APPENDIX A

Alternatives Analysis

Reach 2 Alternative Corridors Analysis

Technical Report – Thornton Water Project

Reach 2 Alternative Corridors Analysis

Prepared for
City of Thornton

September 2016

CH2MHILL

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Acronyms and Abbreviations

CDOT	Colorado Department of Transportation
DFIRM	Digital Flood Insurance Rate Map
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Studies
GIS	Geographic Information System
I-25	Interstate 25
LCR	Larimer County Road
NFHL	National Flood Hazard Layer
NFIP	National Flood Insurance Program
NWI	National Wetland Inventory
ROW	Right-of-way
RTD	Regional Transportation District
Thornton	City of Thornton
TWP	Thornton Water Project
TWTP	Thornton Water Treatment Plant
USA	United States of America
USFWS	United States Fish and Wildlife Service
WCR	Weld County Road
WBWTP	Wes Brown Water Treatment Plant
WSSC	Water Supply and Storage Company
WSSC Reservoir No. 4	WSSC Reservoir Number 4

Executive Summary

This technical report summarizes the analysis used to aid in the selection of a preferred corridor for the Thornton Water Project (TWP) water pipeline for the city of Thornton (Thornton). The analysis was performed on four alternative corridors within a 3- to 5 ½-mile wide path from the Water Supply and Storage Company's (WSSC) Reservoir No. 4 (WSSC Reservoir No. 4) in unincorporated Larimer County to Thornton, terminating at either the Thornton Water Treatment Plant or the Wes Brown Water Treatment Plant, or both. This technical report focuses on Reach 2, the portion of the water pipeline that would extend from WSSC Reservoir No. 4 to 168th Avenue, the County line between Weld and Adams County. The alternative corridors were developed using guidelines including the following:

- Input from potentially affected local governments
- Minimizing impacts to right of way (ROW)
- Minimizing impacts to water bodies and wetlands
- Bypassing geological hazardous areas
- Minimizing impacts to environmentally sensitive areas such as open space or conservation areas
- Minimize impacts to congested areas, typically in developed, densely populated areas
- Utilizing Thornton-owned property
- Following ROW/easements/property lines

After determining locations that met these guidelines, corridor segments were identified and then used to form a complete alternative corridor from the WSSC Reservoir No. 4 outlet structure to the Weld County line at 168th Avenue. A corridor segment is the smallest unique length of an alternative corridor. This exercise identified three alternative corridors: Alternative A, Alternative B, and Alternative C. Typically, alternative corridors are approximately ¼-mile wide.

In 2015, the TWP Team conducted local government outreach meetings with municipalities that TWP construction might encounter in the evaluation area. Based on input received from this local government outreach, an Alternative D was created. Alternative D combines portions of Alternatives B and C and includes the north portion of Alternative B and the south portion of Alternative C. The four alternative corridors were then analyzed using non-economic criteria to determine the preferred TWP corridor.

The non-economic criteria and method of measurement used in the evaluation of alternatives included the following:

- Local Government Preference - Rating scale from 1 to 8 based on compliance with local government preferences
- Geologic Hazards – Estimated length within areas identified as having mine subsidence
- Community Impact- Number of local government boundaries crossed
- Wetland/Riparian Crossing – Estimated length of wetland/riparian areas crossed
- Floodplain Crossings – Estimated length of floodplain areas crossed
- Parcel Owners - Number of unique parcel owners crossed
- ROW - Estimated possible length of water pipeline in ROW

The non-economic analysis was conducted using normalized scores from 1 to 5, with lower scores being more favorable. After weighting the normalized scores Alternative D, which has the most favorable score due to a low value in most criteria except parcel owners, was determined to be the preferred TWP corridor. Alternative B was the least favorable due to poor scoring in most categories.

Section 1 – Introduction

The purpose of this technical report is to document and present the means and methods for evaluating alternative corridors using non-economic criteria for the Thornton Water Project (TWP) Reach 2 and present the results of the evaluation.

The TWP will include a source water pump station in Larimer County and a booster pump station in Weld County, a water storage tank in either Weld or Larimer County, and a buried domestic water pipeline that will convey domestic water from the Water Supply and Storage Company Reservoir Number 4 (WSSC Reservoir No. 4) north of the city of Fort Collins in Larimer County to the city of Thornton (Thornton), terminating at either the Thornton Water Treatment Plant (TWTP) site or the Wes Brown Water Treatment Plant (WBWTP) site, or both. The water pipeline will be constructed in multiple counties and municipalities.

The water pipeline has been divided into the following reaches:

- Reach 1 – 168th Avenue to TWTP (at Thornton Parkway and Downing Street) and WBWTP (at 86th Avenue and Colorado Boulevard)
- Reach 2 – WSSC Reservoir No. 4 outlet structure to 168th Avenue

The analysis of Reach 1 will be conducted after the completion of Thornton's Water and Wastewater 2018 Master Plan and is not a part of this technical report.

This technical report is structured as follows:

Section 1 – Introduction

Section 2 – Guidelines for Development of Alternative Corridors

Section 3 – Development and Description of Alternative Corridors

Section 4 – Description of Non-economic Criteria

Section 5 – Alternative Corridors Analysis

Section 6 – Conclusion

Section 2 – Guidelines for Development of Alternative Corridors

This section describes the guidelines used to develop alternative corridors for Reach 2 of the TWP. Identifying alternative corridors started with outlining an evaluation area, followed by conducting multiple rounds of local government outreach, and then identifying feasible corridor segments based on the guidelines listed below.

Agency Input

Multiple counties and municipalities will be crossed by the TWP. In an effort to determine possible locations for a water pipeline, obtain input from local governments and agencies.

Exclusion Areas

The following areas have been identified as not being conducive for water pipeline locations:

- Road right of way (ROW). Staff in Larimer and Weld Counties indicated a preference that the water pipeline be located outside of the existing and future ROW.
- Bodies of water. A significant portion of the evaluation area is located within existing agricultural areas that rely on the water in the rivers, streams, ditches, and water storage reservoirs as part of daily operations. Minimizing impacts to the water conveyance and storage infrastructure reduces the disruption to agricultural businesses.
- Wetlands/riparian areas. Threatened and endangered species and other wildlife are commonly found in wetland and riparian areas; these species are sensitive to disturbance within their habitats.
- Geologic hazard areas. Geologic hazards consist of areas with known mine subsidence. These areas are not conducive to water pipeline locations.
- Environmentally sensitive areas. Areas identified as federal, state, or locally owned properties and conservation easements are typically designated as open lands or environmentally sensitive areas. These areas are considered to have environmental significance.
- Congested areas. Areas identified as being congested with existing buildings and other infrastructure including areas where a significant number of utilities are assumed to be located, usually in developed, densely populated areas.

Utilization of Thornton-Owned Property

Thornton owns multiple farm properties in Larimer and Weld Counties and, whenever feasible, areas were identified that would maximize the use of Thornton-owned property. This approach minimizes the impacts to the ROW and property owners in the surrounding areas.

Abutting Rights of Way, Easements, and Property Lines

A water pipeline location parallel to ROW, utility easements, property lines, and section and quarter section lines is considered favorable and would limit the disturbance to property owners and the general public.

Section 3 – Development and Description of Alternative Corridors

This section describes the methodology used to develop alternative corridors for Reach 2 of the TWP. First, an evaluation area was defined. Next, corridor segments were established within the evaluation area using the guidelines described in Section 2. Finally, corridor segments were linked to develop a complete alternative corridor. A description of each alternative corridor is included in this section.

Evaluation Area

An initial evaluation area was established to set limitations for the development of alternative corridors. The objective for establishing an alternative corridor was to maintain as straight of a path as feasible from the WSSC Reservoir No. 4 outlet structure to the east side of Interstate 25 (I-25) and then south to 168th Avenue. The limits of the evaluation area are shown on **Figure 3-1** and are described as follows:

- The east/west portion of the evaluation area is approximately 3 miles wide, centered near WSSC Reservoir No. 4. The evaluation area extends from Larimer County Road (LCR) 19 east to Weld County Road (WCR) 17 ½. The southern extent of the evaluation area is bounded by Douglas Road and the northern extent by LCR 60/WCR 96.
- The north/south portion of the evaluation area is approximately 4 to 5 ½ miles wide. It extends from LCR 60/WCR 96 south to 168th Avenue. The evaluation area is bounded by I-25 on the west and WCR 17 ½ on the east.

Desktop Survey

A desktop survey was conducted to identify likely areas where a water pipeline could be constructed. This desktop survey used readily and publicly available geographic information system (GIS) information and aerial imagery as the background for determining viable locations for a water pipeline. This high-level approach quickly identified areas with significant obstructions or other issues, and alternatives around those areas. The desktop survey employed the guidelines presented in Section 2 in the development of alternative corridors; the development process is described in further detail below.

Corridor Segment Development

Potential corridor segments were developed using available data and mapping to create the shortest route possible from the WSSC Reservoir No. 4 outlet structure to 168th Avenue. Corridor segments are the smallest unique length of an alternative alignment corridor.

Portions of the evaluation area were excluded from consideration as viable locations for the TWP water pipeline, as described in Section 2. Exclusion areas were identified based on the desktop survey. Some exclusion areas, such as bodies of water and wetland/riparian areas, cannot be bypassed or, if feasible, a bypass would include a significant length of additional pipe. To limit the immediate and long-term impacts of the crossings, these areas were identified as trenchless construction method crossings. Corridor segments were developed at locations where trenchless construction method crossings appeared feasible based on the desktop survey. Crossing of these areas with trenchless construction methods reduces the potential for the destabilization of banks

Thornton Water Project

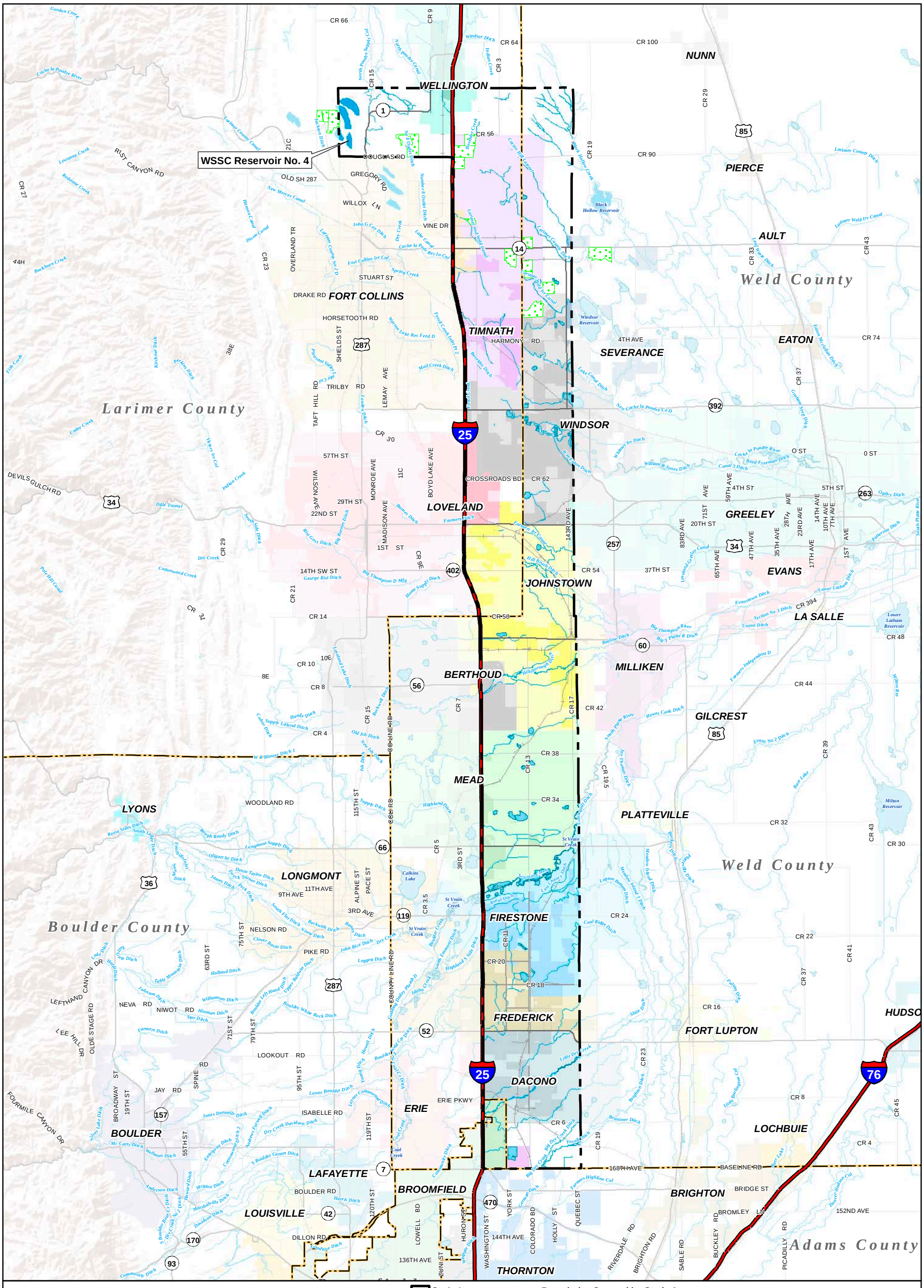

Figure 3-1
TWP Reach 2 Study Area

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and increased incision of the channel bottom that could cause erosion problems at the crossing and downstream of the crossing.

Where feasible, corridor segments were located to utilize Thornton-owned property and to abut existing ROW, easements, and property lines.

Alternative Corridor Development

A review of the corridor segments was completed to determine which corridor segments could be combined to form a complete alternative corridor from the WSSC Reservoir No. 4 outlet structure to 168th Avenue. This review resulted in three distinct alternative corridors: Alternative A, Alternative B, and Alternative C. Each corridor is described in more detail in the sections that follow. TWP staff observed the alternative corridors in the field where public access was available to verify the viability of the alternative corridors. Because water pipeline length is one of the greatest costs, the development of the alternative corridors attempted to limit the east/west movement of each alternative corridor, unless required to route around exclusion areas.

Agency Outreach

The distance of Reach 2 extending from WSSC Reservoir No. 4 outlet structure to 168th Avenue is approximately 60 miles through Larimer and Weld Counties. In an effort to determine the alternative corridor least impactful to local communities in Northern Colorado, Thornton, in 2015, conducted a series of outreach meetings with local governments and agencies that could be impacted by the TWP. During the initial outreach meeting with each local government and agency, the evaluation area was presented to determine preferences and/or determine fatal flaws for possible location of the TWP water pipeline within the local government or agency's jurisdictional and/or growth management area boundaries.

Outreach meetings were conducted with the following local governments:

- Berthoud
- Dacono
- Firestone
- Fort Collins
- Frederick
- Greeley
- Johnstown
- Larimer County
- Loveland
- Mead
- Milliken
- Timnath
- Weld County
- Wellington
- Windsor

Secondary outreach meetings were conducted with local governments and agencies that had incorporated areas or growth management areas overlapping alternative corridor locations to present the three preliminary alternative corridors: Alternatives A, B, and C. During this second round of outreach, additional feedback was collected from the local governments and agencies and, as a result, a fourth alternative corridor, Alternative D, was developed.

Alternative Corridor Descriptions

Following the guidelines discussed in Section 2, the desktop survey produced three viable alternative corridors, Alternatives A, B, and C. A fourth alternative corridor, Alternative D, was developed based on feedback received from local governments and agencies. Alternative corridors are shown in **Figure 3-2.**

Alternative A

The development of Alternative A focused on the south and westerly portion of the east/west and north/south evaluation area, respectively. Alternative A leaves the WSSC Reservoir No. 4 outlet structure and remains south of WSSC Reservoir No. 4, Annex Reservoir No. 8, and Elder Reservoir heading east and generally follows parcel lines and existing roads where feasible (Evans Drive, Bold Venture Way, Grey Rock Drive) to the east side of I-25. Alternative A continues south generally following LCR 3 and LCR 5. South of Highway 52, Alternative A continues south following ROW owned partially by the Regional Transportation District (RTD) and various other owners, including the city of Dacono to 168th Avenue. Alternative A then heads west, terminating at York Street. Further coordination with RTD and the other ROW owners would be required to determine construction feasibility in this location. **Figure 3-3** shows the route for Alternative A.

Alternative B

The development of Alternative B focused on the middle portion of the evaluation area. Alternative B follows the Alternative A route from the WSSC Reservoir No. 4 outlet structure east to LCR 9e where it turns north to LCR 56 and follows LCR 56 east to LCR 1/WCR 13. At WCR 13 it turns south to follow WCR 13 to 168th Avenue at the Weld/Adams County line. **Figure 3-4** shows the route for Alternative B.

Alternative C

The development of Alternative C focused on the north and easterly portion of the east/west and north/south evaluation area, respectively. Alternative C leaves the WSSC Reservoir No. 4 outlet structure in a westerly direction and transitions north through the Braidwood subdivision on the west side of WSSC Reservoir No. 4. Just north of WSSC Reservoir No. 4, the alternative corridor turns east, around Dixon Reservoir, and then continues east generally following LCR 56 to LCR 1/WCR 13 where it turns south. The northern two-thirds of the north/south section traverses back and forth between WCR 13 and WCR 15, along those roads where feasible, following the guidelines outlined in Section 2. The southern third section of the alternative corridor generally follows half-section lines and WCR 17 south to 168th Avenue. **Figure 3-5** shows the route for Alternative C.

Alternative D

Alternative D generally coincides with the path of Alternative B from the WSSC Reservoir No. 4 outlet structure and the south side of Johnstown with a deviation along LCR 56 to take advantage of property already owned by Thornton. This deviation has Alternative D crossing I-25 ½-mile south of LCR 56. South of Johnstown, Alternative D transitions ½-mile east to Alternative C and follows Alternative C to 168th Avenue. **Figure 3-6** shows the route for Alternative D.

Thornton Water Project

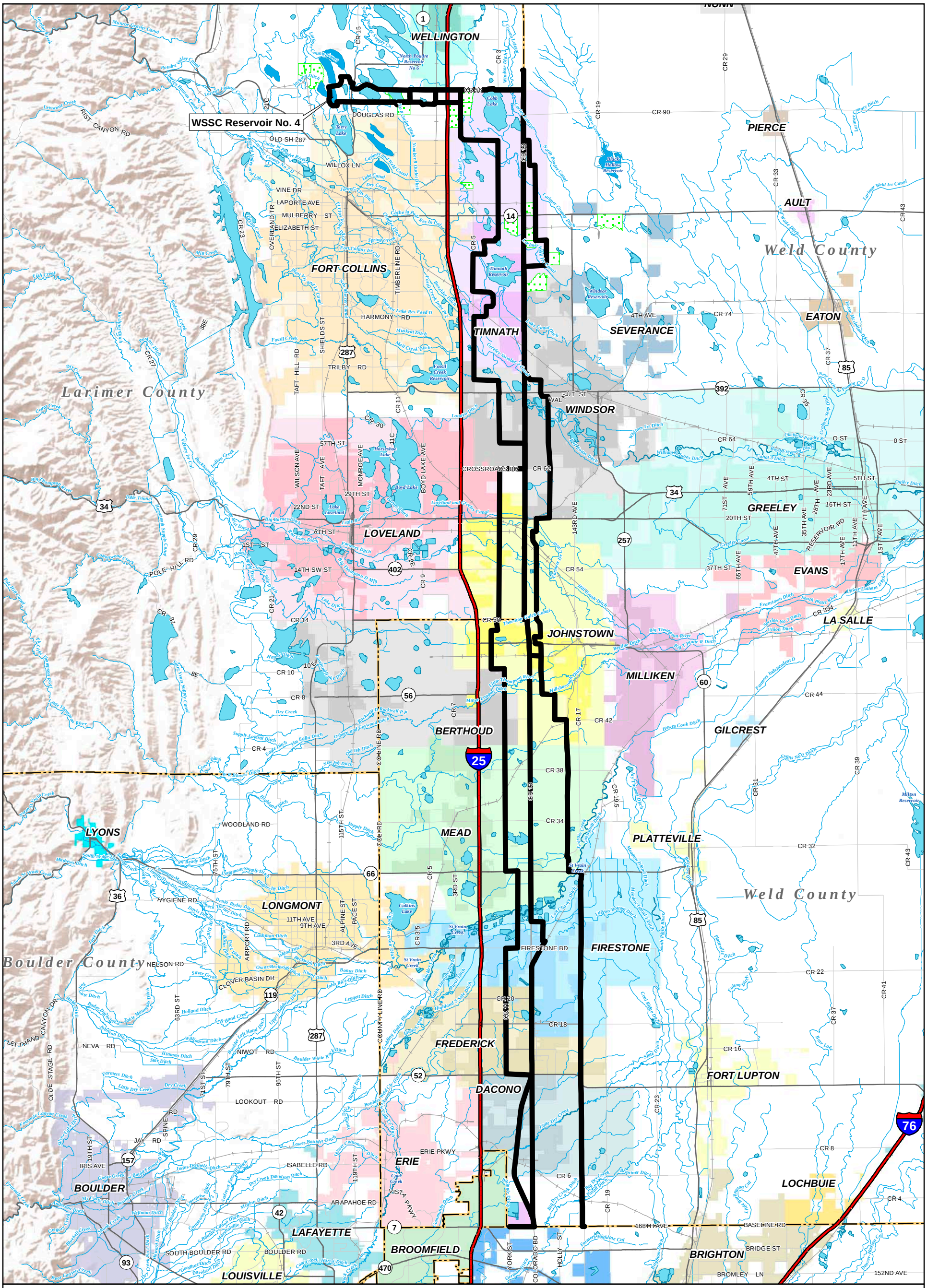

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Figure 3-2
TWP Reach 2
Alternative Corridors

