REGIONAL FLOOD
CONTROL DISTRICT

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May 4, 2006

FEMA Depot
3601 Eisenhower Avenue
Alexandria, VA 22304-6425

Attention: LOMR Depot

RE: Requests for Letter of Map Revision - Virgin River, City of Mesquite, Clark County, NV

To Whom It May Concern:

On July 14, 2005 the Clark County Regional Flood Control District entered into an Agreement for Professional Services with PBS&J, Inc. to prepare a request for map revision for Virgin River, City of Mesquite, Clark County, NV. New hydraulic models are being submitted to detail the condition of the watercourse as it now exists after major flooding that occurred during the winter of 2004/2005. New topographic data was obtained immediately following the event and was used for this analysis.

Inasmuch as this request is based upon new topographic data obtained after a flood event causing natural changes within an existing Special Flood Hazard Area , it is expected that this request is fee exempt in accordance with 44 CFR 72.5. If that is not the case, please request payment of the appropriate amount in writing. Payment will be processed and transmitted immediately thereafter.

Please accept this study to support this request for a Letter of Map Revision. If you should need further information, please call.

Sincerely,

Kevin Eubanks, P.E., CFM
Assistant General Manager

c: Sacha Tohme, Michael Baker, Jr., w/o enclosure
Allen Bell, City of Mesquite Public Works, w/o enclosure
Denis Cederburg, Clark County Public Works, w/o enclosure
Matt Baird, PBS&J, w/o enclosure

KLE:jb

P:\Staff Inbox\Kevin\Virgin R Trans 1.doc

600 S. Grand Central Parkway, Suite 300 • Las Vegas, Nevada 89106-4511
(702) 455-3139 • FAX: (702) 455-3870
Website: *http://www.regionalflood.org*

Virgin River
Request for Letter of Map Revision
May 2006

Prepared for:

REGIONAL FLOOD CONTROL DISTRICT

Prepared by:

PBSJ

2270 Corporate Circle, Suite 100
Henderson, NV 89074
(702) 263-7275

May 2006

PROFESSIONAL ENGINEER-STATE OF NEVADA
HARSHAL B. DESAI
Exp. 12-31-08
CIVIL
No. 17468

05-02-06

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Section 1
Introduction

1.1 Project Background and Purpose

The Virgin River in the vicinity of Mesquite, Nevada experienced a major flood near the magnitude of the 100-year frequency event in January, 2005. In some areas the flooding limits were wider than the mapped 100-year regulatory Federal Emergency Management Agency (FEMA) Special Flood Hazard Area. It is estimated that the flooding caused damage of more than $1 million in public infrastructure. The flood waters also caused damage to approximately 80 homes located in the northeast part of Mesquite, just west of the Nevada-Arizona border. The majority of these homes were outside the regulatory floodplain. As a result of this flood event the Clark County Regional Flood Control District (CCRFCD) is re-mapping the regulatory floodplain associated with the Virgin River extending from the Nevada-Arizona border to just east of the confluence of Toquop Wash and the Virgin River. Please refer to **Figure 1.1: Vicinity Map** which shows the limit of study.

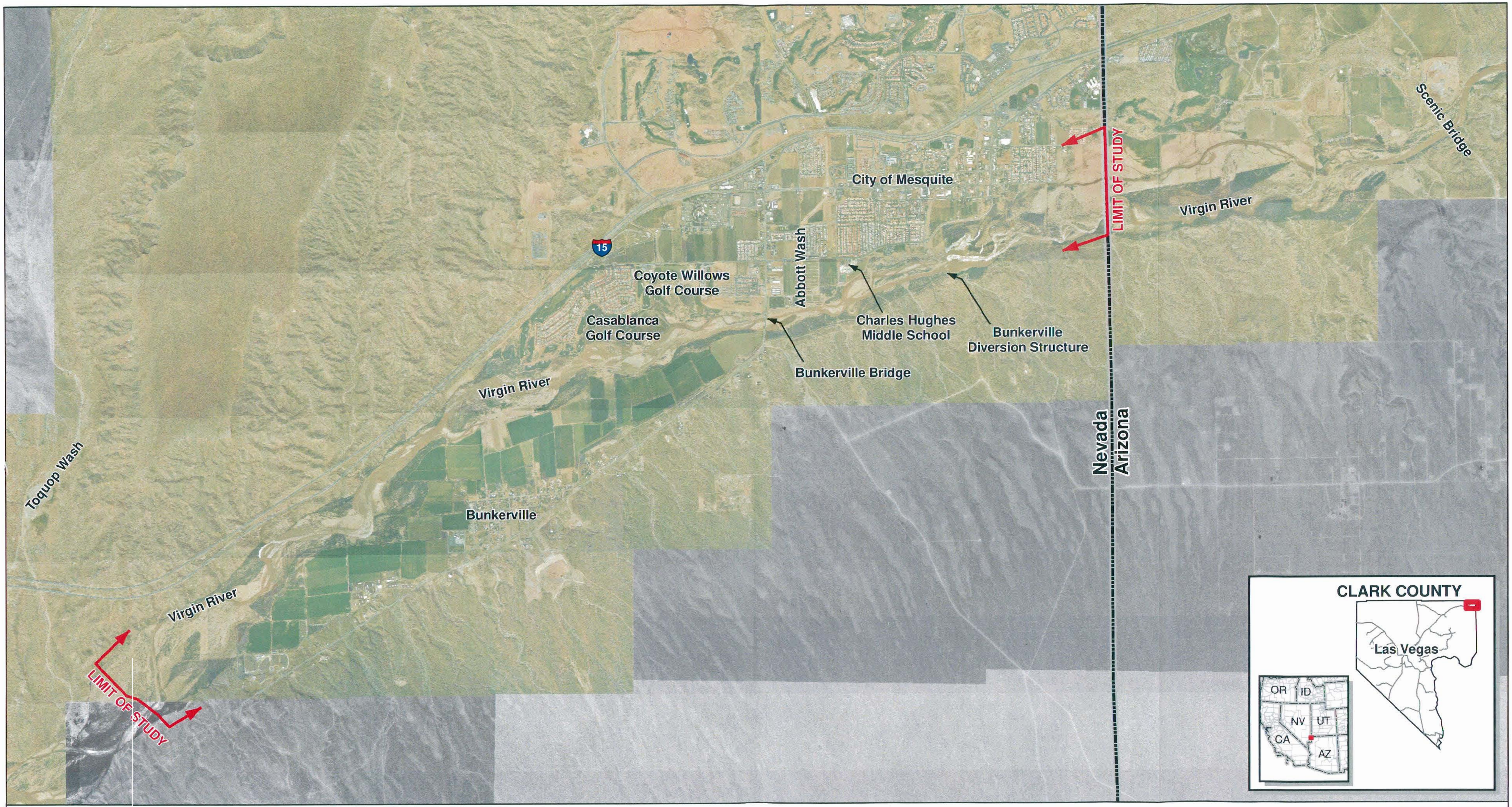
This study is intended to serve as the Letter of Map Revision (LOMR) for the Virgin River through the study reach (which is approximately 9.0 miles long). The purpose of this LOMR is to address needed revisions to the existing FEMA flood zone delineation shown on the current effective Flood Insurance Rate Maps (FIRM) for the City of Mesquite (Community Number 320035) and for Clark County Unincorporated Areas (Community Number 320003), panels 0391 E, 0387 E, 0386 E, 0390 E, 0367 E, 0369 E, and 0370 E. Please refer to **Section 2.4** for FEMA Flood Zone Information and **Figures 2.4 A-B: Effective FEMA Flood Zone Map(s)**.

1.2 Authority for Study

PBS&J was authorized by CCRFCD to perform this LOMR under the contract, *Agreement for Professional Services: Clark County Regional Flood Control District and PBS&J: Flood Hazard Map Revision for the Virgin River, Clark County, and City of Mesquite, Nevada*, dated July 14, 2005.

1.3 Community Coordination

Throughout the course of the project, PBS&J has held monthly coordination meetings with CCRFCD and the City of Mesquite to discuss progress, preliminary results, and to resolve any issues. PBS&J also coordinated with both the Virgin Valley Water District and the Clark County Department of Public Works (CCPW). It should be noted that FEMA Region IX has contracted with HDR Inc. to map the Virgin River floodplain in Mohave County, Arizona, just upstream of the Nevada-Arizona border. As a result, PBS&J has coordinated the mapping efforts with FEMA Region IX / HDR Inc. and has incorporated their comments in the hydraulic model. Public meetings will be held in early June in Mesquite and Bunkerville, to seek public input on the revised floodplain delineation. Each property owner expected to experience an increase and/or decrease in the floodplain width will be notified by certified a mail. All coordination meeting minutes are included in **Appendix C**.


City of Mesquite
Scenic Bridge
LIMIT OF STUDY
Virgin River
15
Coyote Willows Golf Course
Abbott Wash
Casablanca Golf Course
Charles Hughes Middle School
Bunkerville Diversion Structure
Bunkerville Bridge
Virgin River
Nevada
Arizona
Toquop Wash
Bunkerville
Virgin River
LIMIT OF STUDY
CLARK COUNTY
Las Vegas
OR
ID
NV
UT
CA
AZ

Aerial Source: Clark County Spring 2005 & USGS

N W E S

0 1,750 3,500 7,000 Feet

1 inch equals 3,500 feet

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VIRGIN RIVER

REQUEST FOR LETTER OF MAP REVISION

Figure 1.1 - Vicinity Map

REGIONAL FLOOD CONTROL DISTRICT

4:25:06 JB Lasfs01 51 Hydrology PROJECTS 511792 Virgin River FHS GIS MXD Figures 11x17 Figure 1.1.mxd

Section 2
General Information

2.1 Scope of Study

The scope of this study consists of data collection, field investigation, hydraulic modeling (1-D hydraulic analysis), floodplain and floodway mapping and determination of base flood elevations (BFEs). The scope also includes mapping of the 500-year floodplain. As discussed previously, the mapping efforts for this study begin at the Nevada-Arizona border and end just upstream of the confluence of the Toquop Wash and the Virgin River. Please refer to **Figure 1.1: Vicinity Map** which shows the limit of study. The limit of the study represents the limit of the mapping efforts; however, the associated hydraulic models were extended further upstream as discussed below.

An avulsion was formed during the January 2005 flood which begins approximately 1.7 miles upstream of the Nevada-Arizona border. In order to accurately model the floodplain and floodway limits at the Nevada-Arizona border and further downstream it is necessary to model this avulsion. Therefore, PBS&J extended the hydraulic model approximately 2.4 miles upstream of the state line (approximately 1000 feet downstream of the Scenic Bridge) to accurately model the flow split that occurs between the main channel and the avulsion. Please refer to **Section 2.3** for further discussion on the avulsion and **Section 4** for further discussion on the hydraulic analysis.

2.2 Community Description

The study reach of the Virgin River is located in the northeast corner of Clark County within Sections 15-21 and 30 of Township 13 South / Range 71 East, Sections 23-27 and 32-35 of Township 13 South / Range 70 East, and Sections 3-4 of Township 14 South / Range 70 East.

The upstream portion of the study reach, east of the Bunkerville Bridge (please refer to **Figure 1.1: Vicinity Map**), is bordered on the north by the City of Mesquite, comprised primarily of residential, agricultural, and undeveloped land and on the south by undeveloped land. The downstream portion of the study reach, west of the Bunkerville Bridge, is bordered on the north by the City of Mesquite, comprised primarily of residential developments and golf courses. West of the Casa Blanca Golf Course, the study reach is bordered on the north by undeveloped land. This reach is bordered on the south by the town of Bunkerville and agricultural land. West of the agricultural land, this reach is bordered on the south by undeveloped land.

2.3 Principal Flood Problems

The January 2005 floods marked the end of a long drought. During several years of low-flow conditions (prior to the flood), the dense vegetation (mainly Tamarisk) encroached on the Virgin River active channel. As a result, the pre-flood channel was very narrow (roughly about forty-feet wide) and it meandered through these areas of dense vegetation (refer to **Figure 2.1** below). The capacity of this narrow channel was inadequate to convey the discharge associated with the January 2005 flood resulting in significant loss in vegetation, channel widening, avulsions, excessive floodplain sediment deposition, and lateral erosion of channel banks (JEF, 2006). The post-flood aerial photos indicate that the Virgin River active channel is much wider (comprising numerous braids) than the pre-flood active channel (see **Figure 2.1** below). The comparison of the pre and post-flood aerial photos also illustrates that the thalweg has shifted dramatically. It has migrated more than 900-feet in some places. JE Fuller Hydrology and Geomorphology Inc. (J.E. Fuller) conducted geomorphic analysis to identify the cause of recent sediment deposition in the floodplain and predict future lateral migration of the Virgin River main channel. Please refer to JE Fuller's draft *Geomorphic Analysis Report* (electronic copy), in **Appendix D**, for further discussion on the Virgin River's response to the January 2005 flood.

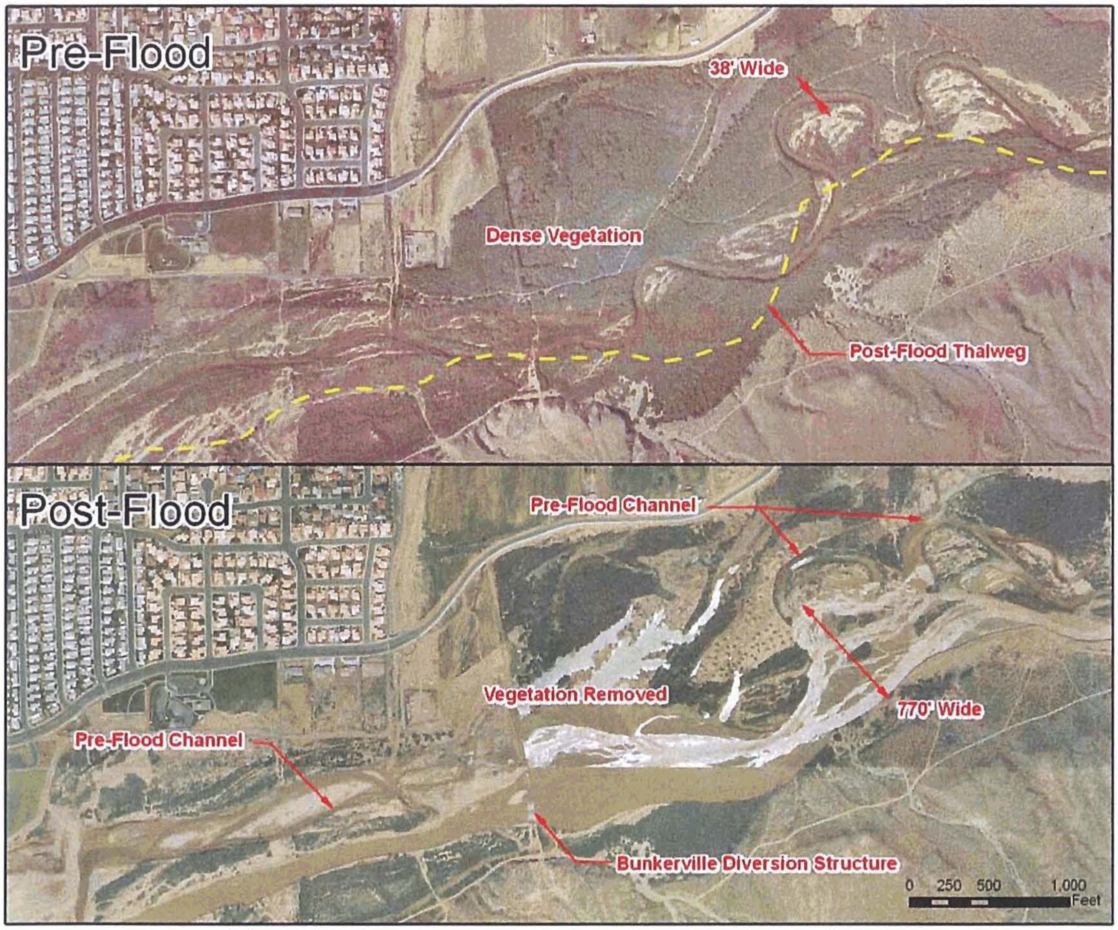
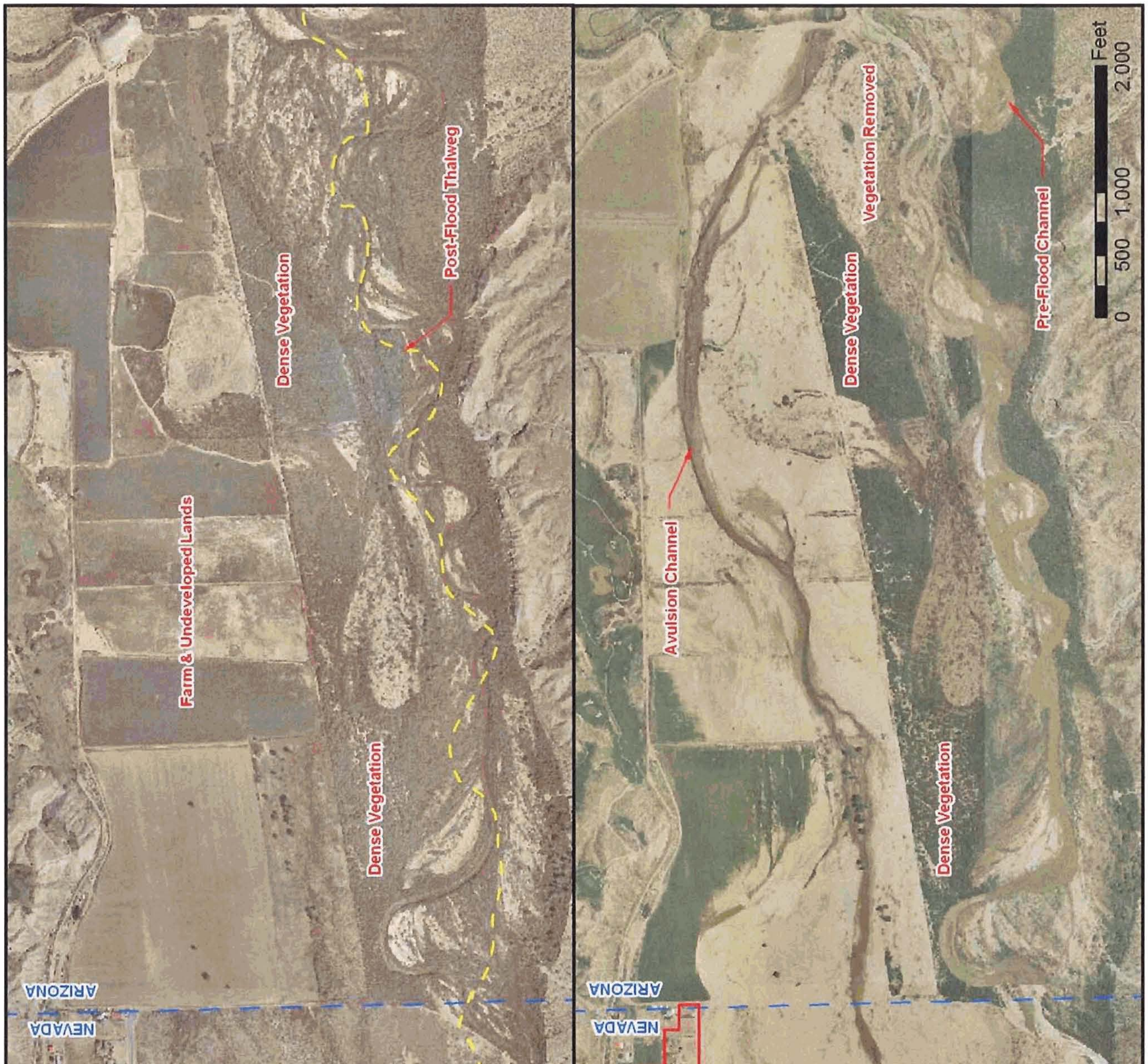

Pre-Flood
38' Wide
Dense Vegetation
Post-Flood Thalweg
Post-Flood
Pre-Flood Channel
Vegetation Removed
770' Wide
Pre-Flood Channel
Bunkerville Diversion Structure
0 250 500 1,000
Feet

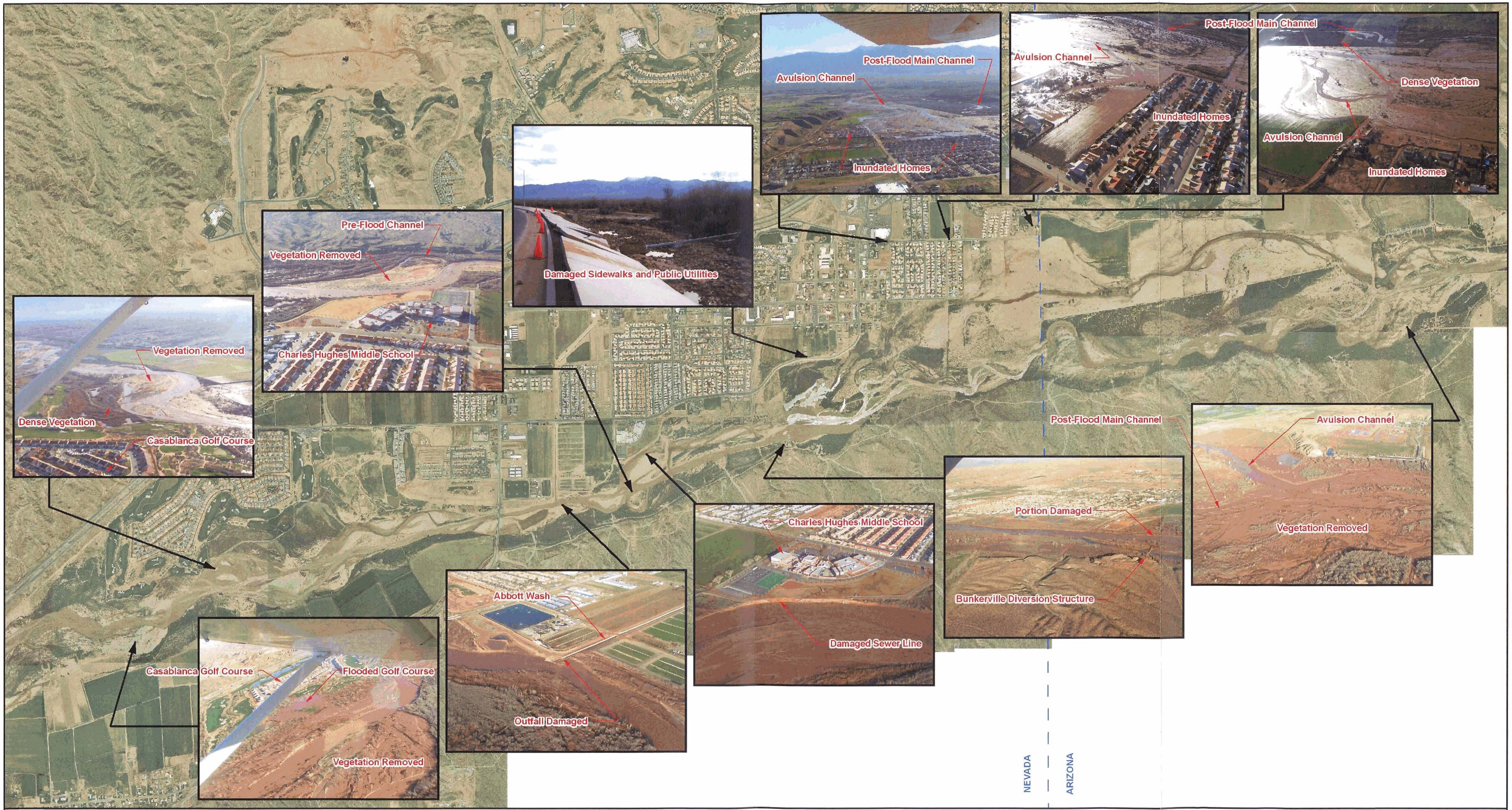
Figure 2.1: Pre and Post-Flood Aerial Photos of the Virgin River.

The most significant avulsion of the Virgin River occurred approximately 1.7 miles upstream of the Nevada-Arizona border. At this location it is believed that a debris blockage occurred in the main channel causing a backwater effect and thereby forcing the flood waters into the right overbank causing an avulsion. It is believed that the debris blockage resulted from uprooted vegetation that was integrated with the flood waters and then became trapped within the narrow active channel. The right overbank did not resist the floodwaters as it is mainly comprised of agricultural fields and undeveloped land which has low roughness coefficients. The right overbank flow appears to have caused a differential water surface, with the overbank flow being higher than the main channel for approximately 2,000 feet. The flood waters flowing through the avulsion ultimately inundated approximately 80 homes in Mesquite, just west of the Nevada-Arizona border, before returning to the main channel (please refer to **Figure 2.2** below). PBS&J believes that one of the reasons the water backed up on the streets (in the vicinity of Ronnie Way) is because of the differential water surface between the main channel and right overbank. A City of Mesquite official confirmed that the water surface elevation (WSEL) through the avulsion was higher than the WSEL through the main channel.

The flood waters washed out a portion of the Bunkerville Diversion Structure, as well as damaging the Abbott Wash Outfall structure. The lateral migration of the channel caused a cut bank to form along southeast edge of the Charles Hughes Middle School site, causing significant damage to a major sewer line. Similarly, the cut banks which formed along the south side of both the Casa Blanca and the Coyote Willows Golf Courses, resulted in substantial property damage. Please refer to **Figure 2.3** for an aerial overview of the above mentioned damages associated with the flood.


Pre-Flood
Post-Flood
Farm & Undeveloped Lands
Dense Vegetation
Dense Vegetation
Post-Flood Thalweg
ARIZONA
NEVADA
Inundated Homes
Avulsion Channel
Dense Vegetation
Dense Vegetation
Vegetation Removed
Vegetation Removed
Pre-Flood Channel
Feet
0
500
1,000
2,000

Figures 2.2: Pre and Post-Flood Aerial Photos of the Avulsion


Post-Flood Main Channel
Avulsion Channel
Inundated Homes
Post-Flood Main Channel
Avulsion Channel
Inundated Homes
Dense Vegetation
Avulsion Channel
Inundated Homes
Damaged Sidewalks and Public Utilities
Pre-Flood Channel
Vegetation Removed
Charles Hughes Middle School
Vegetation Removed
Dense Vegetation
Casablanca Golf Course
Post-Flood Main Channel
Avulsion Channel
Vegetation Removed
Portion Damaged
Bunkerville Diversion Structure
Charles Hughes Middle School
Damaged Sewer Line
Abbott Wash
Outfall Damaged
Casablanca Golf Course
Flooded Golf Course
Vegetation Removed
NEVADA
ARIZONA

Aerial Source: Clark County Spring 2005 & USGS

N
W E
S

0 1,100 2,200 4,400
Feet

1 inch equals 2,200 feet

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VIRGIN RIVER

REQUEST FOR LETTER OF MAP REVISION

Figure 2.3: Flood Photos

REGIONAL FLOOD CONTROL DISTRICT

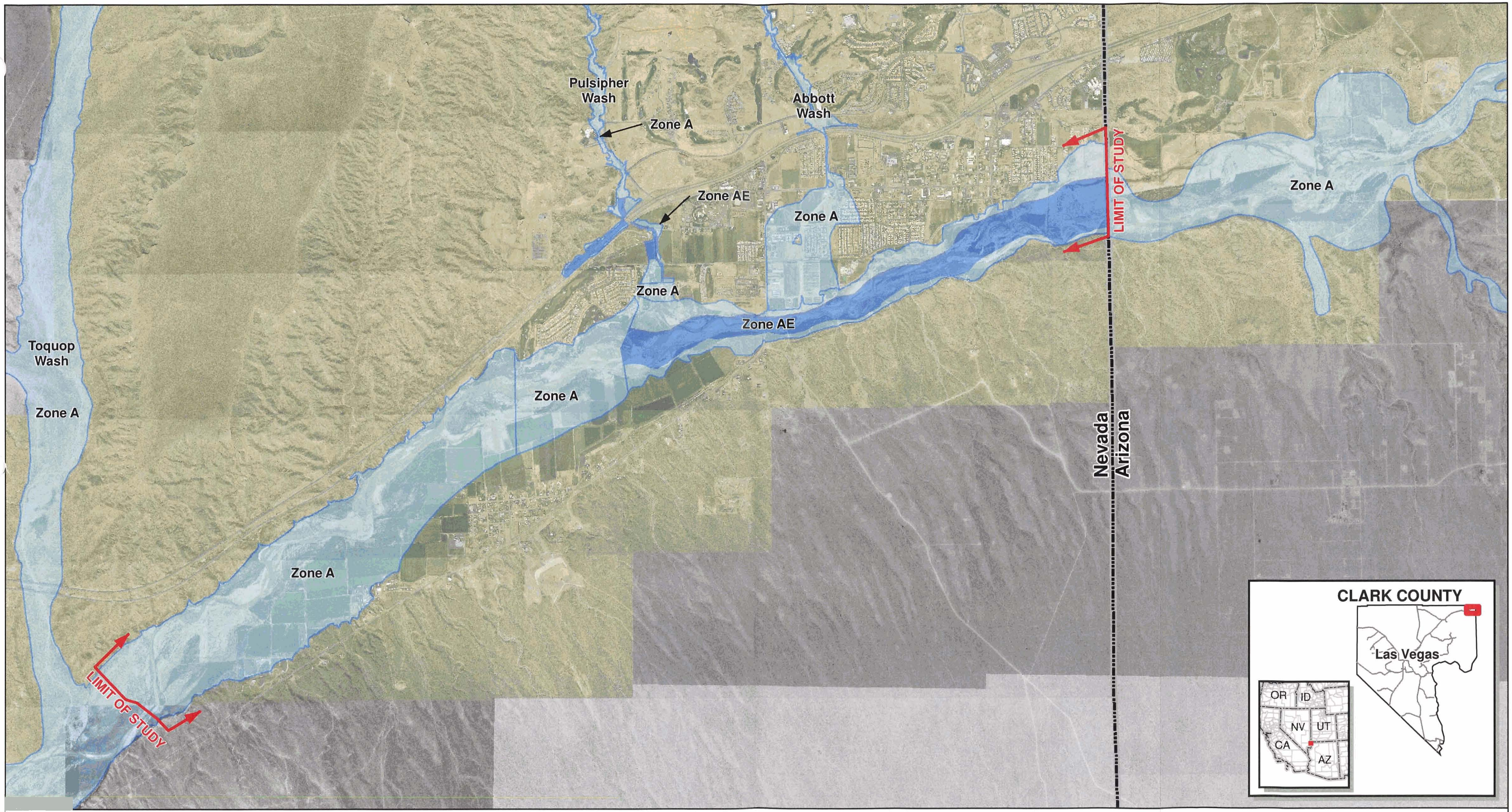
3/15/06 MD \\asfs01\51 - Hydrology\PROJECTS\511702 Virgin River FHS\GIS\MXD\Report_Figures\Figure2_3.mxd

2.4 FEMA Flood Zone Information

Figures 2.4 (A and B) are reproductions of the FEMA Flood Insurance Rate Maps for City of Mesquite (Community Number 320035) and for Clark County Unincorporated Areas (Community Number 320003), panels 0391 E, 0387 E, 0386 E, 0390 E, 0367 E, 0369 E, 0370 E, 0375 E, and 0775 E, all dated September 27, 2002. These figures shows the FEMA flood zones for the entire study reach, extending from the Nevada-Arizona border to just downstream of the confluence of Toquop Wash and the Virgin River. As shown on the figures, a Zone AE flood zone is delineated along the Virgin River from the Nevada-Arizona border to just downstream of the confluence of Pulsipher Wash and the Virgin River. A Zone A flood zone is designated for the remainder of the study reach (downstream of Zone AE). **Figure 2.4A** also includes a reproduction of the FEMA FIRM for Mohave County, Arizona, Community Panel No. 0400580200 B, dated March 15, 1982. A Zone A flood zone is designated for the areas directly east of the Nevada-Arizona border. The Digital Flood Insurance Rate Maps (DFIRM) flood zone delineations for the study reach are shown on **Figure 2.5: Effective FEMA Flood Zone Overlaid on Aerial Photos**. It should be noted that the mapping efforts for this study begin at the Nevada-Arizona border and end just upstream of the confluence of the Toquop Wash and the Virgin River. Therefore, this study would affect all the panels mentioned above except 32003C0375 E (Toquop Wash, downstream of study reach), 32003C50775 E (Toquop Wash, downstream of study reach), and 0400580200 B (Mohave County, upstream of study reach).

2.5 Topographic Information

PBS&J obtained post-flood Light Detection and Ranging (LiDAR) data from the Bureau of Reclamation (BOR). The LiDAR data was acquired on June 7-9, 2005, by Horizon Inc. and was on a coordinate system of Universal Transverse Mercator (UTM) Zone 11, North American Datum 83 (NAD 83), North American Vertical Datum 88 (NAVD 88) and in Metric units. PBS&J obtained the filtered LiDAR Digital Elevation Model (DEM) xyz data and used ArcGIS 9.0.0 to convert the data from UTM Zone 11, Metric units to State Plane coordinates, English units. Using the re-projected data, a triangulated irregular network (TIN) was developed (using 3D Analyst extension in ArcGIS) for the study reach, from the Scenic Bridge to downstream of the confluence of Toquop Wash and the Virgin River. The above mentioned TIN was used as a topographic base for the hydraulic modeling. The TIN was used to generate 2-foot contours for the study reach. The DEM xyz data, post-flood LiDAR TIN and the associated 2-foot contours are included in the data DVD in **Appendix E**. The LiDAR Acquisition/Processing/Quality Control report and Analytical Aerial Triangulation Summary developed by Horizon, Inc. is included in **Appendix D**.


Pulsipher Wash
Zone A
Abbott Wash
Zone AE
Zone A
Zone A
Zone AE
LIMIT OF STUDY
Zone A
Toquop Wash
Zone A
Zone A
Nevada
Arizona
Zone A
LIMIT OF STUDY
CLARK COUNTY
Las Vegas
OR
ID
NV
UT
CA
AZ

Aerial Source: Clark County Spring 2005 & USGS

N
W
E
S
0
1,750
3,500
7,000
Feet

1 inch equals 3,500 feet

Legend

▢	100-Year Floodplain
■	100-Year Floodway

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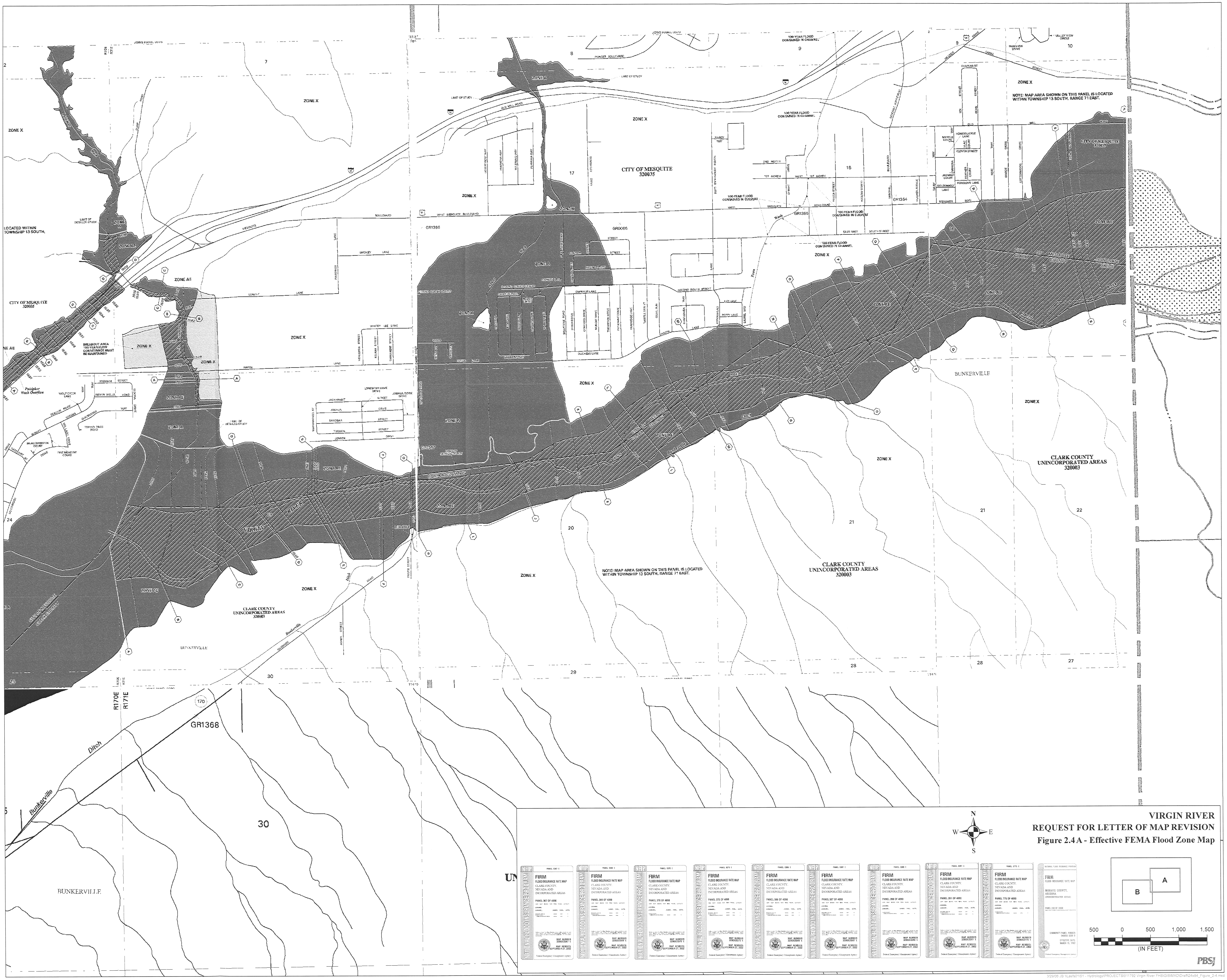
Figure 2.5 - Effective FEMA Flood Zone Overlaid on Aerial Photos

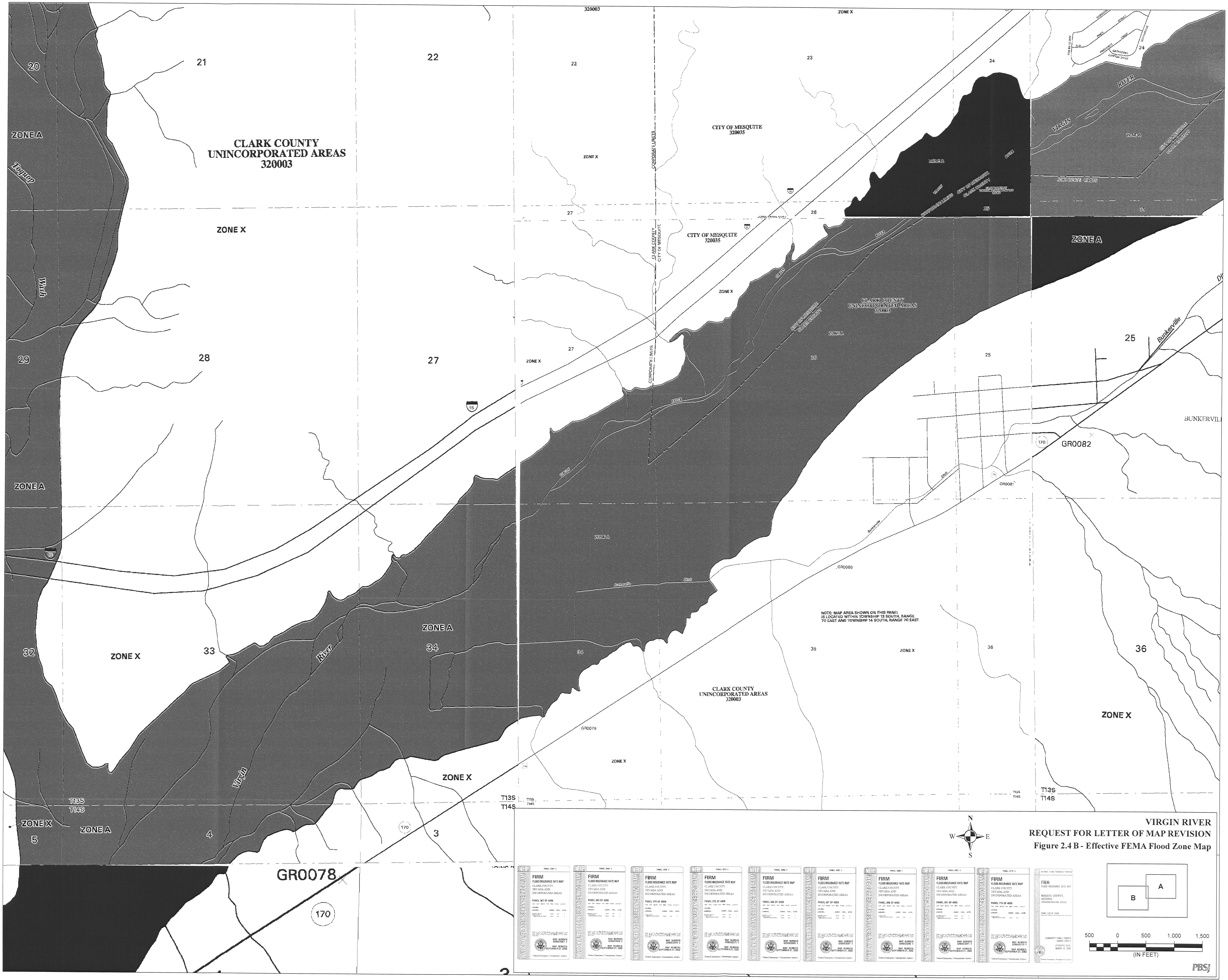
REGIONAL FLOOD CONTROL DISTRICT

4/25/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\11x17_Figure_2-5.mxd


ZONE X
ZONE A
ZONE AE
CITY OF MESQUITE
320035
CLARK COUNTY
UNINCORPORATED AREAS
320003
BUNKERVILLE
VIRGIN RIVER
NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 13 SOUTH, RANGE 71 EAST.
BREAKOUT AREA 100 YEAR FLOW CONVEYANCE MUST BE MAINTAINED
100-YEAR FLOOD CONTAINED IN CHANNEL
100-YEAR FLOOD CONTAINED IN CULVERT
LIMIT OF DETAILED STUDY
WEST MESQUITE BOULEVARD
Bunkerville Ditch
GR1368
R70E
R71E
170
N
E
S
W
A
B
500
0
500
1,000
1,500
(IN FEET)
PBSJ

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 2.4 A - Effective FEMA Flood Zone Map

3/29/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\24x84_Figure_2-4.mxd


CLARK COUNTY
UNINCORPORATED AREAS
320003
ZONE A
ZONE X
Toquop
Wash
CITY OF MESQUITE
320035
CORPORATE LIMITS
CLARK COUNTY
CITY OF MESQUITE
VIRGIN RIVER
Virgin
River
Bunkerville
BUNKERVILL
GR0078
GR0079
GR0080
GR0081
GR0082
15
170
T13S
T14S
20
21
22
23
24
25
26
27
28
29
32
33
34
35
36
3
4
5
NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 13 SOUTH, RANGE 70 EAST AND TOWNSHIP 14 SOUTH, RANGE 70 EAST.
N
E
S
W
FIRM
FLOOD INSURANCE RATE MAP
CLARK COUNTY,
NEVADA AND
INCORPORATED AREAS
PANEL 775 OF 4090
MAP NUMBER
32003C0775 E
MAP REVISED:
SEPTEMBER 27, 2002
Federal Emergency Management Agency
NATIONAL FLOOD INSURANCE PROGRAM
MOHAVE COUNTY,
ARIZONA
(UNINCORPORATED AREAS)
COMMUNITY-PANEL NUMBER
040058 0200 B
EFFECTIVE DATE:
MARCH 15, 1982
A
B
500
0
500
1,000
1,500
(IN FEET)
PBS&J

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 2.4 B - Effective FEMA Flood Zone Map

3/29/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\24x84_Figure_2-4.mxd

Section 3
Hydrology

A peak discharge of 36,500 cfs during the January 2005 flood event for the Virgin River at Littlefield, AZ (about 9 miles upstream of Nevada-Arizona border) was determined by John Wilson of the U.S. Geological Survey (USGS) field office in Henderson, Nevada. This discharge was determined by using flow data obtained from the USGS stream gauge in Littlefield, Arizona (station 0941500). Based on this peak discharge, Will Thomas from the Michael Baker Corporation, estimated the flow rates for various return periods by using the Bulletin 17B frequency analysis. This analysis was provided to PBS&J by HDR/FEMA Region IX, who is currently working on mapping the Virgin River floodplain in Mohave County, Arizona, just upstream of the Nevada-Arizona border. The frequency analysis is included in **Appendix D**. Flow rates for various return periods are listed below:

Return Period	Flow (cfs)
5-Year	9,742
10-Year	14,550
50-Year	30,250
100-Year	39,510
500-Year	68,800

Based on the above analysis, PBS&J used a discharge of 39,510 cfs in the 100-year hydraulic model and a discharge of 68,800 cfs for the 500-year hydraulic model. It should be noted that the effective FEMA hydraulic model used a 100-year flow of 34,400 cfs.

Section 4
Hydraulics

The hydraulic models used within this LOMR include the following: effective hydraulic model, duplicate effective hydraulic model, and corrected effective hydraulic model. These hydraulic models were developed based on the guidelines in a memorandum dated April 30, 2001, *Policy for Use of HEC-RAS in the NFIP*. FEMA encouraged the conversion to HEC-RAS for revisions to Effective Flood Insurance Studies where the effective model is HEC-2. The memorandum sets forth the guidelines for converting to HEC-RAS and includes:

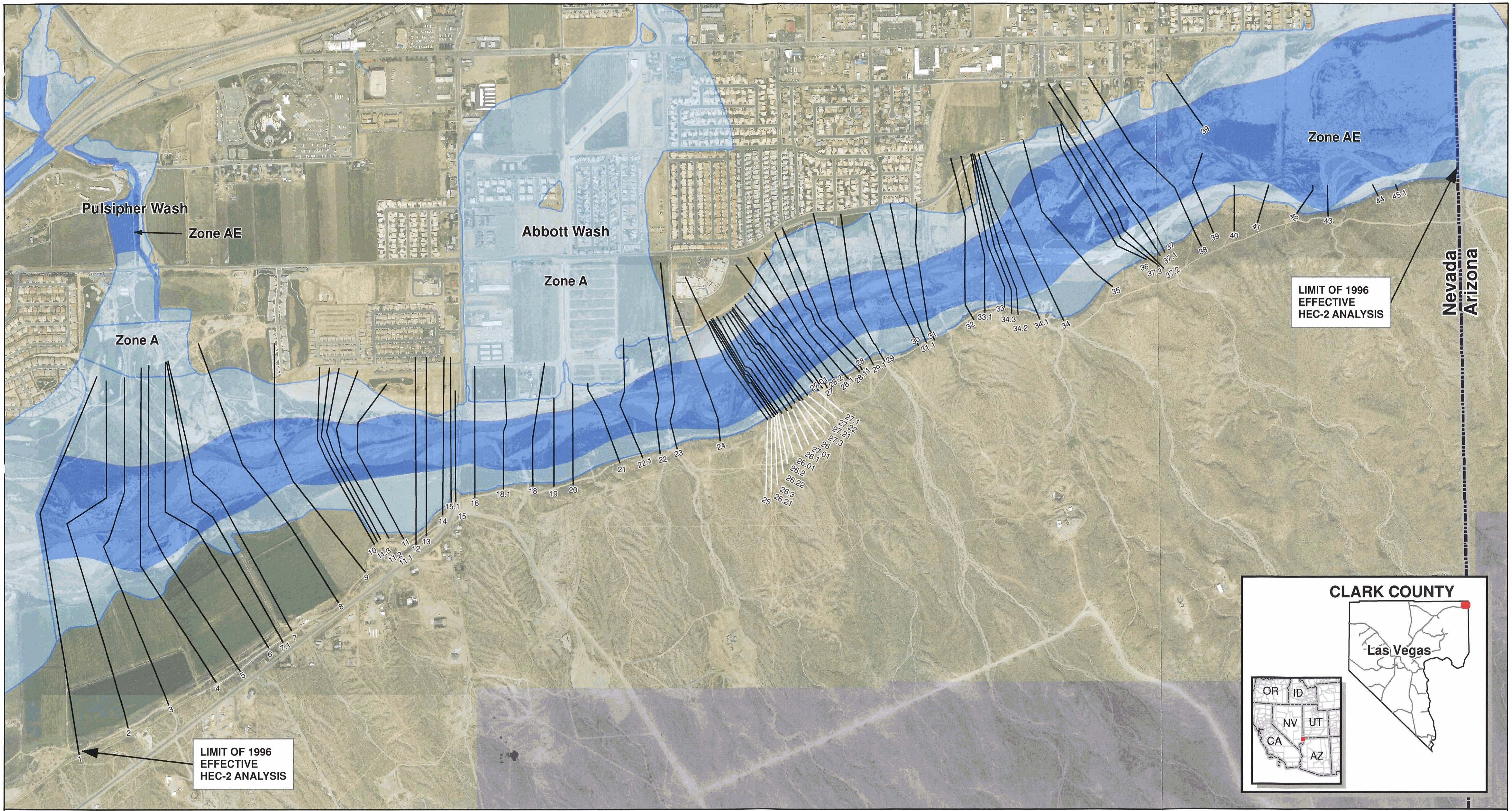
- The effective HEC-2 model should be re-run using HEC-RAS to create a duplicate effective model. The difference in WSEL between the effective model and the duplicate effective model must be documented and explained.
- Once the duplicate effective model has been established, the corrected effective, existing conditions, and post-project conditions models can be created using HEC-RAS model as the basis.
- The HEC-RAS models must tie into the effective water-surface profile within 0.5 feet at the upstream and the downstream ends of the revised reach.

Each of the above mentioned hydraulic models is discussed in detail below.

4.1 Effective Hydraulic Model

The effective hydraulic model is consistent with the hydraulic model for the *Mesquite City Flood Study* performed by Bulloch Brothers Engineering Inc. The hydraulic model for the *Mesquite City Flood Study* was developed using the United States Army Corps of Engineers (USACOE) HEC-2 model. This model was used to establish a Zone AE flood zone for a 4-mile reach of the Virgin River within the City of Mesquite, extending from the Nevada-Arizona border to just downstream of the confluence of Pulsipher Wash and the Virgin River. The FEMA FIRM panels affected by the flood study were 3200350379 D, 0386 D, 0387 D, and 0391 D.

The HEC-2 hydraulic model was analyzed for the 100-year flow of 34,400 cfs using three different steady state simulations, which are defined as Profile 1 through 3. Profile 1 specifies no floodplain encroachment, whereas Profile 2 was developed to compute automated initial values for floodplain encroachment. Profile 3 represents an optimized encroachment for the system by using the initial values computed within Profile 2. The HEC-2 cross-sections were digitized using ArcGIS based on the *Mesquite City Flood Study* work maps, dated February 5, 1996 and are shown on **Figure 4.1** with the associated DFRIM. The effective hydraulic model and associated work maps were obtained from FEMA's Data Repository (Michael Baker Jr., Alexandra, Virginia). It should be noted that PBS&J is missing sheets 1 and 2 of the work maps (as they were not available), and as a result, the associated cross-sections are either incomplete or not shown on **Figure 4.1**. The electronic copy of original work maps, hydraulic model and the results are included on the electronic DVD in **Appendix E.**


Pulsipher Wash
Zone AE
Abbott Wash
Zone A
Zone A
Zone AE
LIMIT OF 1996 EFFECTIVE HEC-2 ANALYSIS
LIMIT OF 1996 EFFECTIVE HEC-2 ANALYSIS
Nevada
Arizona
1
2
3
4
5
6
7.1
7
8
9
10
11.3
11.2
11.1
11
12
13
14
15.1
15
16
18.1
18
19
20
21
22.1
22
23
24
25
26.21
26.3
26.22
26.2
26.1
26.01
26
27.3
27.01
27.2
27.21
27.22
27.1
27
28.2
28.1
28.11
28
29.1
29
30
31
31.1
32
33.1
33
34.3
34.2
34.1
34
35
36
37.3
37
37.1
37.2
38
39
40
41
42
43
44
45.1
39
CLARK COUNTY
Las Vegas
OR
ID
NV
UT
CA
AZ

Aerial Source: Clark County Spring 2005 & USGS

N
W E
S

0 600 1,200 2,400 Feet

1 inch equals 1,200 feet

Note: The HEC-2 cross-sections were digitized based on the Mesquite City Flood Study work maps, dated February 5, 1996. PBS&J is missing sheets 1 and 2 of the work maps; as a result, the cross-sections 39 through 48 are either incomplete or not shown on this figure.

Refer to **Figure 2.5** for overview of all Effective Flood Zones within the study reach.

Legend

— Effective HEC-2 Cross-Sections

🟦 100-Year Floodplain

🟦 100-Year Floodway

PBSJ

VIRGIN RIVER

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Figure 4.1 - Effective FEMA Hydraulic Model Cross-Sections

REGIONAL FLOOD CONTROL DISTRICT

4/25/06 JB \\Lasts01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\11x17_Figure_4-1.mxd

4.2 Duplicate Effective Hydraulic Model

The effective FEMA hydraulic model data was converted from HEC-2 to HEC-RAS, Version 3.1.3, to generate a duplicate effective model. The HEC-2 data was imported into HEC-RAS and then the model was refined in order to accurately represent the original HEC-2 model. The upstream and downstream invert for the Bunkerville Bridge specified in the HEC-2 geometry data showed a vertical drop in the channel invert. The bridge cross-sections in the HEC-RAS model were defined using the HEC-2 input parameters. The above mentioned vertical drop was replicated in the duplicate effective model by adding two cross-sections just upstream and downstream of the bridge.

The WSELs generated by the HEC-2 (effective) and HEC-RAS (duplicate effective) models were compared for Profiles 1 and 3 (refer to **Section 4.1**). Profile 2 for the two models was not compared as it was only generated in order to determine the initial values used in the floodplain optimization of Profile 3. For the comparison between the HEC-2 and HEC-RAS WSELs please refer to **Table 4.1**. The table shows HEC-2 and corresponding HEC-RAS cross-section IDs, the respective WSELs and the associated difference in WSEL. The results show that the difference in the WSEL between the effective hydraulic model and the duplicate effective model is for the most part less than 0.5 feet, however in the vicinity of the bridge the differences in WSEL is slightly higher than the 0.5 feet. The differences in the WSEL can be attributed to the fact that HEC-RAS and HEC-2 use different hydraulic computations to model flow through the bridge. It should be noted that the difference in WSEL between effective and duplicate effective hydraulic model at cross-sections 34.1 (HEC-RAS C/S ID 60) and 7.1 (HEC-RAS C/S ID 7) is higher than 0.5 feet. Again, the difference in WSEL can be attributed to different hydraulic modeling procedures used.

As mentioned earlier, **Figure 4.1** shows the cross-section locations and the associated DFIRM. The duplicate effective HEC-RAS profiles and results are included in **Appendix B**. The electronic copy of the duplicate effective model and the HEC-RAS report is included on the electronic DVD in **Appendix E**.

It should be noted that the effective HEC-2 model used the topographic data with the vertical datum of National Geodetic Vertical Datum (NGVD) 29 and therefore the WSEL shown in **Table 4.1** below uses a vertical datum of NGVD 29.

Table 4.1: Comparison of the Effective and Duplicate Effective WSEL

Table 4.1: WSEL Comparison Between the Effective and Duplicate Effective Hydraulic Models

HEC-2 C/S ID	HEC-RAS C/S ID	HEC-2 Floodplain WSEL* (ft)	HEC-RAS Floodplain WSEL* (ft)	Difference (ft)	HEC-2 Floodway WSEL** (ft)	HEC-RAS Floodway WSEL** (FT)	Difference (ft)	
47	78	1589.42	1589.46	0.04	1590.45	1590.45	0	
46	77	1589.06	1589.12	0.06	1590.03	1590.03	0	
45	76	1588.03	1588.09	0.06	1588.79	1588.79	0	
45.1	75	1587.66	1587.73	0.07	1588.32	1588.33	0.01	
44	74	1587.02	1587.11	0.09	1587.62	1587.64	0.02	
43	73	1585.57	1585.75	0.18	1586.51	1586.52	0.01	
42	72	1585.17	1585.33	0.16	1586.17	1586.17	0	
41	71	1583.94	1584.04	0.1	1584.79	1584.79	0	
40	70	1582.48	1582.58	0.1	1583.28	1583.28	0	
39	69	1581.67	1581.76	0.09	1582.42	1582.43	0.01	
38	68	1580.33	1580.4	0.07	1581.13	1581.13	0	
37	67	1579.19	1579.23	0.04	1579.98	1579.99	0.01	
37.1	66	1578.81	1578.86	0.05	1579.76	1579.76	0	
37.2	65	1578.16	1578.24	0.08	1579.23	1579.23	0	
37.3	64	1577.89	1577.96	0.07	1578.93	1578.93	0	
36	63	1577.68	1577.74	0.06	1578.6	1578.6	0	
35	62	1576.44	1576.54	0.1	1577.37	1577.37	0	
34	61	1574.93	1575.19	0.26	1575.89	1575.89	0	
34.1	60	1573.76	1574.27	**0.51**	1574.43	1574.42	-0.01	
34.2	59	1572.17	1572.24	0.07	1572.13	1572.15	0.02	
34.3	58	1571.39	1571.7	0.31	1572.09	1572.16	0.07	
33	57	1571.37	1571.75	0.38	1572.23	1572.29	0.06	
33.1	56	1570.76	1571.03	0.27	1571.61	1571.61	0	
32	55	1570.16	1570.5	0.34	1571.2	1571.21	0.01	
31	54	1568.72	1568.62	-0.1	1569.26	1569.27	0.01	
31.1	53	1567.81	1567.46	-0.35	1568.23	1568.25	0.02	
30	52	1567.24	1567.33	0.09	1567.95	1567.97	0.02	
29	51	1566.04	1566.17	0.13	1566.66	1566.69	0.03	
29.1	50	1565.77	1565.9	0.13	1566.33	1566.38	0.05	
28	49	1564.86	1564.92	0.06	1565.57	1565.63	0.06	
28.11	48	1564.93	1565.06	0.13	1565.64	1565.7	0.06	
28.1	47	1564.67	1564.82	0.15	1565.45	1565.52	0.07	
28.2	46	1564.49	1564.64	0.15	1565.16	1565.21	0.05	
27	45	1563.81	1563.97	0.16	1564.58	1564.64	0.06	
27.11	44	1563.63	1563.79	0.16	1564.32	1564.38	0.06	
27.1	43	1563.3	1563.49	0.19	1564.04	1564.11	0.07	
27.2	42	1562.87	1563.09	0.22	1563.64	1563.73	0.09	
27.22	41	1562.86	1563.08	0.22	1563.68	1563.77	0.09	
27.21	40	1562.83	1563.05	0.22	1563.65	1563.73	0.08	
27.3	39	1562.77	1562.99	0.22	1563.57	1563.66	0.09	
26	38	1562.69	1562.93	0.24	1563.49	1563.58	0.09	
26.01	37	1562.55	1562.80	0.25	1563.32	1563.42	0.10	
26.1	36	1562.47	1562.73	0.26	1563.22	1563.32	0.10	
26.2	35	1562.27	1562.54	0.27	1562.93	1563.04	0.11	
26.22	34	1562.11	1562.40	0.29	1562.78	1562.90	0.12	
26.21	33	1562.04	1562.32	0.28	1562.65	1562.76	0.11	
26.3	32	1561.95	1562.24	0.29	1562.54	1562.65	0.11	
25	31	1561.67	1561.97	0.30	1562.37	1562.49	0.12	
24	30	1560.54	1560.92	0.38	1561.33	1561.49	0.16	
23	29	1559.43	1559.85	0.42	1560.45	1560.66	0.21	
22	28	1559.17	1559.62	0.45	1560.10	1560.35	0.25	
22.1	27	1558.10	1558.48	0.38	1559.07	1559.35	0.28	
21	26	1557.28	1557.68	0.40	1557.83	1558.22	0.39	
20	25	1556.63	1557.08	0.45	1557.42	1557.87	0.45	
19	24	1556.34	1556.81	0.47	1557.06	1557.55	0.49	
18	23	1555.73	1556.18	0.45	1556.41	1556.97	**0.56**	
18.1	22	1555.26	1555.77	**0.51**	1556.00	1556.63	**0.63**	
16	21	1555.26	1555.82	**0.56**	1556.06	1556.72	**0.66**	Bridge U/S
15	20	1552.50	1552.61	0.11	1553.28	1553.50	0.22	Bridge D/S
15.1	19	1551.31	1551.10	-0.21	1551.60	1551.61	0.01	
14	18	1551.22	1551.02	-0.20	1551.33	1551.35	0.02	
13	17	1550.79	1550.50	-0.29	1550.87	1550.92	0.05	
12	16	1550.71	1550.41	-0.30	1550.79	1550.84	0.05	
11	15	1548.24	1548.09	-0.15	1548.40	1548.46	0.06	
11.1	14	1547.79	1547.48	-0.31	1547.75	1547.83	0.08	
11.2	13	1547.61	1547.19	-0.42	1547.19	1547.31	0.12	
11.3	12	1547.49	1547.03	-0.46	1546.98	1547.11	0.13	
10	11	1545.43	1545.75	0.32	1545.54	1545.56	0.02	
9	10	1543.08	1543.14	0.06	1543.59	1543.59	0.00	
8	9	1541.53	1541.25	-0.28	1541.96	1541.96	0.00	
7	8	1540.06	1539.71	-0.35	1540.34	1540.35	0.01	
7.1	7	1539.56	1538.68	**-0.88**	1539.34	1539.34	0.00	
6	6	1537.92	1537.99	0.07	1538.62	1538.63	0.01	
5	5	1536.66	1536.72	0.06	1537.33	1537.34	0.01	
4	4	1535.86	1535.99	0.13	1536.70	1536.72	0.02	
3	3	1534.68	1534.79	0.11	1535.24	1535.26	0.02	
2	2	1533.70	1533.89	0.19	1534.47	1534.50	0.03	
1	1	1532.55	1532.55	0.00	1533.40	1533.40	0.00	

* Floodplain WSEL is based on Profile 1.
** Floodway WSEL is based on Profile 3.

4.3 100-Year Corrected Effective Hydraulic Model

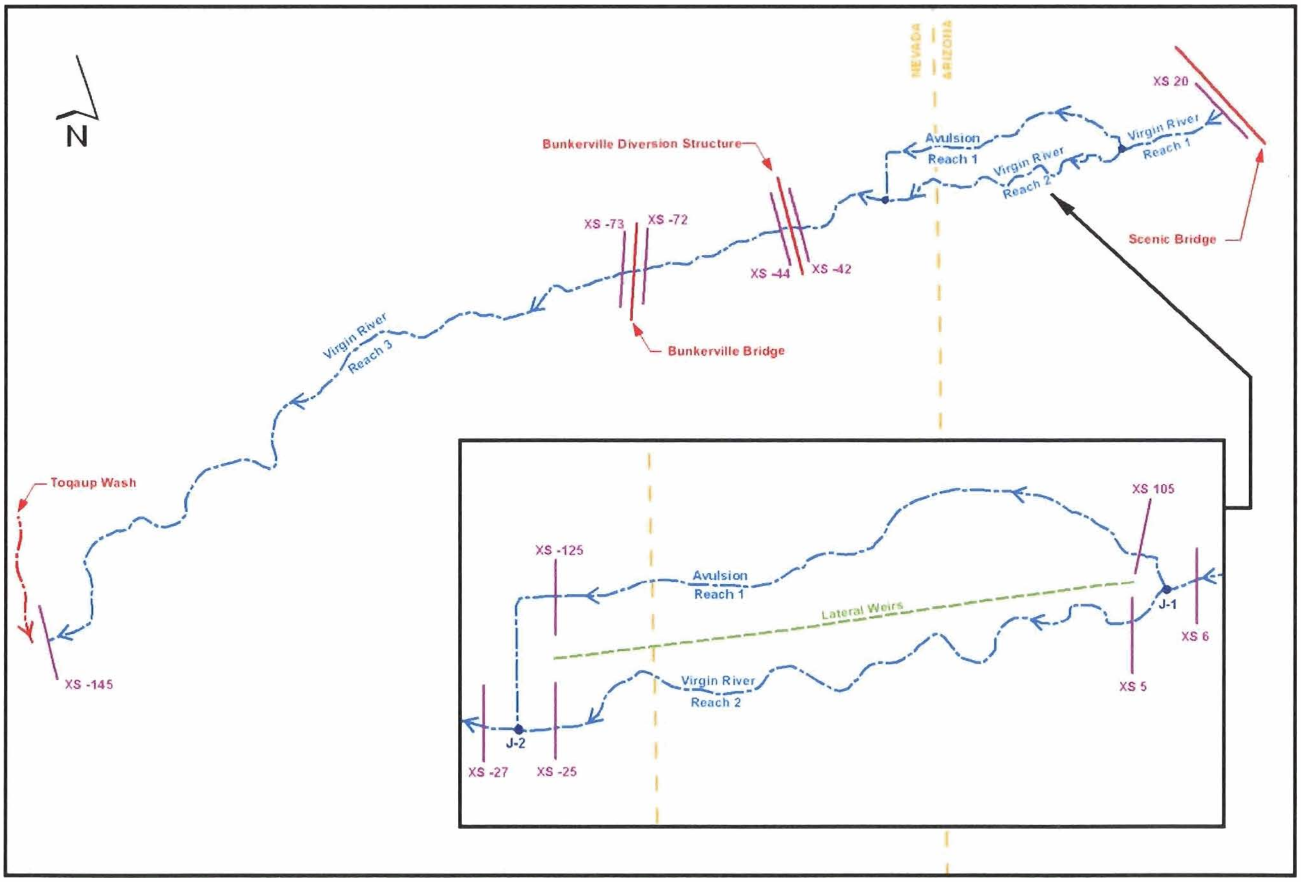
The corrected effective hydraulic model was generated using HEC-RAS, Version 3.1.3. The geometric data used in the HEC-RAS model was generated in ArcGIS using HEC-GeoRAS, Version 4.0, developed by USACOE, in conjunction with the Environmental Systems Research Institute, Inc. (ESRI). The corrected effective hydraulic model and all GIS files used to generate the geometric data used in the hydraulic model are included on the electronic DVD in **Appendix E**.

As discussed earlier in the report, the January 2005 flood was near the magnitude of the 100-year storm event, and in some areas the flooding limits were wider than the current FEMA effective mapping limits. Within the vicinity of the Nevada-Arizona border, 80 residential homes where inundated, a majority of which were outside the effective FEMA flood hazard zone. Therefore, the purpose of the corrected effective hydraulic model is to utilize more accurate and recent topography (post-flood LiDAR data) and the current 100-year flow (39,510 cfs) to re-delineate the 100-year floodplain and floodway.

The January 2005 flood event significantly altered the floodplain characteristics associated with the Virgin River. However, PBS&J believes the corrected effective hydraulic model accurately represents the normal hydraulic conditions of the Virgin River within the study reach. The assumptions and parameters associated with the hydraulic model are discussed in detail below. Please refer to **Figure 4.2: 100-Year Corrected Effective Work Map** which shows the cross-section locations, ineffective flow boundaries, and floodplain delineation based on the hydraulic model discussed below (included at the end of this section).

Geometry and Cross-Sections: The corrected effective model's cross-section data is based on the TIN generated from the post-flood LiDAR data obtained from BOR (refer to **Section 2.5**). As mentioned previously, HEC-GeoRAS was used to derive the geometry data used in the hydraulic model. The mapping limits extend from the Nevada-Arizona border to just upstream of the confluence of Toquop Wash and the Virgin River. However, the hydraulic model was extended approximately 2.4 miles upstream of the state line (about 1,000 feet downstream of the Scenic Bridge), in order to model the flow split associated with the avulsion channel (refer to **Section 2.3**). The upstream boundary of the hydraulic model was selected because the floodplain is confined at this location and outside the influence of the bridge. **Figure 4.3** is a conceptual schematic of the hydraulic model which shows that the model consists of two distinct reaches, the post-flood main channel (Virgin River) and the avulsion. Junction J-1 represents the location of the flow split and commencement of the avulsion channel. It is positioned approximately 1.7 miles upstream of the Nevada-Arizona border. The flow is distributed between the two reaches using the HEC-RAS energy balance optimization. A series of lateral weirs were placed along the high point between the two reaches. They represent a hypothetical divisionary boundary for the cross-sections associated with each reach. As shown on **Figure 4.4**, each cross-section on the avulsion has an equivalent cross-section on Reach 2 of the Virgin River. For example, the avulsion cross-section -107 is an extension of cross-section -7 on the main channel. The purpose of modeling the system using the lateral weirs was to compute the differential WSEL through the main channel and the avulsion by allowing the water to flow (spill) back and forth. The avulsion ultimately makes a 90 degree turn into the main channel at Junction J-2, which is located approximately 0.5 mile downstream of the Nevada-Arizona border.

Two existing structures were incorporated into the hydraulic model: the Bunkerville Bridge and Bunkerville Diversion Structure. The geometry of the Bunkerville Bridge was input into HEC-RAS as a bridge and was based on the construction/design plans supplied by the Nevada Department of Transportation (NDOT). The Bunkerville Bridge plans used to derive the bridge geometry are included in **Appendix D**. In order to accurately model the effects the Bunkerville Diversion Structure on the upstream WSEL, the cross-section for the structure was modeled as an inline weir. The geometry of the Bunkerville Diversion Structure is based on the post-flood LiDAR data. It should be noted that the Bunkerville Diversion Structure is not considered a sanctioned dam and was only modeled to assess the flood hazards it creates.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ARIZONA
XS 20
Virgin River Reach 1
Avulsion Reach 1
Virgin River Reach 2
Bunkerville Diversion Structure
Scenic Bridge
XS -73
XS -72
XS -44
XS -42
Bunkerville Bridge
Virgin River Reach 3
Toqaup Wash
XS -145
XS 105
XS -125
Avulsion Reach 1
Lateral Weirs
J-1
XS 6
XS 5
Virgin River Reach 2
J-2
XS -27
XS -25

Figure 4.3: Conceptual Schematic of the Corrected Effective Hydraulic Model

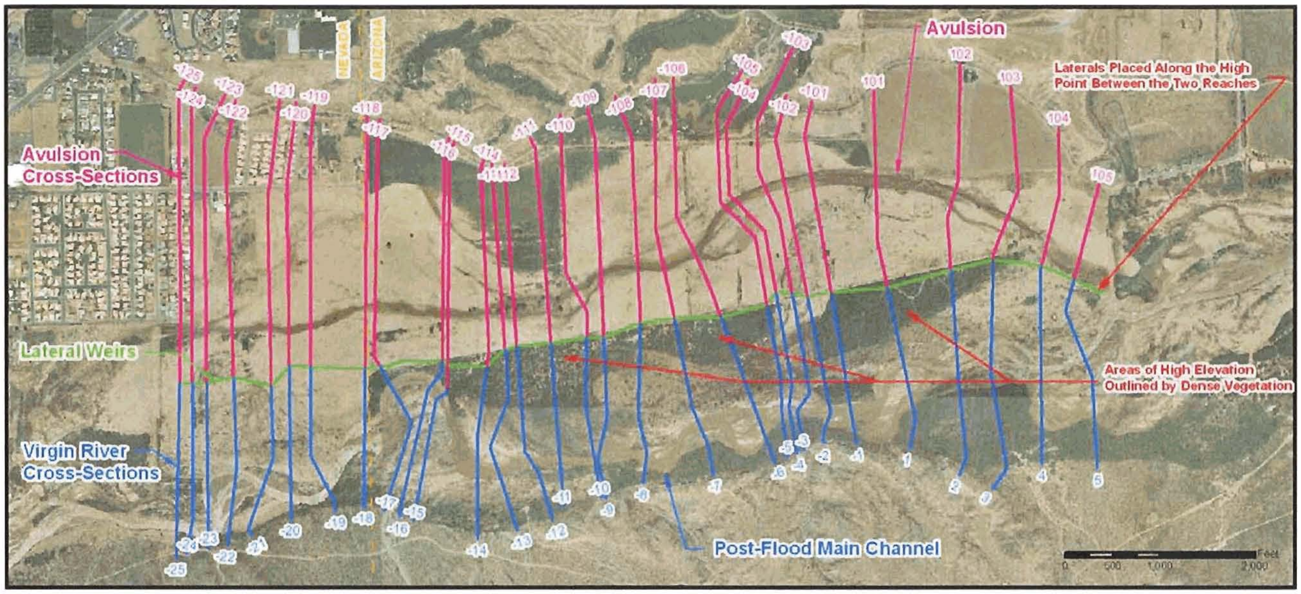
NEVADA
ARIZONA
Avulsion
Laterals Placed Along the High Point Between the Two Reaches
Avulsion Cross-Sections
Lateral Weirs
Areas of High Elevation Outlined by Dense Vegetation
Virgin River Cross-Sections
Post-Flood Main Channel
-125
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Figure 4.4: Placement of Lateral Weirs between the Avulsion and Main Channel

Boundary Conditions: HEC-RAS Normal Depth option with a slope of 0.0025 ft/ft was used as the downstream boundary condition for the corrected effective hydraulic model. This slope represents the slope of the downstream wash. The upstream boundary condition is not used by HEC-RAS as the flow through the floodplain is subcritical.

Roughness Coefficients: The Manning's roughness coefficients (n values) utilized within the model are based on field visits, pre and post-flood aerial photos, and in accordance with recommendations provided in CCRFCD's Drainage Design Manual.

As described in **Section 2.3**, the pre-flood Virgin River active channel was narrow (approximately 40 feet wide) due to the infringement of dense vegetation (mainly Tamarisk). This narrow channel did not have enough capacity to convey the January 2005 flood, and therefore resulted in a significant loss of vegetation and widening of the channel.

Based on the coordination meetings with CCRFCD, City of Mesquite, FEMA Region IX and HDR Inc., it was agreed that the active channel will eventually become narrower as the surrounding barren areas begin to re-vegetate. As a result, it was decided that the roughness coefficients based on fully mature vegetation growth (based on pre-flood aerial photos) with a narrower low-flow channel should be used. The post-flood low-flow channel alignment and location was determined using the fall 2005 aerial photos and the post-flood LiDAR data. The width of the low-flow channel is similar to that of the low-flow channel shown on the fall 2004 (pre-flood) aerial photos. The CCRFCD Hydrologic Criteria and Drainage Design Manual states a roughness coefficient within the range of 0.035 – 0.045, should be applied to natural channels with sand bottoms and vegetation lined banks. As a result, an n value of 0.04 was applied to the low-flow channel. The n value used for the low-flow channel was also confirmed by using Cowan's Method, which is documented in *Open-Channel Hydraulics* (Chow, 1959). Cowan's Method derives an estimate of n value for open channel, by considering all the factors (listed below) that contribute to flow resistance. The analytical equation for Cowan's Method is shown below:

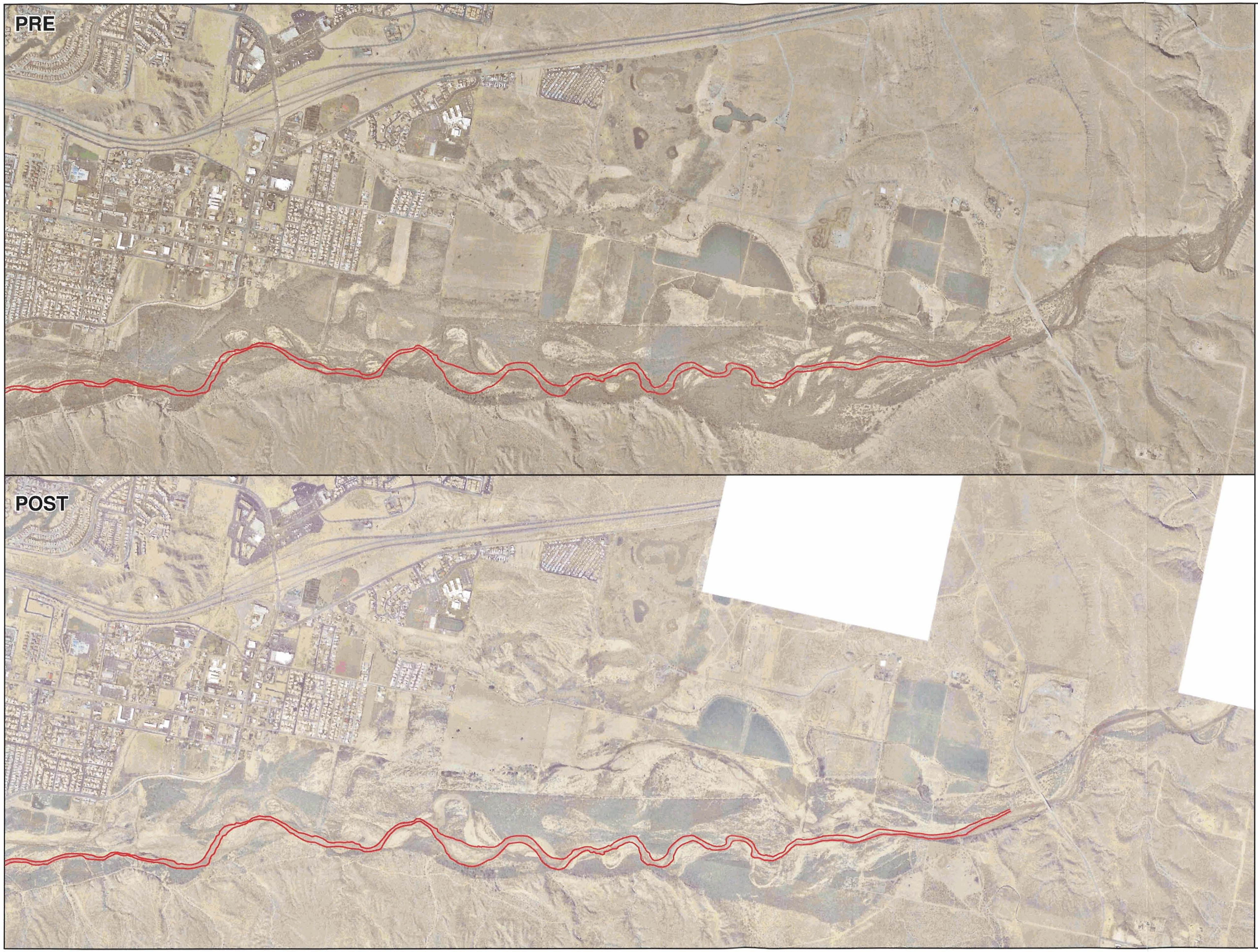
$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m_5$$

Where,

n = Manning's n computed using Cowan's Method
n_0 = Manning's n for a straight, uniform, smooth channel in the natural materials
n_1 = Correction value for effects of surface irregularities
n_2 = Correction value for variations in shape and size of the channel cross-sections
n_3 = Correction value for obstructions
n_4 = Correction value for vegetation and flow conditions
m_5 = Correction factor for meandering of the channel

The Cowan's Method calculation used to determine the n value for the low-flow channel is provided in **Appendix B**. Also, **Figures 4.5A – 4.5C** illustrate the post-flood low-flow channel overlaid on the pre and post-flood aerial photos.

The mature growth n values outside the post-flood low-flow channel were determined using the fall 2004 (pre-flood) aerial photos (please refer to **Figures 4.6A** - **4.6C**). As shown on the figures, an n value of 0.045 was applied to agricultural fields, golf courses, and grasslands. Newly graded areas and natural desert landscaping were assigned values of 0.025 and 0.035, respectively. Based on the pre-flood aerial photos, areas of dense vegetation were assigned a value of 0.12, and the areas of sparse vegetation, within the floodplain, were designated a value of 0.05. For the remaining areas (except residential areas), within the floodplain, a weighted Manning's n was assigned based on the density of the vegetation cover visually determined from the pre-flood aerial photos. The Manning's n calculations associated with these areas are included in **Appendix B.** A value of 0.08 was applied to residential areas, however it should be noted that all residential areas are within the ineffective flow boundaries and as a result, this n value has no affect on the floodplain hydraulics.



REGIONAL FLOOD CONTROL DISTRICT

VIRGIN RIVER
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Feet

1 inch equals 2,000 feet

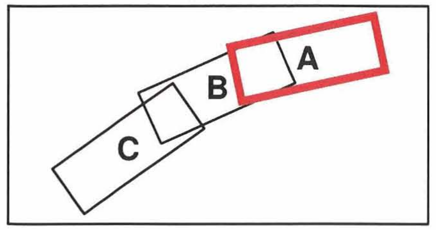
Legend

— Post-Flood Low-Flow Channel

Note: Refer to **Section 4.3** for Determination of Low-Flow Channel

Aerial Source: Clark County, Fall 2004 & Fall 2005

Figure 4.5 A - Low-Flow Channel Overlaid on Aerial Photos



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VIRGIN RIVER
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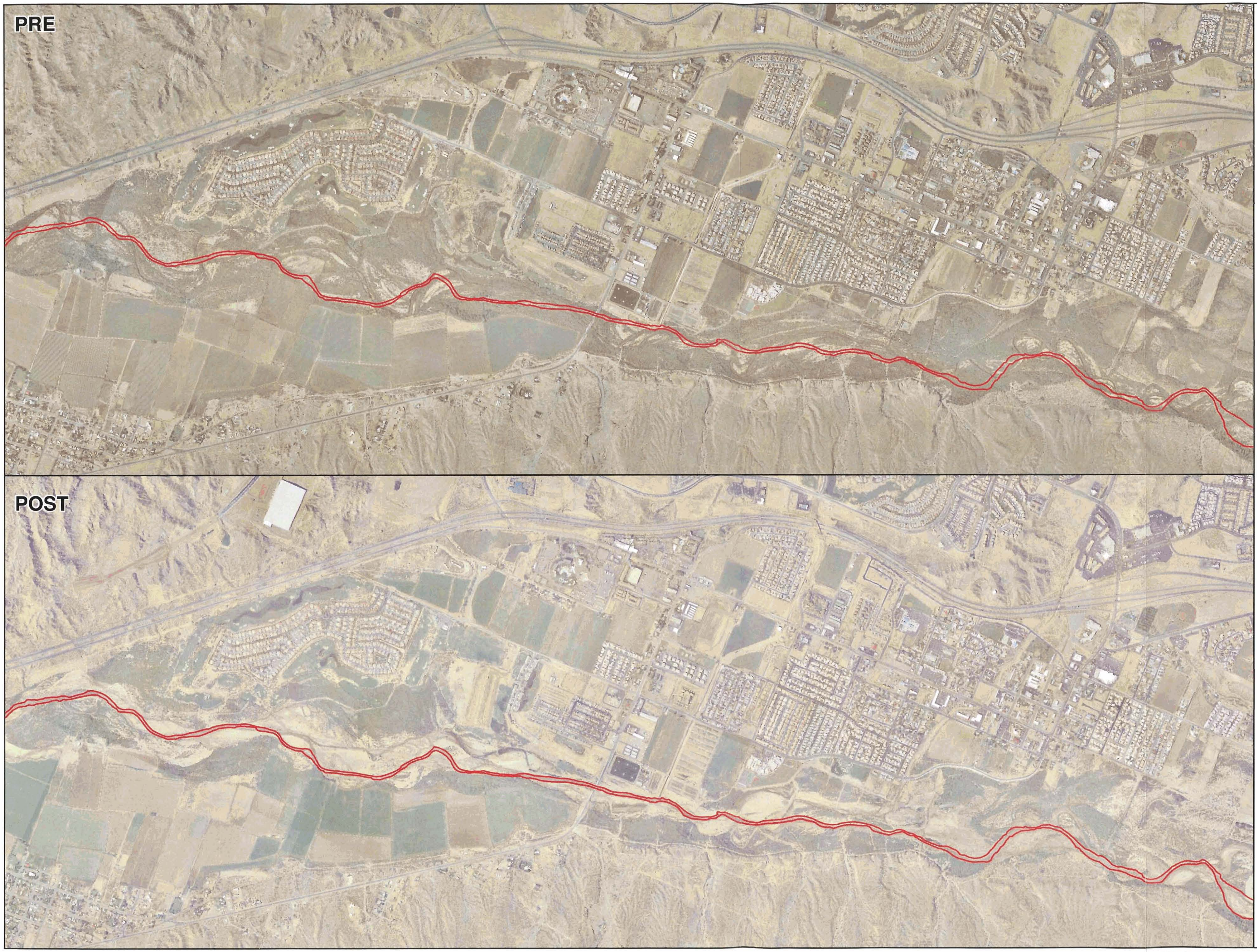
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1 inch equals 2,000 feet

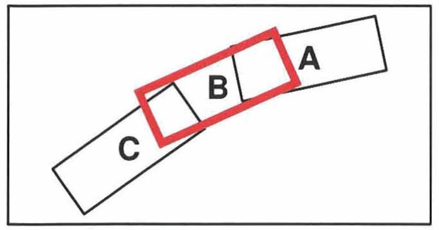
Legend

Post-Flood Low-Flow Channel

Note: Refer to **Section 4.3** for Determination of Low-Flow Channel

Aerial Source: Clark County, Fall 2004 & Fall 2005

Figure 4.5 B - Low-Flow Channel Overlaid on Aerial Photos



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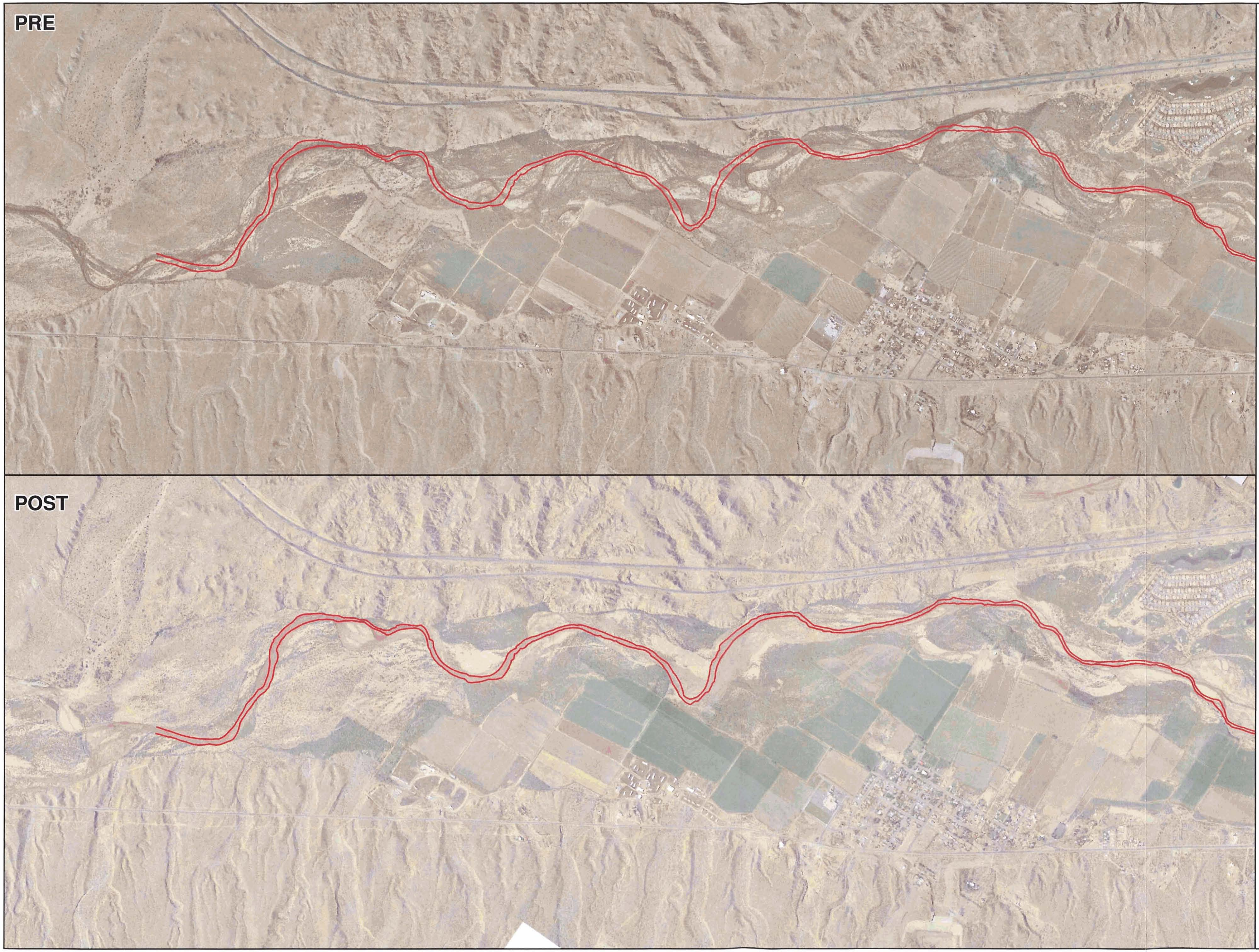

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1 inch equals 2,000 feet

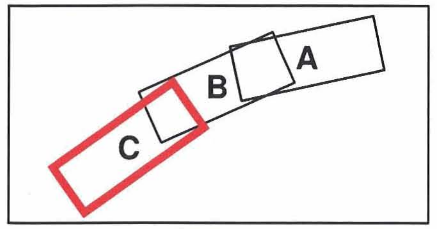
Legend

⎯⎯ Post-Flood Low-Flow Channel

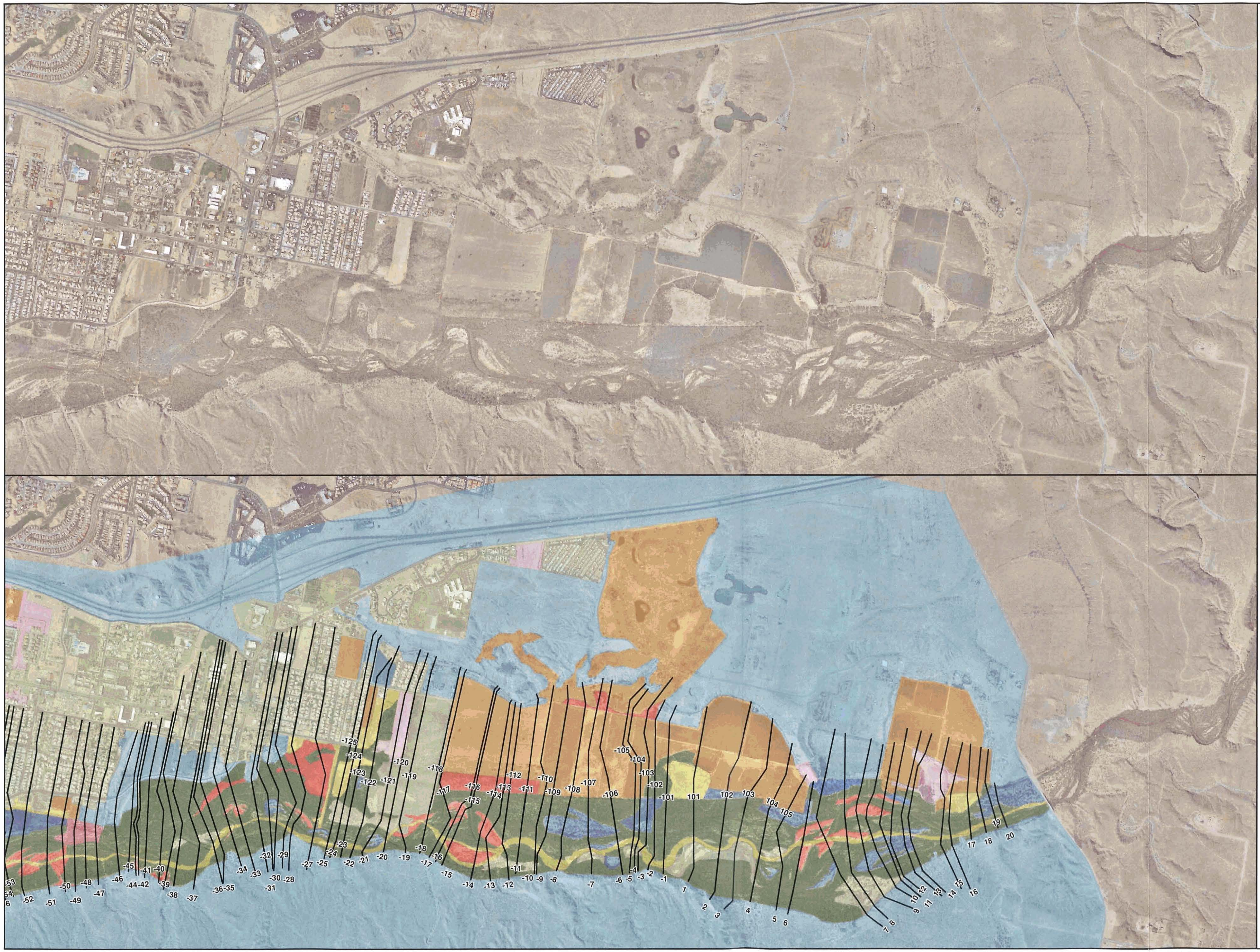
Note: Refer to **Section 4.3** for Determination of Low-Flow Channel

Aerial Source: Clark County, Fall 2004 & Fall 2005

Figure 4.5 C - Low-Flow Channel Overlaid on Aerial Photos



PBS&J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REGIONAL FLOOD CONTROL DISTRICT

VIRGIN RIVER

REQUEST FOR LETTER OF MAP REVISION

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Feet

1 inch equals 2,000 feet

Legend

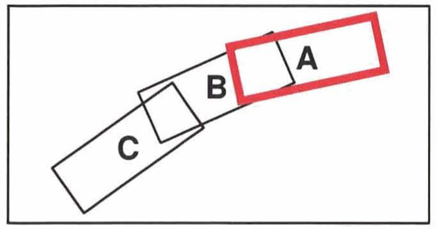
— Corrected Effective Cross Sections

N-Value

☐	0.025
🟦	0.035
🟨	0.04
🟧	0.045
🟥	0.05
🟦	0.06
☐	0.08
🟪	0.1
🟦	0.11
🟩	0.12

Aerial Source: Clark County, Fall 2004

Figure 4.6 A - Mature Growth Manning's N



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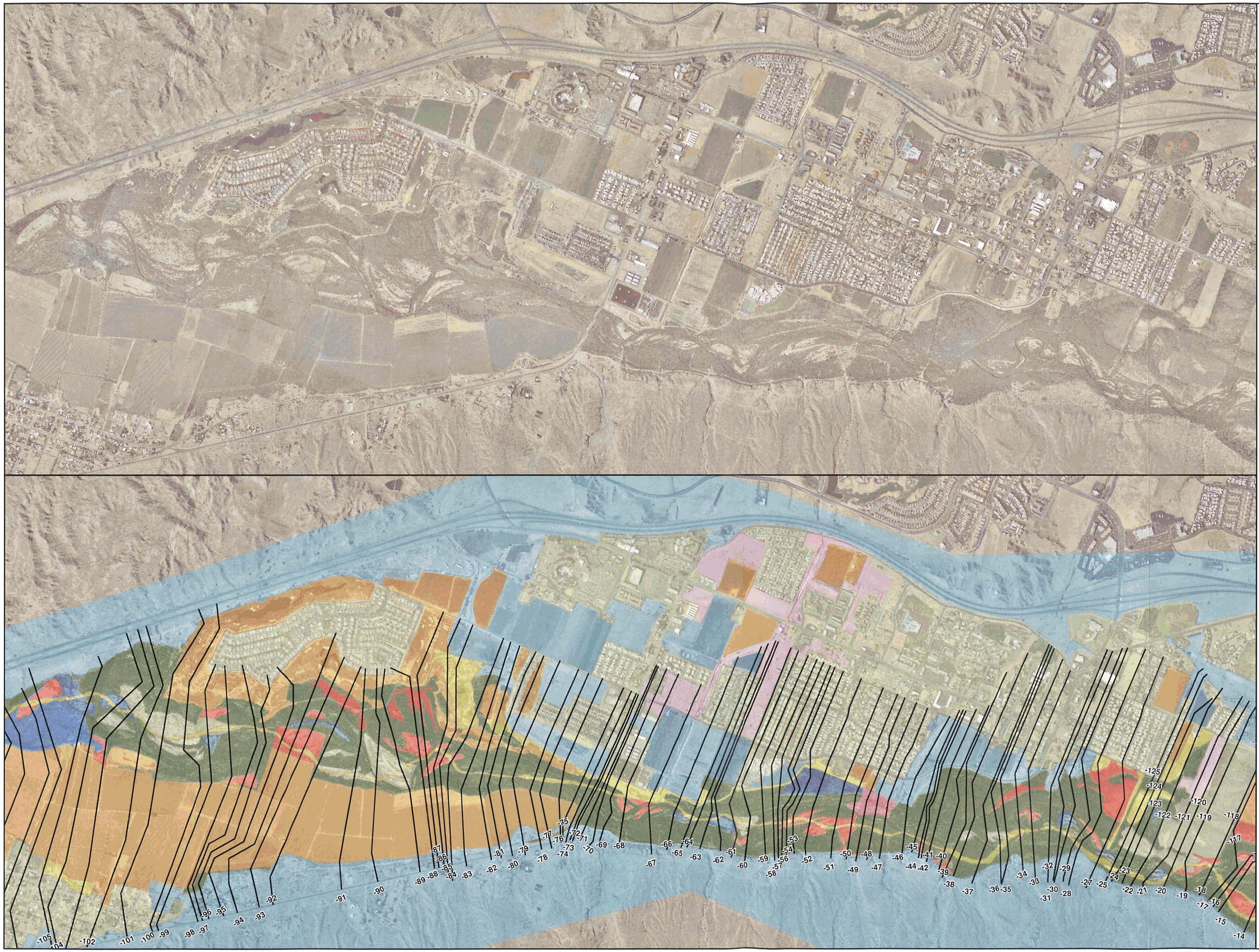
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REGIONAL FLOOD CONTROL DISTRICT

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION

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0 1,000 2,000 Feet

1 inch equals 2,000 feet

Legend

— Corrected Effective Cross Sections

N-Value

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🟧	0.045
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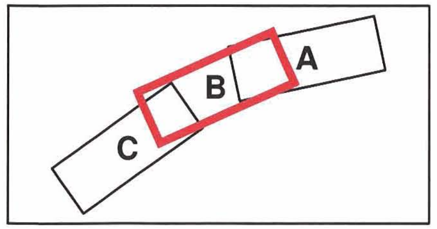
⬜	0.08
🟪	0.1
🟦	0.11
🟩	0.12

Aerial Source: Clark County, Fall 2004

Figure 4.6 B - Mature Growth Manning's N



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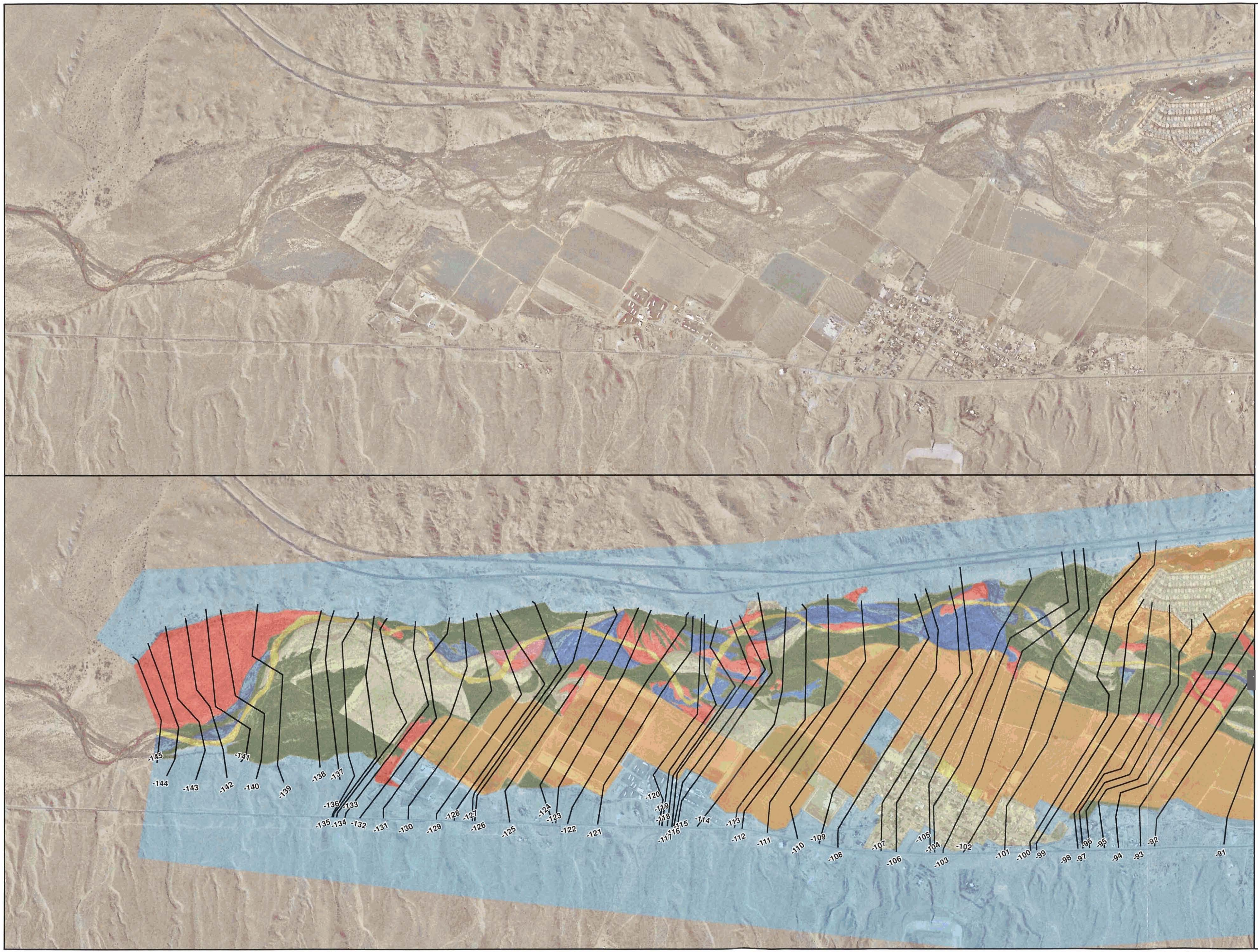
4/25/06 JB \\Lasls01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft-11x17_Figure_4-6.mxd

REGIONAL FLOOD CONTROL DISTRICT

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION

0 1,000 2,000 Feet

1 inch equals 2,000 feet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— Corrected Effective Cross Sections

N-Value

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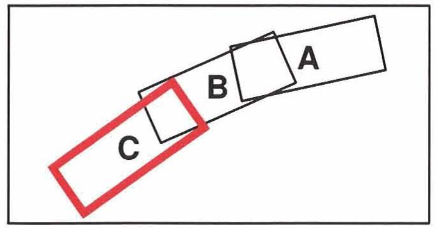
- 🟥 0.05
- 🟦 0.06
- ⬜ 0.08
- 🟪 0.1
- 🟦 0.11
- 🟩 0.12

Aerial Source: Clark County, Fall 2004

Figure 4.6 C - Mature Growth Manning's N



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4/25/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\11x17_Figure_4-6.mxd

Expansion and Contraction Coefficients: The default values of 0.1 and 0.3 for the contraction and expansion coefficients respectively were considered for most of the cross-sections. However these coefficients were increased to 0.3 and 0.5 at cross-sections upstream and downstream of the Bunkerville Bridge.

Ineffective Flow Boundaries: Some areas of the cross-sections contain water that is not actively being conveyed. According to HEC-RAS hydraulic reference manual ineffective areas are often used to describe portions of a cross-section in which water will pond, but the velocity of that water in the downstream direction is effectively zero. These areas are not included as part of the active flow area. The ineffective flow boundaries are normally included where there is sudden expansion or contraction of the floodplain. The ineffective flow boundaries within this model were established using a contraction ratio of 2:1 and expansion ratio of 4:1. However, the ineffective flow boundaries along the north bank of the avulsion in the vicinity of Nevada-Arizona border are defined such that the corrected effective model is optimized to calculate the flow splits along the lateral weirs.

Steady State Analysis and Results: The corrected effective HEC-RAS model was simulated under subcritical flow regime using a 100-year flow of 39,510 cfs (refer to **Section 3**). **Figure 4.2** (included at the end of this section) shows the 100-year floodplain delineation based on the results of the above mentioned hydraulic analysis for the entire study reach. It should be noted that the results of this hydraulic model were used to establish BFEs for the entire study reach.

The results of the hydraulic analysis show that based on the initial flow split, 18,038 cfs will be conveyed through the avulsion, while the remaining 21,472 cfs will continue to flow in the main channel. The WSEL in the avulsion (for the majority of the reach) is higher than the WSEL in the main channel (see **Table 4.2** below). As a result, the flow within the avulsion drains back into the main channel once it overtops the high point (lateral weirs) between the two modeled reaches. The flow in the avulsion gradually reduces over the entire reach until completely returning to the main channel at cross-section -27 of Reach 3. As **Table 4.2** shows, the WSEL through the avulsion (within the vicinity of the residential homes that were flooded in the January 2005 flood event) is as high as 1.86 feet higher than the WSEL in the main channel.

Table 4.2: 100-Year WSEL in the Avulsion and Main Channel

Avulsion C/S ID	Main Channel C/S ID	Avulsion WSEL (ft)	Main Channel WSEL (ft)	Difference (ft)
105	5	1620.54	1620.66	-0.12
104	4	1619.00	1618.78	0.22
103	3	1617.39	1617.43	-0.04
102	2	1615.89	1616.25	-0.36
101	1	1613.90	1614.69	-0.79
-101	-1	1611.68	1612.57	-0.89
-102	-2	1610.76	1609.87	0.89
-103	-3	1610.09	1609.71	0.38
-104	-4	1609.09	1609.32	-0.23
-105	-5	1608.76	1608.71	0.05
-106	-6	1607.48	1607.60	-0.12
-107	-7	1606.87	1605.88	0.99
-108	-8	1606.09	1604.27	1.82
-109	-9	1604.48	1603.31	1.17
-110	-10	1602.95	1602.83	0.12
-111	-11	1601.18	1601.73	-0.55
-112	-12	1600.02	1600.11	-0.09
-113	-13	1599.77	1599.51	0.26
-114	-14	1599.51	1599.24	0.27
-115	-15	1598.88	1598.70	0.18
-116	-16	1598.76	1598.53	0.23
-117	-17	1597.78	1597.56	0.22
-118	-18	1597.58	1596.90	0.68
-119	-19	1595.08	1595.48	-0.40
-120	-20	1594.16	1593.95	0.21
-121	-21	1593.62	1593.31	0.31
-122	-22	1592.65	1592.60	0.05
-123	-23	1592.47	1592.14	0.33
-124	-24	1592.46	1591.13	1.33
-125	-25	1592.46	1590.60	1.86

Arizona
Nevada

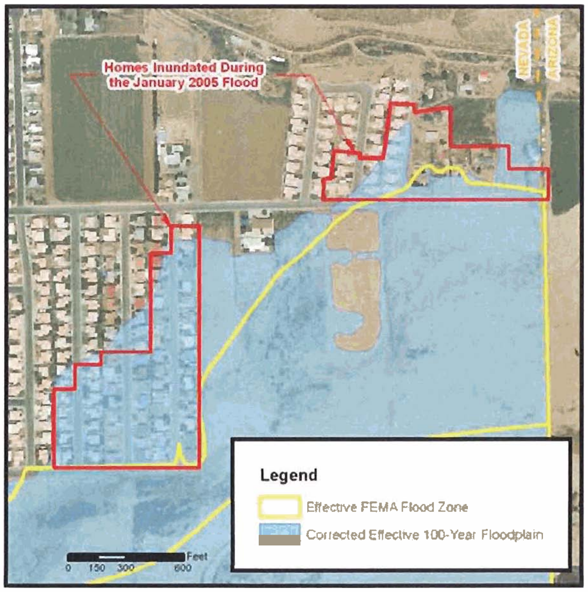
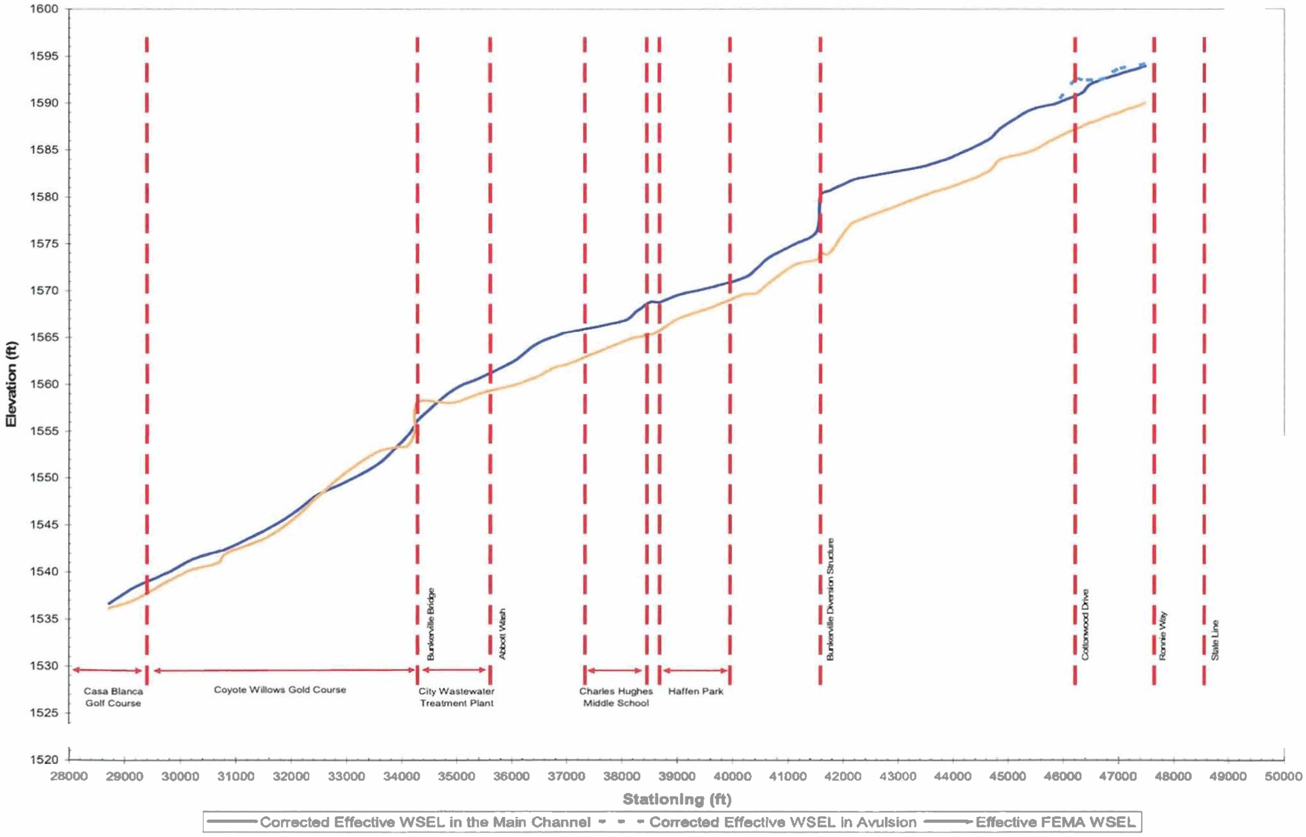

Homes Inundated During the January 2005 Flood
NEVADA
ARIZONA
Legend
Effective FEMA Flood Zone
Corrected Effective 100-Year Floodplain
0 150 300 600
Feet

Figure 4.7: Inundation Downstream of the State Line

Within the area of the residential homes located just downstream of Nevada-Arizona Border, the corrected effective floodplain delineation does not follow the limits of the effective flood zone, but instead closely resembles the inundation associated with the January 2005 flood. **Figure 4.7** shows the comparison between the corrected effective floodplain and the effective FEMA flood hazard zone in the vicinity of the above mentioned homes. As shown in the figure, the corrected effective floodplain is approximately 0 to 1000 feet wider than the effective flood zone.

Chart 4.1 shows the comparison between the WSEL of the corrected effective hydraulic model and the duplicate effective hydraulic model. It should be noted that the post-flood LiDAR data used to generate the corrected effective hydraulic model used a vertical datum of NAVD 88. The duplicate effective WSELs were converted from NGVD 29 to NAVD 88 by adding a vertical adjustment of 2.27 feet to accurately compare the duplicate and corrected effective WSELs. This adjustment was determined based Station 7C30 25E4, located within the southeast quarter of Township 13 South, Range 70 East, approximately 840-feet northeast of the intersection of Virgin Street and Canal Street in Bunkerville. **Chart 4.1** indicates that the corrected effective WSEL is higher than the effective WSEL for the majority of the reach.

Chart 4.1: Corrected and Duplicate Effective WSEL Comparison



In addition, the corrected effective floodplain delineation is also considerably wider than the limits of the effective FEMA flood zone within the farms located along the south bank of Virgin River directly north and northeast of Bunkerville. As compared to the effective flood zone, the increase in the floodplain at this location is approximately 800 to 1600 feet.

The corrected effective mapping limits extend from the Nevada-Arizona border (Cross-Section -18 and -118) to approximately 0.5 miles upstream of the confluence of Toquop

Wash and the Virgin River (Cross-Section -142). The corrected effective floodplain limits at the downstream end, tie into the existing effective flood Zone A within 50 feet. The effective WSEL at the Nevada-Arizona border (Upstream Mapping Limit) is 1591.69 feet, while the differential WSEL determined by the corrected effective hydraulic model in the main channel and the avulsion is 1596.90 feet and 1597.58 feet, respectively. PBS&J understands that the FEMA requirements specify that the corrected effective WSEL must tie into the effective water surface profile within 0.5 feet at the upstream and downstream ends of the revised reach. However, the difference in WSEL at the upstream limits between the corrected effective hydraulic model and the effective hydraulic is based on the following facts below:

- The January 2005 flood significantly altered the Virgin River and the associated floodplain and therefore, the effective FEMA hydraulic model does not accurately portray the current dynamics of the Virgin River within the study reach.
- The effective hydraulic model does not extend upstream of the Nevada-Arizona border and therefore the differential WSEL through the avulsion (that occurs approximately 1.7 miles upstream of state line) is not computed.
- The downstream limits of the floodplain (Zone A) through the Mohave County, AZ, do not match the upstream limits of the effective floodplain (Zone AE) through City of Mesquite at the Nevada-Arizona border.
- The corrected effective hydraulic model was generated utilizing more accurate and recent topography.
- HDR Inc. has been contracted by FEMA Region IX to re-delineate the Virgin River Floodplain upstream of the Nevada-Arizona border. PBS&J has been coordinating the modeling/mapping efforts with FEMA Region IX and HDR Inc. As a result, the water-surface profiles developed by PBS&J and HDR Inc. will meet FEMA requirements and tie into each other within 0 to 0.5 feet, at the Nevada-Arizona border.

The corrected effective hydraulic model is included on the data DVD in **Appendix E**. The GIS shapefiles used to generate the geometric data used in the HEC-RAS model are also included on the DVD. The corrected effective HEC-RAS profiles and results are included in **Appendix B**.

4.4 100-Year Floodway Encroachment Analysis

The BFEs computed using the above mentioned 100-year corrected effective hydraulic model were used as a basis for the floodway encroachment analysis for the entire study reach. Two methodologies were initially considered for the purpose of encroachment analysis. The first methodology involves completely eliminating the avulsion channel by conveying the entire flow through the main channel and checking whether the increase in BFE (corrected effective WSEL) through the main channel was less than a foot. However, as shown in **Table 4.3**, the increase in BFE along the main channel was significant and is as high as 3.64 feet. Therefore this methodology was not considered for the delineation of the floodway.

Table 4.3: Increase in the BFE Associated with Encroachment Methodology 1

HEC-RAS C/S ID	WSEL Based on Encroachment Methodology 1 (ft)	Corrected Effective WSEL, BFE (ft)	Difference (ft)	
5	1623.03	1620.66	2.37	
4	1621.54	1618.78	2.76	
3	1620.47	1617.43	3.04	
2	1619.56	1616.25	3.31	
1	1618.26	1614.69	3.57	
-1	1615.83	1612.57	3.26	
-2	1612.17	1609.87	2.30	
-3	1612.35	1609.71	2.64	
-4	1612.06	1609.32	2.74	
-5	1611.14	1608.71	2.43	
-6	1609.84	1607.60	2.24	
-7	1608.02	1605.88	2.14	
-8	1606.27	1604.27	2.00	
-9	1605.31	1603.31	2.00	
-10	1604.61	1602.83	1.78	
-11	1603.3	1601.73	1.57	
-12	1601.88	1600.11	1.77	
-13	1601.25	1599.51	1.74	
-14	1600.86	1599.24	1.62	
-15	1600.04	1598.70	1.34	
-16	1599.79	1598.53	1.26	
-17	1598.54	1597.56	0.98	Arizona
-18	1597.74	1596.90	0.84	Nevada
-19	1596.22	1595.48	0.74	
-20	1594.43	1593.95	0.48	
-21	1593.65	1593.31	0.34	
-22	1592.79	1592.60	0.19	
-23	1592.26	1592.14	0.12	
-24	1591.16	1591.13	0.03	
-25	1590.68	1590.60	0.08	

The second methodology removed the avulsion reach from the hydraulic model. However, instead of completely eliminating the avulsion cross-sections (Methodology 1), they were combined with their equivalent cross-section on the main channel of the Virgin River. By combining these cross-sections from the two reaches, a single model was developed for the entire floodplain. This single system model was used to develop the 100-year floodway for the entire study reach.

The encroachment analysis was simulated in HEC-RAS using equal conveyance reduction. HEC-RAS Method 4 was used to compute automated initial values for a target water surface increase of 1 foot. These initial values were entered into HEC-RAS Method 1 and used to develop an optimized encroachment for the system. The floodway was delineated based on a maximum rise of one foot in BFE through the Virgin River floodplain. The optimized100-year floodway delineation is shown on **Figure 4.2**. Within the area of flow split there is a differential WSEL between the main channel and the avulsion and therefore, the floodway delineation was governed by the lower of the two WSELs (BFEs). The increase in BFE along the main channel of the Virgin River is shown in **Table 4.4.**

The HEC-RAS profiles and results for the corrected effective encroachment analysis for both the methodologies are included in **Appendix B**.

Table 4.4: Increase in BFE Associated with Encroachment Methodology 2

HEC-RAS C/S ID	WSEL Based on Enroachment Methodology 2 (ft)	Corrected Effective WSEL in the Main Channel, BFE (ft)	Difference (ft)
-18	1597.62	1596.90	0.72
-19	1596.18	1595.48	0.70
-20	1594.47	1593.95	0.52
-21	1593.81	1593.31	0.50
-22	1593.02	1592.60	0.42
-23	1592.56	1592.14	0.42
-24	1591.82	1591.13	0.69
-25	1591.59	1590.60	0.99
-27	1590.77	1589.96	0.81
-28	1589.89	1589.23	0.66
-29	1589.15	1588.56	0.59
-30	1588.52	1587.91	0.61
-31	1588.00	1587.33	0.67
-32	1586.91	1586.04	0.87
-33	1585.84	1584.87	0.97
-34	1585.07	1584.26	0.81
-35	1584.24	1583.55	0.69
-36	1583.89	1583.17	0.72
-37	1583.32	1582.60	0.72
-38	1582.93	1582.17	0.76
-39	1582.71	1581.93	0.78
-40	1582.34	1581.48	0.86
-41	1581.27	1580.62	0.65
-42	1580.32	1580.14	0.18
-44	1577.27	1576.34	0.93
-45	1577.27	1576.35	0.92
-46	1575.87	1574.95	0.92
-47	1573.79	1573.59	0.20
-48	1572.75	1572.31	0.44
-49	1571.84	1571.32	0.52
-50	1571.72	1571.18	0.54
-51	1570.95	1570.32	0.63
-52	1570.31	1569.59	0.72
-53	1569.61	1568.77	0.84
-54	1569.71	1568.85	0.86
-56	1569.51	1568.60	0.91
-57	1569.06	1568.15	0.91
-58	1568.67	1567.75	0.92
-59	1567.66	1566.80	0.86
-60	1567.23	1566.34	0.89
-61	1566.96	1565.99	0.97
-62	1566.50	1565.53	0.97
-63	1566.08	1565.18	0.90
-64	1565.15	1564.51	0.64
-65	1564.98	1564.25	0.73
-66	1562.93	1562.50	0.43
-67	1561.01	1560.77	0.24
-68	1559.49	1559.35	0.14
-69	1557.89	1557.46	0.43
-70	1557.78	1557.28	0.50
-71	1557.09	1556.43	0.66
-72	1556.78	1556.15	0.63
-73	1556.20	1555.56	0.64
-74	1555.40	1554.46	0.94
-75	1553.84	1553.41	0.43
-76	1551.99	1551.32	0.67
-77	1551.01	1550.08	0.93
-78	1550.02	1549.43	0.59
-79	1548.75	1548.20	0.55
-80	1547.60	1547.09	0.51
-81	1546.41	1546.06	0.35
-82	1545.68	1545.30	0.38
-83	1544.80	1544.34	0.46
-84	1543.52	1542.95	0.57
-85	1543.03	1542.41	0.62
-86	1542.64	1542.17	0.47
-87	1541.99	1541.59	0.40
-88	1541.74	1541.35	0.39
-89	1540.42	1539.92	0.50
-90	1539.18	1538.37	0.81
-91	1537.46	1536.64	0.82
-92	1535.83	1534.92	0.91
-93	1535.43	1534.56	0.87
-94	1535.14	1534.34	0.80
-95	1534.75	1534.00	0.75
-96	1533.67	1533.00	0.67
-97	1532.63	1531.87	0.76
-98	1530.36	1529.83	0.53
-99	1529.27	1528.81	0.46
-100	1528.24	1527.82	0.42
-101	1526.38	1526.08	0.30
-102	1524.73	1523.99	0.74
-103	1522.79	1521.89	0.90
-104	1521.97	1521.05	0.92
-105	1520.43	1519.59	0.84
-106	1518.97	1518.00	0.97
-107	1518.49	1517.50	0.99
-108	1517.40	1516.56	0.84
-109	1516.84	1515.84	1.00
-110	1515.80	1514.90	0.90
-111	1514.02	1513.36	0.66
-112	1511.90	1511.23	0.67
-113	1509.86	1509.29	0.57
-114	1508.56	1507.90	0.66
-115	1505.67	1505.14	0.53
-116	1505.41	1504.87	0.54
-117	1504.93	1504.39	0.54
-118	1504.48	1503.98	0.50
-119	1503.83	1503.38	0.45
-120	1503.52	1503.05	0.47
-121	1501.75	1501.22	0.53
-122	1500.79	1500.23	0.56
-123	1499.16	1498.40	0.76
-124	1498.59	1497.63	0.96
-125	1497.75	1496.89	0.86
-126	1495.87	1495.36	0.51
-127	1494.30	1493.75	0.55
-128	1493.14	1492.56	0.58
-129	1492.33	1491.83	0.50
-130	1490.96	1490.57	0.39
-131	1489.72	1489.22	0.50
-132	1488.47	1487.47	1.00
-133	1487.48	1486.66	0.82
-134	1485.66	1484.90	0.76
-135	1484.62	1483.74	0.88
-136	1483.64	1482.69	0.95
-137	1482.33	1481.50	0.83
-138	1481.35	1480.64	0.71
-139	1477.57	1477.08	0.49
-140	1475.42	1474.69	0.73
-141	1474.41	1473.53	0.88
-142	1473.43	1472.53	0.90

* The cross-sections shown are within the effective mapping limits.

4.5 500-Year Corrected Effective Hydraulic Model

The 100-year corrected effective hydraulic model was slightly modified in order to accurately simulate a storm event with a 500-year return frequency. Eleven cross-sections, within Reach 1 of both the avulsion and the Virgin River, were extended north in order to confine the new limits of the floodplain. Also, all ineffective areas were re-determined based on the assumptions discussed in **Section 4.3**. The updated cross-sections and new ineffective flow areas are shown on **Figure 4.8: 500-Year Corrected Effective Work Map**.

The 500-year corrected effective hydraulic model was simulated in HEC-RAS under subcritical flow regime using a flow rate of 68,800 cfs (refer to **Section 3**). The results of the hydraulic analysis show that based on the initial flow split, 32,464 cfs flows through the avulsion, while the remaining 36,336 cfs travels through the main channel. As with the 100-year hydraulic model, the flow split associated with the avulsion channel causes a differential WSEL along the two reaches. **Table 4.5** illustrates the difference in 500-year WSEL between the main channel and the avulsion. The flow mainly travels from the main channel north into the avulsion for the first half of the flow split. Approximately, mid-way through the flow split the WSEL in the avulsion is sufficiently high enough to allow flow to travel back into the main channel. The flow in the avulsion ultimately returns to the main channel at cross-section -27 of Reach 3 of the Virgin River.

Charts 4.2 and **4.3** illustrate the 100 and 500-year corrected effective WSELs for the main channel of the Virgin River and the avulsion, respectively. The modified GIS shapefiles, as well as, the 500-year corrected effective hydraulic model are included on the data DVD in **Appendix E**. **Figure 4.8** shows the cross-section locations and ineffective flow boundaries overlaid on the 500-year floodplain delineation for the study reach.

The HEC-RAS profiles and results for the 500-year corrected effective model are included in **Appendix B**.

Table 4.5: 500-Year WSEL between the Main Channel and Avulsion

Avulsion C/S ID	Main Channel C/S ID	Avulsion WSEL (ft)	Main Channel WSEL (ft)	Difference (ft)	
105	5	1622.39	1622.66	-0.27	
104	4	1620.97	1621.07	-0.10	
103	3	1619.39	1619.87	-0.48	
102	2	1617.63	1618.91	-1.28	
101	1	1615.47	1617.54	-2.07	
-101	-1	1613.08	1615.06	-1.98	
-102	-2	1612.10	1611.58	0.52	
-103	-3	1611.42	1611.67	-0.25	
-104	-4	1610.51	1611.39	-0.88	
-105	-5	1610.19	1610.55	-0.36	
-106	-6	1608.86	1609.33	-0.47	
-107	-7	1608.14	1607.68	0.46	
-108	-8	1607.17	1606.20	0.97	
-109	-9	1605.55	1605.10	0.45	
-110	-10	1603.85	1604.34	-0.49	
-111	-11	1602.65	1602.99	-0.34	
-112	-12	1601.72	1601.83	-0.11	
-113	-13	1601.49	1601.39	0.10	
-114	-14	1601.24	1601.12	0.12	
-115	-15	1600.65	1600.59	0.06	
-116	-16	1600.52	1600.45	0.07	
-117	-17	1599.54	1599.38	0.16	Arizona
-118	-18	1599.30	1598.64	0.66	Nevada
-119	-19	1596.22	1596.80	-0.58	
-120	-20	1595.69	1595.70	-0.01	
-121	-21	1595.26	1595.21	0.05	
-122	-22	1594.78	1594.62	0.16	
-123	-23	1594.67	1594.17	0.50	
-124	-24	1594.67	1593.44	1.23	
-125	-25	1594.67	1593.11	1.56	

Chart 4.2: 100 and 500-Year WSEL along the Main Channel

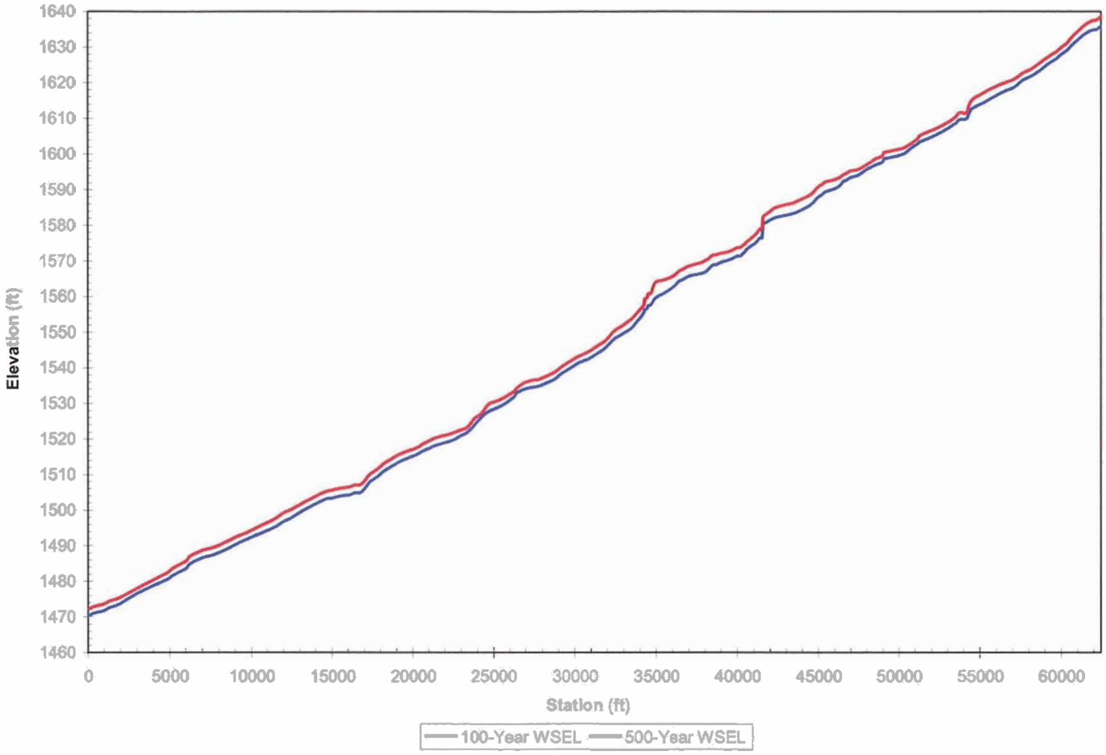
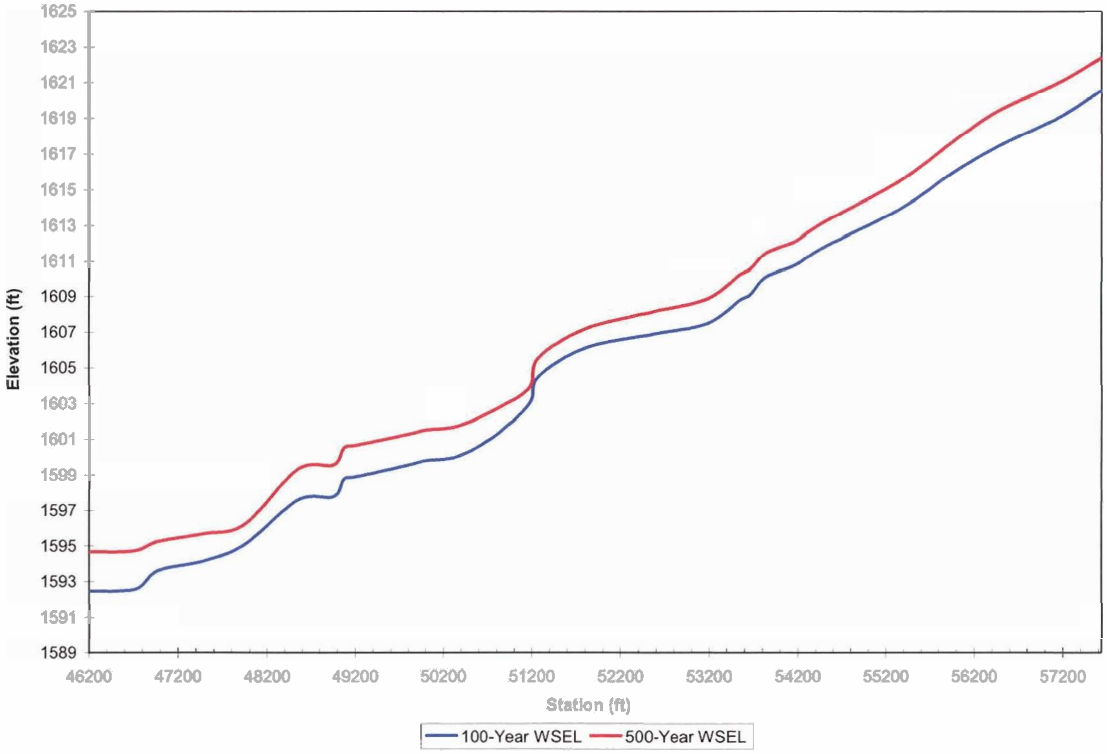


Chart 4.3: 100 and 500-Year WSEL along Avulsion



Toquop Wash
Zone A
Zone A
Zone AE
Limit of Detailed Study
Zone A/AE Boundary
Zone AE
Bunkerville
Zone AE
15
Limit of Detailed Study
Zone A/AE Boundary
Pulsipher Wash
Zone AE
Limit of Detailed Study
Zone A/AE Boundary
Zone A
Zone AE
Bunkerville Bridge
Zone A
Zone AE
Abbott Wash
Zone A
City of Mesquite
Bunkerville Diversion Structure
Clark County
Mohave County
Nevada
Arizona
Zone AE
Zone A
Limit of Detailed Study
Zone A/AE Boundary
Zone A
Scenic Bridge
N
W
E
S
0
800
1,600
3,200
Feet
100-Year Cross Sections
Lateral Weirs
2 Foot Contours
(Based on Post-Flood LiDAR)
100-Year Ineffective Areas
100-Year Floodplain
100-Year Floodway
Revised Zone A

Aerial Source: Clark County, Spring 2005

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 4.2 - 100-Year Corrected Effective Work Map

1 inch equals 800 feet

Note: The hydraulic analysis and the associated flood zone delineation completed for the 100-year Corrected Effective Hydraulic Model within this LOMR are based on topographic information shown on this map. Please refer to **Section 2.5** for further information on topography.

I hereby certify that the topographic information used for 100-year Corrected Effective Hydraulic Model within this LOMR substantially confirms with the current conditions.

05-02-06
Harshal B. Desai, CFM, P.E., NV - 17468

Legend

REGIONAL FLOOD CONTROL DISTRICT

PBS&

15
Limit of Study
Bunkerville
Bunkerville Bridge
Bunkerville Diversion Structure
City of Mesquite
Nevada
Arizona
Clark County
Mohave County
Limit of Study
Scenic Bridge
N
W
E
S
0
800
1,600
3,200
Feet
Legend
500-Year Cross Sections
Lateral Weirs
2 Foot Contours (Based on Post-Flood LiDAR)
500-Year Ineffective Areas
500-Year Floodplain
REGIONAL FLOOD CONTROL DISTRICT
PBSJ

Aerial Source: Clark County, Spring 2005

1 inch equals 800 feet

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 4.8 - 500-Year Corrected Effective Work Map

Note: The hydraulic analysis and the associated flood zone delineation completed for the 500-year Corrected Effective Hydraulic Model within this LOMR are based on topographic information shown on this map. Please refer to **Section 2.5** for further information on topography.

I hereby certify that the topographic information used for 500-year Corrected Effective Hydraulic Model within this LOMR substantially confirms with the current conditions.

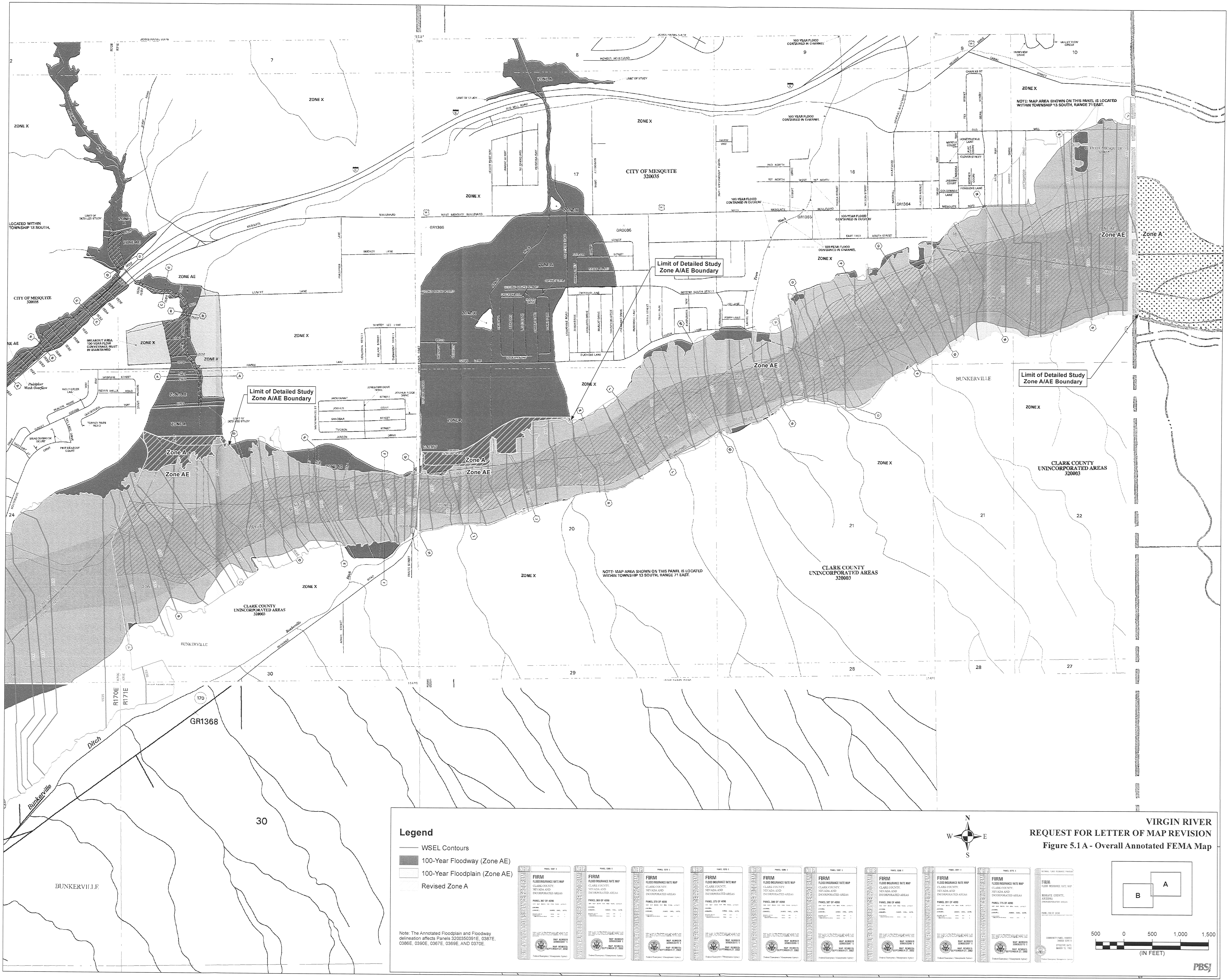
05-02-06

Harshal B. Desai, CFM, P.E., NV - 17468

Section 5
Conclusions

The Virgin River in the vicinity of Mesquite, Nevada experienced a major flood near the magnitude of the 100-year frequency event in January 2005. The flood resulted in extensive damage to both public and private properties, as well as, significantly altered the physical characteristics of the Virgin River and the associated floodplain. The flooding limits were wider than the mapped 100-year regulatory FEMA SFHA. As a result of this flood event the CCRFCD contracted PBS&J to remap the regulatory floodplain associated with the Virgin River extending from the Nevada-Arizona border to just upstream of the confluence of Toquop Wash and the Virgin River. PBS&J developed a corrected effective hydraulic model using the more accurate and recent topography (post-flood LiDAR data) and the newly developed 100-year flow of 39,510 cfs. The BFEs were established based on the results of the corrected effective hydraulic model and the 100-year floodplain and the associated floodway were re-delineated. **Figure 4.2: 100-Year Corrected Effective Work Map** shows the cross-section locations, ineffective flow boundaries, and 100-year floodplain and floodway delineation. PBS&J also developed a corrected effective hydraulic model using 500-year flow of 68,800 cfs. The 500-year floodplain delineation is shown on **Figure 4.8: 500- Year Corrected Effective Work Map.**

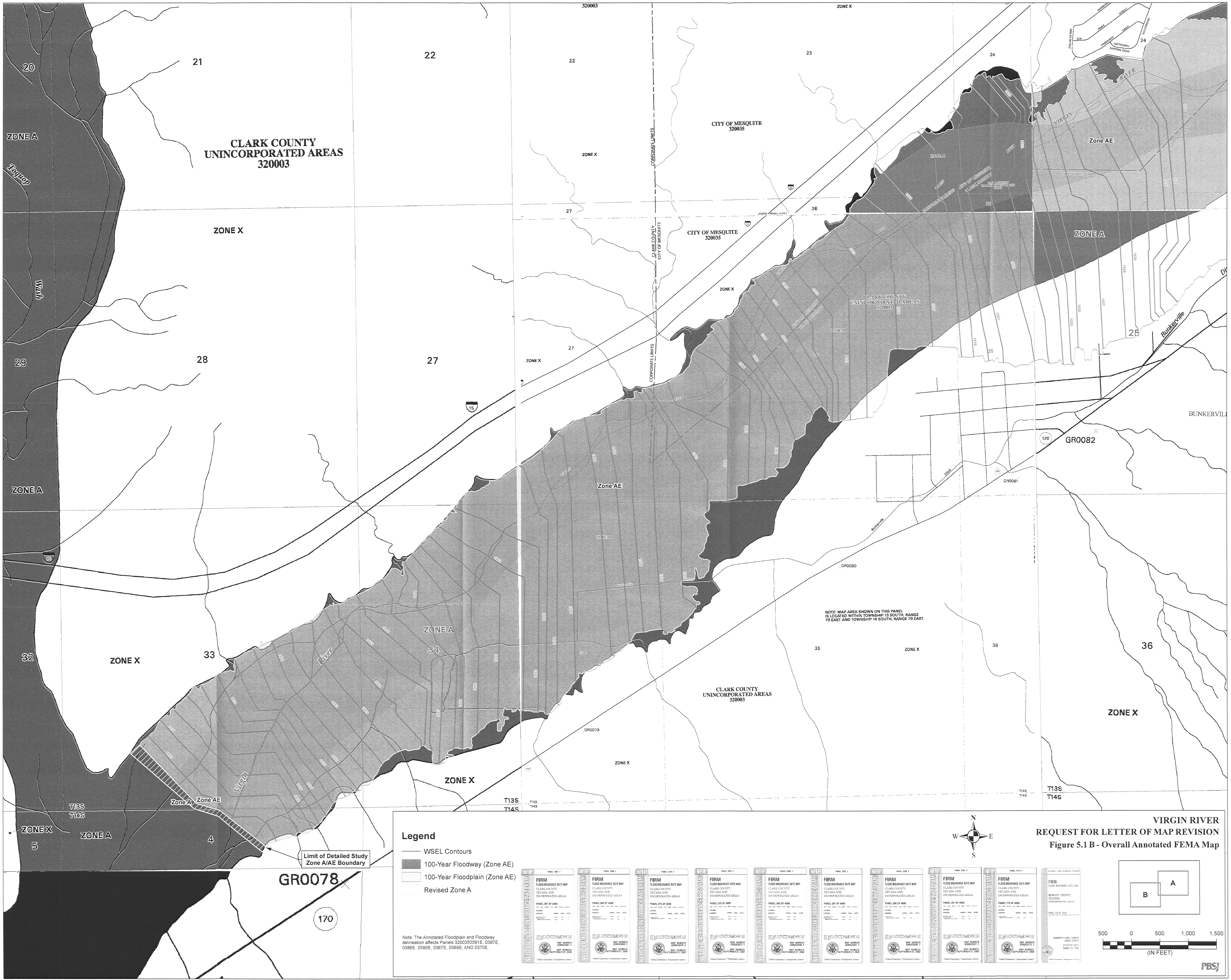
PBS&J believes that based on the data and supporting calculations contained within this LOMR application, the flood zone revisions for the Virgin River, in the vicinity of Mesquite, is warranted. Please refer to **Figures 5.1 A-B: Annotated FEMA Map(s)** for the revisions to the effective flood zone delineation within the study reach.


Legend
WSEL Contours
100-Year Floodway (Zone AE)
100-Year Floodplain (Zone AE)
Revised Zone A
N
W
E
S
A
B
500
0
500
1,000
1,500
(IN FEET)
PBSJ
FIRM
FLOOD INSURANCE RATE MAP
CLARK COUNTY, NEVADA AND INCORPORATED AREAS
PANEL 367 OF 4090
PANEL 369 OF 4090
PANEL 370 OF 4090
PANEL 375 OF 4090
PANEL 386 OF 4090
PANEL 387 OF 4090
PANEL 390 OF 4090
PANEL 391 OF 4090
PANEL 775 OF 4090
MAP REVISED: SEPTEMBER 27, 2002
MOHAVE COUNTY, ARIZONA
NATIONAL FLOOD INSURANCE PROGRAM
Federal Emergency Management Agency
Limit of Detailed Study Zone A/AE Boundary
Limit of Detailed Study Zone A/AE Boundary
Limit of Detailed Study Zone A/AE Boundary
Zone A
Zone AE
ZONE X
CITY OF MESQUITE 320035
CLARK COUNTY UNINCORPORATED AREAS 320003
BUNKERVILLE
GR1368
GR1366
GR1365
GR1364
Ditch
Bunkerville
R170E
R171E
170
30
NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 13 SOUTH, RANGE 71 EAST.
WEST MESQUITE BOULEVARD
MESQUITE BOULEVARD
OLD MILL ROAD
100 YEAR FLOOD CONTAINED IN CHANNEL
100-YEAR FLOOD CONTAINED IN CULVERT
BREAKOUT AREA 100 YEAR FLOW CONVEYANCE MUST BE MAINTAINED
Pulsipher Wash Overflow

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 5.1 A - Overall Annotated FEMA Map

Note: The Annotated Floodplain and Floodway delineation affects Panels 3200350391E, 0387E, 0386E, 0390E, 0367E, 0369E, AND 0370E.

4/25/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\24x84_Figure_5-1.mxd



20
21
22
ZONE A
Toquop
Wash
CLARK COUNTY
UNINCORPORATED AREAS
320003
ZONE X
CITY OF MESQUITE
320035
CORPORATE LIMITS
CLARK COUNTY
CITY OF MESQUITE
23
24
VIRGIN RIVER
Zone AE
ZONE A
26
27
28
29
25
Bunkerville
BUNKERVILLE
170
GR0082
GR0081
GR0080
GR0079
GR0078
15
Zone AE
ZONE A
River
Virgin
33
34
32
35
36
5
4
T13S
T14S
Zone A
Zone AE
Limit of Detailed Study
Zone A/AE Boundary
NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 13 SOUTH, RANGE 70 EAST AND TOWNSHIP 14 SOUTH, RANGE 70 EAST.
N
S
E
W
A
B
500
0
500
1,000
1,500
(IN FEET)
PANEL 0367 E
PANEL 0369 E
PANEL 0370 E
PANEL 0375 E
PANEL 0386 E
PANEL 0775 E
FIRM
FLOOD INSURANCE RATE MAP
CLARK COUNTY, NEVADA AND INCORPORATED AREAS
MOHAVE COUNTY, ARIZONA (UNINCORPORATED AREAS)
PANEL 200 OF 3450
COMMUNITY-PANEL NUMBER 040058 0200 B
EFFECTIVE DATE: MARCH 15, 1982
MAP REVISED: SEPTEMBER 27, 2002
Federal Emergency Management Agency
PBSJ

VIRGIN RIVER
REQUEST FOR LETTER OF MAP REVISION
Figure 5.1 B - Overall Annotated FEMA Map

Legend

- WSEL Contours
- ▨ 100-Year Floodway (Zone AE)
- ▨ 100-Year Floodplain (Zone AE)
- ▨ Revised Zone A

Note: The Annotated Floodplain and Floodway delineation affects Panels 3200350391E, 0387E, 0386E, 0390E, 0367E, 0369E, AND 0370E.

4/25/06 JB \\Lasfs01\51 - Hydrology\PROJECTS\511792 Virgin River FHS\GIS\MXD\Draft\24x84_Figure_5-1.mxd

Section 6
Bibliography and References

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2. Bulloch Brothers Engineering Inc. 1996. Work Maps for the Mesquite City Flood Study. Sheets 3 -14. Prepared for City of Mesquite. February 5, 1996

3. Chow, V.T., ed. 1959. Open-Channel Hydraulics. Reissued 1988. McGraw-Hill, New York, pp. 106-124.

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16. U.S. Army Corps of Engineers. 2005. HEC-GeoRAS: An Extension of Support for HEC-RAS using ArcGIS: User's Manual, Version 4. September 2005.

FEDERAL EMERGENCY MANAGEMENT AGENCY

OVERVIEW & CONCURRENCE FORM

O.M.B No. 3067-0148
Expires September 30, 2005

PAPERWORK BURDEN DISCLOSURE NOTICE

Public reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. Please do not send your completed survey to the above address.

A. REQUESTED RESPONSE FROM FEMA

This request is for a (check one):

☐ CLOMR: A letter from FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60, 65 & 72).

☒ LOMR: A letter from FEMA officially revising the current NFIP map to show the changes to floodplains, regulatory floodway or flood elevations. (See Parts 60 & 65 of the NFIP Regulations.)

B. OVERVIEW

1. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Ex: 480301 480287	City of Katy Harris County	TX TX	480301 48201C	0005D 0220G	02/08/83 09/28/90
320035	City of Mesquite, Clark County	NV	32003C	0367E	10/27/02
320003	Unincorporated Areas, Clark County	NV		0369E	
				0370E	
				0386E	
				0387E	
				0390E	
				0391E	

2. Flooding Source: Virgin River

3. Project Name/Identifier: Virgin River: Request for Letter of Map Revision

4. FEMA zone designations affected: AE &A (choices: A, AH, AO, A1-A30, A99, AE, AR, V, V1-V30, VE, B, C, D, X)

5. Basis for Request and Type of Revision:

a. The basis for this revision request is (check all that apply)

☐ Physical Change ☒ Improved Methodology/Data

☒ Regulatory Floodway Revision ☐ Other (Attach Description)

Note: A photograph and narrative description of the area of concern is not required, but is very helpful during review.

b. The area of revision encompasses the following types of flooding and structures (check all that apply)

Types of Flooding: ☒ Riverine ☐ Coastal ☐ Shallow Flooding (e.g., Zones AO and AH)

☐ Alluvial fan ☐ Lakes ☐ Other (Attach Description)

Structures: ☐ Channelization ☐ Levee/Floodwall ☒ Bridge/Culvert

☐ Dam ☐ Fill ☐ Other, Attach Description

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $_____

☒ No, Attach Explanation

Please see the FEMA Web site at http://www.fema.gov/fhm/frm_fees.shtm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Michele D'Alessandro, E.I., CFM	Company: PBS&J	
Mailing Address: 2270 Corporate Circle Suite 100 Henderson, NV 89074	Daytime Telephone No.: (702) 263-7275 ex. 3001	Fax No.: (702) 263-7200
	E-Mail Address: MD'Alessandro@pbsj.com	
Signature of Requester (required): Michele D'Alessandro		Date: 05-02-06

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Dave Betley, P.E., Principal Engineer		Telephone No.: (702) 455-4808
Community Name: Clark County Public Works	Community Official's Signature (required):	Date: 4/28/06

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Harshal Desai, P.E., CFM	License No.: NV 17468	Expiration Date: 12/31/08
Company Name: PBS&J	Telephone No.: (702) 263-7275	Fax No.: (702) 263-7200
Signature:		Date: 05-02-06

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

PROFESSIONAL ENGINEER-STATE OF NEVADA
HARSHAL B. DESAI
Exp. 12-31-08
CIVIL
No. 17468

Seal (Optional)

05-02-06

C. REVIEW FEE

Has the review fee for the appropriate request category been included?	☐ Yes ☒ No, Attach Explanation	Fee amount: $_____

Please see the FEMA Web site at http://www.fema.gov/fhm/frm_fees.shtm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Michele D'Alessandro, E.I., CFM	Company: PBS&J	
Mailing Address: 2270 Corporate Circle Suite 100 Henderson, NV 89074	Daytime Telephone No.: (702) 263-7275 ex. 3001 E-Mail Address: MD'Alessandro@pbsj.com	Fax No.: (702) 263-7200
Signature of Requester (required): Michele D'Alessandro		Date: 05-02-06

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Allen Bell, P.E., Economic Development Director		Telephone No.: (702) 346-5295
Community Name: City of Mesquite	Community Official's Signature (required):	Date: 27 April '06

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Harshal Desai, P.E., CFM	License No.: NV 17468	Expiration Date: 12/31/08
Company Name: PBS&J	Telephone No.: (702) 263-7275	Fax No.: (702) 263-7200
Signature:		Date: 05-02-06

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☒ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

PROFESSIONAL ENGINEER - STATE OF NEVADA
HARSHAL B. DESAI
Exp. 12-31-08
CIVIL
No. 17468
Seal (Optional)
05-02-06

FEDERAL EMERGENCY MANAGEMENT AGENCY

RIVERINE HYDROLOGY & HYDRAULICS FORM

O.M.B No. 3067-0148
Expires September 30, 2005

PAPERWORK REDUCTION ACT

Public reporting burden for this form is estimated to average 3 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source: Virgin River
Note: Fill out one form for each flooding source studied

A. HYDROLOGY

1. Reason for New Hydrologic Analysis (check all that apply)

☐ Not revised (skip to section 2)
☐ No existing analysis
☒ Improved data
☐ Alternative methodology
☐ Proposed Conditions (CLOMR)
☐ Changed physical condition of watershed

2. Comparison of Representative 1%-Annual-Chance Discharges

Location	Drainage Area (Sq. Mi.)	FIS (cfs)	Revised (cfs)
City of Mesquite, Nevada		34,400	39,510

3. Methodology for New Hydrologic Analysis (check all that apply)

☒ Statistical Analysis of Gage Records
☐ Precipitation/Runoff Model HEC-1 [TR-20, HEC-1, HEC-HMS etc.]
☐ Regional Regression Equations
☐ Other (please attach description)

Please enclose all relevant models in digital format, maps, computations (including computation of parameters) and documentation to support the new analysis. The document, "Numerical Models Accepted by FEMA for NFIP Usage" lists the models accepted by FEMA. This document can be found at: http://www.fema.gov/fhm/en_modl.shtm.

4. Review/Approval of Analysis

If your community requires a regional, state, or federal agency to review the hydrologic analysis, please attach evidence of approval/review.

5. Impacts of Sediment Transport on Hydrology

Was sediment transport considered? ☐ Yes ☒ No If yes, then fill out Section F (Sediment Transport) of Form 3. If No, then attach your explanation for why sediment transport was not considered.

B. HYDRAULICS

1. Reach to be Revised

	Description	Cross Section	Water-Surface Elevations (ft.) Effective	Water-Surface Elevations (ft.) Proposed/Revised
Downstream Limit	Virgin River	-142	n/a	1472.53
Upstream Limit	Virgin River	-18 / -118	1591.69	1596.90 / 1597.58

*Explaination Attached

2. Hydraulic Method Used

Hydraulic Analysis HEC-RAS [HEC-2 , HEC-RAS, Other (Attach description)]

B. HYDRAULICS (CONTINUED)

3. Pre-Submittal Review of Hydraulic Models

FEMA has developed two review programs, CHECK-2 and CHECK-RAS, to aid in the review of HEC-2 and HEC-RAS hydraulic models, respectively. These review programs verify that the hydraulic estimates and assumptions in the model data are in accordance with NFIP requirements, and that the data are comparable with the assumptions and limitations of HEC-2/HEC-RAS. CHECK-2 and CHECK-RAS identify areas of potential error or concern. These tools do not replace engineering judgment. CHECK-2 and CHECK-RAS can be downloaded from http://www.fema.gov/fhm/frm_soft.shtm. We recommend that you review your HEC-2 and HEC-RAS models with CHECK-2 and CHECK-RAS. If you disagree with a message, please attach an explanation of why the message is not valid in this case. Review of your submittal and resolution of valid modeling discrepancies will result in reduced review time.

HEC-2/HEC-RAS models reviewed with CHECK-2/CHECK-RAS? ☐ Yes ☒ No

4. Models Submitted

Duplicate Effective Model*	Natural File Name: Duplicate.prj	Floodway File Name: Duplicate.prj
Corrected Effective Model*	Natural File Name: Corrected.prj	Floodway File Name: Corrected.prj
Existing or Pre-Project Conditions Model	Natural File Name: n/a	Floodway File Name: n/a
Revised or Post-Project Conditions Model	Natural File Name: n/a	Floodway File Name: n/a
Other - (attach description)	Natural File Name: n/a	Floodway File Name: n/a

*Not required for revisions to approximate 1%-annual-chance floodplains (Zone A) – for details, refer to the corresponding section of the instructions.

The document "Numerical Models Accepted by FEMA for NFIP Usage" lists the models accepted by FEMA. This document can be found at: http://www.fema.gov/fhm/en_modl.shtm.

C. MAPPING REQUIREMENTS

A **certified topographic map** must be submitted showing the following information (where applicable): the boundaries of the effective, existing, and proposed conditions 1%-annual-chance floodplain (for approximate Zone A revisions) or the boundaries of the 1%- and 0.2%-annual-chance floodplains and regulatory floodway (for detailed Zone AE, AO, and AH revisions); location and alignment of all cross sections with stationing control indicated; stream, road, and other alignments (e.g., dams, levees, etc.); current community easements and boundaries; boundaries of the requester's property; certification of a registered professional engineer registered in the subject State; location and description of reference marks; and the referenced vertical datum (NGVD, NAVD, etc.).

Note that the boundaries of the existing or proposed conditions floodplains and regulatory floodway to be shown on the revised FIRM and/or FBFM must tie-in with the effective floodplain and regulatory floodway boundaries. Please attach **a copy of the effective FIRM and/or FBFM,** annotated to show the boundaries of the revised 1%- and 0.2%-annual-chance floodplains and regulatory floodway that tie-in with the boundaries of the effective 1%- and 0.2%-annual-chance floodplain and regulatory floodway at the upstream and downstream limits of the area of revision.

D. COMMON REGULATORY REQUIREMENTS

1. For CLOMR requests, do Base Flood Elevations (BFEs) increase? ☐ Yes ☐ No

For CLOMR requests, if either of the following is true, please submit evidence of compliance with Section 65.12 of the NFIP regulations:

- The proposed project encroaches upon a regulatory floodway and would result in increases above 0.00 foot.
- The proposed project encroaches upon a SFHA with BFEs established and would result in increases above 1.00 foot.

2. Does the request involve the placement or proposed placement of fill? ☐ Yes ☒ No

If Yes, the community must be able to certify that the area to be removed from the special flood hazard area, to include any structures or proposed structures, meets all of the standards of the local floodplain ordinances, and is reasonably safe from flooding in accordance with the NFIP regulations set forth at 44 CFR 60.3(a)(3), 65.5(a)(4), and 65.6(a)(14). Please see the MT-2 instructions for more information.

3. For LOMR requests, is the regulatory floodway being revised? ☒ Yes ☐ No

If Yes, attach evidence of regulatory floodway revision notification. As per Paragraph 65.7(b)(1) of the NFIP Regulations, notification is required for requests involving revisions to the regulatory floodway. (Not required for revisions to approximate 1%-annual-chance floodplains [studied Zone A designation] unless a regulatory floodway is being added. Elements and examples of regulatory floodway revision notification can be found in the MT-2 Form 2 Instructions.)

4. For LOMR requests, does this request require property owner notification and acceptance of BFE increases? ☒ Yes ☐ No

If Yes, please attach proof of property owner notification and acceptance (if available). Elements of and examples of property owner notification can be found in the MT-2 Form 2 Instructions.

FEDERAL EMERGENCY MANAGEMENT AGENCY

RIVERINE STRUCTURES FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK REDUCTION ACT

Public reporting burden for this form is estimated to average 7 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source: Virgin River
Note: *Fill out one form for each flooding source studied*

A. GENERAL

Complete the appropriate section(s) for each Structure listed below:

Channelization................complete Section B
Bridge/Culvert.................complete Section C
Dam ....complete Section D
Levee/Floodwall ....complete Section E
Sediment Transport........complete Section F (if required)

Description Of Structure

1. **Name of Structure: Bunkerville Brige**

Type (check one): ☐ Channelization ☒ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

Location of Structure: Approximately 2.7 miles downstream of the Nevada/Arizona Border

Downstream Limit/Cross Section: -73

Upstream Limit/Cross Section: -72

2. **Name of Structure:**

Type (check one): ☐ Channelization ☐ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

Location of Structure:

Downstream Limit/Cross Section:

Upstream Limit/Cross Section:

3. **Name of Structure:**

Type (check one) ☐ Channelization ☐ Bridge/Culvert ☐ Levee/Floodwall ☐ Dam

Location of Structure:

Downstream Limit/Cross Section:

Upstream Limit/Cross Section:

NOTE: For more structures, attach additional pages as needed.

B. CHANNELIZATION

Flooding Source:

Name of Structure:

1. Accessory Structures

The channelization includes (check one):

☐ Levees [Attach Section E (Levee/Floodwall)]
☐ Superelevated sections
☐ Debris basin/detention basin
☐ Other (Describe):

☐ Drop structures
☐ Transitions in cross sectional geometry
☐ Energy dissipator

2. Drawing Checklist

Attach the plans of the channelization certified by a registered professional engineer, as described in the instructions.

3. Hydraulic Considerations

The channel was designed to carry (cfs) and/or the -year flood.

The design elevation in the channel is based on (check one):

☐ Subcritical flow ☐ Critical flow ☐ Supercritical flow ☐ Energy grade line

If there is the potential for a hydraulic jump at the following locations, check all that apply and attach an explanation of how the hydraulic jump is controlled without affecting the stability of the channel.

☐ Inlet to channel ☐ Outlet of channel ☐ At Drop Structures ☐ At Transitions
☐ Other locations (specify):

4. Sediment Transport Considerations

Was sediment transport considered? ☐ Yes ☐ No If Yes, then fill out Section F (Sediment Transport).
If No, then attach your explanation for why sediment transport was not considered.

C. BRIDGE/CULVERT

Flooding Source: Virgin River

Name of Structure: Bunkerville Bridge

1. This revision reflects (check one):

☐ New bridge/culvert not modeled in the FIS
☐ Modified bridge/culvert previously modeled in the FIS
☒ New analysis of bridge/culvert previously modeled in the FIS

2. Hydraulic model used to analyze the structure (e.g., HEC-2 with special bridge routine, WSPRO, HY8): HEC-RAS
If different than hydraulic analysis for the flooding source, justify why the hydraulic analysis used for the flooding source could not analyze the structures. Attach justification.

3. Attach plans of the structures certified by a registered professional engineer. The plan detail and information should include the following (check the information that has been provided):

☒ Dimensions (height, width, span, radius, length)
☐ Shape (culverts only)
☒ Material
☒ Beveling or Rounding
☐ Wing Wall Angle
☐ Skew Angle
☐ Distances Between Cross Sections

☐ Erosion Protection
☐ Low Chord Elevations – Upstream and Downstream
☐ Top of Road Elevations – Upstream and Downstream
☐ Structure Invert Elevations – Upstream and Downstream
☐ Stream Invert Elevations – Upstream and Downstream
☐ Cross-Section Locations

4. *Sediment Transport Considerations*

Was sediment transport considered? ☐ Yes ☒ No If yes, then fill out Section F (Sediment Transport).
If No, then attach your explanation for why sediment transport was not considered.

Statement of Explanation for following sections:

1. MT-2 Form 1 Page 2 of 2 Section C

   Explanation: Since the corrected effective hydraulic model is based solely on more detailed data, no review fee has been included, per FEMA Flood Map-Related Fee Criteria.

2. MT-2 Form 2 Page 1 of 2 Section A 5

   Explanation: Impacts of sediment transport on hydrology was not considered. However, JE Fuller was contracted by PBS&J, as a sub-consultant, to perform the geomorphic analysis to identify the cause of recent sediment deposition in the floodplain and predict future lateral migration of the Virgin River main channel. A copy of the JE Fuller's draft *Geomorphic Analysis Report* (JEF, 2006) is included in **Appendix C.** It should be noted that a sediment transport model was not developed for the study reach.

3. MT-2 Form 2 Page 1 of 2 Section B 1

   Explanation: The effective WSEL at the Nevada-Arizona border (Upstream Mapping Limit) is 1591.69 feet, while the differential WSEL determined by the corrected effective hydraulic model in the main channel and the avulsion is 1596.90 feet and 1597.58 feet, respectively. PBS&J understands that the FEMA requirements specify that the corrected effective WSEL must tie into the effective water surface profile within 0.5 feet at the upstream and downstream ends of the revised reach. However, the difference in WSEL at the upstream limits between the corrected effective hydraulic model and the effective hydraulic is based on the following facts below:

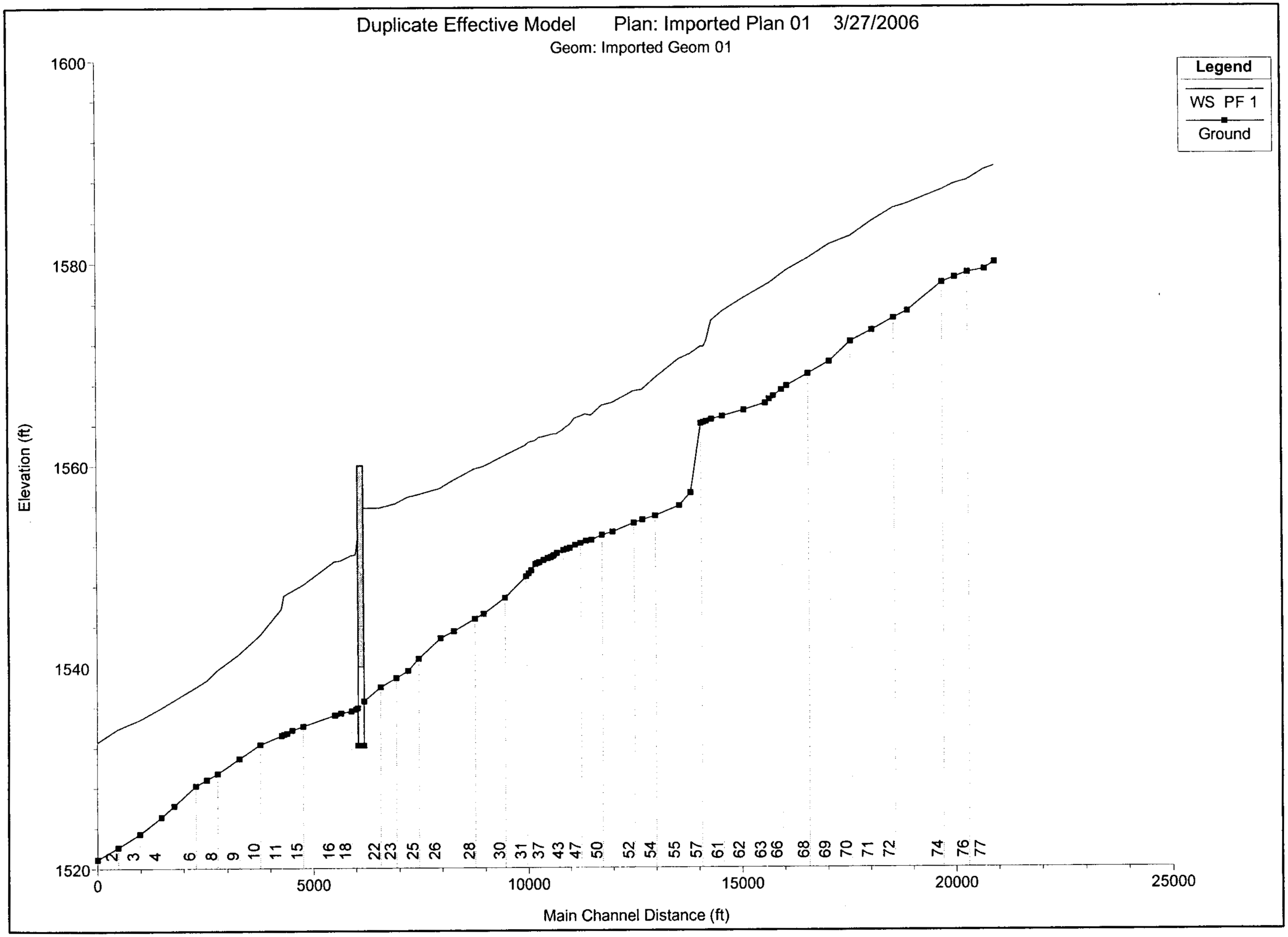
   - The January 2005 flood significantly altered the Virgin River and the associated floodplain and therefore, the effective FEMA hydraulic model does not accurately portray the current dynamics of the Virgin River within the study reach.
   - The effective hydraulic model does not extend upstream of the Nevada-Arizona border and therefore the differential WSEL through the avulsion (that occurs approximately 1.7 miles upstream of state line) is not computed.
   - The downstream limits of the floodplain (Zone A) through the Mohave County, AZ, do not match the upstream limits of the effective floodplain (Zone AE) through City of Mesquite at the Nevada-Arizona border.
   - The corrected effective hydraulic model was generated utilizing more accurate and recent topography.
   - HDR Inc. has been contracted by FEMA Region IX to re-delineate the Virgin River Floodplain upstream of the Nevada-Arizona border. PBS&J has been coordinating the modeling/mapping efforts with FEMA Region IX and HDR Inc. As a result, the water-surface profiles developed by PBS&J and HDR Inc.

will meet FEMA requirements and tie into each other within 0 to 0.5 feet at the Nevada-Arizona border.

4. MT-2 Form 3 Page 2 of 10 Section C 4

   Explanation: Sediment transport was not considered in terms of the Bunkerville Bridge. However, JE Fuller was contracted by PBS&J, as a sub-consultant, to perform the geomorphic analysis to identify the cause of recent sediment deposition in the floodplain and predict future lateral migration of the Virgin River main channel. A copy of the JE Fuller's draft *Geomorphic Analysis Report* (JEF, 2006) is included in **Appendix C.** It should be noted that a sediment transport model was not developed for the study reach.

Duplicate Effective Hydraulic Model (Profile 1)


Duplicate Effective Model Plan: Imported Plan 01 3/27/2006
Geom: Imported Geom 01
Legend
WS PF 1
Ground
Elevation (ft)
1600
1580
1560
1540
1520
Main Channel Distance (ft)
0
5000
10000
15000
20000
25000
2
3
4
6
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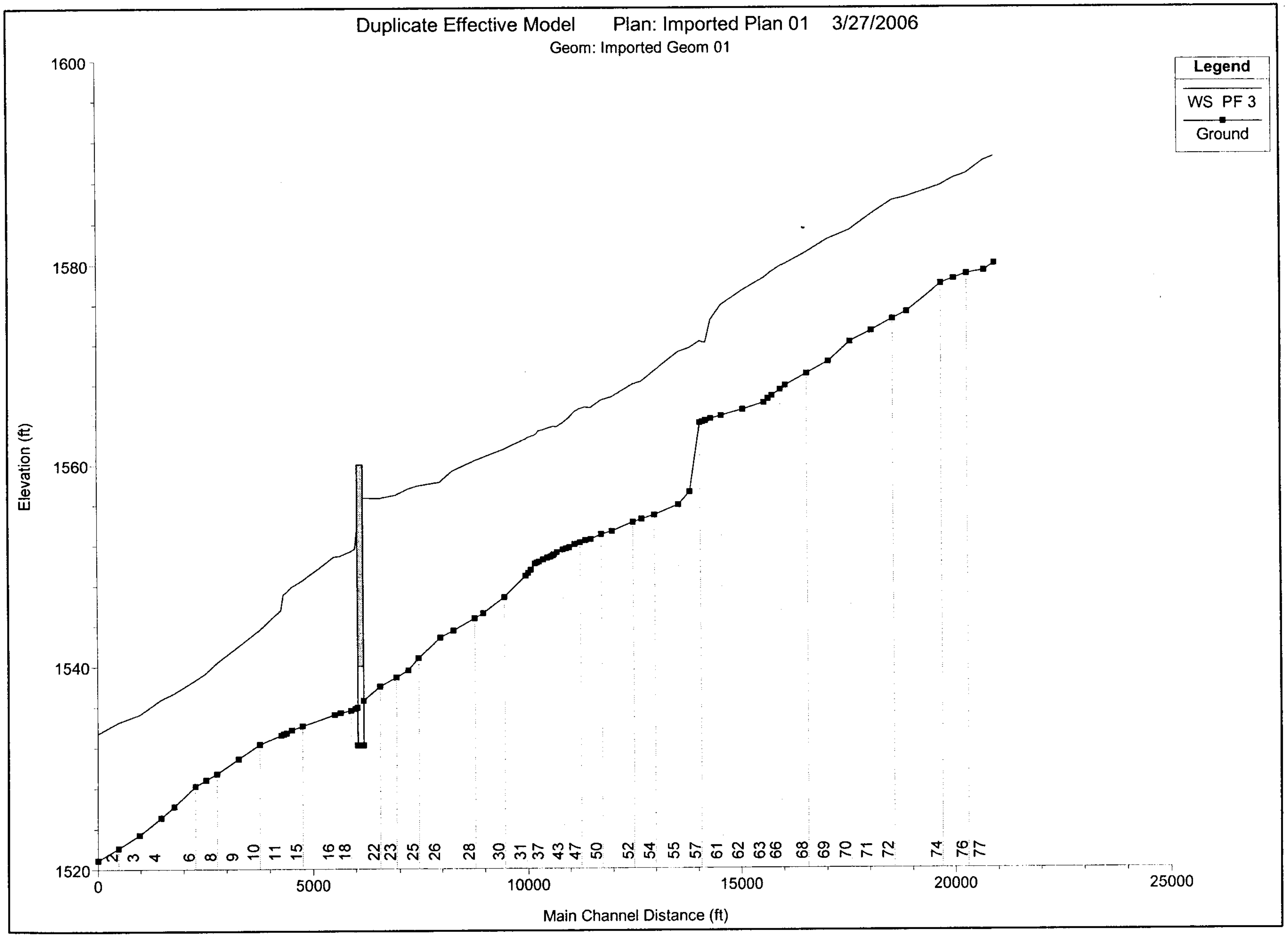
HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	78	PF 1	34400.00	1580.00	1589.46	1586.98	1589.67	0.001183	5.36	14816.21	3175.76	0.32
Reach-1	77	PF 1	34400.00	1579.30	1589.12	1587.35	1589.34	0.001835	6.73	13992.03	3272.24	0.40
Reach-1	76	PF 1	34400.00	1579.00	1588.09	1585.64	1588.22	0.001515	5.99	15513.11	3289.42	0.36
Reach-1	75	PF 1	34400.00	1578.50	1587.73	1585.32	1587.89	0.001454	5.79	15018.77	3111.00	0.35
Reach-1	74	PF 1	34400.00	1578.00	1587.11	1585.53	1587.43	0.002386	7.74	12223.75	2936.60	0.46
Reach-1	73	PF 1	34400.00	1575.20	1585.75	1583.53	1586.02	0.001880	7.25	12185.32	2345.23	0.41
Reach-1	72	PF 1	34400.00	1574.50	1585.33	1582.88	1585.56	0.001975	7.69	13084.91	2701.61	0.42
Reach-1	71	PF 1	34400.00	1573.30	1584.04	1581.89	1584.37	0.002533	8.42	11297.05	2412.68	0.48
Reach-1	70	PF 1	34400.00	1572.20	1582.58	1580.50	1582.98	0.002810	9.02	9695.57	1756.74	0.50
Reach-1	69	PF 1	34400.00	1570.20	1581.76	1578.53	1582.02	0.001847	7.73	11407.69	1850.25	0.41
Reach-1	68	PF 1	34400.00	1569.00	1580.40	1577.04	1580.63	0.002034	8.08	11145.95	1810.75	0.43
Reach-1	67	PF 1	34400.00	1567.80	1579.23	1576.81	1579.65	0.002273	8.28	10119.64	1921.48	0.46
Reach-1	66	PF 1	34400.00	1567.40	1578.86	1576.55	1579.39	0.002375	8.27	9053.90	1714.32	0.46
Reach-1	65	PF 1	34400.00	1566.80	1578.24	1576.75	1578.89	0.003590	9.92	8296.21	1691.28	0.57
Reach-1	64	PF 1	34400.00	1566.50	1577.96	1576.51	1578.53	0.003500	10.04	9038.15	1902.34	0.56
Reach-1	63	PF 1	34400.00	1566.10	1577.74	1576.15	1578.21	0.002515	8.67	10420.18	2232.02	0.48
Reach-1	62	PF 1	34400.00	1565.40	1576.54	1574.43	1576.89	0.002252	7.47	10681.65	2110.77	0.44
Reach-1	61	PF 1	34400.00	1564.80	1575.19	1573.71	1575.71	0.003063	7.73	9176.00	2251.66	0.50
Reach-1	60	PF 1	34400.00	1564.50	1574.27	1572.96	1574.84	0.004249	10.26	8911.12	2077.94	0.61
Reach-1	59	PF 1	34400.00	1564.30	1572.24	1572.24	1573.98	0.008740	12.36	5077.86	1555.63	0.84
Reach-1	58	PF 1	34400.00	1564.20	1571.70	1571.11	1572.98	0.006309	9.91	5289.53	1606.35	0.70
Reach-1	57	PF 1	34400.00	1564.10	1571.75	1569.58	1572.56	0.003303	7.32	5242.70	1154.92	0.51
Reach-1	56	PF 1	34400.00	1557.20	1571.03	1568.29	1571.90	0.002830	11.13	7677.92	1270.60	0.53
Reach-1	55	PF 1	34400.00	1555.90	1570.50	1566.95	1571.21	0.002118	9.88	8525.66	1281.85	0.47
Reach-1	54	PF 1	34400.00	1554.90	1568.62	1566.91	1569.73	0.003287	10.45	6620.14	1420.31	0.56
Reach-1	53	PF 1	34400.00	1554.50	1567.46	1566.16	1568.71	0.003519	10.41	6243.54	1614.93	0.57
Reach-1	52	PF 1	34400.00	1554.20	1567.33	1565.10	1568.01	0.002173	8.50	8593.73	1704.71	0.45
Reach-1	51	PF 1	34400.00	1553.30	1566.17	1564.24	1566.93	0.002131	8.41	7992.99	1561.19	0.45
Reach-1	50	PF 1	34400.00	1553.00	1565.90	1562.82	1566.40	0.001524	6.87	9611.15	1870.91	0.38
Reach-1	49	PF 1	34400.00	1552.50	1564.92	1562.38	1565.87	0.002568	8.48	6498.43	1559.34	0.48
Reach-1	48	PF 1	34400.00	1552.40	1565.06	1561.55	1565.51	0.001340	6.39	9735.37	1875.39	0.35
Reach-1	47	PF 1	34400.00	1552.20	1564.82	1561.50	1565.32	0.001518	6.60	8796.65	1609.82	0.37
Reach-1	46	PF 1	34400.00	1552.00	1564.64	1562.39	1565.05	0.003189	10.18	9086.03	1615.54	0.53
Reach-1	45	PF 1	34400.00	1551.70	1563.97	1562.16	1564.56	0.004431	11.54	7808.75	1477.39	0.62
Reach-1	44	PF 1	34400.00	1551.60	1563.79	1561.34	1564.26	0.003325	10.06	8534.65	1447.50	0.55
Reach-1	43	PF 1	34400.00	1551.50	1563.49	1561.14	1564.03	0.003422	9.61	7971.08	1315.53	0.55
Reach-1	42	PF 1	34400.00	1551.20	1563.09	1560.06	1563.51	0.002846	8.65	8581.85	1351.23	0.50
Reach-1	41	PF 1	34400.00	1551.00	1563.08	1557.89	1563.38	0.000783	4.60	9360.46	1371.54	0.27
Reach-1	40	PF 1	34400.00	1550.90	1563.05	1557.99	1563.36	0.000825	4.67	9232.00	1370.34	0.27
Reach-1	39	PF 1	34400.00	1550.80	1562.99	1558.00	1563.31	0.000858	4.74	9051.41	1356.98	0.28
Reach-1	38	PF 1	34400.00	1550.70	1562.93	1557.96	1563.25	0.000869	4.77	9001.16	1373.43	0.28
Reach-1	37	PF 1	34400.00	1550.50	1562.80	1558.02	1563.16	0.000969	5.00	8510.68	1307.23	0.29
Reach-1	36	PF 1	34400.00	1550.30	1562.73	1558.40	1563.05	0.000978	4.93	9265.64	1385.48	0.29
Reach-1	35	PF 1	34400.00	1550.20	1562.54	1559.09	1562.98	0.001566	6.83	9203.45	1401.49	0.38
Reach-1	34	PF 1	34400.00	1550.10	1562.40	1559.29	1562.92	0.001778	7.55	8714.13	1321.65	0.41
Reach-1	33	PF 1	34400.00	1549.50	1562.32	1559.57	1562.80	0.002263	9.10	9156.10	1362.69	0.47
Reach-1	32	PF 1	34400.00	1549.20	1562.24	1559.49	1562.68	0.002626	9.51	8998.91	1360.01	0.50
Reach-1	31	PF 1	34400.00	1548.90	1561.97	1559.49	1562.50	0.002459	9.37	8891.82	1386.83	0.48
Reach-1	30	PF 1	34400.00	1546.80	1560.92	1557.91	1561.42	0.002301	9.90	8970.96	1283.67	0.47
Reach-1	29	PF 1	34400.00	1545.20	1559.85	1555.69	1560.46	0.001717	8.60	8863.38	1299.41	0.42
Reach-1	28	PF 1	34400.00	1544.70	1559.62	1555.41	1560.12	0.001349	7.30	9298.85	1324.95	0.36
Reach-1	27	PF 1	34400.00	1543.50	1558.48	1554.85	1559.24	0.002899	11.27	7330.64	981.28	0.54
Reach-1	26	PF 1	34400.00	1542.80	1557.68	1554.49	1558.30	0.003030	11.78	7714.52	1011.52	0.55
Reach-1	25	PF 1	34400.00	1540.80	1557.08	1550.75	1557.51	0.000862	5.87	8901.72	1167.00	0.29
Reach-1	24	PF 1	34400.00	1539.60	1556.81	1552.24	1557.22	0.001639	9.72	9363.19	1025.17	0.42
Reach-1	23	PF 1	34400.00	1538.90	1556.18	1551.85	1556.77	0.001513	8.56	9130.57	1252.23	0.39
Reach-1	22	PF 1	34400.00	1538.00	1555.77	1549.81	1556.21	0.001298	7.59	8987.03	1059.62	0.36
Reach-1	21.1	PF 1	34400.00	1536.60	1555.77	1543.19	1555.98	0.000208	3.62	9504.19	1049.85	0.15
Reach-1	21	PF 1	34400.00	1532.20	1555.82	1538.79	1555.94	0.000097	2.79	12332.70	1051.70	0.11
Reach-1	20.5		Bridge									
Reach-1	20	PF 1	34400.00	1532.20	1552.61	1538.66	1552.74	0.000130	2.96	13687.72	969.58	0.12
Reach-1	19.9	PF 1	34400.00	1535.90	1552.51	1542.90	1552.72	0.000301	3.85	11108.88	968.81	0.18
Reach-1	19	PF 1	34400.00	1535.80	1551.10	1549.75	1552.36	0.003258	12.04	6710.32	1155.76	0.57
Reach-1	18	PF 1	34400.00	1535.60	1551.02	1548.87	1551.86	0.002597	9.64	7345.07	1225.86	0.50
Reach-1	17	PF 1	34400.00	1535.40	1550.50	1547.90	1551.31	0.002059	8.65	7736.78	1424.29	0.45
Reach-1	16	PF 1	34400.00	1535.20	1550.41	1547.28	1550.96	0.001764	6.74	8139.43	1536.52	0.40
Reach-1	15	PF 1	34400.00	1534.10	1548.09	1546.80	1549.25	0.003158	11.05	7688.07	1843.34	0.56
Reach-1	14	PF 1	34400.00	1533.70	1547.48	1545.97	1548.41	0.003259	9.58	7748.19	2020.80	0.54
Reach-1	13	PF 1	34400.00	1533.40	1547.19	1545.74	1548.03	0.002860	9.57	8604.14	2083.40	0.52
Reach-1	12	PF 1	34400.00	1533.30	1547.03	1545.49	1547.84	0.002736	9.24	8559.36	2063.53	0.50
Reach-1	11	PF 1	34400.00	1533.20	1545.75	1545.75	1547.48	0.005907	13.61	6446.31	1870.94	0.74
Reach-1	10	PF 1	34400.00	1532.30	1543.14	1542.31	1543.78	0.003124	8.05	9654.01	3263.98	0.51
Reach-1	9	PF 1	34400.00	1530.90	1541.25	1540.20	1542.04	0.003855	8.45	7460.16	2073.46	0.56
Reach-1	8	PF 1	34400.00	1529.40	1539.71	1538.14	1540.25	0.002746	7.41	9005.42	2275.59	0.48
Reach-1	7	PF 1	34400.00	1528.80	1538.68	1537.53	1539.59	0.003789	8.89	7223.13	2162.10	0.57
Reach-1	6	PF 1	34400.00	1528.20	1537.99	1536.15	1538.48	0.002660	7.99	10088.67	2393.04	0.48

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 Profile: PF 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	5	PF 1	34400.00	1526.20	1536.72	1535.43	1537.36	0.002792	8.27	9176.15	2471.38	0.49
Reach-1	4	PF 1	34400.00	1525.10	1535.99	1534.94	1536.62	0.003765	7.61	8365.56	2732.05	0.54
Reach-1	3	PF 1	34400.00	1523.40	1534.79	1533.60	1535.28	0.003583	9.78	10568.87	2804.44	0.56
Reach-1	2	PF 1	34400.00	1522.10	1533.89	1531.33	1534.24	0.001533	5.43	10914.55	3118.82	0.36
Reach-1	1	PF 1	34400.00	1520.90	1532.55	1531.40	1533.07	0.003704	10.99	10658.31	2820.26	0.58

Duplicate Effective Hydraulic Model (Profile 3)


Duplicate Effective Model Plan: Imported Plan 01 3/27/2006

Geom: Imported Geom 01

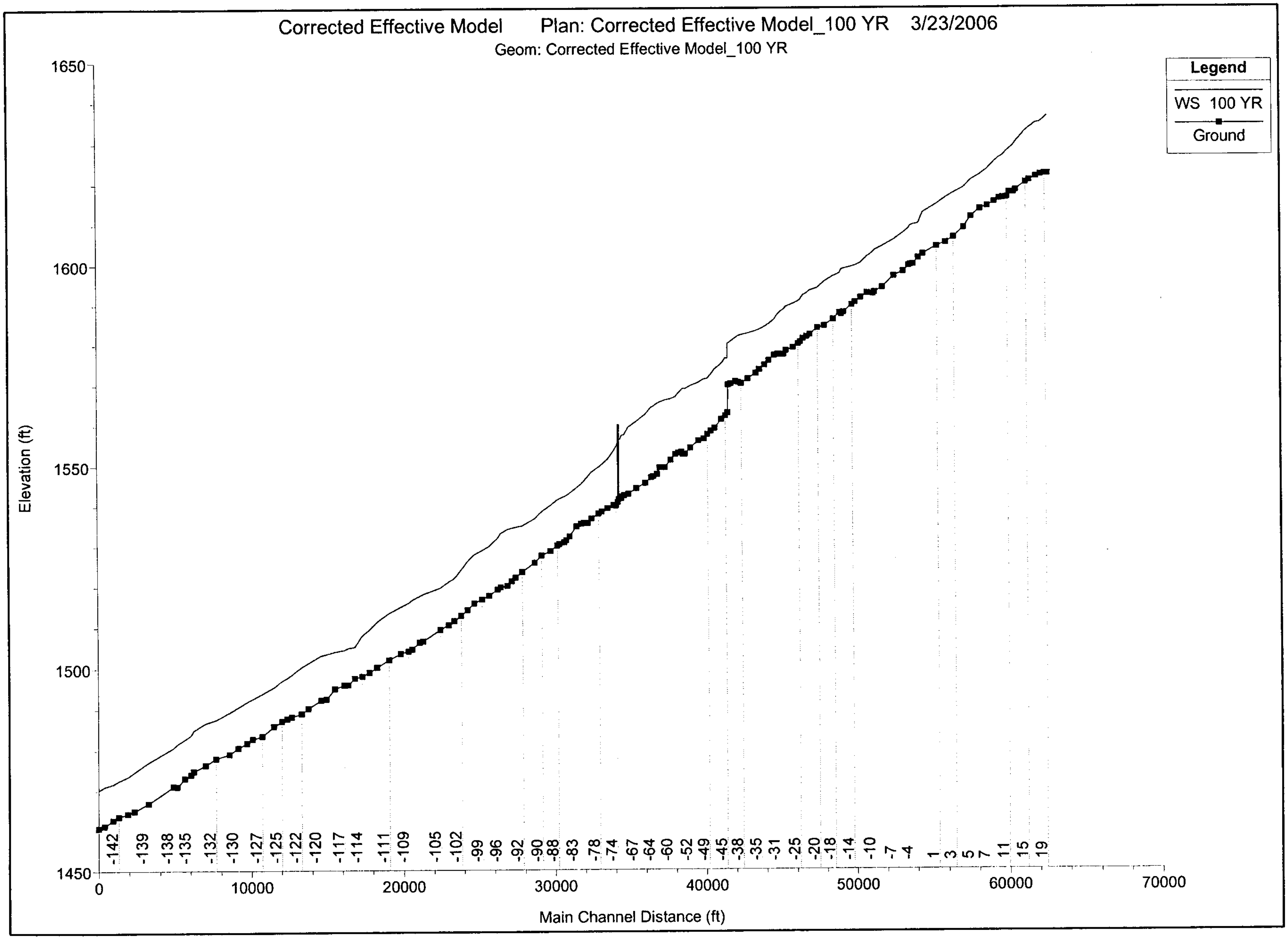
HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 Profile: PF 3

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	78	PF 3	34400.00	1580.00	1590.45	1587.19	1590.72	0.001166	5.62	11877.55	1855.00	0.32
Reach-1	77	PF 3	34400.00	1579.30	1590.03	1587.70	1590.36	0.002106	7.43	10562.26	1840.00	0.42
Reach-1	76	PF 3	34400.00	1579.00	1588.79	1585.76	1589.01	0.001872	6.73	11559.54	1870.00	0.39
Reach-1	75	PF 3	34400.00	1578.50	1588.33	1585.55	1588.59	0.001868	6.69	11325.19	1910.00	0.40
Reach-1	74	PF 3	34400.00	1578.00	1587.64	1585.77	1588.04	0.002670	8.14	9884.19	1885.00	0.47
Reach-1	73	PF 3	34400.00	1575.20	1586.52	1583.55	1586.73	0.001404	6.38	12748.81	2050.00	0.35
Reach-1	72	PF 3	34400.00	1574.50	1586.17	1582.89	1586.39	0.001646	6.92	11644.64	1710.00	0.37
Reach-1	71	PF 3	34400.00	1573.30	1584.79	1582.46	1585.26	0.002678	9.11	8897.58	1400.00	0.50
Reach-1	70	PF 3	34400.00	1572.20	1583.28	1580.79	1583.77	0.002985	9.25	8257.90	1225.00	0.50
Reach-1	69	PF 3	34400.00	1570.20	1582.43	1578.79	1582.77	0.001944	8.25	9542.27	1215.00	0.43
Reach-1	68	PF 3	34400.00	1569.00	1581.13	1577.24	1581.38	0.001834	8.02	10385.36	1360.00	0.41
Reach-1	67	PF 3	34400.00	1567.80	1579.99	1576.92	1580.47	0.002142	8.43	8604.82	1165.00	0.45
Reach-1	66	PF 3	34400.00	1567.40	1579.76	1576.63	1580.25	0.001891	7.82	8657.07	1180.00	0.42
Reach-1	65	PF 3	34400.00	1566.80	1579.23	1576.88	1579.85	0.002828	9.41	7834.00	1170.00	0.51
Reach-1	64	PF 3	34400.00	1566.50	1578.93	1576.78	1579.58	0.003081	10.03	7792.92	1180.00	0.54
Reach-1	63	PF 3	34400.00	1566.10	1578.60	1576.47	1579.29	0.002771	9.61	7756.21	1180.00	0.51
Reach-1	62	PF 3	34400.00	1565.40	1577.37	1574.49	1577.85	0.002309	8.04	8515.88	1230.00	0.46
Reach-1	61	PF 3	34400.00	1564.80	1575.89	1573.78	1576.63	0.003190	8.39	6691.91	1100.00	0.52
Reach-1	60	PF 3	34400.00	1564.50	1574.42	1573.28	1575.53	0.006341	12.68	5796.73	1000.00	0.75
Reach-1	59	PF 3	34400.00	1564.30	1572.15	1572.15	1574.40	0.010649	13.51	3795.39	862.36	0.92
Reach-1	58	PF 3	34400.00	1564.20	1572.16	1570.98	1573.36	0.005211	9.45	4774.47	940.00	0.65
Reach-1	57	PF 3	34400.00	1564.10	1572.29	1569.61	1572.99	0.002575	6.78	5500.78	910.00	0.45
Reach-1	56	PF 3	34400.00	1557.20	1571.61	1568.59	1572.44	0.002464	10.68	6995.03	830.00	0.50
Reach-1	55	PF 3	34400.00	1555.90	1571.21	1566.82	1571.85	0.001714	9.18	7522.55	740.00	0.42
Reach-1	54	PF 3	34400.00	1554.90	1569.27	1567.07	1570.52	0.003182	10.69	5427.56	730.00	0.55
Reach-1	53	PF 3	34400.00	1554.50	1568.25	1566.03	1569.58	0.003176	10.38	5022.60	690.00	0.55
Reach-1	52	PF 3	34400.00	1554.20	1567.97	1564.99	1568.92	0.002451	9.37	6033.76	745.00	0.49
Reach-1	51	PF 3	34400.00	1553.30	1566.69	1563.79	1567.71	0.002374	9.16	5704.34	740.00	0.48
Reach-1	50	PF 3	34400.00	1553.00	1566.38	1562.83	1567.10	0.001816	7.73	6560.31	825.00	0.41
Reach-1	49	PF 3	34400.00	1552.50	1565.63	1562.20	1566.59	0.002237	8.30	5513.67	855.00	0.46
Reach-1	48	PF 3	34400.00	1552.40	1565.70	1561.50	1566.26	0.001393	6.78	7284.69	880.00	0.36
Reach-1	47	PF 3	34400.00	1552.20	1565.52	1561.43	1566.08	0.001430	6.71	7225.26	900.00	0.37
Reach-1	46	PF 3	34400.00	1552.00	1565.21	1562.32	1565.83	0.003745	11.40	6984.70	910.00	0.58
Reach-1	45	PF 3	34400.00	1551.70	1564.64	1562.06	1565.32	0.004212	11.72	6705.62	920.00	0.61
Reach-1	44	PF 3	34400.00	1551.60	1564.38	1561.37	1565.04	0.003779	11.12	6707.08	840.00	0.59
Reach-1	43	PF 3	34400.00	1551.50	1564.11	1561.27	1564.80	0.003529	10.18	6780.02	900.00	0.57
Reach-1	42	PF 3	34400.00	1551.20	1563.73	1559.89	1564.26	0.002892	9.11	7295.74	890.00	0.51
Reach-1	41	PF 3	34400.00	1551.00	1563.77	1557.91	1564.11	0.000764	4.78	7990.23	890.00	0.26
Reach-1	40	PF 3	34400.00	1550.90	1563.73	1558.03	1564.09	0.000816	4.89	7812.14	880.00	0.27
Reach-1	39	PF 3	34400.00	1550.80	1563.66	1558.09	1564.04	0.000883	5.08	7637.09	880.00	0.28
Reach-1	38	PF 3	34400.00	1550.70	1563.58	1558.06	1563.98	0.000911	5.17	7521.23	870.00	0.29
Reach-1	37	PF 3	34400.00	1550.50	1563.42	1558.21	1563.87	0.001073	5.60	7094.92	850.00	0.31
Reach-1	36	PF 3	34400.00	1550.30	1563.32	1558.63	1563.76	0.001140	5.65	7345.76	855.00	0.32
Reach-1	35	PF 3	34400.00	1550.20	1563.04	1559.19	1563.67	0.001819	7.60	6987.56	830.00	0.41
Reach-1	34	PF 3	34400.00	1550.10	1562.90	1559.40	1563.60	0.001993	8.24	6922.39	840.00	0.44
Reach-1	33	PF 3	34400.00	1549.50	1562.76	1559.66	1563.46	0.002742	10.26	7113.42	850.00	0.52
Reach-1	32	PF 3	34400.00	1549.20	1562.65	1559.53	1563.31	0.003185	10.72	6983.67	840.00	0.55
Reach-1	31	PF 3	34400.00	1548.90	1562.49	1559.39	1563.12	0.002486	9.70	7566.88	930.00	0.49
Reach-1	30	PF 3	34400.00	1546.80	1561.49	1557.88	1562.05	0.002185	9.92	7960.37	895.00	0.47
Reach-1	29	PF 3	34400.00	1545.20	1560.66	1555.81	1561.22	0.001389	8.04	7970.09	780.00	0.38
Reach-1	28	PF 3	34400.00	1544.70	1560.35	1555.33	1560.94	0.001331	7.53	7388.69	725.00	0.37
Reach-1	27	PF 3	34400.00	1543.50	1559.35	1554.73	1560.13	0.002446	10.79	6399.38	580.00	0.50
Reach-1	26	PF 3	34400.00	1542.80	1558.22	1554.63	1559.22	0.003806	13.53	5629.28	540.00	0.62
Reach-1	25	PF 3	34400.00	1540.80	1557.87	1550.94	1558.32	0.000774	5.80	7507.77	640.00	0.28
Reach-1	24	PF 3	34400.00	1539.60	1557.55	1551.99	1558.04	0.001634	9.99	8007.66	680.00	0.42
Reach-1	23	PF 3	34400.00	1538.90	1556.97	1551.63	1557.61	0.001409	8.56	7520.45	700.00	0.38
Reach-1	22	PF 3	34400.00	1538.00	1556.63	1549.70	1557.08	0.001159	7.47	7982.65	630.00	0.34
Reach-1	21.1	PF 3	34400.00	1536.60	1556.68	1543.19	1556.87	0.000176	3.44	9993.96	1105.99	0.14
Reach-1	21	PF 3	34400.00	1532.20	1556.72	1538.80	1556.83	0.000089	2.67	12860.86	585.48	0.10
Reach-1	20.5		Bridge									
Reach-1	20	PF 3	34400.00	1532.20	1553.50	1538.67	1553.65	0.000136	3.03	11359.09	585.48	0.12
Reach-1	19.9	PF 3	34400.00	1535.90	1553.37	1542.89	1553.61	0.000303	4.01	8943.43	585.48	0.18
Reach-1	19	PF 3	34400.00	1535.80	1551.61	1549.49	1553.18	0.003768	12.70	4935.82	565.00	0.59
Reach-1	18	PF 3	34400.00	1535.60	1551.35	1549.10	1552.71	0.003587	12.28	5316.45	610.00	0.56
Reach-1	17	PF 3	34400.00	1535.40	1550.92	1547.70	1551.95	0.002245	9.24	5687.19	685.00	0.47
Reach-1	16	PF 3	34400.00	1535.20	1550.84	1547.12	1551.56	0.001878	7.33	5971.67	725.00	0.41
Reach-1	15	PF 3	34400.00	1534.10	1548.46	1546.48	1549.77	0.003185	11.32	5596.91	750.00	0.56
Reach-1	14	PF 3	34400.00	1533.70	1547.83	1545.66	1548.93	0.003329	9.92	5575.50	800.00	0.55
Reach-1	13	PF 3	34400.00	1533.40	1547.31	1545.56	1548.53	0.003557	10.74	5648.18	840.00	0.58
Reach-1	12	PF 3	34400.00	1533.30	1547.11	1545.29	1548.29	0.003416	10.38	5682.80	860.00	0.56
Reach-1	11	PF 3	34400.00	1533.20	1545.56	1545.56	1547.85	0.007335	14.98	4542.95	880.00	0.82
Reach-1	10	PF 3	34400.00	1532.30	1543.59	1541.90	1544.74	0.004123	9.60	5086.71	845.00	0.59
Reach-1	9	PF 3	34400.00	1530.90	1541.96	1539.90	1542.82	0.003330	8.37	5867.53	970.00	0.53
Reach-1	8	PF 3	34400.00	1529.40	1540.35	1537.89	1541.13	0.003045	8.15	6035.09	905.00	0.51
Reach-1	7	PF 3	34400.00	1528.80	1539.34	1537.70	1540.40	0.003901	9.44	5561.75	950.00	0.57
Reach-1	6	PF 3	34400.00	1528.20	1538.63	1536.20	1539.26	0.002792	8.42	7399.05	1130.00	0.49

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 Profile: PF 3 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	5	PF 3	34400.00	1526.20	1537.34	1535.41	1538.10	0.002753	8.53	7127.26	1235.00	0.49
Reach-1	4	PF 3	34400.00	1525.10	1536.72	1534.85	1537.37	0.003087	7.40	6881.80	1330.00	0.50
Reach-1	3	PF 3	34400.00	1523.40	1535.26	1533.82	1536.04	0.004344	11.12	7224.99	1280.00	0.63
Reach-1	2	PF 3	34400.00	1522.10	1534.50	1531.33	1534.90	0.001402	5.48	8467.72	1475.00	0.35
Reach-1	1	PF 3	34400.00	1520.90	1533.40	1531.33	1533.90	0.002895	10.20	8810.50	1400.00	0.52

100-Year Corrected Effective Hydraulic Model (Main Channel)


Corrected Effective Model Plan: Corrected Effective Model_100 YR 3/23/2006
Geom: Corrected Effective Model_100 YR
Legend
WS 100 YR
Ground
Elevation (ft)
1650
1600
1550
1500
1450
Main Channel Distance (ft)
0
10000
20000
30000
40000
50000
60000
70000
-142
-139
-138
-135
-132
-130
-127
-125
-122
-120
-117
-114
-111
-109
-105
-102
-99
-96
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-90
-88
-83
-78
-74
-67
-64
-60
-52
-49
-45
-38
-35
-31
-25
-20
-18
-14
-10
-7
-4
1
3
5
7
11
15
19

HEC-RAS Plan: CE_100 YR Profile: 100 YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	20	100 YR	39510.00	1622.20	1636.43	1634.84	1637.95	0.005570	15.70	6485.77	867.83	0.75
1	19	100 YR	39510.00	1622.19	1635.81	1634.08	1636.94	0.004764	14.40	7377.77	1002.10	0.70
1	18	100 YR	39510.00	1622.02	1634.93	1633.24	1635.88	0.003339	11.67	7320.15	1105.31	0.58
1	17	100 YR	39510.00	1621.51	1634.61	1631.53	1635.11	0.001449	7.71	7934.18	1254.13	0.38
1	16	100 YR	39510.00	1620.59	1633.40	1631.04	1634.18	0.002991	11.00	7680.87	1426.33	0.55
1	15	100 YR	39510.00	1620.06	1632.66	1630.68	1633.62	0.003931	12.35	7961.81	1259.50	0.62
1	14	100 YR	39510.00	1618.14	1630.02	1627.86	1630.64	0.004394	12.43	9364.32	2191.98	0.65
1	13	100 YR	39510.00	1617.61	1629.12	1627.76	1629.96	0.004724	12.03	8939.48	2375.91	0.66
1	12	100 YR	39510.00	1617.62	1628.27	1626.75	1628.86	0.003905	10.84	9274.64	2756.73	0.60
1	11	100 YR	39510.00	1616.39	1627.72	1625.69	1628.17	0.002945	9.45	10269.07	2837.90	0.52
1	10	100 YR	39510.00	1616.26	1626.68	1625.00	1627.19	0.003948	10.74	10477.32	2823.08	0.60
1	9	100 YR	39510.00	1616.08	1626.10	1624.13	1626.41	0.002888	9.14	12117.73	3381.94	0.51
1	8	100 YR	39510.00	1615.25	1625.11	1623.19	1625.51	0.003252	9.33	11832.55	3501.64	0.54
1	7	100 YR	39510.00	1614.20	1623.37	1620.78	1623.73	0.004034	9.68	10196.01	3455.05	0.59
1	6	100 YR	39510.00	1613.49	1621.94	1618.65	1622.07	0.001829	6.44	14881.58	2665.71	0.40
2	5	100 YR	21472.25	1611.55	1620.66	1618.46	1620.87	0.002849	8.56	8982.64	1906.29	0.50
2	4	100 YR	21472.25	1608.87	1618.78	1617.60	1619.37	0.004068	10.28	7103.14	1805.81	0.60
2	3	100 YR	21473.69	1606.54	1617.43	1615.06	1617.78	0.002104	8.18	8252.89	1771.11	0.44
2	2	100 YR	21473.69	1605.26	1616.25	1614.43	1616.67	0.003315	10.23	7874.91	1636.31	0.56
2	1	100 YR	21473.69	1604.27	1614.69	1612.15	1615.06	0.002153	8.05	7450.98	1213.39	0.45
2	-1	100 YR	21473.69	1602.39	1612.57	1609.44	1613.35	0.002389	8.31	4989.65	768.88	0.47
2	-2	100 YR	21473.69	1601.45	1609.87	1609.63	1612.03	0.008800	13.24	2945.58	877.54	0.86
2	-3	100 YR	21577.07	1599.83	1609.71	1608.57	1610.26	0.002886	8.53	6569.78	1637.48	0.51
2	-4	100 YR	21599.88	1599.71	1609.32	1607.62	1609.83	0.002618	8.05	6478.25	1624.14	0.48
2	-5	100 YR	21599.88	1599.49	1608.71	1607.23	1609.45	0.003731	9.41	5170.35	1247.99	0.57
2	-6	100 YR	21599.88	1598.04	1607.60	1605.92	1608.34	0.003595	9.26	5105.66	1032.80	0.56
2	-7	100 YR	21599.88	1596.93	1605.88	1604.05	1606.27	0.002999	8.44	6105.74	1375.54	0.51
2	-8	100 YR	21811.16	1594.09	1604.27	1602.39	1604.76	0.001980	7.07	6662.02	1630.90	0.42
2	-9	100 YR	23998.08	1592.94	1603.31	1601.36	1603.80	0.002269	8.03	7777.59	1614.75	0.45
2	-10	100 YR	24510.61	1592.42	1602.83	1600.56	1603.50	0.002467	8.09	6770.39	1422.80	0.47
2	-11	100 YR	24145.16	1592.67	1601.73	1599.77	1602.36	0.003678	9.42	7426.58	1546.18	0.57
2	-12	100 YR	23691.45	1591.48	1600.11	1599.21	1600.92	0.004827	10.67	6313.87	1765.76	0.65
2	-13	100 YR	23766.20	1590.35	1599.51	1597.67	1599.88	0.002100	6.27	7786.81	1863.96	0.38
2	-14	100 YR	23770.99	1589.67	1599.24	1595.64	1599.48	0.001157	4.61	7962.20	1490.71	0.28
2	-15	100 YR	23770.99	1587.83	1598.70	1594.31	1598.92	0.000993	4.60	8699.26	1393.73	0.26
2	-16	100 YR	23824.43	1587.36	1598.53	1595.18	1598.75	0.001071	5.39	9426.54	1667.78	0.30
2	-17	100 YR	28086.80	1587.70	1597.56	1595.29	1598.04	0.002907	9.03	8884.45	1583.78	0.51
2	-18	100 YR	29406.37	1586.05	1596.90	1593.66	1597.23	0.002538	8.78	9243.33	1400.63	0.48
2	-19	100 YR	32493.71	1584.40	1595.48	1592.54	1595.90	0.002899	9.59	8701.27	1482.90	0.52
2	-20	100 YR	32017.52	1583.90	1593.95	1591.88	1594.72	0.003277	9.73	7525.70	1555.25	0.55
2	-21	100 YR	32968.40	1582.22	1593.31	1589.56	1593.71	0.002406	8.86	9684.92	1562.22	0.48
2	-22	100 YR	34462.01	1581.71	1592.60	1588.55	1592.96	0.001972	7.79	11208.37	1698.31	0.43
2	-23	100 YR	35848.46	1581.23	1592.14	1587.59	1592.42	0.001929	7.92	12498.05	1682.83	0.43
2	-24	100 YR	37314.67	1580.40	1591.13	1589.24	1591.91	0.004356	11.68	9159.70	1694.76	0.64
2	-25	100 YR	39244.54	1579.95	1590.60	1589.10	1591.30	0.003851	10.87	9024.79	1665.94	0.60
3	-27	100 YR	39510.00	1579.04	1589.96	1587.68	1590.30	0.001967	7.77	11885.94	2271.14	0.43
3	-28	100 YR	39510.00	1578.22	1589.23	1585.70	1589.49	0.001745	7.50	12890.25	2208.45	0.40
3	-29	100 YR	39510.00	1577.31	1588.56	1585.17	1588.94	0.003041	9.65	12035.07	1998.91	0.53
3	-30	100 YR	39510.00	1577.26	1587.91	1583.60	1588.19	0.002778	9.12	12440.98	1718.79	0.51
3	-31	100 YR	39510.00	1577.37	1587.33	1583.54	1587.69	0.002683	8.68	11160.38	1652.77	0.49
3	-32	100 YR	39510.00	1577.05	1586.04	1583.74	1586.69	0.006786	12.90	9485.42	1456.89	0.77
3	-33	100 YR	39510.00	1575.78	1584.87	1580.12	1585.10	0.002567	8.04	12116.95	1892.25	0.48
3	-34	100 YR	39510.00	1574.65	1584.26	1579.48	1584.51	0.001897	7.13	12708.65	1756.02	0.41
3	-35	100 YR	39510.00	1573.54	1583.55	1578.56	1583.86	0.002077	7.62	11695.15	1724.02	0.43
3	-36	100 YR	39510.00	1572.63	1583.17	1578.24	1583.50	0.001726	7.11	12719.45	1804.11	0.40
3	-37	100 YR	39510.00	1571.27	1582.60	1577.59	1582.85	0.002043	8.09	14447.99	2075.98	0.44
3	-38	100 YR	39510.00	1570.10	1582.17	1576.25	1582.40	0.001549	7.30	14597.22	2062.41	0.38
3	-39	100 YR	39510.00	1570.36	1581.93	1575.39	1582.14	0.001349	6.70	14890.22	2060.13	0.36
3	-40	100 YR	39510.00	1570.61	1581.48	1575.25	1581.75	0.002365	8.55	12922.98	2043.35	0.47
3	-41	100 YR	39510.00	1570.02	1580.62	1575.50	1580.93	0.002570	8.85	12657.71	1863.85	0.49
3	-42	100 YR	39510.00	1569.81	1580.14	1574.02	1580.38	0.002467	8.70	12987.37	1966.52	0.48
3	-42.5		Inl Struct									
3	-44	100 YR	39510.00	1562.88	1576.34	1572.43	1577.04	0.003490	12.23	10089.57	1623.70	0.59
3	-45	100 YR	39510.00	1562.13	1576.35	1569.42	1576.68	0.002189	10.07	12178.22	1538.59	0.48
3	-46	100 YR	39510.00	1561.26	1574.95	1570.15	1575.68	0.004536	14.29	8746.46	1279.19	0.68
3	-47	100 YR	39510.00	1559.07	1573.59	1567.85	1574.30	0.002384	10.45	9457.32	1443.06	0.49
3	-48	100 YR	39510.00	1558.38	1572.31	1570.05	1573.53	0.003933	13.19	8150.72	1525.73	0.63
3	-49	100 YR	39510.00	1557.54	1571.32	1569.14	1572.51	0.004875	14.68	8210.25	1605.39	0.70
3	-50	100 YR	39510.00	1556.43	1571.18	1566.81	1571.60	0.001882	9.30	9634.67	1747.81	0.44
3	-51	100 YR	39510.00	1555.96	1570.32	1566.58	1570.90	0.002217	10.10	10080.49	1661.27	0.48
3	-52	100 YR	39510.00	1554.17	1569.59	1564.75	1569.92	0.001344	8.20	11367.22	1855.73	0.38
3	-53	100 YR	39510.00	1552.66	1568.77	1564.71	1569.38	0.002210	10.55	10657.44	1824.96	0.48
3	-54	100 YR	39510.00	1552.64	1568.85	1560.64	1569.10	0.001006	7.25	13350.09	1658.90	0.33
3	-56	100 YR	39510.00	1553.20	1568.60	1561.37	1568.96	0.001584	9.04	12204.50	1566.78	0.41
3	-57	100 YR	39510.00	1552.95	1568.15	1562.20	1568.62	0.002126	10.38	11304.69	1464.19	0.47
3	-58	100 YR	39510.00	1552.98	1567.75	1562.67	1568.33	0.002556	11.13	11075.60	1422.92	0.52

