THE INFLUENCE OF LAND USE/LAND COVER WITHIN RIPARIAN ENVIRONMENTS ON CHANNEL CHANGE ON THE GUADALUPE RIVER, TEXAS

THESIS

Presented to the Graduate Council
of Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of APPLIED GEOGRAPHY

by

Matthew M. Thompson B.Sc., Hons.

San Marcos, Texas
May 2005

COPYRIGHT

by

Matthew Mitchell Thompson

2005

ACKNOWLEDGEMENTS

I would like to thank my family for all their love and support throughout the completion of this study. Special thanks to Art and Cathy Wilson for all their support as well as their amazing hospitality while completing the fieldwork required for this project.

I would also like to thank Dr. Fonstad and Dr. Butler for their input and advice on this project. My deep appreciation goes to Dr. Curran for all of her input and support throughout this study. I would also like to thank Jeff Sun for all of his GIS advice and instruction and Amy Wilson for her love and support. Finally, I would like to thank Amanda Keen Zebert for all of her advice, support, guidance and partnership on this project. I really am most grateful for your involvement.

This manuscript was submitted on 4 April, 2005.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Background

Factors that modify geomorphic processes have not received the study they deserve (Goudie 1994). Geomorphic studies designed to understand how geomorphic processes are changed by external forces are of considerable academic interest and have an important role to play in the development of environmental policies and management frameworks (Cooke and Doornkamp 1990). Erosional affect on channel morphology is one such geomorphic process that requires more attention.

High magnitude, low frequency flood events are thought to be the main driving force behind river channel morphology changes (Renwick 1992). However, there are many complicating variables within a river basin that can influence and modify both the operation and the frequency and extent of erosional processes. Of these variables, land use / land cover (LULC) within river basins exerts an important influence over the runoff and sediment transport regimes of the basin. An understanding of how LULC has affected past and present morphologic changes can be used to predict and prepare for future trends (Cooke and Doornkamp 1990).

Problem Statement

Little research has been done to establish the degree of influence that the combined factors of near channel land use, land cover, and the distribution and composition of riparian environments have on river channel change. This research will show the degree and extent to which riparian LULC acts to increase or buffer channel change on the Guadalupe River in Texas from 1955 to present.

Project Justification

The Guadalupe Watershed is an exceptional area in which to observe the morphological responses of stream channels to fluvial geomorphological influences (Patton and Baker 1976). The study area has steep, sparsely vegetated slopes, narrow valleys and thin upland soils with low infiltration over limestone bedrock (Caran and Baker 1986). The majority of annual precipitation within the study area comes from low frequency, high magnitude rainfall events (Votteler 2002). The predominant land use in the study area is rangeland, which makes land use practices and range management strategies especially relevant in this area.

Previous research has focused on either changes in LULC due to external impacts or the importance of riparian vegetation to channel morphology. Hession (2001), Ballie and Davies (2002) and Hession et al. (2003) have investigated a causal link between the extent of riparian vegetation and channel morphologic form and processes. An equally well-established link exists between land use change and overland flow rates (Dunne and Leopold 1978). Although methods to assess and quantify land use and channel change are well developed (Gilliom and Thelin 1997; Setser 2000), research concerning the combined impacts of riparian vegetation and land use on channel morphology is, however, rare (Hession 2001). Therefore, the results of this study will have important implications for the development of river management frameworks that promote the application of sound geomorphic principles.

CHAPTER II

LITERATURE REVIEW

Theoretical Framework – Flood Events Drive Channel Morphology

The observational procedures required for landscape analysis are now viewed as theory-dependent (Rhoads and Thorne 1996). Leopold, Wolman and Miller (1964) were three of the pioneers of evaluating rivers and floodplains in terms of a tendency towards dynamic equilibrium (Setser 2000) which a landform tends to, or fluctuates around in time (Renwick 1992). However, many landforms do not appear to tend towards equilibrium even when relatively long periods of environmental stability occur (Renwick 1992). Geomorphic threshold theory accounts for processes causing both catastrophic and gradual landform change (Coates and Vitek 1980). The landforms are in a state of non-equilibrium with the current conditions as their morphology is a function of the last high magnitude threshold-exceeding event (Renwick 1992). These non-equilibrium landforms undergo substantial and sometimes sudden output or form variations when trying to re-establish equilibrium conditions during periods of high magnitude, low frequency threshold-exceeding events (Renwick 1992). For fluvial systems, it is the high magnitude, low frequency floods that have dominant control over the morphology (Renwick 1992). Thus the channel features that are created are not reworked or recreated during the normal to low flow intervals between these rare events (Wolman and Gerson 1978).

Influence of Land Use on Channel Morphology and Riparian Habitat

Riparian areas are the swaths of land adjacent to a river or stream that serve as a transition or buffer area between the terrestrial and aquatic environments (Brinson et al. 2002). Anthropogenic forces in the riparian zone may include agriculture, grazing, urbanization, timber harvest, fishing, mining, recreation, channelization and the impoundment of rivers by dams. These land use activities can directly affect the natural hydrology or channel morphology of rivers (Malanson 1993; Setser 2000; Baillie and Davies 2002; Kondolf, Piegay, and Landon 2002) by influencing the supply of water and sediment to stream channels (Wolman 1967). Although land use change can result in an increase of riparian vegetation, the majority of land use change can result in the removal of, or a reduction in the size and distribution of, riparian vegetation. This occurs through processes such as grazing, clearing, paving or plowing (Kohler and Hubert 1993).

Influence of Riparian Vegetation on Channel Morphology

Alterations in the size and distribution of riparian environments can result in channel changes, because relationships between fluvial-geomorphic processes and riparian ecology are closely linked (Hupp and Osterkamp 1994). Previous studies on river channel morphology have ignored the complicating influence of riparian vegetation (Hession et al. 2003). In Hession et al. (2003), it is recognized that riparian vegetation along streams has a significant impact on stream channel morphology, especially on the stabilization of channel width, regardless of the level of urbanization in the watershed (Hession et al. 2003). These findings support the conclusions of Baillie and Davies (2002) that stream channels in catchments with dense grasses are usually narrower than those in forested catchments due to the ability of grass to trap and retain sediment along channel banks.

Bank vegetation dissipates energy associated with stream flow (Brinson et al. 2002). The vegetation reduces turbulence which retards near bank velocity and reduces the erosive attack of the flow on the bank (Thorne et al. 1997). Bank vegetation also increases the effective roughness height of the boundary shear stresses responsible for erosion. Riparian zone vegetation increases bank stability through roots and rhizomes that bind the soil and introduce extra cohesion. The spacing of trees or shrubs along the channel has an important influence on bank erosion (Thorne et al. 1997). The closer the vegetation spacing, the more dense the network of roots. This affects soil porosity, grain size distribution, stratigraphy, soil bulk density, soil shear strength and variations in moisture levels (Thorne et al. 1997). The presence of vegetation does not render a bank immune from flow erosion, but the critical condition for changing a vegetated bank becomes the threshold of failure due to plant stems by snapping, stem scour, or uprooting (Thorne et al. 1997). Slopes covered by a healthy stand of close-growing vegetation experience an increase in erosion resistance of between one and two orders of magnitude when compared to an unvegetated area (Thorne et al. 1997). A lack of riparian vegetation can therefore influence channel morphology through increased erosion and deposition in the form of narrowing, widening, shifting and aggrading or degrading the channel bed (Kondolf, Piegay, and Landon 2002).

Riparian vegetation can over stabilize banks against erosion preventing channel widening (Setser 2000). Narrow channels with adjacent vegetation may have a higher channel roughness which may significantly reduce channel capacity and can result in a reduction of overbank flows (Thorne et al. 1997). Sediment that would have been deposited on the floodplain is deposited within the river channel, causing channel narrowing (Friedman, Osterkamp, and Lewis 1996; Setser 2000).

Changes to riparian environments affect a river's morphological response to flood events by influencing bank processes and altering patterns of scour, sediment transport and deposition (Brinson et al. 2002). Common erosional effects that can be associated with flooding include crescent shaped scours around flow obstructions, longitudinal scours, irregularly shaped scour holes, bedrock scour and the lowering of large portions of flood-plain surface (Sullivan 1983).

CHAPTER III

STUDY AREA

Location

The study area covers 134 kilometers along a section of the Guadalupe River that is located in South Central Texas Hill Country (Palmer 1986) spanning across Kerr, Kendall and Comal Counties (see figure 1). The stream segment begins after the second major dam in Kerrville, Texas and follows the course of the river through Kendall and Comal Counties, ending where FM 281 crosses the river in Comal County approximately 10 river kilometers before the river enters Canyon Lake (see figure 2). The final 10 river kilometers upstream of Canyon Lake are influenced by backwater effects of the lake and were thus excluded from the study area. The total contributing drainage area of the study section is approximately 2100 square kilometers.

Physiography

The study area is located in the Edwards Plateau /Texas Hill Country and Balcones Canyonlands districts (Fenneman, 1931). This area is a zone of monoclinal folding and faulting which consists of steep canyons, narrow divides and high gradient drainages (Riskind and Diamond 1986). The districts are located within the Edwards Plateau section, which is in turn located within the Great Plains physiographic province.

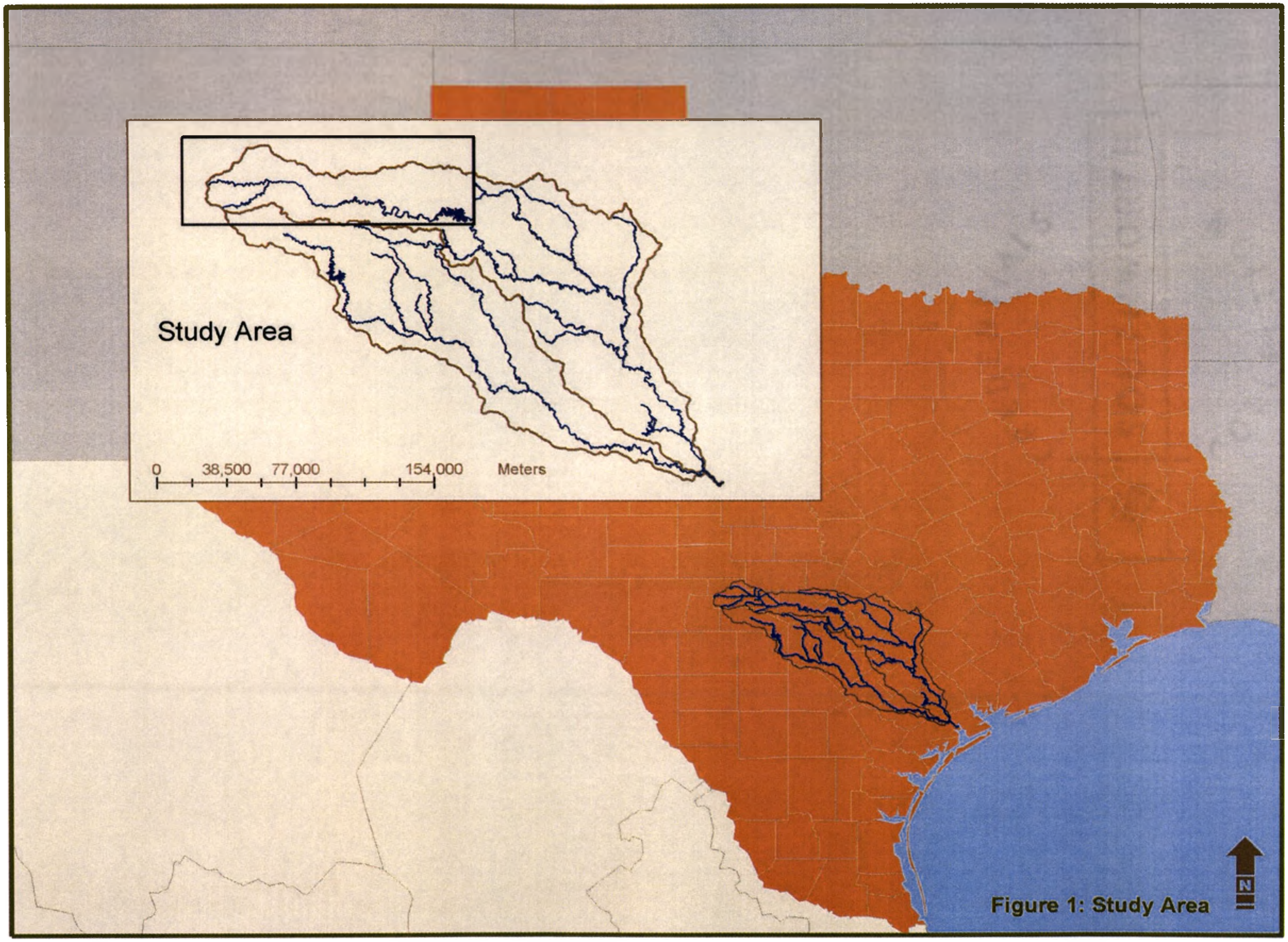
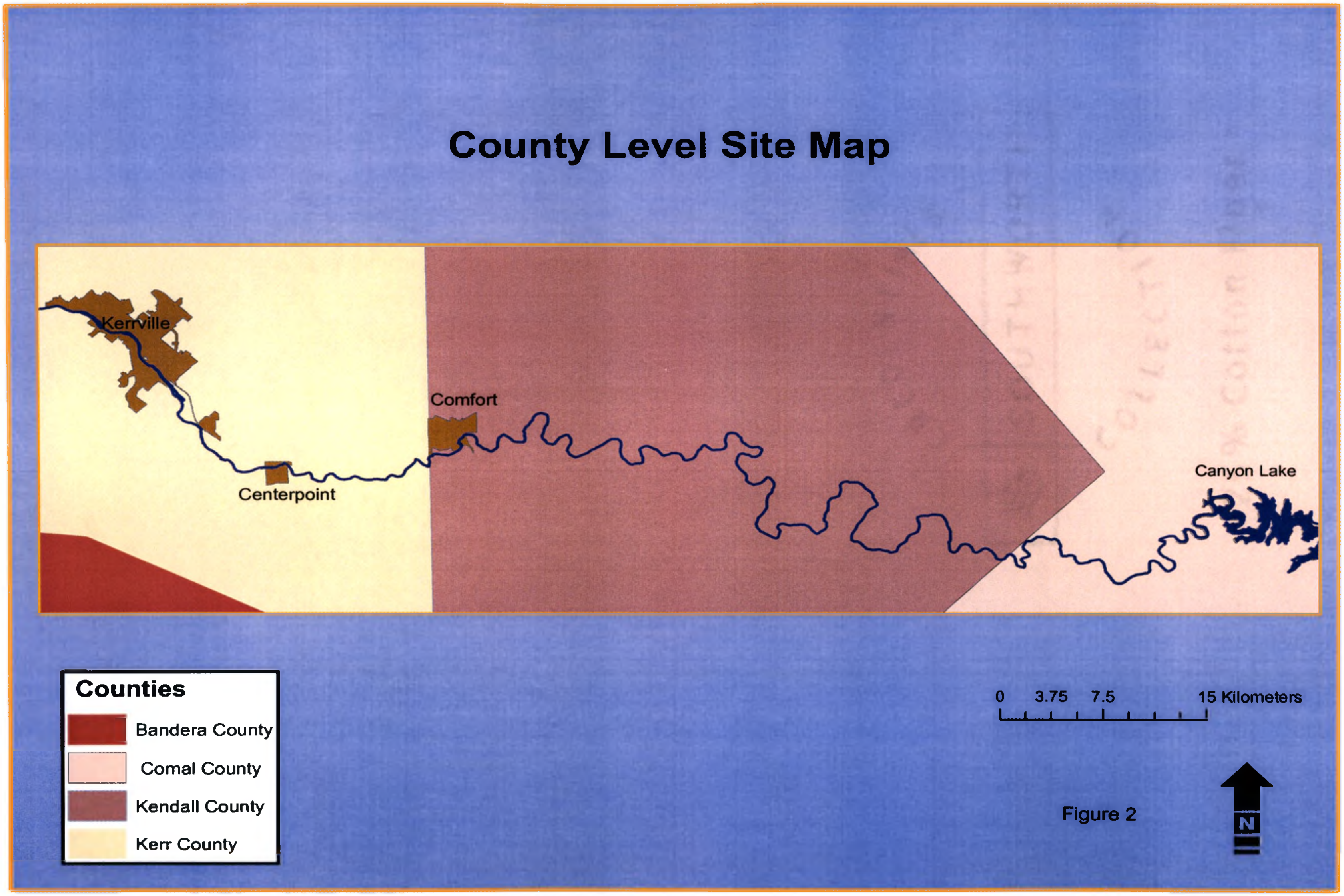


Figure 1: Study Area


County Level Site Map
Kerrville
Comfort
Centerpoint
Canyon Lake
Counties
Bandera County
Comal County
Kendall County
Kerr County
0 3.75 7.5 15 Kilometers
Figure 2
N

Geology

The geology of the area consists of limestone rock of Cretaceous origin. The less eroded areas are dominated by Lower Cretaceous rocks within the limestone group. More highly eroded areas in the Edwards limestone expose older Cretaceous material primarily from the Glen Rose Formation (Riskind and Diamond 1986).

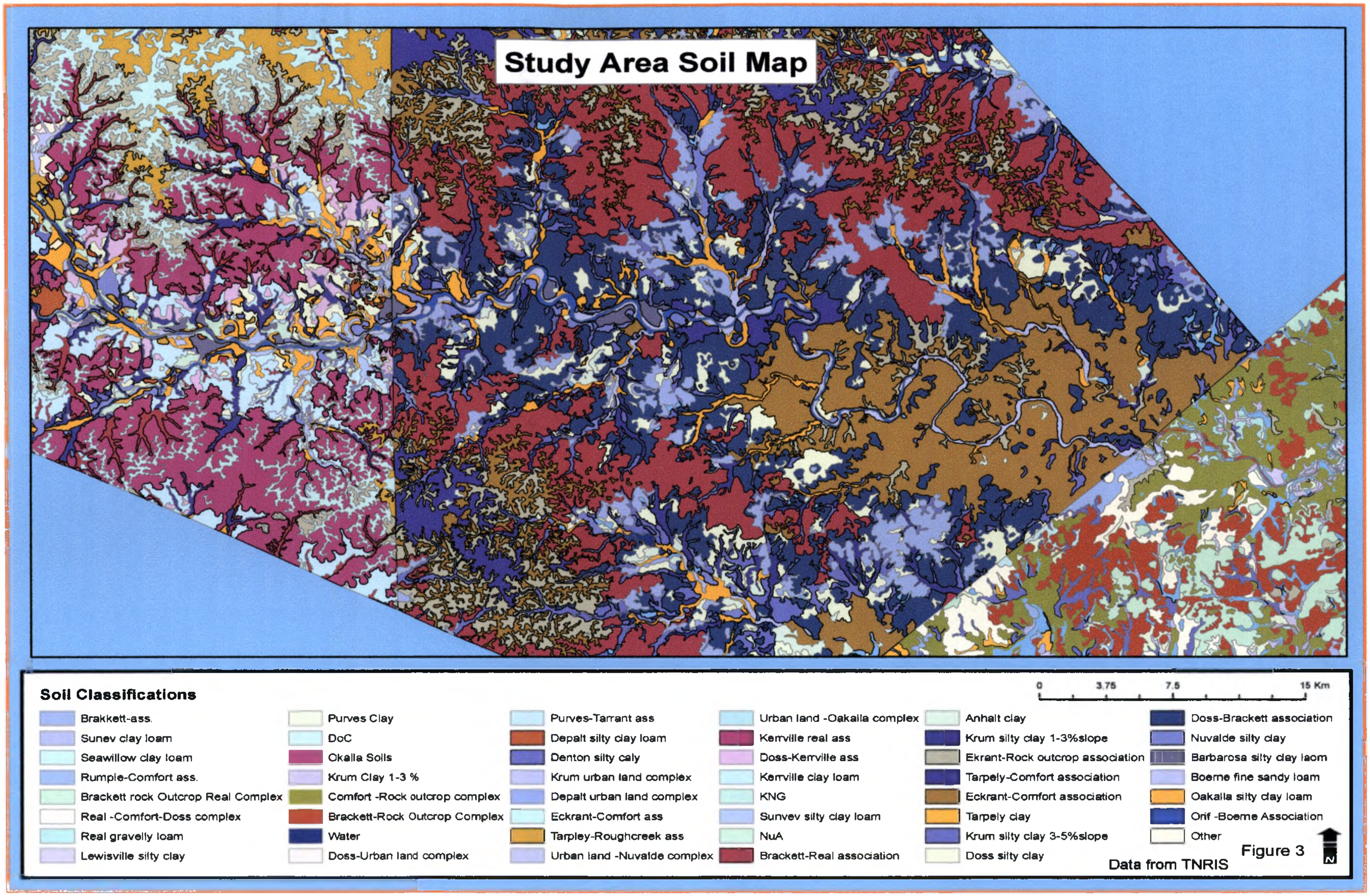
More specifically, over the length of the Guadalupe River from the convergence of the north and south forks of the Guadalupe River, low terrace deposits are found closest to the river channel. These alluvial deposits occur above the flood level along entrenched streams and contain some alluvium, gravel, sand, silt, clay and organic matter. Surrounding these near-channel deposits is the Upper Glen Rose Limestone. This formation consists of limestone, dolomite and marl alternating resistant and recessive beds which forms stairstep topography. Further from the stream, the Glen Rose Limestone is surrounded by Edwards Limestone Fort Terrett Member. This pattern of geology remains the same as the river flows through the towns of Ingram, Kerrville and Legion. From Legion to Centerpoint the in-channel low-terrace deposits become fluviatile terrace deposits composed of gravel, sand, silt and clay. The terrace deposits continue to be surrounded by the Upper Glen Rose Formation.

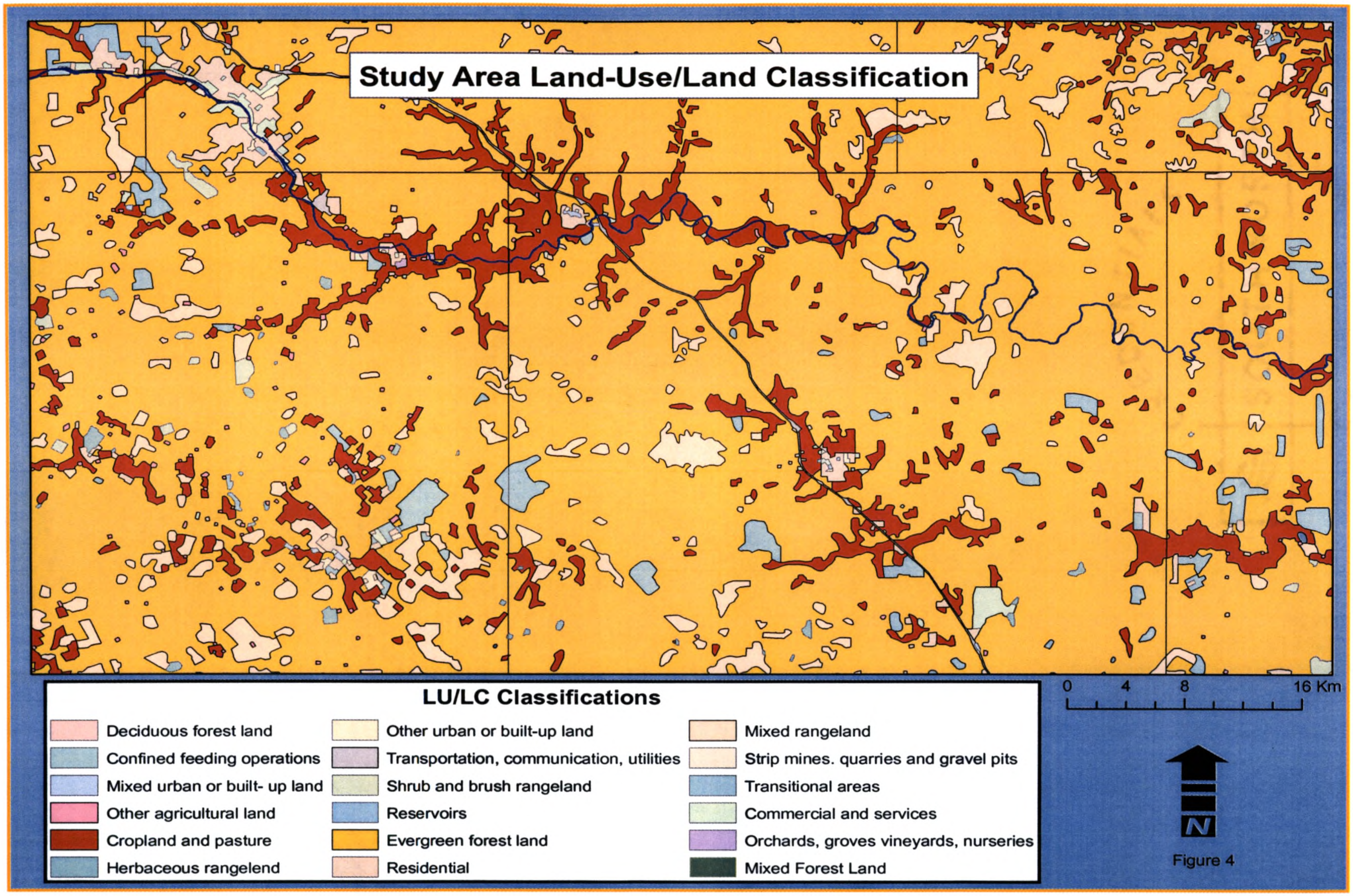
This pattern of geology is evident until Comfort, where a thin band of Lower Glen Rose Formation starts to develop between the fluvatile terrace deposits and the Upper Glen Rose Formation. As the river nears Sisterdale, the fluvatile terrace deposits disappear and the Lower Glen Rose formation dominates the river channel and surrounding area. Near Spring Creek in Kendall County, Hensell Sand and Cow Creek Limestone are found in the immediate river channel. The Lower Glen Rose Formation continues to dominate the geology surrounding the near-channel area. At Springbranch, fluviatile terrace deposits reappear close to the channel along with alternating bands of Edwards Limestone Lower Glen Rose Formation. This geology continues until the river enters Canyon Lake (Bureau of Economic Geology 1992).

Soils

The canyonlands contain shallow, cobbley, clayey to loamy soils overlying the limestone units (Figure 3). The upriver portion of the study area falls within Kerr County, where there is a dominance of the Orif-Boerne association soils around the river channel. These soils consist of loamy and gravely soils. The Orif soil is adjacent to the stream channel with the Boerne soil on the outer edges of the floodplain at a higher elevation. Both soils are well drained and typically produce slow to medium runoff. Permeability is moderately rapid to rapid and available water capacity is low to moderate. The hazard of water erosion associated with these soils is, however, severe. Frequent flooding, the high gravel content and the available water capacity are limiting factors for development on these soils, thus they are primarily used as rangeland (Soil Survey of Kerr County, Texas 1979).

As the river flows eastwards it enters Kendall county. Orif-Boerne association soils continue to dominate the area surrounding the river channel. Adjacent to the channel there is a predominance of Boerne fine sandy loam. This is a deep, gently sloping soil that is found on floodplains or alluvial fans near streams. The soil is well drained with slow surface runoff. The permeability of the soil is moderately rapid and available water capacity is medium. The hazard of water erosion associated with this soil is severe.


