

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

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| <p>16. ABSTRACT</p> <p>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.</p> <p>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.</p> <p>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.</p> | | | |
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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 | hectares | ha | ha | hectares | 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 | 6.895 | kilopascals | kPa | kPa | kilopascals | 0.1450 | poundforce | lbf/in ² |
| | | | per square inch | | | | | per square inch | |

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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

| | Page |
|--|------|
| Acknowledgements..... | 5 |
| I. Introduction..... | 11 |
| II. Study Area | 12 |
| III. Watershed Delineation..... | 13 |
| IV. Hydrology | 21 |
| V. Analysis of Cross-sectional Profiles..... | 37 |
| VI. Analysis of Flow line Profiles | 65 |
| VII. Results..... | 76 |
| VIII. Conclusions | 85 |
| IX. References..... | 86 |
| APPENDIX A – Tables of Cross-sectional geometries for Rush, Wildhorse and Salt Creeks in Oklahoma | 87 |
| APPENDIX B – County Section line maps for Rush, Wildhorse, and Salt Creeks in Oklahoma | 128 |

FIGURES

| | Page |
|---|------|
| 1. USGS National Elevation dataset for the study area | 15 |
| 2. Flow direction Raster Layer | 18 |
| 3. Flow Accumulation Raster Layer | 19 |
| 4. Watershed Boundary of Rush, Wildhorse and Salt Creeks, Washita River | 20 |
| 5. USGS stream flow and rain gaging stations for Rush, Wildhorse and Salt Creeks ... | 24 |
| 6. USGS 07329000 Rush Creek near Purdy, OK | 29 |
| 7. USGS 07329500 Rush Creek near Maysville, OK..... | 30 |
| 8. USGS 07329700 Wildhorse Creek near Hoover, OK | 31 |
| 9. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Cox City, OK..... | 32 |
| 10. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Elmore City, OK..... | 33 |
| 11. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Hennepin, OK | 34 |
| 12. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Pauls Valley, OK | 35 |
| 13. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Tussy, OK..... | 36 |
| 14. Cross-sectional profile at bridge 17568 on I-35 NB over Rush Creek..... | 38 |

| | |
|---|----|
| 15. Picture demonstrating extent of damage to pier at bridge 17568 on I-35 NB over Rush Creek..... | 39 |
| 16. Cross-sectional profiles at bridge 17569 on I-35 SB over Rush Creek..... | 40 |
| 17. Profile picture of bridge 17569 on I-35 SB over Rush Creek | 41 |
| 18. Cross-sectional profiles at bridge 10738 on SH 74 over Rush Creek | 43 |
| 19. Profile picture of bridge 10738 on SH 74 over Rush Creek..... | 44 |
| 20. Picture demonstrating extent of damage to south pier at bridge 10738 on SH 74 over Rush Creek..... | 45 |
| 21. Picture demonstrating extent of damage to pier at bridge 12643 on SH 76 over Rush Creek..... | 46 |
| 22. Picture demonstrating extent of damage to pier at bridge 12643 on SH 76 over Rush Creek..... | 47 |
| 23. Cross-sectional profile at bridge 17590 on I-35 NB over Wildhorse Creek | 48 |
| 24. Picture demonstrating flood water level at pier at bridge 17590 on I-35 NB over Wildhorse Creek | 49 |
| 25. Cross-sectional profile at bridge 17591 on I-35 SB over Wildhorse Creek | 50 |
| 26. Cross-sectional profiles at bridge 21120 on SH 74 over Wildhorse Creek..... | 51 |
| 27. Picture demonstrating extent of damage to piers at bridge 21120 on SH 74 over Wildhorse Creek | 52 |
| 28. Picture demonstrating extent of damage to piers at bridge 21120 on SH 74 over Wildhorse Creek | 53 |
| 29. Cross-sectional profile at bridge 13235 on SH 76 over Wildhorse Creek | 55 |
| 30. Picture demonstrating extent of damage to piers at bridge 13235 on SH 76 over Wildhorse Creek | 56 |
| 31. Picture demonstrating extent of damage at culvert 18199 on SH 29 over Wildhorse Creek | 57 |
| 32. Cross-sectional profiles at bridge 19629 on SH 74 over Salt Creek | 59 |

| | |
|--|----|
| 33. Picture demonstrating extent of damage to piers at bridge 19629 on SH 74 over Salt Creek | 60 |
| 34. Cross-sectional profiles at bridge 13515 on SH 76 over Salt Creek | 61 |
| 35. Picture demonstrating extent of damage to piers at bridge 13515 on SH 76 over Salt Creek | 62 |
| 36. Cross-sectional profile at bridge 13060 on SH 29 over Salt Creek | 63 |
| 37. Picture demonstrating extent of damage to piers at bridge 13060 on SH 29 over Salt Creek..... | 64 |
| 38. Longitudinal profile of Rush Creek..... | 66 |
| 38a. Longitudinal profile of Rush Creek..... | 67 |
| 38b. Longitudinal profile of Rush Creek..... | 68 |
| 39. Longitudinal profile of Wildhorse Creek | 69 |
| 39a. Longitudinal profile of Wildhorse Creek | 70 |
| 39b. Longitudinal profile of Wildhorse Creek | 71 |
| 39c. Longitudinal profile of Wildhorse Creek | 72 |
| 39d. Longitudinal profile of Wildhorse Creek | 73 |
| 40. Longitudinal profile of Salt Creek..... | 75 |
| 41. River degradation rate with trend line of Rush Creek, OK | 79 |
| 42. River degradation rate with trend line of Wildhorse Creek, OK..... | 81 |
| 43. River degradation rate with trend line of Salt Creek, OK | 83 |

TABLES

| | Page |
|---|------|
| 1. Description of USGS stream flow gage stations | 22 |
| 2. Description of USGS rain gage stations | 23 |
| 3. Flood Frequency estimates based on at least 8 years of annual peak discharge data at USGS gage stations | 26 |
| 4. Peak flows recorded at USGS gage stations..... | 26 |
| 5. Summary of river degradation rates of Rush Creek, OK..... | 78 |
| 6. Summary of river degradation rates of Wildhorse Creek, OK | 80 |
| 7. Summary of river degradation rates of Salt Creek, OK..... | 82 |
| 8. Summary of river degradation rates of Washita River, OK | 84 |

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.

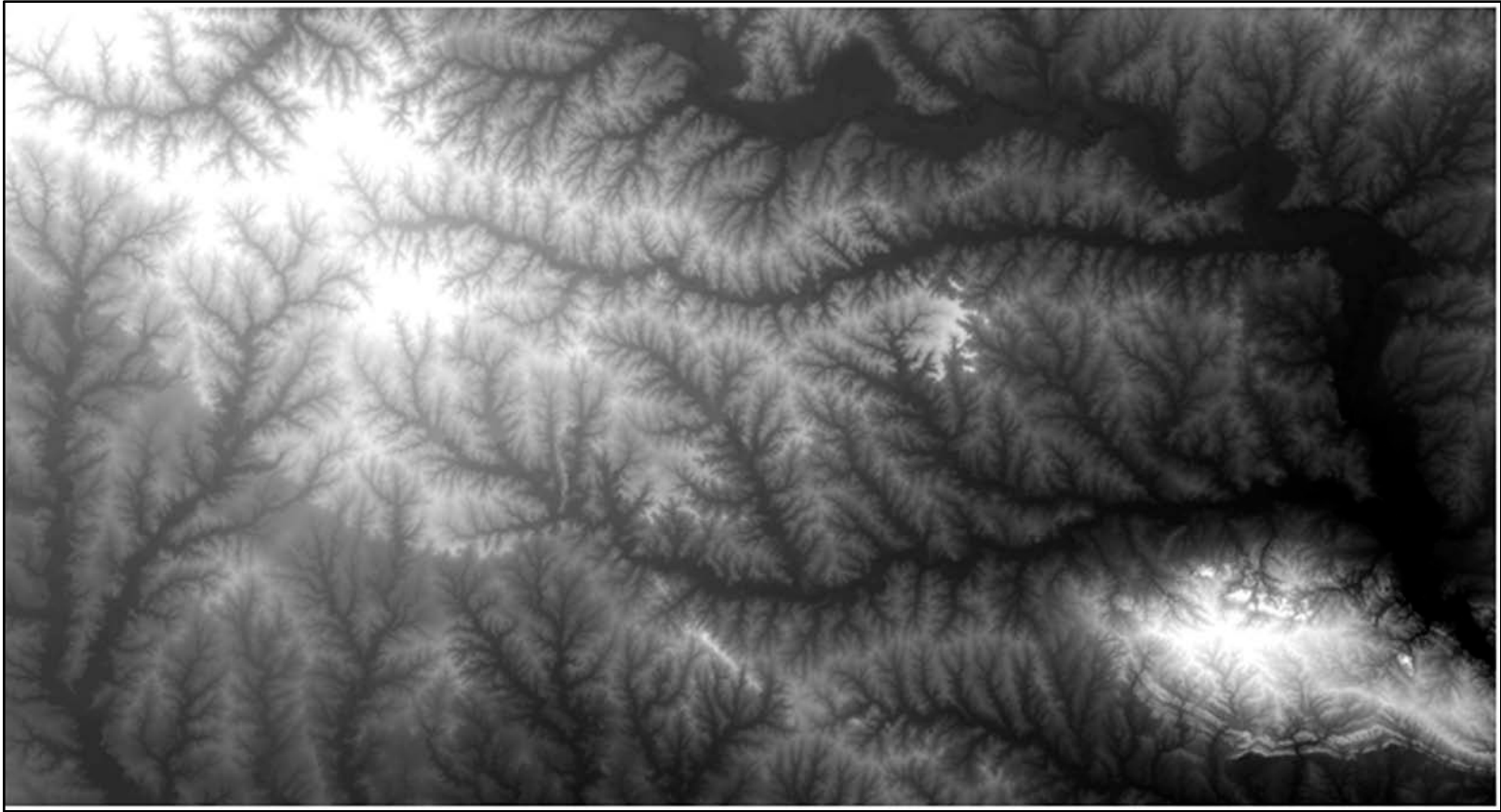


Figure 1. USGS National Elevation dataset for the study area.

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.

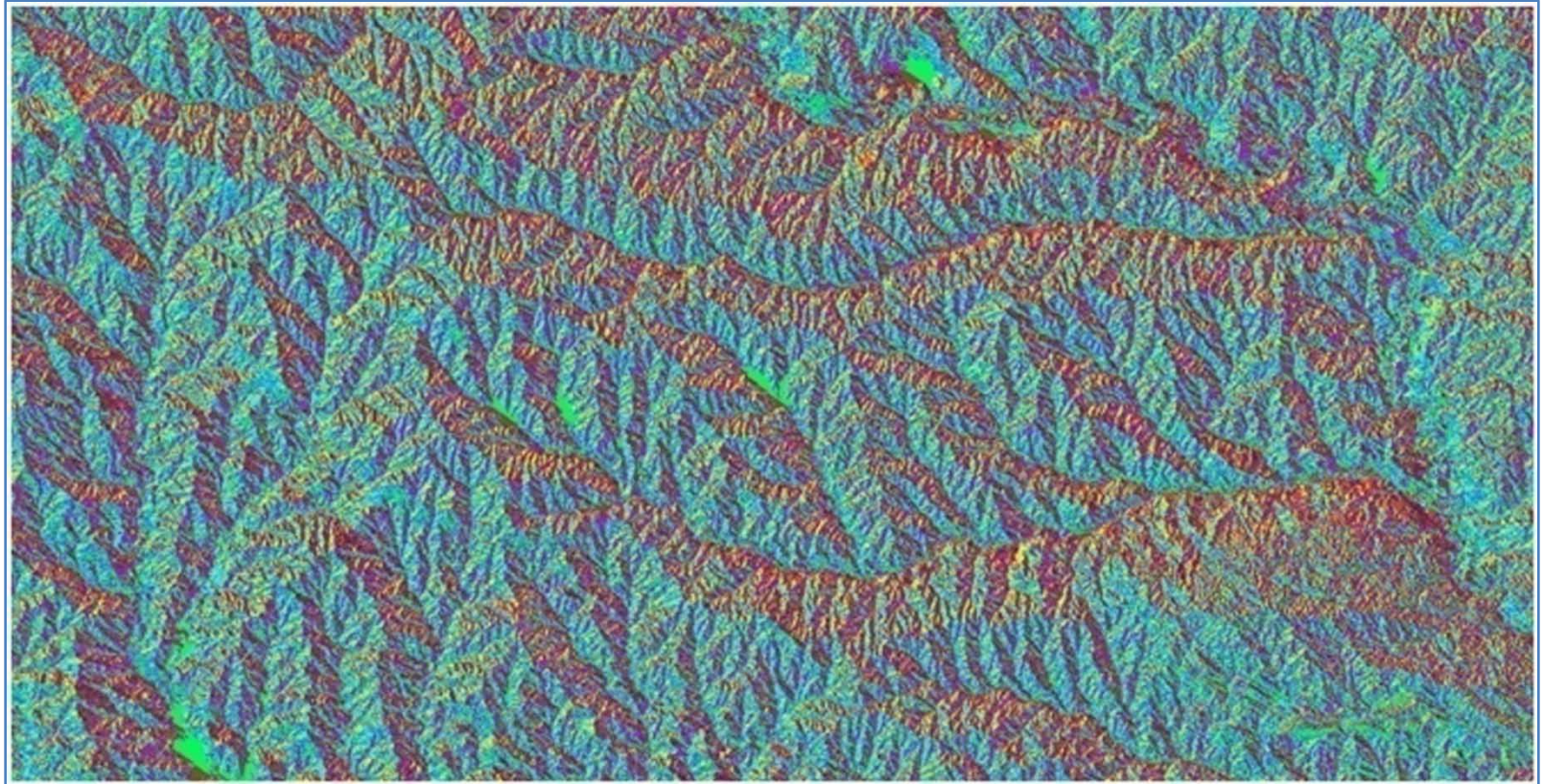


Figure 2. Flow direction Raster Layer.

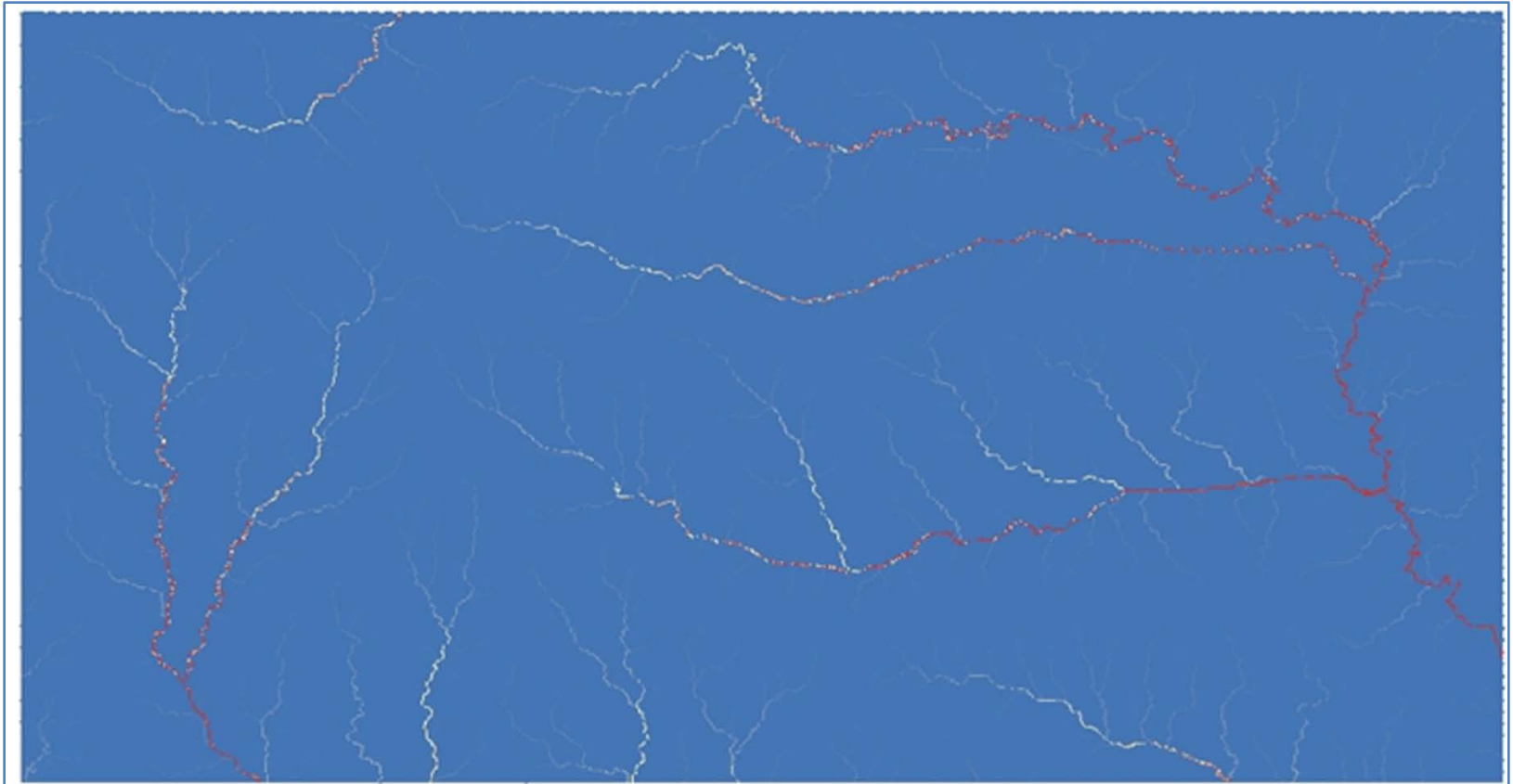


Figure 3. Flow Accumulation Raster Layer.

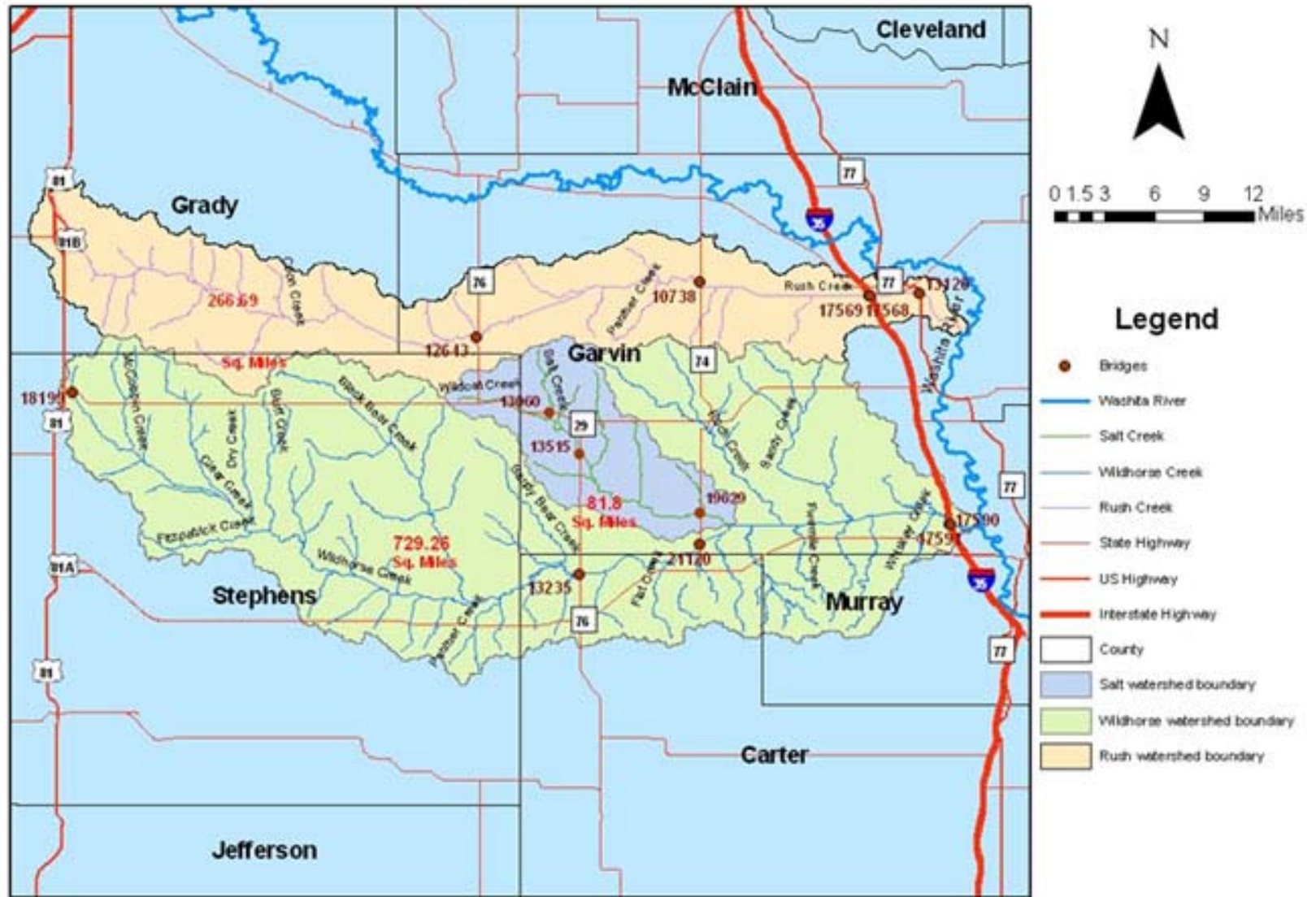


Figure 4. Watershed Boundary of Rush, Wildhorse, and Salt Creeks, Washita River.