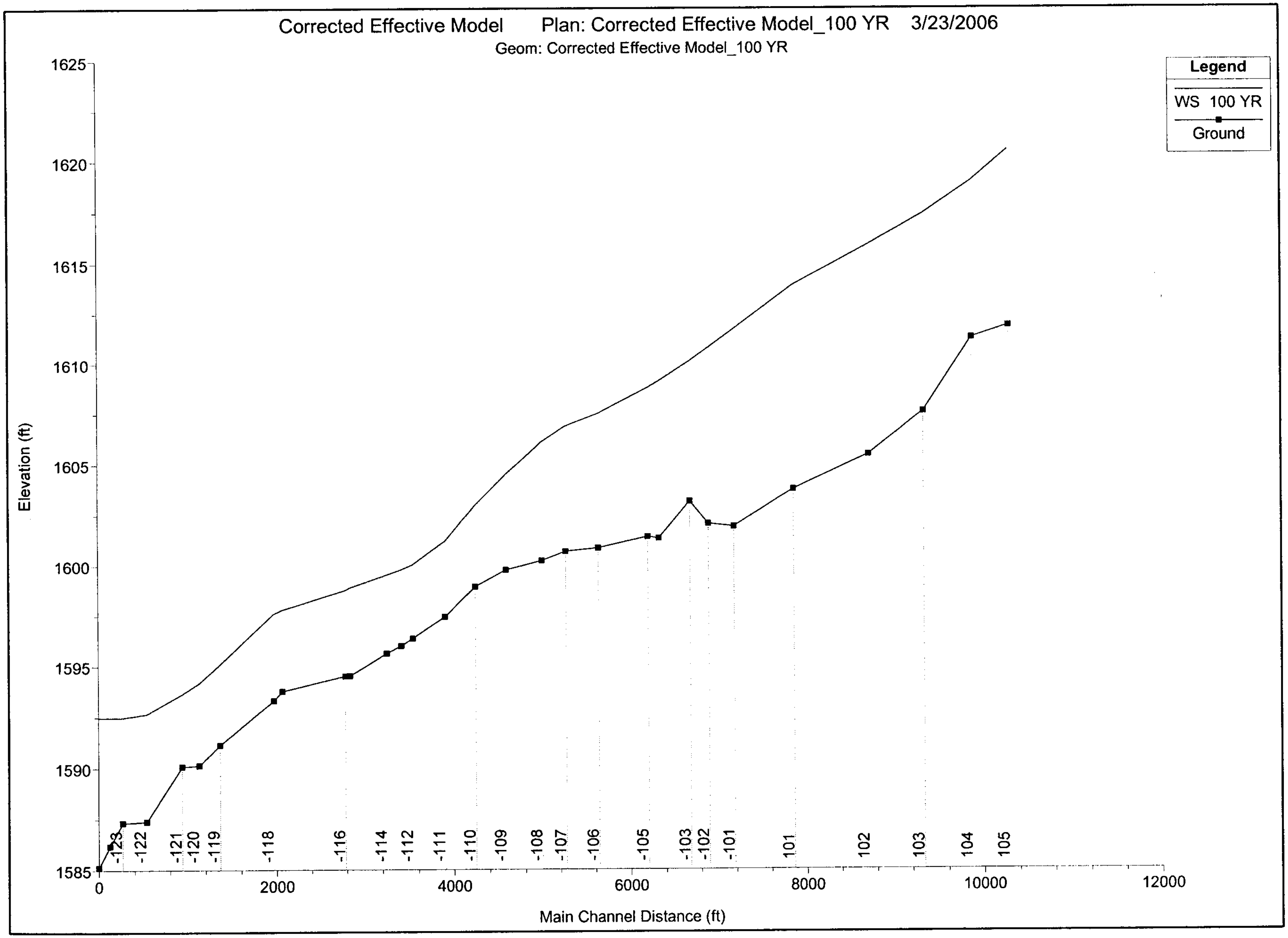
HEC-RAS Plan: CE_100 YR Profile: 100 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	-59	100 YR	39510.00	1552.64	1566.80	1563.38	1567.66	0.003591	12.86	9820.87	1440.18	0.61
3	-60	100 YR	39510.00	1551.18	1566.34	1560.55	1566.75	0.001415	8.43	12304.52	1389.72	0.39
3	-61	100 YR	39510.00	1549.30	1565.99	1559.43	1566.34	0.000950	7.27	12103.60	1419.89	0.32
3	-62	100 YR	39510.00	1549.34	1565.53	1559.13	1565.96	0.001457	8.95	10039.60	1499.58	0.40
3	-63	100 YR	39510.00	1547.67	1565.18	1557.75	1565.57	0.001393	9.26	10620.74	1472.27	0.39
3	-64	100 YR	39510.00	1547.12	1564.51	1559.87	1565.22	0.002037	11.10	10092.19	1455.74	0.47
3	-65	100 YR	39510.00	1546.85	1564.25	1558.27	1564.95	0.001726	10.26	9045.37	1325.11	0.44
3	-66	100 YR	39510.00	1545.43	1562.50	1559.34	1563.97	0.003844	15.05	6704.12	966.91	0.65
3	-67	100 YR	39510.00	1544.17	1560.77	1557.11	1562.21	0.002883	12.69	5719.10	1306.14	0.56
3	-68	100 YR	39510.00	1542.78	1559.35	1555.88	1560.58	0.002743	12.36	6828.67	1383.49	0.54
3	-69	100 YR	39510.00	1542.41	1557.46	1555.65	1559.49	0.004434	14.76	6548.55	810.10	0.68
3	-70	100 YR	39510.00	1541.70	1557.28	1553.12	1558.43	0.003700	13.44	7742.66	915.69	0.62
3	-71	100 YR	39510.00	1542.03	1556.43	1552.56	1557.83	0.004785	14.80	7010.30	786.42	0.70
3	-72	100 YR	39510.00	1541.45	1556.15	1550.35	1557.15	0.003003	11.67	8107.94	963.25	0.55
3	-72.5		Bridge									
3	-73	100 YR	39510.00	1540.69	1555.56	1551.58	1556.68	0.003151	12.36	8098.90	964.31	0.57
3	-74	100 YR	39510.00	1539.84	1554.46	1551.99	1556.09	0.004499	14.43	7069.35	1101.88	0.68
3	-75	100 YR	39510.00	1539.91	1553.41	1552.09	1555.18	0.006199	16.36	6400.59	1220.54	0.79
3	-76	100 YR	39510.00	1539.18	1551.32	1550.10	1552.99	0.006557	15.62	5826.49	1337.31	0.80
3	-77	100 YR	39510.00	1538.36	1550.08	1545.97	1551.09	0.003842	11.43	7551.19	1388.28	0.61
3	-78	100 YR	39510.00	1537.89	1549.43	1544.09	1550.27	0.003494	10.84	7688.67	1397.99	0.58
3	-79	100 YR	39510.00	1536.67	1548.20	1543.76	1548.71	0.003157	10.36	8405.73	1419.75	0.55
3	-80	100 YR	39510.00	1535.53	1547.09	1541.97	1547.65	0.003988	11.34	8980.41	1576.11	0.61
3	-81	100 YR	39510.00	1535.58	1546.06	1542.96	1546.74	0.005011	12.23	9160.72	1727.96	0.68
3	-82	100 YR	39510.00	1535.34	1545.30	1541.75	1545.81	0.003936	10.61	8974.40	2200.37	0.60
3	-83	100 YR	39510.00	1534.69	1544.34	1540.55	1544.76	0.004095	10.69	9235.68	2190.65	0.61
3	-84	100 YR	39510.00	1532.24	1542.95	1540.40	1543.54	0.003562	10.29	8765.23	1796.84	0.57
3	-85	100 YR	39510.00	1531.25	1542.41	1538.59	1542.81	0.002221	8.25	9122.28	2418.29	0.45
3	-86	100 YR	39510.00	1530.78	1542.17	1537.20	1542.49	0.001768	7.30	10152.52	2260.28	0.40
3	-87	100 YR	39510.00	1530.29	1541.59	1537.14	1541.86	0.001567	7.16	10503.68	2248.62	0.38
3	-88	100 YR	39510.00	1529.98	1541.35	1537.01	1541.64	0.001614	7.40	10642.96	2468.94	0.39
3	-89	100 YR	39510.00	1528.62	1539.92	1536.44	1540.41	0.003778	11.33	9563.06	2497.91	0.60
3	-90	100 YR	39510.00	1527.51	1538.37	1536.31	1539.07	0.004346	11.68	8916.38	2714.92	0.64
3	-91	100 YR	39510.00	1525.75	1536.64	1534.67	1537.17	0.004310	11.74	9538.23	2990.99	0.64
3	-92	100 YR	39510.00	1523.45	1534.92	1530.64	1535.24	0.002026	8.29	13002.29	3695.95	0.44
3	-93	100 YR	39510.00	1522.02	1534.56	1528.11	1534.73	0.000694	5.09	13435.76	4282.29	0.26
3	-94	100 YR	39510.00	1521.19	1534.34	1528.20	1534.51	0.000853	5.93	13277.58	4816.58	0.29
3	-95	100 YR	39510.00	1520.04	1534.00	1527.82	1534.21	0.000952	6.39	12551.89	5109.44	0.31
3	-96	100 YR	39510.00	1519.67	1533.00	1528.47	1533.46	0.002165	9.62	11239.07	4527.06	0.47
3	-97	100 YR	39510.00	1519.17	1531.87	1529.88	1532.67	0.006550	16.22	9298.65	4570.64	0.81
3	-98	100 YR	39510.00	1517.62	1529.83	1526.71	1530.56	0.004232	12.46	9089.05	4599.33	0.64
3	-99	100 YR	39510.00	1516.68	1528.81	1524.68	1529.24	0.002106	8.88	9187.61	4884.50	0.45
3	-100	100 YR	39510.00	1515.78	1527.82	1524.61	1528.30	0.003236	10.88	10196.20	4076.43	0.56
3	-101	100 YR	39510.00	1514.12	1526.08	1522.40	1526.52	0.002854	10.02	10993.65	4496.09	0.52
3	-102	100 YR	39510.00	1512.69	1523.99	1522.58	1525.01	0.006962	14.75	8049.55	4286.71	0.81
3	-103	100 YR	39510.00	1511.40	1521.89	1519.93	1522.38	0.003793	10.46	10301.10	4050.38	0.59
3	-104	100 YR	39510.00	1510.42	1521.05	1518.37	1521.30	0.002373	8.33	11803.80	4979.62	0.47
3	-105	100 YR	39510.00	1509.34	1519.59	1517.31	1520.01	0.002987	9.23	10276.57	3723.33	0.52
3	-106	100 YR	39510.00	1506.52	1518.00	1514.52	1518.36	0.001804	7.67	11500.23	2644.13	0.41
3	-107	100 YR	39510.00	1506.23	1517.50	1513.77	1517.88	0.001783	7.66	11205.54	3068.10	0.41
3	-108	100 YR	39510.00	1504.54	1516.56	1512.87	1516.91	0.001965	8.17	11561.49	2970.37	0.43
3	-109	100 YR	39510.00	1504.10	1515.84	1511.44	1516.15	0.001597	7.41	11336.94	2614.87	0.39
3	-110	100 YR	39510.00	1503.49	1514.90	1512.57	1515.29	0.002225	8.62	10226.35	3445.46	0.46
3	-111	100 YR	39510.00	1501.98	1513.36	1510.60	1513.69	0.001995	8.09	11050.24	3110.37	0.43
3	-112	100 YR	39510.00	1500.16	1511.23	1508.23	1511.59	0.002945	9.75	11414.16	2731.53	0.53
3	-113	100 YR	39510.00	1498.91	1509.29	1506.74	1509.85	0.003491	9.98	11660.68	2326.37	0.56
3	-114	100 YR	39510.00	1497.98	1507.90	1504.36	1508.15	0.002435	8.28	12234.75	2558.66	0.47
3	-115	100 YR	39510.00	1497.50	1505.14	1501.36	1505.33	0.002529	7.01	13932.86	2869.45	0.46
3	-116	100 YR	39510.00	1495.94	1504.87	1500.12	1504.98	0.000970	4.65	15484.52	2765.48	0.29
3	-117	100 YR	39510.00	1495.90	1504.39	1501.32	1504.64	0.002365	7.19	12779.37	2707.78	0.45
3	-118	100 YR	39510.00	1494.97	1503.98	1500.38	1504.18	0.001687	6.37	13190.97	2689.13	0.38
3	-119	100 YR	39510.00	1492.50	1503.38	1500.83	1503.71	0.001892	7.42	13262.49	2479.44	0.42
3	-120	100 YR	39510.00	1492.20	1503.05	1499.91	1503.33	0.001910	7.75	13408.12	2531.32	0.42
3	-121	100 YR	39510.00	1490.16	1501.22	1500.21	1501.96	0.003622	10.69	10042.25	4328.27	0.58
3	-122	100 YR	39510.00	1488.88	1500.23	1498.85	1500.72	0.003233	10.39	10457.66	4108.55	0.55
3	-123	100 YR	39510.00	1488.13	1498.40	1495.88	1498.75	0.002816	9.07	10030.10	4116.12	0.51
3	-124	100 YR	39510.00	1487.73	1497.63	1495.01	1497.99	0.002408	8.11	11163.06	4303.96	0.47
3	-125	100 YR	39510.00	1487.10	1496.89	1493.01	1497.09	0.001518	6.46	13681.28	4431.10	0.37
3	-126	100 YR	39510.00	1485.82	1495.36	1493.62	1495.92	0.004760	11.26	10357.25	4472.02	0.65
3	-127	100 YR	39510.00	1483.43	1493.75	1490.36	1494.05	0.001870	7.11	11489.70	4357.23	0.41
3	-128	100 YR	39510.00	1482.75	1492.56	1489.28	1492.84	0.001992	7.31	11289.95	3037.61	0.42
3	-129	100 YR	39510.00	1481.76	1491.83	1488.57	1492.11	0.001612	6.55	11273.80	2865.18	0.38
3	-130	100 YR	39510.00	1480.56	1490.57	1488.54	1490.98	0.003338	9.90	10408.08	3692.25	0.55
3	-131	100 YR	39510.00	1479.07	1489.22	1487.19	1489.59	0.002527	8.38	10521.95	3719.95	0.48
3	-132	100 YR	39510.00	1477.99	1487.47	1485.25	1487.94	0.003201	9.30	10059.66	2658.08	0.54
3	-133	100 YR	39510.00	1476.34	1486.66	1483.93	1486.92	0.002341	8.38	12455.87	3249.82	0.47

HEC-RAS Plan: CE_100 YR Profile: 100 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	**-134**	**100 YR**	39510.00	1474.79	1484.90	1482.54	1485.20	0.002851	9.10	12239.95	3206.66	0.51
3	**-135**	**100 YR**	39510.00	1473.99	1483.74	1481.12	1483.98	0.002504	8.35	13166.70	2964.36	0.48
3	**-136**	**100 YR**	39510.00	1473.08	1482.69	1479.21	1482.85	0.002052	7.49	15834.02	2880.91	0.43
3	**-137**	**100 YR**	39510.00	1471.00	1481.50	1480.02	1481.90	0.003255	9.75	14145.09	2931.74	0.55
3	**-138**	**100 YR**	39510.00	1471.11	1480.64	1478.61	1480.95	0.002495	8.09	15708.20	3071.09	0.47
3	**-139**	**100 YR**	39510.00	1466.88	1477.08	1475.97	1477.52	0.003336	9.34	12972.43	3434.80	0.55
3	**-140**	**100 YR**	39510.00	1464.94	1474.69	1473.80	1475.15	0.003381	9.30	11467.01	3452.46	0.55
3	**-141**	**100 YR**	39510.00	1464.33	1473.53	1472.09	1473.81	0.002713	8.15	12111.14	3320.03	0.49
3	**-142**	**100 YR**	39510.00	1463.53	1472.53	1470.62	1472.77	0.001848	6.68	11513.17	2822.67	0.40
3	**-143**	**100 YR**	39510.00	1462.74	1471.72	1469.70	1471.97	0.001787	6.57	11523.34	2781.75	0.40
3	**-144**	**100 YR**	39510.00	1461.28	1471.06	1469.07	1471.34	0.001954	7.26	10953.04	2422.24	0.42
3	**-145**	**100 YR**	39510.00	1460.72	1470.24	1468.52	1470.60	0.002501	8.00	9880.18	2183.03	0.47

100-Year Corrected Effective Hydraulic Model (Avulsion)



Corrected Effective Model Plan: Corrected Effective Model_100 YR 3/23/2006

Geom: Corrected Effective Model_100 YR

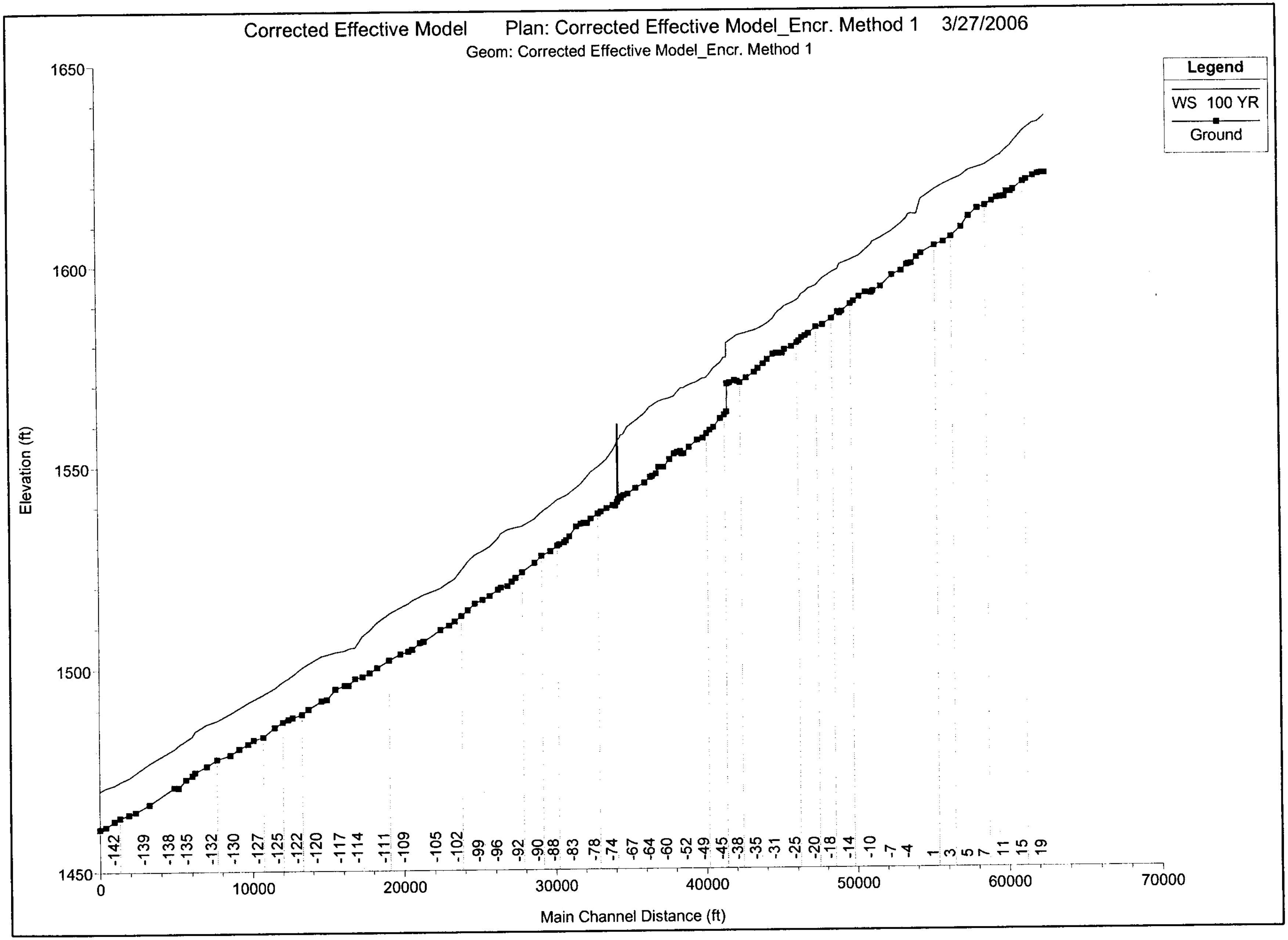
HEC-RAS Plan: CE_100 YR River: Avulsion Reach: 1 Profile: 100 YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	105	100 YR	18037.75	1611.86	1620.54	1618.15	1620.87	0.001610	5.50	4290.13	892.11	0.36
1	104	100 YR	18037.75	1611.26	1619.00	1618.20	1619.84	0.004002	8.27	3025.52	955.89	0.57
1	103.5		Lat Struct									
1	103	100 YR	18036.31	1607.57	1617.39	1615.56	1617.97	0.003020	6.65	3230.49	800.97	0.48
1	102	100 YR	18036.31	1605.44	1615.89	1613.27	1616.48	0.001967	6.76	3548.21	922.31	0.41
1	101	100 YR	18036.31	1603.73	1613.90	1612.60	1614.61	0.002737	8.08	3368.88	1426.57	0.49
1	-101	100 YR	18036.31	1601.89	1611.68	1611.06	1612.50	0.003864	8.64	3395.29	1595.12	0.56
1	-101.5		Lat Struct									
1	-102	100 YR	18036.31	1602.03	1610.76	1609.94	1611.37	0.003889	7.72	3906.20	1781.71	0.55
1	-102.5		Lat Struct									
1	-103	100 YR	17932.93	1603.13	1610.09	1609.16	1610.58	0.003535	6.65	4013.80	1741.64	0.51
1	-103.5		Lat Struct									
1	-104	100 YR	17910.12	1601.31	1609.09	1607.97	1609.49	0.002953	5.67	4161.61	1913.09	0.46
1	-104.5		Lat Struct									
1	-105	100 YR	17910.12	1601.38	1608.76	1607.75	1609.13	0.002813	5.53	4384.43	2083.94	0.45
1	-106	100 YR	17910.12	1600.83	1607.48	1606.22	1607.70	0.002101	5.50	5363.10	1871.29	0.40
1	-107	100 YR	17910.12	1600.66	1606.87	1605.53	1607.05	0.001832	4.82	5661.67	1821.59	0.37
1	-107.5		Lat Struct									
1	-108	100 YR	17698.84	1600.21	1606.09	1605.08	1606.36	0.003709	5.77	4455.98	1794.58	0.50
1	-108.5		Lat Struct									
1	-109	100 YR	15511.92	1599.75	1604.48	1603.77	1604.80	0.003955	5.79	3864.12	1991.44	0.52
1	-109.5		Lat Struct									
1	-110	100 YR	14999.39	1598.92	1602.95	1602.33	1603.33	0.006117	6.20	3304.27	1978.98	0.62
1	-110.5		Lat Struct									
1	-111	100 YR	15364.84	1597.42	1601.18	1600.61	1601.52	0.005995	5.64	3462.75	1916.90	0.60
1	-111.5		Lat Struct									
1	-112	100 YR	15818.55	1596.35	1600.02	1598.68	1600.19	0.002431	3.76	4888.82	1841.58	0.39
1	-112.5		Lat Struct									
1	-113	100 YR	15743.80	1595.98	1599.77	1598.21	1599.91	0.001855	3.37	5372.42	1873.36	0.34
1	-113.5		Lat Struct									
1	-114	100 YR	15739.01	1595.61	1599.51	1597.87	1599.64	0.001656	3.31	5815.78	2037.44	0.32
1	-115	100 YR	15739.01	1594.51	1598.88	1597.30	1598.99	0.001629	3.32	6227.55	2330.70	0.32
1	-115.5		Lat Struct									
1	-116	100 YR	15685.57	1594.49	1598.76	1597.20	1598.89	0.001836	3.54	5569.34	2126.85	0.34
1	-116.5		Lat Struct									
1	-117	100 YR	11423.20	1593.75	1597.78	1595.82	1597.86	0.001066	2.69	5057.34	2350.63	0.26
1	-117.5		Lat Struct									
1	-118	100 YR	10103.63	1593.29	1597.58	1596.00	1597.69	0.002472	3.93	4577.71	2317.43	0.39
1	-118.5		Lat Struct									
1	-119	100 YR	7016.29	1591.13	1595.08	1594.80	1595.49	0.007535	6.88	2139.88	1969.75	0.68
1	-119.5		Lat Struct									
1	-120	100 YR	7492.48	1590.13	1594.16	1593.44	1594.45	0.002818	3.86	1972.65	1867.78	0.41
1	-120.5		Lat Struct									
1	-121	100 YR	6541.60	1590.07	1593.62	1592.81	1593.85	0.002894	3.83	2088.95	1425.91	0.41
1	-121.5		Lat Struct									
1	-122	100 YR	5047.99	1587.38	1592.65	1591.16	1592.76	0.002316	3.30	2250.07	1637.81	0.37
1	-122.5		Lat Struct									
1	-123	100 YR	3661.54	1587.32	1592.47	1589.97	1592.50	0.000323	1.41	3256.31	1780.07	0.14
1	-123.5		Lat Struct									
1	-124	100 YR	2195.33	1586.19	1592.46	1589.02	1592.47	0.000063	0.75	3960.02	1837.90	0.07
1	-124.5		Lat Struct									
1	-125	100 YR	265.46	1585.13	1592.46	1587.29	1592.46	0.000001	0.08	4788.00	1794.82	0.01

HEC-RAS Plan: CE_100 YR River: Avulsion Reach: 1 Profile: 100 YR

Reach	River Sta	Profile	Q US	Q Leaving Total	Q DS	Q Weir	Q Gates	Wr Top Wdth	Weir Max Depth	Weir Avg Depth	Min El Weir Flow	E.G. US.	W.S. US.	E.G. DS	W.S. DS
			(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
1	103.5	100 YR	18037.75	1.44	18036.31	1.44		10.87	0.25	0.13	1618.75	1619.84	1619.00	1617.97	1617.39
1	-101.5	100 YR	18036.31	0.00	18036.31						1610.36	1612.50	1611.68	1611.37	1610.76
1	-102.5	100 YR	18036.31	103.38	17932.93	103.38		165.01	0.40	0.39	1609.71	1611.37	1610.76	1610.58	1610.09
1	-103.5	100 YR	17932.93	22.80	17910.12	22.80		95.39	0.38	0.19	1609.38	1610.58	1610.09	1609.49	1609.09
1	-104.5	100 YR	17910.12	0.00	17910.12						1609.38	1609.49	1609.09	1609.13	1608.76
1	-107.5	100 YR	17910.12	211.29	17698.84	211.29		132.35	1.33	0.67	1604.76	1607.05	1606.87	1606.36	1606.09
1	-108.5	100 YR	17698.84	2186.92	15511.92	2186.92		414.46	1.87	1.60	1602.61	1606.36	1606.09	1604.80	1604.48
1	-109.5	100 YR	15511.92	512.53	14999.39	512.53		176.64	1.87	1.02	1602.61	1604.80	1604.48	1603.33	1602.95
1	-110.5	100 YR	14999.39	-365.40	15364.84	-365.40		268.11	1.20	0.60	1601.08	1603.33	1602.95	1601.52	1601.18
1	-111.5	100 YR	15364.84	-453.49	15818.55	-453.49		316.36	1.24	0.62	1599.68	1601.52	1601.18	1600.19	1600.02
1	-112.5	100 YR	15818.55	74.83	15743.80	74.83		130.04	0.39	0.37	1599.38	1600.19	1600.02	1599.91	1599.77
1	-113.5	100 YR	15743.80	4.80	15739.01	4.80		18.80	0.39	0.20	1599.38	1599.91	1599.77	1599.64	1599.51
1	-115.5	100 YR	15739.01	53.54	15685.57	53.54		26.20	1.58	0.79	1597.18	1598.99	1598.88	1598.89	1598.76
1	-116.5	100 YR	15685.57	4277.13	11423.20	4277.13		671.77	2.15	1.86	1595.63	1598.89	1598.76	1597.86	1597.78
1	-117.5	100 YR	11423.20	1321.95	10103.63	1321.95		146.48	2.46	2.30	1595.12	1597.86	1597.78	1597.69	1597.58
1	-118.5	100 YR	10103.63	3125.84	7016.29	3125.84		570.34	2.46	1.77	1594.01	1597.69	1597.58	1595.49	1595.08
1	-119.5	100 YR	7016.29	-470.21	7492.48	-470.21		224.18	1.10	0.90	1593.62	1595.49	1595.08	1594.45	1594.16
1	-120.5	100 YR	7492.48	956.69	6541.60	956.69		272.98	1.85	1.19	1591.77	1594.45	1594.16	1593.85	1593.62
1	-121.5	100 YR	6541.60	1507.11	5047.99	1507.11		407.39	1.85	1.26	1591.77	1593.85	1593.62	1592.76	1592.65
1	-122.5	100 YR	5047.99	1395.84	3661.54	1395.84		397.90	1.75	1.22	1590.72	1592.76	1592.65	1592.50	1592.47
1	-123.5	100 YR	3661.54	1468.52	2195.33	1468.52		167.43	2.73	2.24	1589.73	1592.50	1592.47	1592.47	1592.46
1	-124.5	100 YR	2195.33	1931.92	265.46	1931.92		129.66	3.66	3.20	1588.80	1592.47	1592.46	1592.46	1592.46

100-Year Corrected Effective Encroachment Model (Methodology 1)


Corrected Effective Model Plan: Corrected Effective Model_Encr. Method 1 3/27/2006
Geom: Corrected Effective Model_Encr. Method 1
Legend
WS 100 YR
Ground
Elevation (ft)
1650
1600
1550
1500
1450
Main Channel Distance (ft)
0
10000
20000
30000
40000
50000
60000
70000
-142
-139
-138
-135
-132
-130
-127
-125
-122
-120
-117
-114
-111
-109
-105
-102
-99
-96
-92
-90
-88
-83
-78
-74
-67
-64
-60
-52
-49
-45
-38
-35
-31
-25
-20
-18
-14
-10
-7
-4
1
3
5
7
11
15
19

HEC-RAS Plan: CE_Encr. M1 River: VirginRiver Reach: 1 Profile: 100 YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	20	100 YR	39510.00	1622.20	1636.43	1634.84	1637.95	0.005570	15.69	6485.88	867.83	0.75
1	19	100 YR	39510.00	1622.19	1635.81	1634.08	1636.94	0.004764	14.40	7377.90	1002.10	0.70
1	18	100 YR	39510.00	1622.02	1634.93	1633.24	1635.88	0.003338	11.67	7320.42	1105.31	0.58
1	17	100 YR	39510.00	1621.51	1634.61	1631.53	1635.11	0.001448	7.71	7934.45	1254.14	0.38
1	16	100 YR	39510.00	1620.59	1633.40	1631.04	1634.18	0.002991	11.00	7681.43	1426.36	0.55
1	15	100 YR	39510.00	1620.06	1632.67	1630.68	1633.62	0.003930	12.35	7962.68	1259.51	0.62
1	14	100 YR	39510.00	1618.14	1630.02	1627.86	1630.65	0.004380	12.41	9375.01	2192.03	0.65
1	13	100 YR	39510.00	1617.61	1629.14	1627.76	1629.97	0.004689	11.99	8964.44	2376.02	0.66
1	12	100 YR	39510.00	1617.62	1628.30	1626.75	1628.88	0.003839	10.77	9332.88	2758.10	0.60
1	11	100 YR	39510.00	1616.39	1627.77	1625.69	1628.21	0.002872	9.36	10364.91	2840.76	0.51
1	10	100 YR	39510.00	1616.26	1626.79	1625.00	1627.27	0.003690	10.46	10750.80	2842.60	0.58
1	9	100 YR	39510.00	1616.08	1626.27	1624.13	1626.55	0.002582	8.75	12591.39	3384.25	0.49
1	8	100 YR	39510.00	1615.25	1625.46	1623.19	1625.79	0.002600	8.55	12845.64	3513.77	0.49
1	7	100 YR	39510.00	1614.20	1624.39	1620.78	1624.60	0.002217	7.75	13241.15	3831.40	0.45
1	6	100 YR	39510.00	1613.49	1623.74	1618.65	1623.81	0.000744	4.69	19738.29	2714.66	0.26
1	5	100 YR	39510.00	1611.55	1623.03	1619.55	1623.28	0.002767	9.86	13497.99	1912.60	0.52
1	4	100 YR	39510.00	1608.87	1621.54	1619.01	1622.03	0.003002	10.54	12335.35	1950.56	0.54
1	3	100 YR	39510.00	1606.54	1620.47	1616.69	1620.81	0.001767	8.88	13826.33	1895.44	0.42
1	2	100 YR	39510.00	1605.26	1619.56	1615.81	1619.94	0.002526	10.72	13219.26	1815.84	0.51
1	1	100 YR	39510.00	1604.27	1618.26	1613.63	1618.66	0.001771	8.93	11878.71	1339.29	0.43
1	-1	100 YR	39510.00	1602.39	1615.83	1611.93	1617.03	0.002679	10.66	7734.83	987.57	0.52
1	-2	100 YR	39510.00	1601.45	1612.17	1612.17	1615.50	0.010218	17.07	4513.34	999.58	0.96
1	-3	100 YR	39510.00	1599.83	1612.35	1609.92	1612.83	0.002192	8.84	10914.49	1655.83	0.46
1	-4	100 YR	39510.00	1599.71	1612.06	1609.32	1612.51	0.001929	8.28	10956.49	1638.86	0.43
1	-5	100 YR	39510.00	1599.49	1611.14	1608.91	1612.15	0.003998	11.52	7602.39	1264.75	0.61
1	-6	100 YR	39510.00	1598.04	1609.84	1607.78	1610.91	0.004216	11.71	7444.80	1052.64	0.63
1	-7	100 YR	39510.00	1596.93	1608.02	1605.39	1608.55	0.003228	10.18	8994.58	1506.62	0.55
1	-8	100 YR	39510.00	1594.09	1606.27	1604.07	1606.92	0.002287	8.70	9931.03	1638.52	0.46
1	-9	100 YR	39510.00	1592.94	1605.31	1602.68	1605.88	0.002347	9.24	11002.55	1624.65	0.48
1	-10	100 YR	39510.00	1592.42	1604.61	1602.15	1605.52	0.002897	9.85	9335.06	1460.36	0.52
1	-11	100 YR	39510.00	1592.67	1603.30	1601.41	1604.17	0.004444	11.59	9868.98	1563.09	0.64
1	-12	100 YR	39510.00	1591.48	1601.88	1600.47	1602.66	0.004386	11.54	10163.54	1794.94	0.64
1	-13	100 YR	39510.00	1590.35	1601.25	1598.76	1601.70	0.002246	7.34	11033.91	1869.41	0.41
1	-14	100 YR	39510.00	1589.67	1600.86	1597.10	1601.23	0.001531	5.94	10190.80	1539.41	0.33
1	-15	100 YR	39510.00	1587.83	1600.04	1595.90	1600.44	0.001586	6.32	10572.00	1401.64	0.33
1	-16	100 YR	39510.00	1587.36	1599.79	1596.42	1600.16	0.001643	7.22	11529.12	1669.62	0.37
1	-17	100 YR	39510.00	1587.70	1598.54	1596.29	1599.19	0.003587	10.70	10437.77	1586.32	0.58
1	-18	100 YR	39510.00	1586.05	1597.74	1594.55	1598.19	0.003145	10.31	10421.16	1403.44	0.55
1	-19	100 YR	39510.00	1584.40	1596.22	1593.05	1596.68	0.003023	10.25	9791.51	1486.99	0.54
1	-20	100 YR	39510.00	1583.90	1594.43	1592.79	1595.37	0.003920	10.98	8267.67	1556.18	0.60
1	-21	100 YR	39510.00	1582.22	1593.65	1590.32	1594.16	0.002963	10.04	10222.77	1562.71	0.53
1	-22	100 YR	39510.00	1581.71	1592.79	1589.02	1593.24	0.002389	8.68	11536.65	1699.42	0.47
1	-23	100 YR	39510.00	1581.23	1592.26	1587.81	1592.59	0.002230	8.58	12706.97	1682.99	0.46
1	-24	100 YR	39510.00	1580.40	1591.16	1589.56	1592.02	0.004819	12.31	9204.18	1694.85	0.67
1	-25	100 YR	39510.00	1579.95	1590.68	1589.10	1591.36	0.003741	10.76	9151.29	1666.13	0.59
1	-27	100 YR	39510.00	1579.04	1589.96	1587.68	1590.30	0.001967	7.77	11885.94	2271.14	0.43
1	-28	100 YR	39510.00	1578.22	1589.23	1585.70	1589.49	0.001745	7.50	12890.25	2208.45	0.40
1	-29	100 YR	39510.00	1577.31	1588.56	1585.17	1588.94	0.003041	9.65	12035.07	1998.91	0.53
1	-30	100 YR	39510.00	1577.26	1587.91	1583.60	1588.19	0.002778	9.12	12440.98	1718.79	0.51
1	-31	100 YR	39510.00	1577.37	1587.33	1583.54	1587.69	0.002683	8.68	11160.38	1652.77	0.49
1	-32	100 YR	39510.00	1577.05	1586.04	1583.74	1586.69	0.006786	12.90	9485.42	1456.89	0.77
1	-33	100 YR	39510.00	1575.78	1584.87	1580.12	1585.10	0.002567	8.04	12116.95	1892.25	0.48
1	-34	100 YR	39510.00	1574.65	1584.26	1579.48	1584.51	0.001897	7.13	12708.65	1756.02	0.41
1	-35	100 YR	39510.00	1573.54	1583.55	1578.56	1583.86	0.002077	7.62	11695.15	1724.02	0.43
1	-36	100 YR	39510.00	1572.63	1583.17	1578.24	1583.50	0.001726	7.11	12719.45	1804.11	0.40
1	-37	100 YR	39510.00	1571.27	1582.60	1577.59	1582.85	0.002043	8.09	14447.99	2075.98	0.44
1	-38	100 YR	39510.00	1570.10	1582.17	1576.25	1582.40	0.001549	7.30	14597.22	2062.41	0.38
1	-39	100 YR	39510.00	1570.36	1581.93	1575.39	1582.14	0.001349	6.70	14890.22	2060.13	0.36
1	-40	100 YR	39510.00	1570.61	1581.48	1575.25	1581.75	0.002365	8.55	12922.98	2043.35	0.47
1	-41	100 YR	39510.00	1570.02	1580.62	1575.50	1580.93	0.002570	8.85	12657.71	1863.85	0.49
1	-42	100 YR	39510.00	1569.81	1580.14	1574.02	1580.38	0.002467	8.70	12987.37	1966.52	0.48
1	-42.5		Inl Struct									
1	-44	100 YR	39510.00	1562.88	1576.34	1572.43	1577.04	0.003490	12.23	10089.57	1623.70	0.59
1	-45	100 YR	39510.00	1562.13	1576.35	1569.42	1576.68	0.002189	10.07	12178.22	1538.59	0.48
1	-46	100 YR	39510.00	1561.26	1574.95	1570.15	1575.68	0.004536	14.29	8746.46	1279.19	0.68
1	-47	100 YR	39510.00	1559.07	1573.59	1567.85	1574.30	0.002384	10.45	9457.32	1443.06	0.49
1	-48	100 YR	39510.00	1558.38	1572.31	1570.05	1573.53	0.003933	13.19	8150.72	1525.73	0.63
1	-49	100 YR	39510.00	1557.54	1571.32	1569.14	1572.51	0.004875	14.68	8210.25	1605.39	0.70
1	-50	100 YR	39510.00	1556.43	1571.18	1566.81	1571.60	0.001882	9.30	9634.67	1747.81	0.44
1	-51	100 YR	39510.00	1555.96	1570.32	1566.58	1570.90	0.002217	10.10	10080.49	1661.27	0.48
1	-52	100 YR	39510.00	1554.17	1569.59	1564.75	1569.92	0.001344	8.20	11367.22	1855.73	0.38
1	-53	100 YR	39510.00	1552.66	1568.77	1564.71	1569.38	0.002210	10.55	10657.44	1824.96	0.48
1	-54	100 YR	39510.00	1552.64	1568.85	1560.64	1569.10	0.001006	7.25	13350.09	1658.90	0.33
1	-56	100 YR	39510.00	1553.20	1568.60	1561.37	1568.96	0.001584	9.04	12204.50	1566.78	0.41
1	-57	100 YR	39510.00	1552.95	1568.15	1562.20	1568.62	0.002126	10.38	11304.69	1464.19	0.47
1	-58	100 YR	39510.00	1552.98	1567.75	1562.67	1568.33	0.002556	11.13	11075.60	1422.92	0.52

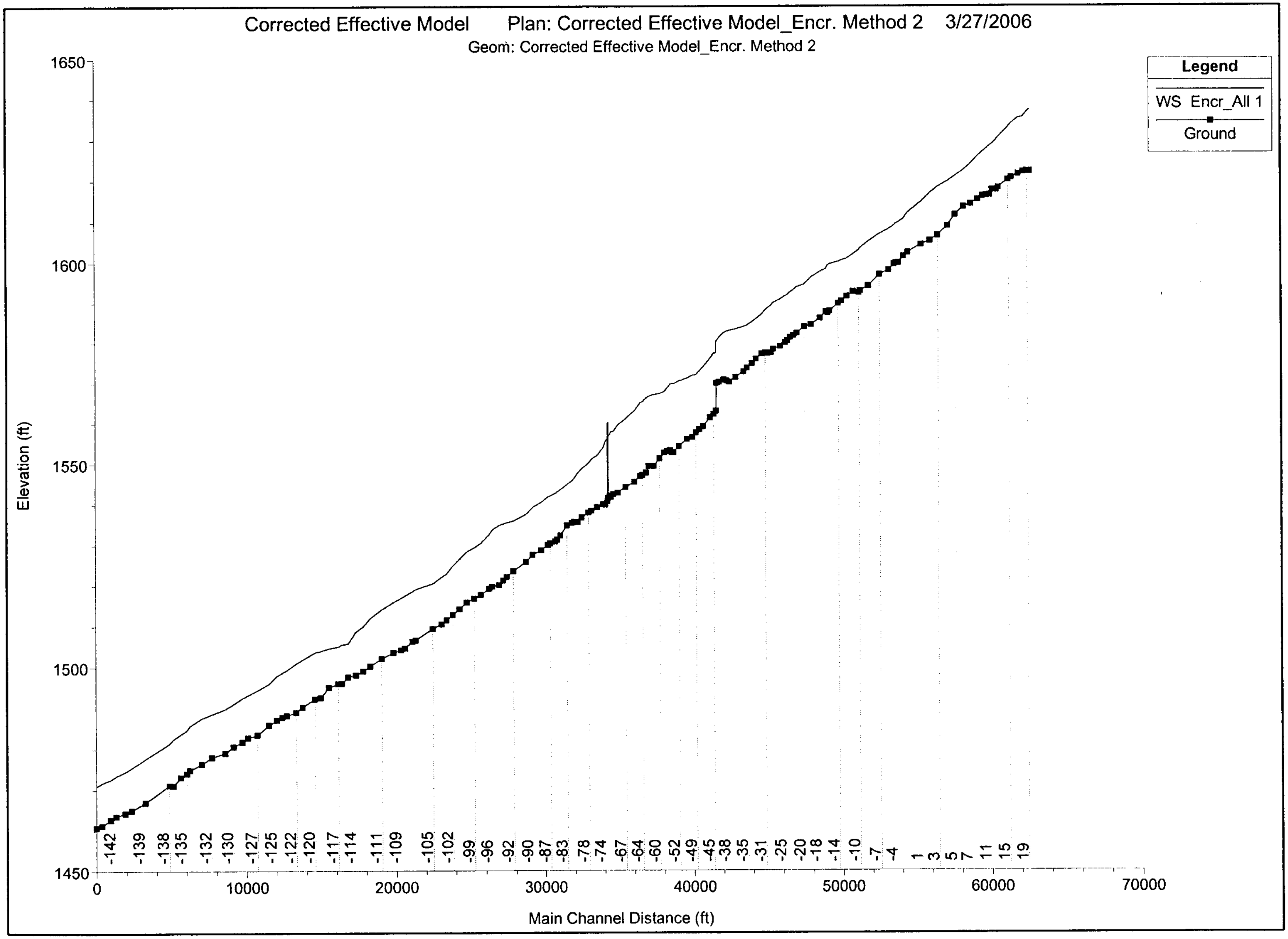
HEC-RAS Plan: CE_Encr. M1 River: VirginRiver Reach: 1 Profile: 100 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	-59	100 YR	39510.00	1552.64	1566.80	1563.38	1567.66	0.003591	12.86	9820.87	1440.18	0.61
1	-60	100 YR	39510.00	1551.18	1566.34	1560.55	1566.75	0.001415	8.43	12304.52	1389.72	0.39
1	-61	100 YR	39510.00	1549.30	1565.99	1559.43	1566.34	0.000950	7.27	12103.60	1419.89	0.32
1	-62	100 YR	39510.00	1549.34	1565.53	1559.13	1565.96	0.001457	8.95	10039.60	1499.58	0.40
1	-63	100 YR	39510.00	1547.67	1565.18	1557.75	1565.57	0.001393	9.26	10620.74	1472.27	0.39
1	-64	100 YR	39510.00	1547.12	1564.51	1559.87	1565.22	0.002037	11.10	10092.19	1455.74	0.47
1	-65	100 YR	39510.00	1546.85	1564.25	1558.27	1564.95	0.001726	10.26	9045.37	1325.11	0.44
1	-66	100 YR	39510.00	1545.43	1562.50	1559.34	1563.97	0.003844	15.05	6704.12	966.91	0.65
1	-67	100 YR	39510.00	1544.17	1560.77	1557.11	1562.21	0.002883	12.69	5719.10	1306.14	0.56
1	-68	100 YR	39510.00	1542.78	1559.35	1555.88	1560.58	0.002743	12.36	6828.67	1383.49	0.54
1	-69	100 YR	39510.00	1542.41	1557.46	1555.65	1559.49	0.004434	14.76	6548.55	810.10	0.68
1	-70	100 YR	39510.00	1541.70	1557.28	1553.12	1558.43	0.003700	13.44	7742.66	915.69	0.62
1	-71	100 YR	39510.00	1542.03	1556.43	1552.56	1557.83	0.004785	14.80	7010.30	786.42	0.70
1	-72	100 YR	39510.00	1541.45	1556.15	1550.35	1557.15	0.003003	11.67	8107.94	963.25	0.55
1	-72.5		Bridge									
1	-73	100 YR	39510.00	1540.69	1555.56	1551.58	1556.68	0.003151	12.36	8098.90	964.31	0.57
1	-74	100 YR	39510.00	1539.84	1554.46	1551.99	1556.09	0.004499	14.43	7069.35	1101.88	0.68
1	-75	100 YR	39510.00	1539.91	1553.41	1552.09	1555.18	0.006199	16.36	6400.59	1220.54	0.79
1	-76	100 YR	39510.00	1539.18	1551.32	1550.10	1552.99	0.006557	15.62	5826.49	1337.31	0.80
1	-77	100 YR	39510.00	1538.36	1550.08	1545.97	1551.09	0.003842	11.43	7551.19	1388.28	0.61
1	-78	100 YR	39510.00	1537.89	1549.43	1544.09	1550.27	0.003494	10.84	7688.67	1397.99	0.58
1	-79	100 YR	39510.00	1536.67	1548.20	1543.76	1548.71	0.003157	10.36	8405.73	1419.75	0.55
1	-80	100 YR	39510.00	1535.53	1547.09	1541.97	1547.65	0.003988	11.34	8980.41	1576.11	0.61
1	-81	100 YR	39510.00	1535.58	1546.06	1542.96	1546.74	0.005011	12.23	9160.72	1727.96	0.68
1	-82	100 YR	39510.00	1535.34	1545.30	1541.75	1545.81	0.003936	10.61	8974.40	2200.37	0.60
1	-83	100 YR	39510.00	1534.69	1544.34	1540.55	1544.76	0.004095	10.69	9235.68	2190.65	0.61
1	-84	100 YR	39510.00	1532.24	1542.95	1540.40	1543.54	0.003562	10.29	8765.23	1796.84	0.57
1	-85	100 YR	39510.00	1531.25	1542.41	1538.59	1542.81	0.002221	8.25	9122.28	2418.29	0.45
1	-86	100 YR	39510.00	1530.78	1542.17	1537.20	1542.49	0.001768	7.30	10152.52	2260.28	0.40
1	-87	100 YR	39510.00	1530.29	1541.59	1537.14	1541.86	0.001567	7.16	10503.68	2248.62	0.38
1	-88	100 YR	39510.00	1529.98	1541.35	1537.01	1541.64	0.001614	7.40	10642.96	2468.94	0.39
1	-89	100 YR	39510.00	1528.62	1539.92	1536.44	1540.41	0.003778	11.33	9563.06	2497.91	0.60
1	-90	100 YR	39510.00	1527.51	1538.37	1536.31	1539.07	0.004346	11.68	8916.38	2714.92	0.64
1	-91	100 YR	39510.00	1525.75	1536.64	1534.67	1537.17	0.004310	11.74	9538.23	2990.99	0.64
1	-92	100 YR	39510.00	1523.45	1534.92	1530.64	1535.24	0.002026	8.29	13002.29	3695.95	0.44
1	-93	100 YR	39510.00	1522.02	1534.56	1528.11	1534.73	0.000694	5.09	13435.76	4282.29	0.26
1	-94	100 YR	39510.00	1521.19	1534.34	1528.20	1534.51	0.000853	5.93	13277.58	4816.58	0.29
1	-95	100 YR	39510.00	1520.04	1534.00	1527.82	1534.21	0.000952	6.39	12551.89	5109.44	0.31
1	-96	100 YR	39510.00	1519.67	1533.00	1528.47	1533.46	0.002165	9.62	11239.07	4527.06	0.47
1	-97	100 YR	39510.00	1519.17	1531.87	1529.88	1532.67	0.006550	16.22	9298.65	4570.64	0.81
1	-98	100 YR	39510.00	1517.62	1529.83	1526.71	1530.56	0.004232	12.46	9089.05	4599.33	0.64
1	-99	100 YR	39510.00	1516.68	1528.81	1524.68	1529.24	0.002106	8.88	9187.61	4884.50	0.45
1	-100	100 YR	39510.00	1515.78	1527.82	1524.61	1528.30	0.003236	10.88	10196.20	4076.43	0.56
1	-101	100 YR	39510.00	1514.12	1526.08	1522.40	1526.52	0.002854	10.02	10993.65	4496.09	0.52
1	-102	100 YR	39510.00	1512.69	1523.99	1522.58	1525.01	0.006962	14.75	8049.55	4286.71	0.81
1	-103	100 YR	39510.00	1511.40	1521.89	1519.93	1522.38	0.003793	10.46	10301.10	4050.38	0.59
1	-104	100 YR	39510.00	1510.42	1521.05	1518.37	1521.30	0.002373	8.33	11803.80	4979.62	0.47
1	-105	100 YR	39510.00	1509.34	1519.59	1517.31	1520.01	0.002987	9.23	10276.57	3723.33	0.52
1	-106	100 YR	39510.00	1506.52	1518.00	1514.52	1518.36	0.001804	7.67	11500.23	2644.13	0.41
1	-107	100 YR	39510.00	1506.23	1517.50	1513.77	1517.88	0.001783	7.66	11205.54	3068.10	0.41
1	-108	100 YR	39510.00	1504.54	1516.56	1512.87	1516.91	0.001965	8.17	11561.49	2970.37	0.43
1	-109	100 YR	39510.00	1504.10	1515.84	1511.44	1516.15	0.001597	7.41	11336.94	2614.87	0.39
1	-110	100 YR	39510.00	1503.49	1514.90	1512.57	1515.29	0.002225	8.62	10226.35	3445.46	0.46
1	-111	100 YR	39510.00	1501.98	1513.36	1510.60	1513.69	0.001995	8.09	11050.24	3110.37	0.43
1	-112	100 YR	39510.00	1500.16	1511.23	1508.23	1511.59	0.002945	9.75	11414.16	2731.53	0.53
1	-113	100 YR	39510.00	1498.91	1509.29	1506.74	1509.85	0.003491	9.98	11660.68	2326.37	0.56
1	-114	100 YR	39510.00	1497.98	1507.90	1504.36	1508.15	0.002435	8.28	12234.75	2558.66	0.47
1	-115	100 YR	39510.00	1497.50	1505.14	1501.36	1505.33	0.002529	7.01	13932.86	2869.45	0.46
1	-116	100 YR	39510.00	1495.94	1504.87	1500.12	1504.98	0.000970	4.65	15484.52	2765.48	0.29
1	-117	100 YR	39510.00	1495.90	1504.39	1501.32	1504.64	0.002365	7.19	12779.37	2707.78	0.45
1	-118	100 YR	39510.00	1494.97	1503.98	1500.38	1504.18	0.001687	6.37	13190.97	2689.13	0.38
1	-119	100 YR	39510.00	1492.50	1503.38	1500.83	1503.71	0.001892	7.42	13262.49	2479.44	0.42
1	-120	100 YR	39510.00	1492.20	1503.05	1499.91	1503.33	0.001910	7.75	13408.12	2531.32	0.42
1	-121	100 YR	39510.00	1490.16	1501.22	1500.21	1501.96	0.003622	10.69	10042.25	4328.27	0.58
1	-122	100 YR	39510.00	1488.88	1500.23	1498.85	1500.72	0.003233	10.39	10457.66	4108.55	0.55
1	-123	100 YR	39510.00	1488.13	1498.40	1495.88	1498.75	0.002816	9.07	10030.10	4116.12	0.51
1	-124	100 YR	39510.00	1487.73	1497.63	1495.01	1497.99	0.002408	8.11	11163.06	4303.96	0.47
1	-125	100 YR	39510.00	1487.10	1496.89	1493.01	1497.09	0.001518	6.46	13681.28	4431.10	0.37
1	-126	100 YR	39510.00	1485.82	1495.36	1493.62	1495.92	0.004760	11.26	10357.25	4472.02	0.65
1	-127	100 YR	39510.00	1483.43	1493.75	1490.36	1494.05	0.001870	7.11	11489.70	4357.23	0.41
1	-128	100 YR	39510.00	1482.75	1492.56	1489.28	1492.84	0.001992	7.31	11289.95	3037.61	0.42
1	-129	100 YR	39510.00	1481.76	1491.83	1488.57	1492.11	0.001612	6.55	11273.80	2865.18	0.38
1	-130	100 YR	39510.00	1480.56	1490.57	1488.54	1490.98	0.003338	9.90	10408.08	3692.25	0.55
1	-131	100 YR	39510.00	1479.07	1489.22	1487.19	1489.59	0.002527	8.38	10521.95	3719.95	0.48
1	-132	100 YR	39510.00	1477.99	1487.47	1485.25	1487.94	0.003201	9.30	10059.66	2658.08	0.54
1	-133	100 YR	39510.00	1476.34	1486.66	1483.93	1486.92	0.002341	8.38	12455.87	3249.82	0.47

HEC-RAS Plan: CE_Encr. M1 River: VirginRiver Reach: 1 Profile: 100 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	-134	100 YR	39510.00	1474.79	1484.90	1482.54	1485.20	0.002851	9.10	12239.95	3206.66	0.51
1	-135	100 YR	39510.00	1473.99	1483.74	1481.12	1483.98	0.002504	8.35	13166.70	2964.36	0.48
1	-136	100 YR	39510.00	1473.08	1482.69	1479.21	1482.85	0.002052	7.49	15834.02	2880.91	0.43
1	-137	100 YR	39510.00	1471.00	1481.50	1480.02	1481.90	0.003255	9.75	14145.09	2931.74	0.55
1	-138	100 YR	39510.00	1471.11	1480.64	1478.61	1480.95	0.002495	8.09	15708.20	3071.09	0.47
1	-139	100 YR	39510.00	1466.88	1477.08	1475.97	1477.52	0.003336	9.34	12972.43	3434.80	0.55
1	-140	100 YR	39510.00	1464.94	1474.69	1473.80	1475.15	0.003381	9.30	11467.01	3452.46	0.55
1	-141	100 YR	39510.00	1464.33	1473.53	1472.06	1473.81	0.002713	8.15	12111.14	3320.03	0.49
1	-142	100 YR	39510.00	1463.53	1472.53	1470.62	1472.77	0.001848	6.68	11513.17	2822.67	0.40
1	-143	100 YR	39510.00	1462.74	1471.72	1469.70	1471.97	0.001787	6.57	11523.34	2781.75	0.40
1	-144	100 YR	39510.00	1461.28	1471.06	1469.03	1471.34	0.001954	7.26	10952.75	2422.24	0.42
1	-145	100 YR	39510.00	1460.72	1470.24	1468.52	1470.60	0.002501	8.00	9880.18	2183.03	0.47

100-Year Corrected Effective Encroachment Model (Methodology 2)



Corrected Effective Model Plan: Corrected Effective Model_Encr. Method 2 3/27/2006

Geom: Corrected Effective Model_Encr. Method 2

HEC-RAS Plan: CE_Encr. M2 River: VirginRiver Reach: 1 Profile: Encr_All 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	20	Encr_All 1	39510.00	1622.20	1637.41	1635.03	1638.97	0.004928	15.47	6316.87	671.42	0.72
1	19	Encr_All 1	39510.00	1622.19	1636.72	1634.38	1638.07	0.004702	14.95	6562.02	706.74	0.70
1	18	Encr_All 1	39510.00	1622.02	1635.52	1633.46	1636.93	0.004161	13.43	6359.42	750.18	0.65
1	17	Encr_All 1	39510.00	1621.51	1635.30	1631.74	1635.95	0.001609	8.42	6967.72	815.00	0.40
1	16	Encr_All 1	39510.00	1620.59	1633.87	1631.42	1634.89	0.003551	12.28	7204.57	988.00	0.60
1	15	Encr_All 1	39510.00	1620.06	1633.01	1631.13	1634.22	0.004524	13.50	7660.90	1092.61	0.67
1	14	Encr_All 1	39510.00	1618.14	1630.54	1627.78	1631.15	0.003862	12.00	8998.92	1289.00	0.61
1	13	Encr_All 1	39510.00	1617.61	1629.85	1627.73	1630.59	0.003707	11.15	9019.14	1390.00	0.59
1	12	Encr_All 1	39510.00	1617.62	1628.90	1627.25	1629.63	0.004267	11.80	8732.98	1493.00	0.63
1	11	Encr_All 1	39510.00	1616.39	1628.40	1625.63	1628.91	0.002871	9.74	9516.14	1579.00	0.52
1	10	Encr_All 1	39510.00	1616.26	1627.57	1625.03	1628.04	0.003103	10.09	10107.18	1701.00	0.54
1	9	Encr_All 1	39510.00	1616.08	1626.90	1624.52	1627.34	0.003388	10.43	10009.45	1736.00	0.56
1	8	Encr_All 1	39510.00	1615.25	1625.82	1623.13	1626.36	0.003435	10.08	10025.94	1726.00	0.56
1	7	Encr_All 1	39510.00	1614.20	1624.01	1621.27	1624.51	0.004113	10.27	8229.39	1674.00	0.60
1	6	Encr_All 1	39510.00	1613.49	1622.41	1619.02	1622.65	0.002241	7.41	10734.59	1722.69	0.44
1	5	Encr_All 1	39510.00	1611.55	1621.02	1618.78	1621.40	0.003338	9.50	9316.57	1859.00	0.55
1	4	Encr_All 1	39510.00	1608.87	1619.73	1617.81	1620.26	0.003613	10.35	8886.43	1779.00	0.58
1	3	Encr_All 1	39510.00	1606.54	1618.32	1615.62	1618.72	0.002260	8.95	9721.91	1684.29	0.47
1	2	Encr_All 1	39510.00	1605.26	1616.77	1615.25	1617.36	0.004737	12.63	8811.64	1787.70	0.67
1	1	Encr_All 1	39510.00	1604.27	1614.61	1612.44	1615.07	0.002836	9.19	8887.27	1960.99	0.51
1	-1	Encr_All 1	39510.00	1602.39	1612.05	1610.17	1612.84	0.003618	9.87	7438.78	1891.11	0.57
1	-2	Encr_All 1	39510.00	1601.45	1610.55	1609.64	1611.62	0.006050	11.65	6391.14	2098.41	0.72
1	-3	Encr_All 1	39510.00	1599.83	1609.76	1608.74	1610.36	0.004057	10.15	9296.07	2746.86	0.60
1	-4	Encr_All 1	39510.00	1599.71	1609.39	1607.81	1609.79	0.002726	8.25	10242.28	2913.89	0.49
1	-5	Encr_All 1	39510.00	1599.49	1608.96	1607.51	1609.45	0.003171	8.84	9209.08	2626.64	0.53
1	-6	Encr_All 1	39510.00	1598.04	1608.05	1606.34	1608.41	0.002353	7.75	10511.05	2438.66	0.46
1	-7	Encr_All 1	39510.00	1596.93	1606.88	1604.97	1607.13	0.002048	7.51	11936.05	2747.43	0.43
1	-8	Encr_All 1	39510.00	1594.09	1604.99	1604.27	1605.67	0.003033	9.22	10150.20	2980.40	0.52
1	-9	Encr_All 1	39510.00	1592.94	1603.41	1602.71	1604.16	0.003994	10.72	9972.52	3027.47	0.60
1	-10	Encr_All 1	39510.00	1592.42	1602.93	1602.19	1603.64	0.003327	9.46	9951.77	2831.34	0.55
1	-11	Encr_All 1	39510.00	1592.67	1601.89	1600.84	1602.32	0.003412	9.19	11394.27	2859.81	0.55
1	-12	Encr_All 1	39510.00	1591.48	1600.84	1599.48	1601.20	0.002777	8.55	11543.06	2934.93	0.50
1	-13	Encr_All 1	39510.00	1590.35	1600.43	1598.55	1600.68	0.001627	5.91	13405.76	2990.72	0.34
1	-14	Encr_All 1	39510.00	1589.67	1600.09	1597.38	1600.33	0.001234	5.07	12935.56	2694.58	0.29
1	-15	Encr_All 1	39510.00	1587.83	1599.47	1596.10	1599.72	0.001255	5.43	13402.23	2579.07	0.29
1	-16	Encr_All 1	39510.00	1587.36	1599.22	1596.58	1599.49	0.001447	6.55	13266.15	2599.27	0.35
1	-17	Encr_All 1	39510.00	1587.70	1598.29	1596.21	1598.66	0.002396	8.61	12378.39	2189.68	0.47
1	-18	Encr_All 1	39510.00	1586.05	1597.62	1594.69	1597.97	0.002690	9.47	12014.73	1965.79	0.51
1	-19	Encr_All 1	39510.00	1584.40	1596.18	1593.34	1596.60	0.002831	9.90	10732.61	1830.90	0.52
1	-20	Encr_All 1	39510.00	1583.90	1594.47	1592.82	1595.37	0.003762	10.79	8663.97	1761.14	0.59
1	-21	Encr_All 1	39510.00	1582.22	1593.81	1590.35	1594.24	0.002626	9.54	11183.68	1893.12	0.50
1	-22	Encr_All 1	39510.00	1581.71	1593.02	1589.06	1593.43	0.002142	8.34	12228.74	1840.33	0.45
1	-23	Encr_All 1	39510.00	1581.23	1592.56	1587.85	1592.85	0.001947	8.16	13624.12	1822.91	0.43
1	-24	Encr_All 1	39510.00	1580.40	1591.82	1589.65	1592.42	0.003250	10.53	10678.74	1831.27	0.56
1	-25	Encr_All 1	39510.00	1579.95	1591.59	1589.20	1591.99	0.002073	8.48	11199.48	1804.98	0.44
1	-27	Encr_All 1	39510.00	1579.04	1590.77	1588.05	1591.22	0.002156	8.56	10682.69	1650.80	0.45
1	-28	Encr_All 1	39510.00	1578.22	1589.89	1586.09	1590.27	0.002197	8.76	11764.40	1656.04	0.46
1	-29	Encr_All 1	39510.00	1577.31	1589.15	1586.05	1589.64	0.003360	10.52	10964.87	1507.86	0.56
1	-30	Encr_All 1	39510.00	1577.26	1588.52	1583.82	1588.85	0.002803	9.53	11426.79	1379.90	0.51
1	-31	Encr_All 1	39510.00	1577.37	1588.00	1583.76	1588.38	0.002455	8.69	10607.87	1279.78	0.48
1	-32	Encr_All 1	39510.00	1577.05	1586.91	1584.01	1587.53	0.005537	12.41	9732.02	1340.53	0.71
1	-33	Encr_All 1	39510.00	1575.78	1585.84	1580.59	1586.11	0.002513	8.52	11556.63	1362.90	0.48
1	-34	Encr_All 1	39510.00	1574.65	1585.07	1580.46	1585.45	0.002404	8.48	11874.10	1387.71	0.47
1	-35	Encr_All 1	39510.00	1573.54	1584.24	1579.22	1584.65	0.002346	8.49	10467.01	1270.04	0.47
1	-36	Encr_All 1	39510.00	1572.63	1583.89	1578.50	1584.27	0.001677	7.34	11546.03	1306.55	0.40
1	-37	Encr_All 1	39510.00	1571.27	1583.32	1577.66	1583.61	0.002027	8.42	13361.03	1426.00	0.44
1	-38	Encr_All 1	39510.00	1570.10	1582.93	1576.38	1583.17	0.001429	7.33	14124.03	1352.00	0.37
1	-39	Encr_All 1	39510.00	1570.36	1582.71	1575.39	1582.92	0.001204	6.63	14485.34	1285.00	0.34
1	-40	Encr_All 1	39510.00	1570.61	1582.34	1575.24	1582.60	0.001927	8.14	13125.32	1192.00	0.43
1	-41	Encr_All 1	39510.00	1570.02	1581.27	1575.73	1581.76	0.003214	10.31	10206.23	977.00	0.55
1	-42	Encr_All 1	39510.00	1569.81	1580.32	1575.23	1580.93	0.004932	12.45	8745.59	858.00	0.68
1	-42.5		Inl Struct									
1	-44	Encr_All 1	39510.00	1562.88	1577.27	1572.28	1578.12	0.003434	12.70	8815.87	796.00	0.60
1	-45	Encr_All 1	39510.00	1562.13	1577.27	1569.52	1577.73	0.002497	11.23	10522.02	811.00	0.51
1	-46	Encr_All 1	39510.00	1561.26	1575.87	1570.47	1576.68	0.004412	14.72	8530.62	756.00	0.68
1	-47	Encr_All 1	39510.00	1559.07	1573.79	1568.76	1574.99	0.003396	12.59	7313.24	676.90	0.59
1	-48	Encr_All 1	39510.00	1558.38	1572.75	1569.49	1574.10	0.003915	13.45	7255.88	735.00	0.63
1	-49	Encr_All 1	39510.00	1557.54	1571.84	1568.51	1573.09	0.004610	14.64	7399.60	773.00	0.69
1	-50	Encr_All 1	39510.00	1556.43	1571.72	1566.70	1572.21	0.001819	9.37	8531.42	804.00	0.43
1	-51	Encr_All 1	39510.00	1555.96	1570.95	1566.47	1571.55	0.002065	10.04	9390.11	929.00	0.46
1	-52	Encr_All 1	39510.00	1554.17	1570.31	1564.80	1570.66	0.001194	7.98	10981.77	1028.00	0.36
1	-53	Encr_All 1	39510.00	1552.66	1569.61	1564.79	1570.18	0.001882	10.10	10738.47	1057.00	0.45
1	-54	Encr_All 1	39510.00	1552.64	1569.71	1560.63	1569.93	0.000825	6.81	14104.54	1102.00	0.30
1	-56	Encr_All 1	39510.00	1553.20	1569.51	1561.44	1569.82	0.001270	8.41	13157.90	1120.00	0.37
1	-57	Encr_All 1	39510.00	1552.95	1569.06	1562.53	1569.53	0.001899	10.21	11378.79	1003.00	0.45
1	-58	Encr_All 1	39510.00	1552.98	1568.67	1563.15	1569.28	0.002360	11.14	10948.45	993.00	0.50
1	-59	Encr_All 1	39510.00	1552.64	1567.66	1564.33	1568.64	0.003500	13.21	9397.97	974.00	0.61
1	-60	Encr_All 1	39510.00	1551.18	1567.23	1561.48	1567.72	0.001438	8.83	11270.54	974.00	0.39
1	-61	Encr_All 1	39510.00	1549.30	1566.96	1559.55	1567.31	0.000841	7.12	11557.86	904.00	0.30

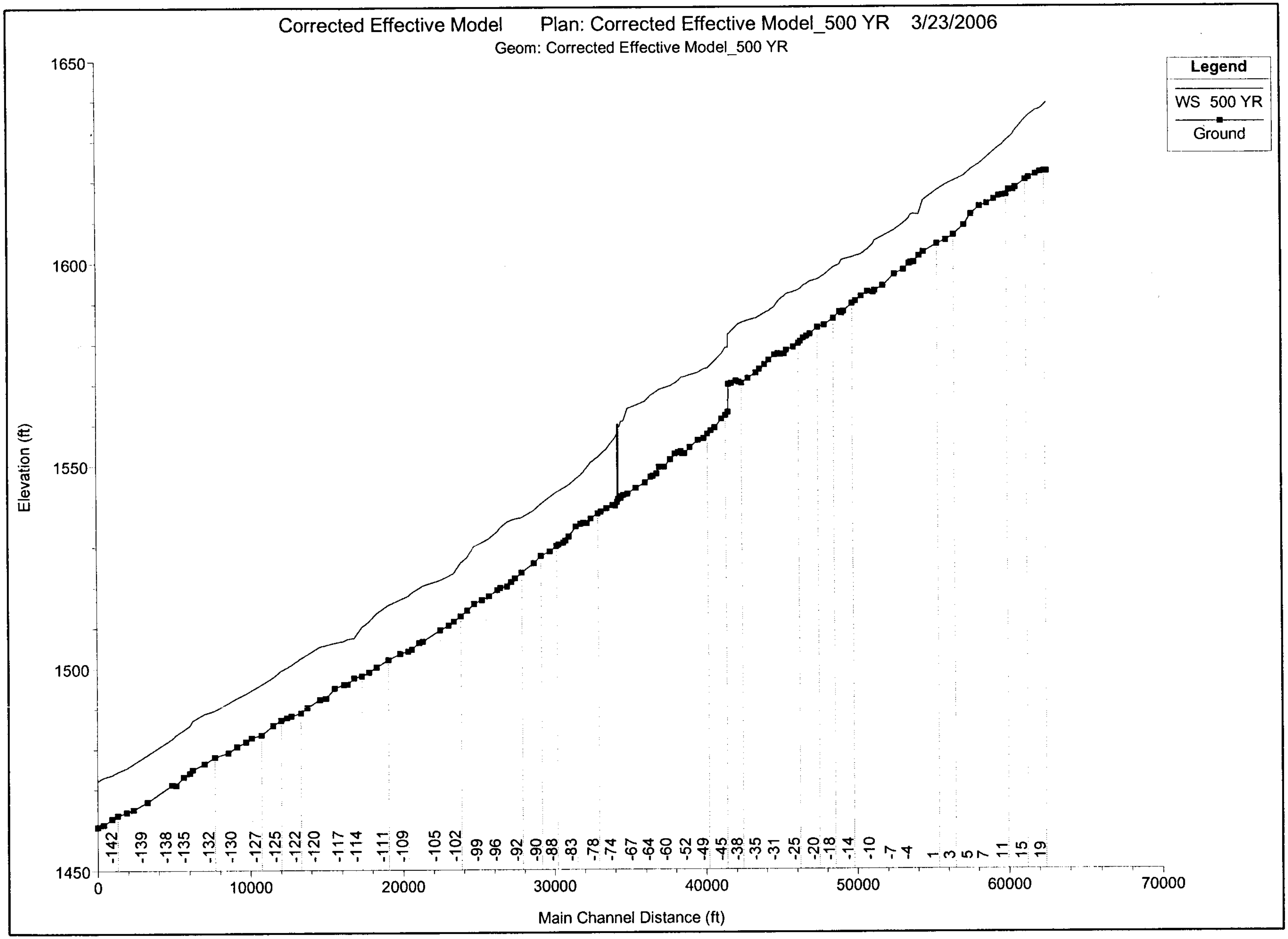
HEC-RAS Plan: CE_Encr. M2 River: VirginRiver Reach: 1 Profile: Encr_All 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	-62	Encr_All 1	39510.00	1549.34	1566.50	1559.06	1566.96	0.001385	9.07	9647.07	774.00	0.39
1	-63	Encr_All 1	39510.00	1547.67	1566.08	1557.62	1566.57	0.001475	9.86	9460.55	697.00	0.41
1	-64	Encr_All 1	39510.00	1547.12	1565.15	1559.62	1566.15	0.002442	12.46	8729.84	647.00	0.52
1	-65	Encr_All 1	39510.00	1546.85	1564.98	1558.37	1565.80	0.001788	10.73	8289.79	600.00	0.45
1	-66	Encr_All 1	39510.00	1545.43	1562.93	1559.48	1564.74	0.004215	16.02	5790.59	478.00	0.68
1	-67	Encr_All 1	39510.00	1544.17	1561.01	1557.52	1562.78	0.003253	13.62	5021.68	432.00	0.59
1	-68	Encr_All 1	39510.00	1542.78	1559.49	1556.12	1560.94	0.003034	13.07	6293.88	566.00	0.57
1	-69	Encr_All 1	39510.00	1542.41	1557.89	1555.73	1559.86	0.004099	14.46	6599.12	690.00	0.66
1	-70	Encr_All 1	39510.00	1541.70	1557.78	1553.03	1558.86	0.003327	13.04	7984.98	673.00	0.59
1	-71	Encr_All 1	39510.00	1542.03	1557.09	1552.52	1558.35	0.004055	14.05	7404.20	661.33	0.65
1	-72	Encr_All 1	39510.00	1541.45	1556.78	1550.35	1557.80	0.002772	11.56	8102.20	676.00	0.54
1	-72.5		Bridge									
1	-73	Encr_All 1	39510.00	1540.69	1556.20	1551.47	1557.32	0.002896	12.20	8030.93	681.00	0.55
1	-74	Encr_All 1	39510.00	1539.84	1555.40	1551.85	1556.84	0.003635	13.54	7225.18	691.00	0.62
1	-75	Encr_All 1	39510.00	1539.91	1553.84	1552.15	1555.88	0.006506	17.12	6200.81	681.00	0.82
1	-76	Encr_All 1	39510.00	1539.18	1551.99	1549.90	1553.61	0.005786	15.22	5884.41	677.89	0.76
1	-77	Encr_All 1	39510.00	1538.36	1551.01	1545.92	1551.97	0.003153	10.93	7614.48	728.00	0.56
1	-78	Encr_All 1	39510.00	1537.89	1550.02	1545.01	1551.19	0.004125	12.20	6876.38	681.00	0.63
1	-79	Encr_All 1	39510.00	1536.67	1548.75	1543.47	1549.38	0.003390	11.09	7646.56	798.00	0.57
1	-80	Encr_All 1	39510.00	1535.53	1547.60	1541.97	1548.26	0.004082	11.83	7864.59	861.00	0.62
1	-81	Encr_All 1	39510.00	1535.58	1546.41	1542.91	1547.30	0.005575	13.20	7577.48	902.00	0.72
1	-82	Encr_All 1	39510.00	1535.34	1545.68	1541.63	1546.28	0.004007	10.98	7719.96	951.00	0.61
1	-83	Encr_All 1	39510.00	1534.69	1544.80	1540.51	1545.29	0.004103	11.03	8117.03	1021.00	0.61
1	-84	Encr_All 1	39510.00	1532.24	1543.52	1540.36	1544.13	0.003250	10.20	8423.32	1092.00	0.55
1	-85	Encr_All 1	39510.00	1531.25	1543.03	1538.76	1543.46	0.002042	8.22	8405.81	1012.00	0.44
1	-86	Encr_All 1	39510.00	1530.78	1542.64	1538.07	1543.15	0.002341	8.66	8184.02	936.00	0.47
1	-87	Encr_All 1	39510.00	1530.29	1541.99	1537.02	1542.41	0.001944	8.17	8367.97	940.61	0.43
1	-88	Encr_All 1	39510.00	1529.98	1541.74	1536.72	1542.16	0.001678	7.73	8780.24	1010.00	0.40
1	-89	Encr_All 1	39510.00	1528.62	1540.42	1536.28	1540.95	0.003573	11.34	8836.29	1172.00	0.59
1	-90	Encr_All 1	39510.00	1527.51	1539.18	1536.35	1539.79	0.003372	10.81	9075.95	1249.00	0.57
1	-91	Encr_All 1	39510.00	1525.75	1537.46	1535.18	1538.12	0.004639	12.80	9216.88	1331.00	0.67
1	-92	Encr_All 1	39510.00	1523.45	1535.83	1530.64	1536.20	0.001889	8.44	11741.34	1231.00	0.43
1	-93	Encr_All 1	39510.00	1522.02	1535.43	1528.44	1535.67	0.000781	5.66	11006.62	1156.00	0.28
1	-94	Encr_All 1	39510.00	1521.19	1535.14	1528.83	1535.43	0.000958	6.55	10106.05	1094.00	0.31
1	-95	Encr_All 1	39510.00	1520.04	1534.75	1528.68	1535.08	0.001124	7.21	9668.10	1035.00	0.34
1	-96	Encr_All 1	39510.00	1519.67	1533.67	1528.92	1534.25	0.002261	10.16	9594.06	993.00	0.48
1	-97	Encr_All 1	39510.00	1519.17	1532.63	1530.01	1533.48	0.006021	16.18	8783.67	1019.00	0.78
1	-98	Encr_All 1	39510.00	1517.62	1530.36	1527.78	1531.35	0.004905	13.83	8406.70	1026.00	0.70
1	-99	Encr_All 1	39510.00	1516.68	1529.27	1525.18	1529.83	0.002398	9.72	8292.95	1025.36	0.49
1	-100	Encr_All 1	39510.00	1515.78	1528.24	1524.72	1528.82	0.003376	11.38	8912.59	1169.00	0.58
1	-101	Encr_All 1	39510.00	1514.12	1526.38	1522.50	1526.97	0.003275	10.92	8972.11	1149.00	0.56
1	-102	Encr_All 1	39510.00	1512.69	1524.73	1522.69	1525.57	0.005257	13.41	8584.24	1238.00	0.71
1	-103	Encr_All 1	39510.00	1511.40	1522.79	1520.01	1523.37	0.003760	11.04	9811.48	1533.00	0.60
1	-104	Encr_All 1	39510.00	1510.42	1521.97	1518.36	1522.29	0.002457	8.99	11106.37	1663.00	0.48
1	-105	Encr_All 1	39510.00	1509.34	1520.43	1517.39	1520.90	0.002888	9.60	10165.26	1580.00	0.52
1	-106	Encr_All 1	39510.00	1506.52	1518.97	1514.82	1519.34	0.001626	7.71	11544.86	1427.00	0.40
1	-107	Encr_All 1	39510.00	1506.23	1518.49	1514.23	1518.90	0.001654	7.82	11209.85	1360.02	0.40
1	-108	Encr_All 1	39510.00	1504.54	1517.40	1513.61	1517.88	0.002370	9.41	10641.93	1299.19	0.48
1	-109	Encr_All 1	39510.00	1504.10	1516.84	1511.60	1517.15	0.001219	6.86	10957.91	1183.49	0.35
1	-110	Encr_All 1	39510.00	1503.49	1515.80	1512.39	1516.35	0.002549	9.73	8969.65	1176.01	0.50
1	-111	Encr_All 1	39510.00	1501.98	1514.02	1510.39	1514.48	0.002317	9.07	9613.08	1169.03	0.47
1	-112	Encr_All 1	39510.00	1500.16	1511.90	1508.08	1512.30	0.002801	9.90	10352.82	1378.65	0.52
1	-113	Encr_All 1	39510.00	1498.91	1509.86	1506.73	1510.57	0.003622	10.56	9734.95	1325.89	0.58
1	-114	Encr_All 1	39510.00	1497.98	1508.56	1504.31	1508.87	0.002329	8.47	10339.29	1339.95	0.47
1	-115	Encr_All 1	39510.00	1497.50	1505.67	1501.42	1505.96	0.002941	7.92	10994.64	1530.73	0.50
1	-116	Encr_All 1	39510.00	1495.94	1505.41	1500.12	1505.57	0.000951	4.81	12980.19	1677.40	0.29
1	-117	Encr_All 1	39510.00	1495.90	1504.93	1501.15	1505.23	0.002382	7.54	11111.77	1789.51	0.46
1	-118	Encr_All 1	39510.00	1494.97	1504.48	1500.27	1504.73	0.001700	6.64	11733.56	1900.87	0.39
1	-119	Encr_All 1	39510.00	1492.50	1503.83	1500.77	1504.21	0.001975	7.81	12526.07	1886.51	0.43
1	-120	Encr_All 1	39510.00	1492.20	1503.52	1499.87	1503.83	0.001878	7.92	13088.84	1874.75	0.42
1	-121	Encr_All 1	39510.00	1490.16	1501.75	1500.19	1502.59	0.003617	11.04	9642.40	1782.60	0.59
1	-122	Encr_All 1	39510.00	1488.88	1500.79	1498.90	1501.37	0.003341	10.92	9923.74	1756.97	0.57
1	-123	Encr_All 1	39510.00	1488.13	1499.16	1495.84	1499.50	0.002295	8.60	10201.70	1653.85	0.46
1	-124	Encr_All 1	39510.00	1487.73	1498.59	1495.03	1498.90	0.001771	7.42	11812.28	1701.95	0.41
1	-125	Encr_All 1	39510.00	1487.10	1497.75	1493.69	1498.05	0.001977	7.82	11950.94	1621.27	0.43
1	-126	Encr_All 1	39510.00	1485.82	1495.87	1493.63	1496.60	0.005056	12.03	8754.98	1306.31	0.68
1	-127	Encr_All 1	39510.00	1483.43	1494.30	1490.41	1494.63	0.001710	7.06	9903.36	1361.40	0.40
1	-128	Encr_All 1	39510.00	1482.75	1493.14	1489.63	1493.47	0.001946	7.53	10182.26	1501.33	0.42
1	-129	Encr_All 1	39510.00	1481.76	1492.33	1489.46	1492.74	0.001890	7.34	9146.45	1395.12	0.42
1	-130	Encr_All 1	39510.00	1480.56	1490.96	1489.11	1491.51	0.003719	10.72	8607.10	1477.52	0.59
1	-131	Encr_All 1	39510.00	1479.07	1489.72	1487.62	1490.14	0.002496	8.61	9846.29	1703.82	0.48
1	-132	Encr_All 1	39510.00	1477.99	1488.47	1485.43	1488.82	0.002080	8.02	10999.40	1875.65	0.44
1	-133	Encr_All 1	39510.00	1476.34	1487.48	1485.25	1487.91	0.003072	10.11	10818.70	1817.88	0.54
1	-134	Encr_All 1	39510.00	1474.79	1485.66	1482.92	1485.99	0.002609	9.15	11510.27	2092.90	0.50
1	-135	Encr_All 1	39510.00	1473.99	1484.62	1481.59	1484.90	0.002304	8.49	12016.63	2082.59	0.46
1	-136	Encr_All 1	39510.00	1473.08	1483.64	1479.65	1483.85	0.001941	7.77	13657.69	2135.89	0.43
1	-137	Encr_All 1	39510.00	1471.00	1482.33	1480.75	1482.89	0.003438	10.57	11553.67	2133.13	0.57
1	-138	Encr_All 1	39510.00	1471.11	1481.35	1479.44	1481.84	0.002976	9.29	12288.92	2208.41	0.52
1	-139	Encr_All 1	39510.00	1466.88	1477.57	1476.12	1478.08	0.003342	9.68	12577.25	2797.71	0.55

HEC-RAS Plan: CE_Encr. M2 River: VirginRiver Reach: 1 Profile: Encr_All 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	-140	Encr_All 1	39510.00	1464.94	1475.42	1474.15	1475.90	0.002959	9.16	11381.26	2738.45	0.52
1	-141	Encr_All 1	39510.00	1464.33	1474.41	1472.33	1474.72	0.002389	8.16	11844.66	2559.62	0.47
1	-142	Encr_All 1	39510.00	1463.53	1473.43	1471.00	1473.74	0.001828	7.10	10207.97	2052.74	0.41
1	-143	Encr_All 1	39510.00	1462.74	1472.51	1470.39	1472.88	0.002103	7.56	9625.80	1993.33	0.44
1	-144	Encr_All 1	39510.00	1461.28	1471.74	1469.55	1472.10	0.002200	8.07	9611.43	1875.94	0.45
1	-145	Encr_All 1	39510.00	1460.72	1470.90	1469.08	1471.30	0.002500	8.38	9298.52	1815.59	0.48

500-Year Corrected Effective Hydraulic Model (Main Channel)


Corrected Effective Model Plan: Corrected Effective Model_500 YR 3/23/2006

Geom: Corrected Effective Model_500 YR

HEC-RAS Plan: CE_500 YR Profile: 500 YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	20	500 YR	68800.00	1622.20	1639.19	1637.54	1641.24	0.006441	19.11	8946.74	901.72	0.84
1	19	500 YR	68800.00	1622.19	1638.51	1636.17	1640.06	0.005578	17.62	10098.29	2078.01	0.78
1	18	500 YR	68800.00	1622.02	1637.64	1635.11	1638.86	0.003537	13.67	10271.41	2291.16	0.61
1	17	500 YR	68800.00	1621.51	1637.28	1633.20	1638.03	0.001583	9.16	10909.15	2552.19	0.41
1	16	500 YR	68800.00	1620.59	1635.98	1633.07	1637.03	0.003273	13.03	10749.66	2919.46	0.59
1	15	500 YR	68800.00	1620.06	1635.19	1632.67	1636.42	0.004294	14.63	11110.01	2523.39	0.67
1	14	500 YR	68800.00	1618.14	1632.20	1629.51	1633.06	0.005180	15.17	12989.23	2249.91	0.73
1	13	500 YR	68800.00	1617.61	1631.20	1629.36	1632.27	0.005299	14.40	12634.83	2401.83	0.72
1	12	500 YR	68800.00	1617.62	1630.32	1628.13	1631.05	0.004145	12.63	13402.83	2855.79	0.64
1	11	500 YR	68800.00	1616.39	1629.74	1627.20	1630.33	0.003221	11.14	14690.25	2934.49	0.56
1	10	500 YR	68800.00	1616.26	1628.70	1626.48	1629.30	0.004015	12.27	15534.20	3129.66	0.63
1	9	500 YR	68800.00	1616.08	1628.14	1625.39	1628.50	0.002737	10.10	17842.35	3409.63	0.52
1	8	500 YR	68800.00	1615.25	1627.11	1624.74	1627.60	0.003339	10.77	17427.94	3600.55	0.57
1	7	500 YR	68800.00	1614.20	1625.55	1622.55	1625.94	0.003611	10.70	16650.10	4039.79	0.58
1	6	500 YR	68800.00	1613.49	1624.00	1619.54	1624.21	0.002013	7.85	20441.72	2716.53	0.43
2	5	500 YR	36336.16	1611.55	1622.66	1619.47	1622.92	0.002894	9.86	12408.68	1911.62	0.52
2	4	500 YR	36336.16	1608.87	1621.07	1618.87	1621.59	0.003264	10.69	10982.09	1936.87	0.56
2	3	500 YR	36135.75	1606.54	1619.87	1616.49	1620.25	0.001946	9.05	12088.29	1868.18	0.44
2	2	500 YR	36135.75	1605.26	1618.91	1615.60	1619.30	0.002682	10.70	12195.90	1803.66	0.52
2	1	500 YR	36135.75	1604.27	1617.54	1613.39	1617.95	0.001888	8.89	10944.49	1278.71	0.44
2	-1	500 YR	36135.75	1602.39	1615.06	1611.52	1616.22	0.002806	10.47	7026.76	898.62	0.53
2	-2	500 YR	34854.46	1601.45	1611.58	1611.58	1614.69	0.010176	16.34	4101.13	980.07	0.95
2	-3	500 YR	35715.21	1599.83	1611.67	1609.68	1612.19	0.002486	9.04	9795.44	1652.43	0.48
2	-4	500 YR	34494.89	1599.71	1611.39	1608.98	1611.83	0.002031	8.16	9845.57	1635.95	0.44
2	-5	500 YR	34430.60	1599.49	1610.55	1608.47	1611.48	0.003882	10.94	7006.82	1262.29	0.60
2	-6	500 YR	34430.60	1598.04	1609.33	1607.30	1610.29	0.003963	10.99	6908.58	1048.71	0.60
2	-7	500 YR	34430.60	1596.93	1607.68	1605.06	1608.13	0.002877	9.40	8525.17	1487.23	0.52
2	-8	500 YR	35410.80	1594.09	1606.20	1603.75	1606.73	0.001898	7.89	9814.23	1638.32	0.42
2	-9	500 YR	40124.18	1592.94	1605.10	1602.72	1605.73	0.002646	9.69	10667.29	1623.62	0.50
2	-10	500 YR	39597.22	1592.42	1604.34	1602.16	1605.33	0.003253	10.26	8935.91	1452.86	0.55
2	-11	500 YR	37272.16	1592.67	1602.99	1601.22	1603.86	0.004571	11.51	9381.80	1559.73	0.65
2	-12	500 YR	34703.19	1591.48	1601.83	1600.00	1602.45	0.003466	10.23	10077.65	1794.51	0.57
2	-13	500 YR	34525.76	1590.35	1601.39	1598.47	1601.72	0.001602	6.26	11302.07	1869.86	0.34
2	-14	500 YR	34845.07	1589.67	1601.12	1596.78	1601.39	0.001071	5.06	10551.60	1551.63	0.28
2	-15	500 YR	34845.07	1587.83	1600.59	1595.59	1600.86	0.001005	5.20	11350.56	1404.96	0.27
2	-16	500 YR	35066.22	1587.36	1600.45	1596.07	1600.68	0.000988	5.80	12629.00	1670.59	0.29
2	-17	500 YR	43029.87	1587.70	1599.38	1596.47	1599.96	0.002963	10.24	11780.63	1588.51	0.53
2	-18	500 YR	45917.42	1586.05	1598.64	1594.94	1599.11	0.002944	10.51	11692.87	1406.49	0.54
2	-19	500 YR	49780.77	1584.40	1596.80	1594.15	1597.42	0.003909	12.05	10665.38	1491.48	0.62
2	-20	500 YR	47645.73	1583.90	1595.70	1592.94	1596.34	0.002474	9.43	10254.52	1558.60	0.49
2	-21	500 YR	48779.30	1582.22	1595.21	1590.87	1595.61	0.002010	9.03	12661.48	1564.94	0.45
2	-22	500 YR	52767.20	1581.71	1594.62	1589.44	1594.98	0.001614	7.94	14647.42	1708.96	0.40
2	-23	500 YR	58757.95	1581.23	1594.17	1588.57	1594.51	0.001811	8.61	15918.95	1685.45	0.42
2	-24	500 YR	62809.40	1580.40	1593.44	1590.34	1594.10	0.003114	11.29	13087.81	1703.08	0.56
2	-25	500 YR	67048.15	1579.95	1593.11	1589.88	1593.69	0.002382	9.88	13222.60	1675.14	0.49
3	-27	500 YR	68800.00	1579.04	1592.64	1588.84	1592.98	0.001576	8.11	18426.96	2872.15	0.40
3	-28	500 YR	68800.00	1578.22	1592.08	1586.91	1592.35	0.001336	7.69	20160.80	2362.41	0.37
3	-29	500 YR	68800.00	1577.31	1591.48	1586.92	1591.89	0.002620	10.58	18612.25	2180.04	0.51
3	-30	500 YR	68800.00	1577.26	1590.85	1585.00	1591.22	0.002738	10.74	18010.98	1798.62	0.52
3	-31	500 YR	68800.00	1577.37	1590.21	1584.97	1590.71	0.002744	10.46	15907.89	1922.85	0.52
3	-32	500 YR	68800.00	1577.05	1588.90	1585.40	1589.72	0.006208	14.92	13774.77	1722.57	0.78
3	-33	500 YR	68800.00	1575.78	1587.91	1581.47	1588.21	0.002383	9.43	18079.14	2010.82	0.48
3	-34	500 YR	68800.00	1574.65	1587.40	1580.83	1587.71	0.001517	7.74	18799.40	2114.12	0.39
3	-35	500 YR	68800.00	1573.54	1586.66	1580.34	1587.11	0.002193	9.45	16912.35	2311.74	0.47
3	-36	500 YR	68800.00	1572.63	1586.18	1580.13	1586.70	0.001985	9.10	17613.49	2100.84	0.45
3	-37	500 YR	68800.00	1571.27	1585.62	1579.17	1585.97	0.002136	9.78	20563.93	2299.77	0.47
3	-38	500 YR	68800.00	1570.10	1585.07	1578.03	1585.45	0.001940	9.53	19810.11	2602.50	0.45
3	-39	500 YR	68800.00	1570.36	1584.77	1577.08	1585.11	0.001710	8.80	20108.57	2427.76	0.42
3	-40	500 YR	68800.00	1570.61	1584.10	1577.05	1584.60	0.003300	11.75	17051.14	2259.61	0.58
3	-41	500 YR	68800.00	1570.02	1582.94	1577.13	1583.47	0.003475	11.80	16568.09	1953.17	0.59
3	-42	500 YR	68800.00	1569.81	1582.30	1575.55	1582.72	0.003405	11.62	17124.24	1986.52	0.58
3	-42.5		Inl Struct									
3	-44	500 YR	68800.00	1562.88	1578.91	1575.55	1579.79	0.003890	14.54	14492.52	1921.65	0.65
3	-45	500 YR	68800.00	1562.13	1578.93	1571.50	1579.37	0.002592	12.27	17419.69	1867.71	0.53
3	-46	500 YR	68800.00	1561.26	1577.44	1573.82	1578.27	0.004589	16.07	13107.37	1831.09	0.71
3	-47	500 YR	68800.00	1559.07	1575.69	1571.70	1576.67	0.003084	13.06	13591.97	1851.18	0.58
3	-48	500 YR	68800.00	1558.38	1574.67	1572.56	1575.84	0.003739	14.32	12967.42	1712.53	0.63
3	-49	500 YR	68800.00	1557.54	1573.79	1571.51	1574.88	0.004408	15.62	13304.19	1725.81	0.69
3	-50	500 YR	68800.00	1556.43	1573.61	1568.87	1574.04	0.001793	10.10	15726.94	1788.13	0.44
3	-51	500 YR	68800.00	1555.96	1572.76	1568.49	1573.37	0.002212	11.24	16043.10	1820.68	0.49
3	-52	500 YR	68800.00	1554.17	1572.15	1566.54	1572.46	0.001150	8.44	19400.66	2071.31	0.36
3	-53	500 YR	68800.00	1552.66	1571.69	1566.25	1572.06	0.001434	9.57	19617.08	1911.26	0.40
3	-54	500 YR	68800.00	1552.64	1571.63	1562.55	1571.89	0.000959	7.92	21482.40	1846.83	0.33
3	-56	500 YR	68800.00	1553.20	1571.50	1562.20	1571.78	0.001146	8.64	20909.43	1801.13	0.36
3	-57	500 YR	68800.00	1552.95	1571.10	1561.79	1571.48	0.001666	10.37	19227.94	1545.75	0.43
3	-58	500 YR	68800.00	1552.98	1570.70	1563.19	1571.23	0.002222	11.75	18485.75	1477.10	0.50

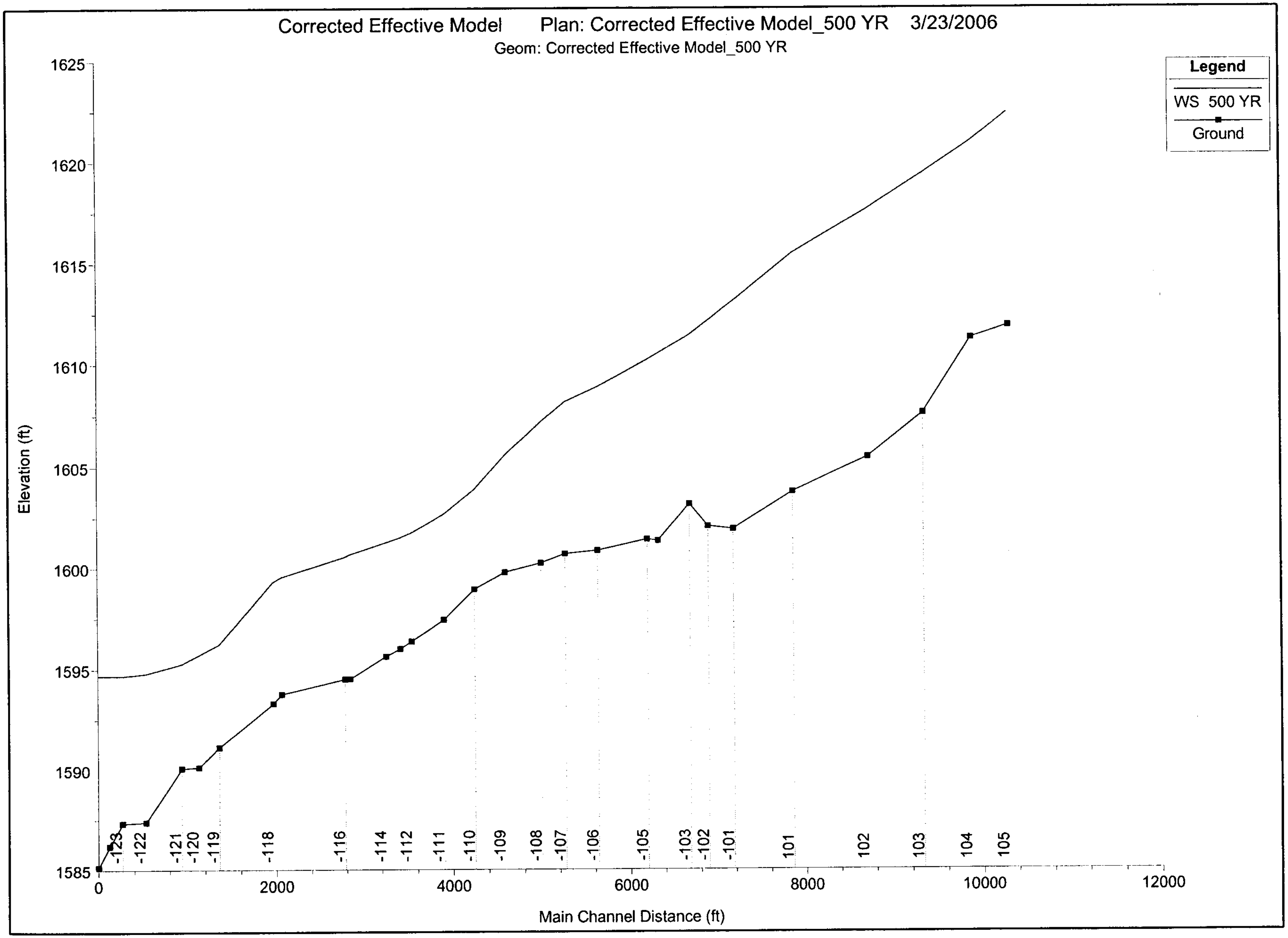
HEC-RAS Plan: CE_500 YR Profile: 500 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	-59	500 YR	68800.00	1552.64	1570.14	1564.22	1570.73	0.002403	12.14	17963.49	1456.44	0.52
3	-60	500 YR	68800.00	1551.18	1569.46	1562.29	1569.99	0.001602	10.18	18657.14	1428.88	0.42
3	-61	500 YR	68800.00	1549.30	1568.95	1562.04	1569.50	0.001309	9.56	17575.43	1446.60	0.39
3	-62	500 YR	68800.00	1549.34	1568.55	1561.75	1569.02	0.001572	10.44	17555.59	1907.93	0.42
3	-63	500 YR	68800.00	1547.67	1568.11	1560.87	1568.61	0.001744	11.50	17442.88	1900.71	0.45
3	-64	500 YR	68800.00	1547.12	1567.46	1562.18	1568.23	0.002204	12.85	17037.75	1861.25	0.51
3	-65	500 YR	68800.00	1546.85	1567.15	1560.80	1567.93	0.001934	12.04	15278.94	1826.64	0.47
3	-66	500 YR	68800.00	1545.43	1565.65	1561.80	1566.95	0.003500	16.11	12068.66	1762.10	0.64
3	-67	500 YR	68800.00	1544.17	1564.62	1558.95	1565.56	0.001812	11.61	12321.74	1891.32	0.46
3	-68	500 YR	68800.00	1542.78	1563.85	1554.84	1564.56	0.001485	10.72	13809.41	1741.28	0.42
3	-69	500 YR	68800.00	1542.41	1560.79	1558.72	1563.61	0.005260	18.42	9776.50	1447.09	0.77
3	-70	500 YR	68800.00	1541.70	1560.66	1556.29	1562.29	0.004462	16.95	11848.77	1510.14	0.70
3	-71	500 YR	68800.00	1542.03	1559.43	1556.38	1561.54	0.006102	19.02	9817.06	1157.85	0.81
3	-72	500 YR	68800.00	1541.45	1559.27	1554.40	1560.56	0.003382	14.19	12687.15	983.94	0.61
3	-72.5		Bridge									
3	-73	500 YR	68800.00	1540.69	1557.70	1554.40	1559.45	0.004619	16.41	11445.48	973.22	0.71
3	-74	500 YR	68800.00	1539.84	1556.68	1554.82	1558.77	0.005535	17.65	10091.33	1207.03	0.77
3	-75	500 YR	68800.00	1539.91	1555.90	1554.43	1557.68	0.005885	17.88	9659.80	1267.02	0.79
3	-76	500 YR	68800.00	1539.18	1553.93	1552.50	1555.72	0.006209	17.35	9183.34	1579.89	0.80
3	-77	500 YR	68800.00	1538.36	1552.54	1549.72	1553.84	0.004228	13.71	11016.61	1848.90	0.66
3	-78	500 YR	68800.00	1537.89	1551.80	1546.50	1552.93	0.003988	13.20	11233.63	1806.44	0.64
3	-79	500 YR	68800.00	1536.67	1550.52	1546.59	1551.22	0.003425	12.25	12277.13	1862.13	0.59
3	-80	500 YR	68800.00	1535.53	1549.28	1545.20	1550.03	0.004578	13.75	12903.90	2020.83	0.67
3	-81	500 YR	68800.00	1535.58	1548.14	1545.57	1549.00	0.005485	14.50	13201.06	2046.01	0.73
3	-82	500 YR	68800.00	1535.34	1547.38	1544.08	1548.01	0.003944	12.08	13530.31	3326.98	0.62
3	-83	500 YR	68800.00	1534.69	1546.45	1542.39	1546.92	0.003907	11.92	14748.80	3577.42	0.62
3	-84	500 YR	68800.00	1532.24	1545.00	1542.38	1545.72	0.003775	11.99	13699.48	3486.95	0.61
3	-85	500 YR	68800.00	1531.25	1544.48	1540.63	1544.92	0.002187	9.25	14705.09	3599.48	0.46
3	-86	500 YR	68800.00	1530.78	1544.17	1538.93	1544.59	0.002089	8.94	15297.49	3538.72	0.45
3	-87	500 YR	68800.00	1530.29	1543.46	1539.20	1543.83	0.001927	8.84	15764.42	3346.87	0.44
3	-88	500 YR	68800.00	1529.98	1543.22	1538.98	1543.57	0.001843	8.78	17111.30	3530.01	0.43
3	-89	500 YR	68800.00	1528.62	1541.97	1538.09	1542.37	0.003254	11.77	18020.88	3804.19	0.57
3	-90	500 YR	68800.00	1527.51	1540.29	1537.83	1540.98	0.004322	13.03	15399.78	3668.16	0.65
3	-91	500 YR	68800.00	1525.75	1538.71	1535.69	1539.20	0.003716	12.28	16002.58	3785.26	0.61
3	-92	500 YR	68800.00	1523.45	1536.96	1532.27	1537.34	0.002164	9.59	19152.86	4212.37	0.47
3	-93	500 YR	68800.00	1522.02	1536.57	1529.91	1536.77	0.000778	5.98	20471.98	4447.93	0.28
3	-94	500 YR	68800.00	1521.19	1536.28	1530.01	1536.53	0.001066	7.29	19436.77	4847.87	0.33
3	-95	500 YR	68800.00	1520.04	1535.84	1530.04	1536.15	0.001238	7.95	17551.38	5164.33	0.36
3	-96	500 YR	68800.00	1519.67	1534.45	1531.39	1535.16	0.003319	12.77	15199.75	4631.19	0.59
3	-97	500 YR	68800.00	1519.17	1533.46	1531.18	1534.20	0.006315	17.25	14804.68	4607.16	0.81
3	-98	500 YR	68800.00	1517.62	1531.77	1528.07	1532.33	0.003344	12.27	16462.78	4813.26	0.59
3	-99	500 YR	68800.00	1516.68	1530.81	1526.84	1531.21	0.001940	9.45	16353.84	5034.01	0.45
3	-100	500 YR	68800.00	1515.78	1529.92	1526.30	1530.37	0.002868	11.44	17042.64	4744.34	0.54
3	-101	500 YR	68800.00	1514.12	1527.19	1524.56	1528.04	0.005197	14.39	13873.57	4830.86	0.72
3	-102	500 YR	68800.00	1512.69	1525.83	1522.84	1526.37	0.003678	11.95	14808.11	5599.87	0.60
3	-103	500 YR	68800.00	1511.40	1523.36	1521.57	1524.03	0.004805	12.92	14205.95	5304.05	0.68
3	-104	500 YR	68800.00	1510.42	1522.66	1519.59	1522.90	0.001933	8.31	19480.70	5310.96	0.43
3	-105	500 YR	68800.00	1509.34	1521.63	1518.94	1521.99	0.002283	9.17	18018.63	4398.92	0.47
3	-106	500 YR	68800.00	1506.52	1520.25	1516.14	1520.70	0.001910	8.96	17833.51	3923.07	0.44
3	-107	500 YR	68800.00	1506.23	1519.66	1515.88	1520.15	0.002097	9.38	17051.91	3789.40	0.46
3	-108	500 YR	68800.00	1504.54	1518.55	1514.95	1519.00	0.002366	10.00	17232.50	3543.89	0.49
3	-109	500 YR	68800.00	1504.10	1517.71	1513.29	1518.10	0.001763	8.63	16970.41	3255.86	0.42
3	-110	500 YR	68800.00	1503.49	1516.85	1513.78	1517.24	0.002026	9.18	16267.27	3937.03	0.45
3	-111	500 YR	68800.00	1501.98	1515.50	1512.27	1515.84	0.001717	8.47	17627.45	4786.66	0.42
3	-112	500 YR	68800.00	1500.16	1513.39	1509.87	1513.81	0.002981	11.10	17757.08	4514.69	0.55
3	-113	500 YR	68800.00	1498.91	1511.45	1508.59	1512.07	0.003424	11.30	17972.92	2713.91	0.58
3	-114	500 YR	68800.00	1497.98	1510.05	1505.85	1510.35	0.002468	9.54	18745.37	3091.98	0.49
3	-115	500 YR	68800.00	1497.50	1507.40	1503.08	1507.63	0.002245	7.91	21403.89	3203.50	0.45
3	-116	500 YR	68800.00	1495.94	1507.12	1501.82	1507.30	0.001062	5.73	22221.22	3734.89	0.31
3	-117	500 YR	68800.00	1495.90	1506.62	1502.95	1506.94	0.002299	8.36	18626.51	3494.25	0.46
3	-118	500 YR	68800.00	1494.97	1506.22	1501.90	1506.50	0.001808	7.71	19032.21	3472.73	0.41
3	-119	500 YR	68800.00	1492.50	1505.61	1502.25	1506.03	0.001995	8.73	18668.66	3421.71	0.44
3	-120	500 YR	68800.00	1492.20	1505.25	1501.48	1505.65	0.002151	9.35	18397.92	3602.16	0.46
3	-121	500 YR	68800.00	1490.16	1503.34	1501.60	1504.17	0.003697	12.22	14747.32	4378.86	0.61
3	-122	500 YR	68800.00	1488.88	1502.41	1500.07	1502.95	0.003049	11.39	15374.01	4218.56	0.55
3	-123	500 YR	68800.00	1488.13	1500.76	1497.56	1501.18	0.002487	9.84	15166.43	4173.72	0.50
3	-124	500 YR	68800.00	1487.73	1500.08	1496.64	1500.50	0.002187	9.02	16605.36	4353.88	0.46
3	-125	500 YR	68800.00	1487.10	1499.33	1494.30	1499.62	0.001609	7.76	19292.43	4554.24	0.40
3	-126	500 YR	68800.00	1485.82	1497.69	1495.01	1498.41	0.004811	13.16	14761.13	4543.73	0.68
3	-127	500 YR	68800.00	1483.43	1495.96	1491.87	1496.39	0.002314	9.11	16419.50	4624.97	0.47
3	-128	500 YR	68800.00	1482.75	1494.52	1490.55	1494.94	0.002396	9.12	16216.74	4511.90	0.48
3	-129	500 YR	68800.00	1481.76	1493.73	1489.66	1494.10	0.001746	7.72	16935.31	4111.97	0.41
3	-130	500 YR	68800.00	1480.56	1492.59	1489.71	1492.99	0.002812	10.28	17918.73	4041.82	0.52
3	-131	500 YR	68800.00	1479.07	1491.35	1488.21	1491.76	0.002273	9.09	16122.24	3850.45	0.47
3	-132	500 YR	68800.00	1477.99	1489.54	1486.75	1490.16	0.003482	11.09	14400.05	3648.37	0.58
3	-133	500 YR	68800.00	1476.34	1488.74	1485.31	1489.10	0.002528	9.87	17395.56	3473.73	0.50

HEC-RAS Plan: CE_500 YR Profile: 500 YR (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	-134	500 YR	68800.00	1474.79	1487.02	1484.11	1487.38	0.002656	10.01	17765.94	3350.81	0.51
3	-135	500 YR	68800.00	1473.99	1485.88	1481.19	1486.18	0.002486	9.52	18879.78	3005.32	0.49
3	-136	500 YR	68800.00	1473.08	1484.75	1480.66	1484.98	0.002316	9.08	21792.30	2897.29	0.47
3	-137	500 YR	68800.00	1471.00	1483.51	1481.10	1483.98	0.003347	11.18	20041.57	2947.61	0.57
3	-138	500 YR	68800.00	1471.11	1482.52	1479.71	1482.93	0.002899	9.88	21494.70	3098.38	0.53
3	-139	500 YR	68800.00	1466.88	1478.60	1477.04	1479.14	0.003652	10.83	18231.48	3484.68	0.59
3	-140	500 YR	68800.00	1464.94	1476.33	1474.81	1476.83	0.003092	9.95	17184.83	3491.10	0.54
3	-141	500 YR	68800.00	1464.33	1475.28	1472.97	1475.61	0.002437	8.73	17973.24	3359.56	0.48
3	-142	500 YR	68800.00	1463.53	1474.35	1471.61	1474.67	0.001750	7.39	16759.65	2899.36	0.40
3	-143	500 YR	68800.00	1462.74	1473.59	1470.64	1473.90	0.001689	7.28	16715.55	2793.25	0.40
3	-144	500 YR	68800.00	1461.28	1472.95	1470.06	1473.31	0.001962	8.22	15524.03	2436.90	0.43
3	-145	500 YR	68800.00	1460.72	1472.10	1469.63	1472.57	0.002501	9.07	13946.72	2194.28	0.49

500-Year Corrected Effective Hydraulic Model (Avulsion)



Corrected Effective Model Plan: Corrected Effective Model_500 YR 3/23/2006

Geom: Corrected Effective Model_500 YR

HEC-RAS Plan: CE_500 YR River: Avulsion Reach: 1 Profile: 500 YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	105	500 YR	32463.84	1611.86	1622.39	1619.57	1622.92	0.001899	6.97	5961.23	910.84	0.41
1	104	500 YR	32463.84	1611.26	1620.97	1619.73	1621.88	0.003437	9.11	4932.75	975.17	0.55
1	103.5		Lat Struct									
1	103	500 YR	32664.25	1607.57	1619.39	1617.31	1620.21	0.003035	8.10	4906.74	896.58	0.51
1	102	500 YR	32664.25	1605.44	1617.63	1615.88	1618.52	0.002531	8.69	5152.61	1242.09	0.48
1	101	500 YR	32664.25	1603.73	1615.47	1614.60	1616.31	0.003044	9.53	5447.20	2009.42	0.53
1	-101	500 YR	32664.25	1601.89	1613.08	1612.47	1614.01	0.004231	10.16	5834.48	1806.10	0.61
1	-101.5		Lat Struct									
1	-102	500 YR	33945.54	1602.03	1612.10	1611.24	1612.81	0.004054	9.00	6555.26	1874.69	0.58
1	-102.5		Lat Struct									
1	-103	500 YR	33084.79	1603.13	1611.42	1610.37	1612.00	0.003541	7.74	6672.12	1886.63	0.53
1	-103.5		Lat Struct									
1	-104	500 YR	34305.11	1601.31	1610.51	1609.24	1610.99	0.002821	6.60	7025.42	2092.97	0.47
1	-104.5		Lat Struct									
1	-105	500 YR	34369.40	1601.38	1610.19	1608.92	1610.64	0.002655	6.41	7282.57	2203.96	0.46
1	-106	500 YR	34369.40	1600.83	1608.86	1607.17	1609.20	0.002279	6.60	7969.30	1937.96	0.43
1	-107	500 YR	34369.40	1600.66	1608.14	1606.29	1608.45	0.002238	6.15	7974.47	1828.42	0.42
1	-107.5		Lat Struct									
1	-108	500 YR	33389.20	1600.21	1607.17	1605.87	1607.62	0.004343	7.29	6304.03	1838.50	0.57
1	-108.5		Lat Struct									
1	-109	500 YR	28675.82	1599.75	1605.55	1604.54	1605.95	0.003775	6.65	6129.09	1999.05	0.52
1	-109.5		Lat Struct									
1	-110	500 YR	29202.78	1598.92	1603.85	1603.18	1604.41	0.006637	7.64	5170.64	2002.16	0.67
1	-110.5		Lat Struct									
1	-111	500 YR	31527.84	1597.42	1602.65	1601.27	1603.02	0.003562	5.78	6656.00	1923.08	0.50
1	-111.5		Lat Struct									
1	-112	500 YR	34096.81	1596.35	1601.72	1599.57	1602.01	0.002239	4.89	7962.84	1846.04	0.40
1	-112.5		Lat Struct									
1	-113	500 YR	34274.24	1595.98	1601.49	1599.11	1601.74	0.001862	4.55	8594.19	1878.00	0.37
1	-113.5		Lat Struct									
1	-114	500 YR	33954.93	1595.61	1601.24	1598.78	1601.46	0.001639	4.38	9358.01	2058.25	0.35
1	-115	500 YR	33954.93	1594.51	1600.65	1598.13	1600.84	0.001509	4.26	10234.67	2399.91	0.33
1	-115.5		Lat Struct									
1	-116	500 YR	33733.78	1594.49	1600.52	1598.11	1600.74	0.001685	4.50	9113.36	2215.83	0.35
1	-116.5		Lat Struct									
1	-117	500 YR	25770.13	1593.75	1599.54	1596.72	1599.71	0.001201	3.79	7964.48	2393.80	0.30
1	-117.5		Lat Struct									
1	-118	500 YR	22882.58	1593.29	1599.30	1596.88	1599.51	0.002691	5.50	7332.30	2364.84	0.44
1	-118.5		Lat Struct									
1	-119	500 YR	19019.23	1591.13	1596.22	1595.71	1596.86	0.009866	9.63	4102.06	2257.94	0.82
1	-119.5		Lat Struct									
1	-120	500 YR	21154.27	1590.13	1595.69	1594.07	1596.03	0.001620	3.89	5035.71	2230.03	0.33
1	-120.5		Lat Struct									
1	-121	500 YR	20020.70	1590.07	1595.26	1594.03	1595.65	0.002110	4.50	4811.90	1994.25	0.38
1	-121.5		Lat Struct									
1	-122	500 YR	16032.80	1587.38	1594.78	1591.74	1594.88	0.001294	3.52	6935.95	1887.18	0.30
1	-122.5		Lat Struct									
1	-123	500 YR	10042.05	1587.32	1594.67	1590.82	1594.70	0.000221	1.60	7675.96	2097.02	0.13
1	-123.5		Lat Struct									
1	-124	500 YR	5990.60	1586.19	1594.67	1589.84	1594.68	0.000070	1.05	8258.76	2226.02	0.07
1	-124.5		Lat Struct									
1	-125	500 YR	1751.85	1585.13	1594.67	1588.20	1594.67	0.000005	0.32	9232.66	2047.77	0.02

HEC-RAS Plan: CE_500 YR River: Avulsion Reach: 1 Profile: 500 YR

Reach	River Sta	Profile	Q US	Q Leaving Total	Q DS	Q Weir	Q Gates	Wr Top Wdth	Weir Max Depth	Weir Avg Depth	Min El Weir Flow	E.G. US.	W.S. US.	E.G. DS	W.S. DS
			(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
1	103.5	500 YR	32463.84	-200.25	32664.25	-200.25		85.48	1.72	0.86	1618.75	1621.88	1620.97	1620.21	1619.39
1	-101.5	500 YR	32664.25	-1283.57	33945.54	-1283.57		242.73	2.96	1.48	1610.36	1614.01	1613.08	1612.81	1612.10
1	-102.5	500 YR	33945.54	853.36	33084.79	853.36		165.01	1.74	1.73	1609.71	1612.81	1612.10	1612.00	1611.42
1	-103.5	500 YR	33084.79	-1220.21	34305.11	-1220.21		167.97	2.15	1.98	1609.38	1612.00	1611.42	1610.99	1610.51
1	-104.5	500 YR	34305.11	-64.27	34369.40	-64.27		30.89	1.59	0.79	1609.38	1610.99	1610.51	1610.64	1610.19
1	-107.5	500 YR	34369.40	980.21	33389.20	980.21		252.68	2.41	1.20	1604.76	1608.45	1608.14	1607.62	1607.17
1	-108.5	500 YR	33389.20	4713.32	28675.82	4713.32		414.46	2.94	2.67	1602.61	1607.62	1607.17	1605.95	1605.55
1	-109.5	500 YR	28675.82	-528.53	29202.78	-528.53		176.64	2.11	2.02	1602.61	1605.95	1605.55	1604.41	1603.85
1	-110.5	500 YR	29202.78	-2325.18	31527.84	-2325.18		382.87	2.58	1.73	1601.08	1604.41	1603.85	1603.02	1602.65
1	-111.5	500 YR	31527.84	-2568.68	34096.81	-2568.68		357.58	2.73	2.03	1599.68	1603.02	1602.65	1602.01	1601.72
1	-112.5	500 YR	34096.81	-175.16	34274.24	-175.16		130.04	2.23	2.08	1599.38	1602.01	1601.72	1601.74	1601.49
1	-113.5	500 YR	34274.24	319.36	33954.93	319.36		101.43	2.11	1.05	1599.38	1601.74	1601.49	1601.46	1601.24
1	-115.5	500 YR	33954.93	221.91	33733.78	221.91		55.62	3.34	1.67	1597.18	1600.84	1600.65	1600.74	1600.52
1	-116.5	500 YR	33733.78	7960.10	25770.13	7960.10		671.77	3.91	3.62	1595.63	1600.74	1600.52	1599.71	1599.54
1	-117.5	500 YR	25770.13	2887.09	22882.58	2887.09		146.48	4.18	4.05	1595.12	1599.71	1599.54	1599.51	1599.30
1	-118.5	500 YR	22882.58	3863.44	19019.23	3863.44		570.34	4.18	3.19	1594.01	1599.51	1599.30	1596.86	1596.22
1	-119.5	500 YR	19019.23	-2135.88	21154.27	-2135.88		224.18	2.63	2.44	1593.62	1596.86	1596.22	1596.03	1595.69
1	-120.5	500 YR	21154.27	1135.84	20020.70	1135.84		272.98	3.49	2.78	1591.77	1596.03	1595.69	1595.65	1595.26
1	-121.5	500 YR	20020.70	3974.70	16032.80	3974.70		407.39	3.49	3.15	1591.77	1595.65	1595.26	1594.88	1594.78
1	-122.5	500 YR	16032.80	5986.04	10042.05	5986.04		397.90	3.95	3.38	1590.72	1594.88	1594.78	1594.70	1594.67
1	-123.5	500 YR	10042.05	4050.90	5990.60	4050.90		167.43	4.94	4.45	1589.73	1594.70	1594.67	1594.68	1594.67
1	-124.5	500 YR	5990.60	4238.36	1751.85	4238.36		129.66	5.87	5.40	1588.80	1594.68	1594.67	1594.67	1594.67

Manning's n Calculations

PBS&J

COMP. BY: MLD
CHK.BY:
DATE: 1-25-06
SHEET NO.: ① OF 2
JOB NO.: 511792.00

ject: MANNING'S N CALCULATIONS
VIRGIN RIVER: REQUEST FOR LETTER OF MAP REVISION

WEIGHTED MANNING'S N

- MATURE VEGETATION ASSUMED FROM FALL 2004 AERIALS
- LOW FLOW CHANNEL LOCATION PER FALL 2005 AERIALS
- 100% VEGETATION COVERAGE ASSUMED TO HAVE A MANNING'S VALUE OF 0.12.
- 100% BARREN EARTH WITHIN THE FLOODPLAIN, ASSUMED TO HAVE A MANNING'S VALUE OF 0.04.

$$N_{WEIGHTED} = \frac{(\text{PERCENT OF VEGETATION COVERAGE})\,0.12 + (\text{PERCENT BARREN})\,0.04}{100}$$

1) MANNING'S N FOR LAND WITH APPROXIMATLY 15% VEGETATION COVER

$$N_{15} = \frac{(15\%)\,0.12 + (85\%)\,0.04}{100}$$

$$\boxed{= 0.05}$$

2) MANNING'S N FOR LAND WITH APPROXIMATLY 25% VEGETATION COVER

$$N_{25} = \frac{(25\%)\,0.12 + (75\%)\,0.04}{100}$$

$$\boxed{= 0.06}$$

3) MANNING'S N FOR LAND WITH APPROXIMATLY 50% VEGETATION COVER

$$N_{50} = \frac{(50\%)\,0.12 + (50\%)\,0.04}{100}$$

$$\boxed{= 0.08}$$

4) MANNING'S N FOR LAND WITH APPROXIMATLY 75% VEGETATION COVER

$$N_{75} = \frac{(75\%)\,0.12 + (25\%)\,0.04}{100}$$

$$\boxed{= 0.10}$$

COMP. BY: MLD
CHK.BY:
DATE: 1-25-06
SHEET NO.: ② OF 2
JOB NO.: 511792.00

ject: MANNING'S N CALCULATIONS
VIRGIN RIVER FHS

5) MANNING'S N FOR LAND WITH APPROXIMATLY 85% VEGETATION COVER

$$N_{85} = \frac{(85\%)0.12 + (15\%)0.04}{100}$$

$$\boxed{= 0.11}$$

6) MANNING'S N FOR LAND WITH APPROXIMATLY 90% VEGETATION COVER

$$N_{90} = \frac{(90\%)0.12 + (10\%)0.04}{100}$$

$$\boxed{= 0.11}$$

MANNING'S N FOR OTHER LAND COVER TYPES ARE:

- NEWLY GRADED N= 0.025
- LOW FLOW CHANNEL N= 0.04
- FARMS / GOLF COURSES N= 0.045
- RESIDENTAL AREAS N= 0.08 (ALL RESIDENTAL AREAS ARE CONSIDERED INEFFECTIVE. AS A RESULT THE MANNINGS VALUE ASSOCIATED WITH THESE AREAS HAS NO EFFECT ON THE FLOODPLAIN.)
- NATURAL DESERT LANDSCAPING N= 0.035

PBS&J

COMP. BY: MLD
CHK.BY:
DATE: 3/27/06
SHEET NO.: ① OF 1
JOB NO.: 511792.00

ject: MANNING'S N CALCULATION
VIRGIN RIVER: REQUEST FOR LETTER OF MAP REVISION

MANNING'S N BASED ON COWAN'S METHOD

COWAN'S METHOD EQUATION: $n = (n_0 + n_1 + n_2 + n_3 + n_4) M_5$

- n_0 = MANNING'S N FOR A STRAIGHT, UNIFORM, SMOOTH CHANNEL IN THE NATURAL MATERIALS

  = 0.020 (ASSUMING: EARTH)*

- n_1 = CORRECTION VALUE FOR EFFECTS OF SURFACE IRREGULARITIES

  = 0.005 (ASSUMING: MINOR)*

- n_2 = CORRECTION VALUE FOR VARIATIONS IN SHAPE AND SIZE OF THE CHANNEL CROSS-SECTIONS

  = 0.005 (ASSUMING: ALTERNATING OCCASIONALLY)*

- n_3 = CORRECTION VALUE FOR OBSTRUCTIONS

  = 0.000 (ASSUMING: NEGLIGIBLE)*

- n_4 = CORRECTION VALUE FOR VEGETATION AND FLOW CONDITIONS

  = 0.010 (ASSUMING: LOW)*

- M_5 = CORRECTION FACTOR FOR MEANDERING OF THE CHANNEL

  = 1.000 (ASSUMING: MINOR)*

⇓

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) M_5$$
$$= (0.020 + 0.005 + 0.005 + 0.000 + 0.010) 1.000$$
$$\boxed{= 0.040}$$

*BASED ON (CHOW, 1959).

MEETING MINUTES

Project	Virgin River FIS	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	July 28, 2005	**Date Prep.**	8/2/2005
Mtg. Time	1:30 pm		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Matt Baird	PBS&J
Brian Loffman	PBS&J
Harshal Desai	PBS&J
Jonathan Fuller (via telephone)	J.E. Fuller, Inc.

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Kevin Eubanks began the meeting by saying that he would like to get started on the Virgin River FIS. He handed out CDs (containing the following electronic data: old FIS data, Fall 2004 and Spring 2005 Aerials, and LIDAR scope location map), FIS work maps, a DVD with Virgin River Aerial Flood Footage (shot February, 2005) and copies of 1991 LOMRs. Matt Baird said that PBS&J already had copies of the LOMRs and asked Kevin whether he wanted PBS&J to copy rest of the data and return it to him. Kevin said he wanted to have the DVD and FIS work maps copied and returned.

Kevin said that based on his coordination with HDR, who is working on a Flood Zone Mapping project upstream of the Nevada state line, that the Virgin River Water District LIDAR (post-flooding) will be completed on 07/29/05. He also said that HDR had developed hydrology for the project using gage data and the Log Pearson Method. Kevin said that he had spoken with Lee Frederiksen from HDR regarding the flow and he was told that the flow is close to the current FEMA flow of 35,500 cfs. He said that HDR suggested that it would be beneficial if PBS&J's hydraulic model for the Virgin River used identical cross-section locations upstream of the Nevada state line. Jon Fuller said that should not be a problem for PBS&J, but could be a problem for HDR if PBS&J's hydraulic model shows a different Water Surface Elevation. Kevin asked Matt to co-ordinate with Lee Frederickson of HDR. Kevin said he has been trying to coordinate with SNWA in order to get the pre-flood LIDAR for the project, but has not received anything yet.

Kevin said that Bulloch Brothers Engineering (BBE) is working on a couple of projects along the Virgin River (within Mesquite city limits) and has received permits from the City of Mesquite to place fill to remove the respective sites from the floodplain. They have asked Kevin whether PBS&J can incorporate their proposed grading into the hydraulic model for the Virgin River LOMR. Matt said that PBS&J would need certified grading plans from BBE in order to incorporate the proposed grading into the hydraulic model.

Matt said that PBS&J would start the field work after they receive the LIDAR information. Jon also said that they would start the field investigation after they receive the LIDAR information. Jon said that preliminary velocity information would help him during field investigation. Kevin said that during one of the field visits he would like to setup a meeting with Allen Bell of the City of Mesquite. Jon said that he would like to get the as-built drawings for the bridge located in Mesquite. He added that if the bridge is new he would also like to get the record drawings for the old bridge for elevation comparisons.

Kevin said that he was told that HDR is planning to complete their hydraulic analysis and flood mapping within 6 to 8 weeks of receiving the LIDAR information. He added that HDR might be planning on using an automated mapping tool. Harshal Desai said that PBS&J was planning on using HEC-GeoRAS for the hydraulic analysis as it has the capability of automated floodplain mapping.

Brian Loffman asked Kevin whether PBS&J was supposed to review the existing FEMA hydrology. Kevin responded that PBS&J could use the new hydrology developed by HDR. He added that it was his understanding that the 100-Yr flow developed using the new hydrology is close to the old hydrology.

Kevin said that the next project meeting would be on August 25, 2005 at 1:30 PM and from then on the project meetings would be held on the last Thursday of every month.

* End of Meeting Minutes *

KICKOFF MEETING AGENDA
July 28, 2005
1:30 P.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

The Scope of Services to be provided will include historical document review and data collection, hydraulic/sediment analysis and mapping/document preparation for the purpose of revising the existing floodplain boundary along a portion of the Virgin River.

PROJECT LIMITS

The Project is an approximate seven mile reach of the Virgin River bounded by the Nevada/Arizona state line to just downstream of the town of Bunkerville. The study area includes both Clark County and City of Mesquite.

PROJECT OBJECTIVES

1) Historical research.
2) Field survey and mapping.
3) Hydrologic review (FIS Flow vs. recent flood gauge data)
4) Hydraulic/sediment modeling.
5) Floodplain delineation.
6) Document/Mapping/Forms preparation

CONSULTANT TEAM

PBS&J

Consultant Project Manager: Matt Baird, PE, CFM

SUBCONSULTANTS

1) Aerial Topo - AeroTech Mapping (if needed)
2) Sediment Transport/Geomorphology – JE Fuller, Inc.
3) Technical Advisor & QA/QC – UNR (Kyle House)

PROJECT CRITERIA

1) FEMA
2) CCRFCD - Uniform Regulations for the Control of Drainage

TOPOGRAPHY

Status of USBR digital ortho photography and topographic mapping for the study area. Consultant shall review topography and determine if supplemental field survey is required.

FIELD INVESTIGATION/SURVEY

Identification and inventory of existing hydraulic structures and natural features within the project reach.

- Documents, photos, plans etc to be reviewed prior to field work
- Field work schedule

PROJECT SCHEDULE

Notice-to-Proceed	July 18, 2005
Data Collection/Field Investigation	Sept 19, 2005
Submit Draft Document to Entities	January 31, 2006
Entity Review Completed	February 14, 2006
Address Entity Comments/Submit to FEMA	March 1, 2006
FEMA Approval	October 3, 2006

PROJECT MEETINGS

Consultant will coordinate and participate in regular progress meetings with the District and City of Mesquite Public Works Department at least monthly, and at milestones in the development of the study. Consultant will prepare and distribute minutes of all meetings.

Next Meeting: August 31, 2005

PROJECT COORDINATION

1) Consultant shall coordinate project issues with CCRFCD (Kevin Eubanks), CCPW/CCDDS and the City of Mesquite (Allen Bell).
2) Consultant shall also coordinate with FEMAs Technical Evaluation Contractor.

OTHER ISSUES

CCRFCD

CITY OF MESQUITE

TOPOGRAPHY

PBS&J

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Brian Loffman
Mtg. Date	August 25, 2005	**Date Prep.**	8/29/2005
Mtg. Time	11:00 pm		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Mike Wallen	SNWA
Michael Johnson	VVWD
Brian Loffman	PBS&J
Harshal Desai	PBS&J
Jonathan Fuller (via telephone)	J.E. Fuller, Inc.

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Michael Johnson stated that the post-flood LIDAR data may be ready as soon as next Tuesday. Kevin asked if FEMA requires field verification of the LIDAR data accuracy. Michael said that was a part of the Bureau of Reclamation's scope and a company called Horizon did the QA/QC of the data. Harshal asked if the data would include all the points in a text file format. Michael said the data we'll receive does and the file size is very large due to the 1' contour accuracy. Michael also noted that due to the amount of data the post processing time was very lengthy.

Kevin asked Jon if it was possible to use the pre and post flood LIDAR to cut cross-sections and compare volumes and other parameters. Jon said yes.

Brian asked Kevin if HDR had finalized their hydrology for the project upstream of Stateline. Kevin said he sent an email this past Monday requesting an update but they have not yet responded. Kevin said that HDR has indicated in a previous conversation that the new flow is close to the current effective flow. Kevin said that without the flow we cannot start any of the modeling. Brian said that at a minimum we are several weeks away from running a preliminary model and there is plenty of work in setting up the model, cutting cross-sections, field work, etc before we need the flow. Harshal added that we can run the model with the current FEMA flow and update the model with the new flow when it becomes available. Brian confirmed with Kevin there would be no revision to the hydrology provided by HDR, i.e. including any tributary area downstream of Stateline. Kevin noted the current effective FEMA flow is one flow rate from Stateline to Lake Mead and thus our analysis will use the HDR flow.

Brian discussed what PBS&J is currently working on while waiting for the LIDAR data. Brian said PBS&J is converting the 1996 BBE Flood Study HEC-2 data into HEC-RAS. Kevin said to check and verify which datum was used for the 1996 study and make the appropriate adjustments in our analysis. Kevin asked how the HEC-2 results compared to the newly created duplicate effective HEC-RAS model. Harshal said that with the exception of a couple of areas the HEC-RAS WSEL's are within 0.5 feet of the HEC-2 WSEL's. Harshal noted that the bridge locations produced WSEL differences of approximately 0.65'. Brian said that in general FEMA will accept this due to the well documented computational differences between HEC-2 and HEC-RAS for bridges. Brian said the old hard copy BBE cross-section work maps have been digitized and converted to TIF images that can be imported into ACAD/GIS and placed on current aerial photos. This would allow us to compare WSEL's to the 1996 study.

Mike Wallen gave PBS&J a CD containing the pre flood LIDAR data that included the grid and raw data points. Harshal asked Jon if he would like for us to process the data and send it to him. JF said yes.

Brian said that PBS&J will wait for a review of the pre and post-flood LIDAR data to schedule the field investigation.

The next project meeting is scheduled for September 29, 2005 at CCRFCD (11:00 a.m.)

* End of Meeting Minutes *

MEETING AGENDA
August 25, 2005
11:00 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items

- Project Status

  - *Pre-Flood LIDAR data*
    PBS&J contacted Mike Wallen to discuss the portion of the pre-flood LIDAR data needed for this project. Mike will bring data to this meeting.

  - *Post-Flood LIDAR Data*
    Waiting on Virgin Valley Water District

  - *Project Hydrology*
    Has HDR finalized flows for area upstream of Project reach?

II. In-Progress

- *HEC-2 Conversion*
  Currently converting 1996 BBE Flood Study HEC-2 data into HEC-RAS.

- *Digitizing BBE Cross-Section Work Maps*
  Created TIF images of BBE cross-section maps for overlay onto Project work maps for WSEL comparisons.

Field investigation will be scheduled upon receipt and review of pre & post-flood LIDAR data.

III. Next Meeting:

11:00 a.m. Thursday
September 29, 2005 at CCRFCD

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	September 29, 2005	**Date Prep.**	10/3/2005
Mtg. Time	9:15am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Matt Baird	PBS&J
Harshal Desai	PBS&J

Meeting Minutes Distribution List:

Name	Organization
Attendees	
Brian Loffman	PBS&J
Jon Fuller	J.E. Fuller
Mike Kellogg	J.E. Fuller
Kyle House	University of Nevada, Reno
Allen Bell	City of Mesquite
Dave Vincelette	City of Mesquite
Lee Frederiksen	HDR
Ron Simms	USBR
Raymond Lenaburg	FEMA
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Matt Baird began the meeting by stating that PBS&J has received the post-flood LIDAR data. He added that PBS&J has converted the data from UTM Zone 11, Metric units to State Plane coordinates, English units. He said some data was missing but PBS&J has received the missing data from Ron Simms. Matt said that PBS&J has developed preliminary cross-section location maps. A copy of the cross-section maps were provided to Kevin. Kevin Eubanks asked whether PBS&J has received the information on the flow rate. PBS&J has received the flow rate, which is approximately 39,000 cfs for the 100-year frequency flood event.

Andrew Trelease asked whether it is the same as the FEMA flow rate. Kevin replied that the flow rate is a little higher than the old flow rate of approximately 35,000 cfs. Kevin added that the new flow rate was developed by HDR who is working for FEMA Region 9 doing a study upstream in Arizona.

Kevin said that we should send the preliminary cross-section locations data to HDR and coordinate with them as to the locations of the cross-sections at the Arizona/Nevada state line. PBS&J will coordinate with HDR and send them a copy of the meeting minutes.

Andrew asked whether the post-flood LIDAR topographic data is public information. Kevin thought it would be since CCRFCD paid for it.

Matt said that PBS&J has the roughness coefficient maps done for the existing conditions. Harshal explained that two sets of roughness coefficient maps were developed. He explained that the first set of roughness coefficient maps shows the post-flood Manning's n on post-flood aerials whereas the second set of roughness maps shows the post-flood Manning's n on the pre-flood aerials. Harshal added that this was done to illustrate the difference in the land cover between post and pre flood conditions. Matt said that PBS&J plans to develop the hydraulic models using both pre and post flood Manning's n to see what the difference is between the WSE due to post-flood and pre-flood land cover. He added that he is not sure whether FEMA will accept the hydraulic analysis with Pre-flood Manning's n as they do not represent the existing conditions. However this would be a more conservative approach and is worth considering because a higher vegetation density will probably exist when the next major flood event occurs. Kevin said we will have to check and see if there is a government agency which has a plan for management of the vegetation within the project limits and is responsible for keeping the vegetation in a certain manner. Tim Sutko added that the government agency also should have funding for the vegetation management. Tim also added that FEMA might have a problem accepting the analysis but we are proposing is a more conservative approach. Kevin concurred and added that FEMA is agreeable to a conservative approach but not an over conservative approach as that can raise the flood-insurance premiums. Matt added that when the WSE from both pre and post flood condition models is compared we can discuss which approach should be taken. Harshal added that both models will use the post-flood flow paths. He said the flow paths changed considerably during the flood.

Kevin pointed out a levee on the map upstream of the school and asked if it was added after the flood. Harshal said he believed the levee was added after the flooding. Tim said that he thought the levee is temporary in nature and City of Mesquite is planning on removing it. Matt said that during a major flood the levee would probably be washed away and should be ignored in the analysis. He said if we ignore the levee we will have to determine how to deal with the fact that it is shown on the topography. Kevin said we will have to document that the levee was not constructed per the standard specifications and will break during a major flood and therefore it was ignored in the hydraulic analysis. He added that we could document the removal with photos if necessary. Tim added that PBS&J should contact Dave Vincelette with City of Mesquite and confirm that they are planning on removing the levee.

Matt said that the Riverside Bridge on the Virgin River is an NDOT bridge and PBS&J will contact NDOT and get the plans for it. Matt said that PBS&J has scheduled their initial field visit on 10/06/05 and 10/07/05. J.E.Fuller will be conducting their field investigation at the end of October. He added that PBS&J might join J.E.Fuller if it is needed. Matt said he will be contacting Kyle House to see if he wants to join J.E.Fuller for the field investigation. Matt said that PBS&J will also obtain available drainage studies along the river from City of Mesquite.

Tim said that the footings of the Riverside bridge are skewed and not parallel to the direction of flow and that may have caused some flooding problems downstream at the Coyote Springs Golf Course. PBS&J will check the bridge during the field visit.

Matt said PBS&J is going to begin the hydraulic analysis and should have a preliminary analysis concluded before the next meeting.

Kevin asked if the 2 foot contours can be easily distributed if somebody needs them. Harshal said that PBS&J has generated 2 foot contours and the GIS surface (TIN) for the project area and can be distributed either on a CD or a DVD. Kevin asked Harshal whether the 2 foot contours shown on the exhibits are the same as those received from Virgin Valley Water District. Harshal said that new 2 foot contours were generated using the TIN developed from the re-projected LIDAR filtered DEM xyz data.

Matt said we will need some certification for the topographic information. Kevin said that the certification is going to come from BOR. Matt added that he will certify that topographic information for unit conversions and re-projection.

Kevin asked whether PBS&J has any 3-D imaginary for the LIDAR data. Harshal replied that PBS&J can generate 3-D images from the TIN but we will have to check with GIS personnel regarding how much time it take.

Tim asked whether we will have to contact the BLM regarding their vegetation management plan along the Virgin River. Kevin said he will be contacting the BLM to check whether they have a funded vegetation management plan.

Kevin asked whether PBS&J can send the preliminary cross-section location maps to Allen Bell. Matt said yes.

* End of Meeting Minutes *

MEETING AGENDA
September 29, 2005
9:00 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items

- Project Status

  - *Post-Flood LIDAR Data*
    PBS&J has re-projected/converted the LIDAR data into State-Plane, English Units.

  - *Preliminary Cross-Section Location*
    Preliminary Cross-Section Location has been finalized.

  - *Post-Flood Roughness Coefficient*

II. In-Progress

- *Plans for Riverside Bridge at Virgin River*
  PBS&J has requested plans from NDOT.

- *Field Investigation*
  PBS&J has scheduled the field work on October 6th and 7th. JE Fuller will be conducting their field work in the end of October.

- *Hydraulic Analysis and Floodplain Delineation*
  PBS&J will complete preliminary hydraulic model and associated floodplain delineation before next meeting.

III. Next Meeting:

11:00 a.m. Thursday
October 27, 2005 at CCRFCD

PBSJ

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	October 27, 2005	**Date Prep.**	11/1/2005
Mtg. Time	11:00am		

Attendees:

Name	**Organization**
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Allen Bell	City of Mesquite
Catherine Lorbeer	City of Mesquite
Matt Baird	PBS&J
Harshal Desai	PBS&J
Michele D'Alessandro	PBS&J
Mike Kellogg (Via Telephone)	J.E. Fuller

Meeting Minutes Distribution List:

Name	**Organization**
Attendees	
Brian Loffman	PBS&J
Jon Fuller	J.E. Fuller
Kyle House	University of Nevada, Reno
Dave Vincelette	City of Mesquite
Lee Frederiksen	HDR
Ron Simms	USBR
Raymond Lenaburg	FEMA
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Matt Baird began the meeting by stating that PBS&J has completed majority of the data collection effort and has completed their field investigation on the 6th and 7th of October, 2005. He added that Dave Vincelette gave PBS&J a tour of flood affected areas along the Virgin River. He said after the completion of field investigation PBS&J worked towards the completion of draft hydraulic model and associated floodplain delineation.

Harshal Desai showed an exhibit illustrating the draft floodplain delineation. He explained that the hydraulic model used for the development of the floodplain used post-flood LiDAR data. He further explained that it was assumed that the roughness coefficients used in the model were based on post-flood vegetation as shown on the Spring-2005 Aerials. He added that the modeling approach assumed that the temporary dikes which were built after the flood will be washed out during a 100-year flood event and therefore were not modeled. He added that the Bunkerville Irrigation Diversion Structure and the associated dike was modeled in HEC-RAS as an inline weir structure. Based on the field investigation and other information collected it seems that the structure is not temporary. Allen Bell asked whether PBS&J has considered a modeling scenario with vegetation growing back in a short period of time. Kevin Eubanks responded that our mapping assumption should assume mature growth for the vegetation. Harshal showed an exhibit which compared the aerials from Fall 2004 and Spring 2005 illustrating the difference in post-flood and pre-flood vegetation. He said that this could affect the water surface elevation and limits of floodplain. He pointed out that PBS&J's draft floodplain delineation does not show the same extent of flooding as compared to 2005 high water line shown on an exhibit developed by City of Mesquite (near the state line where the homes were flooded) because PBS&J's model is using roughness coefficients based on post-flood vegetation and not the mature (fully-grown) vegetation conditions. Allen added that one of the reasons that the water backed up on the streets (in the vicinity of Ronnie Way) is because of the difference in hydraulic gradient between the main channel and right overbank. Matt and Harshal concurred. Harshal explained that to model the differential water surface between the main channel and the right overbank, the model needs to be extended upstream to determine the flow split between the main channel and the right overbank. Matt said that PBS&J will be using a 1-D model to model a 2-D analysis and it is very difficult to do that.

Allen asked how far upstream PBS&J's hydraulic model extends. Harshal responded that the hydraulic model ends approximately 0.8 miles upstream of the state line. Kevin said we should extend the hydraulic model further upstream and try to model the flow split and differential water surface using HEC-RAS before considering the 2-D modeling approach. Harshal asked whether we want to wait for HDR to complete the upstream model. Kevin said no. Matt concurred and asked whether we will map that area. Kevin said that we will be mapping the area within our jurisdiction and that would be downstream of the state line.

Matt said there are two major parameters which need to be projected to determine the future floodplain limits. First parameter is the vegetation, which is relatively easy to deal with by increasing the roughness coefficients based on the comparison between post-flood and pre-flood aerials. Second parameter is that the main channel has degraded and has much more conveyance capacity now than it had before the flood event. Allen said there are areas within the floodplain which have experienced aggradation too. Matt concurred and also said that in the main corridor of conveyance there has been a lot of degradation and thereby flood carrying capacity of the main channel has increased after the flood event. He said we will have to predict how the river and the associated floodplain are going to behave over time with the help of J.E.Fuller's geomorphologic analysis.

Allen said the Quail Creek Dam Break in 1988 resulted in similar flooding extents. He said it might be beneficial to compare the aerial photos after and prior to the dam break (if available) to evaluate the behavior of the river over time. Kevin said based on his conversation with Jon Fuller, he understands that it is possible that the behavior of the Virgin River with respect to the recent flood could be a result of the Quail Creek flood. Mike Kellogg said that based on their analysis at Santa Clara River in Utah, it was determined that a huge amount of bank erosion had occurred and it is possible that transported sediments may have changed the behavior of the Virgin River downstream of its confluence with Santa Clara River. He added that one of the things that J.E. Fuller will be analyzing is how far the sediments were transported and whether the sediments were concentrated enough to cause an avulsion in the river downstream.

Matt said that it is very difficult to predict how the river is going to respond to sedimentation/scouring and therefore the results of a hydraulic model developed using the pre-flood LiDAR data could give us a range in terms of floodplain limits. Matt added that one of the reasons to run the model with the pre-flood LiDAR data is that the results of the post-flood hydraulic model are not close to what happened during the 2005 flood in terms of WSE and floodplain limits. It is possible that the peak flood flow in the river didn't cause the majority of erosion and removal of vegetation and the erosion may have been a result of the receding end of the hydrograph or the subsequent floods. Allen concurred and said that they didn't observe the huge amount of erosion during the peak flow and the majority of the erosion occurred during the receding limb of the hydrograph and the subsequent floods.

Kevin mentioned that the 500-year flow rate is available for the study reach and a 500-year floodplain can be delineated by running the hydraulic model using the 500-year flow. He added that the people within the 500-year floodplain but outside the 100-year floodplain do not have to pay flood insurance.

Kevin said that he understands that it is not under PBS&J's current scope to develop a pre-flood hydraulic model, 500-year flood hydraulic model or extend the model further upstream. He asked Matt to send him the information regarding the additional effort required to complete above mentioned tasks. He mentioned that we will decide whether it is necessary to develop a pre-flood hydraulic model after J.E. Fuller has completed their geomorphologic analysis. He also asked PBS&J to develop a map which shows both the effective FEMA flood zone and the floodplain delineated by PBS&J as a part of this study. He also said the post-flood hydraulic model should assume the roughness coefficient based on the mature growth of the vegetation.

Matt asked Kevin how to account for ongoing / future earth moving activities along the river especially at the Coyote Willow Golf Course and at the school. Kevin responded that he mentioned during Virgin River Flood Control and Restoration Measures Project Meeting (dated 10/20/05) that we will be mapping the floodplain and submitting the LOMR to FEMA based on existing conditions (post-flood LiDAR) and we will make the hydraulic models available to them so that they can incorporate the proposed changes into the model showing that they are not adversely impacting the floodplain. Kevin said that if certified As-Builts are made available to us before we submit the LOMR to FEMA, we may incorporate the changes into the hydraulic models. Matt asked if the work in these areas is under way but not complete at the time the FEMA submittal is made how with certification be made that the FEMA submittal represents existing conditions. Kevin said that we would just pre-date the LOMR and certify that as of a certain data the LOMR represented existing conditions.

Kevin asked Mike whether they have received both post-flood and pre-flood LiDAR data and whether there is an automated way to compute the difference in volumes between the post-flood and pre-flood LiDAR data. Mike responded that he will be using GIS to compare the post-flood and pre-flood LiDAR data and to estimate rough volumes to illustrate the areas of aggradation and degradation.

The next project meeting was scheduled on November 17, 2005 at 10:30 PM along with the Mesquite MPU meeting.

* End of Meeting Minutes *

MEETING AGENDA
October 27, 2005
11:00 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items

- *Plans for Riverside Bridge at Virgin River*
  PBS&J has acquired plans from NDOT.

- *Field Investigation*
  PBS&J did the field work on October 6th and 7th. JE Fuller will be conducting their field work at the end of October.

- *Preliminary 100 – year floodplain delineation*
  PBS&J has completed delineating preliminary 100-year floodplain.

- *Hydraulic Assumptions:*
  Topographic Information used: Post-Flood LiDAR data.
  Roughness Coefficient based on Post-Flood Aerials.
  Temporary Dikes were removed from the model.
  Bunkerville Irrigation Diversion Structure and associated weir was modeled.

II. Decisions to be made

- *Which model to be submitted to FEMA?*
  - Hydraulic Analysis using Pre-Flood LiDAR data and pre-flood vegetation.
  - Hydraulic Analysis using Post-Flood LiDAR data and pre-flood vegetation in the floodplain.

- *How to account for ongoing / future earth moving activities and vegetation management plan in the river?*

- *Status of upstream hydraulic model?*

- *500- Year Floodplain Delineation*

III. Next Meeting:

11:00 a.m. Thursday November 17, 2005 at CCRFCD

PBSJ

MEETING MINUTES

Project Virgin River Flood Hazard Map Revision **Project No.** 511792.00

Location CCRFCD Conference Room **Prepared By** Harshal Desai

Mtg. Date November 17, 2005 **Date Prep.** 11/21/05

Mtg. Time 11:30am

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Allen Bell	City of Mesquite
Catherine Lorbeer	City of Mesquite
Dave Vincelette	City of Mesquite
Ghaith Hamade	PBS&J
Harshal Desai	PBS&J
Mike Kellogg (Via Telephone)	J.E. Fuller

Meeting Minutes Distribution List:

Name	Organization
Attendees	
Matt Baird	PBS&J
Brian Loffman	PBS&J
Michele D'Alessandro	PBS&J
Jon Fuller	J.E. Fuller
Kyle House	University of Nevada, Reno
Lee Frederiksen	HDR
Ron Simms	USBR
Raymond Lenaburg	FEMA
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Harshal Desai began the meeting by stating that J.E.Fuller has completed their field investigation on October 30th, 2005 through November 2nd 2005. He requested Mike Kellogg to go over the email, drafted by Jon Fuller, summarizing the findings of their field investigation. The email is included as an attachment to these meeting minutes. Mike said during their filed investigation they were able to walk through the entire reach of the river within the project limits. He said that they concur with Matt Baird's and Allen Bell's interpretation that the extensive erosion was a late stage phenomena as a result of a two peak hydrograph. He said this is consistent with their findings at Santa Clara River at St. George, Utah.

Mike said that the removal of Tamarisk by BLM was not the primary reason for the avulsion that occurred out of the main channel through the right overbank that caused the flooding of the homes. He added that the debris blockage in the main channel upstream played a critical role in forcing more water through the right overbank and thereby causing an avulsion. Kevin asked Mike whether there are any typical measures to prevent debris blockage. Mike replied that the debris blockage was a result of vegetation (that got integrated with the flood waters) getting trapped within the narrow main channel. He said that pre-flood aerial shows that the main channel was very narrow as compared to the entire width of the floodplain. He said one of the things that can be done to prevent the debris blockage is to establish a low-flow corridor coupled with a vegetation management plan through the main channel and the banks, such that the height of the vegetation is less than the width of the low-flow corridor. So in a flood event any vegetation that gets uprooted and gets integrated with the flood waters can be transported downstream without getting trapped in the main channel. He said this is consistent with what they have proposed in the Master Plan for Santa Clara River at St. George, Utah. Kevin asked Mike whether we should include vegetation management plan for a certain corridor in the river in the Master Plan recommendations. Mike concurred. Allen pointed out that the vegetation management plan is critical upstream of the state line where CCRFCD or City of Mesquite does not have jurisdiction or ability to manage the vegetation.

Kevin asked whether debris blockage at the river crossings should be considered for floodplain mapping. Allen said they didn't loose any bridge as a result of flooding, however some of the bridges were damaged. Mike said during their field investigation, they didn't see any evidence of debris blockage at the Bunkerville Bridge that spans the river at Riverside Road.

Allen made an observation that upstream of the location where the primary avulsion occurred the floodplain is narrow and confined and the floodplain transforms into a wide floodplain just downstream of the avulsion. Harshal concurred with Allen's observation and added that PBS&J's hydraulic model represents the transformation in the floodplain. Mike said they have been looking at the historical topographic data in that area to check whether any long-term aggradation trend exists. Mike said their initial results/findings indicate that the floodplain in that area has not experienced aggradation of a scale that can cause the flooding that occurred at the housing communities. Kevin asked Mike whether J.E. Fuller will able to present these results with the help of maps. Mike said yes.

Allen concluded that the primary reason for the flooding related to the housing was the avulsion out of the main channel which was caused by debris blockage coupled by silt deposition in main channel. Harshal added that since the right overbank elevation is higher than the main channel, the WSE in the right overbank was higher than the WSE in the main channel that resulted in the flooding of the houses. Allen concurred.

Harshal said that in the last meeting it was decided that the hydraulic model needs to be extended upstream to model the avulsion and the associated flow split. He added that another thing that was decided in the last meeting was to use roughness coefficient based on mature growth for the vegetation. Harshal explained PBS&J modified the hydraulic model to incorporate the roughness coefficient based on mature growth for the vegetation. He added that roughness coefficients used in the model were now based on pre-flood vegetation as shown on the Fall-2004 Aerials. He said a lower roughness coefficient was used for the main channel which is much wider than the pre-flood main channel.

He further explained that PBS&J extended their hydraulic model approximately 2.4 miles upstream of the state line. He said that the model starts approximately 1,000 feet downstream of the Scenic Bridge. He said this was done because the floodplain is confined at that location and is outside the influence of the bridge. He explained that PBS&J modeled the avulsion by modeling the main channel and the right overbank as two distinct reaches. The flow was distributed between the two channels using HEC-RAS energy balance optimization. He explained that a series of lateral structures were added in-between the two reaches to allow the water to go back and forth. He said that the results of the modeling shows that about 16,000 cfs will split into the right overbank which will be reduced to about 1000 cfs before it makes a 90 degree turn into the main channel. He explained that this is because the WSE in the right overbank for the most part will be higher than the WSE in the main channel, a lot of flow will tend to flow back into the main channel once it overtops the high point between the two modeled reaches. He said that the results also show that the WSE in the right overbank in the vicinity of housing communities that got flooded was about 3 to 4 feet higher than the WSE in the main channel. He showed an exhibit illustrating the draft floodplain delineation which showed the extents of flooding using the above-mentioned modeling methodology. This floodplain is wider than the previously delineated floodplain by PBS&J. Kevin said that the floodplain delineation approximately follows the limits of the damage that occurred during the flooding. Allen concurred and said that the model depict closely the flooding that occurred.

Harshal pointed out that the draft floodplain delineation closely follows the FEMA effective flood zone except at the left overbank downstream of Coyote Willows Golf Course; where the FEMA effective flood zone is much wider than PBS&J's draft floodplain delineation. Kevin asked Harshal to develop a profile comparing the WSEs between the PBS&J's model and the effective model. He said that if the differences in the WSEs are not significant, we will able to tie into the effective model further upstream, leaving the downstream floodplain a little wider.

Harshal said PBS&J has used a lower roughness coefficient for the area where the Tamarisk was removed. He asked Kevin whether a higher roughness coefficient should be used for that area. Kevin replied that a higher roughness coefficient should be used for that area as that would be a more conservative approach.

Harshal mentioned that Mike found discrepancies between the pre-flood LIDAR data and post-flood LIDAR data ranging from about 2 feet to 13 feet. Mike determined that the pre-flood LIDAR data is shifted and J.E. Fuller has shifted the pre-flood data to more closely match the post-flood data. He said that the shift is not survey grade accurate however is adequate enough for their analysis. Kevin asked whether we have an aerial photo associated with pre-flood LiDAR data. Harshal said that he would check that and let them know.

Harshal said PBS&J will develop a 500-year hydraulic model after the completion of the final 100-year hydraulic model. Kevin concurred. Harshal asked whether PBS&J needs to develop a pre-flood hydraulic model or 2-d model. Kevin said that PBS&J's draft floodplain imitates the flooding that occurred and therefore a pre-flood hydraulic model and a 2-d model is not required.

Harshal asked about the status of the upstream hydraulic model. Kevin said that he would let HDR know that we have completed our preliminary modeling of the avulsion and let them know about the limits of the model.

Harshal asked Kevin whether PBS&J can continue finalizing the above-mentioned hydraulic model. Kevin said yes. The next project meeting was scheduled on December 22, 2005 at 10:30 PM along with the Mesquite MPU meeting.

* End of Meeting Minutes *

MEETING AGENDA
November 17, 2005
10:30 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items

- *Field Investigation*
  J.E. Fuller did their field work on October 31st and November 1st

- *Preliminary 100 – year Hydraulic Model with Upstream Flow Split*
  PBS&J has extended the hydraulic model upstream and modeled the upstream split

- *Hydraulic Assumptions:*
  - Topographic Information used: Post-Flood LiDAR data.
  - Roughness Coefficient based on mature growth (Pre-Flood Vegetation based on Fall 04 Aerials) outside the main channel.
  - Temporary Dikes were removed from the model.
  - Bunkerville Irrigation Diversion Structure and associated weir was modeled.
  - Model needs to be refined in terms of Ineffective Flow Boundaries and Roughness Coefficient

- *Pre-Flood LiDAR Data Rectification*

- *500-year hydraulic model will be developed after the completion of final 100-year hydraulic model*

II. Decisions to be made

- *Pre-flood hydraulic model?*
- *2-D hydraulic model?*
- *Status of upstream hydraulic model?*

III. Next Meeting:

11:00 a.m. Thursday December 29, 2005 at CCRFCD

From: Mike Kellogg [mailto:mike@jefuller.com]
Sent: Friday, November 11, 2005 8:44 AM
To: Baird, Matt; 'Kevin Eubanks'; 'David Vincelette'
Cc: 'Jonathan Fuller'
Subject: RE: Virgin River Field Trip Summary

Project team,
With regard to item 6 below - after a more scrupulous investigation, I've determined that it is the pre-flood LIDAR data that is shifted. I've also determined that the rectification inconsistency between the pre-and post-flood LIDAR is a simple horizontal shift, and not a warp. The distance in the horizontal shift between the two data sets is somewhere between 51 and 52 feet. I've figured out a way to shift the pre-flood data to more closely match that of the post-flood. Although this shift is not "survey grade accurate", I believe it will be adequate enough for our analysis. I don't want to hold up the project progress by waiting for the LIDAR data to be corrected, so we're moving forward using the data that I've shifted.

If you have any concerns with this approach please let me know.

Mike

--
Mike Kellogg, GIT CFM, MS
JE Fuller/Hydrology & Geomorphology Inc
8400 S. Kyrene Rd Suite 201
Tempe, AZ 85284
(480) 222-5706 (voice)
(480) 839-2193 (fax)
www.jefuller.com

From: Jonathan Fuller [mailto:jon@jefuller.com]
Sent: Tuesday, November 08, 2005 10:16 AM
To: 'Baird, Matt'
Cc: 'Kevin Eubanks'; 'Mike Kellogg'
Subject: Virgin River Field Trip Summary

Matt:

Mike & I completed our field work last week, and I thought you might be interested in a brief summary of what we found, particularly in light of some of the questions raised at the last team meeting.

1. We concur with your interpretation (p. 2, 3rd paragraph of meeting notes) that overall conveyance may have increased due to low flow channel incision & widening, despite significant deposition on the distal portions of the floodplain. The low flow channel is clearly wider. Decreased roughness due to loss of vegetation also increased the conveyance.
2. We did not see compelling evidence of a long-term aggradational trend (future or past) in the river. Classic aggradational features are lacking, e.g., channel elevation equal to or higher than floodplain, excessively braided low flow channel, convex cross section, long-term record of deposition. We have not yet done the longitudinal profile, but our suspicion is that profile changes may play a key role in river pattern and flood response.
3. We concur with your interpretation and Allen's observations that extensive erosion was generally a late stage phenomenon (p. 3, 2nd paragraph of notes). That would be consistent with the experience in St. George as well.
4. A pre-flood hydraulic model would be very helpful (p. 3, 4th paragraph of notes).
    a. My guess is that the pre-flood topo will not generate the observed flood stages, but that possibility needs to be eliminated before undertaking the more costly step of generating a 2-d model.

    b. Based on our field observations, I believe the high 2005 flood stages were the result of flow perched in the right overbank floodplain, i.e., the water surface is not horizontal across the floodplain, as is assumed in a 1-d model like HEC-RAS.
    c. I believe that the only way to hindcast the high 2005 flood stages along the right side of the floodplain is to simulate a debris blockage near the upstream avulsion point, force water into the overbank, modeling it with a 2-d model.
    d. There might be a way to produce a quasi-2d model using HEC-RAS to model the right overbank avulsion, but it would be very complicated and tenuous.
    e. Regardless, we need to brainstorm ideas for protecting & designing development near the floodplain, and for setting finished floor elevations near the river. The past approach didn't work.
5. Tamarix removal probably was NOT a significant cause of channel avulsions.
    a. Avulsions occur on the Virgin River with or without tamarix.
    b. Avulsions occurred in Tamarix forested areas downstream of Mesquite.
    c. The nastiest avulsion, the one that impacted homes in Mesquite, seemed to follow areas cleared for agriculture (meadows), rather than tamarix clearing areas.
    d. Debris blockage probably played a role in causing avulsions, and some/much of the debris was tamarix. Tamarix removal would be an improvement if it was replaced with native species.
6. Mike has spent a considerable amount of time trying to rectify the pre- and post-flood LIDAR data, and has concluded that there is a rectification problem with the post-flood LIDAR.
    a. David Vincelette said the City reached a similar conclusion.
    b. Given the extent of the post-flood grading in the channel and floodplain, the LIDAR data will be the only way to quantify the magnitude of floodplain sedimentation and channel change. Therefore, resolving the apparent rectification error is important.
    c. We suggest that we arrange a conference call with whomever produced the LIDAR and see if we're misusing or misinterpreting the data, or whether there really is a rectification problem.

Unfortunately, I've been subpoenaed to testify at a legal proceeding on the 17th, so I can't make the next revised meeting date, but Mike will call in. The schedule is clear for December though, and we should be far enough along to justify a trip to attend in person.

Jon Fuller, PE, RG, PH, MS, CFM
JE Fuller/Hydrology & Geomorphology, Inc.
8400 S. Kyrene Rd, Suite 201
Tempe, AZ 85284

480-222-5710 (voice)
480-839-2193 (fax)
602-451-1992 (cell)

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	December 22, 2005	**Date Prep.**	12/27/05
Mtg. Time	11:00am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Catherine Lorbeer	City of Mesquite
Jon Fuller	J.E. Fuller
Amy LaVoie	U.S. Fish & Wildlife Service
Matt Baird	PBS&J
Harshal Desai	PBS&J

Meeting Minutes Distribution List:

Name	Organization
Attendees	
Michele D'Alessandro	PBS&J
Andrew Trelease	CCRFCD
Allen Bell	City of Mesquite
Dave Vincelette	City of Mesquite
Mike Kellogg	J.E. Fuller
Kyle House	University of Nevada, Reno
Lee Frederiksen	HDR
Ron Simms	USBR
Raymond Lenaburg	FEMA
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Harshal Desai began the meeting by showing the preliminary 100-year floodplain delineation for the study reach. He said that PBS&J has completed developing the 100-year hydraulic model apart from a few minor refinements which may be necessary to finalize the model. He showed a chart illustrating the difference in base flood elevation (BFE) between the duplicate effective model and PBS&J's 100 year hydraulic model.

The chart is included as an attachment with these meeting minutes. After reviewing the chart it was decided to map BFEs for the entire study reach as the new BFEs are substantially different from the BFEs developed by the duplicate effective hydraulic model. He asked Kevin whether we will be mapping differential water surface elevation through the avulsion. Kevin said yes.

Matt Baird asked Kevin Eubanks whether the upstream limit of mapping should be at the Arizona state line or should be upstream of the avulsion (flow split) which is approximately 1.5 miles upstream of the Arizona state line. Kevin replied that we will have to coordinate this with HDR (who is working for FEMA region IX) as they are working on the hydraulic model upstream. He said that our mapping efforts should terminate at their downstream study limit. He will be contacting HDR and will schedule a meeting with them during the 2nd week of January. He asked Harshal to send PBS&J's hydraulic model and the associated data to HDR.

Harshal mentioned that PBS&J will be commencing floodplain encroachment modeling (floodway) and modeling the floodway through the avulsion will be a complicated process. Matt said the first approach PBS&J would take is to encroach through entire avulsion reach (eliminate flow in the avulsion and put all flow in the main channel) and check whether the increase in BFE through the main channel is less than a foot. If the first approach does not work, PBS&J will start encroaching into the right overbank of the avulsion channel to come up with a floodway such that the increase in BFE is always less than a foot. It should be noted that starting the floodway analysis downstream of the flow split will be very complicated and therefore it make sense to start the floodway analysis upstream of the flow split. Kevin said that we will discuss this issue with HDR.

Harshal said that PBS&J is missing sheets 1 and 2 of the works maps for the FEMA effective hydraulic model from the Mesquite City Flood Study, dated February 5, 1996, prepared by Bulloch Brothers Engineering Inc. Kevin said that he got the work maps from Michael Baker and they have sent everything they had. He said unless the missing work maps are critical, there is no need for PBS&J to acquire them.

Harshal said that PBS&J has started the 500-year hydraulic model. He said the model is not converging yet as it needs to be refined in terms of side weir flow optimization and ineffective flow areas. He showed exhibits illustrating the difference between the 500-year floodplain and 100-year floodplain.

Jon Fuller started the discussion on preliminary geomorphologic investigation results. He said that J.E.Fuller tried to quantify and predict the nature of sedimentation and erosion that occurred through the study reach during the January 2005 flood event. He showed an exhibit illustrating the elevation changes between the Pre and Post LiDAR data to quantify the aggradation and degradation that has occurred in floodplain after the January 2005 flood event. He pointed out that most of the scour (degradation) occurred through the channel where as most of the aggradation has occurred through the floodplain. He added that this behavior is a normal characteristic of the river. He said that based on the results they don't predict any excessive long-term aggradation trends through the study reach. He pointed out the avulsion in the right overbank near the state line and added that they believe that one of the primary reasons for the avulsion was debris blockage. He also talked about the avulsions that occurred by the water tank on the Levitt Farm in the left overbank. He further explained that flood water ponded on the farm and then found a way to the main channel and scouring occurred in the overbank due to formation of a headcut which migrated upstream. The exhibit showed the bank scour that occurred near the school and Abbott wash. The exhibit showed 12-14 feet of aggradation in the densely vegetated Tamarisk area between the main channel and the avulsion channel. He explained that the above quantity of aggradation is exaggerated which is attributed to the inability of the LIDAR to pick up the ground elevation through this densely vegetated area.

Jon also showed exhibits illustrating elevation changes between 1978 USGS data and Pre and Post Flood

LiDAR data respectively. He explained that the 1978 topographic data was not as accurate as the corresponding LiDAR data and therefore the results generated were not as accurate. However, there were no signs of excessive long-term aggradation and the majority of the degradation occurred through the channel and most of the aggradation occurred in the floodplain. The exhibit showed aggradation upstream of the Bunkerville diversion structure, which was expected.

Jon showed an exhibit displaying depth times velocity (DV) along the entire floodplain through the study reach which was developed using PBS&J's HEC-RAS results. He said that the areas where the computed DV was higher than 8 are susceptible to further erosion.

He showed lateral bank erosion plots which were developed using historical and recent aerial photos. The results showed that the magnitude of lateral erosion was limited to 500 feet in most areas and to a maximum of 1000 feet. Similar plots were developed for the main channel width using historical and recent aerial pictures. He explained that the overall width of the channel decreases over time and then widens after a major flood event.

He concluded by saying that the river wants to follow the geological floodplain (valley bottom). He said they will be providing a report explaining all the results along with the exhibits and providing certain recommendations summarizing a conceptual plan to mitigate sedimentation and lateral erosion hazards.

Matt told Kevin that PBS&J is planning on submitting the LOMR to CCRFCD for review by the 31st of January. Kevin said that coordination with HDR is necessary and could cause some delay in the submission of the LOMR. PBS&J will not begin the floodway encroachment analysis till the upstream limit has been determined through coordination with HDR.

The next project meeting was scheduled on January 26, 2006 at 11:00 AM after the Mesquite MPU meeting.

* End of Meeting Minutes *

MEETING AGENDA
Thursday, December 22, 2005
10:30 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River Clark County and City of Mesquite, Nevada

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I. Discussion Items

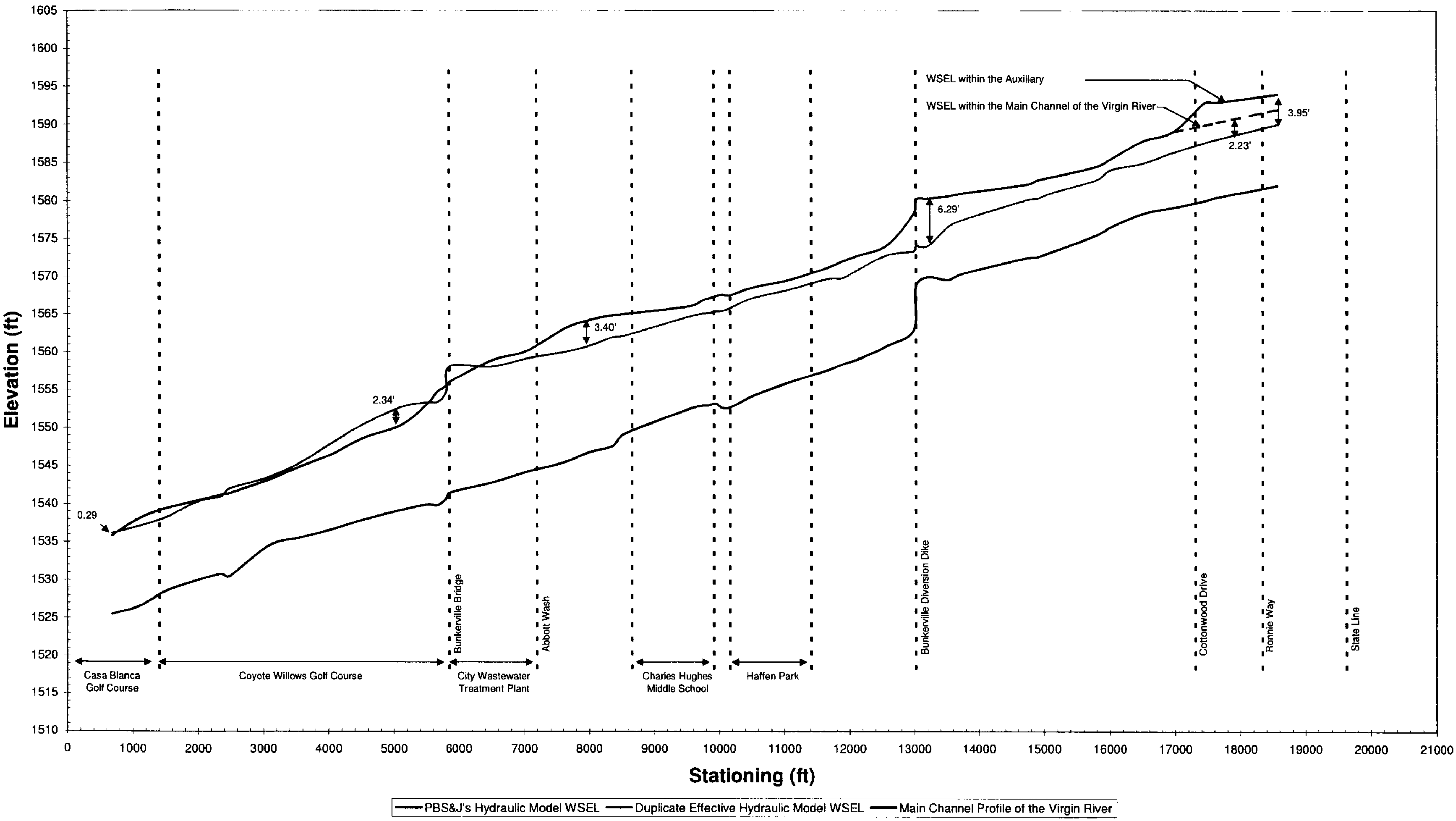
1. *Preliminary 100 – year Hydraulic Model*
    - PBS&J has completed 100 - year hydraulic model.
2. *Mapping Floodplain using differential WSE*
3. *Where should the new hydraulic model tie into the effective model?*
4. *Comparison between the new hydraulic model and the effective model*
    - PBS&J is missing sheets 1 and 2 of the effective work maps.
5. *Floodplain Encroachment in Split flow model*
6. *500 – year hydraulic model*
    - PBS&J has started 500 - year hydraulic model. The model needs to be refined and optimized.
7. *Geomorphologic Analysis Review*
8. *LOMR Submittal Date: 01/31/2006*

II. Next Meeting:

11:00 a.m. Thursday January 26, 2006 at CCRFCD

PBSJ

WSEL Comparison Between the PBS&J's Hydraulic Model and the Duplicate Effective Hydraulic Model



MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	January 9, 2006	**Date Prep.**	1/16/2006
Mtg. Time	8:30am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Matt Baird	PBS&J
Harshal Desai	PBS&J
Raymond Lenaburg (Via Telephone)	FEMA
Lee Frederiksen (Via Telephone)	HDR
Joanna Leu (Via Telephone)	HDR
David Chen (Via Telephone)	HDR

Meeting Minutes Distribution List:

Name	Organization
Attendees	
Allen Bell	City of Mesquite
Dave Vincelette	City of Mesquite
Catherine Lorbeer	City of Mesquite
Ron Simms	USBR
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Jon Fuller	J.E. Fuller
Mike Kellogg	J.E. Fuller
Kyle House	University of Nevada, Reno
Amy LaVoie	U.S. Fish & Wildlife Service
Phil Wisely	Mohave County
Michele D'Alessandro	PBS&J

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Kevin Eubanks began the meeting by explaining that PBS&J has completed 100-year floodplain modeling and the upstream limit of the model is approximately 1000 feet downstream of the scenic bridge in Arizona. He further explained that the hydraulic model was extended upstream to accurately model the avulsion (split) that occurs approximately 1.5 miles upstream of the Arizona/ Nevada state line. He mentioned that PBS&J will be commencing floodplain encroachment modeling (floodway). He asked whether FEMA Region IX /HDR have any concerns if the floodplain/floodway model is extended upstream in Arizona. Lee Frederiksen said that HDR has not started modeling yet and therefore they have no concerns if the PBS&J's model extends upstream in Arizona. Kevin said we will be completing the hydraulic model for the entire reach, but the floodplain mapping will commence from Arizona / Nevada state line. HDR will review the PBS&J developed hydraulic models as they will be using the model to map the flood zones in Arizona. Ray Lenaburg said that the mapping in Arizona needs to be coordinated with Phil Wisely of Mojave County. Kevin said that he will contact him and asked Harshal to send the meeting minutes to him.

Lee asked whether PBS&J can send HDR the background data for roughness coefficients (n value) used in the hydraulic modeling. Harshal said he will be sending him the shape files for the n value used in the hydraulic model. Kevin explained that the roughness coefficient is based on mature growth for the vegetation. He added that roughness coefficients used in the model were based on pre-flood vegetation as shown on the Fall-2004 Aerials. He said a lower roughness coefficient was used for the main channel which is much wider than the pre-flood main channel.

Lee asked Ray whether this approach for selecting n value was acceptable to him. Ray said it is acceptable to use the n value based on mature growth as the vegetation will grow back. He said that a higher value should be used within the channel also as the vegetation will grow back and the channel will not stay as wide as it is now.

PBS&J will be updating the roughness coefficients associated with the hydraulic models to incorporate Ray Lenaburg's comment. PBS&J will send the updated hydraulic models (along with the shape files for updated n value) to HDR for their review.

The next coordination meeting with FEMA Region IX /HDR is scheduled on January 26, 2006 at 12:00 PM Pacific Time (1:00 PM Mountain Time)

* End of Meeting Minutes *

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Michele D'Alessandro
Mtg. Date	January 26, 2006	**Date Prep.**	1/31/2006
Mtg. Time	10:30am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Dave Vincelette	City of Mesquite
Michael Johnson	Virgin Valley Water District
Harshal Desai	PBS&J
Michele D'Alessandro	PBS&J
Mike Kellogg (via Telephone)	J.E. Fuller

Meeting Minutes Distribution List:

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Matt Baird	PBS&J
Ron Simms	USBR
Michael Wallen	SNWA
Frank Shin	CCPW
Jon Fuller	J.E. Fuller
Raymond Lenaburg	FEMA
Lee Frederiksen	HDR
Joanna Leu	HDR
David Chen	HDR
Kyle House	University of Nevada, Reno
Amy LaVoie	U.S. Fish & Wildlife Service
Phil Wisely	Mohave County

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Kevin Eubanks began the meeting by explaining that in determining the Manning's n for the hydraulic models, PBS&J originally used the post-flood LiDAR data to assign a lower Manning's n for the main channel which is much wider than the pre-flood main channel. A Manning's n value of 0.40 was applied to the low flow channel. He continued by saying that during the January 9th meeting with FEMA Region IX and HDR, Raymond Lenaburg (FEMA Region IX), made a comment that the low flow channel will eventually become narrower and the surrounding barren areas will begin to revegatate. As a result, it was determined to use a more conservative approach and run the model assuming fully mature growth with a narrower channel.

Harshal Desai continued by saying that the low flow channel has been updated based on the fall 2005 aerials. The width of the low flow channel is close to that of the low flow channel shown on the fall 2004 (pre-flood) aerials. He said the location of the new low flow channel banks is consistent with the spring 2005 LiDAR data topography. He continued by saying the post-flood Manning's n was then updated based on the new, narrower low flow channel. The mature growth Manning's n outside the new low flow channel was determined using the fall 2004 (pre-flood) aerials.

Mike Johnson asked Harshal if PBS&J had the USGS Report by Marsha Hilmes, since the report could help in determining the thalweg based on past historical data. Kevin responded by saying the report would probably be more useful to the geomorphic analysis, which Mike Kellogg (J.E. Fuller) is currently working on. Mike Kellogg replied by saying that they have already delineated thalwegs for 15 different sets of aerials. He continued by saying the aerials used in determining the approximate location of the historical thalwegs for the active channel corridor were obtained from the records at the USGS office in Henderson, Nevada.

Kevin said that he agrees with the approach that PBS&J used in determining the mature growth Manning's n for the hydraulic models. He noted that in the report, the methods used in determining the Manning's n must be clearly defined. Harshal concurred.

Kevin then handed the discussion over to Harshal, so he can discuss the effects of the new Manning's n on the 100 year and 500 year floodplains. Harshal began by saying the models for the 100 and 500 year floodplains have been completed, however the floodway encroachment analysis has not been started, since PBS&J wished to confirm the new Manning's n approach first. He continued by saying the updated models produced a few areas of much higher WSEL as compared to the original hydraulic model; for instance the farms just northeast of Bunkerville which were not flooded in the original model are now inundated. Kevin asked if these farms were inundated when the flood occurred. Mike Johnson responded by saying no. Kevin stated that the calculated base flood used for the mapping purposes is about 39,500 cfs; which is about 3,000 cfs more then what actually occurred the day of the flood. He also added that the inundation within the farms would not be active flow and would be shallow, so it would not be an encumbrance for future development to place fill in order to be removed from the flood zone. He continued by saying since the flooding in the farms is shallow, it should have little to no effect on the floodway, as a result he does not have a problem with adding them to the flood zone. (After the meeting PBS&J checked the depth of flooding in the farms and found that the depth of flooding actually ranges from 0.5 feet to 8.5 feet approximately.)

Kevin said he agreed with PBS&J's 100 year and 500 year hydraulic models, and to proceed with the floodway encroachment analysis. Harshal asked Kevin if PBS&J can meet with CCRFCD before the next meeting to discuss the preliminary results of the floodway encroachment analysis. Kevin said yes.

Mike Kellogg said that J.E. Fuller's geomorphic analysis has determined that the higher than average annual flows are what has caused the Virgin River to historically migrate. Mike Johnson asked Mike Kellogg if he had a copy of the USGS report for the Upper Virgin Basin, since it could help with the concept of duration verses peak, and what the driving force is behind the river. Mike Kellogg responded that he did not have a copy. Dave Vincellette replied that he had a copy and will scan it and send it to him. Kevin asked if J.E. Fuller will have a draft of their report by the end of February. Mike Kellogg answered by saying they are almost done with the write-up and will have a draft ready soon.

Dave said that Entrix Consultants are currently working on three NCRS projects in the Virgin River under the EWS Program. The first project is the armoring of the river bank just east of the Coyote Willows Golf Course. The second project is to armor the bank along the sewer line, directly south of the Charles Hughes Middle School. The third project is brand new and consists of the redesign of the Abbott Wash Outfall. Dave continued by saying some re-contouring of the Virgin River from the Coyote Willows Golf Course up to the Bunkerville Diversion Structure is also currently being planned. Entrix has begun a preliminary analysis of the re-contouring based on the LiDAR data, and he handed out copies of the current plans to both CCRFCD and PBS&J. He also asked if it would be okay to setup a meeting with PBS&J on February 10th or 13th to discuss the possibility of working with PBS&J for a few days in order to rerun PBS&J's hydraulic model with the proposed re-contouring data and a 10 year flow. Kevin replied by saying that since PBS&J already has the 10 year flow, it should not be hard to incorporate the new geometry and flow into the existing model. Kevin agreed and said that any work involving the incorporating the re-contouring data and the 10 year flow into the model would be out of scope. He asked Dave to coordinate the additional work required with Matt Baird (PBS&J Project Manager). Tim Sutko asked Harshal to inform Ghaith Hamade (PBS&J) about the projects Entrix is currently working on and to share the re-contouring plans with him.

Mike Johnson asked how PBS&J modeled the Bunkerville Diversion Structure and how does it affect the model. Dave also commented that the Bunkerville Diversion Structure has been rebuilt since the Spring 2005 LiDAR data. Harshal replied by saying the diversion structure was modeled as an inline weir and, as a result, it acts like a dam with a drop structure. Mike Johnson replied that it did act like a dam during the flood event, until it blew out the south bank. He also added that the pulse of water caused by the breach of the structure is what caused the soil around the sewer line to be washed away. Harshal commented that PBS&J originally modeled it two different ways: as an inline weir and as if it was completely washed out. The two models produced very similar floodplain widths; however the model run with the diversion structure as an inline weir showed much higher WSELs. As a result, the diversion structure was chosen to be modeled as an inline weir, since it produced more conservative results. Harshal asked if the geometry for the diversion structure needed to be updated since it was recently rebuilt. Tim added that the diversion structure is not a sanctioned dam. Kevin stated that he does not believe the diversion structure in the model needs to be revised.

Kevin concluded the meeting by saying that he looks forward to the draft from J.E. Fuller and the next meeting is scheduled for February 23rd. .

Kevin said that Joanna Leu (HDR) has not received the Manning's n shape files. Harshal responded by saying that he talked to Joanna on Tuesday (January 24th) and informed her that he will send her the shape files after this meeting, pending no required revisions to the Manning's n.

Kevin said when we have a final draft of the flood zone (floodplain and floodway), we will have public meetings. He said it would be prudent to get the public opinion on the flood zone delineation. Mike Johnson asked if the public meetings could be held both in Mesquite and Bunkerville. Kevin noted.

Kevin said that the decision regarding the public meetings needs to be added to next meeting's agenda. He also noted that the decision needs to be coordinated with Sue Baker, the City of Mesquite, and Bunkerville.

* End of Meeting Minutes *

MEETING AGENDA
Thursday, January 26, 2006
11:00 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items:

1. *Roughness Coefficients Updated Based on Raymond Lenaburg's (FEMA Region IX) Comments.*

2. *PBS&J has updated 100-year and 500-year model per the new roughness coefficient.*

3. *PBS&J to start floodplain encroachment analysis if the changes to roughness coefficient are acceptable.*

II. Next Meeting:

To be decided

PBS&J

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Michele D'Alessandro
Mtg. Date	January 26, 2006	**Date Prep.**	1/31/2006
Mtg. Time	12:00 pm		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Dave Vincelette	City of Mesquite
Harshal Desai	PBS&J
Michele D'Alessandro	PBS&J
Lee Frederiksen (Via Telephone)	HDR
Joanna Leu (Via Telephone)	HDR
David Chen (Via Telephone)	HDR

Meeting Minutes Distribution List:

Name	Organization
Attendees	
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Matt Baird	PBS&J
Ron Simms	USBR
Michael Wallen	SNWA
Michael Johnson	Virgin Valley Water District
Frank Shin	CCPW
Tim Sutko	CCRFCD
Andrew Trelease	CCRFCD
Jon Fuller	J.E. Fuller
Mike Kellogg	J.E. Fuller
Raymond Lenaburg	FEMA
Kyle House	University of Nevada, Reno
Amy LaVoie	U.S. Fish & Wildlife Service
Phil Wisely	Mohave County

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Kevin Eubanks began the meeting by explaining PBS&J has finished updating the Manning's n to reflect the comments brought up by Raymond Lenaburg (FEMA Region IX) at the January 9th meeting and are ready to be sent to Joanna Leu. He continued by saying the mature growth Manning's n was determined based on fall 2004 aerials and the new, narrower post-flood low flow channel was determined using the fall 2005 aerials. He added that the new Manning's n produced higher WSELs and a wider floodplain in a few locations. He asked Harshal Desai to send Joanna the shape files for the new Manning's n.

Lee Frederiksen said that HDR has a draft hydrology report ready.

Harshal said PBS&J will also send HDR the latest hydraulic model with the new floodplain delineation. He asked if HDR needed the backup calculations for the Manning's n values. Lee said yes and mentioned that HDR is mainly using the USGS Method to determine their Manning's n values. Harshal responded by saying, PBS&J has not used USGS Method and the Manning's n is based on the vegetation cover shown on the 2004 fall (pre-flood) aerials.

Kevin said the next coordination meeting with FEMA Region IX and HDR is scheduled on February 23rd at 12:00 pm.

* End of Meeting Minutes *

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Michele D'Alessandro
Mtg. Date	February 23, 2006	**Date Prep.**	2/23/2006
Mtg. Time	11:00am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Allen Bell	City of Mesquite
Dave Vincelette	City of Mesquite
Woody Trihey	Entrix
Matt Baird	PBS&J
Harshal Desai	PBS&J
Michele D'Alessandro	PBS&J
Jon Fuller (via Telephone)	J.E. Fuller

Meeting Minutes Distribution List:

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Raymond Lenaburg	FEMA
Lee Frederiksen	HDR
Joanna Leu	HDR
David Chen	HDR
Michael Johnson	Virgin Valley Water District
Kyle House	University of Nevada, Reno
Amy LaVoie	U.S. Fish & Wildlife Service
Phil Wisely	Mohave County

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Harshal Desai began the meeting by saying PBS&J has delineated preliminary floodways using two methodologies for the study reach. He showed a figure which illustrated the preliminary 100-year floodplain overlaid with the two preliminary floodway delineations, and the existing FEMA floodplain and floodway. He continued by saying in order to perform the encroachment analysis, PBS&J had to remove the flow split from the completed 100-year hydraulic model for the reach upstream of the Nevada state line. As a result PBS&J combined the auxiliary channel cross-sections with their equivalent cross-sections on the main channel of the Virgin River. He further said that the difference between the two floodway delineations (using the two methodologies) is confined within the area of the flow split and the two floodway delineations are the same for the rest of the study reach. The first methodology is based on a maximum rise of one foot in the water surface elevation (WSEL) when compared to the 100-year WSEL through the main channel. The second methodology is based on a maximum rise of one foot in the water surface elevation (WSEL) when compared to the 100-year WSEL in the auxiliary channel. The WSEL in the main channel is lower than the corresponding WSEL in the auxiliary channel for the majority of the reach so the resulting floodway (using first methodology) is wider than the floodway delineated using the second methodology.

Kevin Eubanks asked whether PBS&J tried delineating the floodway by completely eliminating the auxiliary channel and conveying the entire flow through the main channel. Harshal replied that if the auxiliary channel is completely removed and all the flow is conveyed through the main channel, the WSEL in the main channel would rise about 2 to 4 feet. Matt Baird said that the 100-year floodplain model (unencroached model) is actually two separate hydraulic models in the area of the flow split/auxiliary channel in order to model the differential water surface between the auxiliary channel and the main channel. For the encroachment analysis these two models were combined because the auxiliary channel could not be completely removed and still meet FEMA criteria for floodplain encroachment. In the area of the flow split/auxiliary channel the floodway delineation would depend on which WSEL FEMA accepts as the base flood elevation (BFE). He further explained that if FEMA accepts the WSELs through the main channel as the BFEs then floodway using the first methodology is accurate. However, if FEMA accepts the WSELs through the auxiliary channel as the BFEs then the floodway using the second methodology is accurate. He asked Kevin which of the two WSELs should be used in delineating the floodway. Kevin replied we will be submitting differential BFEs through the flow split and therefore floodway delineated using the first methodology should be used as it is wider than the floodway delineated using the second methodology.

Matt asked if PBS&J should stop their mapping efforts at the Nevada/Arizona border. Kevin said yes. However, the hydraulic model will be reviewed by HDR before submitting to FEMA. He continued by saying it will be HDR's responsibility to coordinate with Mohave County.

Allen Bell asked what was the basis for selecting the roughness coefficient (Manning's n) in the hydraulic models developed by PBS&J. Harshal replied that a lower Manning's n was applied to the low flow channel determined using the post-flood LiDAR data and post-flood aerials. The Manning's n used for the areas outside the low flow channel is based on the mature vegetation growth per the pre-flood aerials. The width of the low flow channel also assumes that mature vegetation encroaches into the wide post-flood channel and narrows the width to pre-flood conditions.

Matt said that PBS&J's hydraulic model does not assume any of the proposed construction planned at the Charles Hughes Middle School and the Coyote Willows Golf Course. Kevin agreed that the hydraulic model should not consider the construction, since the model is for existing conditions. Matt responded by saying if any of the proposed construction is within the floodway it may have an effect on the hydraulic model and the floodway encroachment analysis. Dave added that Coyote Willows is currently placing fill, however they can only return the golf course to the original location and height. Matt asked Kevin whether PBS&J should try to align the new floodway with the original FEMA floodway within the Casa Blanca/Coyote Willows area since the draft delineation is very close to the original floodway line anyway. Kevin agreed.

Kevin asked if PBS&J was ready to prepare a draft report. Harshal replied that PBS&J will have a draft report completed by next meeting. Kevin said that he would like HDR to review draft report before the public meetings and before submitting to FEMA.

Woody Trihey asked whether PBS&J considered a lower Manning's n for areas adjacent to the low flow channel. He continued by asking if a maintenance plan was developed for Tamarisk removal for about a 300 foot corridor, what difference would that have on the WSEL. Harshal replied that PBS&J's earlier hydraulic model considered a much wider channel, based on post-flood aerials. However, the differences in WSEL between the earlier model and the current model were not quantified. Tim Sutko said that the removal of the Tamarisk can impact the habitat for the birds and other wildlife. Kevin added that removal of vegetation for such a long stretch, from a Floodplain Managers standpoint is both costly and unpredictable.

Kevin asked Jon Fuller whether they have completed the draft geomorphic report. Jon replied that they have completed the report and copies were sent to Kyle House (University of Nevada, Reno) and Matt Baird (PBS&J). He continued by saying once they receive the comments from Kyle House and PBS&J the report will be cleaned up and submitted to CCRFCD for review. Harshal mentioned that JE Fuller used PBS&J's older hydraulic model with a wider channel, for their depth-velocity calculations and asked whether it is necessary to use the newer hydraulic model. Jon responded that the difference in the two hydraulic models would not impact the geomorphic analysis and would not change the conclusions or the recommendations proposed in the draft report. Kevin and Matt agreed.

Matt said that PBS&J will submit JE Fuller's geomorphic analysis report to Kevin and the City of Mesquite after the completion of review. Jon offered to create a PDF copy of the report. Matt replied that PBS&J will send out one hard copy, as well as, electronic CDs of the report.

Kevin said that the public meetings will be held in both Mesquite and Bunkerville .He added that the two Public Meetings would take place either in April or May.

Harshal concluded the meeting by saying the next meeting is scheduled on March 30th.

* End of Meeting Minutes *

MEETING AGENDA
Thursday, February 23, 2006
11:00 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River Clark County and City of Mesquite, Nevada

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I. Discussion Items:

- *Preliminary Floodway Delineation*
  - PBS&J has delineated a preliminary floodway for the entire 100-year floodplain. Two alternative floodways have been delineated within the area of the flow split.
  - Within the area of the flow split, it needs to be determined which of the two 100-year WSELs is to be used as a base for the floodway delineation.
- *Public Meeting*
  - Locations, dates, and times for the Public Meetings need to be determined.
- *JE Fuller Draft Geomorphic Report*

II. Next Meeting:

- 11:00 a.m. Thursday March 30, 2006 at CCRFCD

PBSJ

MEETING MINUTES

Project	Virgin River Flood Hazard Map Revision	**Project No.**	511792.00
Location	CCRFCD Conference Room	**Prepared By**	Harshal Desai
Mtg. Date	March 30, 2006	**Date Prep.**	4/03/2006
Mtg. Time	10:30am		

Attendees:

Name	Organization
Kevin Eubanks	CCRFCD
Tim Sutko	CCRFCD
Catherine Lorbeer	City of Mesquite
Matt Baird	PBS&J
Harshal Desai	PBS&J
Michele D'Alessandro	PBS&J
Mike Kellogg (via Telephone)	J.E. Fuller

Meeting Minutes Distribution List:

Name	Organization
Andrew Trelease	CCRFCD
Allen Bell	City of Mesquite
Dave Vincelette	City of Mesquite
Ron Simms	USBR
Michael Wallen	SNWA
Frank Shin	CCPW
Jon Fuller	J.E. Fuller
Raymond Lenaburg	FEMA
Lee Frederiksen	HDR
Joanna Leu	HDR
David Chen	HDR
Woody Trihey	Entrix
Michael Johnson	Virgin Valley Water District
Kyle House	University of Nevada, Reno
Amy LaVoie	U.S. Fish & Wildlife Service
Phil Wisely	Mohave County

Discussion: The following summarizes our understanding of the meeting. If it differs from yours, please notify us in writing within five days.

Matt Baird began the meeting by saying PBS&J has completed the draft LOMR report for the Virgin River and gave Kevin Eubanks' a copy to review. He continued by saying J.E. Fuller has addressed PBS&J's comments on the draft geomorphic analysis report and provided and updated copy to Kevin for review. He said Kyle House will be completing his review of the geomorphic analysis report the first week of April. Matt handed out a copy of the draft LOMR report to Catherine Lorbeer for Allen Bell's review.

Kevin said that CCRFCD will identify the additions to the effective floodplain limits by comparing it to the floodplain delineation developed in the draft LOMR and will prepare a draft letter to notify the affected property owners. Matt said that based on a recent FEMA comment (on C-1 Channel LOMR), PBS&J had to notify anyone affected by the revised delineation regardless of reductions or additions to the floodplain. Approval of the changes from the property owners was not required, just copies of all the letters that were sent. Kevin asked Harshal if he can provide the shape file for the corrected-effective flood zone. Harshal replied that the shape file is included in the data DVD in Appendix E of the draft LOMR report.

Kevin said he was wondering whether a public meeting at Bunkerville or City of Mesquite is required before the submission of the LOMR to FEMA. He asked Catherine from a Mesquite resident standpoint whether she thought a public meeting is necessary before the submitting the LOMR to FEMA. Catherine replied that she is aware of one development project which is awaiting the outcome of this LOMR before they can proceed. She said that the City Council will be interested in the status/ outcome of this LOMR.

Catherine said one way of doing the public meeting would be to conduct a workshop prior to the council meetings and educate the citizens. They have done this before for other issues. Catherine said that the City of Mesquite's workshops are televised. Kevin asked Catherine regarding the procedure to schedule a workshop. She replied that the city council meetings are at 4:00 PM on the second and the fourth Tuesday of every month. She said the workshop for this project would be held prior to the council meeting. Kevin asked whether this workshop will be open to public. She said that the workshops are on the agenda and would be advertised on the website. After the completion of the workshop the public comments would be noted.

Catherine said that a separate public meeting without the council can also be facilitated. Kevin said he was wondering whether a public meeting between 6:00 and 8:00 PM is possible to allow people to come by after normal working hours. He said that the meeting would be like an open house where people can come and ask questions. He said that we would not necessarily do a presentation but will have exhibits showing the floodplain delineations and will hand out information sheets. Catherine said they can facilitate that and would advertise the meeting on City of Mesquite's website. She said that the local paper can also do a story if necessary.

Kevin said he will prepare a mailing list of property owners who will be impacted by the corrected effective flood zone and notify them prior to the open house, so that they have an opportunity to come to the open house. He said he will let Catherine know when the open house needs to be organized.

Harshal showed the annotated FEMA maps illustrating the corrected effective flood zone with respect to the effective flood zone. He explained that because of the differential hydraulic gradient at the upstream study limit it is not possible to tie into the effective WSE with in 0.5 foot. He further explained that since the modeling/mapping efforts is being coordinated with FEMA Region IX and HDR (who are working on re-delineating the flood zone upstream of Nevada/Arizona border), the water-surface profiles developed by PBS&J and HDR Inc. will meet FEMA requirements and tie into each other within 0.5 feet at the Nevada-

Arizona border once the HDR study is complete and approved by FEMA. Harshal also noted that the effective delineations on each side of the state line do not currently tie in within FEMA requirements. All the reasons why the two flood zones do not tie together are explained in the draft LOMR report. The corrected effective floodplain limits at the downstream end, tie into the existing effective flood Zone A within 50 feet horizontally (10% of the FEMA FIRM Panel Scale). Matt pointed out that the BFE lines are shown on the Annotated FEMA Map. Harshal explained that the jogs in the upstream BFE lines represent the differential WSE in the vicinity of the flow split. The location of the jog is at the location of lateral weir which is placed along the high point between the two reaches (avulsion and the main channel). Harshal explained that the Flood Zones associated with Pulsipher Wash and Abbott Wash were revised at their confluence with the Virgin River in order to tie into the Virgin River corrected effective floodplain delineation.

Harshal said that we will not be including a FEMA submittal fee since the corrected effective hydraulic model is solely based on more detailed data per FEMA Flood Map-Related Fee Criteria. Harshal said that PBS&J has modeled the Bunkerville Irrigation Diversion Structure but has not identified it has a riverine structure in the FEMA forms as it is not a sanctioned dam.

Matt said PBS&J has marked 'Yes' for the common regulatory requirements questions stated in FEMA MT2 Form Section D3 and D4 (refer to the questions below).

"For the LOMR request, is the regulatory floodway being revised?"
"For LOMR requests, does this request require property owner notification and acceptance of BFE increases?"

Kevin said he will review the above questions and let PBS&J know if the answers to the above questions need to be "No".

Kevin said that the Community Acknowledgement Letter from Clark County and City of Mesquite will be need signed by both agencies and included in the Final LOMR submittal.

Kevin asked Harshal to send the draft LOMR report to Lee Frederiksen (HDR), Raymond Lenaburg (FEMA Region IX), Phil Wisely (Mohave County), and Frank Shin (Clark County Public Works) for their review. He said he will complete his review of the draft LOMR report by the end of next week.

Kevin will not be available at the regular date and time of the April progress meeting, so he will let everyone know what the new date and time will be. The Master Plan Update meeting typically held after the Virgin River Meeting will also be re-scheduled for the new date and time.

