Ft. Pearce Wash

Stability Study Update

Washington County, Utah

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Prepared by:

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

8400 S. Kyrene Rd., Suite 201
Tempe, AZ 85284
www.jefuller.com

March 2007

1. INTRODUCTION

1.1. Study Area

Fort Pearce Wash drains about 1,660 square miles of southern Utah and northern Arizona. It is one of the major tributaries of the Virgin River, which it joins at the city of St. George. The Fort Pearce Wash study area described in this report is located within Washington County and extends from the Virgin River confluence to the Utah-Arizona state line (Figure 1).[1] At their confluence, Fort Pearce Wash and the Virgin River have approximately equal drainage areas, though the two watersheds have significant differences in elevation, water supply, and vegetative cover. Unlike the Virgin River, the Fort Pearce Wash is ephemeral, flowing only during floods or where irrigation tailwater is discharged into the stream.

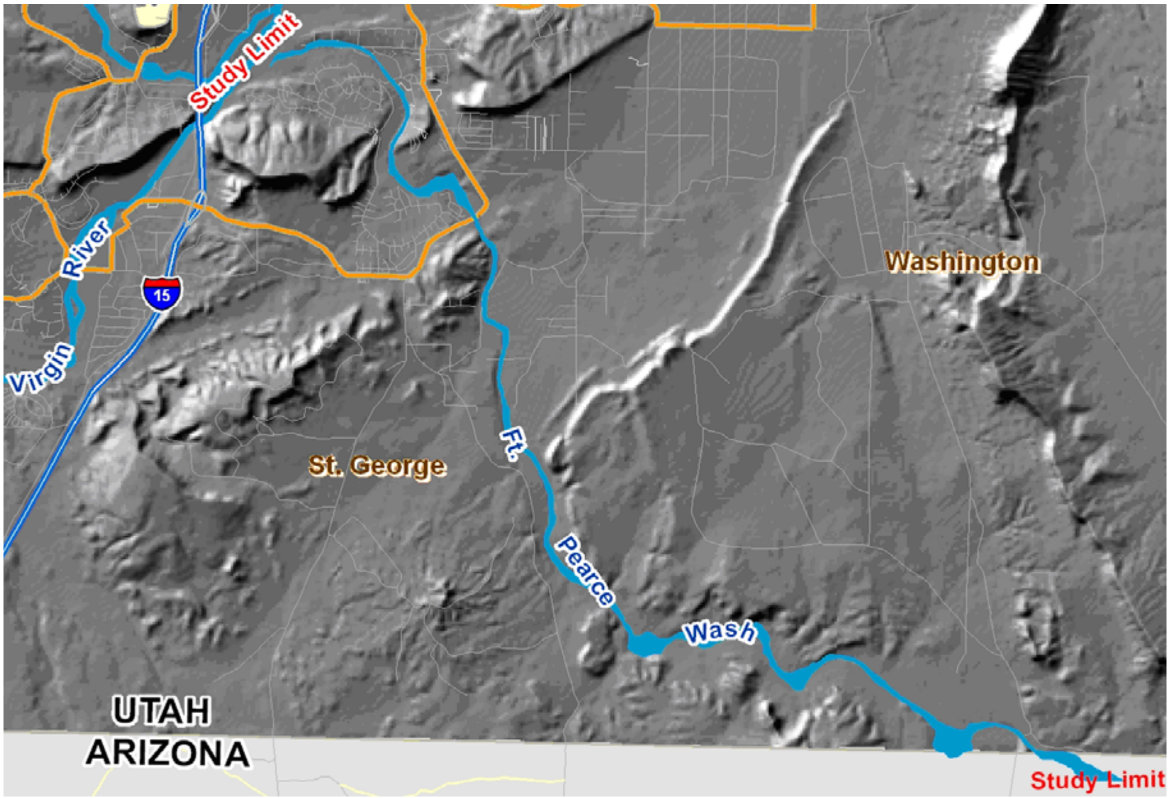

Figure 1. Vicinity map for Fort Pearce Wash.

[1] The upstream study limit is located at the crossing of the Utah-Arizona state line at the southern boundary of Section 31/32, Township 43 South, Range 14 West. East of the upstream study limit, Fort Pearce Wash re-enters Utah and flows within Washington County for several miles that are not addressed in this study.

1.2. Previous Studies

1.2.1. 1997 Study

The City of St. George previously completed a river stability study for the Fort Pearce Wash called *River Stability Study – Virgin River, Santa Clara River and Ft. Pierce Wash* (CH2M HILL, 1997; hereafter, "the 1997 study"). The 1997 study evaluated the geomorphology and historical behavior of the Fort Pearce Wash, summarized the available hydrologic data for the watershed, and documented existing conditions along the watercourse. The major work products for the 1997 study were river management recommendations and erosion hazard zone delineations for Fort Pearce Wash.

1.3. Study Objectives

The primary objective of this evaluation of Fort Pearce Wash is to update the previous erosion hazard zone delineation. An update is needed for the following reasons:

- The study limit is extended from the 1996 City of St. George incorporation limit to the Utah-Arizona state line. The erosion hazard zone delineation was modified and extended upstream approximately 5.1 miles to the new study limit.
- The study area now includes a short reach within unincorporated Washington County. River management recommendations that could be implemented by Washington County are now included.
- Additional years of record are available from which to assess river behavior. Plots of historical channel positions and profiles are provided.
- Significant changes in channel conditions have occurred due to increased in-stream aggregate mining, channelization, and tamarix removal. A sand and gravel mining plan for the Fort Pearce Wash is included as a separate chapter in this report.
- River management strategies within the City of St. George and Washington County have evolved in response to the disastrous flooding on the Santa Clara and Virgin Rivers in January 2005.

This report updates and supplements, rather than replaces, the 1997 CH2M HILL study. As such, text, tables and other information for the Fort Pearce Wash available in the 1997 study are not repeated in this document. Copies of the 1997 report are available from the City of St. George.

1.4. 2005 Flood Impacts

The January 2005 floods were not as significant or damaging on the Fort Pearce Wash as they were on the Santa Clara and Virgin Rivers. The USGS published a peak flow estimate of 440 cfs, which is less than a 2-year event, for Fort Pearce Wash near the upstream study limit.[2] During January 2005, no homes along the Fort Pearce Wash were inundated by flood waters or damaged by riverine erosion, and no bridges or other public

[2] http://ut.water.usgs.gov/FLOODING/Virgin_flood.html

infrastructure were destroyed. Nevertheless, potential for large floods and lateral erosion exist along the study reach, as described in the remainder of this report.

2. GEOMORPHIC EVALUATION

2.1. Available Data

2.1.1. Topographic Data

Topographic mapping for the study reach is summarized in Table 1. Topographic data were used to generate longitudinal profiles of the river as well as to support interpretations of the local geology and geomorphology of the river corridor.

Table 1. Topographic Data

Year	Source	Description
1978	USGS St. George 7.5’ Quad USGS Washington Dome 7.5’ Quad	20-ft. contour interval
2003	St. George City	2-ft contour interval
2006	St. George City	2- & 4-ft contour interval

2.1.2. Photographic Data

Aerial photography served as a foundation of the historical channel position analysis. Table 2 lists the aerial photographs collected for the study reach. Side-by-side comparisons of the historical aerial photography are attached as a separate document.

