APPENDIX G-3

STATE OF ARIZONA
DEPARTMENT OF WATER RESOURCES

Identification of Recent (2005) Agricultural and Riparian Lands on the Hopi Indian Reservation

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Text

1.0 INTRODUCTION

As part of the Little Colorado River (LCR) General Stream Adjudication, the Superior Court of Arizona has ordered the Arizona Department of Water Resources (ADWR) to prepare a Hydrographic Survey Report (HSR) for the Hopi Indian Reservation (Ballinger, 2002). **Figure 1** shows the location of the Reservation. The Hopi have a long history of dryland farming in the region, and their water right claims in the adjudication reflect this history. As requested by the Court, ADWR is verifying the Hopi and United States claims and, among other tasks, estimating current Hopi water use for agriculture.

The Hopi and United States both claim that a total of 38,556 acres of reservation land have been used for crop production (Hopi, 2004 and United States, 2004). However, far less acreage has been apparently cropped in any given year. Historic records suggest that, since the 1850's, between 2,000 to 7,000 acres have typically been cropped each year on the Reservation (Anderson, 2008).

This report provides an estimate of the acreage cropped by the Hopi in 2005 and the methods used to calculate that acreage. The total acreage of riparian vegetation on the reservation in 2005 is also estimated. These acreage estimates will be used in the HSR to approximate water demand for agriculture and riparian vegetation. Note that neither the Hopi nor the United States claim water use by riparian vegetation.

ADWR used a combination of field data and remote sensing to map Hopi agricultural and riparian lands. Due to the rugged terrain and unique farming practices employed, mapping recent agricultural lands on the Reservation has proven particularly challenging. Conventional ground mapping is complicated by the size of the Reservation (over 2,400 square miles) and the relatively poor access to many field sites. Mapping of fields based on inspection of aerial photography or satellite imagery alone is complicated by the sparse vegetation that is characteristic of dryland farming, making segregation of agricultural lands from natural vegetation difficult. By contrast, riparian lands on the Reservation tend to be densely vegetated and easier to differentiate using remote sensing methods.

2.0 DATA SOURCES

2.1 2005 FIELD DATA

Between August and September 2005, ADWR field staff inspected agricultural fields on the Reservation to correspond with the collection of aerial and satellite imagery. A total of 514 agricultural fields were mapped of which 60 % were used for land classification and 40% were reserved as reference data for an accuracy assessment.

2.2 2005 SATELLITE (SPOT) IMAGERY

ADWR purchased 10-meter, multispectral, SPOT (Satellite Pour l'Observation de la Terre) imagery of the Reservation that was collected between 08/18/2005 and 09/13/2005. SPOT imagery is obtained from a satellite orbiting approximately 822 km above the earth in a near polar, sun synchronous, phased orbit. The satellite takes images in 60 km x 60 km paths (3,600 km^2) and repeats each path every 26 days (NERC, 2008). Five paths were necessary to cover the entire Reservation. The SPOT imagery purchased by ADWR included four spectral bands including visible green, visible red, near infrared (NIR) and shortwave infrared. An example of the resolution and quality of this imagery is provided as **Figure 2**.

2.3 2005 AERIAL PHOTOGRAPHY

ADWR also utilized 1-meter, color, orthophotography of the Reservation that was collected in 2005 for the U.S. Census Bureau. The photographs were collected between 6/26/2005 and 10/20/2005 over Coconino County and between 07/02/2005 and 10/24/2005 over Navajo County (SCO, 2005). An example of the resolution and quality of this photography is provided as **Figure 3.**

3.0 METHODOLOGY

This section describes the methodology ADWR used to analyze satellite imagery and aerial photography, perform an accuracy assessment, and conduct a quality control review.

3.1 ANALYSIS OF SATELLITE IMAGERY

3.1.1 Analysis Areas and Sub-areas

ADWR Geographic Information Systems (GIS) Staff divided the Reservation into five areas to process the relatively large satellite imagery datasets. Each area represented a different SPOT path and three of the larger areas were split into sub-areas (**Figure 4**).

For each area and sub-area, surface slopes were mapped using a 30-meter digital elevation model (DEM). Portions of the Reservation with a slope less than or equal to one degree (1º) were coded to indicate they were relatively 'flat' and those portions with slopes above 1º were coded as 'steep'. Adjacent areas with the same coded slope were merged together. The resulting slope determinations were stored as a GIS thematic layer and used later to classify fallow agricultural lands.

The boundary of all agricultural lands mapped by ADWR field staff in 2005 were also stored as a GIS layer and used to classify agricultural lands.

3.1.2 Image Processing (Segmentation)

The next step in analyzing the SPOT imagery was to partition the digital images into a set of regions or segments with similar characteristics such as pixel color, intensity, or texture. The goal of this segmentation was to simplify the image into something more meaningful and easier to analyze. In this case image segmentation was used to identify agricultural and riparian lands on the Reservation.

Definiens is the computer software that ADWR used to segment the SPOT imagery. It automates image analysis by examining each image pixel not in isolation, but in context, grouping pixels into larger objects (segments). Segment generation is a form of pattern

recognition based on the color, shape, texture and size of objects and relationship to other objects (Definiens, 2008).

Several different algorithms are available in Definiens to segment a digital image. ADWR used a multi-resolution segmentation. This algorithm performs a local pair wise merging technique that combines 'seed' objects with adjacent 'candidate' objects and combines those that fall below an upper threshold of homogeneity into larger 'target' objects. Usually starting at the pixel level, objects are merged in several iterative loops. Criteria include spectral values, the use of thematic or vector layers, shape and compactness. The size of the resulting segments is dictated by the scale parameter. Higher values for the scale parameter result in larger image objects, smaller values in smaller image objects (Definiens, 2007).

SPOT values for the visible green, visible red, near infrared (NIR) and shortwave infrared spectral bands were each given equal weight during segmentation. Agricultural field boundaries mapped by ADWR field staff during 2005 were also input during segmentation. In addition, shape smoothness and compactness can be set during segmentation, with each value ranging between 0.1 and 0.9 and summing to 1. ADWR considered shape smoothness and compactness equally and set values of each to 0.5.

3.1.3 Segment Classification

ADWR classified segments identified by Definiens as active agriculture, fallow agriculture or riparian using segment characteristics such as the mean value of one of the four SPOT spectral bands, or a ratio of these bands. For example, active agricultural land was distinguished based on the mean pixel value of near infrared (NIR) or red bands while the mean normalized difference vegetation index (NDVI) was used for the classification of fallow agricultural and riparian lands. Fallow agricultural lands were also classified based on those areas with a slope $\leq 1^{o}$.

Data collected by ADWR field staff were used to find the best spectral band or ratio of spectral bands for segment classification. The red spectral band detects the absorption of solar radiation by the active chlorophyll in green vegetation and the NIR spectral band detects the reflectance of chlorophyll. NDVI uses ratioing of the red and NIR bands to provide a spectrally enhanced single band panchromatic image that directly correlates to the presence of green, healthy vegetation (Lillesand and others, 2004). NDVI is widely used because it conveys the

spectral characteristics of images regardless of variations caused by topographic slope and aspect, shadows, or seasonal changes in illumination conditions (Dappen, 2003). High NDVI values usually indicate recently irrigated cropland, grass or riparian vegetation (phreatophytes) along rivers. NDVI is calculated as:

$$\mathbf{NDVI} = \frac{\mathbf{NIR - Red}}{\mathbf{NIR + Red}}$$

Two functions were applied to classify segments based on the data described above-the Smaller Than Membership Function (STMF) and the Larger Than Membership Function (LTMF) (Definiens, 2007). Both functions employ fuzzy logic, which is a mathematical approach that quantifies uncertainty and allows transition zones between segment classes. These membership functions consist of left and right border values related by function slopes derived from logistic curves. For active and fallow agricultural classifications, data collected by ADWR field staff were used to find optimal transition zones. Segments with characteristics outside of the left or right border values were classified with greatest certainty. Segment characteristics within border values were classified by likelihood of group membership based on their position along the function slope. **Table 1** provides a summary of the membership functions used to classify segments as either riparian, active agriculture or fallow agriculture and border values used to define the transition zones.

As an example, consider the classification of segments in Sub-area 2d. In this sub-area segments with NDVI values greater than 0.6 were classified as riparian, and those with NDVI values less than 0.18 remained unclassified. Some segments within the transition zone between 0.18 and 0.6 were classified as riparian, while some remained unclassified. The closer to the lower 0.18 threshold, the less likely the segment would be considered a 'member' of the riparian classification. Unclassified segments were then classified as active agriculture if their mean NIR values were above 185, with some segments with NIR values below 185 but above 150 also included. Remaining unclassified segments that were also located on relatively flat lands (slopes $\leq 1°$) were classified as fallow agriculture if NDVI values were below 0.07. Some segments within the transition zone between 0.07 and 0.1 were also classified as fallow agriculture, but

with greater frequency as they approached the lower 0.07 border value. All other segments were left unclassified.

Note that Sub-area 1 is located in the Moenkopi portion of the Reservation where much of the agriculture is located along or near Moenkopi Wash. Traditional (non-dryland) irrigation is practiced in this area. STMF on the red spectral band was better in distinguishing active agriculture in this area. For all other sub-areas, where dryland farming is more prevalent, the LTMF was used with near infra-red values.

After each segment was classified, ADWR applied the Merge Region algorithm to each land class. This algorithm merges all neighboring segments of a given class to one segment (Definiens, 2007).

Before exporting the classified and merged segments, some manual editing occurred by ADWR GIS Staff. Using the Manual Editing Toolbar in Definiens, relatively large areas classified based on spectral values and the merging process were determined to not be agricultural or riparian lands and deleted.

3.1.4 Export of Results

Once classification of the SPOT imagery was complete, ADWR GIS staff exported the results to two GIS Shapefiles using the Export Vector Layers algorithm in Definiens. Agricultural (active and fallow) lands were exported as one shapefile and riparian lands were exported as another shapefile. The final class name was the only attribute included in the shapefiles' tabular information.

3.2 ANALYSIS OF AERIAL PHOTOGRAPHY

Results from analysis of the satellite imagery were imported into GIS software (ArcMap 9.2) and visually compa**Analysis of A**red to the 2005 aerial photography (SCO, 2005). During this process, ADWR GIS staff identified and resolved classification errors by scanning the entire Reservation. Two types of errors were found-errors of commission and errors of omission.

Errors of commission occurred where segments or parts of segments were misclassified as agricultural or riparian lands. For example, a segment classified as active agricultural based

on analysis of satellite imagery appeared to be native desert when viewed on the aerial photograph. In these cases, the segment was deleted. Further errors of commission were identified during a quality control check described in Section 3.4.

Errors of omission occurred where segments should have been classified as agricultural or riparian lands but were not. In these cases, missed agricultural fields or riparian areas were manually digitized using the aerial photography and added to the dataset. Note that agricultural lands identified through analysis of aerial photography alone were classified as 'active or fallow'. Final errors of omission for agricultural fields were quantified during the accuracy assessment, described in Section 3.3.

3.3 ACCURACY ASSESSMENT

The final dataset of agricultural lands was compared to data collected from the 40% of fields mapped by ADWR field staff between August and September 2005 and reserved as reference. ADWR field staff recorded information for each field including crop type, irrigation status and irrigation method. If a field was found to be fallow, the crop type was recorded as 'fallow' or 'fallow with weeds'. On occasion, the irrigation status was recorded as 'fallow'. Otherwise, a field was considered active. Those field data were used to classify the reference data as either active or fallow agriculture before comparing it to the agricultural lands classified through analysis of aerial photography and satellite imagery.

Traditionally, the accuracy of remote sensing analysis is assessed by counting correctly and incorrectly classified pixels to produce an error matrix. The relationship between ground truthed reference data and classification data are compared on a category-by category basis (Lillesand and others, 2004). ADWR only had active or fallow agriculture field samples to use for reference but lands were classified as either active agriculture, fallow agriculture, active or fallow agriculture, riparian or unclassified. Also, instead of an image, where each pixel is classified, the results of this analysis were two sets of thematic polygon datasets, with each polygon a different size and shape. For these reasons, a traditional accuracy assessment was not performed and an acreage summation method was used instead. The summation method accounted for whether a given portion of a field was correctly classified, factoring its size, or acreage.

To assess accuracy, the portions of reference fields that overlap with classified fields were determined using the Identity Tool in ArcMap, which computes a geometric intersection of the Input Features (2005 reference data) and Identity Features (classified fields). The portions of the Input Features that overlap with Identity Features inherit the attributes of those Identity Features (ESRI, 2008a). This tool also maintains any unclassified portions of the reference fields so true errors of omission can be calculated. **Figure 5** provides an example of a field and classified and unclassified portions.

Table 2 provides the results of the accuracy assessment performed. Over 86% of the reference field acreage was correctly classified as agriculture. Approximately 2% was classified as riparian and 11% was unclassified. This represents an error of omission of approximately 13%. Active and active fallow reference fields were compared with active and active fallow agriculture classification data. There was no riparian reference data to compare to classified riparian lands so an accuracy assessment was not performed for this land classification.

Some of the acreage that was found to be omitted includes very small (less than 0.019 acres) reference fields. Definiens generally did a satisfactory job at classifying relatively large agricultural areas. However, Definiens was not able to classify very small areas such as small gardens and isolated fruit trees that were mapped by ADWR in the field. As shown in **Figure 6**, it was not possible to differentiate isolated fruit trees and small gardens with higher resolution aerial photography.

3.4 QUALITY CONTROL

The accuracy assessment based on reference field data provided a reasonable estimate of the errors of omission for classified agricultural lands; however it did not reveal potential errors of commission. ADWR decided to conduct a quality control (QC) review of approximately 15% of the Reservation land base to quantify this error. The QC check also allowed both errors of omission and commission to be quantified for classified riparian lands.

ADWR used 1:24,000 USGS topographic quadrangle map (quad) boundaries to divide the Reservation. Quads used for quality control purposes were selected randomly and to ensure that at least one quad per SPOT path and a total area of approximately 15 % of the Reservation (about 385 square miles) was reviewed. **Table 3** lists the 10 quads reviewed during the QC

check and the approximate square mileage of the quads within the Reservation boundary. **Figure 7** shows the location of the selected quadrangles. The QC review was performed by visual inspection of the 2005 aerial photography by ADWR Adjudications Cartography staff.

3.4.1 Errors of Commission/Omission

During the QC review, observed classification errors were recorded by digitizing a polygon of the error and indicating if it was an error of commission or omission, or in some cases, a misclassification. This allowed errors to be calculated as an area. During the QC review, ADWR identified 12 commission errors for classified agricultural lands, covering a total of 17.34 acres. Lands misclassified as agriculture were actually either native desert, riparian lands or developed with structures. **Figure 8** provides an example of one of these errors of commission. ADWR also identified five omission errors for agricultural lands covering a total area of 5.55 acres.

No commission errors were identified for riparian lands. However, ADWR identified 18 omission errors for riparian lands covering a total area of 89.19 acres. **Table 4** provides a summary of QC errors documented for the 15% of the Reservation analyzed and estimated errors for the entire Reservation.

3.4.2 Relation to Impoundments

Several areas classified as agricultural lands were actually found to be either partially or fully within a claimed impoundment. ADWR decided to remove from the dataset those classified agricultural lands within impoundments using the Erase Tool in Arc Map 9.2 (ESRI, 2008b). **Figure 9** provides an example of a claimed impoundment intersecting classified agricultural lands.

To avoid 'double counting' acreage on the Reservation used for both impoundments and agricultural, the entire Reservation land base was checked for intersection of claimed impoundments with classified agricultural lands. A total of 25 agricultural fields were removed from the dataset and four others were reduced in size by the respective impoundment portion. **Table 5** lists seven claimed impoundments that were found to intersect with classified agricultural lands.

Claimed impoundments were also compared to classified riparian lands. ADWR found several areas of relatively isolated riparian vegetation located in and around the impoundments. Impoundments are usually constructed along water courses where vegetation is common. These lands were retained in the dataset as riparian areas, but coded as associated with a classified impoundment. **Figure 10** shows an example of riparian land associated with a claimed impoundment. A total of 85 riparian areas, covering over 1,000 acres, are considered to be associated with claimed impoundments.

4.0 RESULTS

ADWR identified a total of 5,613 acres of agricultural lands on the Hopi Reservation during 2005. Approximately 63% of this total was classified as actively cropped, 6% was classified as maintained but left fallow during that growing season, and the remaining 31% was classified as either active or fallow agriculture. An accuracy assessment described in Section 3.3 revealed an estimated accuracy of 86.82% when comparing classified agricultural lands to reference data collected by ADWR field staff in 2005. This indicates that approximately 13% of the actual agricultural lands on the Reservation were not identified by ADWR. However, a QC review described in Section 3.4 revealed that over a representative 15% of the Reservation, 17.34 acres were classified as agricultural lands where they should not have been (errors of commission) and another 5.55 acres were not identified as agricultural lands where they should have been (additional errors of omission). If omission errors are subtracted from commission errors from the QC check, there was a net commission error of 11.79 acres for 15% of the Reservation. If that acreage is extrapolated to the entire Reservation, the total error of commission would be approximately 77.59 acres. Given both errors of omission and commission, the total area of agricultural lands on the Reservation in 2005 is estimated to have ranged between 5,570 and 6,506 acres.

Using similar methods, a total of approximately 14,459 acres of riparian lands were identified on the Reservation. Of this total, approximately 1,000 acres of riparian lands are believed to be associated with claimed impoundments. However, based on the QC review described in Section 3.4, nearly 90 acres of actual riparian lands were not identified using this methodology on a representative 15% of the reservation. This indicates the actual riparian area within the Reservation could be as high as 15,059 acres.

Most agricultural and riparian lands classified during this project are found within the District 6 portion of the Reservation. **Figure 11** shows three divisions of the Reservation - District 6, Hopi Partitioned Lands and Moenkopi. **Table 6** summarizes the total acreage of agricultural and riparian lands that ADWR identified and the acreages of these lands within each division.

Appendix A presents a series of maps that show the location of agricultural and riparian lands that ADWR identified on the Reservation in 2005. An index map is included in the appendix and shows the location of the 57 quads on the Reservation where these lands were classified.

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Tables

TABLE 1. SEGMENT CLASSIFICATION MEMBERSHIP FUNCTIONS AND THRESHOLDS

LAND CLASS		Riparian	Active Agriculture		Fallow Agriculture
MEMBERSHIP FUNCTION		Larger Than	Smaller Than	Larger Than	Smaller Than
SEGMENT CHARACTERISTICS		Mean NDVI [1]	Mean Red	Mean Near Infrared (NIR)	Mean NDVI (Slope ≤ 1º)
AREAS AND SUBAREAS	1 [2]	0.03 - 0.1	110 - 160	---	0.07 - 0.1
	2a	0.08 - 0.5	---	NA	NA
	2b	0.15 - 0.5	---	NA	NA
	2c	0.08 - 0.4	---	150 - 185	0.07 - 0.1
	2d	0.18 - 0.6	---	150 - 185	0.07 - 0.1
	3a	0.15 - 0.4	---	165 - 185	0.12 - 0.15
	3b	0.1 - 0.55	---	155 - 190	0.12 - 0.15
	3c	0.18 - 0.4	---	165 - 185	0.12 - 0.15
	3d	0.15 - 0.35	---	165 - 185	0.12 - 0.15
	4a	0.15 - 0.5	---	145 - 185	0.07 - 0.1
	4b	0.18 - 0.5	---	135 - 185	0.07 - 0.2
	4c	0.15 - 0.35	---	145 - 185	0.07 - 0.1
	4d	0.15 - 0.45	---	145 - 185	0.07 - 0.1
	5	0.15 - 0.25	---	145 - 185	0.18 - 0.25

Notes:

[1] NDVI = Normalized Difference Vegetation Index = (NIR - Red) / (NIR + Red)

[2] Area 1 is located in the Moenkopi portion of the Reservation, where most agriculture is located along or near Moenkopi Wash. The 'Smaller Than' membership function on the red band produced better results in classifying active agriculture in this area.

TABLE 2. ACCURACY ASSESSMENT RESULTS

CLASSIFICATION DATA (acres)	REFERENCE (GROUND TRUTH) DATA (acres)		
	Active	**Active Fallow**	**All Agriculture**
Active Agriculture	121.99	19.21	141.20
Active Fallow Agriculture	5.09	1.78	6.86
Active or Active Fallow Agriculture	38.63	11.21	49.84
Riparian	4.08	1.22	5.30
Unclassified	17.22	7.52	24.75
Total Acreage	*187.01*	*40.93*	*227.95*
Percent Classified As Agriculture	*88.61%*	*78.63%*	*86.82%*
Percent Classified as Riparian	*2.18%*	*2.99%*	*2.32%*
Percent Unclassified	*9.21%*	*18.38%*	*10.86%*

TABLE 3. USGS QUADRANGLE MAPS REVIEWED DURING QC CHECK

HOPI AREAS (SPOT SWATHS)	1:24K USGS TOPOGRAPHIC QUADRANGLE MAPS	AREA OF QUADRANGLE ON HOPI RESERVATION (square miles)
1	Moenkopi	55.59
2	Begashibito Canyon	60.17
	Big Mountain Dam	26.63
	Hard Rocks	35.68
	Red Slide Peak	2.48
3	Garces Mesas SE	52.47
	Sand Springs	60.53
4	Little Black Spot Mountain	13.30
	Shongopovi	60.45
5	First Flat Mesa	17.69
	Total	***384.98*** [1]

Note:

[1] Represents 15% of the total area of the Hopi Reservation (2,534 square miles).

