

## **APPENDIX B: DATA SOURCES AND METHODS**

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## APPENDIX B DATA SOURCES AND METHODS

This appendix describes the sources of data and methods of analysis for tables and maps presented in Volumes 1-8 of the Atlas. These descriptions may not completely explain some details of the data sources and analysis in all cases. More detailed information may be obtained by contacting the Department. Also, the references cited here may differ slightly from those presented in Volumes 2-8 if additional and/or more recent data became available.

### B.1 Adequate and Assured Water Supply Determinations

#### *Adequacy Determinations*

Information related to the Department's water adequacy determinations is presented on basin-scale maps (*Adequacy Determinations*) and summarized in a table for each basin (*Adequacy Determinations*) in Volumes 2-7. Where water adequacy reports and requests for analysis of adequate water supply have been filed, the tables include subdivision names, number of lots, locational data, Department file numbers, determination dates, reasons for inadequate determinations, and water providers at the time of application. Where water supplies have been designated for water provider service areas, the tables list information on Department file numbers, projected or estimated annual demand, the year the demand is expected, and designation dates. Adequacy determinations are further summarized in this volume by grouping the data into planning areas (Table 1-8) and by plotting on a statewide map (Figure 1-22).

Sources for this information come from the Department and include electronic databases maintained by the Office of Assured and Adequate Water Supply and paper files stored in the Hydrology Division (ADWR, 2010 and 2008e). Database queries were reviewed and some information was excluded from the Atlas based on subdivision location, duplicate applications, etc. Paper files were also reviewed to complete information that had not been entered into the databases such as number of lots and reasons for inadequate determinations.

Each determination of the adequacy of water supplies available to a subdivision is based on the information available to the Department and the standards of review and policies in effect at the time the determination is made.

#### *Assured Water Supply Determinations*

Information related to the Department's assured water supply determinations is presented on AMA scale maps (*Assured Water Supply Determinations*) and summarized in a table for each AMA (*Assured Water Supply Determinations*) in Volume 8. Where assured water supply certificates, water adequacy reports (pre-1980) and requests for analysis of adequate water supply have been filed, the tables include subdivision names, number of lots, locational data, Department file numbers, determination dates, and water providers at the time of application. Where water supplies have been designated, the tables list Department file numbers, information on projected or estimated annual demand, the year the demand is expected, and designation dates. Assured water supply determinations are further summarized in this volume by grouping the data by AMA (Table 1-9) and by plotting on a statewide map (Figure 1-22).

Sources for this information come from the Department and include electronic databases maintained by the Office of Assured and Adequate Water Supply and paper files stored in the Hydrology Division (ADWR, 2010 and 2008e). Database queries were reviewed and some information was excluded from the Atlas based on subdivision location, duplicate applications, etc. Lot count totals may over estimate the actual number of platted lots due to database accounting, changes in file numbering methodology and subsequent development plan changes.

Each determination of assured water supply is based on the information available to the Department and the standards of review and policies in effect at the time the determination is made.

## **B.2 Aquifers**

### ***Flow Direction***

Groundwater flow directions are presented on basin- and some sub-basin scale maps (*Groundwater Conditions*) in Volumes 2-8. This information was taken from a variety of technical reports prepared by the Department and the USGS. Flow directions are not shown for some basins, either because of insufficient groundwater level data and/or complex subsurface geology. The flow directions that are shown in the Atlas generally reflect long-term, regional aquifer flow in the basin and are not meant to depict temporary or local-scale conditions.

### ***Major Types***

Major aquifer types are listed in a table for each basin (*Hydrogeologic Data*) and are generally described in the text for each planning area volume. Information on aquifer types was taken from Volume II of the Department's 1994 *Arizona Water Resources Assessment* (ADWR, 1994b). To ensure consistency and simplify comparison between basins, aquifer descriptions from the 1994 *Assessment* were reviewed and grouped in the Atlas into five basic aquifer types:

- Basin fill;
- Igneous and metamorphic rocks;
- Recent stream alluvium;
- Sedimentary rock; and
- Volcanic rock.

In some basins, two or more of these aquifer types are found. Also, several aquifers in Arizona have been given specific names related to their geologic formation or location. Where known and applicable, this information is included in the Atlas. The aquifers in most basins can be further described by their rock type or sediment grade (e.g. sandstone vs. limestone) and position in the geologic sequence (e.g. upper vs. lower basin fill). This level of detail is not provided in the Atlas, but for reference, can be found in the 1994 *Assessment*. A summary of the major aquifers in Arizona is included in this volume (Table 1-4).

### ***Recharge and Storage***

Estimates of aquifer recharge and storage are listed in a table for each basin (*Groundwater Data*) and described in the overviews of Volumes 2-8. The estimates are based on one or more of six primary data sources:

- *Phase I; Arizona State Water Plan* published by the Arizona Water Commission in 1975 (AWC, 1975);

- A 1986 study by the USGS of predevelopment hydrologic conditions in the alluvial basins of Arizona and adjacent states (Freethy and Anderson, 1986);
- A 1990 internal report by the Department summarizing water resources information for the groundwater basins (ADWR, 1990);
- Volume II of the Department's 1994 *Arizona Water Resources Assessment* (ADWR, 1994b);
- A 1995 report by the USGS describing groundwater flow models developed for selected alluvial basins in south-central Arizona and parts of adjacent states (Anderson and Freethy, 1995);
- The Department's 1999 Third Management Plans (TMP);
- A 2009 Department memo summarizing groundwater storage estimates for the AMAs (ADWR, 2009c); and
- Various hydrologic reports and maps prepared by the USGS and the Department for select basins and subbasins across Arizona.

In many cases, these data sources provide information for areas that do not exactly coincide with the Department's groundwater basins. It was often necessary to adjust reported recharge and storage values to account for these differences in basin area as well as the location of the border between basin fill and bedrock and zones of high recharge (i.e. along or near mountain fronts).

Aquifer recharge is a difficult hydrologic parameter to measure and, on a regional level, it is usually determined indirectly either through development of water budgets and/or use of groundwater flow models. The recharge estimates presented in the Atlas generally represent long-term, natural (predevelopment) conditions. Wet and dry periods are averaged and artificial recharge is not considered. Such factors can significantly affect aquifer recharge in a given year. Aquifer storage is also a difficult parameter to measure and the estimates in the Atlas were usually based on a combination of point data from wells and results from large-scale surface geophysical surveys. Where aquifers consist of consolidated rock and storage is controlled by fractures, storage estimates can be highly unreliable. In light of these uncertainties, the Atlas often provides more than one estimate of aquifer recharge and storage for each basin. A summary of the aquifer recharge and storage estimates for Arizona is included in this volume (Table 1-4).

