CHAPTER 1: INTRODUCTION AND SCOPE

1.1 INTRODUCTION

The Arizona Department of Water Resources (Department or ADWR) prepared this Preliminary Hydrographic Survey Report for the Hopi Reservation (Preliminary Hopi HSR) as part of a judicial proceeding entitled *In re the General Adjudication of All Rights to Use Water in the Little Colorado River System and Source*, No. 6417, pending in the Superior Court for Apache County (LCR adjudication). This report concerns the water rights claimed by the Hopi Tribe, and the United States on the Tribe's behalf, for use on the Hopi Reservation. These judicial proceedings are covered by A.R.S. §§ 45-251 to 264.

In the adjudication proceedings, the Department provides both administrative and technical assistance to the Court. The Department provides administrative support by notifying all potential water right claimants of the commencement of the judicial proceedings, transmitting water right claims and fees to the Court, maintaining a central repository of information concerning water right claims and other documents filed with the Court, and responding to public inquiries. The Department provides technical assistance to the Court by gathering records and data, investigating water uses and claims, and preparing hydrographic survey reports (HSRs) and other technical reports.

The Department prepares both preliminary and final HSRs. The preliminary HSR provides claimants and certain water users with an opportunity to inspect the report and file comments with the Department. The Department then reviews the comments and revises the HSR as necessary before it files a final HSR with the Court. Claimants are also given the opportunity to file objections to the final HSR. See A.R.S. §§ 45-256 and 257.

Figure 1-1 depicts the geographic area of the LCR adjudication, which includes both Indian and non-Indian lands. The non-Indian lands are divided into the Silver Creek watershed, the Upper Little Colorado River watershed, and the Lower Little Colorado River watershed. Indian lands in the LCR adjudication include the Hopi Reservation, parts of the Navajo, Zuni,

and Fort Apache Indian reservations, and lands occupied by the San Juan Southern Paiute Tribe.[1] The Hopi Reservation lands are located within reservations that are referred to in this report as the 1882 Executive Order Reservation and the 1934 Act Reservation.[2] Lands within the 1882 Executive Order Reservation consist of areas known as District 6 and Hopi Partitioned Lands. Lands within the 1934 Act Reservation consist of Moenkopi Village and allotted lands. See **Figure 1-2**. The Hopi Reservation lands are described further in **Chapter 3** of this report.

1.2 HISTORY OF PROCEEDINGS

On November 29, 1985, the Hopi Tribe filed statement of claimant (SOC) No. 39-91443, and the United States, on behalf of the Hopi Tribe, filed SOC No. 39-91441, claiming water rights for the Hopi Reservation. On December 18, 1985, the Department received a revised copy of the United States' SOC to correct a typographical error.

On September 23, 1994, the Department filed a preliminary HSR for the Hopi Reservation as well as the rest of the tribal lands within the LCR adjudication, as required by the adjudication Court.[3] This report was titled "Hydrographic Survey Report for Indian Lands in the Little Colorado River System" (Preliminary Indian Lands HSR), and the deadline for submitting comments on the report was December 22, 1994.[4] On November 22, 1994, shortly before the end of the comment period, the United States filed a "Statement of Amended Claims" on behalf of the Hopi Tribe, the Navajo Nation, the White Mountain Apache Tribe and the Zuni Pueblo.[5] Due to ongoing settlement negotiations, the deadline for submitting comments on the report was stayed by Judge Minker, then presiding over the LCR adjudication. The stay was not lifted until six years later when Judge Dawson, the next presiding judge, reopened the comment period with a deadline of June 30, 2000. See Minute Entry dated May 5, 2000 at 4.

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[1] The lands occupied by the San Juan Southern Paiute Tribe are not depicted on Figure 1-1. The nature, location and extent of these lands are in dispute, but are believed to be generally located north of Moenkopi Village within the Navajo reservation.

[2] The boundary of the Hopi Reservation depicted on Figure 1-1 is based on a map from Ebert & Associates (Ebert), a consultant to the United States. Ebert's map was developed using survey data queried in 2003 from the Bureau of Land Management's Geographic Coordinate Data Base.

[3] See Pre-Trial Order No. 2 dated August 15, 1988 at 1-2, as modified by Order dated January 27, 1994.

[4] See the Department's Notice of Filing Preliminary Indian Lands HSR at 2 (September 23, 1994).

[5] The statement was filed in accordance with an April 18, 1994 Minute Entry of the Court, and the September 23, 1994 "Memorandum from Special Master to Water Rights Claimants in the Little Colorado River General Stream Adjudication." Statement of Amended Claims at 2.

The Department reviewed the comments and submitted a report to the Court on August 10, 2000 in which the Department recommended that separate HSRs rather than a joint HSR be prepared for tribal lands within the LCR adjudication, starting with an HSR for the Hopi Reservation. See Minute Entry dated August 25, 2000, Attachment at 3. Subsequently, Judge Dawson directed the Department to commence the preparation of an HSR for Hopi tribal lands by May 1, 2002, and indicated that the Department would not be expected to update the Preliminary Indian Lands HSR. See Minute Entry dated October 16, 2001 at 8-9.

On January 4, 2002, Judge Dawson retired from the Superior Court. See Minute Entry dated November 9, 2001. By Order dated January 17, 2002, the Arizona Supreme Court assigned Judge Ballinger to the LCR adjudication in the Superior Court for Apache County.[6]

In July 2002, Judge Ballinger ordered the Hopi Tribe and the United States, as trustee for the Hopi Tribe, to amend their SOCs for all reservation and non-reservation lands by December 20, 2002, and submit information to the Department regarding allotted lands. See Minute Entry dated July 16, 2002 (2002 Order) at 5. On August 16, 2002, the United States submitted information concerning allotted lands as ordered by the Court, and stated that it was asserting "water right claims regarding the Hopi Allotted lands on behalf of the Hopi Tribe, its members and Hopi allottees." The Hopi Tribe assisted the United States in gathering information about the Hopi allotments and waters used, and joined in the United States' submittal.

On January 30, 2004, both the Hopi Tribe and the United States filed their amended claims upon Court order extending the prior deadline. See Minute Entry dated May 9, 2003. The United States filed its amendment for the benefit, and on behalf, of the Hopi Tribe (U.S., 2004 at 3). The amendment filed by the Hopi Tribe claimed "the right to all groundwater and surface water in, on, or serving lands owned by the Hopi Tribe or allotted or assigned to its members, or that may hereafter be recognized as belonging to its members" (Hopi, 2004 at 3). The Hopi Tribe's amendment also stated that the Hopi Tribe made these claims "on behalf of and for the benefit of the Tribe, its villages, clans and people" (Hopi, 2004 at 4).

After the amendments were filed, the Department began its investigation of the amended claims. In the course of its investigation, the Department requested additional information from

[6] Previously, by Order dated December 19, 2000, the Arizona Supreme Court assigned Judge Ballinger to the general stream adjudication for the Gila River System and Source in the Superior Court for Maricopa County. As a result, the adjudication of water rights in both the LCR and the Gila River systems is before Judge Ballinger.

the Hopi Tribe and the United States concerning previously unclaimed stock and domestic wells, which was provided to the Department in April 2005 and November 2005. In June 2008, supplemental information was also provided concerning some of the claims that were already included in the 2004 amendments.

1.3 SCOPE

The scope of the Preliminary Hopi HSR is based on Judge Ballinger's 2002 Order, as amended in part by Minute Entry dated November 4, 2004 (2004 Minute Entry). The Court ordered the Hopi and the United States to amend their SOCs, and directed the Department to investigate "all reservation and non-reservation lands for which the Tribe or the United States on behalf of the Tribe claim water rights under federal or state law." 2002 Order at 5. After the amended claims were filed in 2004, the Court revised its 2002 Order and directed the Department to proceed only with "main reservation lands." 2004 Minute Entry at 2. The "main reservation lands" are those that are depicted in **Figure 1-1**, and they do not include the Hopi Industrial Park or other lands known as the Hopi Ranches or "Hopi newly acquired lands," which were also included in the amended claims (Hopi, 2004 at 12; U.S., 2004 at 11).

Under the 2002 Order, the Department is required to evaluate each of the factors listed by the Arizona Supreme Court in a case known as *Gila V*.[7] 2002 Order at 6. Under *Gila V*, the water rights for the Hopi Reservation are to be quantified by determining the minimal need to serve the purpose of the reservation, *i.e.* as a permanent home and abiding place, also referred to as homeland purposes. *Gila V*, 35 P.3d at 76-77. When quantifying federal reserved rights for Indian tribes, the Arizona Supreme Court stated that the following factors should be considered: the tribe's history; tribal culture; geography, topography, and natural resources of the tribal lands, including groundwater availability; the tribe's economic base; past water use; and the tribe's present and projected population. *Gila V*, 35 P.3d at 79-80. The Preliminary Hopi HSR includes an analysis of each of these factors for the 2004 amended claims.

In addition, under the 2002 Order (as modified by the 2004 Minute Entry), the Preliminary Hopi HSR includes the following for the 2004 amended claims:

[7] *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 201 Ariz. 307, 35 P.3d 68 (2001).

a. Hydrological and technical information about available surface water and groundwater resources to meet each claim;
b. Comprehensive information about historic, current and existing water uses;
c. A description of all statements of claimant, including amendments, filed by both the Hopi Tribe and the United States on behalf of the Hopi Tribe;
d. A description of any statement of claimant filed by claimants other than the Hopi Tribe or the United States on behalf of the Hopi Tribe that are associated with the Tribe's reservation lands;
e. A description of statements of claimant associated with fee owned in-holdings, if any;
f. Any water rights claimed by the Hopi Tribe or the United States on behalf of the Hopi Tribe that may claim a priority date earlier than the date the reservation was created;
g. Proposed water right attributes, excluding proposed future water uses; and
h. Descriptive and technical information to serve as a basis for evaluating claims of future uses, excluding descriptions or opinions of the feasibility, profitability or practicability of future uses of water for irrigation or other uses.

2002 Order at 7-9.

As directed by the 2002 Order, the Department also considered comments filed to the Preliminary Indian Lands HSR, conducted field investigations with the cooperation of the Hopi Tribe and the assistance of the United States, and used the most current technical reports and data available. 2002 Order at 6-7, 9. In addition, both the Hopi Tribe and the United States worked cooperatively to provide essential information and supporting documentation to the Department during the course of preparing this report. See 2002 Order at 10-11. Furthermore, as directed by the Court, the Department did not rely on the "simplifying assumptions" that were identified by Special Master Thorson in a memorandum dated September 23, 1994 that was released with the Department's Preliminary Indian Lands HSR. See 2002 Order at 10.

1.4 PUBLICATION AND COMMENT

As required by Pretrial Order No. 6 dated July 26, 2000, the Department took the following steps in order to provide certain claimant and non-claimant water users in the LCR adjudication with an opportunity to comment on the information presented in the report. Upon publication of the Preliminary Hopi HSR, the Department:

a. Filed a notice with the clerk of the Superior Court for Apache County, which specifies where the preliminary HSR is available for inspection or purchase, the deadline and procedure for submitting comments,[8] and procedures for obtaining additional information;

b. Issued a press release containing the information in the Court notice, which was published on the Department's website and in newspapers of general circulation within the LCR adjudication;

c. Sent a copy of the Court notice by first-class mail to those persons included on the Court-approved mailing list for the LCR adjudication, which includes the Hopi Tribe and the United States, as well as a fee land owner and lessee located within the Reservation;

d. Provided a copy of the entire Preliminary Hopi HSR to counsel for the Hopi Tribe, and to counsel for the United States in its capacity as trustee for the Hopi Tribe; and

e. Provided a copy to the fee landowner[9] within the Hopi Reservation of that portion of the Preliminary Hopi HSR describing the water use on the fee land.[10]

The Department will review comments filed on the Preliminary Hopi HSR, revise the report as necessary, and ultimately issue a Final Hopi HSR, as directed by the Court. The Final

[8] The Department establishes the deadline for comments, which may not be less than 90 days after the filing of the notice. The Department may extend the deadline with approval of the Court.

[9] The water uses for the private in-holding are discussed in **Chapter 2** of this report.

[10] Pre-Trial Order No. 6 includes a similar requirement for allottees. The Department did not provide a copy to the allottees within the Hopi Reservation of that portion of the Preliminary Hopi HSR describing the water use on allotted land because the claim filed by the Hopi Tribe stated that it included water uses on allotted lands. See Hopi Amended Claim at 3-4. Also, in its August 16, 2002 submittal, joined by the Hopi Tribe, the United States indicated that it was asserting water right claims on behalf of Hopi allottees.

Hopi HSR will be subject to separate noticing requirements, and will afford an opportunity to file objections to all those who received notice of the Preliminary Hopi HSR as well as all other claimants in the LCR adjudication.

Comments to the Preliminary Hopi HSR must be submitted in writing to the Department, Attn: Adjudications, 3550 N. Central Avenue, 4th Floor, Phoenix, Arizona 85012 on or before March 31, 2009. A comment may be submitted in any form, but should reference the specific parts of the Preliminary Hopi HSR to which it applies. Additional copies of the Preliminary Hopi HSR may be obtained from the Department by calling 1-800-352-8488.

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CHAPTER 2: SUMMARY OF ADJUDICATION CLAIMS RELATED TO THE HOPI INDIAN RESERVATION

2.1 OVERVIEW

This chapter describes water right claims filed by the Hopi Tribe and the United States for the Hopi Indian Reservation. Reservation lands include areas known as District 6 and the Hopi Partitioned Lands, which lie within an area referred to in this report as the 1882 Executive Order Reservation. Additional reservation lands include Moenkopi Village and allotted lands that lie within an area referred to in this report as the 1934 Act Reservation.[1] See **Figure 1-2**. Between 1985 and 2004, both the Hopi and the United States filed claims for these lands. In 2005, additional information that supplemented the 2004 amended claims was filed with the Department. For purposes of this preliminary Hopi HSR, the supplemental information was considered part of the Hopi and United States 2004 amended claims, unless otherwise noted.

This chapter provides a detailed analysis of the 2004 amended claims **(Sections 2.3, 2.6, and 2.9)**, supplemental information that was provided to the Department in 2005 **(Sections 2.7 and 2.8)**, and information regarding allotted lands **(Section 2.10)**. This chapter also describes the claims filed by the Hopi and the United States prior to 2004 **(Sections 2.2, 2.4, and 2.5)**. Copies of the Hopi claims, the United States claims, the 2005 supplemental information and documentation regarding allotments are presented in **Appendices A-1, A-2, A-3**, and **A-4,** respectively.

In addition to the Hopi and the United States claims, this chapter describes other water uses that are associated with the Tribe's Reservation lands, including a summary of SOCs filed by Peabody Western Coal Company (PWCC) **(Section 2.11)**. Also discussed are a notice of appropriation for a certain spring and uses from a municipal water system for a private in-holding **(Section 2.12)**. Documents related to these other water uses are included in **Appendix A-5**.

[1] The 1882 Executive Order Reservation and 1934 Act Reservation lands are described further in **Chapter 3** of this report.

2.2 1985 HOPI CLAIM

On November 29, 1985, the Hopi Tribe filed SOC No. 39-91443 (see **Appendix A-1**) for 140,406 acre-feet per annum (AFA) of surface water and groundwater, plus additional water for one-time first fillings of proposed future impoundments "in, on or serving lands owned by the Hopi Tribe or allotted or assigned to its members, or that may hereafter be recognized as belonging to its members." The Hopi claim was filed on behalf, and for the benefit, of its villages, clans and people, with a claimed priority date of time immemorial, senior to all other claimants Indian or non-Indian. The claim is founded upon the theories of: (1) the federal reserved water rights doctrine; (2) sovereign and historic guardian of its lands; and (3) owner of lands and waters under both Spanish and Mexican rule, under the Treaty of Guadalupe Hidalgo between the United States and Mexico. The claimed water uses are set forth below and are based on "current/recent uses" (as of 1985) as well as proposed "future additional" uses, which respective amounts are indicated parenthetically after the total.

- Irrigation:
  - 71,029 AFA (10,114 + 60,915) from surface water;[2]
  - 17,030 AFA (1,250 + 15,780) from groundwater;
  - 9,545 AFA (186 + 9,359) of surface water for evaporation from irrigation storage; and
  - 91,330 AF (future) for first time filling of the irrigation, recreation, and stock reservoirs.
- Municipal and domestic: 10,285 AFA (2,060 + 8,225) based on population in 1984 and 2040 at 200 gallons per capita per day (gpcd).
- Recreation:
  - 231 AFA (existing and future) for evaporation from recreational lakes; and
  - 404 AF (future) for first time filling of recreational lakes.
- Stockponds and stockwater:
  - 1,799 AF (1,504 + 295) from surface water and groundwater based on stocking rates; and

[2] The Hopi claim 45,790 AFA from the LCR for future irrigation within the 1882 Executive Order Reservation.

    - 286 AF (future) for first time filling.
- Commercial and industrial: 1,102 AFA of groundwater for future large scale commercial and light industrial use.
- Mining and related industry:
    - 10,445 AFA (2,325 + 8,120) of groundwater for mining and slurry activities;
    - 16,000 AFA (future) of groundwater for a 1,000 megawatt coal powered electrical generating station; and
    - 5,000 AFA (future) of groundwater for the development of oil, gas and minerals other than coal including manufacturing of fertilizer or other products from such materials.

2.3 2004 HOPI CLAIM

This section describes the amended claim filed by the Hopi Tribe on January 30, 2004 (Hopi, 2004), which provides information concerning the following:

- Legal Basis of Claim
- Water Sources
- Priority Date
- Past and Present Irrigation Use
- Future Irrigation Use
- Future Domestic, Commercial, Municipal and Industrial Use
- Present Recreation Use
- Stockponds, Springs and Wells
- Future Stockwatering Use
- Future Tourism Projects
- Present and Future Mining and Related Industrial Use
- Hopi Ranches.

A copy of the 2004 Hopi claim is included in **Appendix A-1**, and is summarized below.

2.3.1 Legal Basis of Claim

On behalf, and for the benefit, of the "Tribe, its villages, clans and people," the Hopi claim the right to all groundwater and surface water "in, on, or serving lands owned by the Hopi Tribe, or allotted or assigned to its members, or that may hereafter be recognized as belonging to it or its members," under the following theories:

- As a sovereign and historic guardian of its lands (pre-dating the United States);
- As the owner of lands and waters under both Spanish and Mexican rule, under Articles VIII and IX of the Treaty of Guadalupe Hidalgo between the United States and Mexico dated February 2, 1848 (9 Stat. 922); and
- Under the federal reserved water rights doctrine established in *Winters v. United States*, 207 U.S. 564 (1908); *Arizona v. California*, 373 U.S. 546 (1963); *Cappaert v. United States*, 426 U.S. 128 (1976); and as owner of natural resources under *United States v. Shoshone Tribe of Indians of Wind River Reservation*, 304 U.S. 111 (1938).

2.3.2 Water Sources

The Hopi claim a federal reserved water right to water from various surface water and groundwater sources within reservation lands, including water from springs, wells and impoundments. Surface water sources include five washes (Moenkopi, Dinnebito, Oraibi, Polacca and Jeddito), and minor tributaries that flow from north to south through the Reservation. Groundwater sources include aquifers located beneath the Reservation lands, some of which extend laterally beyond the Reservation boundaries. These aquifers are discussed in **Chapter 7** of this report. The Hopi also claim water rights from water sources located outside the boundaries of its lands, including water from the main stem of the LCR, the Colorado River including Lake Powell, and portions of the Coconino Aquifer. [3]

[3] The Hopi currently hold a contract entitlement to over 5,000 acre-feet per year of 4th and 5th priority Colorado River water which is being leased to farmers within the Cibola Valley Irrigation and Drainage District, located on the Colorado River between Parker and Yuma. The Hopi also hold a contract entitlement to 1,000 acre-feet per year of 6th priority Colorado River water that is only available during times of surplus. The claim filed by the Hopi does not include plans to use its Colorado River entitlement on the Reservation.

2.3.3 Priority Date

Based on historic occupancy and water use, the Hopi claim immemorial priority, senior to all claimants, Indian or non-Indian, to waters located on Hopi lands as well as waters located outside the boundaries of its lands.

2.3.4 Past and Present Irrigation Use

The Hopi claim the right to divert 49,206 AFA for past and present irrigation use from five major washes and several other minor tributaries that flow through the Hopi Reservation. This information is presented in Table 2 of the Hopi claim**,** and is summarized below:

- Moenkopi Wash (5,145 AFA maximum diversion; 3,976 AFA maximum depletion);
- Dinnebito Wash (8,714 AFA maximum diversion; 6,553 AFA maximum depletion);
- Oraibi Wash (13,120 AFA maximum diversion; 9,865 AFA maximum depletion);
- Polacca Wash (15,786 AFA maximum diversion; 11,869 AFA maximum depletion);
- Jadito (Jeddito) Wash (6,371 AFA maximum diversion; 4,790 AFA maximum depletion); and
- Other Minor Tributaries (70 AFA maximum diversion; 52 AFA maximum depletion).

On average, the Hopi claim indicates that the irrigation diversion is 28,700 AFA. However, the Hopi claim the maximum quantity of water required to irrigate all of the past and presently irrigated acreage in order to provide an adequate water supply for irrigation in years when water is not as available.

As set forth in Table 1 of the Hopi claim, this water is utilized to irrigate 38,556 acres, which are further divided into six types of irrigation:

- Perennial Irrigation (564 acres);
- Seasonal Irrigation (6,186 acres);
- Range Pasture (7,522 acres);

- Native Irrigation (23,091 acres);
- Spring Irrigation (151 acres); and
- Precipitation Farming (1,042 acres).

Table 1 also indicates that none of the acres were irrigated with water withdrawn from wells. The locations of these historically irrigated acres are presented in Figures 4 and 5 of the Hopi claim.

2.3.5 Future Irrigation Use

The Hopi claim water for future irrigation uses associated with the Moenkopi Irrigation Project, irrigation from the main stem of the LCR, associated irrigation storage facilities, and ceremonial and subsistence irrigation. These uses are described below.

Moenkopi Irrigation Project

The Hopi claim an additional 3,000 AFA from Moenkopi Wash to irrigate 1,200 acres associated with the Moenkopi Irrigation Project. The proposed locations of the project, the pump and diversion canal, and the off-stream storage reservoir are shown in Figure 6 of the Hopi claim.

Future Irrigation from the Main Stem of the LCR

The Hopi claim a right to 21,060 AFA from the main stem of the LCR to irrigate 7,400 acres of land within the 1882 Executive Order Reservation. The proposed locations of the project, the pumps and diversion pipelines, and the off-stream storage reservoir are shown in Figure 7 of the Hopi claim.

Evaporative Uses and First Fillings for Irrigation Storage Facilities

The Hopi claim a total of 18,542 AF for the first fillings and evaporative use from two off-stream storage reservoirs. For the first fillings the Hopi claim 15,700 AF:

- 4,200 AF for the storage reservoir associated with the Moenkopi Irrigation Project; and

- 11,500 AF for the storage reservoir associated with future irrigation use from the LCR.

Additionally, the Hopi claim a total of 2,842 AFA for evaporation from the proposed storage facilities. This number is not further subdivided in the Hopi claim. See Figures 6 and 7 of the Hopi claim for locations of the proposed reservoirs.

Ceremonial and Subsistence Irrigation

The Hopi claim 12,546 AFA of groundwater (or possibly water sources outside of the reservation, if necessary) for future irrigation of small family garden plots for ceremonial and subsistence purposes. These gardens will be located on 3,136 acres of arable land surrounding the following villages:

- Moenkopi (754 acres);
- Hotevilla (386 acres);
- Bacavi (197 acres);
- Kykotsmovi and Old Oraibi (647 acres);
- First Mesa Villages (542 acres);
- Second Mesa Villages (484 acres); and
- Keams Canyon (126 acres).

2.3.6 Future Domestic, Commercial, Municipal and Industrial Use (DCMI)

The Hopi claim 11,211 AFA of groundwater (or possibly water sources outside of the reservation, if necessary) to meet tribal-wide long-term DCMI demands. The Hopi base this amount on the future projected population of the Reservation (projected by the Hopi to be 62,512 by 2175) multiplied by 160 gallons per capita per day (gpcd), which includes residential indoor and outdoor use, commercial use, light industrial use, public use and system losses. Information related to projected long-term population and long-term DCMI demands is presented in Appendix 1 of the Hopi claim. Water for small commercial institutions such as restaurants, grocery stores, and other establishments is included within the claim for DCMI use, rather than tourism.

2.3.7 Present Recreational Use

The Hopi claim the right to continuously fill four existing recreational lakes, which have an aggregate capacity of 138.8 acre-feet (AF) and evaporation of 56.8 acre-feet, for a total of 195.6 AF. This claim is described in Table 3 of the Hopi claim and is summarized below:

- Keams Lake (capacity of 27.8 AF and evaporation of 12.8 AF);
- Lake Maho (capacity of 7.4 AF and evaporation of 4.0 AF);
- Twin Dam No. 1 (capacity of 11.0 AF and evaporation of 6.8 AF); and
- Twin Dam No. 2 (capacity of 92.6 AF and evaporation of 33.2 AF).

Water sources for the recreational lakes are the watersheds tributary to the lakes, and the water uses are camping, fishing, and stockwatering. However, the Hopi state that these recreational lakes are not included in the stockwater claim. The Hopi claim the right to continuously fill these lakes to their maximum capacities.

2.3.8 Stockponds, Springs, and Wells

The Hopi claim a total of 7,961 AFA from springs, stockponds and wells for multiple uses. The Hopi make separate claims for the 1882 Executive Order Reservation and the 1934 Act Reservation based on information presented in Appendix 2, Tables 1, 2, and 3 of the Hopi claim, as set forth below.[4] These tables list quantities for each impoundment, well and spring, together with location, capacities, discharge rates, and yields, if available. Although the Hopi indicate the total quantity of use for each well and spring, the Hopi do not list the specific type of use for each well and spring, and do not divide the total quantity by type of use. However, the Hopi claim that all springs were used for cultural/ceremonial purposes.

For the 1882 Executive Order Reservation, the Hopi claim the following in Appendix 2 to its claim:

- Table 1: 558 livestock impoundments with a storage capacity of 4,340.10 AF;[5]

[4] The claim mistakenly reverses the discussion of the information in Appendix 2, Tables 2 and 3. Also, the numbers in the claim round the numbers in the tables.

[5] Appendix 2, Table 1 lists 558 livestock impoundments, but no capacities are claimed for the four recreational lakes that are identified in footnote 2 to this table.

- Table 2: 199 wells with a water use of 1,345.1 AFA, some of which are used for domestic and stockwatering purposes; and
- Table 3: 289 springs with a discharge of 1,887.6 AFA for a variety of purposes (cultural, domestic, stock and irrigation).

For the 1934 Act Reservation, the Hopi also claim the following in Appendix 2 to its claim:

- Table 1: 3 livestock impoundments with a storage capacity of 23.34 AF;[6]
- Table 2: 7 wells with a claimed water use of 45.5 AFA, some of which are used for domestic and livestock; and
- Table 3: 49 springs with a claimed water use of 318.5 AFA for a variety of purposes (cultural, domestic, stock, and irrigation).

Based on the above, the Hopi claim a total of 561 stockponds with a storage capacity of 4,363.44 AF, 206 wells with a water use of 1,390.6 AFA, and 338 springs with a discharge of 2,206.1 AFA.

2.3.9 Future Stockwatering Use

The Hopi claim 910 AFA for future stockwatering, based on estimates of total capacity needed to meet future livestock watering needs on lands within both the 1882 Executive Order Reservation and the 1934 Act Reservation. According to the Hopi claim, the Hopi are currently in the process of updating future range and livestock watering plans. The locations of some future impoundments have already been identified, and others are categorized as potential sites. The Hopi indicate that it will provide additional information regarding the claimed quantities and impoundment facilities at a future date.

2.3.10 Future Tourism Projects

The Hopi claim a total of 1,594 AFA of groundwater (or possibly water sources outside of the Reservation, if necessary) for three proposed large-scale tourism projects,

[6] Footnote 4 of this table indicates that the capacities of these impoundments were not measured.

which does not include water for small commercial establishments that are included in the DCMI claim. The resort facilities include:

- Resort facility near Moenkopi (522 AFA);
- Resort facility near Keams Canyon (516 AFA); and
- Resort facility near Hopi Industrial Park at Winslow, Arizona (556 AFA).

Because the claim for the Hopi Industrial Park is located outside of the Hopi Reservation, the Department is not analyzing that claim in this report. See Minute Entry dated November 2, 2004, which limits the scope of this HSR.

2.3.11 Present and Future Mining and Related Industrial Use

The Hopi claim 6,000 AFA of groundwater (or possibly water sources outside of the reservation, if necessary) for present and future mining and slurry needs. This number includes approximately 400 AFA of current and projected future uses for mining activities by PWCC at the Black Mesa Mine. Also included in this claim is approximately 4,000 AFA of current use to slurry the coal to the Mohave Generating Station. This number was projected to increase to 5,600 AFA after 2005. When PWCC ceases its current mining activities, the Hopi claim that at least two additional coal mines may be developed in the future.

For other mineral and industrial uses, the Hopi claim 19,000 AFA of groundwater (or possibly water sources outside of the reservation, if necessary) including 15,000 AFA for a coal-fired 1,200 megawatt power generating plant, and 4,000 AFA for the development of other coal, oil, gas and minerals, including manufacturing of fertilizer and other products. General locations of possible future coal mines, slurry pipeline areas, a power plant, and well fields are provided in Figure 8 of the Hopi claim.

2.3.12 Hopi Ranches

Under the Navajo-Hopi Land Dispute Settlement Act of 1996, the Hopi claim water for five ranches based on state law. These claims are summarized in Table 5 and described in more detail in Appendix 4 of the Hopi claim. As directed by the Court, the

Department is not analyzing these claims in this HSR. See Minute Entry dated November 2, 2004.

2.4 1985 UNITED STATES CLAIM

On November 29, 1985,[7] the United States, in its own right and as trustee, submitted SOC No. 39-91441 (see **Appendix A-2**) on behalf of both the Hopi Tribe and the Navajo Nation, claiming a combined total of 546,872 AFA of water in the LCR watershed, plus 331,082 AF for the first-time filling of irrigation storage reservoirs and recreation lakes (330,000 + 1,082). The claimed priority date is time immemorial, and the basis of the claim is the federal reserved water rights doctrine.

The United States' joint claim does not list the water rights for the Hopi and the Navajo separately, but it does divide the quantities claimed based upon "current/recent uses" (as of 1985) as well as proposed "future additional" uses.[8] The total quantity claimed for each use follows, with the respective amounts claimed for current and future uses indicated parenthetically: (1) 287,910 AFA (33,190 + 254,720) for irrigation from surface water, including the LCR; (2) 109,684 AFA (2,859 + 106,825) for irrigation from groundwater, including LCR alluvium; (3) 31,522 AF (1,155 + 30,367) for evaporation from irrigation storage, plus 330,000 AF for one-time filling (future); (4) 57,365 AFA (4,296 + 53,069) for municipal; (5) 331 AFA (298 + 33) for domestic; (6) 2,694 AF (2,316 + 378) for recreation; (7) 754 AFA (635 + 119) for stockwatering from groundwater; (8) 3,897 AF for stockponds from surface water; (9) 33,201 AFA (129 + 33,072) for industrial; and (10) 19,514 AFA (8,449 + 11,065) for mining.

[7] On December 18, 1985, the Department received a revised copy of SOC No. 39-91441 to correct a typographical error.

[8] This information is found in a summary and report prepared by Stetson Engineers, Inc. dated September 20, 1985 and September 27, 1985 respectively, which were submitted with the claim. Attached to the Stetson report are four maps and 16 tables that provide additional information for each category of claim, including the points of diversion by reference to UTM coordinates and/or a map. The Department did not attempt to segregate the amounts claimed for the Hopi and the Navajo based on the points of diversion in the tables.

2.5 1994 UNITED STATES AMENDMENT

On November 22, 1994, pursuant to court order, the United States, on its own behalf and as trustee for the Navajo Nation, the Hopi Tribe, the White Mountain Apache Tribe and the Zuni Pueblo, filed amended SOCs on behalf of Indian Lands in the Little Colorado River Basin, including SOC No. 39-91441 (see **Appendix A-2**). The claimed water uses set forth in the amendment are set forth below, and are based on "current or recent" (as of 1994) as well as "future additional" uses, which respective amounts are indicated parenthetically after the total.

- Irrigation:
  - 58,717 AFA (42,937 + 15,780) of surface water, including the LCR;
  - 17,030 AFA (1,250 + 15,780) of groundwater, including LCR alluvium; and
  - 9,545 AF (186 + 9,359) of surface water for evaporation from irrigation storage.
- Municipal and domestic: 6,160 AFY (1,793 + 4,367) based on present and future population in 2040 for communities, towns, villages, homesites and farmsteads.[9]
- Recreation: 231 AF (151 + 80) for camping, fishing and evaporation from recreational lakes.
- Stock Water: 4,777 AF (4,601 + 176) from groundwater and surface runoff, including evaporation losses, based on average volume and a single annual fill of stockponds, lakes and reservoirs.
- Industrial: 1,102 AFA (future) of groundwater for processing, light industries, steam power plant cooling and miscellaneous industrial applications.
- Mining: 19,514 AFA (8,449 + 11,065) for Navajo and Hopi (combined) mining uses at the Peabody Coal mine on Black Mesa, including pipeline slurry, dust control, construction, potable purposes, evaporation from sedimentation ponds and related mining activities, together with future mining activities located throughout both reservations.

[9] The claim indicates that 507 wells and springs had been inventoried on the Hopi Reservation for stock and domestic purposes. An additional 23 wells were identified for public water supply purposes.

2.6 2004 UNITED STATES CLAIMS ON BEHALF OF THE HOPI

This section describes the amended claim filed by the United States on January 30, 2004 on behalf of the Hopi Tribe (United States, 2004). In its claim, the United States indicates that the federal government continues to investigate the Hopi water rights and that the claim may be supplemented or amended in the future. The 2004 United States amended claim provides information concerning the following (see **Appendix A-2**):

- Legal Basis of Claim
- Water Sources
- Priority Date
- Past and Present Irrigation Use
- Future Irrigation Use
- Present and Future Domestic, Commercial, Municipal and Industrial Use
- Recreation Use
- Stockponds, Springs and Wells
- Future Stockwatering Use
- Future Heavy Commercial
- Present and Future Heavy Industrial/Mining Related Industry
- Hopi Newly Acquired Acres.

This section summarizes the information presented in the United States claim in the same order as information presented in the Hopi claim to assist in comparison of the claims.

2.6.1 Legal Basis of Claim

The United States claims are based on the federal reserved rights doctrine under *Winters v. United States*, 207 U.S. 564 (1908), *Arizona v. California*, 373 U.S. 546 (1963), *Cappaert v. United States*, 426 U.S. 128 (1976) and *In re the General Adjudication of all Rights to Use Water in the Gila River System and Source*, 201 Ariz. 307, 35 P.3d 68 (2001). The United States claims "sufficient water to provide for the

present and future water needs necessary to fulfill the purposes of the Hopi Reservation as a permanent home and abiding place for the Hopi people."

2.6.2 Water Sources

The United States claims a federal reserved water right to water from various surface water and groundwater sources within reservation lands, including water from springs, wells and impoundments. Surface water sources include five washes (Moenkopi, Dinnebito, Oraibi, Polacca and Jeddito), and minor tributaries that flow from north to south through the reservation. Groundwater sources include the N Aquifer, which is discussed in **Chapter 7** of this report.

2.6.3 Priority Date

The claimed priority date is aboriginal, or time immemorial, based on the Hopi's aboriginal presence on lands within the Hopi Reservation.

2.6.4 Past and Present Irrigation Use

The United States claims the right to divert 49,136 AFA from the five major washes and several other minor tributaries that flow through the Hopi Reservation for irrigation as follows:

- Moenkopi Wash:
  - Main Reservation (3,246 AFA maximum diversion; 2,440 AFA maximum depletion);
  - Moenkopi Island (1,795 AFA maximum diversion; 1,535 maximum depletion);
- Dinnebito Wash (8,714 AFA maximum diversion; 6,552 AFA maximum depletion);
- Oraibi Wash (13,120 AFA maximum diversion; 9,865 AFA maximum depletion);
- Polacca Wash (15,786 AFA maximum diversion; 11,869 AFA maximum depletion);

- Jadito (Jeddito) Wash (6,371 AFA maximum diversion; 4,790 maximum depletion); and
- Minor Tributaries (104 AFA maximum diversion; 59 AFA maximum depletion).

This information is presented in Table 2 of the United States claim, which includes an average irrigation diversion of 28,489 AFA.[10] The United States claims the maximum diversion amount in order to provide an adequate water supply for irrigation in years when water is not as available.

As set forth in Table 1 of the United States claim, this water is utilized to irrigate 37,514 acres, which is the total number of cultivated acres (38,556) less the number of acres used for precipitation farming (1,042). The United States stated that it did not include precipitation acres in its water right claim. Past and presently irrigated acres consist of the following:

- Perennial Irrigation (564 acres);
- Seasonal Irrigation (6,186 acres);
- Range Pasture (7,522 acres);
- Native Irrigation (23,091 acres);
- Spring Irrigation (151 acres); and
- Precipitation Farming (1,042 acres).

A map containing the locations of the claimed presently and historically irrigated acres is contained in Appendix 8 of the United States claim.

2.6.5 Future Irrigation Use

The United States does not make a separate claim for future irrigation uses, beyond the amount already claimed for past and present irrigation uses. However, the United States does not waive its right to assert claims for religious and ceremonial uses of water associated with irrigation, if and when evidence of such uses is made known to the United States.

[10] In the discussion prior to Table 2, the United States uses an average irrigation diversion number of 28,700 AFA.

