TETRA TECH

FINAL REPORT

Little Thompson Watershed Restoration Master Plan






Little Thompson Watershed Restoration Coalition

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Little Thompson Watershed Restoration Master Plan

Prepared for:

Little Thompson Watershed Restoration Coalition
sponsored by the Big Thompson Conservation District
with support from the Colorado Water Conservation Board

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

Acronyms and Abbreviations

CBT	Colorado-Big Thompson
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
cfs	Cubic feet per second
CNHP	Colorado Natural Heritage Program
CR	County Road
CWBC	Colorado Water Conservation Board
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
NEPA	National Environmental Policy Act
LTWRC	Little Thompson Watershed Restoration Coalition
NLCD	National Land Cover Data
NRCS	Natural Resources Conservation Service
SVAP	Stream Visual Assessment Protocol
SWReGAP	Southwest Regional GAP Analysis Project
TSDH	Technical Support Data Network
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
U.S.	United States
WQCD	Water Quality Control Division
WRC	Water Resources Council
WY	Water Year

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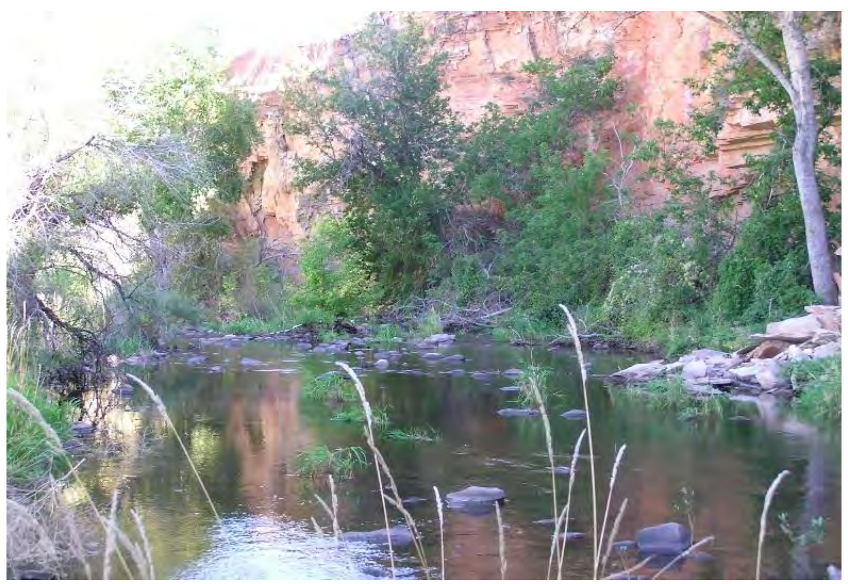
1 INTRODUCTION

1.1 Authorization

This Master Plan was prepared for the Little Thompson Watershed Restoration Coalition (LTWRC). The LTWRC is made up of landowners within the watershed of the Little Thompson River, as well as stakeholders from various government agencies, businesses, and volunteer organizations. The LTWRC formed in response to the September 2013 floods and has been working since then to restore the watershed.

Funding was provided by the Department of Natural Resources, Colorado Water Conservation Board (CWCB) through the Colorado Watershed Restoration Grant Program. The Big Thompson Conservation District acted as the fiscal sponsor.

1.2 Purpose and Need



Located in the northern Front Range of the Colorado Rockies, the Little Thompson River is a unique and beautiful riverine system flowing more than 50 miles from its headwaters in the Roosevelt National Forest to its confluence with the Big Thompson River. The Little Thompson River is a relatively small watershed and difficult to locate and access, as it is the only river in the Front Range that does not follow a major highway. As such, the Little Thompson River is relatively remote and well suited as a wildlife corridor. The upper reaches of the river are defined by tall canyon walls (**Figure 1.1**); while the lower reaches traverse a rich and diverse rural residential and agricultural community.

Figure 1.1. Little Thompson River in a typical canyon-bound reach.

Many plant and animal species depend on the riparian habitat. Anecdotal information and photo reviews indicate the Little Thompson River was well vegetated along the river banks. Beaver activity has been prevalent, at least historically, and often influenced development of pools and the extent of riparian vegetation. Considering the relatively large floods that occurred prior to 1970 and the two more recent floods in 1995 and 1999, floods in the range of 2,000 to 4,000 cubic feet per second (cfs) were not uncommon, and the channel-floodplain system appeared to have remained relatively stable during floods of that magnitude.

In September 2013, the Little Thompson River experienced a catastrophic flooding event, with an estimated peak discharge that exceeded historical measured flood levels by more than three times. Although there have been other floods on the Little Thompson River, none have been as destructive as the September 2013 event. Thirty homes were totally lost or rendered uninhabitable; five dams failed; 28 bridges were damaged or destroyed, isolating several communities for extended time periods (and requiring air evacuation); and there was a significant loss of agricultural land and livestock. The flood destroyed almost the entire riparian corridor, through surges of scour, deposition, or both (**Figure 1.2**). The upper reaches experienced almost a total loss of trees, many of which were large, well established fir trees. The lower reaches experienced deposition of debris and sediment to such an extent that much of the riparian vegetation was buried beyond recovery.

Figure 1.2. Little Thompson River at Blue Mountain neighborhood (formerly X-Bar 7) before and after the September 2013 flood.

Between the upper and lower reaches, both conditions existed with alternating sections of scour and deposition. Although other rivers on the Front Range also experienced catastrophic flooding from the September 2013 event, the Little Thompson River had some of the highest flow per square mile (unit discharge) of any other watershed (**Table 1.1**).

Table 1.1. Comparison of unit discharges in Front Range rivers.

River	Location	Drainage area	2013 estimated peak discharge	2013 estimated unit peak discharge
Little Thompson	Blue Mtn (X-Bar 7)	87 sq mi	15,730 cfs	180 cfs/sq mi
Big Thompson	Drake Gage	314 sq mi	15,300 cfs	49 cfs/sq mi
St Vrain	Lyons	218 sq mi	23,000 cfs	106 cfs/sq mi

Several short-term recovery efforts were implemented on the Little Thompson River immediately after the flood, including temporary river crossings to replace lost bridges and to restore a 2-mile stretch of Highway 36. However, not all immediate needs were addressed, nor were any long-term needs. Thus, the communities and neighborhoods within the Little Thompson River watershed initiated an effort to conduct long-term planning and the development of a Master Plan.

Master planning establishes the framework and key elements of restoration, reflecting a vision created and adopted in a publically open process. It synthesizes private and public goals and objectives, gives them form and organization, and defines a realistic plan for implementation.

It should be noted that some sections of the Little Thompson River could, over time, naturally reestablish its equilibrium slope, planform alignment, and natural geomorphic condition. These geomorphic functions are also likely sufficient to allow for the natural regeneration of riparian plant material through seeding and cloning with no active restoration. The challenge, however, is the time frame, likely decades, required for this extensive regeneration. Active restoration will be critical in many locations to address public safety issues in the case of stabilizing channel banks, land reclamation related to agricultural and economic needs, property reclamation where homes were lost or damaged, and those areas used for water supply and recreation. Based on the visual assessments that were conducted as part of development of this Master Plan, more than half the reaches have sustained flood-related damage to the wetted channels and floodplain instabilities that are of such poor condition that active restoration is recommended. These sites and the specific needs form the basis of much of the recommended restoration outlined in this report. The recommendations for restoration include a wide range of treatments that need to be appropriately integrated in order to be fully functional and efficient because the Little Thompson River is prone to flooding, and given the variety of land uses and infrastructure along the flood corridor.

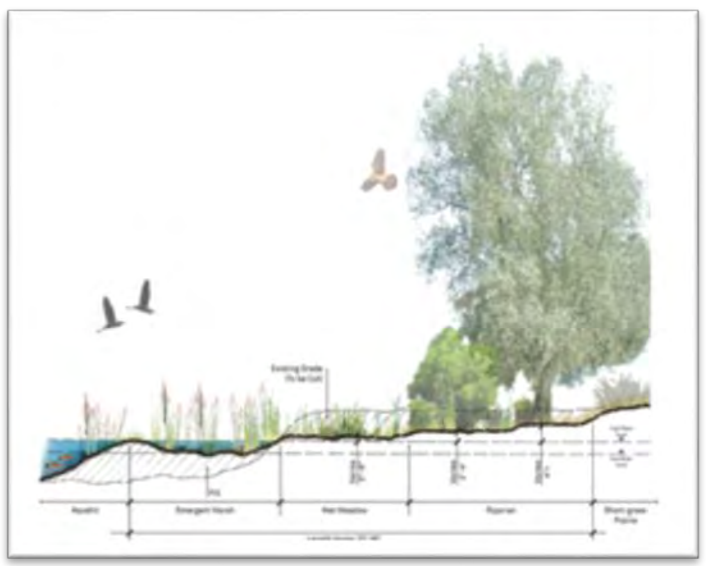


Figure 1.3. Typical cross section from Master Plan details.

This Master Plan is not a regulatory document. Instead, it is a document intended to guide future planning and development of projects that are endorsed and supported by the LTWRC and stakeholders and to provide a planning tool for seeking grants and financial assistance (**Figure 1.3**). All proposed recommendations in this report must be implemented in compliance with all federal, state, and local regulations and require detailed design, permitting, and engineering before they can be implemented.

1.3 Project Scope

The purpose of this Master Plan is to provide a tool for guiding the LTWRC, the counties, and local communities for reconstruction of structures and infrastructure and restoration of the river and the riparian corridor. This Master Plan identifies needs, supports long- and short-term recovery and planning decisions, facilitates future funding opportunities, and presents conceptual recommendations that incorporate strategies to increase resiliency against future floods, while also addressing the following:

- River restoration to reduce impacts from future flooding along the river and provide restoration of aquatic and riparian wildlife habitat;
- Infrastructure and road and bridge reconstruction, associated bank stabilization, and bank stabilization for protection of homes and utilities;
- Preservation of river, wetlands and floodplain corridors; and
- Mitigation of eroded uplands.

1.4 Project Area Description

This Master Plan includes the main stem of the Little Thompson River, the West Fork tributary, and the North Fork tributary, all as defined by U.S. Geological Survey (USGS) topographic maps. The Little Thompson watershed extends from the Roosevelt National Forest just south of Estes Park, Colorado, to its confluence with the Big Thompson River, a tributary of the South Platte River, near the Town of Milliken, Colorado, for a total of 50 miles. Elevations within the watershed range from 11,400 feet above sea level on the peaks of Twin Sisters to 4,730 feet at the Big Thompson River confluence (**Figure 1.4**).

The Little Thompson River flows through Larimer, Boulder and Weld Counties and near or through the towns of Pinewood Springs, Berthoud, Johnstown, and Milliken. The Little Thompson River has the unique characteristic of being the only Front Range drainage that is not followed by a road or highway, with the exception of an 8-mile reach between Pinewood Springs and Estes Park, which parallels U.S. Highway 36. Overall there is little urban development along the river and no publicly accessible open space, with the exception of lands managed by the U.S. Forest Service (USFS). Several parcels in Boulder County include County Conservation Easements and Open Space under lease to private land ownership.

In the upper portions of the watershed, much of the tributary drainage area is within the Roosevelt National Forest, and private land ownership tends to be isolated and landlocked within the USFS boundaries. Land use along the middle reaches of the watershed is largely rural residential. In the lower reaches, land use is agricultural with some rural residential development. There is some potential for urban development on the lower stretches of the river, particularly on land annexed to Johnstown and Berthoud, near I-25. There has been no significant commercial gravel mining within the Little Thompson River watershed.

1.5 Data, Mapping and Information Procurement

Available data were collected and reviewed to help develop a better understanding of the watershed, support investigations, and provide information that can be used to develop recommendations for the Master Plan. Hydrologic and hydraulic data sources are described in those specific sections. All sources of mapping, topography, and aerial photography are documented in **Table 1.2**.

1.6 Stakeholder Engagement

Stakeholder engagement was an important part of Master Plan development. Engagement has been achieved by (1) coordination with the LTWRC via phone and e-mail and attendance at meetings with the coalition, (2) conducting stakeholder work sessions, (3) one-on-one site visits with property owners and neighborhood coordinators, (4) meetings and communication with county staff, USFS, Natural Resources Conservation Service (NRCS), Colorado Department of Transportation (CDOT), CWCB, and the U.S. Army Corps of Engineers (USACE), (5) providing on-line access to the draft Master Plan recommendation maps for comments, and (6) providing one-on-one review of the draft Master Plan Report.

Two stakeholder work sessions were conducted. Meeting 1 was held on the evening of April 16, 2014, and Meeting 2 was held on May 28, 2014. The public was invited. The April 16 meeting included an educational session on river restoration needs and overall goals. The May 28 meeting included considerations and techniques for river restoration, discussion on the basis for evaluation criteria for alternatives, and establishment of priorities. Meeting 2 included a presentation on the findings of the field assessments and conceptual options for restoration. Comments were solicited and incorporated as revisions into the Master Plan. In addition, some follow-up site visits were conducted.

1.7 Acknowledgements

The LTWRC is a proactive and hardworking nonprofit that formed after the September 2013 flood. The LTWRC is organized into two main committees: a steering committee, to oversee strategic planning and funding; and a coordinating committee that oversees implementation and coordinates with the property owners and volunteers. The LTWRC is divided into seven “neighborhoods,” each with a neighborhood coordinator to help facilitate outreach and coordination of information and activities. Many landowners and stakeholders within the watershed and on the LTWRC have contributed to and supported development of this Master Plan. Their insights, information, and discussions contributed to the accuracy and completeness of this study.

A special acknowledgement is extended to Mr. Gordon Gilstrap, president of the Big Thompson Conservation District, who voluntarily served as the executive director for the LTWRC and administrator of the program grant; and Mr. Chris Sturm, Stream Restoration Coordinator in the Watershed and Flood Protection Section of the CWCB who guided the LTWRC and the Tetra Tech Inc. Team through this master planning process.

The Steering and Coordinating committee members are provided below.

Steering Committee

Gordon Gilstrap, Big Thompson Conservation District President
Suzanne Bassinger, Larimer County Long Term Recovery
Julie Cozad, Weld County Commissioner Candidate
Denise Grimm, Boulder County Land Use Department
Bill Markham, Big Thompson Conservation District Board Member
Kevin McCarty, Big Thompson Conservation District Board Member
Terry Parrish, Big Thompson Conservation District Board Member
Nate Stoffregen, Big Thompson Conservation District Treasurer

Coordinating Committee

Cindy Befus, Fiscal & Contract Management
Ron Blackmer, Johnstown and Milliken Neighborhood Coordinator
Brad Clark, Berthoud (CR23 to CLR) Neighborhood Coordinator, Debris Management
Deirdre Daly, Blue Mountain Neighborhood Coordinator, Community Outreach
Denise Cote, Blue Mountain Neighborhood Coordinator
Jerry Fearn, Big Elk Meadows Neighborhood Coordinator
Steve Fitzgerald, Pinewood Springs Neighborhood Coordinator
Sandy Freeo
Larry Glover, Volunteer Coordination
Gordon Gilstrap, Core Tools-Website, Databases
Fran Goss, Boulder County Neighborhood Coordinator
Larry Lempka, Agricultural Programs
Jody Marken, Fiscal & Contract Management
Kevin McCarty, Berthoud (CLR to I25) Neighborhood Coordinator
Terry Parrish, Boulder County Neighborhood Coordinator
Bryan Roberts, Debris Management
Jenny Sanders, Community Outreach. Core Tools-Website, Databases, Volunteer Coordination
Julia Stapp, Berthoud (CR23 to CLR) Neighborhood Coordinator
Norma Stremme, Fiscal & Contract Management
Laura Tyler, Volunteer Coordination
Bill Zawacki, BTCD, Grant Writing, Tetra Tech Liaison
Johanna Zeh, Blue Mountain Neighborhood Coordinator
Seth Hyberger, Milliken Town Planner, Grant Writing

Consulting Team and Primary Contacts

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EMPSi, Inc., David Batts, MS, Natural Resource Planning and Restoration Ecology
HabiTech, Inc., Tom Wesche, PhD, Fisheries Biologist

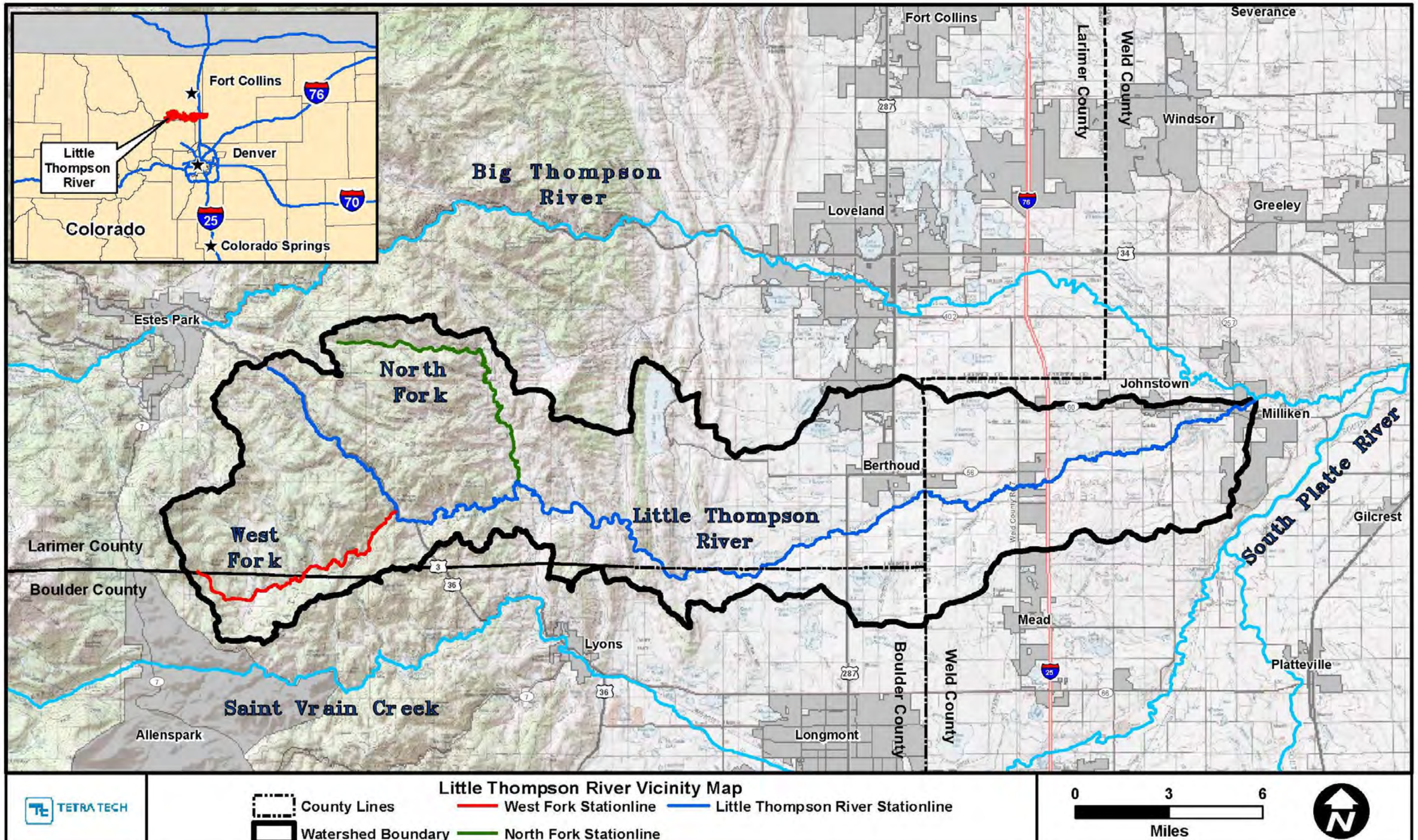

Figure 1.4. Little Thompson Watershed.

Table 1.2. Summary of various mapping, topography, and aerial photography collected for Little Thompson River Master Plan.

Item	Description	Source
Aerial Imagery[2]	Post-flood aerial imagery (*Little Thompson River Station 0+00 to 930+00*); 09/26/2013	Digital Globe
Aerial Imagery	Post-flood aerial imagery (*Little Thompson River Station 930+00 to 1730+00*); Oct/2013	Pictometry/Boulder County
Aerial Imagery	Post-flood aerial imagery of (*Little Thompson River Station 1730+00 to 2360+00; WF River Station 50+00 to 280+00; NF River Station 0+00 to 400+00*); 06/20/2014	Larimer Emergency Telephone Authority (LETA)
Aerial Imagery	Post-flood aerial imagery (*Little Thompson River Station 2360+00 to 2690+00; WF River Station 320+00 to 530+00*); 09/26/2013	Digital Globe
Aerial Imagery	Pre-flood aerial imagery; Entire Watershed (April 2011)	ESRI World Imagery
Geologic Map Data	GIS Database of Geologic Units and Structural Features in Colorado. 2005	USGS
Detailed Soils Map	Weld County Soil Survey (No. CO618); 1980	USDA/NRCS
Detailed Soils Map	Boulder County Soil Survey (No. CO643); 1975	USDA/NRCS
Detailed Soils Map	Larimer County Soil Survey (No. CO644); 1980	USDA/NRCS
Detailed Soils Map	Arapaho-Roosevelt National Forest Soil Survey (No. CO645); 2007	USDA/NRCS
Topographic Data	Post-flood LiDAR data for Colorado Flood; atlas format. Coverage of Entire Watershed; 11/15/2013.	Photo Science Geospatial Solutions for FEMA Region VIII
Land Use Map	2011 National Land Cover Dataset (NLCD)	USDA/NRCS
Land Ownership Map	Weld County Assessor Ownership Parcel Map (polygons); 2014	Weld County Assessor
Land Ownership Map	Larimer County Assessor Ownership Parcel Map (polygons); 2014	Larimer County Assessor
Land Ownership Map	Boulder County Assessor Ownership Parcel Map (polygons); 2014	Boulder County Assessor
Physiography Map	Map of Physiographic Divisions of the Conterminous U. S.; 1946	USGS

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2 WATERSHED DESCRIPTION AND EVALUATION

This Master Plan is based on general scientific and engineering knowledge of the function of river systems, applied to the Little Thompson Watershed to evaluate post-flood conditions and to develop conceptual recommendations for recovery and restoration of the river. Both qualitative and quantitative information were employed, where available, to develop a thorough understanding of the system, and to support long- and short-term recovery and planning decisions. The following sections provide a general description of the watershed and highlight areas where, based on the lack of available data, additional information and analysis are recommended to improve the understanding of the watershed and river system.

2.1 Geomorphic Setting

The geomorphic characteristics along the watershed were assessed to develop an understanding of the factors that control the behavior of the Little Thompson River. Located on the eastern slope of the Front Range of the Rocky Mountains (**Figure 2.1**), the upper portion of the watershed (canyon reach) is relatively steep (channel gradients typically ranging from 1 to more than 3 percent) and largely canyon-bound. The channel bed profile and planform in this area are largely controlled by the valley alignment, geology, and associated bedrock outcrops. The lower portion of the watershed (plains reach) flattens to gradients of approximately 0.25 percent as the river drains onto the Colorado Piedmont of the Great Plains physiographic province (Figure 2.1) (Williams and Chronic 2014). Between the canyon and plains reaches lies a transitional section referred to as the foothills reach. The foothills reach transitions from the steep gradients of the canyon reach to the flatter gradients of the plains reach, where the canyon walls and floodplain widen as the valley walls open to the plains. The Little Thompson River connects downstream with the Big Thompson River and then the South Platte River, which ultimately drains onto the High Great Plains.

The highest portion of the basin consists largely of metamorphic and igneous rocks of the Early and Middle Proterozoic Age, specifically Biotite Schist and Silver Plume Granite (**Figure 2.2**) (Stoeser et al. 2007; USGS 1990 and 1976). As the basin progresses downstream toward the interface with the Great Plains surface, it rapidly passes through various sandstone and limestone formations of typically Permian and Pennsylvanian Age. During development of the Colorado Piedmont, the top layer of the Upper Cretaceous sandstone eroded, exposing the underlying layer of Pierre Shale, sedimentary rock of the Upper Cretaceous that dominates the lower portion of the Little Thompson River (Figure 2.2) (Stoeser et al. 2007; USGS 1990 and 1976; Williams and Chronic 2014).

According to numerous available soil surveys (U.S. Department of Agriculture [USDA] 2013a, 2013b, 2013c, and 2014), soils within the upper part of the basin consist largely of colluvium and residuum weathered from igneous and metamorphic rock. The near-surface soil profiles are commonly gravelly sandy loam. The somewhat shallow soils occur on relatively steep slopes, have low shrink-swell potential, and are somewhat excessively drained. The shallow soils and steep slopes limit infiltration potential and cause rapid runoff during intense storms. Along the lower-elevation foothills, the soils are still somewhat shallow, are well-drained, and consist mainly of loams, clay loams, and sandy loams that formed in material weathered from sandstone (USDA 2013b and 2013c). Along the plains, soils are generally deep with nearly level to moderate slopes. They consist of well drained loams, silt loams, and clay loams that formed in alluvium, eolian deposits, and materials weathered from shale, primarily from fans, terraces, and uplands (USDA 2013c and 2014). These various geologic areas within the watershed also correlate very strongly with the different land use applications. Based on 2011 National Land Cover Data (NLCD), the upper portion of the basin is primarily evergreen forest, the lower-elevation foothills are made up largely of grassland and scrubland, and the downstream portion of the basin is covered with pasture and crop land, in addition to the few localized urban areas (**Figure 2.3**).