* End of Meeting Minutes *

MEETING AGENDA
Thursday, March 30, 2006
10:30 A.M. at CCRFCD

Flood Hazard Map Revision for the Virgin River
Clark County and City of Mesquite, Nevada

I. Discussion Items:

- *PBS&J has completed Draft LOMR Report*
    - Confirm Flood Zone Delineation at upstream and downstream limits
    - Confirm Flood Zone Delineation at the Confluence of Abbott Wash and Virgin River
    - Confirm Flood Zone Delineation at the Confluence of Pulsipher Wash and Virgin River
    - FEMA Review Fees – Not required per FEMA fee submittal criteria
    - FEMA MT 2 Form 2 Page 2 of 2 Section D 3 and D 4
    - PBS&J will submit the draft report to HDR (FEMA Region IX) for their review
- *Public Meeting*
    - Locations, dates, and times for the Public Meetings need to be determined.
- *JE Fuller Draft Geomorphic Report*

II. Next Meeting:

~~11:00 a.m. Thursday April 27, 2006 at CCRFCD~~

Annual Peak Flow Frequency Analysis: Following Bulletin 17-B (Michael Baker Corporation 2005)

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                     U. S. GEOLOGICAL SURVEY
                 ANNUAL PEAK FLOW FREQUENCY ANALYSIS
                 Following Bulletin 17-B Guidelines
                          Program peakfq
                    (Version 4.1, February, 2002)


            Station - 09415000  VIRGIN R AT LITTLEFIELD, AZ
                        2005 MAR 16 16:57:07


                 I N P U T   D A T A   S U M M A R Y

            Number of peaks in record            =       75
            Peaks not used in analysis           =        1
            Systematic peaks in analysis         =       74
            Historic peaks in analysis           =        0
            Years of historic record             =        0
            Generalized skew                     =    0.000
            Standard error of generalized skew   =    0.550
            Skew option                          =  WEIGHTED
            Gage base discharge                  =      0.0
            User supplied high outlier threshold =   --
            User supplied low outlier criterion  =   --
            Plotting position parameter          =     0.00


 *********  NOTICE  --  Preliminary machine computations.         *********
 *********  User responsible for assessment and interpretation.   *********

 **WCF109W-PEAKS WITH MINUS-FLAGGED DISCHARGES WERE BYPASSED.        1
 **WCF113W-NUMBER OF SYSTEMATIC PEAKS HAS BEEN REDUCED TO NSYS =    74
   WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
   WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.            403.0
   WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.     57308.1
   WCF002J-CALCS COMPLETED.  RETURN CODE =  2
1

            Station - 09415000  VIRGIN R AT LITTLEFIELD, AZ
                        2005 MAR 16 16:57:07


        ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                        FLOOD BASE                  LOGARITHMIC
                  ----------------------  -------------------------------
                              EXCEEDANCE               STANDARD
                  DISCHARGE  PROBABILITY     MEAN      DEVIATION     SKEW
                  -------------------------------------------------------
 SYSTEMATIC RECORD      0.0     1.0000     3.6817     0.3697        0.262
 BULL.17B ESTIMATE      0.0     1.0000     3.6817     0.3697        0.204


   ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

    ANNUAL                               'EXPECTED   95-PCT CONFIDENCE LIMITS
  EXCEEDANCE    BULL.17B    SYSTEMATIC PROBABILITY'  FOR BULL. 17B ESTIMATES
  PROBABILITY   ESTIMATE      RECORD     ESTIMATE       LOWER        UPPER

    0.9950        631.6        661.5        594.1        438.7        842.1
    0.9900        754.4        782.6        718.2        537.0        988.2
    0.9500       1247.0       1266.0       1216.0        947.7       1560.0
    0.9000       1647.0       1658.0       1621.0       1294.0       2015.0
    0.8000       2331.0       2327.0       2312.0       1897.0       2788.0
    0.5000       4669.0       4630.0       4669.0       3959.0       5500.0
    0.2000       9742.0       9710.0       9834.0       8153.0      11950.0
    0.1000      14550.0      14610.0      14830.0      11860.0      18610.0
    0.0400      22600.0      22960.0      23430.0      17760.0      30500.0
    0.0200      30250.0      31030.0      31850.0      23120.0      42430.0
    0.0100      39510.0      40940.0      42330.0      29400.0      57500.0
    0.0050      50660.0      53040.0      55360.0      36740.0      76350.0
    0.0020      68800.0      73070.0      77440.0      48300.0     108400.0
    0.6667       3258.0   (  1.50-year flood )
    0.4292       5426.6   (  2.33-year flood )

            Station - 09415000  VIRGIN R AT LITTLEFIELD, AZ
                        2005 MAR 16 16:57:07


                  I N P U T   D A T A   L I S T I N G

   WATER YEAR    DISCHARGE   CODES      WATER YEAR    DISCHARGE   CODES

      1930         6500.0                  1968         2180.0
      1931         3000.0                  1969        21400.0
      1932        18000.0                  1970         8960.0
      1933         1500.0                  1971         6140.0
      1934         1220.0                  1972         8180.0
      1935         1900.0                  1973         3740.0
      1936         2710.0                  1974         5840.0
      1937         1440.0                  1975         5910.0
      1938        22000.0                  1976         5180.0
      1939        13000.0                  1977         7140.0
      1940        11000.0                  1978        22000.0
      1941         6000.0                  1979         4440.0
      1942         3740.0                  1980        10380.0
      1943         2660.0                  1981         2260.0
      1944         1900.0                  1982         4840.0
      1945         4170.0                  1983         6200.0
    1946          5010.0                    1984        4940.0
    1947          9400.0                    1985        1260.0
    1948          1090.0                    1986        1970.0
    1949          2290.0                    1987        5690.0
    1950          3450.0                    1988        8280.0
    1951         12000.0                    1989      -61000.0     D
    1952          7170.0                    1990        2810.0
    1953          5490.0                    1991        1150.0
    1954          6020.0                    1992        3730.0
    1955         19800.0                    1993       12300.0
    1956          2460.0                    1994        1980.0
    1957          3950.0                    1995       20500.0
    1958          7180.0                    1996        5430.0
    1959          3490.0                    1997        5410.0
    1960          2320.0                    1998        7080.0
    1961         10900.0                    1999        2670.0
    1962          5380.0                    2000         877.0
    1963          4720.0                    2001        1500.0
    1964          6300.0                    2002        1700.0
    1965          4040.0                    2003        2080.0
    1966          5490.0                    2005       36500.0
    1967         35200.0

    Explanation of peak discharge qualification codes

   PEAKFQ  WATSTORE
    CODE     CODE   DEFINITION

     D        3     Dam failure, non-recurrent flow anomaly
     G        8     Discharge greater than stated value
     X       3+8    Both of the above
     L        4     Discharge less than stated value
     K      6 OR C  Known effect of regulation or urbanization
     H        7     Historic peak

          Station - 09415000  VIRGIN R AT LITTLEFIELD, AZ
                          2005 MAR 16 16:57:07

 EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

   WATER          RANKED       SYSTEMATIC     BULL.17B
    YEAR        DISCHARGE        RECORD       ESTIMATE

    2005         36500.0         0.0133        0.0133
    1967         35200.0         0.0267        0.0267
    1938         22000.0         0.0400        0.0400
    1978         22000.0         0.0533        0.0533
    1969         21400.0         0.0667        0.0667
    1995         20500.0         0.0800        0.0800
    1955         19800.0         0.0933        0.0933
    1932         18000.0         0.1067        0.1067
    1939         13000.0         0.1200        0.1200
    1993         12300.0         0.1333        0.1333
    1951         12000.0         0.1467        0.1467
    1940         11000.0         0.1600        0.1600
    1961         10900.0         0.1733        0.1733
    1980         10380.0         0.1867        0.1867
    1947          9400.0         0.2000        0.2000
    1970          8960.0         0.2133        0.2133
    1988          8280.0         0.2267        0.2267
    1972          8180.0         0.2400        0.2400
    1958          7180.0         0.2533        0.2533
    1952          7170.0         0.2667        0.2667
    1977          7140.0         0.2800        0.2800
    1998          7080.0         0.2933        0.2933
    1930          6500.0         0.3067        0.3067
    1964          6300.0         0.3200        0.3200
    1983          6200.0         0.3333        0.3333
    1971          6140.0         0.3467        0.3467
    1954          6020.0         0.3600        0.3600
    1941          6000.0         0.3733        0.3733
    1975          5910.0         0.3867        0.3867
    1974          5840.0         0.4000        0.4000
    1987          5690.0         0.4133        0.4133
    1953          5490.0         0.4267        0.4267
    1966          5490.0         0.4400        0.4400
    1996          5430.0         0.4533        0.4533
    1997          5410.0         0.4667        0.4667
    1962          5380.0         0.4800        0.4800
    1976          5180.0         0.4933        0.4933
    1946          5010.0         0.5067        0.5067
    1984          4940.0         0.5200        0.5200
    1982          4840.0         0.5333        0.5333
    1963          4720.0         0.5467        0.5467
    1979          4440.0         0.5600        0.5600
    1945          4170.0         0.5733        0.5733
    1965          4040.0         0.5867        0.5867
    1957          3950.0         0.6000        0.6000
    1942          3740.0         0.6133        0.6133
    1973          3740.0         0.6267        0.6267
    1992          3730.0         0.6400        0.6400
    1959          3490.0         0.6533        0.6533
    1950          3450.0         0.6667        0.6667
    1931          3000.0         0.6800        0.6800
    1990          2810.0         0.6933        0.6933
    1936          2710.0         0.7067        0.7067
    1999          2670.0         0.7200        0.7200
    1943          2660.0         0.7333        0.7333
    1956          2460.0         0.7467        0.7467
    1960          2320.0         0.7600        0.7600
    1949          2290.0         0.7733        0.7733
    1981          2260.0         0.7867        0.7867
    1968          2180.0         0.8000        0.8000
    2003          2080.0         0.8133        0.8133
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1994        1980.0       0.8267       0.8267
1986        1970.0       0.8400       0.8400
1935        1900.0       0.8533       0.8533
1944        1900.0       0.8667       0.8667
2002        1700.0       0.8800       0.8800
1933        1500.0       0.8933       0.8933
2001        1500.0       0.9067       0.9067
1937        1440.0       0.9200       0.9200
1985        1260.0       0.9333       0.9333
1934        1220.0       0.9467       0.9467
1991        1150.0       0.9600       0.9600
1948        1090.0       0.9733       0.9733
2000         877.0       0.9867       0.9867
1989      -61000.0         --           --
```

Bunkerville Bridge: Plan and Profile (State of Nevada: Department of Highways 1931)

ENERAL NOTES:—

ll curves of 5000 foot radius or less shall be superelevated in accordance the following formula:—

$$E = \frac{82.075}{R} \text{ (Maximum Value of } E = 0.125')$$

Where "R" = Radius in feet.
"E" = Superelevation in feet per foot width of roadway.

Full superelevation shall be carried from P.C. to P.T. of eac easement length of 50 x E x W at each end. "W" = width of to shoulder. Where consistant with roadway dr the superelevation shall revolve abo

th of gravel as shown on the plans:

numents shall be placed t and at P.C. & P.T. of

rrow to be ot k E-H

FED.ROAD DIST.NO	STATE	FED.AID PROJ.NO.	FISCAL YEAR	COUNTY	ROUTE	SECTION	SHEET NO	TOTAL SHEETS
2	NEVADA	27	1932	Clark	6	H4	1	16

REOPENED

Contract 252

STATE OF NEVADA
DEPARTMENT O

PLAN A PROPOSED
HIGHWAY

FEDERAL AID PROJECT
No 27 — REOPENED

FED. AID PROJECT No 27
REOPENED

CLARK COUNTY
UPPER VIRGIN RIVER BRIDGE

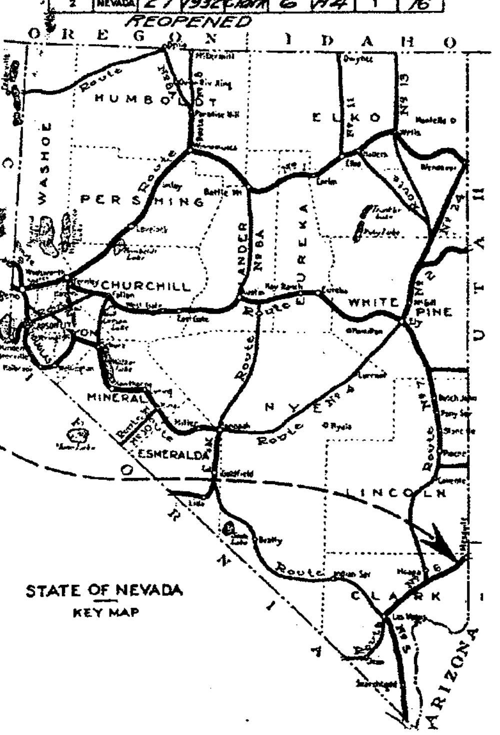
SCALES { PLAN, 1 IN. = 100 FT. PROFILE, HOR. 1 IN. = 100 FT., VERT. 1 IN. = 10 FT.

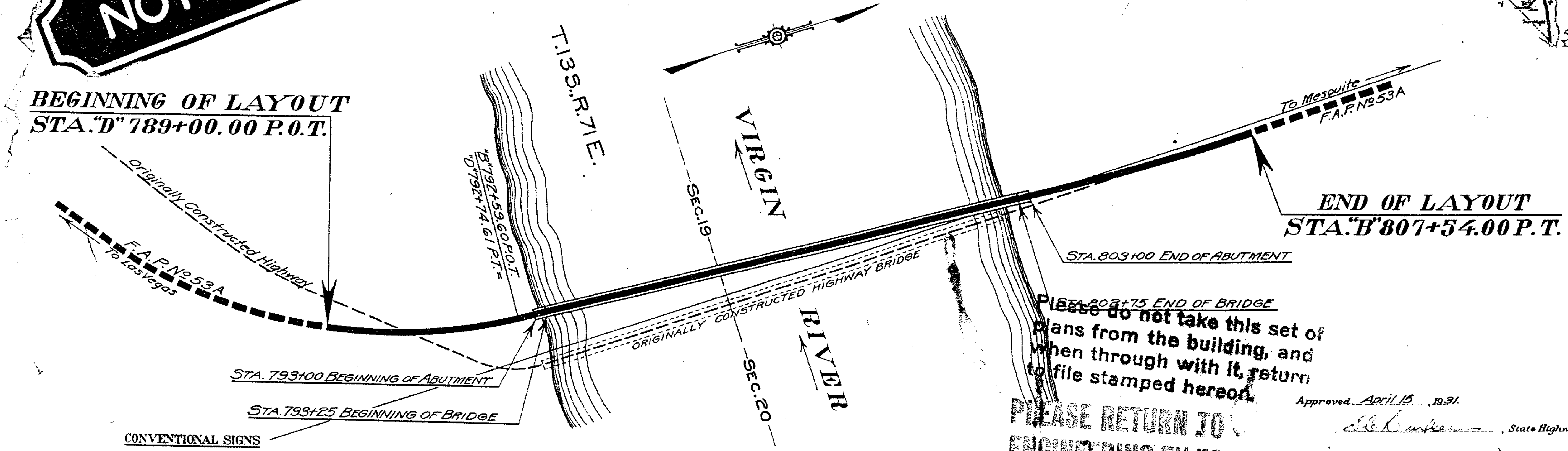
NOT TO BE REMOVED FROM OFFICE

PLEASE RETURN TO ENGINEERING FILES

PLEASE RETURN TO ENGINEERING FILES

Please do not take this set of plans from the building, and when through with it, return to file stamped hereon.


OREGON
IDAHO
HUMBOLDT
ELKO
WASHOE
PERSHING
CHURCHILL
LANDER
EUREKA
WHITE PINE
MINERAL
NYE
ESMERALDA
LINCOLN
CLARK
UTAH
CALIFORNIA
ARIZONA
Route
STATE OF NEVADA
KEY MAP


BEGINNING OF LAYOUT
STA. "D" 789+00.00 P.O.T.
Originally Constructed Highway
F.A.P. No 53A
To Las Vegas
T.13S., R.71E.
"B" 792+59.60 P.O.T.
"D" 792+74.61 P.T. =
VIRGIN
RIVER
SEC. 19
SEC. 20
ORIGINALLY CONSTRUCTED HIGHWAY BRIDGE
STA. 793+00 BEGINNING OF ABUTMENT
STA. 793+25 BEGINNING OF BRIDGE
STA. 802+75 END OF BRIDGE
STA. 803+00 END OF ABUTMENT
END OF LAYOUT
STA. "B" 807+54.00 P.T.
To Mesquite
F.A.P. No 53A

Please do not take this set of plans from the building, and when through with it, return to file stamped hereon.

PLEASE RETURN TO ENGINEERING FILES

LAYOUT

TOTAL LENGTH OF PROJECT AS ORIGINALLY CONSTRUCTED — 1743.87 FT. = 0.330 MI.
" " " " " REVISED — 1869.01 FT. = 0.353 MI.

CONVENTIONAL SIGNS

STATE LINE	— — —	LEVEE	═══
COUNTY LINE	— - —	CULVERTS	┄┄┄
INC'P'D CITY OR TOWN	— — —	RETAINING WALL	═══
TOWNSHIP LINE	———	DROP INLET	▢┄┄┄
SECTION LINE	— — —	TROLLEY POLE	♦
RESERVATION LINE	— - —	POWER POLE	♦
FENCE LINE	— · —	TELEPHONE OR TELEGRAPH POLES	♦
UNFENCED PROPERTY	- - - -	MARSH	≈≈≈
RIGHT OF WAY LINE	———	TREES	●●●●●●●
TRAVELED WAY	═ ═ ═	GROUND ELEVATION	DATUM LINE 172.6
RAILROADS	━━━	GRADE ELEVATION	DATUM LINE 175.5
BASE OR SURVEY LINE 150	———		

Approved April 15, 1931.

, State Highway Engr.

Fred B. Balzar, Chairman
Gray Mashburn
Ed C. Peterson
Board of Directors

RECOMMENDED FOR APPROVAL:

[redacted]

DISTRICT ENGINEER - BUREAU OF PUBLIC ROADS

RECOMMENDED FOR APPROVAL

[redacted]

CHIEF ENGINEER - BUREAU OF PUBLIC ROADS

APPROVED:

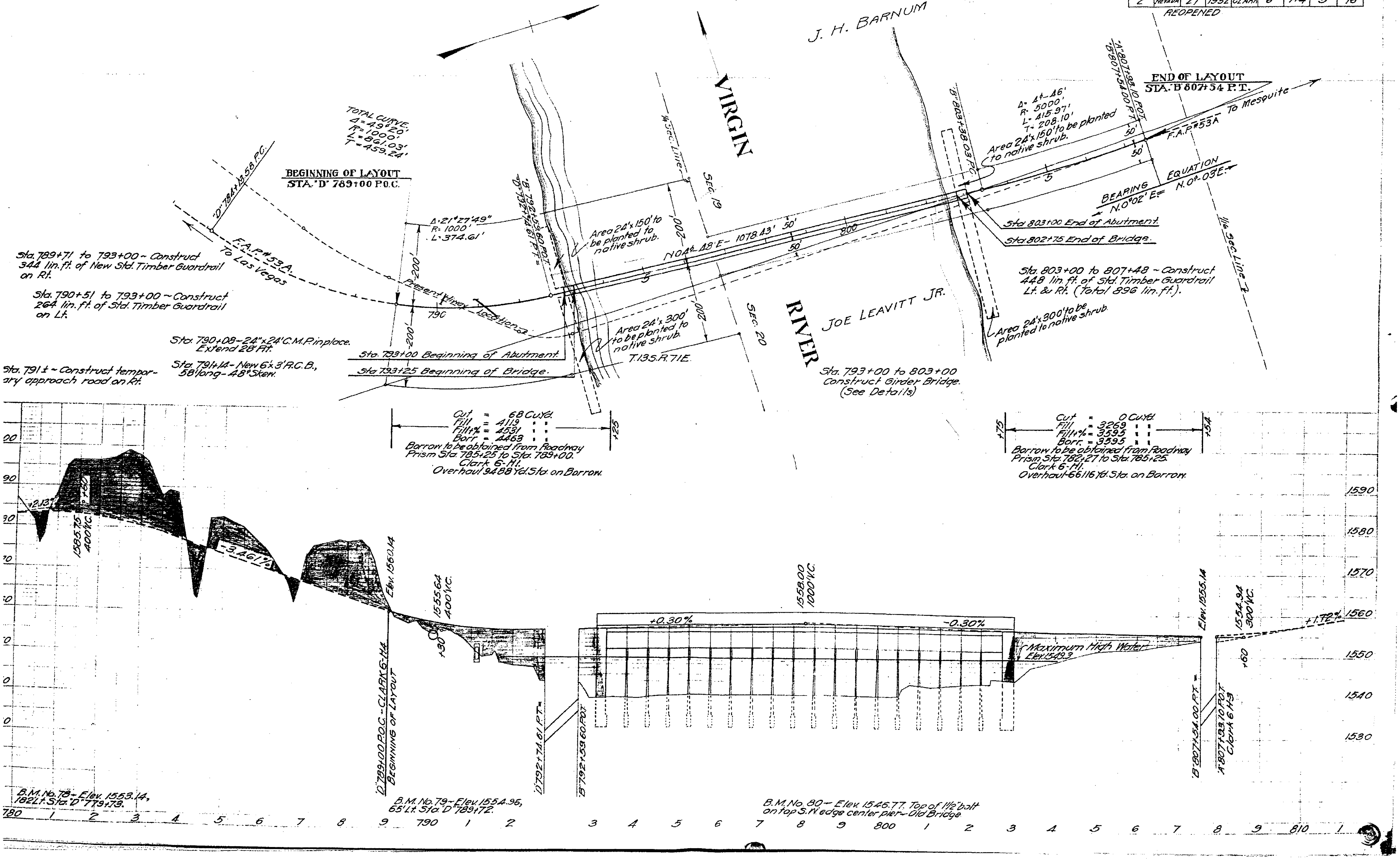
[redacted]

DIRECTOR - BUREAU OF PUBLIC ROADS

SCALE:- 1" = 100'

FED. RD. DIST. NO.	STATE	FED. AID PROJ. NO.	FISCAL YEAR	COUNTY	ROUTE	SECTION	SHEET NO.	TOTAL SHEETS
2	NEVADA	27	1932	CLARK	6	H4	3	16

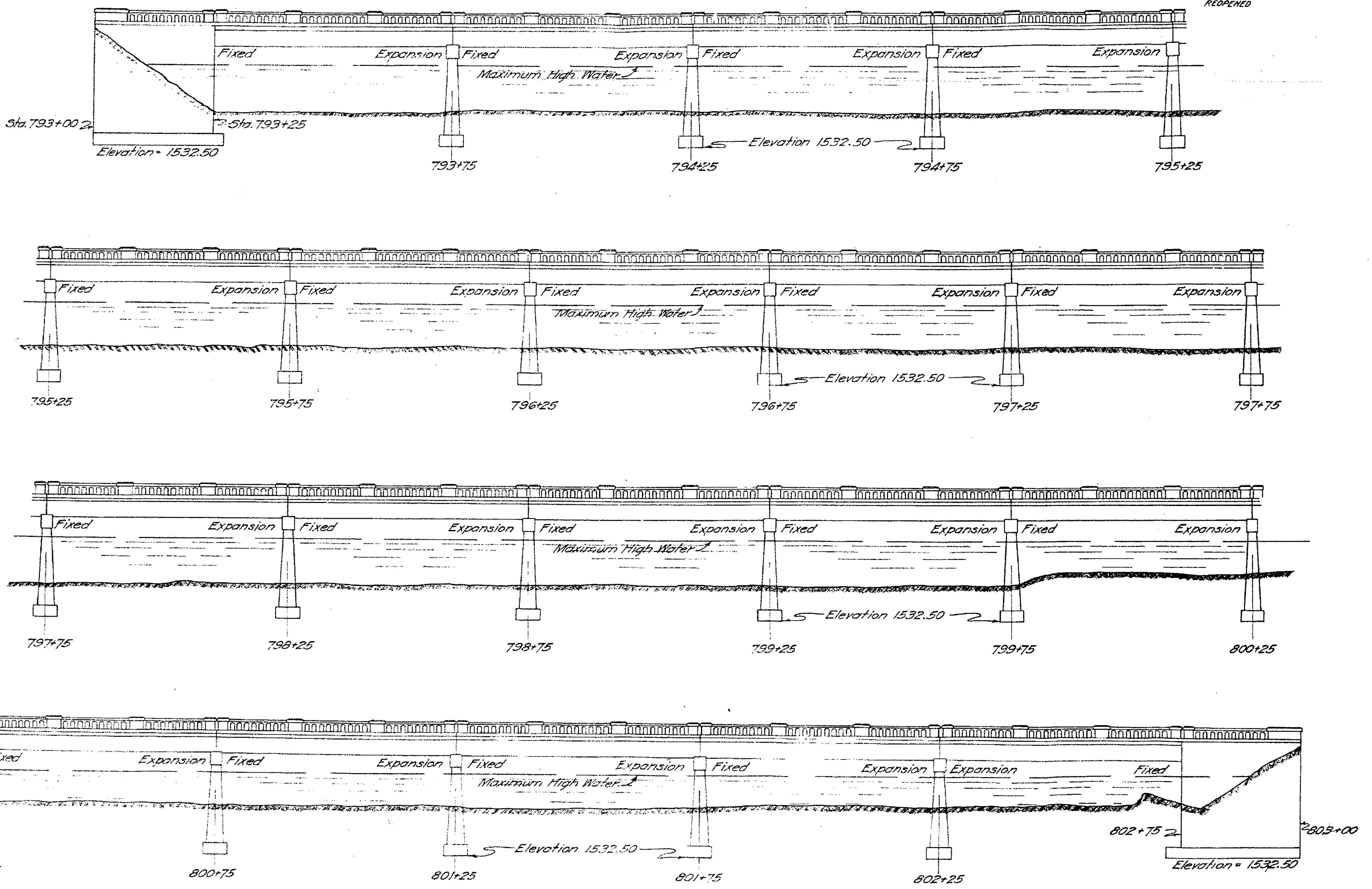
REOPENED


J. H. BARNUM
VIRGIN
RIVER
JOE LEAVITT JR.
TOTAL CURVE.
Δ=49°20'
R=1000'
L=861.03'
T=459.24'
BEGINNING OF LAYOUT
STA. "D" 789+00 P.O.C.
"D" 784+13.58 P.C.
F.A.P. #53A.
To Las Vegas
Present Hiway Location
Δ=21°27'49"
R=1000'
L=374.61'
"B" 792+59.60 P.O.T.
"D" 792+74.61 P.T. =
200'
200'
790
Sta. 789+71 to 793+00 ~ Construct 344 lin. ft. of New Std. Timber Guardrail on Rt.
Sta. 790+51 to 793+00 ~ Construct 264 lin. ft. of Std. Timber Guardrail on Lt.
Sta. 790+08 - 24"x24' C.M.P. in place. Extend 28' Rt.
Sta. 791+14 - New 6'x3' R.C.B., 58' long - 48° Skew.
Sta. 791± ~ Construct temporary approach road on Rt.
Sta. 793+00 Beginning of Abutment.
Sta 793+25 Beginning of Bridge.
Area 24'x150' to be planted to native shrub.
Area 24'x300' to be planted to native shrub.
¼ Sec. Line
SEC. 19
SEC. 20
T.13S.R.71E.
N 04°-48' E ~ 1078.43'
50'
50'
800
5
"B" 803+38.03 P.C.
Δ=4°-46'
R=5000'
L=415.97'
T=208.10'
"A" 807+93.10 P.O.T.
"B" 807+54.00 P.T.
END OF LAYOUT
STA. "B" 807+54 P.T.
To Mesquite
F.A.P. #53A
Area 24'x150' to be planted to native shrub.
BEARING EQUATION
N. 0°02' E = N. 0°-03' E.
Sta 803+00 End of Abutment.
Sta 802+75 End of Bridge.
Sta. 803+00 to 807+48 ~ Construct 448 lin. ft. of Std. Timber Guardrail Lt. & Rt. (Total 896 lin. ft.).
Area 24'x300' to be planted to native shrub.
1/16 Sec. Line
Sta. 793+00 to 803+00 Construct Girder Bridge. (See Details)
Cut = 68 Cu.Yd.
Fill = 4119 " "
Fill+% = 4531 " "
Borr = 4463 " "
Borrow to be obtained from Roadway Prism Sta. 785+25 to Sta. 789+00.
Clark 6-H1.
Overhaul 9488 Yd.Sta. on Borrow.
+25
+75
Cut = 0 Cu.Yd.
Fill = 3269 " "
Fill+% = 3595 " "
Borr. = 3595 " "
Borrow to be obtained from Roadway Prism Sta. 782+27 to Sta. 785+25.
Clark 6-H1.
Overhaul-66116 Yd.Sta. on Borrow.
+54
+2.13%
1585.75
400'V.C.
+80
-3.461%
Elev. 1560.14
1555.64
400'V.C.
+30
"D" 789+00 P.O.C. - CLARK 6-H4
BEGINNING OF LAYOUT
"D" 792+74.61 P.T. =
"B" 792+59.60 P.O.T.
1558.00
1000'V.C.
+0.30%
-0.30%
Maximum High Water
Elev. 1549.3
Elev. 1555.14
1554.94
300'V.C.
+1.72%
+60
"B" 807+54.00 P.T. =
"A" 807+93.10 P.O.T.
Clark 6 H3
1590
1580
1570
1560
1550
1540
1530
B.M. No. 78 ~ Elev. 1553.14, 182' Lt. Sta. "D" 779+73.
B.M. No. 79 ~ Elev. 1554.96, 65' Lt. Sta. "D" 789+72.
B.M. No. 80 ~ Elev. 1546.77. Top of 1½" bolt on top S.W. edge center pier ~ Old Bridge
780
1
2
3
4
5
6
7
8
9
790
1
2
3
4
5
6
7
8
9
800
1
2
3
4
5
6
7
8
9
810
1

FED.RD. DIST. Nº	STATE	FED.AID PROJ. Nº	FISCAL YEAR	COUNTY	ROUTE	SECTION	SHEET Nº	TOTAL SHEETS
2	NEVADA	27	1932	CLARK	6	H4	4	16

REOPENED

Note:- Entire Structure on Vertical Curve


Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Maximum High Water
Sta. 793+00
Sta. 793+25
Elevation = 1532.50
793+75
794+25
Elevation 1532.50
794+75
795+25
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Maximum High Water
Elevation 1532.50
795+25
795+75
796+25
796+75
797+25
797+75
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Maximum High Water
Elevation 1532.50
797+75
798+25
798+75
799+25
799+75
800+25
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Fixed
Expansion
Expansion
Fixed
Maximum High Water
Elevation 1532.50
802+75
803+00
Elevation = 1532.50
800+25
800+75
801+25
801+75
802+25

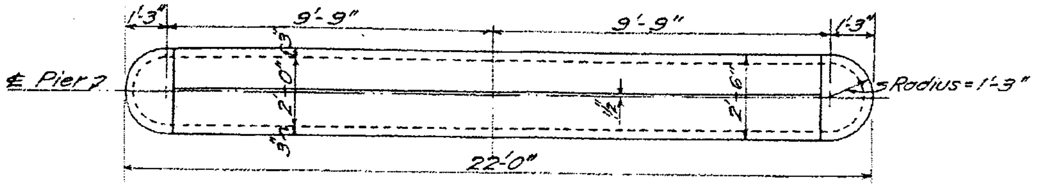
ELEVATION

FED. RD. DIST. No	STATE	FED. AID PROJ. No	FISCAL YEAR	COUNTY	ROUTE	SECTION	SHEET No	TOTAL SHEETS
2	NEVADA	27	1932	CLARK	6	H4	7	16

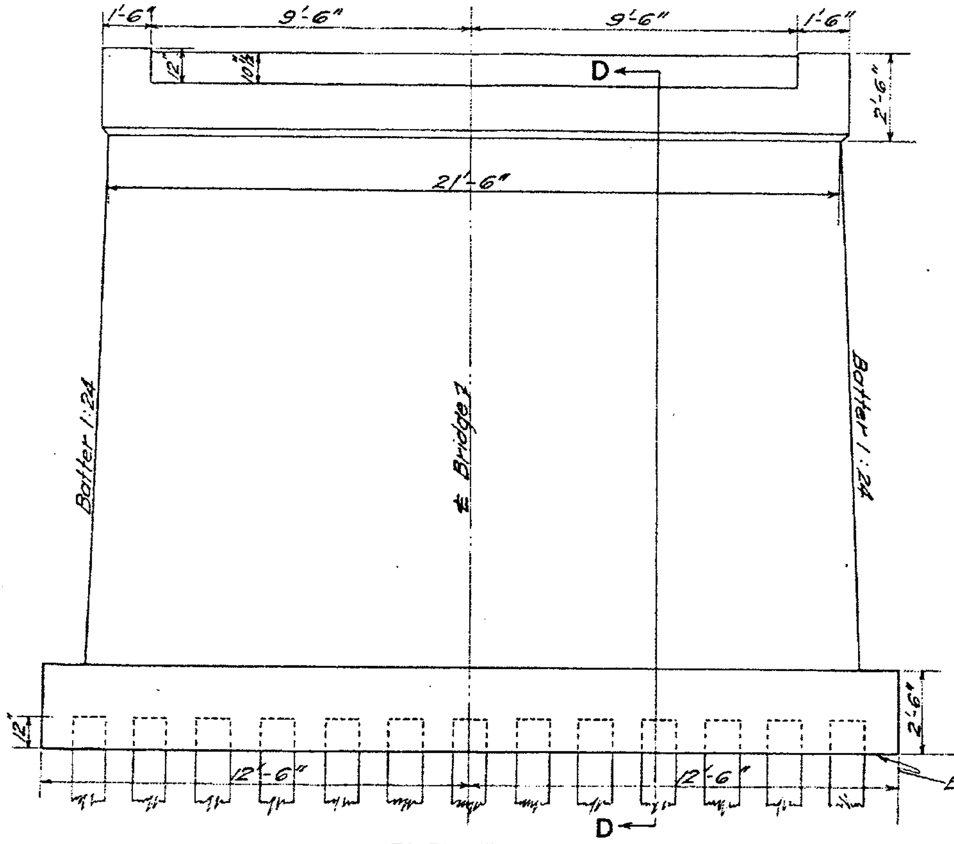
REOPENDED

Revised:- 5-5-31

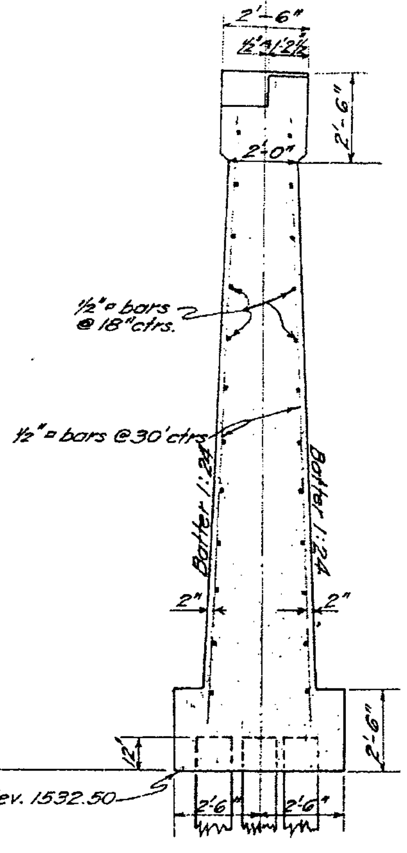
Dimensions and reinforcing not shown are same for all piers.


1'-3"
9'-9"
9'-9"
1'-3"
℄ Pier
Radius = 1'-3"
2'-6"
2'-0"
22'-0"

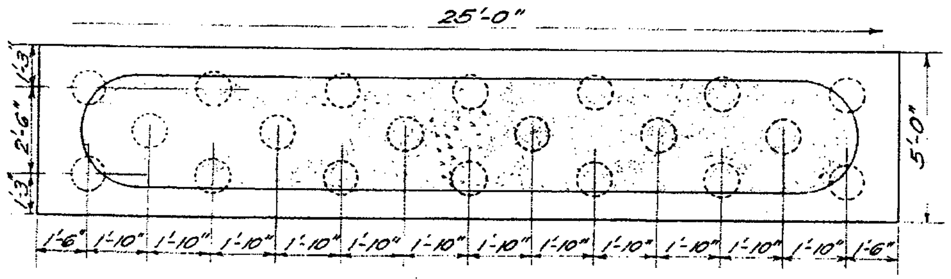
PLAN OF TOP


1'-6"
9'-6"
9'-6"
1'-6"
D
2'-6"
21'-6"
Batter 1:24
℄ Bridge
Batter 1:24
2'-6"
12"
12'-6"
12'-6"
Elev. 1532.50
D

ELEVATION

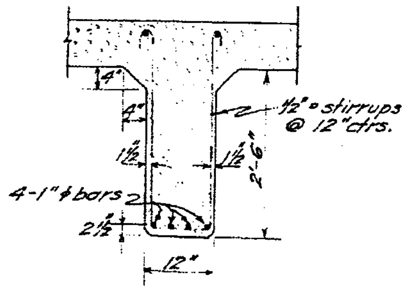

2'-6"
2'-6"
2'-0"
½"⌀ bars @ 18" ctrs.
½"⌀ bars @ 30" ctrs.
Batter 1:24
Batter 1:24
2"
2"
2'-6"
12"
2'-6"
2'-6"

SECTION D-D

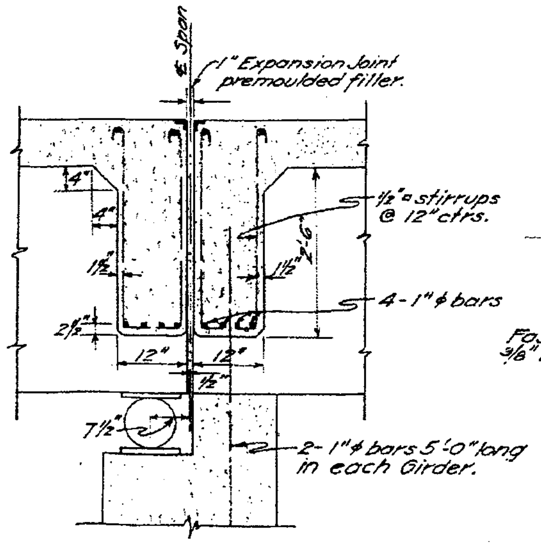

25'-0"
1'-3"
2'-6"
1'-3"
5'-0"
1'-6"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-10"
1'-6"

PLAN OF FOOTING

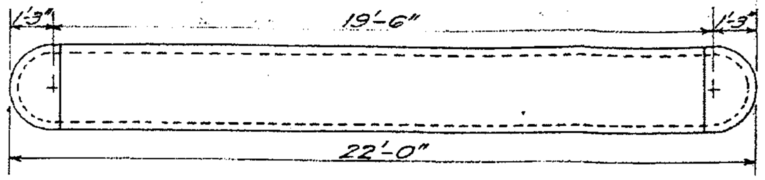
ALL PIERS EXCEPT NO. 18


4"
4"
½"⌀ stirrups @ 12" ctrs.
1½
1½
2'-6"
4-1"⌀ bars
2½
12"

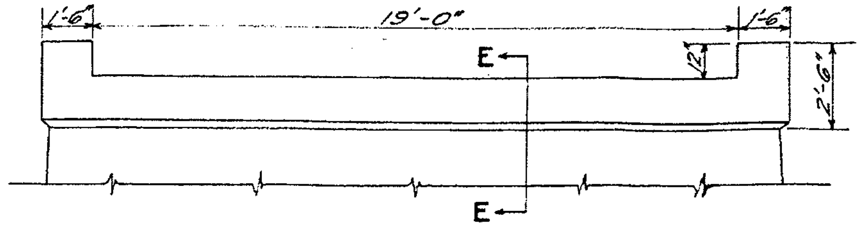
SECTION F-F


℄ Span
1" Expansion Joint premoulded filler.
4"
4"
½"⌀ stirrups @ 12" ctrs.
1½
1½
2'-6"
4-1"⌀ bars
2½
12"
12"
½"
7½
2-1"⌀ bars 5'-0" long in each Girder.

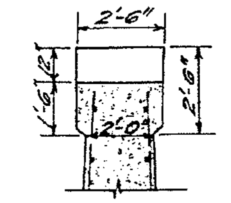
SECTION G-G


1'-3"
19'-6"
1'-3"
22'-0"

PLAN OF TOP

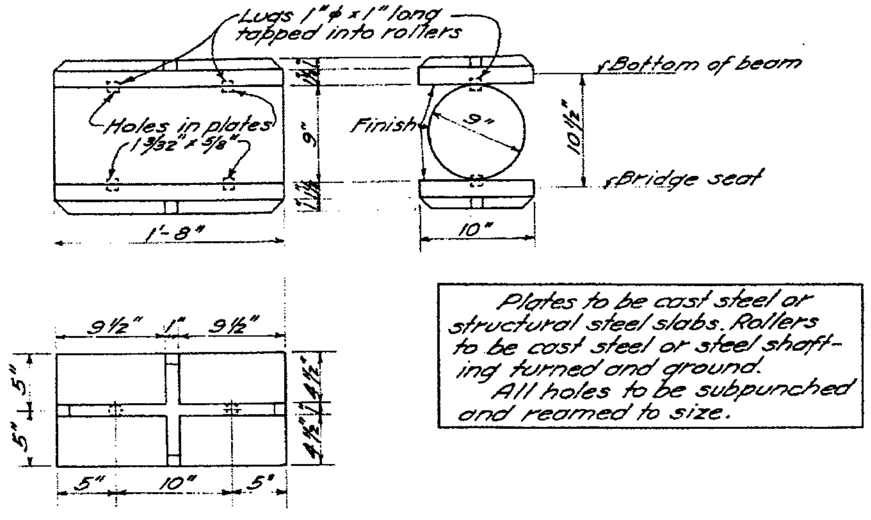

1'-6"
19'-0"
1'-6"
E
12"
2'-6"
E

PART ELEVATION


2'-6"
1'-6"
12"
2'-0"
2'-6"

SECTION E-E

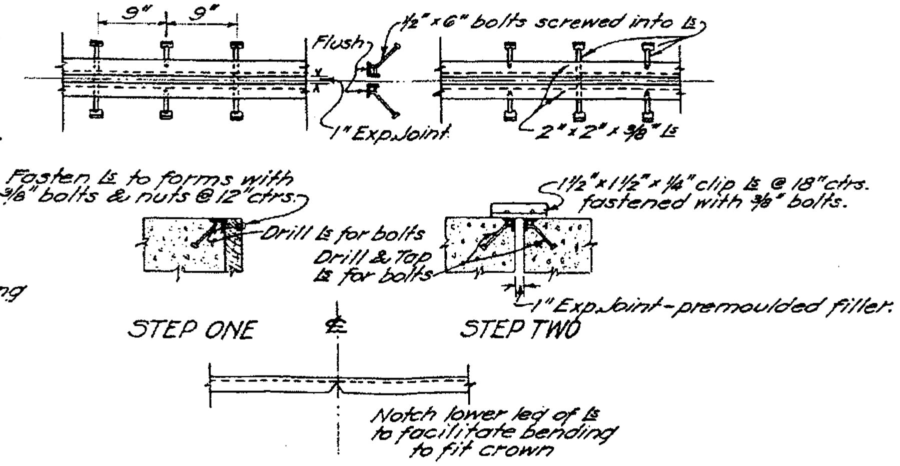
PIER NO. 18 ONLY


Lugs 1"⌀ x 1" long tapped into rollers
Bottom of beam
Holes in plates 1 3/32" x 5/8"
9"
Finish
9"
10½"
Bridge seat
1¼
1'-8"
10"
9½"
1"
9½"
5"
5"
4½"
4½"
5"
10"
5"

Plates to be cast steel or structural steel slabs. Rollers to be cast steel or steel shafting turned and ground.
All holes to be subpunched and reamed to size.

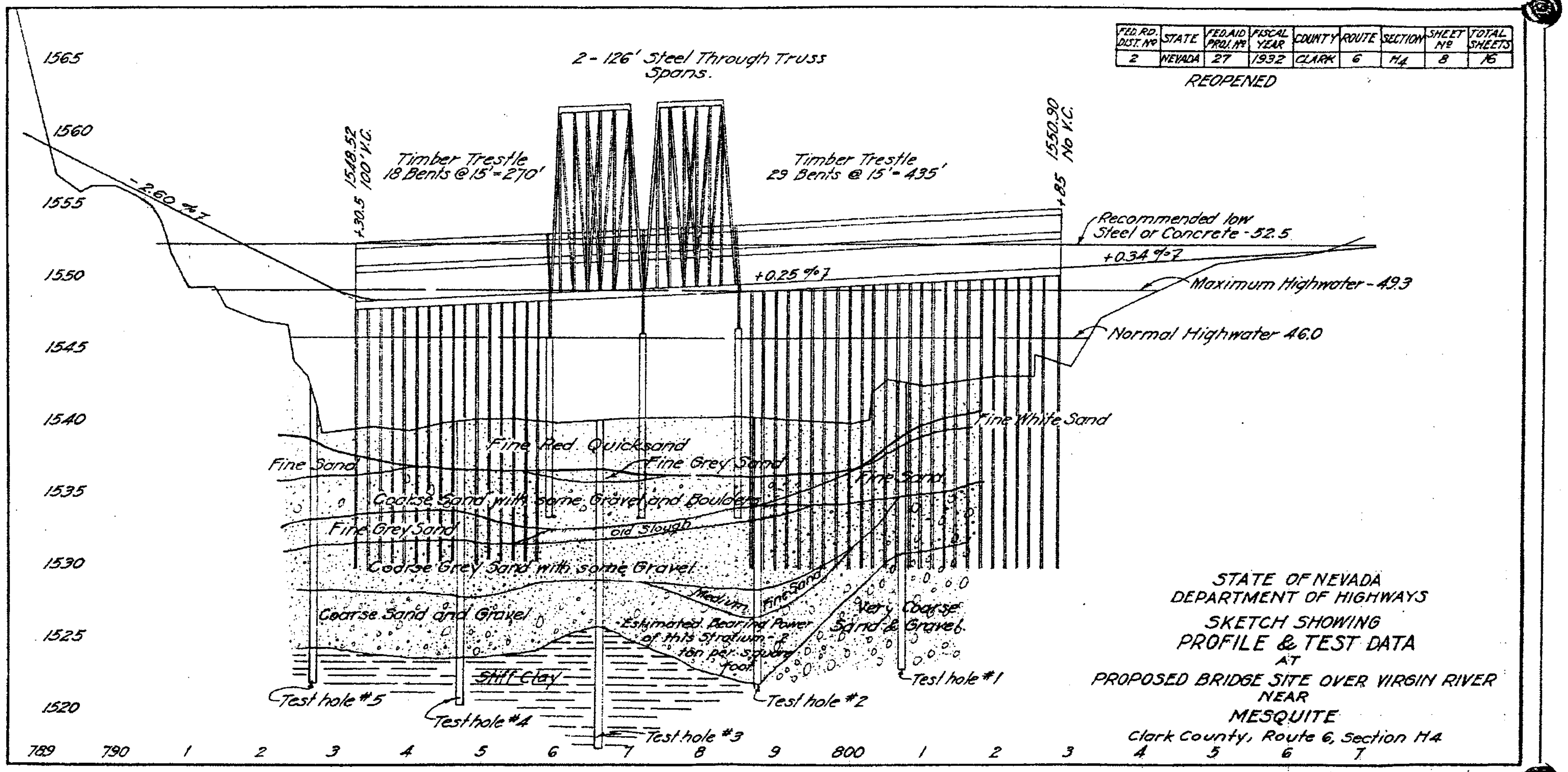
EXPANSION ROCKERS

19 SETS REQUIRED


9"
9"
Flush
½" x 6" bolts screwed into ∠s
1" Exp. Joint
2" x 2" x 3/8" ∠s
Fasten ∠s to forms with 3/8" bolts & nuts @ 12" ctrs.
Drill ∠s for bolts
Drill & Tap ∠s for bolts
1½" x 1½" x ¼" clip ∠ @ 18" ctrs. fastened with 3/8" bolts.
1" Exp. Joint - premoulded filler.
STEP ONE
℄
STEP TWO
Notch lower leg of ∠s to facilitate bending to fit crown

PROTECTION ANGLES AT EXPANSION JOINTS

CLARK G H-4 L.O.7 BC



1565
1560
1555
1550
1545
1540
1535
1530
1525
1520
2 - 126' Steel Through Truss Spans.
Timber Trestle 18 Bents @ 15' = 270'
Timber Trestle 29 Bents @ 15' = 435'
1548.52 100' V.C.
+30.5
1550.90 No V.C.
+85
-2.60 %
+0.25 %
+0.34 %
Recommended low Steel or Concrete - 52.5
Maximum Highwater - 49.3
Normal Highwater 46.0
Fine White Sand
Fine Red. Quicksand
Fine Sand
Fine Grey Sand
Fine Sand
Coarse Sand with some Gravel and Boulders
Fine Grey Sand
old Slough
Coarse Grey Sand with some Gravel
Medium Fine Sand
Coarse Sand and Gravel
Estimated Bearing Power of this Stratum - 2 ton per square foot
Very Coarse Sand & Gravel.
Stiff Clay
Test hole #5
Test hole #4
Test hole #3
Test hole #2
Test hole #1
789
790
1
2
3
4
5
6
7
8
9
800
1
2
3
4
5
6
7

FED. RD. DIST. Nº	STATE	FED. AID PROJ. Nº	FISCAL YEAR	COUNTY	ROUTE	SECTION	SHEET Nº	TOTAL SHEETS
2	NEVADA	27	1932	CLARK	6	H4	8	16

REOPENED

STATE OF NEVADA
DEPARTMENT OF HIGHWAYS

SKETCH SHOWING
PROFILE & TEST DATA
AT
PROPOSED BRIDGE SITE OVER VIRGIN RIVER
NEAR
MESQUITE
Clark County, Route 6, Section H4

Bunkerville Bridge: Construction Plans (State of Nevada: Department of Transportation 1983)

2008 "As-Built Plans"

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	1

INDEX OF SHEETS

1	TITLE SHEET
1A	LOCATION SKETCH
2	TYPICAL SECTIONS & SPECIAL DETAILS
3-3B	GENERAL NOTES, SUMMARIES AND ESTIMATE OF QUANTITIES
4-5	PLAN & PROFILE
6	FRONTAGE ROADS PLAN & PROFILE
7-8	DETOUR "D1" & "D2" PLAN & PROFILE
9-10	SPECIAL DETAILS
TC1-TC4	TRAFFIC CONTROL PLAN
B1-B19	BRIDGE SHEETS
S1-S2	STRUCTURE LIST

SEE BOOK OF STANDARD PLANS FOR ROAD AND BRIDGE CONSTRUCTION, 1983 EDITION.

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

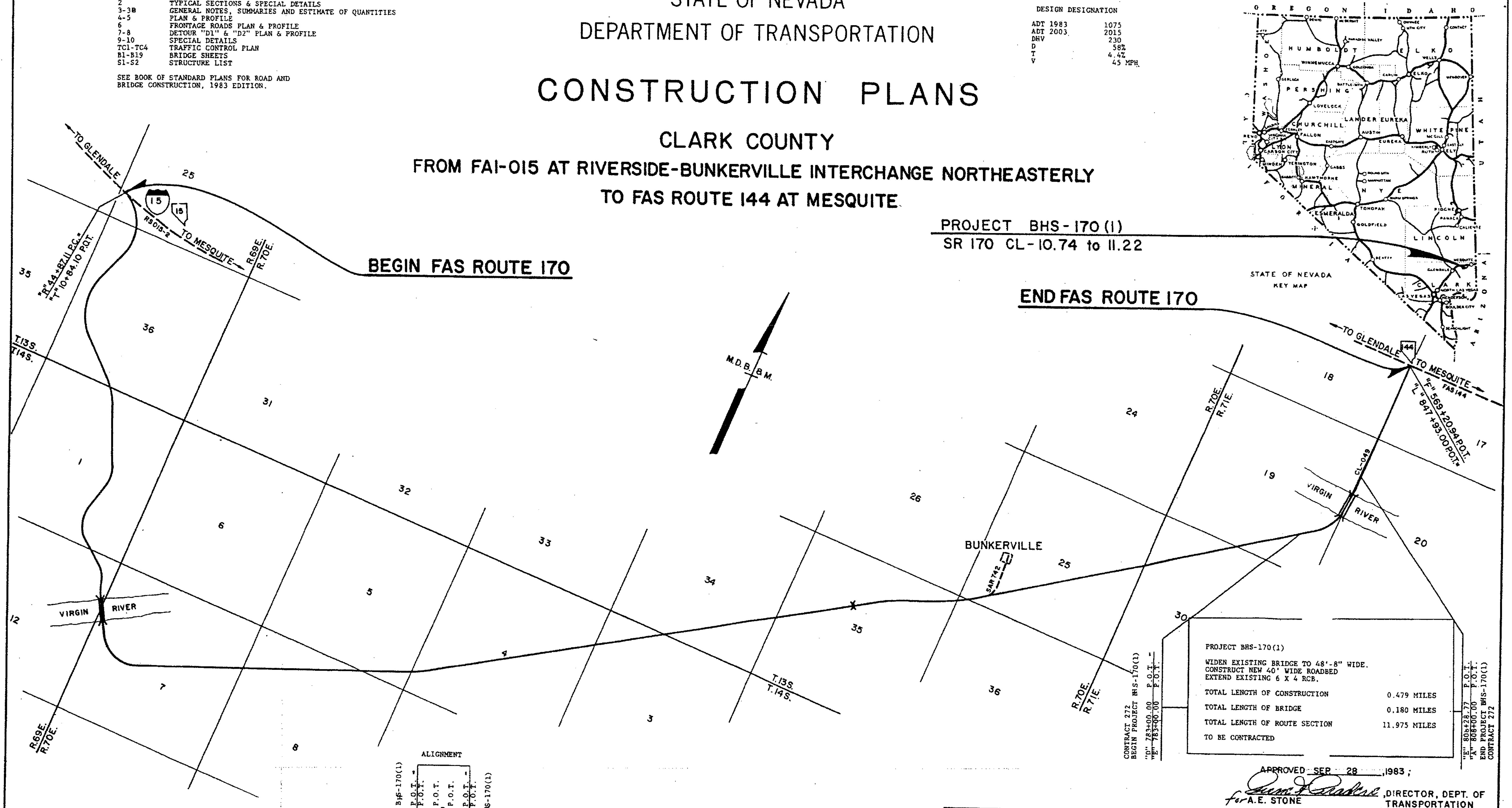
CONSTRUCTION PLANS

CLARK COUNTY
FROM FAI-015 AT RIVERSIDE-BUNKERVILLE INTERCHANGE NORTHEASTERLY TO FAS ROUTE 144 AT MESQUITE

DESIGN DESIGNATION

ADT 1983	1075
ADT 2003	2015
DHV	230
D	58%
T	4.4%
V	45 MPH

PROJECT BHS-170(1)
SR 170 CL-10.74 to 11.22



O R E G O N
I D A H O
HUMBOLDT
ELKO
PERSHING
CHURCHILL
LANDER
EUREKA
WHITE PINE
NYE
ESMERALDA
LINCOLN
CLARK
MINERAL
WINNEMUCCA
LOVELOCK
FALLON
AUSTIN
ELY
TONOPAH
GOLDFIELD
CARSON CITY
RENO
LAS VEGAS
STATE OF NEVADA KEY MAP
TO GLENDALE
TO MESQUITE
15
RS015-2
R.69E.
R.70E.
"R" 44+87.11 P.C.
"T" 10+84.10 P.O.T.
BEGIN FAS ROUTE 170
END FAS ROUTE 170
TO GLENDALE
144
TO MESQUITE
FAS 144
"F" 569+20.94 P.O.T.
"L" 847+93.00 P.O.T.
CL-049
M.D.B.& M.
T.13S.
T.14S.
R.70E.
R.71E.
VIRGIN RIVER
BUNKERVILLE
SAR 742
35
36
25
31
1
32
6
33
5
34
4
35
36
3
7
8
12
26
25
24
18
19
20
17
30

ALIGNMENT

BEGIN PROJECT BHS-170(1)
"D" 783+00.00 P.O.T.
"E" 783+00.00 P.O.T.
"E" 793+06.98 P.O.T.
BRIDGE NO.89
"E" 802+58.98 P.O.T.
"E" 808+28.77 P.O.T.
"A" 808+00.00 P.O.T.
END PROJECT BHS-170(1)

0 1/4 1/2
STATUTE MILE

CONTRACT 272
BEGIN PROJECT BHS-170(1)
"D" 783+00.00 P.O.T.
"E" 783+00.00 P.O.T.

PROJECT BHS-170(1)

WIDEN EXISTING BRIDGE TO 48'-8" WIDE.
CONSTRUCT NEW 40' WIDE ROADBED
EXTEND EXISTING 6 X 4 RCB.

TOTAL LENGTH OF CONSTRUCTION	0.479 MILES
TOTAL LENGTH OF BRIDGE	0.180 MILES
TOTAL LENGTH OF ROUTE SECTION TO BE CONTRACTED	11.975 MILES

"E" 808+28.77 P.O.T.
"A" 808+00.00 P.O.T.
END PROJECT BHS-170(1)
CONTRACT 272

REDUCED PLANS
SCALES REDUCED ACCORDINGLY

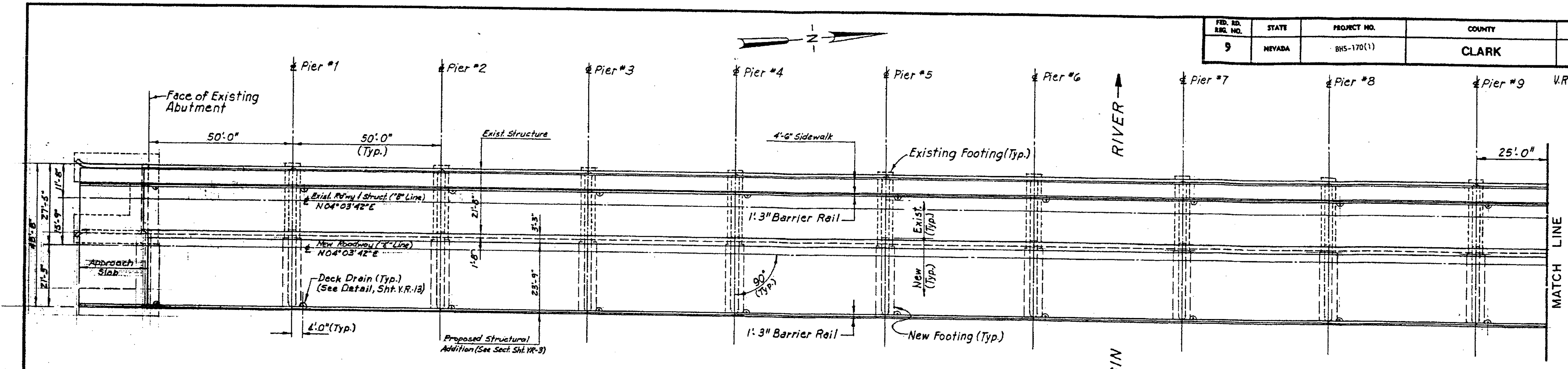
APPROVED SEP. 28, 1983;

for A.E. STONE, DIRECTOR, DEPT. OF TRANSPORTATION

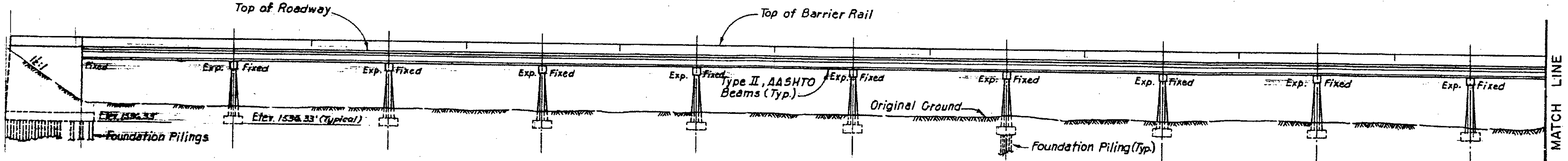
RICHARD H. BRYAN, CHAIRMAN
BRIAN McKAY
DARREL R. DAINES
BOARD OF DIRECTORS

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-1

V.R.-1


N
℄ Pier #1
℄ Pier #2
℄ Pier #3
℄ Pier #4
℄ Pier #5
℄ Pier #6
℄ Pier #7
℄ Pier #8
℄ Pier #9
Face of Existing Abutment
50'-0"
50'-0" (Typ.)
Exist. Structure
4'-6" Sidewalk
Existing Footing (Typ.)
25'-0"
RIVER
VIRGIN
MATCH LINE
48'-8"
27'-5"
11'-8"
15'-9"
21'-5"
Approach Slab
℄ Exist. Rd'wy / Struct. ("B" Line) N04°03'42"E
℄ New Roadway ("E" Line) N04°03'42"E
21'-8"
1'-8"
31'-3"
23'-9"
1'-3" Barrier Rail
Exist. (Typ.)
New (Typ.)
90° (Typ.)
Deck Drain (Typ.) (See Detail, Sht. V.R.-13)
4'-0" (Typ.)
Proposed Structural Addition (See Sect. Sht. YR-3)
1'-3" Barrier Rail
New Footing (Typ.)

PLAN VIEW


Top of Roadway
Top of Barrier Rail
12:1
Fixed
Exp.
Fixed
Exp.
Fixed
Exp.
Fixed
Exp.
Fixed
Type II, AASHTO Beams (Typ.)
Exp.
Fixed
Exp.
Fixed
Exp.
Fixed
Exp.
Fixed
Exp.
Fixed
Elev. 1536.33
Elev. 1536.33' (Typical)
Foundation Pilings
Original Ground
Foundation Piling (Typ.)
MATCH LINE

ELEVATION

NOTE:
Ordinary High Water Elev. = 1544.00

STRUCTURAL DESIGN DIVSION

DESIGN	BY: Crawford	✓	BY: Verma
DRAWING	BY: Parker	✓	BY: Crawford
QUANTITIES	BY: Crawford	✓	BY: Verma

Date: October 1983

APPROVED:
Floyd J. Marcucci
PRINCIPAL BRIDGE DESIGN ENGINEER
Alfred H. Weitzel
ASSISTANT CHIEF BRIDGE ENGINEER
CHIEF BRIDGE ENGINEER

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

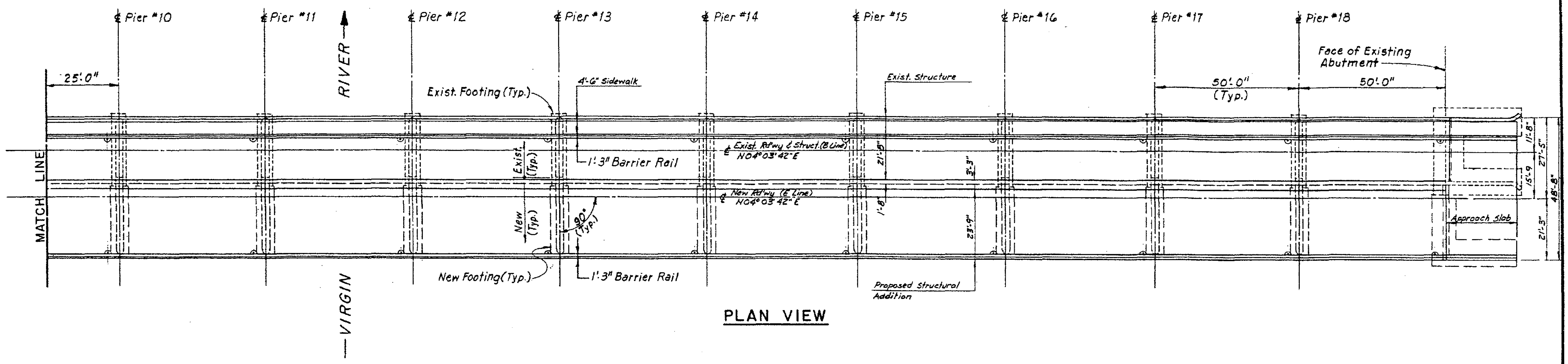
VIRGIN RIVER BRIDGE
NEAR MESQUITE

B-89

DRAWING
TRACING

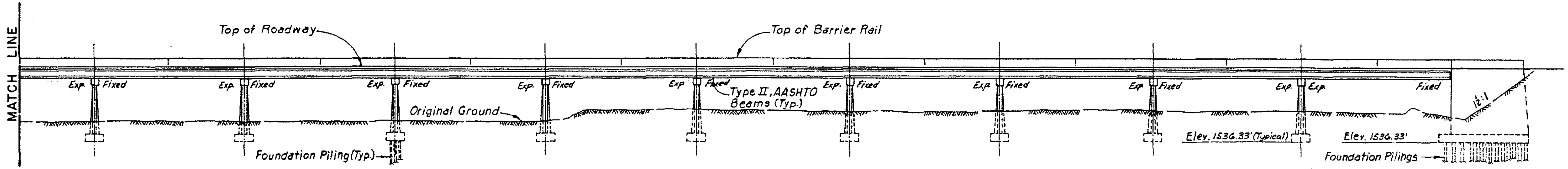
FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-2

V.R.-2



℄ Pier #10
℄ Pier #11
℄ Pier #12
℄ Pier #13
℄ Pier #14
℄ Pier #15
℄ Pier #16
℄ Pier #17
℄ Pier #18
25'-0"
RIVER
VIRGIN
MATCH LINE
Exist. Footing (Typ.)
4'-6" Sidewalk
1'-3" Barrier Rail
Exist. (Typ.)
New (Typ.)
90° (Typ.)
New Footing (Typ.)
1'-3" Barrier Rail
℄ Exist. Rd'wy & Struct. (B Line) N04°03'42"E
℄ New Rd'wy (E Line) N04°03'42"E
Exist. Structure
21'-5"
1'-8"
31'-3"
23'-9"
Proposed Structural Addition
50'-0" (Typ.)
50'-0"
Face of Existing Abutment
Approach Slab
11'-8"
15'-9
27'-5"
48'-8"
21'-3"

PLAN VIEW



MATCH LINE
Top of Roadway
Top of Barrier Rail
Exp.
Fixed
Type II, AASHTO Beams (Typ.)
Original Ground
Foundation Piling (Typ.)
Elev. 1536.33' (Typical)
Elev. 1536.33'
Foundation Pilings
1½:1

ELEVATION

NOTE:
Ordinary High Water Elev. = 1544.00'

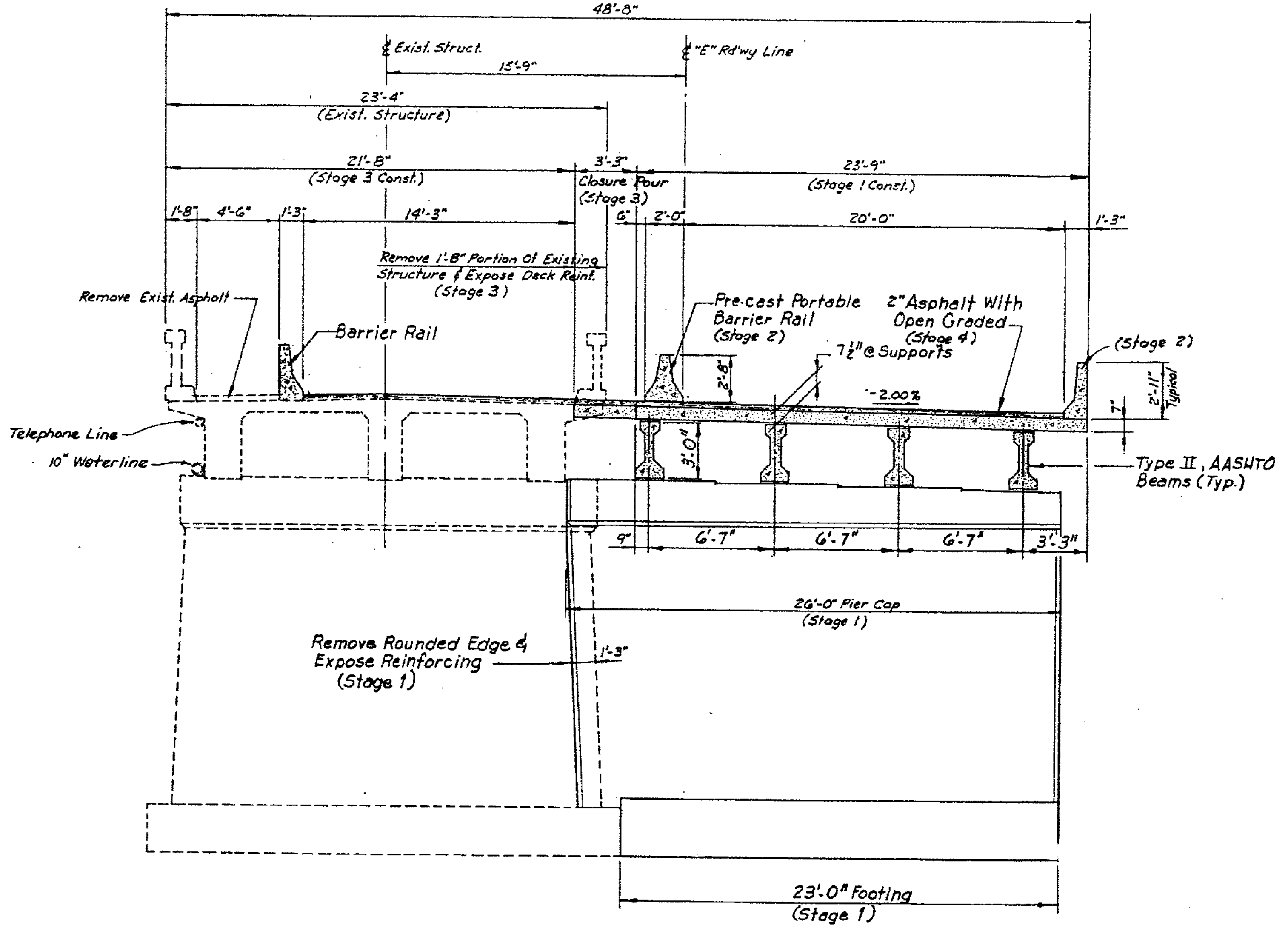
STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

VIRGIN RIVER BRIDGE
NEAR MESQUITE

B-89

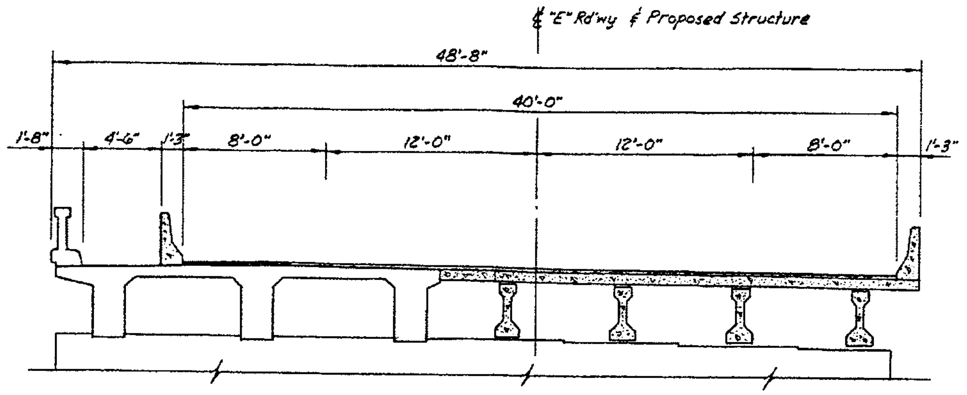
FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-3

V.R.-3


48'-8"
℄ Exist. Struct.
℄ "E" Rd'wy Line
15'-9"
23'-4"
(Exist. Structure)
21'-8"
(Stage 3 Const.)
3'-3"
Closure Pour
(Stage 3)
23'-9"
(Stage 1 Const.)
1'-8"
4'-6"
1'-3"
14'-3"
6"
2'-0"
20'-0"
1'-3"
Remove 1'-8" Portion Of Existing Structure & Expose Deck Reinf.
(Stage 3)
Remove Exist. Asphalt
Barrier Rail
Pre-cast Portable Barrier Rail
(Stage 2)
2" Asphalt With Open Graded
(Stage 4)
7½" @ Supports
(Stage 2)
2'-8"
-2.00%
2'-11" Typical
7"
3'-0"
Telephone Line
10" Waterline
Type II, AASHTO Beams (Typ.)
9"
6'-7"
6'-7"
6'-7"
3'-3"
26'-0" Pier Cap
(Stage 1)
Remove Rounded Edge & Expose Reinforcing
(Stage 1)
1'-3"
23'-0" Footing
(Stage 1)

TYPICAL SECTION

(LOOKING AHEAD ON LINE)


℄ "E" Rd'wy & ℄ Proposed Structure
48'-8"
40'-0"
1'-8"
4'-6"
1'-3"
8'-0"
12'-0"
12'-0"
8'-0"
1'-3"

PROPOSED STRUCTURE

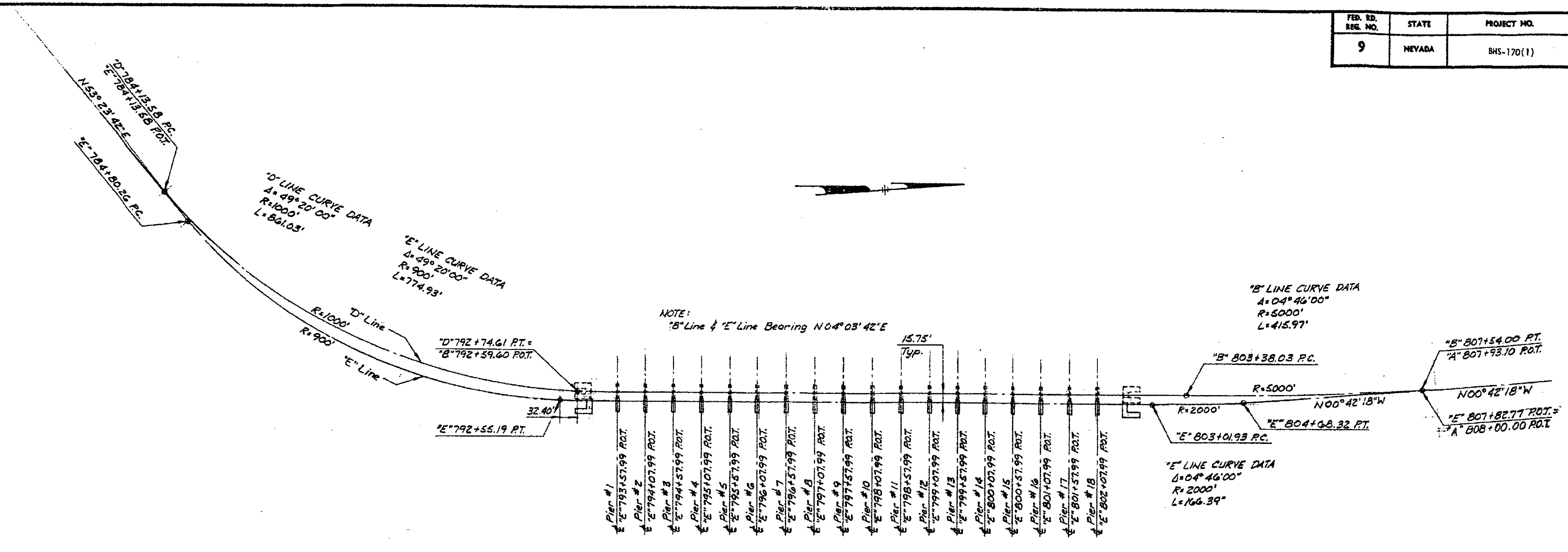
NOTE: Original Construction On Contract 252

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

VIRGIN RIVER BRIDGE
NEAR MESQUITE

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-4

VR-4


"D" 784+13.58 P.C.
"E" 784+13.58 P.O.T.
N53° 23' 42" E
"E" 784+80.26 P.C.
"D" LINE CURVE DATA
Δ= 49° 20' 00"
R=1000'
L=861.03'
"E" LINE CURVE DATA
Δ= 49° 20' 00"
R=900'
L=774.93'
R=1000'
"D" Line
R=900'
"E" Line
"D" 792+74.61 P.T. =
"B" 792+59.60 P.O.T.
32.40'
"E" 792+55.19 P.T.
NOTE:
"B" Line & "E" Line Bearing N 04° 03' 42" E
15.75' Typ.
℄ Pier #1 ℄ "E" 793+57.99 P.O.T.
℄ Pier #2 ℄ "E" 794+07.99 P.O.T.
℄ Pier #3 ℄ "E" 794+57.99 P.O.T.
℄ Pier #4 ℄ "E" 795+07.99 P.O.T.
℄ Pier #5 ℄ "E" 795+57.99 P.O.T.
℄ Pier #6 ℄ "E" 796+07.99 P.O.T.
℄ Pier #7 ℄ "E" 796+57.99 P.O.T.
℄ Pier #8 ℄ "E" 797+07.99 P.O.T.
℄ Pier #9 ℄ "E" 797+57.99 P.O.T.
℄ Pier #10 ℄ "E" 798+07.99 P.O.T.
℄ Pier #11 ℄ "E" 798+57.99 P.O.T.
℄ Pier #12 ℄ "E" 799+07.99 P.O.T.
℄ Pier #13 ℄ "E" 799+57.99 P.O.T.
℄ Pier #14 ℄ "E" 800+07.99 P.O.T.
℄ Pier #15 ℄ "E" 800+57.99 P.O.T.
℄ Pier #16 ℄ "E" 801+07.99 P.O.T.
℄ Pier #17 ℄ "E" 801+57.99 P.O.T.
℄ Pier #18 ℄ "E" 802+07.99 P.O.T.
"B" LINE CURVE DATA
Δ= 04° 46' 00"
R=5000'
L=415.97'
"B" 803+38.03 P.C.
R=5000'
R=2000'
N00° 42' 18" W
"E" 804+68.32 P.T.
"E" 803+01.93 P.C.
"E" LINE CURVE DATA
Δ=04° 46' 00"
R=2000'
L=166.39"
"B" 807+54.00 P.T.
"A" 807+93.10 P.O.T.
N00° 42' 18" W
"E" 807+82.77 P.O.T. =
"A" 808+00.00 P.O.T.

GEOMETRICS

—— GENERAL NOTES ——

1. DESIGN SPECIFICATIONS: AASHTO "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 1977," AND "INTERIM SPECIFICATIONS THROUGH 1981".
2. CONSTRUCTION SPECIFICATIONS: STATE OF NEVADA DEPARTMENT OF HIGHWAYS "STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, 1976," EXCEPT AS NOTED BELOW, AND IN THE SPECIAL PROVISIONS FOR THIS CONTRACT.
3. LIVE LOAD: STANDARD HS 20-44 OR ALTERNATE LOADING.
4. CONCRETE: ALL CONCRETE SHALL BE CLASS A MODIFIED (MAJOR), ULTIMATE COMPRESSIVE STRENGTH f'_c = 4000 psi AT 28 DAYS, UNLESS OTHERWISE NOTED.
5. REINFORCING STEEL: ALL REINFORCING STEEL TO BE ASTM A615 GRADE 60. DIMENSIONS RELATING TO BAR SPACING ARE CENTER TO CENTER. BENDING DIMENSIONS ARE FROM OUT TO OUT OF BARS. BAR SIZES THREE (3) TO NINE (9) ARE INDICATED BY THE FIRST NUMBER IN THE MARK. TEN (10) OR LARGER BY THE FIRST TWO NUMBERS.
6. CAMBER: THE CAMBER SHALL BE AS SHOWN ON THE PLANS.
7. PILING: ALL ABUTMENT AND PIER FOOTINGS SHALL BE FOUNDED ON 70 TON HP 12 x 53 STEEL PILES.
8. STRUCTURAL STEEL: ALL STRUCTURAL STEEL TO BE ASTM A-36.
9. FINE SURFACE FINISH: THE TOP AND INSIDE FACES OF THE BARRIER RAIL SHALL BE FINE SURFACE FINISHED. THE COLOR OF THE FINE SURFACE FINISH SHALL CONFORM TO FEDERAL COLOR NO. 37875 AS SHOWN IN TABLE IX OF FEDERAL STANDARD NO. 595a.
10. CONSTRUCTION TYPE CODE: X081.

NOTE: THE ELEVATIONS AS SHOWN ON THESE PLANS ARE APPROXIMATE AND MUST BE VERIFIED IN THE FIELD. ALL QUANTITIES ARE BASED ON THESE ELEVATIONS.

—— QUANTITIES ——

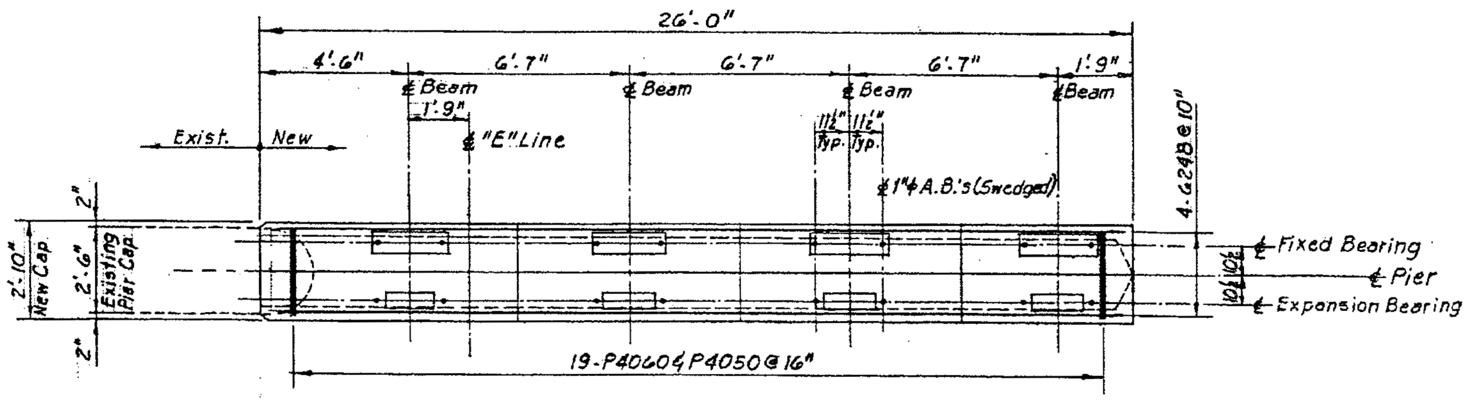
ITEM	UNIT	QUANTITY
REMOVAL OF PORTION OF BRIDGE	LUMP SUM	--
REMOVAL OF BITUMINOUS SURFACE	SQ. YD.	2,216
STRUCTURE EXCAVATION	CU. YD.	2,975
BACKFILL	CU. YD.	2,470
PAVEMENT REINFORCING FABRIC	SQ. YD.	320
DRILL HOLE (2-INCH DIAMETER)	EACH	20
CONCRETE BRIDGE DECK REPAIR	F. A.	--
CLASS A CONCRETE, MODIFIED (MAJOR)	CU. YD.	1,943.3
FINE SURFACE FINISH	SQ. YD.	762
50 - FOOT PRECAST CONCRETE MEMBER	EACH	76
REINFORCING STEEL	POUND	310,780
STRUCTURAL STEEL	POUND	22,430
FURNISH STEEL PILES	LIN. FOOT	5,218
DRIVE STEEL PILES	EACH	188

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

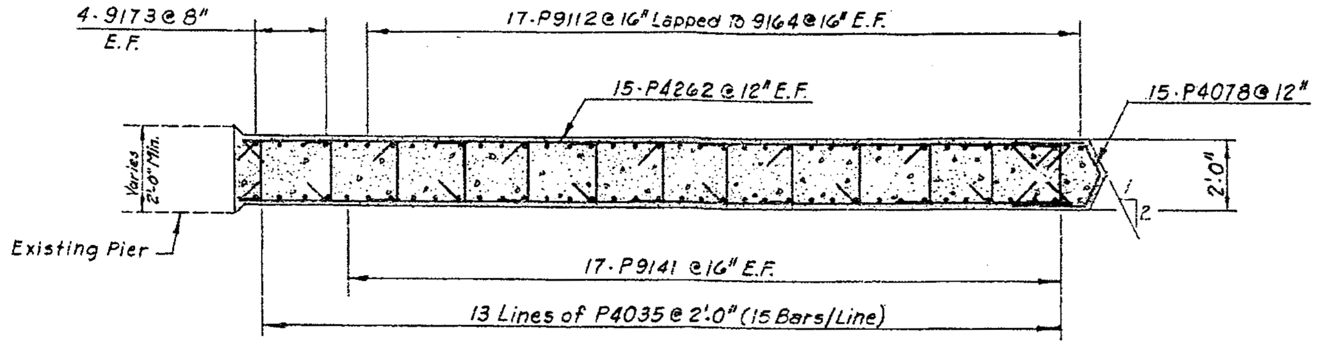
GEOMETRICS

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-8

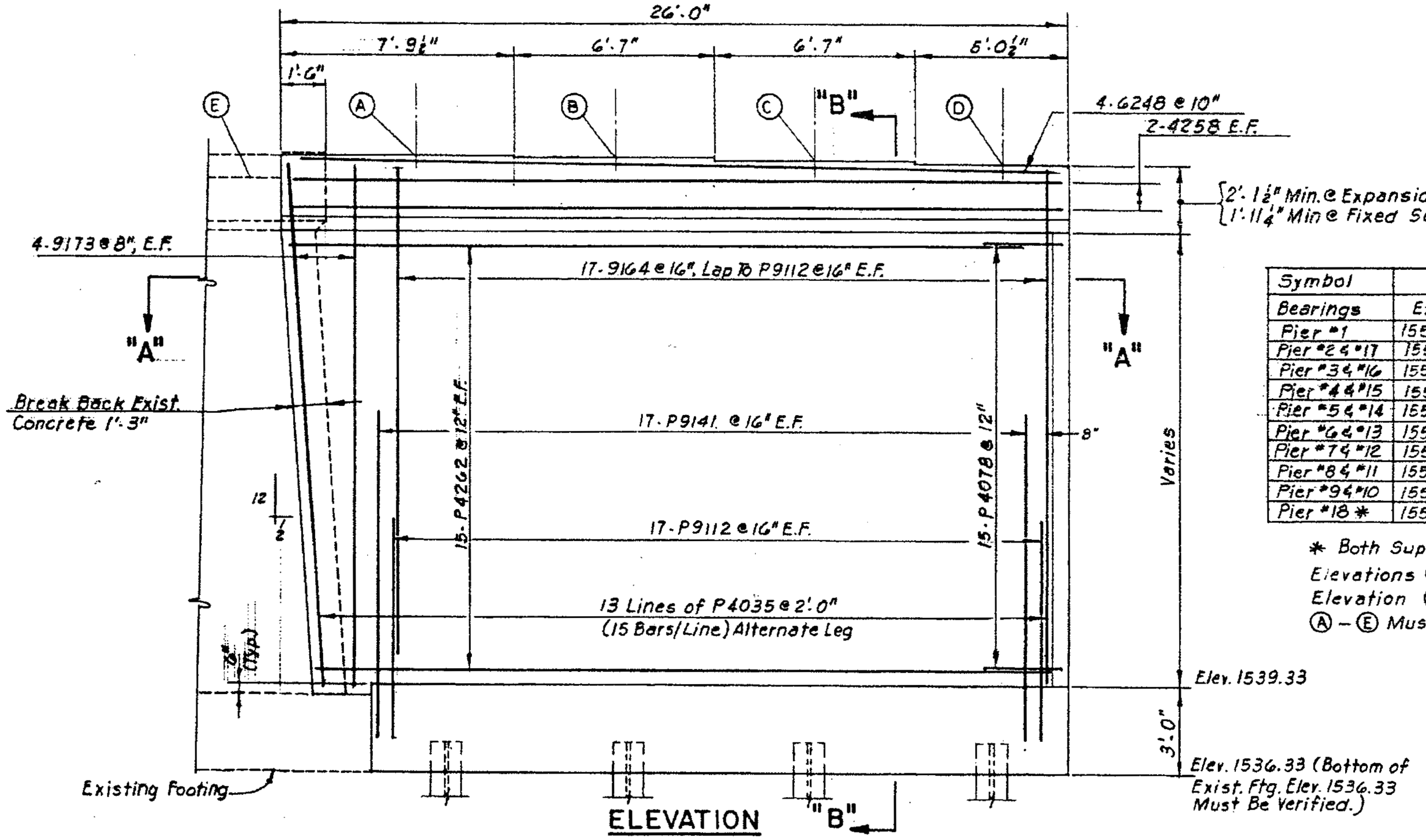
V.R.-8


26'-0"
4'-6"
6'-7"
6'-7"
6'-7"
1'-9"
℄ Beam
℄ Beam
℄ Beam
℄ Beam
1'-9"
℄ "E" Line
1½" Typ.
1½" Typ.
1"⌀ A.B.'s (Swedged)
Exist.
New
4-6248 @ 10"
2"
2'-10" New Cap
2'-6" Existing Pier Cap
2"
10½
10½
℄ Fixed Bearing
℄ Pier
℄ Expansion Bearing
19-P4060 & P4050 @ 16"

PLAN VIEW


4-9173 @ 8" E.F.
17-P9112 @ 16" Lapped To 9164 @ 16" E.F.
15-P4262 @ 12" E.F.
15-P4078 @ 12"
Varies 2'-0" Min.
2'-0"
1
2
Existing Pier
17-P9141 @ 16" E.F.
13 Lines of P4035 @ 2'-0" (15 Bars/Line)

SECTION "A-A"


26'-0"
7'-9½"
6'-7"
6'-7"
5'-0½"
1'-6"
Ⓔ
Ⓐ
Ⓑ
Ⓒ
"B"
Ⓓ
4-6248 @ 10"
2-4258 E.F.
2'-1½" Min. @ Expansion Supports
1'-11¼" Min @ Fixed Supports
4-9173 @ 8", E.F.
17-9164 @ 16", Lap To P9112 @ 16" E.F.
"A"
"A"
Break Back Exist. Concrete 1'-3"
17-P9141 @ 16" E.F.
15-P4262 @ 12" E.F.
15-P4078 @ 12"
8"
Varies
12
2
17-P9112 @ 16" E.F.
13 Lines of P4035 @ 2'-0"
(15 Bars/Line) Alternate Leg
¾" (Typ.)
Elev. 1539.33
3'-0"
Elev. 1536.33 (Bottom of Exist. Ftg. Elev. 1536.33 Must Be Verified.)
Existing Footing
"B"

ELEVATION

Symbol	Ⓐ		Ⓑ		Ⓒ		Ⓓ		Ⓔ
Bearings	Exp.	Fixed	Exp.	Fixed	Exp.	Fixed	Exp.	Fixed	Exist. Exp
Pier #1	1556.60	1556.42	1556.47	1556.28	1556.34	1556.15	1556.21	1556.02	1555.58
Pier #2 & #17	1556.72	1556.54	1556.59	1556.40	1556.46	1556.27	1556.33	1556.14	1555.70
Pier #3 & #16	1556.83	1556.64	1556.70	1556.51	1556.57	1556.98	1556.43	1556.25	1555.81
Pier #4 & #15	1556.92	1556.73	1556.79	1556.60	1556.66	1556.47	1556.52	1556.34	1555.90
Pier #5 & #14	1556.99	1556.81	1556.86	1556.67	1556.73	1556.54	1556.60	1556.41	1555.97
Pier #6 & #13	1557.05	1556.87	1556.92	1556.73	1556.79	1556.60	1556.66	1556.47	1556.03
Pier #7 & #12	1557.10	1556.91	1556.97	1556.78	1556.84	1556.65	1556.70	1556.52	1556.08
Pier #8 & #11	1557.13	1556.94	1557.00	1556.81	1556.87	1556.68	1556.73	1556.55	1556.11
Pier #9 & #10	1557.14	1556.96	1557.01	1556.82	1556.88	1556.69	1556.75	1556.56	1556.12
Pier #18 *	1556.60	1556.60*	1556.47*	1556.47*	1556.34*	1556.34*	1556.21*	1556.21*	1555.58*

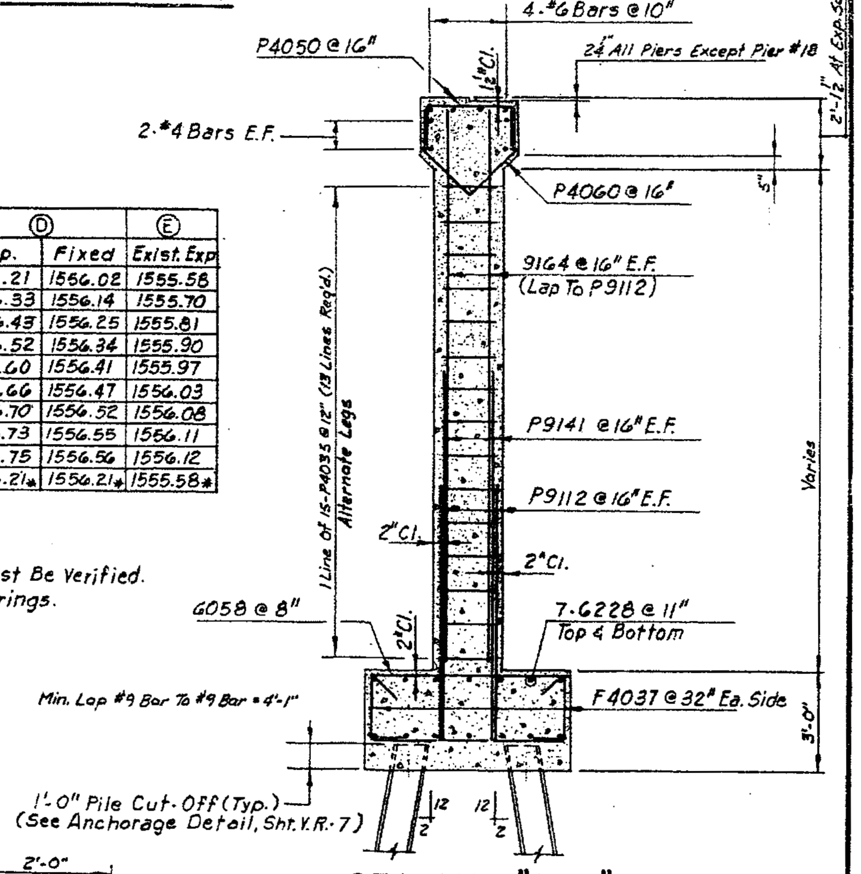
* Both Supports Are Expansion.

Elevations Ⓐ Ⓑ Ⓒ Ⓓ Are New Beam Seat Elevations.

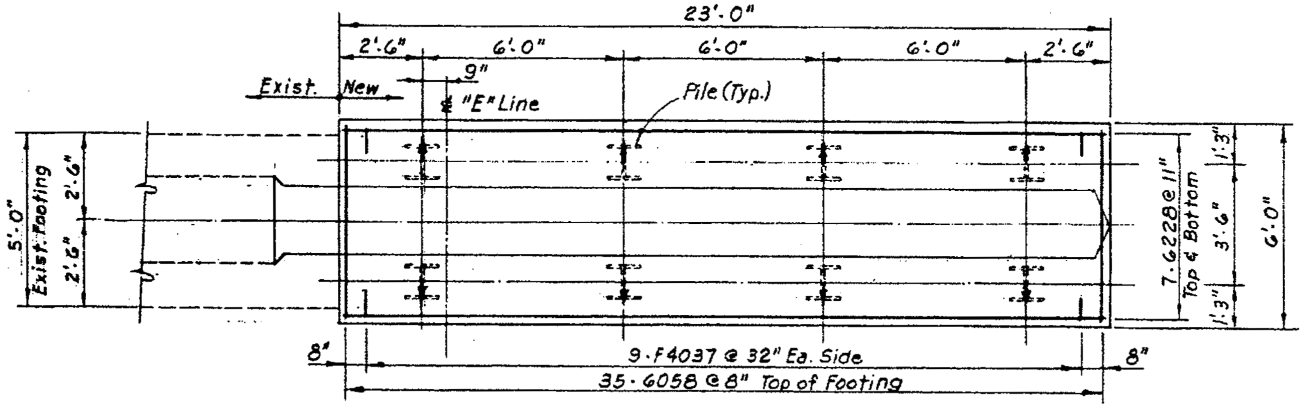
Elevation Ⓔ Is The Existing Expansion Seat Elevations And Must Be Verified.

Ⓐ – Ⓔ Must Equal 12¼" For Exp. Bearings And 10" For Fixed Bearings.

PIER SEAT ELEVATIONS


4-#6 Bars @ 10"
P4050 @ 16"
1½" Cl.
2¼" All Piers Except Pier #18
2'-1½" At Exp. Supports
1"
2-#4 Bars E.F.
P4060 @ 16"
5"
9164 @ 16" E.F. (Lap To P9112)
1 Line of 15-P4035 @ 12" (13 Lines Req'd.) Alternate Legs
P9141 @ 16" E.F.
P9112 @ 16" E.F.
Varies
2" Cl.
2" Cl.
6058 @ 8"
2" Cl.
7-6228 @ 11" Top & Bottom
Min. Lap #9 Bar To #9 Bar = 4'-1"
F4037 @ 32" Ea. Side
3'-0"
1'-0" Pile Cut-Off (Typ.)
(See Anchorage Detail, Sht. V.R.-7)
12
2
12
2

SECTION "B-B"

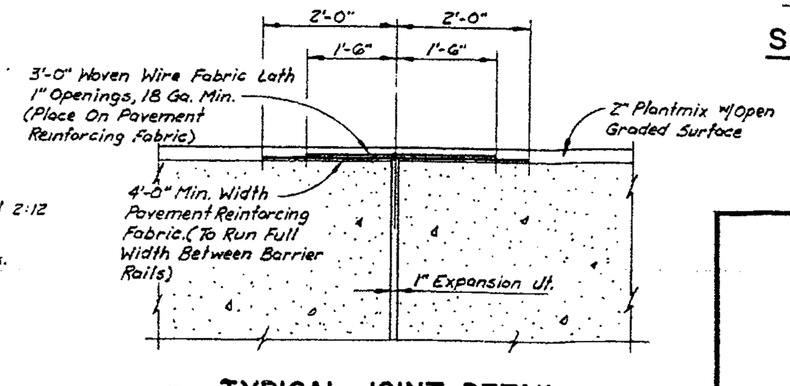

23'-0"
2'-6"
6'-0"
6'-0"
6'-0"
2'-6"
9"
Exist.
New
℄ "E" Line
Pile (Typ.)
5'-0" Exist. Footing
2'-6"
2'-6"
7-6228 @ 11" Top & Bottom
1'-3"
3'-6"
1'-3"
6'-0"
8"
8"
9-F4037 @ 32" Ea. Side
35-6058 @ 8" Top of Footing

FOOTING PLAN

NOTE:

Indicate Pile To Be Battered 2:12

See Sht. V.R.-5 For Pile Notes.


2'-0"
2'-0"
1'-6"
1'-6"
3'-0" Woven Wire Fabric Lath 1" Openings, 18 Ga. Min. (Place On Pavement Reinforcing Fabric)
2" Plantmix w/Open Graded Surface
4'-0" Min. Width Pavement Reinforcing Fabric. (To Run Full Width Between Barrier Rails)
1" Expansion Jt.

—TYPICAL JOINT DETAIL—

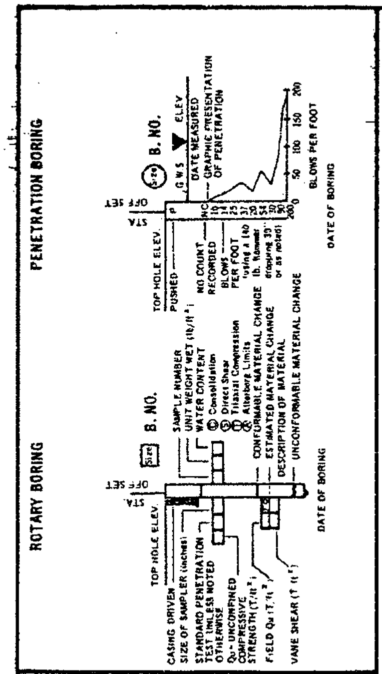
(18 LOCATIONS AT PIERS)

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION

PIER DETAILS

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-16

NOTE: FOUNDATION REPORT AVAILABLE FOR CONTRACTORS STUDY
IN DISTRICT OFFICE AND MATERIALS & TESTING DIVISION


ROTARY BORING
PENETRATION BORING
TOP HOLE ELEV.
STA.
OFF SET
Size
B. NO.
CASING DRIVEN
SIZE OF SAMPLER (inches)
STANDARD PENETRATION TEST UNLESS NOTED OTHERWISE
Qu - UNCONFINED COMPRESSIVE STRENGTH (T/ft²)
FIELD Qu (T/ft²)
VANE SHEAR (T/ft²)
SAMPLE NUMBER
UNIT WEIGHT WET (lb/ft³)
WATER CONTENT
Consolidation
Direct Shear
Triaxial Compression
Atterberg Limits
CONFORMABLE MATERIAL CHANGE
ESTIMATED MATERIAL CHANGE
DESCRIPTION OF MATERIAL
UNCONFORMABLE MATERIAL CHANGE
DATE OF BORING
PUSHED
NO COUNT RECORDED
BLOWS PER FOOT (using a 140 lb. Hammer dropping 30" or as noted)
P
NC
G.W.S.
ELEV.
DATE MEASURED
GRAPHIC PRESENTATION OF PENETRATION
0
50
100
150
200
BLOWS PER FOOT
DATE OF BORING

● PLAN OF ANY BORING
◉ 2" CONE PENETROMETER
□ ROTARY BORING (WET)
▣ AUGER BORING (DRY)
◇ DIAMOND CORE BORING
⌜⌟ TEST PIT
BIT SIZE (O.D.) "AX" - 1-13/16", "BX" - 2-9/32", "NX" - 2-29/32"
CASING SIZES (O.D.) "BX" - 2-7/8", "NX" - 3-1/2"

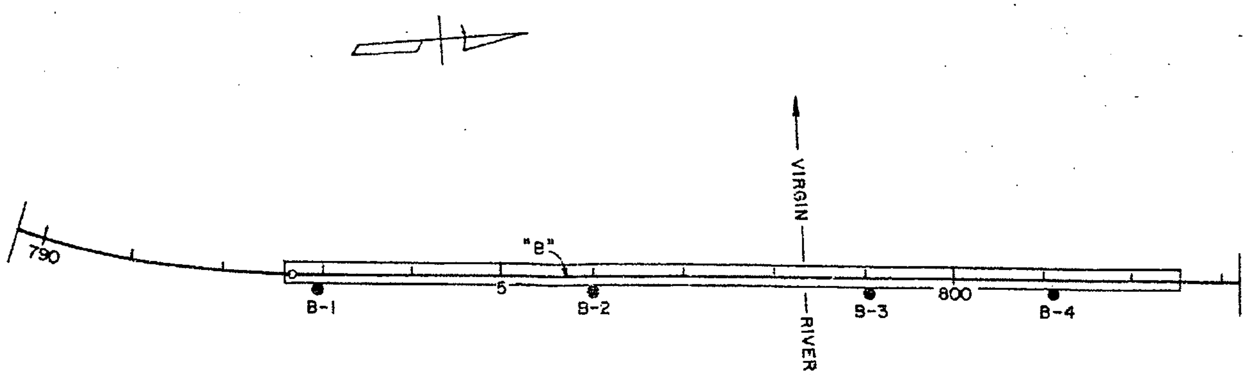
STANDARD PENETRATION CLASSIFICATION

GRANULAR SOIL		CLAYEY SOIL	
BLOWS/FT. *	DENSITY	BLOWS/FT. *	CONSISTENCY
0-4	VERY LOOSE	0-1	VERY SOFT
5-10	LOOSE	2-4	SOFT
	MEDIUM DENSE	5-8	MEDIUM STIFF
25-50	DENSE	9-15	STIFF
OVER 50	VERY DENSE	16-30	VERY STIFF
		31-60	HARD
		OVER 60	VERY HARD

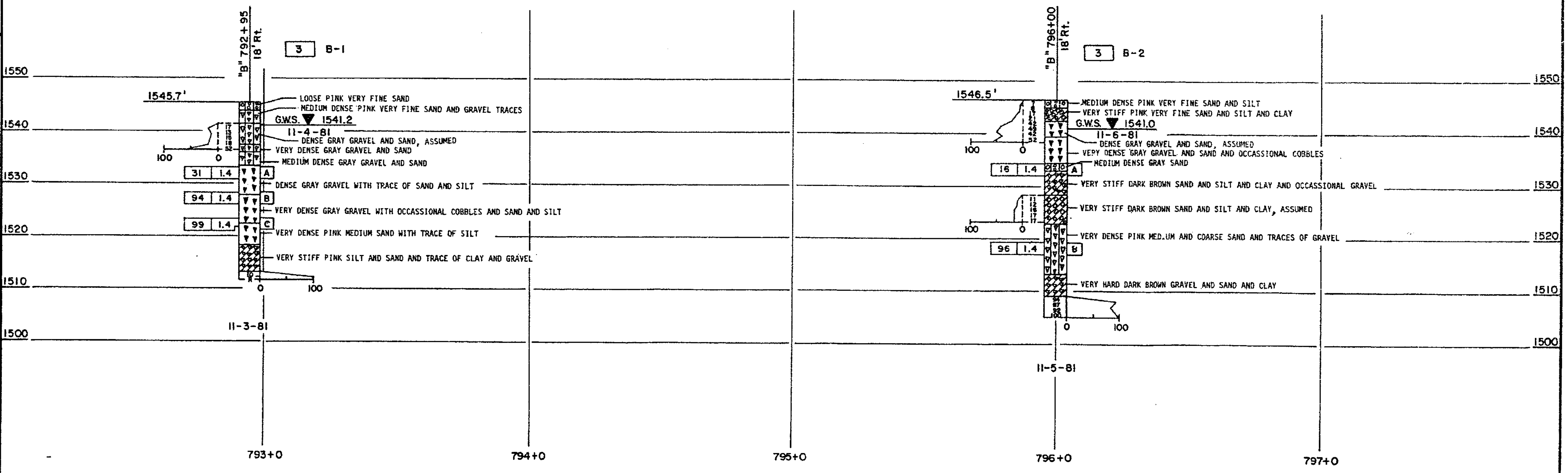
* STANDARD PENETRATION TEST (N) 140 lb. HAMMER, 30" FREE FALL ON 2" O.D. x 1 3/8" I.D. SAMPLER

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYM	DESCRIPTION
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW		WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP		POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC		CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES.
	SAND AND SANDY SOIL	SW		WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP		POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM		SILTY SAND, SAND SILT MIXTURES.
		SC		CLAYEY SAND, SAND-CLAY MIXTURES.
FINE GRAINED MATERIAL	SILTS AND CLAYS LL < 50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY
		OL		ORGANIC SILT AND ORGANIC SILTY-CLAY OF LOW PLASTICITY
	SILTS AND CLAYS LL > 50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS
		CE		CALICHE


790
"B"
5
800
B-1
B-2
B-3
B-4
VIRGIN
RIVER

BORING PLAN


"B" 792+95
18' Rt.
3
B-1
1545.7'
LOOSE PINK VERY FINE SAND
MEDIUM DENSE PINK VERY FINE SAND AND GRAVEL TRACES
G.W.S. 1541.2
11-4-81
DENSE GRAY GRAVEL AND SAND, ASSUMED
VERY DENSE GRAY GRAVEL AND SAND
MEDIUM DENSE GRAY GRAVEL AND SAND
17
13
15
18
52
100
0
31
1.4
A
DENSE GRAY GRAVEL WITH TRACE OF SAND AND SILT
94
1.4
B
VERY DENSE GRAY GRAVEL WITH OCCASSIONAL COBBLES AND SAND AND SILT
99
1.4
C
VERY DENSE PINK MEDIUM SAND WITH TRACE OF SILT
VERY STIFF PINK SILT AND SAND AND TRACE OF CLAY AND GRAVEL
0
100
11-3-81
"B" 796+00
18' Rt.
3
B-2
1546.5'
MEDIUM DENSE PINK VERY FINE SAND AND SILT
VERY STIFF PINK VERY FINE SAND AND SILT AND CLAY
G.W.S. 1541.0
11-6-81
DENSE GRAY GRAVEL AND SAND, ASSUMED
VERY DENSE GRAY GRAVEL AND SAND AND OCCASSIONAL COBBLES
MEDIUM DENSE GRAY SAND
100
0
16
1.4
A
VERY STIFF DARK BROWN SAND AND SILT AND CLAY AND OCCASSIONAL GRAVEL
VERY STIFF DARK BROWN SAND AND SILT AND CLAY, ASSUMED
11
12
16
17
17
100
0
VERY DENSE PINK MEDIUM AND COARSE SAND AND TRACES OF GRAVEL
96
1.4
B
VERY HARD DARK BROWN GRAVEL AND SAND AND CLAY
0
100
11-5-81
1550
1540
1530
1520
1510
1500
793+0
794+0
795+0
796+0
797+0

NEVADA DEPARTMENT OF TRANSPORTATION
MATERIALS AND TESTING DIVISION
Foundations and Engineering Section

VIRGIN RIVER BRIDGE No. 89

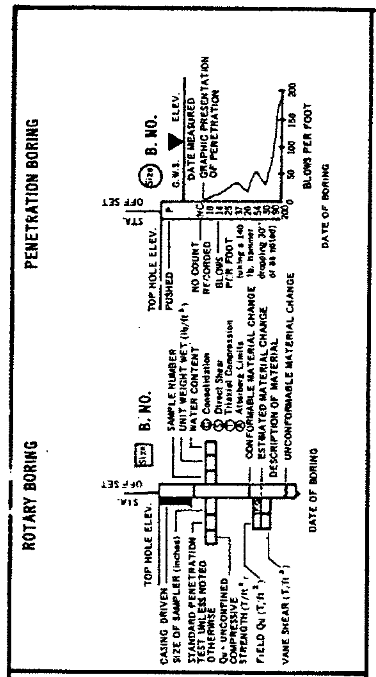
LOG OF TEST BORINGS

BRIDGE NO.	MILE POST	E.A. NO. 71076	SHEET 1	OF 2

Approval
Recommended by ________ Engineering Geologist

FED. RD. REG. NO.	STATE	PROJECT NO.	COUNTY	SHEET NO.
9	NEVADA	BHS-170(1)	CLARK	B-17

NOTE: FOUNDATION REPORT AVAILABLE FOR CONTRACTORS STUDY IN DISTRICT OFFICE AND MATERIALS & TESTING DIVISION


ROTARY BORING
PENETRATION BORING
TOP HOLE ELEV.
STA.
OFF SET
Size
B. NO.
CASING DRIVEN
SIZE OF SAMPLER (inches)
STANDARD PENETRATION TEST UNLESS NOTED OTHERWISE
Qu = UNCONFINED COMPRESSIVE STRENGTH (T/ft²)
FIELD Qu (T/ft²)
VANE SHEAR (T/ft²)
SAMPLE NUMBER
UNIT WEIGHT WET (lb/ft³)
WATER CONTENT
Consolidation
Direct Shear
Triaxial Compression
Atterberg Limits
CONFORMABLE MATERIAL CHANGE
ESTIMATED MATERIAL CHANGE
DESCRIPTION OF MATERIAL
UNCONFORMABLE MATERIAL CHANGE
DATE OF BORING
PUSHED
NO COUNT RECORDED
BLOWS PER FOOT (using a 140 lb. hammer dropping 30" or as noted)
P
NC
10
14
25
37
20
56
50
90
200
G.W.S.
ELEV.
DATE MEASURED
GRAPHIC PRESENTATION OF PENETRATION
0
50
100
150
200
BLOWS PER FOOT
DATE OF BORING

●	PLAN OF ANY BORING
◉	2" CONE PENETROMETER
▢	ROTARY BORING (WET)
⧈	AUGER BORING (DRY)
◇	DIAMOND CORE BORING
⌜ ⌝	TEST PIT

BIT SIZE (O.D.) "AX" = 1-13/16", "BX" = 2-9/32", "NX" = 2-29/32"
CASING SIZES (O.D.): "BX" = 2-7/8", "NX" = 3-1/2"

STANDARD PENETRATION CLASSIFICATION

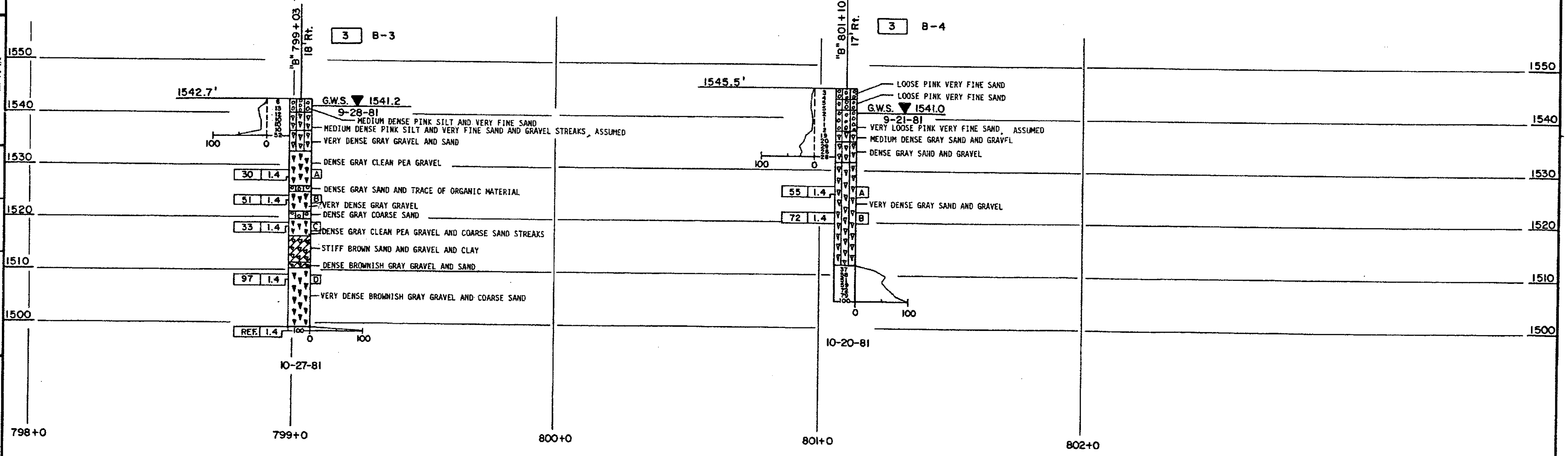
GRANULAR SOIL		CLAYEY SOIL	
BLOWS/FT.*	DENSITY	BLOWS/FT.*	CONSISTENCY
0-4	VERY LOOSE	0-1	VERY SOFT
5-10	LOOSE	2-4	SOFT
	MEDIUM DENSE	5-8	MEDIUM STIFF
25-50	DENSE	9-15	STIFF
OVER 50	VERY DENSE	16-30	VERY STIFF
		31-60	HARD
		OVER 60	VERY HARD

* STANDARD PENETRATION TEST (N) 140 lb. HAMMER, 30" FREE FALL ON 2" O.D. x 1 3/8" I.D. SAMPLER

THE UNIFIED SOIL CLASSIFICATION SYSTEM

	MAJ. DIV.	LETTER	SYM	DESCRIPTION
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW	▽	WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES LITTLE OR NO FINES.
		GP	▼	POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES. LITTLE OR NO FINES
		GM	▽	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC	▽	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES.
	SAND AND SANDY SOIL	SW	°	WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP	•	POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM	°	SILTY SAND, SAND SILT MIXTURES
		SC	°	CLAYEY SAND, SAND-CLAY MIXTURES
FINE GRAINED MATERIAL	SILTS AND CLAYS LL < 50	ML	☰	INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY.
		CL	▨	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL	☰	ORGANIC SILT AND ORGANIC SILTY-CLAY OF LOW PLASTICITY
		MH	☰	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
	SILTS AND CLAYS LL > 50	CH	▨	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
		OH	▨	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
		PT	≈	PEAT AND OTHER HIGHLY ORGANIC SOILS
		CE	☰	CALICHE

RECOMMENDED BY ——— *Engineering Geologist*


1550
1540
1530
1520
1510
1500
798+0
799+0
800+0
801+0
802+0
"B" 799+03
18' Rt.
3
B-3
1542.7'
G.W.S. 1541.2
9-28-81
8
13
12
15
10
10
52
100
0
MEDIUM DENSE PINK SILT AND VERY FINE SAND
MEDIUM DENSE PINK SILT AND VERY FINE SAND AND GRAVEL STREAKS, ASSUMED
VERY DENSE GRAY GRAVEL AND SAND
DENSE GRAY CLEAN PEA GRAVEL
30
1.4
A
DENSE GRAY SAND AND TRACE OF ORGANIC MATERIAL
51
1.4
B
VERY DENSE GRAY GRAVEL
DENSE GRAY COARSE SAND
33
1.4
C
DENSE GRAY CLEAN PEA GRAVEL AND COARSE SAND STREAKS
STIFF BROWN SAND AND GRAVEL AND CLAY
DENSE BROWNISH GRAY GRAVEL AND SAND
97
1.4
D
VERY DENSE BROWNISH GRAY GRAVEL AND COARSE SAND
REF.
1.4
100
0
100
10-27-81
"B" 801+10
17' Rt.
3
B-4
1545.5'
LOOSE PINK VERY FINE SAND
LOOSE PINK VERY FINE SAND
G.W.S. 1541.0
9-21-81
VERY LOOSE PINK VERY FINE SAND, ASSUMED
MEDIUM DENSE GRAY SAND AND GRAVEL
DENSE GRAY SAND AND GRAVEL
19
20
29
28
28
100
0
55
1.4
A
VERY DENSE GRAY SAND AND GRAVEL
72
1.4
B
37
73
79
100
0
100
10-20-81

NEVADA DEPARTMENT OF TRANSPORTATION
MATERIALS AND TESTING DIVISION
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VIRGIN RIVER BRIDGE No. 89

LOG OF TEST BORINGS

BRIDGE NO.	MILE POST	E.A. NO. 71076	SHEET 2	OF 2

REVISION DATES (PRELIMINARY STAGE ONLY)

Analytical Aerial Triangulation Summary (Horizon's Inc. 2005)

HORIZONS®
INCORPORATED

Analytical Aerial Triangulation Summary

BOR-Lower Colorado Region:
Virgin River, NV:
Horizons Project #12981:
Date7-27-05:

Horizons Incorporated acquired the aerial photography for this project utilizing a gyro stabilized wide-angle aerial camera that is equipped with forward motion compensation (HZ13, ZEISS RMK TOP15, SN: 145848, CFL: 153.435). This project was flown at an altitude of 20000' above the mean terrain elevation. During this photo mission Horizons, Inc acquired 4 flights of photography. The flights used for this adjustment were planned to have 60% forward overlap along the flight lines.

Kinematic GPS events are collected at one-second epochs utilizing an ASHTECH Z-12 dual frequency receiver onboard the aircraft. The antenna is mounted on top of the fuselage of the aircraft directly above the center of the camera. An ASHTECH Z-Surveyor dual frequency receiver was used as a static base station on the ground and was operating simultaneously during the photo mission. APPLANIX GRAPHNAV/POSGPS software was used for post processing of the airborne gps data. Differential corrections have been applied to the post-processed kinematic gps data for absolute geo-positioning of each exposure. The antenna phase center to camera station offset is applied to the post-processed airborne gps file supplied for the analytical aerial triangulation adjustment.

15 Post Identified surveyed ground control points were used to control this photo block. Each exposure required for the project was scanned utilizing a ZEISS PHOTOSCAN scanner at a 14-micron resolution. Digital stereo mensurations were collected for each scanned image using a LH SYSTEMS SOCET SET/ORIMA softcopy workstation. The final adjustment was made on the stereo mensurations using ORIMA software. Final adjusted ground control files and exterior orientation parameters for each exposure were output from the ORIMA adjustment.

The coordinate system for this project is as follows:

Horizontal Datum:	UTM Zone 11, NAD83
Vertical Datum:	NAVD88 (Geoid03)
Mapping Units:	meters

Summary of Adjustment Statistics:

Number of Control Points:	15
Number of Terrain Points:	192
Number of Images:	32
Number of Cameras:	1
Number of GPS Profiles:	1
Number of Add. Observations:	147

Summary of Ground Control Statistics

*This data is expressed in **meters***

Point#	Easting	Northing	Elevation	DX	DY	DZ
601	767028.427	4097811.964	655.227	-0.139	0.041	0.550
602	769115.802	4098602.098	736.059	-0.034	-0.144	-0.772
603	772098.821	4085522.924	594.574	0.413	-0.217	0.442
604	775523.878	4086487.300	609.236	-0.022	0.305	0.122
605	773992.841	4083224.165	630.188	-0.808	-1.606	-0.236
606	761485.771	4078744.303	502.265	-0.234	1.744	-0.075
607	762318.666	4075022.583	540.330	0.435	0.391	-0.251
608	747553.364	4070688.290	511.081	-0.646	0.825	0.395
609	751215.285	4069695.417	464.614	0.747	0.046	0.115
610	737076.518	4060211.211	551.072	0.005	-0.385	0.107
611	741197.189	4058739.383	429.180	1.500	-1.176	-0.216
612	735822.069	4051592.837	547.260	-1.380	-0.811	-0.292
613	740452.442	4044435.747	450.170	0.420	0.521	-0.061
614	736582.309	4036699.416	372.582	-1.768	0.911	0.211
615	740271.799	4038635.277	423.066	1.510	-0.444	-0.037

```
Maximum residuals at control points:

 X:     -1.7675    at Point ID: 614
 Y:      1.7439    at Point ID: 606
 Z:     -0.7719    at Point ID: 602

 RMS of changes at control points:

 X:      0.8869
 Y:      0.8208
 Z:      0.3261
```

Summary of ABGPS Statistics

This data is expressed in meters

Flt-Exp	Easting	Northing	Elev	DX	DY	DZ
1_001	737006.093	4035168.155	6555.593	-0.604	-0.063	-0.092
1_002	737348.777	4038630.748	6564.900	-0.336	0.338	-0.073
1_003	737703.463	4042086.305	6562.431	-0.042	0.044	0.070
1_004	738048.122	4045541.784	6560.515	-0.068	0.187	0.001
1_005	738402.716	4049000.069	6561.596	0.215	0.187	-0.143
1_006	738753.657	4052464.365	6557.608	0.707	-0.345	-0.006
1_007	739099.143	4055923.628	6556.308	0.313	-0.574	0.143
1_008	739481.080	4059382.152	6549.497	0.141	-0.481	-0.010
1_009	739853.242	4062843.210	6552.530	-0.464	0.219	-0.120
2_001	738439.478	4058108.483	6574.529	0.135	0.262	0.083
2_002	740796.130	4060665.893	6572.820	0.055	0.314	0.216
2_003	743176.205	4063208.763	6569.317	0.318	0.442	-0.098
2_004	745528.221	4065776.376	6570.286	-0.065	-0.249	0.084
2_005	747875.727	4068352.380	6578.026	-0.154	-0.675	0.079
2_006	750233.950	4070912.404	6573.894	-0.211	0.426	0.030
3_001	748348.203	4069311.538	6592.584	0.023	-0.400	-0.144
3_002	751407.265	4070984.237	6591.324	0.242	0.618	0.139
3_003	754459.665	4072669.658	6590.782	-0.179	-0.165	-0.202
3_004	757513.336	4074337.642	6589.668	-0.525	0.519	0.039
3_005	760563.365	4076027.936	6590.026	0.047	-0.067	-0.017
3_006	763616.686	4077697.376	6591.716	0.039	0.143	0.033
3_007	766669.518	4079371.348	6589.707	0.261	-0.063	-0.130
3_008	769719.976	4081043.573	6587.692	-0.217	-0.305	0.204
3_009	772763.658	4082725.132	6586.008	-0.007	0.073	0.312
3_010	775839.213	4084367.703	6567.316	0.630	1.029	-0.192
4_001	775609.683	4082429.375	6612.705	0.301	-0.771	0.051
4_002	774088.915	4085563.127	6604.972	0.566	-0.171	-0.241
4_003	772530.056	4088688.952	6606.925	0.078	0.063	0.048
4_004	771006.970	4091809.196	6593.105	0.196	-0.067	0.079
4_005	769470.556	4094939.876	6601.508	0.307	-0.421	-0.008
4_006	767919.387	4098060.140	6602.613	-0.539	0.003	0.060
4_007	766398.374	4101183.080	6601.243	-1.164	-0.051	-0.193

```
RMS-X:      0.381
RMS-Y:      0.388
RMS-Z:      0.130
```

Exterior Orientation Parameters

This data is expressed in meters and gons

Flt	Exp	Easting	Northing	Elev	Omega	Phi	Kappa
1	1	737005.667	4035168.575	6557.051	-0.6698304	-0.5924188	-107.5098493
1	2	737348.621	4038631.614	6566.461	-1.3422864	-0.8986364	-112.7149187
1	3	737703.604	4042086.924	6564.219	-0.1592219	-1.5053274	-112.4471134
1	4	738048.239	4045542.593	6562.317	-0.9495064	-0.9627342	-110.2886720
1	5	738403.119	4049000.923	6563.337	-1.3091858	-1.4404412	-108.5942723
1	6	738754.554	4052464.734	6559.570	-0.4276543	-0.8439708	-108.1354043
1	7	739099.649	4055923.814	6558.503	-0.5186959	-0.7270433	-108.0851431
1	8	739481.417	4059382.477	6551.623	-0.5102649	-1.2473172	-108.6153749
1	9	739852.976	4062844.282	6554.630	-0.0892344	-0.6711932	-110.5426171
2	1	738439.795	4058109.533	6576.687	-1.7008807	-0.4502978	-150.3816294
2	2	740796.397	4060667.031	6575.243	-1.1176844	-0.2369491	-150.4726023
2	3	743176.765	4063210.064	6571.560	-1.4286465	-0.1384074	-150.0025619
2	4	745528.427	4065777.023	6572.844	-1.3208191	-0.6672879	-149.6616114
2	5	747875.874	4068352.636	6580.711	-1.2582398	-0.5607360	-149.9171227
2	6	750234.070	4070913.797	6576.663	-0.6016719	-1.0670197	-148.8194784
3	1	748348.532	4069312.081	6595.082	-1.7052895	-0.3523733	-168.7349154
3	2	751407.853	4070985.823	6594.244	-1.4298280	-0.0844451	-167.9255249
3	3	754459.872	4072670.485	6593.499	-0.8989533	-0.2630576	-168.8426589
3	4	757513.236	4074339.178	6592.763	-1.0341420	-0.0686461	-168.1753684
3	5	760563.876	4076028.910	6593.204	-0.6608928	0.1962882	-168.0232041
3	6	763617.229	4077698.584	6595.082	-0.7135907	-0.0070957	-168.2655092
3	7	766670.323	4079372.375	6593.048	-0.7283496	0.1200197	-168.4870665
3	8	769720.343	4081044.382	6591.505	-0.8986565	0.1706230	-168.4387244
3	9	772764.274	4082726.343	6590.066	-0.9230398	-0.0824753	-168.3697420
3	10	775840.506	4084369.895	6571.008	-3.6314059	-1.8139774	-167.3507389
4	1	775610.645	4082429.739	6616.593	-0.1202474	-0.6894665	-86.8587402
4	2	774090.119	4085564.132	6608.581	-0.2008656	-0.8828790	-86.6278397
4	3	772530.750	4088690.232	6610.835	-0.3883747	-1.6101119	-87.5837181
4	4	771007.759	4091810.387	6597.059	-0.2081968	-0.6343055	-87.2350118
4	5	769471.434	4094940.753	6605.389	-0.3528492	-0.9280273	-87.3692852
4	6	767919.396	4098061.482	6606.574	-0.2635758	-0.0039532	-87.7551556
4	7	766397.736	4101184.409	6604.964	0.4602298	-0.8076298	-88.6970830

LiDAR Acquisition/Processing/Quality Control Report (Horizon's Inc. 2005)

Horizon's, Inc.
LiDAR Acquisition/Processing/Quality Control
Virgin River, NV

LiDAR Acquisition

LiDAR Acquisition. LiDAR acquisition for this project was performed by Horizons Inc. in a Cessna 310 equipped with an LH System ALS50-Serial #0036 LiDAR system including an inertial measuring unit (IMU) and a dual frequency GPS receiver. Acquisition was accomplished on June 7 - 9, 2005. Maps identifying the flight lines and LiDAR collection log sheets containing information regarding flights, times, conditions, etc are included in the Appendix. The LiDAR flight specifications follow:

Field of View	30 Degrees
Altitude	6000 feet AMT
Scan Rate	34 Hz
Pulse Rate	48 kHz
Airspeed	150 knots
Average Post Spacing	2.0 meters
Average Swath Width	3215 feet
Intensity Mode	4+3
Total Flight Lines:	40
Number of Lifts	3

GPS Data Collection

GPS Data Collection. A GPS receiver was in constant operation over a National Geodetic Survey (NGS) control point during flight acquisition. The base station identification and location are listed in the following table. The NGS data sheet is also included in the Appendix.

Station	Location
PID AA3459	36 50 00.54404(N), 114 03 16.86969(W)

GPS base station

GPS Data Processing

GPS Data Processing. All GPS phase data was post processed with continuous kinematic survey techniques using "On the Fly" (OTF) integer ambiguity resolution. The GPS data was processed with forward and reverse processing algorithms. The results from each process, using the data collected at the airport, were combined to yield a single fixed integer phase differential solution of the aircraft trajectory. Plots of altitude and the forward and reverse GPS solution residuals are included in the Appendix. The differences between the forward to reverse solution within the project area were within project specifications (<10cm) in both the horizontal and vertical components, indicating a valid and accurate solution.

IMU Data Processing

IMU Data Processing. An IMU was used to record precise changes in position and orientation of the LIDAR scanner at a rate of 200 Hz. All IMU data was processed post flight with a filter to integrate inertial measurements and precise phase differential GPS positions. The resulting solution contains geodetic position, omega, phi, kappa, and time for subsequent merging with the laser ranging information.

LiDAR Data Processing

LIDAR Data Preprocess.

Flight Line Data Acquisition/Quality Control Check. LiDAR data and the IMU files were processed together using LIDAR processing software. The data set for each flight line was checked for project area coverage, data gaps between overlapping flight lines, and tension/compression areas (areas where data points are more or less dense than the average project specified post spacing). Based on this check it appears the entire project area is covered without gaps. LiDAR Coverage Check and Line Overlap Check Diagrams are included in Appendix.

Boresighting Process. Pre-processing of LiDAR corrects for rotational, atmospheric, and elevation differences that are inherent to LiDAR data sets. This process is called bore-sighting. LiDAR data was collected for bi- and cross-directional flight lines over the airport prior to and after acquisition of the project area. Using an iterative process that involves analyzing raster difference calculations the Omega, Phi, Kappa angle corrections of the LiDAR instrument were determined. The corrections were applied to the LiDAR data set for the project area.

Vertical Accuracy Check. Extensive comparisons were made of vertical and horizontal positional differences between points common to two or more LiDAR flight lines. This was done for the airport bore-sight testing area and the project area. All flight lines (airport and project) were within project specifications for vertical accuracy.

LiDAR Intensity Check. An intensity raster for each flight line was generated. The raster was checked and verified that intensity was recorded for each LiDAR point.

Project Coordinate System. LiDAR preprocessing software outputs data to its corresponding UTM zone in meters and a GRS80 ellipsoidal height. LiDAR data was transformed to a project coordinate system of UTM Zone 11, NAD83, NAVD88, meters.

Vertical Bias Correction. LiDAR has a consistent vertical offset. LiDAR ground points were compared to independently surveyed and positioned ground control points at both the airport bore-sight area and the project area. Based on the results of these comparisons, the LiDAR data was vertically biased down to the ground.

Project Ground Control Check. Comparisons between on-site ground survey control points and LiDAR data yielded the following results:

Vertical Accuracy (RMSE)	0.033
Standard Deviation	0.034
Mean Difference	0.003
Number of Points	13

LiDAR Data Surfacing Process.

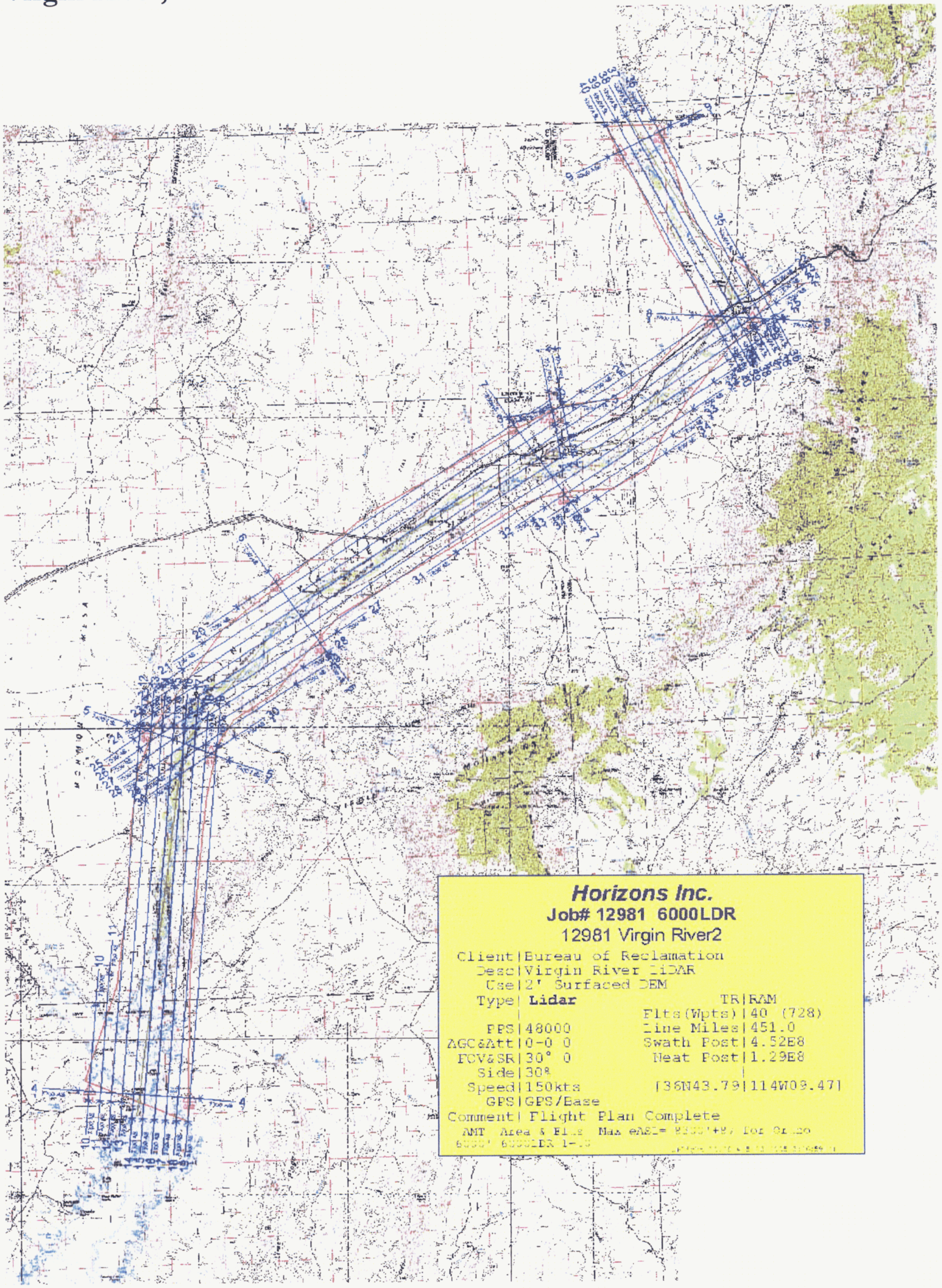
Raw LiDAR Data Set. LiDAR data in overlap areas of project flight lines was removed and data from all swaths was merged into a single data set. The data set was trimmed to the digital project boundary including an additional buffer zone (buffer zone assures adequate contour generation from the DEM). Resulting data set is the Raw LiDAR data. The Raw LiDAR data set was processed through a minimum block mean algorithm and points were classified as either bare earth or non-bare earth. User developed "macros" that factor mean terrain angle and height from the ground, were used to determine bare earth point classification.

LiDAR Surfacing Process. The surfacing process is a 2D-edit procedure that ensures the accuracy of the automated feature classification. Editors used a combination of imagery, intensity of the LiDAR reflection and tin-editing software to assess points. The resulting data set is 2D Surfaced Bare Earth. The LiDAR data is filtered using a quadric error metric to remove redundant points. This method leaves points where there is a change in the slope of surfaces (road ditches) and eliminates points from evenly sloped terrain (flat field) where the points do not affect the TIN LiDAR data. The resulting data set is 2D Surfaced/Filtered Bare Earth

Appendix Items.

Flight Map
LiDAR Collection Logsheet
Diagram – Altitude and Forward/Reverse GPS Solution Residuals
Diagram – Aircraft Trajectory Plot
Diagram - Project Flight Lines Overlap
Diagram – LiDAR Coverage Check for Project Lines
NGS Data Sheet

Flight Map
Virgin River, NV



Horizons Inc.

Job# 12981 6000LDR

12981 Virgin River2

```
  Client|Bureau of Reclamation
    Desc|Virgin River LiDAR
     Use|2' Surfaced DEM
    Type| Lidar                       TR|RAM
        |                  Flts(Wpts)|40 (728)
     PPS|48000             Line Miles|451.0
 AGC&Att|0-0 0             Swath Post|4.52E8
  FOV&SR|30° 0              Neat Post|1.29E8
    Side|30%                         |
   Speed|150kts           [36N43.79|114W09.47]
     GPS|GPS/Base
 Comment| Flight Plan Complete
  AMT  Area & Flts  Max eASL= 8300'+8, for Ortho
 6000' 6000LDR 1-[illegible]
```

LiDAR Collection Logsheet, Lift 1
Virgin River, NV

Project:	Bureau of Reclamation Virgin River	**LiDAR Ser #** 036	**Attenuator:** full	**Mode:** 4 + 3	**FMS** CCNS	**Above Mean Terane:** 6000	**AIRCRAFT**	**Operator:** Joe Doran
Project #: / Lift:	12981 - Lift # 1	**Laser Pulse Rate:** 48000	**AGC # 1** 12	**Hard Dr** 72 GB	**Des. Speed kts:** 150	**IMU Start:** 21:34	Cessna 310 N2636P	**Pilot:** Mark Thomsen
Date / Julian:	7-Jun-05 / 158	**Range Gate:** 3000 - 7559	**AGC # 2** 3	**Session:** A	**UTM Zone:**	**IMU Stop:** 23:31		**Airport ID** K67L

Weather	Grnd Temp	Alt Temp	Atlm
Start:	27c	8c	29.90
End:	26c	8c	29.90

PID #	**Ground Station**	
aa3459	Start	Stop
Ant. Ht. 1.800	20:56	23:45

Horizons line #	Direction Deg.	From WPT	To WPT	GPS Time Beginning	GPS Time End	F. O. V.	Scan Rate:	Speed Kts:	Comments and Conditions:	# Sats	PDOP	MISC.
Test				**213722**	**2138**	30	34			7	1.5	
ap1n	351	1	4	**215132**	**2153**			151				
ap1s	171	4	1	**215604**	**2157**			151		9	1.1	
ap2n	351	1	4	**220048**	**2202**			148		9	1.1	
ap3e	081	1	3	**220653**	**2207**			149		10	1.1	
35n	334	5	1	**221245**	**2214**			148		9	1.2	
35s	154	1	5	**221809**	**2219**			143		9	1.3	
36n	334	15	1	**222250**	**2226**			153	Light Chop	9	1.3	
37s	154	1	16	**222942**	**2233**			153	Light Chop	9	1.4	
38n	334	16	1	**223615**	**2239**			151	Light Chop	9	1.4	
39s	154	1	16	**224240**	**2246**			148	Light Chop	9	1.8	
40n	334	116	1	**224906**	**2252**			146	Light Chop	8	1.8	
9e	064	1	6	**225552**	**2256**			146	Light Chop	8	1.8	
ap2s	171	4	1	**230220**	**2303**			157	Light Chop	8	1.8	
ap1n	351	1	4	**230542**	**2306**			150	Light Chop	8	1.8	
ap1s	171	4	1	**230943**	**2310**			148	Light Chop	8	1.8	
ap3w	262	3	1	**231330**	**2314**			141	Light Chop	7	3.1	

LiDAR Collection Logsheet, Lift 2
Virgin River, NV

Project:	Bureau of Reclamation	**LiDAR Ser #**	**Attenuator:**	**Mode:**	**FMS**	**Above Mean Terane:**	**~~AIRCRAFT~~**	**Operator:**	**Weather**	Grnd Temp	Alt Temp	Atlm
	Virgin River	036	full	4 + 3	CCNS	6000		Joe Doran	**Start:**	30c	11c	29.75
Project #: / Lift:	12981 - Lift # 2	**Laser Pulse Rate:**	**AGC # 1**	**Hard Dr**	**Des. Speed kts:**	**IMU Start:**	Cessna 310 N2636P	**Pilot:**	**End:**	24c	11c	29.70
		48000	12	72 GB	150	0:21		Mark Thomsen	**PID #**		**Ground Station**	
Date / Julian:		**Range Gate:**	**AGC # 2**	**Session:**	**UTM Zone:**	**IMU Stop:**		**Airport ID**	AA3459		Start	Stop
	8-Jun-05 / 159	3000 - 7559	3	A		3:46		K67L	**Ant. Ht.**	1.800	23:49	3:56

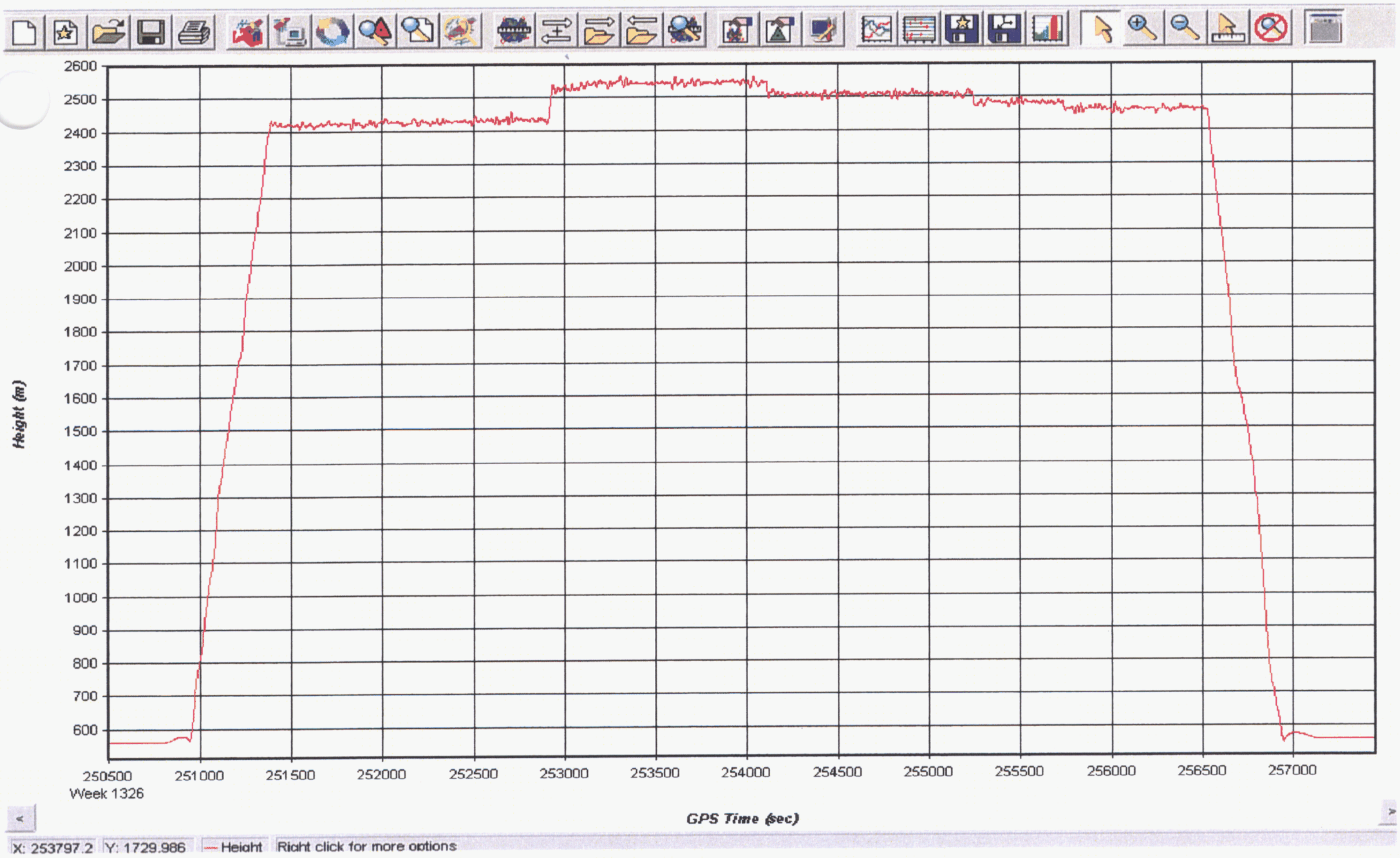
Horizons line #	Direction Deg.	From WPT	To WPT	GPS Time		F. O. V.	Scan Rate:	Speed Kts:	Comments and Conditions:	# Sats	PDOP	MISC.
				Beginning	End							
Test				**002258**	**0023**	30	34		CCNS set for N93HC			
ap1n	351	1	4	**003743**	**0038**			154	Light Chop	9	1.2	
ap1s	171	4	1	**004213**	**0042**			132	Light Chop	9	1.1	
ap2n	351	1	4	**004643**	**0047**			155	Light Chop	9	1.1	
ap3e	081	1	3	**005136**	**0052**			149	Light Chop	10	1.1	
20w	237	22	1	**005538**	**0100**			154	Light Chop	10	1.0	
21e	057	1	29	**010355**	**0110**			157	Light Chop	9	1.2	
22w	237	44	1	**012028**	**0129**			150	Light Chop	6	2.4	
23e	057	1	45	**013253**	**0142**			146	Light Chop	6	2.5	
24w	237	47	1	**014656**	**0157**			148	Light Chop	8	1.6	
25e	057	1	47	**015954**	**0210**			148	Light Chop	8	1.6	
8w	275	7	1	**021506**	**0216**			151	Light Chop	8	1.5	
26w	237	45	1	**022054**	**0230**			153	Light Chop	8	1.4	
27e	057	1	15	**023344**	**0236**			152	Light Chop	8	1.3	
31w	057	1	20	**023836**	**0243**			152	Light Chop	8	1,3	
32e	237	12	1	**024735**	**0250**			152	Light Chop	9	1.2	
33w	057	1	8	**025317**	**0255**			154	Light Chop	9	1.2	
34e	237	6	1	**025911**	**0301**			150	Light Chop	8	1.5	
6n	327	8	1	**030604**	**0307**			157		8	1.6	
7s	147	1	8	**031305**	**0314**			150		8	1.7	
ap2s	171	4	1	**031725**	**0317**			154	Flown in the wrong direction	8	1.7	
ap2s	171	4	1	**032109**	**0321**			147		8	1.8	
ap1n	351	1	4	**032418**	**0324**			168		8	1.8	
ap1s	171	4	1	**032735**	**0328**			149		8	1.8	
ap3w	262	3	1	**033142**	**0332**			149		8	1.8	

LiDAR Collection Logsheet, Lift 3
Virgin River, NV

Project:	Bureau of Reclamation Virgin River	**LiDAR Ser #** 036	**Attenuator:** full	**Mode:** 4 + 3	**FMS** CCNS	**Above Mean Terane:** 6000	**AIRCRAFT**	**Operator:** Joe Doran	**Weather**	Grnd Temp	Alt Temp	Atlm
									Start:	19c	7c	29.80
Project #: / Lift:	12981 - Lift # 3	**Laser Pulse Rate:** 48000	**AGC # 1** 12	**Hard Dr** 72 GB	**Des. Speed kts:** 150	**IMU Start:** 13:50	Cessna 310 N2636P	**Pilot:** Mark Thomsen	**End:**	21c	8c	29.85
Date / Julian:	9-Jun-05 / 160	**Range Gate:** 3000 - 7559	**AGC # 2** 3	**Session:** A	**UTM Zone:**	**IMU Stop:** 16:54		**Airport ID** K67L	**PID #** AA3459 **Ant. Ht.** 1.800	**Ground Station**	Start 13:26	Stop 17:03

Horizons line #	Direction Deg.	From WPT	To WPT	GPS Time Beginning	GPS Time End	F. O. V.	Scan Rate:	Speed Kts:	Comments and Conditions:	# Sats	PDOP	MISC.
Test				**135231**	**1353**	30	34		CCNS set ot N97HC and one day off	8	2.1	
ap1n	351	1	4	**141046**	**1411**			147		9	1.3	
ap1s	171	4	1	**141457**	**1415**			134		9	1.2	
ap2n	351	1	4	**141855**	**1419**			148		8	1.5	
ap3w	262	3	1	**142257**	**1423**			153		8	1.5	
28w	237	12	1	**142815**	**1430**			156		8	1.5	
29e	057	1	10	**143406**	**1436**			154		8	1.5	
30w	237	5	1	**143956**	**1441**			155		8	1.5	
5e	112	1	8	**144444**	**1446**			155		8	1.5	
19s	186	25	1	**145034**	**1456**			150		9	1.3	
18n	006	1	25	**145900**	**1504**			155		9	1.2	
17s	186	26	1	**150736**	**1513**			155		9	1.2	
16n	006	1	26	**151606**	**1521**			159		9	1.2	
15s	186	26	1	**152437**	**1530**			157		7	2.0	
14n	006	1	26	**153329**	**1539**			151		7	2.1	
13s	186	25	1	**154207**	**1547**			154		7	2.1	
12n	006	1	25	**155508**	**1600**			150		7	2.0	
11s	186	9	1	**160511**	**1607**			150		8	1.5	
10n	006	1	7	**161007**	**1611**			154		8	1.5	
4e	096	1	9	**161600**	**1617**			153		8	1.4	
ap3e	081	1	3	**162841**	**1629**			152		8	1.3	
ap2s	171	4	1	**163151**	**1632**			150		8	1.3	
ap1n	351	1	4	**163519**	**1636**			160		8	1.3	
ap1s	171	4	1	**163859**	**1639**			150		9	1.1	

Diagram – Altitude and Forward/Reverse GPS Solution Residuals, Lift 1
Virgin River, NV



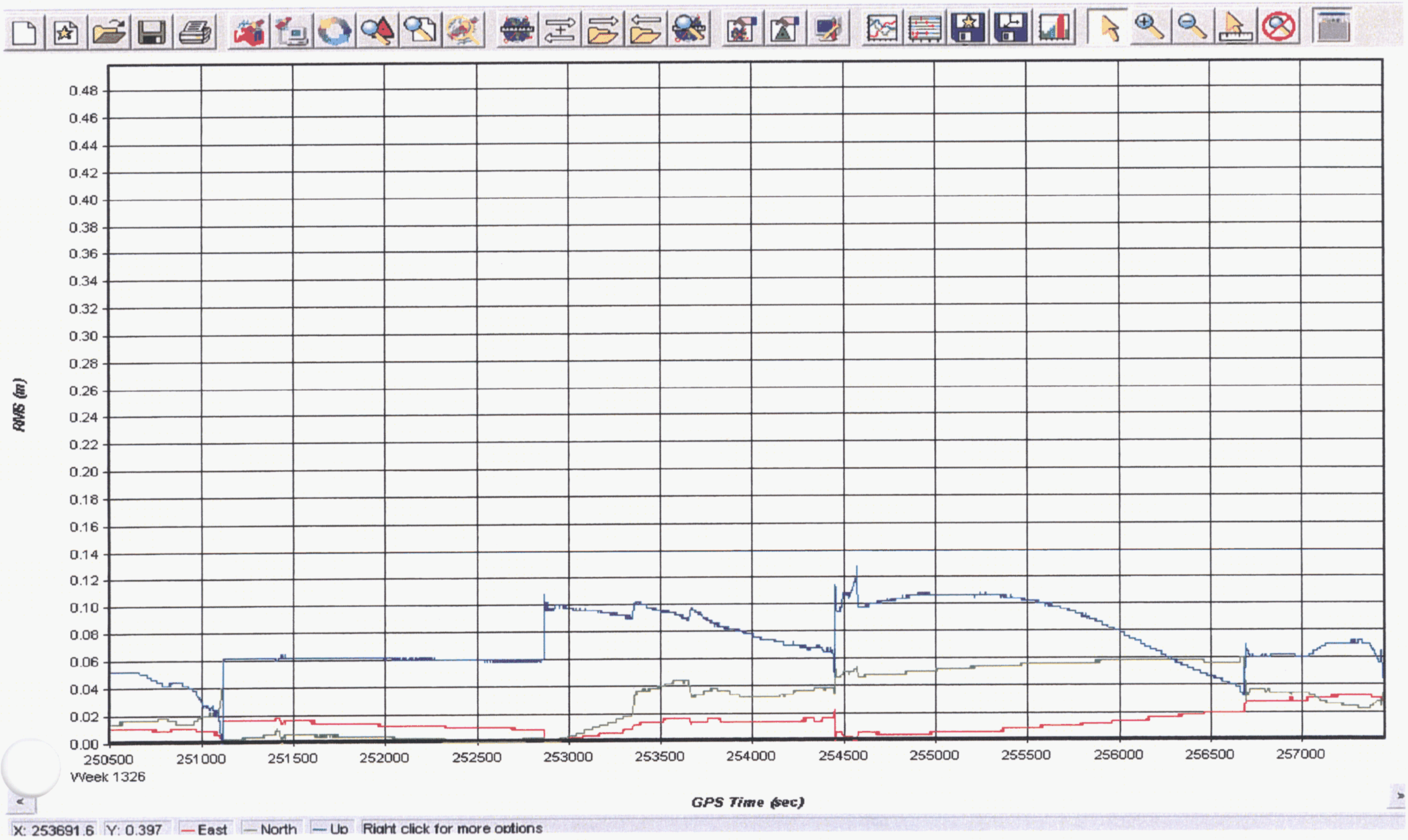
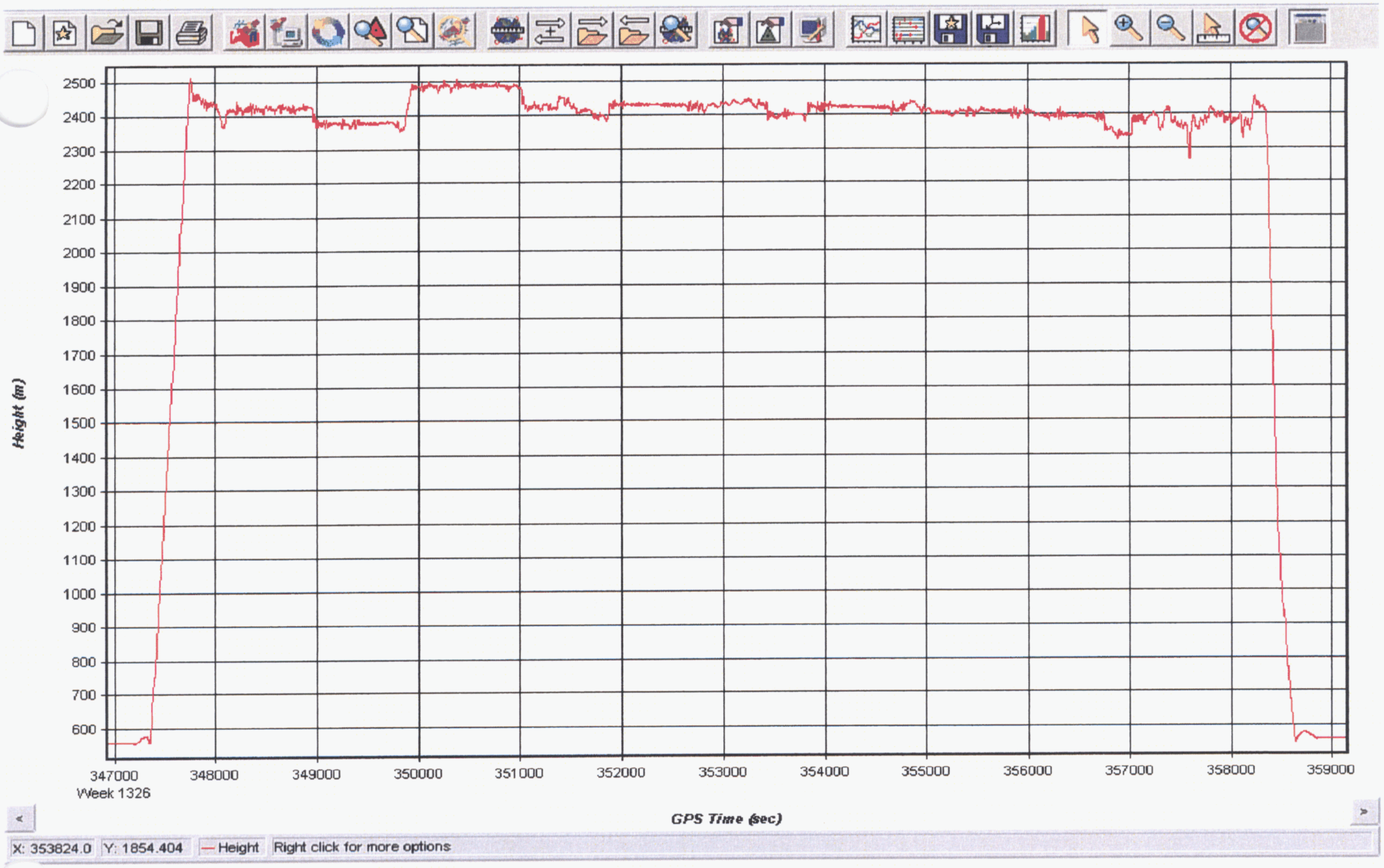


Diagram – Altitude and Forward/Reverse GPS Solution Residuals, Lift 2
Virgin River, NV



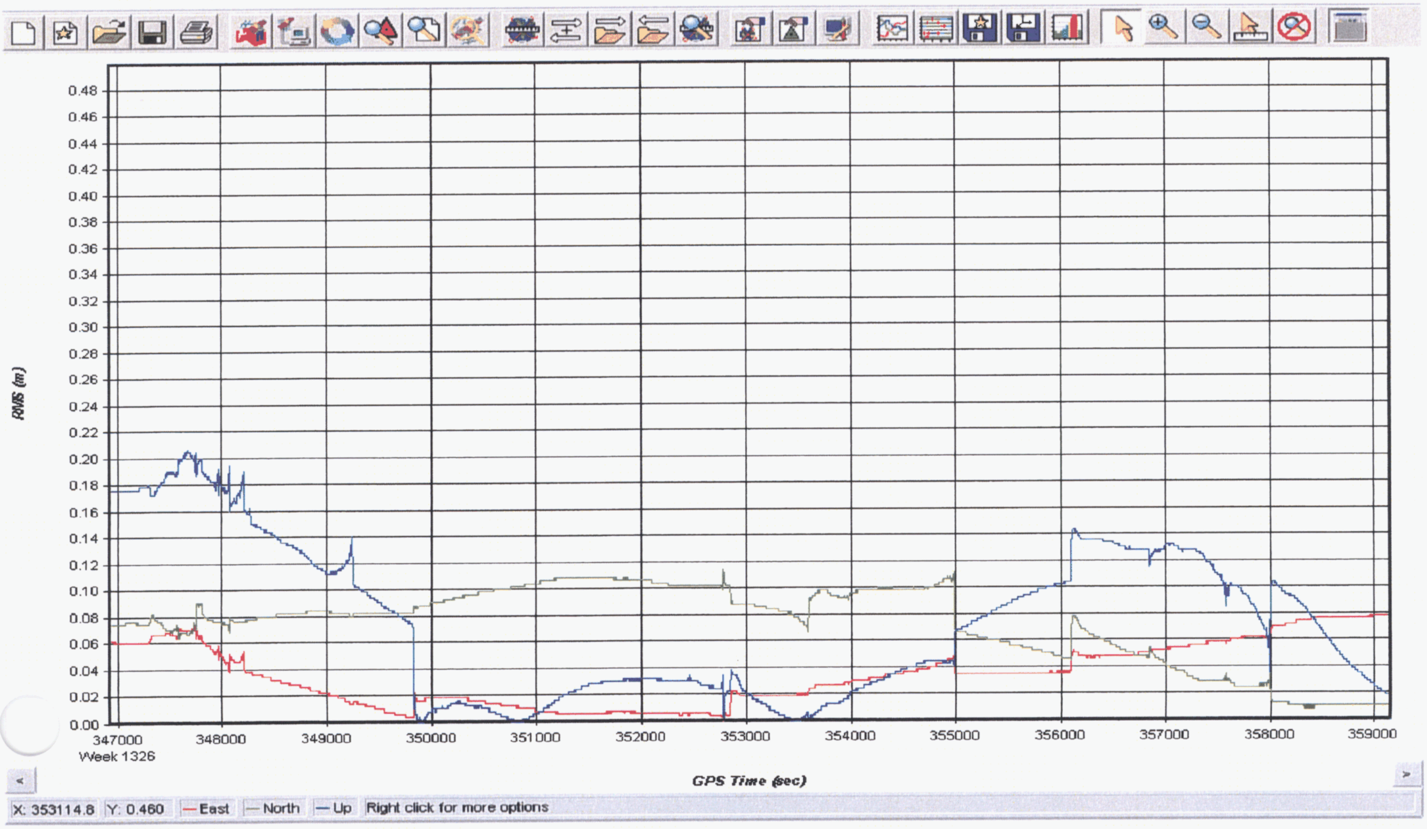
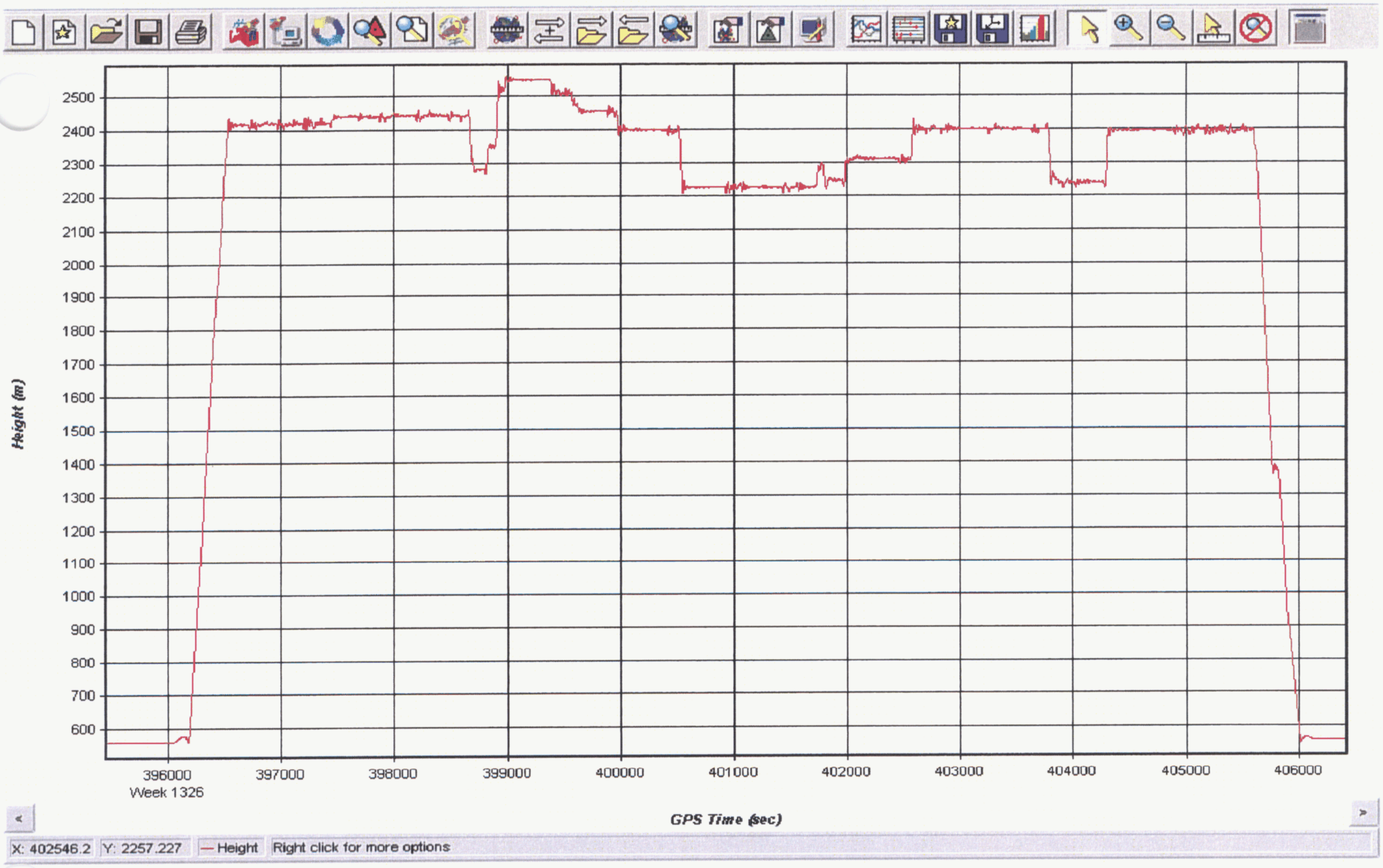


Diagram – Altitude and Forward/Reverse GPS Solution Residuals, Lift 3
Virgin River, NV



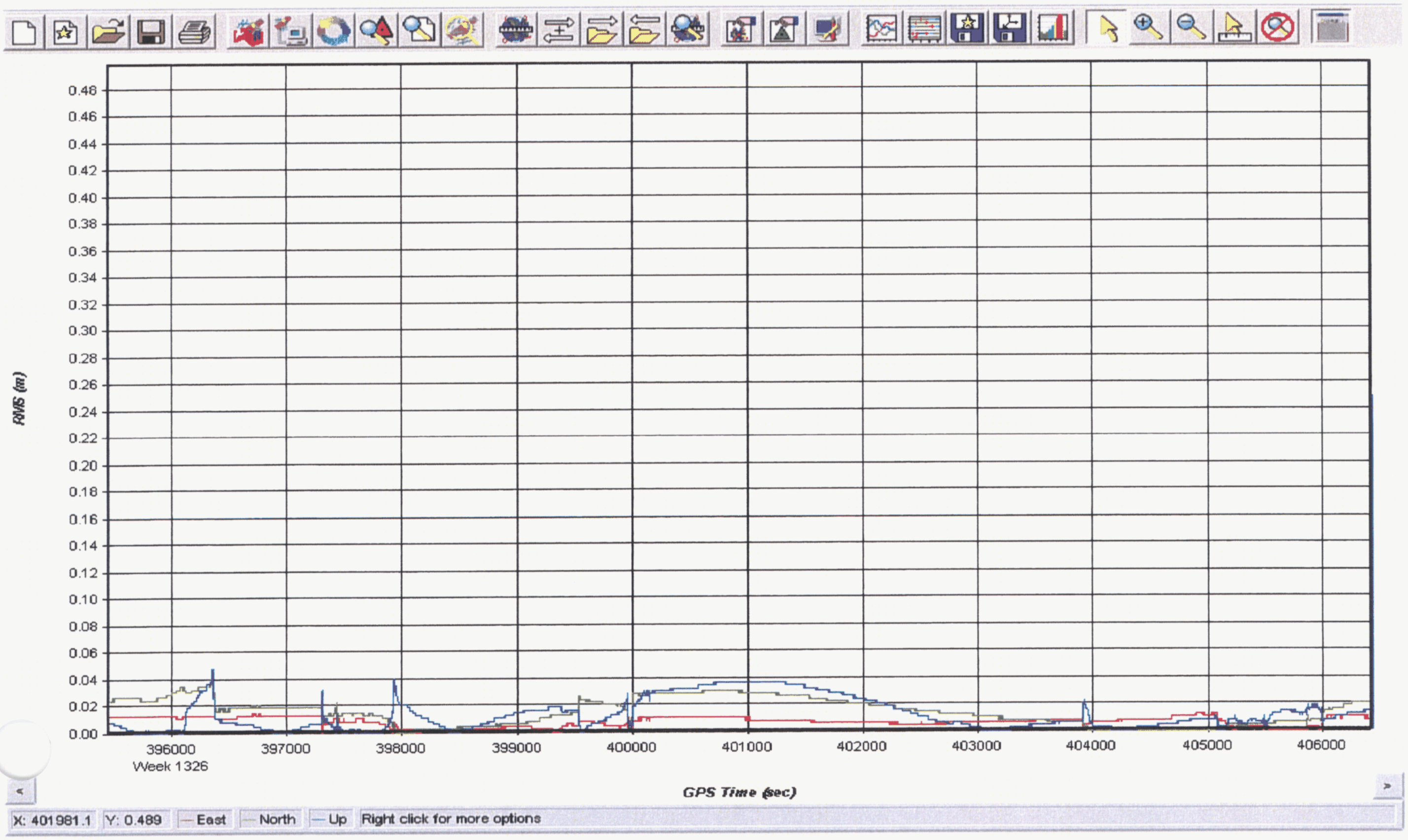
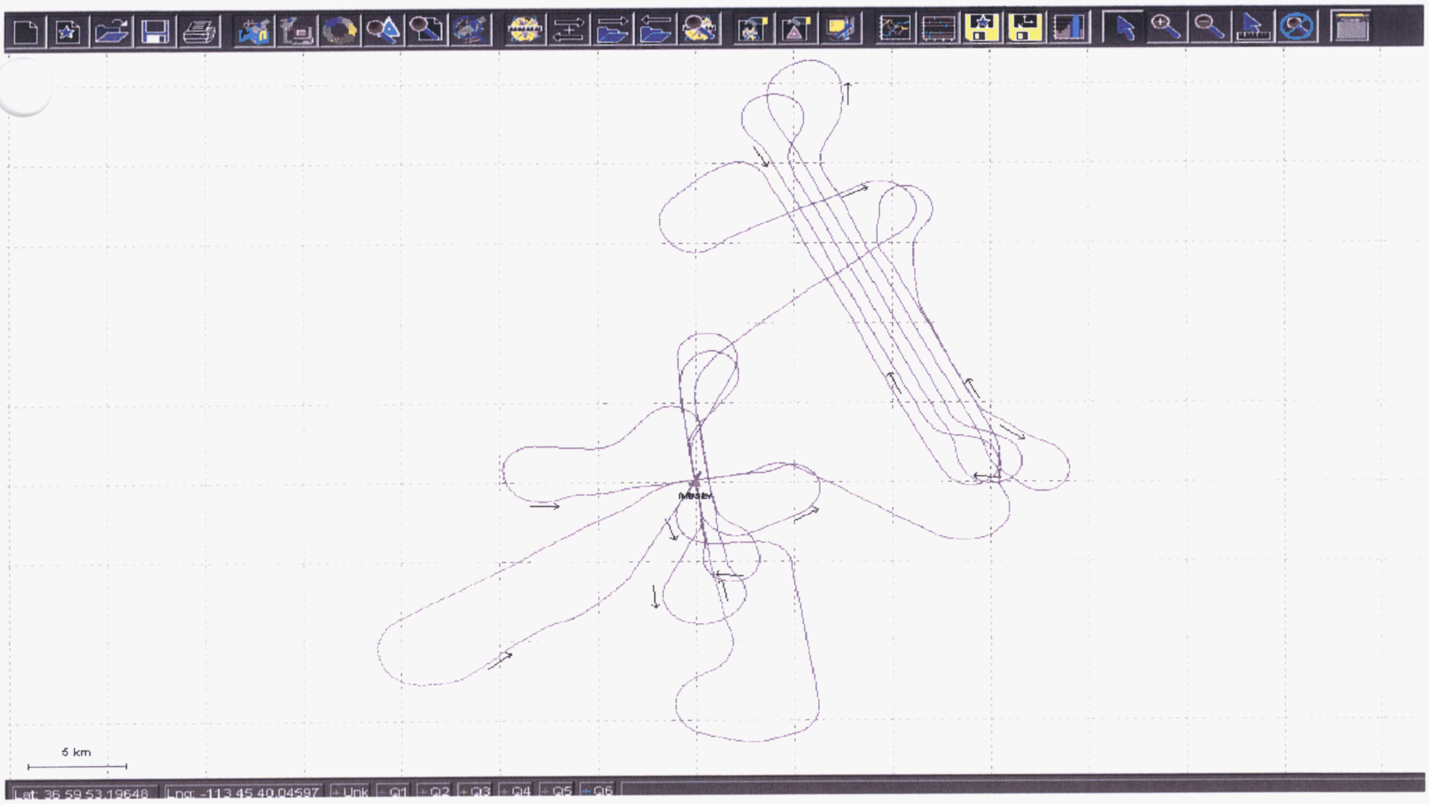


Diagram – Aircraft Trajectory Plot, Lift 1
Virgin River, NV


5 km
Lat: 36 59 53.19648
Lng: -113 45 40.04597
Unk
Q1
Q2
Q3
Q4
Q5
Q6

agram – Aircraft Trajectory Plot, Lift 2
Virgin River, NV

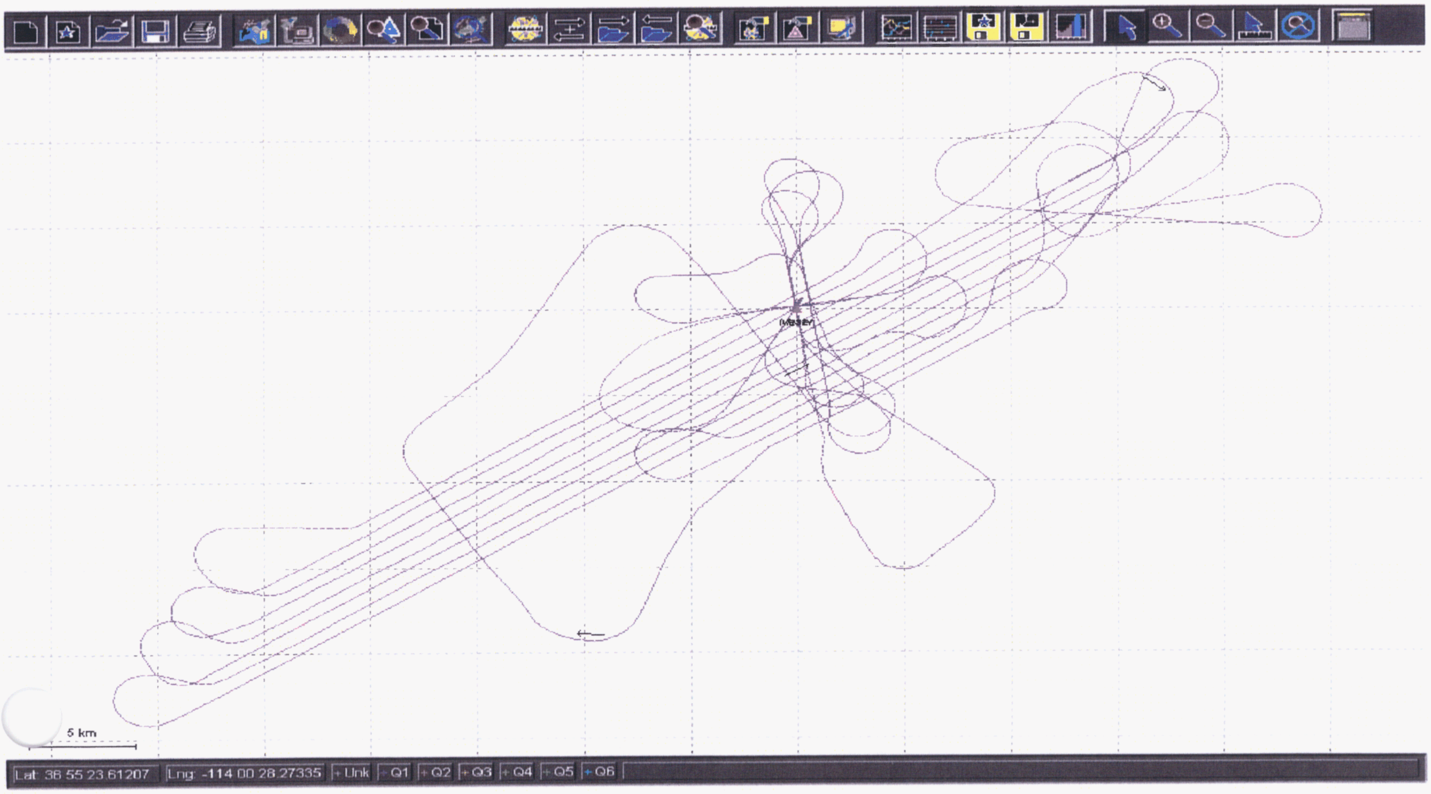
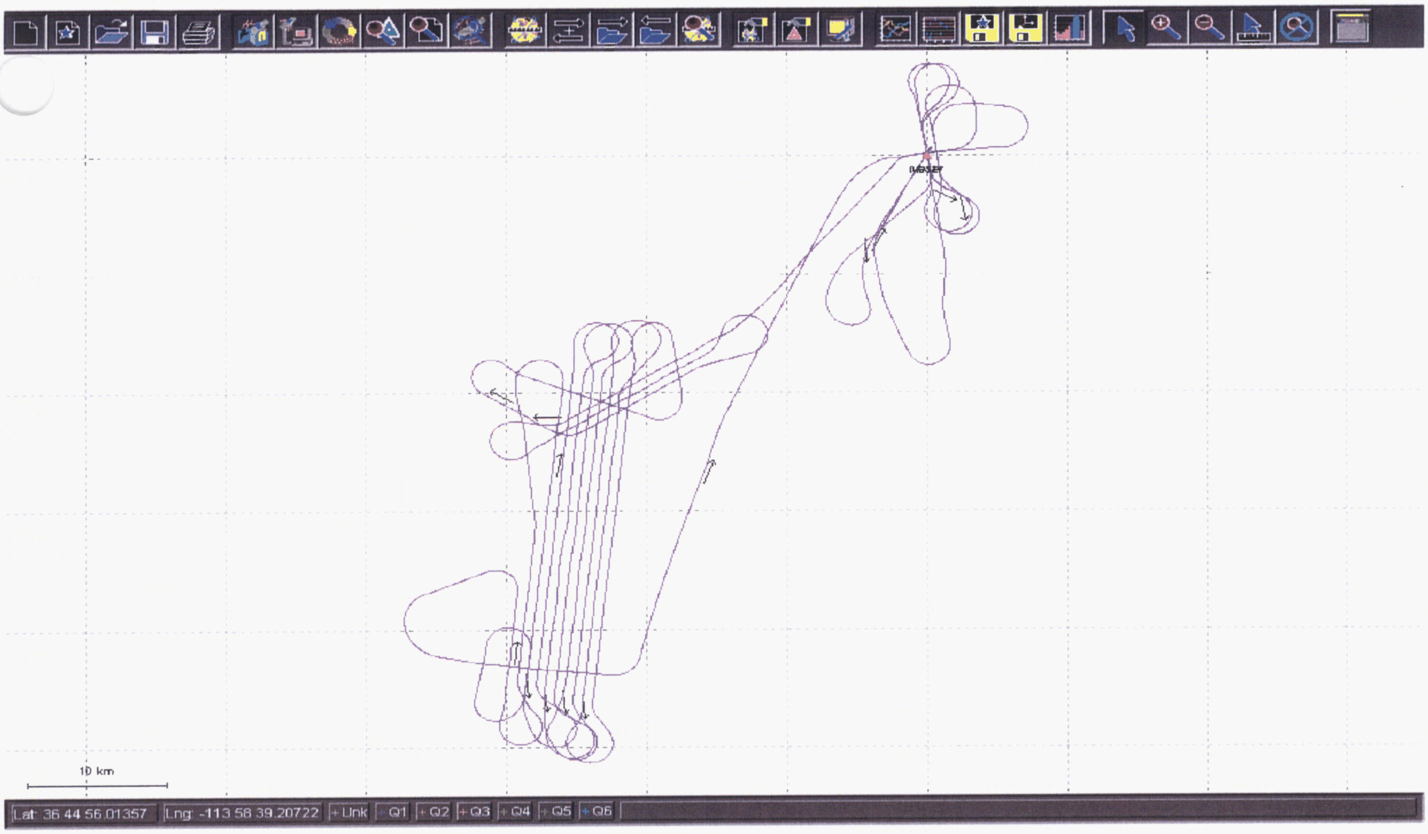

5 km
Lat: 36 55 23.61207
Lng: -114 00 28.27335
Unk
Q1
Q2
Q3
Q4
Q5
Q6

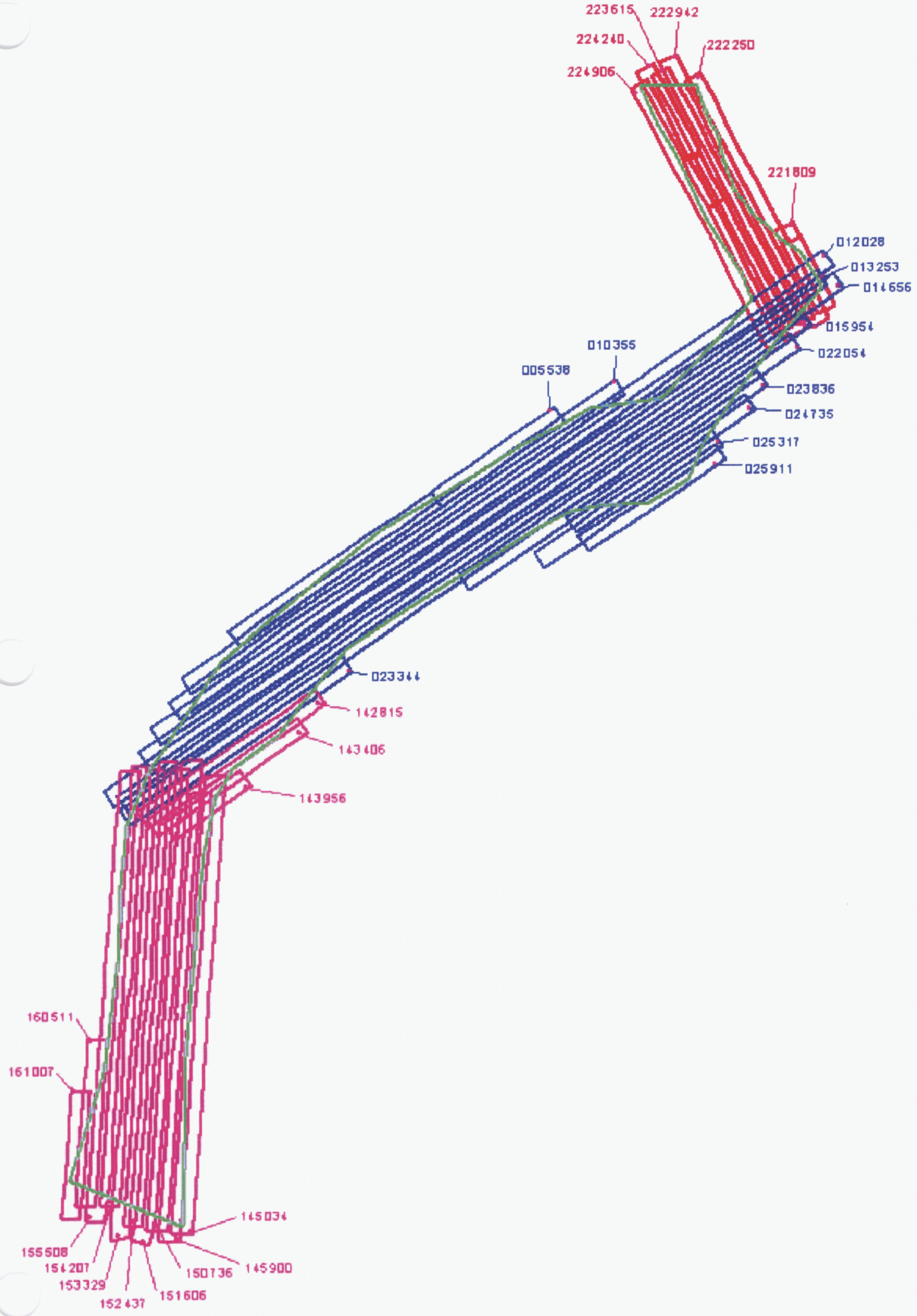
Diagram – Aircraft Trajectory Plot, Lift 3
Virgin River, NV


10 km

Lat: 36 44 56.01357 Lng: -113 58 39.20722

+ Unk
+ Q1
+ Q2
+ Q3
+ Q4
+ Q5
+ Q6

Diagram – Project Flight Lines Overlap
Virgin River, NV


223615
222942
224240
222250
224906
221809
012028
013253
014656
015954
022054
010355
005538
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024735
025317
025911
023344
142815
143406
143956
160511
161007
145034
155508
154207
153329
152437
151606
150736
145900

Diagram – LiDAR Coverage Check for Project Lines
Virgin River, NV

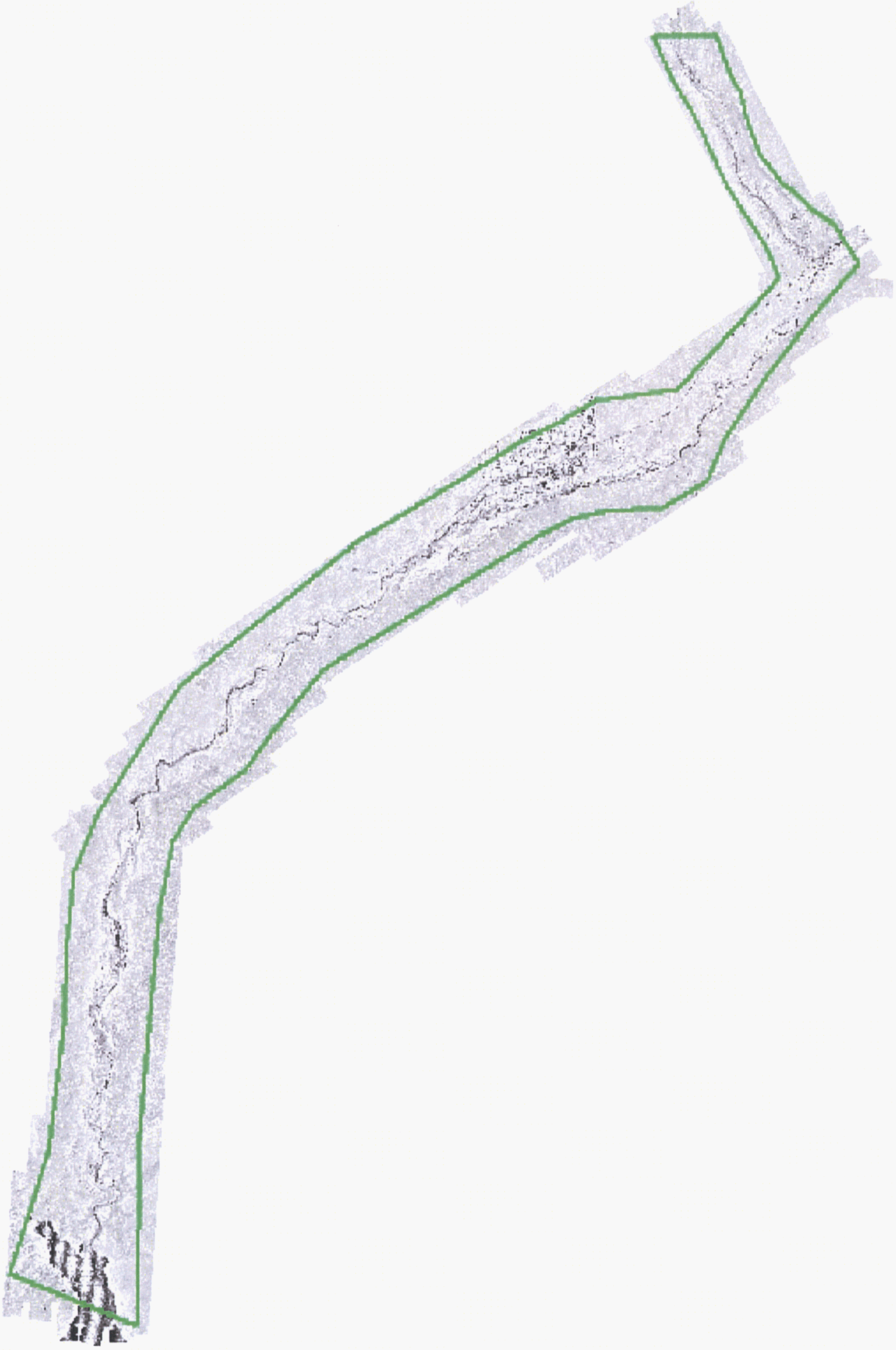

Diagram – NGS Data Sheet
Virgin River, NV

```
DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 7.20
     National Geodetic Survey,   Retrieval Date = JULY 21, 2005
  3459 *****************************************************************************
 AA3459  CBN         - This is a Cooperative Base Network Control Station.
 AA3459  PACS        - This is a Primary Airport Control Station.
 AA3459  DESIGNATION -  FAA 67L A
 AA3459  PID         - AA3459
 AA3459  STATE/COUNTY-  NV/CLARK
 AA3459  USGS QUAD   -  MESQUITE (1985)
 AA3459
 AA3459                      *CURRENT SURVEY CONTROL
 AA3459  ___________________________________________________________________
 AA3459* NAD 83(1999)-  36 50 00.54404(N)    114 03 16.86969(W)     ADJUSTED
 AA3459* NAVD 88     -       591.48   (meters)    1940.5    (feet)  GPS OBS
 AA3459  ___________________________________________________________________
 AA3459  EPOCH DATE  -        1999.37
 AA3459  X          -  -2,083,508.642 (meters)                COMP
 AA3459  Y          -  -4,667,642.241 (meters)                COMP
 AA3459  Z          -   3,802,957.590 (meters)                COMP
 AA3459  LAPLACE CORR-           4.83  (seconds)                   DEFLEC99
 AA3459  ELLIP HEIGHT-         565.06  (meters)          (05/16/00) GPS OBS
 AA3459  GEOID HEIGHT-         -26.40  (meters)                    GEOID03
 AA3459
 AA3459  HORZ ORDER  -  A
 AA3459  ELLP ORDER  -  FOURTH    CLASS I
 AA3459
 AA3459.This mark is at Mesquite Airport (67L)
 AA3459
   3459.The horizontal coordinates were established by GPS observations
 AA3459.and adjusted by the National Geodetic Survey in May 2000.
 AA3459.This is a SPECIAL STATUS position.  See SPECIAL STATUS under the
 AA3459.DATUM ITEM on the data sheet items page.
 AA3459.The horizontal coordinates are valid at the epoch date displayed above.
 AA3459.The epoch date for horizontal control is a decimal equivalence
 AA3459.of Year/Month/Day.
 AA3459
 AA3459.The orthometric height was determined by GPS observations and a
 AA3459.high-resolution geoid model.
 AA3459
 AA3459.GPS derived orthometric heights for airport stations designated as
 AA3459.PACS or SACS are published to 2 decimal places.  This maintains
 AA3459.centimeter relative accuracy between the PACS and SACS.  It does
 AA3459.not indicate centimeter accuracy relative to other marks which are
 AA3459.part of the NAVD 88 network.
 AA3459
 AA3459.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 AA3459
 AA3459.The Laplace correction was computed from DEFLEC99 derived deflections.
 AA3459
 AA3459.The ellipsoidal height was determined by GPS observations
 AA3459.and is referenced to NAD 83.
 AA3459
 AA3459.The geoid height was determined by GEOID03.
 AA3459
   3459;                North        East     Units Scale Factor Converg.
   3459;SPC NV E     - 8,232,240.888  336,354.546   MT  1.00012898   +0 54 59.6
 AA3459;UTM  11     - 4,080,449.869  762,665.624   MT  1.00045005   +1 46 00.1
 AA3459;UTM  12     - 4,080,756.400  227,577.910   MT  1.00051439   -1 49 56.6
```

```
AA3459
AA3459!          - Elev Factor  x  Scale Factor =   Combined Factor
AA3459!SPC NV E    -  0.99991133  x   1.00012898  =   1.00004030
AA3459!UTM  11     -  0.99991133  x   1.00045005  =   1.00036134
AA3459!UTM  12     -  0.99991133  x   1.00051439  =   1.00042567
AA3459
  3459                        SUPERSEDED SURVEY CONTROL
  3459
AA3459  NAD 83(1994)-  36 50 00.54359(N)    114 03 16.86821(W) AD(       ) B
AA3459  ELLIP H (03/30/95)  565.17   (m)                   GP(       ) 4 1
AA3459
AA3459.Superseded values are not recommended for survey control.
AA3459.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
AA3459.See file dsdata.txt to determine how the superseded data were derived.
AA3459
AA3459_U.S. NATIONAL GRID SPATIAL ADDRESS: 11SQA6266680450(NAD 83)
AA3459_MARKER: I = METAL ROD
AA3459_SETTING: 59 = STAINLESS STEEL ROD IN SLEEVE (10 FT.+)
AA3459_STAMPING: FAA 67L A 1994
AA3459_MARK LOGO: NGS
AA3459_PROJECTION: FLUSH
AA3459_MAGNETIC: N = NO MAGNETIC MATERIAL
AA3459_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
AA3459+STABILITY: POSITION/ELEVATION WELL
AA3459_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
AA3459+SATELLITE: SATELLITE OBSERVATIONS - April 11, 2005
AA3459_ROD/PIPE-DEPTH: 3.12 meters
AA3459_SLEEVE-DEPTH  : 0.9 meters
AA3459
AA3459  HISTORY     - Date     Condition        Report By
AA3459  HISTORY     - 1994     MONUMENTED       NGS
AA3459  HISTORY     - 19991013 GOOD             NGS
  3459  HISTORY     - 20050411 GOOD             LVVWD
   459
AA3459                        STATION DESCRIPTION
AA3459
AA3459'DESCRIBED BY NATIONAL GEODETIC SURVEY 1994 (AJL)
AA3459'STATION IS LOCATED ABOUT 3 KM (1.85 MI) NORTHEAST OF MESQUITE, 300 M
AA3459'(984.2 FT) WEST OF THE NEVADA-ARIZONA STATE LINE, AT THE MESQUITE
AA3459'AIRPORT, JUST SOUTH OF THE WINDSOCK POLE IN THE SYMMETRICAL CIRCLE, ON
AA3459'A 3 M (9.8 FT) HIGH BANK, AT AN INTERIOR FENCE CORNER IN THE SOUTHEAST
AA3459'PERIMETER FENCE.  OWNERSHIP--CITY OF MESQUITE, 11 EAST MESQUITE
AA3459'BOULEVARD, MESQUITE, NV 89024.  AIRPORT MANAGER IS KEVIN LEAVITT,
AA3459'PHONE 702-346-2841 (HE LIVES IN TRAILER AT THE AIRPORT). TO REACH FROM
AA3459'THE UNDERPASS AT THE JUNCTION OF INTERSTATE HIGHWAY 15 AND PIONEER
AA3459'DRIVE (EXIT 122) ON THE NORTHEAST SIDE OF MESQUITE, GO NORTHWEST ON
AA3459'PIONEER DRIVE FOR 0.64 KM (0.40 MI) TO A PAVED ROAD RIGHT.  TURN
AA3459'RIGHT, NORTHERLY, ON KITTY HAWK DRIVE FOR 2.01 KM (1.25 MI) TO THE
AA3459'ROAD END AT AIRPORT GATE.  PASS THROUGH GATE FOR 30 M (98.4 FT) TO THE
AA3459'APRON.  BEAR RIGHT, EAST, ON APRON FOR 0.08 KM (0.05 MI) TO THE
AA3459'PARALLEL TAXI.  TURN LEFT, NORTHEAST, ON THE TAXI FOR 0.36 KM (0.20
AA3459'MI) TO A CONNECTOR ON THE RIGHT.  TURN RIGHT, SOUTHEAST, CROSSING
AA3459'RUNWAY TO THE WINDSOCK AND THE STATION. STATION MARK IS A PUNCH HOLE
AA3459'TOP CENTER ON A STAINLESS STEEL ROD IN A 2.5 CM GREASE FILLED SLEEVE
AA3459'90 CM LONG ENCASED IN A 12.7 CM PVC PIPE WITH A LOGO CAP SURROUNDED BY
AA3459'CONCRETE SET FLUSH WITH THE GROUND. IT IS 73.7 M (241.8 FT)
AA3459'EAST-SOUTHEAST OF, AND 3 M (9.8 FT) HIGHER THAN THE RUNWAY CENTER,
AA3459'53.6 M (175.9 FT) SOUTHEAST OF THE WINDSOCK POLE, 4.3 M (14.1 FT)
AA3459'NORTH-NORTHWEST OF A FENCE CORNER, 2.4 M (7.9 FT) WEST-NORTHWEST OF A
   459'FIBERGLASS WITNESS POST IN THE FENCE, AND 3.0 M (9.8 FT)
  3459'NORTH-NORTHEAST OF THE FENCE. DESCRIBED BY D.G. AUG.
AA3459
AA3459                        STATION RECOVERY (1999)
```

