Degradation in Rush, Wildhorse, and Salt Creeks of Washita River in Oklahoma for Transportation Planning

FINAL REPORT - FHWA-OK-09-01

ODOT SPR ITEM NUMBER 2194

By

Avdhesh K. Tyagi
Director

Abdul-Sahib Al-Madhhachi
Graduate Research Associate

James Brown
Graduate Research Associate

Oklahoma Infrastructure Consortium
School of Civil and Environmental Engineering
Oklahoma State University
Stillwater, OK 74078

Technical Advisors:
Robert Rusch, P.E., Bridge Engineer
Kacie Braddy, P.E., Technical Advisor

March 2010

TECHNICAL REPORT DOCUMENTATION PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT=S CATALOG NO.
FHWA-OK-09-01		

4. TITLE AND SUBTITLE	5. REPORT DATE
Degradation in Rush, Wildhorse and Salt Creeks of Washita River in Oklahoma for Transportation Planning	March 2010
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Avdhesh K. Tyagi, Abdul-Sahib Al-Madhhachi, and James Brown	8. PERFORMING ORGANIZATION REPORT
9. PERFORMING ORGANIZATION NAME AND ADDRESS Avdhesh K. Tyagi School of Civil & Environmental Engineering Oklahoma State University Stillwater, OK 74078	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. ODOT SPR Item Number 2194
12. SPONSORING AGENCY NAME AND ADDRESS Oklahoma Department of Transportation Planning and Research Division 200 N.E. 21st Street, Room 3A7 Oklahoma City, OK 73105	13. TYPE OF REPORT AND PERIOD COVERED Final Report 2008 - 2010 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16 . ABSTRACT

The purpose of this research is to analyze the flow line data and relate it to the degradation of the Rush, Wildhorse and Salt Creeks at bridge location in the Washita River tributaries. This information may then be used to replace or rehabilitate those bridges that experienced severe degradation.

This report evaluates channel degradation in three tributaries of the Washita River in Oklahoma. The three creeks include Rush Creek at 29.18 miles of the Washita River and Wildhorse Creek at 54.82 miles of the Washita River and Salt Creek at 14.62 miles in Wildhorse Creek watershed. In Rush Creek, the maximum degradation is computed 0.46 feet per year over 15 years. Salt Creek has a maximum degradation of 0.63 feet per year over 8 years. The maximum degradation for Wildhorse Creek is determined 0.43 feet per year over 35 years. Washita River degradation rates ranged from 0.1 to 0.3 feet per year as determined in a previous study, while the degradation of Rush, Wildhorse and Salt Creeks ranged from 0.22 to 0.46, 0.072 to 0.43 and 0.02 to 0.63 feet per year, respectively.

After detailed hydraulic and geotechnical analysis the following bridges were recommended for further evaluation and possibly rehabilitation; b17568, b17569, b17590, and b17591. The foundation of piers is determined to be very close to the current flow line.

17. KEY WORDS	18. DISTRIBUTION STATEMENT		
Degradation, Washita River, Rush, Wildhorse and Salt Creeks, and Flow lines	No restrictions. This publication is available from the Planning & Research Div., Oklahoma DOT.		
19. SECURITY CLASSIF. (OF THIS REPORT)	**20. SECURITY CLASSIF. (OF THIS PAGE)**	**21. NO. OF PAGES**	22. PRICE
Unclassified	Unclassified	136	N/A

SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					*Approximate Conversions from SI Units*				
Symbol	**When you know**	**Multiply by**	**To Find**	**Symbol**	**Symbol**	**When you know**	**Multiply by**	**To Find**	**Symbol**
		LENGTH					**LENGTH**		
in	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yds
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.00155	square inches	in^2
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectacres	ha	ha	hectacres	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallon	3.785	liters	L	L	liters	0.2642	gallon	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C	°C	degrees Fahrenheit	9/5(°C)+32	degrees Celsius	°F
		FORCE and PRESSURE or STRESS					**FORCE and PRESSURE or STRESS**		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

Acknowledgements

Mr. Bob Rusch, P.E., Bridge Engineer with the Oklahoma Department of Transportation (ODOT) conceived this project and provided guidance during the project period. Ms. Kacie Braddy, P.E., Technical Advisor, ODOT, served as technical coordinator and provided data from ODOT files. This project was funded by the Research and Planning Division, ODOT and Mr. Bryan Hurst served as Project Manager on this research project.

CONTENTS

FIGURES

Page

TABLES

Page

I. Introduction

Currently the Oklahoma Department of Transportation (ODOT) has a $9 billion backlog in maintenance and construction needs for transportation infrastructure, including bridges and culverts. Approximately 1600 bridges are structurally deficient or functionally obsolete structures. Of these, 162 of Oklahoma's bridges are over 80 years old. Without additional funding in the next 10 years, that number will grow to 800 bridges over 80 years old. One of the causes of bridge structure deficiency is loss of soil cover at bridge piers caused by stream bed degradation.

Natural alluvial rivers are seldom in the state of equilibrium. The fluvial process in an alluvial river is a dynamic system, subject to continual changes in discharge, flow characteristics, bed material and sediment complex composition. Both human activities and natural events can disturb the stability of a river causing readjustments of the energy to lower as a result of the aforementioned activities. These readjustments are called "degradation" or "aggradations" if the reverse is true.

A stream channel is considered stable if the streambed does not change its average bed elevation over a relatively long river reach and a long period of time. Whether the hydraulic, hydrologic, and sedimentological characteristics of alluvial rivers are altered naturally or by human interference, the river will adjust dynamically and geometrically as the fluvial system seeks to establish a state of equilibrium. The river equilibrium concept was explained by Macklin (1948) as the "graded" river in which channel size, cross-sectional shape and slope adjust to the quantities of sediment and water transported so that the river bed neither degrades nor aggrades.

This project analyzed the degradation in three tributaries of Washita River which includes Rush Creek and Wildhorse and Salt Creeks. The Washita River has selected portions that experience severe degradation of the riverbed. Field reconnaissance survey (Rush, 2008) of the Washita River indicates that Rush Creek, and Wildhorse and Salt Creeks may be going through severe degradation in specific locations.

This investigation included the following tasks:

1. To collect and review flow line data from ODOT files on three tributaries of the Washita River in Oklahoma: the Rush, Wildhorse and Salt Creeks;
2. To locate structures – bridges and culverts – on Excel platform to manage the database;
3. To analyze the available flow line data at structures in the three creeks;
4. To analyze for flow line degradation with time for the three creeks; and
5. To prepare a final report incorporating the database analyzed and documenting the degradation near specific bridge piers for replacement and rehab of the structures.

II. Study Area

The Washita River forms in eastern Roberts County, Texas near the town of Miami, Texas in the Texas Panhandle. The river is 295 miles long and terminates into Lake Texoma in Johnston County (also Bryan County and Marshall County), Oklahoma and the Red River. It crosses Hemphill County, Texas and enters Oklahoma in Roger Mills County. In Oklahoma it cuts through Roger Mills, Custer, Washita, Caddo, Grady, Garvin, Murray, Carter, and Johnston Counties. Lake Texoma is the border between Bryan County and Marshall County.

Our research focuses on the tributaries of the Washita River which are Rush, Wildhorse, and Salt Creeks. Rush Creek, a tributary of Washita River, generally flows in the east-west direction. The creek begins from Taylor Lake in Grady County and flows to Garvin County where it merges with the Washita River. Wildhorse Creek, a tributary of Washita River, generally flows in the east-west direction. The creek begins from Stephens County and flows through Carter and Murray Counties where it merges into the Washita River. Salt Creek, a tributary of Wildhorse Creek, generally flows in the east-west direction. The creek flows through Garvin County and merges into Wildhorse Creek. Rush and Wildhorse Creeks are the major tributaries of Washita River which drains most of south central Oklahoma. The drainage of these streams is more or less restricted to the Central Redbed Plains Physiographic Province, although some slight contact with the Sandstone Hills Region occurs near their confluence with the Washita River (Snider 1917). Bedrocks in the region are predominantly red sandstone, shale, and clay which weather to form loams or sandy loams (Gray and Galloway 1959). Most of the streambed materials are mixed sandy loam of alluvial origin.

III. Watershed Delineation

Watershed delineation is the process of identifying the total extent to which a stream or a river has the potential to supply water as the drainage basin based on the topography of the area. The area upon which water accumulates and the network through which it travels to an outlet are referred to as a drainage system. The flow of water through a drainage system is only a subset of what is commonly referred to as the hydrologic cycle, which also includes groundwater. The watershed area is delineated by focusing on the movement of water across a surface based on its natural tendency to flow from a higher elevation to a lower elevation and to stagnate in inundations. The watershed area or drainage basin drains the water and other substances to a common outlet. Other common terms for a drainage basin are watershed, basin, catchment, or contributing area. In simple terms the drainage basin area is normally defined as the total area flowing to a given outlet, or pour point. A pour point is the point at which water flows out of the drainage basin and into another basin. This is usually the lowest point along the boundary of the drainage basin. The boundary between two basins is referred to as a drainage divide or watershed boundary.

The National Elevation Dataset (NED) is the source data for all of the hydrologic operations in this project. The National Elevation Dataset is a seamless, digital elevation model (DEM) with coverage of the entire United States, Puerto Rico, U.S. Virgin Islands, and many U.S. territories provided as a free service. The NED was originally developed from individual 7.5-minute DEM's by the USGS with the goals of improving data access and minimizing the need for pre-application processing. Such large datasets are provided as a free download using the USGS seamless server.

The website also provides other GIS data layers besides the NED with excellent graphic interface tools to select data only for the region of interest. From Figure 1, it can be seen that the topography of the area can be clearly identified based on the shaded relief of the NED datasets. Furthermore the most important aspect is the presence of the height (MSL) as an attribute which forms the basis of all hydrologic analysis.

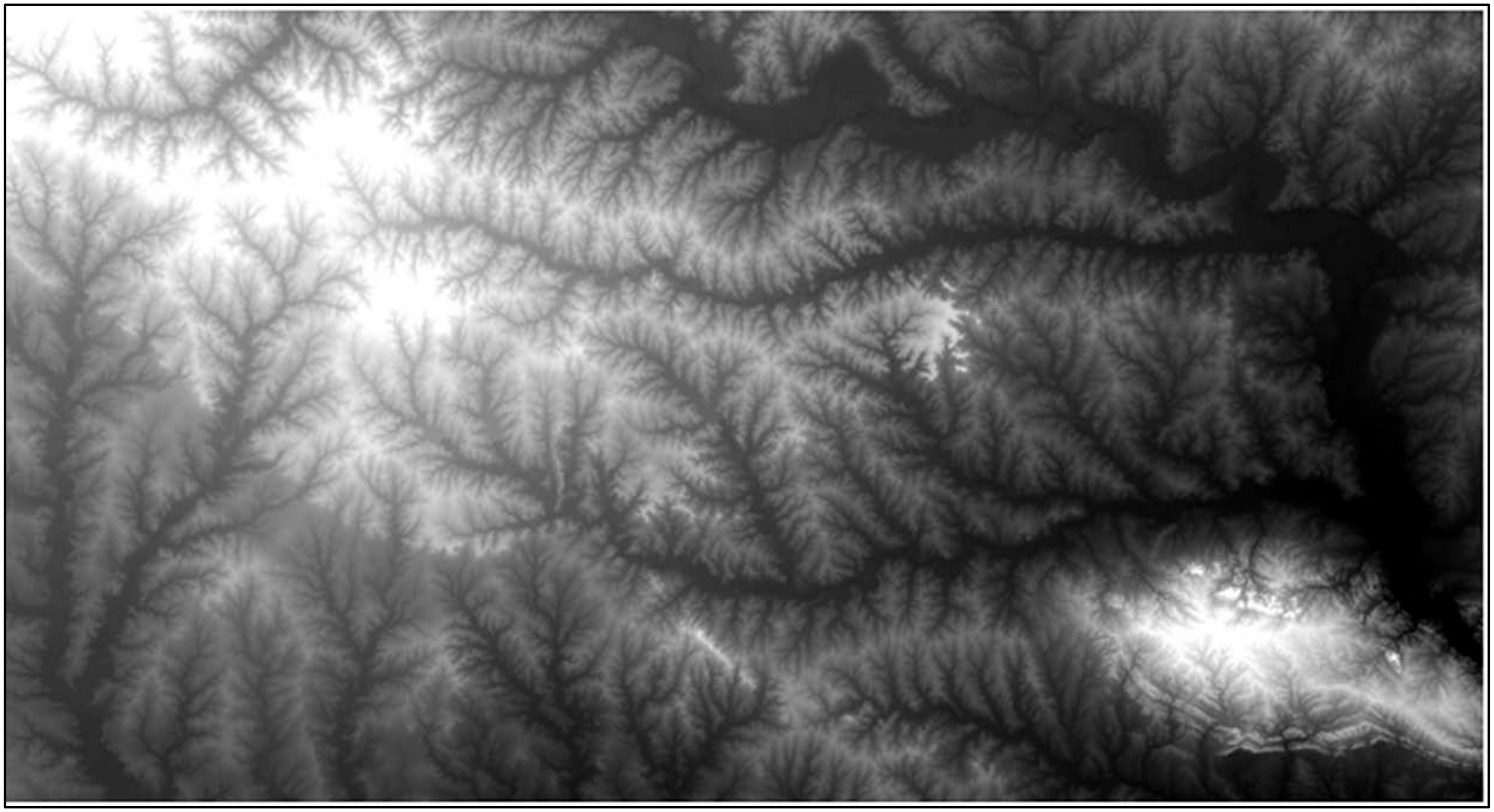


Figure 1. USGS National Elevation dataset for the study area.

GIS is compatible with NED datasets after transformation of the projection system to match the base layers. With GIS tools calculations for watershed characteristics, flow statistics, debris flow probability, and facilitates the watershed delineation by using Digital Elevation Models (DEMs) can be performed with great accuracy and efficiency. We used ArcGIS Spatial Analyst tools to calculate flow across an elevation surface, which provides the basis for creating stream networks and watersheds; calculating flow path length; and assigning stream orders.

Watershed delineation is a step by step approach. Using the hydrologic tools available in ArcTool Box and the USGS NED datasets, we first create a depressionless DEM and then calculate the Flow Direction and the Flow Accumulation layers using the depressionless DEM. A digital elevation model (DEM) free of sinks—a depressionless DEM—is the desired input to the flow direction process as against a USGS NED due to presence of some errors. The presence of sinks may result in an erroneous flow–direction raster.

The depressionless DEM can be prepared by using the “FILL” Tool. The flow direction function takes the depressionless DEM surface as input and outputs a raster showing the direction of flow out of each cell. The output raster as shown in Figure 2 is created showing a ratio of the maximum change in elevation from each cell along the direction of flow to the path length between centers of cells and is expressed in percentages. The layer gives a clear idea of the direction in which the water is bound to flow from any specific pixel on the raster layer.

Now that the direction is known we need to estimate the extent to which water would flow and accumulate. This is calculated using the Flow Accumulation function. From the output (Figure 3), cells with a high Flow Accumulation are areas of concentrated flow and may be used to identify stream channels, and cells with a Flow Accumulation of zero indicates local topographic heights and may be used to identify ridges.

The Flow Accumulation layer does not participate in the watershed delineation process but is rather used to identify the points of confluence for each of the streams. This identification can be achieved by manipulating the symbology to make the high flow pathways visible. The display of the raster layer is changed from a gray scale image to a classified image with two classes consisting of a break value at “5000”. Now the point that has the highest potential on the stream is clearly highlighted from which a vector layer depicting the pour points or the points of confluence can be created.

Finally the “watershed” tool in ArcTool Box is used to create the watershed boundary for the Rush, Wildhorse and Salt Creeks. With the flow direction layer and the pour points as inputs, the watershed boundary is produced as a raster layer from which the total area being drained and other hydrologic calculations can be performed. The watersheds of Rush, Wildhorse and Salt Creeks are shown in Figure 4. It should be noted that the Salt Creek is a part of the Wildhorse Creek watershed.

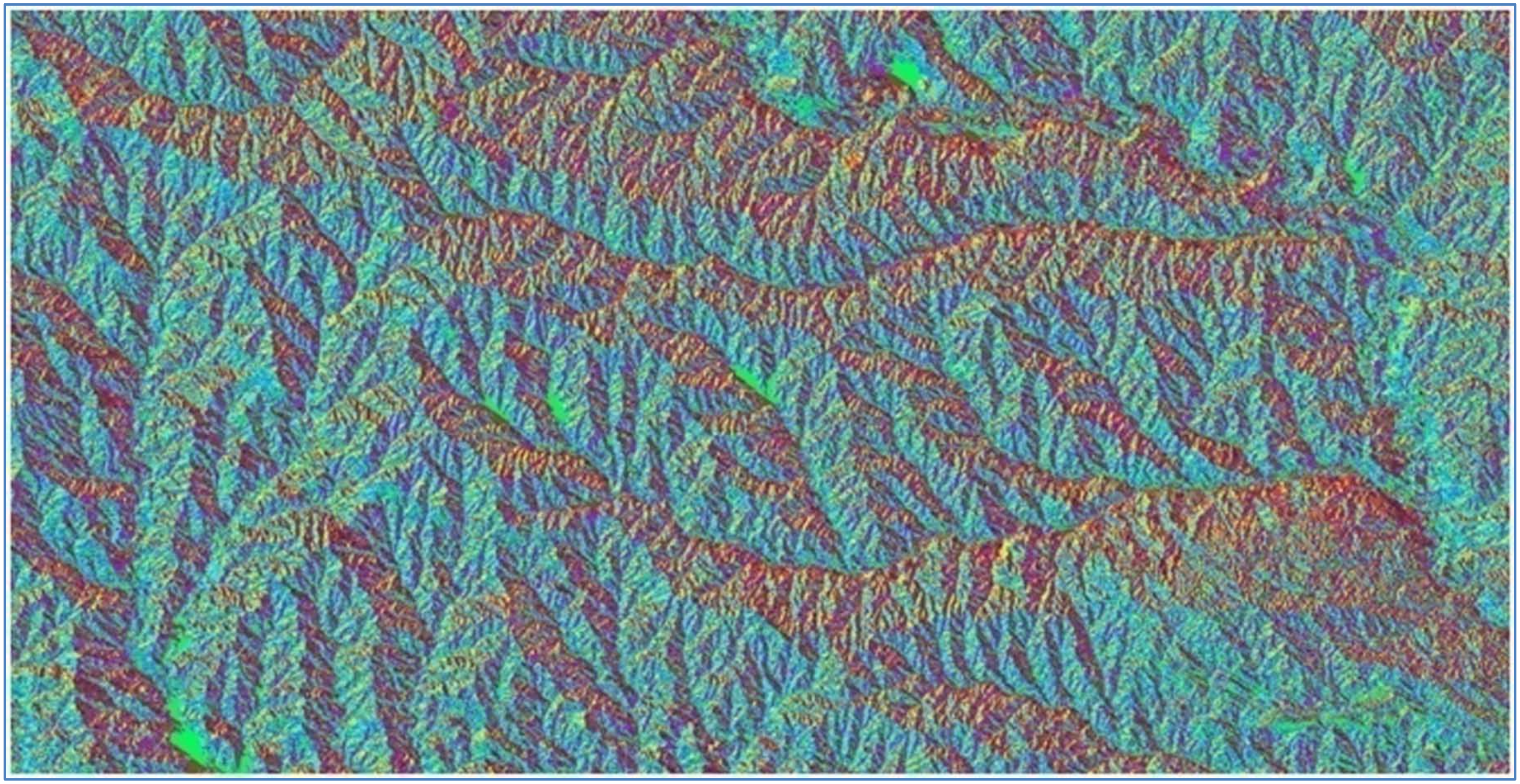


Figure 2. Flow direction Raster Layer.

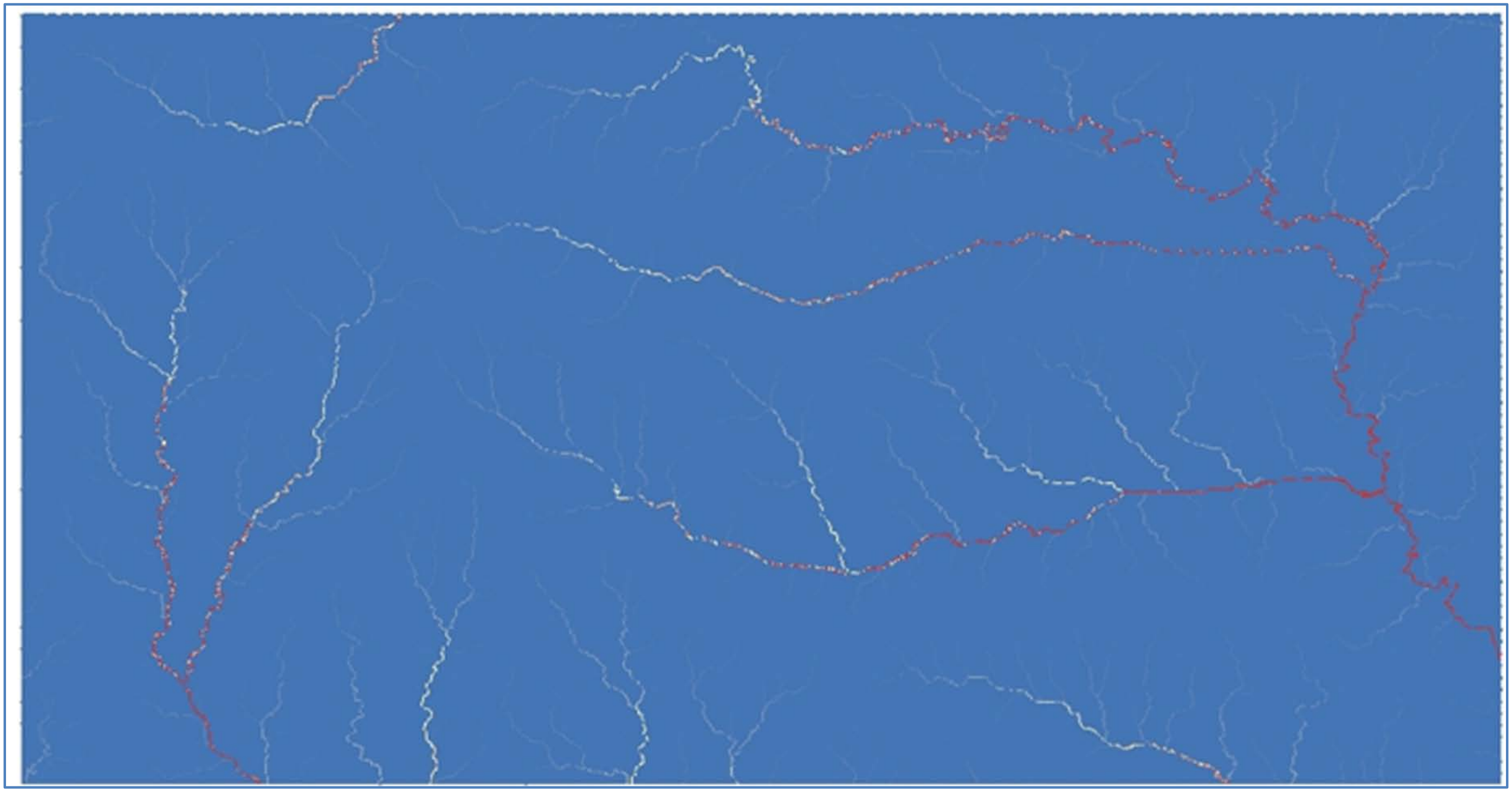


Figure 3. Flow Accumulation Raster Layer.

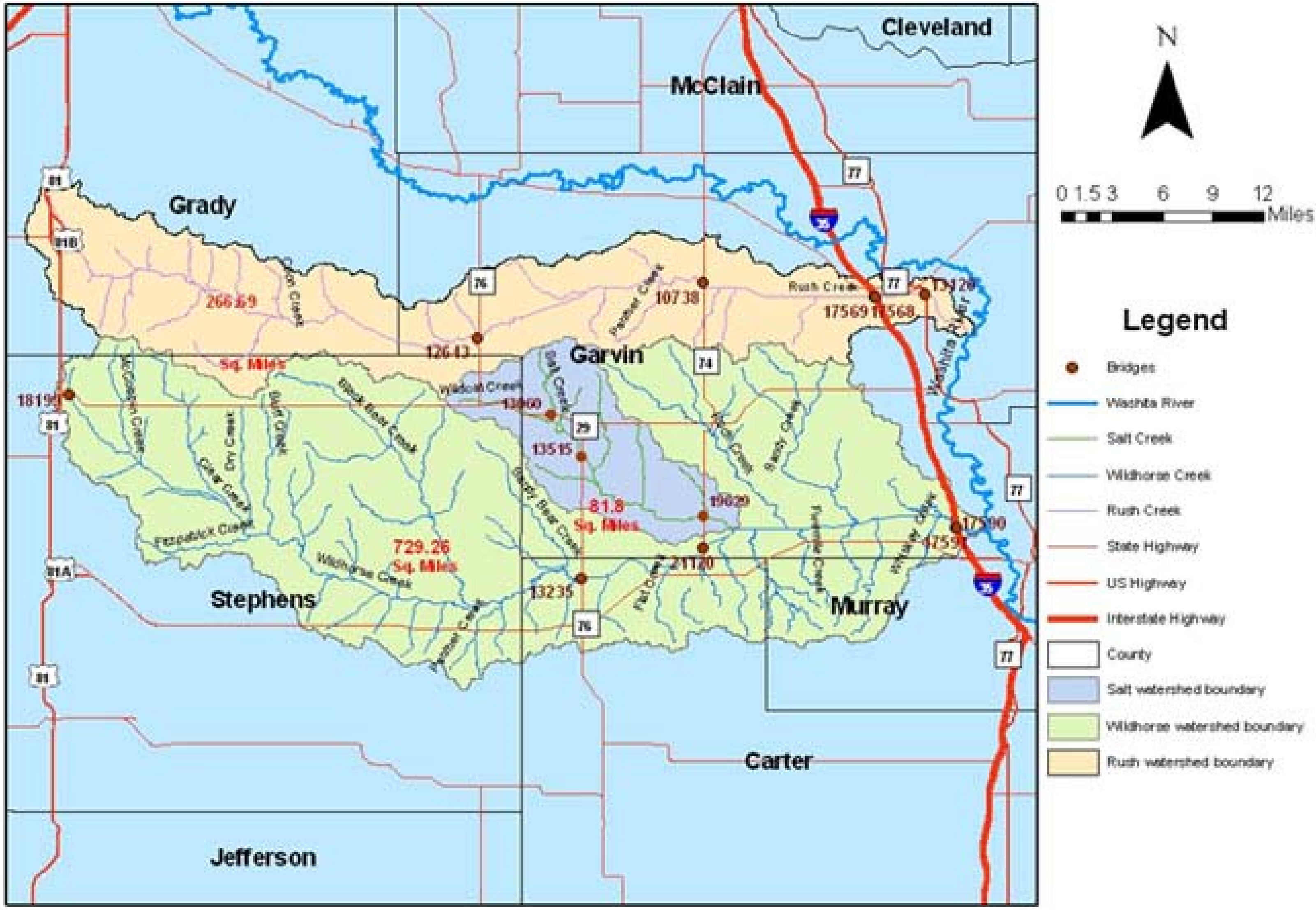


Figure 4. Watershed Boundary of Rush, Wildhorse, and Salt Creeks, Washita River.

IV. Hydrology

Human induced hydrological changes of the stream causes a change in the physical characteristics of the stream. Such changes include stream channel-bed degradation, stream widening, and stream bank erosion. As the stream profile degrades and the stream tries to widen to accommodate higher flows, stream bank erosions increase along with increases in sediment loads. USGS stream flow gage stations have been studied in the study reach. Currently there are three USGS gage stations in the study reach of the Rush, Wildhorse and Salt Creeks as shown in Table 1. USGS Rain gages inside of the study area are shown in Table 2. The locations of three gaging stations are included in Figure 5.

Knowledge of the magnitude and frequency of floods is required for the safe and economical design of highway bridges, culverts, dams, levees, and other structures on or near streams. Flood plain management programs and flood-insurance rates also are based on flood magnitude and frequency information. A flood is any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream (Leopold and Maddock, 1954). The magnitude of a flood is referred to as the flood peak, which is the highest value of the discharge or stage attained by a flood; thus, peak discharge or peak stage (Langbein and Isseri 1960). Three kinds of flood frequency analyses may be conducted; (1) peak discharge; (2) peak stage; and (3) total volume (Dalrymple, 1960). Peak-discharge flood frequency analysis was documented by the U.S Geological Survey for Rush, Wildhorse and Salt Creeks as shown in Table 3.

Table 1. Description of USGS stream flow gage stations.

Data Locations Descriptions	**Data Available**
USGS 07329000 Rush Creek at Purdy, OK Garvin County, Oklahoma Hydrologic Unit 11130303 Latitude 34°41’46”, Longitude 97°35’55” NAD27 Drainage area 145 square miles Contributing drainage area 145 square miles Gage datum 1,004.12 feet above sea level NGVD29.	1938-53 1985-90
USGS 07329500 Rush Creek near Maysville, OK Garvin County, Oklahoma Hydrologic Unit 11130303 Latitude 34°44’46”, Longitude 97°24’18” NAD27 Drainage area 206 square miles Contributing drainage area 206 square miles Gage datum 903.04 feet above sea level NGVD29.	1938-39 1944 1953-75 1977
USGS 07329700 Wildhorse Creek near Hoover, OK Garvin County, Oklahoma Hydrologic Unit 11130303 Latitude 34°32’29”, Longitude 97°14’49” NAD27 Drainage area 604 square miles Contributing drainage area 604 square miles Gage datum 803.30 feet above sea level NGVD29.	1954-55 1962-63 1969-71 1985-90

Table 2. Description of USGS rain gage stations.