TABLE 4. QUALITY CONTROL ERRORS[1]

INCORRECT CLASS	CORRECT CLASS	REPRESENTATIVE 15% OF RESERVATION		ESTIMATED ERROR WHEN APPLIED TO ENTIRE RESERVATION
		Count	Total Acres	
Agricultural Land Commission Errors				
Active Agriculture	NA	4	3.01	19.85
Active Ag Or Fallow	NA	3	1.87	12.33
Active Ag Or Fallow	Impoundment Riparian	2	5.82	38.32
Active Fallow	NA	3	6.63	43.64
	Total	*12*	*17.34*	*114.14*
Agricultural Land Omission Errors				
NA	Active Ag or Fallow	5	5.55	36.56
	Net Agricultural Commission Errors[2]		*11.79*	*77.59*
Riparian Land Omission Errors				
NA	Impoundment Riparian	1	7.10	46.77
NA	Riparian	15	76.27	502.11
Active Ag Or Fallow	Impoundment Riparian	2	5.82	38.32
	Total Riparian Omission Errors	*18*	*89.19*	*587.20*

Notes:

[1] NA = Not Applicable

[2] Net agricultural commission errors = (Commission Errors) - (Omission Errors)

TABLE 5. CLAIMED IMPOUNDMENTS THAT INTERSECT WITH CLASSIFIED AGRICULTURAL LANDS

HOPI IMPOUNDMENT ID NUMBER	UNITED STATES IMPOUNDMENT ID NUMBER
I-5-13	I058
I-9-313	I096
I-9-511	I0934
I-10-427	I1012
I-10-495	I1024
I-13-454	I1330
I-13-460	I1336

TABLE 6. AGRICULTURAL AND RIPARIAN LANDS CLASSIFIED ON THE HOPI INDIAN RESERVATION IN 2005

LAND CLASS	RESERVATION AREA (in acres)			ACREAGE STATISTICS FOR LAND CLASSES					
	District 6	Hopi Partitioned Lands	Moenkopi Area	Min	Max	Mean	Median	Total	Percentage of Total
Active Agriculture	3,057.08	208.62	283.17	0.0494	148.48	3.36	1.56	3,548.87	63.22%
Active Fallow	265.74	28.25	22.42	0.0566	16.68	2.07	1.11	316.40	5.64%
Active Agriculture or Fallow	1,111.81	417.85	218.49	0.0007	43.09	1.67	0.70	1,748.14	31.14%
Total Agriculture	***4,434.63***	***654.71***	***524.08***	***0.0007***	***148.48***	***2.49***	***1.09***	***5,613.42***	***100.00%***
Riparian	4,560.98	8,571.69	324.26	0.0030	1,559.78	8.64	1.73	13,456.93	93.07%
Impoundment Riparian	176.94	825.25	0.00	0.3707	254.10	11.79	2.62	1,002.19	6.93%
Total Riparian	***4,737.92***	***9,396.94***	***324.26***	***0.0030***	***1,559.78***	***8.80***	***1.75***	***14,459.12***	***100.00%***

Figures

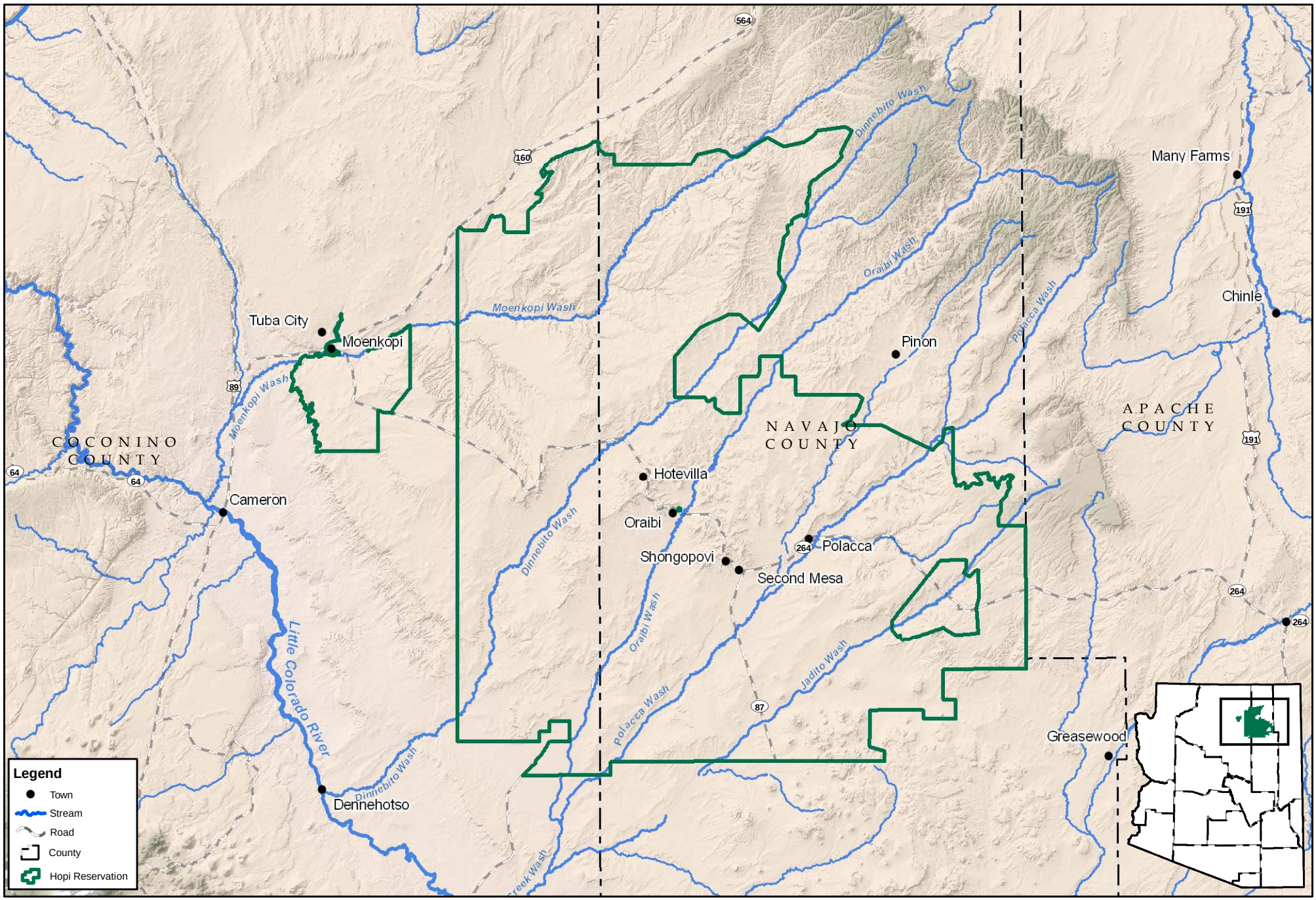

Figure 1. Location of Hopi Indian Reservation

11/17/2008, \\adwrsas1-phx01.azwater.gov\gis-vns, u:\workspaces\statewideplanning\adjudications\projects\hopi_hsr_adjud\maps\recent_ag\mxd\figure1_lochopires.mxd

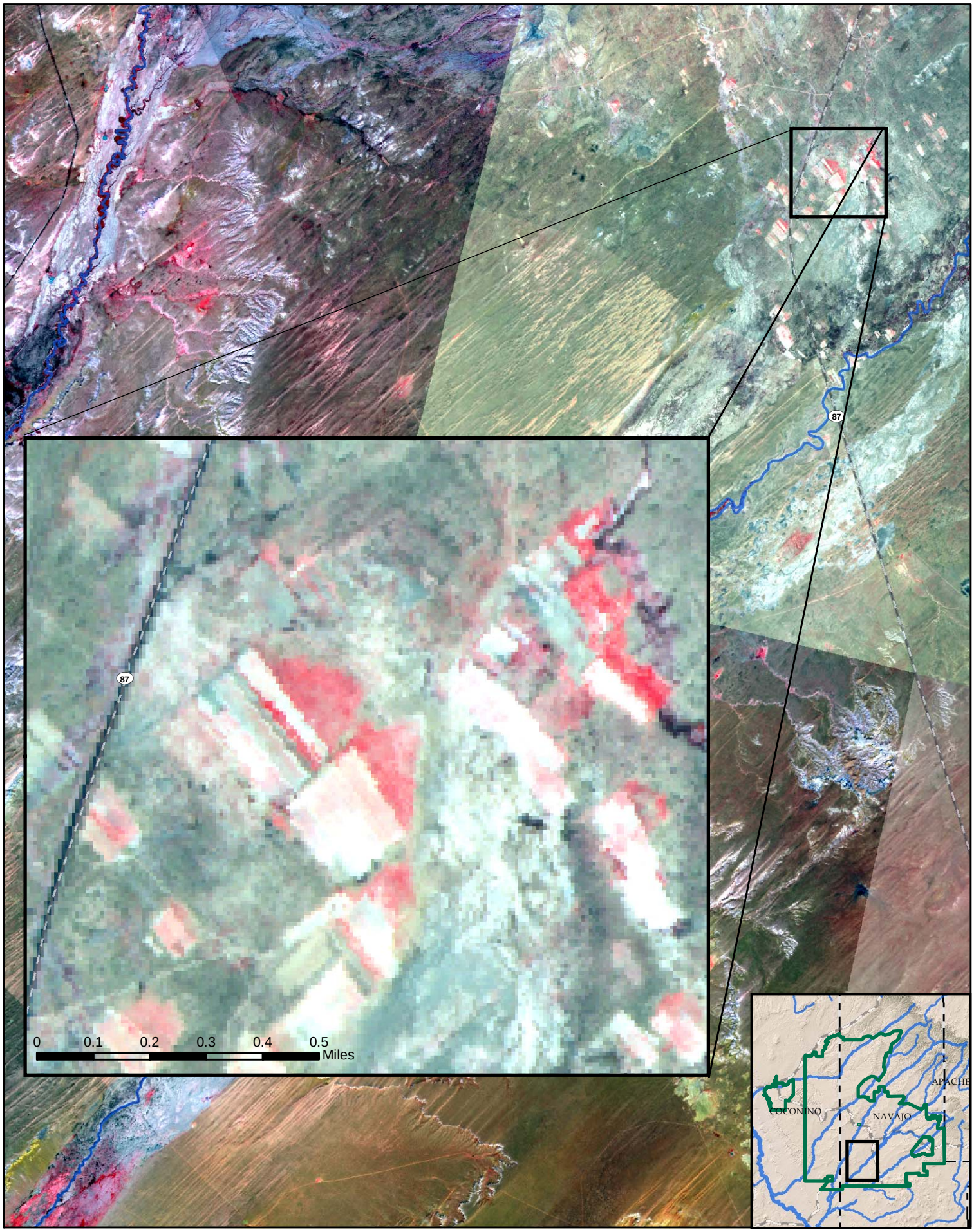

Figure 2. Example of 2005 Satellite Imagery

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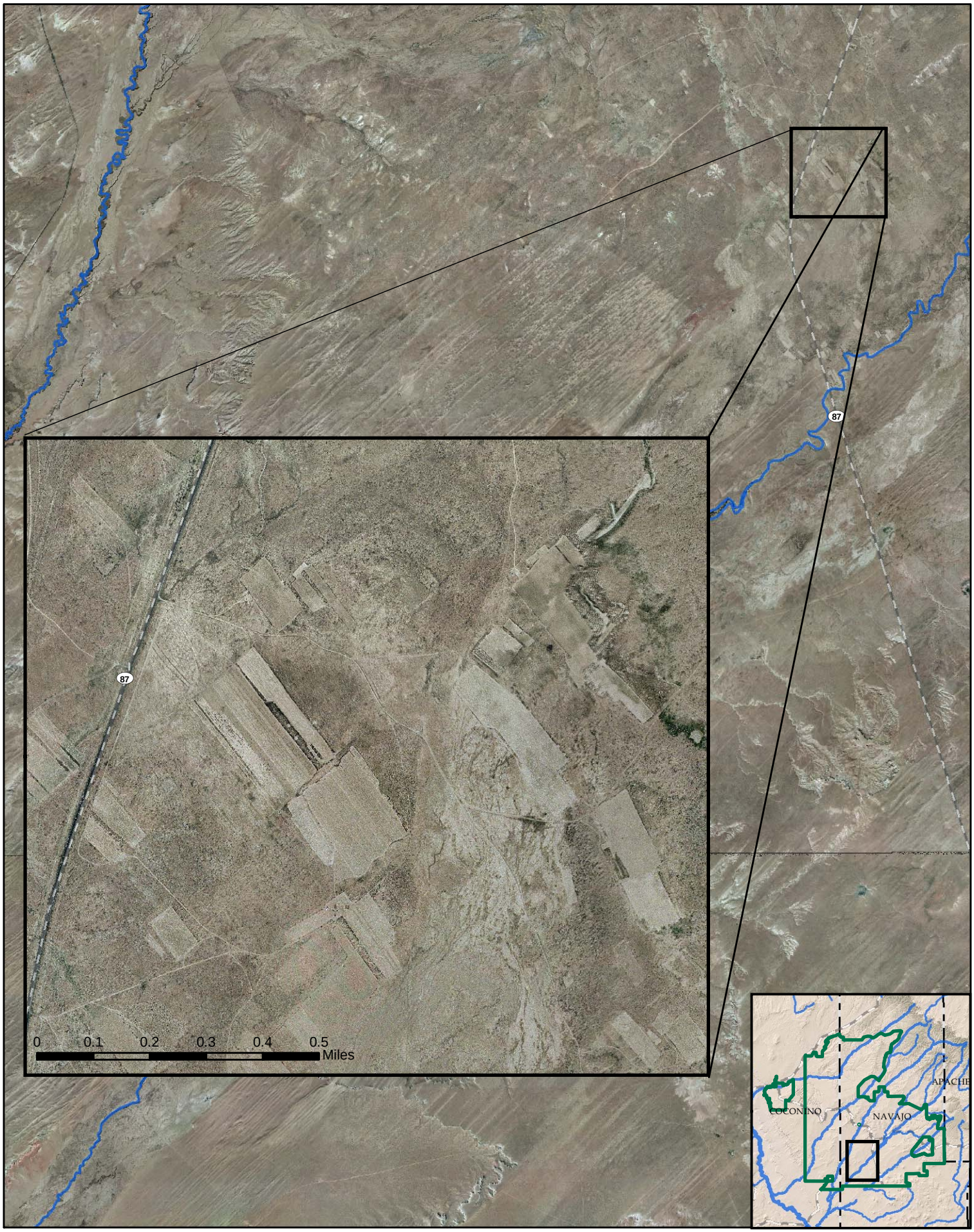

Figure 3. Example of 2005 Aerial Photography

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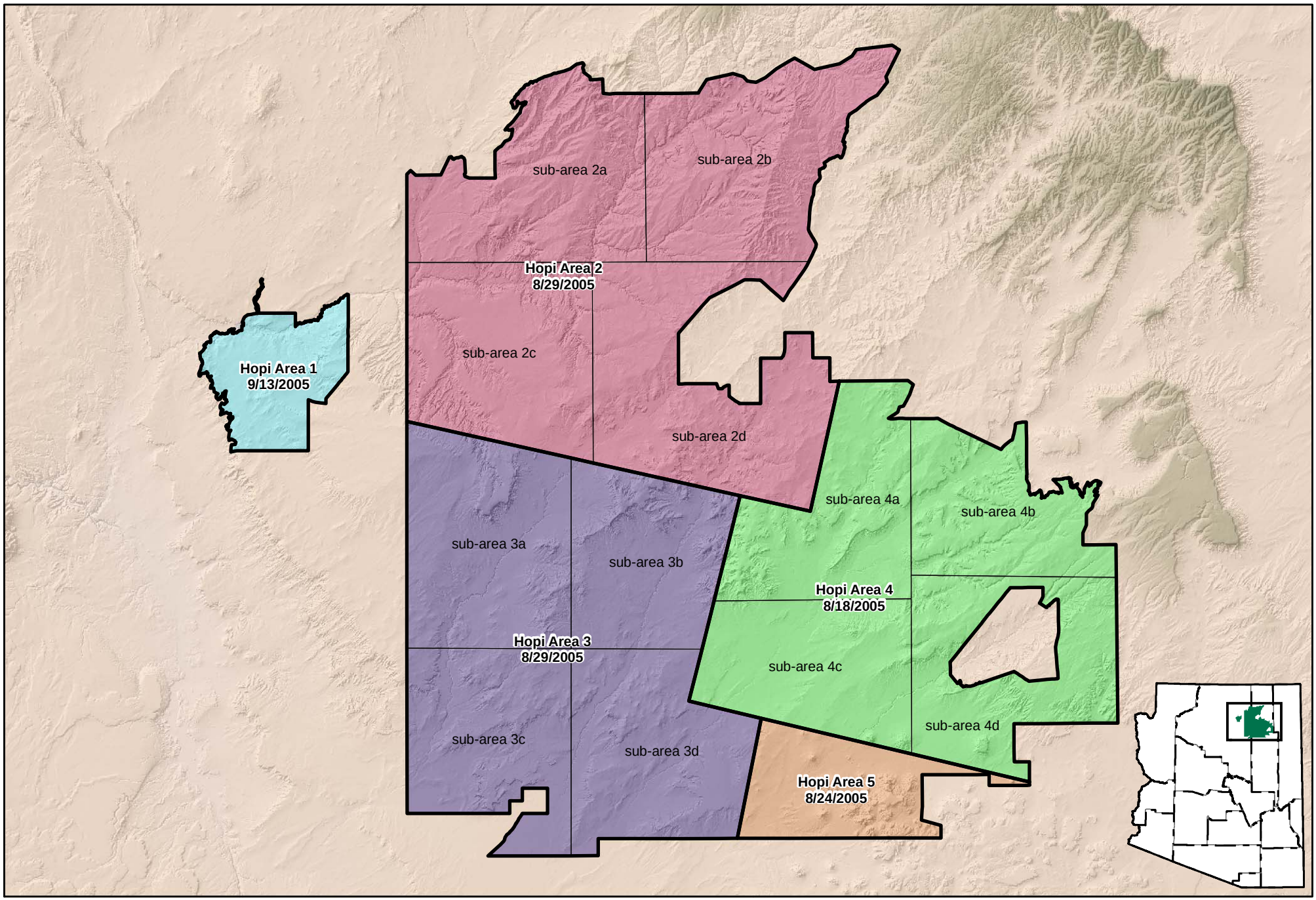

Figure 4. SPOT Imagery Collection Dates and ADWR Analysis Areas

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Figure 5. Reference Field With Classified and Unclassified Portions

Figure 6. Small Reference Fields Not Classified as Agricultural Lands

Active Agriculture Fields Surveyed in 2005

0 75 150 225 300 Feet

ARIZONA DEPARTMENT OF WATER RESOURCES ©

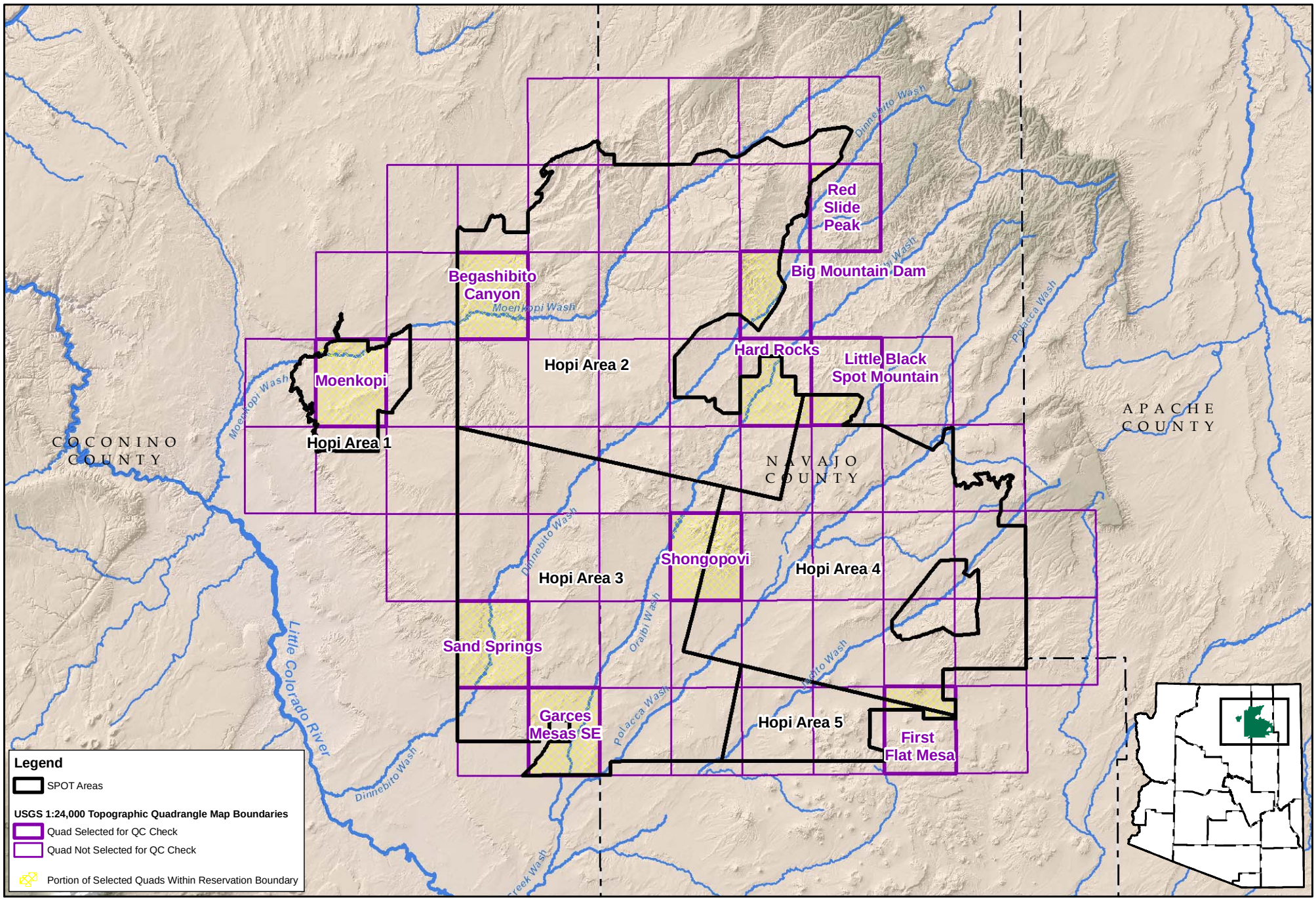

Figure 7. Location of USGS Quadrangle Maps Selected for QC Check

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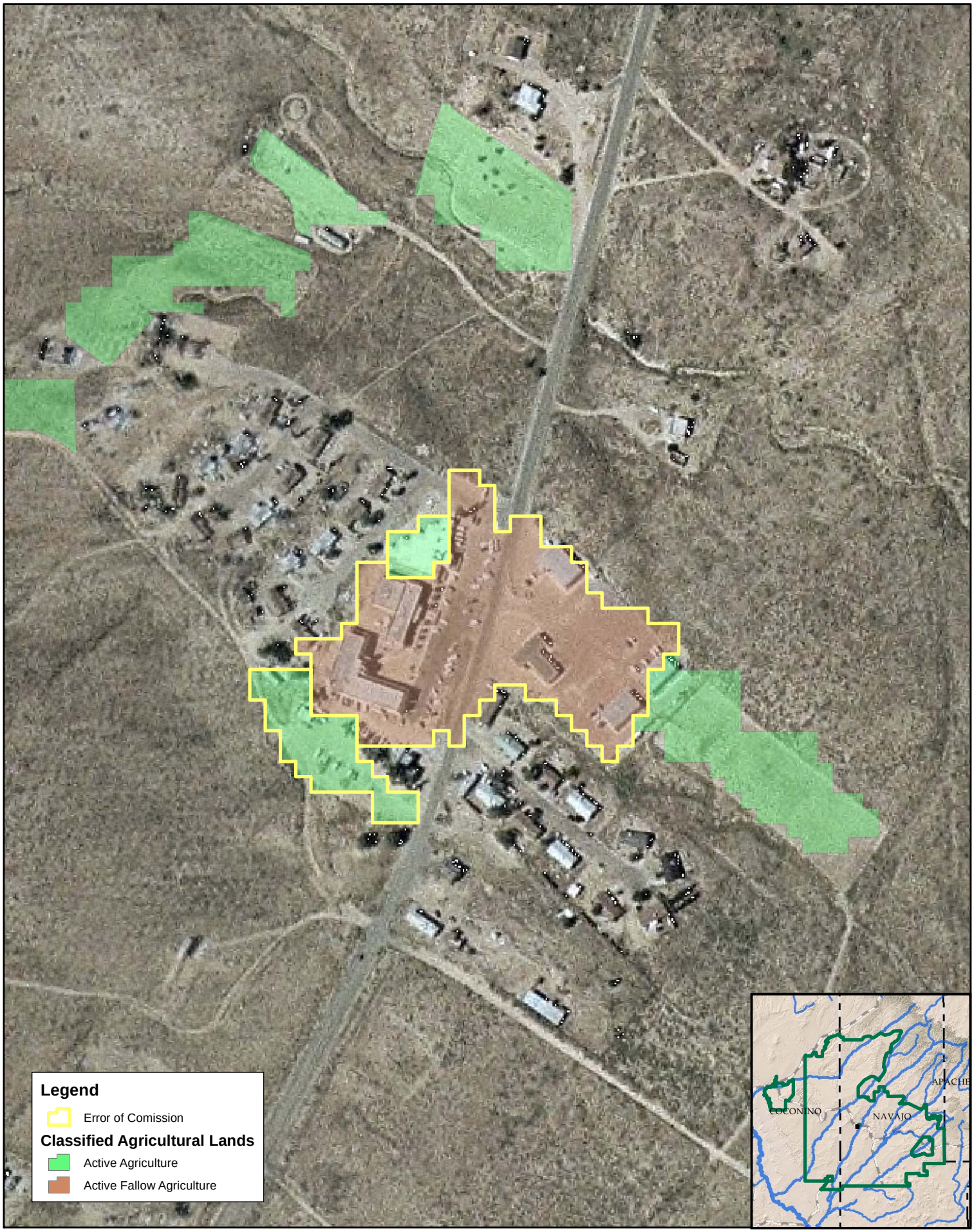

