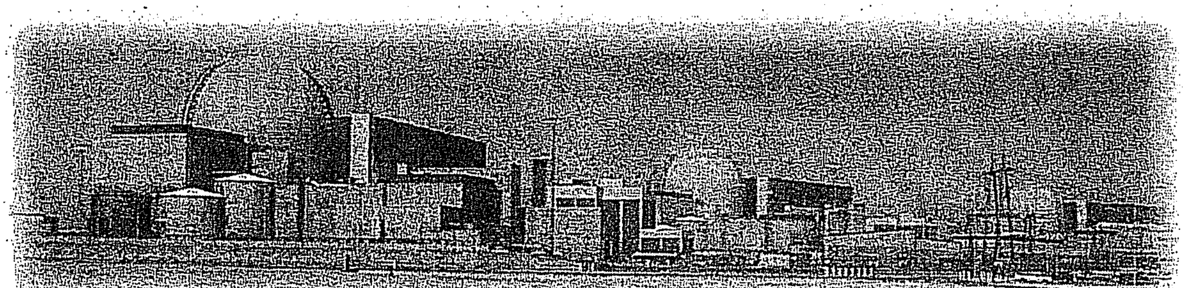
Prepared by:

Arizona Public Service Company
P.O. Box 52034
Mail Station 7626
Phoenix, Arizona 85072-2034



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1.0 INTRODUCTION

This report, for calendar year 2000, is the thirteenth annual report to be submitted per the requirements of Groundwater Quality Protection Permit (GQPP) No. G-0077-07. This permit was issued to the Palo Verde Nuclear Generating Station (PVNGS) by the Arizona Department of Environmental Quality (ADEQ) and became effective on August 21, 1988. This permit is in place pending processing of our application for an Aquifer Protection Permit.

The basic data utilized in preparation of this report were provided in 2000 quarterly reports submitted to ADEQ. These data are summarized in Appendices A through D. Several previous reports and basic data summaries were also utilized. Refer to the references provided in Section 5.0 for a listing of previous reports.

2.0 SITE OVERVIEW

2.1 Site Location, History and Area Land Use

PVNGS (the site) is located on approximately 4,000 acres of relatively flat desert terrain in the Hassayampa River valley about 50 miles west of downtown Phoenix, Arizona. The site is located within the Lower Hassayampa groundwater sub-basin. Much of the site was under cultivation as irrigated agriculture from about 1950 to 1975. Cotton was the principal crop grown on the site prior to the start of power plant construction in 1976. Unit 1 started low power testing in December 1984. Unit 1 began full power generation in June 1985; Unit 2 in April 1986; and Unit 3 in November 1987.

Agriculture, electric power generation and residential development comprise most of the current land use within 10 miles of the site. Cotton is the major agricultural crop. Other crops in the area include alfalfa and barley. Cotton is sold as a cash crop while alfalfa and barley are used primarily as fodder.

2.2 Geology

The geology of the site area has been investigated in detail by mapping of surficial deposits, trenching, geophysical surveys, drilling and logging of more than 600 borings ranging in depth from 25 to over 700 feet, and geologic mapping of construction excavations. The majority of these activities were conducted on the site property. The permitting and commencement of construction of new electric power generating facilities in the area has provided ADEQ with significant additional information about the geology of the site area. A summary discussion of the geology of the area is presented below. This summary establishes the general framework within which local groundwater occurs.

The rocks underlying the site area are divided into three groups: the basement complex, bedrock, and basin sediments. Only the bedrock and basin sediments are considered of importance to the site hydrology and therefore discussion will be restricted to these groups in this report.

2.2.1 Bedrock

Volcanic rocks interbedded with sedimentary rocks of Miocene Age unconformably overlay the basement complex and, for purposes of this report, are termed bedrock. Bedrock is well exposed to the west of the site in the Palo Verde Hills as massive flows, plugs, dikes and flow breccia, with scattered, discontinuous interbeds of tuff and tuffaceous sandstone.

Exploratory drill holes penetrated an arkosic conglomerate, at least 140 feet thick, within the volcanic rock section near the unconformity with granitic basement rocks. Driller's logs for water wells in the northern part of the Lower Hassayampa groundwater sub-basin suggest that the volcanic-sedimentary bedrock sequence may have a thickness greater than 1,400 feet and contain numerous interbedded sandstone and conglomerate layers.

The interbedded arkosic conglomerate includes red to brown argillaceous quartz sandstone, lithic sandstone and granitic pebble-cobble conglomerate. Clasts are primarily composed of feldspar, quartz and granitic debris. Tuffaceous zones are also noted within the unit and have a known maximum thickness of 107 feet. Ferruginous cement is common throughout the unit, as are calcareous cemented zones.

2.2.2 Basin Sediments

Lithified and unlithified sediments, unconformably overlying the basement and bedrock groups, have been divided into six lithologic zones (LZ-1 through LZ-6). The following is a summary discussion generally describing these lithologic zones. In order of ascending stratigraphic position and decreasing age, the stratigraphic subdivisions of the basin sediments at the site area are:

LZ-1	Fanglomerate (Miocene-Pliocene)
LZ-2	Lower silt and lower sand and gravel
LZ-3	Palo Verde Clay (Upper Pliocene)
LZ-4	Upper silty clay
LZ-5	Upper sand and gravel
LZ-6	Fan deposits (Pleistocene to Holocene)

Generalized geologic profiles of the site area and the relative position of the combined hydrogeologic units are depicted in Figures 2 and 3.

LZ-1: The Tertiary (Miocene-Pliocene) fanglomerate contains rounded to angular clasts of predominantly andesite and basalt in a well cemented matrix of sand, silt and occasionally tuffaceous sand. The fanglomerate is exposed along the lower slopes of the Palo Verde Hills and uniformly overlies volcanic bedrock. In the subsurface, the fanglomerate fills depressions in bedrock but is generally absent on the highest bedrock surfaces. Thickness of the fanglomerate ranges from about 35 to 285 feet.

LZ-2: This Upper Pliocene lithologic zone unconformably overlies the fanglomerate and consists of uncemented sand and gravel grading upward into sandy clayey silt. This zone is generally light brown in color and contains scattered caliche stringers. The gravel clasts are commonly volcanic rocks, but granitic gravel and cobbles are also present. The zone varies in thickness, but averages about 30 feet beneath the site.