Valley widths upstream of Stagecoach Trail (near the confluence with the North Fork on Figure 1.1) and to some extent upstream of the canyon mouth at the Boulder-Larimer County line (upstream of Parrish Ranch), are narrow, with the river occupying a significant portion of the valley bottom. The bankfull width-depth ratio is often used to compare the shapes of different channels for assessing their relative stability and state of adjustment to the upstream water and sediment supply. Width-depth ratios for coarse-grained streams that are free to adjust laterally and that are in a state of approximate equilibrium typically range from about 30 to 40 (Chorley et al. 1984; Parker 1979; Andrews 1984). In contrast, although limited data are available, it appears that the pre-flood width-depth ratios in the upper reach of Little Thompson River were considerably lower, closer to values of 20 likely the result primarily of the confined nature of the channel from the narrow valley bottom and possibly reduced or limited flow, which allowed for vegetation encroachment. In some locations, the valley bottom is further narrowed by roads, property development, or infrastructure, all contributing to the space that is available for the river to adjust laterally. The limited overbank area where high, out-of-bank flows can spill, and the low width-depth ratios, cause flow confinement and very intense hydraulic conditions within the channel, which lead to severe erosion of both the channel bed and banks and associated damage to adjacent property and infrastructure during high flows. The channel incised significantly, and eroded laterally where possible, throughout much of the reach upstream of the canyon mouth during the 2013 flood. In most cases, the width-depth ratios of the post-flood channels have increased significantly.

The channel is not as confined downstream of the canyon mouth. As a result, flood flows were able to spill out of bank, which reduced the erosive forces within the channel. The reduced hydraulic intensity and the significant amount of sediment delivered out of the higher-elevation sections of the river resulted in considerable sediment deposition both within the channel margins and along the overbanks. Some degree of bank erosion and lateral channel migration still occurred in these downstream reaches because the relatively high velocities were directed at tight bends in the sinuous portions of the river.

2.2 Hydrology

An understanding of the hydrology is required to provide a basis for assessing the characteristics of the Little Thompson River. All available hydrologic information for the project area was reviewed, including historical discharge records and previous hydrologic analyses. The investigation revealed that very little flow data exist for the Little Thompson River, as discussed in the following sections.

2.2.1 Background

The Little Thompson River flows east through the foothills of the Rocky Mountains to the high plains of northern Colorado (**Figure 2.4**). Its headwaters are located on the peaks of Twin Sisters in the Roosevelt National Forest just south of Estes Park, Colorado, at an elevation of about 11,400 feet. The river flows about 50 miles as it descends almost 6,700 feet to an elevation of about 4,730 feet at the confluence with the Big Thompson River in the Town of Milliken, Colorado.

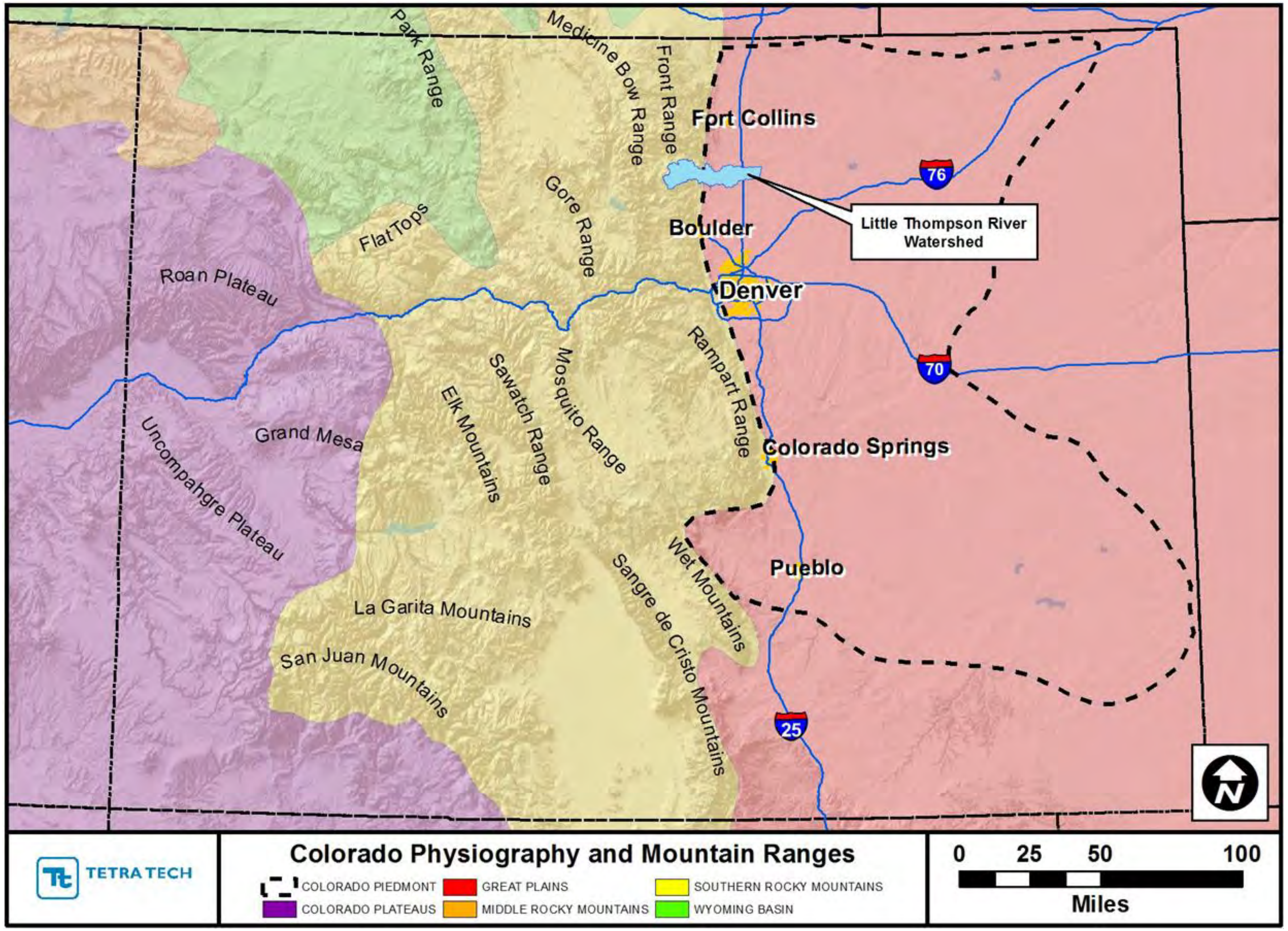

Figure 2.1. Map of Colorado physiography and mountain ranges.

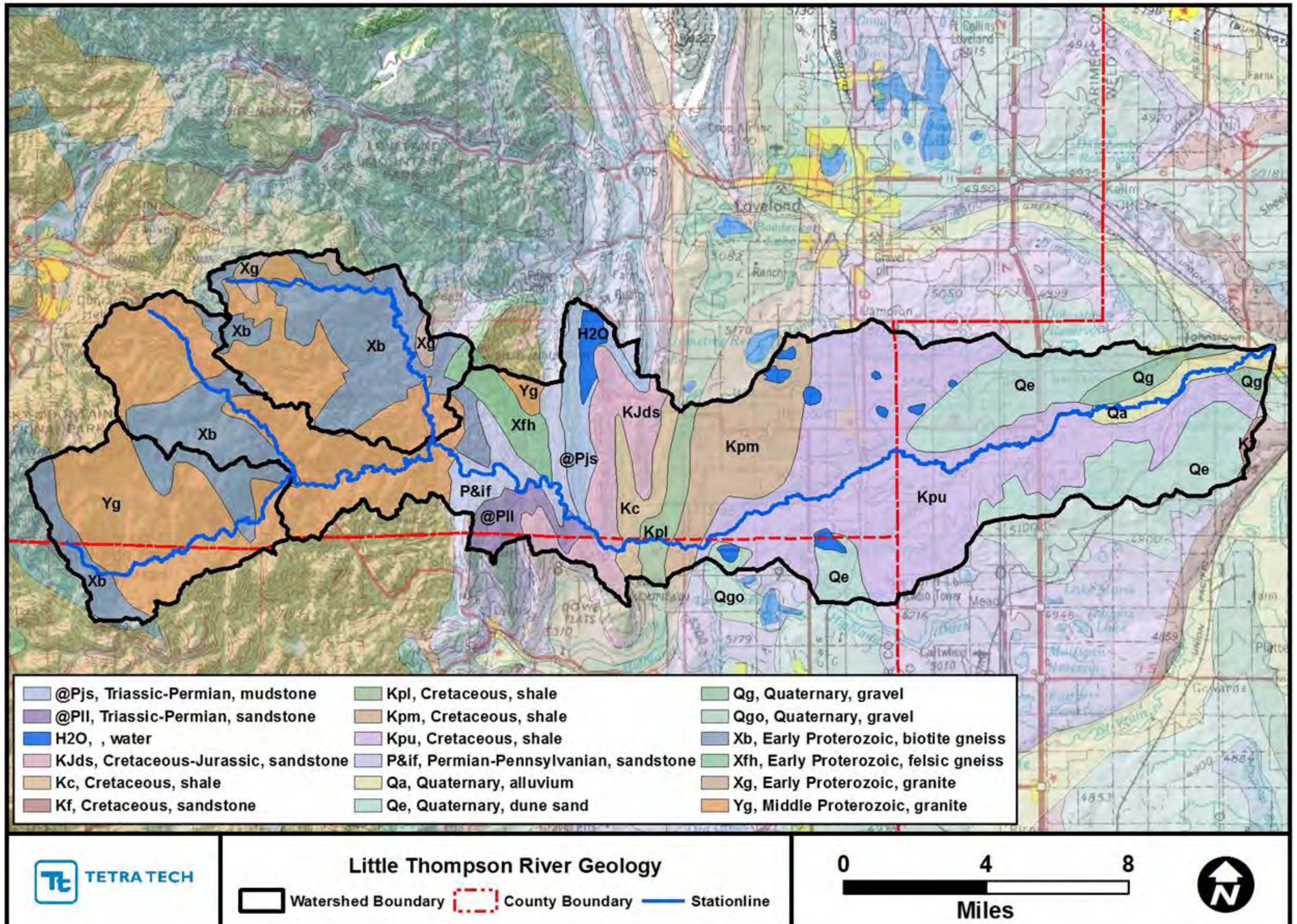

Figure 2.2. Geologic map of Little Thompson River watershed (Source: Stoeser et al., 2007).

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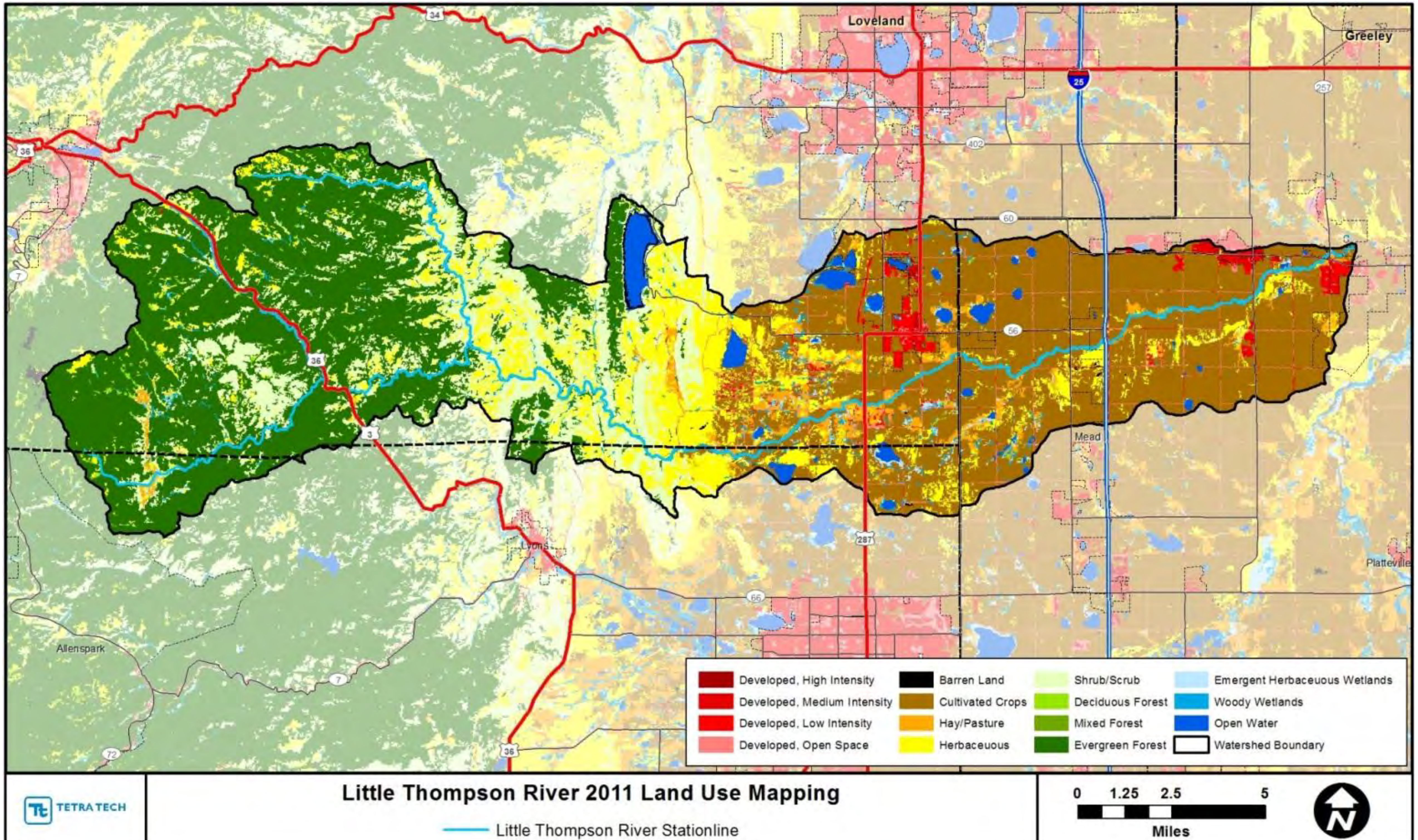

Figure 2.3. Land-use map of Little Thompson River watershed (Source: National Land Cover Data, 2011).

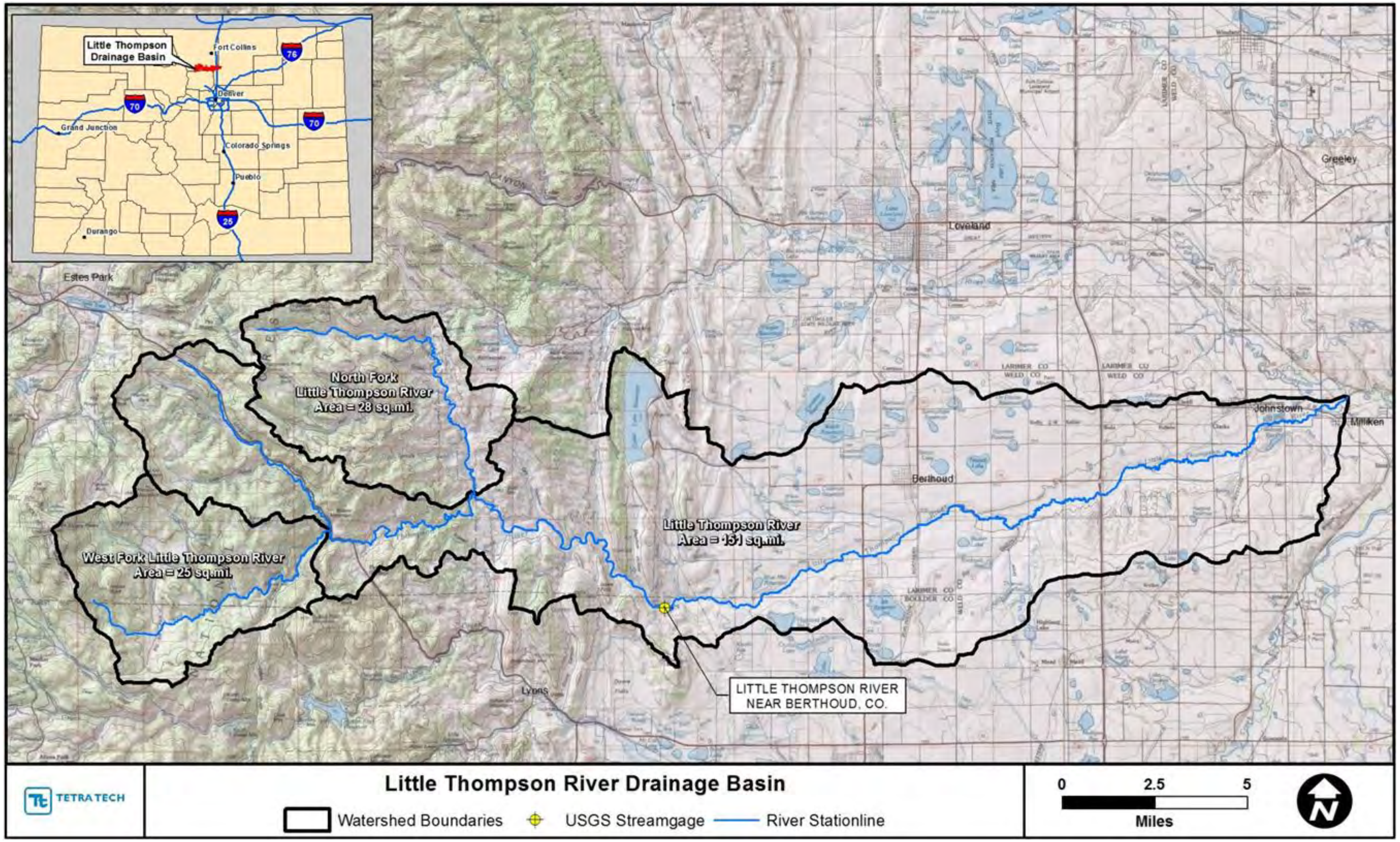

Figure 2.4. Map of the Little Thompson River drainage basin.

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In its entirety, the Little Thompson River watershed has a drainage area of approximately 204 square miles (**Table 2.1**).

Table 2.1. Summary of areas and stream lengths for the Little Thompson Watershed.

Basin	Drainage Area (sq. mi.)
Little Thompson River	151
North Fork	28
West Fork	25
Total	204

The river is used as a source for both domestic and irrigation water. Five in-line water-supply dams exist along the West Fork to support the Big Elk Meadows neighborhood (**Figure 2.5**). Flows can be added to the Little Thompson River through deliveries from the Colorado-Big Thompson (CBT) project. Inflows from CBT occur on the North Fork at Pole Hill power plant and at the St. Vrain Supply Canal (Figure 2.5). Numerous irrigation diversions also exist along the river between the canyon mouth and the Town of Milliken (Figure 2.5 and **Figure 2.6**). The amount, frequency, and timing of flow diversions warrant additional study, outside the scope of this Master Plan, for assessment and consideration of addressing instream flows.

Flood flows on the Little Thompson River can occur during both the spring and late summer to early fall. The upper part of the watershed is not very high in elevation compared with adjacent basins, which can somewhat limit snowpack quantities. Based on available stream flow data, approximately two-thirds of the recorded annual peak discharges are associated with spring snowmelt runoff or rain-on-snow events. The late summer and early fall floods are caused by prolonged rainfall and intense thunderstorms, which can be significant. Before the September 2013 flood, the three largest floods of record occurred in May, June, and August, indicating a combination of precipitation sources.

2.2.2 September 2013 Flood

The flood event in September 2013 was one of the relatively few high-flow events on record that occurred during late summer and early fall and is the largest event on the Little Thompson River in recorded history. A late season subtropical air mass brought substantial and widespread rainfall to the Colorado Front Range. Rainfall occurred within the Little Thompson watershed from September 8 to 18, 2013, which resulted in accumulated rainfall depths of up to about 15 inches.

In addition to damaging homes, land, and infrastructure, the flood destroyed stream flow gages (including the single one on the Little Thompson River) and caused significant erosion and channel adjustments, all of which made measurement of flood flows extremely challenging. As a result, numerous agencies and entities applied indirect methodologies that use observed high-water marks and hydraulic parameters to develop estimates of the peak discharge. **Table 2.2** summarizes the available estimated 2013 peak discharges at various locations along the river.

2.2.3 Stream Gage Data

Only one stream flow gage has historically been operated in the watershed. The gage on the Little Thompson River near Berthoud, Colorado, is essentially located at the mouth of the canyon near the Boulder-Larimer County line south of Carter Lake (Figure 2.5). The gage was initially maintained by the USACE in 1929 and 1930. It was then reestablished by the USGS (USGS Gage No. 06742000) in 1947, and maintained through 1961. The gage was once again reactivated, and the CDWR (Gage ID: LTCANYCO) has maintained the gage and records since 1993, until the gage was destroyed during the September 2013 flood. In total, the gage has a 36-year record between 1929 and 2012.

Table 2.2. Summary of estimated 2013 Flood peak discharges along the Little Thompson River.

Location	Estimated Peak Discharge (cfs)	Source
Little Thompson River approx. 3.5 miles upstream of West Fork confluence	2,470	Jarrett (2013)
Little Thompson River immediately upstream of West Fork confluence	2,680 2,420	Jarrett (2013) CDWR (2014)
West Fork upstream of mainstem confluence (downstream of Big Elk Meadow dams)	6,200 6,215	Jarrett (2013) CDWR (2014)
Little Thompson River immediately downstream of West Fork confluence	7,800 12,300	Jarrett (2013) CWCB (2014)
Little Thompson River at Pinewood Springs	14,600	NRCS (2013)
Little Thompson River near X Bar 7 Subdivision	15,730	CDWR (2014)
Little Thompson River near I-25	14,500	CWCB (2014)

During the available 36-year period of record, it does not appear that the gage was consistently operated during the winter. As a result, only the mean daily flows for the 6 months between April and September were included in the analysis. Based on the available gage data, a mean daily flow-duration curve was developed for the six growing season months (**Figure 2.7**). Based on the flows measured at the mouth of the canyon, which do not account for downstream diversions that could alter downstream flows in the river, the median flow on the Little Thompson River is about 2 cubic feet per second (cfs), and the 10-percent exceedance discharge (one in ten chance of flow being greater than) is about 50 cfs (Figure 2.7).

A peak flood-frequency analysis was also performed using data from the Little Thompson River near Berthoud gage. Recorded annual peak discharges range from only 8 cfs in 2006 to 4,000 cfs in 1957 (**Figure 2.8**). Discharges were not recorded during the 2013 flood event because flows destroyed the gage. However, based on the estimated flood flows in Table 2.1, the 2013 peak discharge at this location was likely greater than 14,000 cfs. The flood-frequency analysis was conducted based on procedures outlined in Water Resource Council (WRC) Bulletin 17B (WRC 1981). The analysis indicates that the 2- and 5-year recurrence interval floods on the Little Thompson River near the canyon mouth are about 330 and 1,180 cfs. These flows are shown on a flood-frequency curve, which is a graph showing the relationship between flood magnitude and their recurrence interval for a specified site (**Figure 2.9**). The 100-year recurrence interval flood at the near Berthoud gage is approximately 9,300 cfs. Based on the computed curve, the 2013 flood exceeded the 100-year recurrence interval flood.

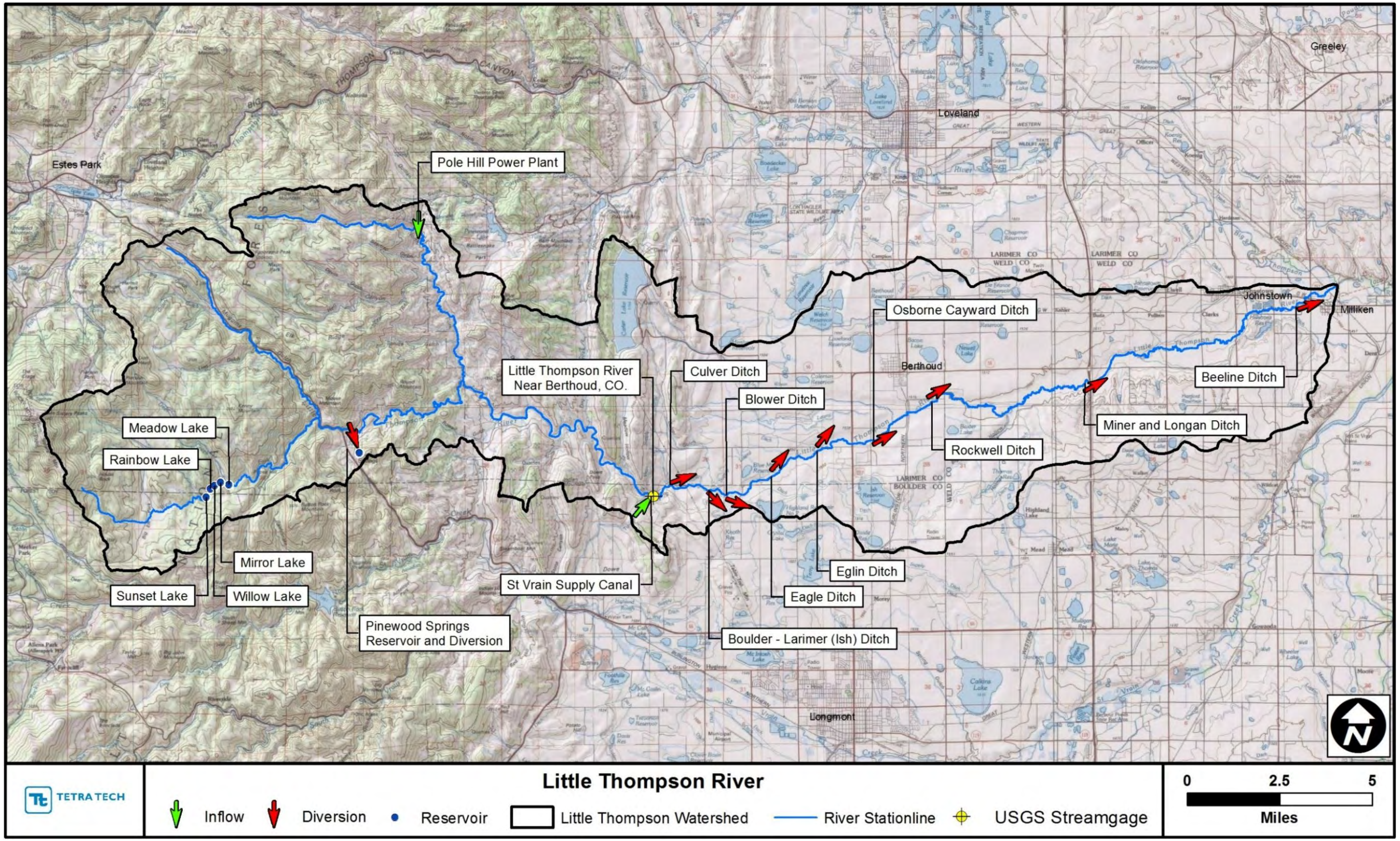

Figure 2.5. Map of the Little Thompson River watershed showing location of in-line reservoirs, inflows, and diversions.