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 |
|--|---|
| <p>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.</p> | <p>1980-2008</p> |
| <p>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.</p> | <p>1947-2008</p> |
| <p>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.</p> | <p>1948-1951 1993-2008</p> |
| <p>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.</p> | <p>1899-2008</p> |
| <p>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.</p> | <p>1993-2005</p> |

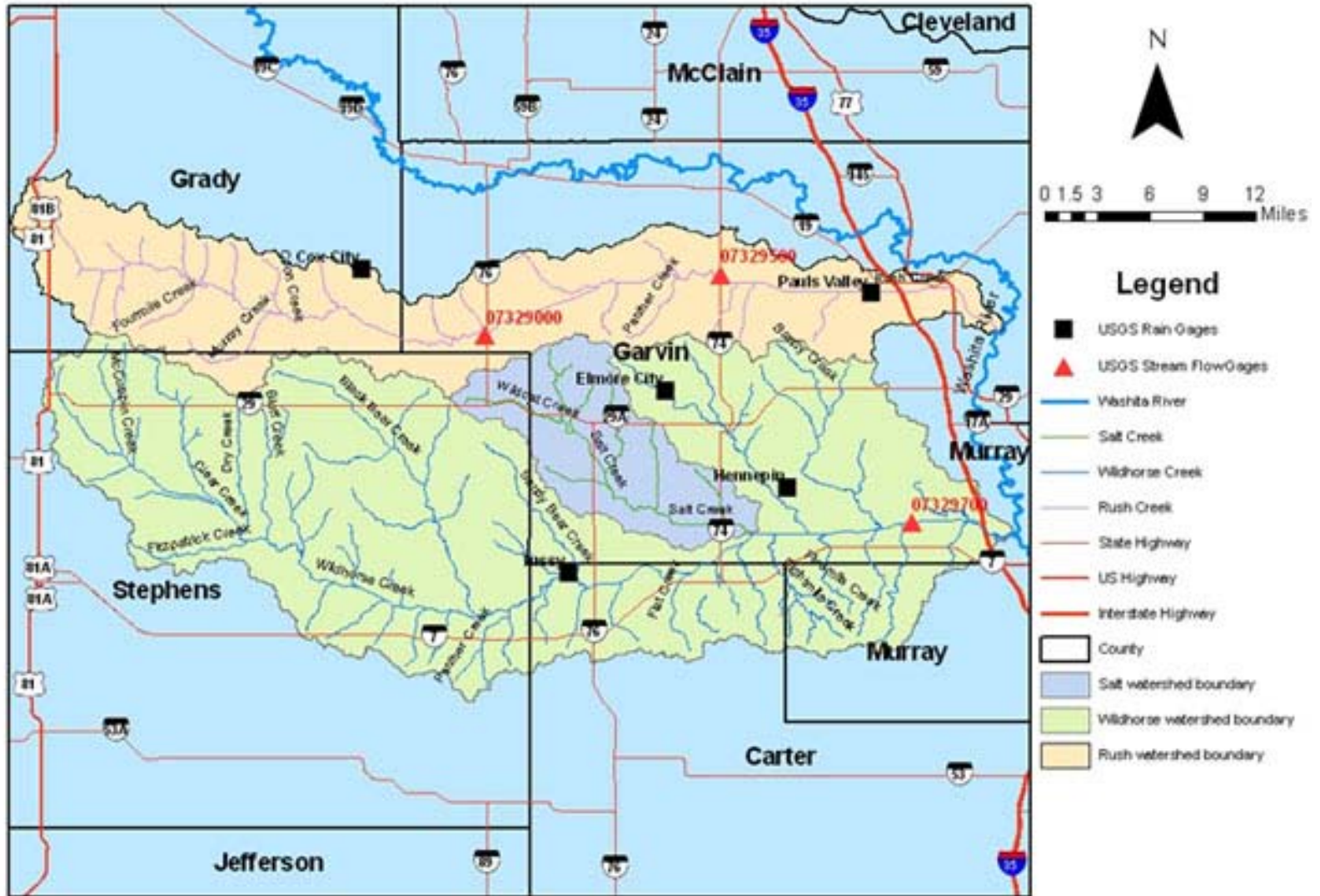


Figure 5. USGS stream flow and rain gaging stations for Rush, Wildhorse and Salt Creeks.

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 |

¹N – Unregulated Basin, ²R – 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.



USGS 07329000 Rush Creek at Purdy, OK

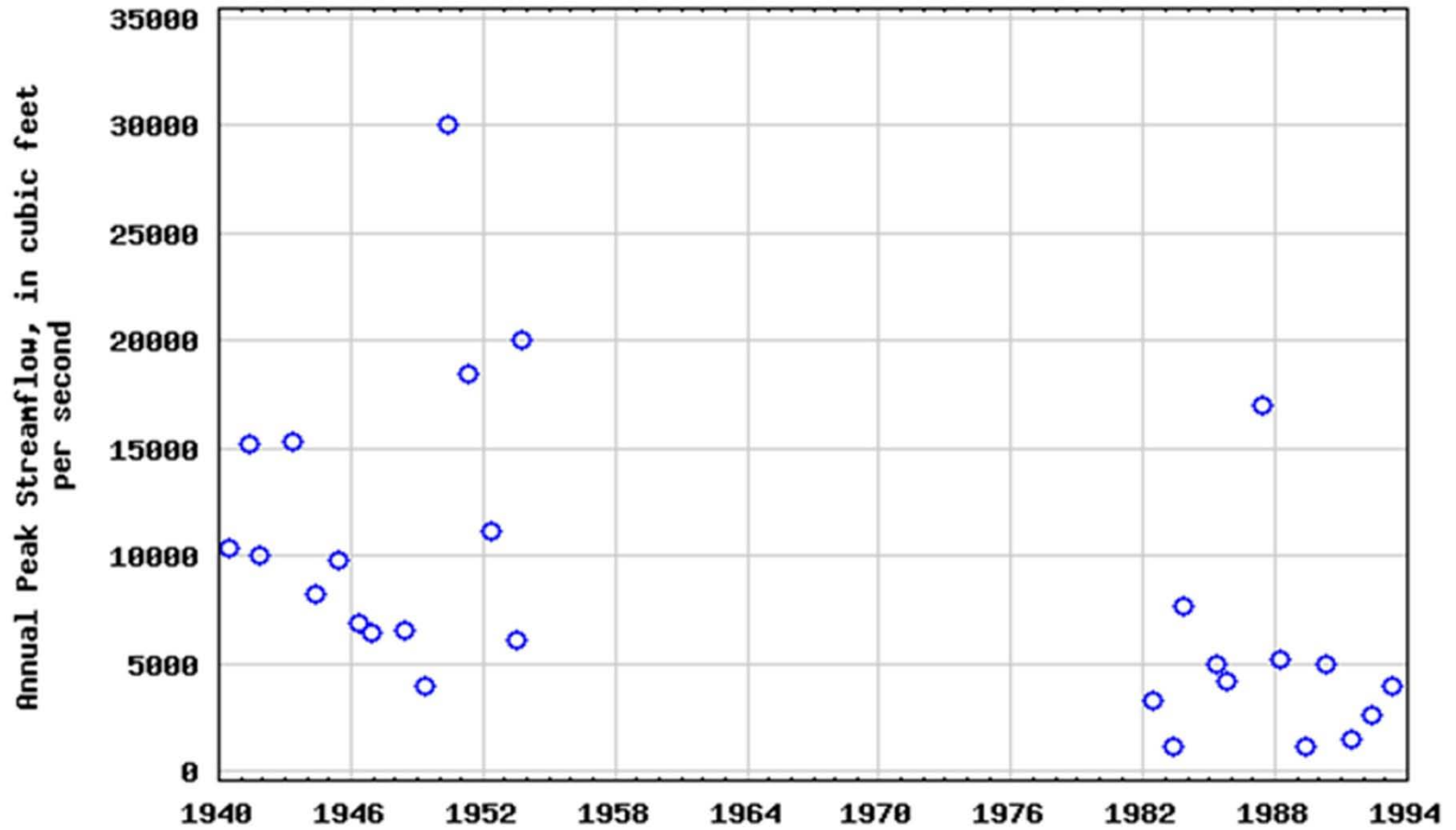


Figure 6. USGS 07329000 Rush Creek at Purdy, OK.

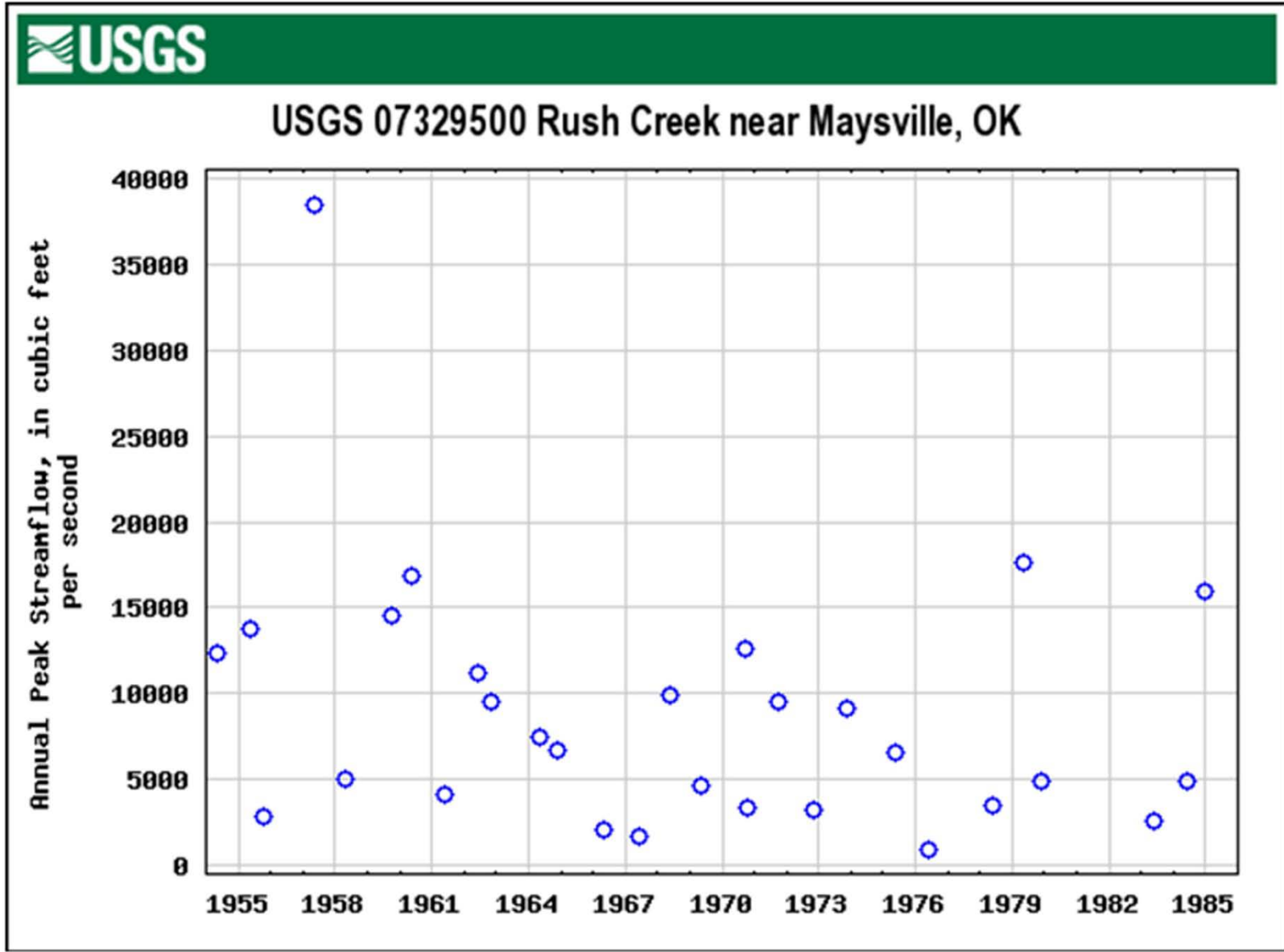


Figure 7. USGS 07329500 Rush Creek near Maysville, OK.

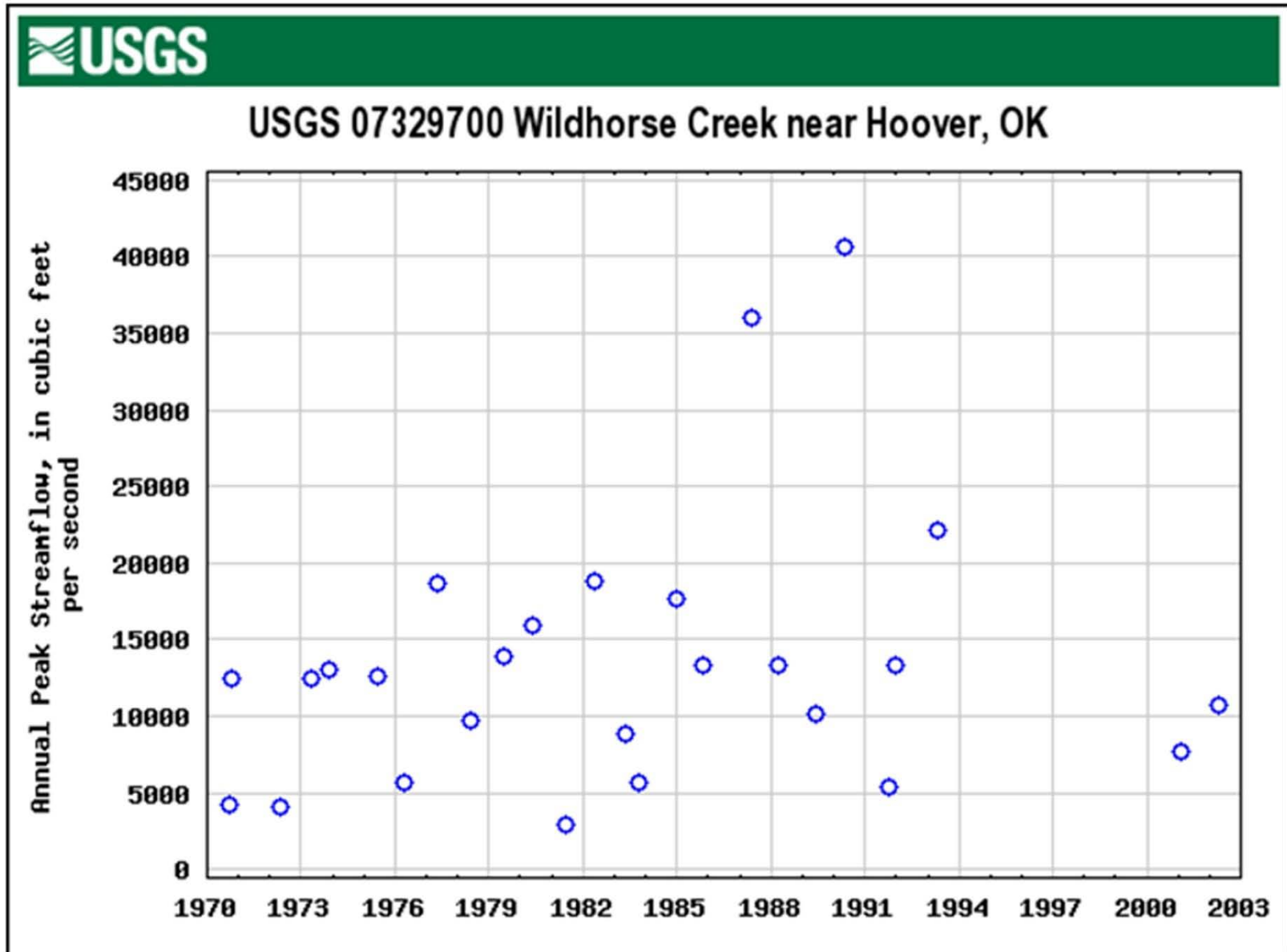


Figure 8. USGS 07329700 Wildhorse Creek near Hoover, OK.

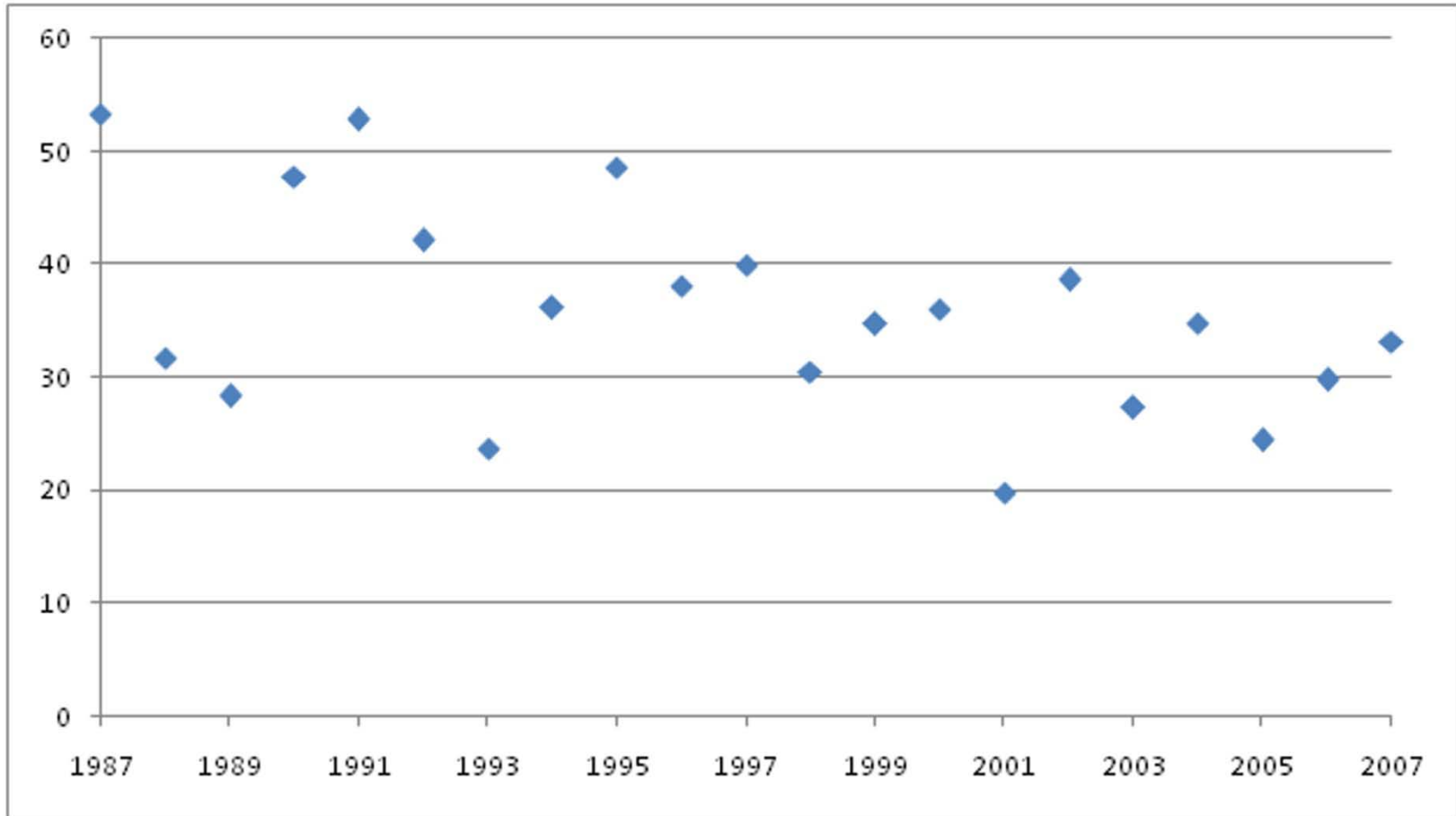


Figure 9. Annual precipitation (in/yr) Oklahoma Climatological Survey Site at Cox City, OK.