Data Locations Descriptions	Data Available
Oklahoma Climatological Survey COOP Site at Cox City, OK Grady County, Oklahoma Central Climate Division (CD 5) Latitude 34°45'00", Longitude 97°42'00" Gage datum 1,184.00 feet above sea level NGVD29.	1980-2008
Oklahoma Climatological Survey COOP site near Elmore City, OK Garvin County, Oklahoma South Central Climate Division (CD 8) Latitude 34°39'00", Longitude 97°27'00" Gage datum 1019.00 feet above sea level NGVD29.	1947-2008
Oklahoma Climatological Survey COOP site at Hennepin, OK Garvin County, Oklahoma South Central Climate Division (CD 8) Latitude 34°34'12", Longitude 97°21'00" Gage datum 969.00 feet above sea level NGVD29.	1948-1951 1993-2008
Oklahoma Climatological Survey COOP site at Pauls Valley, OK Garvin County, Oklahoma South Central Climate Division (CD 8) Latitude 34°43'48", Longitude 97°16'48" Gage datum 939.00 feet above sea level NGVD29.	1899-2008
Oklahoma Climatological Survey COOP site at Tussy, OK Garvin County, Oklahoma South Central Climate Division (CD 8) Latitude 34°30'00", Longitude 97°31'48" Gage datum 974.00 feet above sea level NGVD29.	1993-2005

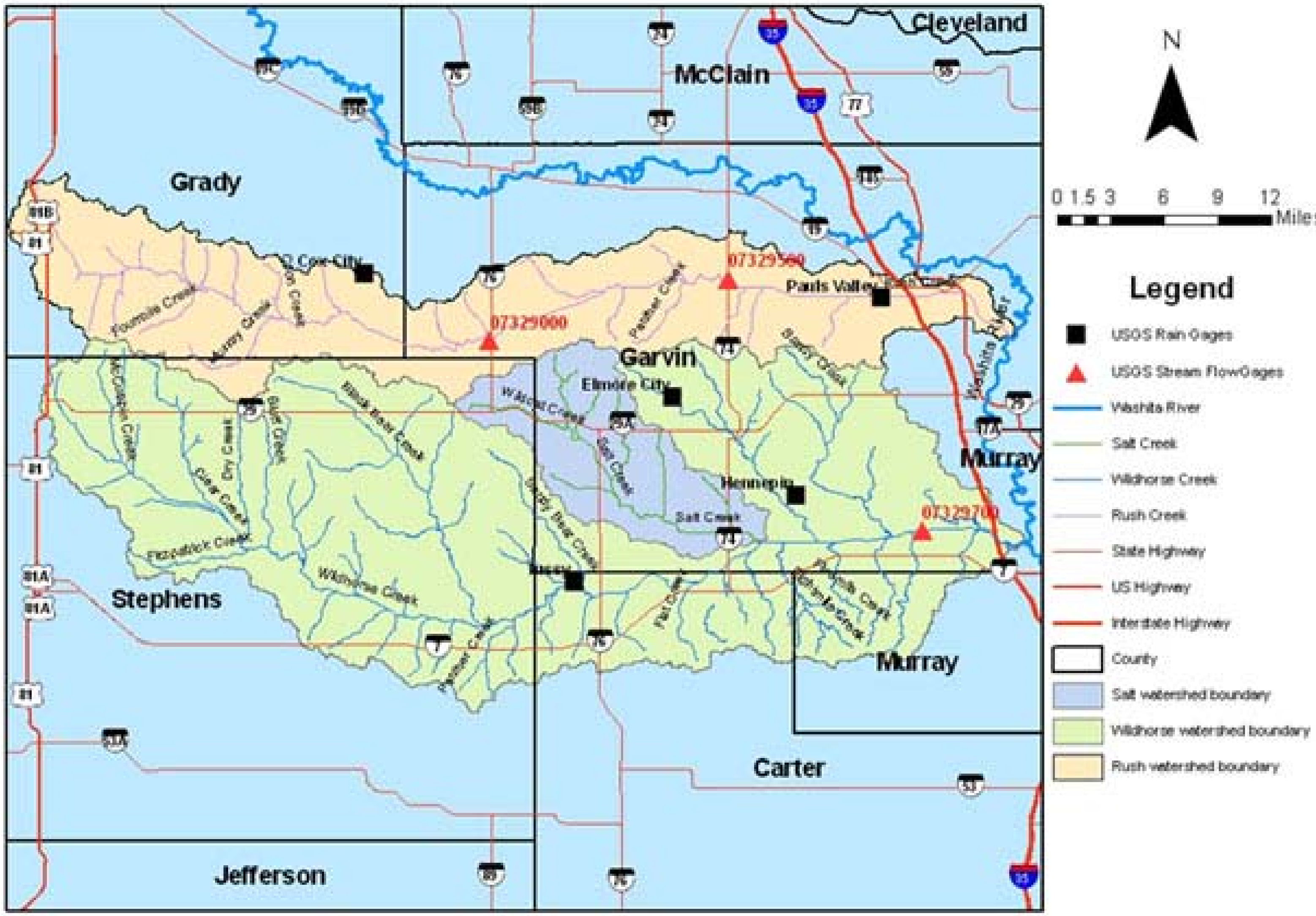


Figure 5. USGS stream flow and rain gaging stations for Rush, Wildhorse and Salt Creeks.

Documentation on the hydrological parameters of the creeks has been extracted from the USGS Water Resources Data in Oklahoma (USGS 2001). The report bears two types of documented extreme peak discharges. These are maximum peak discharges documented at 352 sites with stream flow gaging stations in Oklahoma and selected large peak discharges documented at 162 selected sites in Oklahoma at miscellaneous measurement sites without stream flow gaging stations or stream flow gaging stations with short records, for a total of 671 measurements. Flood frequency estimates are derived by using a Log-Pearson Type III distribution based on historical peak discharge values to define the frequency distribution. The sites are fairly well distributed statewide, however many streams, large and small, have never been monitored.

Annual peak discharge is the annual instantaneous maximum discharge. Changes in land use and urbanization can affect flood discharge which affects on the size and stability of channels. Systematic increases or decreases in the magnitude of annual peak discharges along with the slope and width of the stream channel can cause stream beds to either degrade or aggrade. The maximum degradation should occur during peak discharge due to the greater stream power on the channel and the shear stress (Capesius and Lehman, 2001). To study the stream-bed degradation, annual peak discharges plots were downloaded from USGS gage stations to evaluate past flood occurrences (Table 3). Large peak stream flows were recorded at different time periods. Table 4 shows the large peak flows at different USGS gage stations.

Table 3. Flood Frequency estimates based on at least 8 years of annual peak discharge data at USGS gage stations.

Station Number	Location	Type basin (N/R)	LPIII flood frequency estimates Peak discharge for indicated recurrence interval (cfs)						
			2 year	5 year	10 year	25 year	50 year	100 year	500 year
07329000	Purdy	[1]N	10000	16100	21100	28500	35000	42400	63500
		[2]R	3570	6980	10000	14800	19200	24300	39600
07329500	Maysville	N	9260	17700	25500	38400	50800	65800	114000
		R	5510	9800	13200	18100	22100	26500	38100
07329700	Hoover	R	11600	19800	25800	33900	40200	46700	62600

[1]N – Unregulated Basin, [2]R – Regulated Basin

Table 4. Peak flows recorded at USGS gage stations.

Station Number	Locations	Peak Flows (cfs)	Year
07329000	Purdy (Rush Creek)	30,000	1950
07329500	Maysville (Rush Creek)	38,500	1957
07329700	Hoover (Wildhorse Creek)	40,600	1990

Rush Creek flows through three Oklahoma counties: Garvin, Grady and Stephens. This study covers a tributary length of 58.39 miles intersecting major roadways. The total area of the watershed being drained by the Rush Creek is 266.69 square miles. The Rush Creek is characterized by meandering, medium hard shale, fine and coarse sand-mix, and a sandy soil channel. The channel slopes at an average of 5.97 ft/mile and the river bank height varies from 30 to 33 feet. Most of the measurements related to flow characteristics, riverbed and elevation have been calculated at the five bridges along Rush Creek which are as creek stations. The five bridges include, starting from the confluence of the Washita River, SH 77, I-35 North, I-35 South, SH 74 and SH 76.

Wildhorse Creek also flows through the three Oklahoma counties of Garvin, Grady and Stephens. This study covers a tributary length of 63.89 miles intersecting major roadways. The total area of the watershed being drained by the Wildhorse Creek is 647.46 square miles. Wildhorse Creek is characterized by meandering, medium hard shale, fine and coarse sand-mix, and a sandy soil channel. The channel slopes at an average of 4.87 ft/mile and the river bank height varies from 27 to 29.2 feet. Most of the measurements related to flow characteristics, riverbed and elevation have been calculated at the five bridges along the Wildhorse Creek, which are creek stations. The five bridges include, starting from the confluence of the Washita River, I-35 North, I-35 South, SH 74, SH 76, and U.S. 81.

Salt Creek flows through only Garvin County, Oklahoma. This study covers a tributary length of 19.05 miles intersecting major roadways. The total area of the watershed being drained by the Salt Creek is 81.8 square miles. Salt Creek is characterized by meandering, medium hard shale, fine and coarse sand-mix, and a sandy soil channel. The channel slopes at an average of 8.1 ft/mile and the river bank height varies from 21 to 30 feet. Most of the measurements related to flow characteristics, riverbed and elevation have been calculated at the three bridges along the Salt Creek which are creek stations. The three structures include, starting from the confluence of Wildhorse Creek, SH 74, SH 76 and SH 29.

There are three stream flow gaging stations of interest for this study basin. Two are located on Rush Creek and a third on Wildhorse Creek as shown in Figures 6 thru 8. The stream flow data was acquired from the US Geological Survey. As well, there are five rain gaging stations inside the watershed area as shown in Figures 9 thru 13. The precipitation data from these rain gaging stations was extracted from the Oklahoma Climatological Survey.

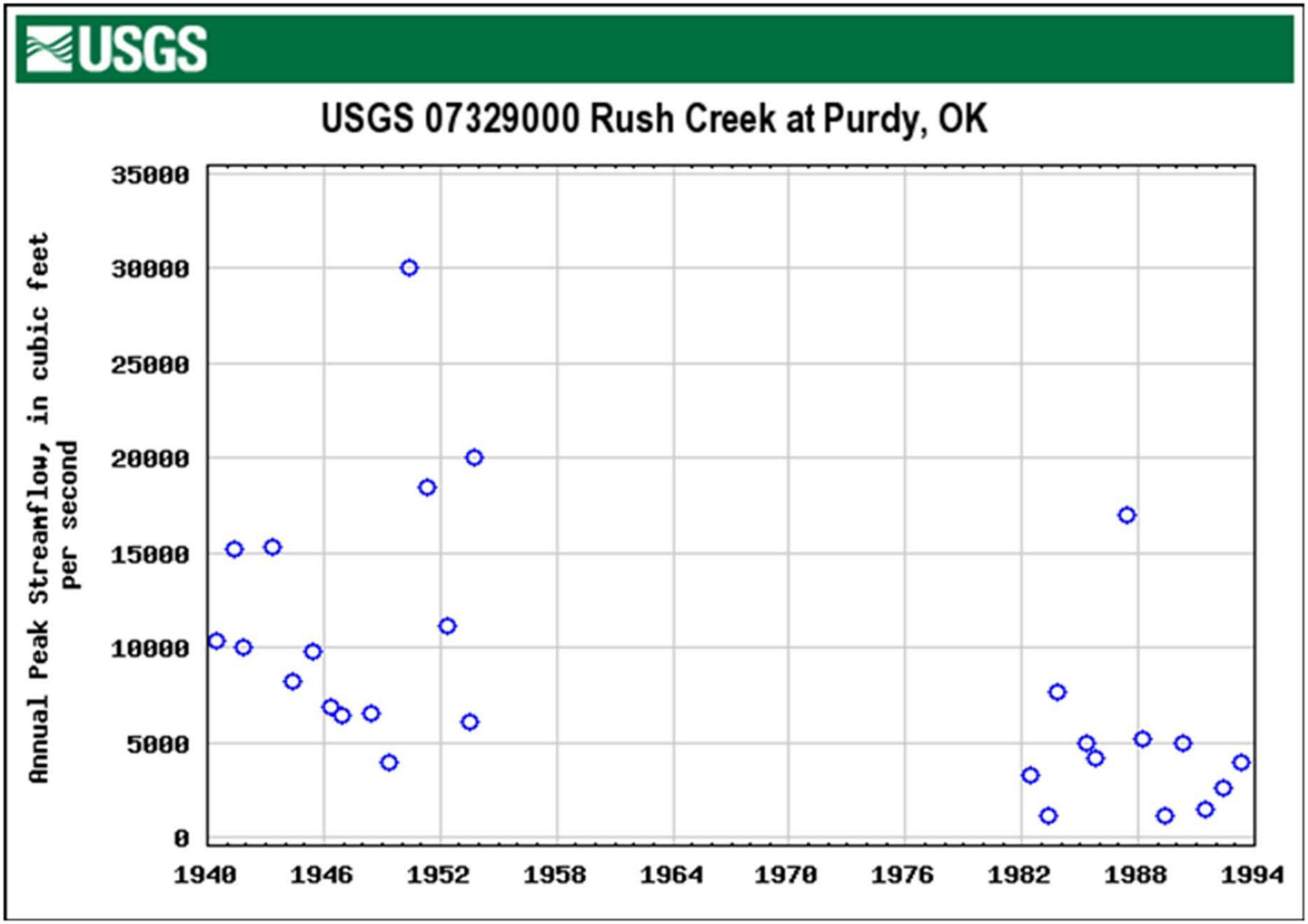


Figure 6. USGS 07329000 Rush Creek at Purdy, OK.

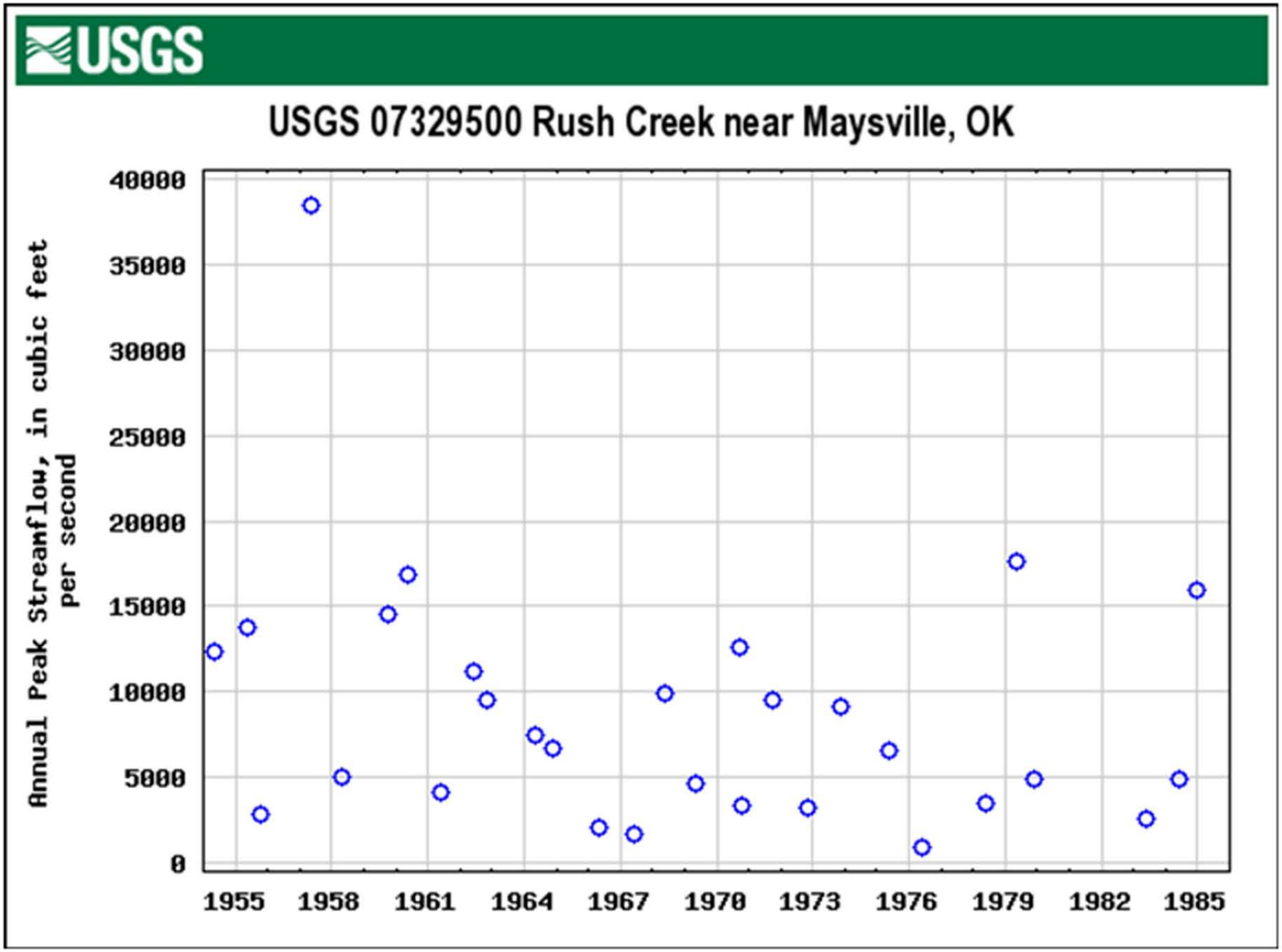


Figure 7. USGS 07329500 Rush Creek near Maysville, OK.

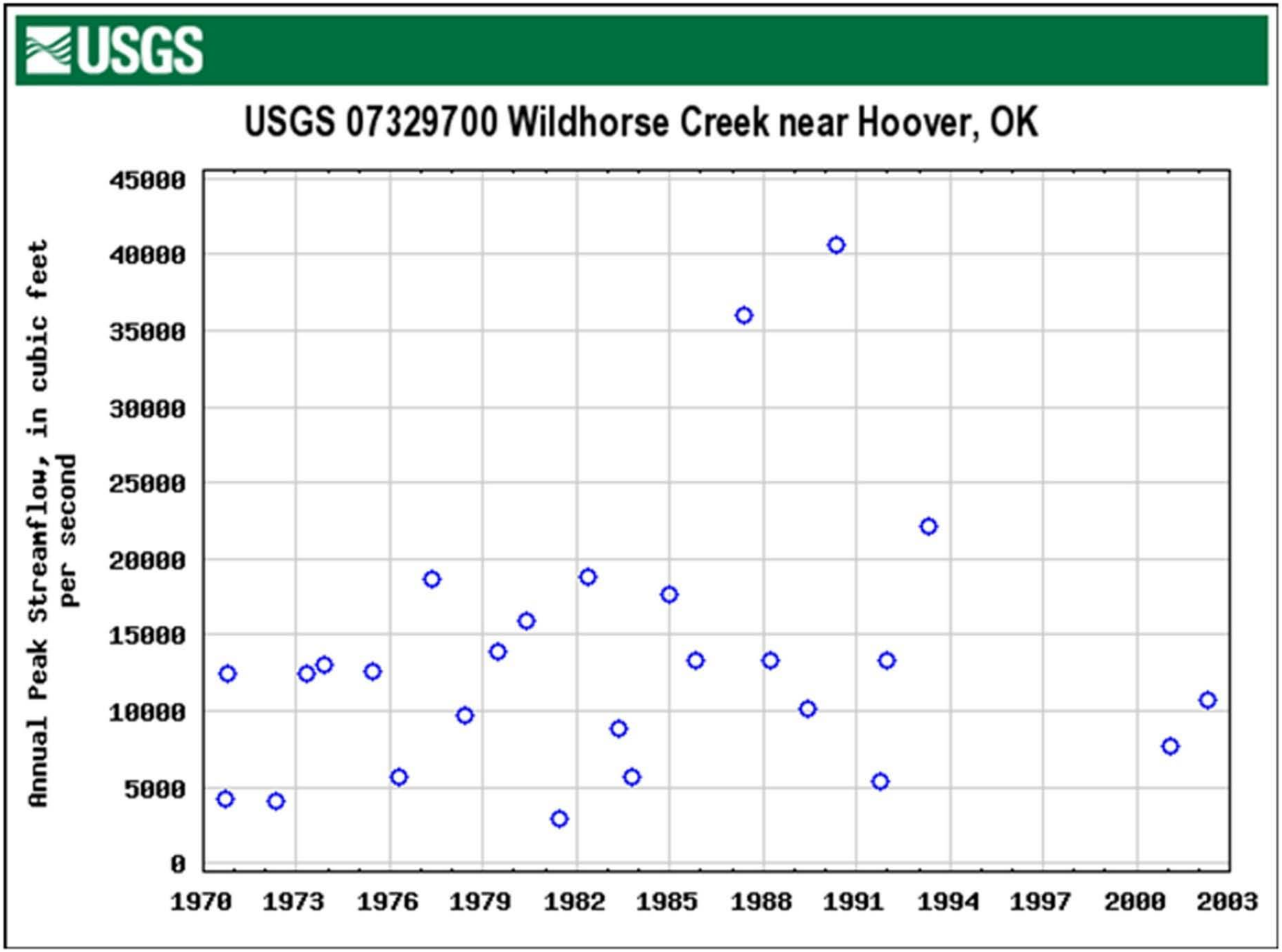


Figure 8. USGS 07329700 Wildhorse Creek near Hoover, OK.

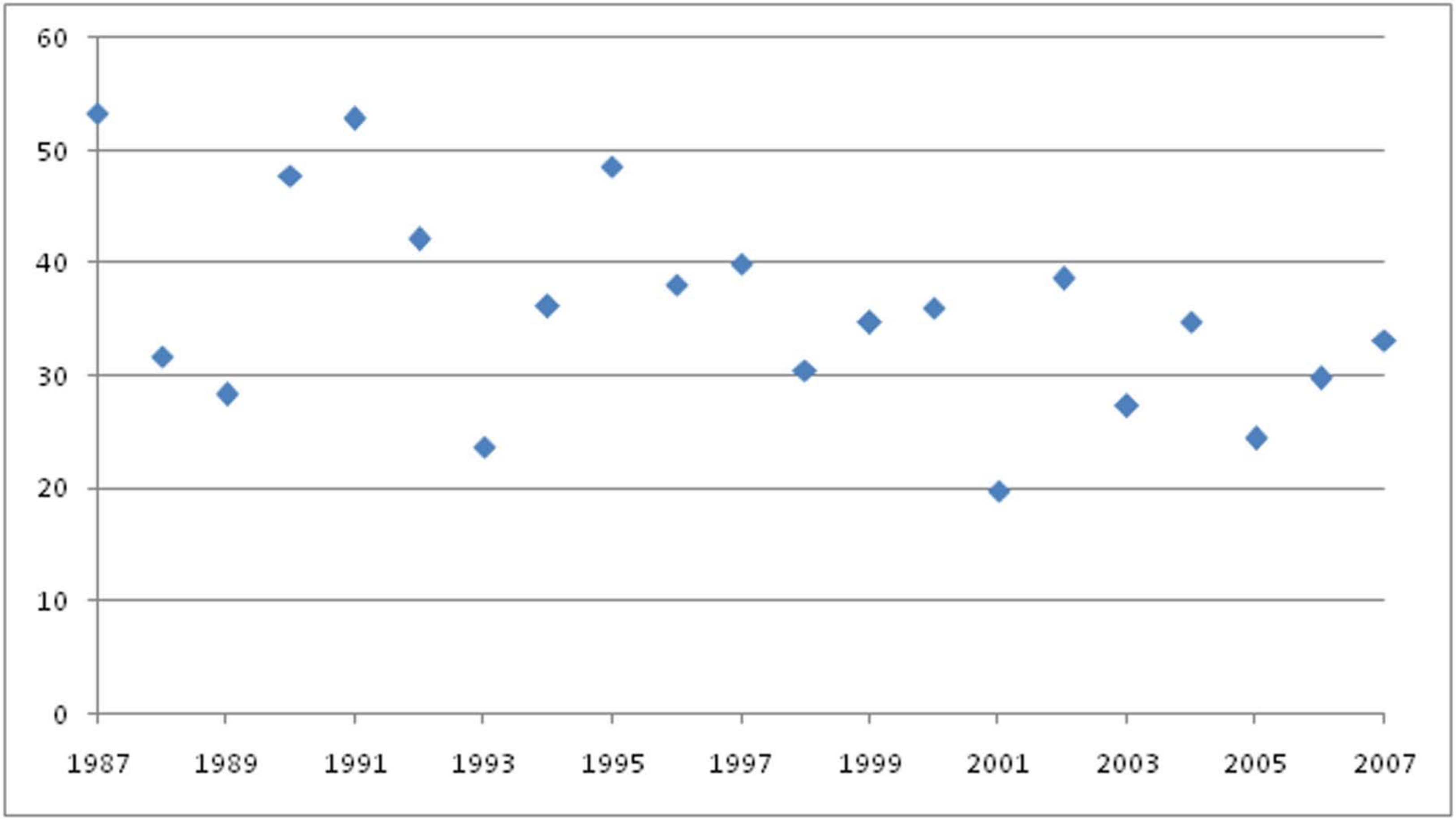


Figure 9. Annual precipitation (in/yr) Oklahoma Climatological Survey Site at Cox City, OK.

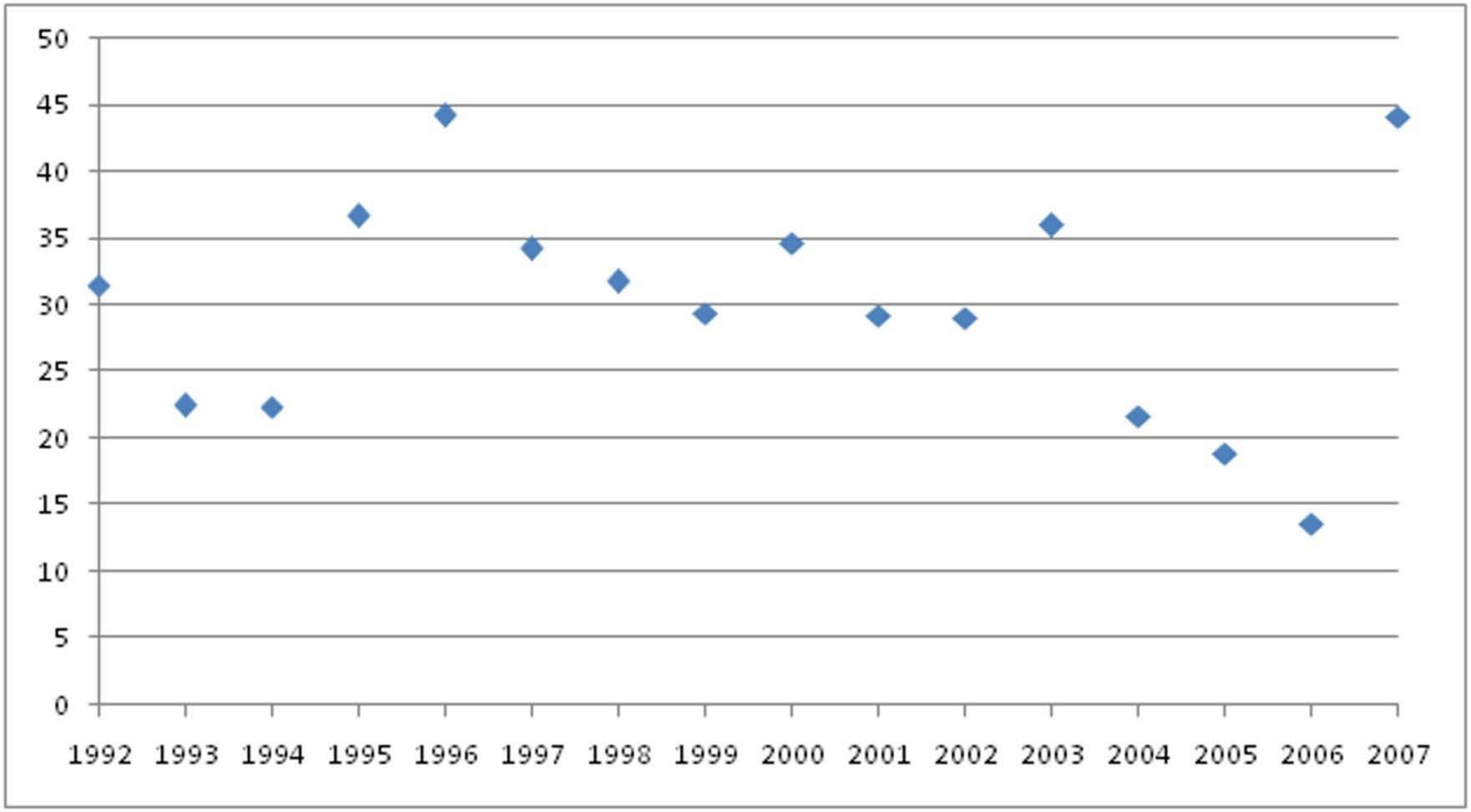


Figure 10. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Elmore City, OK.

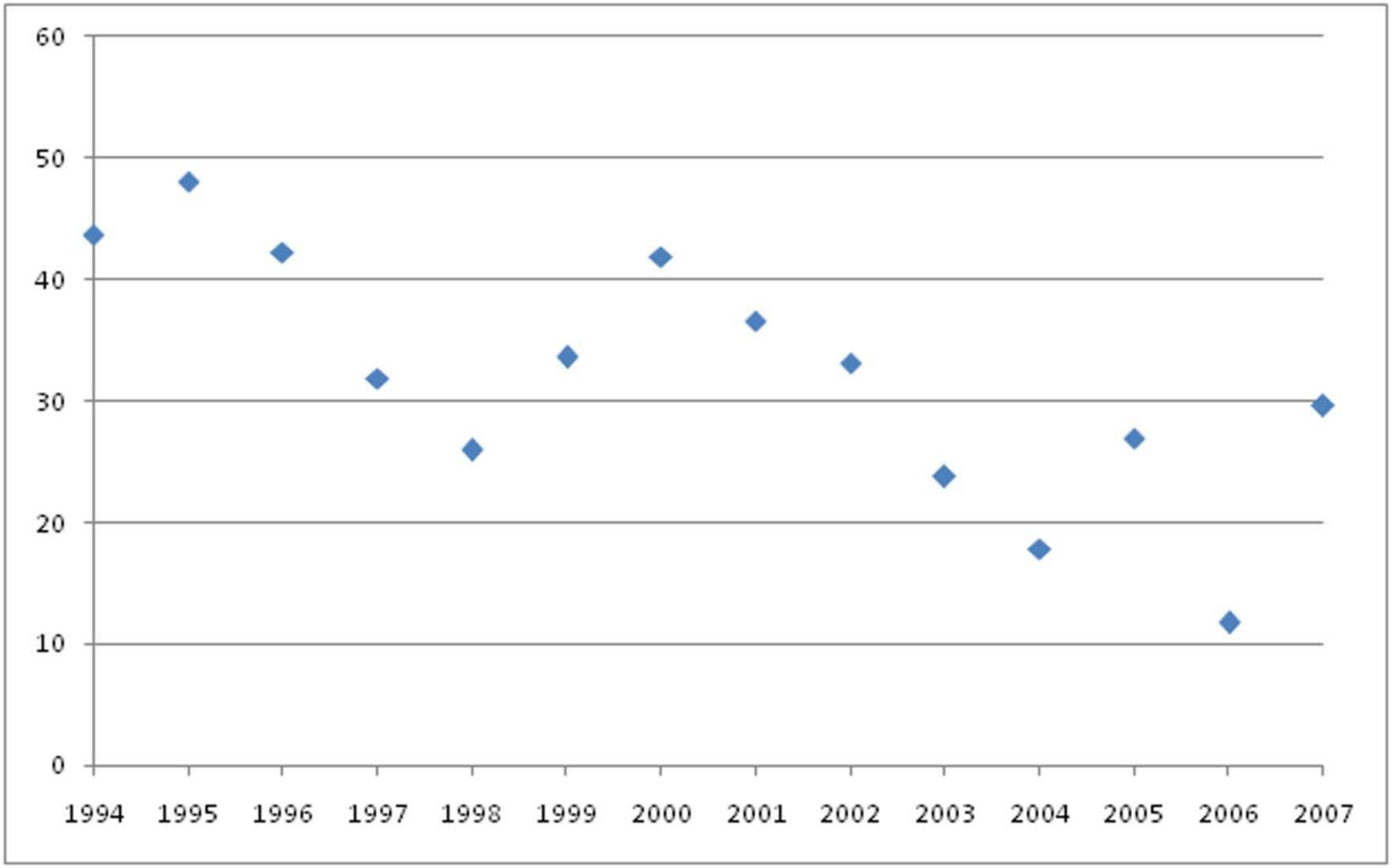


Figure 11. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Hennepin, OK.