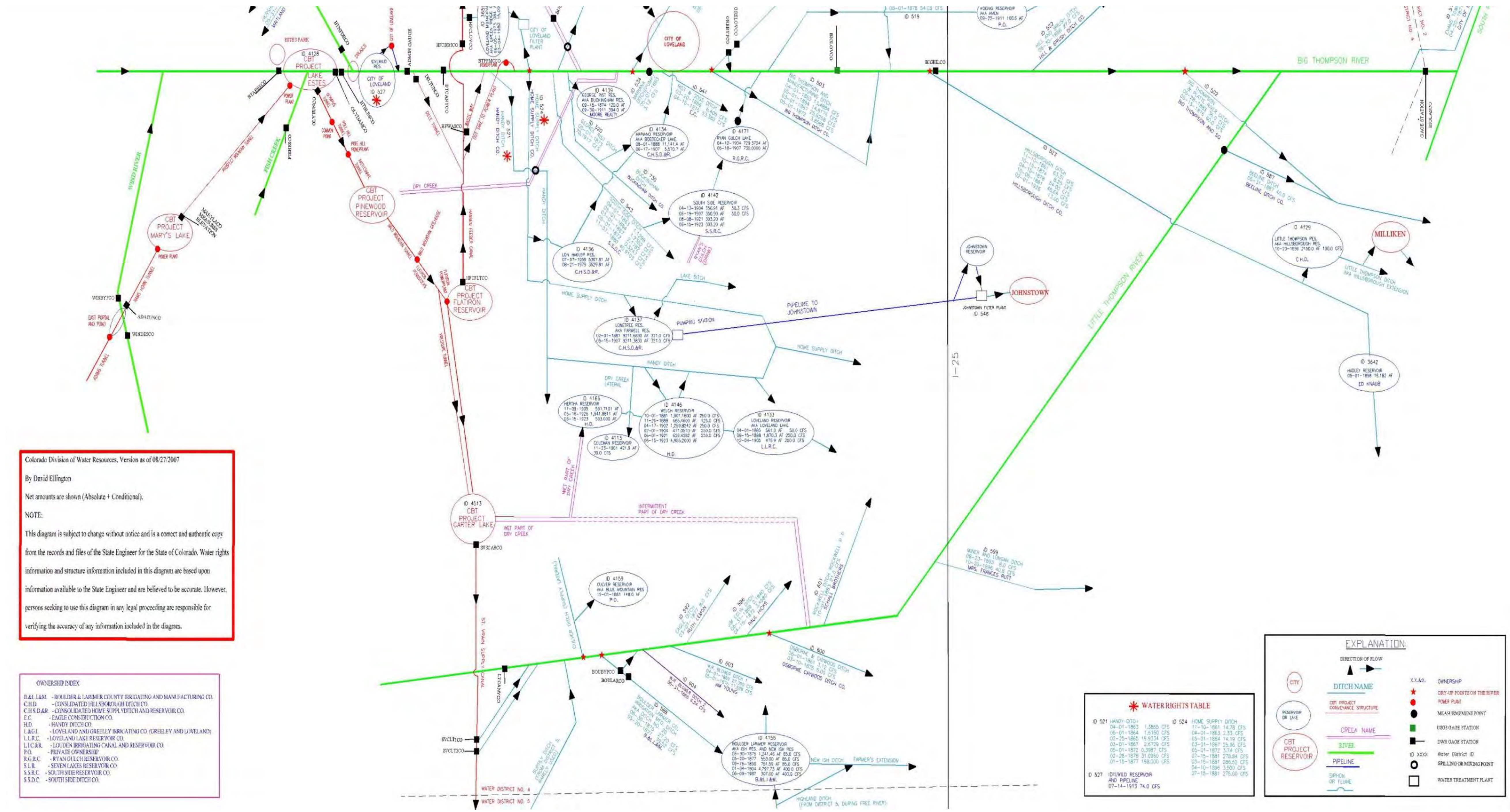

Figure 2.6. Schematic diagram of inflow and outflow locations along a portion of the Little and Big Thompson Rivers (Division 1, District 4) (source: Colorado Division of Water Resources).

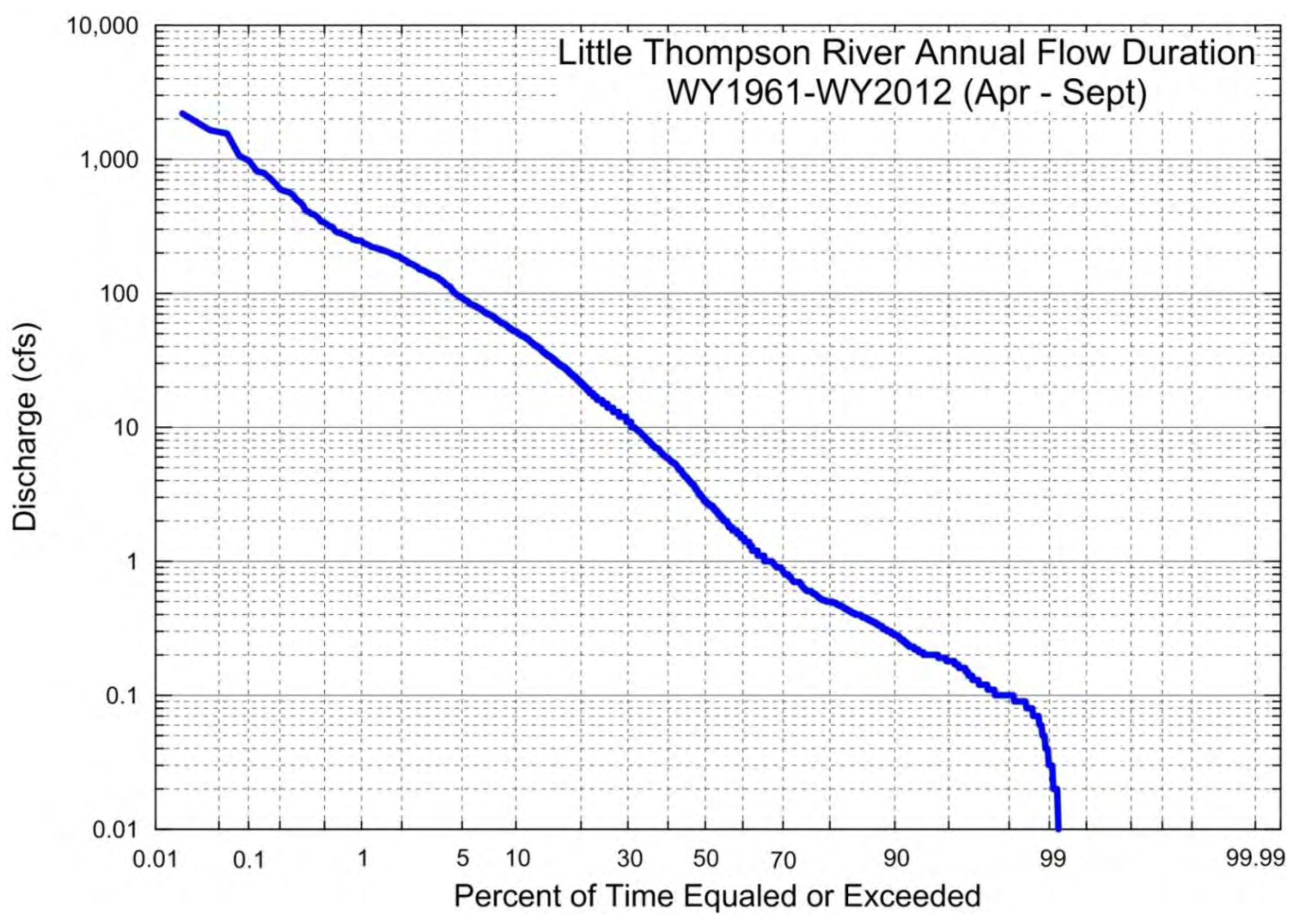

Figure 2.7. Computed mean daily flow-duration curve for the Little Thompson River near Berthoud gage for the broken period-of-record between Water Years (WY) 1921 and 2012 and months April through September.

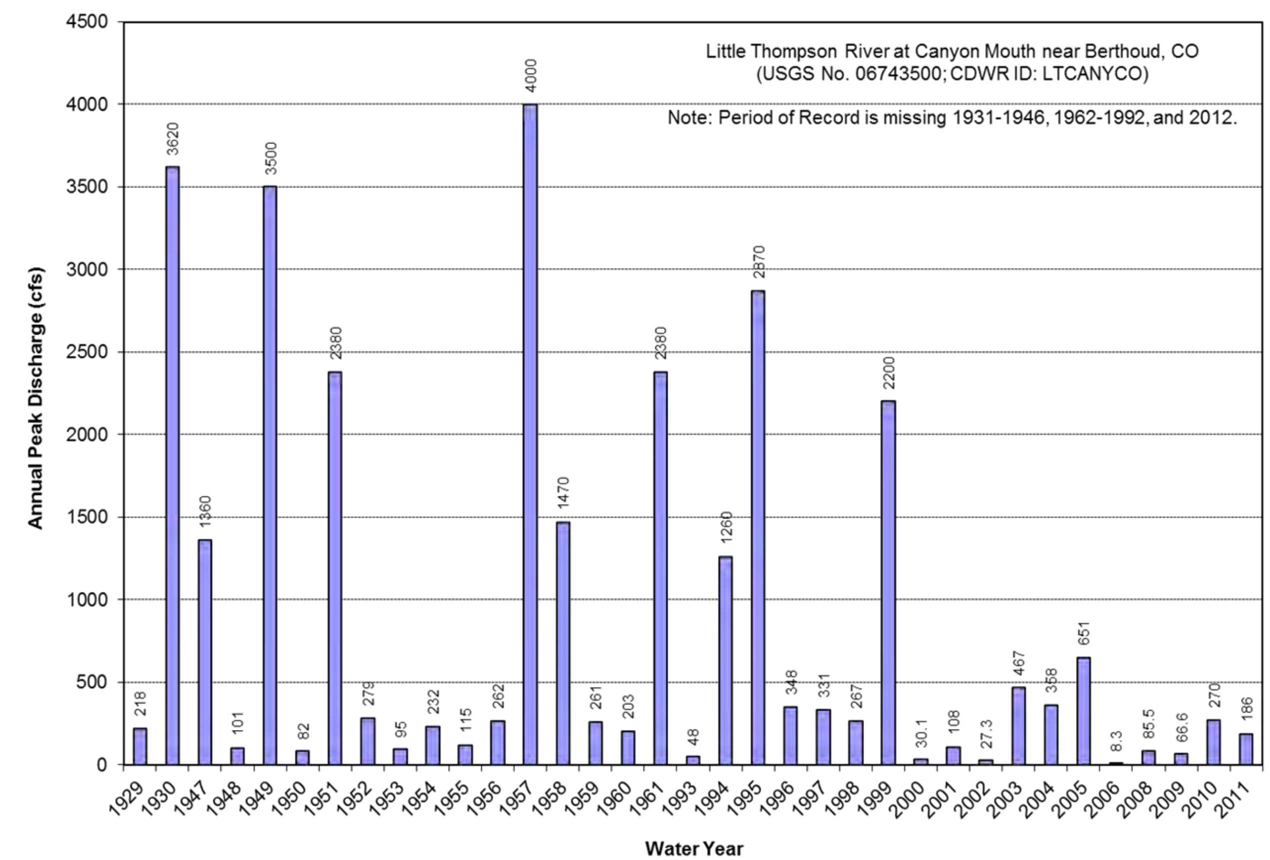

Figure 2.8. Recorded annual peak discharges for the Little Thompson River near Berthoud gage for the broken period-of-record between Water Years (WY) 1921 and 2011.

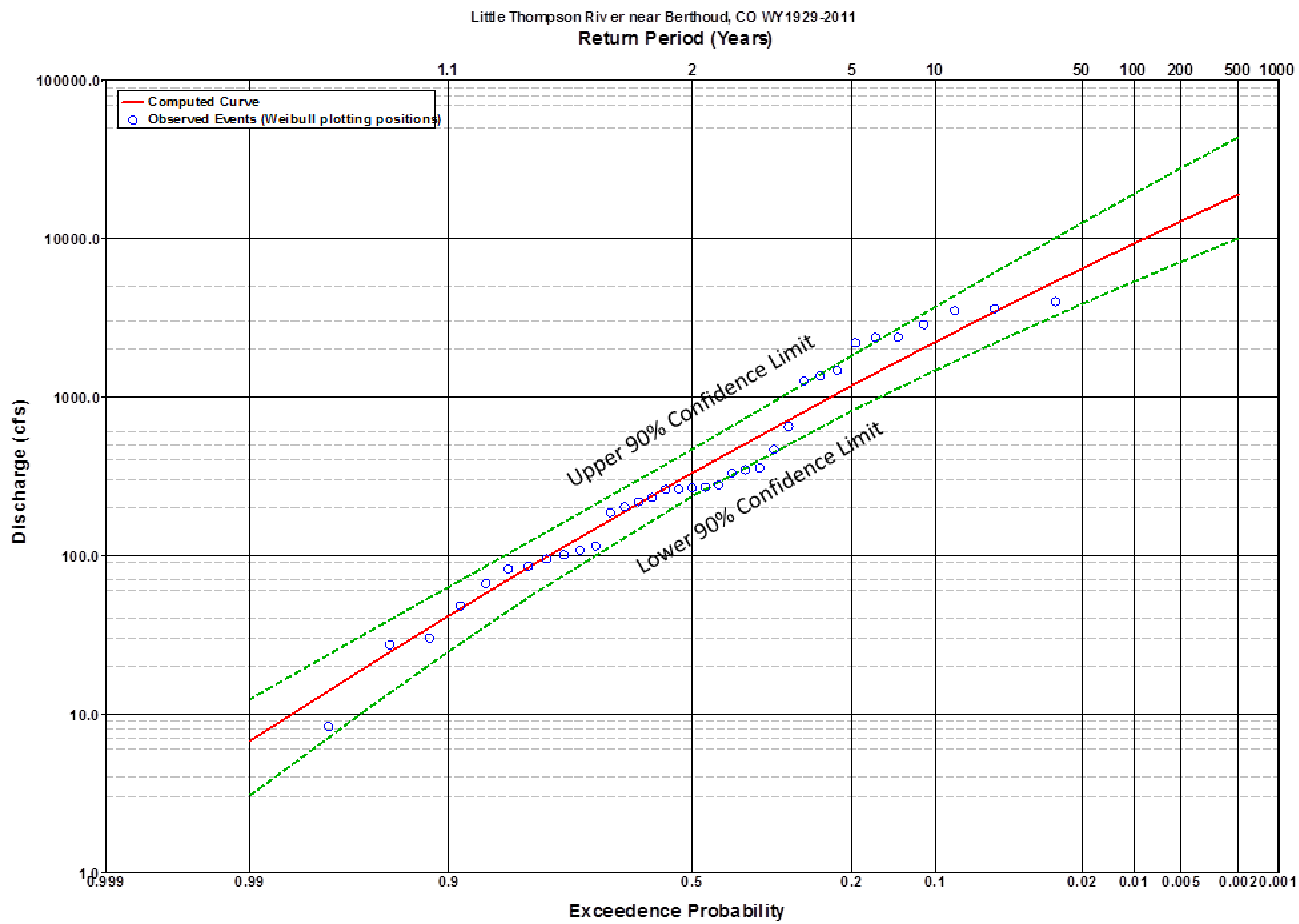

Figure 2.9. Computed flood-frequency curve for the Little Thompson River near Berthoud gage for the broken period-of-record between Water Years (WY) 1921 and 2011.

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2.2.4 Existing Studies

In addition to flow estimates based on regional regression equations, four studies have been published to date documenting hydrologic analyses of the Little Thompson River, as follows:

1. Little Thompson River Hydrology Analysis in support of Flood Insurance Study / Map Revision, Larimer County, Technical Support Data Notebook (TSDN) (Ayres 2010). This document was developed in support of the latest revision to the Larimer County Flood Insurance Study published in 2013. Results are based on regional regression equations. Results predict 100-year recurrence interval flows of 8,000 cfs at Larimer County Road 23E and 9,500 cfs at the Larimer-Weld County Line.

2. Little Thompson River Hydrology Analysis – I-25 Frontage Road Mile Marker 249.847, Weld County, Colorado (CDOT 2011). This document was developed in 2011 for the Colorado Department of Transportation. It is based on a hydrologic model (HEC-HMS) that extends from the head of the watershed downstream to Interstate 25. Model results predict 10-year and 100-year recurrence interval flows at I-25 of 5,540 and 14,730 cfs.

3. Report of September 2013 Little Thompson River Flooding and Big Elk Meadows Dam Failures (CDWR 2014). This document summarizes the results of a hydrologic model (HEC-HMS) that extends from the head of the watershed downstream to the X Bar 7 Subdivision (Blue Mountain neighborhood). Predicted flows are indicated in Table 2.1.

4. Little Thompson River Hydrologic Analysis (CH2MHill 2014). This document was developed for the Colorado Department of Transportation in conjunction with the Colorado Water Conservation Board. It is based on a hydrologic modeling analysis (HEC-HMS) that extends from the head of the watershed downstream to Highway 36 near Pinewood Springs. Calibration data for the model were based on flows developed by Jarrett (2013) indicated in Table 2.1. Model results predict 10- and 100-year recurrence interval flows at Highway 36 of 650 and 3,460 cfs.

2.2.5 FEMA Studies and Effective 100-year Discharges

No regulatory discharges have been approved by the Federal Emergency Management Agency (FEMA) for the upper portion of the Little Thompson River watershed. However, regulatory discharges partially exist within Boulder, Larimer, and Weld Counties downstream of County Road 23E (**Table 2.3**). Most of the effective (regulatory) discharges along the lower portion of the river are based on studies conducted by the USACE between 1974 and 1977 (USACE 1974 and 1977; CWCB 1977), and Ayres Associates Inc. in 2010 (Ayres 2010).

The flood-frequency analysis of the peak flow data at the Little Thompson River near Berthoud gage indicated that the 100-year recurrence interval flow is about 9,300 cfs. This result is slightly higher, but within the same order of magnitude as, the nearest published regulatory 100-year discharge of 8,000 cfs (Table 2.3).

2.2.6 Future Studies

Contemporary estimates of the hydrologic characteristics of the Little Thompson River are necessary for design and implementation of future repair and restoration goals. Based on communication with representatives of the CWCB, that agency, in conjunction with CDOT, plans to expand the 2014 HEC-HMS model that currently exists (head of the watershed to Highway 36 near Pinewood Springs), downstream to the confluence with the Big Thompson River. This hydrologic model could ultimately be used to finalize hydraulic designs and develop regulatory flood discharges along the length of the entire Little Thompson River.

Table 2.3. Summary of FEMA Effective Discharges along the Little Thompson River published in Flood Insurance Studies (FIS) for Boulder, Larimer, and Weld Counties.

Location	1-Percent Annual Chance (100-yr) Discharge (cfs)	Source
At Larimer County Road 23E	8,000	Larimer County FIS (2013)
At Larimer County Road 21	8,300	Larimer County FIS (2013)
At Larimer County Road 17	8,600	Larimer County FIS (2013)
At Confluence with Dry Creek	9,200	Larimer County FIS (2013)
At Larimer-Weld County Line	9,500 7,200	Larimer County FIS (2013) Boulder County FIS (2012)
At Milliken	4,800	Weld County FIS (Preliminary 2013)

2.2.7 Reservoirs

There are five reservoirs on the West Fork, all of which were located in the unincorporated development of Big Elk Meadows. Water is supplied to this community by the Big Elk Water Association, using augmented wells to fill reservoirs that are used for irrigation and domestic use. All five reservoirs failed during the 2013 flood, and all five will be reconstructed. The reservoirs are on-channel structures, constructed in the 1950s to provide a water supply to the Big Elk Meadows community. In a report prepared by the State Engineers office after the 2013 flood (CDWR, 2014), the impact of the dam failures on flood stages downstream was assessed. The state concluded that the dam failures did not cause incremental damages in the downstream channel and that the volume of water from the dams was insignificant relative to the total storm runoff volume and duration. The five dams had a combined normal storage capacity of 125.65 acre-feet and a combined maximum storage of 248.13 acre-feet.

There are two off-line reservoirs filled by water from the Little Thompson. The first serves the Pinewood Springs neighborhood. Water is diverted at the water treatment plant located at Cree Road crossing (Sta. 2200+00 on Figure 1.1) and pumped up to the reservoir located approximately 1 mile away and 200 feet above the river (Figure 2.5). Generally, flows are diverted to the reservoir during spring runoff and stored for use later in the year. The Ish Reservoir is located at the corner of Highway 287 and West County Road 2E, overlapping both Larimer and Boulder Counties. The headgate for the Ish Reservoir is located about 1 mile west of 83rd Road.

Other than the small reservoirs associated with Pinewood Springs, Big Elk Meadows, and the Ish Reservoir, there are no major reservoirs that capture Little Thompson River flows. Carter Lake is basically on the divide between the Big Thompson and Little Thompson, but it is fed by trans-basin CBT water. Likewise, water in Dry Creek Reservoir is mostly trans-basin water from CBT.

2.2.8 Diversions

There are a total of nine ditches on the river. Between 2003 and 2012, they had a combined average annual diversion near 7,000 acre-feet. Northern Colorado Water Conservancy District can deliver CBT water from Carter Lake into the St. Vrain Supply Canal, then into the Little Thompson for distribution to the various ditch companies.

Irrigated lands near Berthoud and downstream cause significant groundwater and surface-water return flows to the river. These flows, along with effluent releases from the Berthoud wastewater treatment plant, result in low, but steady, flows, particularly from east of Berthoud to the Big Thompson confluence. Upstream of Berthoud the combined effects of diversions will often dewater the river (LTWRC 2014).

2.2.9 Water Supply

Flow conditions on the Little Thompson are highly variable, and in the late summer and fall, flows often are reportedly reduced to a trickle, as mentioned by several property owners and supported by the records downstream at the near Berthoud gage (USGS Gage No. 06742000), where extensive periods of zero flow were observed as far back as the late 1940s to early 1960s. These flows are likely the result of a combination of natural hydrologic conditions and diversions for water supply and agriculture.

2.3 Hydraulics and Extent of Flooding

Conceptual recommendations for recovery and restoration can be developed based on the geomorphic assessments of the Little Thompson River. However, a thorough understanding of both the hydrologic and hydraulic characteristics of the river is necessary to refine those concepts into actual designs that will meet the goals for resiliency and stability of the river, while also adhering to regulatory requirements. The hydrology, as discussed above, generally describes the flow regime characteristics of the basin. The purpose of a hydraulic analysis is to estimate the typical in-channel and overbank hydraulic characteristics (velocity, depth, shear stress, water-surface elevations, and floodplain boundaries) within the study reach for a range of discharges.

Very little analysis of the hydraulic conditions along the Little Thompson River has been conducted before the 2013 flood. A few approximate studies were previously performed, largely by USACE, along discrete segments of the river in support of earlier Flood Insurance Studies (FIS). These studies included the delineation of regulatory (100-year flood event) floodplain boundaries. However, not only are many of these studies based only on approximate methods, but they all represent pre-flood conditions along the river. A more recent study was conducted in 2010 in support of the current Larimer County FIS (2013) specified in the hydrology section above (Table 2.3), which included revised flow estimates, but the channel geometry was still based on the same data collected in 1974 and 1977. These pre-existing studies provide very little value for estimating current hydraulic conditions along the river because of the significant changes to the channel (dimensions, vertical profile, and planform alignment) that occurred during the 2013 flood.

Preliminary floodplain mapping was also prepared by the Colorado Water Conservation Board following the 2013 flood. It is Tetra Tech's understanding that this modeling was based on LiDAR mapping collected along the river immediately after the flood. However, the hydraulic parameters and results of the model were not used in this Master Plan because of the uncertainty of the assumptions in development of the model and the specific discharges used to develop the boundary conditions. Thus, recommendations in the Master Plan are based on the in-field geomorphic assessments, evidence of flooding extent, channel dimensions in relatively undisturbed areas, and other ancillary data. This Master Plan strongly recommends that before the recommendations presented in this report can be designed, a detailed hydraulic model and detailed floodplain mapping of the project site and/or all of the Little Thompson River should be developed, and be based on complete and current topography and bathymetry (including the sub-aqueous portion of the channel) to provide a better understanding of the post-flood behavior of the channel, assist with development of final planform recommendations, facilitate sediment transport analyses, and to help comply with future FEMA regulatory requirements.

2.4 Vegetation and Wetlands

2.4.1 Overview

Riparian vegetation in the Little Thompson Watershed is generally characterized by riparian woodlands and shrublands. Riparian woodlands and shrublands are dominated by various willow species (*Salix* spp.), narrowleaf cottonwood (*Populus angustifolia*), plains cottonwood (*Populous deltoides*), and mixed grasslands. Many plant and animal species depend on the riparian habitat characteristics, such as the surface-water regime, groundwater levels, water quality, and aquatic ecosystem components. Vegetation coverage depends on elevation, slope, aspect, groundwater availability, and surface-water regimes.