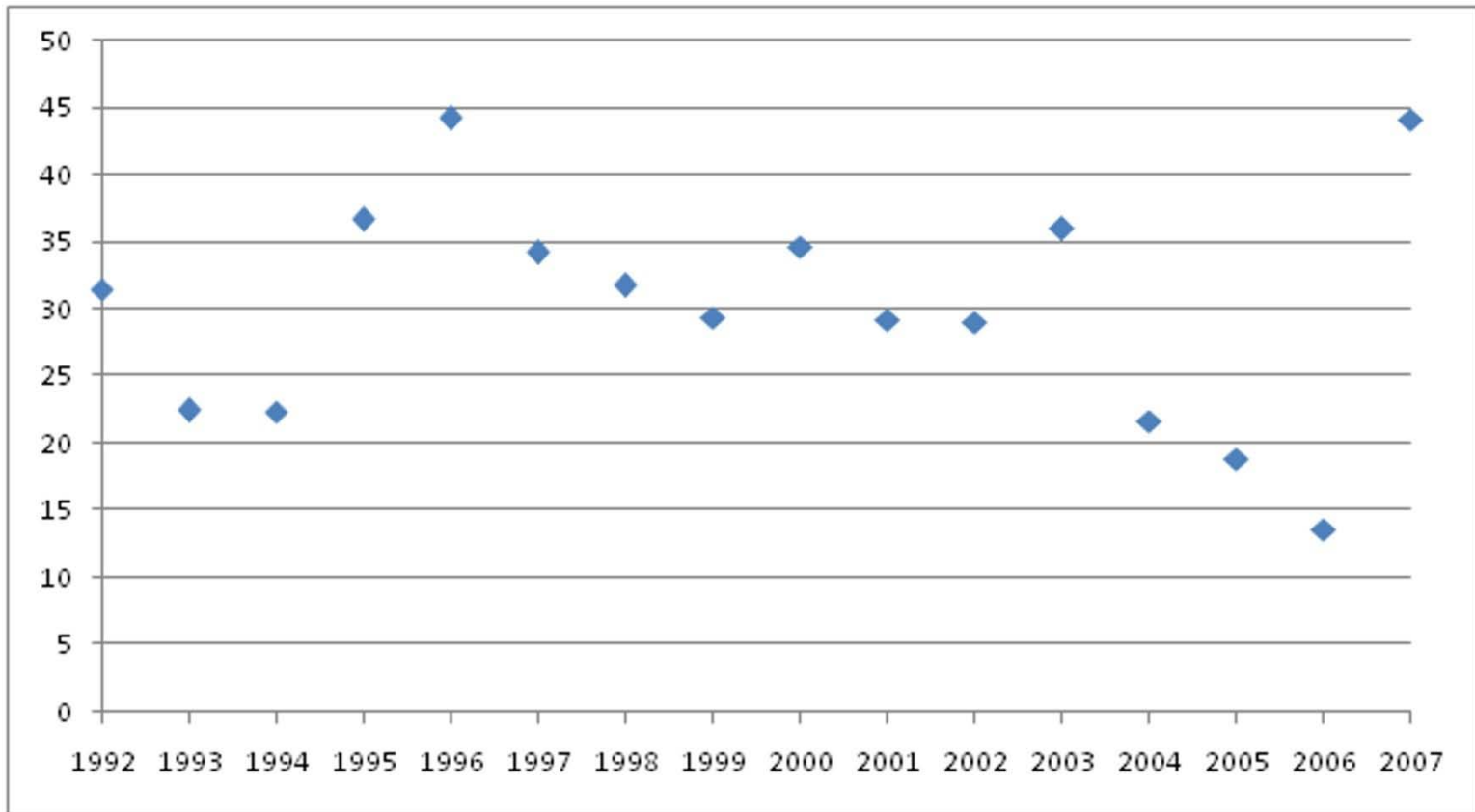


Figure 10. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Elmore City, OK.

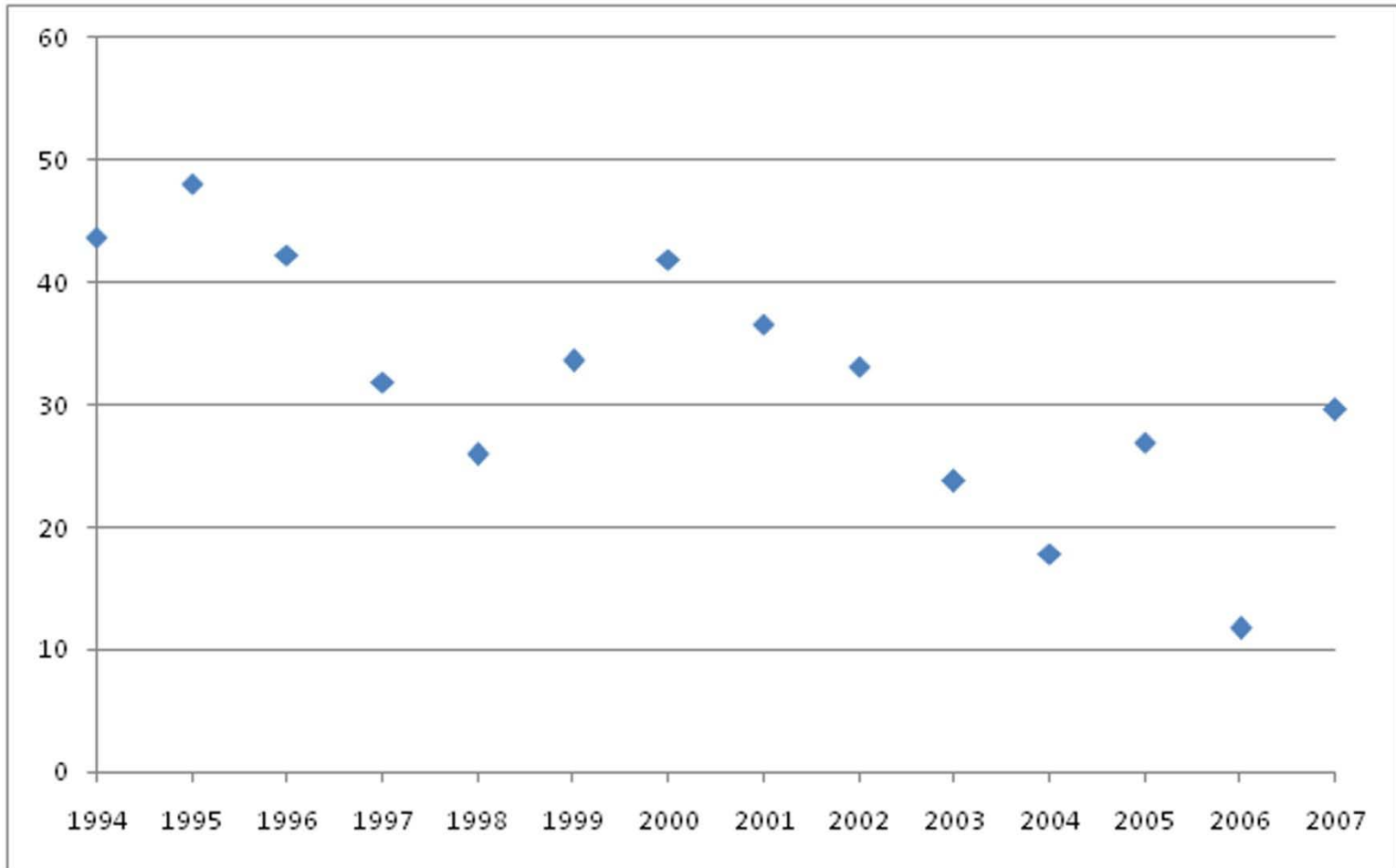


Figure 11. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Hennepin, OK.

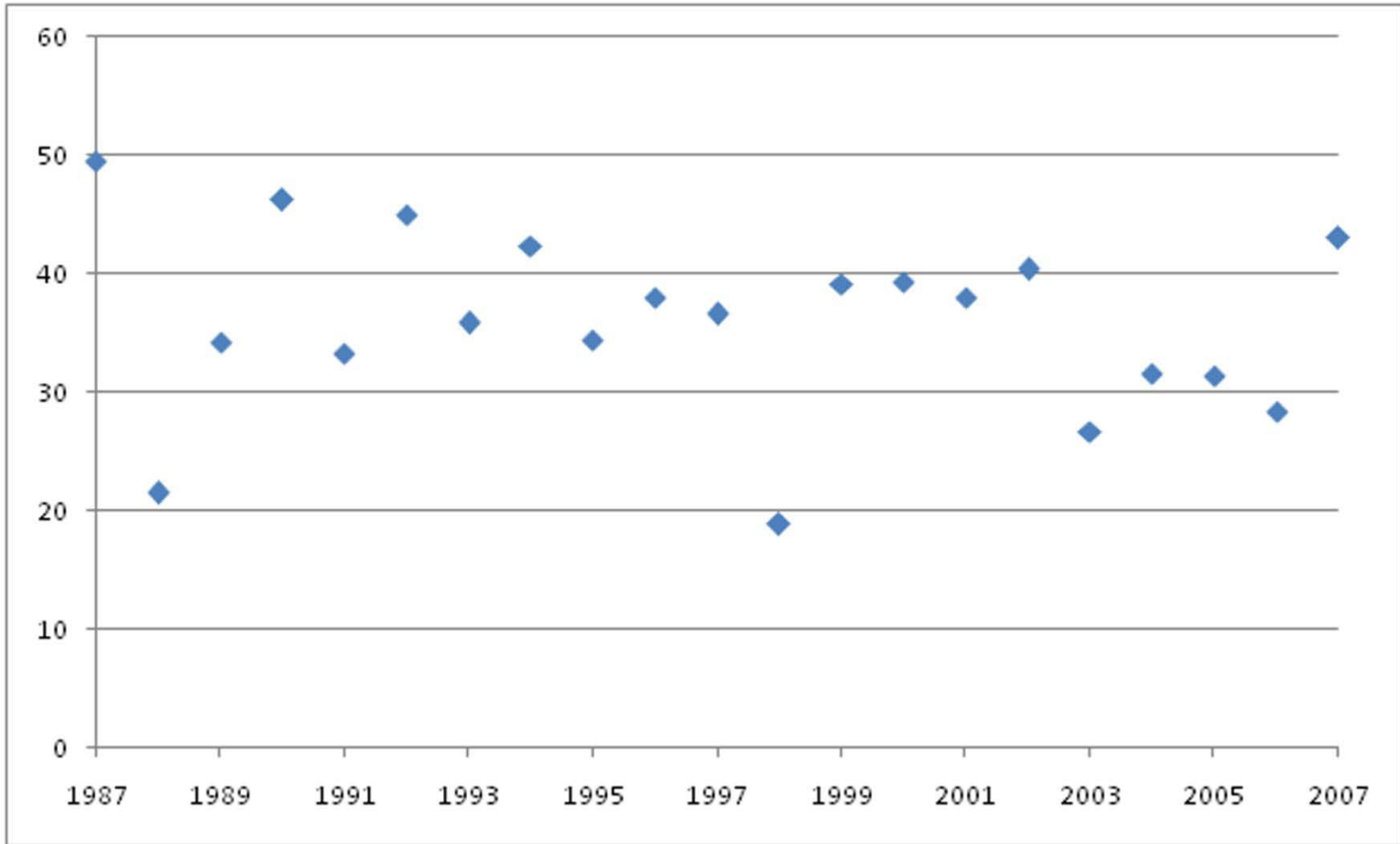


Figure 12. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Pauls Valley, OK.

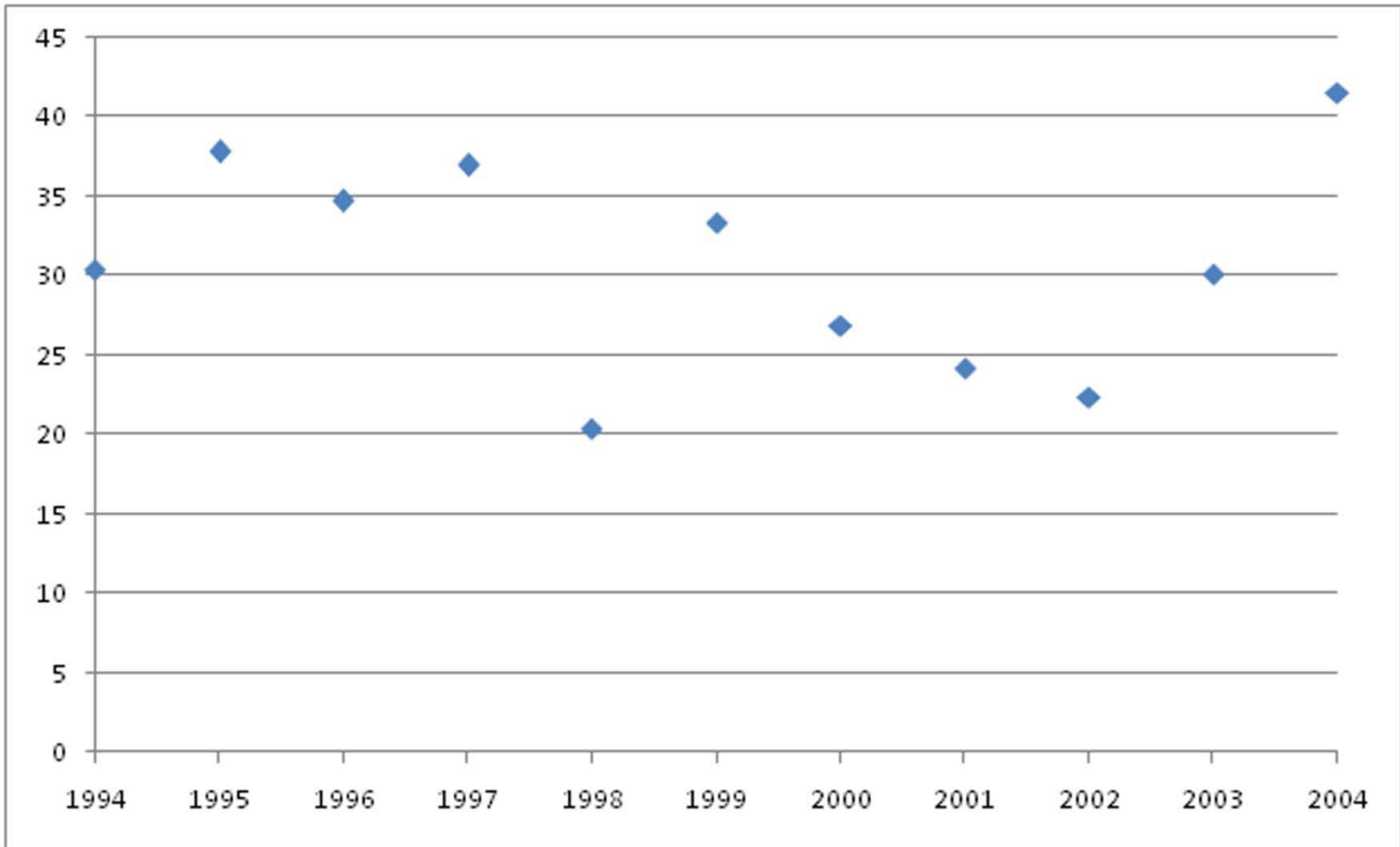


Figure 13. Annual precipitation (in/yr) Oklahoma Climatological Survey site at Tussy, OK.

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 $34^{\circ} 44' 05''$ N and $97^{\circ} 12' 51''$ 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 $34^{\circ} 43' 55''$ N and $97^{\circ} 15' 26''$ 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 $34^{\circ} 43' 54''$ N and $97^{\circ} 15' 28''$ W respectively. Figure 16 demonstrates the extent of river bed degradation at the bridge. Figure 17 shows a roadway profile of this bridge.

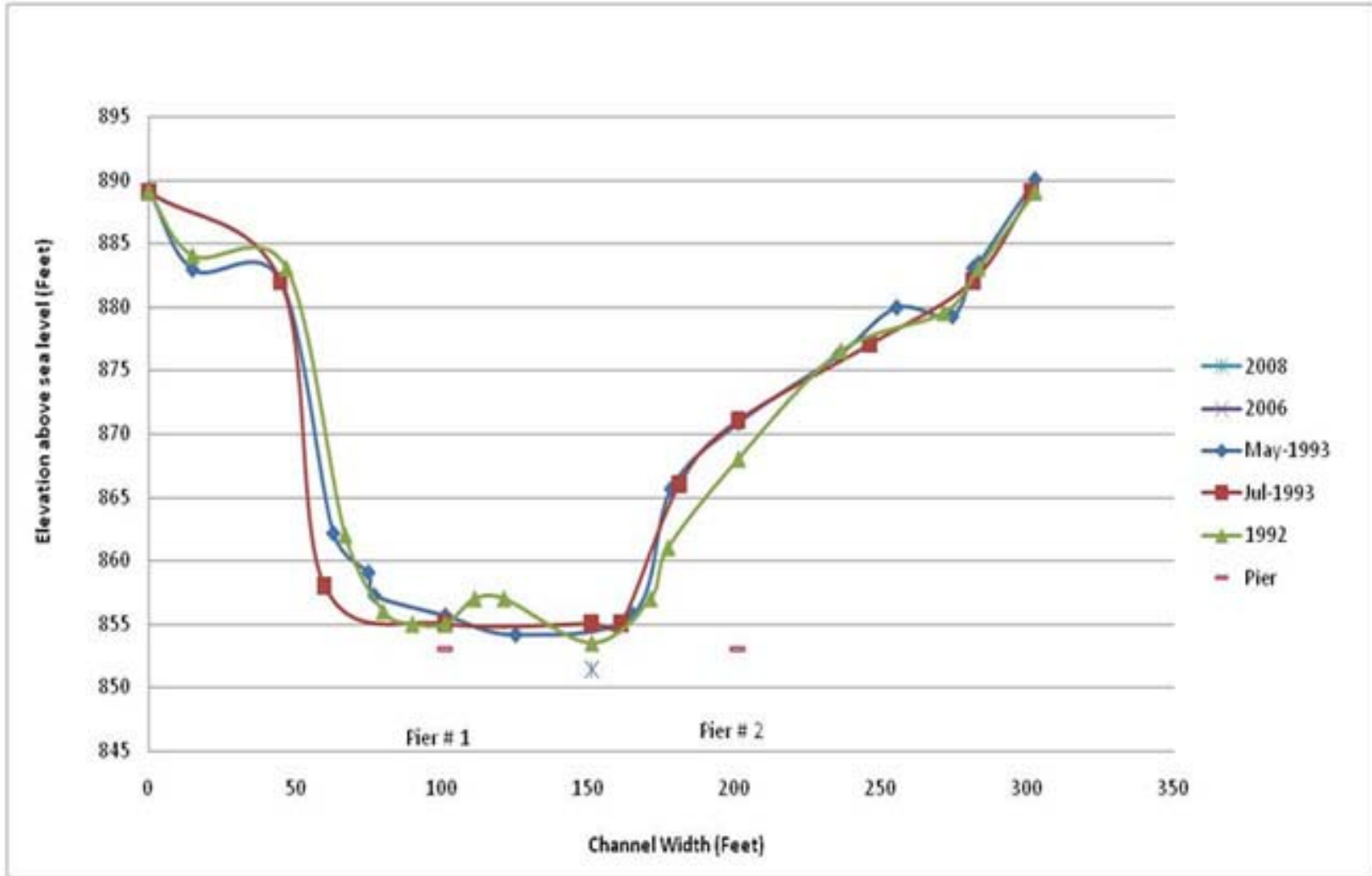


Figure 14. Cross-sectional profile at bridge 17568 on I-35 NB over Rush Creek.



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

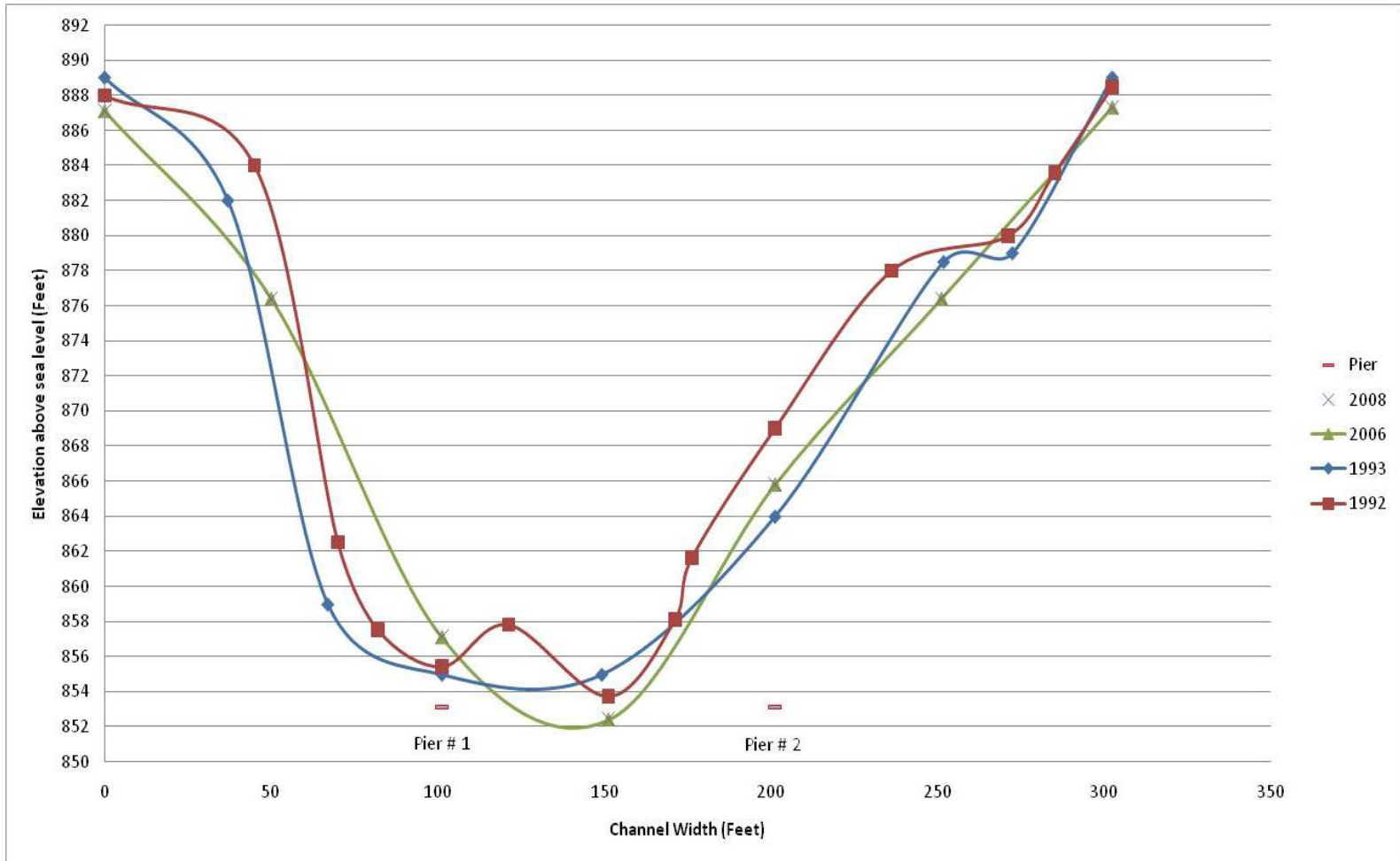


Figure 16. Cross-sectional profiles at bridge 17569 on I-35 SB over Rush Creek.



