TR- 300
2007

Texas Water Resources Institute
make every drop count

Geographical Information System Coverage For Characterization of the Pecos River Basin

Prepared by
J. Villalobos and Z. Sheng
El Paso Agricultural Research and Extension Center
Texas Agricultural Experiment Station

Charles Hart
Stephenville Research and Extension Center
Texas Cooperative Extension

The Texas A&M University System

Texas Agricultural Experiment Station
THE TEXAS A&M UNIVERSITY SYSTEM

Texas Cooperative EXTENSION
The Texas A&M University System

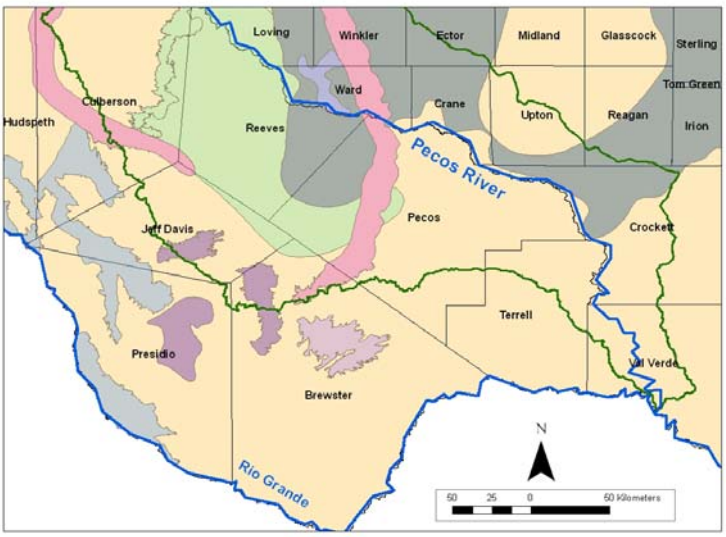
Geographical Information System Coverage
For Characterization of the Pecos River Basin

Submitted to
Texas State Soil and Water Conservation Board (TSSWCB)
U.S. Environmental Protection Agency (EPA)

Prepared by
J. Villalobos and Z. Sheng
El Paso Agricultural Research and Extension Center
Texas Agricultural Experiment Station

Charles Hart
Stephenville Research and Extension Center
Texas Cooperative Extension

The Texas A&M University System



January 2007

This page is left blank intentionally.

Table of Contents

Watershed Protection Plan Development for the Pecos River

Task 1.1 Geographical Information System Coverage For Characterization of the Pecos River Basin

Villalobos, J, Z. Sheng and C. Hart

Introduction

To develop a successful watershed protection plan for the Pecos River, it is very important to correctly characterize the river basin including vegetation coverage, river channel and others. The objective of subtask 1.1 was to delineate the Pecos River and its various characterizations using aerial photography. The aerial photography was high resolution and was acquired for the main channel of the Pecos River. The aerial photos were also taken to help differentiate invasive and non invasive vegetation (i.e. saltcedar and mesquite and other native species). Remote sensing was used to identify the various characteristics of stream channel locations, saltcedar overgrowth and treatment areas, and land use. GIS (Geographical Information Systems) was used to develop a baseline assessment of the Pecos River Basin's characteristics (Stream channel morphology, riparian vegetation aerial photography, etc.). GIS will be the platform to create, view, and utilize data that was created or downloaded via the internet for the study region of the Pecos River Watershed. This report discusses procedures for data processing and mapping, and presented images produced.

Methods and Data Sources

Following procedures were followed to process data and generate maps.

1. Data Collection. A majority of the GIS data of images and files were collected via internet sites. The collection of data was done by searching counties within the Pecos River Watershed boundary (Culberson, Jeff Davis, Brewster, Terrell, Val Verde, Crockett, Upton, Crane, Winkler, Ward, and Loving).
2. Saltcedar (Tamarisk) Delineation. Delineation of unsprayed Tamarisk was accomplished through Tamarisk delineation files from the aerial imagery contract and corrected using existing actual spray coverage acres when an overlap existed. Aerial images were collected prior to the 2004 "saltcedar spraying season" and used to delineate Tamarisk from native vegetation such as mesquite and other deciduous brush species. After 2005 saltcedar spraying on the river, spray coverage files were overlaid on Tamarisk delineation files for comparison. Error adjustments were made and unsprayed Tamarisk areas estimated.
3. Production of shapes files from point data (i.e. well location) was done by displaying the X, Y (latitude and longitude) portion of the .dbf file. Once the points were displayed they were exported as a .shp file for GIS use. Image and map files were also exported via GIS (ArcMap 9.1) as .tif/.jpeg images. Several data sets were exported as several maps to show a better resolution of the data.

Collected images (satellite and aerial photos) and GIS files are listed below.

Satellite Images

Satellite images were obtained via the website. A total of 3 Landsat 7 ETM+ images where used and sub-setted to the Pecos River Basin study region (Figure 1). The Path (P) and Rows (R) of the images used were; P30 / R38: Date- 2003-12-18, Time- 2:28 pm, Reference Datum- WGS 84, Bands 1-8. P30 / R39, Date- 2003-03-26, Time 2:10 pm, Reference Datum- WGS 84, Bands 1-8.P31 / R38. Date- 2003-01-28, Time 2:15 pm, Reference Datum- WGS 84, Bands 1-8. P31 / R38 was cropped to fill in a small region of the counties Crane and Upton. Images were put into GIS and had the Display Background (R, G, B) function set to 0,0,0 to avoid border overlap problems.

Source: www.texasview.org.

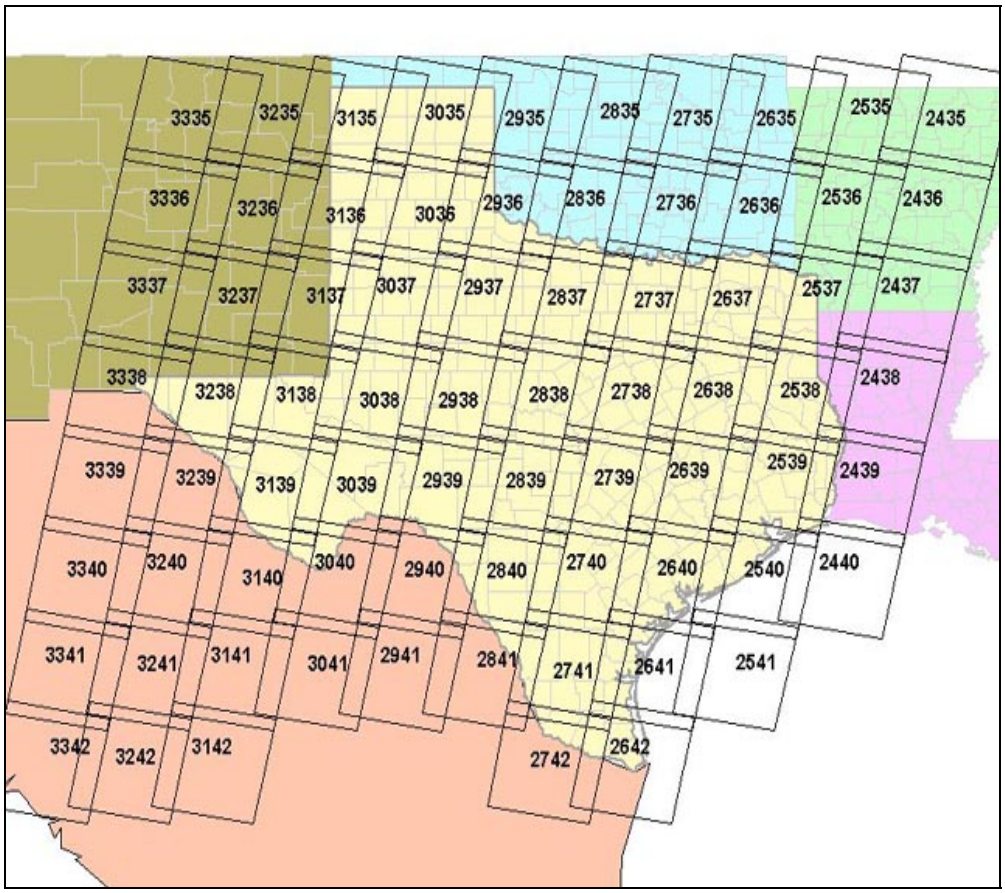


Figure 1. Index of Landsat images

Aerial Photography

This imagery was flown and processed in support of Tamarix (Saltcedar) eradication along the Pecos River. It was flown during a temporal window (May 2004) of deciduous senescence when Tamarix is typically more distinct from associated species (Figure 2).

Grid Coordinate System Name: Universal Transverse Mercator UTM Zone Number: 14. Data was colleted in two types:

1) Normal Tamarix *		2) IR (Infrared) Tamarix *	
crane_sw	imperial	crane_sw	imperial
girvin	indian_mesa_ne	girvin	indian_mesa_ne
girvin_nw	iraan_north	girvin_nw	iraan_north
grandfalls_se	iraan_south_cir	grandfalls_se	iraan_south_cir
juan_cordona_lake	mccamey_south	juan_cordona_lake	mccamey_south
sheffield_north_cir	table_top_mountain	sheffield_north_cir	table_top_mountain

Source: Aerial Imagery Services, LLP

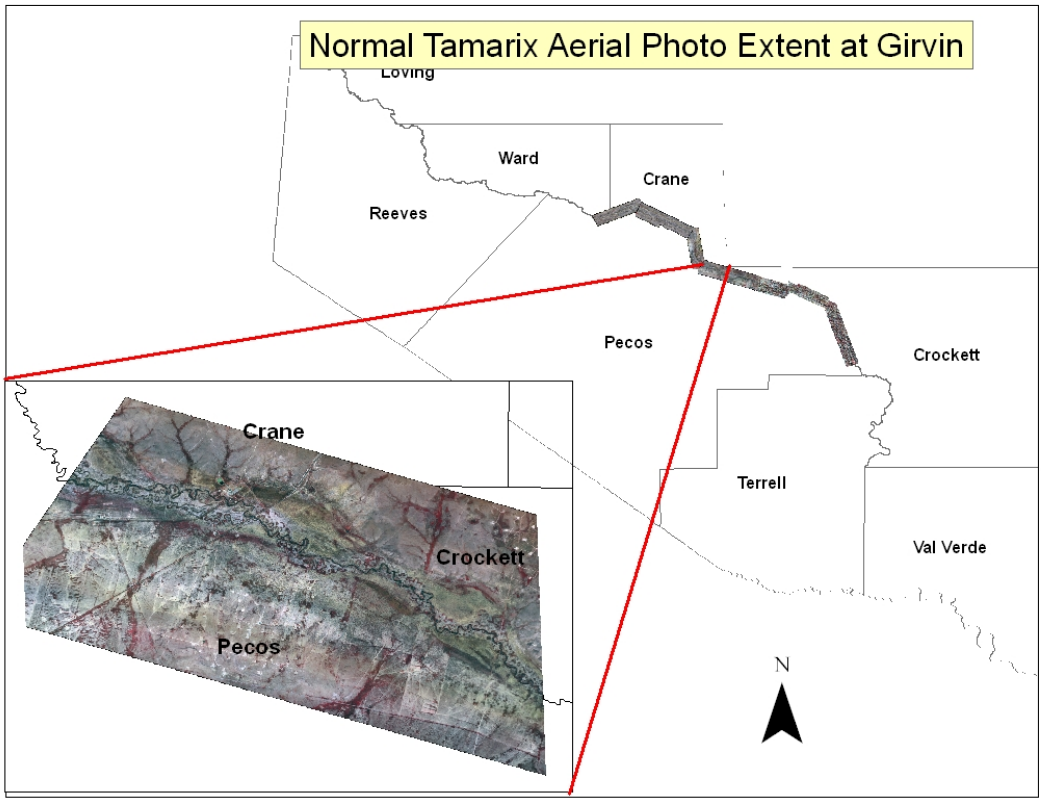


Figure 2 Example of Normal Tamarix Aerial Photo Extent

Wetlands data

NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. The classification system was adopted as a national classification standard in 1996 by the Federal Geographic Data Committee. This dataset is one of a series available in 7.5 minute by 7.5 minute blocks containing ground planimetric coordinates of wetlands point, line, and polygon features and wetlands attributes (Figure 3).

Source: http://www.fws.gov/nwi/

Metadata: http://www.fws.gov/nwi/downloads/metadata/nwi_meta.txt

Files:

Girvin	Tx., N.M., Border
Amistad	Sand Lake
Still Canyon	China Lake
Post Canyon	Juan Cordova
Fort Landcaster	Indian Mesa

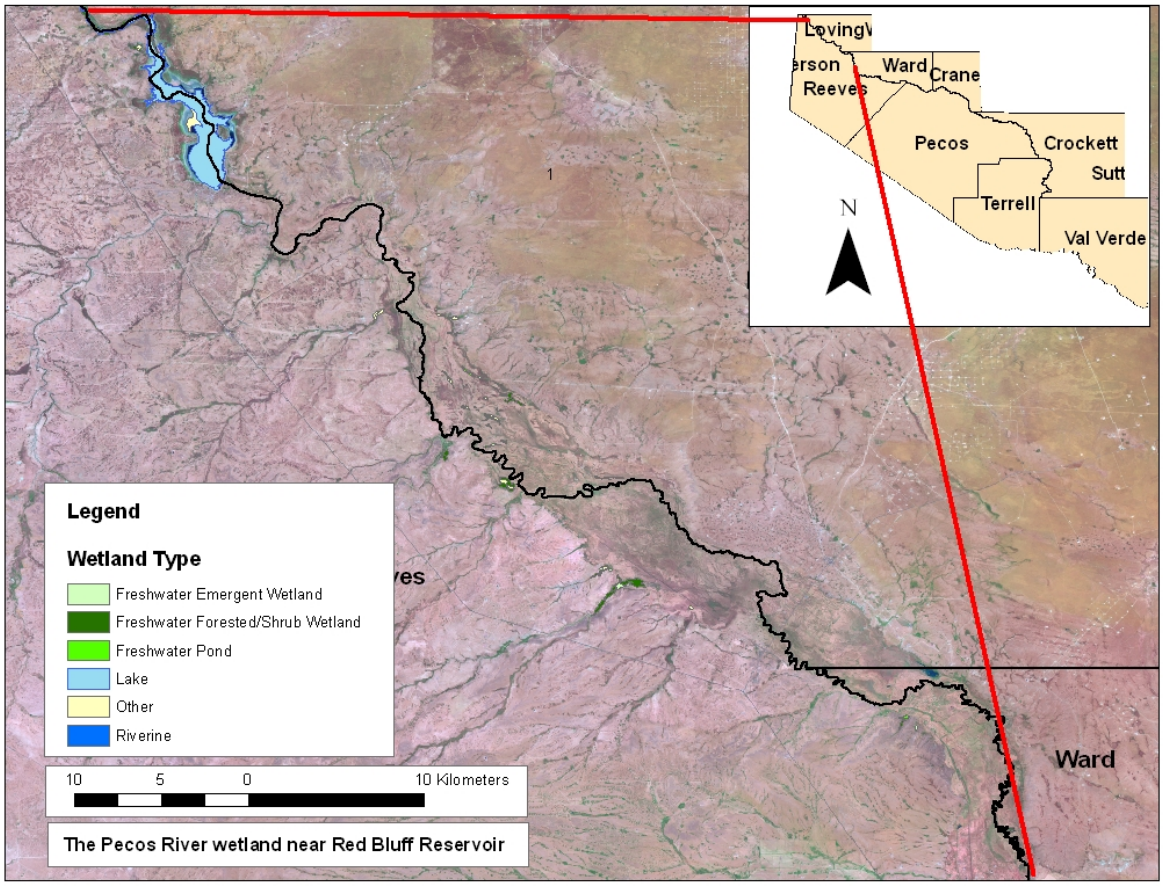


Figure 3. An example of wetland coverage

TWDB Groundwater data

TWDB maintains two groundwater data sets: TWDB Groundwater Database and Submitted Driller's Reports. Data collected from TWDB consist of the Groundwater Database wells and contains: Location, Total Dissolved Solid measurements, State well Number, and year tested. The most recent data was used for all wells and wells with multiple testing for a single year were eliminated (Figure 4).
Source: http://wiid.twdb.state.tx.us/index_explain.asp

Terrain map

Texas Terrain (Hillshade) The image was created from 1:250,000 Texas DEM GRID. The 100 m grid was prepared in ArcMap then exported as JPEG files in 450 dpi resolution. The JPEG image was blurred in Photoshop 6.0 to smooth the edges of the

100m grid cells, and then georeferrenced (registered) in ArcInfo GIS system. TIFF format files were generated by converting the JPEG images into TIFF within ArcInfo GIS.
Source: http://www.twdb.state.tx.us/mapping/gisdata.asp
Metadata:http://www.twdb.state.tx.us/mapping/gisdata/metadata/hillshade.htm

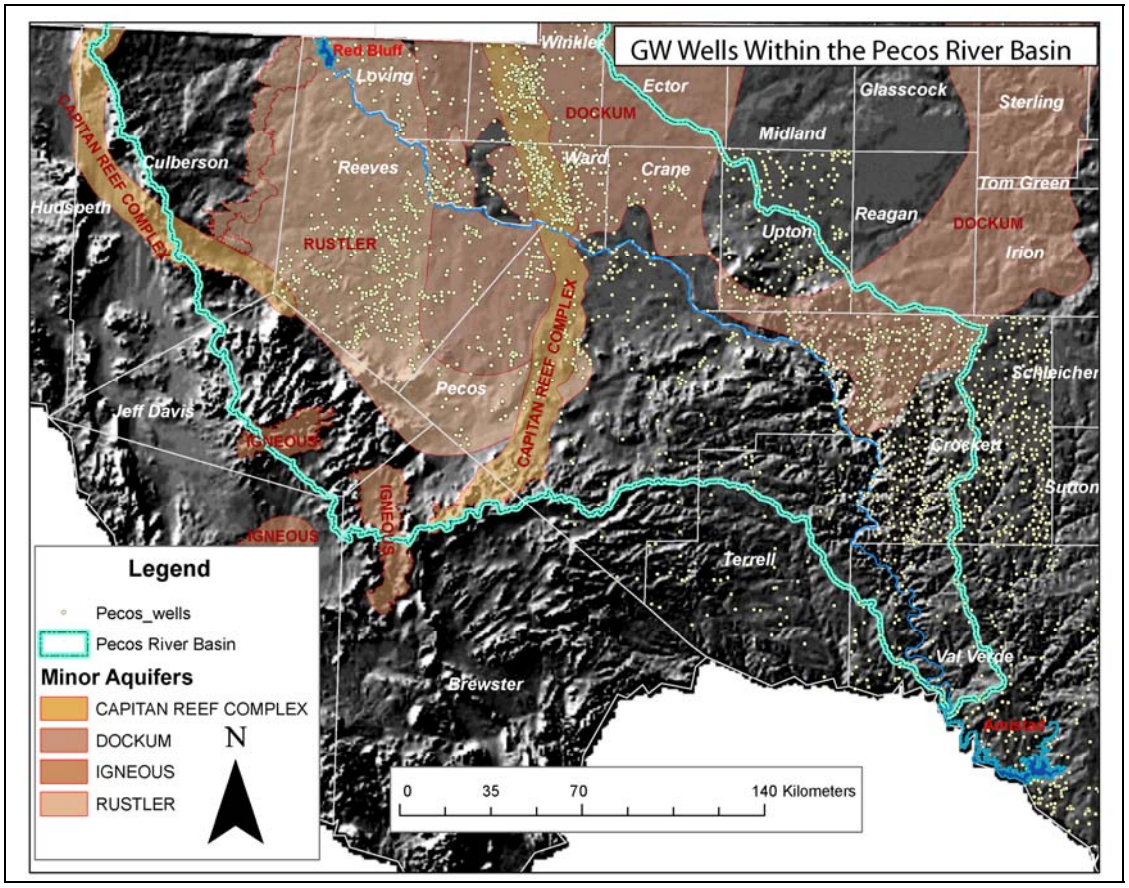


Figure 4. Groundwater wells within the Pecos River Basin

Field locations sites

Field location sites of monitoring wells were collected using a Trimble Geo-XT using WAAS enabled data collection for higher accuracy. USGS aerial 3.75 x 3.75-minute orthophotos were used as base maps for the observation well points.

Saltcedar (Tamarisk) Delineation Results.

Saltcedar delineation is important for planning and implementing the saltcedar control project. To date (through 2006), over 10,000 river acres of saltcedar have been chemically treated along the Pecos River in Texas. An additional 3500 acres have been treated along tributaries and drainage areas. Tamarisk delineation efforts focused on the area from roughly Grandfalls or just north of the Pecos County line to the central part of Val Verde County (see appendix B for coverage area). Delineation of saltcedar was not undertaken north of this area as 95% of the

saltcedar had been treated in years prior to the aerial imagery capture. Areas in the southern portion of Val Verde County were not flown due to the difficulty of high canyon walls and an extremely narrow river corridor making tamarisk delineation difficult at best. Additionally, ground and aerially observations in this lower stretch of the Pecos River indicate low densities of saltcedar exist, until the channel begins to widen just north of the confluence with the Rio Grande River.

Methods

Five years of spatial herbicide application data exists on 4018 acres along the Pecos. These records were derived from North Star Helicopter's onboard GPS equipment and are spatially accurate to within one meter. These spray records were provided as 45-foot buffers of GPS centerlines, reflecting the 45-foot spray booms used for herbicide application.

This analysis assumes that actual spray locations confirm the presence and extent of *Tamarix*. Because of the experience of the applicators and their proximity to the *Tamarix*, this assumption is appropriate. It is possible, therefore, to directly compare actual spray locations with the predicted stands of *Tamarix* and evaluate the accuracy of the original mapping effort (Figure 5).