LZ-3: The Palo Verde Clay (Upper Pliocene) is the most distinctive lithologic zone in the alluvial sequence. This horizon is generally continuous throughout the site and, based on detailed subsurface information, extends at least 5 miles southeast and northeast of the site. Driller's logs from an area near the site indicate that the Palo Verde Clay extends as far southeast as Gillespie Dam (13 miles away). Beneath the site the Palo Verde Clay is generally 80 to 100 feet thick with a maximum known thickness of 136 feet. Based on laboratory hydrometer tests, this unit contains 40 to 70 percent clay-size particles. Nine sub-units within the Palo Verde Clay were identified through detailed analysis of borehole geophysical logs (APS, 1979). The Palo Verde Clay appears to have been deposited under lacustrine or playa conditions. The lower contact is generally gradational and the clay is commonly interlayered with silt or sand near its base. The upper contact of the clay is distinct and, in several borings, the top of the clay is marked by a paleosol which suggests a relatively long period of landscape stability prior to deposition of overlying sediments.

LZ-4: This upper silty clay zone is approximately 150 to 200 feet thick, and contains brown to red-brown silty clay, clayey silt, and silt with lenses of fine sand or silty sand. Discontinuous coarse-grained sand and gravel up to 20 feet thick are found at the base of this zone at many locations. The zone is generally calcareous with irregular caliche stringers and nodules. This zone is continuous throughout the site and overlies bedrock highs with the exception of the volcanics exposed in the Palo Verde Hills. An exposure of the Arlington basalt flow (about 5 miles southeast of the site) unconformably overlies the coarse-grained sediments of LZ-4 and a silt unit, which is probably equivalent to the lower part of LZ-5, beneath the site.

LZ-5: This upper sand and gravel lithologic zone ranges from 25 to 53 feet thick in the northwest portion of the site; thins to 10 or 12 feet farther south and is not present beneath the Arlington basalt to the southeast. This zone is generally much coarser-grained than the underlying zones, although it also contains silt, clayey silt and silty clay in thin, discontinuous beds.

LZ-6: This fan deposit lithologic zone is composed of younger fan deposits which are 8 to 15 feet thick and range in composition from brown sand, sandy silt and sandy gravel to brown gravely silt with interbedded sand. These deposits are chiefly volcanic rock fragments derived from the nearby hills, and quartz, granitic, and metamorphic debris derived from the Belmont Mountains and areas to the north.

The younger fan deposits occur in the vicinity of the site as erosional remnants of fan deposits east of the site in the Hassayampa River drainage. The stratigraphic relationship between the younger fan deposits and the underlying basin fill can be seen in exposed cross sections where the Arlington basalt separates the underlying basin fill deposits from the overlying younger fan deposits.

2.3 Hydrogeology

The site is located within the Lower Hassayampa groundwater sub-basin of the Phoenix Active Management Area as defined by the Arizona Department of Water Resources (ADWR). This groundwater sub-basin encompasses an area of approximately 400 square miles.

The hydrogeologic setting of the site is characterized by three major sedimentary units, each having distinctly different lithologic and hydrologic characteristics (Figures 2 and 3). These hydrogeologic units are composed of combinations of the geologic units described previously. These units, found in most Central Arizona groundwater basins (U.S. Bureau of Reclamation [USBR], 1977), are identified herein as:

Lower Coarse-Grained Unit (LZ-1, LZ-2, and bedrock)
Middle Fine-Grained Unit (LZ-3 and LZ-4)
Upper Alluvial Unit (LZ-5 and LZ-6)

In the vicinity of the site, the groundwater reservoirs consist of an areally extensive regional aquifer which occurs throughout the Lower Hassayampa groundwater sub-basin. In the immediate vicinity of the site, a localized perched water zone occurs, which is separated from the regional aquifer by the previously described Middle Fine-Grained Unit, including the Palo Verde Clay (LZ-3).

2.3.1 Regional Aquifer

In the vicinity of the site, the Lower Coarse-Grained Unit comprises the regional aquifer which extends over an area of approximately 400 square miles. The regional aquifer is bounded by the mountains that encompass the Lower Hassayampa groundwater sub-basin. In the regional aquifer, groundwater occurs under both unconfined and confined conditions. The maximum thickness of the aquifer is not known because it has not been fully penetrated by wells. However, based on driller's logs from existing water wells in the area, the sedimentary sequence, including the volcanic bedrock units, is greater than 1,400 feet thick near the Palo Verde Hills.

The major source of discharge from the regional aquifer is groundwater pumpage. In 1993, the total pumpage from the Lower Hassayampa groundwater sub-basin was approximately 23,000 acre-feet (ADWR, 1995). The majority of this pumpage was for irrigated agriculture. A steady decline in regional groundwater levels in the area surrounding the site began about 1950 due to the increase in long-term pumping in excess of recharge. Since that time, water levels have remained lowered by as much as 100 feet near the centers of cones of depression caused by groups of pumping wells.

The primary source of recharge to the regional aquifer in the area is underflow from the Upper Hassayampa groundwater sub-basin located north of the site. The general direction of groundwater flow is from north to south toward a large cone of depression southwest of the site. The cone of depression is caused by pumpage of groundwater for irrigated agriculture. In the vicinity of the site, infiltration of precipitation, surface runoff and return flow from irrigation comprise only a small portion of the total recharge to the regional aquifer. This is due to the presence of the Middle Fine-Grained Unit that restricts downward migration of recharge water.

Recent data suggest that water levels in the regional aquifer are recovering in the vicinity of the site, because of the general decline in agricultural water use. Pumpage in the Lower Hassayampa groundwater sub-basin reported to ADWR has declined substantially since 1990, from 58,000 acre-feet in 1990 to 23,000 in 1993 (ADWR, 1995). For this reason, water levels have increased in the regional aquifer as pumpage has been curtailed. The water level in the PVNGS regional monitor well, PV-216R, has increased about 27 feet from 1989 to 2000.

Evaluation of groundwater quality from water samples obtained from the regional aquifer both prior to and during extensive agricultural activity in the site vicinity indicates that the groundwater quality has remained fairly consistent over the years (APS, 1979).