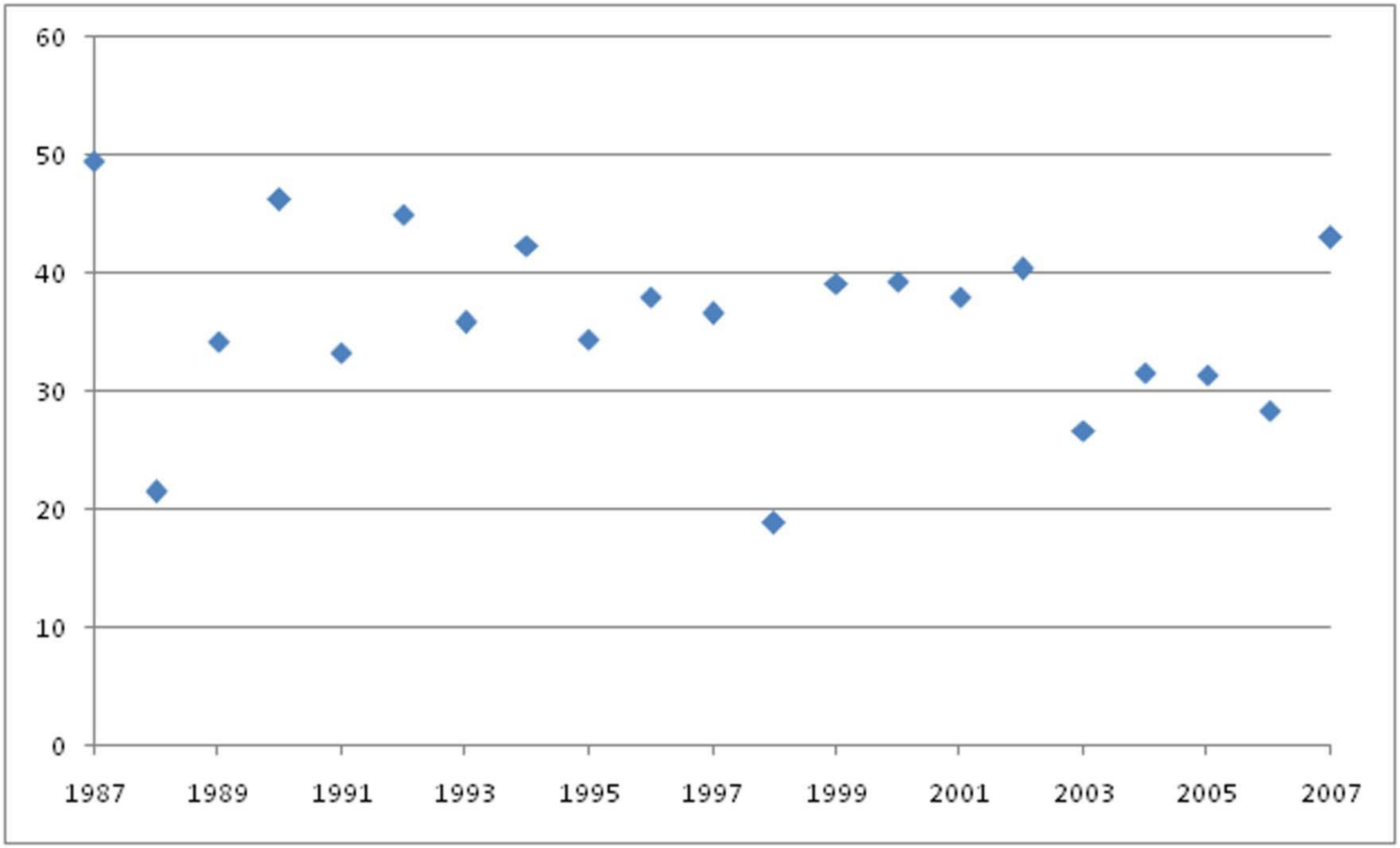


Figure 12. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Pauls Valley, OK.

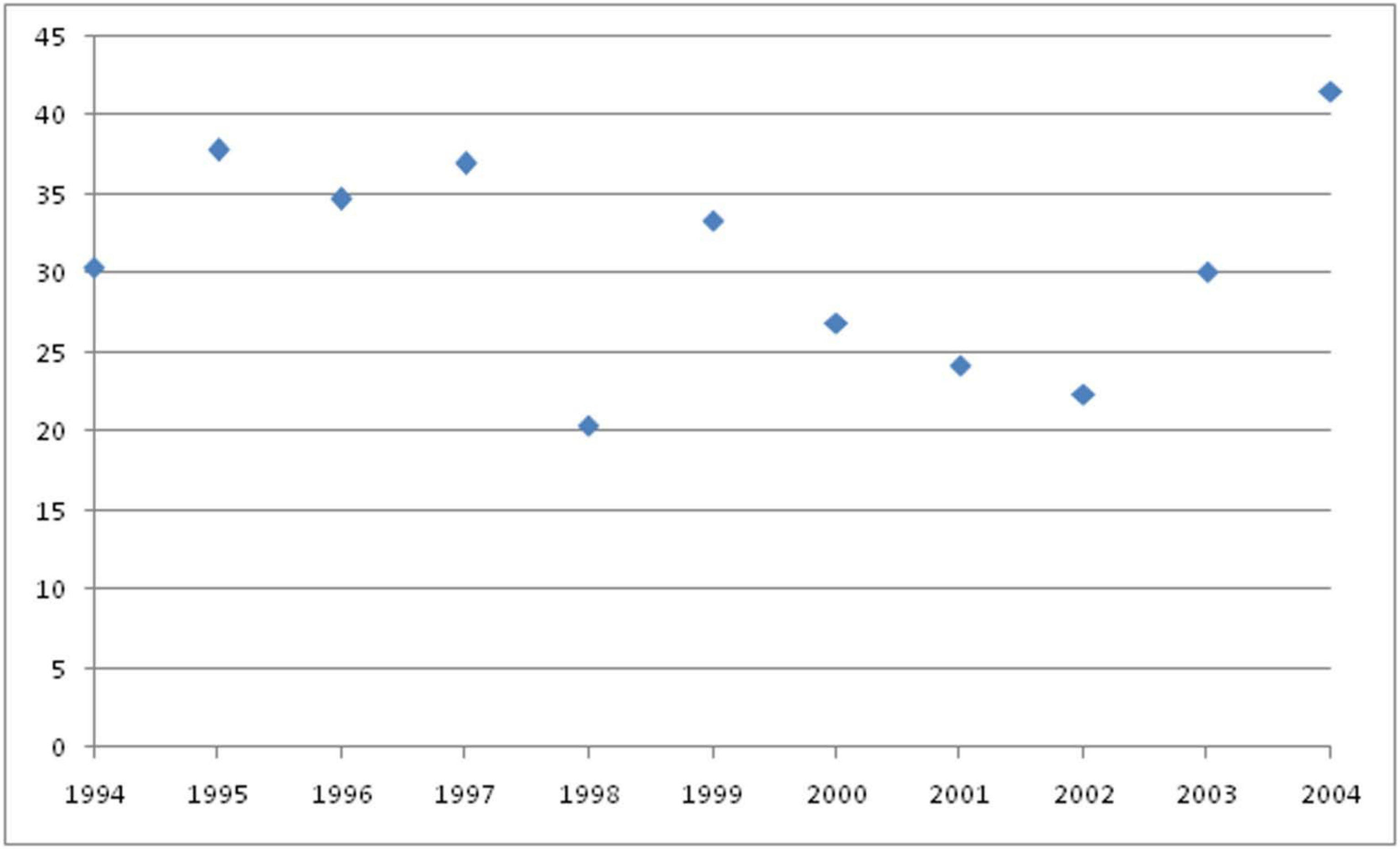


Figure 13. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Tussy, OK.

V. Analysis of Cross-sectional Profiles

Field data measured over a 50-year period by the Oklahoma Department of Transportation (ODOT) was examined in this study. Throughout the study reach, 13 Creek Stations (CS) were selected: CS 1 to CS 5 on Rush Creek, CS 1 to CS 3 on Salt Creek, and CS 1 to CS 5 on the Wildhorse Creek. Eleven out of thirteen stations have cross-section geometry data. All thirteen stations have flow line data which was measured at bridge crossings.

A. Rush Creek consists of five bridges, starting downstream to upstream: b13120, b17568, b17569, b10738, and b12643.

Bridge 13120 on US Highway 77 was built in the year 1953. The location of the bridge in terms of the latitude and longitude of 34° 44’ 05” N and 97° 12’ 51” W respectively. Since cross-sectional profile values were not available for this structure a profile chart could not be generated.

Bridge 17568 on Interstate Highway 35 northbound was built in the year 1969. The location of the bridge is about 6 miles north of the junction of SH 29 and I-35 with the latitude and longitude of 34° 43’ 55” N and 97° 15’ 26” W respectively. Figure 14 demonstrates the extent of river bed degradation at the bridge. Figure 15 shows the typical damage to piers on this bridge.

Bridge 17569 on Interstate Highway 35 southbound was built in the year 1969. The location of the bridge is about 6 miles north of the junction of SH 29 and I-35 with the latitude and longitude of 34° 43’ 54” N and 97° 15’ 28” W respectively. Figure 16 demonstrates the extent of river bed degradation at the bridge. Figure 17 shows a roadway profile of this bridge.

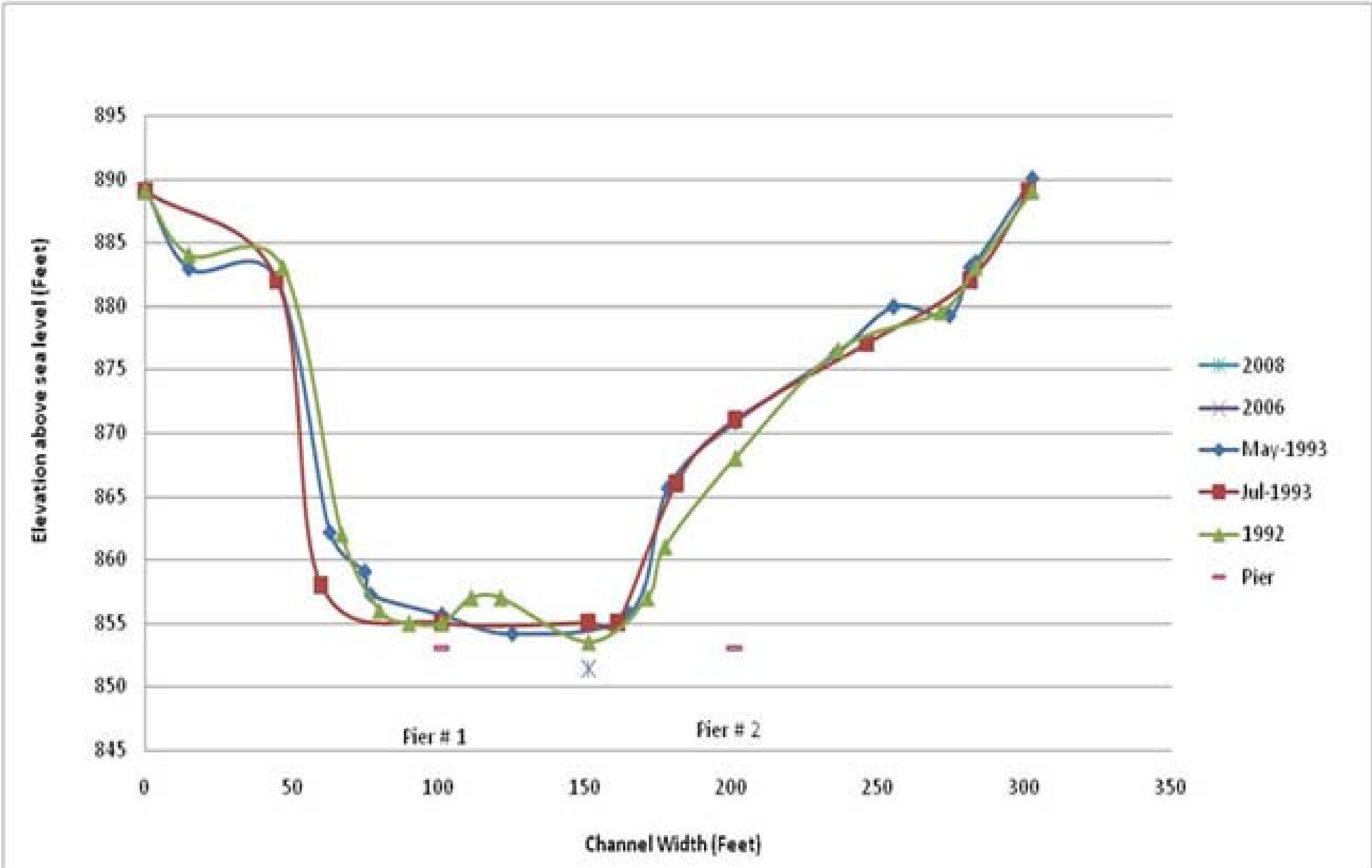


Figure 14. Cross-sectional profile at bridge 17568 on I-35 NB over Rush Creek.

Figure 15. Picture demonstrating extent of damage to pier at bridge 17568 on I-35 NB over Rush Creek.

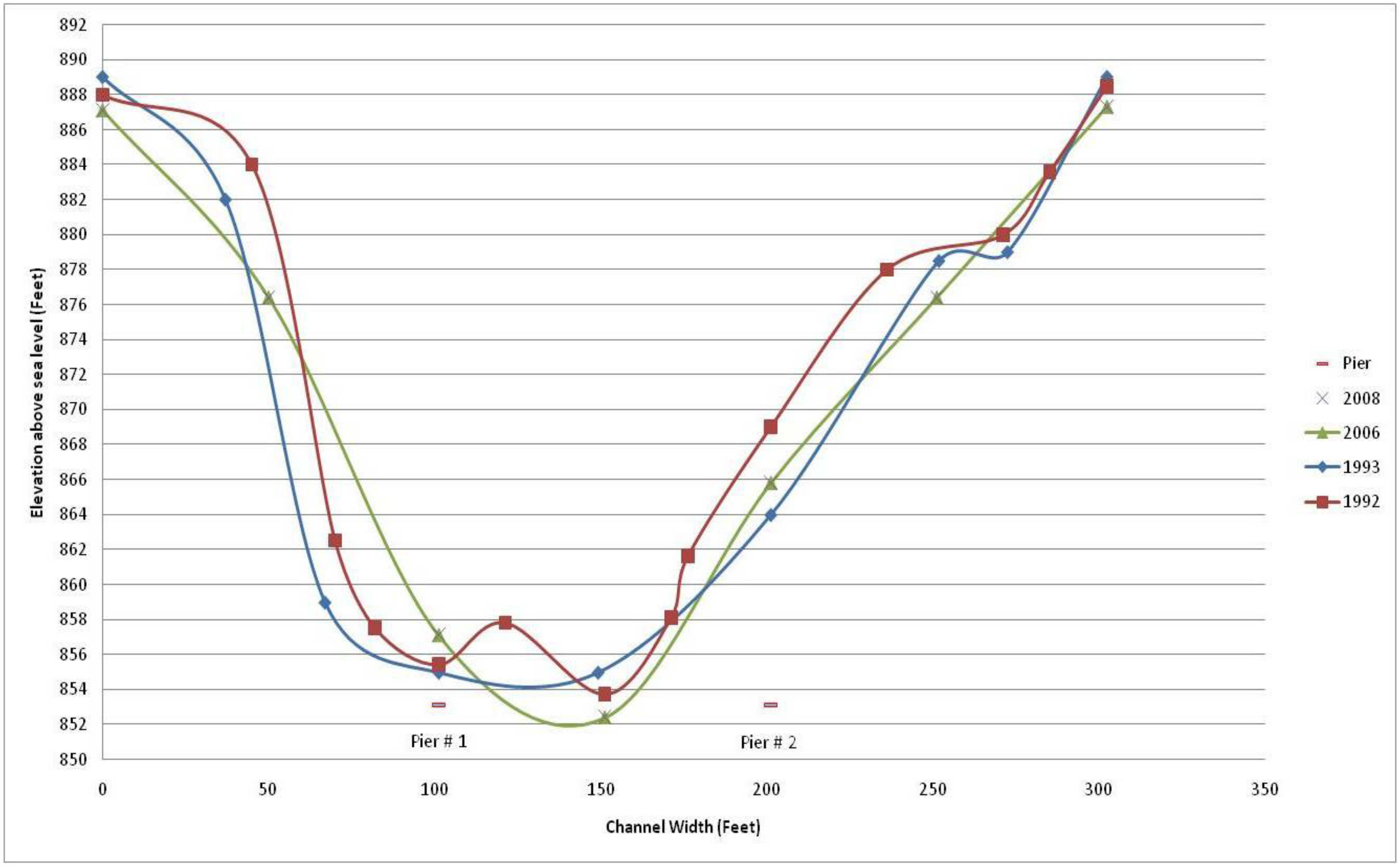


Figure 16. Cross-sectional profiles at bridge 17569 on I-35 SB over Rush Creek.

Figure 17. Profile picture of bridge 17569 on I-35 SB over Rush Creek.

Bridge 10738 on State Highway 74 was built in the year 1947 and is the oldest bridge on Rush Creek. The location of the bridge is about 16.4 miles north of Murray County line with the latitude and longitude of 34° 44’ 36” N and 97° 24’ 20” W respectively. Figure 18 demonstrates the extent of river bed degradation at the bridge. Figure 19 shows a photo of the existing profile of the roadway for this bridge. Figure 20 demonstrates the damage on the south pier of the bridge.

Finally, bridge 12643 on State Highway 76 was built in the year 1951. The location of the bridge in terms of the latitude and longitude of 34° 41’ 46” N and 97° 35’ 57” W respectively. Figure 21 demonstrates the extent of river bed degradation at the bridge. Figure 22 demonstrates the damage on the pier of the bridge. Since cross-sectional profile values were not available for this structure, a profile chart could not be generated.

B. Wildhorse Creek consist of five structures listed from downstream to upstream: b17590, b17591, b21120, b13235, and a culvert c18199.

Bridge 17590 on Interstate Highway 35 northbound was built in the year 1969. The location of the bridge is about 2.0 miles north junction State Highway 7 with the latitude and longitude of 34° 31’ 59” N and 97° 11’ 13” W respectively. Figure 23 demonstrates the extent of river bed degradation at the bridge. Figure 24 demonstrates the flood water level at the pier of this bridge.

Bridge 17591 on Interstate Highway 35 southbound was built in the year 1969. The location of the bridge is about 2.0 miles north junction State Highway 7 with the latitude and longitude of 34° 31’ 59” N and 97° 11’ 15” W respectively. Figure 25 demonstrates the extent of river bed degradation at the bridge. At the time of publication there was no photo available for this structure.

Bridge 21120 on State Highway 74 was built in the year 1985. The location of the bridge is about 0.5 miles north of the Carter Country line at latitude and longitude of 34° 30’ 55” N and 97° 24’ 19” W respectively. Figure 26 demonstrates the extent of river bed degradation at the bridge. Figures 27 and 28 demonstrate the extent of damage to the piers of this bridge.

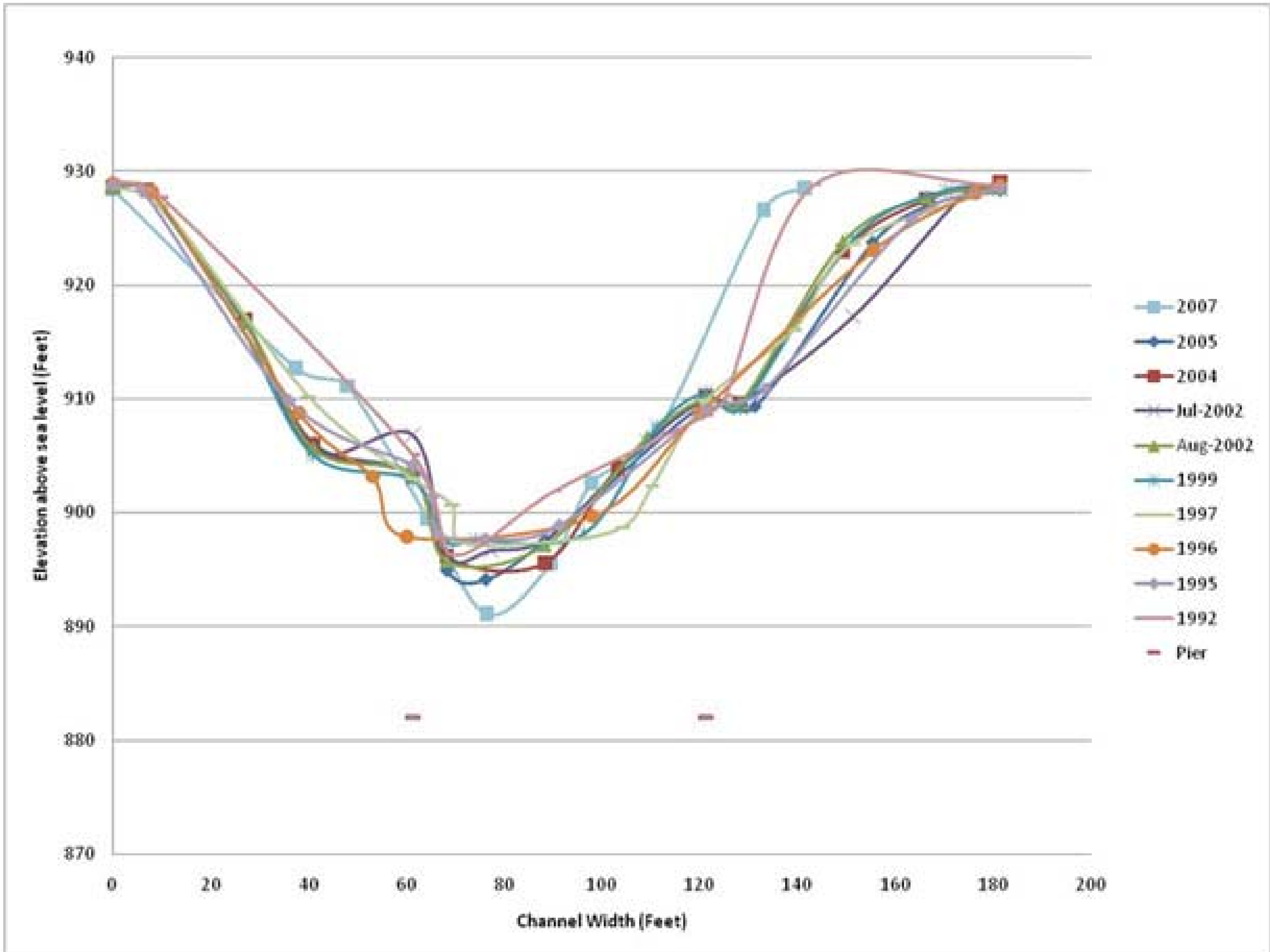


Figure 18. Cross-sectional profiles at bridge 10738 on SH 74 over Rush Creek.

Figure 19. Profile picture of bridge 10738 on SH 74 over Rush Creek.

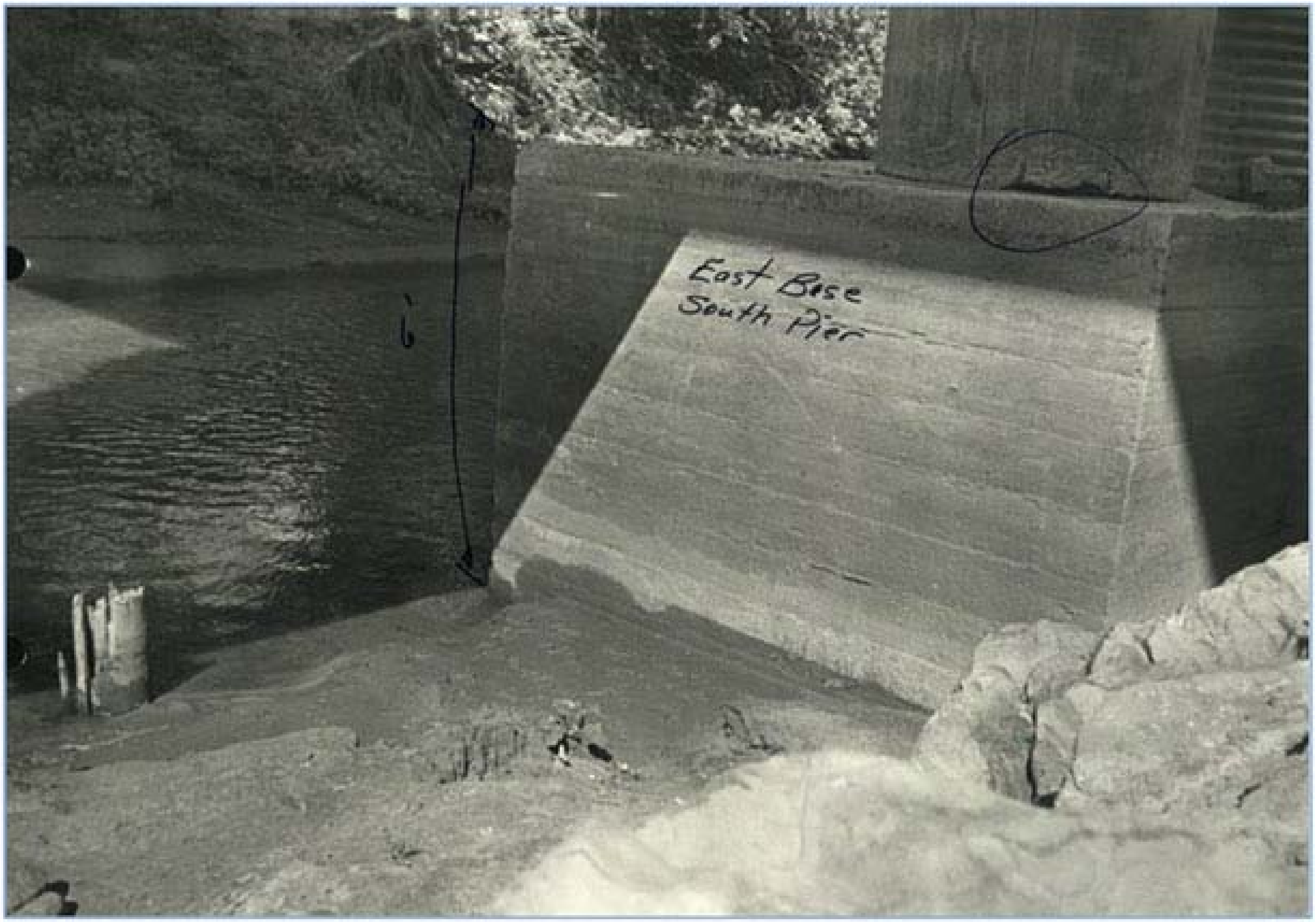


Figure 20. Picture demonstrating extent of damage to south pier at bridge 10738 on SH 74 over Rush Creek.

Figure 21. Picture demonstrating extent of damage to pier.

Figure 22. Picture demonstrating extent of damage to pier ar bridge 12643 on SH 76 over Rush Creek.