2.6.6 Present and Future Domestic, Commercial, Municipal and Industrial Use

The United States claims 11,211 AFA of groundwater for present and future use from the N Aquifer for DCMI purposes.[11] This number is based on a projected population of 62,512 in 2175 multiplied by 160 gpcd. The DCMI includes residential indoor and outdoor use, commercial use, industrial use, public use and system losses. A table outlining the estimate of future Hopi population and geographic distribution is in Appendix 1 of the United States claim. Appendix 2 of the United States claim contains a table that outlines the actual demands in acre-feet per year based on 160 gpcd. Finally, Appendix 3 of the United States claim contains a map that provides a geographic overview of the Hopi population centers combined with the projected long-term DCMI demands.

2.6.7 Present Recreational Use

The United States does not make a separate claim for recreational uses. Instead, it includes water for those uses in its claim for impoundments.

2.6.8 Past and Present Stockponds, Springs, and Wells

The United States claims 2206.1 AFA from springs, 4,499 AFA from stock ponds/impoundments, and 1,339 AFA from wells for a total of 8,044.1 AFA. The water rights claimed from impoundments, wells and springs for multiple uses are based on information presented in Appendices 5, 6 and 7, as set forth below. The United States claimed that all springs were used for cultural purposes.[12] These appendices list quantities for each impoundment, well and spring, together with location, capacities, discharge rates, and yields, if available. For each well and spring with multiple uses, the United States lists the types of uses but does not divide the quantity of use by type of use.

- Appendix 5: 338 springs at an average rate of 6.5 AFA for a total of 2,206.1 AFA for cultural, domestic, stock and irrigation uses;

[11] In Table 4, the United States summarizes its claim and apparently misstates the amount claimed for DCMI as 11,163 AFA.

[12] The United States did not make a separate claim for ceremonial purposes, but reserved the right to do so at a later date.

- Appendix 6: 561 impoundments with a total capacity of 4,499 AF for stockwatering;[13]
- Appendix 7: 206 wells for a total of 1,339 AFA for domestic and stockwatering purposes.

2.6.9 Future Stockwatering Use

The United States did not make a claim for future stockwatering use beyond the amount already claimed for past and present livestock uses.

2.6.10 Future Heavy Commercial

The United States claims 556 AFA of groundwater from the C Aquifer for use at a proposed tourist resort near Winslow, Arizona. As directed by the Court, the Department is not analyzing this claim in this HSR. See Minute Entry dated November 2, 2004.

2.6.11 Present and Future Mining and Related Industrial Use

The United States claims 3,000 AFA of groundwater from the N Aquifer for the present and future uses in the coal mining-related industry.

2.6.12 Hopi Newly Acquired Areas

Under the Navajo-Hopi Settlement Act of 1996, the United States claims water rights for five ranches, although at the time the claim was filed these lands had not been taken into trust by the United States.[14] These claims are summarized in Table 3 of the United States claim. As directed by the Court, the Department is not analyzing these claims in this HSR. See Minute Entry dated November 2, 2004.

[13] The claim for impoundments includes the four lakes claimed by the Hopi for recreational purposes.
[14] By separate notices of submission of information regarding allotted lands dated August 15, 2002, the United States and the Hopi confirmed they would inform the Court and the parties within 30 days of the date that any of the Hopi lands are taken into trust.

2.7 2005 SUPPLEMENTAL INFORMATION

Supplemental information was submitted to the Department in April and November 2005 concerning the amended claims filed by the Hopi and the United States in 2004. The supplemental information is included in **Appendix A-3** of this report.

In April 2005, the United States, on behalf of the Hopi Tribe, provided information to the Department from its consultant, Natural Resources Consulting Engineers (NRCE). This information was presented on a compact disk (CD) and included 22 previously unclaimed springs, 5 each with a quantity of 4 gallons per minute (gpm), and 17 each with a quantity of 19 gpm for a total of 533 AFA. All of the springs were for domestic, stock and ceremonial/cultural purposes. The CD also included information concerning 3 previously unclaimed wells, one with a quantity of 4 gpm and 2 not specified for a total of 6.5 AFA. One of the wells was for domestic use and the use of the other two wells was not specified.

In November 2005, the Hopi submitted a letter and report concerning 25 previously unclaimed wells with no quantity specified. All of these wells were for municipal purposes.

2.8 SUMMARY AND COMPARISON OF HOPI AND UNITED STATES 2004 CLAIMS AND 2005 SUPPLEMENTAL INFORMATION FOR PAST AND PRESENT USES

The 2004 amended claims and 2005 supplemental information are summarized in two tables. **Table 2-1** provides a side-by-side comparison of the Hopi and United States claims for past and present water uses, and **Table 2-2** provides a side-by-side comparison of the Hopi and United States claims for future (new or additional) water uses.[15] This section discusses **Table 2-1.**

Table 2-1 presents information concerning water sources, quantity of use, location, legal basis of claim and priority date for the following past and present uses:[16]

[15] All numbers in the table are rounded to the nearest acre-foot.

[16] For purposes of this report, past and present uses are those uses identified at the time the claims were filed.

- Agriculture (irrigation);
- Domestic, Commercial, Municipal, and Light Industrial (DCMI);
- Heavy Industrial (Mining and Related Industry);
- Livestock;
- Recreation; and
- Ceremonial/Cultural.

In their 2004 amended SOCs, the Hopi and the United States claim 7,961 AFA and 8,044 AFA respectively for cultural, domestic, stock and irrigation uses from the same 561 livestock impoundments, 338 springs and 206 wells. For the livestock impoundments, the Hopi claim a capacity of 138.8 AF for the livestock impoundments used as recreational lakes, plus 4,363.44 AF for the impoundments only used for livestock purposes for a total capacity of 4,502.44 AF. For the same 561 impoundments, the United States claims 4,499 AF. The difference in these numbers appears to be due to minor differences in the claimed capacities for one of the recreational lakes, and the capacities used for the three impoundments in the 1934 Act Reservation for which there were no actual measurements. For the 338 springs, both the Hopi and the United States claim 2,206.1 AFA. For the 206 wells, the Hopi claim 1,390.6 AFA and the United States claim 1,339.0 AFA. These differences are due to different quantities claimed for 16 wells.

As indicated above, in the supplemental information provided to the Department in April and November 2005, the Hopi and the United States included 22 previously unclaimed springs with a total quantity of 533 AFA, and 28 previously unclaimed wells with a total quantity of 6.5 AFA. The Hopi claimed all impoundments solely for livestock purposes, as did the United States, with the exception of four lakes also claimed for recreational purposes. Many wells and springs were also claimed for livestock purposes together with other uses.

Based on the type of use information provided by the United States in the appendices to its 2004 claim together with the supplemental information provided by both the Hopi and the United States, the Department separated the impoundments, springs and wells information by type of use in the “Water Sources” and “Quantity of

Use" columns in **Table 2-1**. However, neither the Hopi nor the United States divided the total quantity of water claimed for each type of water use from each spring and well. As a result, the same quantity of water is included in **Table 2-1** more than once for wells and springs with multiple uses.

2.8.1 Past and Present Agriculture (Irrigation)

The maximum amount of water diverted for agricultural purposes is slightly different in the Hopi and United States claims. The tables in the body of each claim indicate that the Hopi claim 49,206 AFA with an average of 28,700 AFA, and the United States claims 49,136 AFA with an average of 28,489 AFA. There are also differences in the amounts claimed from the Moenkopi wash and the minor tributaries, as described above. See **Sections 2.3.4** and **2.6.4**. In addition, the United States does not include precipitation acres in its water right claim, but the Hopi are silent on this matter. However, these differences do not numerically account for the differences in the total amounts claimed.

2.8.2 Past and Present Domestic, Commercial, Municipal and Light Industrial

The amount claimed by the United States and the Hopi for DCMI purposes is 11,211 AFA of groundwater, which is based on future population projections, although the United States indicates the DCMI claim is for both "present and future" uses. The numbers in **Table 2-1** are based on claims made for domestic purposes from springs and wells. These quantities may be included more than once for wells and springs with multiple uses, because neither the United States nor the Hopi divided the total quantity of water by type of use for each well and spring.

2.8.3 Present Mining and Related Industry (Heavy Industrial)

Both the Hopi and the United States claim water for past and present mining purposes related to the coal mining industry under the categories of "mining and related industry" and "heavy industrial" respectively. The Hopi claim 6,000 AFA of groundwater (or possibly other sources outside of the reservation) for present and future mining and slurry needs. According to the Hopi claim, in 2004, approximately 400 AFA

was used at the Black Mesa mine, and 4,000 AFA was used for the coal slurry pipeline to the Mohave Generating Station. Although this amount was projected to increase to 5,600 AFA after the year 2005, the Department considered 4,400 AFA to be representative of present use when the claim was filed in 2004.

The United States claim 3,000 AFA for present and future coal mining industrial uses. The source is identified as the N Aquifer.

2.8.4 Past and Present Livestock

Neither the Hopi nor the United States claim a separate quantity of water for livestock, but instead include livestock among the purposes for which impoundments, springs and wells are used. As explained above, the Hopi and the United States claim all 561 impoundments for livestock with total capacities of 4,502.24 AF and 4,499 AF respectively, including four impoundments that are also used for recreation. In addition, many springs and wells are also claimed for livestock, among other uses, but the total quantity of water claimed is not divided by type of use. The numbers included in **Table 2-1** reflect the total quantity of water for any impoundment, spring or well that was claimed for livestock purposes, regardless of whether other purposes were also claimed. As discussed above, this results in the same quantity of water being included more than once in the table.

2.8.5 Past and Present Recreation

The Hopi claim 195.6 AF for four existing recreational lakes, with a total capacity of 138.8 AF and evaporation of 56.8 AF. The Hopi indicate that these lakes are also used for stockwatering purposes, but these lakes are not included in the stockwater claim. The United States does not make a separate claim for recreational uses, but instead includes the recreational lakes in its claim as livestock impoundments.

2.8.6 Past and Present Ceremonial/Cultural

Both the Hopi and the United States claim water for cultural purposes from all 338 springs in the quantity of 2,206.1 AFA. However, many of these springs are also used for other purposes, but the total quantity of water in the claims is not divided by type

of use. The numbers in **Table 2-1** include the total quantities claimed for all springs for ceremonial/cultural uses, regardless of whether the springs were also used for other purposes. As discussed above, this results in the same quantity of water being included more than once in the table.

2.9 SUMMARY AND COMPARISON OF HOPI AND UNITED STATES 2004 CLAIMS FOR FUTURE USES

Table 2-2 provides a side-by-side comparison of the Hopi and United States claims for future water uses, and presents information concerning water sources, quantity of use, location, legal basis of claim, and priority date. These uses differ slightly from those listed in **Table 2-1** for past and present uses**.** The future uses in **Table 2-2** include the following:

- Agriculture (Irrigation);
- Domestic, Commercial, Municipal, and Light Industrial;
- Heavy Industrial (Mining and Related Industry), including coal mining and other mineral and industrial use;
- Livestock;
- Ceremonial/Cultural; and
- Tourism.

In the following sections, the information presented in **Table 2-2** concerning future uses is described. For purposes of this table, the Department only included new or additional quantities of water that previously were not claimed as past or present uses. The Department understands that past and present uses are expected to continue into the future in addition to new uses.

2.9.1 Future Agriculture (Irrigation)

The Hopi claim for future irrigation use includes the following: (1) 21,060 AFA from the main stem of the LCR to irrigate 7,400 acres, (2) 3,000 AFA from Moenkopi Wash for the Moenkopi Irrigation Project, (3) 15,700 AF from the first filling of two

off-stream storage reservoirs, and (4) 2,842 AF for evaporation from the storage reservoirs. The United States does not make an additional claim for future irrigation use beyond the amounts already claimed for present irrigation uses.

2.9.2 Future Domestic, Commercial, Municipal and Light Industrial

Both the Hopi and the United States claim 11,211 AFA of groundwater for DCMI uses based on a projected population of 62,512 in the year 2175. The United States indicates that the groundwater will be withdrawn from the N Aquifer. The Hopi also claim water from outside the boundaries of the reservation as a possible source.

2.9.3 Future Mining and Related Industry (Heavy Industrial)

Both the Hopi and the United States claim water for past and present mining purposes related to the coal mining industry under the categories of "mining and related industry" and "heavy industrial" respectively. The Hopi claim 6,000 AFA of groundwater (or possibly other sources outside of the reservation) for present and future mining and slurry needs. According to the Hopi, in 2004, approximately 400 AFA was used at the Black Mesa mine, and 4,000 AFA was used for the coal slurry pipeline to the Mohave Generating Station, which was projected to increase to 5,600 AFA after the year 2005. The Department considered 1,600 AFA to be representative of future use beyond the amount already claimed for present use. In addition, the Hopi claim 19,000 AFA of groundwater (or possibly other sources outside of the reservation) for a coal-fired power generating plant, and for the development of other minerals in the future.

The United States is not claiming water for future mining purposes beyond the 3,000 AFA already claimed for past and present mining purposes.

2.9.4 Future Livestock

The Hopi claim 910 AFA for future stockwatering, and are in the process of updating future range and livestock watering plans. The Hopi indicate that additional information will be provided at a future date. The United States does not make an additional claim for future livestock uses beyond the amounts already claimed for present livestock use.

2.9.5 Future Ceremonial/Cultural

The Hopi claim 12,546 AFA of groundwater (or possibly water outside of the reservation) for future irrigation of 3,136 acres of small family garden plots for ceremonial and subsistence purposes. The United States does not make an additional claim for future ceremonial/cultural uses beyond the amounts already claimed for irrigation uses. However, the United States indicates that it does not waive its right to assert those claims in the future when it becomes aware of evidence of such uses.

2.9.6 Future Tourism

The Hopi claim 1,038 AFA of groundwater (or possibly other water sources outside of the reservation) for two tourism projects located on the reservation. A third tourism project is also included in both the Hopi and the United States claims, but that project is not within the scope of this report.

2.10 ALLOTTED LANDS

On August 16, 2002, pursuant to Court Order dated July 16, 2002, the United States, with the assistance of the Hopi Tribe, submitted information to the Department concerning Hopi allotted lands. The United States provided a table that lists each allotted parcel together with its location, the corresponding irrigated acres, annual diversions and annual depletions.[17] It also provided a series of color maps depicting the identification and location of each allotted parcel. The United States indicated that its water right claims regarding the Hopi allotted lands were on behalf of the Hopi Tribe, its members and Hopi allottees. However, the United States indicated that the information regarding the Hopi allotted lands was preliminary and subject to change after further study. The Hopi Tribe joined in these disclosures. Copies of the papers filed by the United States and the Hopi Tribe, together with the table and the maps, are included in **Appendix A-4**.

[17] By letter dated September 5, 2002, the United States clarified the information in the table. Tracts designated as "AR" are allotments that were deeded pursuant to the General Allotment Act of 1887, 24 Stat. 388. Tracts designated as "TR" are tribally owned trust lands that have been assigned to individuals or families. The "TR" tracts are not allotments and are not *owned* by individuals.

By letter dated June 3, 2008, the Hopi provided the Department with additional information concerning tracts of lands known as "Murphy" tracts.[18] These tracts consist of 21 parcels, approximately 5 acres each that are interspersed among the allotments. According to the letter, the Tribe believes that the federal government surveyed these tracts but did not allot them. Enclosed with the letter is a map showing the allotments and the "Murphy" tracts. A copy of the June 3, 2008 letter and map are also included in **Appendix A-4**.

2.11 PEABODY WESTERN COAL COMPANY CLAIMS

On June 21, 1985, PWCC filed 245 SOCs with the Apache County Superior Court for mining uses on leased lands located on both the Navajo Partitioned Lands and the Hopi Partitioned Lands. These state-based claims are for exploration and aquifer testing wells, mining production wells, sediment ponds, and monitoring wells.

The 245 SOCs filed by PWCC were later amended, supplemented and/or inactivated. On September 23, 1985, 32 of the SOCs were amended. By letter dated September 7, 1994, PWCC requested that 76 SOCs be inactivated. On September 22, 1994, PWCC filed an additional 51 SOCs for monitoring wells and sediment ponds. By letter dated December 1, 1994, PWCC requested that 41 SOCs be inactivated, of which 39 already had been inactivated by letter of September 7, 1994. On December 19, 1994, PWCC amended 38 SOCs, including 36 of the 76 SOCs that were previously inactivated. The Department then reactivated these 36 SOCs. As of December 19, 1994, the Department's records indicate that PWCC had 254 active SOCs, and that PWCC has not made additional SOC filings after that date.

The PWCC sediment ponds and wells located on the Hopi Reservation are identified in **Appendices C** and **E** of this HSR, respectively. The location of the PWCC leasehold is depicted on **Figure 2-1**.

[18] The Hopi also provided information concerning certain in-holdings on the Hopi Reservation, which are discussed in **Section 2.12.**

2.12 OTHER WATER USES

The Department is aware of two parcels of land within the Hopi Reservation on which water may have been used. On March 14, 1892, Freeman Stewart claimed 100 inches of water for mining and milling purposes for springs located in "Blue Canon (sic), about 25 miles East of Tuba City and about one mile west of the Moqui Reservation and about three miles south of the Chah La Pi Coal fields in Coconino County." The Department assigned No. 10-0301013-0601 to this Notice of Appropriation (NOA). It is unclear whether these springs are located on the Hopi Reservation.

Based on information from the Hopi Tribe and the Arizona Land Resource Information System (ALRIS) website[19] maintained by the Arizona State Land Department, there is only one parcel of fee land on the Hopi Reservation at this time consisting of a 40-acre site in the Village of Kykotsmovi for which Patent No. 966986 was issued on September 30, 1925 to the General Conference of Mennonites of North America.[20] According to the patent, when the "lands are no longer used for mission or school purposes said lands shall revert to the Indian owners." According to the Hopi, there is a well on the Mission School property, but it is believed to be inactive and the school currently obtains water from the Kykotsmovi municipal water system. No well was claimed on the property, so ADWR did not attempt to verify whether one is located there. Copies of the NOA and the patent are included in **Appendix A-5**.

[19] The address for the ALRIS website is www.land.state.az.us/alris/.

[20] Between 1910 and 1964, there was another in-holding on the Hopi Reservation. On April 11, 1910, a fee patent was issued to the Women's American Baptist Home Mission Society for five acres of land. On June 9, 1964, this land was conveyed back to the United States to be held in trust for the Hopi Tribe.

CHAPTER 3: HOPI RESERVATION LANDS

This chapter consists of four sections, which describe the pre-reservation history of the Hopi **(Section 3.1)**, the creation of reservation lands by Presidential Executive Order of 1882 (1882 Executive Order) **(Section 3.2)**, the establishment of reservation lands by Congressional Act of 1934 (1934 Act) **(Section 3.3)**, and allotted lands **(Section 3.4)**. Unless otherwise noted, information discussed in this chapter was presented in Anderson (2008).

3.1 PRE-RESERVATION

This section describes the pre-reservation history of the Hopi through 1882. Described first is the period prior to 1540, followed by the periods from 1540 to 1821, 1821 to 1848, and 1848 to 1882.

3.1.1 History to 1540

The Hopi have enjoyed a long tenure on the Colorado Plateau. Although scholars and the Hopi do not always agree on the details, there is agreement that a people who can be considered Hopi were living on and near the Hopi Mesas by the 12th century. Much older evidence of human settlement, from as long ago as the 7th century, has been found in the area, and some scholars have suggested that these early residents were the Hopi's ancestors.

The Hopi are a Pueblo people. Along with the Zuni, Acoma, and Laguna peoples, all of whom live in New Mexico, the Hopi are known as Western Pueblos and as such are presumed to be descendants of the Western Ancestral Puebloans, or Western Anasazi, who inhabited northeastern Arizona and southeastern Utah before 1400. The Hopi call these people the Hisatsinom, which means "our ancestors." The Hopi are typically associated with the Kayenta branch of the Ancestral Puebloans, whose homeland extended from present-day Utah on the north to the Little Colorado River on the south, and from the Colorado River on the west to the

Chinle Valley on the east. Some scholars have made finer distinctions among the Ancestral Puebloans and identified the Tusayan branch, which was centered on the Hopi Mesas, and the Winslow branch, which was centered on the Little Colorado River.

Archeological sites from as early as the 7th century have been found in the Jeddito Valley and Hopi Mesas. These early settlements, which have been dated from the late A.D. 600s to the early A.D. 800s, are believed to have been occupied by people who were culturally affiliated with the Kayenta Ancestral Puebloans. They were typically located on or near major washes and drainages, reflecting the Ancestral Puebloans' reliance on agriculture during this period. Whether the occupants of these earliest sites can be considered ancestors of the Hopi is unclear; however, one historian stated that "the cultural remains present a clear, uninterrupted, logical development culminating in the life, general technology, architecture, and agricultural and ceremonial practices to be seen on the three Hopi Mesas today." (Anderson, 2008, p. 3).

Archaeological evidence suggests that the population of the Kayenta region increased substantially from the 900s to about 1150. The number of settlements increased correspondingly, as did their dispersal over a wider area. This expansion ended in the mid-1100s, at which time some of the Kayenta peripheral areas, such as the Grand Canyon and northern Black Mesa, were abandoned as locations for permanent settlement. The settlers on the southern Black Mesa remained, however, so that the Hopi Mesas, Antelope Mesa, and the Jeddito Valley continued to be occupied. The connection between these 12th century settlements and the villages that now exist on the Hopi Mesas has long been recognized by scholars.

Until the mid-1200s, the prevailing settlement pattern at the Hopi Mesas was one of numerous small pueblos and villages widely dispersed along major drainages and near springs. There were a few large settlements that had as many as a hundred rooms. Oraibi, which was occupied at least by 1150, and Awatovi were among them, but most settlements were small, with only 10 to 20 rooms.

A large-scale relocation of the people living in the Four Corners region and the San Juan River drainage occurred in the late 13th century, possibly due to a severe drought that started around 1276, or to other developments, such as warfare or social breakdown. This caused the population of the Hopi Mesas to increase, while the population of other locations once inhabited by the Kayenta Ancestral Puebloans declined. Additionally, the settlement pattern on the Hopi Mesas changed from many small villages to a few discrete clusters of larger villages. These

larger settlements ranged in size from 100 to more than 1,200 rooms and were very similar in design to other contemporary Pueblo villages. The process of consolidation advanced so rapidly that, by 1300, scholars estimate that only between 11 to 17 pueblos were remaining on the Hopi Mesas.

Toward the end of the 1300s, another major population shift occurred, leaving the Western Pueblo peoples of Arizona and northeastern New Mexico concentrated in the areas in which the Spaniards would find them. As a result of the population shift, many areas that had supported Ancestral Puebloan settlements were abandoned. Based on estimates of the number of rooms in the Hopi villages, the population at the Hopi Mesas appears to have grown rapidly until about 1400, then more slowly until about 1500, at which time the population stabilized and even may have declined somewhat. Immigration from the north in the late 1200s, and from the south in the late 1300s, seems to account for much of the growth, which was eventually halted by a combination of drought and epidemic disease.

Although the Hopi for many centuries lived only in villages on the Hopi Mesas, they long considered their homeland to comprise an area that extended well beyond the Mesas, which the Hopi called Hopitutskwa. The Hopi claim to this broad expanse of land was based not on current occupancy so much as it was on periodic use and past occupancy (or use) by ancestors of the Hopi. Starting in the vicinity of Holbrook, the Hopitutskwa's boundary ran from Woodruff Butte west through the Chevelon Butte area (south of Winslow) to the vicinity of Perkinsville; then north to Point Sublime in the Grand Canyon; then northeast along the Colorado River to its confluence with the Escalante River; then southeast to Navajo Mountain, Marsh Pass, and Lupton (at the Arizona-New Mexico border); and then southwest back to Woodruff Butte. In addition to including all of Black Mesa, the Kaibito Plateau, and the Painted Desert, the Hopitutskwa includes such Arizona landmarks as Mormon Lake, Bill Williams Mountain, Oak Creek Canyon, Mt. Humphreys and the rest of the San Francisco Mountains, a significant part of the Grand Canyon, and Petrified Forest. The major watercourses running through or along the boundary of the Hopitutskwa include the Puerco River, Little Colorado River, San Juan River and Colorado River. The Hopi aboriginal claim for the Hopitutskwa is depicted on **Figure 3-1**.[1]

[1] The docket number in this figure is a reference to an Indian Claims Commission case brought by the Hopi to obtain compensation for aboriginal lands that allegedly had been taken by the federal government. This case is discussed further in **Section 3.2**.

3.1.2 Spanish Empire (1540-1821)

The Hopi's first contact with the Spaniards occurred in 1540, when a small exploring party led by Don Pedro de Tovar arrived at the Hopi Mesas. Tovar was a lieutenant of Francisco Vasquez de Coronado, who had been sent by Spanish authorities to explore what is now the American Southwest. By the time of the first contact with the Spaniards, the number of Hopi villages had dropped below ten. A chronicler of the Coronado expedition put the number of Hopi villages at seven, and more recent studies place the number of Hopi villages between five and seven in 1540.

Further Spanish expeditions by Antonio de Espejo (1583) and Juan de Onate (1598 and 1604) provide additional information about Hopi population. Espejo and his men visited five villages (Awatovi, Walpi, Oraibi, Shungopavi and Mishongnovi) and estimated that there were over 12,000 Indians there. Conversely, scholars using contemporary estimates from the Onate expedition estimate the figure at 3,000. Reports of population from various other expeditions and missions to the Hopi Mesas over the following two centuries vary wildly, from a low of 738 (Juan Bautista de Anza in 1780) to over 10,000 (Fray Carlos Delgado in 1745).

3.1.3 Mexican Period (1821-1848)

As Spanish power in New Mexico waned and then was eclipsed altogether, and as the Spanish and native inhabitants of New Mexico found themselves under a new government, the isolation and lawlessness of the region increased. The Mexican government's limited military resources on its northern frontier were devoted to protecting the Hispanic settlements of the Rio Grande Valley in New Mexico, and, somewhat less so, the settlements of Tucson and Tubac in southern Arizona. This left most of the present-day New Mexico and Arizona without any effective military protection, so that the region's tribes, settlements, and ranches were forced to depend on their own resources.

For the Hopi, this was a time of constant watchfulness punctuated by episodes of violence. The main issue for the Hopi at this time was intertribal conflict with the Navajo, Utes, Paiutes, and to a lesser extent, the Apaches. With the Navajos particularly, this hostility was the result of the tribes' growing proximity. When the Spaniards arrived, the settlement areas of the Hopi and Navajo were well separated. By the early 1800s, however, Navajo settlements could be found on Black Mesa, the Kaibito Plateau, the Painted Desert, and other lands surrounding the

Hopi Mesas. In addition to intertribal conflict, some slave raiders sought Hopi captives during this period.

Mexican authorities visited the Hopi Mesas on only one occasion, an 1823 expedition of Mexican soldiers and Pueblo auxiliaries led by Jose Antonio Vizcarra, governor of New Mexico. This was the first visit by any government official since 1780, and there would not be another one until 1858 by a U.S. Army surveyor. Estimates from the 1823 expedition place the number of Hopi villages at six, with a population of approximately 3,000.

3.1.4 Early Contacts with Americans (1848-1882)

The fact that the country surrounding the Hopi Mesas was peripheral to Mexico served the Hopi well when war erupted between Mexico and the United States in 1846. Situated far from the settled areas that were contested in the war, the Hopi and their Indian neighbors saw no troops and no fighting.

The transfer of sovereignty from Mexico to the United States followed ratification of the Treaty of Guadalupe Hidalgo in 1848. The first official notice taken of the Hopi by the United States government officials came in a report sent by the governor of New Mexico, Charles Bent, to his superiors in Washington. As Governor, Bent was the *ex officio* Indian superintendent for the territory, which until 1863 included Arizona, but he had not personally visited the Hopi Mesas, and the source of his information on the Hopi is not known. The Hopi were an "intelligent and industrious people," Bent wrote, and they "live in permanent villages, cultivate grain and fruits, and raise all the varieties of stock." He estimated their population at about 350 families, or 2,450 persons. (Anderson, 2008, p. 21).

In 1852, the first Army officer set foot on the Hopi Mesas. P. G. S. ten Broeck, an Army surgeon, wrote a detailed description of what he saw and did at the Hopi Mesas, providing the first ethnographic description of the Hopi. Broeck estimated the Hopi population at 8,000 and counted seven villages. He also noted the lack of surface water and the Hopi's dependence on rainfall for the success of their crops. A later estimate made by Colonel Christopher "Kit" Carson during the later years of the Navajo War (1863-64) puts the Hopi population at the time at about 4,000.

The most significant early contacts with Americans were with Mormons who first traveled to the Hopi Mesas in 1858. Although the Mormons failed in their attempts to convert

the Hopi, they did succeed in establishing a settlement on Moenkopi Wash, near the site of present-day Tuba City (see **Figure 1-2**). As a result, the Hopi had more dealings with Mormons, both settlers and missionaries, than they did with any other group of Americans prior to the establishment of the 1882 Executive Order Reservation.

3.1.5 Hopi Agency (1850-1882)

For more than 20 years after the American conquest of the Arizona and New Mexico territories, the Hopi lived almost entirely outside the purview of the Office of Indian Affairs. Generally, this left them free to conduct their affairs and lives as they had before. From 1849 until 1869, there was no Indian agent assigned specifically to the Hopi and, therefore, no Hopi agency. During that time, responsibility for the Hopi lay with the territorial Indian superintendents of New Mexico and then, after 1863, Arizona.

The first Indian superintendent for New Mexico, James S. Calhoun, never visited Hopi country, and his only contact with the Hopi came when Hopi delegations visited him in Santa Fe in 1850 and 1851. Little changed over the next 15 years. After Arizona became a separate territory in 1863, its first Indian superintendent, Charles Poston, also failed to visit the Hopi Mesas. In fact the Hopi continued to look to New Mexico whenever they felt it necessary to seek aid from federal officials. John Ward, the Indian agent at Pena Blanca, New Mexico, was the first Indian agent to visit the Hopi Mesas and all seven villages in 1861, and later provided the Hopis corn and farming implements in 1865.

It was not until 1869 that an Indian agent was given any specific responsibility for the Hopi. That year a special agent was appointed and instructed "to visit them and exercise such oversight of their interests and rights as might be proper." The agent, Army Captain A.D. Palmer, was based at Fort Wingate in New Mexico but traveled to the Hopi Mesas late in 1869 and again in the spring of 1870. On the latter trip he remained at the Mesas for two months, showing the Hopi not only how to "clean out and curb their springs and wells" but also "the best manner of using their tools and cultivating their cornfields and vegetable patches, and in irrigating where there was sufficient water." He estimated their population at only 1,505 and noted that they had suffered from famine in 1866 and 1867, and now were threatened by smallpox. (Anderson, 2008, pp. 26-27).

Over the next 13 years, until the establishment of the Hopi Reservation, there would be frequent turnover among the agents appointed to serve the Hopi, and the location of their headquarters would shift several times. Counting Palmer, the Hopi would be supervised by 11 different agents between 1869 and 1882. Two other agents would be appointed but not serve, and there would be three acting agents in one year alone.

The first Hopi agency, which was called the Moqui Agency or Moqui Pueblo(s) Agency, was established in either 1871 or 1872, the record is not clear. The 1871 report of the Commissioner of Indian Affairs noted the existence of an agent "of the Moquis," W.D. Crothers, but included neither a report from him nor any information on the nature of his appointment or when his agency was established. In 1872, the agency was definitely in existence and Crothers was in charge. At that time, the Hopi were receiving annuity goods of some kind, and a school with 60 students was reported to be open, though where it was located remains unclear. The pattern of absentee management continued as Crothers was based at Fort Defiance rather than the Hopi Mesas.

In 1874 the Moqui Pueblo Agency was finally moved to the Hopi Mesas. Sometime that summer, the agent completed a house near First Mesa and moved there from his previous quarters at Fort Defiance, but by 1879, the Hopi agency had been returned to Fort Defiance. For at least part of the year, the Hopi were placed under the charge of the Pueblo Indian agency at Abiquiu, New Mexico, who filed the official report for the Hopi that year. By this time, affairs at the Hopi agency were clearly in disarray. No report was published for the agency that year, and it is not even clear if there was an agent, although the agency was officially listed as operating out of Fort Defiance.

A new agent, John H. Sullivan, was finally appointed in 1880, and when he arrived at the Hopi Mesas in the fall of that year, he found that "the whole affair was in a bad condition." Sullivan managed to reopen the agency, this time in buildings located at Keams Canyon, and eventually the school was reopened as well. A new agent, Jesse H. Fleming, was promptly appointed, and it was he who was instrumental in the creation of the 1882 Executive Order Reservation.

3.2 1882 EXECUTIVE ORDER RESERVATION LANDS

The Moqui Reservation (later known as the Hopi Reservation) was established by an Executive Order dated December 16, 1882 issued by President Chester A. Arthur.[2] The boundaries of the 1882 Hopi Reservation were based on a drawing by Jesse H. Fleming, the newly appointed Indian agent. He was instructed by the Office of Indian Affairs to describe the boundaries "for a reservation that will include Moqui villages and agency and large enough to meet all needful purposes and no larger." (Anderson, 2008, p. 32). Fleming's drawing included 2.5 million acres in a rectangle 55 miles by 70 miles, the boundaries of which were drawn without regard to topography or natural features, such as watercourses, and without consulting with the Hopi. As instructed, the reservation included all of the villages at the Hopi Mesas, but failed to include the village at Moenkopi, which was occupied by approximately 100 Hopi in 1882. It also did not take into consideration the Hopi's traditional use area outside of the reservation, and other lands in the vicinity of Moenkopi village that were claimed by the Hopi. Although the 1882 Hopi Reservation included all of the lands used by the Hopi for farming, it did not include all of the lands used for grazing. According to the Hopi, the 1882 Executive Order Reservation "was only a portion of the land traditionally and actually occupied by the Hopi Indians." (Hopi, 2004, p. 9).

The 1882 Executive Order withdrew lands not only for the use and occupancy of the Hopi but also for "such other Indians as the Secretary of the Interior may see fit to settle thereon," which included the Navajo. At the time the 1882 Executive Order Reservation was established, there may have been as many as 1,800 Hopi and 300 Navajo living there. Many Navajo settled on the Hopi Mesas where the Hopi confined their residency, and later moved into areas used by the Hopi for ceremonial, religious and agricultural purposes and began raising livestock and building homes. By 1920, each tribe numbered around 2,000 on the 1882 Executive Order Reservation, and by 1925 there were more Navajo than Hopi located there.

[2] In 1918, Congress enacted legislation that barred the President from either creating or adding to any Indian reservation in Arizona or New Mexico by Executive Order, and required instead an act of Congress. Act of May 25, 1918, ch. 86, § 2, 40 Stat. 570. In 1927, Congress enacted legislation that required Congressional approval of boundary adjustments to any Indian reservation created by Executive Order. Act of March 3, 1927, ch. 299, § 4, 44 Stat. 1347.

For decades, the Hopi and the Navajo disputed their respective rights and interests to land within the 1882 Executive Order Reservation, which culminated in litigation. In *Healing v. Jones*, 210 F. Supp. 125, 191-92 (D. Ariz. 1962), *aff'd per curiam*, 373 U.S. 758 (1963), the court determined the Hopi had an exclusive interest in an area known as Land Management District 6 (District 6), and the Hopi and the Navajo had a joint, undivided and equal interest to the remainder of the 1882 Executive Order Reservation outside of District 6 (Joint Use Area). However, due to the court's limited jurisdiction, the Joint Use Area was not partitioned until many years after the *Healing* decision was entered. This case is discussed further below.

3.2.1 District 6 Lands

District 6 was part of a land management district established to implement grazing regulations on Indian Lands. On June 18, 1934, Congress passed the Indian Reorganization Act, which directed the Secretary of the Interior to adopt rules and regulations regarding grazing on Indian lands, *inter alia*.

> The Secretary of the Interior is directed to make rules and regulations for the operation and management of Indian forestry units on the principle of sustained-yield management, to restrict the number of livestock grazed on Indian range units to the estimated carrying capacity of such ranges, and to promulgate such other rules and regulations as may be necessary to protect the range from deterioration, to prevent soil erosion, to assure full utilization of the range, and like purposes.

Ch. 576, § 1, 48 Stat. 984. Accordingly, on November 6, 1935, the Secretary issued grazing regulations, that were expressly limited to the Navajo Reservation, which surrounded the 1882 Executive Order Reservation.[3] Nonetheless, in 1936 when the land management districts were established, they also embraced land within the 1882 Executive Order Reservation, including District 6, which had been used exclusively by the Hopi for livestock and farming. 210 F. Supp. at 158, 173. When first created in 1936, District 6 encompassed 499,248 acres, but it was later expanded to include 631,194 acres of land, the boundaries of which were approved by the Office of Indian Affairs (OIA) on April 24, 1943. 210 F. Supp. at 173. Although this expansion was

[3] The boundaries of the Navajo Reservation were confirmed in 1934 by separate Congressional Act. Act of June 14, 1934, Ch. 521, 48 Stat. 960.

supported by the Indian Superintendents for both tribes, it was not approved by the Department of the Interior's Solicitor or the Hopi Tribal Council. 210 F. Supp. at 166. The Hopi and Navajo continued to be unable to resolve their differences.

On June 2, 1937, comprehensive grazing regulations were approved, and it became the policy of the OIA to forbid the Hopi from living or grazing their livestock outside of District 6 without securing permits, which were issued only on a showing of past use by the Hopi. 210 F. Supp. at 171. In the same year, the Interior Department gave administrative control over District 6 to the Hopi Superintendent of Indian Affairs, and the other districts to the Navajo Superintendent of Indian Affairs. 210 F. Supp. at 159.

After the expansion of District 6, the Hopi and the Navajo each filed claims with the Indian Claims Commission, pursuant to the Indian Claims Commission Act of 1946,[4] seeking compensation for aboriginal lands that allegedly had been taken by the federal government. See **Figure 3-2**. The Navajo filed its claim in 1950, and the Hopi filed its claim in 1951. Because these claims were overlapping, the Commission considered the claims jointly, although separate opinions were issued. In 1970, eight years after the *Healing* decision, and almost 20 years after the claims for compensation were filed by the Hopi and Navajo, the Indian Claims Commission held that the Hopi and Navajo had compensable claims resulting from the extinguishment of aboriginal title to certain lands. The Indian Claims Commission adopted certain findings of fact and conclusions of law issued by the court in *Healing*.[5]

In 1958, several years after the Hopi and Navajo filed their claims with the Indian Claims Commission, Congress passed legislation that authorized a quiet title action to determine the respective rights and interests of the Hopi and Navajo to the 1882 Executive Order Reservation lands.[6] Act of July 22, 1958, Pub. L. No. 85-547, 72 Stat. 403 (1958 Act); 210 F. Supp. at 130. Under this legislation, any land in which the court determined that a tribe had an exclusive interest was to be added to that tribe's reservation and held in trust by the United States. 210 F. Supp. at 130. However, the 1958 Act did not authorize the court to divide or partition land in which the tribes had a joint and undivided interest. 210 F. Supp. at 189-91.