Sources: CDOT, ESRI, Larimer and Weld Counties, CDWR, NHD

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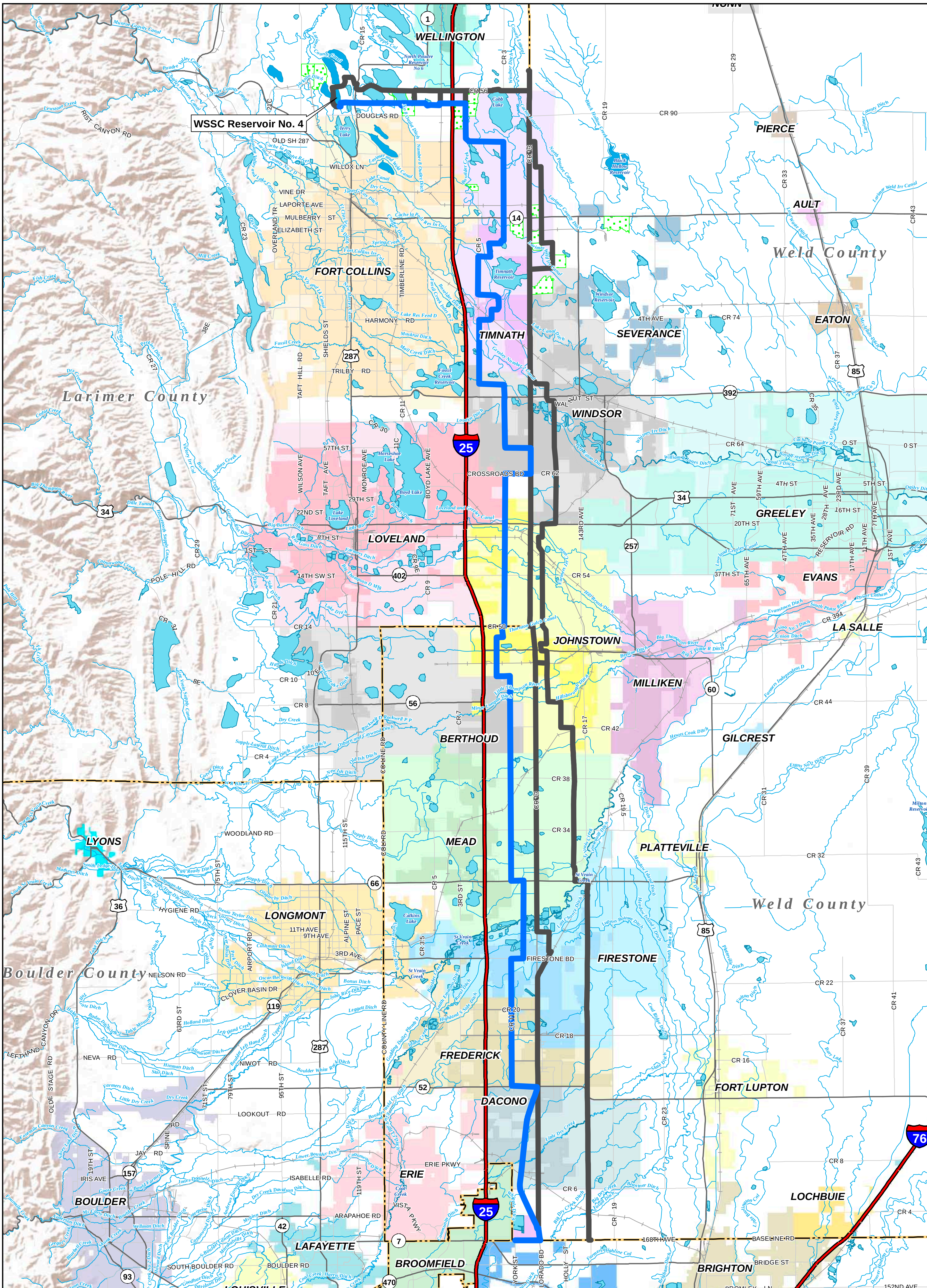

- Alternative A
- Alternative Corridors
- Railroad
- Thornton Farm
- County Boundary
- Lake/Reservoir
- River/Stream/Canal/Ditch

Boundaries Crossed by Study Area	
Corporate Boundary	GMA Boundary
Fort Collins	Fort Collins
Johnstown	Johnstown
Loveland	Loveland
Timnath	Timnath
Wellington	Wellington
Windsor	Windsor

Thornton WATER PROJECT

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N W E S

1 inch = 3.65 miles
0 1.5 3 Miles

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Figure 3-3
TWP Reach 2
Alternative A

Sources: CDOT, ESRI, Larimer and Weld Counties, CDWR, NHD

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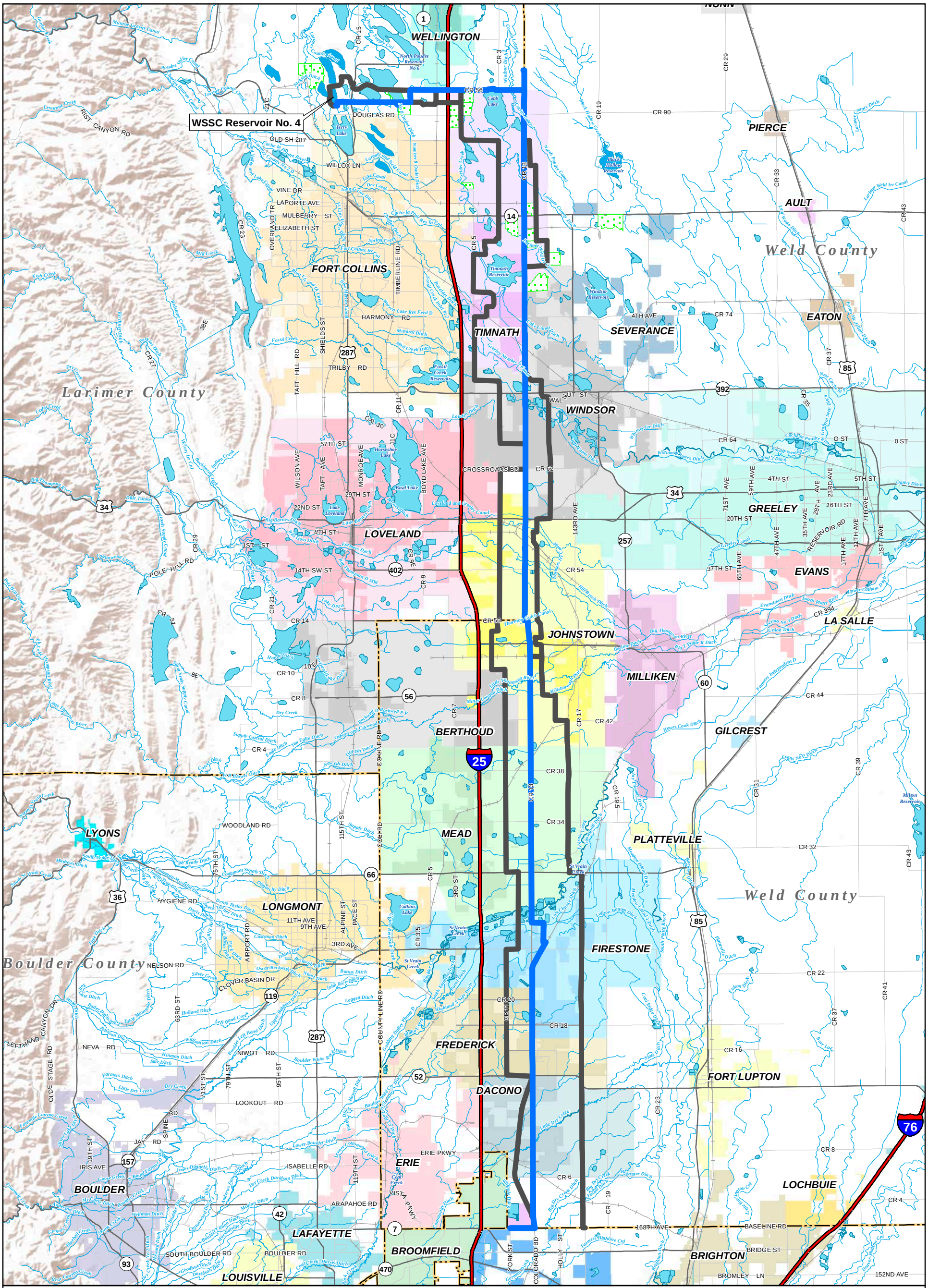

Figure 3-4
TWP Reach 2
Alternative B

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Sources: CDOT, ESRI, Larimer and Weld Counties, CDWR, NHD

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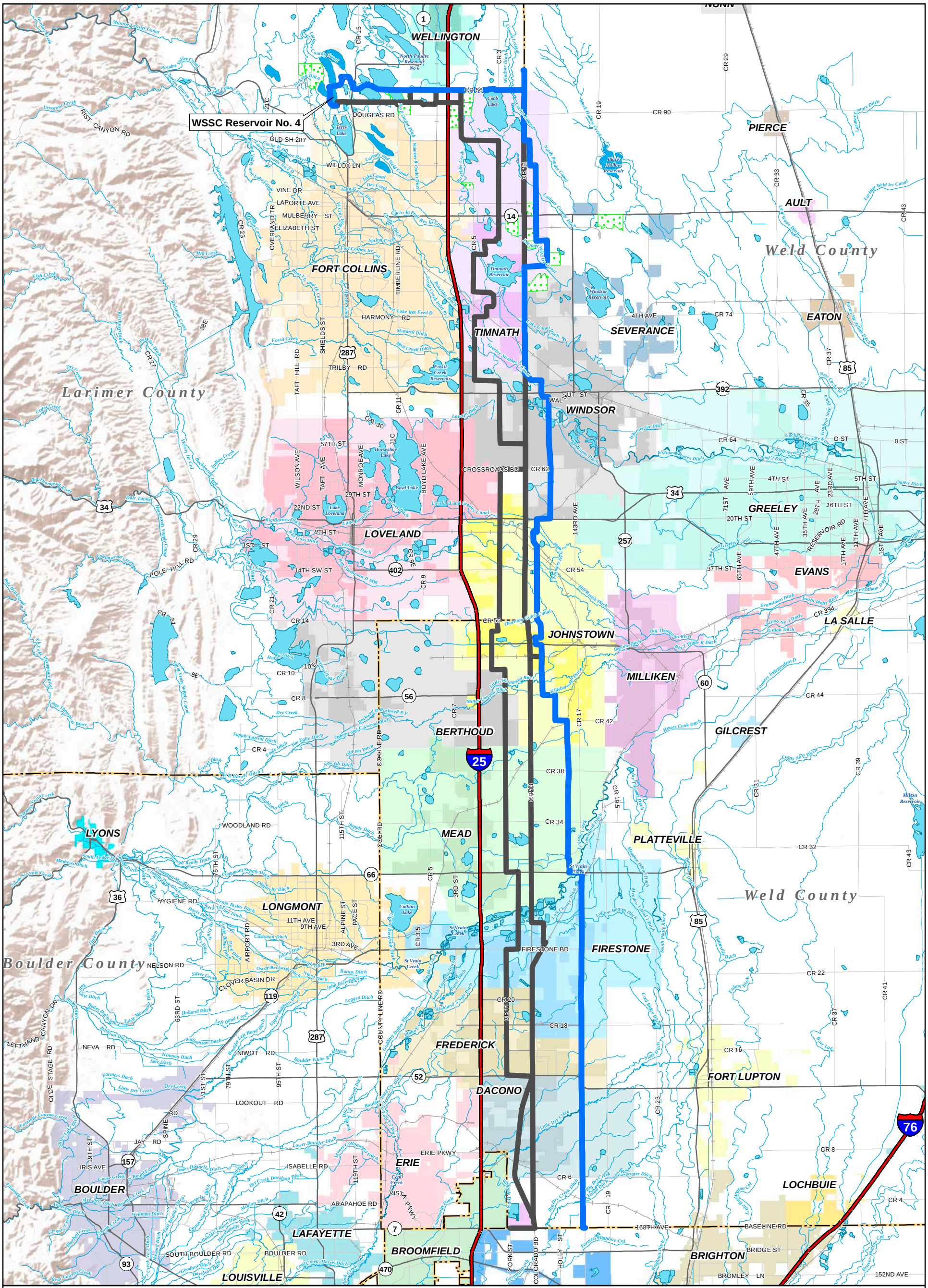

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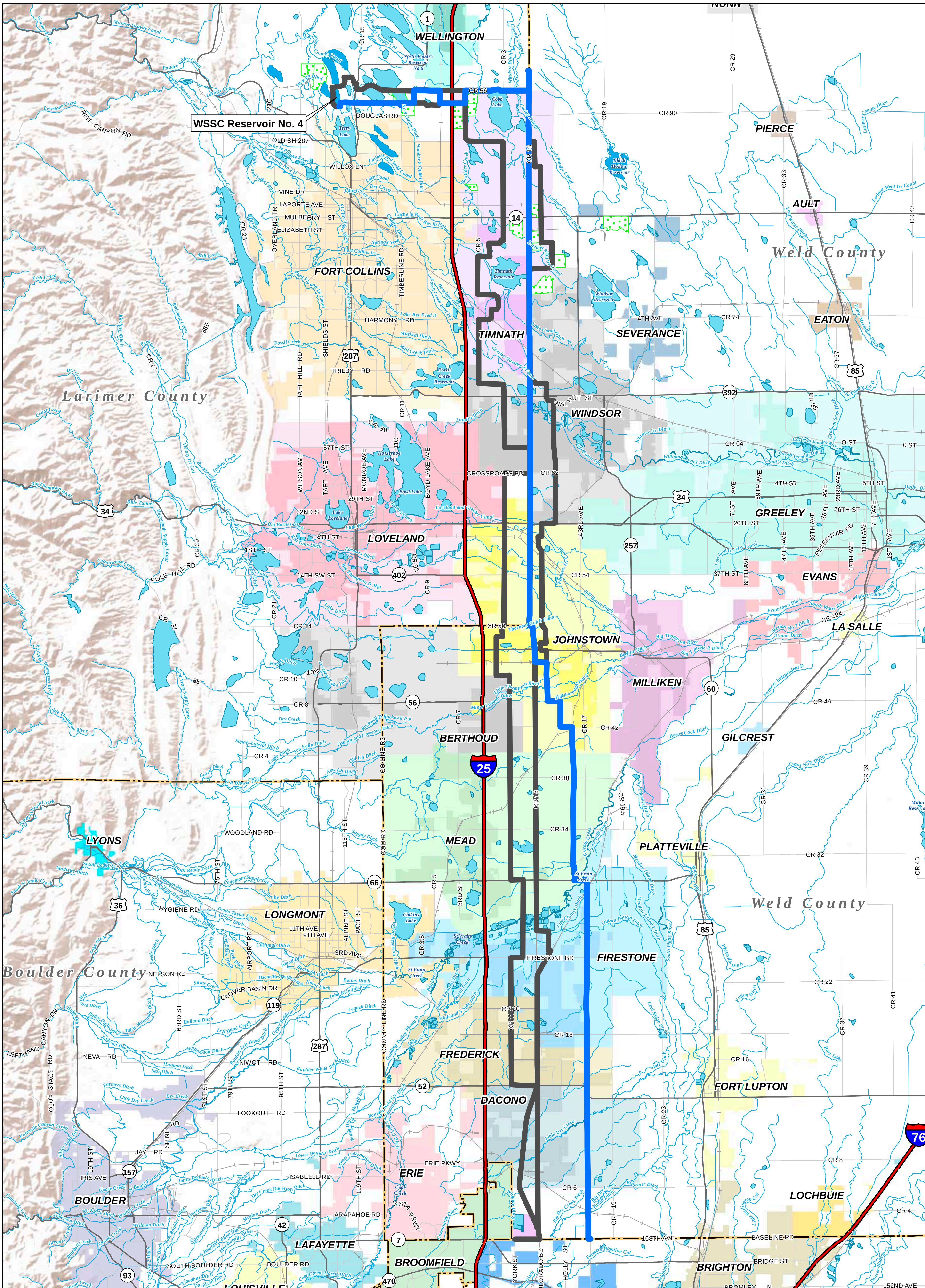

Legend	
Alternative D	
Alternative Corridors	
Railroad	
Thornton Farm	
County Boundary	
Lake/Reservoir	
River/Stream/Canal/Ditch	

Boundaries Crossed by Study Area

Corporate Boundary	GMA Boundary
Fort Collins	Fort Collins
Johnstown	Johnstown
Loveland	Loveland
Timnath	Timnath
Wellington	Wellington
Windsor	Windsor

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N W E S

1 inch = 3.65 miles
0 1.5 3 Miles

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Figure 3-6
TWP Reach 2
Alternative D

Sources: CDOT, ESRI, Larimer and Weld Counties, CDWR, NHD

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Section 4 – Description of Non-economic Criteria

This section describes the non-economic criteria used to compare the alternative corridors. The non-economic criteria were established to aid in the selection of a preferred corridor utilizing qualitative criteria to compare alternative corridors. The criteria were developed specific to the TWP and are intended to address subjective issues affecting corridor selection.

Non-economic criteria are those factors that are important considerations in an alternative analysis, but are not associated with a specific cost.

Seven distinct criteria were defined for evaluation as presented in **Table 4-1**. Raw data was determined based on the method of measurement presented in **Table 4-1**. Further detail for each criterion is given in the sections following the table.

TABLE 4-1
Non-economic Criteria Summary

Criterion	Method of Measurement	Data Source
Local Government Preference	Rating scale from 1 to 8 based on compliance with local government preferences.	Outreach meeting discussions.
Geologic Hazards	Estimated length of areas crossed identified as having mine subsidence.	RJH Consultants Inc. mine subsidence GIS information.
Community Impact	Count of local governments crossed.	Colorado Department of Transportation (CDOT) cities GIS information.
Wetland/Riparian Crossings	Estimated length of areas crossed identified as wetland and/or riparian areas. Wetlands include categories found in the source file, and riparian areas include herbaceous and shrub flora.	Wetland data are from United States Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) GIS information. Riparian data are from the Colorado Natural Heritage Program GIS information.
Floodplain Crossings	Estimated length of areas crossed identified as Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 100-year floodplain.	FEMA 100-Year Flood Zones in the USA from ArcGIS services online.
Parcel Owners	Count of unique property owners crossed.	GIS parcel information from Adams, Larimer, and Weld Counties.
ROW	Estimated possible length within the current ROW. Assumptions were made on number of ROW crossings.	Manual identification in GIS based on a combination of GIS parcel lines and existing and proposed ROW widths from local governments' transportation master plans.

Local Government Preference

Local government preference differs from the other non-economic criteria in that each alternative is measured against the other alternatives, where the other criteria measure each alternative against a criterion.

A significant factor in selecting the preferred corridor is how well an alternative corridor meets preferences indicated by staff in Larimer and Weld Counties and local governments during the outreach meetings. This criterion is measured on a rating scale from 1 to 8 with a point given to the alternative corridor that does not meet the county or local government's preference. A more desirable alternative corridor is one that has the lowest rating score; the least desirable alternative corridor is one that has the highest rating score. **Table 4-2** presents the preferences of the counties and local governments provided during the outreach meetings.

TABLE 4-2
Local Government Preference Summary

Jurisdiction	Alternative Corridor			
	A	B	C	D
Larimer	1	1		1
Weld				
Windsor	1		1	
Timnath	1			
Johnstown	1		1	
Firestone	1	1		
Dacono	1	1		
Frederick	1	1		
Mead	1	1		
Berthoud				
Total Points	8	5	2	1

Geologic Hazards

Based on available GIS data, geologic hazards consist of the appreciable and severe mine subsidence areas as identified in the Geologic Hazards shapefile received from RJH Consultants Inc. in the third quarter of 2015. Mine subsidence areas crossed by the four alternative corridors are found near the tri-towns area (Firestone, Frederick, and Dacono) in Weld County as shown on **Figure 4-1.** Locating a water pipeline in areas with mine subsidence poses significant technical challenges during installation and increases the risk of pipe failure from collapsing soils within the trench section. **Table 4-3** presents the estimated pipe lengths within areas of mine subsidence. A more desirable alternative corridor is one that has a shorter estimated length within a geologic hazard.

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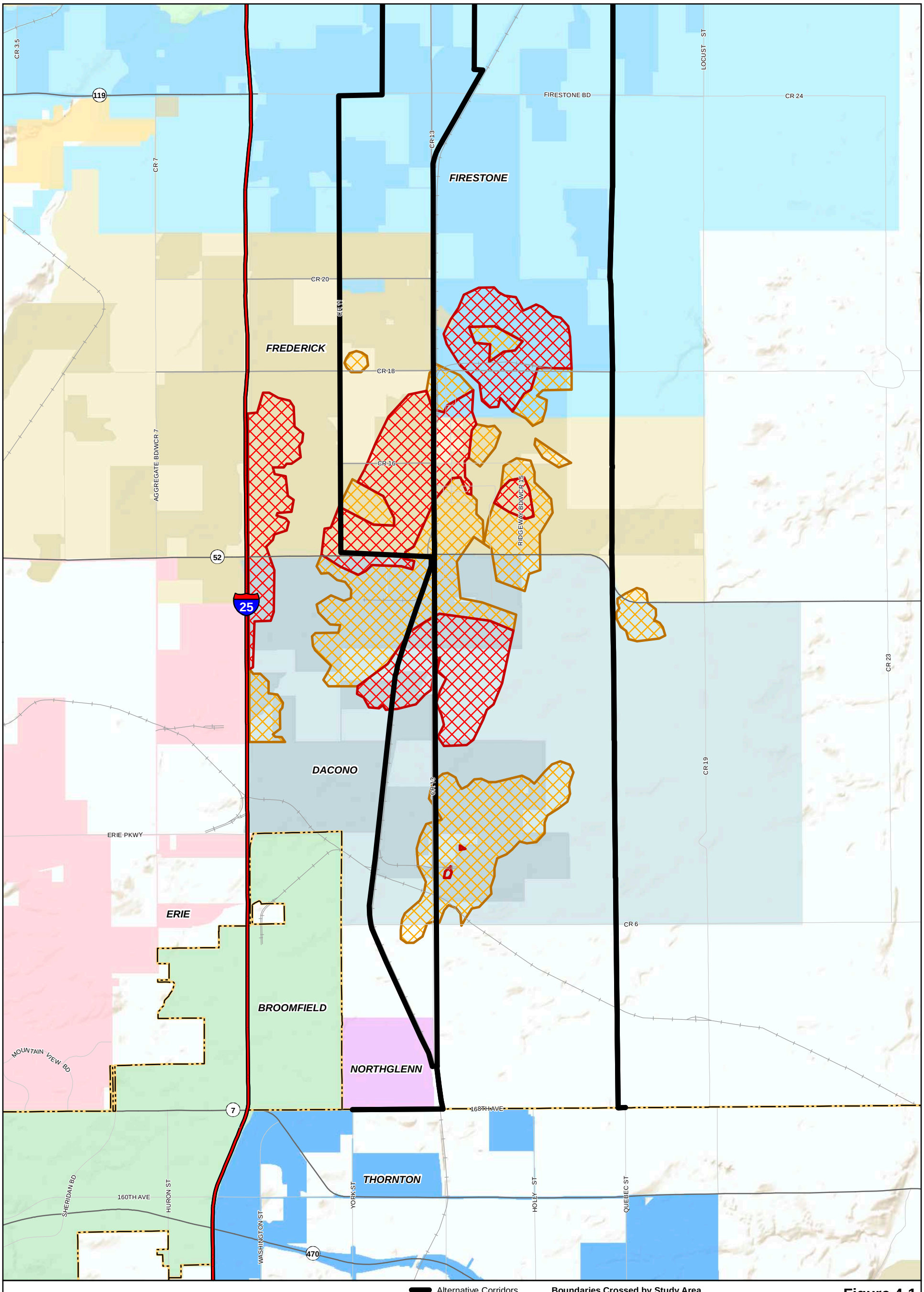

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Figure 4-1
TWP Reach 2
Mine Subsidence Areas

Sources: CDOT, ESRI, Larimer and Weld Counties, CDWR, NHD

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TABLE 4-3
Geologic Hazard Summary

Alternative Corridor	Estimated Geologic Hazard Length Crossed (miles)	
	Larimer County	Weld County
Alternative A	0.00	3.36
Alternative B	0.00	4.72
Alternative C	0.00	0.00
Alternative D	0.00	0.00

Community Impact

The alternative corridors cross Larimer and Weld counties. Limiting the number of local government boundaries that the water pipeline crosses minimizes impacts to local communities and the traveling public because areas within local government boundaries tend to be more congested. The list of local governments that each alternative corridor crosses is presented in **Table 4-4.** A more desirable alternative corridor crosses the least number of local government boundaries.

