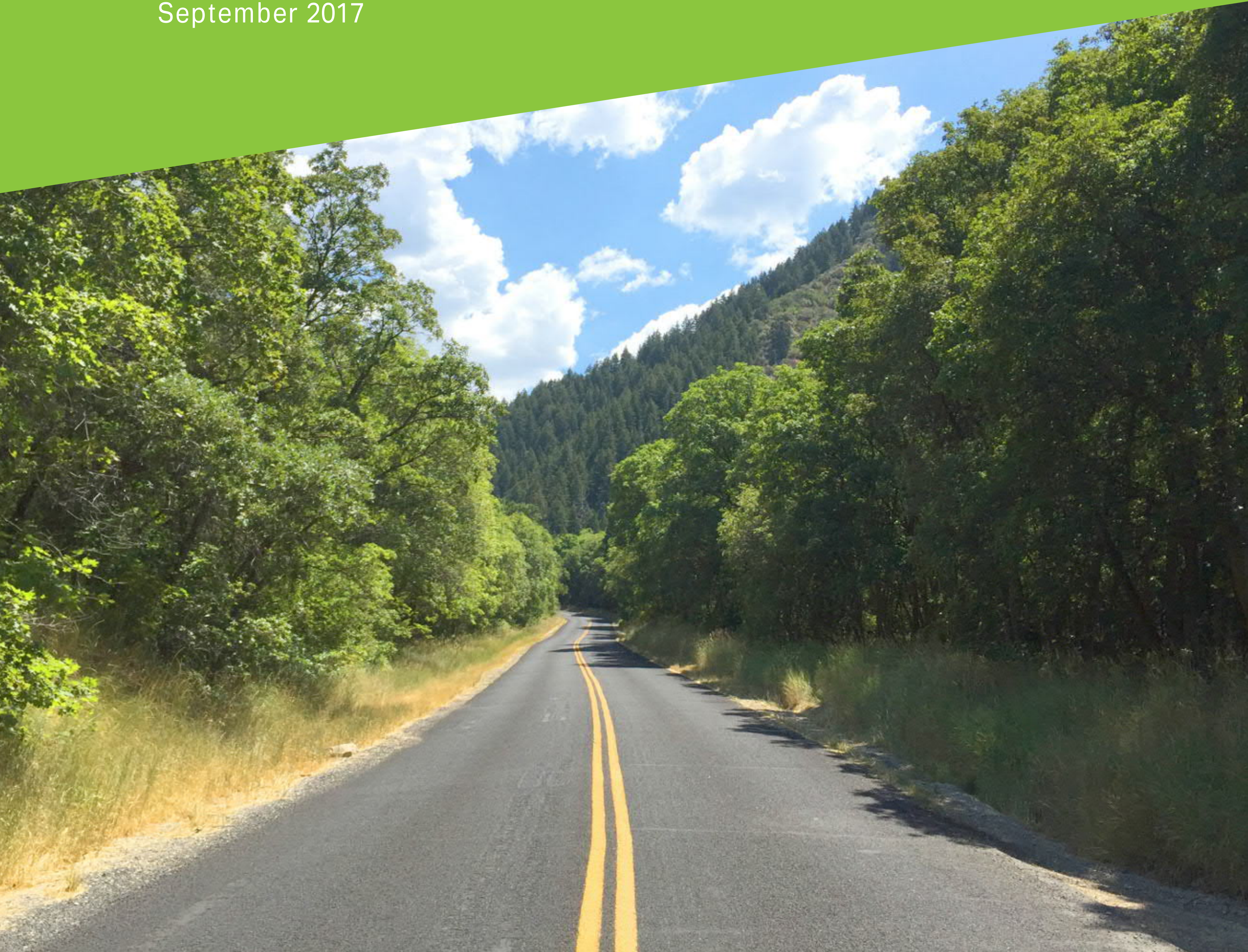
Prepared for:
Wasatch Front Regional Council

AECOM

Oquirrh Connection Feasibility Study Report

September 2017



SUMMARY

The Oquirrh Connection would provide an alternate route between Tooele Valley and southern Salt Lake County and Utah County. Although vehicles may currently travel through Middle Canyon and Butterfield Canyon, the road is narrow, winding, and steep with unpaved sections through Middle Canyon. This currently configured route poses safety concerns for providing the public with a more direct route, and is closed to traffic during the winter. A proposed more direct route would increase safety and reduce the driving distance, resulting in travel time and fuel savings, and reduced air emissions (both criteria air pollutants and greenhouse gases).

This feasibility study looked at three potential roadway connections between the valleys, and narrowed the selection to one preferred feasible alignment. Logical termini for the alignments considered included SR 36 on the west end, SR 73 on the south, and SR 111, Mountain View Corridor, and Bangerter Highway on the east end.

This Project identified the best value alternative(s) and evaluated their benefits, impacts, cost, and feasibility; and provided the project stakeholders with a launching point for financial, social, and technical consideration of a future project.

The proposed Oquirrh Connection is expected to provide benefits to the communities on both sides of the Oquirrh Mountains.

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Acronyms and Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACEC	Areas of Critical Environmental Concern
ACS	American Community Survey (US Census Bureau)
AGRC	Automated Geographic Reference Center
ATV	All Terrain Vehicle
BCA	Benefit-Cost Analysis
BCR	Benefit/Cost Ratio
BLM	Bureau of Land Management
CAP	Criteria Air Pollutants
CNBC	Consumer News and Business Channel
DOD	Department of Defense
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERR	Expected Rate of Return
FHWA	Federal Highway Administration
GHG	Green House Gas
GIS	Geographic Information System
GOPB	Governor's Office of Planning and Budget
HMA	Hot Mixed Asphalt
I	Interstate
iPac	US Fish and Wildlife's Information for Planning and Consultation
IS&R	International Smelting and Refining
MPa	MegaPascal
MPH	Miles per Hour
MSE	Mechanically Stabilized Earth (retaining wall)
NWI	National Wetlands Inventory
NEPA	National Environmental Policy Act
NPV	Net Present Value
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
O&M	Operations and Maintenance
OMB	Office of Management and Budget
PEL	Planning and Environmental Linkages
PSI	Pounds per Square Inch
REMM	Real Estate Market Model
ROI	Return on Investment
ROW	Right-of-Way
RTP	Regional Transportation Plan
SCC	Social Cost of Carbon
SEM	Sequential Excavation Method
SITLA	School and Institutional Trust Lands Administration
SR	State Route
TAZ	Traffic Analysis Zone
TBM	Tunnel Boring Machines
TIGER	Transportation Investment Generating Economic Recovery
TRB	Transportation Research Board

UDOT	Utah Department of Transportation
UGS	Utah Geological Survey
US	United States
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
USTM	Utah Statewide Travel Model
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled
WFRC	Wasatch Front Regional Council

1.0 PROJECT BACKGROUND

The primary connection between the Wasatch Front and Tooele Valley is along Interstate 80 (I-80) on a narrow strip of land between the north tip of the Oquirrh Mountains and the Great Salt Lake. Heading south from Tooele, travelers may also use State Route 36 (SR-36) to State Route 73 (SR-73) to western and northern Utah County. For several years, talk of a more direct connection between the Tooele valley and the Salt Lake and/or Utah valleys has been circulating.

The Oquirrh Connection would provide an alternate route between Tooele Valley and southern Salt Lake County and Utah County. Although vehicles may currently travel through Middle Canyon and Butterfield Canyon, the road is narrow, winding, and steep with unpaved sections through Middle Canyon. This currently configured route poses safety concerns for providing the public with a more direct route, and is closed to traffic during the winter. A proposed more direct route would increase safety and reduce the driving distance, resulting in travel time and fuel savings, and reduced air emissions (both criteria air pollutants and greenhouse gases).

The proposed Oquirrh Connection is expected to provide benefits to the communities on both sides of the Oquirrh Mountains. This study identifies the best value alternative and evaluates its benefits, impacts, cost, and feasibility; and provides the project stakeholders with a launching point for financial, social, and technical consideration of a future project.

1.1 Need for the project

1.1.1 Population and Employment Growth

Currently, Utah's population is estimated at just over 3 million. Utah reached the 3 million mark just 20 years after reaching 2 million in 1995. Current projections have the state achieving 4 million people during 2034 and 5 million people in 2054, according to the University of Utah’s Kem C. Gardner Policy Institute.

In the late 1990s, rising interest rates, increasing home prices, and a shortage of residential inventory forced developers to build outside of Salt Lake City to areas like Tooele, Eagle Mountain, Saratoga Springs and Herriman. These areas saw significant growth but were well outside traditional city limits where most of the real estate demand had been. These areas are also a considerable distance from traditional employment centers and require a longer commute for residents.

Growth in the Tooele Valley has been primarily residential, with nearly half of all workers commuting to the Salt Lake City area. Even with more commercial development, including the conversion of the Tooele Army Depot into the Utah Industrial Depot and the Wal-Mart distribution center in Grantsville, Tooele Valley continues to have a strong commuter community focus. The availability of affordable housing and the short commute to Salt Lake County facilitate this development pattern.

Recently, traditional employment centers have shifted away from existing urban centers to new opportunities such as the existing Utah prison site in Draper and the “Silicon Slopes” area in Lehi and Northern Utah County.

The rate and location of this population and employment growth contributes to increasing congestion and travel time reliability issues, and exacerbates lack of connectivity as employment and commerce patterns shift.

This connection will provide additional economic, recreational, transit, and multi-modal opportunities to the communities on each side of the Oquirrh Mountain range.

1.1.2 Congestion and Mobility

Current travel demand levels on roadway facilities within the study area and surrounding communities impact congestion and travel time reliability during peak and non-peak periods, primarily due to unpredictable roadway conditions that impede travel flows (e.g., road restrictions or closures due to crashes, work zones, and weather). Congestion and travel time reliability are expected to worsen due to capacity demands resulting from population and employment growth. Particularly susceptible are I-80 between Tooele and Salt Lake Counties and SR-36 in Tooele County.

I-80 connects Tooele and Salt Lake Counties across a constricted strip of land between the Oquirrh Mountains and the Great Salt Lake. Currently I-80 is the only access to/from the two counties without major out-of-direction travel. I-80 closes several times a year due to inclement weather or incidents, causing significant traffic congestion until conditions clear.

SR-36 is also vulnerable to weather and incidents. The majority of traffic to/from the Tooele Valley and Salt Lake uses this route and consequently experiences congestion at peak hours due to traffic demand. Conditions on I-80 during inclement weather or incidents are mirrored on SR-36.

The proposed Oquirrh Connection provides a unique opportunity for an additional connection between the Wasatch Front and the Tooele Valley. The roadway type and capacity would not equal that of I-80 but would provide an alternative route for those traveling from Tooele to the south part of Salt Lake County and northern Utah County. This route would be substantially shorter in length and provide shorter travel times.

1.2 Study Area

The Oquirrh Connection study area is shown in **Figure 1**.

The study area boundaries are Barney's Canyon on the north, SR-111/Bacchus Highway on the east, SR-73 on the South, and SR-36 on the West.

Three initial corridors were selected for the alignment alternatives evaluation– North (Barney's Canyon), Middle (Butterfield and Middle Canyons), and South (Oak Canyon, Ophir). The three corridors were based on general topographical differences and possible populations served.

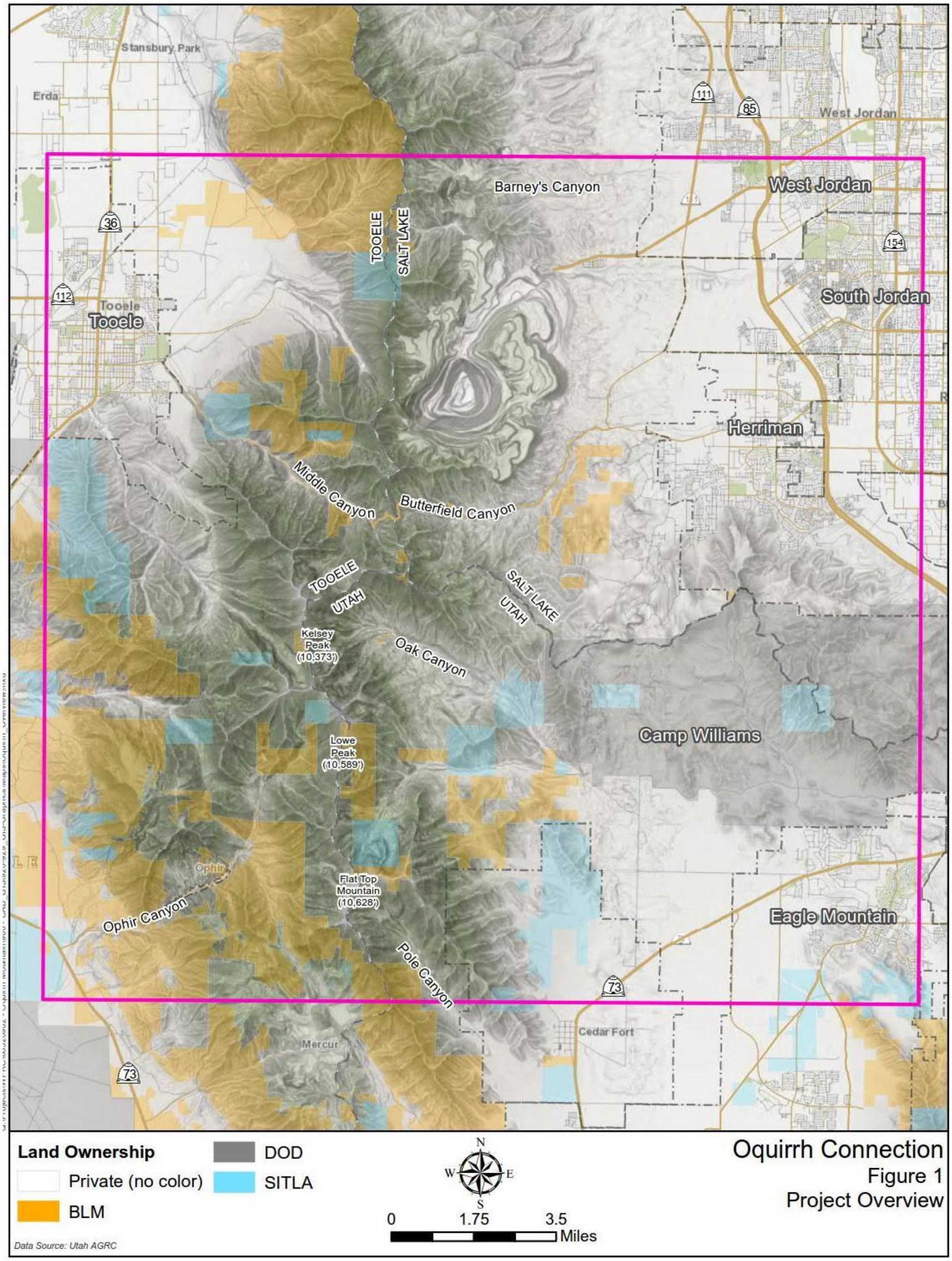


Figure 1 : Oquirrh Connection Study Area Boundary

1.3 Stakeholder Coordination

Early in the project a stakeholder committee was formed consisting of the cities, counties, agencies, and large property owners within the study area. This committee met three times during the course of the study and helped guide the direction of the study as well as establishing the goals and project metrics for the alternatives.

In addition, the project team met with individual stakeholders for exchanges of information and data, and as requested to provide further information and solicit input from elected officials and executive management.

1.3.1 Project Goals

The project team produced a list of questions for the stakeholders, the responses to which would be used to generate project goals and eventually metrics for alternative analysis and screening.

Stakeholders were interviewed via telephone, and answers compiled and presented at a Stakeholder's Goals Workshop held December 5, 2016.

Interview Questions

1. What would a "successful" outcome to this process be for you? What would an "unsuccessful" outcome be?
2. Is a new transportation facility needed? What do you see as deficiencies/needs from the existing transportation systems?
3. Whom do you see benefitting from a new transportation facility?
4. What factors must be considered for a route to be "feasible", and why? How would you rank those factors?
5. Who should own/operate/maintain this facility?

Goals Workshop Results

The following are results from the interview questions:

Question 1 (Successful/unsuccessful outcome)

- Many interview respondents stated a successful outcome included identification of a feasible route (year-round, safe, and viable). Some respondents therefore also stated that an unsuccessful outcome would be one in which no feasible route is identified or there is "no solution". Some respondents indicated that a successful outcome must consider impacts to adjacent cities/communities so that they are supported appropriately.
- Some stakeholders questioned if development of a year-round route was really a reasonable outcome and stated that the Feasibility Study must consider the results of, and be consistent with, a previous study regarding winter closures. (Winter Roadway Closure Study, UDOT June 2014)
- Comments made during the workshop also suggested that a study conclusion that no route was feasible should not necessarily be considered an "unsuccessful outcome"; for example, construction cost could be cost prohibitive, but that is not a

failure of the study itself. Similarly, a determination that these routes are not feasible isn't necessarily the same as "no solution".
- Additional comments included gaining consensus as a group and the future use of gathered data even if no route were deemed feasible.
- Increased recreational opportunities were also identified as a success.

Question 2 (need for a new route and deficiencies in current transportation system)
- Identified deficiencies included seasonal use of road and need for a backup to I-80.
- It was noted that no respondent indicated that a road was not needed; one respondent indicated it was not needed *right now* and some respondents are not yet sure if it is needed. This Feasibility Report will support future phases of the project, so that the team can move forward to alternative analysis and NEPA phases of the project as appropriate.

Question 3 (who would benefit from the road)
- Respondents indicated there was a regional benefit but also noted benefits to specific cities along the route or specific demographics due to ability to commute to areas with lower costs for housing or anticipated job centers. Many respondents mentioned the benefit to all regionally as an alternate route for I-80.

Question 4 ("feasibility" metrics and ranking)
- Most respondents focused on costs, safety, capacity/need, maintenance ability/costs, and engineering feasibility, generally in that order. Other responses included environmental or other impacts, compatibility with long range planning, connectivity/travel time.
- See overarching Route "Feasibility" below for final ranking of feasibility metrics.

Question 5 (new route ownership):
- About half of the respondents said State of Utah (UDOT); the remainder said the county or unknown would ultimately be responsible for ownership and maintenance of a new roadway.

1.3.2 Route "Feasibility" Metrics

Also at the December 5, 2016 Goals Workshop, the stakeholder group identified the following factors as necessary for a route to be considered "feasible":

1. Cost.
2. Safety: Design must incorporate UDOT and the American Association of State Highway and Transportation Officials (AASHTO) standards, and also needs to address user conflicts resulting from combined recreation/vehicular uses.
3. Non-Seasonality: New facility must be a year-round road.
4. Need: New facility needs to benefit a sufficient number of commuters.
5. Recreation: The routes should maintain existing recreational uses and provide for enhanced safety, particular in regards to resolving bicycle/vehicular conflicts (for example, the design should consider a separate bike path, shoulders, "above the curb" facilities, etc.)

Also:

6. Accommodation of Freight: If the need for the route is an alternative for I-80, the capacity to accommodate freight transport should be considered. Accommodation of freight on this road may also be a benefit for the Tooele Depot and other large commercial destinations within the study area.
7. Transit Component: While not a deal breaker, the group indicated that consideration of existing and future transit connections would also be important.

2.0 CORRIDOR ALTERNATIVES DEVELOPMENT

2.1 Design Criteria

For design and consistency purposes, all conceptual designs were created following UDOT's *2017 Standard Drawings*, and AASHTO's *A Policy on Geometric Design of Highways and Streets, 6th Edition.*

Roadway geometry changes as design speed changes, i.e. faster roads have flatter curves and require more cut and fill in mountainous terrain than slower roads. Alignments were produced using three separate design speeds:

- 25-35 miles per hour
- 45 miles per hour
- 55 miles per hour

Roadway alignments were placed in three distinct geographic areas within the study area (as discussed below) using aerial photography and Google Earth. When possible, existing roadways were used, i.e. Middle Canyon Road, otherwise routes followed new alignments. Alignments followed existing terrain as much as possible while maintaining a grade of 6% or less. In steeper sections, tunnels were utilized to maintain a 6% grade.

All designs include 12' travel lanes and 10' multi-purpose shoulders.

2.2 Initial Corridor Alternatives

Three initial corridors were selected – North (Barney's Canyon), Middle (Butterfield and Middle Canyons), and South (Oak Canyon, Ophir). The three corridors were based on topographical location within the study area, whether or not a roadway facility existed, and possible populations served (see **Figure 2**). **Table 1** lists the preliminary corridors, design speeds, tunnel length, and total length of alignment from valley floor to valley floor

Table 1 : Preliminary Corridors

Alignment	Design Speed (MPH)	Tunnel Length (Miles)	Total Travel Distance (Miles)
1 - Barney's Canyon	35	0	21.5
	45	2.1	14.9
	55	2.1	14.9
2 - Middle/Butterfield Canyon	35	0	18.1
	45	0.9	14.2
	55	0.9	14.8
3 - Oak/Middle Canyon	35	2.4	22.3
	45	2.4	22.3
	55	2.4	22.3

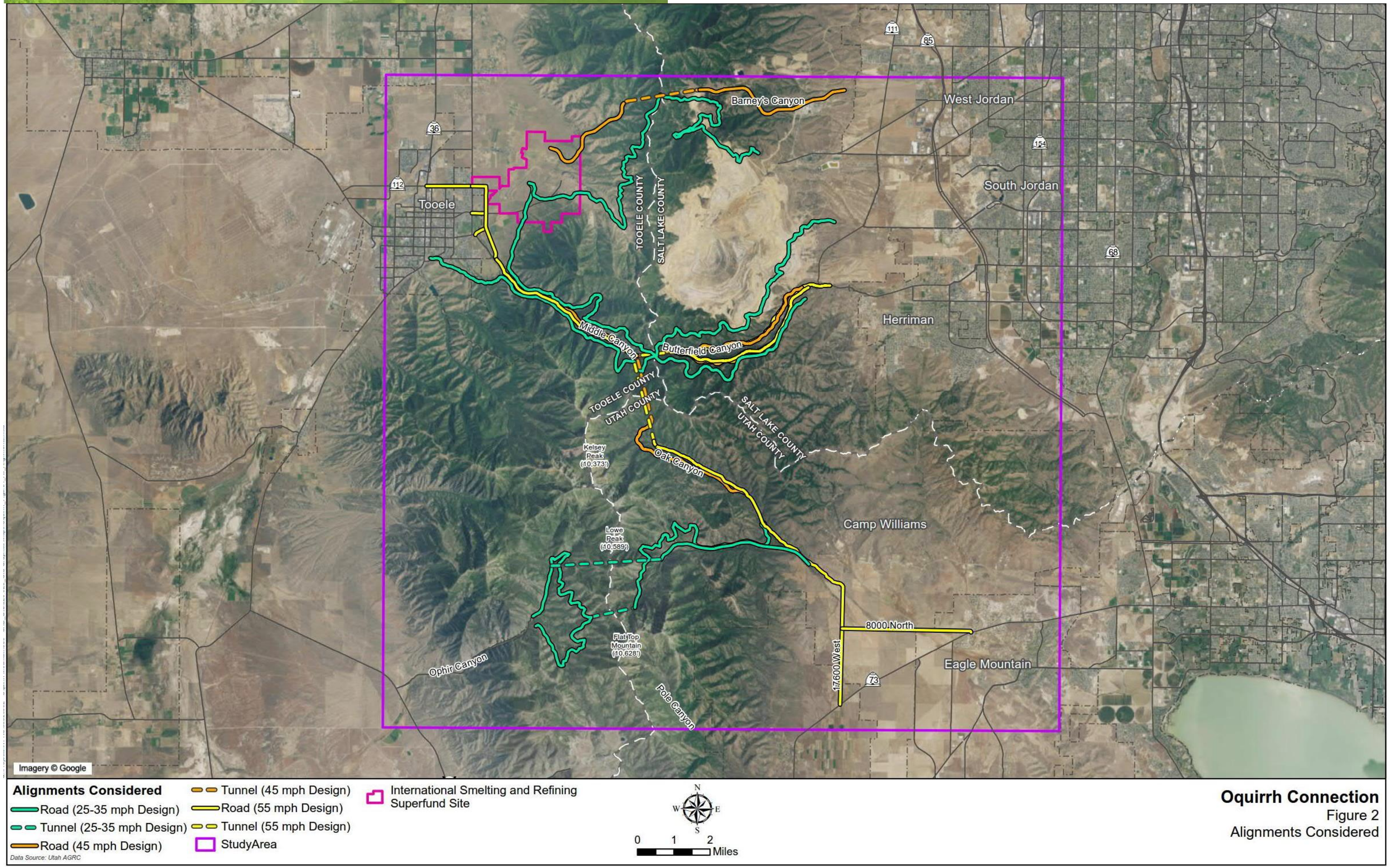


Figure 2: Alignments Considered

2.2.1 North (Barney's Canyon)

The Barney's canyon alignments would connect to SR-111 (Bacchus Highway) or SR-48 (Bingham Highway) in Salt Lake County to the east, cross Kennecott property through Barney's Canyon, and connect to SR-36 in Tooele to the west. Barney's Peak is at an elevation of 8242 feet. The below photograph shows the Bingham Copper mine from the overlook facing north towards Barney's Canyon.