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[4] 60 Stat. 1049.

[5] *Hopi Tribe v. U.S.*, Docket No. 196, 23 I.C.C. 277, 287 (1970), motion to amend findings denied, 31 Ind. Cl. Comm. 16 (1973), *cert. dismissed*, 429 U.S. 1030 (1976); *Navajo Tribe v. U.S.*, Docket No. 229, 23 Ind. Cl. Comm. 244 (1974), *aff'd mem.*, 529 F.2d 533 (Ct. Cl. 1976), *cert. dismissed*, 429 U.S. 1030 (1976).

[6] This legislation also authorized suit to be brought against any other Indian tribe claiming an interest in the 1882 Executive Order Reservation. No such tribes were joined or intervened in the litigation. 210 F. Supp. at 131.

Shortly after the passage of the 1958 Act, the Hopi brought a special action in the U.S. District Court for Arizona to resolve the competing claims of the Hopi and Navajo to 1882 Executive Order Reservation lands. By decision dated September 28, 1962, the *Healing* court held that, as of the date of the 1958 Act, the Hopi had an exclusive interest in the lands encompassed by District 6 consisting of approximately 630,000 acres of land.[7] 210 F. Supp at 138, 173. The court further held that both tribes had "joint, undivided and equal" interests in the lands located outside the boundaries of District 6 consisting of approximately 1.8 million acres, including the surface and sub-surface and "all resources appertaining thereto," subject to the trust title of the United States. The court stated:

> The applicable facts and law of this case do not permit of a declaration that one tribe or the other has the exclusive interest in all of the 1882 reservation; or that all of the 1882 reservation is divisible into areas of *exclusive interest* for one tribe or the other. The only part of the reservation which may be, and herein is, so classified is the *district 6 area*, as defined on April 24, 1943, the Hopi Indian Tribe having the exclusive interest herein. As to the remainder of the reservation, the Hopi and Navajo Indian Tribes have *joint, undivided, and equal interests as to the surface and sub-surface including all resources appertaining thereto*, subject to the trust title of the United States.

(Emphasis added.) 210 F. Supp. at 191-92. However, because the court did not have jurisdiction to partition the jointly-held lands, the court recognized that the controversy between the tribes was not entirely resolved.

> Under the judgment being entered herein about one quarter of the 1882 reservation, consisting of district 6 as defined in 1943, will be completely removed from controversy, having been awarded exclusively to the Hopi Indian Tribe. As to the remainder of the reservation, the facts and law, as herein determined and applied, and our lack of jurisdiction to partition jointly-held lands, preclude a complete resolution of the Hopi-Navajo controversy.

210 F. Supp. at 192.

In 1970, the Hopi Tribe petitioned the court for an order to enforce its rights under the *Healing* decree. In 1972, the federal district court issued an order of compliance and writ of assistance that limited Navajo grazing and development activities in the Joint Use Area, and

[7] Because a metes and bounds description for District 6 had not been established, the boundaries of District 6 were depicted on a map that was included in the decision. 210 F. Supp. at 158.

provided for a division of any income generated from the Joint Use Area. The decision of the lower court was upheld on appeal. See *Hamilton v. MacDonald*, 503 F.2d 1138 (9th Cir. 1974). However, the use and occupancy of the jointly-held lands were not finally resolved until Congress took action, which spawned even further litigation.

3.2.2 Hopi Partitioned Lands

In 1974, Congress passed the Navajo-Hopi Land Settlement Act (1974 Settlement Act), which authorized the appointment of a mediator to assist in negotiations for the settlement and partition of the lands within the Joint Use Area, *inter alia*. Act of December 22, 1974, Pub. L. No. 93-531, 88 Stat. 1712. Subject to certain exceptions, any lands partitioned to the Hopi and Navajo Tribes were to be held in trust by the United States exclusively for each tribe as part of that tribe's reservation. 88 Stat. at 1716, § 10. Previously perfected allotments were not affected.

> Nothing in this Act shall affect the title, possession, and enjoyment of lands heretofore allotted to Hopi and Navajo individuals for which patents have been issued. Such Hopi individuals living on the Navajo Reservation shall be subject to the jurisdiction of the Navajo Tribe and such Navajo individuals living on the Hopi Reservation shall be subject to the jurisdiction of the Hopi Tribe.

88 Stat. at 1720, § 17(a).

The negotiations authorized by the 1974 Settlement Act proved unsuccessful, and the mediator prepared a report with settlement recommendations for review by the Arizona federal district court, which was "authorized to make a final adjudication, including partition of the joint use area, and enter the judgments in the supplemental proceedings in the Healing case." 88 Stat. at 1714, § 4(a). The 1974 Settlement Act directed the mediator and the court to be guided by several considerations regarding the partition of the surface rights to the Joint Use Area, some of which included the following: (1) the rights and interests of the Hopi Tribe in District 6 "shall not be reduced or limited in any manner"; (2) "reasonable provision shall be made for the use of and right of access to identified religious shrines"; and (3) any partition of the Joint Use Area "shall, insofar as is practicable, be equal in acreage and quality"; 88 Stat. at 1714-15, § 6(a), (c) and (d). In addition, Congress indicated that the partition of the surface estate in the Joint Use

Area "shall not affect the joint ownership status of the coal, oil, gas and all other minerals within or underlying such lands." 88 Stat. at 1715, § 7. The 1974 Settlement Act also granted the Hopi Tribe perpetual use of Cliff Spring for religious and ceremonial purposes. 88 Stat. at 1722, § 20.

In 1977, the Arizona federal district court entered an order of partition, and the Navajo appealed. On appeal, the 9th Circuit Court of Appeals held that it was not an abuse of discretion to adhere to the "equal distribution principle" for the partition process, but the court reversed the lower court's order that foreclosed litigation of the question of whether the boundary of the Joint Use Area properly included approximately 50,000 acres that allegedly were already part of the Navajo Reservation. As a result, the partition order was vacated. *Sekaquaptewa v. MacDonald*, 575 F.2d 239, 248 (9th Cir. 1978).

In 1979, upon remand, the Arizona federal district court entered an order that included the disputed 50,000 acres in the Joint Use Area, and partitioned the Joint Use Area into the Hopi Partitioned Lands and the Navajo Partitioned Lands by allocating approximately 900,000 acres to each.[8] On appeal, the 9th Circuit Court of Appeals affirmed. *Sekaquaptewa v. MacDonald*, 626 F.2d 113, 119 (9th Cir. 1980).

Under the 1974 Settlement Act, the partition of lands in the Joint Use Area required the relocation of many Navajo who resided on Hopi Partitioned Lands, and a comparatively small number of Hopi who resided on Navajo Partitioned Lands, to be completed by 1986. The 1974 Settlement Act also created a commission to pay for the major costs of the relocations.[9] In 1977, the necessary relocations began, but progress was slow due to lack of adequate funding and available land. In 1980, Congress passed the Navajo and Hopi Indian Relocation Amendments Act of 1980 (1980 Relocation Act) that amended certain provisions of the 1974 Settlement Act, and increased funding for the relocation program. Pub. L. No. 96-305, 94 Stat. 929. In 1988, Congress again increased funding for the relocation program by enacting the Navajo and Hopi Indian Relocation Amendments, Pub. L. No. 100-666, 102 Stat. 3929.

Just before the 1988 relocation amendments were passed, certain Navajo living on Hopi Partitioned Lands brought suit in the U.S. District Court for Arizona challenging the 1974 Settlement Act and the relocation program on several grounds. The court denied the Navajo's

[8] See *Clinton v. Babbitt*, 180 F.3d 1081, 1084 (9th Cir. 1999) for a description of the legislation and events involved in the partitioning of the Joint Use Area.
[9] See *Clinton*, 180 F.3d at 1084-85.

motion for a preliminary injunction and dismissed the case. *Manybeads v. United States*, 730 F. Supp. 1515, 1522 (D. Ariz. 1989). In 1991, the 9th Circuit Court of Appeals ordered the parties to enter into mediation, which resulted in an Agreement in Principle in 1992 among the Hopi, Navajo and United States, followed by a Settlement Agreement in 1995 between the Hopi Tribe and the United States.[10] *Also see Manybeads v. United States*, 209 F.3d 1164, 1165 (9th Cir. 2000), *cert. denied*, 532 U.S. 966 (2001). Under the 1995 Settlement Agreement, the Hopi agreed to permit Navajo families to remain on Hopi Partitioned Lands under the terms of 75-year leases known as accommodation leases as part of an Accommodation Agreement, and dismiss several claims that had been brought against the United States. In return, the United States agreed to make certain incremental payments to the Hopi Tribe and take into trust up to 500,000 acres of land in northern Arizona for the Hopi Tribe.[11]

In 1996, Congress passed the Hopi-Navajo Land Dispute Settlement Act of 1996, Pub. L. No. 104-301, 110 Stat. 3649 (1996 Settlement Act), which extended funding for the relocation program to the year 2000 and ratified both the 1995 Settlement Agreement and the Accommodation Agreement. However, the Hopi were required to satisfy certain conditions before the United States could take additional lands into trust for the tribe. The 1996 Settlement Act also authorized extensions of the 75-year leases, and confirmed the Hopi Tribe's right to "quiet possession" to use of the Hopi Partitioned Lands under certain circumstances.[12]

3.3 1934 ACT RESERVATION LANDS (MOENKOPI)

In addition to lands within the 1882 Executive Order Reservation, there are Hopi lands within the surrounding Navajo Reservation. The Navajo Reservation was initially created by Treaty of June 1, 1868, 15 Stat. 667, and through various executive orders, the reservation was expanded. In 1934, Congress passed legislation that confirmed the boundaries of the Navajo Reservation resulting from the additions made by the prior executive orders, including an Executive Order dated January 8, 1900. Act of June 14, 1934, Ch. 521, 48 Stat. 960 (1934 Act).

[10] *Id.*
[11] See *Clinton*, 180 F.3d at 1085-86. The Hopi refer to these lands as the Hopi Ranches (Hopi, 2004, p. 12). Under the 1996 Settlement Act, water rights for the Hopi Ranches are based on state law, and are beyond the scope of this Preliminary Hopi HSR.
[12] *Id.*

Under this Executive Order, land immediately west of the 1882 Executive Order Reservation extending to the Little Colorado River and Colorado River was incorporated into the Navajo Reservation, which included Upper and Lower Moenkopi villages as well as surrounding areas to which the Hopi claimed an exclusive interest. This land is often referred to as the 1900 Extension. See **Figure 3-2**.[13]

In addition to confirming the boundaries of the Navajo Reservation, the 1934 Act permanently withdrew those lands for the benefit of the Navajo and "such other Indians as may already be located thereon." This reservation of land is referred to in this report as the 1934 Act Reservation. The status of the 1882 Executive Order Reservation was not affected by the 1934 Act. In pertinent part, the 1934 Act stated that:

> All vacant, unreserved, and unappropriated public lands, including all temporary withdrawals of public lands in Arizona heretofore made for Indian purposes by Executive order or otherwise within the boundaries defined by this Act, are hereby permanently withdrawn from all forms of entry or disposal for the benefit of the Navajo and *such other Indians as may already be located thereon*; however, nothing herein contained shall affect the existing status of the Moqui (Hopi) Indian reservation created by Executive order of December 16, 1882.

(Emphasis added.) 48 Stat. at 961.

In 1974, 40 years after the 1934 Act was passed, Congress passed the 1974 Settlement Act, which authorized both the Navajo and Hopi to bring a quiet title action, if necessary, to determine their respective interests in the lands withdrawn by the 1934 Act. 88 Stat. at 1715, § 8(a). This was the same Congressional Act that authorized the partitioning of lands within the 1882 Executive Order Reservation.

Pursuant to the 1974 Settlement Act, the Hopi Tribe filed suit in the Arizona federal district court in 1977. In 1978, the court held the Hopi had an equitable interest in the 1934 Act Reservation under the "such other Indians as may already be located thereon" clause in the 1934 Act, due to the existence of a Hopi village "Moencopi" prior to and during 1934. The court further held that the Hopi and Navajo each received an undivided one-half interest in the 1934 Act Reservation, and that the 1974 Settlement Act required partitioning of any lands found to be

[13] This map was introduced into evidence by stipulation of the parties in *Sekaquaptewa v. MacDonald*, 448 F. Supp. 1183, 1185 (D. Ariz. 1978), which is discussed further below.

jointly held by the Navajo and Hopi. *Sekaquaptewa v. MacDonald*, 448 F. Supp. 1183, 1187, 1193, 1196 (D. Ariz. 1978). On review, the 9th Circuit Court of Appeals upheld the jurisdiction of the lower court to partition lands that had been jointly occupied or used. However, contrary to the lower court, the appellate court held that the Hopi were entitled to a full interest in lands they had "exclusively possessed, occupied, or used in 1934." The case was remanded for further proceedings. *Sekaquaptewa v. MacDonald*, 619 F.2d 801, 808-09 (9th Cir. 1980), *cert. denied*, 449 U.S. 1010 (1980).

In 1992, on remand, the Arizona federal district court issued three opinions concerning Hopi interests in the 1934 Act Reservation. The court issued its first decision on March 11, 1992 and held that certain railroad and mission lands in the 1934 Act Reservation were not subject to claims by the Hopi or the San Juan Southern Paiute. This decision was upheld on appeal. See *Masayesva v. Zah*, 792 F. Supp. 1155 (D. Ariz. 1992), *aff'd*, 65 F.3d 1445 (9th Cir. 1995), *cert. denied*, *Secakuku v. Hale*, 517 U.S. 1168 (1996).

The court issued its second decision on April 27, 1992, which was amended on June 18, 1992. In this case, the Hopi claimed 80,000 acres in and around Moenkopi, an entitlement to 1.25 million acres of grazing lands, and use of the entire Navajo Reservation for religious or traditional purposes including hunting eagles, erecting and visiting shrines, and gathering plants. The court identified the lands in the 1934 Act Reservation that had been jointly used, and those that had been exclusively used by the Hopi, including the village at Moenkopi, Pasture Canyon and certain surrounding areas.[14] However, the court did not establish specific boundaries, and did not include areas where the Hopi had engaged in religious and gathering activities. On appeal, the 9th Circuit Court of Appeals remanded the case to identify "locations regularly and exclusively used for religious observances or activities by the Hopis" and to award those locations to the Hopi Tribe. *Masayesva v. Zah*, 793 F. Supp. 1495, 1498, 1502-35 (D. Ariz. 1992), *aff'd in part, rev'd in part*, 65 F.3d 1445, 1455 (9th Cir.), *cert. denied*, *Secakuku v. Hale* 517 U.S. 1168 (1996).

The court issued its third decision on September 25, 1992, which was amended on December 21, 1992. In this case, the court more specifically delineated the boundaries of the Hopi exclusive and joint areas, and partitioned the joint use lands based on "fairness and equity,"

[14] The court also recognized the equitable interests of the San Juan Southern Paiute Tribe in the 1934 Act Reservation, but the court held that it was not authorized to partition land to that tribe.

which did not affect allotted lands. The court held that the Hopi were entitled to the exclusive use of 60,518 acres, based on the Hopi exclusive use area lands plus approximately 25% of the Joint Use Area. The court also attempted to partition water sources equitably so that every grazing area would have access to water. The lands partitioned to the Hopi and Navajo were to be held in trust by the United States exclusively for each tribe as part of their respective reservations. The court also lifted the Bennett Freeze, which had been imposed in 1966 to maintain the status quo, and which required the written consent of each tribe before development could occur in the 1900 Extension Area, except for a limited area around Moenkopi and Tuba City where the Freeze was lifted in 1972.[15] On appeal, the 9th Circuit Court of Appeals upheld the partition judgment, and reversed that part of the order that lifted the Bennett Freeze. *Masayesva v. Zah,* 816 F. Supp. 1387, 1415-37 (D. Ariz. 1992), *aff'd in part, rev'd in part,* 65 F.3d 1445, 1460 (9th Cir. 1995), *cert. denied, Secakuku v. Hale,* 517 U.S. 1168 (1996).

Ten years after the U.S. Supreme Court declined to hear further appeals, the Hopi and Navajo entered into the Navajo-Hopi Intergovernmental Compact of 2006 (2006 Intergovernmental Compact). This compact gives the Hopi and Navajo access to religious shrines and traditional use areas located on each other's reservation lands but without changing ownership. 2006 Intergovernmental Compact at Article 2. As part of the compact, the Hopi and the Navajo also agreed to cease all litigation regarding the 1934 Act Reservation, lift the Bennett Freeze, and stipulate to the orders and judgments of partition entered by the Arizona federal district court. 2006 Intergovernmental Compact at §§ 7.1, 7.4.

3.4 ALLOTTED LANDS

Under the Indian General Allotment Act of 1887, also known as Dawes Severalty Act, the President was authorized to allot reservation lands to individual Indians when advantageous for "agricultural and grazing purposes." Act of February 8, 1887, ch. 119, § 1, 24 Stat. 388. As part of the Indian Reorganization Act of 1934, the allotment program ended. 48 Stat. at 984.

The allotments on the Hopi Reservation were established in the early 1900s, and are all located within the 1934 Act Reservation in the vicinity of Moenkopi. These allotted lands are

[15] The Bennett Freeze was codified as part of the 1980 Relocation Act, 94 Stat. at 930.

depicted on **Figure 1-2** and are included within the claims filed by the Hopi and United States as described in **Section 2.10** above. Water uses for these lands are also described in **Section 8.1**. There were two attempts to create allotments within the 1882 Executive Order Reservation, first in 1891 and later in 1908, but these were unsuccessful largely due to resistance by the Hopi Tribe.

CHAPTER 4: PHYSICAL SETTING

This chapter describes the physical setting of the Reservation including its location **(Section 4.1)**, topography **(Section 4.2)**, climate **(Section 4.3)**, vegetation **(Section 4.4)**, soils and geology **(Section 4.5)**, and land use **(Section 4.6)**.

4.1 LOCATION

The Reservation is located in northeastern Arizona within the LCR Adjudication Area (**Figure 1-1**). It covers an area of approximately 1,621,650 acres (2,534 square miles) and portions of two counties – Navajo County to the east and Coconino County to the west.

Flagstaff, which lies about 75 miles southwest of the Reservation, is the largest city in the region with an estimated population of 61,185 in 2005 (ADWR, 2006). Tuba City, located on Navajo lands that border the Moenkopi Area, is the largest city locally with an estimated population of 8,225 in 2000. Polacca and the other villages of First Mesa comprise the largest population center on the Reservation with an estimated population of 1,124 in 2000.

The LCR, which does not cross the Reservation, is the major stream in the region and collects runoff from tributaries draining Hopi and Navajo lands to the northeast. Major roads leading to the Reservation include State Routes 87 and 264 and U.S. Highways 89 and 160.

4.2 TOPOGRAPHY

The Reservation is within the Plateau Uplands physiographic province (ADWR, 2006). The province is characterized by relatively flat-lying sedimentary rocks that have been eroded into canyons and plateaus, and by a few relatively high mountains. Black Mesa is the predominant topographic feature in the area and forms highlands that slope

from northeast to southwest across the Reservation and reach an elevation of 8,210 feet on Navajo lands to the north. Big Mountain, which reaches an elevation of 7,210 feet, is the highest point on the Reservation. See **Figure 4-1**.

Black Mesa slopes downward to an elevation of less than 6,500 feet before extending southwest across the Reservation as a series of smaller mesas. These so-called "Hopi Mesas" include, from east to west, Antelope Mesa, First Mesa, Second Mesa, and Third Mesa. The Hopi Mesas are separated and drained by relatively deep washes that eventually flow into the LCR. Important "Hopi Washes" include, from east to west, Jeddito Wash, Polacca Wash, Oraibi Wash, Dinnebito Wash, and Moenkopi Wash. The lowest elevation on the Reservation occurs where Moenkopi Wash crosses the western Reservation boundary at an elevation of approximately 4,520 feet. **Figure 4-2** is an oblique image of the Reservation that shows the relationship between Black Mesa and the Hopi Mesas.

4.3 CLIMATE

This section summarizes recent climatic conditions on the Reservation including temperature, precipitation, wind, humidity, and surface water evaporation. Representative climate data are available from two meteorological stations operated by the National Weather Service and eight meteorological stations operated by the Hopi Tribe (**Figure 4-3**). Unless otherwise noted, the discussion that follows was taken from ADWR (2008f) and references therein.

Temperature

Winters on the Reservation are characterized by freezing temperatures, with nighttime temperatures falling below 32^{o}F through March and often into April and beginning again in October. Summers are warmer, with high temperatures averaging in the mid-90s during July and August. Monthly and annual temperature data from the meteorological stations at Tuba City and Keams Canyon are summarized in **Table 4-1**.

Precipitation

Mean annual precipitation in the vicinity of the Reservation is shown in **Figure 4-4** for the period 1971-2000 and **Table 4-1** lists precipitation and snowfall data from the Tuba City and Keams Canyon meteorological stations. In Keams Canyon, annual precipitation has averaged 9.94 inches since 1948, with the average monthly precipitation ranging from 0.30 inches in June to 1.61 inches in August. In Tuba City, annual precipitation has averaged 6.47 inches since 1900, with the average monthly precipitation ranging from 0.24 inches in June to 0.85 inches in August.

April through June is typically the driest period on the Reservation with relatively little rainfall until the arrival of the summer monsoon. Summer rains occur from mid-July through mid-September as scattered convective thunderstorms. These storms can be highly localized, often producing heavy rainfall in an area less than a few square miles while adjacent areas remain dry. Rainfall from November to March is relatively light, with 30-50% of winter precipitation falling as snow. Most snow falls between November and March with annual snowfalls usually less than 15 inches. Low temperatures can allow modest accumulations of snow to persist for several weeks before melting.

Wind

Winds on the Reservation are relatively high and prevail from the southwest. From April through September, the typical growing season for local crops, wind speeds have averaged 3.32 meters per second (7.43 miles per hour or mph) at the eight Hopi meteorological stations. Data are available from these stations for the period 2003 through 2007, with measured wind speeds corrected to a height of 2 meters (6.6 feet) above ground surface.

NAU (2008) estimates that the average annual wind at a height of 50 meters (164 feet) above the Reservation is generally between 0 to 12.3 mph, but several areas are noted with average wind speeds between 12.3 to 14.1 mph. The upper range is considered “marginal” for wind power generation and the lower range is considered “poor.”

Humidity

The Reservation is semi-arid, but can experience excessive dryness, particularly during the months of May and June when there is relatively little rainfall. Based on data from the eight Hopi meteorological stations, the relative humidity on the Reservation during the crop growing season has averaged about 35%.

Surface Water Evaporation

ADWR calculated monthly rates of surface water evaporation on the Reservation using the Penman method and measured or estimated values for wind speed, dew point temperature, and minimum and maximum air temperature. Evaporation rates were calculated for the Tuba City and Keams Canyon areas and are listed in **Table 4-2**. The calculations indicate that annual rates of surface water evaporation on the Reservation may total from 63.5 inches (5.3 feet) to 80.2 inches (6.7 feet).

4.4 VEGETATION

Three major, vegetative communities have been identified on the Reservation (USDA, 1981):

- Juniper-Pinyon Woodland
- Plains and Desert Grasslands
- Great Basin Desert Scrub.

Juniper-Pinyon Woodland, which covers about 17% of the Reservation, is typically found at elevations between 5,550 and 7,500 feet with pinyon pine predominant below 6,500 feet. Plains and Desert Grasslands cover about 60% of the Reservation. Plains Grassland occurs at elevations between 5,000 and 7,000 feet and is characterized by grama, a short grass type. Desert Grassland occurs at elevations between 4,000 and 6,000 feet and is characterized by Galleta and black grama grasses and various shrubs. Great Basin Desert Scrub, which covers the remaining 23% of the Reservation, is found where annual

precipitation is limited to 7 to 12 inches and characterized by sparse, low growing shrubs and grasses.

In addition to the major vegetative communities, riparian vegetation occurs locally along washes and around some stock impoundments. Riparian plant species identified on the Reservation include cottonwood, Russian olive, saltcedar, and willow (ADWR, 2008a). **Figure 4-5** shows where ADWR mapped riparian vegetation on the Reservation in 2005 and the location of the major vegetative communities. Photographs of some riparian vegetation on the Reservation are presented in **Figure 4-6**.

4.5 SOILS AND GEOLOGY

4.5.1 Soils

The National Resource Conservation Service (NRCS) has performed two soil surveys recently on Reservation lands:

- AZ714 – *Hopi Area, Arizona, Parts of Coconino and Navajo Counties* (NRCS, 1996)
- AZ707 – *Little Colorado River Area, Arizona, Parts of Coconino and Navajo Counties* (NRCS, 2007a).

Data from Survey AZ707, which includes the Moenkopi Area, is provisional and subject to change upon completion of the survey. **Figure 4-7** shows the boundary of the two soil surveys.

Based on these surveys, NRCS grouped soils on the Reservation into ten "General Soil Map Units" (GSMUs). The GSMUs are comprised of one or more soil series with similar land use and management characteristics. Soil series, in turn, consist of soil families with similar color, texture, structure and composition (NRCS, 2007b). **Figure 4-8** shows the location of GSMUs on the Reservation and **Table 4-3** lists information for these units. The table includes the name and a description of each GSMU, its acreage and percentage of the total Reservation area, its typical elevation range and slope, and common land uses.

In general, shallow soils dominate the steep slopes and edges of Black Mesa to the north and deep loamy soils occur on the plateaus (NRCS, 1996). The southern lowlands of the Reservation consist of relatively wide alluvial valleys mantled with eolian sands. Loamy and clayey soils often underlie floodplains and stream and fan terraces.

4.5.2 Geology

This section describes the stratigraphy of geologic units that underlie the Reservation, regional geologic structures, and the geologic units exposed at ground surface. Unless otherwise noted, the discussion that follows was taken from ADWR (2008d) and references therein.

Stratigraphy

Figure 4-9 is a stratigraphic column that shows some of the important geologic units and associated rock types beneath the Reservation. Geologic units, including those in the figure, can be grouped into five time periods based on their age of deposition (Bates and Jackson, 1980):

- Quaternary Period – 1.8 million years ago (mya) to present
- Tertiary Period – 65 to 1.8 mya
- Mesozoic Era – 225 to 65 mya (includes the Cretaceous, Jurassic, and Triassic Periods)
- Paleozoic Era – 570 to 225 mya (includes the Permian, Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician and Cambrian Periods)
- Precambrian Era – prior to 570 mya.

Precambrian-age units beneath the Reservation include intrusive (granite) and metamorphic (quartzite, gneiss, and schist) rocks that appear to be extensively faulted. Organic-rich mudstone, siltstone, sandstone and shale of the Chuar Group were deposited within irregularities (grabens) of these 'basement' rocks.

Cambrian-age units include the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone of the Tonto Group. This group is typically 110-350 feet thick beneath Black

Mesa. Overlying Devonian rocks are 200-300 feet thick locally and include shale, limestone and dolomite of the Aneth Formation; sandstone, dolomite, and shale of the Ebert Formation; and limestone, dolomite, and shale of the Ouray Limestone.

The Redwall Limestone of Mississippian age overlies the Devonian strata and is typically 175-300 feet thick beneath Black Mesa. A period of large-scale erosion (regional unconformity) separates the Redwall Limestone from the overlying Pennsylvanian Molas Formation. The Molas Formation is up to 100 feet thick and consists of sandstone, siltstone, and shale. It grades upward into the Hermosa Group, a series of sandstones and siltstones that are 400-1,700 feet thick and divided into the Pinkerton Trail, Paradox, and Honaker Trail Formations.

The Supai Group of Permian age is 500-1,400 feet thick and includes mudstone, siltstone, sandstone, and gypsum. This group is overlain by 250-1,500 feet of Coconino Sandstone and from 0-300 feet of Kaibab Limestone. An average of 1,100-1,600 feet of Triassic rocks unconformably overlies these Permian strata. The Triassic rocks include up to 400 feet of mudstone, siltstone, sandstone, and gypsum of the Moenkopi Formation and 850-1,400 feet of alternating mudstone, siltstone, sandstone, and conglomerate of the Chinle Formation.

The Glen Canyon Group of Jurassic age contains the Wingate Sandstone (100-720 feet thick), Moenave and Kayenta Formations (up to 1,000 feet of sandstone interbedded with siltstone), and the Navajo Sandstone (400-1,400 feet thick). The Jurassic-age San Rafael Group unconformably overlies the Glen Canyon Group and contains the Carmel Formation (from 0-300 feet of sandstone and siltstone), Entrada Sandstone (50-600 feet thick) and Cow Springs Sandstone (up to 300 feet thick). The upper Jurassic Morrison Formation consists of up to 600 feet of alternating sandstone, siltstone, and mudstone.

Cretaceous-age units overlie the Jurassic strata and form the highlands of Black Mesa. These rocks are up to 1,700 feet thick and include the Dakota Formation (30-150 feet of sandstone and siltstone), Mancos Shale (about 450 feet thick) and the Mesa Verde Group (500-1,000 feet thick). The latter consists of sandstone of the Toreva Formation; interbedded mudstone, siltstone, sandstone and coal of the Wepo Formation; and the Yale Point Sandstone.

Tertiary-age rocks unconformably overlie the Mesozoic units and are only found in the southeastern portion of the Reservation. The Bidahochi Formation can reach up to 1,000 feet thick and consists of sandstone, mudstone, and volcanic rock (basalt).

Unconsolidated alluvial and eolian deposits of Quaternary age are exposed across the surface of the Reservation. These sandy deposits are typically less than 80 feet thick, but can locally reach thicknesses up to 230 feet and include gravel zones.

Regional Structure

The relatively thick sequence of sedimentary rocks described above is part of a regional, structural basin bordered on the west by the Coconino Plateau and on the east by the Defiance Uplift (**Figure 4-10**). The structural basin is up to 8,500 feet deep and covers an area of approximately 4,000 square miles. It is crossed by numerous, smaller folds and is intruded locally by igneous rocks. At Hopi Buttes, near the southern border of the Reservation, Precambrian basement rocks that underlie the sedimentary units are within 4,000 feet of ground surface. The buttes are remnants of a volcanic episode in the late Tertiary Period that caused over 300 intrusive bodies (diatremes) to penetrate to the surface through the sedimentary units.

Surface Geology

Figure 4-11 shows the surface geology in the vicinity of the Reservation. The following geologic units (and associated map units) are found at ground surface on the Reservation:

- Quaternary surficial deposits (Q, Qo, and Qy);
- Tertiary Bidahochi Formation (Tby and Tsy);
- Cretaceous Mesa Verde Group (Kmv), Mancos Shale (Ks), and Dakota Formation (Ks); and
- Jurassic Morrison Formation (Jm), San Rafael Group (Ja), and Glen Canyon Group (Jgc).

Due to regional uplift, this sequence of sedimentary rocks dips at 3-5 degrees to the northeast. As a result, the older sedimentary rocks are exposed in the southwestern

portion of the Reservation and, as one travels across the Reservation to the northeast, the exposed sedimentary rocks become progressively younger (Hopi, 2001).

4.6 LAND USE

Four categories of land use have been reported on the Reservation (Hopi, 2001):

- Agriculture and range
- Recreation
- Industrial
- Community mixed use.

Figure 4-12 shows the location of these land uses.

By far the largest land use on the Reservation is for livestock grazing. Between 819,000 and 1,326,000 acres of the 1882 Executive Order Reservation are estimated to be useable as range (ADWR, 2008b). The acreage of useable range in the Moenkopi area was not reported. In 2005, between 5,570 and 6,506 acres of the Reservation are estimated to have been actively used for agriculture (ADWR, 2008c).

Approximately 36,860 acres in the northwestern portion of the 1882 Executive Order Reservation are set aside for recreational use (Hopi, 2001). The Blue Canyon Special Management Area was designated by the Hopi Tribal Council in 1992 and dedicated to recreation and conservation purposes. This area has been used by residents of Third Mesa for traditional gathering and was part of a recent watershed rehabilitation project.

Three areas of industrial land use cover approximately 6,200 acres of the Reservation. These include the PWCC coal mine lease in the northeastern portion of the 1882 Executive Order Reservation, a solid waste facility on the 1882 Executive Order Reservation, and a former BIA landfill in the Moenkopi area (Hopi, 2001). The BIA landfill is not shown on **Figure 4-12** or included in the cited industrial acreage.

Approximately 14,600 acres of the Reservation are used for residential, institutional (public service facilities) and commercial purposes (Hopi, 2001). Most Hopi

live in or near these areas of community mixed use. Photographs of Reservation land uses are presented in **Figure 4-13**.

CHAPTER 5: CULTURE

This chapter describes the culture of the Hopi people, including their social organization **(Section 5.1)**, governance **(Section 5.2)**, customs **(Section 5.3)**, and rituals and ceremonies **(Section 5.4)**. Unless otherwise noted, these descriptions were summarized from Andersen (2008) and Volume 9 of the Handbook of North American Indians (Connelly, 1979; Frigout, 1972; and Kennard, 1979). Locations of the geographic features mentioned below are shown in **Figure 4-1**.

5.1 SOCIAL ORGANIZATION

Early social organization of the Hopi has been described as clusters of social units surrounding a core unit. At the smallest level were households, which varied in size and could consist of several biological families that constituted the essential core of the Hopi social structure. At the largest level were villages, which were separate politically, but often connected and dependent upon one another. The village of Walpi was considered the "mother village" of First Mesa, and was responsible for maintaining ceremonies. The First Mesa satellite village of Sichomovi relied upon Walpi for religious initiation, and served as a reservoir of available population for Walpi. Another First Mesa village, Tewa, was populated by refugees from other areas and served as protectors from outside intrusion. Ultimately, Walpi people came to rely on the Tewa people as interpreters (and buffers) who were skilled in English, Spanish, and various other languages. Similar village systems existed on Second and Third Mesas.

Between Hopi households and villages were phratries and clans. The exact relationship between the clan groupings, phratries and the residence clusters is not completely understood. It is known, however, that phratries consisted of several associated clans, whose behavior and responsibilities were defined in relation to a prime clan. The prime clan had the responsibility for assigning commitments and ceremonial offices or duties among the associate clans and their members. Clan priority within a

phratry was not static, and associate clans could increase in social status, even to the position of prime clan.

Historians believe that the lack of a singular governing body for the villages, coupled with the flexible qualities of the phratry system described above, allowed the Hopi to survive in a harsh physical environment. As described by Connelly (1979, p. 544):

> The flexible quality of the phratry allows for the managing of population size in a physical environment where either too small or too large a population creates problems. This may explain in part why political organization appears antithetical to Hopi social patterns. Political alliances tend to produce ever larger groupings, with the goal of power to establish and retain territoriality. However, in an environment where the prime enemy is unpredictable climate and weather, large populations have been vulnerable as illustrated by the demise of the Great Pueblos. Hopi history and archeology demonstrate the importance for survival of division and balance in population.

One of the most important social events to take place on the Hopi Mesas during the early Reservation period was the Oraibi Split. The details of the Oraibi Split are complicated and disputed, but a brief description is provided here because it brought something new to Hopi society. The Oraibi Split demonstrates a fundamental division of Hopi people over the question of how best to structure relations with outsiders and, in particular, with the United States government. It is often viewed as the catalyzing event in the transition of the Hopi polity from its ancient form to its modern form.

In its simplest terms, the Oraibi Split was a clash between two factions at Oraibi in 1906 that resulted in the division of Oraibi village and the founding of two new villages, Hotevilla and Bacavi. Most scholars agree that the split was catalyzed by first, the government's insistence that all Hopi children attend government schools, and second, the government's attempt to allot Hopi lands.

As described in **Section 3.1**, the first school to serve the Hopi Mesas opened in 1872 at the short-lived Hopi Agency at Trout Spring. It was closed in 1878, reopened in 1881 at Keams Canyon as a boarding school, and then closed again in 1883. In 1886, a group of Hopi petitioned the federal government to open a school at First Mesa. Most of

the petitioners lived on First Mesa, and some were from Second Mesa, but no one from Third Mesa appears to have signed the document. Partly in response to this petition, the Office of Indian Affairs agent in charge of the Hopi reopened the boarding school at Keams Canyon in 1887. Almost immediately, there was resistance by some Hopi, and in particular by the residents of Oraibi, to sending their children away to a school that was intended, as a matter of government policy, to undermine traditional Hopi culture and promote the assimilation and acculturation of its Hopi students.

In 1890, the *kikmongwi* (village chief) of Oraibi returned from a trip to Washington, D.C. as a strong advocate of cooperation with the government and its policy of mandatory school attendance. This led to a division of Oraibi into competing factions that government officials called the "Hostiles" and "Friendlies," after what those officials believed was their sharply divergent views toward the United States government. The *kikmongwi's* support did little to end Oraibi's resistance to the school, and in the fall of 1890 a contingent of U.S. Army soldiers was sent to the village to enforce the attendance policy, with the result that some Oraibi children were taken away against their parents' wishes.

The conflict continued into the next year and was sharpened by the dispute over the allotment survey then getting underway at the Hopi Mesas. Troops were again sent to Oraibi in the summer of 1891. The decision in 1894 to abandon the allotment program helped diffuse some of the tension, but in the fall of that year conflict erupted between the Hostiles and Friendlies over land at Moenkopi, which since its settlement in the 1870s had been linked ceremonially and politically to Oraibi. Army troops were once again sent to Oraibi, more leaders were arrested, and this time the prisoners were sent to Alcatraz in California, where they were confined for almost a year.