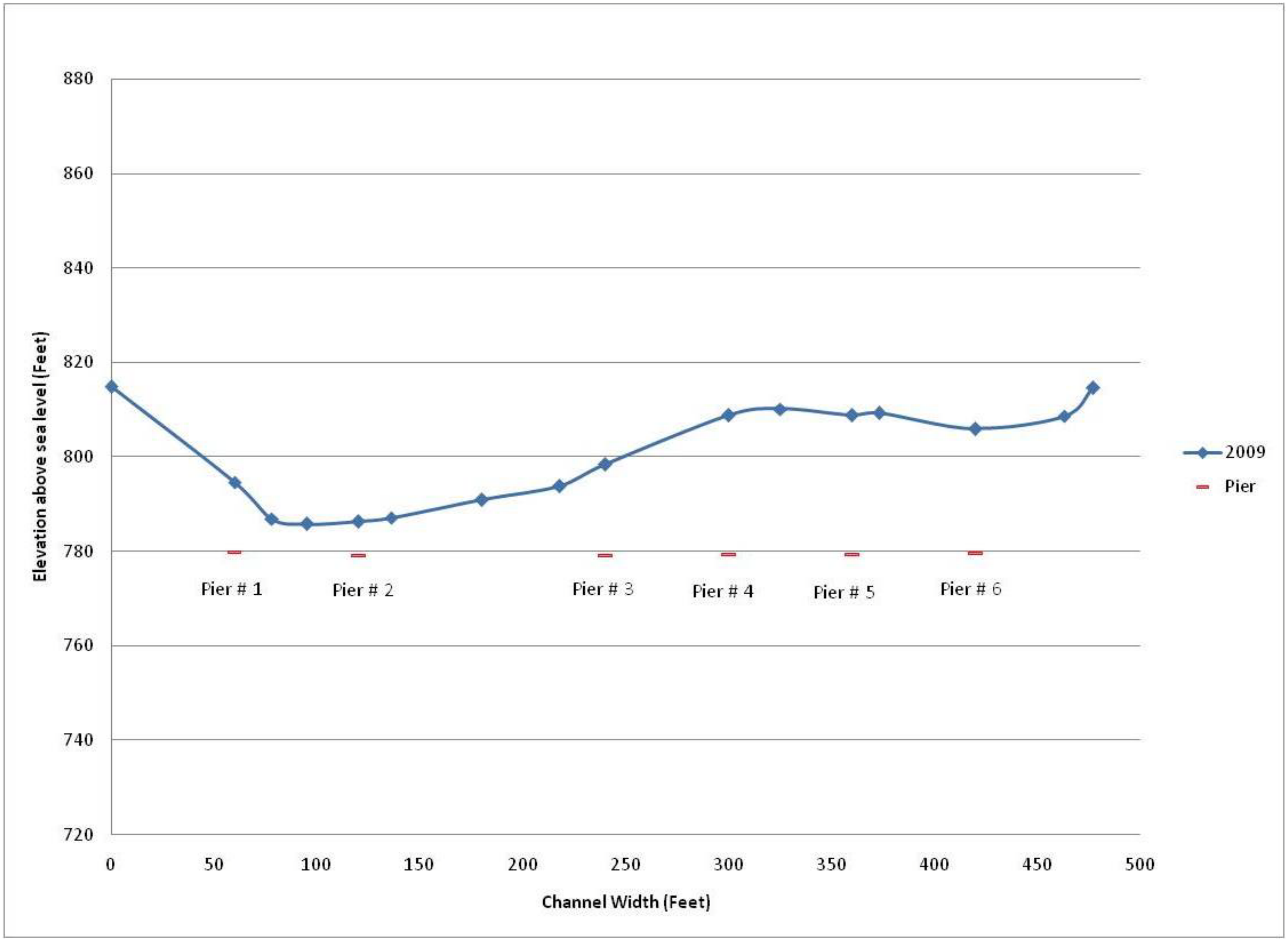


Figure 23. Cross-sectional profile at bridge 17590 on I-35 NB over Wildhorse Creek.

Figure 24. Picture demonstrating flood water level at pier at bridge 17590 on I-35 NB over Wildhorse Creek.

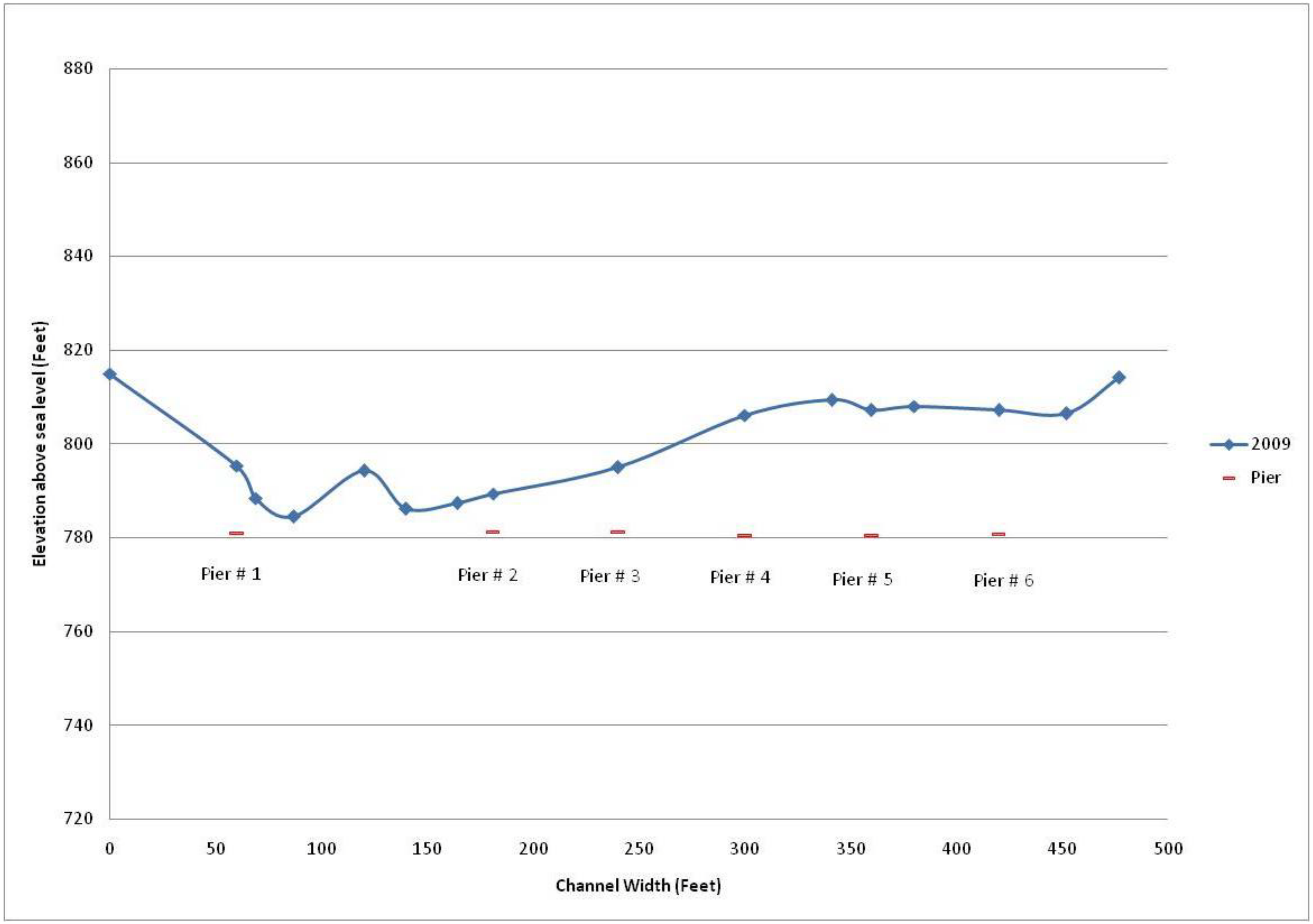


Figure 25. Cross-sectional profile at bridge 17591 on I-35 SB over Wildhorse Creek.

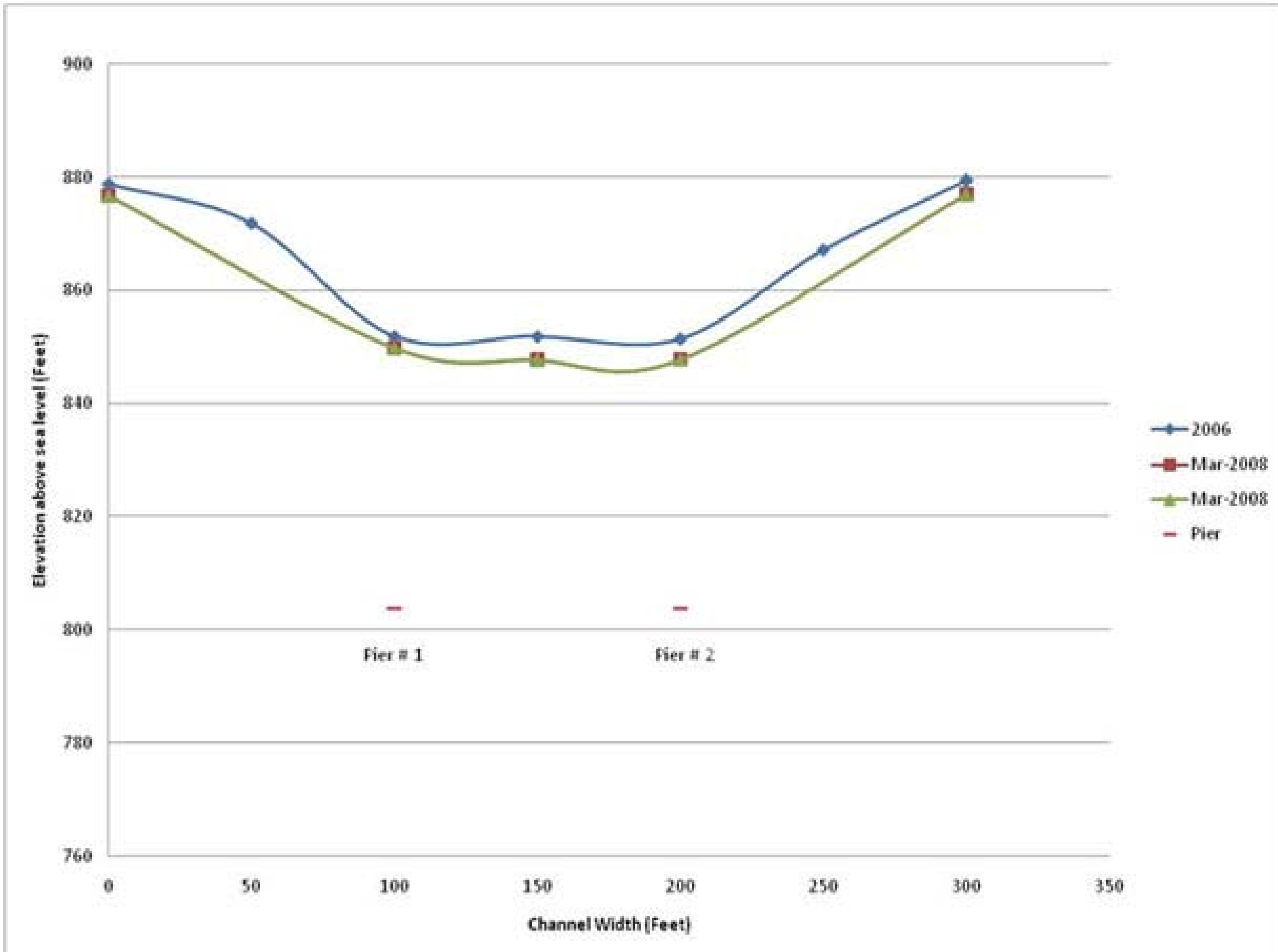


Figure 26. Cross-sectional profiles at bridge 21120 on SH 74 over Wildhorse Creek.

Figure 27. Picture demonstrating extent of damage to piers at bridge 21120 on SH 74 over Wildhorse Creek.

Figure 28. Picture demonstrating extent of damage to piers (b21120).

Bridge 13235 on State Highway 76 was built in the year 1954 and is the oldest bridge on Wildhorse Creek. The location of the bridge is about 2.8 miles north of the junction with State Highway 7 and the latitude and longitude of 34° 29’ 23” N and 97° 30’ 35” W respectively. Figure 29 demonstrates the extent of river bed degradation at the bridge. Figure 30 demonstrates the extent of damage to the piers for this structure.

Finally, culvert 18199 on State Highway 29 was built in the year 1972. The location of the culvert is about 0.4 miles east of the junction with State Highway 81 and the latitude and longitude of 34° 38’ 51” N and 97° 57’ 07” W respectively. Since cross sectional profile values for this culvert were not available, a profile chart could not be created for this bridge. Figure 31 demonstrates the extent of damage to this structure.

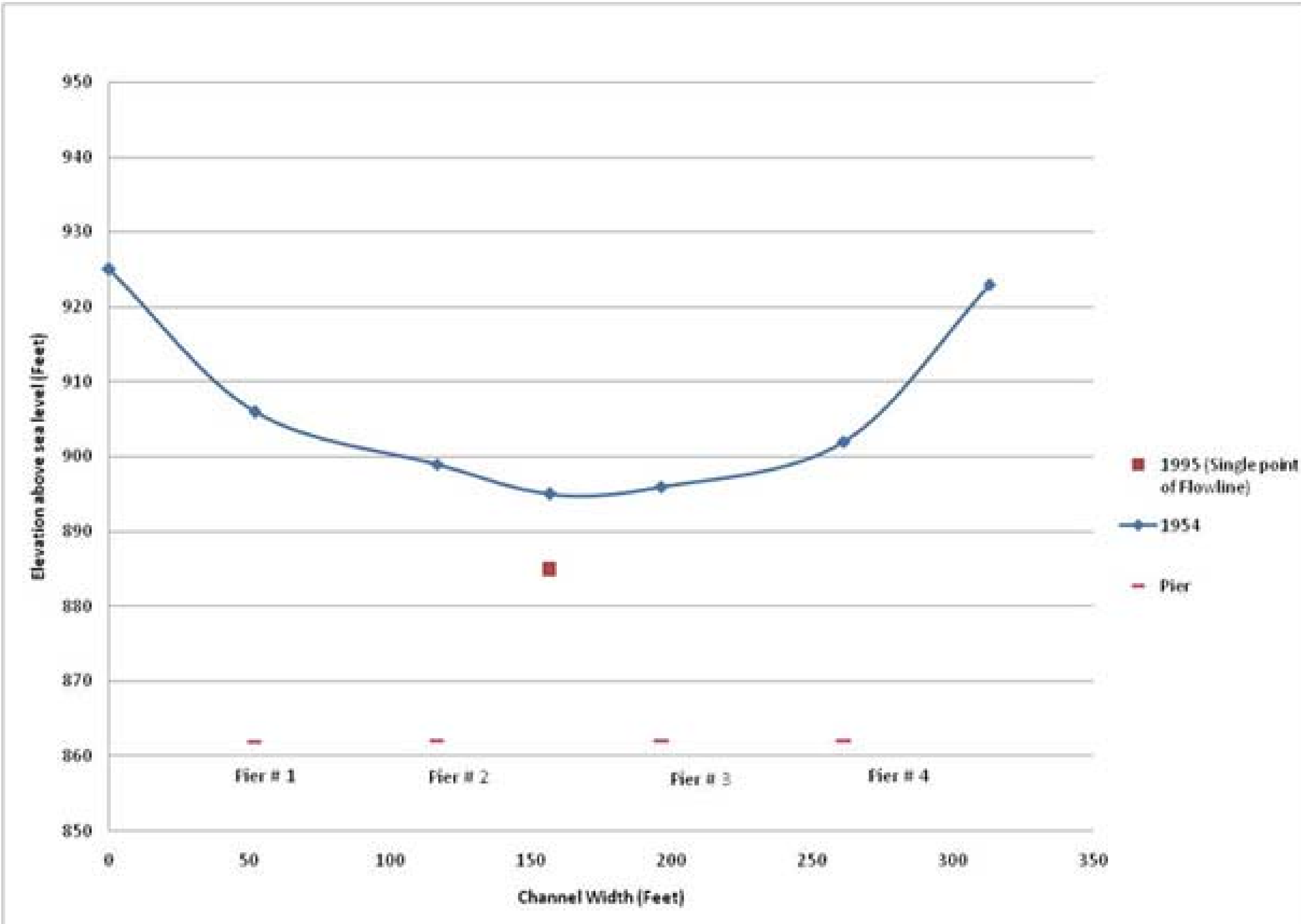


Figure 29. Cross-sectional profile at bridge 13235 on SH 76 over Wildhorse Creek.

Figure 30. Picture demonstrating extent of damage to piers at bridge 13235 on SH 76 over Wildhorse Creek.

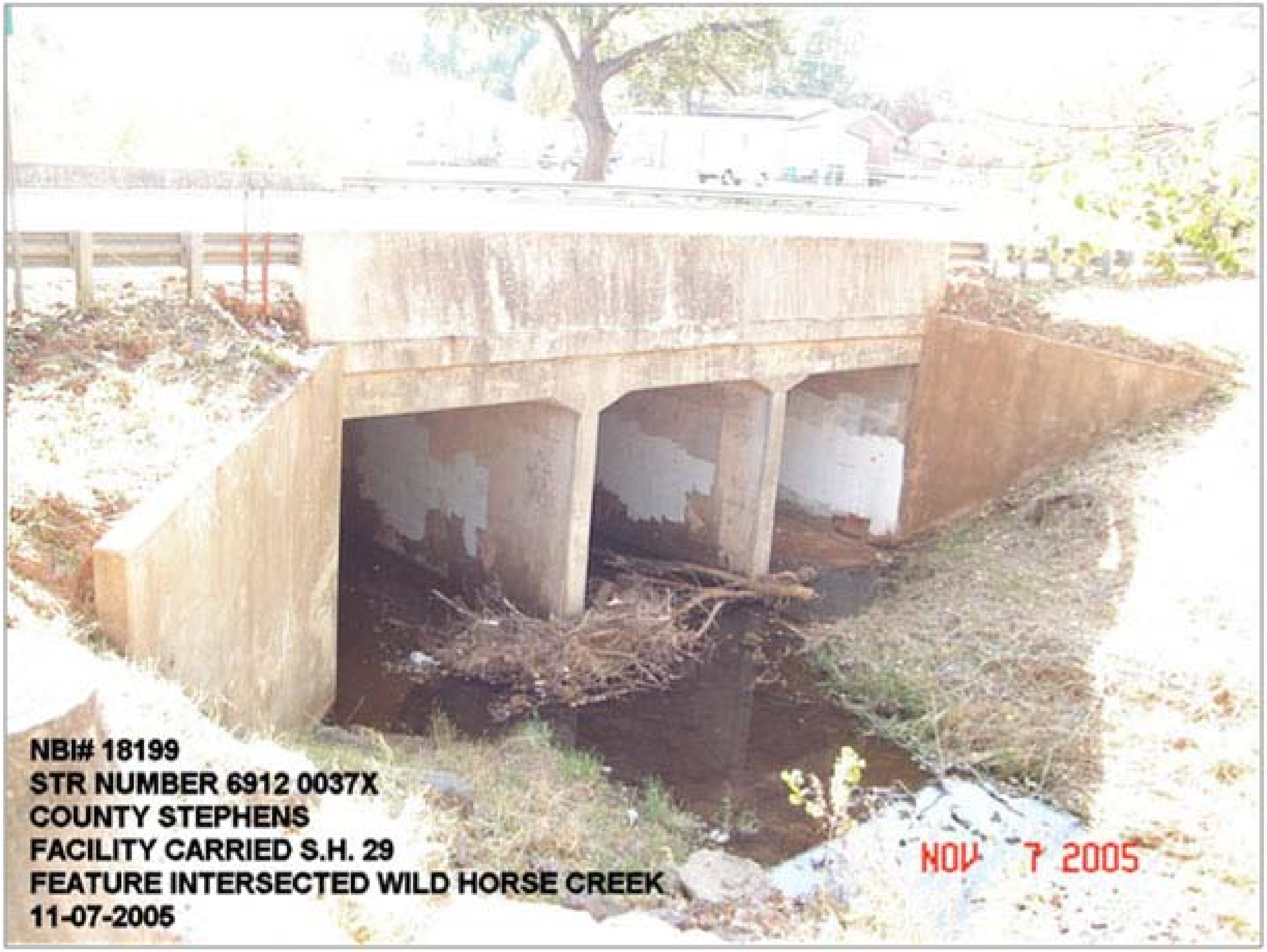


Figure 31. Picture demonstrating extent of damage at culvert 18199 on SH 29 over Wildhorse Creek.

C. Salt Creek consists of three bridges listed from downstream to upstream: b19629, b13515 and b13060.

Bridge 19629 on State Highway 74 was built in the year 1979. The location of the bridge is about 2.5 miles north of the Carter County line at latitude and longitude of 34° 41’ 46” N and 97° 35’ 57” W respectively. Figure 32 demonstrates the extent of river bed degradation at the bridge. Figure 33 demonstrates the extent of damage to the piers for this structure.

Bridge 13515 on State Highway 76 was built in the year 1955. The location of the bridge is about 6.1 miles north of the Carter County line at latitude and longitude of 34° 35’ 43” N and 97° 30’ 37” W respectively. Figure 34 demonstrates the extent of river bed degradation at the bridge. Figure 35 demonstrates the extent of damage to the piers for this structure.

Finally, bridge 13060 on State Highway 29 was built in the year 1953 and is the oldest bridge on Salt Creek. The location of the bridge is about 1.5 miles east of the Stephens County line at latitude and longitude of 34° 37’ 49” N and 97° 32’ 09” W respectively. Figure 36 demonstrates the extent of river bed degradation at the bridge. Figure 37 demonstrates the extent of damage to the piers for this structure.

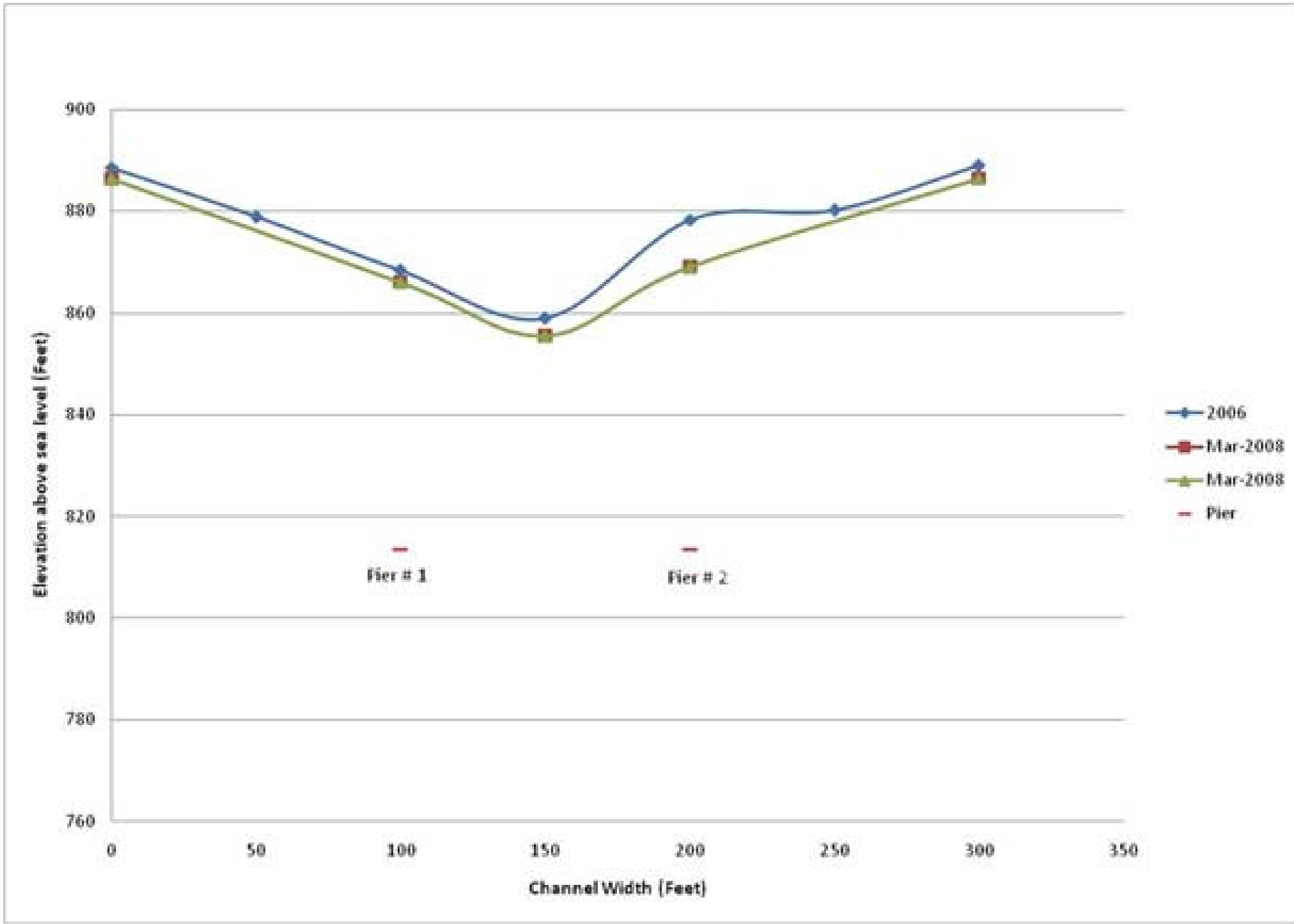


Figure 32. Cross-sectional profiles at bridge 19629 on SH 74 over Salt Creek.

Figure 33. Picture demonstrating extent of damage to piers at bridge 19629 on SH 74 over Salt Creek.

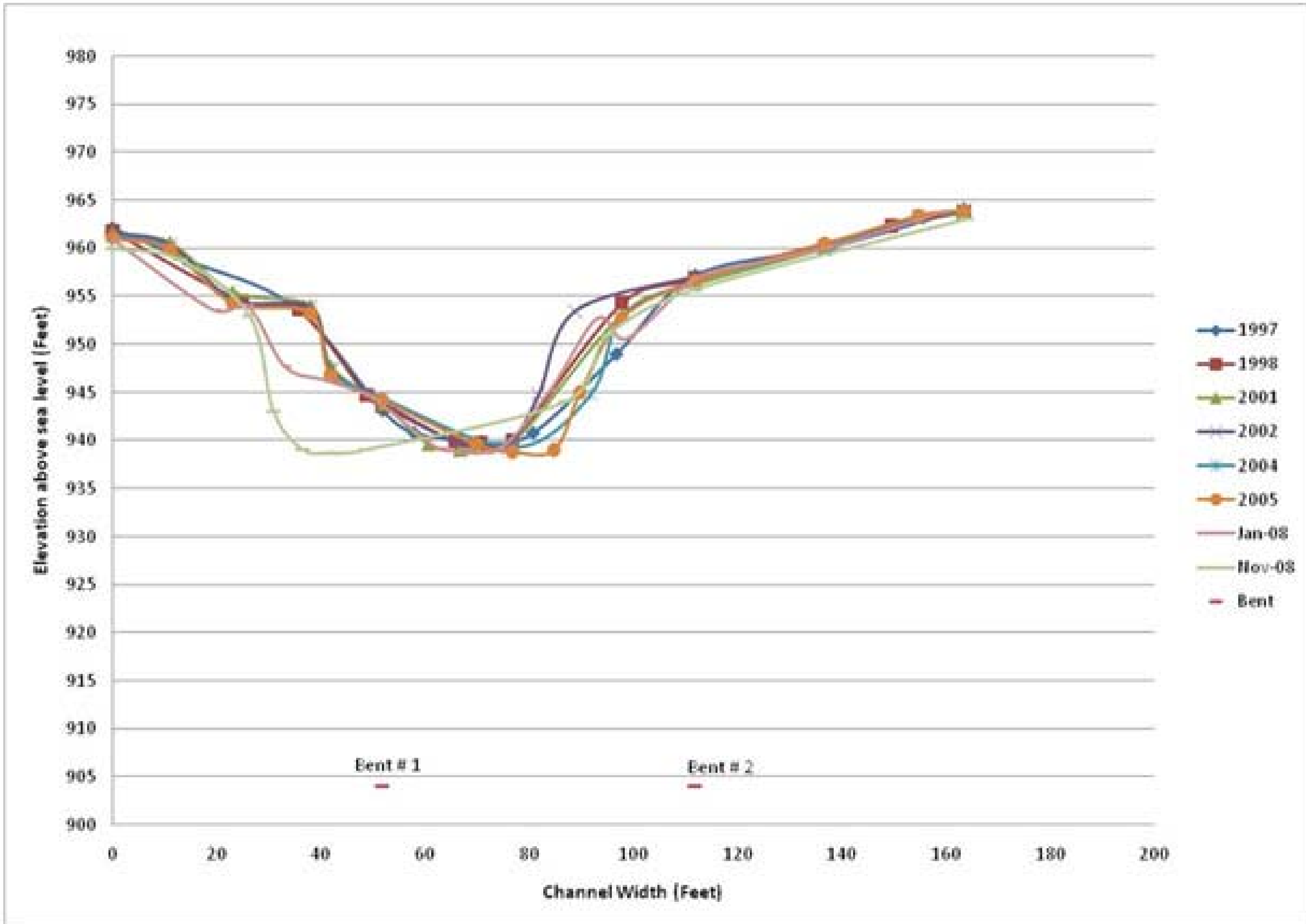


Figure 34. Cross-sectional profiles at bridge 13515 on SH 76 over Salt Creek.

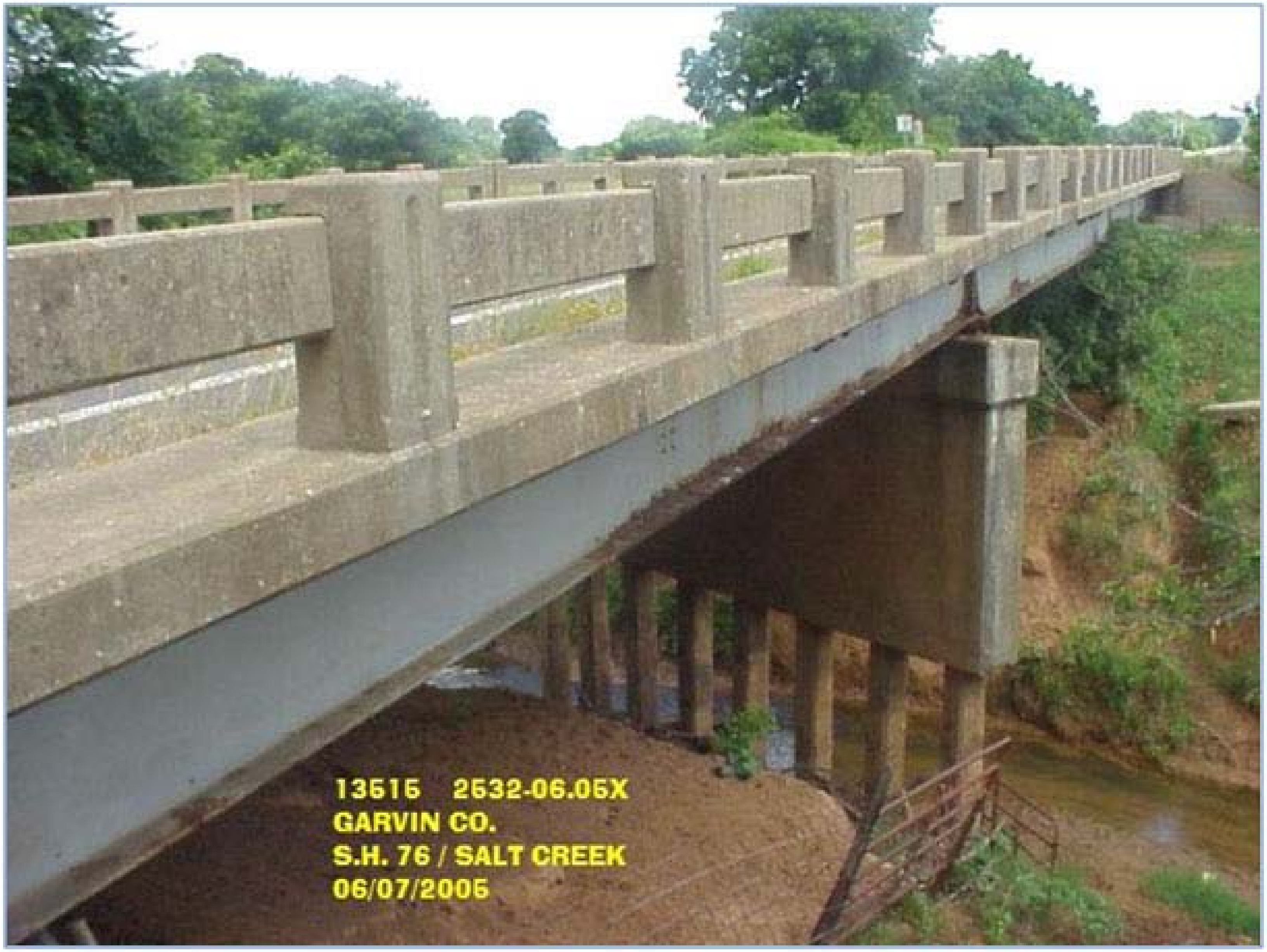


Figure 35. Picture demonstrating extent of damage to piers at bridge 13515 on SH 76 over Salt Creek.