## **B.3 Climate**

### ***Average Annual Precipitation***

Average annual precipitation, in inches, is shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*) in Volumes 2-8 and on a statewide map in this volume (Figure 1-14). Contour lines and color-coding are used on the maps to delineate areas of equal and similar precipitation. This precipitation information comes from the Spatial Climatic Analysis Service (SCAS) at Oregon State University. Using an analytical tool called PRISM (Parameter-elevation Regressions on Independent Slopes Model), SCAS analyzed regional precipitation data averaged over the period 1961-1990 and prepared digital precipitation maps for the United States in 1998. The Department downloaded the PRISM map for Arizona from the SCAS website (SCAS, 1998).

### ***Evaporation Stations***

Evaporation data collected from AZMET and pan stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations*

and Annual Precipitation) in Volumes 2-8 and on a statewide map in this volume (Figure 1-14). Arizona Meteorological Network (AZMET) stations are operated in southern and Central Arizona and provide weather-based information to agricultural and horticultural interests. Pan stations refer to Class A evaporation pans that are used to estimate evaporation rates from natural surfaces such as shallow lakes and wet soils. Summary tables in the Atlas list the name and elevation of these stations, their period of record, and average annual evaporation rates in inches. Note that the pan evaporation rates listed are usually adjusted by multiplying by 0.7 or 0.8 before being used to estimate natural conditions. Reference evapotranspiration (E<sub>o</sub>) rates are listed for the AZMET stations and refer to the amount of water evaporated and transpired by well-maintained, well-watered turf grass.

Data from the AZMET stations were downloaded from a website maintained by the University of Arizona Cooperative Extension (AZMET, 2007), and data from the pan stations were downloaded from a website maintained by the Western Regional Climate Center (WRCC, 2005). Pan data were presented as monthly averages, which the Department summed for all months and presented as an annual average. Some pan stations did not measure evaporation rates during winter months and others estimated those rates using other meteorological data.

Several factors can affect evaporation rates, including air temperature, humidity, and wind. The data presented in the Atlas represent conditions at the measuring stations and provide a general indication of average evaporation rates in the basin. Care should be taken when using these data for site-specific studies.

### ***Precipitation and Temperature Stations***

Precipitation and temperature data from a network of weather stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*) in Volumes 2-8 and on a statewide map in this volume (Figure 1-14). The summary tables list the name and elevation of these stations, their period of record, and temperature and precipitation data. Temperature data include average minimum and maximum temperatures in degrees Fahrenheit and in which months these extremes occur. Precipitation data include average seasonal precipitation and average annual precipitation in inches. Seasons are defined in the Atlas as follows:

- Winter – January through March;
- Spring – April through June;
- Summer – July through September; and
- Fall – October through December.

The weather stations presented are part of a cooperative network maintained by the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS). Data from these stations has been compiled by the WRCC and posted on its website (WRCC, 2008). Statistics presented in the summary tables were downloaded directly from this website. Several factors can affect temperature and precipitation rates, particularly elevation and other geographic features. The data presented in the Atlas represent conditions at the measuring stations and provide a general indication of average temperature and precipitation conditions in the basin. Care should be taken when using these data for site-specific studies.

### ***Snowfall Stations***

Snowfall data from Snowcourse and Snowpack Telemetry (SNOTEL) stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*) in Volumes 2-8 and on a statewide map in this volume (Figure 1-14). The summary tables list the name and elevation of these stations, their period of record, and snowpack measurements. The average snowpack at the beginning of each month is presented as inches of snow water content, also referred to as the snow water equivalent. Only those months when snow surveys are usually conducted (January through June) are included.

Snowcourse and SNOTEL stations are operated by the Natural Resources Conservation Service (NRCS). Data from these stations have been compiled by NRCS and posted on its website. Statistics presented in the summary tables were downloaded directly from this website (NRCS, 2006 and 2005). Many factors can affect snowpack depths such as aspect, elevation and forest cover and NRCS takes great care to locate snow course and SNOTEL stations that provide representative data. Nevertheless, the data presented in the Atlas represents conditions at the measuring stations and only provides a general indication of average snowfall conditions across the highlands of some basins. Care should be taken when using these data for site-specific studies.

### ***Trends in Precipitation and Temperature***

Long-term trends in precipitation and temperature are shown by Planning Area in Volumes 2-8 and in Section 1.4.3 and Appendix E of this volume. Trend data are presented graphically with explanatory text. This information was primarily contributed by researchers at the University of Arizona, including the Institute for the Study of Planet Earth, which is responsible for the Climate Assessment for the Southwest (CLIMAS) program (CLIMAS, 2008). WRCC (2008) provided trend data for the AMAs.

## **B.4 Contamination Sites**

Contamination sites are shown on planning area and AMA maps (*Contamination Sites*) in Volumes 2-8 and on a statewide map in this volume (Figure 1-27). Included are the locations of U.S. Department of Defense (DOD), Voluntary Remediation Program (VRP), Superfund (listed on the National Priorities List or NPL), Resource Conservation and Recovery Act (RCRA), Water Quality Assurance Revolving Fund (WQARF) and Uranium Mill Tailings Remedial Action (UMTRA) sites as well as leaking underground storage tanks (LUST).

The data were provided by ADEQ and included locations for all LUST sites in Arizona, regardless of reported contaminant levels or whether remediation had been completed (ADEQ, 2006). For purposes of the atlas, LUST sites are only shown where contamination is either suspected or known to exist and remediation is required to meet soil and water quality standards. LUST sites that meet applicable standards and/or have been remediated and closed-out are not included.

## **B.5 Cultural Water Demands**

### ***Location of Major Water Use***

Locations of major water use are shown on basin-scale maps (*Cultural Water Demands*) in Volumes 2-8 and on a statewide map in this volume (Figure 1-31). Included on the maps are agricultural

lands, low- and high-intensity developments, mines and power plants. The primary data source for the water use maps was a land cover study of the southwestern United States, completed by the USGS (2004). Land cover types were mapped in this study at a 5- to 12-acre resolution using Landsat satellite imagery collected between 1999 and 2001. The Department supplemented the data with the locations of active power plants and mines (ADMMR, 2005).

Due to its resolution, use of Landsat imagery to map land cover types requires a high degree of interpretation and some areas of water use, particularly agricultural lands, may be misclassified. The Department reviewed the USGS land covers to ensure that they were reasonable and made edits as needed. It should also be noted that the Landsat imagery used by the USGS is now as much as 10 years old, and some land cover types may have changed since the imagery was taken.