The GIS model employs two spatial calculations. The first calculation is a ratio of the mapped *Tamarix* acreage to the actual herbicide sprayed acreage. This ratio reflects whether mapping over or underestimated the subsequently sprayed *Tamarix*. For the second calculation, the mapped but untreated acreage is divided by the ratio producing a new estimate of the *Tamarix* remaining.

Because the river is long and changes character over its length, the model divides the river into samples, calculating ratios that reflect a localized segment of the river. Ratios calculated for the mapped areas within each sample are applied to untreated areas within the same sample. Iterations of the model were performed using 10 samples (~22 river miles) and 28 samples (~12 river miles).

First and Second iterations of the model were calculated using all mapping classifications. The Final iteration was performed using only Probable and Probable Mixed mapping classifications. To complete the analysis, new estimates of *Tamarix* acreage are aggregated by county.

Results

The following tables depict results from the first half of the model during three iterations. The first iteration used all classifications of mapping data with 10 samples (Table 1). The second iteration used all classifications of mapping data with 28 samples (Table 2). And the final iteration used only Probable and Probable Mixed mapping classifications and 10 samples (Table 3). The results of the second half of the model are depicted in Table 4, aggregated by county.

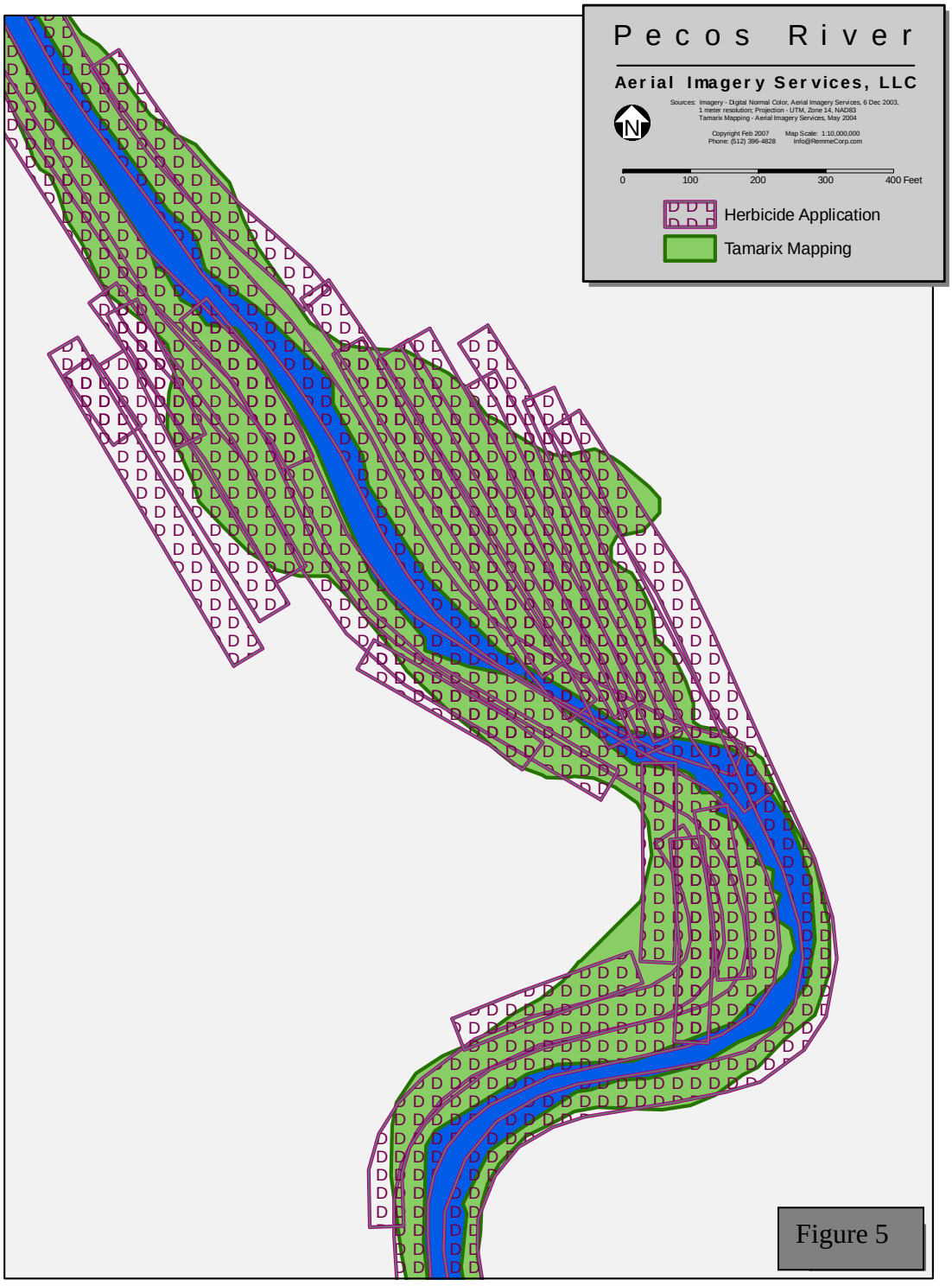
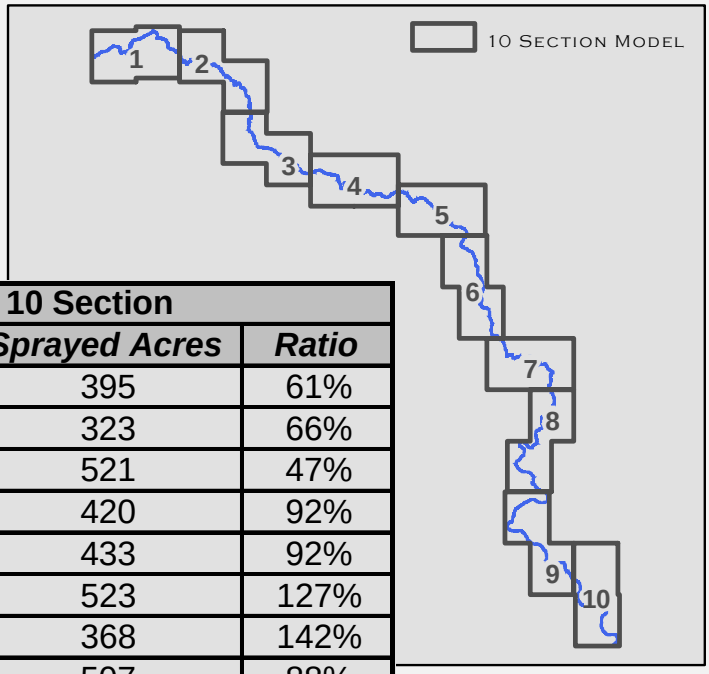


Figure 5. Mapping errors occur because it is difficult to distinguish *Tamarix* from other riparian vegetation and to resolve smaller, juvenile specimen in the photography. Additionally, the physical process of herbicide application does not imitate the cleanly defined areas depicted in mapping.

First Iteration - All Mapping Classifications with 10 Samples

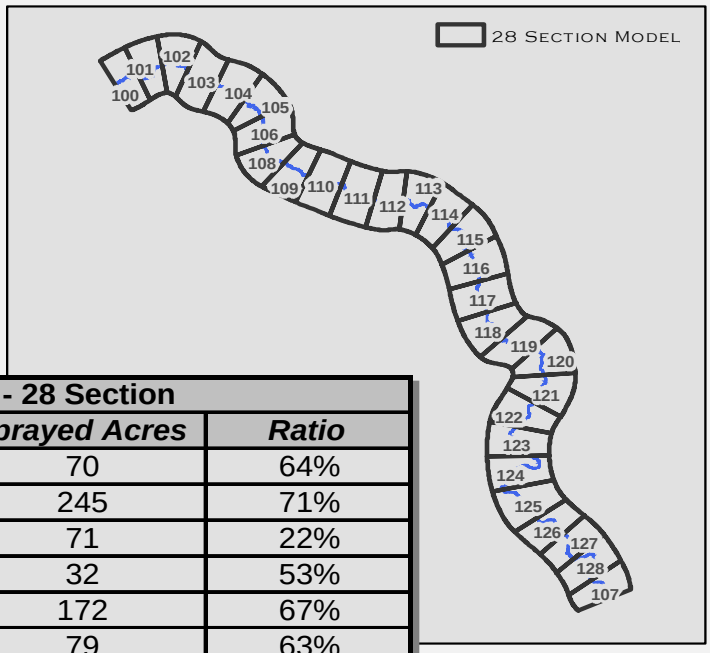
Table 1: The results of the first model do not show a particularly consistent ratio.

Model Results - 10 Section			
Section	***Mapped Acres***	***Sprayed Acres***	***Ratio***
1	241	395	61%
2	214	323	66%
3	243	521	47%
4	389	420	92%
5	397	433	92%
6	665	523	127%
7	522	368	142%
8	444	507	88%
9	247	309	80%
10	62	219	28%



Second Iteration - All Mapping Classifications with 28 Samples

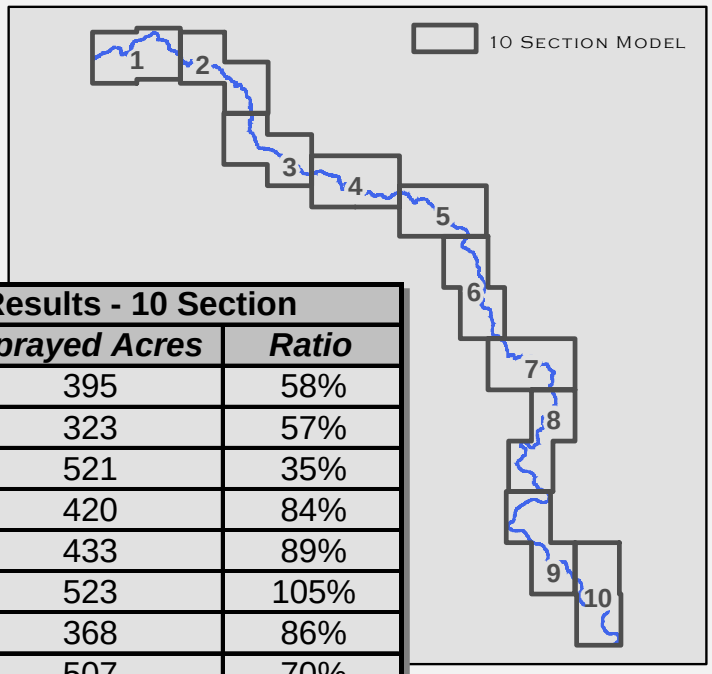
Table 2: The results of the second model clearly highlight local sources of mapping errors. Mapped acres per section vary considerably.



Model Results - 28 Section			
Section	***Mapped Acres***	***Sprayed Acres***	***Ratio***
100	45	70	64%
101	174	245	71%
102	16	71	22%
103	17	32	53%
104	116	172	67%
105	50	79	63%
106	94	173	54%
108	110	276	40%
109	55	79	70%
110	116	169	69%
111	96	115	83%
112	226	207	109%
113	114	109	104%
114	175	188	93%
115	196	233	84%
116	178	160	112%
117	241	175	138%
118	260	113	230%
119	246	165	149%
120	161	170	95%
121	177	177	100%
122	185	186	99%
123	62	105	59%
124	52	141	37%
125	187	153	122%
126	14	34	42%
127	25	42	60%
128	32	94	34%
107	5	84	6%

Final Iteration - Probable Classifications with 10 Samples

Table 3: Using Probable classified mapping results in smaller, but more consistent ratios on upper portions of the study area. However, the removal of Possible classifications in sections 9 and 10 cause small mapping acreages.



Probable Only Model Results - 10 Section			
Section	***Mapped Acres***	***Sprayed Acres***	***Ratio***
1	228	395	58%
2	184	323	57%
3	180	521	35%
4	353	420	84%
5	384	433	89%
6	547	523	105%
7	317	368	86%
8	357	507	70%
9	27	309	9%
10	36	219	16%

Table 4: The following table aggregates the Final Iteration results by county.

Final Model Estimates by County		
County	Untreated Acres	New Estimate (Acres)
Ward	34.8	60.4
Crane	99.4	183.4
Crockett	371.3	585.4
Pecos (above US Hwy 67)	328.3	625.0
Pecos	83.4	155.2
Terrell*	60.5 (88.1)	364.8 (203.4)
Val Verde**	115.1 (0)	787.0 (0)

*The Final Model estimate was not reliable and was replaced by those following in parentheses, which were derived from the Second Model.

**No iteration of the model performed acceptably in Val Verde County. No estimate was submitted.

Discussion

As mentioned earlier, errors occur in vegetation mapping for a variety of reasons. However, an underlying assumption of this analysis is that the original mapping effort is, at least locally, consistent in its errors. Results from the first iteration of the model did not suggest particularly consistent mapping errors.

This prompted further iterations of the model and a second iteration was performed using 28 segment samples. Increasing the sample granularity highlighted sources of mapping errors, but ultimately mapping errors were not locally consistent enough to justify 28 samples.

Visual examination of the spatial data revealed that incorporating mapping classifications into the model might eliminate some inconsistency. Specifically, on upper portions of the study area, few areas classified as Possible were confirmed to be *Tamarix* by subsequent spraying. This prompted the use of only Probable and Probable Mixed classifications for the third iteration of the model. This resulted in more consistent ratios for areas within Ward, Crane, Crockett, and Pecos Counties.

The final estimates for Terrell County and Val Verde counties are suspect. For different reasons, the model performs poorly in each. In Terrell County, two large areas, originally classified as Unknown, strongly affect the results. In this particular case, the second model was judged to be the best of the three models and the aggregated county estimate (Table 3) uses its result. In Val Verde County the mapped acreage is quite small. The ratios calculated in the first half of the model are also quite small, resulting in an extreme new estimate. None of the models produced results for Val Verde County that were acceptable.

Tamarisk delineation results indicate a total of 6309 acres of saltcedar within this region, along the riparian corridor of the main channel of the Pecos River (see table E1). Within this region, the highest density of saltcedar occurs in roughly the lower half of Pecos County and the Upper half of Crockett County. Actual saltcedar sprayed within this region occurred during 2003-2005. A total of 5,575 acres of saltcedar were chemically treated within the stretch of river covered by the aerial imagery. A detailed analysis of spray files overlaid on tamarisk delineation files was performed to adjust estimates of saltcedar acreages left untreated. A total estimated 2,142 acres of untreated saltcedar remain along the main corridor of the Pecos River within the aerial imagery zone.

An additional 506 acres of saltcedar are estimated to remain untreated north of the aerial imagery area (Pecos and Ward Counties) and 385 acres south of the aerial imagery area (Val Verde County), resulting in a total of 3,033 estimated acres of saltcedar remaining untreated along the Pecos River in Texas. Of this acreage, 1,306 acres occur north of the Highway 67 crossing near Girvin, Texas with the remaining 1,727 acres occurring below this point.

With a total estimated 13,349 acres of saltcedar along the Pecos River in Texas and 10,317 acres treated, initial aerial saltcedar treatment along the entire Texas portion of the Pecos River is 82% complete. This treated area covers a total of 289 (69%) of the 419 river miles in Texas.

GIS Coverage and Maps Produced and Discussions

Following is a list of GIS coverage and associated maps.
(1) Pecos wetlands- Large scale map of all wetland areas
- Pecos wetlands (10 total) - smaller scale maps of individual wetland stretches (see Appendix A).

(2) Pecos aerial*- Large scale map of all aerial coverage.
-Pecos aerial (12 total) - smaller scale maps of individual aerial stretches (See Appendix B).

(3) Pecos River LS7ETM+*- Full scale map with all three Landsat 7 ETM+ scenes overlaid (Appendix C).

(4) Groundwater wells aquifers- Map showing all wells contained in TWDB data set for the counties in the Pecos water shed boundary (Appendix D).

(5) PecosGW_TDS - Map showing Total dissolved Solids (TDS) of Pecos watershed region's groundwater quality created using Texas Water Development Board data (Appendix D).

A major challenge in GIS is the abundance of data and the wide range of various sources of this data and the distribution of data within large groups. Data that created or downloaded is often too large to send via email or is best left on a external drive or disk due to its large size (i.e. DVD) making it difficult to share or distribute data over large areas or within large groups. With the many sources of free GIS data is it often unnecessarily reproduced or is lacking the proper metadata describing the attributes of the dataset (owner, date, type of data, projection, etc.). Common feature (i.e. major streams or rivers) are reproduced at different scales reflecting different levels of details. In order to eliminate the problem of unnecessary reproduction or downloading within the project data will eventually need to be shared among various projects via a webserver (i.e. ArcIMS). ArcIMS will allow project team members to view data already downloaded or created and will give access to the data for downloading and viewing. This will also fit the need to assess gaps in data sets or to identify errors within the datasets by other team members. The addition of an ArcIMS website will also benefit the other task's objectives by providing a tool for management, education, and monitoring.
Prove

Acknowledgement
This project is sponsored by U.S. Environmental Protection Agency (EPA) and Texas State Soil and Water Conservation Board (TSSWCB). This report is also based on work in part supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreements No. 2005-34461-15661 and No. 2005-45049-03209, Texas

Cooperative Extension, and Texas Agricultural Experiment Station. The authors would like to thank Monica Gomez and Joel Reyes for their assistance in processing data and preparing maps, Dr. Raghavan Srinivasan for sharing GIS data on delineation of watershed boundary.

References

Texas Water Development Board, Water Information Integration and Dissemination System, available at: http://wiid.twdb.state.tx.us/index_explain.asp, last accessed June, 2006

TWDB, Water Information Index Database, available at: http://wiid.twdb.state.tx.us/index_explain.asp, last accessed June, 2006

Remote Sensing Consortium for Texas, available at: www.texasview.org, last accessed June, 2006

U.S. Fish & Wildlife Service, National Wetlands Inventory, available at: http://www.fws.gov/nwi/, last accessed June, 2006

Texas Water Development Board, GIS Datasets, available at: http://www.twdb.state.tx.us/mapping/gisdata.asp, last accessed June, 2006