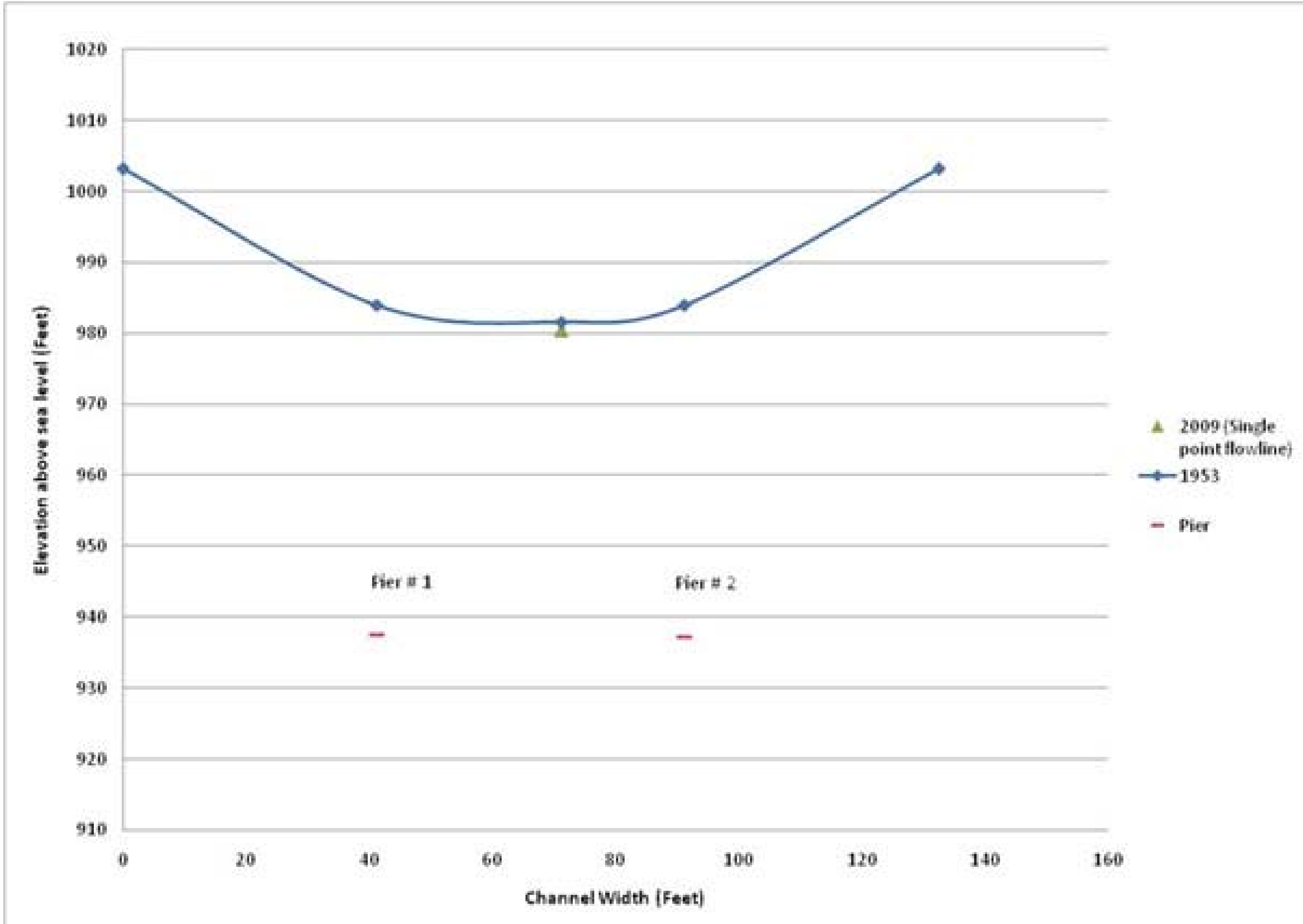


Figure 36. Cross-sectional profile at bridge 13060 on SH 29 over Salt Creek.

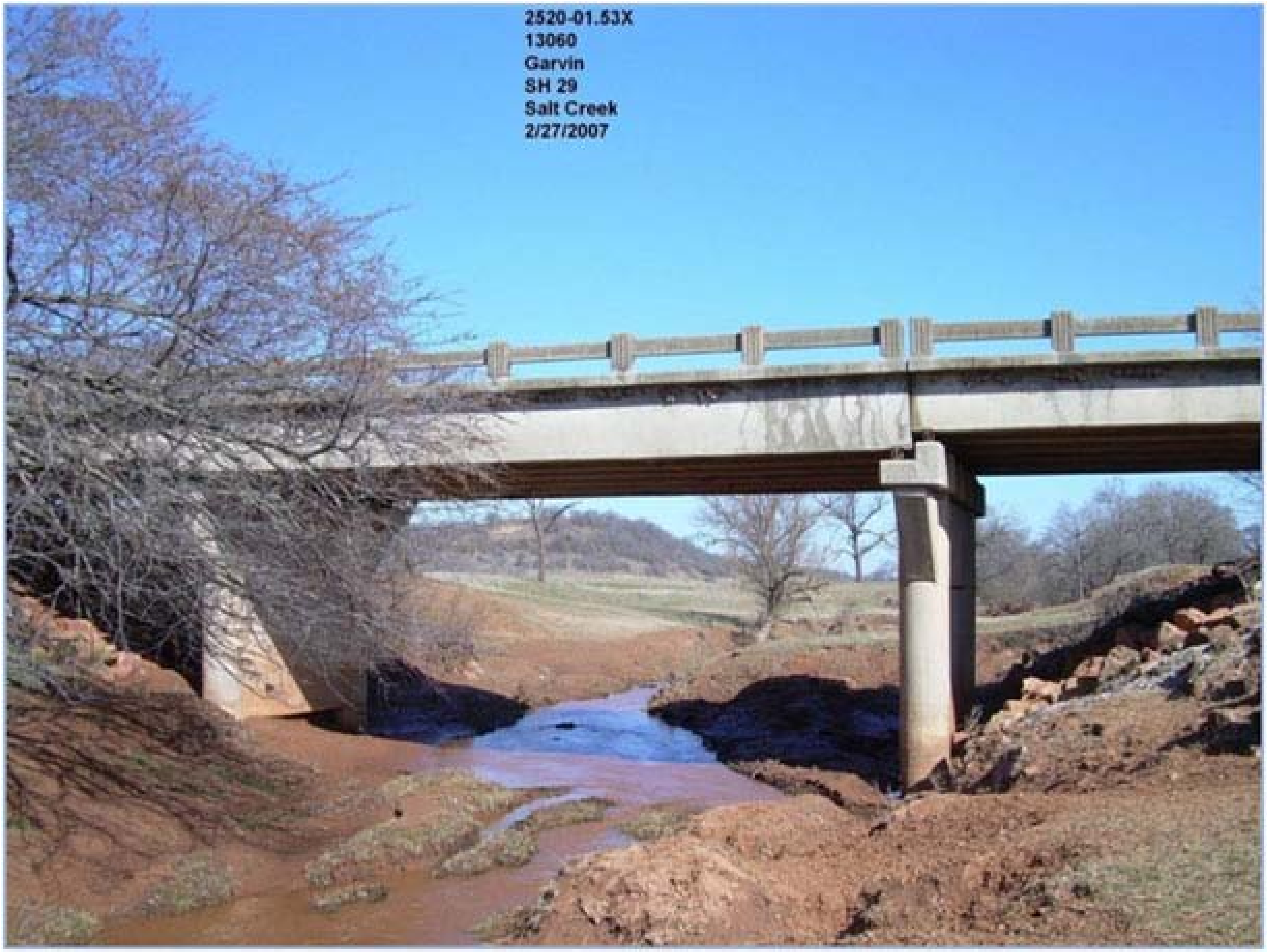


Figure 37. Picture demonstrating extent of damage to piers at bridge 13060 on SH 29 over Salt Creek.

VI. Analysis of Flow line Profiles

The rate of channel-bed elevation change was estimated as the net difference in channel-bed elevation between the start and end dates divided by the time between the two dates.

A. Rush Creek

The trend line of bed-elevation changes was plotted for Rush Creek in Oklahoma and is shown in Figure 38 with zoomed-in plots of Rush Creek in Figures 38a and 38b. The flow elevation data was available for the bridges 13120, 10738 and 12643 starting from the early 1950’s. The remaining two bridges 17568 and 17569 were constructed more recently in 1969 and thus the available data starts in 1970 for these two bridges. Since the flow line changes in the more recent years are considered more important, the flow line change chart was drafted using the elevation values for the years 1983 to 1992.

B. Wildhorse Creek

The trend line of bed-elevation changes was plotted for Study Reach of Wildhorse Creek in Oklahoma and can be seen in Figures 39, 39a, 39c, and 39d. The flow elevation data was available for bridges 17590, 17591, 21120, 13235, and 18199. Since the flow line changes in the more recent years are considered more important, the flow line change chart was drafted using the elevation values from the years ranging from the 1990’s to the 2000’s.

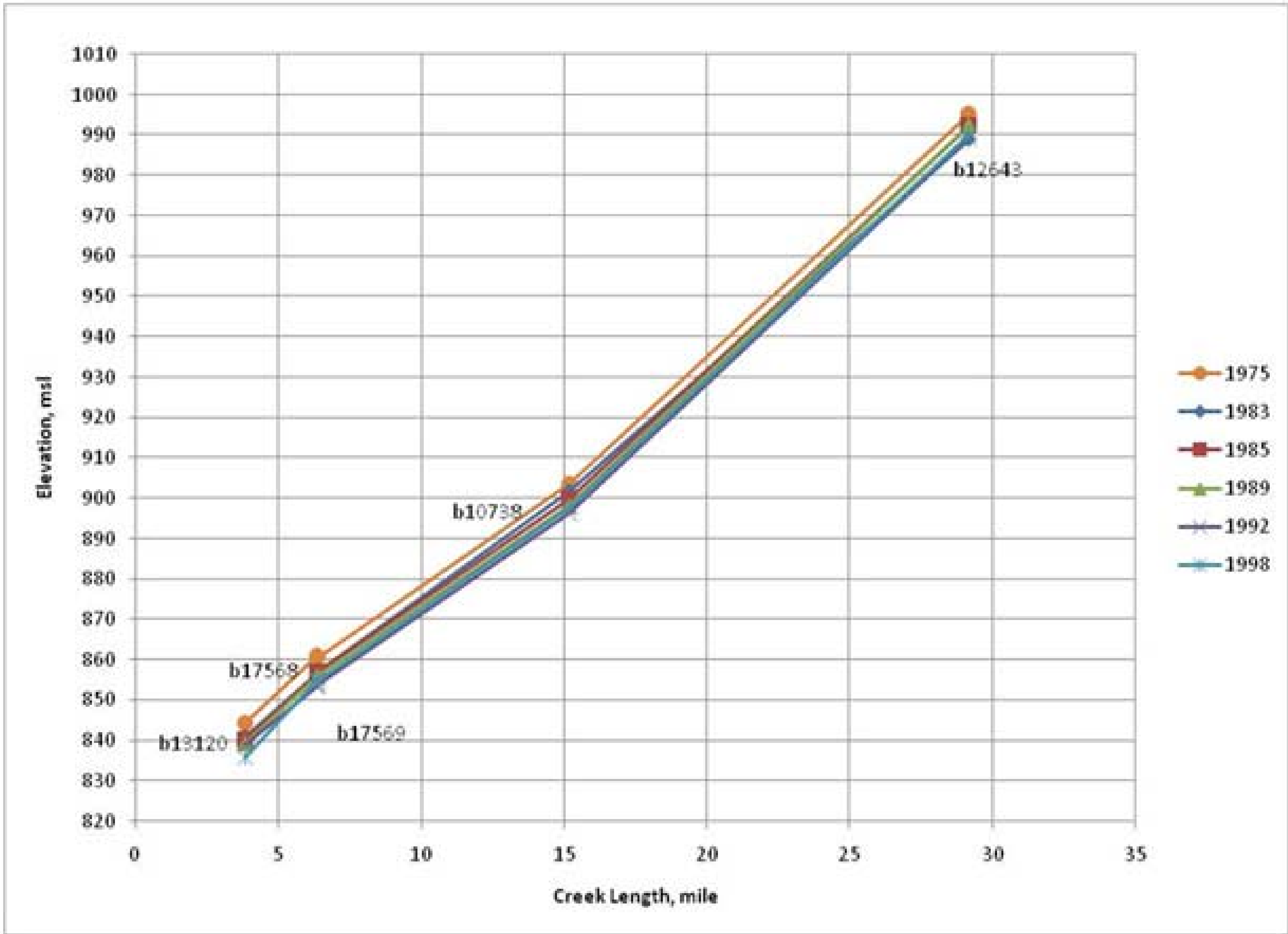


Figure 38. Longitudinal profile for Rush Creek.

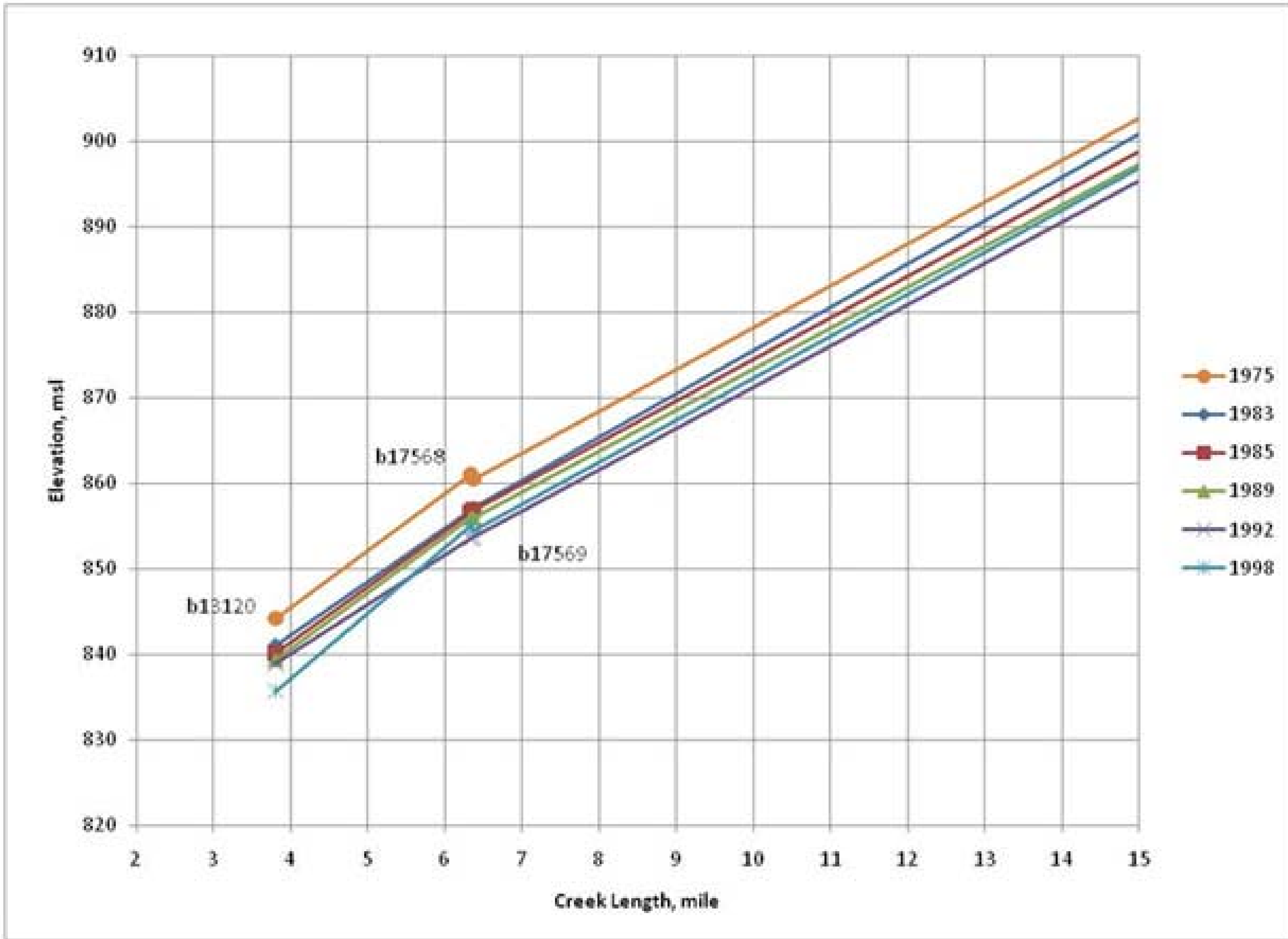


Figure 38a. Longitudinal profile for Rush Creek.

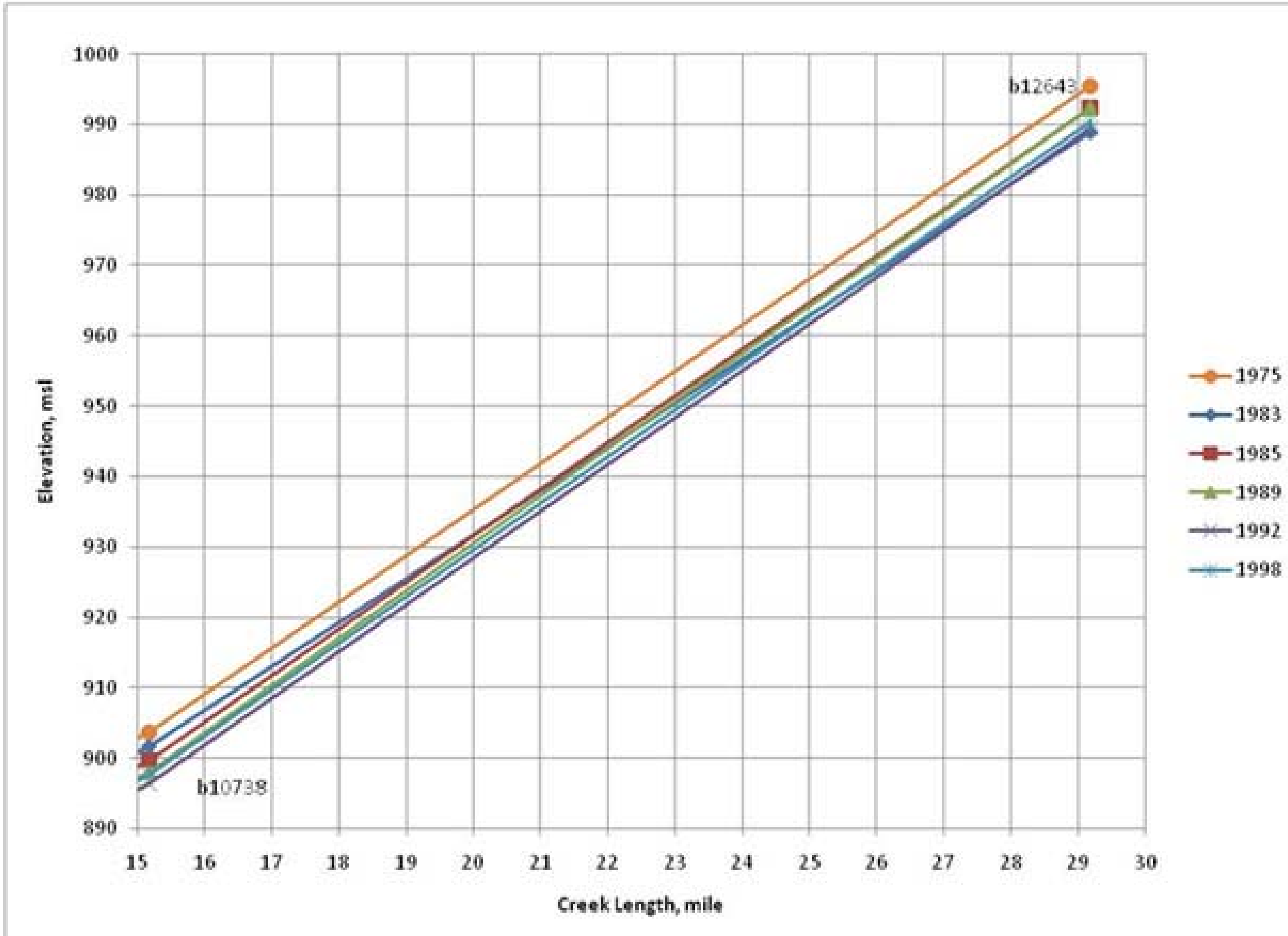
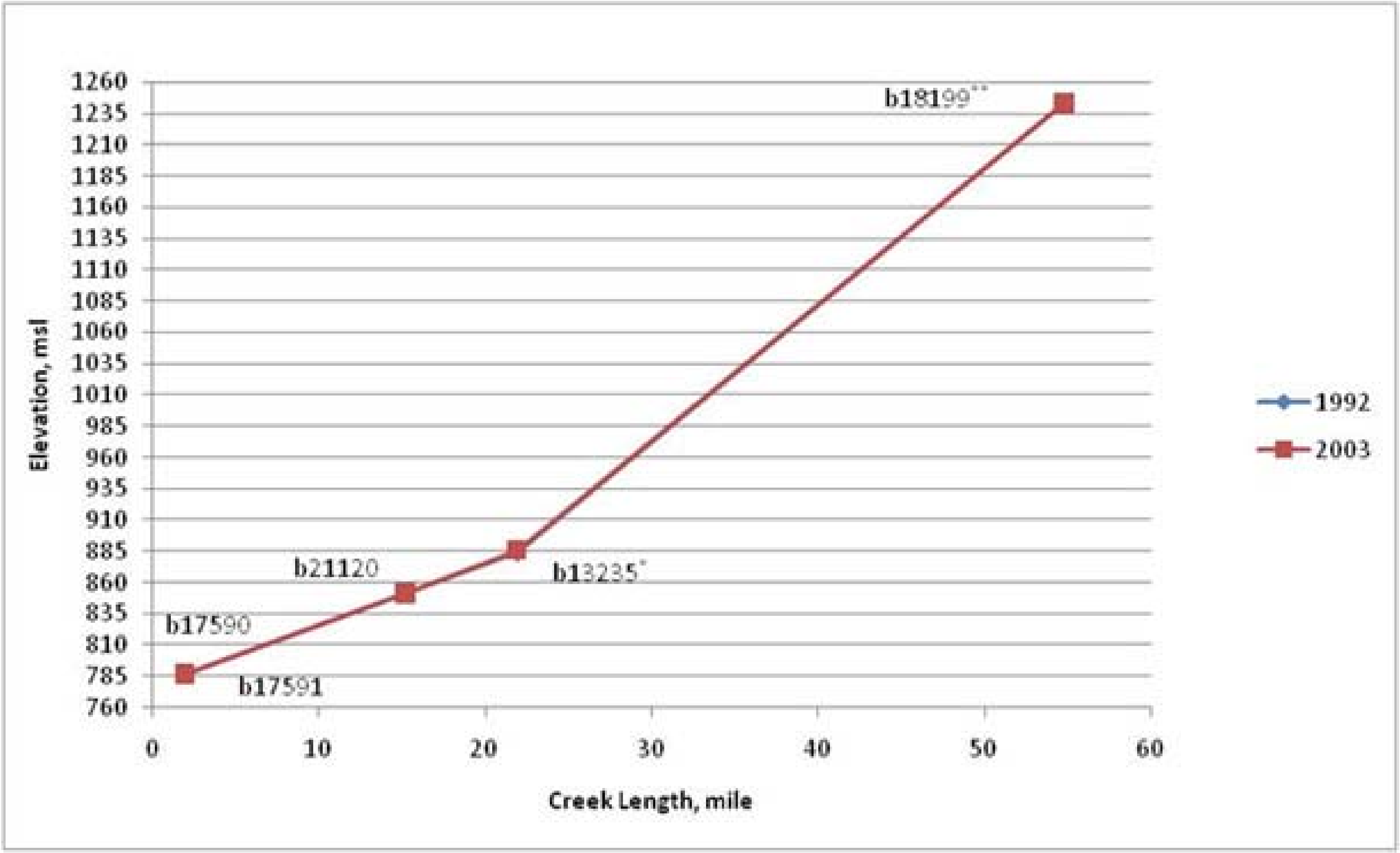


Figure 38b. Longitudinal profile for Rush Creek.



*interpolated value at b13235 for the year 2003

**interpolated value at b18199 for the year 1992

Figure 39. Longitudinal profile of Wildhorse Creek.

Figure 39a. Longitudinal profile of Wildhorse Creek.

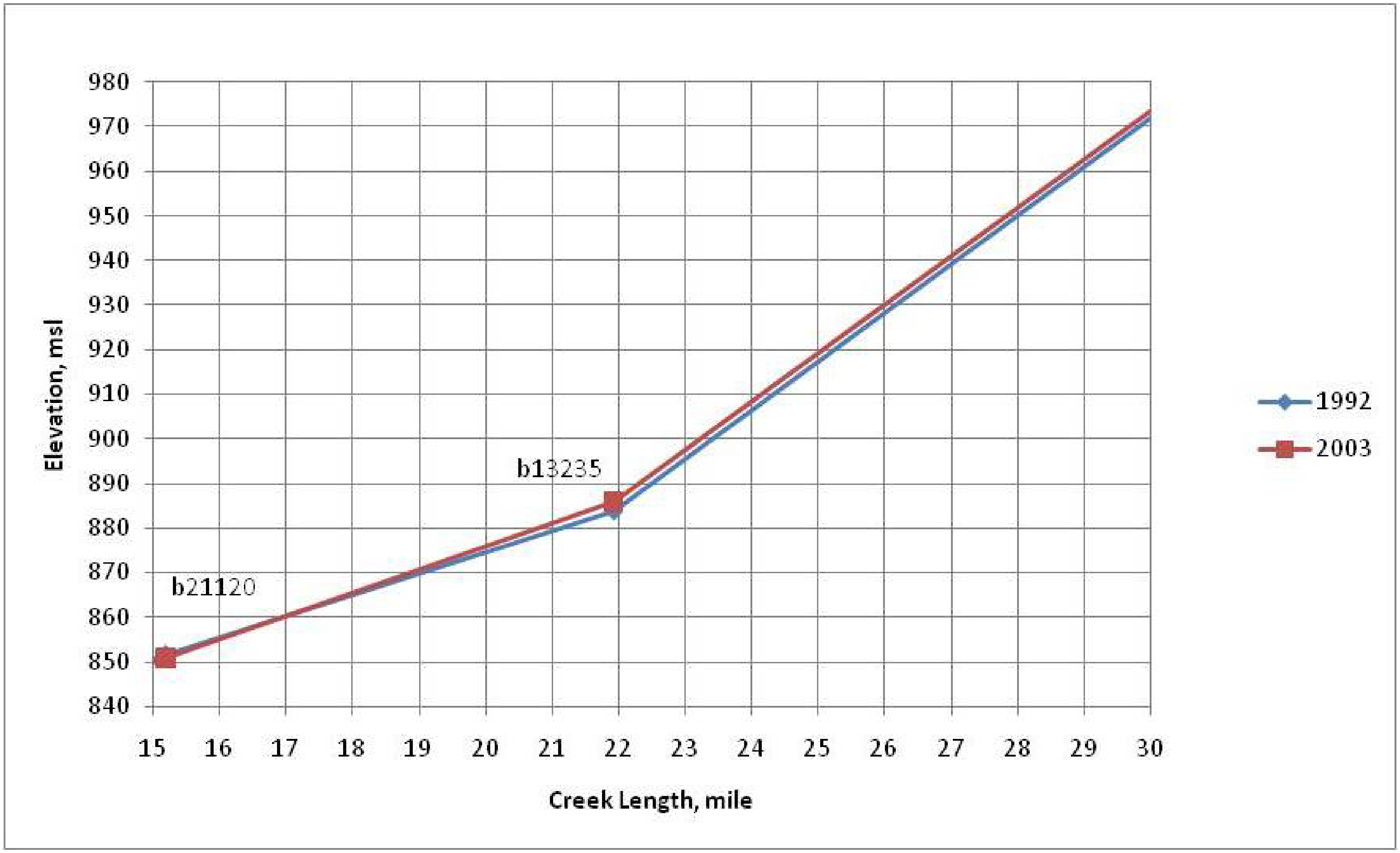


Figure 39b. Longitudinal profile of Wildhorse Creek.