Table 2. Historical aerial photos		
Photo Year	Source	Description
1952	USDA	Black & white, stereo
1960	USDA	Black & white, stereo
1967	USDA	Black & white, stereo
1976	USDA	Black & white, stereo
1977	USDA	Black & white, stereo
1984	UDSA	Black & white, stereo
1993	USDA	Black & white, stereo
1994	City of St.George	Black & white, stereo
1995	USDA	Black & white, stereo
1999	City of St.George	Black & white, orthophoto
2003	City of St.George	Color, digital orthophoto
2004	State of Utah, SGID	Color, digital orthophoto
2005	City of St.George	Color, digital orthophoto
2006	City of St.George	Color, digital orthophoto

2.1.3. Geology

The Utah Geological Survey (UTGS) published two geologic maps (Table 3) that cover the study area. Information derived from the geologic mapping included the following:

- Geologic control (bedrock) on lateral river movement.
- Relative age of terraces and geomorphic surfaces abutting the river

Table 3. UTGS geologic maps			
UTGS Map	Author	Year	Scale
Interim Geologic Map of the St. George Quadrangle, Washington County, Utah	J.M. Higgins and G.C. Willis	1995	1:24,000
Geologic Map of the Washington Dome Quadrangle, Washington County, Utah	J.M. Hayden	2005	1:24,000

Table 3 lists the geologic units generally within the modern geologic floodplain along Fort Pearce Wash. The Quaternary-aged alluvial units (Qa in Table) were all considered erodible, with the degree of erosivity decreasing with age, elevation and induration. Several bedrock units also abut the stream corridor, but were not distinguished by rock type or geologic age for the purposes of this study. Bedrock units were considered non-erodible.

Table 3. UTGS surficial geology			
Map Unit ID	Name	Age	Description
Qal_1	Alluvial stream deposits	Quaternary	Moderately to well-sorted clay to gravel deposits in and adjacent to active drainages
Qat_{2-3}	Stream-terrace deposits	Quaternary	Riverine alluvium of increasing age, elevation and carbonate accumulation
Qao	Older alluvial deposits	Quaternary	Remnants of older alluvial deposits
Qae	Eolian sand & alluvium	Quaternary	Well to very well sorted fine sand

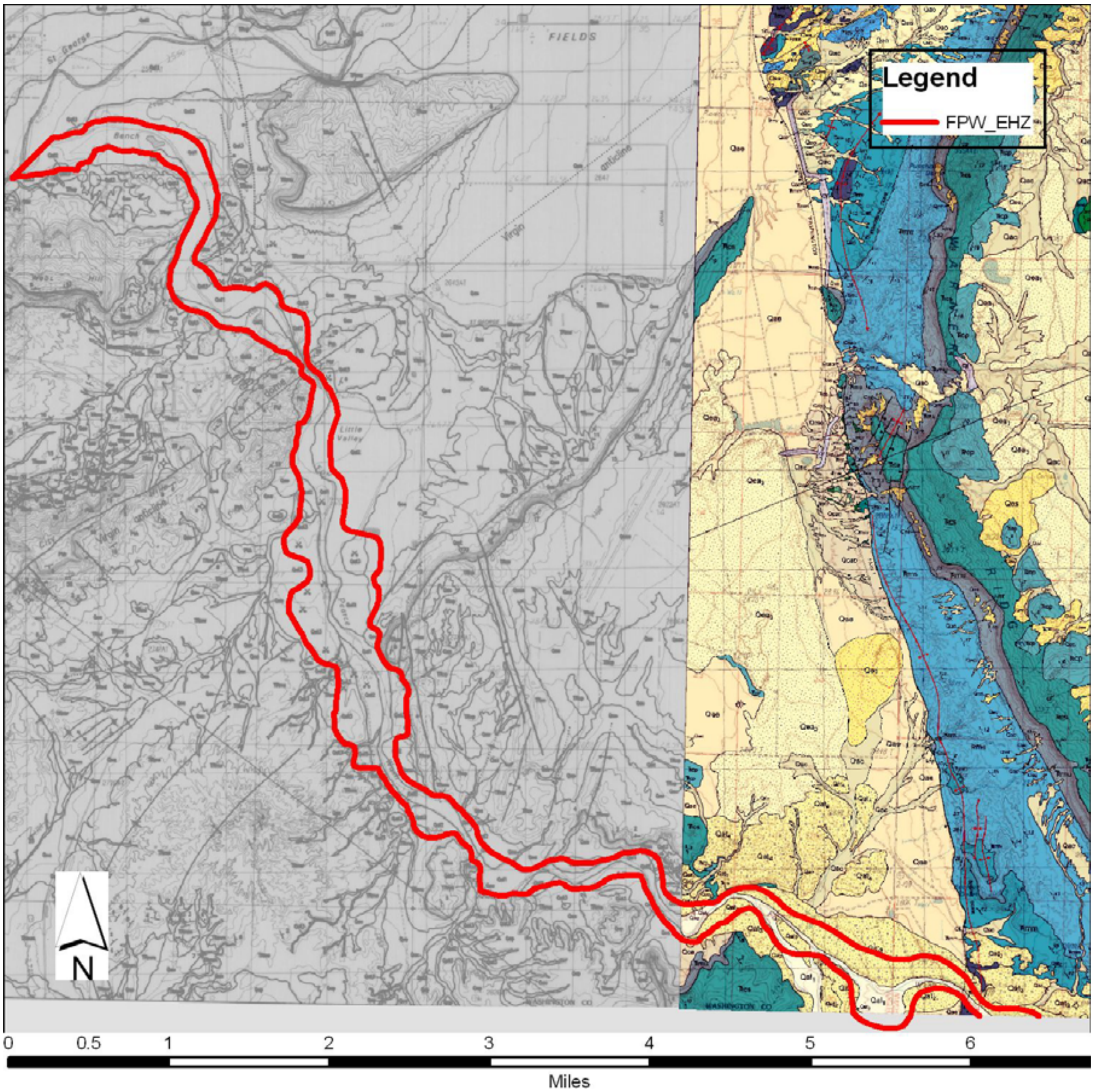

Figure 2. Utah Geological Survey geologic mapping for the Fort Pearce Wash study area. Only one map was published in color.

2.1.4. Hydrology

Hydrologic data for Fort Pearce Wash are available from the USGS (Table 5 and 6) and from the FEMA Flood Insurance Study (Table 7). The most recent discharge estimate by the USGS is nearly double that used in the Fort Pearce Wash Flood Insurance Study. Dates of large floods on Fort Pearce Wash are listed in Table xx.

Table 5. USGS Gage Data for Station 09408195: Fort Pearce Wash near St. George Utah

Drainage area (square miles)	Mean basin elevation (NGVD 1929)	Years of peak record used in analysis	Peak discharge from 2005 flood (cfs)	Gage height (ft)
1,349	5,119 ft	8	440	5.58

Table 6. USGS Peak Discharge Estimate for Fort Pearce Wash in CFS (#09408195)					
2	**5**	**10**	**25**	**50**	**100**
Regression Equation Results					
4,180	8,240	11,500	16,800	21,500	26,300
Analysis of gage record following Bulletin 17B					
1,250	3,790	6,940	13,500	20,900	31,200
Weighted estimate (recommended by USGS)					
1,310	4,240	7,940	14,700	21,200	28,500

FEMA recently adopted revised discharges for Fort Pearce Wash, which resulted in a significant increase in the 100-year peak discharge compared to the old Flood Insurance Study (Table 7), although the values are somewhat less than those recommended by the USGS.

