

APPENDIX B

Note: Appendix B contains information originally presented in the 2008 Hopi Preliminary HSR (Chapters 4-6) and is updated, where appropriate, in response to comments ADWR received related to that report. This information is being provided for background and educational purposes only. ADWR does not anticipate preparing a similar document for future HSRs.

APPENDIX B: PHYSICAL AND CULTURAL SETTING

This Appendix describes the physical and cultural setting of the Reservation. Unless otherwise stated, the information presented is from Chapters 4-6 of the 2008 Preliminary Hopi HSR, modified to reflect the comments received, and updated where data is available. Provided below is information about the geography, topography, and natural resources of Hopi Reservation lands and the culture, economic base, and present and projected population of the Hopi Tribe.

1.0 PHYSICAL SETTING

1.1 LOCATION

The Reservation is located in northeastern Arizona within the LCR Adjudication Area (See **Figure 1-1**). It covers 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 a census estimated population of 65,870 in 2010. Tuba City, located on Navajo lands that border the Moenkopi Area, is the largest city locally with an estimated population of 8,611 in 2010.

The Little Colorado River (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 Bureau of Indian Affairs (BIA) Route 2, State Routes 87 and 264 and U.S. Highways 89 and 160.

1.2 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 (**Figure B-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, Wepo 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 B-2** is an oblique image of the Reservation that shows the relationship between Black Mesa and the Hopi Mesas.

1.3 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 B-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°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 B-1**.

Precipitation

Mean annual precipitation in the vicinity of the Reservation is shown in **Figure B-4** for the period 1971-2000. **Table B-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 B-2**. The calculations indicate that annual rates of

gross surface water evaporation on the Reservation total from 63.5 inches (5.3 feet) to 80.2 inches (6.7 feet).

1.4 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 stockpounds. Riparian plant species identified on the Reservation include cottonwood, Russian olive, salt cedar, and willow (ADWR, 2008c). **Figure B-5** shows where ADWR mapped riparian vegetation on the Reservation in 2005 and the location of the major vegetative communities. Photographs of riparian vegetation on the Reservation are presented in **Figure B-6**.

1.5 SOILS AND GEOLOGY

1.5.1 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, 2012).

Survey AZ707, which includes the Moenkopi Area, was completed and published in 2012. **Figure B-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, 2007). **Figure B-8** shows the location of GSMUs on the Reservation and **Table B-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.

1.5.2 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 B-9 is a stratigraphic column that shows some of the important geologic units and associated rock types beneath the Reservation. Geologic units, including those shown in the figure, were formerly 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.

The Geologic Society of America (GSA) has produced more current versions of the geologic time scale since Figure 2-9 was originally produced. Geologic units and age of deposition as included in the GSA version 4.0 geologic time scale are (GSA, 2015):

- Quaternary Period – 2.6 mya to present
- Neogene Period – 23 mya to 2.6 mya
- Paleogene Period – 66 mya to 23 mya
- Mesozoic Era – 225 to 66 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-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.

Neogene-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 B-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 Neogene that caused over 300 intrusive bodies (diatremes) to penetrate to the surface through the sedimentary units.

Surface Geology

Figure B-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);
- Neogene 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).

1.6 LAND USE

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

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

Figure B-12 shows the location of these land uses. Photographs of Reservation land uses are presented in **Figure B-13**.

In 2005, between 5,570 and 6,506 acres of the Reservation were estimated to have been actively used for agriculture (ADWR, 2008c). 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 has not been reported.

Approximately 36,860 acres in the northwestern portion of the 1882 Executive Order Reservation have been 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 watershed rehabilitation project and is identified as Recreation on **Figure B-12**.

There have been three areas of industrial land use covering approximately 6,200 acres of the Reservation. These have included 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 B-12** or included in the cited industrial acreage because it was discontinued in 1997.

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.

2.0 CULTURAL SETTING

This section describes the culture of the Hopi people, including their governance (Section 2.2.1), customs (Section 2.2.2), and the cultural relevance of water (Section 2.2.3). Locations of the geographic features mentioned below are shown in **Figure B-1**.

2.1 GOVERNANCE

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.

¹Pub. L. No. 73-383, 48 Stat. 984.
December 2015

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 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. Even then, all representatives had to be certified by the *kikmongwi*.

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.

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 have continued to enjoy autonomy and govern themselves supported by the Hopi Tribal Council. The *kikmongwis* also have continued 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 has been based on communal consensus (Hopi, 2001).

Under the Hopi Constitution the Tribal Council holds all legislative, executive and judicial authority. The Council is authorized to delegate the exercise of these powers as it sees fit in the best interest of the Tribe. For example, the Tribal Council can delegate authority to the Council's

Chairman to carry out a broad range of day-to-day executive responsibilities. In addition, the Constitution empowers the Council to establish courts for the resolution of disputes. For example, by Ordinance No. 21 the Tribal Council established the Tribal Court. Finally, the Council can delegate authority for administrative matters to the various departments and programs that comprise the Hopi governmental organization established by the Council.

2.2 CUSTOMS

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 time, chili peppers were introduced from Mexico. Since the first American contact in 1848, the Hopi traditional subsistence economy has been supplemented with a cash economy.

Each Hopi village is autonomous, with its own land. The fields for 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 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, social, subsistence, manufacturing, ceremonial, religious, and medicinal purposes.

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. 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.

Sheep and cattle have been the primary domesticated animals and a form of property. 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. The maximum carrying capacity is discussed in Chapter 4.

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 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 silver-smithing, 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, basket makers, 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.

2.3 CULTURAL RELEVANCE OF WATER

Water plays a central cultural and ceremonial role in Hopi life. As noted by the Hopi in their 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, 2015, p. 15).

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 sites 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, 2015, pp.15-16). 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).

3.0 ECONOMIC BASE

This section describes the economic base of the Reservation including its raw materials (**Section 3.1**), infrastructure and public services (**Section 3.2**), financial resources (**Section 3.3**), and human resources (**Section 3.4**). 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 section are shown in **Figure B-1**.

3.1 RAW MATERIALS AND OPPORTUNITIES

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

3.1.1 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, 2007).

Table B-4 lists definitions for Classes I through VIII.

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, 2007):

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 2-14**). 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 26,921.9 acres on the Reservation. A summary of the Hopi and United States claims is presented in **Chapter 3**.

3.1.2 Rangeland

As described in **Section 1.6**, 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 currently 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 Hopi Partitioned Lands (HPL) (**Figure B-15**). Characteristics of the units are listed in **Table B-5** 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 in their 2004 claim, the Hopi claimed that stock were in the Moenkopi Area based on water uses from ponds, wells and springs. This information is included in **Table B-5**.

Also listed in **Table B-5** 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.

3.1.3 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 3.3, Financial Resources**), 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 1 of this report). The NPL and HPL comprise what was formally referred to as the Joint Use Area. The geologic units mentioned below were described in greater detail in **Section 1.5.2**.

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 B-16**). 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 the Peabody Western Coal Company (PWCC). Known as the Black Mesa Complex, the operation consists of the Black Mesa and Kayenta Mines (**Figure B-16**). 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 has produced about 7.5 million tons of coal annually (PWCC, 2015). This coal is transported 100 miles by conveyor belt and electric train to the Navajo Generating Station (NGS) near Page.

In addition to the Black Mesa Complex, the Wepo Formation contains economically-recoverable coal deposits in the former Joint Use Area 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 of Arizona, Utah, Colorado and New Mexico. 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 B-17**), 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 (**FigureB-17**):

- Cow Springs monocline in the northwestern former Joint Use Area;
- 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 B-18**). One site in the area, the Morale Mine near Hopi Buttes but off the HPL, 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 uranium prices could make the following a target for economic uranium development:

- Chinle Formation in the southwestern former JUA;
- Morrison Formation in the northeastern former 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 B-19 shows the location of non-metal deposits identified in the vicinity of the Reservation. Some of these deposits may be of commercial grade, but 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 17th to 20th 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 former Joint Use Area. 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 former Joint Use Area.

Construction Materials

Figure B-20 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°F. Subsurface temperatures increase to 302-392°F, feasible for electric power generation, but only at depths of over 3.5 miles.

3.1.4 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 B-21**). 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 (ft³/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 ft³/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. Juniper is more commonly used for these products than pinon, and there is an estimated 45.3 million ft³ 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 sold in the United States have been harvested by hand by Native Americans from natural forests. Individual collection rates have been 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 has been reviewing these practices and has also 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 have been 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 have been 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.

3.1.5 Tourism

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

The behavior of early visitors to the Reservation caused concern among some Hopi about tourism. 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. However, results of a 2008 survey indicate that a majority of the Hopi support tourism development on the Reservation (Hopi, 2015).

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 was the only operational motel on the Reservation until the opening of the Moenkopi Legacy Inn and Suites in 2011 at the intersection of U.S. Route 160 and State Route 264. 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 to the Moenkopi Legacy Inn and Suites, economic benefits also derive from the Tuuvi Travel Center located 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.

The most recent plans for tourism on the Reservation include a potential recreational vehicle (RV) park, golf course and other resort amenities and expansion of the Hopi Tribal Cultural Center. Other potential Hopi tourism development includes a possible hotel, casino, golf course, and RV park at the Hopi Industrial Park in Winslow. However, water demands associated with possible development at the Hopi Industrial Park are outside the scope of this HSR (Hopi, 2015). There are no casinos currently on the Reservation. The Hopi turned down gaming twice, first in April 1995 and again in May 2004 (Gallup Independent, 2004).

3.2 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.

3.2.1 Transportation

Transportation on and to the Reservation is available through paved (bituminous) and unpaved roads, an airstrip, and two helicopter landing pads (**Figure B-22**). 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 50% complete as of 2014 (Hopi, 2014). 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 have 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 has been 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).

3.2.2 Utilities

Water

Tetrattech reported in 2006 that sixteen public water systems (PWSs) served 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 B-6** 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 were 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 serving communities reportedly provide drinking water to about 11,000 residents through approximately 1,800 service connections, though the number of reported residents served

is greater than the estimated reservation population. 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 have been 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 have included incomplete or unavailable record keeping, high operator turnover, poor user fee collection, and lack of financing. Elevated arsenic and excessive drawdown also have been a problem for the wells that serve water to First and Second Mesas. Arsenic treatment has been 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 have been remediated and negotiations have been ongoing between the Hopi and United States government over cleanup of the uranium mill site (SWCA, 2008).

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

Wastewater

All but two Hopi villages, Old Oraibi and Walpi, have been served by community wastewater systems. 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 have become old, undersized, inefficient and in frequent need of repair. Septic systems have been prevalent, even in the villages (Hopi, 2001).

Other wastewater systems built on the Reservation have included 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 has served the upper and lower villages in Moenkopi and the new Tuuvi Travel Center and Legacy Inn and

Suites (Hopi, 2008b and SWCA, 2008). The Moenkopi WWTP has been owned and operated by the Hopi and was funded by the Tribal Council.

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 B-7** lists data compiled by ADWR (2006) for four of the Hopi WWTPs. Data for other WWTPs on the Reservation were not available at that time. Based on an IHS priority list, a need for about 60 sanitation projects on the Reservation with an estimated cost of \$36 million has been identified (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, have been provided service from the Navajo Tribal Utility Authority (Hopi, 2001).

Several, relatively isolated homesites on the Reservation have been identified as not receiving electric service. These home sites were 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, has been 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 CellularOne 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 has been located at the police/court complex between Keams Canyon and Polacca and its 69 kilowatt radio tower has been on Antelope Mesa (Hopi, 2001).

3.2.3 Health Care

The following health care facilities have been 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 has been insufficient to meet 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 established in Kykotsmovi using a 2004 grant. The network has provided 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 have sought medical attention in Flagstaff and Winslow (SWCA, 2008).

3.2.4 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 and, in 2005, the Superintendent of BIA's Keams Canyon Agency was working with the Tribe to find alternative funding. As of 2008, the status of the fire program is unknown (SWCA, 2008). The Hopi (2001) indicated that water infrastructure in their villages would be inadequate to address most structural fires.

3.2.5 Schools

There are eight primary schools, two secondary schools and two colleges on the Reservation:

Primary Schools –

- First Mesa Elementary
- Hopi Mission near Kykotsmovi
- Hotevilla-Bacava
- Keams Canyon Boarding
- Hopi Day
- Moenkopi Day
- Second Mesa Day
- Jeddito Public School

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). SWCA reported in 2008 that there were 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).

3.2.6 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).

3.3 Financial Resources

This section presents data on Hopi financial resources including tribal revenues and tribal expenditures.

3.3.1 Tribal Revenue

There have been five general sources of revenue for the Hopi Tribe: (SWCA, 2008)

- 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 have estimated 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 the terms of the 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:

[O]ver 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."

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 have included:

- Hopi Cultural Center on Second Mesa
- Hopi Travel Plaza in Holbrook

- Moenkopi Legacy Inn and Suites
- 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.

3.3.2 Tribal Expenditures

Expenditures by the Hopi Tribe can be divided into two categories – Government Expenditures, and Expenditures from Grants and Contracts. Between 2005 and 2007, annual government expenditures ranged from a low of \$34.3 million in 2007 to a high of \$44.2 million in 2005. Between 2003 and 2007, annual expenditures from grants and contracts ranged from a low of about \$18.8 million in 2005 to a high of \$31.3 million in 2004.

The annual General Fund Budget approved by the Hopi Tribal Council is published in the Hopi Tutuveni, the newspaper of the Hopi Reservation. The January 20, 2015 edition includes the approved budget for fiscal year 2015. The budget totals approximately \$23,500,000 and includes costs for the villages, legislative, executive and judicial branches, departments such as natural resources, community health, public works, and regulated entities such as the Revenue Commission, Hopi Election Office, and Public Defenders Office. Projected revenues for fiscal year 2015 also total approximately \$23,500,000, though the budget does not list the revenue sources.

3.4 Human Resources

This section describes human resources on the Reservation. Hopi demographics are described first followed by the Reservation labor force.

3.4.1 Demographics

This section presents data on the Hopi population and age distribution, and describes housing conditions on the Reservation. Unless otherwise noted, the data and information presented in this section were obtained from the Demographic Analysis of the Hopi Tribe, completed by the Arizona Rural Policy Institute in 2012 for the planning department of the Hopi Tribe (ARPI, 2012).

Population

Table B-8 lists recent and projected Hopi population data. The population on the Reservation grew from 6,946 in the 2000 Census to 7,185 in the 2010 Census. The Hopi Tribal membership as of October 2015 is 14,221 (Hopi Tutuveni, 2015b). Important population centers include, from largest to smallest (Hopi, 2004):

- First Mesa Villages
- Second Mesa Villages
- Moenkopi Villages
- Kykotsmovi
- Keams Canyon
- Bacavi.

The Hopi Enrollment Office reported that in 2010 there were 7,522 members of the Hopi Tribe living on the Reservation and another 6,141 Hopi tribal members living off-Reservation² (Ramboll, 2015a). As of December 31, 2013, the Hopi Tribal Enrollment Office reported a total enrolled membership of 13,947 with 7,848 living on the Reservation and 6,099 living off the Reservation (Hopi, 2015). The estimated population on the Reservation in 2015 is 8,853 (Hopi, 2015). In 2010, about 95% of the Reservation population was determined to be American Indian and Alaska Native with Whites making up most of the remainder at 3% (ARPI, 2012).

Population projections by the Hopi have varied, but indicate the population of the Reservation is estimated to exceed 50,000 persons by 2120 and is expected to stabilize in 2175 at approximately 52,000 people. The Hopi population growth projections on the Reservation are based on a 100-year growth rate of approximately 1.9% (Hopi, 2015).

Age Distribution

² ADWR requested the full Ramboll Environ report from the United States but it was not provided.
December 2015

In 2010, the median age of the Reservation population was 32 years with 31.9% under the age of 18 and 11% at age 65 or older. Compared with other jurisdictions, the population on the Reservation is relatively young. Across Arizona, the percentage of the population under the age of 18 was 25.5% in 2010.

Housing

Unless otherwise noted, the data were compiled by SWCA (2008) with additional information provided by Hopi (2008b). **Table B-9** lists characteristics of housing on the Reservation. The following data, where 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) has managed about 10% of the approximately 3,100 homes on the Reservation. Private home construction has taken place 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 was reported to be nearly 4 in 1990. In 2010, the average persons per household on the Reservation was reported to be 3.4 (ARPI, 2012). 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.