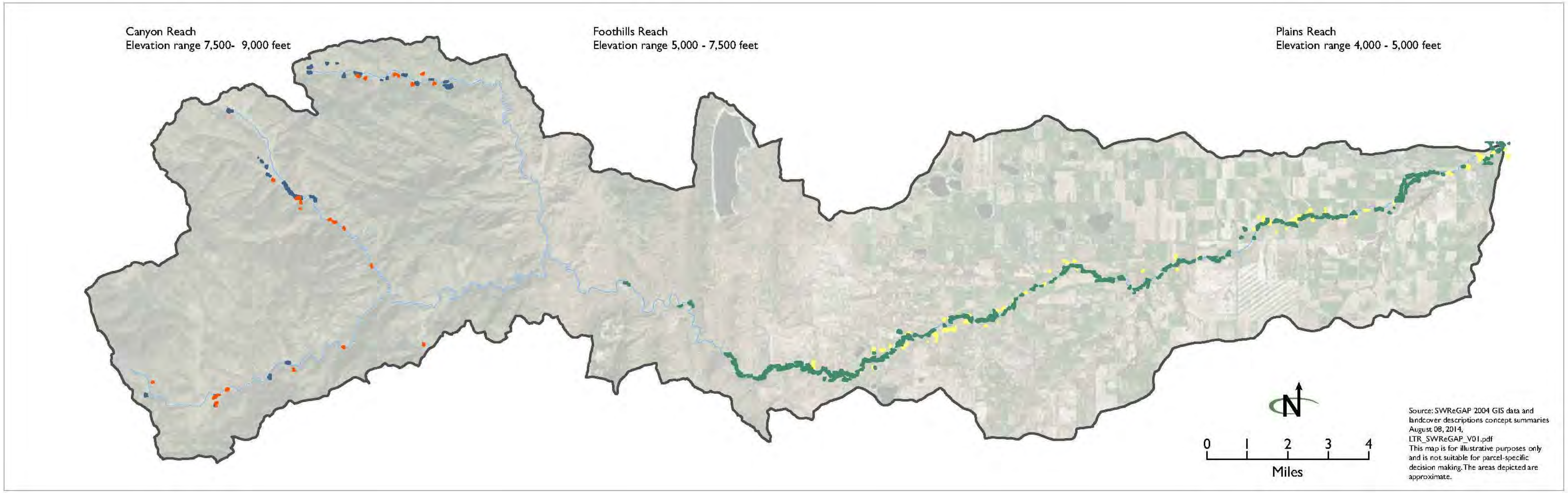
Many wildlife species also closely depend on the riparian habitat. The diversity of the riparian corridor affects wildlife utilization by providing cover and forage. Species in this area that depend on the riparian habitat may include Preble's meadow jumping mouse (*Zapus hudsonius preblei*), Iowa darter (*Etheostoma exile*), and plains stonefly (*Mesocapnia frisoni*).

2.4.2 Pre-flood Conditions

The Little Thompson River flows through a transitional zone extending from the high elevation in the Roosevelt National Forest and through the plains. The watershed has historically provided habitat for plant and animal species, including those that are considered sensitive species and should receive special consideration in restoring stream channel and upslope area. Riparian vegetation in the Little Thompson Watershed is generally dominated by various willow (*Salix* spp.), narrowleaf cottonwood (*Populus angustifolia*), plains cottonwood (*Populous deltoides*) and mixed shrublands and grasslands.

The Southwest Regional Gap Analysis Project (SWReGAP) vegetation data was used to characterize the riparian vegetation of the Little Thompson Watershed. SWReGAP uses satellite imagery from 2000 and 2001 and digital elevation model derived datasets (such as elevation, landform, and aspect) to model and classify natural and semi-natural vegetation. SWReGAP also publishes descriptions of their classifications as land cover descriptions. Four major riparian vegetation types are within the Little Thompson watershed: (1) Rocky Mountain Subalpine-Montane Riparian Shrubland (canyon reach), (2) Rocky Mountain Subalpine-Montane Riparian Woodland (canyon reach), (3) Western Great Plains Riparian Woodland and Shrubland (foothills and plains reaches), and (4) Western Great Plains Floodplain Herbaceous Wetland (foothills and plains reaches) (**Figure 2.10**). The narrow canyon walls along many sections of the canyon and foothills reaches were, under pre-flood conditions quite narrow with a narrow band of vegetation that is not graphically represented in Figure 2.10. Vegetation in these narrow reaches is described in the following sections.

While relatively homogenous in variety, the density and distribution of vegetation can be delineated into three reaches within the watershed: the upstream canyon reach, the middle foothills reach, and the downstream plains reach. The vegetation composition within each of these reaches is discussed below and



SWReGAP Pre-flood Riparian Vegetation

SWReGAP vegetation data was used to characterize the riparian vegetation of the Little Thompson Watershed. SWReGAP uses satellite imagery from 2000 - 2001 and digital elevation model derived datasets (e.g. elevation, landform, aspect) to model and classify natural and semi-natural vegetation. SWReGAP GIS data for Boulder, Larimer, and Weld counties was clipped to the Little Thompson Watershed Coalition project area and riparian vegetation is displayed.

Rocky Mountain Subalpine-Montane Riparian Woodland, 25 acres Seasonally flooded forests and woodlands found at montane to subalpine elevations. This system contains the conifer and aspen woodlands that line montane streams. These communities are tolerant of periodic flooding and high water tables. Dominant tree species include fir, Engelmann spruce Douglas fir, spruce, aspen, and Rocky Mountain Juniper and narrowleaf cottonwood.

Rocky Mountain Subalpine-Montane Riparian Shrubland, 70 acres Montane to subalpine riparian shrublands occurring as narrow bands of shrubs lining streambanks and alluvial terraces in narrow to wide, low-gradient valley bottoms and floodplains with sinuous stream channels. Generally it is found at higher elevations. The dominant shrubs reflect the large elevational gradient and include alder, birch, dogwood, and willow spp.

Western Great Plains Riparian Woodland and Shrubland, 593 acres Riparian areas of medium and small rivers and streams. These are found on alluvial soils in highly variable landscape settings, from deep cut ravines to wide, braided streambeds. Hydrologically, these tend to be more flashy with less developed floodplain than on larger rivers, and typically dry down completely for some portion of the year. Communities within this system range from riparian forests and shrublands to gravel/sand flats. Dominant species include plains cottonwood, willows spp., silver sagebrush, western wheatgrass, sand dropseed, and little bluestem. These areas are often subjected to heavy grazing and/or agriculture and can be degraded.

Western Great Plains Floodplain Herbaceous Wetland, 115 acres Floodplains of medium and large rivers. Alluvial soils and periodic, intermediate flooding (every 5-25 years) typify this system. Dominant communities within this system range from floodplain forests to wet meadows to gravel/sand flats; however, they are linked by underlying soils and the flooding regime. Dominant species include plains cottonwood and willow spp. Grass cover underneath the trees is an important part of this system and is a mix of tallgrass species, including switchgrass and big bluestem.

Little Thompson Watershed

Little Thompson River

Figure 2.10. SWReGAP Pre-flood Riparian Vegetation shows the location of these vegetation types.

summarized in **Table 2.4**. Vegetation noted here is intended to be informative, and not comprehensive. Thus, the list of vegetation is not extensive.

Table 2.4. Plant Species Known or Likely to Occur in the Little Thompson Watershed.
(Compiled from Colorado Natural Heritage Program and *Programmatic Biological Assessment; North I-25 – Adams, Boulder, Broomfield, Denver, Larimer, and Weld Counties, Colorado)*

Canyon Reach			
Common Name	*Scientific Name*	*Origin*	*Primary Location*
ponderosa pine	*Pinus ponderosa*	native	upland
lodgepole pine	*Pinus contorta*	native	upland
chokecherry	*Prunus virginiana*	native	riparian woodland
willows	*Salix* sp.	native and non-native	riparian woodland
plains cottonwood	*Populus deltoides*	native	riparian woodland
narrowleaf cottonwood	*Populus angustifolia*	native	riparian woodland
Foothills Reach			
plains cottonwood	*Populus deltoides*	native	riparian woodland
narrowleaf cottonwood	*Populus angustifolia*	native	riparian woodland
mountain-mahogany	*Cercocarpus montanus*	native	upland
snowberry	*Symphoricarpos albus*	native	riparian woodland
coyote willow	*Salix exigua*	native	riparian
crack willow	(*Salix fragilis*)	non-native	riparian
willows	*Salix* sp.	native and non-native	riparian
Plains Reach			
smooth brome	*Bromus inermis*	non-native	upland
coyote willow	*Salix exigua*	native	riparian
crack willow	(*Salix fragilis*)	non-native	riparian
willows	*Salix* spp.	native and non-native	riparian
plains cottonwood	*Populus deltoides*	native	riparian woodland
Siberian elm	*Ulmus pumila*	non-native	upland
snowberry	*Symphoricarpos* sp.	native	riparian woodland
horsetail	*Equisetum arvense* and *Hippochaete* sp.	native	wetland
spikerush	*Eleocharis* sp.	native	wetland
bulrush	*Schoenoplectus acutus*	native	wetland
cheatgrass	*Bromus tectorum*	non-native	upland
whitetop	*Cardaria* sp.	non-native	upland
Russian olive	*Elaeagnus angustifolia*	non-native	riparian
leafy spurge	*Euphorbia esula*	non-native	
myrtle spurge	*Euphorbia myrsinites*	non-native	
spotted knapweed	*Centaurea maculosa*	non-native	
diffuse knapweed	*Centaurea diffusa*	non-native	
musk thistle	*Carduus nutans*	non-native	
Canada thistle	*Cirsium arvense*	non-native	
common and moth mullein	*Verbascum*	non-native	
houndstongue	*Cynoglossum officinale*	non-native	
Dalmatian toadflax	*Linaria dalmatica*	non-native	

Canyon Reach

The Little Thompson River originates in the Roosevelt National Forest in moderate to steep gradient Ponderosa pine communities. Ponderosa pine is the predominant upland conifer with some lodgepole pine (*Pinus contorta)* communities present throughout the watershed. The stream corridor vegetation is composed mostly of riparian woodlands. The river is usually contained within narrow canyons with a steep river gradient and a river bottom usually made up of cobble, gravel, and hard rock materials. As a result of natural upstream landscape, flood regimes are the primary environmental factor influencing riparian vegetation (CNHP, 2004).

One of two riparian vegetation communities characterized by SWReGAP in the canyon reach is Rocky Mountain Subalpine-Montane Riparian Shrubland, covering about 70 acres as mapped. This community is characterized by montane to subalpine riparian shrublands occurring as narrow bands of shrubs lining streambanks and alluvial terraces in narrow to wide, low-gradient valley bottoms and floodplains with sinuous stream channels. Generally it is found at higher elevations. The dominant shrubs reflect the large elevational gradient and include alder (*Alnus* spp.), birch (*Betula* spp.), dogwood (*Cornus*, spp.), and willow (*Salix* spp.).

The second riparian vegetation community in the canyon reach characterized by SWReGAP is Rocky Mountain Subalpine-Montane Riparian Woodland, covering about 25 acres as mapped. This community is characterized by seasonally flooded forests and woodlands found at montane to subalpine elevations. This system contains conifer and aspen (*Populus tremuloides*) woodlands that line montane streams. These communities are tolerant of periodic flooding and high water tables. Dominant tree species include fir, Engelmann spruce (*Picea Engelmannii*), Douglas fir (*Pseudotsuga menziesii*), spruce, aspen (*Populus tremuloides*), Rocky Mountain Juniper (*Juniperus scopulorum*), and narrowleaf cottonwood (Populus *angustifolia)*.

Foothills Reach

As the Little Thompson flows east through lower canyon slopes and outcroppings toward the plains, the vegetation becomes shrublands characterized by exposed sites, rocky substrates, and dry conditions. The Foothills Reach spans from the confluence of the main stem and West Fork of the Little Thompson River to the St. Vrain supply canal (just south of Carter Lake Reservoir) and includes the downstream portion of the North Fork. This area comprises a mix of developed and rural lands and transitions from steep, hard rock canyons with dense ponderosa pine forest to flatter areas with a more moderate stream gradient. Poorly developed soils support vegetation from shrubland to riparian woodland communities (CNHP 2005a). This area contains sparse ponderosa pine trees, rocky outcrops, and plains vegetation. Narrowleaf cottonwood can be found in the rockier upstream areas. Plains cottonwood, (*Populus deltoides*), smooth brome (*Bromus inermis*), willow (*Salix* spp.), western chokecherry (*Prunus virginiana melanocarpa*),*)*, and wetland species such as horsetail (*Equisetum arvense* and *Hippochaete* sp.), spikerush (*Eleocharis* sp.), and bulrush (*Schoenoplectus acutus*) can be found in the sandier downstream areas (CNHP 2004). Coyote willow (*Salix exigua*) and snowberry (*Symphoricarpos* sp.) also are found in the area, but constitute a low percent of the overall cover (CNHP 2008).

A variety of non-native species, such as cheatgrass (*Bromus tectorum*), whitetop (*Cardaria* sp.), Siberian elm (*Ulmus pumila*), crack willow (*Salix fragilis*), diffuse knapweed *(Centaurea diffusa)* and Russian olive (*Elaeagnus angustifolia*), is present in the area (CNHP 2008). These species are most prevalent in the foothills and plains reaches of the stream, although establishment and colonization of invasive species is a concern during any major natural or anthropogenic disturbance. Diffuse knapweed, in particular, is capable of invasion because of its prior establishment along the corridor. Since the 2013 flood, and as of the time of this report, weeds along the Little Thompson have become plentiful and difficult to eradicate. In response, the LTWRC has been conducting weed management workshops to help the landowners manage their weeds.

One of two riparian communities mapped by SWReGAP in the foothills reach is Rocky Western Great Plains Riparian Woodland and Shrubland, covering about 593 acres. This community is characterized by riparian areas of medium and small rivers and streams. These are found on alluvial soils in highly variable landscape settings, from deep cut ravines to wide, braided streambeds. These settings tend to produce large peak discharges and low baseflow, with less developed floodplain than on larger rivers, and typically dry down completely for some portion of the year. Communities within this system range from riparian forests and shrublands to gravel and sand flats. Dominant species include plains cottonwoods, willow, silver sagebrush (*Artemisia cana*), western wheatgrass (*Pascopyrum smithii*), sand dropseed (*Sporobolus cryptandrus*), and little bluestem (*Schizachyrium scoparium*).

The second riparian vegetation community characterized in the foothills reach is Rocky Western Great Plains Floodplain Herbaceous Wetland, covering about 115 acres. This community is characterized by floodplains of medium and large rivers. Alluvial soils and periodic, intermediate flooding (every 5 to 25 years) typify this system. Dominant communities within this system range from floodplain forests to wet meadows to gravel and sand flats; however, they are linked by underlying soils and the flooding regime. Dominant species include plains cottonwood and willow spp. Grass cover underneath the trees is an important part of this system and is a mix of tallgrass species, including switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*).

The SWReGAP communities Rocky Western Great Plains Riparian Woodland and Shrubland and Rocky Western Great Plains Floodplain Herbaceous Wetland occur in both the foothills and plains reaches.

Plains Reach

Most of the lower Little Thompson Watershed has been developed for agricultural and residential purposes. This reach is low gradient and meanders northeast through the plains area, where the channel flows between towns of Johnstown and Milliken before it joins the Big Thompson River. The riparian area along the stream has previously supported native coyote willow, cottonwood, and grasses. Species that support livestock grazing are likely common in these areas. Non-native species have also been present, including crack willow, Russian olive, Siberian elm, and non-native grasses (CNHP 2004). Little to no riparian vegetation exists in places along the plains reach, and instead there is a distinct transition from stream channel to upland vegetation.

2.4.3 Pre-Flood Sensitive Species

Vegetation Communities

The Little Thompson River watershed supports two sensitive vegetation communities:

- Plains cottonwood and willow (*Salix amygdaloides/Salix exigua)* community is present in the plains portion of the Little Thompson watershed. Stands are located on alluvial sand, silt, and gravel deposited along the stream. Plains cottonwood (*Populous deltoids*) is the dominant species in this community; however, this species regenerates at a slower rate than coyote willow (*Salix exigua*) after major flood events. This natural plant community is ranked as “vulnerable” based on its uncommon presence on Subnational and Global scales according to the Colorado Natural Heritage Program (CNHP 2004).
- Narrowleaf cottonwood (*Populus angustifolia*) and chokecherry (*Prunus virginiana*) community is associated with canyons in the foothills on steeply sloping, narrow stream banks. The riparian woodland has been noted in the upper riparian reaches along the North Fork incorporating canopy of narrowleaf cottonwood and plains cottonwood, and dense understories of chokecherry, willow, and clematis. Due to rare presence, this community has been ranked “imperiled” on the Global (G) scale and “critically

imperiled” in the Subnational (S) scale according to the Colorado Natural Heritage Program (CNHP 2004).

In addition, sensitive wildlife and plant species, including threatened species and species of special concern, depend on the riparian habitat within the watershed. The diversity of the riparian corridor affects utilization by these species by providing opportunity for cover and forage. The riparian corridor, specifically the vegetation, in this area has been impaired by the flood, causing concern for many of these species. Sensitive species found in the aquatic and riparian habitats of the Little Thompson watershed include Preble’s meadow jumping mouse (*Zapus hudsonius preblei*), Iowa darter (*Etheostoma exile*), common shiner (*Notropis cornutus*), plains stonefly (*Mesocapnia frisoni*), Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*), and Ute ladies’-tresses orchid (*Spiranthes diluvialis*).

Preble’s meadow jumping mouse

Preble’s meadow jumping mouse (*Zapus hudsonius preblei*) is a threatened species protected by the Endangered Species Act that has been known to inhabit riparian corridors with well-developed vegetation and undisturbed upland grasslands. Preble’s meadow jumping mouse habitat is present within the 100-year floodplain of a stream, in grass and forb understory with willow shrub canopy. The Preble’s meadow jumping mouse can be found at up to 7,600 feet in elevation and may travel more than 2.3 miles along connected riparian habitat. Suitable habitat for Preble’s meadow jumping mouse has historically been present along the Little Thompson River.

Flash floods in September 2013 altered the stream channel and, in some instances, destroyed riparian ecosystems along the Little Thompson. However, Preble’s meadow jumping mouse is a mobile species that swims well. It is possible that the species may still occupy flooded and damaged riparian and upland areas (USFWS, 2013).

Iowa darter

Iowa darter (*Etheostoma exile*) is a State Special Concern fish. The darter prefers cool water with clear visibility and substrate of sand or organic matter. The darter is a small fish, with adults growing to 3 inches in length (CPW, 2014). Distribution of the Iowa darter in Colorado is confined to streams and ponds in the northeastern part of the state and has historically been present in the Little Thompson River.

Common Shiner

The common shiner (*Notropis cornutus*) is a State Special Concern species that prefers cool, gravelly streams with shade. Although this species is not known to be in the Little Thompson River, the common shiner may be in the river based on historical distribution (CNHP 2004).

Plains stonefly

A rare plains stonefly (*Mesocapnia frisoni*) that is known to be in few streams near the Southern Rocky Mountains has been identified along the Little Thompson River. The Little Thompson River is the only known stream in Colorado where *Mesocapnia frisoni* can be found. The presence of *Mesocapnia frisoni* suggests a good stream. The stonefly emerges in the winter and spends its larval stage in sediments beneath and adjacent to the stream. Siltation of the creek could result in clogging the substrate, thereby degrading their habitat (CNHP 2004).

Colorado butterfly plant

Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) is federally listed as a threatened species. Habitat for Colorado butterfly plant is commonly located 5,800 to 6,200 feet in elevation in sub-irrigated drainage bottoms surrounded by mixed grass prairie (CNHP 1997). Colorado butterfly plant typically flowers from June to September, producing white blooms that turn pink with age. Along the Little Thompson River, potential habitat has been identified where the drainage is crossed by Interstate 25 (ERO 2011).

Ute ladies’-tresses

Ute ladies’-tresses orchid (*Spiranthes diluvialis*) is a threatened plant species protected under the Endangered Species Act and can be found in northern Front Range drainages. The Ute ladies’-tresses grow at elevations from 4,500 to 6,500 feet in elevation in sub-irrigated alluvial soils along stream channels and in open meadows in floodplains. This orchid prefers sun-exposed, open areas with grass and sedge. Small and white bell-shaped flowers bloom on Ute ladies’-tresses from July to September (CNHP 1997). Potential habitat for the Ute ladies’-tresses has been identified within the 100-year floodplain of the Little Thompson near I-25 (ERO, 2011).

2.5 Fish and Aquatic Life

Upstream of the Boulder-Larimer County Line (Culver Ditch at the Parrish Ranch) to the headwaters is classified “Aquatic Life Cold 1” by the Colorado Department of Public Health and Environment – Water Quality Control Division (CDPHE-WQCD). This classification indicates these waters have an average weekly temperature generally less than 20°C and should be capable of sustaining cold water biota where physical habitat, water flows, and water quality conditions result in no substantial impairment of the abundance and diversity of species. From the Culver Ditch downstream to the mouth, the Little Thompson River is classified “Aquatic Life Warm 2,” indicating average weekly temperatures generally exceed 20°C and that these waters are not capable of sustaining a wide variety of aquatic biota based on habitat, flow or water quality conditions. The Clean Water Act Section 303(d) Impairments list includes temperature, dissolved oxygen, and sulfates as high priority for the upper segment, and copper, *E. coli*, and aquatic life use as medium to high priorities in the lower segment (CDPHE-WQCD, 2014).

Relatively few studies have been conducted of the Little Thompson River aquatic biota. Recent fish collections by Colorado Parks and Wildlife (CPW) resulted in the capture of 15 species at four sample sites (**Table 2.5**; Pers. comm., Jay Skinner, CPW 2014). Of the 15 species, 13 were collected at the two downstream sites (near Milliken and Interstate 25), with the predominant species (creek chub, longnose dace, fathead minnow, and white sucker) similar to those reported by Culver (2008) for collections made in 2001, 1997, and 1982. These native species are commonly found in Front Range tributaries of the South Platte River. Iowa darter, a species of State Special Concern, was collected at the Interstate 25 site in 2010, while two non-native, game fish species, brook trout and rainbow trout, were collected at Pinewood Springs in 2013. No greenback cutthroat trout (*Oncorhynchus clarkii stomias*), a subspecies listed as both Federally and State Threatened, were captured during any of these collections and is now thought to be extinct in its native habitat of the upper South Platte River basin. Recent genetic research has found the last remaining pure population of greenback cutthroat trout to be located in Bear Creek in the upper Arkansas River west of Colorado Springs, the result of stocking late in the 19th century (Metcalf et al. 2012). Cutthroat trout of mixed lineage may still reside in the upper Little Thompson River watershed.

While the Little Thompson River fish fauna appear to be commonplace, it is of interest to note that a rare relict assemblage of aquatic macroinvertebrates has been found in the lower segment (Culver 2008). This assemblage, thought to closely resemble communities of small foothills and plains Front Range streams before extensive agricultural and urban development, is composed of mayflies (*Ephemeroptera spp.*), stoneflies (*Plecoptera spp.*) and caddisflies (*Trichoptera spp.*), groups of macroinvertebrates typically used as indicators of stream health. Of special significance is the presence of five stonefly species and two caddisfly species rarely found any longer in highly developed, low-gradient streams along the Front Range that are now characterized by siltation, organic enrichment, and other effects of urbanization. For this reason, the Little Thompson River is being given consideration as a possible reference stream for comparison with other more highly developed streams to evaluate regional stream health (Culver 2008). The effects of the September 2013 flood on the Little Thompson River aquatic community are unknown at this time.

Table 2.5. Little Thompson River fish collections by Colorado Parks and Wildlife (Pers. Comm., Jay Skinner, CPW 2014).

Site	Date	Species	Number
At Milliken near confluence with Big Thompson	11 Sept 2009	Brook stickelback (*Culaea inconstans*)	1
		Creek chub (*Semotilus atromaculatus*)	4
		Fathead minnow (*Pimephales promelas*)	2
		Longnose dace (*Rhinichthys cataractae*)	21
At I-25 bridge crossing	29 Sept 2010	Common carp (*Cyprinus carpio*)	6
		Creek chub	48
		Fathead minnow	52
		Iowa darter (*Etheostoma exile*)	3
		Johnny darter (*E. nigrum*)	7
		Longnose dace	76
		Western mosquitofish (*Gambusia affinis*)	10
		Sand shiner (*Notropis stramineus*)	6
		Green sunfish (*Lepomis cyanellus*)	1
		Central stoneroller (*Campostoma anomalum*)	6
		White crappie (*Pomoxis annularis*)	2
		White sucker (*Catostomus commersoni*)	66
At Pinewood Springs downstream of Crescent Lake	26 June 2013	Brook trout (*Salvelinus fontinalis*)	14
		Rainbow trout (*Oncorhynchus mykiss*)	2
		Creek chub	89
		Fathead minnow	66
West Fork, approx 1/2 mile upstream of confluence with Little Thompson	25 June 2013	Creek chub	1
		Fathead minnow	1

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3 POST FLOOD SITE ASSESSMENTS

Post-flood assessments were conducted by Tetra Tech's team of geomorphologists and hydraulic engineers, ecologists, fisheries biologist, and civil engineers. The assessments were based on site observations and visual assessments, supplemented by literature review and review of pre- and post-flood aerial mapping. Site observations and visual assessments were conducted in April and May 2014. Global positioning system (GPS) cameras were used to document existing conditions.

3.1 Geomorphologic and Overall Channel Conditions

Geomorphic and overall channel conditions were assessed using a site assessment methodology that generally follows the format of the NRCS Stream Visual Assessment Protocol, Version 2 (SVAP2). The SVAP2 is a visually based method for qualitatively evaluating the condition of aquatic ecosystems associated with wadable streams. Some modifications were made to incorporate assessments of flood-related damage to both the ecosystem and infrastructure because the SVAP2 does not specifically address flood damage.

Channel assessments consisted of evaluating 13 channel elements categorized into five groups (A1 through A5 in **Table 3.1**) and three structures and infrastructure elements categorized into three groups (B1 through B3). Each element was scored by comparing observations in the field with the descriptions for each element representing a range of conditions. A value of zero is the worse or most altered conditions and a value of 19 the most functional. The scores for each category were added and then normalized by dividing the sum by the number of applicable categories. Categories that were not applicable were left blank and not included in the total score. A descriptive level of the post-flood condition (such as fair or poor was then assigned based on the normalized numerical results, ranging again from zero for the most severely damaged to 10 for the best conditions **(Table 3.2**). Details of the site assessment protocol and the numerical results are provided in **Appendix A.**

The river was divided into a total of nine reaches; seven along the Little Thompson River Mainstem, plus one reach on the North Fork and one on the West Fork. These reaches are generally described in the following section. In some cases, the reaches were further subdivided to reflect geomorphic changes or other distinct physical characteristics that warranted a separate analysis of a sub-reach.