By the mid-1890s, Oraibi was clearly divided over how to respond to federal government policies, including the mandatory school attendance policy. But, this was not the only point of division among Oraibi residents. There also was rivalry over the *kikmongwi* position, competition over the control of ceremonies (the two factions began holding rival ceremonies), and competition over land, whose distribution was controlled by clan leaders. These divisions among Oraibi's residents were exacerbated by a convergence of external forces including drought; arroyo-cutting; crop failures; friction

with neighboring Mormons and Navajos over land and water; isolation from the Hopi Agency at Keams Canyon; and the intense pressure brought to bear on Hopi society by the government's assimilation policies, which were reflected not only in the schools but in the periodic attempts of the Indian Superintendent to control or even prohibit traditional ceremonies.

In 1904, Oraibi's differences with the government seemed to be eased for a time by the removal of the Indian Superintendent who, since his arrival at the Hopi Mesas in 1899, had aggressively prosecuted the government's assimilation program. But then, in March 1906, a group of Hostiles from Shungopavi arrived in Oraibi, a development that many Hopis would later point to as the precipitating cause of the Oraibi Split. After the Hostiles and Friendlies held rival ceremonies over the summer, the conflict came to a climax on September 6, when the Friendlies moved to expel the Second Mesa Hostiles from the village. By prior agreement with the Friendlies, the Hostiles left the village and established a settlement that became the village of Hotevilla.

Responding to the expulsion, the government once again sent troops to Oraibi, where federal officials delivered the Hostiles an ultimatum – either submit to the federal government's authority or go to prison. More than a hundred Hostile men refused to submit, and most of them were arrested and sentenced to terms of hard labor at either Keams Canyon or Fort Huachuca in southern Arizona. The remainder of this group, generally the younger men, were sent to the Carlisle Indian School in Pennsylvania. This left mostly women and children at Hotevilla, where they remained over the winter awaiting the return of the men from imprisonment. The Friendlies' leader, who was the *kikmongwi* at Oraibi, was sent to the Sherman Institute in California, where he remained for three years.

The Shungopavi Hostiles were escorted back to Second Mesa by Army troops, and the Hostiles who had agreed to submit to federal authority were allowed to return temporarily to Oraibi. They remained until 1909, which was longer than intended, but left that year after the former *kikmongwi* returned to the village. In an effort to reassert his authority, the *kikmongwi* began agitating for the Hostiles' final expulsion. It was this second group of departing Hostiles that founded the village of Bacavi.

Attempting to make sense of these events many years later, Mischa Titiev, the scholar whose enthnographic research produced the most detailed account of the Oraibi Split, saw the split as yet another example of the Hopi's centuries-old method of resolving village disputes by dividing to form new villages. Hopi society was built on "social structures that were best adapted to small communities," Titiev wrote, and when "exceptionally powerful disruptive forces manifested themselves, the pueblos could not withstand their shock and ultimately collapsed in the manner of Oraibi." (Andersen, 2008, p. 38).

Starting in the 1920s and continuing into the early 1930s, the division created by the Oraibi Split played an increasingly central role in Hopi public life. Its impact was uneven across the Hopi Mesas, though, as some villages were more affected than others. Although changes were occurring at the village level, it remained true that, as a people, the Hopi continued to follow their longstanding tradition of having a well defined, but diffuse, system of leadership and no unity beyond the village level. The persistence of village independence can be seen in the various attempts to establish a tribal Hopi Council during the 1920s and 1930s.

5.2 GOVERNANCE

Spanish accounts provide the earliest firsthand information regarding Hopi governance. Most Spaniards who visited the Hopi Mesas reported that each Hopi village was governed by a cacique, one or two captains, and a council of elders. The cacique was clearly the *kikmongwi*, or village chief, and the two captains were likely the village war chief and his assistant. Exactly what kinds of authority these leaders exercised, and how they were selected, was less apparent to the Spaniards, just as it was to the earliest American visitors to the Hopi Mesas. Most early American observers remarked on the apparent independence of the villages from each other, but at times they were uncertain about whether the villages cooperated with each other or not.

Alexander Stephen, who lived on the Hopi Mesas on and off from the early 1880s until his death in 1894, was the first to produce a comprehensive ethnographic account of the Hopi. He found that each village did indeed have a chief, or *kikmongwi*, as well as a

council composed of the clan leaders and other men of ceremonial importance. All of their positions were hereditary, with each leader selecting his successor from among his family, which was defined broadly to include most of his blood relations. More importantly, Stephen observed that decisions were reached by consensus, that is, through informal consultations by the village council that were continued until all of its members were in agreement on what needed to be done. There did not appear to be any legislative or judicial structures beyond the village council, which was typically composed of the *kikmongwi*, the clan and ceremonial society leaders, and one or two town criers.

After the Oraibi Split, Congress passed the Indian Reorganization Act (IRA) of 1934,[1] which for the first time gave authority to tribal governments to be independent of the Office of Indian Affairs. Among its many provisions, the IRA provided a framework for tribes to write their own constitutions, establish tribal councils, and exercise authority over their land and resources. Tribes were not required to have constitutions, but Commissioner of Indian Affairs John Collier nevertheless began urging the Hopi to write one and set up a tribal government. To accomplish that goal, Collier hired Oliver LaFarge, anthropologist and Pulitzer Prize-winning novelist, and sent him to the Hopi Mesas to supervise the drafting of a Hopi tribal constitution and the formation of a Hopi Tribal Council.

The central issue that confronted LaFarge, as it had confronted every previous advocate of a pan-village Hopi council, was how to accommodate the Hopi *kikmongwi*, who would need to be given some kind of role in the new Hopi government. LaFarge decided to do this by giving the *kikmongwi* power to appoint the representatives to the Tribal Council and letting them retain their traditional authority over village affairs. This meant the Tribal Council itself would primarily be used for mediating inter-village disputes and representing the Hopi in its dealings with the outside world.

In the final document, the principle of village autonomy was recognized as follows: "Each village shall decide for itself how it shall be organized. Until a village shall decide to organize in another manner, it shall be considered as being under the traditional Hopi organization and the Kikmongwi of such village shall be recognized as

[1] Pub. L. No. 73-383, 48 Stat. 984.

its leader." (Connelly, 1979, pp. 44-45). Villages could adopt village constitutions and set up councils whose members would be chosen through elections, but they were not required to do so.

Each village was also allowed to decide for itself how its representatives to the Tribal Council would be selected, either by appointment by the *kikmongwi* or by election by its residents. Even then, all representatives had to be certified by the *kikmongwi*. Under LaFarge's proposal, representation on the Tribal Council would be by village, with the number of each village's representatives determined by that village's share of the tribe's population. The First Mesa villages of Walpi, Sichomovi, and Tewa would together have four representatives; Mishongnovi, Shungopavi, Kykotsmovi, Hotevilla, and Moenkopi would each have two; and Shipaulovi, Oraibi, and Bacavi would each have one.

A major power retained by the villages was control over the land. Each village would, through either its *kikmongwi* and council of elders or its elected council, continue to assign all lands traditionally belonging to that village and its clans, and regulate all disputes regarding such lands. Other governing powers specifically given to the villages by the constitution mostly concerned family matters such as inheritance, ownership and division of property, and resolution of disputes.

After the constitution was written, the Office of Indian Affairs was required to secure its approval by a plurality of a majority of the tribe's eligible voters. On October 24, 1936, a referendum on the constitution was conducted in which about half of the tribe's eligible voters went to the polls and approved the document by a vote of 651-104. The results varied considerably from village to village; while Kykotsmovi and Bacavi favored the constitution, for example, Hotevilla opposed it. Support for the constitution was strongest at First Mesa, where the turnout rates were highest.

The tribal government created by the Hopi Constitution of 1936 was not a strong one, given the power handed to the villages, the Hopi's long history of village autonomy and intra-village and inter-village friction, and the low number of Hopi who voted in favor of the document. The turnout at the first Tribal Council election was very low, estimated as low as 14%. Several villages then boycotted the Tribal Council altogether,

by not sending representatives, and as a result the council frequently had trouble meeting its required quorum.

The Hopi Constitution has been amended several times since 1936, yet its provisions governing the relationship between the tribal government and the villages have not changed substantially. Villages continue to enjoy autonomy and govern themselves supported by the Hopi Tribal Council. The *kikmongwis* also continue to play a significant role in Hopi affairs. Their authority is both religious and secular, they remain responsible for the allocation of village and clan lands, and in some villages they continue to name the representatives to the Tribal Council. The *kikmongwis'* power is limited, however, as traditional Hopi decision making is still based on communal consensus (Hopi, 2001).

The Hopi tribal government consists of executive, legislative and judicial branches. The Chairman of the Tribe heads the executive branch, which implements and administers the laws and policies adopted by the Tribal Council. The executive branch also includes programs and offices related to health, education, economic development, administrative services, planning, financial administration, and natural resources management. The Tribal Council constitutes the legislative branch, and is comprised of representatives from the various Hopi villages. The Tribal Council makes tribal law, ordinances and policy, and oversees the conduct of tribal business. The judicial branch interprets and enforces the laws and ordinances enacted by the Tribal Council (Hopi, 2001).

5.3 CUSTOMS[2]

From prehistoric times, Hopi society has been agriculturally based, with the cultivation of corn, beans, squash, gourds and cotton. In the 16th and 17th centuries, the Hopi acquired the peach and apricot tree from the Spanish as well as domesticated animals including horses, burros, mules, sheep and cattle. About the same

[2] This section discusses historical Hopi customs and economic base. See **Chapter 6** for more recent information regarding economic conditions on the Reservation.

time, chili peppers were introduced from Mexico. Since the first American contact in 1848, the Hopi traditional subsistence economy was first supplemented with, and then replaced by, a cash economy.

Each Hopi village is autonomous, with its own land. The fields assigned to each village are divided into sections assigned to various matrilineal clans of the village. Within each clan, fields in more than one location are assigned to women of the clan, but the fields are planted and cultivated by the men. In addition to lands assigned to a clan, individual men have the right to use land beyond the clan fields, subject to the requirement to cultivate the land. Land so used can be assigned to another; however, the land reverts back to the common domain if it is abandoned.

Horses and burros are hobbled, but cattle are allowed to roam freely in areas with relatively permanent water supplies. Sheep are herded and corralled every night. Water from nearby springs is used to irrigate gardens of chili peppers, onions and other vegetables.

The Hopi have cultivated several varieties of corn, many varieties of beans and several species of squash, pumpkins and melons. The Hopi also have used wild plants for personal use, with the roots of yucca used to wash hair, an essential part of every ceremony, and the leaves used for basketry. The Hopi brush was an essential tool in every household and was made from the culms of purple hair grass.

Prior to obtaining domesticated animals in the 16th century, hunting was an important cultural and economic part of the Hopi existence. Hunting was usually done in pairs, and was regarded more as a sport than an effort at subsistence. Deer and antelope were reported to have grazed in the area between the Hopi Buttes and the Little Colorado River and may have been hunted. Rabbit hunting was regularly conducted in the fall and winter as a sport.

Sheep and cattle are the primary domesticated animals and a form of property. From the earliest days of the American Indian Agency at Keams Canyon, there have been government attempts to aid Hopi stockmen, by drilling deep wells with windmills, and constructing storage tanks and water troughs. Additional efforts were made through the purchase of pure bred rams and bulls, but these had limited usefulness because the Hopi did not control the breeding. In 1937, the total livestock on the Hopi Reservation

consisted of 11,203 sheep, 317 goats, 7,695 head of cattle and 5,085 burros and horses. In 1944, the federal government instituted a stock reduction program to bring the total number of animals within the carrying capacity of the range. All stock owners were issued grazing permits and reductions were made in proportion to the number of head owned at the time. Because of efforts to improve and control breeding by fencing pastures, Hopi income was not reduced by the stock reduction. Further discussion of current Hopi agriculture practice and livestock production is presented in **Chapter 8**.

Trade has been an important part of Hopi life. The Hopi traded with the Navajo for sheep and wool, the Havasupai for buckskins, and the Zuni and Eastern Pueblos for turquoise and other goods. The Hopi have weaved ceremonial garments and traded these with other Pueblos for many years.

In 1881, a trading post was operated at Keams Canyon, and "Hubbell's post" was established at Oraibi in 1919 by settlers. All other posts and stores on the Hopi Reservation were owned and managed by Hopi. In 1937, 15 of the 17 licensed trading posts were owned by Hopi. A variety of goods were sold, with craft products, corn and wool taken as payment, in addition to money. As wage work became available through on- and off-reservation sources, and paved roads were completed, a cash economy gradually displaced the traditional subsistence economy. Following this transition, trading posts became supermarkets.

The household production of crafts has been a source of supplementary household income for most families. Since the beginning of the twentieth century, women's products have become specialized with First Mesa producing pottery, Second Mesa creating coiled basketry, and Third Mesa constructing wicker basketry. Hopi men have done the weaving, and the bulk of their work has been to produce ceremonial garments of cotton and wool.

Since about 1930, the Museum of Northern Arizona in Flagstaff has encouraged the production of some of the best pieces of Hopi craftwork, which are sold to the public for the craftsman's price. With the growth of the cash economy, the creation of kachina dolls has become increasingly popular, which are carved and feathered to appeal to the tastes of the buyers. Until 1946, there were few Hopi silversmiths, and their work was indistinguishable from that of the Navajo or Zuni. In 1946, seventeen Hopi veterans were

taught the art of silversmithing, and a set of traditional Hopi design elements were adapted. In 1965, they worked varying seasons and later a guild with its own hallmark was formed. These native products are displayed and sold in the Hopi Craft Guild building on the top of Second Mesa, along with the products of other craftsmen, potters, baseketmakers, weavers and silversmiths.

The household has been the basic economic unit for production and consumption. Every house had a set of three grinding stones, with different degrees of coarseness. These were used to grind corn, which was the essential Hopi foodstuff. The other essential piece of household equipment was the piki stone. This stone was used to cook the piki, which is a wafer-thin bread made of finely ground blue cornmeal. In addition to piki, the standard feast dish has been hominy and mutton stew. The hominy was prepared by the women, and the men butchered the sheep, which were then boiled together. All Hopi ceremonies of the annual cycle require the preparation of these foods.

In Hopi society, traditionally, the family was an extended matrilineal type. The man contributed his work, fruit, livestock or income to the house in which he lived, either his mother's before marriage; his wife's during marriage; or his mother's or sister's, if he was divorced. As it has become easier to construct a home, young couples have moved into their own homes and created nuclear families. A 1961 census of the Second Mesa villages disclosed that families roughly were evenly divided between nuclear and extended matrilineal types. While there are similar effects upon Hopi culture and economy as the result of contact with the larger society, the extent of the impact is variable within the villages, with Moenkopi being the most highly acculturated.

5.4 RITUALS AND CEREMONIES

5.4.1 Ceremonial Cycle

Hopi life has been based on ceremonies that seek to assure both social and individual equilibrium, as well as conciliate supernatural powers in order to obtain rain, good harvests, good health and peace. Hopi ritual and ceremony are organized on the village level. Each traditional village organizes its own ceremonies following a general model that allows for variation. The ceremonial importance of each village varies

according to its cultural conservatism and its antiquity. Although each traditional village organizes its own ceremonies, the villages of Walpai, Shongopavi, Mishongnovi and Hotevilla have served as leaders. It is possible for a Hopi to be involved with all of the ceremonies, but not necessarily in one village or on one mesa. By the early 1970s, only Shongopavi performed the full cycle of ceremonies.

The ceremonial cycle consists of two major periods that are identified as "masked" and "unmasked" ceremonies. The masked ceremonies include masked dancers, called kachinas, who arrive in either January or February, depending upon the calendar and the village, and then depart in July. The first major unmasked ceremony is the Powamu, when children are initiated into the kachina and the Powamu societies. This ceremony is associated with purification and planting (Sweat, 2008). The last unmasked ceremony is the Niman, associated with the summer solstice, which marks a season that begins about a month after the winter solstice and extends until about a month after the summer solstice, coinciding with the end of planting season.

The villages of Shipaulovi, Oraibi-Hotevilla and Shongopavi have also celebrated the Snake-Antelope ceremony in even-numbered years, with Walpi and Mishongnovi performing the Flute ceremony in odd-numbered years. The goal of the Flute and Snake-Antelope ceremonies is to seek rain and fertility (Sweat, 2008). The Butterfly and Buffalo Dances are associated with war, and occur in late summer and after the winter solstice, respectively. The most important ceremony to a Hopi is Soyal, which marks the winter solstice.

There are also ceremonies that have been celebrated separately by societies of men and women. The women's societies consist of the Maraw, Lakon and the Owaqol. In the autumn, these societies participate in harvest dances as part of three ceremonies (Sweat, 2008). The sequence of ceremonies differs among the villages. The men's societies consist of the Agave, Horn, Wuwuchim and Singers. The Agave is associated with war, the Horn with hunting, and the Wuwuchim and Singers with fertility. Every fourth year, each of these societies have performed the Wuwuchim ceremony, which includes an initiation ceremony for young males into manhood. Initiation at Wuwuchim is necessary for a Hopi male to participate in the Soyal ceremony.

The ceremonies mark the yearly cycle, but the Hopi vary among themselves as to the start of the new year. Some Hopi begin the year with Wuwuchim, which includes a new fire ceremony. Other Hopi begin the year with Soyal and the winter solstice, or start the year with Powamu, the first great ceremony of the kachina which marks the start of the agricultural season. All of the major Hopi ceremonies last eight full days, with a preliminary day used for entering into session. Short ceremonies last four days, plus the preliminary day.

5.4.2 Water in Hopi Culture

Water plays a central cultural and ceremonial role in Hopi life. As noted by the Hopi in its claim: "Water is the essence of Hopi secular and religious philosophy. . . . Springs, water, and rain are focal themes in ritual costumes, kiva iconography, mythological narratives, personal names, and songs, which call the cloud chiefs from the varicolored directions to bear their fructifying essence back into the cycle of human, animal, and vegetal life" (Hopi, 2004, pp. 17-18).

The Hopi believe all water supplies to be interconnected, and Hopi philosophy emphasizes the importance of water in sustaining productive activities. Consequently, much of Hopi identity and religious practice focuses on the acquisition and use of water. As stated by Peter M. Whiteley:

> Much of the complex Hopi religious system is devoted, in one way or another, to securing necessary blessings of water – in the form of rainfall, snow, spring replenishment, *etc*. – to sustain living beings – whether humans, animals, or plants. All major ceremonies concentrate in some measure on ensuring beneficial climatic conditions, and bringing rain. From the use of pahos (prayer-sticks, literally "water-arrows"), to the Snake Dance (where the water-serpent is called upon to take the moisture of lakes, rivers, springs, and the Pacific Ocean up into the clouds, and take the rain down to earth via his lightning-snake emissaries . . ., or the very idea of [kachinas] (as the spirits of the Hopi dead reborn as clouds and other moisture sources), Hopi ritual calls on the powers of springs, rivers, and the ocean to renew life, especially via the instrument of rain.

(Whiteley, 2005, p. 17).

While the Hopi believe all water sources to be sacred, springs, which are considered the "breathing holes of the underground water," occupy a special place in Hopi culture and ritual (Whiteley, 2005, p. 19). The Hopi believe that springs attract rain and snow and demonstrate a universal order. Accordingly, springs have been venerated by the Hopi since time immemorial by individual offerings of prayer and blessings of sacralized cornmeal.

Springs are also central to Hopi ceremonies. As stated by the Hopi:

> As part of ceremonies, priests and ordinary initiated members revisit the ancestral cites and collect their resources, including water from springs…Its mythological history and the re-enactment of this in ceremony or the reiteration of it in tradition constitute crucial features of clan identity in Hopi thought. The Orayvi Bow clan, or others associated with the Hopi *Sa'lako*, revisits several shrines (like the Sa'lako spring in Pasture Canyon) and other localities associated with its migration route each time the ceremony is performed and gathers its resources for the ceremony. Similarly, the Water clan continues to return to springs in the south to bring in water and associated resources, especially with regard to *Kwanwimi*, the One Horn ceremony.

(Hopi, 2004, p.18). Springs also play a role in the Flute ceremony, where prayer-sticks are planted at the bottom of a sacred spring by the chief priest to replenish the world's water supplies, as well as several major kachina ceremonies like the *Powamuy* (Bean Dance) and *Niman* (Home Dance) (Whiteley, 2005).

CHAPTER 6: ECONOMIC BASE

This chapter describes the economic base of the Reservation including its raw materials **(Section 6.1)**, infrastructure and public services **(Section 6.2)**, financial resources **(Section 6.3)**, and human resources **(Section 6.4)**. The information presented is intended to provide an overview of existing and potential economic resources on the Reservation and is based on readily available data. The locations of many of the villages and geographic features referenced in this chapter are shown in **Figure 4-1**.

6.1 RAW MATERIALS

The following 'raw materials' on the Reservation are discussed in this section - arable land, rangeland, mineral and energy resources, timber resources, and tourism.

6.1.1 Arable Land

Land is considered arable if fit or used for growing crops. Based on its soil survey of the 1882 Executive Order Reservation, NRCS (1996) states that "the majority of soils on the Hopi Indian Reservation have potential for crop production provided adequate water becomes available."

If irrigated, most soils on the Reservation would be grouped by NRCS under Land Capability Classes II, III, and IV (ADWR, 2008j). Land Capability Classes are used by NRCS to "show the location, amount, and general suitability of the soils for agricultural use" (NRCS, 2007b). **Table 6-1** lists definitions for Classes I through VII.

It is commonly assumed that soils in the first four classes are arable land, suitable for crops, with an increasing need for management from Class I to Class IV (Helms, 1992). As quoted from the National Soil Survey Handbook (NRCS, 2007a):

> Soils in the first four classes are capable of producing adapted plants and common cultivated field crops and pasture plants. Soils in Classes V, VI, and VII are suited to the use of adapted native plants. Some soils in

> Classes V and VI are also capable of producing specialized crops under highly intensive management involving elaborate practices for soil and water conservation.

Although it is common to consider soils Classes I through IV to be arable, this is not necessarily the view of NRCS. According to Camp (2007), "any soil could be arable with enough economic resources."

Approximately 1,023,492 acres or about 63% of Reservation lands have soil types that, if irrigated, would be grouped by NRCS under Classes II, III, and IV (**Figure 6-1**). Only a portion of these soils were found to be irrigated at the time of the NRCS survey (Camp, 2007), and it is implied that the remaining soils would respond similarly if water became available. The other 37% of Reservation lands or approximately 597,758 acres had soil types that were not found to be irrigated during the NRCS survey and, therefore, were not given an Irrigated Capability Class by NRCS.

The Hopi have claimed past and present irrigation of 38,556 acres on the Reservation and future irrigation of another 11,736 acres, for a total of 50,292 acres of arable land. A summary of the Hopi and United States claims is presented in **Chapter 2**.

6.1.2 Rangeland

As described in **Section 4.6**, between 819,000 and 1,326,000 acres of the 1882 Reservation are estimated to be useable as range for livestock grazing. ADWR does not have an estimate of the acreage of useable rangeland in the Moenkopi Area.

In general, bottomlands are the most productive areas for livestock grazing while steep slopes and rough terrain are less productive and more sensitive to overgrazing and soil depletion. Good productivity is possible for bottomlands and loamy washes; good to fair productivity is possible for clay fans and slopes, sandy terraces (former valley floors near washes), and uplands (tops of mesas); and poor to no productivity is possible for barren lands, breaks (edges of mesas and steep hillsides), and sandstone hills (Bell and Norstog, 1985).

For the purpose of range management, Reservation lands have been divided into 53 tracts known as range units (Hopi, 1998). Fifteen range units are located in District 6 and 38 range units are located in the HPL (**Figure 6-2**). Characteristics of the units are

listed in **Table 6-2** including their name and number, acreage, and percentage of area useable as forage. To ADWR's knowledge, separate range units have not been established in the Moenkopi Area. However, the Hopi claim that stock were in the Moenkopi Area based on water uses from ponds, wells and springs. This information is included in **Table 6-2**.

Also listed in **Table 6-2** is the carrying capacity of each range unit based on a 1996 range survey. Carrying capacity is defined by the Hopi (1998) as "the maximum stocking rate possible without inducing damage to vegetation or related resources." Carrying capacity is expressed in the table as the number of animal units that can be grazed on an area of range over a year, or Animal Units Year Long (AUYL). To account for the forage needs of different livestock, the Hopi assume the following factors when calculating AUYLs on the Reservation:

- 0.8 Horse or Burro = 1 AUYL
- 1 Cow = 1 AUYL
- 4 Sheep or Goats = 1 AUYL.

Carrying capacity can vary from year to year due to overgrazing by livestock and/or from natural factors such as drought, fire, and grazing by native animals. Some range units on the Reservation are fragile and require years to recover from damage. Other range units respond quickly to improved range management and soon produce at their full potential (Bell and Norstog, 1985). Since 1984, actual carrying capacities on the 1882 Executive Order Reservation have ranged from 5,000 to 12,250 AUYL and potential carrying capacities have ranged from 10,000 to 24,529 AUYL (ADWR, 2008b). Carrying capacity data for the Moenkopi Area were not available to ADWR.

6.1.3 Mineral and Energy Resources

This section describes mineral and energy resources on the Reservation including:

- Fuels – coal, petroleum, natural gas, and uranium;
- Metals – copper, manganese, mercury, and vanadium;
- Non-metals – clays, carbonates, pumice, specialty sands, and semi-precious stones;

- Construction materials – aggregate and dimension stone; and
- Geothermal resources.

Of these resources, fuels are considered the most important on and near the Reservation. Coal production has been a substantial component of tribal revenues (see **Section 6.3, Finances**), and development of oil, gas and uranium deposits represent a potential future revenue source.

The text that follows was taken from ADWR (2008d) and references therein. Note that geologic resources located on Navajo Partitioned Lands (NPL) are included in the discussion as the Hopi share mineral rights with the Navajo in this area (see 1974 Settlement Act described in **Chapter 3** of this report). The NPL and Hopi Partitioned Lands comprise what is referred to as the Joint Use Area. The geologic units mentioned below are described further in **Section 4.5.2**.

Coal

The Black Mesa region includes both Hopi and Navajo lands and contains the most extensive coal reserves in Arizona. Since the 13th to 17th centuries, and possibly back to the 10th century, Hopi have used Black Mesa coals for domestic fuel and for firing pottery. Early coal production is estimated to have exceeded a total of 100,000 tons which were mined from shallow trenches. Although coal was not commonly used by Hopi after the Reservation was established, Mormon settlers mined relatively small quantities within Coal Mine Canyon.

Local coal production increased in the early 20th century with 10 commercial mines located in the region - four mines produced coal from the Dakota Formation, three mines produced coal from the Toreva Formation, and three mines produced coal from the Wepo Formation (**Figure 6-3**). Less than 300,000 tons of coal is estimated to have been produced from these mines from 1926 to 1967, with much of it consumed locally and the remainder shipped to Flagstaff, Holbrook, and Winslow.

Coal deposits in the Wepo Formation beneath upper Black Mesa have been leased and commercially developed on a large scale by PWCC. Known as the Black Mesa Complex, the operation consists of the Black Mesa and Kayenta Mines (**Figure 6-3**).

The Black Mesa Mine began operations in 1970 and produced about 4.8 million tons of coal annually until operations ceased in December 2005. The coal from this mine was crushed and piped as slurry to the Mohave Generating Station (MGS) near Laughlin, Nevada. MGS was closed in December 2005 due to air quality concerns. The Kayenta Mine opened in 1973 and currently produces about 8.5 million tons of coal annually. This coal is transported 100 miles by conveyor belt and electric train to the Navajo Generating Station (NGS) near Page.

In 2004, prior to operations ceasing at the Black Mesa Mine, PWCC filed for a Life-of-Mine (LOM) Revision to expand the permit area of the Black Mesa Complex leasehold and extend operations until 2026. As of January 2006, the permit area covered 44,073 acres of which 12,270 acres had been mined and reclaimed and 3,900 acres were being actively mined. In November 2008, a final Environmental Impact Statement (EIS) for the complex was issued by the Office of Surface Mining Reclamation and Enforcement (OSM, 2008). The preferred alternative of the EIS (Alternative B) would conditionally approve the LOM Revision and incorporate the surface facilities and coal reserves of the Black Mesa Mine into the Kayenta Mine permit area. Another 18,857 acres would be added to the permit area which would continue to supply coal to NGS at a rate of 8.5 million tons per year until 2026. However, under this alternative, operation of the coal slurry pipeline to MGS would not be resumed.

In addition to the Black Mesa Complex, the Wepo Formation contains economically-recoverable coal deposits in the JUA near Cow Springs and on Navajo lands near Rough Rock. These deposits may total several hundred million tons of high quality coal suitable for commercial mining. There are also an estimated 150 million tons of known reserves in the Dakota Formation, although this coal is considered of low quality and less suitable for mining.

Another 20.3 billion tons of coal in the Black Mesa region is not considered economically recoverable due to thick (greater than 130 feet) overburden. Of this potential resource, the Wepo formation contains an estimated 4.82 billion tons of coal; the Toreva Formation contains about 6 billion tons of coal; and the Dakota Formation contains an estimated 9.45 billion tons of coal.

Petroleum and Natural Gas

Commercial production of petroleum and natural gas in northeastern Arizona has only occurred in the Four Corners region. Although little exploration for this resource has occurred in the vicinity of Hopi lands, the production potential is considered fair to good. The potential to develop coalbed methane is thought to be very good to excellent.

In 1965, six exploratory wells were drilled to basement rocks within the central and southern portions of the Reservation. Five of the wells exhibited hydrocarbon shows (**Figure 6-4**), but none was developed. Between 1965 and 1970, PWCC drilled six water supply wells in their leasehold and, although the wells were relatively shallow, at least one contained an oil show.

The greatest hydrocarbon potential in the region exists for Paleozoic strata based on structural and lithologic similarities to productive areas in the nearby Paradox and San Juan Basins of the Four Corners region. The potential for coalbed methane production is greatest in the overlying Cretaceous strata. Potential drilling depths for coalbed methane wells would likely be 500-2,000 feet compared to depths of 4,000-7,000 feet for oil and gas wells.

Four areas are considered promising for oil and gas reserves and may justify further exploration (**Figure 6-4**):

- Cow Springs monocline in the northwestern JUA ;
- Upper Black Mesa in the northeastern NPL;
- Central Black Mesa along and near Keams Canyon; and
- Hopi Buttes area.

Helium often occurs within natural gas reservoirs and is generally considered of commercial value at concentrations greater than 0.3%. The Holbrook Basin, which extends north into the Hopi Buttes area, has produced helium gas concentrations up to 10%. The greatest production has come from the Coconino Sandstone and Chinle Formation, and the potential for future discoveries is reportedly excellent.

Uranium

There are currently no commercial uranium mining operations on Hopi lands. Eight abandoned uranium mine sites have been documented within the HPL and 22 within the NPL (**Figure 6-5**). One site in the area, the Morale Mine near Hopi Buttes, produced about 200 tons of uranium ore during 1954-1959 from the Bidahochi Formation. The only uranium mill in Arizona was built in Tuba City, adjacent to the Moenkopi Area, and operated from 1966 to 1969. It processed uranium ores from nearby Navajo lands.

Elevated prices could make the following a target for economic uranium development:

- Chinle Formation in the southwestern JUA;
- Morrison Formation in the northeastern JUA;
- Toreva Formation across the Black Mesa region; and
- Bidahochi Formation in the Hopi Buttes area.

Metals

Although minor copper, manganese, mercury, and vanadium deposits are known to exist in the region, there is little potential for commercial production on or near the Reservation.

Non-metals

Figure 6-6 shows the location of non-metal deposits identified in the vicinity of the Reservation. Some of these deposits may be of commercial grade, but to date, they have not been extensively developed.

Clays are known to have been used by Native Americans since about A.D. 1000 for ceramics and construction materials and for adobe and brick manufacturing during the 17^{th} to 20^{th} centuries. A relatively large, low-grade kaolin deposit occurs in the Cow Springs Sandstone within Coal Mine Canyon with smaller deposits exposed near the Hopi villages. Deposits of structural clay are abundant across the Reservation although most are thin and/or have thick overburdens which limit their development to local use.

A commercial grade carbonate deposit has been documented near Cow Springs in the JUA. The limestone occurs as beds within the Navajo Sandstone and would be suitable for lime and cement production. A commercial grade pumice deposit has also been documented. This deposit is located in the NPL near White Cone and occurs as a 4-foot thick bed within the Bidahochi Formation.

Specialty sand deposits are found on and near the Reservation in Quaternary dunes and terraces and as sand lenses within the Mesa Verde Formation. Three relatively large deposits have been identified within District 6 and two others have been identified in the NPL.

Finally, semi-precious stones occur within the Chinle Formation and include agate, jasper and amethyst associated with petrified logs. While of minor economic importance, these stones may provide esthetic, recreational, and artistic resources for the Hopi. The Chinle Formation is exposed across the southern JUA.

Construction Materials

Figure 6-7 shows deposits of construction materials on or near the Reservation**.** Both natural and manufactured aggregates usually have low unit value and are developed for local use. Dimension stone, on the other hand, can be commercially developed for sale depending on its quality.

Fifteen borrow pits have been documented on the Reservation – 12 cover a total of about 40 acres on District 6 and have supplied sand, clay, and gravel and three borrow pits cover about 10 acres on the HPL. Unconsolidated sands of the Bidahochi Formation have also been used for road work near Keams Canyon, and manufactured aggregate has been developed from rocks of the Mesa Verde Formation near Keams Canyon and Oraibi.

Areas of potential natural aggregate development include extensive eolian deposits on Howell Mesa between Moenkopi and Dinnebito Washes and relatively thick (up to 130 feet) deposits of unconsolidated sands within the Bidahochi Formation near Keams Canyon. Manufactured aggregate, including rip rap, could also be developed from limestone beds of the Navajo Formation, sedimentary and volcanic rocks of the

Bidahochi Formation, and cemented terrace gravels. Clay-rich strata that can be used as a sand stabilizer are also found within the Morrison and Chinle Formation.

The Navajo have produced dimension stone commercially from the DeChelly Sandstone and Bidahochi Formation, while the Hopi have only used it locally. Potential commercial dimension stone deposits have been identified near the Hopi villages and include volcanic rock of the Bidahochi Formation and sandstones of the Chinle and Moenkopi Formations.

Geothermal Resources

Geothermal gradients beneath the Reservation are not sufficient for conventional electric power generation, but could be used for direct heating and cooling of buildings and greenhouses, and for industrial applications. At depths of up to 2,140 feet, boreholes drilled on the Reservation had bottom temperatures of less than 106^{o}F. Subsurface temperatures increase to 302-392^{o}F, feasible for electric power generation, but only at depths of over 3.5 miles.

6.1.4 Timber Resources

This section describes the occurrence, development, and management of timber resources on the Reservation and potential threats to these resources. The discussion is based on a study by ADWR (2008e) and associated references.

Occurrence

Woodlands on the Reservation cover the upper portions of Black Mesa and highlands near Hopi Buttes (**Figure 6-8**). Utah juniper and Colorado pinon are the most common trees, often occupying slopes, mesas, plateaus, and ridges above 6,000 feet. Scattered stands of Ponderosa pine and Douglas fir are also found on Black Mesa, but these are too small to practically map.

Surveys conducted on the Reservation and PWCC lease area between 1979 and 2006 indicate that local woodlands have average stand volumes from 331 to 486 cubic feet per acre (ft^3/acre). Compared to other woodlands in the region, these stand volumes

are relatively low. Average stand volumes for Coconino and Kaibab National Forest lands were 605 and 903 ft^3/acre, respectively.

Development

Fuelwood, wood products, and pine nuts are three uses of timber resources on the Reservation with the greatest potential economic value. Fuelwood is already widely used for heating and cooking, and some tribal members cut fuelwood to supplement their income. Dead and downed wood are mostly harvested for fuel with the former preferred by commercial operators. The Reservation is estimated to contain 56,700 cords of dead wood at an average of 0.28 cords per acre (cords/acre). Annual fuelwood production from woodlands on or near the Reservation has been estimated to range from 0.2 to 15 cords/acre. Factors affecting the viability of commercial fuelwood operations include labor and transportation costs, stand densities, species distribution, and terrain.

Wood products available from woodlands on the Reservation include fence posts, poles and rails, and railroad ties. Juniper is more commonly used for these products than pinon, and there is an estimated 45.3 million ft^3 of juniper on the Reservation. However, commercial production may be limited to local markets as relatively low unit values do not support long transport distances. High chipping and hauling costs generally preclude use of pinon and juniper for paper and particle board, although favorable market conditions may allow for fiber products and biomass energy production. In general, the relatively slow growth rates, small size and poor form of trees, high harvest costs, and weak markets have discouraged use of this type of woodlands for wood products.

Potential pine nut production on the Reservation is estimated to range from 7-8 pounds per acre (lb/ac) in an average year to 20-25 lb/ac in a good year. Seed production varies from year to year, with good crops occurring every 4-7 years on average and bumper crops every 10 years or so. Stand composition, tree genetics, site conditions and moisture regime can all affect production rates. Most pine nuts currently sold in the United States are harvested by hand by Native Americans from natural forests. Individual collection rates are estimated to average about 22 pounds per day.

Management

Hopi Tribal Ordinance 47 governs forest management practices on the Reservation and specifies permit requirements. The Tribe is in the process of reviewing these practices and is currently not issuing commercial permits. Recently, the Tribe has identified about 400 acres of woodlands to manage and harvest pine nuts and developed an integrated woodlands management plan with the BIA to protect associated cultural and ecological resources.

Potential Threats

Much of the woodlands on the Reservation are classified as Fire Region Condition Class III. In this class, fire regimes have been substantially altered from historic ranges with respect to fire size, intensity, severity, and landscape patterns. Although no major fires have been documented on Hopi lands, the villages at Second and Third Mesas, Jeddito, and Keams Canyon are considered at moderate risk to forest fire. Pinon is often killed by high-severity surface fires while juniper is more resistant. Natural stand regeneration following fires can take several decades.

In addition to fires, juniper and pinon can potentially be affected by insects. Pests in the region include bark and twig beetles, cone and cedar borers, moths, and weevils. These pests can kill or injure trees and destroy marketable seed crops. Fortunately, most insect infestations are cyclical and transpire rapidly.