Study Area Soil Map
Soil Classifications
Brakkett-ass.
Sunev clay loam
Seawillow clay loam
Rumple-Comfort ass.
Brackett rock Outcrop Real Complex
Real -Comfort-Doss complex
Real gravelly loam
Lewisville silty clay
Purves Clay
DoC
Okalla Soils
Krum Clay 1-3 %
Comfort -Rock outcrop complex
Brackett-Rock Outcrop Complex
Water
Doss-Urban land complex
Purves-Tarrant ass
Depalt silty clay loam
Denton silty caly
Krum urban land complex
Depalt urban land complex
Eckrant-Comfort ass
Tarpley-Roughcreek ass
Urban land -Nuvalde complex
Urban land -Oakalla complex
Kerrville real ass
Doss-Kerrville ass
Kerrville clay loam
KNG
Sunvev silty clay loam
NuA
Brackett-Real association
Anhalt clay
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely-Comfort association
Eckrant-Comfort association
Tarpely clay
Krum silty clay 3-5%slope
Doss silty clay
Doss-Brackett association
Nuvalde silty clay
Barbarosa silty clay laom
Boerne fine sandy loam
Oakalla silty clay loam
Orif -Boerne Association
Other
0
3.75
7.5
15 Km
N
Data from TNRIS
Figure 3



Study Area Land-Use/Land Classification
LU/LC Classifications
Deciduous forest land
Confined feeding operations
Mixed urban or built- up land
Other agricultural land
Cropland and pasture
Herbaceous rangelend
Other urban or built-up land
Transportation, communication, utilities
Shrub and brush rangeland
Reservoirs
Evergreen forest land
Residential
Mixed rangeland
Strip mines. quarries and gravel pits
Transitional areas
Commercial and services
Orchards, groves vineyards, nurseries
Mixed Forest Land
0 4 8 16 Km
N

Figure 4

Thus, the soil is primarily used as cropland and rangeland. As the river passes Goss Creek the Boerne soil replaces the Orif-Boerne association as the dominant soil type (Soil Survey of Kendal County Texas 1979).

As the river passes into Comal county, Boerne fine sandy loam continue to dominate. However, there are localized areas of Oakalla soils present. These are deep soils found on smooth to slightly undulating floodplains which are frequently flooded. The surface texture of these soils is loam, clay loam, silty clay or silty clay loam. The soils are well drained, as surface runoff is slow and permeability is moderate. The available water capacity is high with a slight water erosion hazard. This soil is well suited to use as pastureland and rangeland. Moving further west, Oakalla silty clay loam becomes evident. This soil has the same origins and properties as Oakalla soils but it is more silty throughout because it occurs in areas that are rarely flooded. Around Highway 346 Comfort-Rock outcrop complex soil are evident. This complex consists of shallow, clayey soils. The comfort soil is well drained, surface run off is slow to medium and permeability is slow. The available water capacity is also very low with only a slight water erosion hazard. This complex is interspersed with areas of Orif soils. More Oakalla soil emerges and, as the river crosses Highway 281, Seawillow clay loam is also evident. Seawillow clay loam is a deep soil found on stream terraces. It is well drained, and surface runoff is medium. Permeability is moderate, and the available water capacity is medium. The rooting zone is deep, and the hazard of water erosion is moderate. As the river reaches highway 311, some Sunev clay loam are present. This soil is deep, gently sloping soil found on valley slopes and foot slopes of hills on uplands in the Edwards Plateau Land Resource Area. The soil has the same physical properties as Seawillow clay loam soils. There is a brief distance where Oakalla and Seawillow clay loam soils dominate before Seawillow clay loam continues as the river approaches Canyon Lake. Finally as the river enters Canyon Lake, Boerne fne sandy loam encompasses the area (Soil Survey of Comal County, Texas 1979).

Vegetation

Upland Cedar breaks form a characteristic woody vegetation community in which the dominant trees include juniper (*Juniperus ashei*), live oak (*Quercus texana*) and Texas persimmon (*Diospyros texana*) (Sullivan 1983). These areas are primarily used as range. Dense stands of large bald cypress (*Taxodium distichum*), pecans (*Carya illinoinensis*) and Texas sugarberry (*Celtis laevigata*) dominate the riparian areas which are primarily used for cultivation, pasture and range (Sullivan 1983). Buttonbush (*Cephalanthus occidentalis)* is often found in the shrub stratum in both the upland and riparian areas (Riskind and Diamond 1986). Within the narrow stream side community bald cypress often form monodominant stands (Riskind and Diamond 1986). Away form the channel, the steep slopes of the Canyonlands are composed of short stature woodlands (Riskind and Diamond 1986). These woodlands are primarily composed of evergreen juniper and juniper-oak on the south and west exposures and deciduous mixed oak hardwood woodlands on the north and east exposures (Riskind and Diamond 1986).

Climate

Generally the climate of Central Texas is sub-humid (Caran and Baker 1986). The precipitation pattern is characterized by maximums in late spring and early with minimums in winter and summer (Carr 1967). Meteorological characteristics combine with the orographic influence of the Balcones Escarpment to produce the rainfall patterns for the region (Slade 1986). The area lies in a zone of upper level atmospheric convergence of polar air and easterly waves (Carr 1967; Caran and Baker 1986). The Polar air is characterized by cool temperatures, high pressures and low moisture (Caran and Baker 1986). The easterly waves are westward moving troughs of low pressure which convey warm moist tropical air (Caran and Baker 1986). When a well developed easterly wave approaches high pressure, usually associated with a strong polar surge into the middle latitudes, pronounced instability and heavy rains can result (Caran and Baker 1986).

Orographic effects associated with the Balcones Escarpment augment the propensity for heavy rains. Warm, moisture laden air from the Gulf of Mexico is pushed northward across the gently sloping Coastal Plains by dominant southerly winds (Caran and Baker 1986). As these air masses are pushed over the escarpment they rise to higher altitude and if the air mass is almost saturated when it is at lower elevations, rain storms can occur along the escarpment due to orographic cooling of the air mass (Caran and Baker 1986). Seasonal tropical storms and hurricanes are regular occurrences over the warm waters of the Caribbean and Gulf of Mexico (Caran and Baker 1986). The remains of many hurricanes move inland to Central Texas carrying much moisture from the Gulf of Mexico (Slade 1986). Occasionally these storms can penetrate well into the state and produce heavy rainfall in the Central Texas region (Caran and Baker 1986).

Based upon precipitation data from 1971-2000 for selected stations within the basin, Canyon Dam has an average annual total precipitation of 926 millimeters, Springbranch 855 millimeters, Boerne 949 millimeters, Hunt 786 millimeters and

Kerrville 855 millimeters (Monthly Station Normals 1971-2000). Mean monthly temperatures for the region average around 18.61°C.

Population Statistics

The Upper Guadalupe passes through Kerr, Kendal and Comal Counties. Kerr county has a population of 43, 653. Kendal County has a population of 23, 743 and Comal county has a population of 78, 021. This results in a combined population of 145, 417 for the region (Census 2000). The largest settlement in the Upper Guadalupe basin is Kerrville with a total population of 20, 425 (Census 2000)

Land –Use / Land Cover Classification

Cropland and pasture dominate the upper portion of the study area surrounding the river channel (figure 4). Evergreen forests surround these cropland and pasture areas. In the lower portion of the study site the evergreen forest land closes in on the channel forming the riparian area. Pockets of mixed rangeland are dispersed across the study area (TNRIS).

The early years of the 1900's witnessed continued overgrazing. The overstocking of the area led to declining grass cover and its replacement by woody plants (Palmer 1986). After the Second World War the federal government began to take a more active role in encouraging more informed land-management practices. Soil conservation districts were organized. Since then strategies to reintroduce favorable grass species, avoid overgrazing and prevent soil erosion have been in place. Into the 1980's the raising of livestock remained the dominant agricultural land use in the Hill Country, and accounted for more than 90% of all agricultural income (Palmer 1986). More recently the trend in land ownership has moved toward disaggregating the larger holdings into 10 to 20 acre tracts that are for sale as weekend houses. (Palmer 1986). As a result the high land prices now associated with the area have made it economically unsustainable for many farmers and ranchers to continue in agriculture (Palmer 1986).

CHAPTER IV

METHODS

Data Collection and Recording

Both qualitative and quantitative research methods were employed in the course of this study. A longitudinal survey of the river was conducted in order to collect primary data. The river was divided up into four-mile sections of which one section was covered during each field day. Spatial data were collected using a Trimble GeoXM handheld GPS. Erosional features that showed a clear loss of bank were material were identified. The features that exceeded 10 meters in longitudinal distance and displayed more than 3 meters in horizontal change from the existing stream bank were mapped and photographed. Where the nature of the river bank allowed, direct GPS line measurements were taken by walking the length of the erosional features. Where it was not possible to approach the streambank, distance and bearing measurements were recorded were recorded for the points along the erosion feature from a location that could be accessed. This was achieved by taking distance and bearing measurements using laser rangefinder binoculars. While at the accessible location the distance and bearing measurements were then inputted into the GPS unit to record the position of the inaccessible erosion site.

LULC information was also collected using the GPS unit. The various LULC attribute classes were arranged in the GPS as follows: agriculture, which was sub-divided into crops, pasture, orchard and other; urban features, which was sub-divided into residential, industrial and recreational; rangeland, which consisted of grass and forested rangeland. At each location, the extent and type of riparian vegetation and LULC (where possible) were noted. Due to the structure of the river channel it was not always possible to make accurate visual assessments of the LULC surrounding the erosion features. Secondary data were collected utilizing a variety of sources and methods. These methods included GIS techniques based on Passmore 1997; Johnson et al. 1995 and Lillesand and Kiefer 1994. Statistical and mathematical modeling were based on Atkinson et. al. 2003 and Rhoads, B.L., 1992, and aerial photograph and digital elevation models based on Johnson et. al. 1995; Lillesand and Kiefer 1994; O'Connor and Watson 1998; McGlynn and Seibert 2003.

Land-use and land cover classification and historical channel patterns are commonly mapped from aerial photography and remotely sensed data (Gilliom and Thelin 1997; Lillesand and Kiefer 1994). Land-use land cover and soil shapefiles were downloaded from the Texas Natural Resource Information System (TNRIS). The shapefiles were modified using ESRI ArcMap software in order to produce LULC and soil maps. Aerial photographs were obtained from the U.S. Department of Agriculture offices at Kerr, Kendall and Comal Counties. Coverage from 1950, 1969, 1976, 1990 and 1996 were obtained for Kerr County. Coverage for 1955, 1983, 1990 and 1996 were obtained for Kendall County, and coverage for 1989, 1990 and 1996 were obtained for Comal County. All the photographs were at a scale of 1: 31, 680.

Data Processing and Analysis

During data processing the historical aerial photographs were scanned at 300dpi and saved into a database as .bmp files. Digital orthophoto quarter-quads (DOQQ's) for each county from 1995/1996 were also imported from TNRIS and loaded into the ESRI ArcMap 9.0 software. The point-matching geo-referencing utility contained within the software was then used to geo-rectify the historical aerial photographs which were overlayed on the DOQQ's. Once the aerial photographs were geo-rectified, the images were compared in the same geographic space. Digital representations of the stream channel were produced by digitizing the channels ESRI ArcMap for each set of aerial photographs. These digital channel representations allowed comparisons to be made in which the degree of channel change over time could be clearly quantified (Setser 2000).

Microsoft Excel's data analysis feature was used to randomly produce 30 points between the relevant UTM y- co-ordinates of the study area. These 30 points were plotted on the 1996 channel representations by extending 90° lines from the y – co-ordinate, on a north to south plain, until the line bisected the river channel. Downstream from each of the plotted points 100 river bank meters were measured using ESRI ArcMap 9.0. Using the digitizing function, polygons were created using the 1996 digitized stream channel. Each polygon followed both of the stream banks over the 100 meter section enclosing the river section. Polygons were also drawn for each of the same channel portions using the 1955 digitized channel representations. The area of each polygon was calculated for each channel section for both 1996 and 1955 using the area calculator function in the ESRI ArcMap Toolbox. Each area was then divided by the longitudinal distance of the section, which was 100 meters, to give the area of change per bank meter. The area for each polygon from the 1955 channel distribution was then subtracted from the corresponding 1996 polygon. As a result, the total amount of channel change that was experienced at each channel section per bank meter from 1955 to 1996 was calculated. The mean value from the 30 sites was then calculated to determine the average change that has occurred on the river channel per bank meter between 1955 and 1996.

The primary field data that were collected during the longitudinal survey were exported from the GPS unit into Trimble Pathfinder office software. The field data were differentially corrected and converted into shapefiles that were loaded into ESRI ArcMap 9.0 as a separate layer. This layer contained information regarding the spatial distribution of the present day erosion features. A classification system was developed to organize the data into more accessible units. Erosional sites were grouped by similarities in form and bank process. The sites were classified as flood erosion, channel meander and channel widening sites. These sites were identified by visual assessment of the both primary and secondary data. Flood erosion sites were characterized by erosion scars that occur off the main river channel. They are a result of the dispersal of erosive and depositional energy as the flood water chooses the path of least resistance after bankfull stage has been exceeded. Channel meander sites were characterized by erosion scars that occurred on the outside bank of river channel meanders. These meanders form due to the processes of alternating deposition and erosion. Channel widening sites were characterized by erosion scars that have resulted in the removal of bank material causing a widening of the river channel. These sites were strongly associated with a removal or thinning of the riparian vegetation. The location and the largest difference between the field data and the 1996 digitized channel and the longitudinal reach of each erosion feature was measured and recorded.

The 3 sites that displayed the most change within each category were selected for further analysis. For each of the identified sites, polygons were digitized for the 1996 and

1955 digitized river channels using ESRI ArcMap 9.0. The areas of these polygons were calculated and the total area of each polygon was then divided by the longitudinal distance of the polygon. The 1955 polygons were then subtracted from the areas of the 1996 polygons, resulting in the total channel change per bank meter for each site.

A Student's t- test was run on the absolute value of channel change per bank meter from 1955-1996 for the 30 randomly selected points in order to establish average change for the study section. More calculations were performed to compare the change in the sample sites to the average channel change that was calculated. Z-tests o the 30 test sites as previously described were used to determine if the sample field sites varied significantly from the average overall channel change.

Error Analysis

Due to the inherent nature of this study there is a possibility of introducing error during both data collection and processing. During data collection the operation of the GPS unit needs to be considered. The GPS unit works on calibrating the signals from four or more passing satellites. The longer the GPS unit is left collecting data the more primary points it collects before calculating the final position of the point that it is collecting. Due to changes in satellite geometry, sometimes the speed at which these primary points are received by the unit can vary. As a result, the amount of primary points collected before calculating the final position of the point may be reduced, which can result in a reduction in accuracy. During the study a minimum of 10 pre-points were taken before the unit registered the final dropped point, this ensured sub-meter accuracy after geo-correcting the field data.

Geo-referencing the scanned aerial photographs was a critical part of the analysis. During geo-referencing the number of connection points that are constructed between the aerial photograph and the referencing image can affect how accurately the photograph is georectified. ESRI ArcMap calculates the error involved in geo-referencing an image and reports it as a root mean square (RMS). In order to get a RMS reading, a minimum of four control points must be established between the scanned image and the DOQQ. In this study, although much of the reported RMS error was under 1, an acceptable RMS error was set at less than 2.

When digitizing the river channels from historical aerial photographs, there is potential to introduce an element of error through a number of subjective decisions that are necessary regarding the course of the river. These decisions are relevant where poor image quality make the identification of the channel boundaries on the historical aerial photographs difficult. The primary factors responsible for a poor quality image are the lack of effective contrast, poor scanning resolution, inappropriate scale, the angle of the flight of the airplane as well as the weather conditions and the time of day of the flight (Passmore 1997). The depth of the river at the time of the photograph will also affect where the channel boundaries are digitized.

Although these errors were not quantified in this particular study they were recognized and efforts were taken to minimize them.

CHAPTER V

RESULTS

The data that was recorded during the longitudinal survey is shown in figures 5-8. Due to river access constraints the longitudinal survey was not carried out on a section of river approximately 35 km long from FM 1376 to FM 3150. The digitized river channels from each county and for each flight year are displayed in figures 7-12.

From the polygon study of the 30 randomly generated channel sections it was determined that there is an average of 9.33 square meters of channel change per bank meter occurring on the Guadalupe River within the study area. A total of 138 bank erosion sites were identified using the longitudinal survey data. Of the sites, 54.4% were categorized as areas experiencing channel widening, 38.4% were categorized as erosion that has formed as a result of flooding, and 7.2% of the areas were undergoing channel meandering processes (refer to table 1). Two outliers were excluded from the sample, one from the channel meander category and one from the flood channel category. These erosional scars were excluded because they were recorded to be further off the river channel than seemed possible.

