Section 4
Fluvial Geomorphic Evaluation

4.1 Introduction

Fluvial geomorphology is the process of how moving water shapes the land. Fluvial relates to flowing water and geomorphology refers to the systematic examination of land forms. Combined, fluvial geomorphology is the systematic examination of land formed by flowing water either through erosion or deposition. Correspondingly, the fluvial geomorphic processes are examined in relation to dynamic equilibrium. This equilibrium is the balanced movement of water and sediment under dynamic (variable) flow conditions typically inherent in a natural environment.

The objective of the fluvial geomorphic evaluation for the Cardwell Branch study area was to verify and, if necessary, supplement the geomorphic assessment conducted by USGS, with the overall goal of determining the locations of potential stream stabilization projects. The main elements of this investigation included:

- Review of the draft study, *An Assessment of the Hydrology, Fluvial Geomorphology, and Stream Ecology in the Cardwell Branch Watershed, Nebraska,* completed by USGS in April 2006
- Conducting a field reconnaissance of the main stem and south tributary to verify the conditions found by USGS
- Evaluate the work done by USGS and the results of the field reconnaissance to classify the current conditions of the natural stream system

As summarized above, one of the key objectives of the evaluation was to evaluate the current conditions of the stream system. Schumm (1984) and Simon (1989) have classified the process of how streams reestablish equilibrium after a disturbance to the channel or the watershed. Simon classifies this reestablishment into six stages: I) Pre-Disturbance, II) Disturbance, III) Incision, IV) Widening, V) Deposition, and VI) Recovery and Reconstruction. Figure 4-1 schematically depicts each of these stream stages. The determination of the stream stages for the Cardwell Branch study area was an important component of the evaluation.

4.2 USGS Geomorphic Assessment

The draft study completed by USGS in April 2006 was reviewed before conducting the field reconnaissance of the main stem and south tributary. A comprehensive description of that review is presented in Appendix C. The more notable observations and conclusions presented in the draft USGS report included:

- The main stem of Cardwell Branch has incised 1.3 to 2.3 feet since 1978 with no clear knickpoints (abrupt drops in the channel indicating incision migrating upstream) found during the thalweg survey.
- Using Simon's (1989) process-based stream classification system, all reaches were determined to be Stage IV (widening).