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

3.4.2 Labor Force

Unless otherwise noted, 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 B-10**). The unemployment rate over this period is estimated to have varied from 10.9% in 2006 to 62% in 1999. Hopi unemployment has been relatively high and variable compared to Arizona as a whole. In 2010, the total Reservation workforce was reported to be 2,964 with women comprising approximately 52% (ARPI, 2012).

The government has been 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 are expected to continue to provide limited employment opportunities for Reservation residents. Lands purchased by the Hopi off the Reservation for economic enterprises may provide new employment opportunities. New jobs may be created by MDC which recently opened the Tuuvi Travel Center and Moenkopi Legacy Inn and Suites. MDC has anticipated that its projects could create as many as 400 new Reservation jobs. Other potential employment opportunities for the Hopi have included 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 2010, the per capita income on the Reservation was \$11,753 and 35% of the population was below the poverty level. The per capita income across Arizona that year was \$25,680 and 15% of the population was below the poverty level. The median household income on the Reservation was reported to be \$34,016 in 2010 (ARPI, 2012).

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.

TABLES

TABLE B-1. CLIMATE DATA FROM TUBA CITY AND KEAMS CANYON METEOROLOGICAL STATIONS ^{1, 2}

	MEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TUBA CITY	Max Temperature (°F)	45.3	52.6	61.2	69.9	79.5	89.4	93.7	91.3	84.8	72.7	57.3	45.6	70.3
	Min Temperature (°F)	21	26.2	31.7	38.5	45.9	53.9	61.7	60	52	40.5	28.8	21.3	40.1
	Total Precipitation (inches)	0.49	0.48	0.48	0.41	0.3	0.24	0.72	0.85	0.8	0.75	0.46	0.49	6.47
	Total Snowfall (inches)	1.5	0.9	0.5	0.2	0	0	0	0	0	0	1.5	1.7	6.4
KEAMS CANYON	Max Temperature (°F)	43.2	49	55.3	64.8	73.6	85	89.1	85.4	79.1	68.5	54.8	44.5	66
	Min Temperature (°F)	16.1	21.2	25.1	31.1	39	47.2	55.4	54.7	46.8	35.9	25.3	16.8	34.5
	Total Precipitation (inches)	0.77	0.8	0.87	0.54	0.39	0.3	1.24	1.61	0.88	1	0.67	0.88	9.94
	Total Snowfall (inches)	1.5	2.6	1.8	0.4	0	0	0	0	0	0.1	0.7	3.3	10.5

Notes:

¹ Source: WRCC (2008).

² Period of record is 1900-2007 for the Tuba City station and 1948-2007 for the Keams Canyon station.

TABLE B-2. ESTIMATED SURFACE WATER EVAPORATION RATES AT TUBA CITY AND KEAMS CANYON ¹

	MEAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TUBA CITY	Lower bound (inches)	2.28	2.82	4.55	6.21	7.90	8.95	9.14	8.31	6.61	5.30	3.09	2.31	67.47
	Upper bound (inches)	2.98	3.56	5.52	7.37	9.18	10.37	10.42	9.53	7.75	6.54	3.97	3.01	80.20
KEAMS CANYON	Lower bound (inches)	2.22	2.70	4.24	5.76	7.46	8.62	8.65	7.71	6.14	4.87	3.06	2.07	63.50
	Upper bound (inches)	2.88	3.37	5.09	6.74	8.62	9.93	9.84	8.81	7.16	5.96	3.87	2.81	75.08

Notes:

¹ Source: ADWR (2008f).

TABLE B-3. GENERAL SOIL MAP UNITS ON THE HOPI INDIAN RESERVATION ¹

MAP UNIT NUMBER	SOIL UNIT	ACRES	PERCENT OF TOTAL AREA	ELEVATION (feet)	SLOPE (%)	DESCRIPTION	LAND USES
1	Jocity-Polacca-Wepo	139,205	8.6%	4,800-6,100	0-3	Deep, well drained, nearly level, loamy, loamy over sandy, and clayey soils; on stream terraces, alluvial fans and flood plains.	Mainly used for grazing. A few scattered areas are used for dryland farming. These soils could be used for irrigated crops if water becomes available.
2	Jeddito-Tewa	112,838	7.0%	4,900-6,100	0-5	Deep, somewhat excessively drained and well drained, nearly level and gently sloping, loamy soils; on fan terraces and stream terraces.	Mainly used for grazing. A few scattered areas are used for dryland farming. These soils could be used for irrigated crops if water becomes available.
3	Sheppard-Monue-Nakai	694,574	42.8%	4,800-6,100	1-15	Deep, somewhat excessively drained and well drained, nearly level to strongly sloping, sandy and loamy soils; on dunes, fan terraces, and plateaus.	Mainly used for grazing. A few scattered areas are used for dryland farming. These soils could be used for irrigated crops if water becomes available.
4	Sheppard-Jocity	20,123	1.2%	4,800-5,300	0-8	Deep, somewhat excessively drained and well drained, nearly level to strongly sloping, sandy and loamy, sodic soils; on dunes, floodplains, and alluvial fans.	Mainly used for grazing. These soils could be used for irrigated crops if water becomes available and soils are reclaimed.
5	Strych-Kinan	21,436	1.3%	5,500-6,700	2-60	Deep, well drained and somewhat excessively drained, nearly level to very steep, cobbly and gravelly, loamy soils; on mesas, buttes, and fan terraces.	This unit is used for grazing.
6	Torriorhents-Badland-Rock Outcrop	74,031	4.6%	4,900-6,800	1-60	Badland, rock outcrop, and shallow to deep, well drained, nearly level to very steep, loamy and clayey soils; on highly dissected hills.	Has very limited use. It is sometimes used for grazing.
7	Begay-Penistaja-Mido	316,405	19.5%	5,800-6,800	1-15	Deep, well drained and excessively drained, nearly level to strongly sloping, sandy and loamy soils; on plateaus and dunes.	Mainly used for grazing. A few scattered areas are used for dryland farming. These soils could be used for irrigated crops if water becomes available.
8	Kydestea-Zyme-Tonalea	242,360	14.9%	5,900-6,800	5-20	Very shallow to moderately deep, well drained and excessively drained, gently sloping to steep, channery, loamy, clayey, and sandy soils; on hills and dunes.	This unit is used as grazable woodland or for firewood harvesting.
9	Endoaquolls-Haplofibrists-Torrifluvents	22	< 0.1%	4,800-5,000	0-3	Information unavailable.	Information unavailable.
10	Sheppard-Ives-Torrifluvents	820	0.1%	4,500-5,000	0-3	Information unavailable.	Information unavailable.

Notes:

¹ Sources: Denny (2008) and NRCS (1996).

TABLE B-4. NRCS LAND CAPABILITY CLASS DEFINITIONS¹

CAPABILITY CLASS	DEFINITION
I	Soils have slight limitations that restrict their use.
II	Soils have moderate limitations that restrict the choice of plants or require moderate conservation practices.
III	Soils have severe limitations that restrict the choice of plants or require special conservation practices, or both.
IV	Soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
V	Soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
VI	Soils have severe limitations that make them unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
VII	Soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
VIII	Soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed or esthetic purpose.

Notes:

¹ Source: NRCS (2007).

TABLE B-5. CHARACTERISTICS OF RANGE UNITS ON THE HOPI INDIAN RESERVATION

GENERAL LOCATION	RANGE UNIT (No. or Name) ¹	TOTAL AREA (in acres) ²	% OF AREA USEABLE AS FORAGE ³	1996 CARRYING CAPACITY (in AUYL) ³	PERMITTEES ⁴	
					No.	Year
District Six	Blue Point	22,098	50-75%	76.0	12	1978
	Burro Springs	52,575	75-90%	82.7	23	1978
	East Dinnebito	41,992	<50%	74.4	2	1978
	Five Houses	71,609	75-90%	298.1	15	1978
	Hardrock	62,001	<50%	201.5	29	1978
	North Oraibi	52,428	<50%	81.8	15	1978
	Polacca Wash	53,275	50-75%	119.9	14	1978
	Shongopovi	34,681	<50%	90.5	N/A	1978
	Shonto	37,597	50-75%	130.8	18	1978
	South Oraibi	31,065	<50%	94.5	3	1978
	Talahogan	47,848	75-90%	230.0	29	1978
	Toreva	26,227	75-90%	93.1	6	1978
	Tovar	36,909	50-75%	108.9	11	1978
	Upper Polacca	59,857	<50%	145.8	41	1978
	West Dinnebito	18,374	<50%	45.1	12	1978
	Subtotal	648,535	N/A	1,873	230	N/A
Hopi Partition Lands	251	28,827	>90%	176.0	6	2007
	252	43,657	50-75%	118.0	N/A	2007
	253	50,686	<50%	64.0	2	2007
	254	28,204	<50%	46.0	1	2007
	255	80,116	75-90%	301.0	11	2007
	256	46,486	>90%	169.0	10	2007
	257	42,769	50-75%	176.0	13	2007
	258	10,884	>90%	44.0	2	2007
	259	34,512	75-90%	149.0	9	2007
	260	24,473	<50%	54.0	4	2007
	261	26,829	50-75%	49.0	3	2007
	262	32,972	<50%	42.0	5	2007
	263	52,908	50-75%	95.0	6	2007
	351	27,984	<50%	86.0	6	2007
	451	12,454	<50%	39.0	4	2007
	551	55,297	>90%	228.0	18	2007
	552	35,857	>90%	135.0	9	2007
	553	35,552	50-75%	90.0	4	2007
	554	30,261	50-75%	63.0	4	2007
	555	35,673	<50%	36.0	4	2007
	556	9,868	<50%	7.0	2	2007
	557	7,905	75-90%	31.0	1	2007
	558	11,770	75-90%	64.0	5	2007
	559	27,190	<50%	77.0	7	2007
	560	5,230	N/A	N/A	N/A	2007
	561	1,444	N/A	N/A	N/A	2007
	562	22,398	75-90%	131.0	3	2007
	563	13,797	75-90%	119.0	3	2007
	564	2,782	75-90%	9.0	N/A	2007
	565	14,408	75-90%	96.0	3	2007
	566	8,180	50-75%	21.0	1	2007
	567	12,963	>90%	156.0	8	2007
	568				N/A	
569	12,901	75-90%	114.0	2	2007	
570				N/A		
571	6,716	75-90%	63.0	3	2007	
572	10,080	75-90%	57.0	4	2007	
573	7,617	50-75%	33.0	2	1998	
	Subtotal	911,651	N/A	3,138	165	N/A
Moenkopi	N/A					
TOTAL		1,560,186	N/A	5,011	395	N/A

Notes:

N/A = information not available.

¹ From Hopi Drought Plan by DBSA (2000).

² Calculated by ADWR GIS staff using NRCE (2005) boundary data.

³ Based on 1996 range survey by Knoll (1996).

⁴ Most recent data available from Hopi (2008a).

TABLE B-6. PUBLIC WATER SYSTEMS (PWS) ON THE HOPI INDIAN RESERVATION ^{1,2}

PWS ID NO.	PWS NAME	GEOGRAPHIC AREA	WATER SUPPLY WELLS ³		RECENT WATER DEMANDS (AFA)			SERVICE CONNECTIONS (circa 2006)	PEOPLE SERVED (circa 2006)	CURRENT OPERATOR
			Well Name	Completion Dates	1990	2000	2004			
90400052	BIA Hotevilla (Hotevilla Day School)	Third Mesa	Hotevilla Day School #1 and #2	1957 and 1970	See Hotevilla (PWS 90400700)			18 (includes school and 11 residences)	260	BIA Keams Canyon Agency
90400054	Keams Canyon	First Mesa	Keams Canyon #2 and #3	1970 and 1976	64.2	93.7	62.6	142 (includes school, police station and post office, IHS offices, businesses, and 100 residences)	500	BIA Keams Canyon Agency
90400061	BIA Second Mesa (Second Mesa Day School)	Second Mesa	SMDS #1 (inactive) and #2	1958 and 1968	9.5	6.4	3.9	26	180 students and 40 staff	BIA Keams Canyon Agency
90400104	Upper Moenkopi	Moenkopi Area	Moenkopi #1, #2, and #3	1977, 1982, and 1991	25.0	68.2	92.4	250 (includes residential area, community service buildings, and school)	1,000	Community
90400105	Kykotsmovi	Third Mesa	Kykotsmovi #1 and #2, and Kykotsmovi Day School #3 (inactive)	1967, 1977, and 1968	69.0	67.4	62.4	250 (includes 20 businesses, 200 residences, tribal headquarters, and 2 schools)	1,650	Community
90400106	Polacca	First Mesa	Polacca #5, #6 (inactive), and #8	1986, 1986, and 1998	30.0	134.5	57.1	450 (includes First Mesa Consolidated villages, Hopi Health Care Center, and school)	3,240	Community
90400107	Lower Sipaulovi	Second Mesa	Lower Sipaulovi #1	1978	22.7	23.6	19.7	60 (includes residences and 7 businesses)	535	Community
90400259	Shungopavi		Shungopavi #1	1969	18.9	21.2	37.8	300	1,500	Community
90400260	Hopi Cultural Center		Cultural Center #1	1969	11.2	10.7	6.7	3 (includes hotel, restaurant, business and several homes)	200	Hopi Office of Facilities Management
90400316	Hopi Veterans (Civic) Center	Third Mesa	VMC #1	1977	Not available	2.5	4.9	3 (includes fitness facility, concessions, offices, and residential use)	100	Hopi Office of Facilities Management
90400393	Lower Moencopi	Moenkopi Area	<u>N Aquifer Spring</u>	1988 (chlorination and distribution system completed)	Not available			5 distribution points	200	Community
90400394	Sipaulovi - Mishongnovi	Second Mesa	Mishongnovi-Sipaulovi #1	1978	3.1	6.0	6.1	40	405	Community
90400395	Hopi High School	First Mesa	HHS #1 and #2	1985 and 1984	13.0	38.2	44.0	48 (includes school, college, and 40 residences)	760 students, 225 staff, and 150-200 residents	BIA Facilities Management
90400687	Bacavi	Third Mesa	Bacavi #1	1992	Well not completed	21.5	21.3	134	434	Community
90400688	Spider Mound	Spider Mound	Spider Mound #1 and #2 (inactive)	1994 and 2003	Wells not completed	2.4 ⁴	2.4 ⁴	38 (25 inactive)	150	Community
90400700	Hotevilla	Third Mesa	Hotevilla #1 and #2	1994 and 2004	25.0	4.8	24.0	144 (includes post office, community buildings, service station, residences and 5 public hydrants)	1,200	Community
				Total:	291.6	501.1	445.3			

Notes:

AFA = acre-feet per year.

¹ Sources: Andersen (2008), Litten (1992), TetraTech (2006), Thomas (2002), and Truini and Macy (2006).

² Source: ADWR (2008).

³ All wells completed in the N Aquifer, except for the Spider Mound wells completed in the D Aquifer. Lower Moencopi PWS is supplied by an N Aquifer spring.

⁴ Approximated from TetraTech (2006) pumping rate data.

TABLE B-7. DATA FOR SELECT WASTEWATER TREATMENT PLANTS ON THE HOPI INDIAN RESERVATION ¹

FACILITY NAME ²	AREA SERVED	POPULATION SERVED	EFFLUENT VOLUME TREATED/GENERATED (acre-feet/year)	DISPOSAL METHOD	CURRENT TREATMENT LEVEL ³	LOCAL POPULATION NOT SERVED	YEAR OF RECORD
Bacobi WWTP	Bacavi	550	62	Groundwater Discharge	Not available	70	2000
Oraibi	Oraibi	500	56	Evaporation Pond	Secondary	Not available	2000
Shungopavi WWTF	Shungopavi	400	45	Evaporation Pond	Secondary	Not available	2000
Sipaulovi WWTF	Sipaulovi	500	56	Evaporation Pond	Secondary	200	2000

Notes:

¹ Source: ADWR (2006).

² WWTP = Wastewater Treatment Plant and WWTF = Wastewater Treatment Facility.

³ Wastewater treated to a secondary level has received biological and/or physical/chemical treatment including lagoons and trickling filters (EPA, 2008).