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.

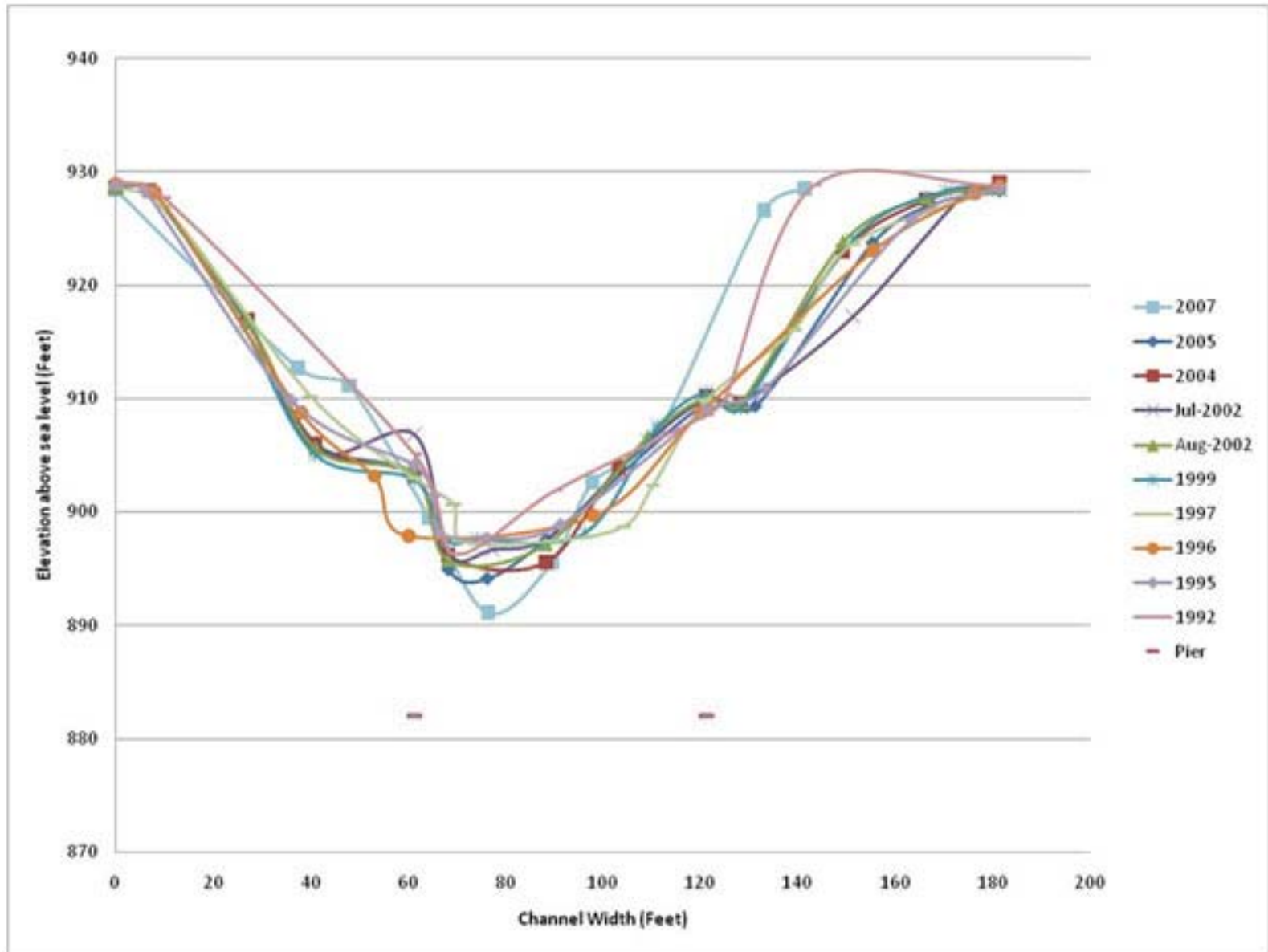


Figure 18. Cross-sectional profiles at bridge 10738 on SH 74 over Rush Creek.

2528-08.42X
10738
Garvin Co.
SH 74
Rush Creek
11/13/2006



44

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.

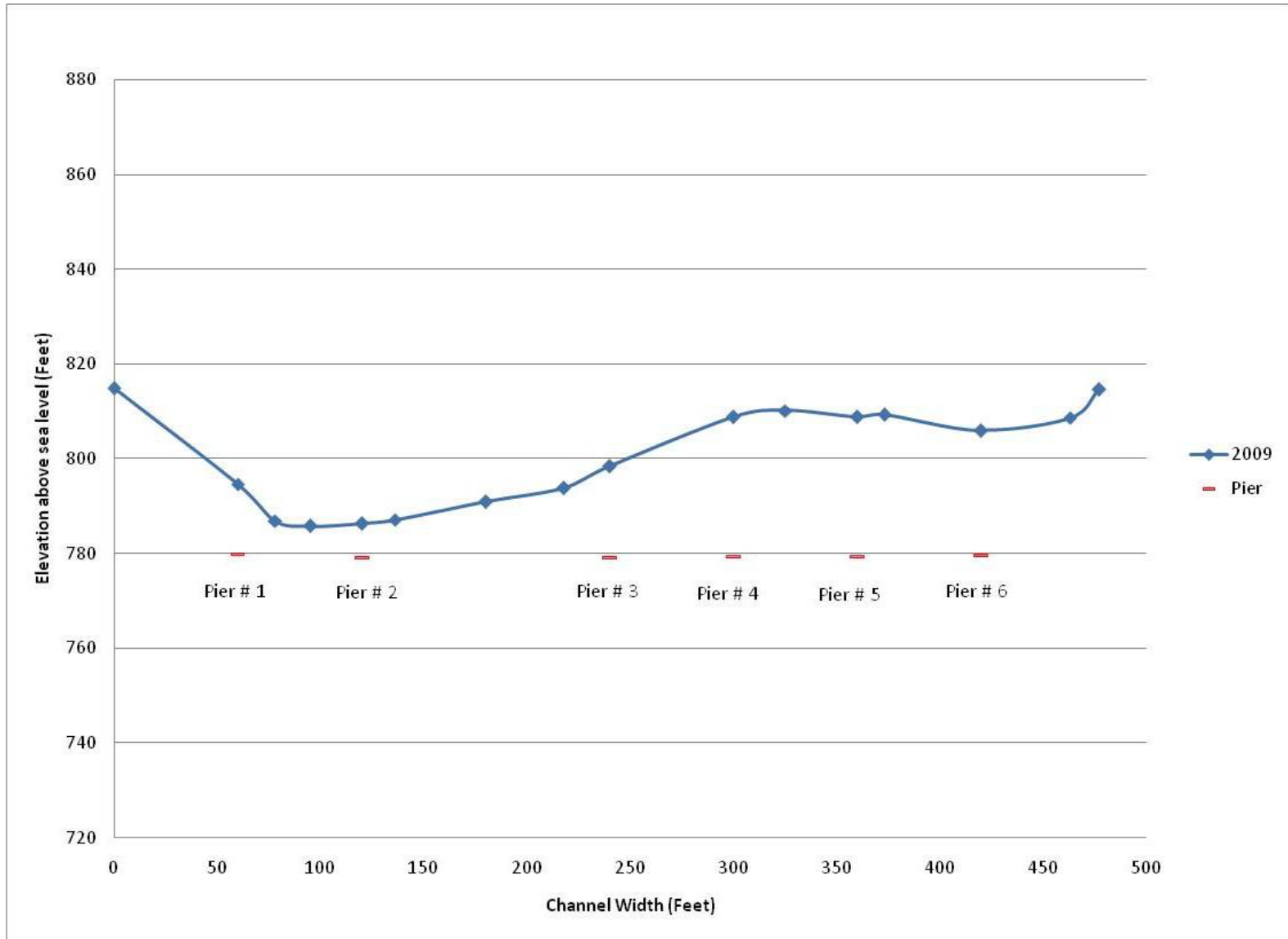


Figure 23. Cross-sectional profile at bridge 17590 on I-35 NB over Wildhorse Creek.



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

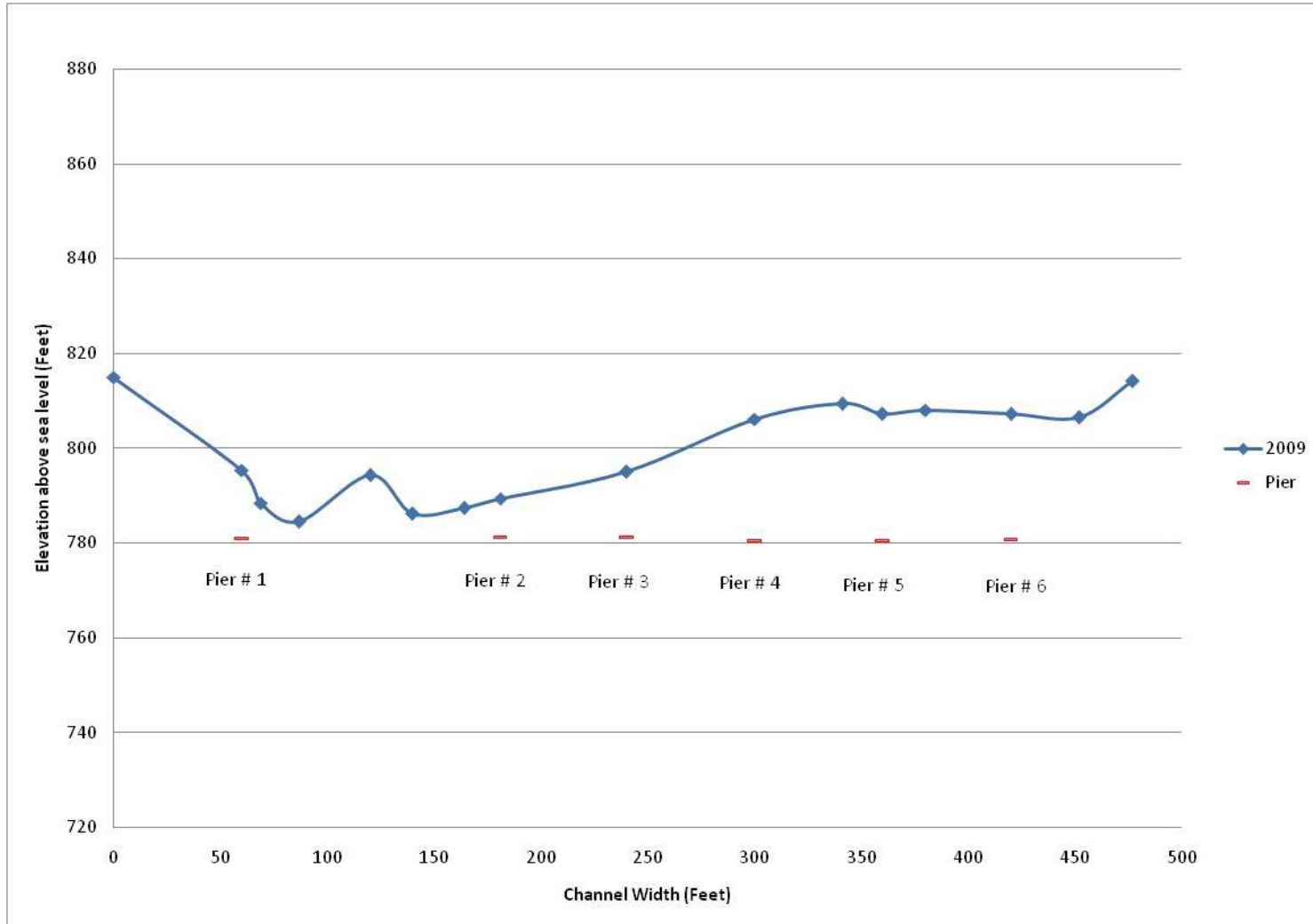


Figure 25. Cross-sectional profile at bridge 17591 on I-35 SB over Wildhorse Creek.

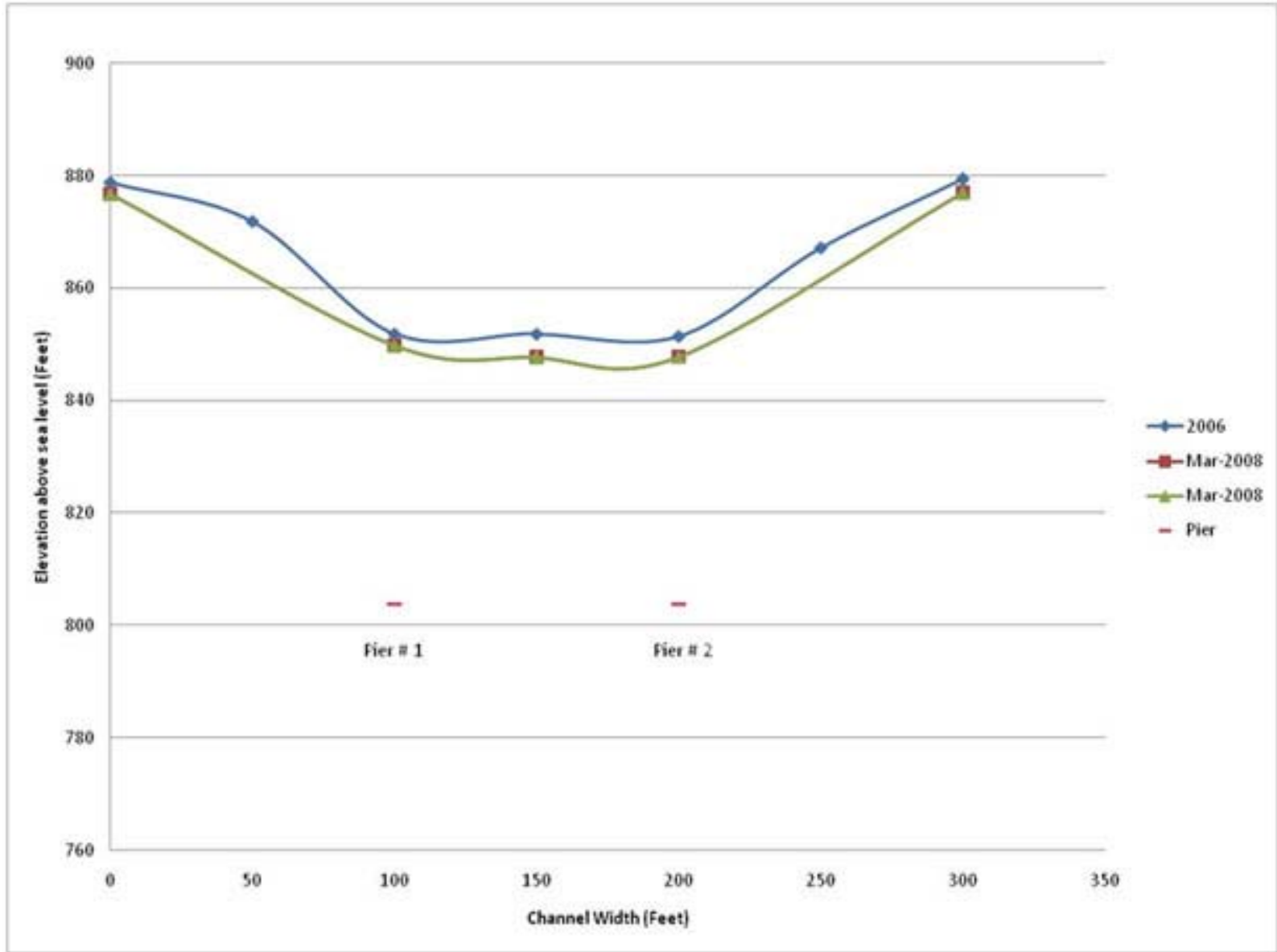


Figure 26. Cross-sectional profiles at bridge 21120 on SH 74 over Wildhorse Creek.



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.

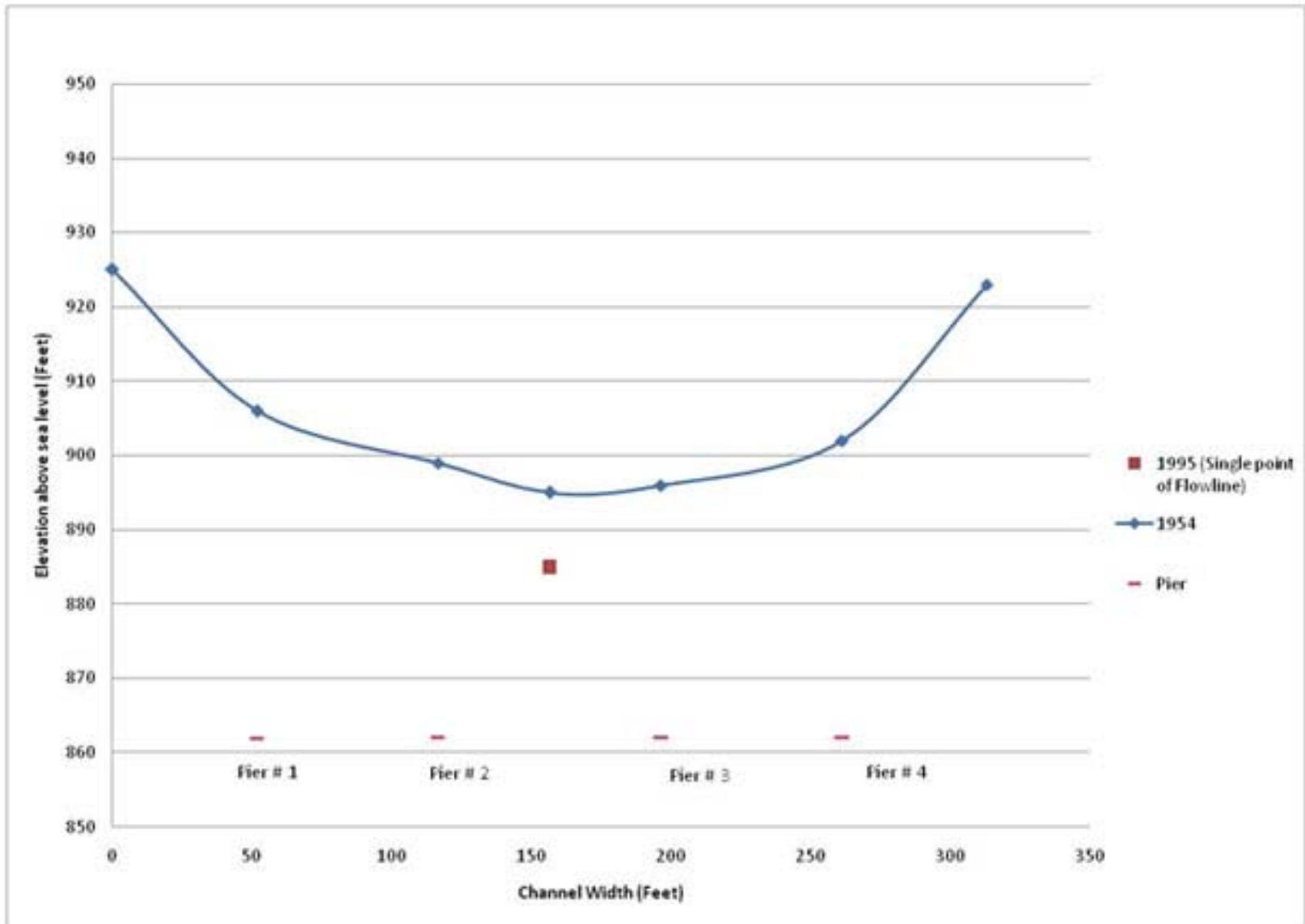


Figure 29. Cross-sectional profile at bridge 13235 on SH 76 over Wildhorse Creek.