Appendix A

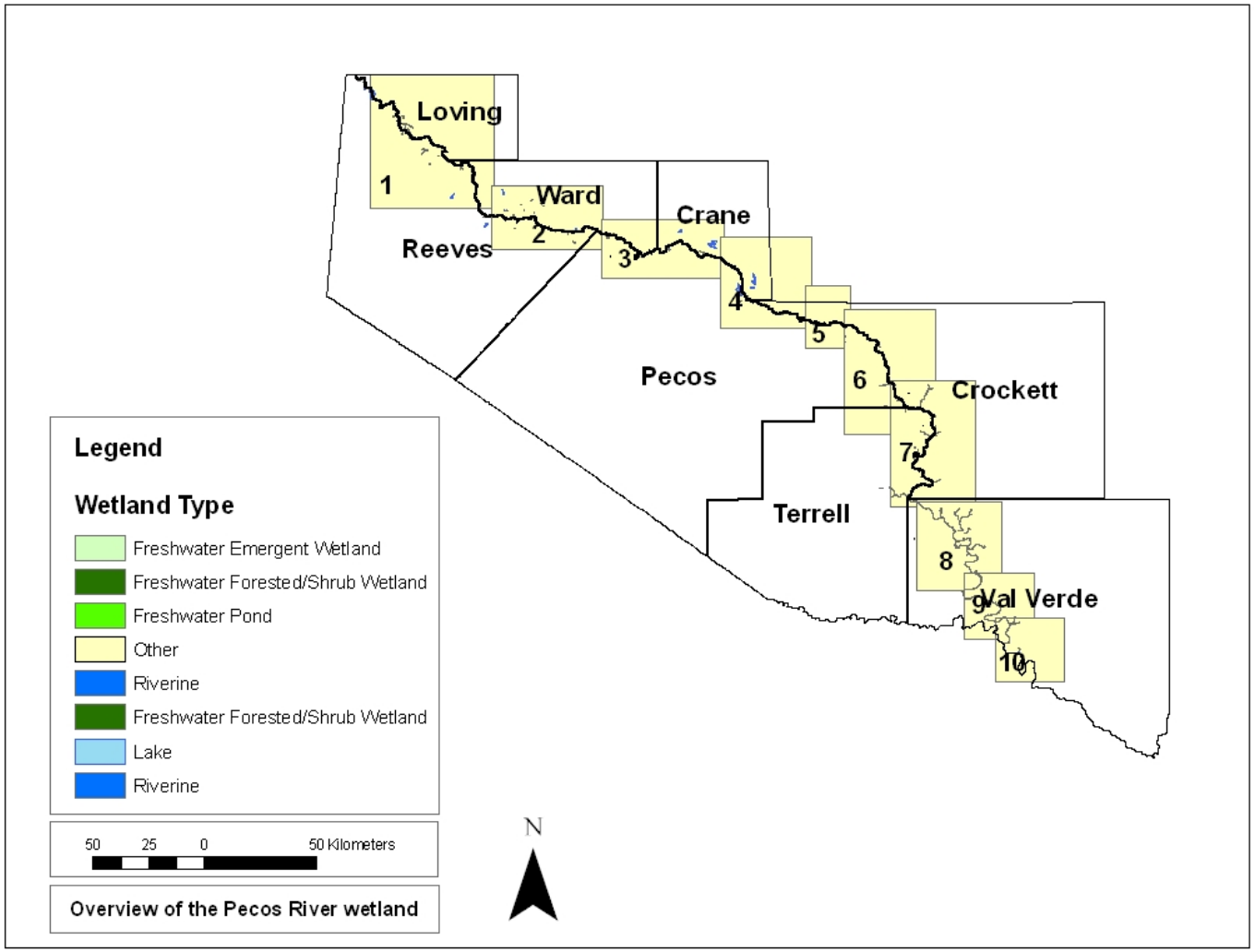


Figure A1. Overview of wetland along the Pecos River

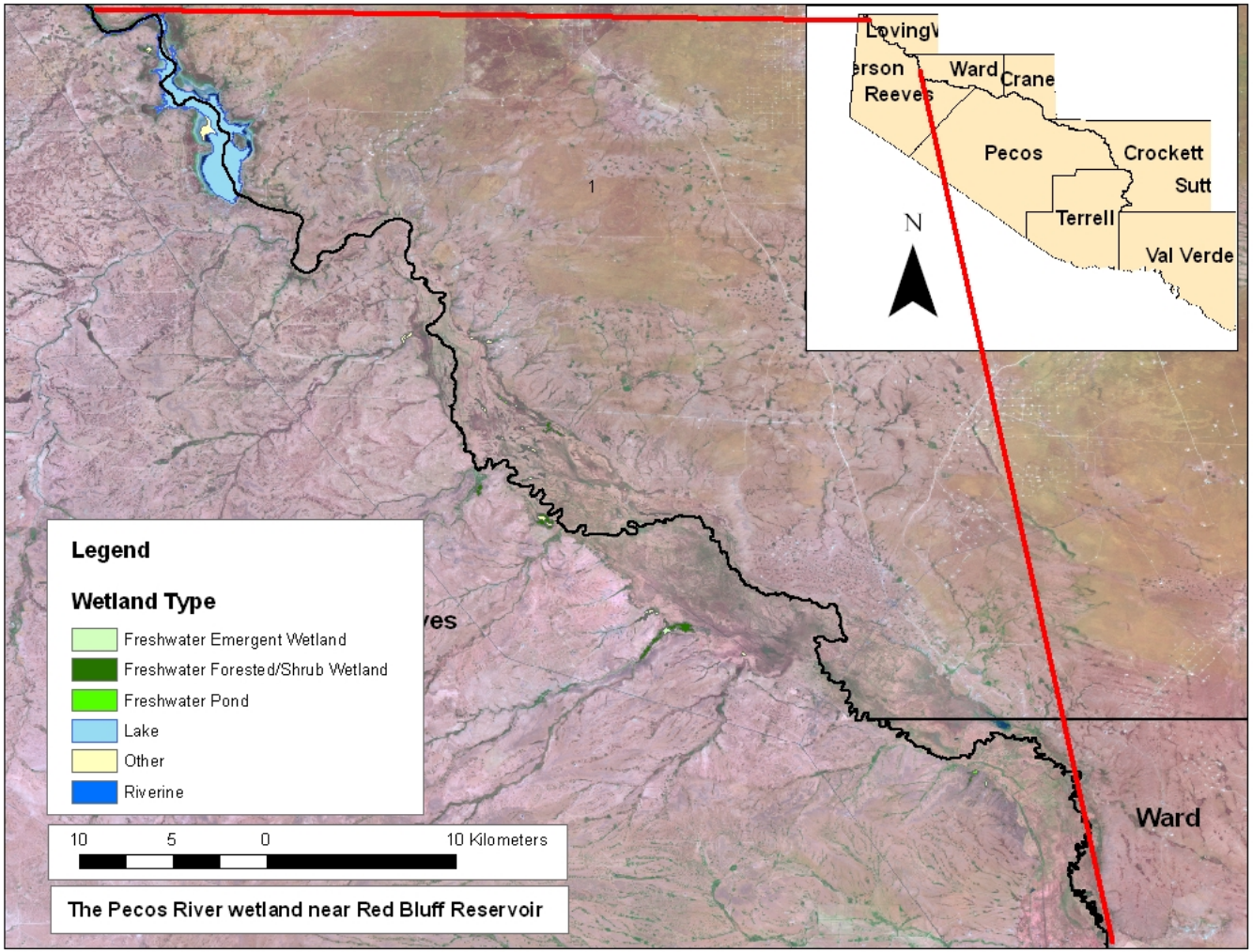


Figure A2. The Pecos River wetland near the Red Bluff Reservoir

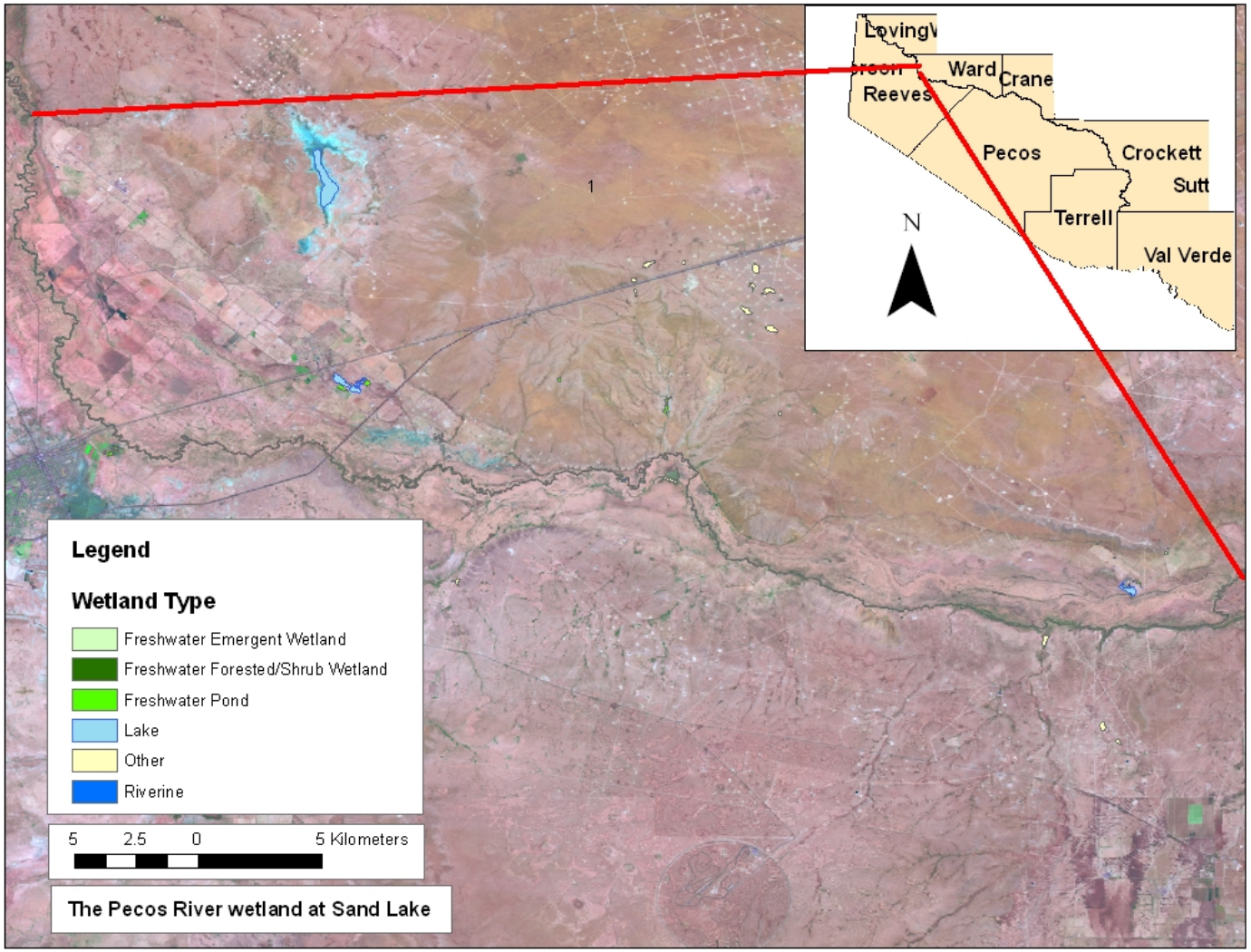


Figure A3. The Pecos River wetland at Sand Lake (SE)