All land from the Oquirrh ridgeline to the east (Salt Lake County) is owned by Rio Tinto (Kennecott) and is site of an active gold mine (Barney's Canyon Mine) as well as mine tailings repository for the Bingham Canyon copper mine. This area is marked by several graded dirt access roads that service communications towers on the peaks as well as a large electrical transmission line running east-west. There are also several large structures and settling ponds associated with mining and ore extraction activities.

Property to the north on the west side of the ridgeline (Tooele County) is owned by the State of Utah and the Federal government.

To the west is primarily private with some interspersed Federal land. At the base of the mountains is the International Smelting and Refining site. This property is an EPA Superfund site that has undergone site cleanup for contamination from mining activities. As part of the cleanup and long term mitigation, the entire site is under a perpetual conservation easement which restricts uses and prohibits motor vehicles.

Two alignments were analyzed in this section of the study area (see **Figure 3 : Oquirrh Connection, North Alignments):**

- The 25-35 mph design alignment does not require a tunnel. However, in order to maintain a 6% grade it is long and winding and would not provide competitive travel times or distances. Overall length from existing roadways to existing roadways is approximately 22 miles.
- The 45mph and 55mph design alignments are virtually the same. Both require a 2.1 mile tunnel and are approximately 15 miles in length from existing roadway to existing roadway.

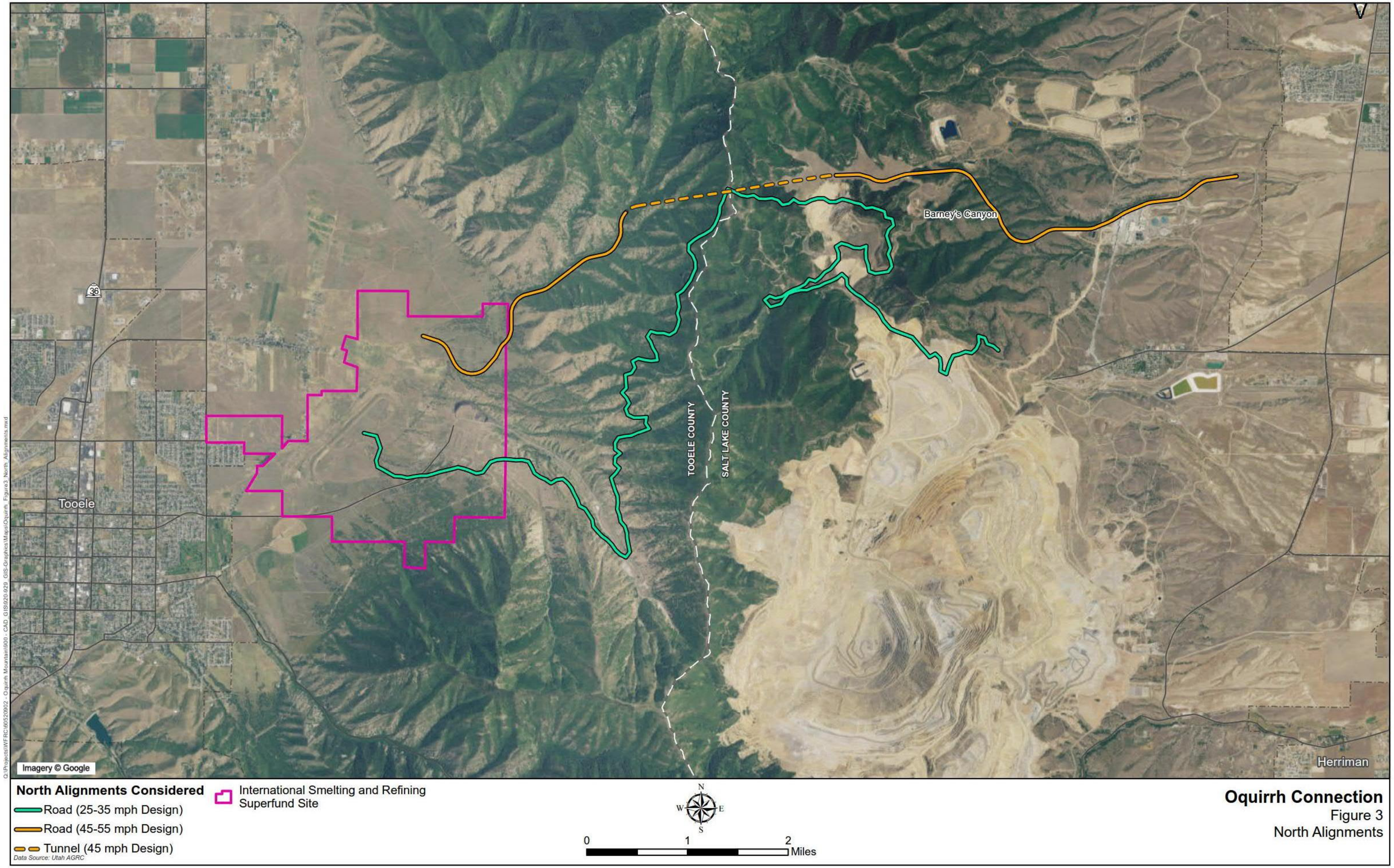
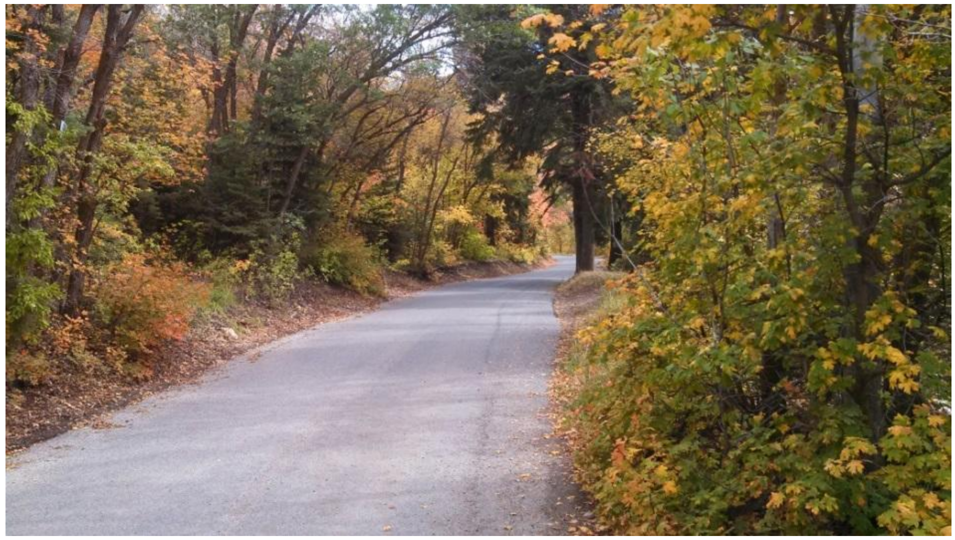


Figure 3 : Oquirrh Connection, North Alignments

2.2.2 Center (Butterfield and Middle Canyons)

The Butterfield/Middle Canyons alignment would connect SR-111 (Bacchus Highway) in Salt Lake County to the east with Middle Canyon Road and SR-36 in Tooele County to the west.

Butterfield Canyon Road is an existing paved road that begins at SR-111 and ends at the Tooele/Salt Lake County boundary at the top of the Oquirrh ridgeline at an elevation of 7780 feet. The roadway in the lower canyon is generally 2-lanes and maintains grades at 6% or lower (photograph to the right).

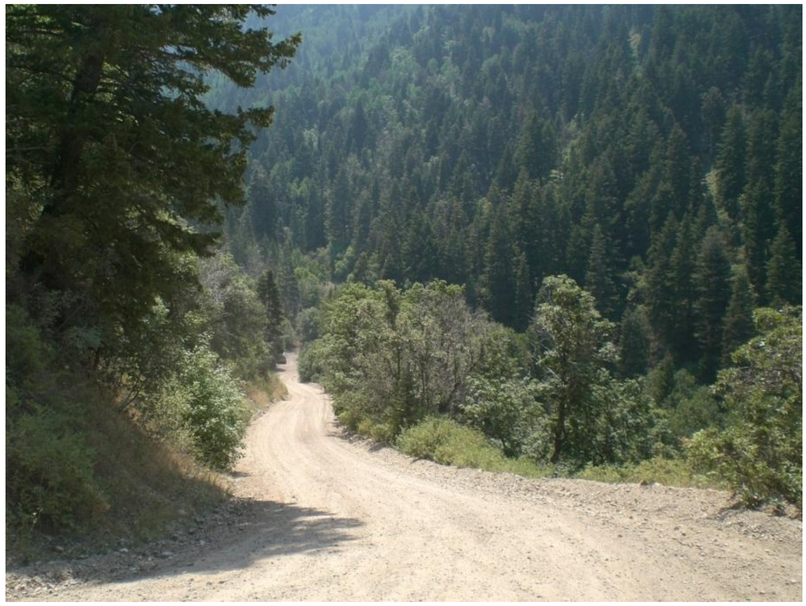


The upper canyon is marked by much steeper grades and narrow sections of single lane roadway (photograph below).

The north side of Butterfield Canyon is primarily owned by Kennecott and is marked by private accesses and infrastructure used for ongoing mining activities such as a complex runoff collection system.

Middle Canyon Road is an existing 2-lane paved road that begins at Vine Street/Droubay Road in Tooele and ends at the Tooele/Salt Lake County Boundary (see left photograph below).

The upper 2 miles are not paved and are fairly steep (see right photograph below). Middle Canyon is heavily used as a recreation destination with picnic areas and day use areas throughout as well as off highway vehicle (OHV) use adjacent to the existing roadway and the upper canyon area.



Alignments analyzed in this area included the existing roadways and both the north and south sides of Butterfield and Middle Canyons (see **Figure 4 : Oquirrh Connection, Center Alignments):**

- The 25-35 mph design alignments do not require tunnels. However, in order to maintain a 6% grade they are long and winding and would not provide competitive travel times or distances. Overall length from existing roadways to existing roadways is approximately 18 miles.
- The 45mph and 55mph design alignments are virtually the same. Both require a 0.9 mile tunnel and are approximately 14 to 15 miles in length from existing roadway to existing roadway.

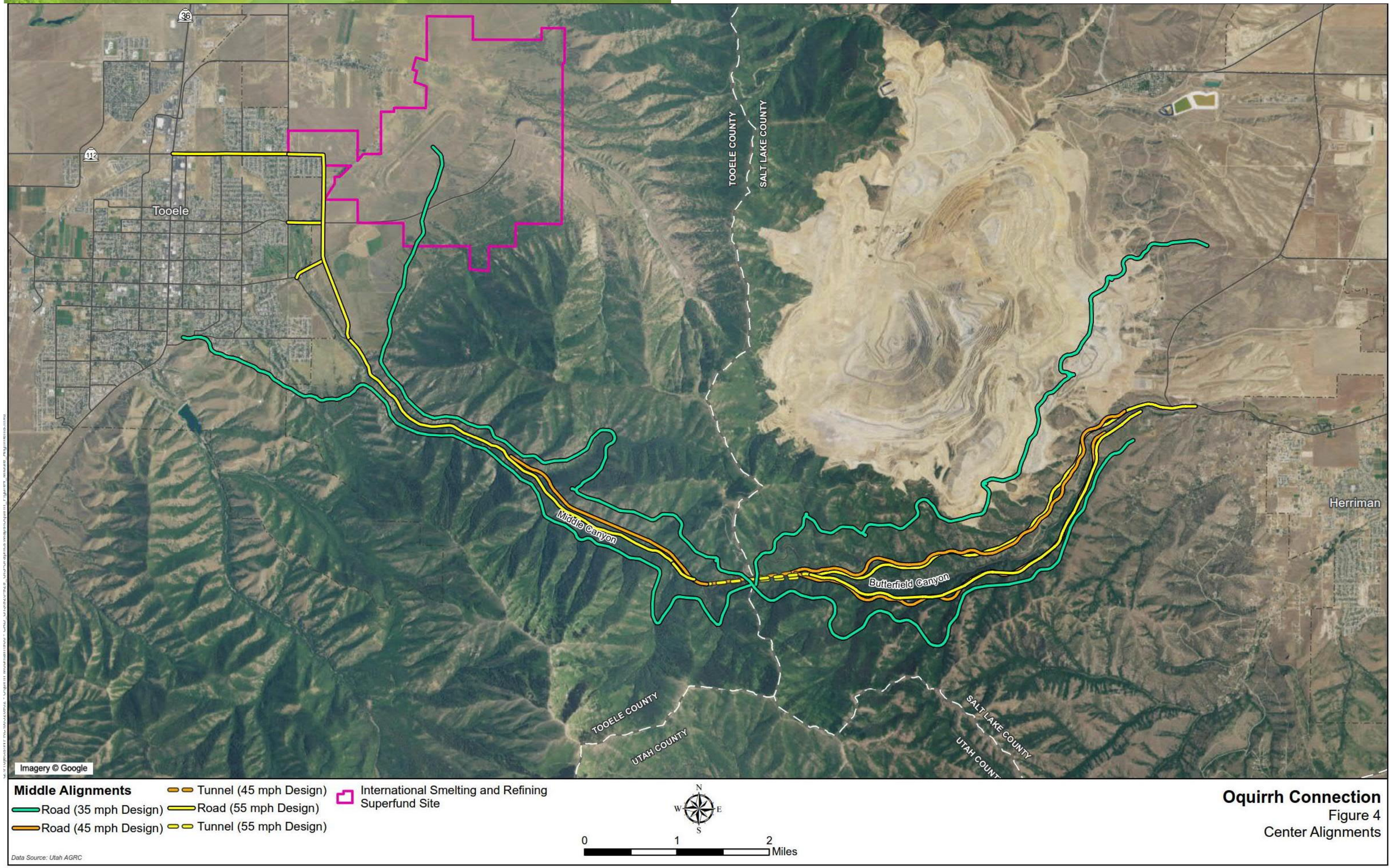


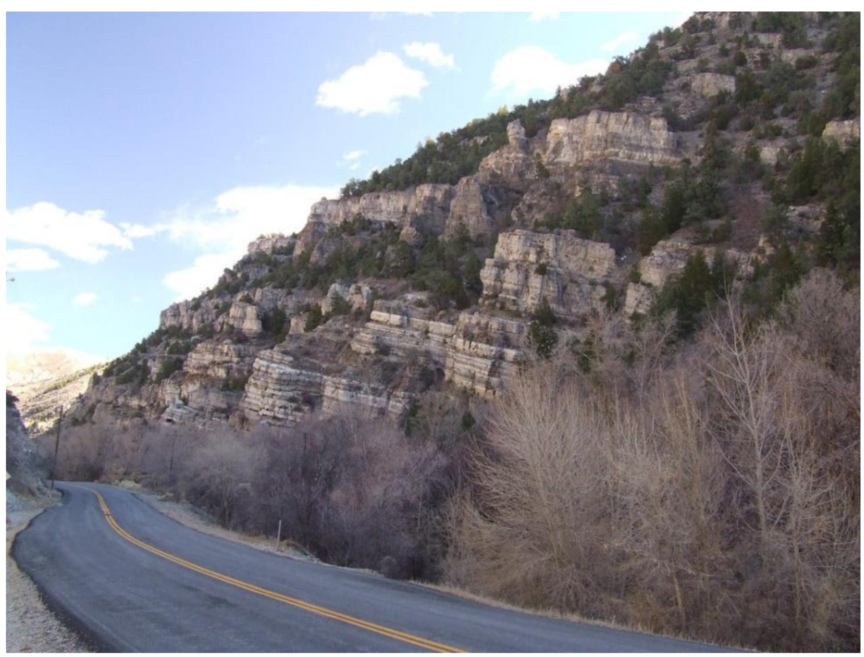
Figure 4 : Oquirrh Connection, Center Alignments

2.2.3 South (Oak Canyon, Ophir)

The Ophir/Oak Canyon alignments extend from SR-73 in Utah County and west to Oak Canyon and then directly west on West Canyon Road, to the town of Ophir, then Ophir Canyon Road to SR-73 in Tooele County approximately 15 miles south of Tooele City.

The Oak Canyon alignments continue north through Oak Canyon to Middle Canyon and then follow the same route as the Center alignment to SR-36 in Tooele. Oak Canyon Road is graded dirt and privately owned, access is controlled by a locked gate. Photograph to the left is view from SR-73 facing north toward Oak Canyon.

The Ophir alternatives have to cross several 10,000'+ peaks, and as such each alignment requires substantial tunnels, up to 3 miles in length. Due to the steep slopes and terrain, only the 25-35 mph design alignment was analyzed since higher speed designs required multiple tunnels and were deemed to be cost prohibitive.



The Town of Ophir consists of a handful of residences and business along Ophir Canyon Road and a shorter parallel road. The existing roadway steepens and turns to graded dirt as it heads east until it eventually becomes a hiking and ATV trail.

The photograph to the right is a view facing down (west) Ophir Canyon. The canyon is quite narrow and marked by steep walls.

Alignments analyzed include **(**see **Figure 5: Oquirrh Connection, South Alignments)**:

- Oak Canyon alignments generally follow the existing road until they start to exceed 6% grade. At this point a 2.4 mile tunnel extends to the northwest connecting to the vicinity of the west tunnel entrance for the Butterfield/Middle Canyon alignment. From this point west, the alignment is the same as described above for the Center alignment. This alternative is approximately 23 miles in length from existing roadway to existing roadway.
- The Ophir alignment follows West Canyon Road until the grades exceed 6% and then follow a new alignment becoming long and windy trying to maintain a 6% grade. Due to steep terrain several tunnels are eventually required. These tunnels measure up to 3 miles in length.

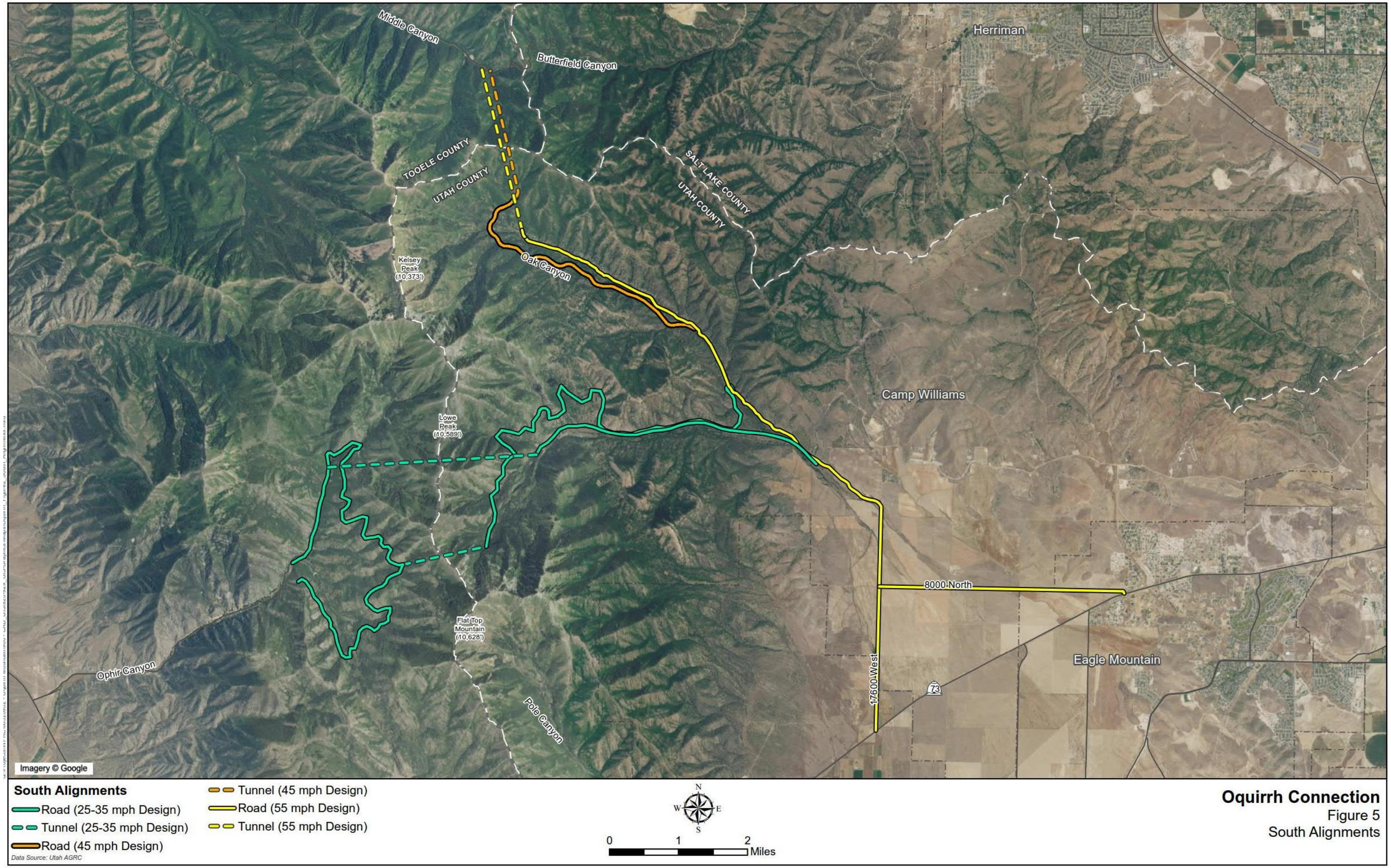


Figure 5: Oquirrh Connection, South Alignments

2.3 Travel Demand

Planning-level demand analysis was examined for the three identified corridor alternatives. This analysis provided perspective on the need for this project and an idea of the magnitude of demand so an appropriately sized and designed facility could be considered.