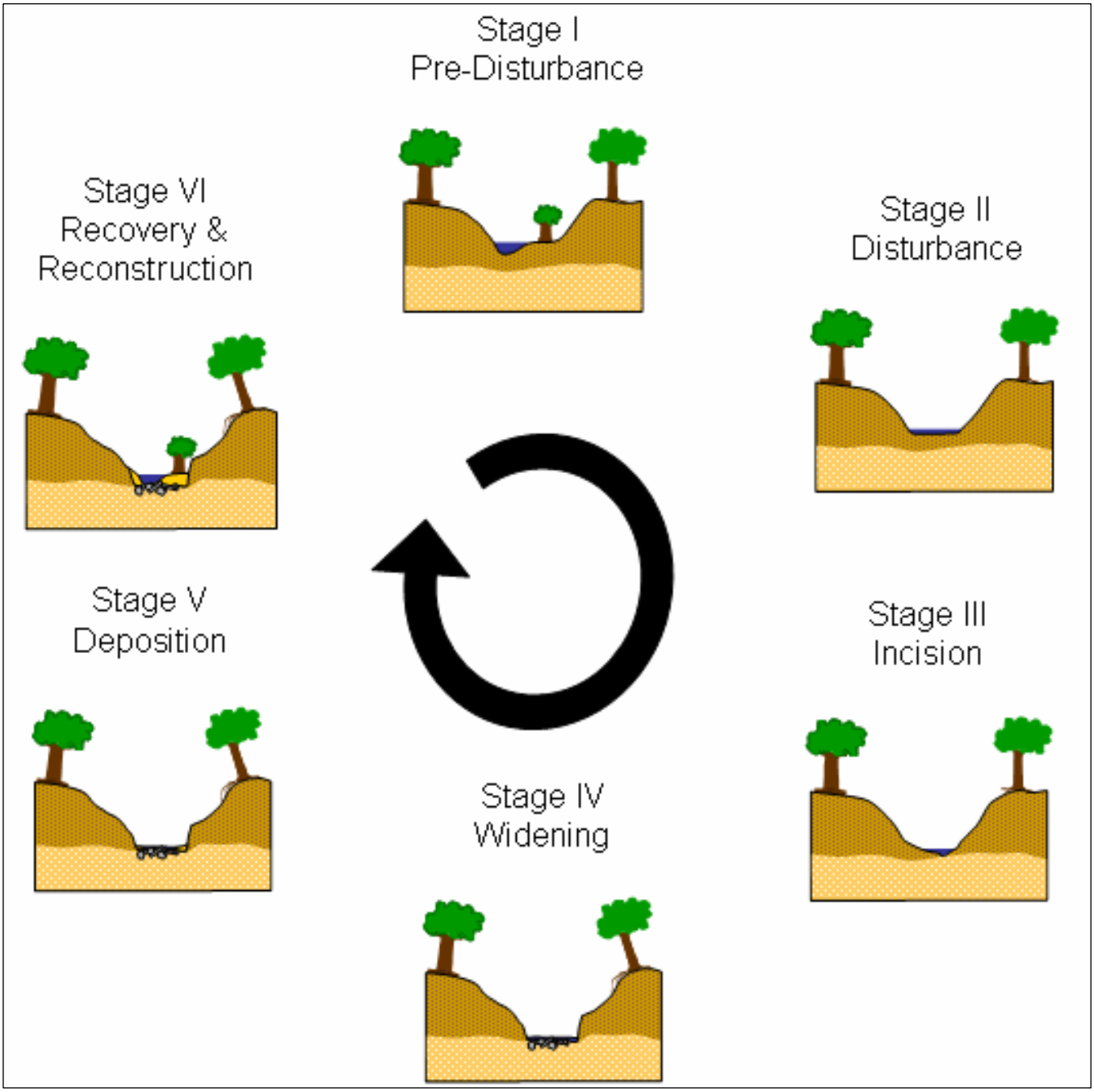

Figure 4-1
Channel Evaluation Model (Simon 1989)

- Sand bar deposition was not observed, and the majority of sediments found in the channels were silt-sized and indicative of local soil source material.

4.3 Geomorphic Field Reconnaissance

During June 2006, a geomorphic field reconnaissance was conducted of the main stem and south tributary. The goal of the field reconnaissance was to verify the observations and interpretations made by USGS. As part of the verification process, the study stream reaches were evaluated, which included field visits at each of the cross sections surveyed by USGS to define fluvial geomorphic characteristics. The field data collected by the project team were compared to the geomorphic data tables developed by USGS, which are presented in Appendix C. The data collection process used pocket personal computers equipped with ArcPad Version 7.0 to record additional data about the channels. The City provided topographic contour, street and stream alignment shapefile layers to locate features. In addition, USGS provided shapefile layers locating their cross sections and supplemental details pertaining to those cross sections.

The supplemental data recorded during the field reconnaissance included: photograph locations, locations of debris jams, knickpoints and knick zones, active meandering segments and other miscellaneous notes. These shapefiles are presented electronically in Appendix A, as well as the photographs taken during the field reconnaissance. At a minimum, two photographs, one looking upstream and the other looking downstream, were taken at each USGS cross section location presented in the tables.

4.4 Evaluation Results

A reach description summary for the stream sections evaluated by USGS and the project team is provided in Appendix C. These reach summaries are a culmination of interpreting the work done by USGS and the verification process and supplemental work completed by the project team. Where field measures differed between USGS and the project team, measurements taken by the project team were used. A synopsis of the findings follows.

4.4.1 Stream Stage Classification

Cardwell Branch Main Stem (Yankee Hill Lake to the Salt Creek Confluence)
USGS classified the main stem as primarily Stage IV (widening), which differs from the project team's stream assessment. A description of the stream classification process and significant features of the channel that were observed by the project team are provided below.