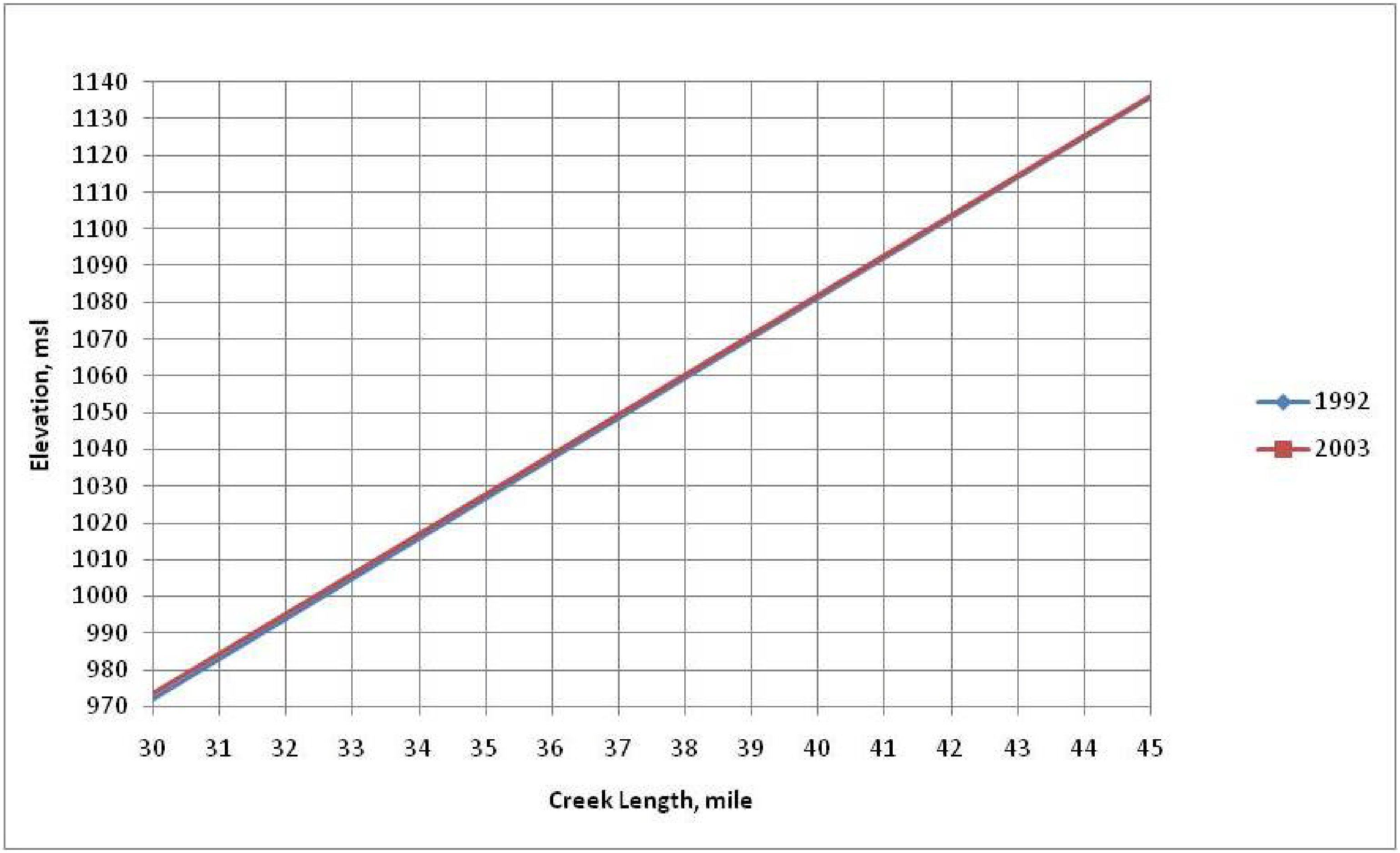


Figure 39c. Longitudinal profile of Wildhorse Creek.

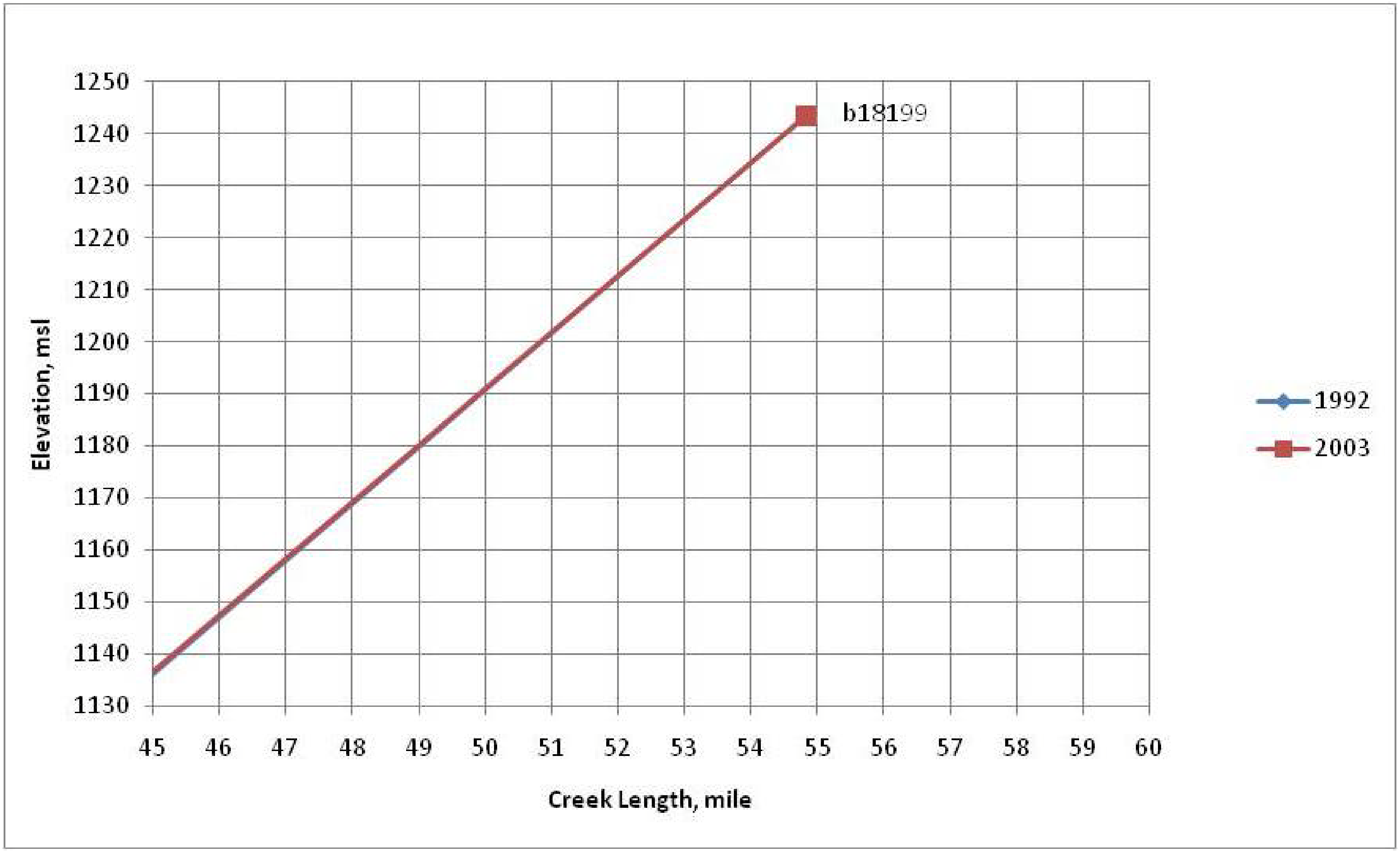


Figure 39d. Longitudinal profile of Wildhorse Creek.

C. Salt Creek

The trend line of bed-elevation changes was plotted for Study Reach of Salt Creek in Oklahoma and can be seen in Figure 40. The flow elevation data was available for the bridges 19629, 13515, and 13060. The flow elevation data available for bridges 13515 and 13060 started in the early 1960’s. The remaining bridge 19629 was constructed in 1979 and thus the available data starts in the 1980’s for this bridge. Figure 40 contains complete flow line data for all three bridges, from the 1980’s to the 2000’s.

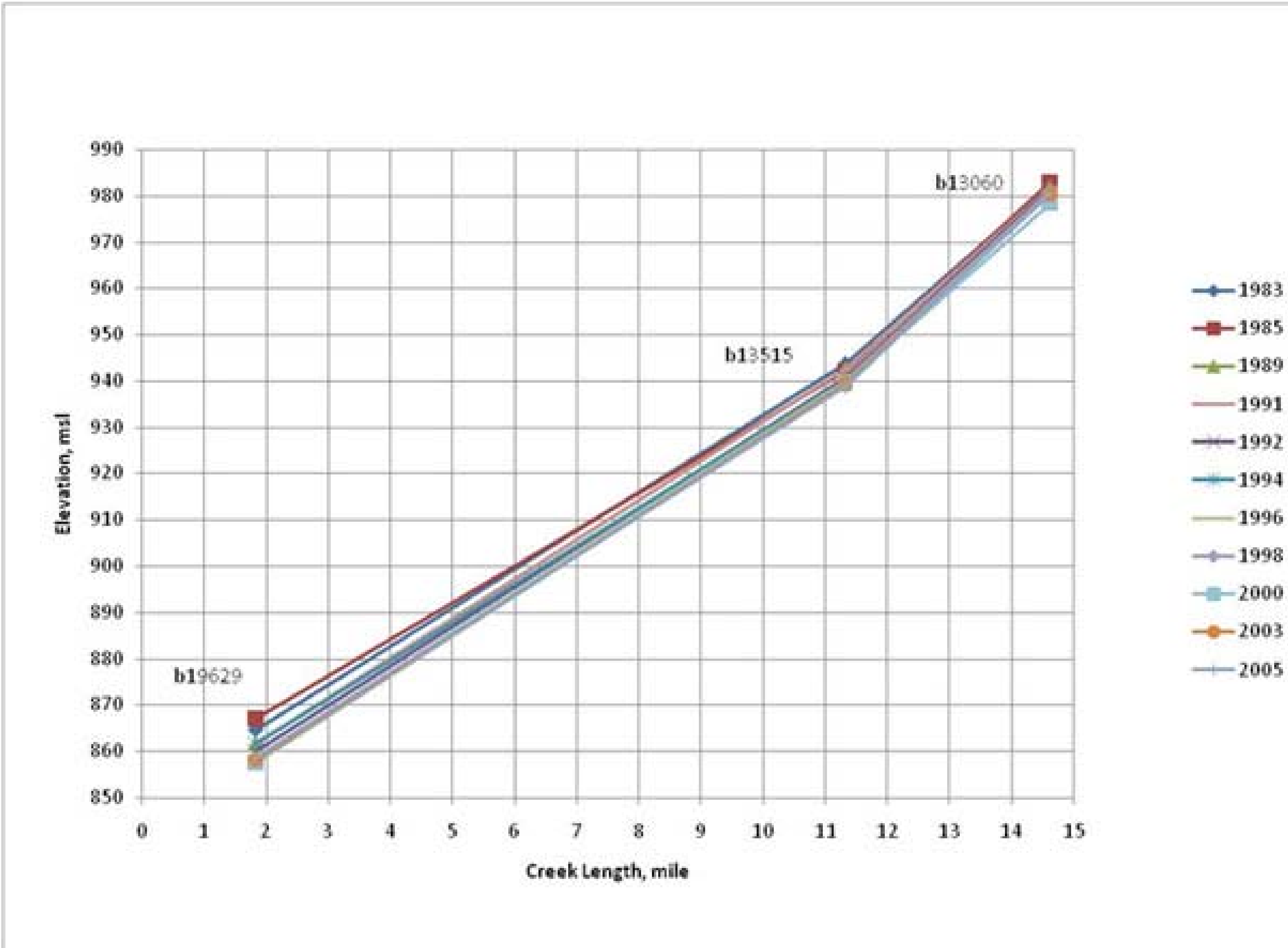


Figure 40. Longitudinal profile of Salt Creek.

VII. Results

The cross section profiles for the bridges of Rush, Wildhorse and Salt Creeks show many bridges with critical degradation near the piers. Among these bridges b17568 and b17569 on Rush Creek have 1 to 2 feet of clearance from the bottom of the pier as shown in Figures 14 and 16. This level of soil cover is insufficient to provide adequate structural support of the bridge structure. Another example of critical degradation is bridges 17590 and 17591 on Wildhorse Creek, which have a range of 2 to 3 feet of soil cover on piers 1 and 2. On the other hand, Salt Creek has no critical degradation bridges at this time.

Table 5 presents the summary of bridges in Rush Creek and their degradation values. Among these five bridges, only one has experienced a degradation rates above 0.40 feet per year. Table 6 presents the summary of bridges in Wildhorse Creek and their degradation values. Among these five bridges, four experienced a degradation rates range between 0.072 and 0.43 feet per year. The last structure on Wildhorse Creek (c18199) is a concrete lined culvert which inherently has lower degradation rates due to the non-erodible properties of concrete. Table 7 presents the summary of bridges in Salt Creek and their degradation values. Among these three bridges, two have degradation rates ranging between 0.37 and 0.63 feet per year. The third bridge (b13060) represents a very low degradation rate, which may be due to inaccurate data collection.

The degradation rates for the Washita River stations are listed in Table 8. These stations were selected due to their proximity to the confluence of the Washita River and Rush and Wildhorse Creeks. The Washita River selected stations generally have lower degradation rates compared to its tributaries (Rush, Wildhorse, and Salt Creeks). This section of the Washita River experiences bed degradation rates ranging from 0.1 to 0.3 feet per year, while the rates for Rush and Wildhorse Creeks range from 0.072 to 0.43 feet per year. Salt Creek a tributary of Wildhorse Creek experienced degradation rates ranging from 0.02 to 0.63.

In order to illustrate the phenomena of increased degradation rates along the length of the three creeks, a regression analysis was performed as shown in Figures 41 through 43. During the regression analysis it became necessary to eliminate a few extreme data point outliers in order to represent an accurate trend line for degradation. The extreme outliers that were eliminated from the regression analysis are c18199 on Wildhorse Creek and b13060 on Salt Creek.

Table 5. Summary of river degradation rates of Rush Creek, OK.

Bridge No.	Creek Station	Miles from Confluence of Washita River	High way	Year Built	Stratum	Max. Scour (Feet)	Duration (Year)	Degradation Rate (feet/year)	Location
b13120	CS1	3.81	US 77	1953	Mixed sand Soil	11.9	53	0.22*	0.5 mile S Jct. SH 19
b17568	CS2	6.3	I-35 NB	1969	Sandy Soil	2.7	13	0.21	6 mile N Jct. SH 29
b17569	CS3	6.37	I-35 SB	1969	Sandy Soil	4	14	0.29	6 mile N Jct. SH 29
b10738	CS4	15.18	SH 74	1947	Sandy clay	6.88	15	0.46	16.4 mile N Murray C/L
b12643	CS5	29.18	SH 76	1951	Sand to Sand stone	14.4	48	0.3*	1.3 mile N Stephens Co.

*Rate computed a from single flow line data.

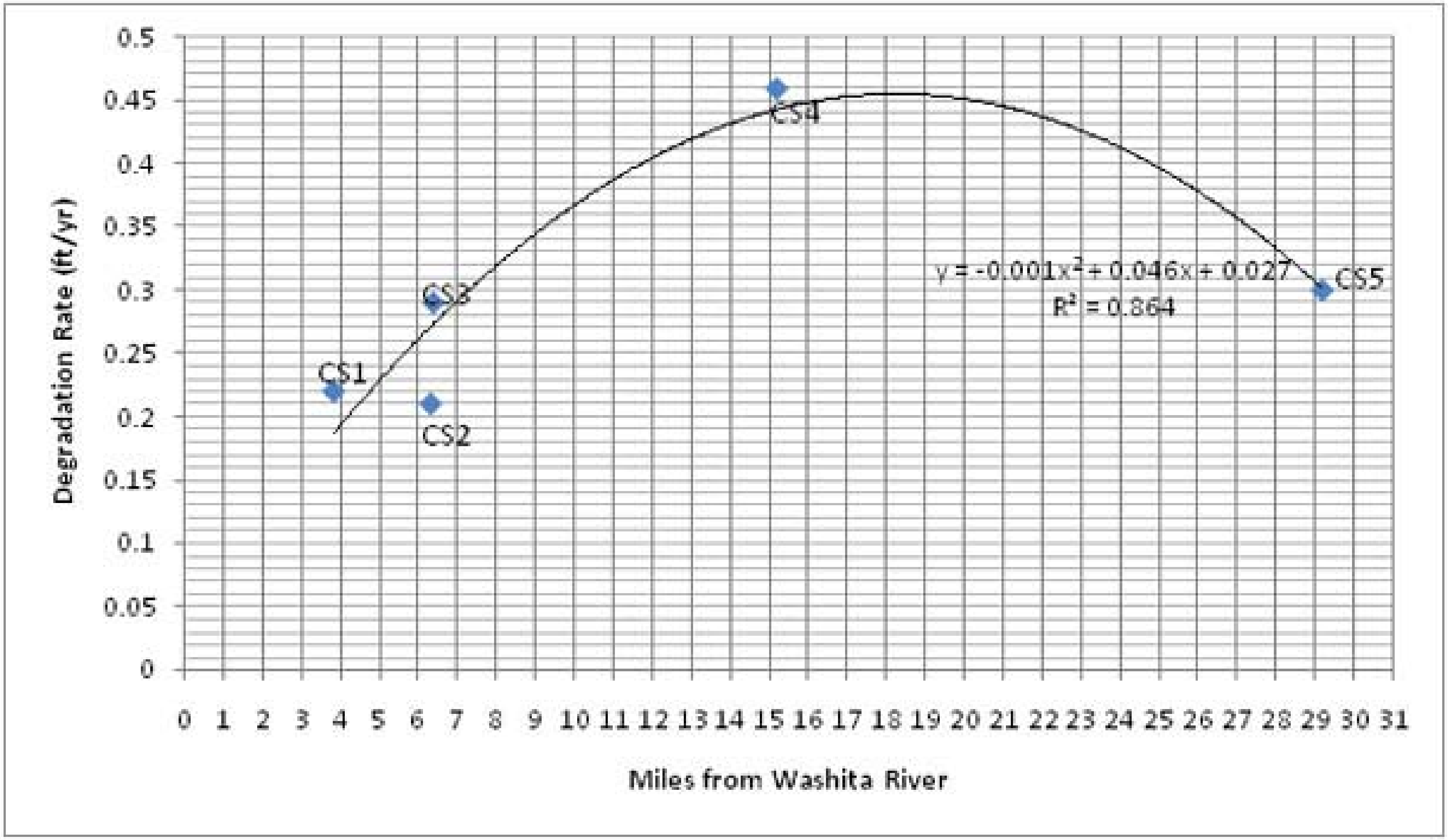


Figure 41. River degradation rate with trend line of Rush Creek, OK.

Table 6. Summary of river degradation rates of Wildhorse Creek, OK.

Bridge No.	Creek Station	Miles from confluence of Washita River	High way	Year Built	Stratum	Max. Scour, (Feet)	Duration, years	Degradation rate, ft/year	Location
b17590	CS1	2	I-35 NB	1969	Sand Stone	2.8	39	0.072	2 mile N Jct. SH 7
b17591	CS2	2	I-35 SB	1969	Sand Stone	4.1	39	0.11	2 mile N Jct. SH 7
b21120	CS3	15.2	SH 74	1985	Sandy clay	7.3	21	0.35	0.5 mile N Carter C/L
b13235	CS4	21.92	SH 76	1954	Sandy soil	15.08	35	0.43	2.8 mile N Jct. SH 7
c18199	CS5	54.82	SH 29	1972	----------	0.5	9	0.083*	0.4 mile E Jct. US 81

*Four-foot drop culvert

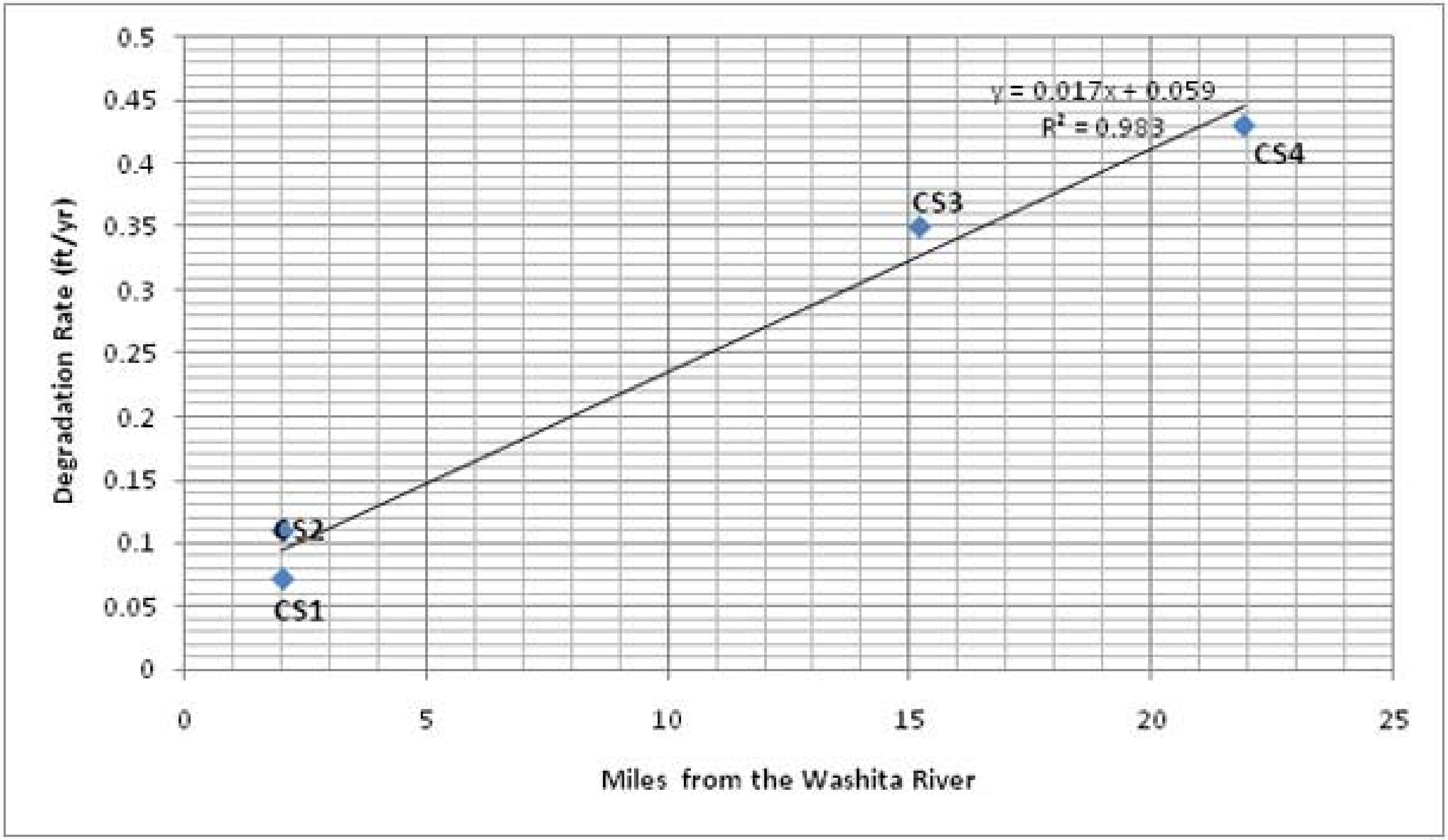


Figure 42. River degradation rate with trend line of Wildhorse Creek, OK.

Table 7. Summary of river degradation rates of Salt Creek, OK.

Bridge No.	Creek Station	Miles from confluence of Wildhorse Creek	Highway	Year Built	Stratum	Max. Scour, (Feet)	Duration, years	Degradation rate, ft/year	Location
b19629	CS1	1.82	SH 74	1979	Sand stone to Shale	9.2	25	0.37	2.5 mile N Carter C/L
b13515	CS2	11.32	SH 76	1955	Sandy soil to sand stone	5	8	0.63	6.1 mile N Carter C/L
b13060	CS3	14.62	SH 29	1953	Sandy to shale	1.2	55	0.02*	1.5 mile E Stephens Co.

*Impact of shale.

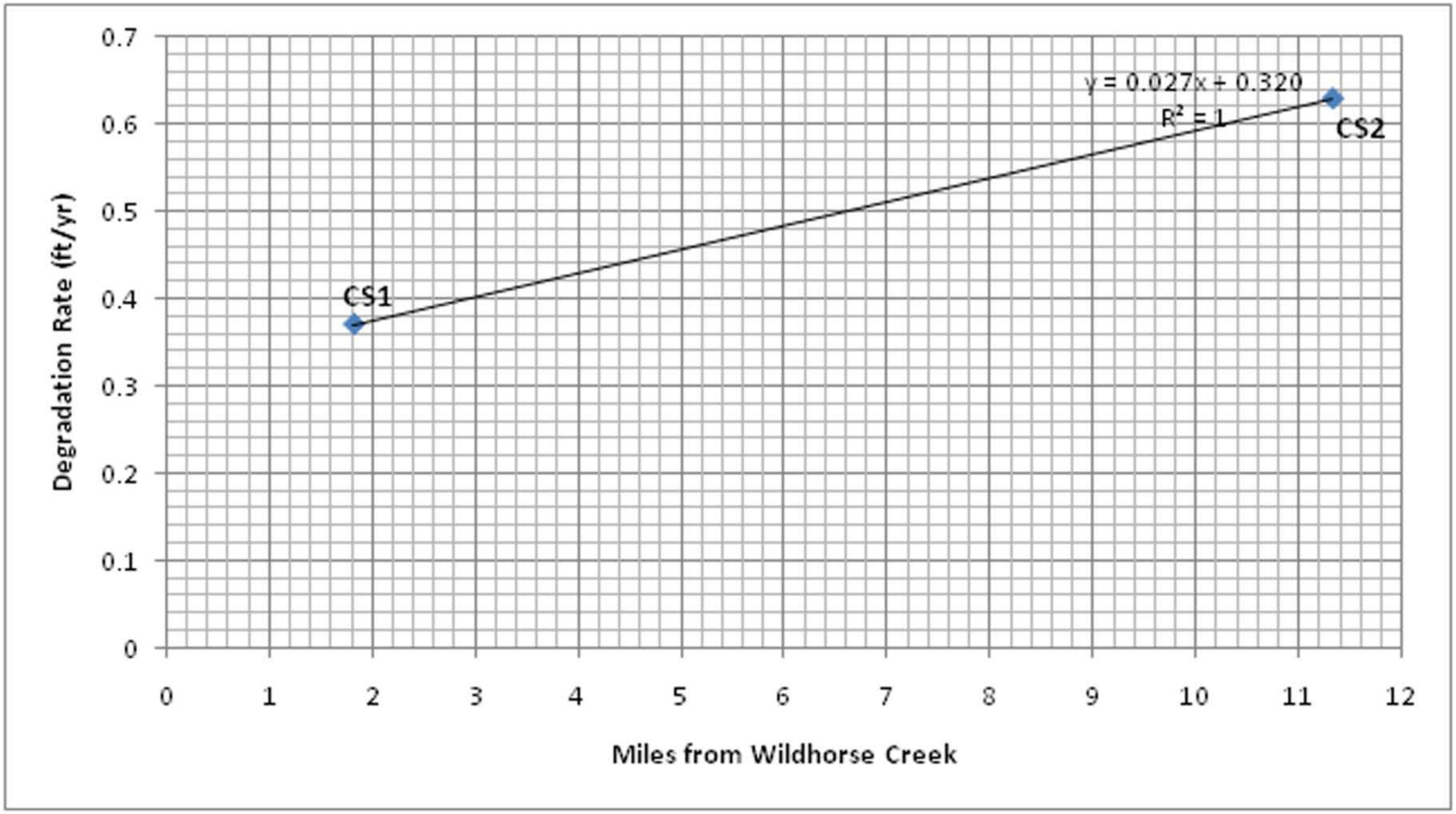


Figure 43. River degradation rate with trend line of Salt Creek, OK.

Table 8. Summary of river degradation rates of Washita River, OK. (Tyagi, 2007)

Bridge No.	River Station	Miles	Highway	Year Built	Maximum Scour (Feet)	Duration (Year)	Degradation Rate (feet/year)	Location
b19273	r33	440.51	SH 7	1976	5.39	30	0.18	0.8 mile W. Jct. US 77
b17956	r31	425.68	SH 17A	1970	9.61	34	0.283	0.8 mile E I-35
b14516	r30	423.08	US 77	1959	4.18	42	0.1	2.7 miles N Murray C/L
b7342	r29	409.94	SH 19	1939	6.48	62	0.105	2.2 miles E Jct. US 77

VIII. Conclusions

The purpose of this research was to analyze the flow line data and relate it to the degradation of the creek beds of bridge locations at Rush Creek, and Wildhorse and Salt creeks. The following conclusions are drawn based on this research:

1) Foundation of piers 1 and 2 is too close to the flow line at bridge 17568 on Rush Creek. This area has experienced severe channel-bed degradation.
2) Foundation of piers 1 and 2 is close to the flow line at bridge 17569 on Rush Creek.
3) Foundation of piers 1 and 2 of bridge 17590 is too close to the flow line of Wildhorse Creek.
4) Foundation of piers 1, 2, and 3 of bridge 17591 is too close to the flow line of Wildhorse Creek.
5) Washita River degradation rates ranged from 0.1 to 0.3 foot per year as determined in a previous study, while the degradation rates of Rush, Wildhorse, and Salt Creeks ranged from 0.22 to 0.46, 0.072 to 0.43 and 0.02 to 0.63 foot per year, respectively in a small reach of the Washita River.
6) None of the bridges in Rush, Salt, or Wildhorse Creeks have experienced channel bed degradation above 16 feet. However, a maximum degradation of 15.1 feet in 35 years was observed at bridge 13235 on S.H. 76, Wildhorse Creek.

IX. References

Chein, N. (1985). "Changes in river regimes after the construction of upstream reservoirs." *Earth Surface Processes and Landform*, *10*, 143-159.

Macklin, J. H. (1948). "Concept of the graded river." *Geological Society of America Bulletin 59*, 463-512.

Oklahoma Climatological Survey, http://climate.mesonet.org/coop.php, Assented Nov. 5, 2009.

Petts, G.E (1979). " Complex response of river channel morphology subsequent to reservoir construction." *Progress in Physical Geography*, *3*(3), 329-362.

Tinney, E. R. (1962). "The process of channel degradation." *Journal of Geophysical Research*, 67(4), 1475-1480.