TABLE 4-4
Community Impact Summary

Alternative Corridor	Number of Local Governments Crossed		
	Larimer County	Weld County	Total[a]
Alternative A	• Unincorporated Larimer County • Timnath • Loveland • Johnstown • Windsor	• Unincorporated Weld County • Windsor • Firestone • Frederick • Johnstown • Berthoud • Dacono • Mead	11
Alternative B	• Unincorporated Larimer County • Timnath • Johnstown • Windsor	• Unincorporated Weld County • Windsor • Firestone • Frederick • Johnstown • Dacono • Mead	9
Alternative C	• Unincorporated Larimer County • Timnath	• Unincorporated Weld County • Windsor • Firestone • Frederick • Johnstown	7
Alternative D	• Unincorporated Larimer County • Timnath • Johnstown • Windsor	• Unincorporated Weld County • Windsor • Firestone • Frederick • Johnstown	7

[a] Some local governments are in multiple counties; however, they are counted only once.

Wetland/Riparian Crossings

Wetland data was obtained from the NWI and includes wetlands designated as freshwater pond, riverine, freshwater emergent, freshwater forested/shrub wetland, lake, and other. The riparian crossings are based on herbaceous and shrub data from the Colorado Natural Heritage Program of Colorado State University. Wetland and riparian areas potentially provide sensitive wildlife habitats, so minimizing impacts to those areas is preferred. A more desirable alternative corridor is one that has the shortest length crossing wetland and riparian areas. The estimated lengths crossing these areas are presented in **Table 4-5.**

TABLE 4-5
Wetland/Riparian Crossings Summary

Alternative Corridor	Estimated Length of Wetlands Crossed (miles)		Estimated Length of Riparian Areas Crossed (miles)	
	Larimer County	Weld County	Larimer County	Weld County
Alternative A	0.32	0.55	1.38	0.53
Alternative B	0.17	0.86	0.45	1.99
Alternative C	0.44	0.98	0.74	1.58
Alternative D	0.17	0.79	0.45	1.21

Floodplain Crossings

For this analysis, floodplain crossings were based on FEMA's 100-year flood zone National Flood Hazard Layer that was developed as part of the FIRM. Below is an excerpt from FEMA's shapefile that further describes the data:

> *"This map service represents Flood Insurance Rate Map (FIRM) data important for floodplain management, mitigation, and insurance activities for the National Flood Insurance Program (NFIP). The National Flood Hazard Layer (NFHL) data present the flood risk information depicted on the FIRM in a digital format suitable for use in electronic mapping applications. The NFHL database is a subset of the information created for the Flood Insurance Studies (FIS) and serves as a means to archive a portion of the information collected during the FIS. The NFHL data incorporates Digital Flood Insurance Rate Map (DFIRM) databases published by Federal Emergency Management Agency (FEMA). The 100-year flood is referred to as the 1% annual exceedance probability flood, since it is a flood that has a 1% chance of being equaled or exceeded in any single year."*

Long-term impacts to floodplains will not occur because the water pipeline will be buried and ground surface elevations restored to pre-construction conditions. Constructability issues could be associated with floodplains because the water pipeline could be subject to scour conditions that require it to be buried deeper. Similar to wetland and riparian areas, floodplains potentially provide sensitive wildlife habitat. A more desirable alternative corridor is one that has the shortest estimated length within the floodplain. The estimated lengths that an alternative corridor crosses a floodplain are presented in **Table 4-6.**

TABLE 4-6
Floodplain Crossings Summary

Alternative Corridor	Estimated Floodplain Length Crossed (miles)	
	Larimer County	Weld County
Alternative A	4.76	0.77
Alternative B	1.16	1.65
Alternative C	0.25	2.46
Alternative D	1.16	2.08

Parcel Owners

Feedback received during the outreach meetings indicated that staff in Larimer and Weld Counties and some local governments preferred that the water pipeline be located in easements on privately owned land. To quantify the effect on property owners, a query of the estimated number of parcels that could be crossed was performed on GIS parcel data received from Larimer and Weld Counties. One property owner could own multiple parcels; therefore, a count of unique parcel owners was compiled to determine the number of individual owners that could be impacted. A more desirable alternative corridor is one with the fewest parcel owners impacted. The breakdown of total parcel counts and unique parcel owners are presented in **Table 4-7.**

TABLE 4-7
Parcel Owners Summary

Alternative Corridor	Count of Parcel Crossings			
	Larimer County		Weld County	
	Parcel Owners	Total Parcels[a]	Parcel Owners	Total Parcels[b]
Alternative A	128	150	67	101
Alternative B	82	94	148	185
Alternative C	47	58	156	198
Alternative D	83	97	144	180

[a] Three parcels in Alternative A, 2 parcels in Alternative B, 4 parcels in Alternative C, and 4 parcels in Alternative D are owned by Thornton in Larimer County.
[b] Three parcels in Alternative B, 3 parcels in Alternative C, and 3 parcels in Alternative D are owned by Thornton in Weld County.

Right-of-Way

Feedback received during the outreach meetings indicated that the staff in Larimer and Weld Counties and some local governments preferred that the water pipeline be located outside ROW. In some instances, entering the ROW appears to be the best option to minimize impacts to property owners. For example, if a residence was located on each side of the road, the ROW was assumed to be the best location for a water pipeline and the length in that ROW was quantified. ROW crossings were also estimated and were assumed to possibly be required where one side of a road was more congested than another. To meet county and local government preferences, a more desirable alternative corridor is one that has the shortest total length in the ROW. **Table 4-8** presents a breakdown of the estimated lengths assumed in ROW per local jurisdiction.

TABLE 4-8
Right-of-Way Summary

Location	Estimated Length within ROW (miles)			
	Alternative A	Alternative B	Alternative C	Alternative D
Larimer County				
Unincorporated Larimer County	1.24	4.00	3.95	2.34
Johnstown	0.15	0.01	0.00	0.01
Loveland	0.03	0.00	0.00	0.00
Timnath	1.86	0.51	0.45	0.51
Windsor	0.04	0.26	0.00	0.26

TABLE 4-8
Right-of-Way Summary

Location	Estimated Length within ROW (miles)			
	Alternative A	Alternative B	Alternative C	Alternative D
Weld County				
Unincorporated Weld County	0.12	1.89	1.08	0.84
Berthoud	0.01	0.00	0.00	0.00
Dacono	3.09	2.08	0.00	0.00
Firestone	1.09	4.44	0.09	0.09
Frederick	0.73	0.98	0.01	0.01
Johnstown	0.03	0.19	1.46	0.58
Mead	0.03	0.02	0.00	0.00
Windsor	<0.01	0.03	4.94	0.03

Section 5 – Alternative Corridors Analysis

The four alternative corridors were compared using the non-economic criteria to aid in the selection of a preferred corridor for the TWP.

Non-Economic Scoring Analysis

Microsoft Excel was used to summarize the raw data presented in Section 4 to determine a value for each non-economic criterion for each alternative corridor. The summarized values were then normalized for better comparison.

A summary of raw data for each non-economic criterion for the alternative corridors is presented in **Table 5-1.** The raw data corresponds to the method of measurement described in Section 4.

TABLE 5-1
Summary of Non-Economic Raw Data

Alternative Corridor	Local Government Preference	Geologic Hazards (miles)	Community Impact	Wetland/ Riparian Crossings (miles)	Floodplain Crossings (miles)	Parcel Owners	ROW (miles)
Alternative A	8	3.4	11	2.8	5.5	195	8.8
Alternative B	5	4.7	9	3.5	2.8	230	12.3
Alternative C	2	0.0	7	3.7	2.7	203	10.0
Alternative D	1	0.0	7	2.6	3.2	227	3.4

The raw data is a representation of impact and were normalized to the same range of numbers for comparison. Once normalized, the information was weighted based on relative importance. To normalize the raw data, a rating scale from 1.0 to 5.0 was chosen with a lower rating being preferred. More than one alternative corridor could have the same rating value if their raw data is the same. Scores were calculated by normalizing the values in **Table 5-1**. The minimum raw data value presented in **Table 5-1** for each criterion received a value of 1.0, and the maximum raw data value for each criterion received a value of 5.0. Other scores were normalized based on ratio of score with highest and lowest raw data values. **Table 5-2** presents the normalized scores.

TABLE 5-2
Non-Economic Relative Normalized Scoring

	(LOW SCORE PREFERRED)						
Alternative Corridor	Local Government Preference	Geologic Hazards	Community Impact	Wetland/ Riparian Crossings	Floodplain Crossings	Parcel Owners	ROW
Alternative A	5.0	3.8	5.0	1.5	5.0	1.0	3.4
Alternative B	3.3	5.0	3.0	4.1	1.2	5.0	5.0
Alternative C	1.6	1.0	1.0	5.0	1.0	1.9	4.0
Alternative D	1.0	1.0	1.0	1.0	1.8	4.7	1.0

The criteria were then weighted to determine the importance of each criterion as compared to the other criteria. The weighting factor assigned to each criterion was based on the relative importance of each category as determined by CH2M HILL based on discussions with Thornton and experience on other similar projects. Figure 5-1 shows how the comparison was made. In this graphic, each criterion is associated with a corresponding letter. Then, using a grid system, the criteria in the rows were compared to the same criteria in the columns. The letter for the criterion that is more important is entered in the intersecting cell. For example, when comparing Geologic Hazards (B) to Community Impacts (C), the disruption to the community was determined to be of more importance than the implications of constructing the pipeline in a geologic hazard of mine subsidence. Therefore, a "C" was placed in the cell. When compared to itself, a criterion gets its own letter. For example, when Floodplain Crossings (E) is compared to itself, a "E" gets placed in the cell. In this way each criterion is represented at least once on the grid.

The count of the letters was summed in the Number of Responses column. Community Impacts (C) was determined to be more important than 3 other criteria and has a total of 5 Cs in the grid. Because there are 28 total letters, each letter is 3.6 percent out of 100 percent of letters (100 percent divided by 28 = 3.6 percent). The count of letters in the grid were then multiplied by 3.6 percent to get a weighted percentage for each criterion.

		A	B	C	D	E	F	G		
	Criteria	Local Government Preference	Geologic Hazard	Community Impacts	Wetland/Riparian Crossings	Floodplain Crossings	Parcel Owners	Right-of-Way	Number of Responses	Weighted Percentage
A	Local Government Preference	A	A	A	A	A	A	A	7	25.0%
B	Geologic Hazard		B	C	D	E	F	G	1	3.6%
C	Community Impacts			C	D	C	C	C	5	17.9%
D	Wetland/Riparian Crossings				D	D	D	G	5	17.9%
E	Floodplain Crossings					E	F	G	2	7.1%
F	Parcel Owners						F	G	3	10.7%
G	Right-of-Way							G	5	17.9%
									28	100.0%

FIGURE 5-1
Non-economic Criteria Weighting Summary

The weights calculated as shown in **Figure 5-1** were used to determine a weighted score for each criterion. **Table 5-3** presents the normalized score from **Table 5-2** that was multiplied by the weighting shown in **Figure 5-1**. For example, the Geologic Hazards score for Alternative A in **Table 5-2** (3.8) was multiplied by the weighted percentage in **Figure 5-1** (3.6 percent) to determine the weighted criteria score (3.8 times 0.036 equals 0.1368, which can be rounded to 0.14). The weighted scores for each alternative were then summed to develop one total score. The lowest total score is more desirable. When considering the importance of each criterion, the weighted scores result in Alternative D being the most desirable alternative corridor, with Alternative B being the least desirable alternative corridor based on non-economic criteria.

TABLE 5-3
Weighted Non-economic Criteria

Alternative Corridor	Local Government Preference	Geologic Hazards	Community Impact	Wetland/ Riparian Crossings	Floodplain Crossings	Parcel Owners	ROW	Total Score
				(TOTAL LOW SCORE WINS)				
Alternative A	0.89	0.14	0.89	0.28	0.89	0.18	0.61	**3.88**
Alternative B	0.59	0.18	0.54	0.72	0.21	0.89	0.89	**4.02**
Alternative C	0.28	0.04	0.18	0.89	0.18	0.34	0.71	**2.62**
Alternative D	0.18	0.04	0.18	0.18	0.32	0.83	0.18	**1.90**

Section 6 – Conclusion

This technical report summarizes the means and methods used to select the preferred corridor for the water pipeline from the WSSC Reservoir No. 4 outlet structure to 168th Avenue. Four alternative corridors were evaluated using non-economic criteria. Alternative D was determined to have the most desirable score as presented in **Table 6-1.**

Alternative A

Alternative A is the third most desirable alternative corridor with a total score of 3.88. It has the fewest estimated number of parcel owners impacted. However, Alternative A has the highest scores for community impacts, floodplain crossings, and local government preference. This alternative corridor crosses the fewest unique parcels owners because the parcels are generally larger in size compared to parcels in other alternative corridors.

Alternative B

Alternative B is the least desirable alternative corridor in terms of non-economic criteria with the highest total score of 4.02. Alternative B is located in more developed areas when compared to other alternative corridors, which increases the scores for parcel owners, ROW, and local government preference. It also has the highest score for geologic hazards. The increased ROW length of Alternative B is due to limitations created by water bodies and development in Windsor.

Alternative C

Alternative C is the second most desirable alternative corridor with a total score of 2.62. Similar to Alternative D, it has the lowest scores for geologic hazards and community impacts. However, it has the highest score for wetland/riparian crossings.

Alternative D

Alternative D is the most desirable alternative corridor with a total score of 1.90. It has the lowest scores for wetland/riparian crossings, ROW, and local government preference. Similar to Alternative C, it has the lowest scores for geologic hazards and community impacts. Alternative D has a higher score relative to some of the other alternative corridors for parcel owners. Based on the analysis, Alternative D is the optimum route.

TABLE 6-1
Weighted Non-economic Criteria

Alternative Corridor	Local Government Preference	Geologic Hazards	Community Impact	Wetland/ Riparian Crossings	Floodplain Crossings	Parcel Owners	ROW	Total Score
				(TOTAL LOW SCORE WINS)				
Alternative A	0.89	0.14	0.89	0.28	0.89	0.18	0.61	**3.88**
Alternative B	0.59	0.18	0.54	0.72	0.21	0.89	0.89	**4.02**
Alternative C	0.28	0.04	0.18	0.89	0.18	0.34	0.71	**2.62**
Alternative D	0.18	0.04	0.18	0.18	0.32	0.83	0.18	**1.90**

Technical Memorandum 5.1.12.2 – Thornton Water Project, Larimer County Alternative Configurations Analysis – WSSC Reservoir Area to Larimer County Road 9

Thornton Water Project
Larimer County Alternative Configurations Analysis – WSSC Reservoir Area to Larimer County Road 9

PREPARED FOR:	City of Thornton
COPY TO:	File
PREPARED BY:	CH2M HILL
DATE:	October 20, 2017

The city of Thornton (Thornton) in May 2016 developed an initial proposed corridor for the Thornton Water Project (TWP) in the area of the Water Supply and Storage Company (WSSC) reservoirs. The location of the proposed corridor was based on the purpose and need for the TWP, as well as information and guidance received from Larimer County Public Works and Planning staff, the city of Fort Collins, and others. The initial proposed corridor was presented to area residents during public open houses (in the fourth quarter of 2016) and an outreach meeting with residents from the areas around WSSC Reservoir No. 4 (in the first quarter 2017). At these meetings, residents requested that Thornton look at alternative water pipeline alignments and pump station locations. Subsequent to the meetings with area residents, Thornton met with Larimer County staff to discuss the concerns and requests of the residents, and Larimer County staff provided guidance for the Larimer County 1041 Permit Application (Application) for the TWP. This technical memorandum addresses the guidance from Larimer County staff.

Larimer County Guidance

Larimer County staff has requested that Thornton propose a preferred alignment with a 500-foot wide corridor for the TWP in the area around the WSSC Reservoirs and east to Larimer County Road 9. The 500-foot wide corridor will allow flexibility in locating the water pipeline during final design of the TWP, and future action or approval by Larimer County under Larimer County's 1041 permit process should not be required so long as the water pipeline is installed within the 500-foot wide corridor.

Larimer County staff requested that an analysis of alternative pump station locations and water pipeline alignments be included in the Application. Larimer County staff indicated that the alternative analysis should be conducted from the connection to the WSSC system to approximately County Road 9. No revisions to the proposed corridor east of County Road 9 were required and Thornton understands that the ⅛ to ¼-mile corridor continues to be acceptable for the Application.

After receiving input from area residents and adopting the *Larimer County Transportation Master Plan in* the third quarter of 2017, Larimer County staff indicated that locating the water pipeline in County road right-of-way (ROW) may be allowed at some locations. Thornton understands that if

the water pipeline is to be located in Larimer County ROW, then this will require Larimer County approval.

Thornton discussed draft proposed alternative water pipeline segments with Larimer County staff on April 17, 2017. Larimer County staff did not indicate that any of the proposed segments were infeasible. **Figure 5.1.12.2-1** shows the proposed alternative alignment segments and proposed alternative locations of pump stations.

Alternative TWP Configurations

The alternative TWP configurations considered have been divided into four general sectors: North, West, Central, and South. The North sector includes pump stations and water pipeline alignments north of WSSC Reservoir No. 4. The West sector includes a pump station that draws from WSSC Reservoir No. 4 and a water pipeline alignment west of that reservoir that connects to the North sector pipeline alignments. The Central sector includes a pump station immediately south of WSSC Reservoir No. 4 and a water pipeline alignment through the Eagle Lake and Woody Creek communities to the Larimer County Road 54-1/2 alignment. The South sector includes a pump station south of WSSC Reservoir No. 4 and water pipeline alignments following Douglas Road.

Alternative configurations were developed by combining a WSSC system connection, pump station(s), and an alternative water pipeline alignment. Alternative water pipeline alignments were developed by connecting alternative water pipeline alignment segments (alignment segments).

Alternative WSSC System Connections

Connections to the WSSC system include connecting to the existing outlet structures at WSSC reservoirs or lake taps. Connections as shown on **Figure 5.1.12.2-1** are the following:

- LT 1 is a lake tap at WSSC Reservoir No. 3 that connects to Pump Station (PS)-1
- LT 2 is a lake tap at WSSC Reservoir No. 4 that connects to PS-2 and discharges to WSSC Reservoir No. 3 or to alignment segment NC
- LT 3 is a lake tap at WSSC Reservoir No. 4 that connects to PS-5
- LT 4 is a lake tap at WSSC Reservoir No. 4 that connects to PS-1
- I1 connects to the WSSC Reservoir No. 3 outlet structure and connects to PS-2
- I2 connects to the WSSC Reservoir No. 4 outlet structure and connects to PS-3
- I3 connects to the WSSC Reservoir No. 4 outlet structure and connects to PS-4

Alternative Pump Station Locations

Five possible pump station locations have been identified. Pump stations as shown on **Figure 5.1.12.2-1** are the following:

- PS-1 is located just east of WSSC Reservoir No. 3 on WSSC-owned property
- PS-2 is located in between WSSC Reservoir No. 4 and WSSC Reservoir No. 3 on WSSC-owned property
- PS-3 is located near the WSSC Reservoir No. 4 outlet on private property
- PS-4 is located along Douglas Road on private property
- PS-5 is located between Kluver Reservoir and Travis Road on WSSC-owned property

CITY OF THORNTON
COLORADO

12450 WASHINGTON ST
THORNTON, CO 80241-2405

9/7/2017

N
W E
S

0 500 1,000 Feet

1 inch = 1,400 feet

River/Stream/Canal/Ditch
Pump Station (PS-#)
Lake Tap
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property

Figure 5.1.12.2-1
Larimer County Alternative Alignment Segments

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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Alternative Water Pipeline Alignments

Ten alternative water pipeline alignments were developed by connecting alignment segments. Alignment segments are shown on **Figure 5.1.12.2-1**.

Preferred Alignment Segments

Two areas along the North sector included alignment segment routes (routes) that are equivalent in that the routes begin at a common point and end at a common point. Identification of preferred routes, and elimination of others, simplifies the alternative water pipeline alignment analysis.

Routes were scored using evaluation criteria and conceptual high-level comparative cost estimates. Evaluation criteria used for comparing alignment segments and the method of measurement for each criterion are presented in **Table 5.1.12.2-1**.

TABLE 5.1.12.2-1
Evaluation Criteria Summary for Routes

Criterion	Method of Measurement	Data Source
Private Property	Number of parcels crossed (WSSC and Thornton-owned parcels not included)	Geographic Information System (GIS) Parcel information from Larimer County
Traffic	Length in feet of alignment segment within ROW	National Agricultural Imagery Program 2015
Environmental	Estimated length of water pipeline in feet in areas identified as riparian areas	Riparian data from the Colorado Natural Heritage Program GIS information

Alignment segment comparisons include the following routes:

- Alignment segments ND + NF vs. segment NE as shown in **Figure 5.1.12.2-2.**

FIGURE 5.1.12.2-2
Comparison of Alignment Segments ND + NF and Segment NE

- Multiple routes from the Larimer County Canal to County Road 56 as shown in **Figure 5.1.12.2-3.**
  - Alignment segments NI + NL
  - Alignment segments NI + NK + NM
  - Alignment segments NJ + NK + NL
  - Alignment segments NJ + NM

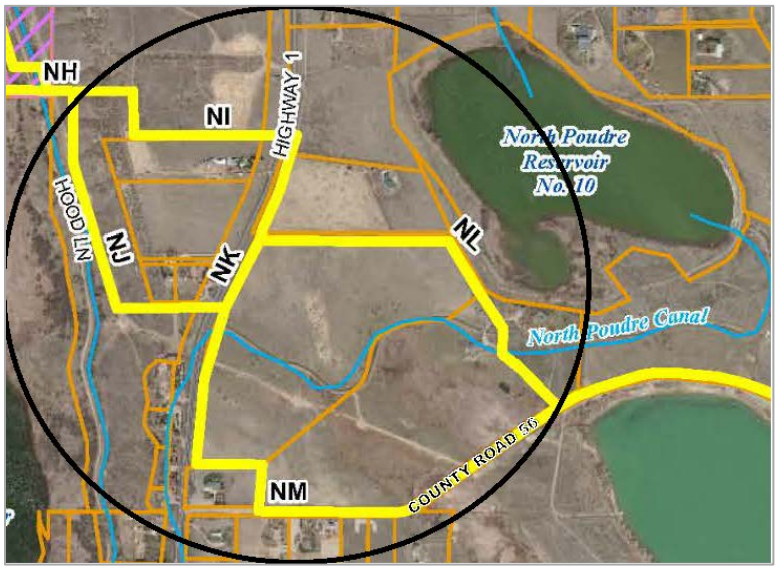


FIGURE 5.1.12.2-3
Comparison of Alignment Segments Larimer County Canal to County Road 56

A summary of raw data for each evaluation criterion for routes ND + NF versus NE is presented in **Table 5.1.12.2-2.** The raw data corresponds to the method of measurement described in **Table 5.1.12.2-1**.