TABLE B-8. RECENT AND PROJECTED HOPI POPULATIONS

YEAR	POPULATION OF HOPI INDIAN RESERVATION	NUMBER OF HOPI		RESERVATION ETHNICITY					DATA SOURCE
		On Reservation	Off Reservation	American Indian	White	Other	Asian / Pacific Islander	Black	
1988		9,738	1,082						Hopi (1988)
1990	7,360 ¹								ADOC (2005)
	8,258								Census (2007)
2000	6,315 ¹	10,336		94%	4%	1%	<1%	<1%	Census (2003a,b and 2007)
	6,633 ¹								Hopi (2004)
	10,571								Hopi (2001)
2004	11,668								Hopi (2001)
		8,000	4,000						Taylor (2004)
2006	12,000 ^{2,3}								TetraTech (2006)
2007		12,575 ⁴							Hopi (2008b)
2010	8,629								Hopi (2004)
	13,532								Hopi (2001)
		7,522	6,141	95%	3%	1%	<1%	<1%	ARPI (2012)
2015	8,853								Hopi (2015)
2020	11,302								Hopi (2004)
	17,322								Hopi (2001)
	10,567								Hopi (2015)
2030	14,771								Hopi (2004)
	14,576								Hopi (2015)
2040	19,222								Hopi (2004)
	19,066								Hopi (2015)
2050	24,745								Hopi (2004)
	24,202								Hopi (2015)
2100	52,639								Hopi (2004)
	47,390								Hopi (2015)
2175 ⁵	62,512								Hopi (2004)
	52,016								Hopi (2015)

Notes:

¹ These reported populations appear low based on comparison to prior and later years.

² Estimated based on number of people served by public water systems on the Reservation.

³ Recent tribal survey estimated that 13% of Reservation population was not enrolled in Tribe, of which 6% were non-enrolled Hopi, 6% were other American Indians, and 1% were non-Indians (SWCA, 2008).

⁴ Tribe anticipates number of members to increase by 40 persons per quarter or 160 new members per year.

⁵ Year that population is projected to stabilize.

TABLE B-9. CHARACTERISTICS OF HOUSING ON THE HOPI INDIAN RESERVATION ¹

HOUSING CHARACTERISTIC		1990	2000	2004	2006	circa 2007
Type	Single Attached or Detached		80.1%			
	Mobile Home		14.9%			
	Multiple (2-9) Units		4.9%			
Occupancy	Households Occupied	75%	78%			
	Average Persons per Household	3.93				2
	New Housing Needs to Address Overcrowding		315 units			26% ²
Fuel Source	Wood		29%			
	Coal		10%			
	Electric		5%			
	Other		34%			
Condition	Lacking Complete Plumbing		40%	18%		
	Repairs Needed					>50% ³
	Dilapidated		447 ⁴			2% ³
Financials	Median Value		\$42,400			
	HTHA funding from Indian Housing Block Grant ⁵				\$2.9 million	\$2.6 million
Total Units		2,476	2,464			3,061 (occupied)

Notes:

¹ Sources: Census (2007), Hopi (2001, 2004, and 2008b), and TDR (2008).

² Percentage of households responding to recent survey.

³ Percentage of occupied housing units.

⁴ Estimated housing units needed to replace those considered beyond structural repair.

⁵ HTHA = Hopi Tribal Housing Authority.

TABLE B-10. EMPLOYMENT AND INCOME DATA FOR THE HOPI INDIAN RESERVATION ¹

CATEGORY / YEAR		1986	1988	1990	1999	2000	2001	2003	2004	2005	2006	circa 2007	2008	2010
Labor Force				2,308	3,055		3,982	3,451	3,457		2,455	2,392 to 3,879		2,964
Women in Workforce						52 to 59%						53.0%		52.0%
Unemployment Rate			32.0%	20.5%	62.0%	18.0%	60.0%	20.9%	18.2%		10.9%	10% to 29.8%	35.6%	
Jobs		1,341				1,869 to 2,700								
Employment Sectors ²	Education, Health, and Social Services	27.3%				33.5 to 37%								34.4%
	Public Administration	35.0%				7 to 25.9%								18.8%
	Manufacturing	2.2%				5.5 to 40%								9.1%
	Wholesale and Retail Trade	27.3%				5 to 8.6%								12.9%
	Construction	4.5%				3 to 10.5%								2.5%
	Transportation and Utilities	1.8%				1.4 to 4%								4.9
	Finance, Insurance, and Real Estate	0%				1 to 1.8%								2.3
	Agriculture	1.5%				0.4 to 3%								2.7%
	Arts, Entertainment, and Recreation	0.0%				0 to 7%								7.3%
	Professional, Science, Management and Waste Services	0.0%				0 to 2.6%								2.5%
Mining	0.4%				0 to 0.6%									
Employer	Government					55%						46%		
	Private Sector					45%						54%		
Earnings	Formal Economy					\$44.8 million								
	Informal Economy ³					≥\$4.2 million								
Income	Per Capita					\$8,637								\$11,753
	Below Poverty Level				61.0%	38.9%								35%
	Median Family				\$15,875	\$22,989								\$34,016

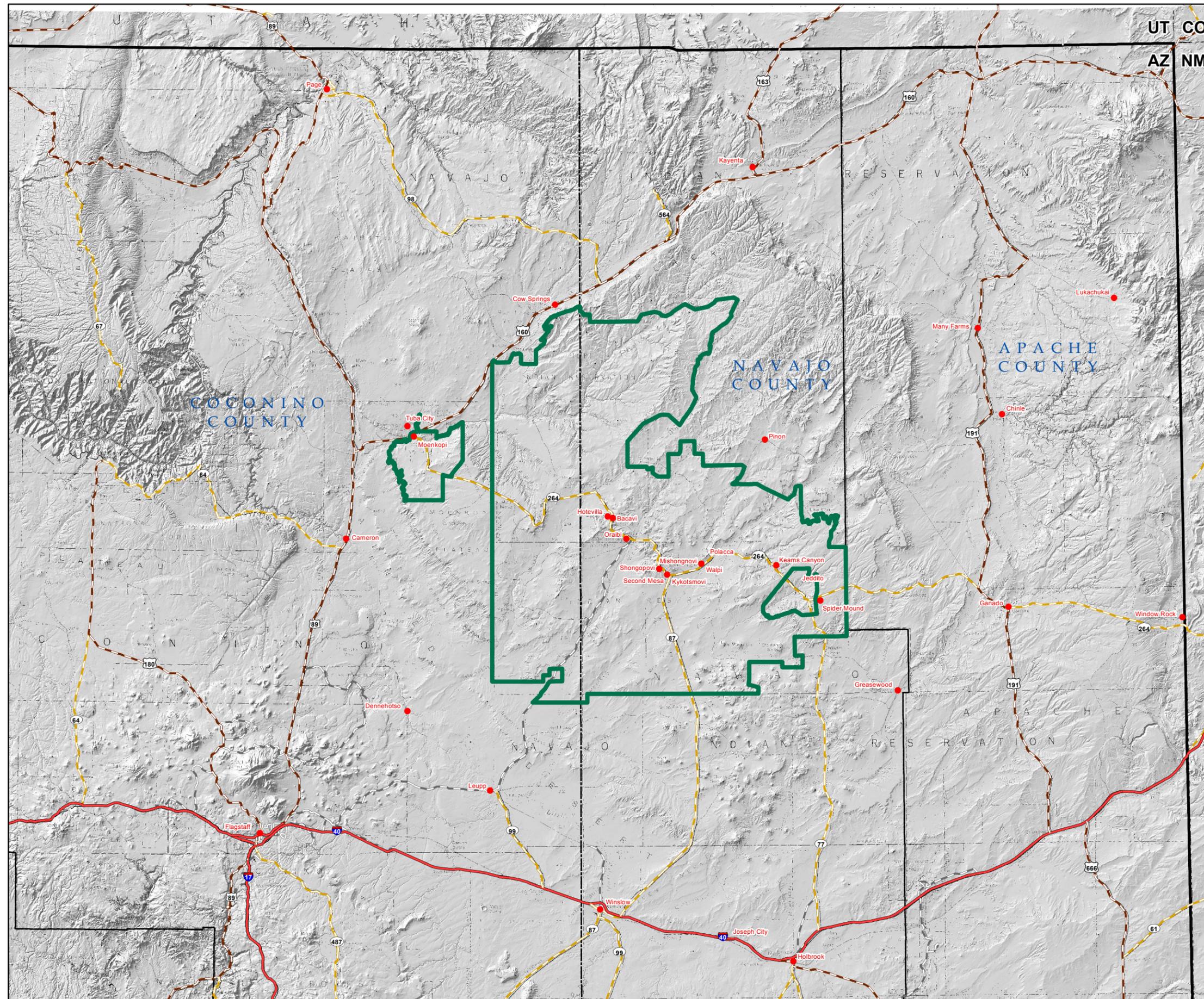
Notes:

¹ Sources: ADES (2008), ADOC (2008a,b), Census (2007), Hopi (1988, 2001 and 2008b), Sonoran Institute (2005), SWCA (2005 and 2008), TDR (2000 and 2008) and ARPI (2012).

² Different data sources and sector definitions may explain the range in values reported for 2000 and some of the differences between values for 2000 and 1986.

³ Includes \$3.6 million in traditional arts and crafts, \$600,000 for local cattle consumption and giveaways, and an unknown amount for corn harvests.

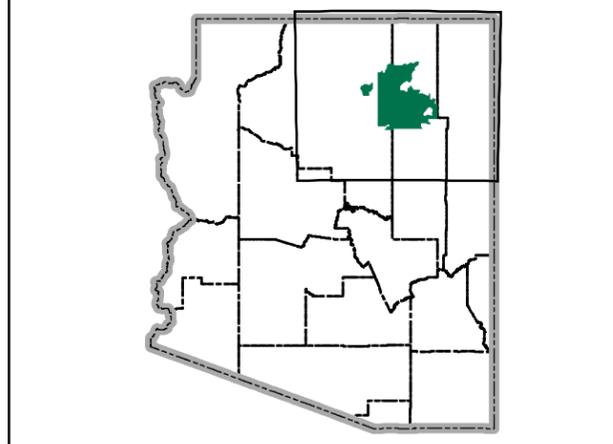
FIGURES



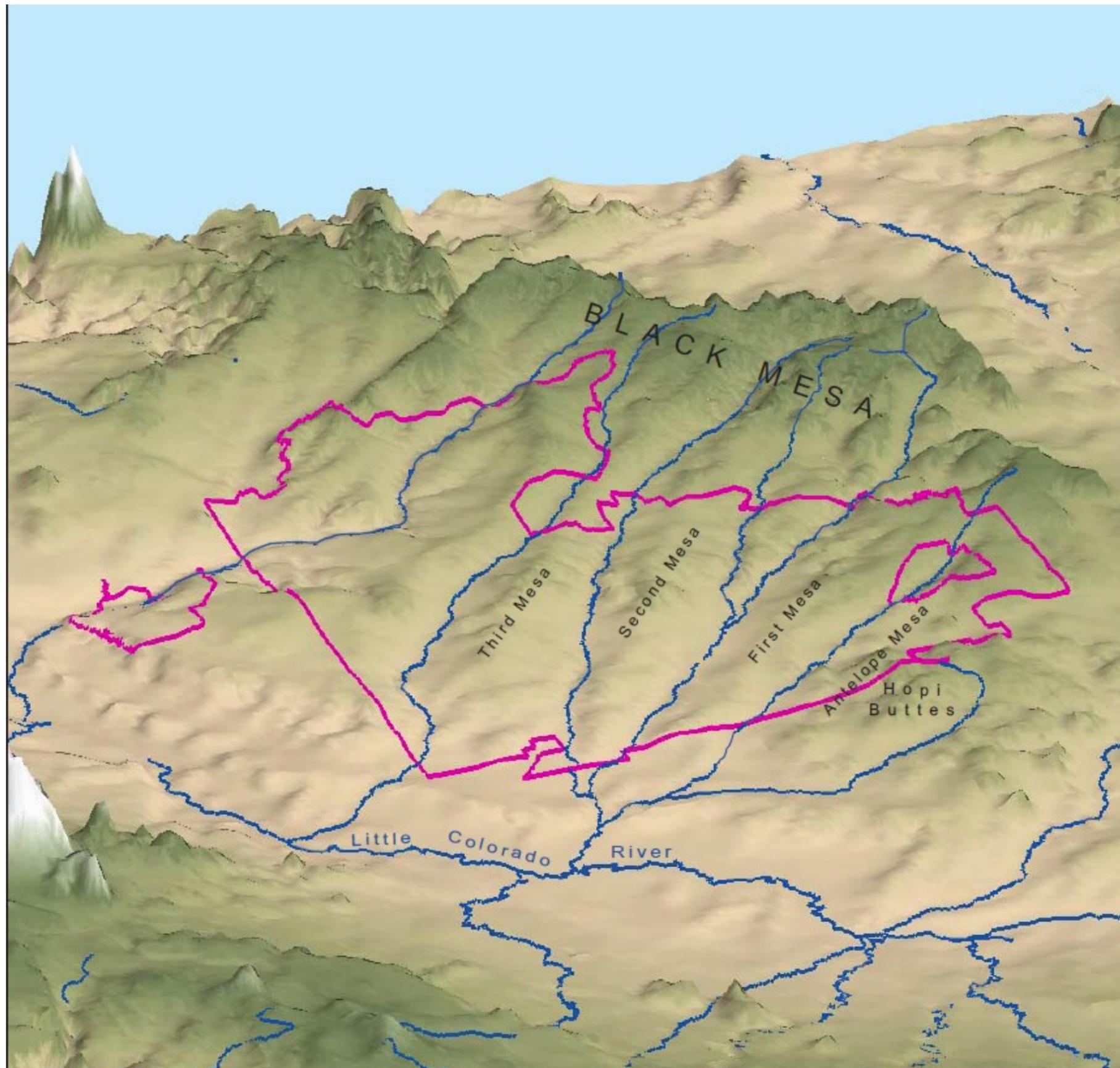
Legend

- City/Town/Village
- ~ Interstate Highway
- ~ U.S. Route
- ~ State Highway
- County
- State
- Hopi Reservation