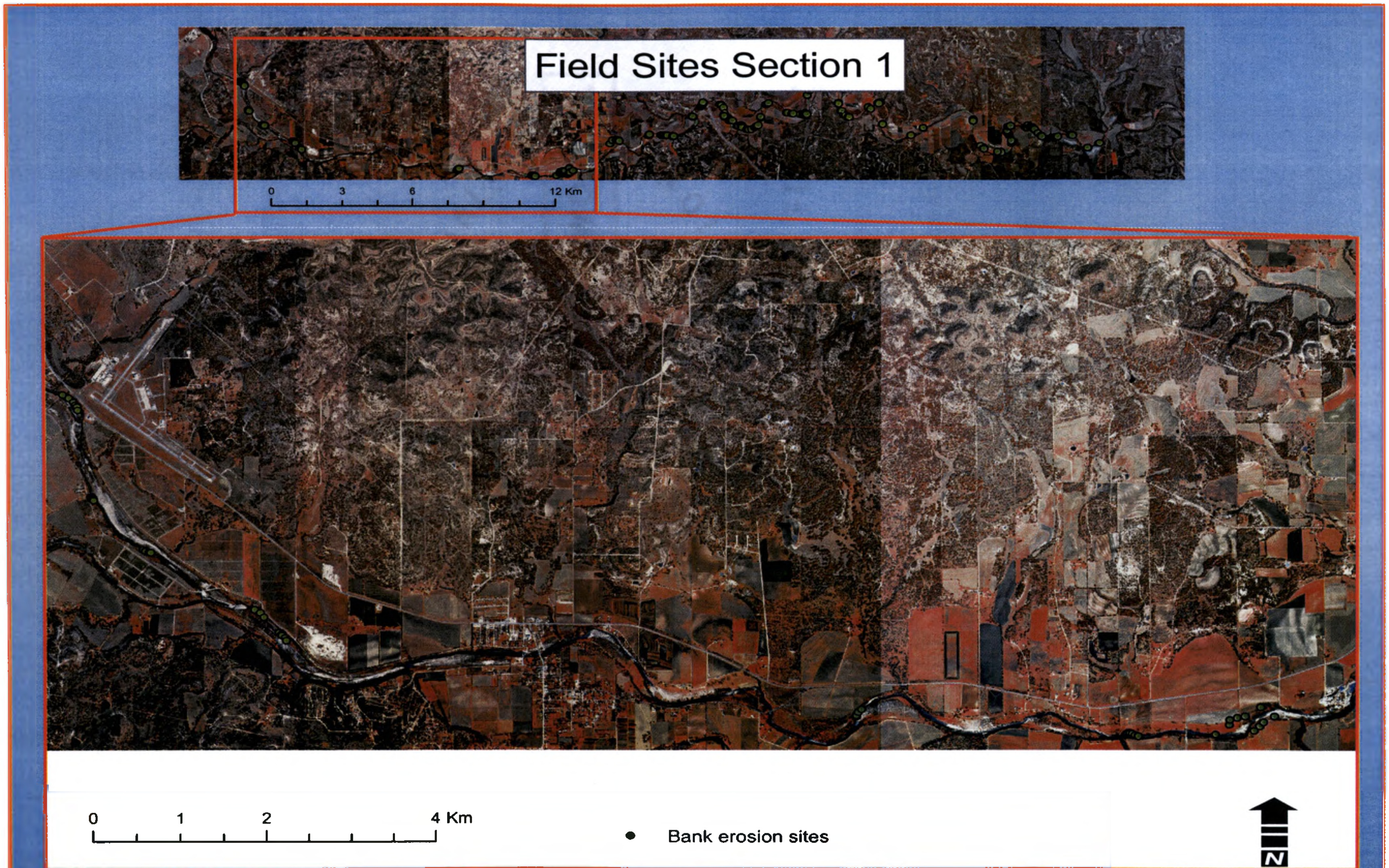


Figure 5

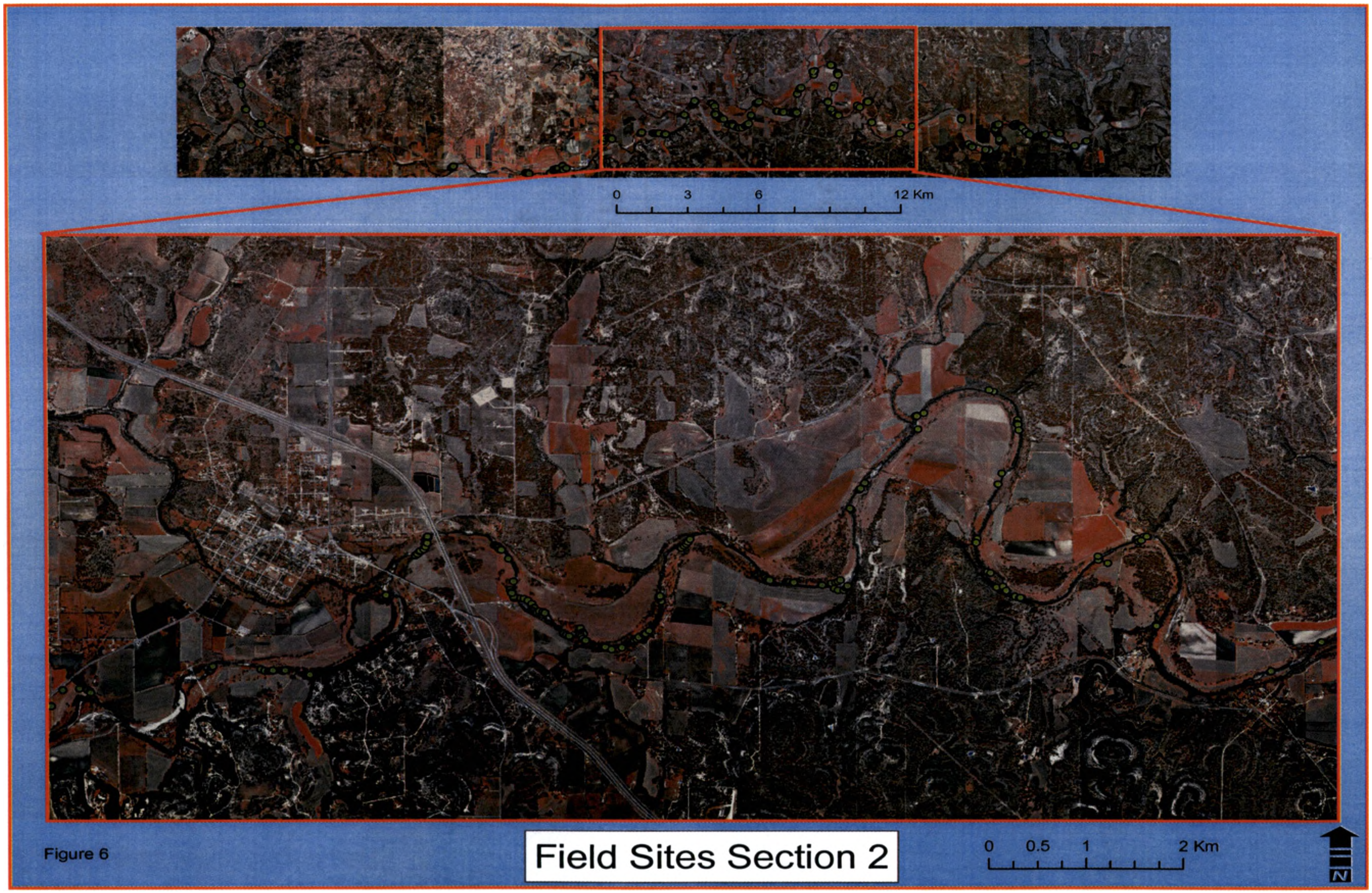


Figure 6

Field Sites Section 2

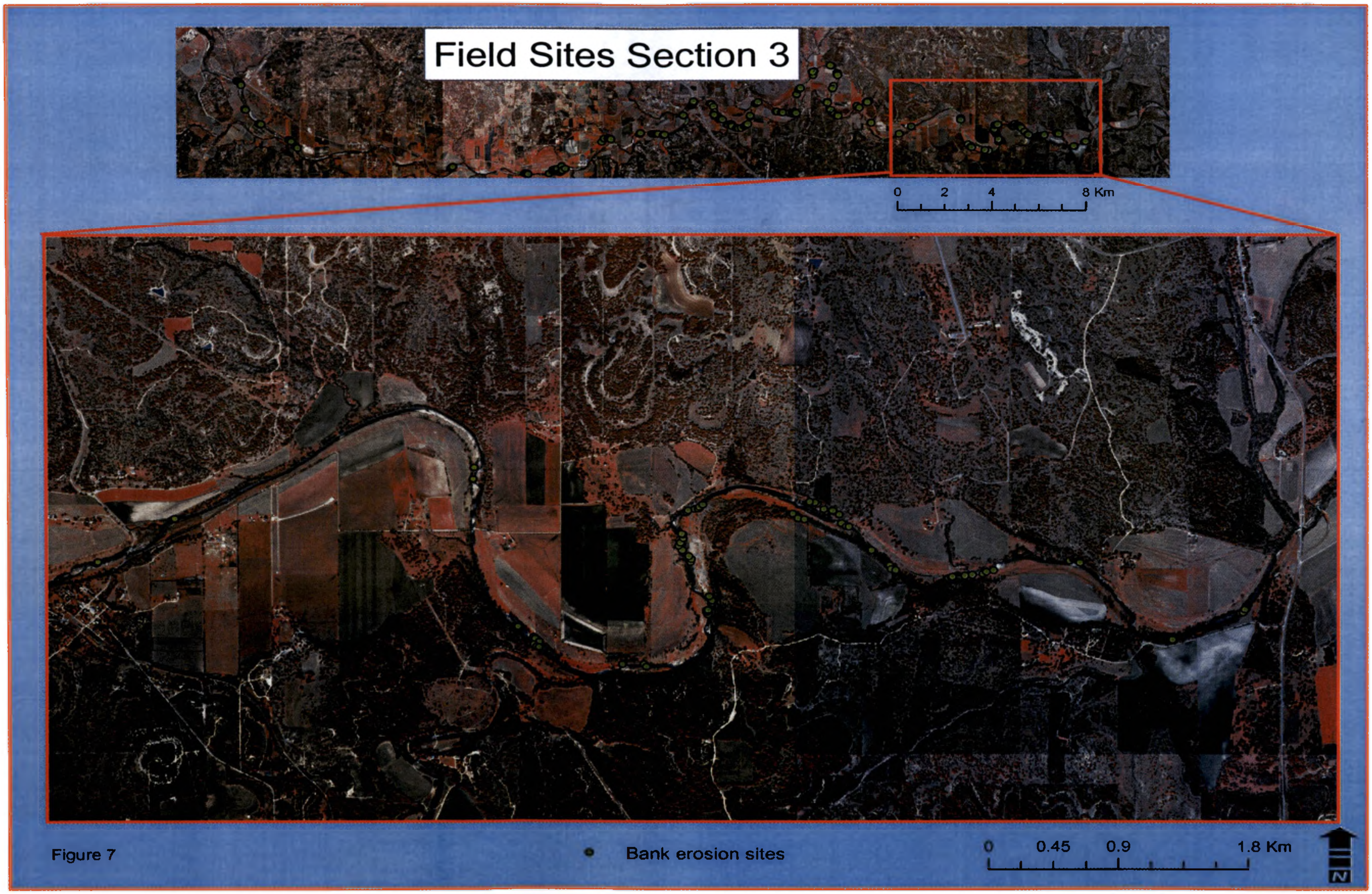

Field Sites Section 3
0 2 4 8 Km
Bank erosion sites
0 0.45 0.9 1.8 Km
N

Figure 7

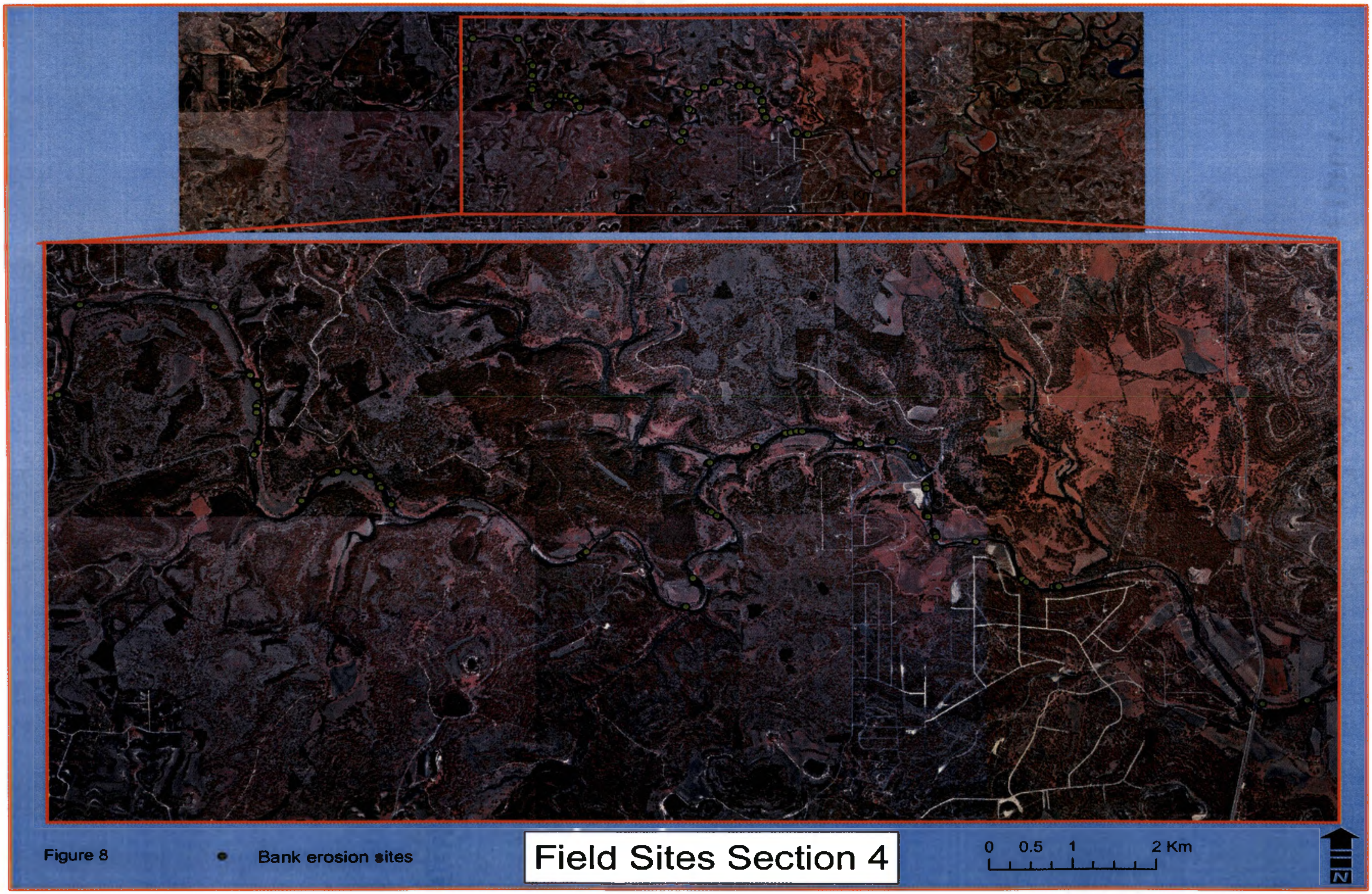


Figure 8
Bank erosion sites
Field Sites Section 4
0 0.5 1 2 Km
N

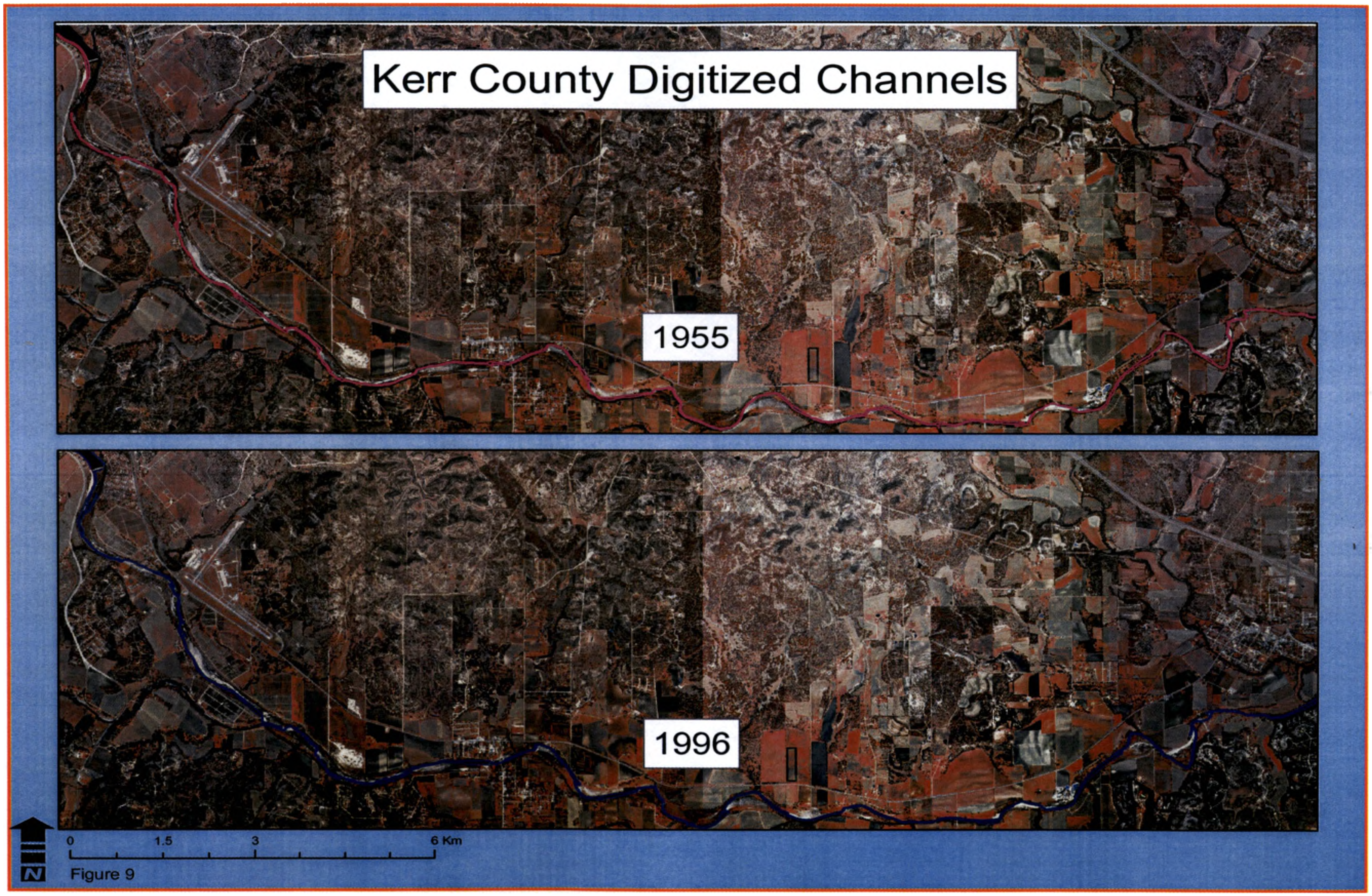


Figure 9

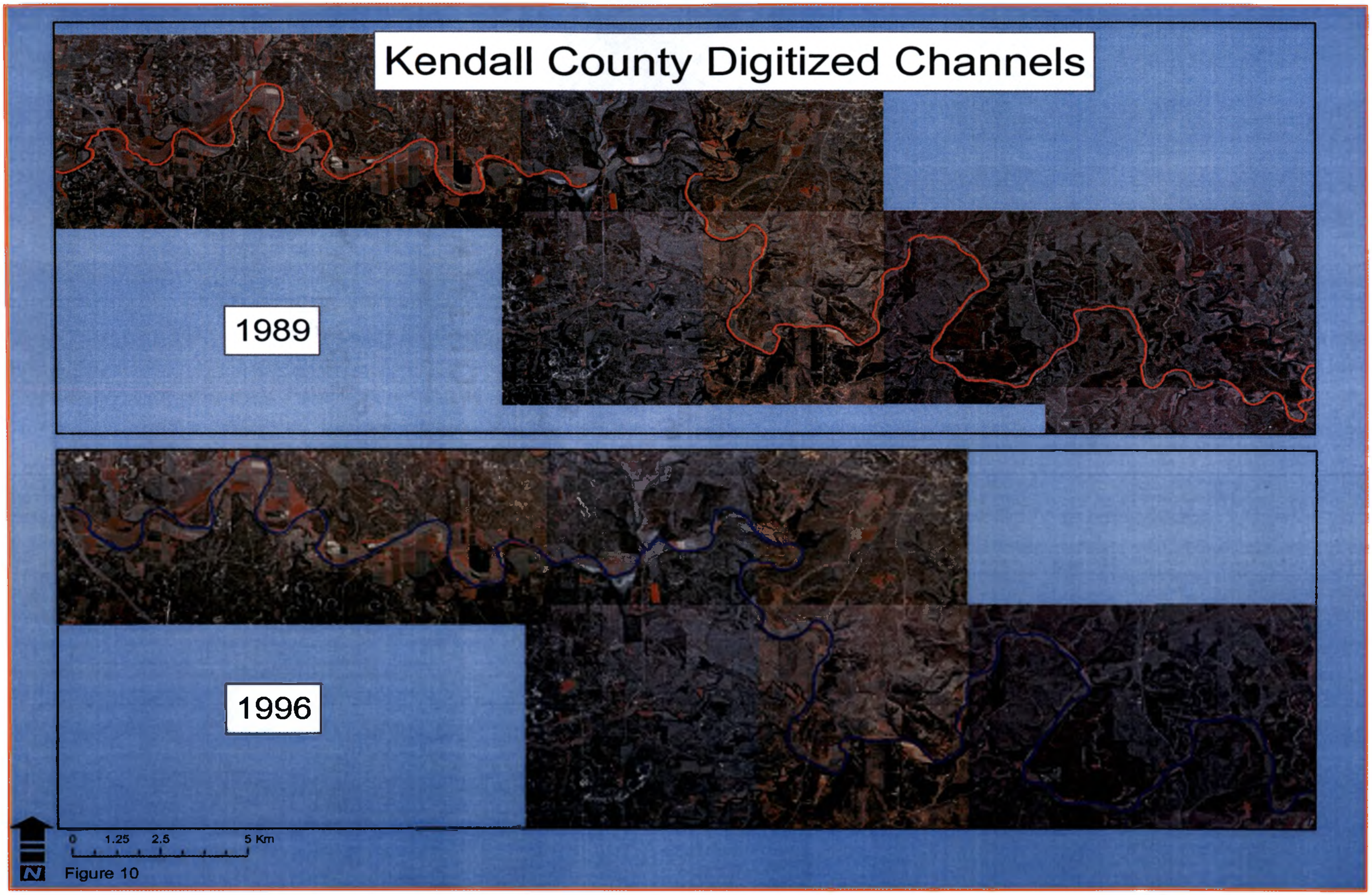


Figure 10

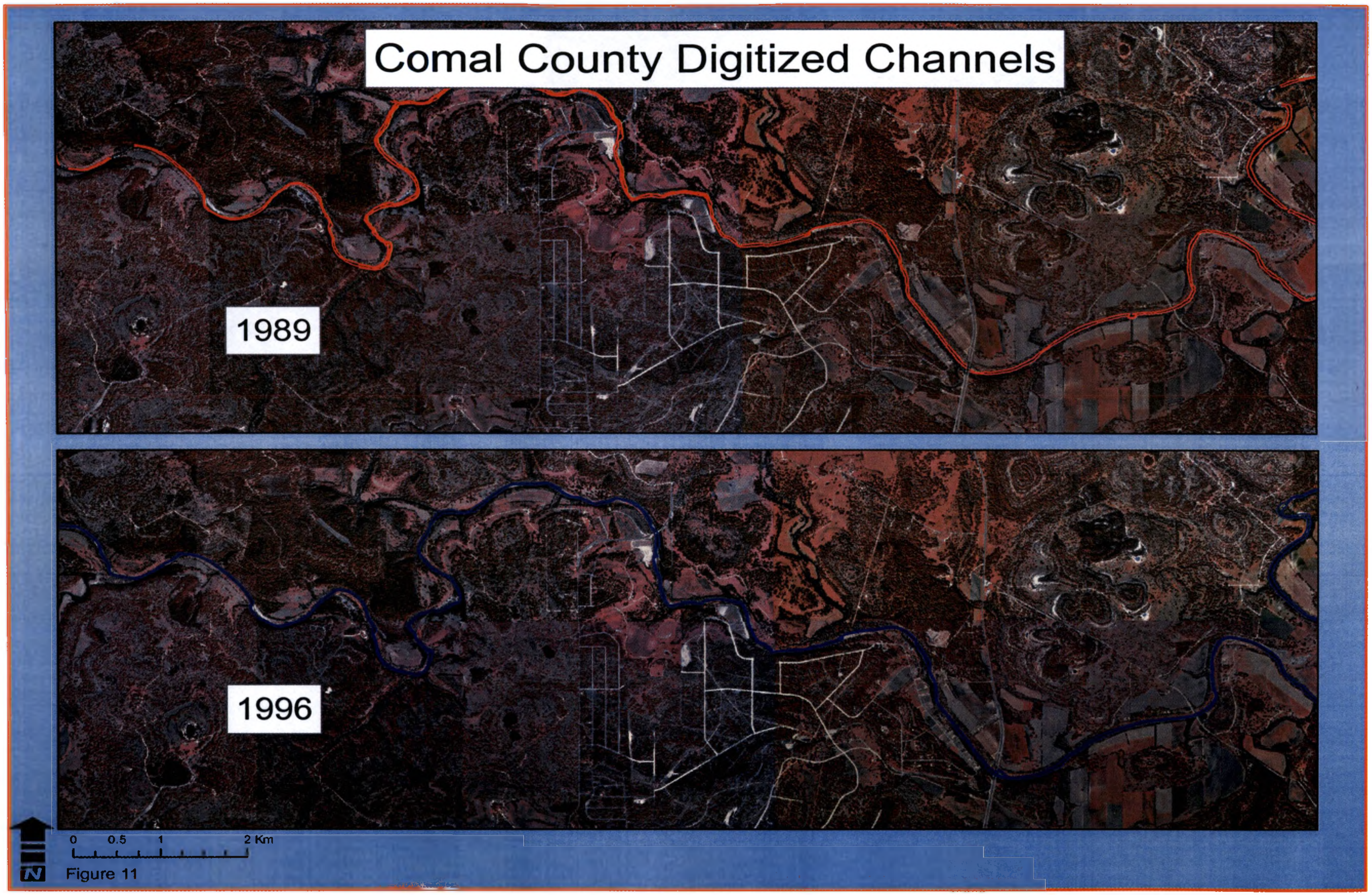


Figure 11

Table 1 Erosion Category Sample Distribution

	Frequency	**Percent of total**
Channel Widening	75	54.4
Flood Channel	53	38.4
Channel Meander	10	7.2
Total	138	100%

Of the 138 sites recorded, the 3 sites that displayed the most measured change when compared to the DOQQ's were selected for further analysis (refer to table 2).

Table 2 Sites Displaying the Largest Changes

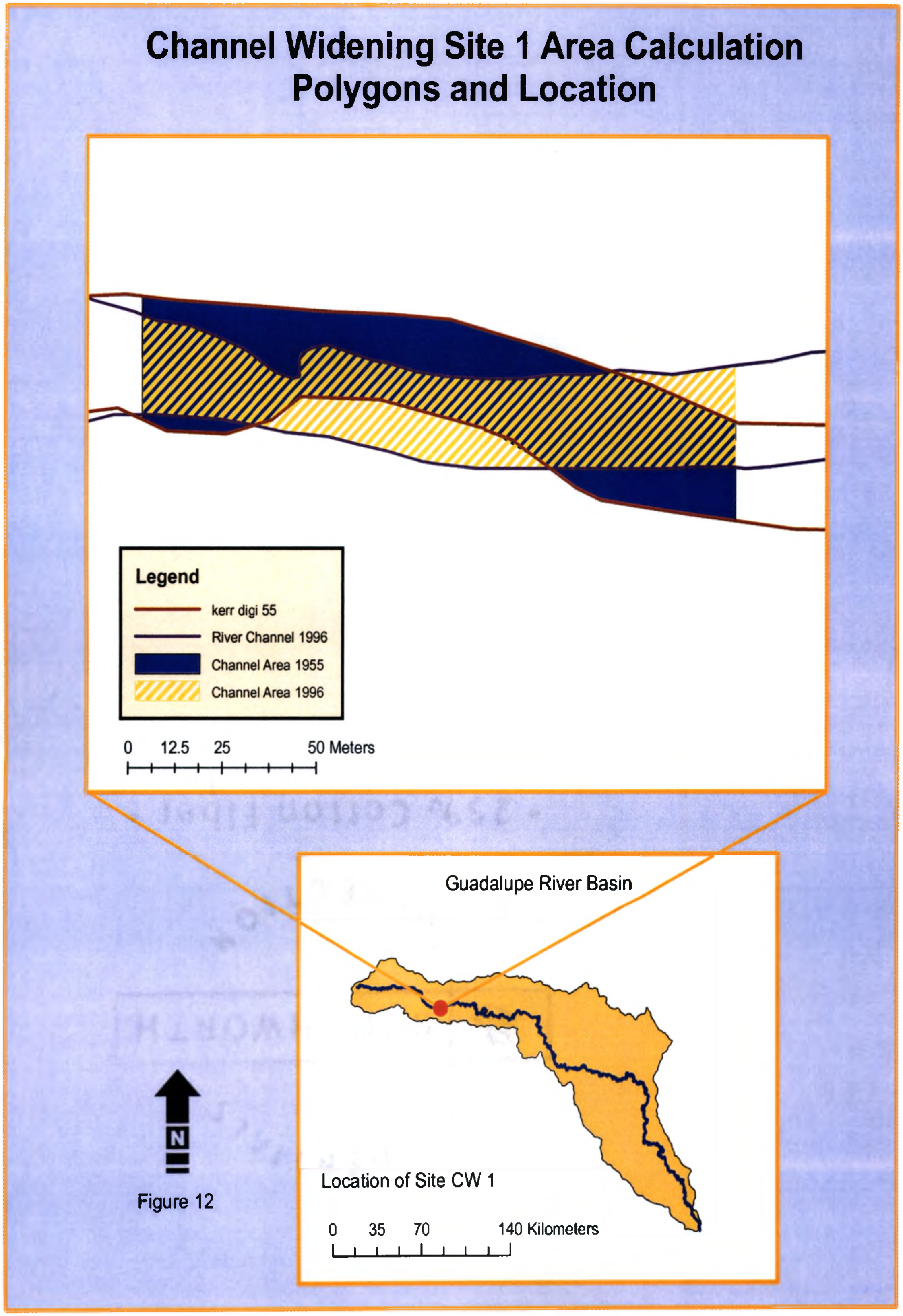
Category	**Site Number**	**Measured change in meters from 1996**	**Distance over which change was measured**
Channel Widening	CW 1	41	181
	CW 2	31	55
	CW 3	24	74
Flood Channel	FC 1	98	133
	FC 2	91	309
	FC 3	89	98
Channel Meander	CM 1	11	113
	CM 2	15	50
	CM 3	26	87

The areas and total channel change in meters per longitudinal bank meter were calculated for the 3 sites that displayed the most channel change within each of the categories channel widening sites 1,2 and 3, flood channel sites 1,2 and 3 and channel meanders 1, 2 and 3 (Table 3 and figures 15-23). The area for Channel Meander Site 3 was not calculated as 1955 data were not available for the site.

Table 3 Calculated Areas for the Sample Sites

Category	Site Number	Channel area per bank meter 1955	Channel area per bank meter 1996	Diff in channel area per bank meter '55 - '96
Channel Widening Site	CW 1	25.9	20.9	- 4.0
	CW 2	19.9	30.2	+ 10.0
	CW 3	16.9	24.0	+ 7.03
Flood Channel	FC 1	36.5	23.8	- 12.06
	FC 2	14.5	23.9	+ 9.4
	FC 3	17.1	19.4	+ 2.3
Channel Meander	CM 1	19.6	30.6	+ 11.0
	CM 2	19.8	27.0	+ 7.2

Refer to figures 24 – 28 for land use/ land cover maps for each of the sample sites and figures 27-31 for the sample sites soil maps.



Channel Widening Site 1 Area Calculation
Polygons and Location
Legend
kerr digi 55
River Channel 1996
Channel Area 1955
Channel Area 1996
0 12.5 25 50 Meters
Guadalupe River Basin
Location of Site CW 1
0 35 70 140 Kilometers
N

Figure 12

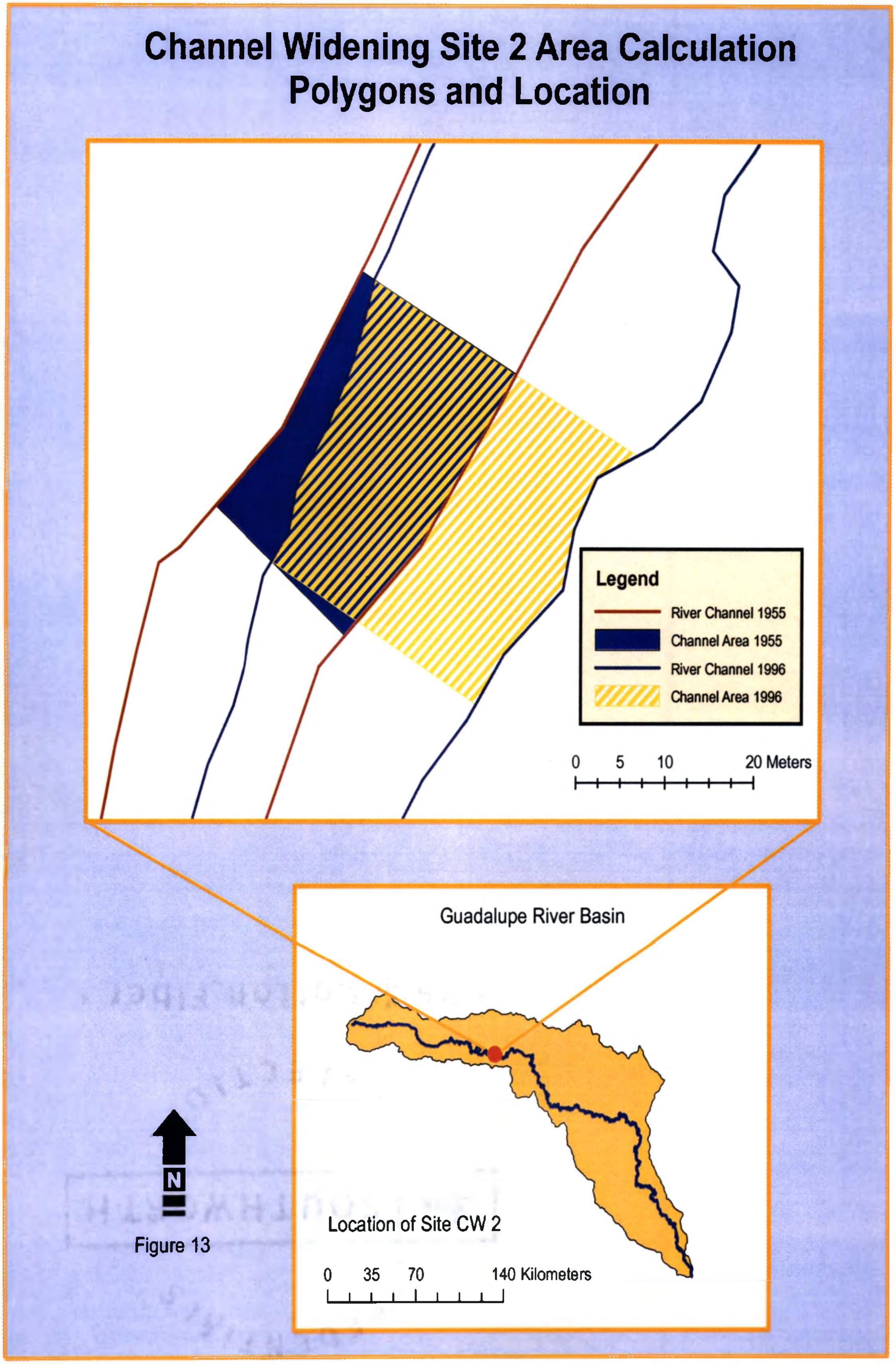

Channel Widening Site 2 Area Calculation Polygons and Location
Legend
River Channel 1955
Channel Area 1955
River Channel 1996
Channel Area 1996
0 5 10 20 Meters
Guadalupe River Basin
Location of Site CW 2
0 35 70 140 Kilometers
N