Figure 8. Example Error of Commission

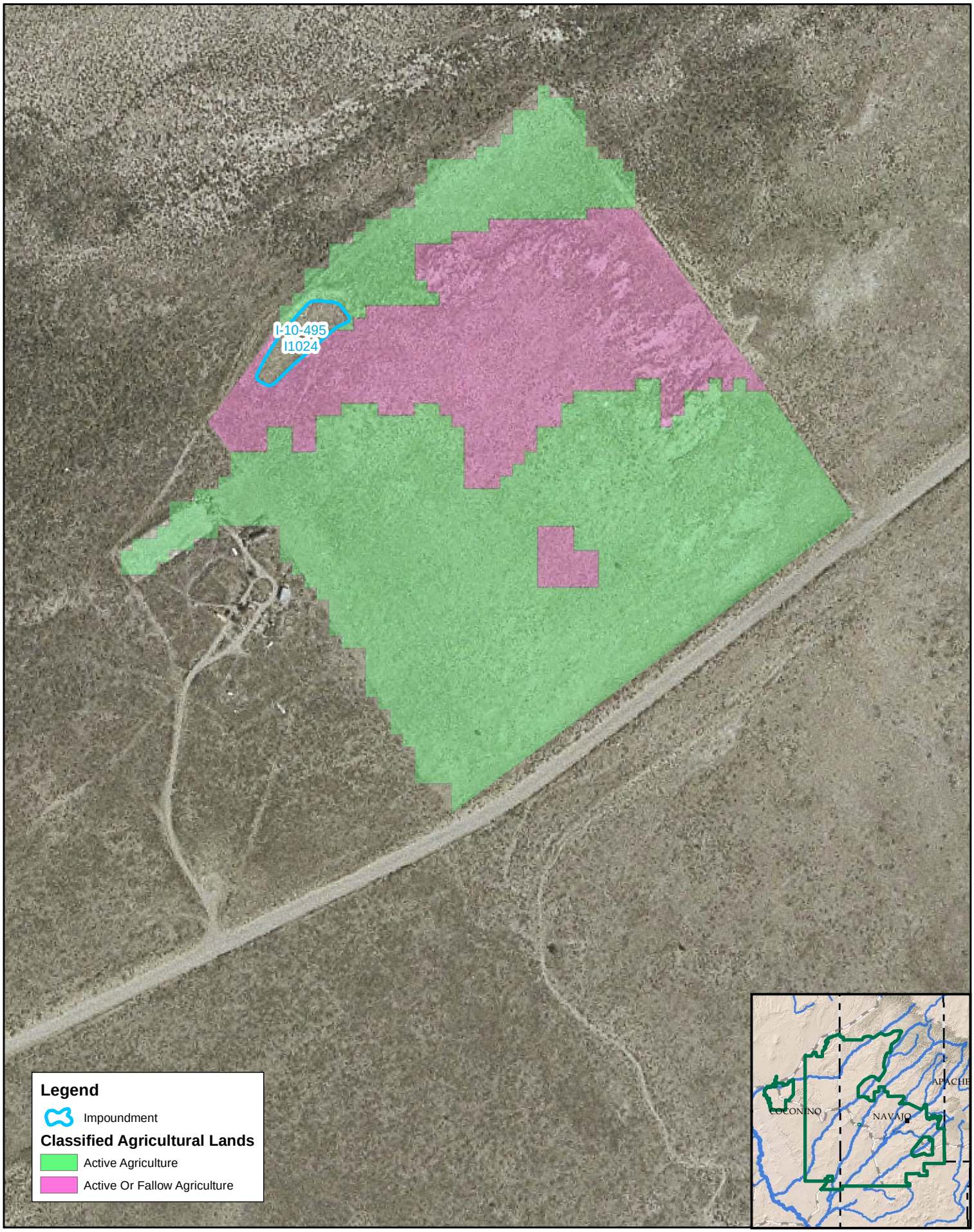

Figure 9. Example of Impoundment Intersecting Classified Agricultural Lands

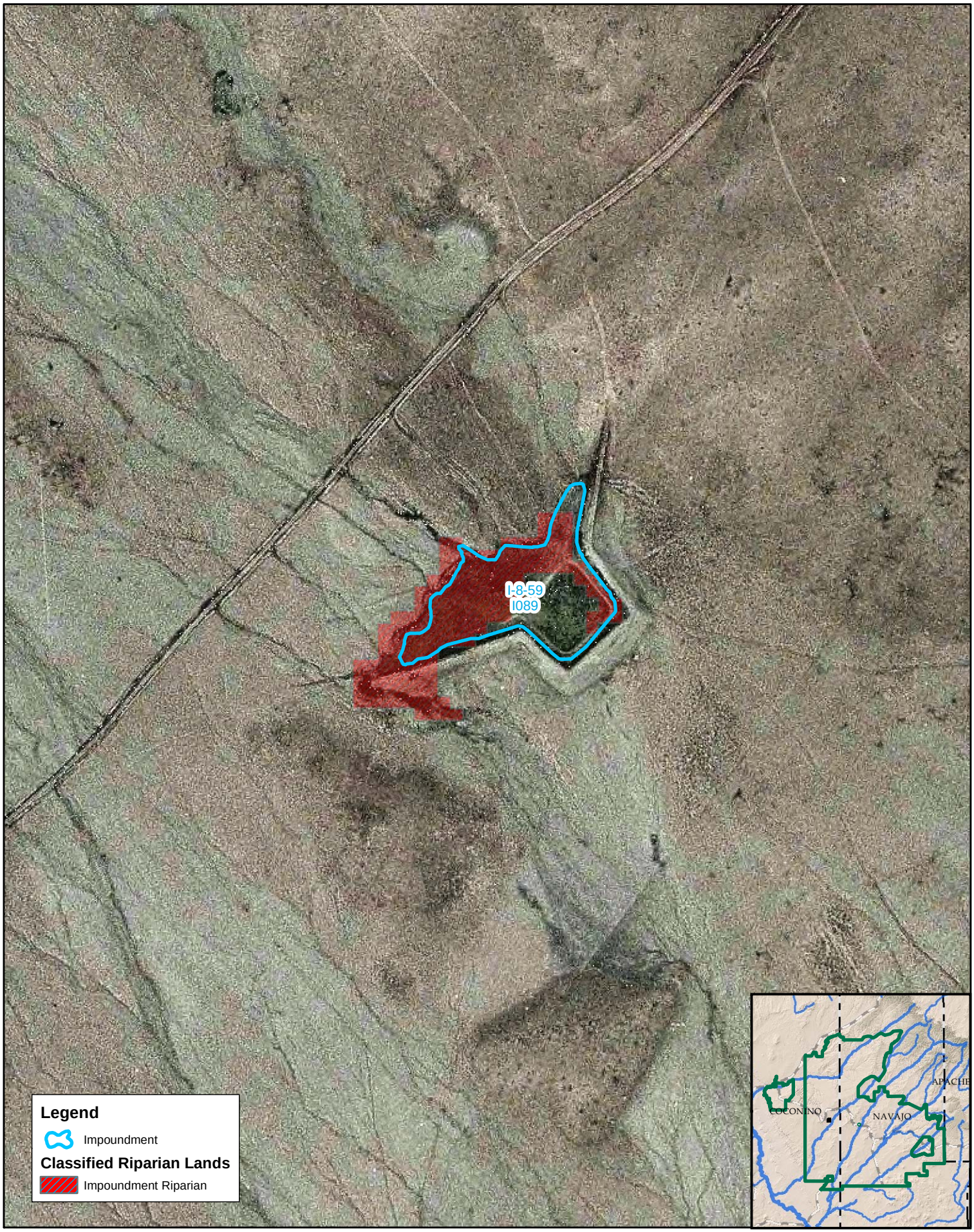

Figure 10. Example Riparian Area Associated with a Claimed Impoundment

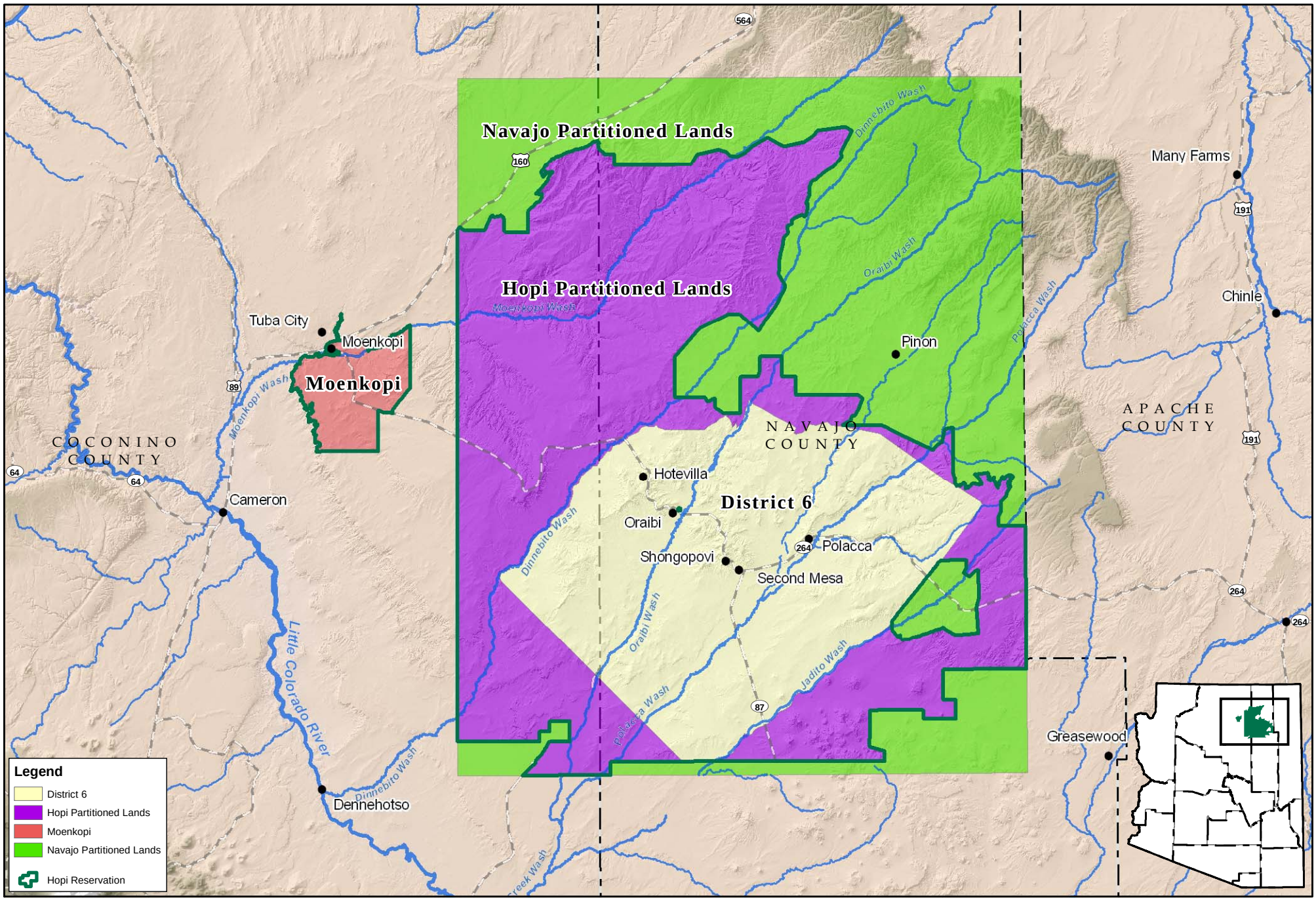

Figure 11. Divisions of the Hopi Reservation

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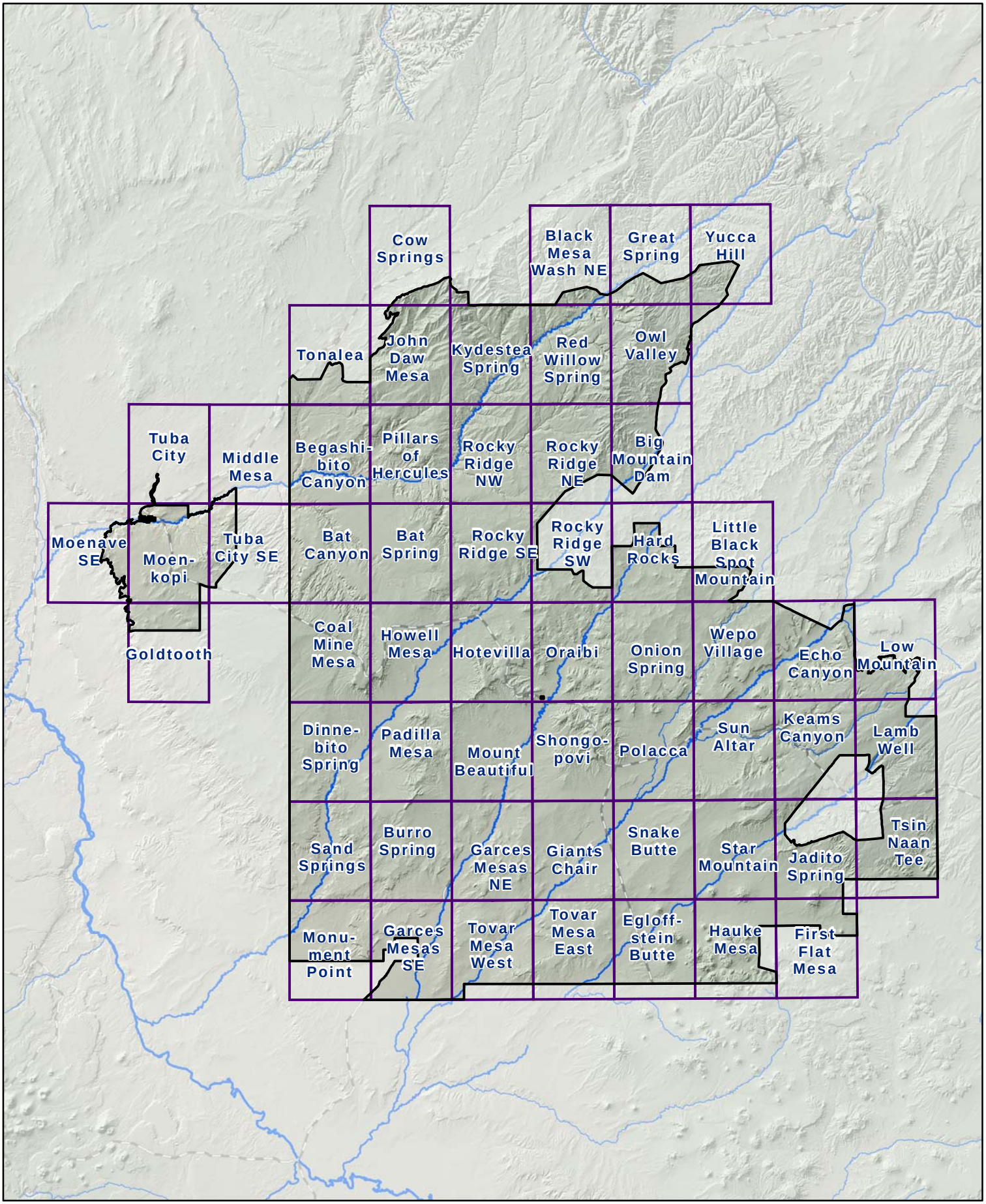
Appendix A



Appendix A. Index Map

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

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Begashibito Canyon
Pillars of Hercules
Rocky Ridge NW
Rocky Ridge SW
Bat Canyon
Bat Spring
Coal Mine Mesa
Howell Mesa
Hotevilla

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Bat Spring Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

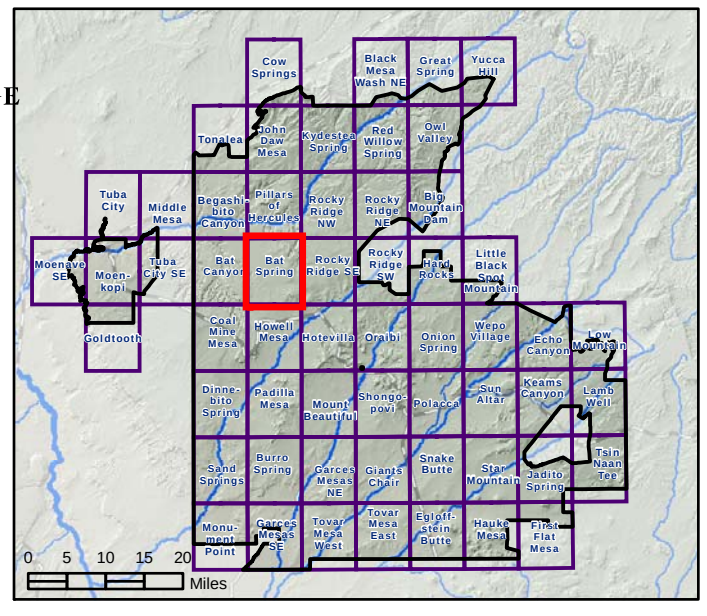
- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation



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Middle Mesa

Begashibito Canyon

Pillars of Hercules

Tuba City SE

Bat Canyon

Bat Spring

Coal Mine Mesa

Howell Mesa

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Bat Canyon Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

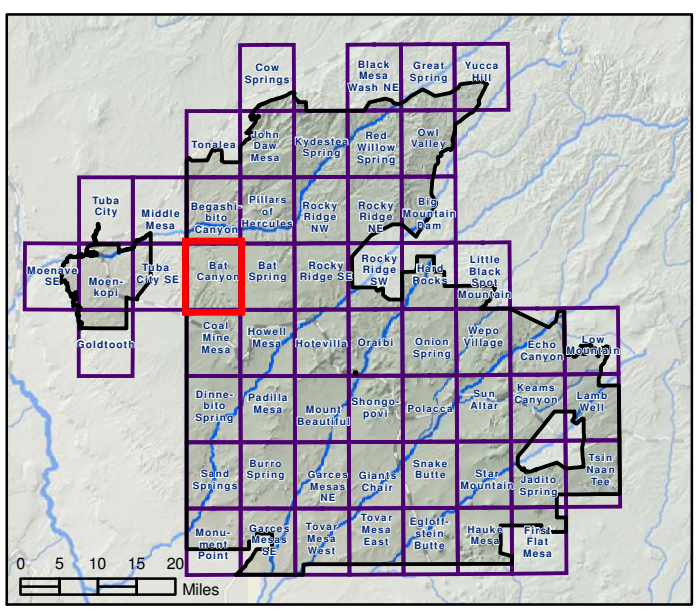
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



ARIZONA DEPARTMENT OF WATER RESOURCES

©

Tonalea

John Daw Mesa

Middle Mesa

Begashibito Canyon

Pillars of Hercules

Tuba City SE

Bat Canyon

Bat Spring

N A V A J O H O P I

J O I N T U S E A R E A

B L U E C A N O N

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Begashibito Canyon Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