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

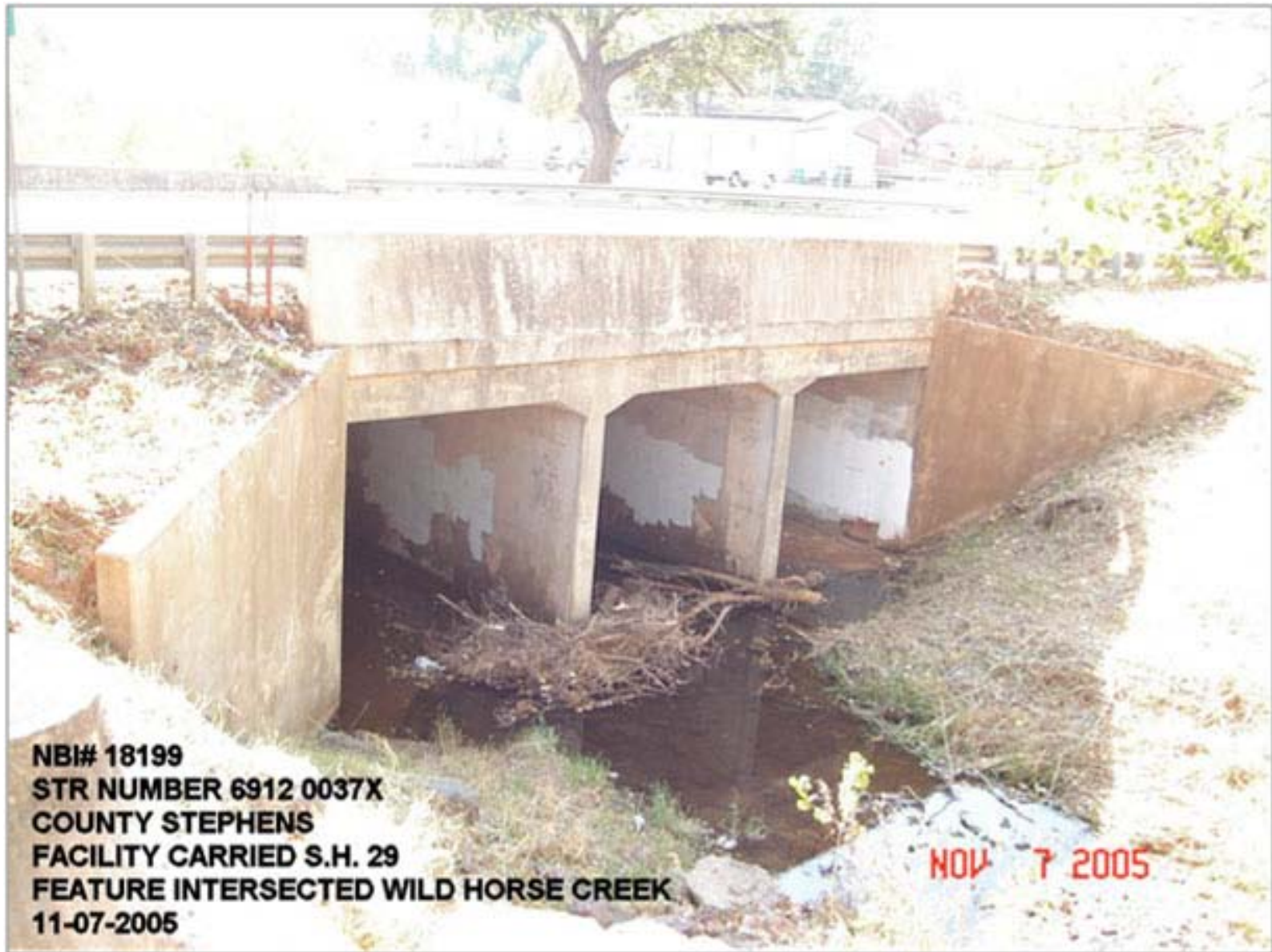


Figure 31. Picture demonstrating extent of damage at culvert 18199 on SH 29 over Wildhorse Creek.

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 $34^{\circ} 41' 46''$ N and $97^{\circ} 35' 57''$ 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 $34^{\circ} 35' 43''$ N and $97^{\circ} 30' 37''$ 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 $34^{\circ} 37' 49''$ N and $97^{\circ} 32' 09''$ 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.

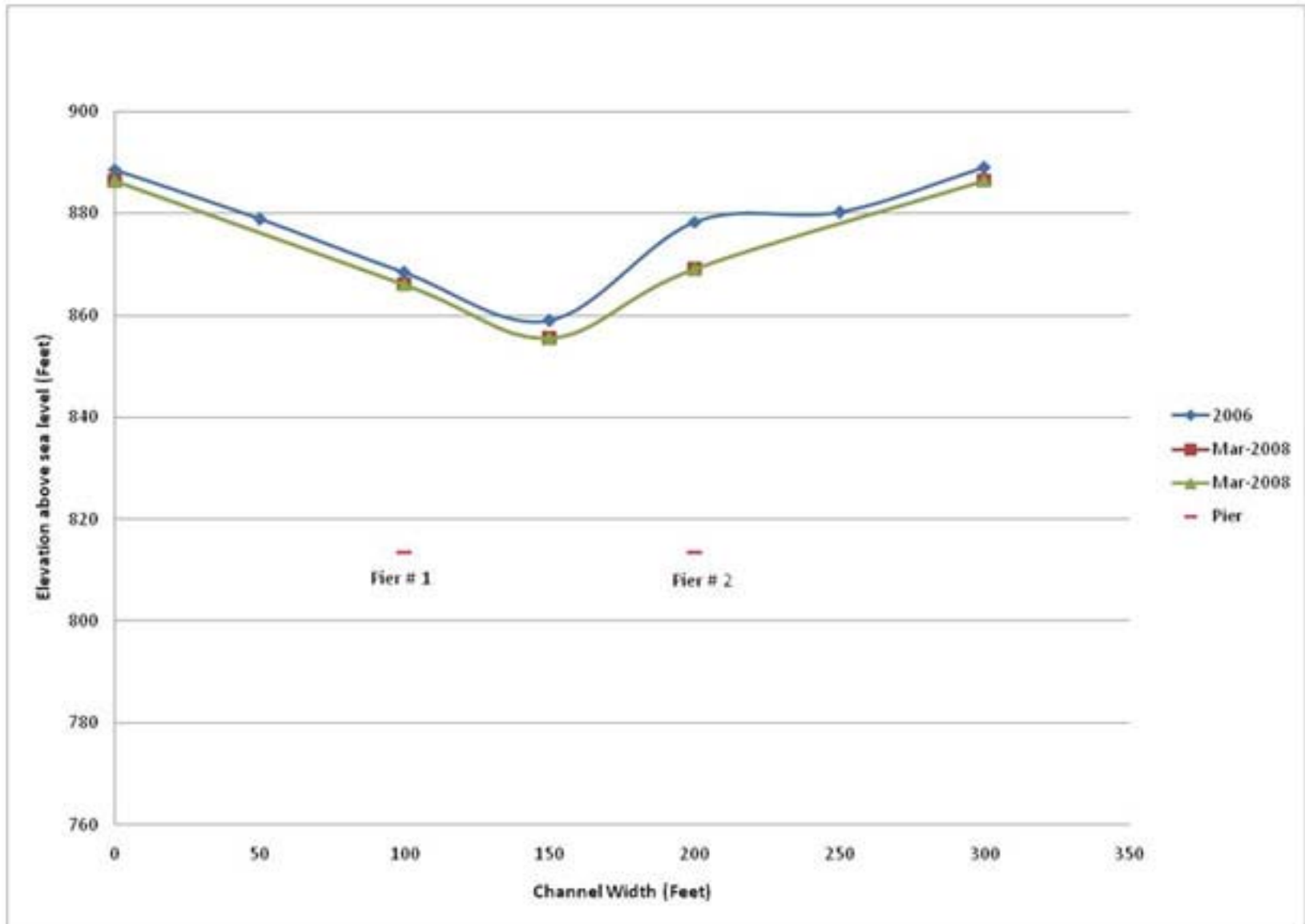


Figure 32. Cross-sectional profiles at bridge 19629 on SH 74 over Salt Creek.



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

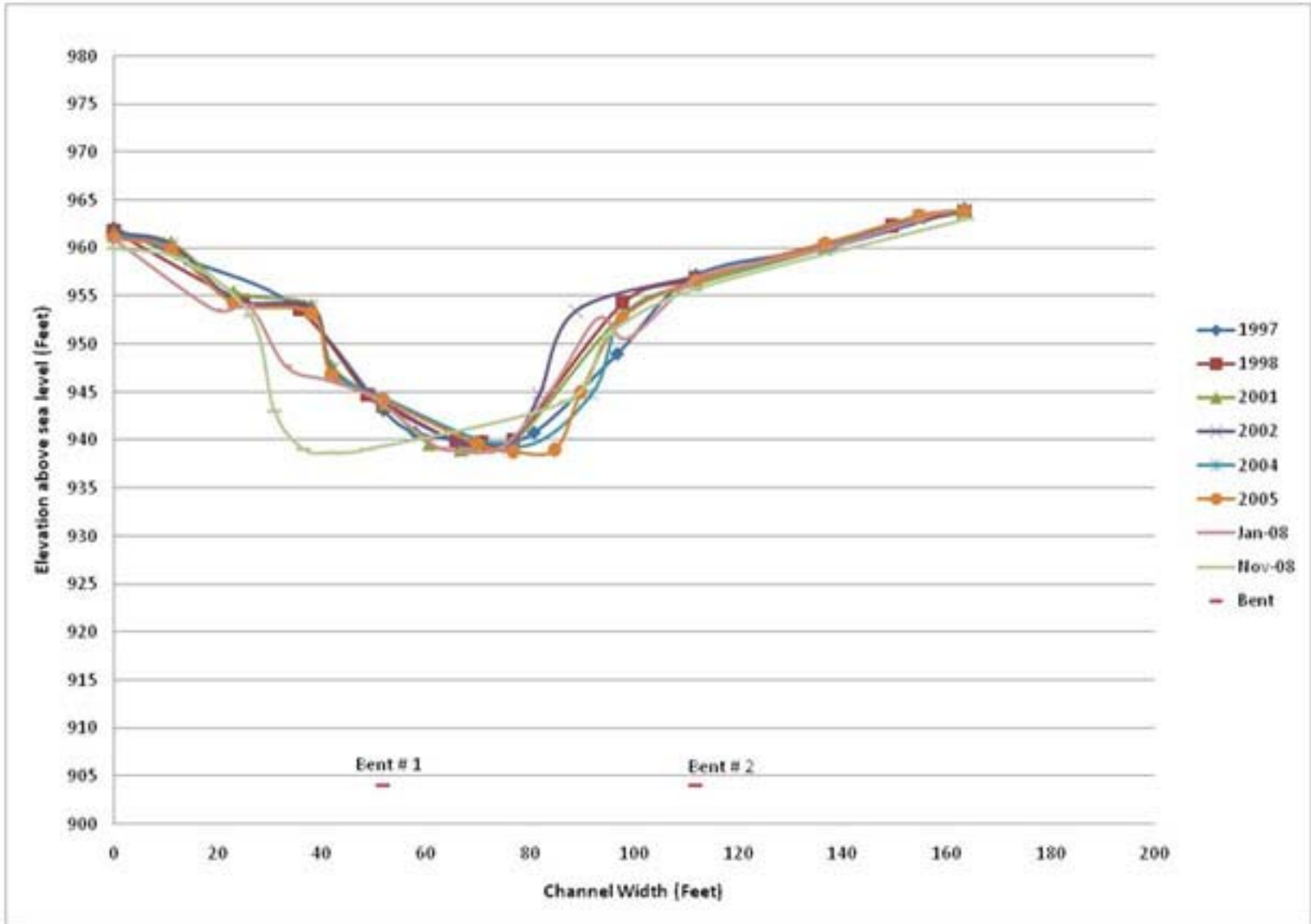


Figure 34. Cross-sectional profiles at bridge 13515 on SH 76 over Salt Creek.



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

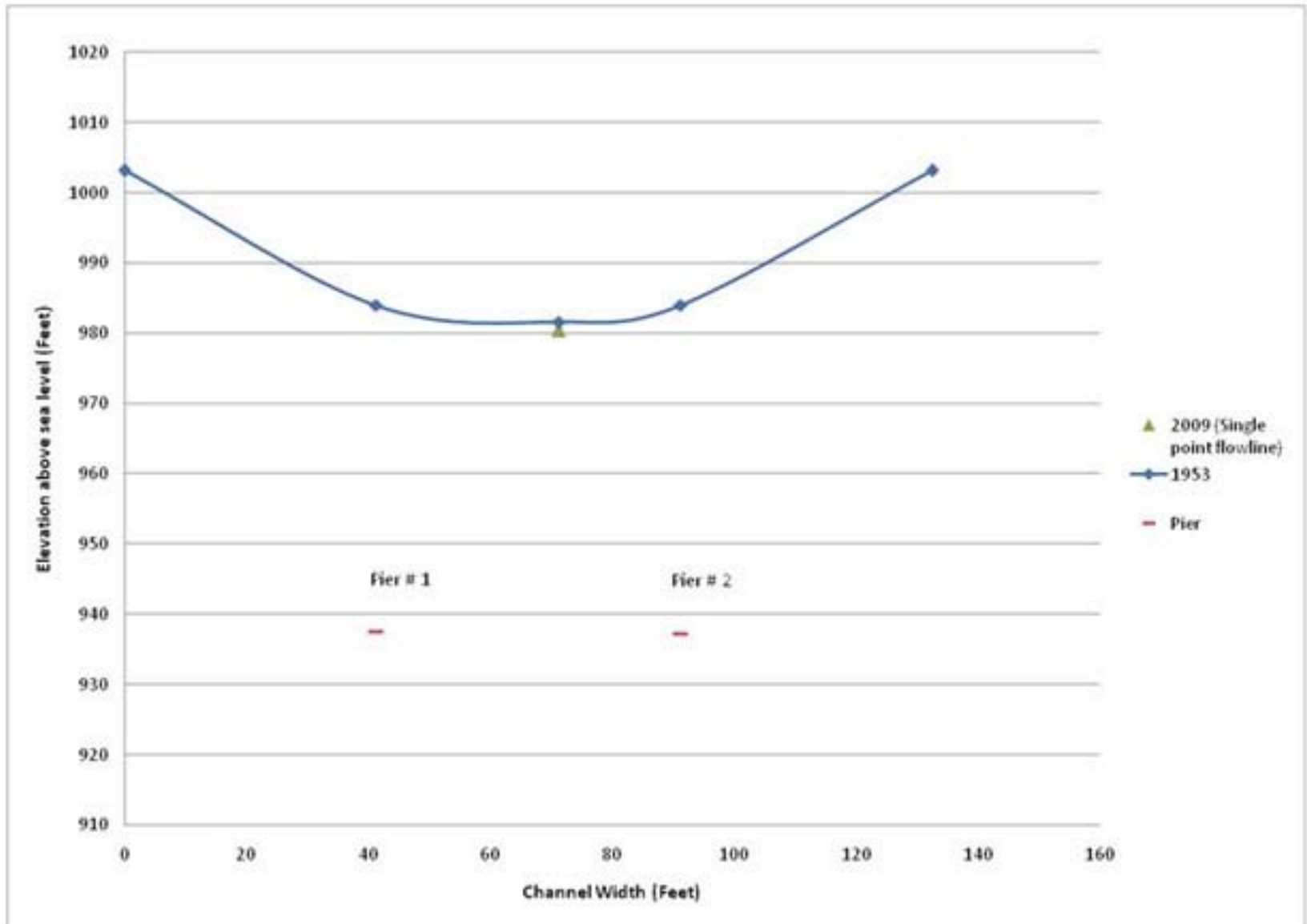


Figure 36. Cross-sectional profile at bridge 13060 on SH 29 over Salt Creek.

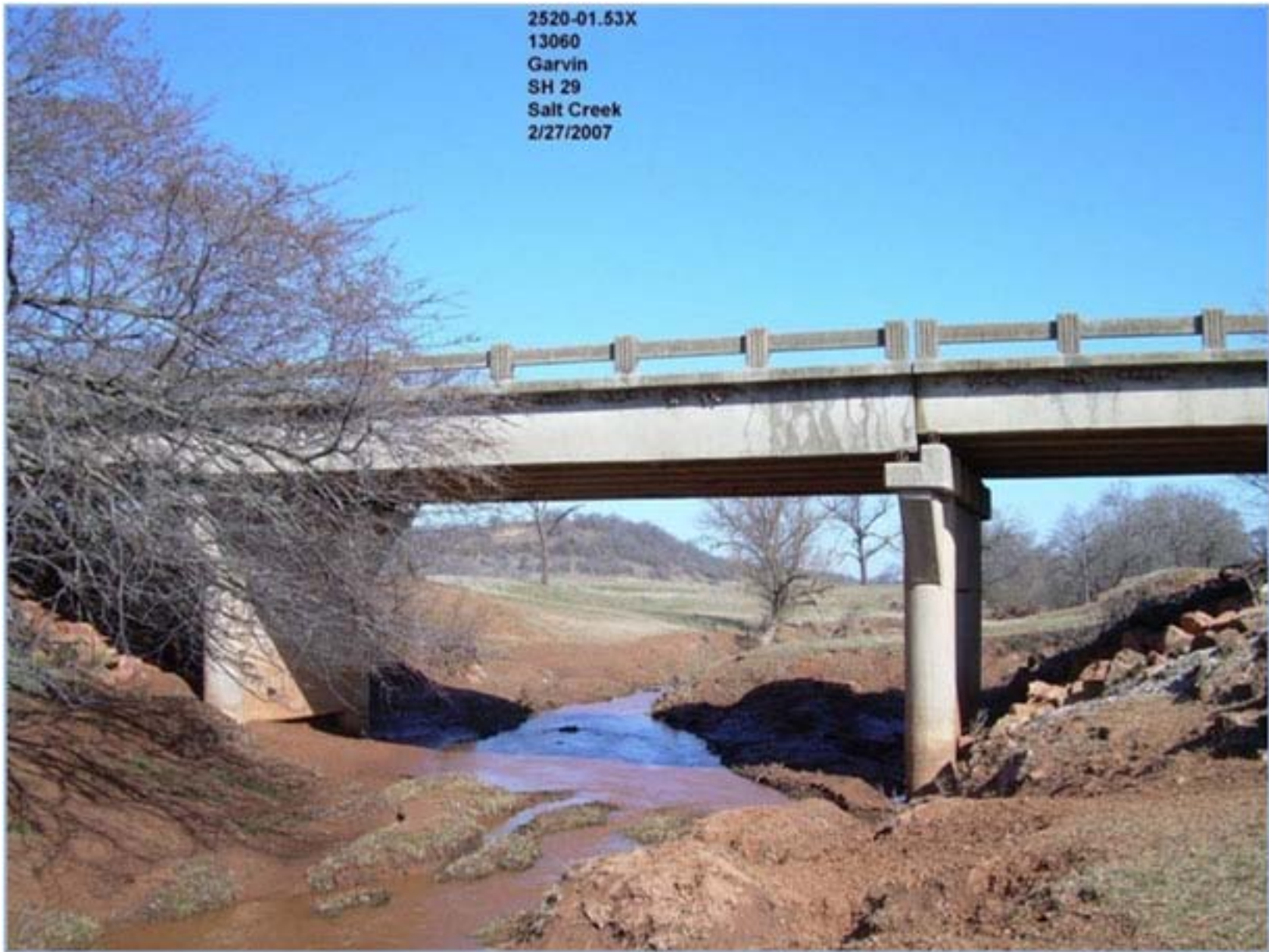


Figure 37. Picture demonstrating extent of damage to piers at bridge 13060 on SH 29 over Salt Creek.

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.

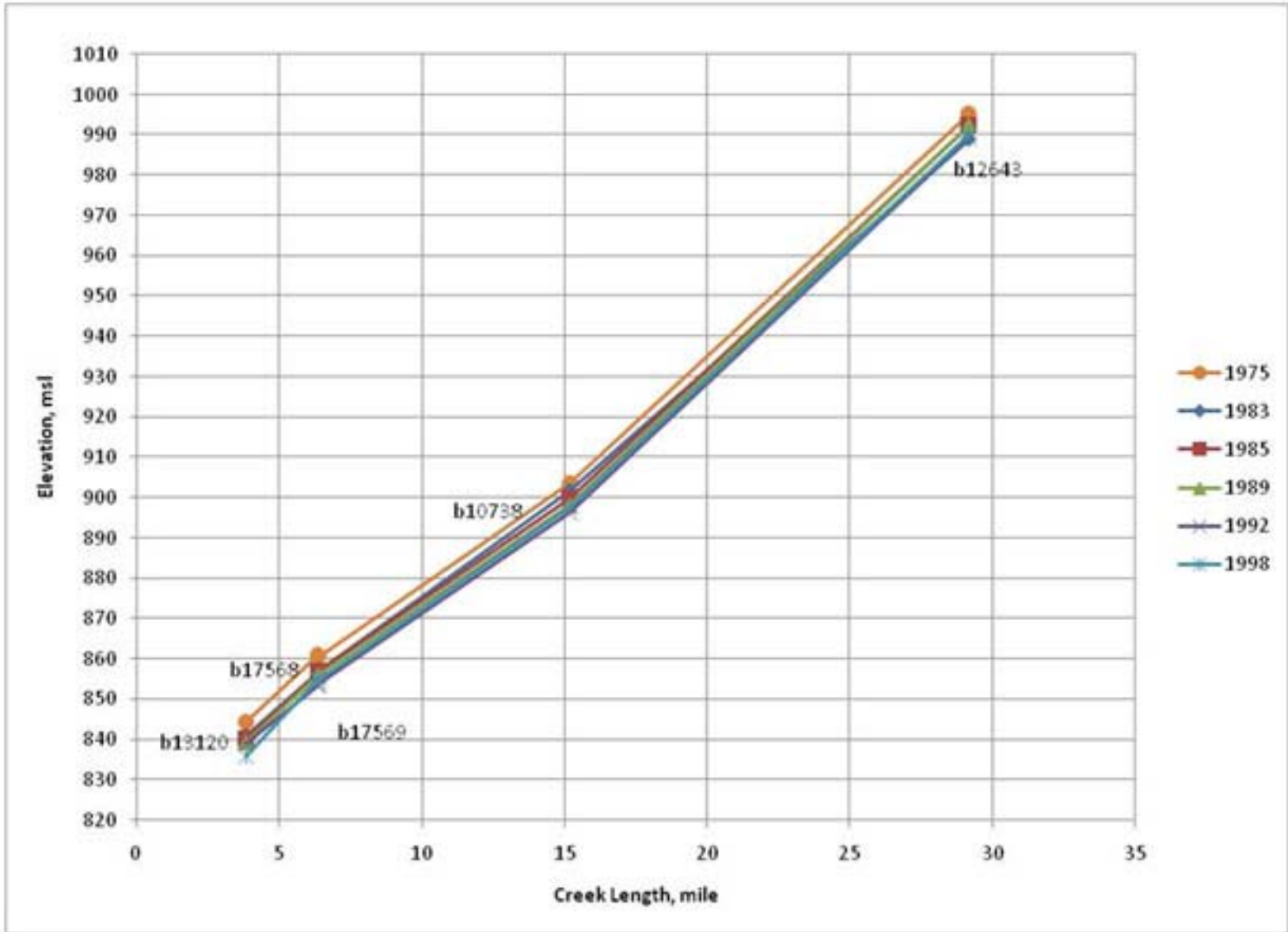


Figure 38. Longitudinal profile for Rush Creek.