TABLE 5.1.12.2-2
ND + NF versus NE Route Evaluation Criteria Raw Data

Route	Evaluation Criteria Data		
	Private Property	Traffic	Environmental
Route ND +NF	2	0	0
Route NE	3	56	0

The raw data were normalized to criterion scores, ranging from 1 to 5 for comparison, with a higher rating being preferred. Scores were calculated by normalizing the values in **Table 5.1.12.2-2**. The minimum raw data value (least impactful/most preferred) for each criterion received a score of 5.0, and the maximum raw data value (most impactful/least preferred) for each criterion received a score of 1.0. More than one alternative configuration could have the same rating value if their raw data are the same. Normalized scores were multiplied by equal weighting as each criterion was recognized as being equally important compared to other criterion (3 criteria; 33-percent weighting for each). **Table 5.1.12.2-3** presents the equally weighted normalized scores.

Using the route ND + NF Private Property criterion as an example, the equally weighted normalized score would be calculated as:

$$\left(1+\left(\frac{(3-2)}{(3-2)}\right)x4\right)x0.33=1.67$$

TABLE 5.1.12.2-3
ND + NF versus NE Route Evaluation Criteria Scores

Route	Evaluation Criteria Equally Weighted Normalized Score			
	Private Property	Traffic	Environmental	Total Normalized Weighted Score
	HIGH SCORE PREFERRED			
Route ND +NF	1.67	1.67	1.67	5.0
Route NE	0.33	0.33	1.67	2.3

Chart 5.1.12.2-1 shows the comparison of individual criterion evaluation criteria scores for the route comparison of route ND + NF versus route NE. The longer bar represents a better score. Route ND + NF has better scores for private property and traffic compared to route NE. The two routes have equal scores for environmental.

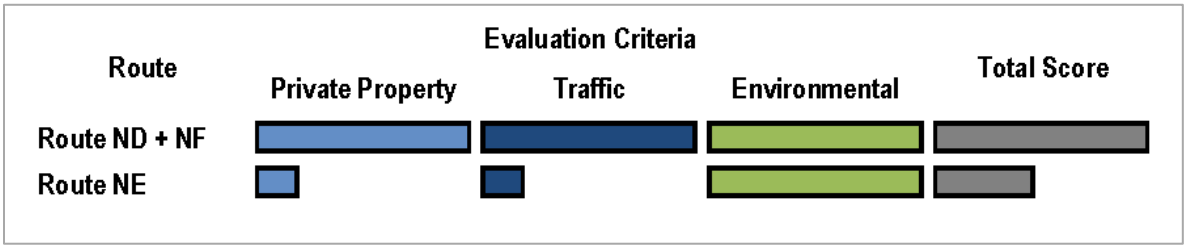


CHART 5.1.12.2-1
Comparison Route ND + NF versus Route NE Evaluation Criteria Normalized Scores

Chart 5.1.12.2-2 shows the total evaluation criteria equally weighted normalized score, conceptual high-level comparative cost estimates, and the normalized cost-to-evaluation criteria ratio score for the route comparison of route ND + NF versus route NE. The comparative cost-to-evaluation criteria ratio was normalized and scored using a rating scale from 1 to 5. The highest normalized comparative cost to evaluation criteria ratio score is the preferred route. For comparison purposes, conceptual high-level comparative cost estimates only include capital costs for pipe material, pipe installation (including tunnels, rock excavation, and dewatering), and surface restoration.

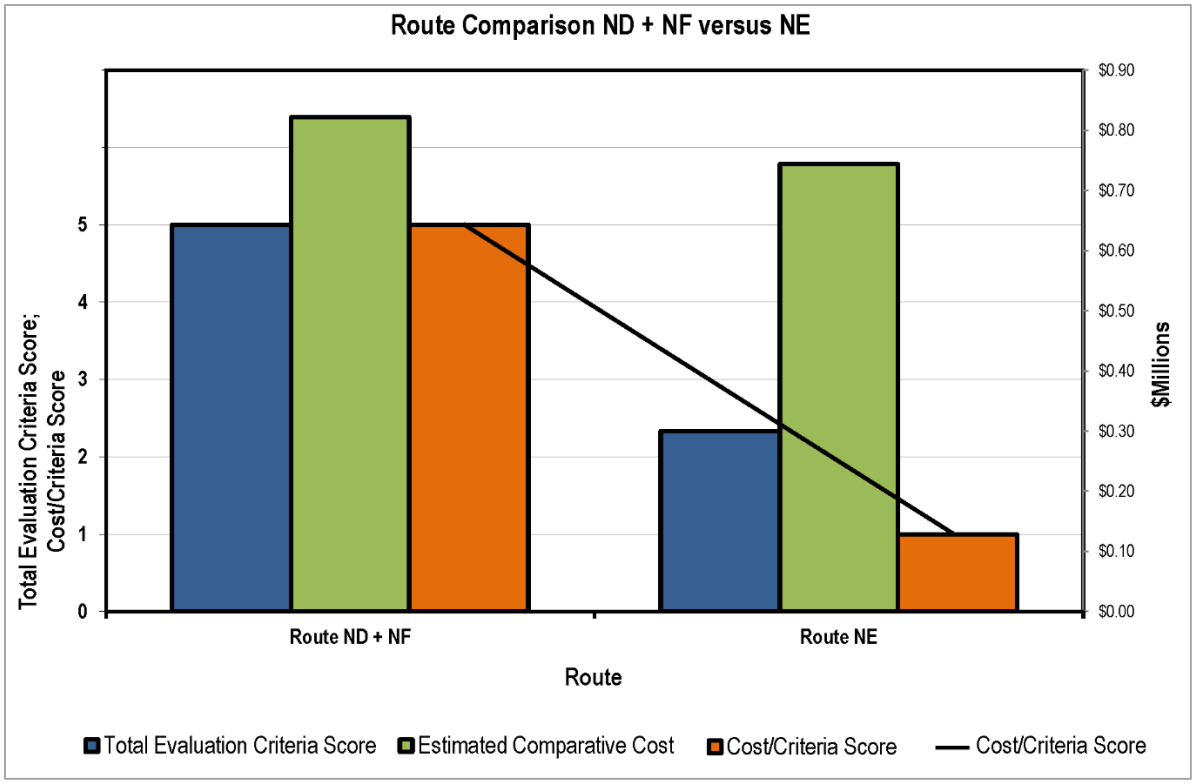


CHART 5.1.12.2-2
Route Comparison ND + NF versus NE

Route ND + NF has a higher estimated comparative cost than route NE due to dewatering cost and a longer length. Route ND + NF also has the highest total evaluation criteria score. Route ND + NF has a higher estimated comparative cost-to-evaluation criteria ratio score; therefore, ND + NF is the preferred route and route NE is not used in any alternative alignment.

A summary of raw data for each evaluation criterion for the Larimer County Canal to County Road 56 routes is presented in **Table 5.1.12.2-4.** The raw data corresponds to the method of measurement described in **Table 5.1.12.2-1**.

TABLE 5.1.12.2-4
Larimer County Canal to County Road 56 Routes Evaluation Criteria Data

	Evaluation Criteria Raw Data		
Route	**Private Property**	**Traffic**	**Environmental**
Route NI + NL	5	0	0
Route NJ + NK + NL	4	0	0
Route NJ + NM	3	2,121	337
Route NI + NK + NM	5	2,121	337

The raw data were normalized to criterion scores, ranging from 1 to 5 for comparison, with a higher rating being preferred. Scores were calculated by normalizing the values in **Table 5.1.12.2-4**. The minimum raw data value (least impactful/most preferred) for each criterion received a score of 5.0, and the maximum raw data value (most impactful/least preferred) for each criterion received a score of 1.0. Other scores were calculated based on a ratio of the range of the highest raw data value and raw data to the range of the highest and lowest raw data value. More than one alternative configuration could have the same rating value if their raw data are the same. Normalized scores were multiplied by equal weighting as each criterion was recognized as being equally important compared to other criterion (3 criteria; 33-percent weighting for each). **Table 5.1.12.2-5** presents the equally weighted normalized scores.

Using the route NJ + NK + NL Private Property criterion as an example, the equally weighted normalized score would be calculated as:

$$\left(1+\left(\frac{(5-4)}{(5-3)}\right)x4\right)x0.33=1.00$$

TABLE 5.1.12.2-5
Larimer County Canal to County Road 56 Routes Evaluation Criteria Scores

	Evaluation Criteria Equally Weighted Normalized Score			
Route	**Private Property**	**Traffic**	**Environmental**	**Total Normalized Weighted Score**
	HIGH SCORE PREFERRED			
Route NI + NL	0.33	1.67	1.67	3.67
Route NJ + NK + NL	1.00	1.67	1.67	4.33
Route NJ + NM	1.67	0.33	0.33	2.33
Route NI + NK + NM	0.33	0.33	0.33	1.00

Chart 5.1.12.2-3 shows the comparison of individual criterion evaluation criteria scores for the Larimer County Canal to County Road 56 routes. The longer bar represents a better score.

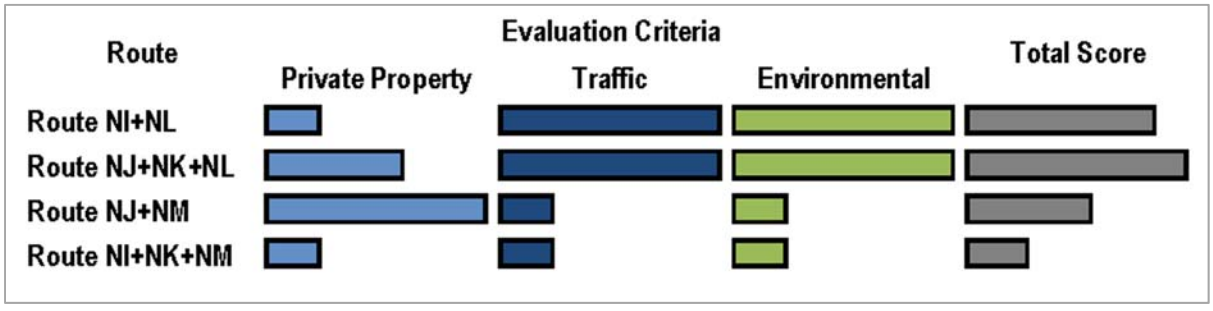


CHART 5.1.12.2-3
Comparison Larimer County Canal to County Road 56 Routes Evaluation Criteria Normalized Scores

Route NJ + NK + NL has the highest (preferred) total evaluation criteria normalized weighted score because it has no traffic or environmental impacts and affects one less parcel compared to route NI + NL. The route NI + NK + NM has the lowest (not preferred) total evaluation criteria equally weighted normalized score due to traffic impacts and environmental impacts.

Chart 5.1.12.2-4 shows the total evaluation criteria equally weighted normalized score, conceptual high-level comparative cost estimates, and the normalized cost-to-evaluation criteria ratio score for the route comparison from the Larimer County Canal to County Road 56. The comparative cost-to-evaluation criteria ratio was normalized and scored using a rating scale from 1 to 5. The highest normalized comparative cost to evaluation criteria ratio score is the preferred route. For comparison purposes, conceptual high-level comparative cost estimates only include capital costs for pipe material, pipe installation (including tunnels, rock excavation, and dewatering), and surface restoration.

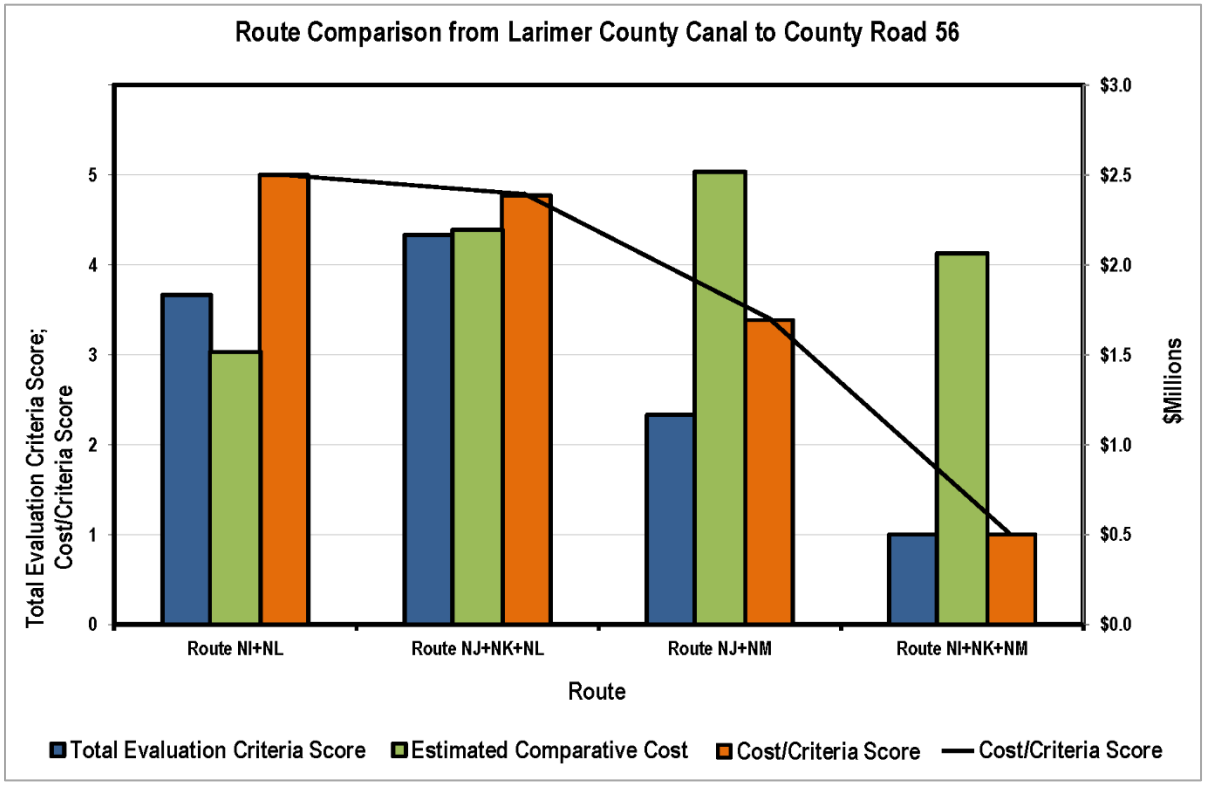


CHART 5.1.12.2-4
Route Comparison Larimer County Canal to County Road 56

Route NJ + NM has the highest estimated comparative cost due to the anticipated construction through rock and because of dewatering. Route NI + NL has the lowest estimated comparative cost due to it having the shortest length. The best route resulting from the estimated comparative cost-to-evaluation criteria ratio score is route NI +NL. Route NI + NL is included in two of the north sector alternatives. Route NJ + NM had the second lowest estimated comparative cost-to-evaluation criteria ratio score; however, it was used for the alternative configuration proposed by residents in and near the Eagle Lake community.

Alternative Configurations

Table 5.1.12.2-6 presents the WSSC system connection, pump station, and alignment segments that were connected to develop each alternative configuration.

The WSSC Board of Directors controls operation of the WSSC Reservoirs so Thornton cannot guarantee any certain water level in any WSSC reservoir. The water levels in the WSSC Reservoirs could be impacted depending upon which connection is used to withdraw water for the TWP. More specifically, the water level in WSSC Reservoir No. 4 and Kluver Reservoir could be lower if TWP water is withdrawn only from WSSC Reservoir No. 3 because there would be no need for WSSC to deliver TWP water to WSSC Reservoir No. 4 or Kluver Reservoir. The TWP maximizes storage by maintaining connection to WSSC Reservoir No. 4. Area residents indicated a preference to maintain flow to, and water levels in, WSSC Reservoir No. 4. Each alternative configuration includes flow to WSSC Reservoir No. 4.

TABLE 5.1.12.2-6
Alternative Configuration Summary

Sector	Alternative Configuration	WSSC System Connection	Pump Station	Alignment Segments
North	North 1	LT1 and LT2	PS-1 and PS-2[1]	NA, NH, NJ, NM, NN
North	North 2	I1 and LT2	PS-2[1]	NC, ND, NF, NG, NH, NI, NL, NN
North	North 3	LT4	PS-1	NB, NF, NG, NH, NI, NL, NN
West	West 1	LT3	PS-5	WB, NC, ND, NF, NG, NH, NI, NL, NN
West	West 2	I2	PS-3	WA, WB, NC, ND, NF, NG, NH, NI, NL, NN
Central	Central	I2	PS-3	CA, CB, CC
South	South 1	I3	PS-4	SA[2], SD[2], SF, CC
South	South 2	I3	PS-4	SB[3], SE[3], SF, CC
South	South 3	I3	PS-4	SA, SC, CB, CC
South	South 4	I3	PS-4	SB, SC, CB, CC

Notes:
1. PS-2 for North 1 is a smaller sized pump station than PS-2 for North 2. PS-2 for North 1 pumps water from WSSC Reservoir No. 4 to WSSC Reservoir No. 3. PS-2 for North 2 pumps water from WSSC Reservoir No. 4 to the water pipeline.
2. Alignment segments SA and SD are outside Douglas Road ROW.
3. Alignment segments SB and SE are within Douglas Road ROW.

Alternative configuration figures described below can be found in Attachment A.

North 1

Figure 5.1.12.2-4 shows the North 1 alternative configuration. North 1 includes a lake tap at WSSC Reservoir No. 4 to PS-2 that discharges into WSSC Reservoir No. 3. This operation maintains flow to WSSC Reservoir No. 4 and allows the TWP to utilize storage in WSSC Reservoir No. 4 and Kluver Reservoir. North 1 includes another lake tap at WSSC Reservoir No. 3 to PS-1. From PS-1 the alignment proceeds north along the WSSC-owned property line to the Larimer County Canal and then follows the canal south to northeast of Dixon Reservoir before heading east and crossing

Highway 1. From the crossing, the alignment follows Highway 1 south outside the ROW and eventually follows County Road 56 east mostly within the ROW to County Road 9. Where feasible without impacting the Larimer County Canal, the water pipeline will be located on Thornton-owned property adjacent to County Road 56 for a portion of the alignment.

This alternative configuration was proposed by residents in and near the Eagle Lake community. Residents indicated that the key objectives of this alternative configuration are as follows:

- Maintain flows to WSSC Reservoir No. 4
- Locate the pump stations on WSSC-owned property
- Locate as much of the water pipeline on WSSC-owned property as feasible
- Locate the water pipeline adjacent to existing infrastructure such as irrigation ditches
- Locate as much of the water pipeline in County Road 56 ROW as feasible

North 2

Figure 5.1.12.2-5 shows the North 2 alternative configuration. North 2 includes a lake tap at WSSC Reservoir No. 4 to PS-2. It also includes a connection to the WSSC Reservoir No. 3 outlet structure to PS-2. From PS-2 the alignment proceeds north on WSSC-owned property to just north of the Eagle Lake community, then extends east along property lines and crosses Highway 1. From the Highway 1 crossing, the alignment continues south and east eventually following County Road 56 mostly within the ROW to County Road 9. Where feasible without impacting the Larimer County Canal, the water pipeline will be located on Thornton-owned property adjacent to County Road 56 for a portion of the alignment.

North 3

Figure 5.1.12.2-6 shows the North 3 alternative configuration. North 3 includes a lake tap at WSSC Reservoir No. 4 to PS-1. From PS-1 the alignment extends east along property lines and crosses Highway 1. From the Highway 1 crossing the alignment continues south and east eventually following County Road 56 mostly within the ROW to County Road 9. Where feasible without impacting the Larimer County Canal, the water pipeline will be located on Thornton-owned property adjacent to County Road 56 for a portion of the alignment.

West 1

Figure 5.1.12.2-7 shows the West 1 alternative configuration. West 1 includes a lake tap at WSSC Reservoir No. 4 to PS-5. From PS-5 the alignment proceeds north and east on WSSC-owned property to just north of the Eagle Lake community, then extends east along property lines and crosses Highway 1. From the Highway 1 crossing the alignment continues south and east eventually following County Road 56 mostly within the ROW to County Road 9. Where feasible without impacting the Larimer County Canal, the water pipeline will be located on Thornton-owned property adjacent to County Road 56 for a portion of the alignment.

West 2

Figure 5.1.12.2-8 shows the West 2 alternative configuration. West 2 includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-3. From PS-3 the alignment proceeds north through the Braidwood community to WSSC-owned property. The alignment proceeds north and east to just north of the Eagle Lake community, then extends east along property lines and crosses Highway 1. From the Highway 1 crossing the alignment continues south and east eventually following County Road 56 mostly within the ROW to County Road 9. Where feasible without impacting the Larimer

County Canal, the water pipeline will be located on Thornton-owned property adjacent to County Road 56 for a portion of the alignment.

Central

Figure 5.1.12.2-9 shows the Central alternative configuration. Central includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-3. From PS-3 the alignment proceeds north and then east through the Eagle Lake community. The alignment then extends east across private property to Highway 1, and then east following Evans Drive, Bold Venture Way, and Grey Rock Drive (Larimer County Road 54-1/2 alignment). The alignment continues east and then north on Thornton-owned property, and then east following County Road 56 mostly within the ROW to County Road 9.

South 1

Figure 5.1.12.2-10 shows the South 1 alternative configuration. South 1 includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-4. From PS-4 the alignment proceeds east on private property parallel to and north of Douglas Road existing and future ROWs to Thornton owned property. The alignment proceeds north and east on Thornton-owned property and then east following County Road 56 mostly within the ROW to County Road 9.

South 2

Figure 5.1.12.2-11 shows the South 2 alternative configuration. South 2 includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-4. From PS-4 the alignment proceeds east in Douglas Road ROW to Thornton-owned property. The alignment proceeds north and east on Thornton-owned property and then east following County Road 56 mostly within the ROW to County road 9.

South 3

Figure 5.1.12.2-12 shows South 3 alternative configuration. South 3 includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-4. From PS-4 the alignment proceeds east on private property parallel to and north of Douglas Road existing and future ROWs to approximately ½ mile east of Hwy 1, then north generally following property lines, and then east following Grey Rock Drive. The alignment then proceeds east and then north on Thornton-owned property, and then east following County Road 56 mostly within the ROW to County Road 9.

South 4

Figure 5.1.12.2-13 shows South 4 alternative configuration. South 4 includes a connection to the WSSC Reservoir No. 4 outlet structure to PS-4. From PS-4 the alignment proceeds east in the Douglas Road ROW to approximately ½ mile east of Hwy 1, then north generally following property lines, then east following Grey Rock Drive. The alignment then proceeds east and then north on Thornton-owned property, and then east following County Road 56 mostly within the ROW to County Road 9.

Proposed Evaluation Criteria and Method of Measurement

Evaluation criteria are those factors that are important considerations in configuration evaluation and selection but are not associated with a specific cost.

Based on experience of performing alternative analyses over the past 20 years, CH2M HILL has established the following guidelines to use in the development of evaluation criteria:

1. Evaluation criteria must be mutually exclusive to prevent double-counting benefits or lack thereof.
2. Evaluation criteria must differentiate among alternatives, otherwise no value is added.
3. Evaluation criteria must be quantitatively measurable to minimize subjectivity and maximize defensibility.
4. A typical maximum number of evaluation criteria is 7 to avoid dilution of the effect of any one criterion.
5. Sub-criteria increase the complexity of the evaluation and explanation of results, and typically offer only minor insight to the decision process as their weight is already superseded by the primary criteria weights. Therefore, they are not used.