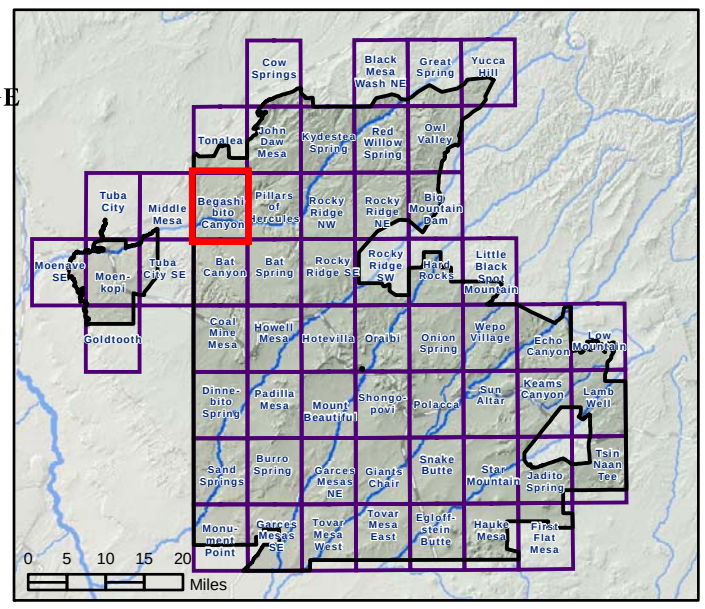
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Red Willow Spring
Owl Valley
Big Mountain Dam
Rocky Ridge NE
Rocky Ridge SE
Hard Rocks
Little Black Spot Mountai

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Big Mountain Dam Quad

© ARIZONA DEPARTMENT OF WATER RESOURCES

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

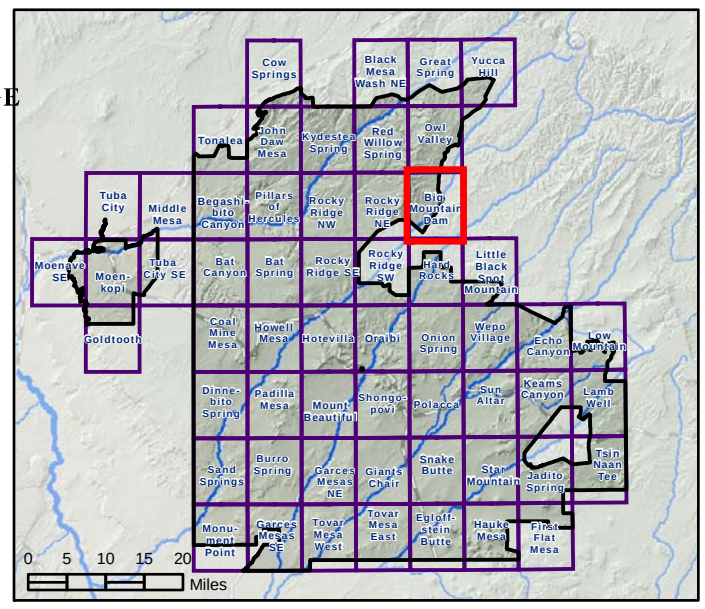
Classified Riparian Lands

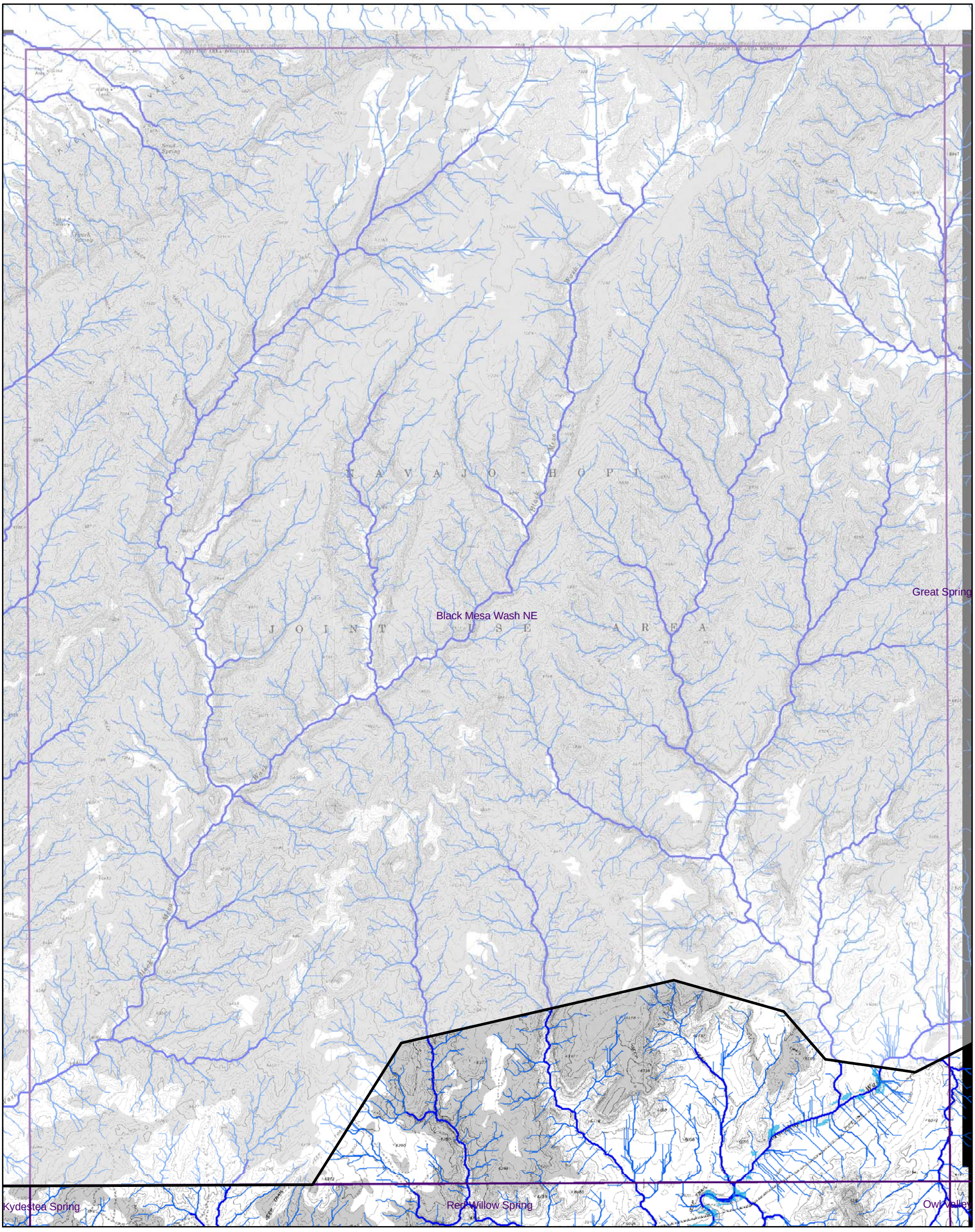
- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S





0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Black Mesa Wash NE Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

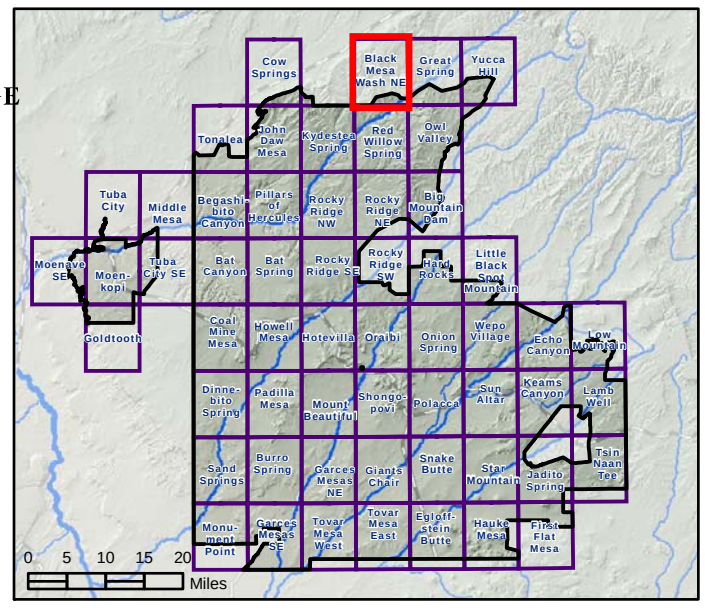
= 1.0 km^2 runoff area

= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation



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Padilla Mesa | Mount Beautiful | Shongopovi

Giants Chair

Burro Spring

Garces Mesas NE

Garces Mesas SE | Tovar Mesa West | Tovar Mesa East

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Burro Spring Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

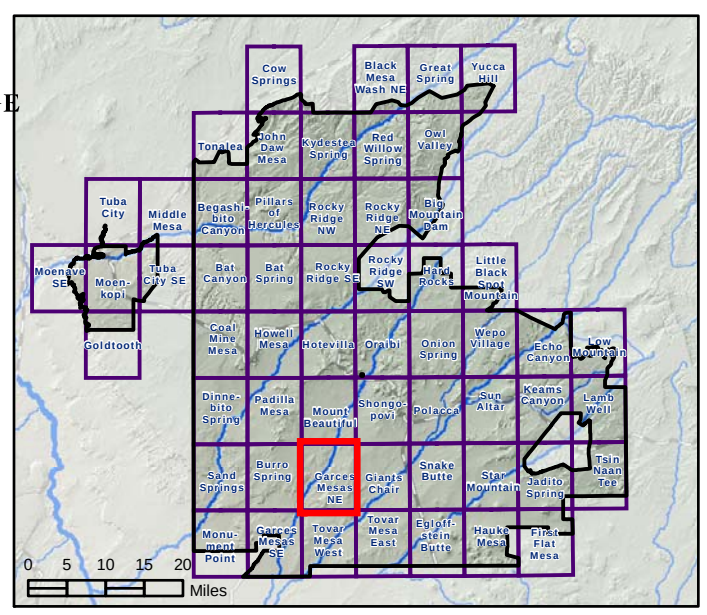
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Tuba City SE

Bat Canyon

Bat Spring

Blue Point

Coal Mine Mesa

Howell Mesa

Dinnebito Spring

Padilla Mesa

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Coal Mine Mesa Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

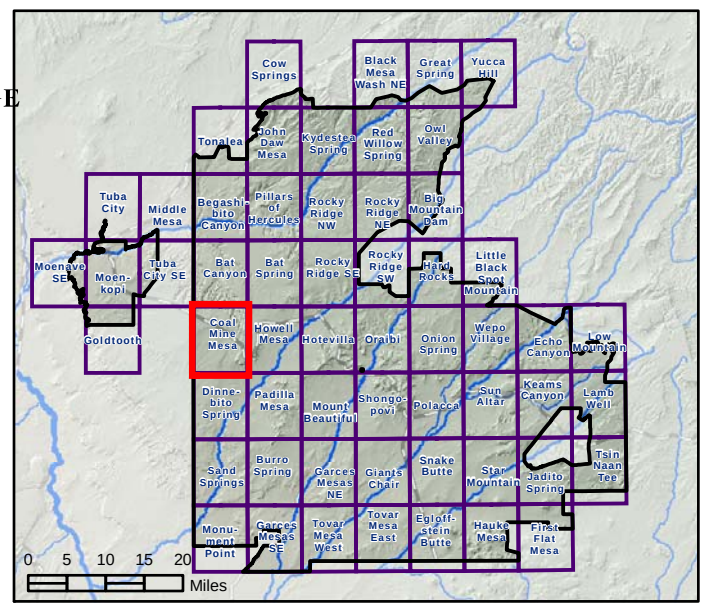
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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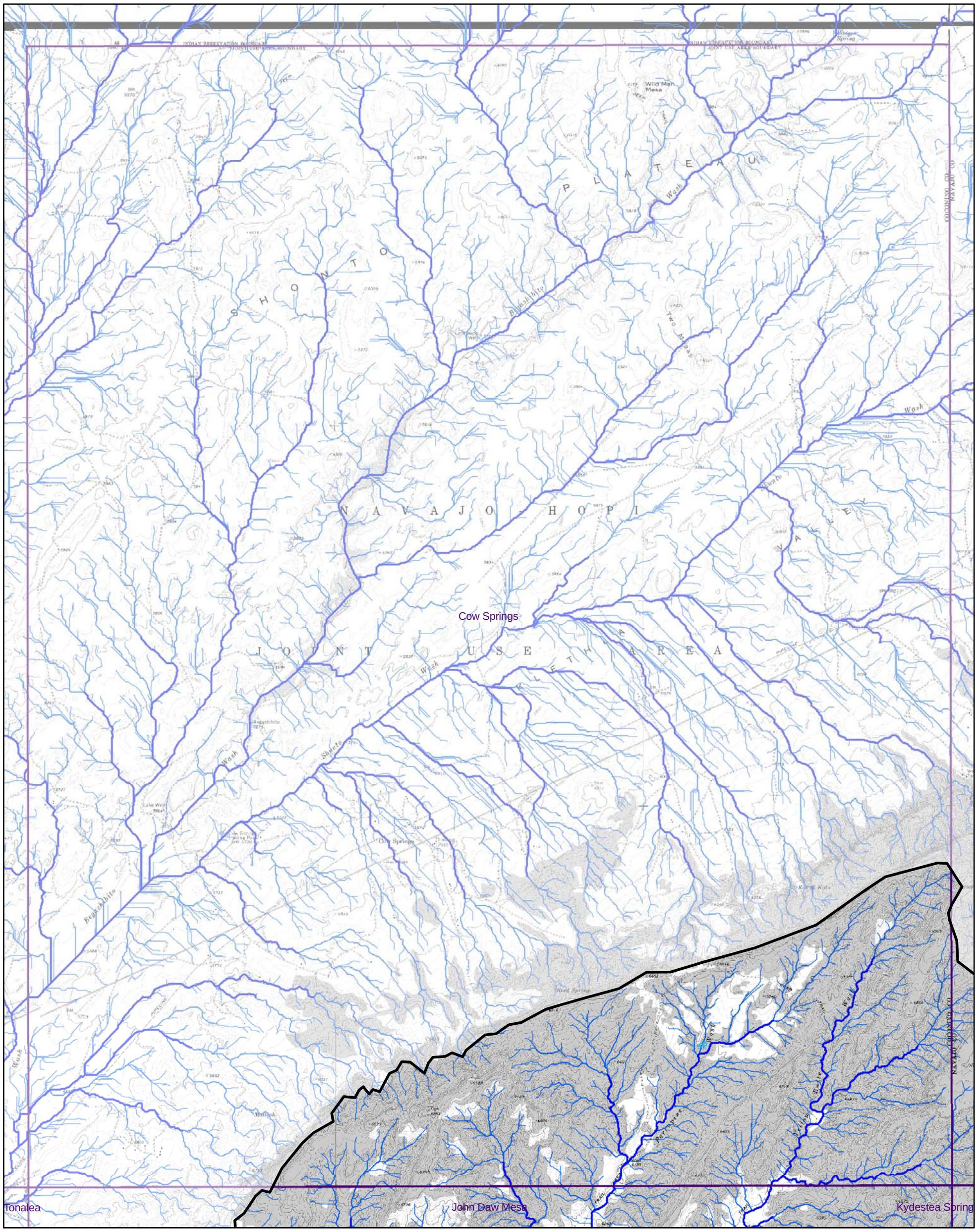


0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Cow Springs Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

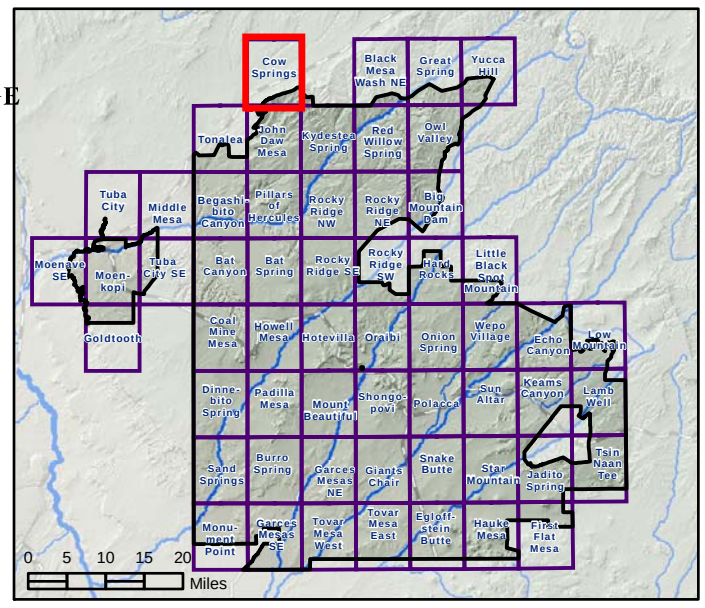
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Coal Mine Mesa

Howell Mesa

Dinnebito Spring

Padilla Mesa

Sand Springs

Garces Mesas NE

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Dinnebito Spring Quad

ARIZONA DEPARTMENT OF WATER RESOURCES

©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

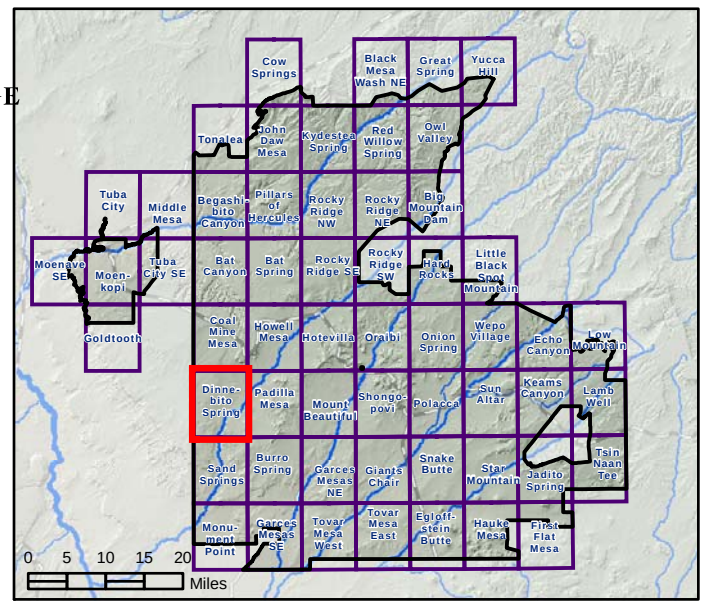
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Little Black Spot Mountai

Low Mountain

Echo Canyon

Wepo Village

Sun Altar

Keams Canyon

Lamb Well

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Echo Canyon Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

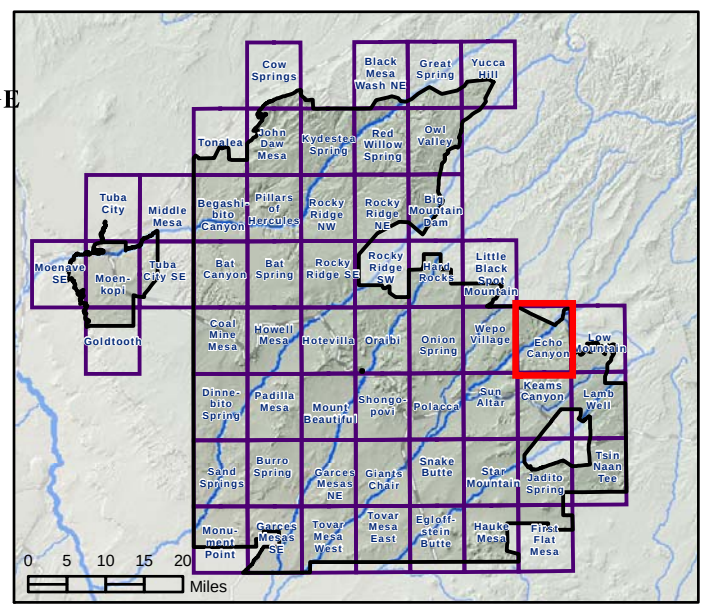
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Giants Chair

Snake Butte

Star Mountain

Tovar Mesa East

Egloffstein Butte

Hauke Mesa

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Egloffstein Butte Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

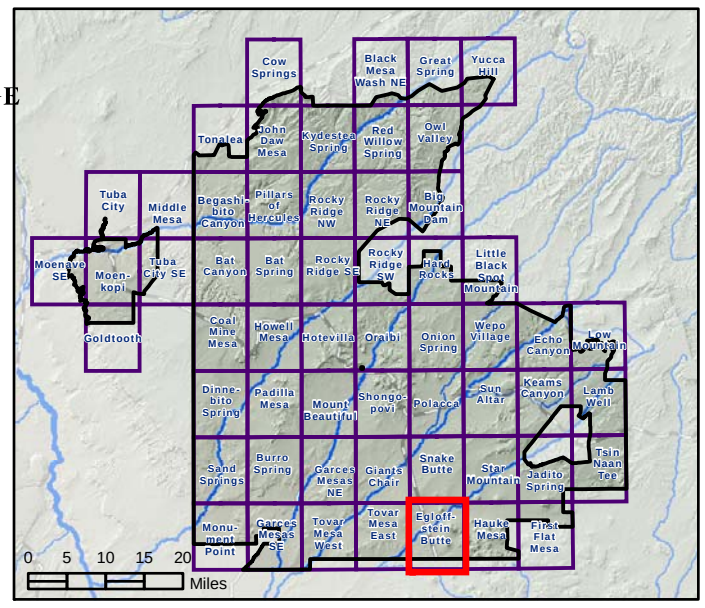
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



Star Mountain

Jadito Spring

Tsin Naan Tee

First Flat Mesa

Hauke Mesa

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

First Flat Mesa Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

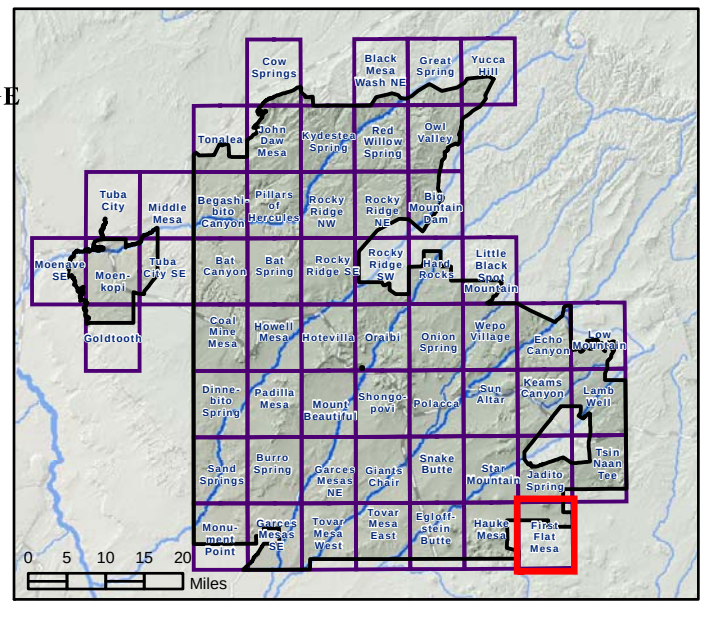
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Dinnebito Spring | Padilla Mesa | Mount Beautiful