The three alternatives are as follows (see also **Figure 6**):

- Alternative 1: North Canyon connection, north of Kennecott Mine. Connects into Tooele County via SR-36 just north of SR-112. Connects into Salt Lake County via Mountain View Corridor at approximately 9000 South.
- Alternative 2: Butterfield Canyon connection, south of Kennecott Mine. Connects into Tooele County at eastern extent of Vine Street. Connects into Salt Lake County at existing Butterfield Canyon entrance.
- Alternative 3: Oak Canyon connection into Utah County. Connects into Tooele County at same location as Alternative 2. Connects into Utah County via SR-73 at approximately the junction of Eagle Mountain Boulevard.

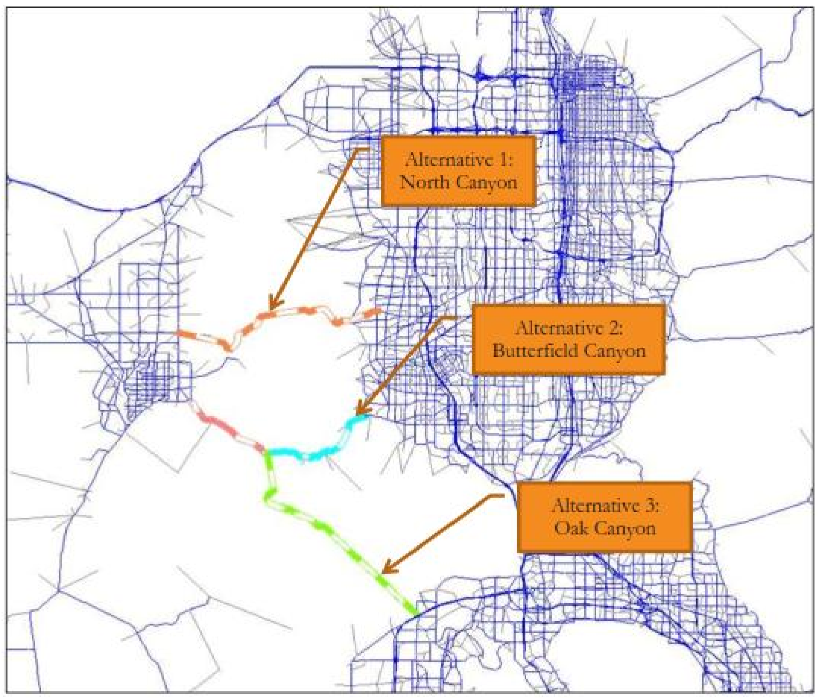


Figure 6: Travel Demand Corridor Alternatives

The Utah Statewide Travel Model (USTM) was used to understand each corridor's travel demand.
Additional metrics, such as travel times and effects on traffic for downstream connections, were also estimated for Alternatives 2 and 3.

The project team decided that the Ophir alternatives would not provide competitive travel times and speeds, did not serve the target populations due to geographic location, and therefore eliminated from further consideration.

2.3.1 Base Roadway Assumptions

Based on discussions with the project team, a list of assumptions for the three alternatives was developed to most accurately reflect what would realistically be built through the Oquirrh Mountain Range. These assumptions are provided below:

- Roadway geometry through the Oquirrh Mountain Range was provided by the project team.
- A base year of 2014 and a future year of 2050 were assumed for all alternatives.

- Connections on the Tooele Valley side were determined through discussions with Tooele City staff.
- The following assumptions were made in the modeling process for all three alternatives:
  - Speed: 45 MPH
  - USTM Functional Type: Principal Arterial
  - Cross-section: 4 lanes (2 lanes in each direction). A four-lane cross-section was assumed to not constrain traffic by causing drivers to re-route due to potential peak period congestion.
  - Although heavy and medium trucks would not be prohibited, the project team assumed that minimal trucks, if any, would use this road due to significant grades and winding mountain roadways. Therefore, the model was set up to prevent trucks in these alternatives.
  - Any necessary capacity improvements at connection points were made to not limit potential trips along the proposed connections. These capacity improvements are listed below:
    - Widen 1000 North east of SR-36 in Tooele to two lanes in each direction
    - Widen Herriman Highway east of proposed Alternative 2 connection to 5600 West to two lanes in each direction.

2.3.2 Modeling

USTM version 1.3 was chosen as the starting point for developing the travel demand estimates. USTM version 1.3 was used by UDOT in the development of the UDOT 2015 Long Range Transportation Plan. All travel demand modeling work was done in Citilabs Cube 6.4.2.

A 2050 scenario was added to the USTM version 1.3 model which included the following land-use/socioeconomic data and transportation network assumptions:

- Wasatch Front Area:
  - Imported into USTM the Wasatch Front travel model version 8.2 zone structure and highway network. Wasatch Front version 8.2 was used for the Wasatch Front Central Corridor Study.
  - Imported into USTM the 2050 socioeconomic data used in the Wasatch Front Central Corridor Study base-case land use scenario. This socioeconomic dataset was developed using the MPO’s Real Estimate Market Model (REMM). This dataset is believed to most closely resemble the 2050 socioeconomic dataset that will be used in the MPO’s 2019 Regional Transportation Plan (RTP).
- USTM Model Outside Wasatch Front Area:
  - Used 2050 socioeconomic dataset and highway network developed for Envision Tomorrow’s base-case scenario.

To be compatible with the 2050 scenario’s highway and zone structure, the 2014 data from the Wasatch Front version 8.2 model was also brought into the USTM model.

The 2014 base year travel model commuting pattern between Tooele and Salt Lake/Utah counties were compared against the 2012 Utah Household Travel Survey. The model was found to be overestimating the number of trips between Tooele County and Salt Lake/Utah County in the base year. A 0.59 correction factor was applied for all alternatives evaluated to most accurately reflect real-world travel patterns between these counties.

2.3.3 Results

2050 AADT results for the three alternatives are presented below in **Table 2.** AADT along all three alternatives range from 12,000 to 18,000 vehicles per day. Alternative 1 offers the most direct connection between major 2050 population centers, and thus is projected to have the highest AADT. Alternative 2, while offering a key connection between two major 2050 population centers, is not as direct as Alternative 1, thus is projected to have a slightly lower AADT. Alternative 3, while providing a direct connection for Utah County, does not offer as significant of a time savings to much of Salt Lake County, thus is projected to have the lowest AADT of the three alternatives.

Table 2 : 2050 Alternate Evaluation Results

Alternative	AADT
1	18,000
2	15,000
3	12,000

Because the project team removed Alternative 1 from consideration fairly early in the study, additional analyses were only completed for Alternatives 2 and 3.

Travel times for Alternatives 2 and 3 were examined between significant locations on both sides of the Oquirrh Mountains. As shown in **Table 3,** both Alternatives 2 and 3 offer significant time savings from Tooele to certain destinations as compared to the existing options of I-80 and SR-73. **Figure 7: 2050 Congested Travel Times (Minutes) Between Tooele and Salt Lake County**, presents these data by showing the specific regions in Salt Lake County where Alternative 2 offers a faster connection than I-80. I-80 is still a faster connection to much of northern Salt Lake County, Alternative 2 is a faster connection to the southwest corner of the valley, and both routes have fairly similar travel times to much of the central valley.

Table 3: 2050 Congested Travel Times (Minutes) Between Tooele and Various Locations in Salt Lake/Utah County

	Alt 2	Alt 3	I-80	SR-73
Herriman	41	51	52	85
Draper Prison	50	54	58	88
Lehi TP	56	49	62	82
Eagle Mtn	57	34	67	69

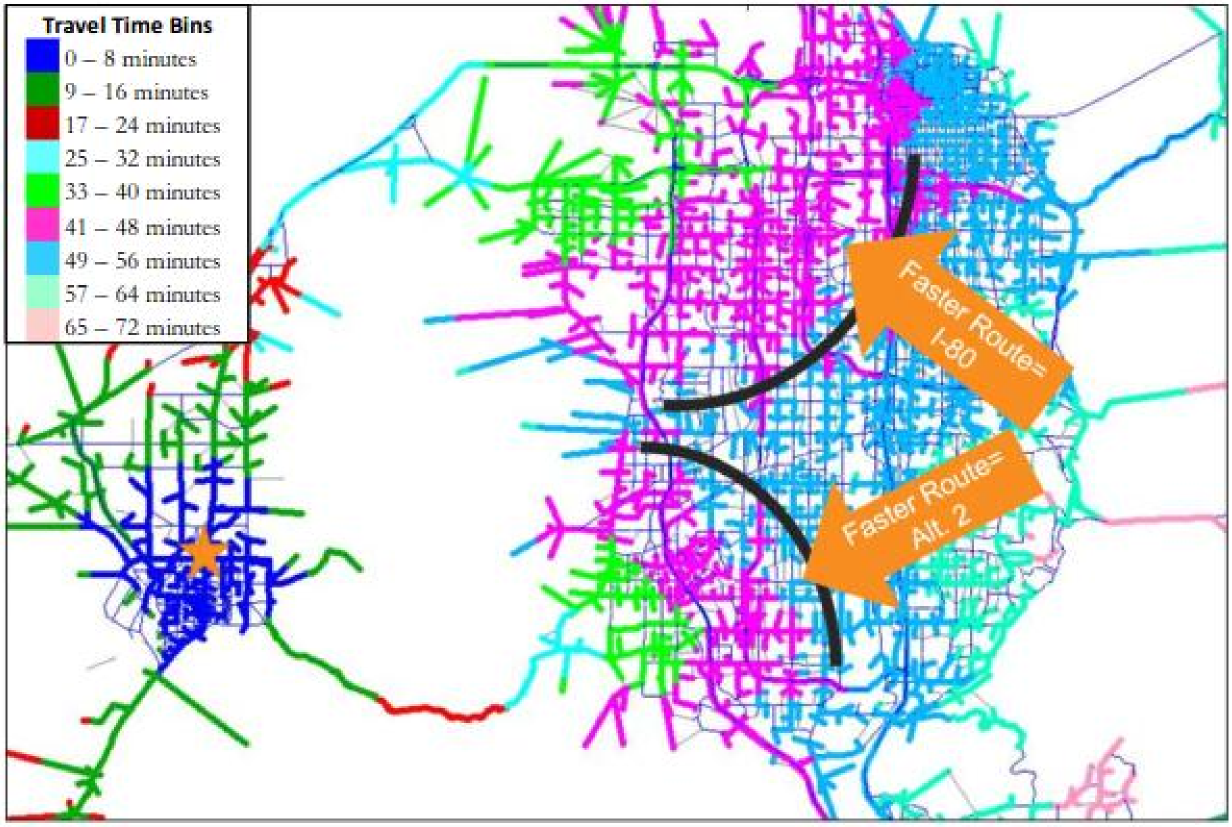


Figure 7: 2050 Congested Travel Times (Minutes) Between Tooele and Salt Lake County

Downstream Volumes

Congestion impacts of the proposed Alternative 2 connection on adjacent roadway tie-in points were examined. This was done to determine the downstream effects of adding a significant connection over the Oquirrh Mountains. For this, AADT with and without the Alternative 2 connection for roadways in Tooele and southwest Salt Lake County were examined.

Figure 8: Downstream Traffic Flows (Alternative 2 in Year 2050), and **Table 4 : Downstream Traffic Flows (Alternative 2 in Year 2050)** present this analysis in graphic and tabular form, respectively. **Figure 8** and **Table 4** include all roadways anticipated to have an increase of at least 2,000 vehicles per day with Alternative 2 in place.

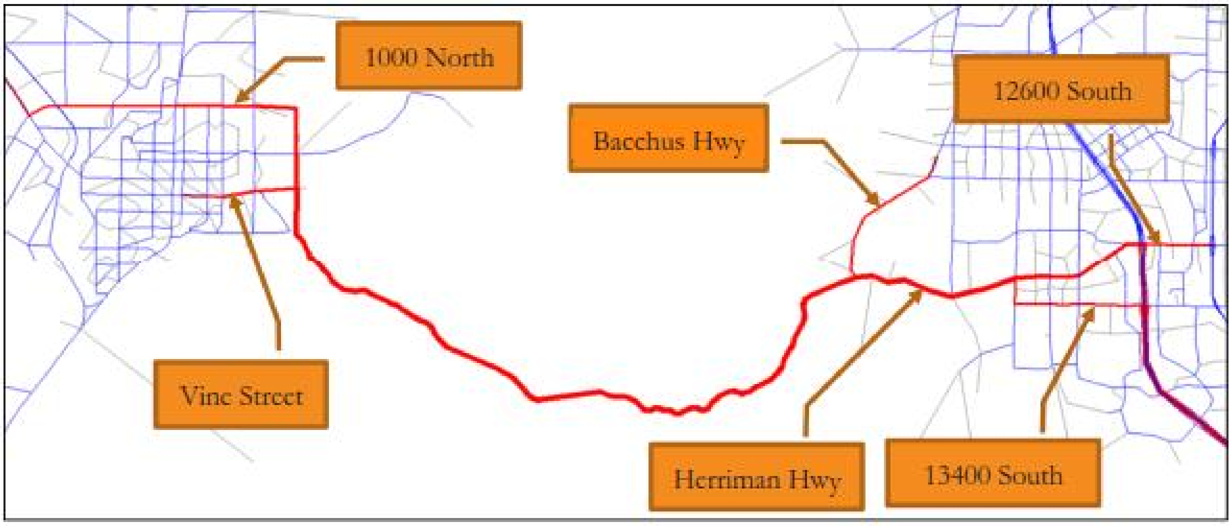


Figure 8: Downstream Traffic Flows (Alternative 2 in Year 2050)

Table 4 : Downstream Traffic Flows (Alternative 2 in Year 2050)

	Route	Start	End	No Build	Alternative 2 Base	New	Total
SL Co	Bacchus Hwy	Just north of Alt 2		4,000	4,000	3,000	7,000
	Herriman Hwy	Canyon Exit	6400 W	11,000	10,000	11,000	21,000
	Herriman Hwy	6400 W	Mtn View/12600 S	19,000	17,000	7,000	24,000
	12600 S	Mtn View	Bangerter	73,000	71,000	3,000	74,000
	13400 S	Herriman Hwy	Mtn View	11,000	9,000	3,000	12,000
Tooele	Vine St			3,000	-	5,000	5,000
	1000 N	East of SR-36		7,000	6,000	7,000	13,000
	1000 N	West of SR-36		13,000	10,000	4,000	14,000

**No Build includes all downstream project improvements from Build Scenario*

On the Tooele side of the proposed connection, 1000 North is projected to carry most of the traffic with an estimated AADT of 7,000 vehicles per day. As shown in **Figure 8**, this is projected to serve most trips between the northwest side of Tooele and Alternative 2. Vine Street is projected to carry 5,000 vehicles per day. As shown in **Figure 8**, Vine Street will likely serve as the key connection between downtown Tooele and Alternative 2.

On the Salt Lake County side of the proposed connection, Herriman Highway is projected to carry most traffic to Mountain View Corridor. Traffic is also projected to use Bacchus Highway to travel north, 13400 South as a secondary connection to Mountain View Corridor, and 12600 South (east of Mountain View Corridor) to connect to Bangerter Highway. Traffic impacts on Mountain View Corridor were disregarded, as this roadway is expected to have excess future capacity to handle increases from this proposed connection.

As Alternative 3 has the same tie-in location as Alternative 2 on the Tooele side, and a lower estimated AADT, no additional analysis was performed at this location. On the Utah County side of the Alternative 3 connection, the roadway will join into a proposed freeway, thus any additional traffic volume will have a negligible effect on congestion.

I-80 and SR-73 Rerouting

Trips using the proposed alternatives are comprised of three primary groups:

- **Re-Routed Trips**: Trips that are currently made between Tooele and Salt Lake or Utah counties and will re-route onto Alternative 2 as it offers a faster alternative to either SR-73 or I-80.
- **Transferred Trips**: Trips that are currently made between Tooele and Salt Lake or Utah counties that will now go to new destinations in Salt Lake or Utah counties that are quicker to get to using Alternative 2.
- **New Trips**: New trips that were not previously made between Tooele and Salt Lake or Utah counties but would now do so.

Table 5: Groups of Alternative 2 Trips shows the AADT expected for each of these three groups in 2034 and 2050. The horizon year 2034 was chosen as this corresponds to the end of the LRP Phase II, which was determined by the project team to be a reasonable assumption for construction of this facility. Approximately two-thirds of the trips using Alternative 2 are expected to be existing trips that are re-routed and no longer using I-80 or SR-73, while one-third of trips are expected to be new trips.

Table 5: Groups of Alternative 2 Trips

Analysis Year	Re-Routed Trips	Transferred Trips	New Trips	Total Trips
2034	4,700	2,200	4,200	11,000
2050	7,400	2,600	5,000	15,000

2.3.4 Sensitivity Analysis

Roadway Design

Additionally, a series of sensitivity analyses were performed to determine how significant of a role roadway design plays in the traffic volumes along Alternative 2. These sensitivity tests were all performed on Alternative 2, and adjusted number of lanes, speed, and route distance to measure the effects of each design element on traffic volumes.

Table 6: Sensitivity Analysis - Roadway Design

Test #	Lanes	Speed	Distance	AADT
1	2	35 MPH	+ 2.0 Miles	7,000
2	2	45 MPH	No change	15,000
Base	4	45 MPH	No change	15,000
3	4	55 MPH	- 0.2 Miles	18,000

As can be seen in **Table 6: Sensitivity Analysis - Roadway Design**, changing just the number of lanes from the base condition has minimal effect on projected traffic volumes, while changing speed and distance has a major effect. By reducing the speed by 10 MPH and lengthening the route by 2 miles traffic volumes are projected to be less than half of the base condition. By increasing the speed by 10 MPH and shortening the route by 0.2 miles traffic volumes are projected to increase by 3,000 vehicles per day.

Land Use

Due to significant uncertainty when projecting land-use changes more than 30 years into the future, a secondary 2050 land-use scenario was evaluated. This was performed to determine how much effect variations in land-use would have on projected traffic along the proposed alternatives.

The secondary scenario evaluated was the 2050 land-use from the 2015 Regional Transportation Plan. The results of this sensitivity analysis are presented below in **Table 7: Sensitivity Analysis - Land Use**.

Table 7: Sensitivity Analysis - Land Use

Alternative	Base AADT	Sensitivity AADT
2	15,000	16,000
3	12,000	11,000

As can be seen in **Table 7,** changes in land-use are not projected to have a major effect on traffic volumes on Alternatives 2 or 3. Even with the redevelopment of the Draper Prison site assumed in the base condition, and not the secondary land-use scenario, traffic volumes are not expected to change much. Alternative 2 is slightly larger in the sensitivity scenario because there is more population in the southwest portions of Salt Lake County as compared to the base scenario. Alternative 3 is slightly higher in the base scenario because population is higher in the northwest portions of Utah County as compared to the sensitivity scenario.

2.3.5 Combined Alternatives

As Alternatives 2 and 3 share the same route west of the Butterfield Canyon Pass, the option of building both alternatives together was evaluated. This resulted in an AADT of 18,000 vehicles per day on the west leg of the connection, which is 3,000 vehicles per day greater than Alternative 2 alone. These 18,000 vehicles per day are estimated to be split evenly (9,000 vehicles per day) between Alternative 2 and 3 east of Butterfield Canyon Pass. No vehicles are expected to use this route to connect southwest Salt Lake County to northwest Utah County.

2.3.6 Intermediate Years

To estimate AADT along the proposed corridor before 2050, the connection was also analyzed with 2014 base year conditions. Linear interpolation was used to estimate travel along the proposed connection for intermediate years. **Table 8: Alternative 2 – Intermediate Years Analysis,** presents Alternative 2 for 2014, 2050, and interpolated 2034 results.

Table 8: Alternative 2 – Intermediate Years Analysis

Year	AADT
2014	6,000
2034	11,000*
2050	15,000

*Interpolated between 2014 and 2050.

2.4 Corridor Alternatives Refinement

2.4.1 North (Barney's Canyon)

Travel demand modeling shows this alternative with the most direct connection and highest daily traffic. However, current and proposed land use are not conducive for a high speed roadway facility. Specifically Kennecott to the east and the International Smelting and Refining site to the west.

The Barney's Canyon alignments were eliminated for the following reasons:

- The area in Salt Lake County has been, and will continue to be, the repository for mine wastes from the Barney's and Bingham Canyon mines. In some locations this waste is many hundreds of feet deep and may not be considered geotechnically stable for roadway construction or tunneling.
- All alignments cross active mining areas and encroach on future mining activities. Overall, all the land to the east belongs to Kennecott and is part of a long term mining operation. Kennecott would prefer to not have its operations bisected by a public roadway.
- Immediately to the west of Barney's Canyon, on the west side of the Oquirrhs, are Lincoln Township and the eastern edge of Tooele City. This area is the site of the International Smelting and Refining Superfund Site. As part of the cleanup and long term mitigation, the entire site is under a perpetual conservation easement which restricts uses and prohibits motor vehicles. All northern alignments would have to cross this easement, and therefore all northern alignments would be eliminated from further consideration

- The 25-35 mph design alignment does not require a tunnel. However, in order to maintain a 6% grade it is long and winding and would not provide competitive travel times or distances.
- Steep mountainous terrain requires a 2-mile tunnel in order to maintain a 6% grade. Engineering and construction would prove to be complex and costly.

2.4.2 Center (Butterfield and Middle Canyons)

As discussed above, property owned by Kennecott begins at the Butterfield Canyon Road, is bounded on the west by the Tooele/Salt Lake County boundary and the east by the Salt Lake Valley floor, and extends north beyond the extent of the Oquirrh Connection study area.

In order to maintain slopes at 6% or less and minimize the length of tunnels, none of the design alignments were able to utilize the existing Butterfield Canyon Road but rather used the north or south sides of the canyon to gain elevation.

In Middle Canyon, alignments followed the existing Middle Canyon Road as well as new alignments on the north and south sides of the canyon. In order to maintain a 6% grade a tunnel is required to connect the existing road through to Butterfield Canyon.

Butterfield/Middle Canyon alternatives eliminated include:

- The 25-35 mph design alignments do not require a tunnel. However, in order to maintain a 6% grade they are long and winding and would not provide competitive travel times or distances.
- All alignments on the north side of Butterfield canyon cross active mining areas and encroach on future mining activities. The land belongs to Kennecott and is part of a long term mining operation.
- Because of the access and overall grade and width of the existing Middle Canyon Road, it was determined that the exiting alignment met the needs of the project and all other alternatives in Middle Canyon were eliminated from consideration.

2.4.3 South (Oak Canyon, Ophir)

Further analysis on the Ophir alignments did not reveal any new data, and in fact only confirmed the project team's initial conclusion to dismiss these alignments from further consideration.

The Ophir alignments were eliminated at an early stage for the following reasons:

- Routes from Utah County to Tooele County through Ophir do not serve populations and are not competitive since the alignment connects to SR-73 approximately 15 miles south of Tooele City. If the purpose is better connectivity from Tooele to southwest Salt Lake County or northern Utah County, then the current routes of I-80 and SR-73 are still better options.
- Ophir Canyon Road, especially through the town of Ophir, is constrained by steep canyon walls. A high speed facility would require limited access and additional right-of-way that does not currently exist without a large number of residential property takes.
- Steep mountainous terrain requires multiple, long tunnels in order to maintain a 6% grade. Engineering and construction would prove to be complex and costly.
- The slower speed design follows existing terrain, and in order to maintain a 6% grade, the longer and windier road would not provide competitive travel times or distances.

The Oak Canyon alignments, when combined with the Butterfield/Middle Canyons alignment, produced competitive travel demand numbers as well as new users. For this reason, the 55 mph design alignment in Oak Canyon tying to SR-73 in Utah County and through a 2 mile tunnel to Middle Canyon will be retained as a future phase.