Evaluation Criteria

Common concerns communicated to Thornton during the public open houses, the outreach meetings, and meetings with Larimer County staff were considered in the development of evaluation criteria. The evaluation criteria are categorized as considerations from operations and considerations from construction activities. Considerations from operations involve longer term effects compared to considerations from construction activities. Considerations from operations occur after construction activities are complete when the TWP is in operation and include:

- Residential
- Pump Station Visual Noise/Vibration
- TWP Operations

Considerations from construction activities are temporary and occur during construction. Considerations from construction include:

- Traffic
- Environmental
- Coordinated Projects Opportunity

The six evaluation criteria used in the alternative configuration evaluation are summarized in **Table 5.1.12.2-7**. Further detail for each criterion is given in the following sections.

TABLE 5.1.12.2-7
Evaluation Criteria Summary for Larimer County Alternative Configurations Analysis

Criterion	Method of Measurement	Data Source
Considerations from Operations		
Residential	Number of homes within 250 feet of the proposed water pipeline alignment location within an easement (does not include water pipeline in ROW, WSSC or Thornton-owned property).	National Agricultural Imagery Program 2015 and Google Imagery 2016.
Pump Station Visual/Noise/Vibration	Visual: Number of homes within ½ mile of pump station with probable line of sight. Noise and Vibration: Number of homes within 250 feet of pump station score 3, within 251-500 feet score 2, within 501-1,000 feet score 1.	National Agricultural Imagery Program 2015 and Google Imagery 2016.
TWP Operations	Length in feet of road within a residential area required to drive to access pump station plus length in feet of easement on private property.	National Agricultural Imagery Program 2015 and Google Imagery 2016.
Considerations from Construction Activities		
Traffic	Ratio of length in feet to the estimated relative production factor to install the pipeline within ROW multiplied by average daily traffic volume (ADT) plus ratio of length in feet to the estimated relative production factor adjacent to ROW multiplied by 25 percent of the ADT.	Traffic count information from Larimer County Road Information Locator GIS or estimated if non-existent per Institute Transportation Engineers Trip Generator Manual.
Environmental	Estimated acres within an assumed 90-foot wide construction work limits crossed identified as riparian and/or populated with trees.	Riparian data from the Colorado Natural Heritage Program GIS information and Tree canopy information from National Agricultural Imagery Program 2015 and Google Imagery 2016.
Coordinated Projects Opportunity	Shared length in feet of possible coordinated projects to minimize community impacts multiplied by the possible number of projects TWP can coordinate with.	National Agricultural Imagery Program 2015 and Google Imagery 2016.

Considerations from Operations

Residential

Alternative alignments include water pipeline locations on residential properties within acquired easements, within ROW, or on WSSC or Thornton-owned properties. Area residents expressed concern regarding permanent impacts on properties where easements are acquired, as well as temporary impacts on nearby properties during construction. Residents also identified permanent impacts to the community at-large if the water pipeline is located within the community. Residents indicated a preference for the water pipeline to be located in ROW or on WSSC-owned property where feasible. To quantify residential impacts, the number of homes within 250 feet of the proposed water pipeline alignment location within an easement (outside the ROW), are estimated. Residential impacts from the water pipeline located within ROW are quantified under the evaluation criterion Traffic. Residents utilizing roads are counted in the ADT.

Pump Station Visual/Noise/Vibration

Visual

The pump station(s), regardless of location, will be visible from some homes, roads, or trails in the area. Views from homes are assumed to be the most important factor in evaluating visual impacts. During design, Thornton will consider suggestions and input on the design and architecture for the pump station(s) that reduce the visual impacts of the pump station(s). Visual impacts are quantified using the number of homes within ½-mile that have a probable line of sight to the pump station from the property. Probable line of sight was determined by creating a Viewshed Analysis using GIS data within ½-mile of each pump station. This analysis identifies which homes have probable line of sight to a pump station. If an alternative configuration incorporates multiple pump stations, the analysis includes visual impacts from all pump stations incorporated within that alternative.

Noise and Vibration

Residents expressed concern with noise and vibration from the long-term operation of the TWP pump station. Thornton will adhere to applicable ordinance requirements for noise and meet the standard level of care for vibration; nevertheless, Thornton recognizes resident's concern and have included noise and vibration from TWP pump station operations as an evaluation criterion.

Sound levels are reduced (attenuated) by distance, intervening obstacles, and other factors between a sound source and a receiver. If a sound is generated at a point source in a *free field*, meaning there are no walls or other obstructions, the sound pressure level will be reduced by 6 decibels each time the distance from the noise source is doubled. (Occupational Safety and Health Administration Technical Manual, OSHA.gov). Additional mitigation measures will be used to reduce sound levels to meet the applicable noise ordinance, if required.

The equipment used for the TWP pump station(s) will be well balanced and designed to produce very low vibration levels throughout the life of the TWP as vibrations in the equipment will lead to premature failure of the equipment. Vibration monitoring systems installed in the equipment are designed to alert operators to vibration levels detrimental to the long-term operation of the equipment and to shut down the equipment if a threshold vibration is exceeded. These protective measures will mitigate impacts related to ground and airborne vibrations to less than significant levels.

While the TWP will be designed and operated in compliance with the noise ordinance, noise and vibration impacts are quantified using the following approach:

The configuration will be given a total score based on the sum of the following:

- Number of homes within 250 feet of a proposed pump station site multiplied by a score of 3.
- Number of homes between 251 feet and 500 feet of a proposed pump station site multiplied by a score of 2.
- Number of homes between 501 feet and 1,000 feet of a proposed pump station site multiplied by a score of 1.

If an alternative configuration incorporates multiple pump stations, the quantification of impacts is based on a sum of the total scores from each of the pump stations identified for that alternative configuration.

TWP Operations

Residents expressed concern with vehicular traffic associated with operations of the TWP. Normal operations and maintenance activities are expected to include TWP operators traveling in a pickup truck to the pump station site once per day to inspect the facility. Access to the pump station could require driving through residential communities. Area residents expressed concern regarding impacts from traffic, noise, and visual impacts associated with normal pump station operations and maintenance. For the water pipeline, normal operations and maintenance activities could include TWP operators periodically traveling in a pickup truck along the water pipeline route visually inspecting the route. To the extent practicable, visual inspections could be from public roads to minimize impacts to property owners. Up to twice per year, it is anticipated that TWP operators will enter water pipeline vault and manhole appurtenances to exercise valves and conduct routine maintenance of equipment. Impacts from operations and maintenance activities are measured by estimating the length in feet of road within a residential area required to travel to access a pump station plus the length in feet of the easement for the water pipeline on private property.

Considerations from Construction

Traffic Impacts

The traveling public will be impacted in areas where construction of the TWP requires work within or adjacent to road ROW. To quantify the impacts to the traveling public associated with in-ROW construction, the estimated relative production factor to construct the water pipeline within the road ROW is multiplied by the road's Average Daily Traffic volume (ADT). To quantify the impacts to the traveling public associated with work adjacent to the ROW, the estimated relative production factor to construct the water pipeline adjacent to the road ROW is multiplied by 25 percent of the adjacent road's ADT. Total traffic impact is quantified as the sum of in-ROW impacts and adjacent-to-ROW impacts.

Estimated relative production factors for pipeline installation used in the analysis are based on production rate information from local contractors for construction in minor, moderate, and heavy congestion areas and tunnel construction. Congestion considers assumptions on underground utilities, other infrastructure, and reduced work area, which reduces production rates. Production rates consider pipeline installation only (trenching, setting pipe, welding, backfill) and do not consider elements such as mobilization, best management practices installation, traffic control installation, restoration, and demobilization. Production factors used for the analysis are relative compared to heavy congestion areas, which is shown below as having a production factor of 100. Construction in minor congestion areas is estimated to be approximately 2.86 times faster than construction in heavy congestion areas and was given a production factor of 286 (2.86 x 100). Relative production factors used in the analysis are as follows:

- Minor Congestion = 286
- Moderate Congestion = 143
- Heavy Congestion = 100
- Tunnel = 23

An example traffic calculation for a 1,000-foot length in heavy congestion ROW with ADT of 2,500 would be calculated as:

$$(1{,}000 \div 100)x2{,}500 = 25{,}000$$

Table 5.1.12.2-8 presents the ADT and congestion designation information used in the analysis:

TABLE 5.1.12.2-8
ADT Information

Road	ADT	Congestion in ROW	Congestion Adjacent to ROW	Alternative Configuration	Source
County Road 11	100	Minor	Minor	North 1, North 2, North 3, West 1, West 2, Central, South 1, South 2, South 3, South 4	Larimer County Road Information Locator Enterprise GIS; 2016; Larimer County Website
County Road 56 (County Road 11 to County Road 9)	100	Moderate	Minor, Moderate, Tunnel	North 1, North 2, North 3, West 1, West 2, Central, South 1, South 2, South 3, South 4	Larimer County Road Information Locator Enterprise GIS; 2016; Larimer County Website
County Road 56 (Highway 1 to County Road 11)	95	Moderate	Minor	North 1, North 2, North 3, West 1, West 2	Larimer County Road Information Locator Enterprise GIS; 2016; Larimer County Website
County Road 13 (Windcrest Lane to County Road 56)	55	Heavy	N/A	Central, South 3, South 4	Larimer County Road Information Locator Enterprise GIS; 2016; Larimer County Website
County Road 13 (Douglas Road to Windcrest Lane)	275	Heavy	N/A	South 1	Larimer County Road Information Locator Enterprise GIS; 2016; Larimer County Website
Eagle Lake South (Pelican Bay to Eagle Lake Drive)	244	Heavy	N/A	Central	Estimated per ITE* Trip Generation Manual
Eagle Lake South (Douglas Road to Eagle Lake Drive	478	Heavy	N/A	South 1, South 4	Estimated per ITE* Trip Generation Manual)
Evans Drive	98	Heavy	Minor, Tunnel	Central	Estimated per ITE* Trip Generation Manual
Grey Rock (east of County Road 13)	59	Heavy	Minor, Heavy	Central, South 3, South 4	Estimated per ITE* Trip Generation Manual)

TABLE 5.1.12.2-8
ADT Information

Road	ADT	Congestion in ROW	Congestion Adjacent to ROW	Alternative Configuration	Source
Grey Rock (west of County Road 13)	39	Heavy	Minor, Heavy, Tunnel	Central, South 3, South 4	Estimated per ITE* Trip Generation Manual
Pelican Bay	39	Heavy	N/A	Central	Estimated per ITE* Trip Generation Manual
Travis Road	200	Heavy	Minor	53	Larimer County Road Information Locator Enterprise GIS; 2014; Larimer County Website
Vista Lake Drive	108	Heavy	N/A	West 2	Estimated per ITE* Trip Generation Manual
La Mesa Drive	225	Heavy	N/A	South 1, South 3	Estimated per ITE* Trip Generation Manual
Private Drive (Davies Mobile Home Park)	195	Heavy	N/A	South 1	Estimated per ITE* Trip Generation Manual
Douglas Road (Highway 1 to County Road 11)	2,500	Heavy	Minor, Heavy	South 1, South 2, South 3, South 4	Larimer County Road Information Locator GIS; 2016; Larimer County Website
Douglas Road (County Road 17 to Highway 1)	3,600	Heavy	Heavy	South 1, South 2, South 3, South 4	Larimer County Road Information Locator GIS 2014; Larimer County Website
Highway 1	5,900	N/A	Heavy	North 1, North 2, North 3, West 1, West 2	CDOT Online Transportation Information System Website, Station ID: 100004

*Notes: ITE = Institute of Transportation Engineers

Environmental Impacts

Residents expressed concern regarding environmental impacts from the TWP, including impacts to wildlife, riparian areas, and areas populated with trees.

Wildlife commonly found in trees, and wetland and riparian areas are sensitive to disturbance within their habitats. The water pipeline crossings of jurisdictional wetlands will be constructed using trenchless construction methods (tunneling or boring) and will, therefore, have no impact to jurisdictional wetlands. Clearing and grubbing activities will impact areas identified as riparian and/or populated with trees. In addition, before construction, site assessment surveys will be completed to determine the boundaries of suitable habitat for federally listed threatened and endangered species. The TWP will be constructed using trenchless construction methods where suitable habitat for federally listed threatened or endangered species habitat is present and will therefore, have no impact on federally listed species. Pre-construction nesting bird surveys will be conducted by a biologist. Thornton will consult with U.S. Fish and Wildlife Service and Colorado Parks and Wildlife before the start of construction and will employ construction methods as recommended by these agencies to minimize impacts to migratory birds.

It is anticipated that there is a potential for short-term impacts from construction activities to non-listed or state-protected wildlife species located in areas identified as riparian and/or populated with trees. Riparian areas may be temporarily impacted during open-cut construction and will be restored to pre-construction conditions once construction is complete, including grading and revegetation. Potential environmental impacts are quantified as the sum of the areas in acres within an assumed 90-foot wide construction work limits crossed identified as riparian and/or populated with trees.

Coordinated Project Opportunity

Area residents expressed concern regarding construction of other future infrastructure projects within the community, in particular, a pipeline for the Northern Integrated Supply Project being proposed by the Northern Colorado Water Conservancy District (Northern Water). It was also noted that Larimer County had long-term plans for rehabilitation/replacement of Douglas Road, including intersection improvements at Highway 1. The major concern of residents was impacts from construction of three projects over a protracted period of time, instead of coordinating the location and construction of one or more of the projects. Thornton met with both Northern Water and Larimer County staff to discuss potential for coordination and identified potential locations of overlap in both location and timing. The opportunity for a coordinated project is quantified by estimating the length in feet of shared corridor of possible coordinated projects multiplied by the possible number of projects.

Other Considerations

Geologic Conditions

Area residents expressed concern regarding geologic conditions in the area. Thornton has reviewed Larimer County geologic hazard maps for hazards in the area around the alternative configurations. These areas are classified as low hazard. In addition, subsurface geotechnical investigations of geologic conditions utilizing soil borings will be completed during design to further determine the subsurface soil conditions and associated geological hazards. Mitigation measures will be refined during design to meet any identified site-specific geological hazards. Because mapping classifies the area as a low geologic hazard and because mitigation measures can be implemented when constructing TWP facilities, geologic conditions were not selected as an evaluation criterion for analysis.

Construction Noise/Vibration Impacts

Area residents expressed concern regarding noise and vibration during construction. Temporary construction activities associated with the TWP are similar to other infrastructure projects, and will adhere to applicable ordinance requirements for noise and meet the standard level of care for vibration; therefore, these impacts were not selected as an evaluation criterion. However, for informational purposes, typical noise and vibration levels for temporary construction activities are provided in **Table 5.1.12.2-9** and **Table 5.1.12.2-11** respectively below.

Noise

During construction, the TWP will comply with Larimer County's noise ordinance applicable at the time (currently Ordinance No. 97-03). Thornton will require contractors to ensure that construction equipment is maintained and equipped with appropriate mufflers. Construction hours will typically be from 7:00 a.m. to 7:00 p.m., Monday through Saturday unless otherwise approved by Larimer County. Construction may extend beyond these hours on an as-required and case-by-case approved basis. For example, some construction activities may be required to complete uninterruptible tasks, meet an in-service date, or minimize short-term impacts to traffic. **Table 5.1.12.2-9** presents typical noise levels decibels (dBA) from construction equipment from the Federal Transit Administration Transit Noise and Vibration Impact Assessment, May 2006 (Guidance Manual FTA-VA-1003-06).

TABLE 5.1.12.2-9.
Construction Equipment Noise Emission Levels

Equipment	Typical Noise Level (dBA) 50 feet from Source
Air Compressor	81
Backhoe	80
Ballast Equalizer	82
Ballast Tamper	83
Compactor	82
Concrete Mixer	85
Concrete Pump	82
Concrete Vibrator	76
Crane, Derrick	88
Crane, Mobile	83

TABLE 5.1.12.2-9.
Construction Equipment Noise Emission Levels

Equipment	Typical Noise Level (dBA) 50 feet from Source
Dozer	85
Generator	81
Grader	85
Impact Wrench	85
Jack Hammer	88
Loader	85
Paver	89
Pile-driver (Impact)	101
Pile-driver (Sonic)	96
Pneumatic Tool	85
Pump	76
Rail Saw	90
Rock Drill	98
Roller	74
Saw	76
Scarifier	83
Scraper	89
Shovel	82
Spike Driver	77
Tie Cutter	84
Tie Handler	80
Tie Inserter	85
Truck	88

Vibration

Threshold limits have been developed regarding preventing vibration-related damage to various structures. Guidance Manual FTA-VA-1003-06 identifies maximum vibration levels (measured at the structure) for preventing damage to structures from construction activities. **Table 5.1.12.2-10** presents a summary of FTA guidance limits for maximum vibration levels. Ensuring that vibration levels at the structure do not exceed the identified limits will prevent damage to the structure. Exceeding these limits at the structure may result in cosmetic damage and, at higher levels, structural damage.

TABLE 5.1.12.2-10
FTA Construction Vibration Damage Criteria

Building Category	Peak Particle Velocity (PPV) (in/sec)
I. Reinforced-concrete, steel or timber (no plaster)	0.5
II. Engineered concrete and masonry (no plaster)	0.3
III. Non-engineered timber and masonry buildings	0.2
IV. Buildings extremely susceptible to vibration damage	0.12

Table 5.1.12.2-11 presents anticipated vibration levels for typical construction equipment at 25 feet, 50 feet, and 100 feet, and identifies if the anticipated vibration is under the FTA guidance limits of 0.5 PPV for Reinforced-concrete, steel or timber (no plaster), and 0.12 PPV for buildings extremely susceptible to vibration damage.

TABLE 5.1.12.2-11
Estimated Vibration from Construction Equipment

Equipment Description	PPV at 25 ft	PPV at 50 ft	PPV at 100 ft	Less than 0.5 PPV	Less than 0.12 PPV
Auger Drill Rig	0.089	0.031	0.011	Yes	Yes
Backhoe	0.088	0.031	0.011	Yes	Yes
Compactor	0.240	0.085	0.030	Yes	**No at 25 ft**
Concrete Mixer/Concrete Pump	0.080	0.028	0.010	Yes	Yes
Dozer (large)	0.089	0.031	0.011	Yes	Yes
Dozer (small)	0.003	0.001	0.0004	Yes	Yes
Dump Truck	0.080	0.028	0.010	Yes	Yes
Excavator	0.088	0.031	0.011	Yes	Yes
Flat Bed Truck	0.080	0.028	0.010	Yes	Yes
Front End Loader	0.088	0.031	0.011	Yes	Yes
Gradall	0.088	0.031	0.011	Yes	Yes
Hoe Ram	0.089	0.031	0.011	Yes	Yes
Insitu Soil Sampling Rig	0.089	0.031	0.011	Yes	Yes
Jackhammer	0.035	0.012	0.004	Yes	Yes
Loaded Truck	0.076	0.027	0.010	Yes	Yes
Mounted Hammer Hoe Ram	1.518	0.537	0.190	**No at 25 and 50 ft**	**No at 25, 50, and 100 ft**
Paver	0.080	0.028	0.010	Yes	Yes
Pickup Truck	0.080	0.028	0.010	Yes	Yes
Scraper	0.003	0.001	0.0004	Yes	Yes
Tractor	0.080	0.028	0.010	Yes	Yes
Tunnel Boring Machine (rock)	0.046	0.016	0.006	Yes	Yes

TABLE 5.1.12.2-11
Estimated Vibration from Construction Equipment

Equipment Description	PPV at 25 ft	PPV at 50 ft	PPV at 100 ft	Less than 0.5 PPV	Less than 0.12 PPV
Tunnel Boring Machine (soil)	0.024	0.008	0.003	Yes	Yes
Vibratory Roller (large)	0.472	0.167	0.059	**No at 25 ft**	**No at 25 and 50 ft**
Vibratory Roller (small)	0.176	0.062	0.022	Yes	**No at 25 ft**
Vibratory Roller	0.210	0.074	0.026	Yes	**No at 25 ft**

Notes: Data from multiple sources –Guidance Manual FTA-VA-1003-06; Washington State Department of Transportation Construction Noise and Vibration Mitigation and Monitoring Plan Evergreen Point Floating Bridge and Landings Project, June 27, 2012 and estimated using recommended procedure from FTA-VA-1003-06.

Vibration from the majority of the equipment anticipated to be used during construction is well below the FTA identified maximum vibration level guidelines for preventing damage to non-historical structures from construction activities. Contractors will be required to initiate, maintain, and supervise safety precautions and programs associated with their work, which will include using proper and safe equipment to complete the work. Contractors will be required to take necessary precautions for safety and provide necessary protection to prevent damage, injury, or loss.

Take Water Downstream of Fort Collins

Area residents stated that Thornton should consider taking Thornton's water further downstream on the Cache la Poudre River and spending more money to treat the resulting lesser quality water. The residents stated that Thornton should consider treating the water by forward osmosis or other low-pressure water treatment systems, including evaporative systems for brine disposal.

Forward osmosis is an emerging technology that appears to occupy a niche in treating smaller-scale flowrates, and is not suitable for large-scale municipal treatment systems. The disposal of brine by-products from treating lower quality waters is also problematic for inland locations. The disposal options possible at inland locations are generally not sustainable for long-term disposal from large-scale municipal treatment works. Evaporation systems such as ponds require large land areas, and mechanical and thermal evaporators are not considered environmentally sustainable for the large-scale flows from a municipal treatment system. The TWP is a large-scale water delivery project. Therefore, forward osmosis is not an operationally or environmentally suitable option for the TWP.

The purpose of the TWP is to convey domestic water from the WSSC system purchased by Thornton in the mid-1980s to enhance Thornton's water supply reliability and drought resiliency, help address existing source water quality issues, and meet municipal and industrial demands of Thornton's water customers through 2065. The TWP provides the means by which Thornton's customers will receive the benefit of Thornton's decades-long planning and investment in this high quality water source. Taking water downstream of Fort Collins will necessarily result in a degradation to the water quality defeating a key purpose and need of the TWP. Therefore, this configuration was not selected as an evaluation criterion for analysis.

Access from Private Roads

Area residents expressed concern regarding the use of neighborhood roads for construction access. Concerns included the following:

- Restoration and maintenance. Areas disturbed by construction activities will be restored to pre-construction grade and vegetation. Surface areas disturbed by construction will be monitored after construction and Thornton will continue to maintain the site until the area is restored to meet property owner and regulatory requirements.
- Dust. Contractors will be required to obtain a Colorado Department of Public Health and Environment Air Permit that will include a fugitive dust control plan.
- Safety for children, animals, and other pedestrians. Caution will be exercised by contractors at all times for the protection of all persons, work, and property, and hazardous conditions will be guarded against or eliminated. Contractors will be required to comply with applicable federal, state, and local laws and regulations regarding safety.
- Privacy. Contractors will be required to stay within the public ROW and within the permanent and temporary construction easements.

Alternative Configuration Analysis

The ten alternative TWP configurations were analyzed based on the above described evaluation criteria and cost. The total evaluation criteria equally weighted normalized scores, described below, were used to develop a normalized cost-effectiveness score. Cost-effectiveness analysis is commonly used in the planning of projects and, in this analysis, is used for comparison of the alternative configurations. The analysis relates each alternative configuration's comparative cost to the total evaluation criteria equally weighted normalized score.

Evaluation Criteria Scoring

A summary of raw data for each evaluation criterion for each alternative configuration is presented in **Table 5.1.12.2-12.** The raw data corresponds to the method of measurement described above.