Table 7. FEMA Peak Discharge Estimate for Fort Pearce Wash in CFS						
Recurrence Interval	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**
Previous FEMA Estimate	2,340	-	6,360	-	11,800	14,700
Current FEMA Estimate	-	-	7,840	-	17,200	22,000

All of the largest floods on the Fort Pearce Wash occurred in late summer during "monsoon" type rainfall events (Table 8), with all but one during the month of August. The largest measured flood occurred in August 1977 and had a peak of about 15,000 cfs.

Table 8. Large Floods on Fort Pearce Wash			
Date	**Peak**	**Comments**	**Source**
August 1902	Unknown	Two floods occurred	Newspaper
1951	13,000 cfs	2nd largest in record	USACE, 1973 (FIS)
August 25, 1955	7,500 cfs		USACE, 1973 (FIS)
August 11, 1959	3,180 cfs		USACE, 1973 (FIS)
September 14, 1962	5,500 cfs		USACE, 1973 (FIS)
August 14, 1964	8,760 cfs		USACE, 1973 (FIS)
August 1977	15,000 cfs	Flood of record	USACE, 1991
August 17, 1989	5,000 cfs	Golf course damaged	USACE, 1991
Information obtained from Table 4-2 of the 1997 CH2M HILL report unless otherwise noted.			

2.2. Historical Evaluation

The primary source of historical information on channel behavior along the study reach was from aerial photographs, although some historical written descriptions of Fort Pearce Wash were available. The 1997 CH2M HILL report included a detailed summary of historical channel changes as well as a chronology of channel change interpreted from aerial photographs dating to 1938. The following key historical observations were made in the 1997 CH2M HILL report:

- Extensive tamarix invasion of the channel and floodplain has occurred from the Virgin River confluence to upstream of River Road. The reaches of tamarix infestation are coincident with the reaches in which irrigation tailwater and aggregate mine processing water is discharged. The reaches which remain ephemeral have only minimal tamarix growth.

- Construction of a golf course, flood control levees, a major sewer line, two bridges, and homes downstream of River Road has narrowed and constrained the natural geologic floodplain.
- Extensive in-stream sand and gravel mining has occurred and continues to occur upstream of the River Road Bridge.
- Minimal channel change was observed during the period of record upstream of the Horseman's Ranch area.

The most significant channel changes on the Fort Pearce Wash since the 1997 CH2M HILL report was completed include the following (Figure 3):

- Increased sand and gravel mining. The number and size of aggregate mines has increased since 1997, and the mining area was extended upstream several thousand feet. Currently, at least two mining interests plan to extend mining even further upstream along the floodplain.
- Mining channelization plan. Upstream of River Road, Fort Pearce Wash was channelized by direct excavation of a deeper, narrower, more defined channel. The excavated channel consists of an earthen, roughly trapezoidal cross section with no engineered grade control structures. The channelization project was intended to remove the floodplain from the Horseman's Ranch area and confine the 100-year discharge to the main channel.
- Tamarix removal. A large-scale tamarix removal and channelization project was recently initiated on the Fort Pearce Wash downstream of River Road. The excavated channel consists of an earthen, vegetated, terraced cross section with a variable cross section and capacity. Smaller scale tamarix removal projects occurred at least twice since 1997 in the reach immediately upstream of the River Road Bridge.

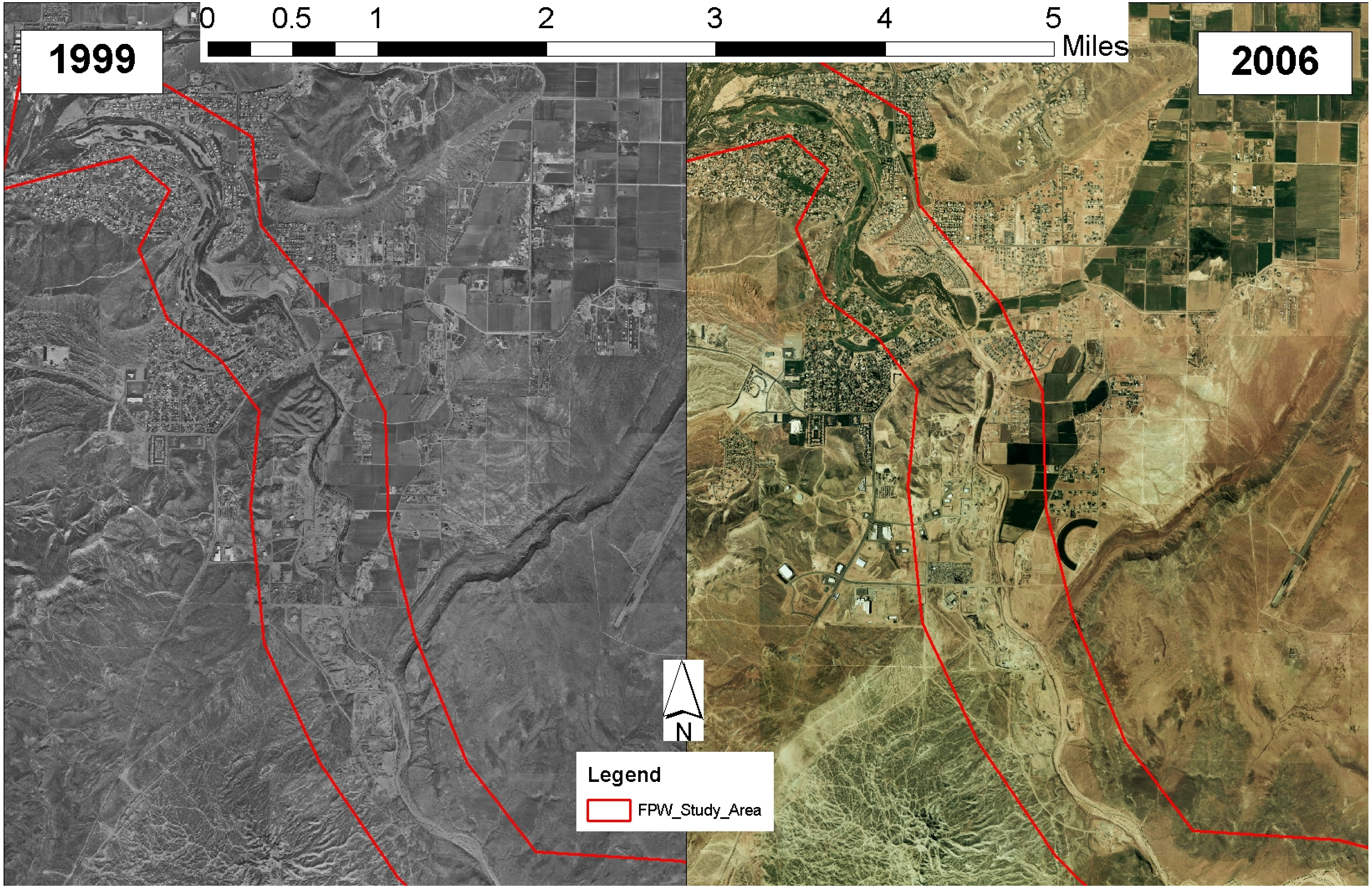

Figure 3. 1999 & 2006 side by side photos showing changes in most actively disturbed reaches.