It is important to note that the site assessments were conducted in April and May 2014; and as such, they represent the conditions observed at that time. Since April and May 2014, various degrees of ongoing reconstruction, restoration, and cleanup have occurred. Any such endeavors known during the preparation of this report have been noted.

Because of its qualitative nature, the protocol may not detect all causes of concern. The ratings represent an overall ranking and do not necessarily describe the worst or best conditions in each reach. Furthermore, many reaches scored similarly both numerically and in the descriptive level, but the elements themselves may have scored very differently. For example, a reach with significant erosion or scour could have the same rating and descriptive level as a reach with significant aggradation. Results of the assessments are discussed in the following sections and summarized in tabular form in Appendix A. A profile is also provided in **Figure 3.1** to facilitate the following discussion.

Table 3.1. Assessment protocol for stream visual assessment.

A Elements: Channel Assessment
A1: Current active/wetted Channel
Banks: bank stability including the presence of vegetation and ability to provide stabilization
Aggradation: degree of aggradation of sediment in wetted channel
Degradation: degree of degradation in wetted channel
Channel revetment : condition of bank revetment, if present
A2: Disturbed floodplain
Banks: bank stability including the presence of vegetation and ability to provide stabilization
Aggradation: degree of aggradation of sediment in floodplain
Degradation: degree of degradation and headcutting in floodplain
A3: Existing overbanks
Banks: bank stability including the presence of vegetation and ability to provide stabilization
Sediment deposition: degree of aggradation of sediment in overbanks
Headcutting: degree of headcutting in floodplain
Land Use: Degree to which the land uses contribute to overbank instability
A4: Riparian Corridor
Presence of natural and diverse riparian vegetation; and presence of invasive species.
A5: Presence of barriers to aquatic species movement
Ability of aquatic organisms to move through outreach (barriers assessment)
B Element: Structures and Infrastructure
B1: Buildings
Presence of buildings in flood corridor and visual assessment of damaged from flood event
B2: Utilities (buried infrastructure, overhead power, other)
Evidence of utilities present, damage and estimate of risk for future damage
B3: Roads
Condition of roads near or in flood damaged corridor and level of estimated risk

Table 3.2. Descriptive level of post-flood conditions.

1 to 2.9 Severely Degraded
3 to 4.9 Poor
5 to 6.9 Fair
7 to 8.9 Good
9 to 10 Excellent

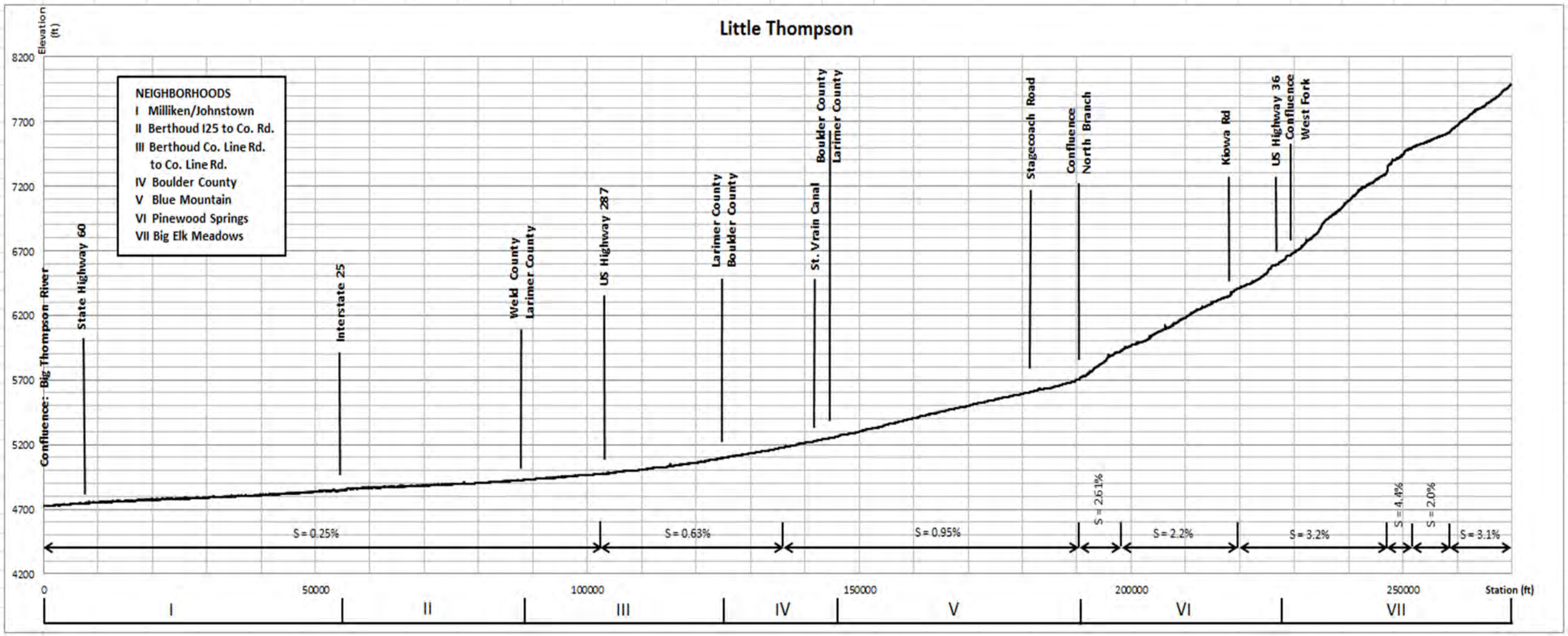

Figure 3.1. Little Thompson channel thalweg profile.

3.1.1 Reach I. Little Thompson, Milliken/Johnstown: Weld County to Interstate 25

Reach I, located within Weld County and extending from the confluence with the Big Thompson River to Interstate 25, is characterized by a low gradient, meandering section of the river of approximately 0.25 percent (Figure 3.1). Most of the river corridor is within privately owned property and land use is agriculture and rural residential. The riparian corridor is narrow (pre- and post-flood) because of encroachments from agriculture, roads, and rural development.

This reach scored in the "fair" category for channel assessments and the "fair" category for structures assessment. The bankfull channel in this reach appears to have a relatively low capacity because of the narrow and low-lying banks. During the September 2013 flood, the overbanks carried significant portions of the flow, thereby providing some energy relief for the main channel. Most of the riparian vegetation were laid over but were not dislodged, indicating the energies along the main channel were relatively low. As a result, lateral migration, significant bank erosion, and channel downcutting were limited. The most consistent problem through this reach appears to have been aggradation in the main channel, along the channel margins, and in the overbanks, as well as accumulations of some debris. Some localized bank erosion was observed that extended from the toe to top of banks and typically occurred at road crossings and bridges. In addition, there was damage to headgates and diversion ditches and inundation at several rural buildings. Many of the bridges, headgates, and diversion ditches had already been repaired or were being repaired by spring 2014.

State Highway 257 near Milliken

3.1.2 Reach II. Little Thompson, Berthoud: Interstate 25 to Weld-Larimer County Line

Reach II is located in Weld County and extends from Interstate 25 to the Weld-Larimer County Line at County Line Road. This reach is characterized by a low gradient section of the river, with an estimated channel slope of approximately 0.25 percent (Figure 3.1). There is a presence of wetland grasses (reeds, and cattails) and a high degree of sinuosity. Most of the riparian corridor is within privately owned property, and land use is agriculture and rural residential. The riparian corridor is narrow because of encroachments from agriculture, roads and rural development. This reach scored in the "fair" category for channel assessments and the "fair" category for structures assessment. The overbanks are relatively low in height, and the riparian vegetation were laid over but were not dislodged during the 2013 flood, indicating the energies along the main channel were relatively low. As a result, lateral migration, significant bank erosion, and channel downcutting were limited, although localized areas showing evidence of each of these items were observed. The most significant and consistent problems through this reach also appears to have been aggradation in the main channel, along the channel margins, and in the overbanks, as well as well as accumulations of debris.

Debris accumulations were significant and in some sections sufficiently large enough to affect flood conveyance. Aggradation along the overbanks was estimated to be, in some cases, as deep as 6 feet. Overbank aggradation consisted primarily of sand. Bridges within this reach typically scoured at the abutment toes, including an exposed footing at the I-25 Bridge. Many of the bridges had already been repaired by spring 2014.

Typical channel conditions, Reach II

3.1.3 Reach III. Little Thompson, Berthoud: Weld-Larimer to Larimer-Boulder County Lines

Reach III is located in Larimer County, spanning from County Line Road at the Weld-Larimer County line to West County Road at the Larimer-Boulder County line. This reach is characterized by a moderate to low channel gradient that transitions from about 0.25 percent to approximately 0.63 percent (Figure 3.1). The river is relatively sinuous with low to moderate bank heights. Most of the riparian corridor is within privately owned property, and land use is agriculture and rural residential. The riparian corridor in many locations is narrow due to encroachments from agriculture, roads and rural development.

This reach scored in the "fair" category for channel assessments and the "'fair" category for structures assessment. Generally, the low-flow channel eroded laterally with alternating bank erosion from left to right through the pre-flood meander pattern. Some channel widening was observed. Much of the smaller forms of riparian vegetation such as willow were laid over but were not dislodged during the 2013 flood, but many of the cottonwood trees did fall as a result of scour. Significant aggradation and degradation within the channel did not occur, although low-elevation sand bars formed in areas where channel widening occurred.

Bank erosion and lateral migration were limited by the presence of historical bank protection. However, some localized bank erosion was observed, particularly in areas with encroachments into the river banks (headgates, bridge abutments). Sand accumulated in many locations of the overbanks. Debris accumulations were significant and in some sections sufficiently large enough to affect flood conveyance. In particular, sediment deposition was significant at the River Mountain Bridge, resulting in wide-spread overbank flooding, spanning up to 1,000 feet in width and significant deposition under the bridge. Bank scour was also observed immediately downstream of W. County Road 4 that could undermine an existing silo. Considerable channel repairs and debris removal were completed or underway by spring 2014 by individual property owners, FEMA, and Larimer County.

Downstream of W. County Rd 4

3.1.4 Reach IV. Little Thompson, Boulder County

The reach is the only section of the Little Thompson located within Boulder County. The reach is approximately 4 miles long, bordered on the up- and down-stream ends by Larimer County. This reach is best described as a transitional reach from the open flatter foothills planform at 0.63 percent slope, to a confined canyon-bound system at approximately 0.95 percent slope. Land us in this reach consists of a mix of privately owned residential properties, County Conservation Easements, County Open Space (closed), and agriculture.

This reach rated in the "poor" category for channel assessments and the "severe" category for structures assessments. Sediment and debris piles (including trees and farming equipment) from the 2013 flood were significant in both size and volume, likely the result of high loading from the upstream canyon reaches. Debris removal was under way in spring and summer 2014.

Looking downstream at temporary culverts placed at 83rd Street

Major changes in channel planform alignment are evident, with the channel currently located in areas that were previously overbank surfaces. Many overbank areas eroded and now represent low-level floodplains adjacent to the channel. The overall channel size was increased significantly and much of the riparian vegetation was lost during the 2013 flood. Both new and existing floodplain surfaces contain large and localized scour holes. Bank erosion along the reach is considerable in many areas. Numerous canals and ditches, diversion structures, and bridges were damaged in this reach, including 83rd Street, which will be replaced by Boulder County, where a temporary culvert crossing currently exists. Several homes and outbuildings were flooded with significant damage, likely beyond repair.

3.1.5 Reach V. Little Thompson, Blue Mountain

This reach extends from the Boulder-Larimer County Line to the confluence with the North Fork of the Little Thompson. Overall slopes are relatively steep at 0.95 percent (Figure 3.1). The river is somewhat canyon bound, limiting the sinuosity and width of the river corridor to that of the canyon planform. Overbanks vary from bedrock walls to pasture or ranch lands. Most of the riparian corridor is within privately owned property, and land use is a mix of agriculture and rural residential. There are several road crossings.

This reach rated in the "fair" category for channel assessments and the "poor" category for structure assessments. Generally, the wet part of the channel moved from inside or middle of bends to outside of bends during the 2013 flood, typically scouring out a wider floodplain, as is the case in several locations, including conditions at Stagecoach Trail and the Riverway neighborhood area, where the river migrated up to 200 feet laterally from its pre-flood location.

Stagecoach Trail

Five buildings were destroyed in this reach in the 2013 flood, including the local fire station. The single access point into the Blue Mountain subdivision, serving 160 homesites, was flooded and plugged by debris, rendering the road impassable. This, in turn, resulted in significant channel damage immediately upstream and downstream of the road crossing because of the overtopping and widespread overbank flows. Two ranch road crossings were also destroyed by debris and overtopping flows.

Residence downstream of Stagecoach Trail

There are portions of this reach that are somewhat remote, have no immediate or significant encroachments, and are confined or controlled both laterally and vertically by rock outcrops. These remote sections had a dense riparian corridor of cottonwoods and willows, lining the pre-flood low-flow channel, most of which were lost during the flood,

3.1.6 Reach V. North Fork, Blue Mountain

The assessed portion of the North Fork extends from the confluence with the Main stem of the Little Thompson to Pole Hill power plant at the CBT power station. The channel slope is relatively steep at 2 percent. The river is somewhat canyon bound, which controls the sinuosity and riparian corridor width. Overbanks vary from bedrock walls to pasture or ranch lands. Most of the riparian corridor is within privately owned property held in a County Conservation Easement.

Typical reach along the North Fork

This reached scored in the "fair" category for channel assessments and the "poor" category for structures assessments based on damage at three small crossings. Overall the river and floodplain were somewhat disturbed from flooding but appeared to have retained vegetation, primarily larger cottonwood trees and willows. Grasses appeared to be re-emerging (since September 2013) and pools and riffles were observed in the river.

In the vicinity of the Pinwheel road where it crosses the North Fork, there was damage to the road and river at several existing river crossings. Spruce Creek (a tributary to the North Fork) also shows signs of a debris flow and a naturally leveed channel that formed as a result of deposition. Hells Canyon (a tributary to North Fork) has large boulder debris fields and downed timber, indicating flows may have been very high in this tributary.

3.1.7 Reach VI. Little Thompson, Pinewood Springs

This reach is steep, ranging in slope from 2.2 to 3.25 percent, and canyon bound with significant natural controls (boulders and bedrock) that limit both horizontal and vertical movement of the river. The lower portion of this reach is on property managed by the USFS; the upper portion is on private property within Pinewood Springs. The most upstream portion of the reach parallels Highway 36 for approximately 1 mile, ending at County Road 47.

Crescent Lake: before (upper left), during (upper right) and after (lower) flood of 2013

This reach rated in the "fair" category for channel assessments and the "poor" category in the structures assessments. The 2013 flood scoured the river, removing topsoil and most of the vegetation, including large pine and fir trees.

The river remains vertically and horizontally confined in the Pinewood Springs neighborhood by the presence of bedrock outcrops that confine much of the river. There are three road crossings, all which sustained some degree of damage during the 2013 flood, two of which suffered severe damage, including loss of adjacent infrastructure, floodplain, and associated banks. At Cree Road, the water treatment plant serving Pinewood

Springs suffered significant damage. Repairs are under way for some of the channel sections on privately owned property and at the water treatment plant. Larimer County is currently designing bridge replacements and repairs for all three bridges in this neighborhood. Debris piles were significantly large and abundant, but much of it had been removed by the local residents as of spring 2014. The USFS has no plans to remove debris or mitigate flood related damage (Gordon 2014).

Damage was also severe along the 1-mile reach of the Little Thompson River where it is located immediately adjacent to U.S. Highway 36, including damaged access to two private residences. The river in this reach is being repaired by CDOT in cooperation with the USFS. There are no plans by CDOT or Larimer County to repair or replace the private accesses.

3.1.8 Reach VII(a). Little Thompson, Headwaters

This reach is steep and canyon-bound with slopes between 2 and 4 percent. Much of the reach is on property managed by the USFS, with some private properties spread throughout. This reach runs parallel to U.S. Highway 36 for approximately 7 miles to its headwaters just outside of Estes Park.

Typical conditions along ReachVII(a)

This reach rated in the "fair" category below Lyons Gulch and the "good" category above Lyons Gulch for channel assessments, and the "poor" category in the structures assessments. This reach sustained flood-related damage, primarily when large debris and boulders moved through the system, and significant scour and loss of soil and vegetation. The most severe damage appears to have occurred just upstream of Lyons Gulch confluence, along a ¼-mile reach of very steep (nearly vertical) and confined section of the river immediately adjacent to Highway 36. Here, the river scoured a deep section of river, removing all the topsoil and vegetation, scoured the banks adjacent to the highway, and then avulsed to a southerly alignment. Preliminary indications are that some restoration and reconstruction of this stretch of the river and road are being considered but the details are yet to be undetermined.

Other, less significant, damage was also observed at culvert crossings or where the floodplain had been encroached by anthropogenic activities. Evidence of mud and debris flow was also observed from an unnamed tributary from the northwest, crossing under U.S. Highway 36 upstream of the West Fork confluence. Neither the USFS nor private property owners have indicated a desire to restore or reconstruct damaged areas within this reach of the river.

Farther upstream from Lyons Gulch, in the headwaters region, there is little damage from flooding. The river is relatively small and in many locations not well defined. There are some indications of channel bank instability associated with culvert crossings or development that encroaches the channel banks, but no signs of significant flood-related damage are evident.

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3.1.9 Reach VII(b). West Fork, Big Elk Meadows

West Fork along County Rd 47

The channel along the first 2 miles of this steep reach (slopes are estimated to be in excess of 3 percent) is canyon bound and restricted by County Road 47 and four culvert crossings. Bedrock outcrops provide horizontal and vertical control for this stream, setting the slope and sinuosity. After the first 2 miles, the road and river separate. Two (river) miles beyond is Big Elk Meadows subdivision with five small water supply dams.

This reach rated in the "fair" category for channel assessment and the "poor" category for structures assessments, primarily because of the multiple culvert crossings that were damaged. Rock outcrops on the banks and bed of the West Fork along County Road 47 provided horizontal and vertical control during the 2013 flood, but all topsoil, vegetation, culverts, and much of the adjacent road was destroyed. All four culvert crossings were destroyed but have since been replaced by Larimer County with temporary concrete culverts. County Road 47 and the four culverts are on property managed by the USFS, and the agency's initial indications are that it may be desirable to reduce the number of crossings, if possible, and replace the crossings with structures that allow for passage of aquatic species. The West Fork between Highway 36 and Big Elk Meadows (BEM) is predominately on lands managed by the USFS. Big Elk Meadows is privately owned property and consist of single family homes.

As mentioned above, there are five small water supply dams in the Big Elk Meadows subdivision. During the 2013 flood, these dams were overtopped and failed. An analysis performed by the CDWR indicates that the failures were the result of the high volume and erosive power of the river during and after the peak discharges. The analysis also indicates that the Big Elk Meadows dam failures did not significantly increase the total discharge in the river to a level that would cause incremental damages in the downstream channel because of the limited volume of the reservoirs and the manner in which they failed.

Large deposits of debris, sand and fine sediment exist immediately below the most downstream dam, which originated from the dams. The sediment deposits are particularly voluminous and are likely the result from the breached dams and the transport of material from behind the dams. The reservoirs are fed by the upper reach of West Fork as well as Deer Creek, a small tributary to the West Fork, which reaches its confluence upstream of Meadow Lake. Flood-related impacts on these tributaries included scour, loss of vegetation, and debris flows generated on the steep hillsides above the riverbed. Slopes with debris flows appeared to have also visible signs of damage and vegetation loss from a 2002 fire. These tributaries are on property managed by the USFS, and currently there are no plans to remove debris or mitigate flood-related damage.

3.1.10 Summary of Geomorphic and Overall Channel Conditions

Channel assessments resulted in all reaches scoring in the 'fair' category with the exception of Reach IV (Boulder), which scored in the "poor" category. Low scores in the channel assessments ("A" elements in Table

3.1) were typically the result of disturbed banks in both the channel and floodplain, instabilities and relocation of the active and wet channel, and disturbance to the floodplain. In the downstream reaches (downstream of Reach IV; Boulder County), vegetation was largely laid over but not dislodged during the 2013 flood, indicating the energies along the main channel were relatively low. Aggradation and deposition of sand are the primary impacts in these reaches. Degradation and scour are the predominant impacts in the upstream reaches, with flood-related damage to the channel being more extensive. However, areas with limited encroachments and, in particular, those reaches that are confined or controlled by bedrock outcrops demonstrated greater lateral and vertical stability. The transitional reaches found in the center of the watershed (Reach IV: Boulder County) had the lowest channel assessment ratings based on the combined impacts from extensive deposition, the relocation of the active wet channel, and lateral instabilities associated with channel migration. Debris accumulation affected most all reaches, depending on slope transitions, bends in the river, and encroachments such as bridges.

The rankings for structural assessments ("B" elements in Table 3.1) generally ranged from fair to poor to severe, with Reach IV again ranking the lowest because of the structural impacts from channel and bank instabilities. Almost all of the structures in or near the river channel, and many of those within the flooded footprint, were damaged to some degree. Scour was evident at almost all bridges. Aggradation was also observed in some cases, particularly in the lower reaches, and debris clogging or debris impacts were likely associated with many of the failures. Many of the bridges had already been repaired or were currently being repair in the spring of 2014. Bridge assessments are discussed further in Subsection 3.4.

3.2 Post Flood Vegetation and Riparian Conditions

Riparian habitat in the canyon reaches was damaged by the flood through removal of trees and shrubs, although not completely destroyed. Many of these areas have remaining trees and shrubs that can regenerate through seeding or propagation through rhizomes. Piles of woody debris are wrapped around trees or exist within the stream.

Strong and fast-moving flood waters in the foothills reach destroyed large amounts of riparian habitat, including removal of stands of large cottonwood trees. Areas that were once covered by cottonwoods and willows are now completely without vegetation, and only sand and rocks remain. Massive amounts of sand and rock deposition occurred throughout the foothills reach. An example of the change in riparian vegetation pre- to post-flood is provided in **Figure 3.2**.

Within the downstream plains reach, the riparian understory was damaged during the flood by sand deposition with some loss of vegetation. Few large cottonwood trees were completely lost. Remaining cottonwood trees in the plains reach may still be threatened in the long term by the sand surrounding their stems and trunks. Deposits of sand and gravel also occurred in the plains reach.

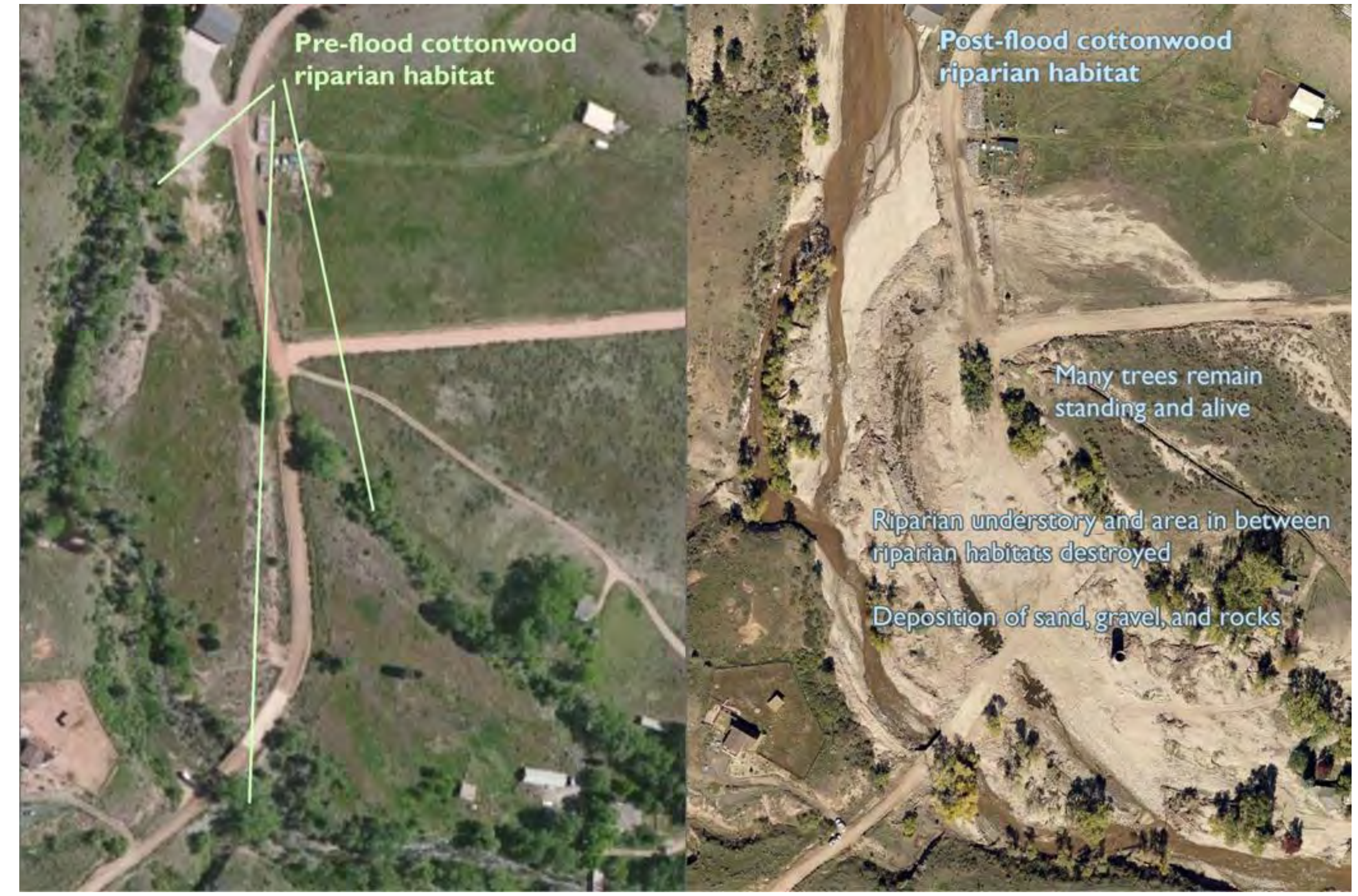


Figure 3.2. Illustration of the Pre- and Post-Flood Riparian Vegetation.