3.0 PREFERRED ALTERNATIVE

As described above, three initial corridors were selected for the corridor alternatives evaluation–North (Barney's Canyon), Center (Butterfield and Middle Canyons), and South (Oak Canyon, Ophir). The North alternative corridor was eliminated due to conflicts with significant active mine operations in Salt Lake County and an EPA Superfund site in Tooele County. The south corridor alternative was eliminated due to mountainous terrain and lack of connectivity to population centers.

This leaves the Center (Butterfield and Middle Canyons) corridor alternative as the preferred alternative. In addition, the 55 mph design alignment in Oak Canyon tying to SR-73 in Utah County and through a 2 mile tunnel to Middle Canyon will be retained as a future phase.

The Butterfield/Middle Canyon alternative for the Oquirrh Connection connects the communities of Tooele (Tooele County) and Herriman (Salt Lake County) in Utah. At its western termini, the alignment connects with 1000 North in the City of Tooele approximately 0.4 miles east of Droubay Road (about 1.6 miles east of Main Street). The alignment then proceeds directly south, along the eastern edge of the Oquirrh Hills Golf Course, for approximately 2 miles where it joins Middle Canyon Road. In Tooele, the new roadway would provide connections to 1000 North, Smelter Road (400 North), and Vine Street. The alignment would follow Middle Canyon Road in a generally eastward direction for approximately 4.5 miles where it would enter a 0.9 mile tunnel punching through to Butterfield Canyon. It is also at this location that a tunnel from Oak Canyon would emerge.

From the eastern portal of the tunnel, the new roadway would run eastward along the southern side of the canyon paralleling the existing Butterfield Canyon Road for approximately 4.8 miles until it joins the existing road ¼ mile west of SR-111.

The length of the new roadway from Vine Street to SR-111 is approximately 12 miles, with overall length approximately 23 miles from SR-36 in Tooele to 5600 West in Herriman.

Figure 9 : Proposed Butterfield Canyon – Middle Canyon Alignment Vertical Profile shows the elevation gain as well as proposed locations for tunnels and bridges as well as new roadway for the Oquirrh Connection.

Figure 10: Oquirrh Connection, Preferred Alignments shows the Middle Canyon to Butterfield Canyon alignment along with the connection from Oak Canyon in Utah County to Middle Canyon in Tooele County.

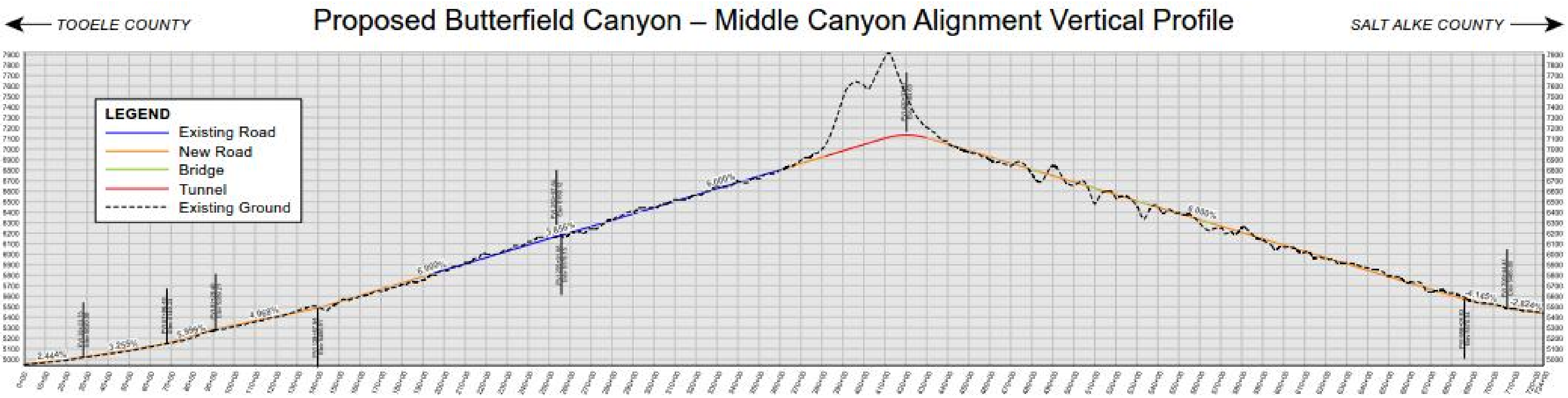


Figure 9 : Proposed Butterfield Canyon – Middle Canyon Alignment Vertical Profile

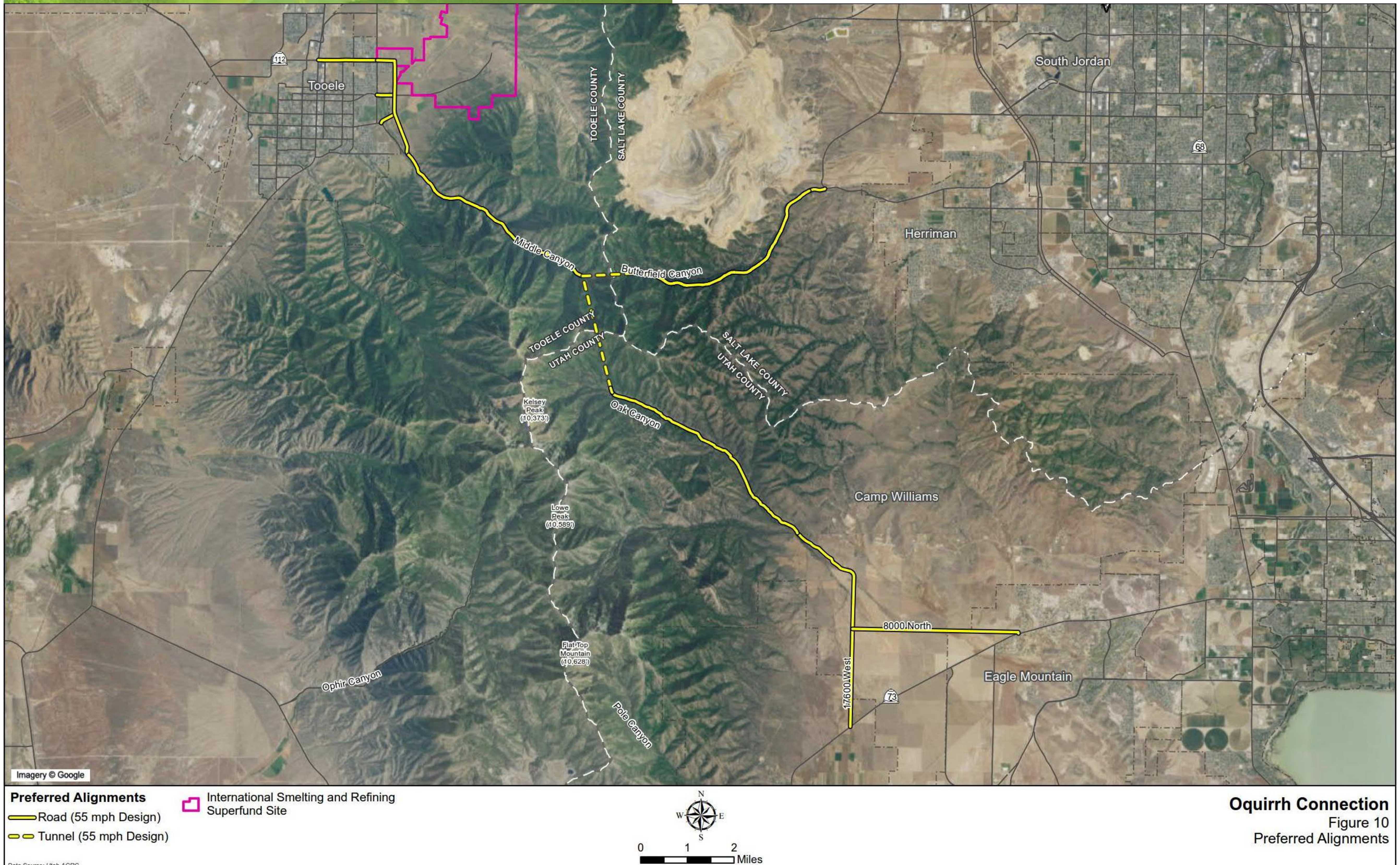


Figure 10: Oquirrh Connection, Preferred Alignments

3.1 Roadway And Engineering Considerations

As previously discussed in *Section 2.1 Design Criteria*, the preferred alternative was designed using UDOT and AASHTO design guides.

Also as previously discussed in *Section 2.3.4 Sensitivity Analysis*, the preferred alternative will be capable of an AADT of 15,000-18,000 vehicles per day with a design speed of 45-55 mph. Ultimate roadway configuration will consist of two 12' travel lanes with two 10' multi-use shoulders (parking and bicycles), see **Figure 11** and **Figure 12** below. Climbing and passing lanes will be required but are not specifically included in this conceptual design.

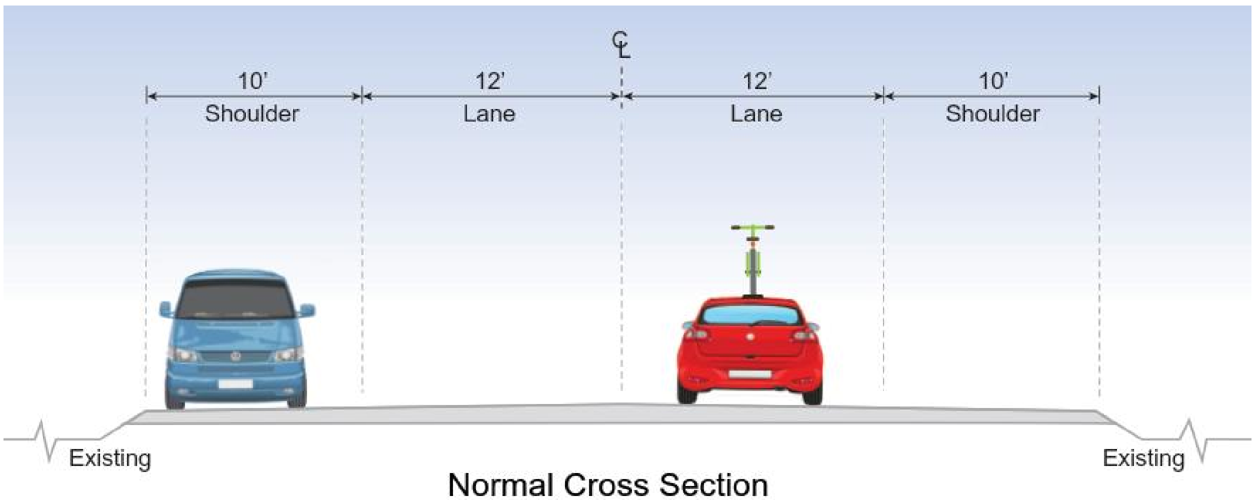


Figure 11: Typical Roadway Cross Section

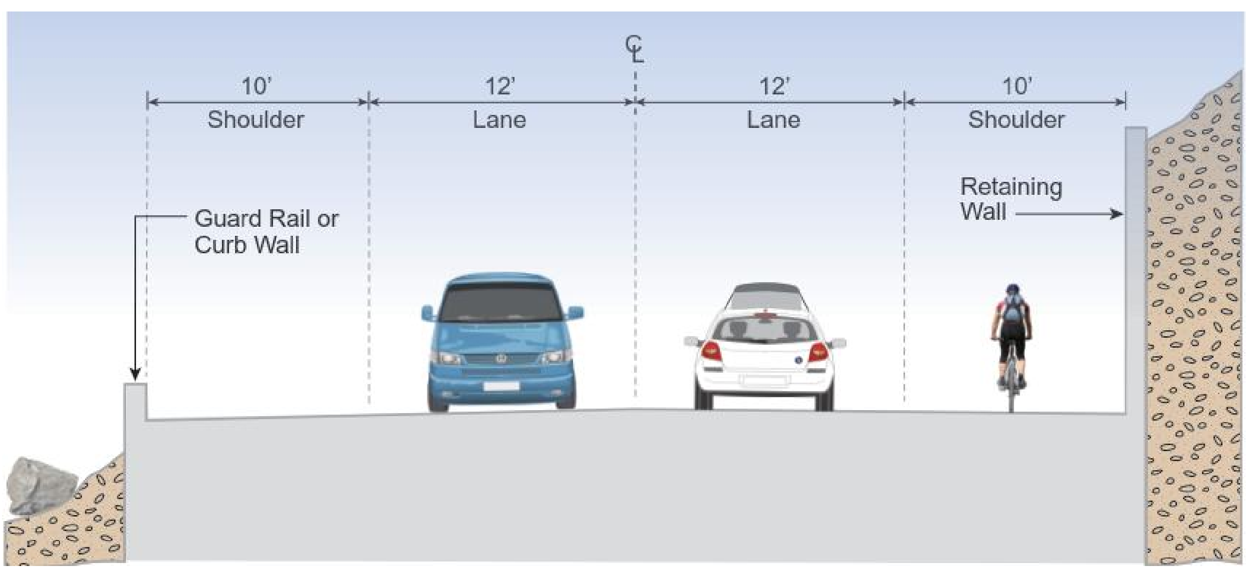


Figure 12: Typical Mountainous Roadway Cross Section

Based upon review and evaluation of currently available geotechnical and geologic information and data, the geotechnical risks for the alignment are relatively low and the preferred alignment and connections with currently proposed tunnel reaches are generally feasible for design and construction. Identified project risks center around normal, though not insignificant challenges associated with design and construction in mountainous terrain; i.e., stability, erosion, drainage, maintenance, safety and seasonal access limitations. These can all be addressed effectively with proper engineering best practices and understanding of local geology and ground behavior, and are further discussed in the following sections.

3.1.1 Topography

The topographic elevation map for the preferred alignment is attached as **Figure 13: Oquirrh Connection, Topographic Elevation Map.** The maximum elevation for the alignment is about 7200 feet. The minimum elevations are at the valley floors which range from 5000 to 5400 feet for Tooele, Utah County, and unincorporated Salt Lake County. The alignment generally follows existing drainages—Middle Canyon in Tooele County, Butterfield Canyon in Salt Lake County, and Oak Canyon in Utah County.

Cut and fill quantities and balance for the proposed alignment have yet to be identified. Cut and fill slope configurations along the alignment will need retaining wall design, drainage design, rock fall protection measures, settlement, and slope stability analyses.

There are two tunnels in the proposed alignments to avoid excessive slopes at the highest elevations of the alignments. One tunnel from Salt Lake County to Tooele County will be about 0.9 miles long, and a second tunnel from Utah County to Tooele County will be about 2.4 miles long. Both tunnels will be built at approximately 7200 feet elevation.

3.1.2 Geology

The geologic map for the preferred alternative (Clark et al., 2012, Clark et al., 2016) is attached as **Figure 14: Oquirrh Connection, Geologic Map.**

The preferred alternative will be underlain by the Paleozoic-aged Oquirrh Group. The Oquirrh Group is composed of three mappable lithologic units: a lower clastic limestone; a middle unit consisting of cyclically repeated limestone, shale, and sandstone; and an upper unit of interlayered thick beds of quartz sandstone and thin beds of carbonate sandstone. The Oquirrh Group consists of the following geologic formations in increasing age and depth: Bingham Mine Formation (limestone and quartzitic sandstone), Butterfield Peak Formation (cyclic shale, limestone and calcareous quartzite), "White Pine" Formation (cyclic shale, limestone and calcareous quartzite), and the Maple Formation (clastic limestone). The Oquirrh Group formations are underlain by the Manning Canyon Shale.

At the uppermost elevations the alignment will be underlain by the Butterfield Peak Formation, with part of the east-west tunnel cutting through a lower member of the Bingham Mine Formation of the Oquirrh Group. Lower elevations of the alignment will be underlain by alluvial and colluvial deposits, crossing some older lahars and debris flows in Butterfield Canyon. The southernmost portion of the north-south tunnel and much of the Utah County alignment will be underlain by West Canyon Limestone of the Oquirrh Group. As the tunnel comes out of the canyon and turns southeast, the geology underlying the Utah County alignment is Manning Canyon Shale.

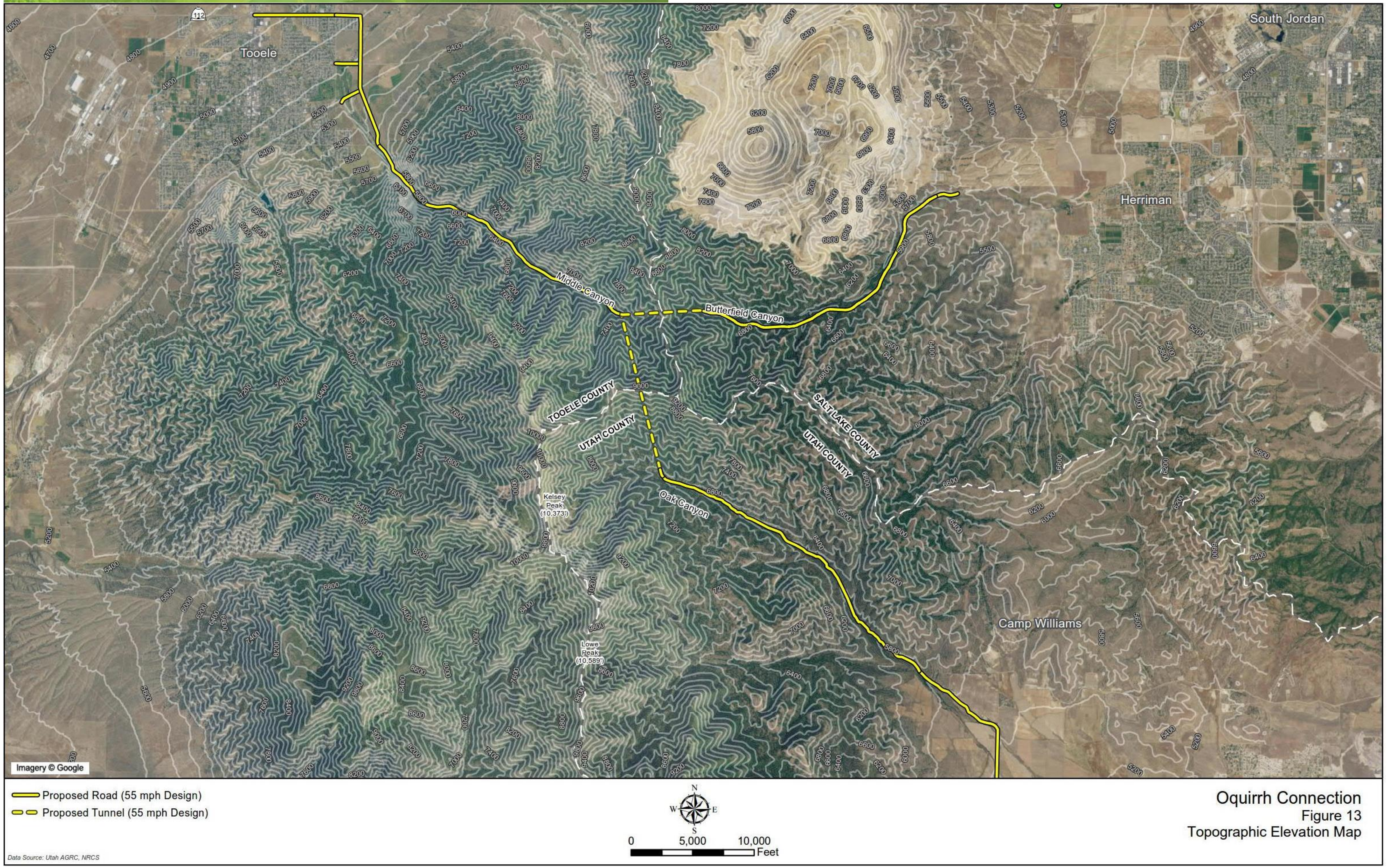


Figure 13: Oquirrh Connection, Topographic Elevation Map

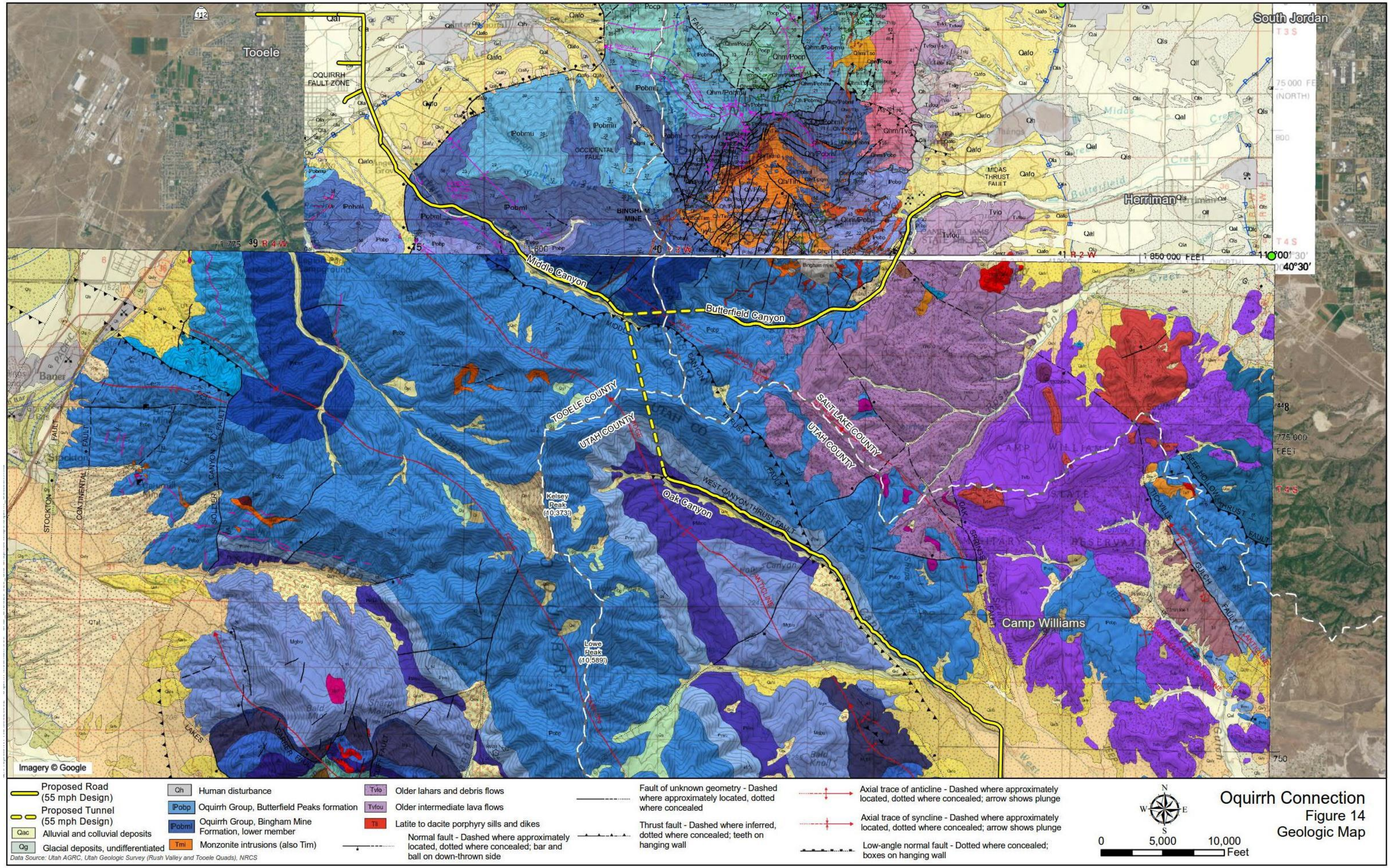


Figure 14: Oquirrh Connection, Geologic Map

Surficial Geology

Shallow deposits overlying the geologic formations vary through the route. The soil map, which uses Natural Resources Conservation Service (NRCS) classification, is attached as Figure 15: Oquirrh Connection, Soils Map**.** Middle Canyon lies on broad, moist - Reywat, moist - Rock outcrop association with 30 to 60 percent slopes and on Podmor, moist Datemark - Rock outcrop association. The last bit of Middle Canyon before and the first third of the east-west tunnel toward Butterfield Canyon lies on shallow Podmor - Datemark, moist – Rock outcrop association. This is also the shallow geology under the northern half of the north-south tunnel toward Utah County. There are darts of Podmor – Onaqui - Rock outcrop association that crosses both tunnels about mid-tunnel. The southern portion of the north-south tunnel and the route's subsequent curve to the southeast is underlain by Parkay - Rock outcrop complex. The rest of the Utah County route is underlain by surficial soils, in order, as follows: Lizzant very cobbly loam; Agassiz very stony loam; Lundy - Rock outcrop complex; and sloping Cumulic Haploxerolls. Butterfield Canyon lies mostly on Fitzgerald gravelly loam and Baird Hollow loam with some patches of Bradshaw-Agassiz Association at higher elevations and patches of Horrocks-Little Pole association crossing the lower elevations. As the Butterfield Canyon route enters the Salt Lake valley, the underlying soils consist of Henefer-Horrocks complex.