2.3.2 Perched System

The PVNGS site is located in an area that was historically used for irrigated agriculture between 1950 and 1975. Groundwater recharge, primarily from excess applied irrigation water, formed a perched groundwater mound under the site. The perched groundwater is primarily contained within the Upper Alluvial Unit (LZ-5 and LZ-6) and has a lower boundary consisting of an aquitard, the Middle Fine-Grained Unit (LZ-3 and LZ-4). Available data suggest the aquitard is continuous beneath the site and the vicinity. Though the upper portion of the Middle Fine-Grained Unit is saturated by downward flow from the Upper Alluvial Unit, it is not considered part of the perched system because of its very low relative permeability. The estimated vertical hydraulic conductivity for the Middle Fine-Grained Unit based on laboratory tests is on the order of 0.001 gallons per day per square foot (gpd/ft^2) (5 x 10^{-8} centimeters per second [cm/sec]).

Water contained in the perched system is generally under water table conditions and is limited mainly to the site, where it is mounded beneath areas which were formerly cultivated and irrigated fields.

2.4 Monitored Facilities

2.4.1 Water Storage Reservoir

The water storage reservoir (reservoir) is located on the northeast portion of the site (Figure 1). The reservoir, which stores treated wastewater effluent, provides makeup to the PVNGS cooling towers. The bottom of the reservoir is lined with a rubberized asphalt compound and the sides are lined with Hypalon™. The reservoir has a surface area of 80 acres and stores approximately 2,000 acre-feet of water.

2.4.2 Evaporation Pond No. 1

PVNGS Evaporation Pond No. 1 is located on the southern portion of the site (Figure 1). Pond No. 1 was constructed in 1981 and put into service in 1984. Pond No. 1 is designed to impound blowdown water from the circulating water system and wastewater from the water reclamation plant and other miscellaneous water sources. Pond No. 1 has a surface area of approximately 250 acres and a storage capacity of approximately 5,500 acre-feet. The bottom of the pond varies in elevation from approximately 914 to 921 feet above mean sea level (AMSL). The elevation of the top of the earth fill embankment is approximately 942 feet AMSL.

The pond bottom and side liners were upgraded during the third and fourth quarters of 1991 and first and second quarters of 1992. The liner upgrade activities, completed March 17, 1992, were outlined in correspondence from Mr. Ronald J. Stevens (APS) to Mr. Ed Pond with ADEQ, dated November 30, 1992. The liner upgrade activities were also described in the 1991 APS Palo Verde Nuclear Generating Station Annual Groundwater Report, Volume I (Groundwater Quality Protection Permit No. G-0077-07).

As part of the relining operation for Evaporation Pond No. 1, conducted in 1991-92, a sump and drainage system was installed. The sumps (located in the southeast and southwest corners of Pond No. 1) collect water from the drainage system installed in the layer between the old liner and the new high-density polyethylene (HDPE) liner. These sumps are monitored weekly for water accumulation. The drainage system consists of six inflow lines into each sump from different areas under the pond, allowing for the determination of the specific location of a leak. Any water that accumulates in the sumps is pumped back into the pond.

2.4.3 Evaporation Pond No. 2

Evaporation Pond No. 2 was constructed during 1987 and became operational in early 1988 (Figure 1). Pond No. 2 is constructed similarly to Evaporation Pond No. 1 and serves similar functions. The bottom and interior side slopes of Pond No. 2 are lined with 80-mil HDPE liner material. The west embankment of Pond No. 2 is the east embankment of Pond No. 1. The other embankments on the east, north and south sides of No. 2 form an enclosure of approximately 220 acres. Storage capacity is approximately 5,900 acre-feet. The elevation of the top of the embankment of the pond is approximately 941 feet AMSL. The elevation of the bottom of the pond varies from approximately 916.5 feet AMSL on the north end to approximately 904.5 AMSL feet on the south. The bottom of the pond lies approximately 5 to 12 feet below the original ground elevation.

2.4.4 Sedimentation Basin No. 1

Sedimentation Basin No. 1 is located immediately north of Evaporation Pond No. 1 in the west-central portion of the site (Figure 1). This basin is an unlined, 15-acre surface impoundment which contains runoff from rainfall events. It has also received small amounts of cooling tower water due to overspray or unintentional releases from the Unit 2 and Unit 3 cooling tower systems. Monitoring of water levels in the basin on a weekly basis began in 1993, and measurements are reported to ADEQ on a quarterly basis and summarized annully.

2.4.5 Sedimentation Basin No. 2

Sedimentation Basin No. 2 is located immediately north of Evaporation Pond No. 2 in the east-central portion of the site (Figure 1). The basin is an unlined, 60-acre surface impoundment that contains runoff from rainfall events. In addition to stormwater, this basin receives discharges from cooling tower overspray, domestic water system drains, fire protection system flushing, construction pond overflow, leaking water valves and lines, and infrequent, unintentional overflows from spray ponds, cooling towers, and Water Reclamation Facility clarifiers. Weekly basin water level monitoring began in 1993, and measurements are reported to ADEQ quarterly and summarized annually.

2.4.6 Additional Monitored Facilities

Additional monitored facilities include two gunite-lined retention basins, the sludge disposal landfill, the rubbish landfill, the concrete landfill and the Hassayampa Pump Station (HPS) holding pond.

The two gunite-lined retention basins are located on the west-central portion of the site (Figure 1). The basins are built above a secondary liner made of 45 mil hypalon and designed to slope towards a center collection trough where a 4 inch drain pipe is laid in a bed of pea gravel. The drain pipe flows to an inspection sump that is monitored for leakage. The combined capacity of the basins is approximately 3 acre-feet. These retention basins receive water from the oily waste system, chemical neutralization wastes and the effluent from the on-site sewage treatment plant when the water reclamation plant is not operational. The retention basins discharge to the evaporation ponds.

The sludge disposal landfill is a drying landfill for disposal of sludge from the water reclamation plant and sediment from the cooling towers. The sludge disposal landfill is located on the northeast portion of the site (Figure 1). Sludge is dewatered prior to being transported to the landfill. The cooling tower sludge is analyzed for radiological and Toxicity Characteristic Leaching Procedure (TCLP) metals parameters prior to disposal.