3.3 Assessment of Post Flood Conditions for Fish and Aquatic Life

The post-flood condition of the Little Thompson River aquatic habitat was surveyed on June 3 and 4, 2014, from Milliken upstream to Big Elk Meadows on the West Fork and Lion Canyon near Estes Park on the mainstem. Overall, and not unexpectedly, the Little Thompson aquatic habitat was found to be severely degraded (**Figure 3.3**). The channel has been extensively widened in many locations, and the formation of bars and braided channels associated with substantial sediment deposition is common. Such deposition was so extensive that at Pinewood Springs, a small floodplain pond (Crescent Lake) was completely filled. Stream flow at the time of the field reconnaissance was moderate, likely on the declining limb of the spring runoff hydrograph, and was generally wide, shallow and riffle-like across the blown-out channels.

Most of the alluvial hydraulic controls were washed out by the 2013 flood, and as a result, pool habitat was scarce. Bank erosion was evident throughout the system, and the remaining riparian vegetation was limited. As a result, high-quality resting areas and shade and cover for fish were in short supply. The water column was turbid at most locations and the stream bed substrate was heavily embedded with sand and silt, substantially reducing habitat quality for fish spawning and rearing, as well as macroinvertebrate production.

3.4 Bridge and Culvert Assessments

Many of the bridges and culverts crossing the Little Thompson were damaged during the 2013 flood by scour at the abutments and footings, debris plugging and overtopping flows, and the lateral migration of erosive flows around bridges resulting in flanking of the abutments. Most of the bridges and culverts are in public rights-of-way, under the jurisdiction of either the counties or CDOT. Bridges were assessed as part of the visual assessments. A summary table is provided in **Appendix B**. Repair work that was either completed or under way at the time of the visual assessment is noted as well as additional notes regarding future related work or if additional assessments and reconstruction should be considered.

3.5 Loss of Homes and Buildings

During the 2013 flood, approximately 30 homes and buildings were damaged, rendered unusable, or totally lost. Many others were damaged but are, or have already been, repaired. This total does not include outbuildings or other types of structures that are generally not for habitation, public utility, or commercial use. Several of these structures were not in a FEMA-identified floodplain, either because the river has not been studied in detail or because the river and floodplain were not close to the home prior to the 2013 flood. Relocation of these buildings should be in compliance with current FEMA, local, and state regulations, and although not specifically addressed here, relocations should be considered where appropriate and possible so as to place the structure in a more stable and flood-resilient location.

One good example of post-flood reconstruction (and added resiliency) is the fire station in Blue Mountain. This structure was originally located along the river banks upstream of Stagecoach Trail. The fire station was destroyed during the 2013 flood and is currently being reconstructed at a site several miles from the river. The water supply cistern, however, will remain to support fire-fighting in the Blue Mountain neighborhood and will remain underground with some foundation reconstruction. The cistern will be generally flush with the bank configuration and, thus, will present a minimal obstruction (or no obstruction) to flood flows.

Figure 3.3. Aquatic habitat conditions observed on the Little Thompson River, June 3 and 4, 2014. Upper Left: Near Milliken, Co; Upper right: At County Road 21 near Berthoud, Colorado; Middle Left: Near Parrish Ranch; Middle Right: At Blue Mountain; Lower Left: At Pinewood Springs; Lower Right: West Fork near Big Elk Meadows.

4 RESTORATION RECOMMENDATIONS AND CONCEPTUAL DESIGN STRATEGIES

4.1 Restoration Recommendations

General recommendations by reach are provide below, followed by an overview of conceptual design strategies. Note that many sections of the Little Thompson River will, over time, reestablish its equilibrium slope and planform alignment, thereby resetting its natural geomorphic condition. The geomorphic functions in many reaches of the Little Thompson River are also likely sufficient to allow for the natural regeneration of riparian plant material through seeding and cloning with no active restoration, although weed management may be required. Some of the channel reaches would be better served with active restoration in light of public safety issues in the case of stabilizing channel banks, land reclamation related to agricultural needs, property reclamation where homes were lost or damaged, and those areas used for water supply and recreation (**Figure 4.1**).

Figure 4.1. Simulation depicting active restoration on Little Thompson River near water treatment plant in Pinewood Springs, Colorado.

Based on the visual assessments, more than half the reaches have sustained flood-related damage to the wetted channels and floodplain instabilities that are of poor condition and thus form the basis of much of the recommended restoration. Strategies include channel reconstruction, typically requiring redefinition or creation of a new low-flow channel; various levels of bank protection depending on the degree of damage or risk; and floodplain stabilization of the large, de-vegetated, and exposed bars and benches within the floodplain.

The nine neighborhoods are divided into 123 map sheets, each at a scale of 1 inch=200 feet for presentation of the detailed restoration and reconstruction recommendations. These are presented in **Appendix C,** under separate cover. **Table 4.1** provides a summary of reaches and maps numbers. A general overview of these strategies is presented in the following subsections.

Table 4.1. Summary of reaches and map numbers.

Reach	River	Description	Map Sheets
I	Little Thompson	Milliken/Johnston: Weld County to Interstate 25	1-16
II	Little Thompson	Berthoud: Interstate 25 to Weld-Larimer County Line (County Rd 1)	16-24
III	Little Thompson	Berthoud: Weld-Larimer County Line to Larimer-Boulder County Line	24-38
IV	Little Thompson	Boulder County	38-46
V	Little Thompson	Blue Mountain	46-62
V	North Fork	Blue Mountain	103-123
VI	Little Thompson	Pinewood Springs	63-72
VII	Little Thompson	Headwaters	73-86
VII	West Fork	Big Elk Meadows	87-107

4.1.1 Reach I. Little Thompson, Milliken/Johnstown: Weld County to Interstate 25

The most consistent problem through this reach appears to have been aggradation in the main channel, along the channel margins, and in the overbanks, as well as accumulations of some debris. The concern with the aggradation in the main channel is the channel capacity may have been reduced, thereby altering flood levels. Therefore, one of the primary recommendations for this reach is to assess the amount of sediment accumulated in the channel and the impacts to the channel capacity. Sediment removal is recommended in cases where flood levels would likely be increased. Other recommendations include the removal of debris where it may impede flows and the removal of sediment where it may impede the regeneration of vegetation.

As previously noted, bridge-related work was typically under way or completed at most crossings in this reach. Some damage was sustained to headgates and diversion ditches, most of which has already been repaired by the Town of Milliken or the ditch companies and owners. Improvements are also being implemented in the Town of Milliken for the storm sewer system, and a drainage master plan is being prepared. Thus, recommendations in this Master Plan should be implemented in conjunction with the town's planned improvements. These and other site-specific recommendations in this reach are shown on sheets 1 through 16 in Appendix C.

4.1.2 Reach II. Little Thompson, Berthoud: Interstate 25 to Weld-Larimer County Line

Issues in this reach include sediment aggradation in the main channel, along the channel margins, and in the overbanks where sand deposits reached depths of 6 feet, covering much of the vegetation. In addition, debris accumulations were significant and in some sections sufficiently large enough to affect flood conveyance. Thus, restoration recommendations in this reach generally include grading and lowering the overbanks to remove sediment, removal of debris as required for the conveyance of floods and to facilitate natural regeneration of vegetation. Note that during the spring and summer 2014, much of the debris had been removed (although sediment still remains) by the landowners and volunteer groups so additional debris removal will likely be minimal.

Localized bank erosion was observed in various locations along this reach. Stabilization of many of these banks is recommended, for the protection of buildings, roads, ditches and agricultural fields. These and other site-specific recommendations in this reach are shown on sheets 16 through 24 in Appendix C.

4.1.3 Reach III. Little Thompson, Berthoud: Weld-Larimer to Larimer-Boulder County Lines

The primary issues in this reach include lateral erosion of the low-flow channel with alternating bank erosion through the pre-flood meander pattern and some channel widening. Thus, recommendations throughout this reach include refining (reconstructing) the low-flow channel and bank stabilization.

This reach also experienced aggradation and deposition in the main channel, along the margins, and in the overbanks, with some loss of vegetation. Thus, overbank grading and floodplain stabilization are recommended to improve conveyance of flows and sediment transport and to stabilize the sediments in the overbank. Active revegetation is recommended to help accelerate vegetation recruitment. Debris was present in this reach, but much of the debris had been removed by the landowners and volunteer groups, so additional debris removal, recommended for conveyance of floods, will likely be minimal.

One area particularly damaged from the 2013 flood is at West County Road 4 and Mountain River Road Bridge. Here, additional analyses are recommended to further assess this reach and develop a design that would improve sediment-transport capacity at low to moderate flows, increase flood capacity (including through Mountain River Road Bridge), and improve functionality of the Eglin Ditch diversion structure. This and other site-specific recommendations in this reach are shown on sheets 24 through 38 in Appendix C.

4.1.4 Reach IV. Little Thompson, Boulder County

Damage in this reach from the 2013 flood was significant as a result of the extensive deposition that occurred as the channel slopes flatten and sediment and debris-laden flows emerged at relatively high velocities from the canyon-bound system. These high flows resulted in the relocation of the active wet channel, lateral instabilities, large and abundant debris accumulation, and major changes in channel planform. Structural damage to buildings, homes, and bridges was also significant.

Recommendations for this reach generally include removal of any remaining debris that may impede the channel capacity to transport flows and sediment, lowering and grading floodplain surfaces to improve conveyance, stabilizing the floodplain, and refining (reconstructing) the low-flow channel. Bank stabilization is also recommended in many locations throughout the reach for the protection of buildings, roads, ditches, and agricultural fields. Active revegetation is also recommended to help accelerate vegetation recruitment. Reconstruction, repairs or improvements located within county-owned conservation easements must be coordinated and approved by Boulder County.

Many of the bridges in this reach were damaged, some extensively, and are either being redesigned (including 83rd Road) or had already been repaired or were being repaired by late 2014. Several homes were extensively damaged. Plans for these homes are currently being assessed by the counties, FEMA, and the landowners. These and other site-specific recommendations in this Reach are shown on sheets 38 through 47 in Appendix C.

4.1.5 Reach V. Little Thompson, Blue Mountain

This reach experienced signification scour from the 2013 flood and velocities were high. Most of the vegetation was lost from scour. Several buildings were destroyed, and the road crossing into the Blue Mountain neighborhood was damaged, as well as the floodplain immediately above and below the road crossing. Several buildings are still in danger from bank instabilities. General recommendations in this reach include refining (reconstructing) the low-flow channel, grading and stabilization of the floodplain and headcut areas, and bank stabilization.

Improvements to Stagecoach Road Trail bridge and approach roads are also recommended. Note that at the time of this Master Plan, Larimer County indicated it would be repairing Stagecoach Trail Bridge to its pre-flood condition. This bridge consists of three large concrete culverts that are likely undersized and easily trap debris. Thus, one of the recommendations for this reach is to reassess the bridge design, the channel, and the elevations of the approach roads, for flood and debris conveyance and the possible replacement or reconstruction of all these elements to reduce flood-related impacts and provide safe and more reliable passage over the river. These and other site-specific recommendations in this reach are shown on sheets 47 through 62 in Appendix C.

Extensive restoration is also recommended at the Riverway Neighborhood, downstream of Stagecoach Trail by 1½ river miles. This reach is located on a sharp bend, and erosion and scour in this area were extensive. In some locations, the floodplain dropped by at least 8 to 10 feet. Restoration recommendations include reconstruction of the river channel banks, reconstruction and stabilization of the overbanks, and bank stabilization to protect a home.

4.1.6 Reach V. North Fork, Blue Mountain

Based on field observations, it appears the North Fork was somewhat disturbed from flooding but appears to have retained some vegetation, primarily larger cottonwood trees and willows. Grasses appear to be emerging at the time of the field visit. The channel bottom is composed of cobbles and boulders with a reformation of pools and riffles after the flood. Geomorphic functions of this reach are likely sufficient to allow for the natural regeneration of cottonwood, willow, and other riparian species through seeding and cloning without active restoration. Thus, no further actions are suggested at this reach, with one exception; the restoration of a short reach of river near Pole Hill power plant to restore the low-flow channel and grade and stabilize the overbanks, and installation of a gage with an automated flood-warning system as a safety precaution should an emergency shut-off occur at the Pole Hill power plant. See sheets 103 through 123 in Appendix C.

4.1.7 Reach VI. Little Thompson, Pinewood Springs

The 2013 flood scoured the river in this steep reach, removing topsoil and most of the vegetation, including large pine and fir trees. Debris piles were significantly large and abundant, but much of it had been removed by the local residents as of spring 2014. Much of this reach is relatively stable and expected to recover without restoration because of the rock outcrops, canyon-bound valley formation, and limited encroachment on the river corridor. The exception in this reach includes areas near two bridge crossings and at Crescent Lake. The Kiowa Bridge, a low-water crossing, failed as a result of flanking flows around the abutments. The Cree Bridge, a single-span bridge, was flanked through debris plugging and partially damaged. Extensive damage to the river and channels above and below these bridges also occurred in conjunction with the bridge failures. Crescent Lake, an off-line, man-made waterbody located immediately downstream of Kiowa Bridge crossing, was destroyed. The lake served as a water supply for firefighting and is therefore a high priority for reconstruction. Larimer County is currently designing and planning for repairs or replacement of the Kiowa and Cree Bridges. Other recommendations for this reach include the reconstruction of Crescent Lake and appurtenances, defining or recreating low-flow channel, and stabilization of banks in several locations.

Immediately downstream of Cree Bridge, one residence is urgently threatened by the condition of the banks immediately adjacent to the home. In addition, the river aggraded by about 4 feet and has created a possible flood condition for the same residence through the loss of channel capacity. Thus, additional recommendations include the removal of sediment for the conveyance of flood flows downstream of Cree Bridge.

Damage was also severe along the 1-mile reach of the Little Thompson River where it is located immediately adjacent to U.S. Highway 36, including damaged access to two private residences. The river is being repaired in this reach by CDOT in cooperation with the USFS. However, there are no plans by CDOT or the county to repair or replace the private accesses. Thus, this Master Plan includes recommendations to replace the private accesses. This work should be done in coordination with CDOT and the USFS to ensure consistency in channel capacity and design.

These and other site-specific recommendations in this reach are shown on sheets 63 through 72 in Appendix C.

4.1.8 Reach VII. Little Thompson, Headwaters

This reach is steep and canyon-bound with slopes between 2 and 4 percent. Much of the reach is on property managed by the USFS, with some private properties spread throughout. This reach sustained flood-related damage primarily when large debris and boulders moved through the system and significant scour and loss of soil and vegetation. The most severe damage appears to have occurred upstream of the confluence with Lyons Gulch immediately adjacent to the highway. Some damage was also observed at culvert crossings or where the floodplain had been encroached by anthropogenic activities. Neither the USFS nor private property owners have indicated a desire to restore or reconstruct damaged areas within this reach of the river. Furthermore, flood-damaged sections appeared to relatively isolated and do not appear to be threatening Highway 36 except upstream of Lyons Gulch. Plans for this reach are unknown at this time. Elsewhere, the geomorphic functions of this reach are likely sufficient to allow for the natural regeneration of cottonwood, willow, and other riparian species through seeding and cloning without active restoration. No further actions are suggested at this time (see sheets 73 through 86 in Appendix C).

4.1.9 Reach VII. West Fork, Big Elk Meadows

This reach was extensively damaged by the 2013 flood. County Road 47, the only access to Big Elk Meadows, was rendered unpassable and the existing (pre-flood) culverts destroyed. Larimer County replaced the culverts with five temporary crossings and reconstructed the road. These culvert crossings along County Road 47 and the road right-of-way are all on property managed by the USFS. The USFS's initial indications are that it may be desirable to reduce the number of crossings, if possible, and replace the crossings with structures that allow for passage of aquatic species. As of the fall of 2014, Larimer County, FEMA, the USFS, and Central Federal Lands are working to repair the road and permanently replace the culverts.

Farther upstream near Big Elk Meadows, large deposits of debris, sand, and fine sediment exist, likely deposits from the dam failures. The sediment deposits are particularly voluminous and are recommended for removal to reduce the potential for transport of sediment-laden runoff downstream. This activity would require coordination with, and approval from, the USFS.

Aerial images, on-site observations, and anecdotal information of the West Fork upstream of Big Elk Meadows indicate a debris flow occurred in the upper watershed that may have contributed to the sediment-laden runoff in the portions of the West Fork in and near Big Elk Meadows. However, the river appears relatively stable and expected to recover without restoration. The USFS has no plans for debris removal or restoration. Geomorphic functions of this reach are likely sufficient to allow for the natural regeneration of willow and other riparian species through seeding and cloning without active restoration. No further actions are suggested at this time (see sheets 87 through 107 in Appendix C).

4.2 Conceptual Design Strategies

4.2.1 Create/Refine Low-flow Channel

One key strategy of this Master Plan is construction of the low-flow channel in reaches where the channel was excessively widened or decimated by the 2013 flood. This portion of the river, in a stable river system, is typically wet and contains flows most of the year. Flood-related damage of the channel typically occurred by either scouring of the entire floodplain or extensive deposition that filled the low-flow channel. Over time, the channel will likely reform itself through natural processes, but recommendations include construction of a low-flow channel in those reaches where reestablishing the low-flow channel is urgent. Depending on the situation, construction of the low-flow channel may require filling in the adjacent floodplain, ore-excavating into an aggraded area, or minor bank restoration, to define the edges of an otherwise overly wide channel.

The low-flow channel is typically defined as the bankfull channel. Although the bankfull discharge of self-adjusting streams can vary widely, the bankfull discharge may be generally defined using the 1.5-year recurrence interval peak discharge (Dunne and Leopold 1978). Based on the hydrologic analysis presented in this report, the 1.5-year recurrence interval peak flood event is approximately 200 cfs at the Little Thompson near Berthoud gage. Note that the 200 cfs has an exceedance probably of approximately 3 percent, so this value may be higher than values normally expected for a bankfull event. Furthermore, the bankfull flow will likely vary widely along the length of the Little Thompson River. Thus, further analysis of the bankfull channel capacity will be required for preliminary and final designs. This Master Plan uses 200 cfs as a placeholder for developing estimates of the channel width and depth for use in the quantities and cost estimates.

Estimates of the bankfull channel widths (wetted channel during spring runoff) using 2012 aerial imagery indicate the pre-flood channel width varies from about 10 to 28 feet along the length of the Little Thompson. The pre-flood bankfull width in the foothills reach appears slightly wider, ranging from about 20 to 28 feet. Farther downstream as the river flattens, the pre-flood bankfull channel widths were, and still are, quite narrow, on the order of 10 feet, likely the result of long-term diverted flows and vegetation encroachment.

Using an average width to depth ratio of approximately 20 and the estimated widths noted above suggests the reconstructed bankfull channel should be about 20 feet wide and 1 foot deep, plus a v-notch bottom, 0.5 to 1 feet deep. On natural systems and in the Little Thompson, it is expected that the v-notch or low-flow point of the channel bottom could move laterally, but the proposed cross section is the template used to start the channel reconstruction. This v-notch bottom is recommended to keep the late season low flows narrow and as deep as possible for the benefit of aquatic species. It also improves conveyance and reduces evaporation potential. The main channel would also be constructed with habitat features for the primary purposes of providing structural diversity within the wetted portion of the river and cover and resting areas for resident and migratory fish. These features would be achieved through the construction of pools, rootwad revetments for cover, boulder clusters, and overhanging banks, as is discussed further in Section 4.27. Note that the low-flow channel presented is for planning purposes only and requires additional study and further analysis to develop the final design flow and channel configuration, including the channel width and width to depth ratios. It's likely the final low-flow channel design will be slightly different than presented here and will probably vary between the downstream and upstream sections. The average channel slopes would generally be similar to those seen under pre-flood conditions varying, depending on the location within the watershed, from an average slope of 0.25 percent in the plains region to 2 to 3 percent in the mountain region. Likewise, the sinuosity (channel length divided by the valley length) would generally be similar to those seen under pre-flood conditions ranging from 1.25 in the plains region to 1.1 in the foothills and canyon regions.

A typical channel template would include a bottom section composed of native bed material with graded banks that are stabilized by a number of different techniques (Levels 1, 2 or 3; discussed in Section 4.2.2) depending on the level of protection required. A typical channel cross section is presented in **Figure 4.2**.

A typical plan view channel alignment with meanders, point bars and thalweg alignment is shown in **Figure 4.3**. Channel reconstruction on bends will include construction of point bars. Point bars are typically located on the inside of bends and will act to increase channel sinuosity and reduce the low-flow channel width. Point bars should be constructed with a gentle cross slope, on the order of 10 percent and be made up of native bed material sediment. Typically, point bars will be inundated during flood conditions and exposed during low flows (see Figure 4.3).

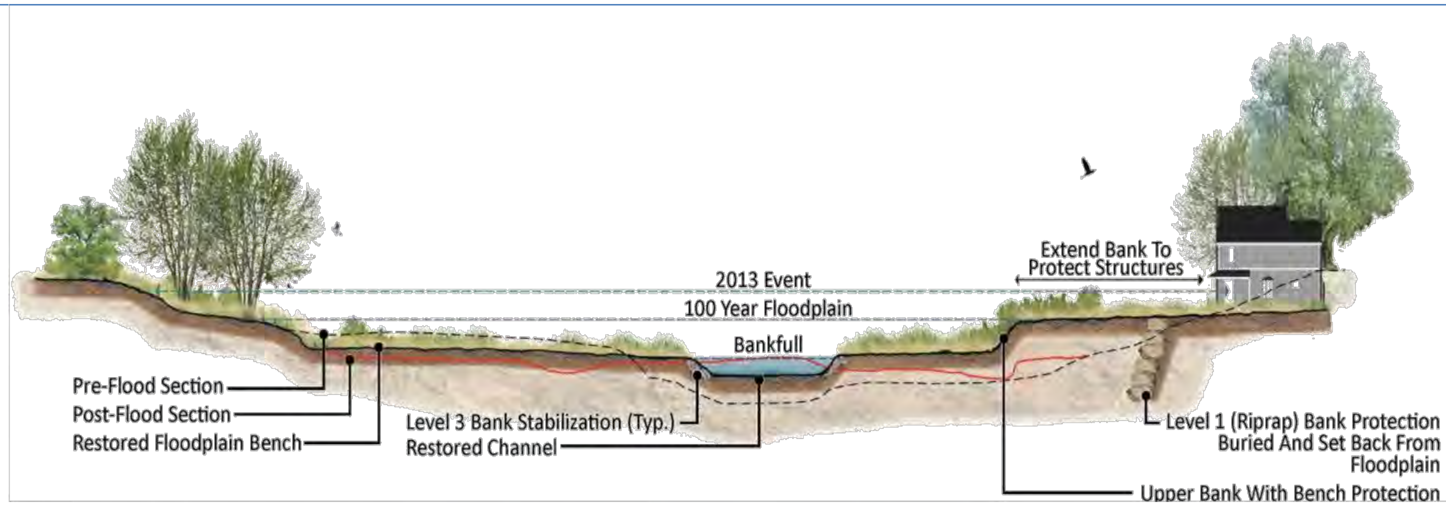


Figure 4.2. Typical restoration section.

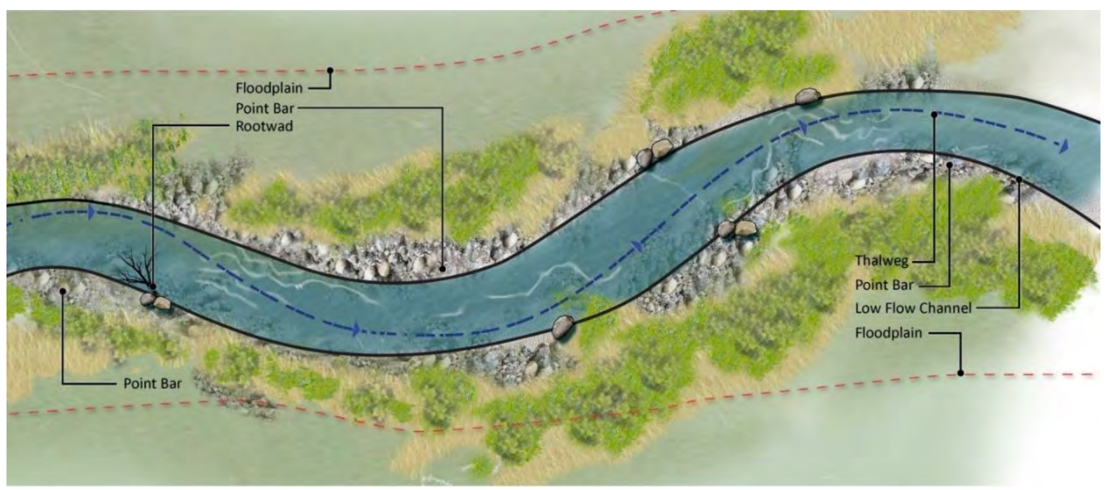


Figure 4.3. Typical plan view.

The low flow channel should also include boulder clusters, which are rocks placed in the stream individually or in groups to add structural and visual diversity to degraded and uniform reaches. They provide cover for aquatic habitat and protection to eroding banks (**Figure 4.4**).

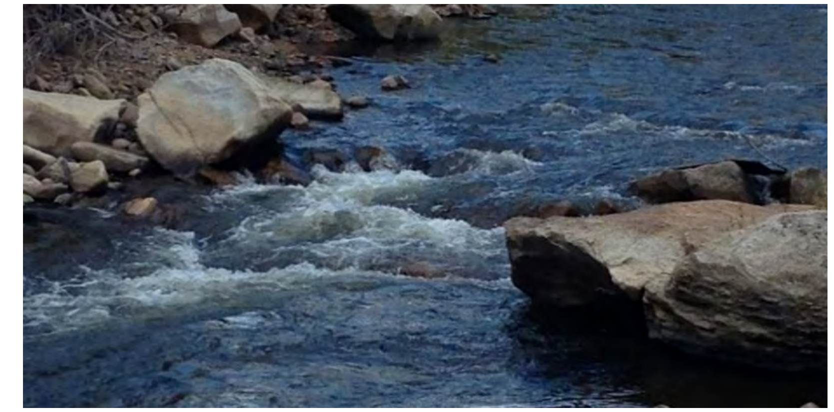


Figure 4.4. Single boulder placed on bank (reader's right).