The majority of the surficial soils are granular and samples will be required for laboratory analyses for geo-engineering design. Particle size and texture will be used to design stable slopes, road base compaction and ground improvement requirements.

Geologic Hazards

As shown on the geologic map in **Figure 14**, the preferred alternative will intersect one main thrust fault and parallel another thrust fault. The routes will also intersect secondary faults. The Middle Canyon Thrust Fault traverses under the north end of the north-south tunnel and crosses the Oak Canyon alignment at about Elevation 6200 feet. The Oak Canyon alignment parallels the West Canyon Thrust Fault, but lies entirely on the fault's foot wall. However, if the alignment moves to the southwest, the route may transverse this fault. There is an additional secondary strike/slip that crosses the Oak Canyon alignment. The Butterfield Canyon route traverses three or more secondary normal faults. There is also a buried fault under a portion of the Butterfield Canyon alignment.

Seismic studies will be required to identify fault age and recurrence interval to establish preliminary seismic design criteria.

3.1.3 Slope Stability and Landslides

The slope stability considerations for this feasibility study are based on published regional literature, denoting historic landslides and unstable slope conditions. Extensive geologic reconnaissance mapping, subsurface exploration, and slope stability analyses are required for a highway development of this scale.

A landslide risk map for the project area was composited from two UGS maps (Christensen and Shaw, 2008) (Elliott and Harty, 2010) and GIS data from the AGRC and NRCS data, the map is included as Figure 16: Oquirrh Connection, Landslide Risk Map. The composite map designates which areas require special landslide studies before development may begin on the land. Some of the mapped landslide risk for both Salt Lake and Tooele Counties is denoted as high solely based on existence of slopes greater than 30% according to available elevation data. The simplistic approach of determining landslide based upon slope grade does not include other significant factors including stratigraphy and variability of soil and rock strength, rock structure, erosion patterns, vegetation, groundwater conditions and precipitation. More detailed investigation of these hazards will be required for design.

All mapped existing landslides are also denoted as high risk areas for re-mobilizing. The Butterfield Canyon alignment, approximately 0.7 miles to the west of the tunnel section, traverses a historic debris flow and will need additional investigation to characterize the soil and rock strength and develop a design approach to maintain adequate stability during construction and operations. Another mapped shallow landslide nearly a mile northwest of lower Butterfield Canyon is anticipated to have little or no affect on the proposed alignment.

There are some observed landslides deposits about 200-600 feet west of the proposed Utah County alignment for nearly four miles, but they are not anticipated to affect the current alignment. The Oak Canyon alignment also traverses landslide deposits for 1000 feet immediately coming out of its tunnel. The current layout of the Utah County alignment also catches the edge of an area of unclassified landslide-type deposits for about 3500 feet at about three miles out of the southern mouth of the tunnel.

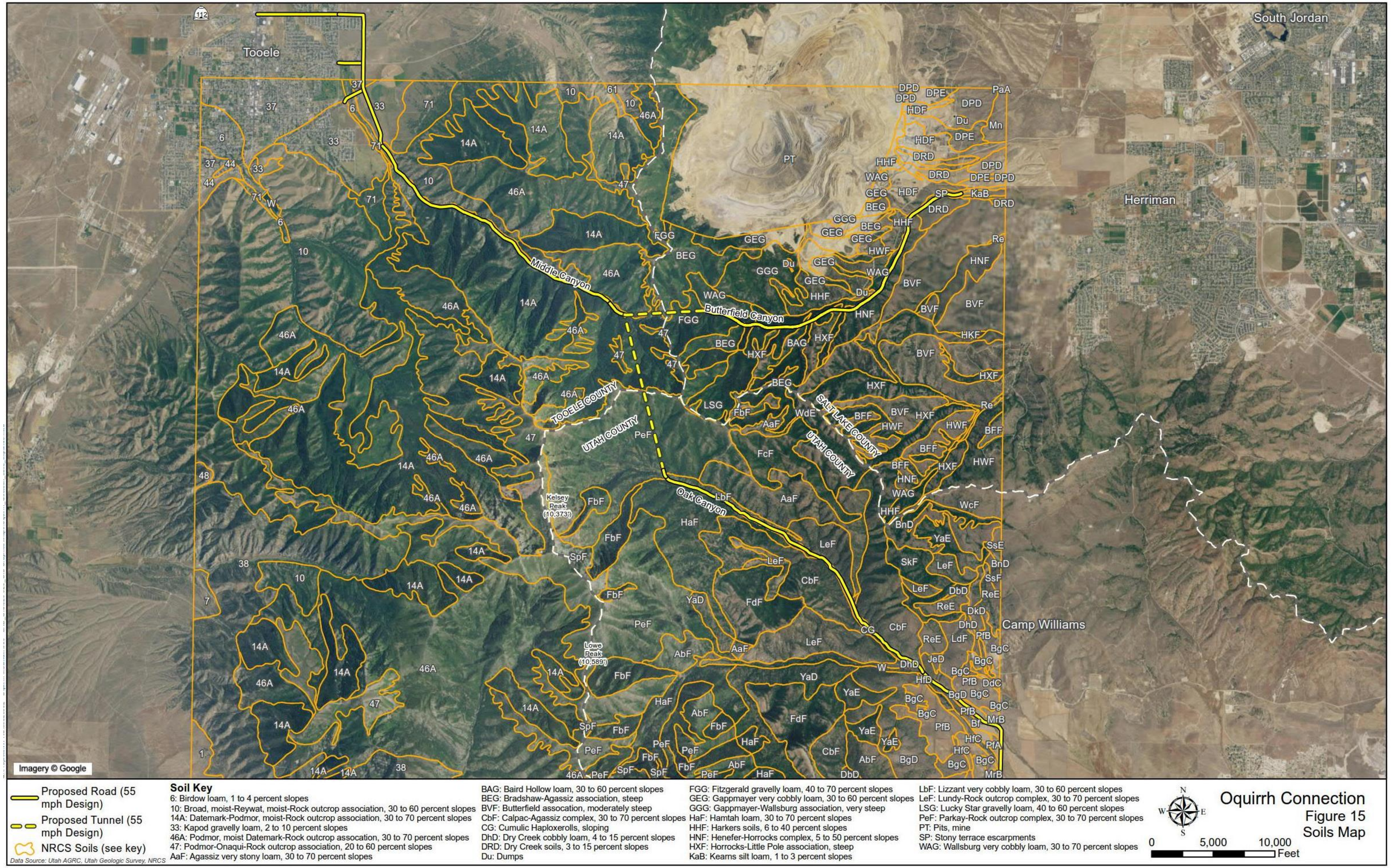


Figure 15: Oquirrh Connection, Soils Map

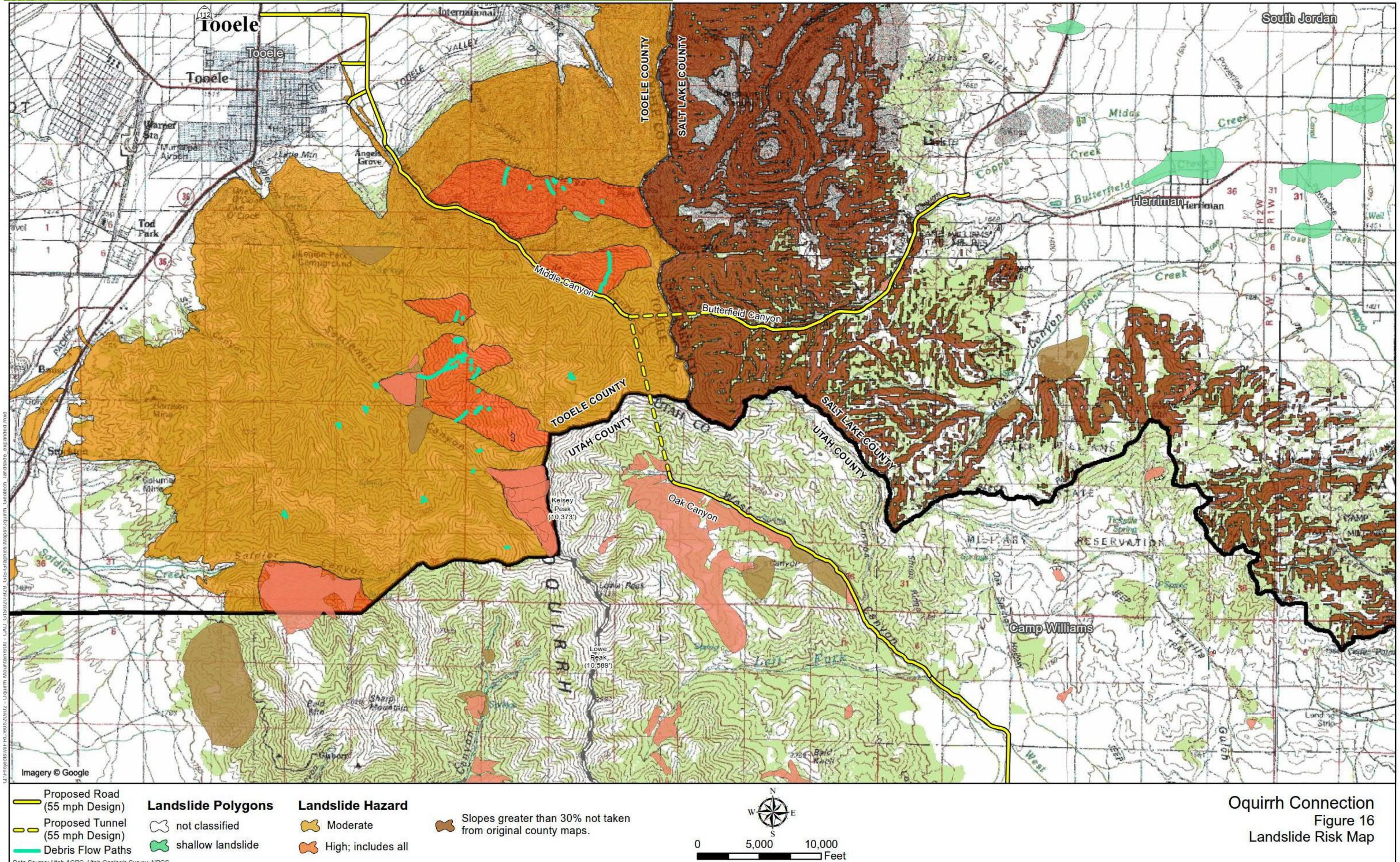


Figure 16: Oquirrh Connection, Landslide Risk Map

3.1.4 Roadway Cuts, Fills, and Bridges

The lower portions of the planned alignments in Middle and Oak Canyons will likely have relatively minor cuts, fills, and retaining walls. However, due to the mountainous topography, substantial cuts, fills, and larger retaining walls will be required along significant portions of the alignments.

Appendix B provides examples of soil stabilization techniques.

Cuts

In general, the steeper the natural slope is, the shallower the soil cover will likely be. Rock cuts will be designed and constructed to be compatible with the intrinsic structure of the rock; i.e., the rock cuts will roughly parallel the strike and dip of the rock to the extent practical. Depending on the height of the cut and the nature of the rock to be explored during design, persistent rock fall may be an issue in the upper reaches of the road and tunnel approach. They would require regular maintenance and design of a catchment ditch and netting system for energy dissipation or to arrest rockfall debris. Cuts can be constructed steeper and rockfall potentially reduced or eliminated using soil nail walls with shotcrete facing or tensioned steel netting.

Soil cuts will likely require erosion control measures. These measures would include a broad range of best practices in conjunction with site design including geotextile filters membranes, geosynthetic reinforcements, drainage and collections system, bio-retention and bio-stabilization engineering with conventional mountain roadway features of reverse grading, storm drains, check dams, siltation basins and swales. Improved new products are also available for spray on erosion control vegetation seeding durable in rugged environments and permeable flowable fill for trenching and stabilization with integral drainage properties. An effective combination of these options should be developed during the design phase.

Fills

Unreinforced fills and embankments will likely have to be constructed at 2H to 1V slope or flatter per standard UDOT requirements. As with cut slopes, the steeper the fill slope, the greater the potential for erosion and the need for erosion control. Along portions of the alignments with flatter natural slopes, which are relatively small portions, standard mechanically stabilized earth (MSE) walls will likely be feasible. Along portions of the alignments with steeper slopes, wall systems with mechanical anchoring will likely be required. Such systems might be tieback walls, hybrid MSE-tieback, soldier pile, and soldier pile with tieback, or other systems. These systems will require design with adequate corrosion protection and will have limited, planned design lifes (typically 75 years).

Bridges

On the Butterfield Canyon alignment, several bridges will be required. Due to seismic demand and steep cross slopes, the design of abutment walls and support bents and foundations will present significant challenges. Challenges include a change in height across the abutment or a rock cut, and a significant maximum height, and/or the design of tall and substantial support bents. Rock socketed shaft foundations or anchored spread footings will likely be required.

3.2 Tunneling

There are two proposed tunnels:

- One east-west tunnel from Middle Canyon to Butterfield Canyon will be about 0.9 miles long
- One north-south tunnel from Middle Canyon to Oak Canyon will be about 2.4 miles long.

The required roadway width for 2 way traffic in a single tunnel is likely to be 28 - 34ft, with a minimum height over the roadway of 14ft and 16ft in the center.

3.2.1 Tunnel Geology

The east-west 0.9 mile tunnel running from Middle Canyon to Butterfield Canyon is likely to be excavated in the Butterfield Peaks Formation which consists of 60% silica cemented orthoquartzite and interbedded with 40% of cherty arenaceous and argillaceous fine grained limestone. The high-silica content rock is typically hard to very hard and exhibits medium to high compressive strengths (>8,000 psi) and is highly abrasive. Field and laboratory testing will be performed to aid in selecting and designing rock excavation equipment.

The west portal of the proposed tunnel lies close to the Middle Canyon thrust fault and the tunnel passes through the Oak Springs Syncline that could bring the Bingham Mine Formation consisting of interbedded orthoquartzite and calcareous quartzite with limestone layers into the tunnel level. Geologic reconnaissance mapping should be performed to define the location and extent of faulted and folded rock structure and conditions and rock stratigraphy. The presence of faults and folded rock structures (i.e., syncline) will create potentially unstable conditions for rock tunneling and portal or shaft development.

Permanent groundwater is not anticipated at a tunnel elevation of approximately 7200 feet, however perched water is possible. Groundwater will be primarily associated with secondary porosity of faulted and jointed rock. Folded rock units will also likely be water-bearing due to secondary porosity (i.e., fracturing). Water levels should be monitored in boreholes during the subsurface drilling investigation and borehole packer-permeability testing should be performed.

The north-south 2.4 mile long tunnel running from Middle Canyon to Oak Canyon will likely be constructed in the West Canyon Limestone. This formation consists mainly of interlayered clastic arenaceous limestone and dense cherty argillaceous crystalline limestone with some thin sandstone beds. The tunnel is likely to pass into the orthoquartzite and arenaceous/argillaceous limestones of the Butterfield Peaks Formation which is found at the north portal. The abrasive character of these formations is similar to that described above. Similar drilling, sampling and laboratory testing should be conducted along this tunnel alignment as above. This tunnel also passes through the Middle Canyon Thrust Zone, which is likely to provide blocky unstable fractured ground conditions and the existence of flowing water in this zone is a possibility.

3.2.2 Tunnel Constructability

Based on the anticipated geology, the rock in the tunnel horizon is likely to be hard to very hard with UCS strength greater than 8,000 psi (greater than 55 MPa). Due to the presence of sandstone, quartzite and arenaceous limestones the abrasivity is likely to be high, with tensile strengths moderate to high which will make liner design more efficient.

The tunnel section will be determined by the lane width requirements to meet UDOT and AASHTO criteria and traffic flow demands. It will likely be a finished tunnel of some 30 feet wide with single lanes in each direction, and with a minimum height over the lanes of 16.5 feet.

Tunnel means and methods and constructability are based on conditions at the excavation face, the required tunnel dimensions, support and stabilization requirements, and the required schedule. It is anticipated that conventional and machine mining methods will be appropriate for the conditions along the tunnel alignments. Conventional mining methods would include dynamic drill-and-blast methods or unlikely mechanical/chemical splitting methods. Machine-mining methods would include large-diameter tunnel boring machines (TBM) or rotary cutter boom-mining machines (such as roadheaders or alpine miners).

A variation of conventional Drill-and-Blast is becoming more common and wide-spread, and is referred to as the Sequential Excavation Method (SEM). SEM consists of a combination of Drill-and-Blast methods and multiple layers of shotcrete in a sequence of excavations.

SEM or conventional Drill-and-Blast construction could be carried out at two or more faces, but the excavation time for the shorter east-west tunnel is likely to take about 2 – 3 years to mine from 2 faces and 4- 5 years for the 2.4 mile north–south tunnel.

Use of a hard-rock disc-cutter tunnel boring machine would appear feasible. Excavation with a TBM is likely to be faster, with the shorter east-west tunnel taking 1-1.5 years and the longer north-south tunnel taking 2.5-3 years. This does not include the possible 10 -12 month delivery time for a new TBM. During this time the portals and a starter TBM launch tunnel could be excavated by Drill-and-Blast allowing for faster start up upon arrival of the TBM.

The logistics of delivery of a TBM to the mountainous sites may be an issue as bridges and roads to the portals need to be suitable for very heavy loads of over 50 tons and access to heavy lift equipment. In addition adequate staging areas for assembly and excavation, and soil handing will be a significant site design consideration. Final design should also include tunnel liner requirements, roadway sections in the tunnel, pavements, lighting, ventilation, signage, safety, and a robust O&M Plan.

3.3 Other Considerations

3.3.1 Water Hazards and Erosion Potential

Both Butterfield and Middle Canyons follow natural drainages and streams. These drainage channels include perennial streams that flow all year, as well as ephemeral streams in subdrainages that flow only in response to spring snowmelt or precipitation events. These drainages, as well ponds, irrigation channels, and roadside ditches, may present erosion hazards. These hazards may include:

- Flooding and erosion
- Debris flows
- Slope instability triggered by streambank erosion at the toe of a slope
- Slope instability from loss of shear strength and softening caused by addition of moisture
- Frost heave and corrosion promoted by drainages
- Seismic liquefaction and lateral spreading of saturated sandy soils located near drainages.

Future phases of the Oquirrh Connection project will need to study the hydrology and hydraulics of the area to ensure that drainage facilities are designed accordingly and erosion control measures are in place. Construction in steeper terrain will impact natural drainages, potentially concentrate runoff, and create cut and fill surfaces initially devoid of vegetation that may be subject to increased erosion. Silt fencing, vegetative cover, erosion control blankets, filters, rip rap, drainage ditches, storm drains, or other appropriate measures will be required.

3.3.2 Environment

Identification of environmental resources was performed using existing sources such as the U.S. Fish & Wildlife Service's Information for Planning and Consultation (iPaC) website, https://ecos.fws.gov/ipac/, and the Utah Automated Geographic Reference Center (AGRC) https://gis.utah.gov/.

Five endangered species and 29 migratory birds have the potential for occurring within the Oquirrh Connection study area. No critical habitats were identified but field surveys would need to be conducted in the future to confirm the findings.

Threatened or endangered species listed under the Endangered Species Act include one mammal, one bird, one fish, and two flowering plants:

- Canada Lynx (Lynx candensis) – threatened
- Yellow-billed Cuckoo (Coccyzus americanus) – threatened
- June Sucker (Chasmistes liorus) – endangered
- Jones Cycladenis (Cycladenisa humilis var. jonesii) – threatened
- Ute Ladies'-tresses (Spiranthes diluvialis) – threatened

A biological assessment will be required to ascertain if the above listed species exist within the study area and to what extent it might be impacted by the proposed project.

Certain birds are protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Any activity that results in the take (to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or to attempt to engage in any such conduct) of migratory birds or eagles is prohibited unless authorized by the U.S. Fish and Wildlife Service.

Migratory birds with potential for occurring within the study are as follows: American Bittern (Botaurus lentiginosus); Bald Eagle (Haliaeetus leucocephalus); Black Rosy-finch (Leucosticte atrata); Black Swift (Cypseloides niger); Brewer's Sparrow (Spizella breweri); Burrowing Owl (Athene cunicularia); Calliope Hummingbird (Stellula calliope); Cassin's Finch (Carpodacus cassinii); Eared Grebe (Podiceps nigricollis); Ferruginous Hawk (Buteo regalis); Flammulated Owl (Otus flammeolus); Fox Sparrow (Passerella iliaca); Golden Eagle (Aquila chrysaetos); Greater Sage-grouse (Centrocercus urophasianus); Lewis's Woodpecker (Melanerpes lewis); Loggerhead Shrike (Lanius ludovicianus); Long-billed Curlew (Numenius americanus); Olive-sided Flycatcher (Contopus cooperi); Peregrine Falcon (Falco peregrinus); Pinyon Jay (Gymnorhinus cyanocephalus); Rufous Hummingbird (selasphorus rufus); Sage Thrasher (Oreoscoptes montanus); Short-eared Owl (Asio flammeus); Snowy Plover (Charadrius alexandrinus); Swainson's Hawk (Buteo swainsoni); Virginia's Warbler (Vermivora virginiae); Western Grebe (aechmophorus occidentalis); Williamson's Sapsucker (Sphyrapicus thyroideus); Willow Flycatcher (Empidonax traillii).

Wetlands and other aquatic resources are also noted to occur within the study area. These are potentially streams and drainages as well as springs. On-the-ground inspection will be required to assess the presence and impacts to these aquatic resources.

3.3.3 Recreation

Bicycles

The Oquirrh Connection would provide 15 miles of new roadway, including a 0.9 mile tunnel to bypass the steeper portions, through the Oquirrh Mountains connecting to existing roadways in Salt Lake and Tooele Counties. Aside from motor vehicles, bicycles would have access to this new facility.

Although the new roadway would have a shoulder large enough for a designated bike lane, the Oquirrh Connection does not currently include this type of facility. The new roadway would include bicycle signage to indicate that cyclists would be sharing the roadway, and signs to direct cyclists to parallel pathways for certain areas (like the tunnel) where it would be safer for cyclists to be separated from the roadway.