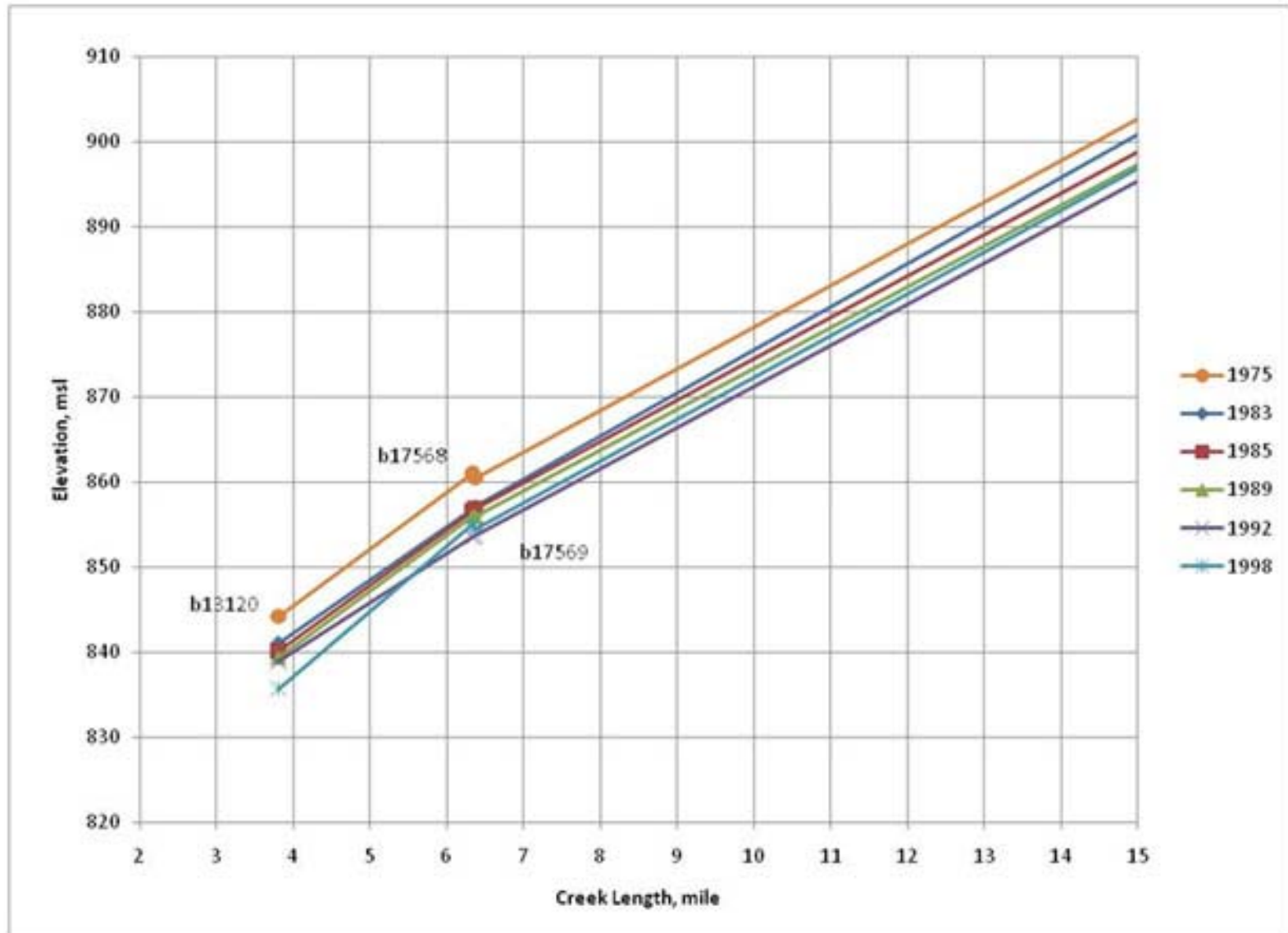


Figure 38a. Longitudinal profile for Rush Creek.

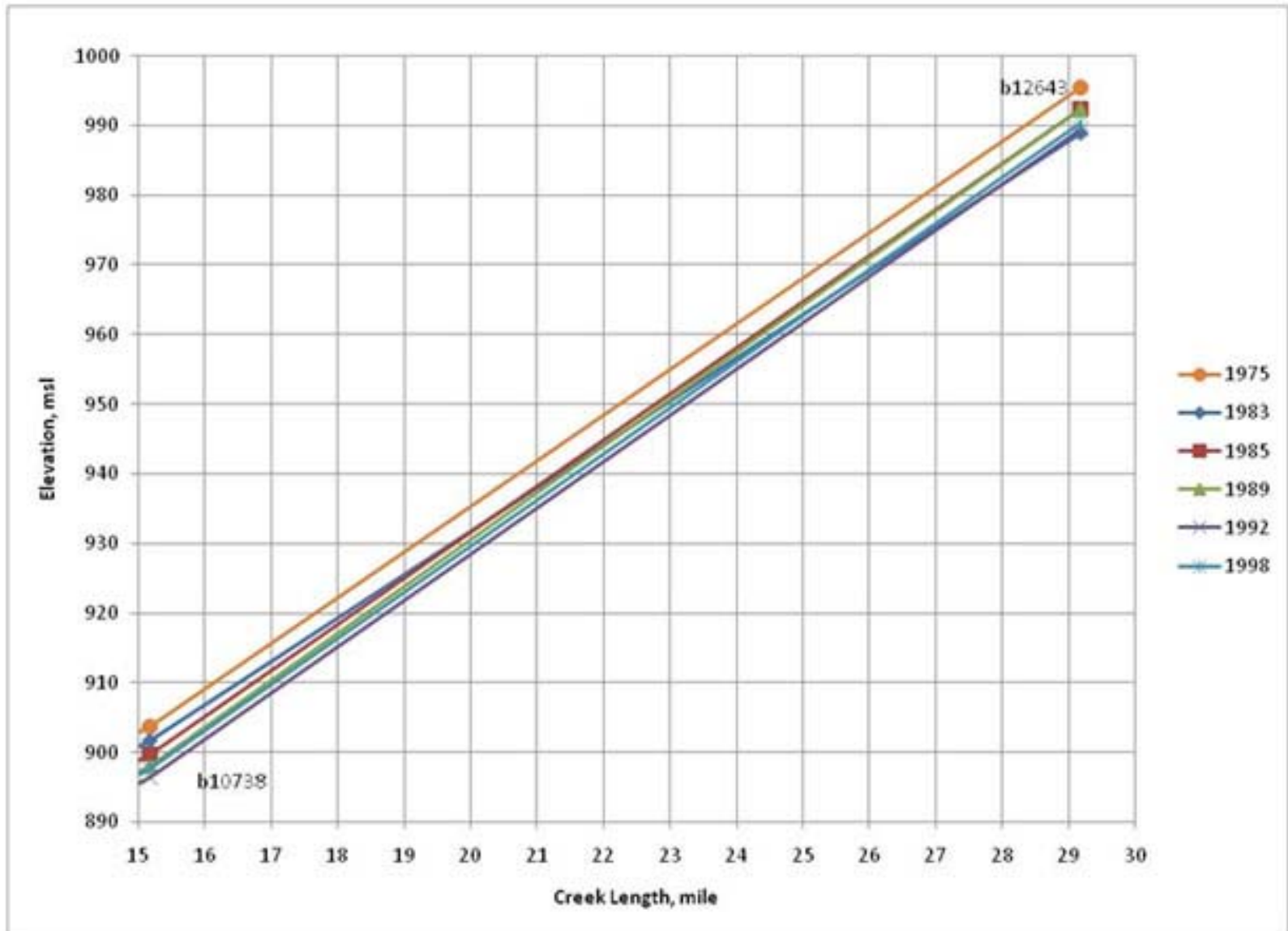
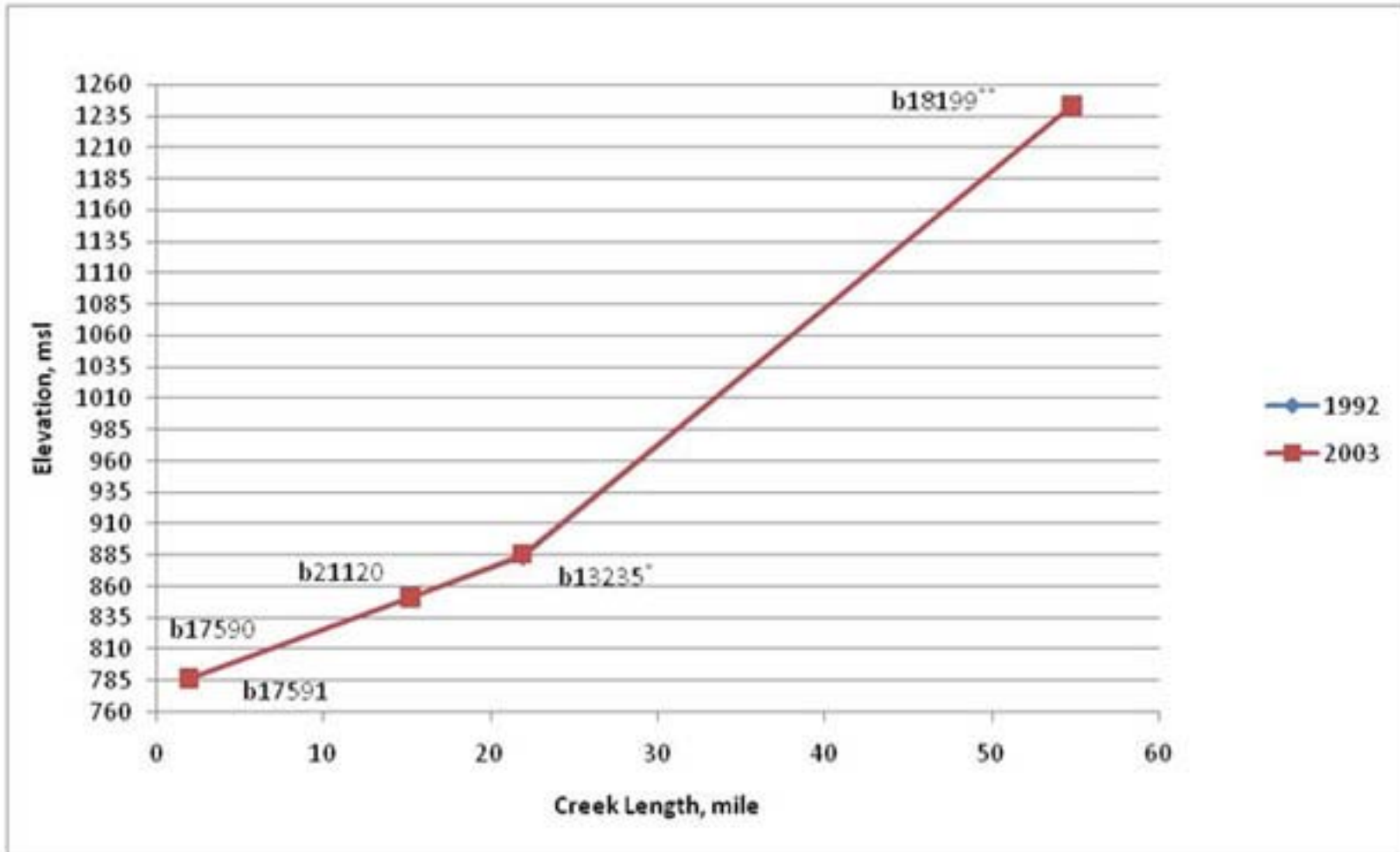


Figure 38b. Longitudinal profile for Rush Creek.



*interpolated value at b13235 for the year 2003

**interpolated value at b18199 for the year 1992

Figure 39. Longitudinal profile of Wildhorse Creek.

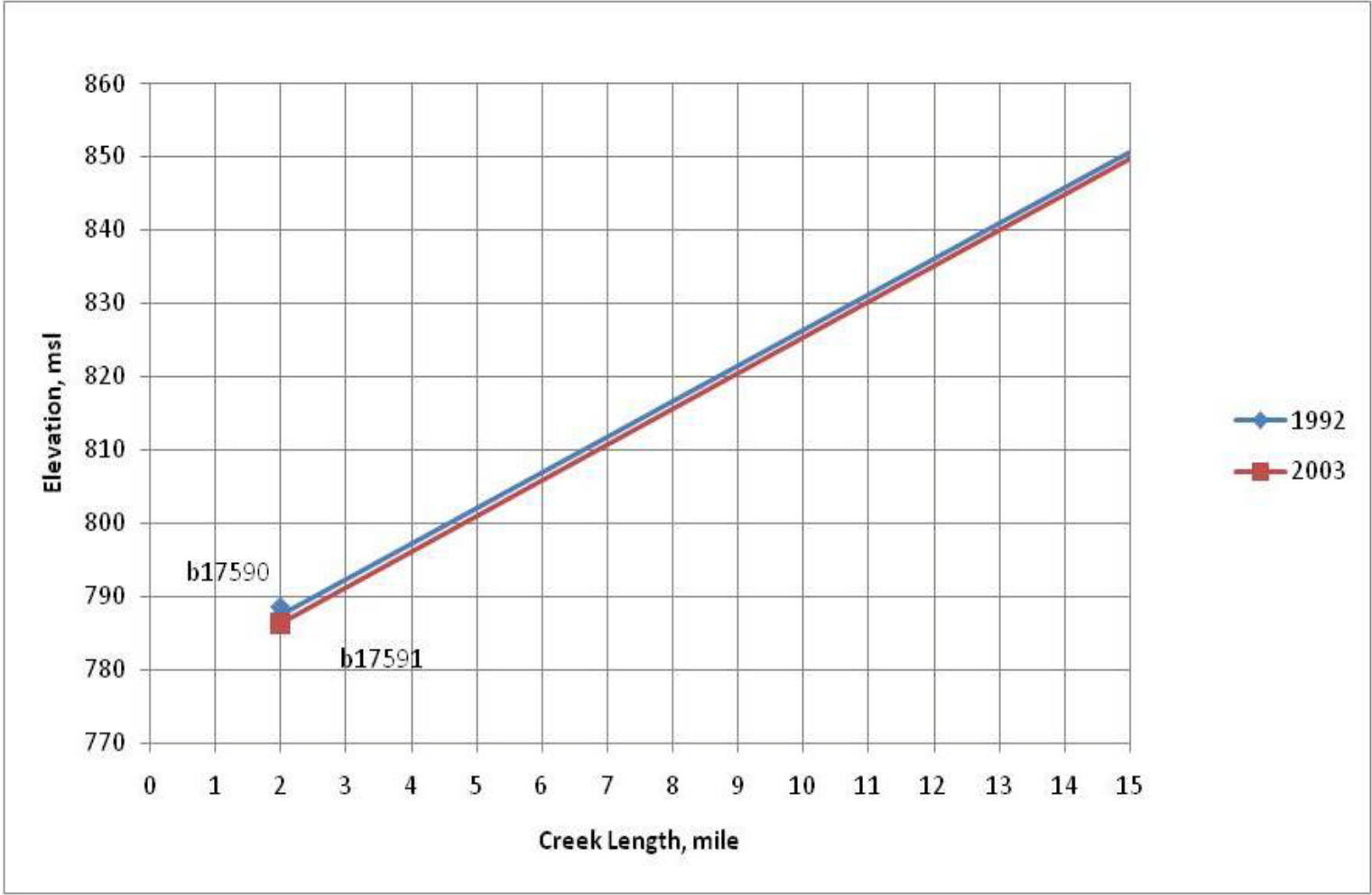


Figure 39a. Longitudinal profile of Wildhorse Creek.

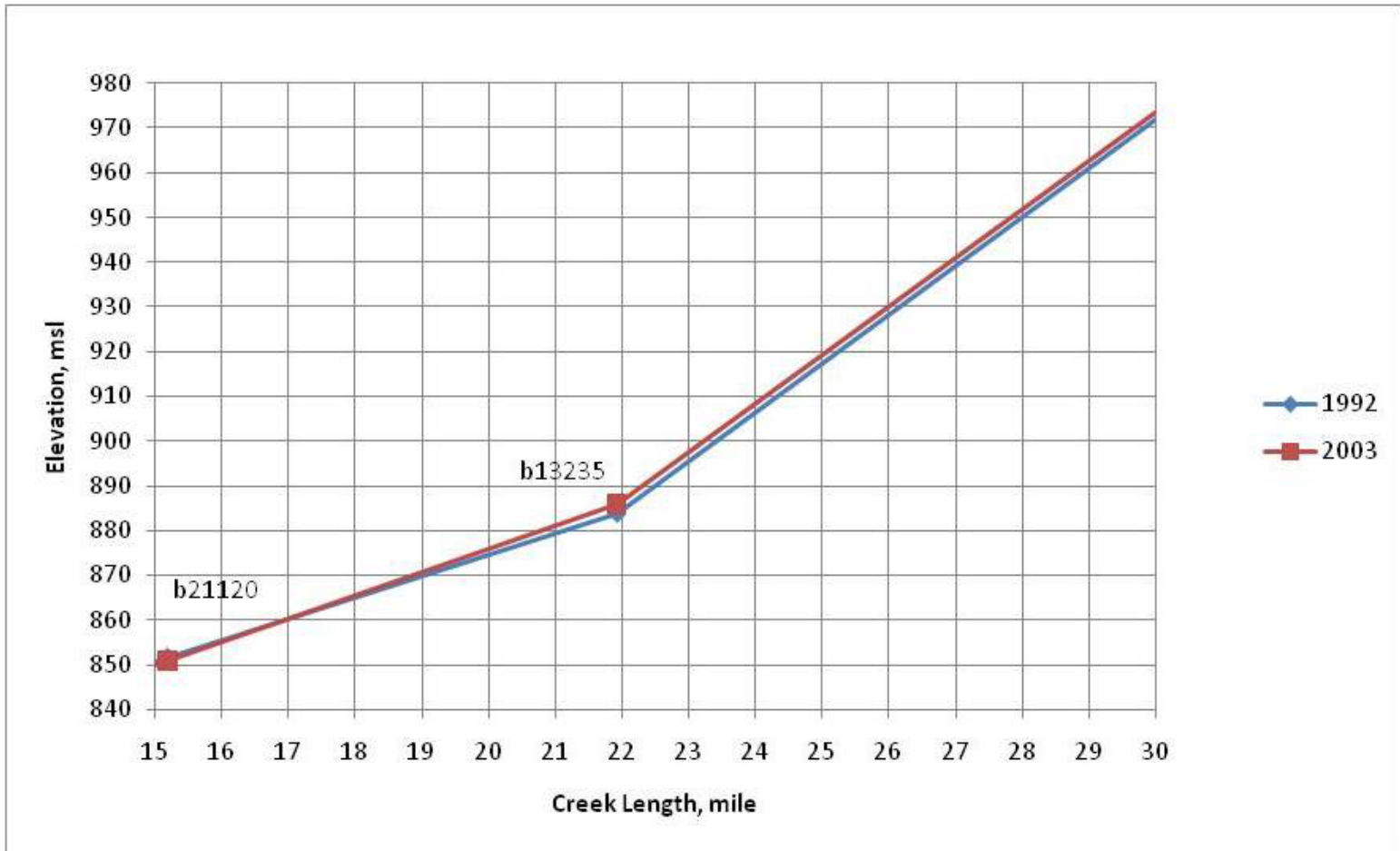


Figure 39b. Longitudinal profile of Wildhorse Creek.