Figure 13

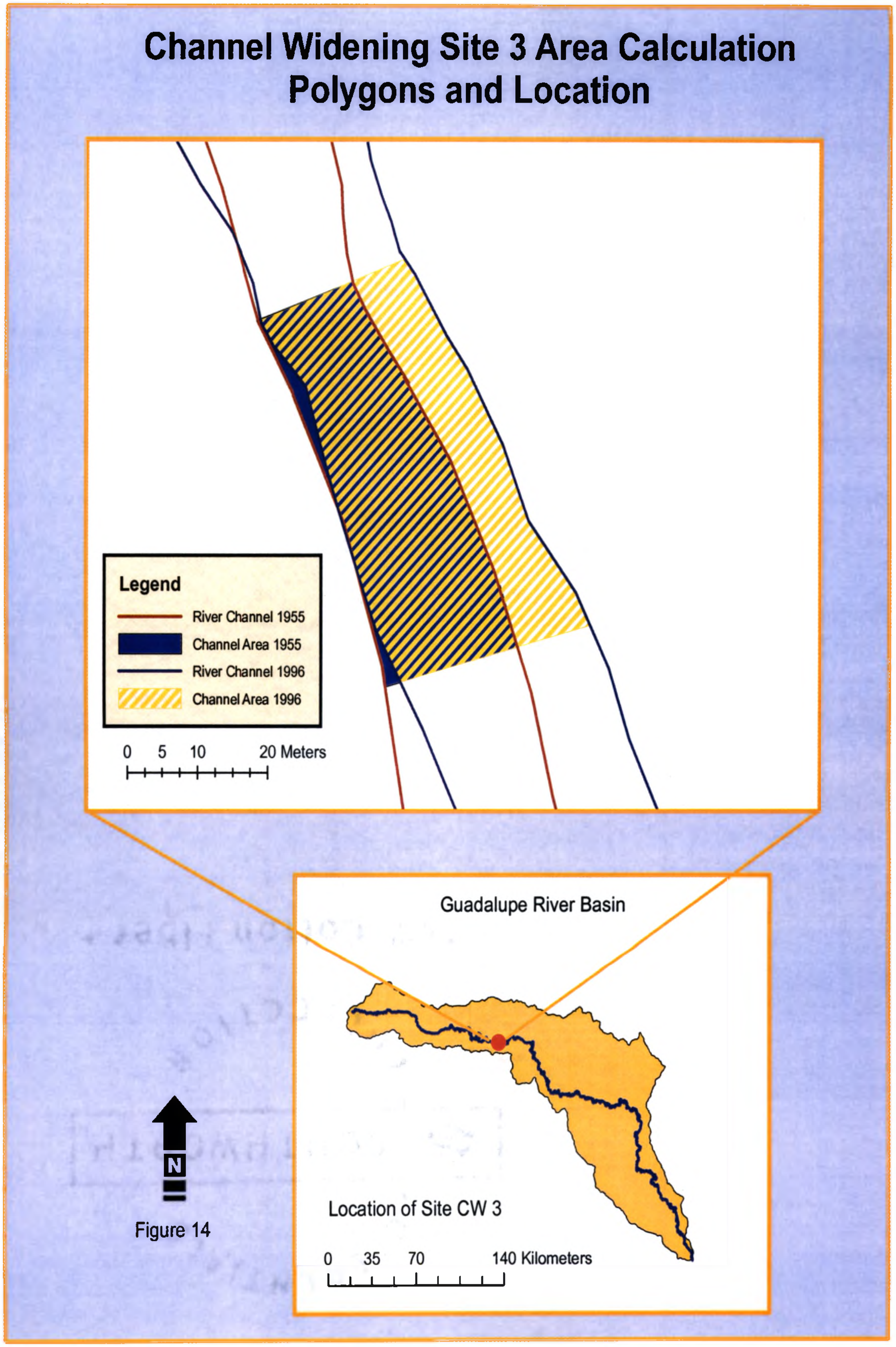

Channel Widening Site 3 Area Calculation
Polygons and Location
Legend
River Channel 1955
Channel Area 1955
River Channel 1996
Channel Area 1996
0 5 10 20 Meters
Guadalupe River Basin
Location of Site CW 3
0 35 70 140 Kilometers
N

Figure 14

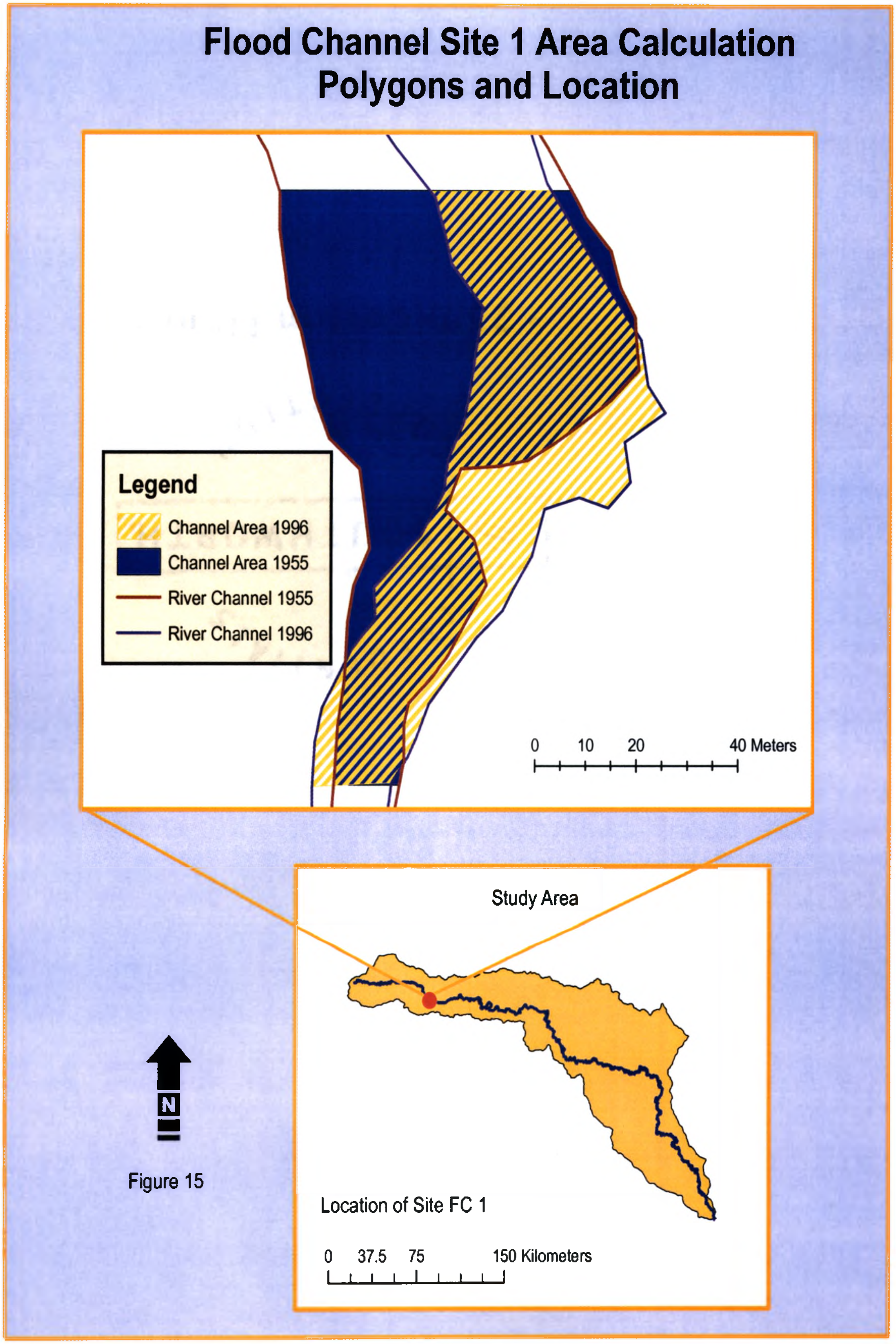
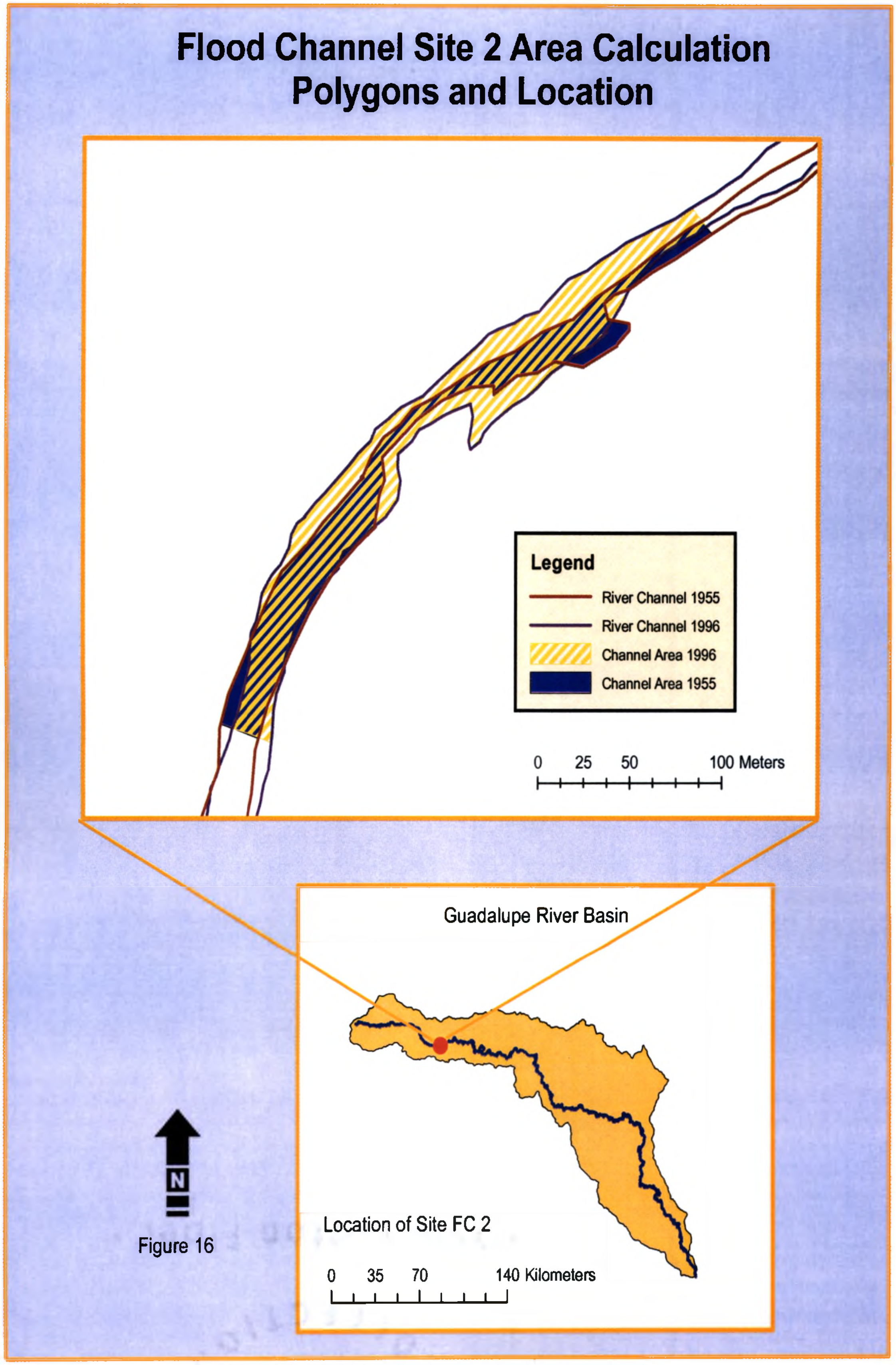

Flood Channel Site 1 Area Calculation
Polygons and Location
Legend
Channel Area 1996
Channel Area 1955
River Channel 1955
River Channel 1996
0 10 20 40 Meters
Study Area
N
Location of Site FC 1
0 37.5 75 150 Kilometers

Figure 15


Flood Channel Site 2 Area Calculation
Polygons and Location
Legend
River Channel 1955
River Channel 1996
Channel Area 1996
Channel Area 1955
0 25 50 100 Meters
Guadalupe River Basin
Location of Site FC 2
0 35 70 140 Kilometers
N
Figure 16

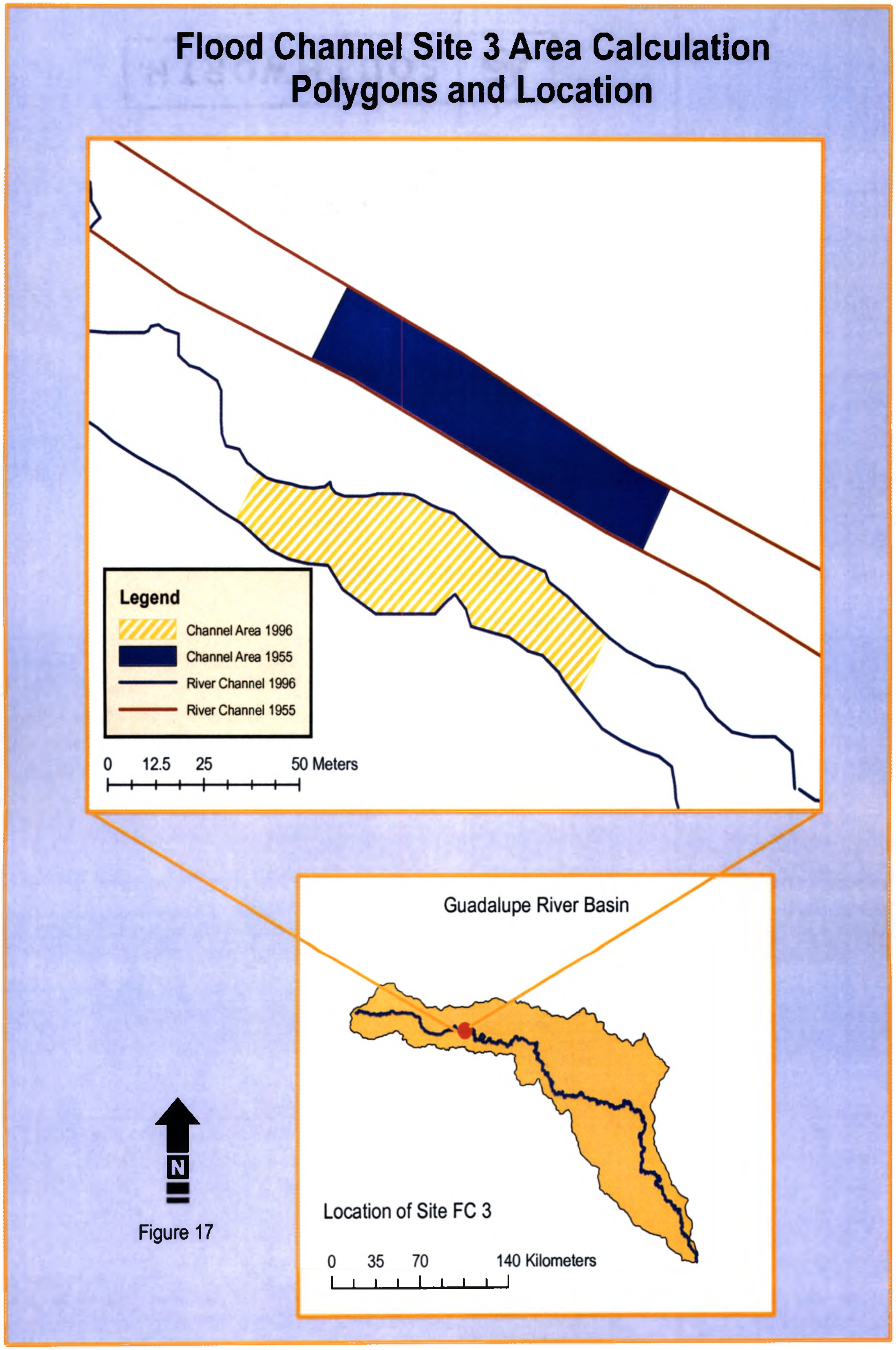

Flood Channel Site 3 Area Calculation
Polygons and Location
Legend
Channel Area 1996
Channel Area 1955
River Channel 1996
River Channel 1955
0 12.5 25 50 Meters
Guadalupe River Basin
Location of Site FC 3
0 35 70 140 Kilometers
N

Figure 17

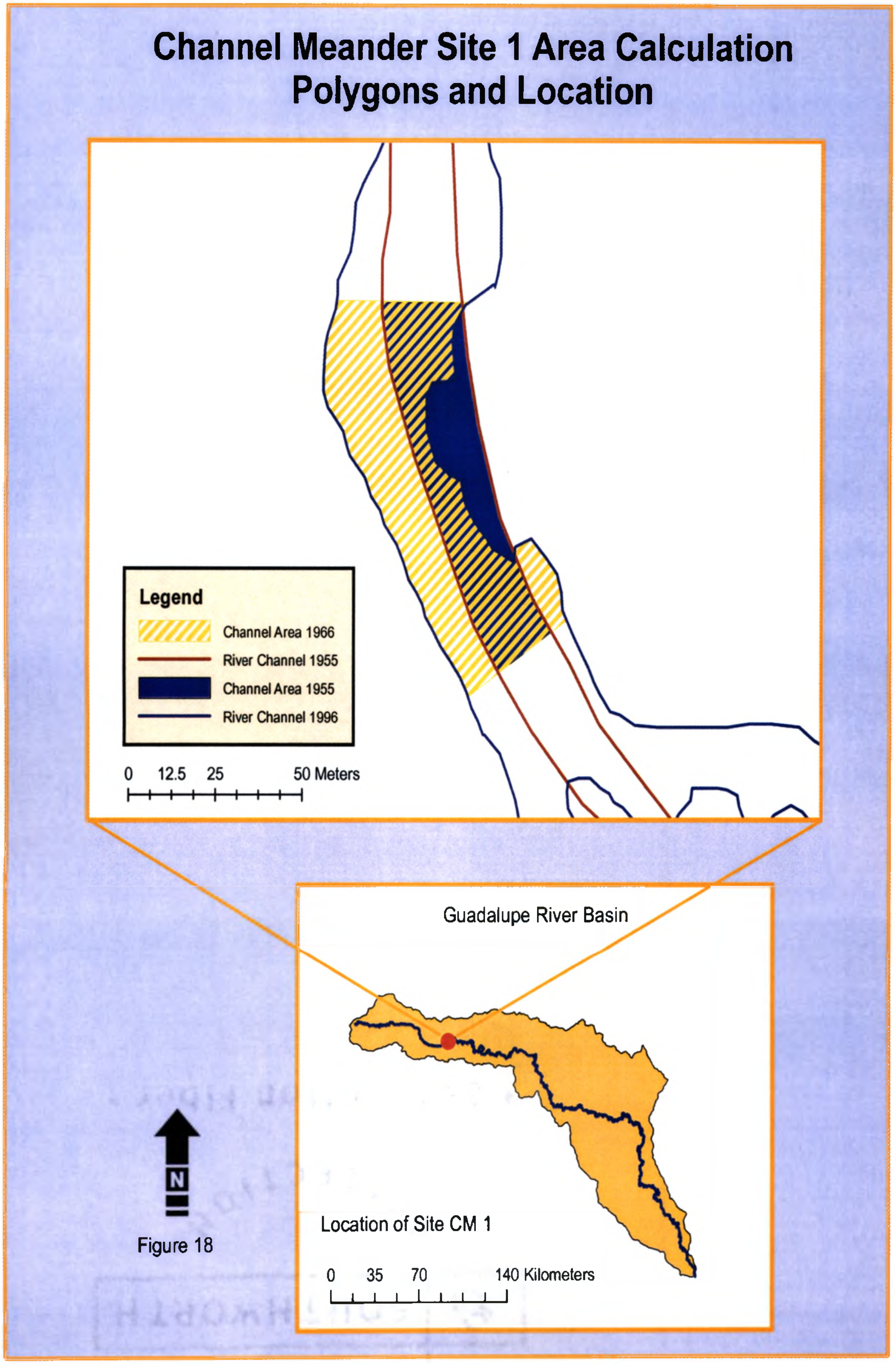

Channel Meander Site 1 Area Calculation Polygons and Location
Legend
Channel Area 1966
River Channel 1955
Channel Area 1955
River Channel 1996
0 12.5 25 50 Meters
Guadalupe River Basin
Location of Site CM 1
0 35 70 140 Kilometers
N

Figure 18

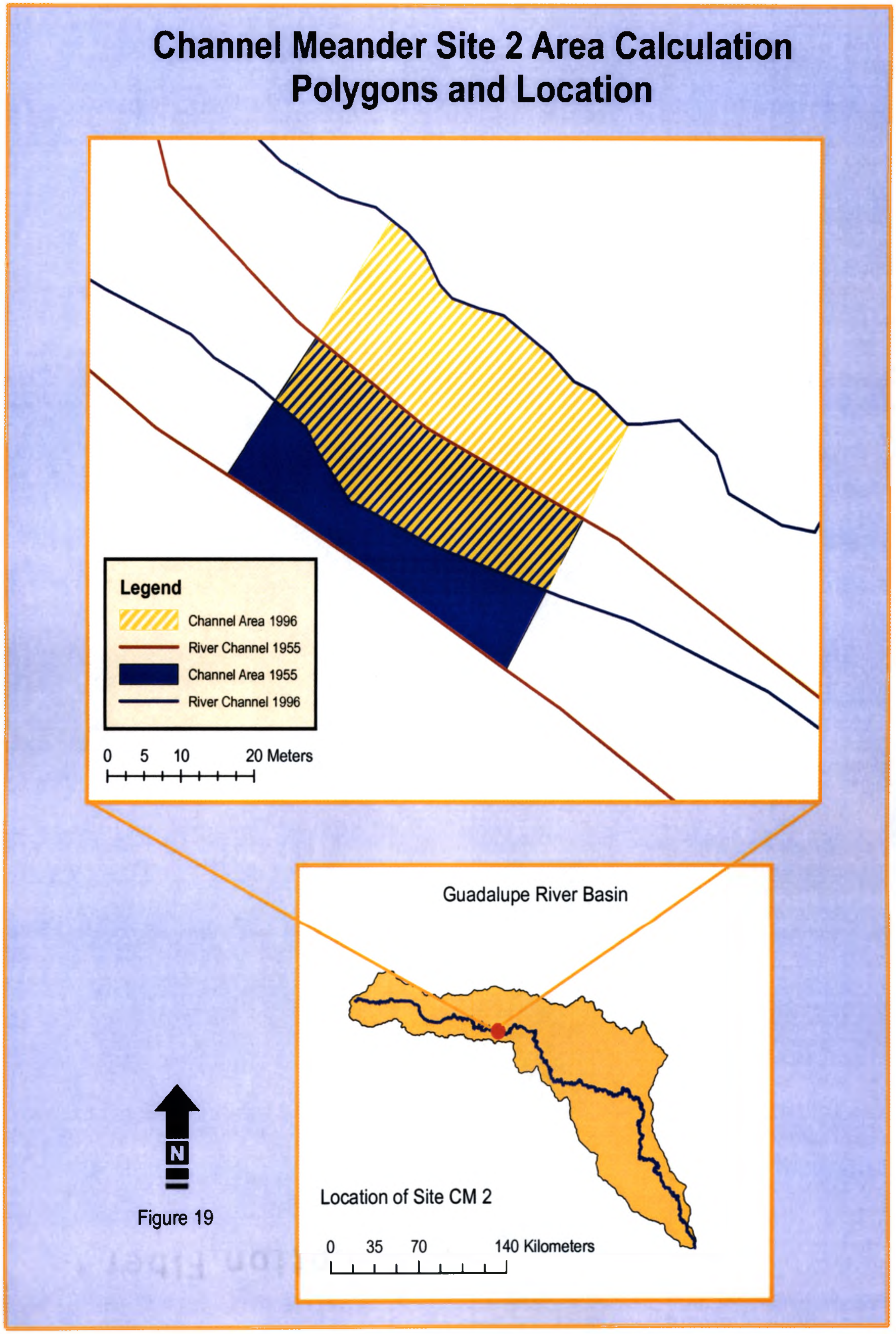
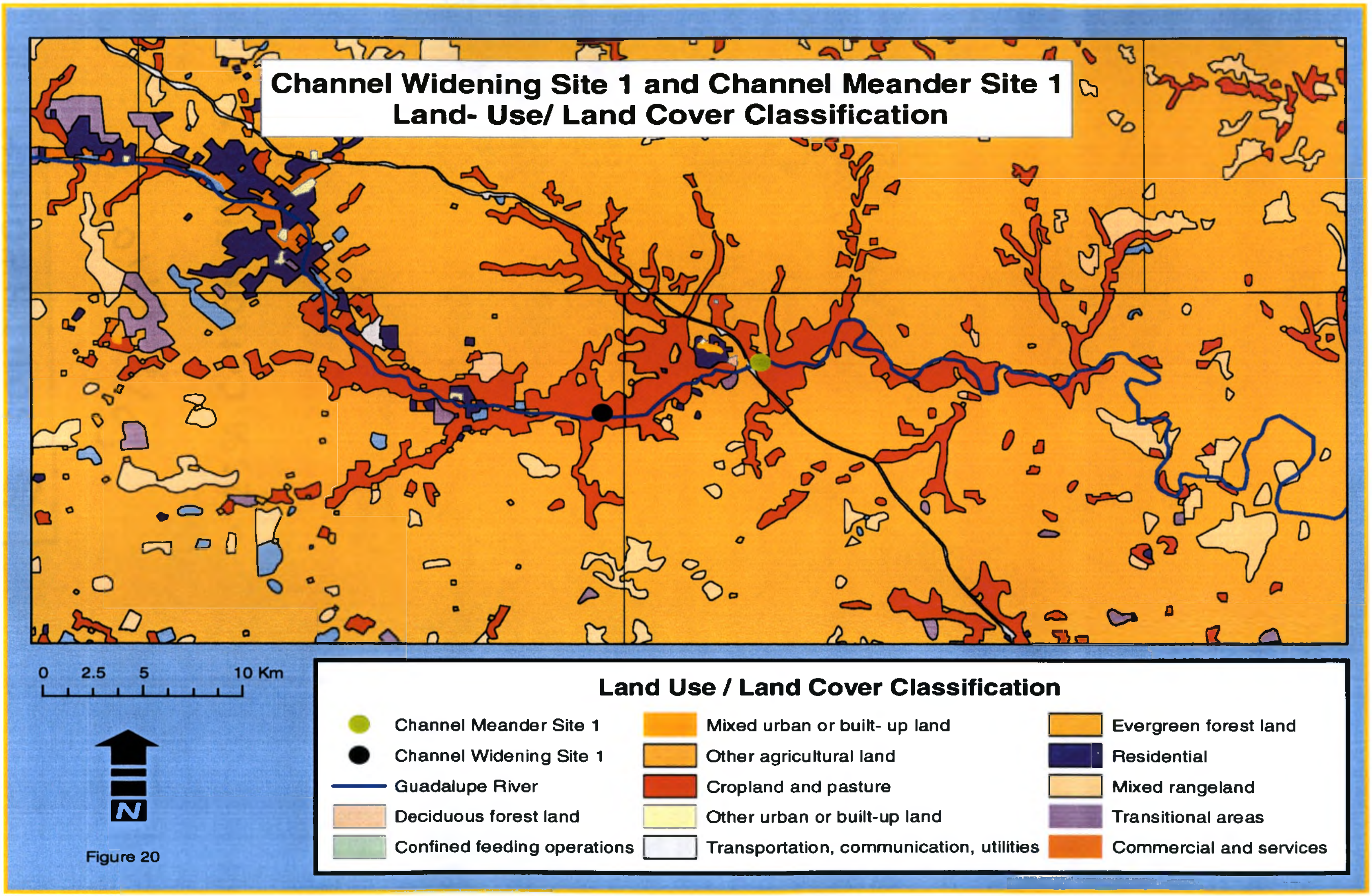

Channel Meander Site 2 Area Calculation
Polygons and Location
Legend
Channel Area 1996
River Channel 1955
Channel Area 1955
River Channel 1996
0 5 10 20 Meters
Guadalupe River Basin
Location of Site CM 2
0 35 70 140 Kilometers
N

Figure 19


Channel Widening Site 1 and Channel Meander Site 1
Land- Use/ Land Cover Classification
0 2.5 5 10 Km
N
Land Use / Land Cover Classification
Channel Meander Site 1
Channel Widening Site 1
Guadalupe River
Deciduous forest land
Confined feeding operations
Mixed urban or built- up land
Other agricultural land
Cropland and pasture
Other urban or built-up land
Transportation, communication, utilities
Evergreen forest land
Residential
Mixed rangeland
Transitional areas
Commercial and services
Figure 20