6.1.5 Tourism

This section summarizes past, current and future tourist opportunities on the Reservation and is based on a study by ADWR (2008k) and associated references.

The behavior of early visitors to the Reservation has caused some Hopi to have a cautious, if not negative, attitude toward tourism today. Problems culminated in 1956 when two village men were killed after flash bulbs from tourist cameras agitated snakes during a Snake Dance Ceremony. Following this incident, tourists were banned from the Reservation. In the years since, the policy toward Hopi tourism has modified somewhat with some villages again open to tourists while others remain closed. Sacred ceremonies

and dances are still closed to all non-Hopi, access for visitors is restricted, and audio-visual recording devices are forbidden.

The Tribe recognizes that tourism is an economic activity, but opportunities are being lost due to inadequate facilities to serve visitors. The Hopi Cultural Center in Second Mesa is the only operational motel on the Reservation and alternative, overnight accommodations are nearly non-existent. There are no RV parks and the few campsites need repair. Popular scenic areas lack paved roads and there are no formal stopping areas along State Route 264 that passes through the villages.

Nevertheless, tribal studies estimate the recent economic benefit of tourism on the Reservation at $3 to $11 million per year. This benefit comes from the Hopi Cultural Center, shops and galleries, and craft producers. Hopi and non-Hopi tour guides are also available and one village, Walpi, has begun to market tours. In addition, the Tuuvi Travel Center was recently opened by the Moenkopi Development Corporation (MDC) in May 2008 at the intersection of U.S. Route 160 and State Route 264. The 16-acre facility features two fast food restaurants, a convenience store and smoke shop, and a gas station and car wash.

Plans to promote future tourism include the Tawaovi Master Plan and the "Gateway to Hopi Land." The former is a planned development about 20 miles north of the Hopi Cultural Center that would include a new motel, restaurant, and museum/cultural center. The latter is a $100 million project by MDC that was due to break ground in July 2008 on 72 acres near the Tuuvi Travel Center. This development would include a 100-room motel and conference center and a business center with an office complex and bank. As of May 2008, MDC had raised $2.2 million for the project through a federal grant.

There are no casinos on the Reservation. The Hopi turned down gaming twice, first in April 1995 and again in May 2004 (Gallup Independent, 2004).

6.2 INFRASTRUCTURE AND PUBLIC SERVICES

Infrastructure and public services on the Reservation are discussed next. These include transportation, utilities (water, wastewater, electric, and telecommunications), health care, public safety, schools, and other public facilities.

6.2.1 Transportation

Transportation on and to the Reservation is available through paved (bituminous) and unpaved roads, an airstrip, and two helicopter landing pads (**Figure 6-9**). Other than State Routes 87 and 264, which are maintained by the Arizona Department of Transportation (ADOT), most roads on the Reservation are part of the Indian Reservation Roads (IRR) system and maintained by BIA's Branch of Roads (Hopi, 2001).

The IRR system on the Reservation consists of 405 miles of paved, all-weather roads, 560 miles of dirt-grade and drain roads, and 70 miles of unimproved roads. These roads total 1,035 miles and cover approximately 8,600 acres. In addition, there are a few ranch roads on the Reservation maintained by the Hopi Office of Range Management and used by local farmers and cattlemen, and an estimated 3,580 miles of non-maintained 4x4 trails and track (Hopi, 2001).

The northeastern portion of the Reservation is still poorly served by the IRR system. Access is provided by the Turquoise Trail (BIA 4) which is mostly unimproved in the area and currently only about half complete. An estimated $50 million is needed to complete the project, and a lack of funding has slowed construction. In the past, the BIA and PWCC worked together to pave the road. Once completed, the Hopi will have access via BIA 4 to the Hard Rock Chapter of the Navajo Nation and improved access to the coal lease area, both of which may improve employment opportunities (SWCA, 2008).

Access to the Reservation by air is currently available via a visual flight recognition (VFR) landing strip near Polacca and two helicopter landing pads. The helipads are also located in the Polacca area – one at the Hopi Health Care Facility and a second at the BIA police/Hopi court complex near Keams Canyon. A second VFR landing strip at Kykotsmovi was abandoned (Hopi, 2001).

6.2.2 Utilities

Water

Sixteen public water systems (PWSs) currently serve the residents of the Reservation. These systems, by definition, have 15 or more service connections or serve at least 25 individuals for 60 days or more each year. **Table 6-3** lists the name and identification number for each PWS on the Reservation, the water supply wells, recent water demands, the number of people served and service connections circa 2006, and the current operator. Further system details including system and contaminant source inventories, a source water delineation, and susceptibility analysis are provided by TetraTech (2006).

PWSs are located in five geographic areas on the Reservation:

- Yu Weh Loo Pahki (Spider Mound)
- First Mesa
- Second Mesa
- Third Mesa
- Moenkopi Area.

The systems provide drinking water to about 12,000 residents through approximately 1,900 service connections. Most systems were completed during the late 1950s through the late 1980s using federal funds. The Indian Health Service (IHS) often designed and constructed the facilities and provided initial operations. The systems are currently operated and maintained by multiple organizations including eleven independent communities, the BIA, and the Hopi Tribe Office of Facilities Management (TetraTech, 2006).

Common system deficiencies include incomplete or unavailable record keeping, high operator turnover, poor user fee collection, and lack of financing. Elevated arsenic and excessive drawdown are also a problem for the wells that serve water to First and Second Mesas. Arsenic treatment is estimated at $500,000 to over $1 million per village in capital costs plus operation and maintenance fees. In addition, water sources in the Moenkopi Area have relatively low yields and have been threatened by off-Reservation contaminant sources including two leaking underground storage tanks (USTs), an

abandoned uranium mill, and the Tuba City Landfill. The UST sites are currently being remediated and negotiations are ongoing between the Hopi and United States government over cleanup of the uranium mill site (SWCA, 2008).

It is estimated that about 18% of homes on the Reservation had incomplete plumbing in 2004. Most of the residents of these homes haul their water from public taps, while some get water from neighbors, springs, and livestock windmills. Water hauling is still common in First Mesa, Lower Moencopi, Mishnongovi, Old Oraibi, Shungopavi, and Walpi (SWCA, 2008).

Wastewater

All but two Hopi villages are currently served by community wastewater systems-Old Orabi and Walpi. Most systems were designed by and built with funding from IHS and have been operated independently by the villages. Many of the wastewater systems on the Reservation are now old, undersized, inefficient and in frequent need of repair. Septic systems are apparently still prevalent, even in the villages (Hopi, 2001).

Other wastewater systems built on the Reservation include those at the Keams Canyon Agency offices, the Hopi junior and senior high schools near Polacca, and the Hopi Court/BIA Police complex between Polacca and Keams Canyon (Hopi, 2001). Also, in November 2007, a wastewater treatment plant (WWTP) was completed in the Moenkopi Area that serves the upper and lower villages in Moenkopi and the new Tuuvi Travel Center (Hopi, 2008b and SWCA, 2008b). The Moenkopi WWTP is owned and operated by the Hopi and was funded by the Tribal Council. There are plans to develop a 100-room hotel and conference center adjacent to the travel center and the Moenkopi WWTP would presumably serve this new development (SWCA, 2008).

Requirements for wastewater collection, pumping, treatment, and disposal systems on the Reservation are outlined in the 2001 *Preliminary Hopi Wastewater Code*. The code has been under review by the Tribe for adoption (TetraTech, 2006). **Table 6-4** lists data compiled by ADWR (2006) for four of the Hopi WWTPs. Data for other WWTPs on the Reservation were not available. Based on an IHS priority list, there is currently a need for about 60 sanitation projects on the Reservation with an estimated cost of $36 million (SWCA, 2008).

Electric

APS is the main electric supplier on the Reservation. The 1882 Executive Order Reservation is served by a three-phase, 56 kilovolt transmission line from the Cholla power plant near Joseph City, Arizona. The line enters this portion of the Reservation from the southeast and comes to a substation near Polacca. From there, the line branches east to serve the Keams Canyon area and west to serve the villages along State Route 264 before terminating at Hotevilla on Third Mesa. The Moenkopi Area is served by a separate APS transmission line from the southwest that also serves nearby Tuba City. Some homesites in the Spider Mound (Yu Weh Loo Pahki) community, near the eastern Reservation border, are provided service from the Navajo Tribal Utility Authority (Hopi, 2001).

Several, relatively isolated homesites on the Reservation still do not receive electric service. These home sites are common in the HPL and the peripheral areas of District 6 (Hopi, 2001). The Tribal Rural Electrification Program, a collaboration of the Arizona Department of Commerce and Arizona State University, is working to provide electricity to these and other Native American homes in Arizona using free solar panels. The Hopi Tribal Utility Regulatory Authority has also established a program for renewable electric systems (SWCA, 2008). The Hopi (2001) estimated that $1.3 million would be required to extend existing transmission lines by about 40 miles to serve five existing Planned Community Development Districts.

Telecommunications

Hopi Telecommunications Inc., established in 2004 by the Hopi Tribal Council, is the primary telecommunications service provider on the Reservation. The tribal-owned company offers residential and business telephone, internet services, and currently has a fiber-optic line running from Keams Canyon west to Bacavi on Third Mesa. Wireless telephone service is provided by AT&T and Cellular One with cell towers at Hotevilla and on Antelope Mesa (SWCA, 2008).

KUYI, a Hopi FM radio station, has been in operation since 2000. Its broadcast station is located at the police/court complex between Keams Canyon and Polacca and its 69 kilowatt radio tower is on Antelope Mesa (Hopi, 2001).

6.2.3 Health Care

The following health care facilities are available in the vicinity of the Reservation (SWCA, 2008):

- Hopi Health Care Facility near Polacca;
- Tuba City Indian Medical Center;
- Medical clinic at the PWCC Mine Complex; and
- Regional Health Care Network in Kykotsmovi.

The Hopi Health Care Facility is operated by IHS and provides primary and preventative care on a 24/7 basis to about 7,000 Hopi and Navajo. Funding comes in part from Hopi Tribal revenues and is insufficient to meet current needs. The facility also provides ambulatory care and allows patients needing more intensive care to be stabilized before transport (IHS, 2008 and SWCA, 2008).

The Tuba City Indian Medical Center is a 65-bed regional hospital with an emergency room and adjacent outpatient clinic. This IHS facility serves the needs of about 35,000 Hopi, Navajo and Paiute. Twenty-four hour emergency care is also provided at PWCC's medical clinic. Although the clinic was designed primarily to serve mine personnel, clinic staff respond to local, resident emergencies. An airstrip at the mine is used for medical evacuations when the nearby Kayenta airstrip on Navajo lands is unavailable due to inclement weather (SWCA, 2008).

The Regional Health Care Network was recently established in Kykotsmovi using a 2004 grant. The network provides information and referrals to individuals that need assistance with health care providers. Flagstaff Medical Center and the Northern Arizona Veterans Hospital have requested to join the network. Some Hopi currently seek medical attention in Flagstaff and Winslow (SWCA, 2008).

6.2.4 Public Safety

Police services are provided across the Reservation by the BIA, stationed between Polacca and Keams Canyon, and by the Hopi Rangers, stationed in Kykotsmovi. County sheriffs and the Arizona Department of Public Services (ADPS) also patrol main Reservation highways (Hopi, 2001).

Fire response is provided by the BIA, which focuses on protecting the federal buildings at and near Keams Canyon. The BIA Fire Department was downsized in the past 10 years and, in 2005, the Superintendent of BIA's Keams Canyon Agency was working with the Tribe to find alternative funding. The current status of the fire program is unknown (SWCA, 2008). The Hopi (2001) indicated that current water infrastructure in their villages would be inadequate to address most structural fires.

6.2.5 Schools

There are 8 primary schools, 2 secondary schools and 2 colleges on the Reservation:

Primary Schools –

- First Mesa Elementary
- Hopi Mission near Kykotsmovi
- Hotevilla Day
- Keams Canyon Boarding
- Kykotsmovi Day
- Moenkopi Day
- Polacca Day
- Second Mesa Elementary

Secondary Schools –

- Junior High in Polacca
- Senior High in Polacca

Colleges –

- Northern Arizona University (NAU) branch in Polacca
- Northland Pioneer College (NPC) branch in Polacca.

Except for the privately run mission near Kykotsmovi, all of the primary and secondary schools are public and operated either directly by the BIA or contracted by the Hopi Board of Education. The junior and senior high schools serve the entire Reservation population. NPC, a two-year community college with approximately 230 Reservation

residents enrolled as full-time students, began offering programs at the senior high in 2001 (SWCA, 2008).

There are currently plans to build a community school at Third Mesa, new facilities for the junior high, and replacement facilities at the Keams Canyon School (SWCA, 2008).

6.2.6 Other Public Facilities

Other public facilities on the Reservation include a small public library run by the Hopi Department of Education at Second Mesa, and the Hopi Veterans Memorial Center. The memorial center is a multi-purpose recreational facility owned and operated by the Tribe and located between Second and Third Mesas. The Tribe also owns the Hopi Cultural Center, a 33-room hotel and restaurant complex operated by an enterprise entity at Second Mesa (Hopi, 2001).

Most facilities related to the executive and legislative branches of the Hopi tribal government are located in Kykotsmovi. Hopi court facilities are located adjacent to the BIA police station between Polacca and Keams Canyon (Hopi, 2001).

6.3 FINANCIAL RESOURCES

This section presents data on Hopi financial resources including tribal revenues and tribal expenditures. Recent tribal revenues are listed in **Table 6-5**, and recent tribal expenditures are listed in **Table 6-6**. Available data were compiled by SWCA (2008) with additional information provided by the Hopi (2008b).

6.3.1 Tribal Revenue

There are five general sources of revenue for the Hopi Tribe (**Table 6-5**):

- Coal-related
- Investment earnings
- Leases and rentals
- Fees, fines and forfeitures
- Miscellaneous.

The Tribe does not receive revenue from ad valorem property taxes, which can be a significant funding source for non-tribal governments.

PWCC has provided a substantial portion of Hopi revenue through its mining lease on Black Mesa. These revenues have included coal and water royalties, coal bonuses, contributions to a Hopi education fund, and payment of abandoned mine land reclamation fees. The latter have been used to reclaim small mines on the Reservation as well as fund public facilities including village and building restorations, water treatment plants, and new facility construction.

The Hopi estimate that recent closure of the Black Mesa Mine and MGS have resulted in an annual loss of between $3.6 million and $6.8 million of tribal revenue. PWCC anticipates that operations at the Kayenta Mine will continue for about 30 years. Assuming terms of the current lease agreement, PWCC expects payments to the tribe to continue during this period and total from $10-12 million per year over the next few years.

Regarding future tribal revenues, the Hopi (2008b) note that:

> …over the past several years low-sulfur coal prices have increased dramatically, both in the western United States and globally, and the economic value of the Hopi Tribe's share of the Back (sic) Mesa coal reserves has thus skyrocketed. The greatly enhanced value of these coal resources is a largely untapped capital asset that can be used to finance major economic development activities on the Hopi Reservation and to mitigate the short-term impacts of the closure of the Mohave Generating Station and to offset the absence of a substantial tax base. Thus while there is necessarily uncertainty in making economic projects, over the long term, the Tribes natural resources supply a basis for assuming growth. However, water is a critical component to the Tribe's plans to develop this valuable asset for future posterity…the tribe requires imported water in order to alleviate existing "substandard living conditions" and to ensure "future economic growth on the Reservation."

Recent plans by the Tribe to develop coal-fired power plants and a coal liquefaction plant on the Reservation were abandoned due to a lack of a sustainable water supply (SWCA, 2008).

Tribal revenues have also come from a variety of on- and off-Reservation ventures operated by the Hopi Tribe Economic Development Corporation. These investment earnings and leases and rentals include:

- Hopi Cultural Center on Second Mesa
- Hopi Travel Plaza in Holbrook
- Hopi Ranches (Aja, Bar 26, Clear Creek, Drye, and Hart)
- Flagstaff commercial properties
- Kokopelli Inn in Sedona
- Walpi housing on First Mesa.

Fees, fines and forfeitures, including utility rights-of-way, have provided another revenue source for the Hopi. Between 1986 and 2007, this revenue source ranged from $223,000 in 1986 to over $1 million in 2002. Miscellaneous revenues over the same period ranged from about $1.5 million in 2003 to over $11 million in 2002.

6.3.2 Tribal Expenditures

Expenditures by the Hopi Tribe are presented in **Table 6-6**. Recent expenditures can be divided into two categories – Government Expenditures and Expenditures from Grants and Contracts. Between 2005 and 2007, annual government expenditures ranged from $34.3 million in 2007 to $44.2 million in 2005. Between 2003 and 2007, annual expenditures from grants and contracts ranged from about $18.8 million in 2005 to $31.3 million in 2004.

Tribal expenditures for certain years prior to 2003 are also listed in the table, but it is unclear to ADWR whether these data represent all or a portion of total annual expenditures. The earlier data do, however, indicate some of the types of tribal expenditures, which are listed below in order from generally highest to lowest:

- Villages
- Administrative and technical services
- Natural resources
- Executive branch
- Legislative branch

- Human services
- Special programs
- Investments (enterprises)
- Capital outlays
- Regulated entities
- Judicial branch
- Criminal justice.

There have also been "excess revenues" which the Tribe reported as expenditures. These revenues totaled about $65 million in 2000, $8.2 million in 2001, and $13.8 million in 2002. Due to decreased coal revenues, village expenditures were cut by about $1 million in 2006 and ongoing water and wastewater projects are being slowed by a lack of funding.

6.4 HUMAN RESOURCES

This chapter concludes with a discussion of human resources on the Reservation. Hopi demographics are described first followed by the Reservation labor force.

6.4.1 Demographics

This section presents data on the Hopi population and age distribution, and describes housing conditions on the Reservation. Unless otherwise noted, the data were compiled by SWCA (2008) with additional information provided by Hopi (2008b).

Population

Table 6-7 lists recent and projected Hopi population data. The population on the Reservation is reported to have grown to approximately 12,000 in 2006. Important population centers include, from largest to smallest (Hopi, 2004):

- First Mesa Villages
- Second Mesa Villages
- Moenkopi Villages

- Kykotsmovi
- Keams Canyon
- Bacavi.

In 2000, about 94% of the Reservation population was determined to be American Indian with Whites making up most of the remainder. In 2004, there were an estimated 8,000 members of the Hopi Tribe living on the Reservation and another 4,000 Hopi tribal members living off-Reservation. The total number of Hopi tribal members living on and off the Reservation was reported at 12,575 in 2007.

Population projections by the Hopi have varied, but indicate the population of the Reservation could exceed 50,000 persons by 2100 and is expected to stabilize in 2175 at over 60,000 people. This equates to an annual growth rate of up to 2.2%.

Age Distribution

In 2000, the median age of the Reservation population was 29.4 years with 39% of school age (5 to 19 years old) and 10% at age 65 or older. Compared with other jurisdictions, the population on the Reservation is relatively young. Across Arizona, the percentage of the population of school age was 22.1% in 2000.

Housing

Table 6-8 lists characteristics of housing on the Reservation. The following data, when available, are listed for the period 1990-2007:

- Total housing units
- Housing types (single attached or detached, mobile, and multiple units)
- Percentage of units occupied
- Average persons per household
- New housing needs to address overcrowding
- Fuel types (wood, coal, electric and other)
- Percentage of units lacking complete plumbing and needing repairs
- Dilapidated housing
- Median home value

- New housing needs
- Funding for new housing.

The Hopi Tribal Housing Authority (HTHA) currently manages about 10% of the approximately 3,100 homes on the Reservation. Private home construction is made on land assignments to individuals, and families can get financing from the Hopi Credit Association (SWCA, 2008). HTHA funding through the Indian Housing Block Grant was $2.9 million in 2006 and $2.6 million in 2007.

Average persons per household on the Reservation have dropped from nearly 4 in 1990 to about 2 in 2007. In 2000, an estimated 447 new housing units were needed on the Reservation to replace those considered beyond structural repair, and another 315 new units were needed to address overcrowding. Recently, 26% of households responding to a tribal survey indicated overcrowding was still a problem.

Many Reservation households rely on wood and coal for heating. Wood can be gathered by non-commercial permit, and PWCC provides free coal for residents to haul from the lease area. The latter is an important heating source, as both wood and propane can be costly for many Hopi to use during the winter months.

6.4.2 Labor Force

This section presents data on the Hopi labor force and includes a discussion of tribal employment and income. The discussion is based on SWCA (2008) and references therein.

Employment

Between 1990 and 2007, the Reservation labor force has totaled from 2,308 in 1990 to 3,982 in 2001 and consisted from 52% to 59% women (**Table 6-9**). The unemployment rate over this period varied from 10.9% in 2006 to 62% in 1999. Hopi unemployment is relatively high and variable compared to Arizona as a whole, where rates since 1990 have remained at or below 6.2%.

The government is by far the largest employer on the Reservation and is expected to be so in the future. Important employment sectors have recently included education,

health and social services, public administration, and wholesale and retail trade. There were 1,341 jobs available on the Reservation in 1986 and from 1,869 to 2,700 jobs available in 2000.

Outlying communities such as Flagstaff, Page, Winslow, Holbrook, and Gallup will probably continue to provide only limited employment opportunities for Reservation residents. New jobs may be created by MDC which recently opened the Tuuvi Travel Center and has plans for a nearby 100-room hotel, conference center, and business and apartment complexes. MDC anticipates that its projects could create as many as 400 new Reservation jobs. Other potential employment opportunities for the Hopi include HTHA-related jobs, new public buildings or expansion of existing facilities, road and utility construction, airport development, and water and wastewater projects.

Income

In 2000, earnings from the "formal" Hopi economy totaled $44.8 million and another $4.2 million was estimated that year from the "informal" economy. The latter represents cultural activities on the Reservation producing traditional goods that are used locally, traded between clans and families, or given as gifts. The informal Hopi economy in 2000 consisted of $3.6 million in traditional arts and crafts, $600,000 for local cattle consumption and giveaways, and an unknown amount from corn harvests.

In 2000, the per capita income on the Reservation was $8,637 and 38.9% of the population was below the poverty level. The per capita income across Arizona that year was $20,275 and 13.6% of the population was below the poverty level. The median family income on the Reservation has increased from $15,875 in 1999 to as much as $41,250 in 2007.

Indian lands, property, and income are not taxed by the State of Arizona, and Indians are exempt from state and local taxes on consumer goods purchased on the Reservation. Reservation residents do pay state tax on gasoline, electric motors, natural gas, and telephone service as well as federal income taxes.

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CHAPTER 7: WATER RESOURCES

This chapter describes the availability of water resources in the vicinity of the Reservation. These resources include streams **(Section 7.1)**, stockponds and reservoirs (impoundments) **(Section 7.2)**, springs **(Section 7.3)**, and aquifers **(Section 7.4)**.

7.1 STREAMS

The following description of streams on and adjacent to the Reservation comes from separate reports prepared by ADWR (2008g and 2008i). Streamflow characteristics and water quality conditions in washes on the Reservation are presented first. Streamflow characteristics of the LCR, which collects runoff from the washes but is located downstream and off the Reservation, are presented next. The section concludes with a discussion of how streamflows in the LCR and Hopi washes have varied historically.

7.1.1 Hopi Washes

The Reservation is drained by five major washes – Jeddito (Jadito) Wash, Polacca Wash, Oraibi Wash, Dinnebito Wash, and Moenkopi Wash. Locations of the Hopi Washes and U.S. Geological Survey (USGS) stream gages are shown in **Figure 7-1**. Streamflow data collected from the gages are summarized in **Table 7-1** and include the identification number, contributing drainage area, period of record, number of daily mean flow measurements taken, annual and seasonal flow statistics, typical flow durations, and streamflow regimes (perennial, intermittent, and ephemeral). Recent photographs of the USGS gages on the Hopi Washes are provided in **Figures B-1** through **B-5** of **Appendix B**.

Flow Conditions

Streamflows have been continuously monitored since the mid-1990s in four of the Hopi Washes (Dinnebito, Jeddito, Oraibi, and Polacca). Streamflows in Moenkopi Wash

have been continuously monitored since the 1920s, and gages along Coal Mine Wash and two of its tributaries were monitored from the late 1970s through the early 1980s. Coal Mine Wash drains part of the PWCC leasehold and is a tributary to Moenkopi Wash.

Based on available USGS data, median streamflows in the Hopi Washes have ranged from a low of 145 AFA in Jeddito Wash to a high of about 7,000 to 10,000 AFA in Moenkopi Wash. Measured flows at these gages have been highly variable from year to year, with maximum annual flows exceeding minimum annual flows by a factor of between 6 and 22. On average, the majority (over 50%) of annual streamflow volumes have occurred during the summer in response to monsoon storms. Streamflows have usually been lowest in the spring when precipitation is also at its lowest and evapotranspiration (ET) of riparian vegetation begins. Typical seasonal variability in streamflows along the Hopi Washes and tributaries is illustrated in **Figures 7-2** through **7-4**.

Several hydrologic factors may affect Reservation streamflows. In addition to storm runoff and ET, factors include snowmelt, baseflow (groundwater inflow), transmission losses, and well pumpage. Storm runoff, snowmelt and baseflow can result in streamflow gains while ET, transmission losses, and well pumpage can result in streamflow losses. **Table 7-2** lists which factors are likely affecting streamflows at each of the USGS gages on and near the Reservation and in which season(s) these effects are likely occurring. Streamflow gains are believed to occur at most of the gages from storm runoff and snowmelt (minor effect), and at some gages from baseflow. Streamflow losses are believed to occur at all of the gages from ET and transmission losses and at most gages from well pumpage (minor effect).

Median daily flows were used to identify recent streamflow regimes at the gage sites. Available data presented in **Table 7-1** indicate that perennial flows occur along sections of Dinnebito and Polacca Washes, intermittent flows occur along Moenkopi Wash, and ephemeral flows occur along Jeddito and Oraibi Washes. It was assumed that streamflows at the gages were ephemeral if the percentage of days each year with measurable flow was typically less than 10% and intermittent if this percentage was 10% or greater but less than 100% (perennial). Additional flow duration data from the gages are listed in **Table B-1** and **Figures B-6** through **B-8** of **Appendix B**.

Figure 7-5 shows the recent streamflow regimes based on gage data as well as historic perennial stream reaches on and near the Reservation. Maps of the latter were published in 1916, 1942 and 1969 and generally coincide with the recent intermittent and perennial streamflow regimes. One notable exception is a relatively long perennial reach identified along Jeddito Wash on the 1942 and 1969 stream maps. Recent (1993-2005) streamflow data indicates this reach of Jeddito Wash has become ephemeral. The occurrence of wet and dry periods over the region, described further in **Section 7.1.3**, may explain this difference in streamflow regime.

Ephemeral stream reaches generally occur within smaller watersheds or on larger streams where baseflow contributions are minimal. Runoff is relatively low and infrequent in these reaches and results mainly from stormflow during the late summer and early fall. Intermittent reaches can occur where adjacent aquifers supply baseflow that exceeds alluvial aquifer outflows on a seasonal basis, or where tributary surface flows are significant. At higher elevations, intermittent reaches can experience runoff from snowmelt during the late winter and early spring while at lower elevations most runoff comes from summer and fall storms. Perennial reaches in the area occur immediately downstream of springs and seeps where groundwater inputs exceed ET and transmission losses.

Regional Flow Analysis

Estimated streamflows entering and leaving the Reservation are listed in **Table 7-3**. ADWR made these estimates for the period 1981-2006 using regional watershed characteristics and existing USGS and PWCC gage data. The gage data were analyzed statistically to determine mean and median streamflows at several points on the Reservation boundary where there are no stream gages. **Table 7-3** lists estimated streamflows at 13 Reservation inflow points and 8 Reservation outflow points and includes upper and lower bounds for these estimates based on uncertainties in the regression equations developed from the statistical analysis. Locations for the inflow and outflow points are shown in **Figure 7-6** and details on the statistical analysis are provided in ADWR (2008g).

The regional flow analysis determined that, during 1981-2006, an average of 6,820 AFA of streamflow entered the Reservation from Navajo lands to the northeast and an average of 13,900 AFA of streamflow left the Reservation and flowed back onto Navajo lands to the southwest. This difference between outflows and inflows (7,080 AFA) is an estimate of the average quantity of streamflow that was generated on the Reservation but flowed off. By comparison, median inflows were estimated to total 10,800 AFA and median outflows were estimated to total 16,900 AFA, with a difference of 6,100 AFA.

Due to the shape of the Reservation and the orientation of its drainages, the outflows from some Hopi washes become inflows to the Reservation downstream. As a result, care should be taken when comparing inflows to outflows along the same wash to avoid double counting.

Water Quality

Available data suggest that water in most Reservation streams is suitable for irrigation and livestock use, but would require treatment if used for drinking water. ADWR (2008i) identified 24 sample sites on the Reservation where streams have exceeded water quality standards. **Figure 7-7** shows the location of the sample sites and **Table 7-4** lists which water quality standards were exceeded at the sites.

One or more secondary drinking water standards were exceeded at all sites, livestock standards were exceeded at seven sites, and irrigation and primary drinking water standards were each exceeded at two sites. Sulfate, pH, and specific conductivity measurements most commonly exceeded water quality standards. Specific conductivity can be used to approximate total dissolved solids (TDS). Local geologic strata including marine shale, gypsum beds, and other evaporates are the likely source for these exceedences.

Streams on the Reservation are also characterized by relatively high sediment loads. Most sediment loads in the region originate from eroding gulleys and streambanks along alluvial valleys and from soils derived from poorly consolidated shale, mudstone, and siltstone. The latter are exposed updgradient of the Reservation and across it (see

Section 4.5). Sediment loads can affect water treatment methods and the use of irrigation canals and storage reservoirs.

Mean annual sediment loads have been estimated at several stream sites on and near the Reservation. **Figure 7-8** shows the location of these sites and **Table 7-5** lists their contributing drainage area and estimated mean annual sediment loads. Most major streams in the region are estimated to have sediment loads that exceed 20 acre-feet of sediment per year (AFSA) and several are estimated to exceed 50 AFSA. To illustrate the impact of sediment load on storage reservoirs, consider a hypothetical 500 acre-foot capacity reservoir built along a Hopi wash. Assuming 100% of the sediment load was trapped and none cleaned out, it would take about 25 years for the reservoir to fill with sediment at a loading rate of 20 AFSA, and about 10 years to fill at a loading rate of 50 AFSA.

Figure 7-9 is a photograph of Polacca Wash taken by ADWR in 2007 that shows active erosion of the streambank, a source of sediment load. The salt deposits seen along the channel are probably the result of elevated TDS in the baseflow that feeds the stream.

7.1.2 Little Colorado River

The LCR collects runoff from the Hopi Washes and flows downgradient of the Reservation from southeast to northwest before joining the Colorado River in Grand Canyon National Park (**Figure 7-1**). Streamflows have been continuously monitored in this lower section of the LCR since 1925.

Table 7-1 lists data for three lower LCR stream gages operated by the USGS. For the two gages with a relatively long period of record, median streamflows in the lower LCR have ranged from about 135,000 to 160,000 AFA. As with the Hopi Washes, flows in the lower LCR have been highly variable from year to year with maximum annual flows exceeding minimum annual flows by a factor of over 30. Flows are generally lowest in the fall and, on average, greatest during the winter months during which time they contribute about 35-38% of the total annual flow. Typical seasonal variability in lower LCR streamflows is illustrated in **Figure 7-10**.

Snowmelt and storm runoff are considered important hydrologic factors that result in streamflow gains along this reach of the LCR and ET and transmission losses are

considered important factors in streamflow losses. Note that one of the USGS gages (09402300 near Desert View) is located just a few miles upstream of the LCR confluence with the Colorado River and immediately downstream of the Blue Springs area, a major discharge point for the regional Coconino (C) Aquifer. Baseflow is an important factor affecting streamflows at this gage and ET and transmission losses are believed to be insignificant.

Due to its relatively large baseflow component, streamflows at the Desert View gage are perennial. Flows at the upstream LCR gages near Cameron and at Grand Falls are intermittent and typically occur during about 80% of the days each year. Additional flow duration data for these LCR gages are listed in **Table B-1** and shown in **Figure B-9** of **Appendix B**.

As with the Hopi Washes, sediment loads are relatively high in the lower LCR. Sediment loads are estimated to average from 4,730 to 5,710 AFA at the USGS gage at Cameron and 3,560 AFA at USGS gage at Grand Falls (see **Figure 7-8** and **Table 7-5**).

7.1.3 Long-term Flow Variability

Flow measurements and tree-ring studies suggest that streams in the region have long been affected by dry and wet periods, and such periods will likely occur again. **Figure 7-11** shows how streamflows measured in Moenkopi Wash and the lower LCR have varied since 1926 and, for reference, how undepleted streamflows estimated in the Colorado River at Lees Ferry upstream of the confluence with the LCR have varied since 1906. To illustrate trends in flow, annual data are compared to the mean flow for the period of record and plotted as a 10-year moving average.

Compared to the mean, flows at the Moenkopi Wash gage were relatively high during the 1930s and 1940s, low during the 1950s, high again during the 1960s and 1970s, and low since the 1980s (**Figure 7-11**). Similar trends in flow occurred at the lower LCR gage at Cameron and on the Colorado River at Lees Ferry, but departures from mean flow conditions were less extreme than along Moenkopi Wash. Annual variability in streamflow apparently increases as watershed area decreases, suggesting that washes in the region with smaller drainages than Moenkopi Wash could experience even greater flow variability.

Figure 7-12 puts these regional streamflows into a longer, historical context. The gage data depicted in **Figure 7-11** for Moenkopi Wash and the lower LCR are plotted against tree-ring estimates of flow in the lower LCR since the 1400s and in the Colorado River at Lees Ferry since the 700s. The earlier flow estimates suggest that the variability observed during the 20th century was not unique and has been characterized by extreme wet and dry periods. Potential changes to the climate related to global warming could bring still further variability to streamflows in the area.

7.2 IMPOUNDMENTS

A total of 561 impoundments, including four reservoirs, were claimed by the Hopi and by the United States on the Tribe's behalf. ADWR identified another 180 impoundments on the Reservation which were not claimed, including two additional reservoirs. **Figure 7-13** shows the location of the claimed and unclaimed impoundments, and **Appendix C** presents a detailed impoundment inventory. Following is a general discussion of the condition and capacity of the impoundments based on ADWR's inventory and an estimate of their surface water depletions.

7.2.1 Condition

ADWR verified the location of 557 or about 99% of the 561 claimed impoundments through use of aerial photography and/or ground inspections (**Table 7-6**). It was unable to verify 4, or about 1% of the remaining claimed impoundments through either means of verification. Of the 180 unclaimed impoundments on the Reservation, ADWR identified 172 through photo analysis and 8 in the field.

A total of 294 claimed and unclaimed impoundments were determined by ADWR to have breached berms. The berms at another 44 claimed impoundments were determined to be degraded or eroded, one berm was found under construction, and one berm was removed during mine reclamation. Ten claimed and one unclaimed impoundments appear to be natural depressions without berms and, at four claimed impoundments, berms are located within natural depressions.

Several impoundments found by ADWR were affected by the relatively high sediment loads in the region (see **Section 7.1.1**). Fifty-six claimed and unclaimed impoundments had limited storage due to siltation, 4 had upstream silt traps, and 13 had multiple impoundments at the same site. Sediment loads probably also contributed to several impoundments having breached berms. Of the 441 claimed and unclaimed impoundments without breached berms or with berms that were not under construction or removed, ADWR determined that 227 of them had a surface area less than 1 acre and 214 had a surface area of 1 acre or larger.

All of the claimed impoundments were reportedly used for stockwatering and four reservoirs were also claimed for recreation:

- Keams Lake or Beaver Reservoir (Hopi ID No. I-11-431)
- Lake Maho (I-11-408)
- Twin Dam No. 1 (I-11-415)
- Twin Dam No. 2 (I-11-407).

With the exception of Keams Lake, ADWR found these reservoirs to be partially or completely silted in. It also found two other unclaimed reservoirs along Pasture Canyon near Moenkopi. Pasture Canyon Reservoir captures the discharge from a series of springs along the canyon and is used for both irrigation and recreation. Lower Lagoon Reservoir is located immediately downstream of Pasture Canyon Reservoir and apparently used to capture storm water above Moenkopi Village. Nineteen (19) other claimed and unclaimed impoundments appear to be used for flood and/or erosion control, and 38 were associated with agricultural lands identified in 2005 (ADWR, 2008c). One claimed impoundment (Hopi No. I-11-147) forms a pond that is partly located on Navajo lands.

Twenty impoundments were identified on the Reservation within the PWCC leasehold including 13 temporary PWCC sediment ponds that may be removed after 2010, 5 existing stockponds, 1 permanent PWCC sediment pond, and 1 PWCC sediment pond that was recently removed. Of the total impoundments identified on the leasehold, 9 were claimed and 11 were unclaimed.

Photographs that show the condition of several impoundments on the Reservation are included with the inventory in **Appendix C** (**Figures C-1** through **C-10**).

7.2.2 Capacity

The Hopi and United States claimed that impoundments on the Reservation have a total capacity of 4,499 acre-feet (**Table 7-7**). Of this total, 2,039 acre-feet were claimed for impoundments that ADWR determined had breached berms, and 24 acre-feet were claimed for impoundments that ADWR could not verify, found under construction, or were removed. The remaining 2,436 acre-feet were claimed for 318 impoundments that ADWR determined had berms that were not breached.

Using field measurements and photo analysis, ADWR estimated that the claimed impoundments without breached berms had a total capacity of 2,190 acre-feet. Note that ADWR determined that 53 of these impoundments had limited storage capacity due to siltation and 44 impoundments had degraded or eroded berms. No attempt was made to reduce capacity estimates for these conditions. Note also that the capacity of silt traps observed at some claimed impoundment sites were not estimated, but the capacity of multiple impoundments at the same claim site were estimated and added together. ADWR did not estimate the capacity of claimed impoundments that it could not verify or determined had breached berms, were under construction, or removed. It was assumed that impoundments with breached berms store relatively little or no water and, therefore, may not be part of the available water resources in the vicinity of the Reservation.