Humans were the primary agent of channel change in the study reach during the past 69 years. Human impacts on stream morphology included in-stream mining, channelization, discharge of irrigation tailwater, levee construction, road crossings, and floodplain encroachment for a variety of development types. The undisturbed reaches of Fort Pearce Wash experienced relatively little lateral or vertical channel change during the period of record. Side-by-side plots of all of the years of coverage by historical aerial photographs are attached to this report in the Exhibits Maps Book.

To quantify the extent and magnitude of historical channel change, the active channel corridor was delineated on each of the sets of historical aerial photographs listed in Table 2. The active channel corridor is defined as the portion of the floodplain in which sediment is actively eroded and transported and which is dominated by channel processes. The active channel corridor includes the main channel and the overbank channels that are most frequently inundated. A plot of the channel limits for the entire record is provided in Figure 4. As shown in Figure 4, particularly when viewed at the scale displayed, it is evident that lateral channel change along Fort Pearce Wash has been constrained with a relatively defined corridor.

The maximum measured channel movement during the 54 year period of photographic record at any point in the study reach, not including man-made river realignments was only about 150 feet. Man-made realignments have shifted the active channel by up to 700 feet in several places. Much of the difference in channel position shown in Figure 4 is the result of incomplete rectification, rather than actual channel movement.

Vertical changes in the channel bed elevation are shown in Figure 5. Fort Pearce Wash has experience net long-term degradation downstream of Fort Pearce Drive, net aggradation between Fort Pearce Wash and River Road, net degradation in the mining reach, and very little change upstream of the mining reach. A significant feature shown in the profile is the rapid filling of the mined in-channel pit at the downstream end of the mining reach. Fill of about 10 feet occurred between 2003 and 2006, during a period that lacked any major floods.

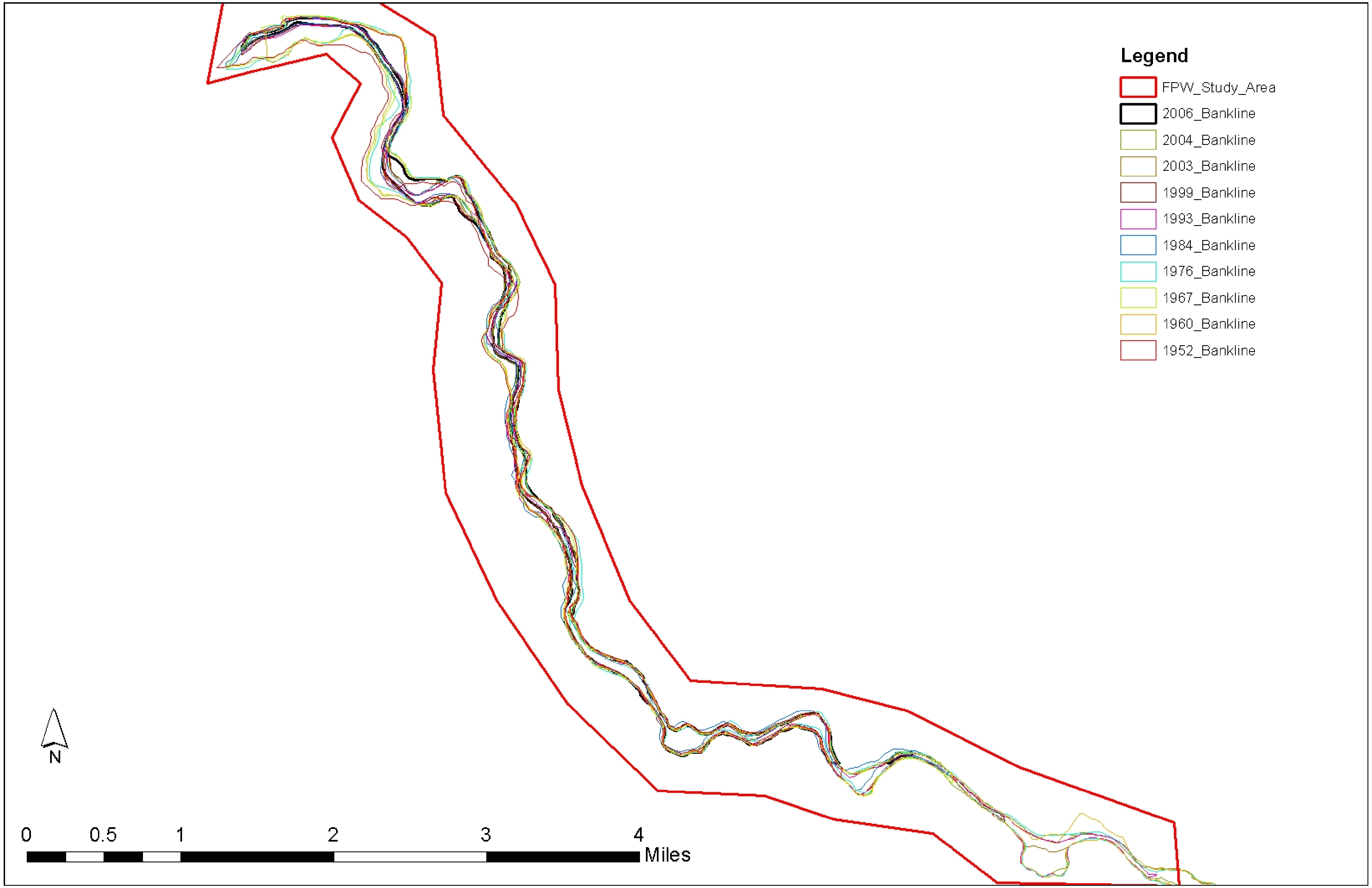

Figure 4. Historical active channel boundaries, 1952-2006, for Fort Pearce Wash. More detailed plots of channel position and historical aerial photographs are provided in the Exhibits Map Book.

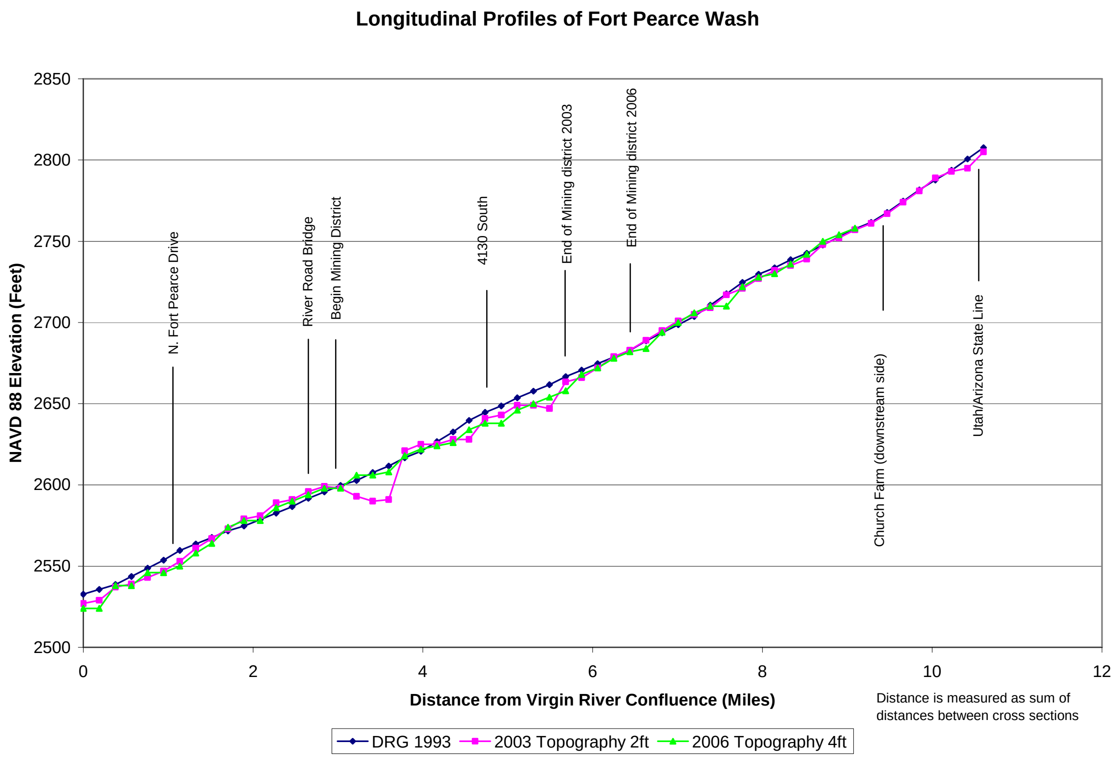

Figure 5. Longitudinal profiles of Fort Pearce Wash, 1993-2006.