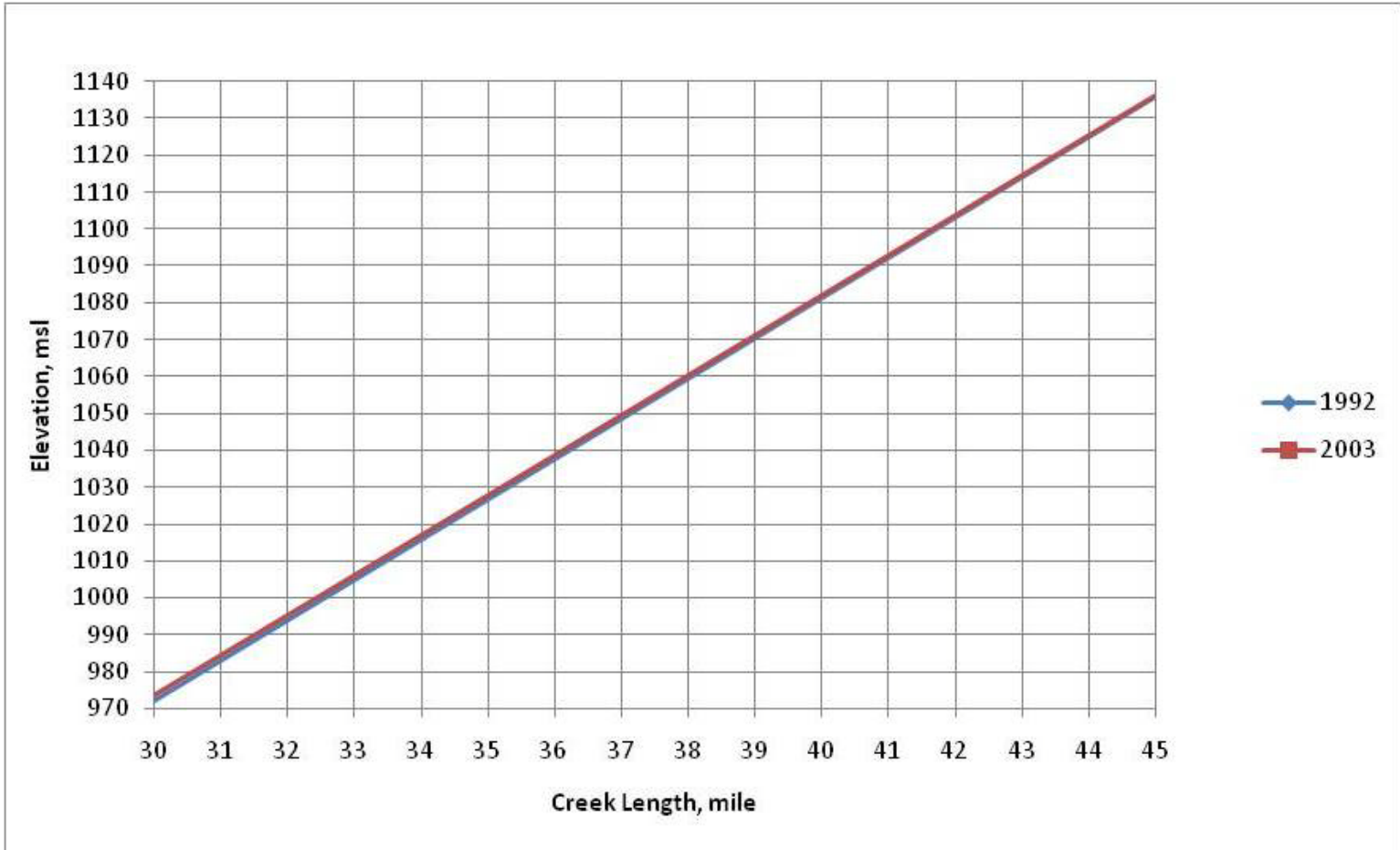


Figure 39c. Longitudinal profile of Wildhorse Creek.

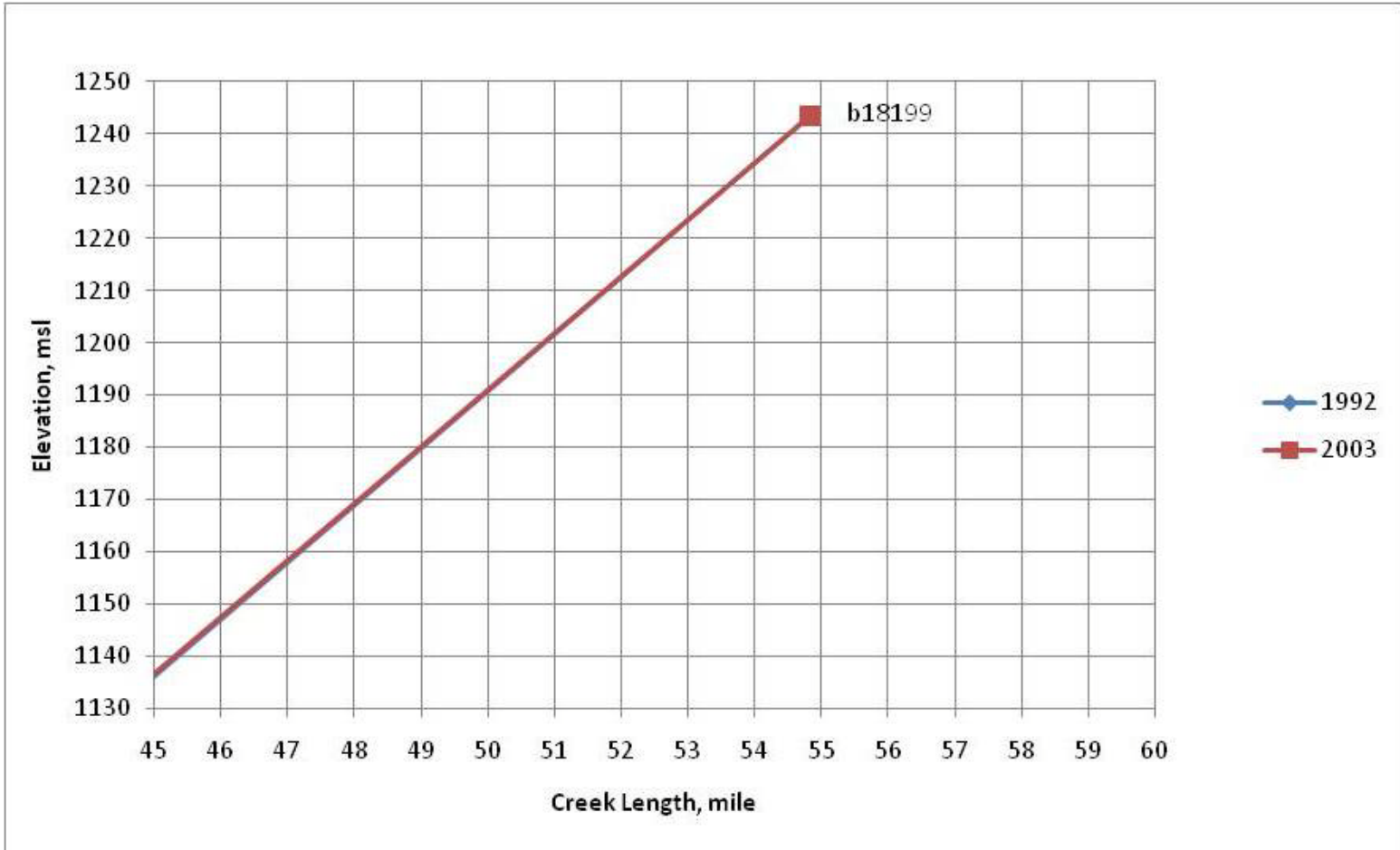


Figure 39d. Longitudinal profile of Wildhorse Creek.

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.

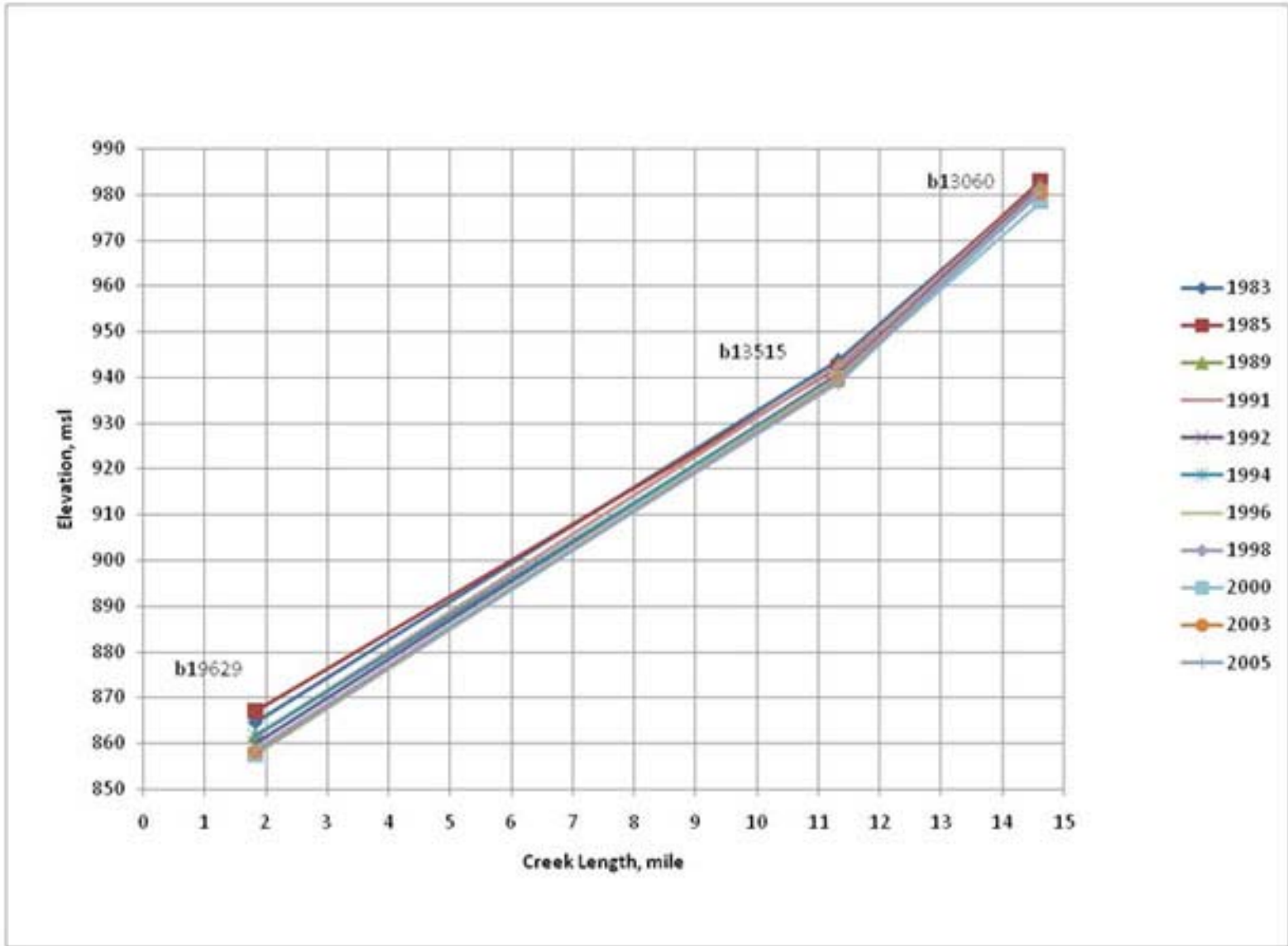


Figure 40. Longitudinal profile of Salt Creek.

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.

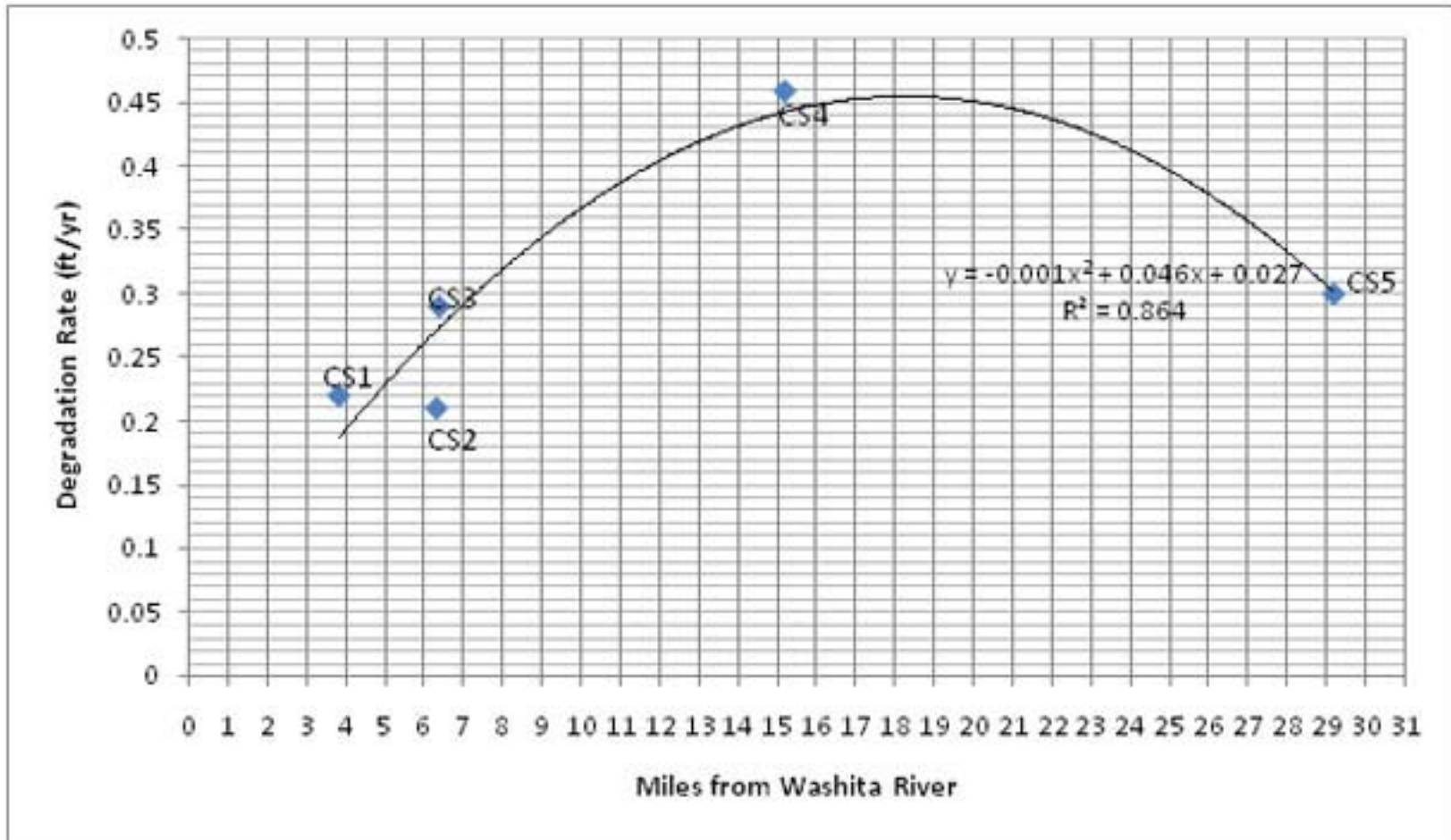


Figure 41. River degradation rate with trend line of Rush Creek, OK.

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

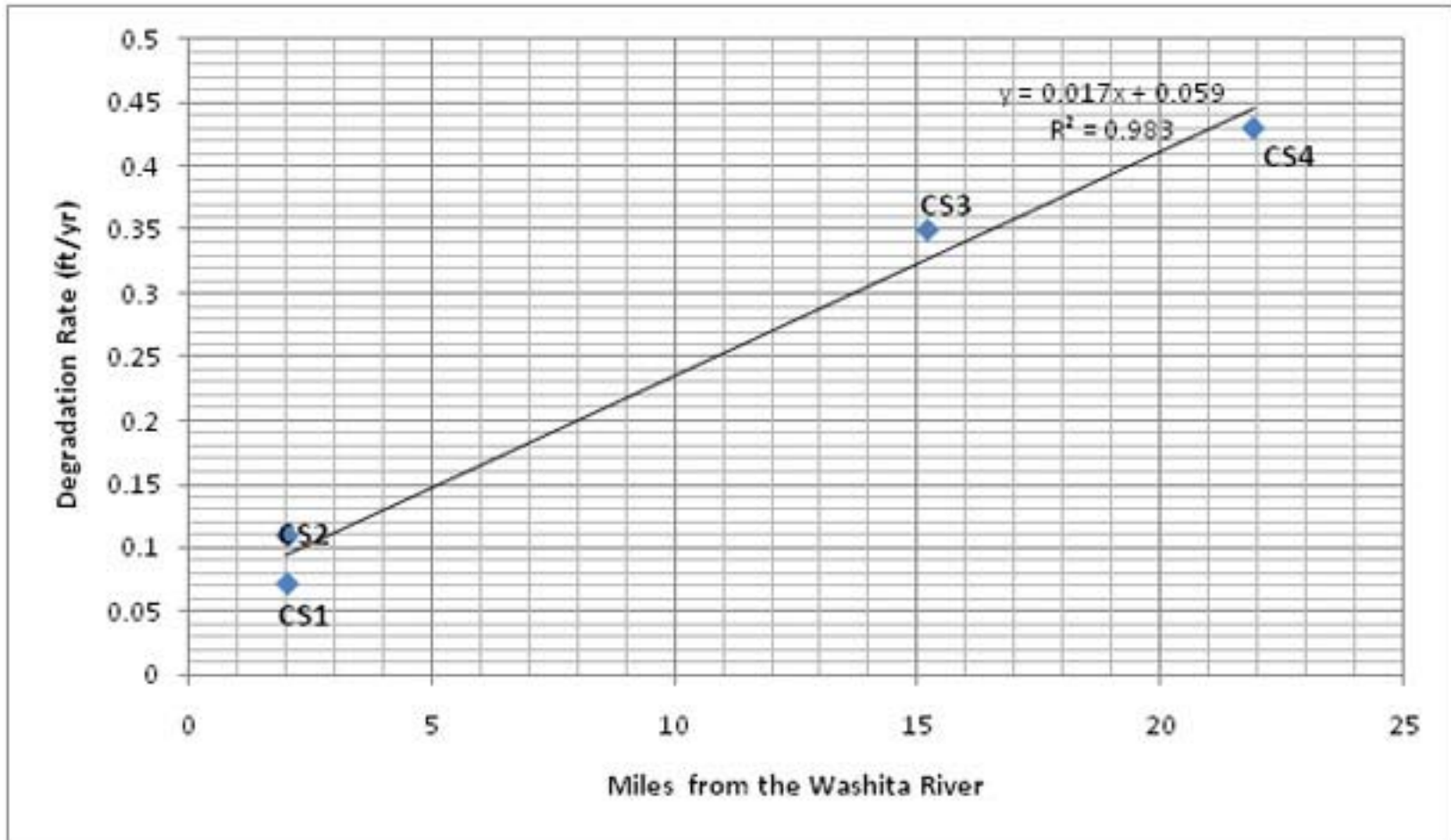


Figure 42. River degradation rate with trend line of Wildhorse Creek, OK.

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.

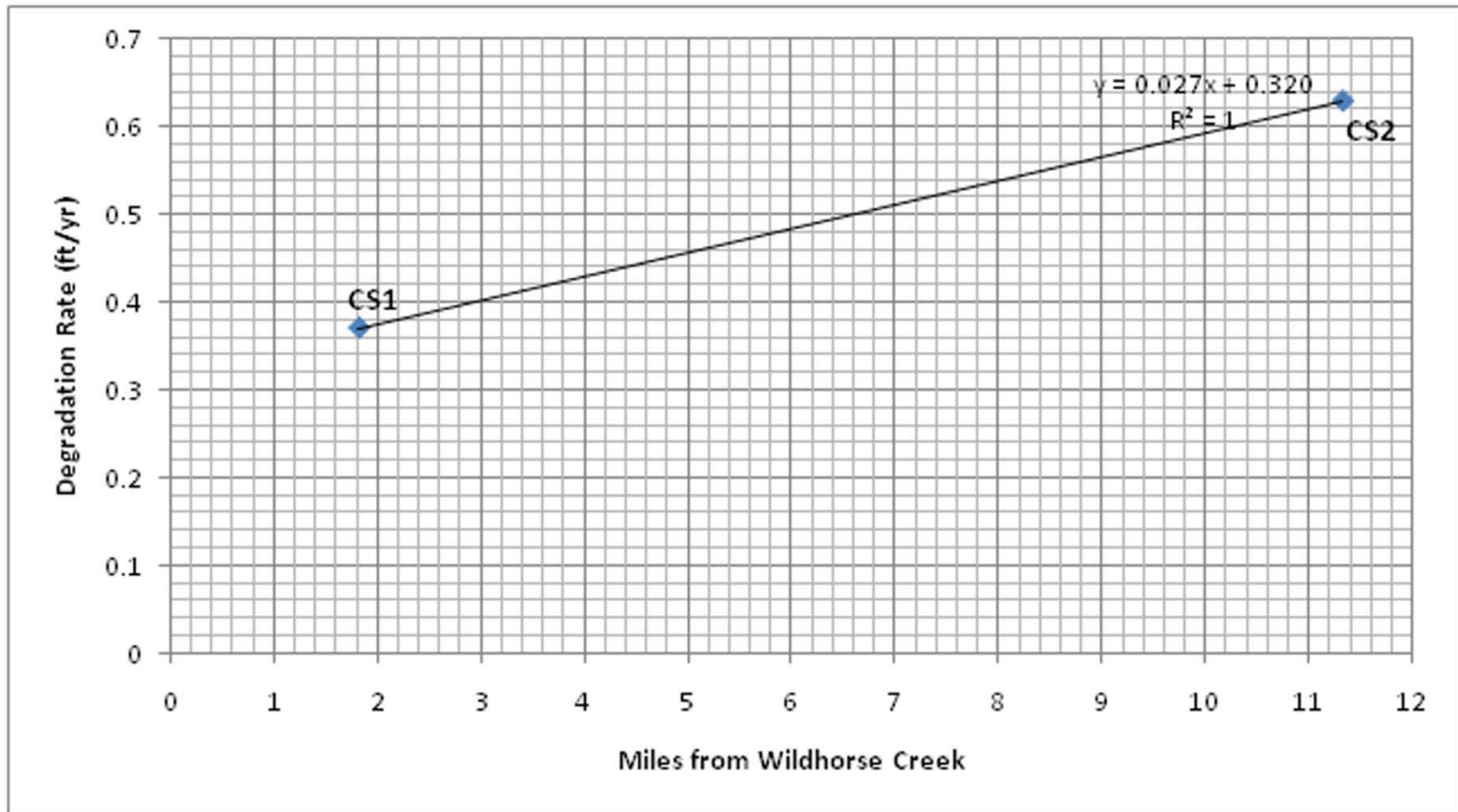


Figure 43. River degradation rate with trend line of Salt Creek, OK.