```
AA3459
AA3459'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1999
AA3459'THE STATION WAS RECOVERED IN GOOD CONDITION.  THERE ARE SOME VERY
AA3459'CRYPTIC NOTES WRITTEN ON THE ORIGINAL DESCRIPTION THAT MAY HELP IN THE
AA3459'RECOVERY IF ONE WERE IN THE AREA.  THESE NOTES ARE IN THE TO REACH
AA3459'SECTION OF THE DESCRIPTION AND ARE AS FOLLOWS, FOLLOW SIGNS, 0.7 M
  3459'(2.3 FT) ON OASIS BLVD AND AFTER THE STATMENT CONNECTOR ON THE RIGHT
AA3459'THE NOTETAKER PUT IN THE LETTER C.  I AM SURE THERE WAS GOOD INTENTION
AA3459'HERE BUT I DO NOT HAVE ENOUGH INFORMATION TO PUT IT ALL TOGETHER.
AA3459
AA3459                    STATION RECOVERY (2005)
AA3459
AA3459'RECOVERY NOTE BY LAS VEGAS VALLEY WATER DISTRICT 2005 (TJW)
AA3459'RECOVERED IN GOOD CONDITION.
```

Virgin River Flood Study: Draft Geomorphic Analysis Report
(J.E. Fuller 2006)

Virgin River Flood Study

Geomorphic Analysis Report

October 2006

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

www.jefuller.com

Electronic copy of final document, original sealed document with the Clark County Regional Flood Control District.

-Jonathan Edward Fuller, P.E.
Registered Professional Engineer
#11393, State of Nevada

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Appendices

Appendix A – Field photos and locations
Appendix B – Cross-section profile plots
Appendix C – General development guidelines
Appendix D – 1938 and 2005 aerial photo comparison exhibit map

Attachments

Historical Aerial Photograph Exhibit Book – separate volume

1. INTRODUCTION

1.1. Purpose

The purpose of the geomorphic assessment was to compile, analyze, and present the best available information representative of the historical geomorphic processes for a portion of the Virgin River located near Mesquite, NV and Bunkerville, Nevada (Figure 1). The primary tasks were to analyze the river's response to the January 2005 flood in the context of the historical information, synthesize this information for the purpose of providing insight into the potential future behavior of the river system, and finally provide recommendations for future river management practices.

1.2. Objectives

This Summary Report is organized into five primary sections, each of which is discussed in detail, and includes:

- Data Collection
- Field Assessment
- Sedimentation Analysis
- Lateral Migration Analysis
- Recommended Plan

1.2.1. Data Collection

A suite of data types was collected and utilized in the geomorphic assessment. Collected data were combined with field information to develop an understanding of the historical behavior of the Virgin River and its response to the 2005 flood in particular. The types of data collected and/or utilized include:

- Historical aerial photography
- Historical topography
- Hydrology
- Computer models
- Previous studies

1.2.2. Field Assessment

Geomorphology is a field-based science of observation that relies heavily on the judgment and interpretation of the investigator. Although a significant amount of geomorphic information can be obtained by non-field-based analyses (such as aerial photography interpretation), a detailed field assessment is critical for understanding the river system, verifying mapping, and ground-truthing landform interpretations. A detailed field investigation was conducted for the Virgin River geomorphic assessment. The following types of field data were collected:

- Vegetation characteristics of both the active channel corridor and the floodplain
- The condition of the channel banks
- The impacts of structures on the behavior of the river
- Overall evidence of channel stability

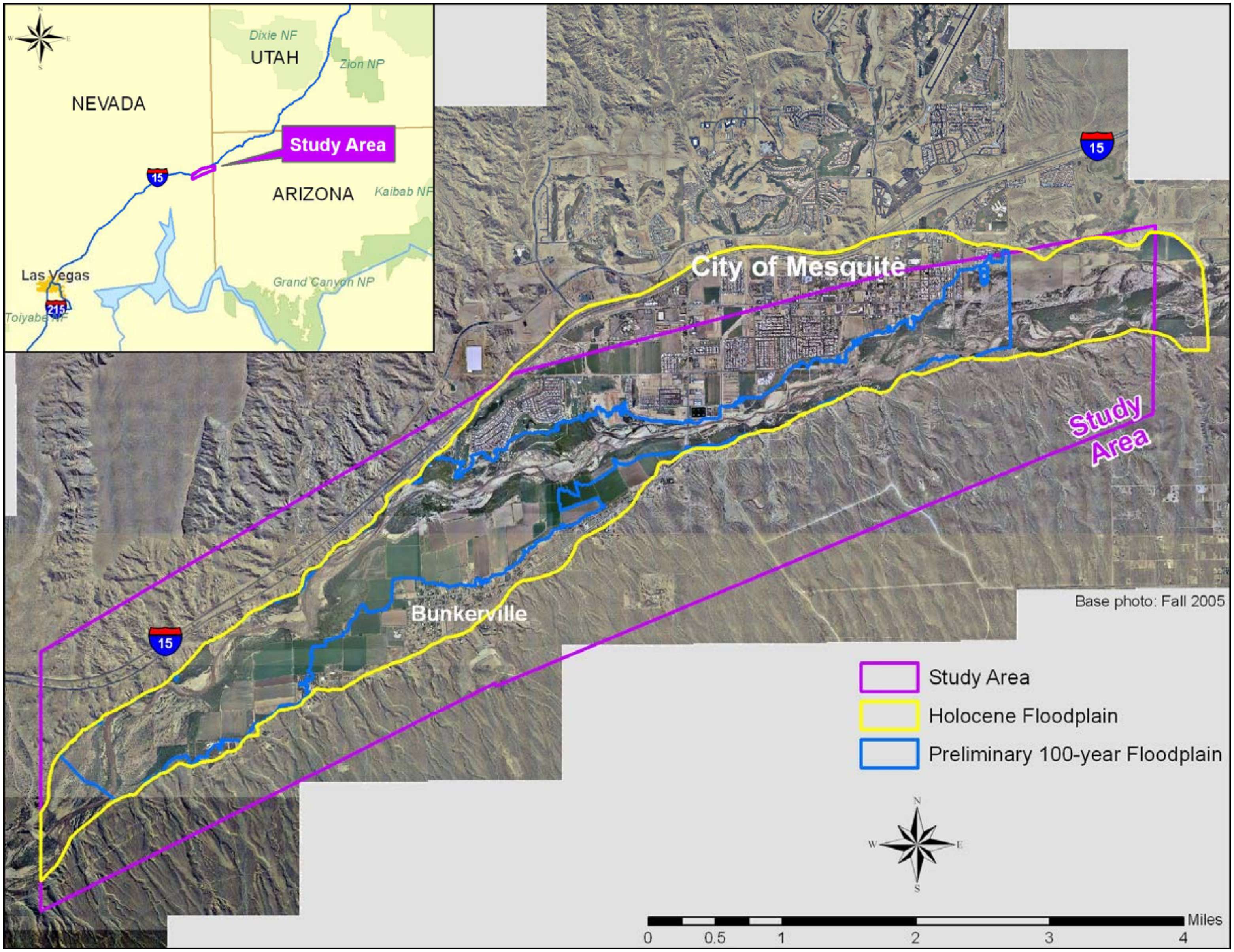

NEVADA
UTAH
ARIZONA
Dixie NF
Zion NP
Kaibab NF
Grand Canyon NP
Las Vegas
Toiyabe NF
15
215
Study Area
City of Mesquite
Bunkerville
15
Study Area
Base photo: Fall 2005
Study Area
Holocene Floodplain
Preliminary 100-year Floodplain
N
S
E
W
0
0.5
1
2
3
4
Miles

Figure 1. Vicinity map

1.2.3. Sedimentation Analysis

The purpose of the sedimentation analysis was to quantify the magnitude of floodplain and channel aggradation and/or degradation and determine the long-term impacts of such processes. Additionally, the impacts of sedimentation during the 2005 flood were examined. Historical topography formed the foundation of this analysis.

1.2.4. Lateral Migration Analysis

The objective of the lateral migration analysis was to estimate the potential for future lateral migration of the Virgin River and to identify areas of expected future lateral erosion within the study area. The lateral migration analysis relied on the results from the analyses described above in conjunction with the following methodologies:

- Historical Channel Position Analysis: Changes in lateral channel position and channel width were quantified using semi-rectified historical aerial photographs. Channel position changes were segregated by incremental processes and long-term processes.
- Hydraulic Data Analysis: Hydraulic data obtained from the PBS&J Virgin River Flood Hazard Study (in progress) one-dimensional hydraulic model were used to plot spatial distribution maps for the purpose of identifying potential areas of future avulsions in addition to areas of expected erosion.
- Impacts of Historical Flood Events: Channel changes occurring in response to specific large floods were described and quantified using the semi-rectified historical aerial photographs.

2. DATA COLLECTION

2.1. Historical Aerial Photography

Photography spanning the past 67 years was collected in both contact print and digital formats. Contact print aerial photos were scanned and semi-rectified using GIS software. The digital aerial photography collected was previously orthorectified. The aerial photography was the primary data source used in the lateral migration analysis (Section 5). Table 1 lists the aerial photographs collected. Not all photo sets collected covered the entire study area.

Table 1. Collected aerial photography

Photo Date	Source	Description
1938	USGS[1]	Black & white scanned digital
1952	USDA[2]	Black & white stereo
1953	USDA	Black & white stereo
1973	USDA	Black & white stereo
1977	USGS	Black & white scanned digital
1978	USGS	Black & white scanned digital
1981	USGS	Black & white scanned digital
1983	USGS	Black & white scanned digital
1984	USDA	Black & white stereo
1994	USDA	Black & white stereo
1995	USGS	Black & white scanned digital
1997	USDA	Black & white stereo
2000	USDA	Black & white stereo
2002	Clark County[3]	Color, digital, orthorectified
2004	Clark County	Color, digital, orthorectified
2005	Clark County	Color, digital, orthorectified

2.2. Historical Topography

Four sources of topography were collected for the geomorphic assessment. The historical topography was the primary source of data for the sedimentation analysis (Section 4) in addition to portions of the lateral migration analysis (Section 5). Table 2 lists the topography collected.

---

[1] USGS = United States Geological Survey (Henderson, Nevada field office)

[2] USDA = United States Department of Agriculture (Aerial Photography Field Office, Salt Lake City, UT)

[3] Clark County, Nevada

Table 2. Collected topographic data

Year	Resolution	Type	Source
1978	10 meter	Digital DEM	USGS
1996[4]	-	Digital HEC-2	CCRFCD[5]
2004	-[6]	Digital LiDAR DEM	SNWA[7]
2005	-[6]	Digital LiDAR DEM	USBR[8]

Both the 1978 USGS and the 2004 and 2005 topography were collected in the form of digital elevation model (DEM) data. The USGS DEM data files are gridded digital representations of contoured elevation data from 7.5-minute quadrangle raster maps. The 2004 and 2005 DEMs were derived from Light Detection and Ranging (LiDAR) aerial mapping data. A triangular irregular network (TIN) surface was generated using GIS software for each of the collected DEM data. The raw TIN data were used for cutting cross-sections and generating longitudinal profiles (Section 4). The TIN models were converted to raster images for use in the elevation change analyses (Section 4). The 1996 HEC-2 cross-sections were used in the cross-section and longitudinal profile comparison analyses.

2.2.1. Vertical Datum

The 1978 USGS DEM data in addition to the 1996 HEC-2 data were based on the National Geodetic Vertical Datum (NGVD) of 1929. The 2004 and 2005 LiDAR DEM data were based on the North American Vertical Datum (NAVD) of 1988. In order to compare the data sets, a conversion from NGVD to NAVD was performed for the 1978 and 1996 data. A vertical conversion factor of 2.29 feet was determined using the software program VERTCON developed by the National Geodetic Survey. This vertical conversion factor was applied to the 1978 and 1996 topographic data for use in this study.

2.3. Hydrology

USGS gage data from several sites were collected and synthesized to determine historical flows for the Virgin River within the study area. Figure 2 is a plot of the annual peak flows for USGS gage #9415000 at Littlefield, AZ (upstream of study area). The plot indicates the January 2005 flood peak is the largest natural flood in the gage record. The largest unnatural flood (61,000 cubic feet per second (cfs)) resulted from the 1989 Quail Creek Reservoir dam breach. At the time of this report, the peak discharge estimate for the 2005 flood was 36,500 cfs (shown on Figure 2 for reference), and the 100-year regulatory discharge estimate was 39,500 cfs. The plot is colored by season in which the peak flood occurred. The two largest natural peak floods (1967 and 2005) occurred in winter, however the next three largest occurred in the spring. Several large summer floods are also shown in the plot. This suggests that no single flood season has been dominant within the gage record.

---

[4] 1996 data were collected in the form of HEC-2 cross-sections derived from *Virgin River Flood Study* (Bulloch Bros. Engineering, Inc., 1996).

[5] CCRFCD = Clark County Regional Flood Control District

[6] Both the 2004 and 2005 LiDAR data consisted of random points and varied in density within each data set, thus no data resolution could be defined.

[7] SNWA = Southern Nevada Water Authority

[8] USBR = United States Bureau of Reclamation

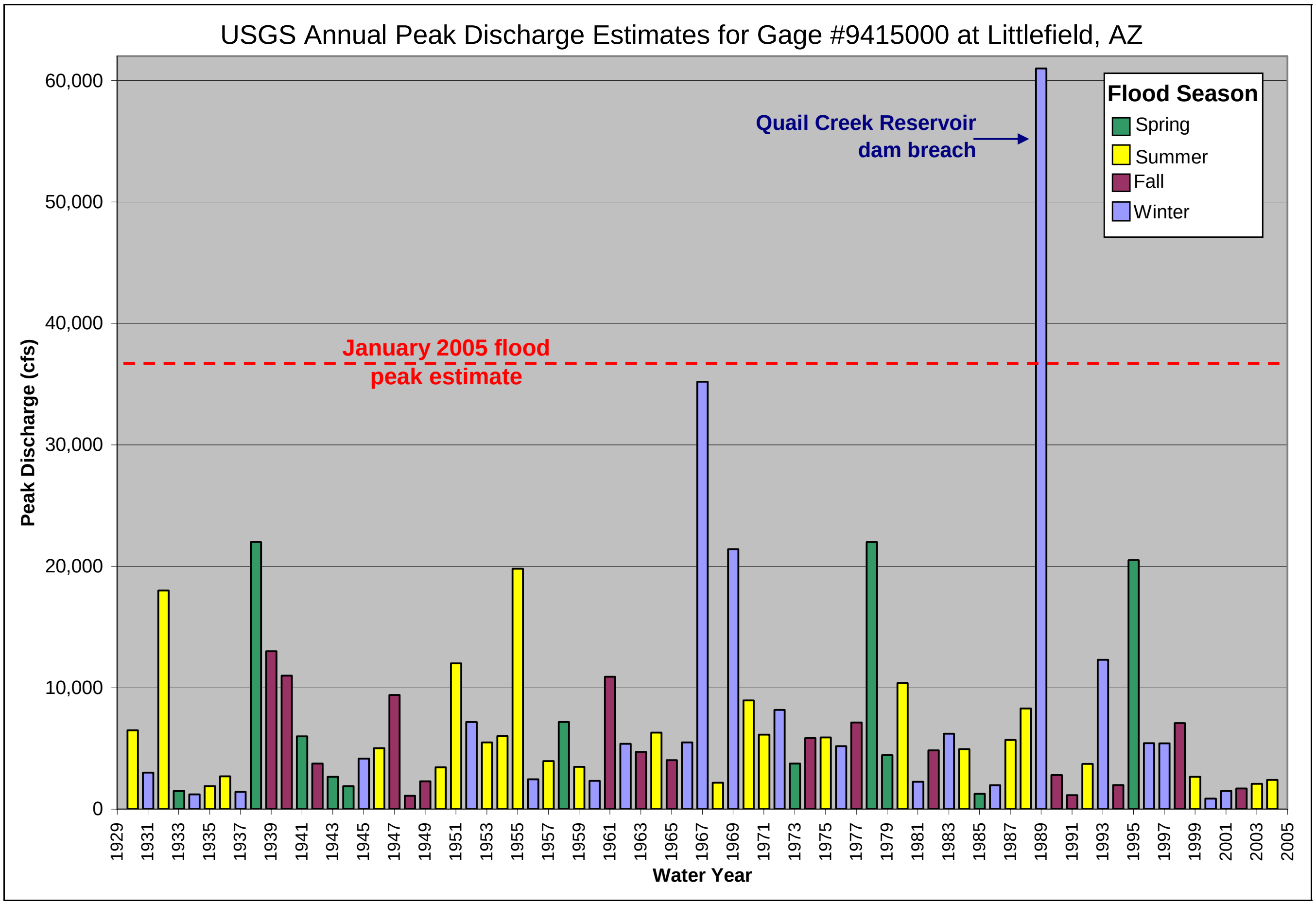


Figure 2. Annual peak flow discharge estimates for USGS gage at Littlefield, AZ

2.4. Computer Models

Several hydraulic computer models were collected for multiple uses in the geomorphic assessment. The HEC-2 model from the *Virgin River Flood Insurance Study* (Bulloch Bros. Engineering, Inc., 1996) was used to compare both the cross-section and longitudinal profiles of the 1978 and 2004-2005 topography. The HEC-RAS model developed for the *Virgin River Flood Hazard Study* (PBS&J, in progress) was used in the hydraulic data analysis (Section 4).

2.5. Previous Studies

Relevant reports from several previous studies were collected and synthesized for this analysis. Each of these reports are listed and briefly summarized below:

Paleofloods and a Dam-Failure Flood on the Virgin River, Utah and Arizona (Enzel et al., 1993) - The focus of this study was to place the historical record and the 1989 Quail

Creek dam-break event in a long-term context using geological data from pre-historical floods. The study concluded that within the past 1,000 years, multiple natural floods within the Virgin River gorge have equaled or exceeded the magnitude of the 1989 Quail Creek Reservoir dam breach flood. Flood frequency analysis results of the study concluded that the 1989 flood had a 250-year recurrence interval, and that the 100-year flood estimate increased from 31,042 cfs (using only gage data) to 45,555 cfs (combining paleoflood data with the gage record). For comparison, the 2005 flood peak estimate was 36,500 cfs.

Flood of the Virgin River, January 1989, in Utah, Arizona, and Nevada (Carlson et al., 1995) - The purpose of this report was to chronicle the Quail Creek Reservoir dam breach, to discuss the hydrology of the flood, and to generally describe post-flood channel corridor changes and damages to manmade structures. The report summarized significant damage to residences, businesses, agricultural equipment, crops, livestock, roads, bridges, and irrigation structures with damages estimates exceeding $12 million.

Estimates of Bridge Scour at Two Sites on the Virgin River, Southeastern Nevada, Using a Sediment-Transport Model and Historical Geomorphic Data, (Hilmes et al., 1997) – The focus of the USGS study was to estimate bridge scour at the Mesquite and Riverside Bridges using both a sediment transport model (BRI-STARS) and a geomorphic evaluation. The BRI-STARS model was calibrated using 1994 surveyed cross-section data and 1995 post-flood surveyed cross-section data from five reaches of the Virgin River between Littlefield, AZ and Riverside, NV. The BRI-STARS model predicted 0.66 feet of aggradation for the simulated 100-year flood, and 0.72 feet of aggradation for the simulated 500-year flood at the Bunkerville Bridge. The model predicted 1.34 feet net scour for the 100-year flood and 1.54 feet of net scour for the 500-year flood at the Riverside Bridge. The geomorphic evaluation concluded that climate and streamflow reduction had resulted in channel narrowing and vegetation encroachment on the floodplain. Additionally, the greatest historical channel changes resulted from long-duration floods with multiple peaks in the hydrograph, and not from large magnitude peak floods with short durations.

All of the previous studies concluded that the Virgin River experiences large floods, during which lateral erosion and scour should be expected. Significant channel changes may also occur during periods of long-duration and above-average runoff.

3. FIELD ASSESSMENT

Geomorphologists from JE Fuller/Hydrology & Geomorphology, Inc. (JEF) conducted a field investigation in late October and early November of 2005, which consisted of observing key features of the study area, preparing systematic field notes, and obtaining photographs of channel and floodplain conditions. Field photos are shown throughout this report and are referenced by photo number. A map showing field photo locations and subsequent photo numbers is attached in Appendix A. The results of the field investigations are presented in this section. The following channel and floodplain characteristics relevant to lateral erosion and channel stability were observed and recorded in the field:

- Cutbanks – location and sediment characteristics
- Headcuts – density, extent, and depth
- Avulsion Potential – overbank areas at risk of avulsion
- Floodplain Sediment Accumulation – evidence of overbank flow depths, direction, and velocities
- Vegetation – channel, floodplain, type, and density
- Structures – levees, bridges, bank protection, and grade control
- Disturbed Areas – areas directly altered by human activity

3.1. Active Channel and Floodplain Conditions

3.1.1. Vegetation

The presence of dense, deeply rooted channel bank vegetation can enhance bank stability and reduce rates of lateral erosion. Root material binds soil material and can increase resistance to stream erosion. Vegetative litter produces a mat that can reduce the degree of water to soil contact. Plant stems, branches, and leaves increase roughness, resulting in decreased flow velocities, all of which can contribute to reduced lateral erosion potential. Vegetation characteristics generally vary by geomorphic surface, soil substrate, water availability, frequency of flood inundation, and human influence.

The vegetation variability along the Virgin River active channel within the study area was relatively low. Both the active channel and floodplain vegetation were dominated by tamarisk of varying maturity and density, with slackwater areas frequently containing sparse cottonwood trees and willow. As with many watercourses in the western United States, tamarisk has become the dominant plant species and influences geomorphic behavior and channel stability of the Virgin River. Tamarisk was thought to have first been introduced into the United States by nurserymen in the early 1800s and used as a landscape ornamental, wind barrier, and for stabilization of channel banks (Robinson, 1965). Encroachment of dense vegetation such as tamarisk can influence channel behavior (Graf, 1978; Kunzmann et al., 1987, and others). For example, during the low-flow years of 2001-2004, tamarisk encroached on the Virgin River active channel within the study area resulting in an overly-narrow conveyance corridor. This corridor was insufficient to convey the discharge from the 2005 flood resulting in channel widening, avulsions, excessive floodplain sediment deposition, and lateral erosion of channel banks.

A significant amount of bank vegetation was lost during the 2005 flood as a result of channel widening. Although the 2004 aerial photography indicated dense bank vegetation throughout much of the study area, this vegetation appeared to provide moderate to no protection from lateral erosion. This was likely due to highly erosive flow velocities confined to the narrow conveyance corridor which resulted in scour below the tamarisk rooting layer. The encroachment of vegetation on the low-flow channel was likely caused by persistent years of drought, combined with a lower frequency of moderate to large flood events. The result was a narrow channel that was densely vegetated along both the banks and the floodplain. The active channel width in 2004 was narrower than any other time in the period of record (see Section 5.2), a direct result of repeated low-flow years and tamarisk encroachment.

The 2005 flood demonstrated that when a large-magnitude, low frequency flood occurs during this condition, the narrow channel is insufficient to convey the flow, thus must create a wider conveyance corridor. This process removes bank vegetation and creates vertical, unstable cutbanks. These processes occurred during the 2005 flood. The plot of USGS peak flow values shown in Figure 2 indicates a series of low-flow years from 1996 to 2004, the longest span between large floods in the 74-year gage record at Littlefield, AZ. This resulted in a narrow, over-grown channel insufficient for conveying a discharge of 36,500 cfs (peak 2005 flood). Figure 3 shows a typical example of pre- and post-flood channel and bank vegetation conditions within the study area.

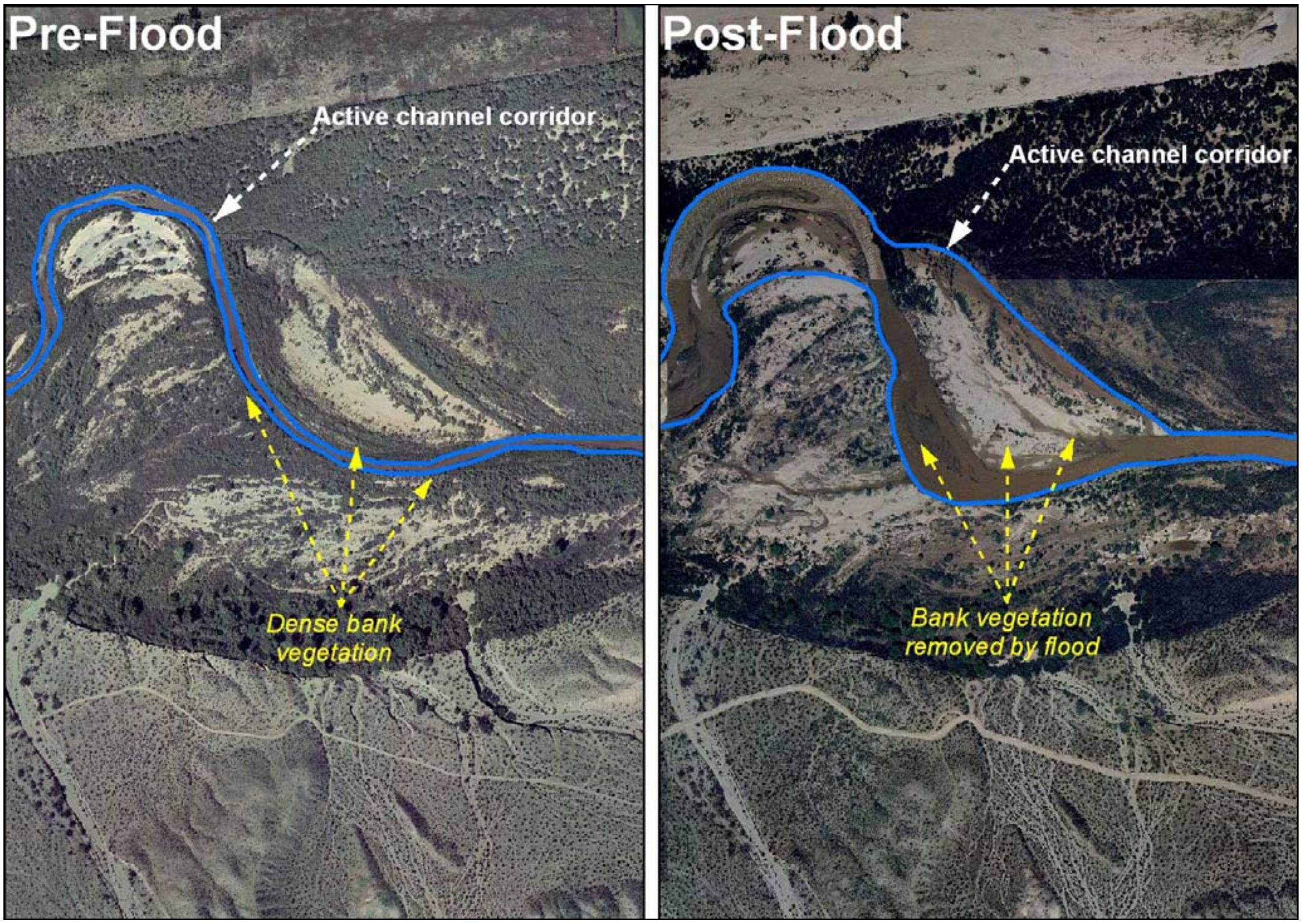
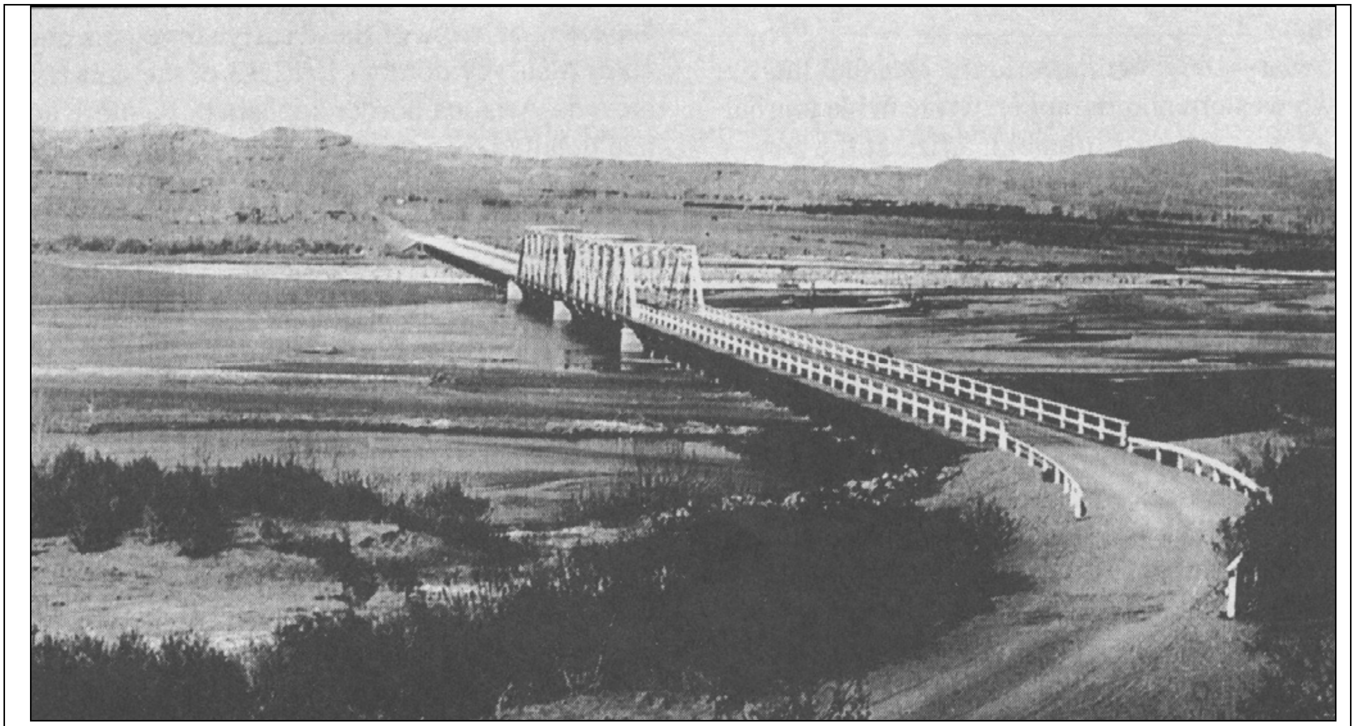
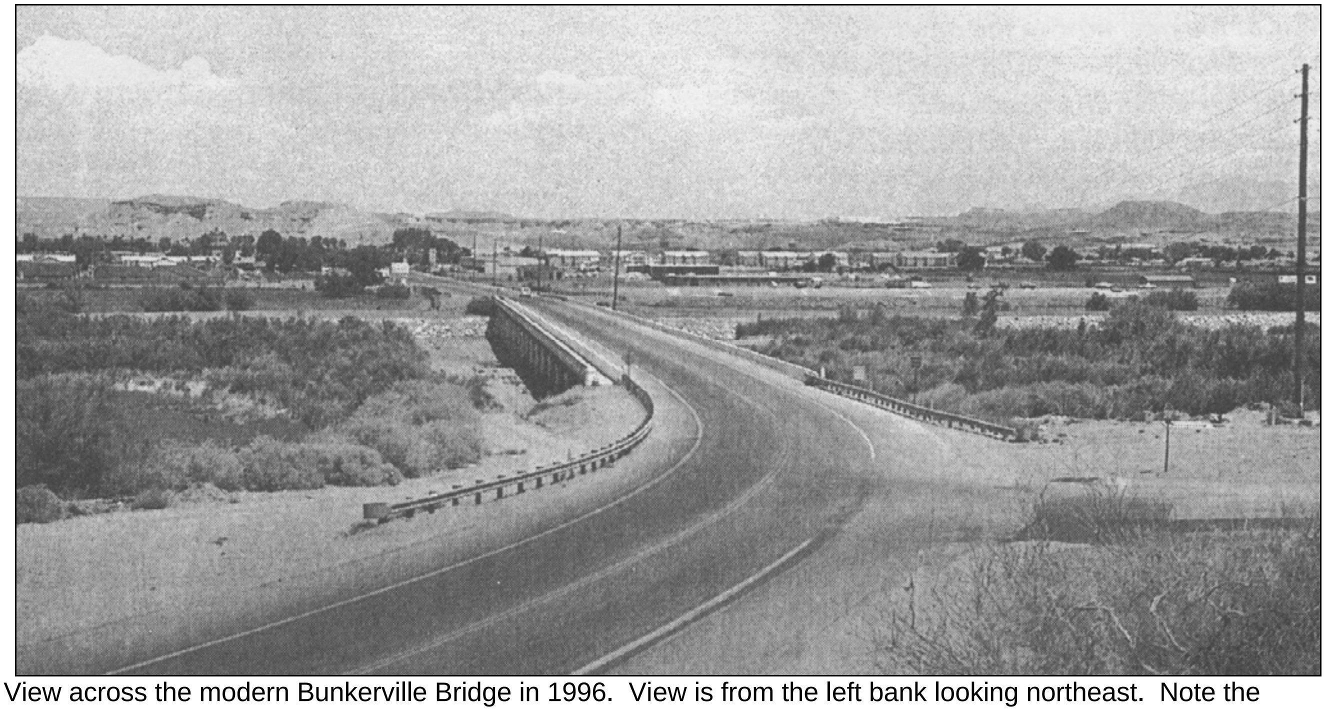


Figure 3. Pre- and post-flood channel and bank vegetation

Historical aerial photos of the study area show the long-term expansion of tamarisk from 1938 through 2005 (see Appendix Companion Book, separate volume). The photos also show the rapid rate of re-colonization of tamarisk following high flow conditions when the floodplain vegetation is eroded and removed. Prior to the introduction and dominance of tamarisk, the Virgin River floodplain within the study area was sparsely vegetated which allowed for natural meandering of the low-flow channel in addition to providing overbank storage and conveyance during large floods. Figure 4 and Figure 5 show a comparison of ground photos taken in the 1920s and late 1990s and illustrate the impacts of tamarisk on the floodplain. Note the dramatic loss of floodplain conveyance area between the older and newer photos. A large-format map is included in Appendix D to further illustrate the changes in the floodplain conveyance between 1938 and 2005.

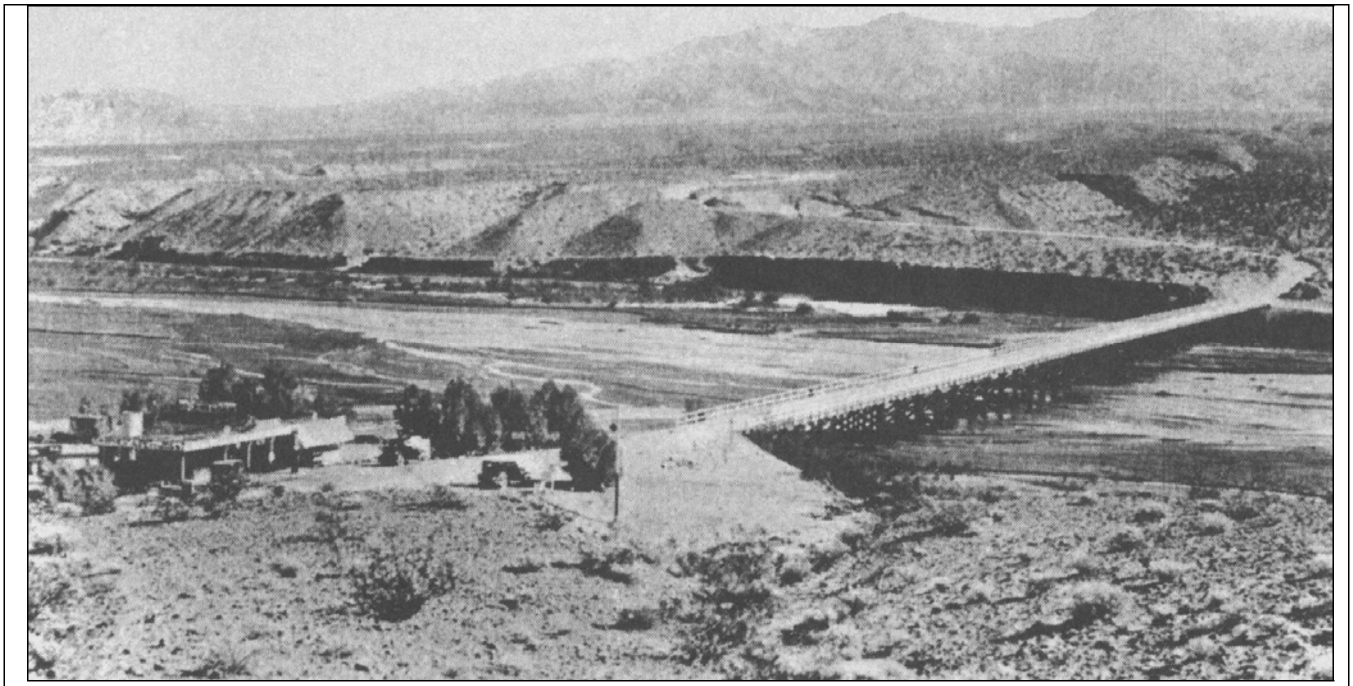


View across the Bunkerville Bridge in 1924. View from left bank looking northeast. The alignment is slightly upstream from the modern bridge alignment shown below. Note the lack of vegetation in the floodplain and the wide, shallow low-flow channel. *(Photo source: Hilmes et al., 1997)*

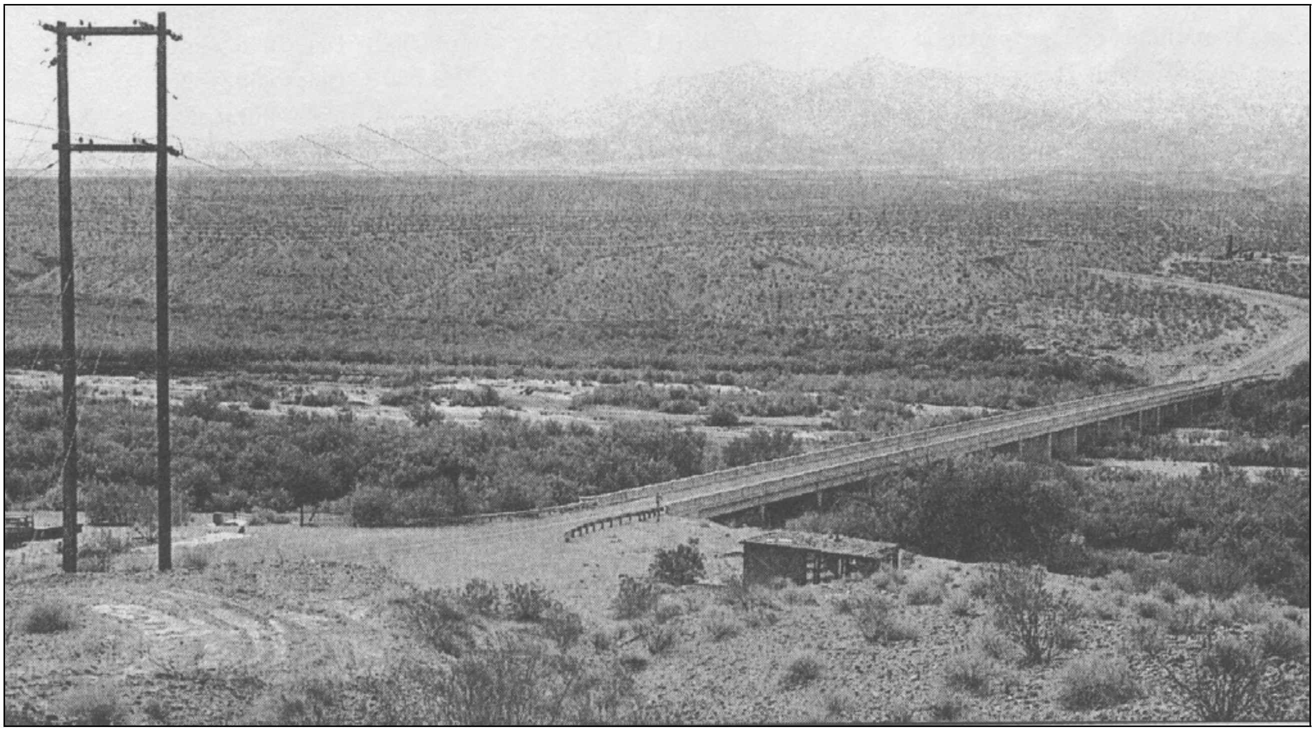


View across the modern Bunkerville Bridge in 1996. View is from the left bank looking northeast. Note the dense tamarisk in the floodplain. *(Photo source: Hilmes et al., 1997)*

Figure 4. Historical ground photos of floodplain vegetation near the Bunkerville Bridge



View across the Riverside Bridge (downstream of study area boundary) in the late 1920s. View is from the right bank looking southeast. Note the lack of vegetation in the floodplain. *(Photo source: Hilmes et al., 1997)*



View across the modern Riverside Bridge in 1996. The modern bridge occupies approximately the same alignment as the photo above. Note the dense vegetation in the floodplain and the narrower low-flow channel. *(Photo source: Hilmes et al., 1997)*

Figure 5. Historical ground photos of floodplain vegetation near the Riverside Bridge

3.1.2. *Bank Stability*

A cutbank is a stream bank that has been eroded (cut) to a steep, vertical or overhanging slope. The presence of cutbanks generally indicates active lateral migration processes within the active channel corridor, but can also result from incision. Cutbanks can result from both high- and low-frequency flood events. Vertical cutbanks are generally unstable and result in the calving of large blocks of bank material that can occur independent of river flows. Vertical cutbanks also generally indicate highly erodible bank sediments, but can form in more resistant bank material such as caliche. Vertical banks found in resistant or cohesive material (e.g. caliche or clay) generally have much slower rates of lateral erosion (e.g. hundreds to thousands of years) than non-resistant material (tens of days to years). The rapid channel widening that occurred during the 2005 flood resulted in vertical to near-vertical cutbanks at multiple locations within the study area. Figure 6 shows cutbanks observed during the field investigation.

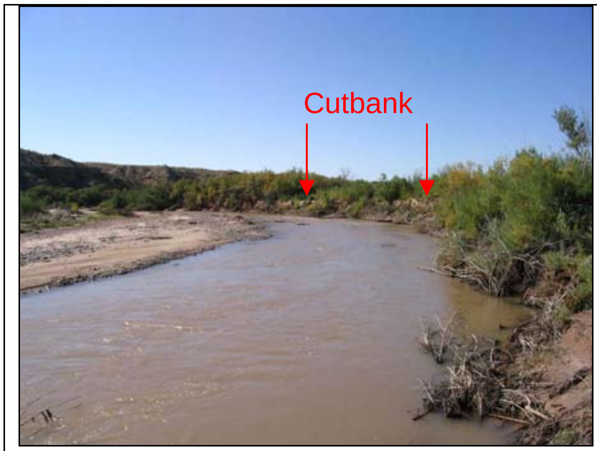


Photo 32. View downstream.

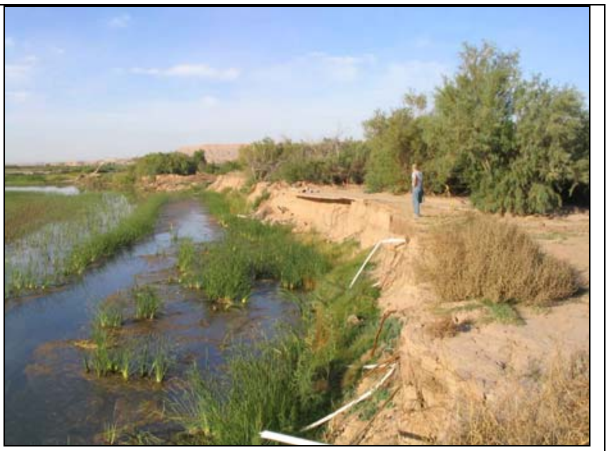


Photo 90. View downstream.

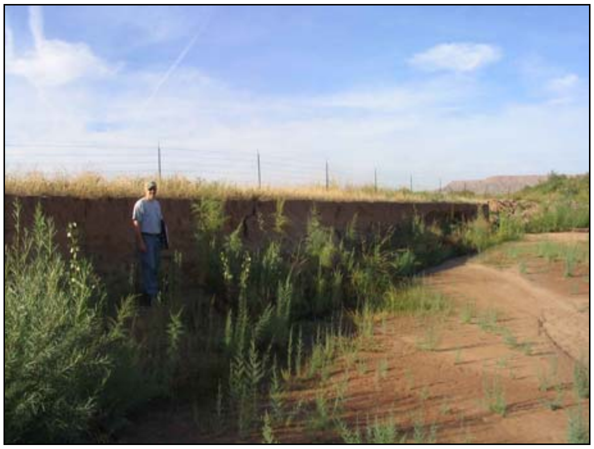


Photo 94. View downstream.

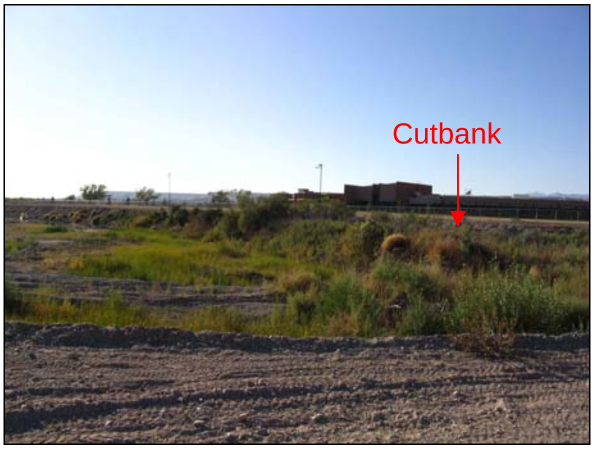


Photo 75. View downstream.

Figure 6. Cutbanks

3.1.3. *Impacts of Manmade Structures*

Manmade structures can adversely impact channel morphology and future channel behavior. Conversely, natural channel changes can adversely impact manmade structures. At minimum, manmade structures provide a reference point from which to measure progressive channel changes. Channel features at and near structures observed during the field visit were inventoried to identify clues about the existing and future channel stability.

Three structures directly impacted by the active channel were identified during the field investigation and included the Bunkerville Ditch diversion structure, the Bunkerville Bridge, and the Abbott Wash outfall. Each of these structures were observed, documented, and photographed.

3.1.3.1.Bunkerville Ditch Diversion Structure

At the time of the field investigation, the Bunkerville Ditch diversion structure was composed of a two-step, concrete drop structure approximately 330 feet in length and spanning most of the active channel (Figure 7). A portion of the structure failed during the 2005 flood but had been re-constructed at time of the field investigation. City officials indicated the northern portion of the structure was flanked by overbank flows resulting in 10+ feet of scour which eroded a portion of the structure. Throughout its history, the diversion structure has been destroyed by flooding on multiple occasions, and subsequently rebuilt following each event (Hilmes et al., 1997). Although designed for diversion, the feature also serves as a grade-control structure for the Virgin River.

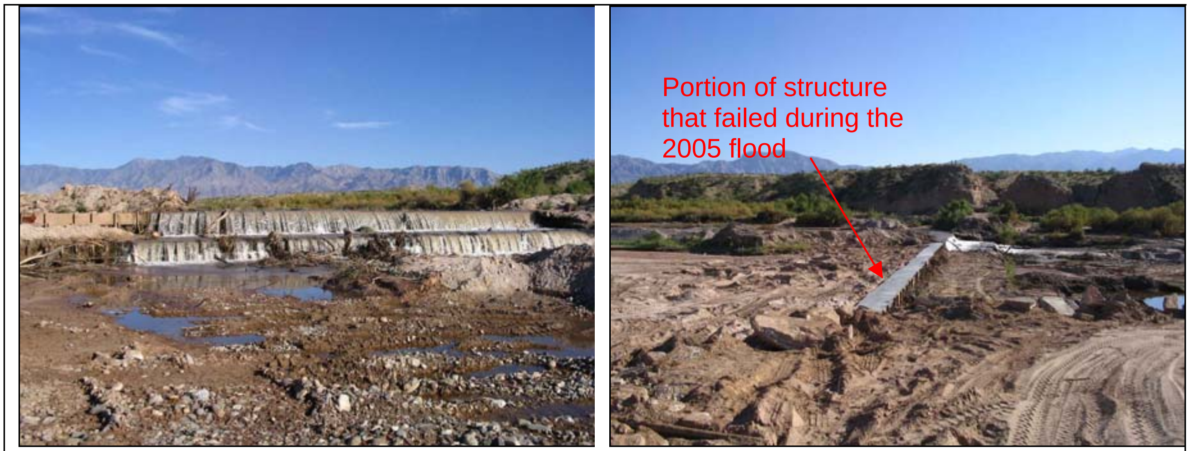


Photo 70. Diversion structure. View upstream.

Photo 65. Newly constructed section of the diversion structure. View southeast.

Figure 7. Field photos of Bunkerville Ditch diversion structure

3.1.3.2.Bunkerville Bridge

The Bunkerville Bridge appeared to have been minimally impacted by the flood. It was difficult to ascertain the geomorphic character (alignment, angle of attack) of the channel during the floods due to the significant amount of manmade excavation and channel realignment that had occurred in the time between the flood and the field investigation. One of the primary goals in the field inspection of the Bunkerville Bridge was to determine the amount of scour and/or sedimentation that had occurred during the flood. The bridge creates one of the narrowest sections in the study area, however, no significant adverse impacts to the channel were found during the field investigation. The degree of sedimentation could not be determined due to the manual removal of sediment from the bridge openings (Figure 8). Silt lines were present on the bridge piers, but it was unclear if they were from pre-flood accumulated sediment, or from sediment accumulated during the flood (Figure 8). A significant amount of debris had accumulated on the upstream face of the piers, but appeared to have had minimal impact. A post-flood elevation change analysis was performed for this study (see Section 4.2) which indicated no significant net scour occurred during the 2005 flood immediately upstream or downstream of the bridge.

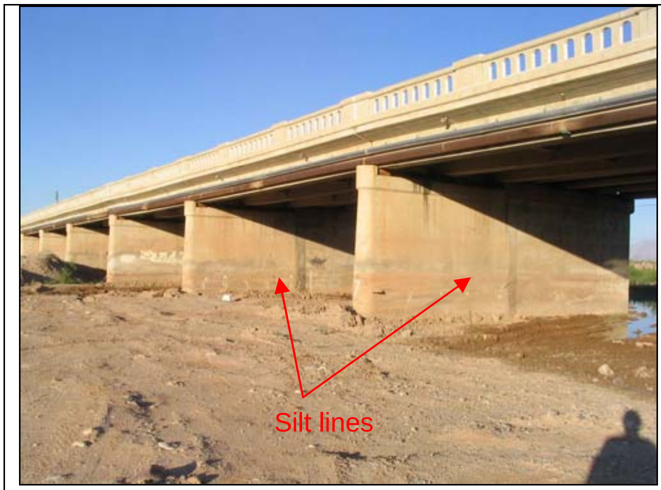


Photo 88. Downstream face of bridge looking north. Note fresh silt lines on piers and dozer scrape marks in the wet sediment.

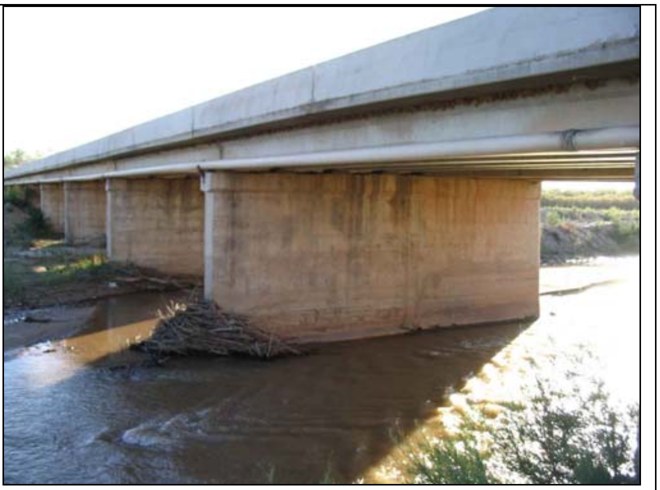


Photo 85. Debris pile on upstream face of pier. View south.

Figure 8. Bunkerville Bridge field photos

3.1.3.3.Abbott Wash Outfall

The Abbott Wash Outfall structure was damaged by the 2005 flood. During the field investigation, the only remnant of the structure was a series of concrete energy-dissipating blocks (Figure 9). The main channel immediately downstream of the outfall structure experienced significant scour during the flood. This suggests the flow adjacent to the outfall structure had high velocities, resulting in the lateral migration of the bank and the subsequent damage to the structure.

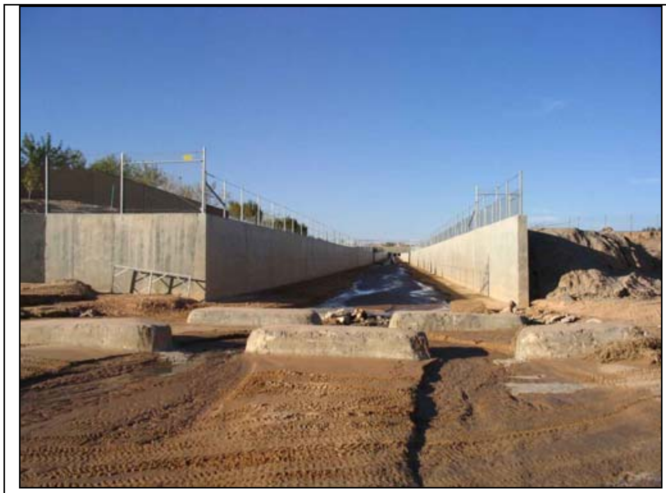


Photo 80. Abbott Wash Outfall structure. View north into Abbott Wash channel.

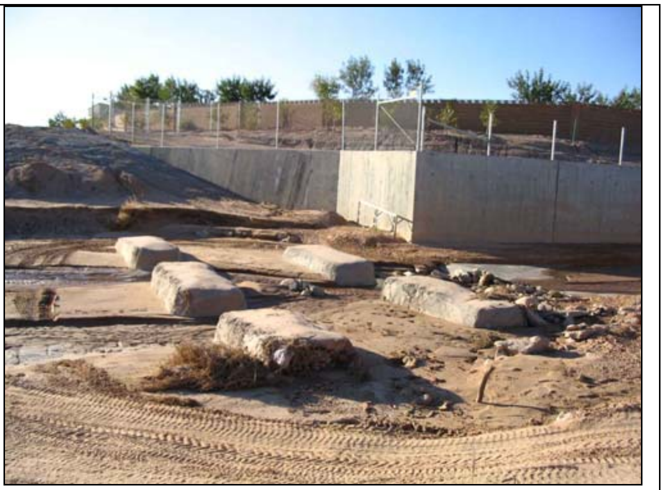


Photo 82. Remaining Abbott Wash Outfall structure. View downstream.

Figure 9. Abbott Wash Outfall structure

3.2. Summary

A post-2005 flood field investigation of the Virgin River within the study area was conducted in late October and early November of 2005. The purpose of the investigation was to assess the existing conditions of the river following the January floods in addition to collecting data to be used in the geomorphic assessment. Field photographs taken during the investigation are included in Appendix A.

4. SEDIMENTATION ANALYSIS

An avulsion is the formation of a channel in a portion of the floodplain not previously occupied by a channel. Avulsions are often responsible for some of the most significant lateral channel movement on the large stream systems in the Southwest. Generally formed during flood events, avulsions can be responsible for dramatic changes in river course orientation, causing flooding and erosion hazards in parts of the floodplain that had not previously experienced such hazards. Multiple avulsions occurred along the Virgin River study reach during the 2005 flood, the largest of which resulted in the flooding of several homes that were located outside the existing regulatory 100-year floodplain. One potential cause of such avulsions is high-velocity flow on the floodplain associated with high flood stage. Another is aggradation, or sedimentation, within the active channel corridor. Sedimentation increases the water surface elevation and forces flow onto the floodplain, where it creates new channels and flow paths called avulsions. Aggradation of the active channel can be a gradual, long-term process spanning multiple years which may go undetected until a large magnitude flood results in an avulsion. It can also occur during a single flood event given the right conditions, such as rapid expansion of the active channel causing deposition of suspended sediment, high-roughness conditions (vegetation, man-made structures), or changes in channel slope. During the early stages of this study, flood observers and local officials suspected channel aggradation may have been a factor in the 2005 flood avulsion. Aggradation of the active channel, both long-term and single-event, was investigated using a variety of methods to determine what effect, if any, it had on the 2005 flood avulsions.

4.1. Cross-Section Comparisons

Historical cross-section comparisons can be highly informative about the vertical and lateral changes of an active channel and floodplain over time. Like most historical analyses, the further back in time the data extends, the better the understanding of long-term processes. Potential limitations that frequently exist in historical cross-section comparisons are data accuracy and the variability in topographic resolution. These limitations were encountered in this analysis and were considered in the interpretation of the data. Figure 10 shows the locations of the cross-sections used for this study.

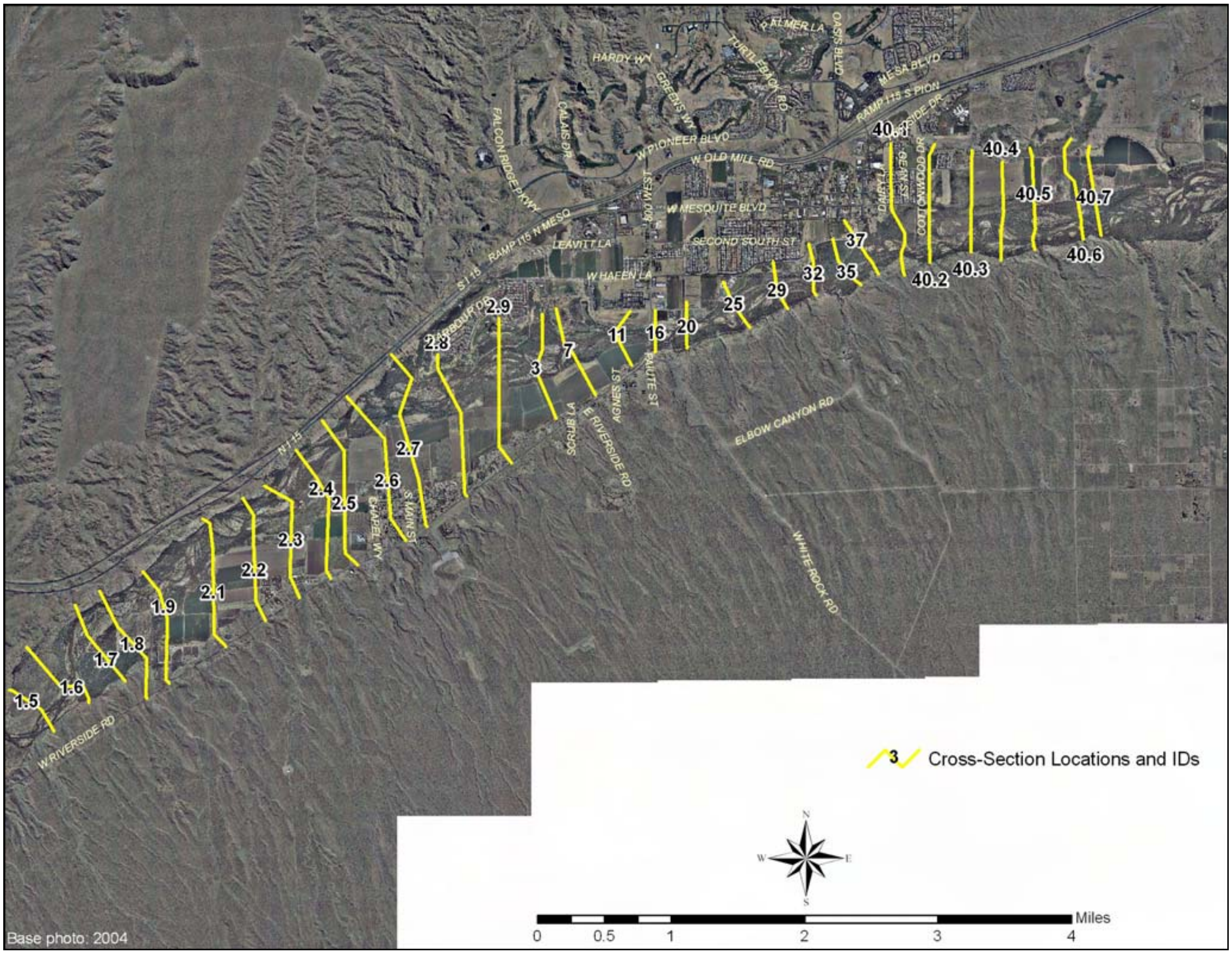

PALMER LA
OASIS BLVD
HARDY WY
TURTLEBACK RD
GREENS WY
MESA BLVD
RAMP I15 S PION
SIDE DR
FALCON RIDGE PKWY
CALAIS DR
W PIONEER BLVD
W OLD MILL RD
800 WEST
W MESQUITE BLVD
RAMP I15 N MESQ
LEAVITT LA
SECOND SOUTH ST
W HAFEN LA
S I 15
HARBOUR DR
DAIRY LA
GEAN ST
COTTONWOOD DR
40.1
40.2
40.3
40.4
40.5
40.6
40.7
37
35
32
29
25
20
16
11
7
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
1.9
1.8
1.7
1.6
1.5
N I 15
AGNES ST
PAIUTE ST
SCRUB LA
E RIVERSIDE RD
ELBOW CANYON RD
WHITE ROCK RD
S MAIN ST
CHAPEL WY
W RIVERSIDE RD
3 Cross-Section Locations and IDs
N
W
E
S
0
0.5
1
2
3
4
Miles
Base photo: 2004

Figure 10. Locations of cross-sections used in this study

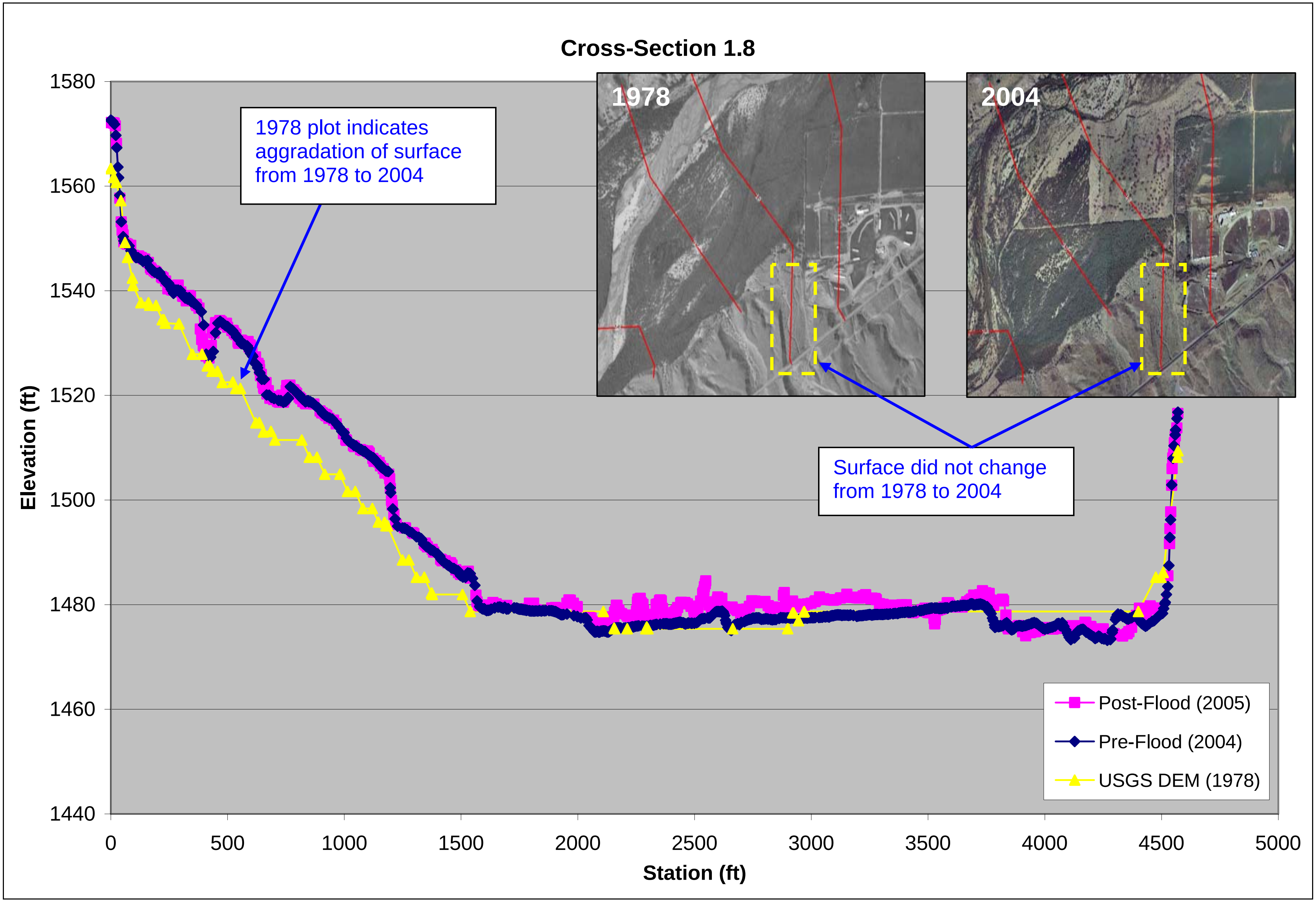
The cross-section profile plots are shown in entirety in Appendix B, and the cross-section source data are listed in Section 2.2. The 1978, 2004, and 2005 cross-section profiles were extracted from the TIN models using GIS software tools. The 1996 cross-sections were derived from the Bulloch Brothers Flood Insurance Study (FIS) HEC-2 model. For consistency, the cross-section IDs from the FIS study were maintained. Those cross-sections outside the Bulloch Brothers FIS study area were derived from the 2006 PBS&J *Virgin River Flood Hazard Study* and were arbitrarily labeled for this analysis to conform to the Bulloch Brothers FIS identifications (IDs). The 1978 cross-sections were derived from USGS DEM models. The horizontal resolution of the USGS data set was 10 meters (32.8 feet), which is relatively low compared to the 2004 and 2005 data. When plotting the 1978 cross-sections with the 2004 and 2005 data, several discrepancies were consistently observed throughout the entire data set:

- Vertical shifts outside the active channel and floodplain where no change in elevation occurred such as on older, geologically stable surfaces and developed surfaces with infrastructure (e.g. buildings, etc.). This falsely suggests aggradation and degradation in areas where it is known by observation that such no change occurred (Figure 11).

- Lateral shifts outside the active channel and floodplain areas. This falsely suggests lateral changes on surfaces that have not been altered as indicated by examination of aerial photography (Figure 12).

The results of this comparison suggest the 1978 cross-section data are highly suspect compared to the more recent topographic data. The discrepancies are significant enough that elevation change comparisons at site-specific locations could not be interpreted with confidence. The 1978 plots are informative, however, in showing changes in the general shape of the channel and floodplain. When combined with aerial photography, the 1978 cross-sections were also useful in identifying large magnitude lateral changes in the active channel (Figure 13).

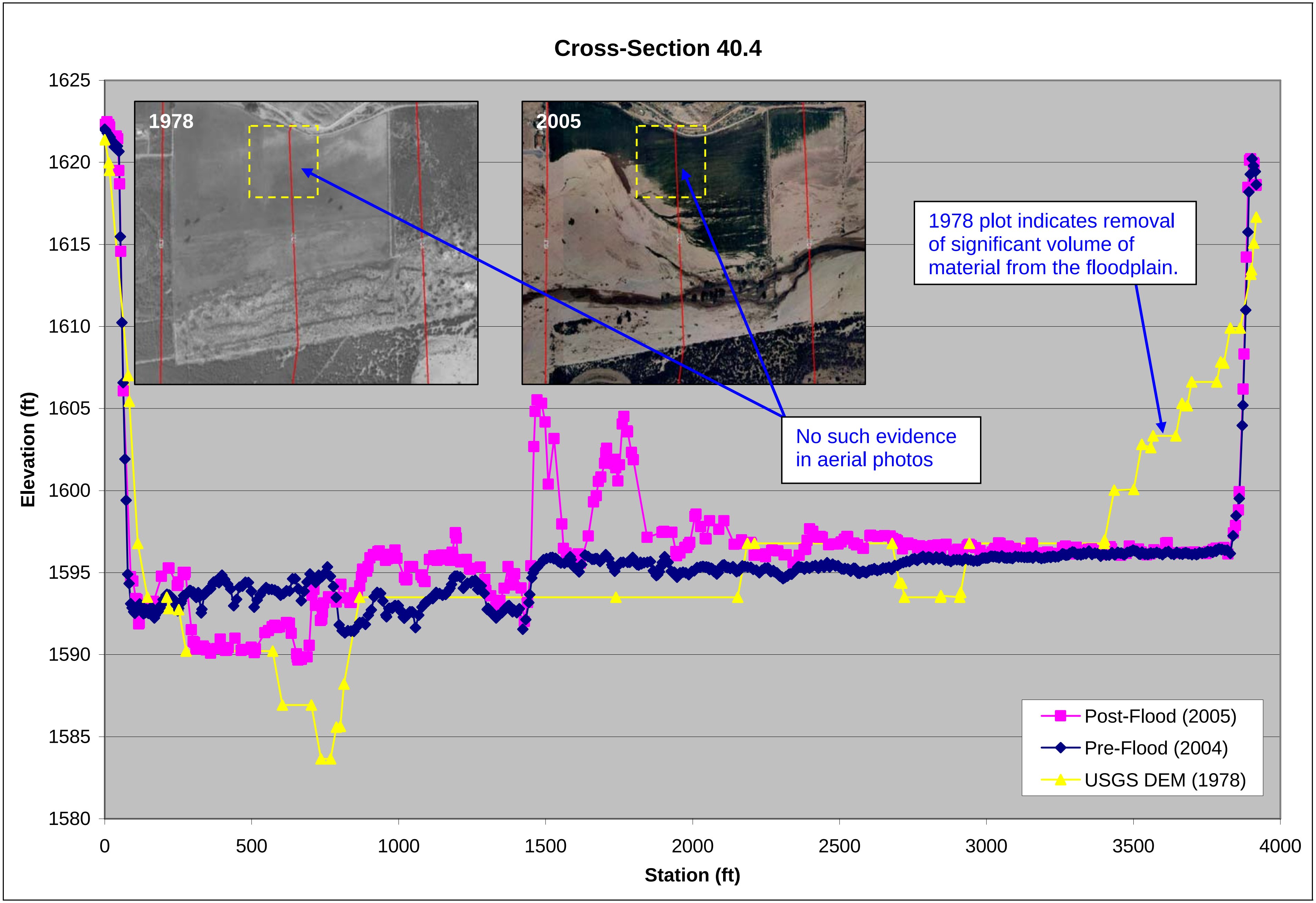
Comparison of the 2004 and 2005 data sets provided insight into the magnitude and types of changes that occurred as a result of the 2005 flood. Channel widening, aggradation, degradation, and lateral migration of the active channel were all observed in the comparison plots. Figure 14 shows a cross-section comparison for pre- and post-flood conditions. The results of the cross-section comparisons were used in conjunction with the lateral migration analysis results (Section 5) to estimate the extent of future lateral erosion (Section 6).



1978 plot indicates aggradation of surface from 1978 to 2004

Surface did not change from 1978 to 2004

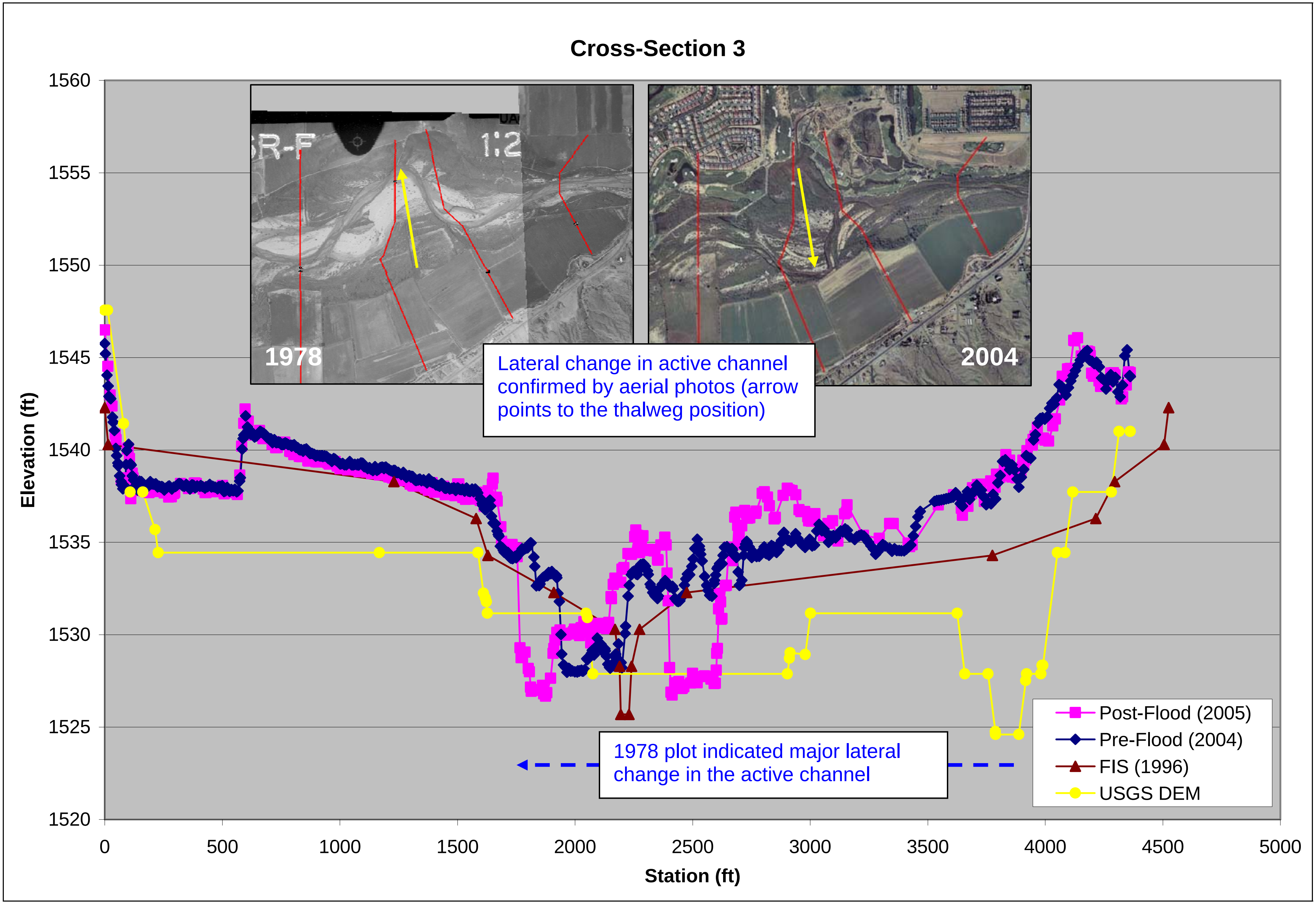
Figure 11. Cross-section comparison plot showing 1978 data discrepancy



1978 plot indicates removal of significant volume of material from the floodplain.

No such evidence in aerial photos

Figure 12. Cross-section comparison plot showing 1978 data discrepancy



Lateral change in active channel confirmed by aerial photos (arrow points to the thalweg position)

1978 plot indicated major lateral change in the active channel

Figure 13. Cross-section comparison showing major lateral change in active channel location

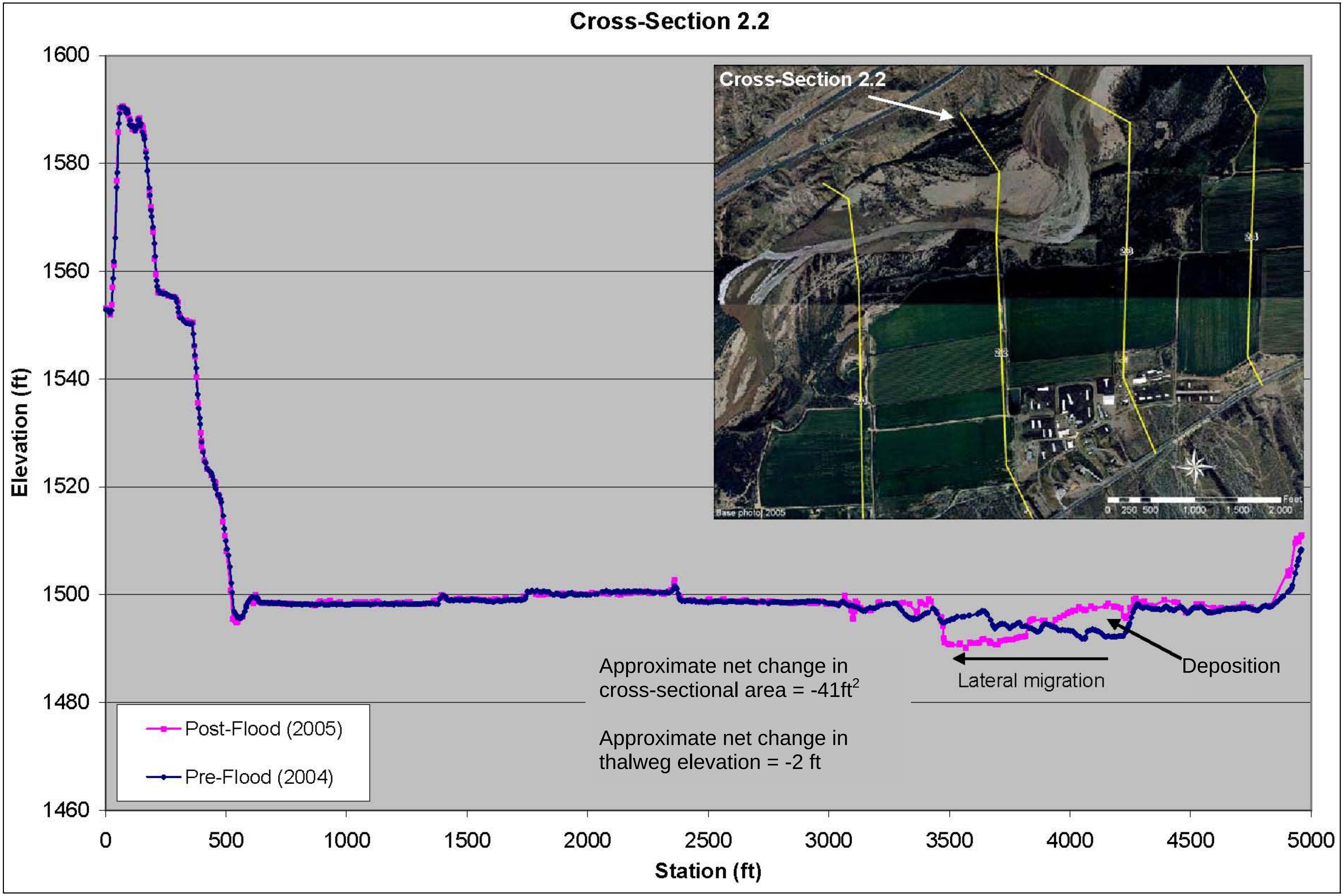


Figure 14. Cross-section example

4.2. Elevation Change Analysis

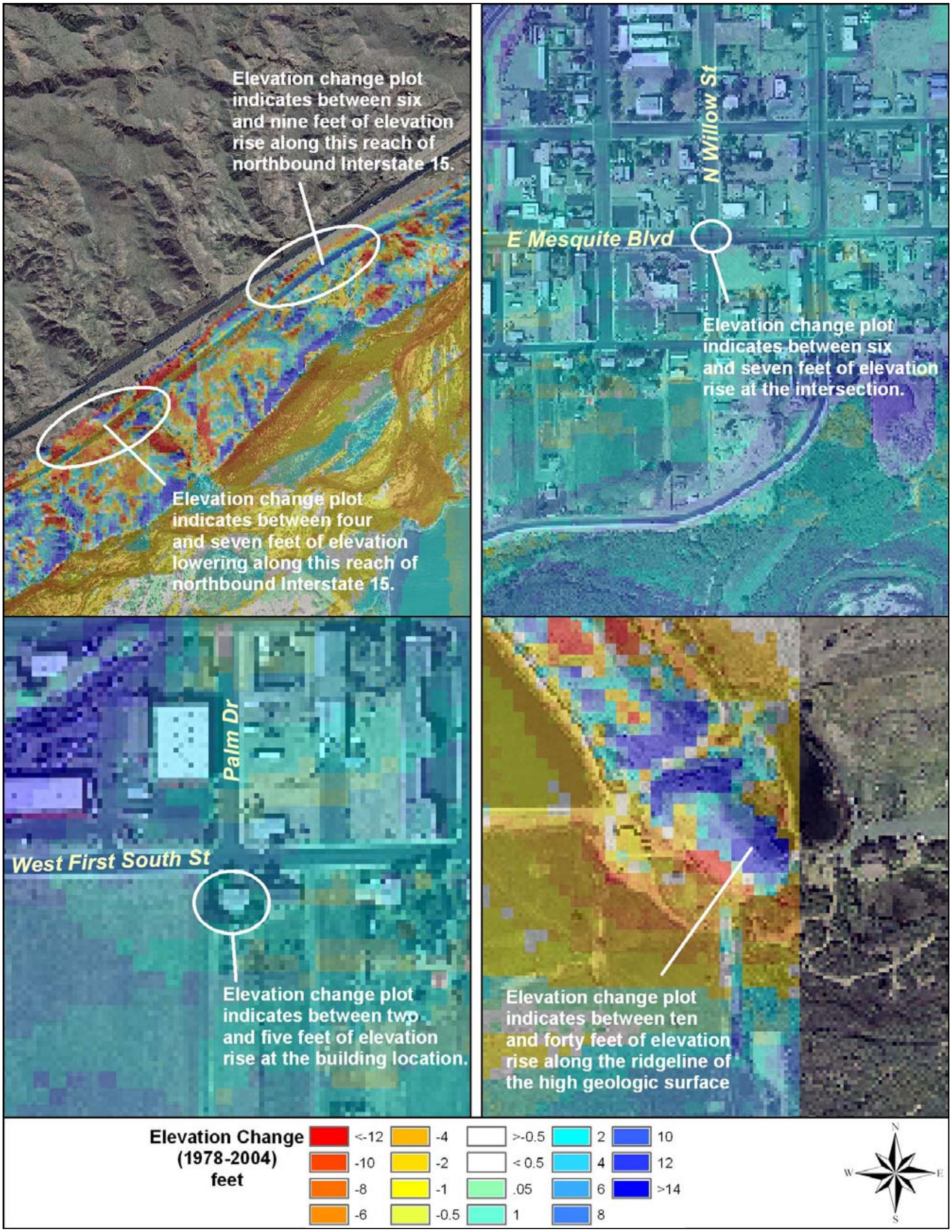
A spatial analysis to determine the change in elevation for the channel and floodplain within the study area was conducted using historical and recent elevation data and GIS tools. The purpose of this analysis was to attempt to determine if long-term trends (either aggradation or degradation) could be established for the active channel and floodplain, and if such trends directly influenced the behavior of the river during the 2005 flood. The analysis was conducted using the 1978 USGS DEM, and 2004 and 2005 LiDAR data. Each grid data set was converted to a TIN model using GIS, and the TIN models were then converted to raster data sets. Using advanced geoprocessing tools within the GIS software, the raster data sets were then subtracted from one another resulting in new raster data representing the difference. The difference, either positive or negative, represented a raising (aggradation) or lowering (degradation) of the ground surface. Three data sets were analyzed:

- 1978 to 2004
- 1978 to 2005
- 2004 to 2005

When comparing the resulting raster from the 2004 and 2005 data it was found that the 2004 LiDAR contained the lateral shift in the coordinate plane. To compensate, both the 2004 and 2005 raster data were converted to vector contour data and the 2004 data was manually shifted to closely match the 2005. The manual shift resulted in an approximate match, but was not precise. Upon completion of the manual shift, the 2004 contour data was converted back to a raster and was re-subtracted from the 1978 and 2005 raster data. The results of the elevation change analysis are shown in Figure 16 through Figure 18.

4.2.1. Interpretation

As discussed in Section 4.1, the discrepancies in the 1978 elevation data suggest that a site-specific detailed elevation comparison with the later data sets would not be accurate; however, a comparison of elevation data on a more regional scale provided some insight into potential long-term trends. Both Figure 16 and Figure 17 indicate a general trend of aggradation within the active channel corridor and adjacent floodplain throughout most of the study area. The figures can be misleading with respect to the active corridor by suggesting long-term aggradation, when the process is actually lateral migration. Since the elevation data is a snapshot in time, changes in the lateral position of the channel between data sets will result in apparent aggradation, when in reality the channel migrated laterally and the former location of the channel subsequently became floodplain, likely filling-in with flood deposits and vegetation. This elevation change would appear as long-term aggradation on the plot, when in reality, long-term processes cannot be conclusively inferred. In order to determine the relative accuracy (or inaccuracy) of the difference in elevation between the 1978 and 2004 data sets, calibration points were selected at locations where no actual vertical change occurred between data sets. These locations included a high geologic bank, roadways, and structures which were present for both data sets (Figure 15). The results of the site-specific elevation comparisons are listed in Table 3.


N Willow St
E Mesquite Blvd
Palm Dr
West First South St
Elevation Change
(1978-2004)
feet
<-12
-10
-8
-6
-4
-2
-1
-0.5
>-0.5
< 0.5
.05
1
2
4
6
8
10
12
>14
N
W
E
S

Elevation change plot indicates between six and nine feet of elevation rise along this reach of northbound Interstate 15.

Elevation change plot indicates between four and seven feet of elevation lowering along this reach of northbound Interstate 15.

Elevation change plot indicates between six and seven feet of elevation rise at the intersection.

Elevation change plot indicates between two and five feet of elevation rise at the building location.

Elevation change plot indicates between ten and forty feet of elevation rise along the ridgeline of the high geologic surface

Figure 15. 1978 and 2004 elevation comparison locations

Table 3. Site-specific discrepancies in 1978 and 2004 elevation data

Location Description	Elevation Difference from 1978 to 2004
Northbound Interstate 15	+6 to +9 feet, -4 to -7 feet
Roadway intersection – E Mesquite Blvd & N Willow St	+6 to +7 feet
Building at the intersection of W First South St & Palm Dr	+2 to +5 feet
High geologic bank	+10 to +40 feet

The results shown in Table 3 indicate significant discrepancies between the 1978 and 2004 elevation data sets. One possible explanation for the discrepancy is the significantly lower resolution of the 1978 USGS data (10 meter (32.8 ft)). Site-specific comparison analysis was repeated for the 1978-2005 elevation change data at the same locations as the 1978-2004 analysis. The results of the 1978-2005 comparison were very similar to those in Table 3. Both these comparisons suggest that a quantitative estimate of long-term trends in elevation change, either within the active corridor or the floodplain cannot be accurately assessed.

Quantification of elevation change from the 2005 flood was conducted utilizing the pre- and post-flood LiDAR data (Figure 18). The plot clearly identifies the changes in both width and depth of the active channel, and when compared with the pre-flood channel position, shows locations of channel avulsions and high energy overbank flows. The extent of sediment deposition in the floodplain is also clearly identified and quantified in the plot. Sedimentation in the inundated portions of the floodplain was generally between two and five feet. The dark blue area in the far upstream, right-overbank in Figure 18 indicates between 12 and 16 feet of aggradation during the 2005 flood. This location contains one of the densest tamarisk thickets found in the study area. Field investigation of this site indicated between three and four feet of sediment accumulation within the thicket. The false elevation change values in the plot are likely due to the post-flood LiDAR data being unable to accurately represent the true ground elevation within the dense tamarisk thicket, despite the bare-Earth vegetation filtering that was conducted on the data prior to use in this study. This effect is also apparent at other locations within the study area, especially downstream of Bunkerville.

In addition to quantifying the magnitude of deposition, the 2004 to 2005 elevation change plot also identifies areas that experienced scour during the 2005 flood. The analysis shows several areas that experienced up to 18 feet of degradation (shown in dark red on Figure 18). This was the result of lateral migration which eroded the high cutbanks located on the outside of channel bends where high-energy velocities generally occur. All of these locations are found near the narrowest portion of the active channel which is constrained by the Bunkerville Bridge. The area that experienced the most significant scour was the large avulsion channel which formed along the far-right-overbank in the upstream portion of the study area. The elevation change plot indicates this area experienced up to 14 feet of scour as the avulsion channel cut through the floodplain sediments. The plot also indicates between one and six feet of general channel degradation occurred during the floods as the channel widened and deepened to convey the flow. A generalized plot of aggradation vs. degradation from the 2004 to 2005 elevation change data is shown in Figure 19. This plot provides a more general overview of the processes that occurred during the 2005 flood.

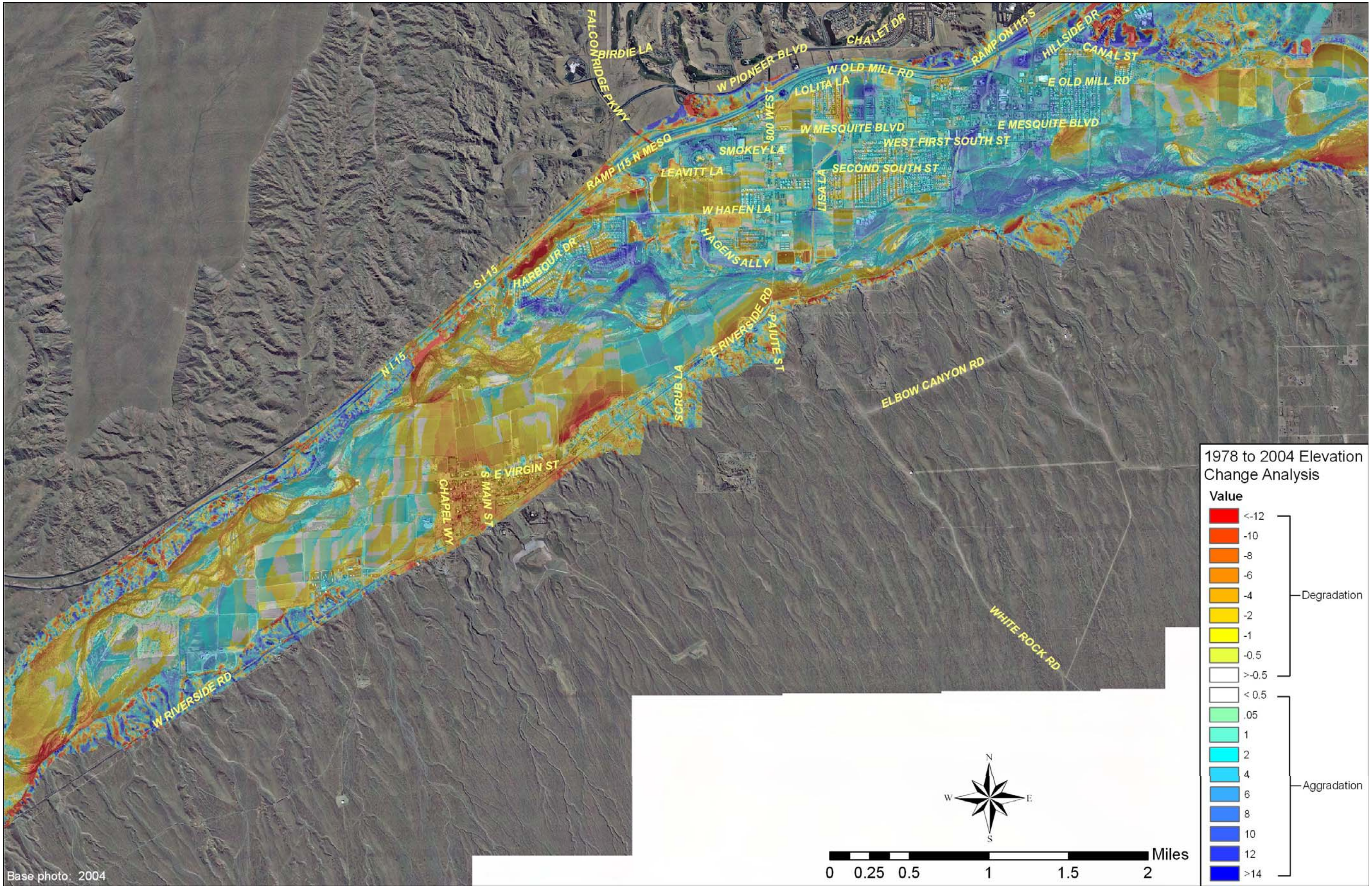

FALCONRIDGE PKWY
BIRDIE LA
W PIONEER BLVD
CHALET DR
RAMP ON I15 S
HILLSIDE DR
CANAL ST
W OLD MILL RD
LOLITA LA
E OLD MILL RD
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
SMOKEY LA
RAMP I15 N MESQ
LEAVITT LA
SECOND SOUTH ST
LISA LA
W HAFEN LA
HAGENS ALLY
HARBOUR DR
S I 15
E RIVERSIDE RD
PAIUTE ST
SCRUB LA
ELBOW CANYON RD
N I 15
E VIRGIN ST
S MAIN ST
CHAPEL WY
WHITE ROCK RD
W RIVERSIDE RD
Base photo: 2004
N
W
E
S
0
0.25
0.5
1
1.5
2
Miles
1978 to 2004 Elevation Change Analysis
Value
<-12
-10
-8
-6
-4
-2
-1
-0.5
>-0.5
Degradation
< 0.5
.05
1
2
4
6
8
10
12
>14
Aggradation

Figure 16. 1978 to 2004 elevation change plot

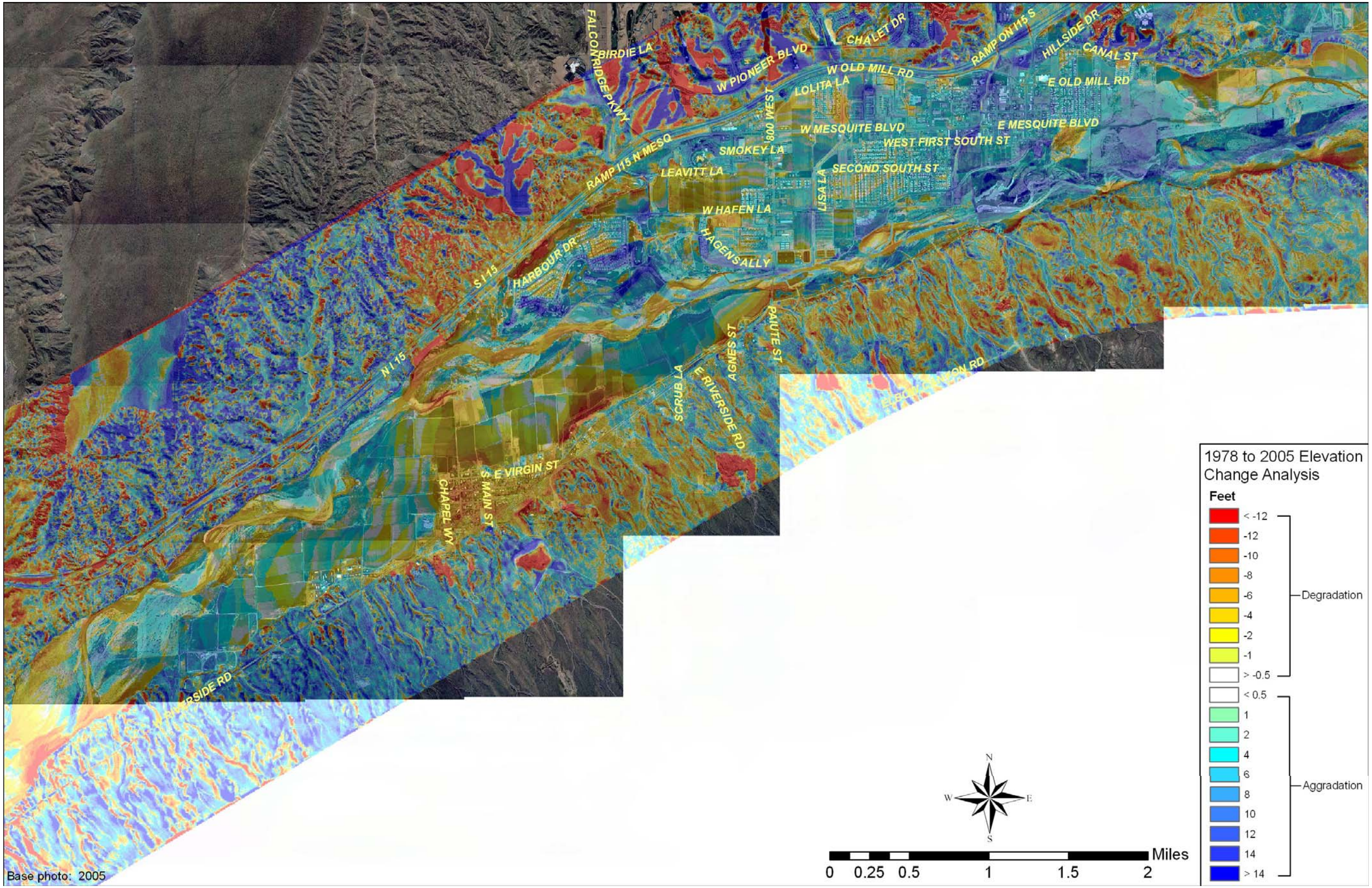

BIRDIE LA
FALCONRIDGE PKWY
W PIONEER BLVD
CHALET DR
W OLD MILL RD
RAMP ON I15 S
HILLSIDE DR
CANAL ST
E OLD MILL RD
LOLITA LA
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
SMOKEY LA
RAMP I15 N MESQ
LEAVITT LA
SECOND SOUTH ST
LISA LA
W HAFEN LA
HAGENS ALLY
HARBOUR DR
S I 15
N I 15
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
S E VIRGIN ST
CHAPEL WY
S MAIN ST
RIVERSIDE RD
Base photo: 2005
N
W
E
S
0
0.25
0.5
1
1.5
2
Miles
1978 to 2005 Elevation Change Analysis
Feet
< -12
-12
-10
-8
-6
-4
-2
-1
> -0.5
Degradation
< 0.5
1
2
4
6
8
10
12
14
> 14
Aggradation

Figure 17. 1978 to 2005 elevation change plot

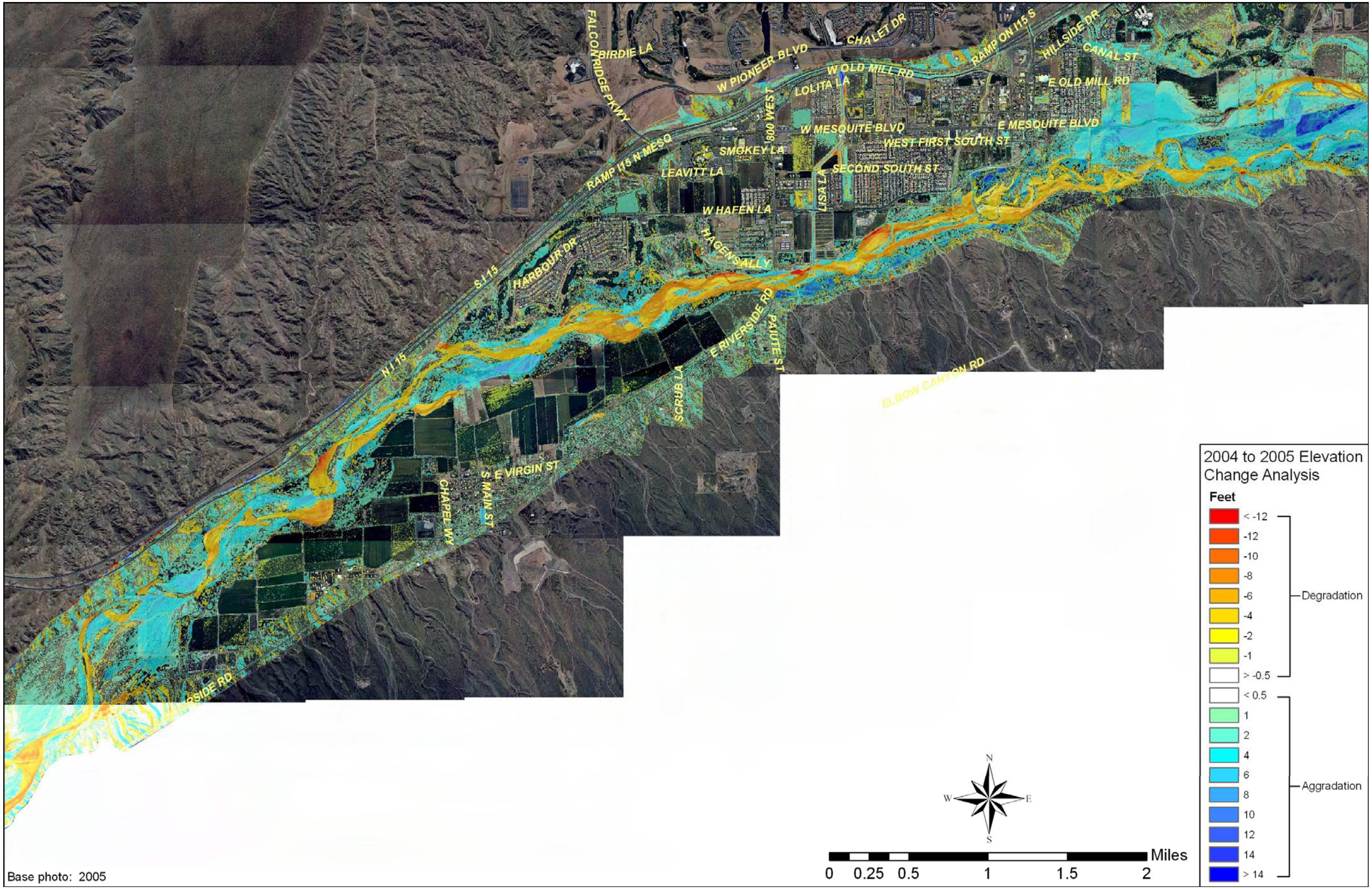

FALCONRIDGE PKWY
BIRDIE LA
W PIONEER BLVD
CHALET DR
RAMP ON I15 S
HILLSIDE DR
CANAL ST
W OLD MILL RD
E OLD MILL RD
LOLITA LA
1800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
SMOKEY LA
SECOND SOUTH ST
LEAVITT LA
LISA LA
RAMP I15 N MESQ
W HAFEN LA
HAGENS ALLY
HARBOUR DR
S I 15
E RIVERSIDE RD
PAIUTE ST
N I 15
SCRUB LA
ELBOW CANYON RD
S E VIRGIN ST
S MAIN ST
CHAPEL WY
RSIDE RD
N
S
E
W
0
0.25
0.5
1
1.5
2
Miles
Base photo: 2005
2004 to 2005 Elevation Change Analysis
Feet
< -12
-12
-10
-8
-6
-4
-2
-1
> -0.5
Degradation
< 0.5
1
2
4
6
8
10
12
14
> 14
Aggradation

Figure 18. 2004 to 2005 post-flood elevation change plot

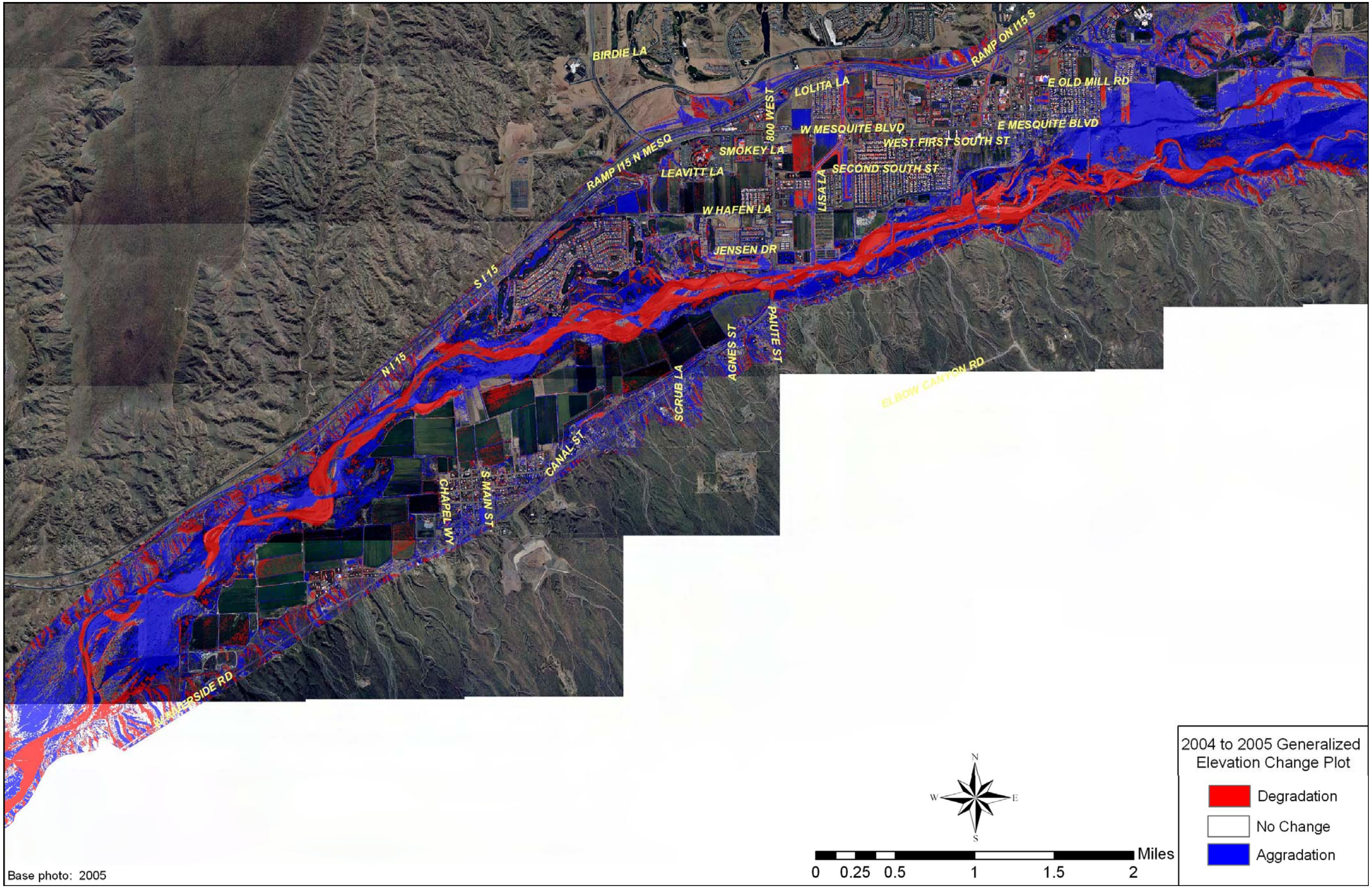

BIRDIE LA
RAMP ON I15 S
LOLITA LA
E OLD MILL RD
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
RAMP I15 N MESQ
SMOKEY LA
LEAVITT LA
SECOND SOUTH ST
LISA LA
W HAFEN LA
JENSEN DR
S I 15
PAIUTE ST
AGNES ST
N I 15
SCRUB LA
ELBOW CANYON RD
CANAL ST
S MAIN ST
CHAPEL WY
RIVERSIDE RD
N
W
E
S
0
0.25
0.5
1
1.5
2
Miles
Base photo: 2005
2004 to 2005 Generalized Elevation Change Plot
🟥 Degradation
☐ No Change
🟦 Aggradation

Figure 19. Generalized plot of 2004 to 2005 elevation change

4.3. Hydraulic Data Spatial Analysis

A type of spatial analysis developed by JEF was conducted using the PBS&J *Virgin River Flood Hazard Study* 100-year HEC-RAS hydraulic data and GIS map techniques to identify and predict areas with erosive flow depths and velocities. The plots of the HEC-RAS hydraulic data provide a visual representation of velocity and depth to aid in identifying potential avulsion areas and to estimate the limits of erosive processes during the simulated 100-year flood. The potential avulsion zones were then defined using the draft *Erosion Hazard Delineation and Development Guidelines* developed for the Flood Control District of Maricopa County (JEF, 2003), which define the following characteristics as indicative of avulsion potential:

- *100-year maximum (not average) floodplain flow depth greater than two feet.*
- *100-year maximum floodplain velocity greater than four ft/sec, or the product of 100-year floodplain depth and velocity squared greater than 18 ($dv^2 > 18$).*

A velocity and depth distribution for each cross-section was calculated in HEC-RAS using the model's maximum flow distribution value of 43. From this, three output reports representing the channel and both overbank areas were generated using HEC-RAS. The output data was listed by left and right of each of the 43 intervals across the section. Using a Python macro, the center of each distribution was calculated and a geographic coordinate assigned. This technique resulted in a spatial coordinate (X,Y) at each interval along the cross-sections. A grid was then generated in GIS using the (X,Y) coordinates for the lateral position and the velocity or depth value at each interval for the Z value. Finally, a TIN model was generated from the grid data.

The result was a spatial distribution plot of velocity "zones" that were definable by the velocity unit value (ft/s). This same process was then repeated for flow depths to create a spatial depth distribution Finally a depth-velocity (DV) product input value was used to generate a spatial DV plot. Figure 20 shows illustrative examples of each of these flow distributions. Velocities of 4 ft/s or greater were considered erosive velocities, thus areas for potential avulsion. Additionally, DV values of eight or greater (velocity=4 ft/s * depths=2 feet) were considered erosive values. 100-year velocity, depth, and depth-velocity product plots for the entire study area are shown in Figure 21 to Figure 23. The results of the hydraulic data spatial analyses were used in determining the expected areas of lateral erosion (Section 6).

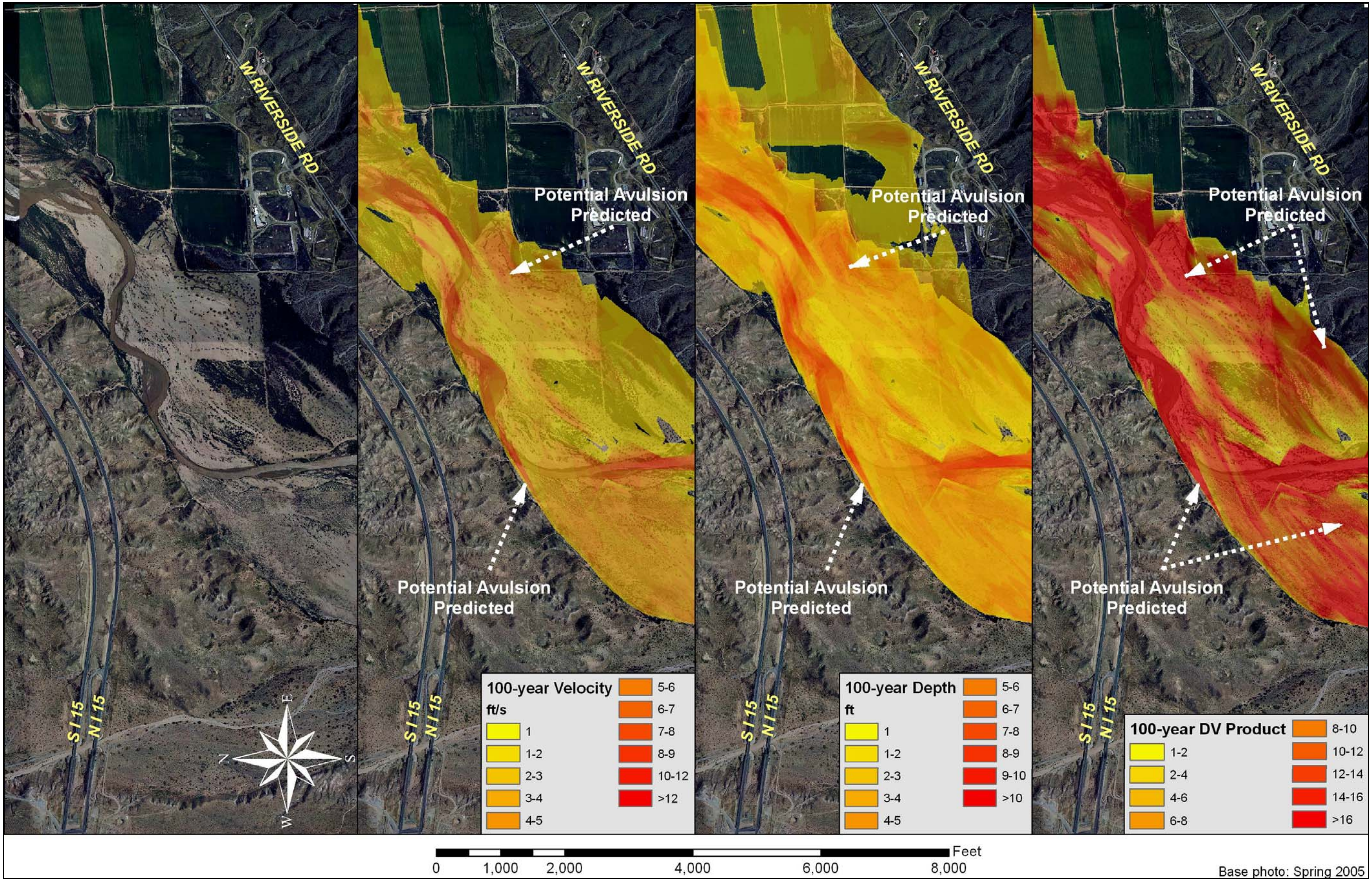

W RIVERSIDE RD
Potential Avulsion Predicted
Potential Avulsion Predicted
S I 15
N I 15
E
N
S
W
100-year Velocity
ft/s
1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
10-12
>12
100-year Depth
ft
1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
>10
100-year DV Product
1-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
>16
Feet
0
1,000
2,000
4,000
6,000
8,000
Base photo: Spring 2005

Figure 20. Examples of hydraulic data spatial plots

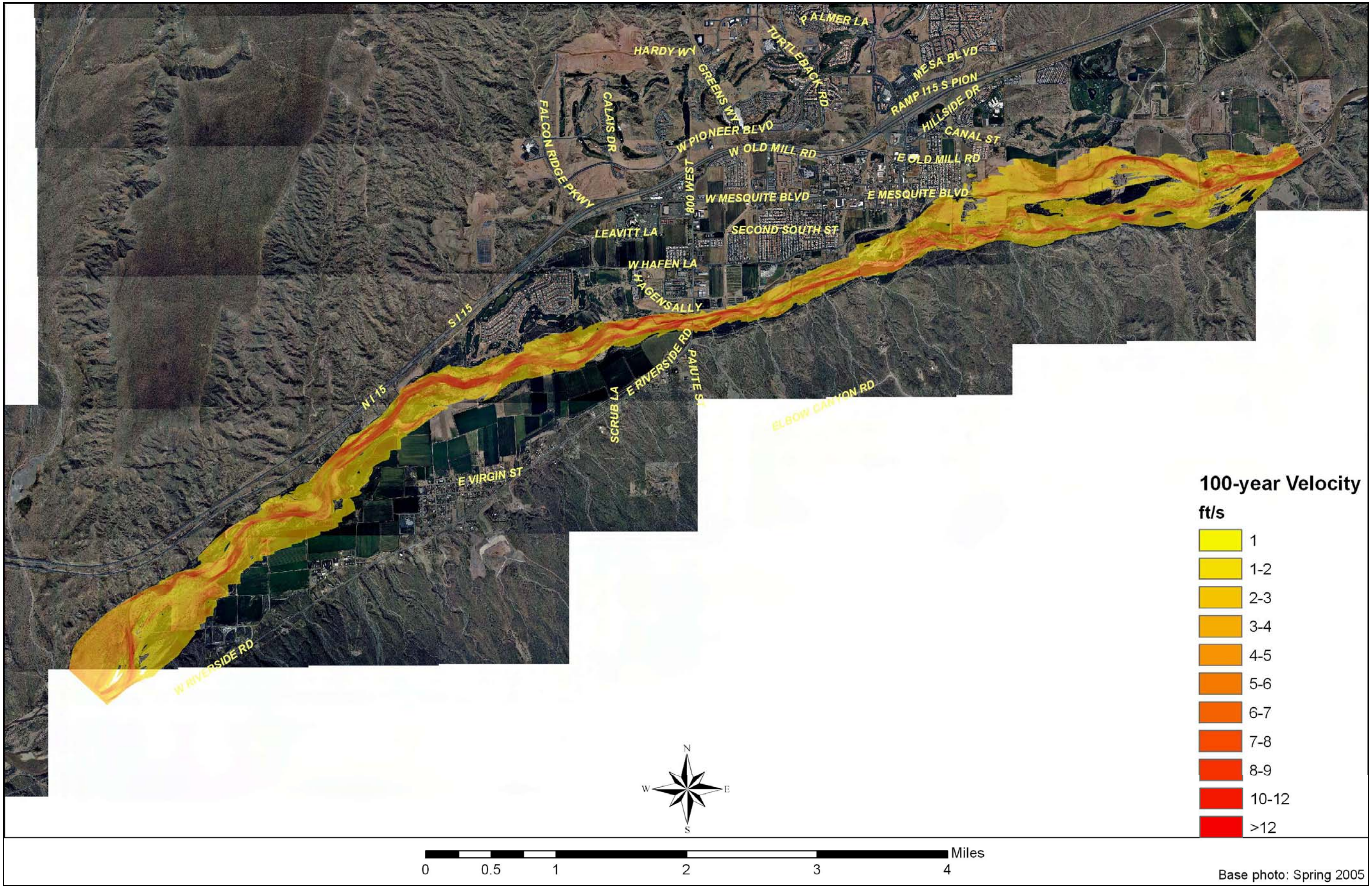

PALMER LA
HARDY WY
TURTLEBACK RD
GREENS WY
MESA BLVD
RAMP I15 S PION
HILLSIDE DR
CANAL ST
CALAIS DR
FALCON RIDGE PKWY
W PIONEER BLVD
W OLD MILL RD
E OLD MILL RD
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
LEAVITT LA
SECOND SOUTH ST
W HAFEN LA
HAGENS ALLY
S I 15
E RIVERSIDE RD
PAIUTE ST
ELBOW CANYON RD
N I 15
SCRUB LA
E VIRGIN ST
W RIVERSIDE RD
N
W
E
S
100-year Velocity
ft/s
1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
10-12
>12
0
0.5
1
2
3
4
Miles
Base photo: Spring 2005

Figure 21. 100-year velocity data spatial plot

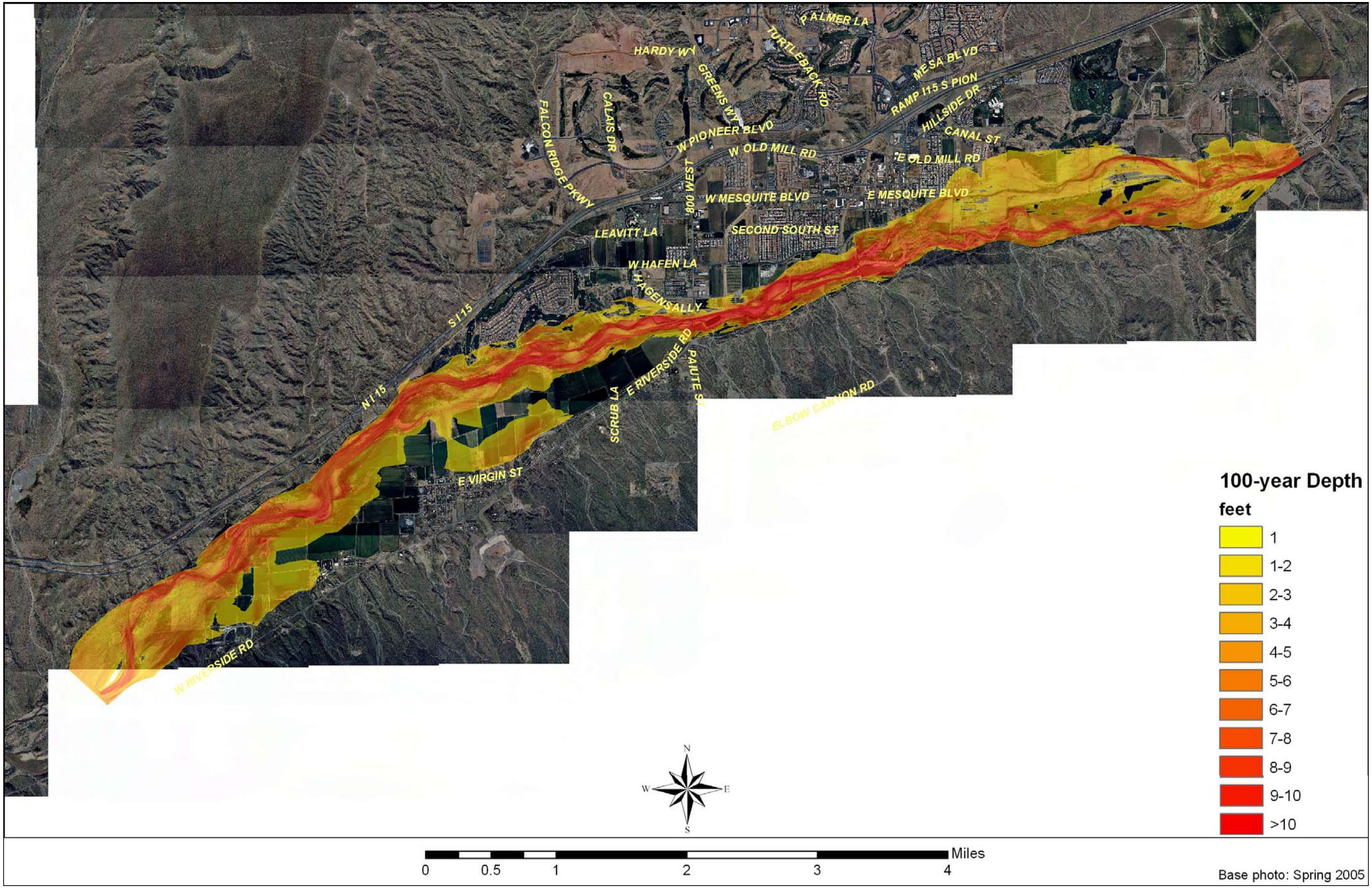

PALMER LA
HARDY WY
TURTLEBACK RD
GREENS WY
MESA BLVD
RAMP I15 S PION
HILLSIDE DR
FALCON RIDGE PKWY
CALAIS DR
W PIONEER BLVD
W OLD MILL RD
CANAL ST
E OLD MILL RD
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
LEAVITT LA
SECOND SOUTH ST
W HAFEN LA
HAGENS ALLY
S I 15
E RIVERSIDE RD
PAIUTE ST
SCRUB LA
N I 15
ELBOW CANYON RD
E VIRGIN ST
W RIVERSIDE RD
100-year Depth
feet
1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
>10
N
W
E
S
0
0.5
1
2
3
4
Miles
Base photo: Spring 2005

Figure 22. 100-year depth data spatial plot

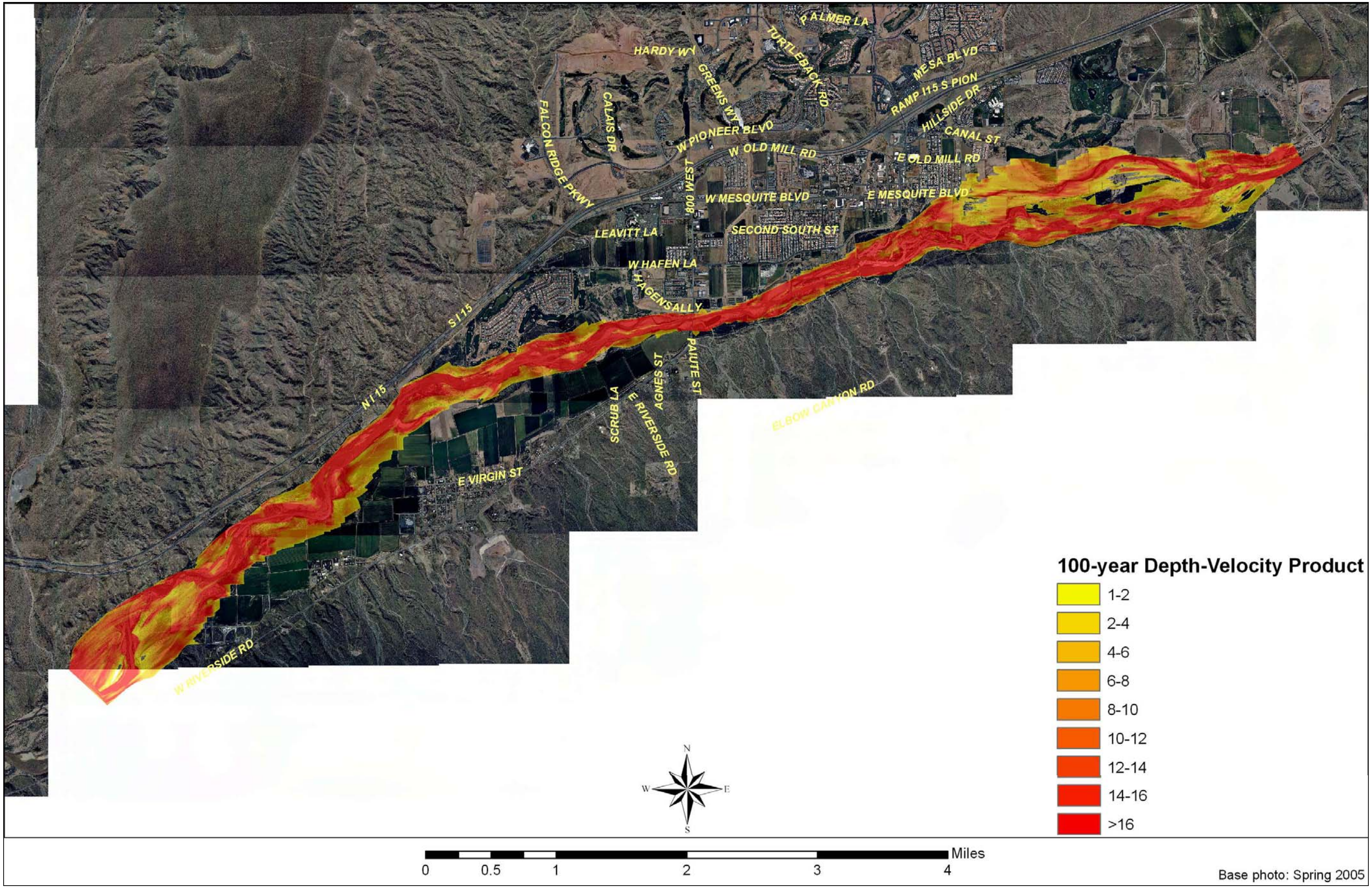

PALMER LA
HARDY WY
TURTLEBACK RD
MESA BLVD
GREENS WY
RAMP I15 S PION
HILLSIDE DR
FALCON RIDGE PKWY
CALAIS DR
W PIONEER BLVD
CANAL ST
W OLD MILL RD
E OLD MILL RD
800 WEST
W MESQUITE BLVD
E MESQUITE BLVD
LEAVITT LA
SECOND SOUTH ST
W HAFEN LA
HAGENS ALLY
S I 15
N I 15
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
ELBOW CANYON RD
E VIRGIN ST
W RIVERSIDE RD
N
W
E
S
100-year Depth-Velocity Product
1-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
>16
0
0.5
1
2
3
4
Miles
Base photo: Spring 2005

Figure 23. 100-year depth-velocity product spatial plot.

4.4. Longitudinal Profile Analysis

A longitudinal profile is a plot of the channel thalweg elevation versus distance. Analysis of the longitudinal profile can be used to identify slope irregularities, over-steepened or flat reaches, headcuts, and areas of natural grade control. Interpretation of the longitudinal profile also provides information on the expected lateral stability of the stream. Reaches with lower slopes than upstream reaches will tend to experience net deposition (aggradation) and bank erosion associated with meandering and avulsions. Reaches with steeper slopes than upstream reaches will tend to experience net degradation and bank erosion associated with braiding, undercutting, and scour. Comparison of historical profiles with modern profiles can be used to indicate where degradation and aggradation have occurred in the recent past, and where future adjustments of channel geometry are most likely to occur. A longitudinal profile analysis was performed on the Virgin River to address these issues within the study area.

Topographic data used in the longitudinal profile analysis consisted of the same data sources described in Section 2.2 (Table 2). The minimum elevation at each cross-section was extracted to represent the lowest bed elevation, or channel thalweg, for each time period represented by topographic data. The river distance, or thalweg length, was computed using the reach length values calculated by the GIS software. Figure 25 shows the longitudinal profile plot for each topographic data set collected.

During the initial post-flood aerial photograph interpretations, JEF observed that the active channel pattern was more braided upstream of the Bunkerville Ditch diversion structure (Figure 24). A braided channel pattern is generally indicative of a steep slope and wide, shallow channels. The more highly braided channel pattern upstream of the diversion structure was confirmed during the field investigation. To determine if the channel slope varied upstream and downstream of the diversion structure, a longitudinal profile plot was constructed. The plot results are shown in Figure 26.

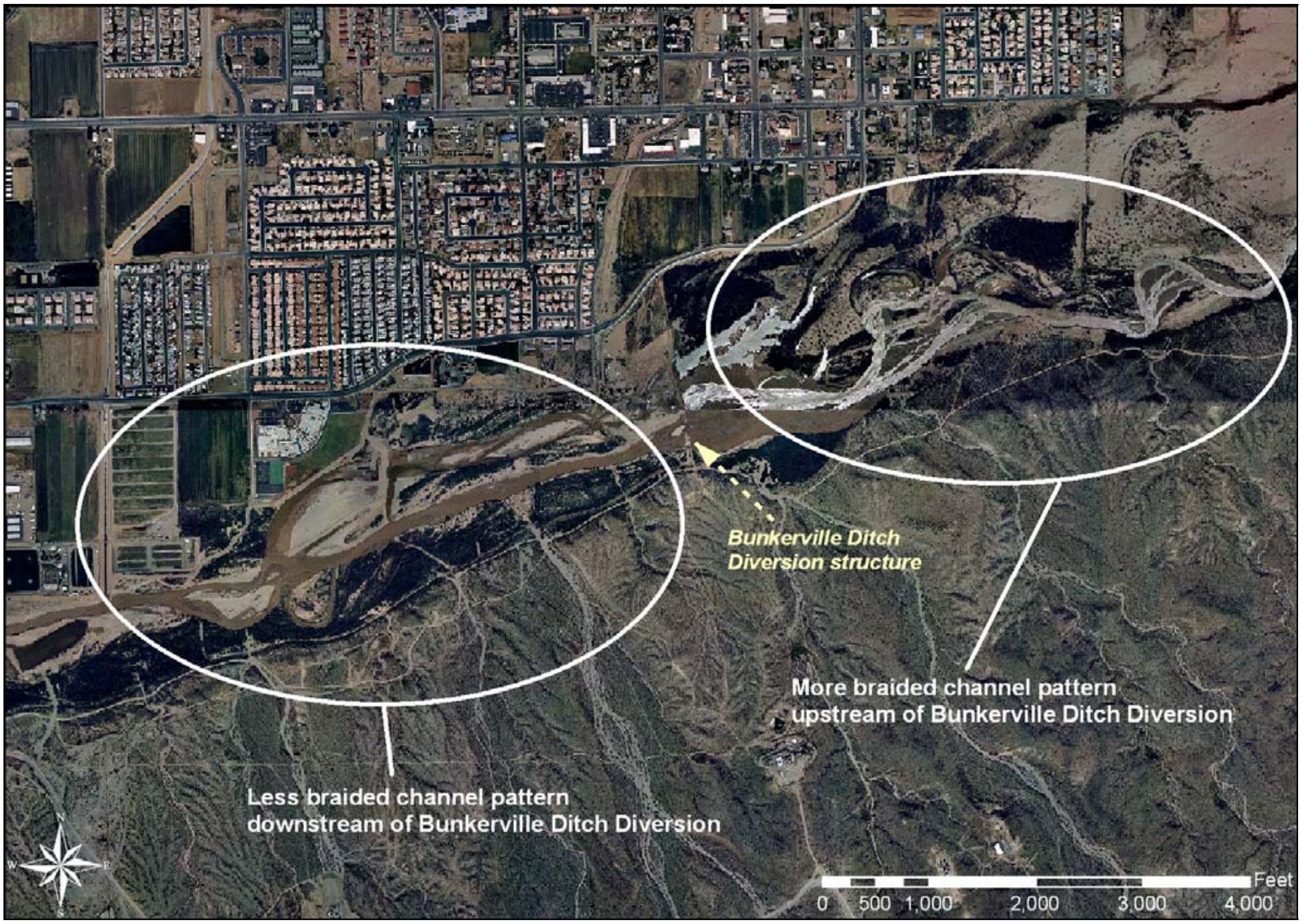

Bunkerville Ditch Diversion structure
More braided channel pattern upstream of Bunkerville Ditch Diversion
Less braided channel pattern downstream of Bunkerville Ditch Diversion
Feet
0
500
1,000
2,000
3,000
4,000
N
W
E
S

Figure 24. Post-flood channel pattern near Bunkerville Diversion structure

4.4.1. Interpretation

As was discussed in Section 4.1, cross-section comparisons from the 1978 USGS DEM models with the later data sets revealed inconsistencies in elevations both within and outside the Virgin River floodplain. Those results suggested the resolution of the 1978 data was insufficient for a direct, accurate comparison with the later data sets. A direct comparison could be made, however, between the 1996, 2004, and 2005 data sets. Those results indicated mean channel aggradation of 0.4 feet between 1996 and 2004, a period of generally low-flow conditions and lack of large floods. The 1996 cross-section data collected by Bulloch Bros for the FIS represented channel conditions following a large flood in March of 1995 (20,500 cfs) and above average mean annual flows for that year. This suggests that extended periods of low annual mean flows and lack of large floods results in minimal aggrading channel conditions. The results of the 2004 and post-flood 2005 longitudinal plots indicated mean channel degradation of 0.2 feet within the entire study area, and a maximum value of 3 feet. These post-flood values of channel scour are lower than those resulting from the Elevation Change Analysis (Section 4.2). The Longitudinal Profile Analysis only represents the minimum channel bed elevations at the cross-section locations. The Elevation Change Analysis incorporated the entire study area, including the areas between cross-sections. Figure 25 indicates that the area which experienced the greatest scour was downstream of the Bunkerville Bridge. The constriction of the bridge likely resulted in increased velocities which scoured the bed downstream.