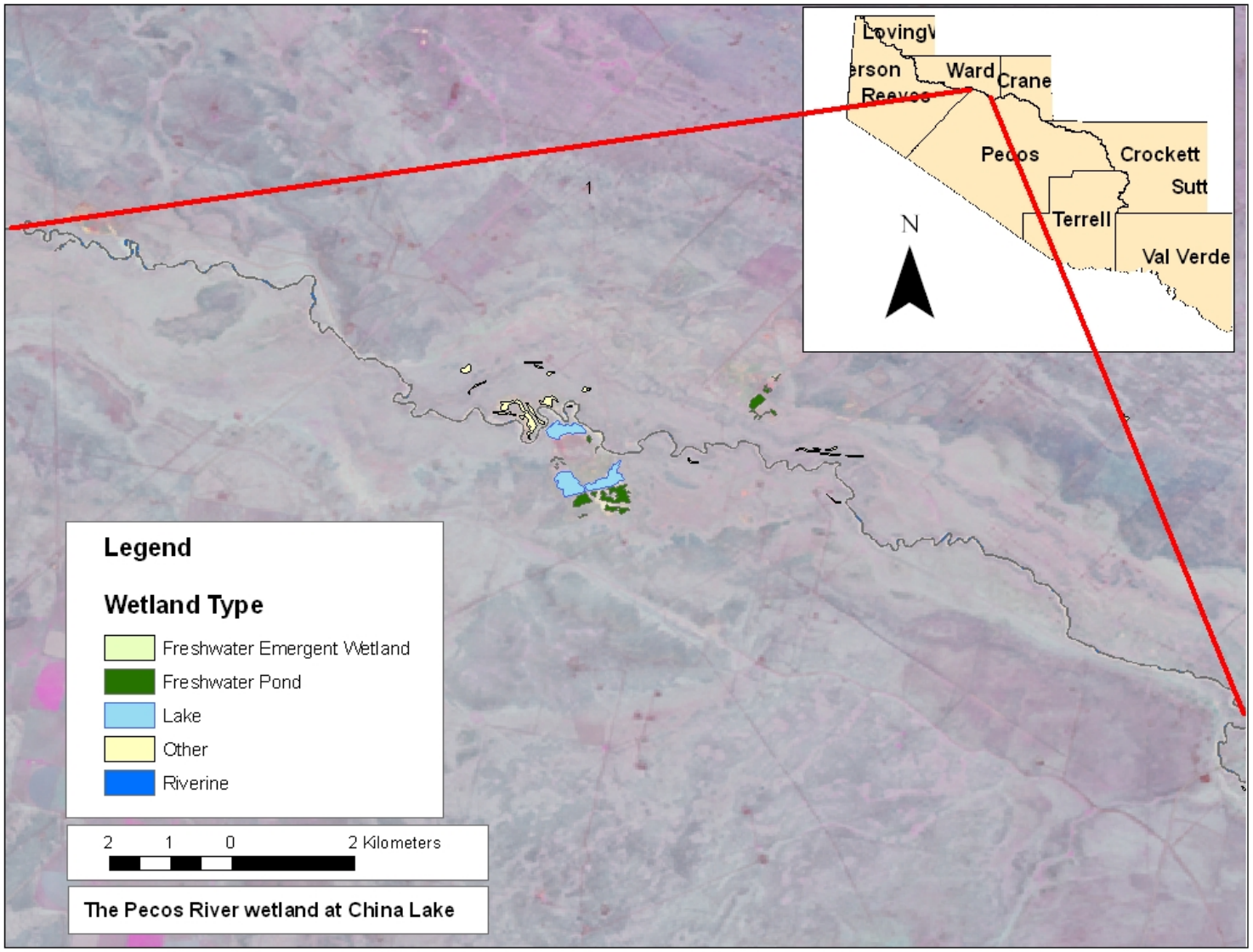


Figure A4. The Pecos River wetland at China Lake

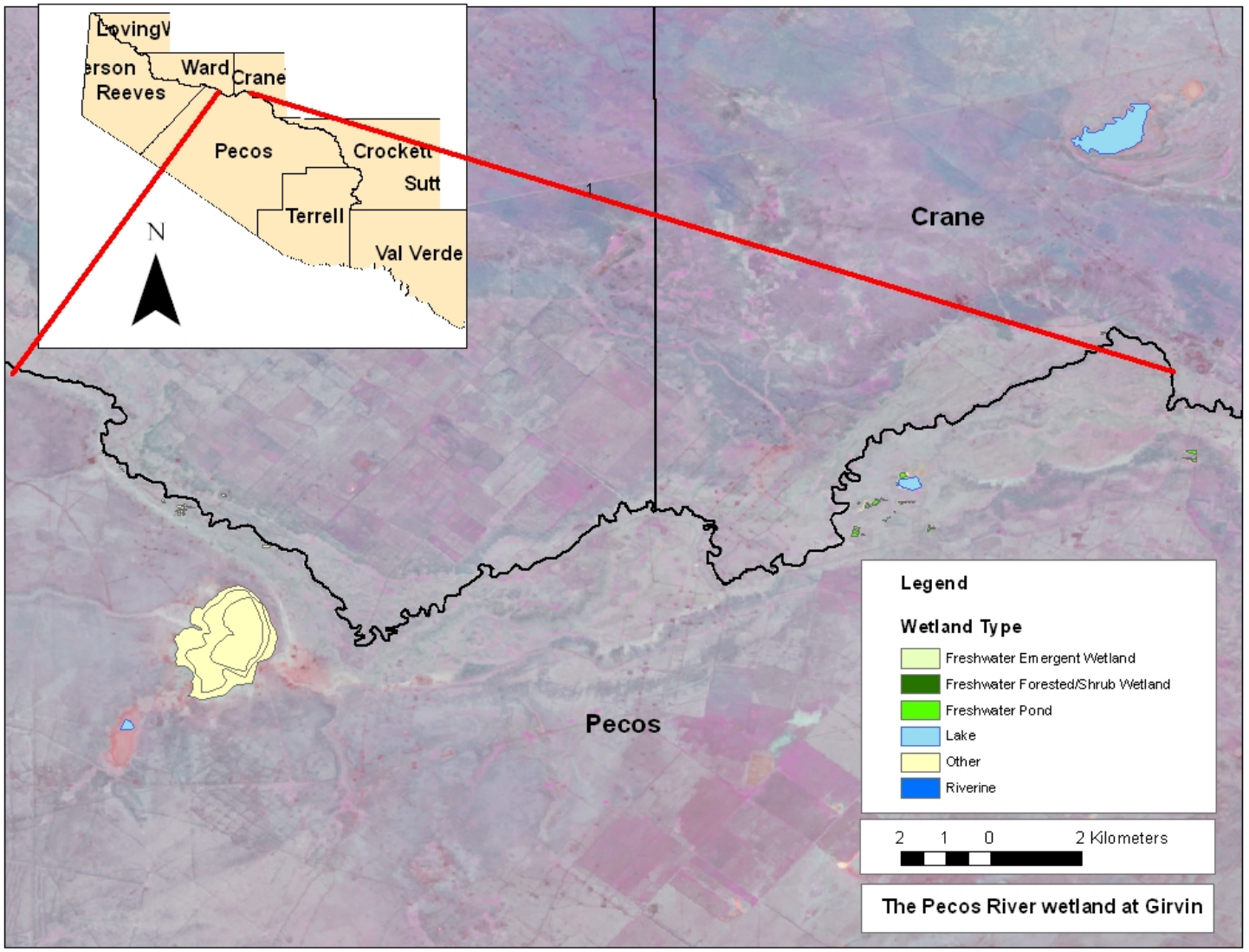


Figure A5. The Pecos River Wetland at Girvin

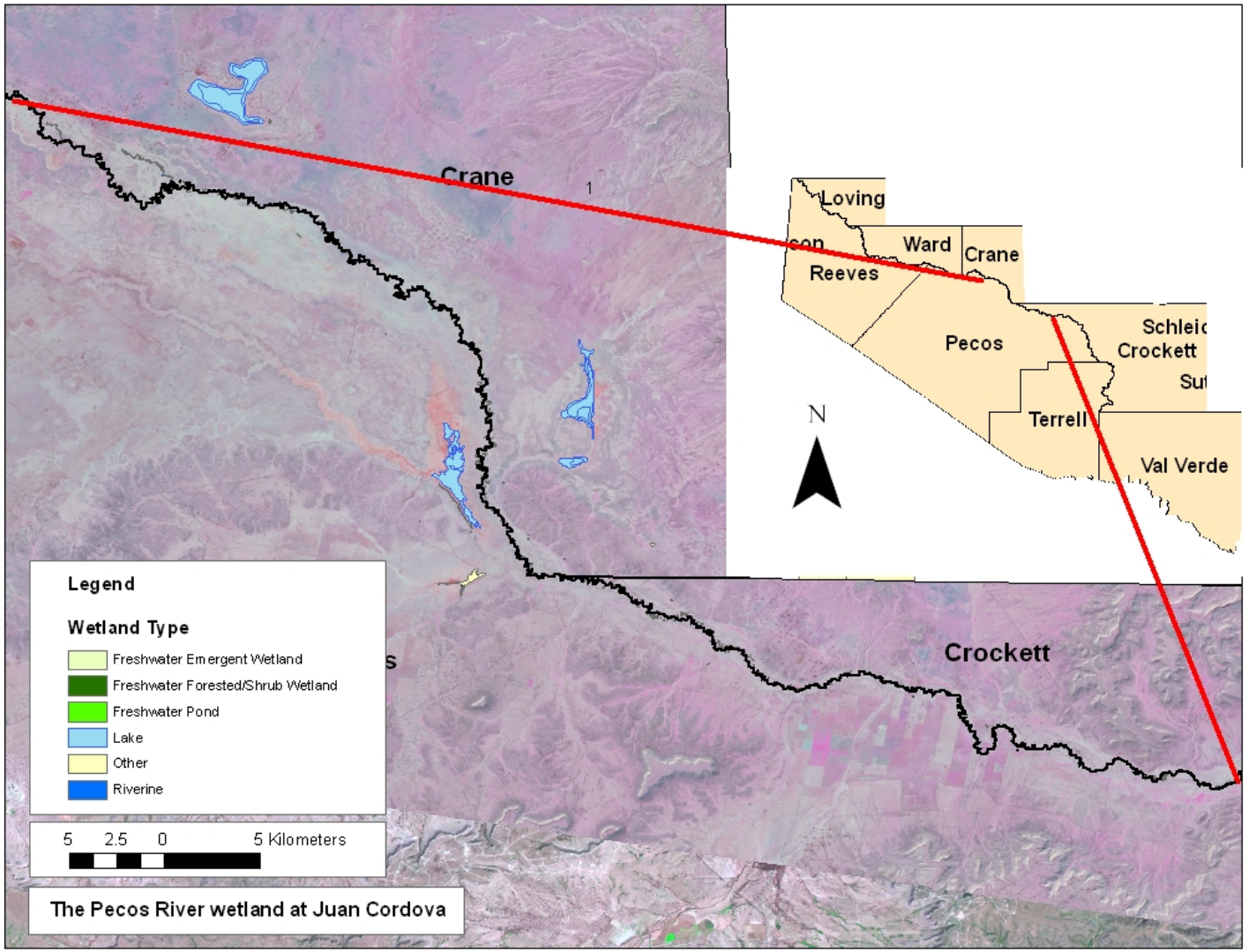


Figure A6. The Pecos River wetland at Juan Cordova

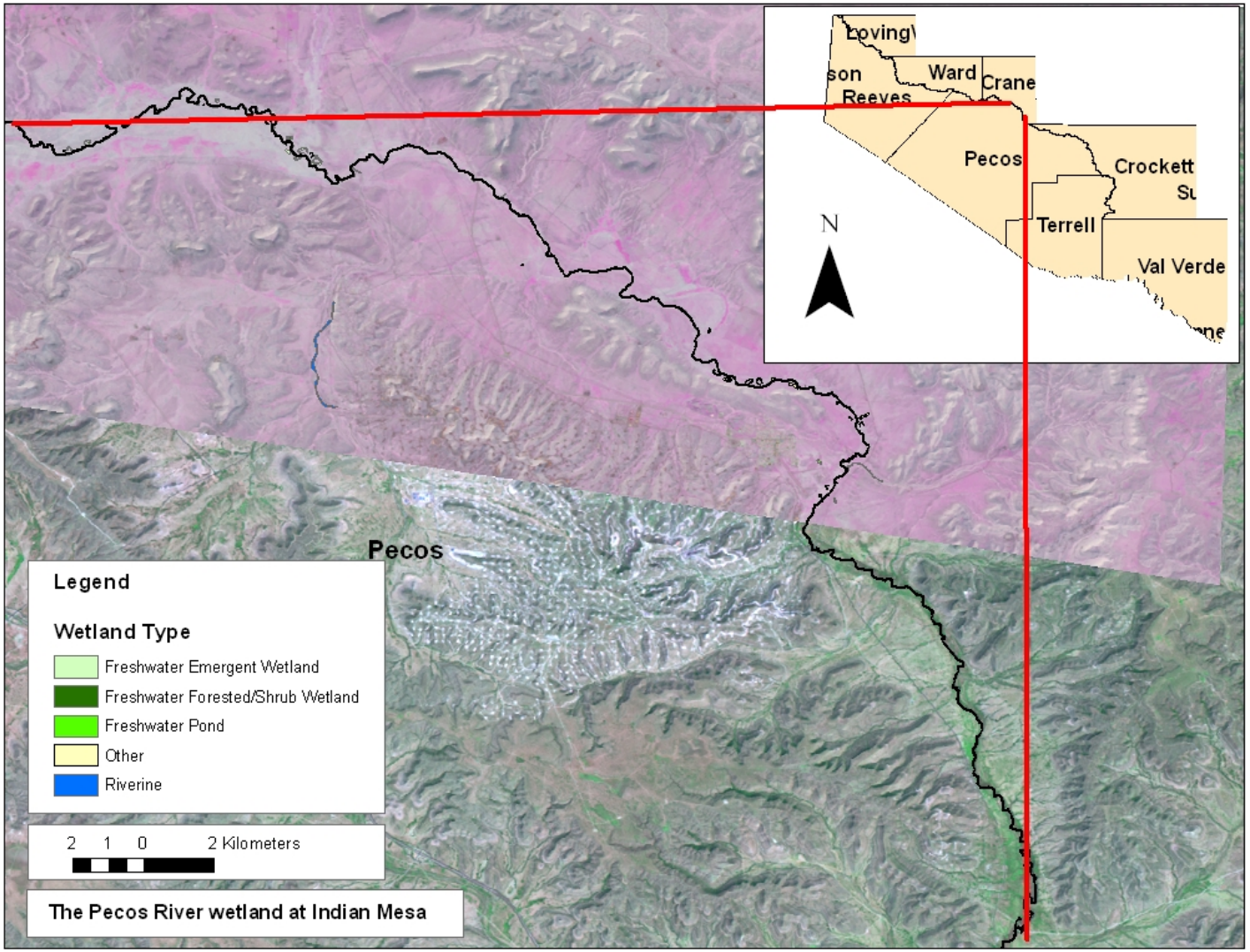


Figure A7. The Pecos River wetland at India Mesa

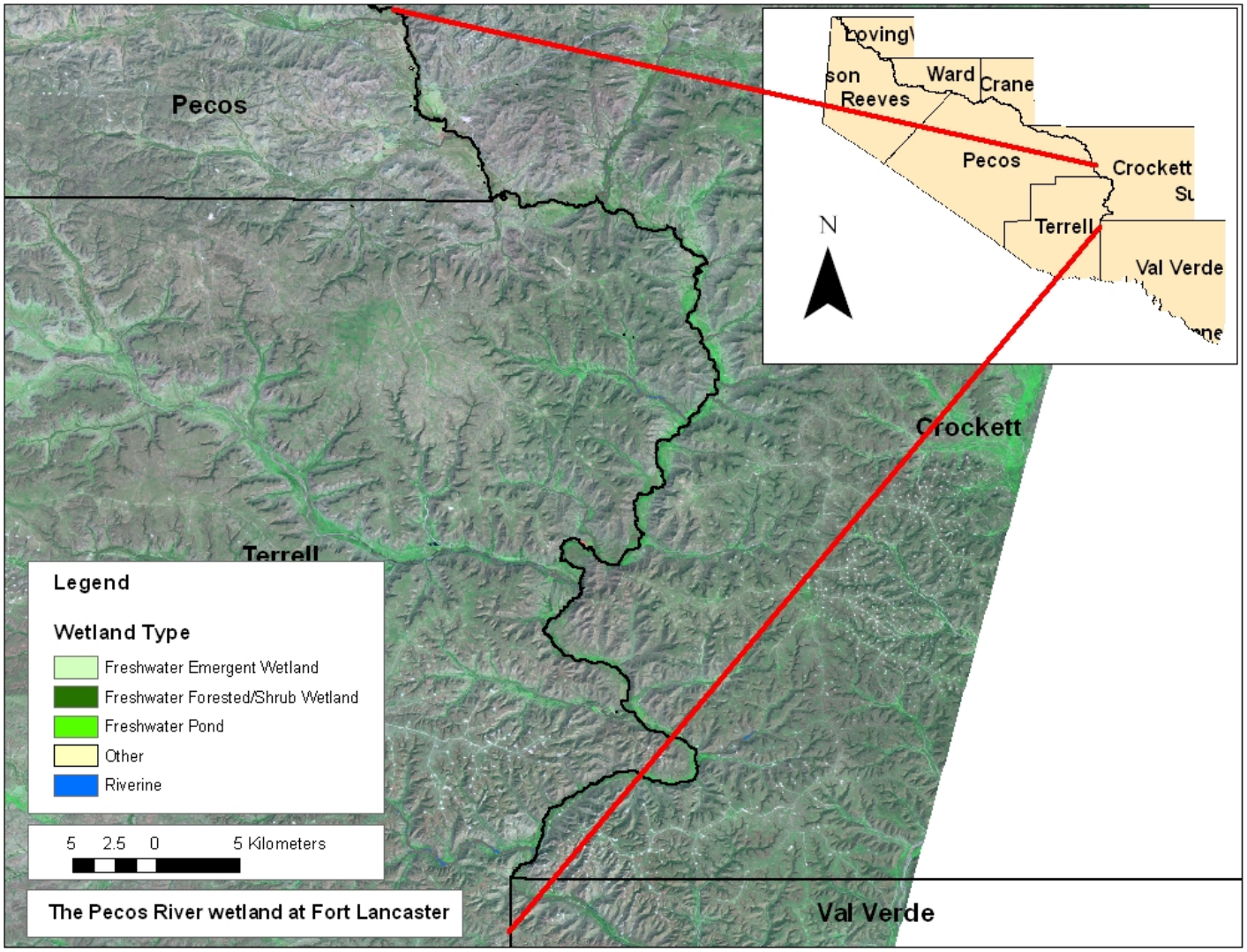


Figure A8. The Pecos River wetland at Fort Lancaster

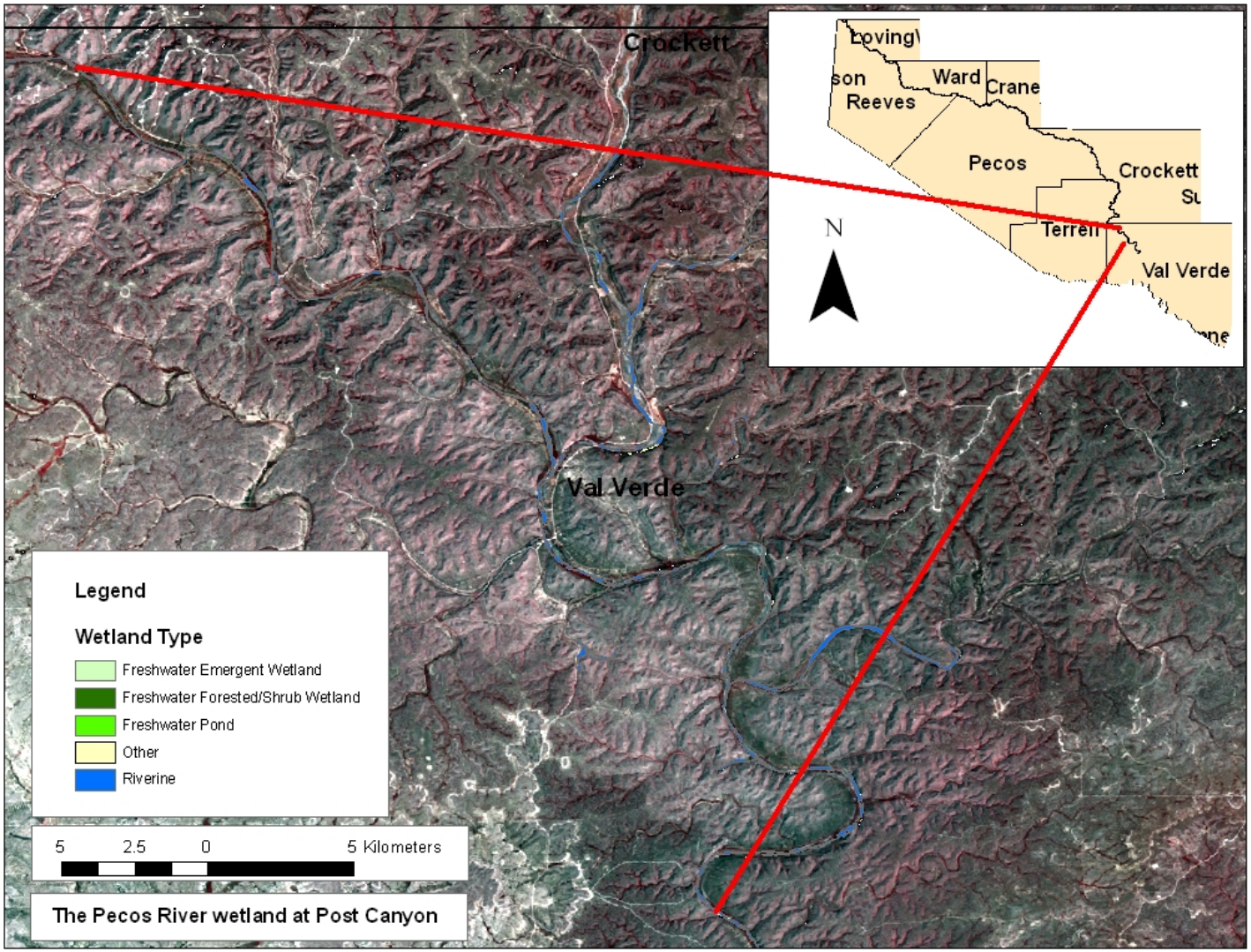


Figure A9. The Pecos River wetland at Post Canyon

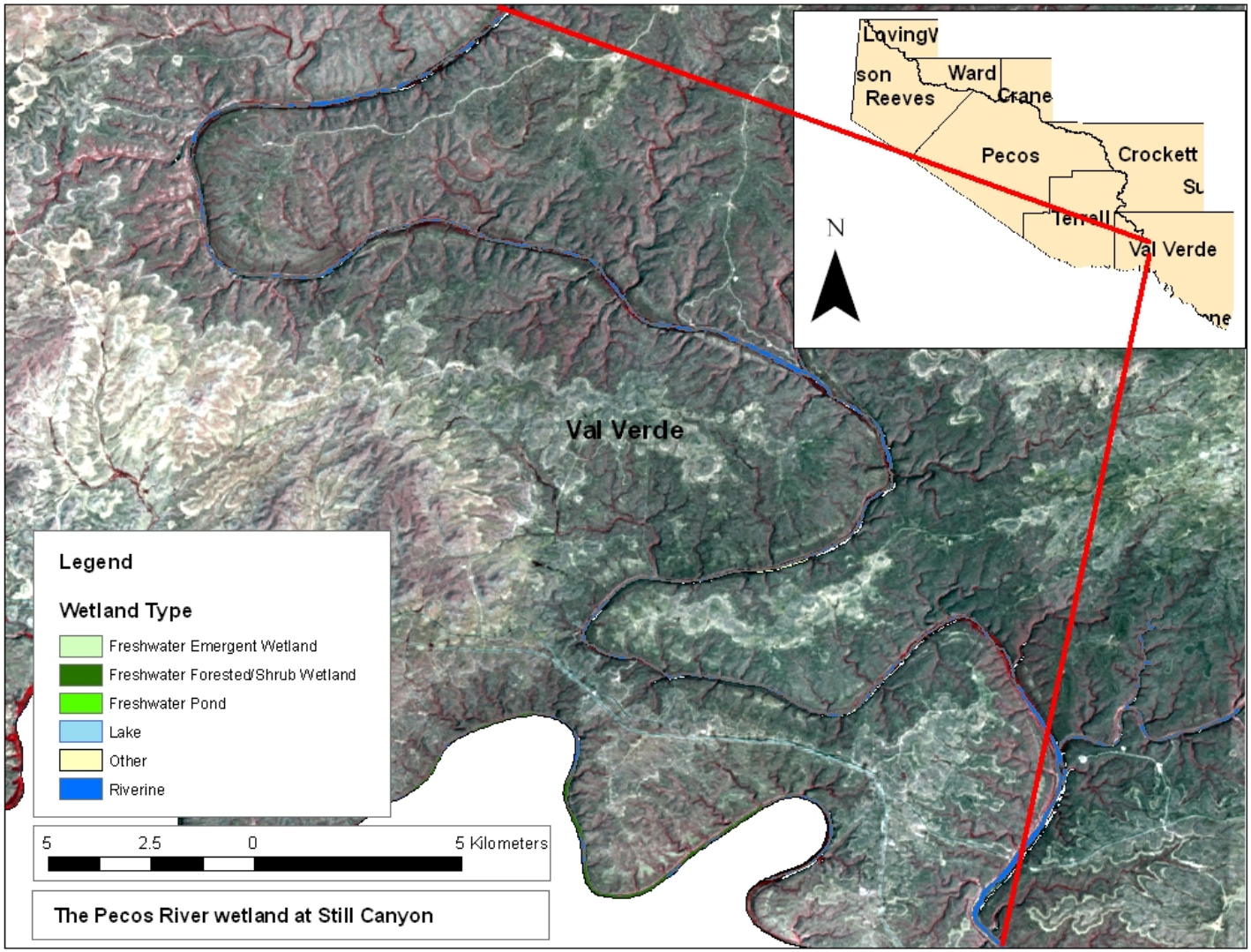


Figure A10. The Pecos River wetland at Still Canyon