TABLE 5.1.12.2-12
Evaluation Criteria Raw Data

Alternative Configuration	Evaluation Criteria					
	Residential[1]	Pump Station Visual/Noise/ Vibration[2]	TWP Operations[3]	Traffic[4]	Environmental[5]	Coordinated Project Opportunity[6]
North 1	6	48	12,753	17,830	6.3	13,620
North 2	2	33	11,707	10,673	4.4	12,933
North 3	2	15	11,743	10,673	4.4	12,933
West 1	2	62	8,463	10,956	4.7	12,933
West 2	14	91	10,889	8,430	4.7	12,933
Central	29	91	16,189	3,381	3.8	2,836
South 1	53	61	24,347	120,231	8.6	2,839
South 2	0	61	2,464	393,514	2.0	35,476
South 3	25	61	19,789	59,948	6.4	2,836
South 4	10	61	13,424	211,888	2.9	16,316

Method of Measurement:

1. Number of homes within 250 feet of the water pipeline alignment where the water pipeline is proposed to be located within an easement (outside the ROW).
2. Visual: Number of homes within ½ mile of pump station with probable line of sight from the property. Noise and Vibration: Number of homes within 250 feet of pump station score 3, within 251-500 feet score 2, within 501-1,000 feet score 1.
3. Length in feet of road within a residential area required to drive to access pump station plus length in feet of easement on private property.
4. Ratio of length in feet to the estimated relative production factor to install the pipeline within ROW multiplied by ADT plus ratio of length in feet to the estimated relative production factor adjacent to ROW multiplied by 25 percent of the ADT. See Attachment B for additional information.
5. Estimated acres crossed within an assumed 90-foot wide construction work limits identified as riparian and/or populated with trees.
6. Shared length in feet of possible coordinated projects to minimize community impacts multiplied by the possible number of projects.

The raw data were normalized to criterion scores, ranging from 1 to 5 for comparison, with a higher rating being preferred. Scores were calculated by normalizing the values in **Table 5.1.12.2-11**. For evaluation criteria for residential, pump station visual/noise/vibration, TWP operations, traffic, and environmental, the minimum raw data value (least impactful/most preferred) for each criterion received a score of 5.0, and the maximum raw data value (most impactful/least preferred) for each criterion received a score of 1.0. For evaluation criterion coordinated projects opportunity, the highest raw data value (most opportunity/most preferred) received a value of 5.0 and the minimum raw data value (least opportunity/least preferred) received a value of 1.0. Other scores were calculated based on a ratio of the range of the highest raw data value and raw data to the range of the highest and lowest raw data value. More than one alternative configuration could have the same rating value if their raw data are the same. Normalized scores were multiplied by equal weighting as each criterion was recognized as being equally important compared to other criterion

(6 criteria; 16.7% weighting for each). **Table 5.1.12.2-13** presents the equally weighted normalized scores.

Using the North 1 Residential criterion as an example, the equally weighted normalized score would be calculated as:

$$\left(1+\left(\frac{(53-6)}{(53-0)}\right)x4\right)x0.167=0.76$$

TABLE 5.1.12.2-13
Evaluation Criteria Equally Weighted Normalized Scoring

Alternative Alignment	Evaluation Criteria						
	Residential	Pump Station Visual/Noise/ Vibration	TWP Operations	Traffic	Environmental	Coordinated Project Opportunity	Total
North 1	0.76	0.54	0.52	0.81	0.40	0.39	3.42
North 2	0.81	0.68	0.55	0.82	0.60	0.37	3.83
North 3	0.81	0.83	0.55	0.82	0.60	0.37	3.98
West 1	0.81	0.42	0.65	0.82	0.56	0.37	3.63
West 2	0.66	0.17	0.58	0.83	0.56	0.37	3.16
Central	0.47	0.17	0.42	0.83	0.65	0.17	2.70
South 1	0.17	0.43	0.17	0.63	0.17	0.17	1.73
South 2	0.83	0.43	0.83	0.17	0.83	0.83	3.93
South 3	0.52	0.43	0.31	0.74	0.39	0.17	2.54
South 4	0.71	0.43	0.50	0.48	0.74	0.44	3.30

Chart 5.1.12.2-5 shows the relative individual criterion evaluation criteria scores for the alternative configurations, and **Chart 5.1.12.2-6** shows the total evaluation criteria equally weighted normalized scores for the alternative configurations. A longer bar is considered to be more favorable. North 3 and South 2 have similar high (favorable) total evaluation criteria scores at 3.98 and 3.93, respectively. North 3 had the highest score for pump station visual/noise/vibration and second highest scores for residential and traffic. South 2 had the highest scores for residential, TWP operations, environmental, and coordinated project opportunity and the lowest score for traffic. South 1 has the lowest total evaluation criteria score of 1.73 due to having the lowest scores for residential, TWP operations, environmental, and coordinated project opportunity.

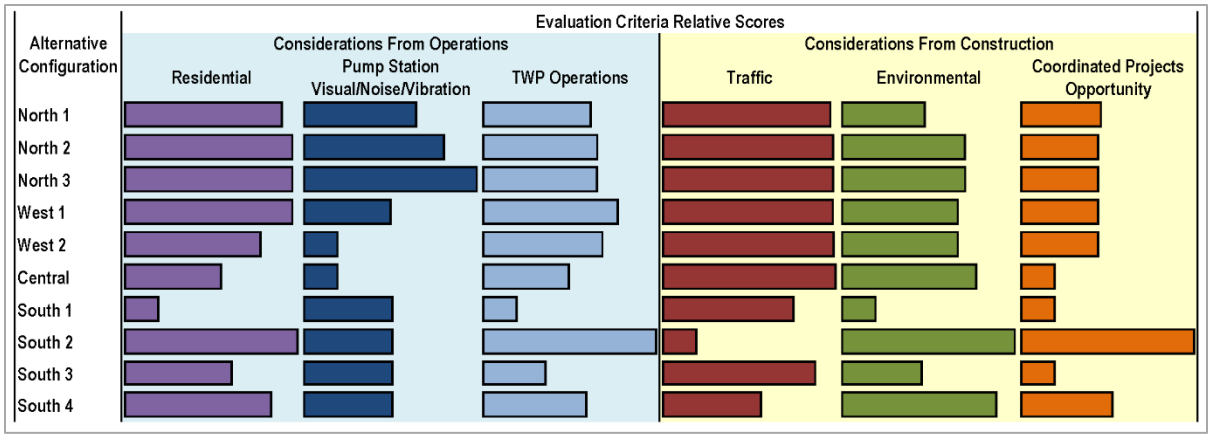


CHART 5.1.12.2-5
Evaluation Criteria Relative Scores

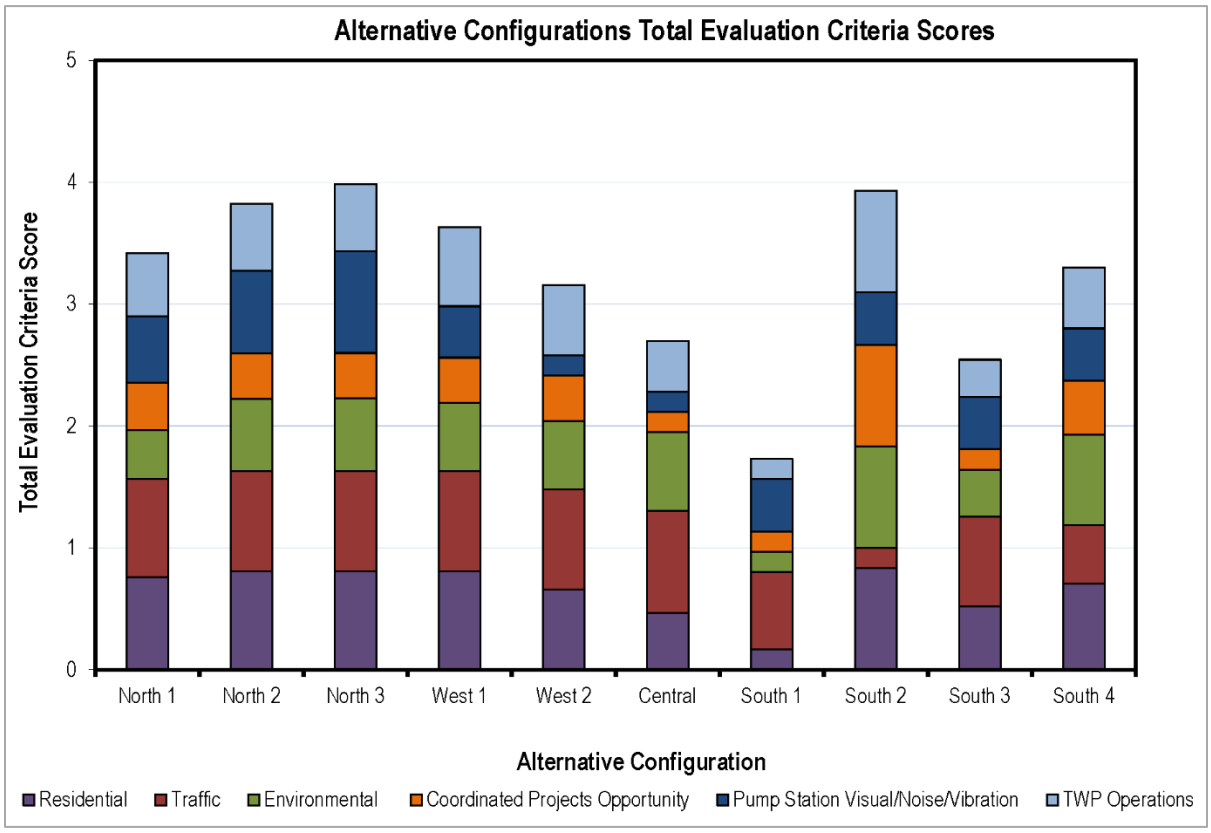


CHART 5.1.12.2-6
Alternative Configurations Total Evaluation Criteria Scores

Economic Consideration

Thornton City Council's Vision, Mission, Values, Guiding Principles for the TWP include finding common-sense solutions that are financially responsible and achievable. Therefore, cost is important in determining a preferred alternative, although, as demonstrated by this analysis, is not the only factor considered. High-level comparative cost estimates were developed to aid in the comparison of alternative configurations.

The comparative cost estimates focus on the costs associated with construction, easements, and present worth of pump station life cycle energy costs. Comparative cost estimates exclude soft costs such as program management, engineering services, construction management, or other incidental costs. Easement costs assume a 50-foot wide permanent easement and 40-foot wide temporary construction easement.

Comparative construction costs include the following:

- Pipeline construction. Pipeline materials, appurtenances, traffic control, and installation. Installation costs consider a number of factors including groundwater conditions, congestion, and construction in rock.
- Pump Stations. Equipment, building materials, construction and life-cycle energy costs. Estimate based on the total installed horsepower to pump water from the WSSC system connection to the proposed location of the water tank east of Interstate 25.
- Tunnels. Tunnel crossings were assumed at possible wetlands, water bodies, and irrigation ditches. Tunnel costs consider dry or groundwater conditions and include tunnel shafts, casing pipe, dewatering, tunneling, and muck disposal.
- Surface restoration. Open country, gravel road, asphalt paving. Open country costs consider revegetation including seeding, mulching, and erosion control measures across the full width of the work limits. Gravel road costs consider a 28-foot wide, 9-inch thick section of gravel installation. Asphalt paving costs consider removal and replacement of an 8-foot wide trench area plus a 14-foot wide overlay.
- Reservoir connections. Lake taps and reservoir outlet connections. Lake taps consider mobilization, watertight shafts, tunneling, initial lining, final lining and normal shaft structures. Outlet connections consider valves and vaults needed to connect to existing outlet piping.

Chart 5.1.12.2-7 shows the comparative cost breakdown for each alternative configuration. The longer bar represents higher relative cost.

- Pipeline construction. South 2 and South 4 have the highest pipeline construction costs relative to other alternative configurations due to installation in congested area.
- Pump stations. North 1 pump station costs are slightly higher relative to other alternative configurations because there are two pump stations.
- Tunnels. South 1 has the highest tunnel costs due to the highest total length of tunnel crossings of possible wetland areas, open waters, and irrigation ditches.
- Surface restoration. South 2 has the highest surface restoration cost relative to other alternatives due to its location within pavement.
- Reservoir connection. North 1, North 2, North 3, and West 1 have higher relative connection costs due to lake taps.

- Easements. South 1 has the highest easement cost relative to other alternative configurations due to it being located primarily on private property.
- Present Cost of Annual Operation. The present cost of annual operation for the life of the project is relatively similar for all alternative configurations.

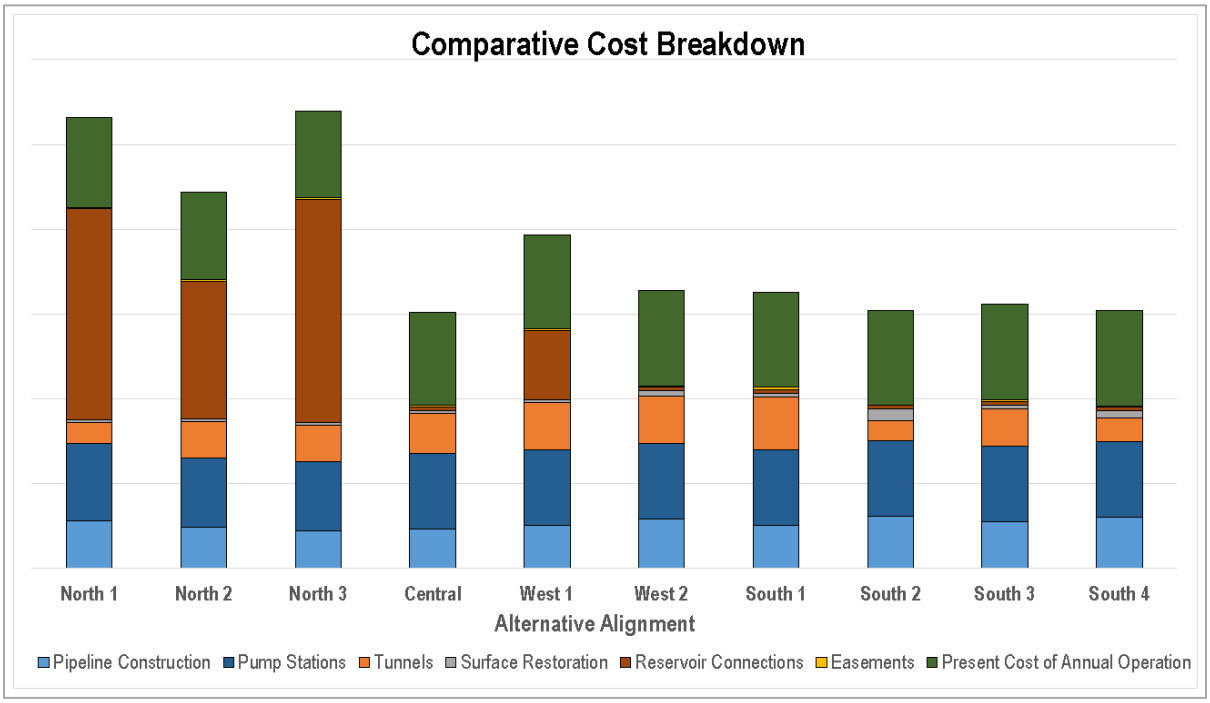


CHART 5.1.12.2-7
Comparative Cost Breakdown

Chart 5.1.12.2-8 shows comparative costs of the alternative configurations. The blue bars represent the comparative costs in millions of dollars for the alternative configurations. The green line represents the ratio of the comparative cost for each alternative configuration relative to the alternative configuration with the lowest cost. Central, with the lowest comparative cost, is shown as 1.000. North 3, with the highest comparative cost, is shown as 1.784 or 78.4 percent higher cost than Central, reflecting an almost $50 million difference. South 2 comparative cost is slightly higher than Central (0.5 percent), reflecting an almost $300,000 difference.

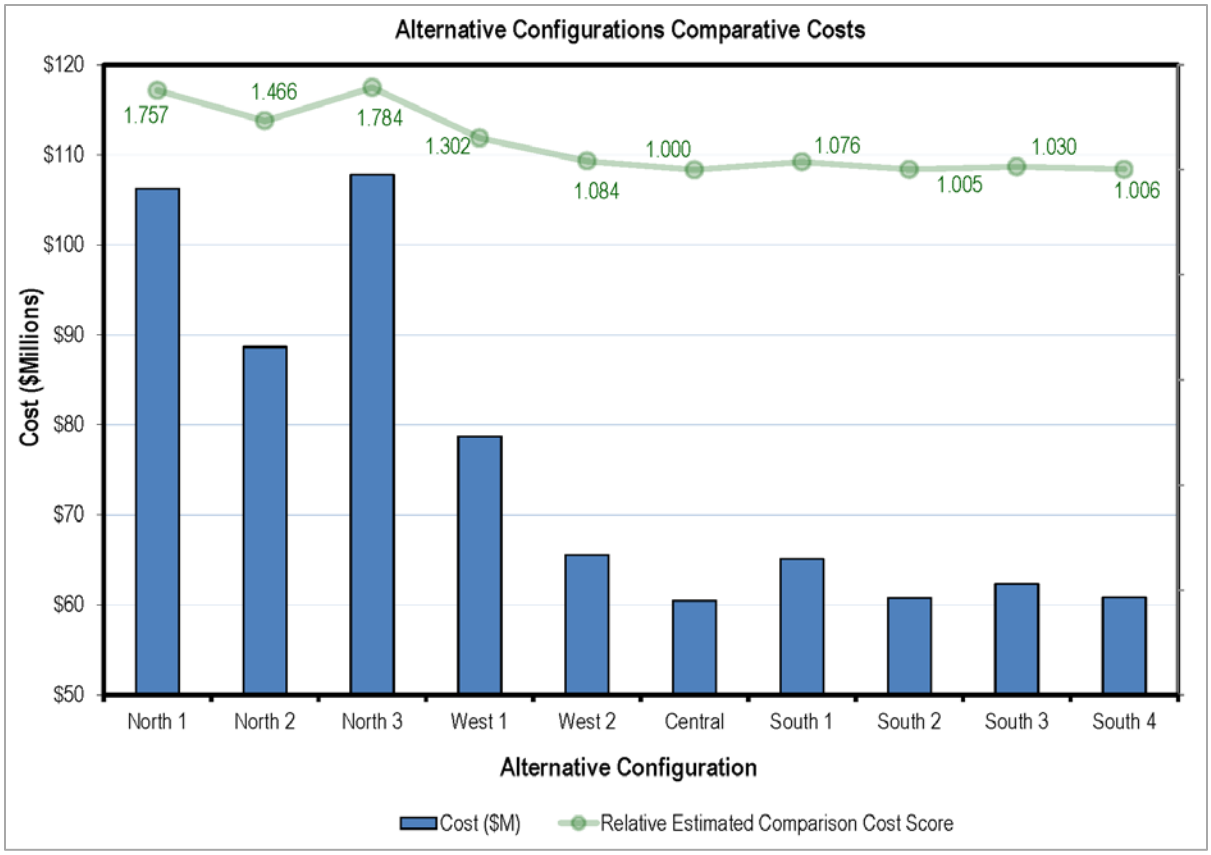


CHART 5.1.12.2-8
Alternative Configurations Comparative Costs

Analysis Results and Recommendation

To determine the preferred alternative configuration both the total evaluation criteria score and comparative costs were considered, as was a calculation of the ratio of the comparative cost to the evaluation criteria score (cost/criteria). The results of the calculation were normalized and scored from 1 to 5 with the higher number being preferred. **Chart 5.1.12.2-9** shows the most to least preferred alternative configurations in order and includes comparative costs in millions of dollars and the total evaluation criteria score. As described previously, Central had the lowest comparative cost; however, based on the analysis results, South 2 has the best cost/criteria score. Relative to South 2, South 4, and West 1 have slightly lower cost/criteria scores, similar comparative costs, but lower total evaluation criteria scores.

Based on the analysis, the South 2 alternative configuration has the highest comparison cost to evaluation criteria score, as well as the second highest total evaluation criteria score, and is the preferred alternative, even though it costs approximately $300,000 more than the lowest comparison cost alternative.