Changes in plotted channel profiles indicate changes in channel slope. Slope changes over time may suggest disequilibrium conditions. Channel slope is a function of several factors including sediment load and discharge. If sediment influx is greater than the river's transport capacity, excess sediment will be deposited (aggradation) resulting in an overall steeper slope. If sediment influx is less than transport capacity, the river will pick-up excess sediment from the bed and banks (degradation) resulting in an overall flatter slope and vertical, unstable banks.

Unlike a direct comparison of site-specific elevations as discussed above, comparisons of slope can be made with inconsistent data (such as those from 1978) because slope is computed by elevations within an individual data set, and not directly compared with elevations from other data sets at site specific locations. Therefore, a direct comparison of the 1978 slope with the later data sets was conducted. It should be noted that the 1996 data only covers a portion of the study area, whereas the 2004 and 2005 data extend the entire length of the study area. Comparing the 1996 data with the remainder data in entirety would provide misleading results; therefore a separate comparison was conducted using only the portion of the 1978, 2004, and 2005 data that fit within the 1996 limits (Table 4).

Table 4. Computed historical channel slope using 1996 data limits

1978	1996	2004	2005
0.0031 ft/ft	0.0031 ft/ft	0.0032 ft/ft	0.0034 ft/ft

Table 4 indicates a consistent steepening of slope over the 27 years represented by the topographic data in this abbreviated reach. Within this time period the Virgin River experienced three large floods greater than 20,000 cfs, and seven years of high annual mean flow conditions within the study area. This suggests that no one specific event can fully account for the trend. It is also unknown whether this trend is regional or confined to the general study area. Further analysis is required to determine the regional context of the slope trend.

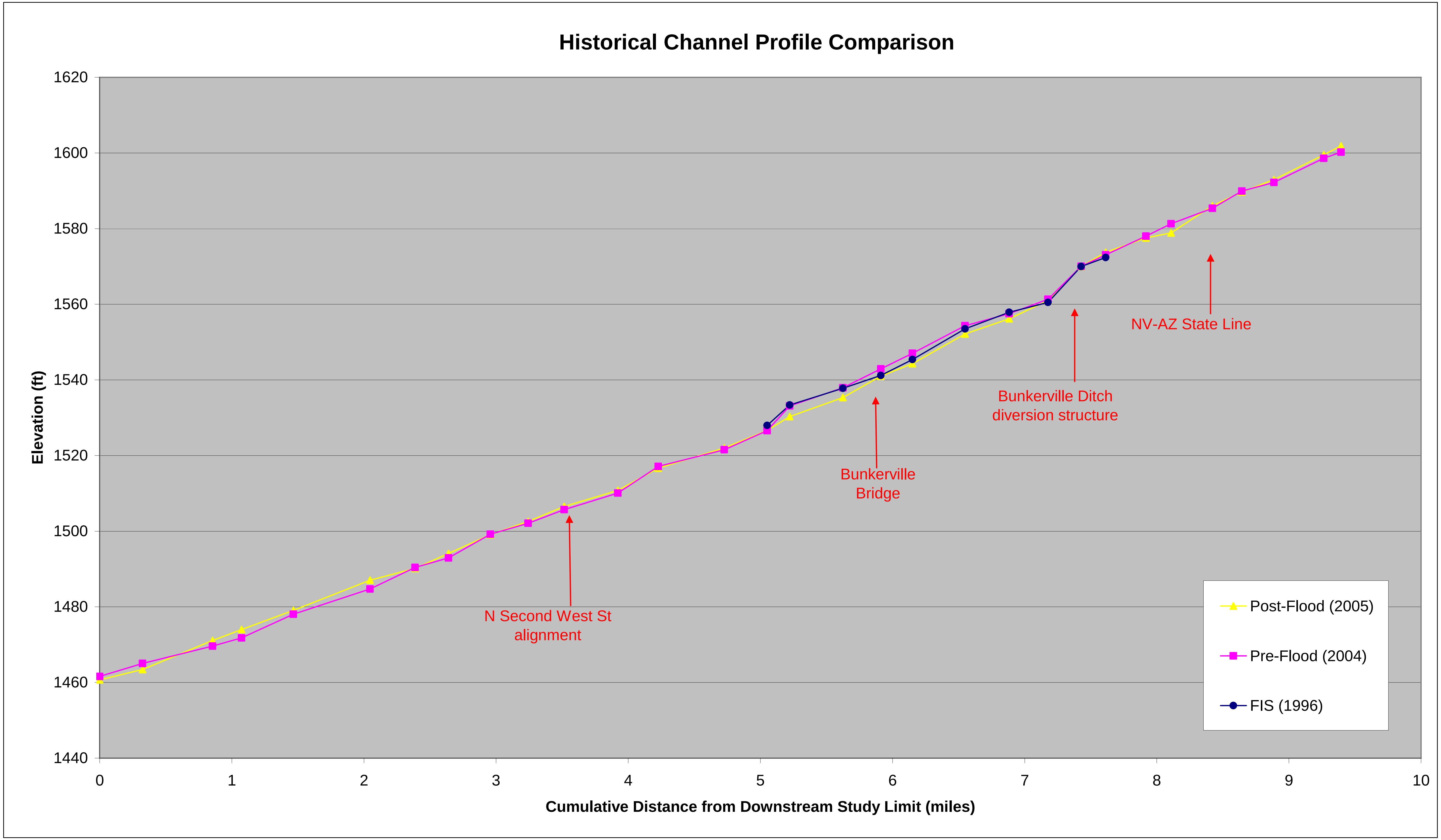


Figure 25. Longitudinal profile comparison plot

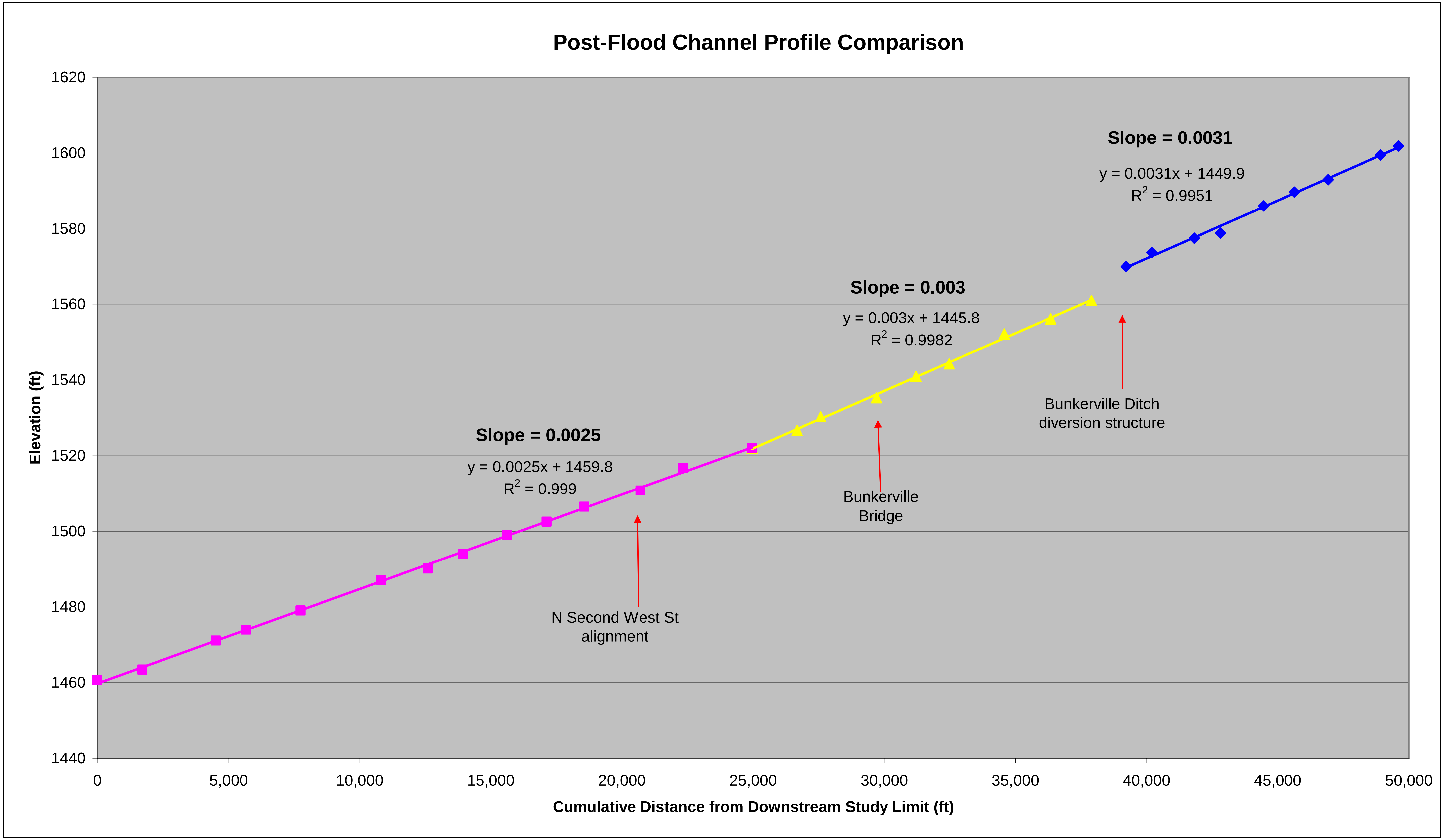


Figure 26. Longitudinal profile showing varying channel slope

In order to evaluate the entire study area, a slope profile analysis was conducted that excluded the 1996 data set; the results are listed in Table 5. These results also suggest a slight steepening trend of the channel slope from 1978 to 2004. The slope between 2004 and post-flood 2005 remained constant which indicates the 2005 flood had little impact on the slope. This suggests that the slope trend is driven more by long-term processes than individual large-magnitude processes.

Table 5. Computed historical channel slope for the entire study area

1978	2004	2005
0.0027 ft/ft	0.0029 ft/ft	0.0029 ft/ft

The nearly consistent slope immediately upstream and downstream of the Bunkerville Diversion structure (Figure 26) suggests it has little impact on overall channel slope, but has an obvious local impact. The figure also shows a dramatic break in slope downstream from the Bunkerville Bridge. It is at this location that the floodplain begins to widen after being constricted by floodplain encroachment upstream of the bridge. The slope again increases just upstream of the N. Second West Street alignment due to floodplain encroachment from agricultural fields in Bunkerville. The overall convex-up shape of the longitudinal profile in Figure 26 is indicative of a degrading river system, whereas aggrading rivers will typically reflect a convex-down longitudinal profile shape, however the relatively short time span (27 years) represented by the data is not sufficient to accurately predict long-term trends in channel slope.

4.5. Summary

The sedimentation analysis described in this section included historical cross-section comparison analysis, elevation change analysis, hydraulic data spatial analysis, and longitudinal profile analysis. The results of these analyses included the following:

Cross-Section Analysis

- Historical cross-section plots indicate significant lateral migration of the active channel occurred between 1978 and 2005 (Appendix B).
- The plots identified areas of lateral migration, channel aggradation and degradation, and channel widening from the 2005 flood, both within the active channel corridor and within the floodplain.

Elevation Change Analysis

- Quantitative estimates of long-term (1978-2005) vertical changes to the channel and floodplain were inconclusive due to significant data discrepancies.
- The 2004 to 2005 elevation change analysis indicated that between two and four feet of aggradation occurred in the floodplain, most of which occurred in the far upstream and downstream portions of the study area (Figure 18).
- The 2004 to 2005 elevation change analysis also indicated erosion of high floodplain banks occurred at multiple locations within the area of the Bunkerville Bridge (Figure 18).
- General channel degradation from the 2005 flood was between one and six feet within the study area (Figure 18).

Hydraulic Data Spatial Analysis

- Velocity, depth, and depth-velocity product hydraulic spatial plots were used to determine potential future avulsion locations from the simulated 100-year flood event. The results indicated nearly the entire floodplain is subject to future erosion risk (Figure 21 through Figure 23).

- The hydraulic spatial plots identified areas of potential erosive flows during the simulated 100-year event (Figure 21 through Figure 23).

Longitudinal Profile Analysis

- The longitudinal profile comparison identified areas of channel degradation and aggradation from 1996 to post-flood 2005 (Figure 25).
- The longitudinal profile comparison indicated channel degradation from the 2005 flood (less than three feet) in the one-mile reach downstream of the Bunkerville Bridge (Figure 25).
- The longitudinal profile also indicated minor, localized channel aggradation from the 2005 flood, primarily in the lower study area (Figure 25).
- Slope profile analysis showed the Virgin River experienced a slight steepening of channel slope from 1978 to 2004 (Figure 26).
- The overall convex-up shape of the post-flood longitudinal profile suggests an overall trend of degradation and not aggradation within the 27 year time-span represented by the data (Figure 26).

Overall these results indicate a preference for lateral movement, extreme potential for future lateral movement, limited historical vertical change, floodplain aggradation, and a complex response of bed elevation change that is a function of wet/dry/flood climatic cycles. No compelling evidence of a significant aggradational trend was found within the period of record.

5. LATERAL MIGRATION ANALYSIS

5.1. Lateral Migration History

5.1.1. Impacts of Floods

In the geomorphic assessment portion of the Virgin River Bridge Scour Study (Hilmes et al., 1997), the authors suggest the possibility that the dominant processes that have the greatest impact on geomorphic change of the Virgin River is not large magnitude floods, but high average annual flows (Schumm and Lichty, 1963; Burkham, 1972). The concept of geomorphically effective floods was discussed by Costa and O'Connor in a 1995 study in which they investigated the impact on channel and floodplain morphology from two small dam failures. They discovered that the impacts of large magnitude, short duration floods on the channel and floodplain were minimal. They attributed the lack of geomorphic impact on the relatively short duration (low volume) of the events and the low stream-power per unit area. One of the results of their investigation was the development of a conceptual stream-power graph (Figure 27) that can estimate the approximate geomorphic effectiveness of varying flood events. The authors defined stream-power as:

$$\omega = \gamma QS / w$$

ω = stream power in watts per square meter (W/m^2)
γ = spec. wt. of fluid
Q = *discharge*
S = *energy slope*
w = *water surface width*

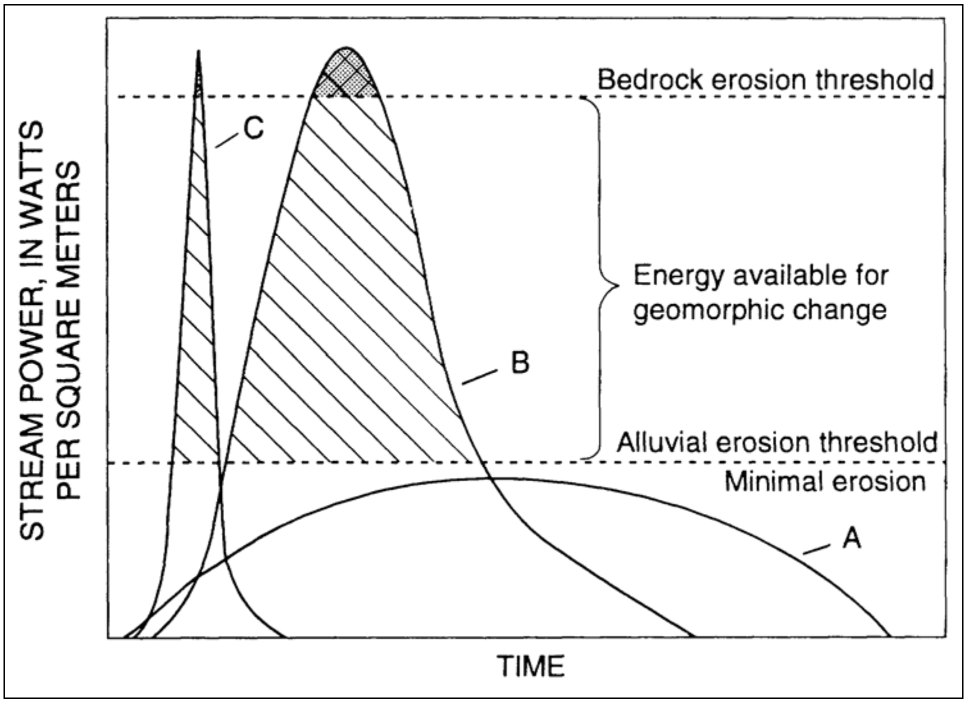
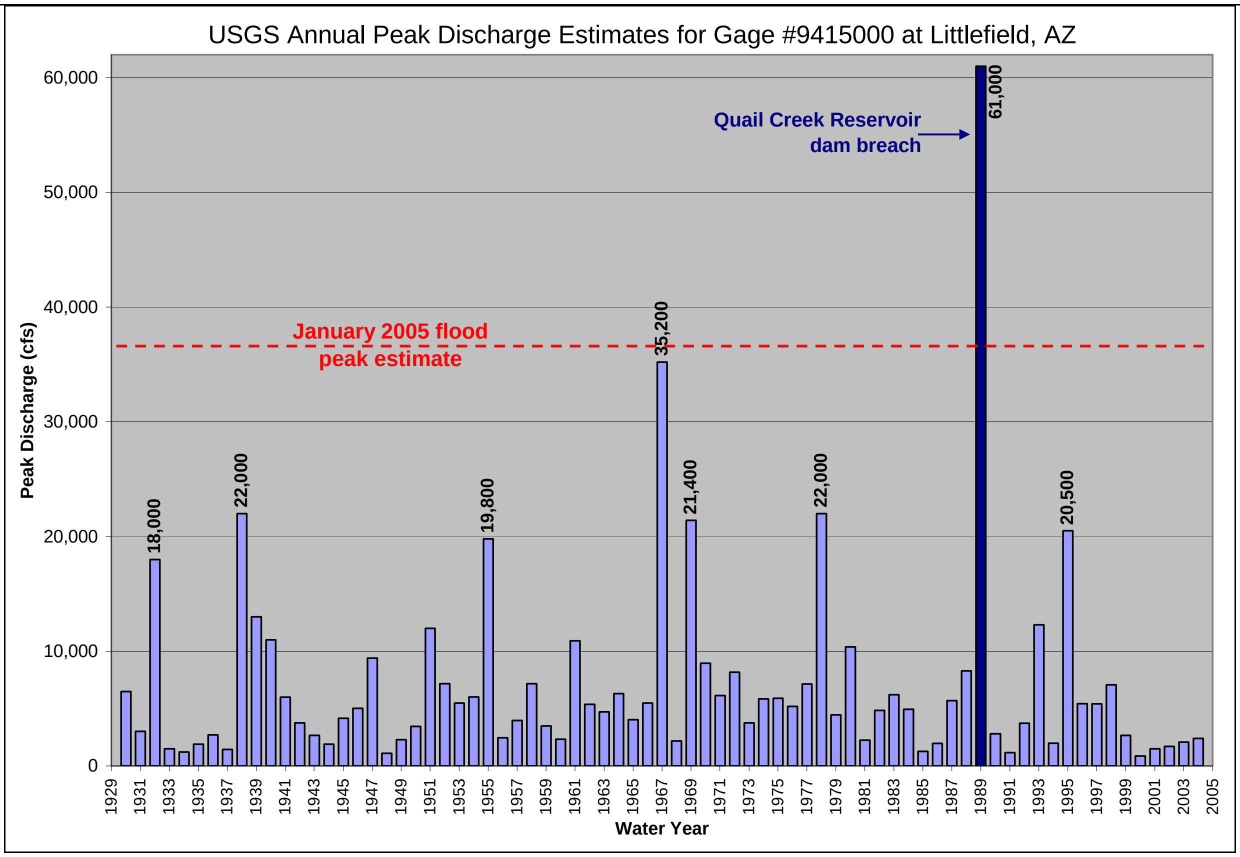


Figure 27. Conceptual stream-power graph *(Costa and O'Connor, 1995)*

Figure 27 suggests that floods with low stream power but long duration (plot A) are ineffective in producing geomorphic changes to the fluvial system. Additionally, floods with very high stream-power but low duration (plot C) are minimally effective in producing geomorphic changes. The ideal condition in producing geomorphic changes to the system is moderate to high stream power combined with sufficient duration (plot B). These processes are of course dependent on what defines the local thresholds of erosion.

The 1989 Quail Creek Dam failure flood on the Virgin River resulted in the largest peak flow in the gage record to date. Although the exact duration of the event could not be determined at the USGS Littlefield gage due to damage of the manometer-orifice line, anecdotal evidence suggested it lasted between 1.5 to 2 hours (Carlson et al., 1995). Using pre- and post-flood Landsat Thematic Mapper images depicting the area near the Riverside Bridge (just downstream of the study area) and other areas on the Lower Virgin River, Hilmes (1997) concluded that the Quail Creek flood resulted in very minimal geomorphic changes to the channel and floodplain. This is consistent with plot C in Figure 27 (high stream-power, low duration). Plots illustrating the difference between annual peak and annual mean discharge estimates for USGS gage #9415000 at Littlefield, AZ are shown in Figure 28. Hilmes (1997) also found that significant lateral changes to the active channel occurred near the Bunkerville Bridge in 1980. When comparing the plots in Figure 28, the annual peak value for 1980 was 10,380 cfs (an approximate 5-year flood at that time), however, the average annual value was 647 cfs, the second highest in the gage record. With the exception of 1938, 1978 and 1995, the years of high annual peak values do not correspond with years of high annual mean. Based on the results from both Costa and O’Connor (1995) and Hilmes et al. (1997), flow duration can be more significant than peak in geomorphic effectiveness.

For this study, an attempt was made to evaluate the magnitude of geomorphic change that had occurred due to high annual peak flows verses high mean annual flows. For this to be accomplished, aerial photography for each year of high annual peak flows and photography for each year of high annual mean flows would be required. Of the collected photos, only the 1938, 1978, and 1995 illustrate years of high peak flows. Coincidentally, they are the only three years in which the Virgin River experienced high mean annual flows and high peak flows within the same year. Therefore, such an evaluation was not possible.



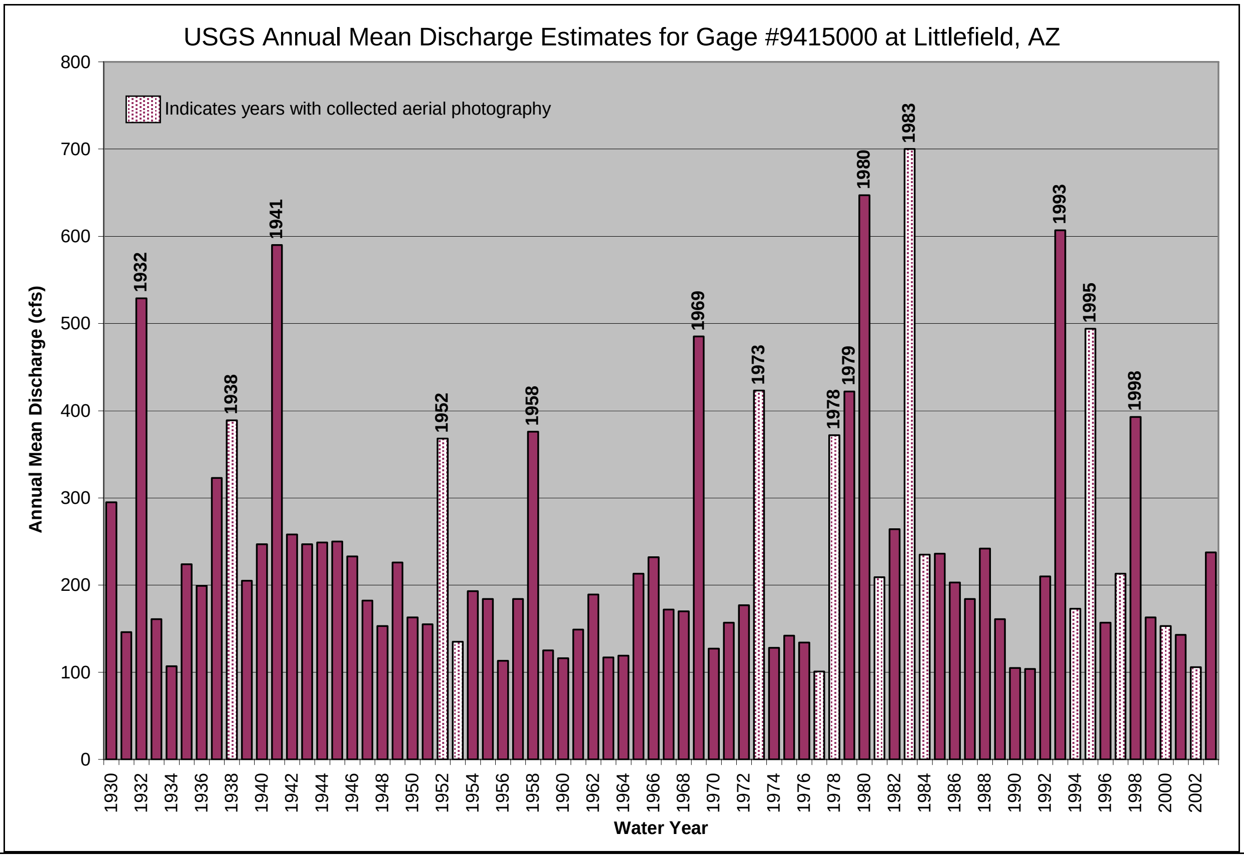


Figure 28. Annual Peak vs. Annual Mean discharge estimates

5.1.2. Incremental Channel Change

The incremental channel change between dates of photographic coverage was measured from the historical aerial photos. These measurements were performed for the left and right active channel banks independently. The bank movement information was determined by calculating the maximum lateral change that occurred between consecutive sets of aerial photographs (Figure 29 and Figure 30). Once the active channel movement in each incremental set of photographs was measured, the maximum measurement was extracted. The maximum value is significant in that it represents the maximum incremental change known to have occurred, and thus can reasonably be used as a prediction of the minimum magnitude of future single-event changes. Larger changes could be induced by floods larger than those in the period of record, or by human impacts to the watershed or watercourse. Table 6 lists the results of the maximum incremental channel change analysis for the study area by photo coverage set. These values represent the maximum lateral migration distance by bank (left or right) that occurred between successive sets of aerial photography within the entire study area. Table 7 lists the maximum incremental channel change by location (see Figure 10 for cross-section locations). These values represent the maximum lateral migration distance that occurred at each cross-section considering the entire aerial photo record.

Table 6. Maximum incremental lateral migration channel changes by photo coverage

Left Bank (feet)										
1938 to 1952-53	1952-53 to 1973	1973 to 1977	1977 to 1978	1978 to 1983*	1983* to 1984	1984 to 1994	1994 to 1997*	1997* to 2002	2002 to 2004	2004 to 2005
1313	1308	1025	509	101	195	1138	644	585	451	772
Right Bank (feet)										
1938 to 1952-53	1952-53 to 1973	1973 to 1977	1977 to 1978	1978 to 1983*	1983* to 1984	1984 to 1994	1994 to 1997*	1997* to 2002	2002 to 2004	2004 to 2005
1164	1101	683	542	269	448	571	516	517	1123	1444

**Aerial photo coverage does not include entire study area*

Table 7. Maximum incremental lateral migration change by location

Cross-Section ID	Max Change (ft)	Photo Coverage	Cross-Section ID	Max Change (ft)	Photo Coverage
1.5	286	1952-53 - 1973	11	983	1938 - 1952-53
1.6	610	1938 - 1952-53	16	612	1938 - 1952-53
1.7	1164	1938 - 1952-53	20	390	1952-53 - 1973
1.8	1024	1938 - 1952-53	25	569	1938 - 1952-53
1.9	1313	1938 - 1952-53	29	542	1938 - 1952-53
2.1	857	1984-1994	32	591	1952-53 - 1973
2.2	652	2004-2005	35	1075	1952-53 - 1973
2.3	1444	2004-2005	37	969	1952-53 - 1973
2.4	508	2004-2005	40.1	937	1952-53 - 1973
2.5	366	1997-2002	40.2	724	1952-53 - 1973
2.6	925	1938 - 1952-53	40.3	444	1997-2002
2.7	1025	1973-1977	40.4	579	1952-53 - 1973
2.8	900	1938 - 1952-53	40.5	647	1952-53 - 1973
2.9	1138	1984-1994	40.6	1239	1952-53 - 1973
3	582	1952-53 - 1973	40.7	1308	1952-53 - 1973
7	580	2004-2005			

Interpreting the results from Table 6 and Table 7, the largest magnitude incremental lateral change that occurred within the period of record was over 1,400 feet and was located at cross-section 2.3 (see Figure 10). The results shown in Table 6 and Table 7, combined with the plots in Figure 29 and Figure 30, were used when predicting future areas of lateral erosion (Section 6).

5.1.3. Cumulative Channel Change

The long-term or cumulative channel change was calculated for the left and right banks for the Virgin River within the study reach. Long-term channel change was determined by measuring the maximum change in active channel position between the earliest and most recent set of historical aerial photographs. The estimates of long-term active channel change aid in defining long-term trends of channel migration. For example, the maximum lateral change that occurred between 1938 and 2005 (67 years) occurred in the direction of the left bank and was approximately 4,000 feet (about 59 feet/year), which indicates a reasonable estimate of a minimum lateral distance in which future migration of the active channel might occur over moderate time durations (Figure 31). In several cases, the comparison of channel position over the period of record failed to capture the real magnitude of channel movement because channel migration back and forth over the floodplain returned the channel to a position close to the initial position, resulting in a relatively low cumulative estimate of movement. Table 8 summarizes the results of the long-term channel change analysis. To gage the magnitude of the 2005 flood, a plot of the pre- and post-flood bank location change due to lateral migration was compared with the long-term channel change plot and is shown in Figure 32.

Table 8. Cumulative maximum lateral migration summary (1938 to 2005)

Cross-Section ID	Left Bank	Right Bank	Cross-Section ID	Left Bank	Right Bank
1.5	-	-	11	225	1995
1.6	855	68	16	63	815
1.7	2951	1099	20	604	408
1.8	3900	1268	25	515	153
1.9	1728	879	29	438	227
2.1	2003	31	32	146	248
2.2	168	1121	35	9	347
2.3	968	101	37	171	862
2.4	824	109	40.1	426	331
2.5	993	98	40.2	3835	1938
2.6	698	291	40.3	1119	5
2.7	717	421	40.4	666	1045
2.8	262	1749	40.5	3437	2498
2.9	379	1543	40.6	291	323
3	2041	2509	40.7	68	578
7	865	2141			

These results show significant lateral migration of the Virgin River has occurred in the study area within the past 67 years.

5.1.4. Lateral Migration Constraints

The historical analysis and field investigations identified locations in the study area that, within the period of record, were stable due to bedrock outcrops, erosion-resistant soils, or manmade structures. The locations of historical channel stability are important for determining the extent of future potential lateral migration. Some factors such as locations of bedrock and erosion-resistant soils are reliable indicators of future lateral stability, while other features such as tributary deposits and manmade structures are less reliable because of the potential for human intervention. In general, the active channel and floodplain of the Virgin River has historically been constrained within the Holocene[9] geologic floodplain. Tributary deposits have also provided lateral stability to the Virgin River by the input of sediment which forms deltaic-like deposits within the floodplain. As long as the rate of sediment influx from the tributaries is greater than the ability of the Virgin River to remove the sediments during flood events, then the sediments will continue to accumulate. If the rate of tributary sediment-influx decreases or the transport rate in the Virgin River main stem increases, due to human impacts on the channel and/or watershed, control provided by the tributaries will be reduced. Figure 33 shows an example of stable surfaces found within the study area. The figure is of an area along the left bank near the downstream limit of the study area. The yellow triangle shows the approximate location, direction, and ID of the photo shown in the bottom of the figure.

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[9] The Holocene Epoch represents the past 10,000 years from the present.

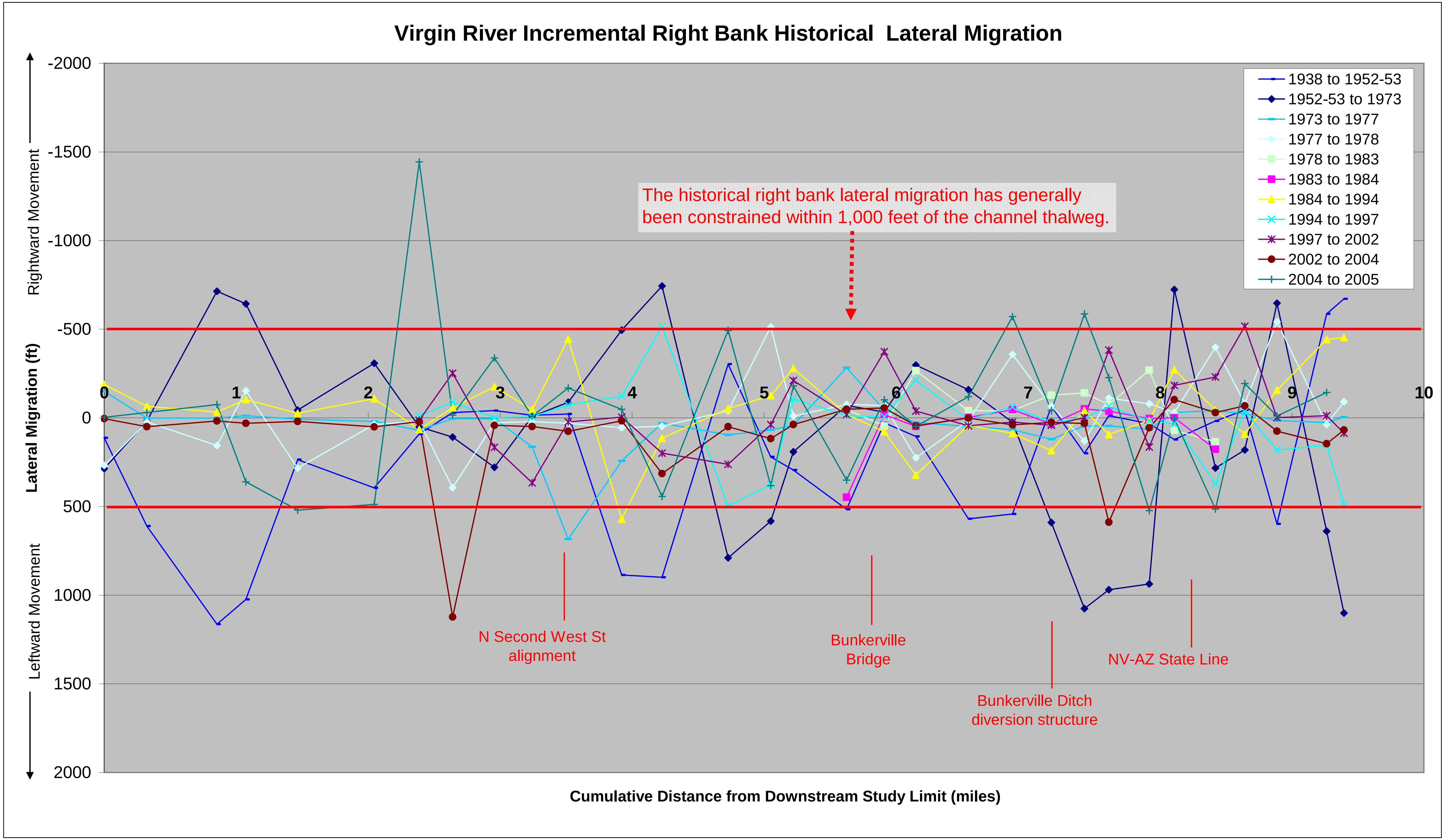

Figure 29. Right bank incremental lateral migration summary

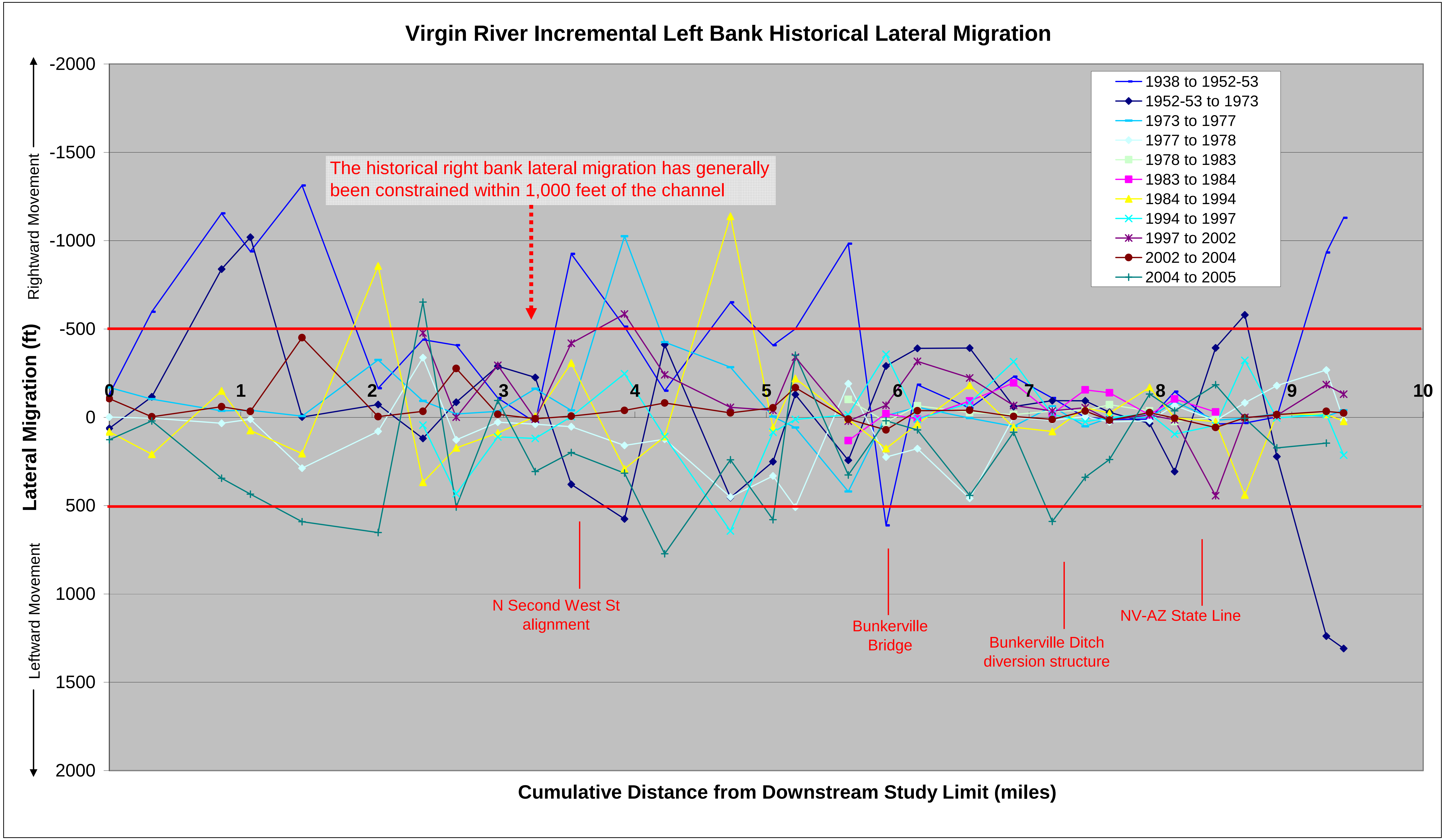

Figure 30. Left bank incremental lateral migration summary

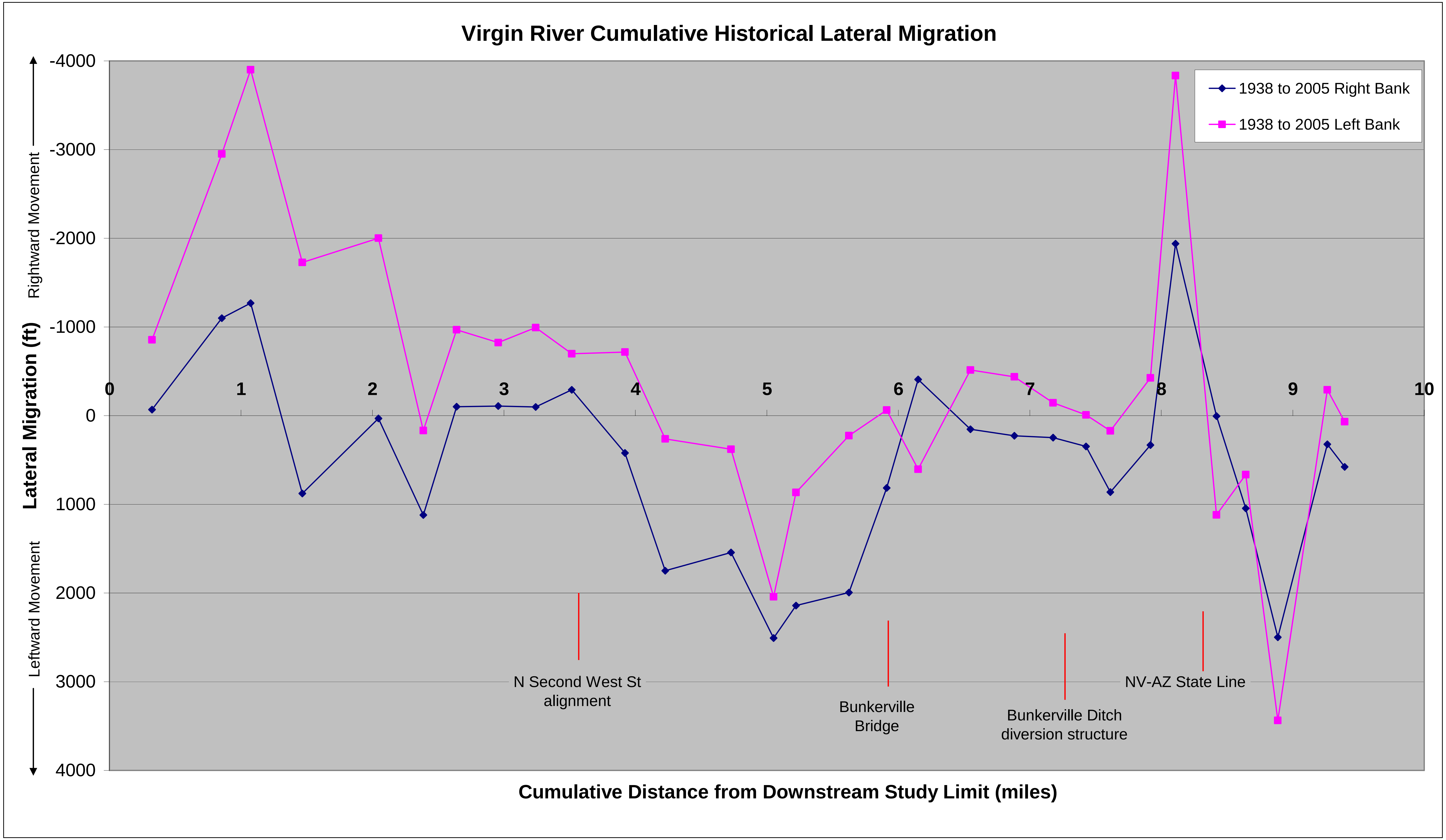

Figure 31. Cumulative lateral migration plots

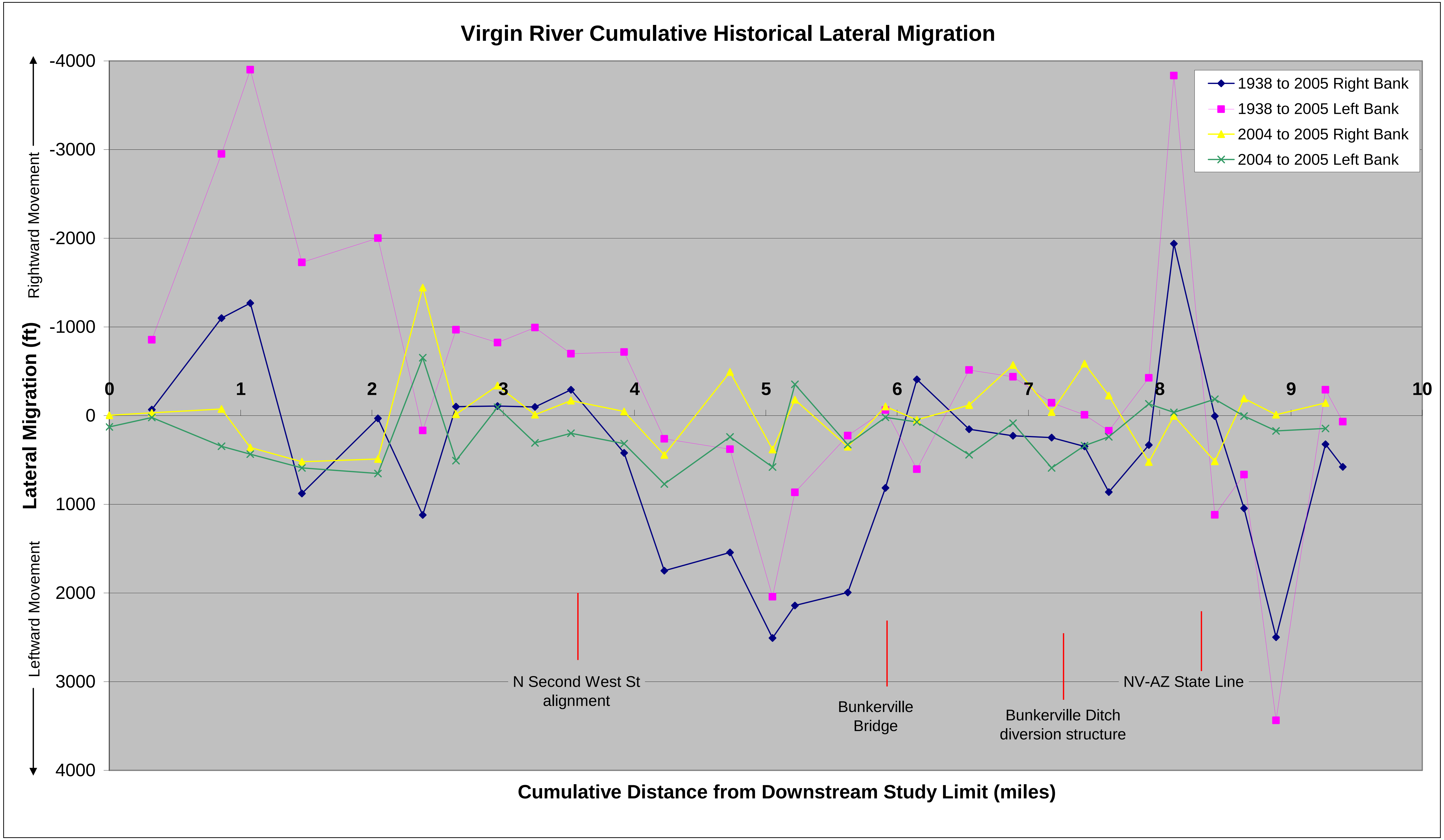

Figure 32. Cumulative vs. post-2005 flood lateral migration plot

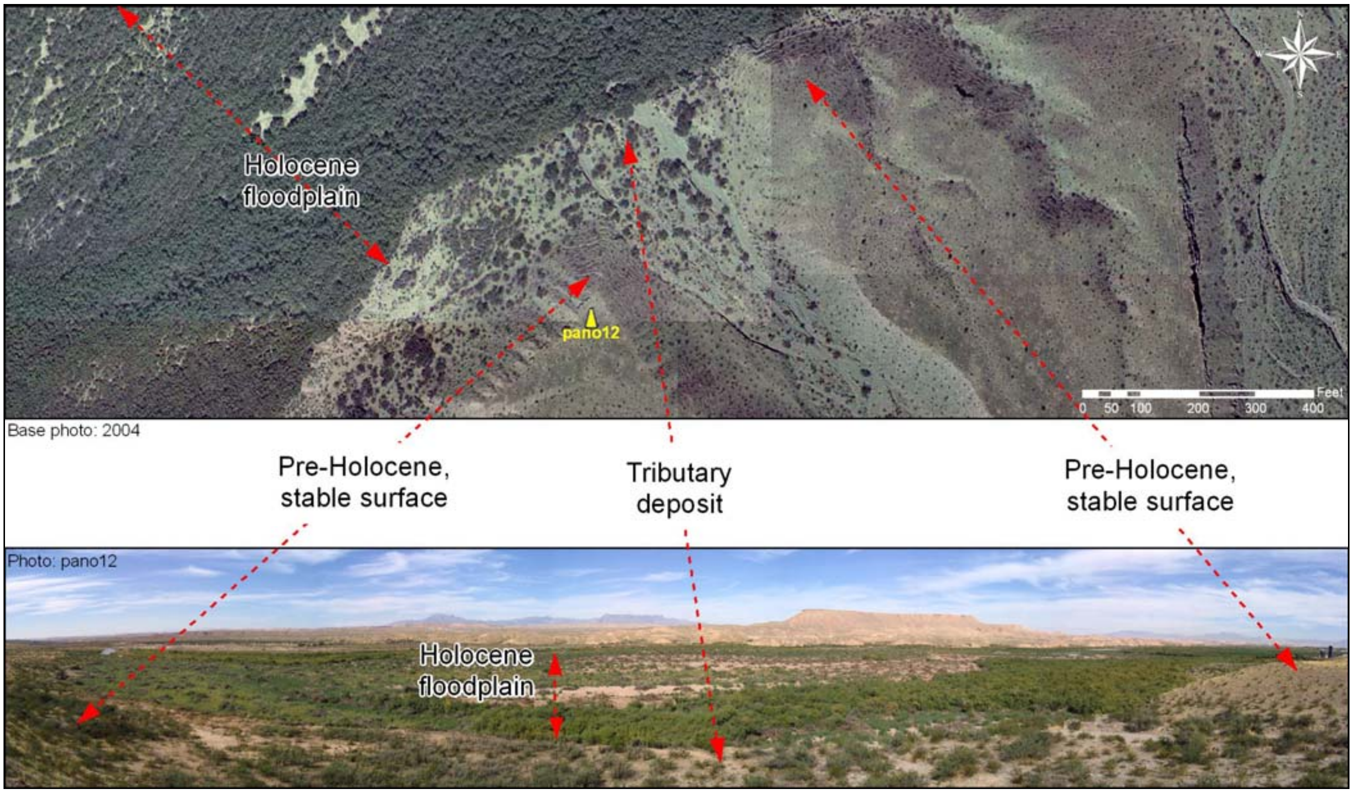

Figure 33. Example of stable surfaces within the study area

Manmade structures can provide reliable, lateral stability when properly engineered and maintained. The Bunkerville Bridge located within the study area has provided lateral stability within the historical period of record. However, given the magnitude of historical channel change, future floods could potentially erode abutments or other structure elements, if maintenance or repair is not performed. Scour is another potential geomorphic impact that can affect channel stability at structures, although less important a process as compared with lateral migration (Hilmes et al., 1997). A component of the Hilmes et al. 1997 study was to determine the potential for bridge scour at both the Bunkerville and Riverside Bridges. This was accomplished using both cross-section comparison techniques and computer modeling. The authors used field-surveyed cross-section data collected immediately upstream of the bridge between 1993 and 1995 for the cross-section comparison analysis. The result of the analysis was that the Bunkerville Bridge experienced approximately 0.3 feet of net scour within that two-year time period; taking into account a relatively large (20,500 cfs) flood that occurred in March of 1995. The other method used by Hilmes in estimating scour was the BRI-STARS (Molinas, 1990) sediment transport model for the 100-year and 500-year simulated flow events, immediately upstream and downstream of the Bunkerville Ditch diversion structure. At this location, the BRI-STARS model predicted approximately 0.98 feet of aggradation for the 100-year event and approximately 1.57 feet of scour for the 500-year event.

The elevation change analysis conducted as part of our study (Section 4.2) indicated isolated locations of channel scour that far exceeded the BRI-STARS estimate. Therefore, the channel scour values observed during the 2005 flood should be considered when designing future structures and engineered bank protection.

5.2. Width Change

Changes in channel width can occur independent of, but often occur in conjunction with, lateral channel migration. Changes in width can be the result of natural processes or human impacts (e.g. encroachment, levees, bridges, etc.). Channel width changes often create adverse conditions by disrupting sediment continuity, as at bridge constrictions that increase flow velocities, or along levees that cut off normal floodplain storage. Natural channel width changes often occur during floods as the river adjusts to the increased discharge and sediment load. Whether natural or human caused, changes in channel width are a direct reflection of the system adjusting to the imposed water and sediment discharges. A width change analysis was performed for the Virgin River to identify and quantify areas of historical lateral stability and instability. Width measurements were calculated for each set of historical aerial photography at the cross-section locations (see Figure 10). Figure 35 shows the summary of the width change analysis. The plot indicates high variability in historical channel widths. Note that after 1938, the width lines are somewhat grouped at the Bunkerville Bridge and immediately upstream. This suggests that the bridge has been effective in controlling channel width in this reach. Overall, the high degree of variability in the entire data set suggests lateral instability of channel width within the 67 year period of record. Figure 36 shows the variability in channel width over the period of record.

Figure 35 and Figure 36 indicate steep trend of channel narrowing from 1938 to 1977, a period of relatively low annual mean flow values. From 1978 to 1997 the rate of channel narrowing had slowed significantly. Relatively consistent high annual flows occurred during this period of time. Between 1997 and 2004 the rate of channel narrowing increased dramatically in conjunction with years of severe drought and floodplain vegetation encroachment. The 2005 flood caused a significant jump in channel width from the 2004 values. However, when compared with the entire data set, the 2005 plot falls generally below the mean. This suggests that although the channel experienced a significant increase in width from the 2005 flood, the post-flood width was not anomalous and in many areas was narrower than historical values, thus additional future widening should be expected.

5.3. Sinuosity

Sinuosity is the ratio of the valley length to the stream length. Straight (low sinuosity) streams in an alluvial valley are generally unstable if they remain straight for any significant length of time (Ritter et al., 1995). Under natural conditions, a river may change its sinuosity to balance the energy between stream power and sediment load. Changes in sinuosity over time can reflect changes in equilibrium slope, floodplain encroachment, or upstream watershed conditions. Changes in sinuosity can also be a mechanism for changing gradient without major vertical changes. A sinuosity analysis was performed for the Virgin River within the study area. The results are shown in Figure 34.

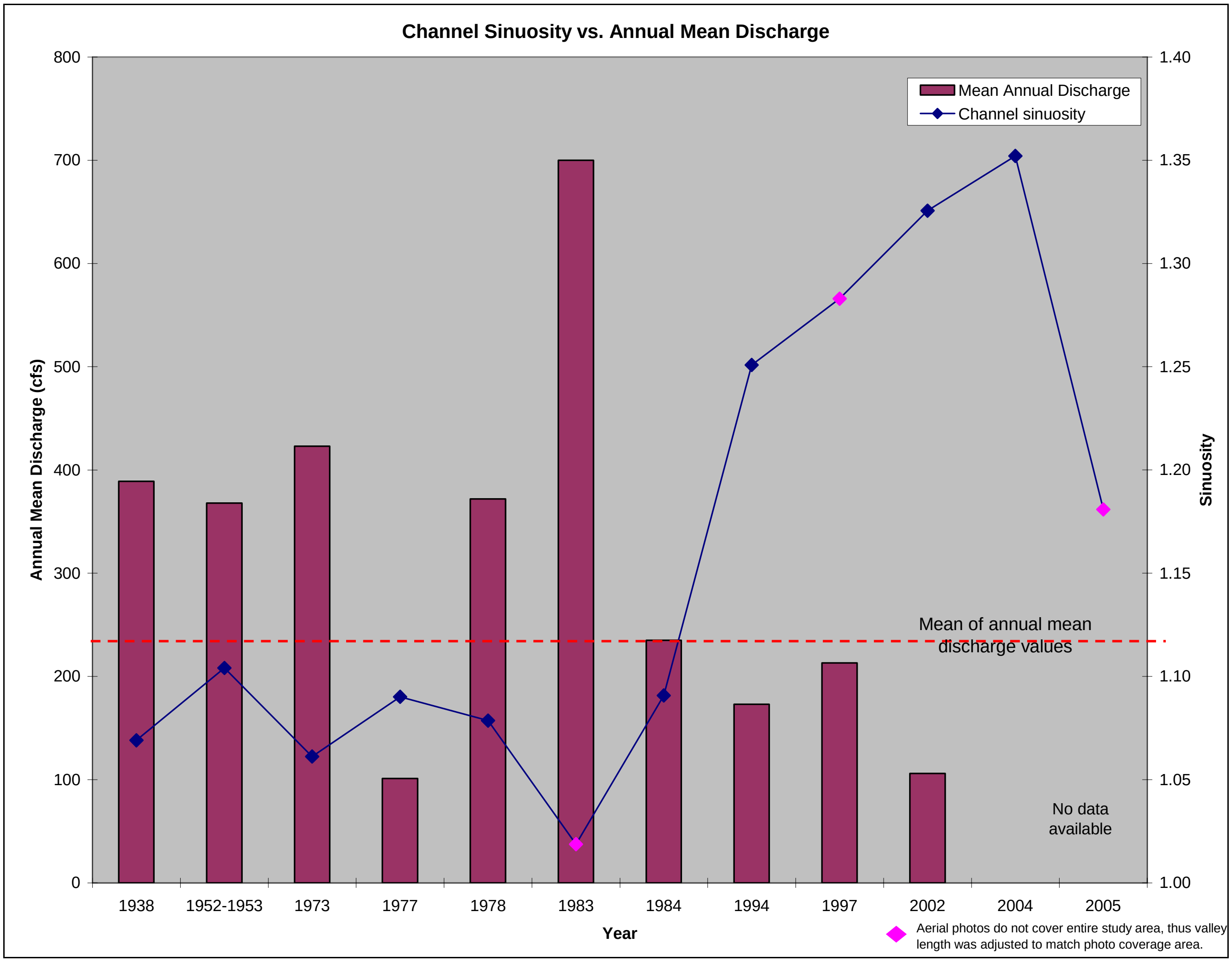

Figure 34. Channel sinuosity vs. Annual Mean discharge

Note the consistent inverse relationship between high annual mean flow and channel sinuosity. During the drought years of the 1990s, the sinuosity increased significantly. This was accompanied by encroachment of floodplain vegetation and extreme narrowing of the channel width. No annual mean flow data were available for 2004 and 2005 at the time of this report; however the plot indicates the 2005 flood had a dramatic impact on sinuosity. The pre-flood (2004) channel sinuosity was the highest in the period of record. Additionally, the pre-flood channel width was the narrowest in the period of record. These unique conditions, combined with the largest natural flood in the gage record (2005) resulted in an extreme straightening and widening of the channel. This was likely a function of both flow duration and peak discharge. Figure 34 suggests that if drought conditions persist, the channel will likely return to a highly sinuous (and narrow) pattern which could result in unanticipated behaviors during the next large magnitude flood, as was experienced in 2005.

5.4. Interpretations and Conclusions

The following conclusions were reached from the lateral migration analysis for the Virgin River within the study area:

- Previous studies on both the Virgin River and other rivers within the western United States have concluded that high peak, low duration floods are not always geomorphically effective as defined in Section 5.1.1.
- The 1989 Quail Creek Dam failure flood was the largest peak event in the gage record to-date, but resulted in minimal lateral migration of the Virgin River active channel below the Virgin River gorge. The Quail Creek event was not a large volume event.
- Years of large magnitude channel change (both width and lateral migration) on the Virgin River correspond better to years of high mean annual flows than years containing high magnitude, lower duration floods; suggesting that flows confined to the channel for longer periods of time result in greater amounts of channel migration.
- Historical, incremental channel change analyses indicate the Virgin River has experienced significant lateral changes in the active channel within short time periods.
- The largest incremental change in the period of record occurred during the 2005 flood in which the right bank migrated over 1,400 feet at a single location.
- Historical, cumulative channel change analyses indicate the Virgin River has migrated nearly 4,000 feet at a single location, and has migrated an average of 942 feet within the study area in the past 67 years.
- The Virgin River has been constrained within the Holocene geologic floodplain during the period of record, and has laterally migrated within a significant portion of the geologic floodplain during that time.
- The Virgin River has experienced significant changes in channel width, generally correlating to periods of varying mean annual flows.
- Within the study area, the Virgin River channel width has been the most stable at the Bunkerville Bridge and immediately upstream.
- The maximum channel width within the period of record was over 3,000 feet in 1938. The narrowest width within the period of record was approximately 30 feet in 2004, immediately preceding the 2005 flood.
- Historical channel sinuosity has consistently increased during periods of sustained drought associated with vegetation encroachment and channel narrowing. Historical channel sinuosity has decreased during years of high annual mean flows associated with channel widening and removal of floodplain vegetation.

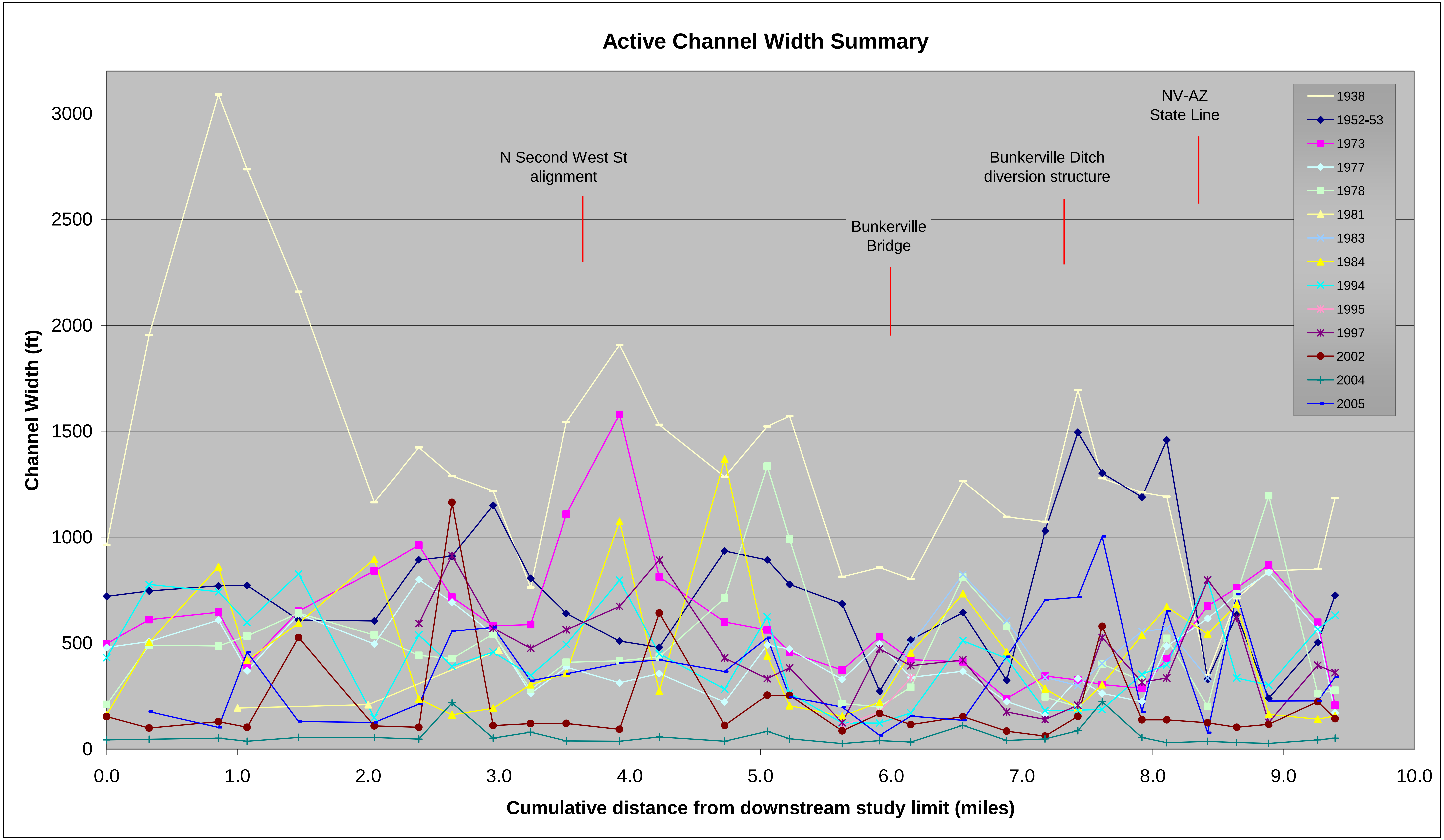

Figure 35. Historical channel width summary

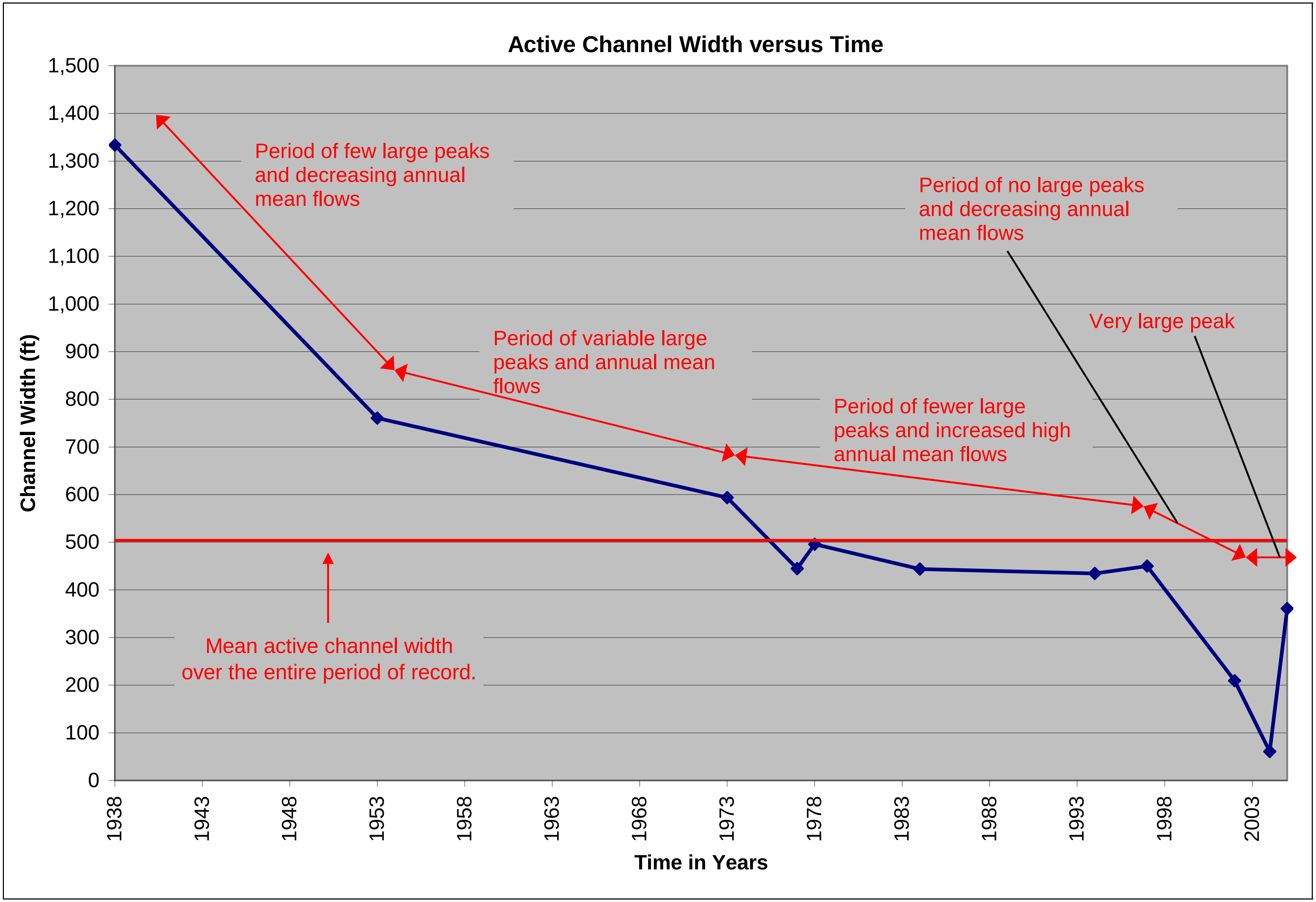

Figure 36. Active channel width changes over time

6. AREA OF EXPECTED LATERAL EROSION

For the purposes of this study, the areas of expected lateral erosion consist of the channel margin areas likely to be eroded by a “typical” series of floods over sixty-year period, plus the erosion that would be caused by a 100-year flood. These areas also include the natural channel movement due to geomorphic processes such as meander migration or channel avulsion. The basis of mapping the area of expected lateral erosion included the following:

- Maximum, historical lateral channel change considering multiple mechanisms (incremental channel change, cumulative channel change).
- Spatial distribution of erosive 100-year velocities as predicted by one-dimensional, hydraulic modeling (Figure 21).
- Spatial distribution of erosive depth-velocity product values as predicted by HEC-RAS hydraulic modeling (Figure 23).
- Natural and manmade physical constraints on lateral erosion (Figure 33).
- Field data, such as channel pattern (which indicates bend angle, preferred direction of erosion) and evidence of recent bank erosion (or stability), as well as evidence of sediment transport and scour on the non-channel floodplain surfaces.
- Engineering judgment based on applications and principles of fluvial geomorphology.

The limits of the areas of expected lateral erosion are wider in reaches where the field assessments and spatial distribution of erosive velocities and depth-velocity products indicate a high potential for future erosion, where evidence of ongoing erosion has been observed, and in reaches where accelerated erosion is expected due to channel bends or over-steepened banks. Both historical and field evidence indicates the Virgin River has been active within much of the Holocene floodplain area within the period of record. As a result, the area of expected lateral erosion was frequently defined by the Holocene floodplain limits. Figure 37 shows the area of expected lateral erosion based on the above described criteria.

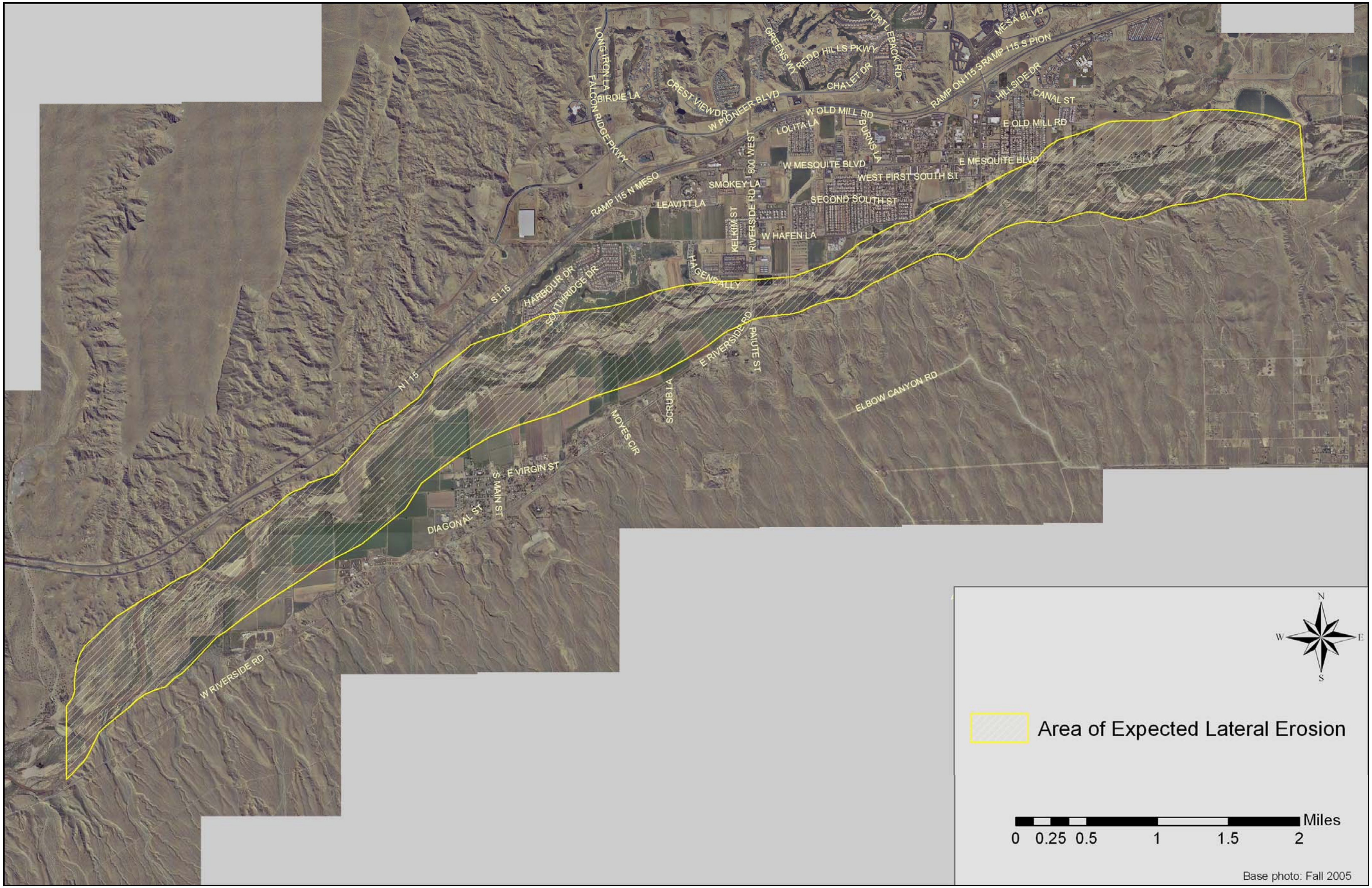
LONG IRON LA
FALCON RIDGE PKWY
BIRDIE LA
CREST VIEW DR
W PIONEER BLVD
GREENS WY
REDD HILLS PKWY
CHALET DR
TURTLEBACK RD
MESA BLVD
RAMP ON I15 S
RAMP I15 S PION
HILLSIDE DR
CANAL ST
E OLD MILL RD
W OLD MILL RD
LOLITA LA
BURNS LA
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
SECOND SOUTH ST
SMOKEY LA
800 WEST
RIVERSIDE RD
KELKIM ST
W HAFEN LA
LEAVITT LA
RAMP I15 N MESQ
S I15
N I15
HARBOUR DR
SOUTHRIDGE DR
HAGENS ALLY
E RIVERSIDE RD
PAIUTE ST
SCRUB LA
ELBOW CANYON RD
MOYES CIR
E VIRGIN ST
S MAIN ST
DIAGONAL ST
W RIVERSIDE RD
N
S
W
E
Area of Expected Lateral Erosion
Miles
0
0.25
0.5
1
1.5
2
Base photo: Fall 2005

Figure 37. Area of expected lateral erosion

7. 2005 FLOOD

Although the direct effects of the 2005 flood have been discussed in varying contexts throughout this report, it was necessary to consider the specific factors that influenced channel behavior during the flood. In particular, the causes and impacts of avulsions, the influence of channel and floodplain vegetation, and floodplain aggradation.

7.1. Avulsion Mechanisms of 2005 Flood

Two primary avulsion mechanisms were identified by this study: 1) debris blockage of the main channel, and 2) stream piracy. Many avulsions occurred within the active floodplain limits and had little impact on adjacent development. A few, however, caused significant inundation and erosion damage to structures and property.

7.1.1. Debris Blockage

Both anecdotal and field data indicated one of the causal mechanisms for abrupt changes in channel bank location was debris blockage of the pre-flood active channel. Evidence of this mechanism was observed during the field investigation. Figure 38 shows an example of a small scale debris dam that occurred just upstream of the study area. The debris dam was one factor that caused the channel to avulse into the right overbank floodplain. Debris dam blockage was responsible for some of the most devastating erosion-related damage to property along the Santa Clara River within the cities of Santa Clara and St. George, Utah during the floods of January 2005. Figure 39 shows an avulsion on the Santa Clara River directly attributed to a debris dam blockage.

As discussed in Section 5.2, the width of the Virgin River prior to the 2005 flood was at its narrowest in the period of record. Additionally, the preceding drought years had resulted in encroachment of dense tamarisk into the active channel corridor, and an increase in sinuosity. As the 2005 flood widened the channel, it accumulated a large load of vegetation debris from bank erosion within the study area as well as upstream. This debris frequently became trapped by remaining bank and channel vegetation, resulting in the formation of dams that created backwater, which raised the water surface elevations and forced flow into the overbank resulting in avulsions. It is believed that debris blockage was a primary cause of the large avulsion that occurred just upstream of the study area resulting in inundation and erosion damage to the homes along Cottonwood Drive and Grayce Drive (Figure 40). Anecdotal evidence (David Vincelette, City of Mesquite, personal communication, 2005) indicated debris blockage just downstream of the avulsion point resulted in backwater for a significant distance upstream. The avulsion path in which the overbank channel formed had historically been the alignment of the main channel during multiple time periods. Thus, it was not surprising that the avulsion occurred at this location. Figure 41 is a time series of aerial photographs comparing the 2005 avulsion channel alignment to past channel positions, showing clear evidence of multiple avulsion events at that location. Field investigation, in addition to aerial photo interpretation, has concluded that the large avulsion was the result of a combination of debris blockage causing backwater and the incorporation of a previous avulsive path, and not a result of channel and/or floodplain aggradation.

One of the primary questions that needed to be answered by this analysis was not only why the avulsion occurred, buy why the avulsive flows traveled such a great distance along the overbank before re-joining the main channel. Aerial photo and detailed field analysis of the avulsion channel suggests that once the flows were able to flank the dense tamarisk along the right overbank, the overbank flow path was relatively smooth allowing for high energy flows to concentrate and scour the non-cohesive, erodible, sandy, floodplain soils. The pre-flood floodplain surface in this area was comprised of flat, smooth, and slightly elevated agricultural fields. Between the fields and the main channel, a row of extremely dense tamarisk served as a barrier preventing the avulsive flows from re-entering the main channel. The pre- and post-flood cross-sections for this reach indicate the slope of the floodplain increased significantly toward the main channel at cross-sections 40.2 and 40.1 (see Figure 10 for cross-section locations). Consequently, this area of increased slope was the point at which the avulsion channel deflected back toward the main channel. In summary, the combination of the debris dam and the historical main channel location caused the initial 2005 avulsion. The low-roughness, relatively flat, highly erodible floodplain combined with the dense vegetation barrier allowed the avulsive flows to concentrate and remain perched to form a defined channel, and the dense floodplain vegetation flanking the main channel served as an effective barrier in preventing the overbank channel from rejoining the main stem.

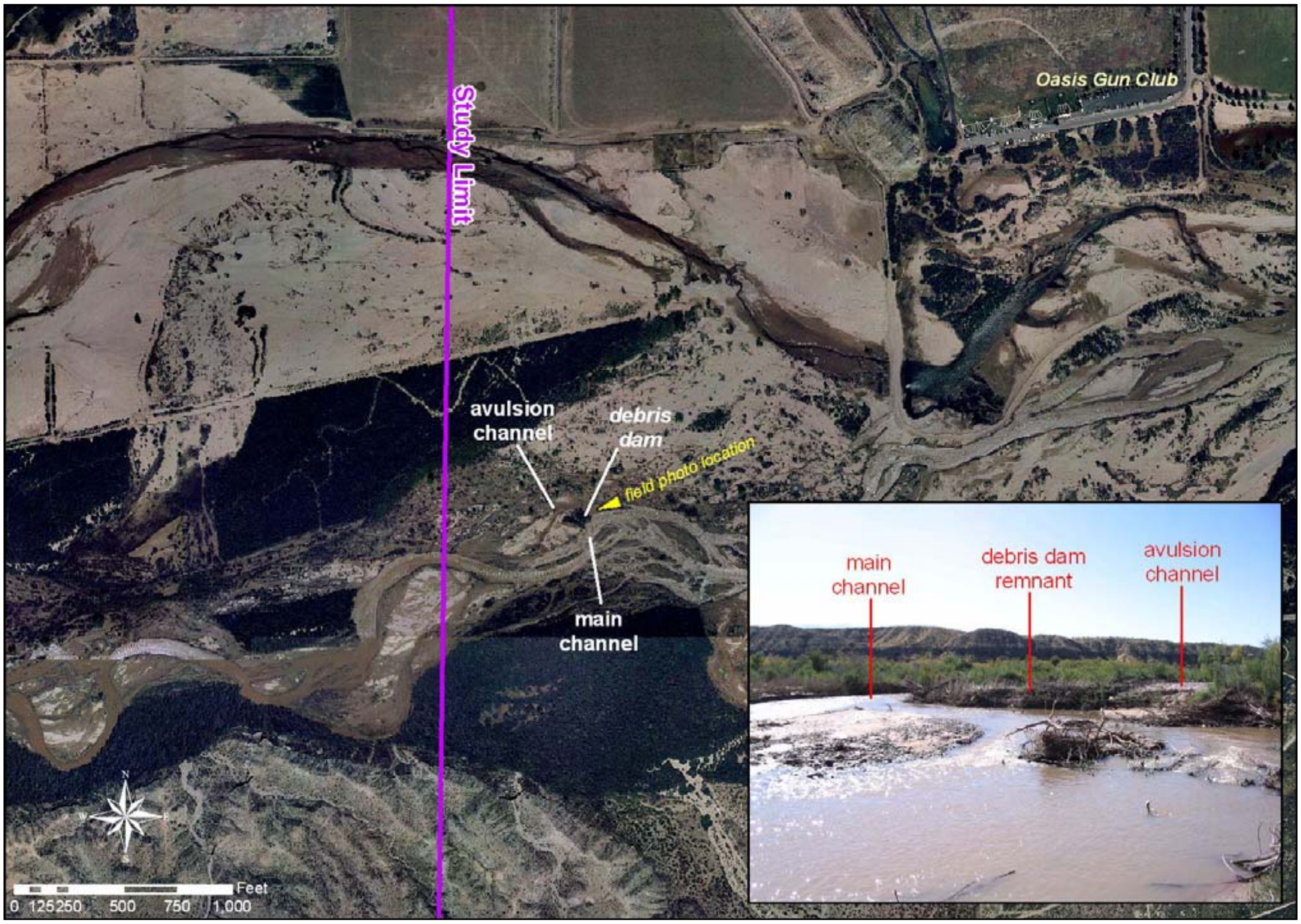
Oasis Gun Club
Study Limit
avulsion channel
debris dam
field photo location
main channel
main channel
debris dam remnant
avulsion channel
N
W
E
S
Feet
0 125250 500 750 1,000

Figure 38. Example of debris blockage resulting in channel avulsion

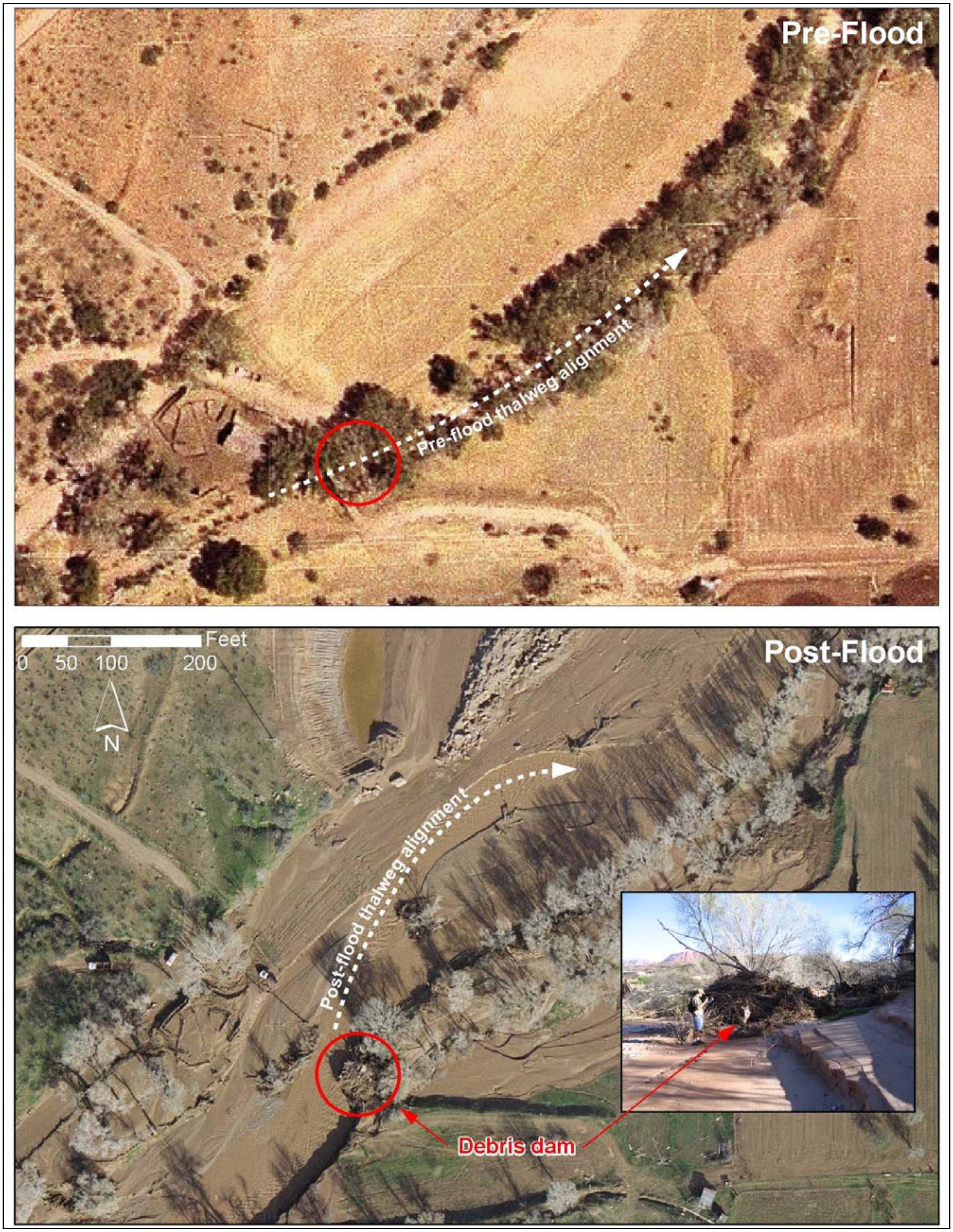
Pre-Flood
Pre-flood thalweg alignment
Feet
0 50 100 200
N
Post-Flood
Post-flood thalweg alignment
Debris dam

Figure 39. Debris dam on the Santa Clara River, UT - January 2005

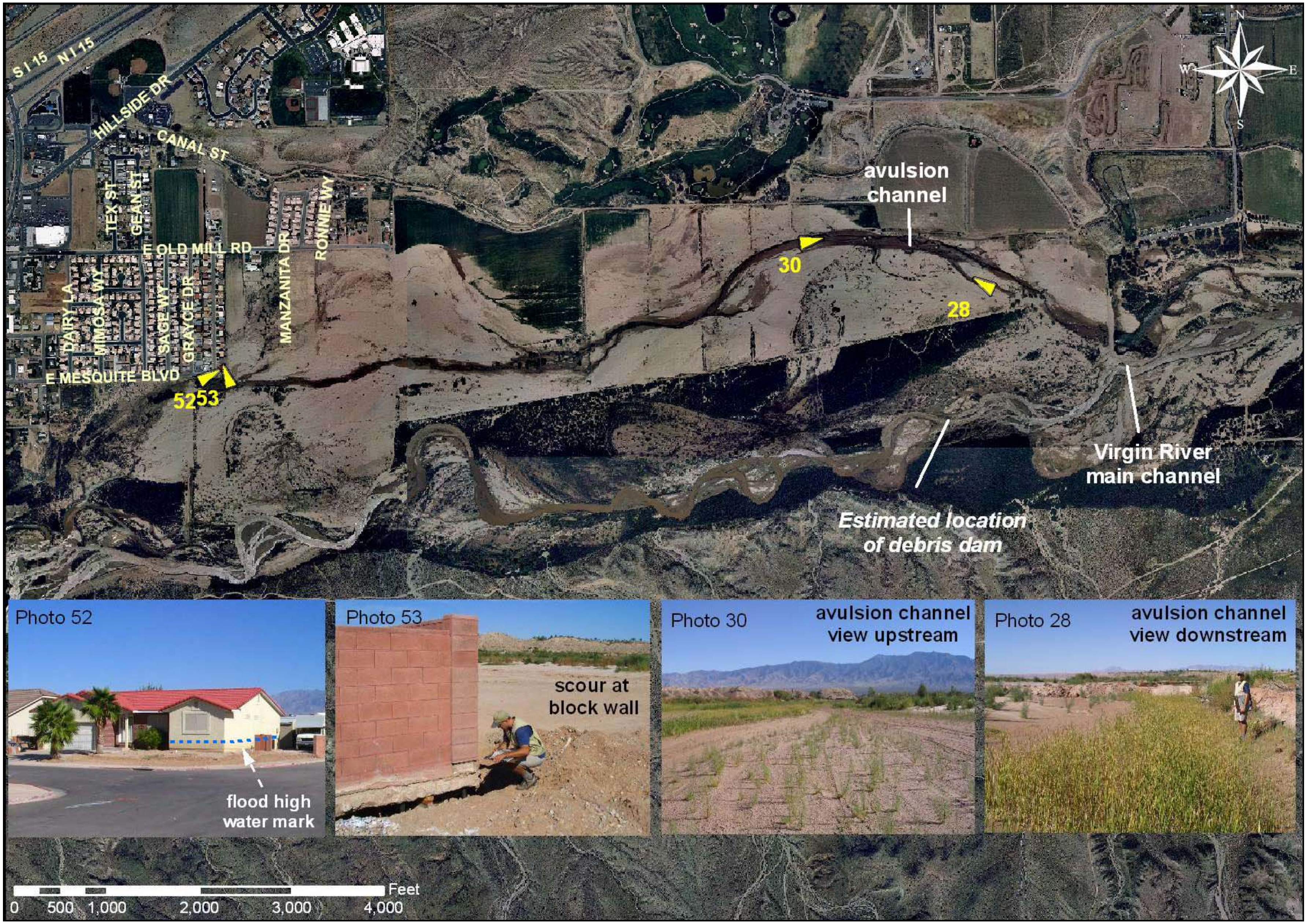
S I 15
N I 15
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
E OLD MILL RD
MANZANITA DR
RONNIE WY
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
E MESQUITE BLVD
52
53
30
28
N
E
S
W
avulsion channel
Virgin River main channel
Estimated location of debris dam
Photo 52
flood high water mark
Photo 53
scour at block wall
Photo 30
avulsion channel view upstream
Photo 28
avulsion channel view downstream
Feet
0
500
1,000
2,000
3,000
4,000

Figure 40. Large avulsion in upstream study area

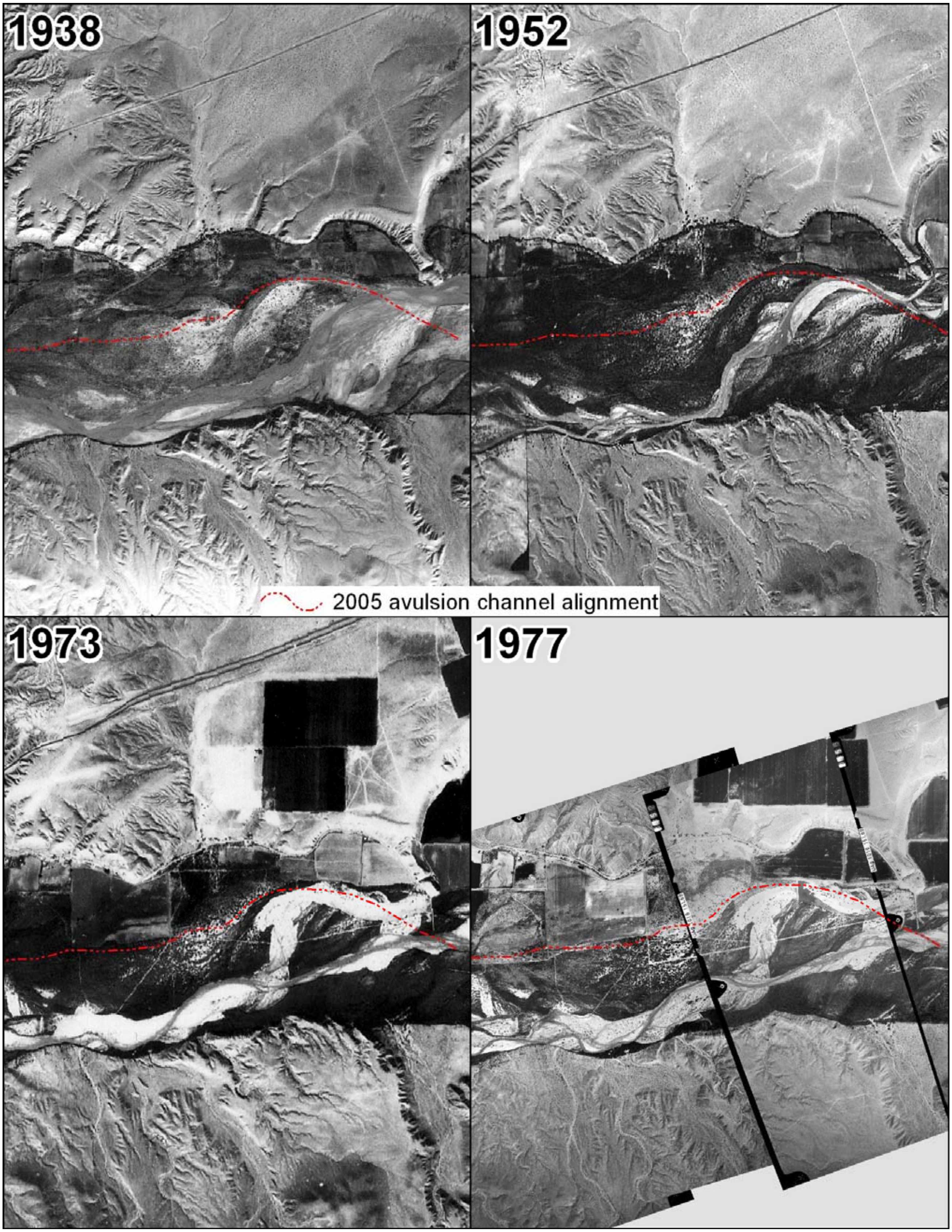
1938
1952
2005 avulsion channel alignment
1973
1977

Figure 41. 2005 avulsion location time series comparison

7.1.2. Stream Piracy

Stream piracy was identified as the other major mechanism for channel avulsion on the Virgin River during the 2005 flood. Stream piracy is the headward (upstream) erosion of a floodplain channel that eventually intercepts the main channel, diverting it in an avulsive manner. Both aerial photographs and field evidence indicated that piracy was the cause of the large avulsion channel that formed along the left overbank adjacent to the Leavitt property near Bunkerville in the downstream study area (Figure 42). The Leavitt avulsion resulted in the erosion and loss of prime agricultural pasture land. Avulsion channels that form by stream piracy are typically characterized by increasing channel depth in the downstream direction, indicative of headward erosion. The opposite is generally true of avulsion channels that form due to debris blockage or other similar mechanisms. These channels generally decrease in depth in the downstream direction, as was the situation for the avulsion channel discussed in the previous section.

Aerial video taken by the U.S. Bureau of Reclamation following the 2005 flood showed multiple instances of stream piracy causing the cutoff of large meanders. Figure 43 is a screen capture of the video and shows headcuts that stopped just short of connecting with the main channel. Had the headcuts continued to migrate upstream, the main channel would have likely avulsed, resulting in the cutoff of the large meander bend in the foreground.

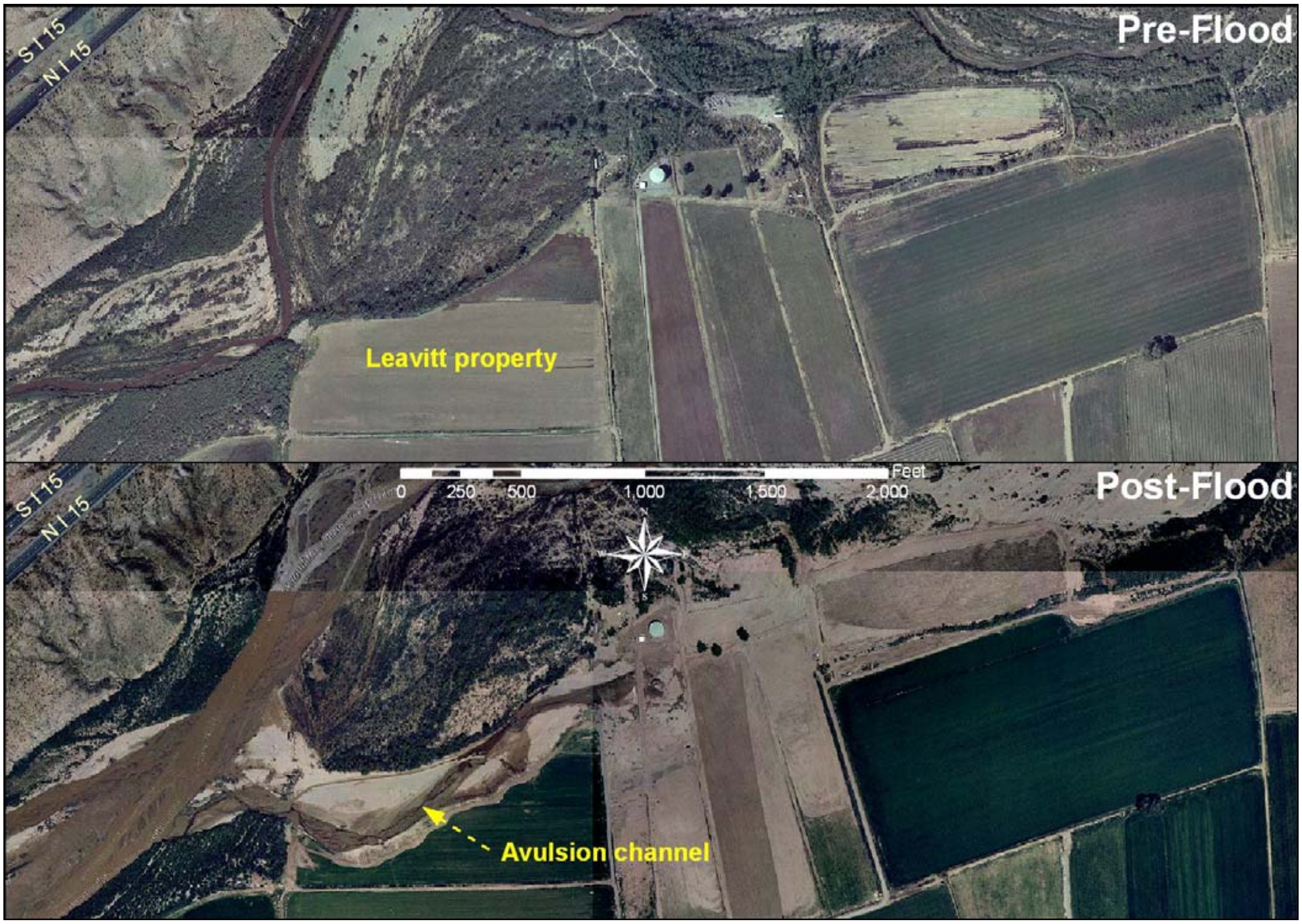

Figure 42. Leavitt avulsion channel

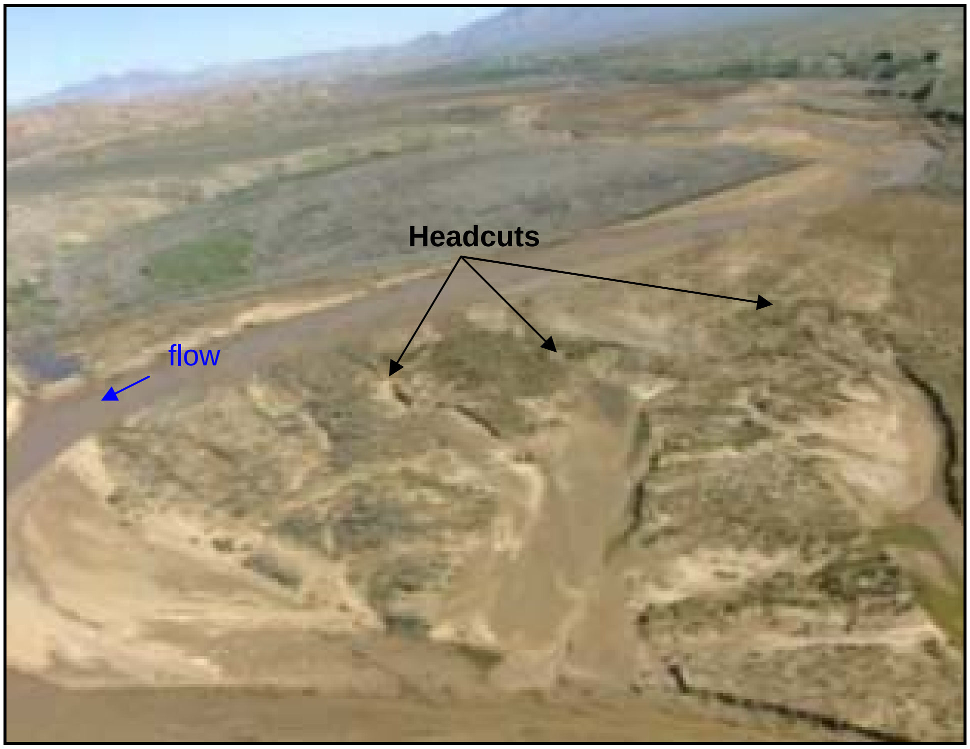

Figure 43. Example of stream piracy

7.2. Impacts of Floodplain Vegetation Removal

Beginning in 2004 the U.S. Bureau of Land Management (BLM) initiated the City of Mesquite Hazardous Fuel Reduction Project (BLM Project Number JE25). The purpose of the BLM project is to manage the wildfire fuel hazard caused by the invasive tamarisk, and to restore the native riparian vegetation to the Virgin River floodplain. Initially, the target acreage for the reduction project was set between 500 and 1,000 acres. Table 9 shows the initial level of effort estimates for the project.

Table 9. BLM Fuel Reduction Project statistics

Fiscal Year (FY)	Acres	Revegetation Status
2004	300	100 acres in FY05
2005	300	300 acres in FY06
2006	100	300 acres in FY07
2007	233	233 acres in FY08

One of the areas which had been cleared of tamarisk prior to the 2005 flood as part of JE25 was located in the right overbank floodplain adjacent to the Grayce Drive and Cottonwood Drive alignments (Figure 44). Following the floods, local officials were concerned as to whether the tamarisk removal played a role in the avulsive behavior of the river. The potential impacts of the vegetation clearing were investigated as part of this study. The post-flood field investigation determined that although the area was significantly inundated during the flood, the cleared area itself was not the primary factor causing the avulsion and subsequent damage sustained by the homes along Cottonwood Drive and Grayce Drive. The stockpiles of cut tamarisk that are visible in the pre-flood photo in Figure 44 were removed by the flood and may have adversely impacted areas downstream due to debris damming, but that cannot be demonstrated definitively. The presence of the uncut tamarisk may have prevented avulsive flow from returning to the main channel, but more detailed modeling would be required to separate the topographic impact of the high ground on which the tamarisk lies.

Another area of pre-flood vegetation clearing that occurred within the study area was located in the left overbank floodplain near the downstream study limit (Figure 45). The cleared area was approximately 55 acres, and like the upstream clearing was characterized by large stockpiles of cut tamarisk. One of the potential concerns that such vegetation clearing can pose is allowing overbank flows to concentrate due to the resulting low surface roughness. Concentrated flows contain significantly higher velocities which can erode through floodplain soils creating new channel that could potentially result in main channel avulsions. Flood channels had begun to form in the clearing area, but fortunately remained relatively small and did not result in any known significant adverse impacts on the adjacent property (Figure 45). 2005 flood sediment deposition in this area was between one and three feet.

Large floods in alluvial channels are dynamic and will result in channel changes including migration, widening, and avulsion. Riparian vegetation has a complex role in each process ranging from the build-up of the potential for major, flood-related changes before a major flood, to the causation and exacerbation of major changes during a flood.

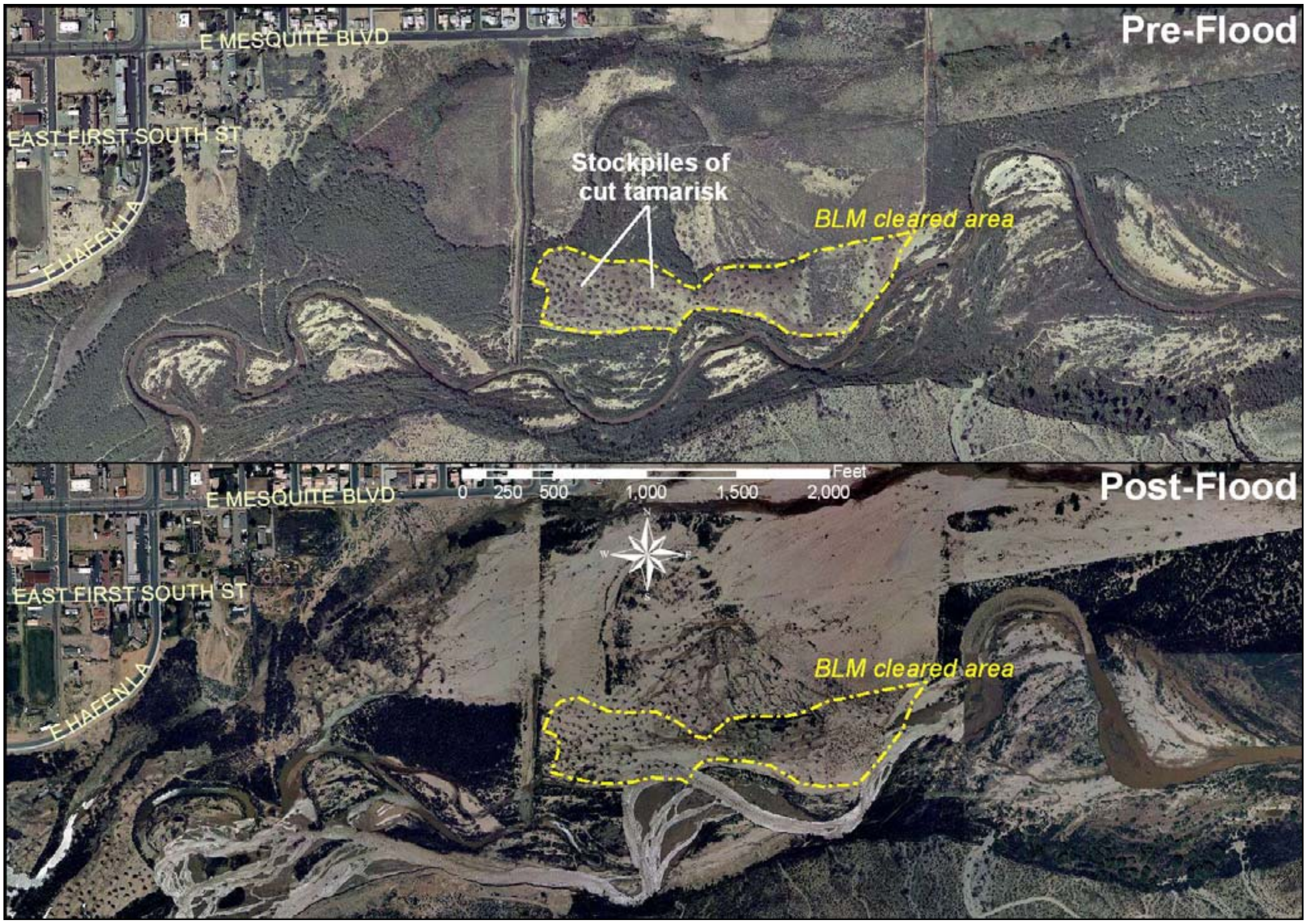
Pre-Flood
E MESQUITE BLVD
EAST FIRST SOUTH ST
E HAFEN LA
Stockpiles of cut tamarisk
BLM cleared area
Post-Flood
E MESQUITE BLVD
0 250 500 1,000 1,500 2,000
Feet
EAST FIRST SOUTH ST
E HAFEN LA
BLM cleared area

Figure 44. Pre- and post-flood comparison of the BLM vegetation cleared area

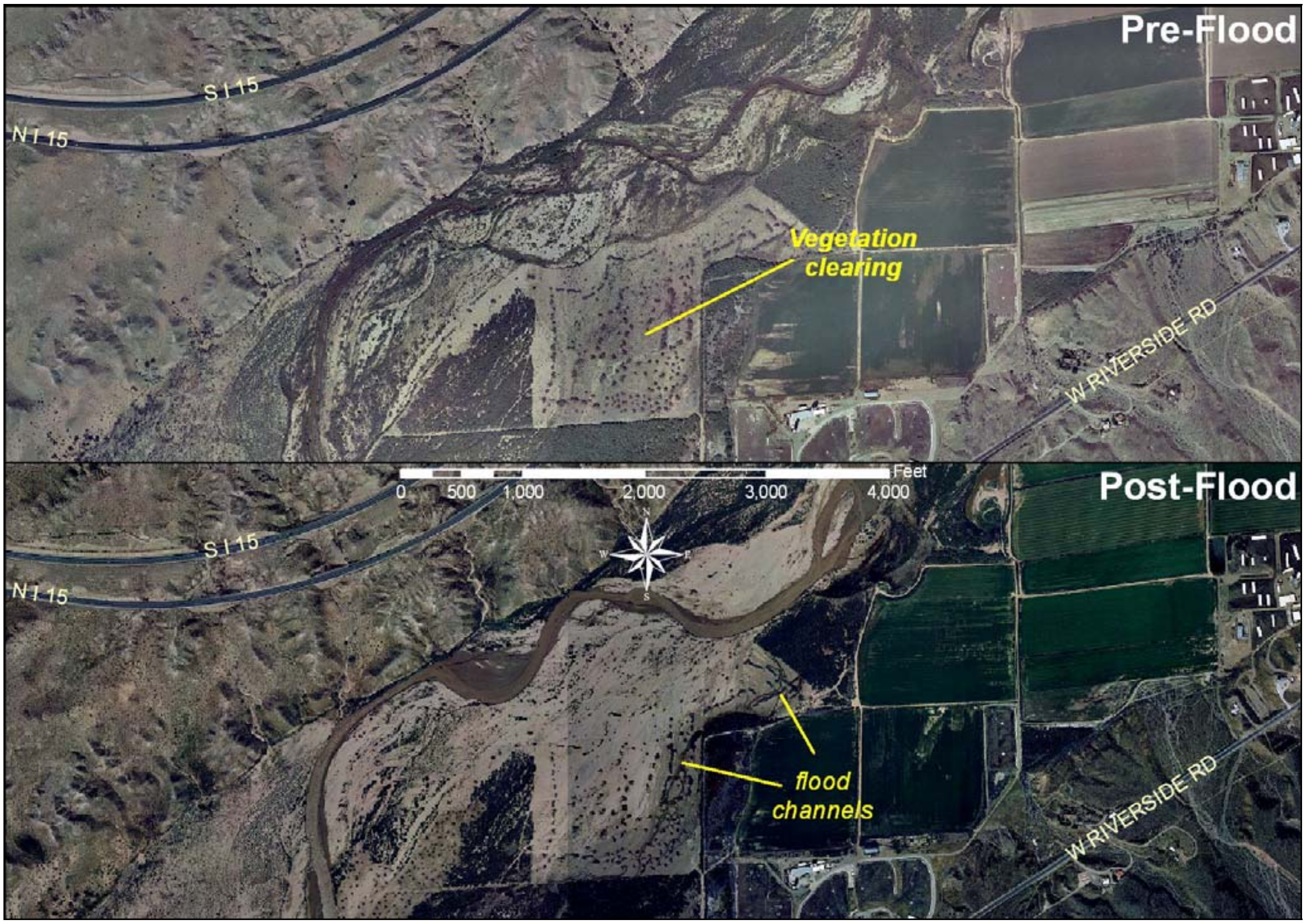
Pre-Flood
S I 15
N I 15
Vegetation clearing
W RIVERSIDE RD
Post-Flood
0
500
1,000
2,000
3,000
4,000
Feet
N
E
S
W
S I 15
N I 15
flood channels
W RIVERSIDE RD

Figure 45. Vegetation-cleared area near the downstream study limit

8. CONCEPTUAL RECOMMENDED PLAN

This section describes a conceptual plan to mitigate sedimentation and lateral erosion hazards along the north bank of the Virgin River. The scope of services requires that the conceptual sedimentation and erosion mitigation plan include the following elements:

- FEMA guidelines for delineation of lateral erosion hazards and delineation of floodplains on aggrading streams.
- A scope of services for additional analysis required to support design of structural sediment and erosion control measures.
- Development guidelines that can be implemented at the local level.

It is important to note that this study found that there is no sedimentation or erosion "problem" with the river. The "problem" occurs where development is too close to the river. The recommended plan is conceptual in nature. More detailed analyses would be required to establish a final recommended plan and to implement the plan.

8.1. FEMA Guidelines

To date, FEMA has not adopted official guidelines for delineation of lateral erosion hazards or for delineation of floodplains on aggrading streams. Therefore, the conceptual recommended plan described in this section is based on engineering judgment, best management practices and design guidelines adopted by other arid west communities, and the results of the geomorphic and sedimentation engineering analysis of the Virgin River discussed in the previous sections of this report.

8.1.1. Erosion Hazard Delineation & Management

FEMA regulations recognize that erosion hazard management is a vital component of sound flood control planning, and is especially important in arid west communities like Mesquite, Nevada. In their study of riverine erosion hazards, FEMA (1999) specifically noted that significant, well-documented erosion problems have occurred in the arid west. Nationwide, severe erosion problems result in damages of more than $450 million each year.[10] Because of the extent of erosion damages, the National Flood Insurance Program (NFIP) enabling legislation (44 CFR Chapter 1, Parts 60.5 & 60.24) establishes minimum standards for management of erosion-prone areas, and requires that local communities require permits for all development in flood-related erosion hazard areas and to determine whether development is safe from flood-related erosion. The NFIP legislation further requires that if improvements are in erosion areas, relocation or protective measures are required. Management of erosion hazards can also result in CRS credits for NFIP member communities.

In the 1999 Riverine Erosion Hazard Area (REHA) mapping and feasibility study, FEMA concluded that mapping of riverine erosion hazards is feasible, and described a variety of erosion hazard delineation methodologies. However, FEMA has not adopted any specific methodologies for delineating riverine erosion hazards. The geomorphic methodologies used in this study to depict the erosion and sedimentation hazards on the Virgin River near Mesquite are described favorably in the FEMA REHA study, both in general and specifically for the Virgin River (at St. George, Utah).

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[10] Damages in 1999 dollars.

The Clark County Uniform Regulations for the Control of Drainage (2003) also recognizes the importance of managing erosion hazards by including erosion in its definition of "flooding," but does not include any specific delineation or management strategies.

8.1.2. Floodplain Delineation on Aggrading Streams

There are no FEMA guidelines specifically for floodplain delineation on, or management of, aggrading streams.[11] Alluvial fans are the only aggrading landform for which FEMA has developed specific management and delineation strategies. The Virgin River is not an alluvial fan. Furthermore, the evidence identified in this study does not support the conclusion that significant long-term aggradation occurred within the study area during period of record. However, there is a FEMA requirement to re-map riverine floodplains and update Flood Insurance Rate Map (FIRM) panels if river conditions change due to encroachment, channelization or natural factors. Therefore, periodic inspection and evaluation of river conditions to determine if the channel has changed sufficiently to warrant re-mapping of the floodplain is recommended as part of the river management plan.

8.2. Scope of Services for Analysis of Structural Measures

Structural measures to control sedimentation and erosion hazards include engineered bank protection, grade control, and levees. Bank protection has been installed in numerous places along the banks of the Virgin River near the City of Mesquite. In general, the bank protection appears to consist of emergency measures placed during floods, rather than engineered facilities. Some degree of grade control is provided by the Bunkerville Diversion, although this structure was flanked and partially destroyed in the 2005 flood. During the 2005 flood, a number of levees were constructed to attempt to direct overbank flooding back toward the main channel. It is unlikely that these levees meet FEMA or CCRFCD standards.

Specific criteria for the design of engineered flood control structures are given in the CCRFCD Hydrologic Criteria and Drainage Design Manual (1999) and are not repeated here. If structural measures are employed as part of the recommended plan or are implemented outside the master plan, their design should specifically address the following criteria, in addition to those outlined in the CCRFCD Manual:

- Freeboard. For the purposes of erosion control, it is not always necessary for erosion control structures to fully contain the 100-year peak discharge. However, it is vital that flow which is not contained by the structure does not have erosive depths and/or velocities, and that non-contained flow outside the protection cannot concentrate and form avulsive flow paths. Therefore, computation of freeboard is typically governed by hydrologic and hydraulic factors related to flood inundation, rather than erosion. The analysis of freeboard for sedimentation and erosion control structures should include sediment modeling sufficient to demonstrate the structural measures will not cause sediment deposition that could compromise the design freeboard or induce long-term erosion that would undermine the structure's foundation. In addition, modeling of water surfaces to determine freeboard should consider the potential for future channel alignment and geometry changes, and changes in roughness due to vegetation and land use.

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[11] Personal communication from Mike Grimm/FEMA on April 11, 2005.

- Toe Down. Adequate toe down is required to assure proper function of structural flood control measures. Toe down should be calculated by computing the total scour depth (general, local, and long-term scour) using with-project, worst-case hydraulic conditions for the design flood. Given the high potential for significant lateral movement of the main channel of the Virgin River, toe down should be measured from the invert of the main channel rather than from the existing, pre-construction ground elevation of the floodplain or terrace where the structural measure is to be constructed. Similarly, scour should be computed using the main channel geometry and hydraulic data, regardless of where within the floodplain the structural measure is to be constructed.

- Lateral Tie In. The Virgin River has experienced main channel lateral movement of several thousand feet within the past few decades and is also vulnerable to avulsive channel change. Therefore, any proposed structural measure should be designed to prevent flanking due to upstream channel movement or overbank flow concentration landward of the structure. The geomorphic analysis conducted for this study concluded that the entire modern Holocene geologic floodplain is vulnerable to some degree of lateral erosion, and therefore nearly all land within the floodplain is at risk of flanking. The need for lateral tie within a wide erosion hazard zone is one of the main reasons to avoid piecemeal construction.

- Impacts to Adjacent Properties. Adverse impacts to adjacent properties should be avoided. In particular, where bank protection is added on one side of the river corridor, it may be necessary to add bank protection on the opposite side and/or downstream to prevent accelerated erosion rates on adjacent river reaches. Detailed draft criteria, developed by JEF for other river studies, for assessing potential adverse impacts to adjacent properties and for determining a standard of non-impact are attached in Appendix C.

In general, piecemeal construction of flood control measures at individual properties along the river is not recommended. Instead, structural sediment and erosion control measures should be constructed within a master plan to minimize the potential for adverse impacts to adjacent properties and to better assure the long-term effectiveness of the proposed structural measures.

8.3. Development Guidelines

The most reliable means of avoiding riverine sedimentation and erosion damages is for development to stay out of the river corridor. The further development is from the floodplain, the less likely it is to experience problems with flooding and erosion. The more the natural river system is altered by development, encroachment, channelization, and urbanization, the more the river will affect the human environment. There is less to fix if the river corridor is left alone. However, given economic and political realities, development is likely to continue in areas subject to flooding and erosion. Therefore, the following three elements are suggested as development guidelines that can be implemented at the local level as part of an overall river master plan intended to minimize sedimentation and erosion damages:

- Education & Awareness. Simply acknowledging that the river corridor is subject to erosion and sedimentation hazards is an effective means of managing the hazard. This report documents the extent of the lateral erosion hazard along the Virgin River, as well as the sedimentation impacts that occurred during the 2005 flood. Figure 23 shows areas of high flow depth and velocities. Figure 37 shows the areas of expected future lateral erosion. Land owners within these zones should be informed of the potential erosion hazard so that they are aware of the risk and can formulate their land use and development plans accordingly. Proposed development within the erosion hazard zone should formally acknowledge the erosion hazard and propose designs that mitigate the risk.

- Regulation & Management. The City of Mesquite, the Town of Bunkerville, and Clark County should adopt the zone of expected lateral erosion based on Figure 37 and regulate development within that zone. Any development within the delineated zone is at some risk of future erosion damage, either in a single large flood or over the long term. Regulation could include measures such as buyout of non-buildable, at-risk properties, rezoning of hazardous properties to include more appropriate uses such as agriculture, open space, and trails, implementation of an overall river management plan as outlined below, and/or construction of structural measures.

- Structural Measures. Structural measures can be an effective way to mitigate sedimentation and erosion hazards if they are adequately engineered, properly maintained, and are constructed within a well-design river management plan. Specific conceptual measures for the Virgin River corridor near the City of Mesquite are described in the following section.

8.4. Recommended Conceptual Plan

The recommended conceptual plan for mitigation of sedimentation and erosion hazards along the Virgin River near the City of Mesquite is based on the results of the analyses described in the previous sections of this report. In general, this report concludes the following:

- The Virgin River narrows during periods of low flow and widens during floods and periods of above-average flow. These channel morphology adjustments are natural processes and should be expected to continue in the future.
- The Virgin River experiences extreme magnitudes and rates of lateral channel movement. Over time, the river will occupy most of its geologic floodplain unless structural measures are constructed that restrict the natural migration.
- The January 2005 flood was one of the largest recorded floods on the Virgin River, but the river's flood response was not unusual, unexpected, or unpredictable. The channel avulsion that resulted in flood inundation of homes and property in Mesquite followed abandoned, historical flow paths. Lateral erosion occurred along channel bends, at constrictions narrowed by development, and where tamarisk blocked conveyance corridors. Deposition occurred on floodplains where low flood velocities caused low sediment transport rates.
- No significant long-term trends of net aggradation or degradation were documented for the Virgin River for the period of record.

- Invasion of non-native tamarisk species on the Virgin River floodplain and channel banks altered the expected natural flood response during the 2005 flood. Tamarisk contributed to debris blockage of the main channel and increased the hydraulic roughness along flow corridors, diverting flow to open areas and raising water surface elevations.
- Debris blockage of the main channel of the Virgin River led to increased overbank flow, channel avulsion, and lateral erosion.

The recommended conceptual river management plan attempts to address the observed channel behavior in light of potential continued development of the river corridor. The recommended conceptual plan consists of the following elements:

- Maintenance of an open conveyance corridor along the main channel
- Maintenance of channel and floodplain vegetation
- Implementation of development guidelines
- Adoption of the erosion hazard zone as a management tool
- Maintenance and inspection

8.4.1. Conveyance Corridor

One of the conclusions of the historical analysis in this study was that the 2004 channel width was overly narrow due to an extended drought and vegetation encroachment. The 2004 channel width was insufficient to convey the January 2005 flood, resulting in channel widening, entrainment of extensive bank and floodplain vegetation into the flood waters, significant inundation and sediment deposition in the floodplain, and multiple channel avulsions. Historical analysis indicates that the mean active channel width of the Virgin River within the study area has been about 500 feet during the period of record (Figure 36). The two outliers in this data set were 1938 and 2004, representing anomalously high and low values, respectively. When excluding these outliers from the historical analysis, the mean active channel width was 460 feet. The mean post-2005 active channel width was approximately 360 feet, indicating that a minimum conveyance corridor of 460 feet would be sufficient to pass the 2005 flood magnitude. Although floodplain inundation would likely still occur during such a flood, the potential for large magnitude avulsions and excessive sedimentation in the floodplain would be decreased because the active channel corridor would be of sufficient width to pass the high velocity flows, suspended sediment, and entrained vegetation debris without clogging. Figure 47 shows a possible 460 foot corridor alignment within the zone of expected lateral erosion.

The river conveyance corridor management plan should be implemented that includes the following key elements (illustrated in Figure 46):

- A tamarisk-free channel conveyance corridor should be established. Growth of other native, non-woody species should be encouraged within the corridor, with the recognition that period low flow channel movement and natural channel migration will result in some local vegetation loss.
- The conveyance corridor width should be a minimum of 460 feet. The exact vertical and horizontal dimensions of each component of the corridor, as shown in Figure 46 should be established by more detailed geomorphic analysis of the low flow channel characteristics.
- In general, the conveyance corridor geometry should increase in elevation and vegetative density with distance from the thalweg.

- The area outside the conveyance corridor should be graded and/or vegetated to minimize the potential for flow path concentration, perching of overbank flows, and creation of continuous corridors with low roughness.
- The low flow channel and floodplain geometry within the corridor should be allowed to form naturally, or should be created using stream restoration techniques. Future movement of the low flow channel within the corridor should be expected in response to floods, seasonal flow variation, and climatic cycles.

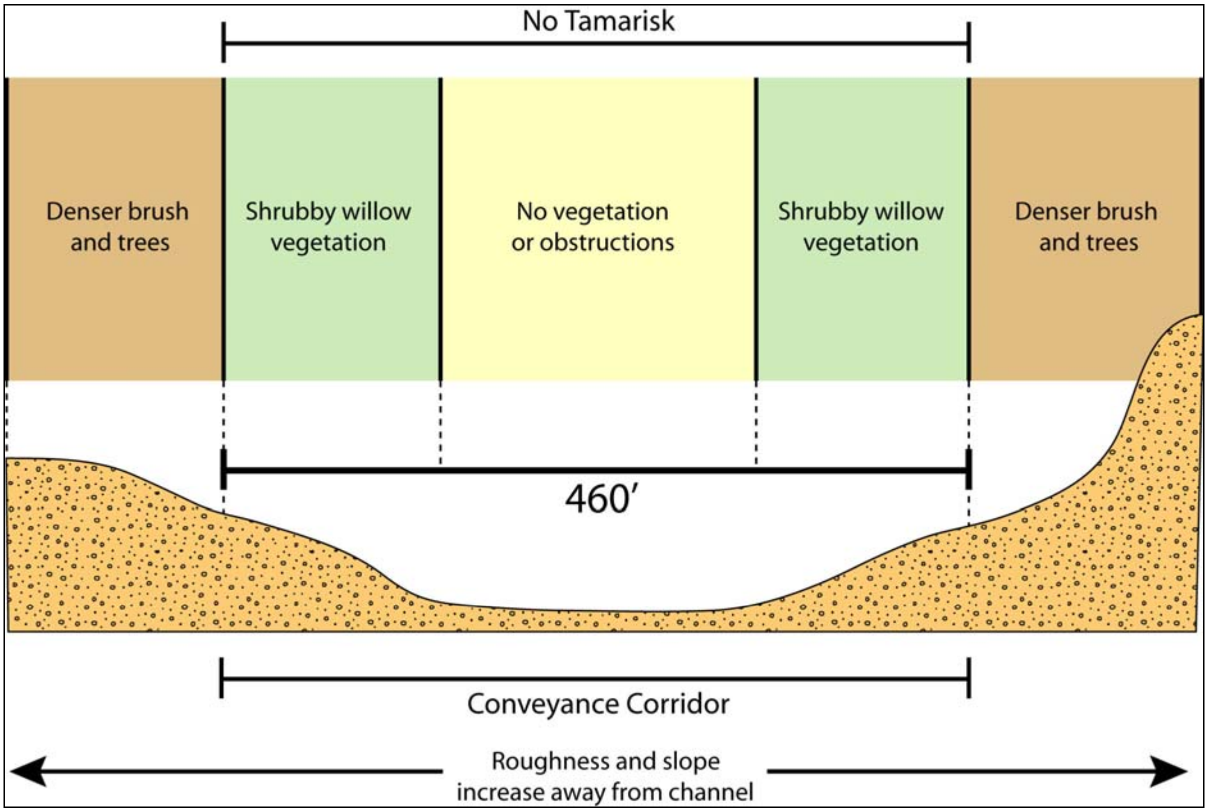
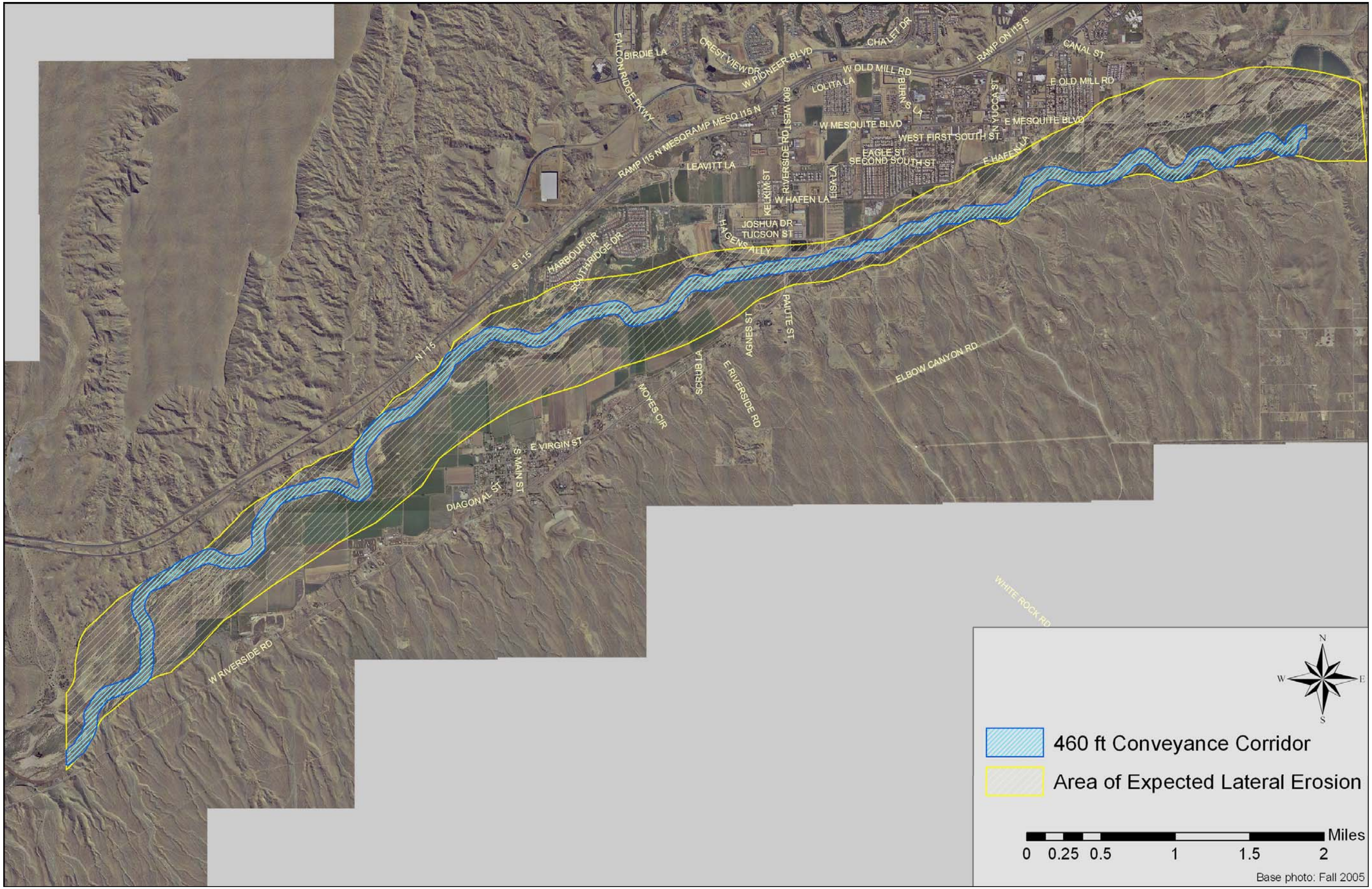

No Tamarisk
Denser brush and trees
Shrubby willow vegetation
No vegetation or obstructions
Shrubby willow vegetation
Denser brush and trees
460′
Conveyance Corridor
Roughness and slope increase away from channel

Figure 46. Example of recommended conveyance corridor

8.4.2. Vegetation Management

There are on-going tamarisk removal projects in several places along the Virgin River. Beginning in 2004, the BLM initiated their City of Mesquite Hazardous Fuels Reduction Project. The official goal of this project is to significantly reduce the potential for fire hazard by removing the dense tamarisk vegetation from the Virgin River floodplain within the City of Mesquite, and replacing the tamarisk with native riparian species. The following recommendations for vegetation removal and restorations in the floodplain are meant to reduce future adverse geomorphic impacts on the system due to high annual mean flows and large magnitude, low frequency floods:

- Floodplain vegetation removal and restoration should be done beginning at the low flow channel and progressing away from the thalweg, rather than beginning in the floodplain and working toward the main channel. Maintaining increased conveyance by removing tamarisk along the low flow channel increases conveyance in the active channel, reduces the potential for avulsive overbank flows, and reduces the potential for debris blockage by decreasing the supply of debris and increasing the width required to form a debris dam.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BURKS LA
E OLD MILL RD
N YUCCA ST
E MESQUITE BLVD
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LEAVITT LA
KELKIM ST
LISA LA
W HAFEN LA
JOSHUA DR
TUCSON ST
HAGENS ALLY
HARBOUR DR
SOUTHRIDGE DR
S I15
N I15
AGNES ST
PAIUTE ST
ELBOW CANYON RD
SCRUB LA
E RIVERSIDE RD
MOYES CIR
E VIRGIN ST
S MAIN ST
DIAGONAL ST
W RIVERSIDE RD
WHITE ROCK RD
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E
S
460 ft Conveyance Corridor
Area of Expected Lateral Erosion
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0.25
0.5
1
1.5
2
Miles
Base photo: Fall 2005

Figure 47. 460 foot conveyance corridor footprint

- Vegetation restoration should follow the guideline that channel roughness should increase away from the conveyance corridor. This will allow the highest velocity flows to remain within the corridor and reduce the potential for avulsions in the overbank floodplain.

8.4.3. Development Guidelines

Recommended development guidelines were provided in Sections 8.2 and 8.3 above. Other development guidelines related to implementation of a conveyance corridor include best management practices for the floodplain outside the conveyance corridor. One of the major factors that enabled the 2005 avulsion channel to persist for such a great distance was the relatively flat floodplain surface. Floodplain terraces that are flat and, even worse, adversely sloped from the conveyance corridor, trap overbank flows resulting in perched flow paths. The following floodplain geometry recommendations are meant to limit the adverse geomorphic impact of overbank flows during large magnitude floods:

- Floodplain terraces should be graded to maintain a positive slope away from the conveyance corridor. This will aid in directing overbank flow bank toward the main channel and preventing high velocity flows outside the conveyance corridor.
- Flat and adverse slopes should be avoided. Low roughness areas like agricultural fields should be graded to maintain a positive slope away from the corridor, or should include topographic or vegetative barriers to prevent flow concentration and high velocities.
- Where flat floodplain slopes or low areas exist, perpendicular dikes or dense vegetative wind rows should be created to trap overbank flows and prevent flow concentration (Figure 48). These features will tend to trap sediment, cause deposition and raise the floodplain to create the desired terraced geometry.

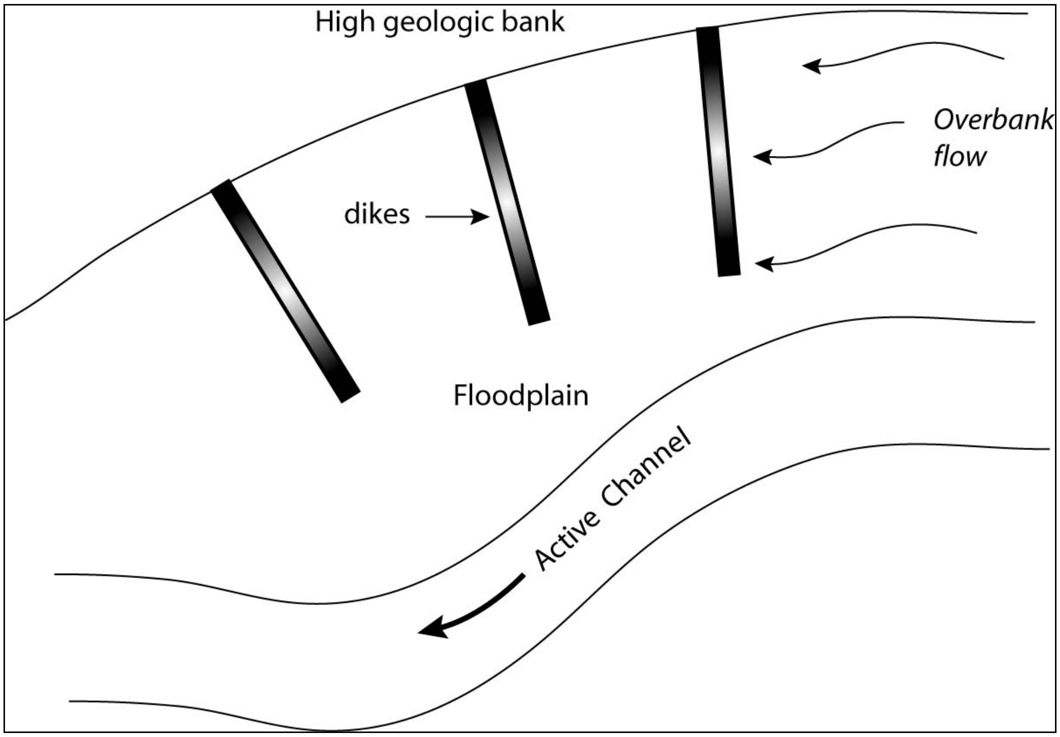

Figure 48. Example of perpendicular dikes

8.4.4. Zone of Expected Lateral Erosion

Based on the geomorphic analysis, the Virgin River can be expected to migrate laterally within the zone of expected lateral erosion (Figure 37) given a series of “typical” high average annual flows over a 60-year period, in addition to a 1 percent chance magnitude flood. Any critical development that occurs within this zone is subject to some degree of short-term or long-term lateral erosion hazard, and requires engineered bank protection. Non-critical development in this discussion would be those in which loss due to lateral erosion would be acceptable (e.g. parking lots, parks, etc.) Design recommendations for bank protection are discussed in Section 8.2.

8.4.5. Maintenance & Inspection

Periodic inspection of the existing channel and floodplain should be performed by appropriate agencies with floodplain management authority to document that channel conditions have not significantly changed from those when the floodplain and erosion zone were delineated. Any structural measures implemented as part of the river management plan should similarly be inspected and maintained regularly, and repaired as needed.

8.5. Final Recommended Plan

Full implementation of the recommended conceptual plan will require more detailed analysis to refine the following plan characteristics:

- Floodplain corridor width
- Low-flow channel geometry
- Low-flow channel plan form
- Sediment transport impacts from floodplain encroachment
- Sediment supply impacts from bank stabilization
- 100-year water surface elevation changes
- Sedimentation impacts at constrictions and expansions upstream and downstream of the channelized corridor reach
- Hydrologic impacts on flow attenuation from channelization
- Implementation plan for phased construction
- Environmental permitting for channel and vegetation maintenance

9. REFERENCES

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APPENDIX A

FIELD PHOTOS AND PHOTO LOCATIONS

Explanation for identifying field photo ID values from the Field Photo pages:

Each photo contains a caption embedded in the filename identifying the photo ID value and the date the photo was taken.

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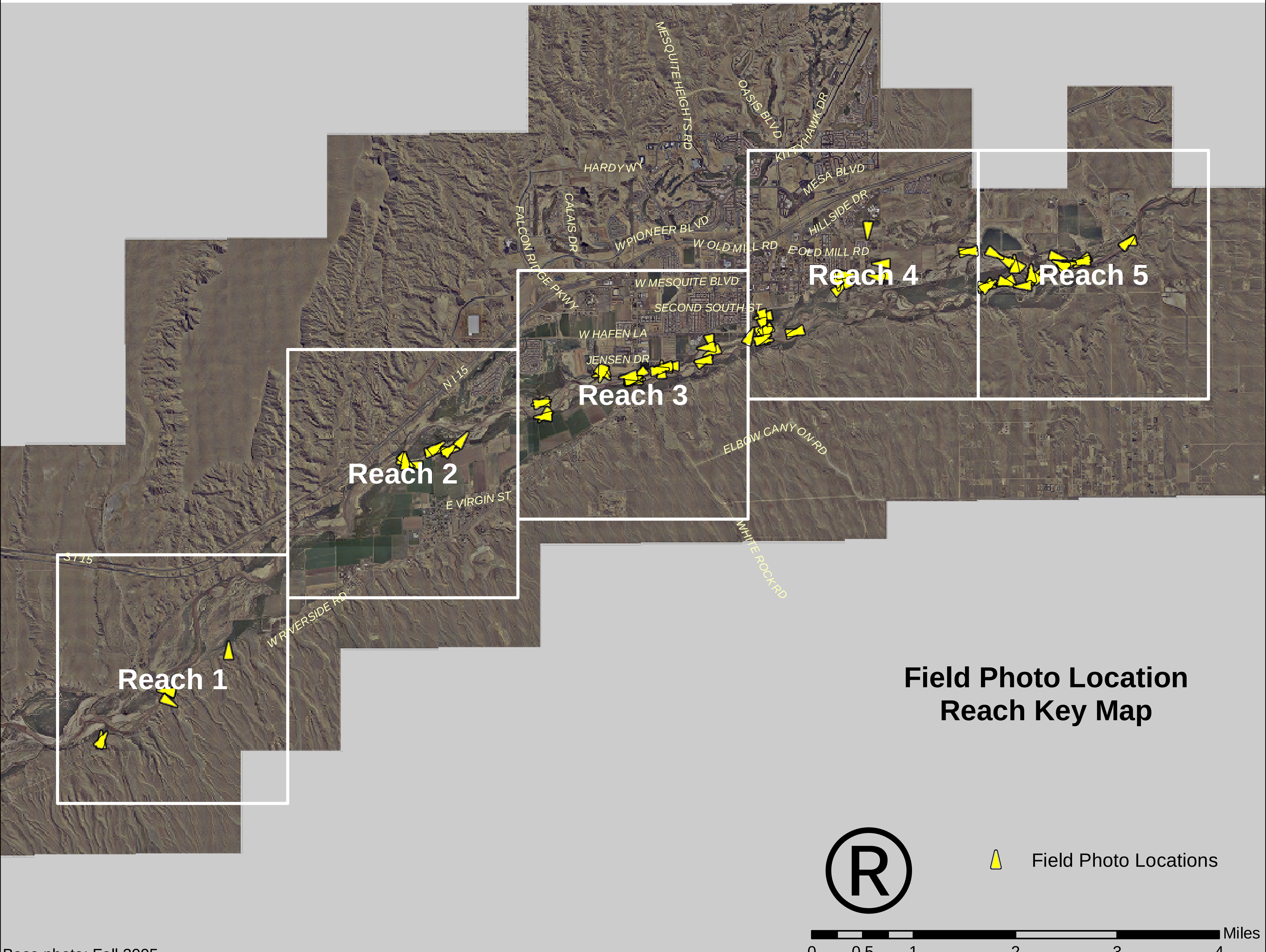
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W HAFEN LA
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W RIVERSIDE RD
ELBOW CANYON RD
WHITE ROCK RD
Reach 1
Reach 2
Reach 3
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Reach 5
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Field Photo Location Reach Key Map

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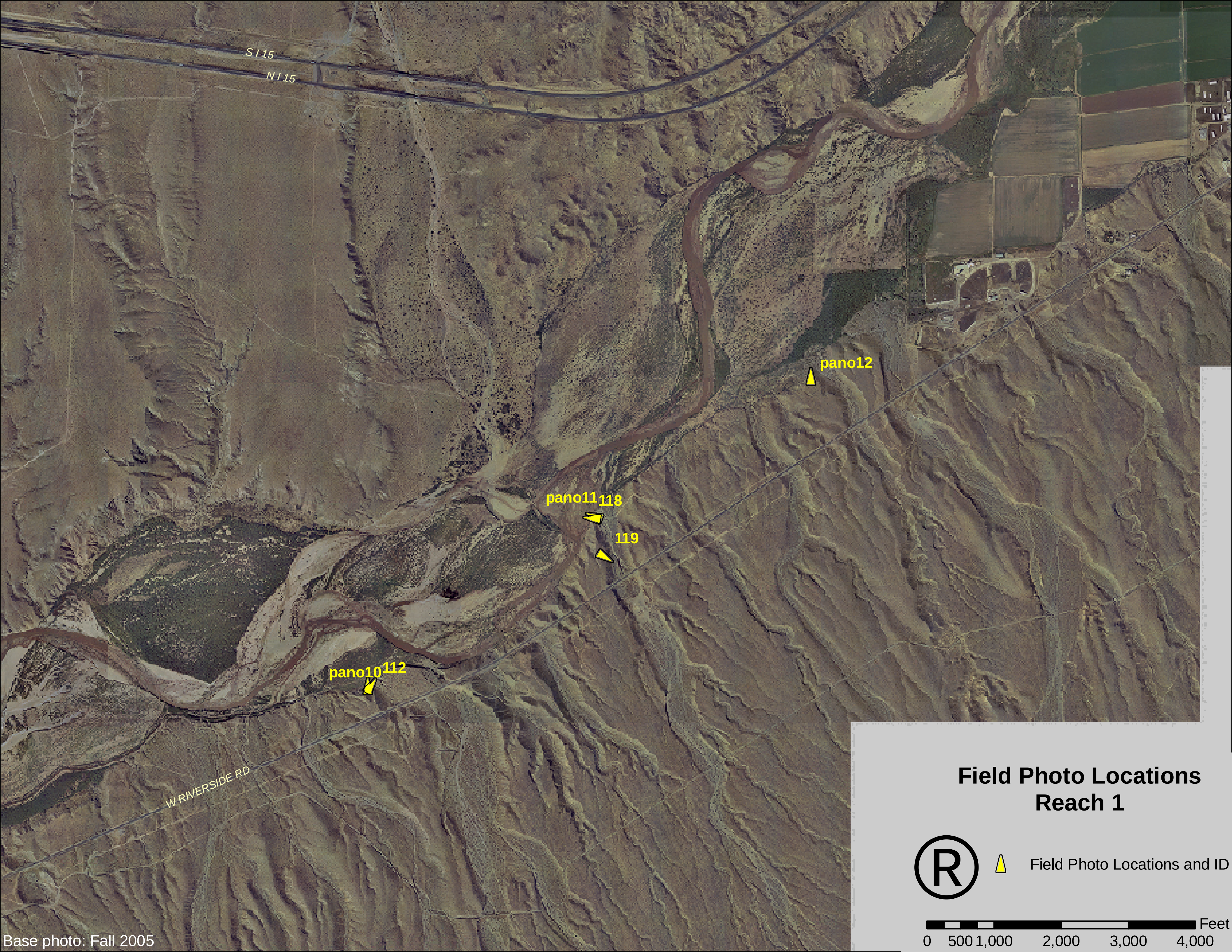
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Field Photo Locations
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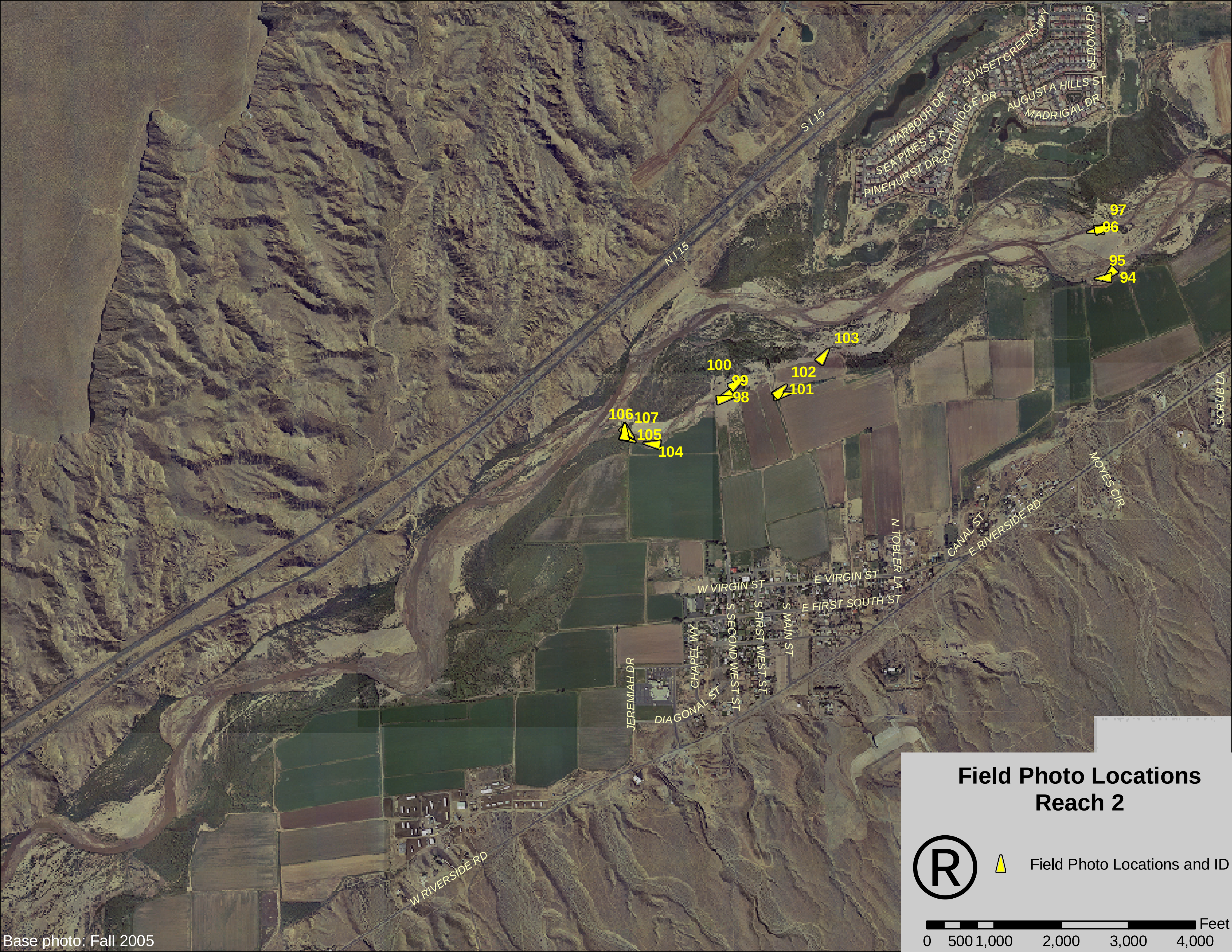

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SCRUB LA
MOYES CIR
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CANAL ST
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S SECOND WEST ST
CHAPEL WY
DIAGONAL ST
JEREMIAH DR
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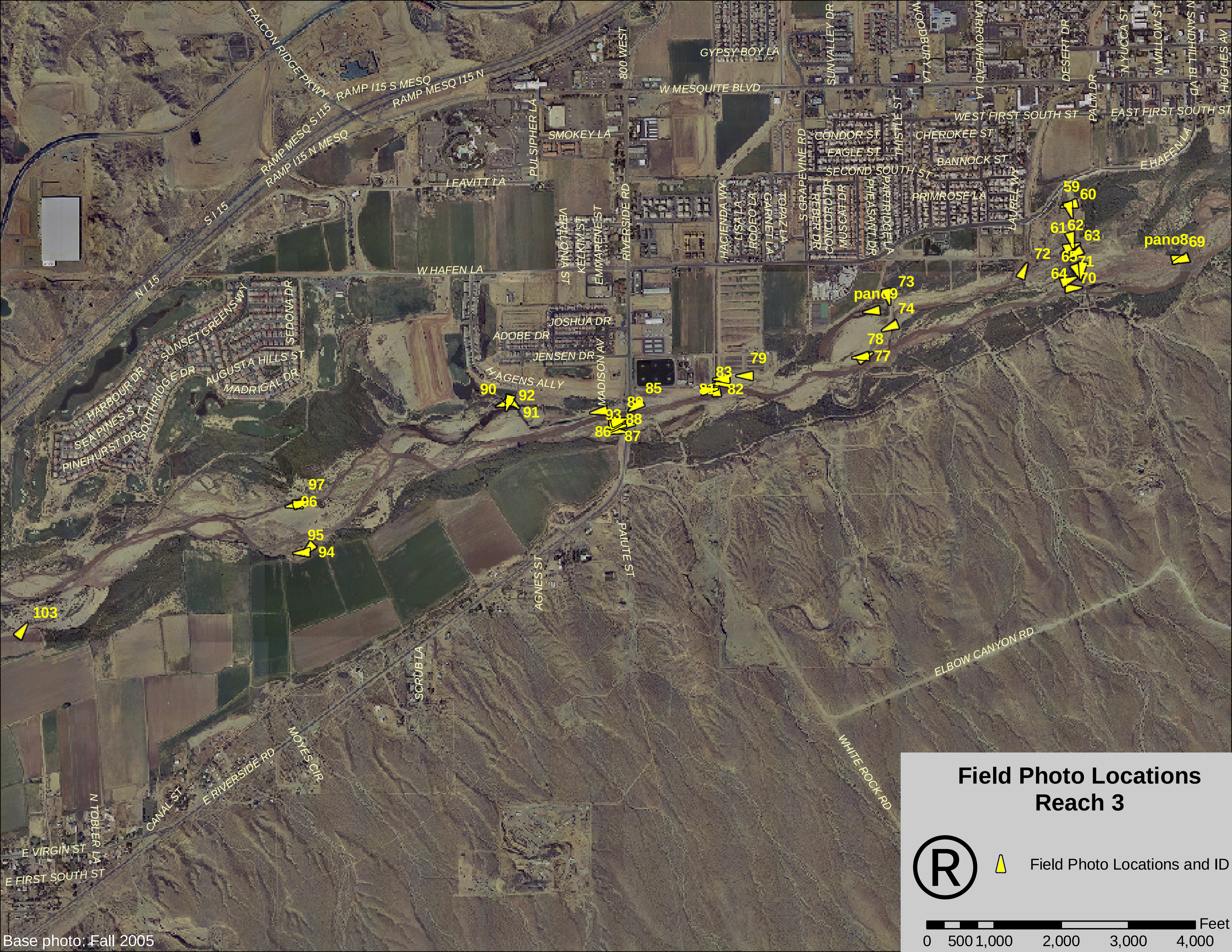
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LEAVITT LA
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N SANDHILL BLVD
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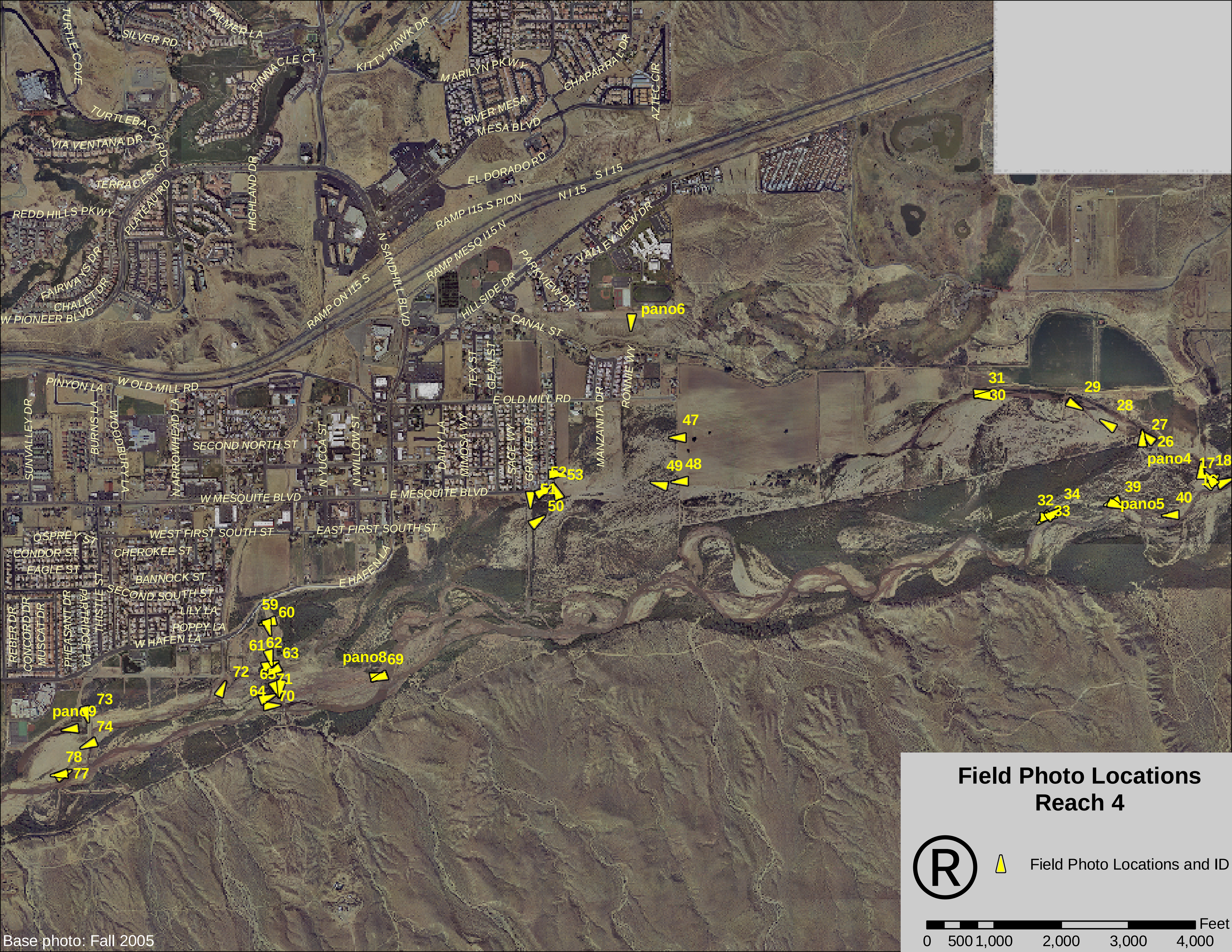
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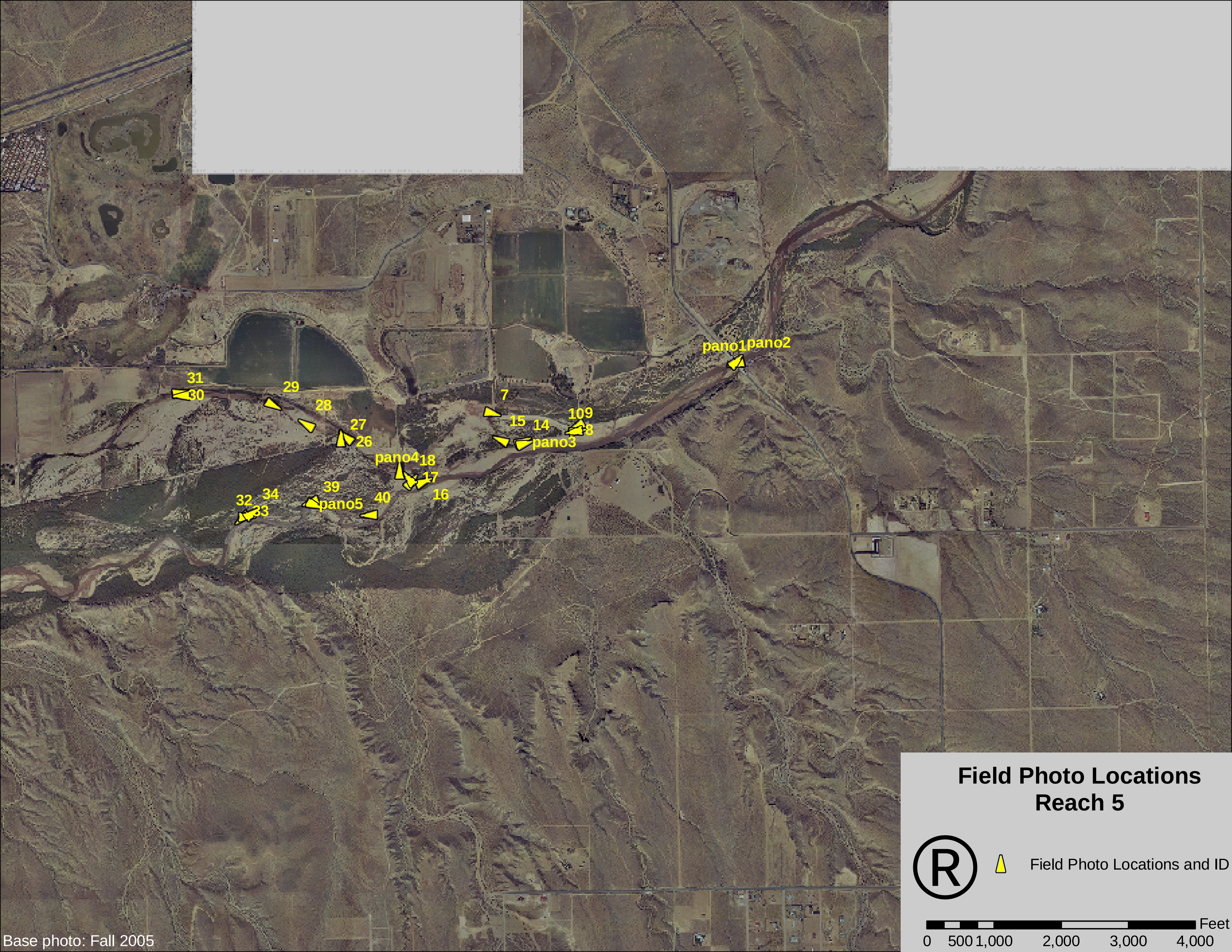
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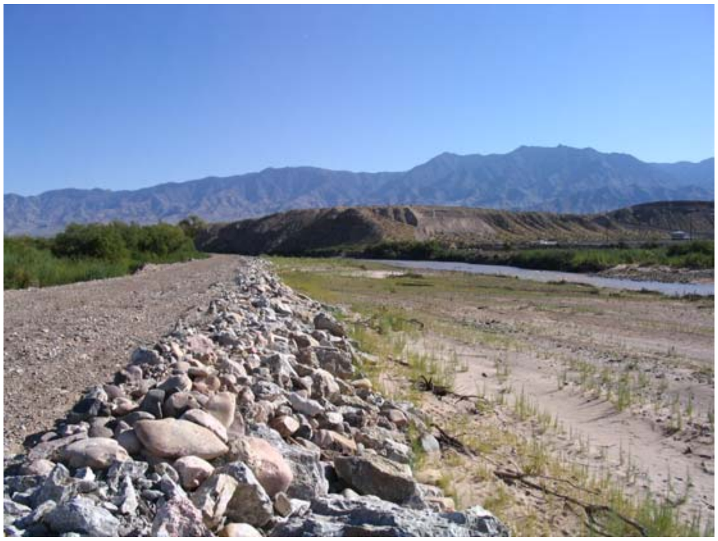
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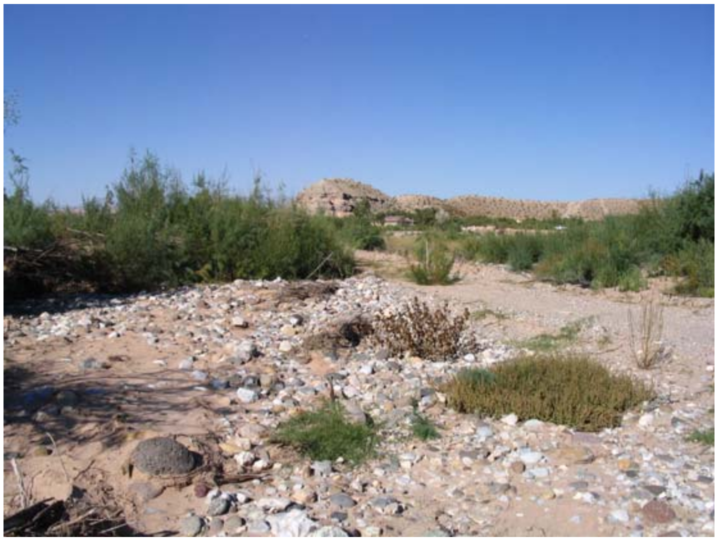
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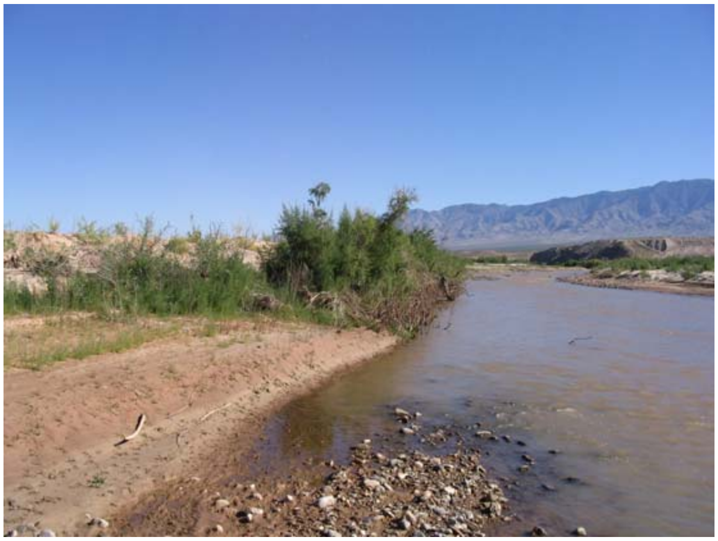
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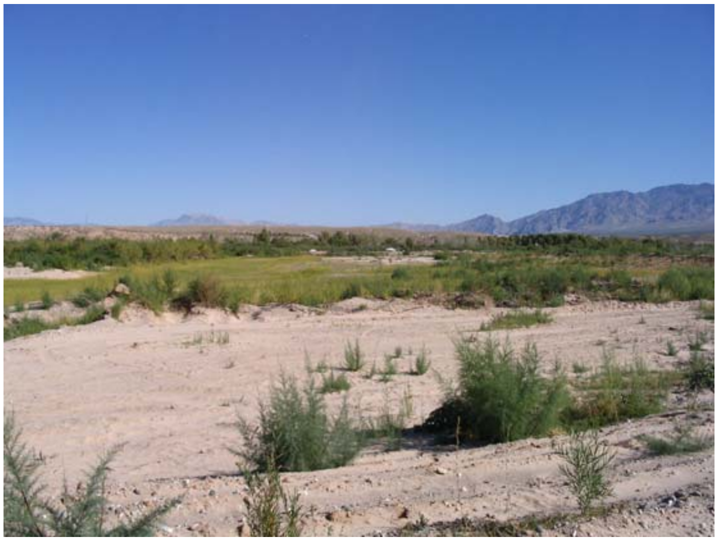
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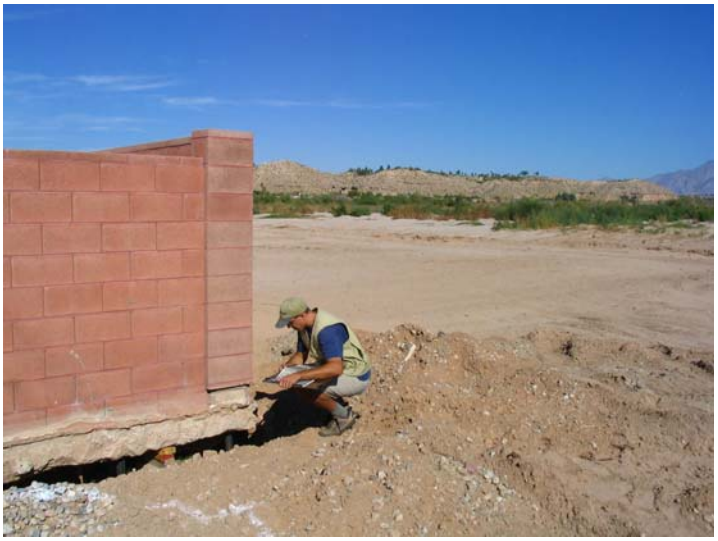
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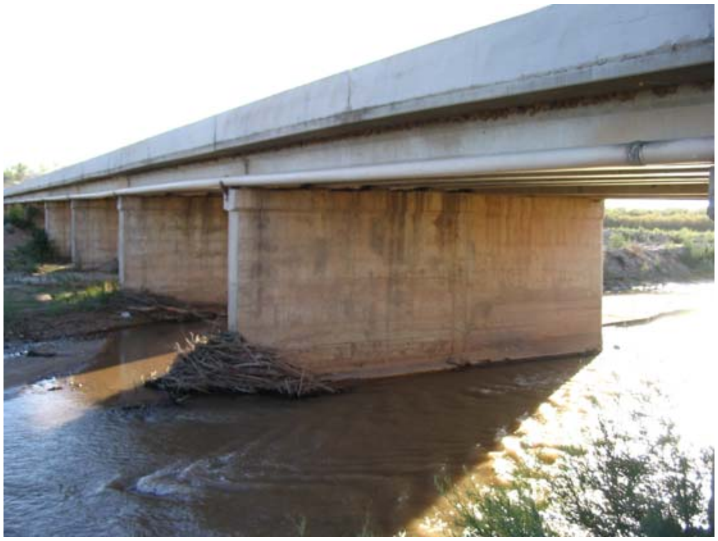

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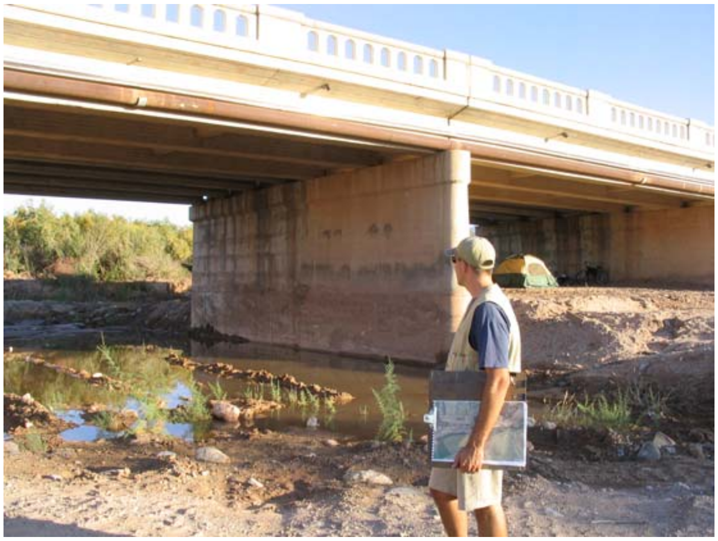

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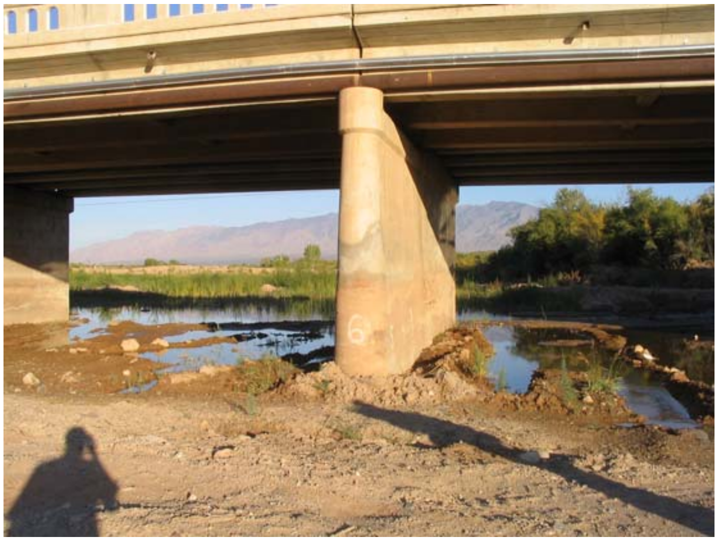

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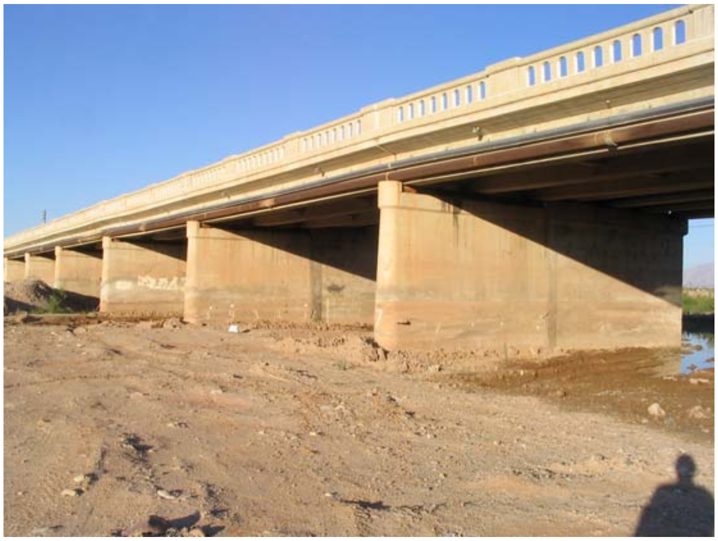

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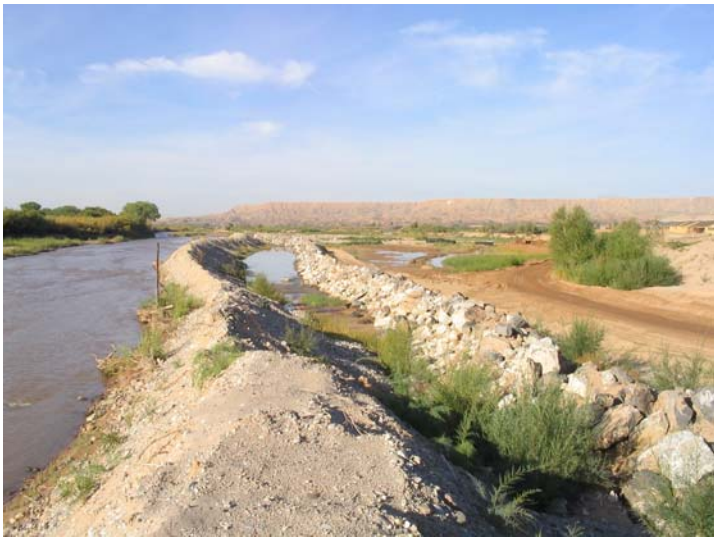

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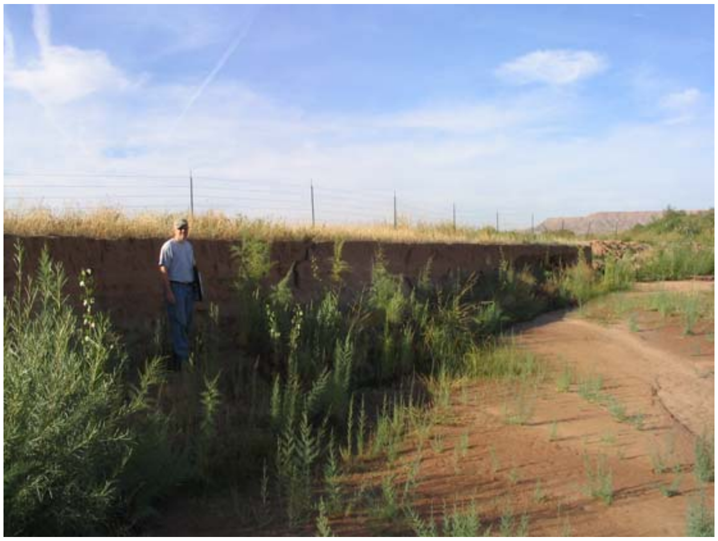

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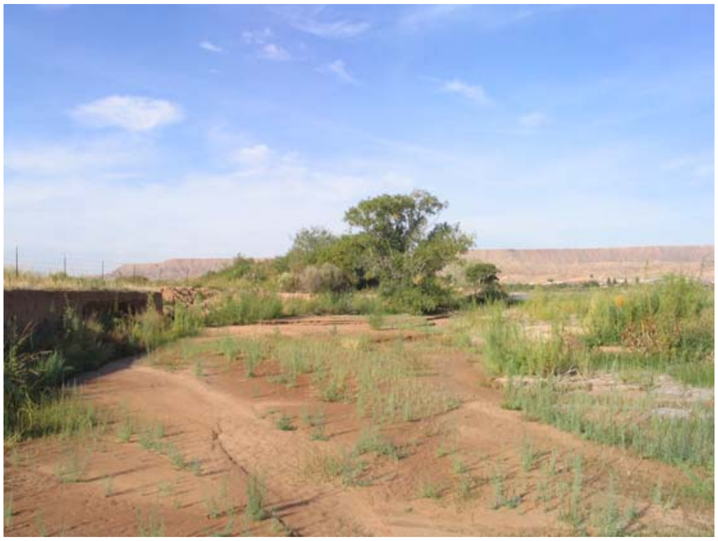

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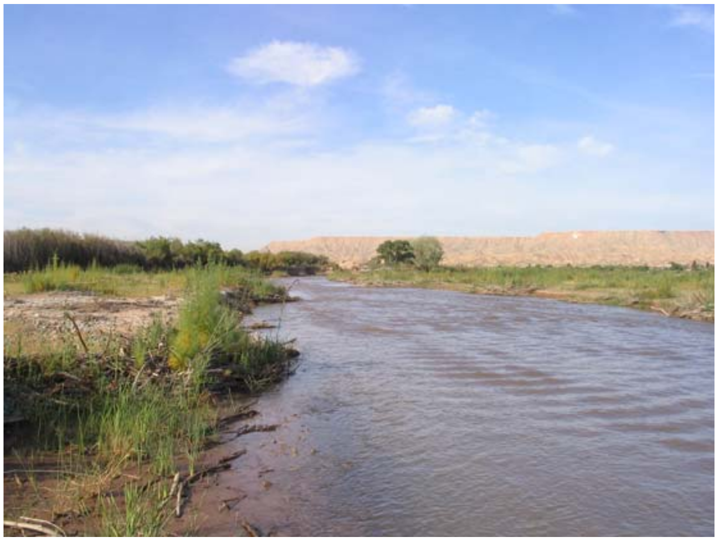

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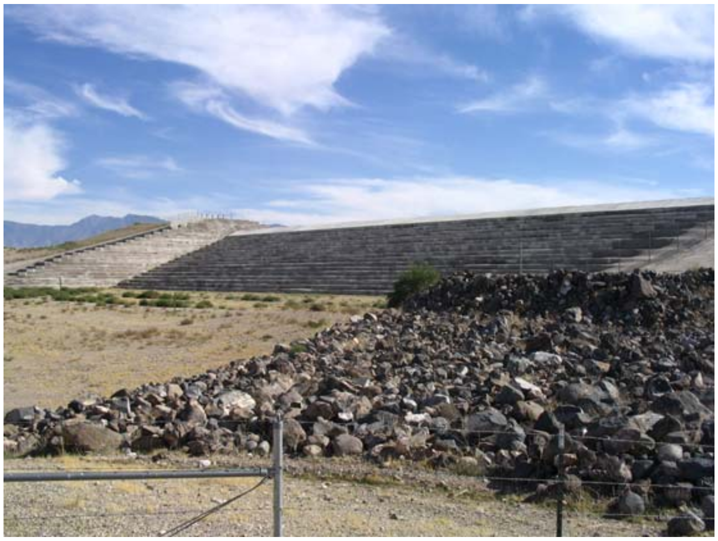
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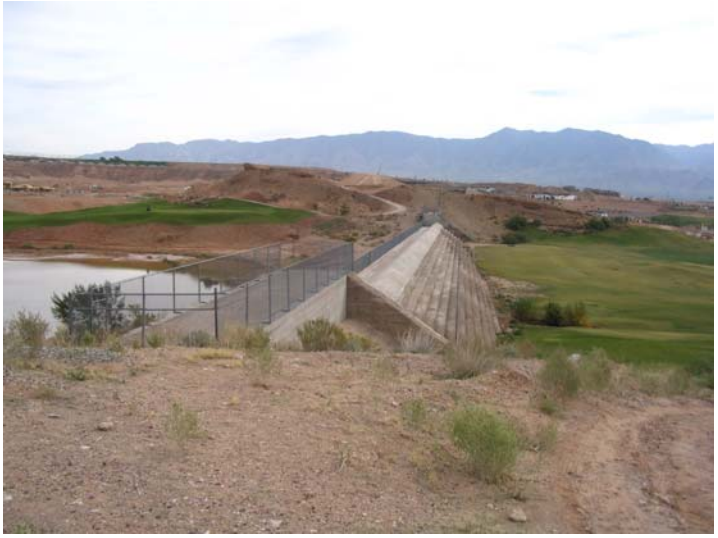
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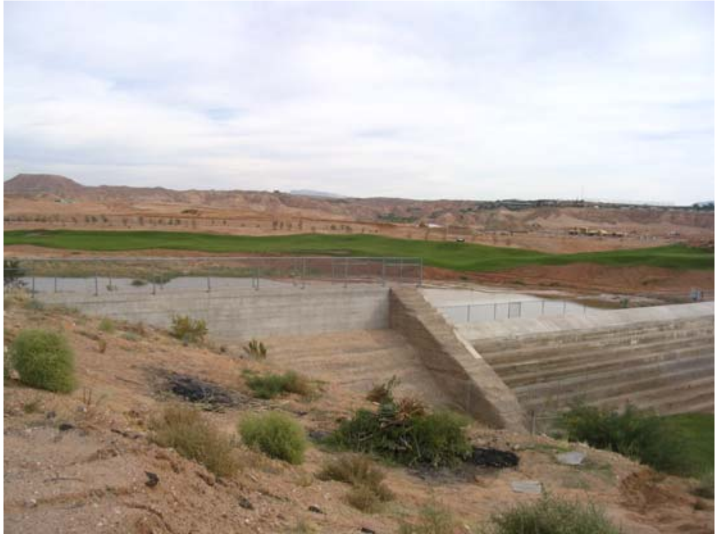
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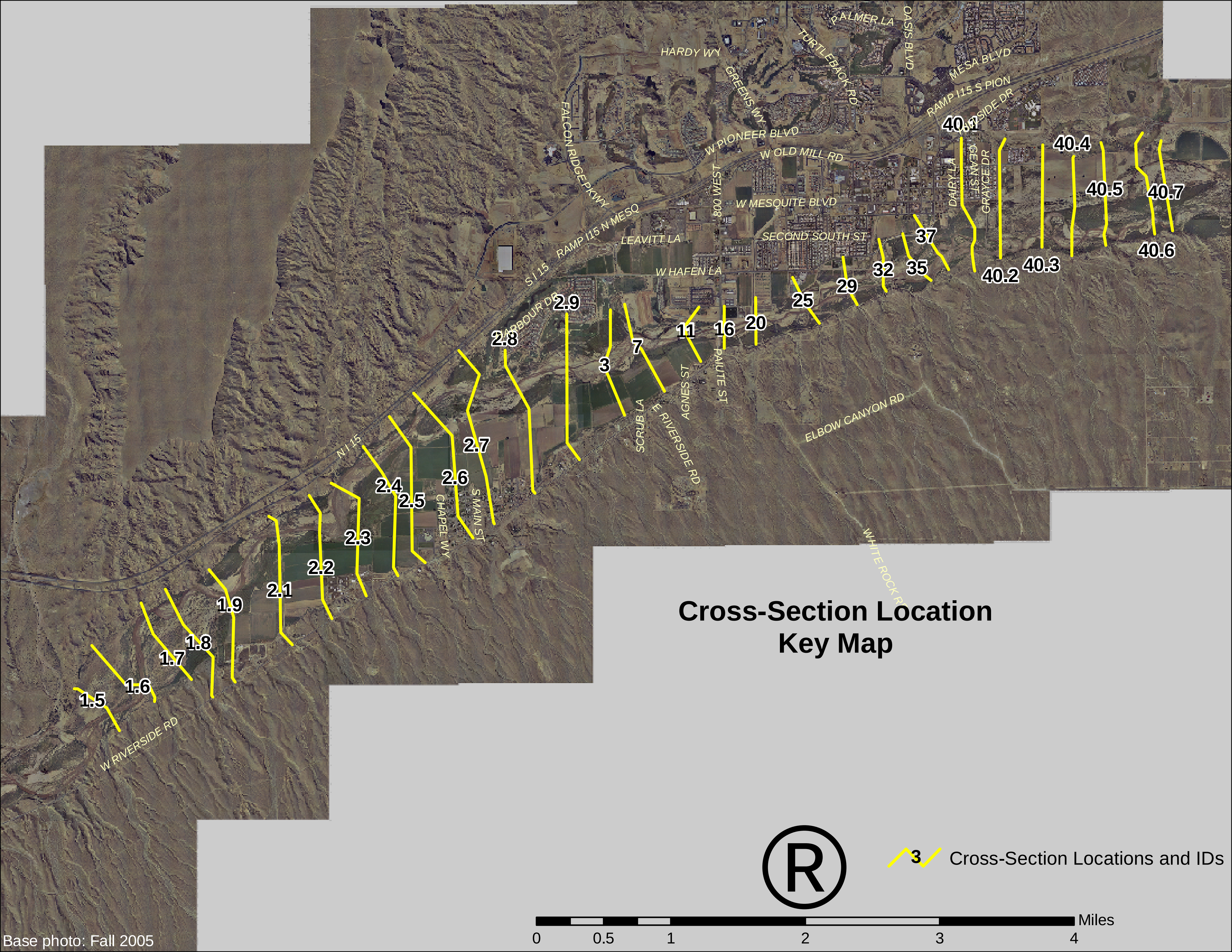
APPENDIX B

CROSS-SECTION PROFILE PLOTS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TURTLEBACK RD
HARDY WY
MESA BLVD
GREENS WY
RAMP I15 S PION
RIVERSIDE DR
FALCON RIDGE PKWY
W PIONEER BLVD
W OLD MILL RD
800 WEST
W MESQUITE BLVD
DAIRY LA
DEAN ST
GRAYCE DR
RAMP I15 N MESQ
LEAVITT LA
SECOND SOUTH ST
W HAFEN LA
S I 15
HARBOUR DR
N I 15
SCRUB LA
E RIVERSIDE RD
AGNES ST
PAIUTE ST
ELBOW CANYON RD
CHAPEL WY
S MAIN ST
WHITE ROCK RD
W RIVERSIDE RD
1.5
1.6
1.7
1.8
1.9
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
7
11
16
20
25
29
32
35
37
40.1
40.2
40.3
40.4
40.5
40.6
40.7
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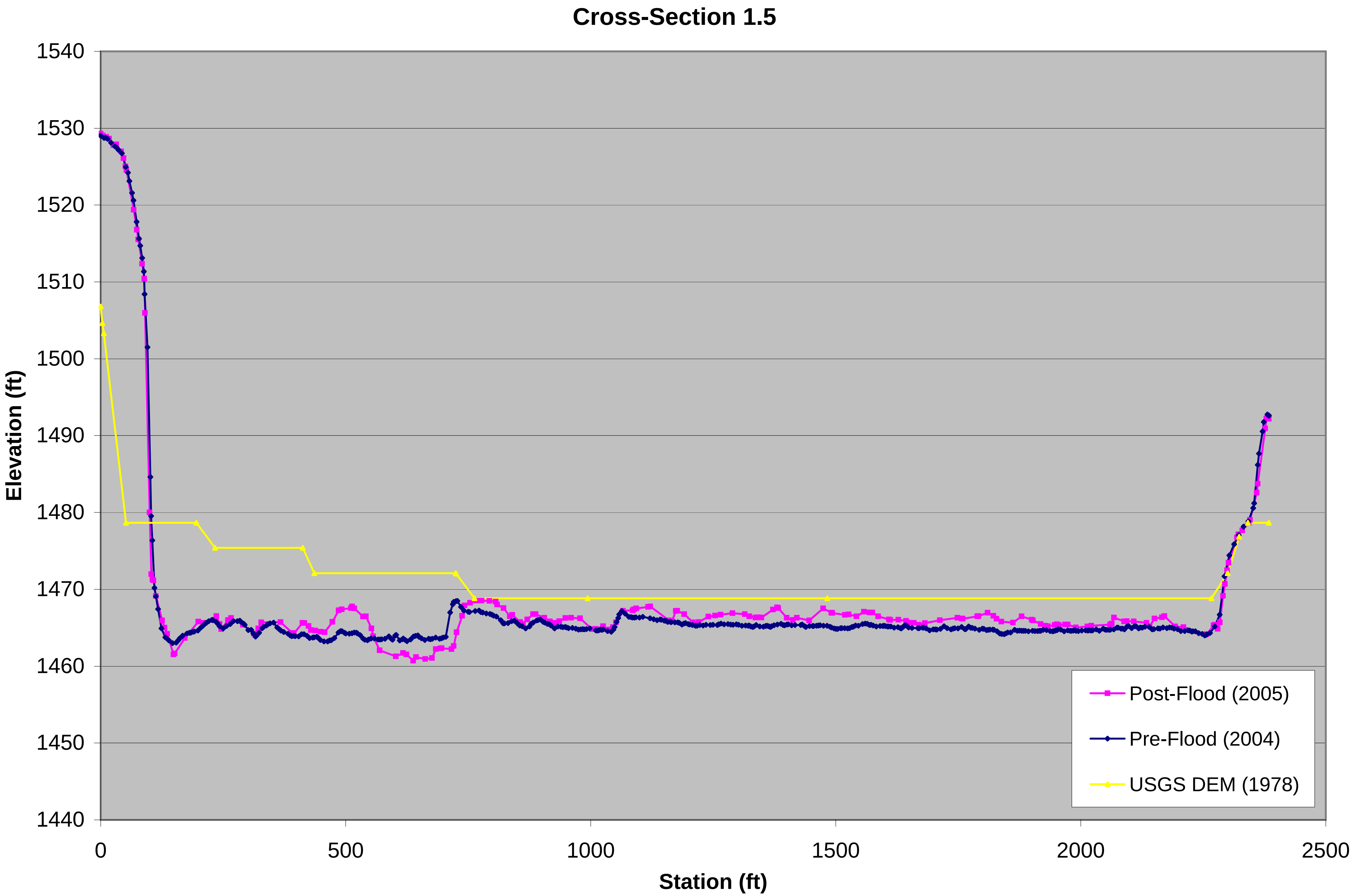
1
2
3
4
Miles

Cross-Section Location Key Map

Cross-Section Locations and IDs

Base photo: Fall 2005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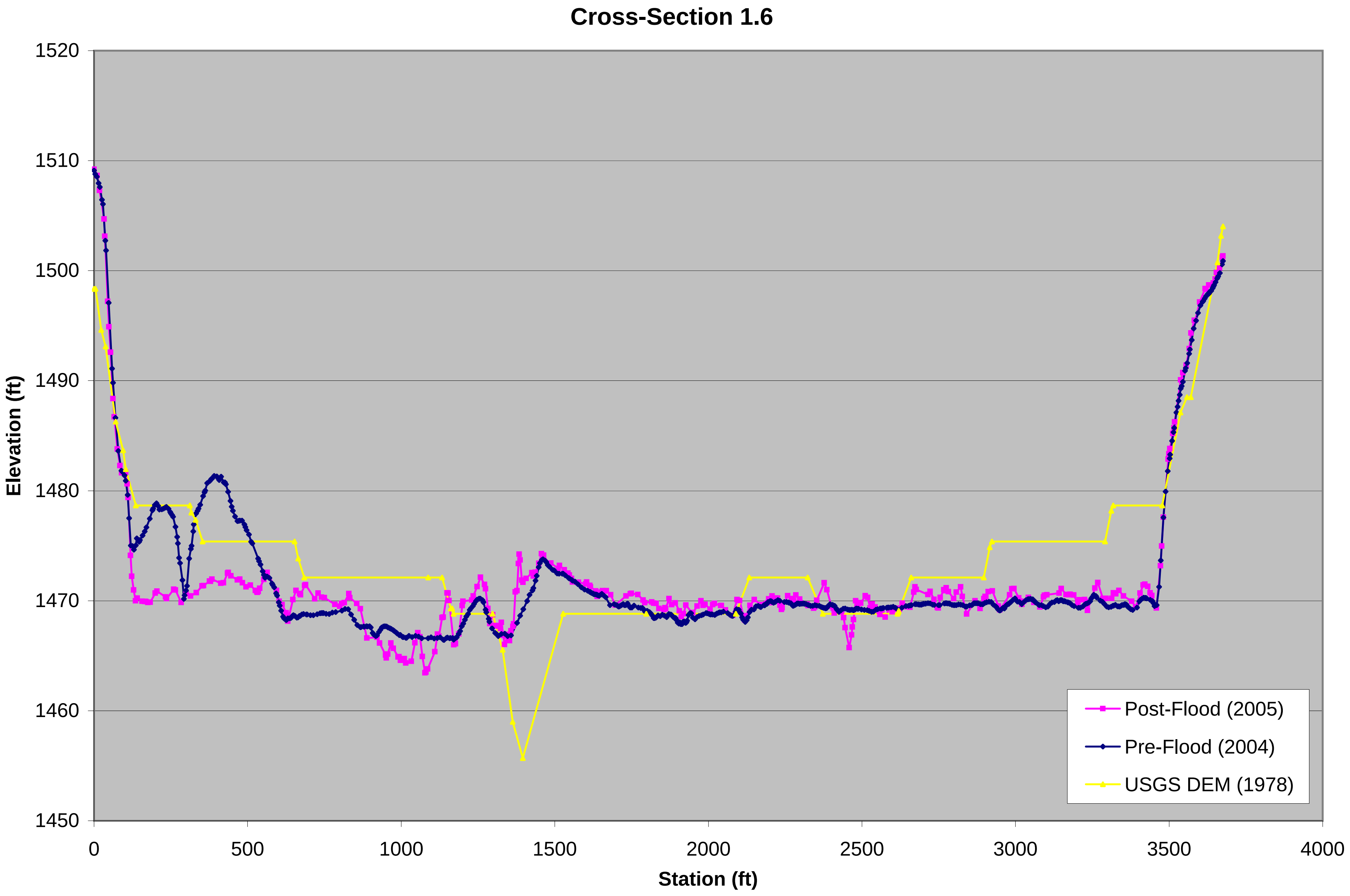
2000
2500
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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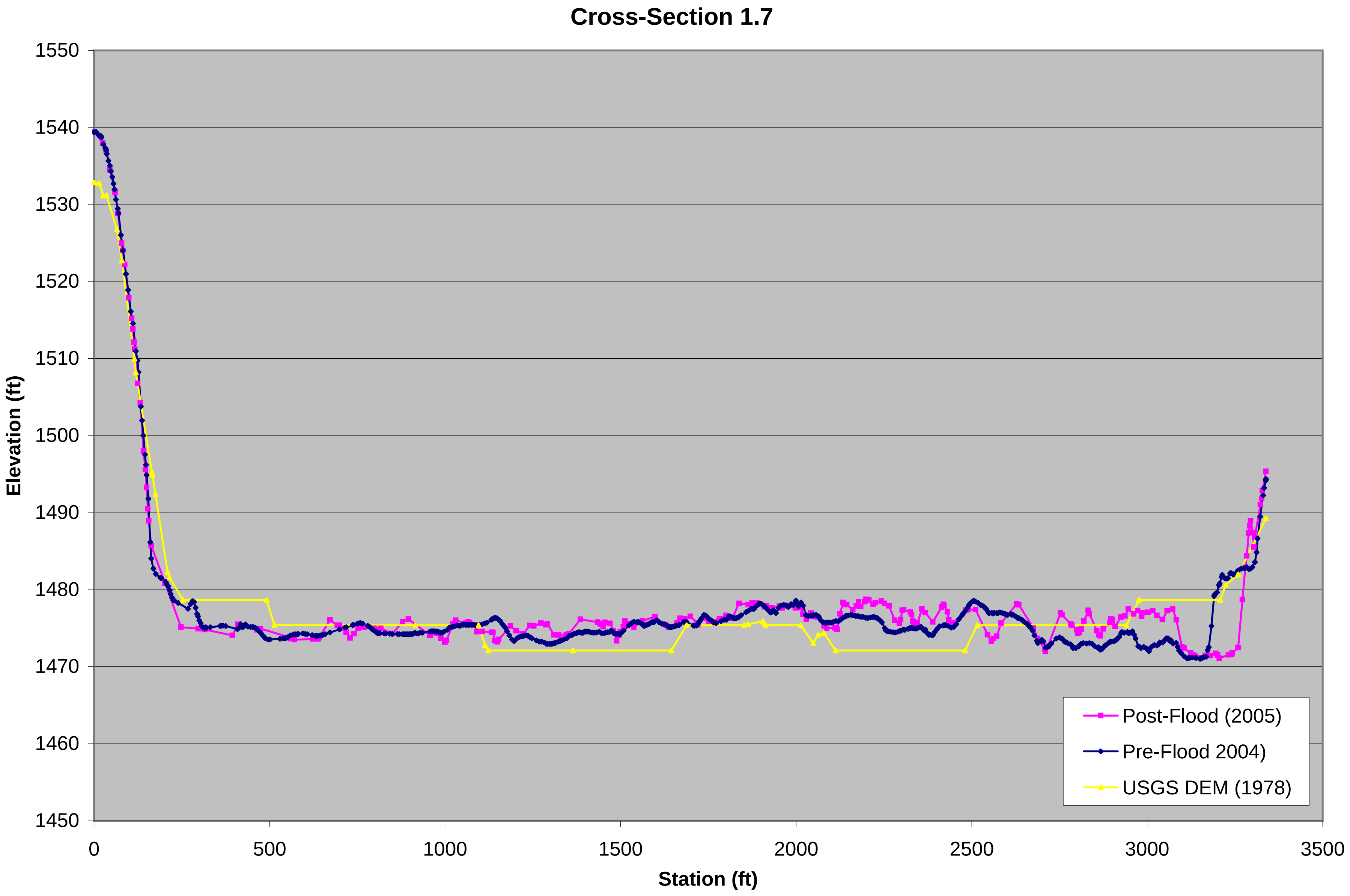
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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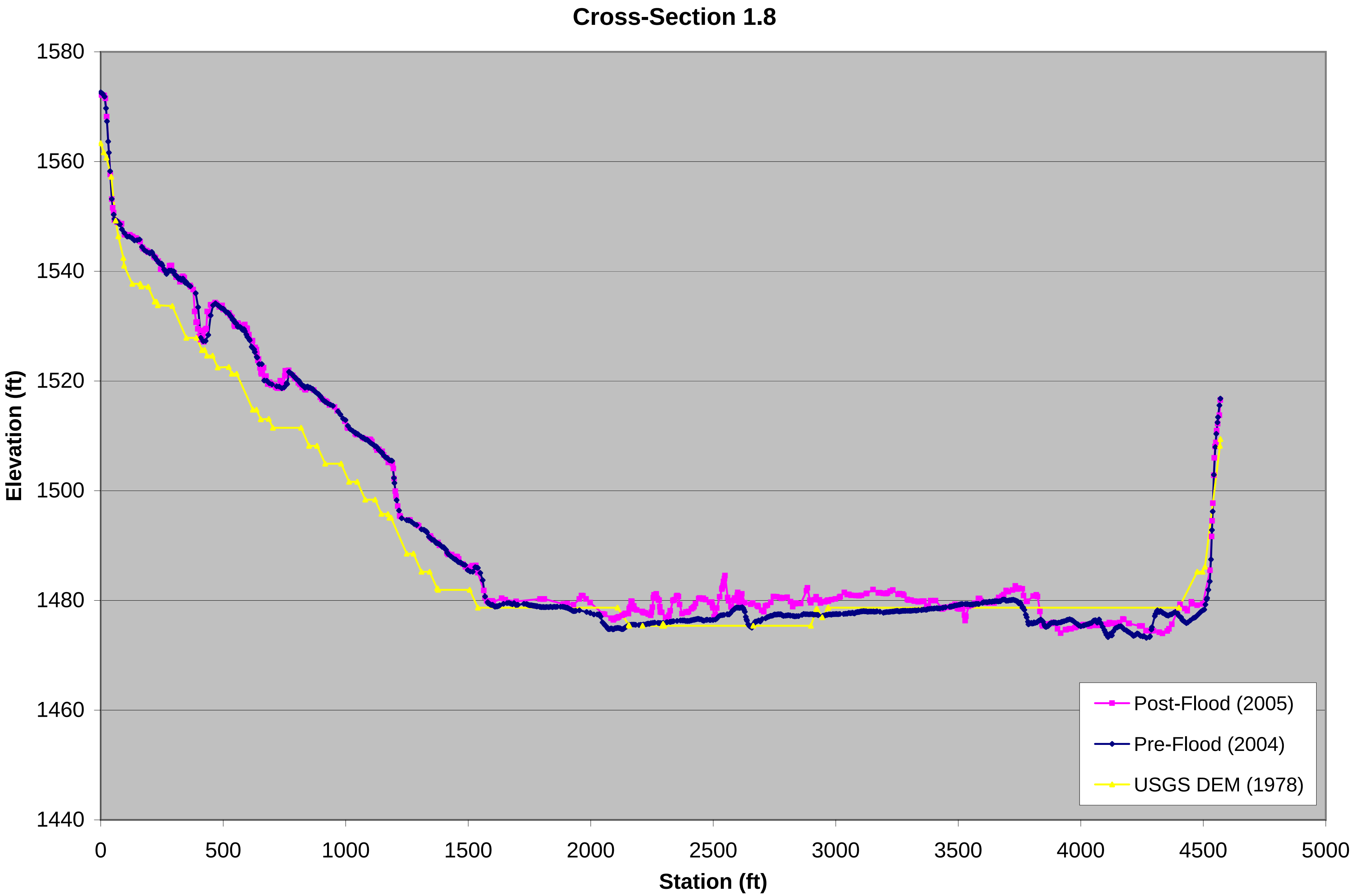
Station (ft)
Post-Flood (2005)
Pre-Flood 2004)
USGS DEM (1978)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Station (ft)
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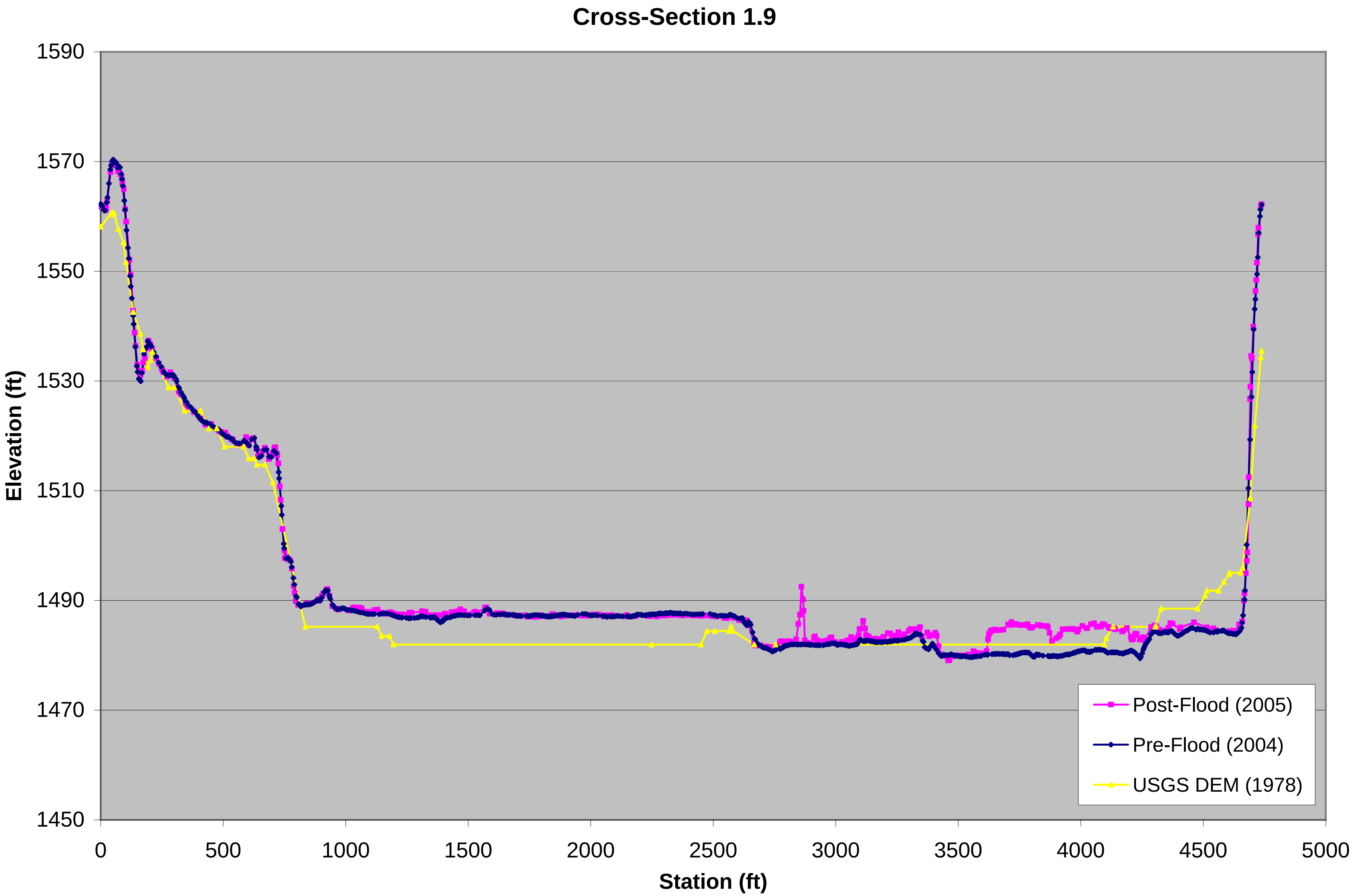
Pre-Flood (2004)
USGS DEM (1978)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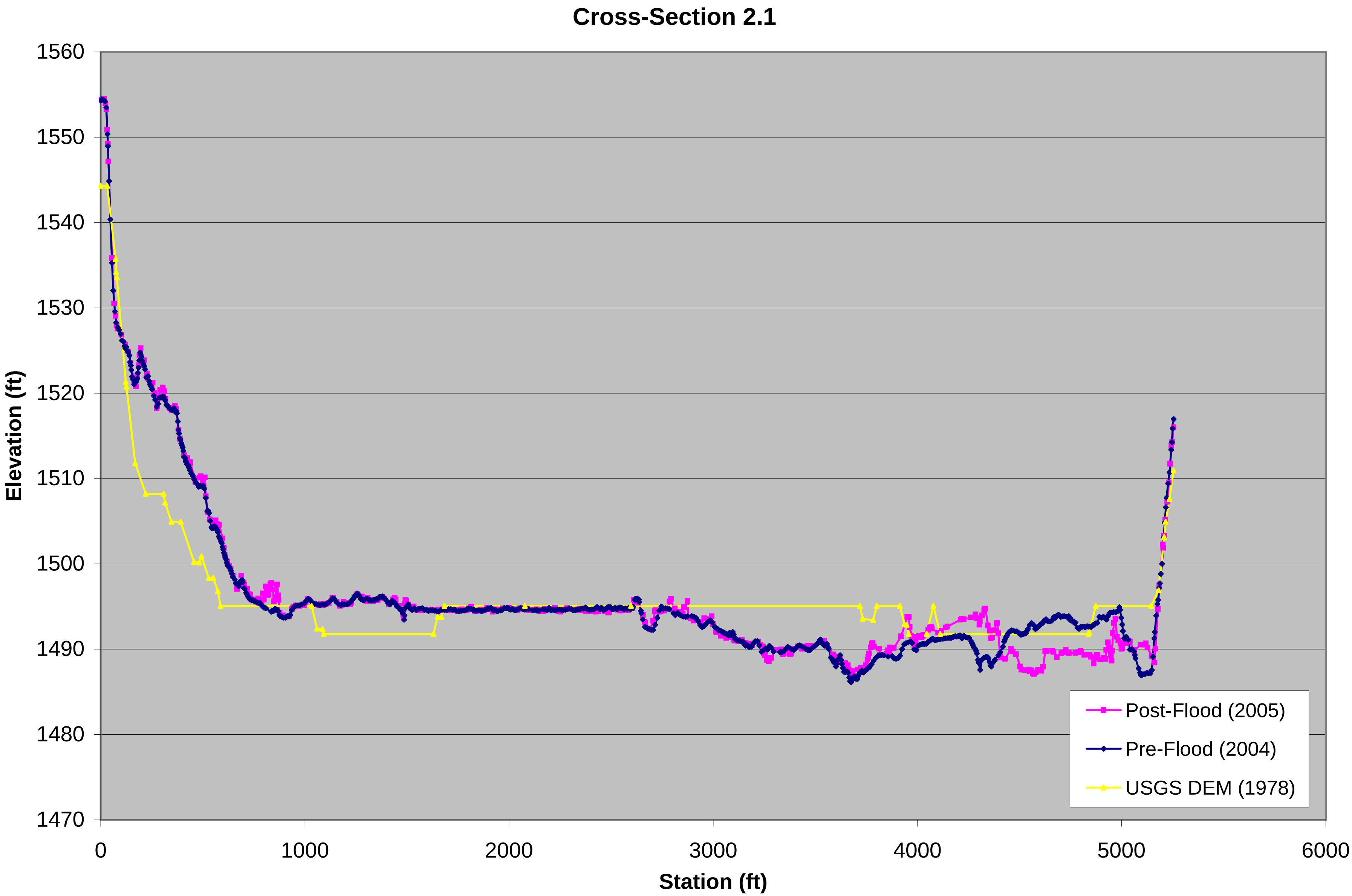
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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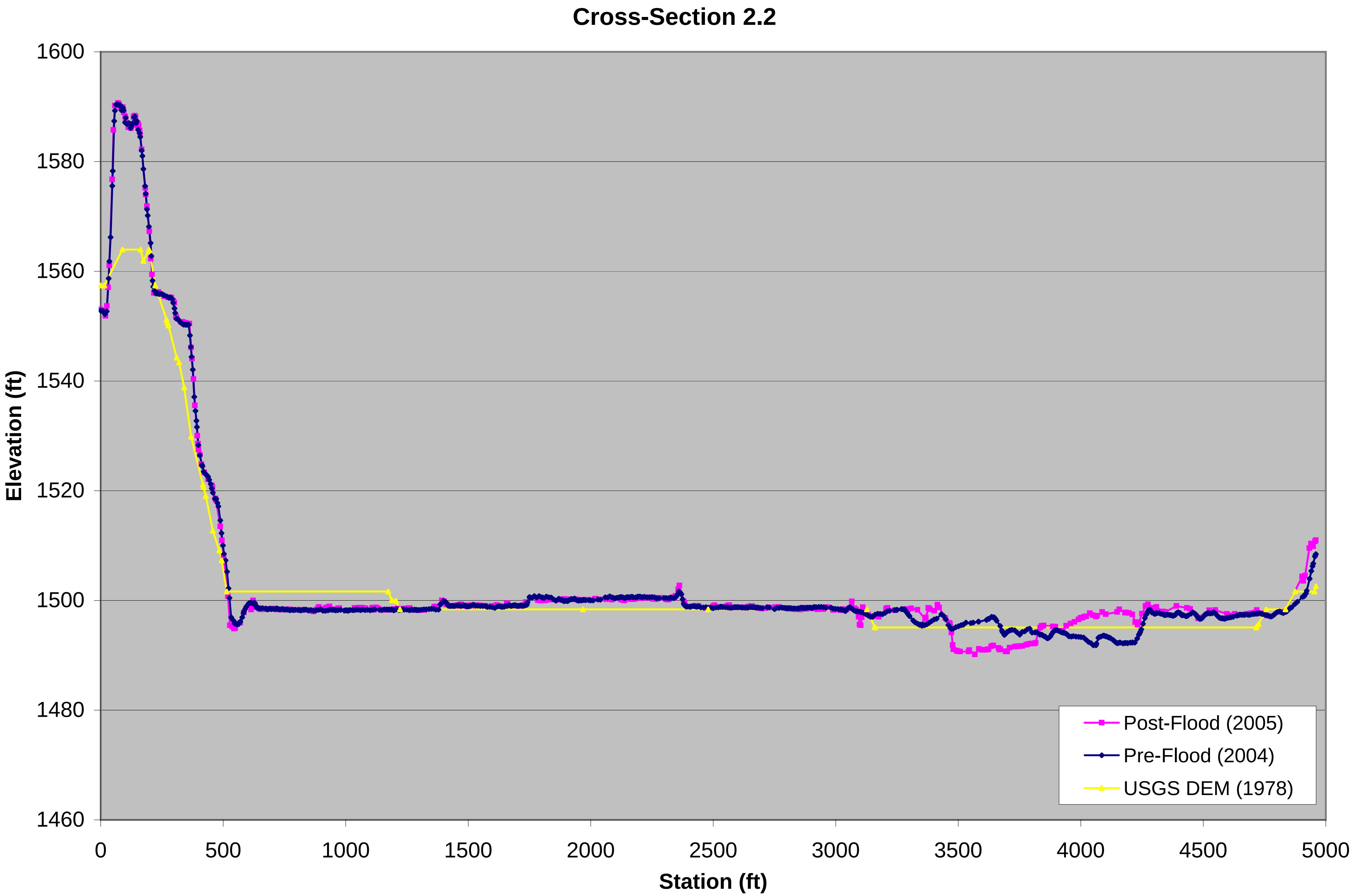
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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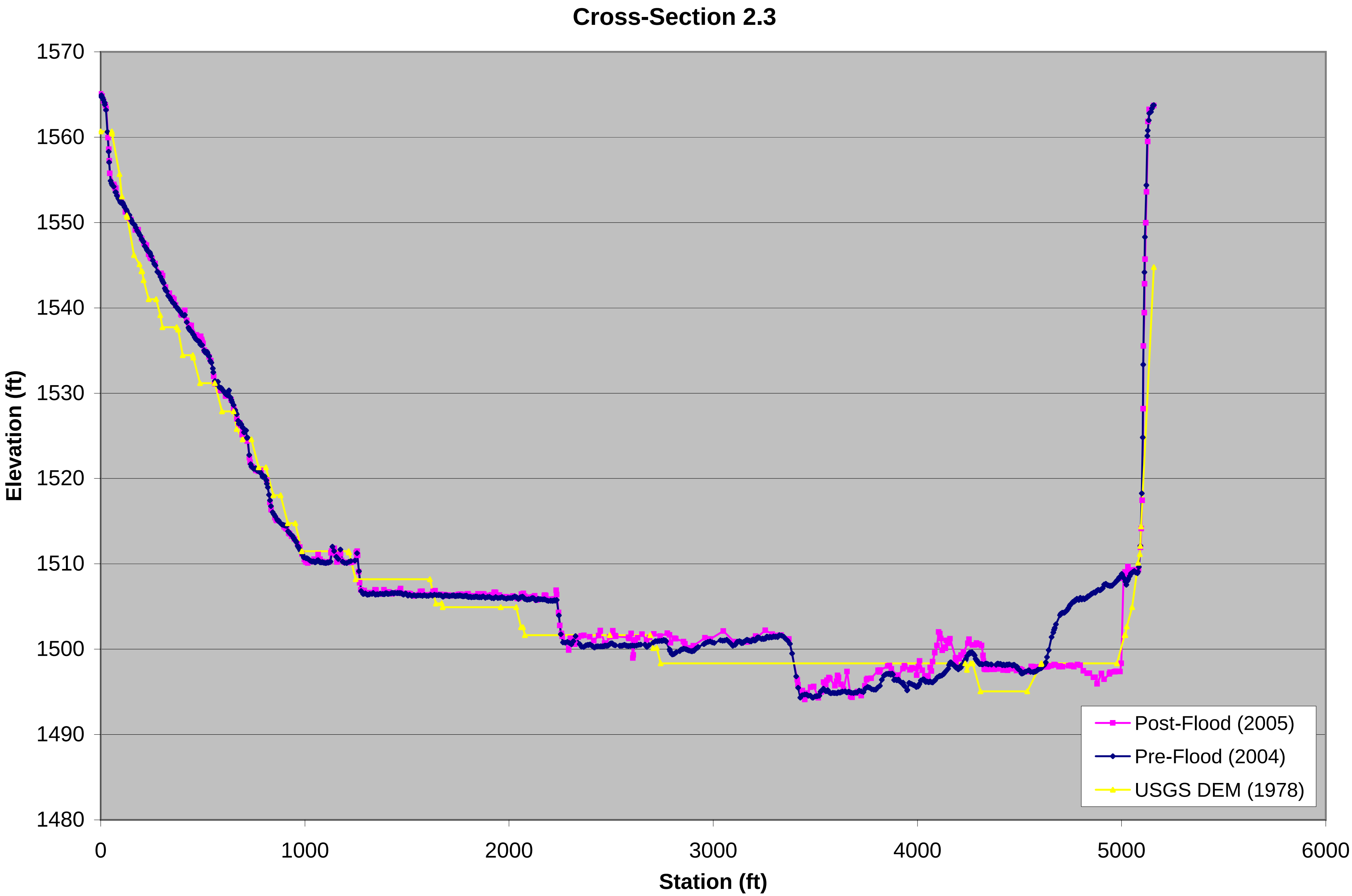
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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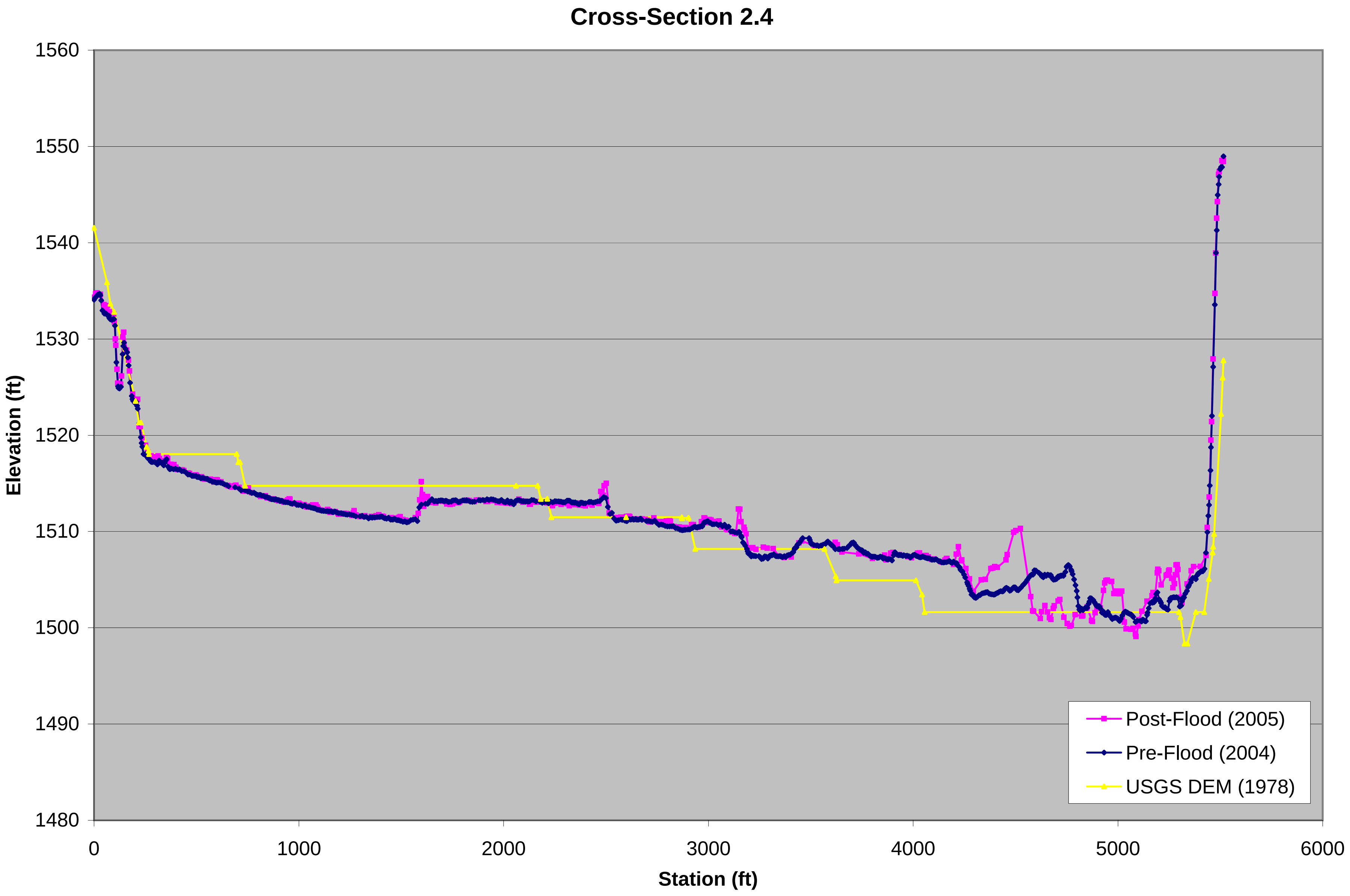
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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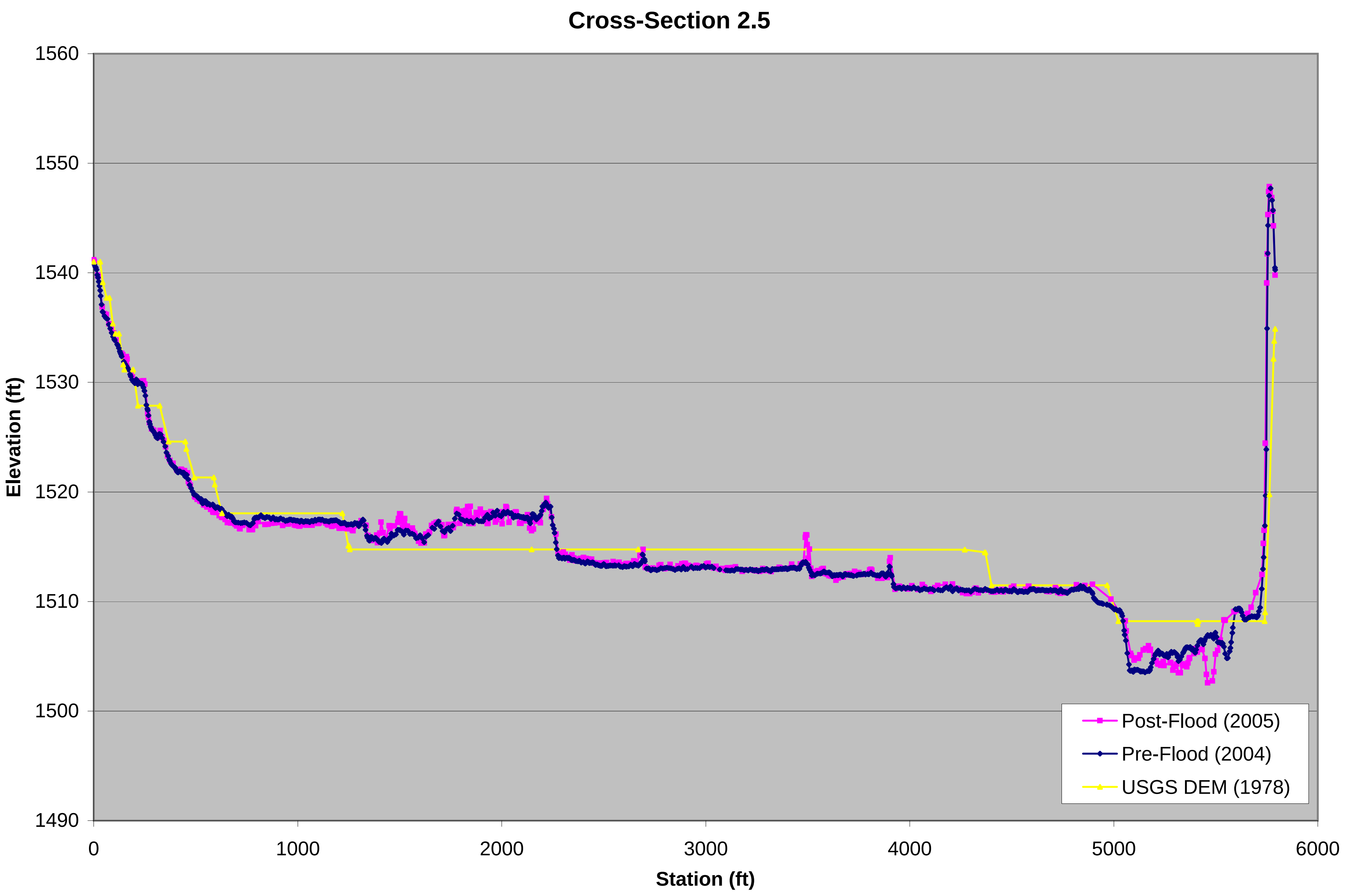
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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Station (ft)
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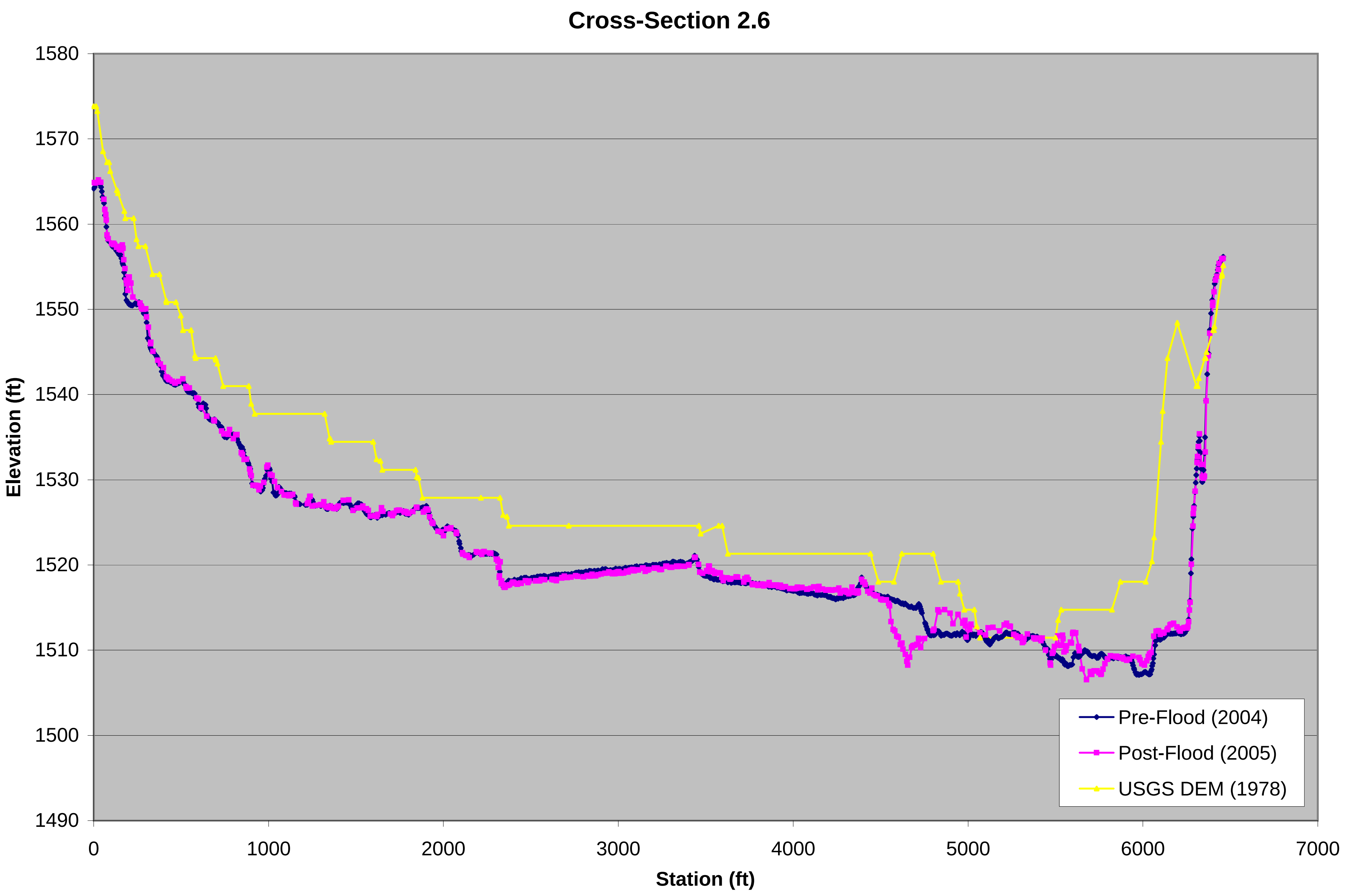
Pre-Flood (2004)
USGS DEM (1978)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Station (ft)
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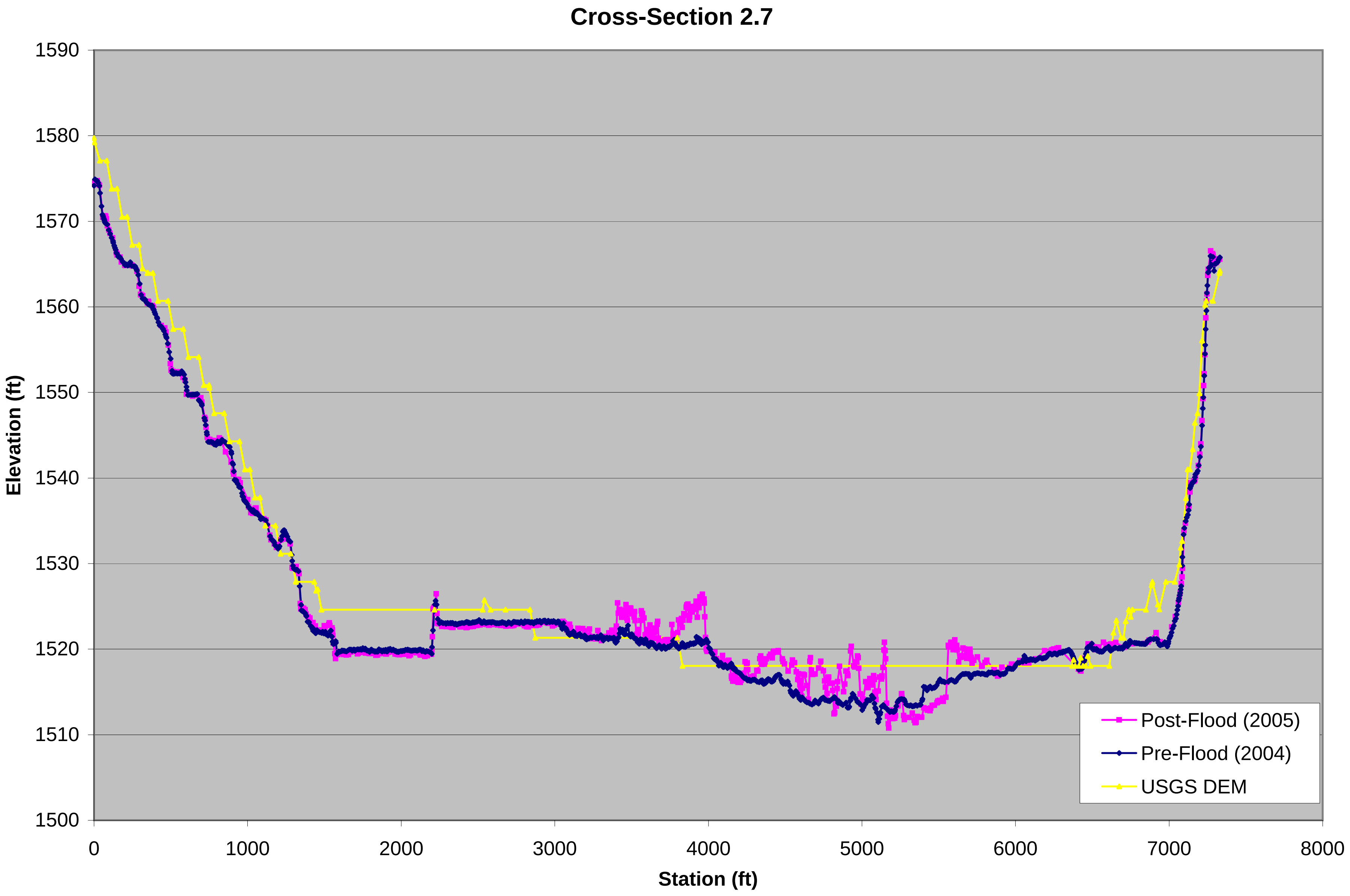
Pre-Flood (2004)
Post-Flood (2005)
USGS DEM (1978)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Station (ft)
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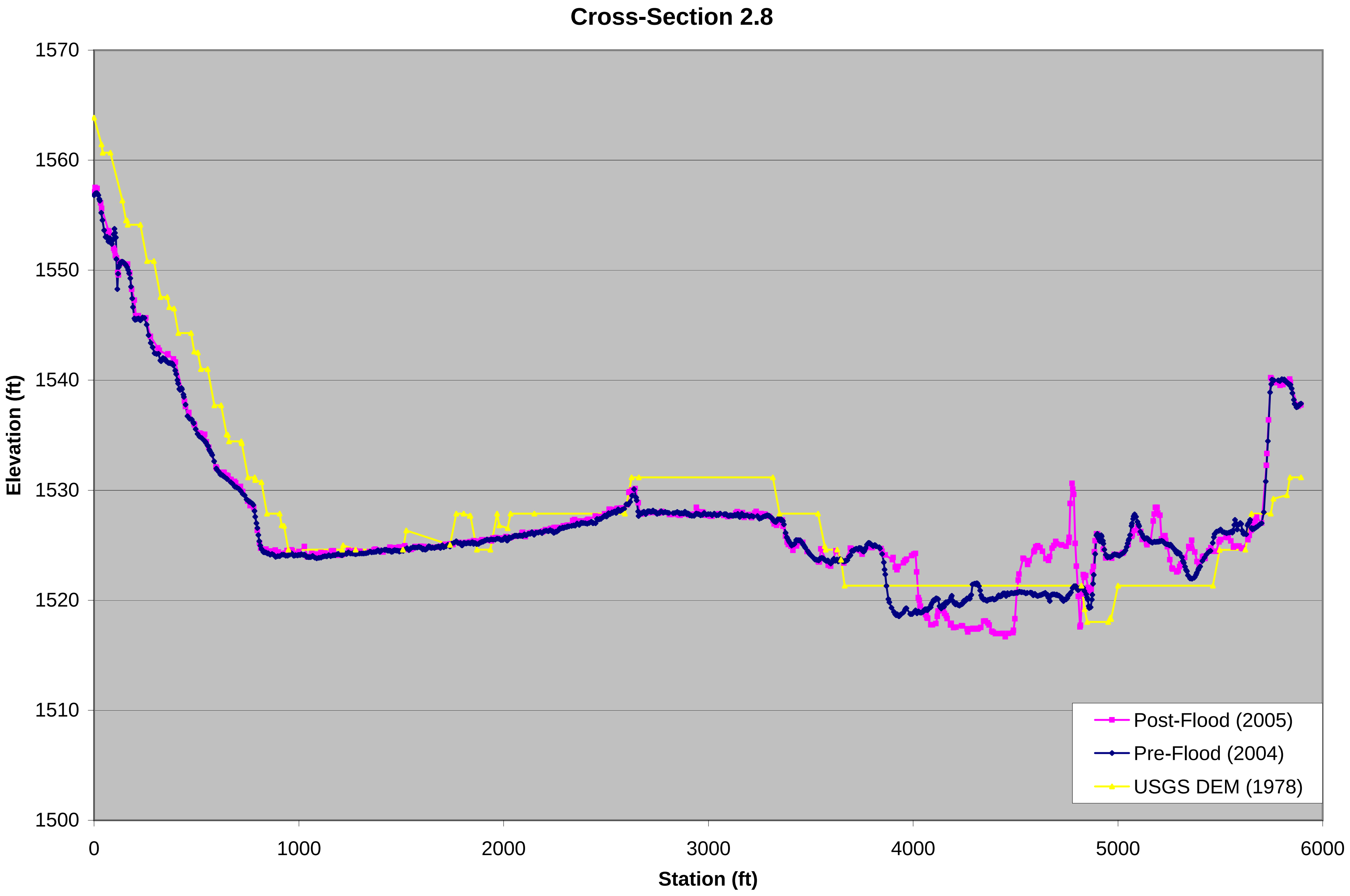
Pre-Flood (2004)
USGS DEM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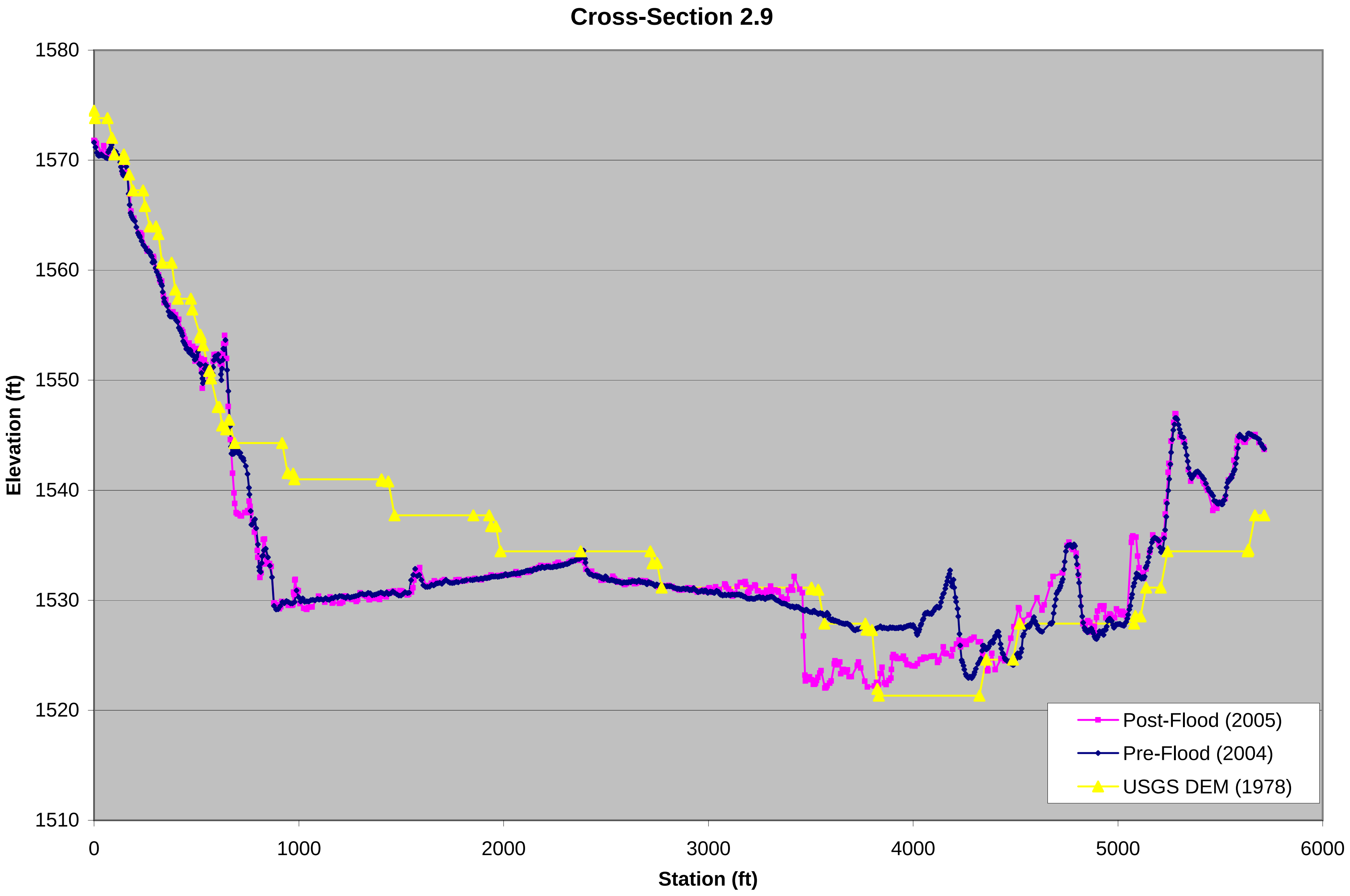
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)



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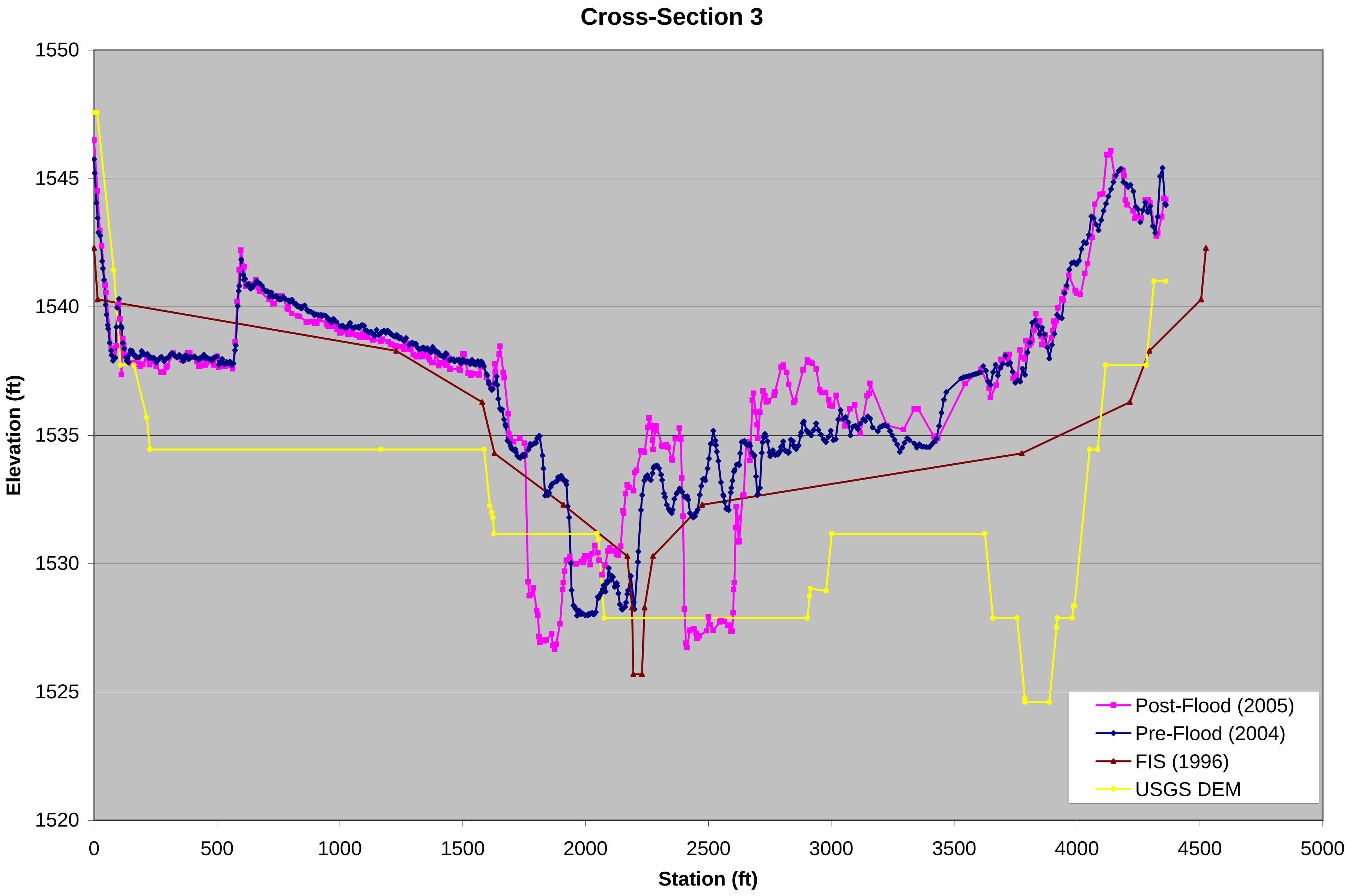
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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1520
Station (ft)
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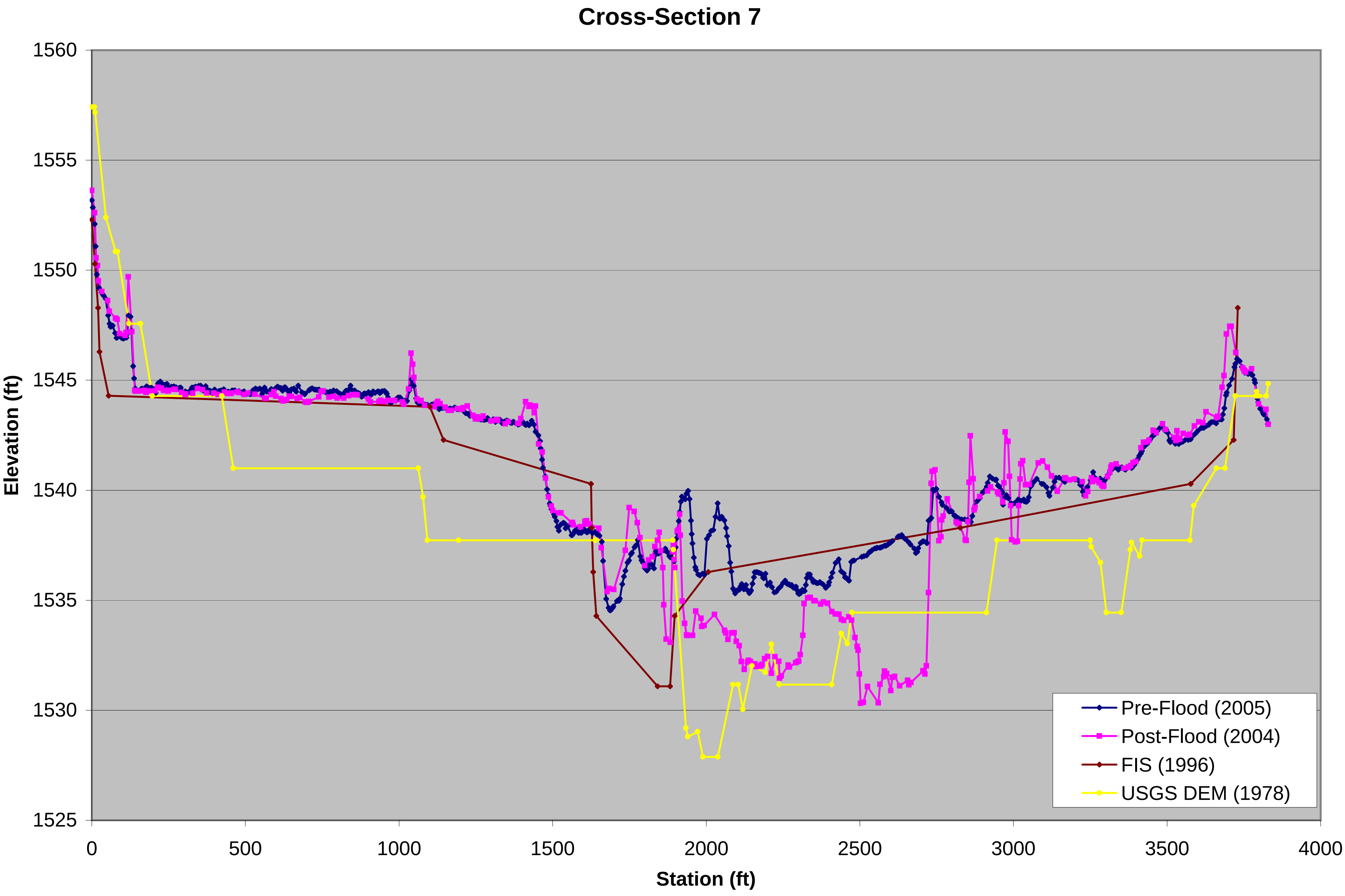
Post-Flood (2005)
Pre-Flood (2004)
FIS (1996)
USGS DEM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1530
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Station (ft)
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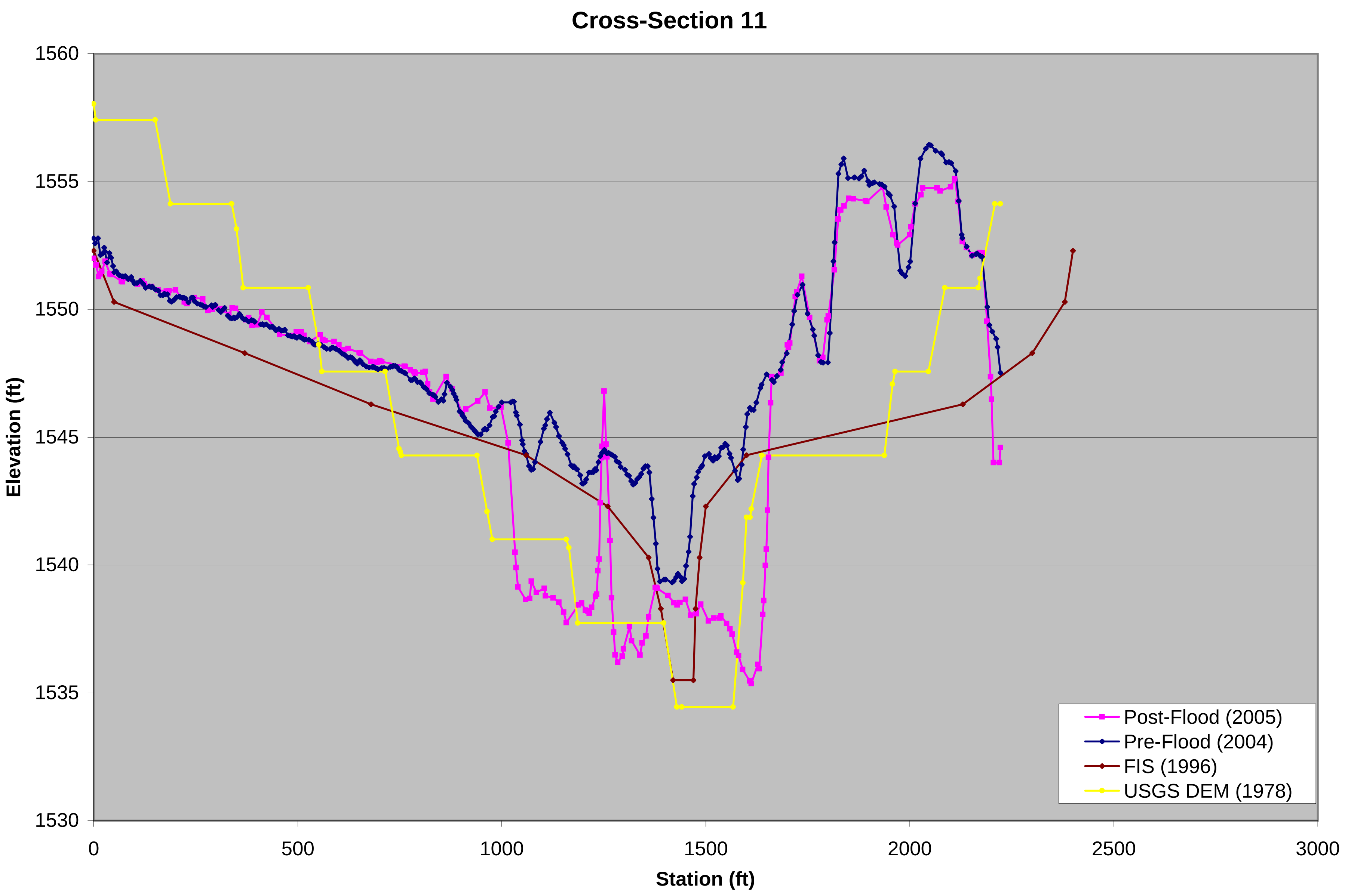
Pre-Flood (2005)
Post-Flood (2004)
FIS (1996)
USGS DEM (1978)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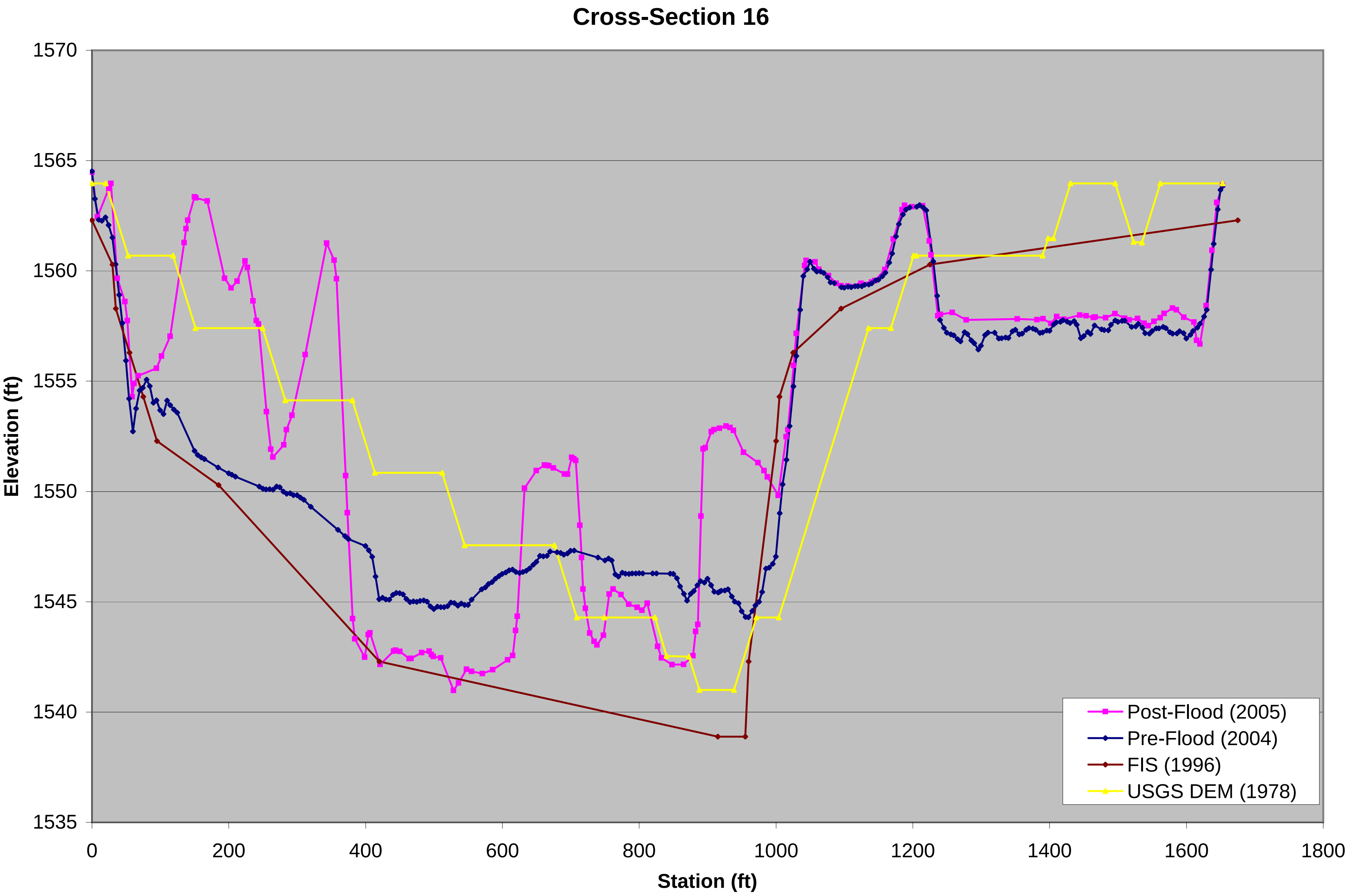
Pre-Flood (2004)
FIS (1996)
USGS DEM (1978)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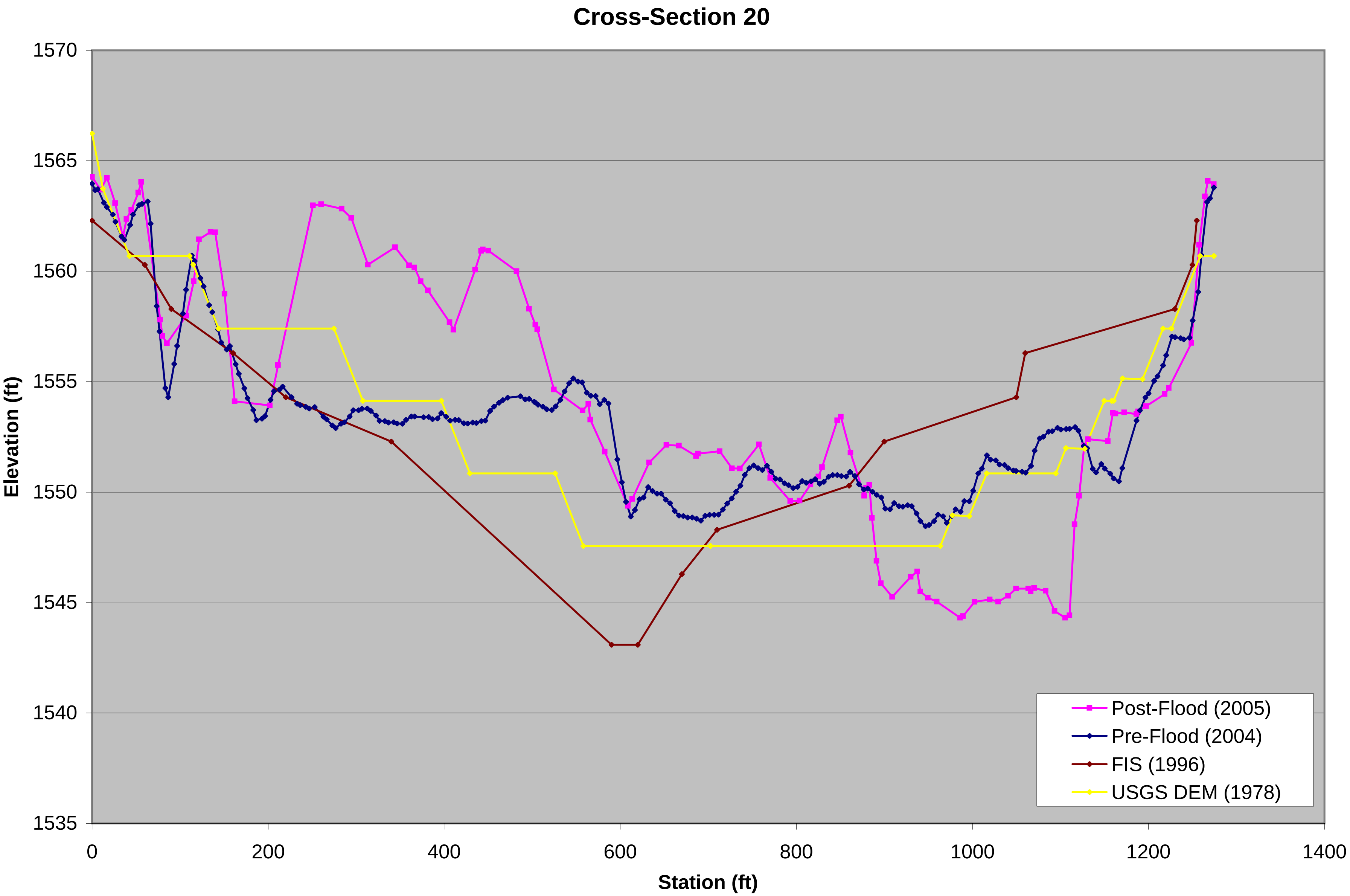
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
FIS (1996)
USGS DEM (1978)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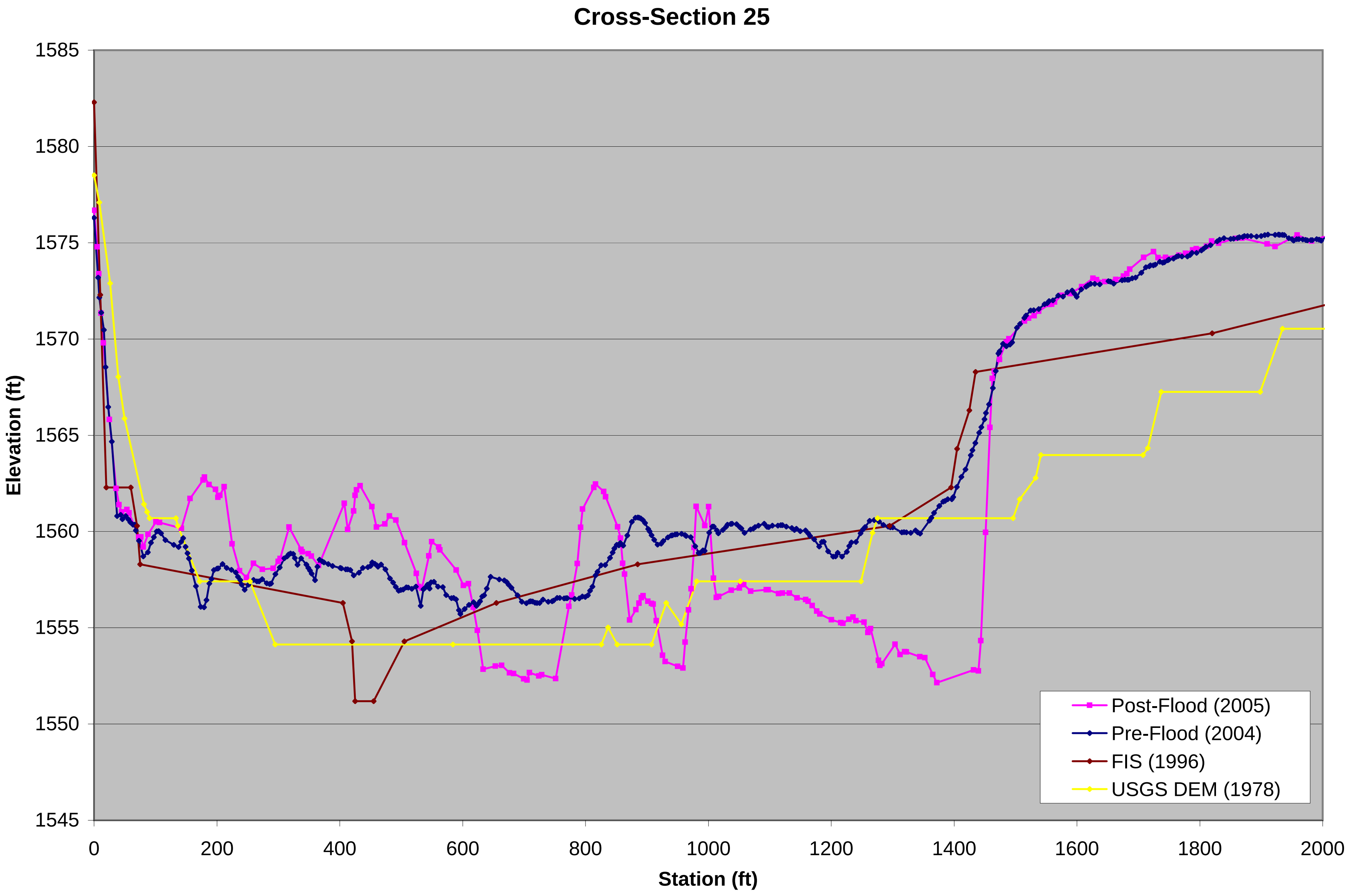
Post-Flood (2005)
Pre-Flood (2004)
FIS (1996)
USGS DEM (1978)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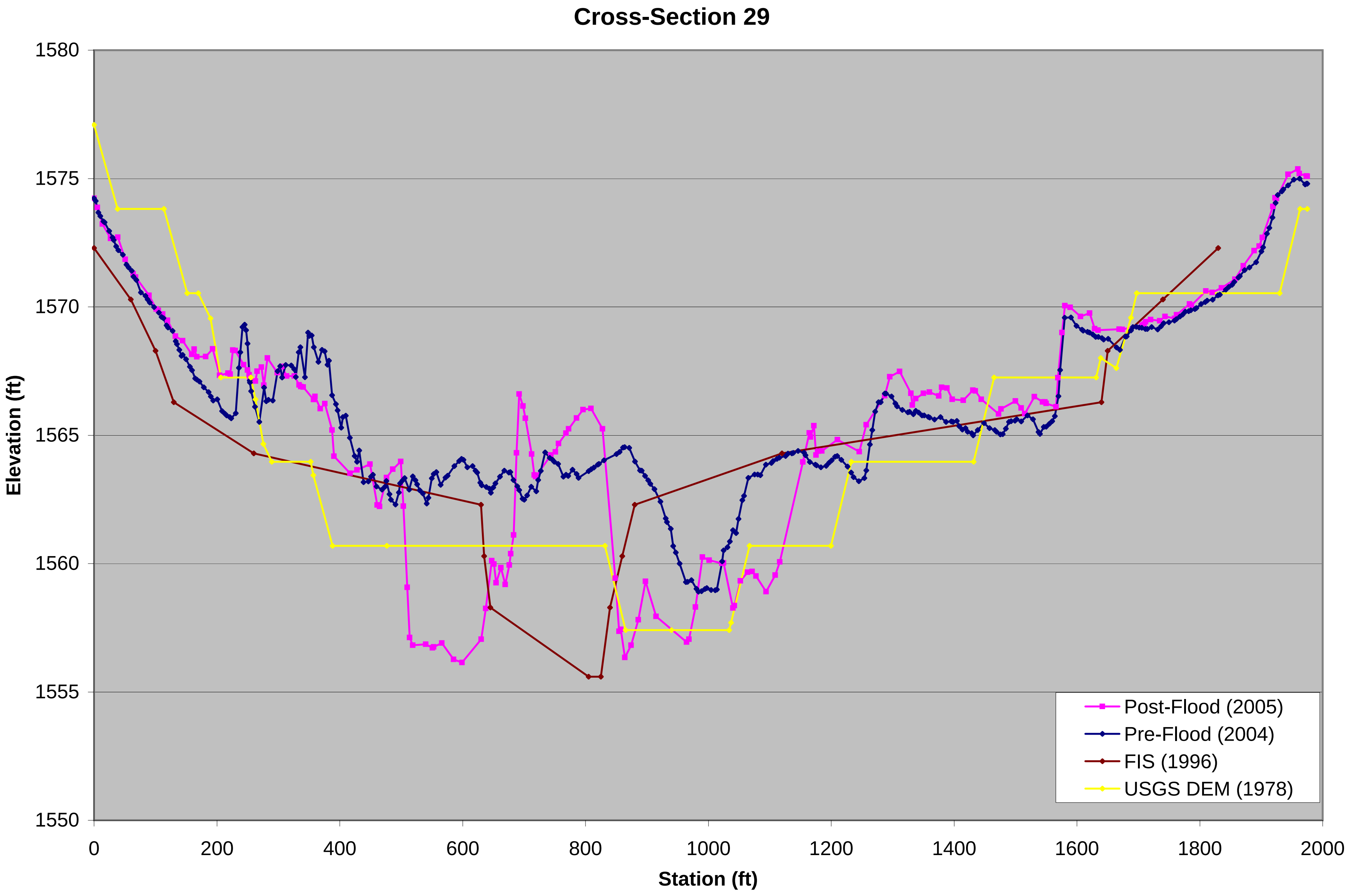
Post-Flood (2005)
Pre-Flood (2004)
FIS (1996)
USGS DEM (1978)



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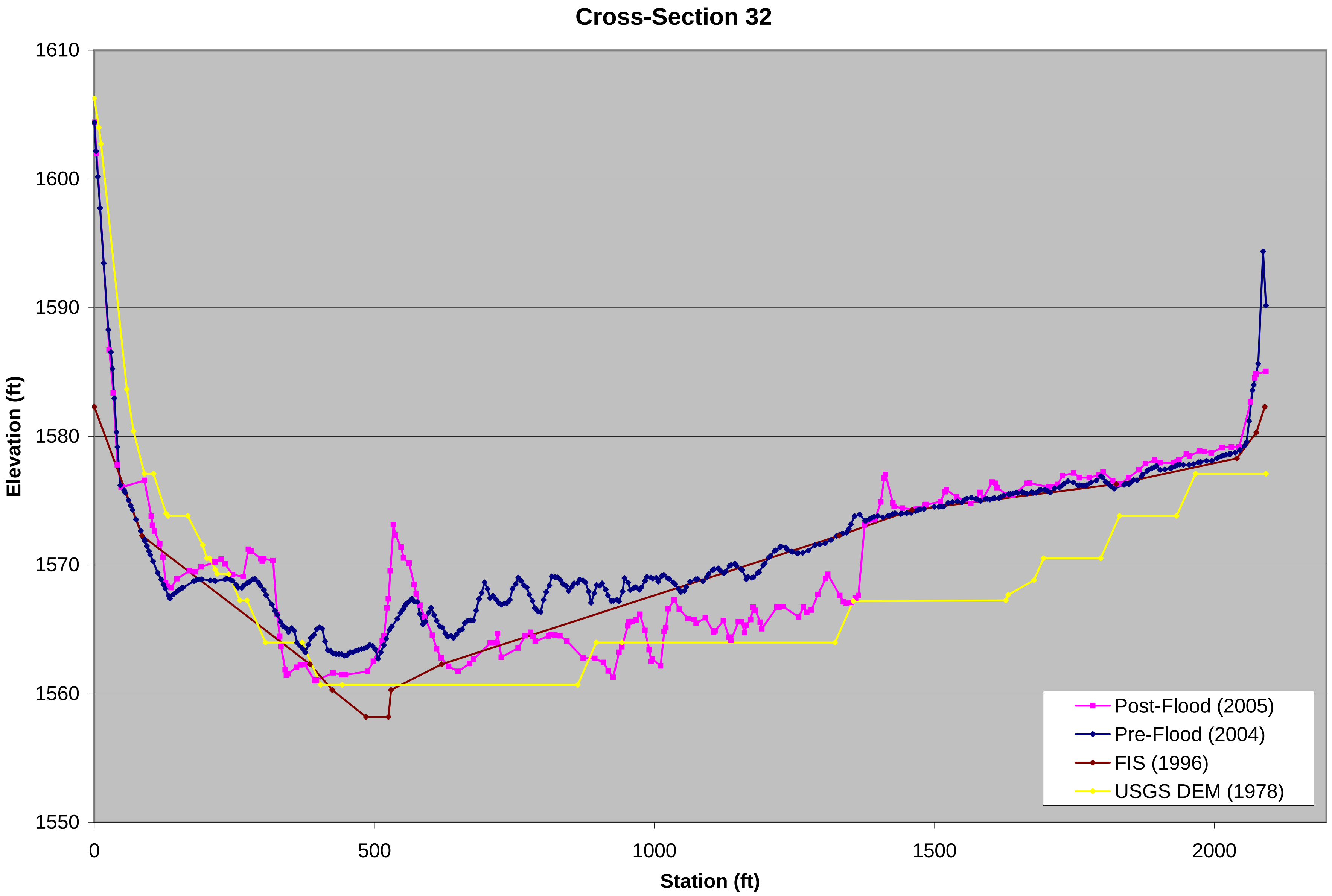
Post-Flood (2005)
Pre-Flood (2004)
FIS (1996)
USGS DEM (1978)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Pre-Flood (2004)
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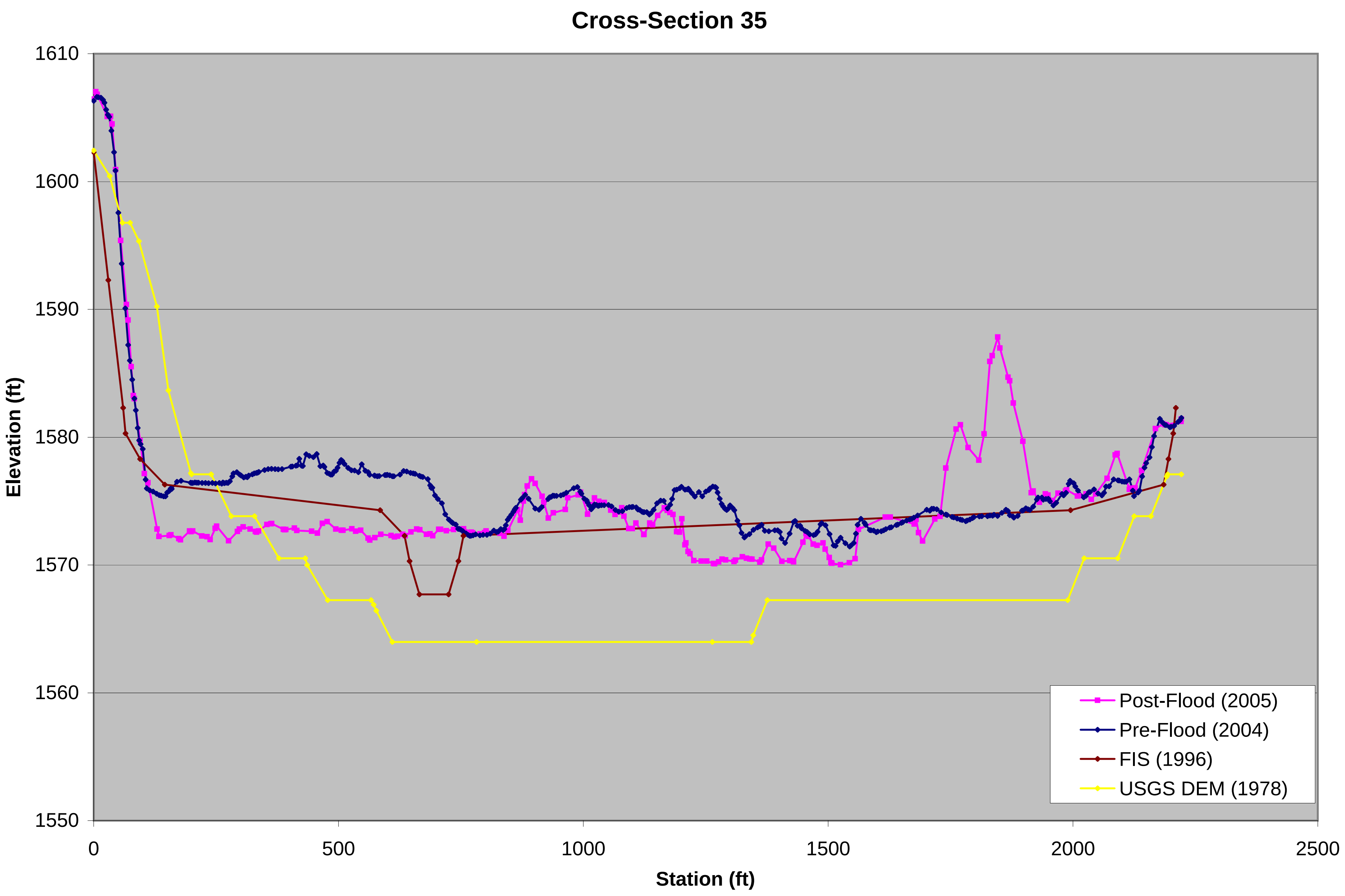

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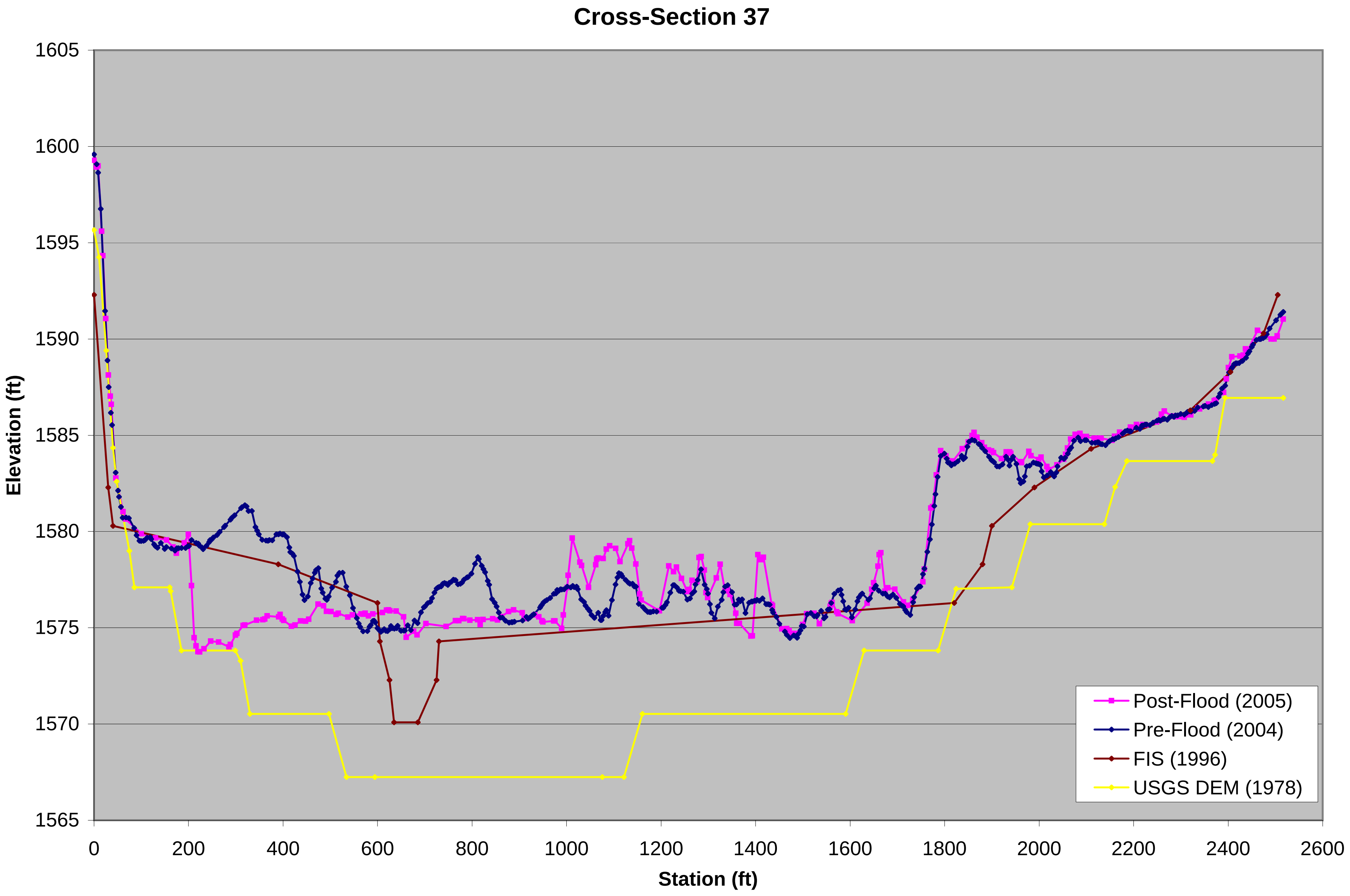
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Station (ft)
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Pre-Flood (2004)
FIS (1996)
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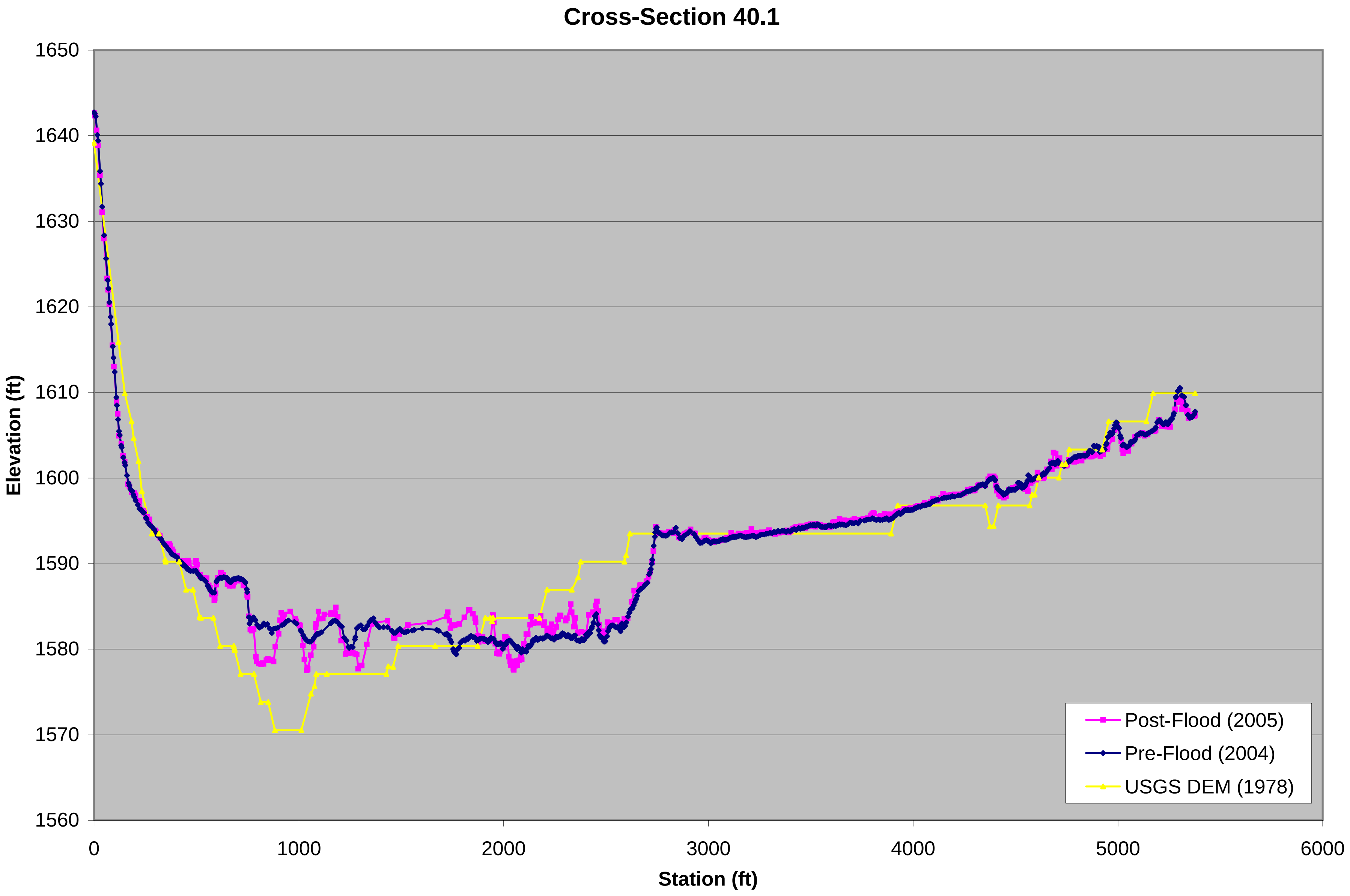
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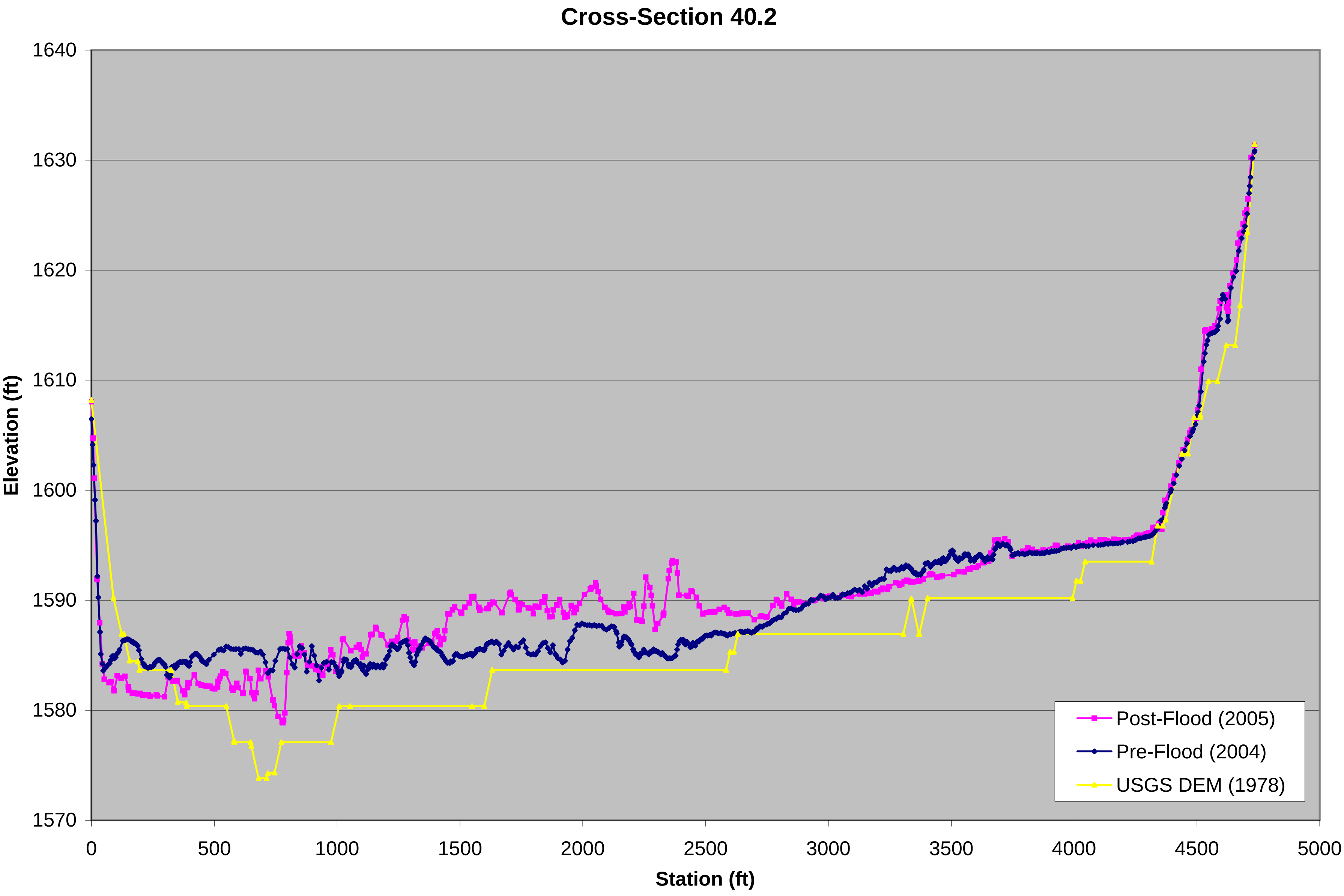
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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1610
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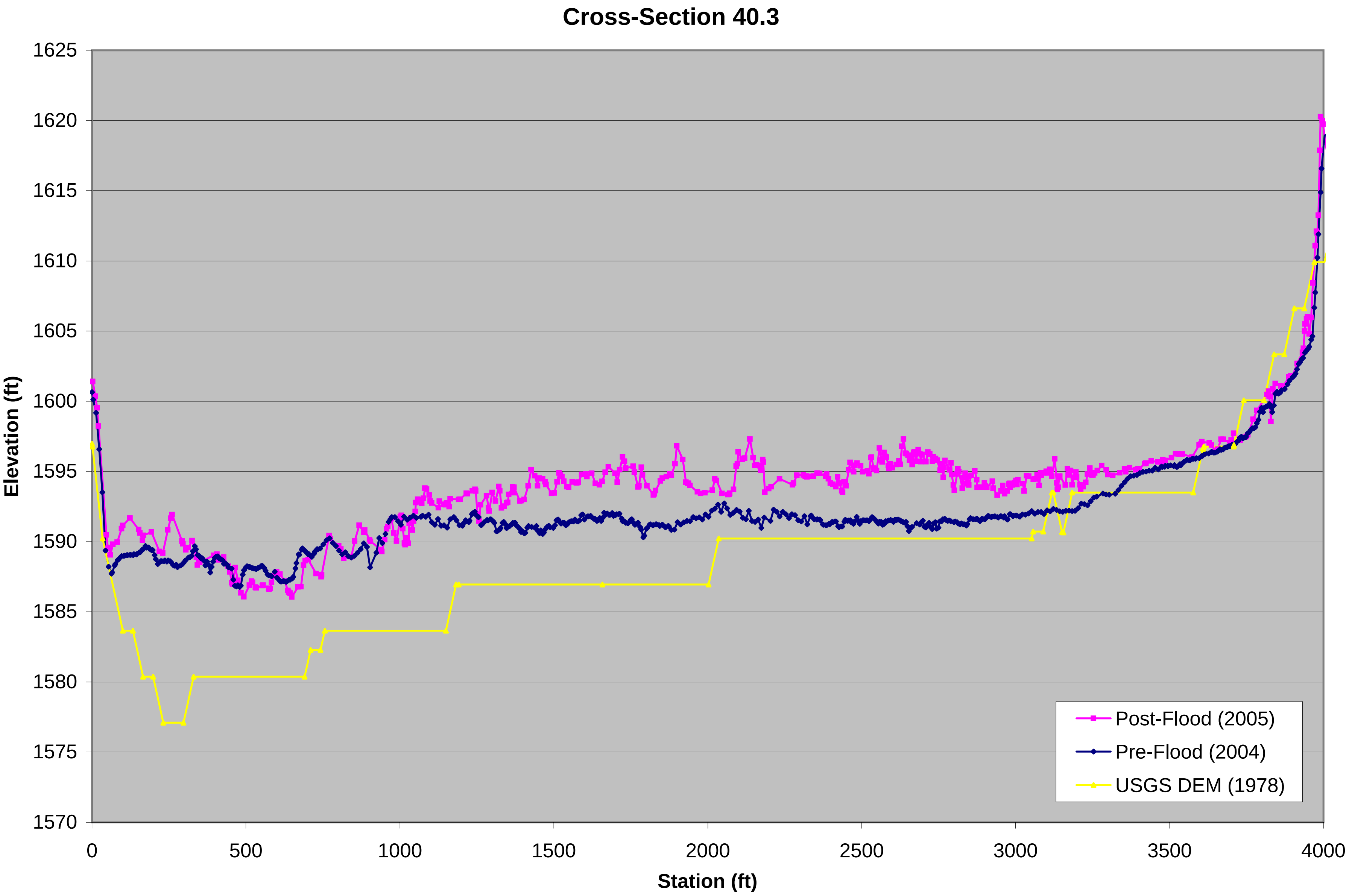
5000
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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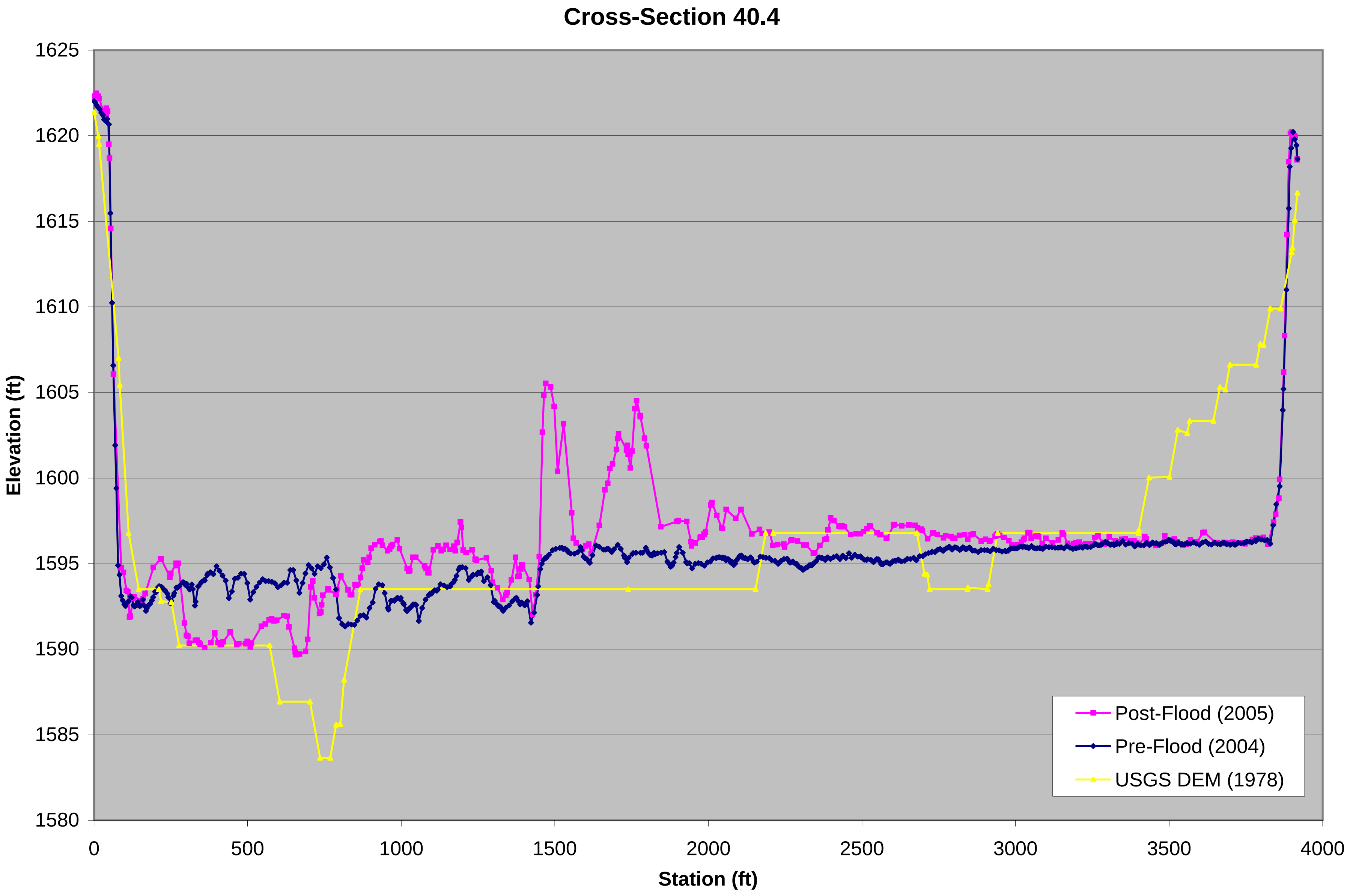
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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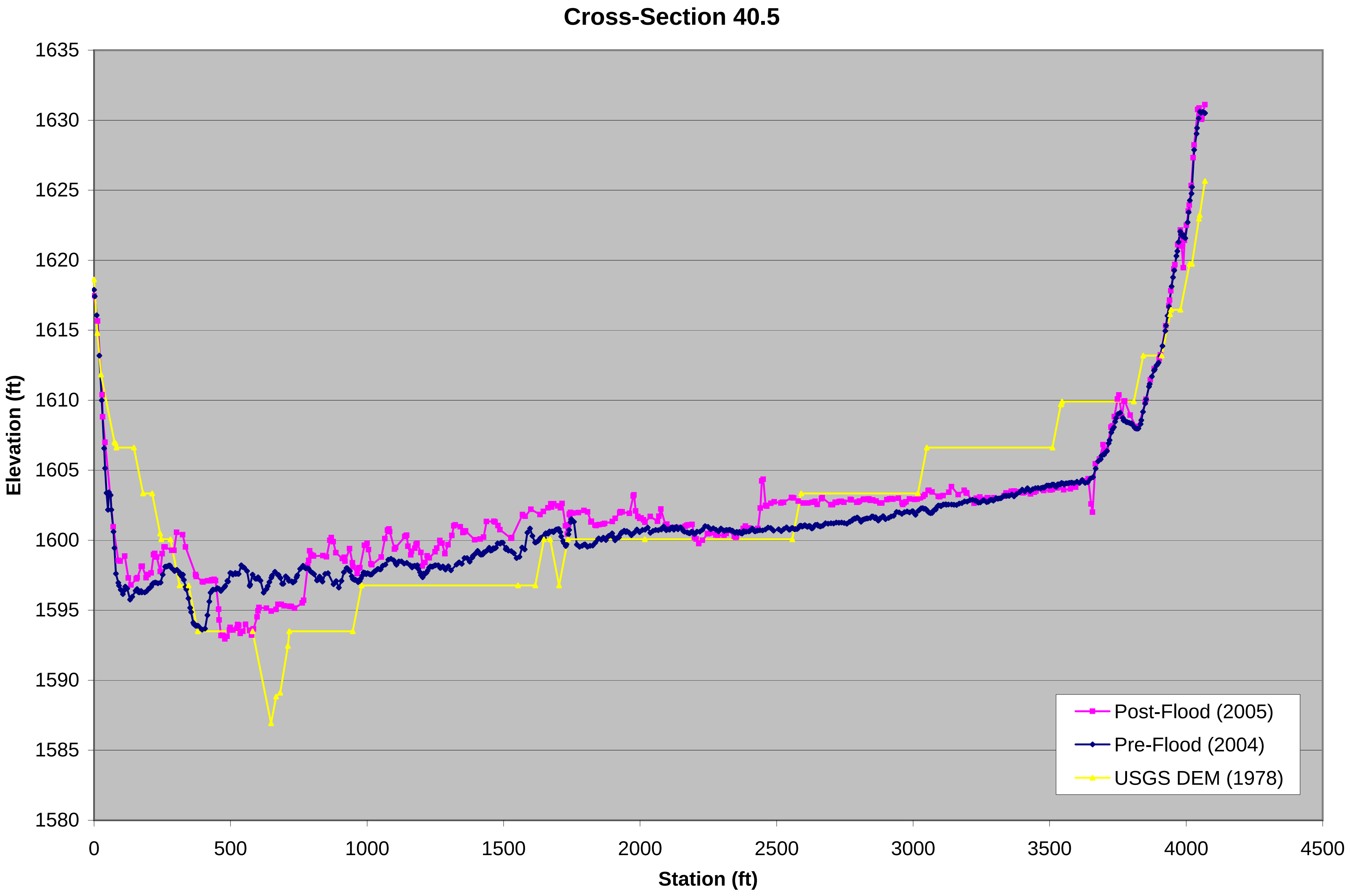
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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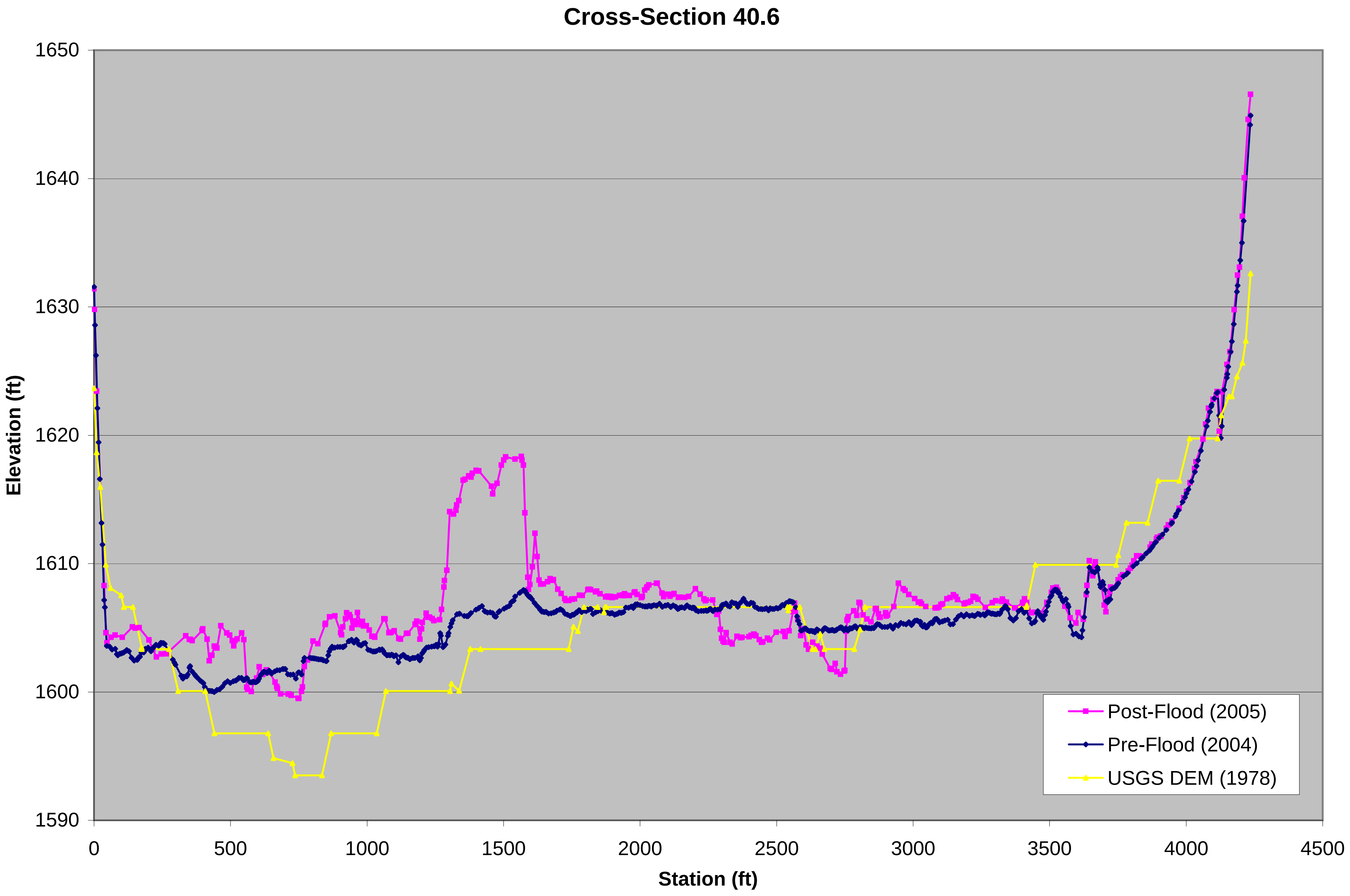
Station (ft)
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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Station (ft)
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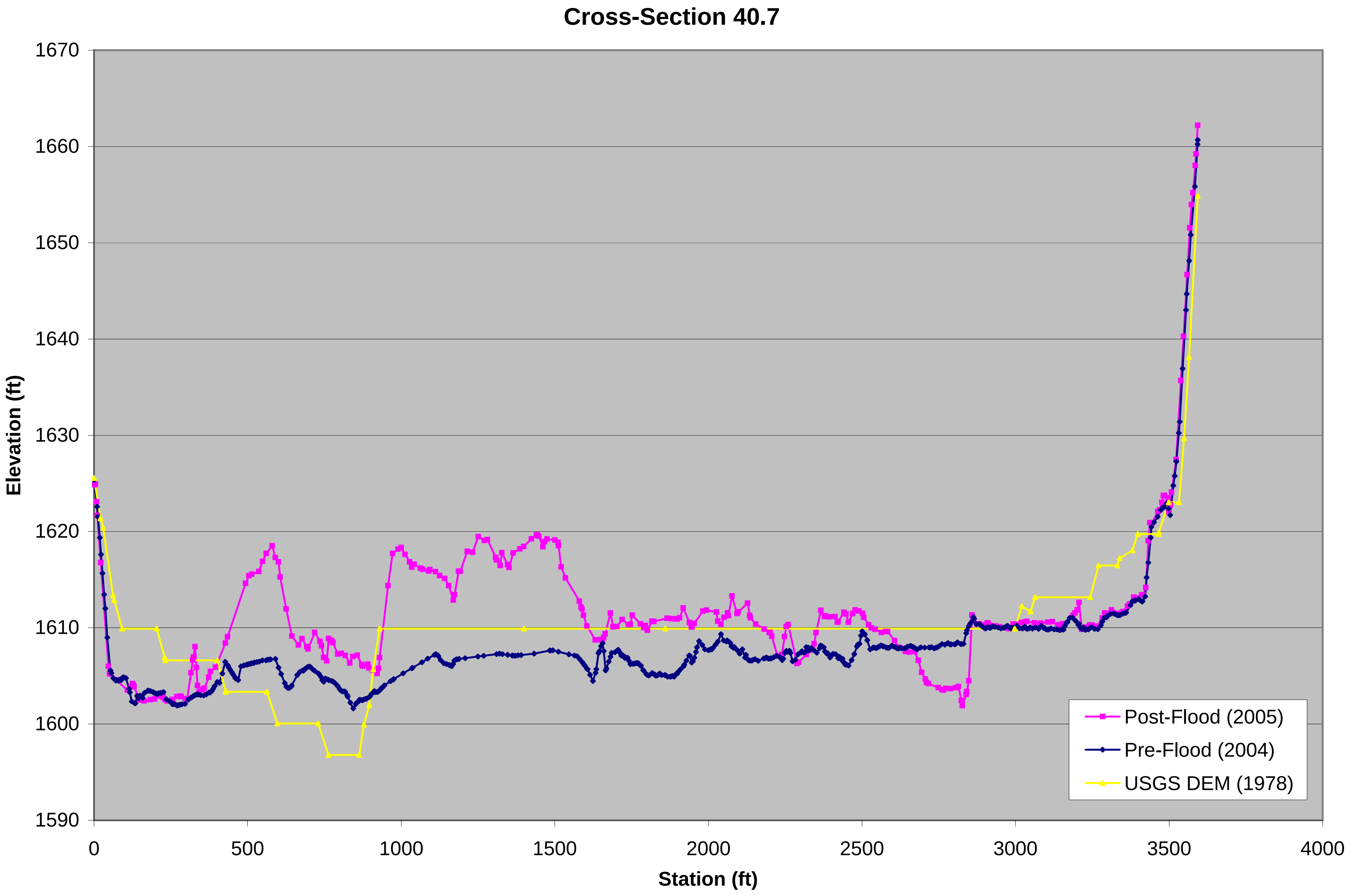
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)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1610
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Station (ft)
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1000
1500
2000
2500
3000
3500
4000
Post-Flood (2005)
Pre-Flood (2004)
USGS DEM (1978)

APPENDIX C

GENERAL DEVELOPMENT GUIDELINES

Development Guidelines

The following preliminary guidelines are designed to assist both city and county officials in addition to property owners in determining impacts of proposed channel improvements and engineering structures.

Scope of Services to Determine if Adverse Impacts to Adjacent Properties Occur

Sound floodplain management requires that structural erosion control measures not negatively impact flood and erosion hazards on adjacent properties and stream reaches. Therefore, it is required that an engineering assessment of erosion control structures impacts be reviewed and approved prior to development. To facilitate review of proposed structural measures, it is recommended that the following criteria be adopted that, if met, it may be assumed that minimal impacts will occur.

Low impact structural measures should be implemented wherever possible. The best way to minimize impacts on stream corridors is to maintain the form and function of the natural stream system to the greatest degree possible. The following definition of low impact criteria is intended to achieve the goals of minimum disturbance of the natural system:

- Minimal velocity increase.
  - The average 10-year velocity in the channel or overbank should not change (± 0.0 fps).
  - The average 100-year velocity in the channel or overbank should not change (increase or decrease) by more than 10 percent or 1 foot per second (fps), whichever is less.
- Minimal water surface elevation increase.
  - The 10-year water surface elevation or energy grade line should not change (± 0.0 feet.).
  - The 100-year water surface elevation or energy grade line should not increase or decrease by more than 0.1 foot.
- Minimal change in floodplain width
  - The 10-year floodplain width should not change (± 0.0 feet.).
- Minimal disturbance of the main channel.
  - The natural bankfull width of the main channel should not decrease.
  - The streambed in the main channel should not be excavated or deepened.
  - Bank vegetation should not be removed. Where bank vegetation is temporarily disturbed by construction, it should be replaced, monitored for health, and irrigated if required to assure its survival.
  - The low-flow channel should not be relocated within the floodplain.
- Minimal disturbance of the 10-year floodplain
  - Alteration of the natural vegetation and ground elevations within the 10-year floodplain should be minimized, except for purposes of restoration of disturbed areas to natural conditions.
- No offsite impacts.
  - No erosion, sedimentation, or flood impacts to adjacent properties shall occur without the written permission of all affected property owners.
- Preservation of natural landscape character and habitat within the floodplain.

In general, the less the natural channels and floodplains are disturbed, the less sedimentation, erosion and flood problems will occur.

Impact Analysis

If a proposed development in an erosion hazard zone does not meet the Low Impact Criteria defined above, an analysis of the potential impacts of the development on adjacent properties and the watercourse system sediment balance is required. Note that, in general, it is assumed that any channelization or other forms of structural erosion control will impact adjacent parcels and will have negative cumulative impacts on the watercourse that will require mitigation. It is the developer's responsibility to demonstrate that any such impacts are minimal, justified, and consistent with the local jurisdiction's regulatory objectives. An engineering analysis of stream impacts typically consists of the following elements:

1. Regulatory Floodplain/Floodway Impacts. Hydraulic modeling of the pre- and post-project channel and floodplain conditions must be submitted and approved by the local floodplain manager to document the following:
    a. Floodplain.
        i. Changes in the 100-year water surface elevation must be less than one foot within the property limits.
        ii. No changes in the 100-year water surface elevation may occur on adjacent properties.
    b. Floodway.
        i. No changes in the regulatory floodway elevation are permitted, either within or adjacent to the proposed project limits.
2. Stream Stability and Sedimentation Impacts. Engineering analyses must be submitted to document that no adverse impacts occur on adjacent properties due to the proposed structural measures. It is recommended that the applicant's engineer meet with local floodplain management staff prior beginning any analyses to discuss and review the engineering methodologies to be used to evaluate sedimentation impacts.
    a. Sedimentation impacts from floodplain encroachment or channelization. The engineering analysis must address each of the following types of sedimentation impacts:
        i. Deflection scour. Deflection scour occurs on a stream bank when the channel or floodplain alignment is modified causing changes in flow direction, or where only one bank is protected, thus limiting the available sources of sediment in the reach. The following conditions can lead to reflective scour:
            1. Change in the main channel alignment
            2. Change in the overbank flow path alignment
            3. Concentration of overbank flow
            4. Increase in percentage of flow carried in the main channel due to overbank encroachment or deflection
            5. Protection of only one channel bank
            6. Severe contraction of the channel or floodplain

            The evaluation of potential deflection scour should account for development of adverse channel alignment caused by exposure of proposed flood control structures following long-term channel movement. Channelization or structural measures located within the EHZ should be designed with smooth transitions.

    ii. Contraction scour. Floodplain encroachment increases flow velocity and depth, which results in increased channel bed erosion and sediment transport capacity. Hydraulic data from the pre- and post-project hydraulic models should be used in conjunction with an approved sediment transport function to demonstrate that the proposed mining plan does not increase scour, erosion, or deposition on any adjacent property.
    iii. Upstream scour and degradation. Upstream scour occurs when floodwater enters an excavated channel reach that is below the grade of the surrounding floodplain or channel. Upstream scour consists of two primary elements: (1) a headcut that migrates upstream as floodwater falls over a steep face into the excavation, and (2) long-term degradation as the watercourse adjusts to a new base level provided by the bottom of the excavation. Long-term and single headcut migration should be limited to the property owned by the applicant. Long-term degradation should also be assessed.
    iv. Downstream degradation. Downstream degradation is caused when sediment is trapped or depleted in a reach, and sediment-deprived water flows downstream. Downstream degradation potential should be estimated.
  b. Cumulative impacts analyses. Effect on the river system, adjacent properties, and public infrastructure will be considered as if all landowners along the watercourse were allowed the same degree of impact on the river system as the permit applicant. On streams lacking a watercourse master plan, local floodplain administrators may require a cumulative impacts analysis as part of the floodplain use permit application engineering report.
  c. Guidelines for Use of Computer Sediment Transport Modeling. Guidelines for use of computer sediment transport models are provided elsewhere. To facilitate the permitting process and to prevent any wasted effort and funds by permit applicants, engineers are strongly advised to coordinate any computer modeling efforts with local floodplain managers prior to undertaking the modeling effort and prior to submittal of results.

3. Statement of Findings.
  a. An engineering report shall be prepared summarizing the methodologies used to support the impact analysis, the assumptions and limitations of those methodologies, and the results of the analysis. The report shall include all computations and other documentation supporting the analyses and conclusions. An engineer's certification shall be provided with the impact analysis report.

Identifying Lateral Erosion Hazards

The following guidelines to help identify erosion hazards along streams and watercourses in southern Nevada. Stream channel erosion can increase local flood hazards by causing bank failures or undermining structures. Channel erosion can occur on all stream types, including perennial streams, ephemeral washes, man-made channels, or in areas of sheet flow. The following guidelines are intended to help identify watercourses that could be subject to erosion.

Identifying Characteristics for Stream Channel Erosion

Streams that have experienced erosion exhibit certain characteristics that can be readily identified in the field. The lists of characteristics shown below are divided into those that can be observed along natural reaches (no structures present), and those that can be observed where structures have been built in the channel. In addition, the following general rules apply to streams in southern Nevada:

- Streams that have experienced erosion problems in the past will experience erosion problems in the future.
- Disturbance is likely to alter or exacerbate natural patterns of erosion and deposition in stream channels.
- As a stream and its watershed become more disturbed, the stream is more likely to experience channel erosion.
- The most effective way to avoid erosion damages is to avoid construction or other development activities in the floodplain.
- Bank erosion occurs more rapidly on the outside of bends (meanders) than on the inside of bends.
- Vertical bank slopes are the most readily identified sign of high potential for channel erosion

Natural Features. The following list of natural channel features are evidence that stream erosion has occurred in the recent past, or is likely to occur in the future. However, erosion can occur on any streams, regardless of its current appearance.

- **Cut or undercut stream banks**. Cut banks occur where erosion has left stream banks steeper than the natural angle of repose of the soil material. Signs of cut banks include lack of bank vegetation, loose soil material (slides when touched), tension cracks in the soils adjacent to the banks, piles of soil at the base of the bank slope, and bank vegetation leaning into the stream corridor.
- **Vertical banks**. Vertical banks are the most easily identified evidence of bank erosion. Except where the vertical banks are composed of solid bedrock, vertical banks are never stable, and indicate recent channel erosion.
- **Bank vegetation leaning into channel**. Trees and other bank vegetation will fall into the channel as the soil around the roots is removed by erosion. Once the bank vegetation fails, bank erosion occurs more rapidly.
- **Roots of bank vegetation exposed**. Exposed roots of bank vegetation indicate that soil material has been removed from the banks and that erosion is beginning to occur.
- **Lack of bank vegetation**. Where no vegetation is present along the banks, especially on perennial or intermittent streams, it has either been artificially removed or eroded away by the stream. Where a stream’s bank vegetation is discontinuous

compared to upstream and downstream reaches, the stream is more likely to erode its banks.

- **Mid-channel bars higher than floodplain elevation**. Where the elevation of the top of the mid-channel bars is close to or higher than the floodplain elevation, rapid bank erosion and channel avulsions are more likely.

- **Gully formation in the watershed**. Gully formation in a watershed indicates excess runoff and a sediment deficit, which may cause bank erosion on main stem streams.

- **Irregular channel geometry**. Natural channels generally have gradual changes in the channel width and depth over short reaches. Where channel width and depth change rapidly without a recognizable pattern, it is likely that the channel is unstable and subject to erosion.

- **Piping of bank soils**. Piping, or formation of zones of high hydraulic conductivity in a stream bank, can destabilize the banks and lead to more rapid erosion.

- **Perched tributaries**. Tributaries normally join the main stream at an elevation equal to the bed elevation of the main channel. Where the elevation of the tributary mouth is significantly higher than the main stem, it is likely that accelerated bank erosion of the main stem will occur.

Man-Made Features Man-made structures, since they are generally not designed to move, offer a reference point from which to assess the magnitude of channel change since their construction date. Some types of structures that can be used to identify erosion include the following:

- **Failed bank protection**. Failures of bank protection, such as slumped riprap or cracked concrete, may indicate long term degradation of the channel or channel movement.

- **Footings of structures.** Footings are typically designed below the elevation of the stream bed. If exposed or undercut, it can be assumed that the stream channel has degraded or moved.

Activities That Can Increase the Potential for Stream Erosion:
The following human activities can increase the potential for river erosion:

- Removing vegetation from channel banks or the channel bed.
- Excavating sand and gravel material from the channel bed.
- Lining only one bank with permanent bank protection such as riprap.
- Changing the natural channel geometry by channelization or grading.
- Straightening a naturally sinuous channel.
- Increasing the frequency of runoff by discharging urban runoff into a stream.
- Developing within the floodplain.
- Constructing an on-line detention basin or dam upstream.
- Removing a large number of trees from a forested watershed.
- Removing of watershed vegetation by overgrazing.

Erosion hazards should be considered in the design of structures along any watercourse that exhibits any of the features described above.

APPENDIX D

1938 AND 2005 AERIAL PHOTO COMPARISON MAP

Virgin River Flood Study

Geomorphic Analysis Report

Historical Aerial Photo Exhibit Book

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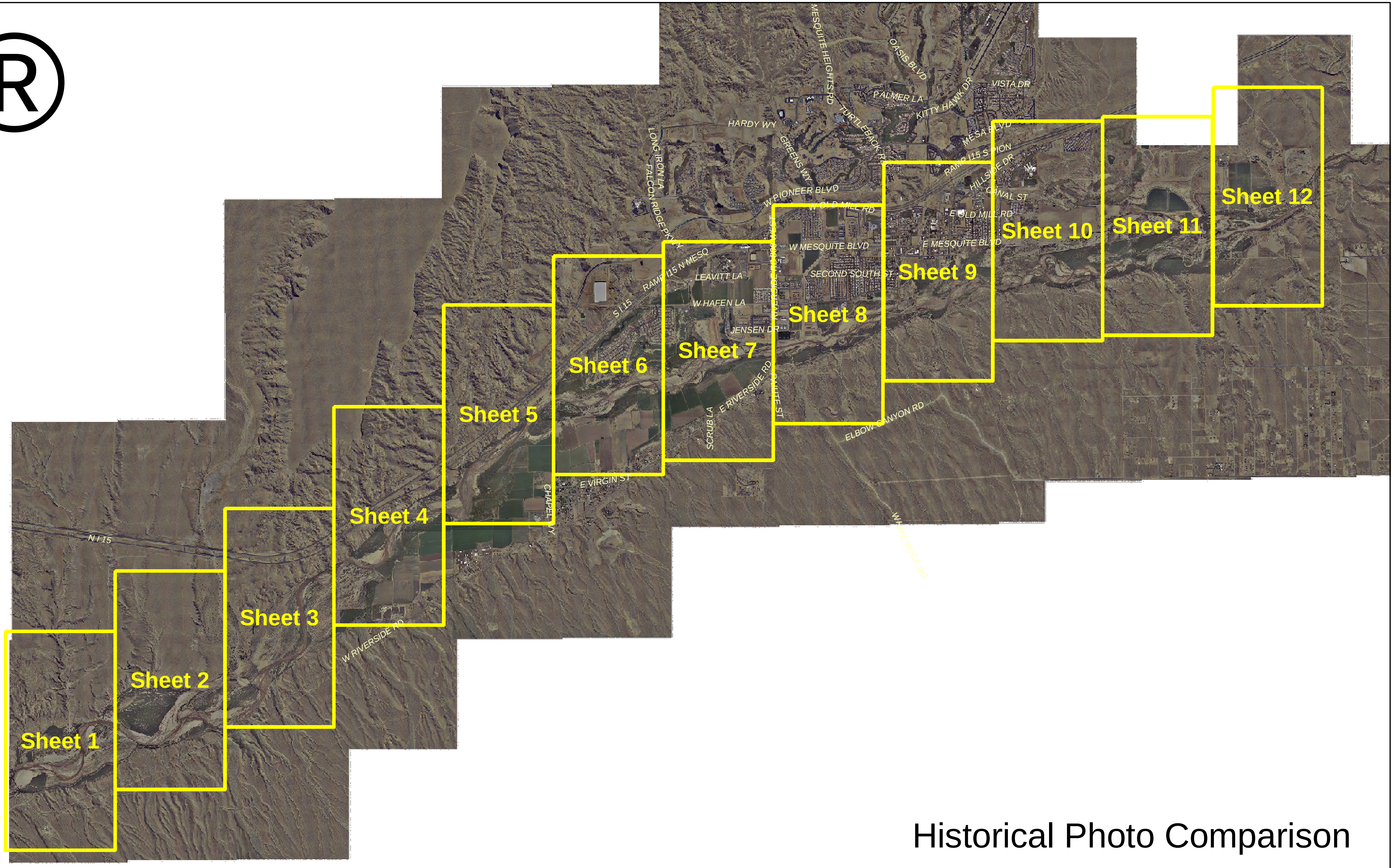
February 2006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Historical Photo Comparison

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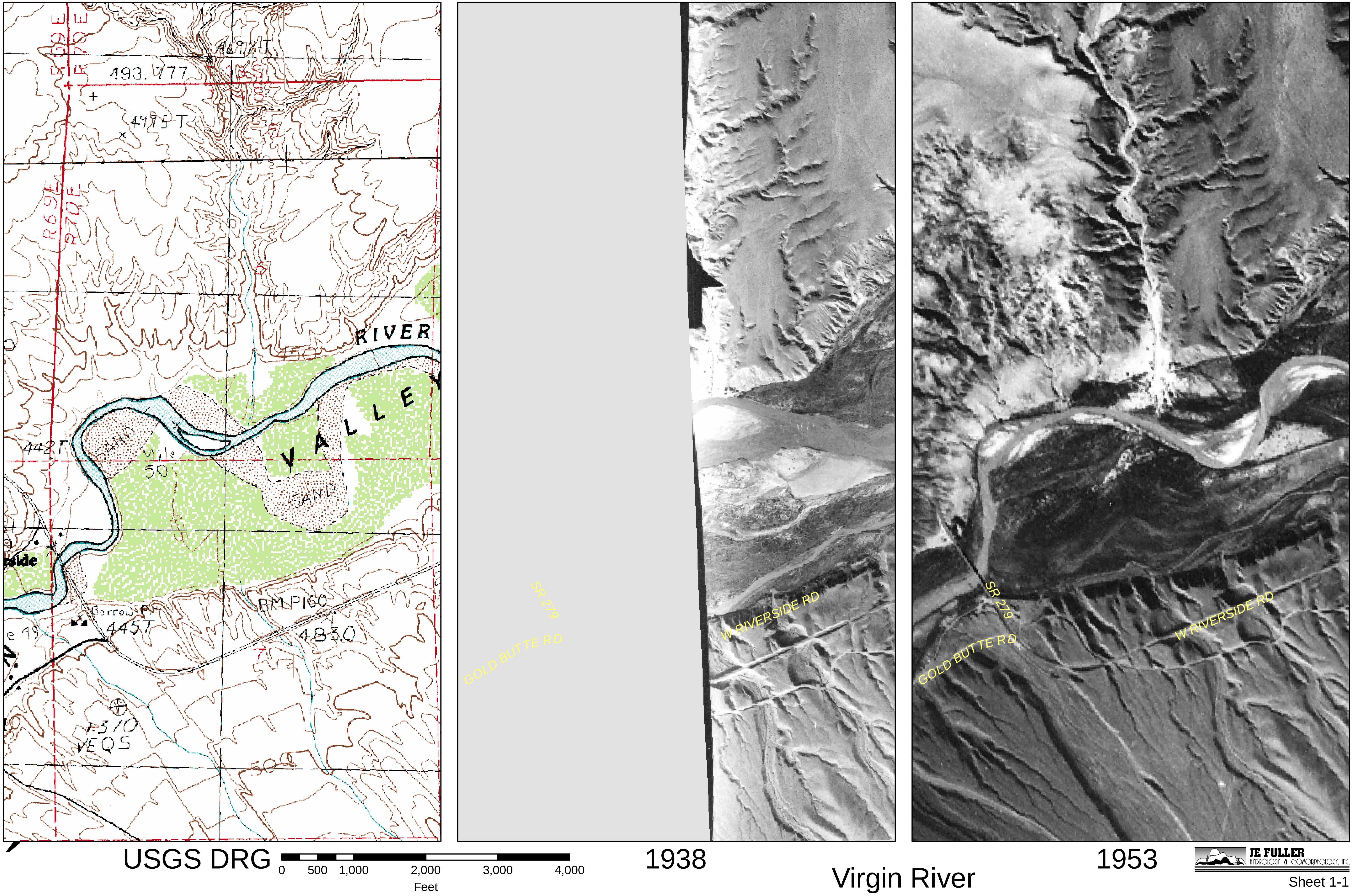
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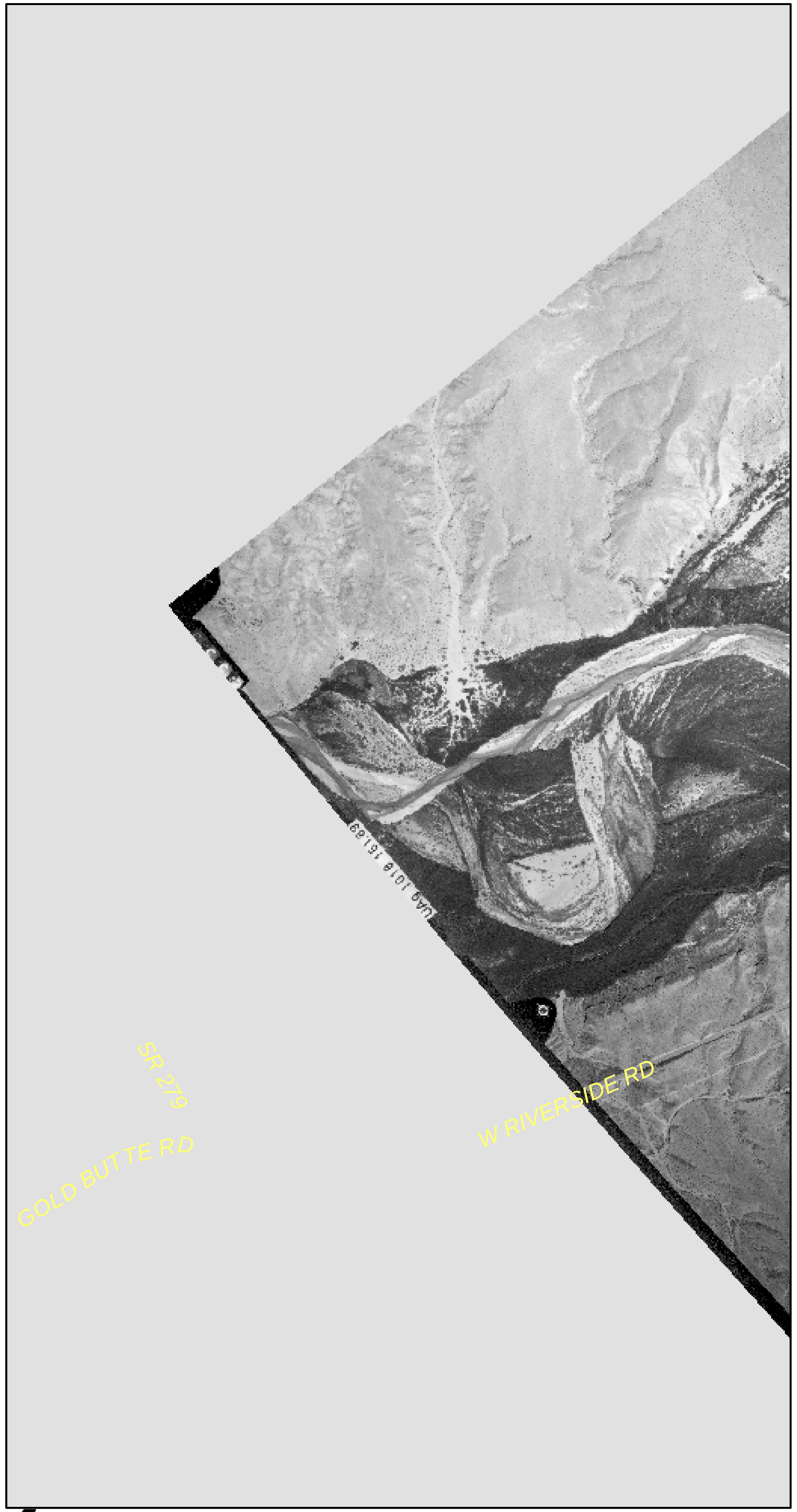
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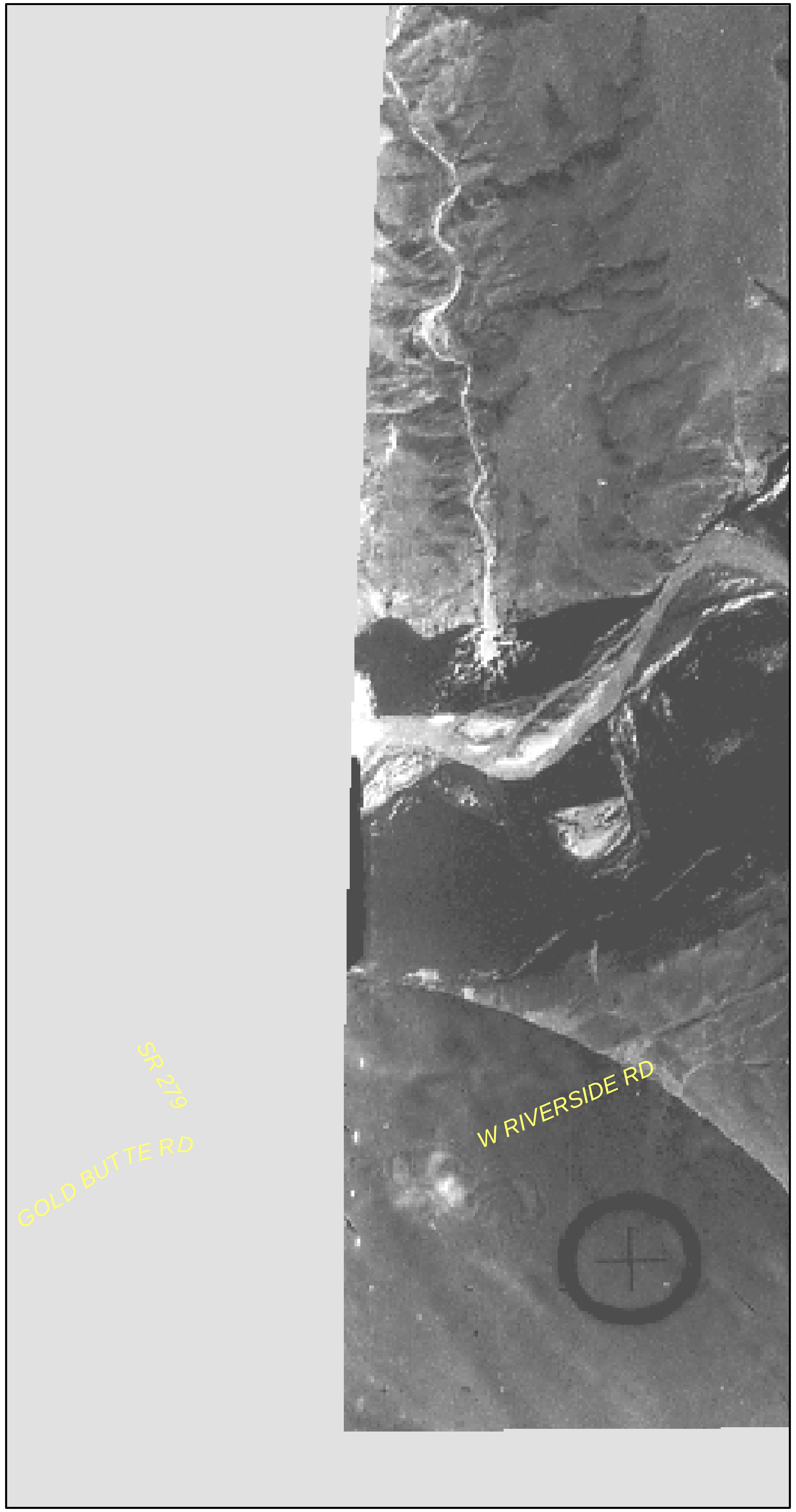
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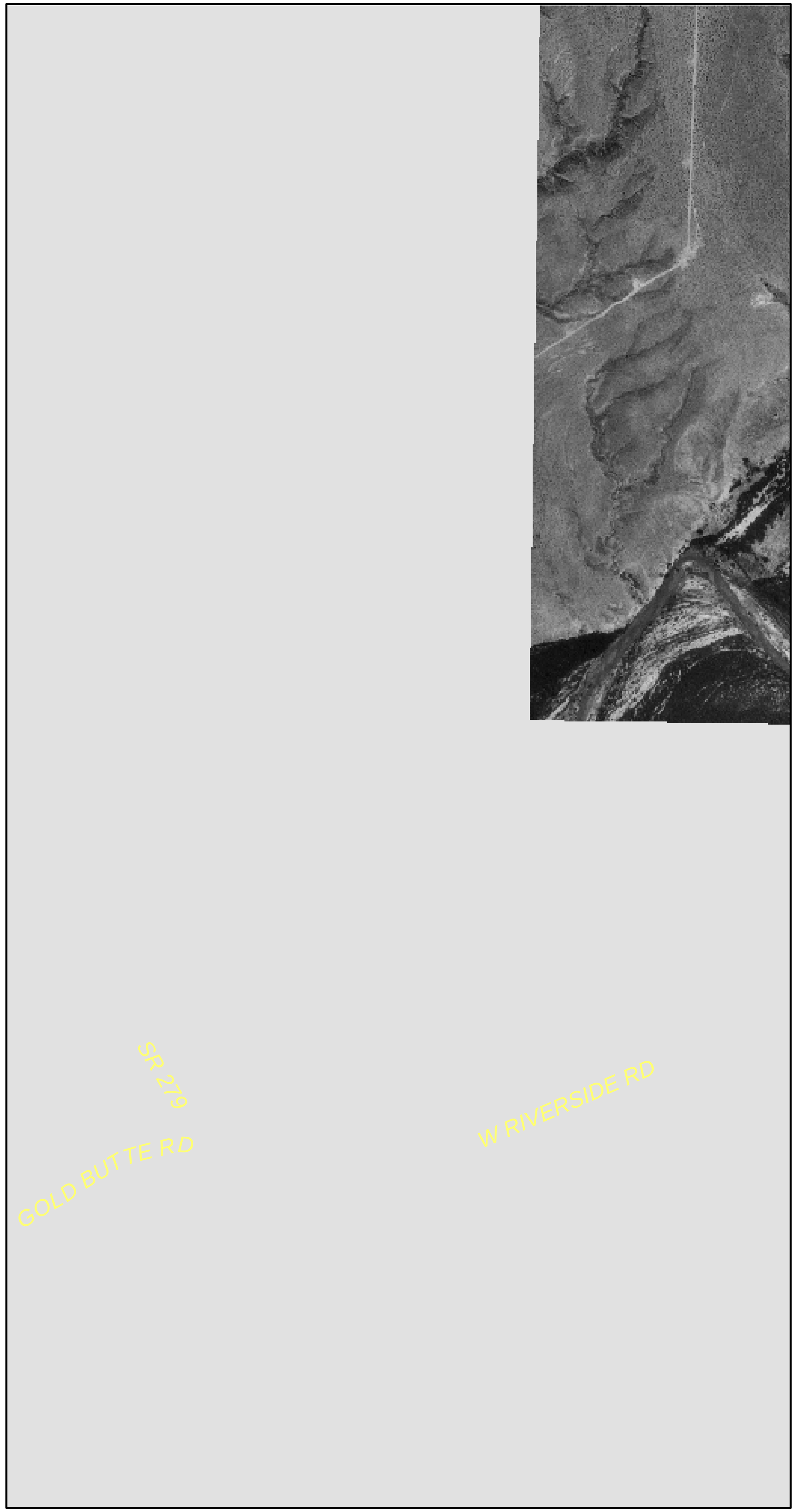
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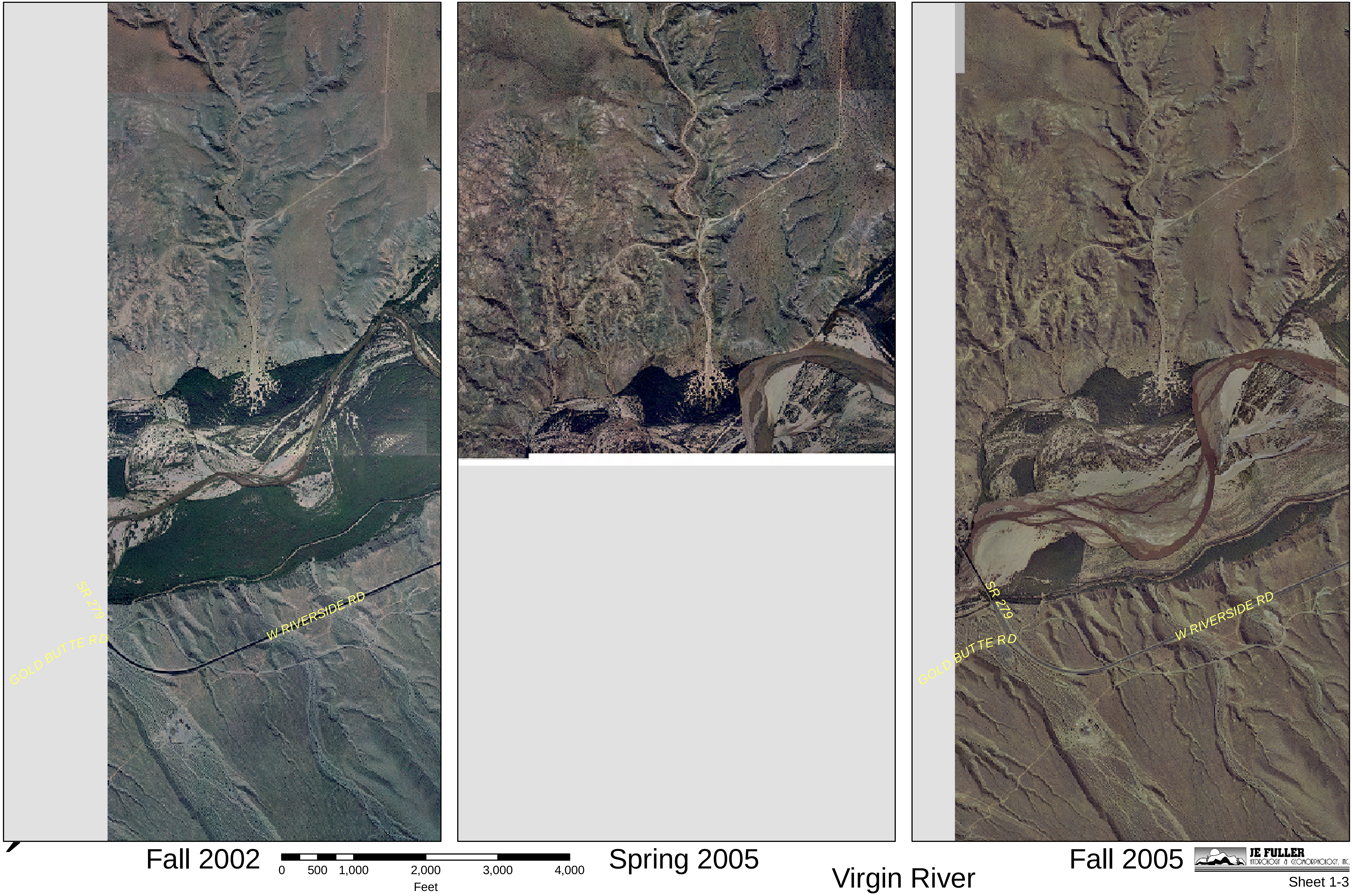
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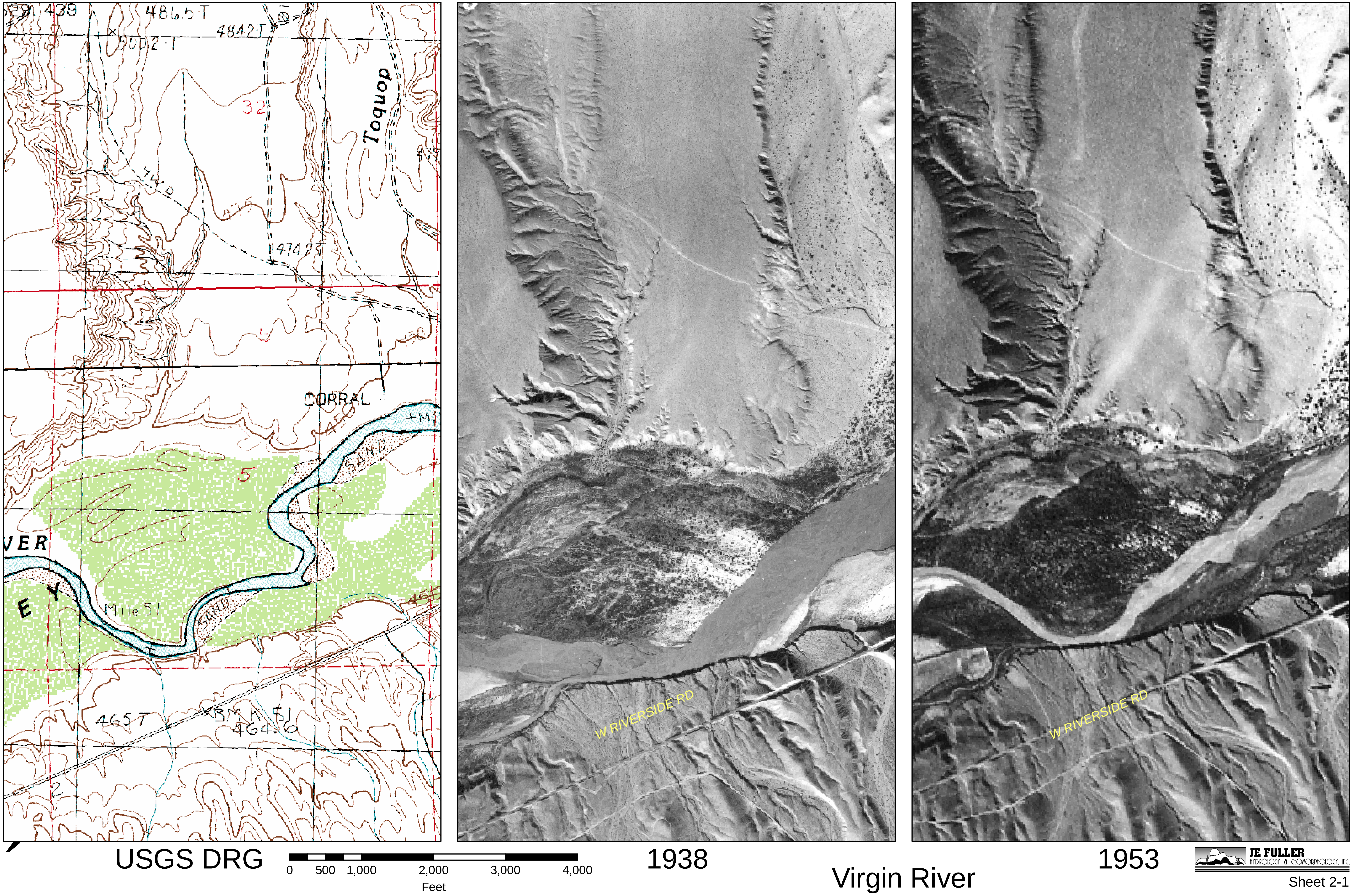
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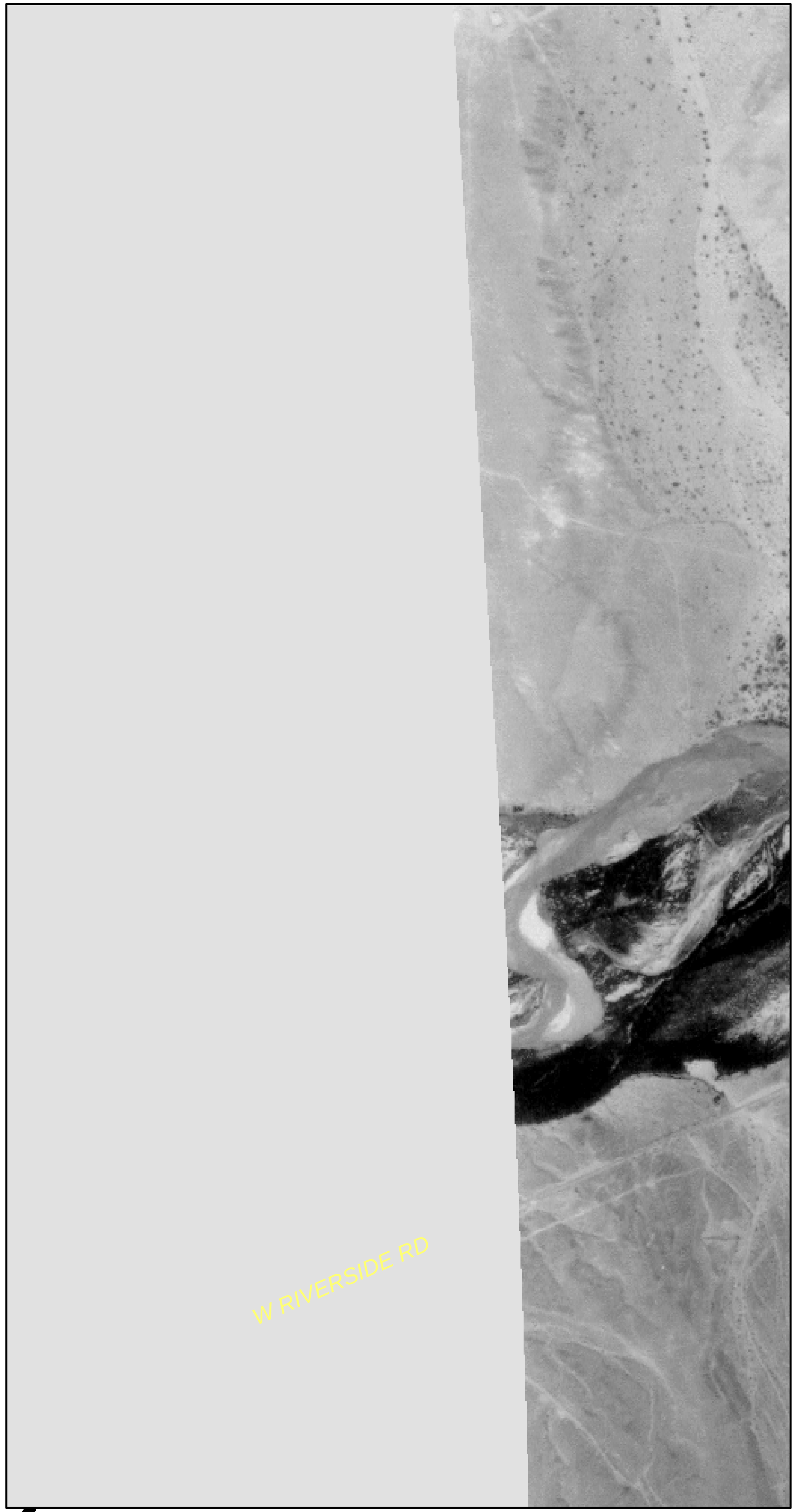
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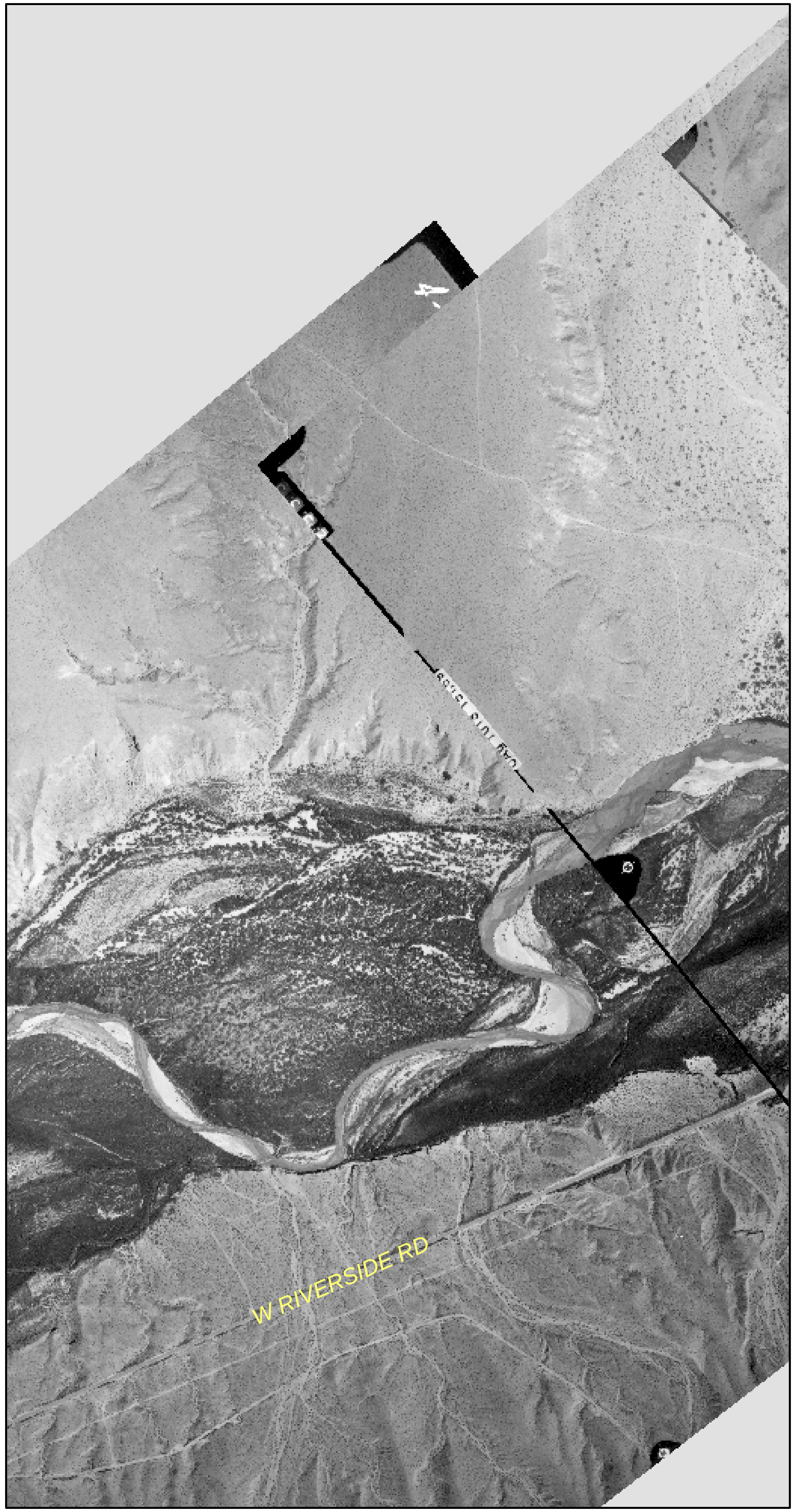
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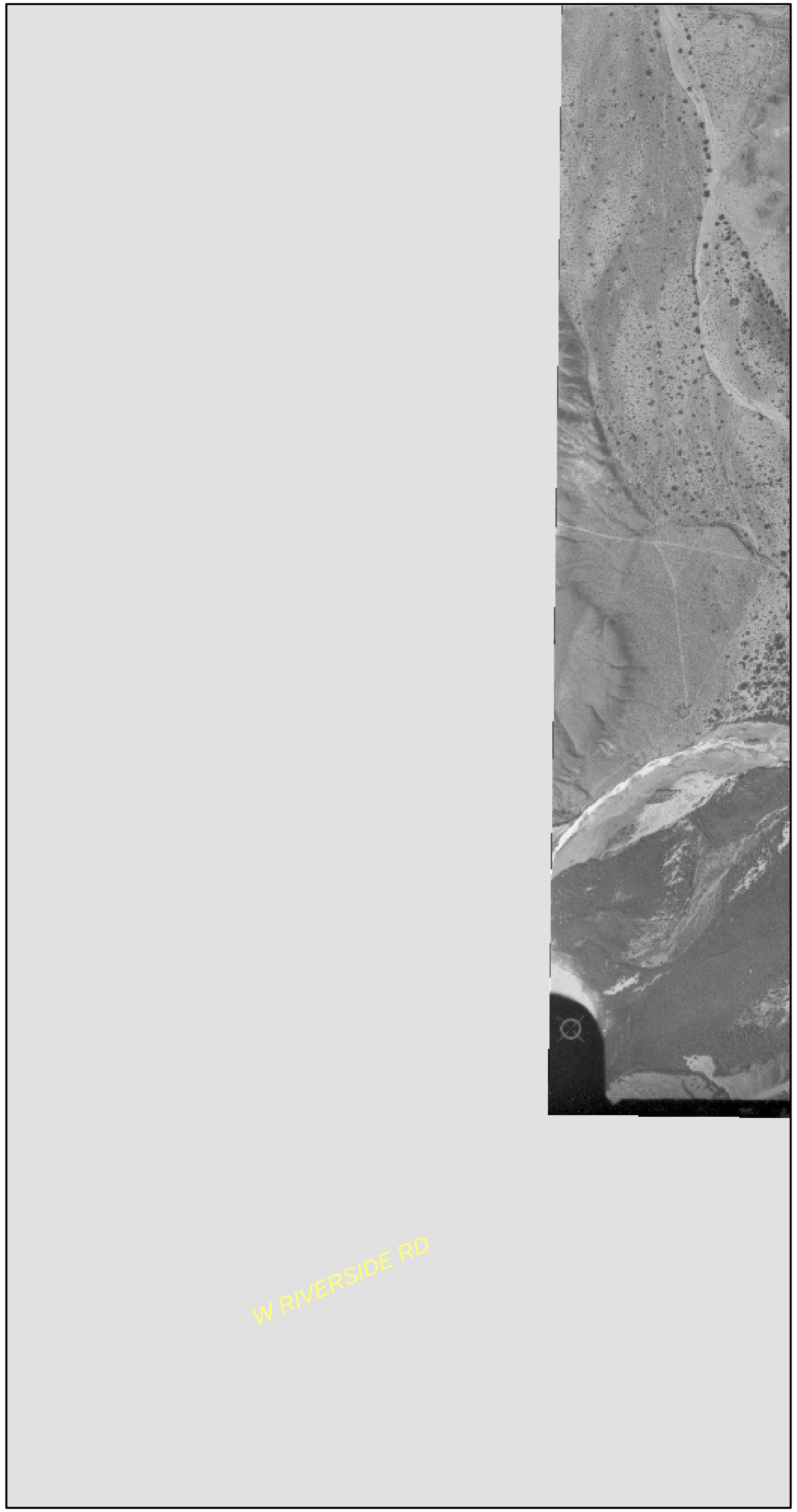
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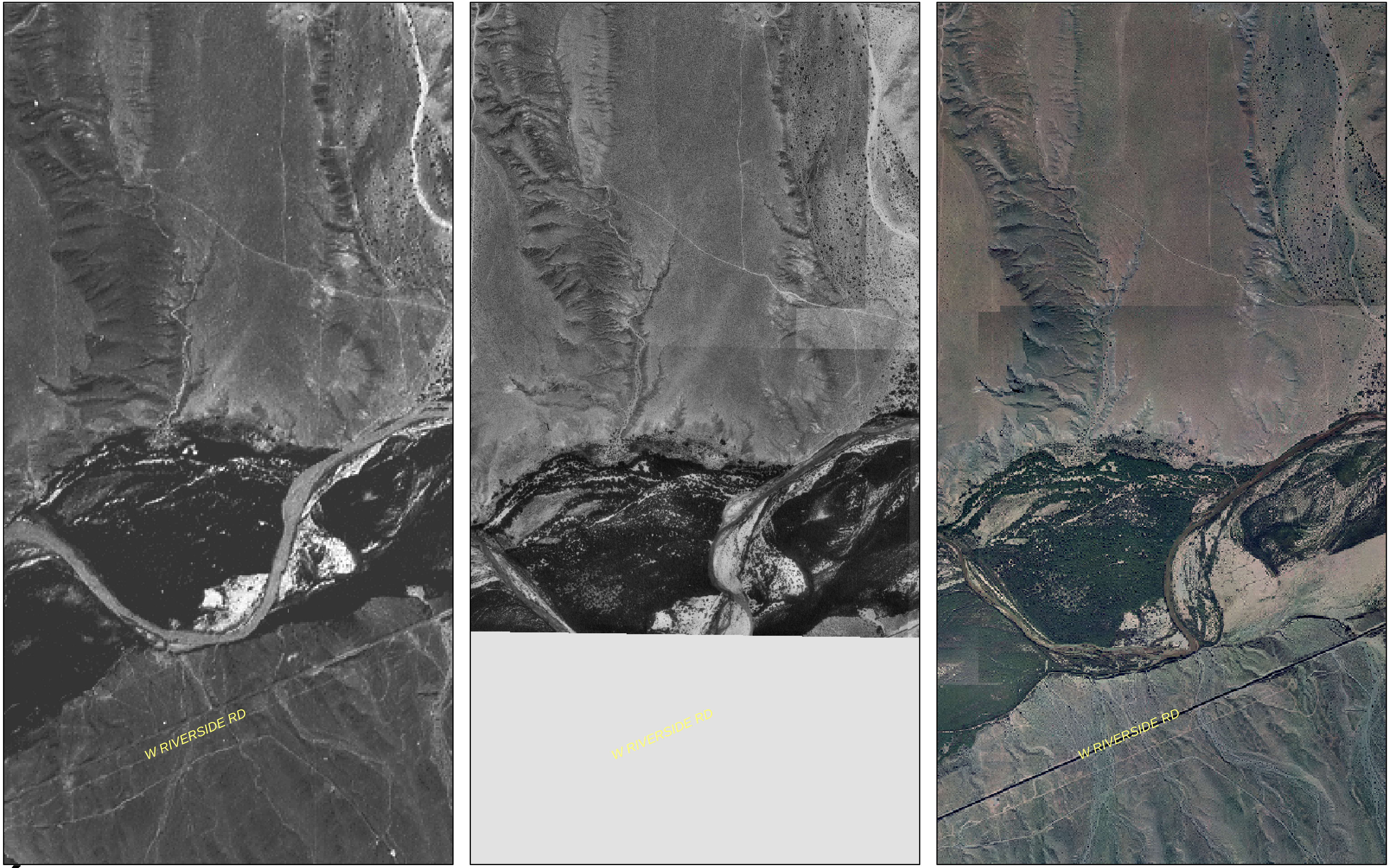
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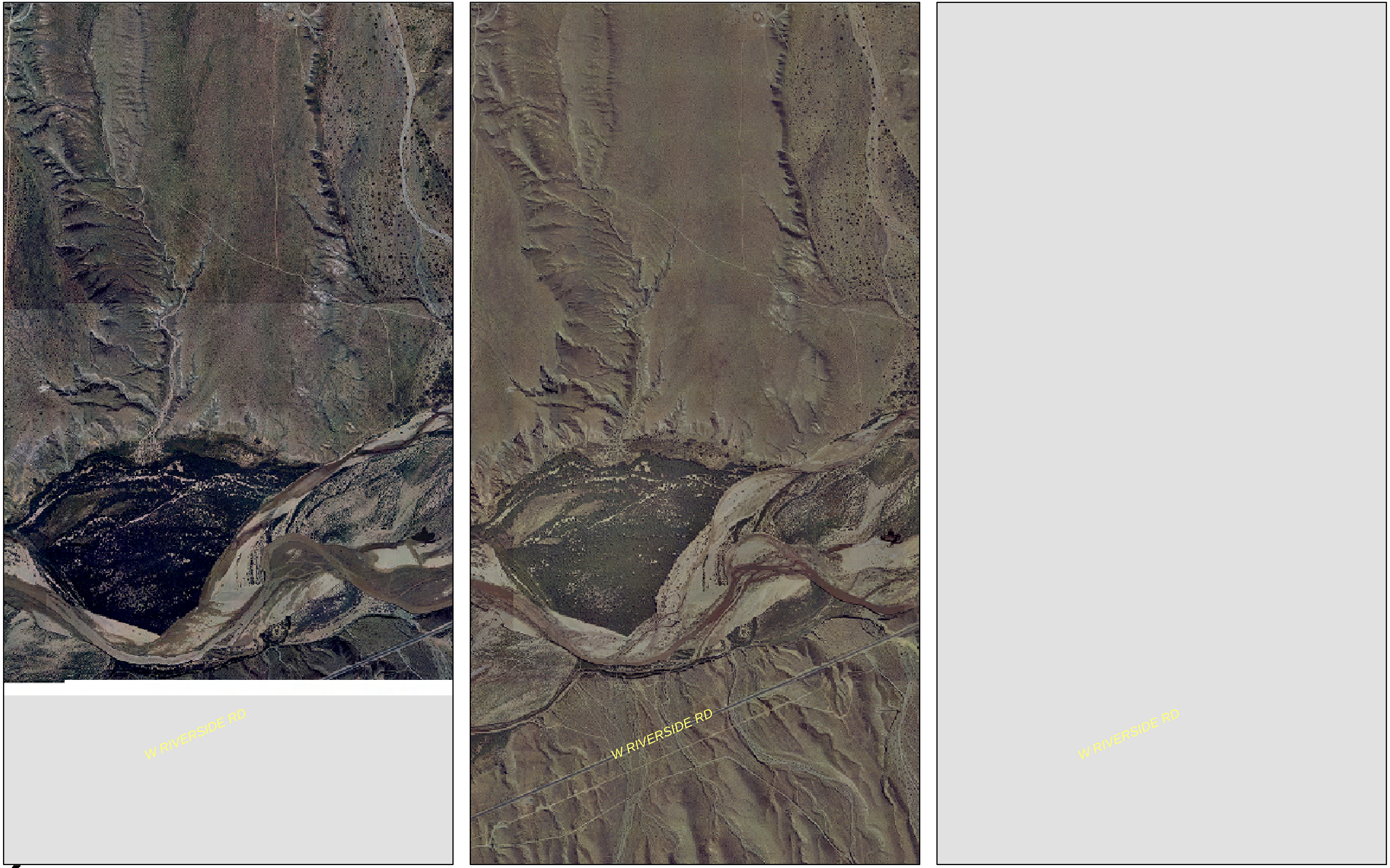
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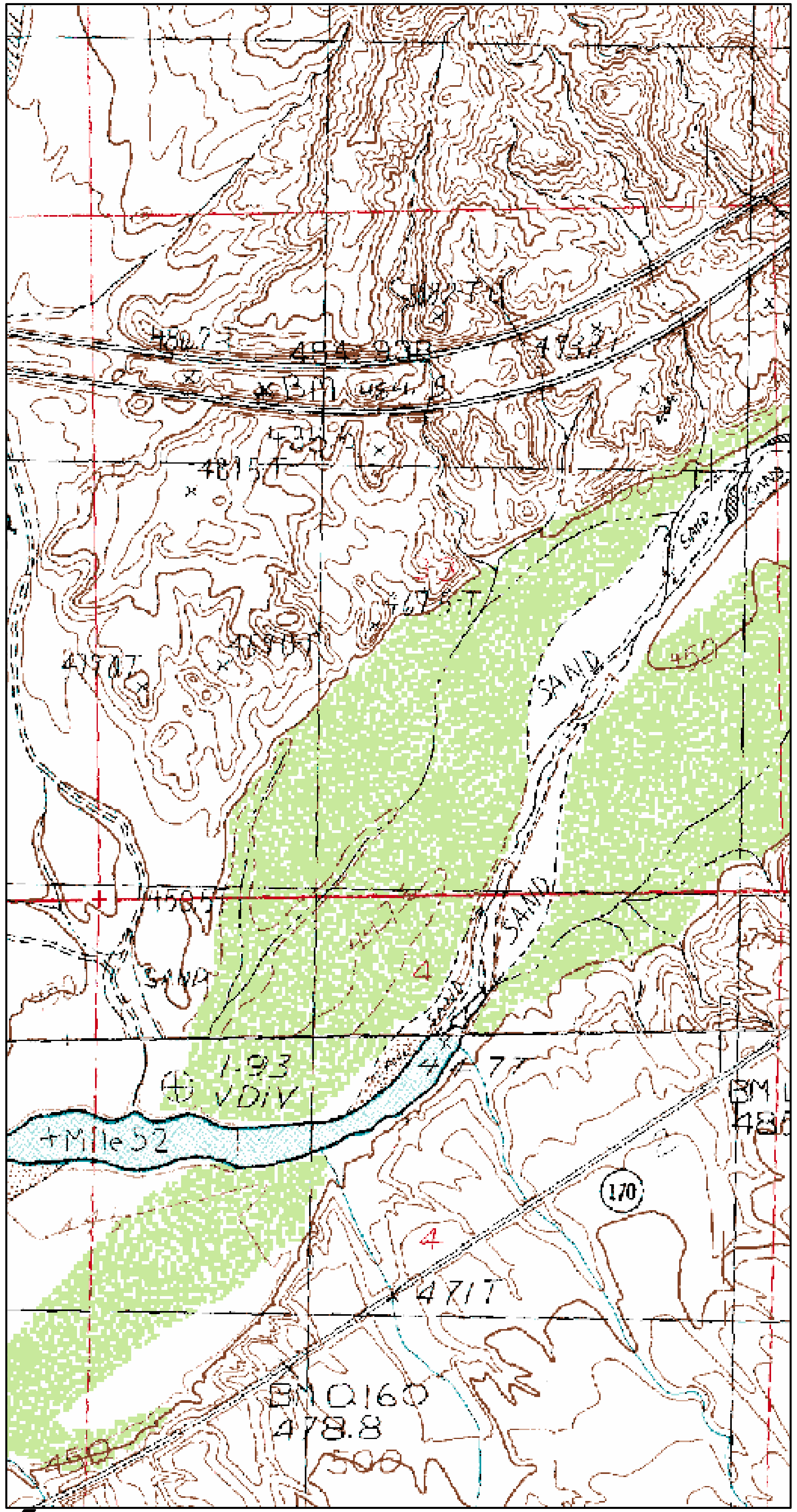
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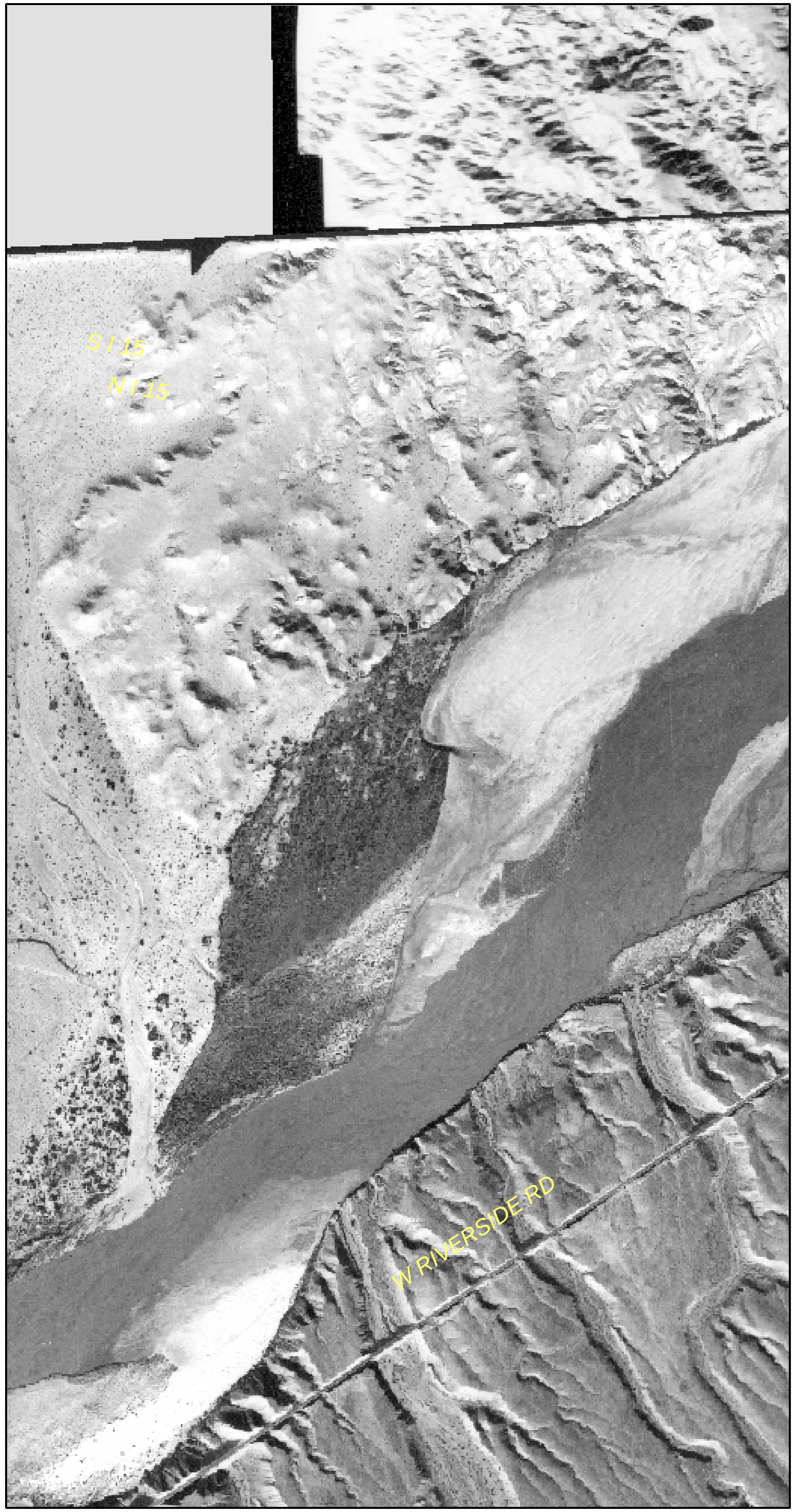
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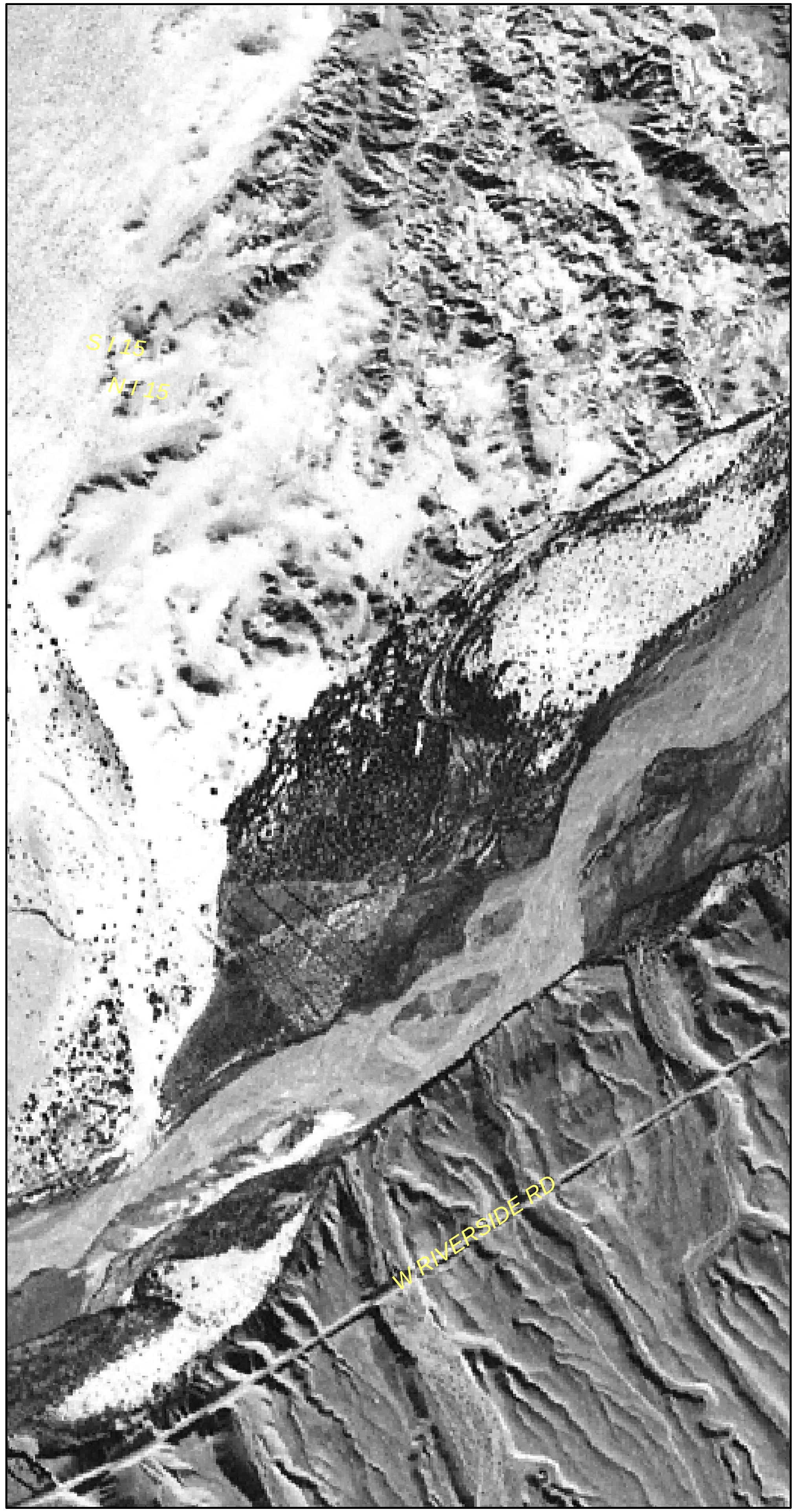
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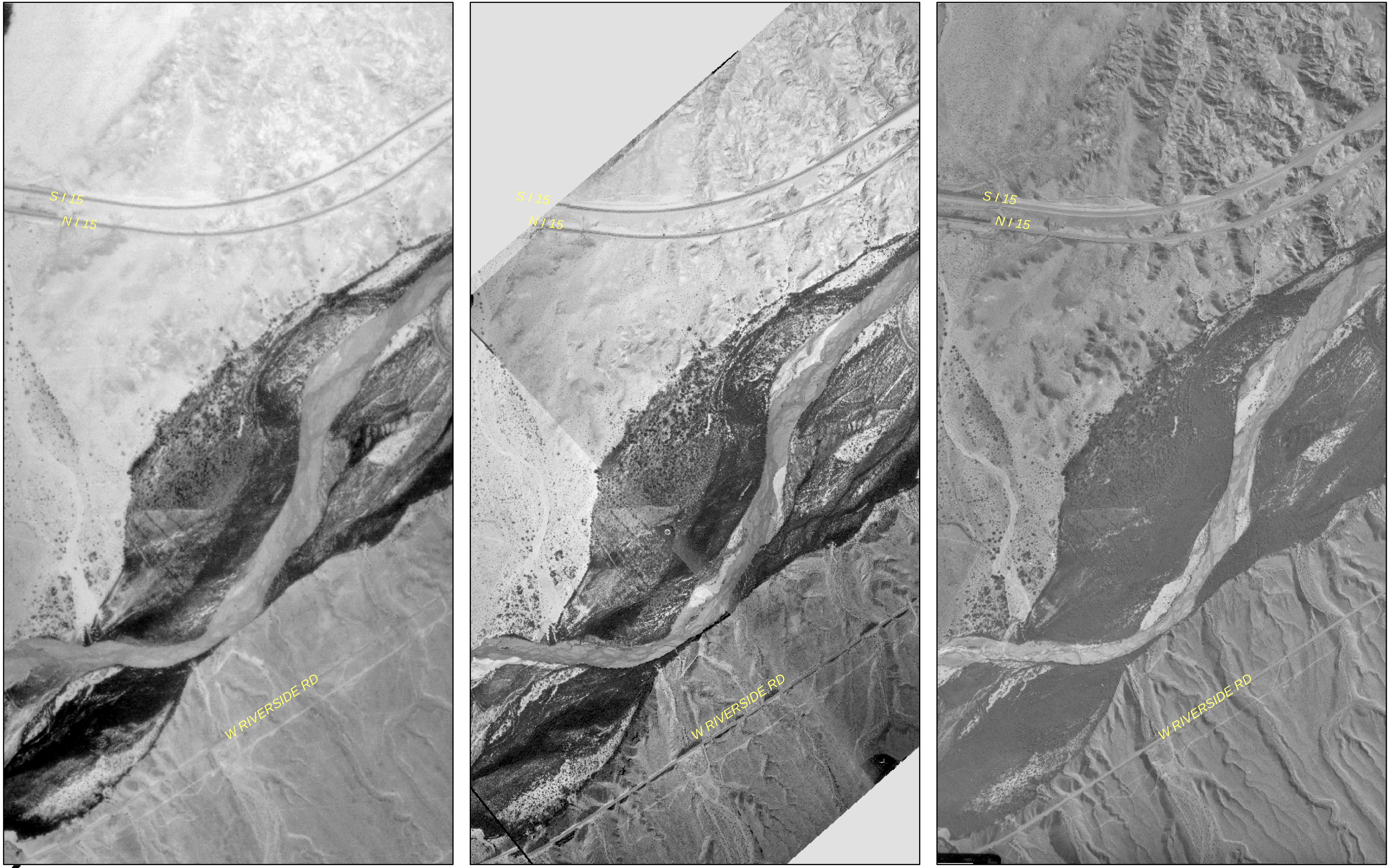
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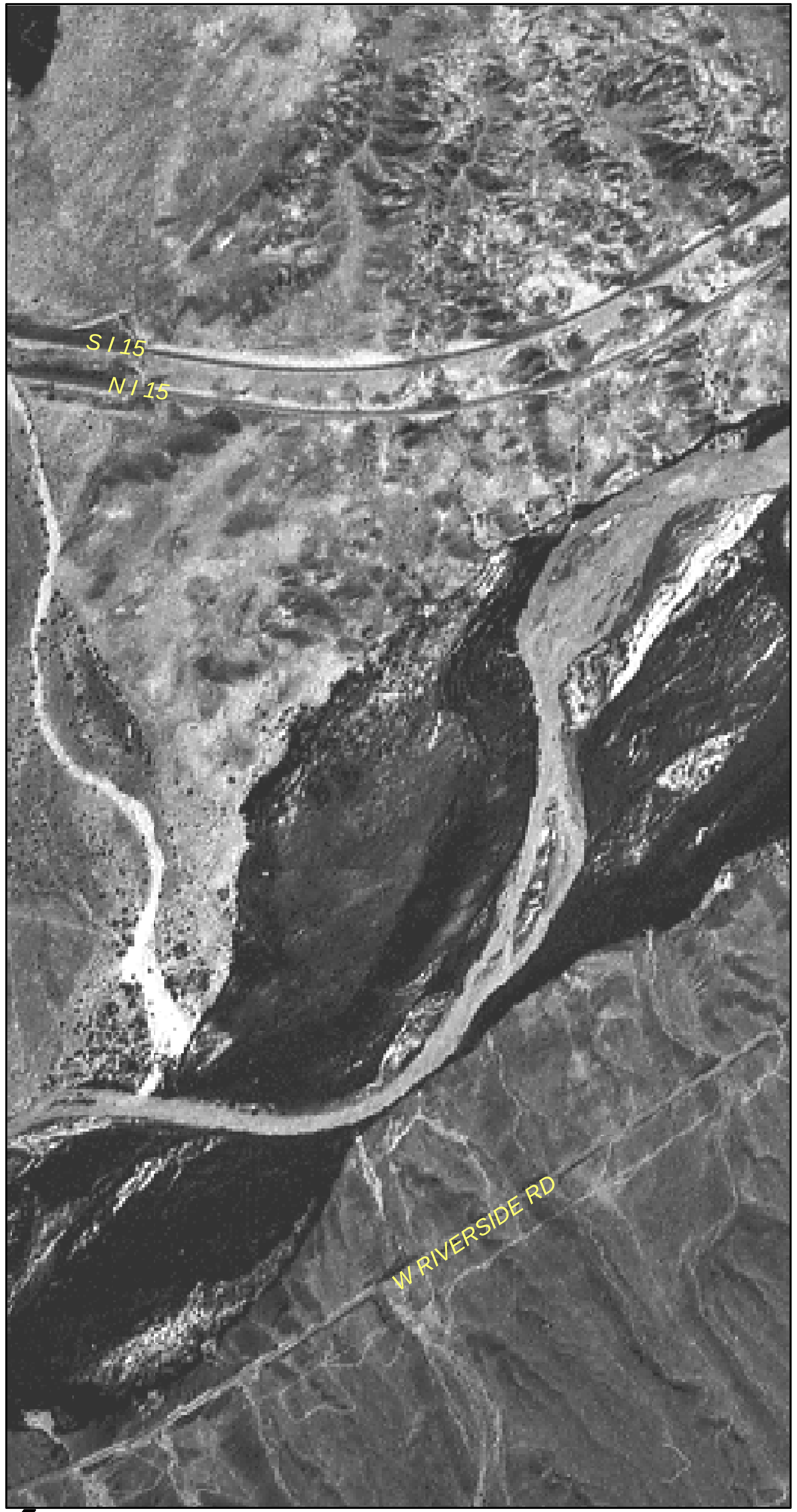
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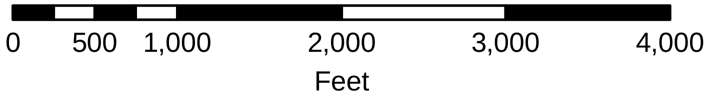
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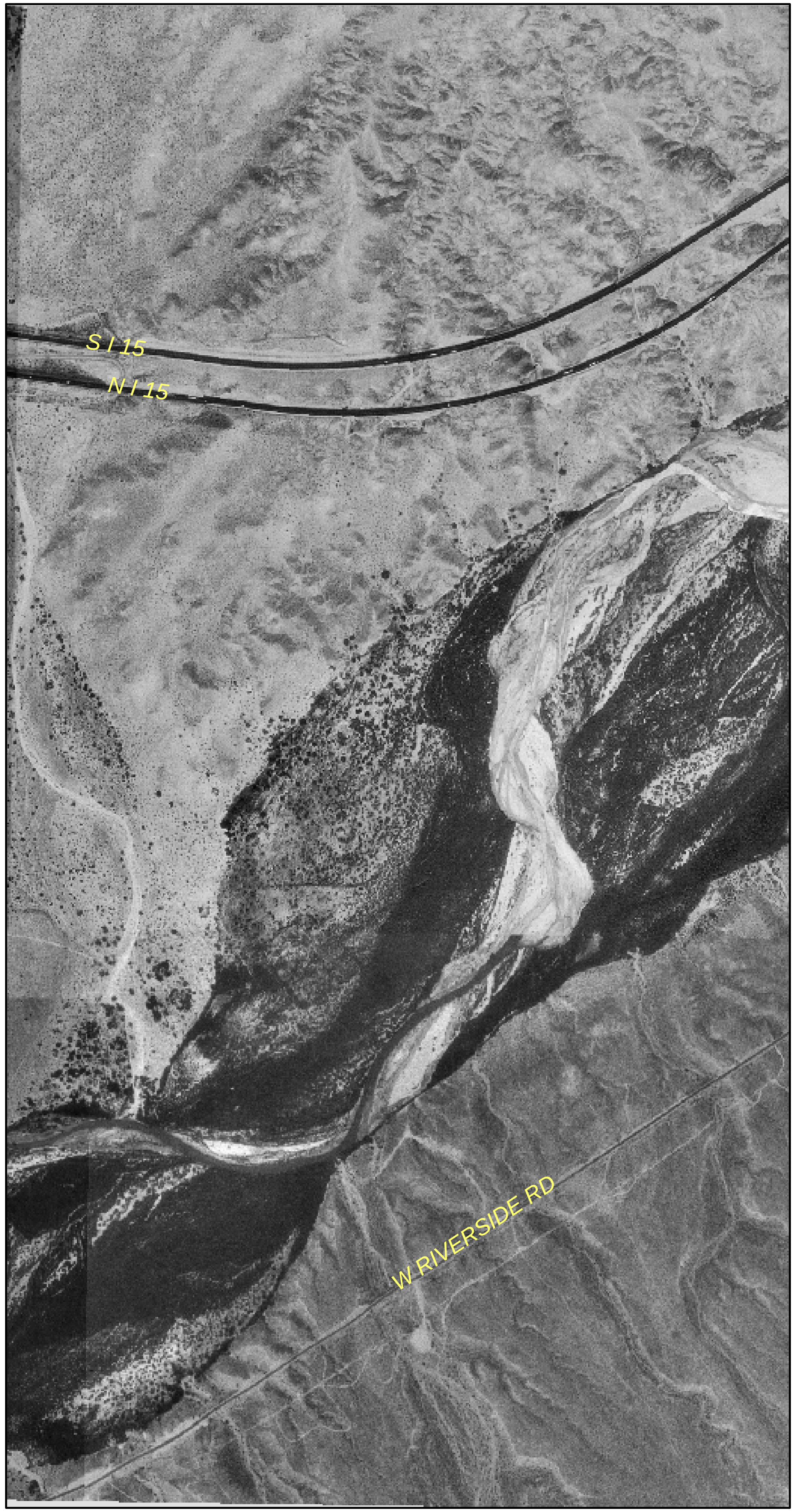
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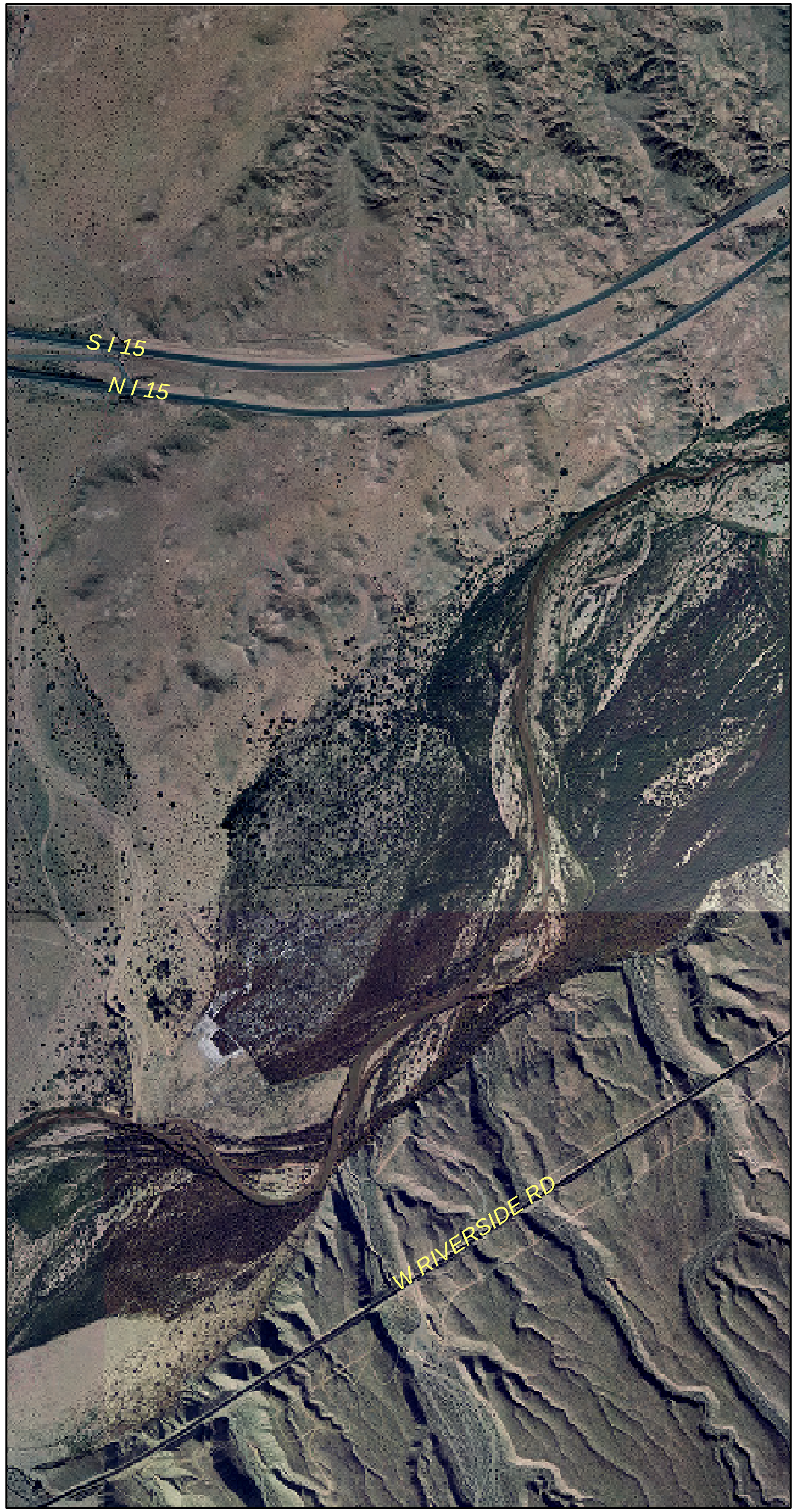
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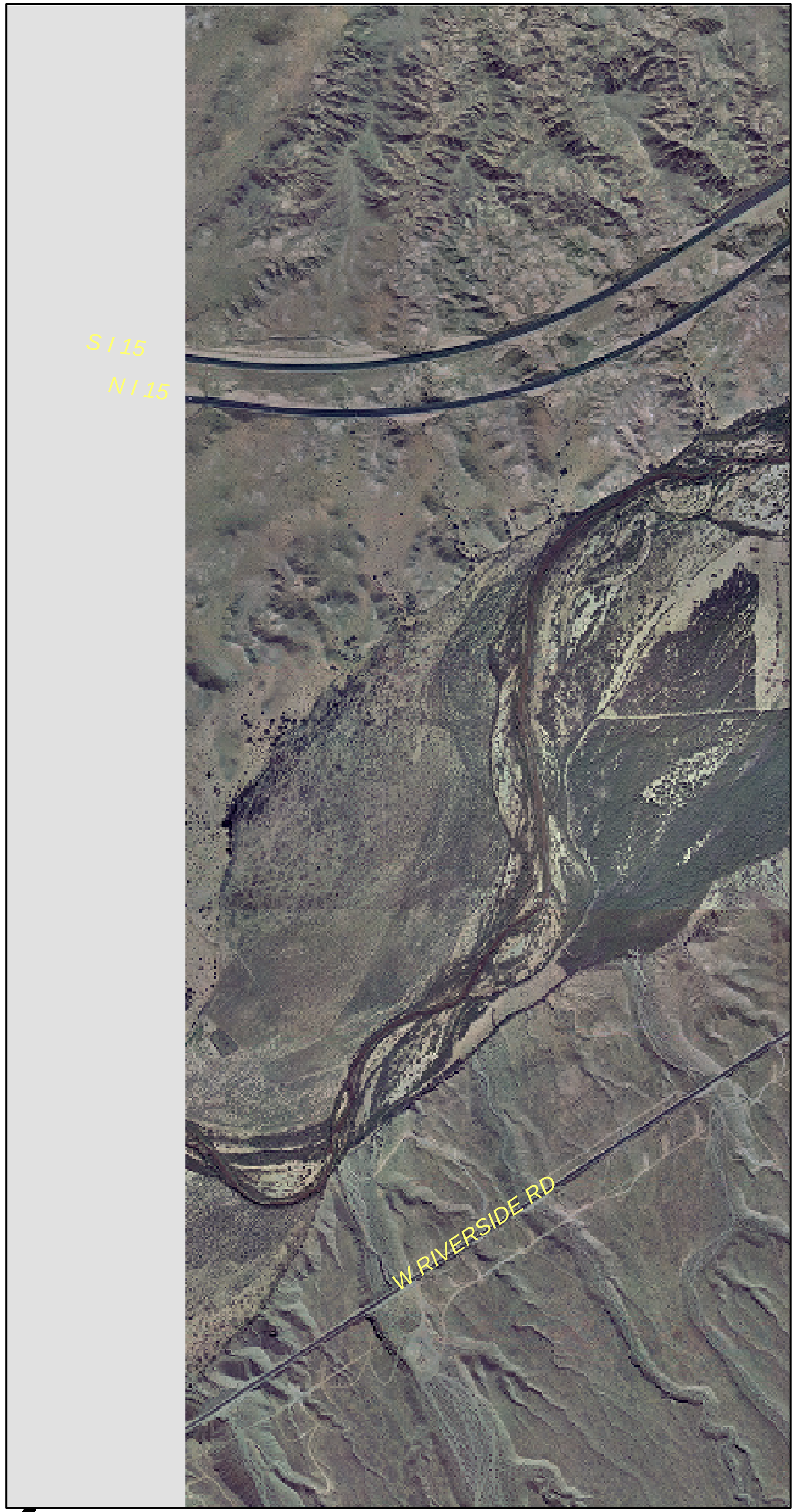
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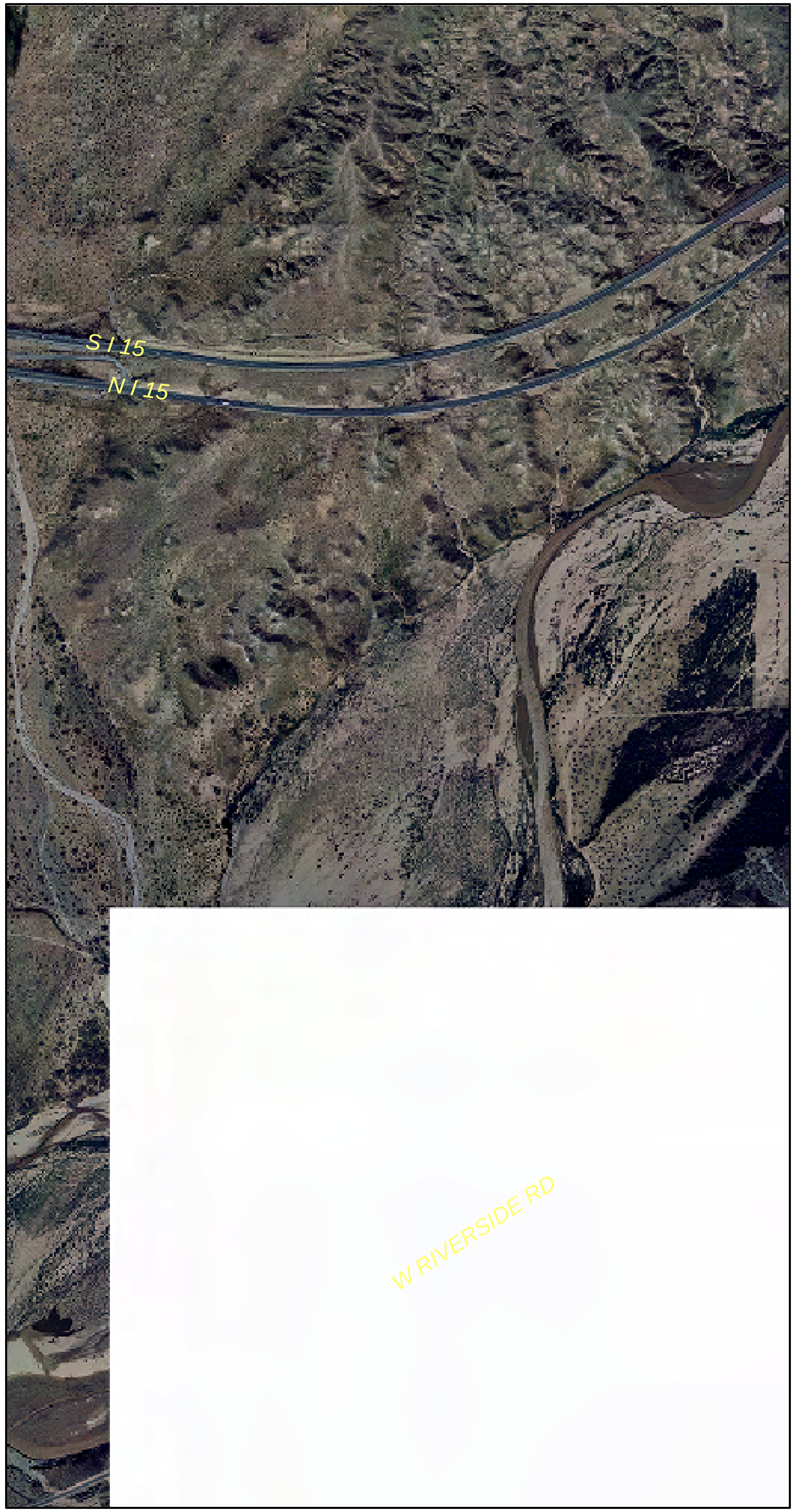
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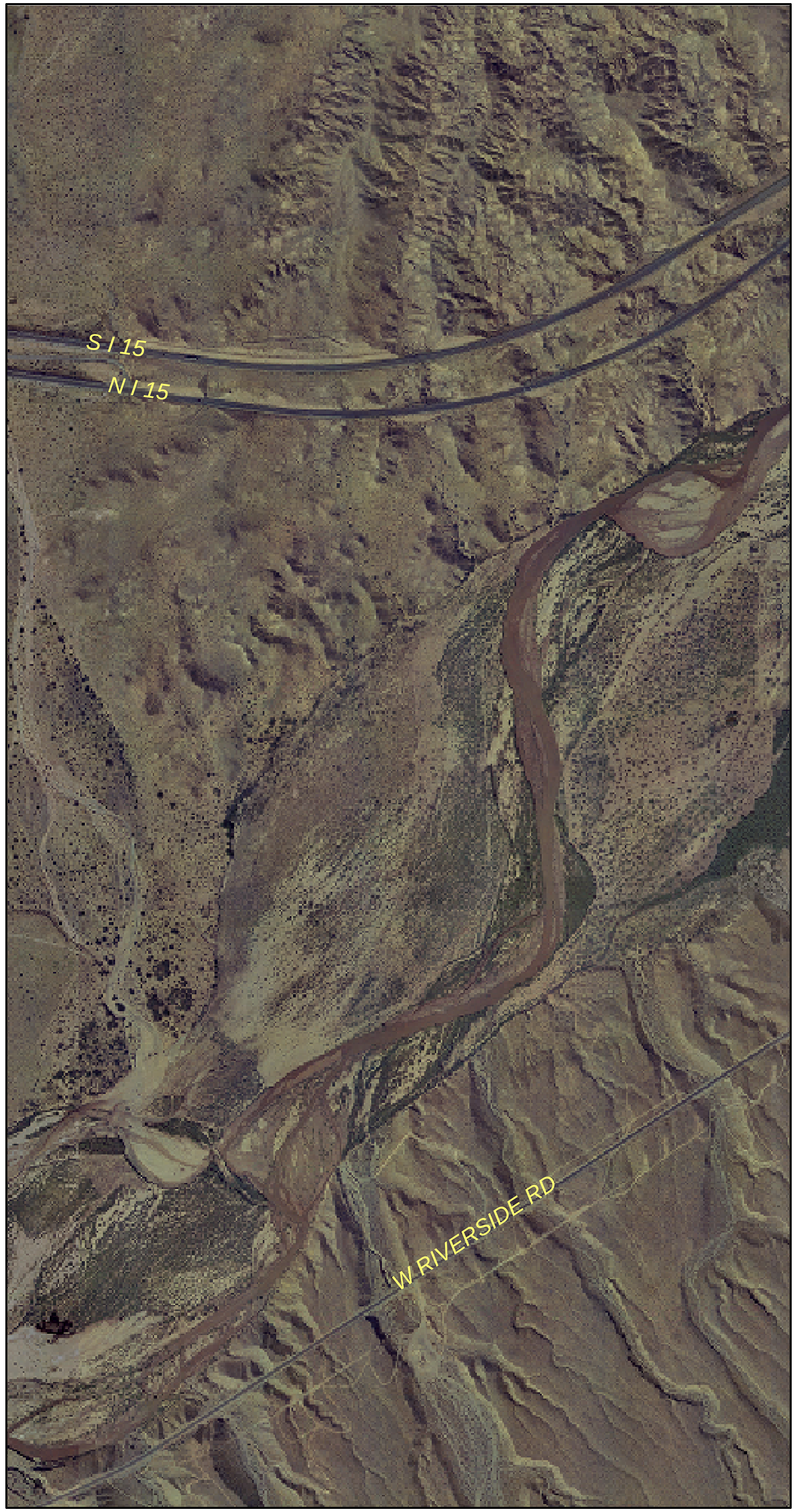
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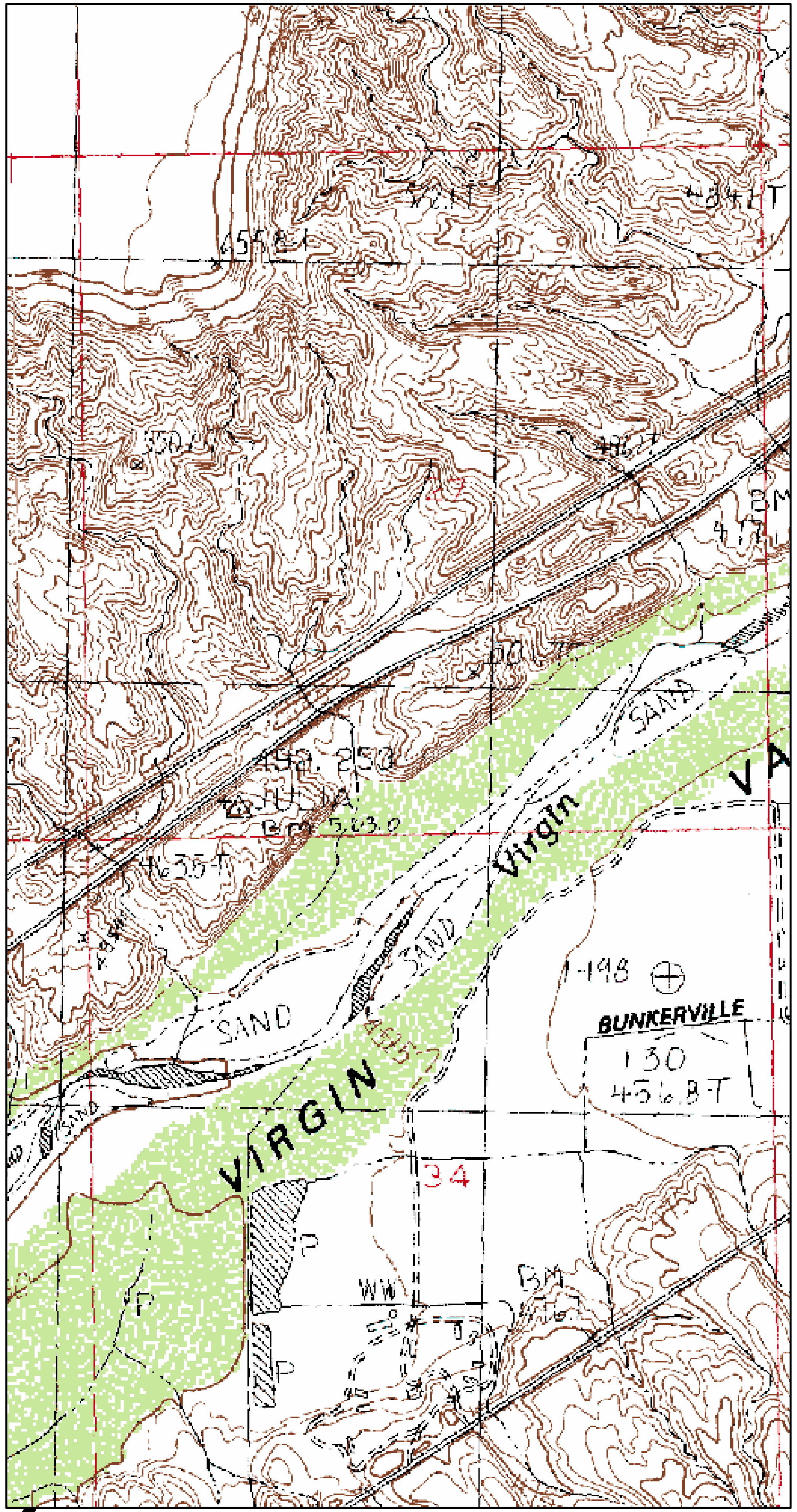
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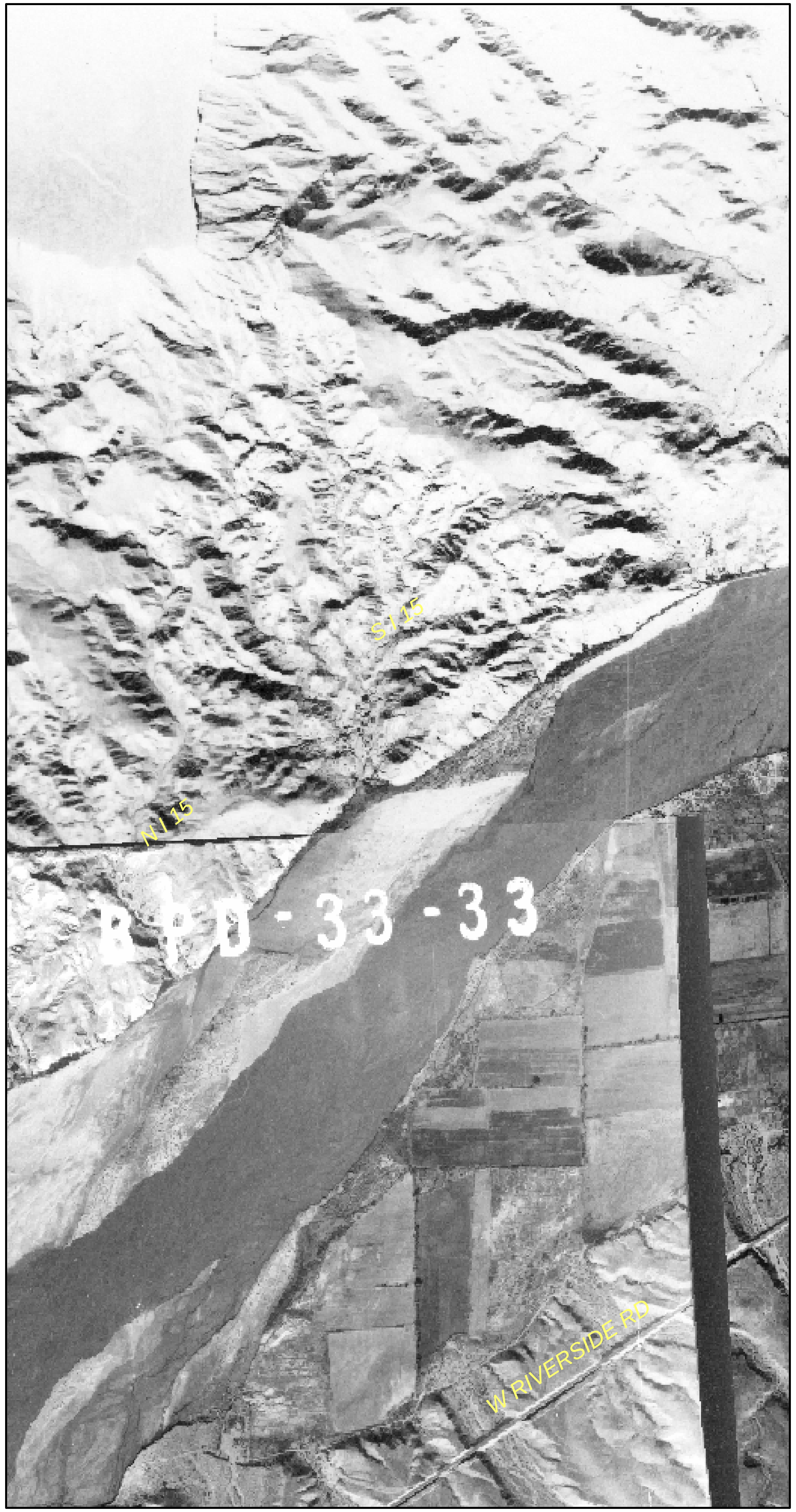
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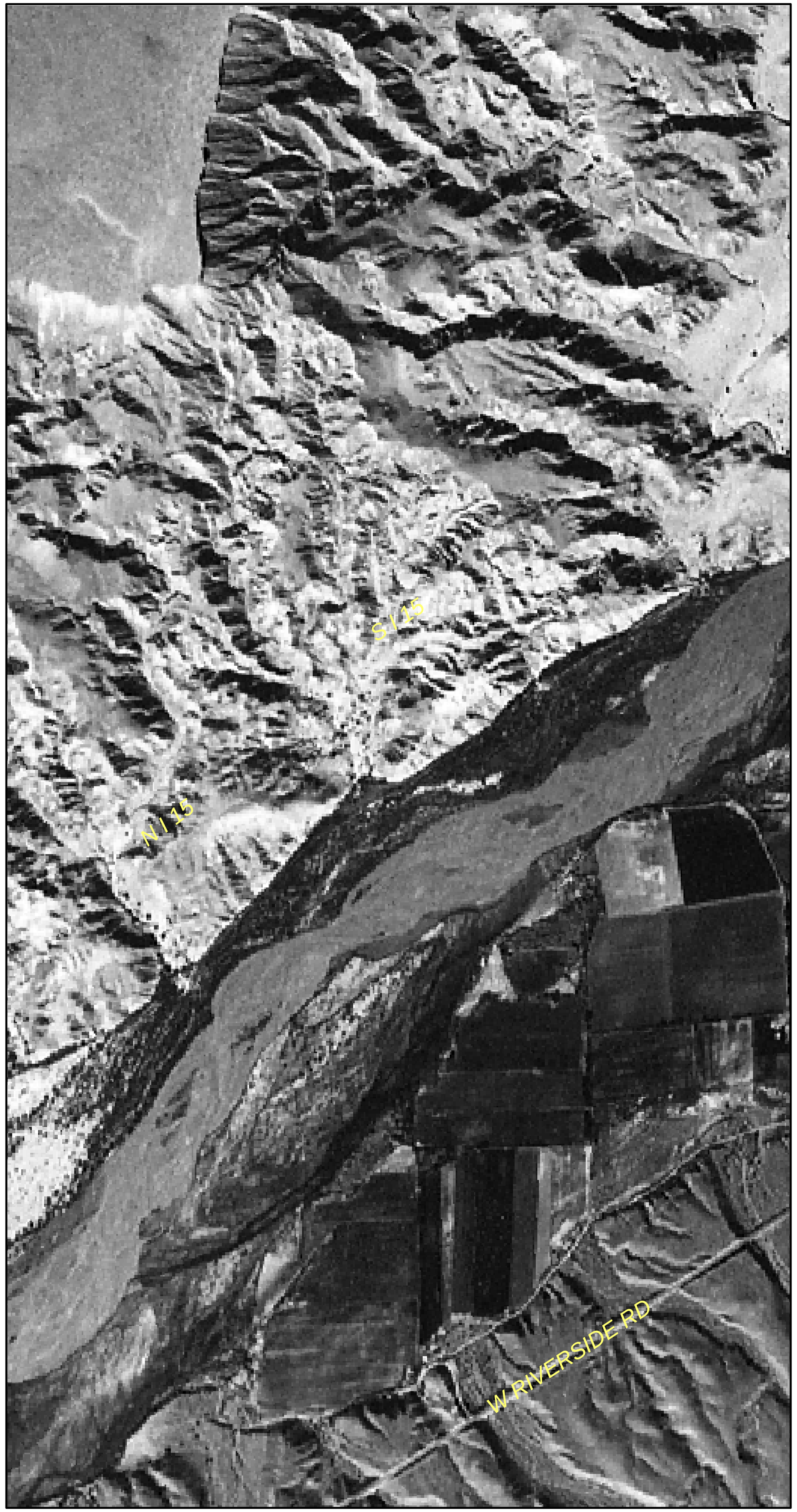
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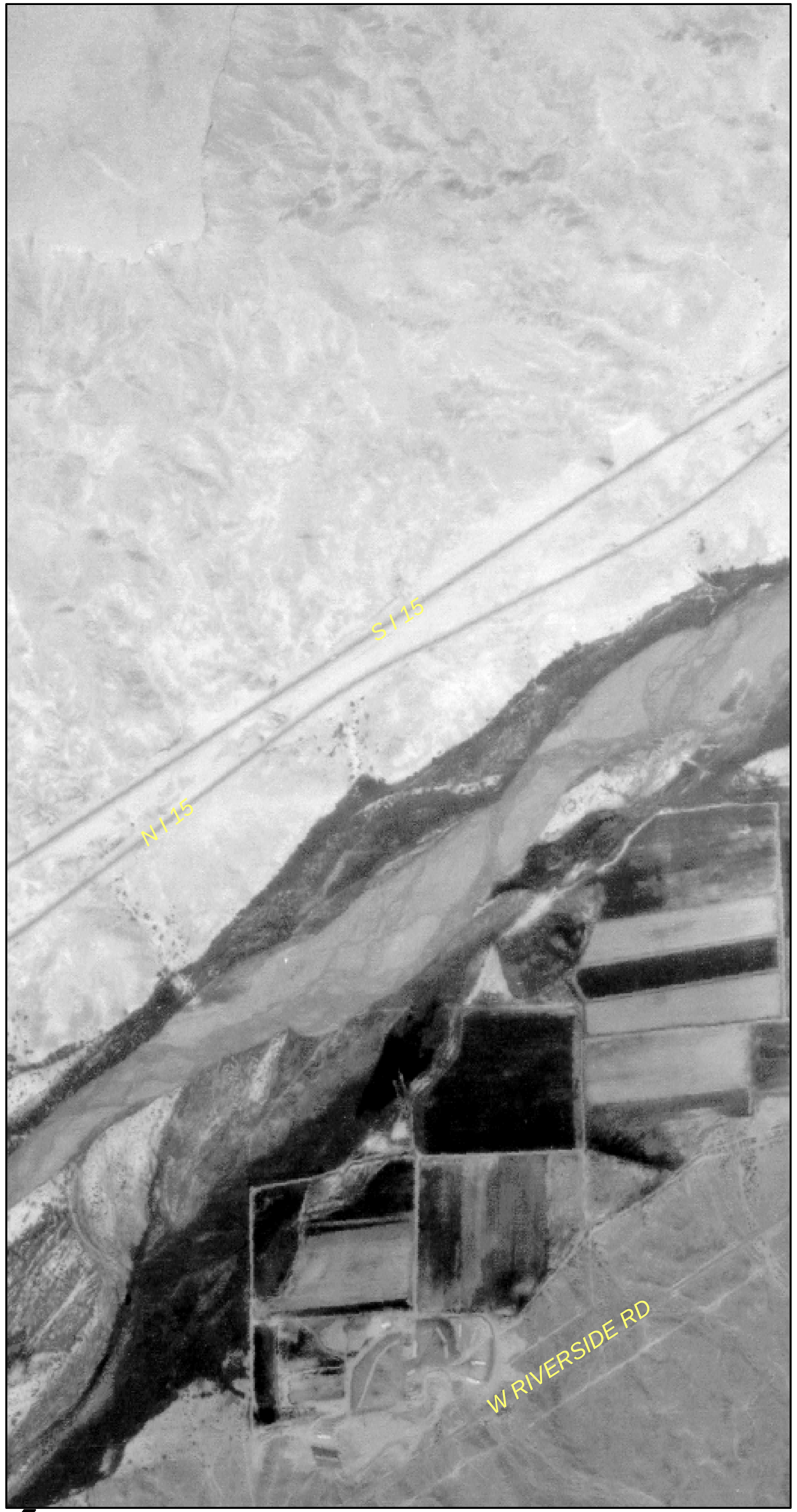
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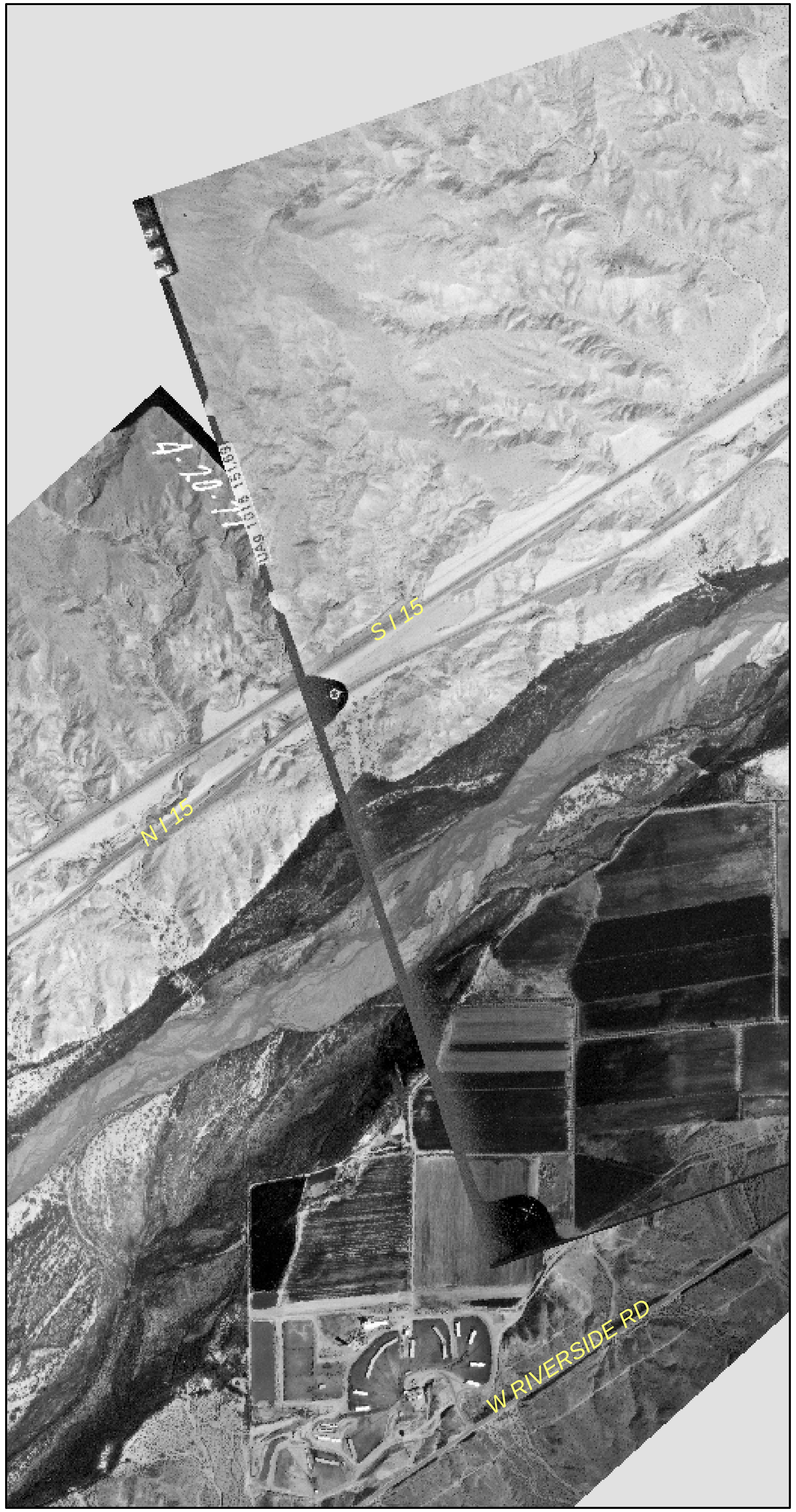
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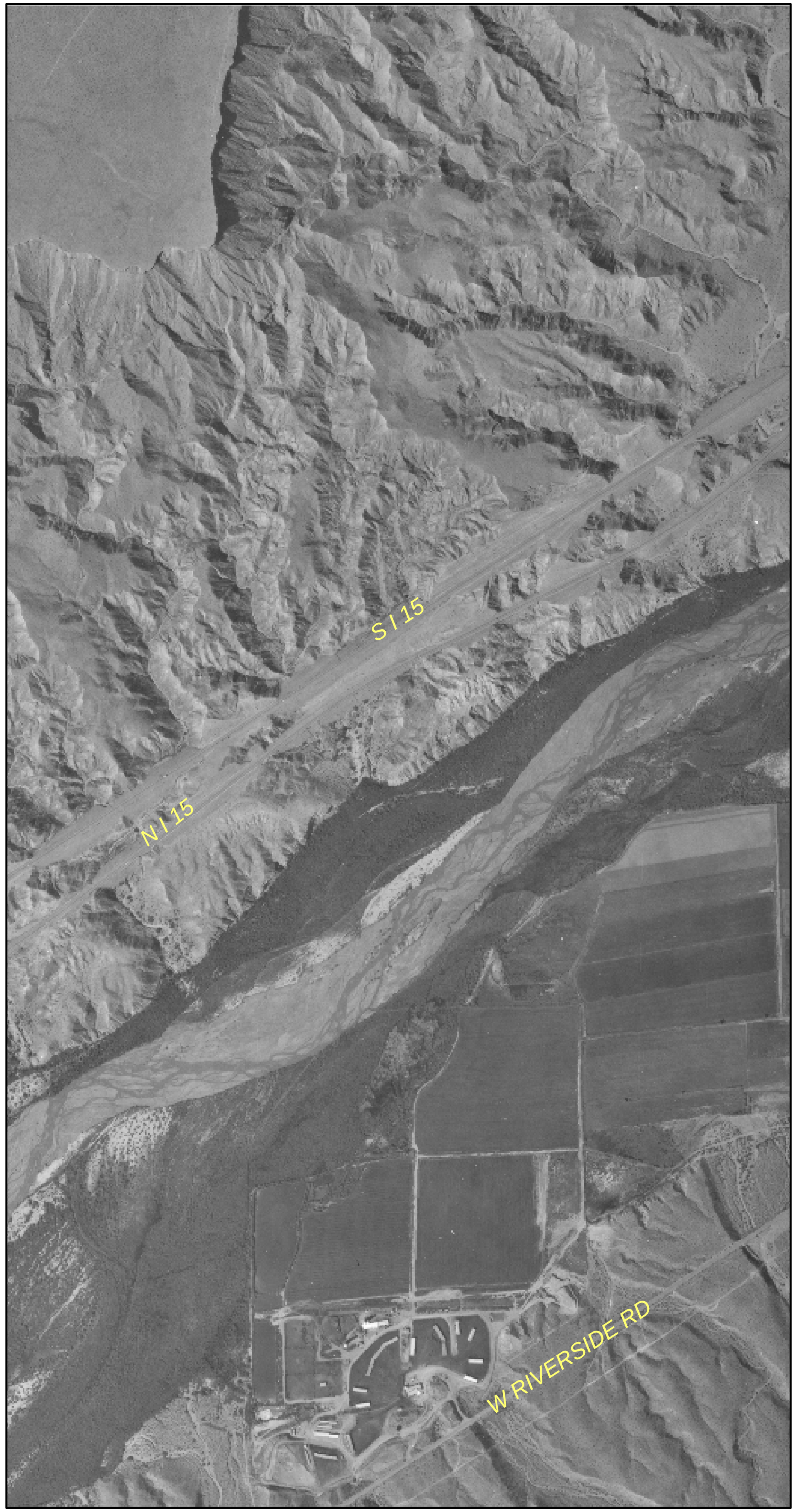
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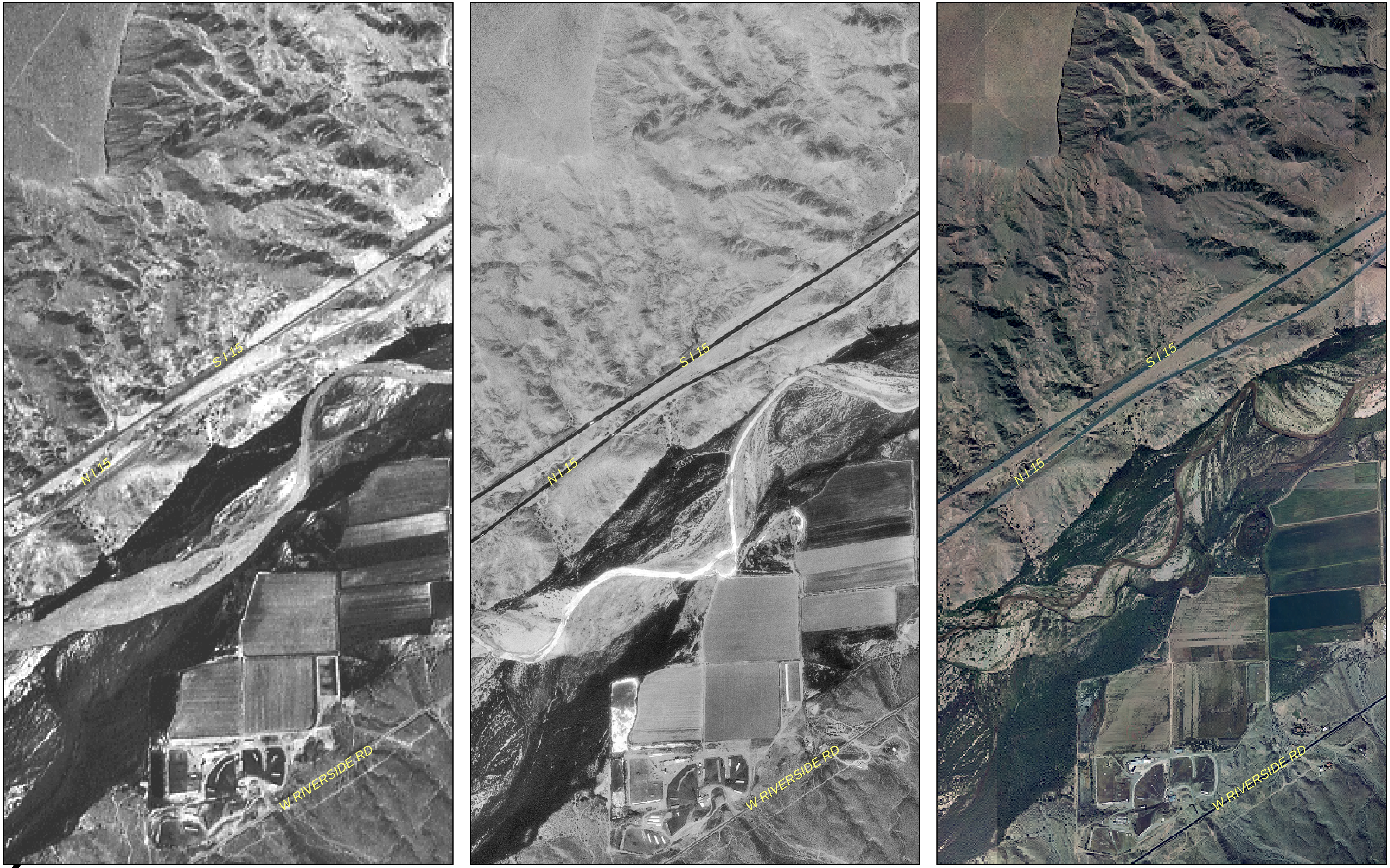
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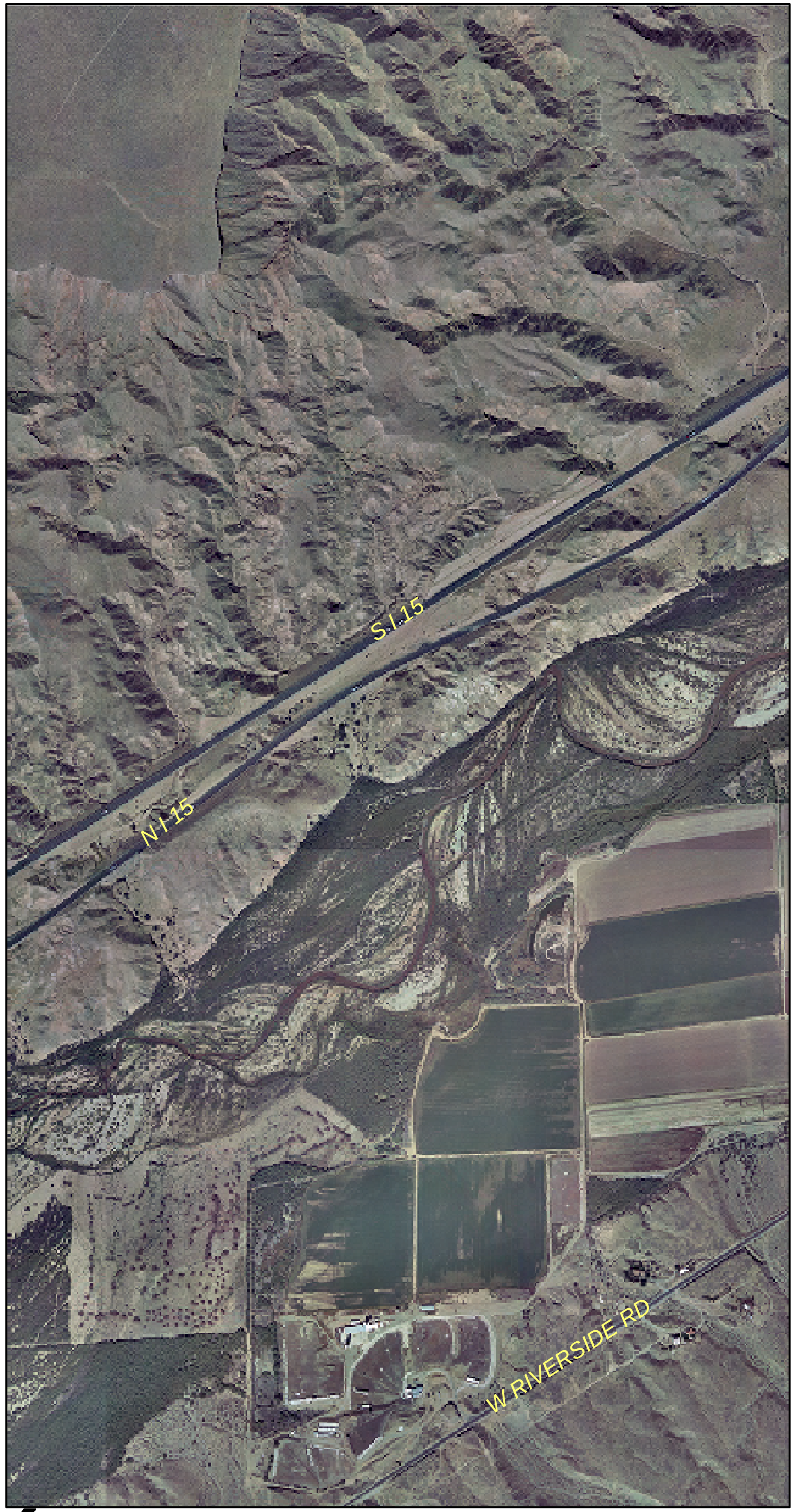
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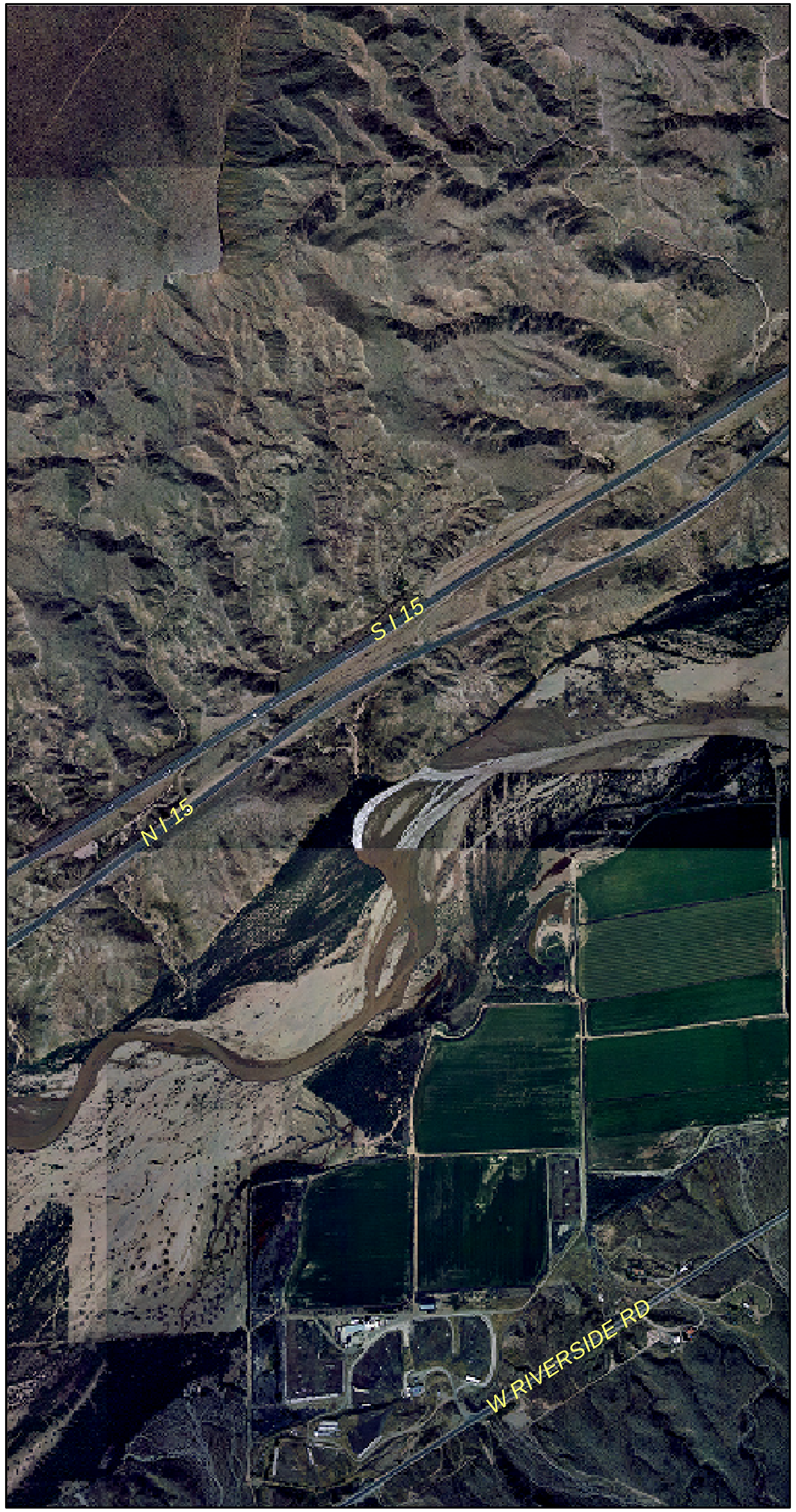
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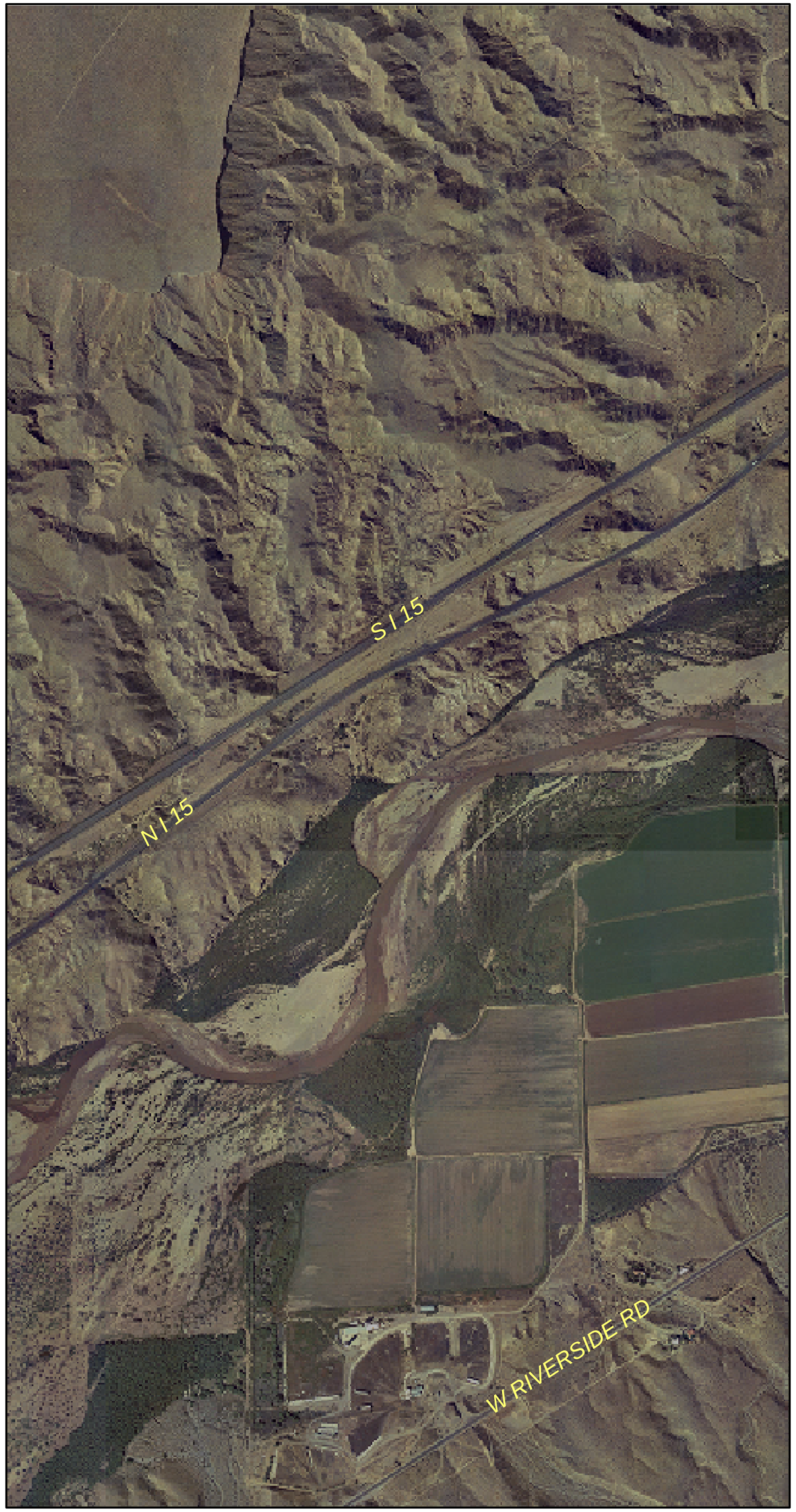
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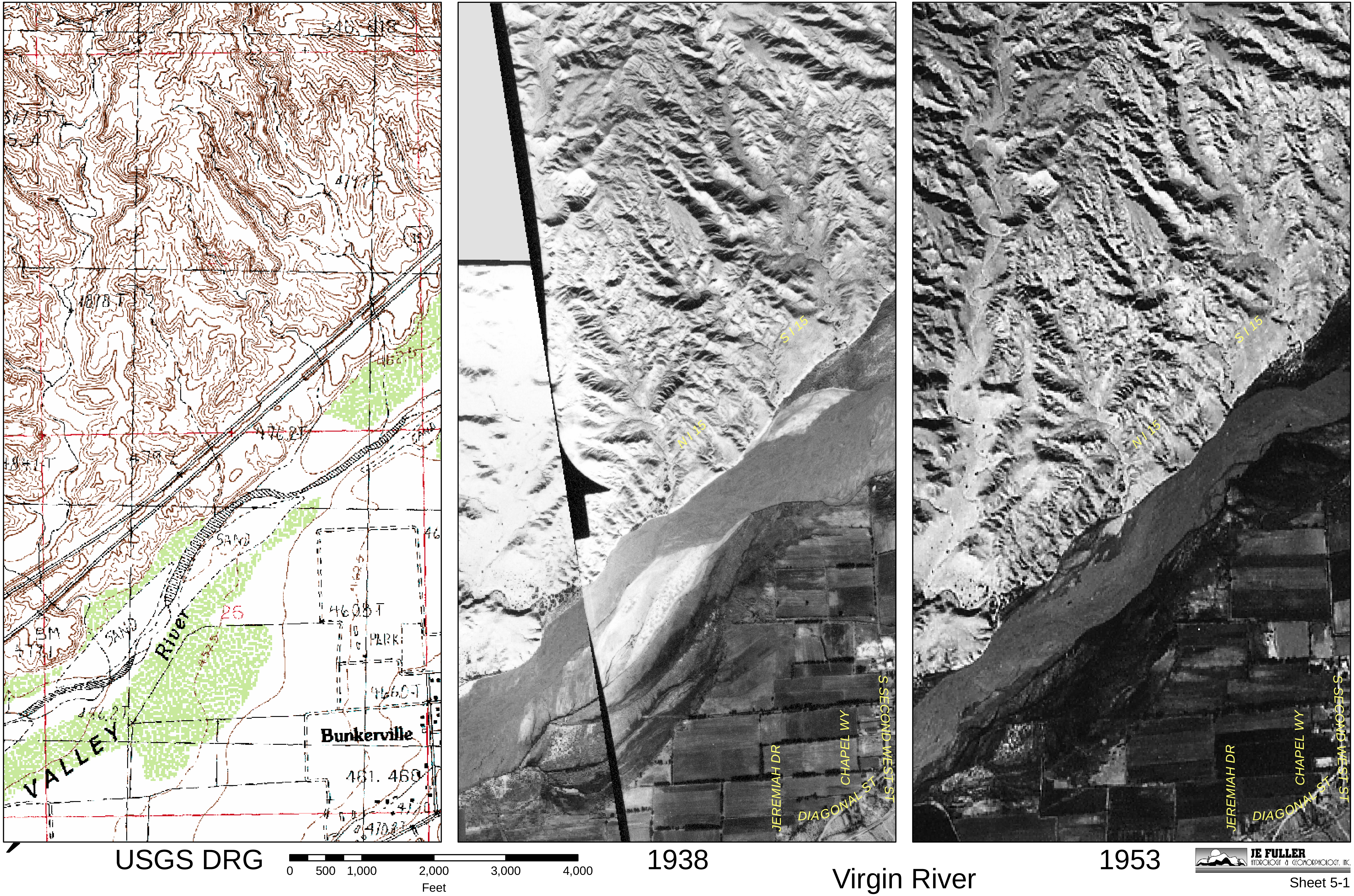
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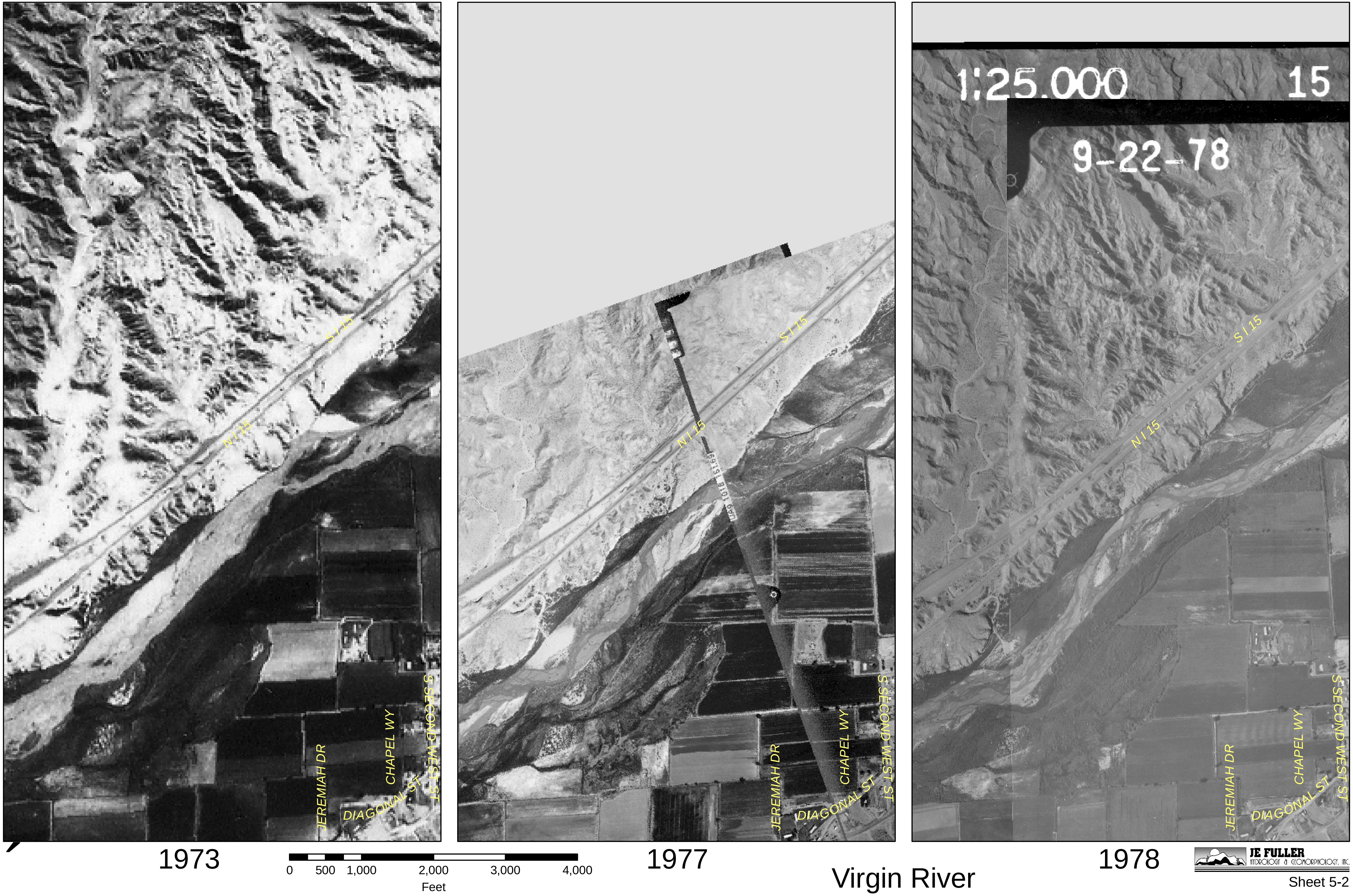

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Feet

1973

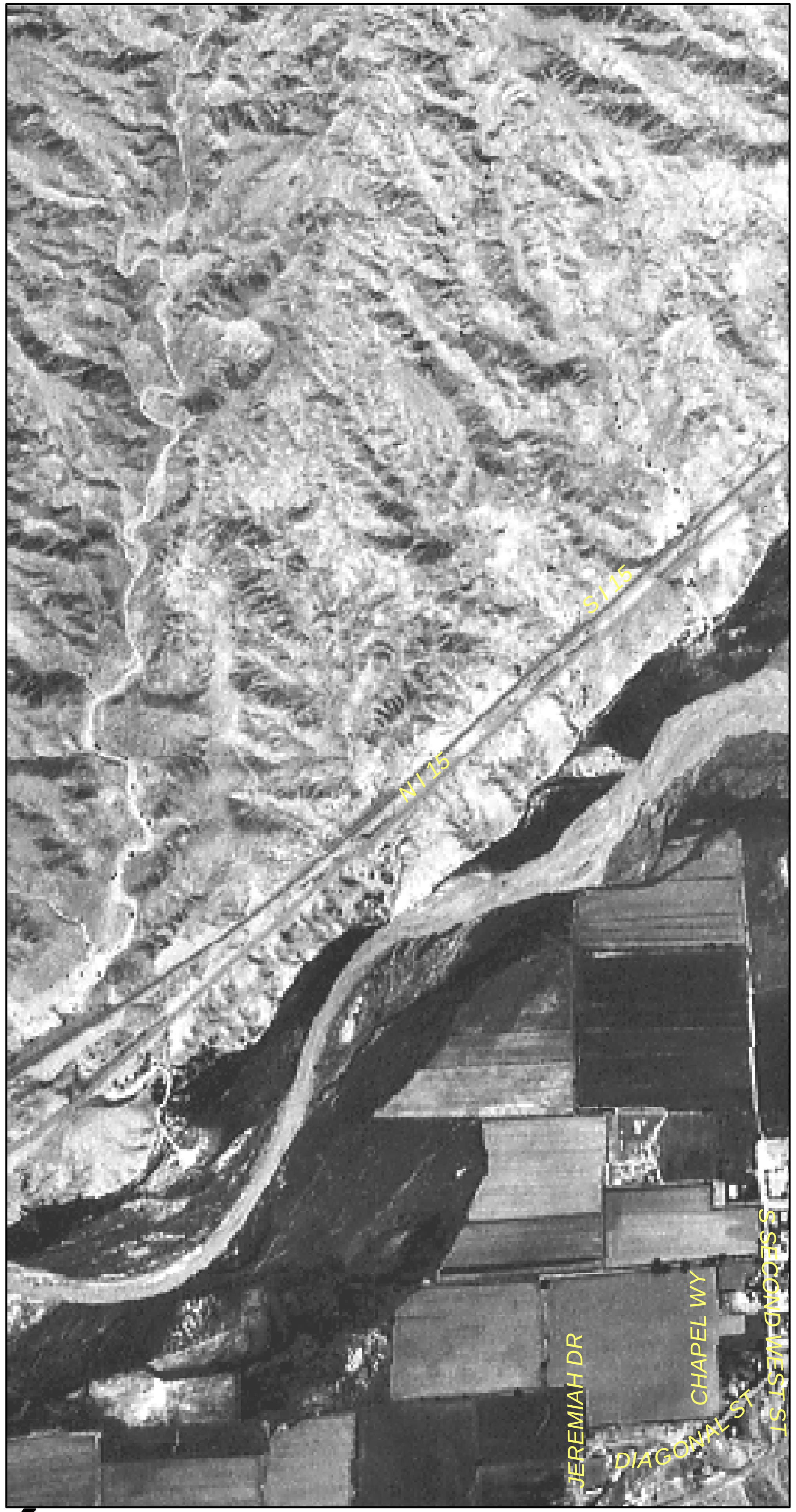
1977

1978

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 5-2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1984

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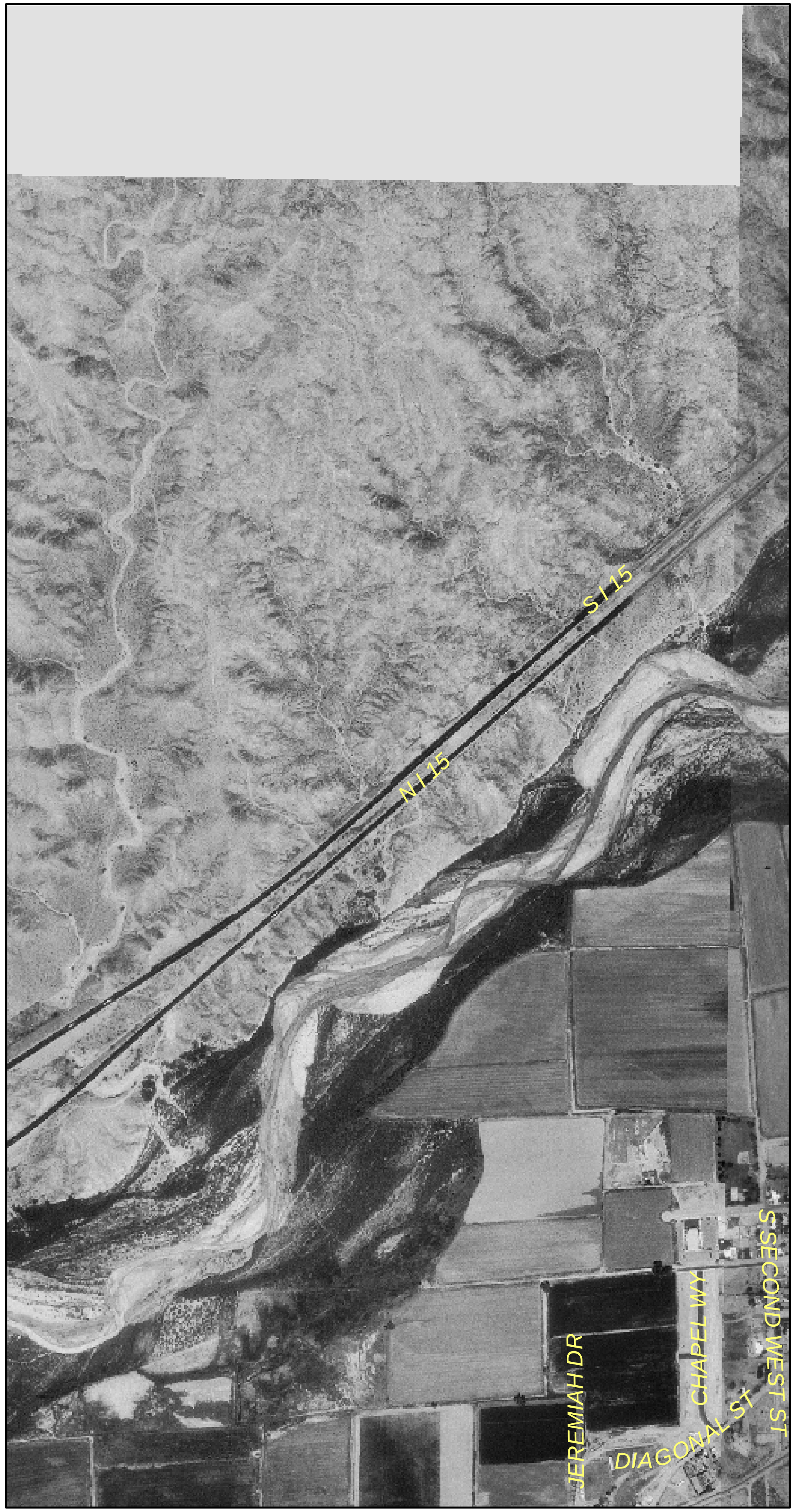
Feet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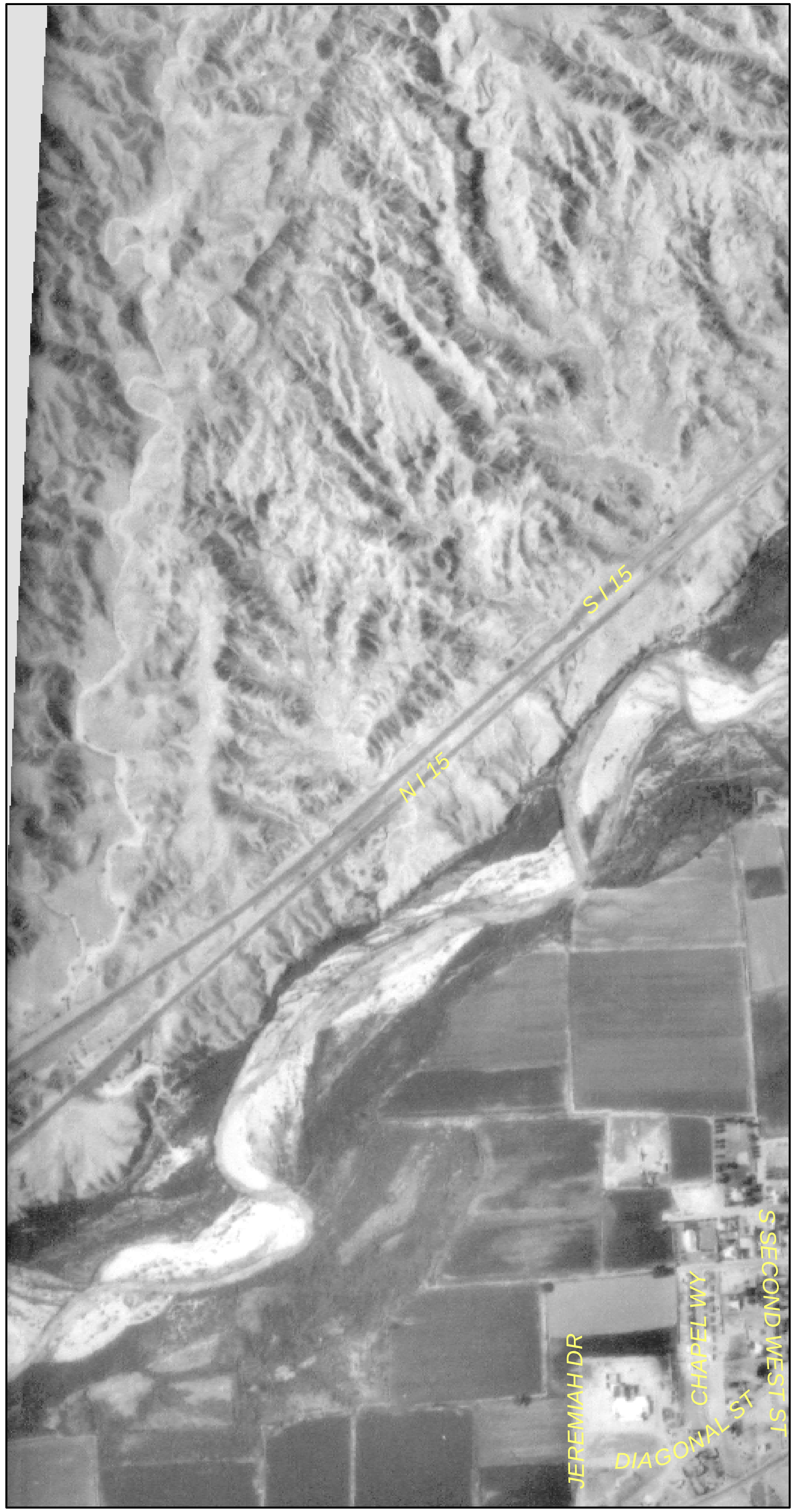
1994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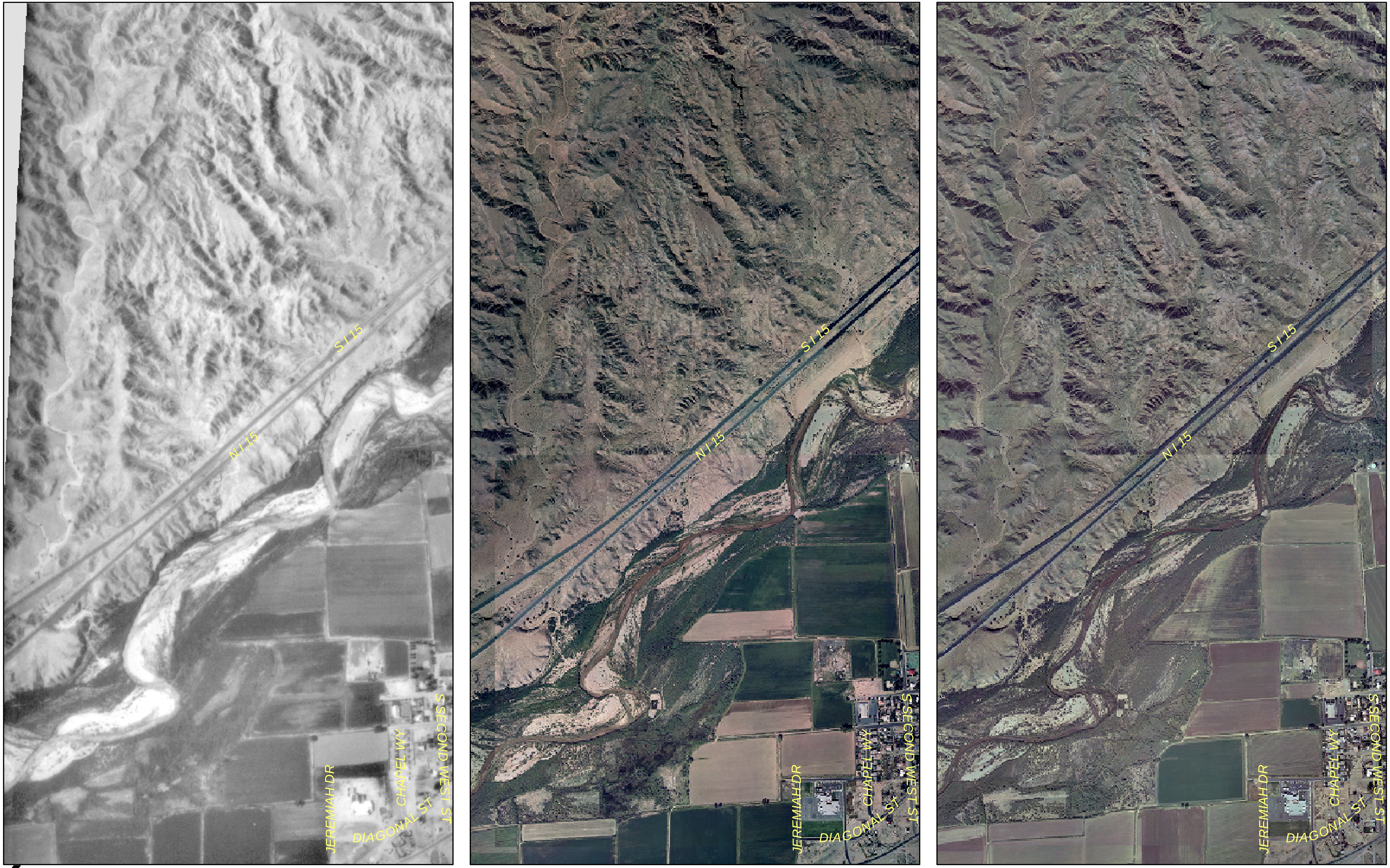
1995

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 5-3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DIAGONAL ST
S SECOND WEST ST
S I 15
N I 15
JEREMIAH DR
CHAPEL WY
DIAGONAL ST
S SECOND WEST ST

1997

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Feet

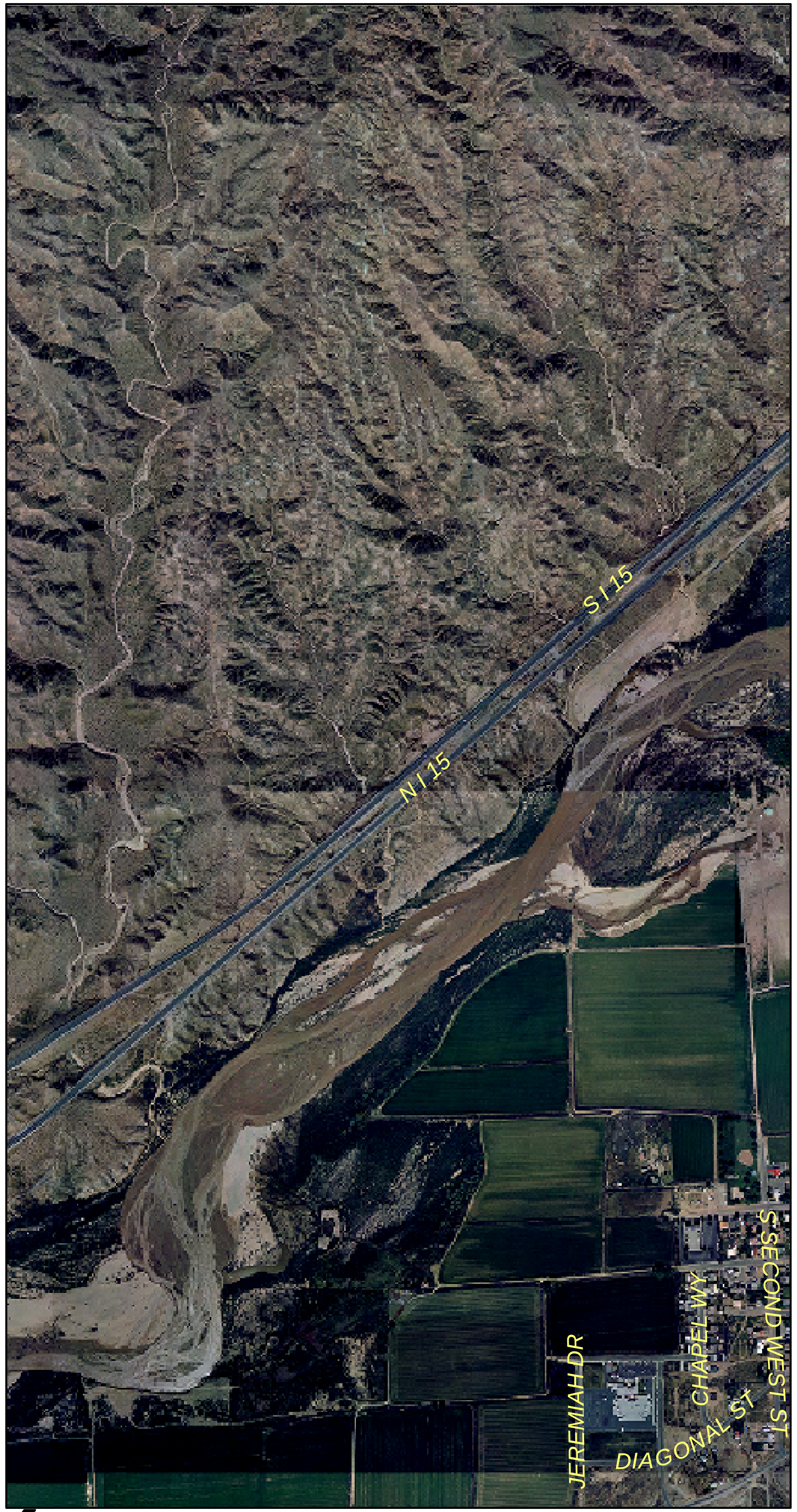
Fall 2002

Fall 2004

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Virgin River

Sheet 5-4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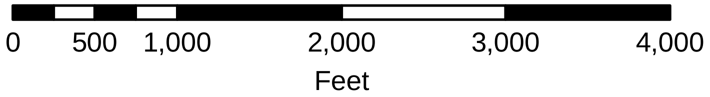
JEREMIAH DR
CHAPEL WY
DIAGONAL ST
S SECOND WEST ST

Spring 2005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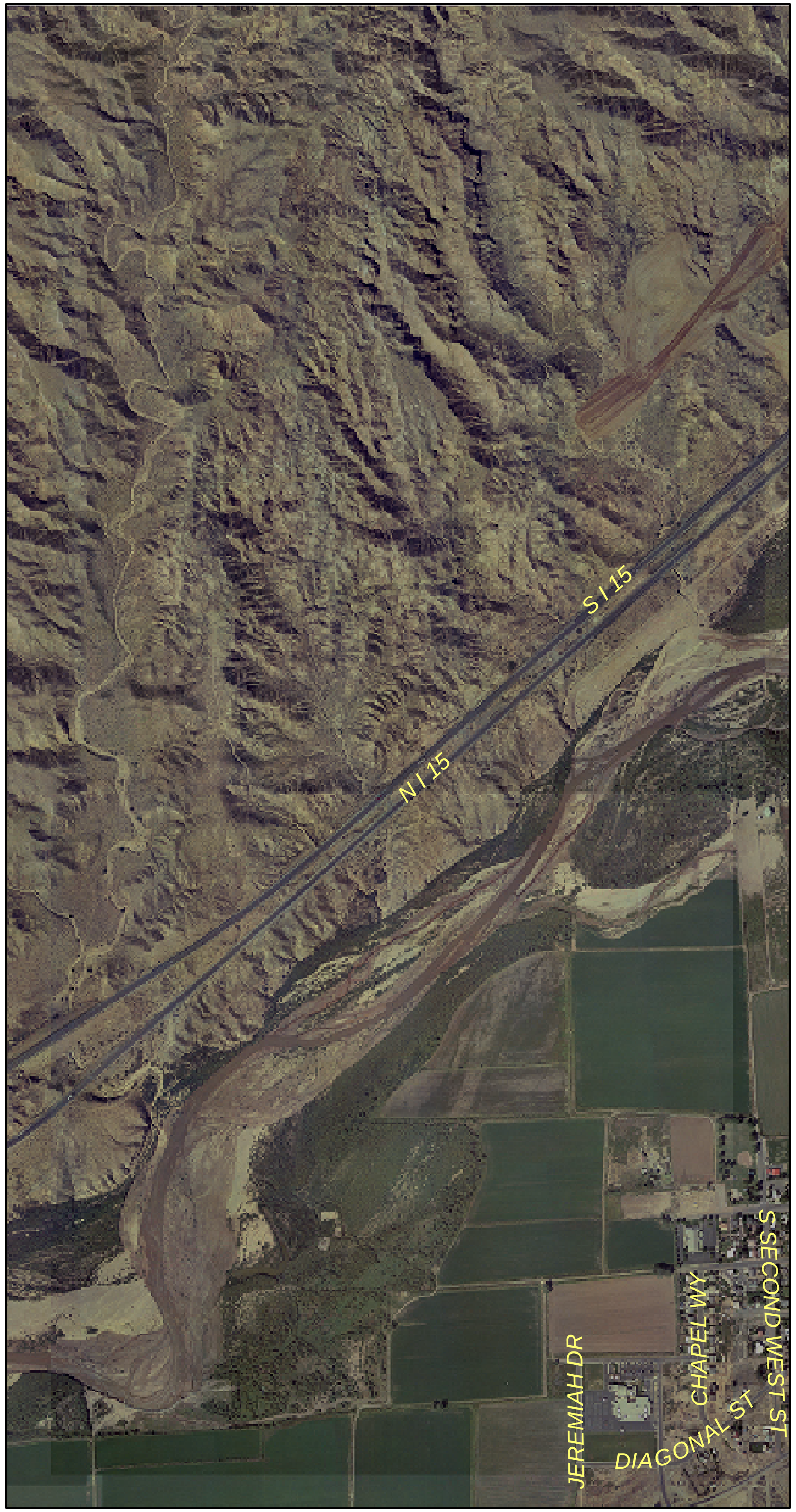
4,000
Feet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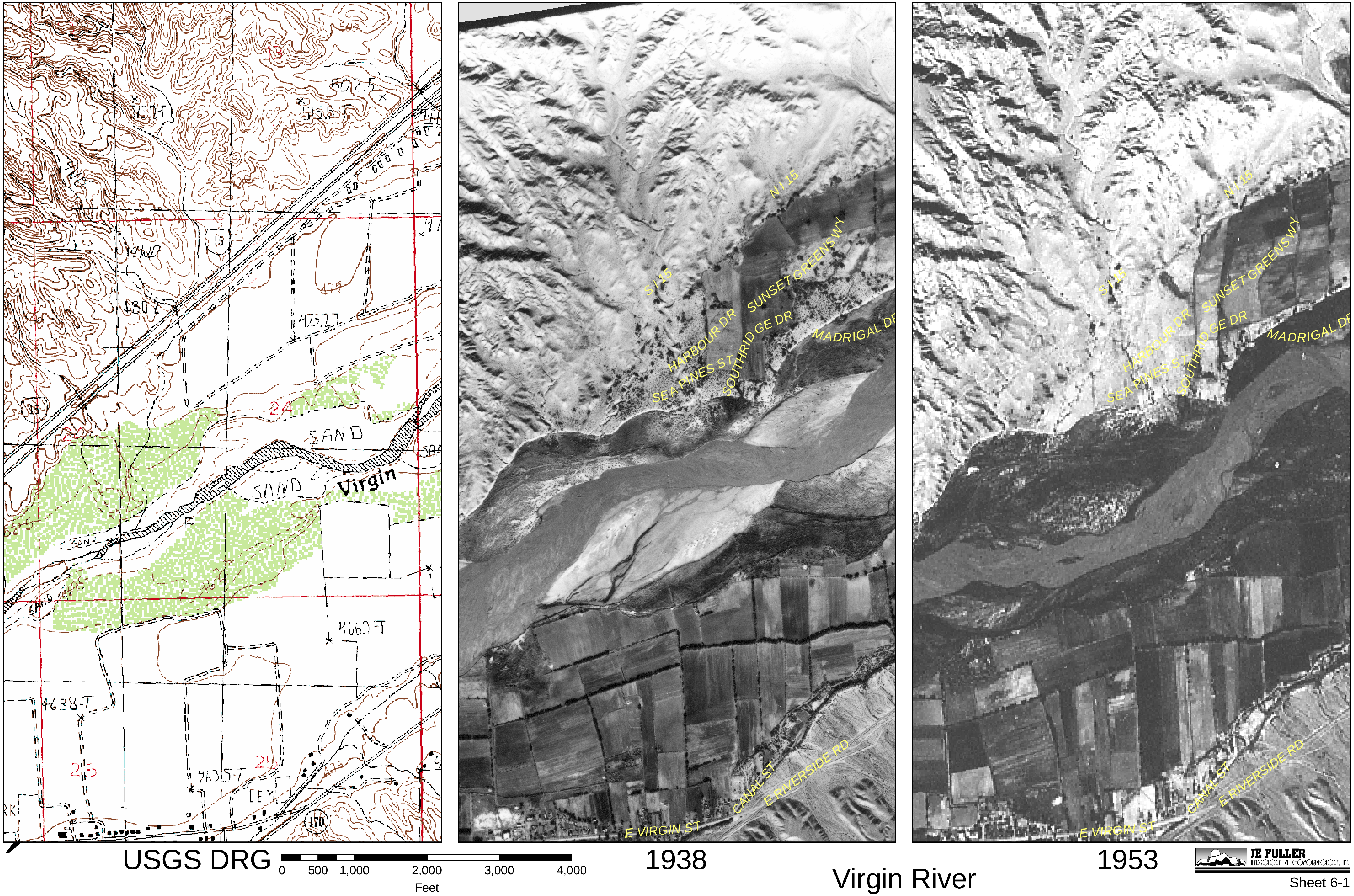
Fall 2005

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 5-5


Virgin
SAND
SAND
4662 T
4638 T
4635 T
CEM
24
25
15
170
N I 15
S I 15
SUNSET GREENS WY
HARBOUR DR
SOUTHRIDGE DR
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST
0
500
1,000
2,000
3,000
4,000
Feet

USGS DRG

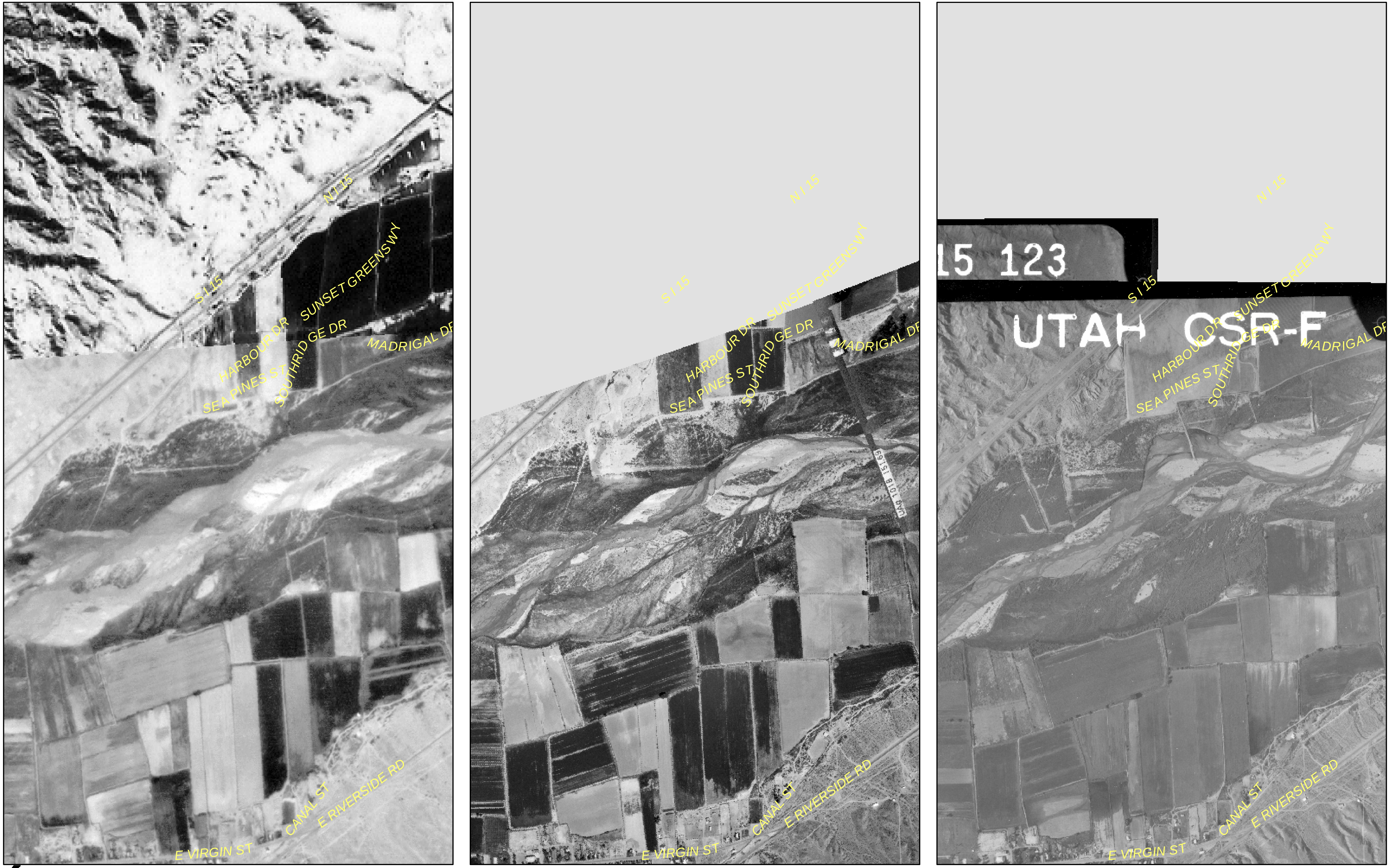
1938

1953

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 6-1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E VIRGIN ST
15 123
UTAH CSR-F
UAQ 1018 151-53
0
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2,000
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Feet

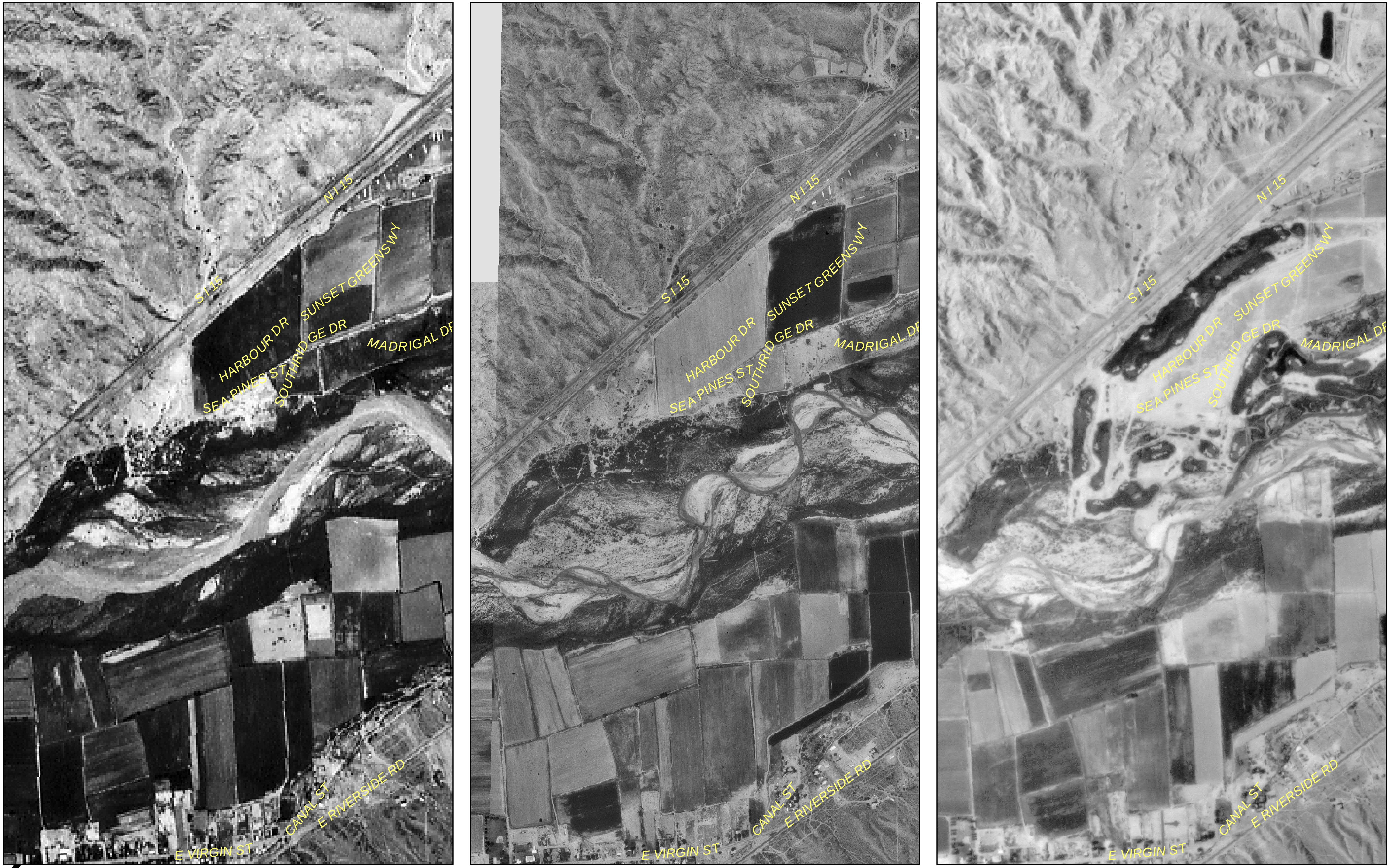
1973

1977

1978

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.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E VIRGIN ST
N I 15
S I 15
SUNSET GREENS WY
HARBOUR DR
SOUTHRIDGE DR
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST
N I 15
S I 15
SUNSET GREENS WY
HARBOUR DR
SOUTHRIDGE DR
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST
0
500
1,000
2,000
3,000
4,000
Feet

1984

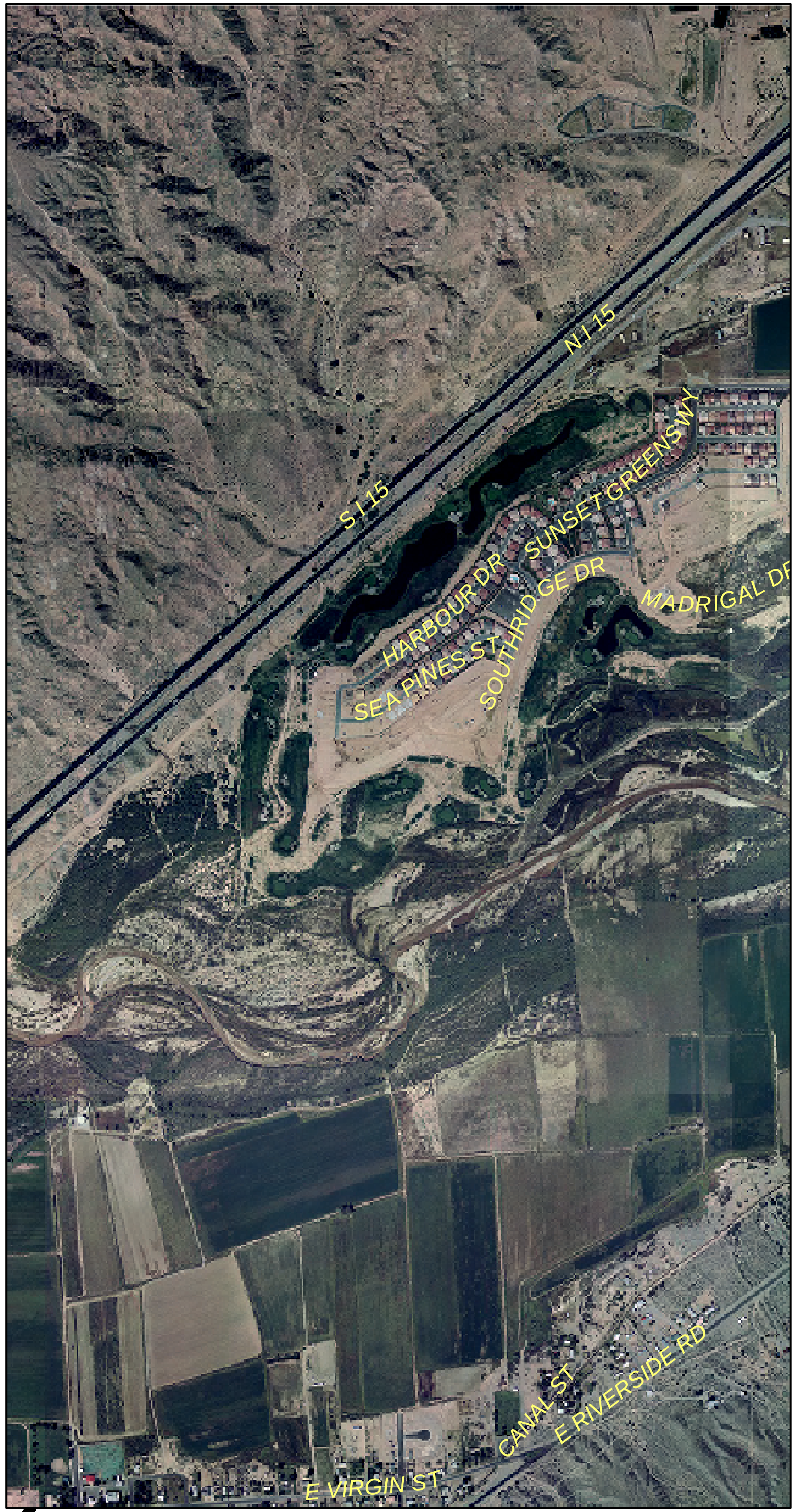
1994

1997

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 6-3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S I 15
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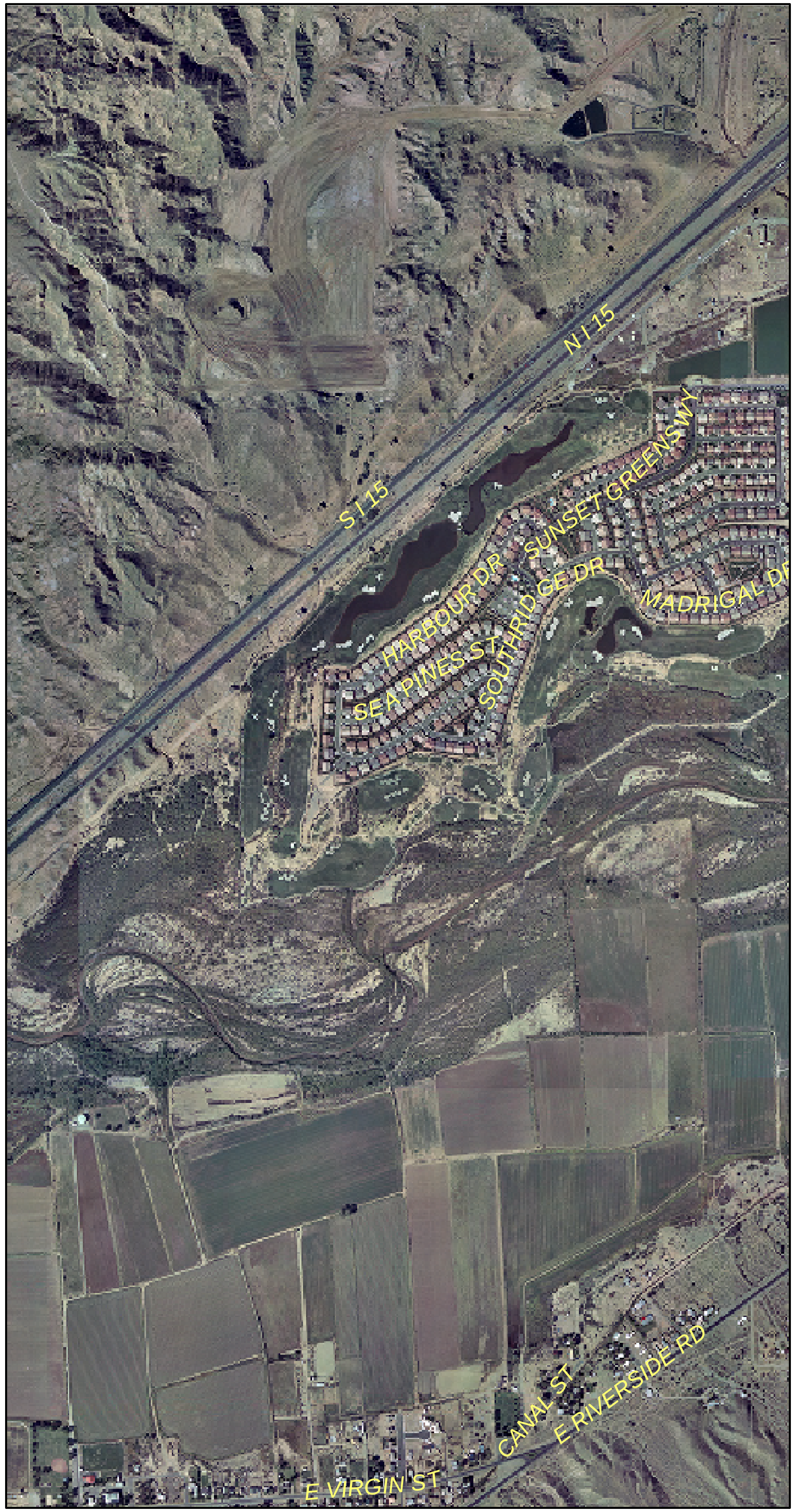
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST

Fall 2002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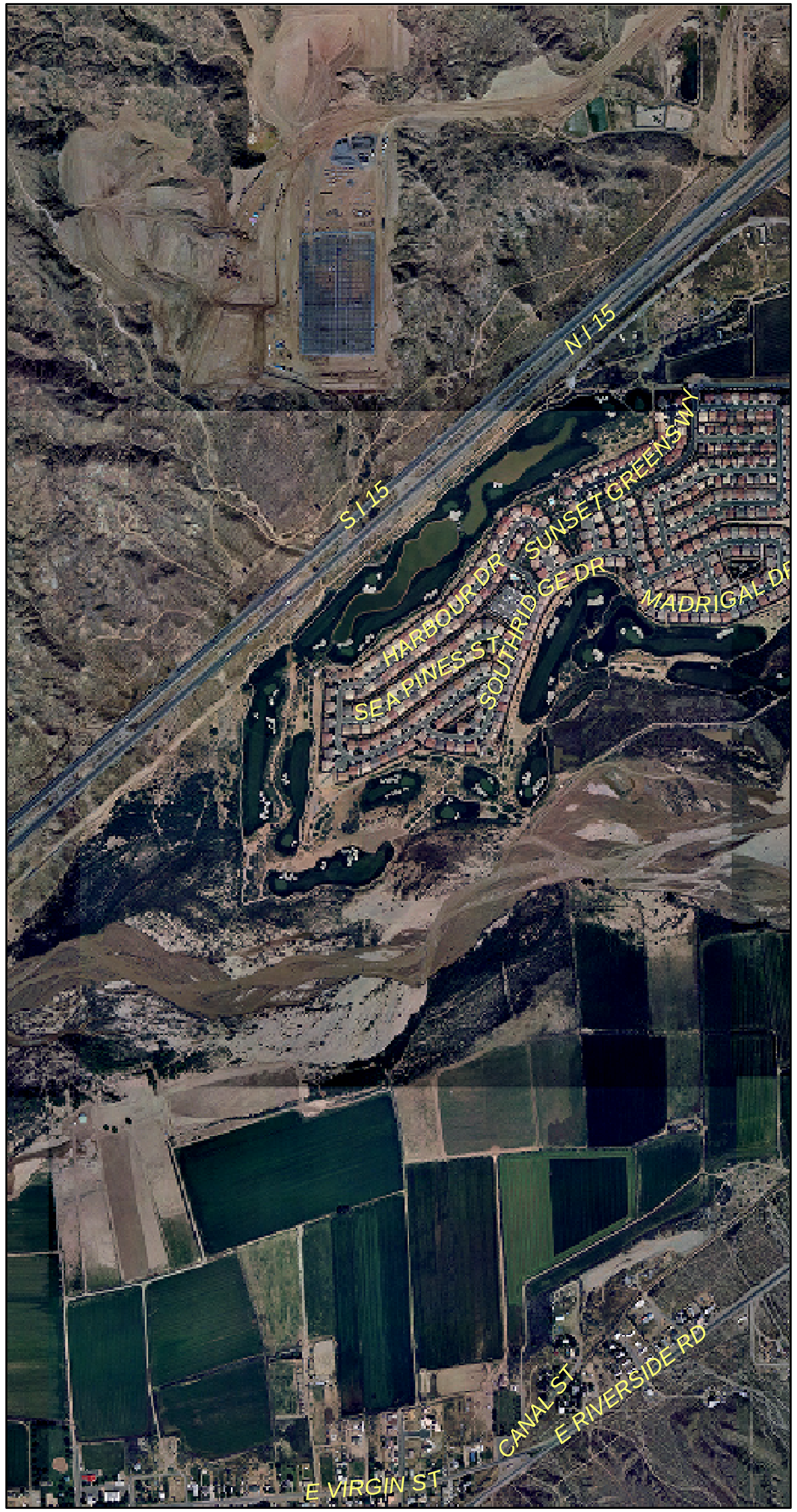
CANAL ST
E RIVERSIDE RD
E VIRGIN ST

Fall 2004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SOUTHRIDGE DR
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST

Spring 2005

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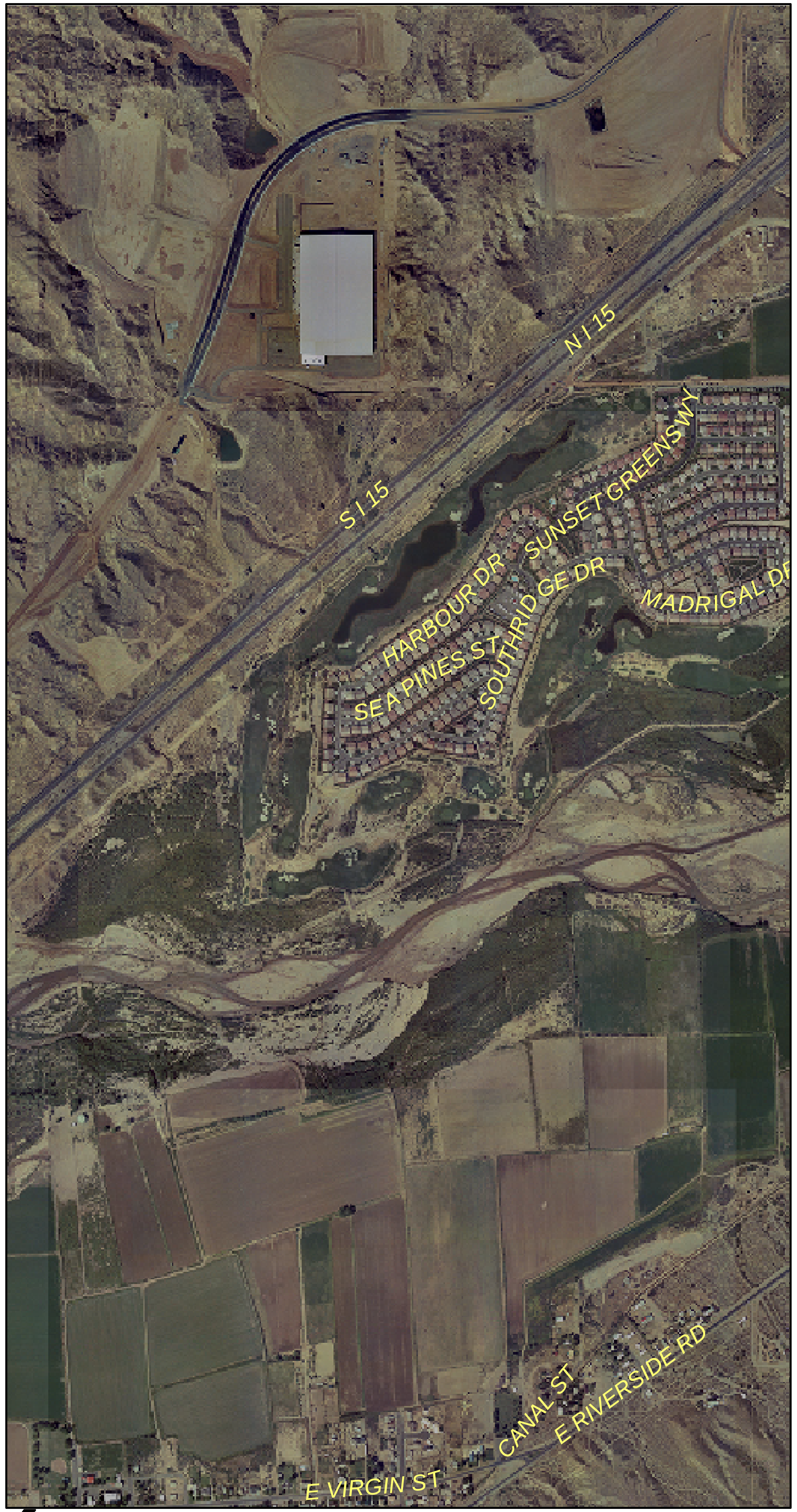
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 6-4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S I 15
SUNSET GREENS WY
HARBOUR DR
SOUTHRIDGE DR
MADRIGAL DR
SEA PINES ST
CANAL ST
E RIVERSIDE RD
E VIRGIN ST

Fall 2005

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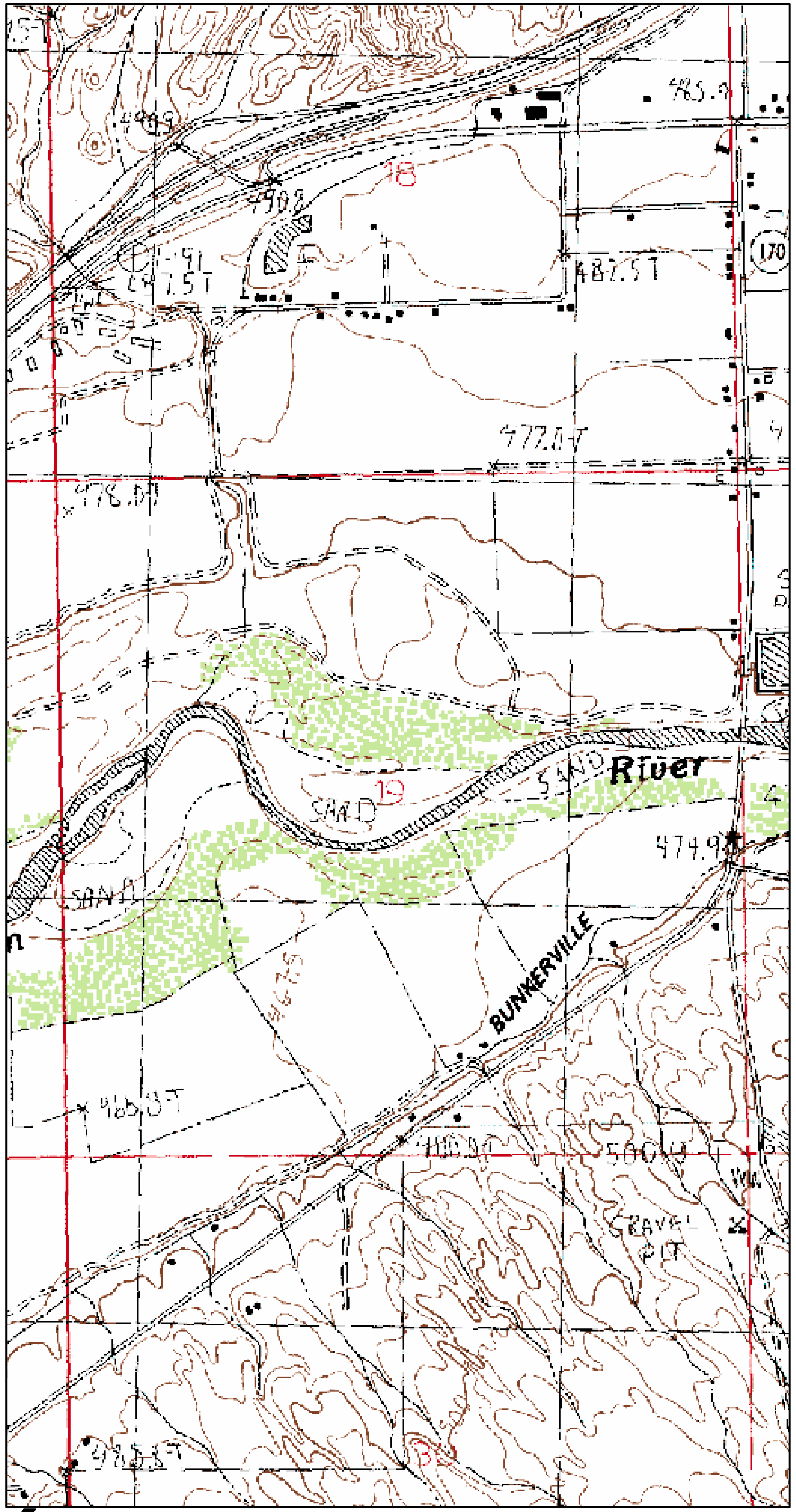
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 6-5


18
170
River
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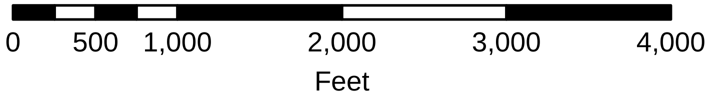
19
BUNKERVILLE
GRAVEL PIT

USGS DRG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3,000
4,000
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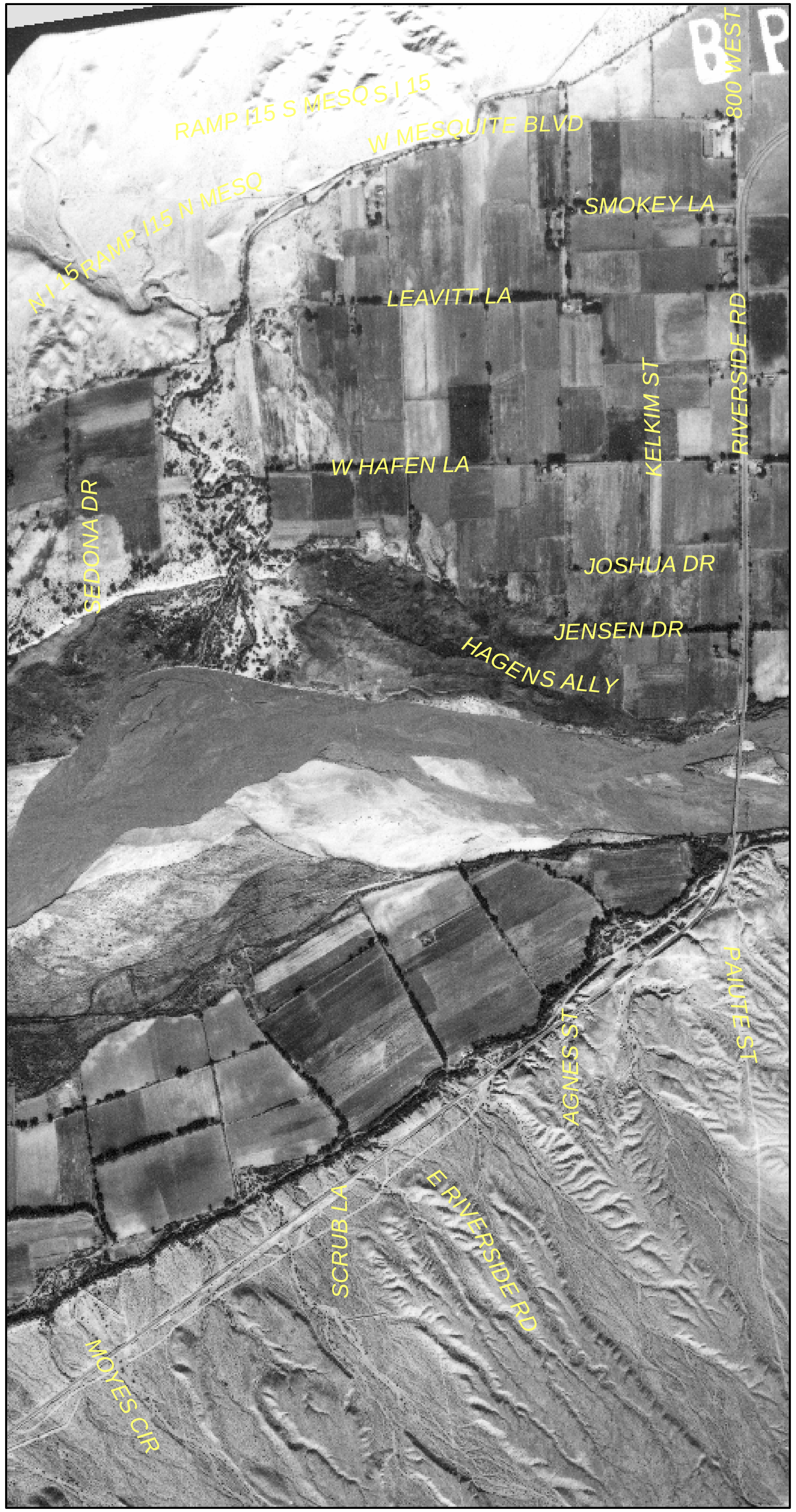
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800 WEST
N I 15 RAMP I15 N MESQ
SMOKEY LA
LEAVITT LA
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RIVERSIDE RD
W HAFEN LA
SEDONA DR
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PAIUTE ST
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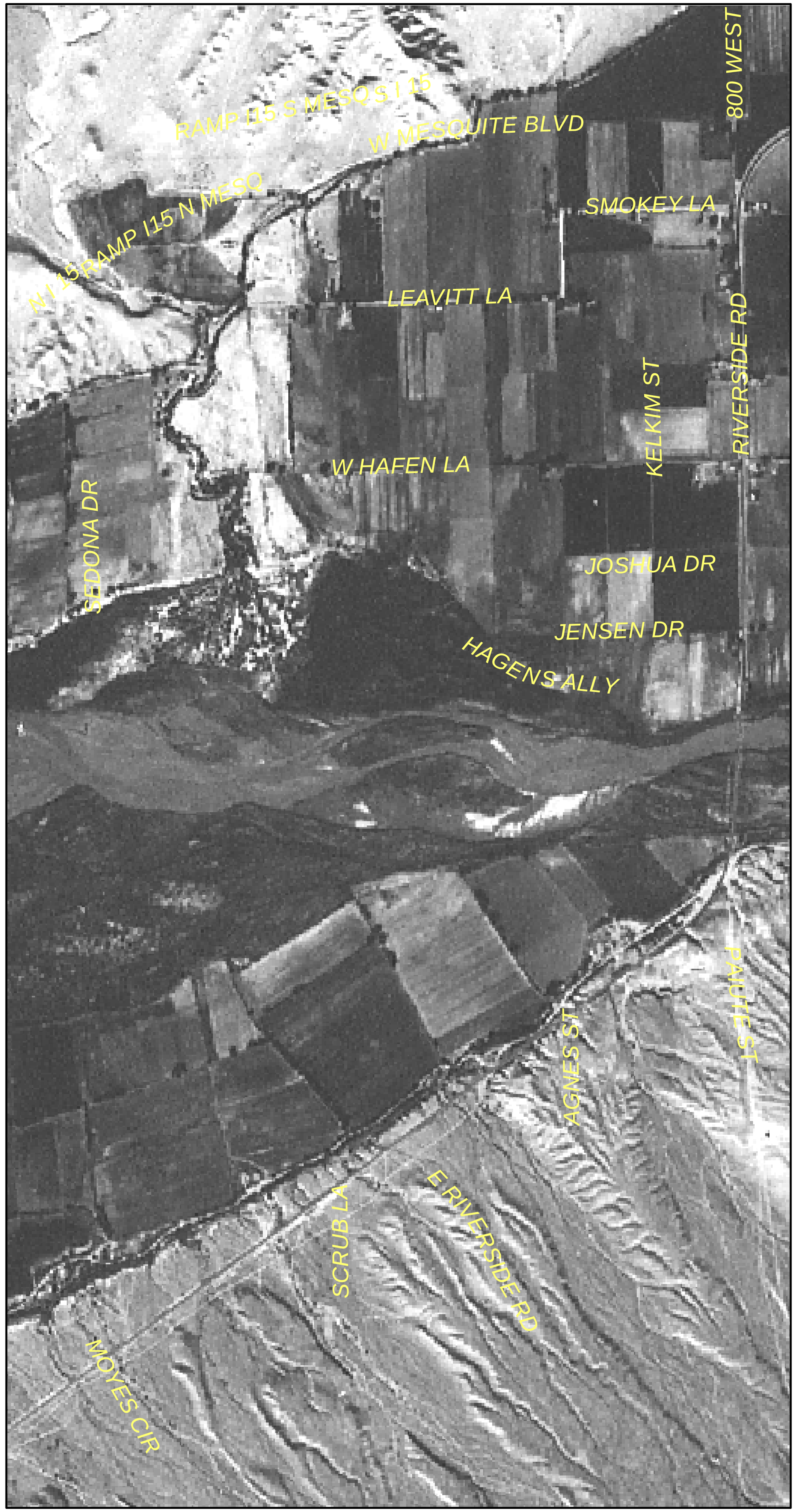
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1938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LEAVITT LA
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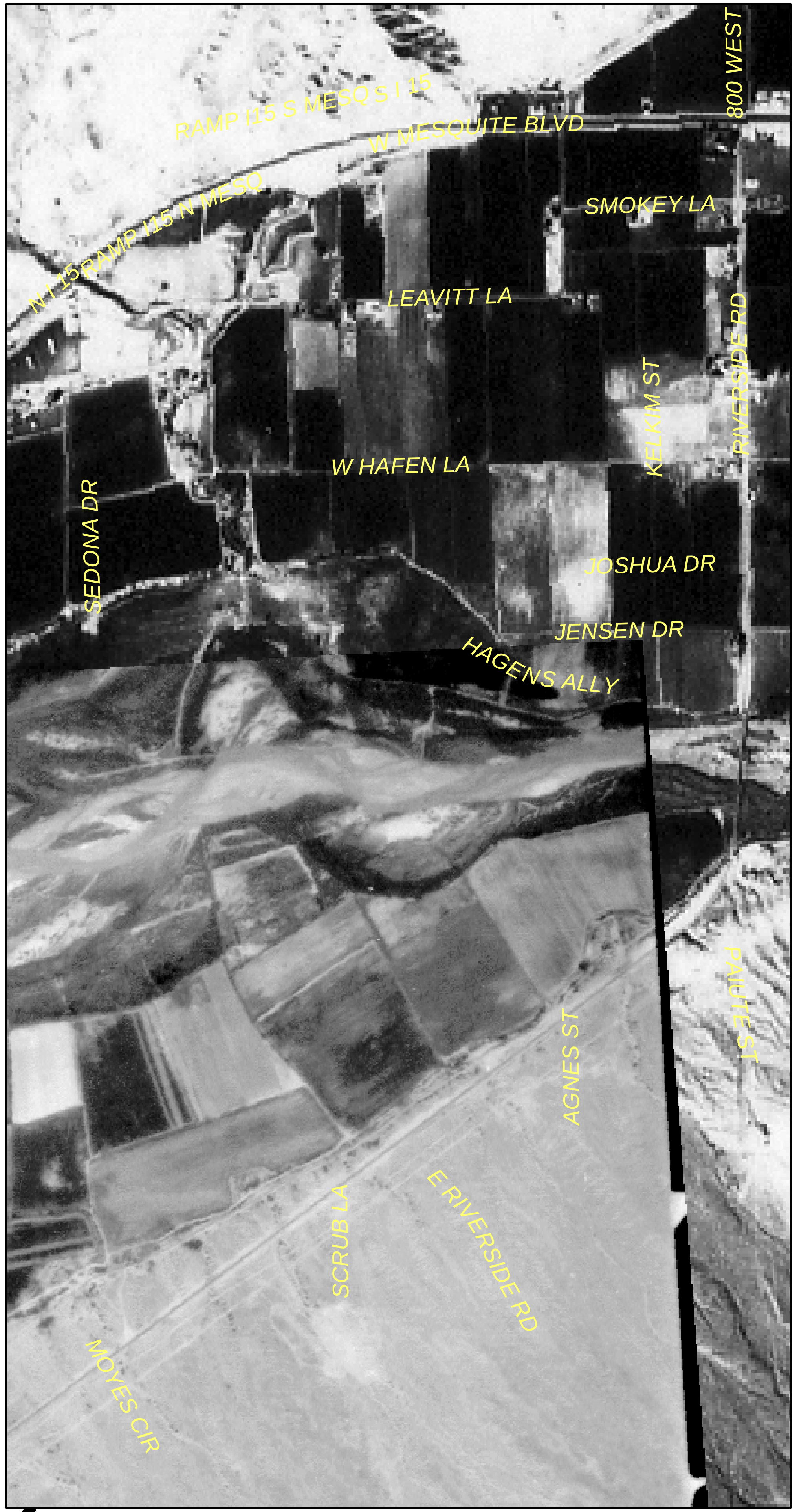
RIVERSIDE RD
W HAFEN LA
SEDONA DR
JOSHUA DR
JENSEN DR
HAGENS ALLY
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1953

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 7-1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LEAVITT LA
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W HAFEN LA
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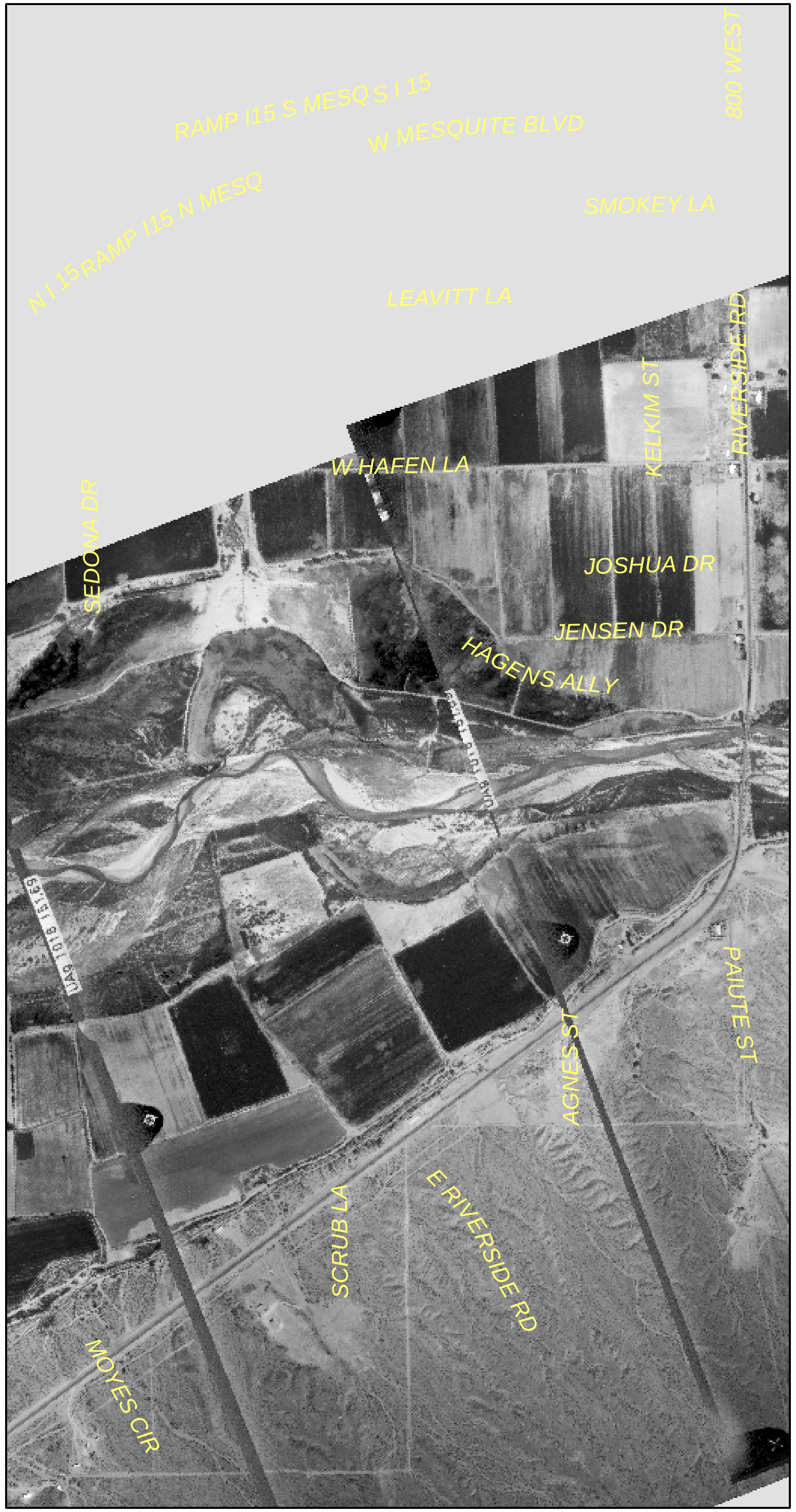
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1973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LEAVITT LA
KELKIM ST
RIVERSIDE RD
W HAFEN LA
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AGNES ST
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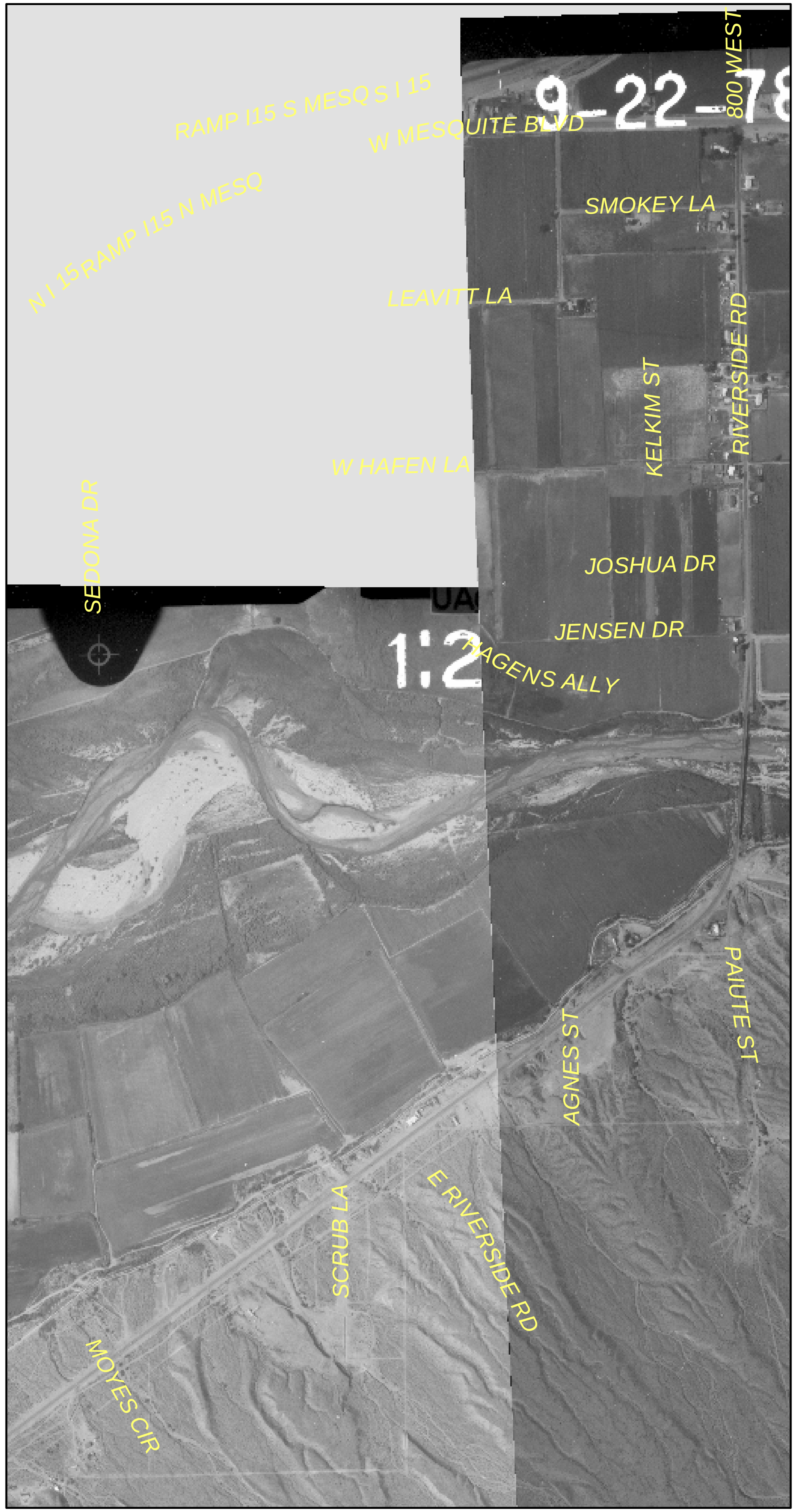
E RIVERSIDE RD
MOYES CIR

1977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SMOKEY LA
LEAVITT LA
KELKIM ST
RIVERSIDE RD
W HAFEN LA
SEDONA DR
JOSHUA DR
JENSEN DR
UA
1:2
HAGENS ALLY
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

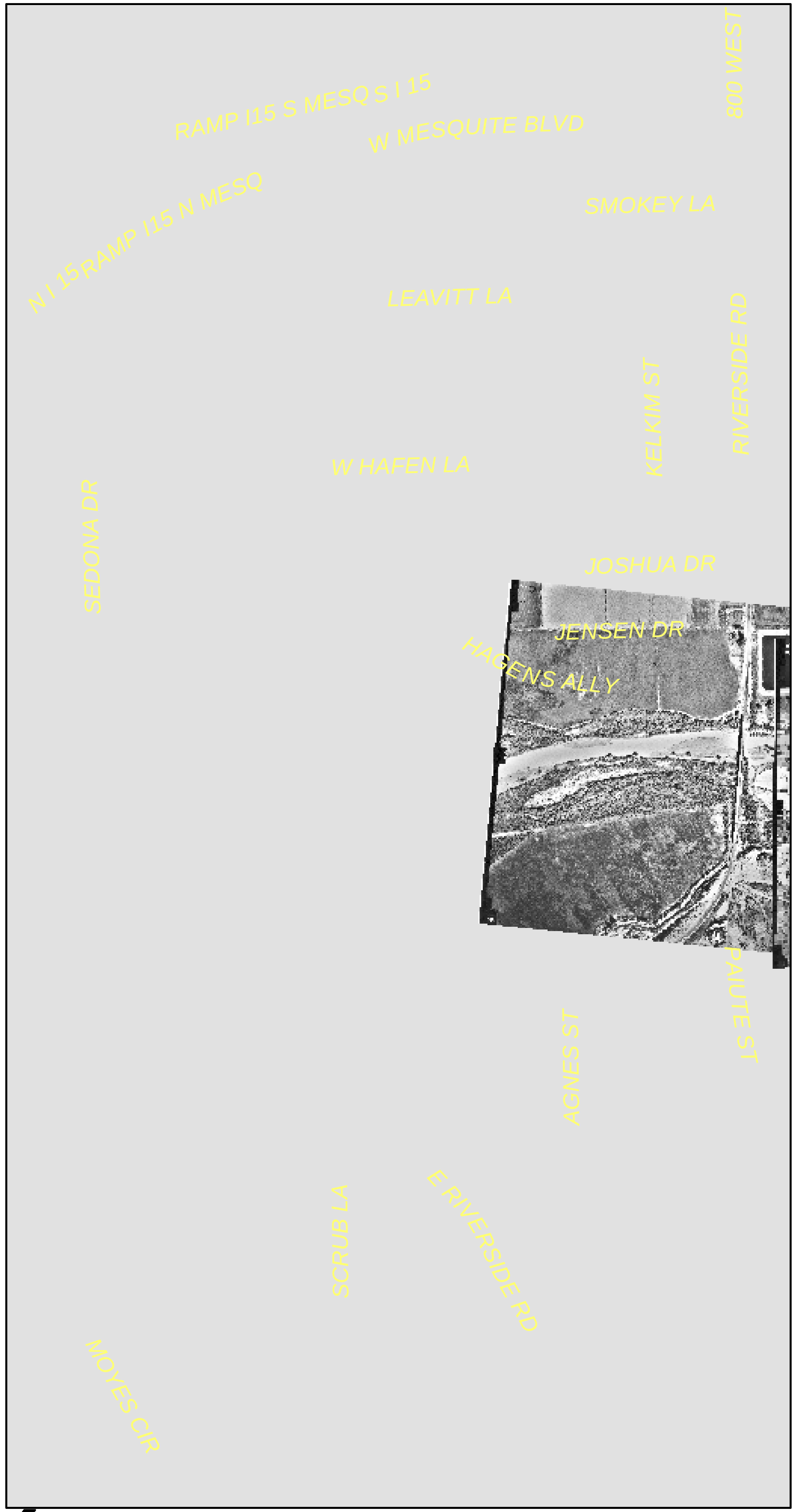
1978

0 500 1,000 2,000 3,000 4,000
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 7-2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RIVERSIDE RD
W HAFEN LA
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JENSEN DR
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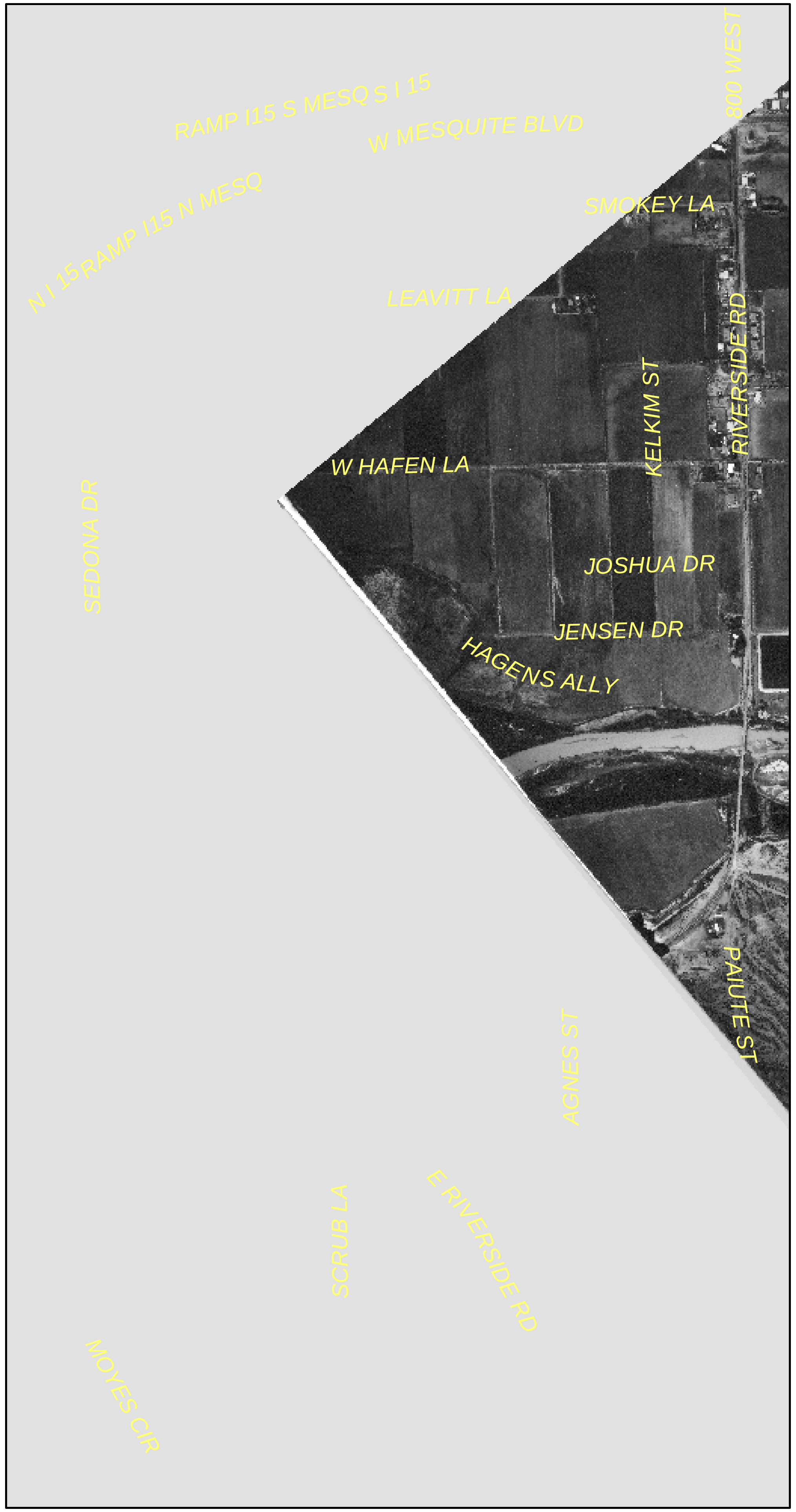
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1981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RIVERSIDE RD
W HAFEN LA
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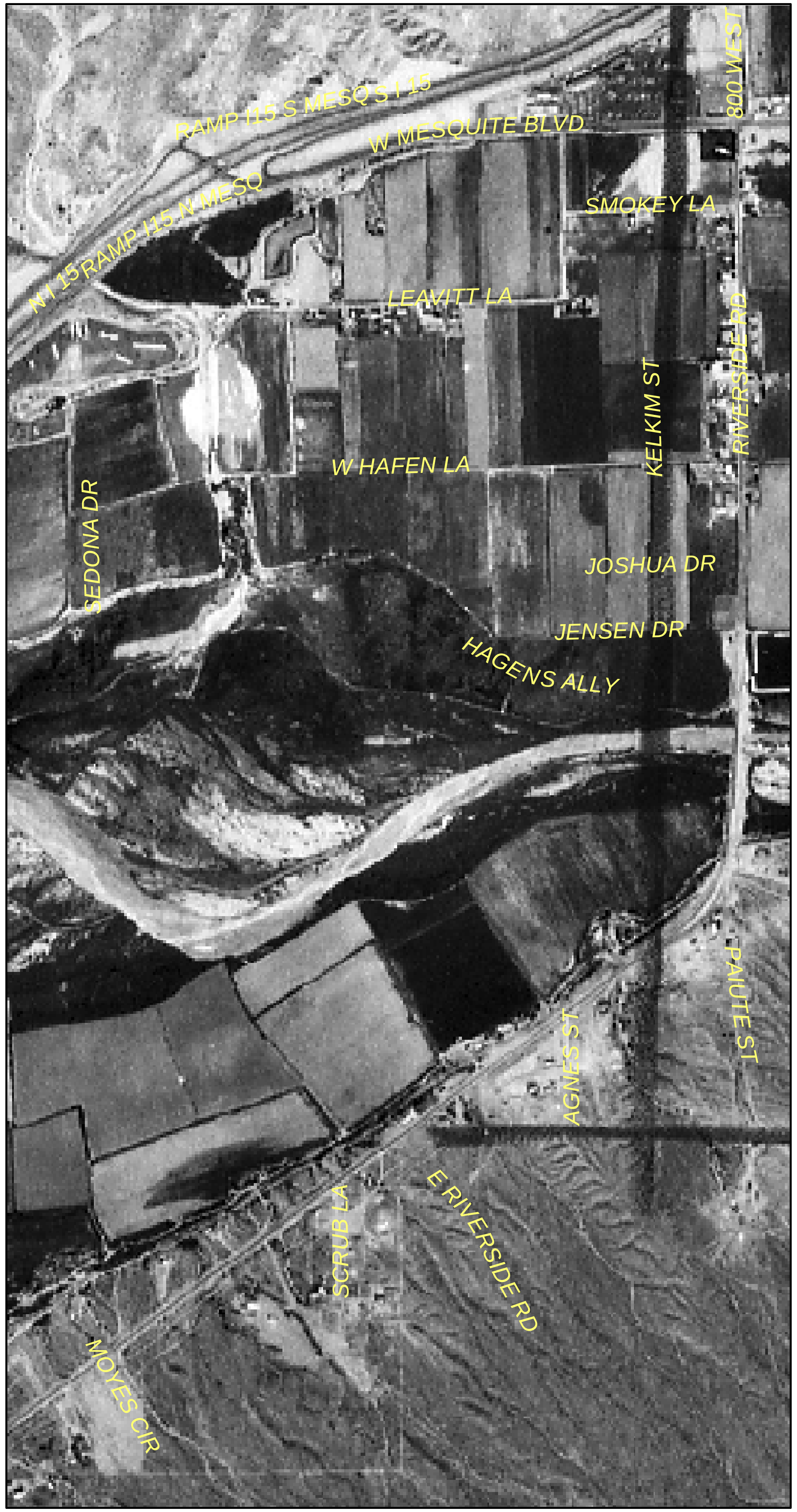
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1983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SEDONA DR
JOSHUA DR
JENSEN DR
HAGENS ALLY
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

1984

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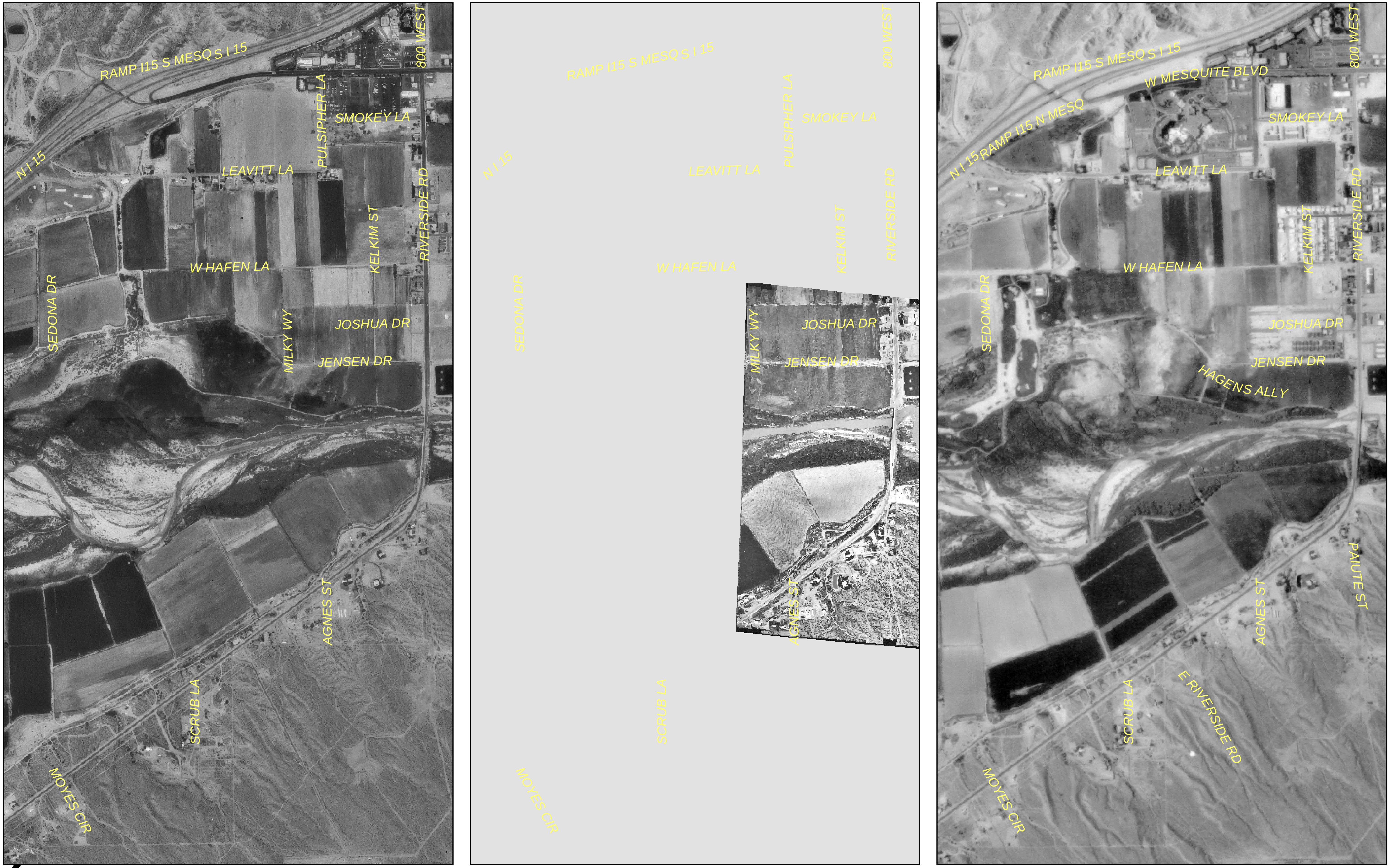
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 7-3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JOSHUA DR
MILKY WY
JENSEN DR
AGNES ST
SCRUB LA
MOYES CIR
W MESQUITE BLVD
RAMP I15 N MESQ
HAGENS ALLY
PAIUTE ST
E RIVERSIDE RD

1994

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Feet

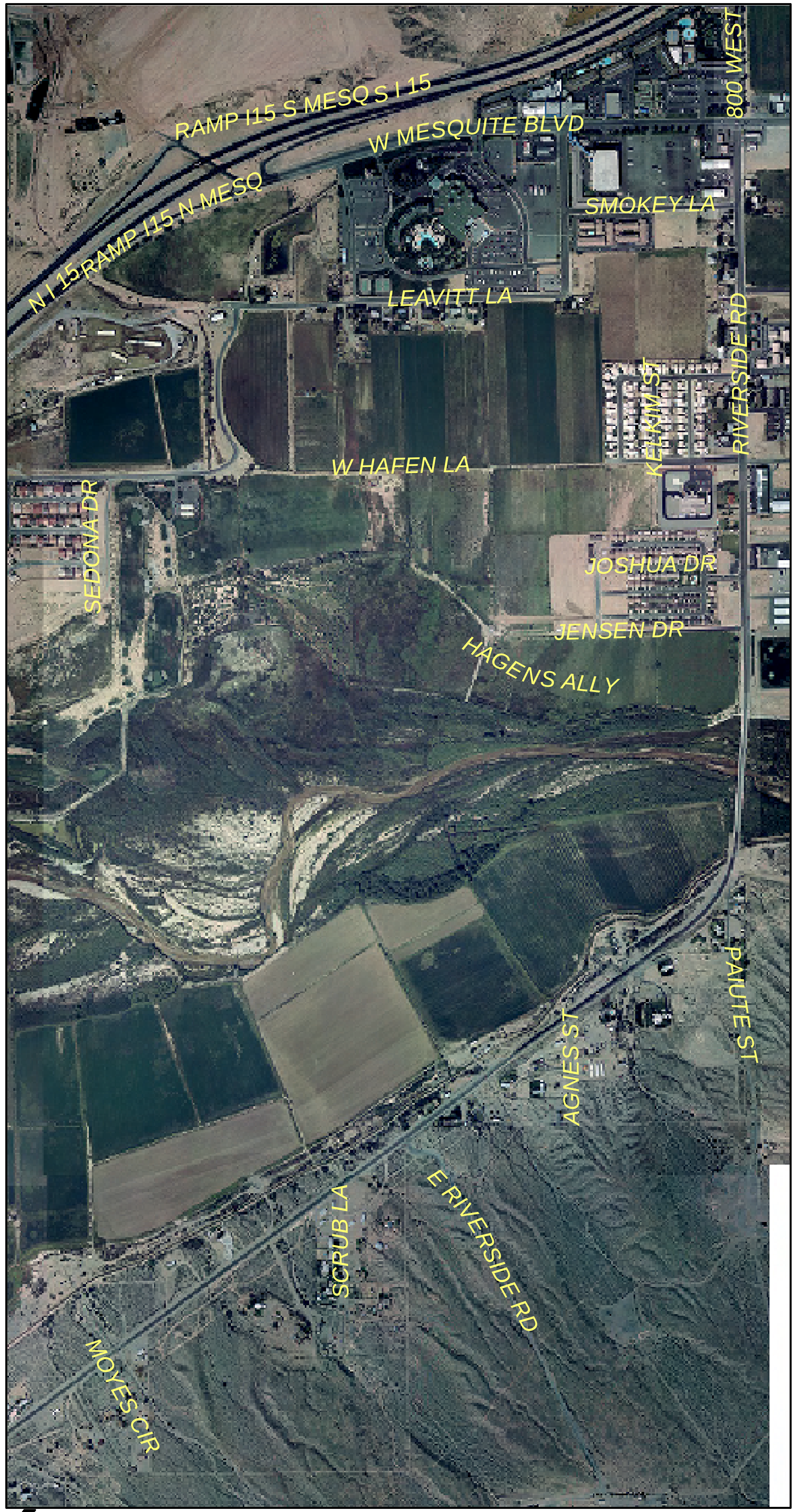
1995

1997

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Virgin River

Sheet 7-4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RIVERSIDE RD
W HAFEN LA
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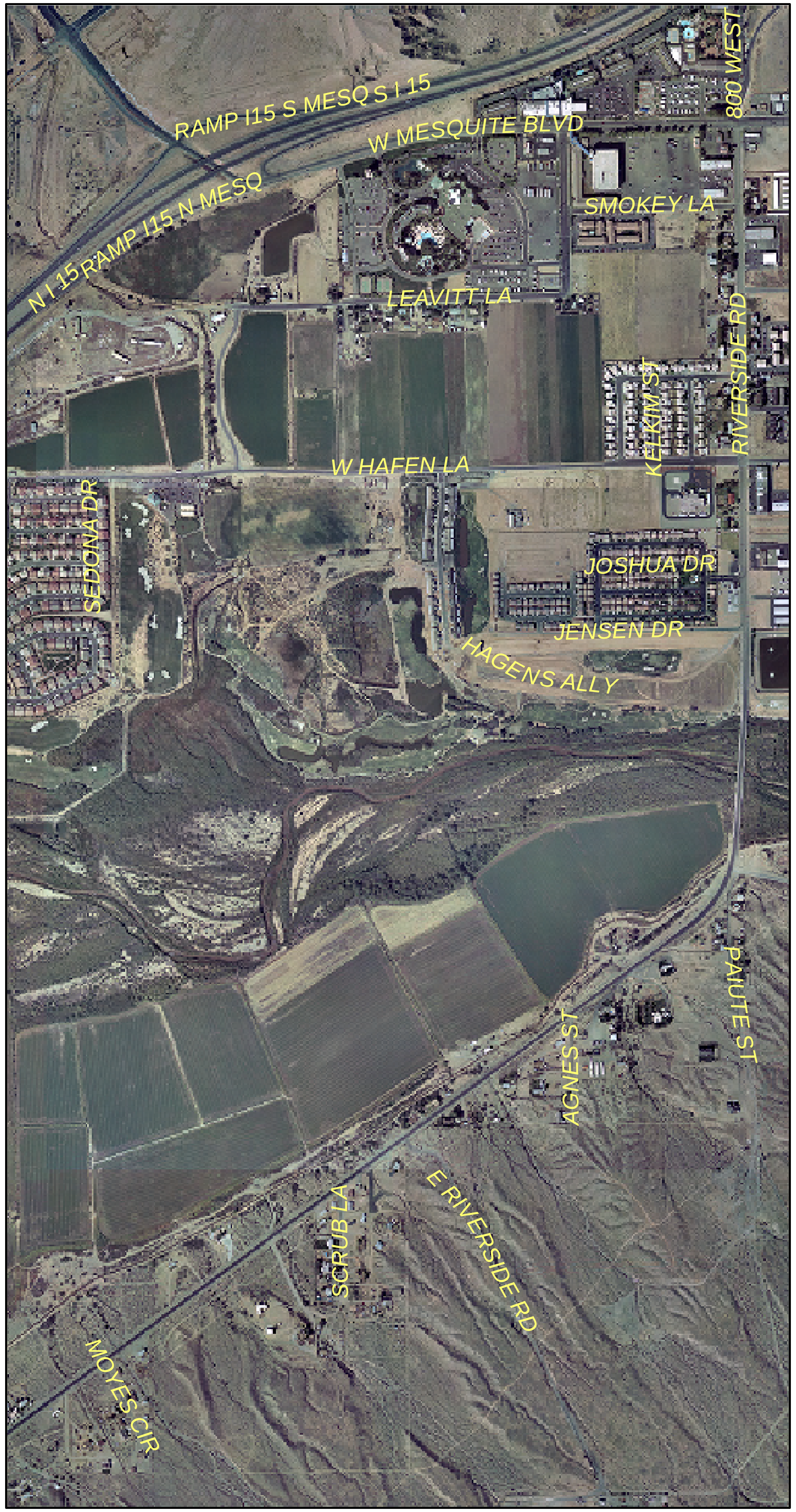
E RIVERSIDE RD
MOYES CIR

Fall 2002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W HAFEN LA
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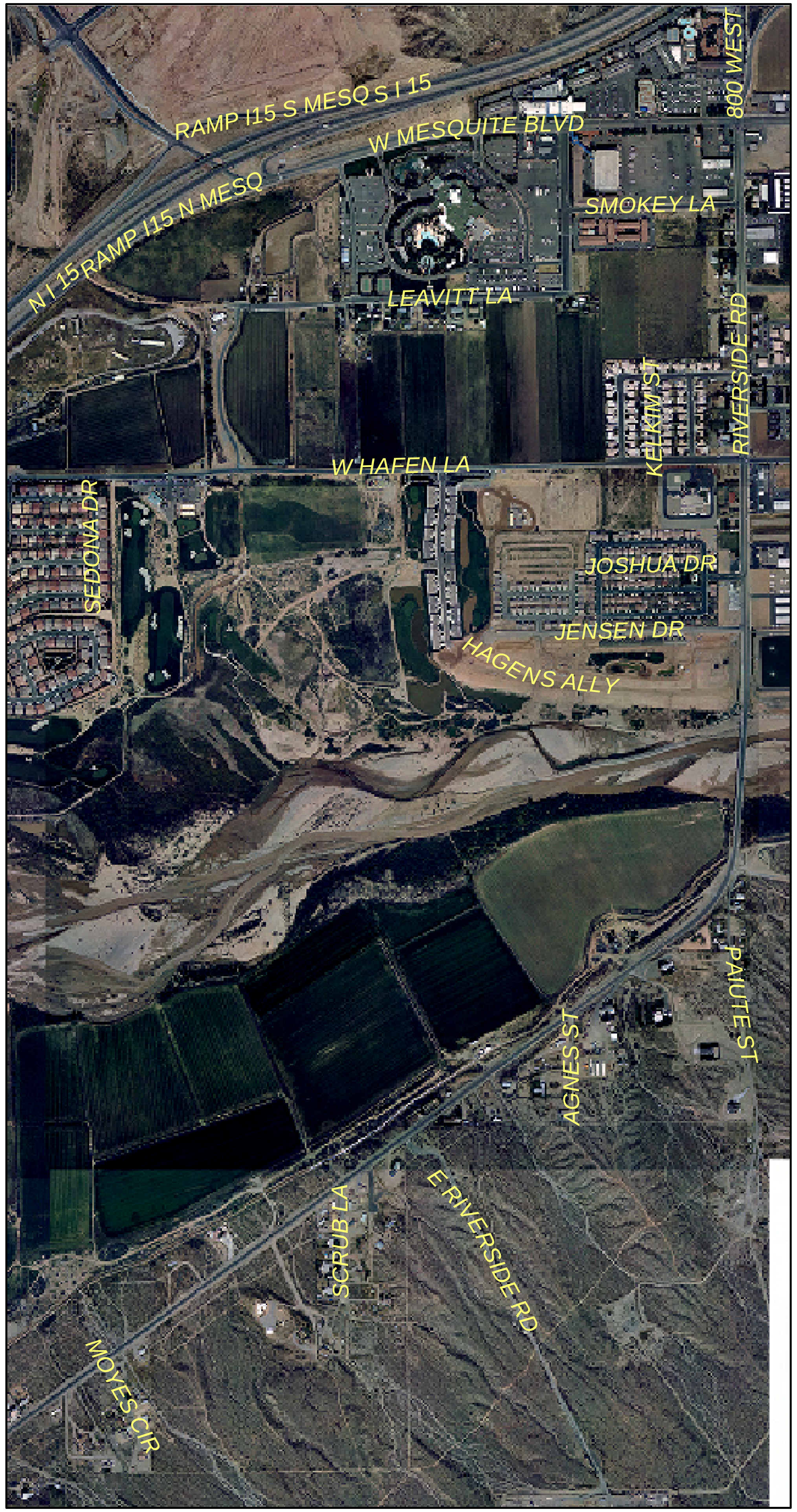
SCRUB LA
E RIVERSIDE RD
MOYES CIR

Fall 2004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SEDONA DR
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JENSEN DR
HAGENS ALLY
PAIUTE ST
AGNES ST
SCRUB LA
E RIVERSIDE RD
MOYES CIR

Spring 2005

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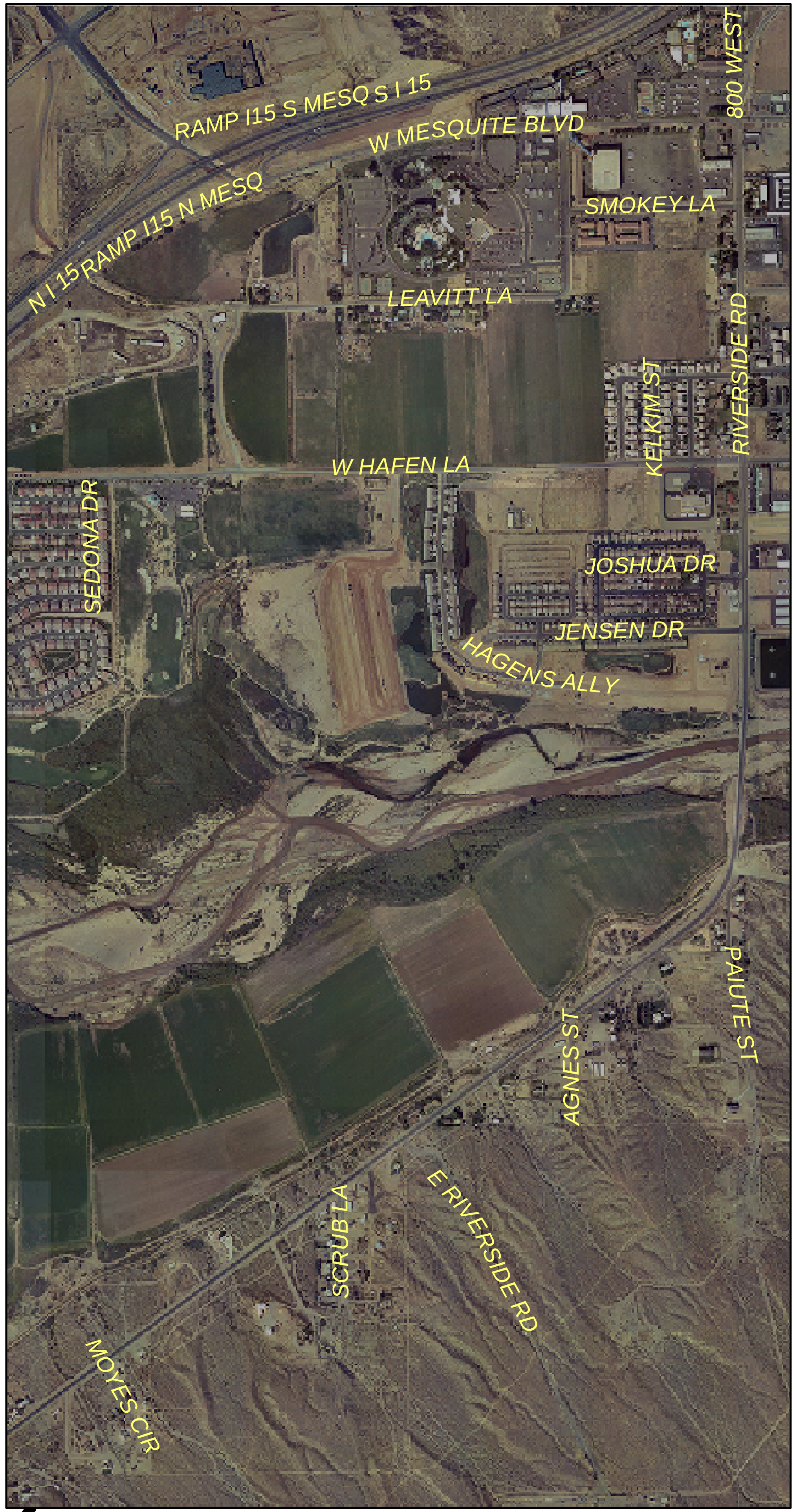
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 7-5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LEAVITT LA
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W HAFEN LA
SEDONA DR
JOSHUA DR
JENSEN DR
HAGENS ALLY
PAIUTE ST
AGNES ST
E RIVERSIDE RD
SCRUB LA
MOYES CIR

Fall 2005

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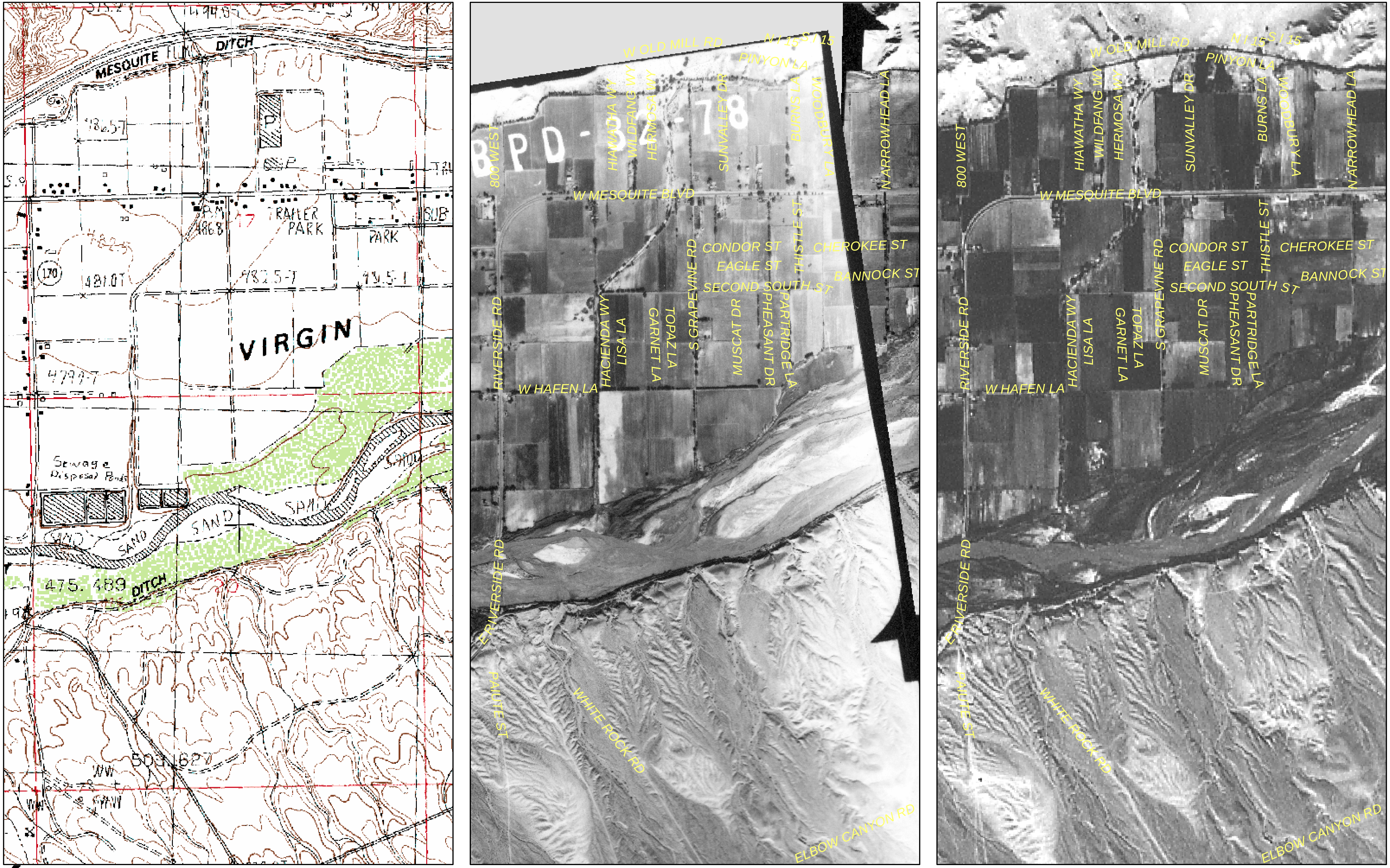
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 7-6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PARK
SUB
VIRGIN
Sewage Disposal Ponds
SAND
DITCH
BPD-32-78
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N I 15
S I 15
PINYON LA
800 WEST
HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
S GRAPEVINE RD
CONDOR ST
EAGLE ST
THISTLE ST
CHEROKEE ST
BANNOCK ST
SECOND SOUTH ST
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

USGS DRG

0 500 1,000 2,000 3,000 4,000
Feet

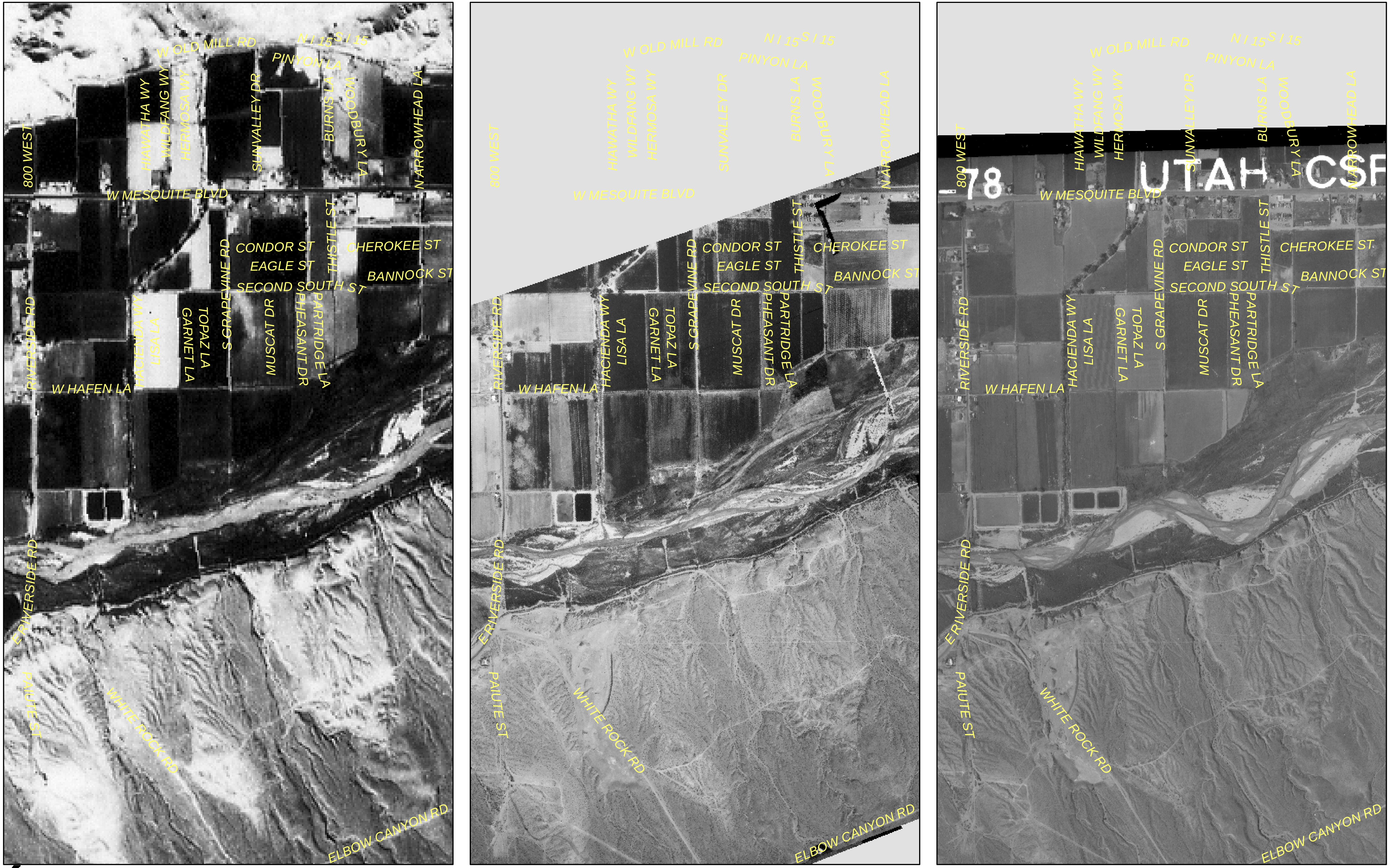
1938

1953

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-1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S I 15
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BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
THISTLE ST
CONDOR ST
CHEROKEE ST
EAGLE ST
BANNOCK ST
SECOND SOUTH ST
S GRAPEVINE RD
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD
-78
UTAH CSF

1973

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Feet

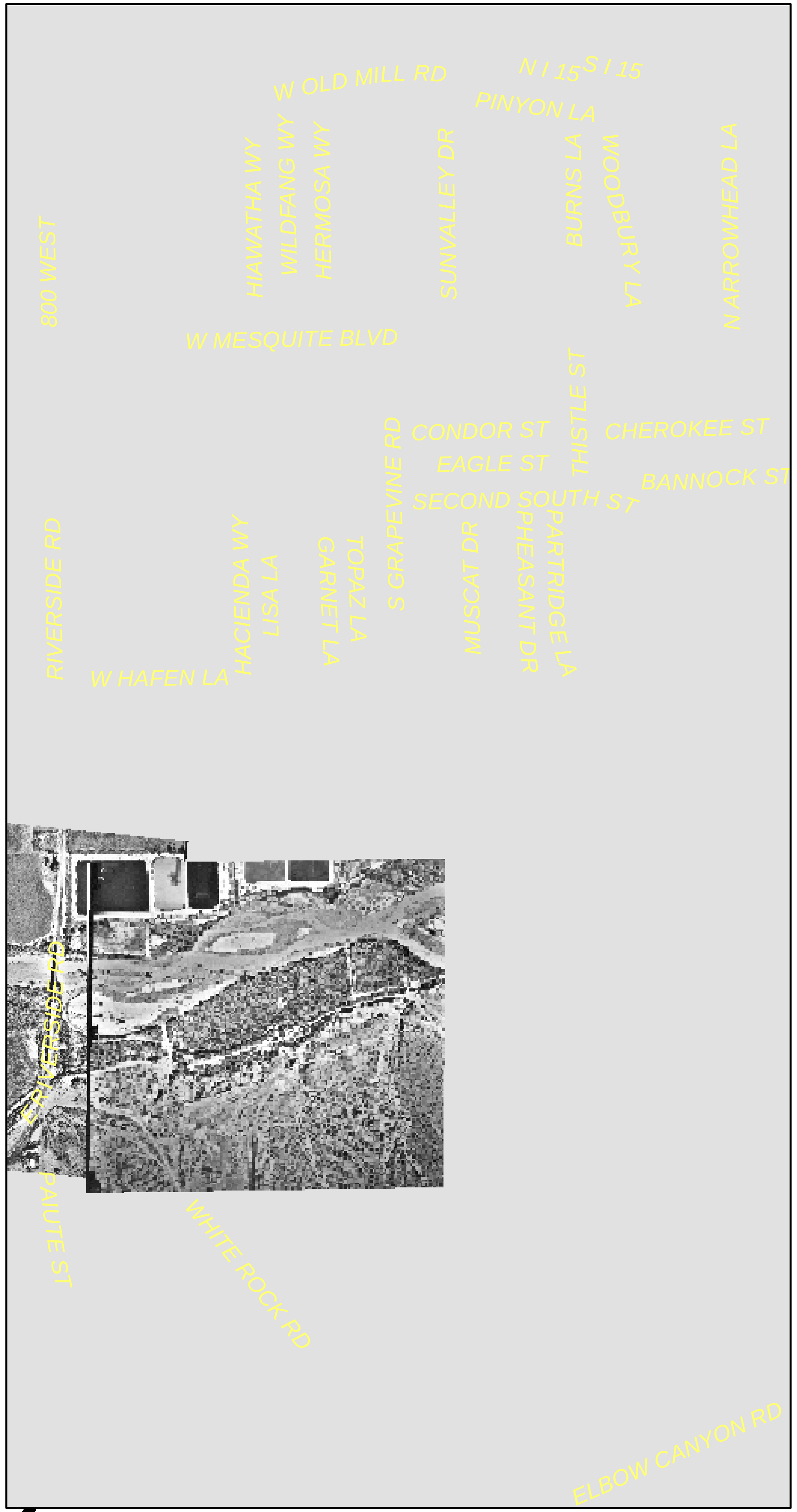
1977

Virgin River

1978

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-2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S I 15
PINYON LA
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HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
S GRAPEVINE RD
CONDOR ST
THISTLE ST
CHEROKEE ST
EAGLE ST
SECOND SOUTH ST
BANNOCK ST
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
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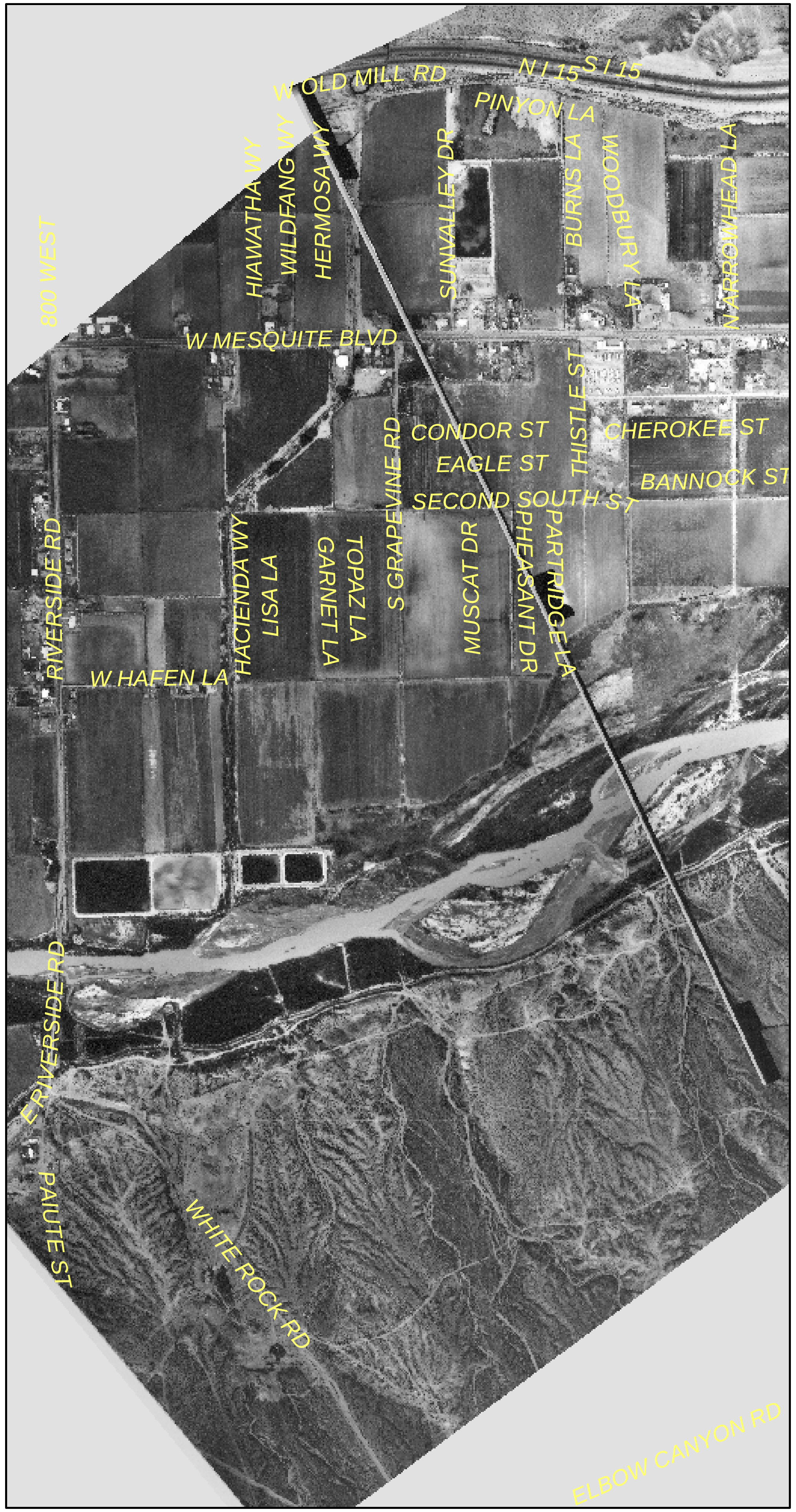
WHITE ROCK RD
ELBOW CANYON RD

1981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S I 15
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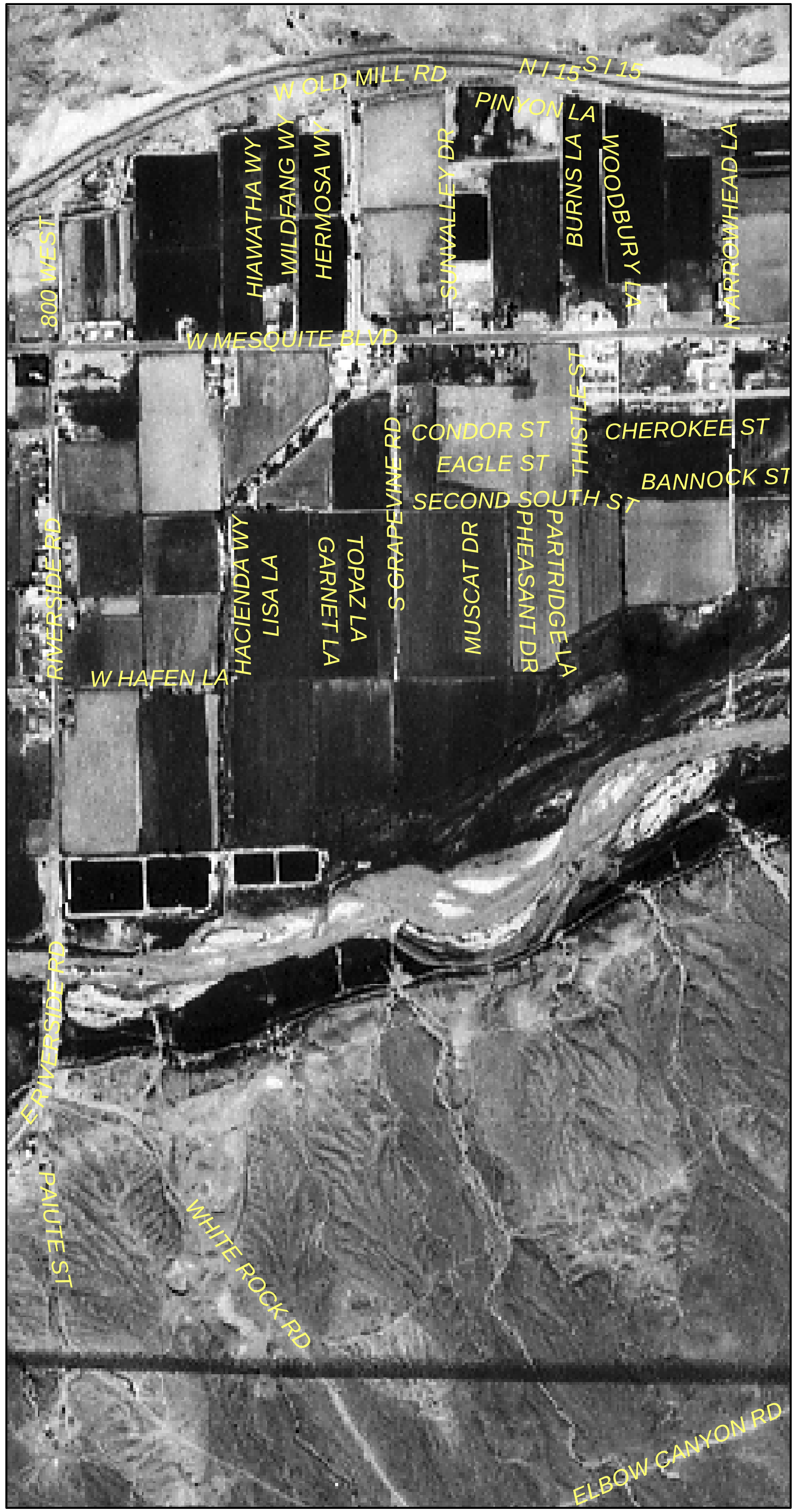
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
S GRAPEVINE RD
CONDOR ST
THISTLE ST
CHEROKEE ST
EAGLE ST
SECOND SOUTH ST
BANNOCK ST
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

1983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N I 15
S I 15
PINYON LA
800 WEST
HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
S GRAPEVINE RD
CONDOR ST
THISTLE ST
CHEROKEE ST
EAGLE ST
SECOND SOUTH ST
BANNOCK ST
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

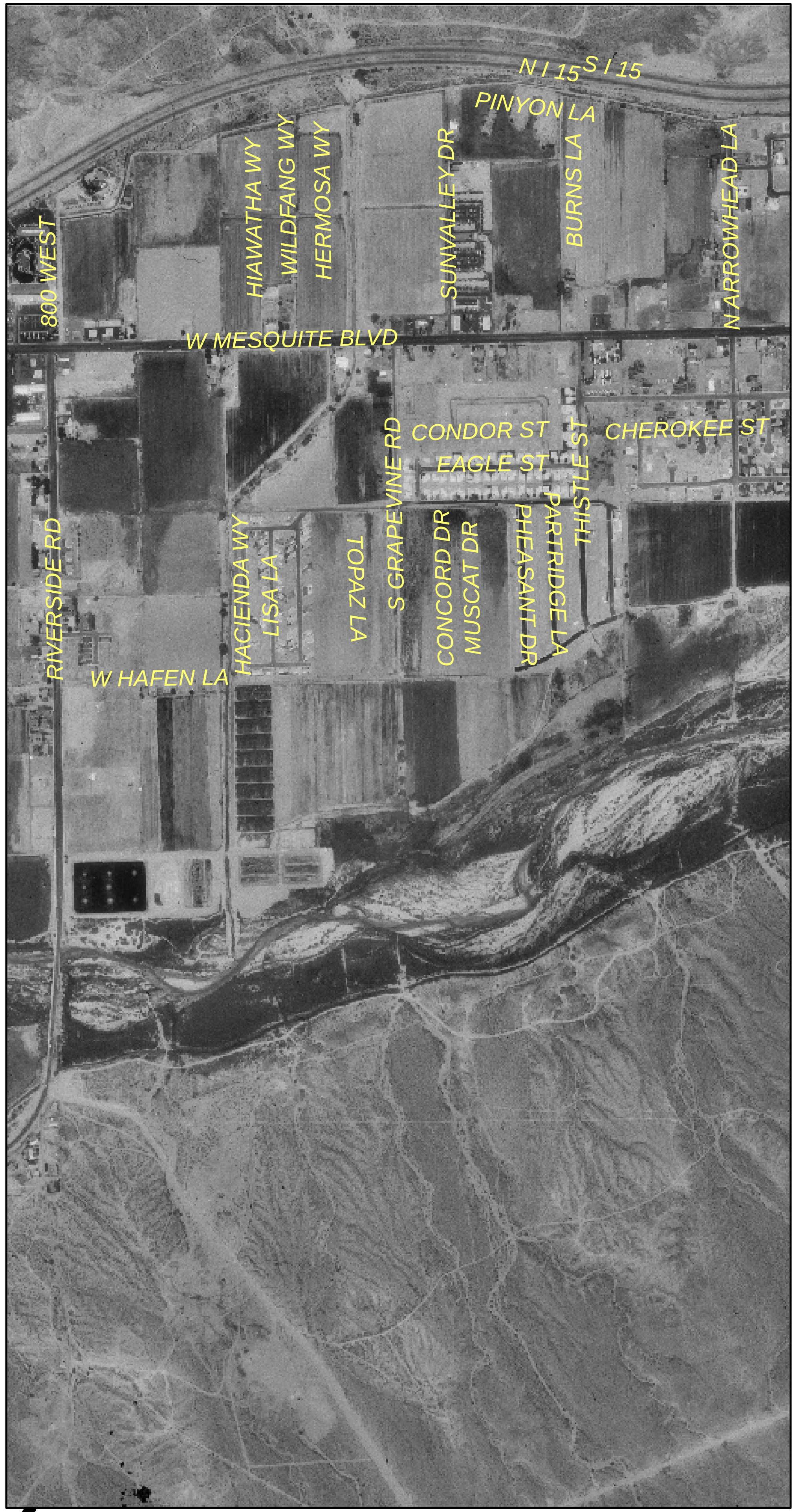
1984

0 500 1,000 2,000 3,000 4,000
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-3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BURNS LA
N ARROWHEAD LA
W MESQUITE BLVD
CONDOR ST
CHEROKEE ST
EAGLE ST
S GRAPEVINE RD
THISTLE ST
RIVERSIDE RD
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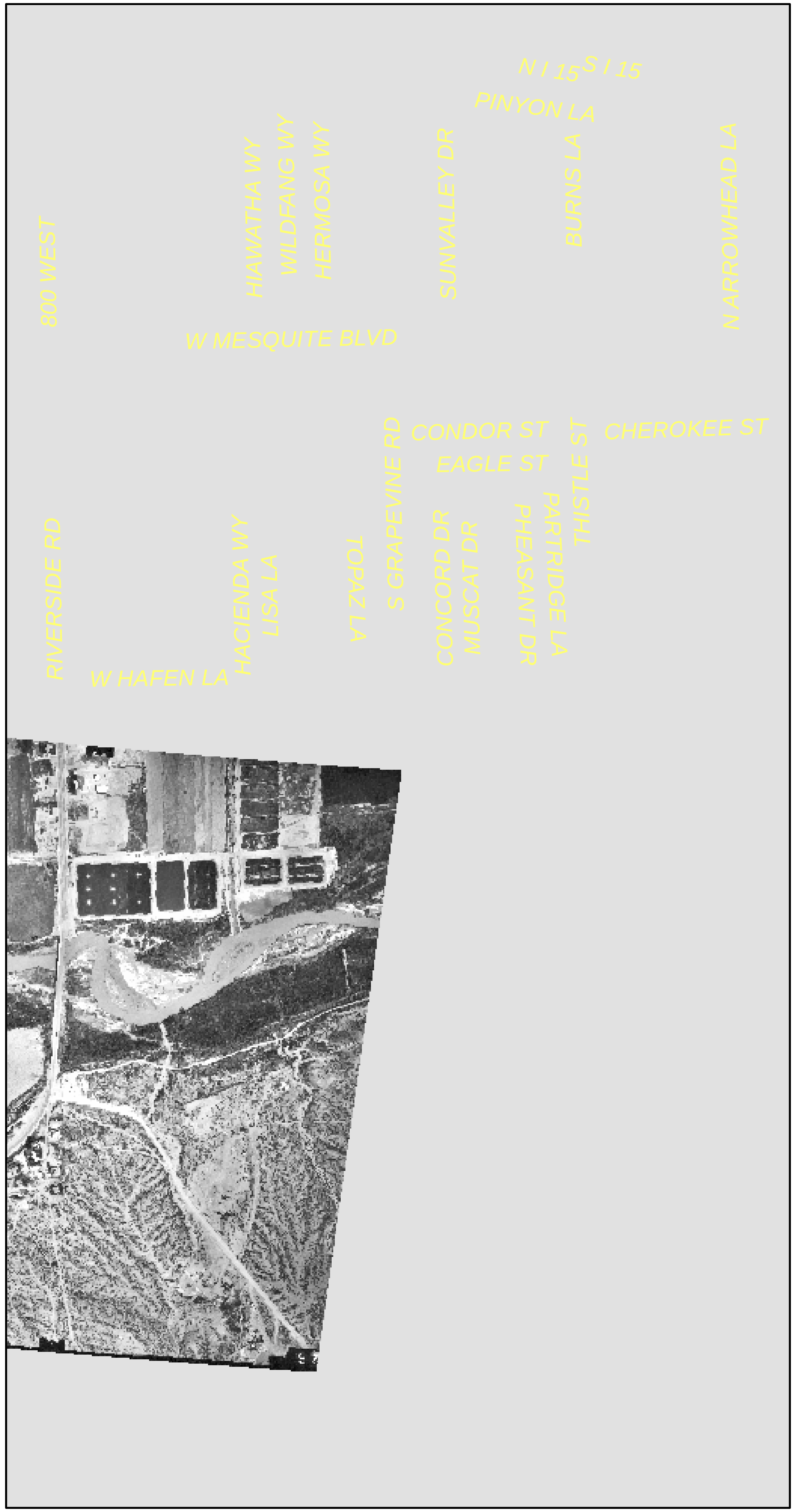
LISA LA
TOPAZ LA
CONCORD DR
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA

1994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S I 15
PINYON LA
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HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
N ARROWHEAD LA
W MESQUITE BLVD
S GRAPEVINE RD
CONDOR ST
CHEROKEE ST
EAGLE ST
THISTLE ST
RIVERSIDE RD
W HAFEN LA
HACIENDA WY
LISA LA
TOPAZ LA
CONCORD DR
MUSCAT DR
PHEASANT DR
PARTRIDGE LA

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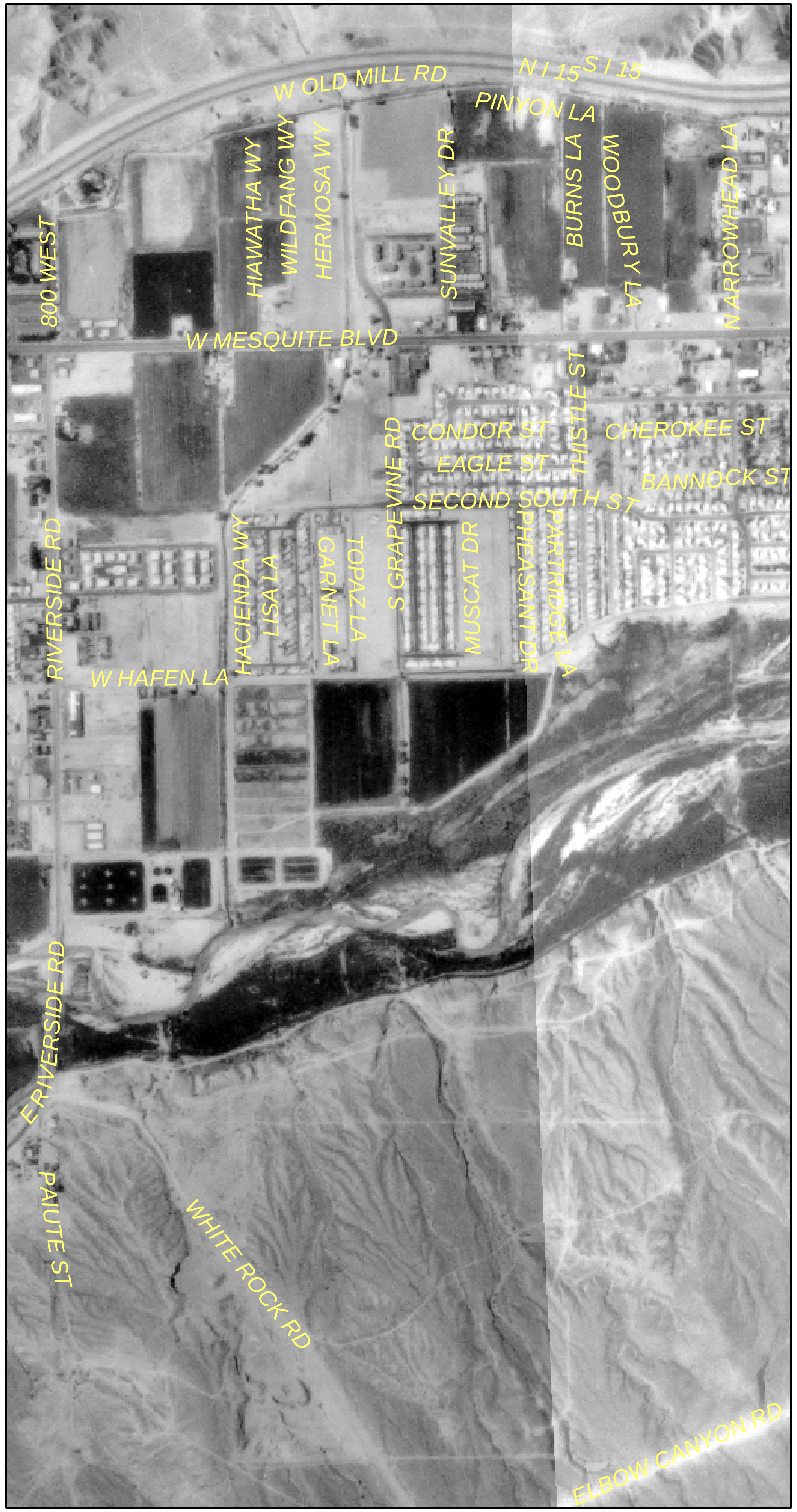
Feet

1995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S I 15
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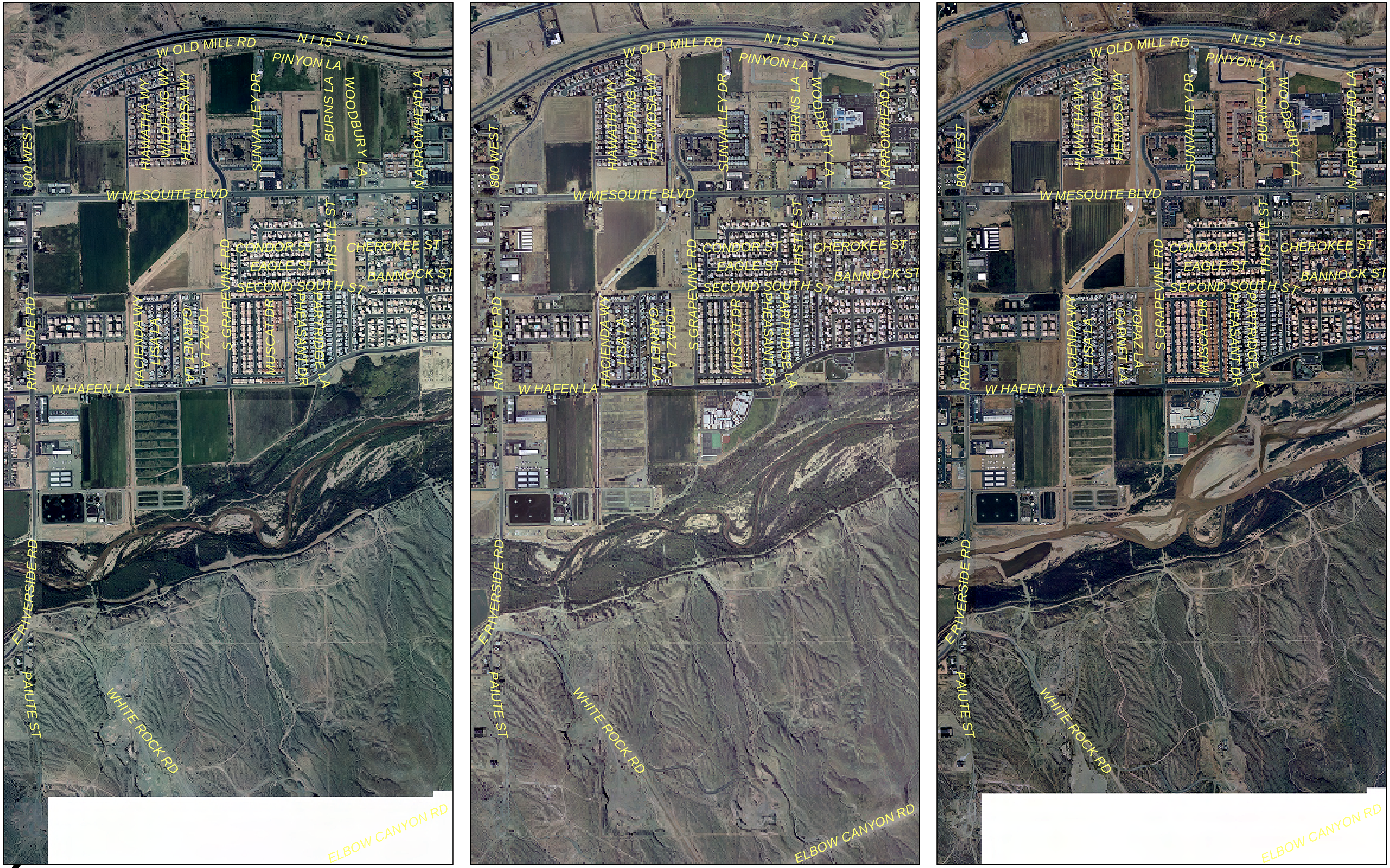
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
W MESQUITE BLVD
THISTLE ST
CONDOR ST
CHEROKEE ST
EAGLE ST
BANNOCK ST
SECOND SOUTH ST
S GRAPEVINE RD
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

1997

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-4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N I 15
S I 15
PINYON LA
HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