Tortorelli, R.L., and McGabe, L. P. (1998). "Flood Frequency Estimated and Documented Potential Extreme Peak Discharge in Oklahoma." USGS/WRIR 01-4152.

Tyagi, A. K. (2007). "Channel-bed Degradation in Major Oklahoma Streams."Volume V: Washita River, Oklahoma Infrastructure Consortium, School of Civil and Environmental Engineering, Stillwater, OK.

Williams, G. P. and Wolman, M. G. (1985). "Effects of dams and reservoirs on surface-water hydrology-changes in rivers downstream from dams." *USGS National Water Summary 1985*, Water Availability issues, 83-88.

APPENDIX A

TABLES OF CROSS-SECTIONAL GEOMETRIES FOR RUSH, WILDHORSE, AND SALT CREEKS IN OKLAHOMA

Rush Creek

Table A-I. Summary of river degradation rates for Rush Creek, OK.

Bridge No.	Creek Station	Miles from confluence of Washita River	Highway	Year Built	Stratum	Max. Scour (Feet)	Duration (Year)	Degradation Rate (feet/year)	Location
b13120	CS1	3.81	US77	1953	Mixed sand Soil	11.9	53	0.22	0.5 mile S Jct SH 19
b17568	CS2	6.3	I35 NB	1969	Sandy Soil	2.7	13	0.21	6 miles N Jct. SH 29
b17569	CS3	6.37	I35 SB	1969	Sandy Soil	4	14	0.29	6 miles N Jct. SH 29
b10738	CS4	15.18	SH74	1947	Sandy clay	6.88	15	0.46	16.4 miles N Murray C/L
b12643	CS5	29.18	SH76	1951	Sand to Sand stone	14.4	48	0.3	1.3 miles N Stephens Co.

Table A1. Structure cross-section, and flow line details Bridge No. 13120 on Rush Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B13120	0.5 mile S. Jct SH 19	34° 44’ 05”	97° 12’ 51”	US 77	1953	535.1 ft.

Year	Nov-54	Aug-57	Mar-60	Sep-65	Mar-70	Aug-75	May-78	Apr-81
Flow line	36[2]	36.8[2]	36.5[2]	36.4[2]	38.6[2]	40.2[2]	32.6[2]	42.2
Year	Jul-83	Feb-85	May-87	Jun-89	May-91	Oct-92	Oct-94	Nov-96
Flow line	43.4	44.3	45	45	45	45.5[1]	45.8[1]	50.3[1]
Year	Nov-98	Nov-00	Oct-02	Feb-07				
Flow line	50.8[1]	50.1[1]	50[1]	50[1]				

[1] Measured from the top of rail
[2] Measured from the top of curb

Table A2. Structure cross-section, and flow line details Bridge No. 17568 on Rush Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B17568	6 miles N Jct. SH 29	34^{o} 43’ 55”	97^{o} 15’ 26”	I-35 NB	1969	301.8 ft.

REPORT 1, bridge 17568 on Rush Creek			
Date: 05-05-1993 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 4 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end.			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	9.8	0	889.2
2	16.1	15	882.9
3	17	45	882
4	36.9	63	862.1
5	40	75	859
6	41.8	77	857.2
7 (Pier 1)	43.4	101.25	855.6
8	44.9	125.25	854.1
9	43.3	165.25	855.7
10	33.4	178.25	865.6
11 (Pier 2)	28.2	201.25	870.8
12	22.9	235.25	876.1
13	19.1	255.25	879.9
14	19.8	274.25	879.2
15	16	281.25	883
16	15.6	283.25	883.4
17 (North Abutment End)	9	302.5	890

Table A2. (continued)

REPORT 2, bridge 17568 on Rush Creek			
Date: 07-08-1993 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 1 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	10	0	889
2	17	45	882
3	41	60	858
4 (Pier 1)	44	101.25	855
5	44	151.125	855
6	44	161.25	855
7	33	181.25	866
8 (Pier 2)	28	201.25	871
9	22	246.25	877
10	17	281.5	882
11 (North Abutment End)	10	301.5	889

Table A2. (continued)

REPORT 3, bridge 17568 on Rush Creek			
Date: 03-09-1992 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 3.5 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	10	0	889
2	15	15	884
3	16	47	883
4	37	67	862
5	43	80	856
6	44	90	855
7 (Pier 1)	44	101.25	855
8	42	111.25	857
9	42	121.25	857
10	45.5	151.25	853.5
11	42	171.25	857
12	38	177.25	861
13 (Pier 2)	31	201.25	868
14	22.5	236.25	876.5
15	19.5	271.25	879.5
16	16	283.25	883
17 (North Abutment End)	10	302.5	889

Table A2. (continued)

Year	Apr-71	Jun-75	Oct-77	Apr-83	Mar-85	Jul-89	Sep-90	Mar-92
Flow line	36.8[2]	36.8[2]	40.8	42.2	42.4	43	43	45.5[3]
Year	Nov-92	May-93	Sep-94	Nov-97	Nov-98	Oct-06	Apr-08	
Flow line	44	44.9[3]	44.5	44	44	47.6	47.6	

[2] Measured from the top of curb
[3] Measured from the top of parapet

Table A3. Structure cross-section, and flow line details Bridge No. 17569 on Rush Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B17569	6 miles N Jct. SH 29	34° 43’ 54”	97° 15’ 28”	I-35 SB	1969	301.8 ft.

REPORT 1, Bridge 17569 on Rush Creek			
Date: 07-08-1993 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 1 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of Parapet (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	10	0	889
2	17	37	882
3	40	67	859
4 (Pier 1)	44	101.25	855
5	44	149.25	855
6 (Pier 2)	35	201.25	864
7	20.5	251.875	878.5
8	20	272.5	879
9 (North Abutment End)	10	302.5	889

Table A3. (continued)

REPORT 2, Bridge 17569 on Rush Creek			
Date: 03-09-1992 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 3.5 Feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of Parapet (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11	0	888
2	15	45	884
3	36.5	70	862.5
4	41.5	82	857.5
5 (Pier 1)	43.6	101.25	855.4
6	41.2	121.25	857.8
7	45.3	151.25	853.7
8	40.9	171.25	858.1
9	37.4	176.25	861.6
10 (Pier 2)	30	201.25	869
11	21	236.25	878
12	19	271.25	880
13	15.4	285.25	883.6
14 (North Abutment End)	10.5	302.5	888.5

Table A3. (continued)

REPORT 3, bridge 17569 on Rush Creek			
Date: 10-26-2006 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 1.5 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11.9	0	887.1
2	22.6	50	876.4
3 (Pier 1)	41.9	101.25	857.1
4	46.6	151.25	852.4
5 (Pier 2)	33.2	201.25	865.8
6	22.6	251.25	876.4
7 (North Abutment End)	11.7	302.5	887.3

Table A3. (continued)

REPORT 4, bridge 17569 on Rush Creek			
Date: 4-02-2008 Top of Parapet Elevation from MSL = 899 Feet Depth of Water: 1.5 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11.9	0	887.1
2	22.6	50	876.4
3 (Pier 1)	41.9	101.25	857.1
4	46.6	151.25	852.4
5 (Pier 2)	33.2	201.25	865.8
6	22.6	251.25	876.4
7 (North Abutment End)	11.7	302.5	887.3

Year	Apr-71	Jun-75	1977	Apr-83	Mar-85	Jul-89	Jul-90	Mar-92	Nov-92
Flow line	36.1[2]	37.3[2]	40.3	41.8	42.1	43	43	45.3[3]	44[1]
Year	Sep-94	Jul-93	Nov-97	Nov-98	Oct-06	Apr-08			
Flow line	43[2]	44[3]	44.5[3]	44.5[3]	46.1	46.1			

1 Measured from the top of rail
2 Measured from the top of curb
3 Measured from the top of parapet

Table A4. Structure cross-section, and flow line details Bridge No. 10738 on Rush Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B10738	16.4 miles N Murray C/L	34° 44’ 36”	97° 24’ 20”	S.H. 74	1947	181.1 ft.

REPORT 1, bridge 10738 on Rush Creek			
Date: 06-06-2005 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 3 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.6	0	928.52
2	6.8	7	928.32
3	18.4	27	916.72
4	29	41	906.12
5 (Pier 1)	31.8	61.25	903.32
6	40.2	68.25	894.92
7	41	76.25	894.12
8	37.6	88.25	897.52
9 (Pier 2)	25.4	121.25	909.72
10	25.8	131.25	909.32
11	11.4	155.25	923.72
12	8	167.25	927.12
13 (North Abutment End)	6.8	181.33	928.32

Table A4. (continued)

REPORT 2, bridge 10738 on Rush Creek			
Date: 05-11-2004 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 1 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.5	0	928.62
2	6.8	7	928.32
3	18.2	27	916.92
4	29.2	41	905.92
5 (Pier 1)5	31.9	61.25	903.22
6	39	68.25	896.12
7	39.6	88.25	895.52
8	31.2	103.25	903.92
9 (Pier 2)	25	121.25	910.12
10	25.6	128.25	909.52
11	12.2	149.25	922.92
12	7.6	166.25	927.52
13 (North Abutment End)	6.11	181.33	929.01

Table A4. (continued)

REPORT 3, bridge 10738 on Rush Creek			
Date: 08-30-2002 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 1 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.5	0	928.62
2	6.8	7	928.32
3	18.2	27	916.92
4	29.5	41	905.62
5 (Pier 1)	31.7	61.25	903.42
6	39.4	68.25	895.72
7	38	88.25	897.12
8	28.5	109.25	906.62
9 (Pier 2)	25	121.25	910.12
10	25.5	128.25	909.62
11	11.3	149.25	923.82
12	7.4	166.25	927.72
13 (North Abutment End)	6.5	181.33	928.62

Table A4. (continued)

REPORT 4, bridge 10738 on Rush Creek			
Date: 07-30-2002 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 1.5 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.5	0	928.62
2	6.7	7	928.42
3	18.3	27	916.82
4	29.7	41	905.42
5 (Pier 1)	28.3	61.25	906.82
6	38.9	68.25	896.22
7	38.5	77.25	896.62
8	37.3	89.25	897.82
9	28.9	109.25	906.22
10 (Pier 2)	25.2	121.25	909.92
11	25.5	128.25	909.62
12	17.9	151.25	917.22
13	7	174.25	928.12
14 (North Abutment End)	6.7	181.33	928.42

Table A4. (continued)

REPORT 5, bridge 10738 on Rush Creek			
Date: 06-20-1996 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 1 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.2	0	928.92
2	6.9	8.08	928.22
3	26.4	38.08	908.72
4 (Pier 1)	32	53.08	903.12
5	37.3	60.08	897.82
6 (Pier 2)	35.5	98.08	899.62
7	26.4	120.08	908.72
8	12.1	155.33	923.02
9	7	176.33	928.12
10 (North Abutment End)	6.4	181.33	928.72

Table A4. (continued)

REPORT 6, bridge 10738 on Rush Creek			
Date: 08-19-1999 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 0.5 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.5	0	928.62
2	6.7	7	928.42
3	18.7	26	916.42
4	30.1	41	905.02
5 (Pier 1)	32.3	61.25	902.82
6	37.7	68.25	897.42
7	37.6	74.25	897.52
8	37	96.25	898.12
9	27.6	111.25	907.52
10 (Pier 2)	24.6	121.25	910.52
11	26	128.25	909.12
12	11.1	151.25	924.02
13	6.8	170.25	928.32
14 (North Abutment End)	6.7	181.33	928.42

Table A4. (continued)

REPORT 7, bridge 10738 on Rush Creek			
Date: 09-17-1997 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 1 feet Information relevant to Downstream data, starting from East abutment end to the West abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.56	0	928.56
2	8.2	10	926.92
3	24.928	40	910.192
4 (Pier 1)	32.144	61.25	902.976
5	34.44	69.25	900.68
6	37.72	71.25	897.4
7	37.72	89.25	897.4
8	36.408	104.25	898.712
9	32.8	110.25	902.32
10 (Pier 2)	25.256	121.25	909.864
11	19.024	139.25	916.096
12	11.48	151.25	923.64
13 (North Abutment End)	6.56	181.33	928.56

Table A4. (continued)

REPORT 8, bridge 10738 on Rush Creek			
Date: 08-09-1995 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 2.5 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.3	0	928.82
2	6.8	6	928.32
3	25.3	36	909.82
4 (Pier 1)	31	61.25	904.12
5	33.8	65.25	901.32
6	37	66.25	898.12
7	37.5	76.25	897.62
8	36.3	91.25	898.82
9 (Pier 2)	26.2	121.25	908.92
10	24.3	133.25	910.82
11	9.4	163.25	925.72
12 (North Abutment End)	6.6	181.33	928.52

Table A4. (continued)

REPORT 9, bridge 10738 on Rush Creek			
Date: 01-17-1992 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 6 feet Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	5.9	0	929.22
2	7.4	10	927.72
3 (Pier 1)	30	61.25	905.12
4	38.8	69.25	896.32
5	33.2	90.25	901.92
6 (Pier 2)	26.5	121.25	908.62
7	24.8	125.25	910.32
8	6.3	143.25	928.82
9 (North Abutment End)	6.3	181.33	928.82

Table A4. (continued)

REPORT 10, bridge 10738 on Rush Creek			
Date: 12-13-2007 Top of Curb Elevation from MSL = 935.12 Feet Depth of Water: 2.5 foot Information relevant to Downstream data, starting from South abutment end to the North abutment end			
Location #	**Elevation (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.7	0	928.42
2	22.4	37.4	912.72
3	24	48	911.12
4 (Pier 1)	35.6	64.4	899.52
5	44	76.5	891.12
6	39.6	89.5	895.52
7	32.5	97.9	902.62
8 (Pier 2)	28	111.5	907.12
9	8.5	133.1	926.62
10 (North Abutment End)	6.6	141.5	928.52

Year	Feb-50	Nov-54	Sep-65	Mar-70	Aug-75	May-78	Apr-81	Jul-83
Flow line	30[2]	29.6[2]	29.9[2]	31.3[2]	31.5[2]	30.9[2]	33	33.4
Year	Aug-85	May-87	Jun-89	Jan-92	Oct-92	Aug-95	Jun-96	Sep-97
Flow line	35.4	35	37	38.8[2]	37.7[2]	37.5[2]	37.3[2]	37.7[2]
Year	May-98	Aug-99	Jul-00	Jul-02	Aug-02	Aug-03	May-04	Jun-05
Flow line	37.4[2]	37.7[2]	38.2[2]	38.9[2]	39.4[2]	39.4[2]	39[2]	41[2]
Year	Nov-06	Dec-07						
Flow line	39[2]	44[2]						

[2] Measured from the top of curb

Table A5. Structure cross-section, and flow line details Bridge No. 12643 on Rush Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B12643	1.3 miles N. Stephens Co.	34^{o} 41’ 46”	97^{o} 35’ 57”	S.H. 76	1951	299.9 ft.

Year	Mar-60	Mar-70	Aug-75	Jun-78	Apr-81	Jul-83	Feb-85	May-87
Flow line	34[2]	38.4[2]	42.5[2]	41[2]	43	48.9	45.5	46
Year	Jun-89	Jul-90	Jul-92	Oct-92	Sep-94	Mar-97	1998	Oct-06
Flow line	45.5	45[2]	48.4[1]	46[2]	48[2]	47.5[2]	47.5[2]	48.4
Year	Apr-08							
Flow line	48.4							

[1] Measured from the top of rail
[2] Measured from the top of curb

Wildhorse Creek

Table A-II. Summary of river degradation rates of Wildhorse Creek, OK.

Bridge No.	Creek Station	Miles from confluence of Washita River	High way	Year Built	Stratum	Max. Scour, (Feet)	Duration, years	Degradation rate, ft/year	Location
b17590	CS1	2	I-35 NB	1969	Sand Stone	2.8	39	0.072	2 miles N Jct. SH7
b17591	CS1	2	I-35 SB	1969	Sand Stone	4.1	39	0.11	2 miles N Jct. SH7
b21120	CS1	15.2	SH74	1985	Sandy clay	7.3	21	0.35	0.5 mile N Carter C/L
b13235	CS1	21.92	SH76	1954	Sandy soil	15.08	35	0.43	2.8 miles N Jct. SH7
b18199	CS1	54.82	SH29	1972	----------	0.5	9	0.083*	0.4 mile E Jct. US 81

***Four-foot drop culvert**

Table A6. Structure cross-section, and flow line details Bridge No. 17590 on Wildhorse Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B17590	2.0 miles N. Jct. SH 7	34^{o} 31’ 59”	97^{o} 11’ 13”	I-35 NB	1969	482.9 ft.

Table A6. (continued)

REPORT 1, bridge 17590 on Wildhorse Creek			
Date: 01-13-2009 Top of parapet Elevation from MSL = 821.7 Feet Total length of the bridge = 482.9 feet Depth of Water: 3 feet Information relevant to upstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of Parapet (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.75	0	814.95
2 (Pier 1)	27	60	794.7
3	34.8	78	786.9
4 (Flow line)	35.9	95	785.8
5 (Pier 2)	35.3	120	786.4
6	34.5	136	787.2
7	30.7	180	791
8	27.9	218	793.8
9 (Pier 4)	23.3	240	798.4
10 (Pier 5)	12.9	300	808.8
11	11.5	325	810.2
12 (Pier 6)	12.8	360	808.9
13	12.3	373	809.4
14 (Pier 6)	15.7	420	806
15	13	463	808.7
16 (North Abutment End)	7	477	814.7

Table A6. (continued)

Year	Aug-70	Jan-76	Sep-80	May-84	Sep-85	Jan-87	Oct-88	Oct-90
Flow line	31.4[2]	31.3[2]	31.2	31.9	30.5	30.3	29.5	32.4[3]
Year	Nov-92	Dec-94	Dec-95	Feb-99	Feb-00	Jan-01	Jan-02	Jan-03
Flow line	33.1[3]	34.6[3]	35[3]	35.16[3]	35[3]	35[3]	35.08[3]	35.58[3]
Year	Jan-09							
Flow line	35.9[3]							

[2] Measured from the top of curb
[3] Measured from the top of parapet

Table A7. Structure cross-section, and flow line details Bridge No. 17591 on Wildhorse Creek.

Bridge No.	**Location**	**Latitude**	**Longitude**	**Highway**	**Year Built**	**Length**
B17591	2.0 miles N. Jct. SH 7	34° 31’ 59”	97° 11’ 15”	I-35 SB	1969	482.9 ft.

Table A7. (continued)

REPORT 1, Bridge 17591 on Wildhorse Creek			
Date: 01-12-2009 Top of parapet Elevation from MSL = 821.7 Feet Total length of the bridge = 482.9 feet Depth of Water: 3.9 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	6.75	0	814.95
2 (Pier1)	26.3	60	795.4
3	33.3	69	788.4
4 (Flow line)	37.2	87	784.5
5	27.4	120	794.3
6	35.5	140	786.2
7	34.3	164	787.4
8 (Pier 2)	32.3	181	789.4
9 (Pier 3)	26.7	240	795
10 (Pier 4)	15.6	300	806.1
11	12.3	341	809.4
12 (Pier 5)	14.5	360	807.2
13	13.7	380	808
14 (Pier 6)	14.5	420	807.2
15	15.2	452	806.5
16 (North Abutment End)	7.5	477	814.2

Table A7. (continued)

Year	Aug-70	Jan-76	Sep-80	May-84	Sep-85	Jan-87	Oct-88	Oct-90
Flow line	31.4[2]	31.3[2]	31.5	32.9	31.5	31.4	33.6	32.9[3]
Year	Nov-92	Dec-94	Feb-99	Jan-01	Jan-03[2]	Jan-09		
Flow line	34.2[3]	36[3]	34.75[3]	35.5[3]	35.42[2]	37.2[3]		

[2] Measured from the top of curb
[3] Measured from the top of parapet

Table A8. Structure cross-section, and flow line details Bridge No. 21120 on Wildhorse Creek.

Bridge No.	**Location**	**Latitude**	**Longitude**	**Highway**	**Year Built**	**Length**
B21120	0.5 mile N. Carter C/L	34° 30’ 55”	97° 24’ 19”	S.H. 74	1985	301.8 ft.

REPORT 1, Bridge 21120 on Wildhorse Creek

Date: 09-27-2006
Top of parapet Elevation from MSL = 889 Feet
Total length of the bridge = 301.8 feet
Depth of Water: 1.8 feet
Information relevant to downstream data, starting from South abutment end to the North abutment end

Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	10.1	0	878.9
2	17.1	50	871.9
3 (Pier 1)	37.1	100	851.9
4 (Flow line)	37.1	150	851.9
5 (Pier 2)	37.5	200	851.5
6	21.8	250	867.2
7 (North Abutment End)	9.6	300	879.4

Table A8. (continued)

REPORT 2, Bridge 21120 on Wildhorse Creek			
Date: 03-11-2008 Top of parapet Elevation from MSL = 889 Feet Total length of the bridge = 301.8 feet Depth of Water: 1.8 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12.3	0	876.7
3 (Pier 1)	39.2	100	849.8
4 (Flow line)	41.3	150	847.7
5 (Pier 2)	41.2	200	847.8
7 (North Abutment End)	12	300	877

REPORT 3, Bridge 21120 on Wildhorse Creek			
Date: 03-26-2008 Top of parapet Elevation from MSL = 889 Feet Total length of the bridge = 301.8 feet Depth of Water: 1.8 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12.3	0	876.7
3 (Pier 1)	39.2	100	849.8
4 (Flow line)	41.3	150	847.7
5 (Pier 2)	41.2	200	847.8
7 (North Abutment End)	12	300	877

Table A8. (continued)

Year	May-87	Oct-92	Nov-94	Dec-96	Dec-98	Nov-00	Jan-03	Jan-05
Flow line	34	37.5[1]	38.5[1]	38.7[1]	38.7[1]	37.9[1]	38.2[1]	38.5[1]
Year	Sep-06	Mar-08	Mar-08					
Flow line	38.9	41.3	41.3					

1 Measured from the top of rail

Table A9. Structure cross-section, and flow line details Bridge No. 13235 on Wildhorse Creek

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B13235	2.8 miles N. Jct. SH 7	34° 29' 23"	97° 30' 35"	S.H. 76	1954	312 ft.

REPORT 1, Bridge 13235 on Wildhorse Creek			
Date: March - 1954 Top of curb Elevation from MSL = 928 Feet Total length of the bridge = 312 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	3	0	925
2 (Pier 1)	22	51.9	906
3 (Pier 2)	29	116.7	899
4 (Flow line)	33	156.7	895
5 (Pier 3)	32	196.57	896
6 (Pier 4)	26	261.3	902
7 (North Abutment End)	5	313.23	923

Table A9. (continued)

Year	Sep-60	Jan-65	Aug-70	Dec-80	Sep-85	Nov-86	Sep-88	Jul-90
Flow line	28[2]	27[2]	33.7[2]	36.7	38.4	39.4	40.1	42
Year	Sep-90	Jul-92	Oct-92	Jul-95	2003			
Flow line	41[2]	43.5[1]	44[2]	45.08[1]	44[*]			

[1] Measured from the top of rail
[2] Measured from the top of curb
[*] Calculated value from degradation rate (interpolation)

Table A10. Structure cross-section, and flow line details Structure No. 18199 on Wildhorse Creek.

Bridge No.	**Location**	**Latitude**	**Longitude**	**Highway**	**Year Built**	**Length**
B18199	0.4 mile E. Jct. US 81	34^o 38’ 51”	97^o 57’ 07”	S.H. 29	1972	34.1 ft.

Year	Jun-90	1992	Jan-95	Nov-97	Nov-99	Nov-03	Nov-05	2008
Flow line	0.83	0.83[*]	0.83	1	0.5	1	1	1

[*] Calculated value from degradation rate (interpolation)

Salt Creek

Table A-III. Summary of river degradation rates for Salt Creek, OK.

Bridge No.	Creek Station	Miles from Wildhorse Creek	Highway	Year Built	Stratum	Max. Scour, (feet)	Duration, years	Degradation rate, ft/year	Location
b19629	CS1	1.82	SH74	1979	Sand stone to Shale	9.2	25	0.37	2.5 miles N Carter C/L
b13515	CS2	11.32	SH76	1955	Sandy soil to sand stone	5	8	0.63	6.1 miles N Carter C/L
b13060	CS3	14.62	SH29	1953	Sandy to shale	1.2	55	0.02*	1.5 miles E Stephens Co.

*Impact of shale.

Table A11. Structure cross-section, and flow line details Bridge No. 19629 on Salt Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B19629	2.5 miles N Carter C/L	34^{o} 41’ 46”	97^{o} 35’ 57”	S.H. 74	1979	303 ft

Table A11. (continued)

REPORT 1, Bridge 19629 on Salt Creek			
Date: 09-27-2006 Top of parapet Elevation from MSL = 899.55 Feet Total length of the bridge = 303.1 feet Depth of Water: 1.2 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	10.9	0	888.65
2	20.6	50	878.95
3 (Pier 1)	31.2	100	868.35
4 (Flow line)	40.6	150	858.95
5 (Pier 2)	21.2	200	878.35
6	19.3	250	880.25
7 (North Abutment End)	10.6	300	888.95

Table A11. (continued)

REPORT 2, Bridge 19629 on Salt Creek			
Date: 03-11-2008 Top of parapet Elevation from MSL = 899.55 Feet Total length of the bridge = 303.1 feet Depth of Water: 1.2 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	13.3	0	886.25
2 (Pier 1)	33.5	100	866.05
3 (Flow line)	44.1	150	855.45
4 (Pier 2)	30.5	200	869.05
5 (North Abutment End)	13.1	300	886.45

Table A11. (continued)

REPORT 3, Bridge 19629 on Salt Creek			
Date: 03-26-2008 Top of parapet Elevation from MSL = 899.55 Feet Total length of the bridge = 303.1 feet Depth of Water: 1.2 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	13.3	0	886.25
2 (Pier 1)	33.5	100	866.05
3 (Flow line)	44.1	150	855.45
4 (Pier 2)	30.5	200	869.05
5 (North Abutment End)	13.1	300	886.45

Year	Jul-83	Apr-85	May-87	Jun-89	May-91	Oct-92	Nov-94	Nov-96
Flow line	34.9	32.5	37.4	38.1	38.1	39.6[1]	38[1]	41.1[1]
Year	Dec-98	Nov-00	Jan-03	Jan-05	Sep-06	Mar-08	Mar-08	
Flow line	41.8[1]	42.1[1]	41.4[1]	41.1[1]	41.8	44.1	44.1	

1 Measured from the top of rail

Table A12. Structure cross-section, and flow line details Bridge No. 13515 on Salt Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B13515	6.1 miles N Carter C/L	34^{o} 35’ 43”	97^{o} 30’ 37”	S.H. 76	1955	34.1 ft.

REPORT 1, Bridge 13515 on Salt Creek			
Date: 09-17-1997 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 0.65 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11.5	0	962.1
2	14.8	14	958.8
3	19.7	35	953.9
4 (Pier 1)	30.5	51.8	943.1
5	32.8	57.9	940.8
6 (Flow line)	33.8	70.8	939.8
7	32.8	80.8	940.8
8	24.6	96.8	949
9 (Pier 2)	16.4	111.8	957.2
10	13.45	137.8	960.15
11 (North Abutment End)	9.5	163.6	964.1

Table A12. (continued)

REPORT 2, Bridge 13515 on Salt Creek			
Date: 08-18-1998 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 6 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11.8	0	961.8
2	19.1	24.8	954.5
3	20	35.8	953.6
4	28.9	48.8	944.7
5 (Pier 1)	30	51.8	943.6
6	33.7	65.8	939.9
7 (Flow line)	33.9	70.8	939.7
8	33.6	76.8	940
9	19.3	97.8	954.3
10 (Pier 2)	16.8	111.8	956.8
11	11.3	149.6	962.3
12 (North Abutment End)	9.9	163.6	963.7

Table A12. (continued)

REPORT 3, Bridge 13515 on Salt Creek			
Date: 08-03-2001 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 6 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	11.9	0	961.7
2	13	11	960.6
3	18.2	23	955.4
4	19.6	38	954
5	25.9	42	947.7
6 (Pier 1)	29.8	51.8	943.8
7	34	60.8	939.6
8 (Flow line)	34.6	66.8	939
9	33.8	76.8	939.8
10	20.5	97.8	953.1
11 (Pier 2)	17.4	111.8	956.2
12	13.6	136.8	960
13	10.3	154.8	963.3
14 (North Abutment End)	10	163.6	963.6

Table A12. (continued)

REPORT 4, Bridge 13515 on Salt Creek			
Date: 07-30-2002 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 6 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12	0	961.6
2	13.2	11	960.4
3	18.9	23	954.7
4	19.7	38	953.9
5	26.1	42	947.5
6 (Pier 1)	29.7	51.8	943.9
7	34	66.8	939.6
8 (Flow line)	34.4	73.8	939.2
9	33.8	76.8	939.8
10	28.8	81.8	944.8
11	20.2	88.8	953.4
12 (Pier 2)	16.5	111.8	957.1
13	13.6	136.8	960
14	10.3	154.8	963.3
15 (North Abutment End)	9.7	163.6	963.9

Table A12. (continued)

REPORT 5, Bridge 13515 on Salt Creek			
Date: 05-24-2004 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 6 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12.2	0	961.4
2	13.6	11	960
3	19.2	23	954.4
4	20.3	38	953.3
5	26.4	42	947.2
6 (Pier 1)	29.2	51.8	944.4
7 (Flow line)	34.3	76.8	939.3
8	28.8	91.8	944.8
9	20.7	97.8	952.9
11 (Pier 2)	17	111.8	956.6
12	13.4	136.8	960.2
13	10.2	154.8	963.4
14 (North Abutment End)	9.6	163.6	964

Table A12. (continued)

REPORT 6, Bridge 13515 on Salt Creek			
Date: 06-07-2005 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 6 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12.5	0	961.1
2	13.7	11	959.9
3	19.3	23	954.3
4	20.4	38	953.2
5	26.8	42	946.8
6 (Pier 1)	29.4	51.8	944.2
7	34	69.8	939.6
8 (Flow line)	34.8	76.8	938.8
9	34.6	84.8	939
10	28.6	89.8	945
11	20.8	97.8	952.8
12 (Pier 2)	17	111.8	956.6
13	13.1	136.8	960.5
14	10.2	154.8	963.4
15 (North Abutment End)	9.7	163.6	963.9

Table A12 (continued)

REPORT 7, Bridge 13515 on Salt Creek			
DATE: 01-09-2008 Top of rail Elevation from MSL = 973.6 Feet Total length of the bridge = 162.1 feet Depth of Water: 1 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	12.7	0	960.9
2	20	19.5	953.6
3	19.6	26	954
4	25.9	33	947.7
5	27.3	40.5	946.3
6 (Pier 1)	29	49.4	944.6
7	33.5	60	940.1
8 (Flow line)	34.5	63	939.1
9	34.4	74	939.2
10	28.3	84	945.3
11	20.9	93	952.7
12	23	98.7	950.6
13 (Pier 2)	17.5	110	956.1
14	16	115	957.6
15	13.6	137	960
16 (North Abutment End)	9.8	159	963.8

Table A12 (continued)

REPORT 8, Bridge 13515 on Salt Creek

DATE: 11-05-2008
Top of rail Elevation from MSL = 973.6 Feet
Total length of the bridge = 162.1 feet
Depth of Water: 5 feet
Information relevant to downstream data, starting from South abutment end to the North abutment end

Location #	Distance from top of curb (Feet)	Channel width (Feet)	Elevation of River bed from MSL (Feet)
(South Abutment End) 1	11	0	960
2	12.2	13	958.8
3	18	26.3	953
4	28	30.9	943
5	32	36.6	939
6 (Flow line)	32.3	41.9	938.7
7 (Pier 1)	32	48.5	939
8	26.9	87	944.1
9	20	95	951
10(Pier 2)	15.2	112	955.8
11 (North Abutment End)	8	164	963

Year	Mar-60	Sep-65	Mar-70	Aug-75	May-78	Jul-83	Feb-85	Apr-87
Flow line	22.6[2]	23.9[2]	25.9[2]	26.3[2]	26.4[2]	27.4	29	28
Year	Jun-89	May-91	Oct-92	Nov-94	Dec-96	Sep-97	Sep-98	Aug-99
Flow line	28.3	28.3	30.2[2]	30.6[2]	33.8[1]	33.8[1]	33.9[1]	33.9[1]
Year	Aug-00	Aug-01	Jul-02	Jul-03	May-04	Jun-05	Nov-06	Nov-08
Flow line	34[1]	34.6[1]	34.4[1]	34.3[1]	34.3[1]	34.8[1]	34.5[1]	32.25[2]
Year	Jan-08							
Flow line	34.5[1]							

[1]Measured from the top of rail
[2]Measured from the top of curb

Table A13. Structure cross-section and flow line details Bridge No. 13060 on Salt Creek.