Sand Springs | Garces Mesas NE | Burro Spring

Monument Point | Garces Mesas SE | Tovar Mesa West

HOPI INDIAN RESERVATION

NAVAJO HOPI JOINT USE AREA

GARCES MESAS

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Garces Mesas NE Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

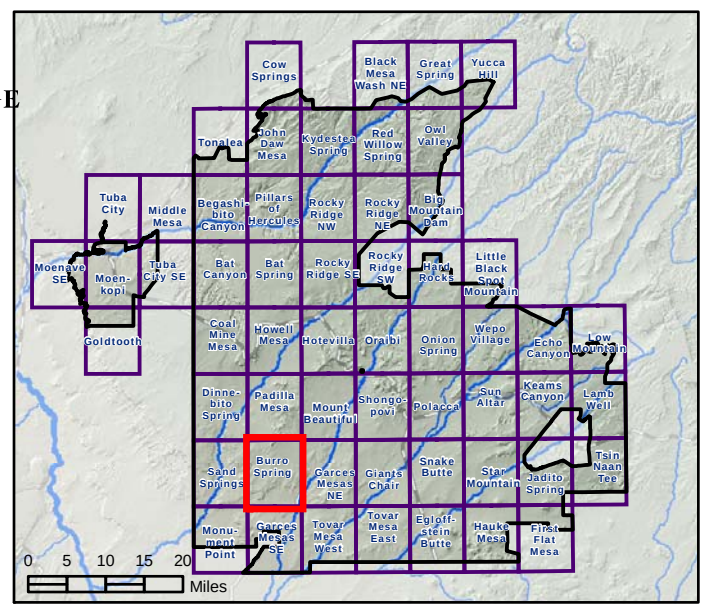
- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation



ARIZONA DEPARTMENT OF WATER RESOURCES ©

Sand Springs

Garces Mesas NE

Burro Spring

Monument Point

Garces Mesas SE

Tovar Mesa West

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Garces Mesas SE Quad

© ARIZONA DEPARTMENT OF WATER RESOURCES

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

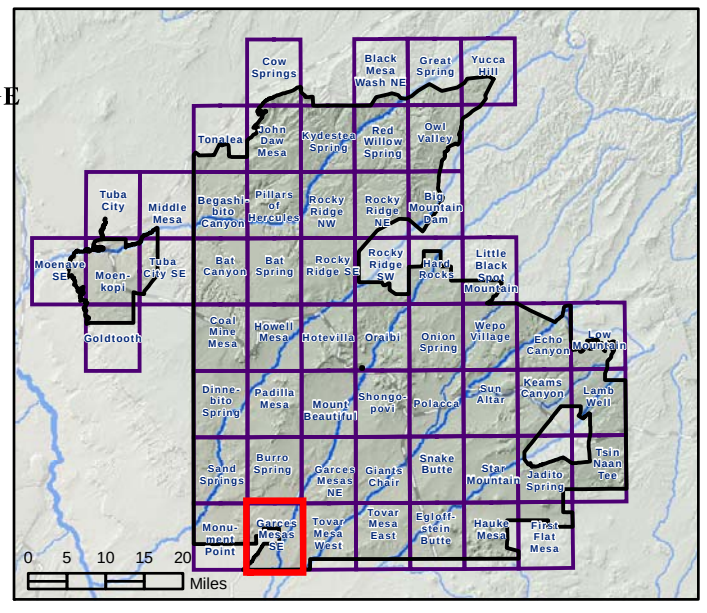
Classified Riparian Lands

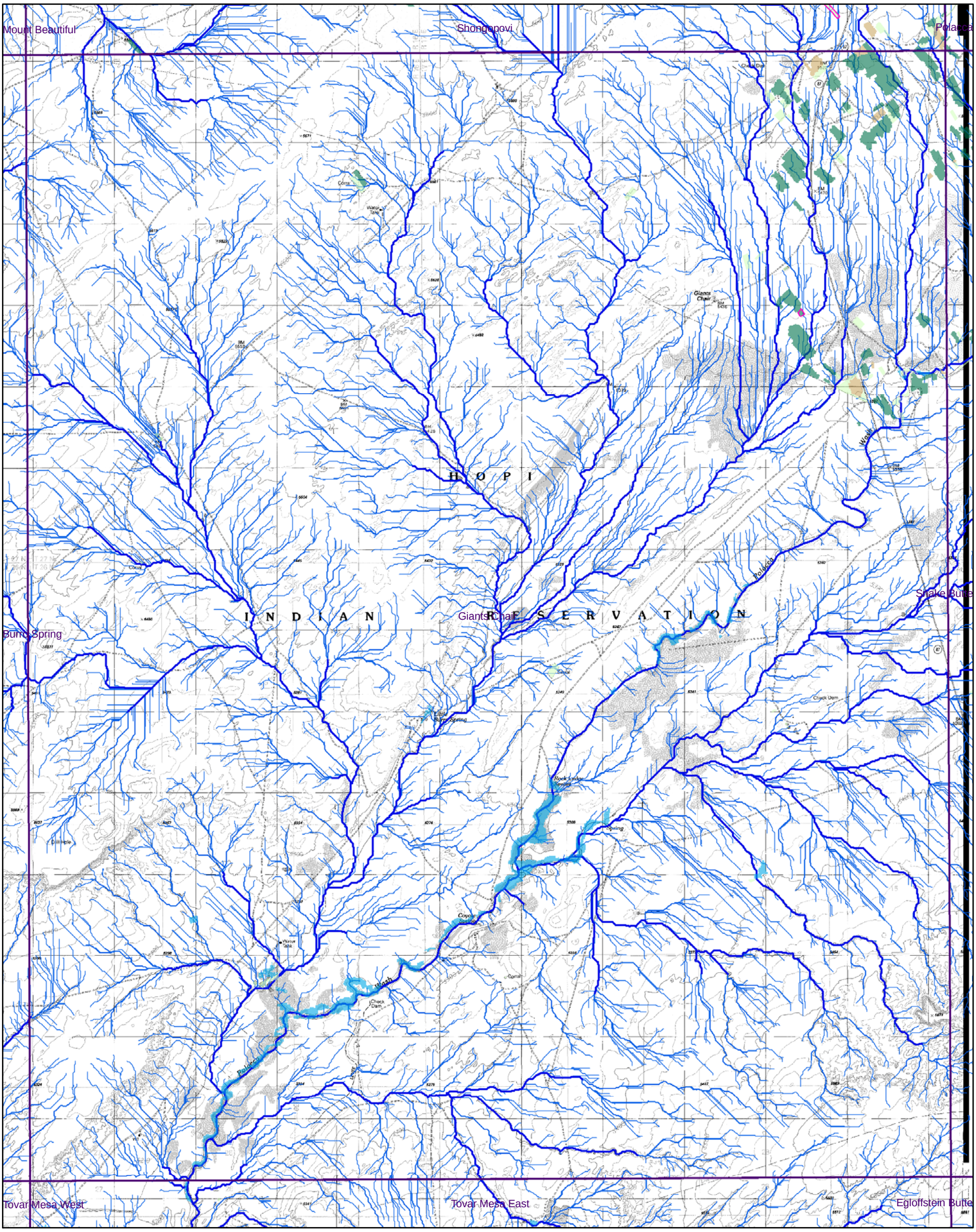
- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S





0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Giants Chair Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

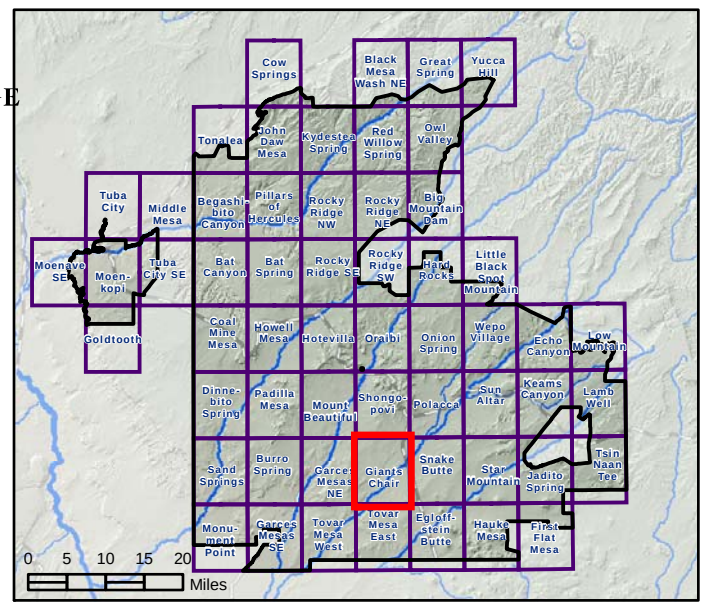
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Moenave SE

Moenkopi

Tuba City SE

Goldtooth

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Goldtooth Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

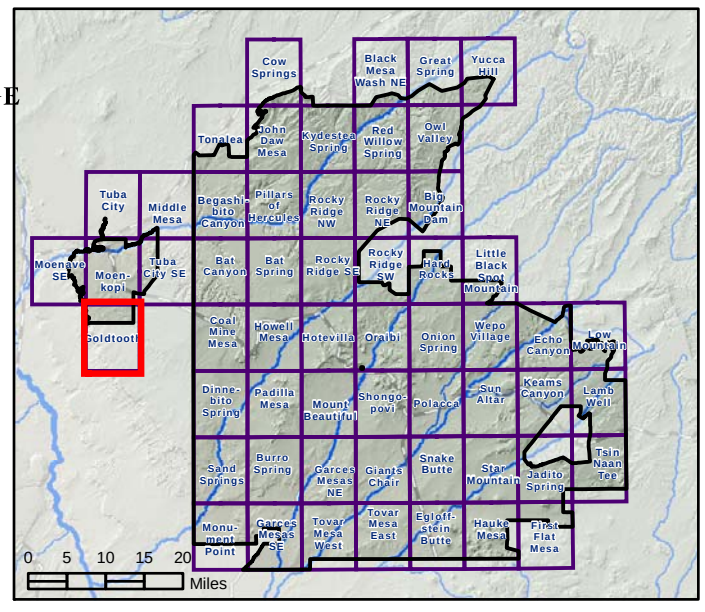
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Great Spring

Black Mesa Wash NE

Yucca Hill

Red Willow Spring

Owl Valley

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Great Spring Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

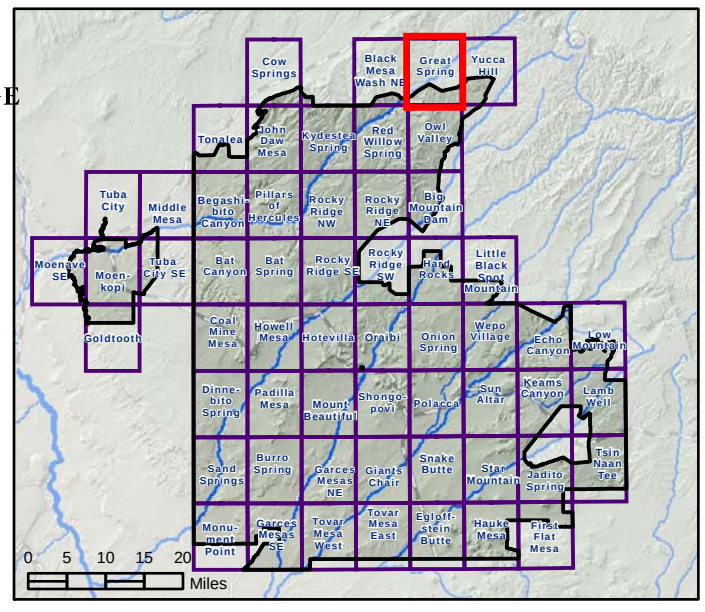
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Rocky Ridge NE

Big Mountain Dam

Little Black Spot Mountai

Hard Rocks

Rocky Ridge SE

Oraibi

Onion Spring

Wepo Village

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Hard Rocks Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

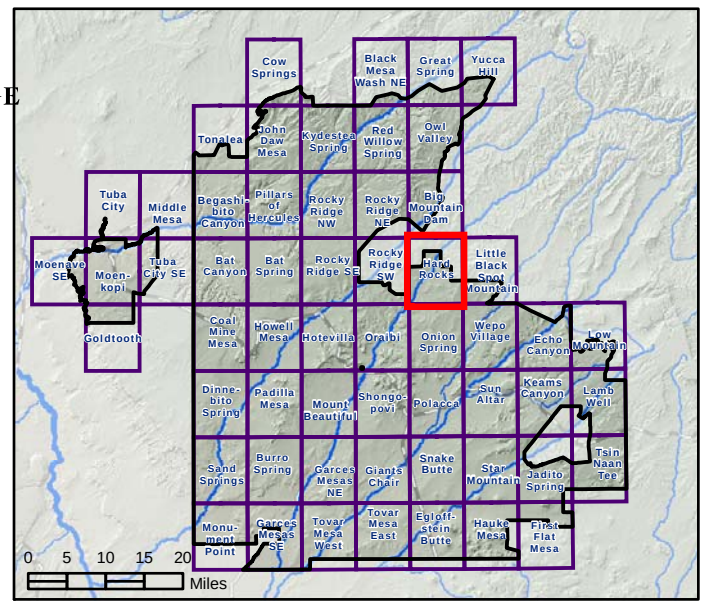
= 1.0 km^2 runoff area

= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation



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Snake Butte

Star Mountain

Jadito Spring

First Flat Mesa

Hauke Mesa

Egloffstein Butte

HOPI BUTTES

HOPI INDIAN RESERVATION

NAVAJO INDIAN RESERVATION

HAUKE MESA

Wash

Check Dams

Bull Butte

Horse Butte

Water Tank

Spring

Hauke

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Hauke Mesa Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

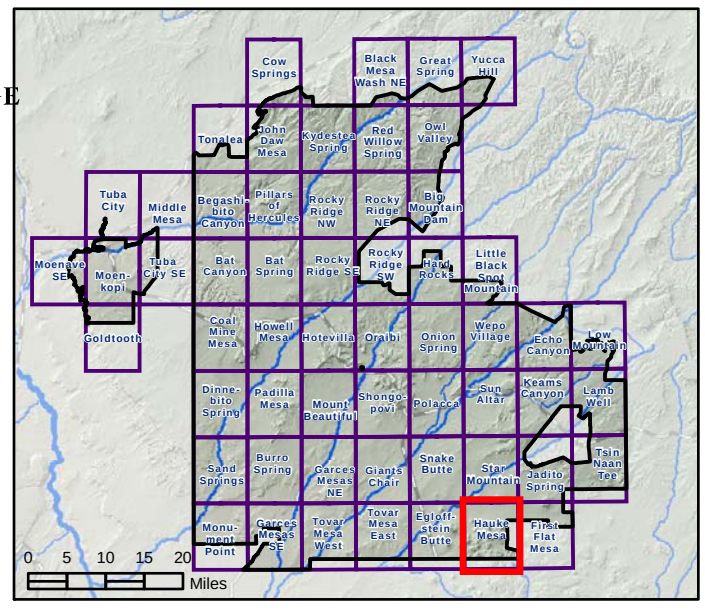
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Bat Spring | Rocky Ridge SW | Rocky Ridge SE

Howell Mesa | Hotevilla | Oraibi

Padilla Mesa | Mount Beautiful | Shongopovi

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Hotevilla Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

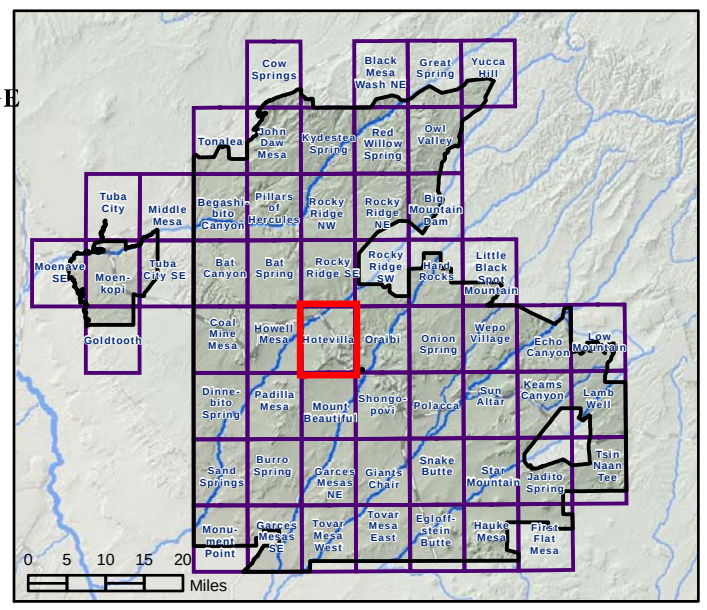
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Bat Canyon
Bat Spring
Rocky Ridge SW
Coal Mine Mesa
Howell Mesa
Hotevilla
Dinnebito Spring
Padilla Mesa
Mount Beautiful

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Howell Mesa Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture
Active Or Fallow Agriculture
Active Fallow Agriculture

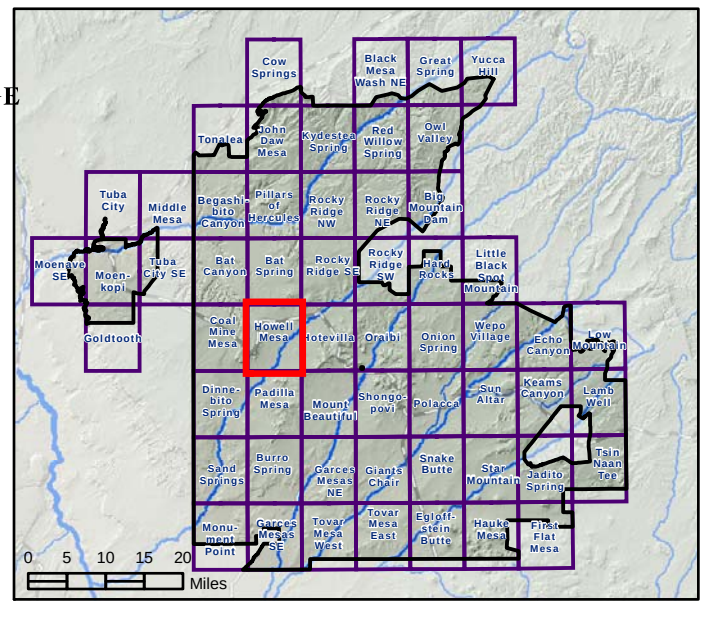
Classified Riparian Lands

Riparian
Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area
= 0.1 km^2 runoff area
= 0.01 km^2 runoff area
USGS Topo Quad Boundary
Hopi Reservation

N
W E
S



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Sun Altar
Keams Canyon
Lamb Well
Jadito Spring
Tsin Naah Tee
Star Mountain
Hauke Mesa
First Flat Mesa

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Jadito Spring Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

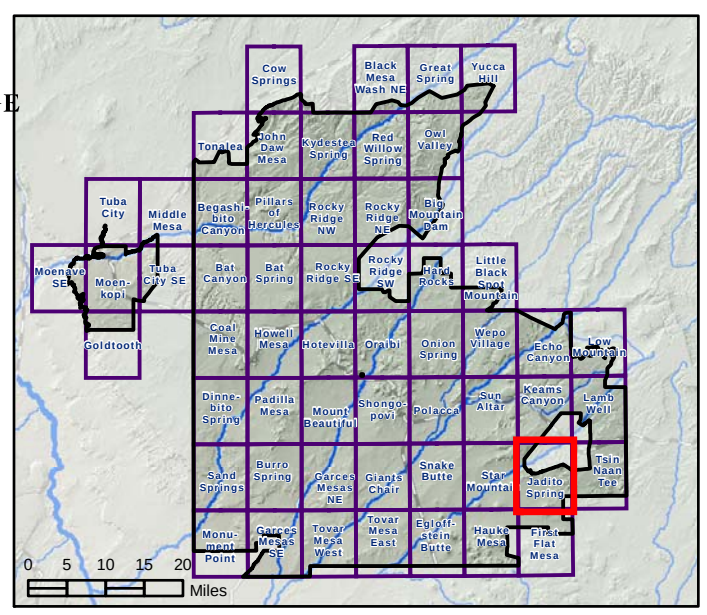
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Cow Springs