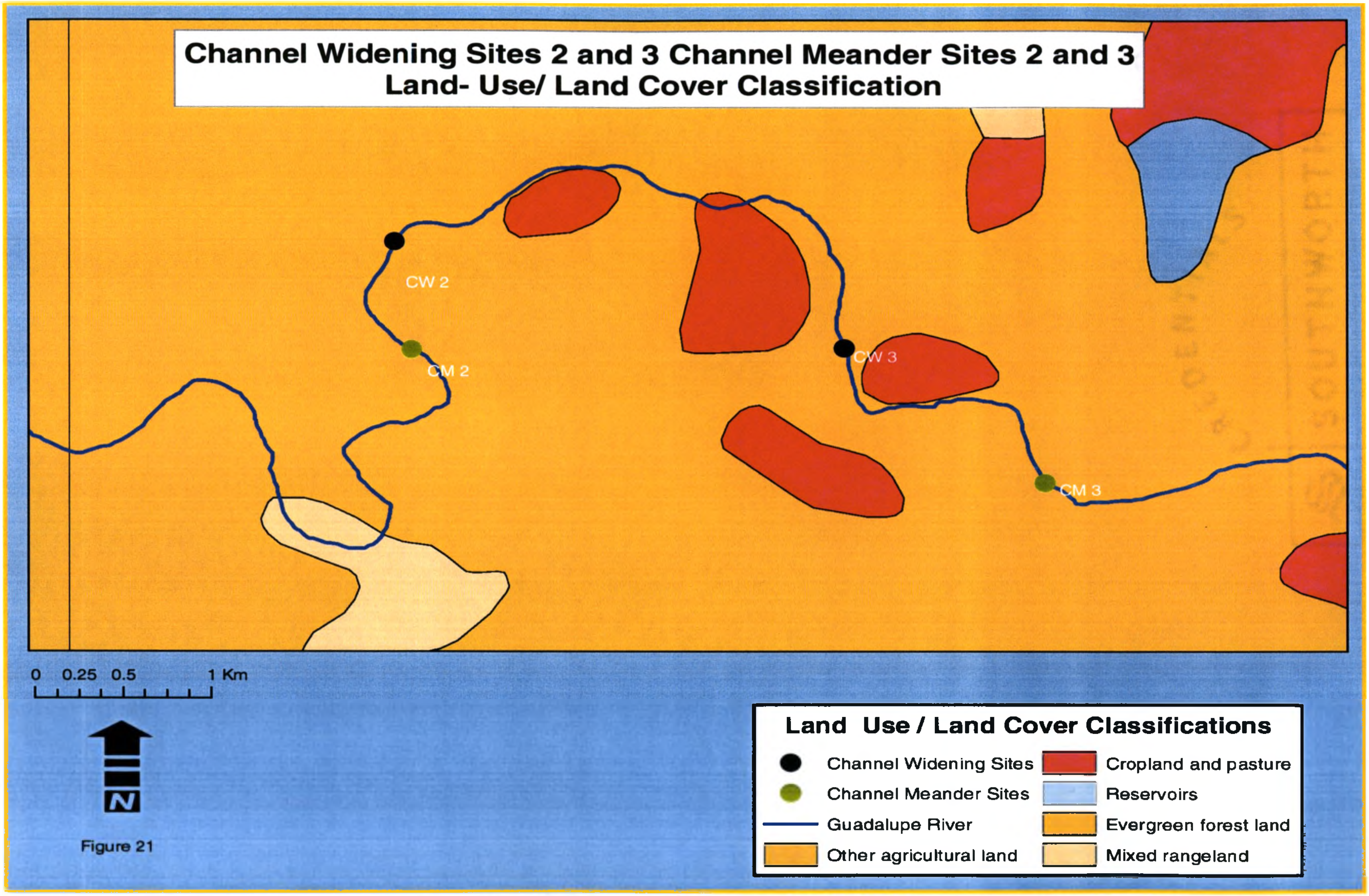
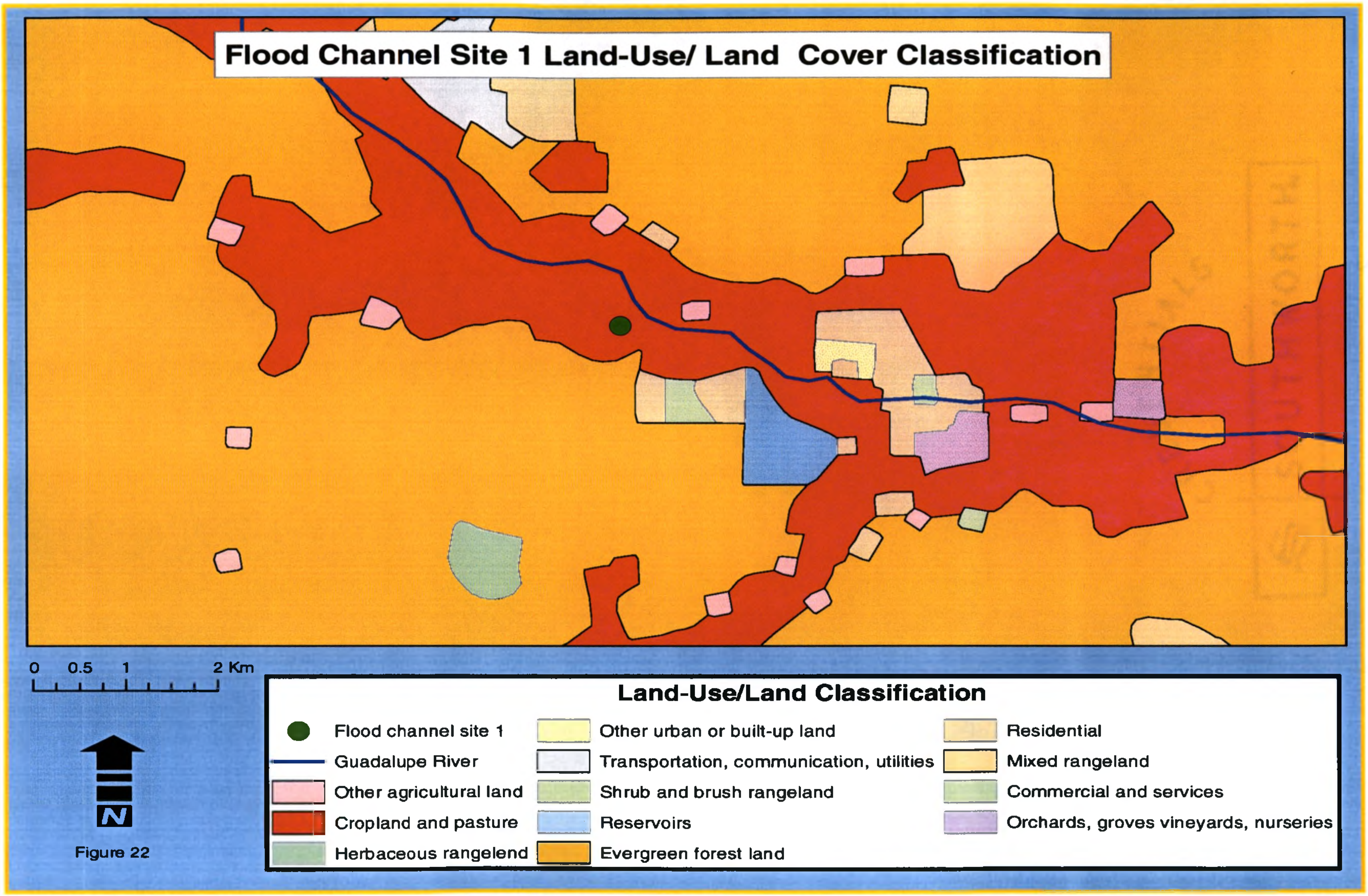

Channel Widening Sites 2 and 3 Channel Meander Sites 2 and 3
Land- Use/ Land Cover Classification
CW 2
CM 2
CW 3
CM 3
0 0.25 0.5 1 Km
N
Land Use / Land Cover Classifications
Channel Widening Sites
Channel Meander Sites
Guadalupe River
Other agricultural land
Cropland and pasture
Reservoirs
Evergreen forest land
Mixed rangeland

Figure 21


Flood Channel Site 1 Land-Use/ Land Cover Classification
0 0.5 1 2 Km
N
Land-Use/Land Classification
Flood channel site 1
Guadalupe River
Other agricultural land
Cropland and pasture
Herbaceous rangelend
Other urban or built-up land
Transportation, communication, utilities
Shrub and brush rangeland
Reservoirs
Evergreen forest land
Residential
Mixed rangeland
Commercial and services
Orchards, groves vineyards, nurseries
Figure 22

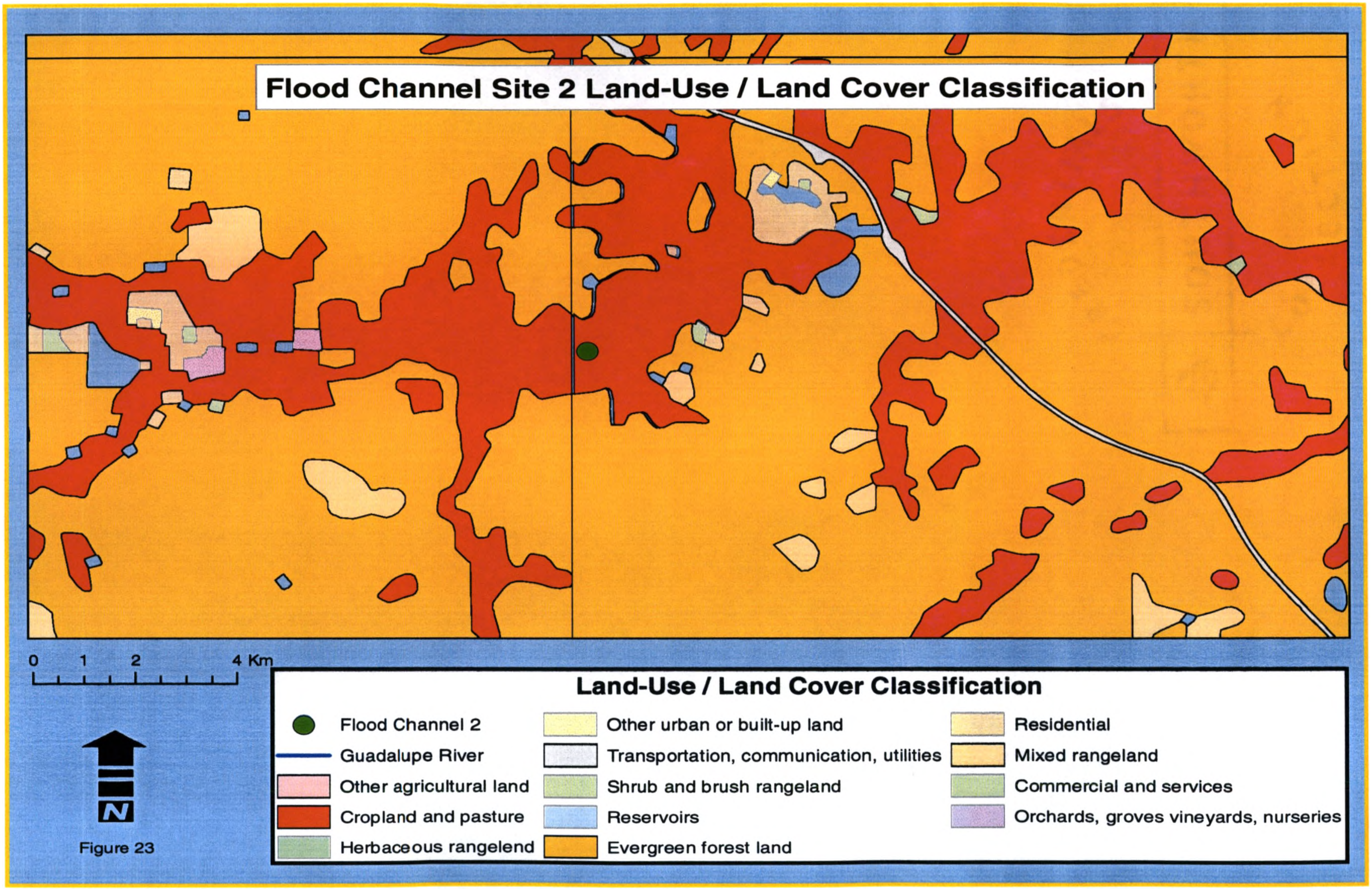

Flood Channel Site 2 Land-Use / Land Cover Classification
0 1 2 4 Km
N
Land-Use / Land Cover Classification
Flood Channel 2
Guadalupe River
Other agricultural land
Cropland and pasture
Herbaceous rangelend
Other urban or built-up land
Transportation, communication, utilities
Shrub and brush rangeland
Reservoirs
Evergreen forest land
Residential
Mixed rangeland
Commercial and services
Orchards, groves vineyards, nurseries

Figure 23

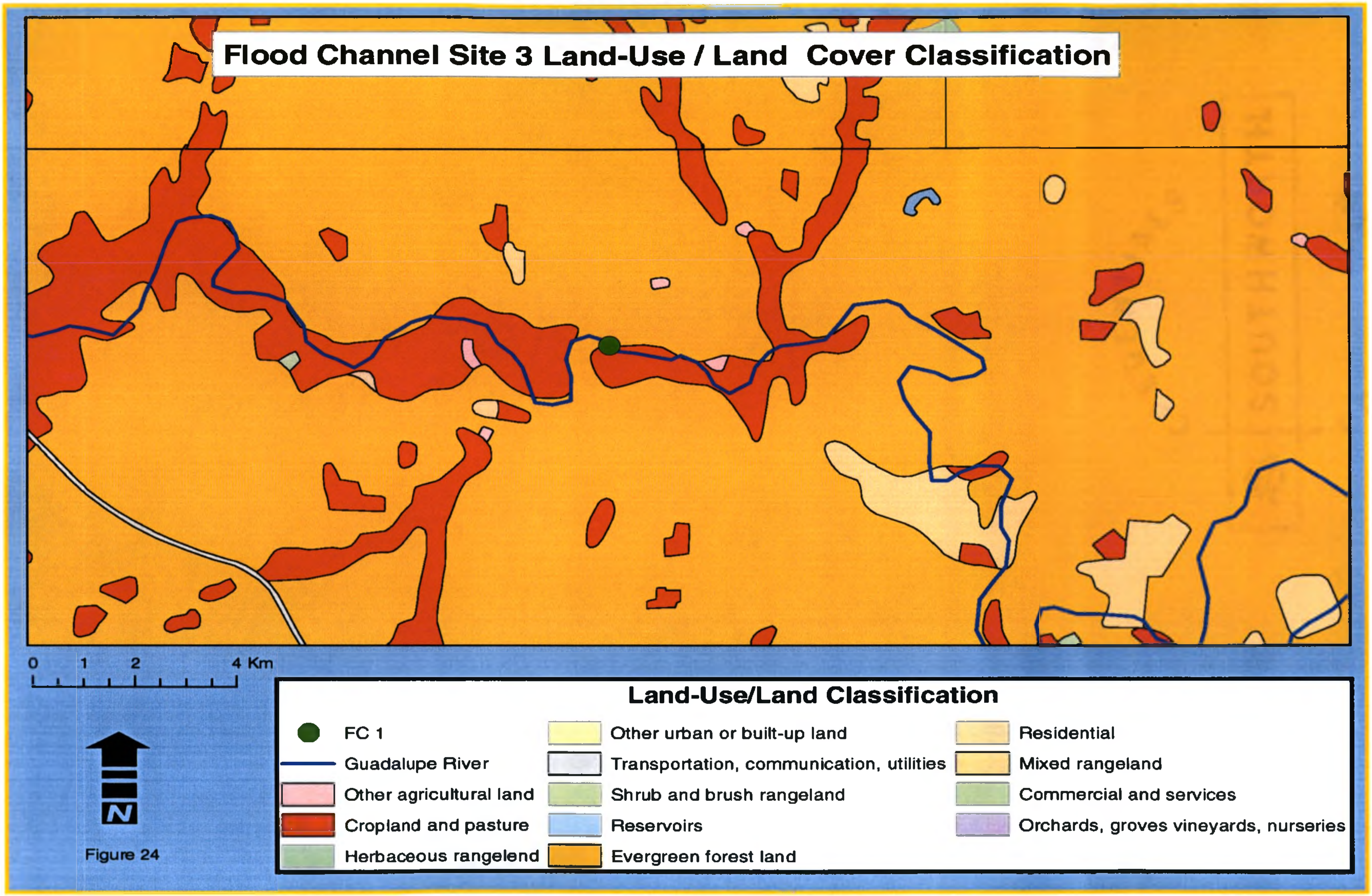
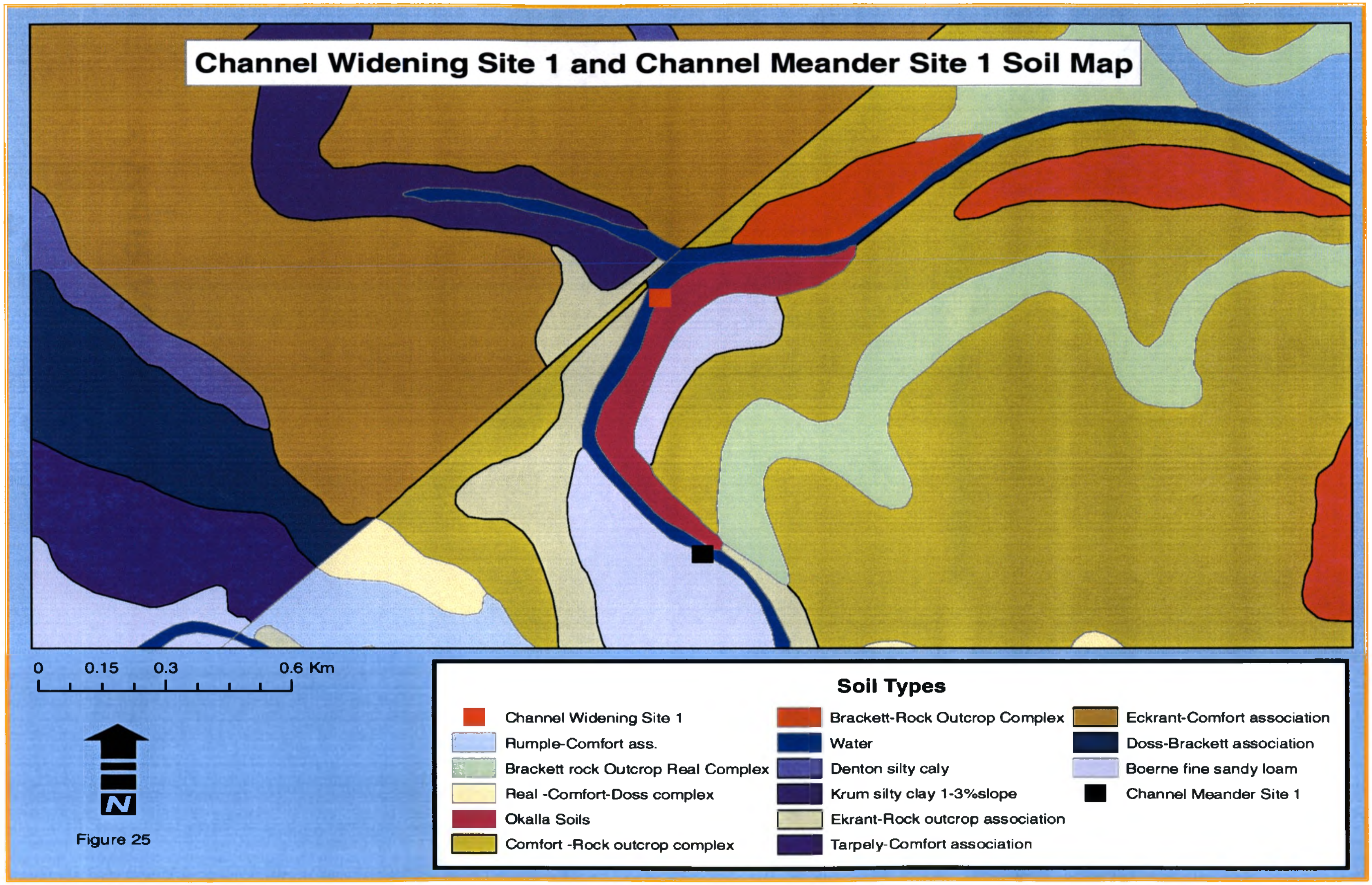

Flood Channel Site 3 Land-Use / Land Cover Classification
0 1 2 4 Km
N
Land-Use/Land Classification
FC 1
Guadalupe River
Other agricultural land
Cropland and pasture
Herbaceous rangelend
Other urban or built-up land
Transportation, communication, utilities
Shrub and brush rangeland
Reservoirs
Evergreen forest land
Residential
Mixed rangeland
Commercial and services
Orchards, groves vineyards, nurseries

Figure 24


Channel Widening Site 1 and Channel Meander Site 1 Soil Map
0 0.15 0.3 0.6 Km
N
Soil Types
Channel Widening Site 1
Rumple-Comfort ass.
Brackett rock Outcrop Real Complex
Real -Comfort-Doss complex
Okalla Soils
Comfort -Rock outcrop complex
Brackett-Rock Outcrop Complex
Water
Denton silty caly
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely-Comfort association
Eckrant-Comfort association
Doss-Brackett association
Boerne fine sandy loam
Channel Meander Site 1
Figure 25

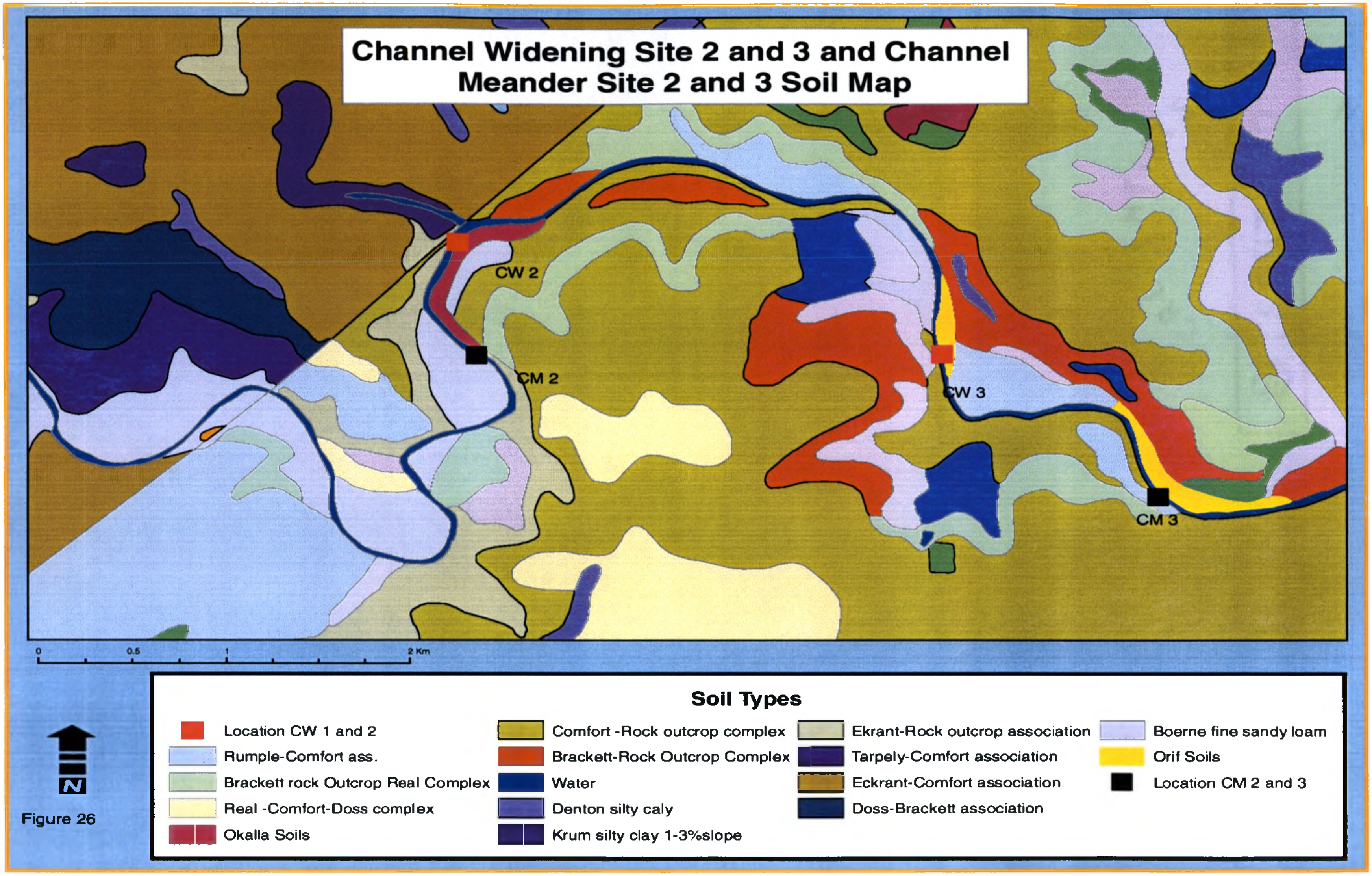
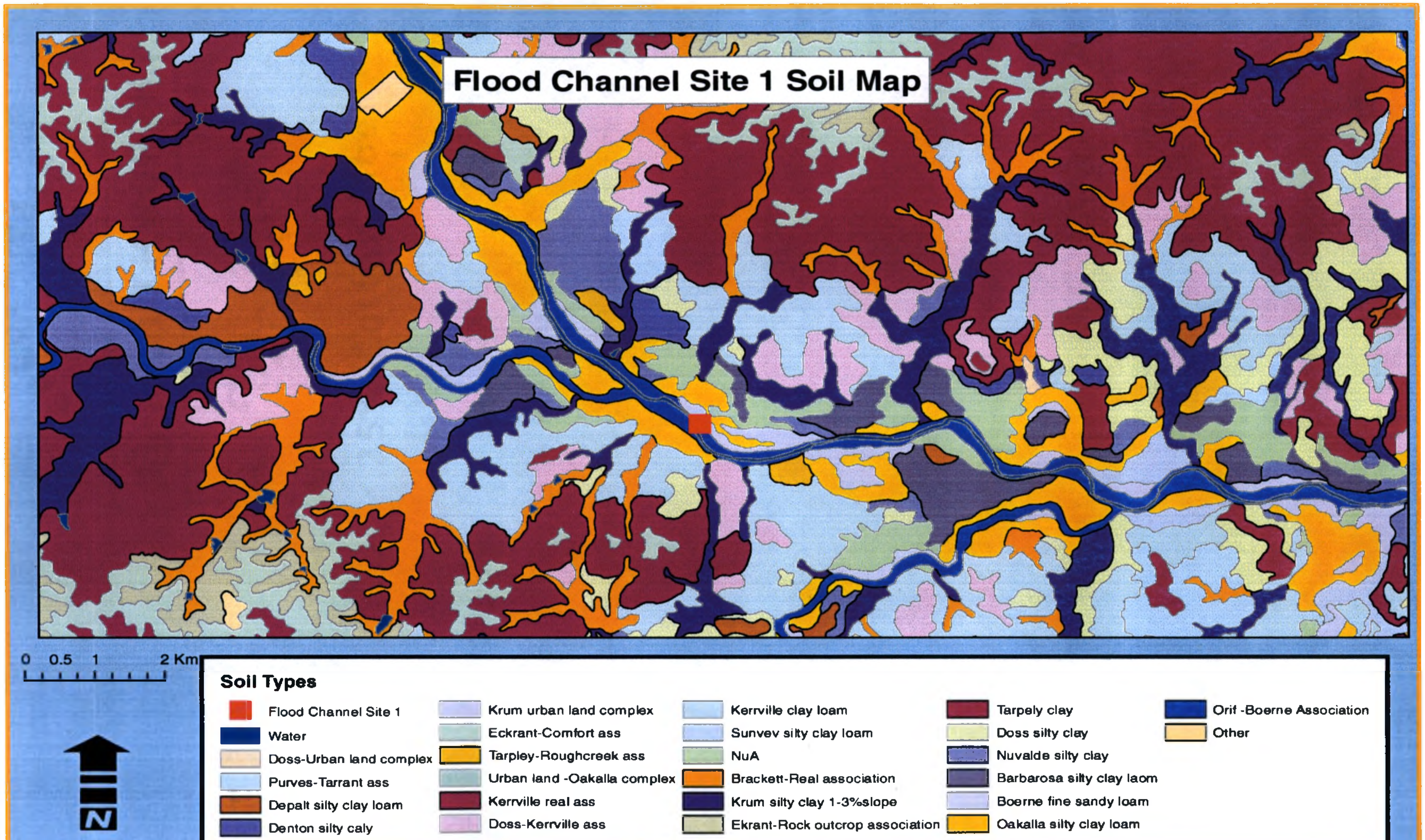