The new roadway is proposed to have 10-foot shoulders that could be jointly used for roadside parking and bicycling. A wider joint/use shoulder will improve movement and safety for cyclists as well as encourage more use by recreational cyclists. For non-motorized traffic, a tunnel bypass would be provided. The bypass would connect in Butterfield Canyon in Salt Lake County before the tunnel by creating a new paved trail, approximately ¼ mile in length, from the preferred roadway alignment to the existing Butterfield Canyon Road. The existing road would remain in its current condition and used by local traffic and cyclists that choose to not use the new on-street bicycle facility. At the top where Butterfield and Middle Canyon meet, the road would be paved to trail width (10 to 14-feet) for approximately 1.5 miles, down Middle Canyon, until it meets the western tunnel portal. The separated multi-use paved path would also link to the Kennecott Canyon overlook road where its access would remain from the Middle Canyon side.

Camping/Day Use

Google Earth shows 40+ locations where people leave the existing roadway in Middle Canyon to access day use, picnic, and camping sites. For safety reasons this would have to be drastically reduced when the new roadway is constructed. Consolidating access points into areas that would have parking and signage indicating trailheads would increase safety and enhance the recreation experience. Recreation can be improved further with the introduction of permanent campgrounds or day use areas and side access roads to keep slow moving recreational vehicles off of the main road. Signage for existing recreation trails and sites would be included as part of the new roadway.
As discussed earlier, a 10’ wide multi-use shoulder would allow for roadside parking at designated locations. These locations could be trailheads or for scenic viewing.

Additionally, an existing parking area at the west tunnel portal would remain. This area could be used by all types of recreationists including a loading and unloading area for ATVs. This parking area would mark the beginning of the multi-use trail as well as the existing graded dirt road to the top of the canyons and the Kennecott overlook road.

3.4 Costs

A rough order of magnitude cost estimate was prepared for the preferred alignment. Unit costs were based on UDOT's average unit bid prices on recent construction projects.

Right-of-way costs used were between $2 and $3 a square foot, or approximately $100,000/acre. Bridge and MSE retaining walls were calculated on a square foot basis and unit costs of $250 and $50 per square foot, respectively.

Tunnel costs were calculated on a linear foot basis. For the Middle/Butterfield Canyon tunnel the linear foot cost was $27,500. For Oak Canyon it was assumed the longer tunnel, although more expensive overall, would have a reduced linear foot cost due to economies of scale of a longer tunnel.

Since this cost estimate is for conceptual design, preliminary engineering, construction engineering, and contingency percentages were included in the total cost. Costs presented in **Table 9 : Butterfield – Middle Canyon Conceptual Cost** Estimate and **Table 10: Oak Canyon Conceptual Cost** Estimate**,** are for planning purposes only and should be updated as designs are progressed.

Table 9 : Butterfield – Middle Canyon Conceptual Cost Estimate

Oquirrh Connection
Conceptual Cost Estimate
Middle Canyon and Butterfield Canyon Options

1-Aug-17

Description	Quantity	Unit	Unit Price	Total
General				
Mobilization	1	Lump	6.0%	$7,200,000.00
Traffic Control	1	Lump	2.0%	$2,400,000.00
Survey	1	Lump	5.0%	$6,000,000.00
General Subtotal				**$15,600,000.00**
Roadway				
Roadway Excavation	2,247,700	cu yd	$15.00	$33,715,500.00
HMA - 5-1/2 Inch	133,800	Ton	$75.00	$10,035,000.00
Granular Borrow (Plan Qty)	168,600	cu yd	$12.00	$2,023,200.00
Untreated Base Course (Plan Qty)	147,900	cu yd	$25.00	$3,697,500.00
Guardrail	11,800	ft	$20.00	$236,000.00
Crash Cushion	64	each	$3,500.00	$224,000.00
ROW	206	Acre	$100,000.00	$20,600,000.00
Right-of-Way Fence	149,300	ft	$7.50	$1,119,750.00
Roadway Subtotal				**$37,935,450.00**
Structures				
Bridge	98,100	sq ft	$250.00	$24,525,000.00
MSE Retaining Wall	331,900	sq ft	$50.00	$16,595,000.00
Tunnel	4,800	ft	$27,500.00	$132,000,000.00
Structures Subtotal				**$173,120,000.00**
CONSTRUCTION SUBTOTAL				**$226,655,450.00**
Preliminary Engineering (10%)				**$22,666,000.00**
Construction Engineering (10%)				**$22,666,000.00**
25% CONTINGENCY				**$56,664,000.00**
			Subtotal	**$101,996,000.00**
TOTAL PROJECT COST				***$328,652,000.00***

Table 10: Oak Canyon Conceptual Cost Estimate

Oquirrh Connection
Conceptual Cost Estimate
Oak Canyon Option

1-Aug-17

Description	Quantity	Unit	Unit Price	Total
General				
Mobilization	1	Lump	6.0%	$ 9,700,000.00
Traffic Control	1	Lump	2.0%	$ 3,300,000.00
Survey	1	Lump	5.0%	$ 8,100,000.00
			General Subtotal	**$ 21,100,000.00**
Roadway				
Roadway Excavation	48,600	cu yd	$ 15.00	$ 729,000.00
HMA - 5-1/2 Inch	91,100	Ton	$ 75.00	$ 6,832,500.00
Granular Borrow (Plan Qty)	115,900	cu yd	$ 12.00	$ 1,390,800.00
Untreated Base Course (Plan Qty)	99,800	cu yd	$ 25.00	$ 2,495,000.00
Guardrail	0	ft	$ 20.00	$ -
Crash Cushion	0	each	$ 3,500.00	$ -
ROW	171	Acre	$ 100,000.00	$ 17,100,000.00
Right-of-Way Fence	100,400	ft	$ 7.50	$ 753,000.00
			Roadway Subtotal	**$ 28,571,300.00**
Structures				
Bridge	0	sq ft	$ 250.00	$ -
MSE Retaining Wall	0	sq ft	$ 50.00	$ -
Tunnel	12,875	ft	$ 15,000.00	$ 193,125,000.00
			Structures Subtotal	**$ 193,125,000.00**
			CONSTRUCTION SUBTOTAL	**$ 242,796,300.00**
			Preliminary Engineering (10%)	**$ 24,280,000.00**
			Construction Engineering (10%)	**$ 24,280,000.00**
			25% CONTINGENCY	**$ 60,700,000.00**
			Subtotal	**$ 109,260,000.00**
			TOTAL PROJECT COST	***$ 352,057,000.00***

4.0 PREFERRED ALTERNATIVE – LAND USE

4.1 General Plans And Land Use Policy Documents

The key community and county level general plans and land use policy documents were reviewed to establish a baseline for the future anticipated land use within the study area. Available population growth projections within the general plans have also been summarized in the following sections.

4.1.1 Tooele County General Plan Update 2016

The 2016 update of the General Plan focused on land use and housing. According to population projections based on past trends, the population in Tooele County is projected to increase from 65,782 in 2015 to 127,340 by 2040, for an overall increase of 61,558. Eighty-six percent of this growth is anticipated to take place within the Tooele Valley, with the Tooele population increasing by 27,816, and the unincorporated Tooele Valley by 12,551. **Table 11: Population Change in Tooele County (2015-2040)** summarizes the projected population change within Tooele County from 2015 to 2040. **Figure 17: Projected Population Change (2015-2040) by TAZ**, illustrates the projected population growth in Tooele County spatially.

Table 11: Population Change in Tooele County (2015-2040)

	2015	2020	2030	2040
Tooele Valley				
Grantsville	10,198	11,794	16,216	22,139
Lake Point	1,266	1,400	1,633	1,880
Stansbury Park	8,998	9,145	9,290	9,537
Stockton	622	691	838	996
Tooele City	35,367	39,839	49,855	63,183
Unincorporated Tooele Valley	4,712	6,507	11,312	17,263
Tooele Valley Total	61,163	69,376	89,144	114,998
Unincorporated County	4,619	5,506	7,777	1,2342
Tooele County Total	65,782	74,882	96,921	127,340

The highest population growth in the County is expected to occur immediately east of the Tooele City limits, generally concentrated on the northeast and southeast sides of 1000 North and Droubay Roads. This location is part of the International Smelter and Refining (IS&R) Superfund Site (Atlantic Richfield Company). The IS&R site was placed on the Environmental Protection Agencies (EPA) National Priority List in July of 2000. The future land use of this area is expected to be rural residential, per Tooele County future land use map (see **Figure 18: Tooele County Future Land Use**).

While the updated General Plan was prepared in concert with the updated Tooele County Transportation Plan 2015, there was no indication that a future Oquirrh Mountain Connection was considered. Within the Tooele City limits, the land use surrounding the western termini of the Oquirrh Mountain Connection selected alignment has been identified as medium density residential (see **Figure 19: Tooele City Land Use Element**).

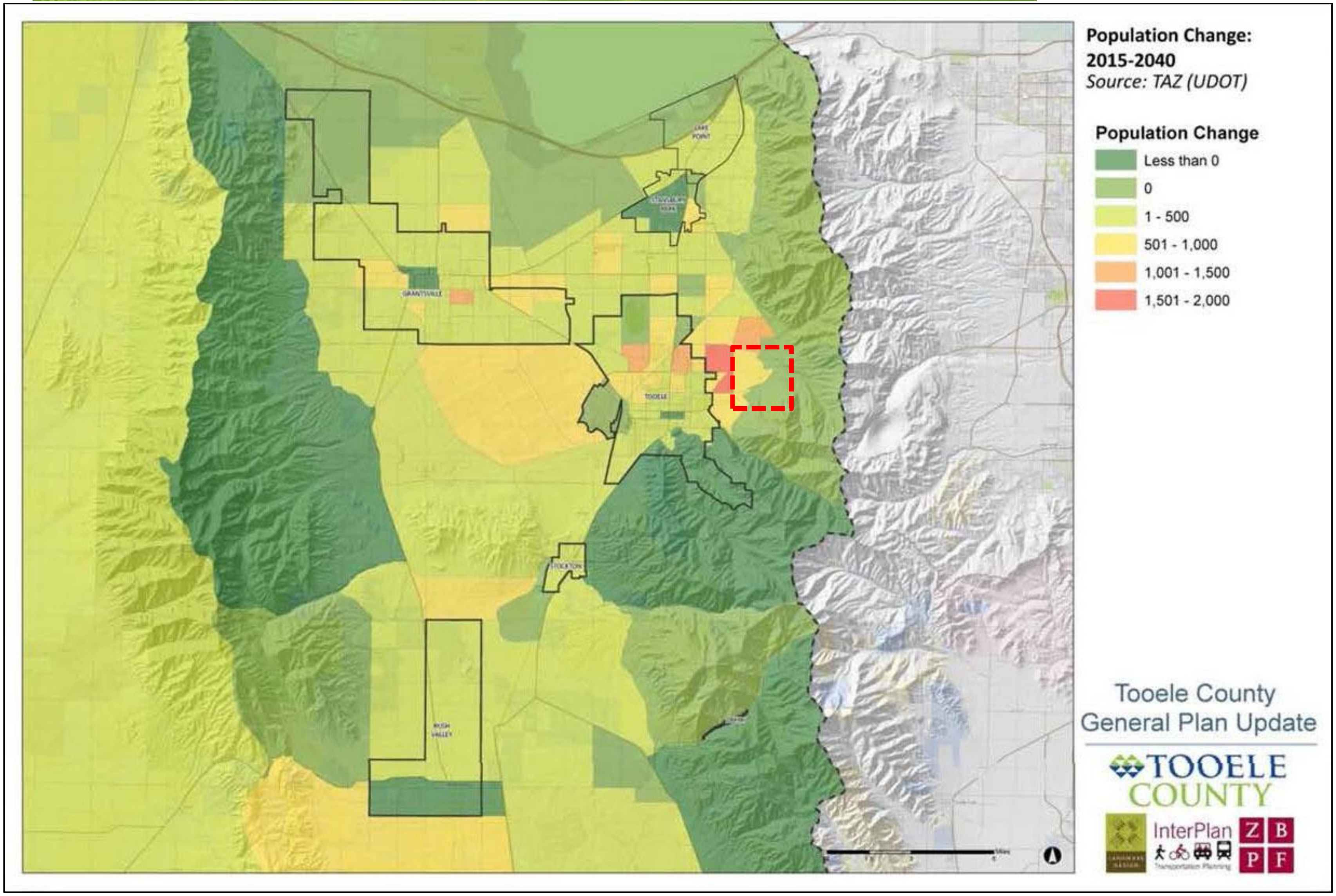


Figure 17: Projected Population Change (2015-2040) by TAZ

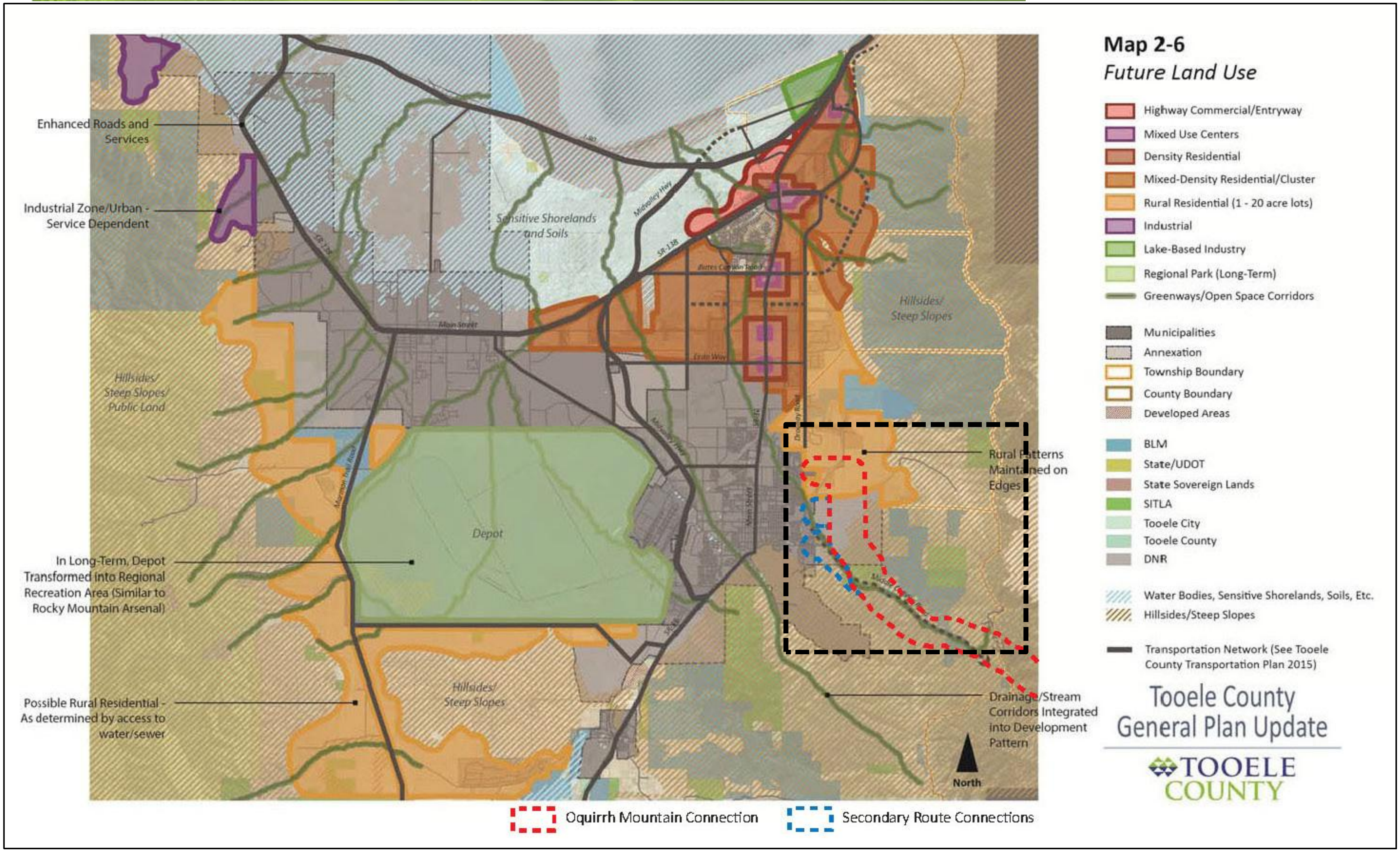


Figure 18: Tooele County Future Land Use

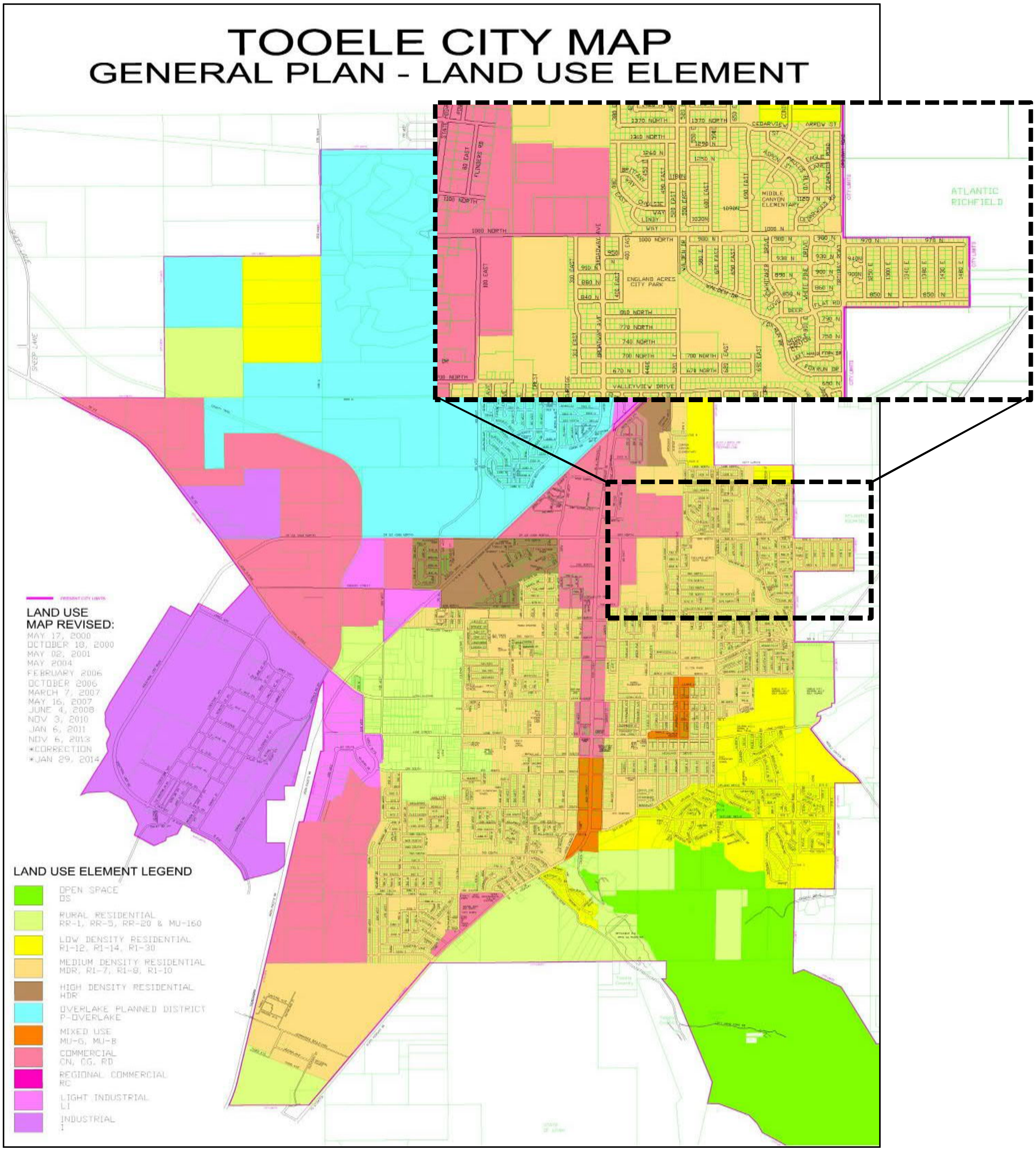


Figure 19: Tooele City Land Use Element

4.1.2 Salt Lake County Combined Land Use Map

The Salt Lake County's combined land use map identifies Mountain Residential (and related facilities), Open Space (agriculture, grazing, wetlands, watershed, Forest Land, Reserve Land),

and Major Recreation Areas (Parks, Golf Courses, Open Space) as the primary land uses along the selected alignment of the Oquirrh Mountain Connection (see **Figure 20: Salt Lake County Combined Land Use Map**).

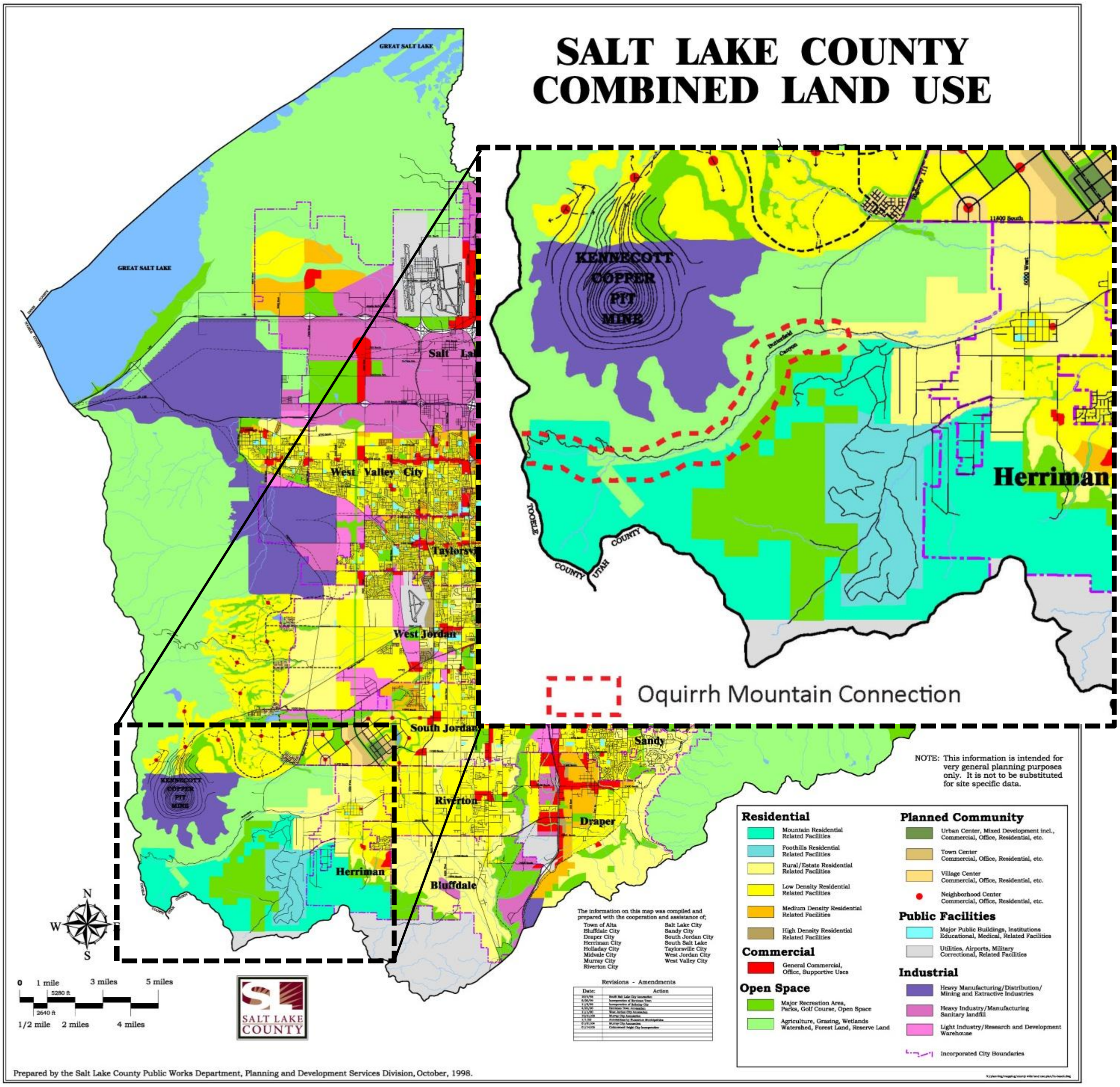


Figure 20: Salt Lake County Combined Land Use Map

4.1.3 Herriman City 2025 General Plan Amendment

Herriman City's 2025 General Plan Update envisions a community that is healthy, diverse and livable, and which has a unique and desirable "sense of place". The plan identifies the southwest corner of the Salt Lake Valley as a very desirable location for real estate development.