### ***Surface Water Diversions***

Annual surface water diversions for agriculture, industrial, and municipal uses are listed in a table for each basin (*Cultural Water Demand*) in Volumes 2-8 and on a statewide table in this volume (Table 1-14). For the AMAs, surface water diversions are grouped with other non-groundwater supplies which can include Central Arizona Project (CAP) water, effluent, and spill and tail waters

Surface water demand data for the period 1971-1990 (and through 1985 in the AMAs) were taken from the Department's 1994 *Assessment* (ADWR, 1994a). A variety of sources were utilized to determine more recent surface water demands for the period 1991 through 2005. ADEQ (2005b) furnished a list of municipal water providers who utilize surface water and the ACC (2005b) supplied annual reports for some of these providers indicating how much surface water they were diverting and/or delivering. USGS (2007) provided data on surface water demands for agriculture for those basins where the diversions have been metered. Most other surface water demands had to be determined by the Department through one or more methods including review of existing Department, BOR, county, and consultant reports; analysis of recent aerial photography; Internet and records research; questionnaires and phone interviews; consultation with the USGS; and, limited fieldwork (ADWR, 2008f). The Department's Colorado River Management Section was an important data source and provided records of Colorado River water users, locations and annual diversion volumes (ADWR, 2006). Department Annual Withdrawal and Use Reports provided data on most surface water demands in the AMAs since 1986 (ADWR, 2008g).

In many cases outside of the AMAs, the Department had to estimate the quantity of surface water demand because the records were nonexistent, imprecise or incomplete (ADWR, 2008f and 2005b). For example, to estimate unmetered surface water diversions for agriculture, the Department made assumptions about the number of cropped acres and water duty. For some irrigated areas, diversion amounts were adjusted to account for basin boundaries. Similarly, for most non-AMA golf courses determined to be using surface water, the Department estimated demand based on the number of holes and local irrigation needs for turf (ADWR, 2008j). The surface water demand of municipal water providers was estimated in some cases based on the number of hookups, an assumed per capita use rate and delivery losses.

As previously mentioned, the surface water demand for agricultural, industrial, and municipal use was often unmetered and had to be estimated by the Department. Historic demands were assumed

to represent current conditions and vice versa if information was not available. Assumptions were also made where water demands were met by combining surface water diversions and well pumpage, but the precise volume of each was not known. Furthermore, it is likely that several relatively small surface water diversions were simply not identified by the Department and not included in the Atlas. The values presented in the Atlas should, therefore, not be considered precise, but they provide an estimate of these demands and indicate where surface water is an important water source to meet cultural demands. The following conventions were used to round cultural demand values met by surface water:

- 0 to 1,000 acre feet – round to the nearest 50 acre-feet (af);
- 1,000 to 10,000 acre-feet – round to the nearest 100 af;
- 10,000 to 100,000 acre-feet – round to the nearest 500 af; and
- 100,000 to 1,000,000 acre-feet – round to the nearest 1,000 af.

Recent non-groundwater demands in the AMAs were generally rounded to the nearest 100 af.

Finally, it should be noted that surface water stored in reservoirs and stockponds and diverted through fish hatcheries were not included in the cultural demand tables. Practically all of the surface water diverted by fish hatcheries passes through the facilities and is released for use downstream. Surface water stored in reservoirs and stockponds may or may not be released for use downstream and some of this water is lost to evaporation.

### ***Well Pumpage***

Annual well pumpage for agricultural, industrial, and municipal uses is listed in a table for each basin (*Cultural Water Demand*) in Volumes 2-8 and on a statewide table in this volume (Table 1-14). Data on well pumpage are also summarized by planning area in the text of the planning area volumes. Well pumpage data for the period 1971 through 1990 (and through 1985 in the AMAs) are from the Department's 1994 *Assessment* (ADWR, 1994a). Outside of the AMAs, the primary data source for well pumpage for the period 1991 through 2005 was the USGS (2007), which describes its methodology, assumptions, and data limitations in the 2005 report *Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000* (Tadayon, 2004). The Department's Annual Withdrawal and Use Reports provided most well pumpage data for the AMAs since 1986 (ADWR, 2008g).

The Department had to adjust the USGS pumpage values for a few basins where mining companies pump from the same wells to supply both industrial and municipal needs and, in other basins where springs have been identified as a water source. The USGS accounted for water use from springs as well pumpage, whereas the Department considers these to be surface water diversions. In addition, the USGS did not evaluate water use by feedlots and golf courses. The Department considers both to be industrial uses and, for the Atlas, estimated well pumpage following methods similar to those used to estimate surface water diversions (ADWR, 2008j and 2008k). To estimate well pumpage for feedlots, the Department identified feedlots by using ADEQ's list of active feedlots in Arizona (ADEQ, 2005a) and, based on the type and number of animal units at each feedlot, applied a consumptive rate.

Outside of the AMAs, the quantity of well pumpage for agricultural, industrial and municipal use was not always metered, requiring estimation in some cases (ADWR, 2008f). Historic pumpage was assumed to represent current conditions, and vice versa, if information was unavailable.

Assumptions were also made where water demands were met by combining well pumpage and surface water diversions, but the precise volume of each was unknown. Lastly, it is likely that several relatively small well withdrawals were simply not identified by the USGS or the Department and are not included in the Atlas. The values presented in the Atlas should, therefore, not be considered precise, but they provide an estimate of pumpage and indicate where well water is an important water source to meet cultural demands. The following conventions were used to round cultural demand values met by well pumpage:

- 0 to 1,000 acre feet – round to the nearest 50 af;
- 1,000 to 10,000 acre-feet – round to the nearest 100 af;
- 10,000 to 100,000 acre-feet – round to the nearest 500 af; and,
- 100,000 to 1,000,000 acre-feet – round to the nearest 1,000 af.

In the AMAs, recent well pumpage was rounded to the nearest 100 af.

### ***Community Water System Annual Reports***

Beginning in 2006, all community water systems in the state must submit an annual report of water withdrawals, diversions and deliveries to the Department. Systems in the AMAs have been reporting this information to the Department since 1984 under provisions of the Groundwater Management Act. A community water system is defined as a public water system that serves at least 15 service connections used by year-round residents or that regularly serves at least 25 year-round residents. A.R.S. § 45-341. This information has been compiled by planning area in the Appendices of Volumes 2-7 and data for the largest water providers are included in water demand summary tables in the overview of these volumes.

### ***Planning Area Summaries***

The overview of Volumes 2-8 summarize the basin surface water diversion and well pumpage data described above by planning area. Average cultural water demands during the period 2001-2005 are listed in tables and displayed on graphs and pie charts. For comparison, water demands for the periods 1991-1995 and 1996-2001 are also listed in certain tables and tribal water demands are presented separately. These planning area data are further summarized in Section 1.4.7 of this volume.

## **B.6 Drought**

Drought conditions in the planning areas are discussed under the Climate Section of Volumes 2 through 8 and in Appendix E of this volume. This information was provided by the Department's Drought Planning Section, University of Arizona Cooperative Extension, CLIMAS/Institute for the Study of Planet Earth, and the USGS (CLIMA, 2005).

## **B.7 Effluent**

### ***Facility Data***

Information on facilities that treat and discharge effluent is summarized in a table for each basin (*Effluent Generation*) in Volumes 2-8 and summarized in a planning area table (Table 1-13) of this volume. For each treatment facility, the tables list the name, owner, city/location served, population served, volume of effluent treated/generated annually, effluent disposal methods, levels of treatment, unserved population, and year of record.