The rubbish landfill (inert landfill) is located on the east-central portion of the site, south of the water storage reservoir (Figure 1). The landfill is a trench type and receives non-hazardous waste material resulting from construction, operation and maintenance of the plant.

The concrete landfill is located on the west-central portion of the site near the gunite-lined retention basins (Figure 1). The concrete landfill receives only concrete waste, cement, and concrete truck wash water.

The Hassayampa Pump Station holding pond is an unlined, gravel bottomed, low area that can receive secondary treated effluent water from the HPS pressure relief valves (rupture discs) or dewatering activities from the Water Reclamation Supply System (WRSS) pipeline. The rupture discs are safety devices that release water if the pressure in the pipeline exceeds the specified design limits. Dewatering of the pipeline may be required to perform certain inspections and repairs of the pipeline necessary to insure the integrity of the conveyance system.

2.5 Groundwater Monitoring Program Summary

The PVNGS Groundwater Monitoring Program is designed to collect, review, analyze and evaluate hydrological data and associated information. The program became operational in June 1982. The goal of the monitoring program is to provide a methodology for the early detection of leakage from permitted facilities should leakage occur. Depending on the magnitude of the leak, both the groundwater levels and the water quality in the perched groundwater system could be affected. However, the water quality in the perched system is so poor that detection of leaks via analysis of water quality data alone would likely prove very difficult. Because of this difficulty, early detection of leakage is accomplished through an integrated hydrological monitoring program including facility inspections, water level and water quality monitoring.

Prior to the issuance of the GWQPP, water quality information was primarily collected for inorganic constituents. The groundwater permit conditions have since expanded the monitoring program to include radiological, volatile and semi-volatile organic and TCLP metals analyses at selected locations.

This program was modified by agreement with ADEQ in August, 1993, based on a meeting held on December 8, 1992 between APS and ADEQ Plan Review and Permits staff. The modifications are described in correspondence from Mr. Ed Pond, ADEQ Plan Review and Permits Section, dated August 8, 1993, and are summarized below:

- Increase in groundwater level monitoring from quarterly to monthly for twenty-four wells (see Section 3.1 of this report for listing of wells), with continued quarterly water level measurements from all monitor wells completed in the perched groundwater system beneath the PVNGS site to detect the source(s), extent, and direction of movement of groundwater in the perched system.

- Increase in water level monitoring from quarterly to monthly for data collected from a series of piezometers located on the cap and toe of the dike around Evaporation Ponds No. 1 and No. 2. These piezometers were installed as part of the Dam Safety Program at PVNGS. Water levels were collected monthly from April 1988 to September 1990, then quarterly from September 1990 through July 1993. Since July 1993 water levels have been collected monthly in accordance with the modifications to the permit.

- Decrease groundwater quality monitoring frequency from quarterly to annually for all wells, with the exception of eight wells which will be monitored quarterly (see Section 3.1 of this report for details). These data are continually compared to previous water quality data to provide information regarding any potential long term changes in water quality.

- Decrease monitoring frequency for moisture content detectors from quarterly to annually. Moisture content of the unsaturated zone is monitored by the use of a neutron soil moisture detector. This monitoring occurs at several locations in the vicinity of Evaporation Ponds No. 1 and No. 2. The neutron soil moisture monitoring was a part of the PVNGS Dam Safety Program, this phase of the program became operational in June 1982 and soil moisture data have been collected regularly since that time.

- Additionally, water levels in the evaporation ponds and sedimentation basins are now monitored weekly. Staff gauges were installed in Sedimentation Basins No. 1 and No. 2, and data is reported to ADEQ quarterly and summarized annually.

- Weekly inspections of the evaporation pond dam/dike structures, liners and leachate collection/leak detection sump system will be conducted.

- Establishment of an action leakage rate (ALR) as an alert level for Evaporation Pond No. 1 leak detection sumps of 200 gallons per day per acre. This parameter will be monitored on a weekly basis, and reported to ADEQ on a quarterly basis, except in the case of exceedance of the alert level, which shall trigger the alert level reporting requirement to ADEQ.

A minor modification to GQPP No. G-0077-07 was approved by ADEQ on November 30, 1995. This modification reflects the requirements of the Arizona Radiation Regulatory Agency (ARRA) Special Approval License No. 7-368 regarding the disposition of sludge and operation of the sludge landfill. The new language provides for operational equivalence of procedures specified in the ARRA license and the GWQPP, both of which adopt the PVNGS Procedure No. WROP-8ZZ04 as the permitted procedure for handling cooling tower sediment.

Analysis of the perched zone water levels and water quality data from the site since 1982 strongly suggests that perched zone groundwater level changes are a far more reliable and timely indicator than water quality data of any potential facility leakage. Additional comments supporting these findings are found in Sections 3.2 and 3.3 of this report.

2.6 2000 Operational History

2.6.1 Operational Changes

There were no significant operational changes during 2000.

2.6.2 Unintentional Discharges

On July 6, 2000, approximately 4,045 gallons of cooling tower blowdown water were unintentionally released to the unlined ditch that carries storm water to Sedimentation Basin No. 2. Verbal notification of this incident was made to ADEQ on July 7, 2000. Written notification was made in letter number 291-02635-AKK/FDD dated July 12, 2000. We do not believe that this release had an impact on groundwater due to the volume and area of impact of the release and the 40 foot plus depth to the perched aquifer in the area of the release.

On October 30, 2000, approximately 30,000 gallons of chlorinated secondary treated effluent were unintentionally released to the unlined ditch that carries storm water to Sedimentation Basin No. 2. Verbal notification of this incident was made to ADEQ on November 2, 2000. Written notification was made in letter number 291-02662-AKK/FDD dated November 6, 2000.

We do not believe that this release posed a risk to human health or had a negative impact on the environment. The water had been chlorinated prior to release and met reuse permit limits for fecal coliform. In addition, the release occurred during a significant rainfall event and became a very small portion of the water that reached the sedimentation basin. The release was preceded and followed by rainwater flow to the basin. Rainfall recorded at the site on October 30 was 0.40 inches. On October 31, the water level in the 60-acre Sedimentation Basin No. 2 was measured at one foot.