Tonalea

John Daw Mesa

Kydestea Spring

Begashibito Canyon

Pillars of Hercules

Rocky Ridge NW

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

John Daw Mesa Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

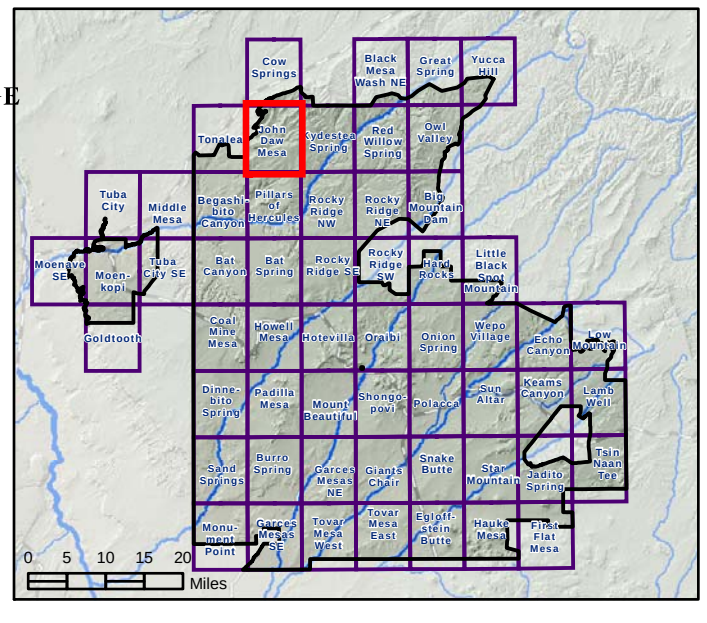
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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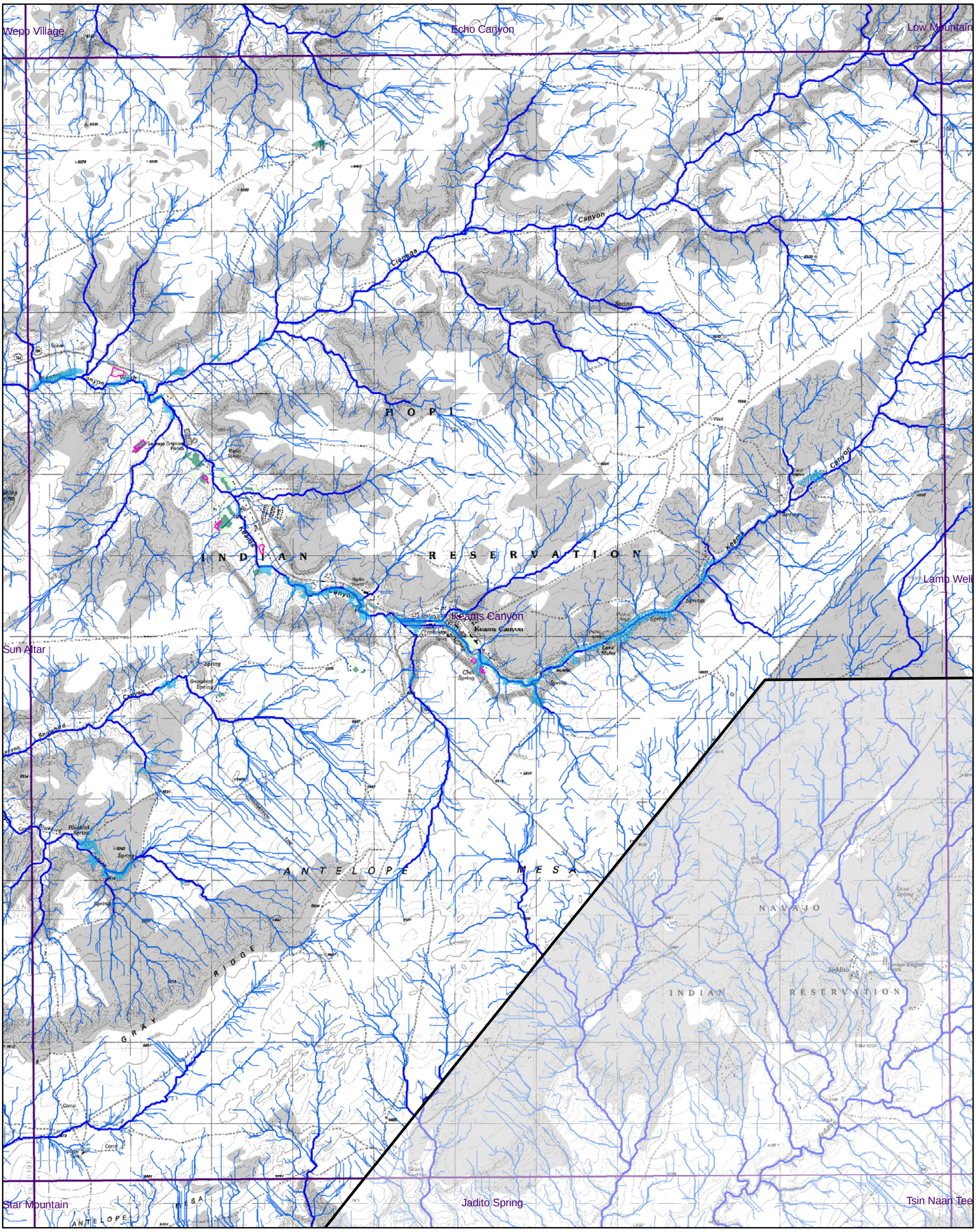

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Keams Canyon Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

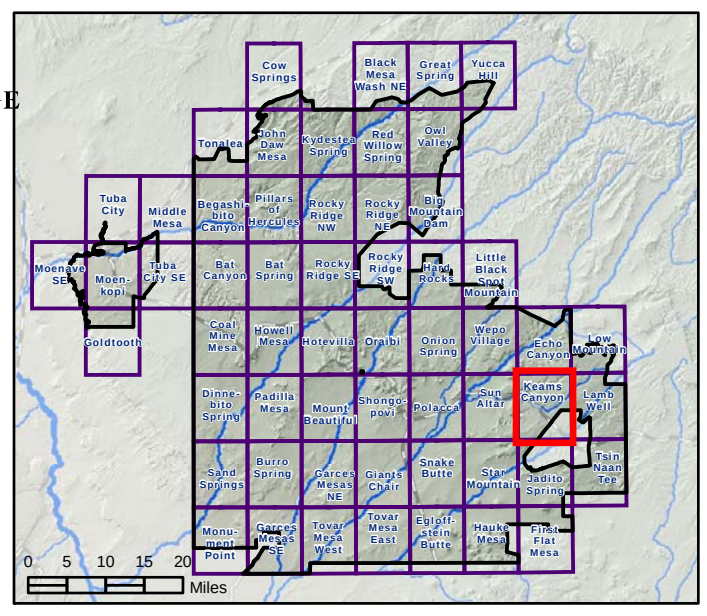
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Cow Springs

Black Mesa Wash NE

John Daw Mesa

Kydestea Spring

Red Willow Spring

Pillars of Hercules

Rocky Ridge NW

Rocky Ridge NE

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Kydestea Spring Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

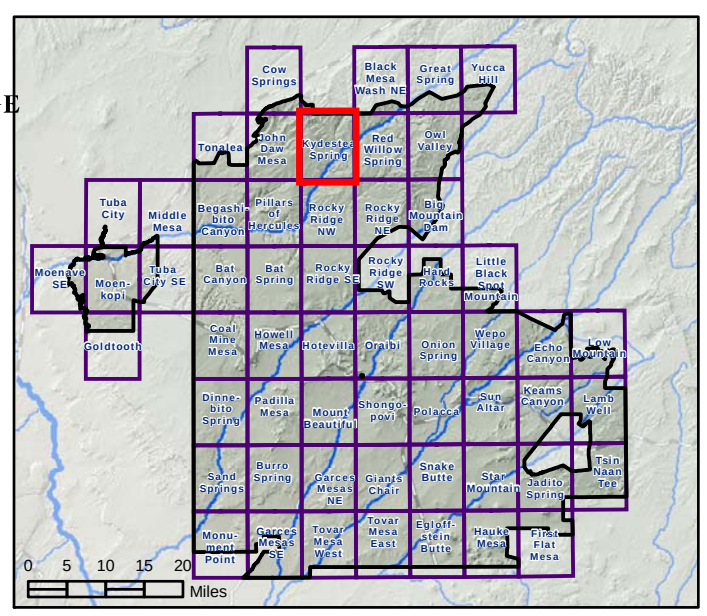
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Echo Canyon

Low Mountain

Lamb Well

Keams Canyon

Jadito Spring

Tsin Naan Tee

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Lamb Well Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

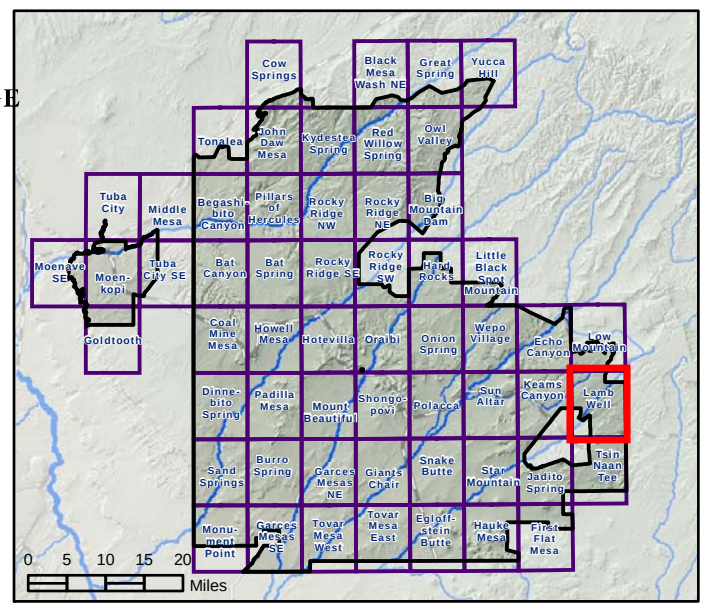
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Big Mountain Dam

Little Black Spot Mountai

Hard Rocks

Onion Spring

Wepo Village

Echo Canyon

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Little Black Spot Mountain Quad

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ARIZONA DEPARTMENT OF WATER RESOURCES

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N
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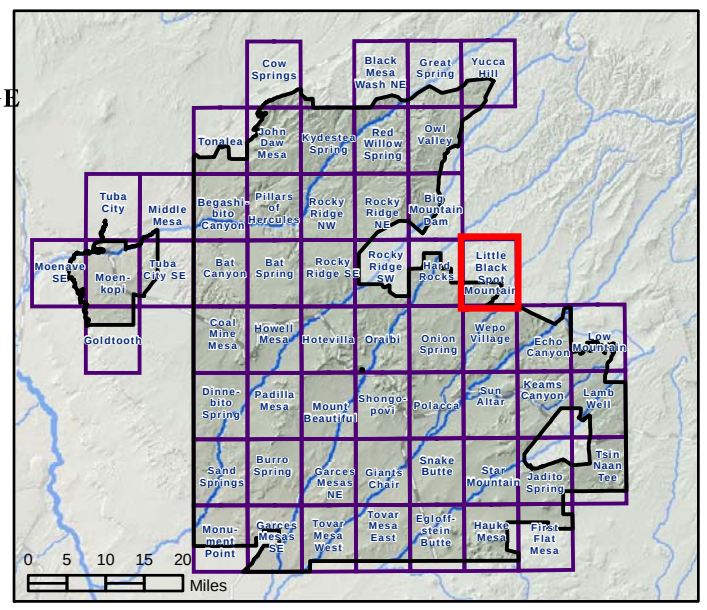


Low Mountain

Echo Canyon

Keams Canyon

Lamb Well

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Low Mountain Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

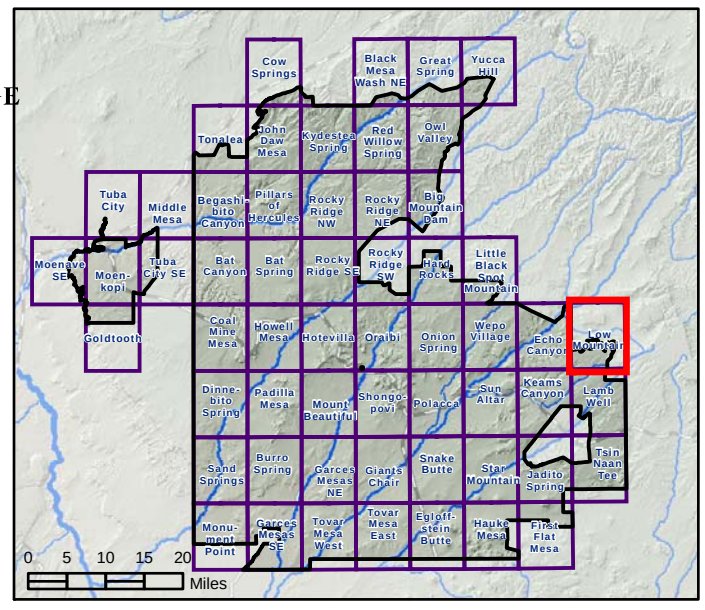
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N
W E
S



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©

Tonalea

Tuba City

Middle Mesa

Begashibito Canyon

Moenkopi

Tuba City SE

Bat Canyon

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Middle Mesa Quad

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ARIZONA DEPARTMENT OF WATER RESOURCES

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

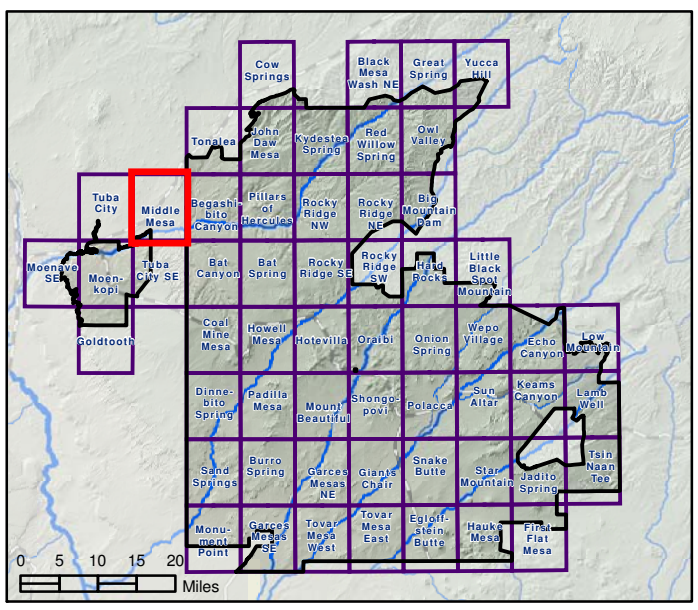
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



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Tuba City

Moenave SE

Moenkopi

Goldtooth

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Moenave SE Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

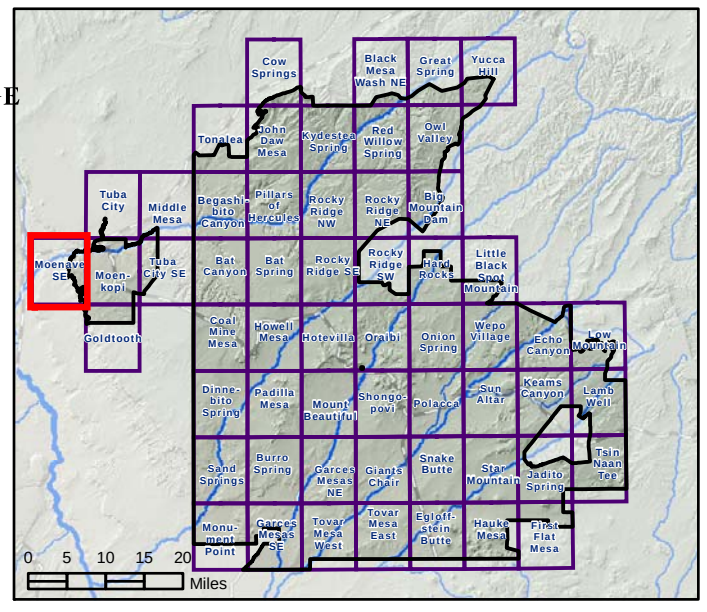
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Tuba City

Middle Mesa

Moenave SE

Moenkopi

Tuba City SE

Goldtooth

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Moenkopi Quad

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

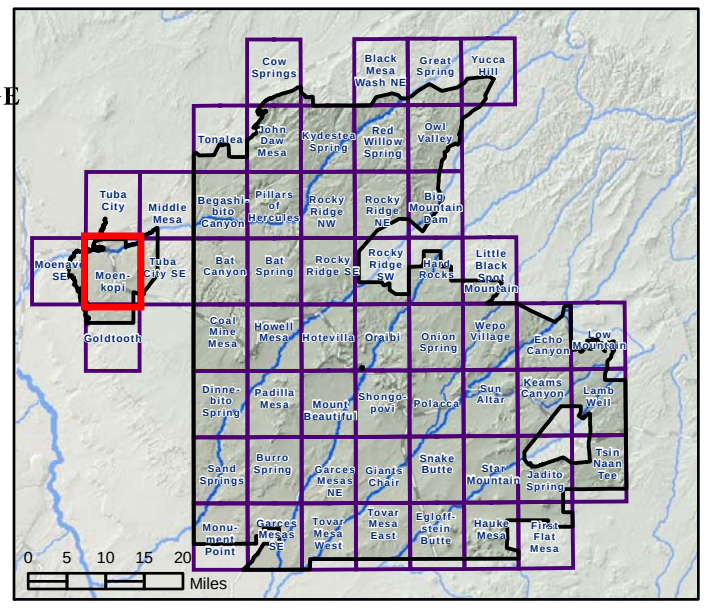
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Sand Springs

Garces Mesas NE

Monument Point

Garces Mesas SE

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Monument Point Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

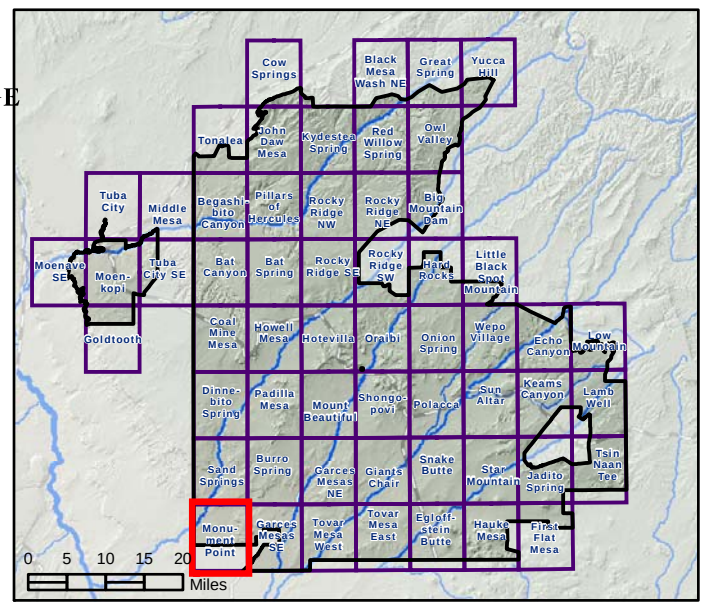
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Howell Mesa
Hotevilla
Oraibi
Shongopovi
Mount Beautiful
Padilla Mesa
Garces Mesas NE
Burro Spring
Giants Chair

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Mount Beautiful Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture
Active Or Fallow Agriculture
Active Fallow Agriculture

Classified Riparian Lands

Riparian
Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area
= 0.1 km^2 runoff area
= 0.01 km^2 runoff area
USGS Topo Quad Boundary
Hopi Reservation

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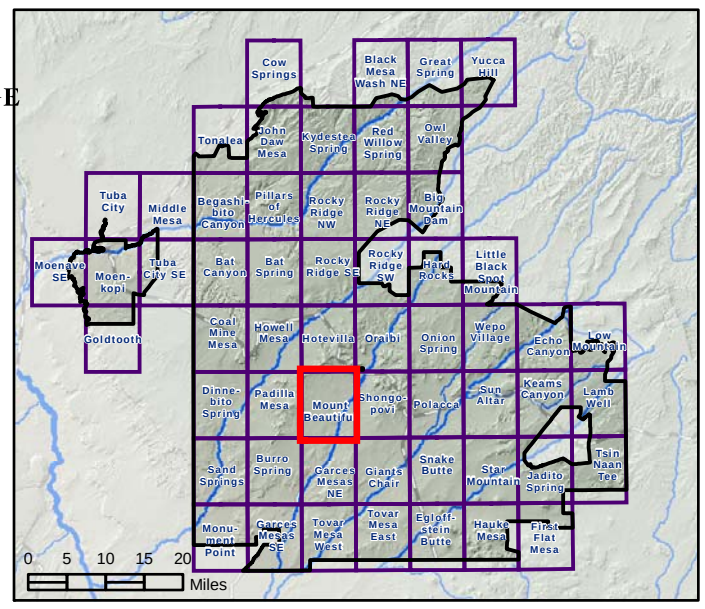

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Rocky Ridge SE
Hard Rocks
Little Black Spot Mountai
Wepo Village
Onion Spring
Orajbi
Shongopovi
Polacca
Sun Altar

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Onion Spring Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

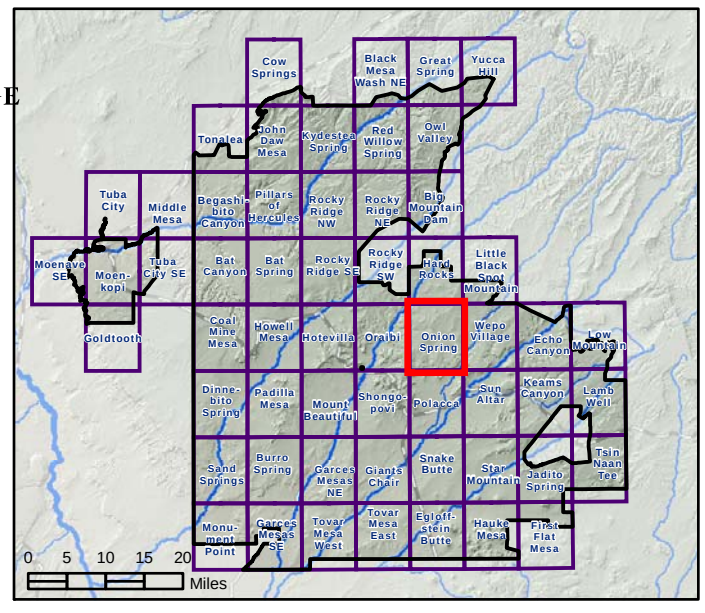
Active Agriculture
Active Or Fallow Agriculture
Active Fallow Agriculture