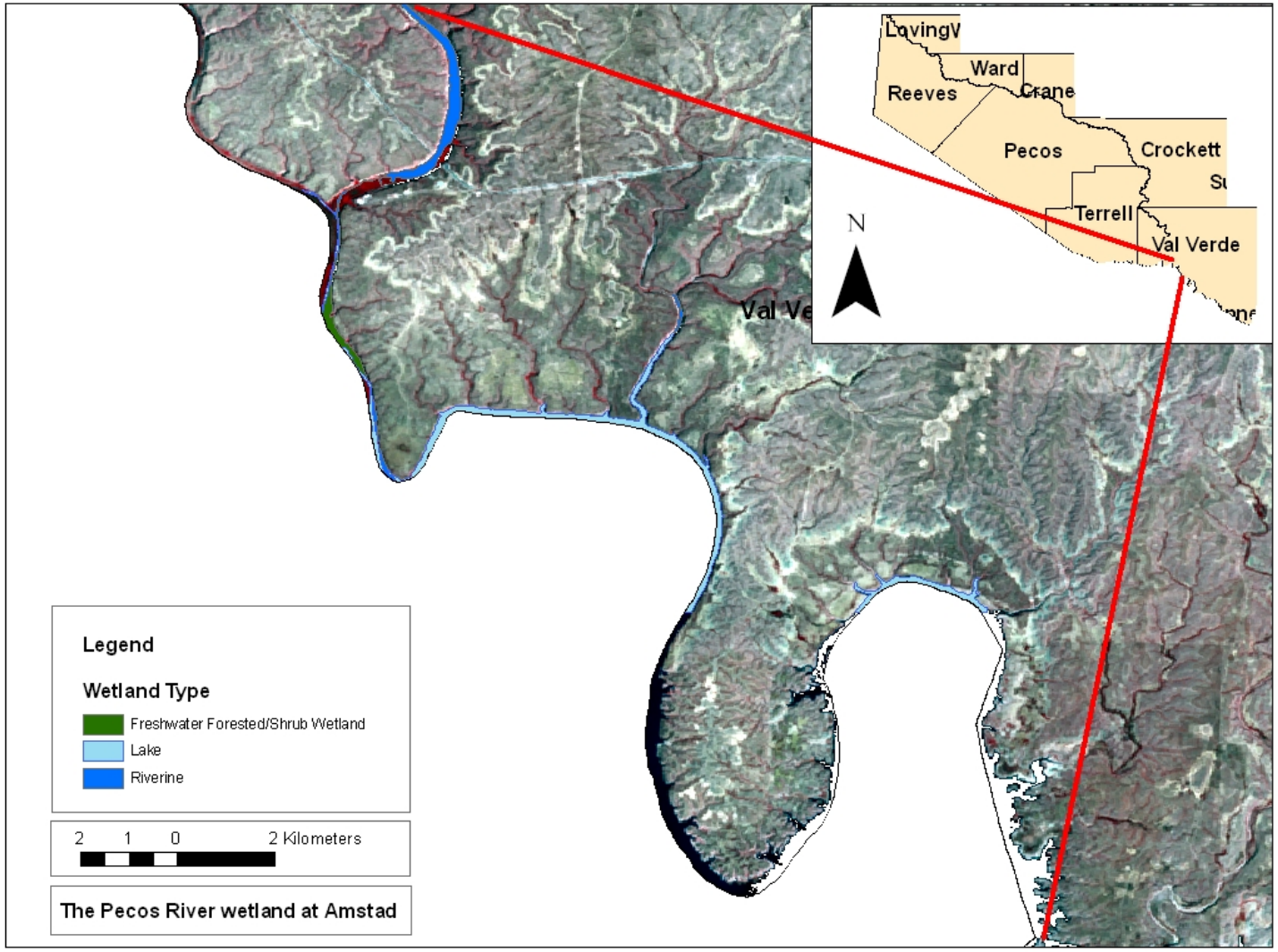


Figure A11. The Pecos River wetland at Amstad

Appendix B

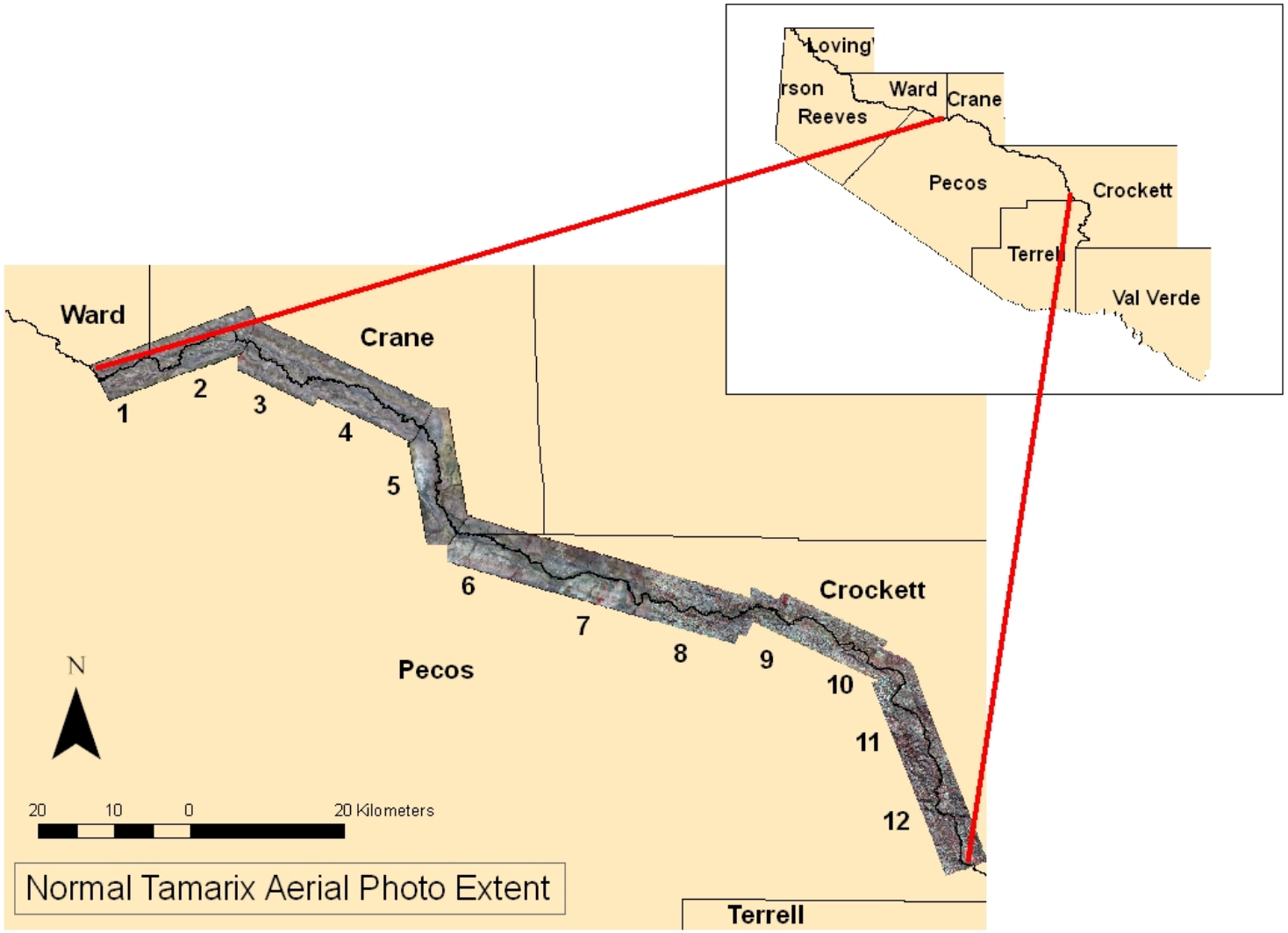


Figure B1 Overview of aerial photo coverage for Normal Tamarisk

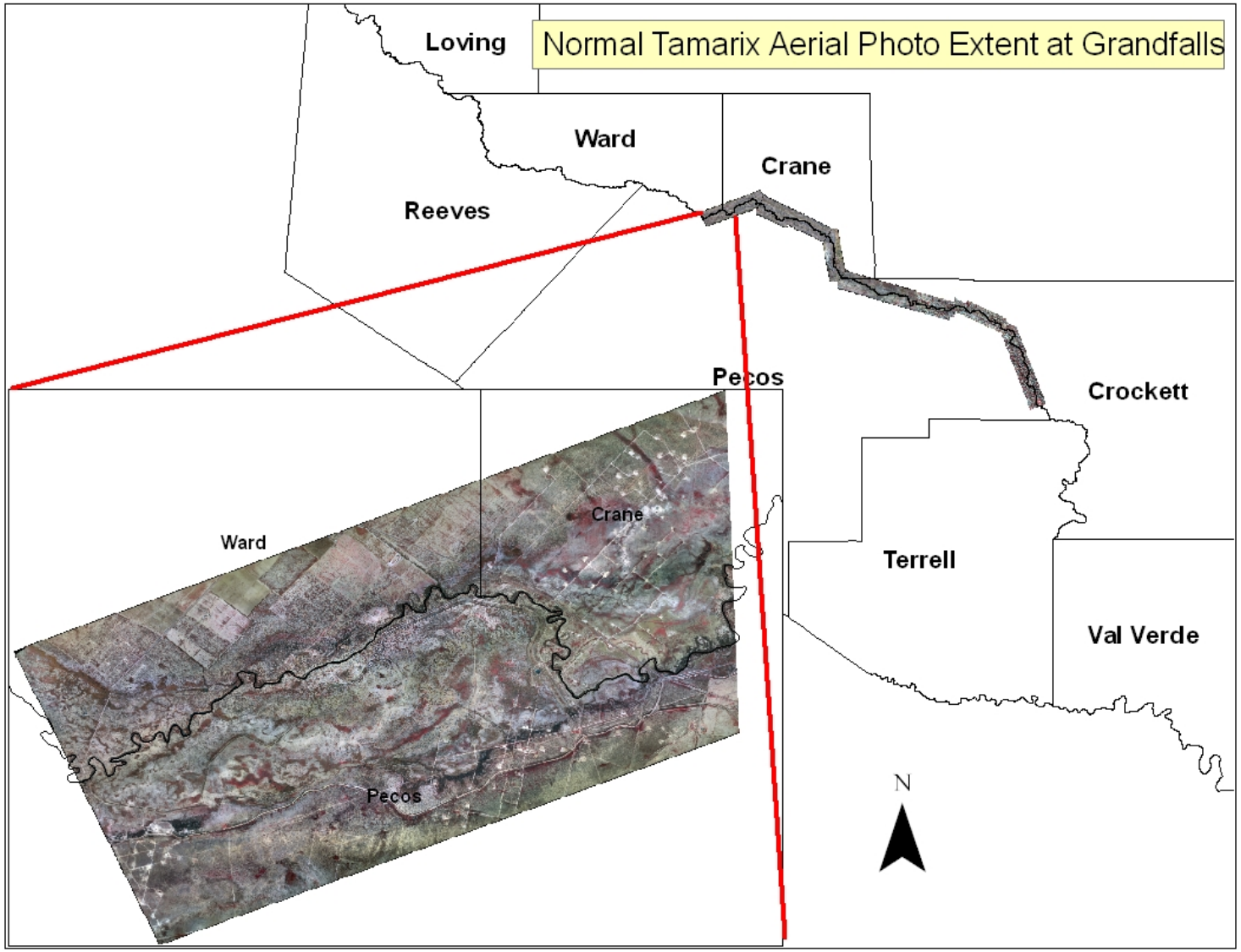


Figure B2 Aerial coverage at Grandfalls_SE

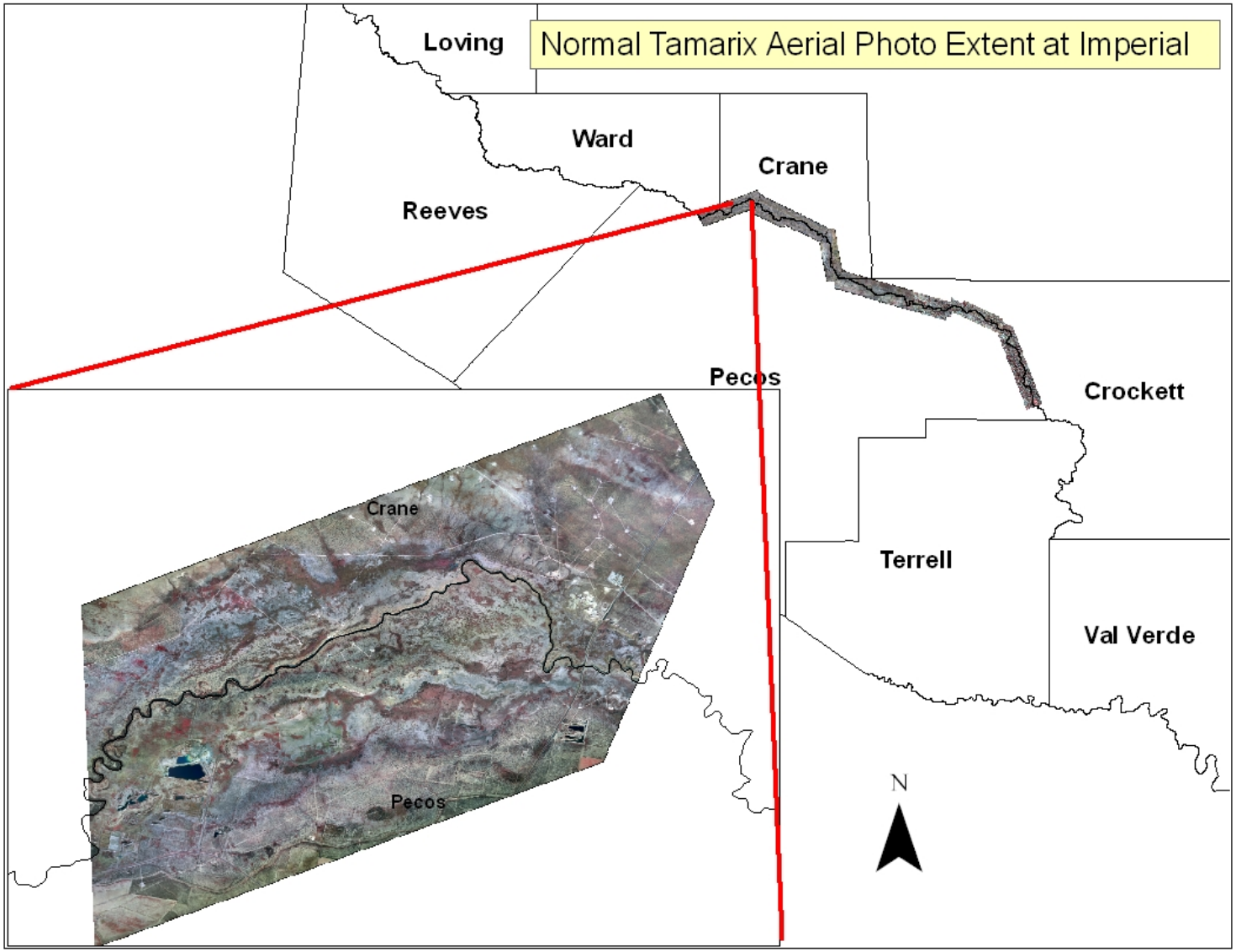


Figure B3 Aerial coverage at Imperial

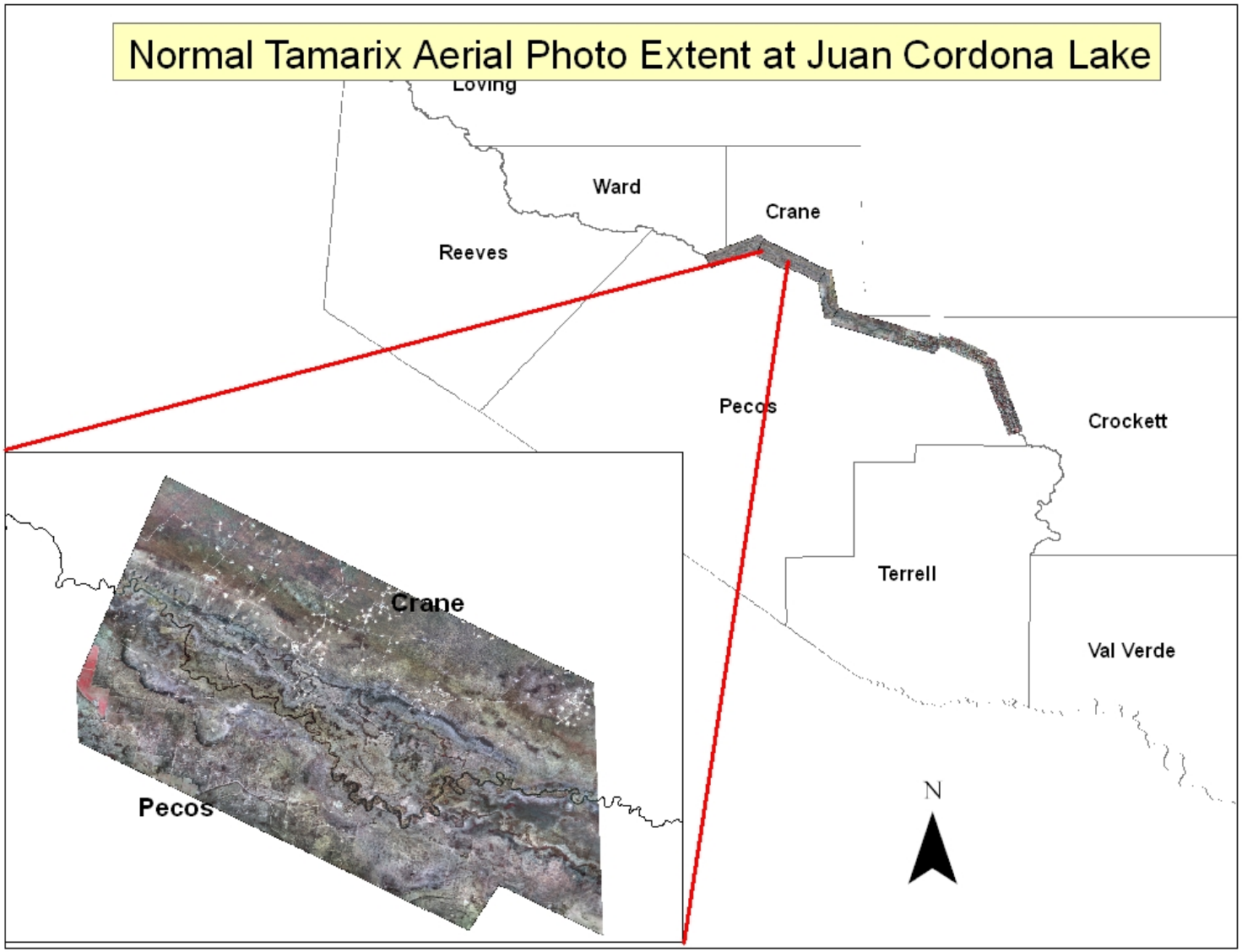


Figure B4 Aerial coverage at Juan_Cordona_Lake

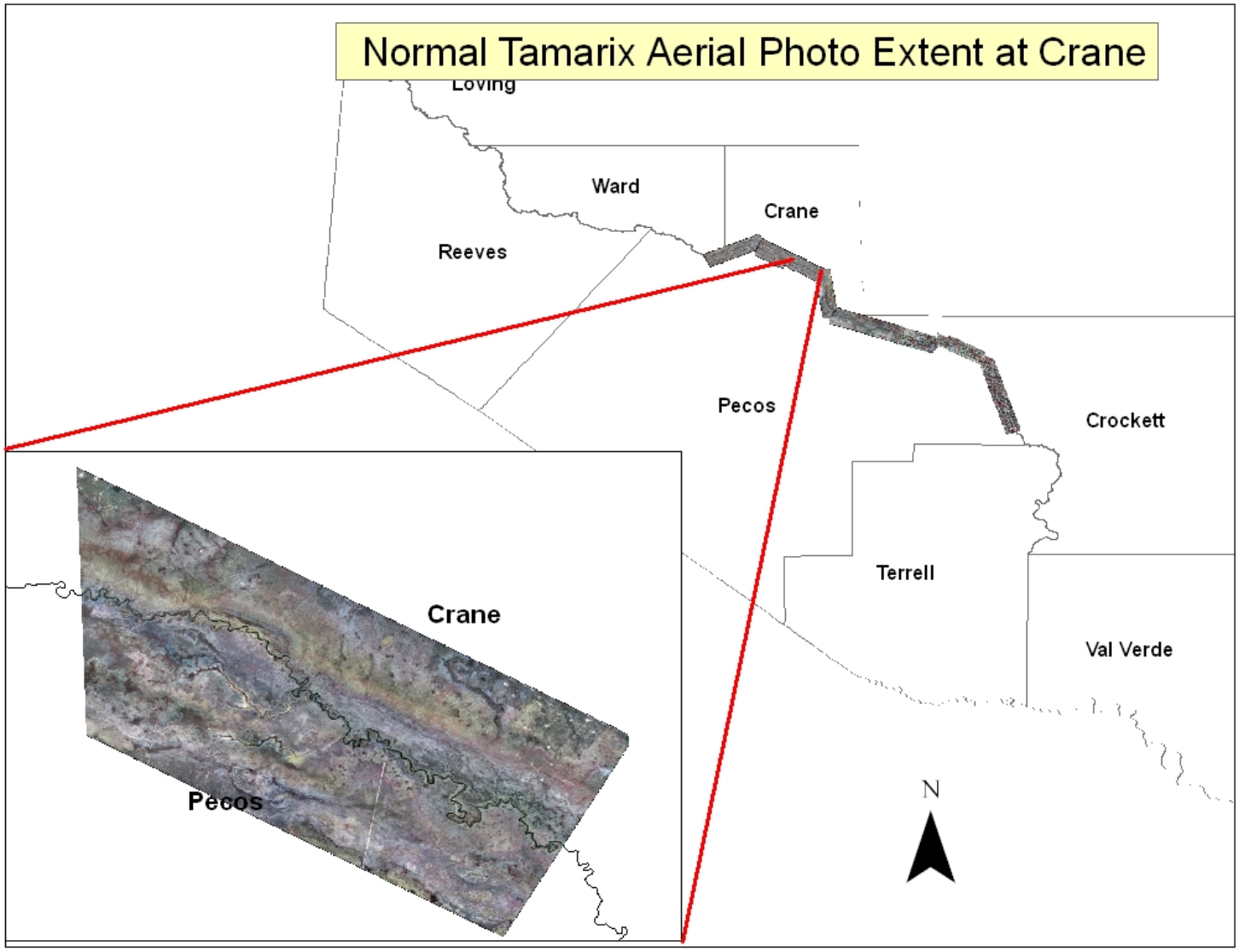


Figure B5 Aerial coverage at Crane_SW

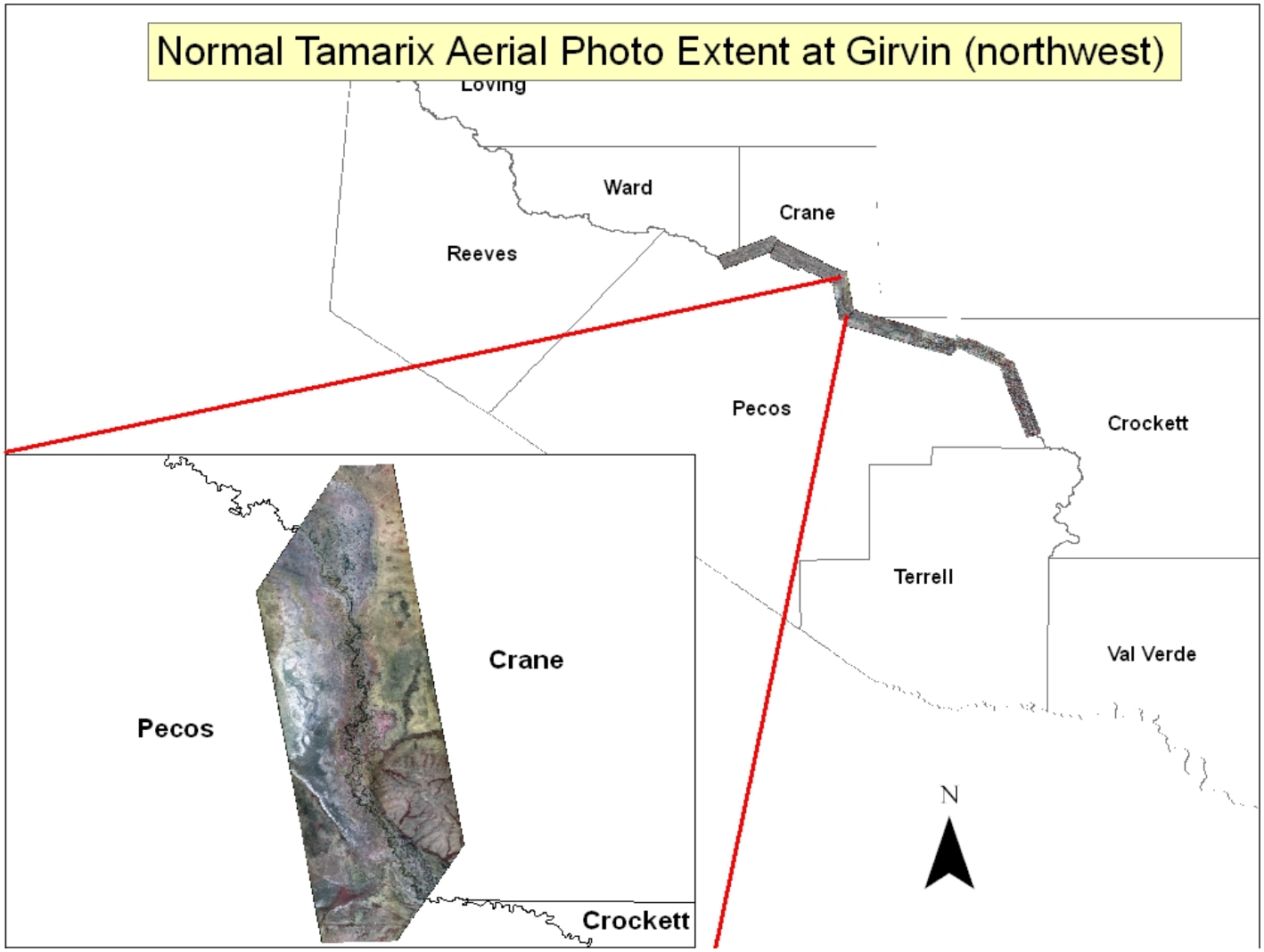


Figure B6 Aerial coverage for Girvin_NW