In addition to the claimed impoundments, ADWR estimated that 123 unclaimed impoundments on the Reservation without breached berms have a total capacity of 363 acre-feet. Pasture Canyon Reservoir is the largest unclaimed (and claimed) impoundment on the Reservation with an estimated capacity of 202 acre-feet and Lower Lagoon Reservoir is the next largest with an estimated capacity of 51 acre-feet. The capacity of 57 unclaimed impoundments with breached berms was not estimated.

7.2.3 Surface Water Depletion

In a prior study of the hydrology of the Little Colorado River system, ADWR (1989) assumed that stockponds and small reservoirs in the region with a surface area of

less than one acre fill twice a year (in spring and summer), and those with a surface area of one acre or larger fill once a year. It was further assumed that 50% of the volume captured by the stockponds and small reservoirs would be felt as a loss at the drainage mouth. In other words, half of the impounded water would have otherwise been lost to infiltration and evaporation en-route to the mouth of the drainage even under natural conditions.

Using the above assumptions, ADWR estimates that up to approximately 1,156 acre-feet of surface water are currently depleted each year by claimed impoundments on the Reservation and approximately 198 acre-feet are currently depleted by unclaimed impoundments. **Table 7-7** lists the number and capacity of claimed and unclaimed impoundments on the Reservation and their respective surface areas. Depletion estimates do not include unverified impoundments or those impoundments that ADWR found under construction, with breached berms, or removed. Impoundments with limited storage due to siltation are included, so the above depletion estimate should be considered an upper limit.

7.3 SPRINGS

A total of 338 springs were claimed in the SOCs filed by the Hopi and by the United States on their behalf in January 2004. In April 2005, a consultant to the United States sent ADWR electronic data for the 338 springs plus 22 other springs that were not previously claimed (NRCE, 2005). ADWR learned during subsequent conversations with the United States and Hopi that they anticipate amending their 2004 SOCs to include the other springs (Hopi, 2005a). *For the purposes of this preliminary HSR, ADWR included all of the 360 springs identified by the Hopi and United States in the claimed category.*

ADWR identified an additional 41 springs on and near the Reservation which are not being claimed. **Figure 7-14** shows the location of the claimed and unclaimed springs and **Appendix D** presents a detailed spring inventory. The inventory identifies those springs that were originally claimed and those that were added later. Following is a

general discussion of the characteristics and discharge of Hopi springs based on ADWR's inventory.

7.3.1 Characteristics

ADWR verified the location of 328 or about 91% of the claimed springs through topographic maps, existing reports, and/or ground inspections (**Table 7-8**). ADWR was unable to verify 32 or about 9% of the remaining claimed springs through any of these means. Of the 42 unclaimed springs on and near the Reservation, ADWR identified 12 springs in the field and 30 springs through topographic maps and existing reports.

Where known, water sources for most springs on and near the Reservation are from the T Aquifer (103 springs) and N Aquifer (82 springs). Other water sources include alluvial aquifer (25 springs), colluvial aquifer (23 springs), spring (travertine) deposits (7 springs), and the D Aquifer (5 springs). The water source(s) for the remaining 157 claimed and unclaimed springs are unknown to ADWR. Further discussion of aquifers in the region is presented in **Section 7.4**.

Water quality data were available for 76 of the claimed and unclaimed springs and indicate that 51 springs have exceeded one or more water quality standard. Available data were compared to standards for drinking water (primary and secondary), irrigation, and livestock. Common water quality exceedences included nitrate (22 springs exceeded the primary drinking water standard), sulfate (22 springs exceeded the secondary drinking water and/or livestock standard), and total dissolved solids (34 springs exceeded the secondary drinking water standard). See **Table 7-8** and **Appendix D**.

Some form of development has been noted at 83 spring sites. The most common improvements were troughs (44 springs) and spring boxes (22 springs).

Of the 360 springs identified by the Hopi and the United States, many were claimed for more than one use. All springs were claimed for ceremonial/cultural use, 351 were claimed for stock use, 339 were claimed for domestic use, and 17 were claimed for irrigation use. Reports and/or ADWR field observations indicate that another 52 of the claimed springs have also been used for irrigation and 3 have been used as a public water supply. Uses for the unclaimed springs have included domestic (11 springs), irrigation (8 springs), stock (7 springs), and ceremonial/cultural (1 spring).

ADWR determined that 18 claimed springs and 3 unclaimed springs are located outside and immediately upstream of the Reservation along Pasture Canyon, 3 unclaimed springs are located on Hopi allotted lands, 1 claimed spring is located on the Reservation within the PWCC leasehold, and 1 spring (Cliff Spring) is located on Navajo Partitioned Land east of the Reservation. It was also determined that six springs are potential duplicates of other claimed springs and one claimed spring appears to have been dual claimed as a well.

Photographs that show the characteristics of several springs on the Reservation are included with the inventory in **Appendix D** (**Figures D-1** through **D-13**).

7.3.2 Discharge

A total of 1,701 gpm or about 2,750 AFA were claimed for the 360 springs located on and near the Reservation (**Table 7-9**). ADWR found or collected discharge data for 208 or about 58% of these springs. Measured discharges totaled from 360 to 1,103 gpm and were greatest from the N Aquifer (207 to 777 gpm) and T Aquifer (99 to 202 gpm). Discharge measurements for each individual spring ranged from 0 to 326 gpm.

Discharge data were also available for 29 of the 41 unclaimed springs. Measured discharge for these springs totaled from 30 to 31 gpm, and ranged from 0 to 8.5 gpm for each individual spring. The greatest discharge was from the T Aquifer (about 18 gpm) and unknown water sources (about 10 gpm).

The spring inventory in **Appendix D** includes the number of unique discharge measurements that ADWR identified and, where multiple measurements were taken at a spring, low and high discharge values are provided. Otherwise, single discharge values are shown in the inventory or, if no measurement data are available, no value is shown. ADWR assumed a discharge of 0 gpm for those springs found to be dry and a discharge of <0.01 gpm at sites where seeps were noted or where only standing water, damp soil, or indicator vegetation were found.

The N Aquifer discharges water to several springs located along Pasture Canyon, upstream of the villages of Upper Moenkopi and Lower Moencopi. Most spring flow occurs in the upper portion of the canyon and, since August 2004, the USGS has

continuously monitored the combined discharge of the springs at its Pasture Canyon gage (see **Figure D-13)**. Before installing the gage, the USGS had measured a total spring discharge of greater than 300 gpm in this area, although measurements have generally been lower and some were apparently affected by irrigation diversions. The earliest measurements were made during 1908 and 1948 when total discharges of 224 and 210 gpm were recorded, respectively (Brown and Halpenny, 1948). Between 1948 and 1954, 13 discharge measurements were reported and averaged 177 gpm (Chambers & Campbell, 1962).

7.4 AQUIFERS

This chapter concludes by describing aquifers that underlie the Reservation. An overview is provided first, followed by more detailed descriptions for six, separate aquifers:

- Alluvial/Colluvial Aquifer
- Bidahochi Aquifer
- Toreva (T) Aquifer
- Dakota (D) Aquifer
- Navajo (N) Aquifer
- Coconino (C) Aquifer.

Aquifer descriptions include their occurrence, flow direction, natural recharge and discharge, well development, and water quality. The D and N Aquifers have been the most heavily utilized in the region and are discussed here in more detail. For these aquifers, data are also presented on their estimated water in storage and for the N Aquifer, aquifer properties and measured and potential future hydrologic impacts are also discussed.

Water wells have been completed on the Reservation in each of the six aquifers. A total of 206 stock and domestic wells were claimed in SOCs filed by the Hopi and by the United States on their behalf in January 2004. In April 2005, a consultant to the United States sent ADWR electronic data for the 206 wells plus 3 other wells that were

not previously claimed (NRCE, 2005). In November 2005, ADWR received information from the Hopi for another 25 previously unclaimed wells and learned during subsequent conversations with the United States and Hopi that they anticipate amending their 2004 SOCs to include these additional wells (Hopi, 2005a). For the purposes of this preliminary HSR, ADWR included all 234 wells identified on the Reservation by the Hopi and United States in the "claimed" category.

Figure 7-15 shows the location of claimed and unclaimed wells on the Reservation by aquifer type and **Appendix E** presents a detailed inventory and representative photos of the wells. Based on the inventory, well characteristics are summarized in **Tables 7-10** and **7-11**. **Table 7-10** reports water sources, available water quality data, well uses, and special circumstances. **Table 7-11** reports well and water level depths and claimed quantities, available water quality data, well uses, and special circumstances.

Of the 234 claimed wells, ADWR verified 51 through ground inspections and another 169 through review of reports and/or topographic maps, or about 94% of the total. ADWR was unable to verify 14 of the claimed wells, but it did identify an additional 58 wells on the Reservation which apparently are not claimed. One claimed well is located on the Reservation within the PWCC leasehold.

7.4.1 Overview

Figure 4-9 is a stratigraphic column that shows the sequence of aquifers beneath the Reservation and their associated geologic strata. The shallowest aquifer occurs near surface in unconsolidated deposits of alluvium and colluvium. The C Aquifer is the deepest and occurs locally at depths of several thousand feet in limestone and sandstone. The Bidahochi, T, D, and N Aquifers are encountered at intermediate depths.

The lateral extent of these aquifers and general direction of flow, if known, is shown in **Figure 7-16**. The general flow direction in the Bidahochi and T Aquifers is unknown. Only the C Aquifer is encountered beneath the entire Reservation but, as indicated above, it is several thousand feet deep. The D and N Aquifers are found beneath all but the far southwestern portions of the Reservation, whereas the Bidahochi and T Aquifers are only encountered in the southeast and northeast, respectively. The

Alluvial/Colluvial Aquifer is limited to areas of the Reservation along washes and at the base of some slopes.

Figures 7-17 and **7-18** illustrate the expected water level in wells drilled on the Reservation with yields of at least 25 gpm and 500 gpm, respectively. **Figure 7-17** indicates that wells yielding at least 25 gpm could be completed across most of the Reservation, but pumping levels would be variable, ranging from less than 100 feet below ground surface in some areas and up to 2,000 feet in others. Pumping levels were estimated assuming continuous pumping for 100 days at the specified discharge. **Figure 7-18** indicates that wells yielding at least 500 gpm could only be completed in the northeastern portion of the Reservation. Pumping levels for these wells would be expected to range from 300 feet up to 2,000 feet below ground surface.

A conceptual hydrologic model of the region is provided in **Figure 7-19**. The model shows how water is recharged to, and discharged from, three Reservation aquifers (Alluvial/Colluvial, D, and N). The model also shows the flow of water between the aquifers. Further discussion of these processes is provided below.

7.4.2 Alluvial/Colluvial Aquifer

Occurrence

Some of the unconsolidated sediments recently deposited along drainages and at the base of slopes are saturated and form local aquifers. These unconfined aquifers are relatively thin and of limited aerial extent, but can locally contain sand and gravel beds that are more permeable than the underlying bedrock (Cooley and others, 1969). Combined, the shallow aquifers are referred to here as the Alluvial/Colluvial Aquifer. See **Figure 7-16**.

Flow Direction

Water in the Alluvial/Colluvial Aquifer generally flows from higher to lower ground elevations, following the surface topography of the Reservation.

Natural Recharge and Discharge

Recharge to the Alluvial/Colluvial Aquifer comes from direct precipitation, infiltration of streamflow, and discharge from adjacent bedrock springs. The location of bedrock springs on the Reservation is shown in **Figure 7-14.**

Discharge from the Alluvial/Colluvial Aquifer can occur as baseflow to streams, evapotranspiration by riparian vegetation, spring discharge, and underflow. **Figure 7-5** shows the location of recent and historic perennial stream reaches on the Reservation that are fed by baseflow, and **Figure 4-5** shows where ADWR mapped riparian vegetation on the Reservation in 2005.

Approximately 14,500 acres of riparian vegetation were identified along Reservation drainages, of which about 1,000 acres were associated with impoundments (ADWR, 2008c). As discussed further in **Section 8.6**, the water demand of this vegetation is met by direct precipitation and discharge from the Alluvial/Colluvial Aquifer via root uptake. It is estimated that the riparian water demand met by aquifer discharge on the Reservation could total from 23,200 to 56,550 AFA.

ADWR identified 46 claimed springs and 2 potentially unclaimed springs on the Reservation that also discharge water from the Alluvial/Colluvial Aquifer (**Table 7-8**). Based on data for 30 of these springs, discharges have ranged from 0 to 25 gpm and totaled from 36 to 94 gpm or about 58 to 152 AFA (**Table 7-9**). ADWR does not have an estimate of the quantity of underflow that leaves the Reservation from this aquifer.

Well Development

ADWR identified 33 claimed wells and 10 potentially unclaimed wells on the Reservation that were completed in the Alluvial/Colluvial Aquifer (**Table 7-10**). Four to 5 gpm were claimed for each well with a total claimed quantity of 132 to 135 gpm or about 213 to 218 AFA (**Table 7-11**). The median depth of the claimed and unclaimed wells is less than 100 feet with median water levels less than 50 feet below ground surface. Six of the wells in the Alluvial/Colluvial Aquifer were either reported or found by ADWR to be dry (**Table 7-11**).

Water Quality

Water quality data for the Alluvial/Colluvial Aquifer is available from 19 springs and 25 wells on the Reservation (see **Appendices D** and **E**). The following water quality standards were commonly exceeded at these springs and wells:

- Nitrate (primary drinking water standard)
- Sulfate (secondary drinking water and/or livestock standards)
- Total dissolved solids (secondary drinking water and/or livestock standards).

These constituents occur naturally in the Alluvial/Colluvial Aquifer and in the bedrock aquifers that provide it recharge.

7.4.3 Bidahochi Aquifer

Occurrence

The Bidahochi Aquifer is encountered beneath a relatively small area in the southeastern portion of the Reservation (**Figure 7-16**). The aquifer is generally unconfined and comprised of Tertiary-age volcanic and sedimentary rocks including basalt, rhyolitic ash, mudstone, and sandstone (**Figure 4-9**). The main water-bearing unit locally is associated with breccia-filled volcanic pipes (Farrar, 1980).

Flow Direction

ADWR does not have data on the direction of flow in the Bidahochi Aquifer beneath the Reservation.

Natural Recharge and Discharge

Most recharge to the Bidahochi Aquifer probably occurs from direct precipitation, where the Tertiary rocks are exposed at or near ground surface (ADWR, 1989). Discharge probably occurs largely as leakage to the underlying T Aquifer and as underflow that leaves the Reservation. ADWR did not identify any Reservation springs that discharge water from this aquifer, and there are no reported perennial stream reaches in the area of the Reservation where it is encountered.

Well Development

ADWR only identified one claimed well on the Reservation completed in the Bidahochi Aquifer (**Table 7-10**). It has a claimed quantity of 4 gpm and is reported to be 350 feet deep with a water level of 209 feet (**Table 7-11**). This well also receives water from the underlying T Aquifer. Other Bidahochi Aquifer wells completed in the region have generally yielded from 10 to 20 gpm (ADWR, 1989 and Farrar, 1980).

Water Quality

No water quality data were available to ADWR for the one Bidahochi well on the Reservation. However, the aquifer is reported to have generally good water quality across the region and is used for livestock and domestic purposes (ADWR, 1989).

7.4.4 T Aquifer

Occurrence

The T Aquifer is encountered beneath the northeastern portion of the Reservation (**Figure 7-16**) and comprised of sandstone units within the Cretaceous-age Mesa Verde Group. These units include the Yale Point Sandstone and sandstones of the Wepo and Toreva Formations (**Figures 4-9**). Although confined conditions occur locally, the aquifer is generally unconfined and often consists of perched water-bearing zones formed above relatively low permeability coal, siltstone, and mudstone layers. Water levels in the T Aquifer vary both vertically and horizontally and wells completed in the aquifer may yield water from several, separate zones (Levings and Farrar, 1977).

Flow Direction

ADWR does not have data on the direction of flow in the T Aquifer, but it is expected to be complex due to the occurrence of perched water-bearing zones.

Natural Recharge and Discharge

Most recharge to the T Aquifer probably occurs from direct precipitation where units of the Mesa Verde Group are exposed at or near ground surface. Some recharge to the aquifer may also occur via leakage from the overlying Bidahochi Aquifer. Discharge

probably occurs largely from springs, baseflow to streams, and as underflow. Leakage to the underlying D Aquifer is probably limited by several hundred feet of Mancos Shale.

ADWR identified 90 claimed springs and 13 unclaimed springs on the Reservation that discharge water from the T Aquifer (**Table 7-8**). Based on data for 78 of these springs, discharges have ranged from 0 to 50 gpm and totaled from 117 to 220 gpm or about 189 to 355 AFA (**Table 7-9)**.

Perennial stream reaches in the headwaters of Moenkopi Wash are believed to have been fed by the T Aquifer (**Figure 7-5**). This reach was observed near the beginning of the 20th century during a wet period and is currently intermittent (ADWR, 2008g). The quantity of underflow that potentially leaves the Reservation from the T Aquifer has not been determined.

Well Development

ADWR identified 24 claimed wells and 9 potentially unclaimed wells on the Reservation that were completed in the T Aquifer (**Table 7-10**). The claimed quantity for these wells ranged from 4 to 8 gpm and totaled from 96 to 101 gpm or about 155 to 163 AFA (**Table 7-11**). The actual yield of most T Aquifer wells on the Reservation is believed to be less than 1.25 gpm (DBSA, 2000).

Median depths of the T Aquifer wells range from 413 feet for the claimed wells to 164 feet for the unclaimed wells. Median water levels for these wells were 195 feet and 133 feet, respectively, with two wells reported dry (**Table 7-11**).

Water Quality

Water quality data for the T Aquifer is available from 23 springs and 11 wells on the Reservation (see **Appendices D** and **E**). The following water quality standards were commonly exceeded at these sites:

- Nitrate (primary drinking water standard)
- Sulfate (secondary drinking water)
- Total dissolved solids (secondary drinking water).

These constituents occur naturally in the T Aquifer.

7.4.5 D Aquifer

Occurrence

The D Aquifer extends beneath all but the southwestern portion of the Reservation (**Figure 7-16**), and is comprised of a series of Cretaceous- and Jurassic-age sandstones. The Dakota Sandstone is the most important water-bearing unit, with water also obtained from the Entrada Sandstone and sandstones of the Morrison and Carmel Formations (**Figure 4-9)**. The sandstones are separated by mudstone and siltstone layers and are locally discontinuous (Cooley and others, 1969).

The D Aquifer is generally thickest (up to 1,300 feet) near its center and thins to the southeast (700 feet) and northwest (100 feet) (Lopes and Hoffman, 1997). It is confined by mudstone and gypsum beds of the overlying Mancos Shale (Cooley and others, 1969).

Flow Direction

Water in the D Aquifer currently flows under pressure from an elevation of about 6,200 feet just east of the Reservation to an elevation of about 5,300 feet to the southwest (**Figure 7-20**). Flows are locally restricted where the sandstone units are folded or pinch out (Cooley and others, 1969).

Natural Recharge and Discharge

The total recharge to the D Aquifer has been estimated at 5,392 AFA (GeoTrans and Waterstone, 1999). Most of this recharge probably occurs outside of the Reservation along the eastern slope of Black Mesa, where units of the aquifer outcrop (Lopes and Hoffman, 1997). Recharge may also occur locally along ephemeral washes where these units are at or near ground surface. The age of water from the D Aquifer water is estimated to range from 4,000 to 11,000 years old near the main recharge area and up to 33,000 years old downgradient (Truini and Longsworth, 2003).

The D Aquifer discharges water via springs, leakage to the underlying N Aquifer, baseflow to streams and as underflow along the Hopi Washes. ADWR identified four claimed springs and one unclaimed spring on the Reservation that discharge water from

the D Aquifer (**Table 7-8**). Discharge from four of these springs has been relatively low, ranging from <0.01 to 2 gpm and only totaling from 2 to 5 gpm (**Table 7-9**).

Leakage of water from the D Aquifer to the N aquifer has apparently been occurring for thousands of years, with the area of greatest leakage in the southeastern portion of the Reservation. In this area, the N Aquifer is relatively thin and the difference in predevelopment water levels between the D and N Aquifers is small (Truini and Longsworth, 2003).

Water from the D Aquifer is also discharged on the Reservation as baseflow to streams and as underflow (Cooley and others, 1969). Perennial stream reaches historically observed along Dinnebito and Jeddito Washes are believed to have been fed by the D Aquifer (**Figure 7-5**), although the reach along Jeddito Wash was only observed during wet periods **(**ADWR, 2008g). During dry periods, discharge from the D Aquifer probably still occurs along these and the other Hopi Washes as recharge to underlying alluvial aquifers (**Figure 7-21**). The quantity of D Aquifer water that potentially leaves the Reservation as underflow along the washes has not been determined. However, it has been estimated that a relatively large quantity of water in the alluvial aquifer is consumed locally by riparian vegetation (see **Figure 4-5** and **Section 7.4.2**).

Well Development

ADWR identified 48 claimed wells and 12 unclaimed wells on the Reservation that were completed in the D Aquifer (**Table 7-10)**. The claimed quantity for these wells ranged from 0 to 8 gpm and totaled from 184 to 199 gpm or about 297 to 321 AFA (**Table 7-11**). The actual yield of most D Aquifer wells on the Reservation is believed to be less than 1.25 gpm (DBSA, 2000), although yields up to 20 to 25 gpm are reported in the region (ADWR, 1989 and Farrar, 1980).

Median depths of D Aquifer wells on the Reservation range from 705 feet for the claimed wells and 715 feet for the unclaimed wells. Median water levels for these wells were 268 feet and 162 feet, respectively, with five wells reported as flowing and two wells reported dry (**Table 7-11**).

Water Quality

Water quality data for the D Aquifer is available from 2 springs and 31 wells on the Reservation (see **Appendices D** and **E**). The following water quality standards were commonly exceeded at these sites:

- Fluoride (primary and secondary drinking water and livestock standards)
- Sulfate (secondary drinking water standards)
- Total dissolved solids (secondary drinking water standards).

The primary drinking water standard for arsenic was also exceeded at two Hopi public water supply wells (Polacca #5 and #6) completed in the D Aquifer. One of these wells also exceeded the primary drinking water standard for nitrate and secondary drinking water standard for chloride, and both wells exceeded secondary drinking water and livestock standards for pH. Polacca #5 is currently inactive and Polacca #6 is used as an emergency backup (Tetra Tech, 2006). All of these constituents occur naturally in the D Aquifer.

Water in Storage

ADWR (1989) estimated the total volume of water stored in the D Aquifer at 15 million acre-feet. The estimate applies to the entire LCR watershed and includes Navajo lands outside of the Reservation. More than half of the total D Aquifer water appears to be stored beneath the Reservation.

7.4.6 N Aquifer

Occurrence

The N Aquifer extends beneath all but the southwestern portion of the Reservation (**Figure 7-16**), and is comprised of a series of Jurassic-age sandstones. The Navajo Sandstone is the primary water-bearing unit, with water also obtained from underlying sandstones in the Kayenta Formation and the Lukachukai Member of the Wingate Sandstone (**Figure 4-9**). The Kayenta Formation pinches out locally and, in some areas, siltstones in the Moenave Formation separate it from the Wingate Sandstone (Cooley and others, 1969).

In the vicinity of the Reservation, the N Aquifer is generally thickest (up to 1,000 feet) in the northwest and thins to between 200 and 400 feet in the east and west and less than 200 feet in the south (**Figure 7-22**). It is confined over much of this area by siltstone and mudstone of the Carmel Formation. Unconfined conditions occur in a recharge area to the north, a discharge area to the west, and in the southeast where the N Aquifer is relatively thin and receives leakage from the D Aquifer (**Figure 7-23**).

Flow Direction

Figure 7-23 shows the general direction of flow in the N Aquifer prior to 1972, when substantial development of the aquifer began. Water levels were highest in the Shonto area, north of the Reservation, and reached an elevation of over 6,500 feet. From there, water flowed to the south and west with levels dropping to less than 4,800 feet near Moenkopi, and flowed to the northeast with levels dropping to less than 5,000 feet.

Across much of this area, water in the N Aquifer occurred under confined conditions with water levels in wells rising as much as 1,800 feet above the top of the aquifer surface. Along the aquifer margins, the water was unconfined with water levels in wells at or below the top of the aquifer (Brown and Eychaner, 1988). These conditions generally still occur today, although industrial and municipal pumping has locally altered water levels and associated flow directions by forming drawdown cones around well sites.

Natural Recharge and Discharge

Recharge to the N Aquifer is estimated to range from 2,600 and 20,248 AFA, with a median recharge of 13,000 AFA (OSM, 2008). Geochemical analysis and groundwater flow and transport modeling suggest that N Aquifer recharge was 50% lower from 6,000 to 11,000 years ago and 2 to 3 times higher from 11,000 to 31,000 years ago. Variations in recharge are explained by effects from glacial and post-glacial periods (Zhu and others, 1998). The age of water in the N Aquifer is estimated to be older than 10,000 years where the aquifer is confined and about 35,000 years where it is unconfined and discharges to Moenkopi Wash and Laguna Creek (Lopes and Hoffman, 1997). See **Figure 7-24**.

Water is discharged from the N Aquifer via springs, baseflow to streams, and as underflow along the Hopi Washes. ADWR identified 75 claimed springs and 7 unclaimed springs on the Reservation that discharge water from the N Aquifer (**Table 7-8**). Discharge from 74 of these springs has ranged from 0 to 326 gpm and totaled from 202 to 777 gpm or about 326 to 1,253 AFA (**Table 7-9**).

Perennial and intermittent stream reaches historically and currently observed along Moenkopi, Dinnebito, Polacca, and Jeddito Washes are also believed to have been fed by the N Aquifer (**Figure 7-5**). The aquifer also recharges alluvial aquifers that underlie the Hopi Washes (**Figure 7-21**), although the quantity of this water that leaves the Reservation as underflow has not been determined. A relatively large quantity of water from the alluvial aquifer (from 23,200 to 56,550 acre-feet) has been estimated to be consumed each year by riparian vegetation (see **Section 7.4.2**). A portion of this likely originates from the N Aquifer.

Aquifer Properties

Figure 7-24 shows how the permeability of the N Aquifer varies in the vicinity of the Reservation. The hydraulic conductivity of the aquifer, a measure of its permeability, is estimated to range from 0.1 to 1.8 feet/day with the highest values in the southwest and near the center of the area. These values were input to a USGS groundwater flow model and are based on long-term (over 6-year) aquifer tests conducted in the PWCC well field and 40 other short-term aquifer and well tests.

Figure 7-25 shows how the transmissivity of the N Aquifer varies over the same model area**.** Transmissivity is a measure of an aquifer's ability to transmit water and is the product of its hydraulic conductivity and saturated thickness. Transmissivity is an important factor in evaluating well yields and, in general, as transmissivity increases, pumping rates can increase without additional water level decline (drawdown). The transmissivity of the N Aquifer, as modeled by the USGS, ranges from 20 to over 1,000 $feet^2$/day. The highest transmissivity values appear in the north where PWCC completed its well field in the N Aquifer.

As described earlier, water in the N Aquifer is encountered under both unconfined and confined conditions. Specific yield is a measure of the amount of water that an

unconfined aquifer releases from storage when its water level declines. For confined aquifers, storage coefficient is a measure of the amount of water that is released from storage with a decrease in water pressure. In the vicinity of the Reservation, specific yield and storage values for the N Aquifer are reported to range from 0.1 to 0.15 and from 0.00022 to 0.0008, respectively (Eychaner, 1983). A practical implication of this is the relatively large drawdowns that have been measured in several wells completed in confined portions of the N Aquifer where storage coefficients are comparatively low. For a given pumping rate and aquifer transmissivity, water levels decline more quickly in wells as specific yield and storage coefficient values decrease.

Yields of wells completed in the N Aquifer range from less than 5 gpm to over 300 gpm (Farrar, 1979 and 1980), with some wells in the PWCC leasehold yielding over 500 gpm. Pumping rates for municipal wells completed on the Reservation in the N Aquifer are reported to range from 8.5 to 121 gpm (Tetra Tech, 2006).

Water in Storage

Table 7-12 lists estimates of the volume of water stored in the N Aquifer. The estimates vary based on the year that water level data were collected and differences between the groundwater flow models used to calculate storage. ADWR (2008h) reviewed three models of the N Aquifer:

- U.S. Geological Survey Model
- Peabody Western Coal Company Model
- Western Navajo-Hopi N Aquifer (WNHN) Model.

Simulation areas and assumptions regarding aquifer thickness vary between the models and explain some of the storage differences. Further discussion of the models is provided later in this section.

The WNHN Model covers the largest area and was used by ADWR (2008h) to calculate storage in the N Aquifer beneath the Reservation and surrounding Navajo lands. In 2000, it was determined that approximately 159 million acre-feet (MAF) of N Aquifer water were stored beneath the Reservation and about 90 MAF were stored beneath the adjacent Navajo Partitioned Lands. An additional 277 MAF were estimated to be stored

in the N Aquifer beneath other Navajo lands in Arizona for a total of about 526 MAF for the state. As described below, well development is estimated to have removed a relatively small percentage (less than 0.1%) of this total volume.

Well Development

ADWR identified 61 claimed wells and 7 unclaimed wells on the Reservation that were completed in the N Aquifer (**Table 7-10)**. Median well depths range from 745 feet for the claimed wells to 938 feet for the unclaimed wells. Median water levels for these wells were 353 feet and 130 feet, respectively, with two wells reported dry (**Table 7-11**).

The claimed quantity for N Aquifer wells on the Reservation ranged from 0 to 8 gpm and totaled from 160 to 170 gpm or about 258 to 274 AFA (**Table 7-11**). By comparison, a total of 585 acre-feet were pumped during 2005 from Hopi municipal wells completed in the N Aquifer (Truini and Macy, 2007). **Appendix E** lists the public water supply systems on the Reservation that are served by N Aquifer wells. Note that only two Hopi municipal wells had a claimed quantity (each at 4 gpm), and most N Aquifer wells on the Reservation were claimed for stock and/or domestic use.

The N Aquifer has been the most heavily developed of the region's six aquifers. In addition to Hopi municipal pumping, the Navajo and PWCC have several wells completed in the N Aquifer for municipal and industrial use, respectively. **Table 7-13** lists the total and average annual withdrawals from these wells since 1965, and **Figure 7-26** shows well locations and withdrawals for 2005. Over 218,000 acre-feet of water have been pumped from the N Aquifer over the period from 1965 to 2005 and, since 1972, annual withdrawals have steadily risen from 4,300 acre-feet in 1972 to 8,000 acre-feet in 2002 (Truini and Macy, 2007). Approximately 37% of total withdrawals have been for municipal use by the Navajo and Hopi and 63% have been for industrial use by PWCC. Hydrologic impacts from this development of the N Aquifer are discussed below.

Truini and Macy (2007) estimate that total withdrawals from other wells completed in the N and D Aquifer wells are less than 1% of the total municipal and industrial withdrawals from the N Aquifer. These other wells are used for stock and domestic purposes and their flows are generally not monitored.

Measured Hydrologic Impacts from Development

Figure 7-27 shows the water level change measured by the USGS in several N Aquifer wells since aquifer development began during the early 1970s. Between 1965 and 2006, water levels generally dropped in the confined portion of the aquifer, but were little changed in the unconfined portion. The median water level change over this period was -46.6 feet for 16 wells completed in the confined aquifer and -0.2 feet for 13 wells completed in the unconfined aquifer (Truini and Macy, 2007). The largest declines were measured at municipal pumping centers and near the PWCC leasehold. A municipal well (PM2) near Keams Canyon showed a water-level decline of 196.2 feet, a USGS monitoring well (BM2) northeast of the leasehold showed a change of -87.8 feet, and a USGS monitoring well (BM6) between the leasehold and municipal well showed a change of -161.7 feet.

Since operation of the Black Mesa Mine ceased in December 2005, water levels in two N Aquifer observation wells on the leasehold have risen substantially (**Figure 7-28**). Between 2002 and 2005, PWCC estimated that the static water level depth was about 1,150 feet in observation well NAVOBS3 and about 1,344 feet in observation well NAVOBS6. Due to a decrease in pumping, water levels in these wells have risen by over 100 feet during the past two years.

Since the late 1980s and early 1990s, the USGS has also routinely monitored discharge from four N Aquifer springs in the vicinity of the Reservation. **Figure 7-29** shows the location of the springs and how their discharge has varied over time. With the exception of an unnamed spring on Navajo land near Dennehotso, discharges from springs on the Reservation appear to have declined. Accounting for annual and seasonal fluctuations, discharges from Burro, Moenkopi School, and Pasture Canyon Springs appear to have declined by about 0.1 gpm, 3 gpm, and 5 to 10 gpm, respectively.

Figure 7-29 also shows variations in the discharge along four streams believed to be fed by N Aquifer discharge. The USGS monitors flows in Moenkopi, Dinnebito and Polacca Washes on the Reservation and flows in Laguna Creek on adjoining Navajo land. To remove potential short-term effects from snowmelt, riparian evapotranspiration, and monsoon storms, flow data collected during November through February were analyzed separately (Truini and Macy, 2006). From the late 1970s to the mid-1990s, fall and

winter flows in Moenkopi Wash have varied considerably but do not appear to follow a trend. However, since the mid-1990s, fall and winter flows in all of the streams except Moenkopi appear to have declined. It is unclear to ADWR whether these streamflow declines can be attributed solely to development of the N Aquifer. For reference, **Figure 7-29** also shows annual precipitation data from a nearby meteorological station. The observed trends in streamflow seem to track, in part, variations in annual precipitation, suggesting that wet and dry periods may also be affecting flows.

Future Hydrologic Impacts from Development

Three numeric groundwater flow models have been developed to simulate existing hydrologic impacts from well development in the N Aquifer and predict future impacts. A detailed review and comparison of the models is presented in ADWR (2008h). For the following reasons, ADWR finds the PWCC model is best suited for future studies:

- Incorporates seven, distinct water-bearing (hydrostratigraphic) units;
- Explicitly simulates regional geologic structures in the area (Organ Rock and Comb Ridge Monoclines);
- Simulation area extends further south than the USGS model, but unlike the WNHN model, does not include the Colorado and San Juan Rivers and associated numerical problems;
- Most thoroughly tested of the three models, with the most extensive model results available; and
- Assumptions regarding evapotranspiration and aquifer recharge, permeability, and thickness have been evaluated.

However, even the PWCC model has its limitations. Based on data availability and model calibration, the reliability of the PWCC model is greater near the leasehold than the Hopi villages. Also, comparison of actual to simulated conditions in the Moenkopi/Tuba City area suggest that predicted hydrologic impacts in this area are overestimated.

Figure 7-30 shows the PWCC model grid and where discharge from the N Aquifer (drain cells) was simulated. Predicted changes in N Aquifer water levels, spring discharge, and baseflow to streams are summarized in **Table 7-14**. The predictions are based on running the PWCC model and assuming that Alternative B, the preferred alternative of the Black Mesa Project Final EIS, is selected (see **Section 6.1.3**). Under this alternative, PWCC would pump from the N Aquifer an average 1,236 AFA through 2025, up to 505 AFA for reclamation and public use from 2026 through 2028, and up to 444 AFA for post reclamation maintenance and public use from 2029 through 2038 (OSM, 2008). During this period, Hopi and Navajo municipal pumping from the N Aquifer are assumed to increase annually at a rate of 2.7% from levels measured in 1996.

Water Quality

Water quality data for the N Aquifer were available from 11 springs and 31 wells on the Reservation (see **Appendices D** and **E**). The following water quality standards were commonly exceeded at these sites:

- Arsenic (primary drinking water standard)
- pH (secondary drinking water and livestock standards)
- Total dissolved solids (secondary drinking water standard).

The primary drinking water standard for nitrate and/or fluoride was also exceeded at seven Hopi public water supply wells and two claimed springs fed by the N Aquifer.

Although the above constituents occur naturally in the N Aquifer, some may be originating via leakage from the overlying D Aquifer through poorly constructed wells (TetraTech, 2006). The cost to treat arsenic levels at the municipal wells has been estimated by the Hopi to range from $500,000 to over $1 million per village (SWCA, 2008).

In addition to naturally occurring constituents, the N Aquifer underlying the Moenkopi Area has been threatened by contamination from two leaky underground fuel storage tank sites (Thriftway 3701 and Sunshine-Western), an abandoned uranium mill tailings site, and the Tuba City Dump. The storage tank and mill tailings sites are

currently being remediated to prevent petroleum and uranium plumes from reaching Hopi springs and wells (EPA, 2003b and SWCA, 2008).

The Tuba City Dump was opened by the BIA a mile east of the town and located on Hopi and Navajo lands. It was used for more than 50 years before being closed in 1997. Elevated levels of radionuclides and metals have since been detected in shallow (perched) water beneath the dump, but to date, the underlying N Aquifer appears unaffected (BIA, 2008). A 5-year plan to cleanup the dump site was submitted in 2008 to the House Committee on Oversight and Government Reform. The plan includes development of a Remedial Investigation/Feasibility Study (RI/FS) workplan, installation of shallow and deep monitoring wells, surface and groundwater quality sampling, remediation if necessary, and long-term groundwater monitoring. Closure of the dump is planned to occur between July 2010 and December 2012.

7.4.7 C Aquifer

Occurrence

The C Aquifer is encountered beneath the entire Reservation (**Figure 7-16**) and consists of the Permian-age Kaibab Limestone, Coconino Sandstone, and upper Supai Formation (**Figure 4-9**). It also underlies much of the LCR Basin, extending from the Mogollon Rim in the south to an area west of the LCR River and northeast into New Mexico (Hart and others, 2002). Locally, the C Aquifer is confined by the Chinle and Moenkopi Formations which restrict downward leakage from the overlying N Aquifer.

Flow Direction

Water in the C Aquifer generally flows in a west-northwest direction across the southern portion of the Reservation (**Figure 7-16**). C Aquifer flows beneath the central and northern parts of the Reservation reportedly are less well defined and restricted by low permeability units. Few C Aquifer wells have been completed in the vicinity of the Reservation due to poor water quality conditions and the relatively high well construction and pumping costs associated with developing this deep aquifer (Cooley and others, 1969 and Hart and others, 2002).