Primary data sources were the Clean Water Needs (CWN) Surveys sponsored by the Water Infrastructure Financing Authority (WIFA), and annual reports provided by the ACC. CWN Surveys are conducted every two to four years and are used to assist treatment facilities in obtaining funding. To capture data for as many treatment facilities as possible, survey results from 1996, 2000, 2004 and 2006 were used for the Atlas (EPA, 2005a, 2005b, 2002, 2000 and 1996). The ACC regulates private treatment plants and requires that operators file annual reports that sometimes included data on effluent production (ACC, 2005). The data were supplemented, when possible, with information from facility operators, from ADEQ (2005c,d,e,f), which issues facility discharge permits), and city, county and Department reports. The latter include Annual Withdrawal and Use Reports (in AMAs) and Community Water System annual reports.

Wastewater treatment is a dynamic industry with frequent changes in plant names, treatment levels and effluent volumes. Although the last CWN survey was conducted in 2006, updated information was not available for all facilities. The Department used the most recent data available, which for some facilities is over 10 years old (WIFA, 2005a and b).

### ***Effluent Dependent Waters***

The location of effluent-dependent waters, including lakes and stream reaches, are shown on basin-scale maps (*Water Quality Conditions*) in Volumes 2-8. A GIS cover of effluent-dependent waters in Arizona was provided by ADEQ (2005g). These reaches are also listed and described by ADEQ in their surface water quality rules (A.A.C. R18-11-113).

## **B.8 Environmental Conditions**

### ***Biotic Communities and Ecoregions***

Information on biotic communities (Brown and Lowe, 1980) and ecoregions (Olson and others, 2001) are discussed in the overview and shown on planning area-scale maps (*Biotic Communities and Ecoregions*) in Volumes 2-8. A statewide map is presented in Figure 1-18 of this volume.

### ***National Parks, Monuments, Wildlife Refuges and Wilderness Areas***

A discussion of National Parks, Monuments, Wildlife Refuges and Wilderness Areas is provided in the overview of Volumes 2-8 and their location is shown on planning area maps (*Protected Areas*) in these volumes (BLM, 2008 and 2006; USFS, 2007). A table of wilderness areas with total acres and brief description of prominent features is also found in the overview of Volumes 2-8.

### ***Riparian Areas***

The location of riparian areas (AZGF, 1993) is shown on planning area maps (*Instream Flow Applications*) in Volumes 2-8 and a statewide map is presented in Figure 1-19 of this volume.

### ***Threatened and Endangered Species***

A table listing threatened and endangered species (USFWS, 2008) by planning area and their elevation and habitat is found in the overview of Volumes 2-8.

## B.9 Geology

### *Surface Maps*

Surface geologic conditions are shown on planning area maps (*Surface Geology*) in the overviews of Volumes 2-8 and on a statewide map (Figure 1-3) in this volume. The maps display nine generalized geologic units based on more detailed mapping by Reynolds (1988).

### *Cross Sections*

The Eastern and Western Plateau planning areas are underlain by a sequence of sedimentary rocks with water-bearing formations most common in sandstones and limestones. The relationship between the formations is shown on cross sections in the overviews of Volumes 2 and 6 and in this volume (Figure 1-5, ADWR 1989). Cross-sections of typical subsurface geologic conditions in other planning areas are shown in Figure 1-6 (ADWR, 1993) and Figure 1-7 (Parker and Flynn, 2000) of this volume.

## B.10 Land Ownership

Land ownership information is presented on basin-scale maps (*Land Ownership*) and summarized in the text of Volumes 2-8. Included on the maps are the location of major landowner types (e.g. private, BLM, NPS, etc.) and the percentage that each type comprises of the total basin area. Data on current land ownership was downloaded from the Arizona Land Resource Information System (ALRIS) website maintained by the Arizona State Land Department (SLD) (ALRIS, 2004). A statewide summary table (Table 1-2) is presented in this volume.

## B.11 Lands Survey

A number of Atlas maps show township and range lines. Most lands in Arizona have been mapped according to a rectangular coordinate system known as the Public Lands Survey. Under this survey, lands are divided into “townships” and “sections.” A township is a square parcel of land six miles on each side that is subdivided into 36 equal parts called sections. A section covers one square mile or 640 acres. Because of the earth’s curvature, surveying errors and other factors, not all townships are square, not all townships contain 36 sections, and not all sections contain 640 acres.

Townships are located relative to a point that forms at the intersection of an east-west “baseline” and a north-south “meridian.” Locations are referenced as being so many six-mile units, called “Townships”, north or south of the baseline and so many six-mile units, called “Ranges,” east or west of the meridian. Most of Arizona’s townships were surveyed relative to the point of intersection of the Gila and Salt Rivers, referred to as the Gila and Salt River Baseline and Meridian. Approximately 20 townships in Apache County were surveyed from the Navajo Baseline and Meridian established in New Mexico, and a small portion of land near the town of Yuma was surveyed from the San Bernardino Baseline and Meridian established in California (ASLD, 2006).

Townships surveyed from the Gila and Salt River Baseline and Meridian are plotted on all basin-scale maps in the Atlas. This information was digitized from USGS Quads. Townships surveyed from the Navajo and San Bernardino Baselines and Meridians have generally not been plotted,

but these are included on the base map that was used to prepare *Geographic Features* maps. Note that in some areas in Arizona no townships have been surveyed. These include a large portion of the Navajo and Hopi Indian Reservations in northeastern Arizona, a small portion of the San Carlos Indian Reservation in east-central Arizona, and several Spanish land grants in southeastern Arizona. To provide general mapping reference, Department staff protracted these unsurveyed areas extending townships based on the Gila and Salt River Baseline and Meridian into these areas. These unofficial townships are included on maps in the Atlas.

## **B.12 Physiographic Regions**

Based on differences in geography, Fenneman and Johnson (1946) divided Arizona into three physiographic regions – the Colorado Plateau, Transition Zone, and Basin and Range. The overview of Volumes 2-8 and Figure 1-3 of this volume show the location of the three regions and associated topographic conditions.

## **B.13 Population**

Population data are listed in a table for each basin (*Cultural Water Demand*) in Volumes 2-8. The tables include yearly estimates of population from 1980-2005 and population projections every 10 years from 2010-2030. Data from the U.S. Bureau of Census (Census, 2006) were used to estimate past populations and Arizona Department of Commerce data were used for population projections (ADOC, 2009). The overviews of Volumes 2-8 also list communities in the planning areas with 2000 Census populations greater than 1,000 and this volume summarizes population data by planning area (Table 1-6) and lists the largest communities and highest growth rates statewide (Table 1-7). Communities with annual growth rates greater than 2% are shown on Figure 1-21 of this volume.

The Census provided spatial data for the years 1980, 1990 and 2000, which were organized into tracts (largest), groups, and blocks (smallest). Using GIS software, the Department divided the Census blocks into their respective basins and, as necessary, proportionally split by area those blocks that covered two or more basins. Populations between Census years were estimated by straight-line interpolation.