In general, the incising portions (Stage III) were found along the upstream portion, where active knickpoints were found at several locations. The creek progressed to widening (Stage IV) in the middle portions and widening to deposition (Stage IV to V) along the downstream portions. The presence of Stage V conditions may have been more prevalent if the primary source of sediment was coarser. The silt and clay and very fine sand of the alluvium, loess and glacial till comprising the uplands, banks, and channel bottom typically remained as washload during flood flows and thus did not deposit in bars. The mechanism of sediment transport was observed following the rainfall early on June 12, 2006. Figure 4-2 graphically illustrates the stream classification of the main stem as determined by the project team.

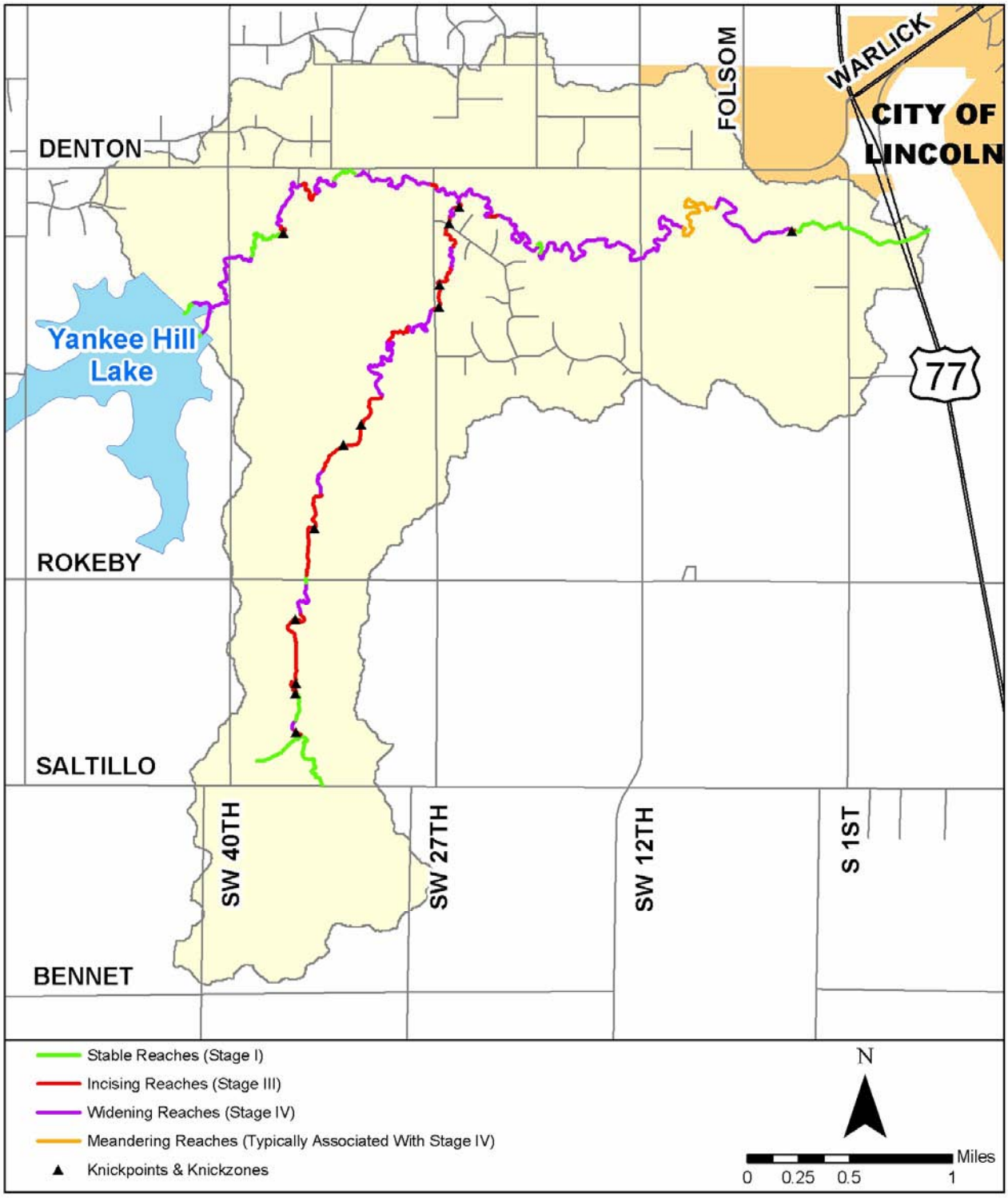

Figure 4-2
Cardwell Branch Geomorphic Processes

The bankfull/dominant discharge heights and widths were significantly different than those determined by USGS at several locations. The project team's determination of bankfull/dominant discharge heights were based on field observations of bank slope inflections and benches, bank vegetation or lack thereof, and trash or debris lines. Correspondingly, the reassessed measurements appear to transition better with those measurements upstream and downstream of the cross sections in question.