3.0 ANALYSIS AND EVALUATION OF THE MONITORING DATA

3.1 Overview

During 2000, water level data were collected as follows:

Monitoring Frequency	Number & Type Of Facility	Facility Listing
Weekly	5 Surface Impoundments	Evaporation Ponds 1 & 2 Sedimentation Basins 1 & 2 Water Storage Reservoir
Monthly	24 Wells	PV-191A & B PV-203A & B PV-192A & B PV-204A & B PV-193A & B PV-28HA & HB PV-198A & B PV-29H & HB PV-201A & B PV-33H & HB PV-202A & B PV-34H & HB
	24 Piezometers	See Appendix A
Quarterly	23 Additional Wells	Including Regional Well PV-216R See Appendix A

Water level data for 2000 is presented in Appendix A of this report.

During 2000, water quality data were collected as follows:

Monitoring Frequency & Type	Number & Type Of Facility	Facility Listing
Quarterly Inorganics	4 Surface Impoundments	Evaporation Ponds 1 & 2 Sedimentation Basin 2 Water Storage Reservoir
	8 Wells	PV-28HA & HB PV-34H & HB PV-196A & B PV-205A & B
Annual Inorganics (Collected Third Quarter)	31 Additional Wells (No Sample for PV-162A)	Including Regional Well PV-216R
	1 Piezometer	PV-210C See Appendix C
Annual Semi-Volatile & Volatile Organics (Collected First Quarter) (EPA Methods 624, 625 & 608)	4 Surface Impoundments	Evaporation Ponds 1 & 2 Sedimentation Basin 2 Water Storage Reservoir
Quarterly Radionuclides (Tritium & Gamma Isotopes)	4 Surface Impoundments	Evaporation Ponds 1 & 2 Sedimentation Basin 2 Water Storage Reservoir
Annual Radionuclides (Collected Third Quarter) (Tritium & Gamma Isotopes)	12 Additional Wells	PV-193A & B PV-204A & B PV-202A & B PV-33H & HB PV-203A & B PV-201A & B
	1 Piezometer (Tritium Only)	PV-210C
(Collected Second Quarter)	1 Process Water (Tritium Only)	Pumpback (Cooling Tower Blowdown)

Inorganic water quality data for 2000 are presented in Appendix C, Part 1 of this report.

Annual inorganic water quality data were collected during the third quarter of 2000 at 39 well sites and 1 piezometer, PV-210C. Wells PV-191A, PV-191B, PV-207A, and PV-207B were dry throughout the year and no samples were collected. Wells PV-192A and PV-24HA were too shallow to collect samples.

Water samples for volatile and semi-volatile organic analysis were collected from Evaporation Ponds No. 1 and 2, Sedimentation Basin No. 2 and the Water Reclamation Reservoir during the first quarter of 2000.

Tritium and Gamma Isotope analyses were performed during the third quarter on the required 10 wells and 2 additional wells, PV-201A and PV-201B. Quarterly samples were analyzed on Evaporation Ponds No. 1 & 2, Sedimentation Basin No. 2 and the Water Reclamation Reservoir. In addition, single samples of piezometer PV-210C and pumpback (cooling tower blowdown) were collected for tritium analysis only.

With the exception of PV-192A being too shallow to sample, no unusual problems were encountered while collecting water quality samples in 2000.

3.2 Water Level Data

The groundwater monitor wells at the site, except PV-216R, are used to monitor the water levels in the perched groundwater system. At most monitor well locations, two or three wells are installed at different depths. Where there are multiple wells at a monitoring site, the wells are referred to as full column wells (well name-"H", or "A"), upper column wells (well name-"HA"), and lower column wells (well name-"HB", or "B") depending on the relative location and length of the perforated interval. The piezometers surrounding the evaporation ponds are labeled "C" or "T" for cap and toe, respectively.

Figure 4 shows the location of the well and piezometer sites. Figure 4 also shows the December 2000 water level elevations and the 2000 water level changes for the wells. Water elevations and change in water levels are generally listed for the shallowest non-dry well at each location. Appendix A of this report contains a summary of all the water level data collected in 2000. Appendix B contains hydrographs of selected wells covering the period 1989 through 2000.

5.28 inches of rain were recorded at the site in 2000. Months with the heaviest precipitation were March (2.12 inches), August (1.39 inches) and October (1.45 inches). There were 6 months with no measurable precipitation. Figure 5 illustrates the monthly rainfall distribution for 2000.

3.2.1 Long Term Trends

Data presented in Figure 4 and Appendices A and B indicate that water levels declined through 2000 in all wells at the site with the exception of PV-193B, PV-R2A and PV-R2B. PV-193B's increase for the year was 0.01 feet.

Wells PV-25HA, PV-195A, PV-195B, PV-196A, PV-196B, PV-197A, PV-197B, PV-205A, PV-205B, PV-206A and PV-206B are examples of wells on the periphery of the perched aquifer with a continuing trend of declining water levels. In 2000, the water level in wells PV-206A and PV-206B declined an average of 1.57 feet. Declines in the other wells ranged from 0.35 to 0.80 feet.

Wells PV-198A and PV-198B are directly south of Sedimentation Basin No. 1. December 2000 water levels for PV-198A and PV-198B were down 2.06 and 1.92 feet respectively over December 1999 levels. All other wells in the vicinity of Sedimentation Basin No. 1 remained dry or experienced declining water levels during 2000.

Wells PV-201A and PV-201B are directly south of Sedimentation Basin No. 2. December 2000 water levels for PV-201A and PV-201B were down 2.19 and 2.30 feet respectively over December 1999 levels.

Wells PV-198A, PV-198B, PV-201A and PV-201B continue to show seasonal water level fluctuations in response to recharge from standing water in Sedimentation Basins No. 1 and No. 2. These fluctuations are especially noticeable following periods of extended or heavy precipitation. The more pronounced fluctuations in PV-201A and PV-201B are the result of a larger recharge area. Seasonal and long term trends are indicated by historical water level data. See Appendix B, Figure 5.

Wells PV-28HA, PV-28HB, PV-29H and PV-29HB are directly north of Sedimentation Basin No. 2. Their hydrographs (Appendix B, Figure 4) indicate similar, but less dramatic, trends as wells PV-201A and PV-201B. All four wells showed a decline in water level in 2000. The largest decline was 2.03 feet in PV-28HA.