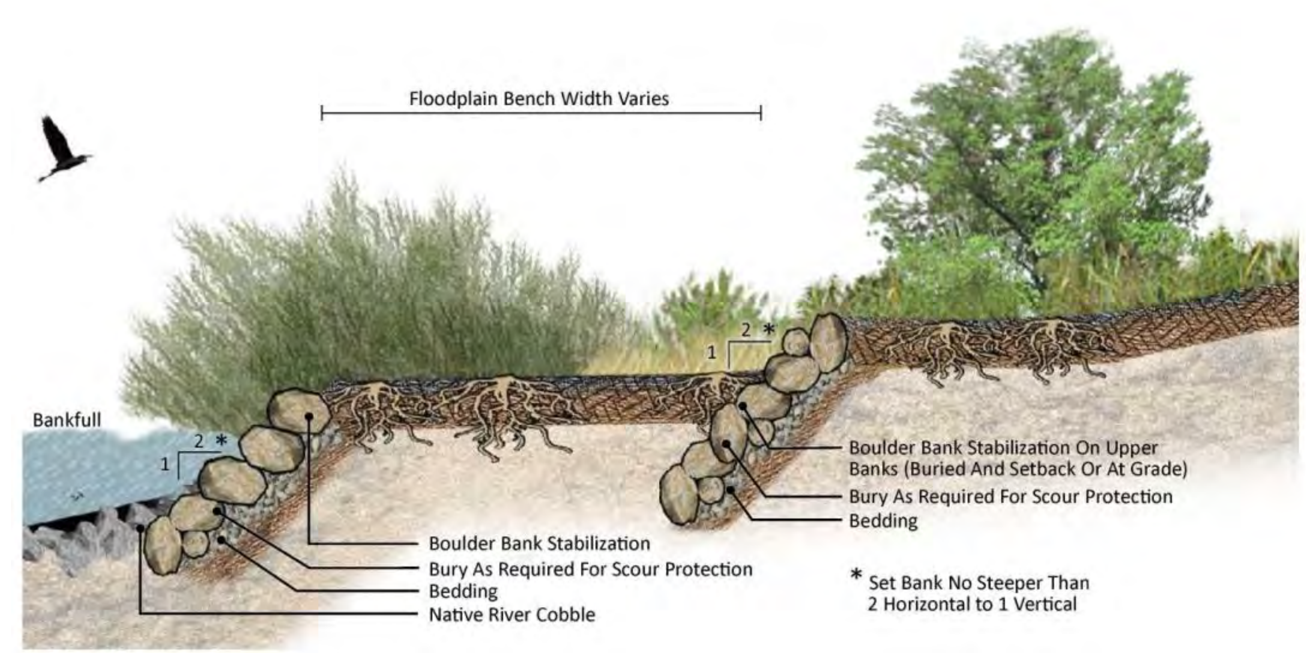


Figure 4.5. Level 1 – Boulder bank protection detail showing both channel and upper bank protection.

4.2.2 Excavate and Grade Low-flow Channel (capacity)

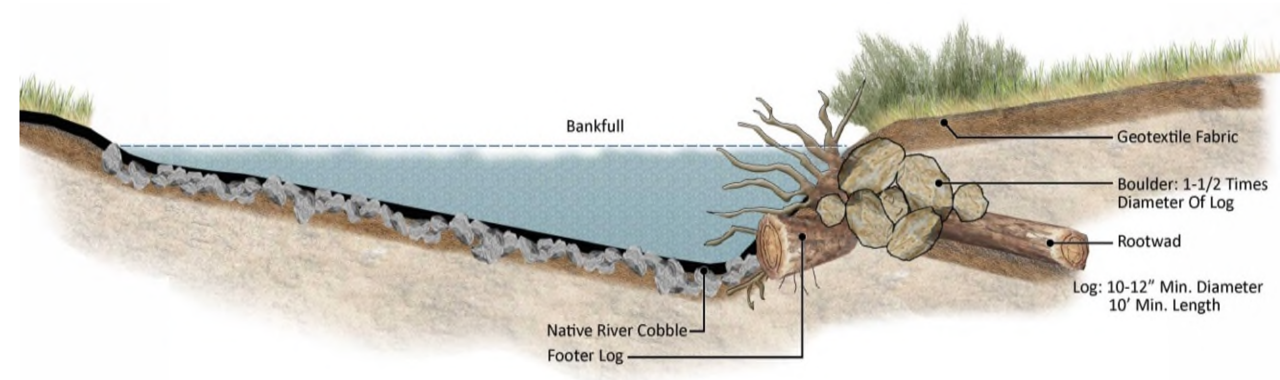
The lower reaches near the confluence with the Big Thompson are typically depositional, composed of sandy material and subject to lateral movement and vertical instability. However, most of the existing channel remains close to pre-flood conditions, with the exception of sediment deposition in the low-flow channel and localized bank instabilities, because the overbanks are relatively low in elevation and carry significant portions of flood flows, which provide some energy relief for the main channel. Therefore, recommendations include excavation and removal of sediment from the existing channel, coupled with bank restoration in the lower reaches of the Little Thompson River.

4.2.3 Bank Restoration

Three levels of recommended bank restoration were developed for both the channel banks and the upper floodplain banks: Level 1, representing the most structured bank protection; Level 3 the most natural bank protection; and, Level 2 a combination of structural techniques and vegetation. Level 1 protection would typically be riprap, soil cement, gabions, or other similar types of protection for those areas at high risk and generally in reaches that include some type of encroachment requiring protection from future bank failures. Thus, the use of Level 1 protection is generally limited to banks protecting bridge abutments, roads, and existing homes or buildings. Where possible, the Level 1 protection should be buried and set back in the landward side of a floodplain bench. An example of Level 1 protection is shown on **Figure 4.5** and includes riprap set at a maximum slope of 2H:1V, buried below the channel bottom for scour protection.

Level 2 bank protection includes a range of bio-engineered techniques that typically combine some type of revegetation with scour toe protection to minimize the loss of the vegetation through scour failures while the vegetation becomes established. Level 2 protection could include rootwads with scour toe protection (**Figure 4.6**), coir-encapsulated deformable banks, and channel bend banks with scour toe protection. The two details in **Figure 4.7** include the use of coil encapsulated soil lifts with live willow plugs and scour toe protection. The coir fabric is a biodegradable material that requires about 3 to 5 years to degrade. The purpose of coir fabric lifts is to stabilize the newly constructed channel banks for a sufficient period of time to allow for the establishment of the vegetation, primarily willows, which will in turn provide stabilization with its roots and take over the role of bank stabilization. As the coir fabric degrades, the banks will lose some of the soil immediately under the willow layers, which in turn simulates an undercut bank (hence the term deformable) and creates an undercut bank. Level 3 includes bank construction with native bed material, planting live willow layering, and grading and seeding in the overbank. Level 3 bank protection also includes the use of rootwads without the scour toe protection (**Figure 4.8**).

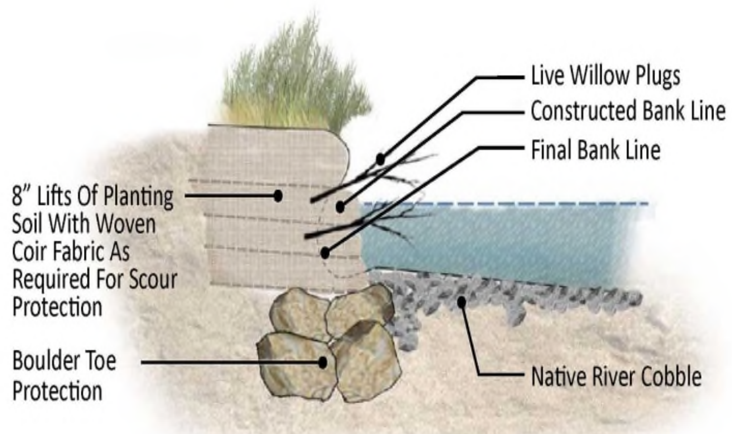
Rootwad revetment with scour toe protection and vegetated bank stabilization, Laramie, WY



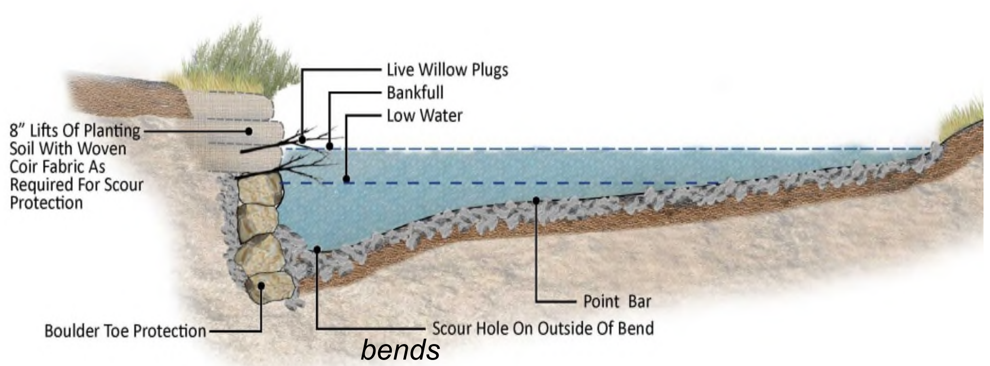
Typical rootwad detail

Figure 4.6. Level 2 - Rootwad revetment with scour toe protection example.

Before and after pictures of deformable bank construction along the Blue River in Summit County Colorado

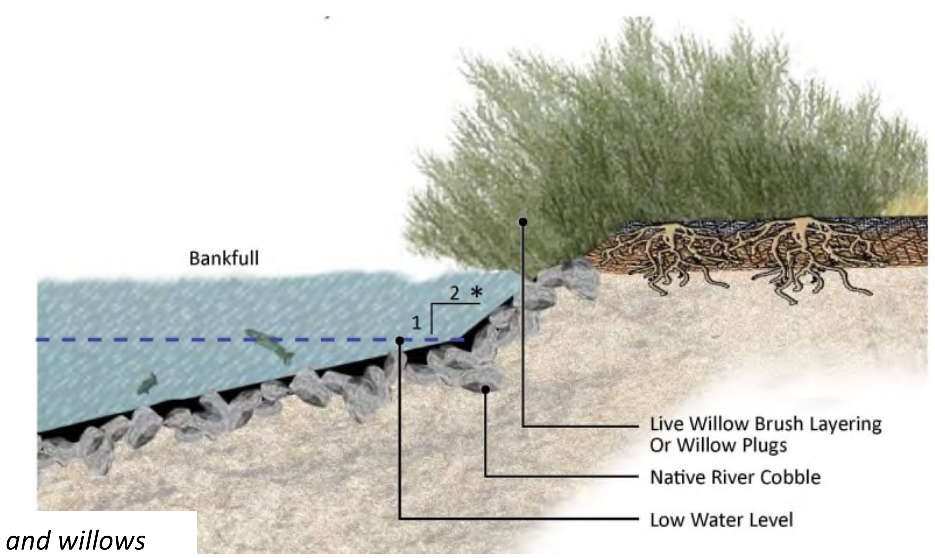


straight reaches

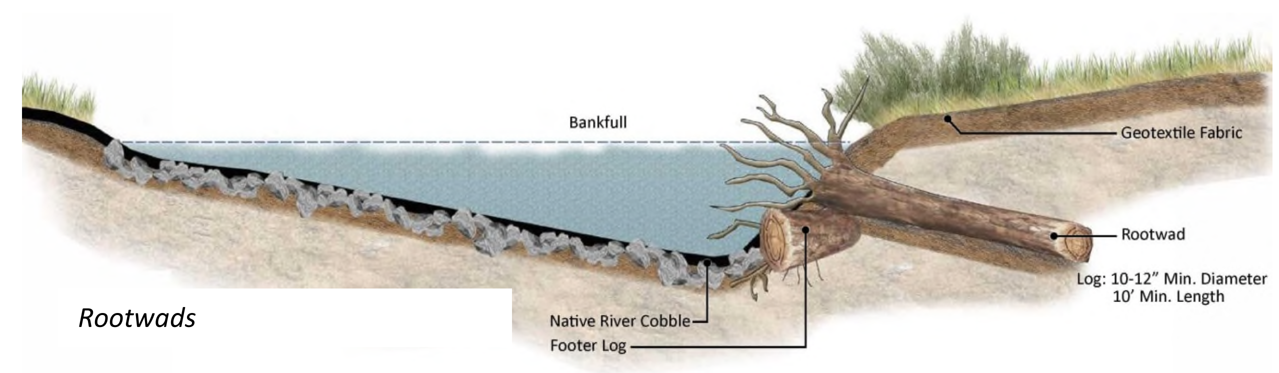


bends

Figure 4.7. Level 2 - Deformable bank examples.



Native bed material and willows



Rootwads

Figure 4.8. Level 3 – Native river bed material for bank construction, willows and rootwad installation without scour toe protection examples.

4.2.4 Floodplain Grading and Stabilization

As with the river channel, much of the floodplain was destroyed, and either lowered through scour or elevated through aggradation to the extent that the floodplain is now disconnected from the low-flow channel (aggraded sections) or the low-flow channel now occupies the entire floodplain and is overly wide (scoured or degraded sections). The floodplain was also de-vegetated in the foothills and canyon reaches, which included the loss of willows, grasses cottonwood trees, and fir trees. The floodplain vegetation in the plains region was generally laid down and not fully scoured, although in some of the highly aggraded areas the vegetation is significantly buried. In either case, the floodplain, either in concert with the channel reconstruction or as a stand-alone effort, should be restored. In some cases, this simply requires the grading of the floodplain area to smooth out the floodplain surface; in other cases the removal of sediment, or the addition of fill material, is required to form a distinct floodplain and reestablish proper hydraulic connectivity between the floodplain and low-flow channel.

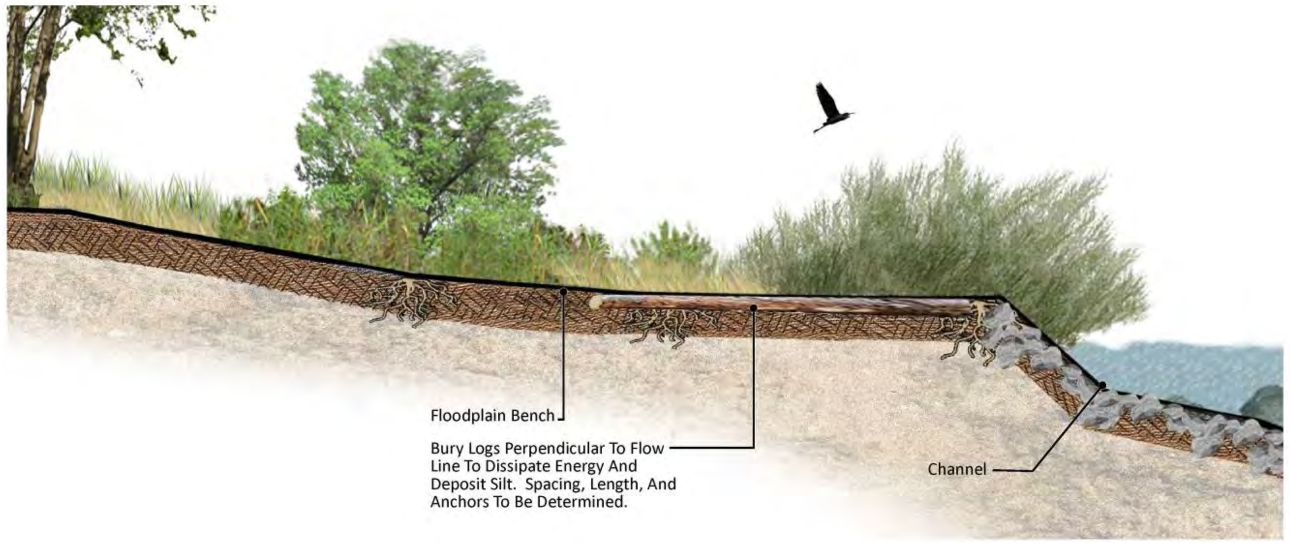


Figure 4.9. Floodplain grading and stabilization including the use of log silt fence.

After reconstruction and grading the floodplain, the surface of the floodplain should be stabilized with vegetation, including grasses, willows and cottonwoods (**Figure 4.9**). In some cases, the use of log silt fences may be considered to dissipate energy and encourage silt deposition where the floodplain area is sizeable and re-vegetating the area is not economically feasible, or additional stabilization is warranted because of the high velocities (Figure 4.9).

4.2.5 Land Reclamation and Fill of Overbanks

Land reclamation and fill are recommended in some portions of the plains and foothills reaches where the channel banks are low and overtopping flood flows caused headcutting into the overbanks, or sediment deposition was of sufficient depths to bury the existing vegetation. This recommendation includes grading and revegetation and possible placement of fill (compacted and graded) to repair headcutting, and removing or grading sediment followed by revegetation. Revegetation of overbanks would include final grading, seeding, weed management, and temporary irrigation.

4.2.6 Riparian Regeneration

Large events that change the course of the river and the associated erosion and deposition are natural functions of a river. Plant and tree species associated with riparian forests have also adapted to these conditions. These adaptations for certain species, such as cottonwood and willows, include reproductive methods such as seeding (where seeds fall from tree branches to grow into another tree), cloning (where a piece of a plant can break off and grow), and from root shoots (where a new tree can grow from the offshoot of a root of a parent tree). These methods allow for the regeneration of a species after a large flow event in depositional areas of a river. Floods can also break branches off of mature trees and bury them into depositional fields nearby or downstream. Once floodwaters recede, these branches can sprout and form new plants. This process also occurs annually on a smaller scale, where small sticks, or branchlets, naturally detach from the tree and float downstream and establish in good habitat to form new trees (Oregon State Extension Service 2002).

Deposition in each of the reaches described below can reach levels of 4 feet or more. When depositional fields become this large, they tend to become disconnected from the river and nearby water table. Disconnection causes the sand banks to dry out quickly, making cottonwood reproduction from seeds or branchlets difficult (Oregon State Extension Service 2002). In addition, portions of these deposits of sandy soil may begin to move downstream during larger flow events, destabilizing the substrate and any seedlings that may have sprouted. It is possible that these depositional fields could eventually stabilize and create good habitat for riparian vegetation in the future.

Canyon Reach

The canyon reach is composed of riparian woodlands within a narrow, rocky canyon. Because of the surviving vegetated conditions, many river and ecosystem functions are still intact. Natural regeneration of vegetation is expected to occur in remote areas away from disturbance. In particular, cottonwoods and chokecherry are expected to reestablish first in these areas because of their ability to easily grow from broken branches, rhizomes, or root crowns, and their ability to grow in exposed areas (Welch undated; Oregon State Extension Service 2002). Natural geomorphic and vegetative functions of these sections will allow cottonwood, willow, and other riparian species to regenerate through seeding and cloning. It is not expected that the location of the river and associated vegetation types will change much in the future.

Cottonwood, chokecherry, and small riparian species naturally occur at the toe of the bank near the river's edge, but reestablishment of vegetation on areas at the top or on the sloping edge of these banks will be best facilitated if done in concert with bank stabilization.

Foothills Reach

Narrowleaf and plains cottonwoods and willows characterize the foothills reach. Sand, gravel, cobble, and boulder depositions are found downstream of the confluence of the mainstem and West Fork. These deposits may add some stability to the river and allow for an increase in natural revegetation success in areas where there is good soil surrounding or intermixed in these hard surfaces. Narrowleaf cottonwood would be the most likely to be the first to establish here based on the plant's ability to clonally reproduce and because of its preference for high gradient, higher elevation, coarse substrate streams (D'Amico 1997). Native willow species would also be likely to establish in these types of substrates. However, it may require grading and floodplain stabilization to support the reestablishment of riparian vegetation in areas with too much hard rock and gravel and sand.

The soil composition changes to sand and clay dominant soils with larger depositional fields and mature stands of plains cottonwood in locations where the river gradient transitions from steep to moderate. The portions of these depositional fields located within close proximity to the river and water table have a high probability of establishing the riparian forest naturally, since plains cottonwood and willows prefer bare, moist soils protected from disturbance (Scott et al. 1996). There are stands of mature cottonwood trees that may be disconnected from their river by a change in the course of the river. Thus, recommendations in these areas include grading the floodplain to facilitate reconnection to the existing river and water table.

Plains Reach

This reach contains mostly large parcels of private land with some development, agriculture, and livestock grazing. The vegetation types are similar to those identified in the downstream portion of the foothills reach, including plains cottonwood, crack willow, smooth brome, horsetail, spikerush, bulrush, coyote willow, and snowberry. The river is relatively flat with many meanders and depositional areas, which are good areas for riparian regeneration. However, there are large amounts of sand and clay dominant soil deposits in river bends and on the flood plain are proposed for removal, which should in turn provide suitable areas for riparian regeneration.

The forest provided good bank protection against the strong currents and allowed the river structure and vegetation to remain relatively intact in most areas where a dense riparian forest existed before the flood. This dense riparian forest allowed for the formation of naturally occurring point bars on the banks and mid-channel bars in the middle of the river. The soils that accumulated on the inside banks of the meanders provide good habitat for new growth from seedlings or buried broken branches. If high enough, sandy mid-channel bars also provide good habitat for cottonwood regeneration. However, these sand bars tend to be disturbed annually by high and moderate flows, which destabilize the substrate and any seedlings that may have established. For the first year or two after the flood, seedlings or clone saplings are expected to appear in areas where the river channel widened and left large expansions of moist soil, but the mortality rate could be high through scouring from the river (D'Amico 1997). The highest terraces from the flood would be too high for sapling survival, but bands of cottonwoods could establish closer toward the river edge in locations that are close enough to the river to provide wet soils but high enough to avoid scouring from river flows Scott et al. 1996).

4.2.7 Active Revegetation

Given the nature of the flood and the diverse communities present within the watershed, there are several different types of areas that could benefit from active revegetation. The best restoration method should be based on conditions such as the severity of damage, slope, aspect, and soil type (CPW 1998). Potentially, some sites should be considered for use as reference sections to help select appropriate seed mixes, plant material, and planting rates. Some practices serve multiple functions and may directly or indirectly benefit the riparian community.

The type of desired vegetation should be considered before re-vegetation begins. For example, the desired vegetation could be cottonwood or willow, or mostly varied low-lying grasses and forbs. Generally, grasses and forbs are at the toe of the stream bank, and cottonwood and willow are farther upland (Hoag 2007). Only native seed should be used for restoration projects to prevent the spread of invasive plant species. A diverse native seed mix as opposed to exotic pastures mixes will provide added erosion control benefits.

Self-sustaining riparian forests can be restored with extensive efforts including pole plantings and habitat reestablishment. Self-sustaining riparian forest can be used to promote a diverse range of plant species and age classes to create a complex riparian forest. It is suggested that locally sourced materials are used when possible. These sources include native seed mixes and riparian pole plants from within the watershed to the extent possible. Trees and shrubs should be planted within the riparian area with a connection established between the roots and the subsurface flows to and from the river (for example, pole plantings at a depth to reach groundwater). This approach to planting will reduce a need for irrigation and help their survival rate. However, given the variable flows present in the Little Thompson, and thus likely variable groundwater depth, temporary irrigation would help facilitate survival rates.

Establishment of other vegetation, such as grasses and forbs, will also greatly benefit from irrigation. Seeding in the early spring is recommended to benefit from late winter snow and spring rains. Depending on the year, it should be adequate for germination. However, here again, there is risk that the rainfall is not sufficient, and temporary irrigation would be beneficial. Thus temporary irrigation should be included in the revegetation planning and implementation. A list of suggested seed mixes is provided at the end of **Appendix D**, Riparian Re-vegetation.

Weed control should be used to prevent infestations from noxious and non-native plants to the extent practical. It is suggested that weed control techniques, such as using weed-free seed, quick establishment of native plants, periodic monitoring, and applicable weed removal techniques, are employed, if needed. Weed control should be used on larger efforts, such as habitat restoration and self-sustaining riparian forest restoration, and smaller efforts, such as slope stabilization.

4.2.8 Fish Habitat

Several opportunities for aquatic habitat restoration along the Little Thompson River that may provide fishery benefits are provided below. Note that, based on post-flood conditions and indications of pre-flood assessments, the fishery has been marginal. Contributing to this assessment is the apparent intermittency of stream flow, as mentioned by several property owners in the Pinewood Springs area and supported by the limited records downstream at USGS Gage No. 06742000, where extensive periods of zero flow were observed in the late 1940s to early 1960s. Related to this are likely water temperature concerns as well. Thus, recommendations focus on refuge and resting opportunities to protect aquatic species under stressful low-flow and warm water conditions.

- Reconstruct the wetted channel using habitat features for the primary purposes of providing cover and resting areas for resident and migratory fish. Reconstruction would be accomplished through the formation of cover and pool formations and overhanging banks.
- Incorporate rootwads to encourage pool development, increase fish cover and resting habitat, and provide large woody surfaces for insect colonization. Rootwads are also recommended as possible components of Level 1 and 2 bank stabilization. When properly angled in an upstream direction, rootwads also provide important stream bank protection by directing flow toward mid-channel away from potentially erosive banks.
- Place boulders or boulder clusters in mid-channel, to provide pocket water, streambed diversity, and resting and cover areas to benefit both fish and insect life. This recommendation would be appropriate for the foothills and canyon regions.
- The use of boulder-step structures or vanes in locations such as the augmented flow section of the Little Thompson River below the St. Vrain Supply Canal, where there has been an established trout population.
- The development of small floodplain ponds in more densely populated areas such as Pinewood Springs and Blue Mountain that could provide opportunities for fishing as well as other water-based recreation such as swimming and ice-skating. (See publications such as USDA Natural Resource Conservation Service Agriculture Handbook 590, "Ponds – Planning, Design, Construction" for additional information.)