Along the upstream portion of the creek, cleared segments of riparian buffer were observed that have overgrown with reed canary grass, but not to the extent found along the upstream portions of the south tributary. In addition, significant large to small woody debris was present along the entire reach, often forming debris jams and *de facto* grade controls. Similar to the south tributary, the origin of the woody debris ranged from natural succession of the riparian forest to cleared wood placed along the tributary. Except along a few isolated segments of the creek where active meandering was observed, extensive degradation of the banks was not found. Further near-term endangerment of existing infrastructure (roads and crossings) appeared minimal except at the SW 27th Street crossing.

South Tributary

As with the main stem, the main difference between the project team's evaluation and the USGS assessment is the stage classification assignment. In general, the south tributary contains significant lengths that are classified as Stage III (incising) and Stage IV (widening) of the channel evolution model (Figure 4-2). USGS determined that the entire tributary was widening. Typically, the project team found that the sequence of incising in the upstream end and widening in the downstream end repeated itself between the crossings. Active knickpoints were also found at several locations. At several locations, the bankfull/dominant discharge heights and widths were observed to be significantly different than those found by USGS. As with the main stem, the reassessed measurements appear to transition better with those cross section measurements upstream and downstream.

The riparian buffer width generally widened in the downstream direction as did the density of the tree canopy. In the upstream portion of the tributary, especially upstream of SW 27th Street, the buffer was segmented with significant portions of the alignment bounded by invasive reed canary grass. Significant large to small woody debris was found along the entire tributary, often forming debris jams and *de facto* grade controls. The origin of the woody debris ranged from natural succession of the riparian forest to cleared wood placed along the tributary. Extensive degradation of the banks was not observed and endangerment of existing infrastructure (roads and crossings) appeared minimal.

4.4.2 Summary Discussion

The stream reaches that are downcutting or incising typically contain knickpoints or knick zones that are migrating as headcuts upstream at varying rates or are temporarily abated by channel armoring. The knickpoints and zones are depicted on Figure 4-2. The stream lengths that are widening typically show more scouring along the bank toes; however, the rate of scour appears slow and for the most part the banks are not imminently endangered. The single stream length along the main stem that indicates active meandering is a location where significant scouring and mass wasting of

alternating banks were observed. Finally, the stable stream lengths are located where the channel appears to be in relative balance or shows significant progress in mending itself.

Figure 4-3 presents the shear in the channel at the bankfull height (depth), which should be the stage of the channel-forming flow. This figure depicts shear along the channel, which was calculated using the slopes between each of the cross sections surveyed by USGS. The resulting values were then grouped in ranges of shear. As with USGS, a correlation was observed between the higher shear to higher erosion indicators, especially along the south tributary.

Specifically, calculated shears of 0.4 pounds per square foot (psf) or higher were found along the south tributary, where significant incision and widening were observed. Typically the calculated shears along the main stem were 0.2 psf or higher, where widening, more isolated incision and active re-meandering were observed. The highest shear calculated was along the south tributary between Rokeby and SW 27th Streets, which coincided with the severe incision conditions.

The direct correlation of specific shear values to specific erosion potential is not possible because of the variability of channel soils, vegetation, groundwater, and other external influences. However, shear values 0.6 psf and higher appear to correlate with longer lengths of incision found in the south tributary and shear values of approximately 0.4 psf appear to correlate with widening and shorter lengths of incision, as found along the main stem.