Basemap:
USGS 1:500,000 Topographic Map

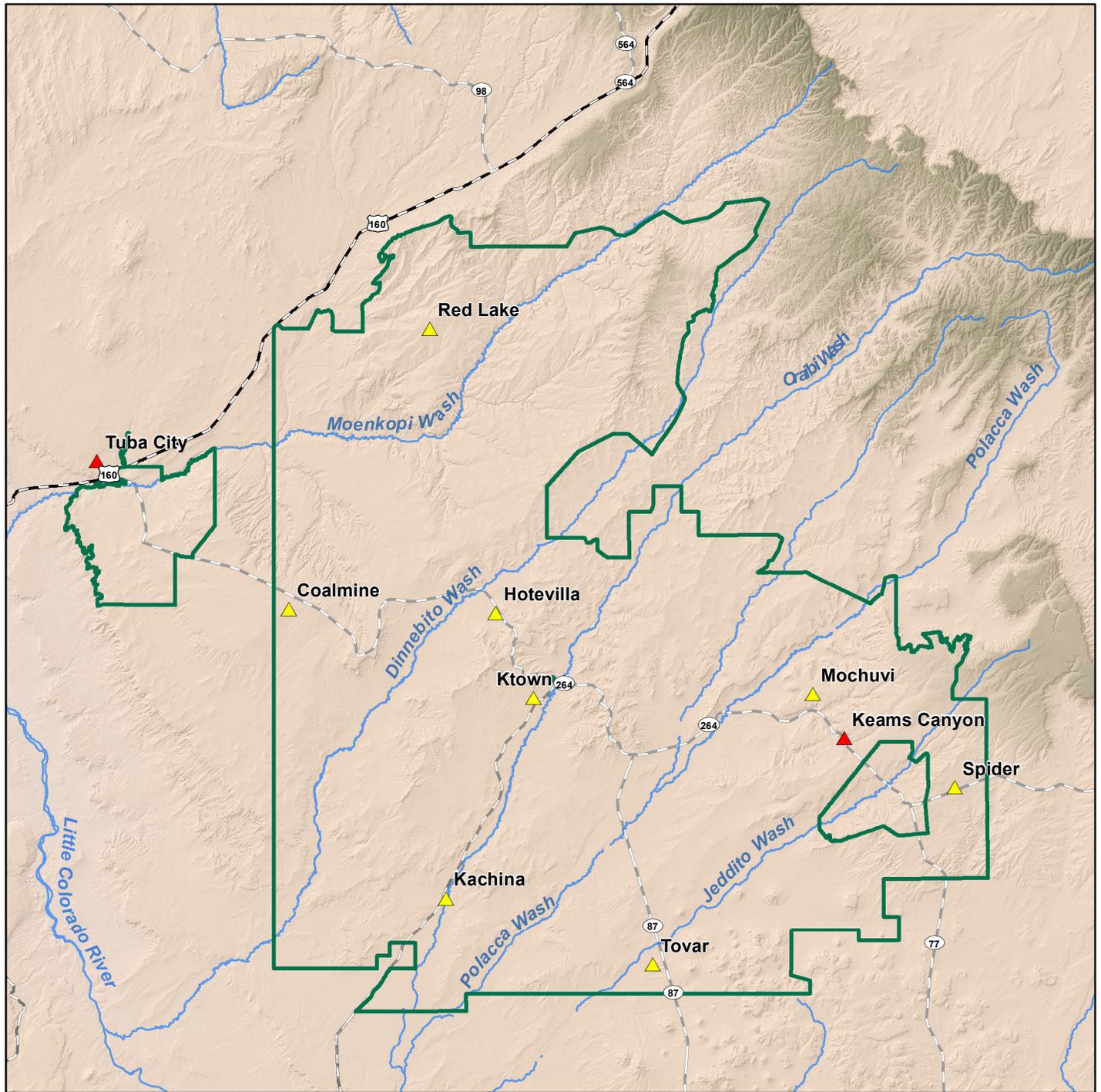


Appendix B
Figure B-1
Location and Topography
of the Hopi Indian
Reservation



Base Map: 30 Meter DEM

<p>Appendix B Figure B-2 Oblique Aerial Image of the Hopi Indian Reservation</p>
<p>Final Hopi HSR December 2015</p> 



Legend

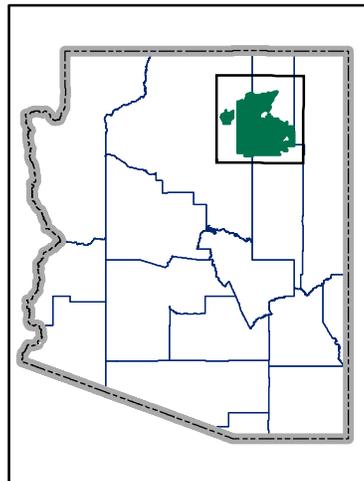
Meteorological Stations

Agency

-  Hopi Tribe
-  National Weather Service
-  Streams
-  U.S. Route
-  State Highway
-  Local
-  Hopi Reservation



Sources:
 1. HWRP (2007)
 2. WRCC (2008)

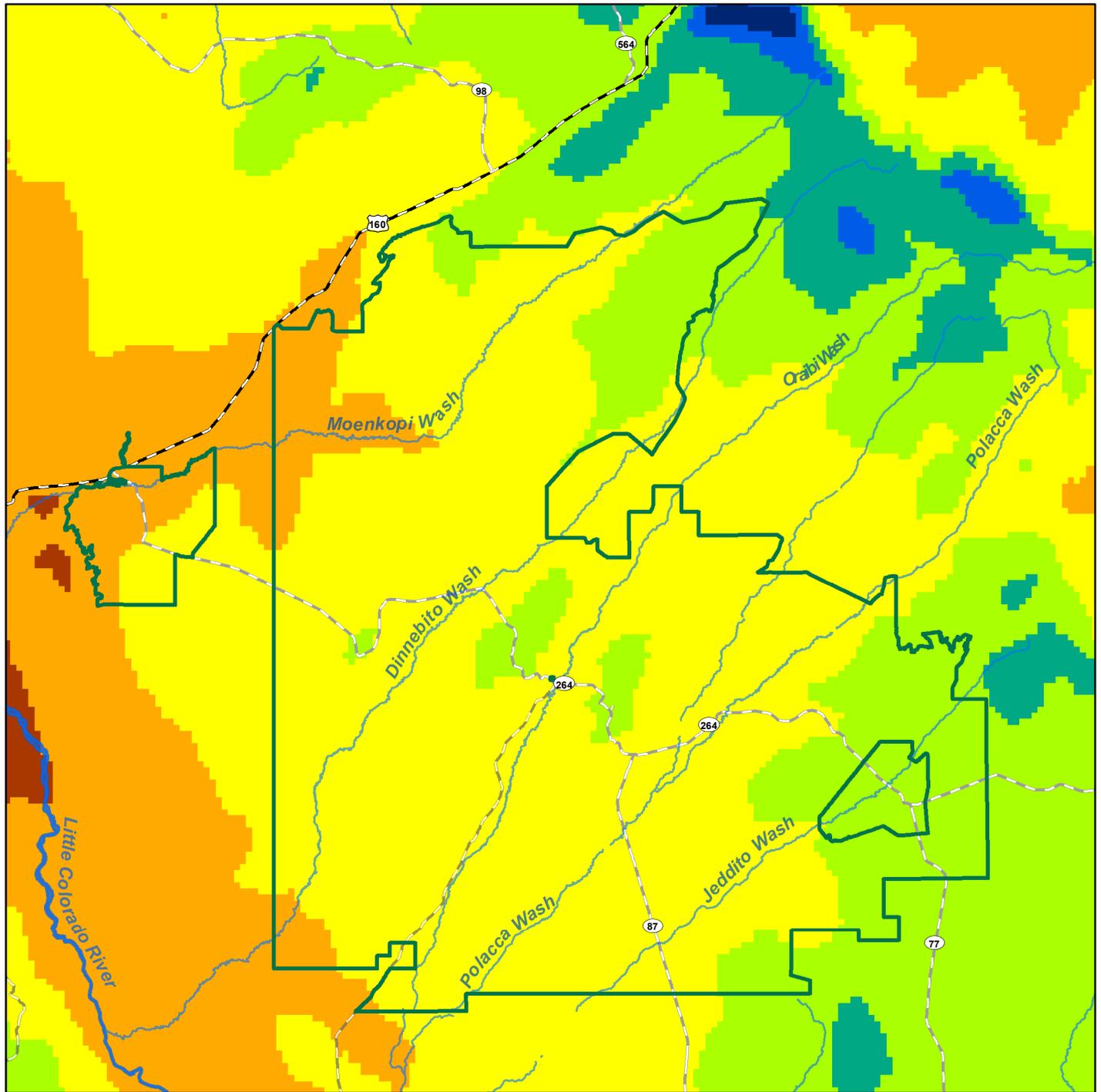


**Appendix B
 Figure B-3**

Meteorological Stations
 on and Adjacent to the
 Hopi Indian Reservation

**Final Hopi HSR
 December 2015**



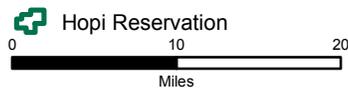


Legend

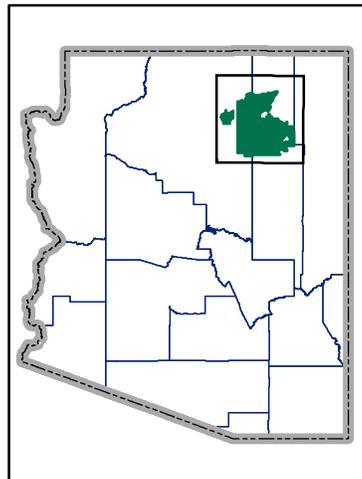
Average Annual Precipitation from 1971-2000 (in inches)

- 4.01-6
- 6.01-8
- 8.01-10
- 10.01-12
- 12.01-14
- 14.01-16
- 16.01-18
- Streams

- U.S. Route
- State Highway
- Local
- Hopi Reservation



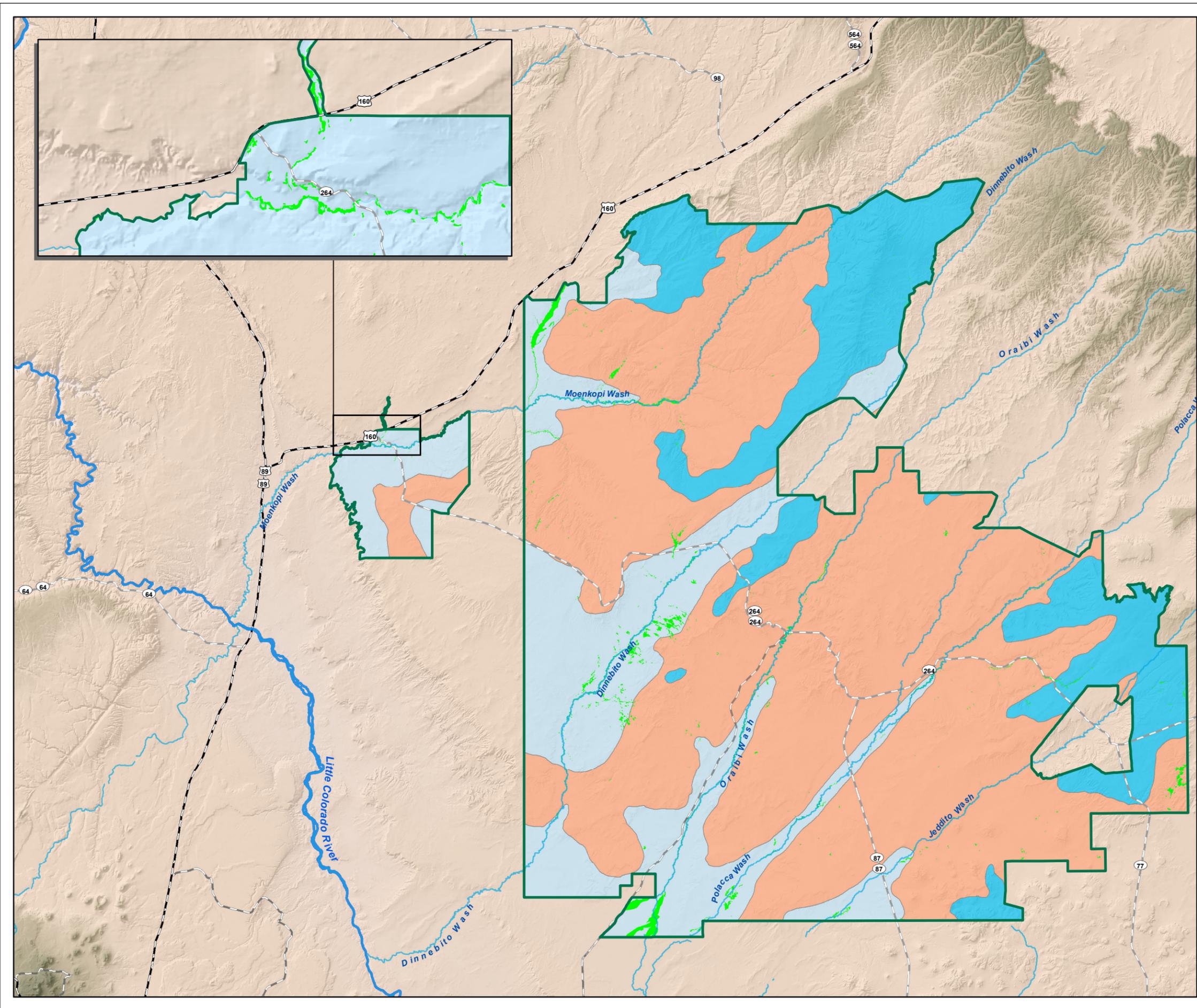
Source:
Daly and others (2002)



Appendix B
Figure B-4
Mean Annual
Precipitation in the
Vicinity of the
Hopi Indian Reservation

Final Hopi HSR
December 2015





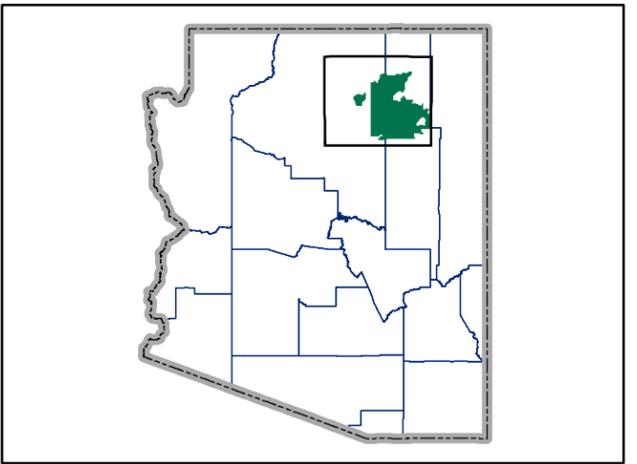
Legend

- Streams
- U.S. Route
- State Highway
- Hopi Reservation
- Great Basin Conifer Woodland
- Great Basin Desert Scrub
- Plains and Great Basin Grassland
- Riparian Vegetation in 2005

Source:

- 1) Vegetative Communities: Brown and Lowe (1980).
- 2) Riparian Vegetation: ADWR (2008c).

0 10 20
Miles



Appendix B
Figure B-5
 Vegetative Communities and
 Riparian Vegetation on the
 Hopi Indian Reservation



Figure 1: Cottonwood in Keams Canyon



Figure 2: Russian Olive near Keams Canyon



Figure 3: Salt Cedar along Lower Coal Mine Wash



Figure 4: Willow along Moenkopi Wash

Appendix B

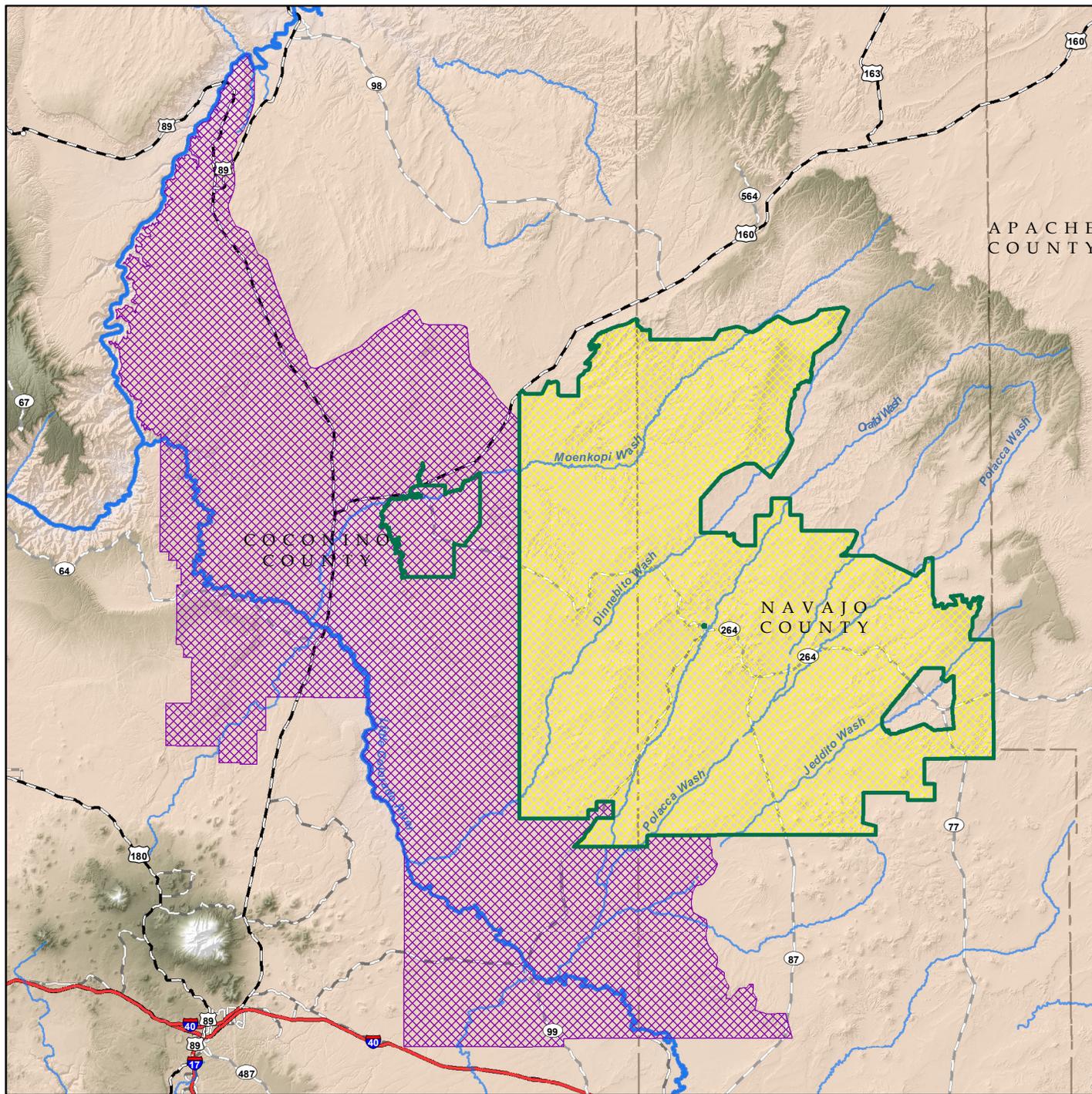
Figure B-6

Riparian Vegetation on the Hopi
Indian Reservation

Final Hopi HSR

December 2015

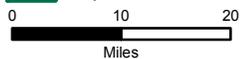




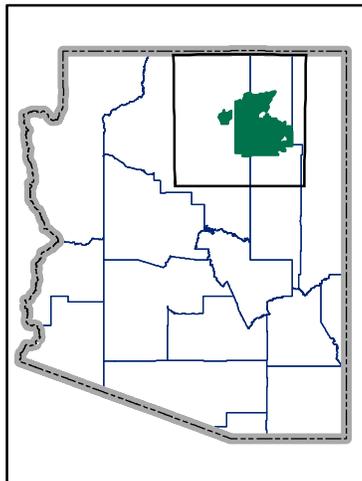
Legend

Soil Surveys

-  Hopi Area, Arizona, Parts of Coconino and Navajo Counties
-  Little Colorado River Area, Arizona, Parts of Coconino and Navajo Counties
-  Streams
-  Interstate Highway
-  U.S. Route
-  State Highway
-  Local
-  County
-  Hopi Reservation



Source:
NRCS (1996 and 2012).