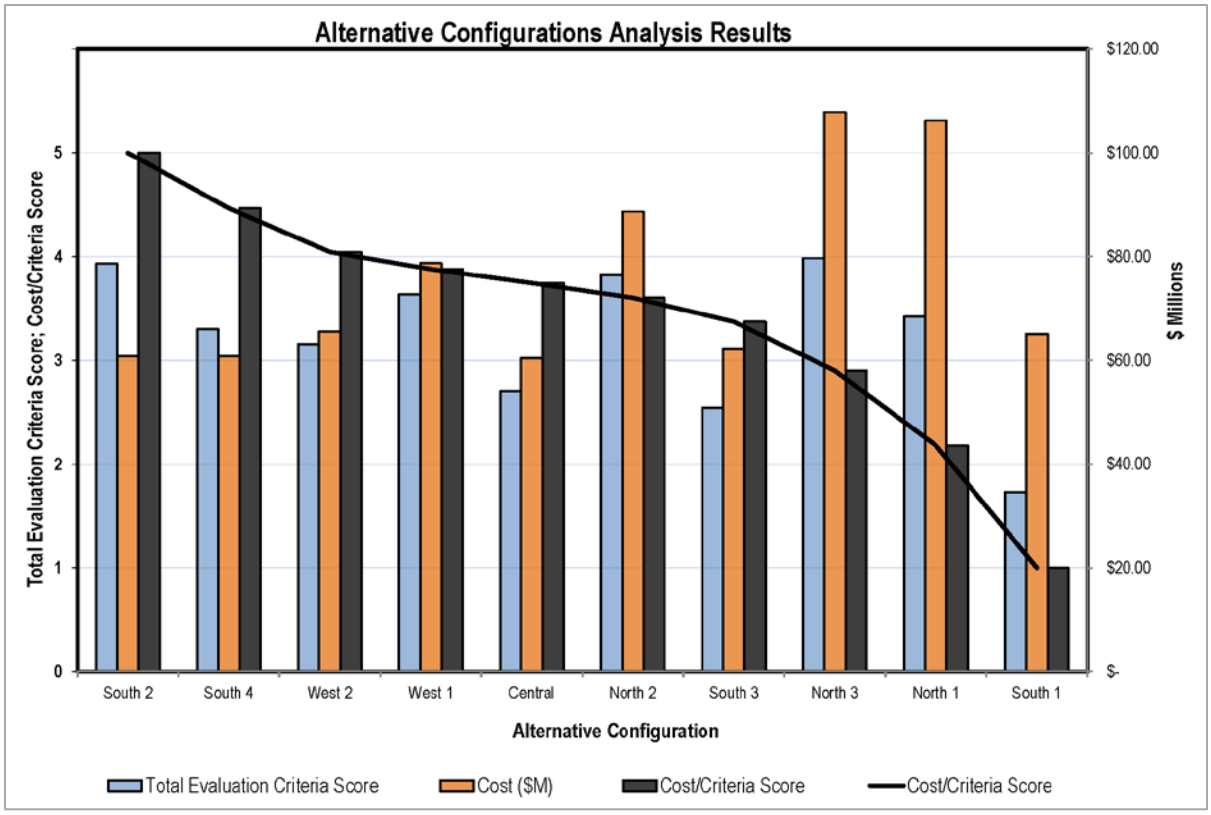
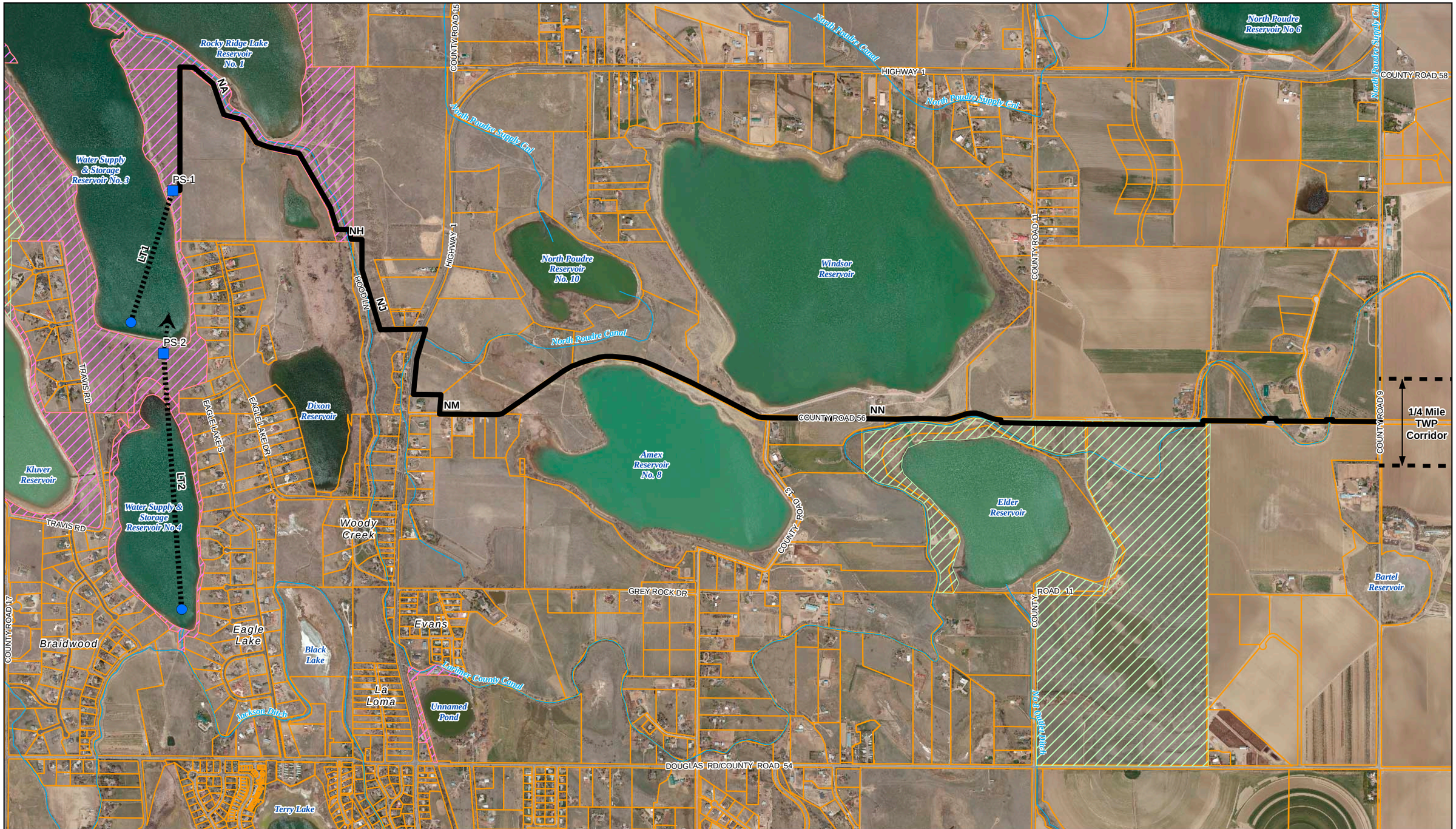


CHART 5.1.12.2-9
Alternative Configurations Analysis Results

ATTACHMENT A
Alternative Configuration Figures



CITY OF THORNTON
COLORADO

12450 WASHINGTON ST
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1 inch = 1,400 feet

River/Stream/Canal/Ditch
Pump Station (PS-#)
Lake Tap
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
North 1 Alternative Alignment

Figure 5.1.12.2-4
Larimer County
North 1 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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Rocky Ridge Lake Reservoir No. 1
Water Supply & Storage Reservoir No. 3
COUNTY ROAD 15
North Poudre Canal
HIGHWAY 1
North Poudre Reservoir No 6
North Poudre Supply Cnl
COUNTY ROAD 58
North Poudre Reservoir No. 10
Windsor Reservoir
COUNTY ROAD 11
NF
NG
NH
NI
NL
NN
ND
NC
I1
PS-2
HOOD LN
HIGHWAY 1
North Poudre Canal
COUNTY ROAD 56
TRAVIS RD
EAGLE LAKE S
EAGLE LAKE DR
Dixon Reservoir
Amex Reservoir No. 8
COUNTY ROAD 13
Elder Reservoir
1/4 Mile TWP Corridor
COUNTY ROAD 6
Kluver Reservoir
Water Supply & Storage Reservoir No 4
LT2
TRAVIS RD
Woody Creek
GREY ROCK DR
COUNTY ROAD 11
Bartel Reservoir
COUNTY ROAD 17
Braidwood
Eagle Lake
Black Lake
Evans
Larimer County Canal
La Loma
Unnamed Pond
Jackson Ditch
No 2 Outlet Ditch
DOUGLAS RD/COUNTY ROAD 54
Terry Lake

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Pump Station (PS-#)
Lake Tap
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
North 2 Alternative Alignment

Figure 5.1.12.2-5
Larimer County
North 2 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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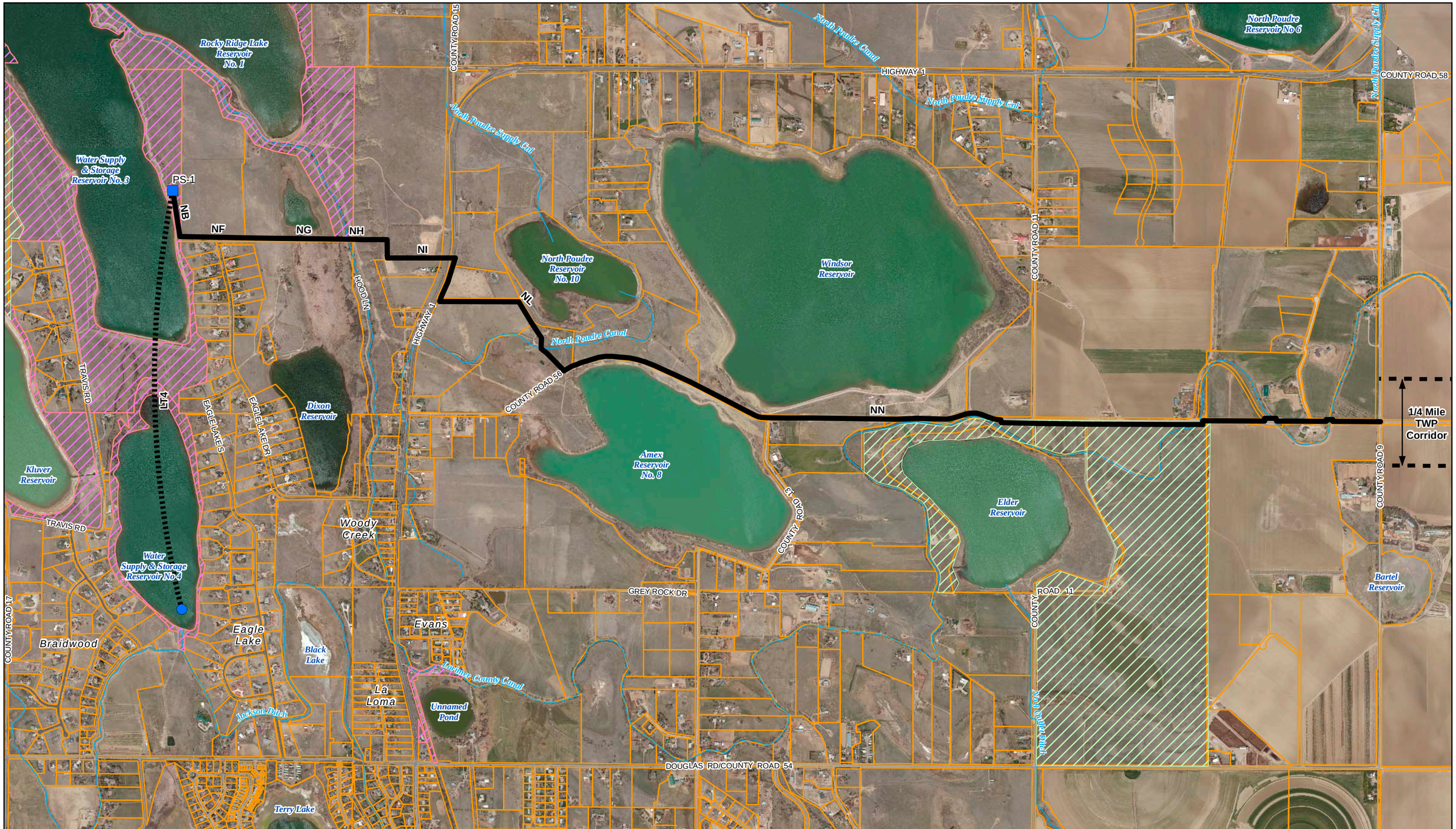

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River/Stream/Canal/Ditch
Pump Station (PS-#)
Lake Tap
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
North 3 Alternative Alignment

Figure 5.1.12.2-6
Larimer County
North 3 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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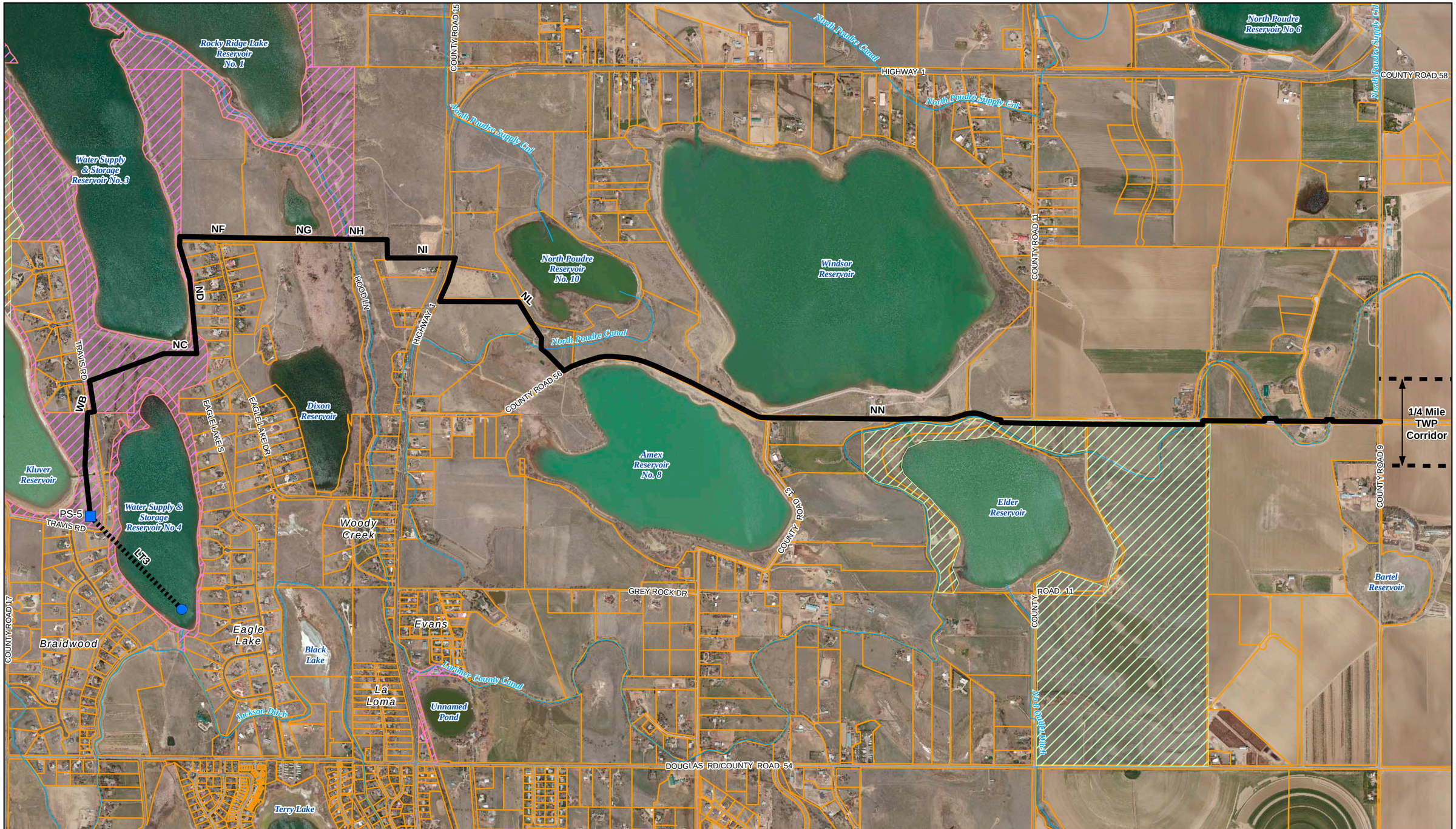

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River/Stream/Canal/Ditch
Pump Station (PS-#)
Lake Tap
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
West 1 Alternative Alignment

Figure 5.1.12.2-7
Larimer County
West 1 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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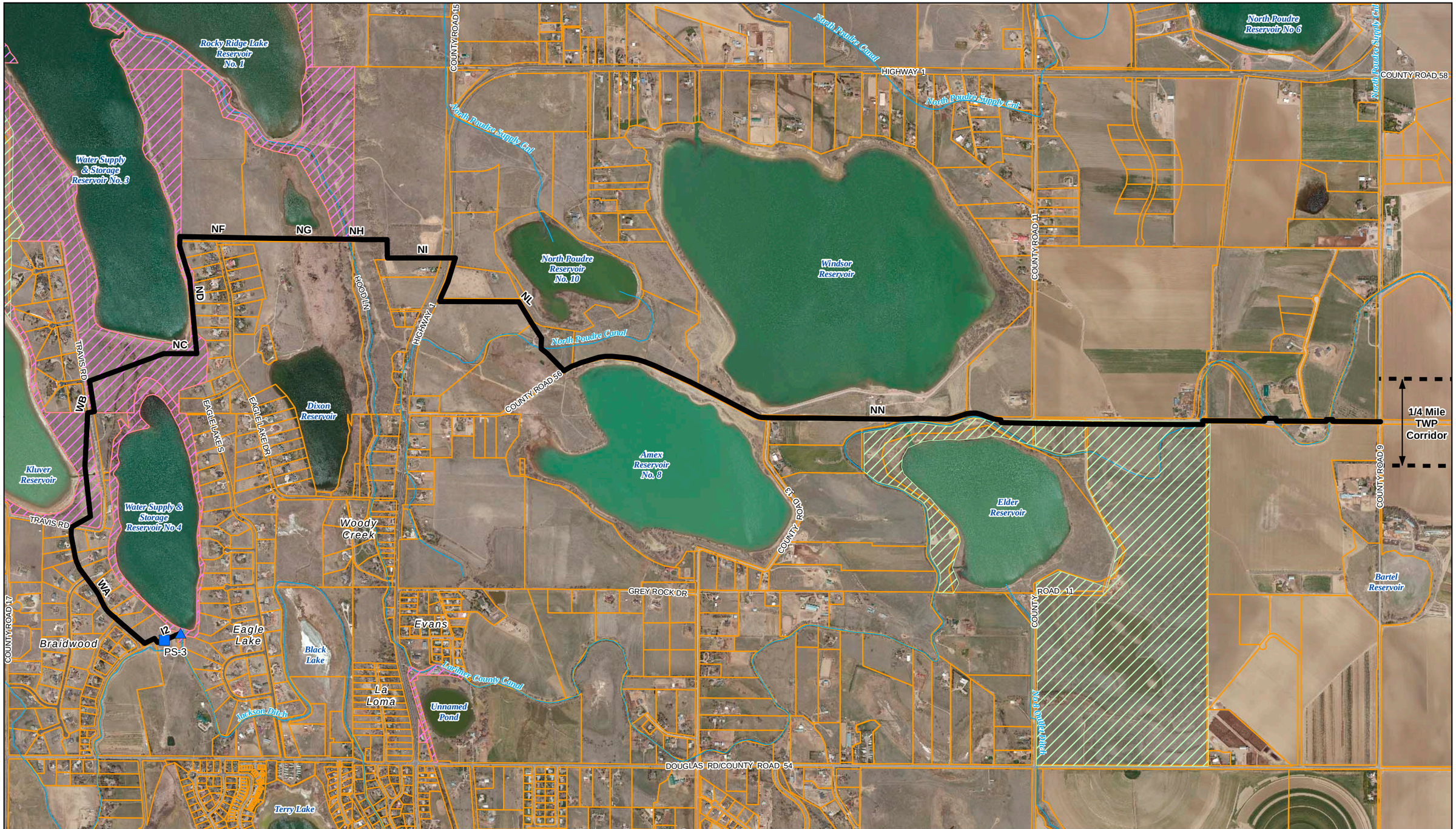

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River/Stream/Canal/Ditch
Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
West 2 Alternative Alignment

Figure 5.1.12.2-8
Larimer County
West 2 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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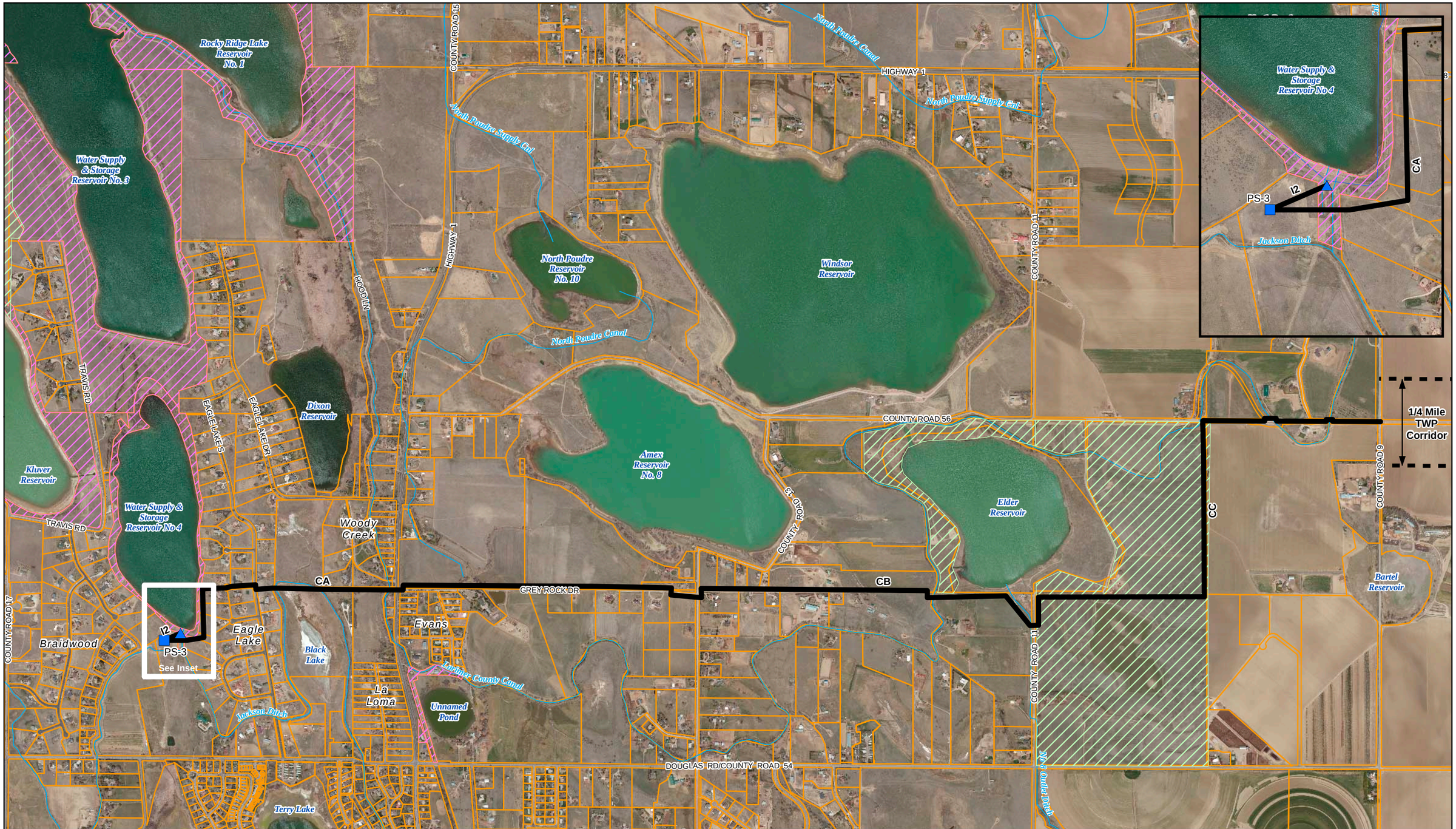

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Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
Central Alternative Alignment