ADOC provided projections of how the population in Census places, such as towns and cities, would change in the future. The Department identified the Census places in each basin and applied the projected ADOC population change, as a percentage, to the 2000 Census data. If more than one Census place occurred in the same basin, the projected changes were averaged and applied across the basin. For three basins (Dripping Springs Wash, Paria, and San Simon Wash) there was insufficient data to make population projections and it was assumed that basin populations have been and will remain the same from 2001 through 2030.

## **B.14 Recharge Facilities**

Recharge facilities permitted by ADWR are located in the Phoenix, Pinal, Prescott and Tucson AMAs and include underground storage facilities (USF) and Groundwater Savings Facilities (GSF). The location and permitted capacity of the USF and GSF sites are shown on a map for

each AMA (*Recharge Sites*). A table (*Recharge Sites*) accompanies each map with associated data from ADWR's Office of Assured and Adequate Water Supply and Recharge Permitting. The tables list the facility name, number and type, the permittee and permitted annual quantity of recharge water, and source of water.

## B.15 Reservoirs

### *Location, Capacity and Use*

Information on large to small reservoirs is summarized in a table for each basin (*Reservoirs and Stockponds*) and locations of the large reservoirs are shown on basin-scale maps (*Surface Water Conditions*) in Volumes 2-8. A statewide map showing the location of large reservoirs, Figure 1-10, is presented in this volume. Natural water bodies, such as dry and intermittent lakes, as well as man-made reservoirs, are included.

Large reservoirs are defined in the Atlas as water bodies with a maximum storage capacity of 500 acre-feet or greater, or where capacity data were unavailable to the Department, a maximum surface area of 50 acres or greater. Small reservoirs are defined as water bodies with a capacity of greater than 15 but less than 500 acre-feet, or a maximum surface area of between 5 and 50 acres. The tables list the name of each large reservoir and the name of the dam (if different), the owner/operator, the maximum storage or surface area, its use (recreation, power, water supply, etc.) and jurisdiction (federal, state, tribal or private). The tables also list the total number of small reservoirs in a particular basin and their combined maximum storage capacity and surface area.

Reservoir information was obtained from 5 primary data sources:

- National Inventory of Dams maintained by the U.S. Army Corps of Engineers (USACE, 2004 and 2005);
- The Department's database of jurisdictional and non-jurisdictional dams in Arizona (ADWR, 2005c and 2005d);
- Arizona Game & Fish Department's waterways file and lake classification study (AZGF, 2005 and 1982);
- Digital versions of 1:100,000 scale USGS topographic maps (ALRIS, 2005b); and
- The Department's registry of surface water right and adjudication filings (see further discussion in this section under 'Stockponds').

For consistency, the Atlas lists maximum storage capacities for most large reservoirs. When these values were not available, normal storage capacities are presented and noted or, as described above, maximum surface area is presented. Several reservoirs were identified by more than one data source. To avoid duplication, reservoir locations were compared and the most recent data source was typically used. In most cases, reservoir locations presented in the Atlas represent the center of the reservoir, but in some cases, it marks the middle of the dam.

For the purpose of establishing dam jurisdiction, large reservoirs located on federal lands, such as national forests and national parks, were assumed to be under federal jurisdiction. Similarly, large reservoirs located on tribal lands were assumed to be under tribal jurisdiction. Some reservoirs listed in the data sources probably no longer exist, either because they have filled in with sediment and/or have been breached. Where more recent information indicates that a dam has filled with sediment or has been breached, it was not included in the Atlas.

The location of major (>20,000 acre-feet capacity) reservoirs in Arizona are shown on Figure 1-11 of this volume

### ***Storage Trends***

Figure 1-13 of this volume shows recent (1980-2008) trends in reservoir storage along Arizona's four major rivers – the Colorado, Salt, Verde, and Gila. May 1<sup>st</sup> storage quantities are shown separately for Lakes Mead and Powell on the Colorado River; are combined for Roosevelt, Apache Canyon and Saguaro lakes on the Salt River and Horseshoe and Bartlett reservoirs on the Verde River; and shown for San Carlos Reservoir on the Gila River. ADWR plotted these storage hydrographs using data compiled by the BOR (2010a), SRP (2008) and Gila Commissioner (various dates), respectively. Capacities for the individual lakes and reservoirs along the Salt and Verde Rivers are displayed on a schematic in Volume 8 (Figure 8.0-17) and Volume 5 (Figure 5.0-6) and a graph of changes in the end of month water level elevation for Lake Mead since 1980 is included in Volume 4 (Figure 4.0-13).

## **B.16 Rural Watershed Initiative Partnerships**

Arizona's Rural Watershed Initiative Partnerships are tabulated in Appendix D of Volumes 2-7 along with their activities, accomplishments, and identified issues in 2008 and a statewide summary table and map showing the location of partnerships are found in Appendix I of this volume. The Regional Strategic Planning Office at the Department tracks the status of the partnerships and provided the partnership information presented in the Atlas. Note that the issues identified by partnership participants may not represent all of the water resource issues currently faced in rural Arizona.

## **B.17 Springs**

Major and minor springs are listed in a table for each basin (*Springs*) in Volumes 2-8. A spring was considered 'major' if its discharge was 10 gallons per minute (gpm) or greater and 'minor' if its discharge was between 1 and 10 gpm. The tables include the name of the major and minor springs, their location (latitude/longitude), the most recent discharge measurement, and the measurement date. The tables also include an estimate of the total number of springs, regardless of discharge, that have been mapped in the basin. Locations of the major springs are shown on basin-scale maps (*Perennial/Intermittent Streams and Major ( $\geq 10$  gpm) Springs*) in Volumes 2-8 and in Figure 1-12 of this volume.

Spring data were obtained from a variety of sources, most notably the USGS (2006a), which maintains a database of spring discharge records. Reports compiled from universities and public land agencies such as the U.S. Forest Service, National Park Service, and BLM were also useful (ADWR, 2008b). To estimate the total number of springs in each basin, the Department downloaded GIS covers from ALRIS (2005c) and the National Hydrography Data Set (NHD) that incorporate spring locations from the USGS Geographic Names Information System (GNIS or Geonames) database and from USGS Digital Line Graphs (DLGs) (USGS, 2006b). ALRIS and NHD do not indicate how or when the USGS located these springs. It is also not known whether a detailed, ground survey would now identify more springs or, in light of recent drought conditions, less spring sites.

Many of the springs with discharge data were listed in more than one data source. To avoid over-counting, the Department compared spring names, locations, discharge rates, and dates of measurement and removed obvious duplicates. Topographic maps were also checked to verify that the springs had been mapped. Those springs not verified on topographic maps were included in the Atlas but noted accordingly. For most springs, the location and point of discharge measurement were, for practical purposes, the same. But in some areas, particularly the Grand Canyon, access was poor and discharge measurements had to be made at a point significantly downstream of the spring orifice.