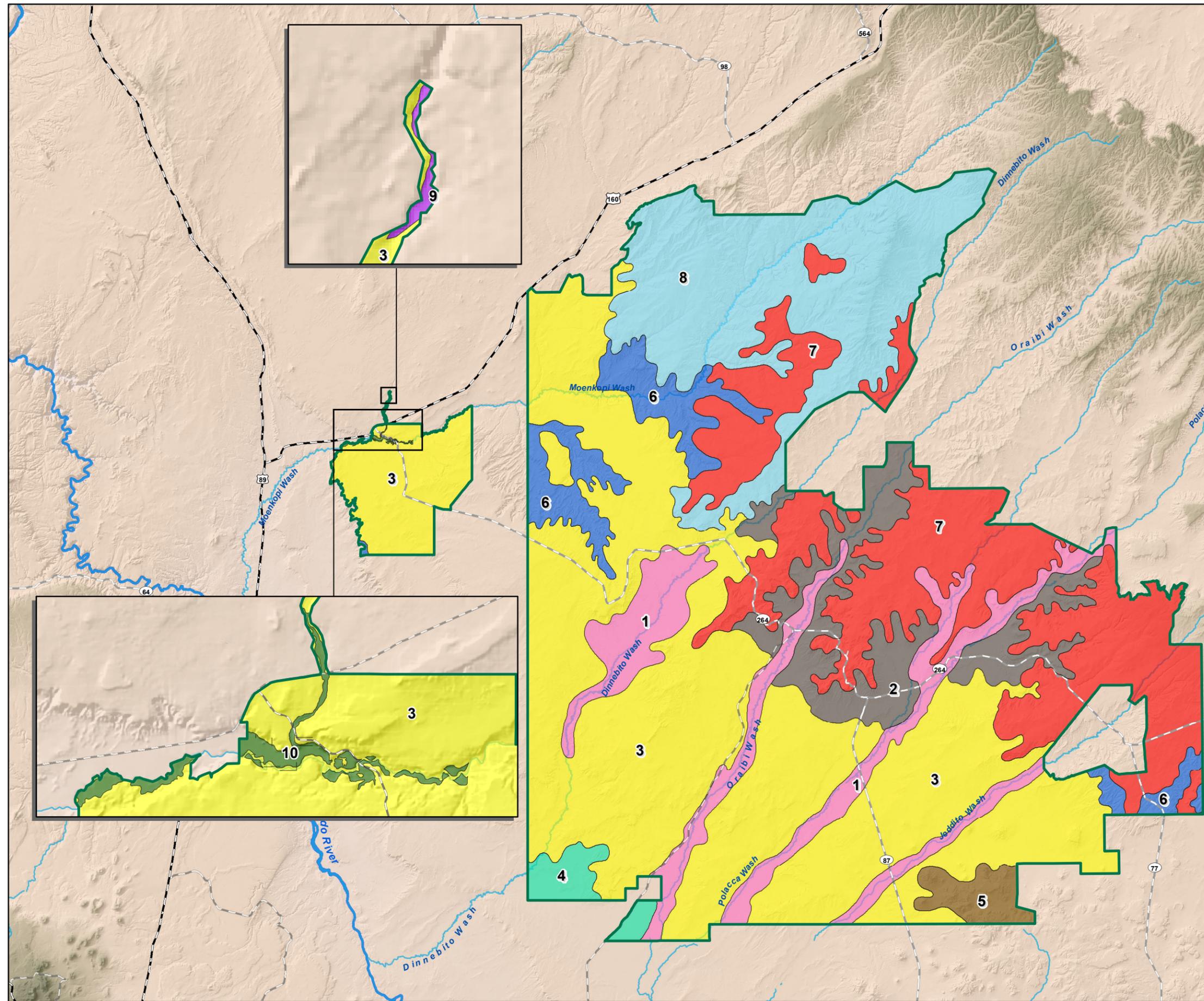


**Appendix B
Figure B-7**

NRCS Soil Surveys
of the Hopi
Indian Reservation

Final Hopi HSR
December 2015

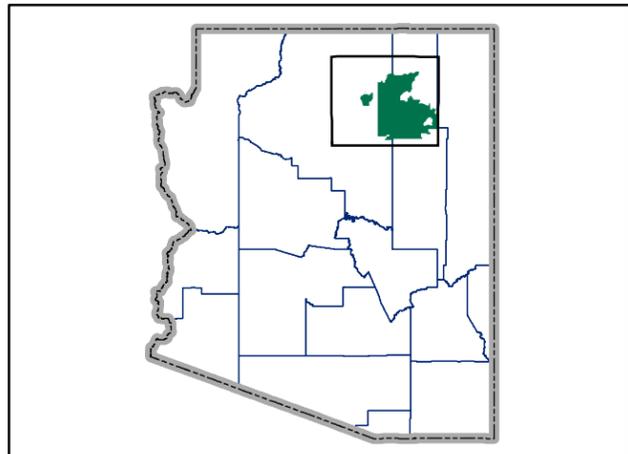




Legend

- Hopi Reservation
 - U.S. Route
 - State Highway
 - Local
 - Streams
- General Soil Map Units**
- 1 Jocity-Polacca-Wepo
 - 2 Jeddito-Tewa
 - 3 Sheppard-Monue-Nakai
 - 4 Sheppard-Jocity
 - 5 Strych-Kinan
 - 6 Torriorthents-Badland-Rock Outcrop
 - 7 Begay-Penistaja-Mido
 - 8 Kydestea-Zyme-Tonalea
 - 9 Endoaquolls-Haplofibrists-Torrifluvents
 - 10 Sheppard-Ives-Torrifluvents

Source:
NRCS (1996 and 2012)



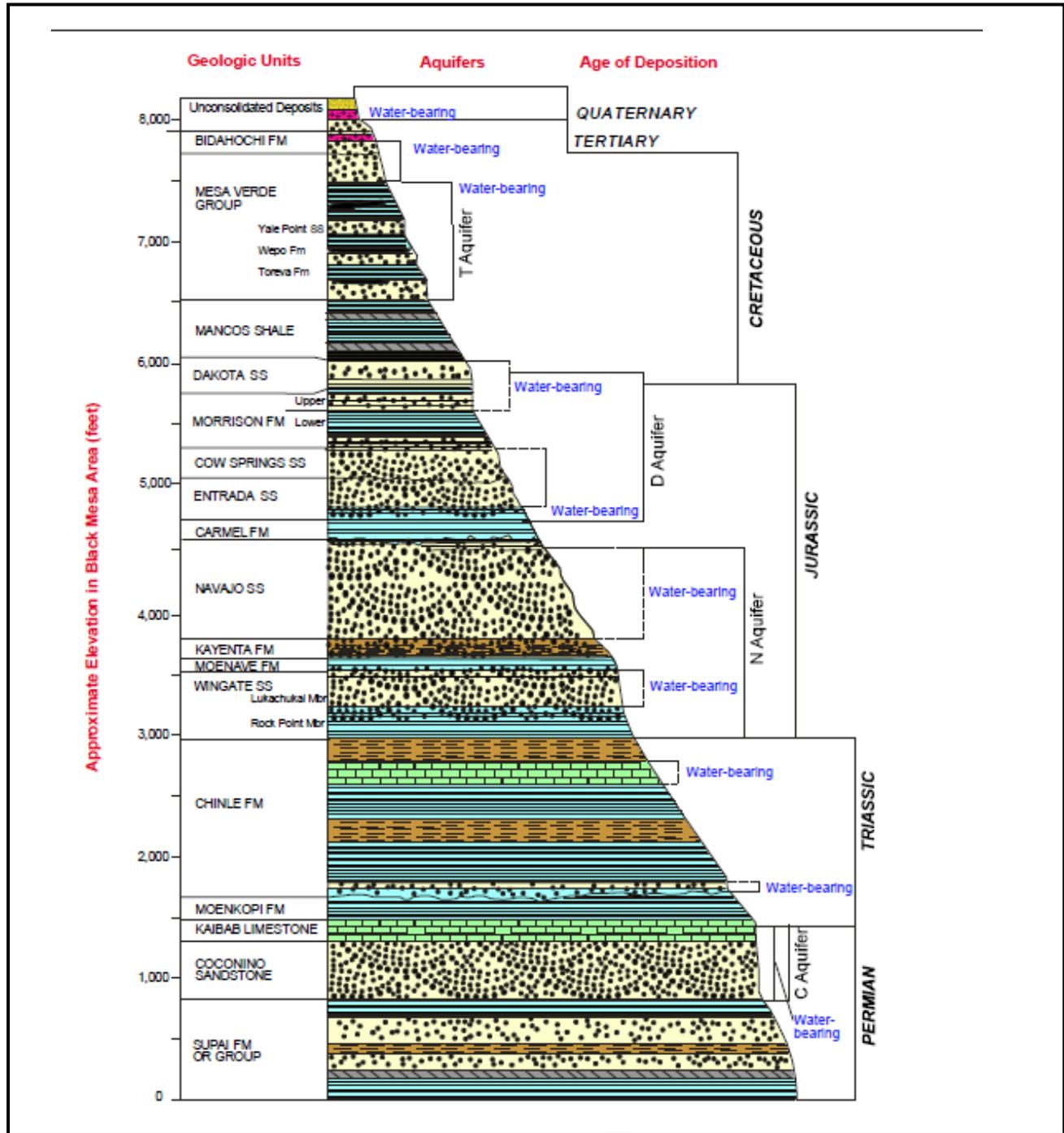
**Appendix B
Figure B-8**

General Soil Map Units
on the Hopi
Indian Reservation

Final Hopi HSR

December 2015





Rock Types

- Alluvium/Colluvium
- Volcanic Rock
- Coal
- Sandstone
- Siltstone
- Siltstone, Mudstone
- Shale
- Limestone

Source: GeoTrans and Waterstone (1999)

Appendix B

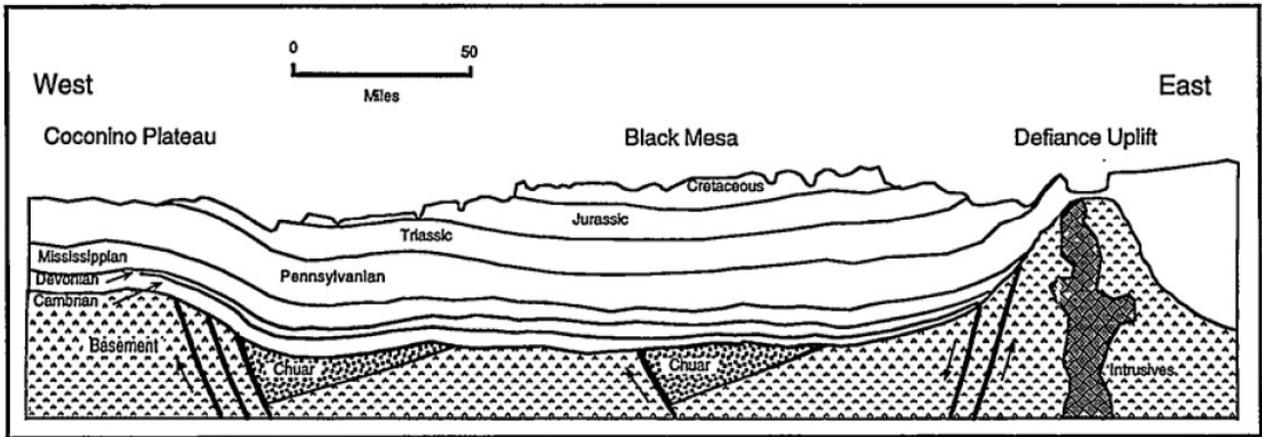
Figure B-9

Important Geologic Units and
Aquifers Underlying the Hopi
Indian Reservation

Final Hopi HSR

December 2015





Appendix B

Figure B-10

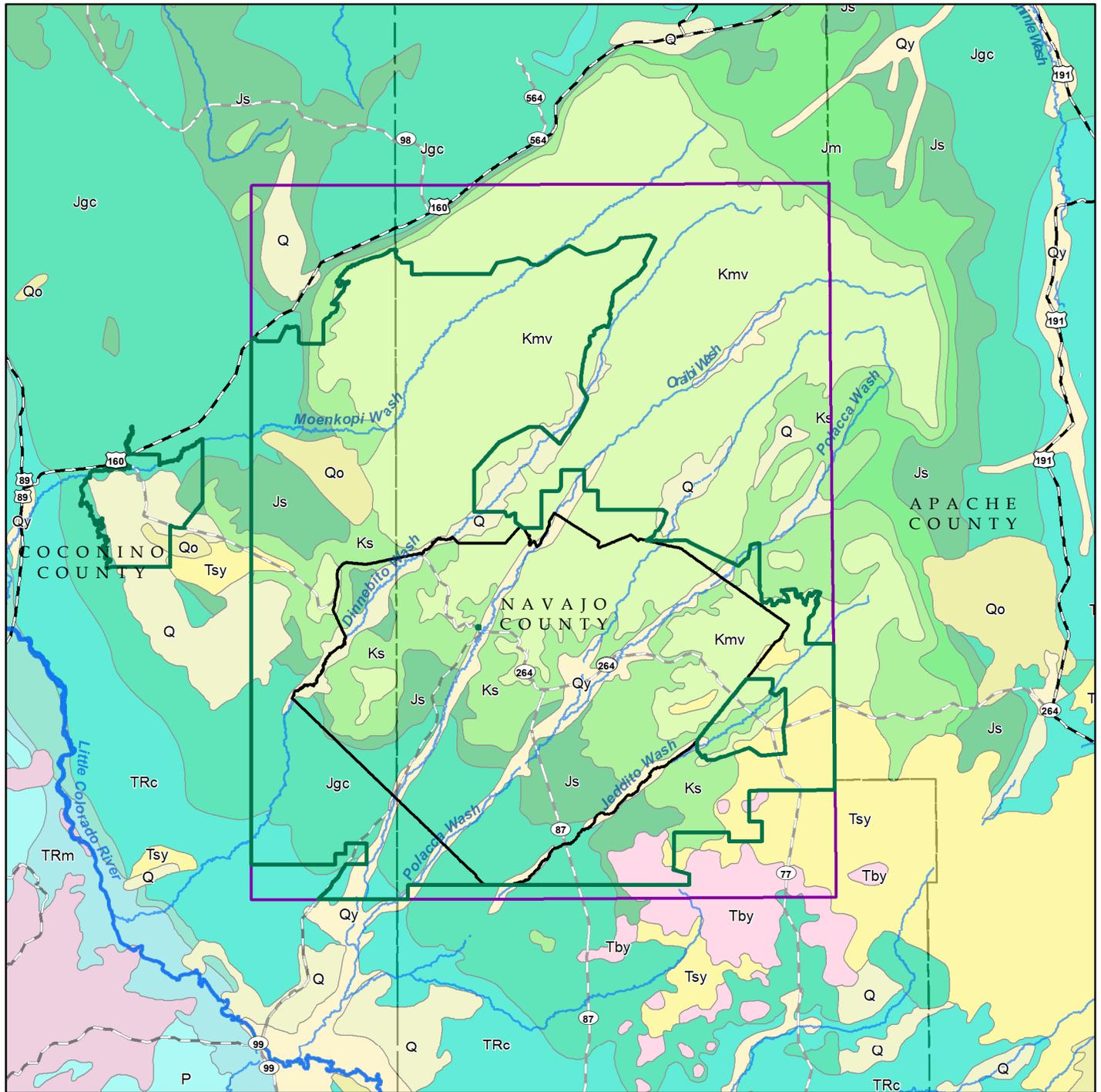
Structural Geologic Cross Section of
the Black Mesa Area