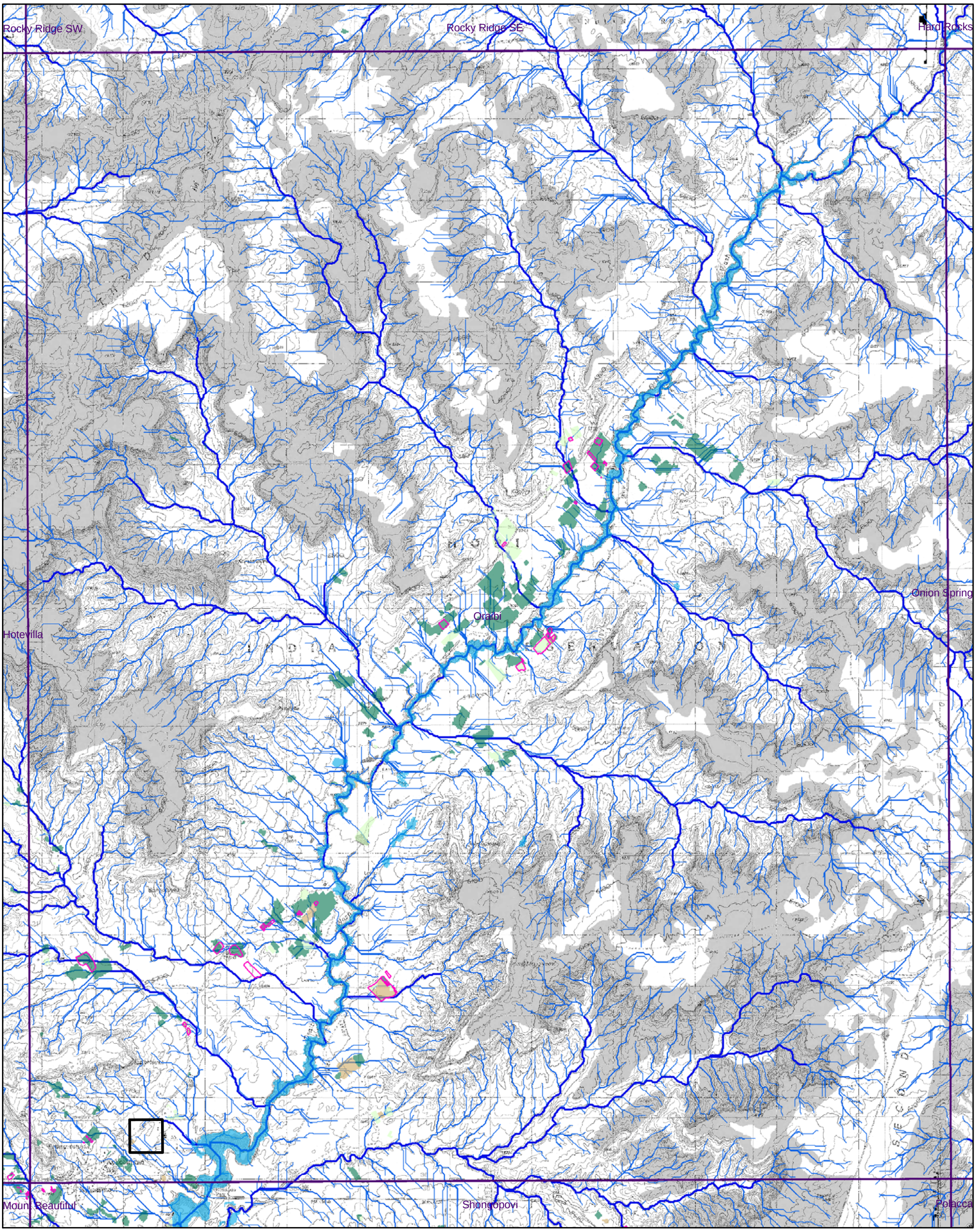
Classified Riparian Lands

Riparian
Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area
= 0.1 km^2 runoff area
= 0.01 km^2 runoff area
USGS Topo Quad Boundary
Hopi Reservation





0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Oraibi Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

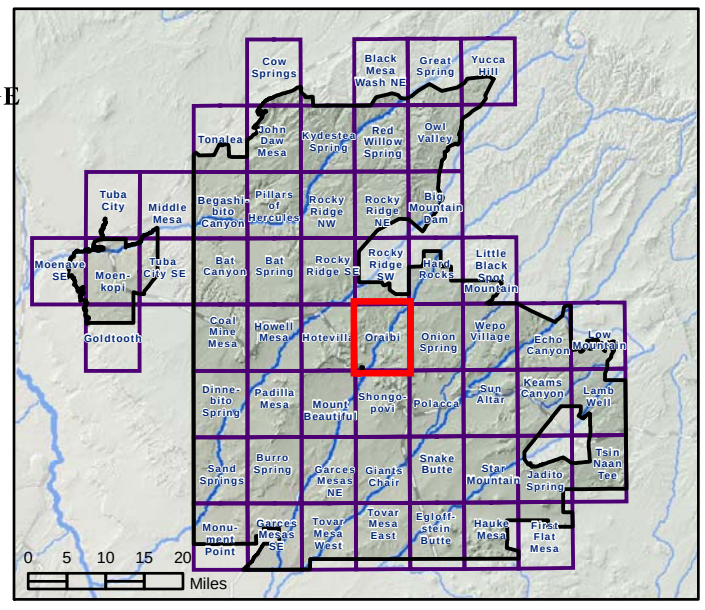
- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation



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Black Mesa Wash NE
Great Spring
Yucca Hill
Owl Valley
Red Willow Spring
Rocky Ridge NE
Big Mountain Dam

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Owl Valley Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture
Active Or Fallow Agriculture
Active Fallow Agriculture

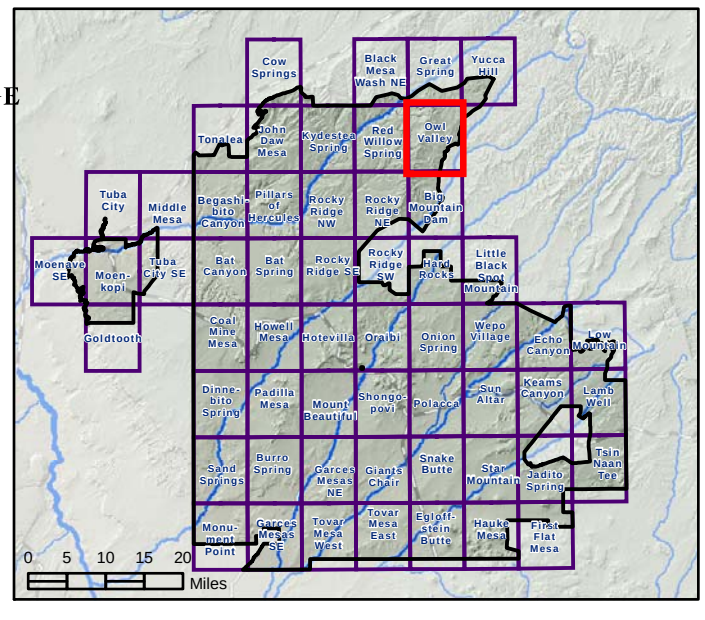
Classified Riparian Lands

Riparian
Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area
= 0.1 km^2 runoff area
= 0.01 km^2 runoff area
USGS Topo Quad Boundary
Hopi Reservation

N W E S



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Coal Mine Mesa
Howell Mesa
Hotevilla
Dinnebito Spring
Padilla Mesa
Mount Beautiful
Sand Springs
Garces Mesas NE
Burro Spring

0 0.5 1 1.5 2 Kilometers
0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Padilla Mesa Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

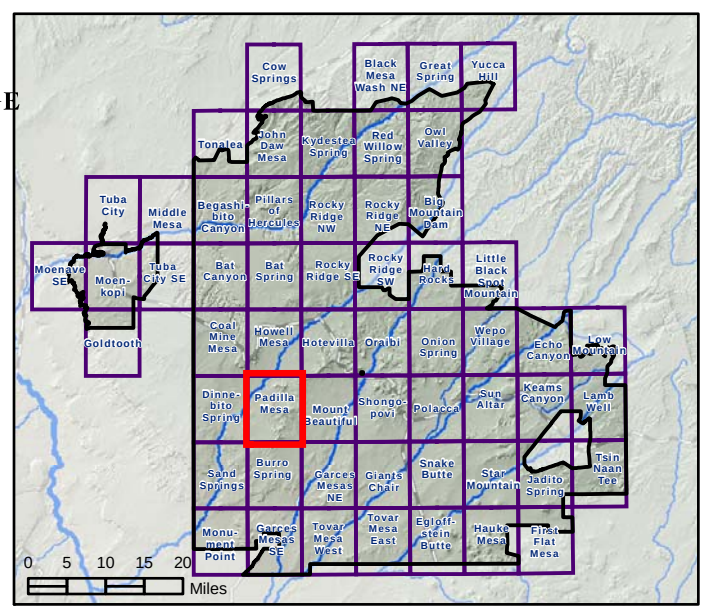
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Tonalea

John Daw Mesa

Kydestea Spring

Begashibito Canyon

Pillars of Hercules

Rocky Ridge NW

Bat Canyon

Bat Spring

Rocky Ridge SW

0 0.5 1 1.5 2

Kilometers

0 0.4 0.8 1.2 1.6

Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Pillars of Hercules Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

= 1.0 km^2 runoff area

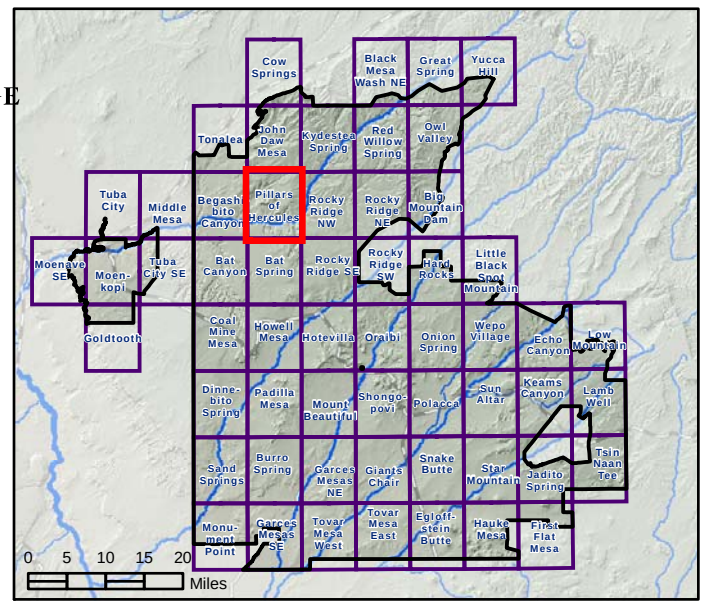
= 0.1 km^2 runoff area

= 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N W E S



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Oraibi

Onion Spring

Wepo Village

Polacca

Shongopovi

Sun Altar

Giants Chair

Snake Butte

Star Mountain

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Polacca Quad

©

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

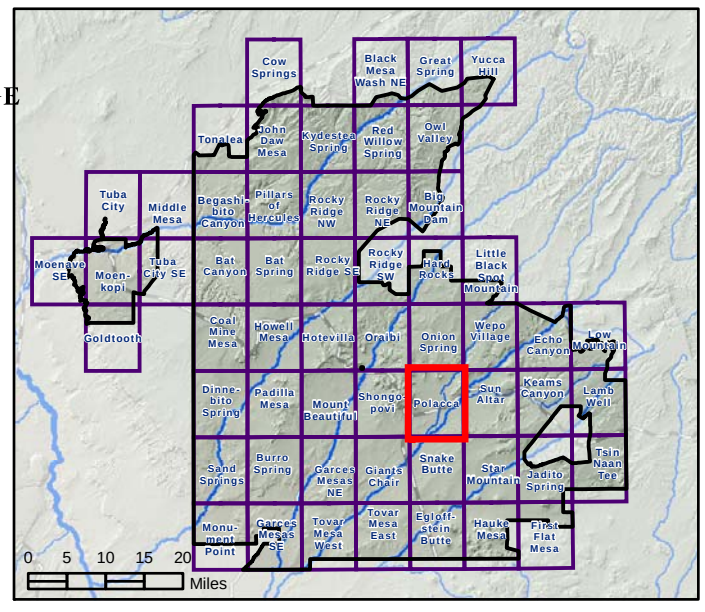
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Black Mesa Wash NE

Great Spring

Owl Valley

Red Willow Spring

Kydestea Spring

Rocky Ridge NW

Rocky Ridge NE

Big Mountain Dam

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Red Willow Spring Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

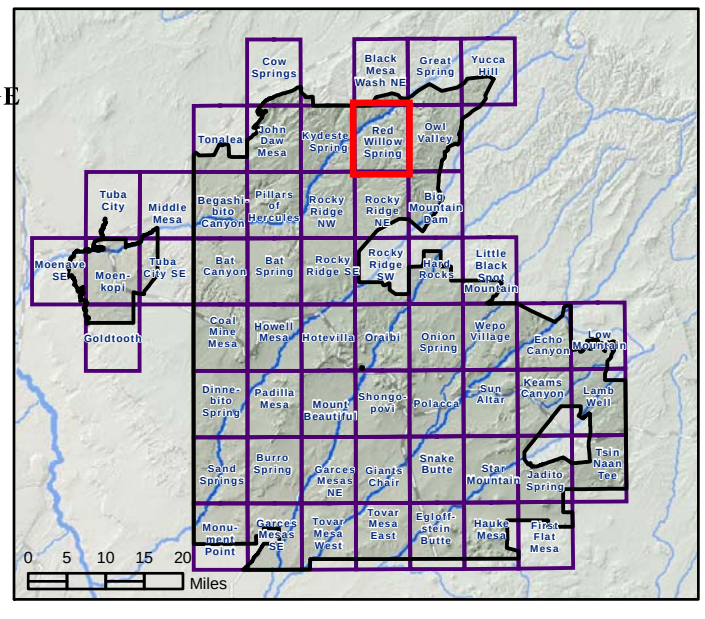
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



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Rocky Ridge NW

Rocky Ridge NE

Big Mountain Dam

Pillars of Hercules
Rocky Ridge NW
Rocky Ridge NE
Rocky Ridge SW
Rocky Ridge SE
Bat Spring
Howell Mesa
Hotevilla
Oraibi

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Rocky Ridge SW Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

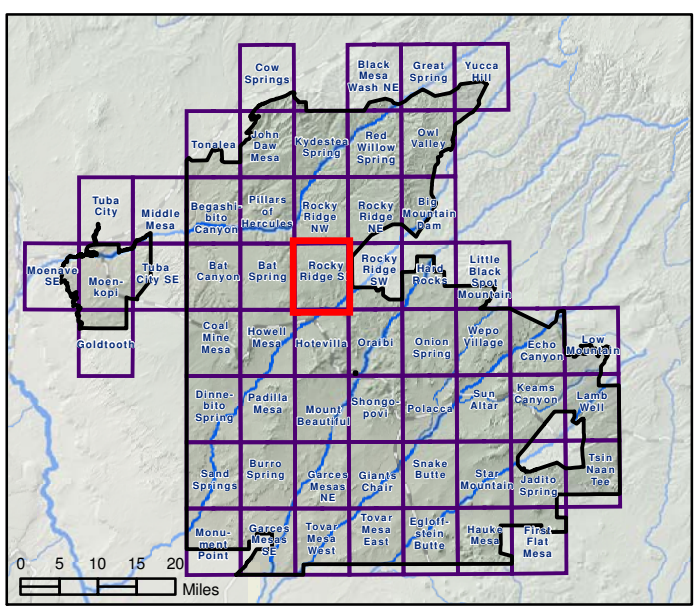
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



Kydestea Spring
Red Willow Spring
Owl Valley
Rocky Ridge NW
Rocky Ridge NE
Big Mountain Dam
Rocky Ridge SW
Rocky Ridge SE
Hard Rocks

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Rocky Ridge NE Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

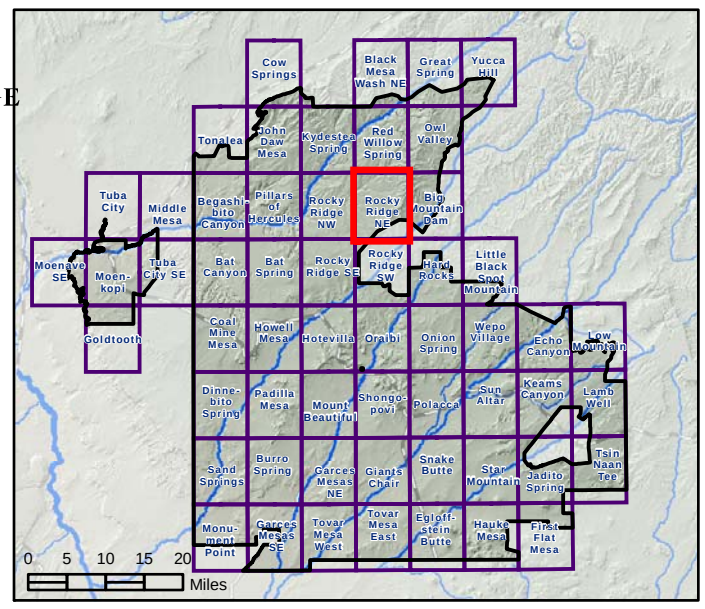
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



John Daw Mesa | Kydestea Spring | Red Willow Spring

Pillars of Hercules | Rocky Ridge NW | Rocky Ridge NE

Bat Spring | Rocky Ridge SW | Rocky Ridge SE

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Rocky Ridge NW Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

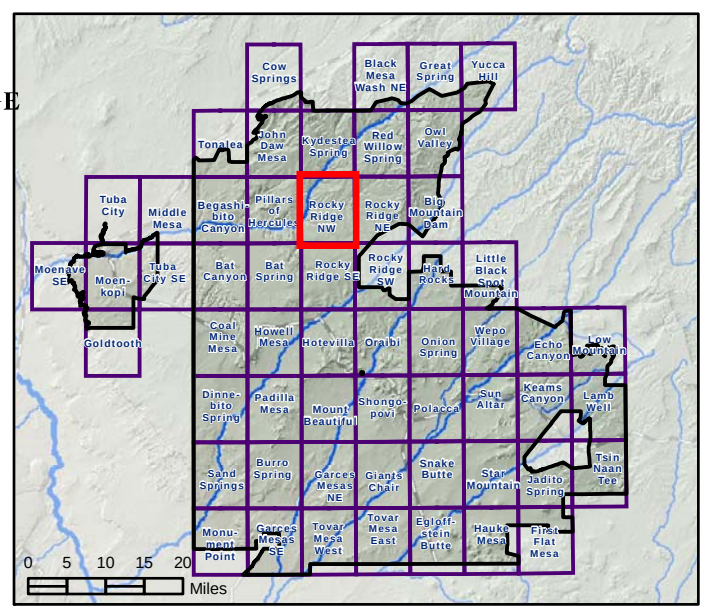
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Rocky Ridge NW

Rocky Ridge NE

Big Mountain Dam

Hard Rocks

Rocky Ridge SE

Rocky Ridge SW

Hotevilla

Oraibi

Onion Spring

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Rocky Ridge SE Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

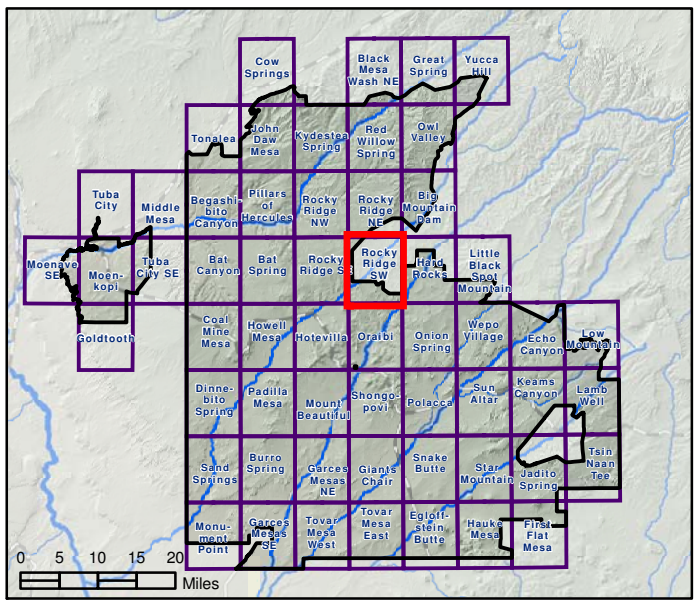
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



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Dinnebito Spring

Padilla Mesa

Sand Springs

Garces Mesas NE

Monument Point

Garces Mesas SE

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Sand Springs Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

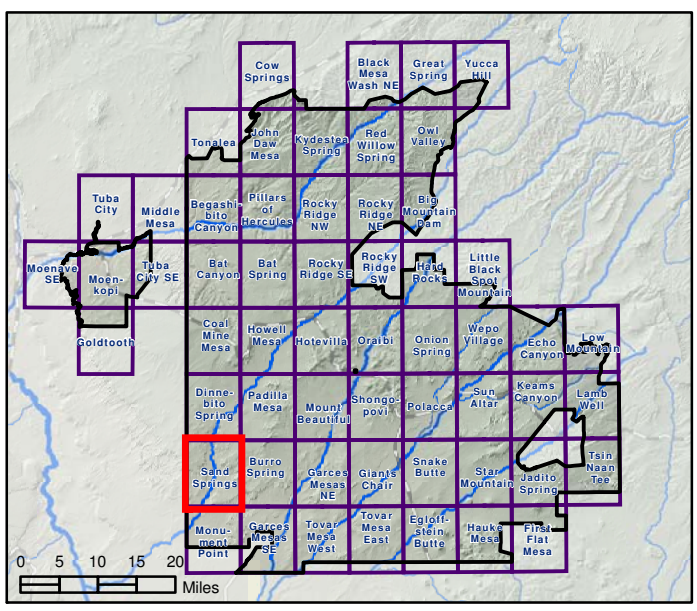
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



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Hotevilla
Oraibi
Onion Spring
Shongopovi
Polacca
Mount Beautiful
Burro Spring
Giants Chair
Snake Butte

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Shongopovi Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

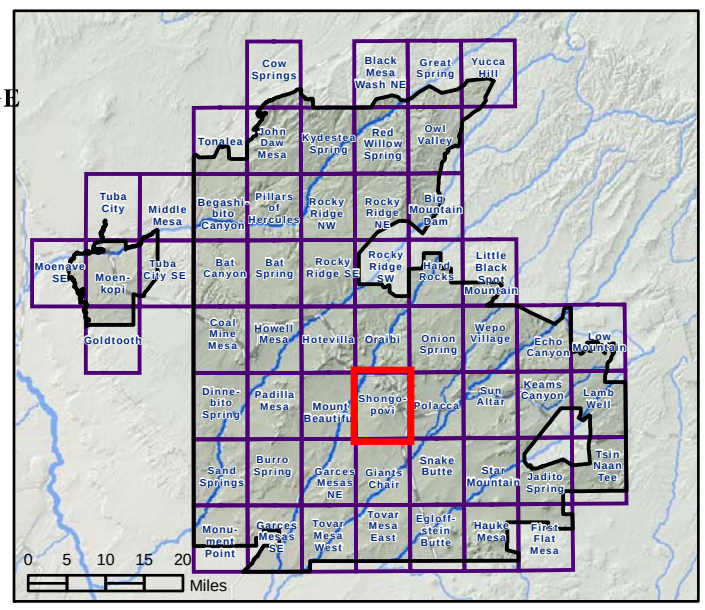
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- = 1.0 km^2 runoff area
- = 0.1 km^2 runoff area
- = 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N W E S