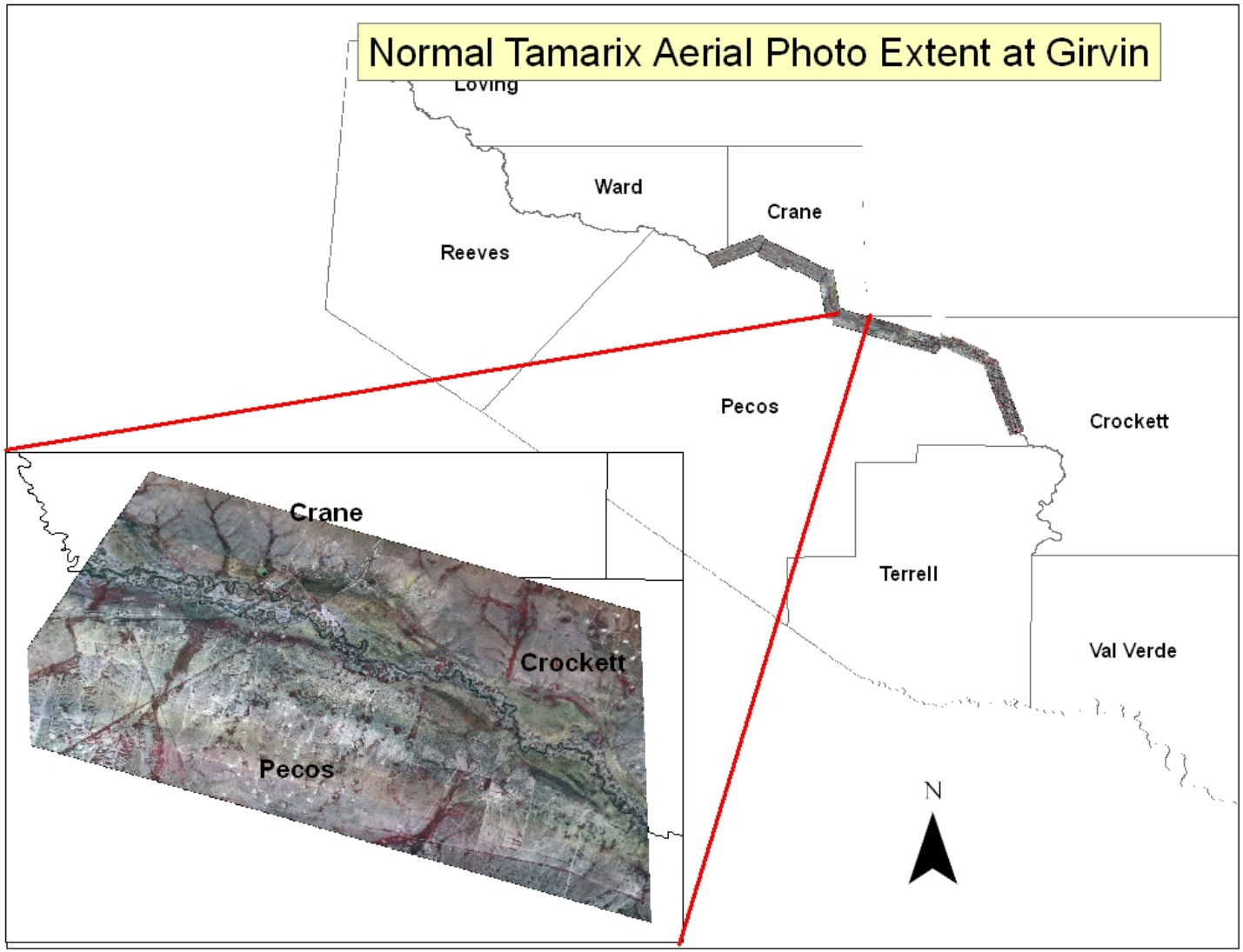


Figure B7 Aerial coverage at Givin

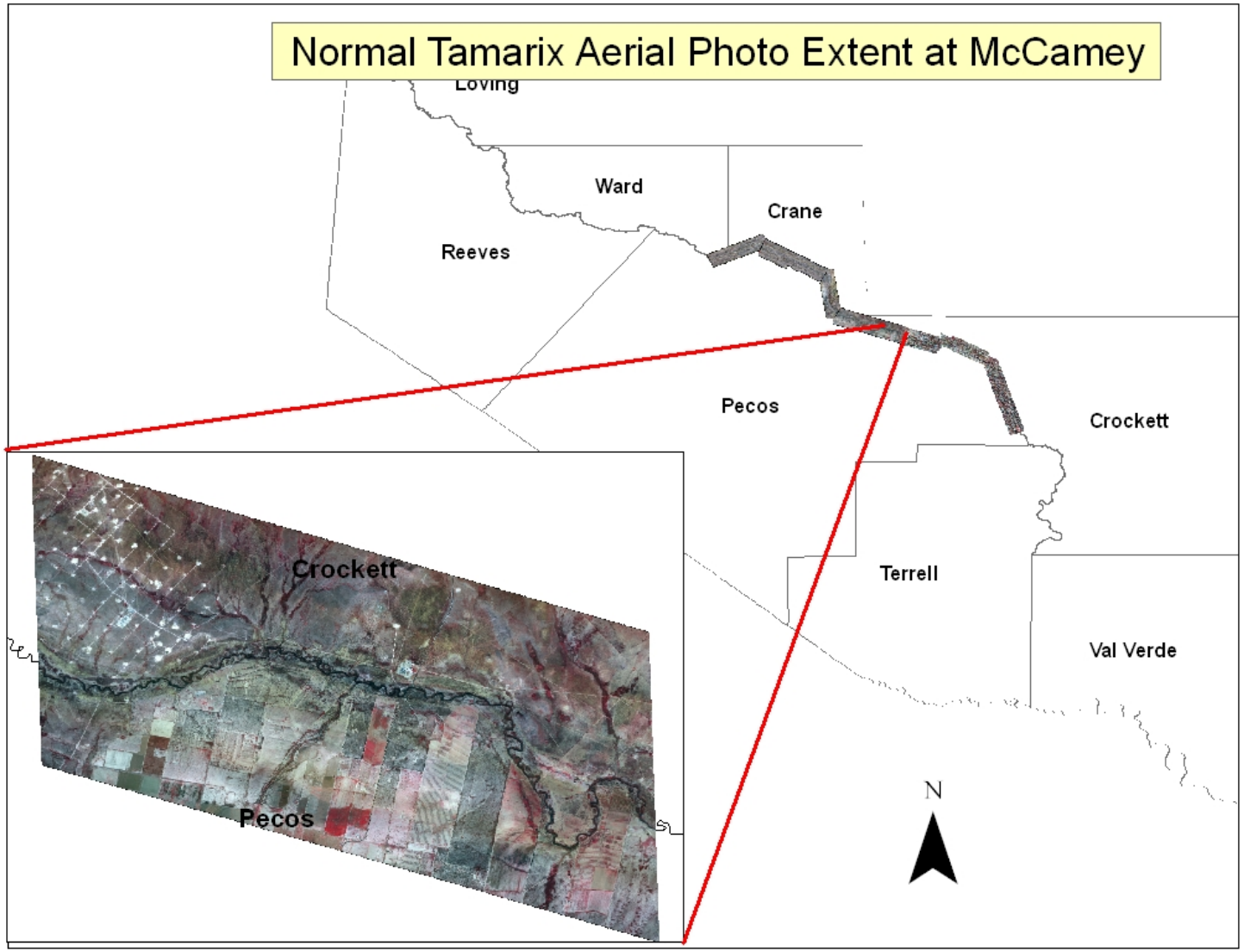


Figure B8 Aerial coverage at McCamey_South

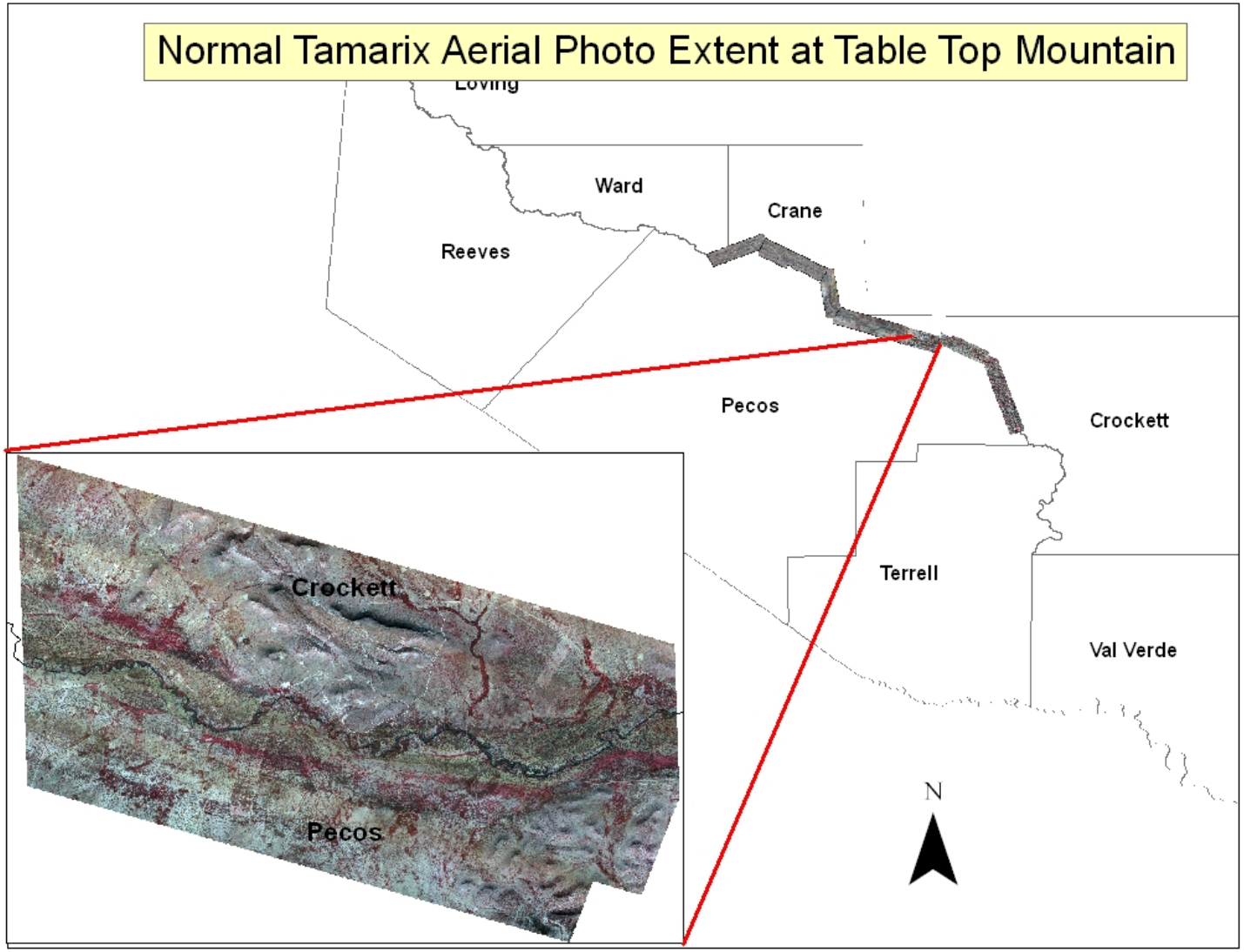


Figure B9 Aerial coverage at Table_Top_Mountain

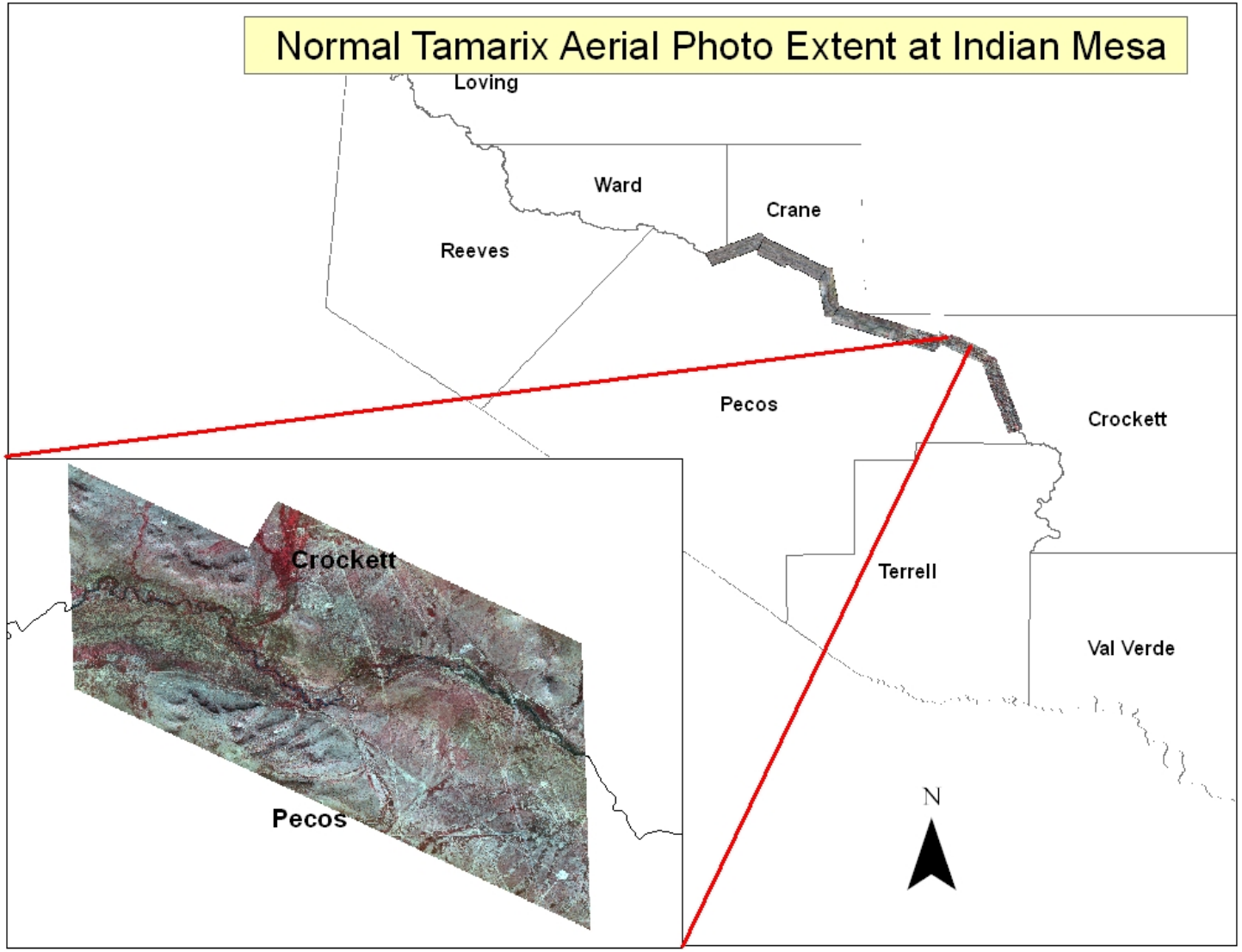


Figure B10 Aerial coverage at Indian_Mesa_NE

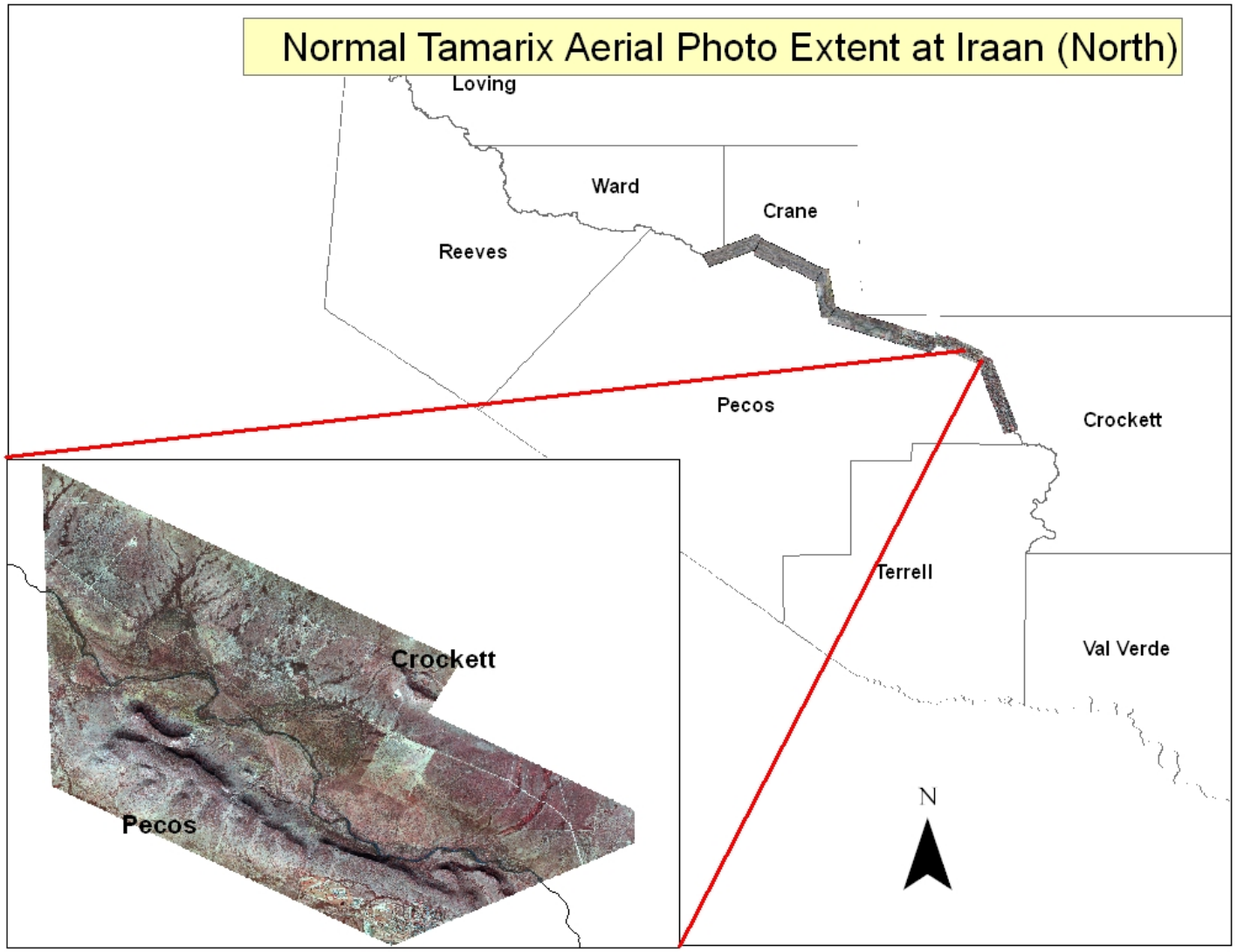


Figure B11 Aerial coverage at Iraan_North

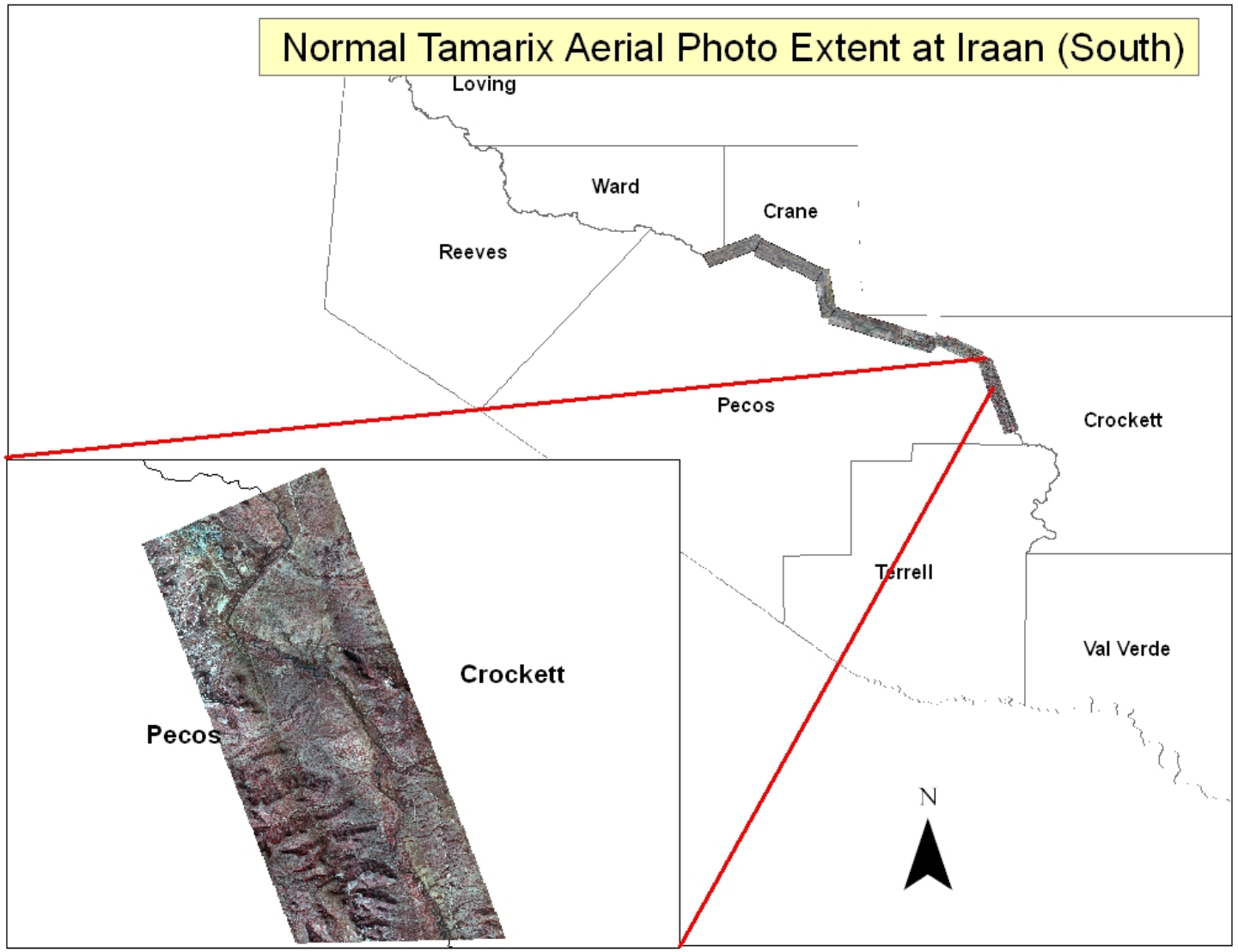


Figure B12 Aerial coverage at Iraan_South_Cir

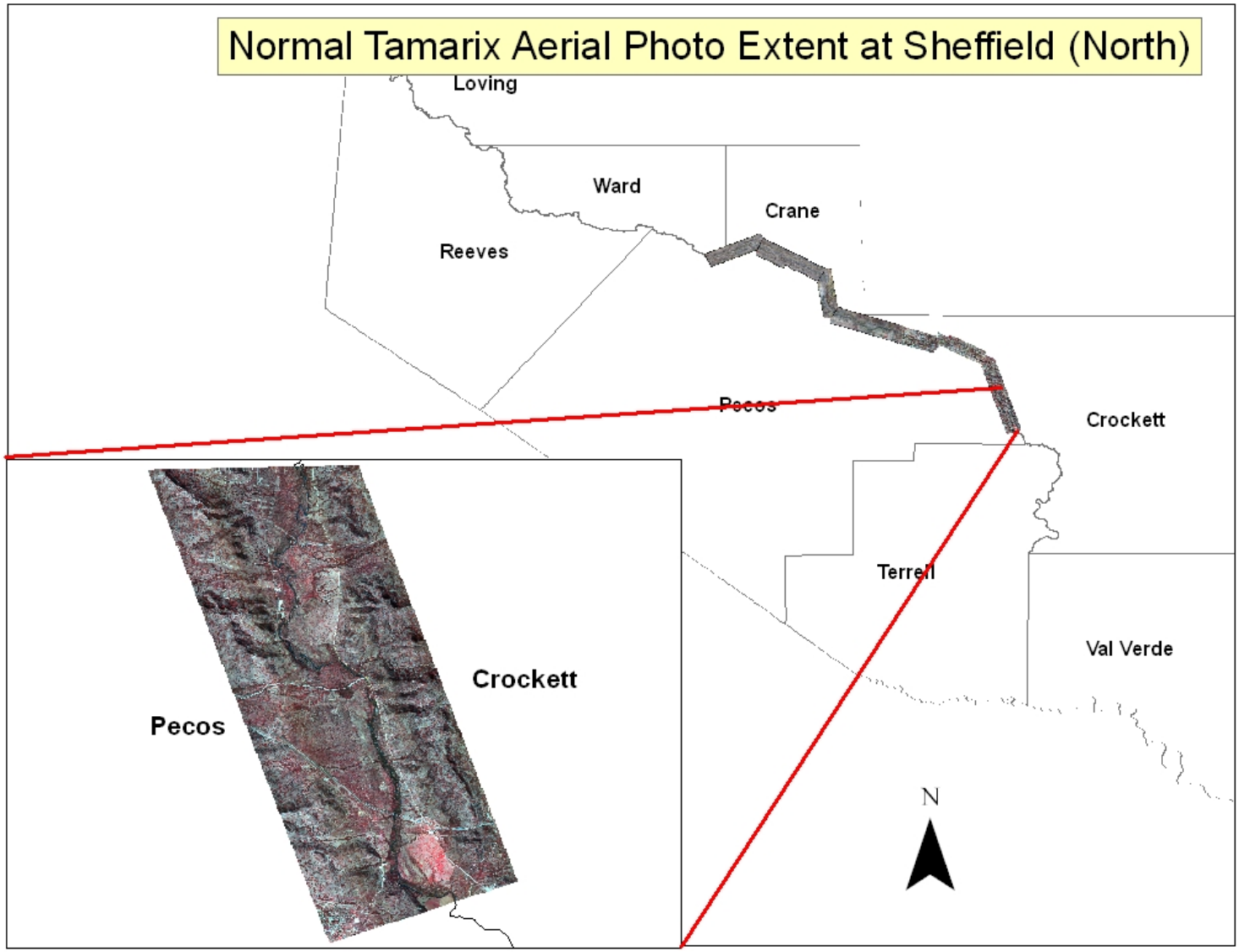


Figure B13 Aerial coverage at Sheffield_North_Cir

Appendix C

Figure C1 Pecos River LS7ETM+.