2.3. Expected Behavior – Natural Geomorphic Trends

Rivers usually behave similarly to their historical trends, except where the natural system has been disturbed by human activities. Prior to human activity, Fort Pearce Wash was a relatively straight ephemeral stream generally subject to a small degree of lateral movement during most floods with some potential for extreme lateral movement during large floods or over longer periods of time. The bed and banks of the wash are typically composed of unconsolidated alluvium (sand, gravel and cobbles) that are subject to lateral erosion and scour. Bedrock which crops out in the banks or at the margin of the geologic floodplain provides a natural limit to lateral erosion. The bank stability assessment performed for the 1997 CH2M HILL report indicated that flood flow velocities typically exceed erosive thresholds and that the bank erosion potential ranges from low to extreme, with the highest potential for unstable banks occurring where long-term degradation has over-steepened the banks. Despite the relatively consistent channel corridor width delineated and displayed in Figure 4, there are a few reaches that give an indication of a more extreme range of channel movement possible along Fort Pearce Wash.

The first reach is at an unusual bend with a meander amplitude of about 2,300 feet located adjacent to the church farm property. The meander in this reach stands in stark contrast to the remainder of the study reach which has a relatively low sinuosity and low meander amplitude (Figure 6). The meander developed prior to 1960, the earliest year of aerial photographic or map coverage for this reach, but appears to be a freshly formed, active feature in the 1960 aerial. The cause of the meander near the church farm property is not known, but our investigation could find no link to any known human activity[3] or geologic phenomenon.[4] Therefore, the meander should be viewed as an indication of the potential for future channel movement or meander formation within the study reach, with half the meander amplitude (~1,300 ft) as an estimate of the magnitude of potential future lateral movement. It was noted that another meander feature of similar size and shape in a slightly different geomorphic setting occurs several miles upstream of the study limit. These abrupt anomalous meanders may be end members of the sharp bend patterns observed elsewhere along Fort Pearce Wash, as described in the next paragraph. Possible causes of the meander feature may include response to a temporary blockage of the channel that deflected flow against an erodible bank[5] or tectonic forces (faulting) that initiated valley slope changes initiating a geomorphic response in the channel pattern. As shown in Figure 6, the upstream portion of the meander feature was filled and replaced by farm fields between 1960 and 1976. The river has not reclaimed any of the encroached meander since that time.

The second indication of the potential for lateral channel movement on Fort Pearce Wash can be interpreted from the large variability in active channel corridor width observed at most channel bends in the study reach (Figure 7). Straight reaches generally consist of a straight, well-defined main channel with an average active corridor width of about 150 to 200 feet. The active corridor width, as measured from the outer limits of the multiple active flow paths, averages about 450 to 750 feet. The width differential between straight reaches and bends is up to 600 feet at certain locations. Therefore, it may be assumed that as bends develop or evolve, width increases of up to 600 feet might occur.

[3] No evidence of human activity was identified in any of the historical aerial photographs and maps. There were no roads leading directly to the area, the reach is not located near historic Fort Pearce, and is located in a portion of Washington County that is and was uninhabited prior to 19xx.
[4] Geological phenomenon considered included tectonic activity, change in soil erodibility, slope change, change sediment supply, tributary sediment deposition, and position relative to upstream bedrock canyons. Without regard to concepts such as complex response or equifinality, all of the possible geological causes can be eliminated by observation and comparison with the remainder of the reach. The most plausible explanation considered was a temporary blockage of the channel that directed flow against one of the banks, with ensuing lateral erosion.
[5] Similar processes occurred on the Santa Clara River during the January 2005 floods.