Natural Recharge and Discharge

The C Aquifer water beneath the Reservation is recharged nearly 100 miles to the south along the Mogollon Rim and 50 miles to the east on the Defiance Uplift (Hart and others, 2002). Blue Springs, the major discharge area in the region, is located about 40 miles west of Moenkopi along the lower LCR (**Figure 7-1**). Due to its depth, no discharge from the aquifer occurs locally.

Well Development

One C Aquifer well was claimed on the Reservation (**Table 7-10**). It was completed in the Moenkopi Area to a depth of 3,215 feet and has a water level of approximately 963 feet (**Table 7-11**). Due to poor water quality, this well is reportedly not being used (TetraTech, 2006). Yields of C Aquifer wells near the Reservation have ranged from 10 to 35 gpm (SWCA, 2008).

Water Quality

The concentration of total dissolved solids in the C Aquifer is expected to range from 3,000 to 10,000 mg/l beneath the Reservation (ADWR, 1989). This salt content would make the water unsuitable for most uses without treatment. The Hopi have stated that a $1.4 million reverse-osmosis treatment system is needed to make water from the C Aquifer well potable (Arizona Daily Sun, 2007).

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CHAPTER 8: WATER DEMANDS

This chapter describes historic, recent, and future water demands on the Reservation. Water demands are described for the following use sectors:

- Agriculture **(Section 8.1)**
- Domestic, Commercial, Municipal, and Light Industrial **(Section 8.2)**
- Heavy Industrial **(Section 8.3)**
- Livestock **(Section 8.4)**
- Recreation **(Section 8.5)**
- Tourism **(Section 8.6)**
- Ceremonial **(Section 8.7)**
- Riparian Evapotranspiration **(Section 8.8)**.

For purposes of this HSR, recent water demands include those that have occurred since about 1985, when the original claims were filed by the Hopi and United States Demands occurring before that time are considered historic in this report. The discussion of future water demands is based largely on what has been claimed and on what readily available information ADWR could find that supports or refutes those claims (see 2002 Order, as described in **Chapter 1**).

8.1 AGRICULTURE

The largest claims for water on the Reservation are for irrigation of agricultural lands. About 63% of the Reservation, or over 1 million acres, have been determined to have soils that could potentially grow crops if irrigated (ADWR, 2008j). The Hopi have a long history of farming in the region and have developed traditional practices to adapt to a limited water supply and relatively harsh climate. The latter is characterized by strong winds, early and late frosts, and a semi-arid climate. Many traditional Hopi farming practices are still being used to grow crops on the Reservation today.

This section describes historic, recent, and future water demands for agriculture on the Reservation and how these demands have been, and would be, met. Methods to quantify agricultural water demands are summarized first and provide a context for later discussions.

8.1.1 Quantification

To ADWR's knowledge, the quantity of irrigation water applied to Hopi fields has not been measured directly. ADWR estimated agricultural water demands on the Reservation utilizing the following commonly used factors:

- the type of crops being grown;
- the net irrigation requirement of the crops (i.e., the amount of water needed to supplement local precipitation);
- the efficiency of the irrigation system; and
- the cropped acreage.

Recent and historic surveys of Hopi fields indicate that corn has typically been the most common crop grown on the Reservation, followed by orchards, beans, melons, and squash. Using local climate data and accounting for the traditional farming practices of the Hopi, ADWR (2008l) estimated the water demands of these crops. Results are summarized in **Table 8-1** and include a range of values that accounts for variations in climate across the Reservation and whether the crops are grown using traditional Hopi farming practices or more modern agricultural methods. The table also includes composite and net irrigation requirements based on a typical crop mix for the Reservation and accounting for the effective precipitation in the area. Composite irrigation requirement is defined here as the irrigation requirement of different crop types weighted by their percentage in the crop mix. Net irrigation requirement is calculated by reducing the composite irrigation requirement by the annual effective precipitation.

ADWR determined that crops grown following traditional Hopi farming practices have a net irrigation requirement of 0.35 to 0.86 acre-feet per acre. If the same crop mix were grown using modern agricultural methods, this demand would increase to between 1.72 and 2.46 acre-feet per acre. The lower net irrigation requirement of traditional

farming practices reflects the Hopi's ability to adapt to a limited, local water supply. A copy of ADWR's crop water demand study is provided in **Appendix F**.

ADWR's estimate of the net irrigation requirement of traditionally farmed Hopi fields is comparable to the "irrigation depletion" claimed by the United States and Hopi. A consultant for the United States used a computer model to simulate the quantity of surface water depleted by irrigation of Hopi fields. When adjusted for the acreage of irrigated fields that were claimed, these depletions are equivalent to an average water demand of 0.61 acre-feet per acre, with a maximum water demand of 0.99 acre-feet per acre. Presumably, the model simulations include a factor to account for the efficiency of Hopi irrigation systems. ADWR's request for a copy of the surface water model was denied.

The efficiency of an irrigation system compares the quantity of water actually used by a field crop to the quantity that is diverted or pumped to the field. Water losses decrease system efficiencies and can occur from evaporation and seepage along irrigation canals and within fields and from runoff of excess irrigation water (return flows). Efficiencies of irrigation systems can be highly variable and depend on the design and maintenance of the system. In the Silver Creek Watershed, ADWR (1990) identified 15 categories of irrigation system efficiency with values ranging from 32% to 80%. ADWR is unaware of studies to assess the efficiency of traditional Hopi irrigation systems, and it is unlikely that the values assumed for the Silver Creek area would be transferable to most Hopi fields as the former are representative of more modern agricultural methods.

More modern agricultural methods are being used by the Hopi in the Moenkopi Area. As described further in **Section 8.1.3**, a relatively large reservoir has been constructed along Pasture Canyon to capture spring discharge and is currently being used to irrigate 179 acres near Moenkopi Wash. The United States reported that crops grown on allotted lands served by the Pasture Canyon irrigation system have an annual "depletion rate" of 1.81 acre-feet per acre (see **Appendix A-4**). The rate is within the range ADWR estimated for crop water demand on the Reservation if modern agricultural methods are used (1.72 to 2.46 acre-feet per acre). An annual "diversion rate" of 2.01 acre-feet per acre was also reported by the United States for the allotments. Comparison of the depletion and diversion rates indicates an irrigation efficiency of 90%.

The last factor used in estimating irrigation water demand is cropped acreage. **Figure 8-1** shows how the area farmed by the Hopi has varied since the 1870s. Available data indicate that, since that time, cropped acreage on the Reservation has ranged from 1,000 to 9,330 acres each year, with farming peaking in the 1950s and 1960s. In most years, the area cropped has totaled between 3,500 and 6,500 acres. Further discussion of recent and historic water demands for Hopi agriculture is provided below, followed by a description of future irrigation plans.

8.1.2 Historic (Pre-1985)

Traditional Farming

Table 8-2 summarizes traditional farming practices used by the Hopi to grow crops. Floodwaters have been diverted onto the floodplains and terraces of large washes, fields have been placed at the mouth of small washes (ak-chin farming), and check dams have been constructed along small washes (trinchera fields). Springs have also been developed to water terrace gardens at and near the Hopi villages and sand dunes on the sides and tops of mesas have been dryland farmed.

Because of channel downcutting that began in the late 1800s, fields along large washes are less common than previously recorded. However, ak-chin farming has increased over the period and trinchera fields can still be found on the Reservation. In 2005, ADWR identified active fields associated with 7 claimed and 31 unclaimed impoundments. Springs continue to water terrace gardens, although wells and hoses are now being used at some of these to supplement the water supply. Finally, farming of sand dunes continues to be prevalent and was the most common farming practice observed by ADWR in 2005.

Historic accounts suggest the Hopi have used these farming practices for centuries (Andersen, 2008). The Spanish reported Hopi growing a surplus of beans, corn, cotton, squash, and other vegetables as early as 1583 near the Hopi Mesas, and as early as 1604 in the Moenkopi Area. Several crops including fruits (apples, apricots, and peaches), onions, peppers, and wheat were introduced by the Spanish and later adopted by the Hopi. In an early survey of the District 6 area, Mayhugh (1892) identified 12 springs and pools that he reported were being used by the Hopi to water gardens and peach orchards.

Archeological evidence suggests the Hopi may have farmed other areas as far east as Canyon De Chelly, as far south as the LCR, as far west as the Kerley Valley, and the Coal Mine Mesa and Moenkopi Plateau region that currently lies on Navajo land between the Hopi Partitioned Land (HPL) and Moenkopi Area.

Use of Reservation land for farming has, and apparently continues to be, bound by land ownership rules (Andersen, 2008). Each Hopi village reportedly has claims to the best farmland, and clans within the villages have their own claims based on tenure. **Figure 8-2** shows clan lands mapped at Second Mesa during 1931. Within clans, Hopi families can own individual farm tracts and may try to have two or more fields located on different streams and/or in different areas to improve their chances for a successful crop. Prior to Navajo encroachment, some Hopi would reportedly travel up to 45 miles to tend to corn and wheat fields, including traveling from their villages to seasonal fields in the Moenkopi Area.

Although traditional farming practices have been modified somewhat to incorporate new tools, similar techniques are generally still being employed today (Andersen, 2008). For example, rather than using hoes to cultivate fields by hand, horses and now tractors are employed to plow or disk fields in the spring prior to planting, during the growing season to control weeds, and in the fall after harvest. On sand dunes, tin cans and tires have replaced rock and brush fences as wind breaks. Fields are, however, still harvested and largely planted by hand and pesticides are generally not used. In her study of Hopi farms, Manolescu (1995) found that up to one-third of crops grown on the Reservation were lost to pests. She also found that the best fields were still those less than three acres large, located along or near streams, and hand planted.

What has notably changed about traditional Hopi farming is the number of acres farmed *per person*. Prior to 1930, Bradfield (1971) estimated that an equivalent of 2.5 acres of crops was grown annually for each Hopi. Due to various factors, including the growth of non-traditional jobs, this ratio had dropped to 1.75 after 1930. Based on data collected by ADWR in 2005, the ratio appears to have dropped even further. If it were assumed that 8,000 Hopi were living on the Reservation in 2005 and they successfully cropped 5,000 acres that year, the ratio now would be less than 1. The ratio would be

even lower if the entire population of the Reservation at the time (about 12,000) were assumed.

Irrigation Projects

The first attempt at more modern farming methods on the Reservation appears to be the efforts of Mormon settlers in the Moenkopi Area (Andersen, 2008). Mormons were established in the area by 1875 and afterward, Hopi began to return to fields they had previously farmed before Navajo encroachment. Prior to the Navajo, the Hopi reportedly used traditional farming practices in and around Moenkopi, including use of the relatively abundant spring water along Pasture Canyon.

Sometime before 1903, the Mormons built an upper dam and middle dam along Pasture Canyon that were raised in 1908 (Andersen, 2008). The middle dam was later abandoned, and the upper dam rebuilt by the federal government in the 1920s and 1930s, and raised again in the 1970s to form present day Pasture Canyon Reservoir. It is unclear whether a third dam presently located along lower Pasture Canyon (Lower Lagoon Reservoir) was built by the Mormons prior to 1912 or afterward by the federal government. Either way, by 1914, crops including corn, wheat, melons, squash, and fruit were being grown using the Pasture Canyon irrigation system. When the federal government first took back ownership of the Moenkopi, the Hopi and Navajo apparently shared use of the irrigation system. The number of acres cropped by Hopi in the area increased from 385 in 1907 to between 600 and 860 in the 1930s, and 550 in 1963. However, it is not clear to ADWR what portions of these lands were being irrigated from Pasture Canyon Reservoir. In 1958, it was reported the Pasture Canyon irrigation system was serving an area of approximately 300 acres, but only 40% of this area (120 acres) was being cropped at that time (Chambers & Campbell, 1962).

The federal government constructed other irrigation projects on the Reservation, but none have been as successful as Pasture Canyon. **Table 8-3** lists these projects including their general location, date of completion, system components, annual acreage cropped, years in operation, and status. The projects were generally completed between the 1890s and 1940 and all appear to have been lost by 1960, either through flooding, abandonment, or both. More recently (circa 2000) an irrigation system was completed

along Dinnebito Wash consisting of an instream pump and drip lines. ADWR visited the site in 2005 and found about 1.2 acres was being cropped. According to a Hopi guide, the system was constructed with grant money by an Israeli contractor.

Claims

The claims by the Hopi and United States for past irrigation on the Reservation are the same as for present irrigation. They claim a maximum diversion of approximately 49,200 AFA of surface water and spring discharge to irrigate a total of 37,514 acres of farmland, with another 1,042 acres claimed as "precipitation farmed" but with no corresponding diversion amount. They indicate that actual diversions for irrigation on the Reservation have averaged about 29,000 AFA, but are claiming the larger amount to provide an adequate water supply during years when less water is available.

These claims represent a composite of all lands the Hopi and United States determined, through analysis of historic aerial photographs, had at one time been farmed on the Reservation. ADWR obtained a copy of the photographs they analyzed and attempted to verify that these lands were cropped in the past. Results from ADWR's analysis are presented in a separate report (ADWR, 2008n) and summarized below. A copy of the report is included in **Appendix G-1**.

A total of 8,210 individual agricultural fields were claimed. ADWR reduced this total to 2,214 by joining fields that bordered each other. Thirty-four percent (34%) of the resulting, joined fields were reviewed by ADWR, covering 29,399 acres or about 76% of the total claimed area. During its review, ADWR used the following levels of evidence to verify that a field had been previously cropped:

- Complete – convincing photographic evidence of agriculture within the entire claimed area;
- Partial – convincing photographic evidence of agriculture within part of the claimed area;
- Questionable – inconclusive photographic evidence of agriculture within the claimed area; and
- No – no convincing photographic evidence of agriculture within the claimed area.

Since the claim represents a composite of all farming activity that had previously occurred on the Reservation, ADWR only attempted to verify that a given field had been cropped at least once during the period. Once complete evidence was found, ADWR did not review other photography. Alternatively, if no evidence was found in a given year, other photography was reviewed and the best available evidence reported. ADWR did not attempt to verify the type of irrigation that had been claimed for each field, only whether there was photographic evidence the claimed agricultural lands had been previously cropped.

Of the 76% of claimed acreage that ADWR reviewed:

- Approximately 11% was found to have complete evidence of agricultural activity;
- Approximately 55% was found to have partial evidence of agricultural activity in one or more years; and
- Approximately 34% was found to have either questionable or no evidence of agricultural activity in the available photography.

ADWR used these results to estimate the evidence of agricultural activity for the claimed fields that it did not attempt to verify. The total claimed area (38,565 acres)[1] was multiplied by the percentage of fields that ADWR determined had complete, partial or questionable, or no evidence of agriculture. Based on this extrapolation, ADWR estimates that there is convincing or partial evidence of farming on 25,261 acres of the Reservation that were claimed as agricultural lands and questionable or no evidence of farming on the other 13,304 acres that were claimed for that purpose. A separate drainage analysis by ADWR (2008m) suggests that all or part of most of the claimed fields may obtain water from surface runoff.

8.1.3 Recent

In 2005, ADWR surveyed some of the agricultural lands on the Reservation. Survey results are summarized in **Table 8-4** and representative field photos are presented in **Appendix G-2**. A total of 514 fields were mapped covering an area of about 651

[1] The total acreage of agricultural lands listed in the claims (38,556) was slightly lower than that shown on maps provided to ADWR by the claimants (38,565). ADWR completed its analysis on the latter.

acres. Field size ranged from less than 0.01 acre to over 26 acres, with the 10 largest fields covering 24% of the total mapped area. The water source for most fields appeared to be either precipitation/overland flow or surface water that was diverted from nearby washes or otherwise reached the fields during flood events. Several (74) of the fields surveyed were found to obtain their water from springs, and 5 fields were supplied by wells. The latter were gardens that covered a total area of less than 0.1 acre. Unlined ditches were the most common means found to convey water to the fields from washes and springs, while hoses were used to convey water from the wells.

Agricultural lands in the Moenkopi Area of the Reservation are unique and were surveyed by ADWR during 2005, 2006, and 2008. **Figure 8-3** shows the main irrigation system for this area. Water for most fields originates as spring discharge along upper Pasture Canyon that is stored downstream in Pasture Canyon Reservoir. Flows into the reservoir are gauged, presumably by the Bureau of Indian Affairs, but ADWR did not obtain the inflow data. Below the reservoir, the water is piped both below and above ground surface to a main canal that feeds a series of unlined lateral ditches. A total of 179 acres were found to be served by this relatively modern irrigation system, most of which are located on Hopi allotments. Another 55 acres of agricultural lands were identified in the immediate vicinity of the Pasture Canyon irrigation system, but these lands appear to be farmed using traditional Hopi practices. Abandoned instream pumps were observed along Moenkopi Wash that may have previously been used to irrigate some fields in the area. A new wastewater treatment plant has been completed near the western boundary of the Moenkopi Area. According to Hopi guides, reclaimed water from the plant is planned to be used to irrigate Hopi and adjoining Navajo lands.

ADWR used data from its 2005 field survey along with 2005 aerial photography and satellite imagery to identify all of the agricultural lands across the Reservation. Results from the study are presented in a separate report by ADWR (2008c) that includes further discussion of the data sources used, analysis of the remote sensing data, and accuracy and quality control assessments. Also included in the report is a map for each topographic quadrangle that covers the Reservation showing the location of fields classified as agricultural lands, which of the fields were surveyed by ADWR in 2005, the lands that ADWR classified as riparian (see **Figure 4-5**), and the location of surface

water drainages. ADWR (2008m) used digital elevation model (DEM) data and geospatial modeling to further delineate drainages on the topographic maps. Drainages with runoff areas of 0.01, 0.1 and 1.0 square kilometers are plotted on the maps and provide an indication of which fields may obtain water from surface water runoff. Copies of the two ADWR reports are included in **Appendices G-3** and **G-4**.

During 2005, ADWR identified a total of 5,613 acres of agricultural lands on the Reservation of which 63% were classified as actively cropped, 6% were classified as maintained but apparently left fallow during that growing season, and 31% were classified as either actively cropped or recently fallowed.[2] Some of the recently fallowed fields may have been planted in 2005, but due to a lack of water or other factors, the crops were unsuccessful. Most agricultural lands identified on Reservation lands were located in District 6 (79%), with the remainder located on the Hopi Partitioned Land (12%) and in the Moenkopi Area (9%). Fields averaged about 2.5 acres in area, with a median area of 1.1 acre. The runoff analysis showed that surface water drainages pass through or in close proximity to most of the fields and could provide a source of water. Most other fields are apparently dryland farmed or obtain water from springs and/or wells. See **Appendix G-3**.

It is difficult to directly compare ADWR's water demand estimates with the past and present claims for irrigation water. As described in **Chapter 2**, the Hopi and United States have each claimed a maximum diversion of about 49,200 AFA of surface water and spring discharge to irrigate a total of 37,514 acres. Another 1,042 acres were claimed as "precipitation farmed" but did not have a corresponding diversion amount. These claims represent a composite of all lands that they determined were previously farmed on the Reservation, and assume that all of these lands are farmed at the same time. Actual diversions for irrigation are claimed to average about 29,000 AFA, but a maximum amount is claimed to provide adequate water for years when water is less available.

The historic and recent data compiled in **Figure 8-1** indicate that, since the 1870s, the total acreage cropped by the Hopi in any given year has not exceeded 9,330 acres, and has typically ranged between 3,500 and 6,500 acres. The total area that ADWR

[2] Accuracy and quality control assessments indicated that the actual acreage of agricultural lands on the Reservation during 2005 was somewhere between 5,570 to 6,506 acres.

estimated was cropped by the Hopi in 2005 (5,570 to 6,506 acres) is within this range. Long-term precipitation records from Keams Canyon and Tuba City indicate that the months immediately preceding the 2005 planting season were relatively wet and may have supported good crop yields that year using traditional farming practices. At Keams Canyon, precipitation totaled approximately 6.9 inches from January through April of 2005 compared to an average of approximately 3.2 inches. At Tuba City, precipitation from January through April of 2005 totaled approximately 2.9 inches compared to an average of approximately 1.9 inches.

Using traditional farming practices, the acreage previously cropped by the Hopi would have had a substantially lower annual water demand than the Hopi and United States claimed or consider as average. Moreover, it is unclear to ADWR whether the springs that are claimed to provide water to some fields are being claimed twice. Seventeen springs were separately claimed for irrigation use and another 52 claimed springs were found by ADWR, or have been reported by others, to have been used for irrigation **(Appendix D**). Whitely (2005) visited 14 springs between 2003 and 2004 that reportedly were still being used for irrigation of gardens.

8.1.4 Future

The Hopi, but not the United States, have also claimed water for future irrigation. In addition to new garden plots located near their villages (see discussion of future ceremonial uses in **Section 8.7**), they have claims for two new irrigation projects. The location of the projects is shown in **Appendix A**.

The Moenkopi Irrigation Project would require 3,000 AFA to irrigate 1,200 acres in the Moenkopi Area. Water for the project would come directly from Moenkopi Wash and, as needed, from a 4,200 AF capacity off-stream reservoir. The irrigation system would also include a diversion canal, sedimentation reservoir, and service area.

The Mainstem LCR Irrigation Project would require 21,060 AFA to irrigate 7,400 acres on HPLs near the southwestern border of the Reservation. Water for this project would be diverted from the LCR and pumped to two storage reservoirs with a combined capacity of 11,500 AF. The diversion, reservoirs and associated pipelines and pumps would be located on Navajo lands. Note that the Hopi claims include another 15,700

AFA for the first time filling of the three proposed reservoirs and 2,842 AFA for reservoir evaporation.

As described in **Section 6.1.1**, the arable land base of the Reservation is estimated to exceed 1 million acres. The Hopi and United States claim that 38,556 acres on the Reservation have been previously cropped.[3] The new irrigation projects described above, including the new village gardens claimed, would cover an additional 11,736 acres for a total of 50,292 cropped acres.

The equivalent water demand of the Moenkopi and Mainstem LCR Irrigation Projects is 2.5 acre-feet per acre and 2.8 acre-feet per acre, respectively. ADWR estimated that the net irrigation demand of crops typically grown on the Reservation would range from 1.72 and 2.46 acre-feet per acre if modern irrigation methods are used. ADWR's estimates do not consider irrigation system efficiency which could reasonably increase these water demands to 3.0 acre-feet per acre or higher. For example, a total of 2.86 acre-feet per acre would need to be diverted to a field with a net irrigation demand of 2 acre-feet per acre and an irrigation system efficiency of 70%.

The flow data presented in **Section 7.1** suggests that there is enough surface water physically available for these projects. Since 1926, an average of over 8,000 AFA has flowed past the proposed diversion point along Moenkopi Wash and, from 1925 through 1995, an average of over 190,000 AFA has flowed near the proposed diversion point along the LCR. The proposed storage reservoirs would presumably address the seasonal and long-term variations in flow that have been reported for these streams. However, water quality data also presented in **Section 7.1** suggest that sediment loads in the streams could pose a challenge to both projects. Regular maintenance would likely be required to avoid siltation of diversions structures, reservoirs, and irrigation canals.

[3] ADWR only found convincing or partial evidence of past farming on a total of 25,261 acres of the Reservation.

8.2 DOMESTIC, COMMERCIAL, MUNICIPAL AND LIGHT INDUSTRIAL

This section describes historic, recent, and future water demands for domestic, commercial, municipal and light industrial uses on the Reservation. Methods to quantify these demands are discussed first.

8.2.1 Quantification

Unless these demands are measured directly, DCMI water use is often calculated based on population data and an assumed per capita usage. **Figure 8-4** shows how the population on the Reservation has varied historically, and **Table 6-7** lists recent and projected Hopi populations. The available data indicate the Reservation populations have ranged from less than 1,000 to 12,000. The following per capita usage has been reported for the Reservation:

Recent

- 10 to 35 gallons per capita per day or gpcd (Hopi, 2005b)
- 40 gpcd (Hopi, 2001)

Future

- 105 gpcd by 2010 and 160 gpcd by 2020 (BOR, 2006)
- 160 gpcd (Hopi and United States claims).

Water to meet these demands has come from both wells and springs. **Figure 8-5** shows the location of 206 wells and 339 springs on and near the Reservation that were claimed for domestic and/or municipal use. As described in **Sections 7.3** and **7.4,** the Hopi and United States identified additional wells and springs on the Reservation after they filed their SOCs in 2004. For purposes of this preliminary HSR, ADWR considered these additional wells and springs as claimed. **Figure 8-5** also shows the location of 39 unclaimed wells and springs identified by ADWR that reportedly have also been used for domestic or municipal purposes.

8.2.2 Historic (Pre-1985)

Before wells were completed on the Reservation, the Hopi probably obtained most of their water from springs and by capturing rainwater. In an early survey of the District 6 area, Mayhugh (1892) identified 21 springs and pools that were reportedly being used by the Hopi for domestic purposes. Early water development projects included drilling test wells along Oraibi and Polacca Washes in 1910. In the years that followed, several more wells were drilled along Hopi washes, most of which were equipped with windmills, were less than 100-feet deep, and yielded less than 600 gallons per hour (10 gpm). By 1932, 19 wells had been dug, 30 wells drilled on the Reservation, and 83 springs developed. By 1944, District 6 alone had 13 dug wells, 26 drilled wells, and 31 developed springs (Andersen, 2008).

The Navajo-Hopi Rehabilitation Act of 1950 brought new infrastructure projects to the Reservation, including construction of domestic water and sewer systems and additional wells with windmills. Most of the public water systems that currently serve the Reservation were constructed during the late 1950s through the late 1980s. By 1988, the Tribe reported that 2 of its villages were still without public utilities, and 58% of the homes in 10 other villages did not have water connections and had to haul water (Andersen, 2008). **Appendix E** lists dates of completion for the claimed and unclaimed domestic and municipal wells that ADWR identified on the Reservation.

Historic water demands for DCMI uses on the Reservation are estimated by ADWR to have totaled less than 300 AFA. This estimate is based on historic accounts of the Reservation population (**Figure 8-4**) and assumes a previous per capita usage between 10 and 20 gpcd. The latter is consistent with a reported per capita usage between 10 and 15 gpcd for those that still haul water on adjacent Navajo lands (BOR, 2006).

8.2.3 Recent

Residents of the Reservation are currently served by 16 public water systems. Since 1990, the measured water demand of these systems has totaled from 292 to 501 AFA (**Table 6-3**). This is equivalent to approximately 32 to 43 gpcd when the population data in **Table 6-7** are taken into account. Some Hopi still haul water from springs and

livestock wells and do not use public taps (SWCA, 2008). ADWR does not know the number of Hopi using water from non-public sources, and did not consider them when calculating per capita usage. Whitely (2005) visited at least one spring between 2003 and 2004 that was reportedly still being used for domestic purposes. The Hopi claim that current DCMI water demands on the Reservation total about 700 AFA (Hopi, 2004).

By comparison, a quantity of 716 to 742 gpm (1,154 to 1,196 AFA) has been claimed for past and present use from 204 domestic and municipal wells on the Reservation. A total of 337 springs have also been claimed for past and present domestic uses with a claimed quantity of 1,609 gpm (2,595 AFA).[4] Most of these wells and springs were also claimed for stock use, but the claims do not specify a separate quantity for each use. ADWR was unable to verify 12 of the claimed domestic wells and 31 of the springs claimed for domestic use, some of which may be duplicate claims. Some of these wells were also previously reported or found by ADWR to be abandoned, dry, or inactive/unused (see **Appendices D** and **E**).

8.2.4 Future

The Hopi and United States claim 11,211 AFA to meet long-term DCMI demands. This claim assumes that the population of the Reservation grows annually at 2.2% and stabilizes in 2175 at 62,515. It also assumes that per capita usage on the Reservation increases to 160 gpcd. Future water uses include residential indoor and outdoor use, public use, commercial and industrial use, and system losses. The United States claims this water from the N Aquifer and the Hopi claim it from groundwater or, as necessary, from possible other water sources outside of the Reservation.

The claims describe how future populations would be distributed across the Reservation. Much of the growth is planned to occur in or around five Planned Community Development Districts (PCDDs):

- Howell Mesa East
- Moenkopi
- Side Rock Well

[4] The well and spring totals include both the 2004 claims and 2005 supplemental information.

- Tawaovi
- Yu Weh Loo Pahki.

Each PCDD would contain commercial, institutional, recreational, and residential development and eventually be capable of local governance (Hopi, 2001). To date, master plans have been developed for all but the Howell Mesa East PCDD (SWCA, 2008). The location of the PCDDs is shown in **Appendix A**.

The future per capita usage assumed in the claims is within the range recently reported for large communities in the region. In 2000, the cities of Williams and Page had an estimated per capita water use of 198 and 351 gpcd, respectively. For Flagstaff, per capita water usage was estimated at 120 gpcd in 2005 and 132 gpcd in 2002 (BOR, 2006).

8.3 HEAVY INDUSTRIAL

This section describes historic, recent, and future water demands for heavy industrial use. Coal mining is the only heavy industry that ADWR identified on or near the Reservation that has used appreciable quantities of water. The PWCC has commercially mined coal from a leasehold located in the far northeastern corner of the Reservation and on adjacent Navajo lands (**Figure 6-3**). The so-called Black Mesa Complex consists of the Black Mesa Mine which opened in 1970 and the Kayenta Mine which opened in 1973.

Water for the PWCC mines has come from eight production wells completed in the N Aquifer of which seven are located on Navajo lands and one is located on the HPL **(Figure 7-30**). In addition to receiving royalties and bonuses for the coal mined, the Hopi have received royalties for water pumped from the PWCC well field (**Table 6-5**). In 1987, the Hopi Tribal Council negotiated new rates for coal and water that significantly increased these royalty payments (Andersen, 2008).

8.3.1 Historic

Commercial coal mining in the Black Mesa region began in the early 20th century with 10 mines estimated to have produced less than 300,000 tons of coal between 1926 and 1967 (see **Section 6.1.3)**. ADWR does not have records of the water use associated with these mines, but it is expected to be minor compared to more recent well pumpage by PWCC.

Truini and Macy (2007) report that well pumpage by PWCC began in 1968 and totaled 100 acre-feet that year. This was followed by 40 acre-feet pumped in 1969, 740 acre-feet in 1970 and 1,900 acre-feet in 1971. From that point, well pumpage notably increased and averaged about 3,800 AFA through 1985. The highest well pumpage reported for any given year occurred in 1982 (4,740 AF).

8.3.2 Recent

Table 7-13 lists annual average and total volumes of water pumped from the PWCC well field between 1965 and 2005. From 1986 to 2004, an average of 4,111 acre-feet was pumped each year. A total of 4,480 acre-feet was pumped in 2005 before the Mohave Generating Station (MGS) was closed in December 2005 due to air quality issues. The MGS received coal from the Black Mesa Mine via a slurry pipeline. Closure of the Black Mesa Mine followed, while operations at the Kayenta Mine have continued.

The Hopi claim 6,000 AFA of groundwater for continued operation of the Black Mesa Mine and coal slurry pipeline (400 AFA and 5,600 AFA, respectively), and the United States claims 3,000 AFA of groundwater from the N Aquifer for these uses.

8.3.3 Future

The Hopi also claim 6,000 AFA of groundwater for future operation of the Black Mesa Mine and coal slurry pipeline, and another 19,000 AFA of groundwater (or other, off-Reservation water source as necessary) for new mineral and industrial uses. The latter includes 15,000 AFA for a new, 1,200 megawatt coal-fired power generating plant and 4,000 AFA for future development of coal, oil, gas and minerals. The United States claim for future industrial water use is the same as their current claim of 3,000 AFA of N Aquifer water for coal-mining related activities.

In 2002, the Hopi Tribe entered into a joint development agreement with Reliant Energy to evaluate construction of a 1,200 megawatt, dry-cooled power plant. Three years later, in 2005, the Tribe began discussions with Headwaters, Inc. to construct a coal liquefaction plant and 300 megawatt power generating station. Both projects were abandoned, lacking a sustainable water supply (SWCA, 2008).

A final EIS for the Black Mesa Complex was issued in November 2008. The preferred alternative assumes that the coal slurry pipeline from the Black Mesa Mine remains closed and PWCC well pumpage decreases as follows (OSM, 2008):

- Through 2025 – average of 1,236 AFA for Kayenta Mine operations and public use;
- 2026 through 2028 – up to 505 AFA for mine reclamation and public use; and
- 2029 through 2038 – up to 444 AFA for post reclamation maintenance and public use.

8.4 LIVESTOCK

This section describes historic, recent, and future water demands for livestock on the Reservation. Methods to quantify these demands are discussed first.

Livestock grazing has been, and is currently, the largest land use on the Reservation with an estimated 819,000 to 1,326,000 acres of useable rangeland in the 1882 Executive Order Reservation and an unknown acreage in the Moenkopi area (see **Section 6.1.2**). Reservation lands have been divided into 53 range units – 15 in District 6 and 38 on the HPL. Separate range units apparently have not been established in the Moenkopi Area.

Regulation of livestock on the Reservation is described in Tribal Ordinance 43– *Control of Livestock and Grazing on the Hopi Reservation.* The ordinance governs "the allocation of grazing and accommodation permits to, and the use of the Hopi Reservation for grazing purposes by tribal members and Accommodation Agreement (Navajo) signatories, and shall otherwise control the presence of livestock on the Hopi Reservation" (Hopi, 1998). Provisions of the ordinance are carried out by staff of the

Hopi Tribal Office of Range Management (ORM) and Hopi Resources Enforcement Services (HRES), while the BIA has authority over Navajo still grazing the HPL.

Water sources for Hopi livestock have included impoundments (stockponds), wells, and springs. **Table 6-2** lists the number of water sources claimed for livestock in each range unit and in the Moenkopi Area. **Figure 6-2** shows the location of these water sources. As described in **Sections 7.3** and **7.4,** the Hopi and United States identified additional wells and springs on the Reservation after they filed their SOCs in 2004. For purposes of this preliminary HSR, ADWR considered these additional wells and springs as claimed.

8.4.1 Quantification

The water demand of livestock can be calculated based on the number and type of livestock and their water needs. A recent Hopi Drought Plan assumes 19.5 gallons of water per day (gpd) per animal unit (AU) based on a livestock water demand of 15 gpd and a 30% delivery loss from the water source (DBSA, 2000). The Hopi (1998) calculate AUs as follows:

- 0.8 horse or burro = 1 AU
- 1 cow = 1 AU
- 4 sheep or goats = 1 AU.

ADWR (2000) assumes that a cow or horse needs 12 gpd and a sheep needs 1.5 gpd, which is equivalent to 6 to 12 gpd per AU. Historic and recent livestock inventory data and associated water demands are presented below.

8.4.2 Historic

Table 8-5 lists historic accounts of the number and type of livestock grazed on the Reservation. These accounts and the discussion that follows were summarized from Andersen (2008) and references therein. Assuming livestock historically needed up to 19.5 gpd/AU (DBSA, 2000), the past water demand of Hopi livestock may have approached 500 AFA.

Available data indicate that the Hopi have grazed livestock at least since 1775 and, since then, the number of Hopi livestock has varied substantially. Livestock water demands are expected to have varied as well, but were probably greater than recent demands due to more Hopi livestock in the past. Claims filed by the Hopi and United States for past livestock water use are the same as those filed for current livestock water use on the Reservation.

Other than domestication of the turkey, the raising of livestock was not an aboriginal activity of the Hopi. With the Spanish introduction of sheep, goats, cattle, horses, and burros, herding of livestock, particularly sheep, became an important part of Hopi subsistence. Livestock eventually replaced hunting as the main source of dietary protein, while wool became a preferred weaving material.

At the time of the Navajo migration, the Hopi reportedly had relatively large sheep herds ranging south to the LCR, north to Marsh Pass, west to Moenkopi, and east to Ganado Valley. As the Navajo presence in northern Arizona grew, the range of Hopi sheep reportedly decreased due to raiding and competition for rangeland. With establishment of the Hopi Reservation in 1882 and a return to more peaceful conditions, Hopi cattle and sheep grazing again increased to the point when, by 1930, livestock rivaled farming as an economic activity.

In 1892, an agreement was reached between Navajo and Hopi Indian agents that generally restricted Hopi livestock to a district including the Hopi villages and clan lands and an area extending about 15 miles from the villages along Jeddito Wash from Antelope Mesa to Tovar Mesa, west to Dinnebito Wash, and north to a line cutting across the Tusayan Washes from Third Mesa and back to Antelope Mesa. This general area later became known as District 6. Hopi livestock in the adjacent Moenkopi Area were reportedly almost non-existent around 1900 but, by 1910, one cattle herd had been formed and, by the 1930s, up to five Hopi were grazing sheep in this area, and there was another cattle herd.

Up to this point, there probably had been little development of livestock water sources on Hopi and adjacent Navajo lands. Most livestock in the region likely obtained their water from springs and along the perennial and intermittent reaches of streams. In an early survey of the District 6 area, Mayhugh (1892) identified 11 springs and pools

that were reportedly being used by the Hopi for livestock water. Early water development projects were reported in 1916 and, by 1929, the federal government had expended more than $750,000 on improvements in the area. Improvements included piping or directing spring water to troughs, drilling wells and equipping them with windmills and troughs, and building impoundments to form stockponds. By 1932, 83 springs had been developed on the Reservation, 19 wells dug and 30 wells drilled. By 1944, District 6 had 31 developed springs, 13 dug wells, 26 drilled wells, and 77 stockponds.

A government program in the 1930s to reduce the size of Navajo and Hopi herds decreased the number of sheep and coincided with the de facto restriction of Hopi livestock to District 6. About 20,000 animals were removed from Hopi lands during this period. After the Second World War, District 6 was divided into 15 range units. By then, Hopi sheep herds had decreased to the point of being a minor activity, while cattle grazing had increased. The Navajo-Hopi Rehabilitation Act of 1950 brought new stock wells to the Reservation along with new stock tanks and troughs, and fencing of range land.