Hydrographs for wells PV-Q5, PV-Q5B, U5-PTWA and U5-PTWB (Appendix B, Figure 6) located between Sedimentation Basins 1 and 2, also show declines through 2000. The largest decline was 1.63 feet in PV-Q5 and PV-Q5B.

Water levels in all wells in the vicinity of Evaporation Ponds No. 1 and 2 declined through 2000 with the exception of PV-193B. Well PV-193B was essentially constant with an increase of 0.01 feet in 2000.

A comparison of TDS data for Evaporation Pond No. 1 and wells PV-33H, PV-193A, PV-196A and PV-198A is presented in Figure 6. The TDS values indicated on the graph are much greater for Evaporation Pond

No. 1. If Evaporation Pond No. 1 was leaking and directly influencing any of these adjacent wells, a closer correlation of water quality data would be expected. The water level in PV-33H continues a long term trend of decline while the water level in PV-193A has remained fairly constant over the last three years. The data does not indicate any evidence of leakage from Evaporation Pond No. 1.

A comparison of TDS data for Evaporation Pond No. 2 and wells PV-34H, PV-201A and PV-205A is presented in Figure 7. The TDS values indicated on the graph are much greater for Evaporation Pond No. 2. If Evaporation Pond No. 2 was leaking and directly influencing any of these adjacent wells, a closer correlation of water quality data would be expected. In addition, water levels in wells PV-203A, PV-203B, PV-202A, and PV-202B continue to slowly decline following a long-term trend. PV-34H tends to be influenced by major rainfall events. The data does not indicate any evidence of leakage from Evaporation Pond No. 2.

3.2.2 Anomalous Water Level Changes

A. On March 3, 2000, approximately 2 inches of water was observed in the Evaporation Pond No. 2 northeast sump. The sump remained damp or slightly wet through June 2, 2000. Cooling tower blowdown to Evaporation Pond #2 was discontinued on April 26, 2000 to lower the water level and to allow for inspections of the pond liner. Two small tears were found on July 6, 2000 on the north embankment liner just below the water level. It is believed that these tears were the source of the water in the northeast sump.

As of December 31, 2000, the water level in the pond had dropped 3.69 feet. The water level is still being lowered and periodic inspections of the liner are being performed. Any liner tears found in these inspections will be repaired prior to putting cooling tower blowdown back into the pond.
The northeast sump has been dry since June 2, 2000. The southeast and southwest sumps remained dry.

B. The April monthly water level monitoring showed water level increases in wells PV-201A and PV-201B of 2.52 feet and 2.33 feet respectively. Follow-up monitoring through the rest of the year showed significant and continuous decreases in the water levels for both wells. December 2000 water levels for PV-201A and PV-201B were down 2.19 and 2.30 feet respectively over December 1999 levels.

The water levels in these wells have historically tracked precipitation at the site. The wells are located around both the evaporation ponds down gradient of Sedimentation Basin No. 2. During the months of February and March, a total of 2.30 inches of precipitation was measured at Palo Verde. Sedimentation Basin No. 2 contained water from March 8 through April 11, 2000. On March 8, 2000, the basin staff gauge showed a water level of 2.75 feet. Historical water levels in PV-201A and PV-201B were compared against historical water levels in Sedimentation Basin No. 2. The data showed a definite correlation between the water levels in the wells and the water levels in the basin. We believe all these wells were influenced by rainfall and standing water in the sedimentation basin. This data and data analysis will be presented in greater detail in the annual interpretive report.

Samples of PV-201A and PV-201B were collected on May 25, 2000 and August 24, 2000 for water quality analysis. All analytical parameters fell within the historical data range and none indicated influence from evaporation pond water. Samples were collected on May 24, 2000 for tritium analysis and August 24, 2000 for tritium and gamma emitting isotopes analysis. All radiological parameters fell within the historical data range and none indicated influence from evaporation pond water.

C. Water level measurements taken on July 26, 2000 and August 30, 2000 showed water levels in piezometer PV-210C. PV-210C had been dry since May 28,1998.

Telephone notification of this condition was made to the Arizona Department of Environmental Quality (ADEQ) by voice mail message on September 1, 2000. Additional information was provided to ADEQ in a telephone conversation on September 6, 2000. Written notification was made in letter number 291-02649-AKK/FDD dated September 22, 2000.

PV-210C is located on the crest of the northeast corner of Evaporation Pond No. 2's dike. Sedimentation Basin No. 2, the primary source of recharge for the perched aquifer, is located adjacent to the north dike of Evaporation Pond No. 2. The perforations in the piezometer casing extend below the pond dike into the upper region of the perched aquifer. The bottom perforations are at an elevation of about 905.30 feet. The bottom of Sedimentation Basin No. 2 is at an elevation of about 921 feet.

The water level in PV-210C has continued to decline since the initial level measurement. The depth of water was estimated to be about 2.19 feet on July 26 and 1.04 feet on December 14, 2000. Historical data shows that PV-210C has had periods of wet and dry. A graphic presentation showing the water level changes in PV-210C from February 1991 to December 2000 is provided in Appendix E.

Water samples were bailed from the piezometer on September 5 and 6 for in-house analyses. Conductivity, pH, total alkalinity, calcium, chloride and tritium analyses were performed. An average of the two sample results is presented below with a comparison to the average contract laboratory results for the same parameters for 1999 and 2000 for Evaporation Pond No. 2.

Parameter	PV-210C September 5 & 6 Averages	Evap Pond 2 1999 & 2000 Averages
Conductivity	21,200 µmhos	109,000 µmhos
pH	7.1 SU	8.6 SU
Total Alkalinity	443	419
Calcium	599 ppm	419 ppm
Chloride	6,600 ppm*	34,000 ppm
Tritium	<292+/-171 pCi/l*	1181+/-193 pCi/l
* = Only one sample was analyzed for this parameter.		

The above analyses are significantly different and indicate that the source of water in PV-210C is not Evaporation Pond No. 2. Samples of PV-210C were collected on September 14, 2000 for complete water quality analysis. See Appendix C, Part 1. None of the analytical parameters indicated influence from evaporation pond water. This data shows that the presence of this water in PV-210C is not the result of a saturated condition in the pond's dike.

Data indicates that Piezometer PV-210C can be, and is now, influenced by conditions in the perched aquifer. Water levels in the piezometer could indicate either saturation in the pond dike or water level changes in the perched aquifer. This is also the case with Piezometer PV-213C.