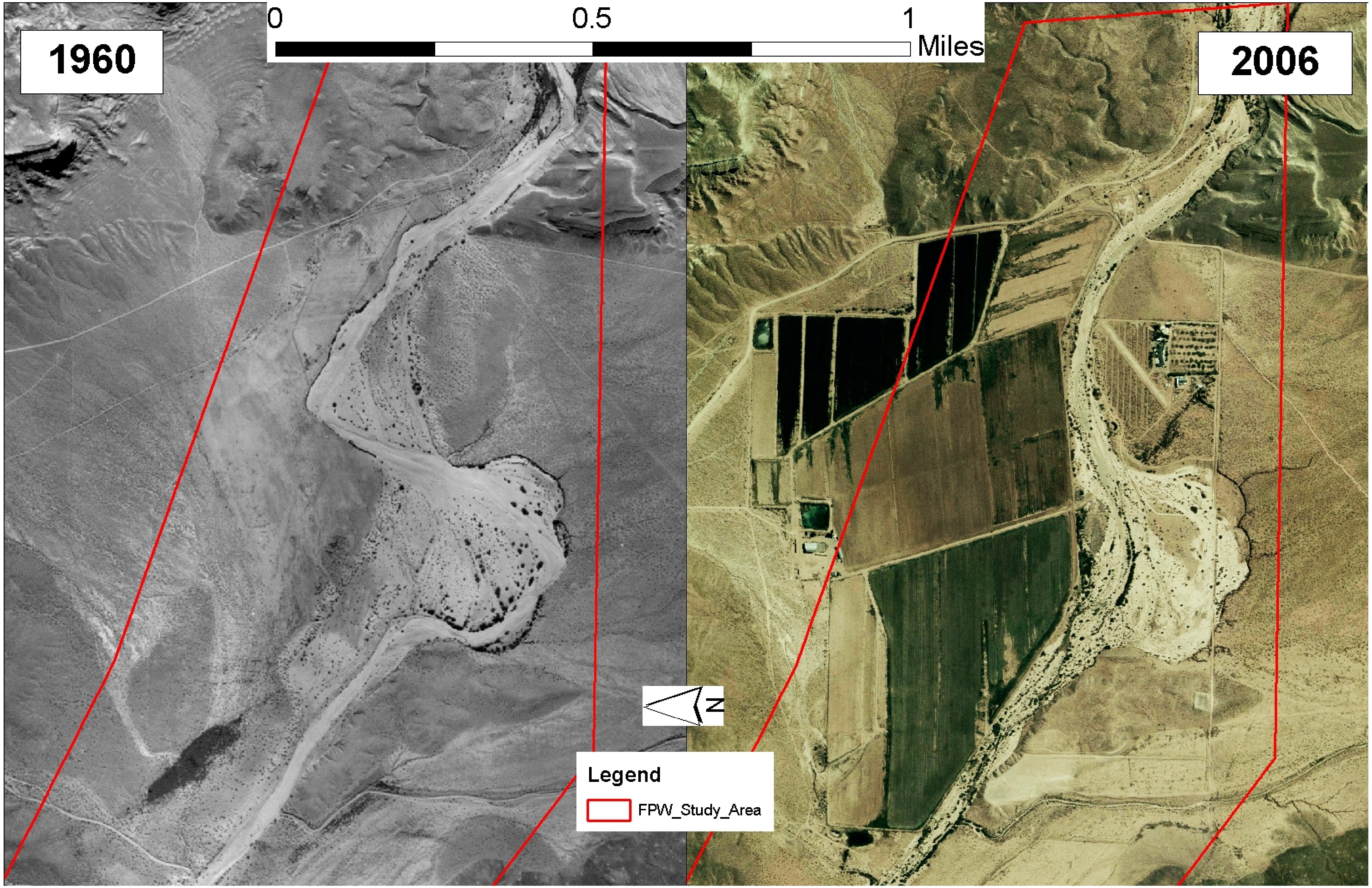

Figure 6. Side by side views of 1960 & 2004 aerials at major bend erosion.

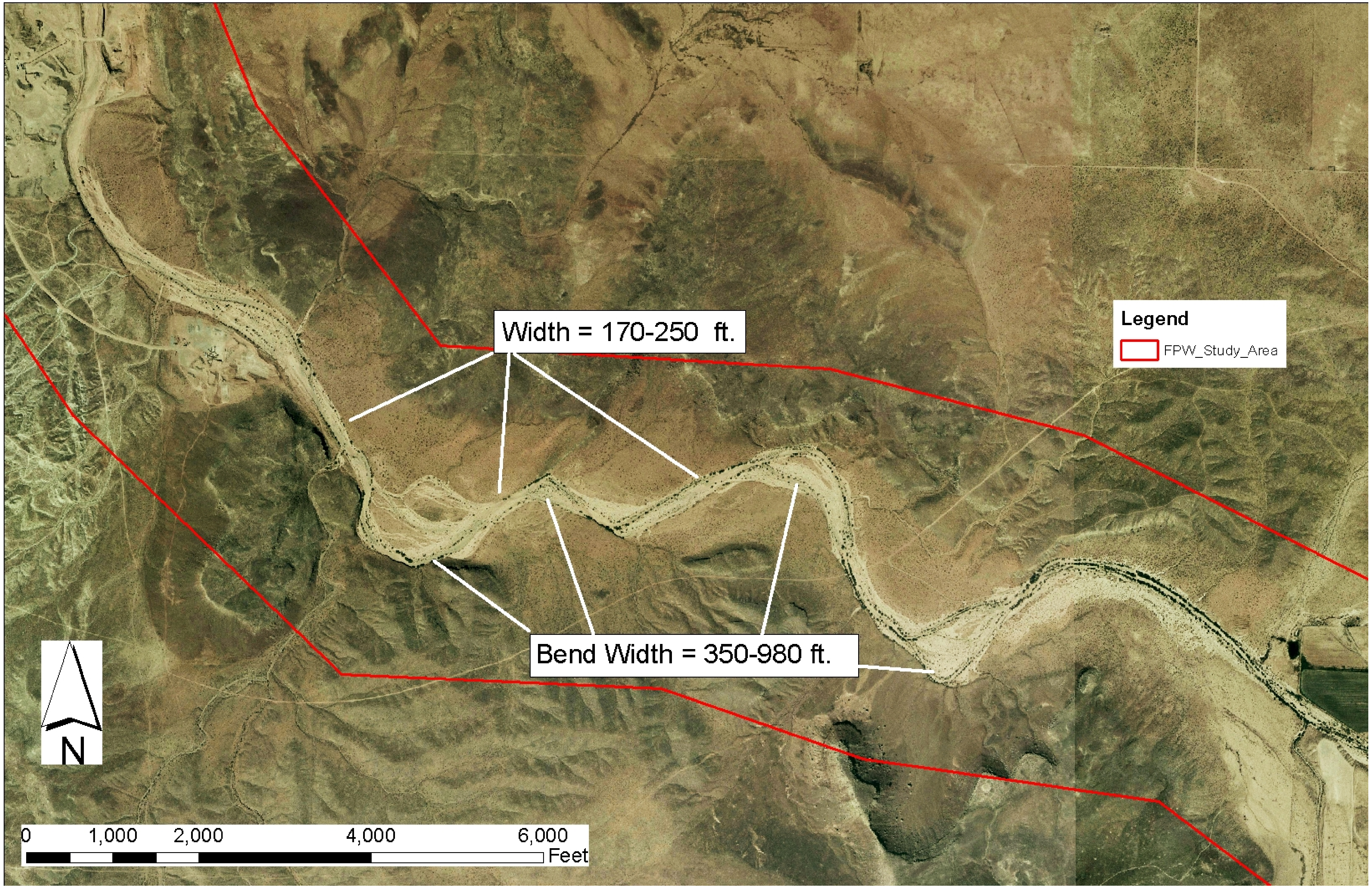

Figure 7. 2004 aerial showing width variation as measured in straight reaches and bends.

The third indication of (long-term) potential lateral migration comes from the width of the modern geologic floodplain. The modern geologic floodplain (Qa1, Qa2 – See Figure 2) deposits represent former active channels and floodplains, i.e., the position of the active channel over recent geologic history. These geologic surfaces typically have minimal cohesion or erosive resistance and are composed of materials that are readily transported by the river. Therefore, they are vulnerable to future erosion and may be used as a proxy for lateral channel movement over long planning periods.

2.4. Expected Behavior – Response to In-Stream Mining and Channelization

Most of the Fort Pearce Wash study reach has been extensively altered by in-stream sand and gravel mining or channelization. In the near future, it is likely that the river will be entirely channelized to some degree from the Virgin River confluence to the church farm property. The expected river response within channelized reaches will be somewhat different than the expected river behavior within relatively undisturbed reaches. In general, channelization and mining has made the river and/or floodplain narrower and deeper, with higher flood velocities and less available sediment supply. As a consequence of these changes, the channel banks tend to more vulnerable to lateral erosion and failure, although the expected lateral distance over which erosion is likely to occur will tend to be less than for the natural floodplain condition, at least where the channelization or mining increased the channel capacity and eliminated the potential for overbank flooding. Where channelization has inadequate capacity and there is a high likelihood of overbank flooding, there will be a high potential for channel avulsions, particularly where grading or low levees hydraulically separate the main channel and the floodplain.

The expected geomorphic response to in-stream sand and gravel mining is long-term scour and degradation. Long-term scour in the mining reach was demonstrated in the longitudinal profile plots in Figure 5. The response to scour and degradation is similar to that described for channelization above. In-stream commonly causes two forms of long-term degradation, headcutting and tailcutting. Headcuts form as flood water spills into an in-stream pit excavation or into a pit that has been breached by lateral channel migration. Acceleration of flow over the lip of the pit results in high velocities that transport sediment from the stream bed into the excavation. Headcuts have been known to travel miles upstream of large, breached pits in a single flood. Headcut depth is commonly thought to be limited to half the pit depth (below the channel bed elevation), but may in fact be greater for large actively mined pits. Tailcutting occurs when flood waters exit in in-stream or breached pit. Because most of the stream's bed-material load tends to be deposited in the low-energy environment of the pit, flood water leaving the pit is sediment deprived, which leads to scour and lateral erosion. Tailcuts tend to be shallower than headcuts, but many extend for long distances downstream, depending on the volume of the excavation relative to the sediment supply.