800 WEST
W MESQUITE BLVD
THISTLE ST
CONDOR ST
CHEROKEE ST
EAGLE ST
BANNOCK ST
SECOND SOUTH ST
S GRAPEVINE RD
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

Fall 2002

0
500
1,000
2,000
3,000
4,000
Feet

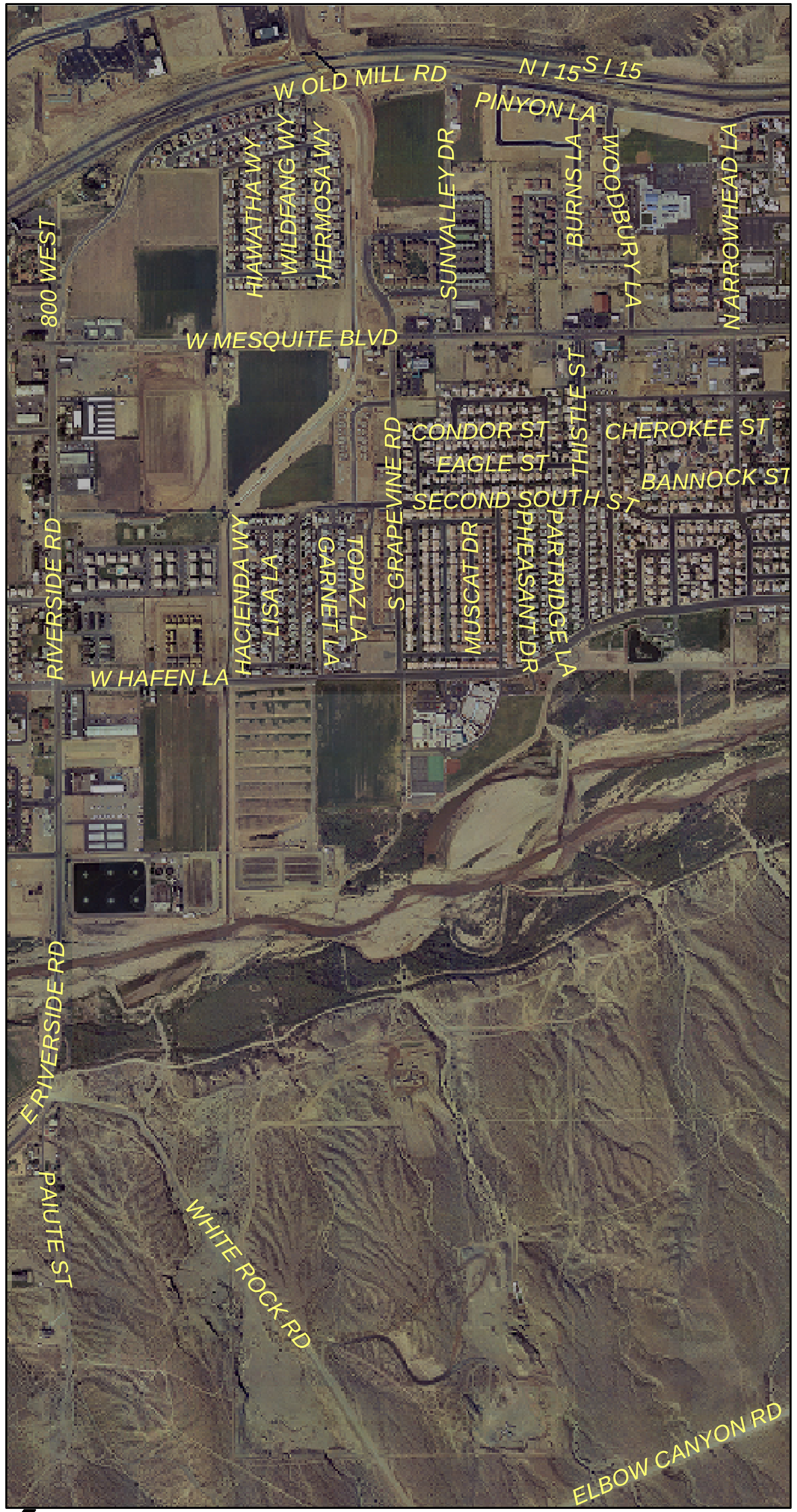
Fall 2004

Spring 2005

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-5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PINYON LA
HIAWATHA WY
WILDFANG WY
HERMOSA WY
SUNVALLEY DR
BURNS LA
WOODBURY LA
N ARROWHEAD LA
800 WEST
W MESQUITE BLVD
THISTLE ST
CONDOR ST
CHEROKEE ST
EAGLE ST
BANNOCK ST
SECOND SOUTH ST
S GRAPEVINE RD
RIVERSIDE RD
HACIENDA WY
LISA LA
GARNET LA
TOPAZ LA
MUSCAT DR
PHEASANT DR
PARTRIDGE LA
W HAFEN LA
E RIVERSIDE RD
PAIUTE ST
WHITE ROCK RD
ELBOW CANYON RD

Fall 2005

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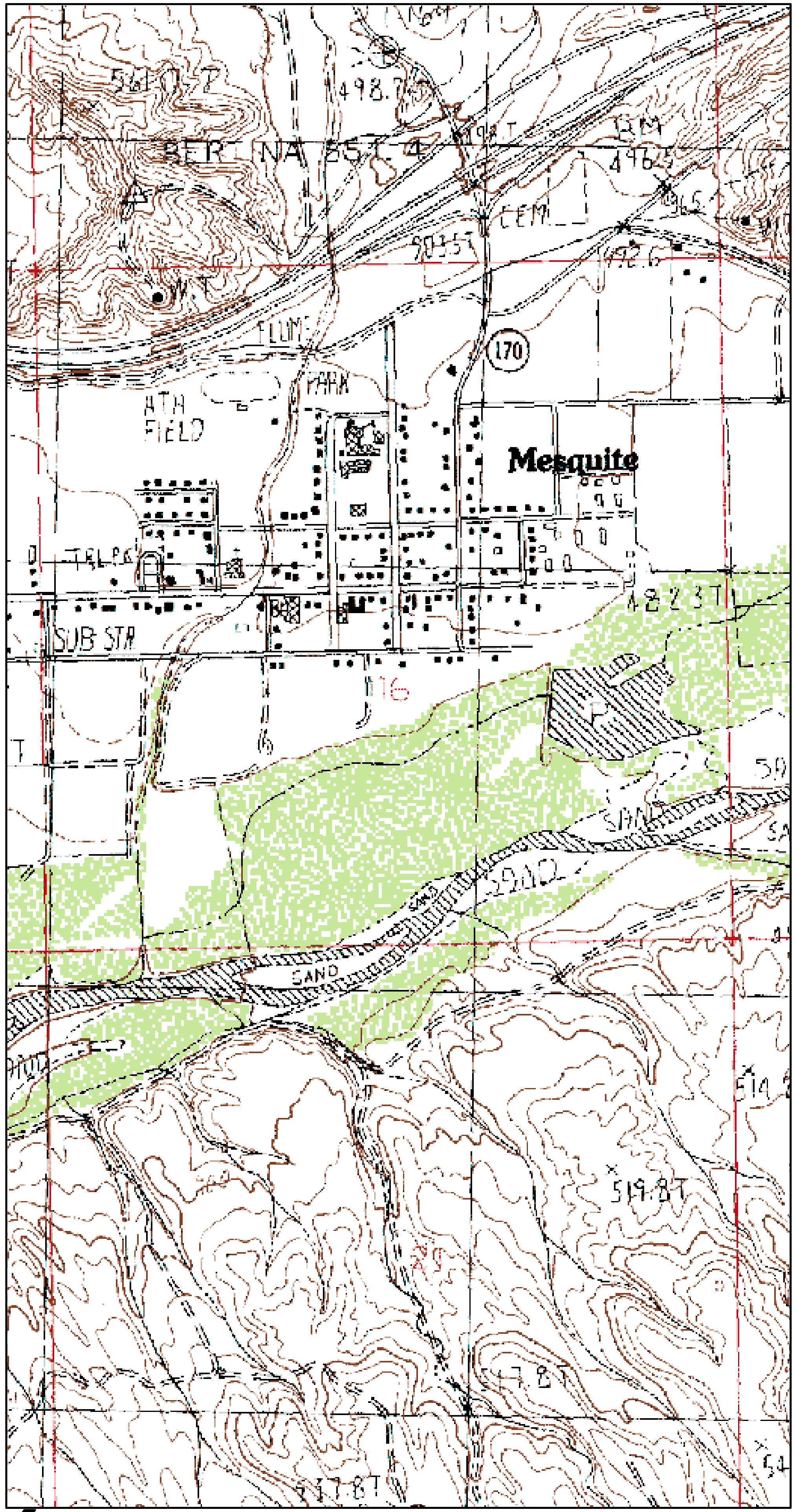
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 8-6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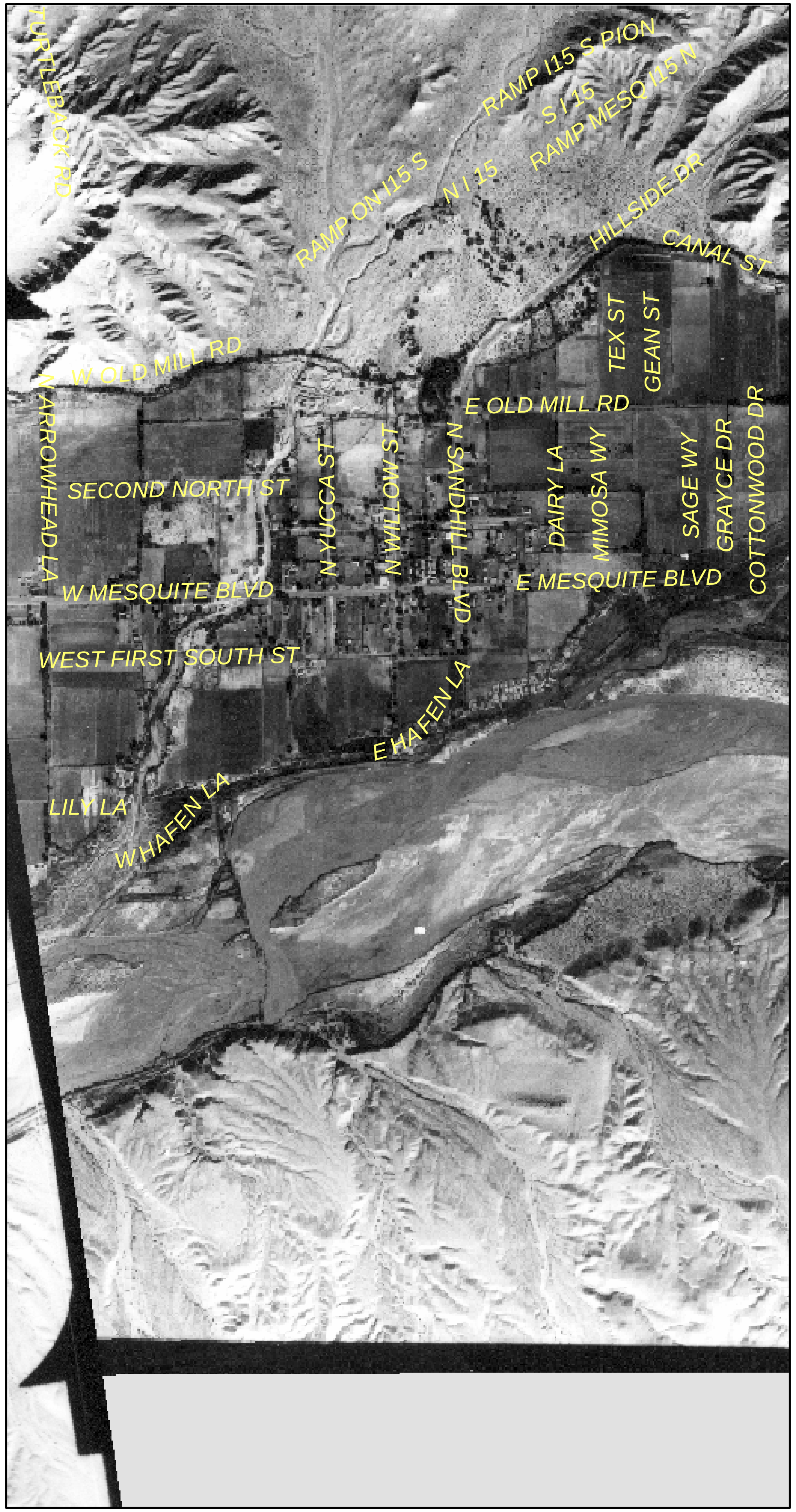
170
CEM
PARK
ATH FIELD
SUB STA
SAND
4223 T

USGS DRG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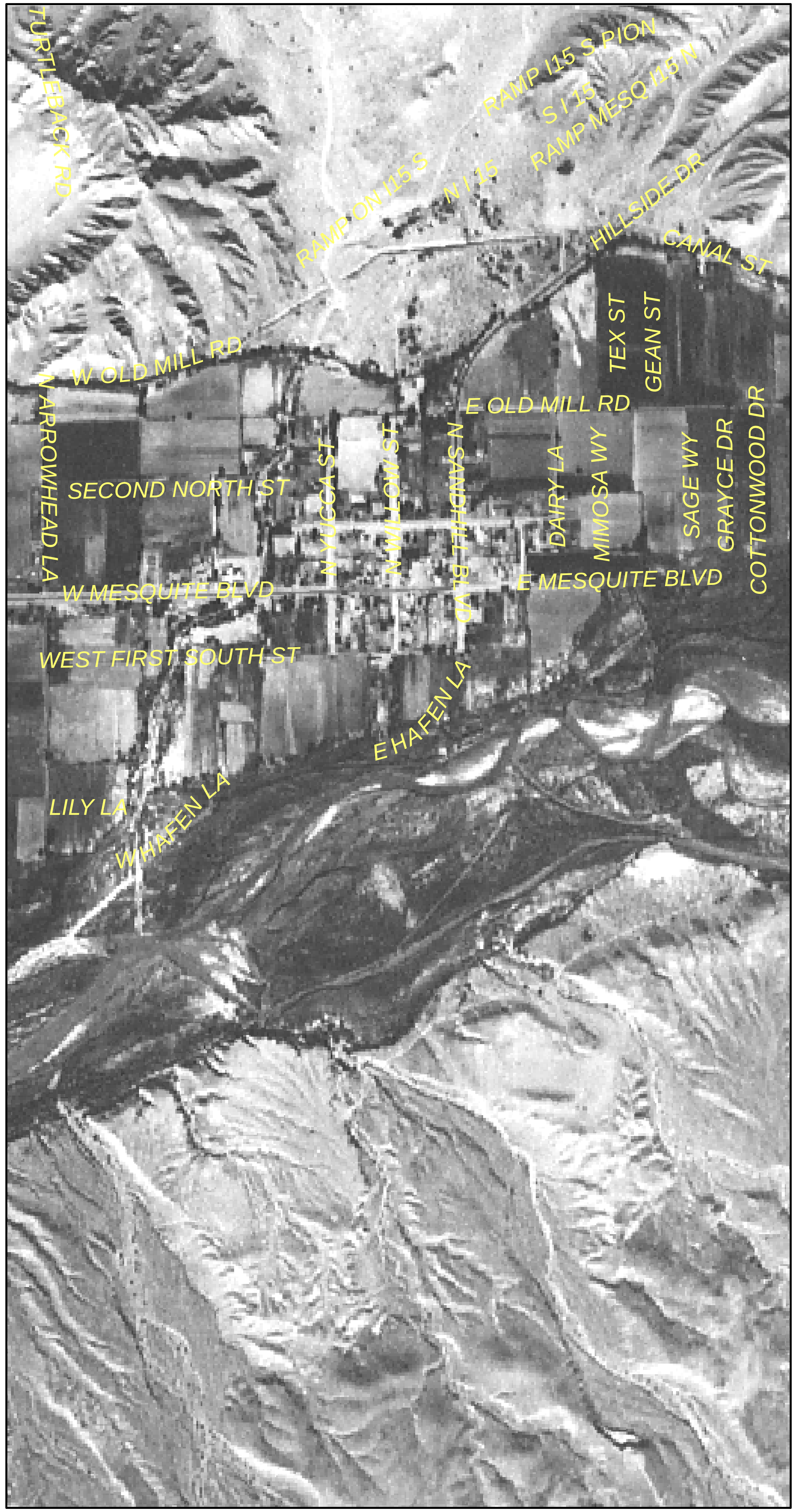
RAMP I15 S PION
S I 15
RAMP MESO I15 N
RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

1938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RAMP ON I15 S
N I 15
HILLSIDE DR
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TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

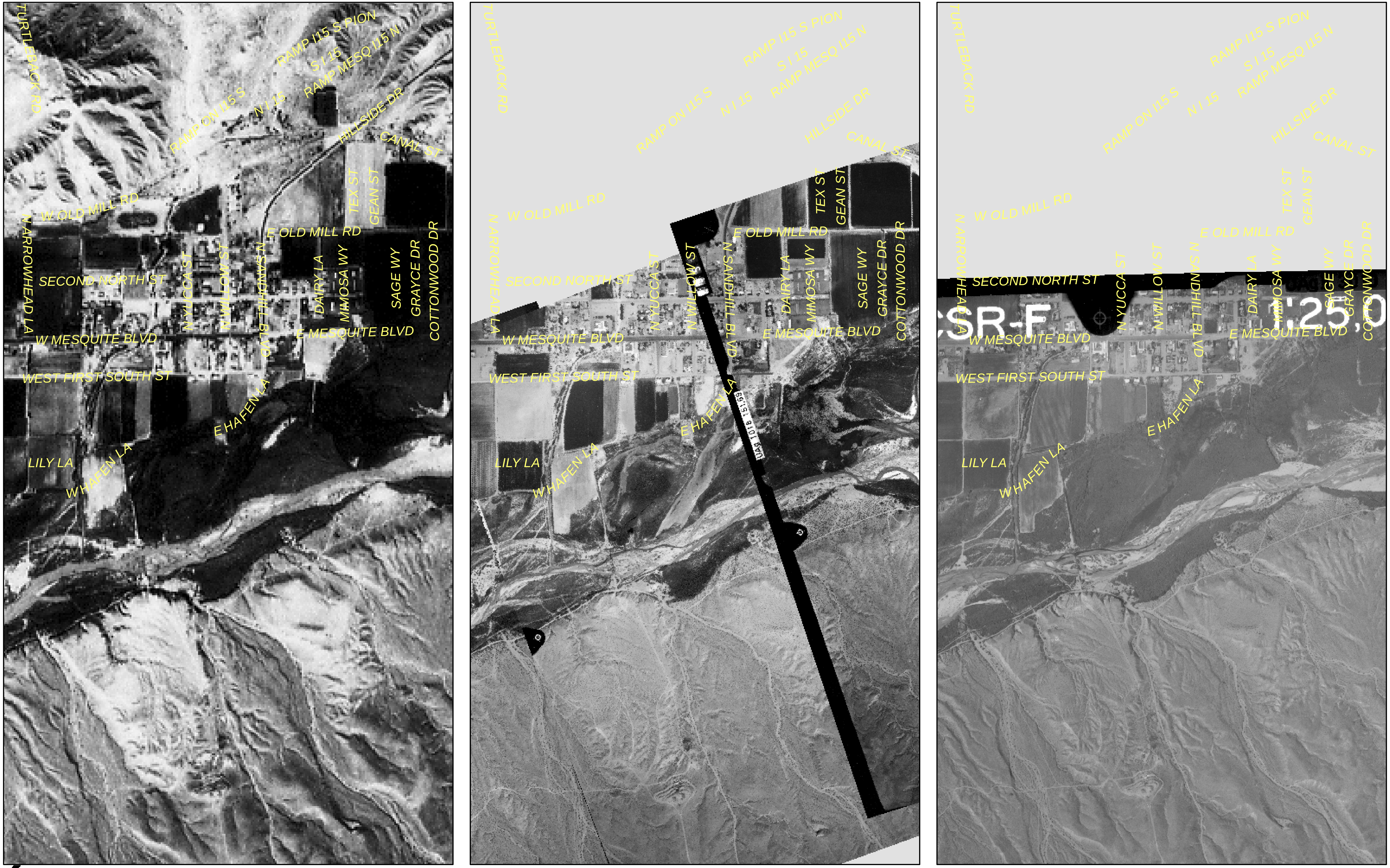
1953

0 500 1,000 2,000 3,000 4,000
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-1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RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA
UA5 1018 151,69
CSR-F
1:25,0

1973

0
500
1,000
2,000
3,000
4,000
Feet

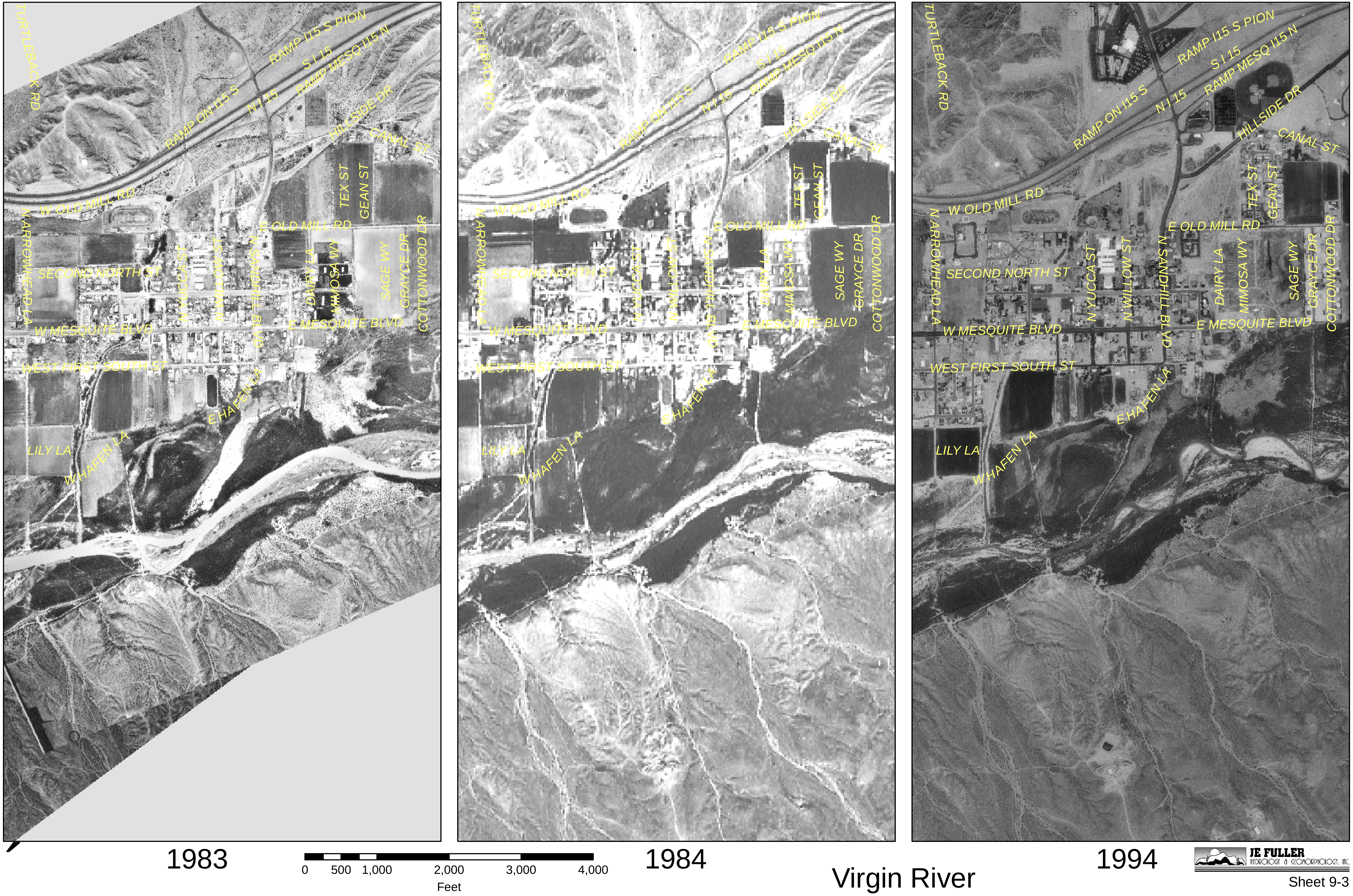
1977

1978

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-2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S I 15
RAMP MESQ I15 N
N I 15
RAMP ON I15 S
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
W HAFEN LA
LILY LA
0
500
1,000
2,000
3,000
4,000
Feet

1983

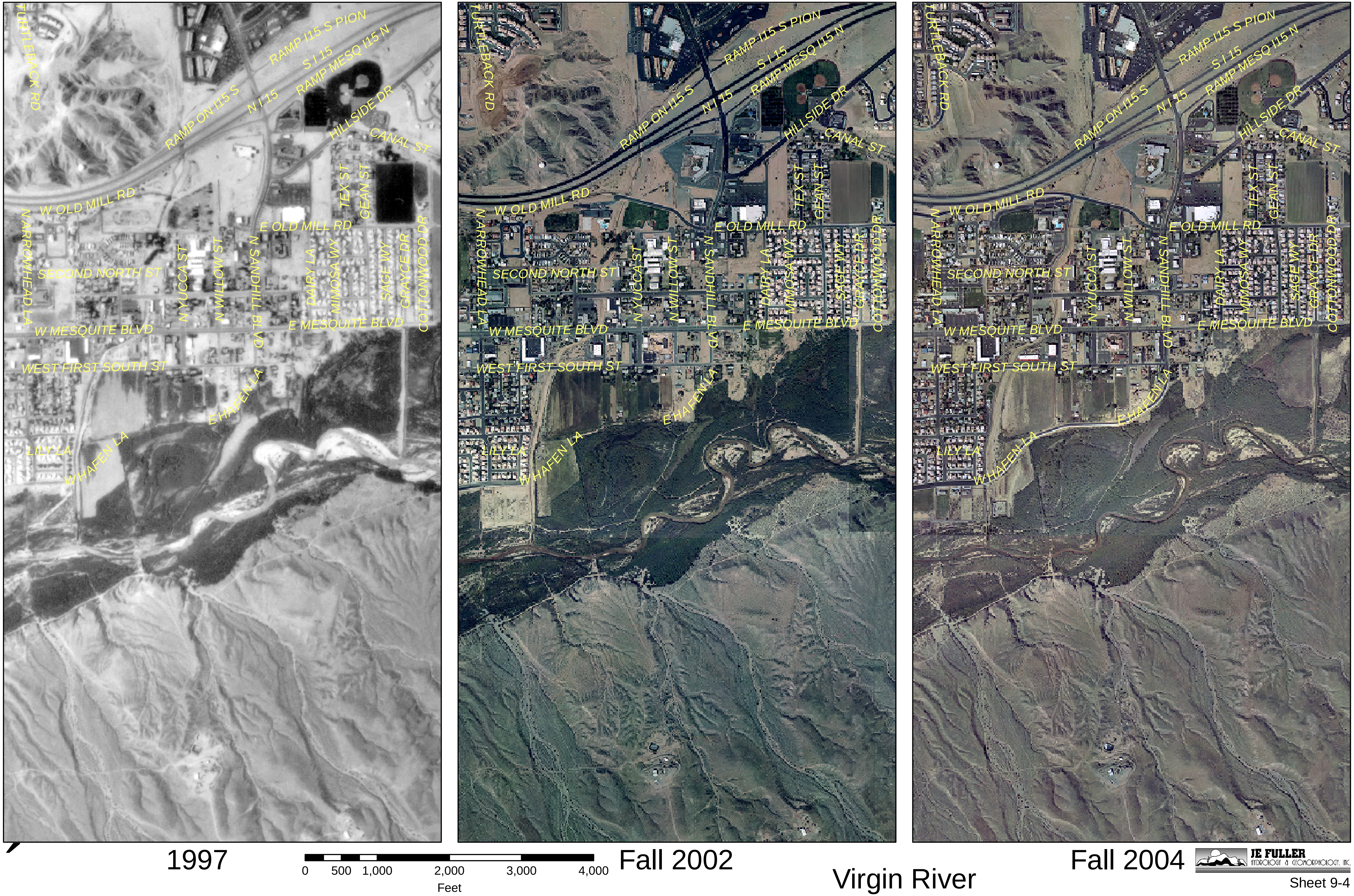
1984

1994

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-3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RAMP ON I15 S
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CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA
0
500
1,000
2,000
3,000
4,000
Feet

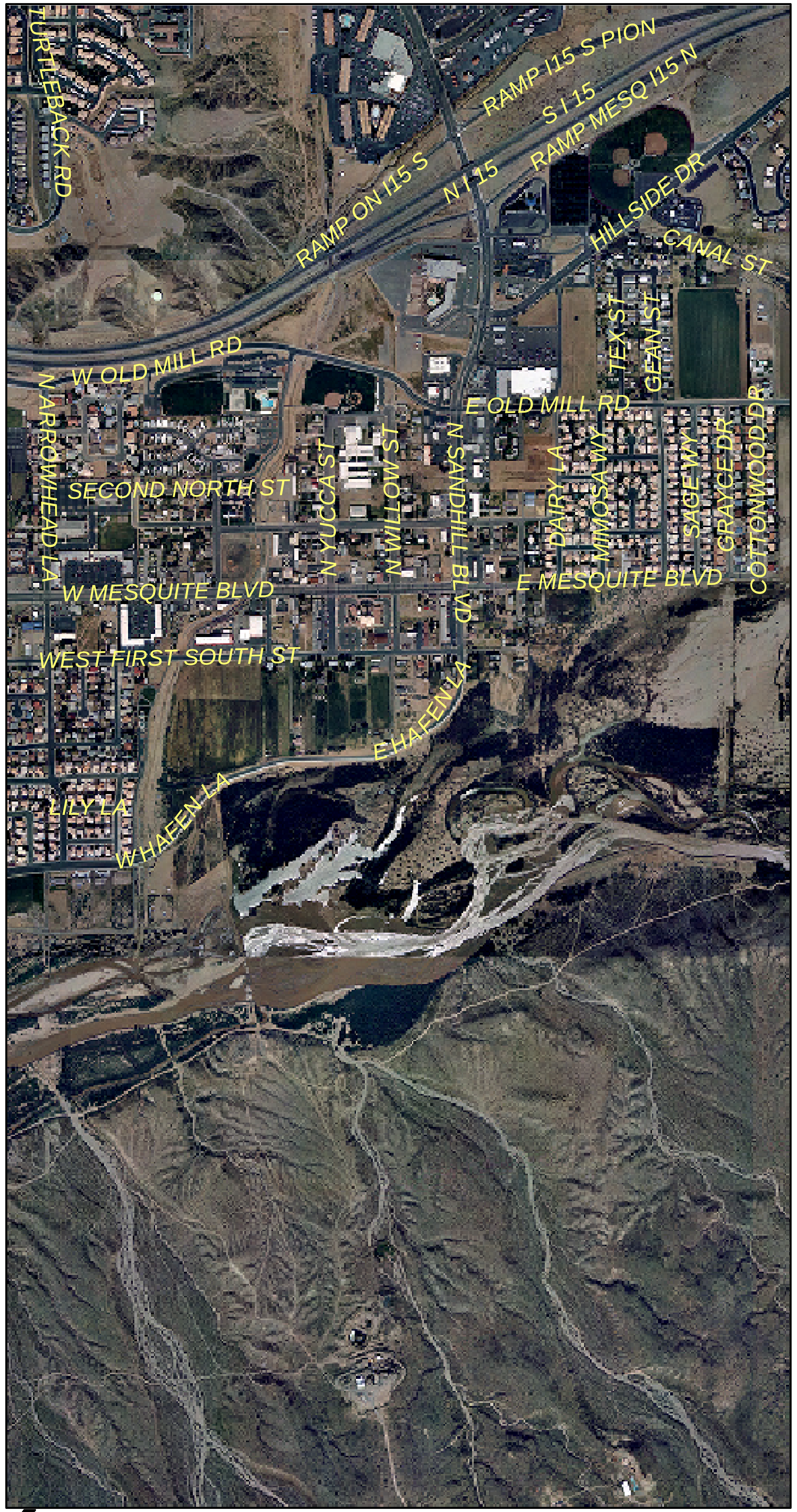
1997

Fall 2002

Fall 2004

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.


TURTLEBACK RD
RAMP I15 S PION
S I 15
RAMP MESQ I15 N
RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

Spring 2005

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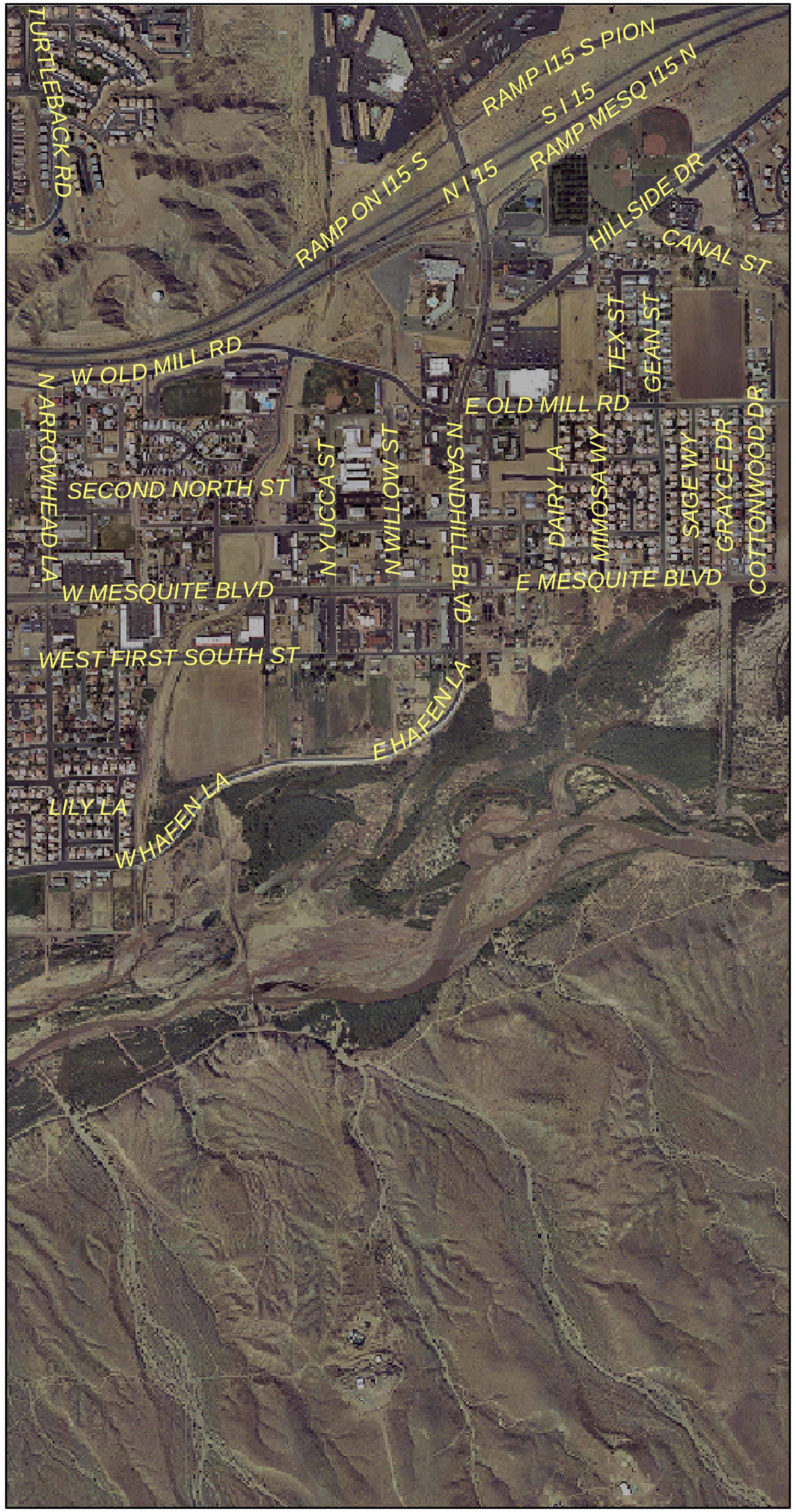
Feet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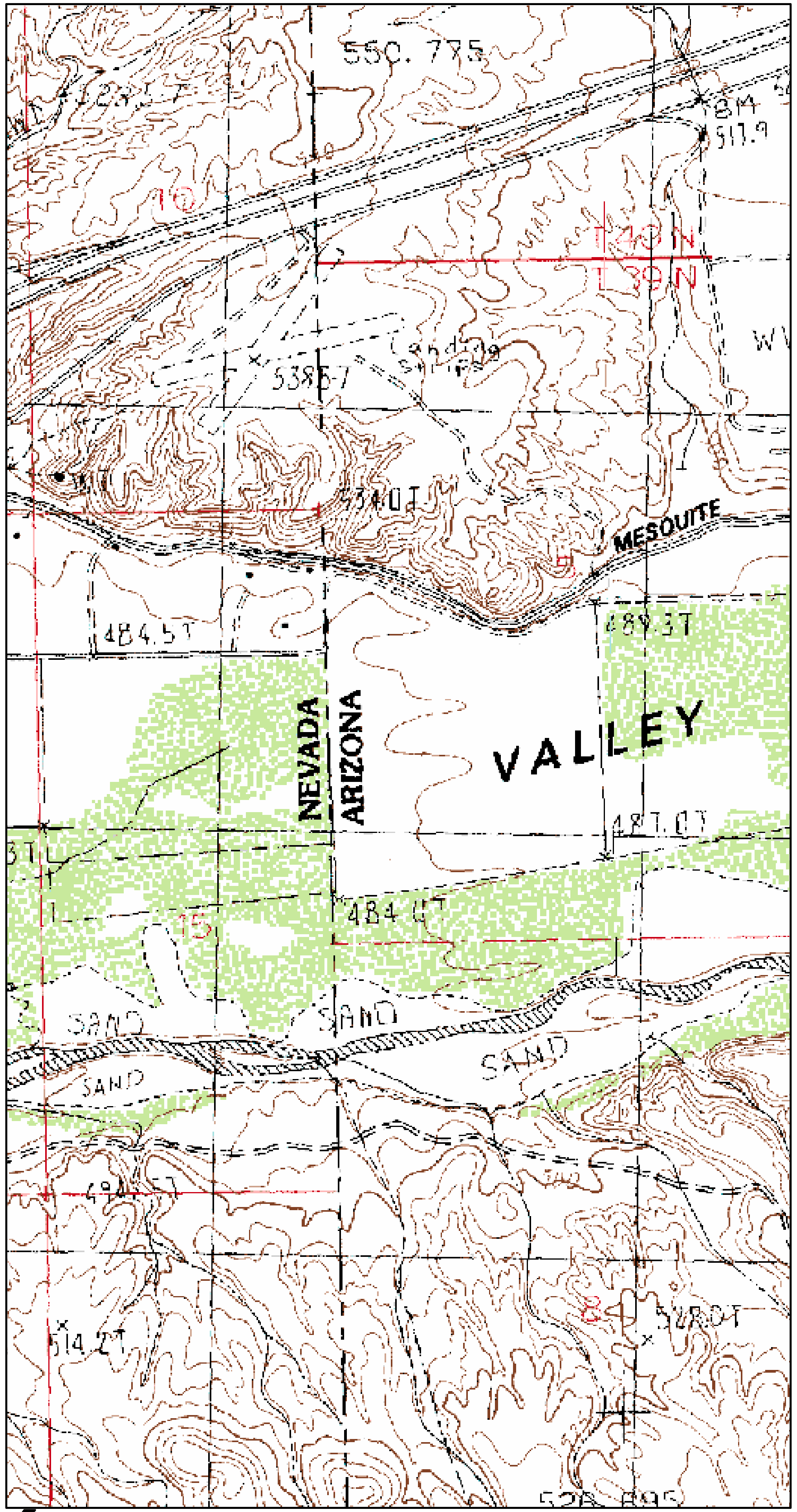
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

Fall 2005

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-5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T40 N
T39 N
Landing Strip
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ARIZONA
VALLEY
487.0T
484.4T
15
SAND
SAND
SAND
SAND
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528.0T
528 895

USGS DRG

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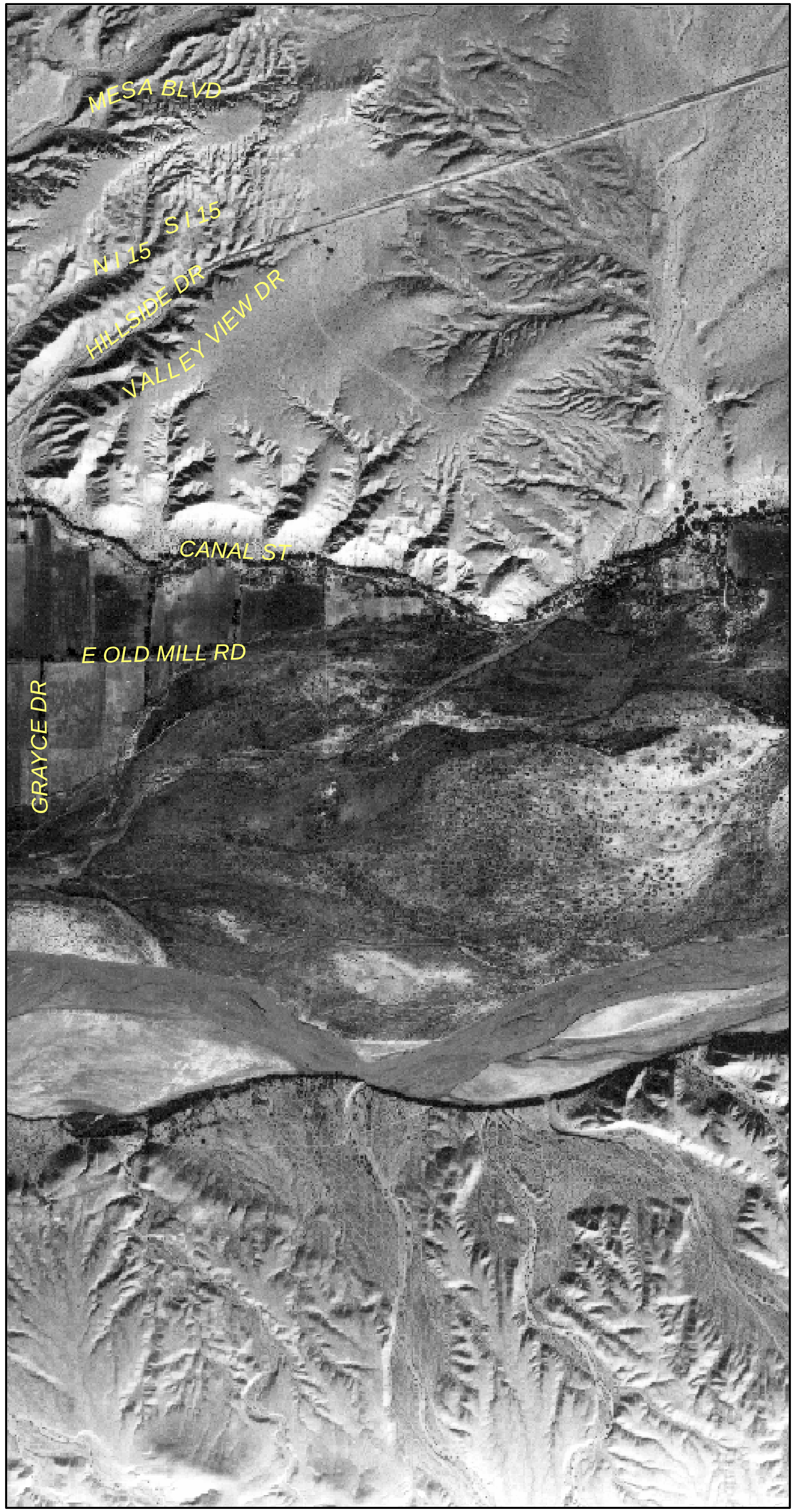
Feet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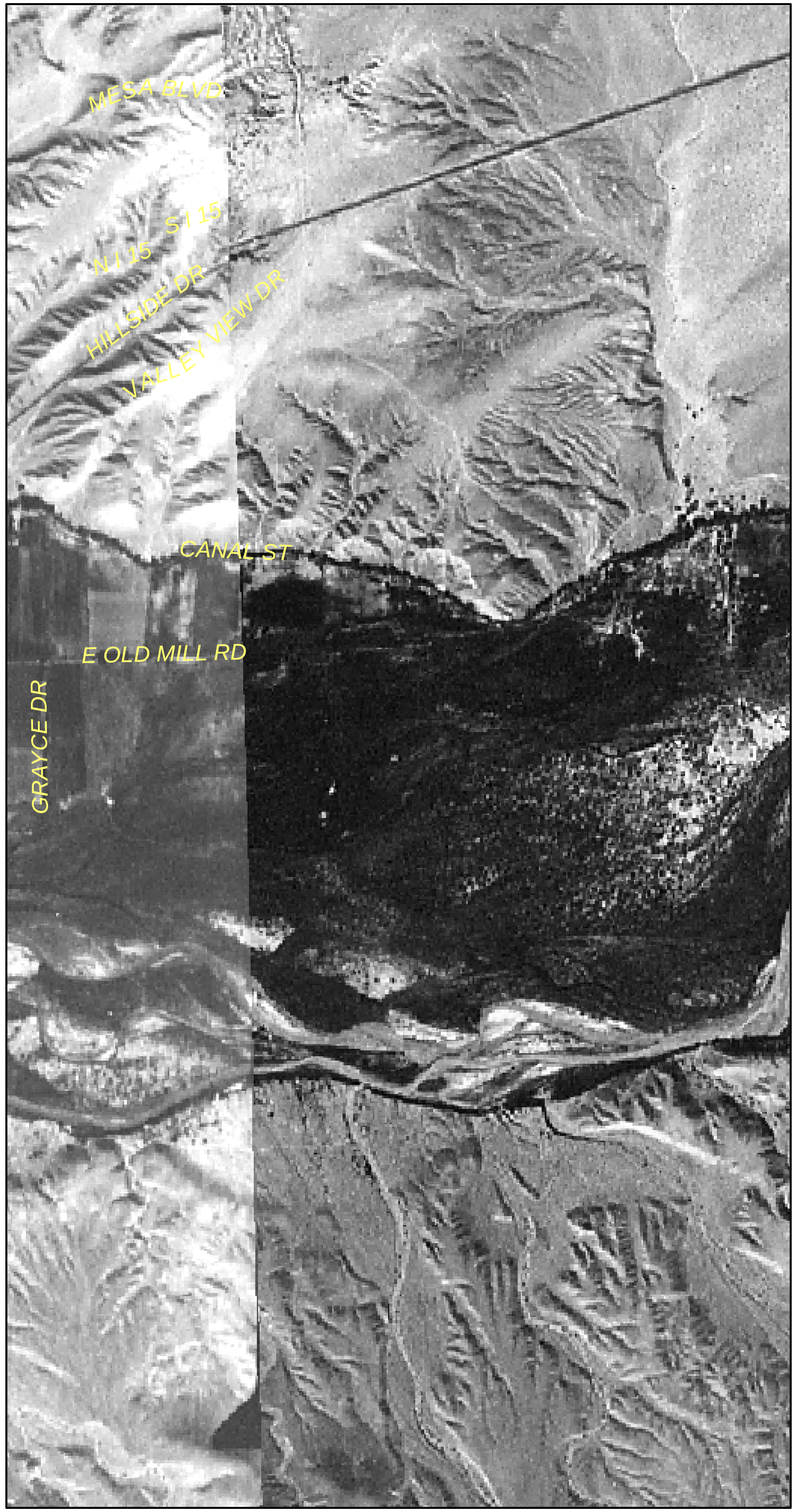
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

1938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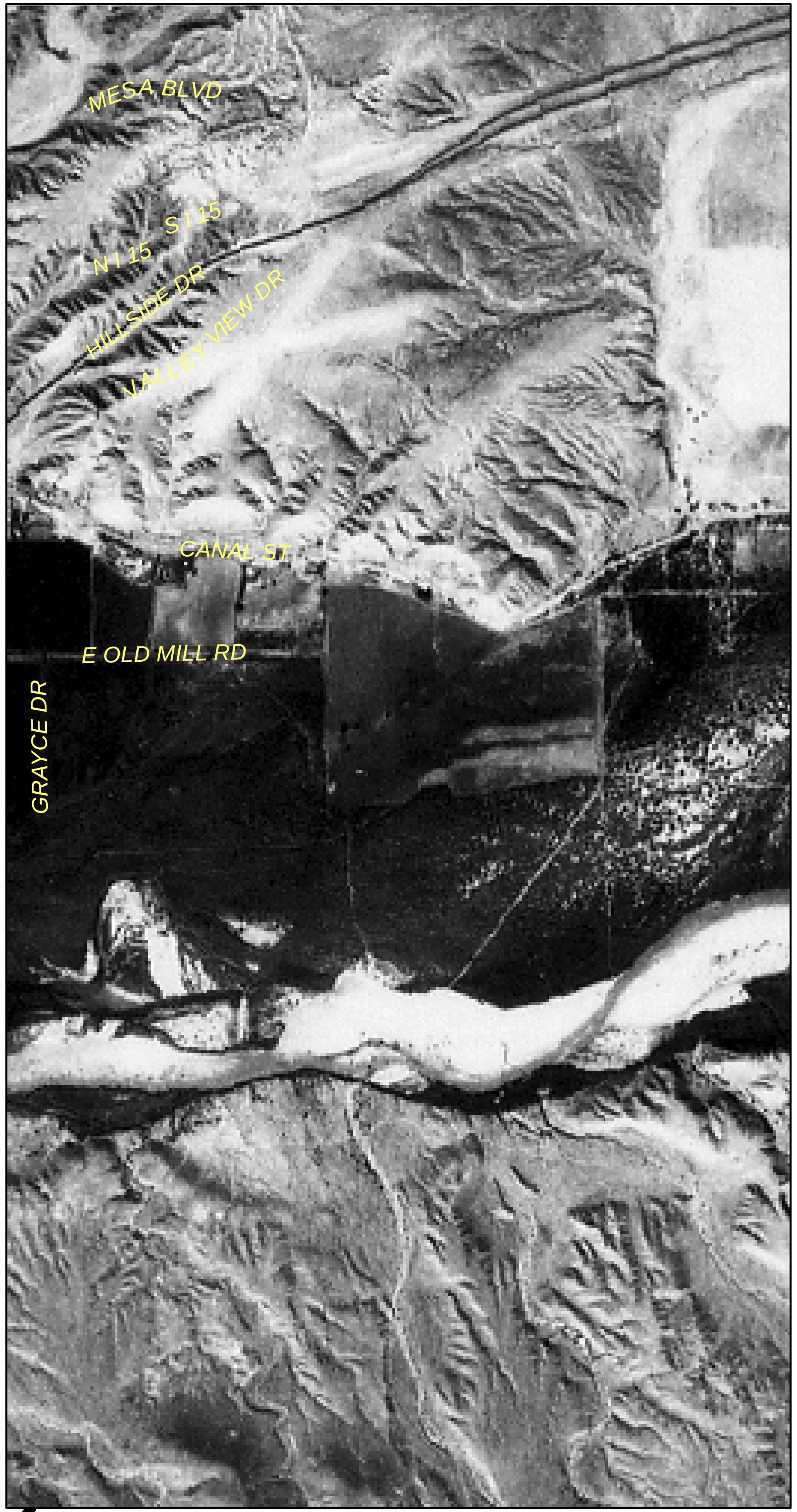
S I 15
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

1952

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 10-1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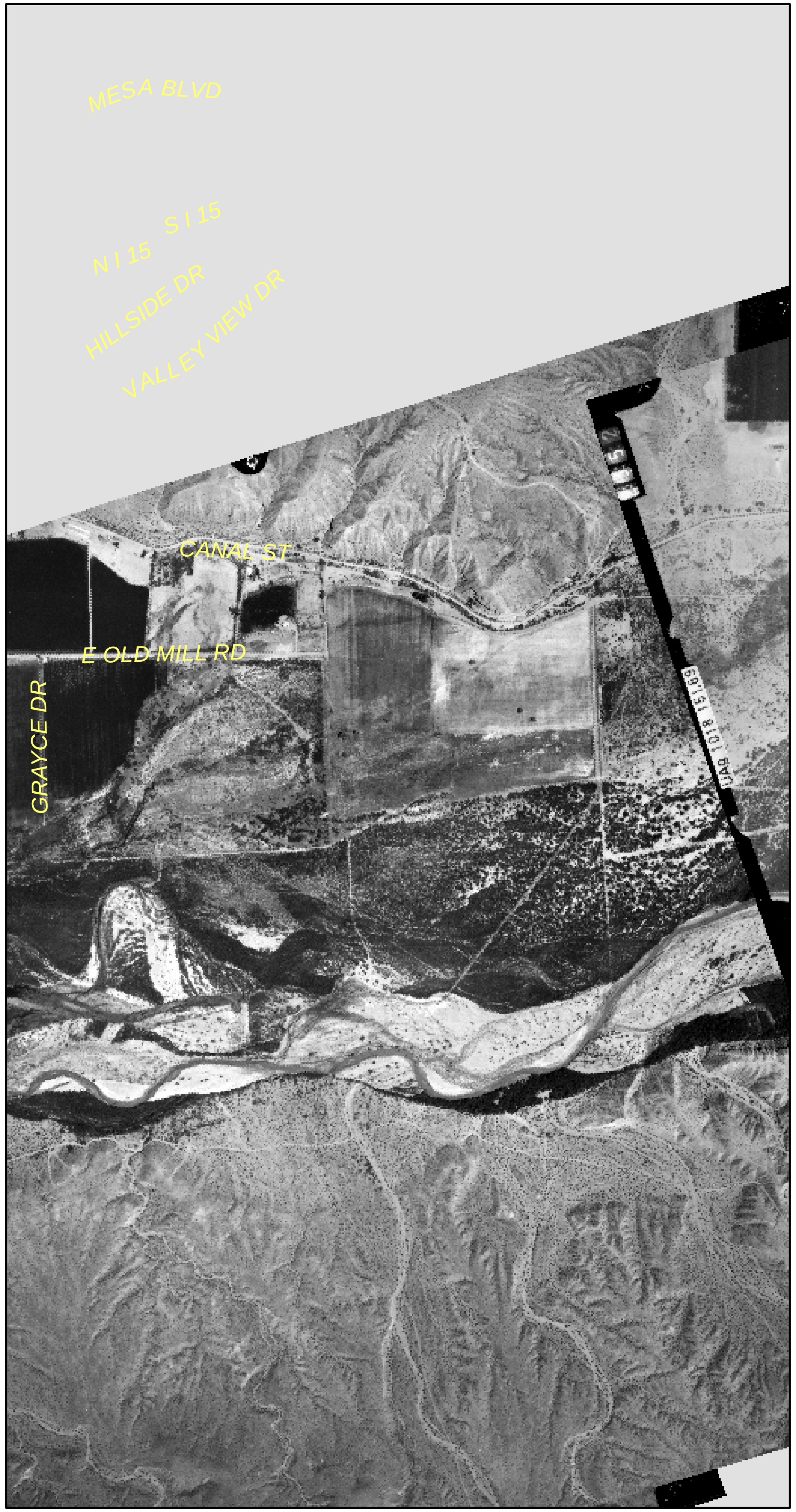
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

1973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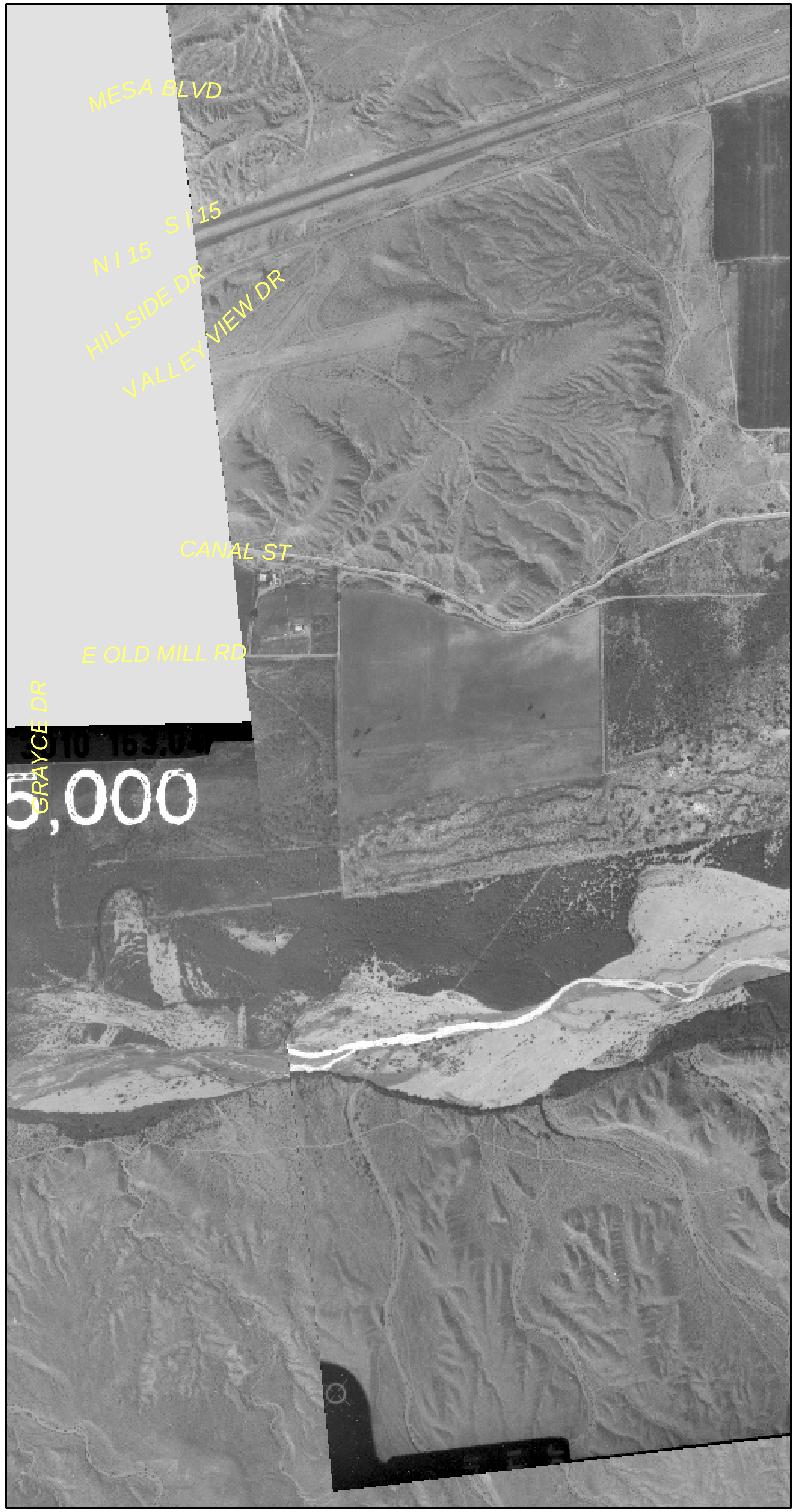
E OLD MILL RD
GRAYCE DR

1977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N I 15
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR
5,000

1978

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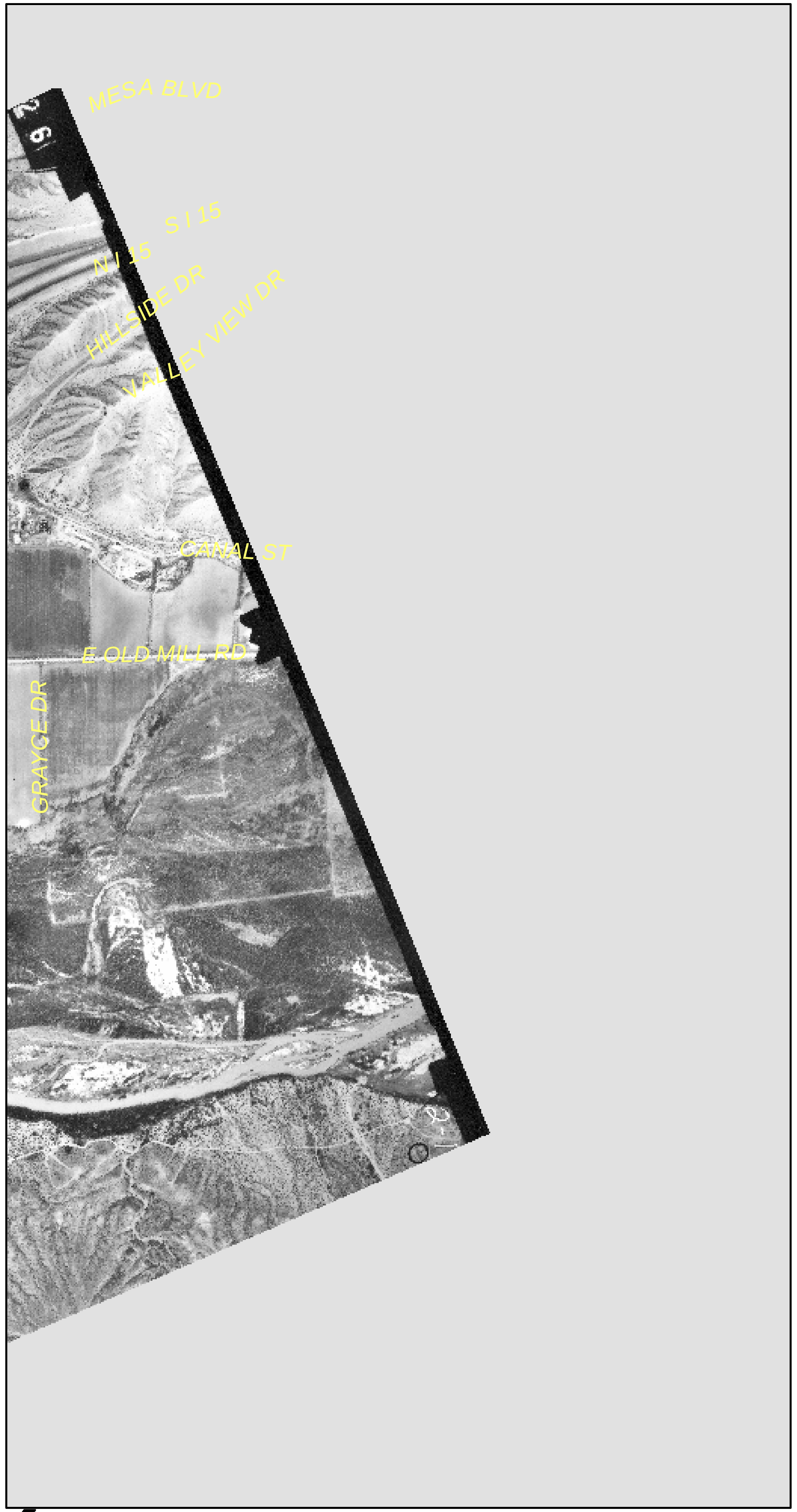
Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 10-2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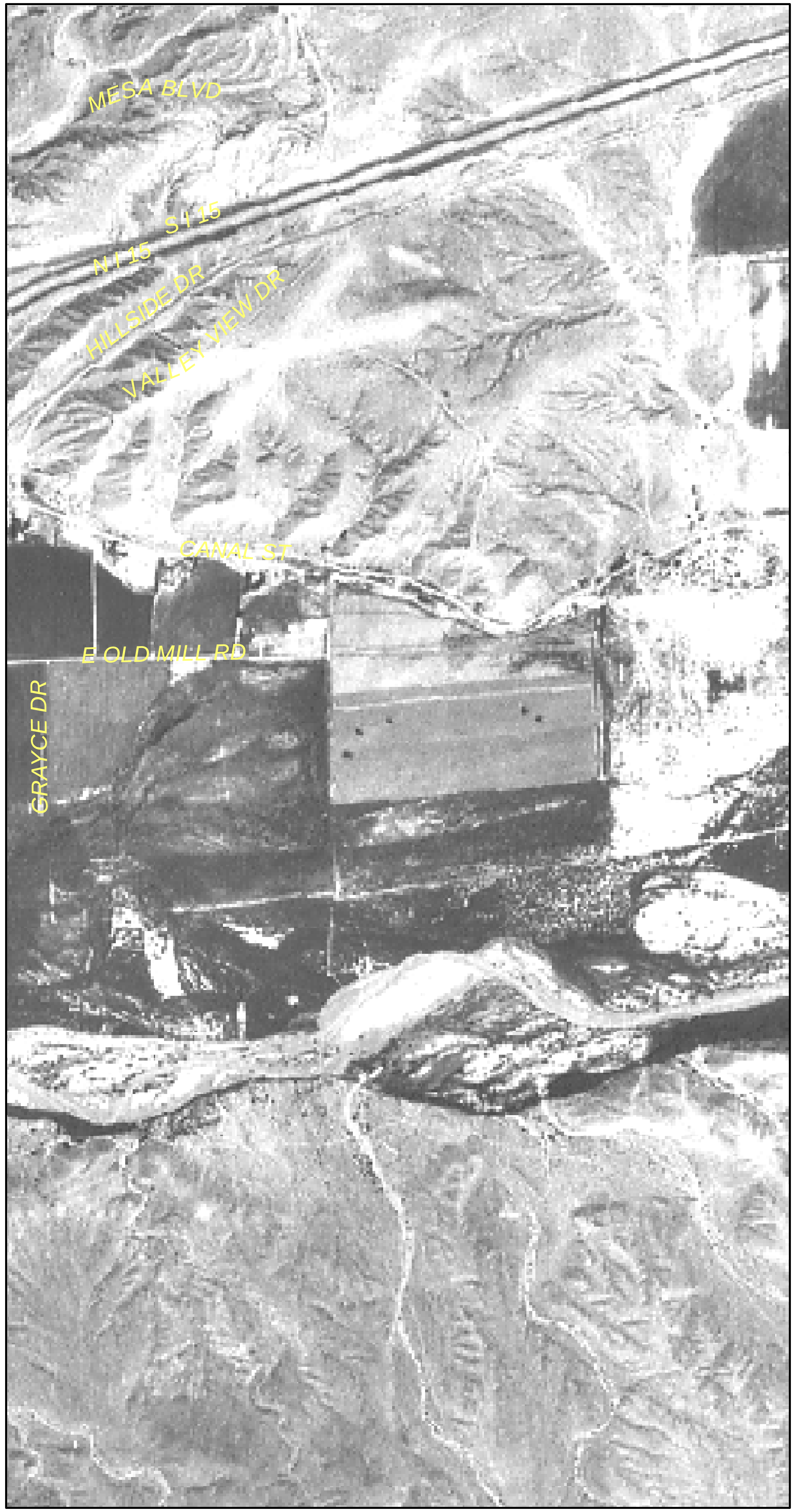
N I 15
S I 15
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

1983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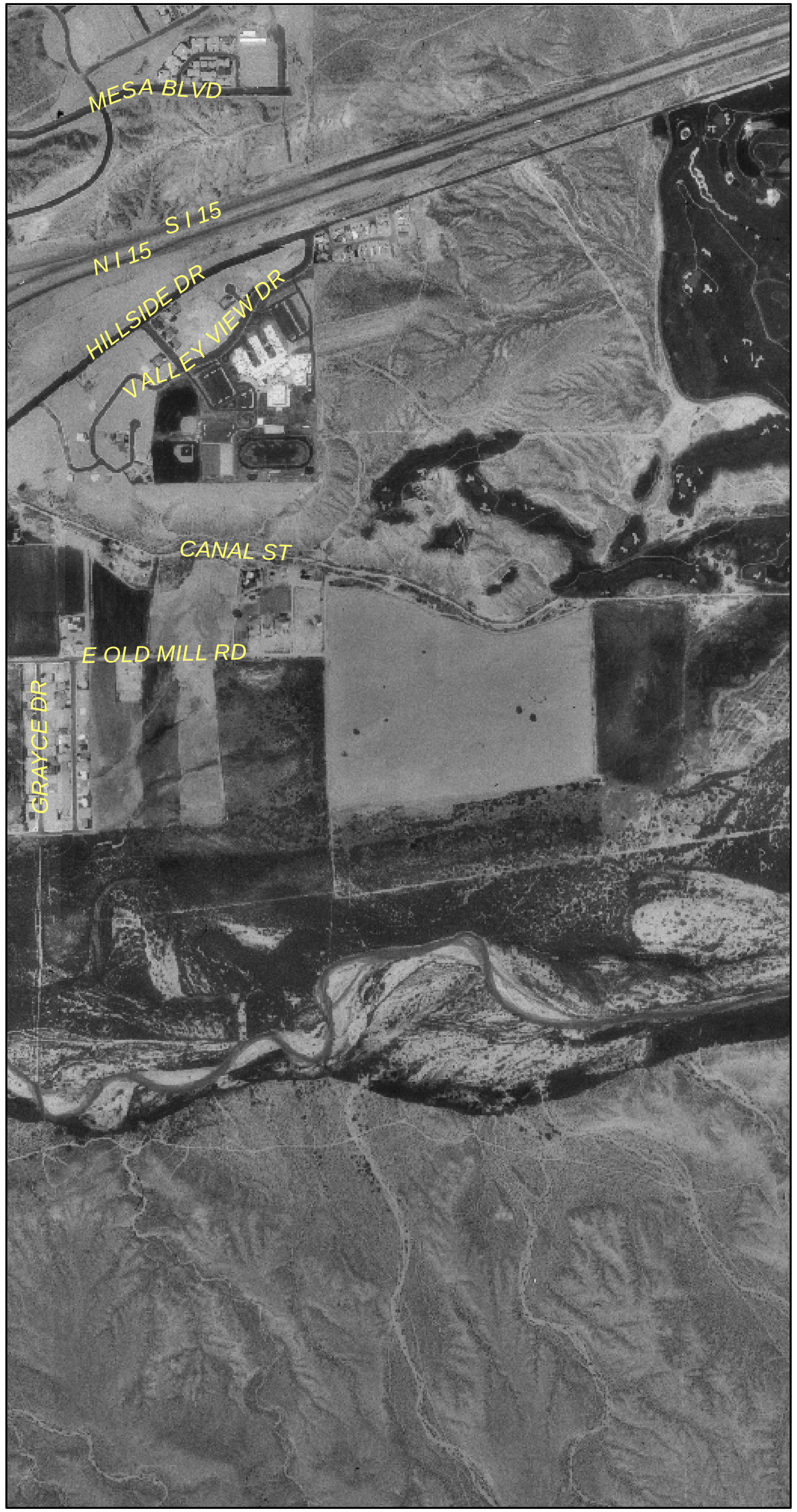
1984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S I 15
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

1994

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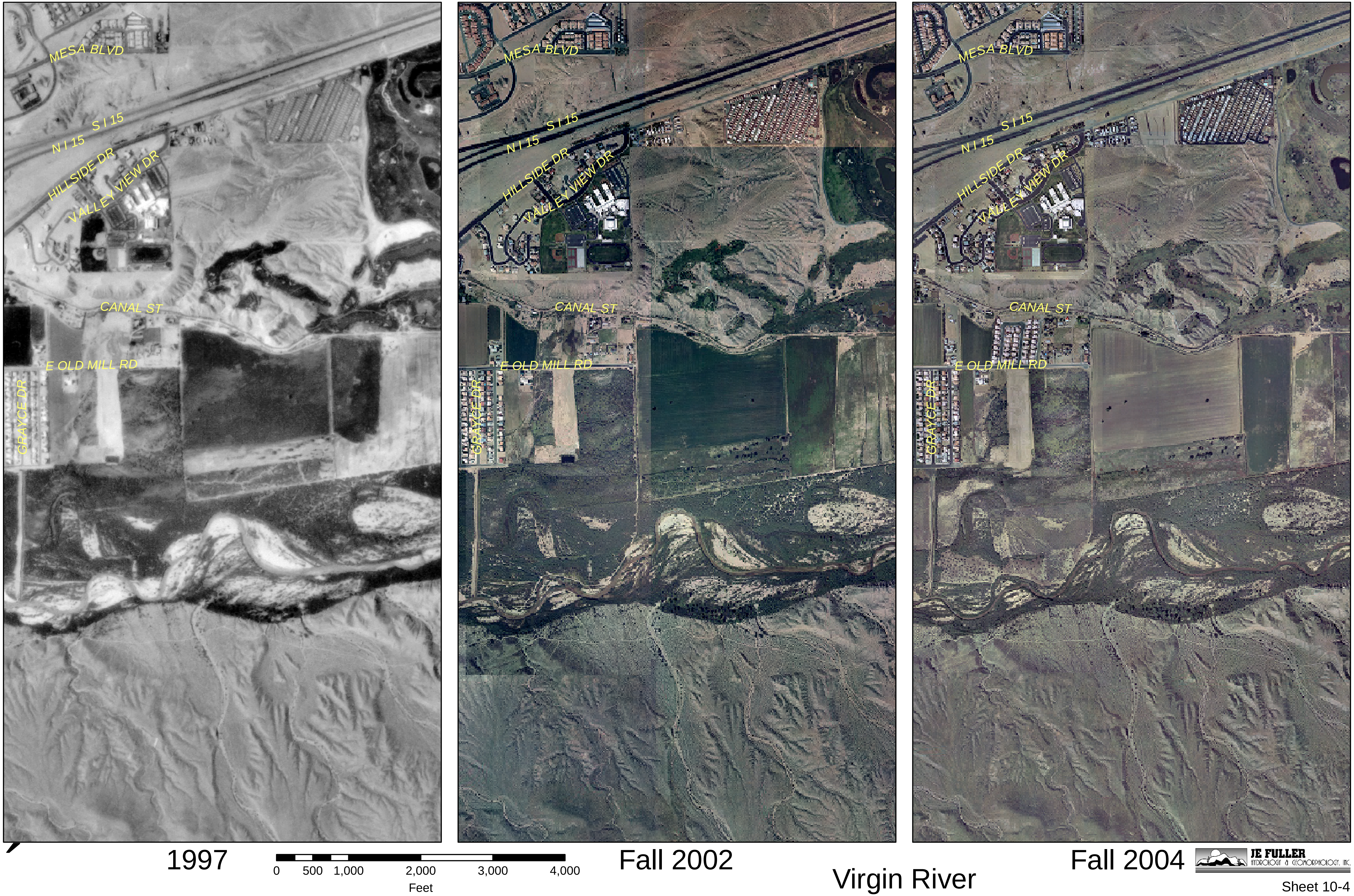
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 10-3


MESA BLVD
S I 15
N I 15
HILLSIDE DR
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR
0
500
1,000
2,000
3,000
4,000
Feet

1997

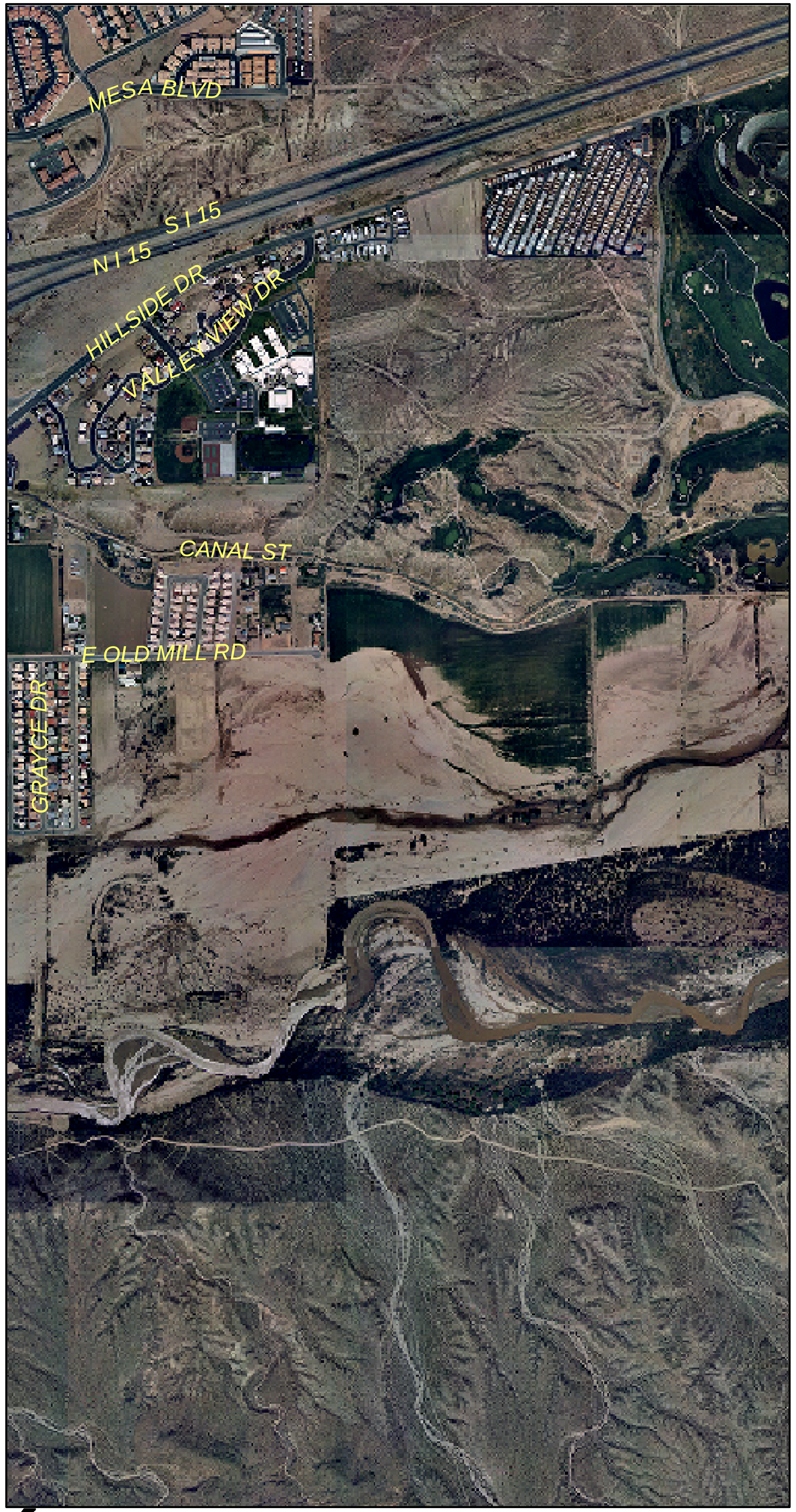
Fall 2002

Fall 2004

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 10-4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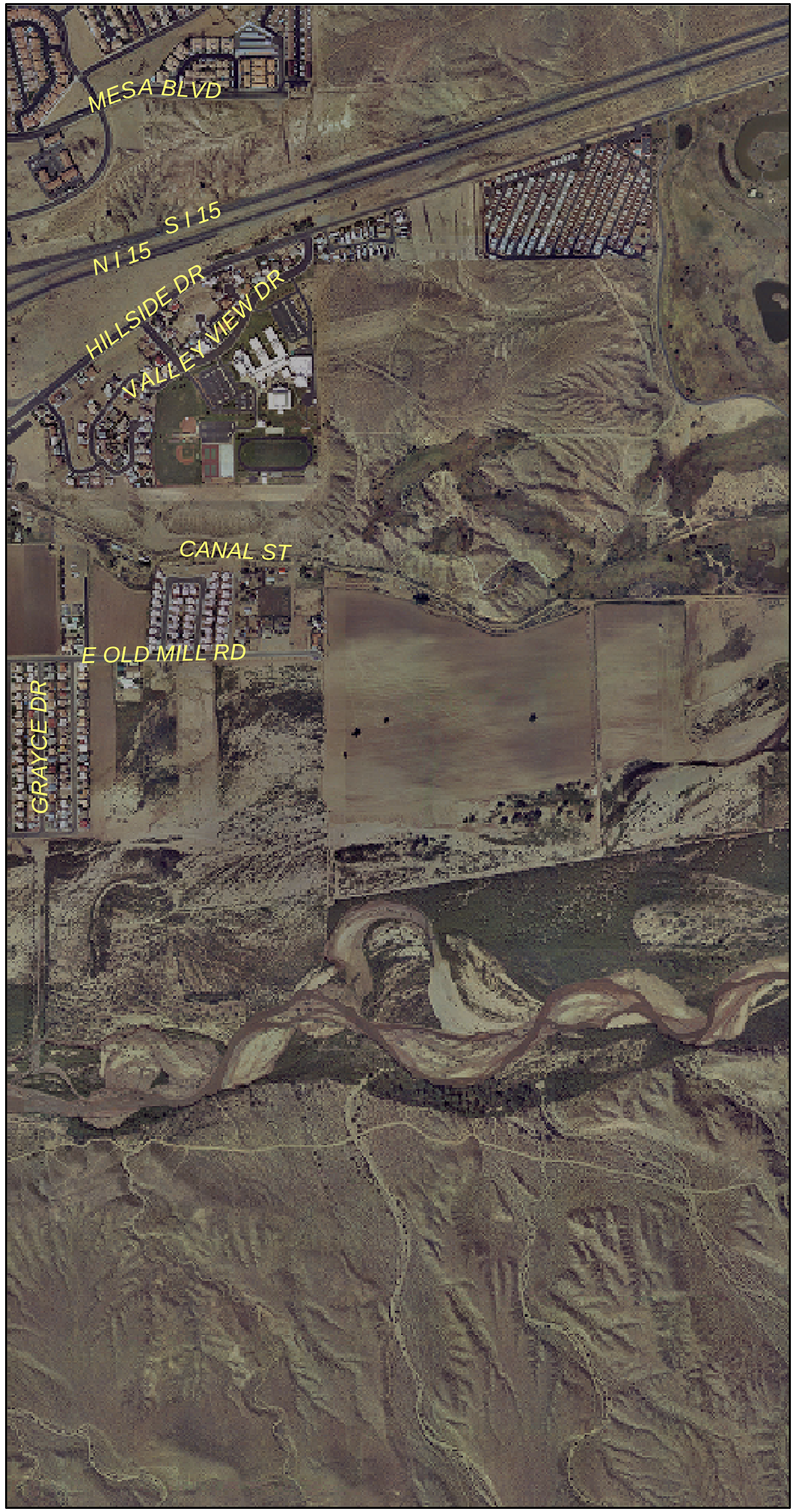
VALLEY VIEW DR
CANAL ST
E OLD MILL RD
GRAYCE DR

Spring 2005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HILLSIDE DR
VALLEY VIEW DR
CANAL ST
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GRAYCE DR

Fall 2005

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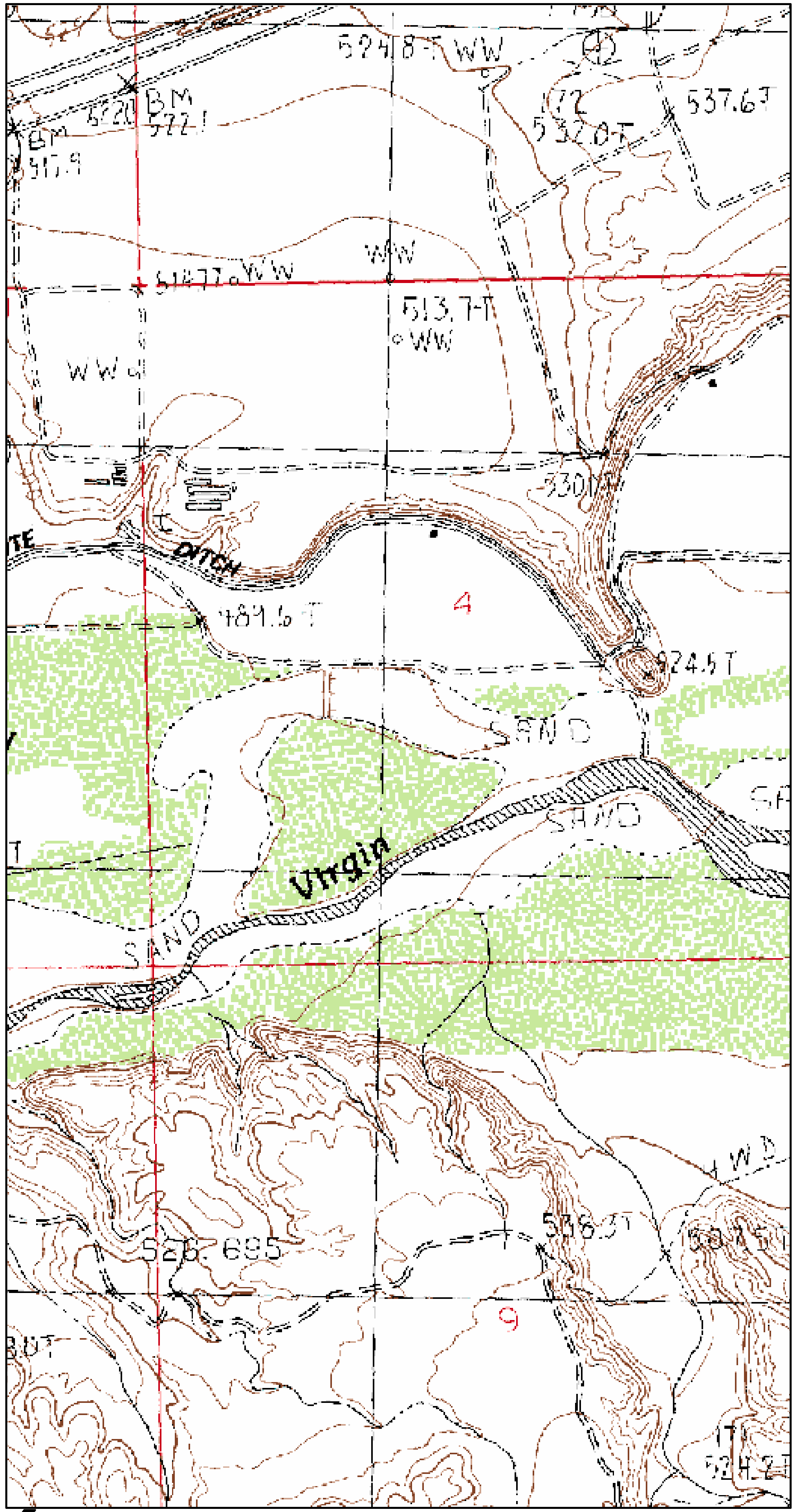
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.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WW
5147.7 WW
513.7 T
WW
WW
5301 T
DITCH
4
481.6 T
524.5 T
SAND
SAND
Virgin
SAND
WD
538.3 T
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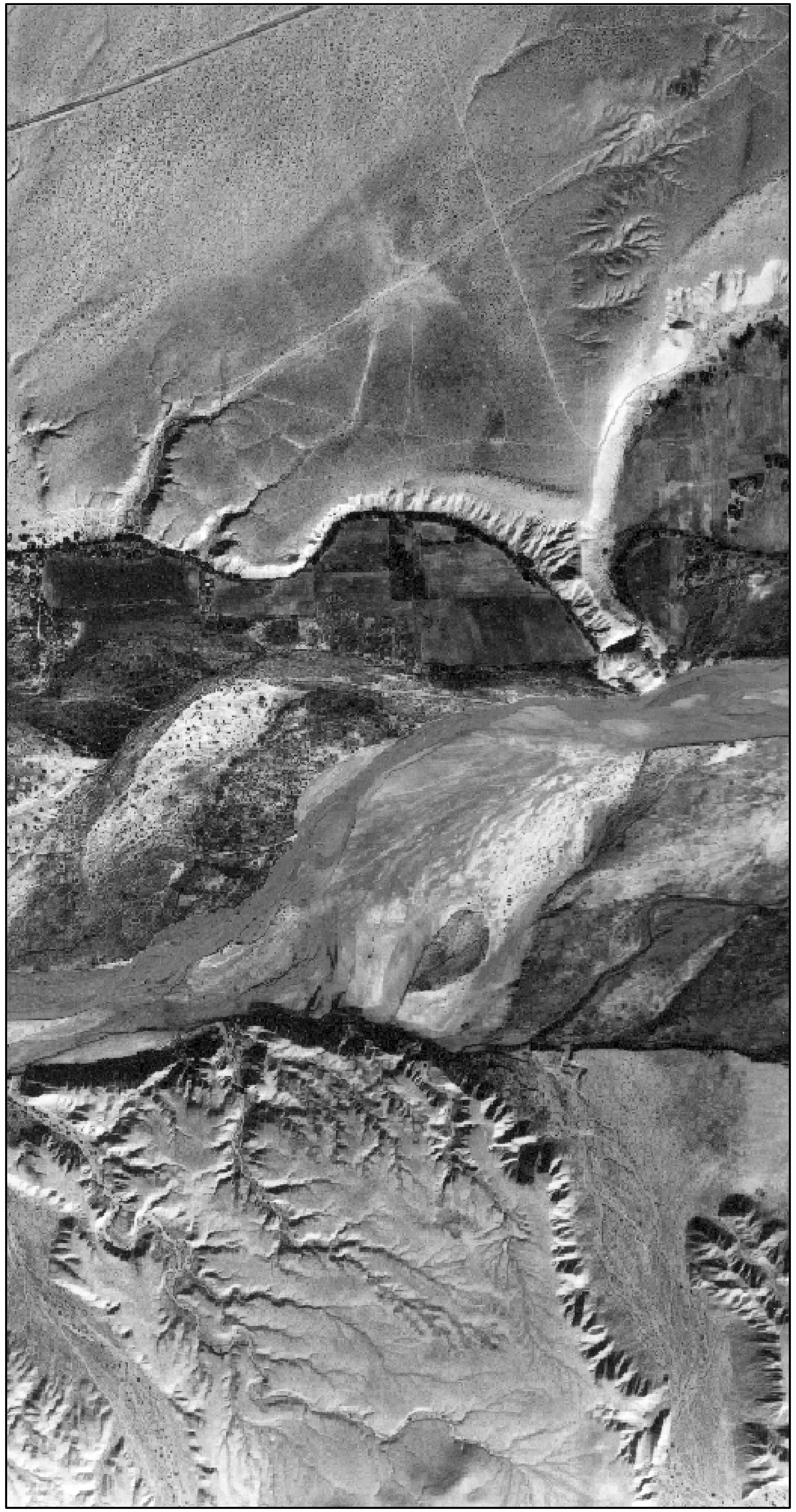
9
524.2 T

USGS DRG

0
500
1,000
2,000
3,000
4,000
Feet



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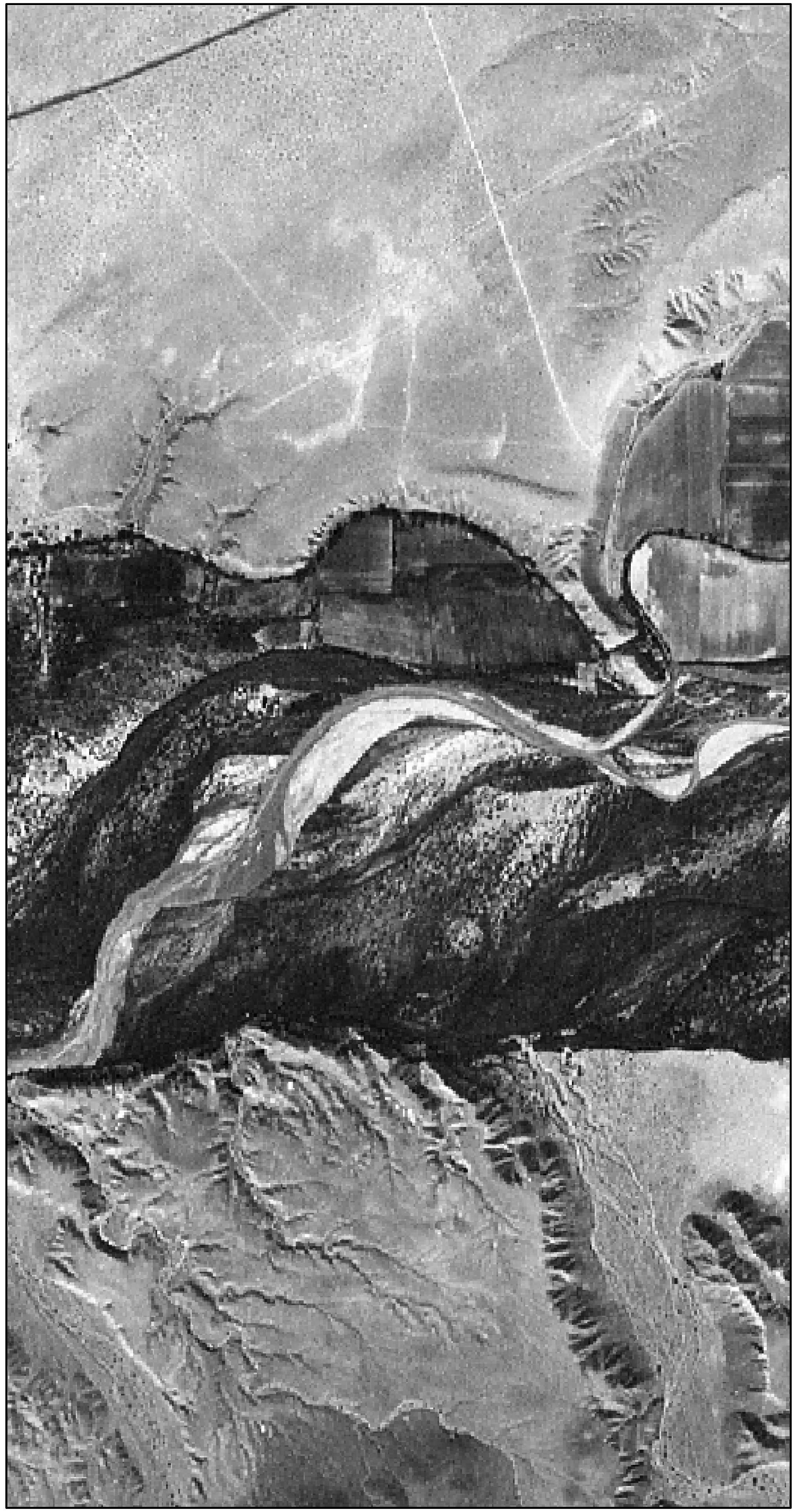
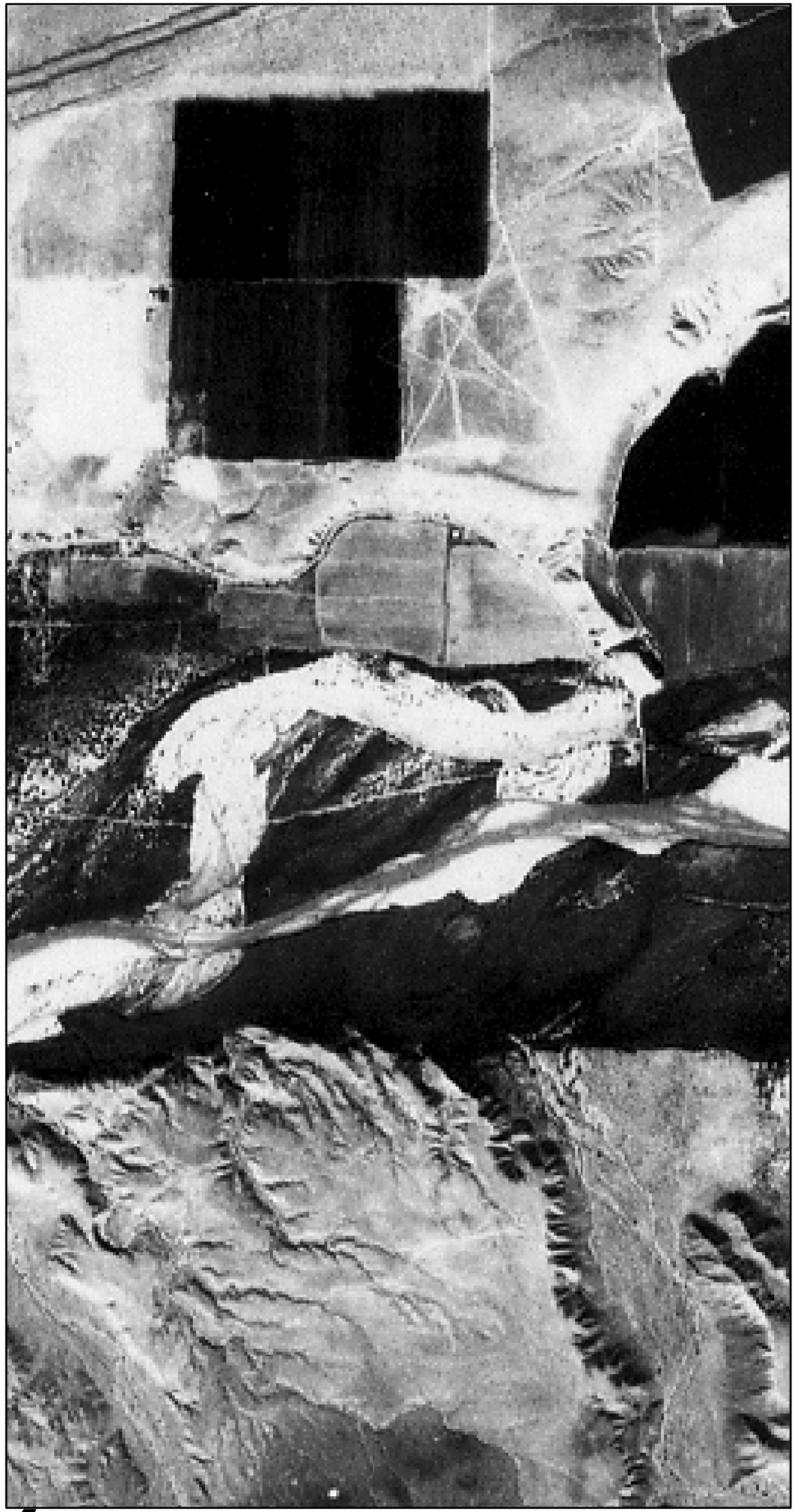


1952

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.



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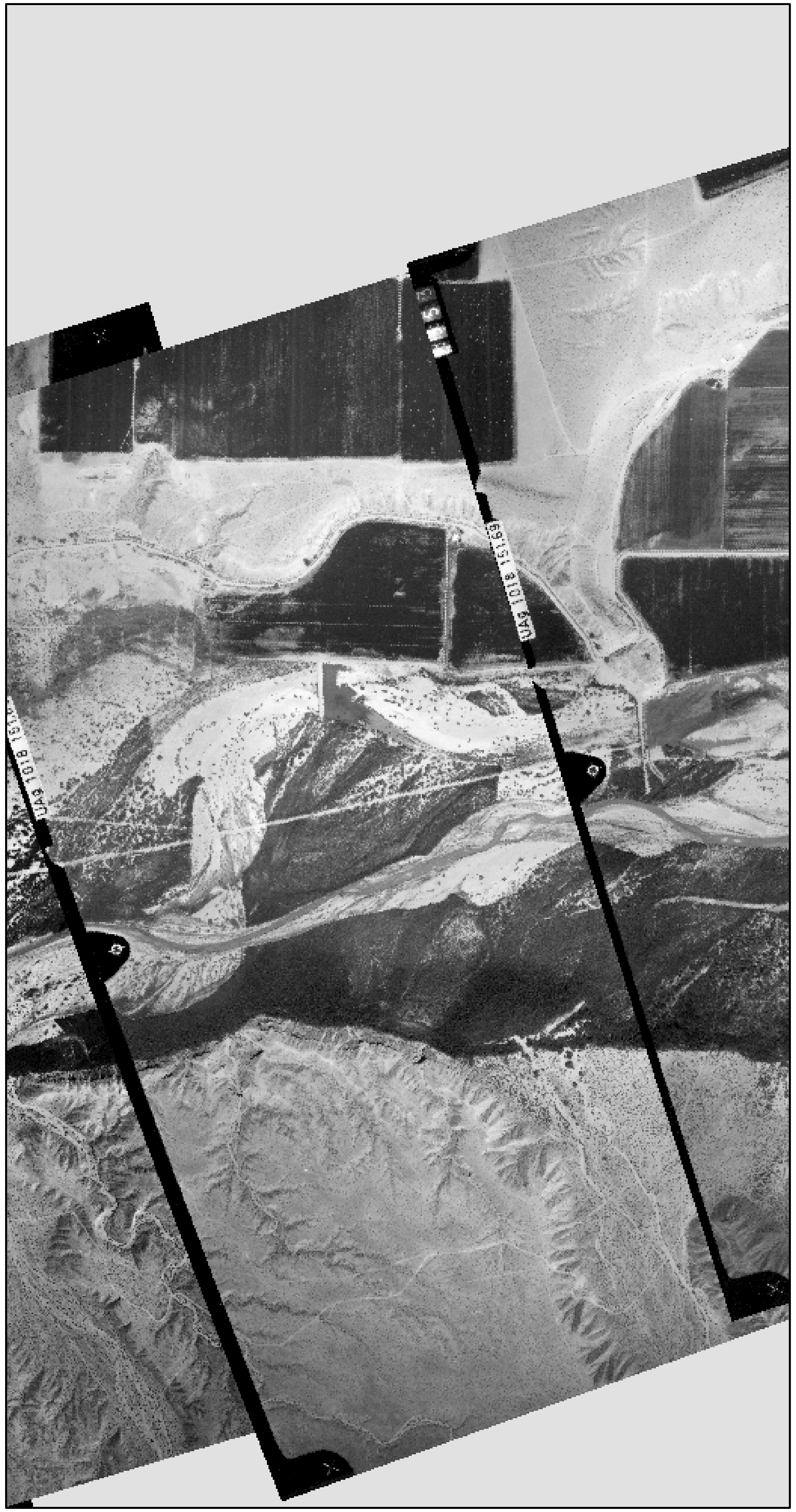
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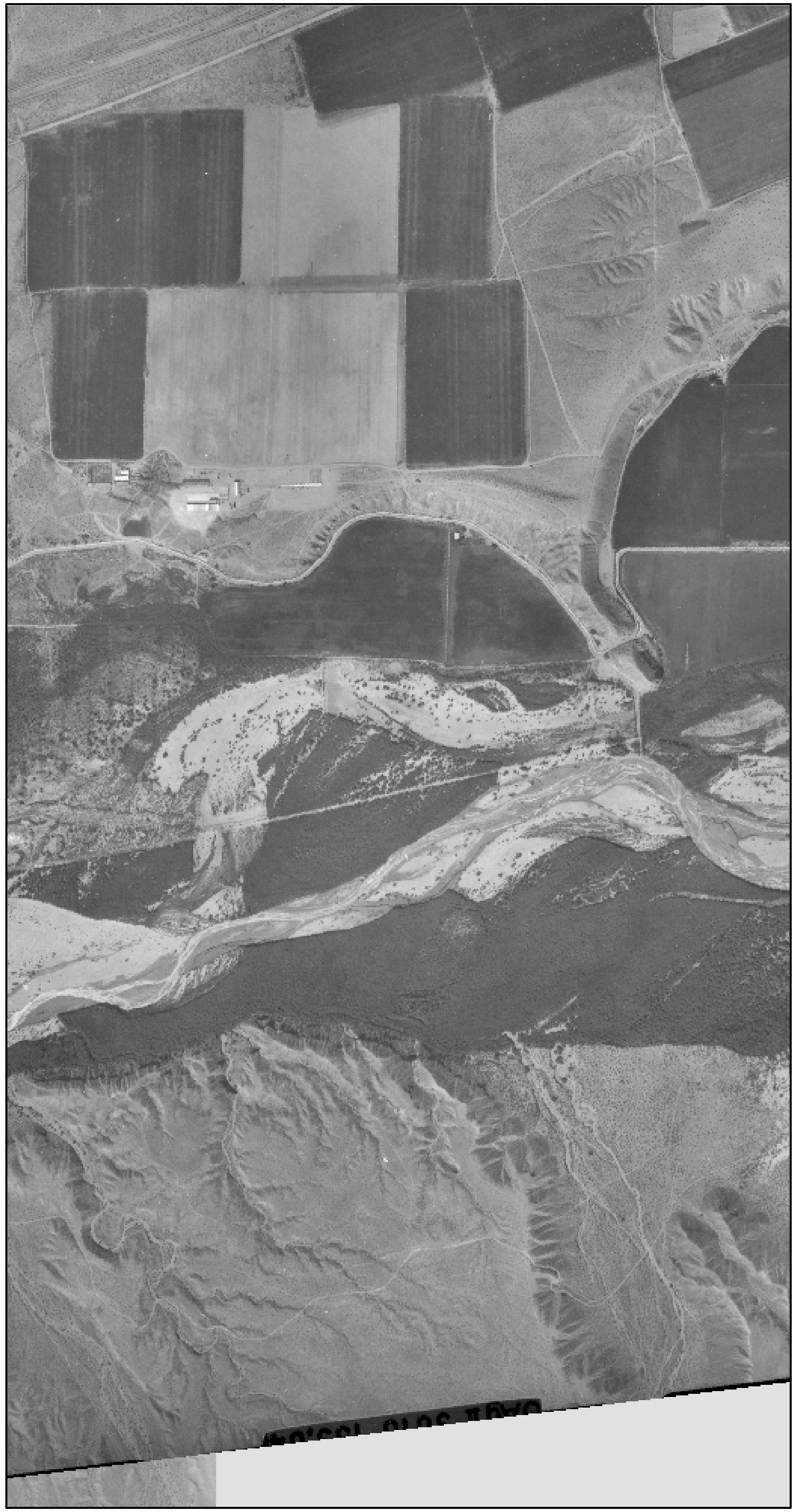
1977



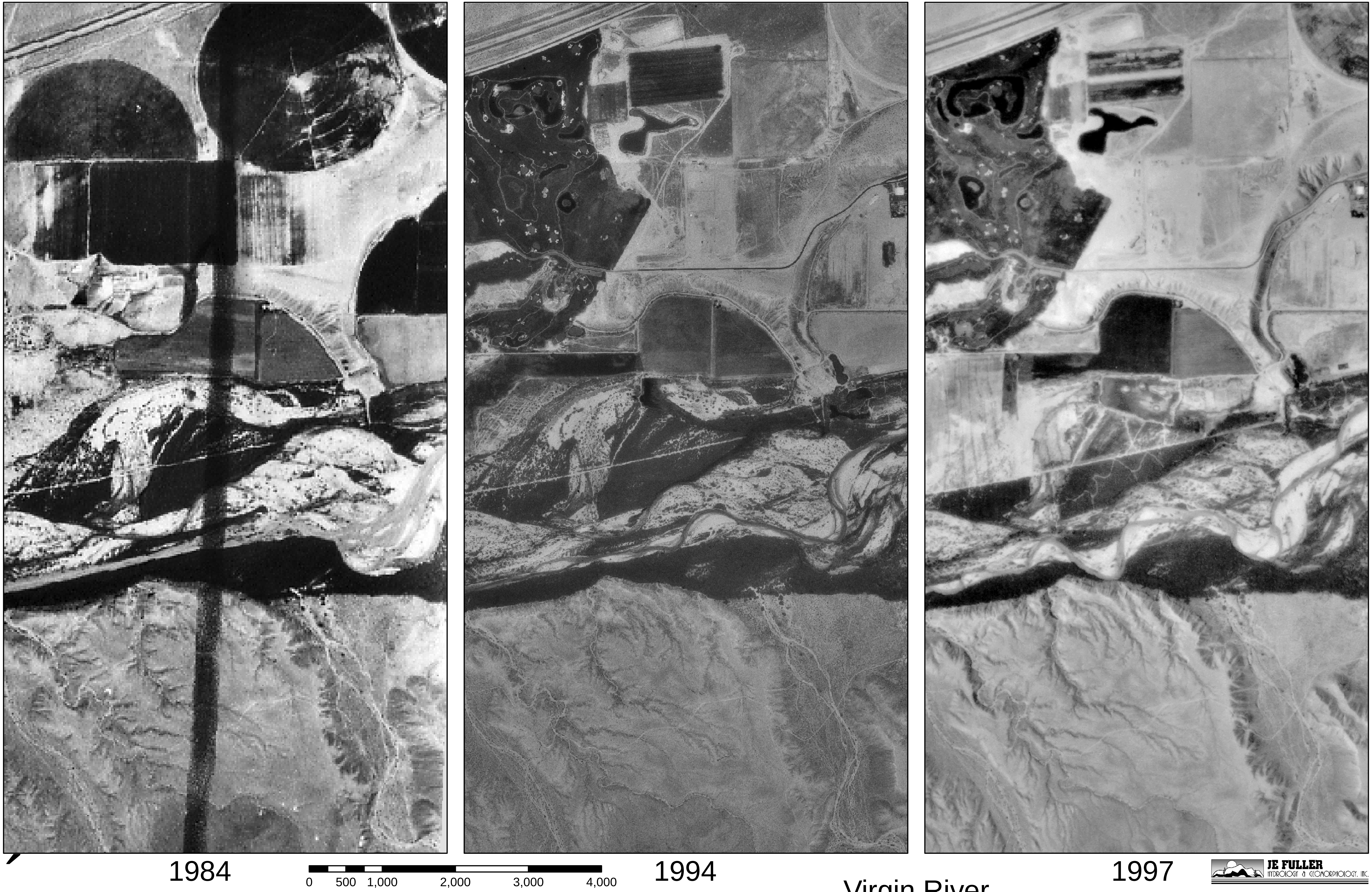
1978

0 500 1,000 2,000 3,000 4,000

Feet

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.


1984

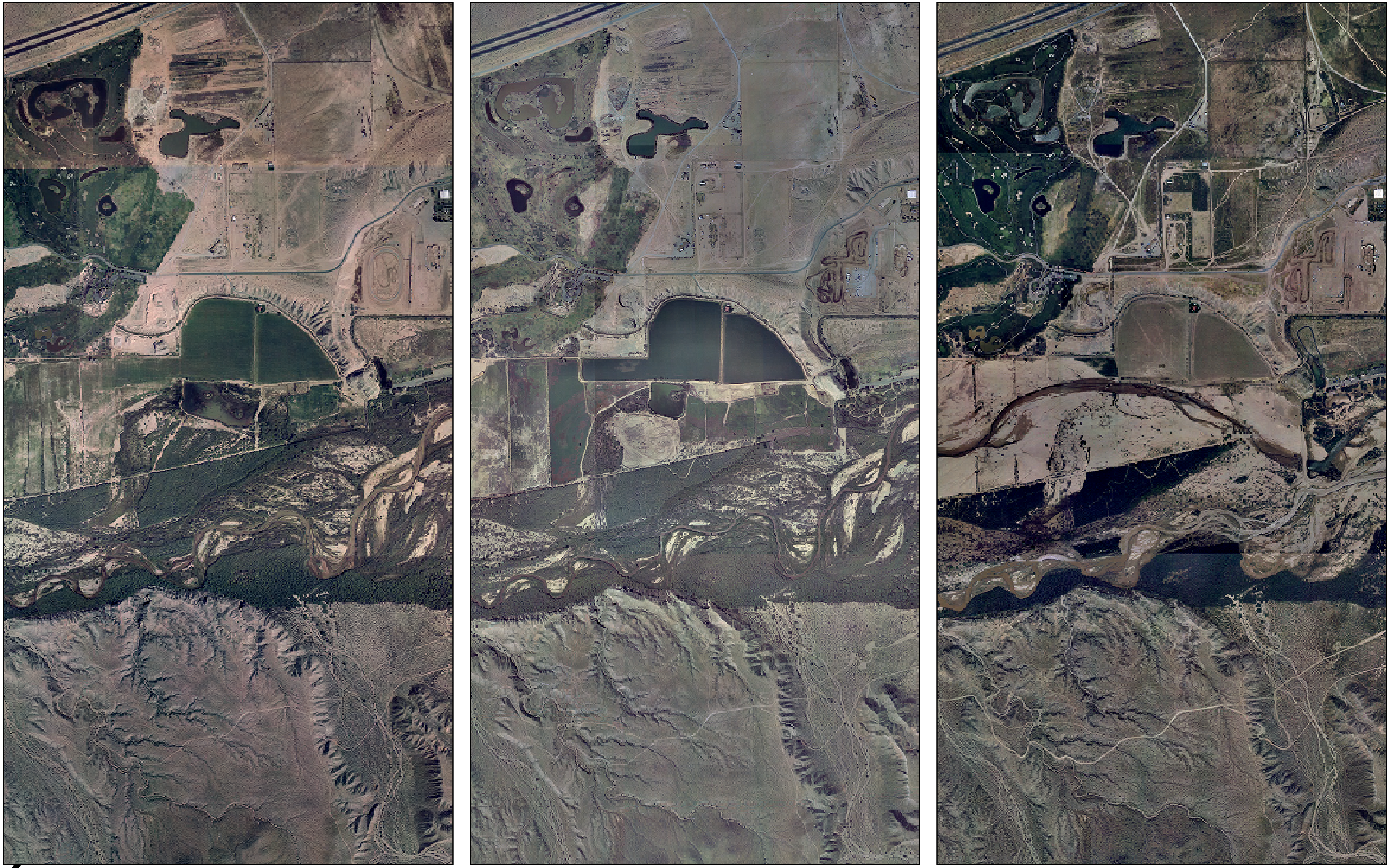
1994

1997

0
500
1,000
2,000
3,000
4,000
Feet

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Virgin River



Fall 2002

Fall 2004

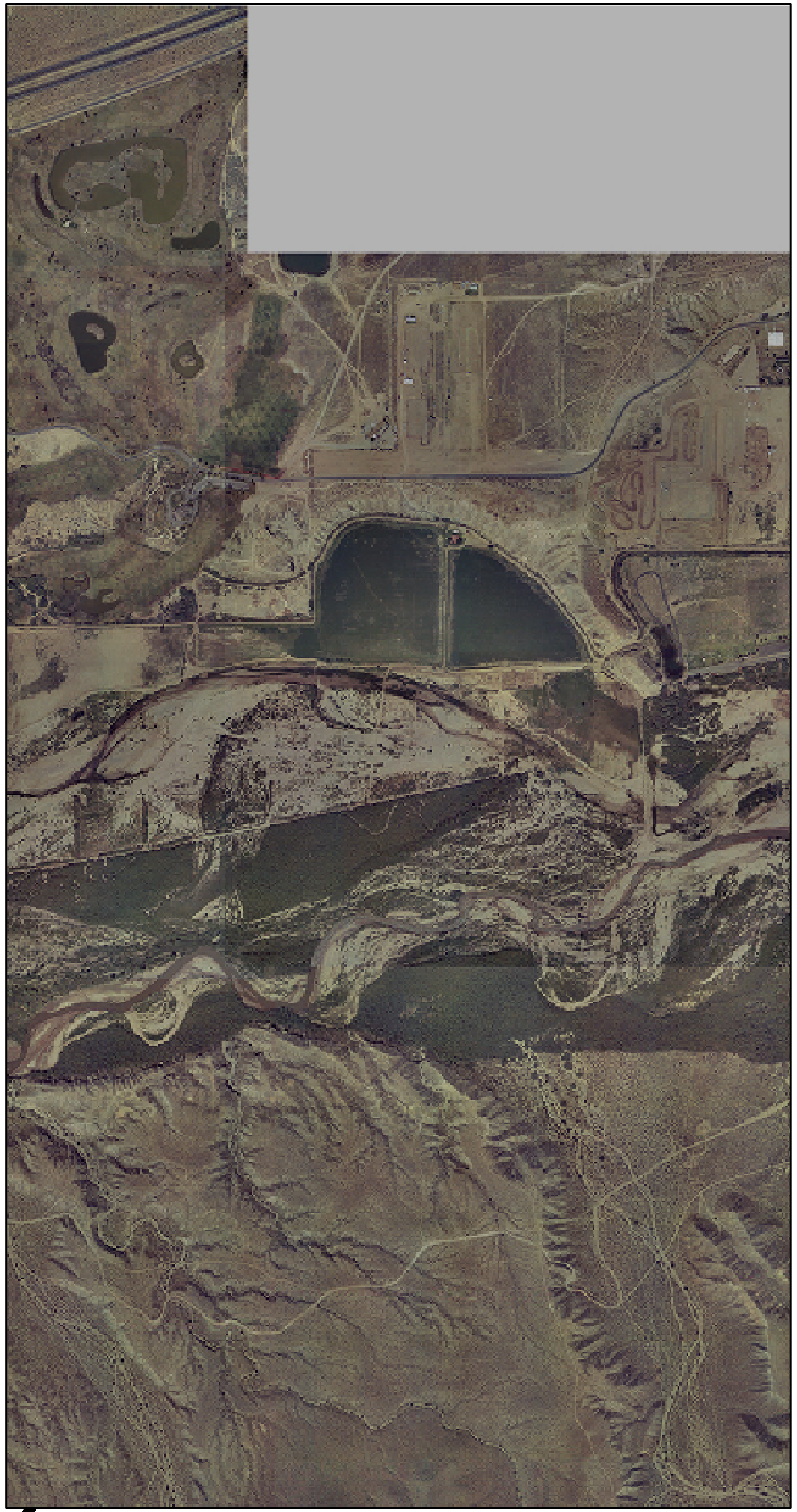
Spring 2005

0
500
1,000
2,000
3,000
4,000
Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 11-4

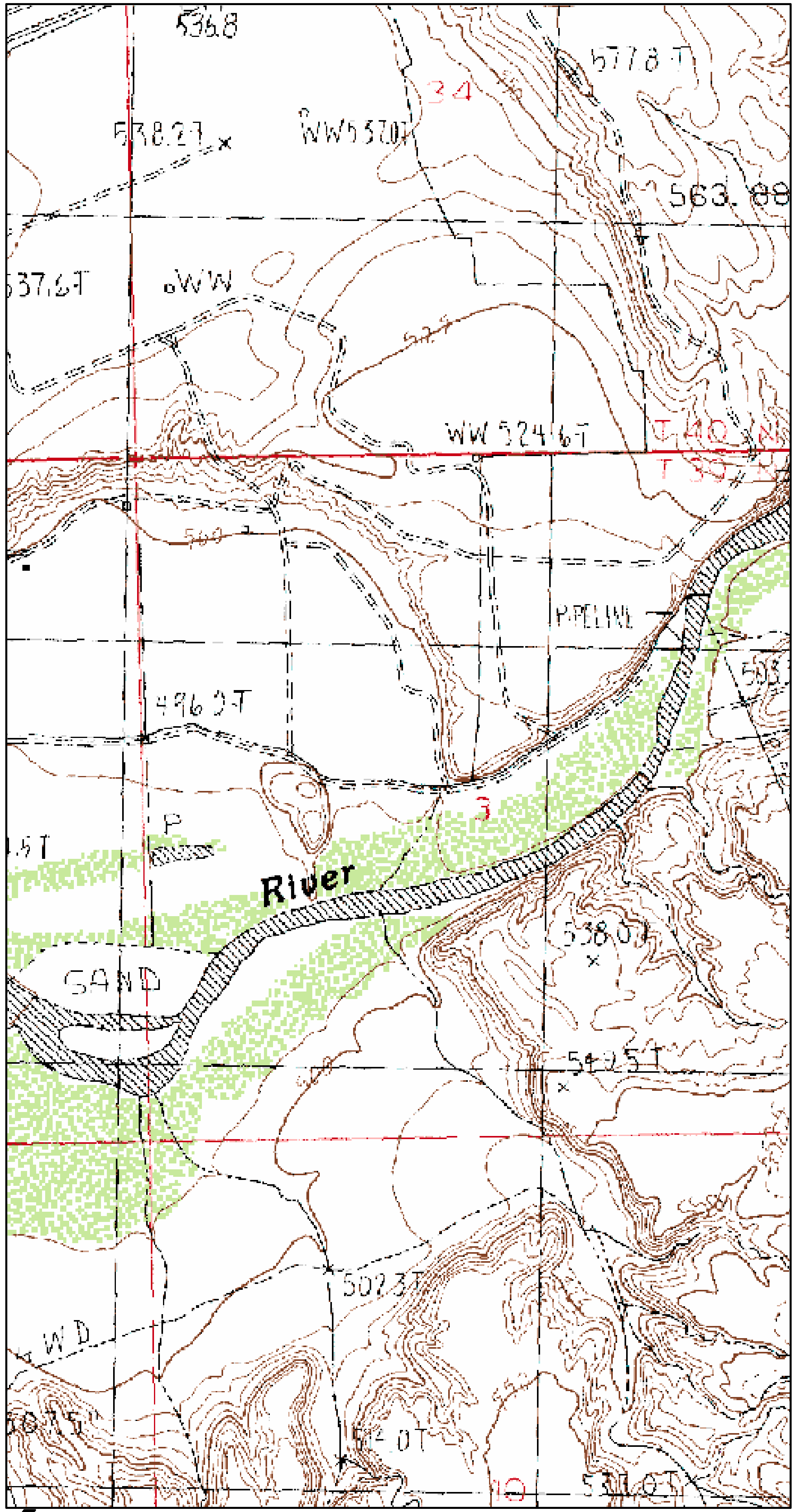


Fall 2005

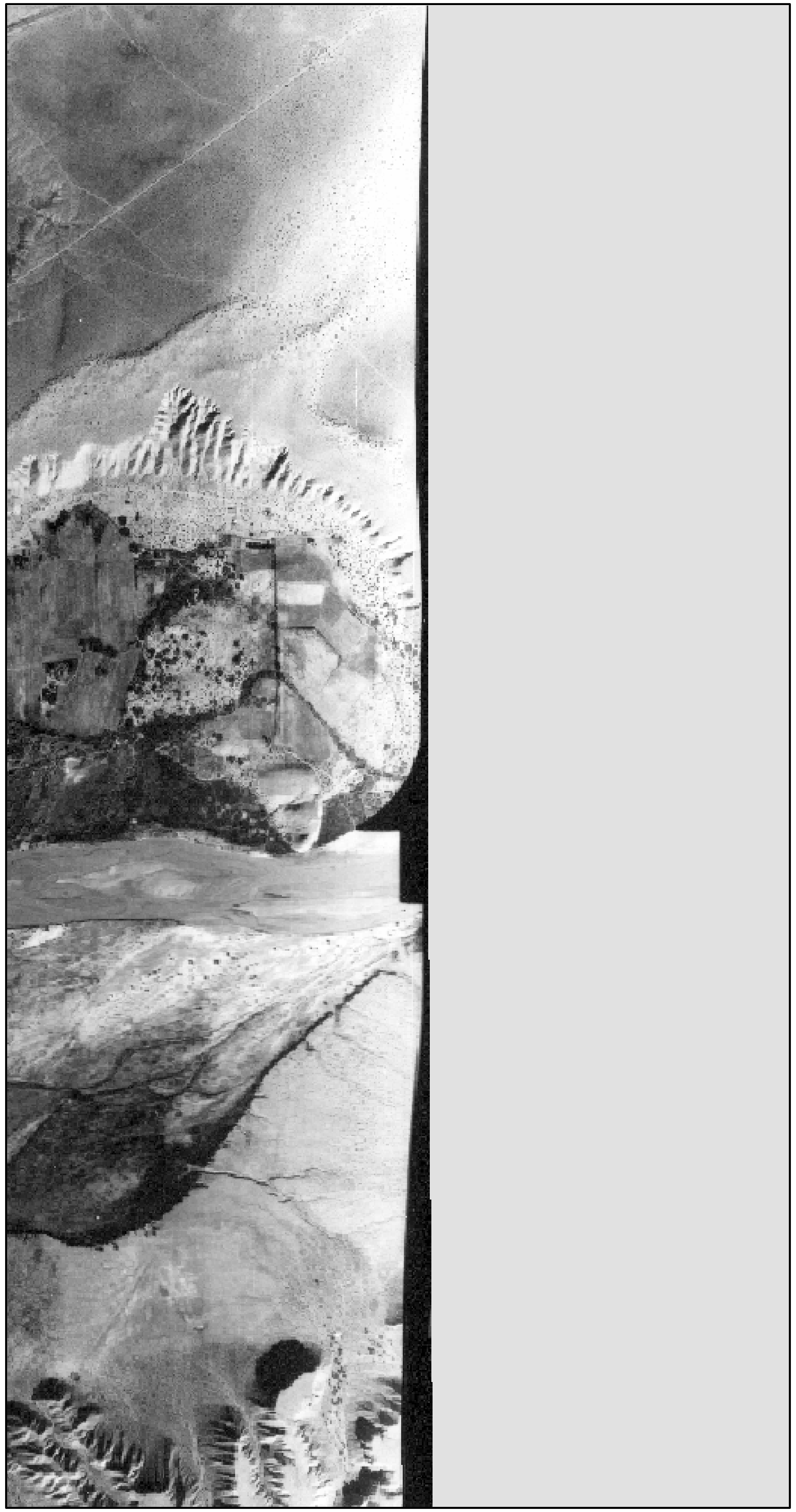
0
500
1,000
2,000
3,000
4,000
Feet

Virgin River

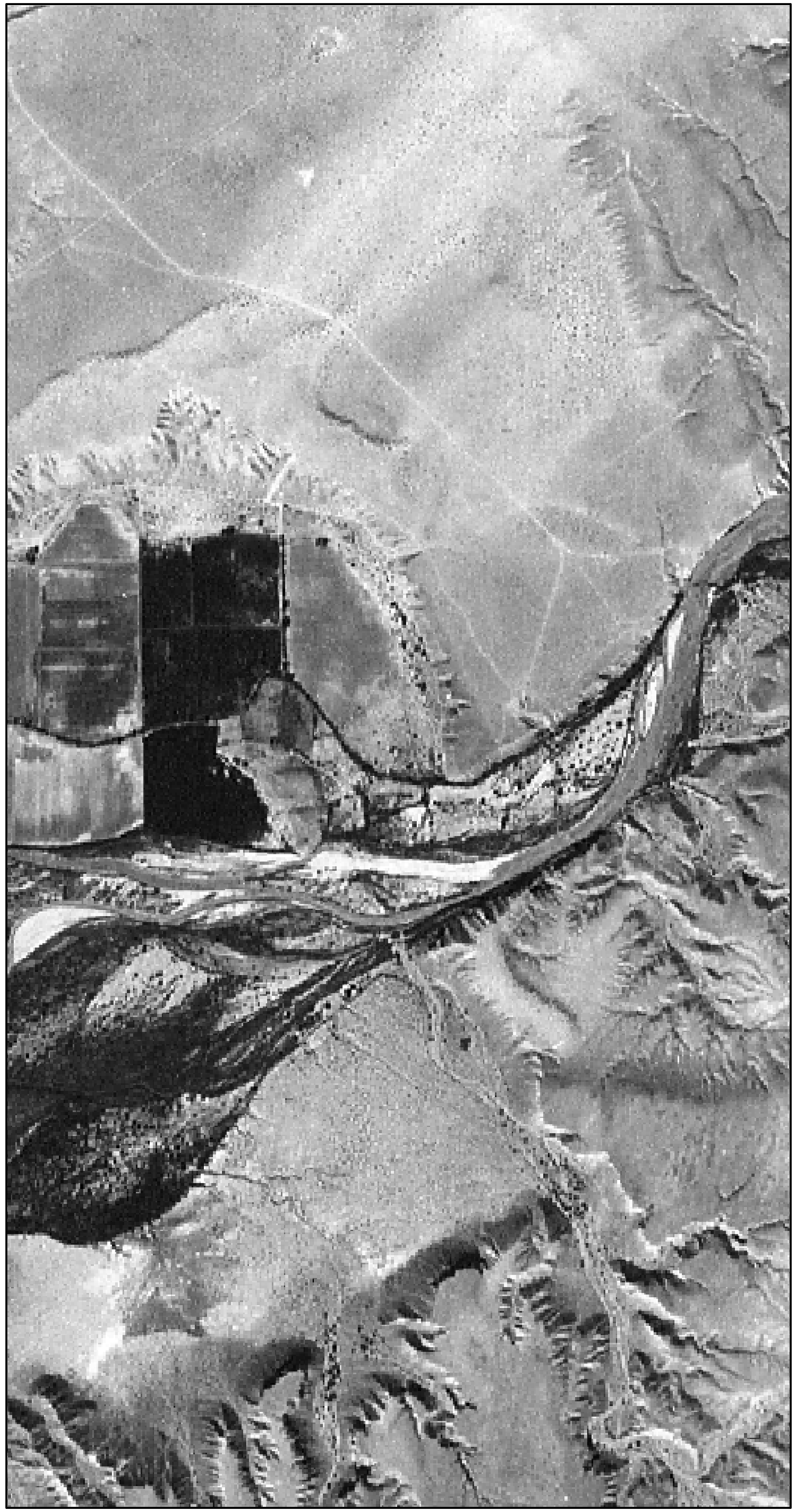
JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.


536.8
577.8 T
34
538.2T
WW 530T
563.88
537.6T
WW
WW 524.6T
T 40 N
T 39 N
PIPELINE
496.0T
P
3
River
SAND
538.0T
542.5T
502.3T
W.D.
10
531.0T

USGS DRG



1938

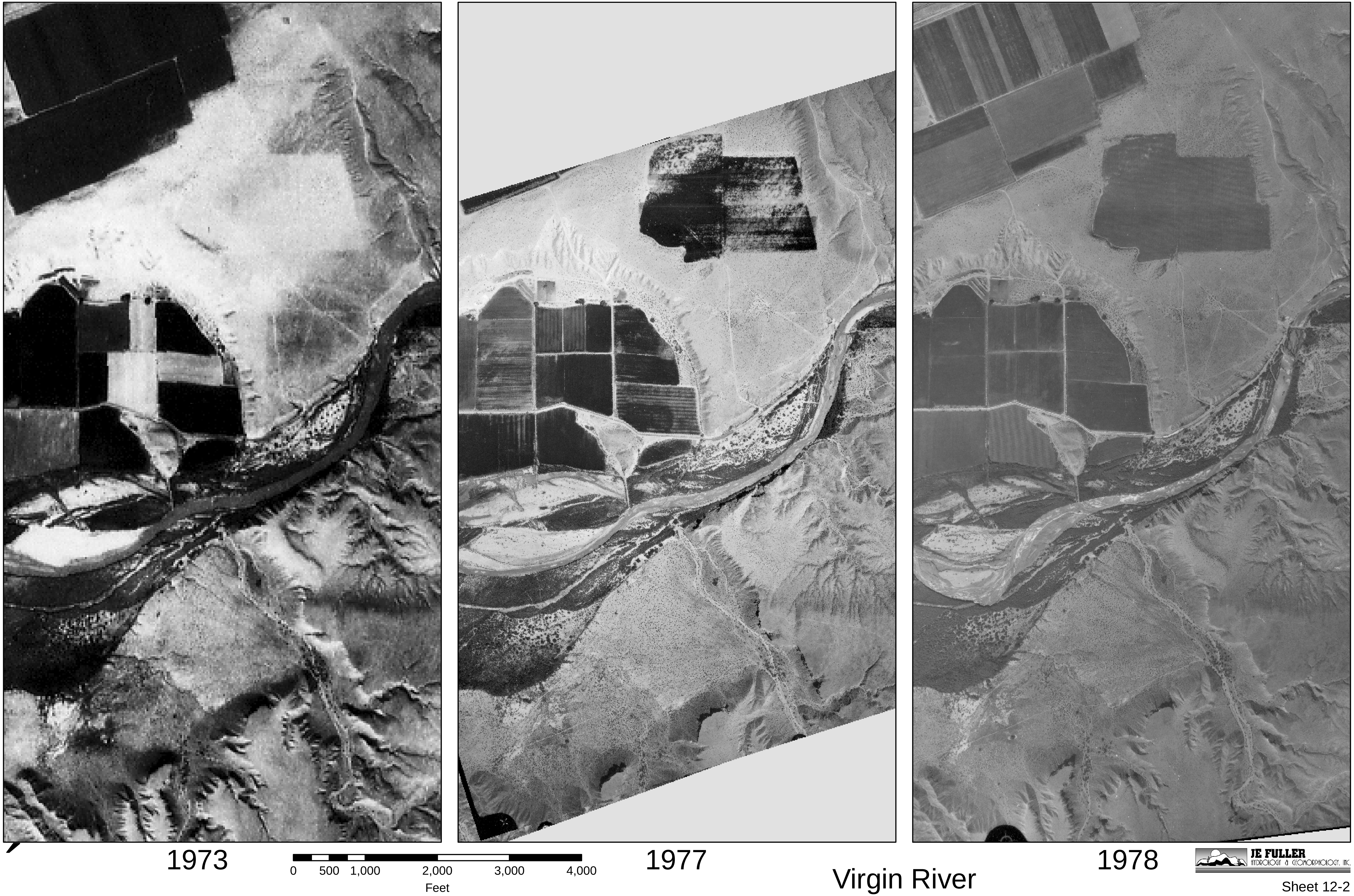


1952

0 500 1,000 2,000 3,000 4,000
Feet

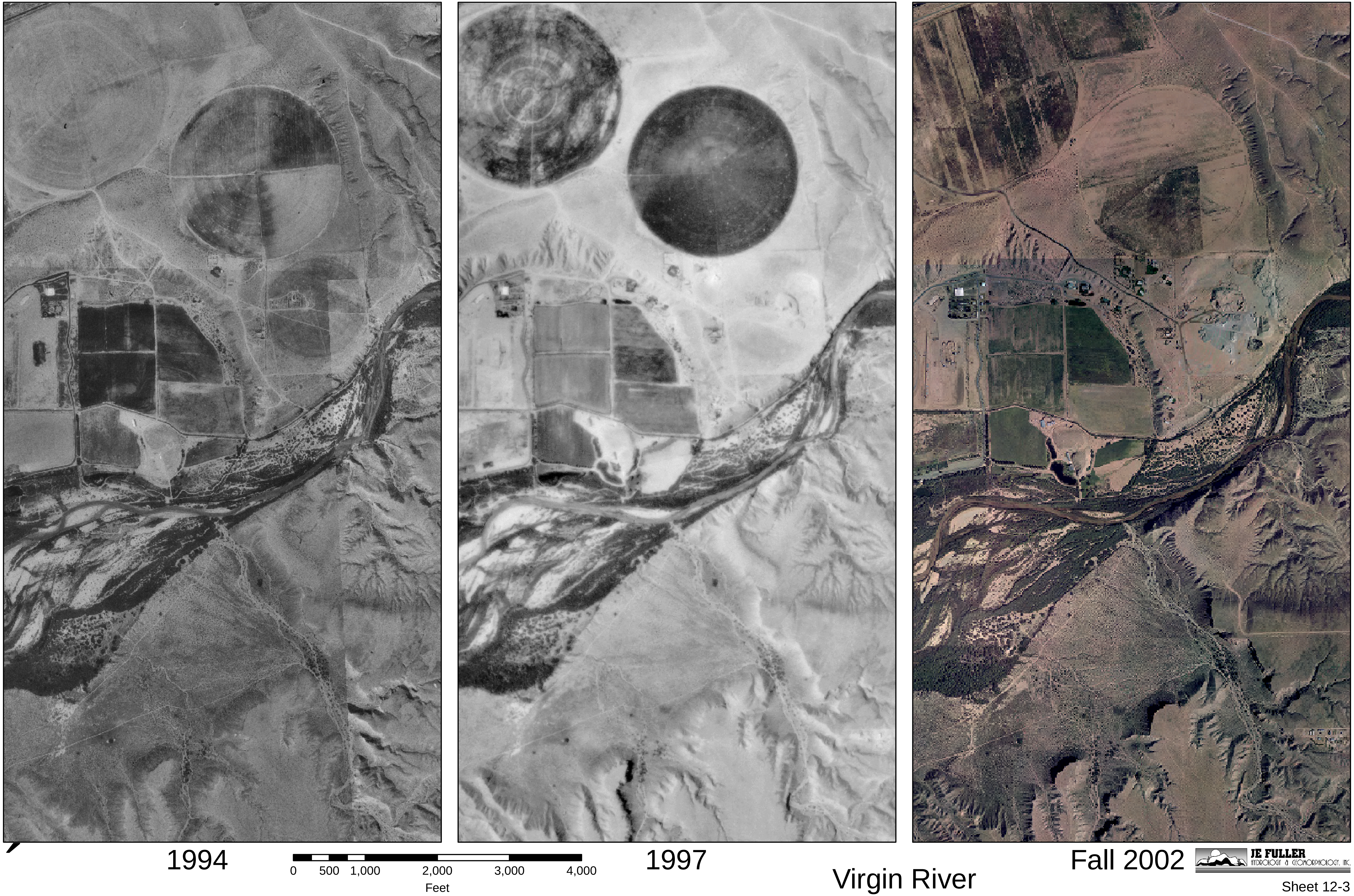
Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.


1973
0
500
1,000
2,000
3,000
4,000
Feet
1977
1978

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.


0
500
1,000
2,000
3,000
4,000
Feet

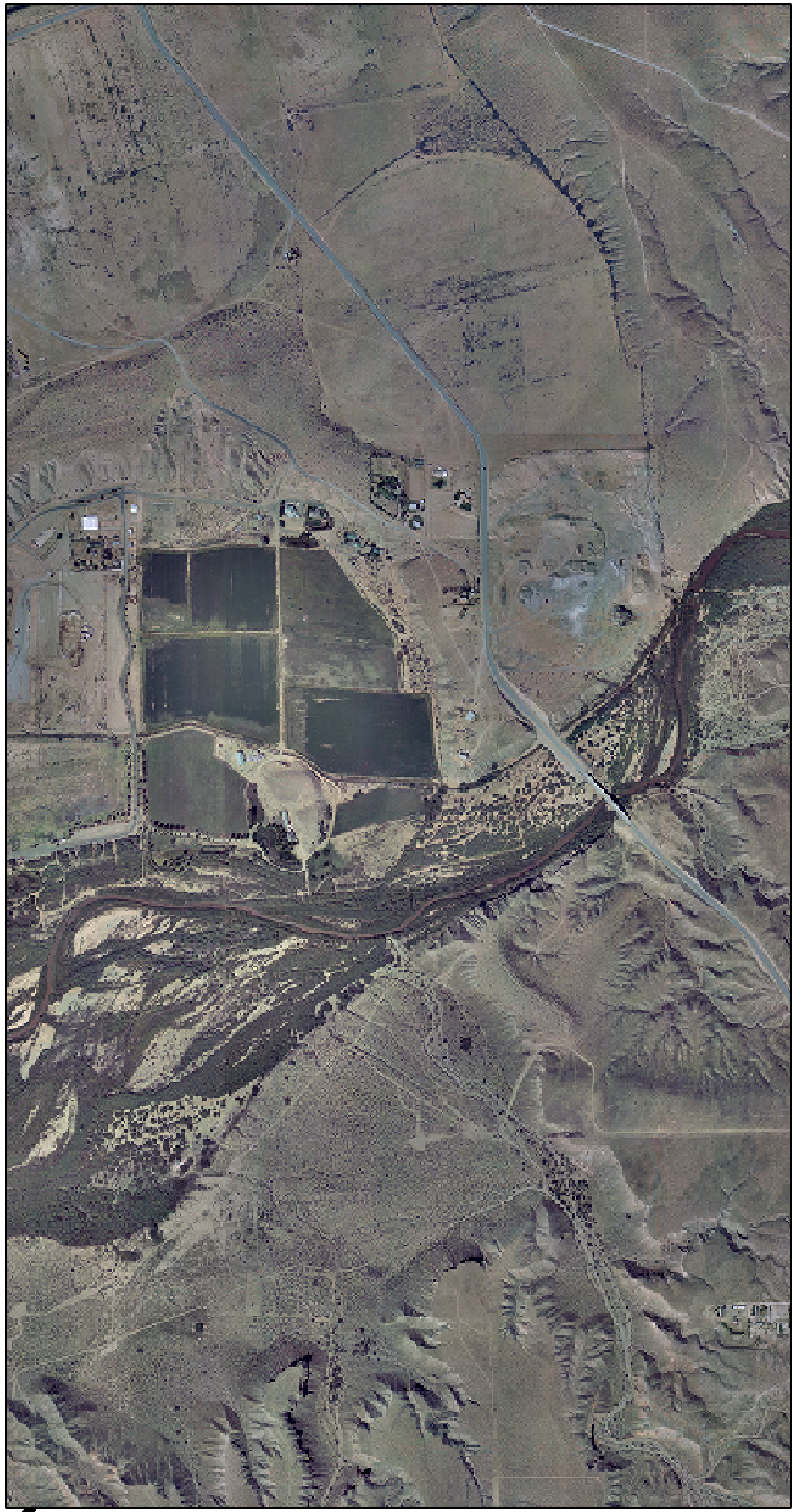
1994

1997

Fall 2002

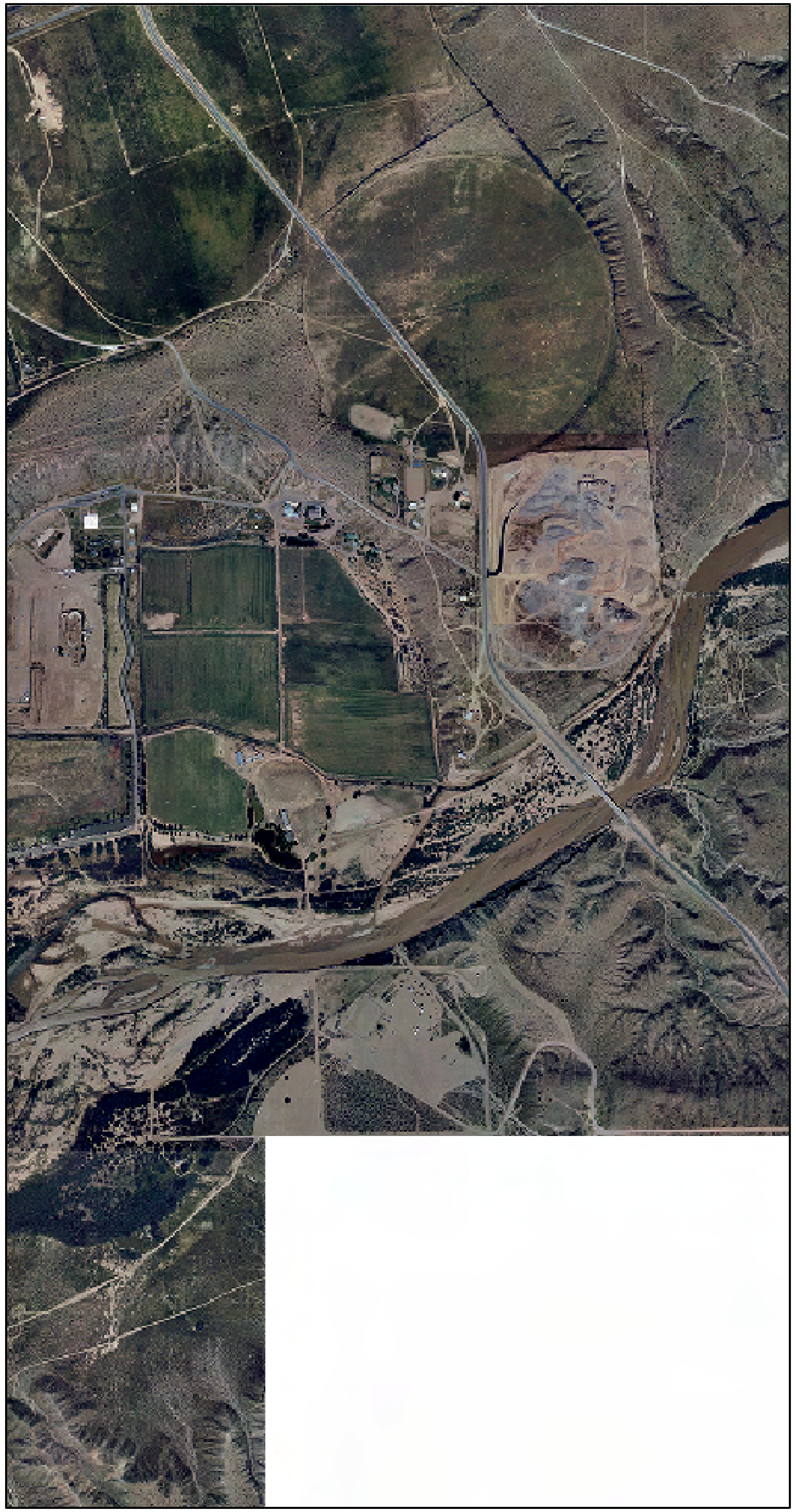
Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

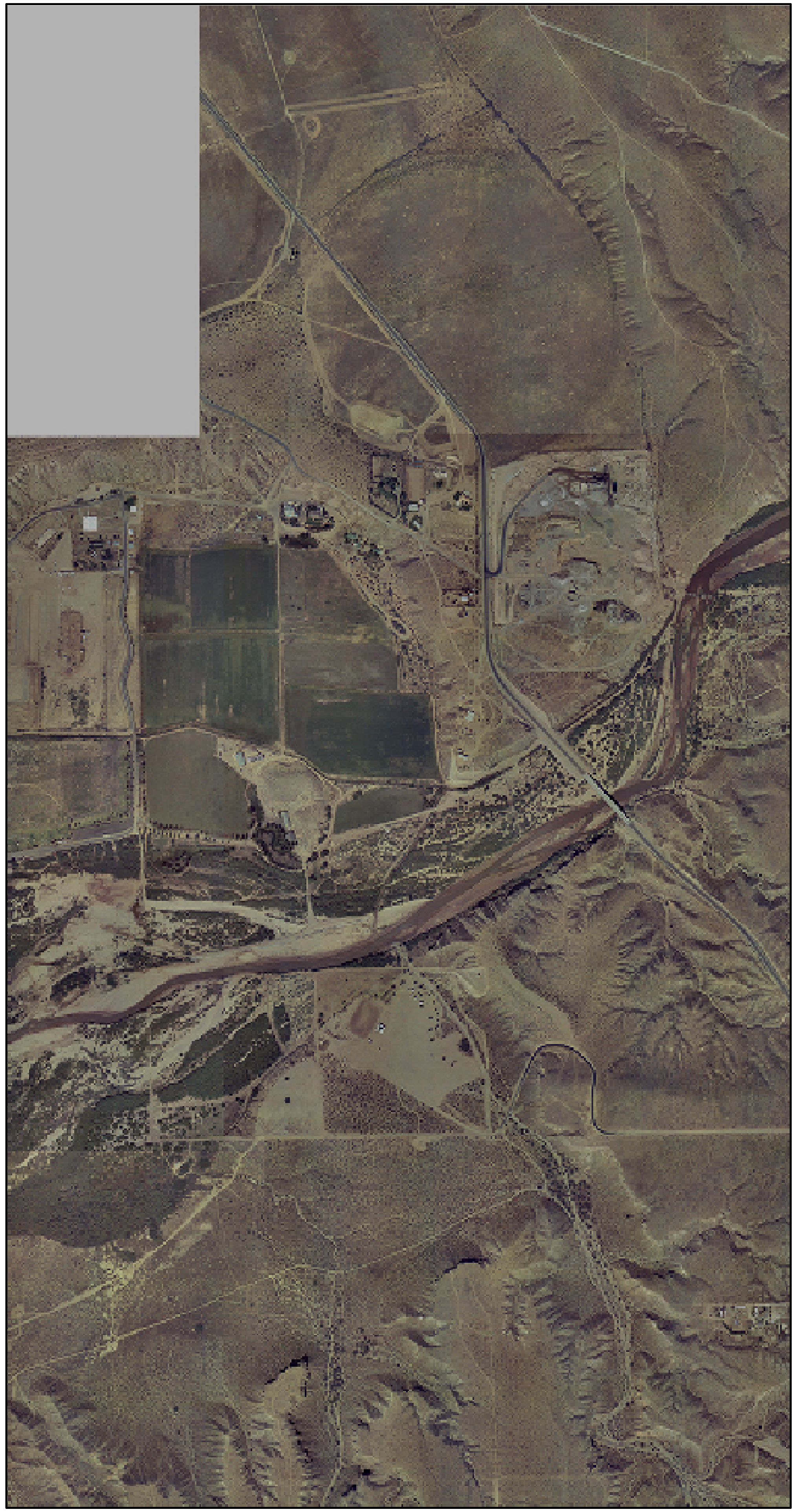


Fall 2004

0
500
1,000
2,000
3,000
4,000
Feet



Spring 2005

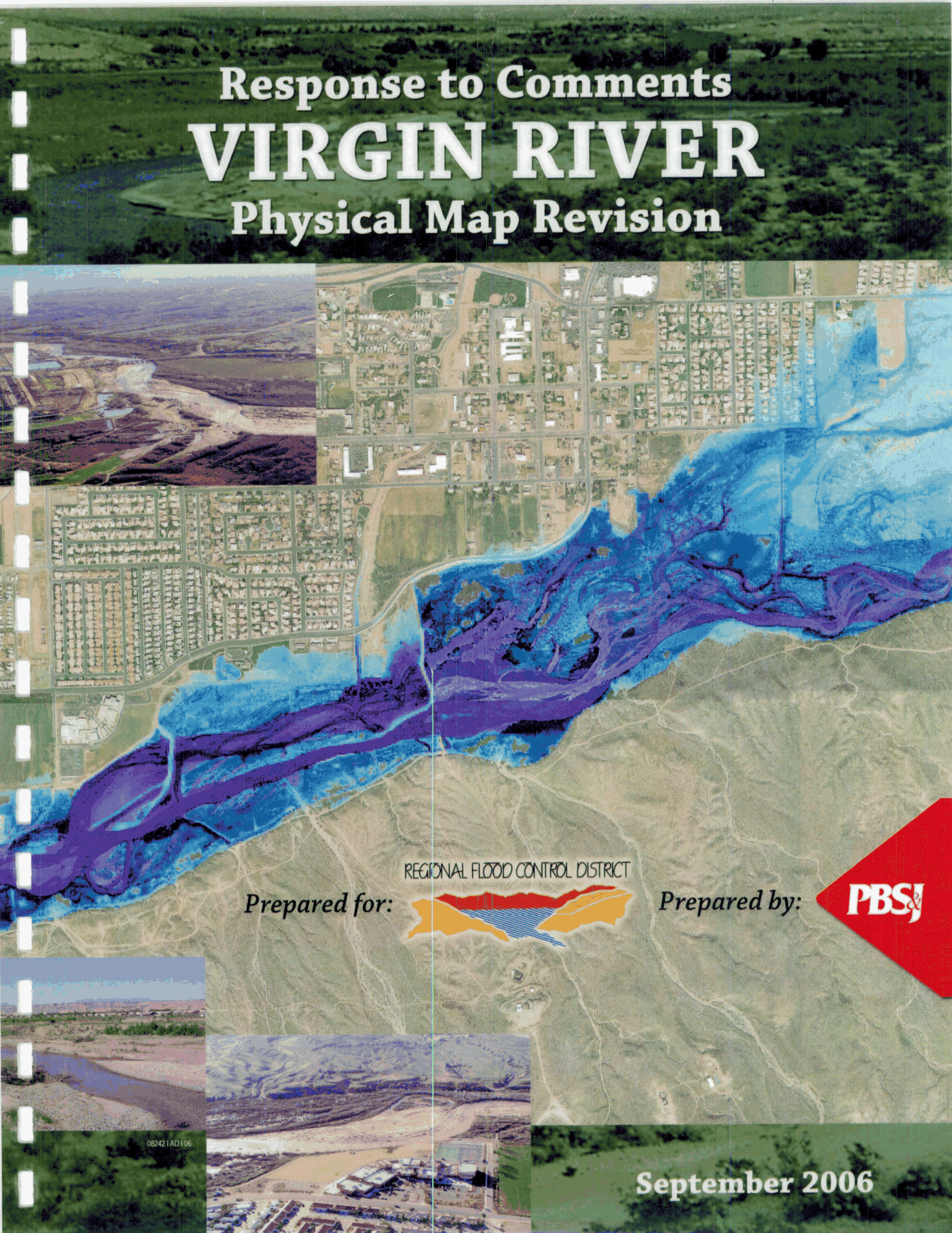


Fall 2005

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Response to Comments
VIRGIN RIVER
Physical Map Revision



Prepared for: REGIONAL FLOOD CONTROL DISTRICT

Prepared by: PBS&J

08242 | AD | 06

September 2006

RESPONSE TO COMMENTS
VIRGIN RIVER PHYSICAL MAP REVISION

Communities: City of Mesquite and Clark County, Nevada
Community Nos: 320035 and 320003

Prepared for:

Clark County Regional Flood Control District
600 S. Grand Central Pky. Ste. 300
Las Vegas, NV 89106

Prepared by:

PBS&J
2270 Corporate Circle, Suite 100
Henderson, Nevada 89074-6382
Phone: (702)-263-7275

PROFESSIONAL ENGINEER - STATE OF NEVADA
HARSHAL B.
DESAI
Exp. 12-31-08
CIVIL
No. 17468

09-18-06

September 18, 2006

September 18, 2006

Eric Simmons, CFM
Engineer, FEMA Region IX
U.S. Department of Homeland Security
1111 Broadway, Suite 1200
Oakland, CA 94607-4052

RE: VIRGIN RIVER PHYSICAL MAP REVISION
COMMUNITIES: City of Mesquite and Clark County, Nevada
COMMUNITY Nos: 320035 and 320003

Dear Mr. Simmons:

This letter and the attached documents are in response to your comments provided in a letter dated July 12, 2006. The information provided within this letter is intended to supersede the information provided in *Virgin River Request for Letter of Map Revision* (May 4, 2006).

A copy of the comment letter from the Federal Emergency Management Agency (FEMA) is included in **Appendix A** and responses to the comments follows:

Regulatory Comments

Comment 1: The proposed changes to the designated regulatory floodway require public notification in accordance with paragraph 65.7(b) (1) of the National Flood Insurance program (NFIP) regulations. Please submit copies of the public notices stating the intent to revise the regulatory floodway, or provide statements signed by an official form each community that he/she has notified all affected property owners and affected adjacent jurisdictions. Please also submit documentation that the City of Mesquite and Clark County will adopt and enforce the modified floodway since it is proposed that the regulatory floodway be shifted from the location currently adopted by each community.

Response 1: Noted; Please refer to email correspondence between CCRFCD (Kevin Eubanks), Michael Baker (Mark Delorey), and FEMA (Eric Simmons) provided in **Appendix B**.

Comment 2: The corrective effective HEC-RAS model includes a diversion structure at Cross Section (-) 42.5 that was previously not analyzed in the effective HEC-2 model. The diversion structure causes increases in 1-percent annual chance (100-year) water surface elevations due to fill in the floodway in excess of those created by the updated 1-percent annual chance discharge or by the new topography. Please provide evidence that the structure was built prior to the effective floodway or provide evidence that it complies with all the requirements shown in Paragraph 65.12(a) of the NFIP regulations.

Response 2: The Bunkerville Diversion Structure modeled in the corrected effective HEC-RAS model, was not previously analyzed in the effective HEC-2 model, despite being constructed prior to the effective hydraulic analysis. As shown below on **Figure 1**, the Bunkerville Diversion Structure can be clearly seen the Effective Work Maps (Sheet 5), right between cross-sections 33 and 33.1. A copy of Sheet 5 of the Effective Work Maps is located in **Appendix C-1**. Furthermore, the Bunkerville Diversion Structure is seen on aerial photos dating back as far as 1973. Please refer to J.E. Fuller's *Virgin River Flood Study: Geomorphic Analysis Report: Historical Aerial Photo Exhibit Book*, provided in **Appendix C-2**.

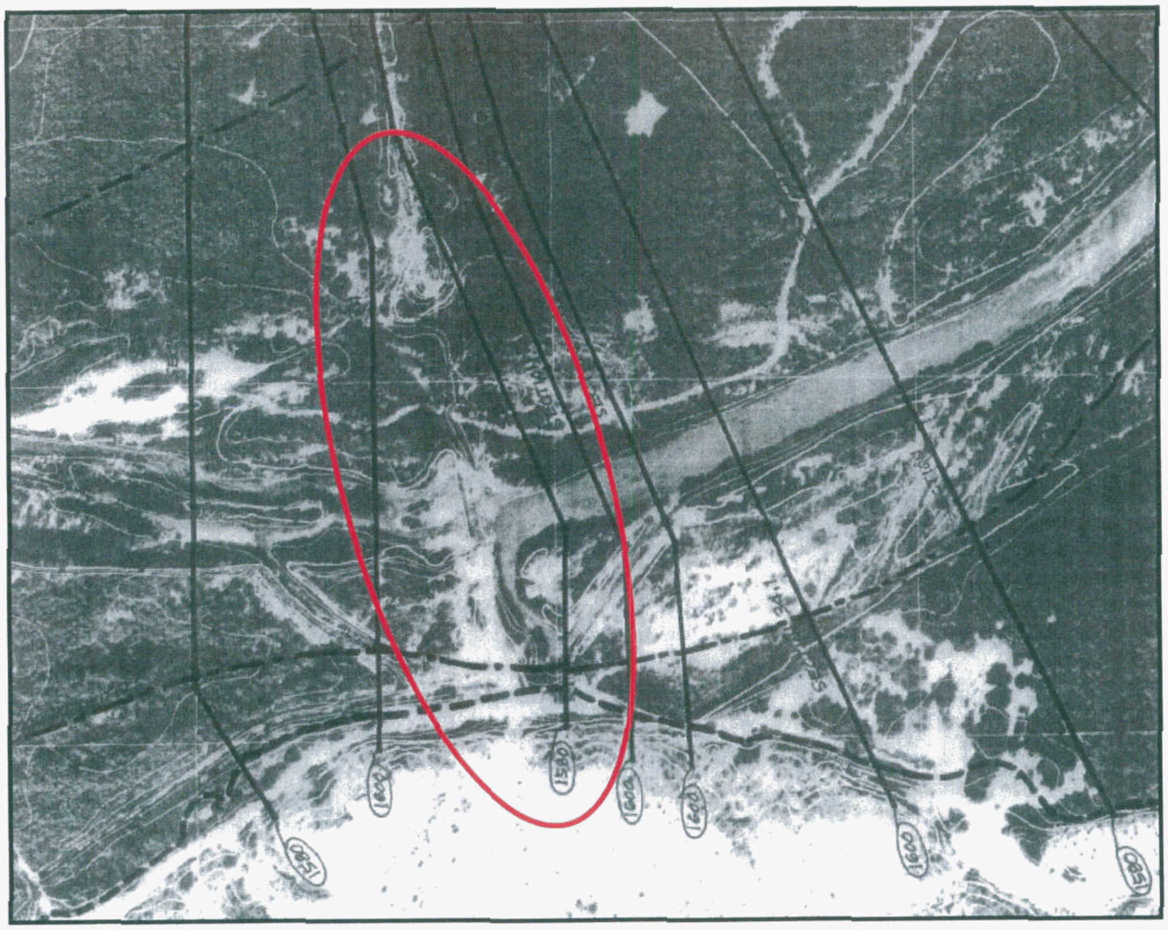


Figure 1: The Bunkerville Diversion Structure as shown on a reproduction of Sheet 5 of the Effective Work Maps.

Hydrology Comments

Comment 1: The corrected effective HEC-RAS model does not include the 10-percent annual chance (10-year) and 2-percent annual chance (50-year) discharges. Please add both discharges to the corrected effective HEC-RAS model.

Response 1: The corrected effective HEC-RAS model does not include discharges for the 10-percent annual chance (10-year) and 2-percent annual chance (50-year). In order to accurately represent the hydraulics associated with these discharges, through the study reach, major revisions to the corrected effective hydraulic model will be required. The revisions involve balancing the flow split at the upstream end and refining the ineffective flow boundaries for both 10-year and 50-year model. We believe that 10-percent annual chance and 2-percent annual chance model will not add any value to the community floodplain protection/maintenance plan. Should flood profiles for the 10-year and 50-year flow become necessary in the future, they can be developed at that time with a specific objective in mind using the corrected effective model as a starting point. Please refer to **Appendix D** for correspondence between CCRFCD and Michael Baker related to this comment. We hope this is satisfactory.

Hydraulic Comments

Comment 1: Please submit a floodway data table for the proposed Virgin River floodway revision.

Response 1: The floodway data table for the proposed Virgin River floodway revision is shown below. An electronic copy of the floodway data table is provided on the electronic DVD in **Appendix F**.

Table 1: Floodway Data Table (Continues on Page 4)

FLOODING SOURCE			FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION			
HEC-RAS CROSS-SECTION	ASSOCIATED LETTER CROSS-SECTION	DISTANCE (FEET)	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD 88)	WITHOUT FLOODWAY (FEET NAVD 88)	WITH FLOODWAY (FEET NAVD 88)	INCREASE (FEET)
-142	A	0.00	2517.68	11144.06	3.55	1472.53	1472.53	1473.43	0.90
-141	B	596.32	2777.38	11198.72	3.53	1473.53	1473.53	1474.41	0.88
-140	-	1021.37	2781.07	10204.08	3.87	1474.69	1474.69	1475.42	0.73
-139	-	1933.69	2657.16	11000.06	3.59	1477.08	1477.08	1477.57	0.49
-138	-	3559.83	2195.03	12596.19	3.14	1480.64	1480.64	1481.35	0.71
-137	-	3819.68	2133.17	11762.25	3.36	1481.50	1481.50	1482.33	0.83
-136	-	4316.64	2125.90	13714.92	2.88	1482.69	1482.69	1483.64	0.95
-135	C	4733.33	2017.46	11818.69	3.34	1483.74	1483.74	1484.62	0.88
-134	D	4915.06	2062.07	11580.60	3.41	1484.90	1484.90	1485.66	0.76
-133	-	5692.14	1907.60	11437.93	3.45	1486.66	1486.66	1487.48	0.82
-132	E	6365.84	1799.99	10992.81	3.59	1487.47	1487.47	1488.47	1.00
-131	-	7247.28	1583.13	9327.39	4.24	1489.22	1489.22	1489.72	0.50
-130	-	7813.72	1353.30	8321.06	4.75	1490.57	1490.57	1490.96	0.39
-129	-	8409.09	1296.16	8925.52	4.43	1491.83	1491.83	1492.33	0.50
-128	-	8784.59	1412.77	9962.04	3.97	1492.56	1492.56	1493.14	0.58
-127	-	9413.42	1357.83	10208.33	3.87	1493.75	1493.75	1494.30	0.55
-126	F	10181.03	1303.26	8867.10	4.46	1495.36	1495.36	1495.87	0.51
-125	-	10707.96	1617.69	12001.37	3.29	1496.89	1496.89	1497.75	0.86
-124	-	11073.21	1697.44	11844.09	3.34	1497.63	1497.63	1498.59	0.96
-123	-	11367.96	1647.16	10224.22	3.86	1498.40	1498.40	1499.16	0.76
-122	G	12007.05	1733.86	9924.11	3.98	1500.23	1500.23	1500.79	0.56
-121	-	12433.12	1748.97	9588.31	4.12	1501.22	1501.22	1501.75	0.53
-120	H	13268.21	1836.27	12975.73	3.04	1503.05	1503.05	1503.52	0.47
-119	-	13649.20	1856.67	12464.39	3.17	1503.38	1503.38	1503.83	0.45
-118	-	14208.08	1899.07	11744.84	3.36	1503.98	1503.98	1504.48	0.50
-117	-	14841.13	1783.76	11108.06	3.56	1504.39	1504.39	1504.93	0.54
-116	-	15085.84	1653.89	12837.45	3.08	1504.87	1504.87	1505.41	0.54
-115	I	15513.64	1510.51	10905.09	3.62	1505.14	1505.14	1505.67	0.53
-114	J	16012.77	1300.56	10298.82	3.84	1507.90	1507.90	1508.56	0.66
-113	-	16490.99	1310.03	9768.03	4.04	1509.29	1509.29	1509.86	0.57
-112	K	16983.85	1313.42	10074.92	3.92	1511.23	1511.23	1511.90	0.67
-111	-	17760.01	1162.63	9655.93	4.09	1513.36	1513.36	1514.02	0.66

Table 1: Floodway Data Table (Continued from Page 3)

FLOODING SOURCE			FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION			
HEC-RAS CROSS-SECTION	ASSOCIATED LETTER CROSS-SECTION	DISTANCE (FEET)	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD 88)	WITHOUT FLOODWAY (FEET NAVD 88)	WITH FLOODWAY (FEET NAVD 88)	INCREASE (FEET)
-110	-	18524.55	1152.09	8918.50	4.43	1514.90	1514.90	1515.80	0.90
-109	-	19037.28	1252.54	11601.50	3.41	1515.84	1515.84	1516.84	1.00
-108	L	19287.74	1258.77	10759.81	3.67	1516.56	1516.56	1517.40	0.84
-107	-	19787.93	1338.37	10880.87	3.63	1517.50	1517.50	1518.49	0.99
-106	-	20015.69	1411.64	11203.13	3.53	1518.00	1518.00	1518.97	0.97
-105	M	21142.00	1580.00	10076.74	3.92	1519.59	1519.59	1520.43	0.84
-104	-	21728.18	1663.00	11067.19	3.57	1521.05	1521.05	1521.97	0.92
-103	N	22077.86	1533.00	9788.28	4.04	1521.89	1521.89	1522.79	0.90
-102	-	22523.36	1238.00	8580.00	4.60	1523.99	1523.99	1524.73	0.74
-101	-	22952.80	1149.00	8970.71	4.40	1526.08	1526.08	1526.38	0.30
-100	O	23426.30	1169.00	8911.88	4.43	1527.82	1527.82	1528.24	0.42
-99	-	23935.16	1025.36	8292.57	4.76	1528.81	1528.81	1529.27	0.46
-98	P	24396.52	1026.00	8406.57	4.70	1529.83	1529.83	1530.36	0.53
-97	-	24962.42	1019.00	8783.67	4.50	1531.87	1531.87	1532.63	0.76
-96	Q	25152.10	993.00	9594.06	4.12	1533.00	1533.00	1533.67	0.67
-95	R	25605.70	1035.00	9668.10	4.09	1534.00	1534.00	1534.75	0.75
-94	-	25883.64	1094.00	10106.05	3.91	1534.34	1534.34	1535.14	0.80
-93	-	26131.22	1156.00	11006.62	3.59	1534.56	1534.56	1535.43	0.87
-92	S	26566.94	1231.00	11741.34	3.37	1534.92	1534.92	1535.83	0.91
-91	T	27404.70	1331.00	9216.88	4.29	1536.64	1536.64	1537.46	0.82
-90	-	27866.83	1249.00	9075.95	4.35	1538.37	1538.37	1539.18	0.81
-89	-	28453.85	1172.00	8836.29	4.47	1539.92	1539.92	1540.42	0.50
-88	U	28904.93	1010.00	8780.24	4.50	1541.35	1541.35	1541.74	0.39
-87	-	29042.57	940.61	8367.97	4.72	1541.59	1541.59	1541.99	0.40
-86	-	29367.53	936.00	8184.02	4.83	1542.17	1542.17	1542.64	0.47
-85	V	29514.03	1012.00	8405.81	4.70	1542.41	1542.41	1543.03	0.62
-84	-	29727.89	1092.00	8423.32	4.69	1542.95	1542.95	1543.52	0.57
-83	W	30186.92	1021.00	8117.03	4.87	1544.34	1544.34	1544.80	0.46
-82	-	30504.16	951.00	7719.96	5.12	1545.30	1545.30	1545.68	0.38
-81	-	30680.30	902.00	7577.48	5.21	1546.06	1546.06	1546.41	0.35
-80	-	30910.98	861.00	7864.59	5.02	1547.09	1547.09	1547.60	0.51
-79	-	31169.02	798.00	7646.56	5.17	1548.20	1548.20	1548.75	0.55
-78	-	31625.58	681.00	6876.38	5.75	1549.43	1549.43	1550.02	0.59
-77	-	31829.10	728.00	7614.48	5.19	1550.08	1550.08	1551.01	0.93
-76	X	32218.84	677.89	5884.41	6.71	1551.32	1551.32	1551.99	0.67
-75	-	32618.35	681.00	6200.81	6.37	1553.41	1553.41	1553.84	0.43
-74	Y	32784.28	691.00	7225.18	5.47	1554.46	1554.46	1555.40	0.94
-73	-	32920.29	681.00	8030.93	4.92	1555.56	1555.56	1556.20	0.64
-72	Z	32973.59	676.00	8102.20	4.88	1556.15	1556.15	1556.78	0.63
-71	AA	33077.20	661.33	7404.20	5.34	1556.43	1556.43	1557.09	0.66
-70	AB	33161.03	673.00	7984.98	4.95	1557.28	1557.28	1557.78	0.50
-69	AC	33324.64	690.00	6599.12	5.99	1557.46	1557.46	1557.89	0.43
-68	AD	33612.74	566.00	6293.88	6.28	1559.35	1559.35	1559.49	0.14
-67	-	34139.68	432.00	5021.68	7.87	1560.77	1560.77	1561.01	0.24
-66	AE	34734.27	478.00	5790.59	6.82	1562.50	1562.50	1562.93	0.43
-65	-	35126.77	600.00	8289.79	4.77	1564.25	1564.25	1564.98	0.73
-64	-	35269.12	647.00	8729.84	4.53	1564.51	1564.51	1565.15	0.64
-63	AF	35506.99	697.00	9460.55	4.18	1565.18	1565.18	1566.08	0.90
-62	AG	35686.17	774.00	9647.07	4.10	1565.53	1565.53	1566.50	0.97
-61	AH	36023.47	904.00	11557.86	3.42	1565.99	1565.99	1566.96	0.97
-60	-	36426.86	974.00	11270.54	3.51	1566.34	1566.34	1567.23	0.89
-59	AI	36733.24	974.00	9397.97	4.20	1566.80	1566.80	1567.66	0.86
-58	-	36946.12	993.00	10948.45	3.61	1567.75	1567.75	1568.67	0.92
-57	-	37041.35	1003.00	11378.79	3.47	1568.15	1568.15	1569.06	0.91
-56	AJ	37137.86	1120.00	13157.90	3.00	1568.60	1568.60	1569.51	0.91
-54	AK	37240.13	1102.00	14104.54	2.80	1568.85	1568.85	1569.71	0.86
-53	AL	37372.04	1057.00	10738.47	3.68	1568.77	1568.77	1569.61	0.84
-52	-	37735.27	1028.00	10981.77	3.60	1569.59	1569.59	1570.31	0.72
-51	-	38276.58	929.00	9390.11	4.21	1570.32	1570.32	1570.95	0.63
-50	-	38642.26	804.00	8531.42	4.63	1571.18	1571.18	1571.72	0.54
-49	AM	38876.74	773.00	7399.60	5.34	1571.32	1571.32	1571.84	0.52
-48	-	39108.88	735.00	7255.88	5.45	1572.31	1572.31	1572.75	0.44
-47	-	39359.74	676.90	7313.24	5.40	1573.59	1573.59	1573.79	0.20
-46	-	39808.55	756.00	8530.62	4.63	1574.95	1574.95	1575.87	0.92
-45	AN	40068.46	811.00	10522.02	3.75	1576.35	1576.35	1577.27	0.92
-44	AO	40209.65	796.00	8815.87	4.48	1576.34	1576.34	1577.27	0.93
-42	AP	40273.49	858.00	8745.59	4.52	1580.14	1580.14	1580.32	0.18
-41	-	40433.85	977.00	10206.23	3.87	1580.62	1580.62	1581.27	0.65
-40	AQ	40746.38	1192.00	13125.32	3.01	1581.48	1581.48	1582.34	0.86
-39	-	40939.00	1290.96	14546.47	2.72	1581.93	1581.93	1582.71	0.78
-38	AR	41118.49	1279.81	13531.77	2.92	1582.17	1582.17	1582.93	0.76
-37	-	41554.07	1417.25	13572.77	2.91	1582.60	1582.60	1583.32	0.72
-36	AS	42092.94	1289.48	11502.68	3.43	1583.17	1583.17	1583.89	0.72
-35	-	42321.29	1257.35	10615.69	3.72	1583.55	1583.55	1584.24	0.69
-34	-	42673.17	1371.45	11880.98	3.33	1584.26	1584.26	1585.07	0.81
-33	-	42937.58	1375.69	11782.86	3.35	1584.87	1584.87	1585.84	0.97
-32	AT	43311.79	1304.01	9824.98	4.02	1586.04	1586.04	1586.91	0.87
-31	-	43553.25	1273.56	10740.32	3.68	1587.33	1587.33	1588.00	0.67
-30	-	43705.74	1340.33	11570.86	3.41	1587.91	1587.91	1588.52	0.61
-29	AU	43946.97	1451.96	10863.41	3.64	1588.56	1588.56	1589.15	0.59
-28	AV	44089.40	1504.48	11468.14	3.45	1589.23	1589.23	1589.89	0.66
-27	-	44557.74	1629.64	10688.93	3.70	1589.96	1589.96	1590.77	0.81
-25	-	44890.50	1788.75	11178.51	3.53	1590.6 / 1592.46*	1590.60**	1591.59	0.99
-24	AW	45041.89	1851.40	10752.88	3.67	1591.13 / 1592.65*	1591.13**	1591.82	0.69
-23	-	45220.41	1883.86	13823.28	2.86	1592.14 / 1592.47*	1592.14**	1592.56	0.42
-22	-	45450.11	1896.91	12320.16	3.21	1592.6 / 1592.65*	1592.60**	1593.02	0.42
-21	AX	45670.14	2037.05	11175.35	3.54	1593.31 / 1593.62*	1593.31**	1593.81	0.50
-20	AY	46176.81	1917.05	9028.97	4.38	1593.95 / 1594.16*	1593.95**	1594.49	0.54
-19	-	46630.54	1930.18	10846.32	3.64	1595.48 / 1595.08*	1595.48**	1596.07	0.59
-18	AZ	47238.88	1956.71	11816.31	3.34	1596.9 / 1597.58*	1596.90**	1597.53	0.63

*Cross-sections -18 through -25 are associated with a single floodplain, however two separate reaches. As a result, there is a differental water surface elevation associated with them.

**The maximum encroachment into the floodway was determined by using the lower of the two Regulatory WSELs; which is the worst case scenario.

Mapping Comments

Comment 1: The proposed floodway is shown outside the mapped 1-percent annual chance floodplain (e.g., at Cross Section -35). Please revise the mapped floodway so that it is either coincidental with the 1-percent annual chance floodplain with its boundary.

Response 1: The proposed floodway has been revised accordingly and all associated figures have been updated and are included in **Appendix E**.

Comment 2: Please revise the proposed floodway delineation along the areas where it follows contours (e.g., at Cross Section (-) 132). The mapped floodway boundary should be shown as a smooth line.

Response 2: The proposed floodway delineation along the areas where if follows contours has been revised in order to be shown as a smooth line. The corrected effective hydraulic model, as well as the floodway data table, have been updated to reflect these changes to the floodway and are included on the electronic DVD in **Appendix F**. The floodway data table is also shown above. All associated figures are located in **Appendix E**.

Comment 3: Please indicate which numbered cross sections will be used for the revised lettered cross section on both the topographic map and revised FIRM panels. Information for these cross sections should also be shown on the requested floodway data table.

Response 3: The revised lettered cross sections have been indicated on the topographic map (Figure 4-2), revised FIRM panels (Figure 5-1A and Figure 5-1B), and associated floodway data table. The updated figures are included in **Appendix E** and the floodway data table is located above, as well as, on the electronic DVD in **Appendix F**.

Comment 4: Please revise or confirm that the whole foot BFE lines have been drawn in accordance with Section C.6.3 of Appendix C of FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners. The drawn BFE lines should be able to replicate the 1-percent annual chance profile to within 0.5 foot.

Response 4: The BFE lines were generated directly from the water surface elevation (WSEL) triangulated irregular network (TIN) used to delineate the 100-year corrected effective floodplain. Using 3D Analyst, an extension in ArcGIS, the above mentioned TIN was used to generate 1-foot WSEL contours for the study reach. The locations of the whole foot base flood elevation (BFE) lines selected from the 1-foot WSEL contours have been reviewed and are in accordance with Section C.6.3 of Appendix C of FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners.

PBS&J appreciates your consideration of this matter. If you have any further questions regarding this letter report, please contact our office at (702) 263-7275.

Sincerely,

PBS&J

PROFESSIONAL ENGINEER-STATE OF NEVADA
HARSHAL B. DESAI
Exp. 12-31-08
CIVIL
No. 17468

09-18-06

Michele D'Alessandro, E.I, CFM
Hydrologist

Harshal Desai, P.E., CFM
Associate Project Manager

List of Appendices

Appendix A: FEMA Comment Letter

Appendix B: Regulatory Comment 1

Appendix C: Regulatory Comment 2

- ***Appendix C-1:*** Effective Work Map, Sheet 5 (Bulloch, 96)
- ***Appendix C-2:*** Historical Aerial Photo Exhibit Book (Fuller, 06)

Appendix D: Hydrology Comment 1

Appendix E: Updated Figures

- ***Appendix E-1:*** 100-Year Corrected Effective Work Map
- ***Appendix E-2:*** 500-Year Corrected Effective Work Map
- ***Appendix E-3:*** Overall Annotated FEMA Maps

Appendix F: Electronic DVD

U.S. Department of Homeland Security
1111 Broadway, Suite 1200
Oakland, CA 94607-4052

FEMA

July 12, 2006

Mr. Kevin Eubanks, P.E., CFM
Assistant General Manager
Regional Flood Control District
600 S. Central Parkway, Suite 300
Las Vegas, NV 89106-4511

IN REPLY REFER TO:
Communities: City of Mesquite and Clark County, Nevada
Community Nos.: 320035 and 320003

316-AD

Dear Mr. Eubanks:

This responds to your request dated May 4, 2006, that the Department of Homeland Security's Federal Emergency Management Agency (FEMA) issue a revision to the Flood Insurance Rate Map (FIRM) for Clark County and Incorporated Areas. Please note that due to the size of the revision this request will not be processed as a Letter of Map Revision. Pertinent information about the request is listed below.

Flooding Source:	Virgin River
FIRM Panels Affected:	320030367E, 0369E, 0370E, 0386E, 0387E, 0390E, and 0391E

The data required to complete our review, which must be submitted within 90 days of the date of this letter, are listed on the enclosed summary.

If we do not receive the required data within 90 days, we will suspend our processing of your request. Any data submitted after 90 days will be treated as an original submittal.

If you have general questions about your request, FEMA policy, or the National Flood Insurance Program, please call the FEMA Map Assistance Center, toll free, at 1-877-FEMA MAP (1-877-336-2627). If you have specific questions concerning your request, please call Mr. Mark Delorey at (510) 879-0953.

Sincerely,

Eric Simmons

Eric Simmons, CFM
Engineer, FEMA Region IX

Enclosure

cc: Mr. Allen Bell, City of Mesquite Public Works
Mr. Denis Cederburg, Clark County Public Works
Mr. Matt Baird, PBS&J

Mapping Comments

Preliminary review of the topographic map, annotated FIRM panels, and digital data indicates the following:

1. The proposed floodway is shown outside the mapped 1-percent annual chance floodplain (e.g., at Cross Section -35). Please revise the mapped floodway so that it is either coincidental with the 1-percent annual chance floodplain or within its boundary.

2. Please revise the proposed floodway delineation along the areas where it follows contours (e.g., at Cross Section (-) 132). The mapped floodway boundary should be shown as a smooth line.

3. Please indicate which numbered cross sections will be used for the revised lettered cross section on both the topographic map and revised FIRM panels. Information for these cross sections should also be shown on the requested Floodway Data table.

4. Please revise or confirm that the whole foot BFE lines have been drawn in accordance with Section C.6.3 of Appendix C of FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners. The drawn BFE lines should be able to replicate the 1-percent annual chance profile to within 0.5 foot.

D'Alessandro, Michele

From: Kevin Eubanks
Sent: Tuesday, July 18, 2006 2:02 PM
To: Mark Delorey
Cc: 'Simmons, Eric'; 'Baird, Matt'; Allen Bell; Robert Thompson
Subject: Virgin River PMR
Attachments: Notice Increase.pdf; Notice 500 Yr.pdf; Notice Decrease.pdf; Pages from Uregs.pdf

Mr. Delorey,

I received the 316-AD letter fro this project dated July 12, 2006. I have briefly reviewed the comments and will work with my consultant to respond with the additional data requested.

With regard to item #1 under Regulatory Comments:

- I have attached copies of individual notices sent to all property owners affected by this proposed map change. Using our GIS system we were able to develop a mailing list for properties expected to experience an increase in flood plain area, a decrease in flood plain area and those which will be within the 500 year flood plain. Letters to those expected to experience an increase in flood plain area were sent out certified mail. I have those receipts on file should you need to see them. Information regarding the flood mapping study was presented to the Bunkerville Town Advisory Board on June 1, 2006 and again at a public open house in the City of Mesquite on June 5, 2006.
- The flood plain ordinances adopted by Clark County and the City of Mesquite are the same as the Uniform Regulations for the control of drainage incorprated in their individual municipal codes. Incorporation of the regulations in this manner is a condition of participation in the Regional Flood Control District. The attached section of the Uniform Regulations indicates that the entity enforces the effective Flood Insurance Study and Flood Insurance rate Maps and all amendments. Therefore, the City of Mesquite and Clark county are bound to enforce the proposed floodway once made effective by FEMA.
- Allen Bell with the City of Mesquite and Robert Thompson with Clark County have been copied on this e-mail. Their concurrence with the statements above by affirmative reply to this e-mail will further support these statements on their communities behalf.

I hope this adequately addresses this comment. If you need further information to address this item, please let me know. Additional information addressing other items will follow shortly.

Thank you.

Kevin Eubanks, P.E., CFM
Assistant General Manager
Clark County Regional Flood Control District
600 Grand Central Parkway
Las Vegas, Nevada 89106-4511
702.455.3139

KEubanks@ccrfcd.org
Website: www.ccrfcd.org

REGIONAL FLOOD
CONTROL DISTRICT

Gale Wm. Fraser, II, P.E.
General Manager/Chief Engineer

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City of Boulder City

Bruce L. Woodbury
Clark County

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

May 11, 2006

Property Owner
Owner Address

APN:

RE: Increase in Flood Plain Area

This letter is being sent to you on behalf of the City of Mesquite and Clark County to inform you that the Clark County Regional Flood Control District has submitted a flood map revision request to the Federal Emergency Management Agency (FEMA) to change the floodplain, floodway and base flood elevations associated with an nine (9) mile reach of the Virgin River extending from the Nevada state line.

You have been identified as the owner of the property referenced above which is expected to be affected by an increase in flood plain area as a result of this map revision request. The changes result from an analysis of the flood plain subsequent to major flooding that occurred during the winter of 2004/2005 on the Virgin River. As a result of this study, a change in the base flood elevation and the flood plain boundary may occur when compared with the currently published FEMA Flood Insurance Rate Maps.

Information relative to this map revision will be presented at the Bunkerville Town Advisory Board meeting on June 1, 2006. A public information Open House will be held in training Rooms A&B, upstairs at City Hall in the City of Mesquite, 10 E. Mesquite Blvd., on June 5, 2006. You are invited to come to the Open House any time between the hours of 6:00 p.m. and 8:00 p.m. and District staff and consultants will address any concerns or questions you may have.

If you should have any questions please contact me at 455-3139.

Sincerely,

Kevin Eubanks, P.E., CFM
Assistant General Manager

KLE:jb

Attachment(s)

P:\Letters and Memos\FEMA - LOMRs\2006\Public Notice added.doc

600 S. Grand Central Parkway, Suite 300 • Las Vegas, Nevada 89106-4511
(702) 455-3139 • FAX: (702) 455-3870
Website: *http://www.regionalflood.org*

[illegible]

ITY OF MESQUITE
E MESQUITE BLVD
IESQUITE, NV 890274706

CITY OF MESQUITE
10 E MESQUITE BLVD
MESQUITE, NV 890274706

CITY OF MESQUITE
10 E MESQUITE BLVD
MESQUITE, NV 890274706

CITY OF MESQUITE
EAST MESQUITE BLVD
IESQUITE, NV 890274706

CITY OF MESQUITE
10 EAST MESQUITE BLVD
MESQUITE, NV 890274706

TESCHNER DAVID L & REBECCA
1111 TOBLER LN
BUNKERVILLE, NV 890070000

LEAGUE GIGI A
117 TOBLER LN
UNKERVILLE, NV 890070000

LONG THEODORE J & GAIL T
115 GRAYCE DR
MESQUITE, NV 890274147

HIGGINS DONALD K FAMILY
TRUST
115 SAGE WY
MESQUITE, NV 890274164

AWSON FAMILY TRUST
16 COTTONWOOD DR
IESQUITE, NV 890274113

MOORE RICHARD V & CONNIE G
116 SAGE WY
MESQUITE, NV 890274164

WOTRING PATRICIA J & TERRY A
131 GRAYCE DR
MESQUITE, NV 890274147

IOORE WILLIAM H & JULIE F
31 SAGE WY
IESQUITE, NV 890274164

JENSEN JERRY & CARRIE
132 GRAYCE DR
MESQUITE, NV 890274147

MANN FREDERICK M & MARLA B
132 SAGE WY
MESQUITE, NV 890274164

MULHOLLAND ROBERT L &
AROL D
376 CATHEDRAL CANYON DR
IESQUITE, NV 890276749

OSGUTHORPE FRED & CAROL
1382 POLO LN
WEST JORDAN, UT 840886676

TANNER DENNIS L & CONNIE JO
14 W 1ST SOUTH
MESQUITE, NV 890276304

HOUSER MARK W & SHAUNA F
47 COTTONWOOD DR
IESQUITE, NV 890274114

HEINKE BOBBIE E & DEBRA J
147 GRAYCE DR
MESQUITE, NV 890274147

THOMPSON CHARLES & SAYO Y
148 GRAYCE DR
MESQUITE, NV 890274147

WILLIAMS JAMES MILLS REV TR
5 COTTONWOOD DR
IESQUITE, NV 890274111

BUTTERFIELD FAMILY TRUST
16 COTTONWOOD DR
MESQUITE, NV 890274112

GUNDERSON PATRICIA
163 GRAYCE DR
MESQUITE, NV 890274147

HISM DAVID S & DEBRA D
64 GRAYCE DR
IESQUITE, NV 890274147

STUBBS MICHAEL & SHANNA
176 N 1050 W
CEDAR CITY, UT 847202340

BARKER MARY F & DANNY L
180 COTTONWOOD DR
MESQUITE, NV 890274113

TOKES SUSAN E
80 EAST FIRST SOUTH ST
IESQUITE, NV 890276313

STOKES SUSAN E
180 EAST FIRST SOUTH ST
MESQUITE, NV 890276313

WURSTEN BRIAN J & CRISTIE
180 GRAYCE DR
MESQUITE, NV 890274148

COTTEN LARRY O & LILA
91 S W DIAGONAL
AVERKIN, UT 847455631

KRETSCHMANN GARY & JOLENE
195 COTTONWOOD DR
MESQUITE, NV 890274115

ELLETT JERROD
20 SAGE WY
MESQUITE, NV 890274167

FUGATE CHARLES & SHARON
16 COTTONWOOD DR
ESQUITE, NV 890274117

HINCHCLIFF L GRANT
231 COTTONWOOD DR
MESQUITE, NV 890274117

DERBY KAREN & WILLIAM
1994 TR
232 COTTONWOOD DR
MESQUITE, NV 890274117

LASSEN STEVEN A & MARSHA
460 OAKHAVEN DR
PANISH FORK, UT 846609307

SORENSEN F R B J REV LIV TR
248 COTTONWOOD DR
MESQUITE, NV 890274117

JENSEN NEPHI FAMILY TRUST
251 RIVERSIDE RD
MESQUITE, NV 890275903

ENSEN NEPHI FAMILY TRUST
51 RIVERSIDE RD
ESQUITE, NV 890275903

STRICKLER RONALD L &
ROXANNE F
263 COTTONWOOD DR
MESQUITE, NV 890274117

CARMICHAEL RICHARD L &
SHIRLEY A
264 COTTONWOOD DR
MESQUITE, NV 890274117

ZAPLEWSKI FAMILY TRUST
80 COTTONWOOD DR
ESQUITE, NV 890274117

SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

CHOOL BOARD OF TRUSTEES
832 E FLAMINGO
AS VEGAS, NV 891215205

SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

SCHOOL BOARD OF TRUSTEES
32 E FLAMINGO RD
AS VEGAS, NV 891215205

SALAZAR MARTIN P & SANDRA
308 N JOSEPH ST
MESQUITE, NV 890274178

BUSBY ORRIN & MARIE
31 COTTONWOOD DR
MESQUITE, NV 890274111

HEALEY SHAWN P & CYNTHIA L
1 SAGE WY
ESQUITE, NV 890274167

ARAKAWA STEPHEN K
REV LIV TR
311 RONNIE WY
MESQUITE, NV 890274181

HOPKINS FAMILY TRUST
314 JOSEPH ST
MESQUITE, NV 890274178

YERS CLYDE JR & DARLENE B
15 WOODBURY LN
ESQUITE, NV 890278143

MARQUARDT RONALD M &
YVONNE L
32 COTTONWOOD DR
MESQUITE, NV 890274112

BIGOS FRANCES T
32 GRAYCE DR
MESQUITE, NV 890274165

USSER ALICE
SAGE WY
ESQUITE, NV 890274167

RICHARD CLIFFORD J & DAWN A
323 RONNIE WY
MESQUITE, NV 890274181

MADSEN EVELYN W
329 RONNIE WY
MESQUITE, NV 890274181

BOWLER JOSEPH L JR & DIXIE
30 N SANDHILLD RD #D
MESQUITE, NV 890270000

HERNANDEZ PATRICIA
3321 E BARTLETT AVE
NO LAS VEGAS, NV 890306639

ZAPPIA JOHN A & MARY
335 RONNIE WY
MESQUITE, NV 890274181

PENTEL MIKE
808 S EAGLE
AURORA, CO 800144106

PENTEL MIKE
3808 S EAGLE
AURORA, CO 800144106

PENTEL MIKE
3808 S EAGLE
AURORA, CO 800144106

HAFEN BRYAN K & DAWN N
31 VERLLONIA ST
MESQUITE, NV 890275811

COYOTE WILLOWS GOLF L L C
405 N 600 W
PLEASANT GROVE, UT 840622144

COYOTE WILLOWS GOLF L L C
405 N 600 W
PLEASANT GROVE, UT 840622144

COYOTE WILLOWS GOLF L L C
405 N 600 W
PLEASANT GROVE, UT 840622144

Z M H DEVELOPMENT INC
405 N 600 W
PLEASANT GROVE, UT 840622144

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405 N 600 W
PLEASANT GROVE, UT 840622144

BRINGHURST MORGAN G &
OYCE B P
4068 W 5050 S
KEARNS UT, UT 841184216

BRINGHURST MORGAN G &
JOYCE B P
4068 W 5050 S
KEARNS UT, UT 841184216

OLD MILL INC
4181 FRANCISCAN CT
LAS VEGAS, NV 891215014

PARK BRANDON J & CAMRIN
1 HAGENS ALLEY
MESQUITE, NV 890275815

ELIZALDE JOSEFINA
4624 W HENDERSON
SANTA ANA, CA 927041132

HARDMAN FAMILY TRUST
47 GRAYCE DR
MESQUITE, NV 890274166

STANTON DENNIS & PATRICIA J
SAGE WY
ESQUITE, NV 890274146

CONRIQUEZ ERNIE & ELIZABETH
4716 N TORREY PINES DR
LAS VEGAS, NV 891302302

LIBBY EDITH LUCILLE
48 GEAN ST
MESQUITE, NV 890274151

BUTLER R & FONTAINE J REV TR
48 GRAYCE DR
ESQUITE, NV 890274166

TRUJILLO JOSE ANTONIO
48 SAGE WY
MESQUITE, NV 890270000

COUNTY OF
CLARK(ADMINISTRATIVE)
500 S GRAND CENTRAL PKWY
LAS VEGAS, NV 891550000

C SYSTEMS INC
5024 SAINT FRANCIS WY
ROCKLIN, CA 956774422

L C SYSTEMS INC
5024 SAINT FRANCIS WY
ROCKLIN, CA 956774422

L C SYSTEMS INC
5024 ST FRANCIS WY
ROCKLIN, CA 956774422

BENTLEY CHARLES & ANN
REV TR
17 W MESQUITE BLVD #1224
ESQUITE, NV 890278139

CHRISTENSEN NORMA
EVOCABLE TR
721 HERON AVE
AS VEGAS, NV 891073622

CHRISTENSEN NORMA
EVOCABLE TR
721 HERON AVE
AS VEGAS, NV 891073622

ADAMS IRVIN W REV LIV TR
GMT
9 PANGLOSS ST
ENDERSON, NV 890156540

ATHWAY HOLDINGS NEVADA
LC
19 S BLUFF ST TWR 2
T GEORGE, UT 847705448

AMIREZ ALBERTO & JUANA
3 GRAYCE DR
ESQUITE, NV 890274166

HAFEN MERLIN & VICTORIA FAM
R
36 SAWGRASS WY
ESQUITE, NV 890276769

HANEY ROBERT A & DINAH
4 SAGE WY
ESQUITE, NV 890274146

EDERSON FAMILY TRUST
78 OLD MILL RD
ESQUITE, NV 890274157

HEARER WEAVER J
GRAYCE DR
ESQUITE, NV 890274166

NOEL GARRY L & JOY L
54 W FIRST SOUTH ST
MESQUITE, NV 890276304

CHRISTENSEN NORMA
REVOCABLE TR
5721 HERON AVE
LAS VEGAS, NV 891073622

SCHAFFER ARCHIE W & JO
ELLEN
575 E THOMAS
OAK VIEW, CA 930229228

ADAMS WAYNE IRVIN
REV LIV TR
59 PANGLOSS ST
HENDERSON, NV 890156540

PATHWAY HOLDINGS NEVADA
LLC
619 S BLUFF ST TWR 2
ST GEORGE, UT 847705448

MONTGOMERY WILLIAM R &
LESLEE D
63 SAGE WY
MESQUITE, NV 890274146

TRAVIS CLAYTON
64 COTTONWOOD DR
MESQUITE, NV 890274140

PEDERSON FAMILY TRUST
678 E OLD MILL RD
MESQUITE, NV 890274157

PEDERSON FAMILY TRUST
678 OLD MILL RD
MESQUITE, NV 890274157

VANLANT WALLACE G &
ROBERTA J
798 PEACHTREE
MESQUITE, NV 890270000

RUVALCABA-LOPEZ JESUS
549 E MESQUITE BLVD
MESQUITE, NV 890274129

CHRISTENSEN NORMA
REVOCABLE TR
5721 HERON AVE
LAS VEGAS, NV 891073622

ADAMS IRVIN W REV LIV TR
AGMT
59 PANGLOSS ST
HENDERSON, NV 890156540

PATHWAY HOLDINGS NEVADA
LLC
619 S BLUFF ST TWR 2
ST GEORGE, UT 847705448

PATHWAY HOLDINGS NEVADA
LLC
619 S BLUFF ST TWR 2
ST GEORGE, UT 847705448

HAFEN MERLIN & VICTORIA
FAM TR
636 SAWGRASS WY
MESQUITE, NV 890276769

SUAZO TERRY
64 GRAYCE DR
MESQUITE, NV 890274166

PEDERSON FAMILY TRUST
678 OLD MILL RD
MESQUITE, NV 890274157

COVERT DONN & ETHELYN
REV LIV TR
690 E OLD MILL RD
MESQUITE, NV 890274157

HAMBY J W & CAROLE
800 S STATE ST #99
SUTHERLIN, OR 974799856

TOWER RICHARD W & JOANNE R
816 SOUTHRIDGE DR
MESQUITE, NV 890276742

AMEN KEVIN & JAMAE
855 OLD MILL RD
MESQUITE, NV 890274118

RIVER VIEW L L C
910 MESQUITE
MESQUITE, NV 890275204

RIVER VIEW L L C
910 MESQUITE
MESQUITE, NV 890275204

RIVER VIEW L L C
910 MESQUITE
MESQUITE, NV 890275204

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RIVER VIEW L L C
910 MESQUITE
MESQUITE, NV 890275204

RIVER VIEW L L C
910 MESQUITE
MESQUITE, NV 890275204

WOODS CHARLES HALE & VERA
MAE
910 OLD MILL
MESQUITE, NV 890274119

JOHNSON KENT C & LORI I
5 COTTONWOOD DR
MESQUITE, NV 890274139

R B G L L C
950 W MESQUITE BLVD
MESQUITE, NV 890275204

REED ROBERT G & MARJORIE L
96 COTTONWOOD DR
MESQUITE, NV 890274140

MILNE RUTH A FAMILY TRUST
96 GRAYCE DR
MESQUITE, NV 890274166

HAKES JAMES JR & DEBORAH D
96 SAGE WY
MESQUITE, NV 890274146

HAFEN TILMAN & JENNIFER
FAM TR
989 OLD MILL RD
MESQUITE, NV 890274119

VK PO Box- [illegible]

UCCARELLI LILLIAN K EST
.O. Box 247
OPEWELL, NV 85250247

ZUCCARELLI LILLIAN K EST
P.O. Box 247
HOPEWELL, NV 85250247

LINFORD DALE H FAMILY TRUST
P.O. Box 238
LIBERTY, UT 843100238

OLDEN THOMAS MICHAEL &
EON
R1 BOX 246
AIRVIEW, UT 846299529

CEDAR DEV CORP
P.O. Box 130
CEDAR CITY, UT 847210130

CEDAR DEV CORP
P.O. Box 130
CEDAR CITY, UT 847210130

EDAR DEV CORP
.O. Box 130
EDAR CITY, UT 847210130

CEDAR DEV CORP
P.O. Box 130
CEDAR CITY, UT 847210130

CEDAR DEV CORP
P.O. Box 130
CEDAR CITY, UT 847210130

EDAR DEV CORP
.O. Box 130
EDAR CITY, UT 847210130

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P.O. Box 130
CEDAR CITY, UT 847210130

CEDAR DEV CORP
P.O. Box 130
CEDAR CITY, UT 847210130

EDAR DEV CORP
.O. Box 130
EDAR CITY, UT 847210130

CEDAR DEVELOPMENT
CORPORATION
P.O. Box 130
CEDAR CITY, UT 847210130

CEDAR DEVELOPMENT
CORPORATION
P.O. Box 130
CEDAR CITY, UT 847210130

EAVITT LAND & INVESTMENT
C
.O. Box 130
EDAR CITY, UT 847210130

LEAVITT LAND & INVESTMENT
INC
P.O. Box 130
CEDAR CITY, UT 847210130

LEAVITT LAND & INVESTMENT
INC
P.O. Box 130
CEDAR CITY, UT 847210130

SECURITY LAND & LIVESTOCK
.O. Box 130
EDAR CITY, UT 847210130

SECURITY LAND & LIVESTOCK
P.O. Box 130
CEDAR CITY, UT 847210130

SECURITY LAND & LIVESTOCK
INC
P.O. Box 130
CEDAR CITY, UT 847210130

ECURITY LAND & LIVESTOCK
NC
.O. Box 130
EDAR CITY, UT 847210130

SECURITY LAND & LIVESTOCK
INC
P.O. Box 130
CEDAR CITY, UT 847210130

UNKNOWN OWNER
P.O. Box 130
CEDAR CITY, UT 847210130

OODS MICHAEL GARY OR LISA
.O. Box 785
UNKERVILLE , NV 890070000

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P.O. Box 7093
BUNKERVILLE, NV 890070093

ANDERSON JERI LYNN
P.O. Box 7128
BUNKERVILLE, NV 890070128

& R FARM PROPERTIES L L C
.O. Box 7149
UNKERVILLE, NV 890070149

R & R FARM PROPERTIES L L C
P.O. Box 7149
BUNKERVILLE, NV 890070149

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P.O. Box 7149
BUNKERVILLE, NV 890070149

EID BUNKERVILLE TRUST
.O. Box 446
ESQUITE, NV 890240446

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P.O. Box 446
MESQUITE, NV 890240446

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P.O. BOX 550
MESQUITE, NV 890240550

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MESQUITE, NV 890240550

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ESQUITE, NV 890241020

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P.O. Box 1030
MESQUITE, NV 890241030

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ESQUITE, NV 890241052

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ELLETT REVOCABLE TRUST
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ESQUITE, NV 890241345

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MESQUITE, NV 890241413

DRASKOVICH ROBERT M &
JANICE V
P.O. Box 1413
MESQUITE, NV 890241413

RASKOVICH ROBERT M &
ANICE V
O. Box 1413
ESQUITE, NV 890241413

DRASKOVICH ROBERT M &
JANICE V
P.O. Box 1413
MESQUITE, NV 890241413

DRASKOVICH ROBERT M &
JANICE V
P.O. Box 1413
MESQUITE, NV 890241413

RASKOVICH ROBERT M OR
ANICE
O. Box 1413
ESQUITE, NV 890241413

BURTON CHARLES H & NANCY
P.O. Box 1885
MESQUITE, NV 890241885

BUNK FARM L L C
P.O. Box 2067
MESQUITE, NV 890242067

UNK FARM L L C
.O. Box 2067
ESQUITE, NV 890242067

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P.O. Box 2097
MESQUITE, NV 890242097

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P.O. Box 2169
MESQUITE, NV 890242169

R & R FARM PROPERTIES L L C
.O. Box 7149
UNKERVILLE, NV 890070149

BUNKER FARM INC
P.O. Box 7150
BUNKERVILLE, NV 890070150

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BUNKERVILLE, NV 890070176

HARDY JAY F & NAN
.O. Box 7184
UNKERVILLE, NV 890070184

HARDY JAY F & NAN R
P.O. Box 7184
BUNKERVILLE, NV 890070184

PENNISE RICHARD
P.O. Box 7192
BUNKERVILLE, NV 890070192

RASKOVICH MARK & ANGELA
.O. Box 7242
UNKERVILLE, NV 890070242

STREET ARTHUR D & HEATHER A
P.O. Box 7295
BUNKERVILLE, NV 890070295

BUNKERVILLE IRRIGATION CO
P.O. Box 7337
BUNKERVILLE, NV 890070337

BUNKERVILLE IRRIGATION CO
.O. Box 7337
UNKERVILLE, NV 890070337

BUNKERVILLE IRRIGATION CO
P.O. Box 7337
BUNKERVILLE, NV 890070337

TODD BRENDA B
P.O. Box 8000-191
MESQUITE, NV 890240000

ITY OF MESQUITE
.O. Box 69
ESQUITE, NV 890240069

WOODS CHARLES VAL & CAROL
P.O. Box 116
MESQUITE, NV 890240116

WOODS CHARLES VAL & CAROL
P.O. Box 116
MESQUITE, NV 890240116

OODS CHARLES VAL & CAROL
.O. Box 116
ESQUITE, NV 890240116

HAFEN KRAIG & SUSAN
P.O. Box 142
MESQUITE, NV 890240142

HAFEN KRAIG & SUSAN
P.O. Box 142
MESQUITE, NV 890240142

HAFEN BRYAN K & DAWN N
RUST
.O. Box 158
ESQUITE, NV 890240158

HAFEN BRYAN K & DAWN N
TRUST
P.O. Box 158
MESQUITE, NV 890240158

HAFEN BRYAN K & DAWN N
TRUST
P.O. Box 158
MESQUITE, NV 890240158

ENSEN THERON N FAMILY
RUST
.O. Box 193
ESQUITE, NV 890240193

JENSEN THERON N FAMILY
TRUST
P.O. Box 193
MESQUITE, NV 890240193

JENSEN THERON N FAMILY
TRUST
P.O. Box 193
MESQUITE, NV 890240193

UTH CLAWSON WADE &
RPHA WOODS
.O. BOX 202
ESQUITE, NV 890240202

RUTH CLAWSON WADE &
ORPHA WOODS
P.O. BOX 202
MESQUITE, NV 890240202

LEAVITT MITCHEAL D
P.O. Box 304
MESQUITE, NV 890240304

ARDUNG LAVENE H 1976 TRUST
.O. Box 369
ESQUITE, NV 890240369

HARDUNG LAVENE H 1976 TRUST
P.O. Box 369
MESQUITE, NV 890240369

REID BUNKERVILLE TRUST
P.O. Box 446
MESQUITE, NV 890240446

BROWER REVOCABLE TRUST
P.O. Box 2170
MESQUITE, NV 890242170

VANBERCKELAER FAMILY
TRUST
P.O. Box 2227
MESQUITE, NV 890242227

FREEMAN PHILIP J & JULIA J
P.O. Box 2285
MESQUITE, NV 890242285

SALAZAR SAMUEL S &
HORTENCIA D
P.O. Box 2326
MESQUITE, NV 890242326

LEE CHARLES B & SANDRA J
P.O. Box 2352
MESQUITE, NV 890242352

HAFEN BRYAN TILMAN &
JENNIFER
P.O. Box 2827
MESQUITE, NV 890242827

MONTOYA NICHOLAS F &
STEPHANIE W
P.O. Box 2991
MESQUITE, NV 890242991

NUNEZ RICARDO F
P.O. Box 3092
MESQUITE, NV 890243092

YOUNG HOWARD W & SHARON L
P.O. Box 3490
MESQUITE, NV 890243490

ARNOLD MICHAEL W &
K D REV TR
P.O. Box 420
ARNOLD, CA 952230420

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May 15, 2006

APN:

RE: Flood Plain Mapping

Following heavy rain and flooding during the winter of 2004/2005, the Clark County Regional Flood Control District began an analysis of the flood plain along the Virgin River. This study has been finalized and submitted to the Federal Emergency Management Agency (FEMA) to change the floodplain, floodway and base flood elevations associated with a nine (9) mile reach of the Virgin River extending from the Nevada state line.

The study focused primarily on the aerial extent and base flood elevation of the 100-year flood plain. However, for the first time, the study also mapped property in the 500-year flood plain. Your property is one of those identified in the 500-year flood plain. While this designation does not require you to purchase flood insurance, the District wanted you to be informed of this new information.

A public information Open House will be held in training Rooms A&B upstairs at City Hall in the City of Mesquite, 10 E. Mesquite Blvd., on June 5, 2006. You are invited to come to the Open House any time between the hours of 6:00 p.m. and 8:00 p.m. and District staff and consultants will address any concerns or questions you may have.

If you should have any questions please contact me at 455-3139.

Sincerely,

Kevin Eubanks, P.E., CFM
Assistant General Manager

KLE:jb

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600 S. Grand Central Parkway, Suite 300 • Las Vegas, Nevada 89106-4511
(702) 455-3139 • FAX: (702) 455-3870
Website: *http://www.regionalflood.org*

AMEN KEVIN & JAMAE
355 OLD MILL RD
MESQUITE, NV 890274118

BERGSTROM RUSSELL &
SUSAN
65 GEAN ST
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1384 CATHEDRAL CANYON DR
MESQUITE, NV 890276749

BOWLER JOSEPH L JR & DIXIE
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COGDILL LEONARD R &
SANDRA J
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LITTLETON , CO 801213313

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MESQUITE, NV 890274176

CONRIQUEZ ERNIE &
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4716 N TORREY PINES DR
LAS VEGAS, NV 891302302

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500 S GRAND CENTRAL PKWY
LAS VEGAS, NV 891550000

COUNTY OF CLARK(PK &
COMM SERV)
500 S GRAND CENTRAL PKWY
LAS VEGAS, NV 891550000

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690 E OLD MILL RD
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840871127

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163 GRAYCE DR
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FAM TR
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MESQUITE, NV 890274117

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MESQUITE, NV 890275903

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1117 TOBLER LN
BUNKERVILLE, NV 890070000

LEAVITT DAVID A &
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1388 CATHEDRAL CANYON DR
MESQUITE, NV 890276749

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8 GEAN ST
MESQUITE, NV 890274151

LUNA RAFAEL C
248 SAGE WY
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MESQUITE, NV 890274181

MANN FREDERICK M &
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32 SAGE WY
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232 GRAYCE DR
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380 CATHEDRAL CANYON DR
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264 GRAYCE DR
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NICKERSON CATHY
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ESQUITE, NV 890274157

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296 COTTONWOOD DR
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MESQUITE, NV 890274181

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MESQUITE, NV 890274117

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REVOCABLE TRUST
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609 E OLDMILL RD
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MESQUITE, NV 890274149

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TRUST
800 SOUTHRIDGE DR
MESQUITE, NV 890276742

WALKER DONNA M FAMILY
TRUST
800 SOUTHRIDGE DR
MESQUITE, NV 890276742

WILSON EDWARD H &
CAROLE A
147 SAGE WY
MESQUITE, NV 890274164

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452 SEDONA DR
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WISNE ROBERT T LIVING
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VERA MAE
910 OLD MILL
MESQUITE, NV 890274119

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472 VALLEY VIEW CIR
MESQUITE, NV 890273111

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MESQUITE, NV 890274148

ZAPPIA JOHN A & MARY