In the future, whenever water or water level increases are observed in either Piezometer PV-210C or PV-213C, samples will be drawn for in-house analysis to determine whether the condition is due to dike saturation or perched aquifer conditions. Permit reporting requirements will be followed if analysis indicates a saturated condition. Water levels due to perched aquifer water level changes will be addressed in quarterly reports and the annual interpretive report.

D. PV-R2A and PV-R2B have a long term trend with fluctuating rises and falls but an overall upward trend in the last seven years. We do not believe that these wells are part of the perched aquifer because of the very high quality of water in the wells. Reference Appendix B, Figure 2 and Appendix C, Part 1. We believe these wells are recharged by precipitation flows in the East Wash.

E. We believe an error was made in the measurement or recording of water levels for wells PV-14H and PV-14HB on June 22, 2000. The recorded values do not track each other as they historically have over the last 4 ½ years and fall outside the data trend. A re-measurement of the wells on July 19, 2000 supports this conclusion as these values do track each other and fall within the data trend. Both the June 22 and July 19 recorded values are reported, however, we believe the June 22 values to be in error.

3.3 Water Quality Data

3.3.1 Perched System

Monitor wells at the site are generally located to provide water quality monitoring data in the vicinity of permitted facilities. Monitor wells in the perched groundwater system have been sampled quarterly since the fall of 1982 and a database has been established. These data are contained in previous reports (see Section 5.0 for a listing of reports). The water quality data for the 2000 monitoring program are found in Appendix C, Parts 1 through 4 of this report.

General inorganic water quality data for the perched groundwater system of the southern half of the PVNGS site indicate a large spatial variation in water quality between wells. This large variation in water quality is probably related to multiple factors including but not limited to: the screened interval of the well(s); the source(s) of the sampled water (e.g., older recharge from irrigated agriculture, recent recharge from rainfall runoff from PVNGS facilities, or a combination of both); location of well(s) with respect to the sedimentation basins; continuing changes in water levels in the perched aquifer; and the complex hydrogeology of the perched groundwater system including the possible presence of evaporite deposits. Because of the interfingering of fine-grained layers within the Upper Alluvial Unit, and coarse-grained layers within the Middle Fine-Grained Unit, various mixes of water from different strata may be sampled. Examination of water quality data from closely spaced wells with different depth and screened intervals also confirms the complex hydrogeochemistry.

Long-term water quality trends have also remained consistent. Comparison of 2000 water quality data with those of previous years indicates no anomalous changes.

Tritium concentrations detected during the 2000 monitoring of water in the surface impoundments ranged from less than the lower level detection limit (LLD) to 1622 +/- 199 picocuries per liter (pCi/l). These concentrations are consistent with historical data with no evidence of an increasing trend.

All gamma isotopic analyses for the surface impoundments were below detection limits except for $Iodine_{131}$ and $Cesium_{137}$. $Iodine_{131}$ is introduced into the Palo Verde water systems via radiopharmaceutical discharges into the metropolitan Phoenix sewage system. Phoenix sewage effluent is treated and used as makeup to the recirculating cooling tower water systems. $Iodine_{131}$ concentrations ranged from less than LLD to 23.31 +/- 4.78 pCi/l. These concentrations are consistent with historical data.

$Cesium_{137}$ was detected in the first, second and third quarter samples collected from Evaporation Pond No. 2. Cesium values ranged from 6.11 +/- 5.05 to 10.43 +/- 4.92 pCi/l. The $Cesium_{137}$ values are consistent with historical data.

Twelve wells were sampled for tritium and gamma isotope analysis during the third quarter of 2000. All samples were below the detection limit for tritium and all gamma isotopes. Year 2000 radiological monitoring data is provided in Appendix C, Part 3.

Water samples were collected in the first quarter from Evaporation Pond No. 1, Evaporation Pond No. 2, Sedimentation No. 2 and the Water Storage Reservoir for analysis of volatile and semi-volatile organic chemicals, using EPA Test Methods 624, 625 and 608. Low levels of chloroform, chloromethane and chlorodibromomethane were detected in the Evaporation Pond No. 1 sample. Low levels of chloromethane were detected in the Evaporation Pond No. 2 sample. Low levels of chloroform were detected in the Reservoir sample. The 2000 organic monitoring data is provided in Appendix C, Part 2.

The presence of trihalomethane (THM) compounds is the result of chlorination of the Water Reclamation Facility treated water. The treated water is stored in the Water Storage Reservoir, used in the cooling towers, and subsequently discharged to the evaporation ponds. In addition, chlorine and bromine is added to the cooling towers for microbiological control. It should be noted that the concentrations detected were below the Aquifer Water Quality Standard (AWQS) limit of 100 μg/l for total THMs in drinking water.

A review of inorganic water quality data for the sampled wells was conducted by comparing the 2000 water quality results with the 1999 water quality results. In general, the inorganic water quality data for 2000 are very similar to the 1999 data.

Chromium, which has been detected sporadically, was detected in 28 perched wells during 2000. In 1999, none of the perched wells exceeded the AWQS for chromium of 0.10 milligrams per liter (mg/l). One sample exceeded the AWQS in 2000. PV-205B's fourth quarter sample measured 0.11 mg/l. The chromium concentration in the sample from the regional aquifer well, PV-216R, was 0.084 mg/l. Last year's measured value was 0.12 mg/l.

Selenium, originally detected in the fourth quarter of 1990, was present in more than 30 of the water samples collected throughout 1991. In 1999, selenium was detected in 20 of the 40 perched wells. Five of the wells were above the AWQS of 0.05 mg/l. In 2000, selenium was detected in 17 perched wells. Six of the wells were above the AWQS. Selenium was reported as less than the detection limit of 0.0040 mg/l in the 2000 sample from PV-216R.

Water quality data for 2000 indicates that arsenic concentrations for 21 monitoring wells exceeded the arsenic AWQS of 0.05 mg/l. The reported arsenic concentrations in the groundwater sample from PV-216R exceeded the AWQS with a concentration of 0.055 mg/l. This is comparable to historical values from well PV-216R. The highest reported concentration was 0.12 mg/l in 1990.