Recent Census estimates from 2012 put the City's population at 24,433. Conservative estimates by the Governor's Office of Planning and Budget (GOPB) project continued growth at the highest rate of any city in Salt Lake County (see **Table 12 : Salt Lake County Population Projections**).

Table 12 : Salt Lake County Population Projections

	2010	2020	2030	2040	2050	2060	Percentage Change (2010-2060)	Annual Growth Rate
Salt Lake County	118,554	140,950	179,643	218,527	259,050	302,619	155.26%	1.89%
Bluffdale	7,598	10,099	16,777	19,499	22,098	25,125	230.68%	2.42%
Herriman	21,785	27,003	38,458	50,114	64,896	81,310	273.24%	2.67%
Riverton	38,753	44,339	50,150	56,512	61,974	67,192	73.39%	1.11%
South Jordan	50,418	59,509	74,258	92,403	110,083	128,992	155.84%	1.90%

Source: GOPB

Within the Herriman City limits, the 2025 Future Land Use Map identified Medium Density Residential, Agriculture Residential, and Open Space as the key land uses in the vicinity of the eastern termini of the selected alignment of the Oquirrh Mountain Connection (**Figure 21: Herriman General Plan – 2025 Future Land Use**).

4.1.4 Southwest Community Land Use Plan

The Southwest Community Land Use Plan, prepared by the Salt Lake County Planning and Development Services in 2008 mimics the land use shown in the Salt Lake County Combined Land Use Plan. The key land uses adjacent to the selected alignment of the Oquirrh Mountain Connection include Mountain Residential, Open Space, and Industrial Mining (see **Figure 22: Southwest Community Land Use Plan**).

In addition, the Wasatch Front Regional Council provided a property ownership map for the Butterfield Canyon Corridor (Salt Lake County line to Herriman) which identifies Herriman Irrigation Company, Salt Lake County, Kennecott Utah Copper, BLM, and The Last Holdout LLC as the main property owners along the corridor (see **Figure 23: Property Ownership Along Butterfield Canyon Corridor**).

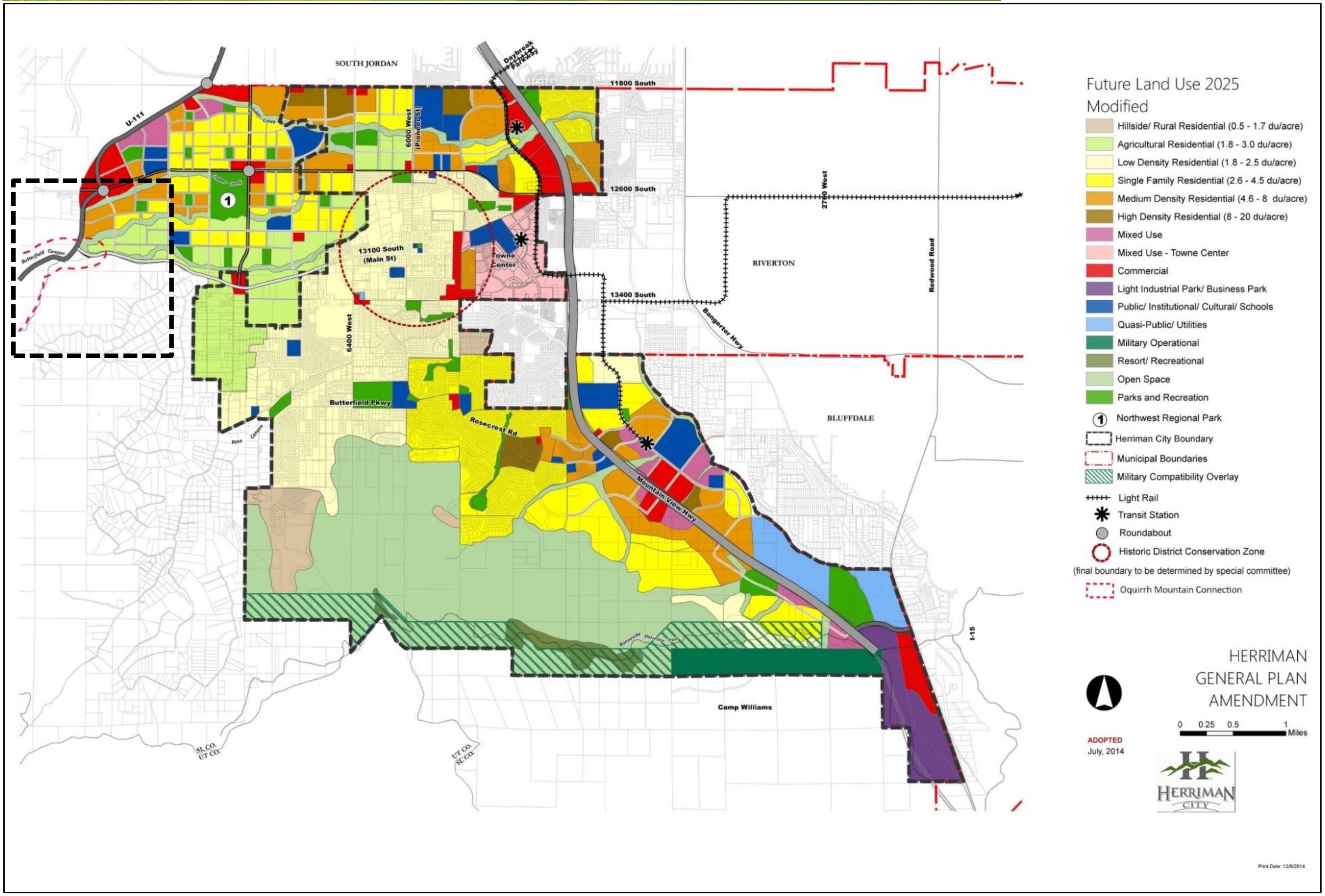


Figure 21: Herriman General Plan – 2025 Future Land Use

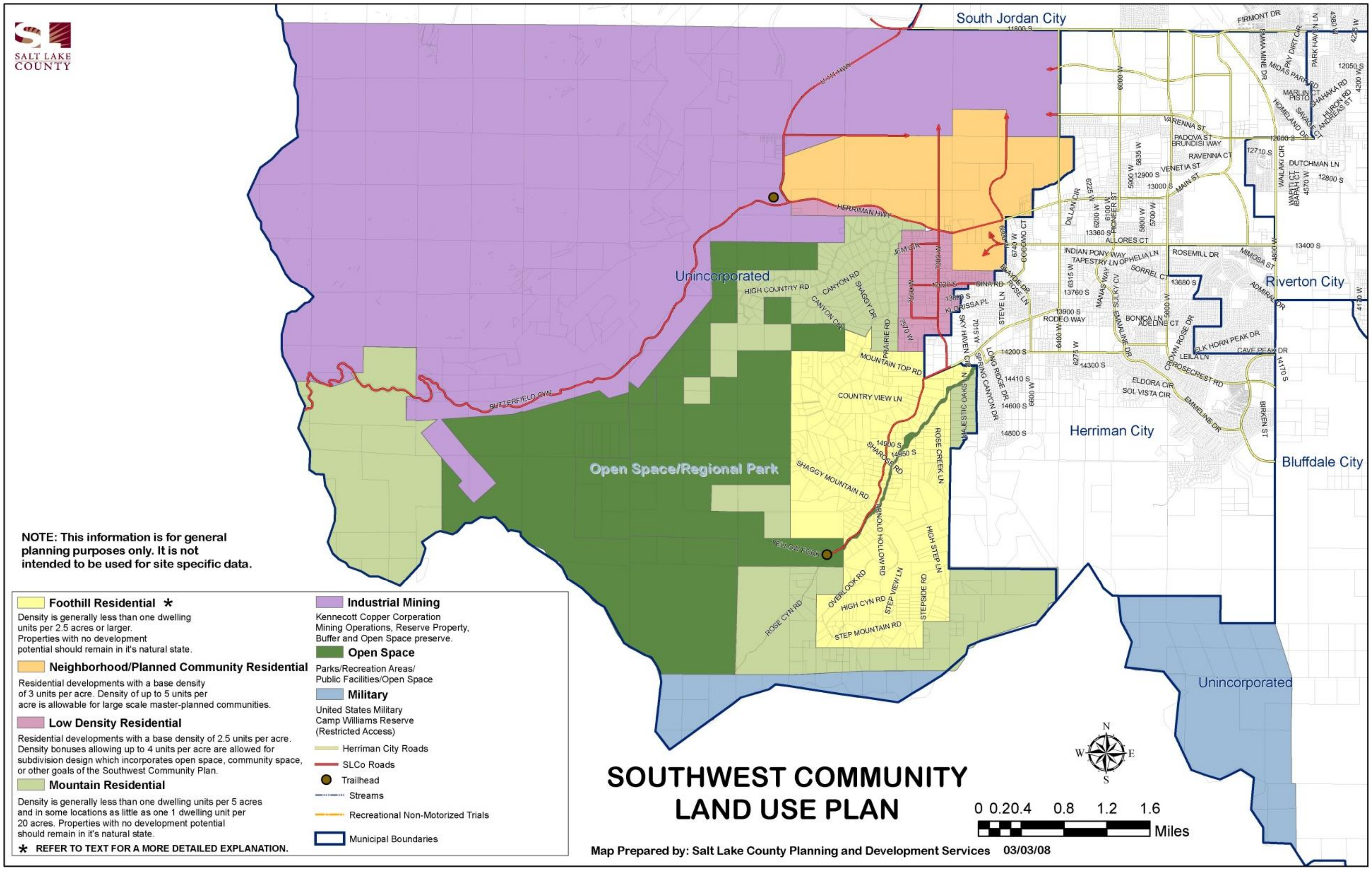


Figure 22: Southwest Community Land Use Plan

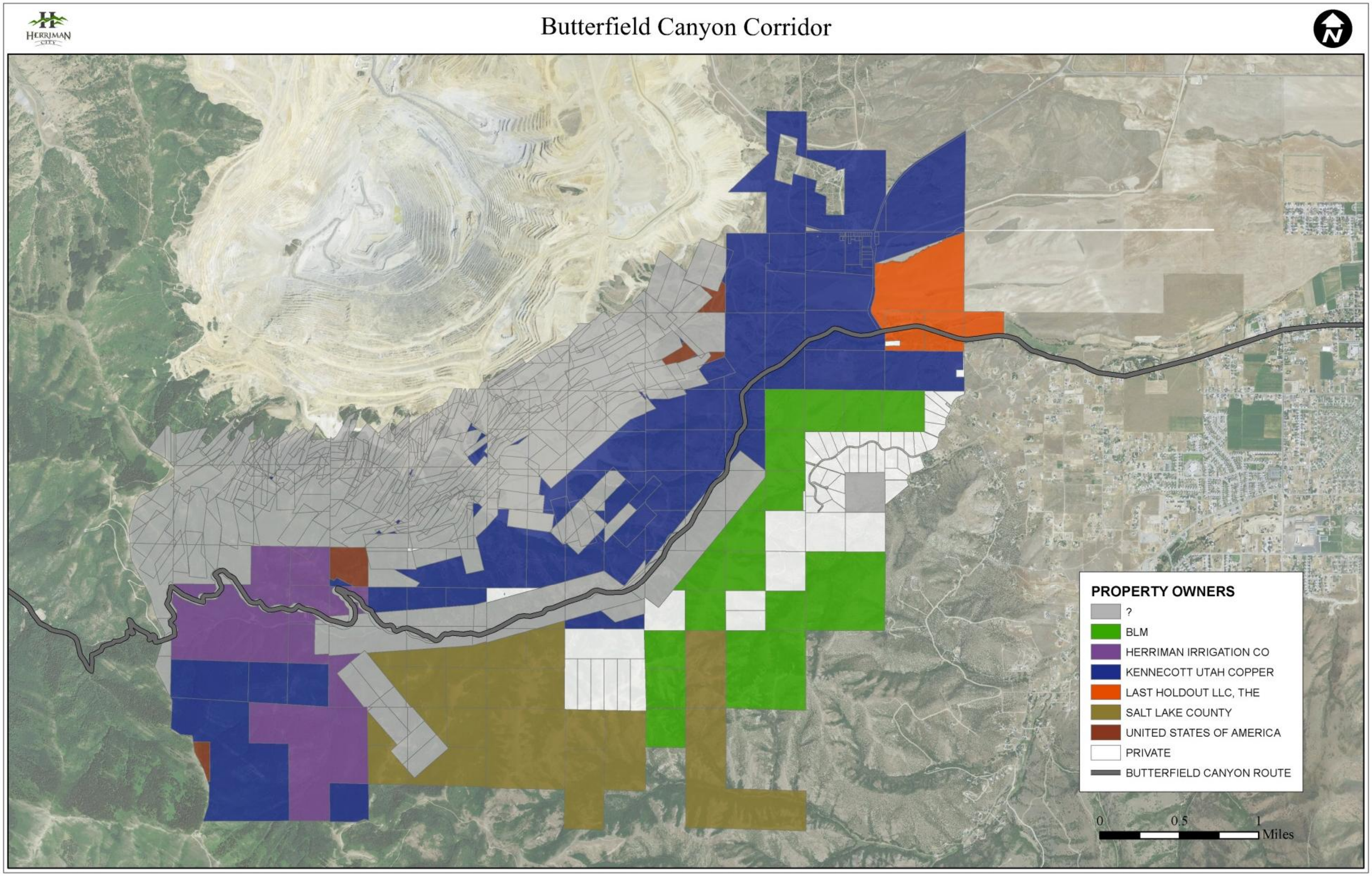


Figure 23: Property Ownership Along Butterfield Canyon Corridor

4.2 Assessment Of Potential Land Use Impacts

4.2.1 Methodology

For the purpose of assessing impacts to existing land uses, publicly-available parcel level use data for the Tooele and Salt Lake counties was utilized. GIS Shapefile data available on the Utah Automated Geographic Reference Center (AGRC) website was accessed and downloaded on March 22, 2017.

Available County-level parcel datasets include a "Property Class" attribute that identifies the existing use (e.g., residential, commercial, mixed-use, etc.) of each property. This attribute was utilized for assessing potential impacts to land uses within a 1/4-mile buffer of the Selected Oquirrh Mountain Connection Alternative.

4.2.2 Potential Land Use Impacts In Tooele County

As mentioned earlier, a 1/4-mile buffer along the Selected Oquirrh Mountain Connection Alternative was created to identify the "Area of Potential Land Use Impacts" (see **Figure 24: Existing Land Use and Land Ownership Along the Oquirrh Mountain Connection**). The key land uses identified along the selected alignment alternative include:

- Middle Canyon Elementary School (approximately 6 acre site) is within a 1/4-mile of the Oquirrh Connection's western termini where it connects with 1000 North at Droubay Road
- The following subdivisions fall within the area of land use impacts, in the vicinity of 1000 North and Droubay Road:
    - Cedarwood Estates
    - Carr Fork
    - Holt Meadows
    - North Fork
    - Middle Canyon Estates
- Agricultural land along the north and west side of the selected alignment, north of Smelter Road
- Oquirrh Hills Golf Course located on the south-east corner of Smelter Road and Droubay Road
- Residential and Agricultural Land along Ericson Road, between Smelter Road and Anaconda Highway
- Agricultural Land (classified as Land Greenbelt or Agricultural) between Smelter Road and Oquirrh Mountain foothills
- Some of the parcels illustrated as 'Unclassified' are either BLM land, or State Trust land

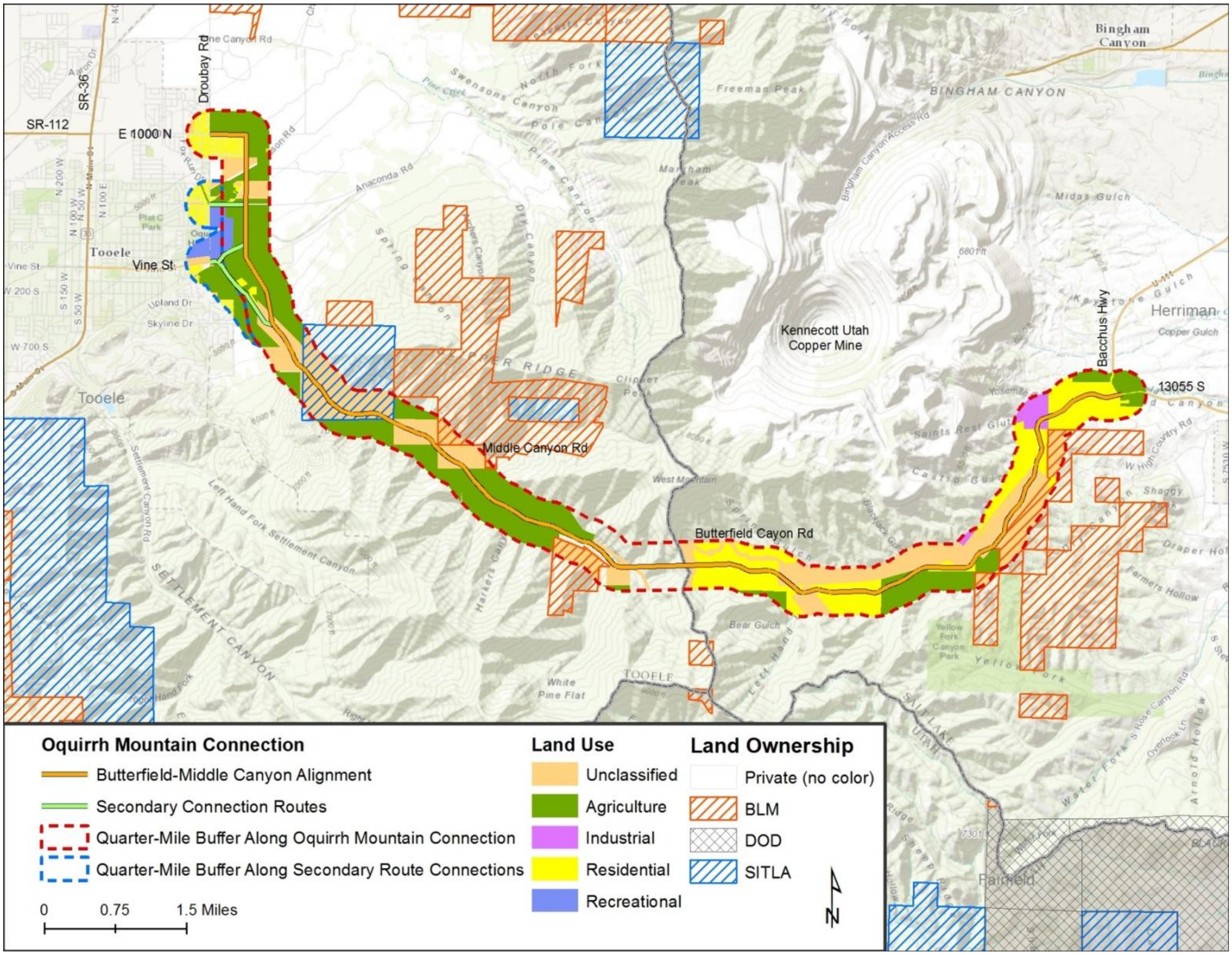


Figure 24: Existing Land Use and Land Ownership Along the Oquirrh Mountain Connection

Table 13: Potential Land Use Impacts Within Tooele County below provides a summary of the land use impacts within Tooele County.

Table 13: Potential Land Use Impacts Within Tooele County

Existing Land Use	Number of Properties Potentially Impacted	Land Area in Acres
Agriculture	62	1270.7
Residential	397	98.5
Recreational (Golf Course)	8	32.3
Other (Unclassified)	22	832.2

4.2.3 Potential Land Use Impacts In Salt Lake County

The key land uses identified along the selected alignment alternative within Salt Lake County (see **Figure 20: Salt Lake County Combined Land Use Map**) include:

- Land with "Residential" classification, east of the Tooele/Salt Lake County Line
- Agricultural land along the selected alignment
- Industrial parcels on the south and east of the Kennecott Copper Mine
- Residential land on the south and east of the Kennecott Copper Mine
- Residential and agricultural land at the eastern termini of the Oquirrh Mountain Connection selected alignment, where it connects with Bacchus Highway
- Some of the parcels illustrated as 'Unclassified' are State Trust land

Table 14: Potential Land Use Impacts Within Salt Lake County below provides a summary of the land use impacts within Salt Lake County.

Table 14: Potential Land Use Impacts Within Salt Lake County

Existing Land Use	Number of Properties Potentially Impacted	Land Area in Acres
Agriculture	15	326.1
Residential	16	847.2
Industrial	4	74.1
Other (Unclassified)	53	718.9

4.2.4 Potential Secondary Land Use Impacts In Tooele County

The primary land use impacts, discussed in the sections above, were identified within the Area of Potential Land Use Impacts along the Oquirrh Mountain Connection. In addition to the main alignment, additional routes in Tooele County will intersect with the selected alignment, and provide access to the Tooele community. These routes include:

1. Smelter Road (east-west connection to Droubay Road)
2. Middle Canyon Road (connection to Vine Street)
3. New Roadway Connection to Vine Street

Secondary land Use impacts have been identified along these routes, which include:

- Residential subdivisions within a quarter-mile of the intersection of Smelter and Droubay Roads:
  - Lakeview Heights
  - Oquirrh Hills Estate
  - Spring Meadows
  - Chelsea Cove
  - Middle Canyon Estates
- Agricultural land on the north east corner of Smelter and Droubay Roads

- Additional land underlying the Oquirrh Hills Golf Course
- Residential subdivisions within a 1/4-mile of the intersection of Vine Street and Droubay Road:
  - East Highlands
  - Vine Street Villas
  - Crestview Estates
- Loma Vista Subdivision on the east side of Middle Canyon Road
- Agricultural land along Middle Canyon Road

Table 15: Potential Land Use Impacts Along Additional Route Connections in Tooele County below provides a summary of the secondary land use impacts along the additional route connections to Tooele City.