Channelization and in-stream mining both result in long-term degradation of the channel bed. Such degradation removes the basal support of the banks and leads to bank failures. Note that while human activities tend to make the channel banks more vulnerable to scour and increase the rate of bank failures, on braided systems the overall width of the erosion hazard zone may decrease due to increased channel capacity and narrowing caused by the degradation and encroachment.

3. FIELD INVESTIGATION

3.1. Field Observations

Detailed field visits were conducted from August 30 to September 1, 2006. The field visit consisted of walking the entire study reach, observing channel and floodplain conditions, and documenting significant geomorphic features. The following field observations were made:

- Recent channelization/tamarix removal on golf course. The golf course channelization reach was not yet in equilibrium during the field visits. Both the bed and banks of the newly excavated channel are actively eroding. Cut banks were observed on both sides of the channel in many places. A number of small headcuts were observed throughout the reach, in addition to other evidence of local and general scour. The river appears to be trying to move toward a more sinuous channel pattern with pool and riffle slope breaks.
- Recent flood impacts. Recent flooding, probably the August 12, 2006 event, eroded the bed and banks of the recently channelized reach downstream of River Road and deposited thick layers of fine-grained sediment within the remaining tamarix forests. Upstream of River Road, the recent flood had less significant impacts but did cause some localized bank failures, scour of overbank channels, and headcut migration. The USGS reported a peak discharge of 1,550 cfs and a hydrograph duration of about 2 hours for the August 12, 2006 event.
- Grade control. Grade control is provided by the box culvert at Fort Pearce Drive and by a concrete weir at a cart/pedestrian bridge on the golf course. The concrete weir at the cart bridge closest to the Virgin River, which apparently was designed as a fish barrier, was flanked by lateral erosion and was no longer is effectively controlling long-term scour. During subsequent visit, the lateral flanking has been repaired.
- Golf course elevation. Many of the golf course fairways appear to be at lower elevations than the main channel of Fort Pearce Wash, particularly where excessive tamarix occurs along the watercourse, creating a perched channel condition. Channel avulsions and extreme floodplain erosion are likely where the main channel is perched above the floodplain.
- Natural channel pattern. Upstream of the Quality Materials excavations, the channel has a chute and splay braided channel pattern. The chute and splay pattern consists of relatively straight single defined channel reaches interrupted by more densely vegetated, highly braided reaches. Flows leaving the braided reaches re-form into a single channel pattern (chutes). Within the chute reaches, the channel slope is broken up by irregularly spaced (dry) pools and riffles. The overall channel pattern has low sinuosity (< 1.1) where most bends are dictated by the regional bedrock geology.
- Main channel capacity. Field evidence suggests that the August 2006 flood overtopped the main channel and inundated the floodplain in many places,

suggesting a main channel bankfull capacity of less than the 2-year event in the less disturbed reaches.

3.2. Changes Since 1997 Study

The most significant changes in channel conditions since the 1997 study include the following:

- Golf Course Channelization. A permit for construction of a terraced, earthen channel between River Road and the Virgin River confluence was granted to St. George City. At this time, the grading for the channelization is partially complete.
- Tamarix Removal. In conjunction with the golf course channelization, extensive stands of tamarix have been removed between River Road and the Virgin River confluence. At this time, the tamarix removal has not yet been completed. Tamarix has been removed at least twice from the reach immediately upstream of River Road as part of the effort to control excess sediment deposition at the River Road Bridge.
- Mining Channelization. The reach upstream of River Road adjacent to the Horseman's Park area was excavated to create additional channel capacity in an effort to reduce flood hazards in the Horseman's Park area. As shown in Figure xx, over-excavation of the channel was rapidly filled by sediment delivered during the small floods that occurred between 2003 and 2006.
- Increased Aggregate Mining. The mining district along Fort Pearce Wash expanded dramatically since 1997. Existing and proposed mines now extend several miles upstream of the 1997 mined areas.

The net result of these changes was to reduce the length of natural channel reaches and increase the length of disturbed, non-natural reaches.

4. EROSION HAZARD ZONE DELINEATION

4.1. Methodology

An erosion hazard zone was delineated for Fort Pearce Wash from the Virgin River confluence to the Utah-Arizona state line. The erosion hazard zone is an area in which properties or structures have a reasonable expectation to be impacted by lateral erosion over a 50 to 100 year period or the design life of the structure, whichever is longer. The erosion hazard zone should not be interpreted as a "no-build" zone, but instead as an area in which the site design should accommodate or prevent erosion damage without adverse impacts to adjacent properties.

The Fort Pearce Wash erosion hazard zone was delineated using the following resources:

- Recent aerial photographs
- Historical aerial photographs
- Detailed soils mapping by the Natural Resource Conservation Service (NRCS)
- Detailed geologic mapping by the Utah Geological Survey

- Recent topographic mapping
- Historical topographic mapping
- FEMA floodplain mapping
- Field observations
- Engineering judgment

Resources that would have been helpful, but that were not available included construction plans for bridges and grade control structures, levee design plans, sewer line plans, subdivision plans showing bank stabilization measures (if any), detailed hydrologic and flow frequency data for the Fort Pearce Wash watershed, sediment transport modeling, mining plans, channelization plans, and geotechnical soils testing information. It is possible that refinements of the erosion hazard zone delineation could be made with more detailed analyses that included some of the elements not available or authorized for this study.

The erosion hazard zone delineation for Fort Pearce Wash was based on the following assumptions and methodologies:

- Conservative. The erosion hazard zone delineation is conservative with respect to public safety and prevention of flood damages. It is possible that more detailed, site-specific erosion hazard analyses could be conducted to modify the erosion hazard zone limits in some areas if additional site information were considered.

- Defensible. The erosion hazard zones were delineated using techniques that have been applied and accepted by local, state, and federal floodplain management agencies elsewhere in the Southwest. The methodologies have been calibrated by comparison of historical channel behavior, compared favorably to mathematical modeling techniques, and verified by comparison of pre- and post-flood channel movement.

- Advisory. The erosion hazard zones are intended to be used to advise the public of potential risk of future damage by flood-related erosion. There are numerous means to protect properties from erosion. Therefore, with proper engineering, development within the erosion hazard zone is feasible.

- Existing Conditions. The erosion hazard zone was delineated for conditions documented during the August 2006 field visit and by the most recent aerial photography used (2006). It is necessary to periodically update the erosion hazard zones to reflect channel changes caused by flooding and human activities like channelization or mining.

- Historical Channel Movement. The active channel corridor was delineated for each year of coverage by aerial photographs (See Figure xx and the Exhibits Map Book). The erosion hazard zone was delineated to be wide enough to contain all of the known historical active channel limits. In addition, the maximum historical channel movement was applied as a buffer to the existing channel bank line. That is, the erosion hazard zone limit was set back from the existing back at least as far as the maximum historical channel movement within the entire study reach.

- Regulatory Floodplain. The erosion hazard zone is not coincident with the 100-year floodplain, and may be wider or narrower with the regulatory floodplain mapped for FEMA floodplain studies. Where available, hydraulic modeling developed for the FEMA floodplain delineations was considered when delineating the erosion hazard zone. In general, the erosion hazard zone encompasses the regulatory floodway.