The Atlas generally presents the most recent discharge measurement identified at a spring site. However, for springs fed by shallow water sources, discharge rates can vary dramatically from year to year or even from day to day. To address this issue, some springs were included in the Atlas even if their last discharge measurement had dropped below 10 gpm for major springs or 1 gpm for minor springs. For these springs, the date of measurement is an earlier date when the discharge was greater.

## **B.18 Stockponds**

An estimate of the total number of stockponds is listed in a table for each basin (*Large and Small Reservoirs and Stockponds*) in Volumes 2-8. The estimates are based on analysis of the Department's registry of surface water rights and adjudication claims (ADWR, 2009b). The registry includes the following water right filings:

- Applications to appropriate public water, permits and certificates of water right (Department file numbers beginning with "33", also known as "33s");
- Water right registrations filed pursuant to the Water Rights Registration Act of 1974 ("36s");
- Stockpond registrations filed pursuant to the Registration of Stockponds Act of 1977 ("38s");
- Statement of claimants filed by Indian tribes, or the federal government on their behalf, as part of the Gila River and Little Colorado River Adjudications ("39s"); and,
- Court decreed water rights ("4As" and "BBs").

Only those filings for ponds with a capacity of 15 acre-feet or less were considered. Because the same stockpond can often have 2 or more associated filings, an effort was also made to avoid overcounting the number of ponds by comparing stockpond names and locations and eliminating duplicates. Stockpond locations were not verified through field investigations or by analysis of topographic maps and aerial photographs. As a result, it is unknown whether additional ponds exist but were never claimed, or whether the ponds that were claimed are still in use. In areas of the state where stockpond locations have been previously verified, estimates based only on water right filings appear to be within an order of magnitude.

## **B.19 Streams**

*Diversions (see Cultural Water Demands)*

### ***Flood Warning (ALERT) Gages***

The location of flood warning gages is shown on basin-scale maps (*Surface Water Conditions*) and information related to these gages is summarized in a table for each basin (*Flood ALERT Equipment*) in Volumes 2-8. The tables include the name and identification number of the gaging stations, station types (precipitation, stage, repeater, or some combination of these), dates of installation, and who is responsible for operation and maintenance (flood control districts, cities, etc.).

This information was obtained from the Department's Surface Water Division, which maintains a database of flood warning equipment across Arizona (ADWR, 2005e). The Department's database was queried in fall 2005 and the information presented in the Atlas was accurate at that time. According to staff in the Surface Water Division, new flood warning gages are routinely added to the ALERT (Automated Local Evaluation in Real Time) network so the current number of stations may be greater than presented.

### ***Flow Gages***

The location of USGS streamflow gages is shown on basin-scale maps (*Surface Water Conditions*) and information related to the gages is summarized in a table for each basin (*Streamflow Data*) in Volumes 2-8. The tables include the following information for all continuous flow gages, active or discontinued, with at least one year of record:

- Name and identification number of the station;
- Drainage basin area and gage elevation;
- Period of record;
- Average seasonal streamflows, as a percentage of annual flow;
- Annual streamflow statistics (minimum, median, mean, and maximum); and,
- Number of years of annual streamflow data used to calculate statistics.

The Atlas does not include data from USGS peak flow gages or from continuous flow gages with less than one year of record.

Gage information was obtained from USGS sources including their National Water Information System (NWIS) on-line database (USGS, 2008a and 2005b), recent Water-Data Reports (USGS, 2003 and 2002), and a 1998 report that summarizes streamflow data and drainage basin characteristics for selected gaging stations (Pope and others, 1998). The Department calculated average seasonal streamflows using mean monthly streamflow data downloaded from NWIS. Note that mean streamflow values in the Southwest may be affected by a few large flows which are common in the region. Seasons were defined in the Atlas as follows:

- Winter – January through March;
- Spring – April through June;
- Summer – July through September; and
- Fall – October through December.

Annual streamflow statistics were calculated using mean annual streamflow data also downloaded from NWIS. These statistics were not necessarily run on a gage's entire period of record, as the USGS only calculates annual streamflows for years with a complete 12-month dataset. Also, annual statistics are only presented for gages with 3 or more years of record and all calculations are based on Calendar Year, not Water Year. Average seasonal streamflows and annual streamflow statistics were calculated using data retrieved in 2005 or 2007 (AMAs only).

Streamflow statistics are affected by the length of record (e.g. 3 years vs. 50 years of data) as well as the hydrologic conditions occurring when the data were collected (e.g. drought vs. wet period). In addition, isolated conditions may affect streamflow at one station but not at another station nearby. In light of these constraints, the statistics presented in the Atlas should only be used as a general indication of streamflow conditions in the basins and not for site-specific studies.

This volume includes a map (Figure 1-10) showing the location of USGS streamflow gages. The location of gages on major Arizona streams are shown on Figure 1-11 and an accompanying data are summarized in Table 1-5. Streams were considered major if calculated median or mean annual flows exceed 20,000 and 30,000 acre-feet, respectively.

### ***Instream Flow***

Information on instream flows is summarized in a table for each planning area (*Instream Flow Claims*). The location of instream flow claims are shown on planning-area maps (*Instream Flow Applications*) in Volumes 2-8 and on a statewide map in Figure 1-19 of this volume. The tables include the name of stream reaches with instream flow claims, the name of applicants who have filed for instream flow rights, application numbers and dates of filing and, whether applications have been permitted and certificated by the Department. This information was provided by the Permitting Unit of the Department's Surface Water Division which maintains a database that tracks the status of instream flow applications (ADWR, 2008d).

### ***Intermittent and Perennial Reaches***

Recent perennial and intermittent streams are shown on basin-scale maps (*Perennial/Intermittent Streams and Major (>10 gpm) Springs*) in Volumes 2-8 and on a statewide map (Figure 1-12) in this volume.

Locations of perennial streams were primarily taken from a 1993 report prepared by the Arizona Game and Fish Department (AZGF) as part of the Statewide Riparian Inventory and Mapping (SRIM) Project (AZGF, 1993). In that report, AZGF identified perennial reaches based on an earlier AZGF map (Brown and others, 1981) that AZGF revised after consultation with several government agencies (the Department, ADEQ, BLM, and USFS), private sector hydrologists, and academics. Locations of intermittent streams were primarily taken from a 1997 AZGF report prepared during the last phase of the SRIM Project. Intermittent stream reaches were identified on topographic maps by staff of AZGF, BLM, NPS, and USFS (AZGF, 1997).

Due to the prolonged drought that has recently affected Arizona, some of the perennial stream reaches identified by AGFD may now be intermittent and some of the intermittent reaches may now be ephemeral. As climatic conditions change in the future, it is expected that many of these streams will likely return to their previously classified flow conditions, except where impacted by development.