Channel Widening Site 2 and 3 and Channel Meander Site 2 and 3 Soil Map
CW 2
CM 2
CW 3
CM 3
0
0.5
1
2 Km
N
Soil Types
Location CW 1 and 2
Rumple-Comfort ass.
Brackett rock Outcrop Real Complex
Real -Comfort-Doss complex
Okalla Soils
Comfort -Rock outcrop complex
Brackett-Rock Outcrop Complex
Water
Denton silty caly
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely-Comfort association
Eckrant-Comfort association
Doss-Brackett association
Boerne fine sandy loam
Orif Soils
Location CM 2 and 3

Figure 26


Flood Channel Site 1 Soil Map
0 0.5 1 2 Km
N
Soil Types
Flood Channel Site 1
Water
Doss-Urban land complex
Purves-Tarrant ass
Depalt silty clay loam
Denton silty caly
Krum urban land complex
Eckrant-Comfort ass
Tarpley-Roughcreek ass
Urban land -Oakalla complex
Kerrville real ass
Doss-Kerrville ass
Kerrville clay loam
Sunvev silty clay loam
NuA
Brackett-Real association
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely clay
Doss silty clay
Nuvalde silty clay
Barbarosa silty clay laom
Boerne fine sandy loam
Oakalla silty clay loam
Orif -Boerne Association
Other
Figure 27

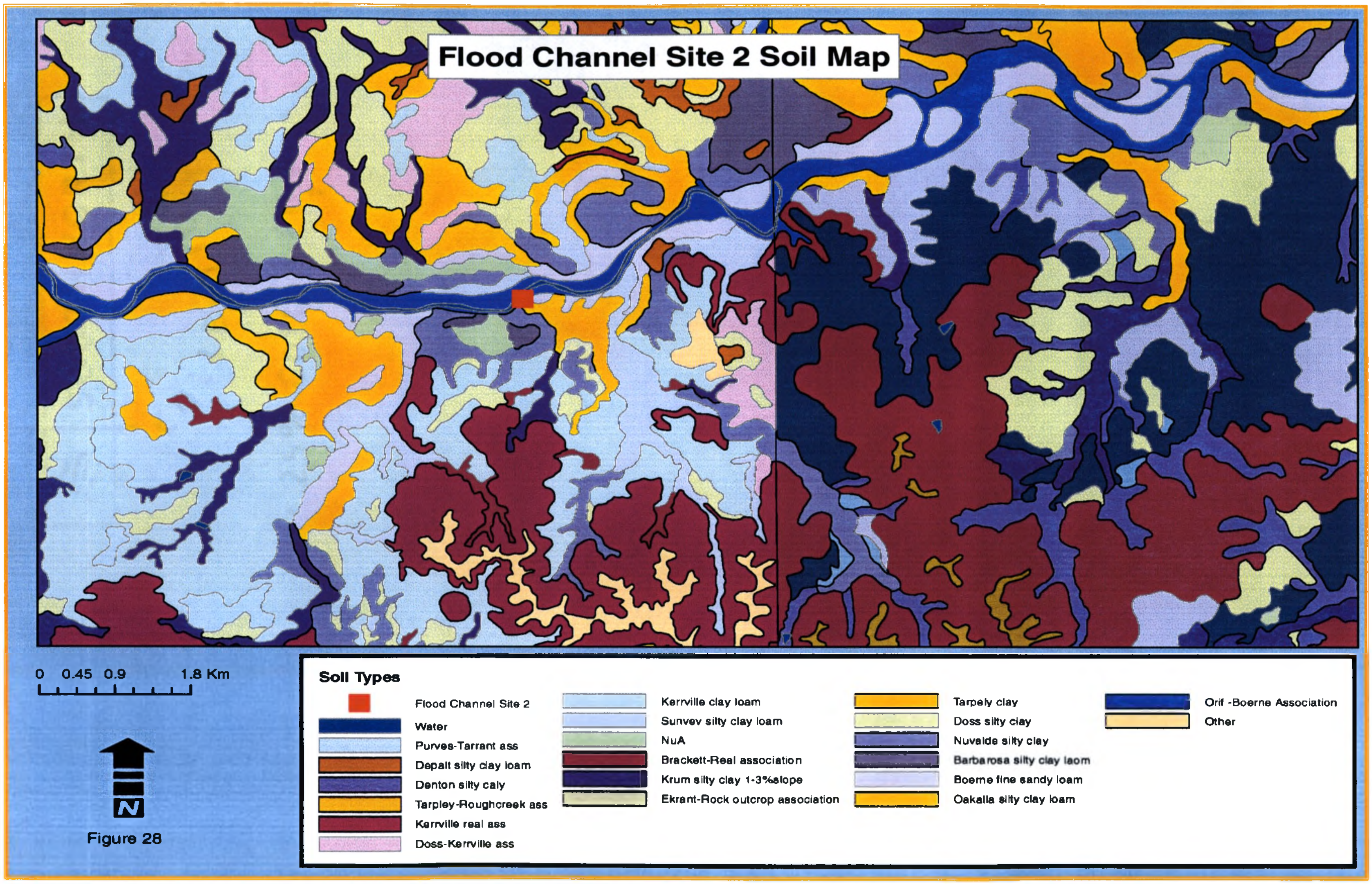
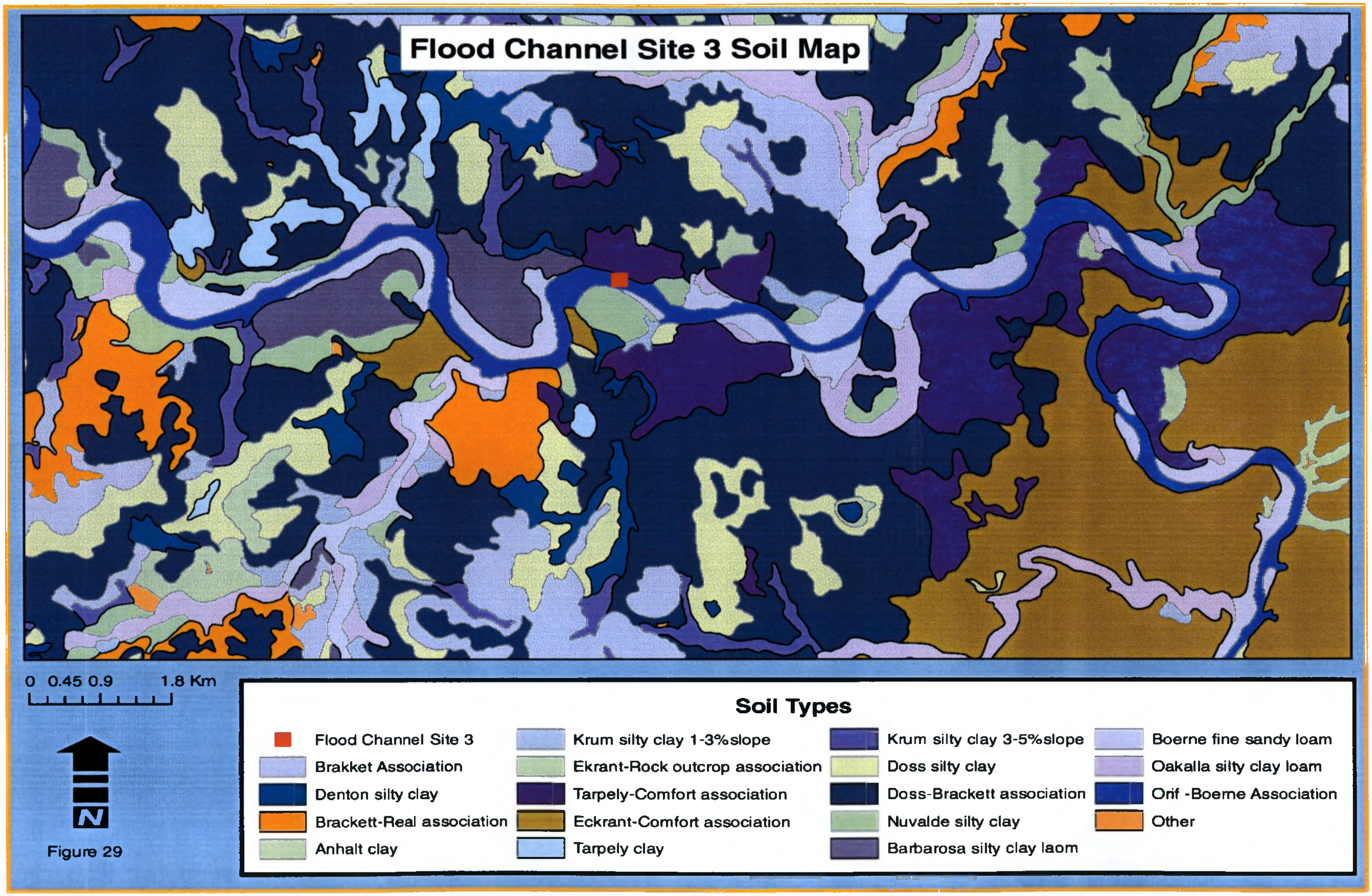

Flood Channel Site 2 Soil Map
0 0.45 0.9 1.8 Km
N
Soil Types
Flood Channel Site 2
Water
Purves-Tarrant ass
Depalt silty clay loam
Denton silty caly
Tarpley-Roughcreek ass
Kerrville real ass
Doss-Kerrville ass
Kerrville clay loam
Sunvev silty clay loam
NuA
Brackett-Real association
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely clay
Doss silty clay
Nuvalde silty clay
Barbarosa silty clay laom
Boerne fine sandy loam
Oakalla silty clay loam
Orif -Boerne Association
Other

Figure 28


Flood Channel Site 3 Soil Map
0 0.45 0.9 1.8 Km
N
Soil Types
Flood Channel Site 3
Brakket Association
Denton silty clay
Brackett-Real association
Anhalt clay
Krum silty clay 1-3%slope
Ekrant-Rock outcrop association
Tarpely-Comfort association
Eckrant-Comfort association
Tarpely clay
Krum silty clay 3-5%slope
Doss silty clay
Doss-Brackett association
Nuvalde silty clay
Barbarosa silty clay laom
Boerne fine sandy loam
Oakalla silty clay loam
Orif -Boerne Association
Other
Figure 29

The amount of change per longitudinal bank meter from 1955 to 1996 was statistically significant at a 99.9 %confidence level. Channel Widening Site 1 has experienced channel narrowing of 4 meters from 1955 to 1996 which was calculated to be significant at a confidence level of 91%. Channel widening site 2 has widened 10 meters per longitudinal bank meter from 1955 to 1996 and Channel widening site 3 has increases in width by 7.03 meters per bank meter. Both of the sites were calculated to be significantly different from the calculated channel change average between 1955 and 1996 with confidence levels of 97% and 96% respectively.

Two of the three flood channel sites were calculated to be significantly different from the average amount of channel change with slightly less confidence than the channel widening sites. Flood channel site 1, which had changed 12.6 meters was calculated to be significantly different from the calculated channel change average between 1955 and 1996 with a confidence level of 93%. Flood channel site 3 has increased in size by 2.3 meters per longitudinal bank meter and was calculated to be significantly different for the calculated channel change average between 1955 and 1996 with a confidence level of 86%. Flood channel 2 which has increased by 9.4 meters per longitudinal bank meter between 1955 and 1996 was calculated to be significantly different with a confidence level of 99%.

Both channel meander site 1 and 2, which had increased in area by 11 and 7.2 meters per longitudinal bank meter respectively, were calculated to be significantly different from the calculated channel change average between 1955 and 1996 with a confidence level of 96%.

The following table is a summary of the characteristics of each of the chosen sample sites

Table 4 Summary of Sample Site Characteristics

Category	Site Number	Land Use / Land Cover	Geology	Soil Type
Channel Widening	CW 1	Cropland and pasture	Fluviatile terrace deposits	Orif-Boerne association
	CW 2	Evergreen forest land	Cow Creek Limestone	Oakalla Soils
	CW 3	Evergreen forest land	Cow Creek Limestone	Orif soils
Flood Channel	FC 1	Cropland and pasture	Fluviatile terrace deposits	Orif-Boerne association
	FC 2	Cropland and pasture	Fluviatile terrace deposits	Orif-Boerne association
	FC 3	Cropland and pasture	Fluviatile terrace deposits	Denton silty clay
Channel Meander	CM 1	Cropland and pasture	Cow Creek Limestone	Orif-Boerne association
	CM 2	Evergreen forest land	Cow Creek Limestone	Boerne fine sandy loam
	CM 3	Evergreen forest land	Cow Creek Limestone	Seawillow clay loam

CHAPTER VI

DISCUSSION

During normal flow conditions the associated low flow velocity will result in marginal but steady erosion processes (Wasson and Wasson 2000). However, the longitudinal survey data and the historical channel distribution in this study recorded levels of channel change and erosional channel features that are far in excess of what would be created by normal flow processes. From the hydrologic record of the river, it is clear that large magnitude flooding is a common occurrence along the Guadalupe. As these extreme flows can result in major rearrangements of sediment, it is reasonable to assume that the observed channel change has been drastically accelerated by flooding events (Wasson and Wasson 2000). The aim of this research is to assess how riparian area LU/LC has accelerated or buffered the bank erosion processes associated with large magnitude flooding.

Isolating the controlling role of riparian vegetation over the stability of a river channel is difficult. Catchments that are, for example, converted from native vegetation to agricultural uses undergo multiple changes over time, including clearing, grazing, cultivation and dam building. All of these land use changes affect channel stability by altering the runoff and sediment transport regimes of the basin (Wasson and Wasson 2000). Therefore, it is not clear if the morphological changes recorded on the river channel after large magnitude flooding events are a result of changes to the catchment wide hydrology and sediment movement, due to an alteration in the riparian environment, or a combination of both (Wasson and Wasson 2000). In the Guadalupe River basin, much of the current land use patterns have been well established for many decades. According to the land use data for the area, the basin is dominated by cropland and pasture in the upper regions and evergreen forest land in the lower region (TNRIS). From historical aerial photography and extensive field observations, however, it is evident that much of the evergreen forest region has been converted for use as pasture. Although urban development of the basin is increasing, the area remains sparsely settled as large tracts of rangeland dominate the landscape. Thus, it is possible that the catchment-wide hydrology and sediment distributions associated with major shifts in land use were incorporated into the system when the land was first converted to rangeland and pasture land, prior to the first aerial photographs of the 1950's. Channel change since the 1950's can be attributed mainly to changes to the near-channel portion of the river rather than to alterations in basin wide hydrological and sediment movement.

Channel Widening

Channel widening sites were the most common erosional features recorded during the longitudinal survey. Channel widening occurs due to a number of factors, including changes in channel depth, roughness, bed material composition, channel planform and riparian vegetation. This research has focused on alterations in riparian vegetation. Land use change and cattle grazing have been identified as the primary factors through which riparian vegetation can be modified or lost. River channels tend to enlarge when riparian vegetation is lost. This loss of vegetation reduces cohesiveness along the river bank. During increased flows, extensive erosion occurs as the resistance of the bare soil is lower than the erosive power of water (Wasson and Wasson 2000). As a result, bank material is entrained and channel widening occurs.

Channel Widening Site 1 (Figures 30 and 31)

Channel widening site 1 occurs just downstream of the entry of Cherry Creek into the main river channel. The land use surrounding the site is cropland and pasture. The geology of the area consists of fluviatile deposits, and Orif-Boerne soils are dominant. It is clear from the historical images that channel widening has been an ongoing process in this area since the 1950's. During periods of increased flow, the increased fluvial force exerted on the bank of the Guadalupe by Cherry Creek have resulted in channel widening. This process has likely been enhanced by the reduction of riparian vegetation that can be seen from the historical aerial photograph study.

Channel Widening Site 2 (Figures 32 and 33)

This site consists of Oakalla soils and Cow Creek Limestone geology. Surrounding land use is evergreen forest. In 1955 a thick stand of riparian vegetation with large trees lining the channel is visible on both banks of the river, measuring 55 meters wide at its largest extent. Since 1996, the riparian zone has drastically thinned on both sides of the river. Many of the large trees have been removed and only one large tree remains. This site is located at the upstream part of a slight turn in the river. Flow entering the turn will increase hydraulic pressure on the area. The remaining large tree acts as a barrier to erosion, but due to the lack of further trees, creates a localized eddy in which bank erosion has been enhanced.

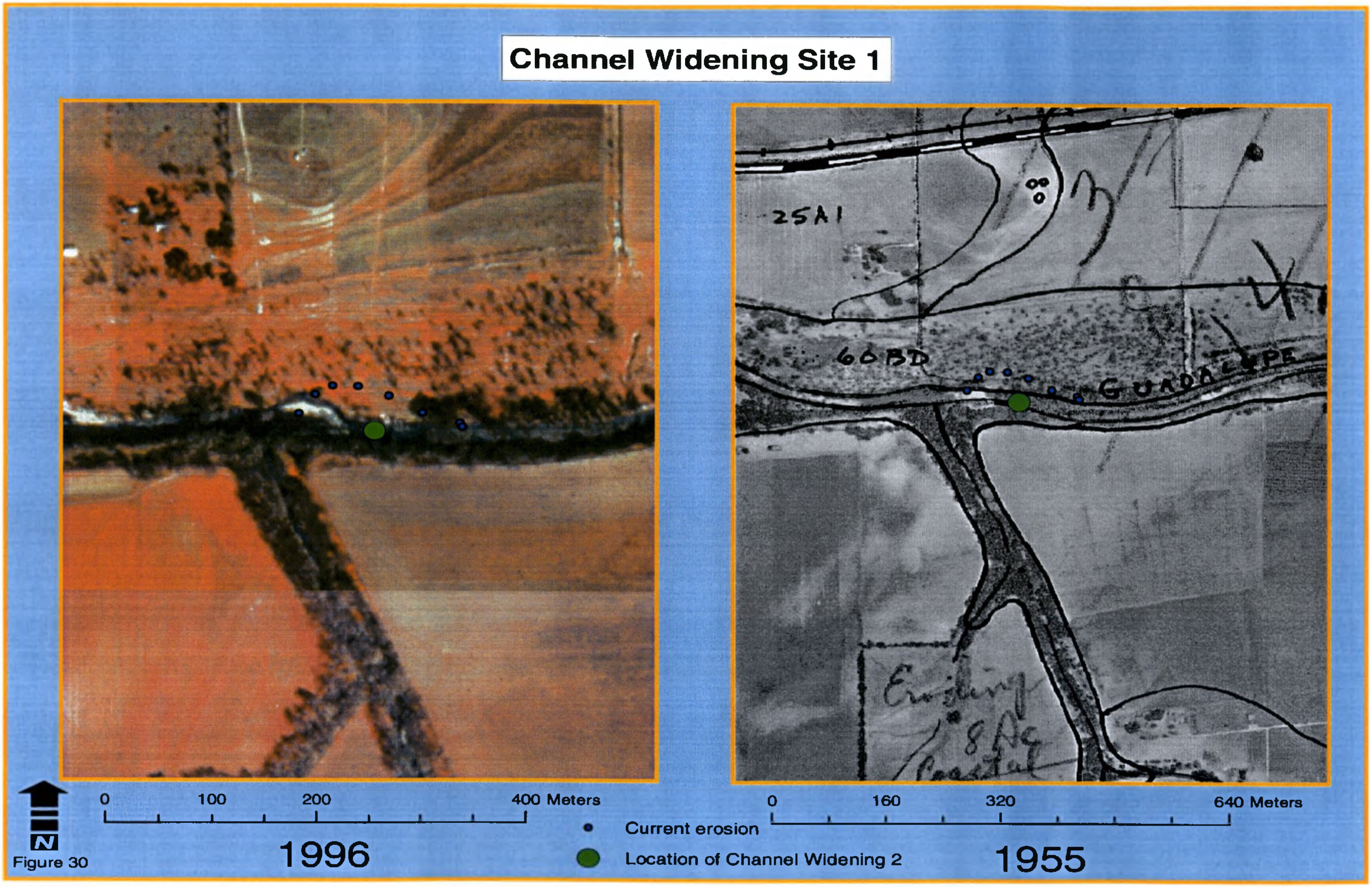
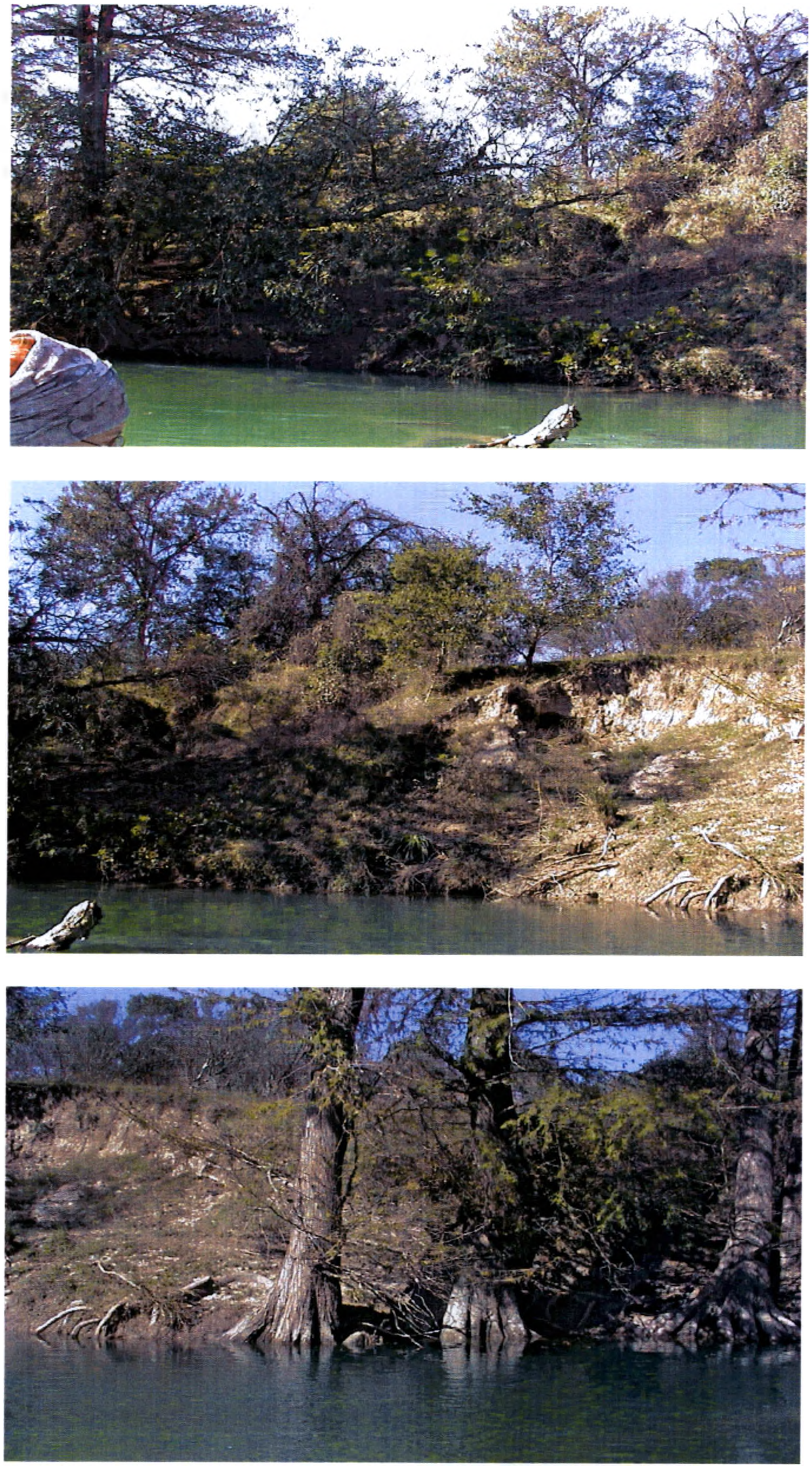

Channel Widening Site 1
25A1
60BD
GUADALUPE
0 100 200 400 Meters
1996
Current erosion
Location of Channel Widening 2
0 160 320 640 Meters
1955

Figure 30

Figure 31 Channel Widening Site1


Channel Widening Site 2
0
235
470
940 Meters
1996
Current erosion
Location of Channel Widening 2
0
195
390
780 Meters
1955
N
Figure 32

Figure 33 Channel Widening Site 2



Channel Widening Site 3 (Figures 34 and 35)

The characteristics of site 3 are the same as at site 2 with the exception that Oakalla soils have been replaced by Orif soils. At this site, the riparian vegetation was 50 meters wide in 1955. It is reduced to 40 meters wide in 1989 and 33 meters wide in 1996. The riparian vegetation has been reduced, and as a result, channel widening processes have been enhanced.

Flood Channels

As flooding occurs, the river overtops its banks and spills over into the floodplain. On the floodplain, energy is dissipated as the power of flow diminishes and the distance from the river channel increases. However, on the Guadalupe, some of the flooding is so severe that the flow maintains its energy after it exceeded bankfull stage. The erosive and depositional energy are dispersed as the flood water chooses the path of least resistance. As the flood waters recede, large erosion scars often become visible. These scars occur relatively far away from the stream channel that is utilized during normal flow conditions. These erosion patterns, although destructive, serve as useful reminders of the potential of the river and as indicators of future channel movements.