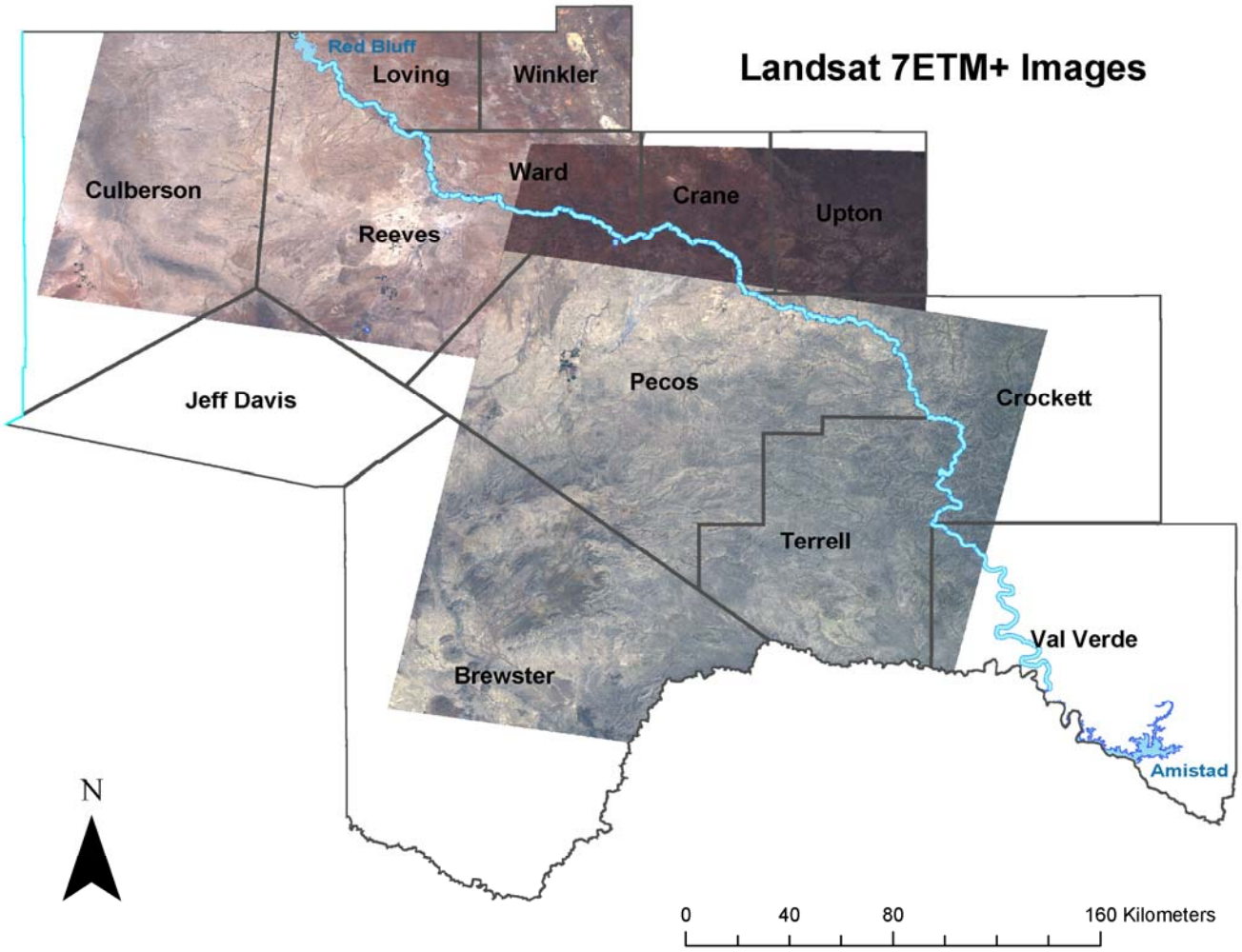


Figure C1 Pecos River LS7ETM+.

Appendix D

Figure D1 Groundwater wells within the Pecos River watershed.

Figure D2. Groundwater TDS within the Pecos River watershed.

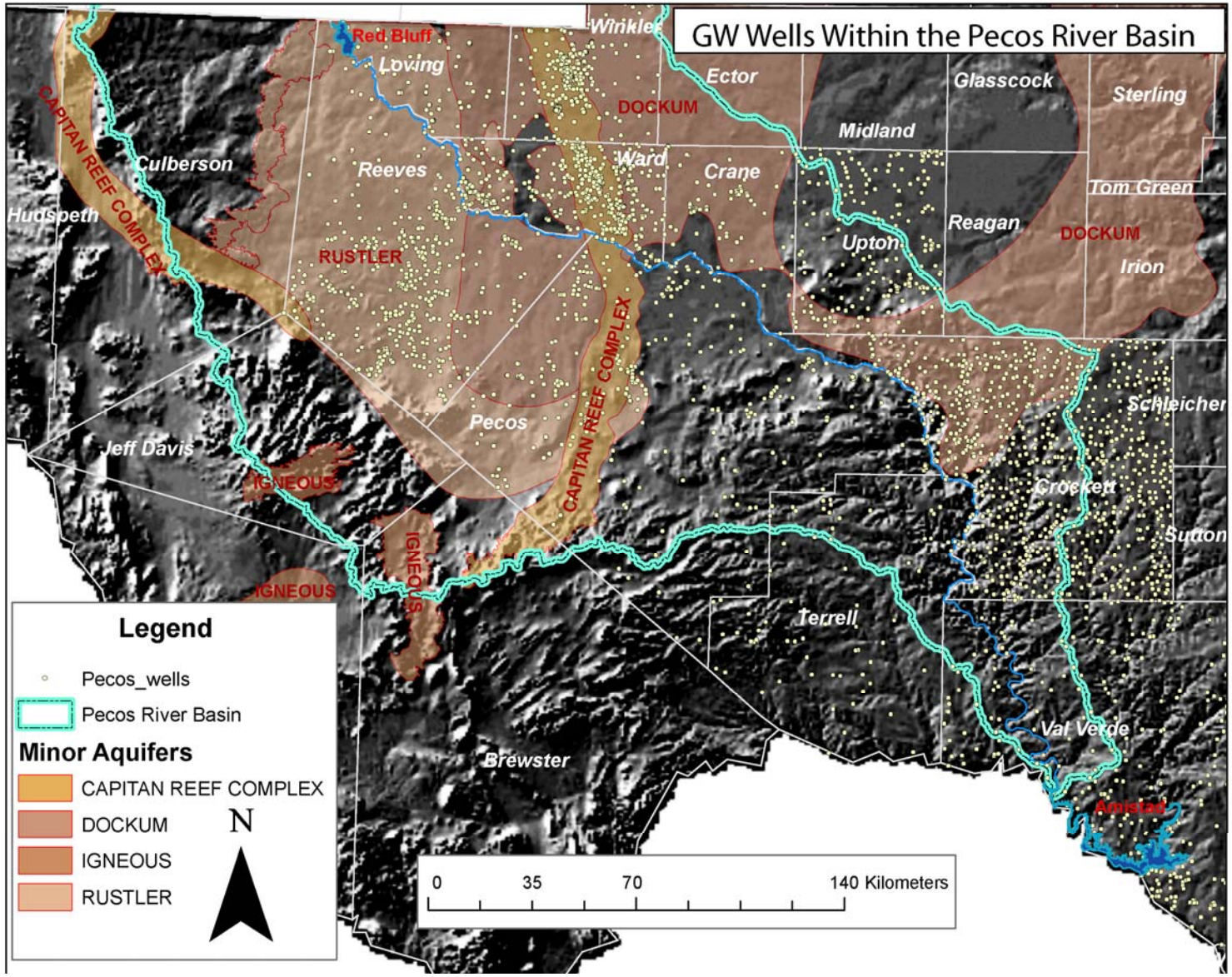


Figure D1 Groundwater wells within the Pecos River watershed.

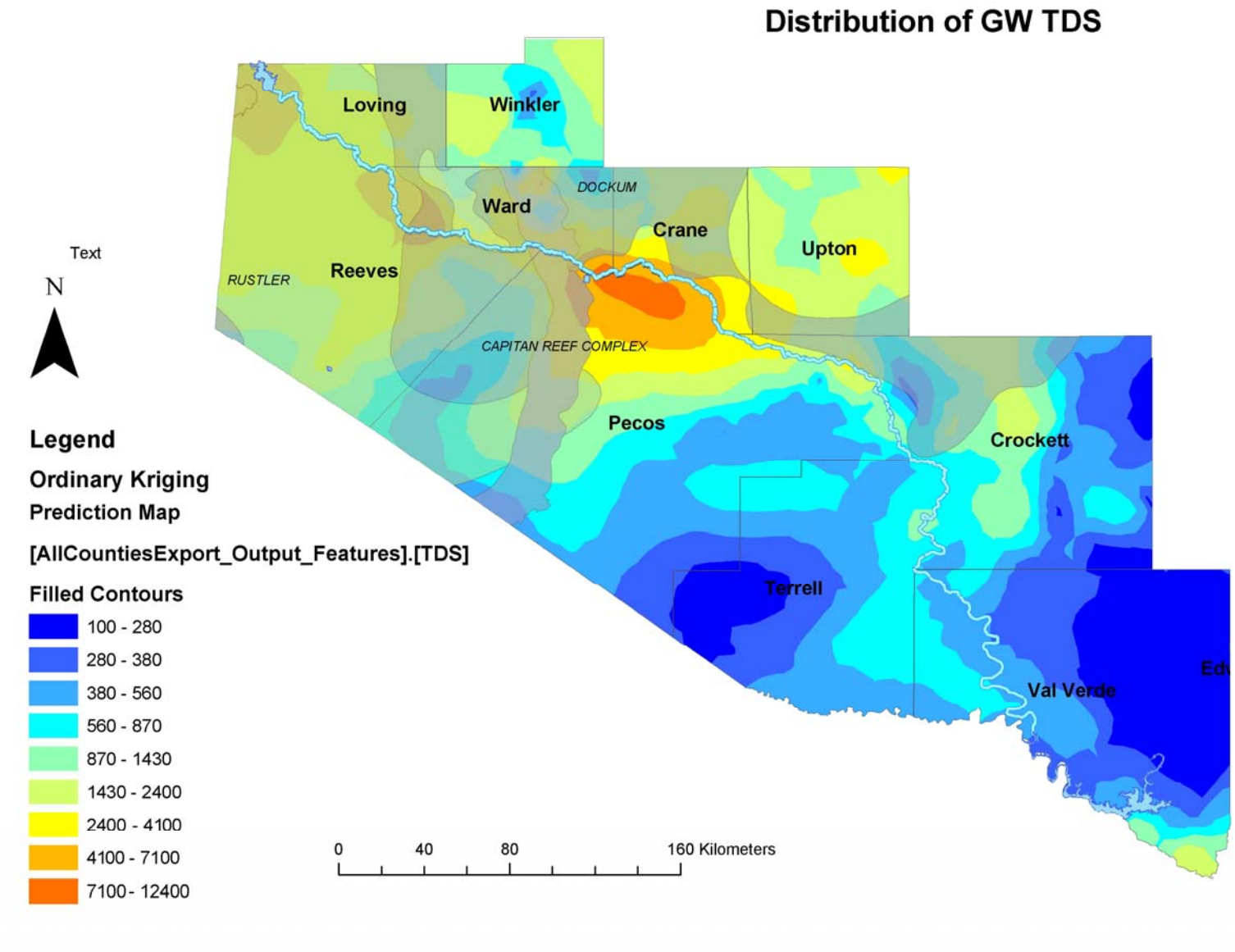


Figure D2. Groundwater TDS within the Pecos River watershed.

Appendix E

Figure E1. Example Tamarisk Delineation Map on the Pecos River.

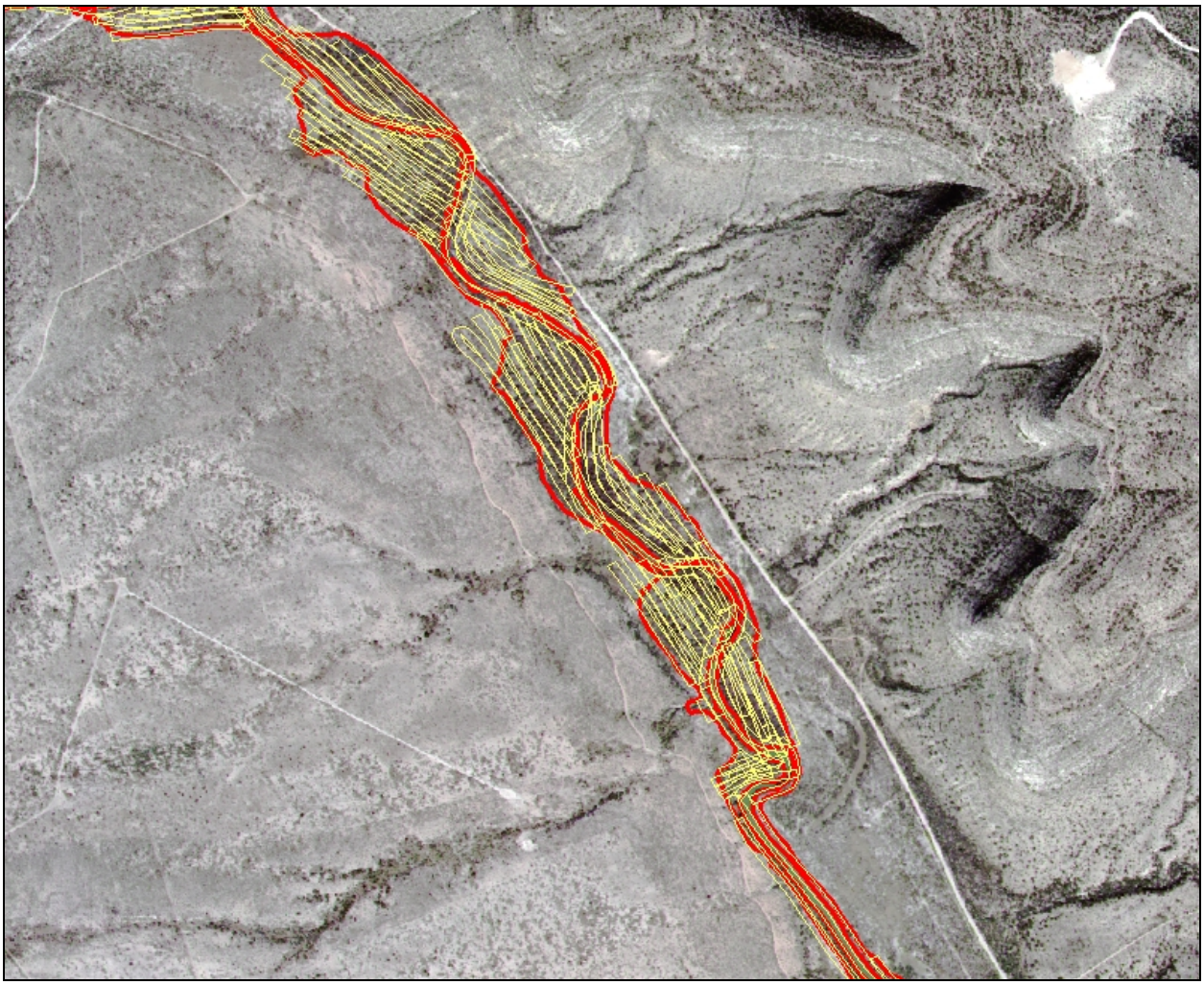


Figure E2. Example of Tamarisk delineation (in red) and GIS spray files of area sprayed (yellow) overlaid on aerial imagery.

Table E.1. Estimates and corrected estimates of digitized saltcedar acreage left unsprayed in Ward, Crane, Pecos, Crockett, Terrell, and Val Verde Counties after 2005 spray season.

	Ward	Crane	Pecos	Crockett	Terrell	Val Verde	Total	
Total Digitized Acres	**67.32**	**562.79**	**3185**	**1551.27**	**515.17**	**427.9**	**6309.52**	acres
Digitized acres after 2004 spraying	34.4	263.9	658.6	532.54	85.97	132.16	1707.57	acres
Digitized acres after 2005 spraying	34.4	163.11	591.7	430.18	85.97	132.16	1437.52	acres
Digitized Acres sprayed 2003-04	32.92	298.89	2526.47	1018.73	429.2	295.74	4601.95	acres
Digitized Acres sprayed 2005	0	100.79	66.9	102.36	0	0	270.05	acres
Total Digitized Acres sprayed	**32.92**	**399.68**	**2593.37**	**1121.09**	**429.2**	**295.74**	**4872**	**acres**
Actual Acres sprayed in 2003-04	42.78	604	1539	1417	506	513	4621.78	acres
Actual Acres sprayed in 2005	0	365	102	186	0	0	653	acres
Total Acres sprayed	**42.78**	**969**	**1641**	**1603**	**506**	**513**	5274.78	acres
Corrected digitized acres after 2005 spraying	**51.4**	**223.4**	**641.9**	**586.4**	**151.2**	**487.6**	**2141.8**	**acres**
River miles left within aerial images	3.8	15.0	45.0	34.0	14.0	62.0	173.8	miles
Acres per river mile	13.6	14.9	14.3	17.2	10.8	7.9	12.3	acres
Total River Miles Left after 2005 spraying	20	15	65	34	14	111	259	miles/side
Corrected est. acres left after 2005	**271.77**	**223.37**	**927.25**	**586.38**	**151.21**	**872.90**	**3032.87**	**acres**
acres outside imagery	220.4	0.0	285.3	0.0	0.0	385.3		
Total acres sprayed through 2005	1333	969	1641	1603	506	513	6565	acres
Total estimated acres of saltcedar	1604.77	1192.37	2568.25	2189.38	657.21	1385.90	9597.87	acres

Table E2. River Miles Treated by County (one side of river)

County	Total Miles To Treat	Miles Treated Pre-2003	2003 Miles Treated	2004 Miles Treated	2005 Miles Treated	Total Miles Treated	Miles Untreated	Percent Completed
Loving	42.8	43	0	0	0	43	0	100%
Reeves	124.0	124	0	0	0	124	0	100%
Ward	107.1	85	2	0	0	87	20	82%
Crane	60.6	0	31	0	15	46	15	76%
Pecos	167.2	0	46	45	10	102	65	61%
Crockett	131.0	0	39	47	10	97	34	74%
Terrell	50.1	0	23	13	0	36	14	71%
Val Verde	154.7	0	11	33	0	44	111	28%
Total	**837**	**252**	**153**	**138**	**35**	**578**	**260**	**69%**

Table E3. River Acres Treated by County (one side of river)

		River Acres	2003		2004		2005		Total	Total
County	Total Est. River Acres	Treated Pre-2003	Total Acres Treated	Total River Acres Treated	Total Acres Treated	Total River Acres Treated	Total Acres Treated	Total River Acres Treated	River Acres Treated	River Acres Untreated
Culberson	0	0	280	0	730	0	0	0	**0**	**0**
Loving	1237	1237	0	0	0	0	0	0	**1237**	**0**
Reeves	2515	2515	494	0	0	0	0	0	**2515**	**0**
Ward	1605	1278	96	55	0	0	40	0	**1333**	**272**
Crane	1192	0	604	604	0	0	365	365	**969**	**223**
Pecos	2568	0	1155	907	632	632	139	102	**1641**	**927**
Crockett	2189	0	543	543	874	874	186	186	**1603**	**586**
Terrell	657	0	432	432	74	74	0	0	**506**	**151**
Val Verde	1386	0	126	126	387	387	0	0	**513**	**873**
Total	**13349**	**5030**	**3730**	**2667**	**2698**	**1967**	**730**	**653**	**10317**	**3032**
								Percent of Total	**77.3%**	**22.7%**

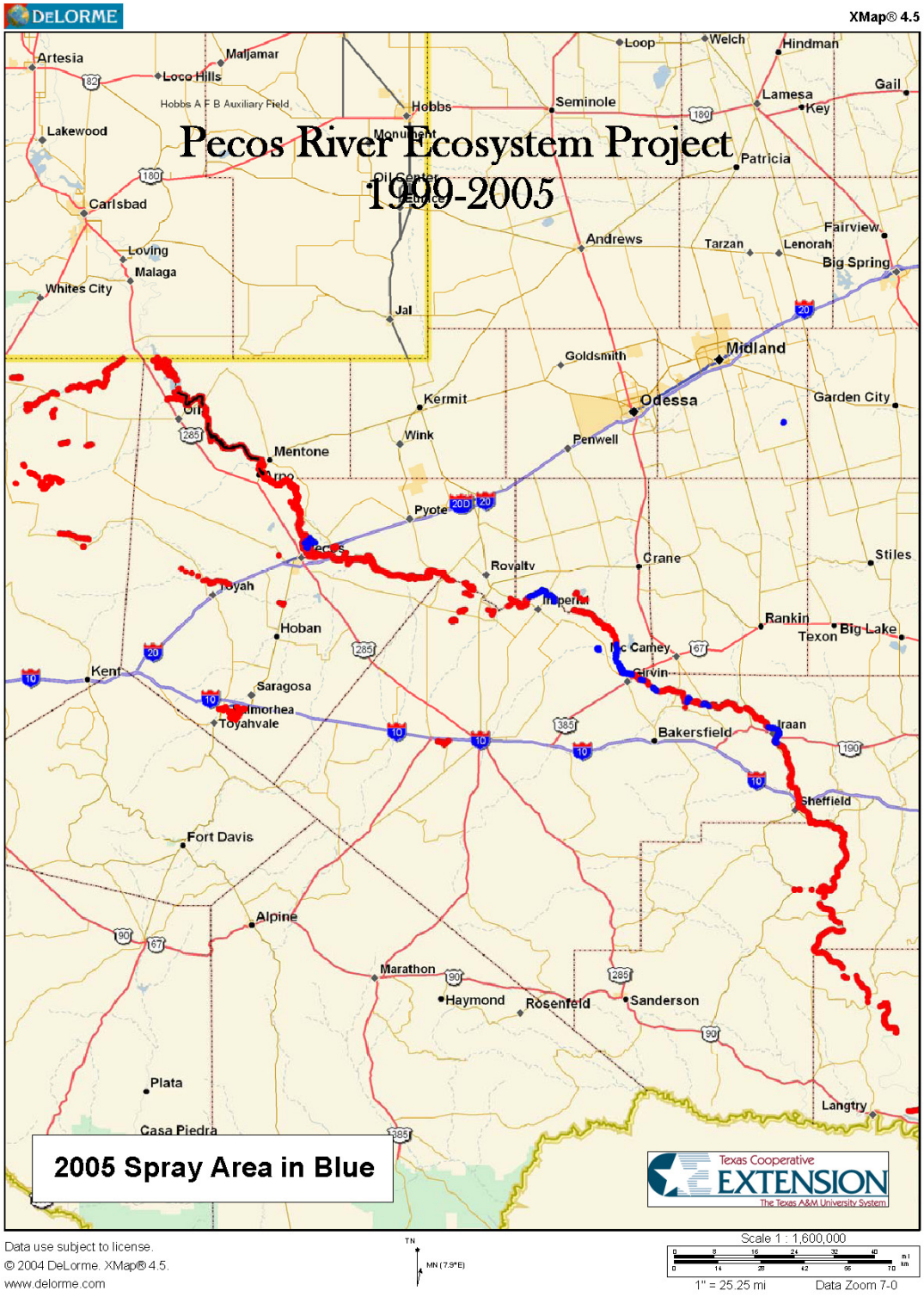


Figure E3. Areas sprayed for saltcedar control on the Pecos River in Texas, 1999-2005.