### ***Major Drainages***

Major stream drainages are shown on basin-scale maps (*Surface Water Conditions*) in Volumes 2-8. Drainage locations were taken from ALRIS, which provides a GIS cover of Arizona streams (ALRIS, 2005a). The ALRIS stream cover is based on 1:100,000 scale USGS topographic maps that were enhanced with data from EPA and several state agencies.

ALRIS classifies streams into five cartographic orders based generally on drainage basin size. Cartographic Order 1 streams drain the largest areas and include major rivers like the Colorado, Verde, Salt, Gila, etc. The *Surface Water Conditions* maps show the location of Cartographic Order 1, 2 and 3 streams distinguished by width and include stream names for the first two orders.

### ***Runoff***

Average annual or ‘unit’ runoff contours are plotted on basin-scale maps (*Surface Water Conditions*). The contours show the magnitude and spatial variation in runoff, in inches per year, based on streamflow data collected by the USGS during 1951 through 1980. The data reflects the runoff in tributary streams, rather than in major rivers, as an indication of how runoff varies regionally with precipitation and other geographic features.

The streamflow data were compiled by the USGS in 1985 and, in 1987, a 1:2,000,000-scale unit-runoff contour map of the conterminous United States was published (Gerbert and others, 1987). The map has since been digitized and posted on the USGS website where the Department downloaded it for use in the Atlas (USGS, 2006c).

### ***Watersheds***

The USGS divides the United States into hydrologic units based on watershed size. From largest to smallest, these units consist of regions, subregions, accounting units and cataloging units. Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits depending on unit level. A 6-digit code corresponds to accounting units, which are used by the USGS for designing and managing their National Water Data Network (USGS, 2005a).

Watersheds delineated by USGS accounting units are shown on planning area maps (*USGS Watersheds*) in the overview of Volumes 2-8 and on a statewide map in this volume (Figure 1-10). Text that accompanies these maps summarizes the important features of each watershed including its drainage area, major streams and springs, large reservoirs, and flow conditions.

## **B.20 Surface Water Rights**

An inventory of surface water right and adjudication filings for each basin is tabulated in the overview of Volumes 2-8. The number and type of filings were determined by querying ADWR’s surface water right and adjudication registries in February 2009 (ADWR, 2009b). A file was only counted if it provided sufficient information to allow a Point of Diversion (POD) to be mapped within a given basin. If a file listed more than one POD in a basin, it was only counted once however multiple filings for the same POD were counted. Appendix C of Volumes 2-8 and Table 1-12 of this volume summarize the total number of these filings by planning area.

The location of PODs based on the surface water filings are shown on planning area maps (*Registered Wells and Surface Water Diversion Points*) in the overview of Volumes 2-8 and on statewide map in Appendix C of those volumes and in Figure 1-24 of this volume.

## **B.21 Water Protection Fund**

Information on Water Protection Fund grants is summarized in a table (*Arizona Water Protection*

*Fund Grant Summary*) and shown on a statewide map (*Arizona Water Protection Fund Grant Locations*) in Appendix F of this Volume. The table includes grant numbers issued through FY 2008, project titles and categories, and associated groundwater basins. Similar information is also presented in tables by planning area in Appendix A of Volumes 2-8.

The tables and map are based on a database maintained by the Department's Office of Water Protection (ADWR, 2008c). For purposes of the Atlas, Water Protection Fund projects were grouped into categories by type (watershed restoration, revegetation, research, etc.) and organized by groundwater basin.

## **B.22 Water Quality**

Water quality data are summarized in tables for each basin (*Water Quality Exceedences*) and sample locations are shown on basin-scale maps (*Water Quality Conditions*) in Volumes 2-8. The maps show the location of wells, springs, and mines that have equaled or exceeded drinking water quality standards and lakes and streams that are impaired for designated uses. Tables for the wells, springs, and mines list the type of sampling site, its location (township, range and section), and relevant water quality parameters. Tables for the lakes and streams list the name and type of impaired water body, its length (streams) or area (lakes), and which water quality parameters have exceeded designated uses standards. Sample dates and parameter concentrations are not included in the tables, but this information has been compiled by the Department and is available for review.

Water quality data for the wells, springs, and mines were obtained from the following primary sources:

- The Department's Groundwater Site Inventory (GWSI) database (ADWR, 2005f);
- USGS's National Water Inventory System (NWIS) database (USGS, 2005b);
- ADEQ's Safe Drinking Water (SDW), Rural Watershed Study, and Arsenic databases (ADEQ 2005h and 2004a,b,c); and
- Various technical reports prepared by the Department, ADEQ and USGS.

Data on impaired lakes and streams comes from ADEQ's 2006 report *The Status of Water Quality in Arizona – 2004, Arizona's Integrated 305(b) Assessment and 303(d) Listing Report* (Diroll and Marsh, 2006).

Several of the well, spring, and mine sites have been sampled more than once and/or results from the same sampling date are listed in more than one data source. An effort was made to remove duplicate data using available information on site location. The water quality data presented in the Atlas indicate areas where water quality exceedences have previously occurred. Additional areas of concern may currently exist where water quality samples have not been collected or sample results were not reviewed by the Department. For example, as part of ADEQ's Underground Storage Tank (UST) and Aquifer Protection Permit (APP) programs, thousands of water quality samples have been collected and analyzed. Results from these analyses were not included in the Atlas. What is included for these and other environmental programs is a 2006 map from ADEQ that shows the location of contaminated sites across the state (See *Contamination Sites*).

Finally, note that the water quality data presented in the Atlas may not reflect the quality of water being supplied by public water systems. The latter are required by federal and state law to supply water that meets drinking water standards. The Atlas indicates areas where private well owners and surface water users may want to test the quality of their water or restrict its use. The distribution of common ground water quality exceedences in Arizona ground waters (arsenic, fluoride, nitrate and total dissolved solids) is shown in Figure 1-26 of this volume.

## **B.23 Wells**

### ***Automated Recorder Sites***

The location of automatic water-level recorders (automated wells) across Arizona is shown in Figure 1-25 of this volume. Automated wells collect numerous measurements daily, filling in the gaps between annual measurements. Information on these well sites comes from the Department's Field Services Unit (ADWR, 2005g), USGS, and the Cities of Flagstaff and Williams and further discussed in the overview of Volumes 2-8.

### ***Basin Sweeps***

A well sweep refers to a large number of measurements of water levels in wells throughout a basin. While efforts are made to target specific wells, the process has been largely random in nature, and is intended to provide the best aerial and vertical coverage in the basin. It is not intended to, and does not include every well in the basin. The date of the most recent well sweep and the number of wells measured during the sweep is listed in a table for each basin (*Groundwater Data*) in Volume 2-8 and in Table 1-4 of this volume. Information on well sweeps comes from the Department's Groundwater Site Inventory (GWSI) database (ADWR, 2005f).