After the Joint Use Area was established in 1962, Hopi livestock grazing in this area increased and helped lead to the eventual creation of the HPL. Navajo grazing in the HPL continued, however, and in 1973 an estimated 765 Navajo houses and 626 hogans were counted there. By 1978, herds in the HPL had been reduced to their carrying capacity, and Navajo still living on these lands and awaiting relocation were allowed to obtain permits for up to half of the range carrying capacity. The BIA issued 200 permits to the Navajo in 1983 to allow their grazing of up to 3,500 sheep, or their equivalents, in the HPL.

Starting in the early 1980s, the Tribe began to maintain range water sites which, at the time, included 57 wells with windmills in District 6 and 53 wells with windmills in the HPL. By 1988, the Tribe's range water program consisted of 56 springs with troughs or storage facilities, 40 windmills, and 70 miles of pipeline for 23 of the range units in the HPL. The range water program did not maintain windmills and spring sites in District 6.

8.4.3 Recent

Lower Quantification Limit

ADWR calculated a lower quantification limit for recent livestock water use based on livestock water demands. Recent inventories of Hopi livestock are listed in **Table 8-6**. Available data suggest that the number of livestock in District 6 and associated water demands are declining. Reported AUs in this area have decreased from 5,327 AUs in 1984 to 1,598 in 2006 with estimated water demands decreasing from 72-116 AFA to 21-31 AFA. Livestock inventory data for the HPL and Moenkopi Area were limited. In the HPL, 1,562 AUs were reported in 1984 and 2,539 AUs were reported in 1997, with associated water demands estimated at 21-34 AFA and 31-55 AFA, respectively. In the Moenkopi Area, 341 AUs were reported in 1991 and 365 AUs were reported in 1992, with associated water demands estimated at 5-8 AFA. If the lowest and highest AUs for District 6, the HPL, and Moenkopi Area are added, the result is an overall range of 3,501 to 8,231 AUs and 47 to 179 AFA of livestock water use on the Reservation.

Upper Quantification Limit

ADWR calculated an upper quantification limit for recent livestock water use based on available livestock water supplies, which are summarized in **Table 8-7**. ADWR found that several claimed Hopi stockponds have breached berms, one was under construction, one had been removed, and four could not be verified. Several claimed Hopi stock wells also could not be verified by ADWR and, based on the Hopi Drought Plan (DBSA, 2000), the actual yield of most of these wells is less than 1.25 gpm (2 AFA), lower than the 4 to 8 gpm typically claimed. Several (49) springs claimed for stock use also were not verified by ADWR and, based on available flow data, actual discharge rates for most springs were considerably lower than the 4 to 8 gpm typically claimed. Flow data were unavailable for nearly half of the claimed springs.

ADWR identified several unclaimed livestock water sources on the Reservation including 180 stockponds, 18 stock wells, and 7 springs. The additional stockponds are estimated to have a combined capacity of 363 acre-feet, and the wells and springs are estimated to have a combined yield of about 23 and 5 gpm, respectively. Other

unclaimed wells and springs were identified by ADWR, but they were not reported for stock use.

Based on stockpond capacities and yields from stock wells, ADWR calculated up to 2,615 AFA as an upper quantification limit for livestock water use on the Reservation. Because springs have multiple uses, ADWR did not include spring discharges in these calculations.

Use of stockponds on the Reservation by livestock has been limited by the availability of precipitation and runoff, lack of maintenance, and inability to retain water during dry periods. In addition, use of some springs by livestock is restricted by the Hopi to protect source areas for wetland habitat, ceremonial use, and cultural gardens. Hopi springs and stock wells are, in general, less vulnerable to droughts than stockponds (DBSA, 2000). In 2000, the Tribe was investing $500,000 annually to improve range management facilities on the Reservation (Hopi, 2001).

8.4.4 Future

The Hopi claimed 910 AFA to meet the future water needs of livestock on the Reservation. According to their claims, range and livestock watering plans are currently being updated and will provide additional information on claimed quantities and facilities. The United States did not specify future stock water use on the Reservation.

The carrying capacity of rangelands provides an indication of the maximum, future water needs of Reservation livestock. The Hopi (1998) define carrying capacity as the "maximum stocking rate possible without inducing damage to vegetation or related resources." The carrying capacity of the Reservation can vary from year to year due to overgrazing by livestock and/or from natural factors such as drought, fire and grazing of native animals. The potential carrying capacity of the 1882 Executive Order Reservation has been reported to range from 10,000 to 24,529 animal units per year (AUYL). Carrying capacity data for the Moenkopi Area were not available (ADWR, 2008b).

Based on these potential carrying capacities, the future water needs of livestock on 1882 Executive Order Reservation could total up to 330 to 536 AFA. These totals assume ADWR and Hopi livestock water demands of 12 and 19.5 gpd/AU, respectively.

8.5 RECREATION

This section describes historic, recent, and future water demands for recreation. Four lakes were claimed by the Hopi for recreational use – Keams Lake (Beaver Reservoir), Lake Moho, and Twin Dam Nos. 1 and 2. The Hopi claim the right to continuously fill each lake to its maximum capacity and an associated volume for lake evaporation. Recreational use was not claimed by the United States, but it did claim these lakes for stock use.

ADWR identified an unclaimed lake on the Reservation (Pasture Canyon Reservoir) that reportedly is also used for recreation. **Table 8-8** lists the following data that ADWR compiled for the unclaimed and claimed lakes:

- Location
- Water source
- Surface drainage area
- Date of construction
- Hopi Claim Number
- Dam height
- Lake surface area
- Reservoir capacity
- Estimated annual evaporation
- Siltation.

Photographs of the lakes are presented in **Appendix C**.

8.5.1 Historic

The Hopi claim the same capacity and evaporation rate for past and current use of their recreational lakes. The USDA (1980) cites substantially larger capacities for these lakes than were claimed, but ADWR is unable to determine whether the former represent as-built or current conditions (see **Table 8-8**). Each of the claimed lakes was completed in 1956 while Pasture Canyon Reservoir was constructed during the 1920s/1930s and modified in 1975 (Hagstrom, 2008).

8.5.2 Recent

The Hopi claim that their four recreational lakes, all located along Keams Canyon, have a combined surface area of 14.2 acres and capacity of 138.8 acre-feet. ADWR visited the lakes in 2005 and 2008 and found two of them (Lake Maho and Twin Dam No. 1) silted in and probably not useable for recreation. ADWR determined that the surface area and capacity of the four lakes was 17.3 acres and 92 acre-feet, respectively. See **Table 8-8**.

The Hopi also claimed 56.8 AFA for lake evaporation based on the surface areas of the lakes and a uniform evaporation rate of 4.0 feet/year. ADWR (2008f) calculated an evaporation rate of 5.3 to 6.3 feet for Keams Canyon using local climate data which corresponds to 92 to 109 AFA of lake evaporation, if ADWR's measurement of lake surface area is used.

Pasture Canyon Reservoir is located upstream of Moenkopi along Pasture Canyon and, according to Hopi field guides, it is used for recreation as well as for irrigation. ADWR determined that this unclaimed reservoir has a surface area of 34 acres and a capacity of 202 acre-feet. Using climate data from nearby Tuba City, ADWR calculated a local evaporation rate of 5.6 to 6.7 feet which corresponds to a lake evaporation of 190 to 228 AFA.

8.5.3 Future

No claims were made by the Hopi or United States for future recreational lakes. ADWR could not find any plans to build new recreational lakes on the Reservation (Hopi, 2001 and SWCA, 2008).

8.6 TOURISM

This section describes historic, recent, and future water demands for tourist purposes.

8.6.1 Historic

Neither the Hopi nor the United States filed water right use claims for past tourism.

8.6.2 Recent

Neither the Hopi nor the United States filed water right use claims for current tourism. However, since 1990, the Hopi Cultural Center, the primary tourist attraction on the Reservation, has used between 5.7 and 11.2 AFA (DBSA, 2000 and various USGS reports).

8.6.3 Future

The Hopi claim a total of 1,038 AFA of groundwater, or other water source as necessary, for future tourism. This includes 522 AFA for a resort in Moenkopi and 516 AFA for a resort in Keams Canyon, but it does not include new restaurants, grocery stores, and other public uses which are considered part of their future DCMI claims. The United States did not claim future water use for tourism on the Reservation.

As described in **Section 6.1.5**, the Tuuvi Travel Center recently opened in the Moenkopi Area and includes two fast food restaurants, a convenient store, smoke shop, gas station, and car wash. The Moenkopi Development Corporation has planned a 72-acre project adjacent to the travel center. The so-called "Gateway to Hopi Land" is planned to include a 100-room motel and conference center, and a business center with an office complex and bank. ADWR is not aware of any plans for a resort in Keams Canyon, but a new motel, restaurant, and museum/cultural center has been planned at Tawaivi, located about 20 miles north of the existing cultural center.

8.7 CULTURAL/CEREMONIAL

This section describes historic, recent, and future water demands for ceremonial purposes. As described in **Section 5.4,** springs have long played an important role in the rituals and ceremonies of the Hopi.

8.7.1 Historic and Recent

Whitely (2005) visited a total of 16 springs between 2003 and 2004 and before that he reported were still being used by the Hopi for ceremonial purposes. Based on historic and recent use, a total of 360 springs were claimed in 2004 and 2005 by the Hopi for ceremonial/cultural purposes, and by the United States for cultural use, with a claimed quantity of 1,701 gpm (2,744 AFA). Most of these springs were also claimed for stock and/or domestic uses, but the claims do not specify separate quantities for each use.

ADWR was unable to verify all of the claimed ceremonial springs. The 32 springs not verified had a claimed quantity of 128 gpm (206 AFA). For ceremonial springs that were verified, ADWR found that claimed quantities were generally greater than reported discharges. Of the 208 springs with discharge data, reported discharges totaled from 360 to 1,103 gpm (581 to 1,779 AFA) compared to a claimed quantity of 1,411 gpm (2,276 AFA).

ADWR identified another 42 springs on the Reservation that were not claimed. Of the unclaimed springs, 29 had discharge data with reported discharges totaling from 30 to 31 gpm (48 to 50 AFA). These springs may have also been used by the Hopi for cultural/ceremonial purposes.

8.7.2 Future

The Hopi, but not the United States, claimed future irrigation of garden plots for ceremonial and subsistence purposes. The gardens would be located on 3,136 acres near seven villages on the Reservation and be watered with groundwater or, as necessary, other water sources possibly outside of the Reservation. A total of 12,546 AFA of water is claimed for this future use, equivalent to a water demand of 4.0 acre-feet per acre. ADWR determined that crops grown on the Reservation following traditional Hopi farming practices have a net irrigation requirement of 0.35 to 0.86 acre-feet per acre. Even if the irrigation systems for these future fields were only 50% efficient, the actual water demand would probably be less than 2.0 acre-feet per acre.

8.8 RIPARIAN EVAPOTRANSPIRATION

While not claimed, this chapter concludes with a discussion of historic, recent, and future water demands by riparian vegetation (phreatophytes) on the Reservation. As described in **Section 4.4**, riparian vegetation occurs locally along washes and around some stock impoundments. The vegetation relies on water both from precipitation and underlying alluvial aquifers, and is distinct from that observed on adjacent woodland, grassland, and scrubland. This discussion is included here because riparian evapotranspiration is a substantial water demand on the Reservation.

8.8.1 Historic

Historic evidence suggests that the extent and density of riparian vegetation on the Reservation increased substantially during the 20th century (Webb and Leake, 2006 and Webb and others, 2007). Riparian vegetation was apparently sparse throughout the region in the late 19th and early 20th centuries during a period of natural arroyo entrenchment and channel widening. Beginning in the 1930s and 1940s, channels stabilized and floodplains developed that supported relatively dense riparian vegetation. During this time, construction of impoundments also became widespread on the Reservation (Anderson, 2008), and saltcedar that had been introduced began to colonize streams in the region, occupying reaches that did not otherwise support native riparian vegetation.

The riparian water demands in the late 19th and early 20th century are likely less than estimates of recent riparian water demands discussed below. **Figure 8-6** shows how riparian vegetation changed along Moenkopi Wash near Tuba City from 1932 to 2001, and changed along the LCR at Cameron from 1914 to 2000.

8.8.2 Recent

Using 2005 aerial photography and satellite imagery, ADWR (2008c) mapped approximately 14,500 acres of riparian vegetation along Reservation drainages of which about 1,000 acres were associated with impoundments. **Table 8-9** lists the acreage of riparian vegetation by Reservation subregion and associated water demands.

The annual water demand of the vegetation is estimated to range from 2.3 to 4.4 acre-feet per acre. This estimate is based on an evapotranspiration study conducted recently in New Mexico under similar climatic conditions and with the same riparian vegetation (Cleverly and others, 2006 and Shafike and Cleverly, 2007). Riparian plant species identified on the Reservation include cottonwood, willow, Russian olive, and saltcedar (ADWR, 2008a). The latter two are invasive species that are not native to the area. It is assumed that an average of 0.5 to 0.7 acre-feet per acre of the riparian water demand is met by effective precipitation (ADWR, 2008f). The remaining demand is largely met with water removed from underlying alluvial aquifers via root uptake. Across the Reservation, it is estimated that alluvial aquifers may discharge a total of up to 23,100 to 56,400 AFA to riparian vegetation.

8.8.3 Future

Two Arizona Water Protection Fund projects were recently approved on the Reservation that included plans to remove Russian olive and saltcedar from certain stream reaches and revegetate the areas with native riparian species (ADWR, 2008a). It is unknown whether these plans have been implemented and, if so, whether they were successful. Such efforts on a larger scale could lower Reservation riparian water demand by decreasing the extent and/or density of the exotic vegetation.

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CHAPTER 9: ADWR'S ANALYSIS OF HOPI WATER RIGHTS AND PROPOSED WATER RIGHT ATTRIBUTES FOR PAST AND PRESENT WATER USES

This preliminary HSR concludes by describing ADWR's analysis of Hopi water rights and proposed water right attributes for past and present water uses on the Reservation. Presented first is a summary of ADWR's evaluation of past and present Hopi water uses (**Section 9.1**). A comparison of ADWR's evaluation to the water use quantities claimed by the Hopi and United States follows (**Section 9.2**). The chapter ends with ADWR's recommended water right attributes for past and present water uses on the Reservation[1] (**Section 9.3**).

9.1 SUMMARY OF ADWR'S EVALUATION OF PAST AND PRESENT TRIBAL WATER USES

Table 9-1 provides a summary of ADWR's evaluation of past and present tribal water uses on the Reservation. The summary is based on data previously presented in this preliminary HSR and includes information on water sources, quantification, and locations for six types of water use. Specific data sources are listed in the table for each water use type with selected sources mentioned below. Types of water use include agriculture (irrigation); domestic, commercial, mining, and light industrial (DCMI); heavy industrial (mining and related industry); livestock; recreation; and ceremonial/cultural. In addition to providing a total quantity (in AFA) for each use, the table also lists the factors that ADWR considered for quantification purposes and a range of factor values. A brief description of Hopi past and present water uses and ADWR's findings follow.

[1] As required by the 2002 Order, the claims of the Hopi and United States for future uses are summarized in **Chapter 2**. **Chapter 8** includes a discussion and technical information related to future Hopi water uses, but not a feasibility analysis. Information related to the economic base for the Hopi is presented in **Chapter 6**.

9.1.1 Agriculture

The Hopi used both traditional and modern farming practices to grow crops on the Reservation with water from springs and washes. For each of these farming methods, **Table 9-1** lists a range of acreages cropped annually and ADWR's estimates of crop water demand.

ADWR calculated the quantity of water used each year by the Hopi for agriculture by multiplying the range of cropped acreages by respective water demands. Based on these calculations, ADWR determined that traditional farming used from 350 to 7,921 AFA and irrigation projects used from 0 to 1,582 AFA. Irrigation system efficiency is not included in the calculations.

An ADWR drainage analysis suggests that many of the traditionally farmed fields on the Reservation are located along or adjacent to washes that may have provided a direct source of floodwater. Other fields have been dryland farmed, and springs have provided water to nearby terrace gardens. See **Appendices G-1** and **G-3**. Most streams that cross the Reservation, including those that have supplied water to the irrigation projects, originate on and drain back to Navajo lands. Surface water supplies in these streams can be unreliable due to several factors including ephemeral flow conditions, effects from frequent and long-term droughts, and elevated sediment loads.

9.1.2 DCMI[2]

Water for DCMI use has come from five aquifers that underlie the Reservation and from springs fed by these aquifers. To quantify the amount of DCMI water use by the Hopi, ADWR multiplied the Reservation population by per capita use rate. Ranges for these numbers are provided in **Table 9-1**.

Based on these data, ADWR calculated that DCMI water use by the Hopi ranged from less than 11 to 578 AFA. By comparison, up to 501 AFA was recently delivered by 16 public water supply systems that serve the Reservation. **Figure 8-5** shows the location of wells and springs that have been used to divert DCMI water, and **Figure 4-1** shows the location of population and commercial/industrial centers where the water has

[2] ADWR assumes that DCMI includes water use at the Hopi Cultural Center and other tourist attractions.

been used. Some Hopi reportedly still haul water from windmills and public supply wells, and use springs for domestic purposes.

Most municipal wells on the Reservation pump water from the N Aquifer. This aquifer underlies much of the area and is shared by the Hopi and Navajo. Development of the N Aquifer is believed to have impacted the discharge and baseflow of some Reservation streams and springs, respectively, and these impacts are expected to continue in the future.

9.1.3 Heavy Industrial

Since the late 1960s, the N Aquifer has also provided water for two coal mines and related activities on the PWCC leasehold. **Figures 6-3** and **7-30** show the location of the leasehold and PWCC's production wells, respectively. Seven of the production wells are located on Navajo lands adjacent to the Reservation and one production well is located on the HPL. Annual pumpage from the PWCC well field has ranged from a low of 40 AFA in 1969 to a high of 4,740 AFA in 1982.

9.1.4 Livestock

Water for Hopi livestock has come from aquifers, springs, and surface water impoundments. ADWR used two approaches to quantify the amount of livestock water used by the Hopi. ADWR calculated a lower quantification limit based on livestock water demands by multiplying the head of livestock counted on the Reservation by an estimate of their water needs and determined a range of 47 to 179 AFA. ADWR calculated an upper quantification limit based on available livestock water supplies on the Reservation by adding the estimated capacity of stockponds and typical yield of stock wells, which total up to 2,615 AFA. **Table 9-1** lists a range of values for each of these factors.

To avoid over counting, ADWR did not include the capacity of four claimed lakes and one unclaimed lake in the upper quantification limit, which the Hopi claimed for both recreation and livestock. Also the upper quantification limit for livestock water does not include discharges from springs, which have been used for multiple purposes including livestock.

Figures 7-13 through **7-15** show the locations of the impoundments, springs, and wells used to divert stockwater, respectively. Water use by Hopi livestock is expected to occur at or close to these diversion locations. Use of stockponds by livestock has been limited by availability of precipitation and runoff, lack of maintenance, and inability to retain water during dry periods.

9.1.5 Recreation

ADWR identified four lakes along Keams Canyon and one lake along Pasture Canyon used by the Hopi for recreational purposes. To quantify the amount of water the Hopi used annually for recreation, ADWR added the capacity of each lake and its annual evaporation. **Table 9-1** lists the total capacity of the lakes as measured by ADWR between 2005 and 2008, estimates of lake evaporation rates for Keams and Pasture Canyons, and recent lake surface area measurements. To calculate annual lake evaporation, ADWR multiplied the surface areas by their respective lake evaporation rates.

ADWR estimated that the Hopi used a total of 576 to 631 AFA for recreational purposes based on the above calculations. **Figure 7-13** shows the location of the lakes.

9.1.6 Ceremonial/Cultural

Both the Hopi and the United States claim that all springs on the Reservation are used by the Tribe for cultural purposes. The Hopi, but not the United States, also claim these springs are used for ceremonial purposes. **Figure 7-14** shows the location of springs that ADWR identified on and near the Reservation. To quantify this water use, ADWR compiled available spring discharge data. Several of the springs did not have discharge data, so their use was not quantified.

ADWR found that 208 claimed and 29 unclaimed springs had one or more discharge measurements. Summing these discharges, ADWR determined the total quantity of water used by the Hopi for ceremonial/cultural purposes ranged from 629 to 1,829 AFA.

9.2 COMPARISON OF QUANTITIES OF WATER FOR PAST AND PRESENT USES CLAIMED BY THE HOPI AND UNITED STATES TO QUANTITIES OF WATER DETERMINED BY ADWR

This section compares the quantities of water included in the claims filed by the Hopi and United States,[3] as summarized in **Chapter 2** of this report, to the quantities of water that ADWR determined based on its evaluation of past and present tribal water use on the Reservation, as summarized in **Section 9.1** of this report. There are significant differences between the claimed amounts and the amounts determined by ADWR, which are primarily due to different quantification approaches. The comparison is presented in **Table 9-2** and described below for each type of water use claimed.

9.2.1 Agriculture

According to the claims filed by the Hopi and United States, actual diversions for irrigation from five major washes and several minor tributaries on the Reservation have averaged about 28,000 AFA. However, the Hopi and United States claim maximum diversions in the amounts of 49,206 AFA and 49,136 AFA, respectively, to provide an adequate water supply during years when less water is available, plus 116 AFA from springs claimed to be used for irrigation. The amounts from the washes and tributaries are based on a surface water model for a composite of 38,556 acres of land that had been farmed historically to the present.

Using the same historical photographs as those used by the Hopi and United States, ADWR determined that the composite number of acres that had at one time been farmed historically was less than the amount claimed. ADWR estimated there is convincing or partial evidence of farming on 25,261 acres of the Reservation, and questionable or no evidence of farming on the other 13,304 acres that were claimed as agricultural lands. [4] These numbers in turn reduce the amount of water that would have been required for historical farming.

[3] There are several differences between the Hopi and United States claims. These differences are described in **Chapter 2**.

[4] The total acreage of agricultural lands listed in the claims (38,556) is slightly lower than that shown on maps provided to ADWR by the claimants (38,565). ADWR completed its analysis on the latter.

ADWR did not use a composite acreage approach, but instead determined the number of acres irrigated in any one year. ADWR used cropped acreage information dating back to the 1870s as well as data from a 2005 field survey that included on-ground field mapping and analysis of aerial photography and satellite imagery. ADWR calculated past and present agricultural use by multiplying the cropped acreage by an estimated crop water demand. The resulting amounts range from 350 to 7,921 AFA for traditional farms and 0 to 1,582 AFA for irrigation projects, which results in a total of 350 AFA to 9,503 AFA for agricultural purposes in any one year. Further details concerning ADWR's evaluation of agricultural lands is presented in **Table 9-1**.

9.2.2 DCMI

Both the Hopi and United States claim 11,211 AFA for DCMI purposes based on a projected population of 62,512 in the year 2175. However, neither the Hopi nor United States claim a separate amount for only past or present DCMI use. Instead, they each claimed multiple water uses from a group of springs and wells in the amounts of 3,597 AFA and 3,545 AFA, respectively. In 2005, both the Hopi and the United States supplemented their claims with 28 additional wells and 22 springs for DCMI, stock and ceremonial/cultural uses in the amount of 559 AFA.

In the appendices to their claims, the United States, but not the Hopi, lists the types of uses for each spring and well. For those numerous wells and springs with multiple uses, the United States did not separate the quantity of use claimed for a particular well or spring for each type of use claimed. In order to evaluate the claims, ADWR totaled the amount of water claimed from the springs and wells that were listed by the United States for DCMI uses in the 2004 amended claim and the 2005 supplemental filing.

In **Chapter 8**, ADWR used a different approach and calculated the DCMI water demands for the Reservation based on population data and reported per capita usage. ADWR multiplied the population by the per capita consumption, which resulted in a range from <11 to 578 AFA year. Further details regarding these calculations are presented in **Table 9-1**.

9.2.3 Heavy Industrial (Mining and Related Industry)

The Hopi and United States claim 4,400 AFA and 3,000 AFA, respectively, for heavy industrial uses, which include mining and related industries. According to the Hopi, these uses are based on coal mining and slurry activities associated with the Black Mesa Mine and the Mohave Generating Station. The claim filed by the United States is generally for the coal mining related industry.

ADWR examined records of well pumping by the Peabody Western Coal Company, which has commercially mined coal from the Black Mesa Complex, consisting of the Black Mesa and Kayenta mines, located at the northeastern corner of the Reservation and on adjacent Navajo lands. Withdrawals between 1968 and 2005 ranged from a low of 40 AFA in 1969 to a high of 4,740 AFA in 1982. See **Table 9-1**. The Mohave Generating Station closed in December 2005, followed by the Black Mesa Mine. The Kayenta Mine is still in operation.

9.2.4 Livestock

Neither the Hopi nor United States claim a separate amount of water for only past or present livestock use. Instead, they each claimed water use from a group of stockponds, springs and wells in the amounts of 7,961 AFA and 8,044 AFA. In 2005, they supplemented their claims with 28 additional wells and 22 springs for DCMI, stock and ceremonial/cultural uses in the amount of 559 AFA. Although the amounts claimed from many of the springs and wells are for multiple uses, neither the Hopi nor the United States claim a separate amount for just stockwatering use.

In the appendices to its claims, the United States, but not the Hopi, lists the types of uses for each spring and well. For those numerous wells and springs with multiple uses, the United States did not separate the quantity of use claimed for a particular well or spring for each type of use claimed. In order to evaluate the claims, ADWR totaled the amount of water claimed from the stockponds plus springs and wells that were listed by the United States for livestock uses in the 2004 amended claim and the 2005 supplemental filing.

In **Chapter 8**, ADWR used a different approach and calculated the livestock water demands for the Reservation based on the number and type of livestock and their

water needs. To calculate a lower quantification range, ADWR multiplied the number of head of livestock by the water needs, which resulted in a range of 47 to 179 AFA. To calculate an upper quantification range, ADWR determined the amount of water necessary for stock by calculating stockpond capacities and adding the yields from stock wells on the Reservation, which resulted in a total of less than or equal to 2,615 AFA. Further details regarding these calculations are presented in **Table 9-1**.

9.2.5 Recreation

The Hopi claim 196 AFA for recreational purposes based on a combined capacity of 138.8 AF for four recreational lakes and a lake evaporation rate of 56.8 AF. The United States does not make a separate claim based on recreational use.

ADWR conducted field inspections of the four lakes, calculated their capacities and surface areas, and obtained local climate data to determine lake evaporation. Also, during ADWR's field inspections, ADWR identified a reservoir that had not been claimed that was used for both recreation and irrigation. ADWR's calculations resulted in a range between 576 to 631 AFA for recreational purposes. See **Table 9-1**.

9.2.6 Ceremonial/Cultural

The Hopi and United States both claim that all 338 springs in their 2004 amendments (2,206 AFA) plus the 22 springs they included in their 2005 supplement (553 AFA), for a total of 2,759 AFA, were used for cultural purposes. The Hopi also claim these springs were used for ceremonial purposes.[5] ADWR verified all but 32 of the claimed springs, and identified 42 additional springs that had not been claimed. For 237 springs with discharge data, reported discharges totaled from 629 to 1,829 AFA.

9.2.7 Total Quantities

At the end of **Table 9-2**, ADWR total the minimum and maximum quantities determined by ADWR for each type of use. The totals range from 1,653 to 19,896 AFA.

[5] The United States did not include a claim for ceremonial purposes, but reserved the right to do so in the future.

9.3 ADWR'S RECOMMENDED WATER RIGHT ATTRIBUTES FOR PAST AND PRESENT WATER USES ON THE HOPI RESERVATION

This section describes ADWR's proposed water right attributes for past and present water uses on the Hopi Reservation. These attributes are based on the implied federal reserved water rights doctrine and ADWR's analysis of water uses on the Reservation as directed by the Court. However, ADWR did not make recommendations for certain attributes that involve pending legal issues. Described below are the implied federal reserved water rights doctrine as it applies to Indian reservations, ADWR's recommended water right attributes for past and present uses on the Reservation, and pending legal issues concerning the claims for water rights on the Reservation.

9.3.1 Implied Federal Reserved Water Rights Doctrine for Indian Reservations

In a decision known as *Gila V,* the Arizona Supreme Court set forth standards for quantifying Indian water rights under the federal reserved water rights doctrine. *In re the General Adjudication of all Rights to Use Water in the Gila River System and Source*, 201 Ariz. 307, 35 P.3d 68 (2001). Based on decisions by the United States Supreme Court, including the seminal case of *Winters v. United States*,[6] the Arizona Supreme Court reiterated the principle that a federal reserved water right impliedly reserves enough water to fulfill the purpose for which the reservation was created, and that the purpose of an Indian Reservation is to provide a permanent home and abiding place, and a livable environment. The Court stated:

> We agree with the Supreme Court that the essential purpose of Indian reservations is to provide Native American people with a "permanent home and abiding place," *Winters*, 207 U.S. at 565, 28 S.Ct. at 208, that is, a "livable environment." *Arizona I*, 373 U.S. at 599, 83 S.Ct. at 1497.

201 Ariz. at 313, 35 P.3d at 74.

[6] 207 U.S. 564, 28 S.Ct. 207 (1908).

The Court went on to note that *Winters* retained the concept that the quantity of water reserved was only that amount necessary to fulfill the minimum needs of the reservation for both present and future uses. The Court stated:

> The *Winters* doctrine retains the concept of "minimal need" by reserving "only that amount of water necessary to fulfill the purpose of the reservation, no more." *Cappaert*, 426 U.S. at 141, 96 S.Ct. at 2071. The method utilized in arriving at such an amount, however, must satisfy both present and future needs of the reservation as a livable homeland. *See Arizona I*, 373 U.S. at 599-600, 83 S.Ct. at 1497-98, *Winters*, 207 U.S. at 577, 28 S.Ct. at 212.

201 Ariz. at 316, 35 P.3d at 77.

In order to quantify the amount of water necessary to accomplish the homeland purpose, the Court in *Gila V* rejected the trial court's reliance on the practicably irrigable acreage standard (PIA) developed in *Arizona v. California*, 373 U.S. 546 (1963) as the exclusive standard for quantifying federal reserved water rights on Indian lands. 201 Ariz. at 318, 35 P.3d at 79. By contrast, the Court found that the homeland purpose was broad and must be liberally construed in order for tribes to achieve "the twin goals of Indian self-determination and economic self-sufficiency." The Court further found that the permanent homeland concept allows for "flexibility and practicality" as homeland purposes evolve and economies are diversified. 201 Ariz. at 315, 35 P.3d at 76.

Relying on an earlier decision in a case known as *Gila III*,[7] the Court held that a fact-intensive inquiry must be undertaken on a reservation-by-reservation basis in order to quantify water rights for an Indian reservation under the federal reserved water rights doctrine. The Court listed several factors that may be considered as part of the analysis: (1) history, including historical practices requiring water use; (2) past water uses of a cultural nature; (3) the tribal land's geography, topography, natural resources, and groundwater availability; (4) tribal economic base and economic development plans; (5) past water use on the Reservation and proposed water projects that are practical and

[7] *In re the General Adjudication of all Rights to Use Water in the Gila River System and Source*, 195 Ariz. 411, 989 P.2d 739 (1999).

economical; and (6) present and projected future population. 201 Ariz. at 319, 35 P.3d at 80. The Court emphasized that the preceding list is not exhaustive, and that courts should be given latitude to consider all information deemed relevant in quantifying federal reserved water rights. However, the proposed uses must be "reasonably feasible," and must satisfy the following two tests:

> First, development projects need to be achievable from a practical standpoint - - they must not be pie-in-the-sky ideas that will likely never reach fruition. Second, projects must be economically sound. When water, a scarce resource, is put to efficient uses on the reservation, tribal economies and members are the beneficiaries.

201 Ariz. at 320, 35 P.3d at 81.

For purposes of this Hopi Preliminary HSR, the adjudication Court directed ADWR to apply the factors set forth in *Gila V*. However, the adjudication Court specifically stated that ADWR was not to undertake a feasibility analysis for future uses. *See* 2002 Order.

9.3.2 ADWR's Recommended Water Right Attributes

Pursuant to the 2002 Order, ADWR presents in **Table 9-3** its recommended water right attributes for past and present water uses on the Reservation based on the factors set forth in *Gila V*. Each of the attributes is discussed below.

Legal Basis. ADWR's recommended water rights for the Reservation are based on the federal reserved water right doctrine as defined by the Arizona Supreme Court in *Gila III* and *Gila V*. The Department did not analyze whether the Hopi are entitled to a water right pursuant to Articles VIII and IX of the Treaty of Guadalupe Hidalgo, or whether the Hopi have a right to water from sources located outside the boundaries of the Hopi Reservation as claimed by the Hopi. These legal issues are before the Court and the Special Master,[8] as described in **Section 9.3.3.**

[8] The Special Master is a judicial officer appointed by the Court to hear cases arising out of adjudications and report on factual and legal issues referred by the Court.

Types of Use. Both the Hopi and the United States claimed past, present and future uses for the following types of use: agriculture (irrigation), DCMI (domestic, commercial, municipal and light industrial), heavy industrial (mining and related industry), livestock, recreation and ceremonial/cultural purposes. As discussed further below, the Department examined the claims and analyzed data obtained from independent sources in order to quantify the Hopi federal reserved right for past and present uses. However, *Gila V* indicates that water for homeland purposes is not restricted by past and present uses, but may be used for multiple uses in the future as long as they satisfy the "reasonable feasibility" test discussed above. 201 Ariz. at 319-320, 35 P.3d at 80-81.

Water Source. ADWR analyzed the availability of surface water and groundwater for the Reservation, both of which had been claimed by the Hopi and the United States. The Hopi also claimed off-reservation surface water sources. ADWR's analysis of these water sources is set forth in **Chapter 7**. The availability of surface water and groundwater sources are affected variously by drought, location, water quality considerations and legal issues.

The legal issues have not yet been resolved. Because the Court has not yet determined whether the Hopi are entitled to use surface water sources that do not cross the Reservation, and because the Court has not yet analyzed or quantified proposed future uses, ADWR cannot make a recommendation regarding whether the Hopi federal reserved water right extends to groundwater. Also as described in **Section 9.3.3**, the issue of whether the Hopi are entitled to water from sources located outside the boundaries of the Hopi Reservation is pending before the adjudication Court. Under *Gila III*, a federal reserved water right may include groundwater in those cases where it is required to satisfy the present and future needs of the reservation, and where "other waters are inadequate to accomplish the purpose of a reservation." 195 Ariz. at 420, 989 P.2d at 748. Further direction from the Court is required before ADWR makes any recommendations regarding water source.

Quantity of Use. The Department recommends up to 19,896 AFA for past and present water uses on the Reservation. To determine this number, the Department used the quantities listed in **Table 9-1** and added the high end of the range in the Total

Quantity column for each type of use, in recognition of the directive in *Gila V* that the homeland purpose is broad and should be liberally construed. The methods of quantification are described in **Section 9.1**.

Location (diversion and place of use). **Chapter 8** discusses the locations of past and present points of diversions and places of use on the Reservation. However, under *Gila V*, the water reserved for homeland purposes on an Indian reservation is not restricted to a specific parcel and may be utilized elsewhere on the reservation. *See* 201 Ariz. at 313, 35 P.3d at 74. Thus, the Hopi may divert water at any location from water sources available to them, and may put the water to use anywhere within the Reservation. The issue of whether the Hopi are entitled to water from sources located outside the boundaries of the Hopi Reservation is pending before the Court. See **Section 9.3.3**.

Priority Date. The Hopi and the United States claim a time immemorial priority date for the water rights on the Reservation covered by this preliminary report. This claimed priority date raises several legal issues that are before the Special Master. These issues are described in **Section 9.3.3**.

9.3.3 Legal Issues Pending Before the Court and Special Master

Currently, there are several legal issues pending before the Court and the Special Master that affect water rights for the Reservation. These legal issues concern the availability of water sources off the Reservation to satisfy the claimed water rights, and the priority date of the rights claimed. In this preliminary HSR, ADWR takes no position on the pending legal issues. As indicated above, until the legal issues before the Court and the Special Master are resolved, ADWR is unable to recommend certain water right attributes. Once these legal issues are resolved, ADWR will incorporate them into the final Hopi HSR.

Water Sources. By order dated March 19, 2008, the Court took under advisement the legal issue concerning the availability of surface water sources off the Reservation to satisfy water rights for the Reservation. As stated by the Court, the issue is "whether the Court should summarily dispose of a portion of the Hopi Tribe's pending claims in this adjudication by finding that the Hopi Tribe and the United States acting as trustee for the Hopi Tribe are precluded from claiming a right to water from surface streams that are

located within the Little Colorado River Basin, but do not traverse any part of the Hopi Reservation. . . ." A briefing schedule was set, and on October 29, 2008, the Court heard argument. Supplemental briefs and responses were due by December 15, 2008.[9]

Priority Date. By order dated March 19, 2008, the Court also directed the Special Master to address several issues regarding the priority date of water rights for the Reservation. By case initiation order dated September 8, 2008, the Special Master identified the following issues for briefing:

- Does the Hopi Tribe hold water rights with a priority of time immemorial?
- Does the Hopi Tribe hold water rights with a priority date of 1848 as a result of the Treaty of Guadalupe Hidalgo, 9 Stat. 922 (Feb. 2, 1848)?
- Does the Hopi Tribe possess water rights with a priority date of 1882 as a result of the establishment of the Hopi Reservation under the Executive Order of December 16, 1882?
- Does the Hopi Tribe possess water rights with another date of priority as a result of Congressional acts and court decisions adding property to the Hopi Reservation?
- Does claim or issue preclusion or both preclude any claims by or on behalf of the Hopi Tribe to water rights more senior to those held by any other claimant?
- Does accord and satisfaction preclude any claims by or on behalf of the Hopi Tribe to water rights more senior to those held by any other claimant?
- May the Hopi Tribe assert a priority that is senior to the Navajo Nation for water resources that are shared by both tribes in light of the process for the allocation of resources established by the Act of July 22, 1958, Pub. L. No. 80-547, 72 Stat. 403, and the Act of December 22, 1974, Pub. L. No. 93-531, 88 Stat. 1712, as amended?

The September 8, 2008 order included timelines to be completed in 2009 for disclosure statements, discovery and motions. Dates for oral argument and/or evidentiary hearings have not yet been set.

[9] In **Chapter 7**, ADWR includes information regarding the availability of surface water in the Little Colorado River near the Reservation.