Figure 5.1.12.2-9
Larimer County
Central Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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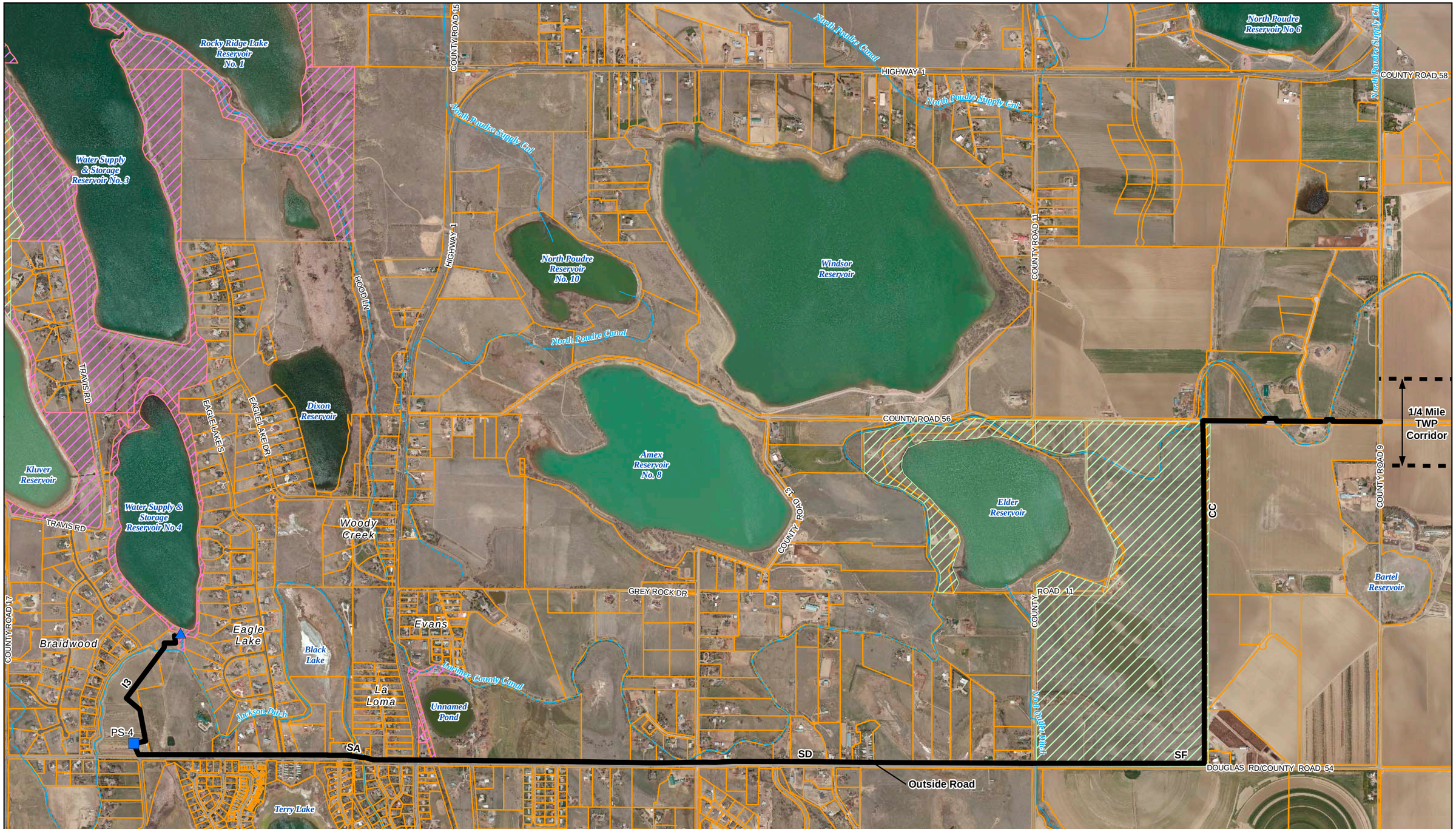

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River/Stream/Canal/Ditch
Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
South 1 Alternative Alignment

Figure 5.1.12.2-10
Larimer County
South 1 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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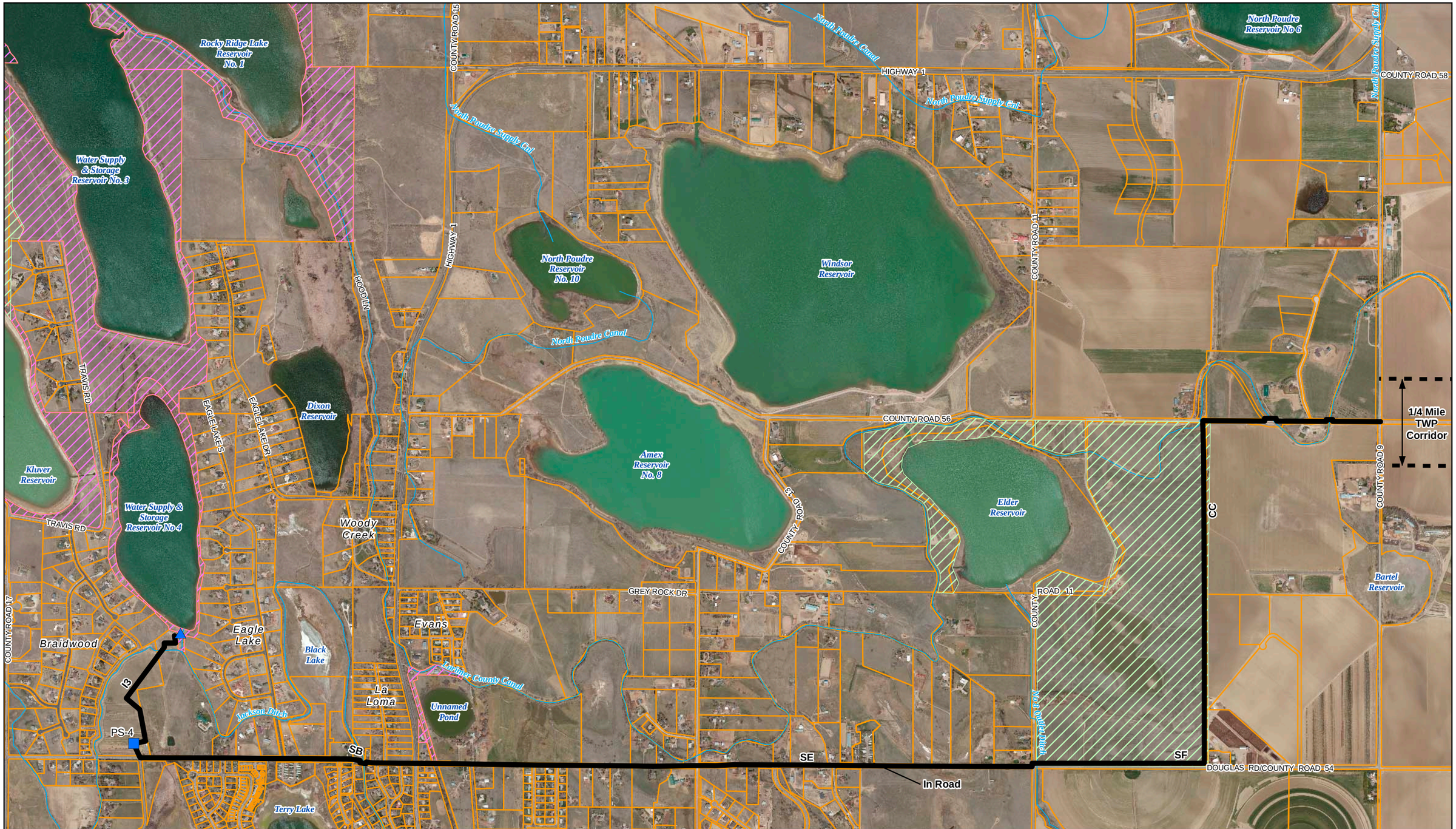

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River/Stream/Canal/Ditch
Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
South 2 Alternative Alignment

Figure 5.1.12.2-11
Larimer County
South 2 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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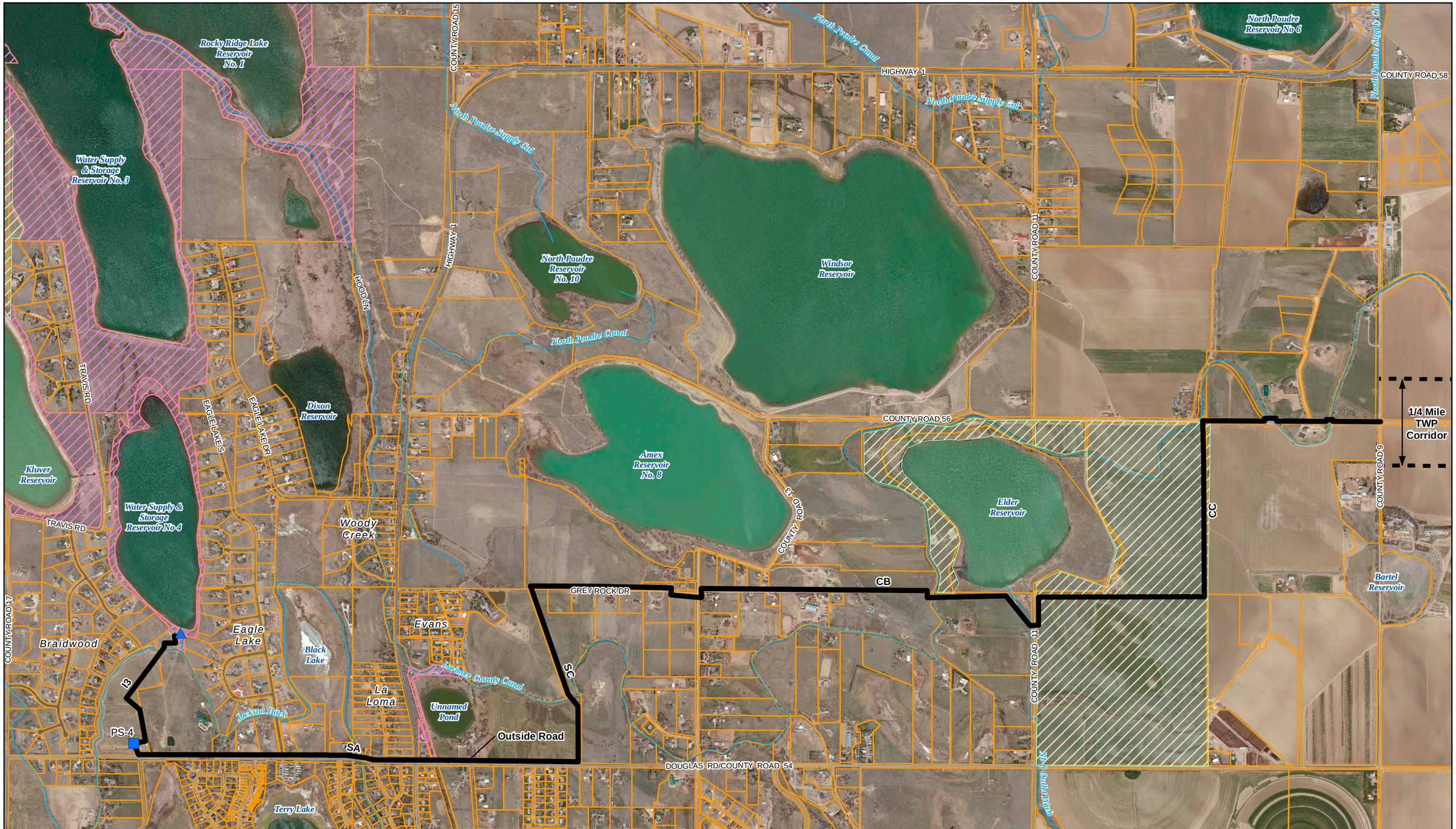

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Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
South 3 Alternative Alignment

Figure 5.1.12.12-12
Larimer County
South 3 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

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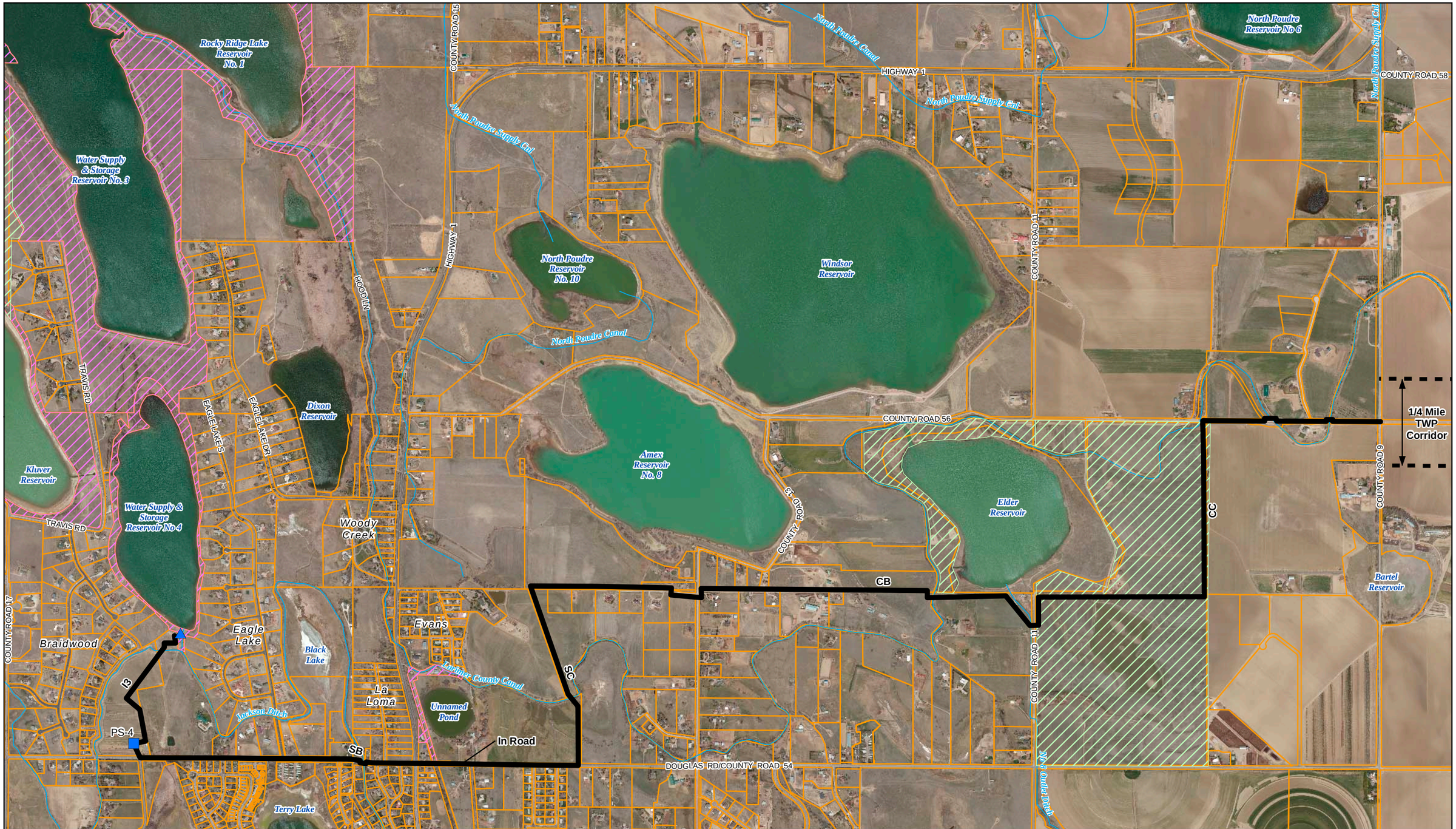

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12450 WASHINGTON ST
THORNTON, CO 80241-2405

8/29/2017

N
W E
S

0 500 1,000 Feet

1 inch = 1,400 feet

River/Stream/Canal/Ditch
Pump Station (PS-#)
WSSC Reservoir Outlet Structure
Parcel Boundary
Thornton Owned Property
WSSC Owned Property
South 4 Alternative Alignment

Figure 5.1.12.2-13
Larimer County
South 4 Alternative Alignment

Sources: NHD, CDWR, Larimer County, CDOT, ESRI

W:\478988_THORNTON_NORTHERN_PROJECT\TASK_ORDER_5\5.1_PERMITTING\GIS\MAPFILES\LARIMER_ALTERNATIVES_ANALYSIS\WEST_LARIMER_COUNTY_ALT_ANALYSIS\S4_ALIGNMENT.MXD JQUAN 8/29/2017 11:23:38 AM

ATTACHMENT B
Traffic Data

Construction in ROW

North 1							North 2							North 3						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product
CR 11	1	286	30	1	100	100	CR 11	1	286	30	1	100	100	CR 11	1	286	30	1	100	100
CR 56 west	2	143	9050	63	95	6018	CR 56 wes	2	143	6959	49	95	4628	CR 56 wes	2	143	6959	49	95	4628
CR 56 east	2	143	2497	17	100	1748	CR 56 eas	2	143	2497	17	100	1748	CR 56 east	2	143	2497	17	100	1748
						7,866							6,476							6,476

Assume Traffic Impacted 100 percent of the time.
RPF = Estimated Relative Production Factor

Construction adjacent to ROW

North 1							North 2							North 3						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%
CR 56 (wes	1	286	1284	4	95	107	CR 56 (we	1	286	1284	4	95	107	CR 56 (we	1	286	1284	4	95	107
CR 56 (eas	1	286	1367	5	100	120	CR 56 (eas	1	286	1367	5	100	120	CR 56 (eas	1	286	1367	5	100	120
CR 56 (eas	2	143	460	3	100	81	CR 56 (eas	2	143	460	3	100	81	CR 56 (eas	2	143	460	3	100	81
Hwy 1	1	286	946	3	5900	4884	Hwy 1	1	286	704	2	5900	3634	Hwy 1	1	286	704	2	5900	3634
CR 56 (eas	tunnel	23	234	10	100	256	CR 56 (eas	tunnel	23	234	10	100	256	CR 56 (eas	tunnel	23	234	10	100	256
Hwy1	tunnel	23	70	3	5900	4517														
						9,964							4,197							4,197

Assumed Traffic Impac 25% of the time.
RPF = Estimated Relative Production Factor

Construction in ROW

Central							West 1							West 2						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product
CR 11	1	286	38	1.0	100	100	CR 11	1	286	30	1.0	100	100	CR 11	1	286	30	1.0	100	100
CR 13	3	100	31	1.0	55	55	CR 56 wes	2	143	6959	48.7	95	4627.735	CR 56 west	2	143	6959	48.7	95	4627.735
CR 56 east	2	143	2497	17.5	100	1747.9	CR 56 east	2	143	2497	17.5	100	1747.9	CR 56 east	2	143	2497	17.5	100	1747.9
Eagle Lake	3	100	91	1.0	244	244	Travis Roa	3	100	21	1.0	200	200	Travis Roac	3	100	21	1.0	200	200
Evans Dr	3	100	100	1.0	98	98								Vista Lake I	3	100	1624	16.2	108	1753.92
Grey Rock (	3	100	18	1.0	39	39														
Grey Rock (	3	100	18	1.0	59	59														
Pelican Bay	3	100	482	4.8	39	187.98														
						2,531							6,676							8,430

Assume Traffic Impacted 100 percent of the time.
RPF = Estimated Relative Production Factor

Construction adjacent to ROW

Central							West 1							West 2						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%
CR 11	1	286	1436	5.0	100	125.65	CR 56 (wes	1	286	1284	4.5	95	106.7325	CR 56 (wes	1	286	1284	4.494	95	106.7325
CR 56 (east	2	143	112	1.0	100	25	CR 56 (eas	1	286	1367	4.8	100	119.6125	CR 56 (east	1	286	1367	4.7845	100	119.6125
Grey Rock (	1	286	2996	10.5	39	102.2385	CR 56 (eas	2	143	460	3.2	100	80.5	CR 56 (east	2	143	460	3.22	100	80.5
Grey Rock (	3	100	605	6.1	39	58.9875	Hwy 1	1	286	704	2.5	5900	3634.4	Hwy 1	1	286	704	2.464	5900	3634.4
Grey Rock (	1	286	2470	8.6	59	127.5138	Travis Roa	1	286	474	1.7	200	82.95	Travis Roac	1	286	474	1.659	200	82.95
Grey Rock (	3	100	198	2.0	59	29.205	CR 56 (eas	tunnel	23	234	10.2	100	255.9375	CR 56 (east	tunnel	23	234	10.2375	100	255.9375
Evans Dr	1	286	781	2.7	98	66.97075														
CR 56 (east	tunnel	23	162	7.1	100	177.1875														
Grey Rock (	tunnel	23	149	6.5	39	63.55781														
Evans Dr	tunnel	23	69	3.0	98	73.95938														
						850							4,280							4,280

Assumed Traffic Impact 25% of the time.
RPF = Estimated Relative Production Factor

Construction in ROW

South 1							South 2							South 3						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product
CR 11	1	286	28	1.00	100	100	CR 11	1	286	28	1	100	100	CR 11	1	286	38	1	100	100
CR 13	3	100	52	1.00	275	275	CR 56	2	143	2497	17	100	1748	CR 13	3	100	31	1	55	55
CR 56	2	143	2497	17.48	100	1748	Douglas Rd	3	100	9451.2	95	2500	236280	CR 56	2	143	2497	17	100	1748
Eagle Lake	3	100	61	1.00	478	478	Douglas Rd	3	100	4033.8	40	3600	145217	Eagle Lake	3	100	61	1	478	478
La Mesa Dr	3	100	30	1.00	225	225								Grey Rock	3	100	18	1	39	39
Private Driv	3	100	30	1.00	195	195								Grey Rock	3	100	18	1	59	59
														La Mesa D	3	100	30	1	225	225
						3,021							383,345							2,704

Assume Traffic Impacted 100 percent of the time.
RPF = Estimated Relative Production Factor

Construction adjacent to ROW

South 1							South 2							South 3						
Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%	Road	Install	RPF	Length (ft)	Length/RPF	ADT	Product x 25%
CR 56	2	143	112	1	100	25	CR 56 (east	2	143	112	1	100	25	CR 11	1	286	1436	5	100	126
Douglas Rd	1	286	6062	21.217	2500	13261	Douglas Rd	1	286	2583	9	2500	5650	CR 56 (ea	2	143	112	1	100	25
Douglas Rd	3	100	5279.4	52.794	2500	32996	Douglas Rd	3	100	35	1	3600	900	Douglas R	1	286	1391	5	2500	3043
Douglas Rd	3	100	3747.3	37.473	3600	33725	CR 56 (east	tunnel	23	162	7	100	177	Douglas R	3	100	1001	10	3600	9009
CR 56 (east	tunnel	23	162	7.0875	100	177	Douglas Rd	tunnel	23	40	2	2500	1094	Douglas R	3	100	3747	37	2500	23419
Douglas Rd	tunnel	23	326	14.2625	2500	8914	Douglas Rd	tunnel	23	59	3	3600	2323	CR 56 (ea	tunnel	23	162	7	100	177
Douglas Rd	tunnel	23	341.6	14.945	2500	9341								Douglas R	tunnel	23	86	4	2500	2352
Douglas Rd	tunnel	23	476.7	20.855625	3600	18770								Douglas R	tunnel	23	477	21	3600	18782
														Grey Rock	1	286	2470	9	59	128
														Grey Rock	3	100	198	2	39	19
														Grey Rock	1	286	2057	7	59	106
														Grey Rock	3	100	605	6	39	59
						117,210							10,169							57,244

Assumed Traffic Impact: **25%** of the time.
RPF = Estimated Relative Production Factor

Construction in ROW

South 4						
Road	Installation	RPF	Length (ft)	Length/RPF	ADT	Product
CR 11	1	286	38	1	100	100
CR 13	3	100	31	1	55	55
CR 56	2	143	2497	17	100	1748
Douglas Rd	3	100	2536.2	25	2500	63405
Douglas Rd	3	100	4033.8	40	3600	145217
Grey Rock (w	3	100	18	1	39	39
Grey Rock (e	3	100	18	1	59	59
						210,823

Assume Traffic Impacted 100 percent of the time.
RPF = Estimated Relative Production Factor

Construction adjacent to ROW

South 4						
Road	Installation	RPF	Length (ft)	Length/RPF	ADT	Product x 25%
CR 11	1	286	1436	5	100	126
CR 56 (east)	2	143	112	1	100	25
Douglas Rd (	3	100	94	1	2500	625
CR 56 (east)	tunnel	23	162	7	100	177
Grey Rock (e	1	286	2470	9	59	128
Grey Rock (e	3	100	198	2	39	19
Grey Rock (w	1	286	2057	7	59	106
Grey Rock (w	3	100	605	6	39	59
						1,265

Assumed Traffic Impact: **25%** of the time.
RPF = Estimated Relative Production Factor