4.2.9 Debris Cleanup

Debris cleanup is recommended throughout the river where the debris creates an obstruction to flows in the main channel. The removal of overbank debris may also be warranted, particularly where the size of the debris piles is significant and result in reduced flood flow conveyance. Debris cleanup was under way at the time of the field reconnaissance, has continued throughout the planning process, and will likely be complete, particularly on private properties, before this Master Plan is implemented. Thus, debris removal is not included as a restoration strategy.

On lands managed by the USFS, management activities must be in line with the Land and Resource Management Plan (Forest Plan) for the forest and in some reaches does not include debris removal. The general exception is for those reaches along transportation corridors where road crossing and adjacent roads require reconstruction. Leaving the debris on USFS-managed lands raises several concerns. First, debris could, in some locations, result in capacity limitations. Some of the reaches on USFS-managed lands should be evaluated for the potential to flood adjacent lands not managed by USFS such as private property or public rights-of-way. A second concern is the accumulation of trash and loose debris that may break loose at a later time and move downstream. Thus, one of the recommendations presented here is for the USFS directly, or with the assistance of the LTWRC, to assess the need for and implement a debris removal program.

4.2.10 Ponds

Three neighborhoods along the Little Thompson River, Pinewood Springs, Blue Mountain, and Big Elk Meadows depend on local water supplies for fire-fighting. In Pinewood Springs, Crescent Lake was used for water supply to fight fires. The lake also provided a training area for the fire department. Crescent Lake, the river, and banks immediately adjacent to it were destroyed by the 2013 flood. Recommendations in this Master Plan include reconstruction of the lake, including appurtenances for firefighting (installation of a dry hydrant and access to the lake) and for recreation. In addition, recommendations include designs that also provide fish refuge, opportunities for fishing as well as other water-based recreation such as swimming and ice-skating.

In the case of Blue Mountain, a fire station and cistern were located upstream of Stagecoach Trail. The 2013 flood totally destroyed the fire station and undermined the foundation of the stream-side cistern. Work is currently under way to re-stabilize the cistern foundation. Additional recommendations in this Master Plan include improvements of access to the cistern and the construction of a pond potentially with appurtenances to serve as a back-up water source for fire-fighting and to provide fish refuge and opportunities for fishing, swimming and ice-skating.

The third neighborhood is Big Elk Meadows. As previously mentioned, there are five small water supply dams in the Big Elk Meadows subdivision. During the 2013 flood, these dams were overtopped by the Little Thompson River and failed. At the time this Master Plan was being prepared, plans were being made to reconstruct all five dams.

4.2.11 Culvert and/or Bridge Replacement

As previously noted, many bridges require replacement or major reconstruction. CDOT and all three counties have either repaired bridges or are currently in the planning and design stages for replacement or reconstruction. Limited funding prevents reconstruction for some bridges that would be required to return the bridge to the pre-flood condition. Bridge replacement or reconstruction to improve capacity and stability is recommended in two cases where the pre-flood condition for bridge or culvert repair work is likely insufficient, as evident by reports of frequent failures or extensive post-flood impacts. The Master Plan includes recommendations for analysis and design of modifications or replacement for privately owned culverts and bridges that were damaged or destroyed, or where the visual assessment indicates the repair work is likely insufficient. Even if no specific recommendations are indicated on the maps, the Master Plan recommends that all bridge approaches and abutments be protected to an appropriate toe-down depth and tied into the adjacent banks to prevent flanking.

4.2.12 Water Supply

Several stakeholders and property owners have expressed a concern over the lack of a constant flow of water in the river for the support of fisheries, riparian vegetation, wildlife habitat, and agricultural uses. As previously noted, the shortage of late season water has occurred for many years (at least as far back as the 1940s) as recorded at the near Berthoud gage (USGS Gage No. 06742000), where extensive periods of zero flow were observed. The shortage of late-season water is likely a combination of natural hydrologic processes and water diversions. Many factors would need to be considered to create a reliable, year-round baseflow, including an assessment of the watershed's natural hydrology, existing and future water uses, CBT diversions, agricultural uses, and opportunities to improve the existing water regime through acquisition of water rights and conversion from existing uses. To that end, the LTWRC is currently seeking a grant to prepare a water supply study. This study will be an ongoing and parallel effort with the implementation of this Master Plan.

4.2.13 Resiliency Planning

The term "resiliency" is used to describe the ability of a river system to return to its functional state after a disturbance. The disturbance is often temporary, but of some recurrence regularity that often results in ecosystem evolution that adapts to or depends on the disturbance (Darby and Sear 2008). The goal with resiliency planning is to break the disaster-rebuild cycle by developing new approaches to restoration that provide improved methods for flood response, thereby making the river system more resilient to extreme flow conditions.

River restoration projects that might be considered in terms of providing improved resiliency include the relocation of structures from the floodplain, single-span bridge replacements of existing culverts, expanding the riparian corridor with native vegetation, revised floodplain regulations, and increased setbacks, among a variety of other actions. Some of these recommendations are incorporated into the recommendations presented in this Master Plan, such as the replacement of a culvert with a single-span bridge and additional riparian plantings. Other recommendations will require additional planning and regulatory efforts that are beyond the focus of this Master Plan. This recommendation is provided as a placeholder for future consideration of the LTWRC, planning and regulatory development, and implementation of post-flood development.

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5 IMPLEMENTATION

5.1 Implementation

Many of the recommended improvements could be constructed as stand-alone projects. This is particularly true of smaller, isolated and non-contiguous improvements such as bank stabilization, sediment removal and land reclamation shown along the lower 10 to 15 miles of the river in the plains reach. Other improvements would be better if implemented together and are typically contiguous improvements that together comprise a larger project such as many of the areas shown within the foothill reach. Five illustrative drawings are presented in **Appendix F**, prepared for the purpose of graphically depicting a group of improvements in a specific location using an artistic presentation. These are shown only for illustrative purposes and are not intended to depict a sequential or specific preference or recommendation.

Implementation of the recommended improvements could be accomplished either by the individual landowners and/or homeowner associations who would be ultimately responsible for construction and long-term maintenance. Alternatively, construction could be overseen by the LTWRC (as a non-profit watershed group), or a municipality (city or county). Under these conditions, and depending on funding sources, implementation of project easements may be required, with the easements being dedicated to the responsible entity for the purposes of construction and long-term maintenance.

Further consideration is required to assess the details of implementation including the cost related to easements and agreements for construction and maintenance, which are unknown at this time and not included herein. Further, all recommendations are subject to modifications pending a detailed hydraulic analysis and the acquisition of additional data, design and a review of constraints.

5.2 Floodplain Management and Development

The National Flood Insurance Program (NFIP) is a Federal program created by Congress to mitigate flood losses through community-enforced building and zoning ordinances and to provide access to insurance for property protection. Participation in the NFIP requires that the community enforce a floodplain management ordinance to reduce future flood risk in the Special Flood Hazard Areas (SFHAs). The SFHA is a high-risk area defined as any land that would be inundated by a flood having a 1-percent chance of occurring in a given year. Generally, the SFHA is identified on Flood Insurance Rate Maps (FIRMs). The FIRMs may also depict a floodway, which is defined as the stream channel plus the portion of the floodplain outside the channel banks that must be kept free from encroachment so that flows may pass without increasing the flood levels by a designated amount (typically 0 to 1 foot depending on the community). Development may take place within an SFHA provided that development complies with local and Federal floodplain ordinances. Development in a floodway is generally discouraged unless it can be proven that the encroachment will not alter flood elevations.

Most of the communities within the Little Thompson watershed participate in the NFIP and have effective FIRMs with which they have relied on to regulate development in or near the SFHA and floodway. However, the 2013 flood altered the alignment of the Little Thompson, as well as the elevations of the channel and, in many cases, the floodplain. Some areas only experienced minor alterations, but the changes in many areas were significant. In either case, the current effective FIRMs may not be accurate indicators of the extent of the SFHA and flood elevations. At some point the FIRMs will be updated, but typically this is a long term process which could take several years to accomplish. In the meantime, community officials also have available to them preliminary floodplain mapping prepared by the Colorado Water Conservation Board, which provides additional guidance on approximate flood extent and elevations.

The recommended improvements in this Master Plan are typically within the SFHA and will require approval from community floodplain administrators prior to implementation. Depending on the timing, it may be possible to obtain approval to implement this work before the FEMA FIRMs are updated. In this case, floodplain managers may choose to utilize the current effective FIRMs and/or information from CWCB mapping to inform a decision on the approval of the project. It is also likely that applicants for floodplain permits will need to prepare a hydraulic analyses of the existing and proposed conditions to demonstrate that a project can be implemented in compliance with the NFIP. Prior to implementing improvements recommended in this Master Plan, consultation with the local community floodplain administrator will be necessary. Requirements for approvals from the communities for reconstruction or restoration within a SFHA will be assessed on a case by case basis.

A project could be a single project representing one property/recommendation or the collective work proposed for a series of adjacent and contiguous improvements. A project may also be considered emergency repair work in which case submittal and permitting requirements fall under those guidelines presented in Section 5.4 and outlined in Appendix E.

5.3 Considerations during construction

In general, much of this work will be performed in areas already highly disturbed from the 2013 flood, thus requiring extra care to minimize soil loss and erosion due to construction traffic and staging. In addition work in the river will also be required for low-flow channel construction and/or refinement and, in some areas where bank stabilization is recommended adjacent to the river. Specific considerations are presented below. Note that the construction considerations will be defined in more detail during the preparation of preliminary and final plans.

Site Access and Staging

Construction operations will typically take place on privately owned property, and the necessary access, space required for project staging, material lay down, and job office set-up must also be provided either on private property or in easements acquired for construction and maintenance.

Water Quality

A water control plan will be required for constructing the low-flow channel. This may require a temporary diversion of the river and should be implemented in later summer or fall when flows are low and can easily be diverted in a culvert or temporary channel. Pumping may be required during construction of subgrade improvements such as scour toe protection, in which case a settling pond may be required.

Construction in the upland areas will generally be performed in the dry and will have minimal impacts on sediment in the river. However, to limit stormwater erosion these areas will require best management practices (BMPs) such as silt fences, hay bales, sediment basins, etc. A stormwater management plan and permit, to be developed with construction drawings, will be required from the State of Colorado for control of stormwater runoff, as well as for dewatering during excavation.

BMPs to minimize impacts to native vegetation

There are areas of riparian species, which survived the flood, that are to be protected within the construction disturbance area. Work in and around these areas must be executed in a manner that protects the native vegetation and seed sources for natural recruitment. These areas should be marked with signs and/or flagging to restrict access during construction. In some cases, hand work may be required.

5.4 Permitting for Master Plan implementation

The purpose of requiring permits for development in the floodplain is to ensure all construction complies with federal, state, and local requirements specified in current codes, standards, flood ordinances, and recommended construction techniques to help prevent damage in future flood events. Permitting processes, requirements, and standards that guide development in the floodplain vary from jurisdiction to jurisdiction. Some communities have adopted ordinances that enforce more stringent standards than the minimums specified by FEMA and CWCB, while others have developed additional permits to help streamline relief efforts. The following list provides some of the common permits and certificates that may be required when rebuilding in the floodplain. A description of these permits including additional community-specific details and a contact list (current as of 2014) is provided in **Appendix E**.

Local Permits

- Building Permit
- Electrical Permit
- Temporary and Emergency Building/Repair Permit
- Floodplain Development Permit
- 1041 Permit
- Septic System Permit
- Temporary and Emergency Building Permit
- Stormwater Quality Management Permit

State permits

- Construction Stormwater Permit (Section 401)

Federal Permits/ Certificates

- FEMA Elevation Certificate
- FEMA No-Rise Certificate
- FEMA Floodproofing Certificate
- USACE Section 404 Permit
- National Environmental Policy Act (NEPA)

5.5 Opinion of Probable Costs

A conceptual level Opinion of Probable Costs is present in Appendix C generally on a site-by-site basis, with the specific strategies grouped together on a sub-reach basis. For example, a 1,000-foot section within a reach may include creating a new low-flow channel, grading, and floodplain stabilization to meet all of the objectives for restoration for that given subreach. In this example, all three strategies (low-flow channel, grading, and floodplain stabilization) would be included in the cost detail for the 1,000-foot section. The cost estimates reflect a series of individual projects and assume they will be implemented on a project-by-project basis because the restoration improvement are not continuous for the entire length of the river, and because the river is not contiguous in terms of access and transportation corridors. Combining projects may in some cases provide cost savings for items such as mobilization, permitting, and preparation of contract documents. However, planning on individual projects provides improved flexibility for implementation.

This estimate is based on unit pricing and the conceptual drawings presented here. Preliminary and final designs would be required to refine these estimates. Unit prices do not consider possible cost inflation created by a higher than usual demand for materials such as boulders, topsoil, and planting material. However, an additional 12-percent mark-up is added in an attempt to reflect inflated prices based on contractor availability and competitive bidding conditions. Quantities for this estimate are prepared without the use of topographic mapping and without a detailed hydraulic analysis. Thus, the quantities are subject to modification. Important assumptions considered in the preparation of the cost estimate are noted below and in the description of cost items. Finally, landowners and stakeholders began and in some cases completed some of these improvements during the time period when this Master Plan was prepared. It is anticipated that additional improvements will be implemented by the landowners on a site-by-site basis before funding is secured and this Master Plan implemented. Note that the quantities and costs presented here reflect full construction as assessed at the beginning of the site assessments and have not been modified to reflect landowner improvements.

5.5.1 Assumptions and Notes

General Assumptions

- No restoration or cleanup will be implemented on lands managed by the USFS, totaling 14 miles, except adjacent to Larimer County Road 47 and US Highway 36,
- Restoration at the dams in Big Elk Meadows and removal of sediment below the dams are not included in this estimate.
- Costs for restoration efforts by CDOT along Highway 36 and at county and city bridges are covered by each entity and not included in this estimate,
- Restoration quantities are estimated without design confirmation, and
- Unit prices are not confirmed by bids or construction estimates.

Clearing and Grubbing

This estimate assumes clearing and grubbing is generally not needed, or relatively minor, as most of the work will be conducted within the riparian corridor where there is currently no or little vegetation.

Utilities

The location of utilities within the project reach is unknown at this time. Utility locations will be required for preliminary and final planning and design and should be performed in conjunction with preparation of base mapping.

Construction Methodology

Standard construction practices, materials, and equipment are anticipated on this project

Unusual Conditions (Soil, Water, Weather)

It is anticipated that work in unusual conditions for this Master Plan will not significantly alter the cost or effort for construction. Care shall be taken when working in inclement weather as well as working in and about any waterway. The proximity to any bodies of water should be approached with due care to prevent debris, erosion, and spills from entering into the waterway. Similar care is to be taken during operations taking place near roadway and highway areas.

5.5.2 Description of Cost Items

Mobilization and Demobilization

Mobilization will include all activities and associated costs for transportation of contractor's personnel, equipment, and operating supplies to the site; establishment of offices, buildings, and other necessary general facilities for the contractor's operations at the site; premiums paid for performance and payment bonds and insurance. Demobilization will include disassembly, removal, and site cleanup of offices, buildings, and other facilities assembled on the site specifically for this contract. Mobilization and demobilization are estimated as a single line item at 5 percent of the overall project cost.

Dewatering

Dewatering will be required for those work items in the wetted channel. Costs assume this work will be done in fall or early winter and include the construction of a temporary channel to by-pass the river flows, plus intermittent pumping to dewater subgrade excavations required to place bank stabilization., It is likely this assumption is conservative because the Little Thompson often goes dry in late summer.

Create/refine Low-flow Channel

This item includes costs to create or redefine the low-flow channel in areas that were either scoured to a very wide channel section or deposition of material filled the low-flow channel, also essentially creating an overly wide channel. The work includes the cost to excavate or shape and elevate the channel banks and installation of a 6-inch layer of native bed material on the bottom and banks of the low-flow channel. The low flow channel is based on a channel width of 20 feet and depth of 2 feet for estimating quantities.

Excavate, Grade Low-flow Channel (capacity)

This item includes reaches, generally in the lower plains reaches, where deposition must be removed to restore the capacity of the channel. Capacity and sizing must be assessed as data and modeling become available, including comparison of pre-flood and post-flood capacities and flood elevations for a range of flow conditions including the bankfull and 100-year capacities. This estimate assumes that deposition is 3 to 5 feet deep within a 20-foot-wide section and the material is excavated and hauled off site. A cost savings could be realized if the material could be used nearby; however, placing the material near the river and in the floodplain is discouraged, as it may reduce the conveyance capacity of high flows in the overbanks.

Grading

This item is for work required to grade portions of the floodplain and overbank areas altered by the flood that left the surfaces irregular with deposits and scour holes. Some of the localized deposition is of sufficient depth to cover tree roots and potential seed sources, so grading and removing the deposits and reshaping the surfaces will facilitate the recovery of vegetation. This item assumes minor fill or grading or tilling over the top 1 foot of the floodplain and overbank surfaces and that the quantities balance and no haul-off or import is required.

Floodplain Stabilization

The purpose of this work is to stabilize floodplain overbanks and other surfaces that are expected to flood on a relatively frequent basis. Post-flood conditions have left these surfaces vegetated and vulnerable to erosion. Stabilization includes a combination of log silt fences, pole plantings, and seeding. Grading, if required, is covered in the grading item. Seed mix will be a native riparian species and wildflowers.

Lowering and Grading

This item is for work required to grade and lower portions of the floodplain with excessive deposition on the surfaces to facilitate vegetation regrowth, increase flood conveyance and reduce the amount of material available for downstream transport. Quantities assume 1 to 3 feet of sediments with an average of 2 feet over the footprint of the area. The costs assume the excess material will be transported to a location within the footprint of the project site but above the 100-year floodplain, so trucking off site is not required. Costs include final grading or tilling.

Point Bar Creation

In conjunction with the create/refine low-flow channel, point bars will be built, on the inside of bends along the low channel and composed of native material. This estimate assumes the point bars vary from 0 to 10 feet wide for an average of 5 feet along its length for a 2-foot depth.

Bank Stabilization, Level 1

This estimate assumes that Level 1 bank protection will be riprap. Other materials are possible and could include soil cement, gabion baskets, and grouted riprap. This item assumes the channel is 2 feet deep at the banks, the existing channel banks are at a 2H:1V slope , with a 3-foot buried toe-down for scour protection This item assumes that rock riprap must be at least 30 inches in diameter, be angular or quarried boulders, and be bedded with a gravel filter layer. The costs include pole plantings placed between the rows of boulders at 2-foot intervals. Weed control and irrigation are included with the ‘temporary irrigation’ item.

Bank Stabilization, Level 2

Level 2 bank stabilization is a combination of Levels 1 and 3 in one of many types of bio-engineered configurations. These configurations might include coir-wrapped soil lifts on top of stone toe scour protection, or stone toe reinforced rootwads. Weed control and irrigation are included with the temporary irrigation item. Unit costs for this item are estimated by assuming the riprap is half the cost from Level 1 and revegetation costs are approximately equal to those for Level 3.

Bank Stabilization, Level 3

Level 3 bank stabilization costs include costs for native vegetation and/or river cobble to form the channel banks. Weed control and irrigation are included with the temporary irrigation item.

Land Reclamation Fill

This item includes the cost to fill, compact holes, and grade or till head cuts, that moved inland into the overbanks.

Upper Bank Stabilization, Level 1

This estimate assume Level 1 bank protection will be riprap. Other materials are possible and could include soil cement, gabion baskets, and grouted riprap. This item assumes a bank 3 feet tall at a 1 to 1 slope, with a 1-foot buried toe for scour protection. This item assumes boulders must be at least 18 inches in diameter, be angular or quarried boulders, and be bedded with a gravel filter layer. The Level 1 upper stabilization does not include vegetation, as it is likely too high above the groundwater to support willow growth. Seeding costs behind the riprap are covered under the seeding line item presented below.

Upper Bank Stabilization, Level 2

Level 2 bank stabilization is a combination of Levels 1 and 3 in one of many types of bio-engineered configurations. These configurations might include geotextile-reinforced slopes with native grass, or coir wrapped soil lifts on top of stone toe scour protection. Weed control and irrigation are included with the temporary irrigation item. Unit costs for this item are estimated by assuming the riprap is half the cost from Level 1 and revegetation costs are approximately equal to those for Level 3.

Upper Bank Stabilization, Level 3

Costs for this item includes regrading the banks at 3H:1V and seed with wildflowers or other uplands seed mix.

Seeding

This estimate assumes that all the surface areas designated for grading, floodplain stabilization, lowering and grading, and land reclamation fill will be reseeded.

Temporary Irrigation and Weed Management

Temporary irrigation and weed management may be required for revegetation in some areas, typically those that are planted at levels relatively high above the river and above access to groundwater. Actual costs may differ substantially, as this item is subject to many unknown variables. The assumption includes 25 percent of the cost of the areas to be seeded (graded, floodplain stabilization, lowering and grading, and land reclamation/fill), plus 25 percent of the cost of bank stabilization since they include revegetation components.

Debris and Trash Removal on USFS Managed Lands

This item is included as a lump sum cost for the Little Thompson River until additional detail can be identified as to the extent of work and logistical issues of allowing debris removal on public lands. Implementation will require the cooperation of the USFS, counties, and community in a manner that has yet to be discussed.

Site-specific

Site-specific costs are added for those items not covered in the categories noted above. This category includes culverts and small crossings, road reconstruction, irrigation headgate replacement, and a flood-warning gage.

Other Costs

In addition to the construction costs, 15 percent is added for contingencies, 2.5 percent for permitting, 15 percent for detailed design, and 10 percent for supervision and administration. Design, plans, specification, and construction administration includes final analysis (hydraulic and sediment transport), surveying, preliminary and final design, preparation of plans and technical specifications and administration of the construction contract.

Effective Dates for Labor, Equipment, Material Pricing

The Opinion of Probable Cost was generated during August 2014 and is based on this Master Plan, including the Conceptual Design Drawings contained in Appendix C, and typical unit costs for the features of work. However, given the amount of restoration-related work that is currently on going in the Front Range on all the affected watersheds, a high demand inflation cost factor is added of 12 percent.

5.5.3 Summary of Costs

As mentioned above, the Little Thompson River is divided into 123 maps sheets, each at a scale of 1 inch =200 feet for presentation of the detailed restoration and reconstruction recommendations, including costs. These sheets are presented in Appendix C along with the restoration recommendations, mapping, and site description. Note that the sheets depict sites by stations, but the recommendations are often grouped together within a sheet page or along a portion of a reach. Thus, the stationing of the sheet reaches does not necessarily match the stations of the recommended improvements and is noted on the individual map sheets.

The cost estimates reflect a series of recommended improvements, grouped together in a logical manner to form a series of projects, because the restoration improvement are not continuous along the entire length of the river, nor is the river contiguous in terms of access and transportation corridors. A summary of these costs are presented in **Table 5.1**.

The opinion of cost also includes an estimate for resiliency planning and implementation. Projects not directly identified in this Master Plan, which might be considered in the future for providing improved resiliency, include relocation of structures from the floodplain, additional single-span bridge replacements of existing culverts, expanding the riparian corridor with native vegetation, revised floodplain regulations, and increased set-backs, among other actions. The cost may be notably different than assumed here, as it is subject to many unknown variables and future planning. The estimate for resiliency implementation assumes the relocation of several homes, replacement of several culverts with single-span bridges, and additional riparian planting along 40 miles of river.

5.6 Next Steps

This Master Plan is conceptual and based on the best data available immediately after the 2013 flood. The next major step is to develop and complete preliminary and final plans and application for permits. Some of the more detailed analyses needed to support plan preparation are listed below, although the list is not exhaustive.

1. Collect topographic information including site-specific surveys at proposed improvements.
2. Develop detailed hydrology for the low-flow channel conditions including an analysis of the impacts of diversions downstream of the St. Vrain Canal.
3. Develop hydraulic analysis and sediment-transport analysis.
4. Consult with the floodplain administrator to determine submittal requirements for the acquisition of a floodplain permit. Prepare required hydraulic analyses.
5. Refine the design of the low-flow channel using appropriate geomorphic principles; update and refine the hydraulic analysis (Step 3) for further balancing the high-water overflow with the required flows for sediment transport.
6. Define channel profiles and incorporate riffles, runs, and pools.
7. Continue to coordinate with the Counties, Cities and CDOT on bridge designs.
8. Evaluate potential for utility conflicts.
9. Locate rock sources and/or develop alternatives to riprap such as soil cement.

10. Develop preliminary plans, with grading and details. Refine grading as required to balance earthwork. Prepare preliminary technical specifications.
11. Quantify water requirements for irrigation. Secure water sources.
12. Refine cost estimates and secure funding.
13. Consult with permitting agencies and prepare and submit permit applications.
14. Prepare final plans, construction drawings and technical specifications.
15. Implement a water supply study to assess the feasibility of increasing low and base flows.
16. Develop a vegetation monitoring plan for both constructed improvements and those areas left to natural recovery.

Table 5.1. Little Thompson River Restoration Master Plan opinion of probable cost.

Item Description	Total Cost
Mobilize/Demobilize	$ 978,100
Dewatering	$ 1,850,700
Create/refine Low Flow Channel	$ 719,500
Excavate, Grade Low Flow Channel (capacity)	$ 2,726,400
Grade Control	$ -
Grading	$ 732,000
Floodplain Stabilization	$ 507,000
Lowering and Grading	$ 1,489,100
Point Bar Creation	$ 140,400
Bank Stabilization, Level 1	$ 1,350,800
Bank Stabilization, Level 2	$ 1,266,800
Bank Stabilization, Level 3	$ 882,300
Land Reclamation Fill	$ 786,600
Upper Bank Stabilization, Level 1	$ 47,100
Upper Bank Stabilization, Level 2	$ 24,700
Upper Bank Stabilization, Level 3	$ 16,700
Seeding	$ 1,767,300
Temporary irrigation and weed management	$ 1,054,600
Site Specific	$ 4,032,900
SUBTOTAL	$ 20,373,000
Contingency, 15% of subtotal	$ 3,056,000
Permitting , 2.5% of subtotal	$ 509,300
Design, plans, specification, contract administration, 15%	$ 3,056,000
Supervision & Administration, 10%	$ 2,037,300
SUBTOTAL	$ 29,031,600
High demand inflation cost, 12%	$ 3,484,000
Resiliency planning and implementation	$ 5,658,000
TOTAL	**$ 38,200,000**

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