4.5 Stream Improvements

Based on the field reconnaissance effort, the Cardwell Branch stream reaches will continue to degrade until stream improvements are implemented. The focus of the stream improvements will be to address the channel incision which is causing instability problems throughout the study area. The knickpoints and knickzones are sites where the hydraulic slope is locally high enough to cause migrating erosion. Installing grade control structures will lower the slope below the threshold for bed erosion in this stream system. Because of the high erodibility of the streambed, it is necessary to dissipate the energy gradually over the length of the grade control structure. For this application, Newbury-style grade control structures are recommended, which provide artificial riffles along the streambed to distribute energy, while improving water quality by increasing dissolved oxygen and providing habitat. Figure 4-4 provides a typical Newbury-style grade control structure. Section 5 provides additional details on the recommended improvements to address the high priority stream stability problem areas.

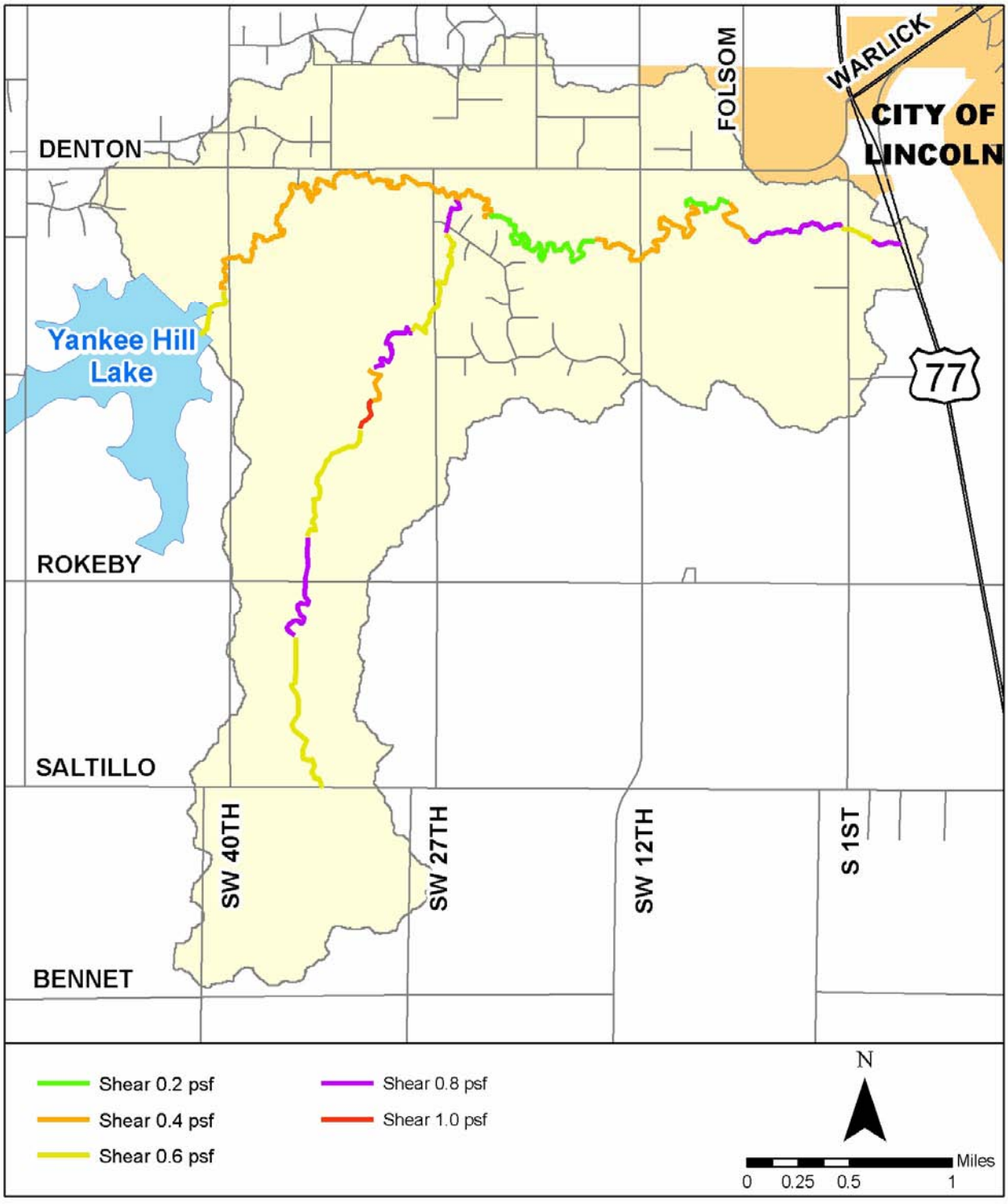

Figure 4-3
Cardwell Branch Shear Stress Values

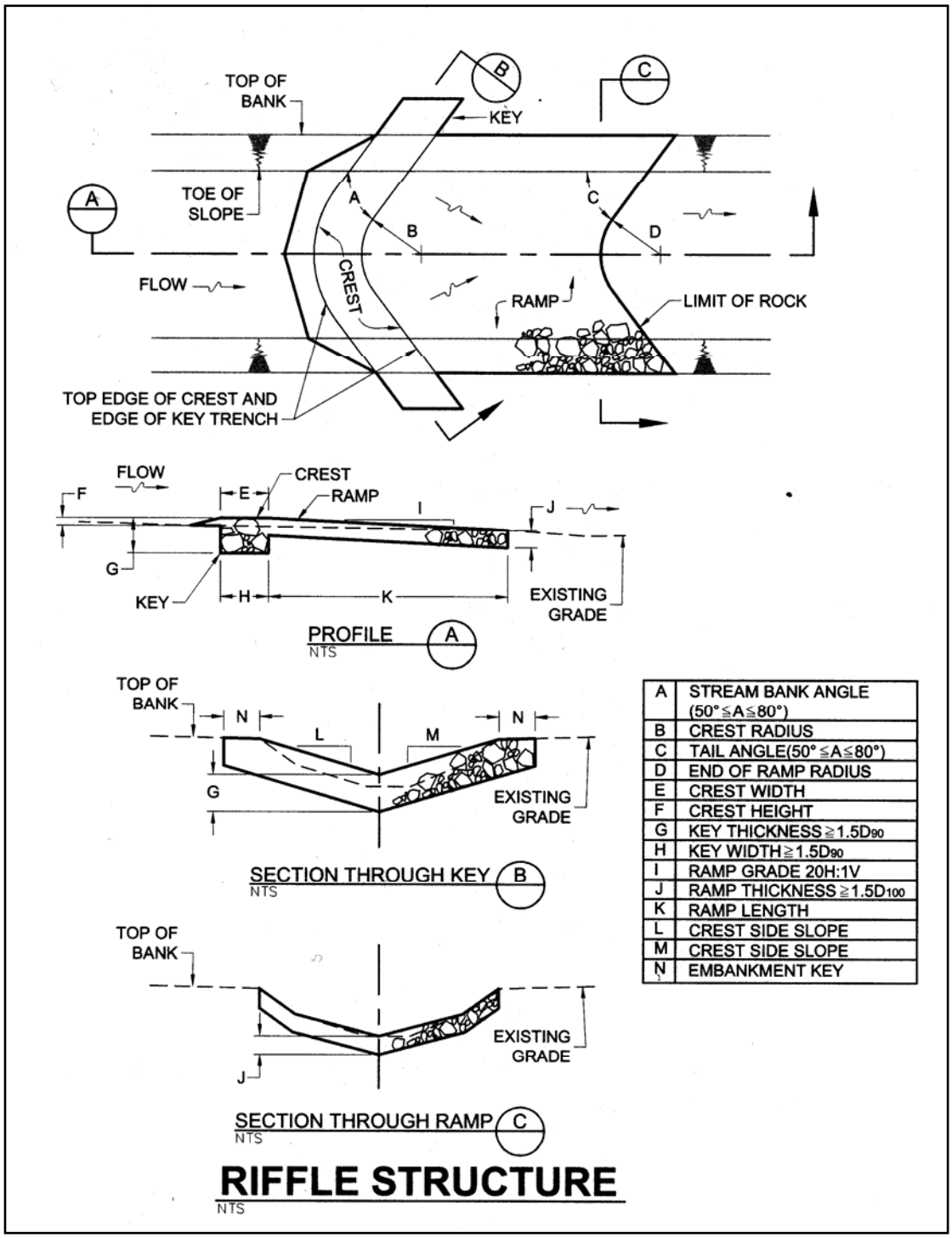

Figure 4-4
Newbury-Style Grade Control Structures