Bridge No.	Location	Latitude	Longitude	Highway	Year Built	Length
B13060	1.5 miles E Stephens Co.	34° 37' 49"	97° 32' 09"	S.H. 29	1953	34.1 ft.

REPORT 1, Bridge 13060 on Salt Creek			
Date: Jan-1952 Top of curb Elevation from MSL = 1007.5 Feet Total length of the bridge = 130.9 feet Information relevant to downstream data, starting from South abutment end to the North abutment end			
Location #	**Distance from top of curb (Feet)**	**Channel width (Feet)**	**Elevation of River bed from MSL (Feet)**
(South Abutment End) 1	4.28	0	1003.22
2 (Pier 1)	23.5	41.25	984
3 (Flow line)	24.5	71.25	983
4 (Pier 2)	23.5	91.25	984
5 (North Abutment End)	4.28	132.5	1003.22

Year	Nov-54	Mar-60	Sep-65	Mar-70	Aug-75	May-78	Jul-83	Feb-85
Flow line	25.9[2]	25.2[2]	28[2]	25[2]	25[2]	24.3[2]	25.3	24.6
Year	Apr-87	Jun-89	May-91	Oct-92	Nov-94	Dec-96	Dec-98	Dec-00
Flow line	26	25.7	25.7	26[2]	26.5[2]	29.2[1]	29.1[1]	29.2[1]
Year	Jan-03	Jan-05	Feb-07	Mar-09				
Flow line	29.6[1]	29.3[1]	29.6[1]	29.6[1]				

[1] Measured from the top of rail
[2] Measured from the top of curb

APPENDIX B

COUNTY SECTION LINE MAPS FOR RUSH, WILDHORSE, AND SALT CREEKS IN OKLAHOMA

Figure B-1. Watersheds of Rush, Wildhorse and Salt Creeks, OK.

COUNTY SECTION LINE MAP LEGEND

Rush Creek, OKLAHOMA

Source: http://www.okladot.state.ok.us/hqdiv/p-r-div/maps/2003county/index.htm

County Name
Grady
Garvin

COUNTY SECTION LINE MAP LEGEND

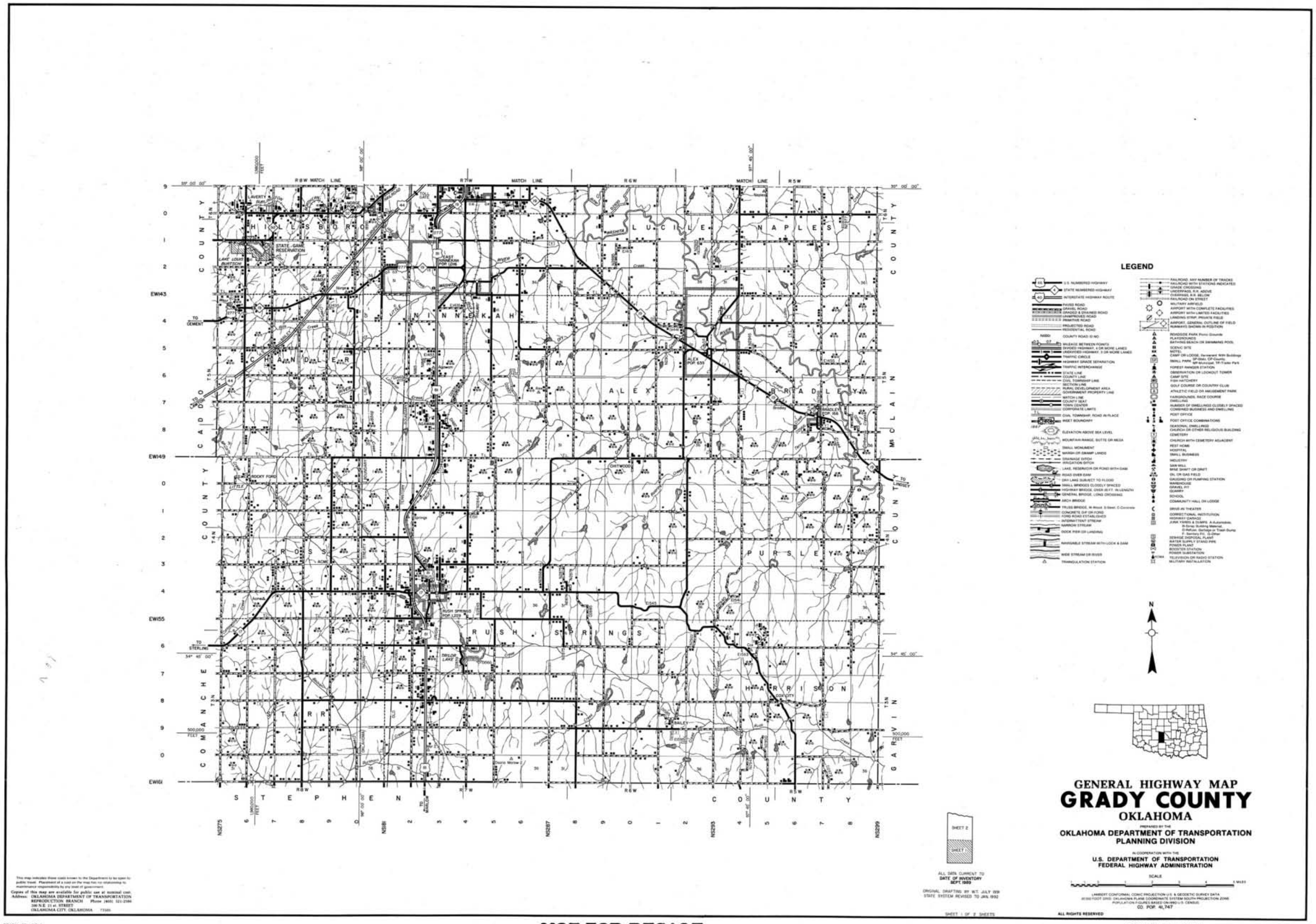
Wildhorse Creek, OKLAHOMA

County Name
Stephens
Murray
Carter

COUNTY SECTION LINE MAP LEGEND

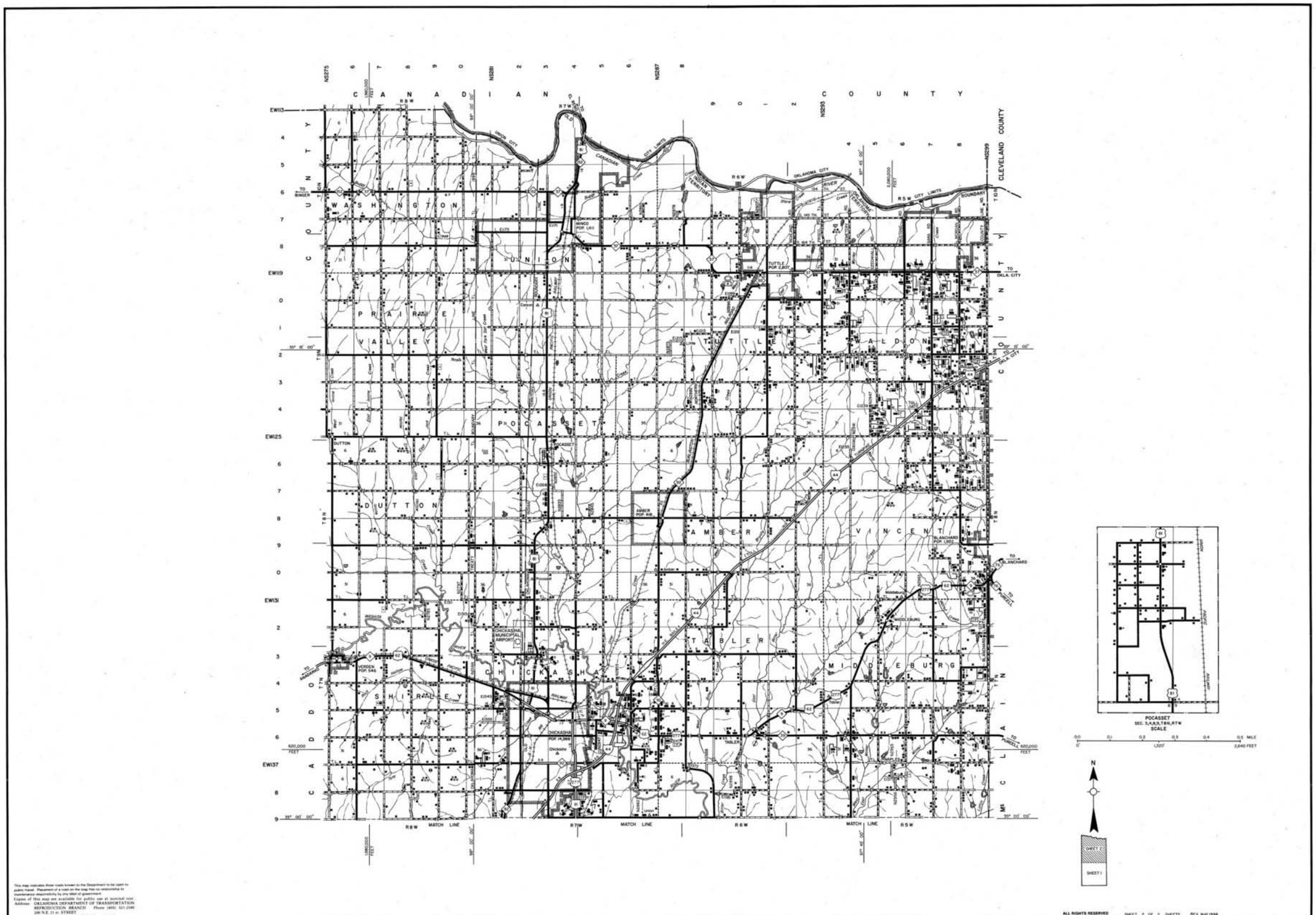
Salt Creek, OKLAHOMA

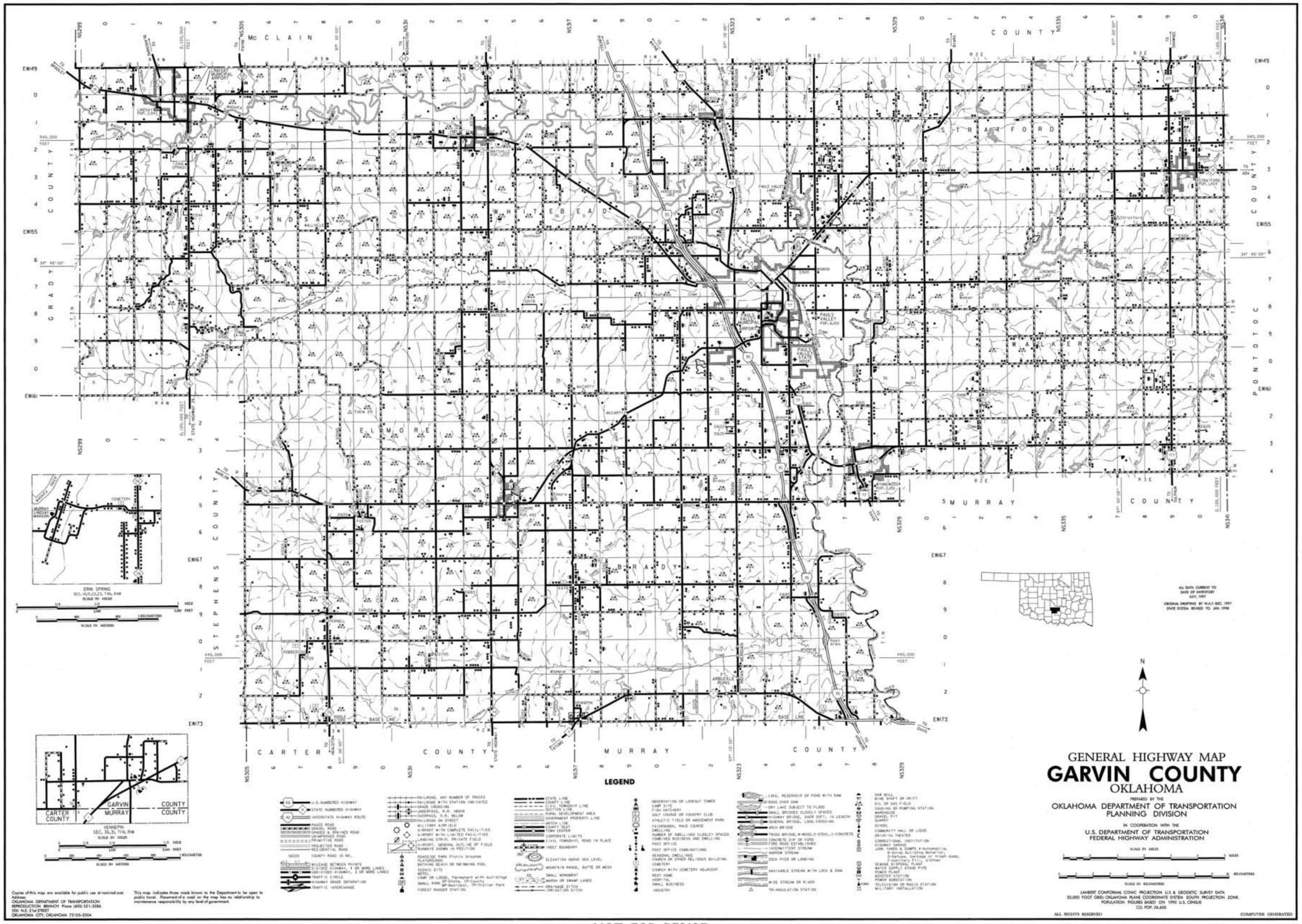
County Name
Garvin

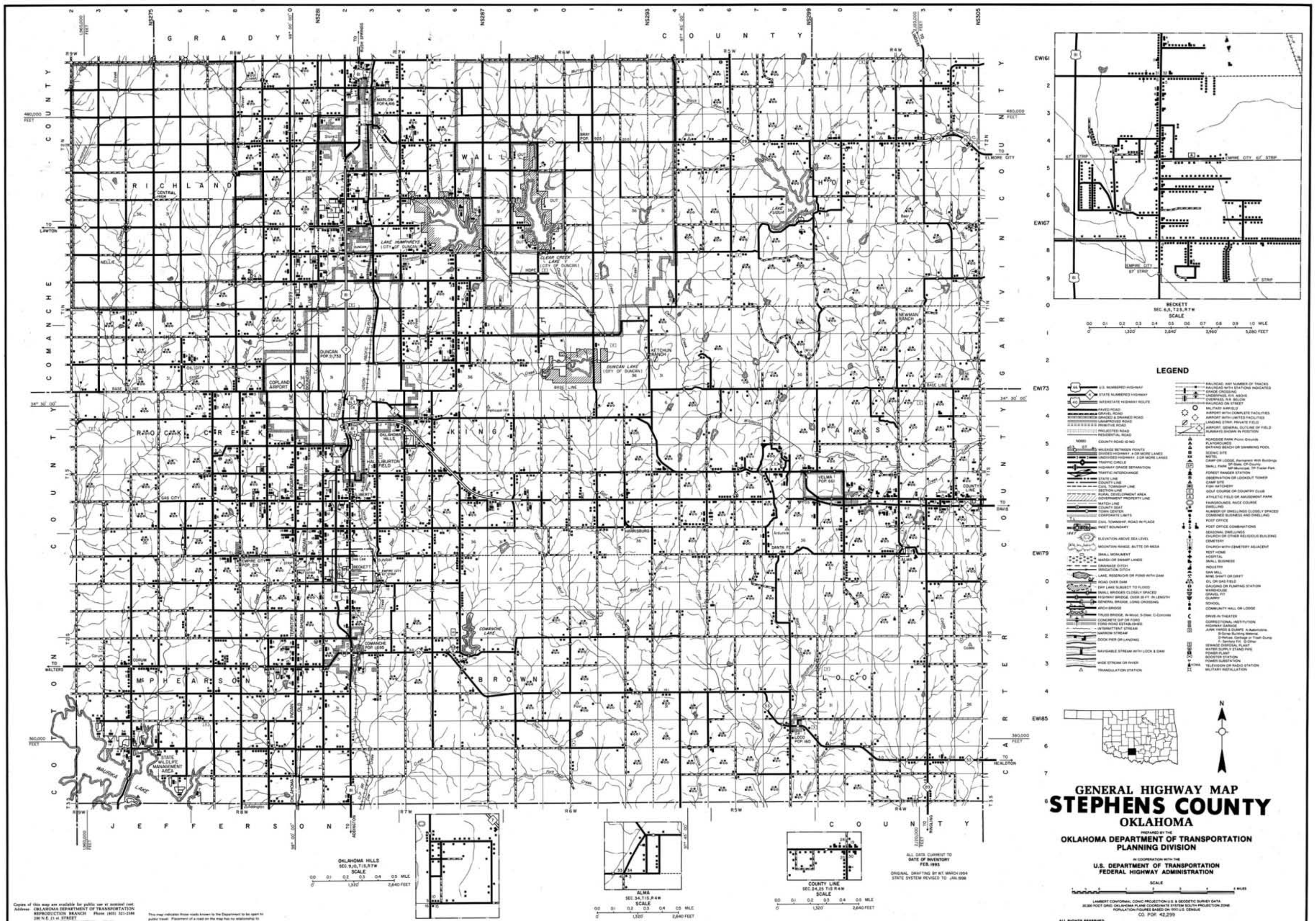


GRADY CO. NO. I

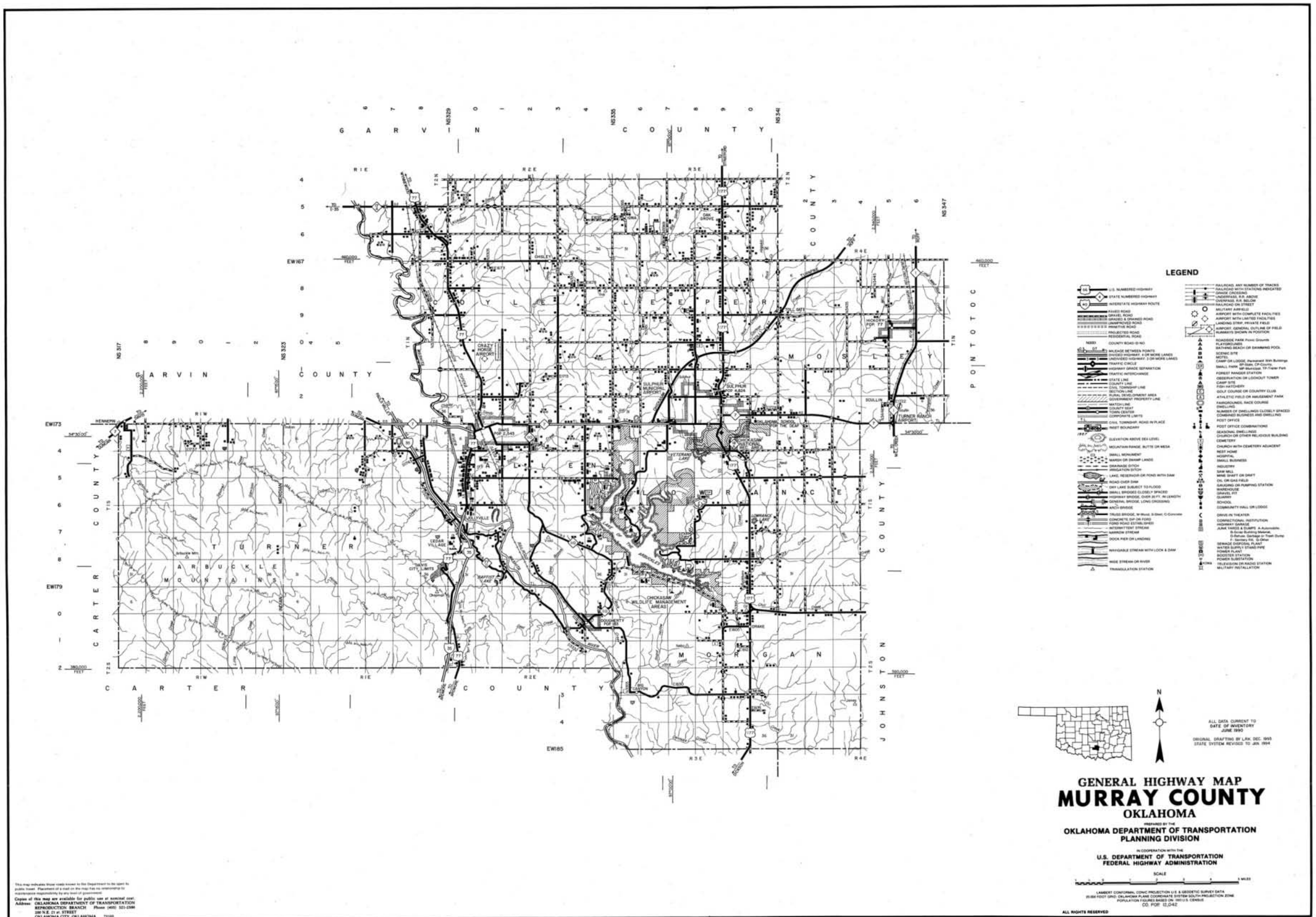
NOT FOR RESALE


CANADIAN COUNTY
CLEVELAND COUNTY
CADDO COUNTY
WASHINGTON
UNION
PRAIRIE VALLEY
TUTTLE
POCASSET
DUTTON
AMBER
VINCENT
TABLER
MIDDLEBURG
CHICKASHA
SHIRLEY
MATCH LINE
POCASSET
SCALE
ALL RIGHTS RESERVED

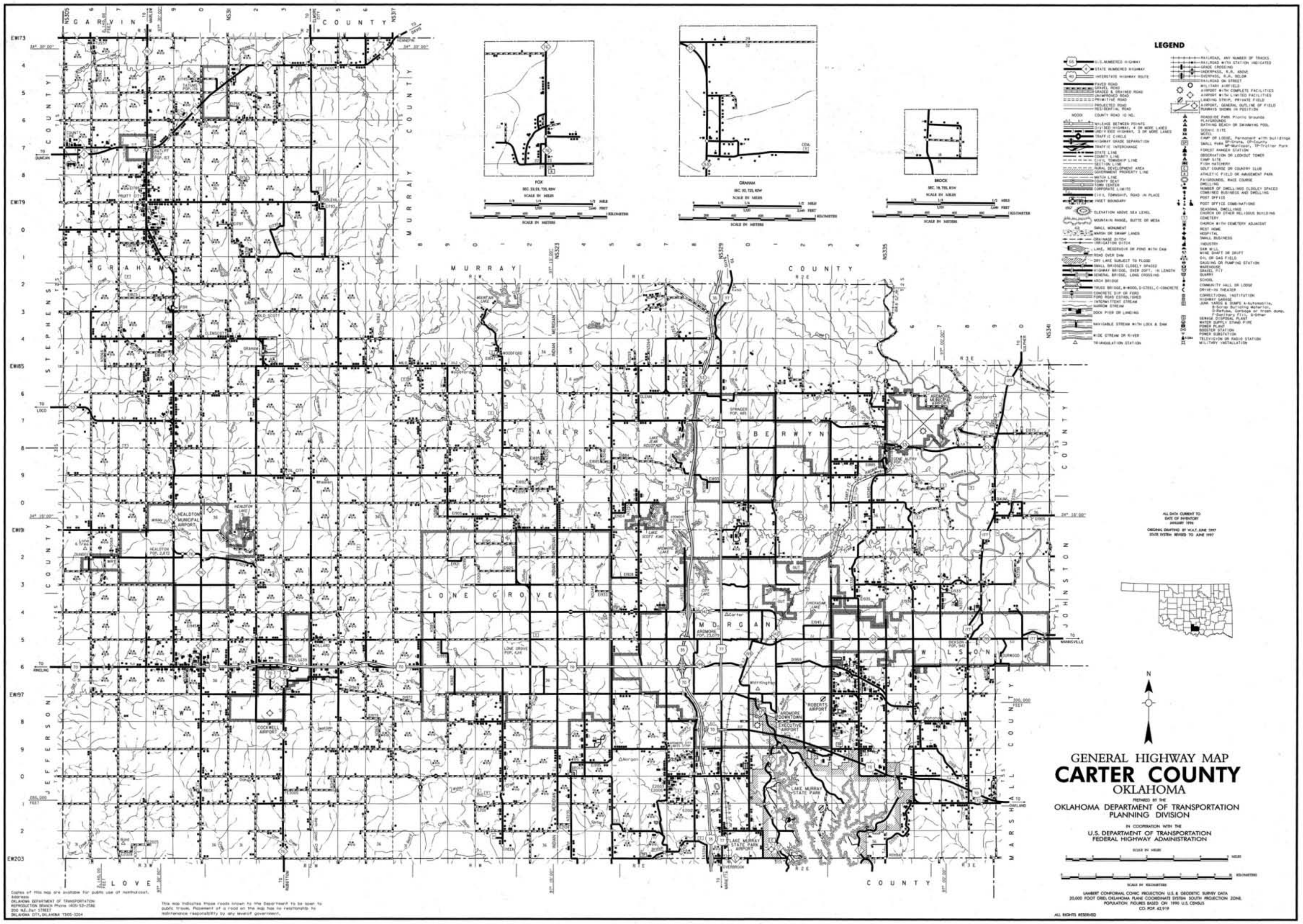

GENERAL HIGHWAY MAP
GARVIN COUNTY
OKLAHOMA
PREPARED BY THE
OKLAHOMA DEPARTMENT OF TRANSPORTATION
PLANNING DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
SCALE IN MILES
SCALE IN KILOMETERS
LAMBERT CONFORMAL CONIC PROJECTION U.S. & GEODETIC SURVEY DATA
20,000 FOOT GRID; OKLAHOMA PLANE COORDINATE SYSTEM SOUTH PROJECTION ZONE.
POPULATION FIGURES BASED ON 1990 U.S. CENSUS
CO. POP. 26,605
ALL RIGHTS RESERVED
COMPUTER GENERATED
LEGEND
Mc CLAIN COUNTY
GRADY COUNTY
STEPHENS COUNTY
CARTER COUNTY
MURRAY COUNTY
PONTOTOC COUNTY
STRATFORD
LINDSAY
PAULS VALLEY
ELMORE
HENNEPIN
SEC. 36,3, T1N, R1W
CARTER COUNTY
GARVIN
MURRAY
COUNTY
Copies of this map are available for public use at nominal cost.
Address:
OKLAHOMA DEPARTMENT OF TRANSPORTATION
REPRODUCTION BRANCH Phone (405) 521-2586
200 N.E. 21st STREET
OKLAHOMA CITY, OKLAHOMA 73105-3204
This map indicates those roads known to the Department to be open to public travel. Placement of a road on the map has no relationship to maintenance responsibility by any level of government.



NOT FOR RESALE



GARVIN COUNTY
CARTER COUNTY
JOHNSTON COUNTY
PONTOTOC COUNTY
ARBUCKLE MOUNTAINS
CHICKASAW WILDLIFE MANAGEMENT AREAS
LEGEND
ALL DATA CURRENT TO DATE OF INVENTORY JUNE 1990
ORIGINAL DRAFTING BY LRK DEC. 1993
STATE SYSTEM REVISED TO JAN. 1994
GENERAL HIGHWAY MAP
MURRAY COUNTY
OKLAHOMA
PREPARED BY THE
OKLAHOMA DEPARTMENT OF TRANSPORTATION
PLANNING DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
SCALE
CO. POP. 12,042
ALL RIGHTS RESERVED


LEGEND
GARVIN COUNTY
MURRAY COUNTY
STEPHENS COUNTY
JEFFERSON COUNTY
LOVE COUNTY
MARSHALL COUNTY
JOHNSTON COUNTY
GRAHAM
HEWITT
LONE GROVE
MORGAN
BERWYN
FOX
GRAHAM
BROCK
GENERAL HIGHWAY MAP
CARTER COUNTY
OKLAHOMA
PREPARED BY THE
OKLAHOMA DEPARTMENT OF TRANSPORTATION
PLANNING DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
LAKE MURRAY STATE PARK
N