The condition and extent of the riparian zone have important roles to play in controlling the frequency and severity of erosion that occurs during high flow events. The roughness of the riparian zone functions in this instance to absorb the extra flow energy created during flood conditions. The flood events do not cause a permanent change in the river's course, and the river reverts to its normal channel as the flow recedes. A stand of closely growing vegetation will diffuse more energy and introduce more cohesion to the river bank than a poor stand of riparian vegetation. The presence of a dense stand of

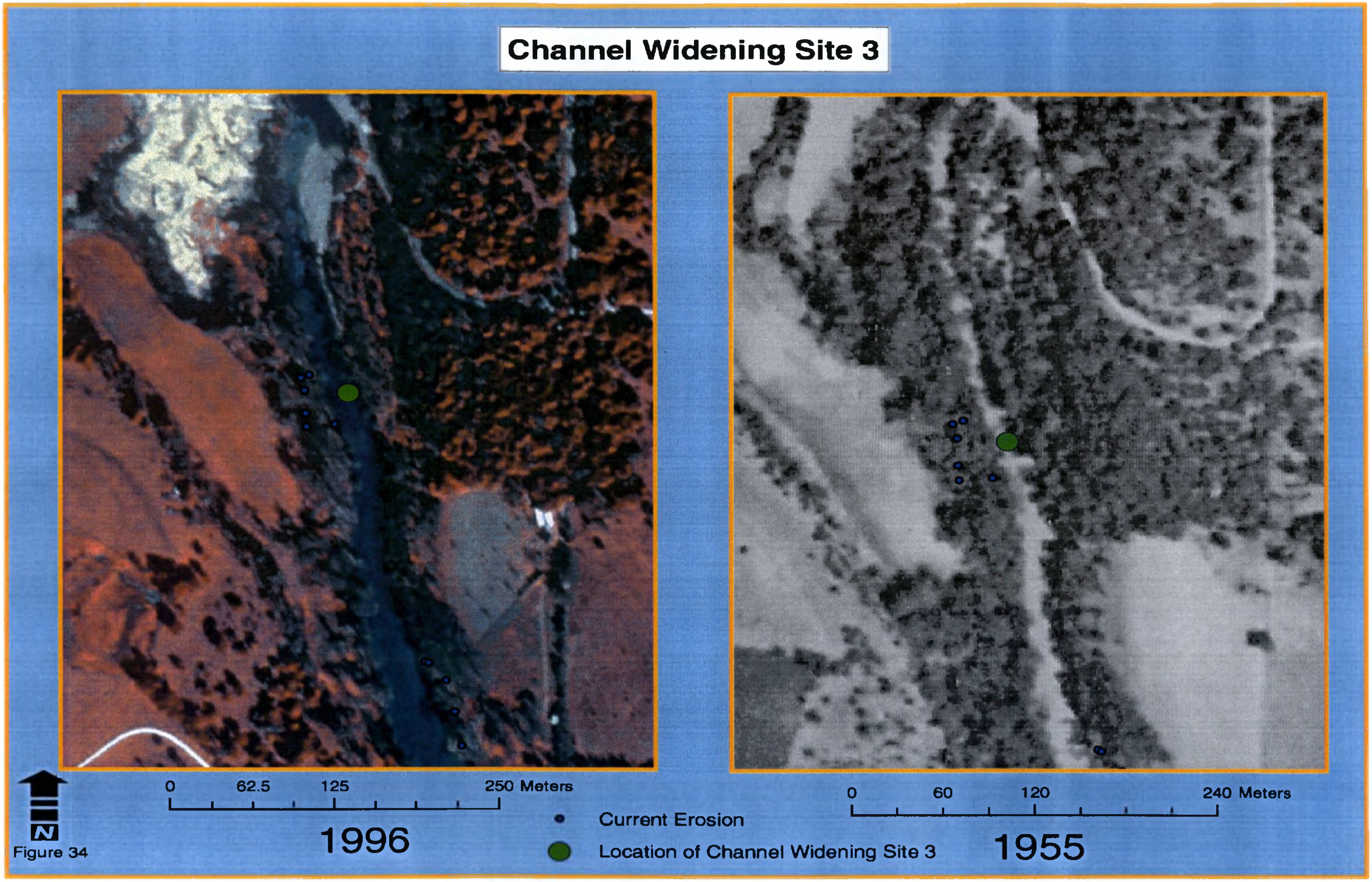
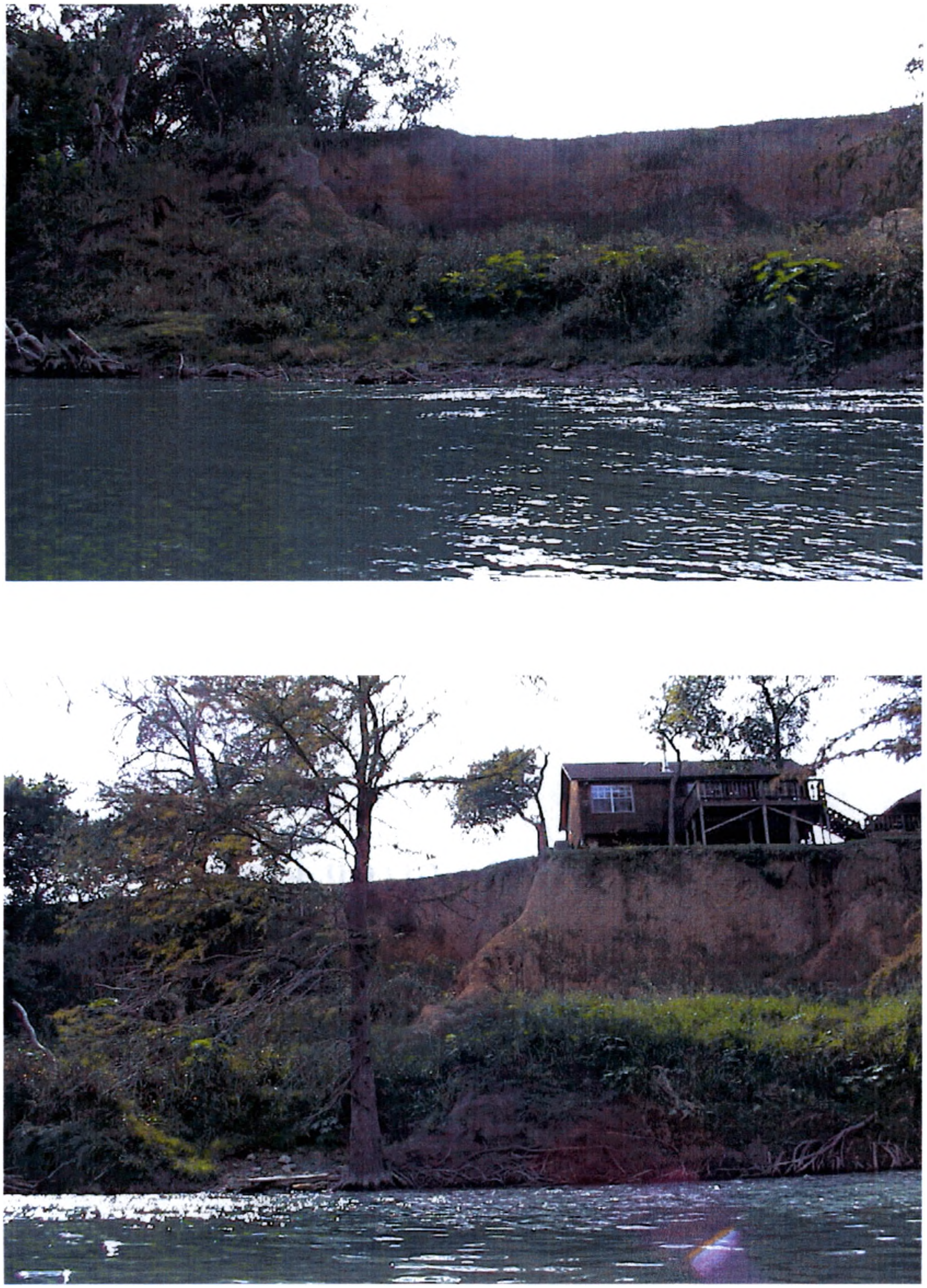

Channel Widening Site 3
0
62.5
125
250 Meters
1996
0
60
120
240 Meters
1955
Current Erosion
Location of Channel Widening Site 3
N
Figure 34

Figure 35 Channel Widening Site 3



riparian vegetation can therefore act as a buffer against the erosive forces of overbank flood flow.

All of the flood channel sites discussed below have geology of fluviatile terrace deposits surrounded by cropland pasture and with predominately Orif- Boerne soils.

Flood Channel Site 1 (Figures 36 and 37)

This site is a good illustration of the process that is outlined above. It is clear that as the river exceeds bankfull stage a new channel is formed to carry and dissipate the increased flow energy. In this example the river has straightened its course. Under normal conditions the river would flow through a series of bends, but as the increased water volume fills the channel, the flow travels straight across and over the river bends.

This site has emerged as significant due to the large distance of the observed erosion feature from the channel during normal flow conditions. On the 1955 images there is scattered vegetation in the area that has been eroded by flood flows by 1996. On the 1996 image the scouring action of the increased flood flow on the river bank is evident.

Flood Channel Site 2 (Figures 38 and 39)

At this site the increased flow of a flood event has gone past bank fullheight and established a new floodplain. Large lines of erosion are visible on either side of the channel. On the 1955 aerial photographs agricultural activities in close proximity to the channel are observed and only a small riparian area is visible. The 1996 images illustrate how the riparian vegetation has been thinned further. Large amounts of land have been lost as the area has become dominated by depositional bars both above and below the erosion sites.

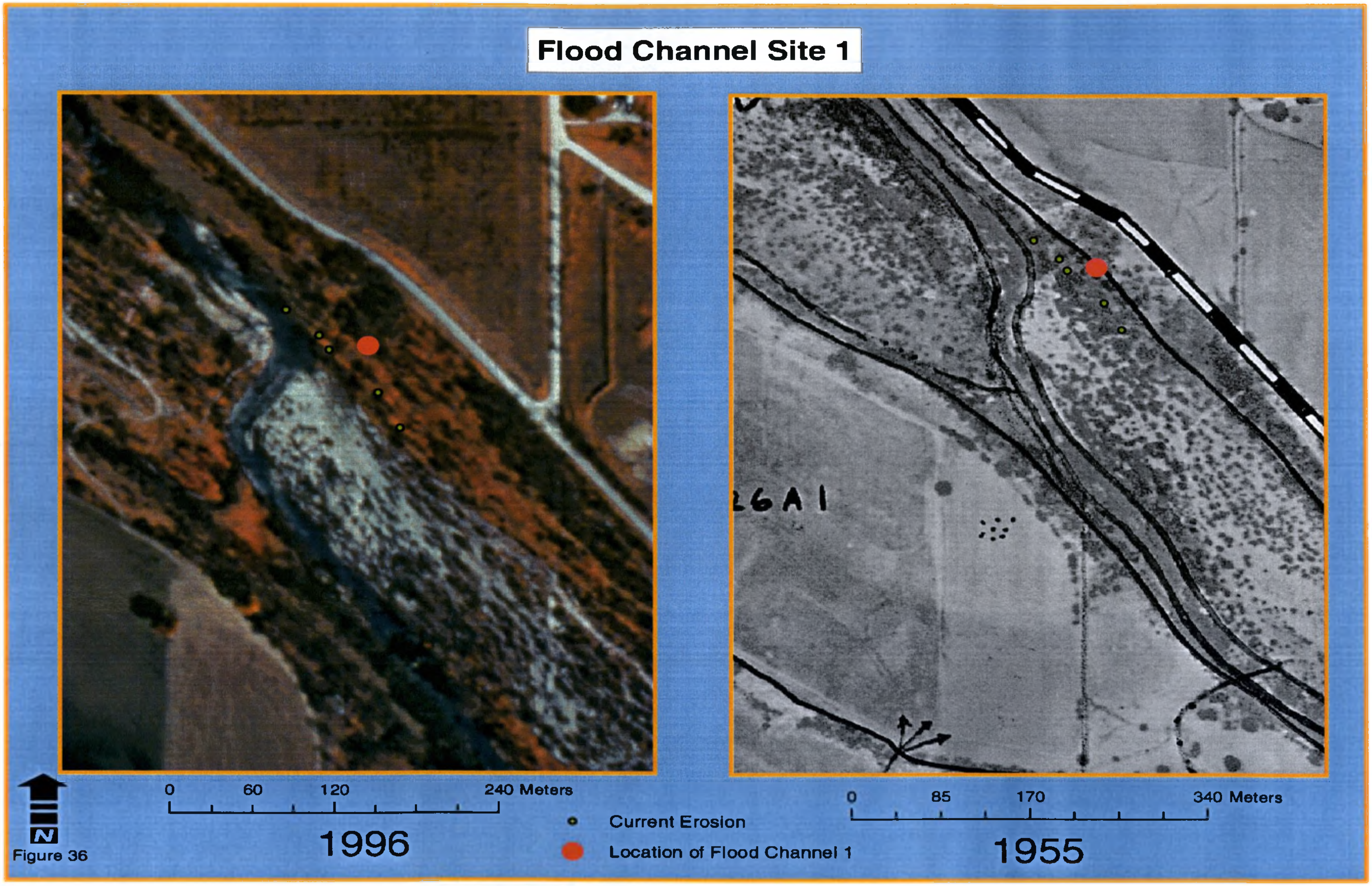
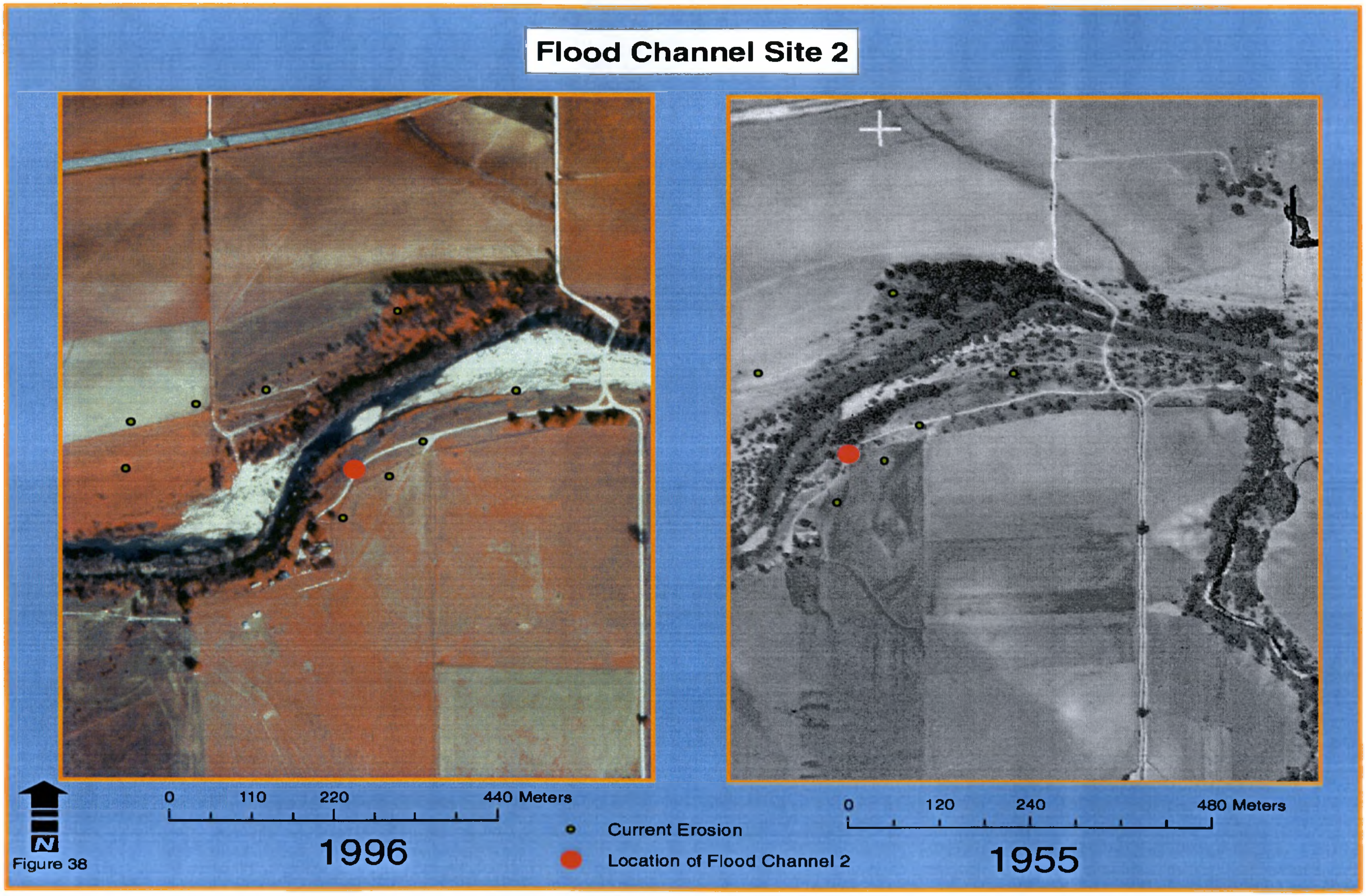

Flood Channel Site 1
N
0
60
120
240 Meters
1996
Current Erosion
Location of Flood Channel 1
0
85
170
340 Meters
1955

Figure 36

Figure 37 Flood Channel 1



Flood Channel Site 2
0 110 220 440 Meters
1996
Current Erosion
Location of Flood Channel 2
0 120 240 480 Meters
1955
N
Figure 38

Figure 39 Flood Channel 2

Flood Channel Site 3 (Figures 40 and 41)

This site is another example of the results of flows beyond bankfull flow. There is evidence of riparian vegetation thinning but unfortunately the 1955 aerial photograph has been marked on, making interpretation of the site difficult.

Meandering Channels

As the river channel enters Kendall County, large channel meanders become prevalent. These meandering processes occur due to processes of alternating deposition and erosion. Most straight river channels will eventually erode into meandering channels. Erosion occurs on the outer bank of a developing channel meander due to the increased flow velocity found on the outside of the bend. The increased velocity provides energy for erosion and entrainment of bank material. On the inside of the bends, deposition of suspended sediments occurs to form point bars due to localized lower flow velocity. As a result the river channel tends to form a pattern of meander migration across the floodplain. The three sites discussed below were recorded as displaying the largest channel change of the sample sites due to channel meandering processes. At these sites, Cow Creek Limestone continues to dominate the near in-channel geology.

Channel Meander Site 1 (Figures 42 and 43)

At its smallest in 1955, the riparian vegetation band was 26 meters wide. It was further reduced to 11 meters in 1996. Deposition of a sediment bar on the inside of the channel indicates on-going meandering processes. An associated increase in velocity on the outside of the bend combines with reduction in riparian vegetation to cause visible amounts of channel change. The reduction in vegetation in combination with the increased velocity on the outside of the bend have resulted in the channel change that is

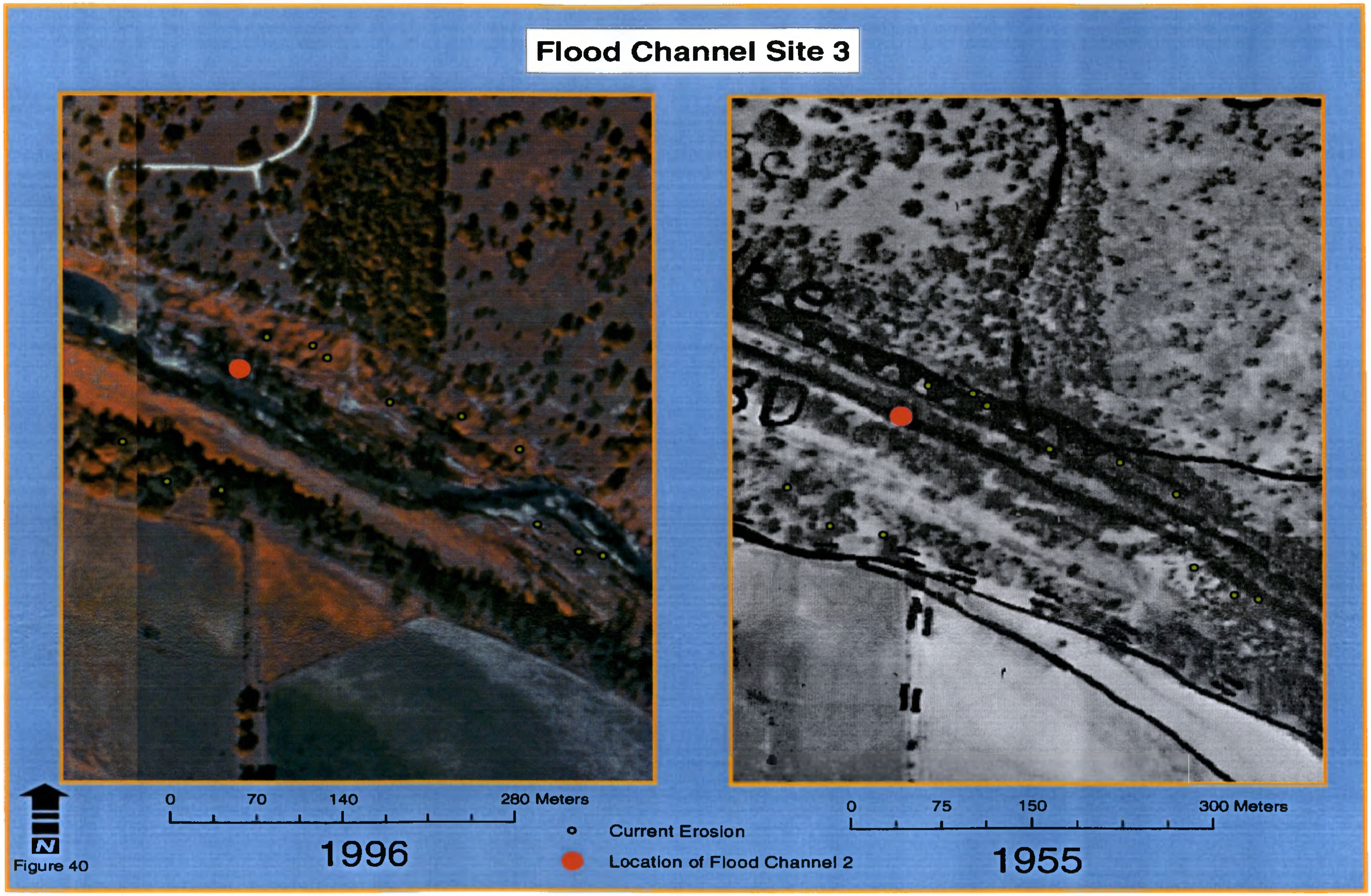

Flood Channel Site 3
0 70 140 280 Meters
1996
Current Erosion
Location of Flood Channel 2
0 75 150 300 Meters
1955
N
Figure 40

Figure 41 Flood Channel 3

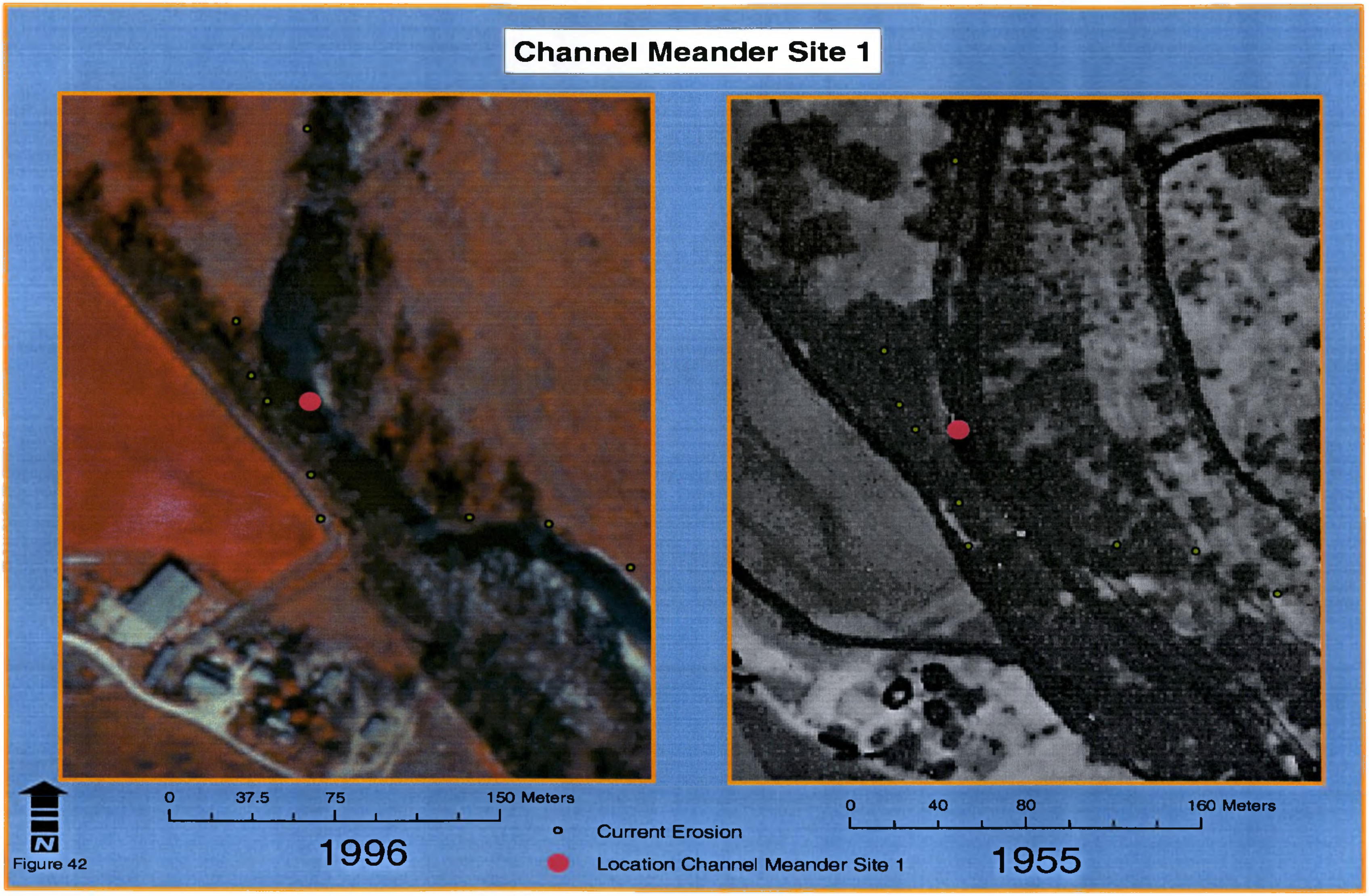

Channel Meander Site 1
0
37.5
75
150 Meters
1996
Current Erosion
Location Channel Meander Site 1
0
40
80
160 Meters
1955
N
Figure 42

Figure 43 Channel Meander 1

evident. More generally one can see a development in the area near the affected portion of river.

Channel Meander Site 2 (Figures 44 and 45)

This site represents a relatively untouched area, which in 1955 had a riparian zone approximately 135 meters in diameter at its largest point. The width of the riparian area had been reduced to approximately 32 meters in 1996. This illustrates a distinct reduction in the size and thinning of the riparian zone vegetation. The increased velocity on the outside of the bend combines with the reduced riparian vegetation cover to increase erosion rates beyond what they would be if the vegetation was still thick.

Channel Meander Site 3 (Figures 46 and 47)

This site occurs on the outside of a riverbend. A well developed riparian area is evident throughout the period of study as channel meander processes are taking place.

The Effect of Grazing on Vegetation and Subsequent Influences on Bank Stability

It is clear from these study sites that the removal or thinning of riparian vegetation is taking place. An important factor to consider in this context is the role of cattle in this process. It is possible that the expansion of cattle grazing into riparian areas maybe a form of land use change that is occurring in the study area. If this is the case, there are a number of ways in which cattle can impact riparian vegetation and bank stability.

Compaction resulting from the movement of cattle can reduce the availability of water and air to the roots of plants (Trimble and Mendel 1995). This can impact plant vitality and density. Over time the bank vegetation will thin or completely die off. The further removal of phytomass by grazing can also reduce plant fertility and soil organic content, decreasing soil aggregate stability (Thurow et al. 1986).As a result, the riparian zone's resistance to erosive flow is reduced and altered channel forms can result (Beschta and Platts 1986; Magilligan and McDowell 1997).

The movement of cattle on the upland slopes, as evident in the study area, can result in soil compaction (Trimble and Mendel 1995). Soil compaction causes a reduction in infiltration capacity which can transform the runoff regime from variable source to unsaturated overland flow (Trimble and Mendel 1995). Riverine and riparian erosion can therefore be increased by this enhanced runoff regime.

While entering and leaving the riparian areas the powerful force of hooves tramping the ground can tear off slices of bank material. Grass covered fine textured banks are particularly vulnerable to trampling as the ease of entry and exit points can often result in uniformly reduced banks (Trimble and Mendel 1995). Higher or wooded riverbanks offer the cows fewer locations to enter or exit the stream, as a result the force applied by the scrambling hooves is concentrated, which creates trough-shaped routes termed cow ramps (Trimble and Mendel 1995). The reduced hydraulic roughness in these areas accelerates bank erosion (Trimble and Mendel 1995).