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 | High way | 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° 43' 55" | 97° 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° 41' 46" | 97° 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° 31' 59" | 97° 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 (Pier 1) | 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° 38' 51" | 97° 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° 41' 46" | 97° 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° 35' 43" | 97° 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 | | | | | | | |

¹Measured from the top of rail

²Measured 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

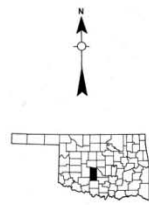
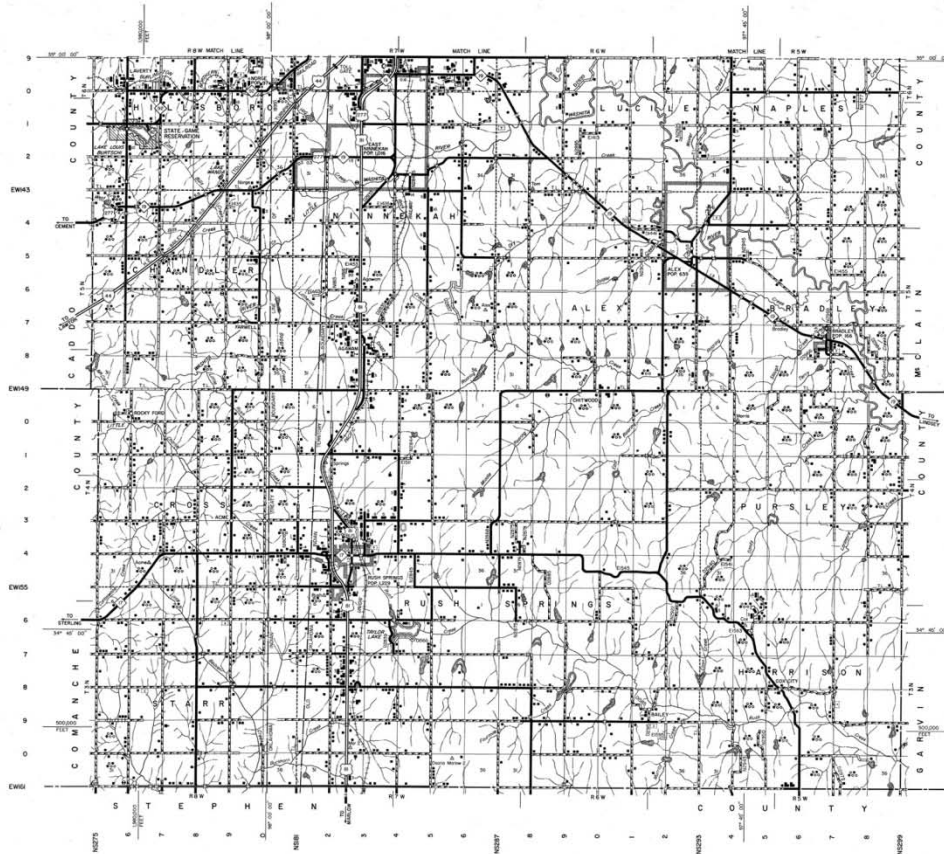
Wildhorse Creek, OKLAHOMA

| County Name |
|--------------------|
| Stephens |
| Murray |
| Carter |

COUNTY SECTION LINE MAP LEGEND

Salt Creek, OKLAHOMA

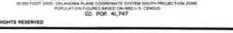
| County Name |
|--------------------|
| Garvin |



**GENERAL HIGHWAY MAP
GRADY COUNTY
OKLAHOMA**

PREPARED BY THE
**OKLAHOMA DEPARTMENT OF TRANSPORTATION
PLANNING DIVISION**

IN COOPERATION WITH THE
**U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION**



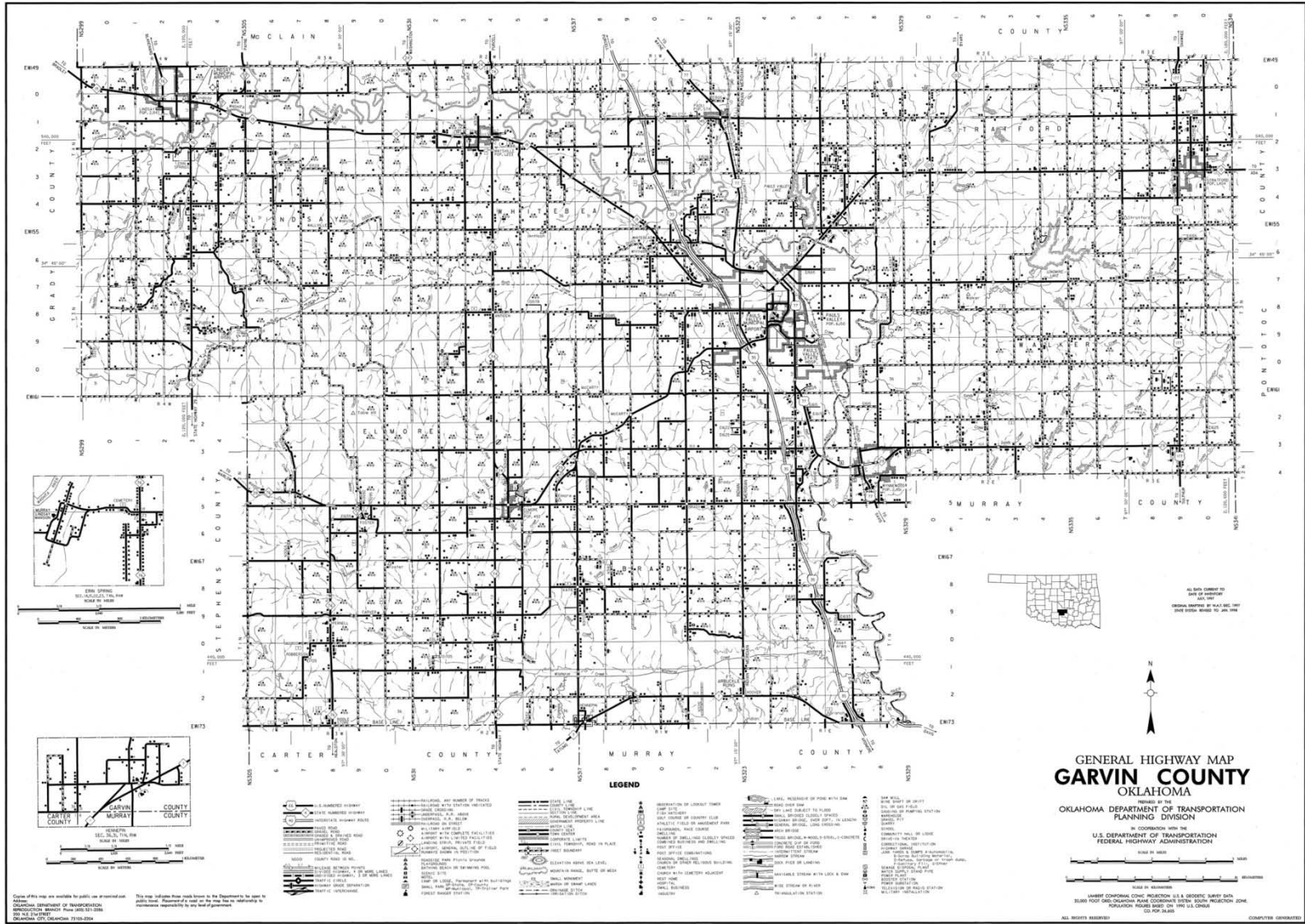
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The Oklahoma Department of Transportation, Planning Division,
1000 North Lincoln Street, Oklahoma City, Oklahoma 73102
Phone: (405) 521-2200
FAX: (405) 521-2201
OKLAHOMA CITY, OKLAHOMA 73102

SHEET 1
SHEET 2

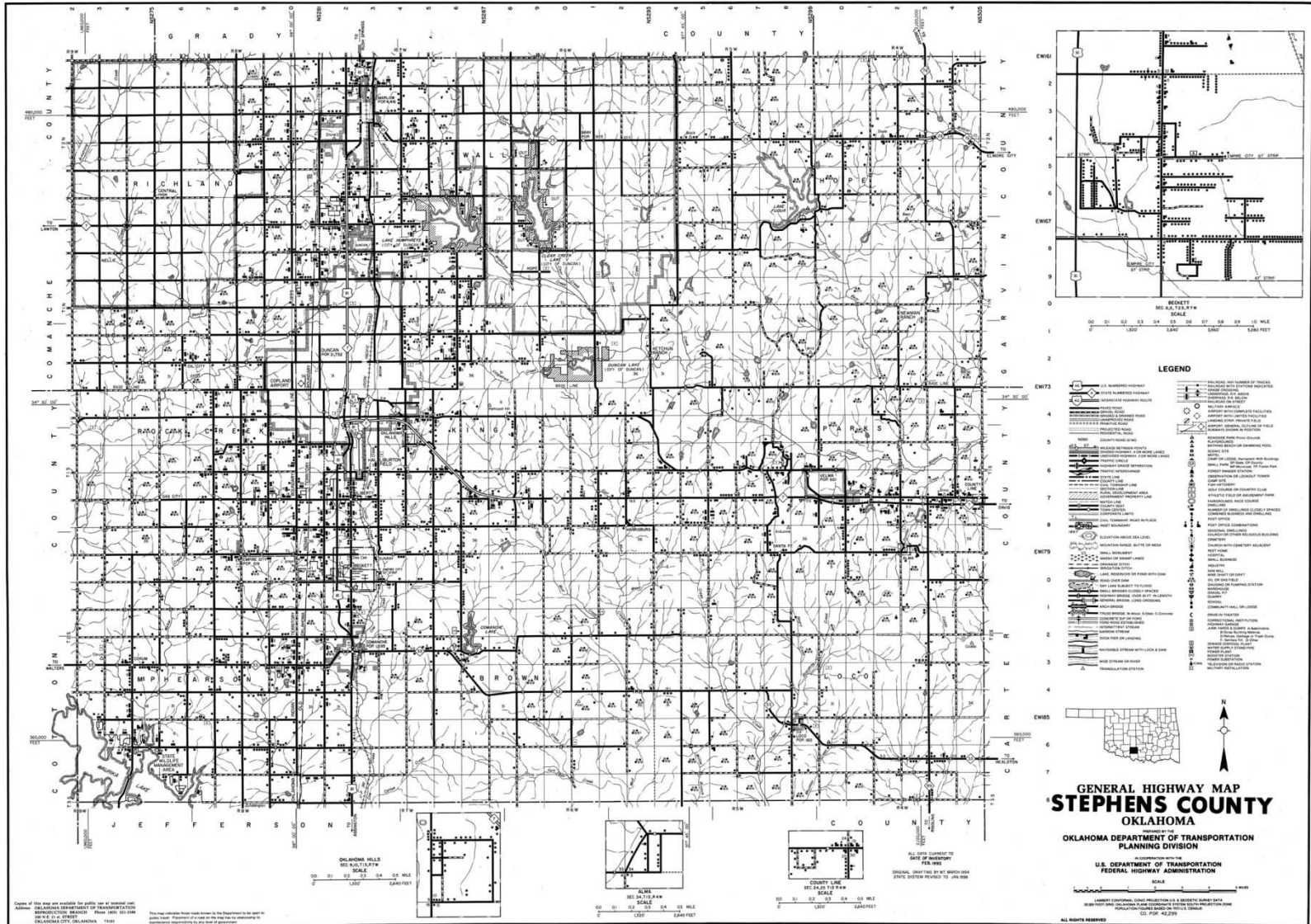
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STATE OF OKLAHOMA
ORIGINAL DATED BY AEC JULY 1969
STATE DESIGN REVISION TO JAN 1982
DESIGNED BY AEC
SHEET 1 OF 2 SHEETS

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GENERAL HIGHWAY MAP GRADY COUNTY OKLAHOMA

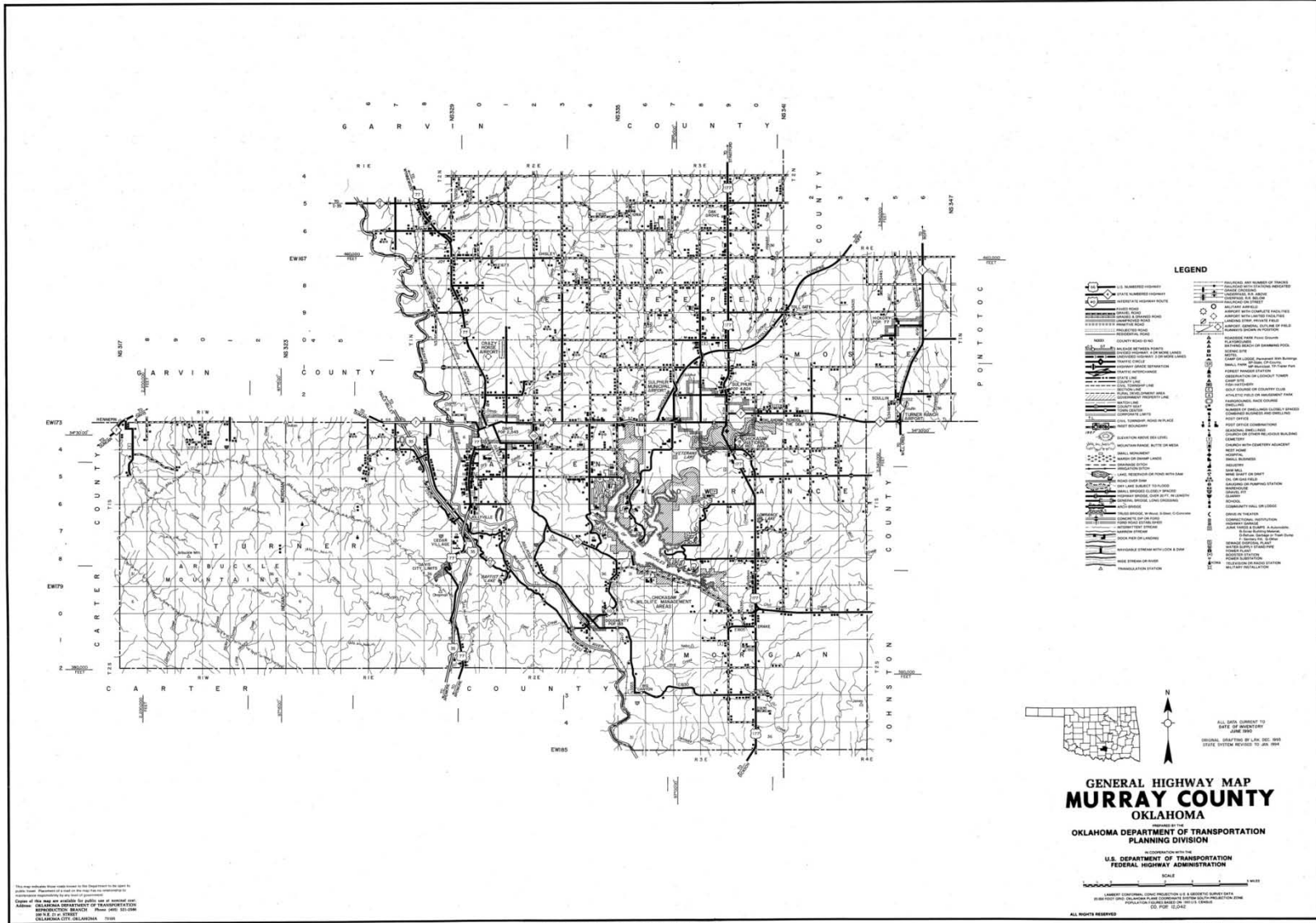
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ALL DATA CURRENT TO DATE OF PUBLICATION: JUNE 1988

ORIGINAL DRAFTED BY LAW 882-889 STATE SYSTEM REVISED TO JAN. 1984

**GENERAL HIGHWAY MAP
MURRAY COUNTY
OKLAHOMA**

OKLAHOMA DEPARTMENT OF TRANSPORTATION
PLANNING DIVISION

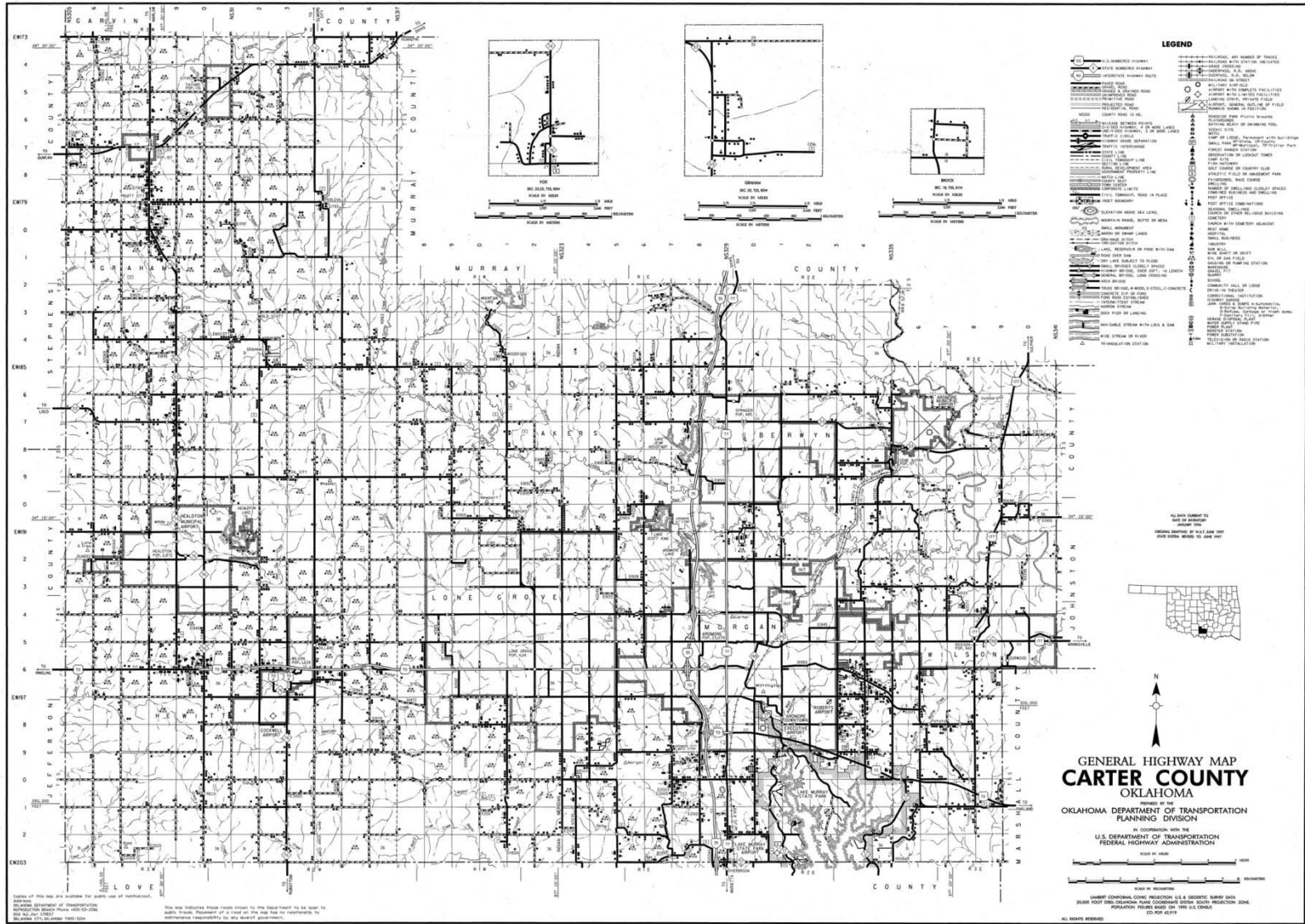
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

SCALE: 1" = 10 MILES

POPULATION DATA FROM 1980 U.S. CENSUS
COUNTY POPULATION: 10,000
POPULATION DENSITY: 100 PER SQ. MILE

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CARTER CO.

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GENERAL HIGHWAY MAP CARTER COUNTY OKLAHOMA 10