Shongopovi

Polacca

Sun Altar

Star Mountain

Snake Butte

Giants Chair

H O P I

I N D I A N R E S E R V A T I O N

Tovar Mesa East

Egloffstein Butte

Hauke Mesa

0 0.5 1 1.5 2
Kilometers

0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Snake Butte Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

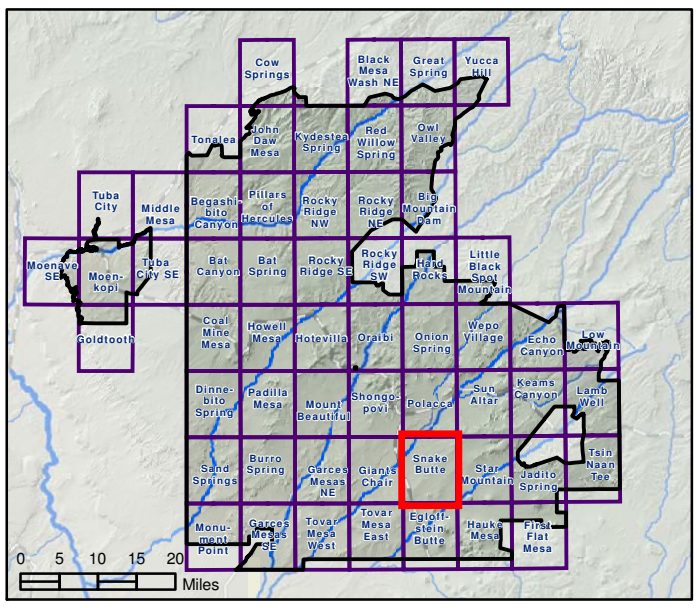
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



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Polacca

Sun Altar

Keams Canyon

Jadito Spring

Star Mountain

Snake Butte

Egloffstein Butte

Hauke Mesa

First Flat Mesa

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Star Mountain Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

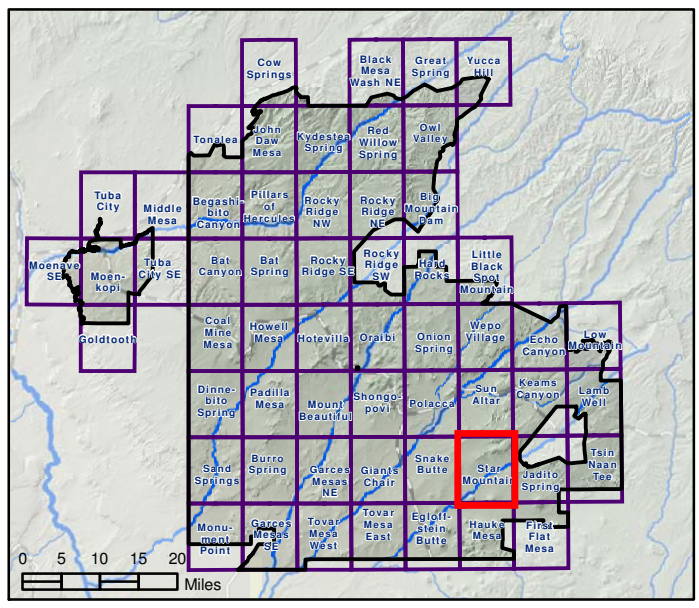
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



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Onion Spring
Wepo Village
Echo Canyon
Keams Canyon
Sun Altar
Polacca
Snake Butte
Star Mountain
Jadito Spring

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Sun Altar Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture
Active Or Fallow Agriculture
Active Fallow Agriculture

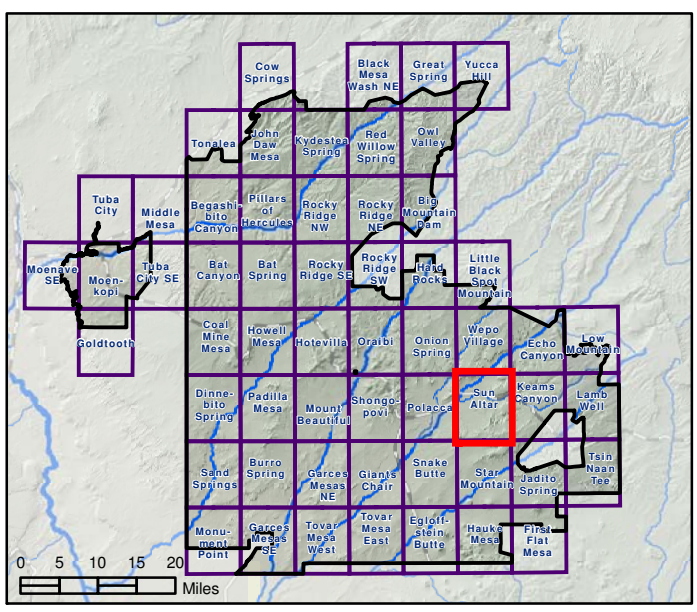
Classified Riparian Lands

Riparian
Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area
≥ 0.1 km^2 runoff area
≥ 0.01 km^2 runoff area
USGS Topo Quad Boundary
Hopi Reservation

N



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Cow Springs

Tonalea

John Daw Mesa

Middle Mesa

Begashibito Canyon

Pillars of Hercules

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tonalea Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

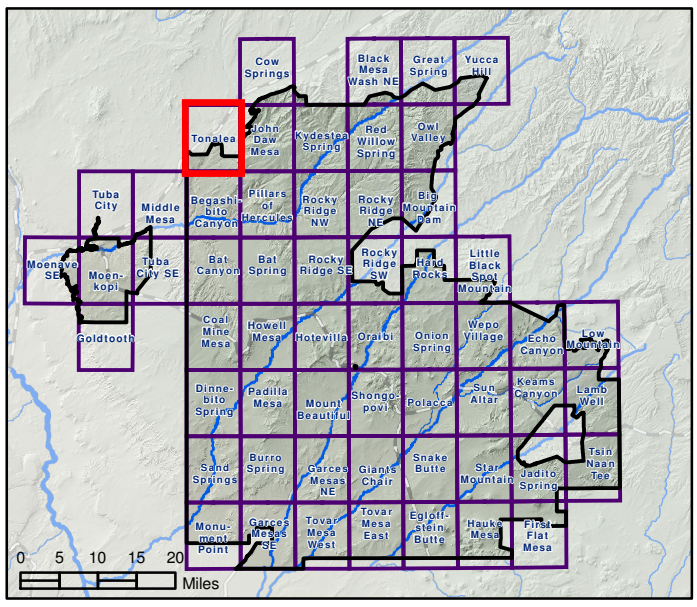
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



Burro Spring

Giants Chair

Snake Butte

Tovar Mesa West

Tovar Mesa East

Eglofstein Butte

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tovar Mesa East Quad

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Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

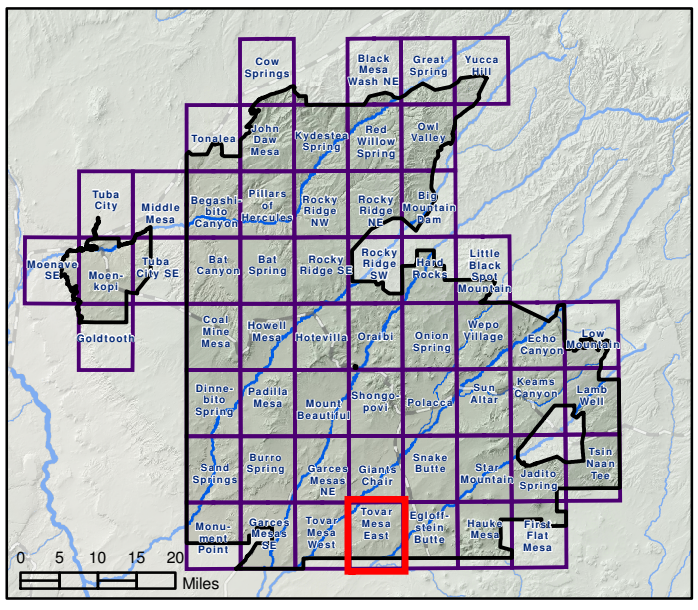
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



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Garces Mesas NE

Burro Spring

Giants Chair

Tovar Mesa West

Tovar Mesa East

Garces Mesas SE

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tovar Mesa West Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

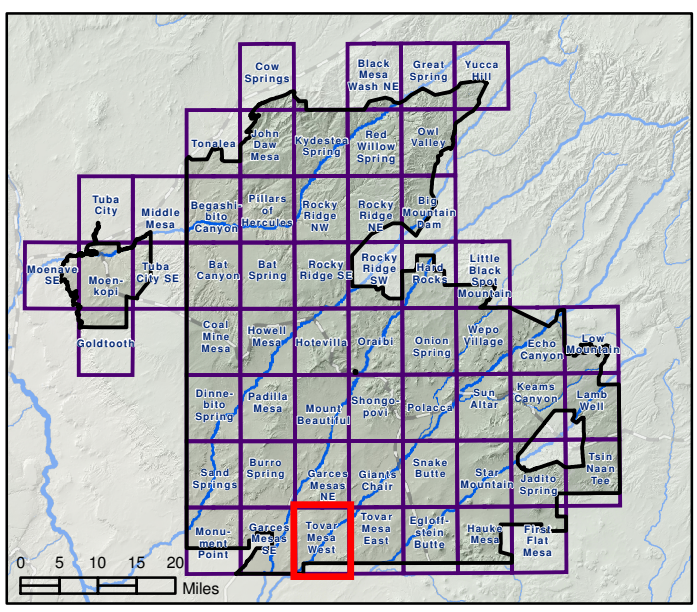
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



Keams Canyon

Lamb Well

Tsin Naan Tee

Jadito Spring

First Flat Mesa

0 0.5 1 1.5 2 Kilometers

0 0.4 0.8 1.2 1.6 Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tsin Naan Tee Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

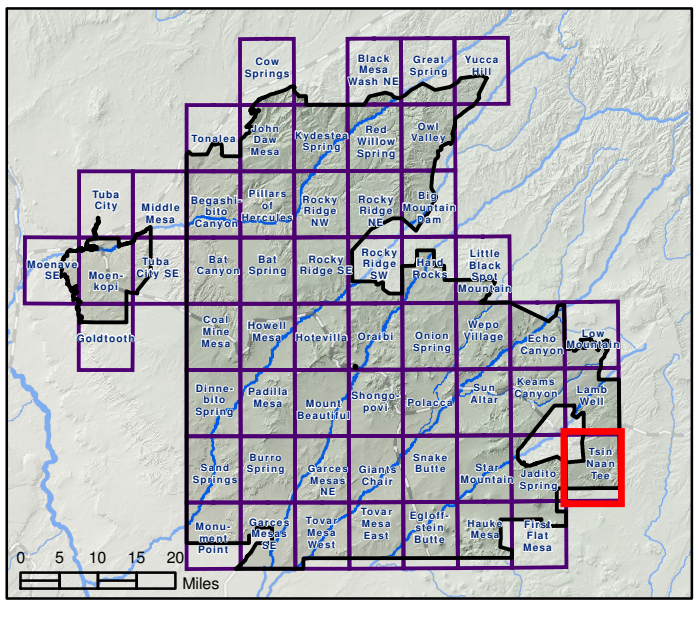
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



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Tuba City

Middle Mesa

Moenave SE

Moenkopi

Tuba City SE

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tuba City Quad

Legend

- Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

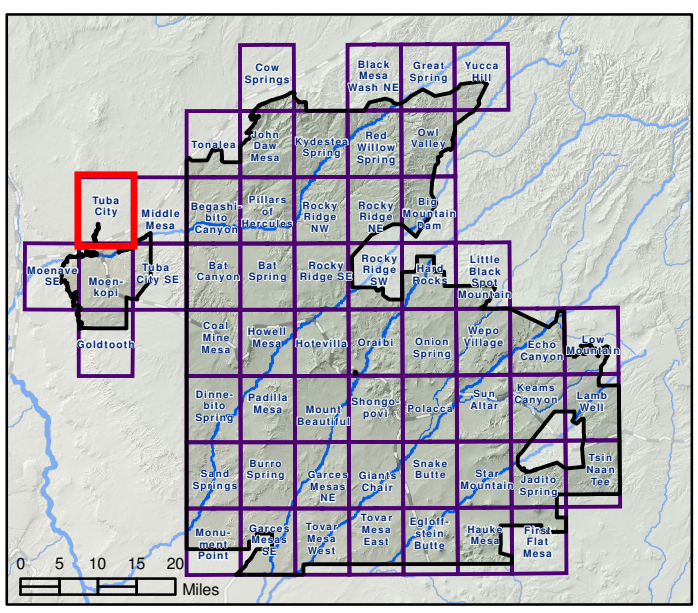
Classified Riparian Lands

- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N



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Tuba City

Middle Mesa

Begashibito Canyon

Moenkopi

Tuba City SE

Bat Canyon

Goldtooth

Coal Mine Mesa

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Tuba City SE Quad

Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

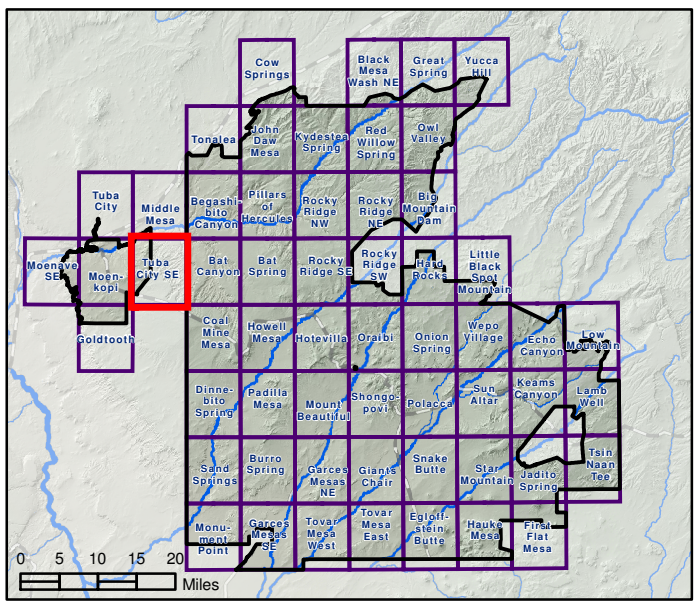
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



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Hard Rocks

Little Black Spot Mountai

Wepo Village

Onior Spring

Echo Canyon

Polacca

Sun Altar

Keams Canyon

0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Wepo Village Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

- Active Agriculture
- Active Or Fallow Agriculture
- Active Fallow Agriculture

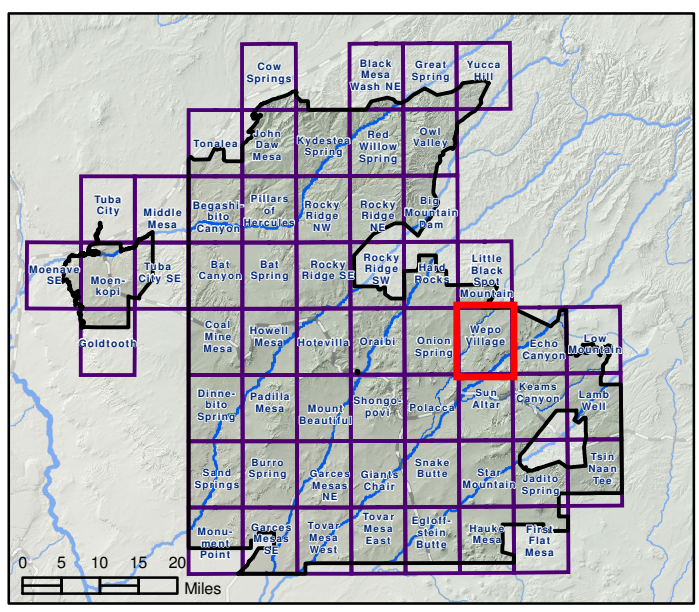
Classified Riparian Lands

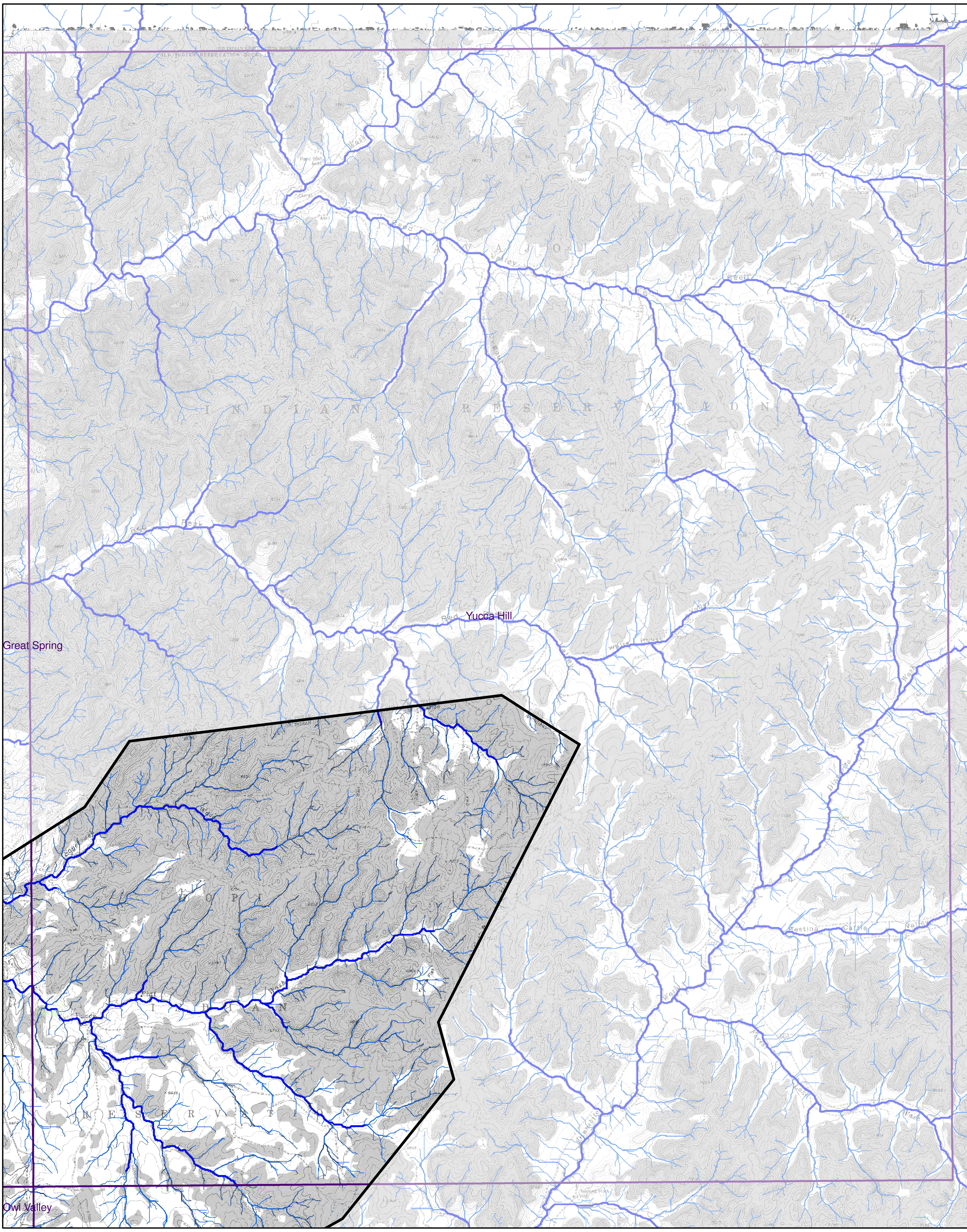
- Riparian
- Impoundment Riparian

Drainages Derived by ADWR Analysis

- ≥ 1.0 km^2 runoff area
- ≥ 0.1 km^2 runoff area
- ≥ 0.01 km^2 runoff area
- USGS Topo Quad Boundary
- Hopi Reservation

N





0 0.5 1 1.5 2
Kilometers
0 0.4 0.8 1.2 1.6
Miles

2005 Agricultural and Riparian Lands on the Hopi Indian Reservation

Yucca Hill Quad

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Legend

Agricultural Field Inspected by ADWR Field Staff

Classified Agricultural Lands

Active Agriculture

Active Or Fallow Agriculture

Active Fallow Agriculture

Classified Riparian Lands

Riparian

Impoundment Riparian

Drainages Derived by ADWR Analysis

≥ 1.0 km^2 runoff area

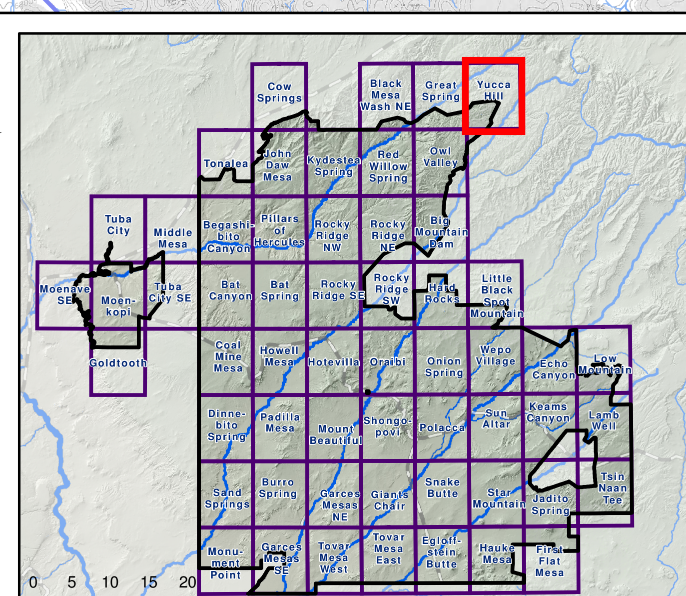
≥ 0.1 km^2 runoff area

≥ 0.01 km^2 runoff area

USGS Topo Quad Boundary

Hopi Reservation

N



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