Final Hopi HSR

December 2015

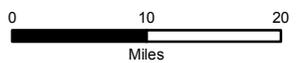
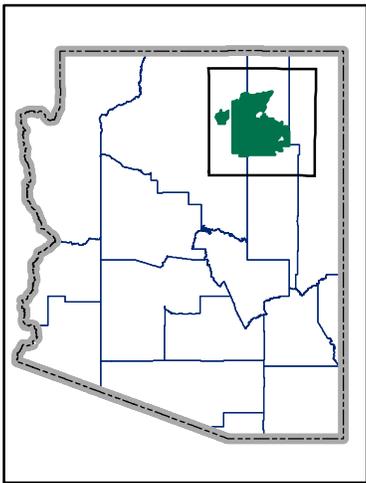


Source: Reeves and others (1999)



- Legend**
- Streams
 - Interstate Highway
 - U.S. Route
 - State Highway
 - Local
 - County
 - Hopi Reservation
 - District 6
 - Navajo Partition Land

- Surface Geology Units**
- Q- Quaternary Surficial Deposits Undivided
 - QTb- Holocene to Middle Pliocene Basaltic Rocks
 - QTv- Holocene to Middle Pliocene Volcanic Rocks
 - Qy- Holocene Surficial Deposits
 - Qo- Early Pleistocene to Latest Pliocene Surficial Deposits
 - Tsy- Pliocene to Middle Miocene Depsits
 - Tby- Pliocene to Late Miocene Basaltic Rocks
 - Kmv- Sedimentary Rocks of the Upper Cretaceous Mesaverde Group
 - Ks- Cretaceous Sedimentary Rocks
 - Jm- Morrison Formation
 - Js- San Raphael Group
 - Jgc- Glen Canyon Group
 - TRc- Chinle Formation
 - TRcs- Shinarump Conglomerate Member
 - TRm- Moenkopi Formation
 - P- Permian Sedimentary Rock



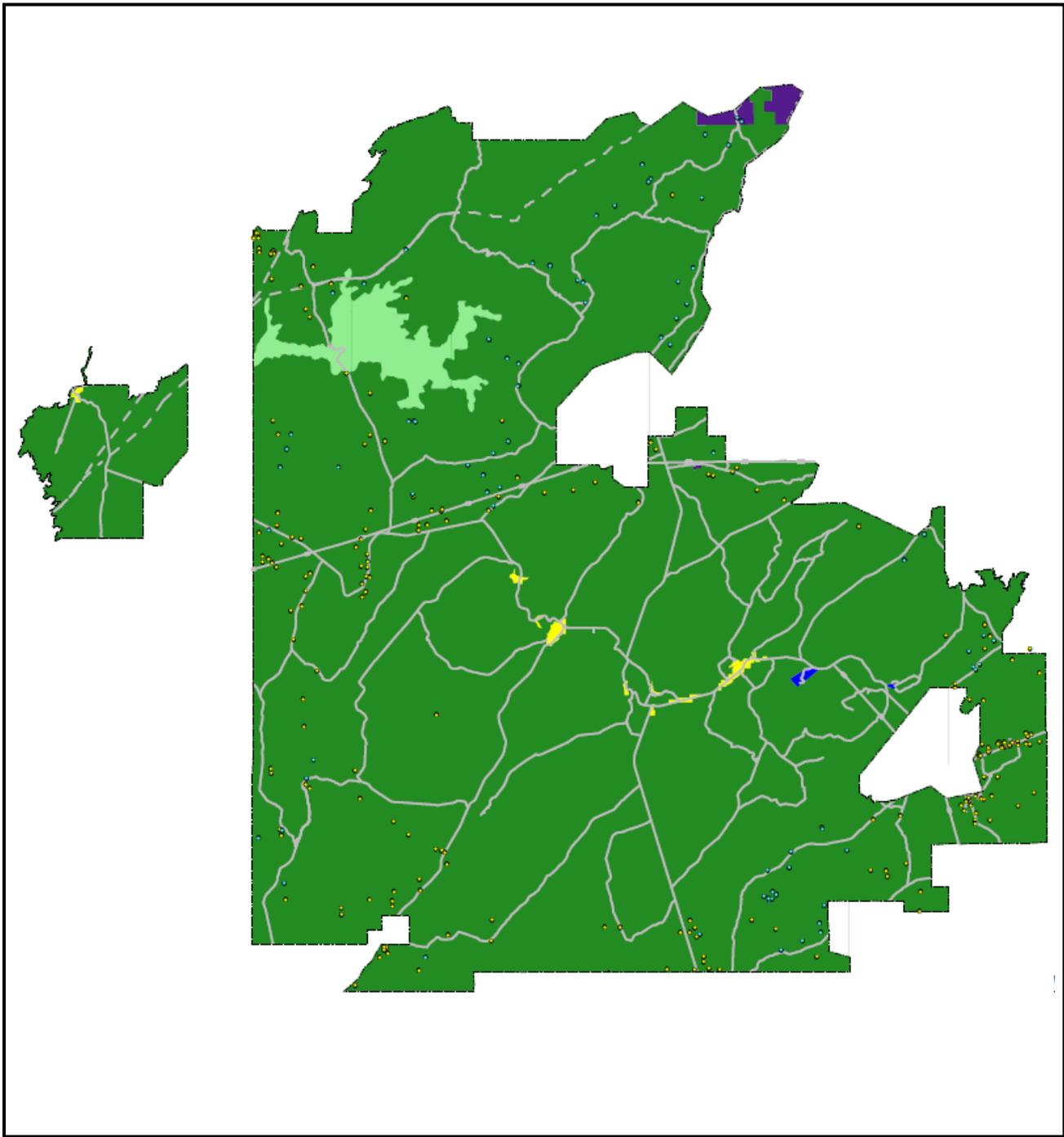
Source:
Richards and others (2000)
Original Scale 1: 1,000,000

Appendix B Figure B-11

Surface Geology in the
Vicinity of the Hopi
Indian Reservation

Final Hopi HSR
December 2015





- Land Uses**
- Recreation
 - Industrial
 - Community Residential
 - Agriculture & Range
 - Institutional
- Rights-of-way**
- BIA Indian Reservation Roads System
 - Electrical Transmission Line
 - Pipeline
- Home Sites**
- Navajo
 - Hopi



Source: Hopi, (2001)

Appendix B

Figure B-12

2000 Land Use on the
Hopi Indian Reservation

Final Hopi HSR

December 2015





Range



Dry Land Farming



Irrigated Agriculture



Institutional



Mining

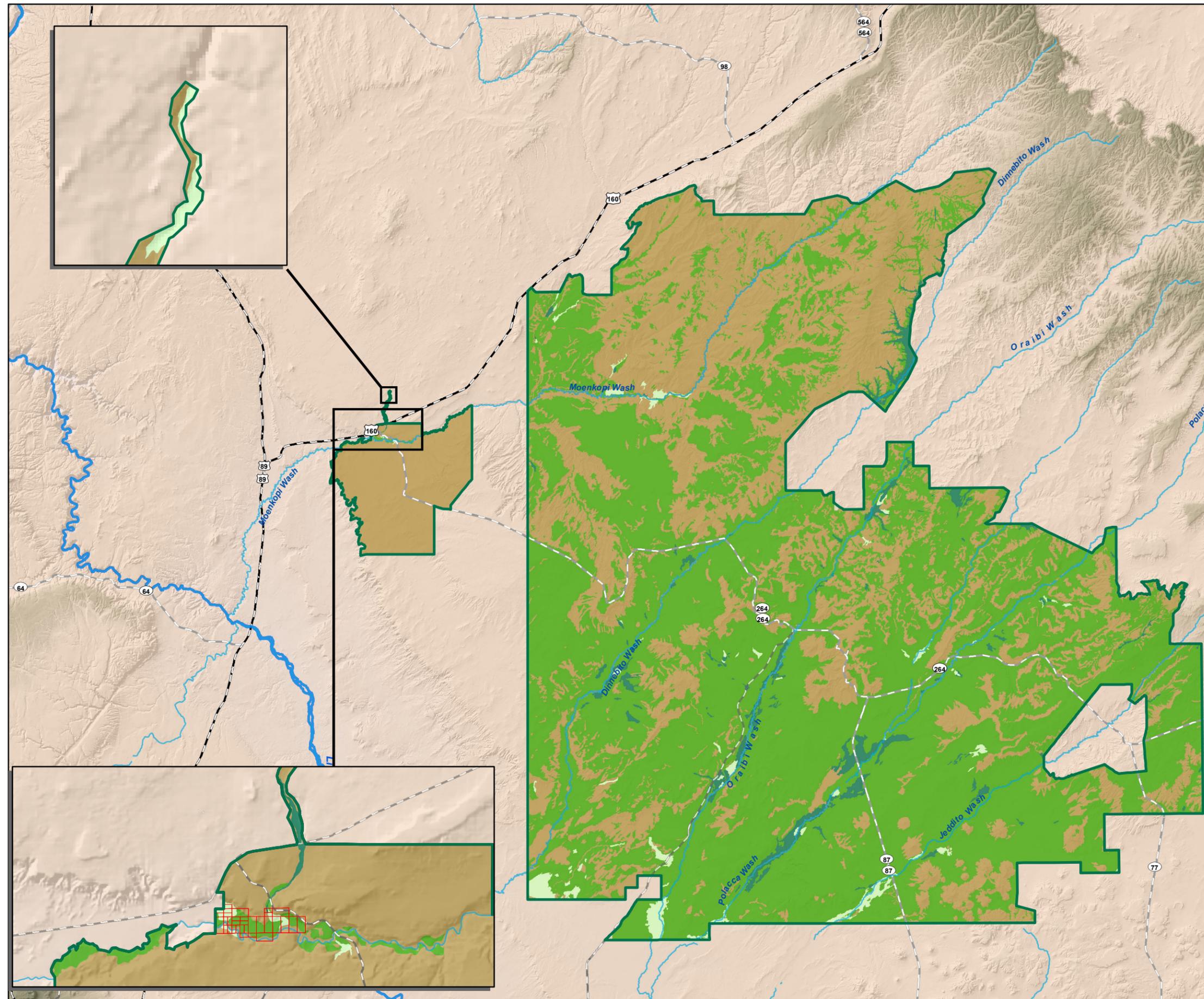


Tourism

Appendix B
Figure B-13
Photographs of Recent Land Use on
and near the Hopi Indian
Reservation

Final Hopi HSR
December 2015

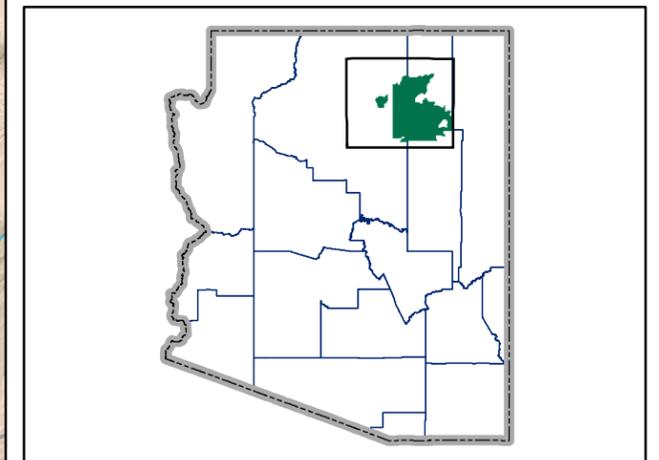
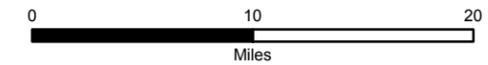




Legend

-  Hopi Reservation
-  Hopi Allotment
-  Streams
-  Interstate
-  Road
-  Local
-  Class II (29,595 acres)
-  Class III (977,392 acres)
-  Class IV (16,505 acres)
-  Not Classified (597,758 acres)

Source:
NRCS (1996 and 2007a)

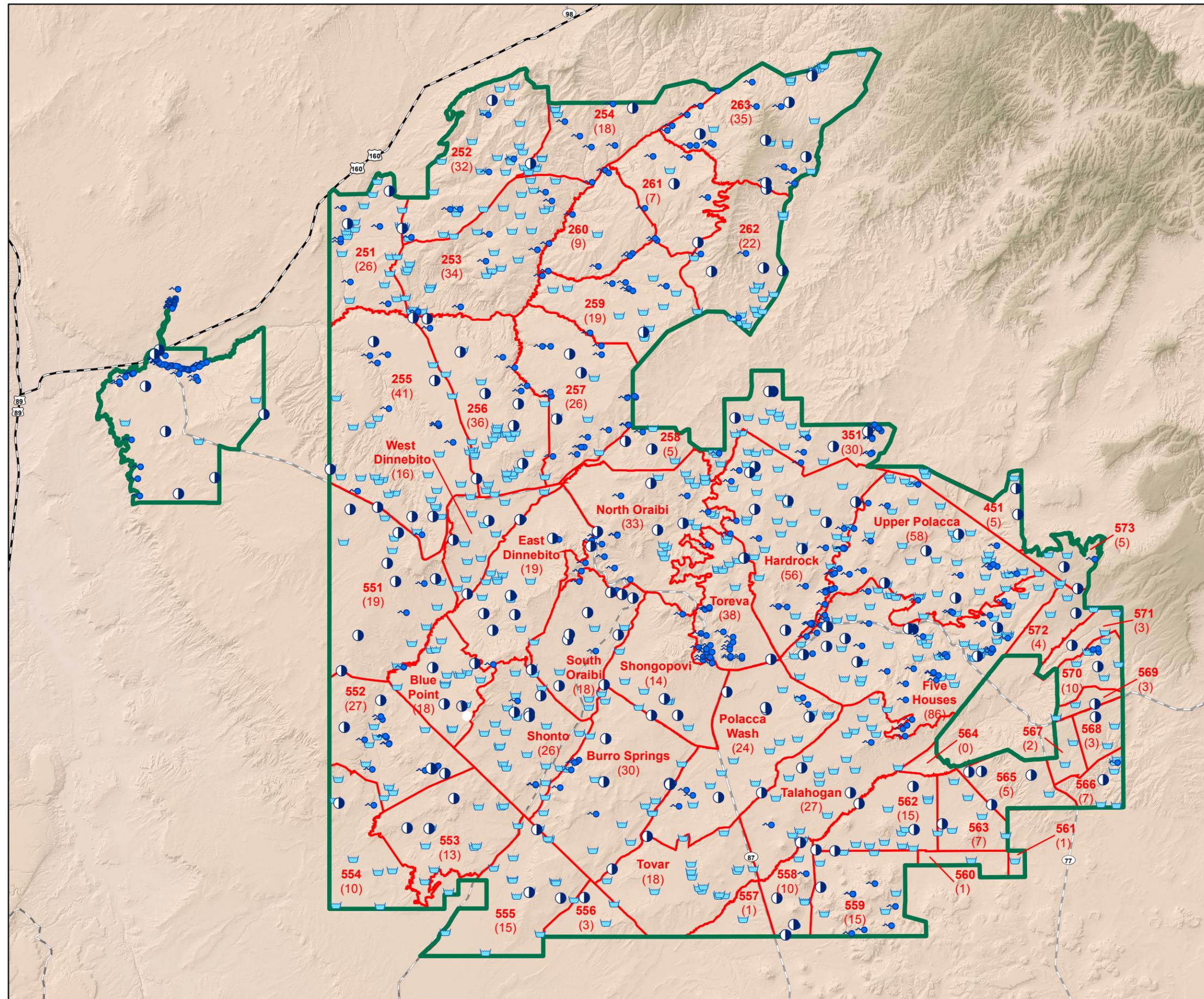


Appendix B
Figure B-14
Irrigated Capability Classes
for Soils on the
Hopi Indian Reservation