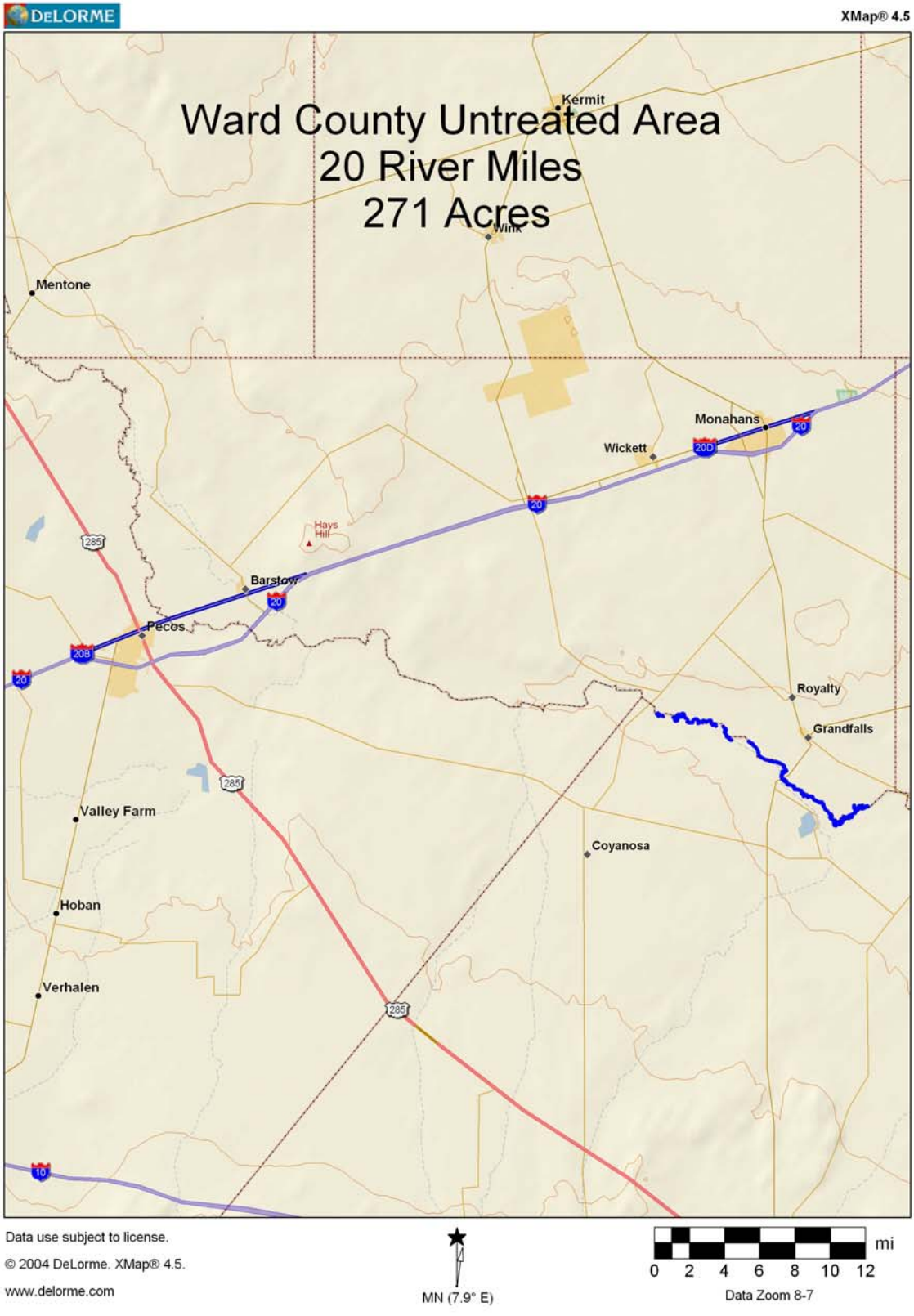


Figure E4. Untreated saltcedar located in Ward County along the Pecos River.

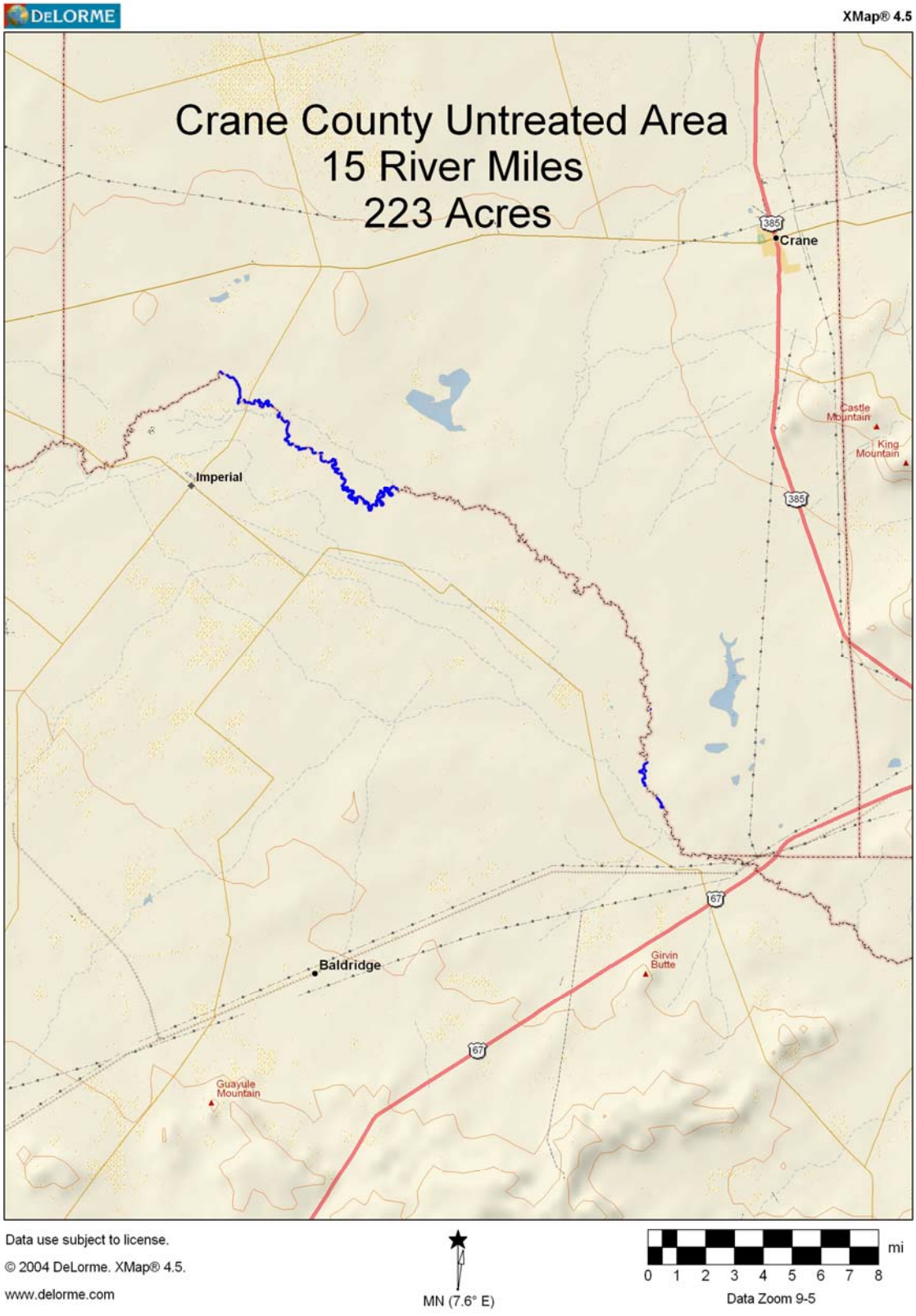


Figure E5. Untreated saltcedar located in Crane County along the Pecos River.

Figure E6. Untreated saltcedar located in Pecos County along the Pecos River.

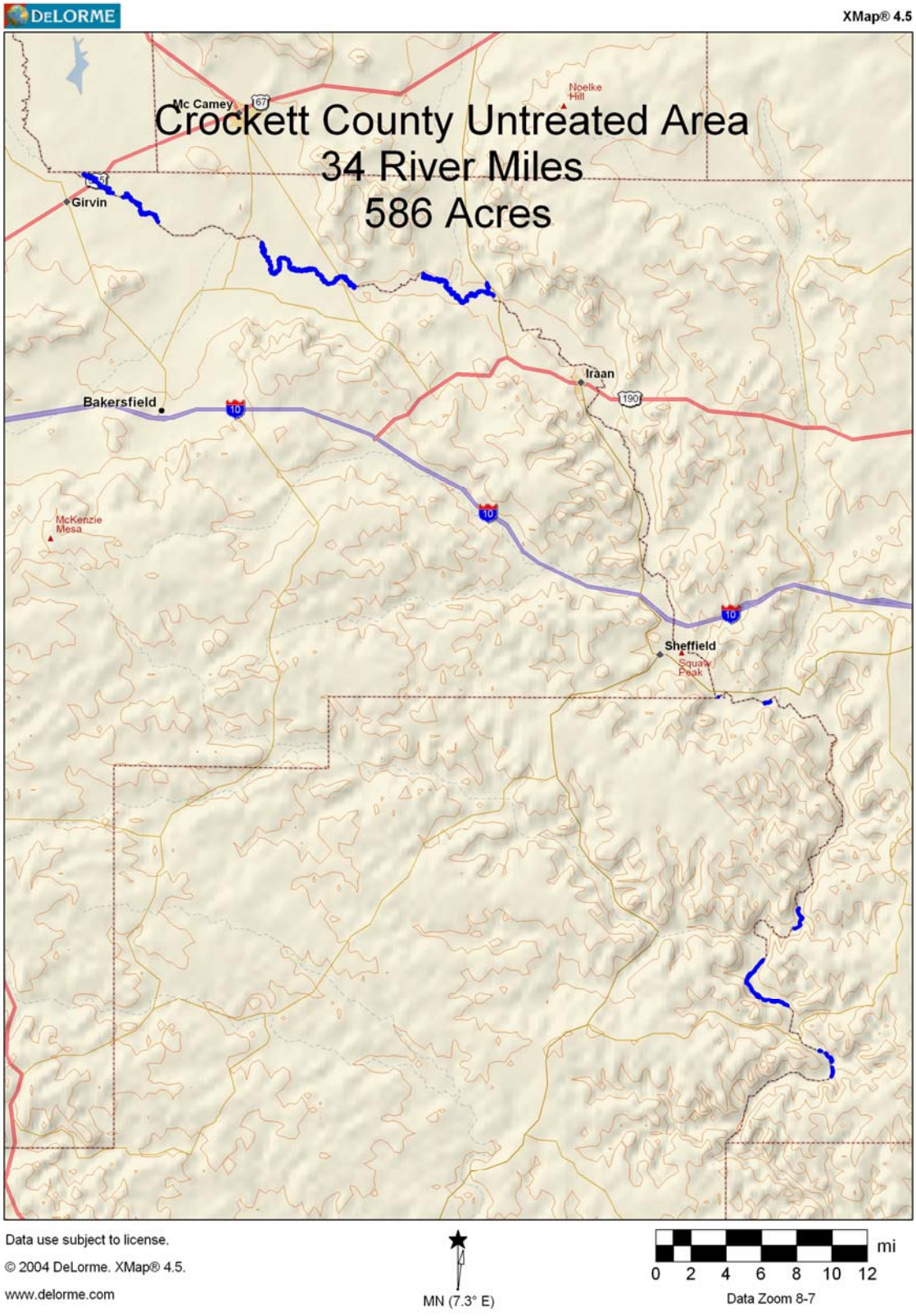


Figure E7. Untreated saltcedar located in Crockett County along the Pecos River.

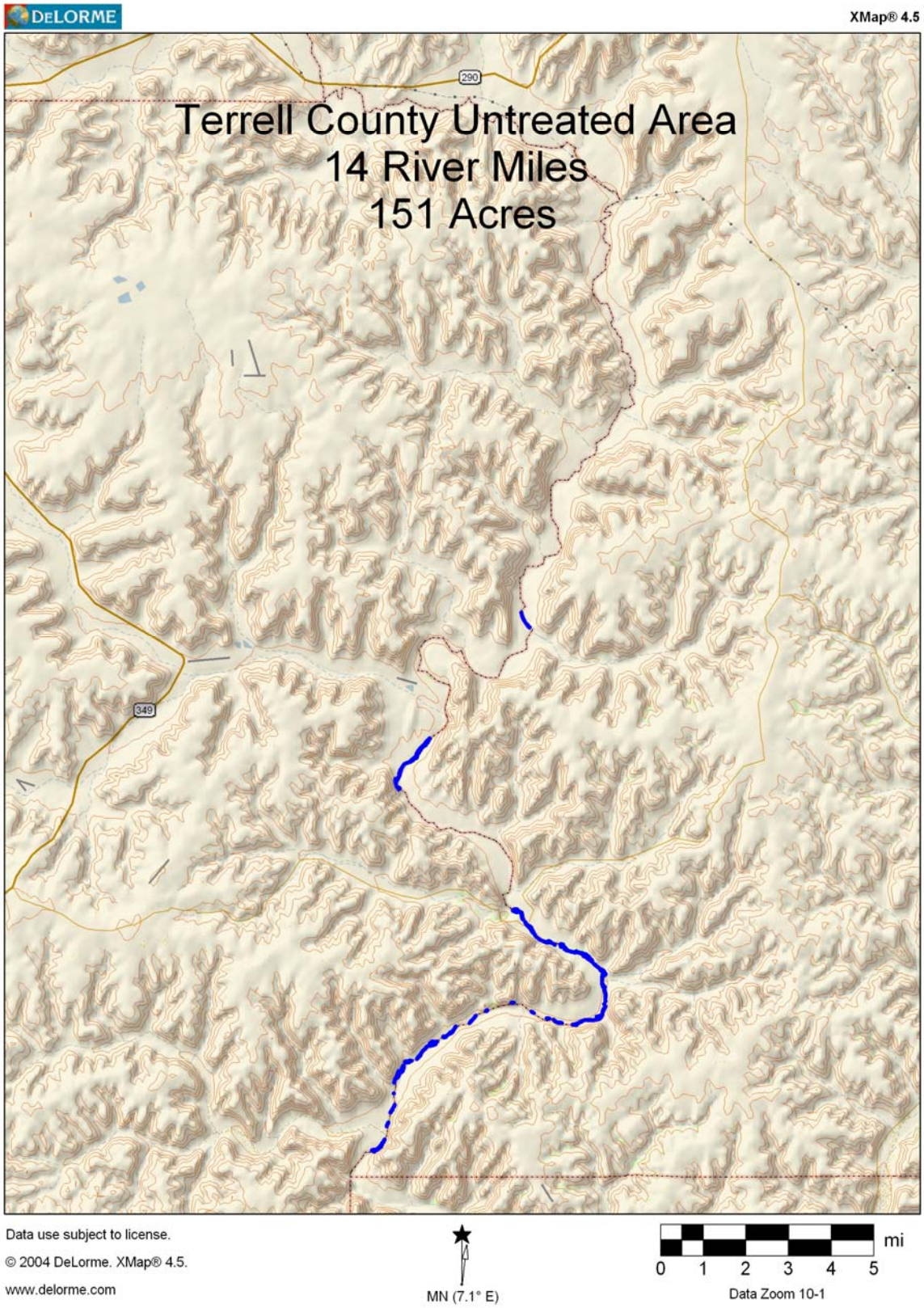


Figure E8. Untreated saltcedar located in Terrell County along the Pecos River.

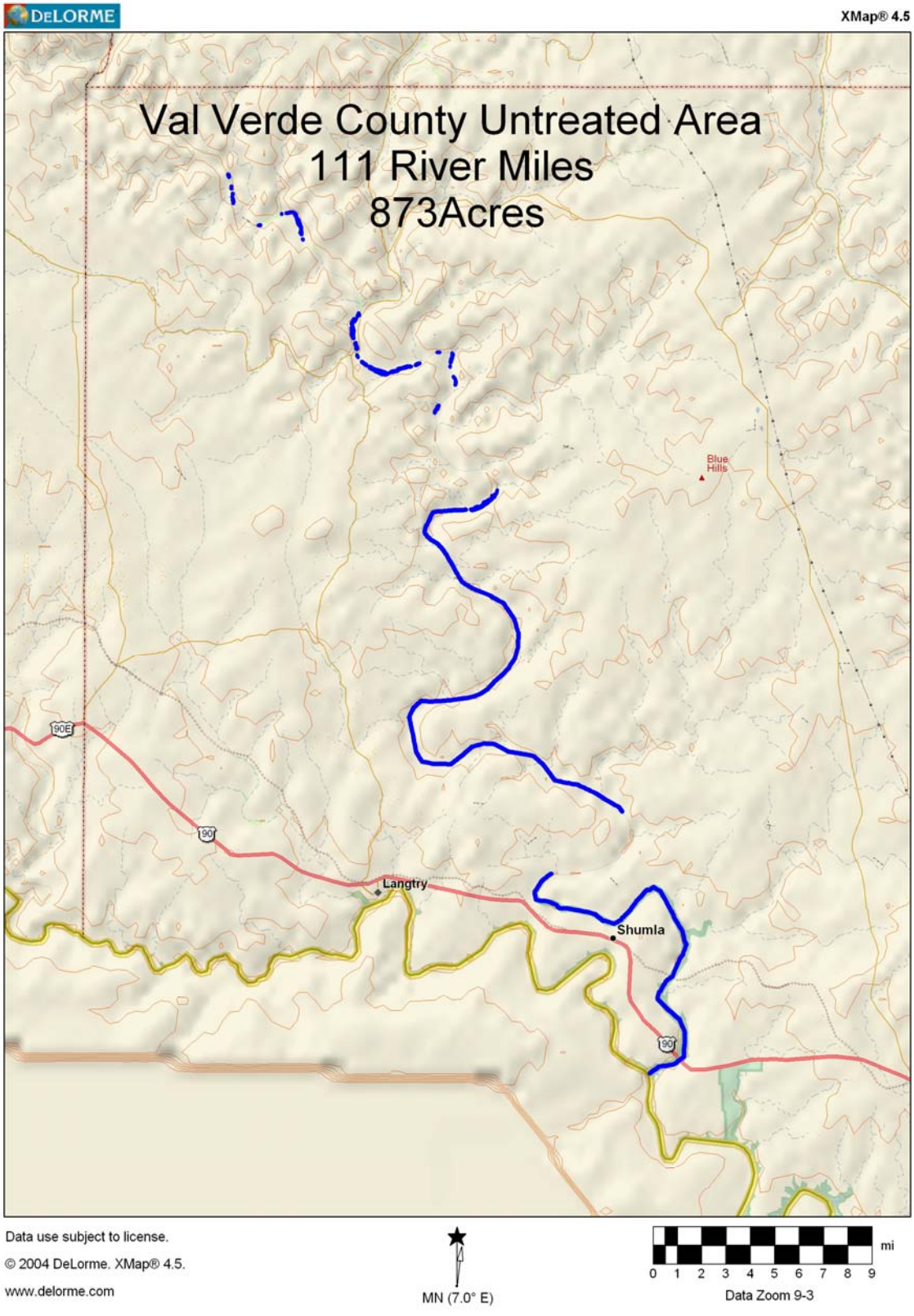


Figure E9. Untreated saltcedar located in Val Verde County along the Pecos River.