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MESQUITE, NV 890274181

ZERKLE SHIRLYN
120 E 1ST SOUTH WILLOW
MESQUITE, NV 890240000

ANDERSON JERI LYNN
P. O. BOX 7128
BUNKERVILLE, NV 890070128

BEAN JAMES S
P. O. BOX 1172
MESQUITE, NV 890241172

BIASI BRUNO 1983 TRUST
P. O. BOX 550
MESQUITE, NV 890240550

BROTHERSON FAMILY TRUST
P. O. BOX 7145
BUNKERVILLE, NV 890070145

BROWER REVOCABLE TRUST
P. O. BOX 2170
MESQUITE, NV 890242170

BROWN LYNN R & MYRNA W
P. O. BOX 1569
MESQUITE, NV 890241569

BUNKER FARM INC
P. O. BOX 7150
BUNKERVILLE, NV 890070150

BURTON CHARLES H & NANCY
P. O. BOX 1885
MESQUITE, NV 890241885

BUTLER JANAE
P. O. BOX 2936
MESQUITE, NV 890242936

CAYIAS STEVE & DEBBIE
P. O. BOX 7093
BUNKERVILLE, NV 890070093

CEDAR DEV CORP
P. O. BOX 130
CEDAR CITY , UT 847210130

CROWTHER GLENN W & A CLAIRE
P. O. BOX 357
MESQUITE, NV 890240357

DESERT TURQUOISE L L C
P. O. BOX 68
MIDWAY , UT 840490068

DEWOLF CLEVE & DESIRAY
P. O. BOX 537
MESQUITE, NV 890240537

DIROSA ROGER
P. O. BOX 418
AJO , AZ 853210418

DRASKOVICH MARK & ANGELA C
P. O. BOX 7242
BUNKERVILLE, NV 890070242

DRASKOVICH ROBERT M OR JANICE
P. O. BOX 1413
MESQUITE, NV 890241413

DUNCAN CORY C & PAMELA K
P. O. BOX 3002
VISTA , CA 920853002

EATON TRAVIS O & MELISSA R
P. O. BOX 1269
MESQUITE, NV 890241269

ESTRADA JOSE A & MARIA M
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MESQUITE, NV 890242442

EVANS BOYD & MELANIE
P. O. BOX 1052
MESQUITE, NV 890241052

GASCA ROBERTO & SYLVIA
P. O. BOX 1743
MESQUITE, NV 890241743

GLEAVE JOHN & SHEREE
P. O. BOX 7176
BUNKERVILLE, NV 890070176

HABIB ASMA
P. O. BOX 280
OVERTON , NV 890400280

HAFEN BRYAN K & DAWN N TRUST
P. O. BOX 158
MESQUITE, NV 890240158

HAFEN KRAIG & SUSAN
P. O. BOX 142
MESQUITE, NV 890240142

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HAFEN KRAIG & SUSAN
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MESQUITE, NV 890240142

HARDUNG LAVENE H 1976 TRUST
P. O. BOX 369
MESQUITE, NV 890240369

HARDY JAY F & NAN R
P. O. BOX 7184
BUNKERVILLE, NV 890070184

HARRIS CRISTINE
P. O. BOX 2314
MESQUITE, NV 890242314

JENSEN THERON N FAMILY TRUST
P. O. BOX 193
MESQUITE, NV 890240193

JONES JANICE
P. O. BOX 1635
MESQUITE, NV 890241635

KLEVMOEN DAVID J
P. O. BOX 1236
MESQUITE, NV 890241236

LEAVITT DANNIE ROLAN & SHARON
P. O. BOX 7073
BUNKERVILLE, NV 890070073

LEAVITT LILLIAN
P. O. BOX 7245
BUNKERVILLE, NV 890070245

LEAVITT MITCHEAL D
P. O. BOX 304
MESQUITE, NV 890240304

LINFORD DALE H FAMILY TRUST
P. O. BOX 238
LIBERTY , UT 843100238

MACIAS LEOPOLDO & JULIA
P. O. BOX 3006
MESQUITE, NV 890243006

MONTOYA NICHOLAS F &
STEPHANIE W
P. O. BOX 2991
MESQUITE, NV 890242991

MORGAN WILLIAM
P. O. BOX 1903
MESQUITE, NV 890241903

OROZCO SAUL
P. O. BOX 1562
MESQUITE, NV 890241562

ORTIZ ELIZABETH
P. O. BOX 7348
BUNKERVILLE, NV 890070348

OWENS JAMES J III & BONNIE L
P. O. BOX 1330
MESQUITE, NV 890241330

PENNISE RICHARD
P. O. BOX 7192
BUNKERVILLE, NV 890070192

PRATHER TIMOTHY M & JUDY K
P. O. BOX 68
MCHENRY , MD 215410068

REBER LARRY & COLLEEN TRUST
2001
P. O. BOX 7065
BUNKERVILLE, NV 890070065

REID BUNKERVILLE TRUST
P. O. BOX 446
MESQUITE, NV 890240446

RUTH CLAWSON WADE & ORPHA
WOODS
P. O. BOX 202
MESQUITE, NV 890240202

SALAZAR SAMUEL S & HORTENCIA
D
P. O. BOX 2326
MESQUITE, NV 890242326

SAVINSKY FAMILY TRUST
P. O. BOX 3174
MESQUITE, NV 890243174

STREET ARTHUR D & HEATHER A
P. O. BOX 7295
BUNKERVILLE, NV 890070295

STREET NELLADEE
P. O. BOX 7328
BUNKERVILLE, NV 890070328

TANNER EVAN O & LEONA
P. O. BOX 7234
BUNKERVILLE, NV 890070234

WAITE STEPHEN DOUGLAS & EMILY
P
P. O. BOX 7249
BUNKERVILLE, NV 890070249

WHITAKER JOHN R & M JOYCE
P. O. BOX 3131
MESQUITE, NV 890243131

WOODS CHARLES VAL & CAROL JOY
P. O. BOX 116
MESQUITE, NV 890240116

REGIONAL FLOOD
CONTROL DISTRICT

ale Wm. Fraser, II, P.E.
General Manager/Chief
Engineer

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Bruce L. Woodbury
Clark County

May 15, 2006

«AddressBlock»

APN: «PARCEL»

RE: Decrease in Flood Plain Area

This letter is being sent to you on behalf of the City of Mesquite and Clark County to inform you that the Clark County Regional Flood Control District has submitted a flood map revision request to the Federal Emergency Management Agency (FEMA) to change the floodplain, floodway and base flood elevations associated with an nine (9) mile reach of the Virgin River extending from the Nevada state line.

You have been identified as the owner of the property referenced above which is expected to be affected by a decrease in flood plain area as a result of this map revision request. The changes result from an analysis of the flood plain subsequent to major flooding that occurred during the winter of 2004/2005 on the Virgin River. As a result of this study, a change in the base flood elevation and the flood plain boundary may occur when compared with the currently published FEMA Flood Insurance Rate Maps.

Information relative to this map revision will be presented at the Bunkerville Town Advisory Board meeting on June 1, 2006. A public information Open House will be held in training Rooms A&B, upstairs at City Hall in the City of Mesquite, 10 E. Mesquite Blvd., on June 5, 2006. You are invited to come to the Open House any time between the hours of 6:00 p.m. and 8:00 p.m. and District staff and consultants will address any concerns or questions you may have.

If you should have any questions please contact me at 455-3139.

Sincerely,

Kevin Eubanks, P.E., CFM
Assistant General Manager

KLE:jb

I:\Public Notice removed.doc

600 S. Grand Central Parkway, Suite 300 • Las Vegas, Nevada 89106-4511
(702) 455-3139 • FAX: (702) 455-3870
Website: *http://www.regionalflood.org*

OK - 100 ft box - Removed

AMEN KEVIN & JAMAE
855 OLD MILL RD
MESQUITE, NV 890274118

BEARE ROSALIE
946 JENSEN DR
MESQUITE, NV 890277034

BENTLEY CHARLES &
ANN REV TR
517 W MESQUITE BLVD #1224
MESQUITE, NV 890278139

BOWDEN RAY L & PEGGY F
5393 EAST 3850 NORTH
EDEN, UT 843109648

BUSBY DONALD & CARON
471 HAGENS ALLY
MESQUITE, NV 890275815

CARSTENSEN FAMILY TRUST
332 POPPY LN
MESQUITE, NV 890276237

CHRISTENSEN NORMA
REVOCABLE TR
5721 HERON AVE
LAS VEGAS, NV 891073622

CHRISTENSEN NORMA
REVOCABLE TR
5721 HERON AVE
LAS VEGAS, NV 891073622

CITY OF MESQUITE
10 E MESQUITE BLVD
MESQUITE, NV 890274706

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FRAZIER TERRY K &
RIZALINDA L G
934 JENSEN DR
MESQUITE, NV 890277034

GODINEZ SALVADOR &
VIRGINIA
2465 E 7TH ST
LOS ANGELES , CA 900231328

GONZALEZ JUAN
352 POPPY LN
MESQUITE, NV 890276237

GOTT NATHAN F & BARBARA
942 JENSEN DR
MESQUITE, NV 890277034

GRISCAVAGE CAROL
926 JENSEN DR
MESQUITE, NV 890277034

HAFEN NELSON & LAUREL
843 E 970 S CIR
ST GEORGE, UT 847904037

HART GERALD F & JUDITH A
634 HAGENS ALLY
MESQUITE, NV 890277032

JENSEN NEPHI FAMILY TRUST
251 RIVERSIDE RD
MESQUITE, NV 890275903

KINDEL JAMES M &
MYRNA LORENA
895 E OLD MILL RD
MESQUITE, NV 890274118

KNIGHT NORMAN A & CYNTIA
938 JENSEN
MESQUITE, NV 890277034

LINSDELL SHARON
633 HAGENS ALLEY
MESQUITE, NV 890277032

LOWER WILLOW LTD
889 S 1750 W
CEDAR CITY, UT 847208235

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TRACI
362 POPPY LN
MESQUITE, NV 890276237

OLD MILL INC
2187 FRANCISCAN CT
LAS VEGAS, NV 891210000

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OLD MILL INC
4187 FRANCISCAN CT
LAS VEGAS, NV 891215014

PATHWAY HOLDINGS
NEVADA LLC
619 S BLUFF ST TWR 2
ST GEORGE, UT 847705448

PENTEL MIKE
3808 S EAGLE
AURORA , CA 800144106

PORE EDGAR A & SHARON M
342 POPPY LN
MESQUITE, NV 890276237

R B G L L C
950 W MESQUITE BLVD
MESQUITE, NV 890275204

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RICKS JACK W FAMILY TRUST
374 POPPY LN
MESQUITE, NV 890276237

RIVER VIEW L L C
910 MESQUITE
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SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

SCHOOL BOARD OF TRUSTEES
2832 E FLAMINGO
LAS VEGAS, NV 891215205

SLEPPY WALTER & PAMELA
386 HAFEN LN
MESQUITE, NV 890276276

SPREEN TRUST
344 W HAFEN LN
MESQUITE, NV 890276276

STANTON SHARON L
627 HAGENS ALLEY
MESQUITE, NV 890277032

TANNER DENNIS L &
CONNIE JO
14 W 1ST SOUTH
MESQUITE, NV 890276304

TANNER DENNIS L &
CONNIE JO
14 W 1ST SOUTH
MESQUITE, NV 890276304

OWER RICHARD W & JOANNE
16 SOUTHRIDGE DR
MESQUITE, NV 890276742

WIKE JAMES R & MERCEDES
186 BEACH OAK AVE
HENDERSON , NV 890159178

WISNE ROBERT T
LIVING TRUST
364 HAFEN LN
MESQUITE, NV 890276276

WOODS CHARLES HALE &
VERA MAE
910 OLD MILL
MESQUITE, NV 890274119

Z M H DEVELOPMENT INC
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IASI BRUNO 1983 TRUST
.O. BOX 550
ESQUITE, NV 890240550

BIASI BRUNO 1983 TRUST
P.O. BOX 550
MESQUITE, NV 890240550

BIASI BRUNO 1983 TRUST
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ESQUITE , NV 890240550

BIASI BRUNO 1983 TRUST
P.O. BOX 550
MESQUITE, NV 890240550

BUNKER FARM INC
P.O. BOX 7150
BUNKERVILLE, NV 890070150

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.O. BOX 7150
UNKERVILLE, NV 890070150

BUNKER FARM INC
P.O. BOX 7150
BUNKERVILLE, NV 890070150

BUNKER FARM INC
P.O. BOX 7150
BUNKERVILLE, NV 890070150

UNKER ROBERT & JOCELYN
.O. BOX 7425
UNKERVILLE, NV 890070425

BUNKER ROGER M FAMILY
L P III
P.O. BOX 7149
BUNKERVILLE, NV 890070149

BUNKER ROGER M FAMILY
L P III
P.O. BOX 7149
BUNKERVILLE, NV 890070149

EDAR DEV CORP
.O. BOX 130
EDAR CITY, UT 847210130

CEDAR DEV CORP
P.O. BOX 130
CEDAR CITY, UT 847210130

EDAR DEV CORP
P.O. BOX 130
CEDAR CITY, UT 847210130

EDAR DEV CORP
.O. BOX 130
EDAR CITY, UT 847210130

CEDAR DEVELOPMENT
CORPORATION
P.O. BOX 130
CEDAR CITY, UT 847210130

CROWTHER GLENN W &
A CLAIRE
P.O. BOX 357
MESQUITE, NV 890240357

ARDUNG LAVENE H
976 TRUST
.O. BOX 369
ESQUITE, NV 890240369

HARDUNG LAVENE H
1976 TRUST
P.O. BOX 369
MESQUITE, NV 890240369

HARDUNG LAVENE H
1976 TRUST
P.O. BOX 369
MESQUITE, NV 890240369

ARTLEY BETTY J TRUST
.O. BOX 1020
ESQUITE, NV 890241020

HARTLEY BETTY J TRUST
P.O. BOX 1020
MESQUITE, NV 890241020

HARTLEY BETTY J TRUST
P.O. BOX 1020
MESQUITE, NV 890241020

EAVITT DANNIE ROLAN &
HARON
.O. BOX 7073
UNKERVILLE, NV 890070073

LEAVITT THOMAS D SR EST
P.O. BOX 130
CEDAR CITY, UT 847210130

MITCHELL JOHN M
P.O. BOX 1446
MESQUITE, NV 890241446

OUNTAIN VIEW ESTS
OWNERS ASSN
.O. BOX 1807
ESQUITE, NV 890241807

PRATHER TIMOTHY M & JUDY
P.O. BOX 68
MCHENRY, MD 215410068

PUTMAN EDDY W & LUZ E
P.O. BOX 3366
MESQUITE, NV 890243366

& R FAM PROPERTIES L L C
.O. BOX 7149
UNKERVILLE, NV 890070149

RAYNOR LIVING TRUST
P.O. BOX 87
MESQUITE, NV 890240087

REID BUNKERVILLE TRUST
P.O. BOX 446
MESQUITE, NV 890240446

EID BUNKERVILLE TRUST
.O. BOX 446
IESQUITE, NV 890240446

TANNER EVAN O & LEONA
P.O. BOX 7234
BUNKERVILLE, NV 890070234

WELFARE FARM TRUST
P.O. BOX 446
MESQUITE, NV 890240446

VOODS CHARLES VAL &
AROL JOY
O. BOX 116
IESQUITE, NV 890240116

ZUCCARELLI LILLIAN K EST
P.O. BOX 247
HOPEWELL, NJ 85250247

10.020 Areas of Special Flood Hazard

The areas of special flood hazard within the District are those areas identified by the Federal Insurance Administration, through the Federal Emergency Management Agency, in the report entitled:

- The Flood Insurance Study for the Clark County and incorporated Areas, September 27, 2002 and subsequent amendments and revisions.

The study is accompanied by Flood Insurance Rate Map(s) (FIRM). Each is hereby adopted by reference and declared to be a part of these Regulations. These studies and maps shall be superseded by more current information as it becomes available. Flood insurance studies and rate maps are on file at the offices of the Local Administrators, (see 10.080.A).

The areas of special flood hazard, identified in the above listed studies and FIRMs, means the land within the flood plain that is subject to a one percent (1%) or greater chance of flooding in any given year and are identified as Zones A, AO, AH, A1-A30, AE, or A99.

These areas may be further defined as Floodway and Floodway Fringe. The Floodway Fringe may include areas of shallow flooding. In general, the following apply:

A. Floodway: Within areas of special flood hazard (established in Section 10.020) are areas designated as Floodways. Identification of the Floodway creates and preserves areas which are reasonably required to carry the flood flow. The Floodway is designed to restrict encroachments to the extent permitted in paragraph 2 below. Encroachments include but are not limited to fill, new construction, substantial improvements, and other development that would unduly affect the capacity of the Floodway or unduly increase flood heights. Since the Floodway is an extremely hazardous area due to the velocity of floodwaters which carry debris, potential projectiles, and erosion potential, the following provisions apply:

   1. Uses Allowed: Uses having a low flood damage potential may be allowed to the extent that they are not prohibited by other regulation, code, or ordinance; provided, that they do not require permanent structures, fill or other obstruction to the flow of flood water in the Floodway and provided that they do not adversely affect the capacity of the channels or Floodways of any tributary to the main system, drainage ditch, or any other drainage facility or system. These uses may be allowed only upon application to the Entity and the Chief Engineer and issuance of a Floodplain Use Permit by the Entity. Permits for these uses do not preclude the appropriate requirements for flood insurance. Allowed uses may include:

      a. Nonstructural agricultural uses.

D'Alessandro, Michele

From: Robert Thompson [rbt@co.clark.nv.us]
Sent: Wednesday, July 19, 2006 8:59 AM
To: Kevin Eubanks; Mark Delorey
Cc: Simmons, Eric; Baird, Matt; Allen Bell
Subject: RE: Virgin River PMR

I concur with Kevin's statements.

From: Kevin Eubanks [mailto:KEubanks@ccrfcd.org]
Sent: Wednesday, July 19, 2006 8:33 AM
To: Mark Delorey
Cc: Simmons, Eric; Baird, Matt; Allen Bell; Robert Thompson
Subject: Virgin River PMR

Mr. Delorey,

I received the 316-AD letter fro this project dated July 12, 2006. I have briefly reviewed the comments and will work with my consultant to respond with the additional data requested.

With regard to item #1 under Regulatory Comments:

- I will be sending in another e-mail copies of individual notices sent to all property owners affected by this proposed map change. Using our GIS system we were able to develop a mailing list for properties expected to experience an increase in flood plain area, a decrease in flood plain area and those which will be within the 500 year flood plain. Letters to those expected to experience an increase in flood plain area were sent out certified mail. I have those receipts on file should you need to see them. Information regarding the flood mapping study was presented to the Bunkerville Town Advisory Board on June 1, 2006 and again at a public open house in the City of Mesquite on June 5, 2006.
- The flood plain ordinances adopted by Clark County and the City of Mesquite are the same as the Uniform Regulations for the control of drainage incorporated in their individual municipal codes. Incorporation of the regulations in this manner is a condition of participation in the Regional Flood Control District. The attached section of the Uniform Regulations indicates that the entity enforces the effective Flood Insurance Study and Flood Insurance rate Maps and all amendments. Therefore, the City of Mesquite and Clark county are bound to enforce the proposed floodway once made effective by FEMA.
- Allen Bell with the City of Mesquite and Robert Thompson with Clark County have been copied on this e-mail. Their concurrence with the statements above by affirmative reply to this e-mail will further support these statements on their communities behalf.

I hope this adequately addresses this comment. If you need further information to address this item, please let me know. Additional information addressing other items will follow shortly.

Thank you.

Kevin Eubanks, P.E., CFM
Assistant General Manager
Clark County Regional Flood Control District
600 Grand Central Parkway
Las Vegas, Nevada 89106-4511
702.455.3139
KEubanks@ccrfcd.org
Website: www.ccrfcd.org

D'Alessandro, Michele

From: Allen Bell [abell@ci.mesquite.nv.us]
Sent: Thursday, July 27, 2006 4:41 PM
To: Kevin Eubanks; Mark Delorey
Cc: Robert Thompson; Eric Simmons; Baird, Matt
Subject: Re: Virgin River PMR

I concur with Kevin's comments.

Allen Bell, P.E.
City Engineer
Director of Economic Development
and Engineering
City of Mesquite
10 East Mesquite Blvd.
Mesquite, NV 89027
abell@ci.mesquite.nv.us
Ph:702-346-5295
Fx: 702-346-2795
http://www.mesquitenv.com/

>>> "Kevin Eubanks" <KEubanks@ccrfcd.org> 7/19/2006 8:33 am >>>
Mr. Delorey,

I received the 316-AD letter fro this project dated July 12, 2006. I have briefly reviewed the comments and will work with my consultant to respond with the additional data requested.

With regard to item #1 under Regulatory Comments:

* I will be sending in another e-mail copies of individual notices sent to all property owners affected by this proposed map change. Using our GIS system we were able to develop a mailing list for properties expected to experience an increase in flood plain area, a decrease in flood plain area and those which will be within the 500 year flood plain. Letters to those expected to experience an increase in flood plain area were sent out certified mail. I have those receipts on file should you need to see them. Information regarding the flood mapping study was presented to the Bunkerville Town Advisory Board on June 1, 2006 and again at a public open house in the City of Mesquite on June 5, 2006.

* The flood plain ordinances adopted by Clark County and the City of Mesquite are the same as the Uniform Regulations for the control of drainage incorporated in their individual municipal codes. Incorporation of the regulations in this manner is a condition of participation in the Regional Flood Control District. The attached section of the Uniform Regulations indicates that the entity enforces the effective Flood Insurance Study and Flood Insurance rate Maps and all amendments. Therefore, the City of Mesquite and Clark county are bound to enforce the proposed floodway once made effective by FEMA.

* Allen Bell with the City of Mesquite and Robert Thompson with Clark County have been copied on this e-mail. Their concurrence with the statements above by affirmative reply to this e-mail will further

support these statements on their communities behalf.

I hope this adequately addresses this comment. If you need further information to address this item, please let me know. Additional information addressing other items will follow shortly.

Thank you.

Kevin Eubanks, P.E., CFM
Assistant General Manager
Clark County Regional Flood Control District
600 Grand Central Parkway
Las Vegas, Nevada 89106-4511
702.455.3139
KEubanks@ccrfcd.org
Website: www.ccrfcd.org

Appendix C-1: Effective Work Map, Sheet 5 (Bulloch, 96)

CALCULATED FLOODWAY LIMIT
SECTION 34
SECTION 35
1580
1600
1580
1600
1600
1600
1580
1600

DATE	DATE
DRAWN	CHECKED

SCALE 1" = 100'

CONTOUR INTERVAL 2'
PHOTOGRAPHY DATE SEPT 9 1992

MESQUITE CITY
FLOOD STUDY
EXHIBIT A - VIRGIN RIVER

City of Mesquite
Nevada

BULLOCH BROS. ENGINEERING INC.
ENGINEERS - LAND SURVEYORS - LAND PLANNERS

36 NORTH 300 WEST
CEDAR CITY, UTAH 84720
P.O. BOX 1405 (801) 586-9592

BOX 925
MESQUITE, NEV 89024
(702) 346-5101

2 WEST ST. GEORGE BLVD
ST. GEORGE, UTAH 84770
(801) 628-4700

NO.	DATE	REVISION	BY
1	1-24-95	1st REVIEW COMMENTS	GEP
2	5-1-95	CORPS COMMENTS	GEP
3	2-5-96	FEMA COMMENTS	GEP

	4	2
6	5	3
7		

SHEET INDEX

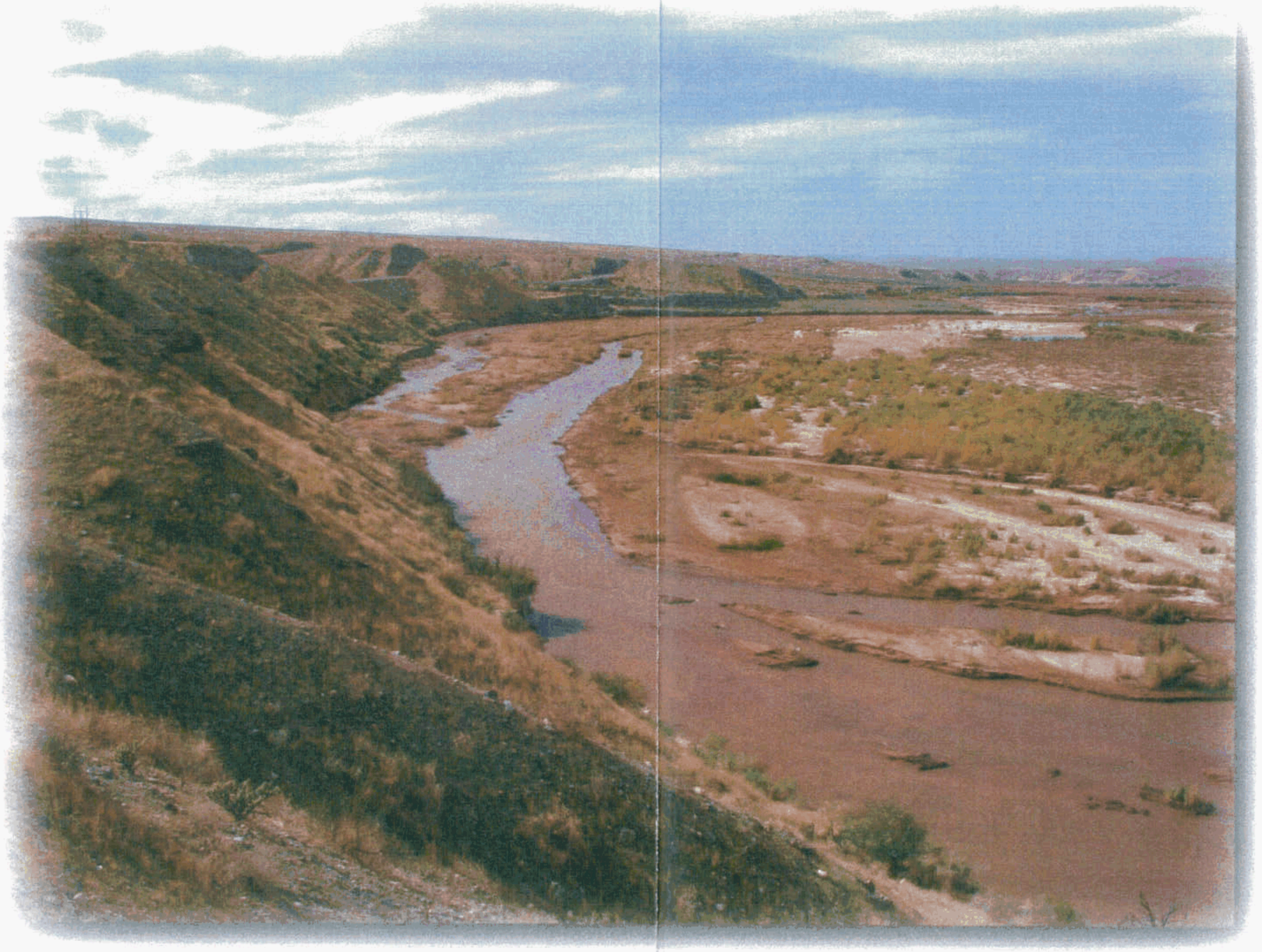
SHEET NO.
5

FILE NO.

Appendix C-2: Historical Aerial Photo Exhibit Book (Fuller, 06)

Virgin River Flood Study

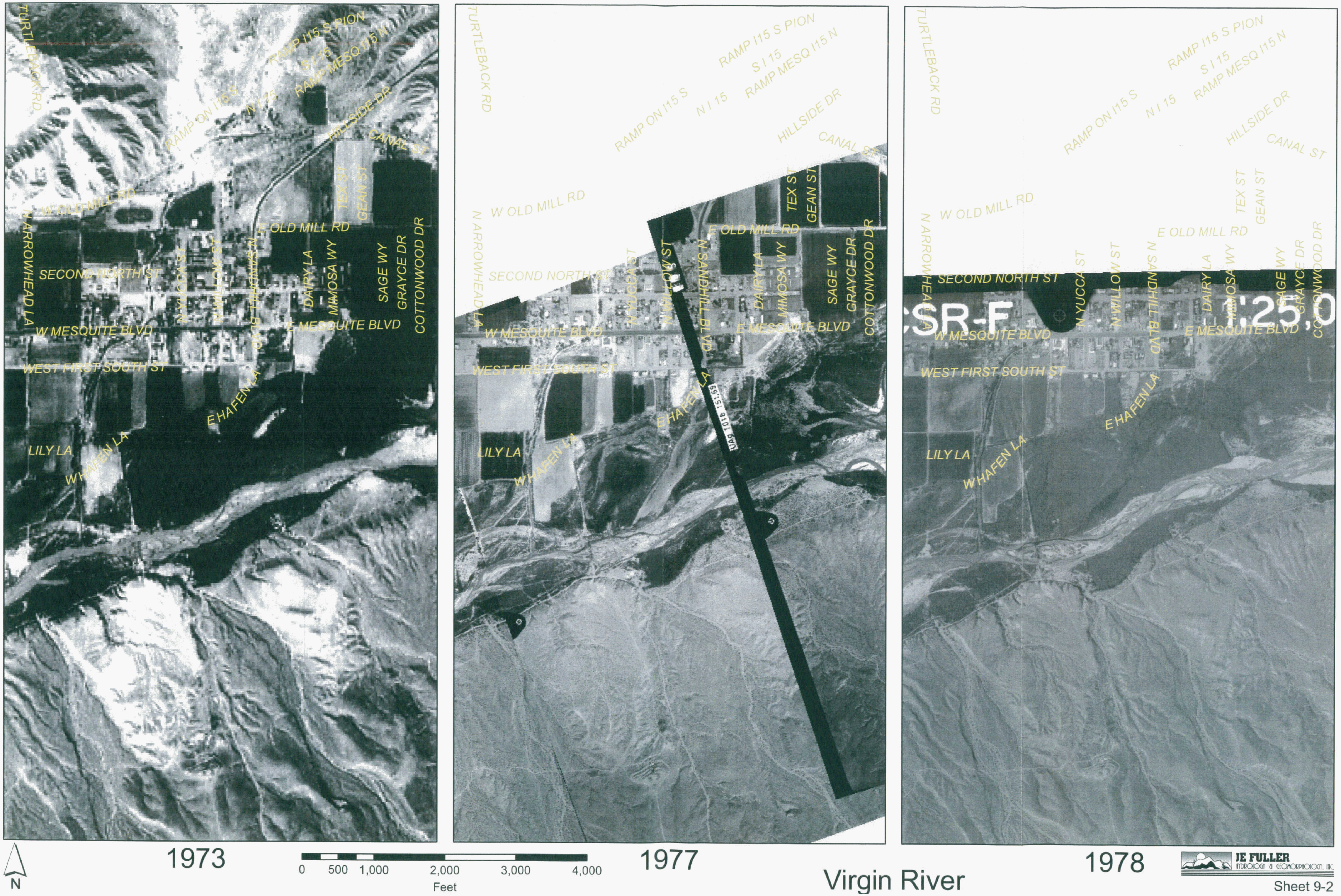
Geomorphic Analysis Report



Historical Aerial Photo Exhibit Book

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
www.jefuller.com

February 2006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S I 15
RAMP MESQ I15 N
RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
WHAFEN LA
N
0
500
1,000
2,000
3,000
4,000
Feet

1973

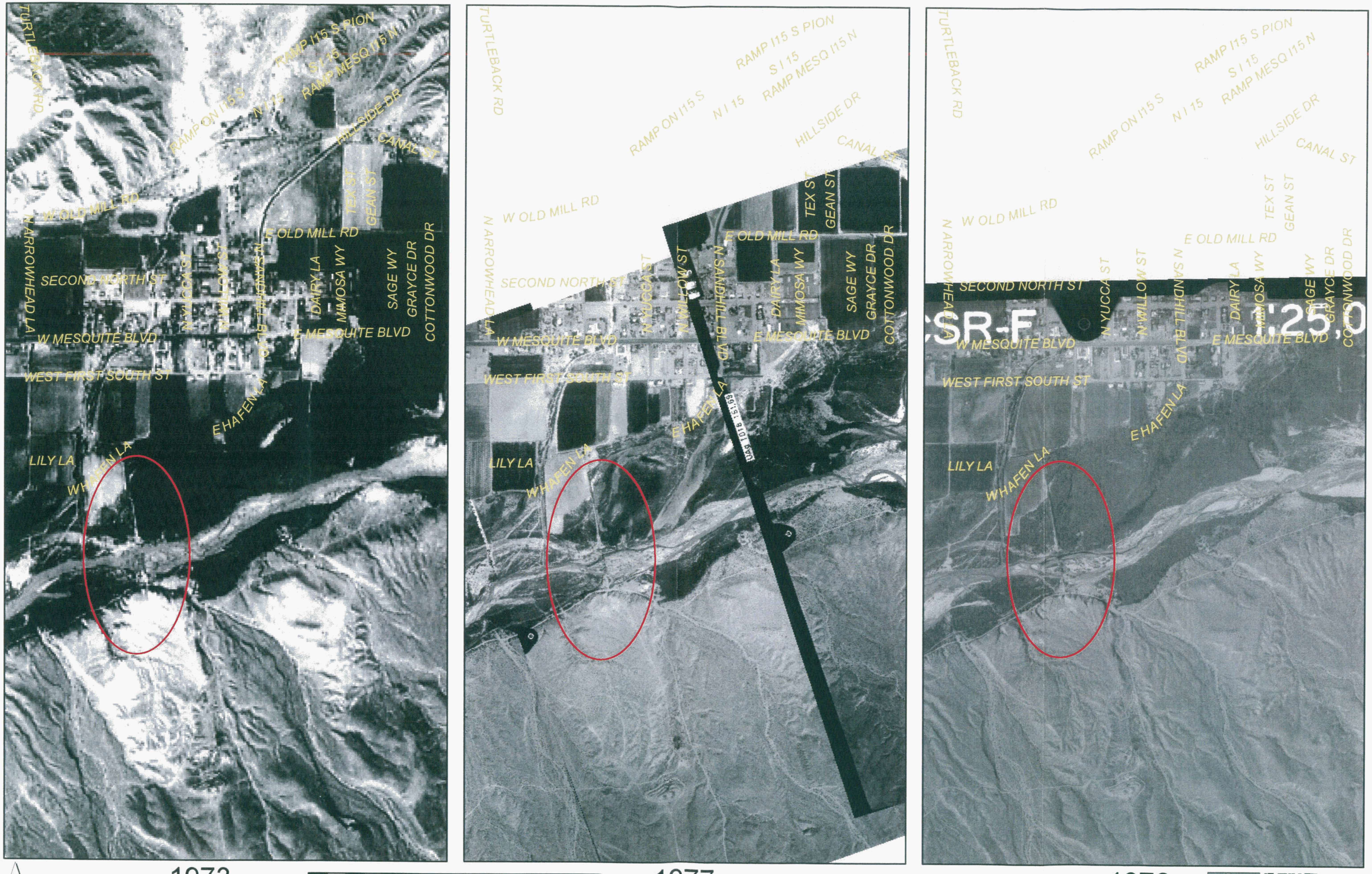
1977

1978

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-2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TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
WHAFEN LA
UAG 1018 151.69
CSR-F
1:25,0

1973

1977

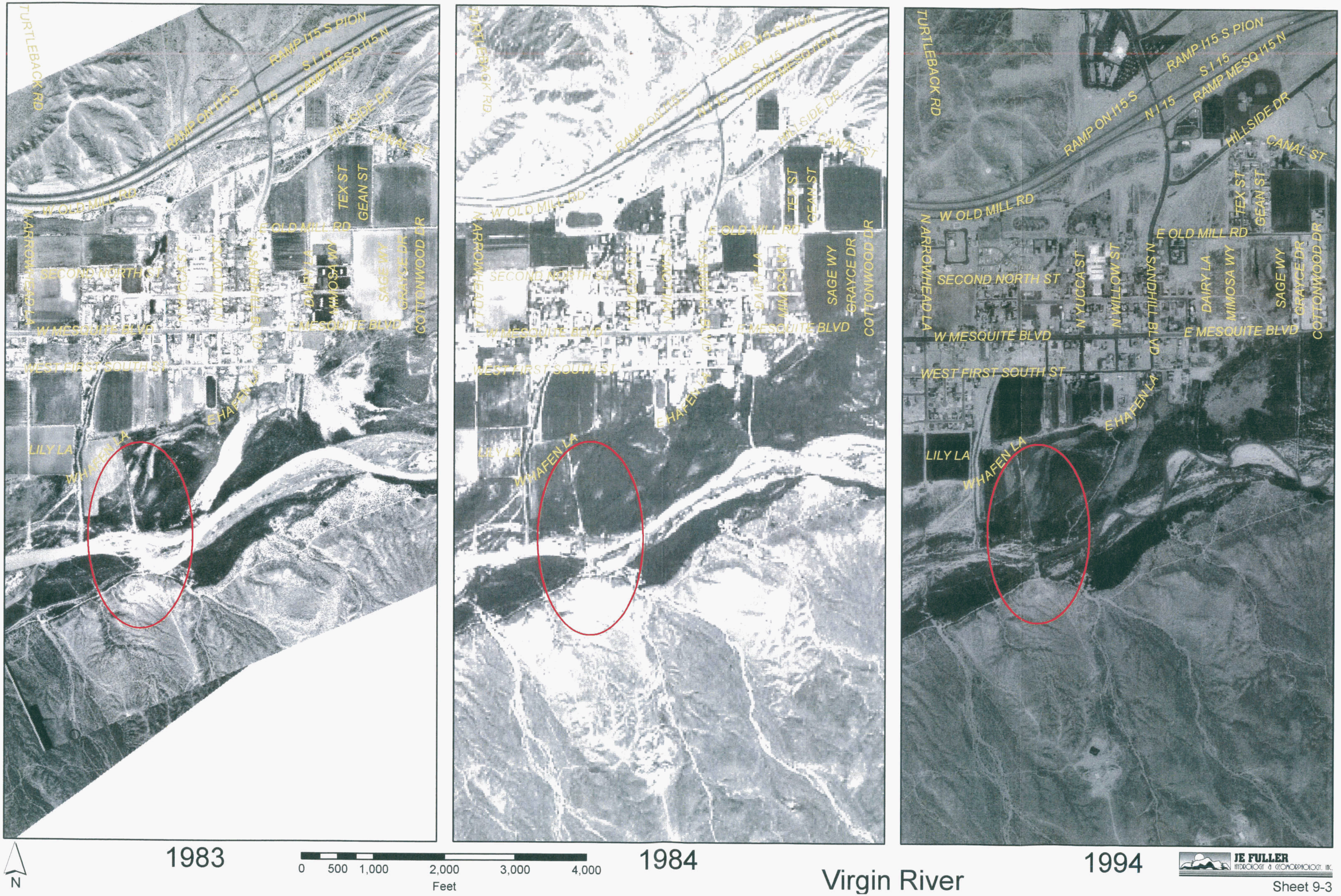
1978

N
0
500
1,000
2,000
3,000
4,000
Feet

Virgin River

JE FULLER
Hydrology & Geomorphology, Inc.

Sheet 9-2



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TEX ST
GEAN ST
W OLD MILL RD
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
W HAFEN LA
LILY LA
0
500
1,000
2,000
3,000
4,000
Feet
N

1983

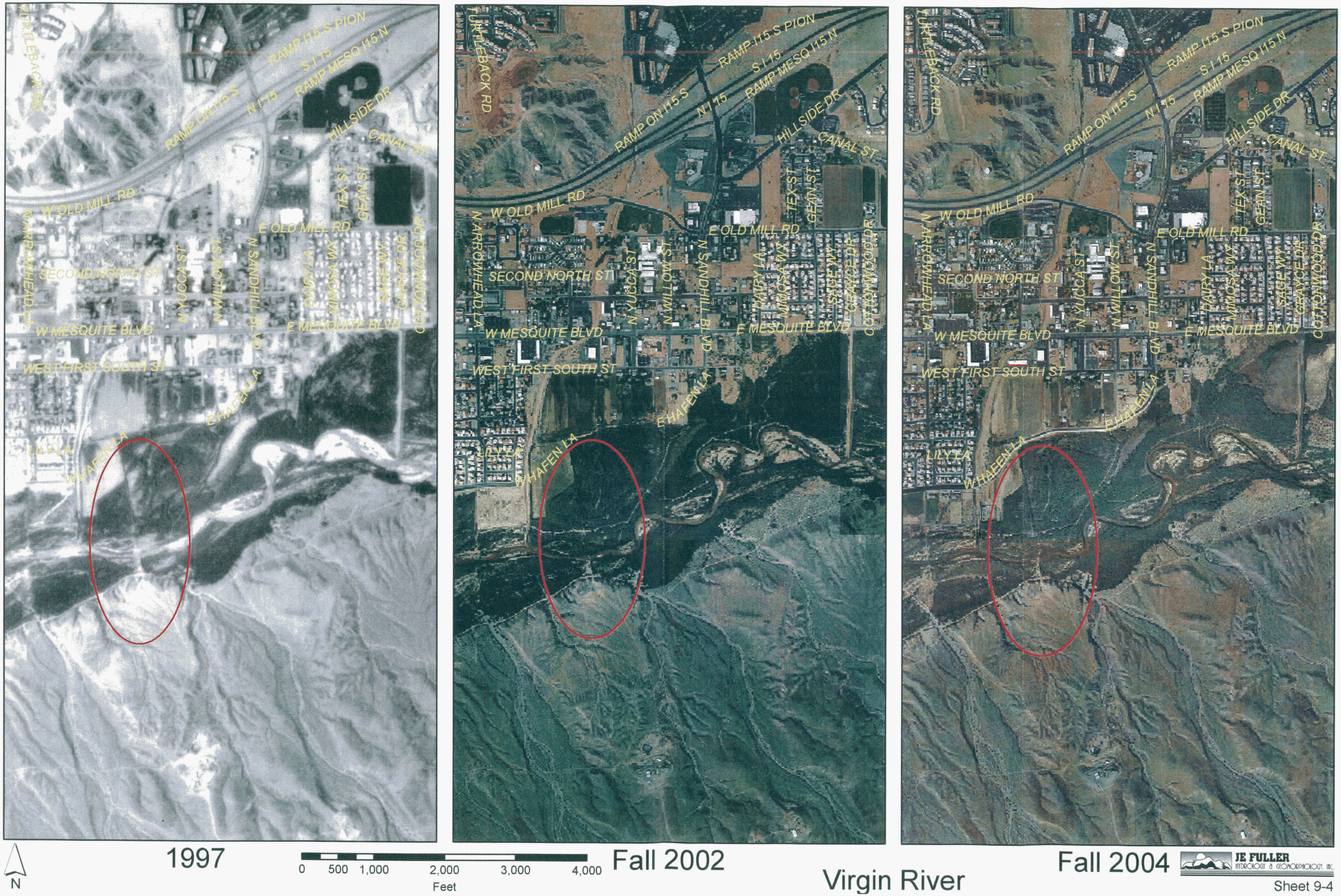
1984

1994

Virgin River

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-3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HILLSIDE DR
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TEX ST
GEAN ST
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
CEAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
W HAFEN LA
LILY LA
N
0
500
1,000
2,000
3,000
4,000
Feet

1997

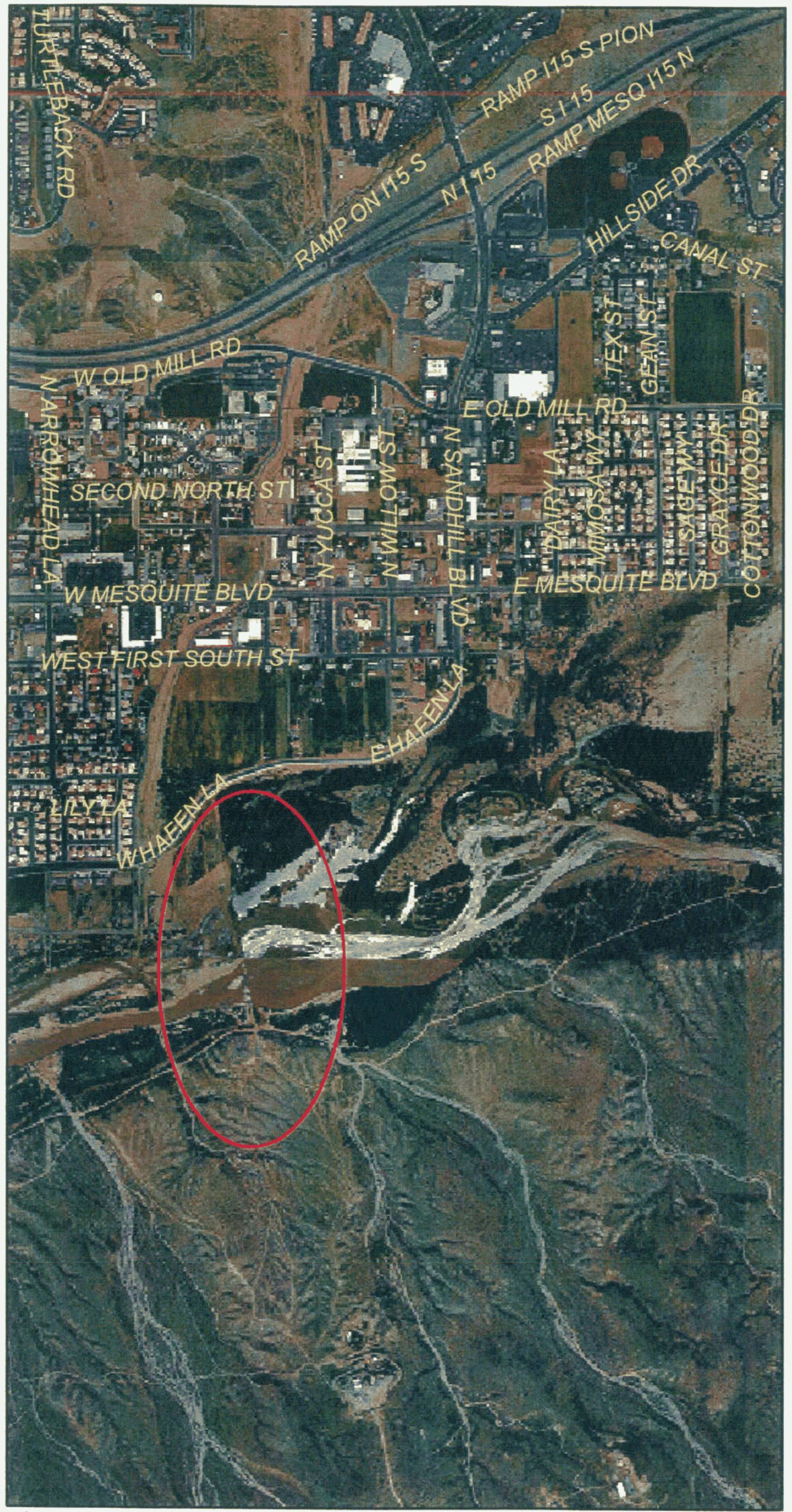
Fall 2002

Fall 2004

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-4



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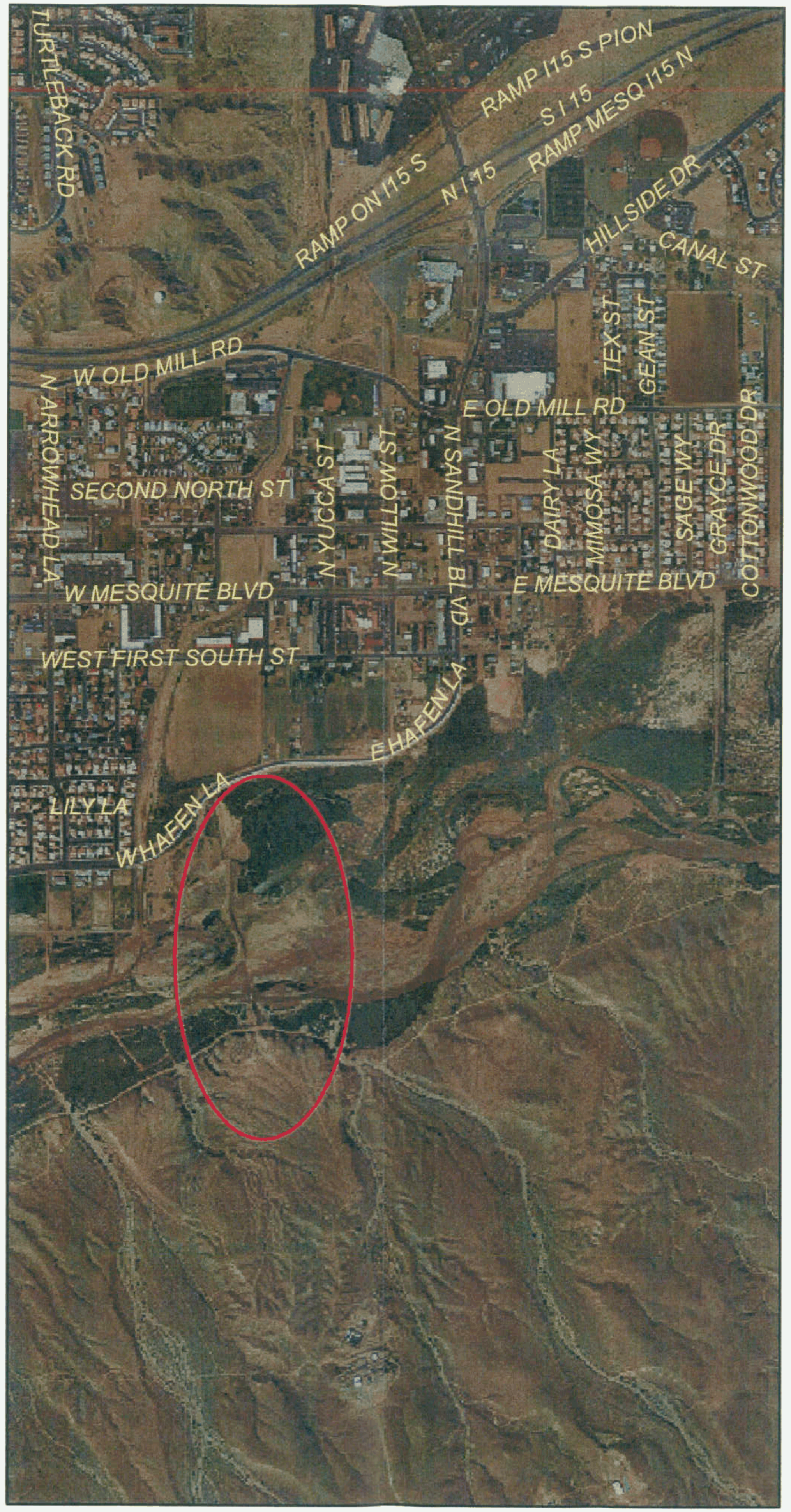
RAMP MESQ I15 N
RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
W OLD MILL RD
TEX ST
GEAN ST
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

Spring 2005



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RAMP ON I15 S
N I 15
HILLSIDE DR
CANAL ST
W OLD MILL RD
TEX ST
GEAN ST
E OLD MILL RD
N ARROWHEAD LA
SECOND NORTH ST
N YUCCA ST
N WILLOW ST
N SANDHILL BLVD
DAIRY LA
MIMOSA WY
SAGE WY
GRAYCE DR
COTTONWOOD DR
W MESQUITE BLVD
E MESQUITE BLVD
WEST FIRST SOUTH ST
E HAFEN LA
LILY LA
W HAFEN LA

Fall 2005

N

0 500 1,000 2,000 3,000 4,000

Feet

Virgin River

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Sheet 9-5

APPENDIX D

D'Alessandro, Michele

From: Desai, Harshal
Sent: Monday, July 24, 2006 9:13 AM
To: D'Alessandro, Michele
Subject: FW: Virgin River PMR

Harshal Desai, P.E., CFM
Associate Project Manager
PBSJ
702-263-7275 EXT. 3047
Fax: 702-263-7200
hdesai@pbsj.com

From: Baird, Matt
Sent: Monday, July 24, 2006 9:05 AM
To: Desai, Harshal
Subject: FW: Virgin River PMR

FYI

Matt Baird, P.E., CFM
Associate Vice President
Water Resources
PBS&J
mbaird@pbsj.com
Office:(702)263-7275
Cell: (702)528-0982
Fax: (702)263-7200

From: Kevin Eubanks [mailto:KEubanks@ccrfcd.org]
Sent: Monday, July 24, 2006 9:02 AM
To: Mark Delorey
Cc: Simmons, Eric; Baird, Matt
Subject: Virgin River PMR

Mark,

Thanks for taking the time to go over the comments offered in the 316-AD letter dated July 12, 2006. All of the comments are straight forward and we are proceeding with development of a response. The only one that I had any question on was Hydrology Comment #1. I would like to avoid providing models of the 10-yr and 50-yr flows in the corrected effective HEC-RAS model. My consultant tells me, and I believe, that this effort would be more extensive ($$$) than it might sound. The complexities involved with balancing the overflow modeling at the upstream end and correcting ineffective flow boundaries for each flow rate make this effort rather involved. If there is no value added by performing this analysis, I would like to avoid the time and expense. If it is something that we just must do according to regulations and FEMA standard practice, then so be it, we will get it done. As I understand after our discussion, you will be running this by Eric for final guidance.

Thanks again.

Kevin Eubanks, P.E., CFM
Assistant General Manager
Clark County Regional Flood Control District
600 Grand Central Parkway
Las Vegas, Nevada 89106-4511
702.455.3139
KEubanks@ccrfcd.org
Website: www.ccrfcd.org

APPENDIX E

Appendix E-1: 100-Year Corrected Effective Work Map

Appendix E-2: 500-Year Corrected Effective Work Map

Appendix E-3: Overall Annotated FEMA Maps

APPENDIX F

BB BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972
ARIZONA ★ NEVADA ★ UTAH

Date: April 30, 2007

City of Mesquite
10 East Mesquite Boulevard
Mesquite, Nevada 89027

Attention: Allen Bell, P.E., City Engineer

Regarding: FIS Appeal for Parcel No. 001-16-401-006

Dear Mr. Bell,

The Owners of Parcel No. 001-16-401-006, Charles & Ann Bentley, are appealing the flood plain boundary shown on the proposed FIS mapping prepared by PBS&J for the Regional Flood Control District. The map in question is Map Number 32003C3387F which shows a portion of their property, Parcel 001-16-401-006, to be located within the proposed 100 year floodplain. The appeal is based on fill dirt placed after the Aerial Topography was acquired. Exhibit A represents the floodplain limits through their property as mapped by PBS&J based on the Aerial Topography post 2005. Exhibit B represents the revised Floodplain limits adjacent to their property based on the additional fill dirt placed. Bulloch Brothers Engineering have modified the current Hec-Ras model completed by PBS&J to account for the revised grading on the subject parcel. The revised grading removes the subject parcel out of the proposed floodplain. The technical data submitted with the exhibits indicates insignificant or minor modifications to the water surface elevation up and downstream of the subject parcel. Two cross sections, -45A and -45B were added to model the upstream edge of the placed fill. Cross Section -46A is an interpolated section between Sections -46 and -47. The modified Hec-Ras model and Exhibits have been included on a CD.

If you have any questions regarding this appeal please contact our office at (702) 346-5100.

Sincerely,

Weston L. Nelson, P.E.
Bulloch Brothers Engineering, Inc.

WESTON L. NELSON
Exp. 12/31/07
CIVIL
No. 14044

CC: Kevin Eubanks, P.E., Clark County Regional Flood Control District
Charles and Ann Bentley, Property Owners.
Attch: Exhibits A & B

Bullhead City
P.O. Box 23066
Bullhead City, AZ 84639
928.415.0706
928.415.0463 Fax

Cedar City
P.O. Box 3174
Cedar City, UT 84721
435.586.9592
435.586.4995 Fax

Mesquite
750 W. Pioneer Blvd.
Mesquite, NV 89027
702.346.5100
702.346.5102 Fax

Park City
3100 W. Pinebrook Rd. Ste 1000
Park City, UT 84098
435.655.0956
435.655.0958 Fax

Pleasant Grove
1909 W. State Street, Ste 200
Pleasant Grove, UT 84062
801.763.8467
801.763.8472 Fax

BB BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972
ARIZONA ★ NEVADA ★ UTAH

Date: April 30, 2007

City of Mesquite
10 East Mesquite Boulevard
Mesquite, Nevada 89027

Attention: Allen Bell, P.E., City Engineer

Regarding: Completed Site Grading Regarding FIS Appeal for Parcel No. 001-16-401-006

Dear Mr. Bell,

The proposed FIS mapping completed by PBS&J for the Regional Flood Control District, which is currently in the appeal process per FEMA criteria, is based on the latest flood event that occurred in January of 2005. The aerial topography utilized for this study was flown shortly after the flood event and represents existing ground elevations following the flood event. In an effort to protect his property from a similar event, and to avoid going through the LOMR process as an individual property owner who owns a relatively small piece of property adjacent to the Virgin River, the owner of the subject parcel has imported fill and re-graded his property as shown on Exhibit B after the flood event. The Owner of the subject parcel has requested to appeal the proposed mapping based on the revised grading of his property. The following exhibit represents the grading completed and currently in place at the site. Please consider this document as certification to that effect.

If you have any further questions regarding this matter, please contact me at (702) 346-5100.

Sincerely,

Weston L. Nelson

Weston L. Nelson, P.E.
Bulloch Brothers Engineering, Inc.

PROFESSIONAL ENGINEER STATE OF NEVADA
WESTON L. NELSON
Exp. 12/31/07
CIVIL
No. 14044

5-1-07

CC: Kevin Eubanks, P.E., Assistant General Manager
Charles & Ann Bentley, Property Owners

Attch: Exhibits A & B

Bullhead City
P.O. Box 23066
Bullhead City, AZ 84639
928.415.0706
928.415.0463 Fax

Cedar City
P.O. Box 3174
Cedar City, UT 84721
435.586.9592
435.586.4995 Fax

Mesquite
750 W. Pioneer Blvd.
Mesquite, NV 89027
702.346.5100
702.346.5102 Fax

Park City
3100 W. Pinebrook Rd. Ste 1000
Park City, UT 84098
435.655.0956
435.655.0958 Fax

Pleasant Grove
1909 W. State Street, Ste 200
Pleasant Grove, UT 84062
801.763.8467
801.763.8472 Fax

RESULTS PER 100 YEAR FLOODPLAIN ESTABLISHED BY PBS&J FROM 2005 TOPO

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	-38	100 YR	39510	1570.10	1582.17	1576.25	1582.40	0.00155	7.30	14597.22	2062.41	0.38
3	-39	100 YR	39510	1570.36	1581.93	1575.39	1582.14	0.00135	6.70	14890.22	2060.13	0.36
3	-40	100 YR	39510	1570.61	1581.48	1575.25	1581.75	0.00237	8.55	12922.98	2043.35	0.47
3	-41	100 YR	39510	1570.02	1580.62	1575.50	1580.93	0.00257	8.85	12657.71	1863.85	0.49
3	-42	100 YR	39510	1569.81	1580.14	1574.02	1580.38	0.00247	8.70	12987.37	1966.52	0.48
3	-42.5		Inl Struct									
3	-44	100 YR	39510	1562.88	1576.34	1572.43	1577.04	0.00349	12.23	10089.44	1623.68	0.59
3	-45	100 YR	39510	1562.13	1576.35	1569.42	1576.68	0.00219	10.07	12178.09	1538.59	0.48
3	-46	100 YR	39510	1561.26	1574.95	1570.15	1575.68	0.00454	14.29	8746.35	1279.16	0.68
3	-47	100 YR	39510	1559.07	1573.59	1567.85	1574.30	0.00238	10.45	9457.20	1443.05	0.49
3	-48	100 YR	39510	1558.38	1572.31	1570.05	1573.53	0.00393	13.19	8150.36	1525.71	0.63
RESULTS PER 100 YEAR FLOODPLAIN WITH REVISED GRADING FOR 2007 APPEAL (PARCEL 001-16-401-006)												
3	-38	100 YR	39510	1570.10	1582.18	1576.25	1582.41	0.00155	7.30	14599.82	2062.55	0.38
3	-39	100 YR	39510	1570.36	1581.93	1575.39	1582.14	0.00135	6.70	14892.93	2060.33	0.36
3	-40	100 YR	39510	1570.61	1581.48	1575.25	1581.76	0.00236	8.55	12925.80	2043.45	0.47
3	-41	100 YR	39510	1570.02	1580.62	1575.50	1580.93	0.00257	8.85	12661.56	1863.88	0.49
3	-42	100 YR	39510	1569.81	1580.14	1574.02	1580.38	0.00247	8.70	12991.74	1966.59	0.48
3	-42.5		Inl Struct									
3	-44	100 YR	39510	1562.88	1576.47	1572.43	1577.15	0.00334	12.03	10233.69	1647.99	0.58
3	-45	100 YR	39510	1562.13	1576.48	1569.42	1576.80	0.00211	9.95	12313.27	1541.32	0.47
3 (45A)	-45.384*	100 YR	39510	1561.80	1576.12	1570.36	1576.51	0.00232	10.47	11115.43	1513.07	0.49
3 (45B)	-45.769*	100 YR	39510	1561.46	1575.09	1571.72	1576.08	0.00574	15.99	7570.18	833.64	0.77
3	-46	100 YR	39510	1561.26	1574.69	1570.44	1575.67	0.00597	16.18	7890.82	892.17	0.78
3 (46A)	-46.178*	100 YR	39510	1560.87	1574.61	1570.01	1575.26	0.00304	11.66	8610.30	933.22	0.56
3	-47	100 YR	39510	1559.07	1573.59	1567.85	1574.30	0.00238	10.45	9457.20	1443.05	0.49
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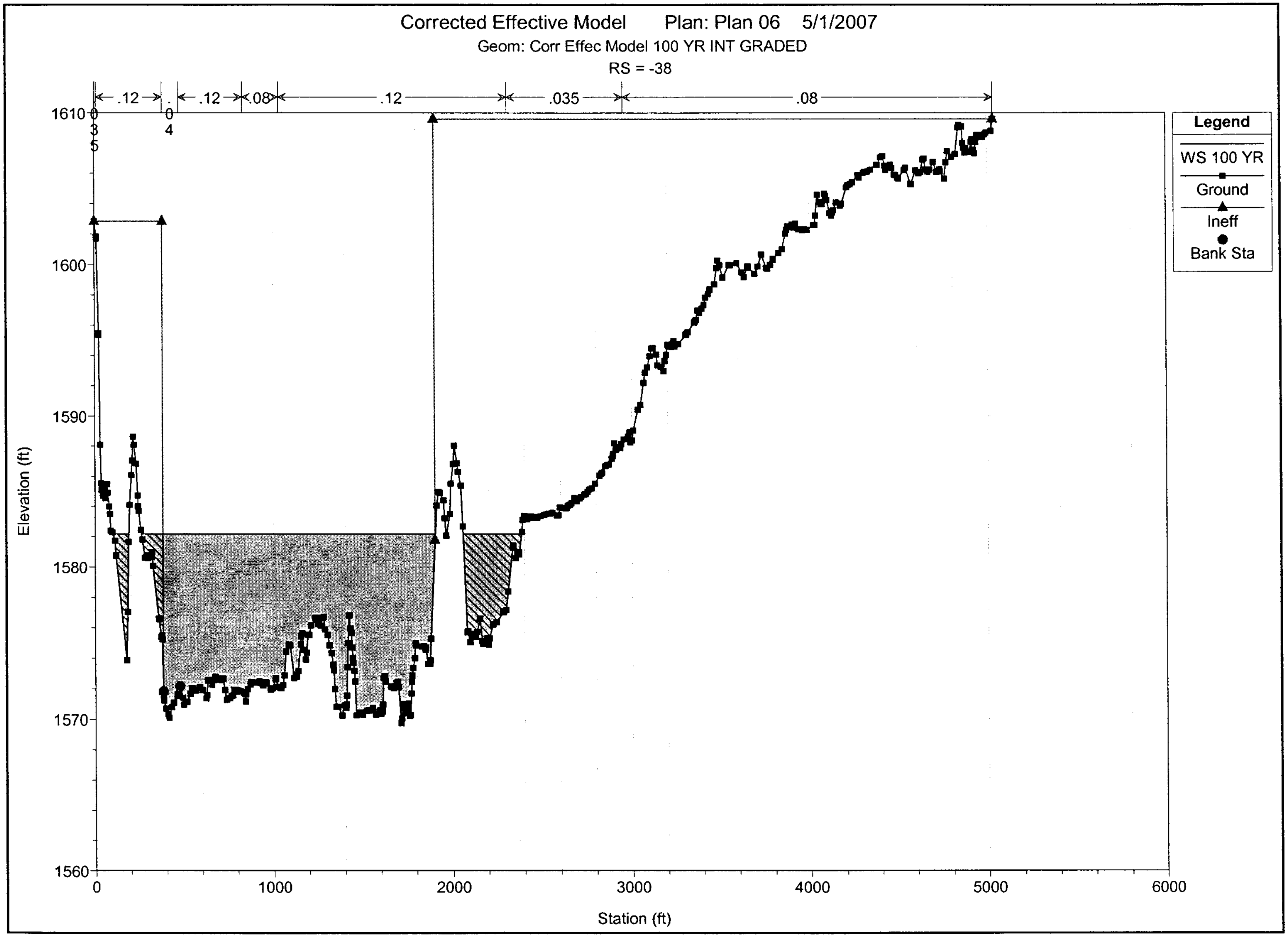
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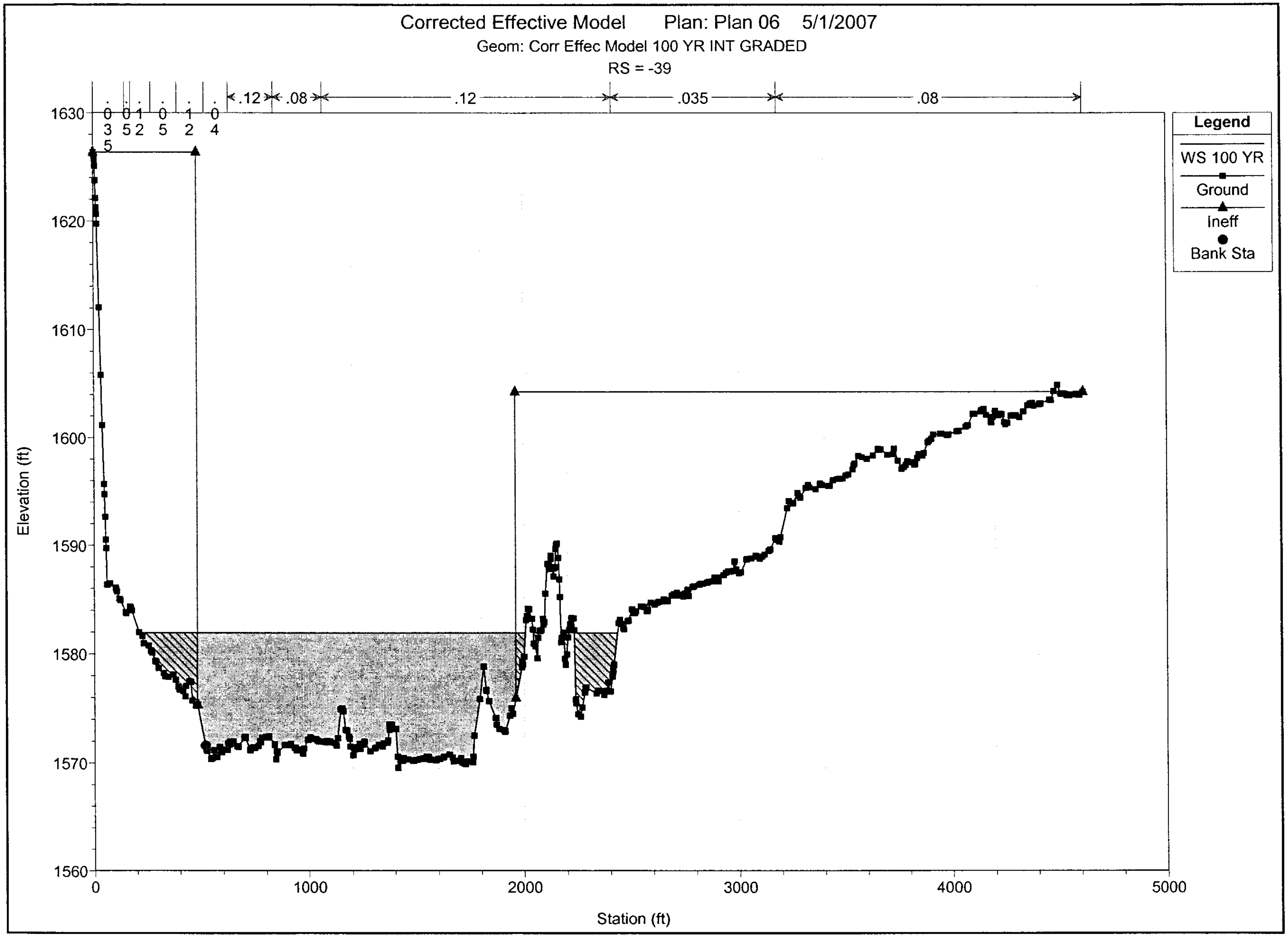
.12
.
.12
.08
.12
.035
.08
0
3
5
0
4
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
1610
1600
1590
1580
1570
1560
Station (ft)
0
1000
2000
3000
4000
5000
6000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.12
.08
.12
.035
.08
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
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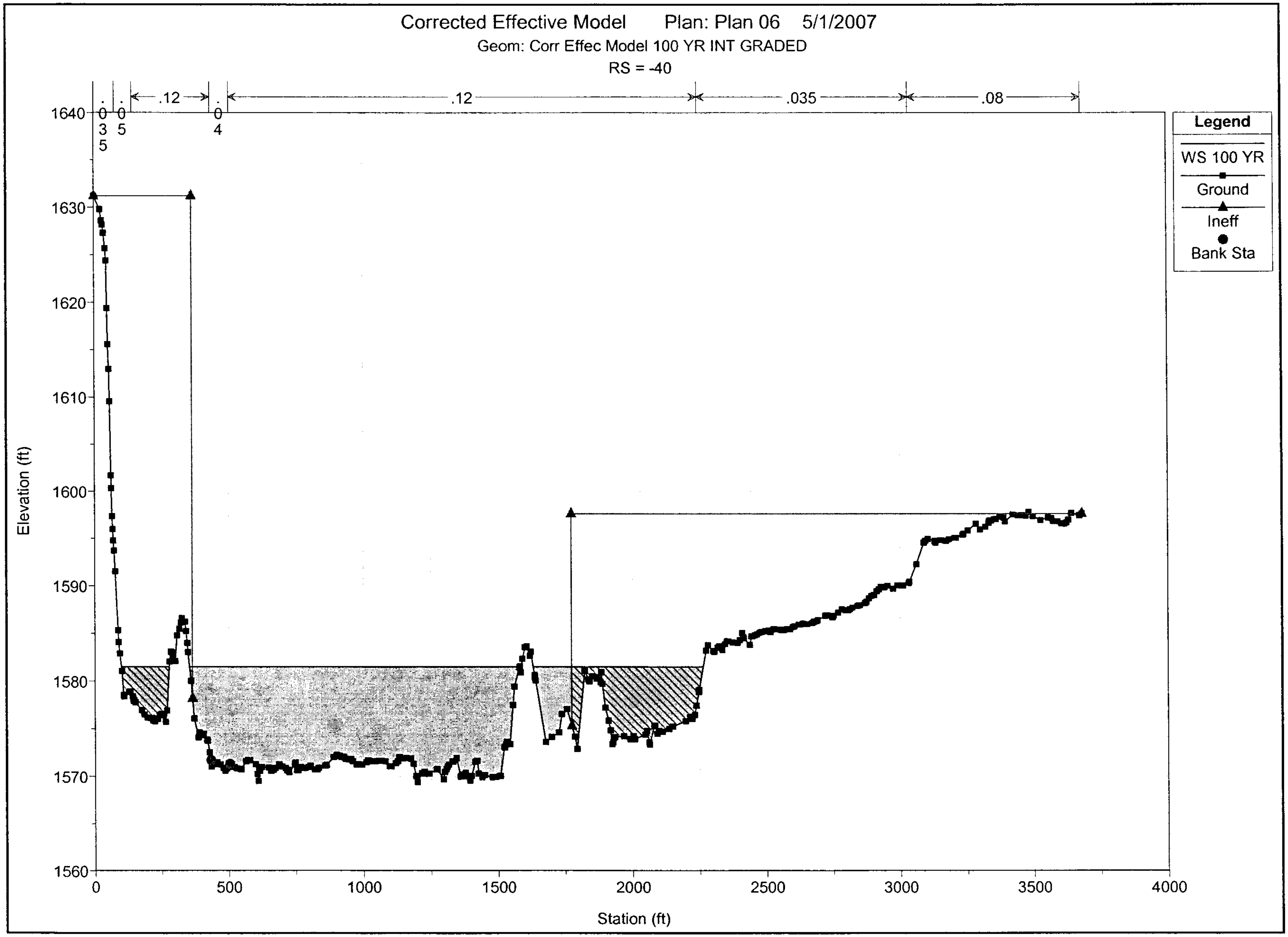
1570
1560
Station (ft)
0
1000
2000
3000
4000
5000



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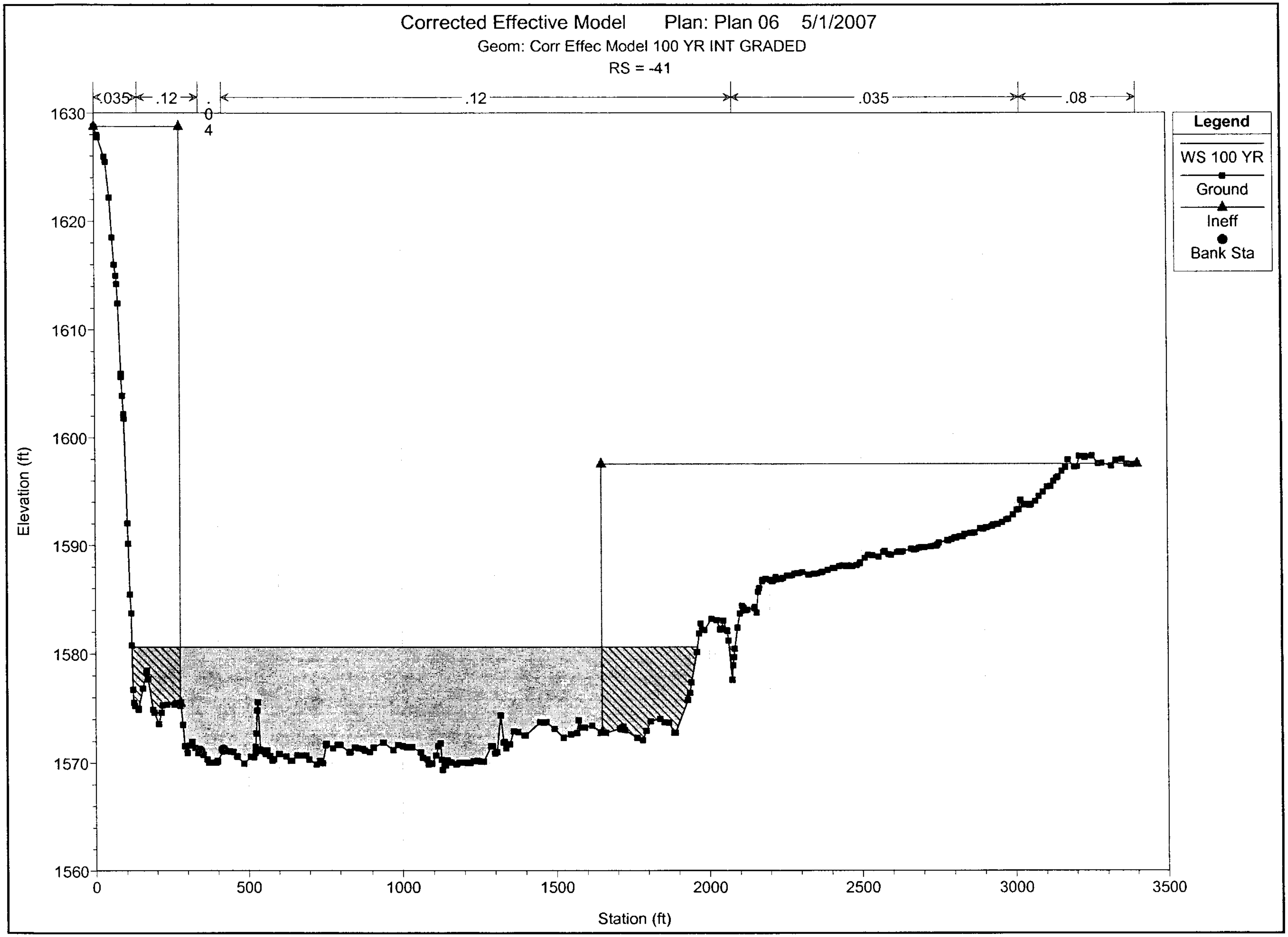
Geom: Corr Effec Model 100 YR INT GRADED

RS = -40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.035
.12
.
0
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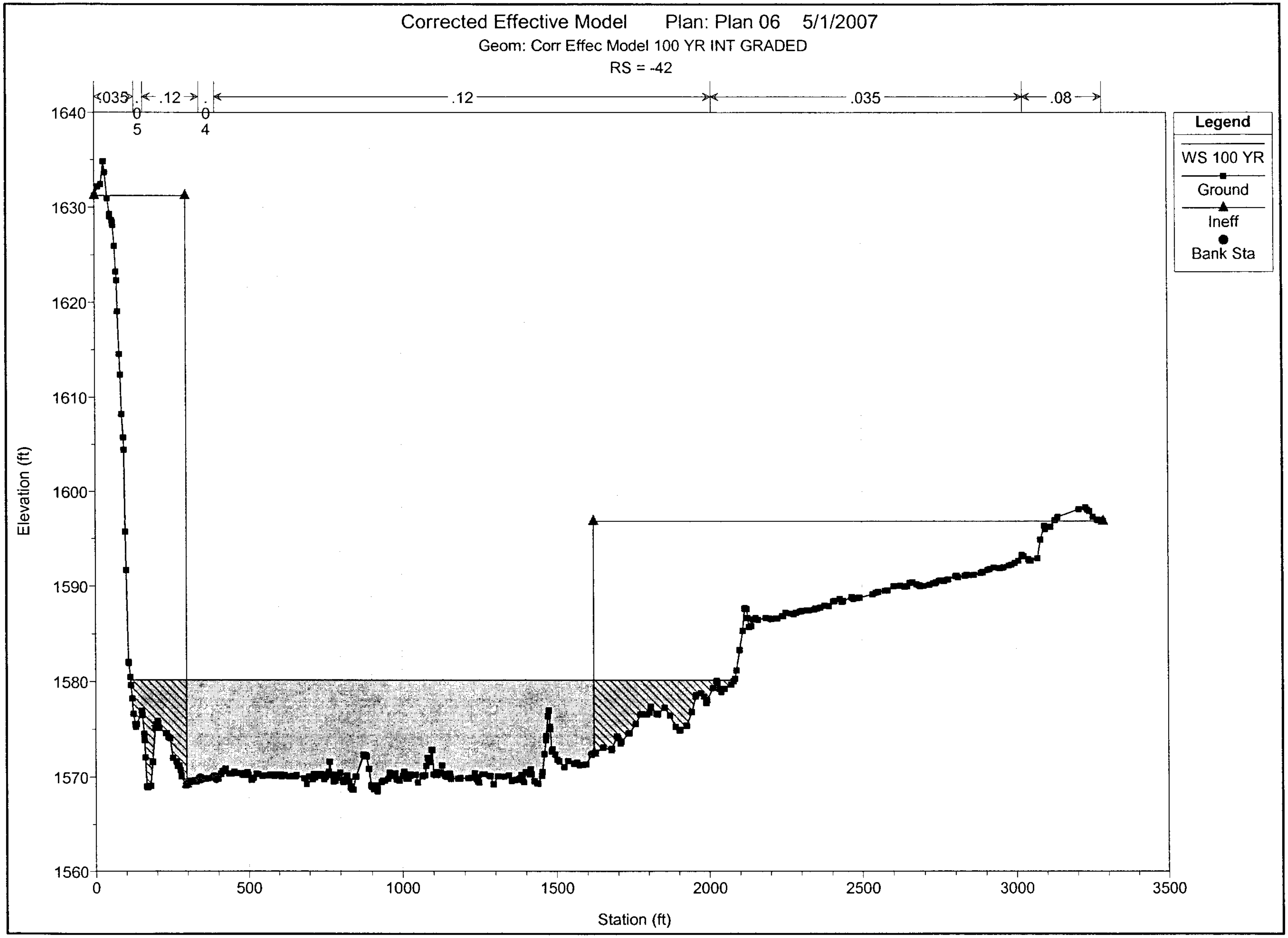
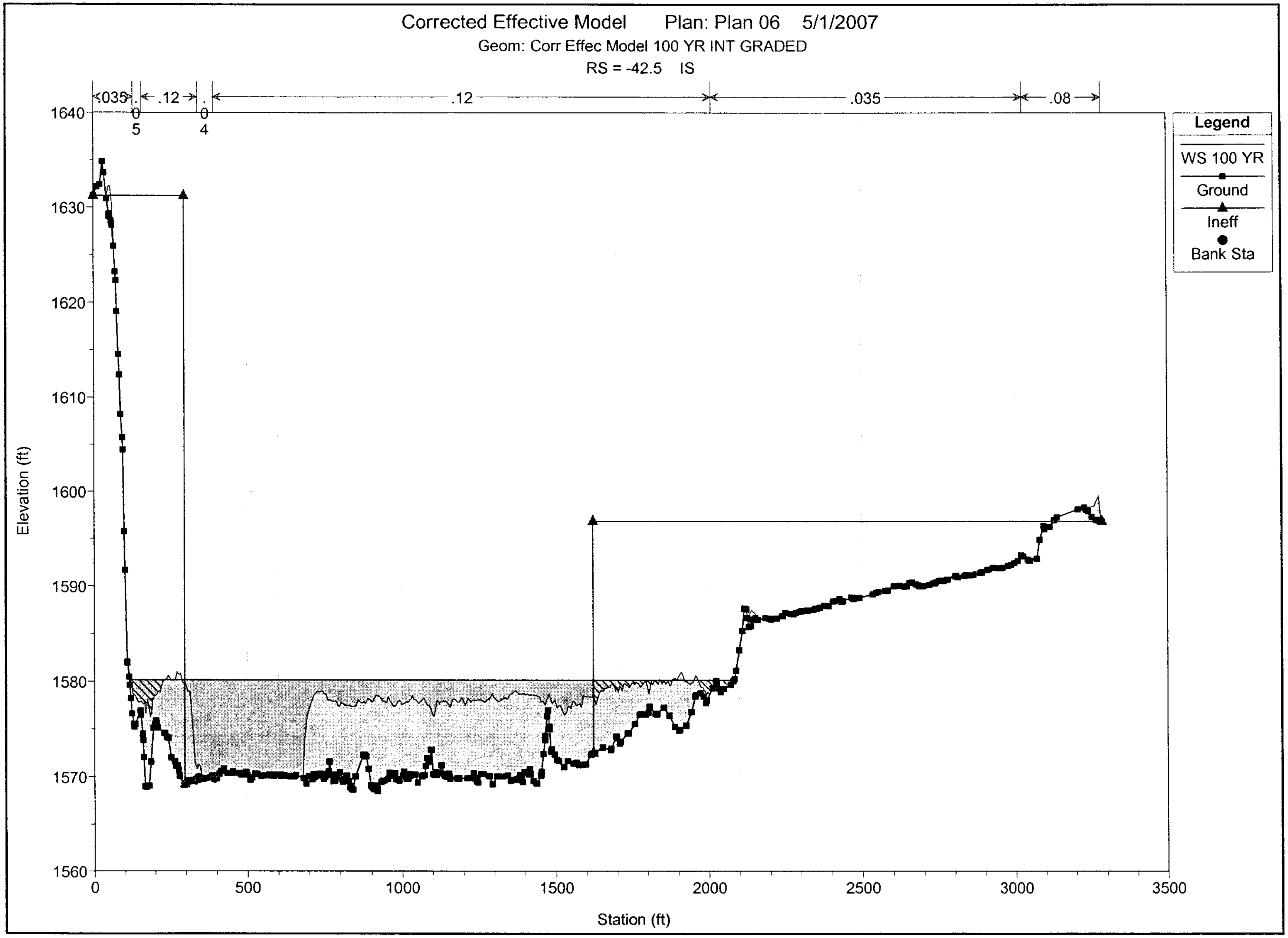
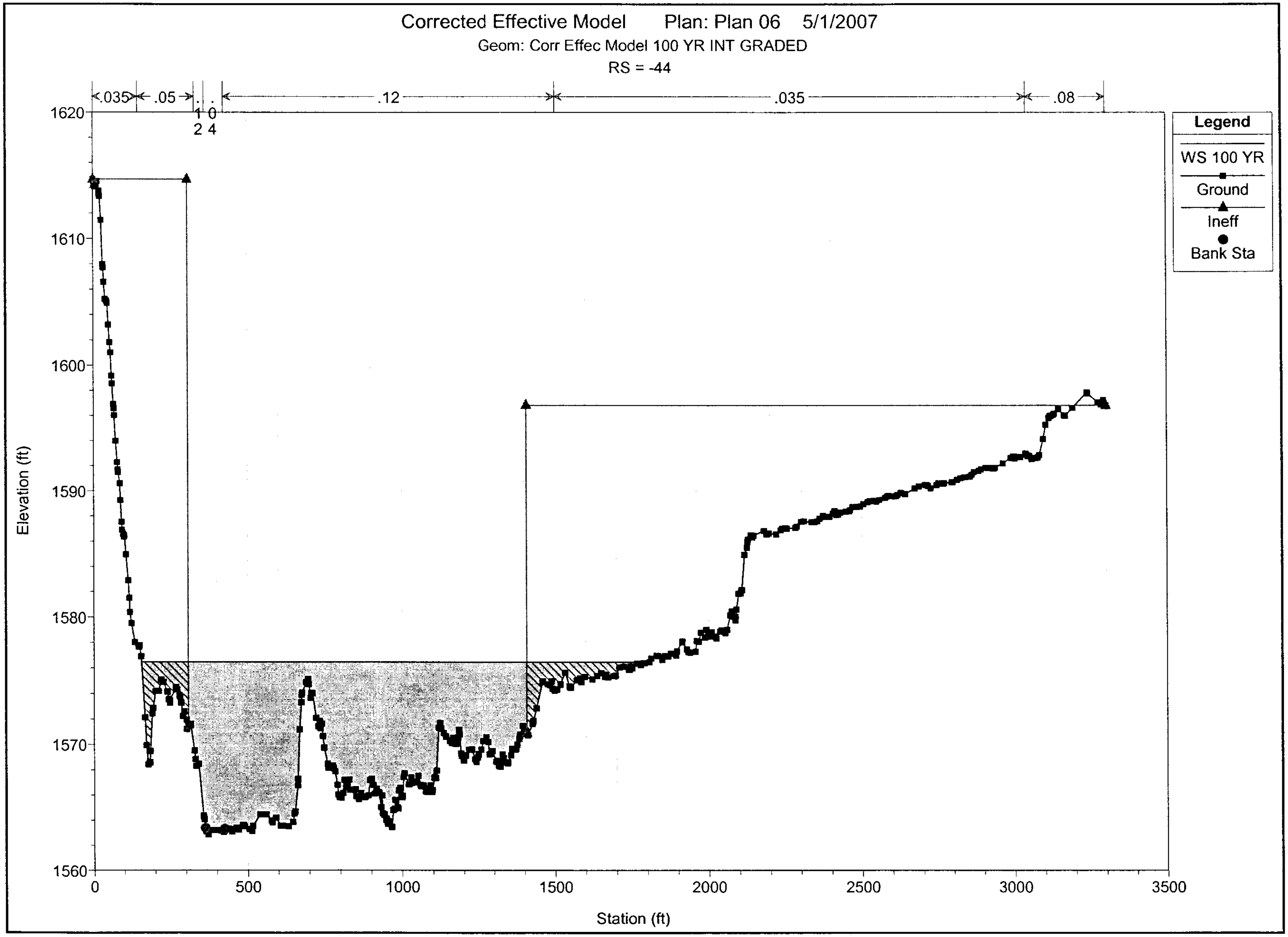
.12
.035
.08
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
1630
1620
1610
1600
1590
1580
1570
1560
Station (ft)
0
500
1000
1500
2000
2500
3000
3500


Corrected Effective Model Plan: Plan 06 5/1/2007
Geom: Corr Effec Model 100 YR INT GRADED
RS = -42
.035
.0
5
.12
.0
4
.12
.035
.08
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
1640
1630
1620
1610
1600
1590
1580
1570
1560
Station (ft)
0
500
1000
1500
2000
2500
3000
3500

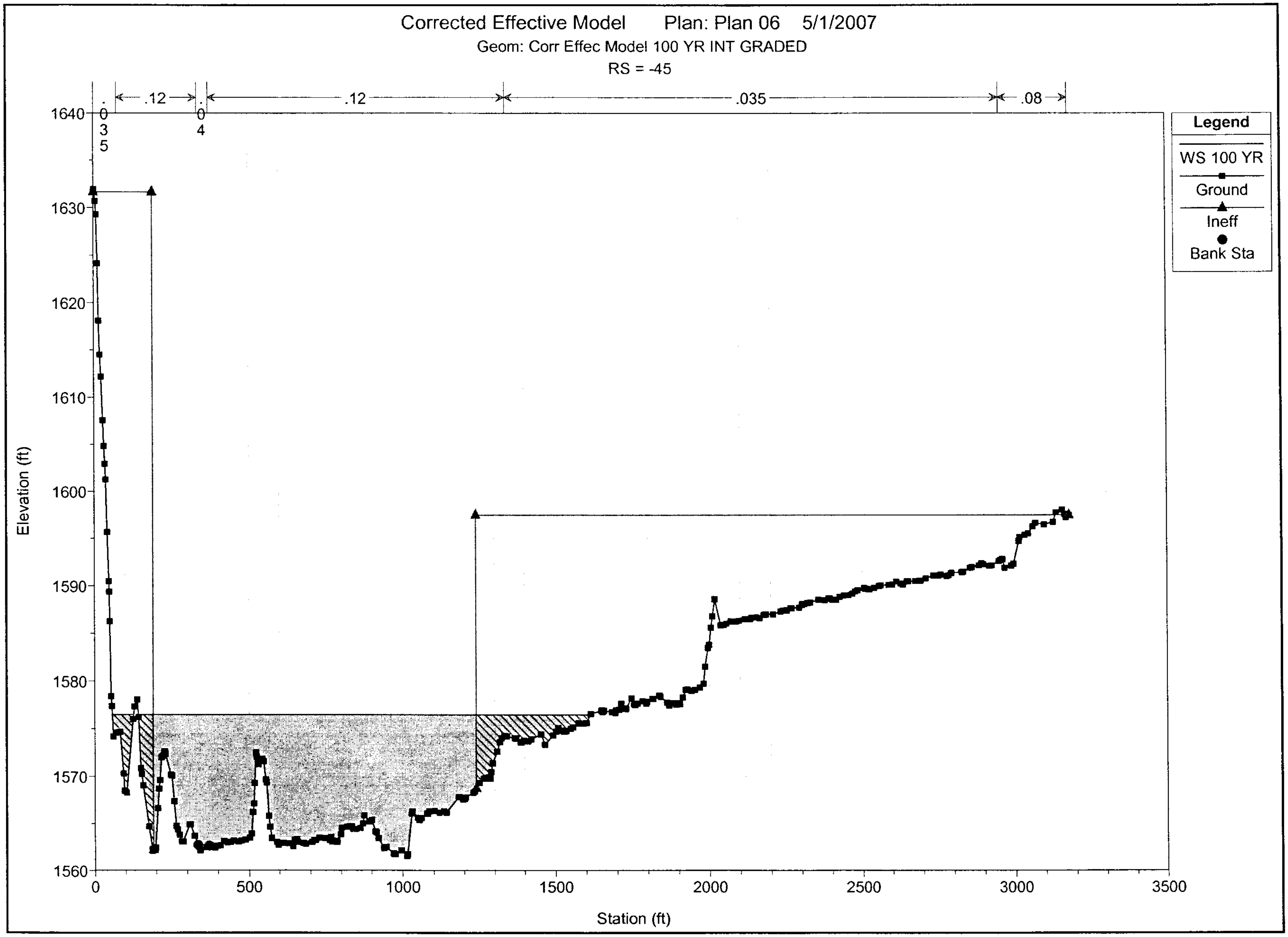

Corrected Effective Model Plan: Plan 06 5/1/2007
Geom: Corr Effec Model 100 YR INT GRADED
RS = -42.5 IS
.035
.05
.12
.04
.12
.035
.08
1640
1630
1620
1610
1600
1590
1580
1570
1560
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
Station (ft)
Legend
WS 100 YR
Ground
Ineff
Bank Sta

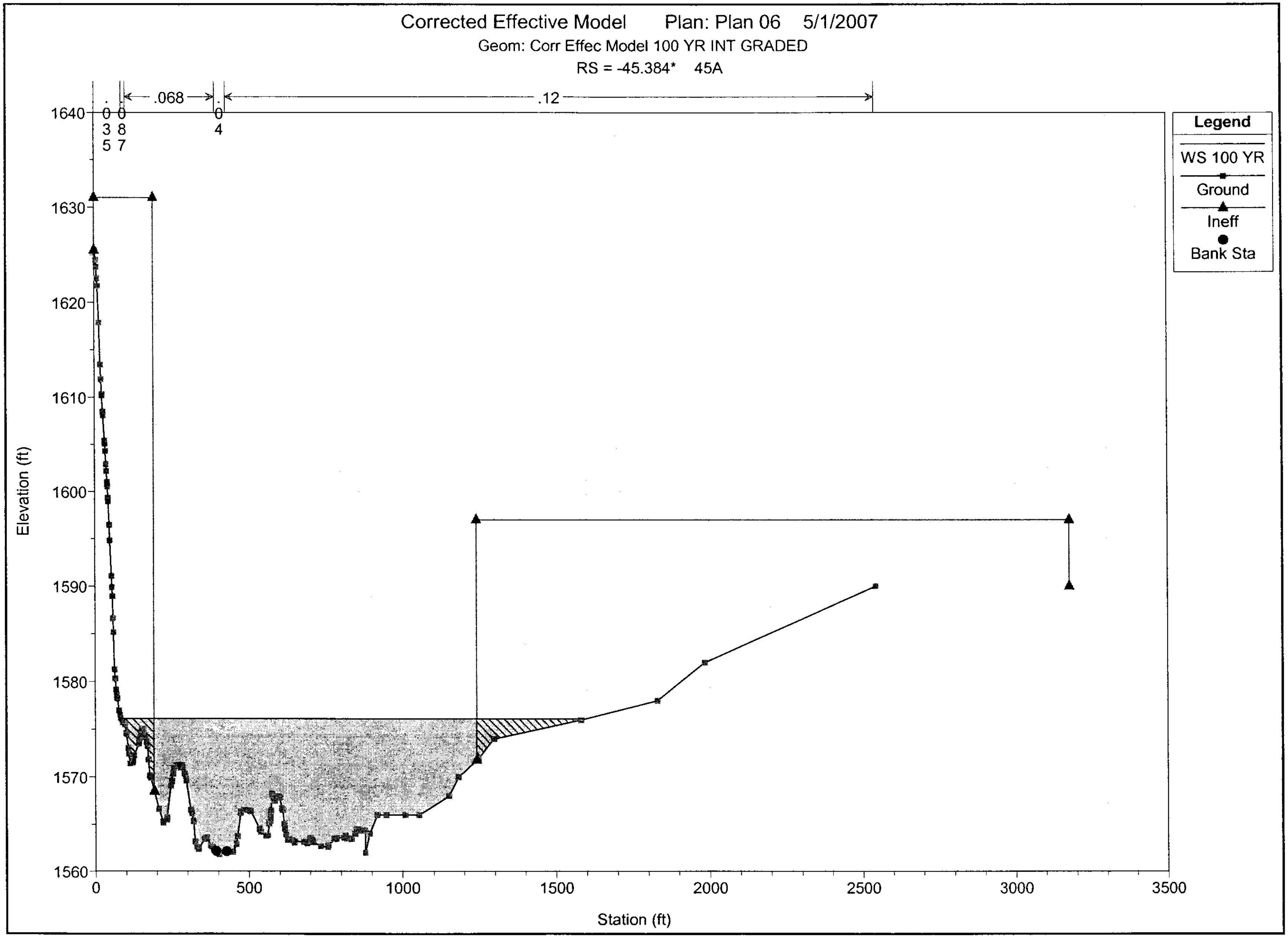


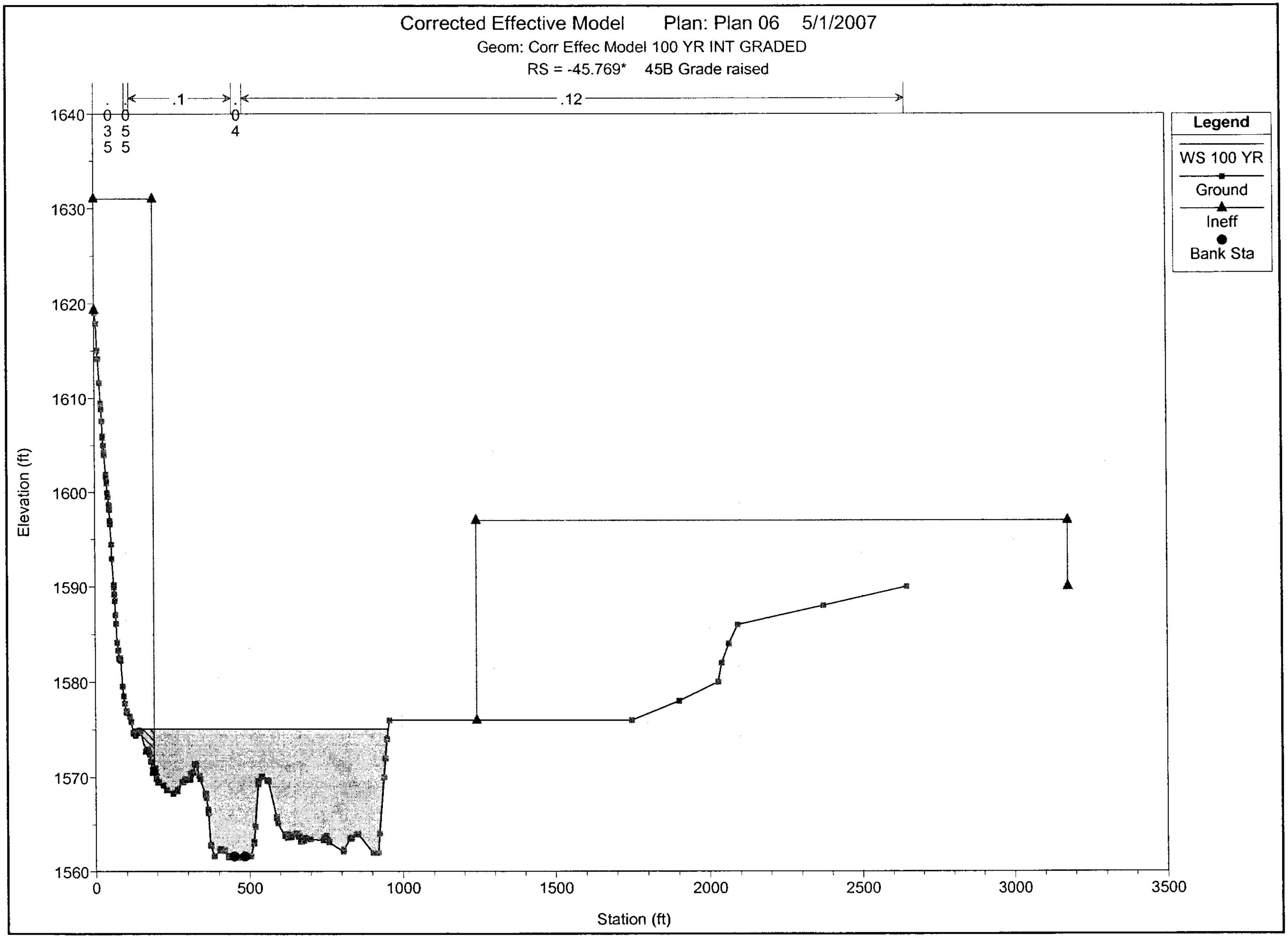
Corrected Effective Model Plan: Plan 06 5/1/2007

Geom: Corr Effec Model 100 YR INT GRADED

RS = -44


Corrected Effective Model Plan: Plan 06 5/1/2007
Geom: Corr Effec Model 100 YR INT GRADED
RS = -45
.035
.12
.04
.12
.035
.08
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
1640
1630
1620
1610
1600
1590
1580
1570
1560
0
500
1000
1500
2000
2500
3000
3500
Station (ft)

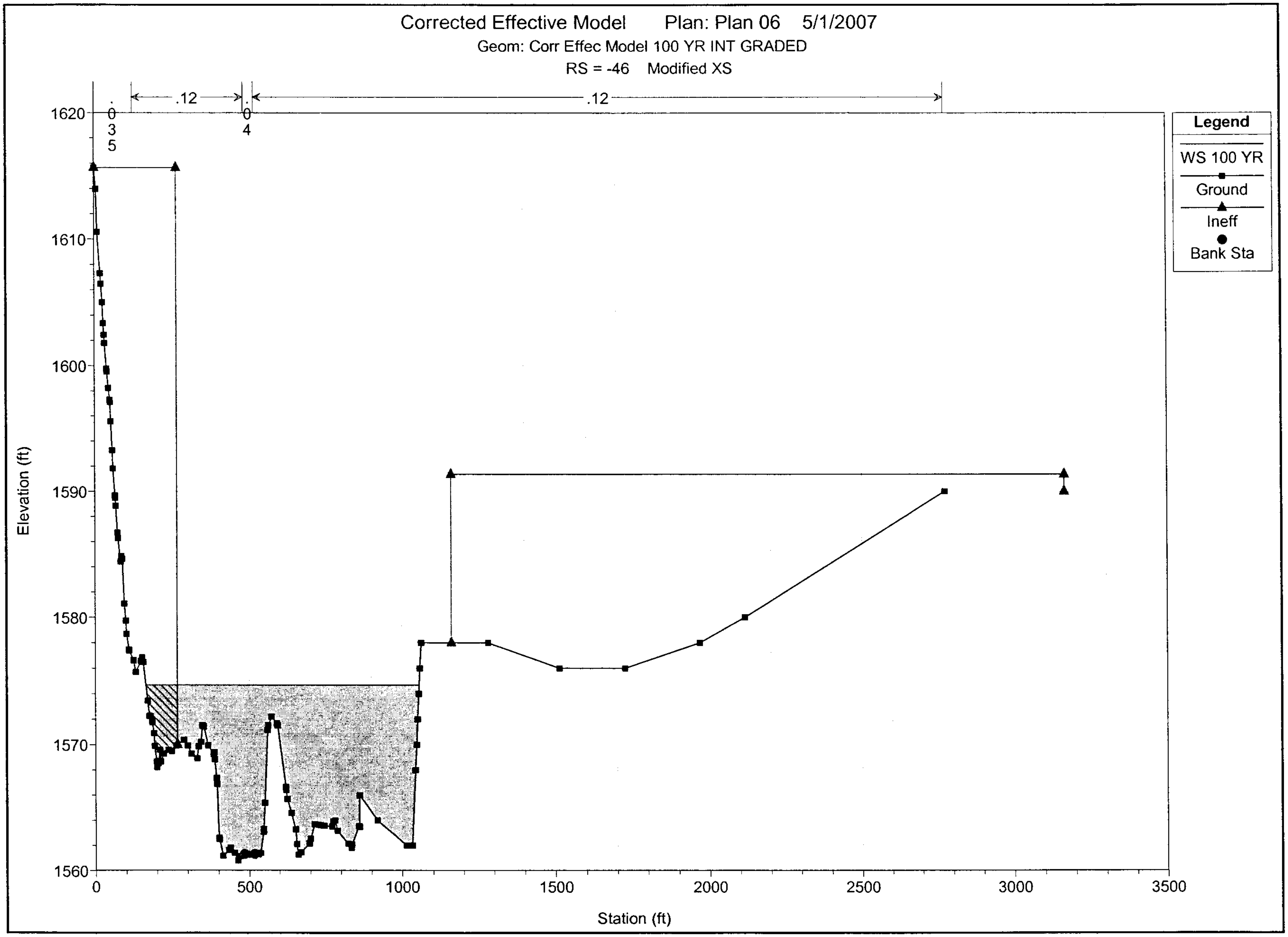

Corrected Effective Model Plan: Plan 06 5/1/2007
Geom: Corr Effec Model 100 YR INT GRADED
RS = -45.384* 45A
.035
.087
.068
.04
.12
Legend
WS 100 YR
Ground
Ineff
Bank Sta
Elevation (ft)
1640
1630
1620
1610
1600
1590
1580
1570
1560
Station (ft)
0
500
1000
1500
2000
2500
3000
3500



Corrected Effective Model Plan: Plan 06 5/1/2007

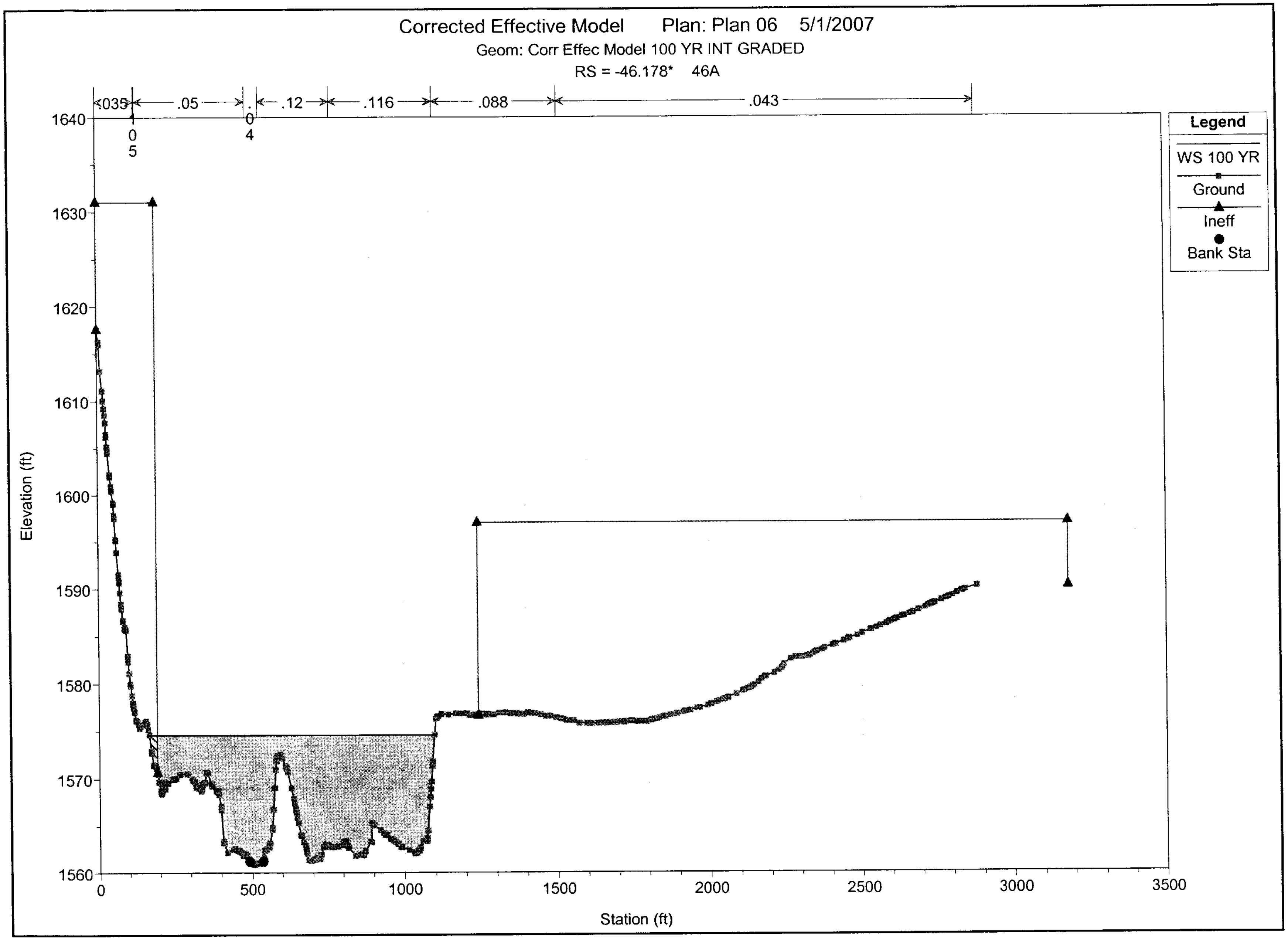
Geom: Corr Effec Model 100 YR INT GRADED

RS = -45.769* 45B Grade raised


Corrected Effective Model Plan: Plan 06 5/1/2007

Geom: Corr Effec Model 100 YR INT GRADED

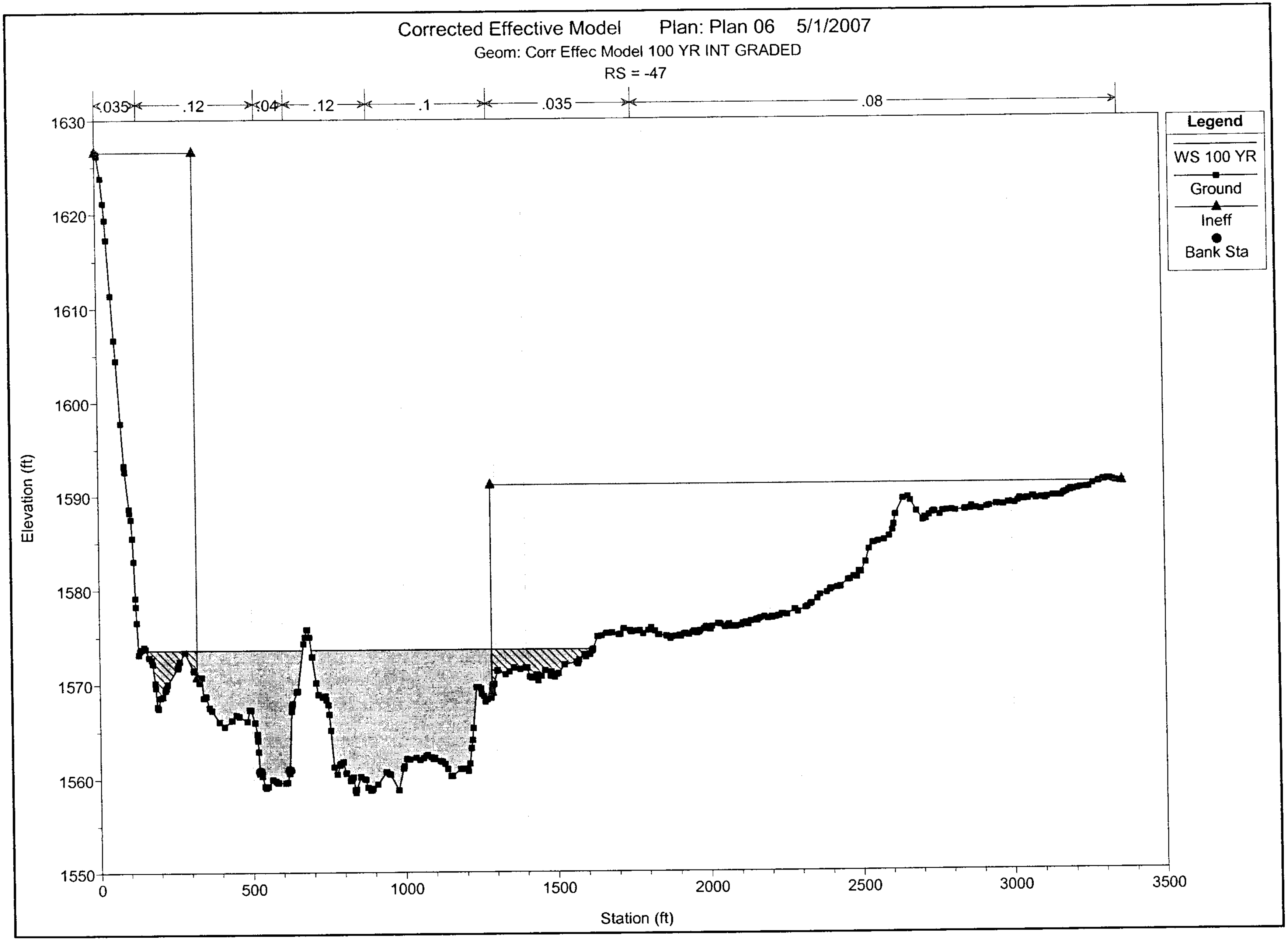
RS = -46 Modified XS



Corrected Effective Model Plan: Plan 06 5/1/2007

Geom: Corr Effec Model 100 YR INT GRADED

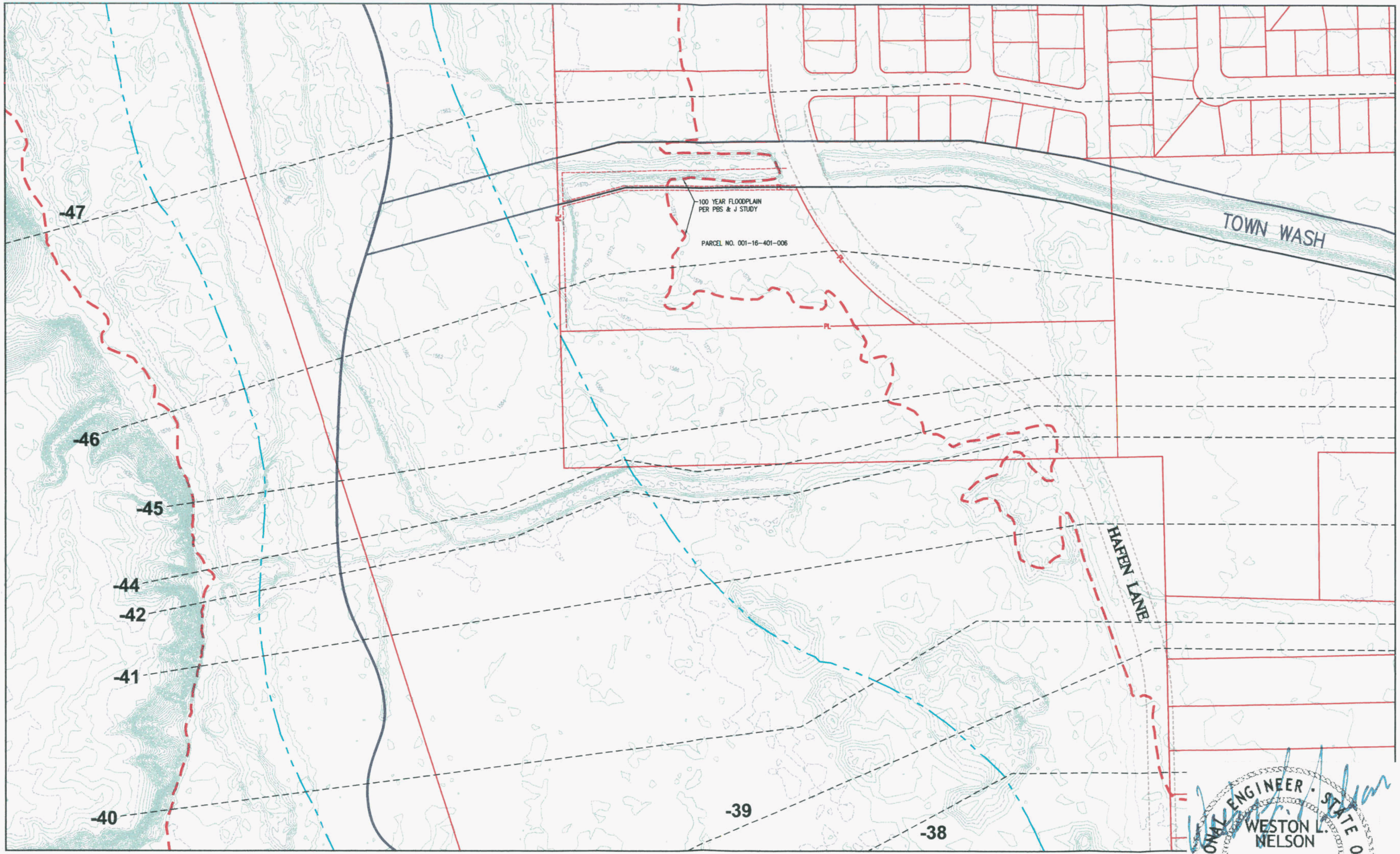
RS = -46.178* 46A


Corrected Effective Model Plan: Plan 06 5/1/2007

Geom: Corr Effec Model 100 YR INT GRADED

RS = -47

EXHIBIT A: 100 YEAR FLOODPLAIN PER 2005 PBS & J STUDY FOR PARCEL NO. 001-16-401-006 (RIVER STATIONS -38 THRU 37)


-47
-46
-45
-44
-42
-41
-40
-39
-38
100 YEAR FLOODPLAIN PER PBS & J STUDY
PARCEL NO. 001-16-401-006
TOWN WASH
HAFEN LANE

LEGEND

- - - - = 10' CONTOUR ELEVATION
———— = 2' CONTOUR ELEVATION
— — — — = HECRAS CROSS SECTION
CWSEL = COMPUTED WATER SURFACE ELEVATION
— — — = 100 YEAR FLOODPLAIN LIMITS PER PBS & J (2005)
———— = VIRGIN RIVER THALWEG PER PBS & J (2005)
— - — = FLOODWAY LIMITS PBS & J (2005)
———— = LOT LINE

CROSS SECTION	PBS & J CWSEL
-47	1573.59
-46A	------
-46	1574.95
-45B	------
-45A	------
-45	1576.35
-44	1576.34
-42	1580.14
-41	1580.62
-40	1581.48
-39	1581.93
-38	1582.17

AREIAL SOURCE: CLARK COUNTY, SPRING 2005
VERTICAL DATUM BASED ON NAVD 1988

GRAPHIC SCALE

100 0 50 100 200 400

(IN FEET)
1 inch = 100' ft.

Not To scale

WESTON L. NELSON
Exp. 12/31/07
CIVIL
No. 14044

5-1-07

NO	DESCRIPTION	DATE	BY	APPROVED
REVISIONS				

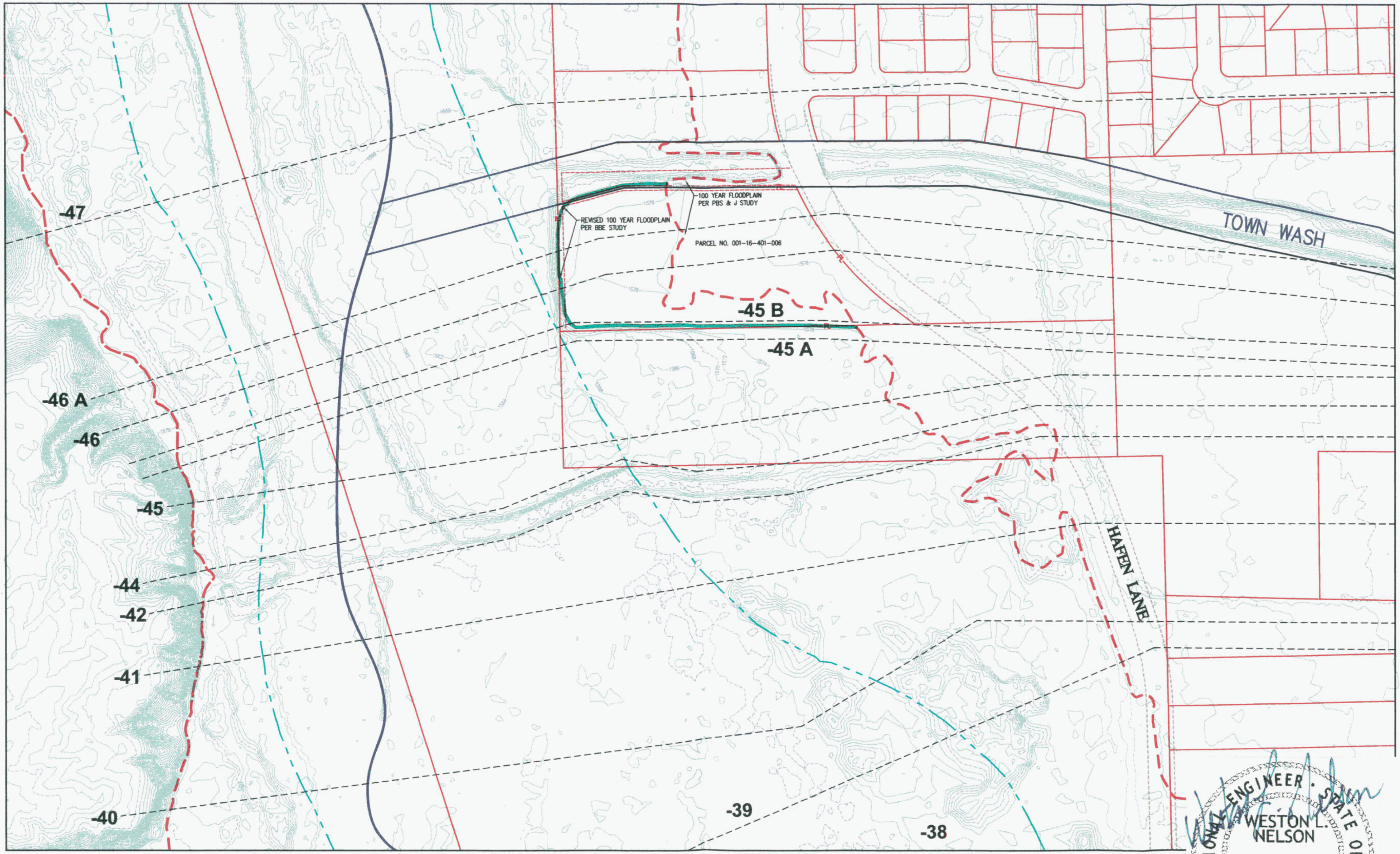
BULLOCH BROTHERS ENGINEERING INC.
CIVIL ENGINEERS-LAND SURVEYORS-LAND PLANNERS
– www.bullochbrothers.com –

P.O. BOX 3174 CEDAR CITY UT 84720 (435) 586-9592
P.O. BOX 23066 BULLHEAD CITY AZ 86439 (928) 415-0708
750 W. PIONEER BLVD. MESQUITE NV 89027 (702) 346-5100
1909 W. STATE ST., SUITE 200 PLEASANT GROVE UT 84062 (801) 763-8467
3100 W. PINEBROOK RD., SUITE 1000 PARK CITY UT 84098 (435) 655-0956

EXHIBIT A: 100 YEAR FLOODPLAIN
PER 2005 PBS & J STUDY
(RIVER STATIONS -38 THRU -47)
FOR
PARCEL NO. 001-16-401-006
MESQUITE, NEVADA

PROJECT NO: 1011-11
SCALE: 1" = 100'
DATE: MAY 2007
DRAWN BY: IR/DRC
SHEET NO: 1 OF 1
CHECKED BY: W.N.

EXHIBIT B: REVISED 100 YEAR FLOODPLAIN PER 2007 APPEAL
FOR PARCEL NO. 001-16-401-006 (RIVER STATIONS -38 THRU 37)


-47
-46 A
-46
-45
-44
-42
-41
-40
-39
-38
-45 B
-45 A
100 YEAR FLOODPLAIN PER PBS & J STUDY
REVISED 100 YEAR FLOODPLAIN PER BBE STUDY
PARCEL NO. 001-16-401-006
TOWN WASH
HAFEN LANE
1578

LEGEND

- = 10' CONTOUR ELEVATION
- = 2' CONTOUR ELEVATION
- = HECRAS CROSS SECTION
- CWSEL = COMPUTED WATER SURFACE ELEVATION
- = 100 YEAR FLOODPLAIN APPEAL PER BBE (2007)
- = 100 YEAR FLOODPLAIN LIMITS PER PBS & J (2005)
- = VIRGIN RIVER THALWEG PER PBS & J (2005)
- = FLOODWAY LIMITS PBS & J (2005)
- = LOT LINE

CROSS SECTION	PBS & J CWSEL	REVISED GROUND CWSEL
-47	1573.59	1573.59
-46A	------	1574.61
-46	1574.95	1574.69
-45B	------	1575.09
-45A	------	1576.12
-45	1576.35	1576.48
-44	1576.34	1576.47
-42	1580.14	1580.14
-41	1580.62	1580.62
-40	1581.48	1581.48
-39	1581.93	1581.93
-38	1582.17	1582.18

AREIAL SOURCE: CLARK COUNTY, SPRING 2005
VERTICAL DATUM BASED ON NAVD 1988

GRAPHIC SCALE

100
0
50
100
200
400

(IN FEET)
1 inch = 100' ft.

Not To Scale

WESTON L. NELSON
Exp. 12/31/07
CIVIL
No. 14044
5-1-07

NO	DESCRIPTION	DATE	BY	APPROVED

BULLOCH BROTHERS ENGINEERING INC.
CIVIL ENGINEERS–LAND SURVEYORS–LAND PLANNERS
– www.bullochbrothers.com –

P.O. BOX 3174	CEDAR CITY	UT	84720	(435) 586-9692
P.O. BOX 23066	BULLHEAD CITY	AZ	86439	(928) 415-0706
750 W. PIONEER BLVD.	MESQUITE	NV	89027	(702) 346-5100
1909 W. STATE ST., SUITE 200	PLEASANT GROVE	UT	84062	(801) 763-8467
3100 W. PINEBROOK RD., SUITE 1000	PARK CITY	UT	84098	(435) 655-0956

EXHIBIT B REVISED 100 YEAR FLOODPLAIN
PER 2007 APPEAL
(RIVER STATIONS -38 THRU -47)
FOR
PARCEL NO. 001-16-401-006
MESQUITE, NEVADA

PLOT DATE

PROJECT NO: 1011-11	SCALE: 1" = 100'
DATE: MAY 2007	DRAWN BY: IR/DRC
SHEET NO.: 1 OF 1	CHECKED BY: W.N.

BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972
ARIZONA ★ NEVADA ★ UTAH

RFCD
2007 MAY -4 PM 1:17

Date: May 1, 2007

City of Mesquite
10 East Mesquite Boulevard
Mesquite, Nevada 89027

Attention: Allen Bell, P.E., City Engineer

Regarding: FIS Appeal for Abbott Wash Conveyance Outlet Protection Facility

Dear Mr. Bell,

As you are aware, the gabion facility installed at the outlet of Abbott Wash into the Virgin River was damaged during the 2005 flood event. During this event, the Virgin River course shifted to the north by approximately 60 feet. Since the flood event there has been some discussion as to the final location of the Virgin River. Improvement Plans to repair or rebuild the outlet structure have been on hold pending a decision regarding the location of the river. The proposed FIS mapping submitted by PBS&J show the floodway encroaching into the original gabion structure (See Exhibit A). The proposed location of the floodway with respect to the outlet structure (Gabion) does not leave much flexibility to design an effective outlet protection structure. Nor does it allow for much bank protection adjacent to the waste water treatment facility and trails adjacent to the river. We propose that the floodway be shifted south to allow for more flexibility in the design options for Abbott Wash at this location. It appears that there is enough room to do so. While there is no grading that would negate the PBS&J results at this location, it is our opinion that the City and Regional Flood Control District would want to consider the location of the outlet structure for Abbott Wash. We recommend the City to appeal the location of the floodway at the Abbott Wash confluence.

If you have any questions regarding this appeal please contact our office at (702) 346-5100.

Sincerely,

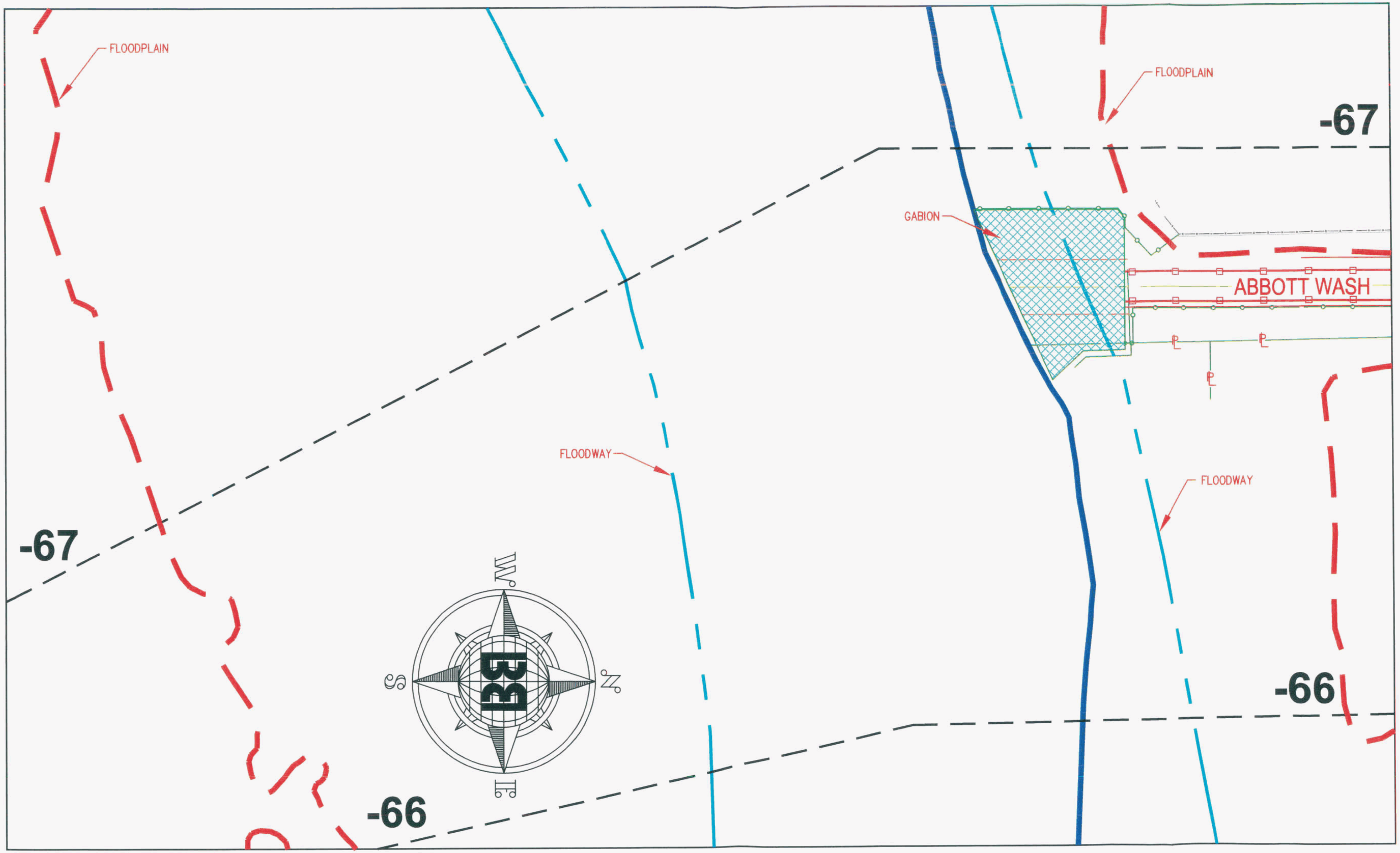
Weston L. Nelson, P.E.
Bulloch Brothers Engineering, Inc.

CC: Kevin Eubanks, P.E., Clark County Regional Flood Control District
Kurt O. Sawyer, Director of Building and Capital Improvements
Greg L. Bulloch, P.E., Bulloch Brothers Engineering, Inc.

Attch: Exhibit A

Bullhead City	Cedar City	Mesquite	Park City	Pleasant Grove
P.O. Box 23066	P.O. Box 3174	750 W. Pioneer Blvd.	3100 W. Pinebrook Rd. Ste 1000	1909 W. State Street, Ste 200
Bullhead City, AZ 84639	Cedar City, UT 84721	Mesquite, NV 89027	Park City, UT 84098	Pleasant Grove, UT 84062
928.415.0706	435.586.9592	702.346.5100	435.655.0956	801.763.8467
928.415.0463 Fax	435.586.4995 Fax	702.346.5102 Fax	435.655.0958 Fax	801.763.8472 Fax

EXHIBIT A: FLOODWAY & ABBOTT WASH OUTFALL LOCATION PER 2005 FIS PBS& J STUDY



AREIAL SOURCE: CLARK COUNTY,
SPRING 2005
VERTICAL DATUM BASED ON NAVD 1988

GRAPHIC SCALE

100
0
50
100
200
400

(IN FEET)
1 inch = 100' ft.

LEGEND

- 🟥 = 100 YEAR FLOODPLAIN LIMITS PER PBS & J (2005)
- = VIRGIN RIVER THALWEG PER PBS & J (2005)
- = FLOODWAY LIMITS PBS & J (2005)
- = HECRAS CROSS SECTION PBS & J (2005)

NO	DESCRIPTION	REVISIONS DATE	BY	APPROVED

BULLOCH BROTHERS
ENGINEERING INC.
CIVIL ENGINEERS–LAND SURVEYORS–LAND PLANNERS
– www.bullochbrothers.com –

P.O. BOX 3174 CEDAR CITY UT 84720 (435) 586-9592
P.O. BOX 23066 BULLHEAD CITY AZ 86439 (928) 416-0706
750 W. PIONEER BLVD. MESQUITE NV 89027 (702) 346-5100
1909 W. STATE ST., SUITE 200 PLEASANT GROVE UT 84062 (801) 763-8467
3100 W. PINEBROOK RD., SUITE 1000 PARK CITY UT 84098 (435) 655-0866

EXHIBIT A: FLOODWAY & ABBOTT WASH OUTFALL
LOCATION PER 2005 FIS PBS & J STUDY
FOR
THE CITY OF MESQUITE
MESQUITE, CLARK CO. NEVADA
MESQUITE, NEVADA

SCALE NO SCALE	PROJECT NO 1025-190-05
DRAWN BY DRC	DATE MAY 2007
CHECKED BY WN.	SHEET NO. 1 OF 1

PLOT DATE

BB BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972

Date: May 7, 2007

City of Mesquite
10 East Mesquite Boulevard
Mesquite, Nevada 89027

Attention: Allen Bell, P.E., City Engineer

Regarding: Community: City of Mesquite, NV (Community No. 320035)
FIS appeal for Coyote Willows PUD Phase 1 Units 3 and 4
Parcel No. 001-19-115-025

Dear Mr. Bell,

The following appeal material for Coyote Willows PUD Phase 1 units 3 and 4, (Parcel No. 001-19-115-025) is being submitted by Bulloch Brothers Engineering, Inc., on behalf of the property owners regarding the proposed FIS completed by PBS&J. We believe the evidence presented is based on scientific data sufficient to justify an appeal. Please submit the information to FEMA as required through their appeal process for the current FIS completed by PBS&J for the Clark County Regional Flood Control District (CCRFCD).

Sincerely,

Travis H. Anderson

Travis H. Anderson, P.E.
Bulloch Brothers Engineering, Inc.

TRAVIS H. ANDERSON
Exp. 12/31/08
CIVIL
No. 16479

5-8-07

CC: James Johnson, Mapping Supervisor, FEMA Region IX RMC
Eric Simmons, FEMA Region IX
Kevin Eubanks, P.E., CFM, Assistant General Manager, CCRFCD

2007 MAY 14 PM 1:01
RFCD

Cedar City
P.O. Box 3174
Cedar City, UT 84721-3174
435.586.9592
435.586.4995 Fax

Pleasant Grove
1909 W. State Street, Suite 200
Pleasant Grove, UT 84062
801.763.8467
801.763.8472 Fax

Mesquite
750 W. Pioneer Blvd.
Mesquite, NV 89027
702.346.5100
702.346.5102 Fax

BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972

2007 MAY 14 PM 1:01
RFCD

Date: May 7, 2007

City of Mesquite
10 East Mesquite Boulevard
Mesquite, Nevada 89027

Attention: Allen Bell, P.E., City Engineer

Regarding: FIS Appeal for Coyote Willows PUD Phase 1, Units 3 and 4
Parcel No. 001-19-115-025

Dear Mr. Bell,

The developers of Coyote Willows Planned Unit Development (ZMH Development) are appealing the flood plain boundary shown on the proposed FIS mapping prepared by PBS&J for the Regional Flood Control District. The map in question is Map Number 32003C0386F which shows a portion of their property, Parcel 001-19-115-025, to be located within the proposed 100 year floodplain. The appeal is based on fill dirt placed after the Aerial Topography was acquired. The enclosed exhibit which represents the floodplain limits through their property as mapped by PBS&J based on the Aerial Topography post 2005 along with the new floodplain limit based on the fill material. Bulloch Brothers Engineering have modified the current Hec-Ras model completed by PBS&J to account for the revised grading on the subject parcel. The revised grading removes the subject parcel out of the proposed floodplain. The technical data submitted with the exhibits indicates insignificant or minor modifications to the water surface elevation up and downstream of the subject parcel. The modified Hec-Ras model and Exhibits have been included on a CD.

If you have any questions regarding this appeal please contact our office at (702) 346-5100.

Sincerely,

Travis H. Anderson

~~Weston L. Nelson, P.E.~~ TRAVIS H. ANDERSON, P.E.
Bulloch Brothers Engineering, Inc.

TRAVIS H. ANDERSON
Exp. 12/31/08
CIVIL
No. 16479
5-8-07

CC: Kevin Eubanks, P.E., Clark County Regional Flood Control District
Charles and Ann Bentley, Property Owners.
Attch: Exhibits A & B

CLARK COUNTY REGIONAL FLOOD CONTROL DISTRICT (DISTRICT)

The District has received the appeal material submitted for Coyote Willows PUD Phase 1 Units 3 and 4 Parcel No. 001-19-115-025 regarding the proposed FIS completed by PBS&J. The District has completed a cursory review and believes the evidence presented is based on scientific data sufficient to justify an appeal. The information is being submitted to FEMA who has stated that they will review the material on it's own merit and make a final determination regarding this appeal.

Sincerely,

Kevin Eubanks, P.E., CFM, Assistant General Manager

CITY OF MESQUITE

The City has received the appeal material submitted for Coyote Willows PUD Phase 1, Units 3 and 4 Parcel No. 001-19-115-025 regarding the proposed FIS completed by PBS&J. The City has completed a cursory review and believes the evidence presented is based on scientific data sufficient to justify an appeal. The information is being submitted to FEMA who has stated that they will review the material on it's own merit and make a final determination regarding this appeal.

Sincerely,

Allen Bell, P.E., City Engineer

BB BULLOCH BROTHERS ENGINEERING
ENGINEERS ★ SURVEYORS ★ LAND PLANNERS
Established in 1972

April 30, 2007

Mr. Kevin Eubanks, P.E., CFM
Assistant General Manager
Clark County Regional Flood Control District
600 South Grand Central Parkway
Las Vegas, Nevada 89106

Project: **Coyote Willows Planned Unit Development Phase I Units 3 and 4, located in Mesquite Nevada.**

Dear Mr. Eubanks:

Grading for Coyote Willows Planned Unit Development Phase 1, Units 3 and 4 is complete, and in-place as shown on the improvement plans. Please consider this document as certification that the project was constructed within substantial conformance of the improvement plans.

If you have any questions or comments regarding this correspondence, please feel free to contact me at (702) 346-5100.

Sincerely,

Travis H. Anderson

Travis H. Anderson, P.E.
Bulloch Brothers Engineering

Travis H. Anderson

PROFESSIONAL ENGINEER STATE OF NEVADA
TRAVIS H. ANDERSON
Exp. 12/31/08
CIVIL
No. 16479

4-30-07

Coyote Willows River Model

7-May-07

C/S ID	Without grading plan			With grading plan		WS increase
	BFE (ft)	FFE (ft)	Difference (ft)	BFE (ft)	Difference (ft)	(ft)
-82	1545.28	1558.30	13.02	1545.28	13.02	0.00
-83	1544.34	1551.50	7.16	1544.35	7.15	0.01
-84	1542.95	1550.50	7.55	1542.91	7.59	-0.04
-85	1542.41	1553.12	10.71	1542.42	10.70	0.01
-86	1542.17	1556.72	14.55	1542.18	14.54	0.01

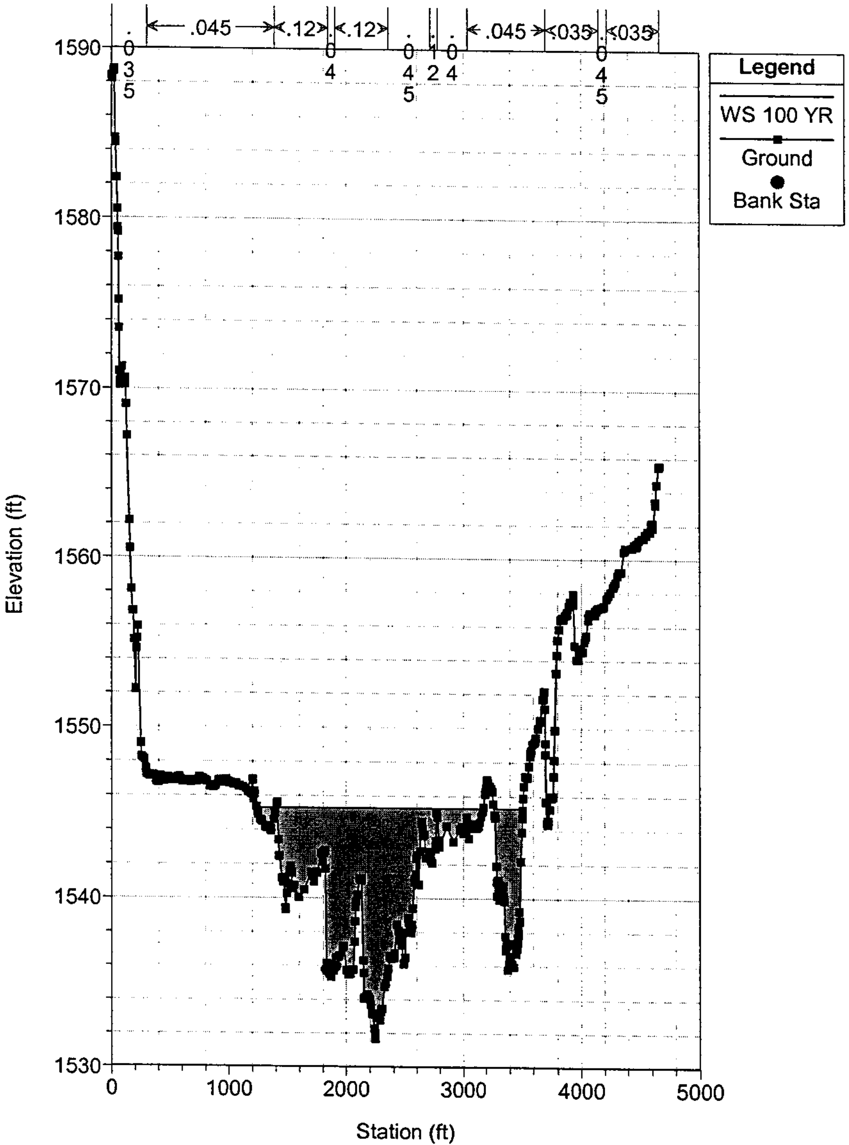
BFE	Base Flood Elevation
FFE	Finished Floor Elevation (same for both scenarios)

N:\1352-09 Coyote Willows Ph2-Unit-1 (Ph-4)\Hydrology Documentation\Flood Mapping\Coyote Willows\BFE and FF Comparison April 2007

Corrected Effective Model   Plan: Corrected Effective Model_100 YR   4/4/2007

Geom: Corrected Effective Model_100 YR

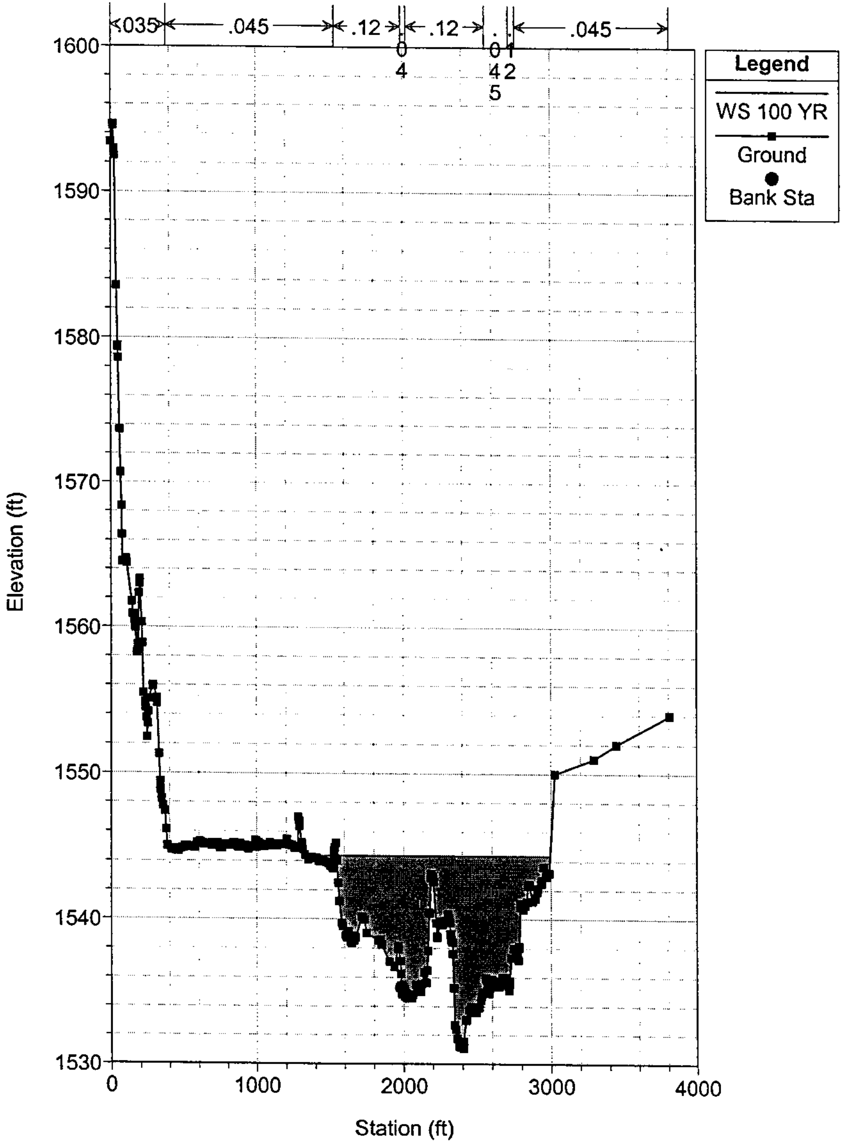
RS = -82



Corrected Effective Model   Plan: Corrected Effective Model_100 YR   4/4/2007

Geom: Corrected Effective Model_100 YR

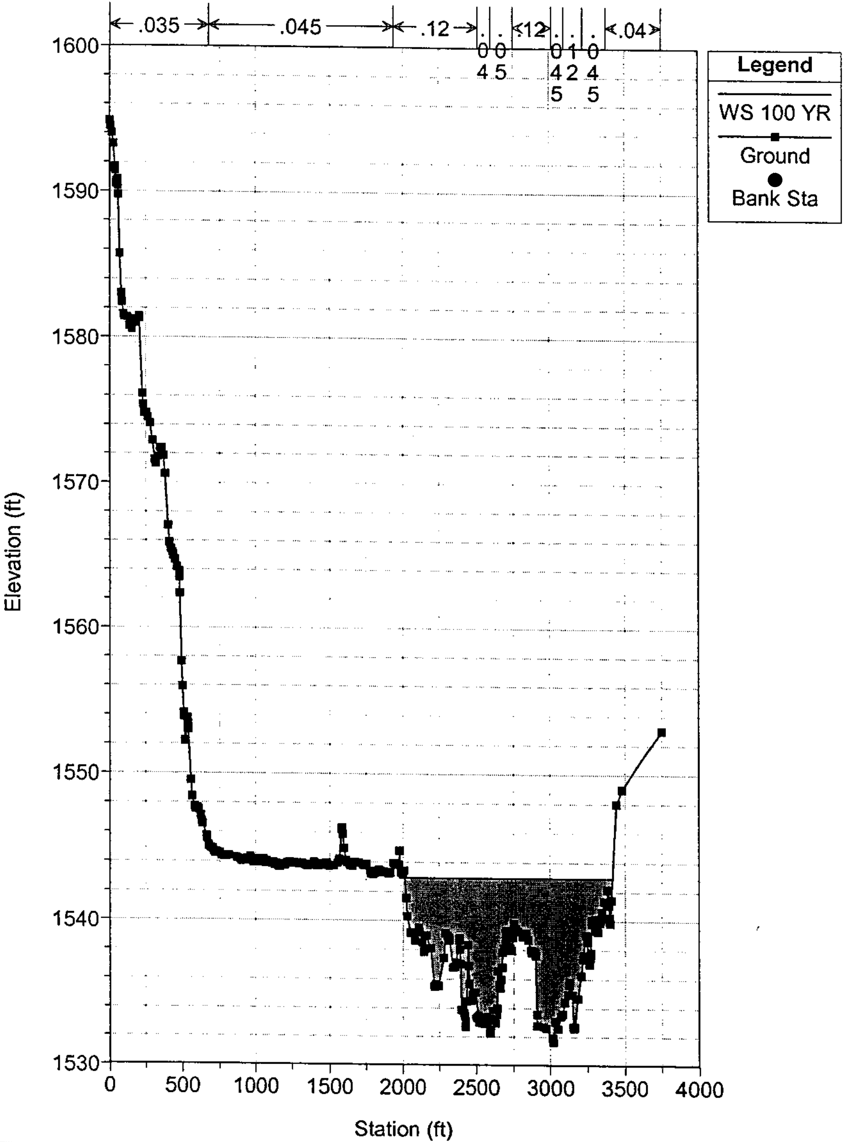
RS = -83   Coyote Willows XS



Corrected Effective Model Plan: Corrected Effective Model_100 YR 4/4/2007

Geom: Corrected Effective Model_100 YR

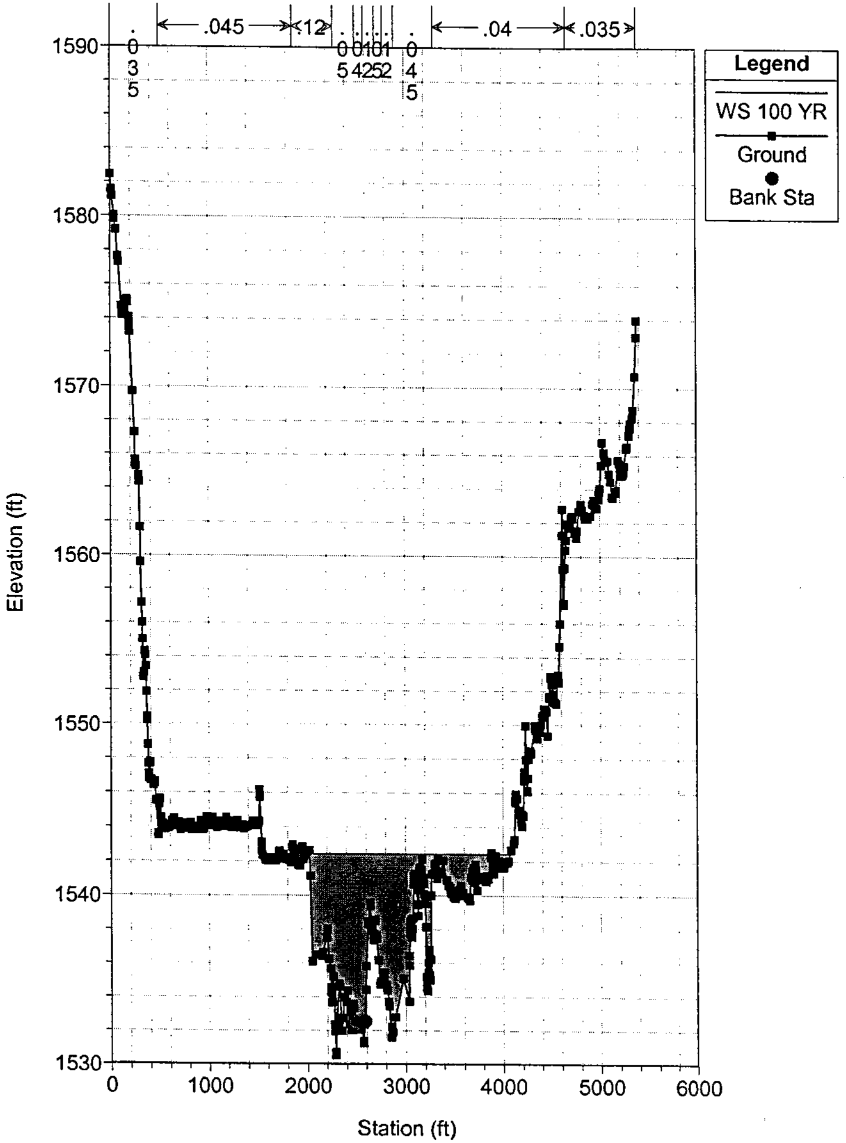
RS = -84 Coyote Willows XS

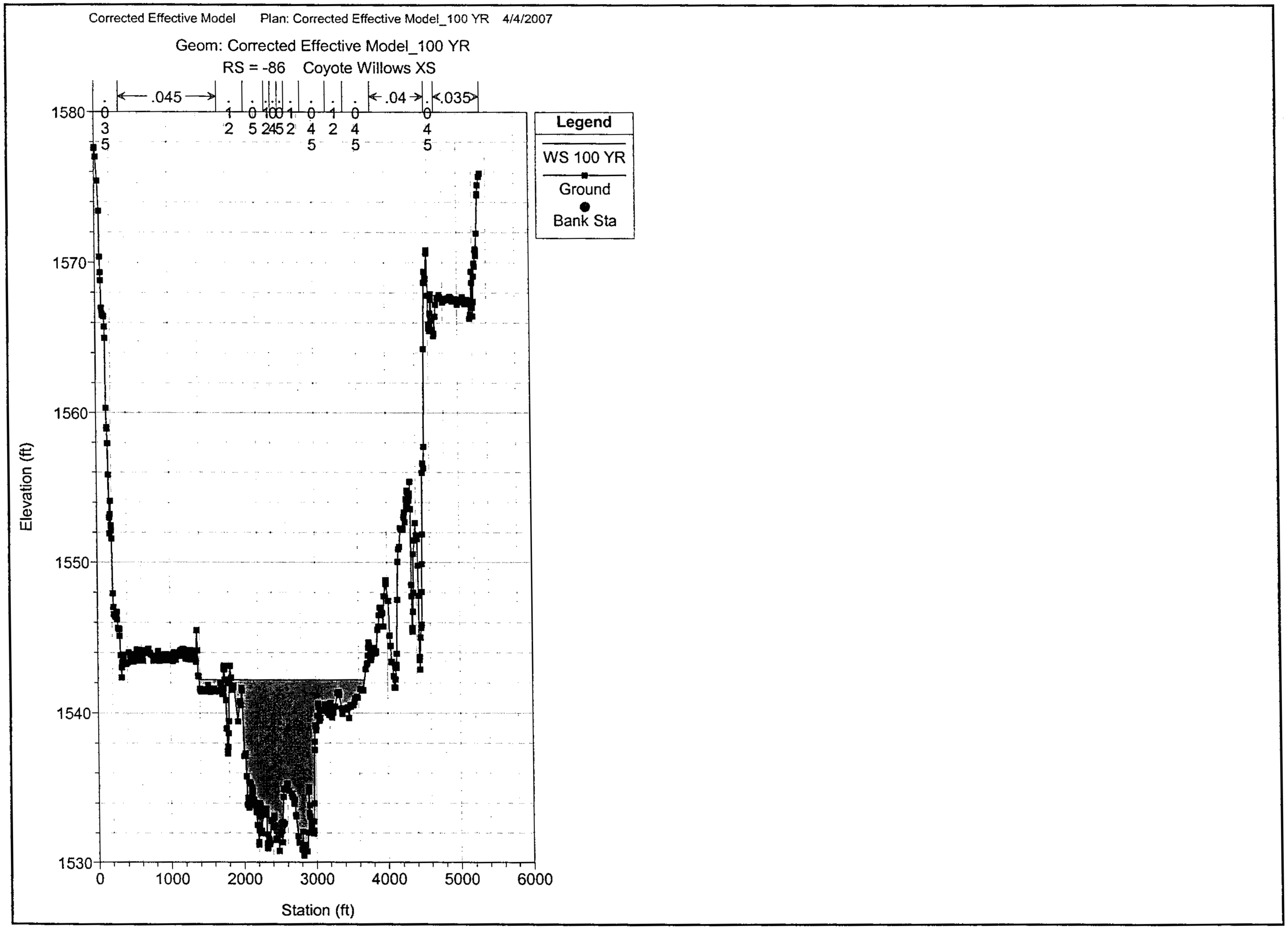


Corrected Effective Model Plan: Corrected Effective Model_100 YR 4/4/2007

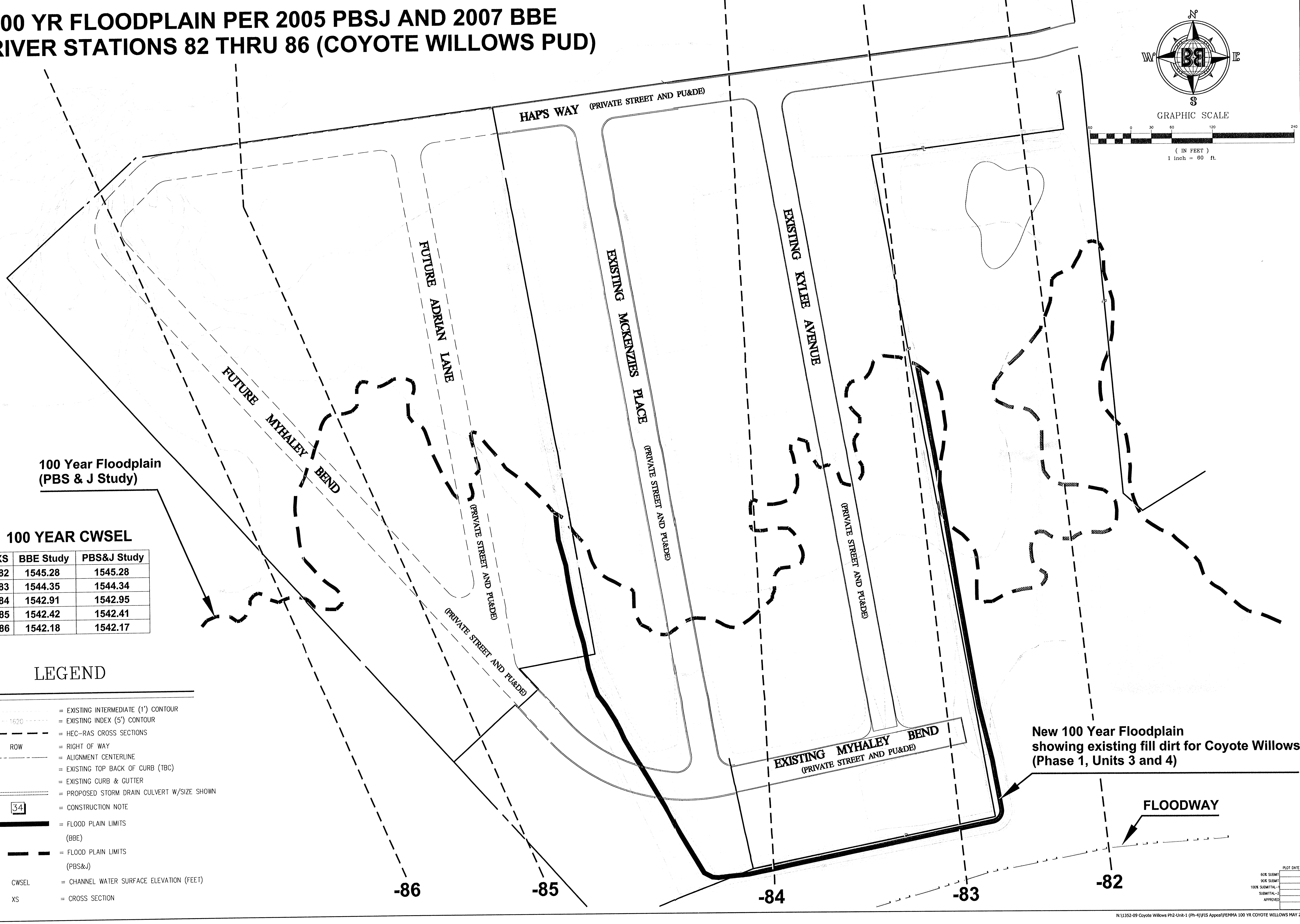
Geom: Corrected Effective Model_100 YR

RS = -85 Coyote Willows XS




Corrected Effective Model
Plan: Corrected Effective Model_100 YR 4/4/2007
Geom: Corrected Effective Model_100 YR
RS = -86 Coyote Willows XS
.045
.04
.035
.035
.12
.05
.12
.045
.12
.045
.045
Legend
WS 100 YR
Ground
Bank Sta
Elevation (ft)
1580
1570
1560
1550
1540
1530
Station (ft)
0
1000
2000
3000
4000
5000
6000

100 YR FLOODPLAIN PER 2005 PBSJ AND 2007 BBE RIVER STATIONS 82 THRU 86 (COYOTE WILLOWS PUD)


HAP'S WAY (PRIVATE STREET AND PU&DE)
FUTURE ADRIAN LANE
(PRIVATE STREET AND PU&DE)
EXISTING MCKENZIES PLACE
(PRIVATE STREET AND PU&DE)
EXISTING KYLEE AVENUE
(PRIVATE STREET AND PU&DE)
FUTURE MYHALEY BEND
(PRIVATE STREET AND PU&DE)
EXISTING MYHALEY BEND
(PRIVATE STREET AND PU&DE)
-86
-85
-84
-83
-82
N
W
E
S
GRAPHIC SCALE
60
0
30
60
120
240
(IN FEET)
1 inch = 60 ft.

100 Year Floodplain
(PBS & J Study)

New 100 Year Floodplain
showing existing fill dirt for Coyote Willows
(Phase 1, Units 3 and 4)

FLOODWAY

100 YEAR CWSEL

XS	BBE Study	PBS&J Study
-82	1545.28	1545.28
-83	1544.35	1544.34
-84	1542.91	1542.95
-85	1542.42	1542.41
-86	1542.18	1542.17

LEGEND

┈┈┈┈	= EXISTING INTERMEDIATE (1') CONTOUR
- - - 1620 - - -	= EXISTING INDEX (5') CONTOUR
— — — —	= HEC-RAS CROSS SECTIONS
ROW	= RIGHT OF WAY
—— - —— - ——	= ALIGNMENT CENTERLINE
	= EXISTING TOP BACK OF CURB (TBC)
	= EXISTING CURB & GUTTER
═══	= PROPOSED STORM DRAIN CULVERT W/SIZE SHOWN
34	= CONSTRUCTION NOTE
━━━━	= FLOOD PLAIN LIMITS (BBE)
▬ ▬ ▬	= FLOOD PLAIN LIMITS (PBS&J)
CWSEL	= CHANNEL WATER SURFACE ELEVATION (FEET)
XS	= CROSS SECTION

PLOT DATE	
60% SUBMIT	
90% SUBMIT	
100% SUBMITTAL-1	
SUBMITTAL-2	
APPROVED	

REVISIONS

NO	DESCRIPTION	DATE	BY	APPROVED

BULLOCH BROTHERS
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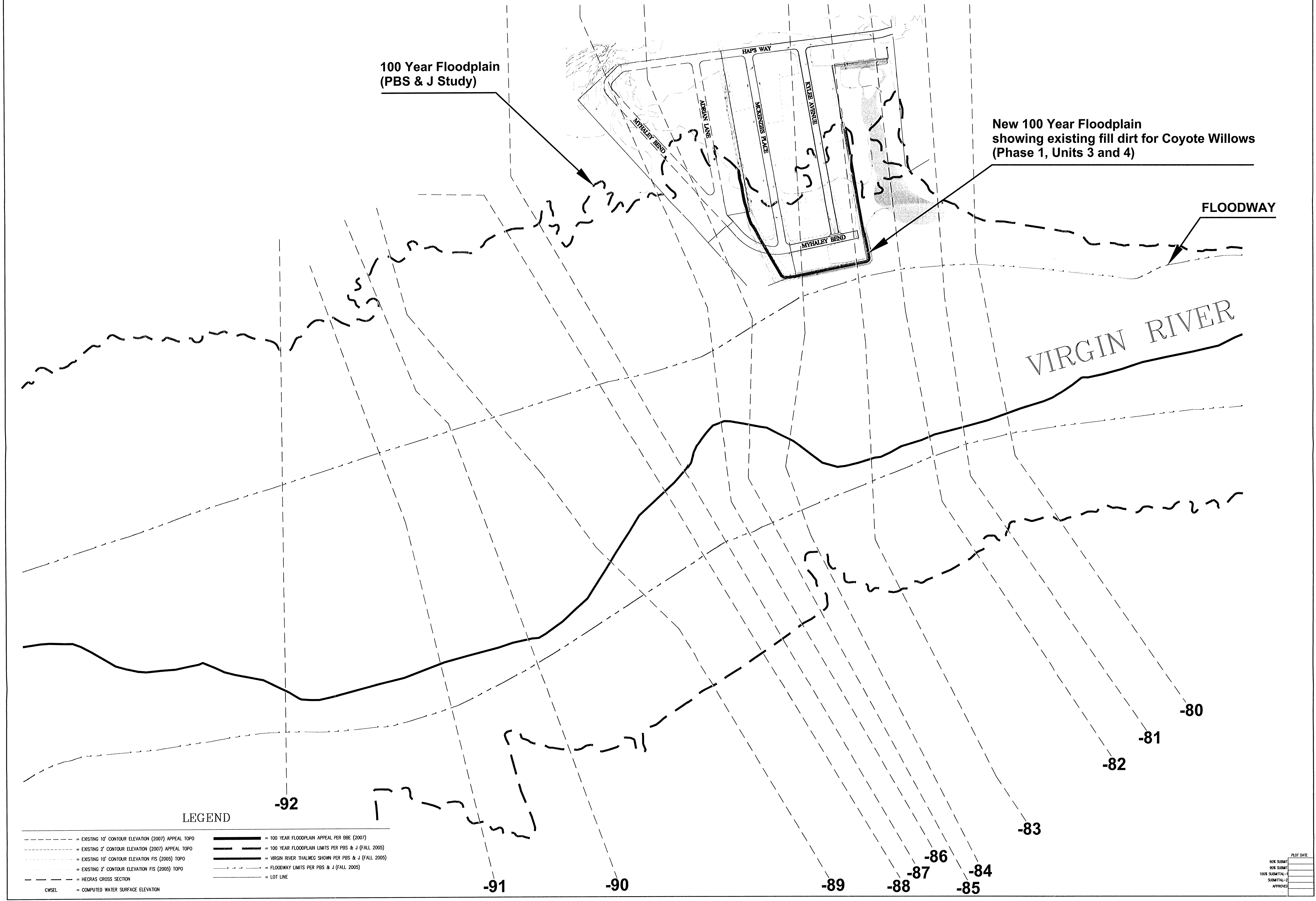
750 W. PIONEER BLVD.	MESQUITE	NV	89027	(702) 346-5100
1909 W. STATE ST. SUITE 200	PLEASANT GROVE	UT	84062	(801) 763-8467
3100 W. PINEBROOK RD. SUITE 1000	PARK CITY	UT	84098	(435) 655-0956

100-YR FLOODPLAIN
PER 2005 PBSJ AND 2007 BBE
FOR
COYOTE WILLOWS PUD
MESQUITE, NEVADA

PROFESSIONAL ENGINEER STATE OF NEVADA
TRAVIS H. ANDERSON
Exp. 12/31/08
CIVIL
No. 016479
Travis H. Anderson
5-8-07

SCALE: 1" = 60'	DRAWN BY: IR/DRC	CHECKED BY: T.A.
PROJECT NO: 1352-09	DATE: MAY 2007	SHEET NO: 1 OF 1

N:\1352-09 Coyote Willows Ph2-Unit-1 (Ph-4)\FIS Appeal\FEMMA 100 YR COYOTE WILLOWS MAY 2007.dwg, 5/8/2007 12:17:44 PM, Travis



100 Year Floodplain (PBS & J Study)

New 100 Year Floodplain showing existing fill dirt for Coyote Willows (Phase 1, Units 3 and 4)

FLOODWAY

LEGEND

- – – – – – = EXISTING 10' CONTOUR ELEVATION (2007) APPEAL TOPO
- - - - - - - = EXISTING 2' CONTOUR ELEVATION (2007) APPEAL TOPO
- ········ = EXISTING 10' CONTOUR ELEVATION FIS (2005) TOPO
- ········ = EXISTING 2' CONTOUR ELEVATION FIS (2005) TOPO
- — — — = HECRAS CROSS SECTION
- CWSEL = COMPUTED WATER SURFACE ELEVATION
- ━━━ = 100 YEAR FLOODPLAIN APPEAL PER BBE (2007)
- ━ ━ = 100 YEAR FLOODPLAIN LIMITS PER PBS & J (FALL 2005)
- ━━━ = VIRGIN RIVER THALWEG SHOWN PER PBS & J (FALL 2005)
- —·-·— = FLOODWAY LIMITS PER PBS & J (FALL 2005)
- —— = LOT LINE

	PLOT DATE
60% SUBMIT	
90% SUBMIT	
100% SUBMITTAL-1	
SUBMITTAL-2	
APPROVED	

NO	DESCRIPTION	DATE	BY	APPROVED
	REVISIONS			

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750 W. PIONEER BLVD.	MESQUITE	NV	89027	(702) 346-5100
1041 HANCOCK ROAD, SUITE E	BULLHEAD CITY	AZ	86442	(928) 704-0110
1909 W. STATE ST., SUITE 200	PLEASANT GROVE	UT	84062	(801) 763-8467
3100 W. PINEBROOK RD., SUITE 1000	PARK CITY	UT	84098	(435) 655-0956

EXHIBIT B: 100 YEAR FLOODPLAIN PER 2007 APPEAL
FOR
COYOTE WILLOWS PUD

MESQUITE, NEVADA

PROFESSIONAL ENGINEER
TRAVIS H. ANDERSON
Exp. 12/31/08
CIVIL
No. 016479
STATE OF NEVADA
Travis H. Anderson
5-8-07

SCALE: 1" = 200'	DRAWN BY: DRC	CHECKED BY: T.A.
PROJECT NO: 1352-09	DATE: MAY 2007	SHEET NO: 1 OF 1

N:\1352-09 Coyote Willows Ph2-Unit-1 (Ph-4)\Hydrology Documentation\Flood Mapping\FEMA 100 YR COYOTE WILLOWS 200 Scale.dwg, 5/8/2007 9:01:22 AM, DaveC