Final Hopi HSR

December 2015





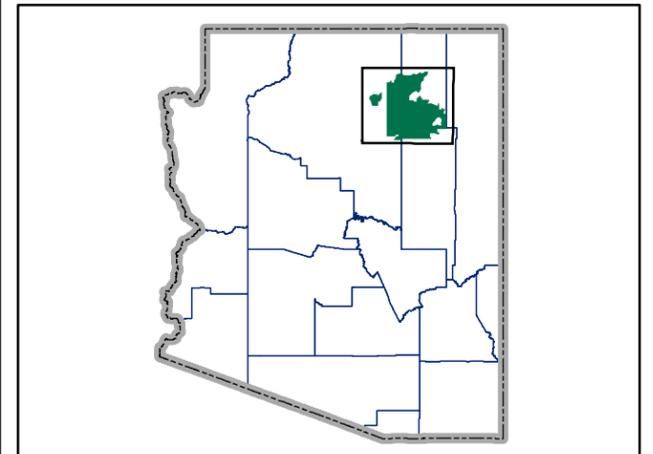
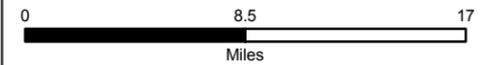
Legend

Claimed Sources of Stock Water (Hopi, 2004)

- Well
- Spring
- Pond

555 = Range Unit Name or Number
(15) = (Number of Claimed Stock Water Sources)

- Range Units
- Hopi Reservation



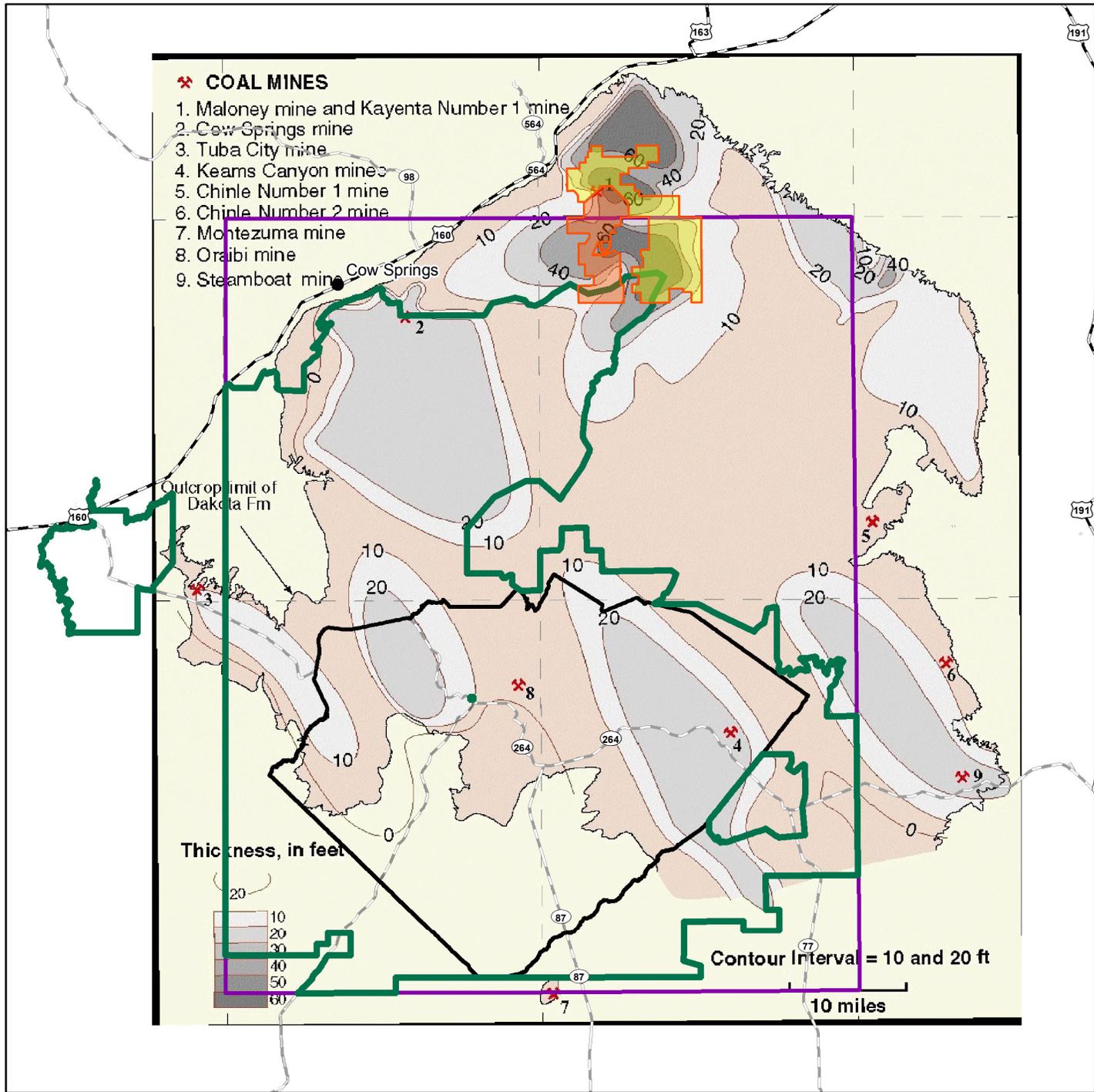
Appendix B Figure B-15

Range Units and Sources
of Stock Water on the
Hopi Indian Reservation

Final Hopi HSR

December 2015





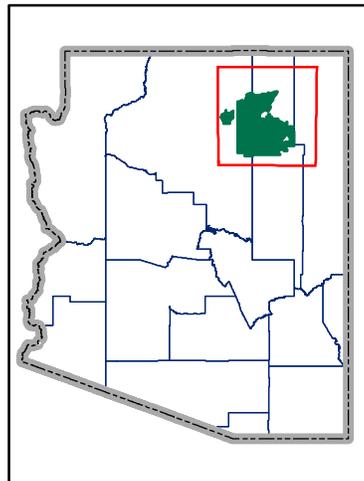
Legend

- Hopi Reservation
- District 6
- Navajo Partitioned Land
- Town/Village
- Interstate Highway
- U.S. Route
- State Highway
- Local

Peabody Western Coal Mine (PWCC) Leasehold

- Kayenta Mine
- Black Mesa Mine

Source: Nations and others (2000).



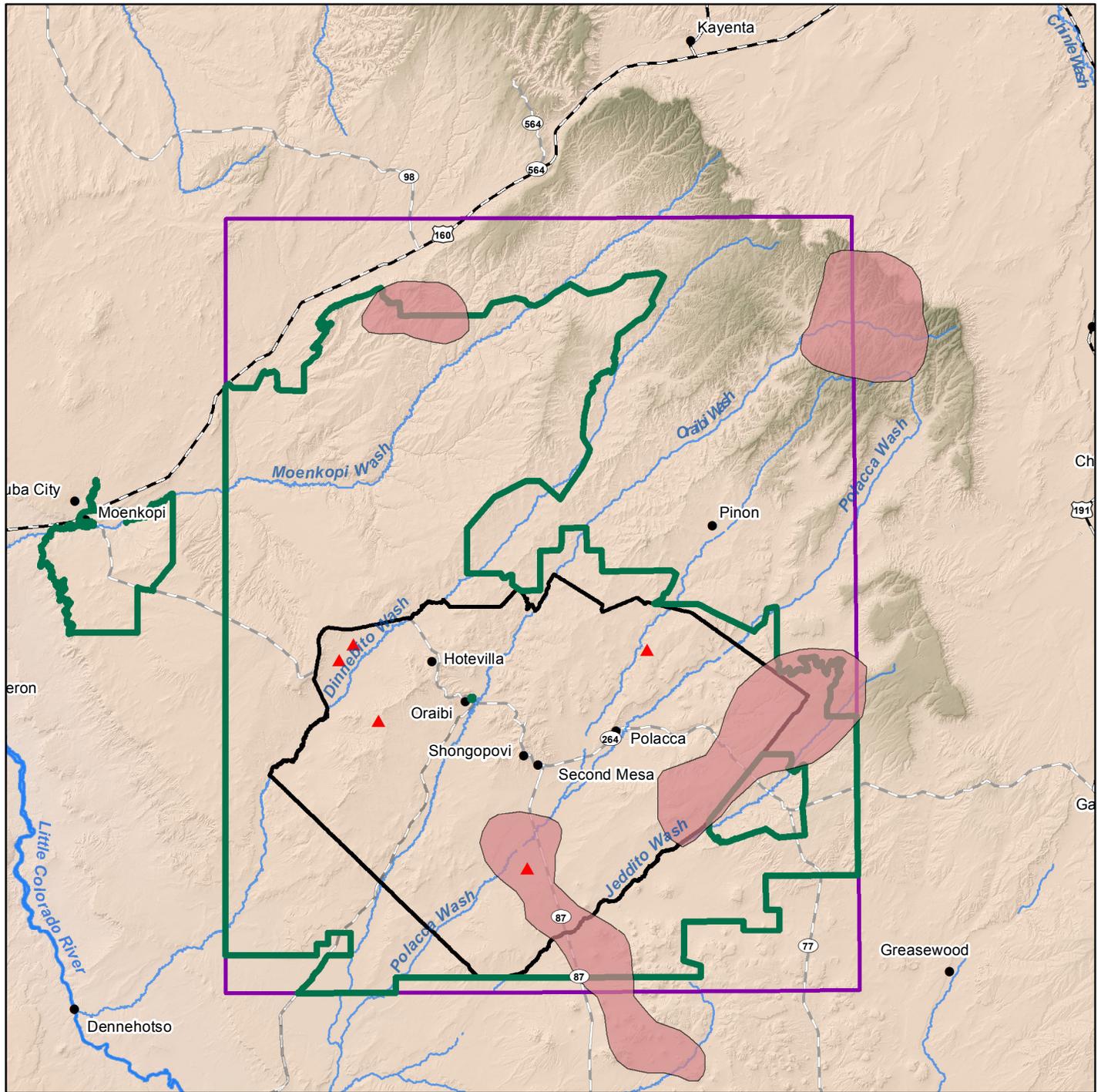
**Appendix B
Figure B-16**

Coal Mines and Deposits
in the Vicinity of the
Hopi Indian Reservation

Final Hopi HSR

December 2015



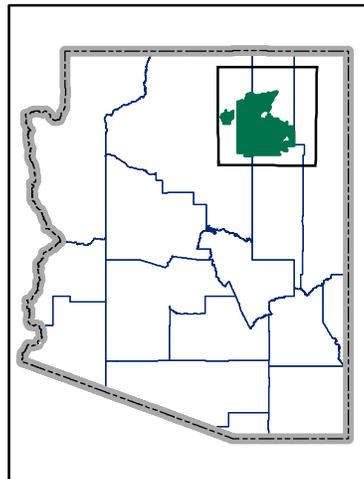


Legend

- ▲ Hydrocarbon Show
- Potential Oil and Gas Reserve
- ▭ Hopi Reservation
- ▭ Hopi District 6
- ▭ Navajo Partitioned Land
- Town/Village
- ~ Streams
- ~ U.S. Route
- ~ State Highway
- ~ Local



Source: Sharma and others (1999).

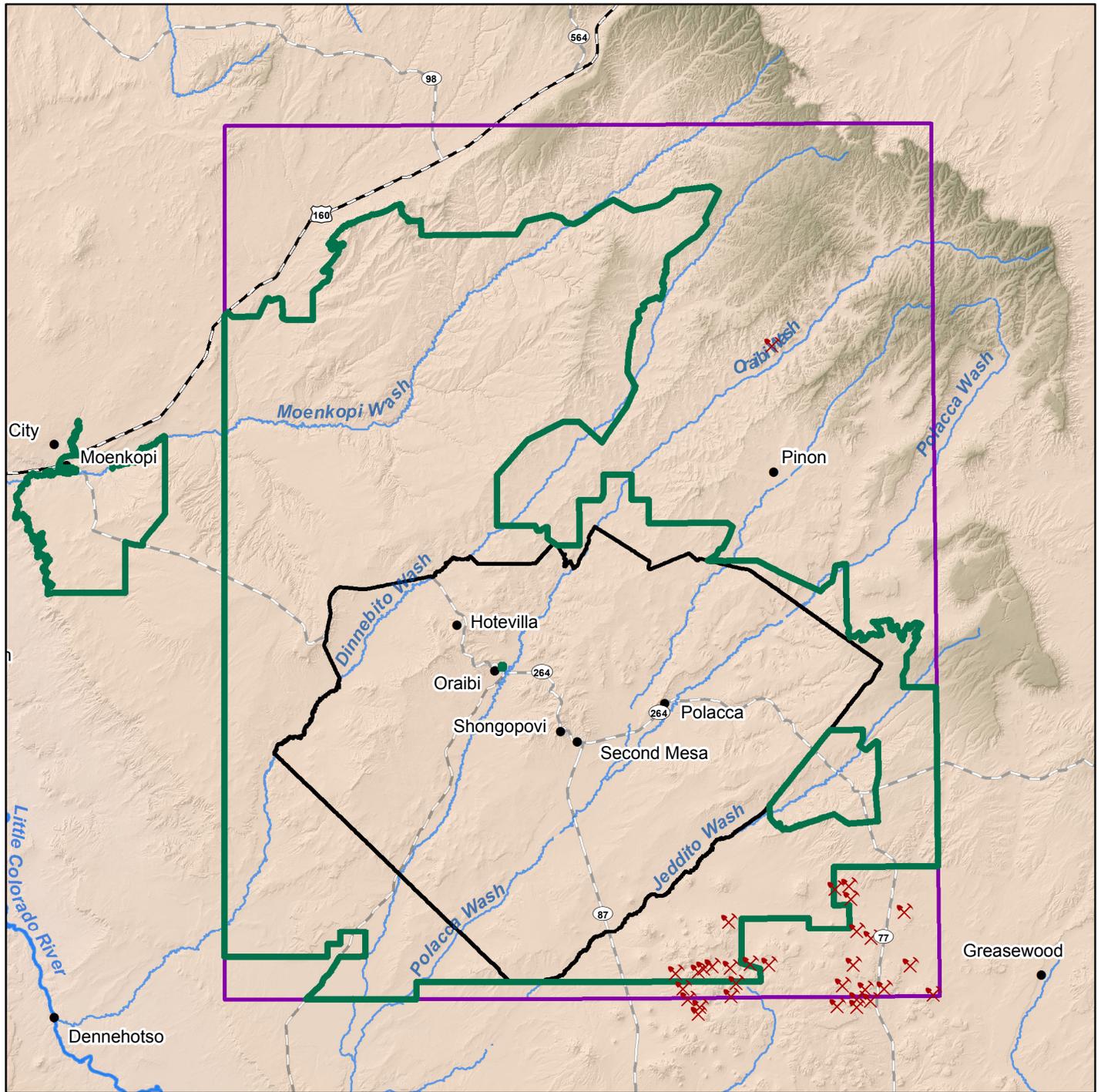


**Appendix B
Figure B-17**

Hydrocarbon Shows and
Potential Oil & Gas
Reserves in the Vicinity of
the Hopi Indian Reservation

Final Hopi HSR
December 2015

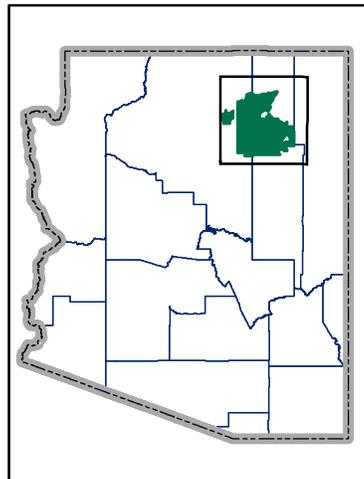




Legend

- Abandoned Uranium Mine
- Hopi Reservation
- Hopi District 6
- Navajo Partitioned Land
- Town/Village
- Streams
- U.S. Route
- State Highway
- Local

Source:
Terra Spectra Geomatics (2000).