3.3.2 Regional Aquifer

The goal of the PVNGS Groundwater Monitoring Program is to acquire information that would aid in the early detection of seepage from the PVNGS site facilities that could adversely impact the water quality in the regional aquifer in the vicinity of the site. Frequent monitoring of water levels and water chemistry in the perched groundwater system is the primary techniques used to determine potential impacts to the regional aquifer. To more completely evaluate the success of this program, water quality data have also been acquired from the regional aquifer since 1977 for the area around the site. A summary of these data for 1977-1978, which includes maximum, minimum, and mean parameter values is included in Table 1. Groundwater from the regional aquifer is a sodium chloride-sulfate type (USBR, 1977) and has a TDS concentration ranging from approximately 400 mg/l to over 3,000 mg/l. Most regional aquifer wells have TDS concentrations in excess of the EPA recommended drinking water standard of 500 mg/l.

In order to acquire recent, site-specific, regional aquifer water quality data downgradient of the PVNGS site, monitor well PV-216R was completed along the southern boundary of the property in 1989 (see Figure 4). Historical water quality data from 1977-78 and the December 2000 sample data for this well are listed in Table 1. Comparison of the historical water quality data in Table 1 with the 2000 data for well PV-216R reveals little difference, indicating that activities at PVNGS have had no adverse impact on regional aquifer water quality. All measured concentrations in 2000 are within the previous detected range of concentrations.

3.4 Neutron Moisture Detector Data

The moisture content of the unsaturated sediments is monitored in the vicinity of Evaporation Ponds No. 1 and 2 using a Campbell Pacific Nuclear neutron soil moisture detector. Readings are taken at five foot intervals at each moisture detector borehole. The moisture detector is calibrated to read in pounds of water per cubic foot (PCF).

The locations of the moisture detector borings, MD-1 through MD-9, are shown on Figure 4. The moisture detector reads and graphs of 1999 and 2000 moisture content profiles and percent change in moisture content are included in Appendix D of this report. The alert level of 20% for a change in moisture content was not exceeded.

Data from neutron soil moisture detector borings MD-1 through MD-4 and MD-6 through MD-9 were reviewed with regard to soil moisture content and relative changes in moisture content for the soil profile represented by each detector location. Soil moisture at MD-5 was not measured since 1991 due to casing damage. The casing damage, occurring 44 feet below grade, was first discovered in June 1991. Soil moisture detector boring MD-10 was abandoned in 1988 during construction of Evaporation Pond No. 2. Soil moisture detector boring MD-11, located near the Water Storage Reservoir, was damaged and abandoned in 1990. The measurable depths for soil moisture detectors MD-1, MD-2, MD-3, MD-4, MD-6, MD-8 and MD-9 has decreased by 5 to 15 feet since they were installed. These conditions are believed to be primarily the result of introduction of construction debris during the Evaporation Pond No. 1 relining project in 1992.

As reported in Volume I of the 1991 APS Palo Verde Nuclear Generating Station Annual Report (Groundwater Quality Protection Permit No. G-0077-07), MD-7 indicated a moisture increase at an elevation of 900 feet during September 1991. This increase was attributed to Evaporation Pond No. 1 relining activities. The 1992 moisture readings from MD-7 continued to indicate high soil moisture content in response to Evaporation Pond No. 1 relining operations. Data collected in March 1993, December 1994 and December 1995 also show similar results. However moisture readings have been indicating a definite downward trend. The drilling and modeling activities conducted at the Water Storage Reservoir during 1995 indicate that low permeability layers beneath the PVNGS site have trapped this moisture.

The monitoring data shows a small decrease in moisture content within the logged soil profiles for all eight boreholes during 2000. The data also shows that all moisture values are either below 1987 values or lower than some values measured in previous years. Historic data indicates that the decreased moisture readings are within the normal variations of the instrumentation and test methodology.

3.5 Evaporation Pond Sump Monitoring

The evaporation pond drainage sumps are monitored on a weekly basis and reported to ADEQ on a quarterly basis. An Action Leakage Rate (ALR) alert level of 200 gallons per day per acre for Evaporation Pond No. 1 was established in the permit. An exceedance of this alert level would trigger the alert level reporting requirement. During 2000, the sumps located around the Evaporation Ponds were dry, with the exception of the Evaporation Pond No. 1 southeast sump. In 2000 approximately 7,644 gallons of water were pumped from the sump back into the evaporation pond.

Although the cause of the inflow to the sump has not been determined, it appears that the drainage collection system is functioning as designed. The leakage rate did not exceed the ALR at any time during this event, and no anomalous water level changes in nearby wells have been noted.

3.6 Sludge Disposal Data

Composite samples were collected from the Sludge Disposal Landfill in May and December 2000. None of the alert levels were exceeded during either round of monitoring. Sludge sample results are presented in Appendix C, Part 4.

Cooling tower sediment originating from Units 1, 2 and 3 was placed in the PVNGS Sludge Disposal Landfill in 2000. A summary of the gamma spectroscopy results from the sediment samples can be found on page 27 of the Annual Radiological Environmental Operating Report for 2000 provided in Appendix F.

All sludge landfill sampling and sampling results met the requirements of the Groundwater Quality Protection Permit and the current Arizona Radiation Regulatory Agency Special Approval License No. 7-368.

3.7 Releases to HPS Holding Pond

There were four releases of secondary treated effluent from the Water Reclamation Supply System (WRSS) pipeline to the Hassayampa Pump Station (HPS) Holding Pond in 2000. The four releases were related to pipeline inspections and repair activities. Approximately 7,298,000 gallons of water were released to the holding pond in 2000.

4.0 CONCLUSIONS

The following conclusions are made based on a review of the 2000 PVNGS Groundwater Monitoring Program data:

- Review of water level and water quality data for the 2000 reporting period indicates that previously defined trends within the perched groundwater system continue. The perched groundwater system continues to exhibit generally declining water levels and generally poor water quality. Some wells continue to show temporary water level gains after significant rainfall events and associated recharge.

- The volume of water quality data presently available is more than adequate to establish baseline water quality conditions in the perched groundwater system. The consistent nature of water quality data continues to indicate that PVNGS facilities do not adversely impact the perched groundwater zone.

- Available data indicate no discernible changes in regional aquifer water quality.

- Available data indicate no leakage from the evaporation ponds.

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