The movement of cows on top of the riverbank may also break off small chunks of the bank which either fall into the river or are left hanging for the next high flow to entrain. Bank slumping can also be enhanced by cows grazing these high banks (Trimble and Mendel 1995).

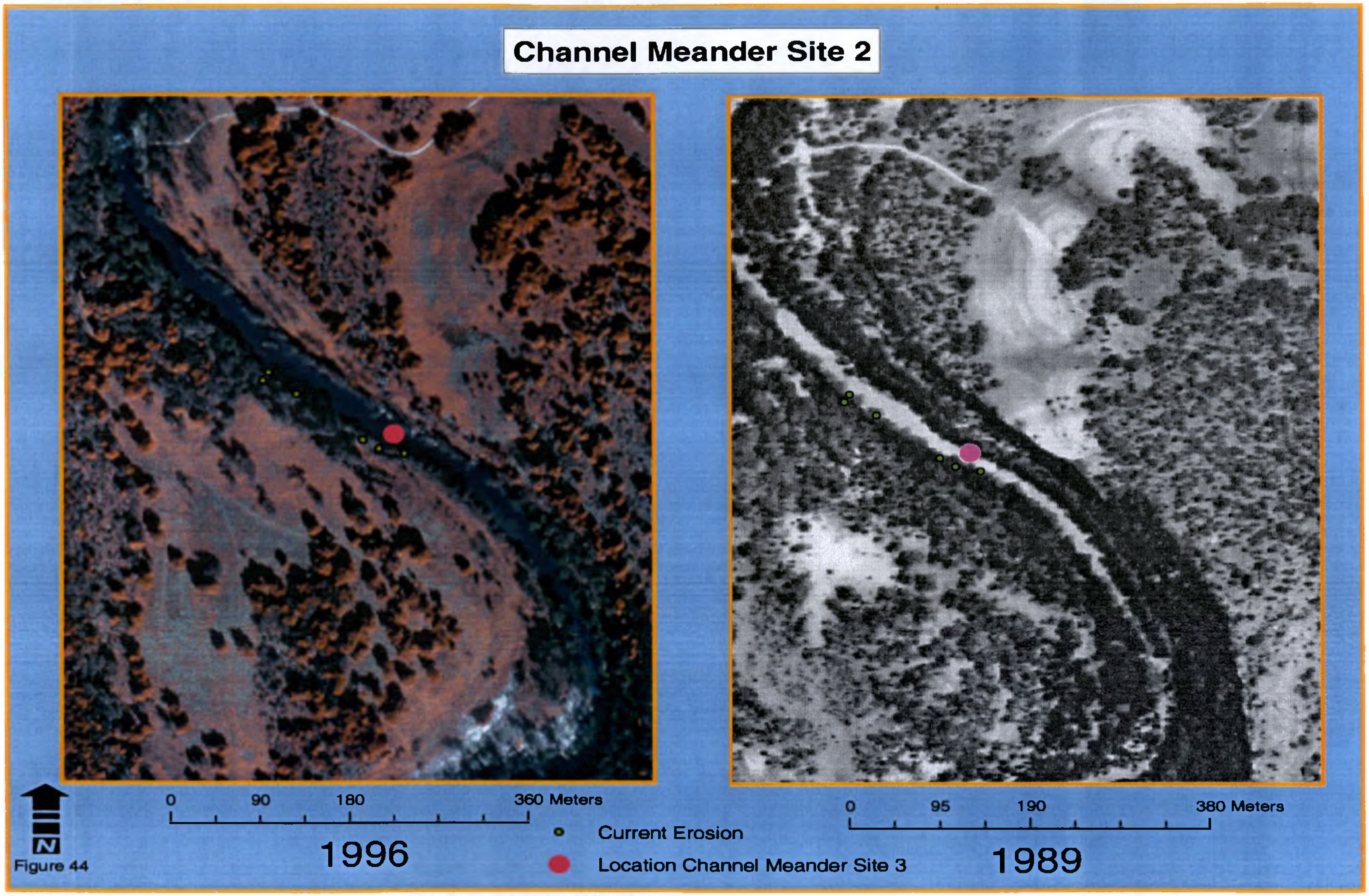
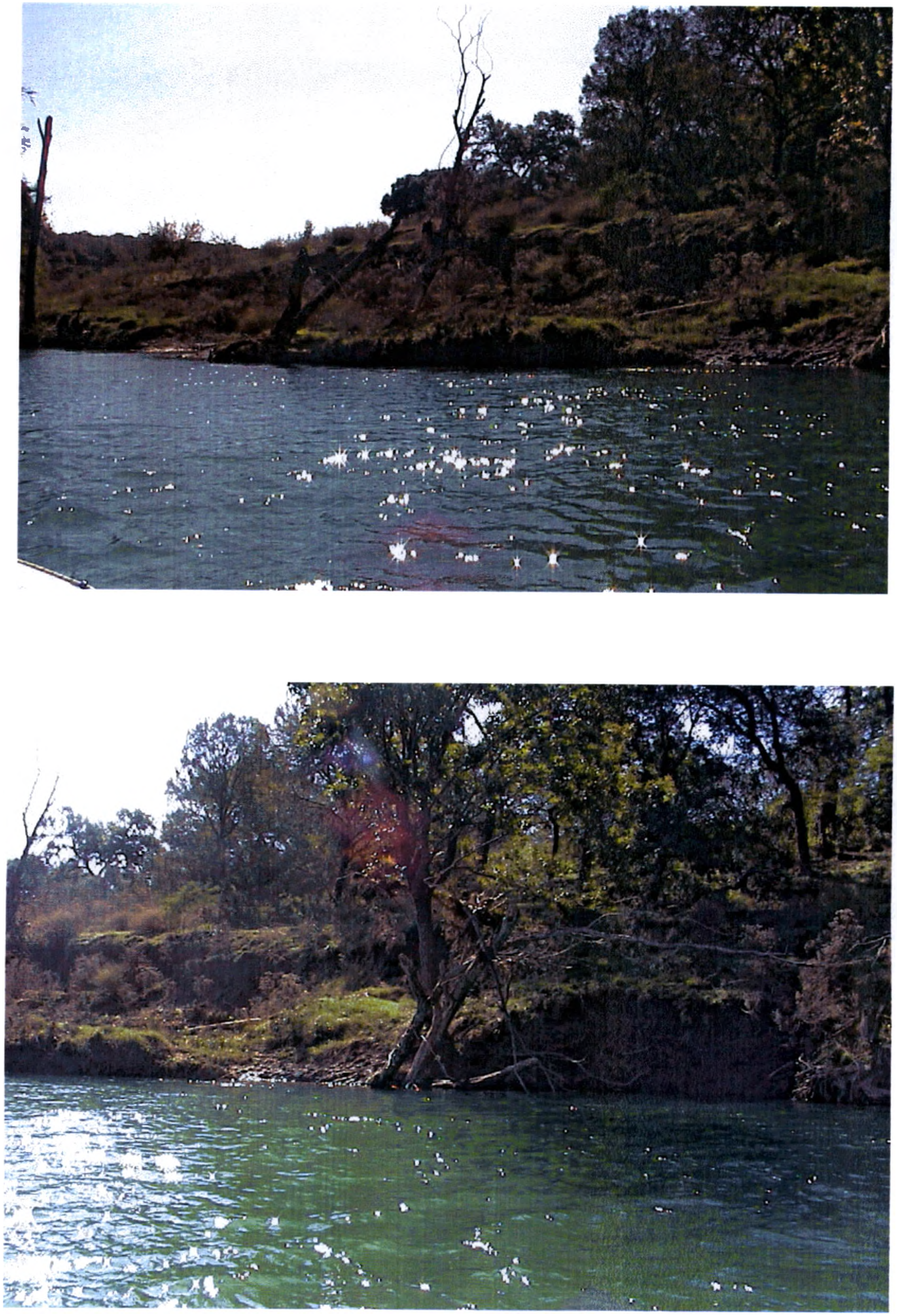

Channel Meander Site 2
0
90
180
360 Meters
1996
N
Current Erosion
Location Channel Meander Site 3
0
95
190
380 Meters
1989
Figure 44

Figure 45 Channel Meander 2



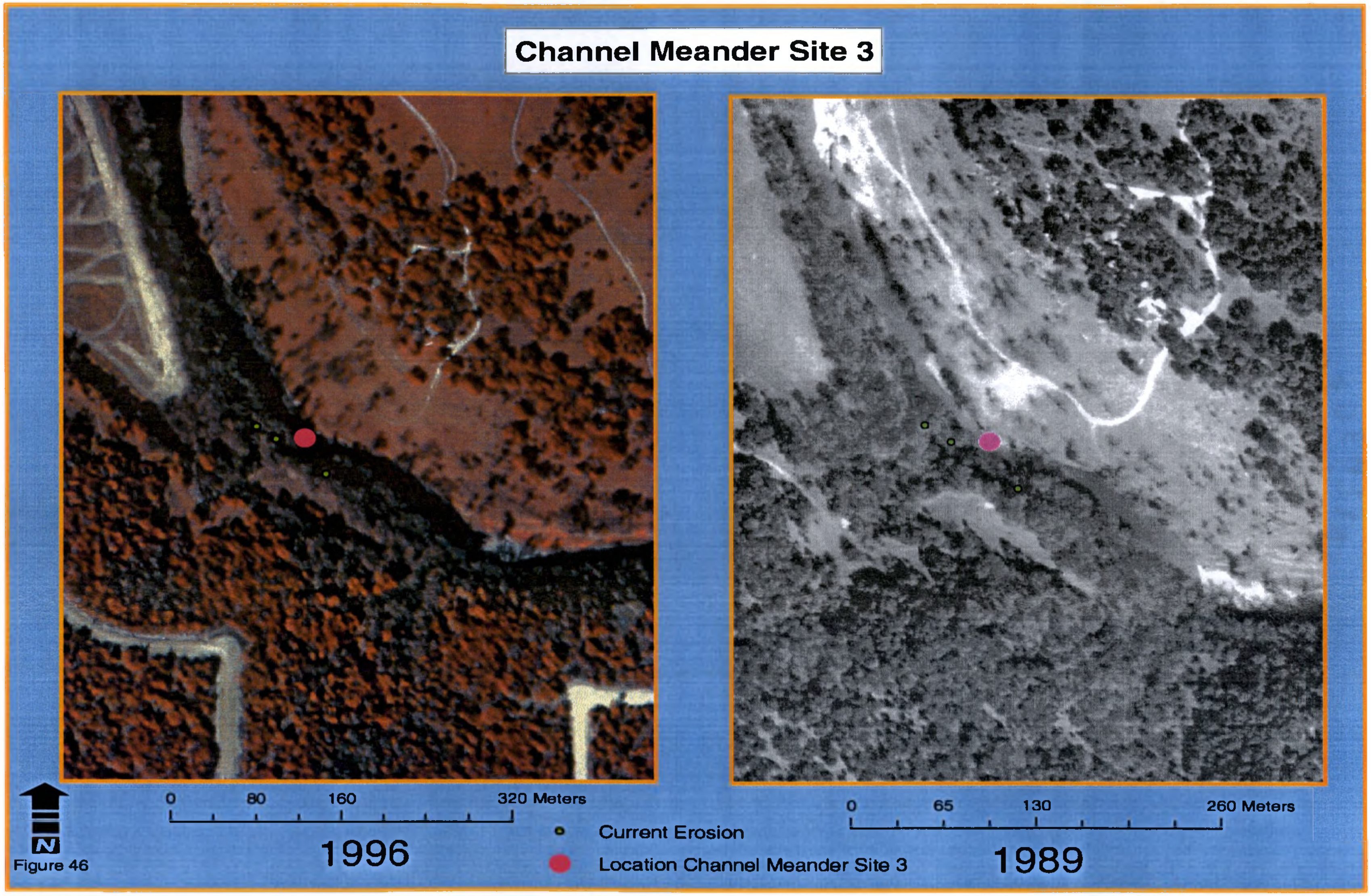
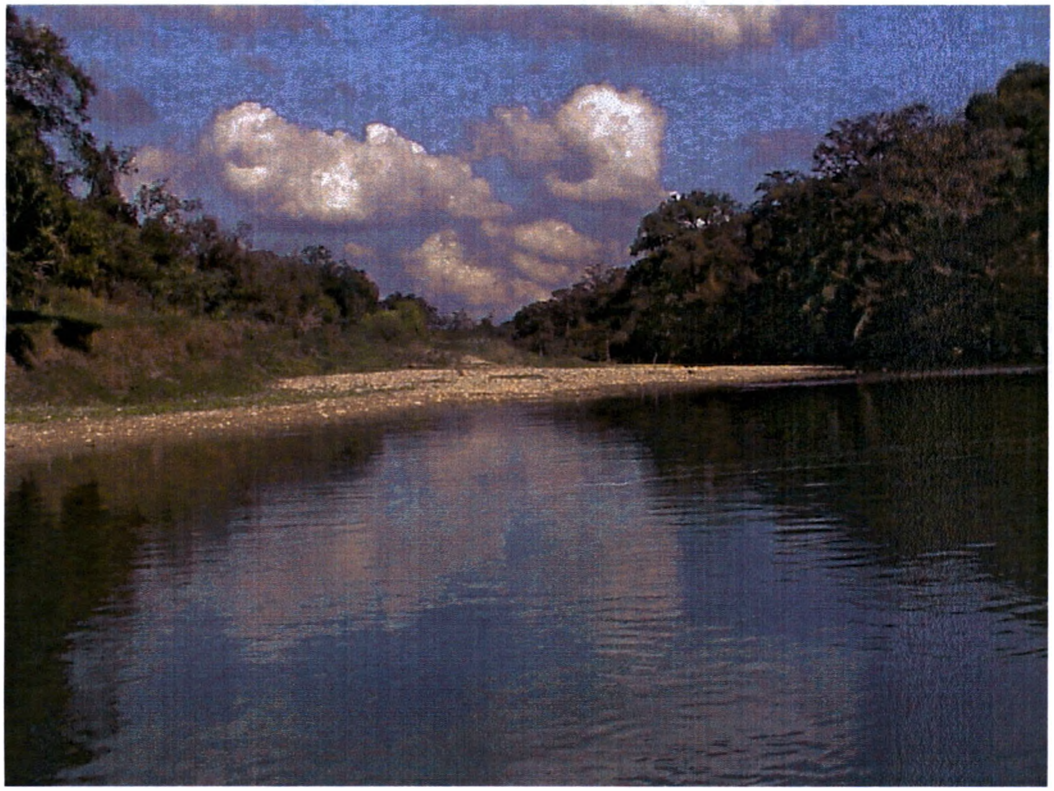
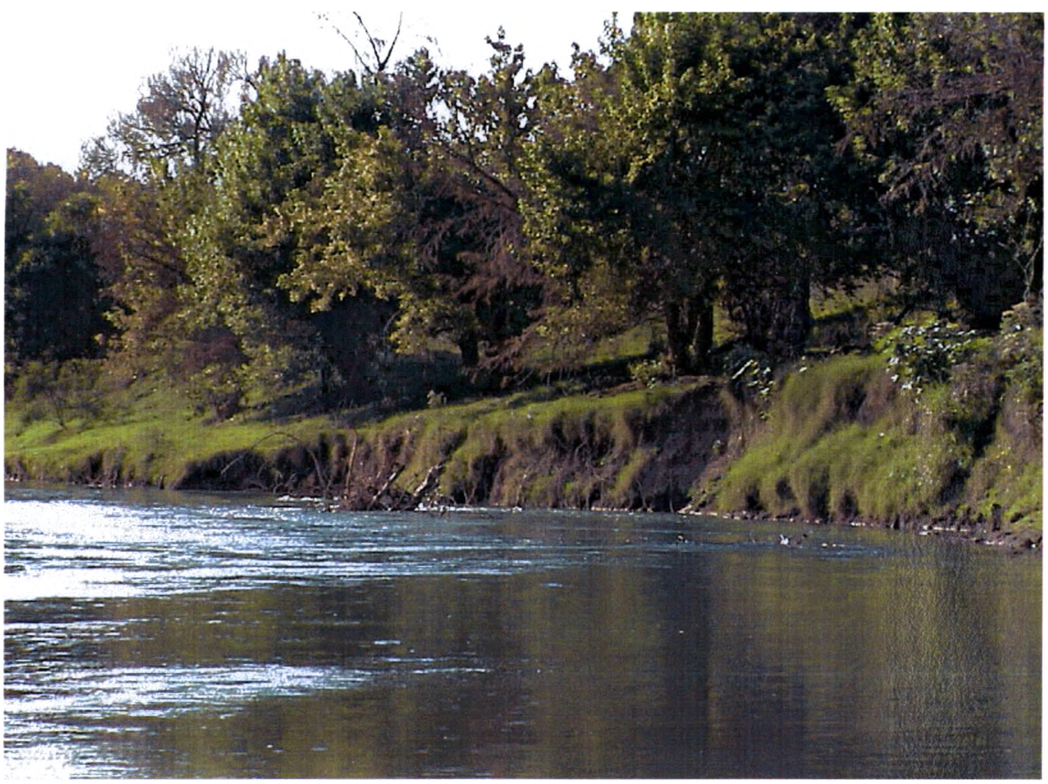

Channel Meander Site 3
0
80
160
320 Meters
1996
Current Erosion
Location Channel Meander Site 3
0
65
130
260 Meters
1989
N
Figure 46

Figure 47 Channel Meander 3





CHAPTER VII

CONCLUSION

Erosion and channel change associated with flooding is an inevitable reality on the Guadalupe River. Although this process cannot be stopped, strategies can be developed and implemented that will help mitigate the impacts of these floods. This research has shown that there is a clear connection between near-channel land use practices and channel morphology. Of the 138 sites that were recorded, a large percentage of the sites showed a discernable change in the extent and position of the riparian zone. Although the loss of riparian habitat is not the only factor attributing to channel change and erosion, this research establishes a strong connection between the alteration of riparian habitat and the occurrence of channel erosion.

The dominance of cattle grazing activities along the river could have strongly contributed to the general observed thinning of the riparian zone vegetation. As much as 81% of the total amount of forage removed by livestock in a watershed can come from the 2 % of land area occupied by the riparian zone (Kauffman et al. 1983). Management practices need to be established that encourage the preservation of the riparian zone vegetation. These will involve the effective control of cattle grazing and guidelines to try to curb the encroachment of other types of agriculture into the riparian zone.

An important facet of developing these types of plans is further research. Short-term research goals would include the completion of the longitudinal study as well as further analysis of a larger sample of the field sites. A number of longer-term research goals would include incorporating the type and associated characteristics of the riparian vegetation at each location. The scope of the study would benefit by establishing a paired watershed study with the nearby Medina River.

REFERENCES

- Atkinson, Peter, Sally German, David Sear and Mıchael Clark. 2003. Exploring the relatıons between rıverbank erosıon and geomorphologıcal controls usıng geographically weıghted logistıc regression. *Geographical Analysis* 35: No.1. Pgs. 58-81.
- Bailie, B.R and T.R. Davıes. 2002. Effects of land use on the channel morphology of streams in the Moutere gravels, Nelson New Zealand. *Journal of Hydrology (New Zealand)* 41:19-45.
- Beschta, R.L and W.S Platts. 1986. Morphological features of small streams: sigmficance and functıon. *Water Resources Bulletin* 22: 369-379.
- Brınson, M, L. MacDonnell, D. Austen, R.Beschta, T. Dıllaha, D. Donahue, S. Gregory, J. Harvey, M. Molles, E. Rogers and J. Stanford. 2002. *Riparian areas: Functions and strategies for management.* Washington D.C. National Academy Press.
- Caran, S.C. and V.R Baker. 1986. Flooding along the Balcones escarpment, Central Texas. In Abbott, P.L and C.M Woodruff eds. *The Balcones escarpment, Central Texas.* Geological Society of America pgs.1-14
- Carr, J.T Jr. 1967. The climate and physiography of Texas: Austin Texas Water Development Board Report 53.
- Census 2000 data available at: http://census.dfwinfo.com/

- Coates, Donald and John Vitek, eds. 1980. *Thresholds in geomorphology*. New York: Dowden and Culver, Inc.
- Cooke, R.U. and J.C. Doornkamp. 1990. *Geomorphology in environmental management*. Clarendon Press: Oxford.
- Dunne, T and L. B. Leopold. 1978. *Water in environmental planning*. W.H. Freeman: San Francisco.
- Fenneman, N.M. 1931. *Physiography of Western United States*. McGraw- Hill Book Company, Inc: New York and London.
- Friedman, J.M, W.R. Osterkamp and W.M. Lewis. 1996. The role of vegetation and bed-level fluctuations in the process of channel narrowing. *Geomorphology* 14: 341-351
- Gilliom, Robert and Gail Thelin. 1997. Classification and mapping of agricultural land for national water quality assessment. *U.S. Geological Survey Circular 1131*.
- Goudie, A 1994. The *human impact on the natural environment*. The MIT Press: Cambridge, Massachusetts.
- Hession, W.C. 2001. Riparian forest and urban hydrology influences on stream channel morphology: implications for restoration. In *Proceedings of the world water and environmental resources congress*.ed. Phelps, D and G. Sehlke. Orlando Florida
- Hession, W.C, J.E. Pizzuto, T.E Johnson, R.J Horwitz. 2003. Influence of bank vegetation on channel morphology in rural and urban watersheds. *Geology* 31: 147-150.

- Hupp, C.R. W.R. Osterkamp. 1994. Riparian vegetation and fluvial geomorphic processes. *Geomorphology* 14: 277-295.
- Johnson, W.C., M.D Dixon, R.Simons, S.Jenson, K. Larson. 1995. Mapping the response of riparian vegetation to possible flow reductions in the Snake River, Idaho. *Geomorphology* 13: 159-173.
- Kaufman, J.B and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. *Journal of Range Management* 37: 430-438
- Kaufman, J.B, W.C Krueger and M. Vavra. 1983. Impacts of cattle on streambanks in northeastern Oregon. *Journal of Range Management.* 36: 683-685.
- Kohler, C and W. Hubert. 1993. *Inland fisheries management in North America.* Bethesda, Maryland. American Fisheries Society.
- Kondolf, G, H. Piegay and N.Landon. 2002. Channel response to increased and decreased bedload supply from land use change: contrasts between two catchments. *Geomorphology* 45: 35-51.
- Leopold, L.B., Wolman, G.M. and J.P. Miller, 1964. *Fluvial processes in geomorphology.* New York:Dover.
- Lillesand, T.M and R.W. Kiefer. 1994. *Remote sensing and image interpretation* (third edition). New York: John Wiley and Sons, Inc.
- McGlynn, B.L and J.Seibert, 2003. Distributed assessment of contributing area and riparian buffering along stream networks. *Water Resources Research* 39: No.4.

- Magilligan, F.J and P.F. McDowell. 1997. Stream channel adjustments following elimination of cattle grazing. *Journal of the American Water Resources Association* 33: No. 4.
- Malanson G.P. 1993. *Riparian Landscapes.* Cambridge University Press. Great Britian
- *Monthly Station Normals* 1970-2000. U.S. National Climate Data center.
- National Co-operative Soil Survey 1979. Kerr Kendall and Comal County, Texas. Soil Conservation Survey.
- O'Connor, Matt and Greg Watson. 1998. Geomorphology of channel migration zones and implications for riparian forest management. O'Connor Environmental Inc.
- Palmer, E.C. 1986. Land use and cultural change along the Balcones escarpment: 1718-1986. In Abbott, P.L and C.M Woodruff eds. *The Balcones escarpment, Central Texas.* Geological Society of America pgs.153-162.
- Passmore, J. 1997. Construction of a dynamic GIS tool kit for the visualization, analysis and prediction of bankline movement along the Jamuna River, Bangladesh. MSc Geographic Information Systems. University of Nottingham, UK.
- Patton, P. C. and V.R. Baker. 1976. Morphometry and floods in small drainage basins subject to diverse hydrogeomorphic controls. *Water Resources Research.* Vol. 12 No. 5.
- Renwick, W.H. 1992. Equilibrium, disequilibrium and nonequilibrium land forms in the landscape. *Geomorphology* 5: 265-276.

- Rhoads, B.L. and C.E. Thorne. 1996. Towards a philosophy of geomorphology. In *The Scientific Nature of Geomorphology*. eds. Rhoads and Thorne. New York: John Wiley & Sons.
- Riskind, D.H and D.D Diamond. 1986. Plant communities of the Edwards Plateau of Texas: an overview emphasizing the Balcones escarpment zone. In Abbott, P.L and C.M Woodruff eds. *The Balcones escarpment, Central Texas*. Geological Society of America pgs. 21-31.
- Riskind, D.H. and D.D. Diamond. 1988. An introduction to environments and vegetation, eds. Amos, B and F. Gehlbach. Pgs.1-16. *Edwards Plateau vegetation: plant ecological studies in central Texas.* Waco, Texas: Baylor University Press.
- Setser, Yvonne. 2000. *A historical investigation of morphological change in the Rio Grande channel below to upstream hydrologic control initiatives.* M.A.G. thesis, Texas State University.
- Slade, R.M. Jr. 1986. Large rainstorms along the Balcones escarpment in Central Texas. In Abbott, P.L and C.M Woodruff eds. *The Balcones escarpment, Central Texas.* Geological Society of America pgs.15-20.
- Sullivan, J.E. 1983. *Geomorphic effectiveness of a high-magnitude rare flood event in central Texas.* Masters of Arts thesis, University of Texas at Austin.
- Texas Natural Resources Information Systems available at http://www.tnris.org
- Thorne, Collin, Ivan Amarasinghe, John Gardiner, Christine Perala-Gardiner and Robert Sellin. 1997. *Bank Protection using vegetation with special reference to willows*. The Engineering and Physical Sciences Research Council 1997

- Trimble, S.W and A.C. Mendel. 1995. The cow as a geomorphic agent- a critical review. *Geomorphology* 13: 233-253.
- Thurow, T.L, Blackburn, W.H and C.A Taylor. 1986. Hydrologic characteristics of vegetation types as affected by livestock grazing systems, Edwards Plateau, Texas. *Journal of Range Management* 39: 505-509.
- Votteler, Todd. 2002. *Flood.* Texas Parks and Wildlife March 2002.
- Wasson, A and R. Wasson. 2000. Riparian vegetation and river channel size. *Natural Resource Management* Vol. 3 No. 1.
- Wolman, M.G. 1967. A cycle of sedimentation and erosion in urban river channels. *Geografiska Annaler* 49: 385-395.
- Wolman, Gordon and Ran Gerson. 1978. Relative scales of time and effectiveness of climate in watershed geomorphology. *Earth Surface Processes* 3: 189-208.

VITA

Matthew Mitchell Thompson was born in Cape Town, South Africa, on January 8, 1979, the son of Jennifer Anne Thompson and Leigh Frank Thompson. After completing high school at Rondebosch Boy's High School, Cape Town, South Africa, he spent a year traveling. After returning from his travels he entered the University of Cape Town. He received a Bachelor of Science degree from the University of Cape Town in 2000. During 2001 he completed an Honors degree in Environmental Management also from the University of Cape Town. The following years he spent living and working in London, England. After briefly returning home to South Africa he then entered the Graduate College at Texas State University-San Marcos in August 2003.

Permanent Address: Fairhill Farm

Charnwood Avenue, Tokai

7945

Cape Town, South Africa

This thesis was typed by Matthew Mitchell Thompson.