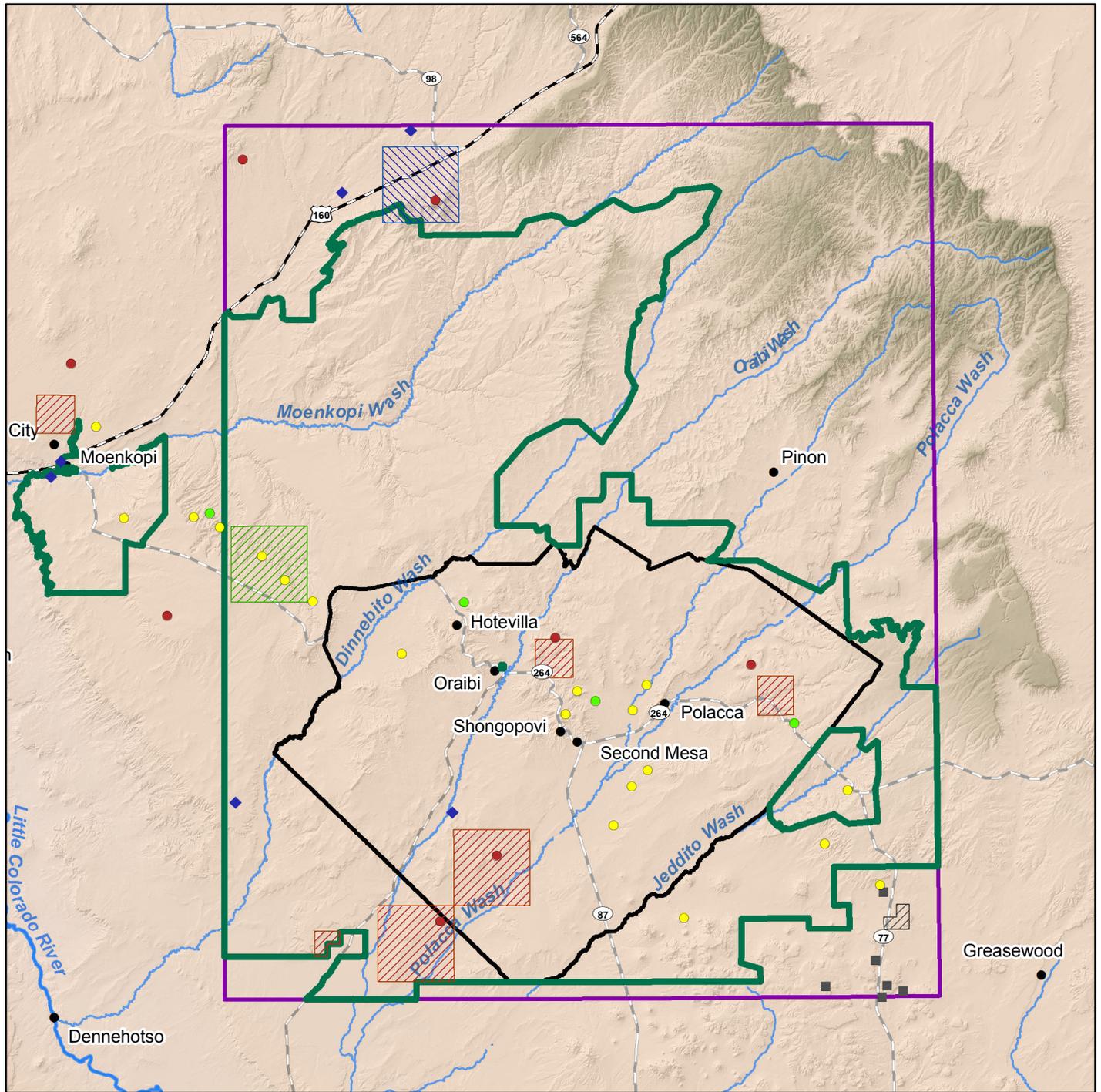


**Appendix B
Figure B-18**

Abandoned Uranium
Mines in the Vicinity of
the Hopi Indian Reservation

**Final Hopi HSR
December 2015**

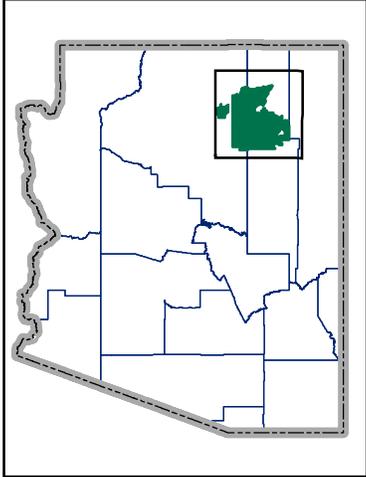
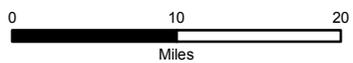




Legend

- Non-metal Deposits**
- ◆ Carbonate Materials
 - Kaolin
 - Specialty Sands
 - Pumice
 - Structural Clay
- ▭ Hopi Reservation
 - ▭ Hopi District 6
 - ▭ Navajo Partitioned Land
 - Town/Village
 - ~ Streams
 - ~ U.S. Route
 - ~ State Highway
 - ~ Local

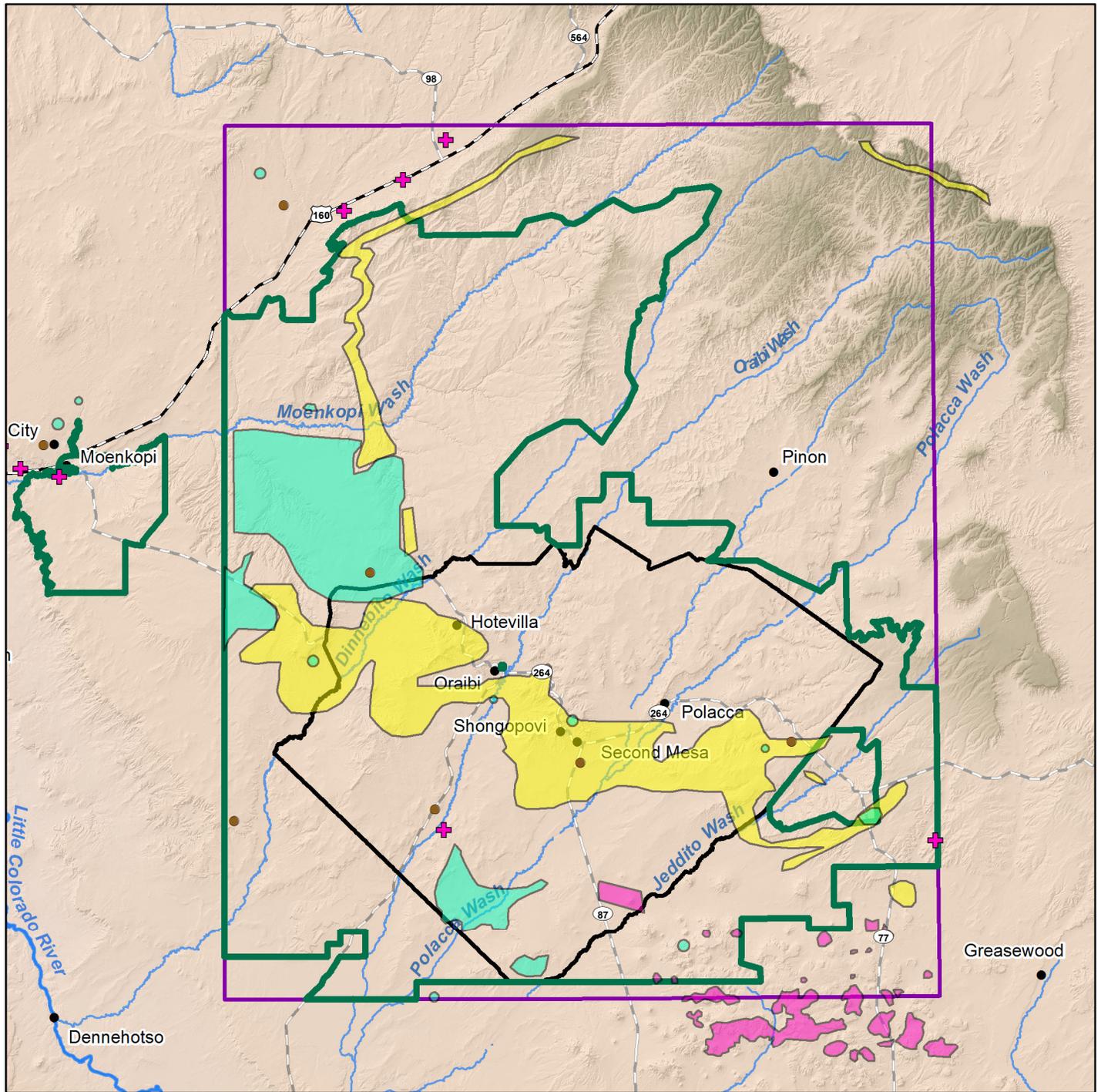
Sources:
 1) Haff and Kiersch (1955)
 2) Kiersch (1955a and b) and
 3) Kiersch and Haff (1955).



Appendix B
Figure B-19

Non-metal Deposits
 Mines in the Vicinity of
 the Hopi Indian Reservation

Final Hopi HSR
 December 2015



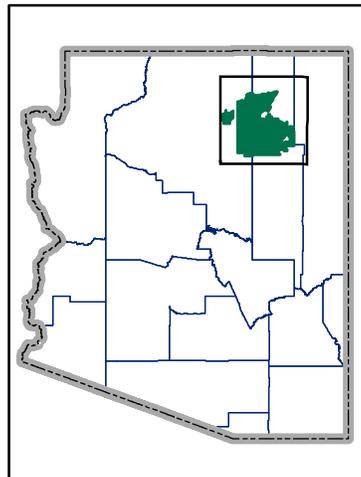
Legend

Construction Material Deposits

- Natural Aggregate
- Rip Rap
- Sand Stabilizer
- Dimension Stone
- Hopi Reservation
- Hopi District 6
- Navajo Partitioned Land
- Town/Village
- Streams
- U.S. Route
- State Highway
- Local

Sources:

- 1) Haff and Kiersch (1955)
- 2) Kiersch (1955a and b) and
- 3) Kiersch and Haff (1955)
- 4) Peirce (1955).

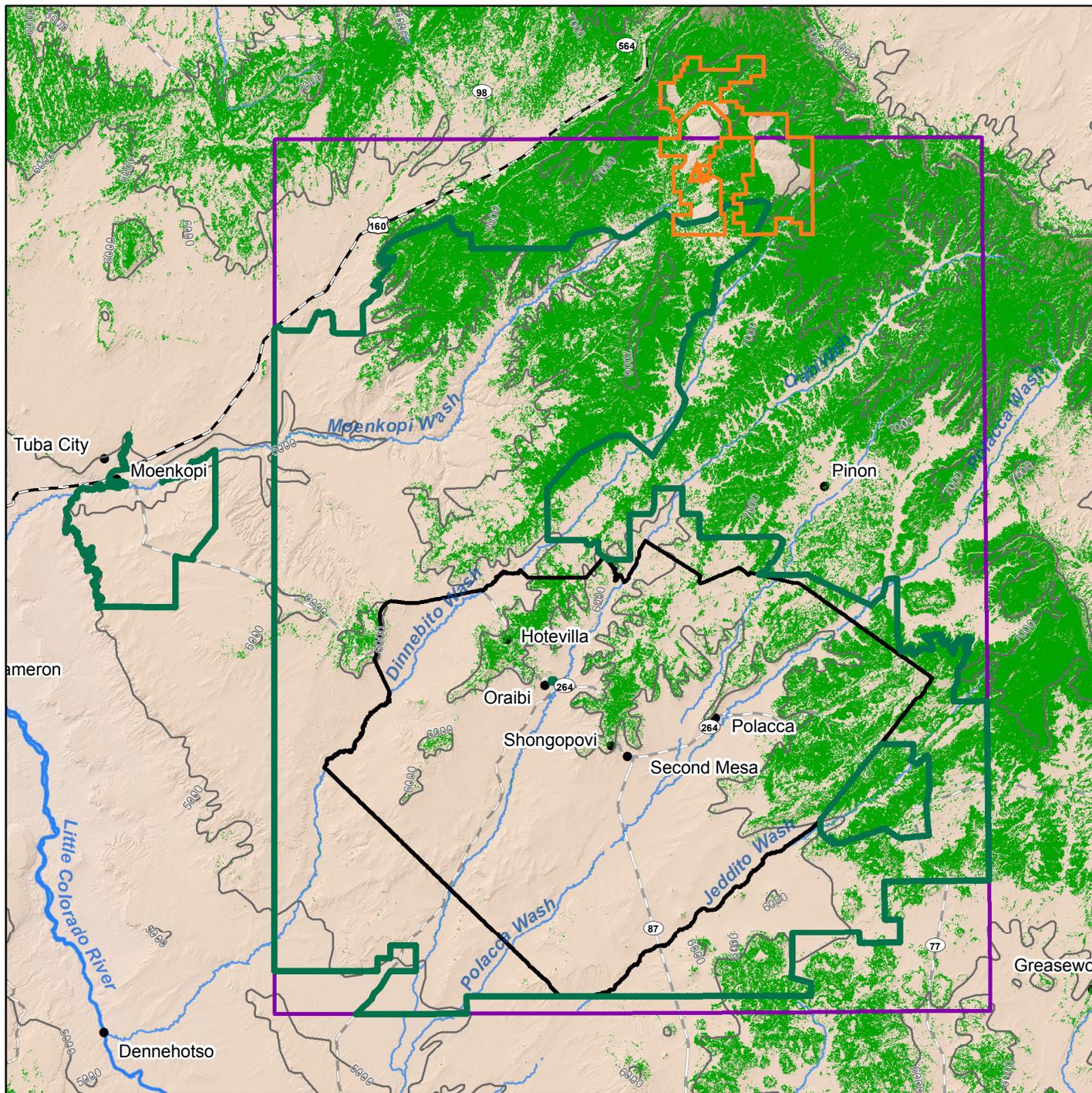


**Appendix B
Figure B-20**

Construction Material
Deposits in the Vicinity of
the Hopi Indian Reservation

**Final Hopi HSR
December 2015**



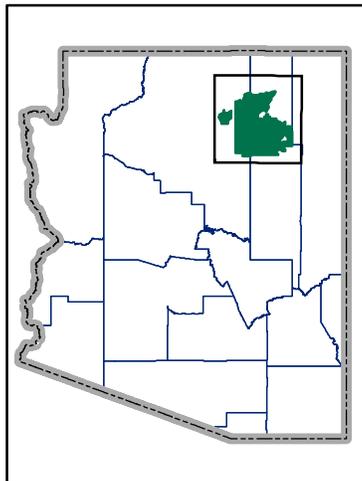


Legend

- Woodland
- PWCC Leasehold
- Hopi Reservation
- Hopi District 6
- Navajo Partitioned Land
- Town/Village
- 1,000-Foot Elevation Contours
- Streams
- U.S. Route
- State Highway
- Local



Source:
USU (2005).



**Appendix B
Figure B-21**

Woodlands in the
Vicinity of the
Hopi Indian Reservation

Final Hopi HSR
December 2015