- Sand and Gravel Excavations. Sand and gravel excavations were included within the erosion hazard zone due to the potential for breach and capture of off-line pits, or channel movement within on-line pits. It would be possible to remove the sand and gravel mines from the erosion hazard zone if engineered structures were constructed to isolate the pits from the floodplain or from the potential for breaching the pits. A narrow buffer was applied to the outside of the excavation limits to account for collapse of pit walls if the pits were to be captured and filled by flood waters. If excavations are expanded beyond the limits shown on the 2006 aerial photographs, the erosion hazard zone should be moved proportionately.

- Geology. Alluvial surfaces such as stream terraces were considered to be erodible. Older surfaces were considered to be less erodible due to increased induration, calcification, and clay accumulation. Older surfaces also tend to erode laterally at slower rates because they tend to be higher and thus deliver greater volumes of eroded material per unit of lateral movement. Bedrock was considered non-erodible within the time scales considered for the delineation.

- Channel Pattern. The erosion hazard zones tend to be wider on the outside of bends compared to the inside of bends to account for likely channel pattern evolution. The active corridor width in bends, as described above, was used as an indication of long-term potential lateral movement.

- Tamarix. Dense tamarix can slow flood velocities and induce sediment deposition on floodplains. However, due to long-term scour that undercuts the banks and root zones, tamarix provides only marginal increases in bank stability along the main channel. Furthermore, dense tamarix has been shown to block flood conveyance and cause erosive flood waters to be diverted along the outside of the tamarix forest. Finally, tamarix eroded from the floodplain and channel banks can accumulate on bridge piers and hydraulic structures, resulting in flow diversions and channel avulsions. Therefore, in general, tamarix was considered to be a destabilizing force with respect to channel stability.

- Golf Course. It was assumed that the proposed channelization project located immediately downstream of River Road will not have capacity for the 100-year discharge recently estimated by the USGS and thus will be at risk of overtopping. The U.S. Army Corps of Engineers (1991) estimated the capacity of the levees downstream of River Road at about the 4-year recurrence interval. In addition, because engineering information was not available for the channelization project, because field observations indicated that bank protection was not included in the design, and because parts of the golf course are lower than the main channel, it was assumed that floods could overtop the channel and result in avulsive flood erosion anywhere within the natural floodplain downstream of River Road. Finally, the low capacity of the bridges may result in diversion of flows outside the main channel. Thus, most of the golf course is mapped within the erosion hazard zone. Upon completion of the channelization project, this assumption should be re-evaluated and any necessary changes in the erosion hazard zone be made.

- Smoothing. Rivers tend to form smooth curvilinear patterns, rather than follow rectilinear or orthogonal lines typical of property and jurisdictional boundaries. In some places, the erosion hazard zone boundary was smoothed to better reflect a more riverine appearance.

4.2. Results

The updated erosion hazard zone for Fort Pearce Wash is shown in Figure 8. The erosion hazard zone differs slightly from the 1997 CH2M HILL report primarily due to better available topographic mapping and better map rectification procedures than were available a decade ago.

5. RECOMMENDED RIVER MANAGEMENT PLAN

The updated Fort Pearce Wash erosion hazard zone is recommended for adoption by the City of St. George and Washington County. General river management alternatives are discussed elsewhere in the Master Plan Report as well as in the 1997 CH2M HILL report. A sand and gravel mining plan for the Fort Pearce Wash is discussed in a separate chapter of the Master Plan Report.

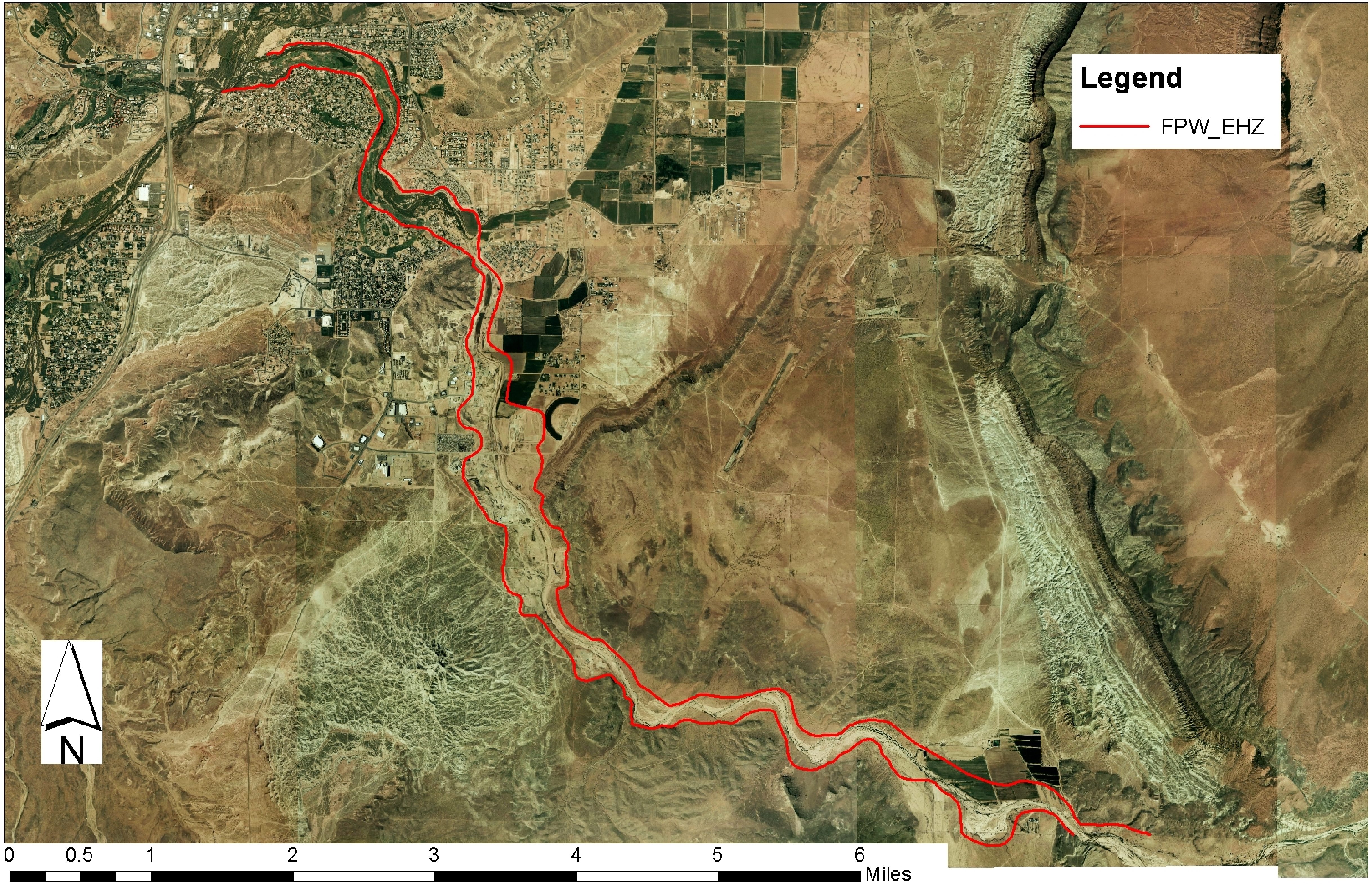

Figure 8. Recommended (red) and 1997 (purple) erosion hazard zone delineations for Ft Pearce Was