### ***Index Sites***

The number of index wells is listed in a table for each basin (*Groundwater Data*) in Volumes 2-8 and shown on a statewide map (Figure 1-25) in this volume. Water levels in index wells are measured manually at specific times, or continuously using automatic recording devices. These wells are representative of aquifer conditions over a large geographic area and their measurement allows a lower density of monitoring to occur in years between basin sweeps.

Information on index wells came primarily from the Department's GWSI database (ADWR, 2005f). This was supplemented outside of the AMAs with information from several organizations including the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (Navajo Nation), a city (Flagstaff), and two utilities (SRP and TEPCO).

### ***Registrations***

Numbers of registered water supply wells are listed in a table for each basin (*Cultural Water Demand*) in Volumes 2-8. The tables include the total number of wells completed through 1980 and the number of new wells completed in 5-year increments from 1981 through 2005. Also included is the total number of wells drilled without completion dates.

Information on well completions comes from the Department's well registry, commonly referred to as the "Wells55" database (ADWR, 2005h). Wells in the registry were queried first by basin and reported pump capacity. This resulted in two well lists for each basin – wells with a maximum

pump capacity of 35 gallons per minute (gpm) or less and wells with a maximum pump capacity greater than 35 gpm. In the AMAs, wells with a maximum pump capacity of greater than 35 gpm are “non-exempt” wells and wells with a maximum pump capacity of 35 gpm or less are “exempt” wells. The resulting well lists were then filtered to exclude registrations for wells that apparently were never drilled and/or those wells not used for water supply purposes.

The Department’s wells registry only lists data for wells that have been registered with the Department, as required by statute. For the purpose of the Atlas, no attempt was made to verify the accuracy of the data or to conduct field surveys to determine whether additional wells have been drilled but never registered or whether the wells that were drilled and registered are still operable today. For example, wells drilled on Indian Reservations are generally not counted since the tribes have no requirement to register these wells with the Department.

Locations for the registered exempt and non-exempt wells are shown on planning area maps (*Registered Wells and Surface Water Diversion Points*) in the overview of Volumes 2-8 and plotted on statewide maps in Appendix C of those volumes and in Figure 1-24 of this volume.

### ***Pumpage (see Cultural Water Demands)***

#### ***Recent Water-Level Depths***

Recent (2002-2005) depths to water in wells are shown on basin-scale maps (*Groundwater Conditions*) in Volumes 2-8 and a statewide summary map (Figure 1-9) is presented in this volume. Depth values, in feet below land surface, are presented on the maps next to each well symbol. Most of the water level data were taken from the Department’s GWSI database (ADWR, 2005f). These data were supplemented outside of the AMAs with measurements made by the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (NTUA), a city (Flagstaff), and two utilities (SRP and TEPCO).

Water levels were reviewed and data that appeared unreasonable were excluded from the Atlas. Some of the included data were adjusted first to ensure consistency and account for the different measurement methods used.

#### ***Water-level Changes***

Water-level changes in wells are shown on basin-scale maps (*Ground-water Conditions*) and on hydrographs for each basin (*Hydrographs Showing Depth to Water in Selected Wells*) in Volumes 2-8. A summary map for the state is presented as Figure 1-9 of this volume. The maps use colored dots to show how water levels have changed over the period that began in the early-1990s and ended in the early- to mid-2000s. As many as eight different colors are used to represent the range of recorded water-level changes. A positive change indicates a rise in water level over the period and negative change indicates a decline. The hydrographs show water-level changes for selected wells over the 30-year period from 1975 to 2005. Included on the hydrographs are a well identifier (cadastral), well depth, principal aquifer (outside AMAs only), and water use. Care was taken to select wells that were representative of aquifer conditions both horizontally and vertically.

Most of the water-level data used to generate the maps and hydrographs were taken from the Department’s GWSI database (ADWR, 2005f). These data were supplemented outside of the

AMAs with measurements made by the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (Navajo Nation), a city (Flagstaff), and two utilities (SRP and TEPCO). All water levels were reviewed and data that appeared unreasonable were excluded from the Atlas. Some of the included data were adjusted to ensure consistency and account for the different measurement methods used.

An effort was made to use data collected during the period when the wells were not actively being pumped or only minimally pumped. This period was typically from about September through about May. However, in some areas, like the Navajo Reservation, water-level data from wells were less abundant and the data used in the Atlas may have been affected by pumping.

### ***Yields***

Wells yields are listed in a table for each basin (*Groundwater Data*) and shown on basin-scale maps (*Well Yields*) in Volumes 2-8. The maps use colored dots to show the location of well yields measured by the Department and USGS. Five different colors are used on the maps to represent the range of recorded well discharges. The tables list summary statistics for these and other estimates of well yield.

Information on well yields was primarily taken from databases maintained by the Department (GWSI and Wells55) and USGS (NWIS). Also used for basins outside of the AMAs was a 1990 internal report by the Department that summarizes water resources information by basin (ADWR, 1990) and a 1994 annual report by USGS on groundwater conditions across Arizona (Anning and Duet, 1994). To estimate well yields using the Wells55 database, only wells with a casing diameter greater than 10 inches were considered. It was assumed that such wells were drilled to produce a maximum amount of water and, therefore, their reported pump capacities are indicative of the aquifer's potential to yield water to a well.

Many factors can affect well yields, including local and regional aquifer properties, well design, the size and condition of the pump, and the age of the well. The data presented in the Atlas provides a general indication of the quantity of water that can be produced from basin aquifers under optimal well conditions. Actual well yields may be significantly lower than those presented based on the factors described.

A map and table that summarize well yields across the state is presented in this volume as Figure 1-4 and Table 1-4, respectively.

## **B.24 Water Issues**

### ***Non-AMA***

Rural water issues are summarized in separate tables (*Planning Area Issues Identified from the 2003 and 2004 Rural Questionnaires*) with explanatory text for each non-AMA planning area in the overview of Volumes 2-7. Issues were primarily identified through two questionnaires sent out by the Department in 2003 and 2004 (ADWR, 2005a). Results from the 2003 questionnaire are summarized in the Department's *Rural Water Resources 2003 Questionnaire Report* (ADWR, 2004). Other issues were identified through Arizona's Rural Watershed Initiative Program, through studies and other sources.

Data from the Department's questionnaires were entered into a database and queried for various attributes such as total responses, responses by location, issues ranking, type of respondent, etc. Note that the 2003 and 2004 questionnaires were not identical and some questions were asked differently. Also, the number of respondents did not represent a statistically valid sample. Therefore, any conclusions drawn from the questionnaires should, not be considered representative of all of rural Arizona or even representative of a given planning area or basin. Issues can vary dramatically by respondent and location.

### **AMA**

Water resource issues in the AMA planning area were identified by the Department through its management plans, stakeholder meetings, government committees, an Arizona town hall, and numerous community water resource groups. These issues are described in the overview of Volume 8.

Issues are summarized by planning areas in Section 1.4.8 of this volume and statewide results from the 2004 Rural Questionnaire are listed in Table 1-16.

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