Table 15: Potential Land Use Impacts Along Additional Route Connections in Tooele County

Existing Land Use	Number of Parcels Potentially Impacted	Land Area in Acres
Agriculture	22	114.5
Residential	316	58.1
Commercial	1	2.6
Recreational (Golf Course)	6	66.3
Other (Unclassified)	9	18.9

4.2.5 Land Ownership

The selected alignment of the Oquirrh Mountain Connection has proximity to the following land ownership, as illustrated in **Figure 24: Existing Land Use and Land Ownership Along the Oquirrh Mountain Connection**, and **Figure 25 : Land Ownership – Tooele and Salt Lake Counties**:

- BLM Land (Tooele County)
- State Trust Land (Tooele County)
- BLM Land (Salt Lake County)
- Private Land
  - Mountain Residential (Salt Lake County)
  - Major Recreation Area, Parks, Golf Course, Open Space
  - Agriculture, Grazing, Wetlands, Watershed, Forest Land, Reserve Land

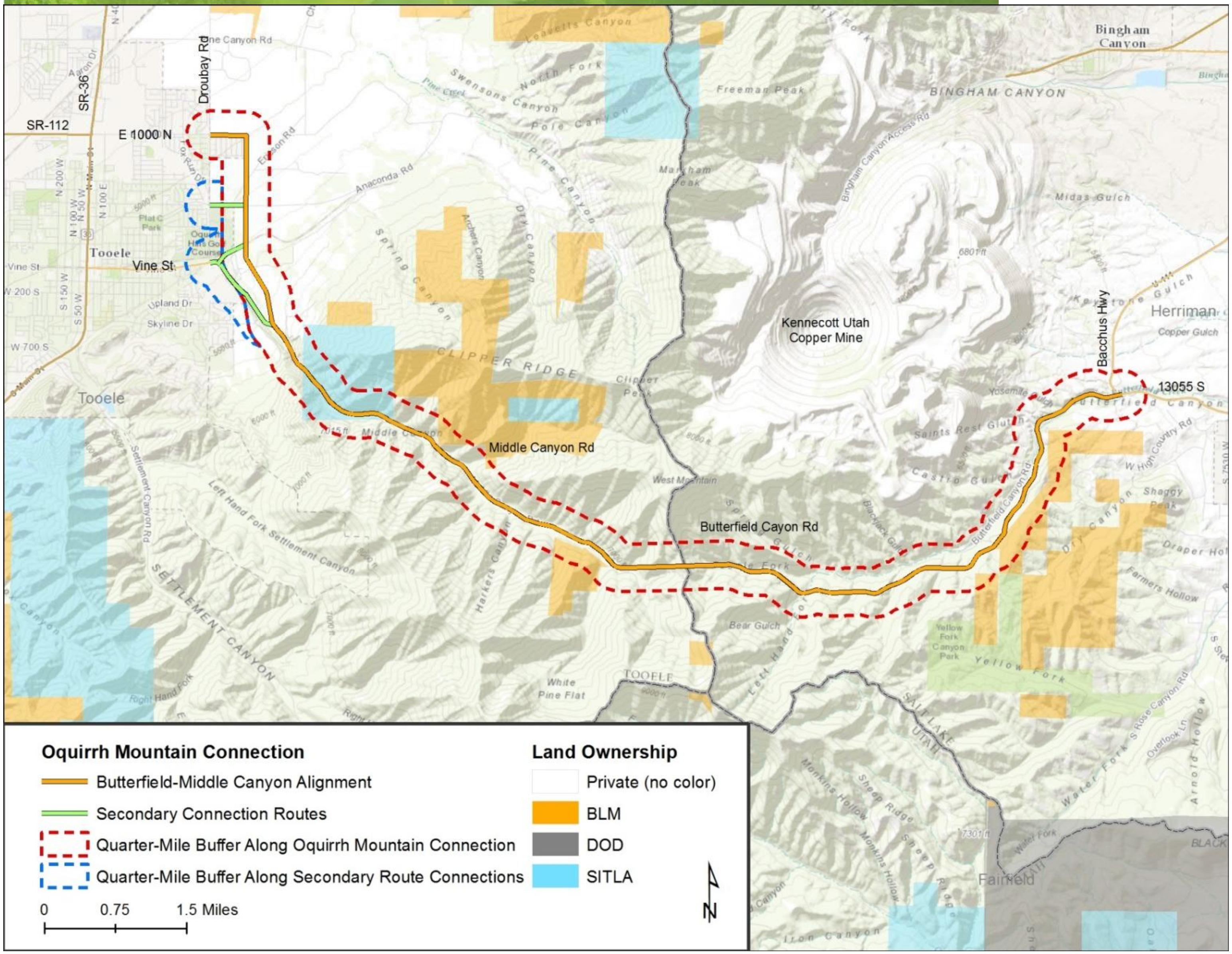


Figure 25 : Land Ownership – Tooele and Salt Lake Counties

4.3 Land Use Susceptibility For Change

Transportation investments have the ability to significantly alter development patterns. The susceptibility of land use for change is dependent on a variety of factors, which include:

- *Access to Transportation Corridors* - In this case, the Oquirrh Mountain Connection could provide the transportation access necessary to facilitate development.
- *Availability of Land with Development or Redevelopment Potential* - As illustrated in the Tooele County General Plan through extensive analysis of developable land, the majority of the growth is expected to occur around the eastern termini of the corridor where developable land is available. This area has a future land use designation of Rural Residential.
- *Proximity to Transportation Nodes* - A total of four transportation nodes (key intersections) exist along the entire length of the corridor. These include:
  - 1000 North & Droubay Road (Tooele)
  - Smelter Road & Droubay Road (Tooele)
  - Vine Street & Middle Canyon Road (Tooele)
  - Bacchus Highway & 13055 South (Herriman)

In the context of the Oquirrh Mountain Connection, a majority of the corridor follows the Middle Canyon Road and Butterfield Canyon Road through agricultural land or open space, which includes mountain slopes and vegetation. In the absence of any major roadway nodes in the central part of the corridor, land use changes are not expected to occur between Tooele and Herriman.

Changes to land use may be expected on either end of the corridor where it connects with the communities of Tooele and Herriman. **Figure 26: Land Use Susceptibility for Change** illustrates the four transportation nodes identified above, and the area around them within a half-mile radius that may be susceptible to change.

On the Tooele City side, the existing land uses within the susceptibility zone consist of agriculture, residential, and recreational. The agricultural areas in the vicinity of 1000 North and Droubay Road are classified as Rural Residential (very low density) in the future land use plan. These areas may evolve into slightly higher density residential, likely smaller lot higher-end housing. Some townhouse/rowhouse or apartment style housing may also evolve in this area, if demand warrants. The transportation nodes are also expected to attract convenience commercial development (e.g., convenience retail, neighborhood services, small professional offices, child care, dry-cleaning, etc.) immediately around the roadway intersections. Often times, transportation nodes similar to that described here could eventually develop with neighborhood-oriented commercial/services on two of the intersection corners and mid- to higher-density housing on the other two intersection corners.

On the Herriman City side, the area to the north and east of the Bacchus Highway/13055 S side is classified as Agricultural Residential and Medium Density Residential. This area may also see similar increase in density with higher-end slightly smaller lot housing development. Since this is the last transportation node out of Herriman towards Tooele City, greater intensity convenience-commercial development could also occur at this location.

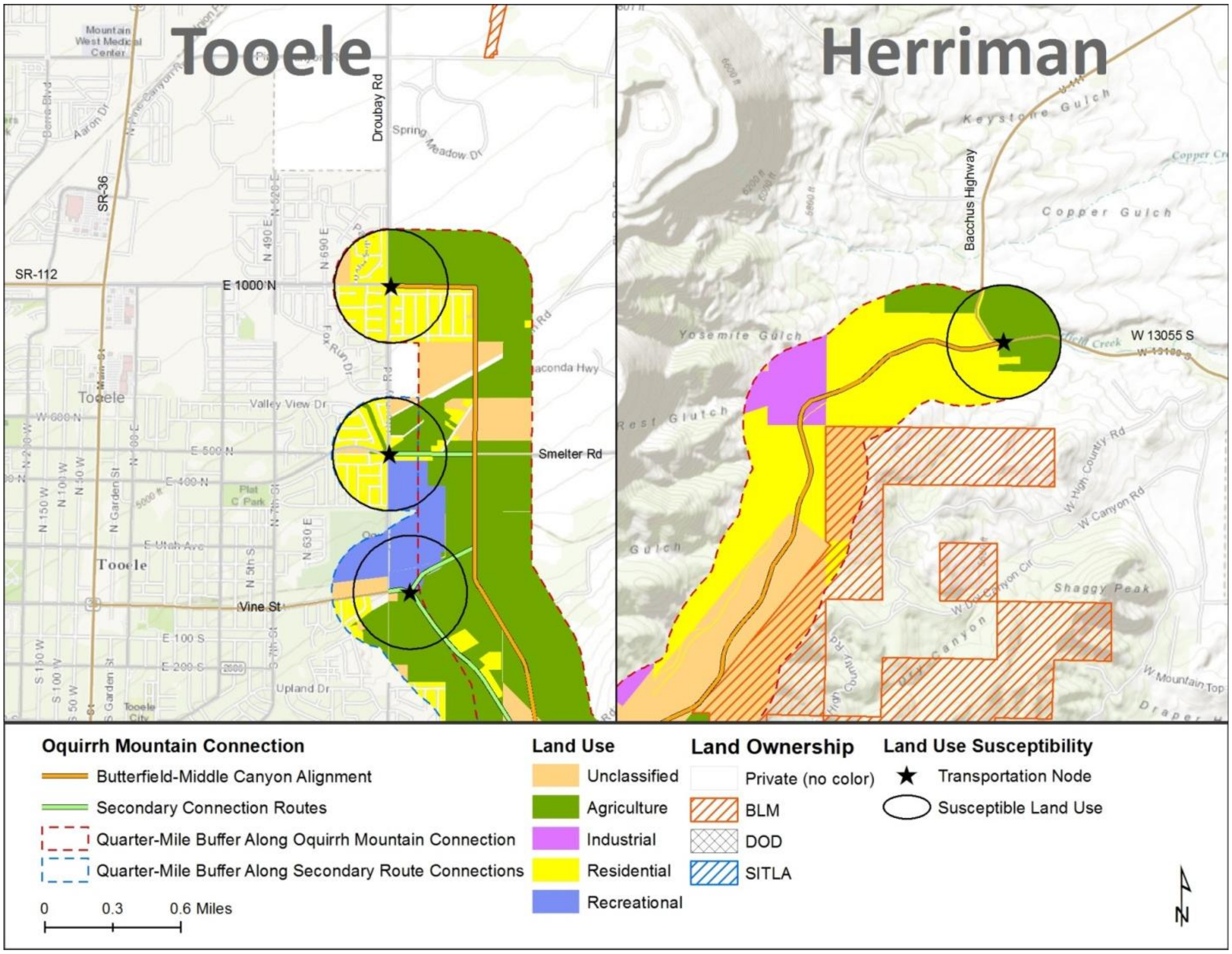


Figure 26: Land Use Susceptibility for Change

5.0 BENEFIT COST ANALYSIS – PREFERRED ALTERNATIVE

According to CNBC, Utah was America's top state for business in 2016 based on more than 60 measures of competitiveness, such as workforce, cost of doing business, infrastructure, economy, quality of life, technology & innovation, education, and business friendliness. In eight of the past ten years, Utah has ranked in the top five on CNBC's Top States for Business (CNBC, 2016). Three Utah cities made Forbes top 10 Best Places for Business and Careers in 2016, and in 2015. Salt Lake City was named one of the best places to launch a startup outside of New York City and Silicon Valley (Forbes, 2015 and 2016).

Lower land prices and newer housing options in Tooele County have attracted home buyers from Salt Lake County that are willing to "drive 'til you qualify" for a home loan (meaning the farther from Salt Lake City, the more affordable homes become). According to the Tooele County Assessor's Office, 82 percent of the housing units in Tooele County are single-family homes. The median value of owner-occupied units for 2015 was $177,700. More than half the homes (54 percent) have been built since 1990 and 33 percent of homes have been built since 2000 (ACS, 2016).

According to the 2016 General Plan Update, Tooele County is projected to increase to a population of over 127,000 by 2040, almost double the current population of nearly 65,000 (2016 estimate from the U.S. Census Bureau). These estimates consider the current growth constraints related to limited water resources and the lack of centralized sewer infrastructure. Actual numbers could be greater if technological advances resolve current growth constraints. Based on the average persons per household, about 20,000 additional households will be needed to accommodate the projected population growth (Tooele County General Plan, 2016).

At the other end of the Project, Herriman is one of the fastest growing cities in Utah. Similar to Tooele, this is a bedroom community with 86 percent of units categorized as single-family homes. In Herriman City, 92 percent of homes have been built since 1990 and 79 percent of homes have been built since 2000. The median value of owner-occupied units for 2015 was $293,400 (ACS, 2016). According to the Herriman City 2025 General Plan Amendment (2013), the population is projected to grow to over 100,000 by 2040 – an average of 769 new households per year.

In Herriman there are only 0.32 jobs per household in contrast to Salt Lake County where there are 1.72 jobs per household (Herriman City, 2013). The neighboring Riverton community has few jobs per household as well (0.81). This reflects that most citizens work outside of Herriman. There are few large employers in Herriman and none with more than 250 employees.

Creating new access through the Oquirrh Mountains is likely to encourage housing development in Tooele County and provide more affordable housing options for people working in southern Salt Lake County and Utah County. There is also potential for larger employers to consider locating in Tooele County.

5.1 Benefit-Cost Analysis Framework

The Benefit-Cost Analysis (BCA) was conducted using the *TIGER Benefit-Cost Analysis Resource Guide* (USDOT, 2016b) for preferred methods and monetized values and follows the guidance from the United States Department of Transportation (USDOT, 2016a and 2003). A custom BCA model was developed to estimate the Project's future costs and benefits. Benefits were estimated over a 20-year period beginning in 2034 until 2053. The base year is when costs are expected to begin accruing (2031) and all values were discounted to the base year. It was assumed that 2034 would be the first year that the roadway would be open and benefits would begin accruing at the beginning of the year. All costs and benefits are in constant 2017 dollars.

The proposed Project is a 23-mile road that would connect Tooele and Herriman via Butterfield-Middle Canyons. The base case or No Build Alternative is the most likely scenario if the Project were not built. For the No Build Alternative, it is expected that I-80 and I-15 would be used to travel between Tooele, Salt Lake, and Utah counties. The Project was compared to the No Build Alternative to identify incremental costs and benefits.

In accordance with USDOT guidance (USDOT, 2015a), the BCA focuses on the system-wide traffic improvements resulting solely from the Project. In addition to reducing driving distance and travel times, the Project is expected to generate new trips between the three counties that would not occur under the No Build Alternative.

Although the average speed for the No Build Alternative is higher than the Build Alternative, creating a route that is less than half the distance of the No Build Alternative would result in travel time savings, vehicle operating cost savings, improved safety, and air quality benefits. The addition of a bike lane on the new roadway and an off-road paved trail to bypass the tunnel would create mobility, recreation, and health benefits.

The improved travel time and reduced distance between Tooele and Herriman can be expected to increase development in Tooele and attract some drivers who would otherwise not take a trip (induced trips). However, these induced trips were not included in the BCA and were assessed qualitatively in Section 5.2.5.4.

5.1.1 Benefit-Cost Analysis (BCA) Model

A custom BCA model was created to estimate the Project's total future benefits and costs over a 23-year lifecycle. Although benefits are expected to accrue after the 23-year period of analysis, residual value estimates for Project components that would continue to have any remaining period of useful operating life beyond the period of analysis were not included.

Generally, USDOT standard factors and prices were used for the BCA calculation except in cases where more Project-specific values or prices were available. In all such cases, modifications are noted and references are provided for data sources.

5.1.2 Key Assumptions

The key assumptions for the BCA are identified and discussed in the following sections, as well as assumptions applicable solely to specific benefits or costs and their respective quantification.

5.1.2.1 2017 Constant Dollars

The benefits and costs are expressed in constant dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The gross domestic product chained price index from the Office of Management and Budget was used to adjust past cost estimates or price values into 2017 dollar terms (OMB, 2017).

5.1.2.2 Real Discount Rate

The use of constant dollar values requires the use of a real discount rate for discounting to the present value. Future values were discounted using a 7 percent discount rate in accordance with both the USDOT guidance for the TIGER grant application and standard federal BCA methodology recommendations (USDOT, 2016a; OMB, 1992 and 2003). Results are also presented using a 3 percent real discount rate. All costs and benefits were discounted to 2031 (base year).

5.1.2.3 Period of Analysis

The analysis period for the BCA begins in 2031 and ends in 2053. Benefits are estimated over a 20-year period, assuming the roadway would open at the beginning of 2034.

5.2 Benefit Analysis

Five primary categories of user benefits were quantified: vehicle operating cost savings, safety benefits, travel time savings, air quality, and bicycle facility benefits. It is also expected that the Project would result in livability improvements; however, these benefits were not included in the BCA.

5.2.1 Vehicle Operating Cost Savings

Compared with the current route to travel between Tooele, Salt Lake, and Utah counties using I-80 and I-15, the Oquirrh Connection would reduce the travel distance to less than half of the No Build distance between Tooele and Herriman. Fewer vehicle miles traveled (VMT) reduces vehicle operating costs.

5.2.1.1 Reduced Fuel Use

The fuel savings for future highway users were valued using average annual gasoline and diesel prices from the Energy Information Administration's (EIA) 2017 Annual Energy Outlook "reference case" for projected fuel prices (EIA, 2017). Fuel price projections were adjusted to 2017 dollars. It was assumed that all vehicles would be passenger vehicles (autos) that use gasoline.

Average speeds from traffic modeling were compared with fuel consumption rates (gallons per mile) for automobiles (Cohn, et. al., 1992; AASHTO, 2010) to calculate the number of gallons consumed. The average fuel consumption by travel speed was based on the forecasts in **Table 16 : Projected Volume, Distance, and Average Speed (2034 and 2050)** that were generated using the Utah Statewide Travel Model.

Table 16 : Projected Volume, Distance, and Average Speed (2034 and 2050)

Alternative	Volume (vehicles per day)	Distance (miles)	Average Speed (miles per hour)
2034 No Build	4,711	45.8	52.2
2034 Build	4,711	20.2	33.5
2050 No Build	7,367	45.8	52.7
2050 Build	7,367	20.2	29.8

Annual VMT was calculated as the product of the volume of vehicles per year (vehicles per day annualized using a conservative factor of 300) and distance. VMT for the period of analysis (2034 – 2053) was projected from this primary data using linear interpolation. The annual total value of the expected vehicle fuel cost savings was based on the vehicle type (passenger vehicle), annual VMT, the average travel speeds for each segment, and the corresponding value for fuel.

Over the 20-year period of analysis, the Project is expected to result in over 35 million gallons of fuel saved and more than $214 million (undiscounted) in fuel cost savings for its highway users. The net present value of the Project's expected fuel cost savings are estimated to be $89.3 million using a 7 percent discount rate and $143.7 million using a 3 percent discount rate.

5.2.1.2 Other Vehicle Cost Savings

Other non-fuel vehicle operating expenses include tire wear, maintenance, and depreciation. These costs are based on VMT changes between the No Build and Build Alternatives. Costs per were obtained from the American Automobile Association (2016) and updated to 2017 dollars. The conservative estimate of $0.19 per VMT is the composite average marginal cost of tires, maintenance, and half of depreciation.

Over the 20-year period of analysis, the Oquirrh Connection is expected to result in $185 million (undiscounted) in other vehicle cost savings (besides fuel) for its highway users. The net present value of the Project's expected other vehicle cost savings are estimated to be $80.7 million using a 7 percent discount rate and $126.4 million using a 3 percent discount rate.

5.2.1.3 Combined Vehicle Operating Cost Savings

Combining reduced fuel costs, less tire wear, lower maintenance costs, and depreciation results in a total vehicle operating cost savings of nearly $400 million over the 20-year period of analysis (undiscounted). The net present value of the Oquirrh Connection's total vehicle operating cost savings are estimated to be $170 million using a 7 percent discount rate and over $270 million using a 3 percent discount rate.

5.2.2 Safety Benefits

Changes in VMT result in changes to the number of vehicle-related accidents. By reducing

VMT, the Project is expected to reduce the number of future vehicle-related accidents. The safety benefits were derived from avoiding fatalities and reducing accident-related personal injuries and property damage from accidents (to vehicles and structures). When the number of accidents is reduced, emergency responder, time delay, emissions, and excess fuel burn costs would also be reduced; however, these additional benefits were not included in the BCA.

In the absence of specific accident rate information for the Project, national average accident rates were used to estimate the number of fatalities, injuries, and crashes based on changes to VMT. National average accident rates per 100 million vehicle-miles were obtained from the Bureau of Transportation Statistics. Preliminary estimates for 2015 are 1.13 fatalities, 79 injuries, and 203 crashes per 100 million vehicle-miles (BTS, 2015).

Safety benefits were calculated as the net difference between the accident costs of the Build and No Build alternatives. Accident costs were estimated from annual VMT, the type and severity of the accidents, and the unit costs of accidents. Methodologies in U.S. DOT guidance documents were followed to estimate the severity and cost of accidents using the accident rates per 100 million VMT (USDOT, 2016b). The accident cost was estimated to be $0.27 per VMT.

Over the 20-year period of analysis, the Oquirrh Connection is expected to result in total safety benefits of over $260 million for its highway users (undiscounted). The net present value of the safety benefits are estimated to be $113.4 million using a 7 percent discount rate and $177.7 million using a 3 percent discount rate.

5.2.3 Travel Time Savings

The value of travel time savings depends on the characteristics of the travelling population, the mode, time, purpose of travel, and in some cases the location and/or availability of alternative transportation modes under the No Build and Build Alternatives. The value users assign to their travel time depends on their opportunity cost for that time. Travel time value varies by trip purpose: work travel time or personal time (which includes commuting).

Table 17: Projected Volume and Travel Time (2034 and 2050) presents the volume per day and travel time for both the Build and No Build Alternatives for 2034 and 2050. Vehicle hours travelled (VHT) for the period of analysis (2034 – 2053) was projected from this primary data using linear interpolation. The No Build Alternative was compared with the Build Alternative to calculate the hours saved by the Project.

Table 17: Projected Volume and Travel Time (2034 and 2050)

Alternative	2034 Volume (vehicles per day)	2050 Volume (vehicles per day)	2034 Travel Time (minutes)	2050 Travel Time (minutes)
No Build	4,711	7,367	52.6	52.2
Build	4,711	7,367	36.1	40.7

The annual total value of the expected VHT was calculated by multiplying the number of vehicles per day by the travel time and then annualized using a factor of 300 (instead of 365 days) because the Utah Statewide Travel Model does not differentiate well between weekday and weekend traffic at a localized level. The VHT savings is the difference between the VHT for the No Build and Build Alternatives. The travel time benefit is the net VHT savings multiplied by the corresponding value of time estimates.

Average vehicle occupancy varies by the time of day, location, and whether in the general purpose or express lanes. For simplicity, the travel time benefits in the BCA were conservatively estimated assuming that there is only one person per passenger vehicle even though vehicle occupancy rates are expected to be higher.

The proposed Project is estimated to initially result in nearly 389,000 hours of travel time saving in 2034 and over 430,000 hours by 2053. Over the 20-year period of analysis, the Oquirrh Connection is expected to result in total time travel savings of nearly 8.2 million hours for future highway users. All traffic estimates are for passenger vehicles since it is unclear whether commercial trucks will use the new route created by the Project.

The analysis uses values of time following the USDOT's Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (2016c). The income data used in the USDOT guidance are derived from regularly updated public sources. Due to the unavailability of a breakdown of trip purposes, the intercity travel value of time for all purposes of travel was used and updated to 2017 dollars, resulting in an hourly value of $21.02 per person.

A future increase in wages greater than the rate of inflation would result in a real growth in the value of employees' wages, which would increase the value of time for future roadway users. However, the BCA conservatively assumes that the real value of current wage rates will remain constant over the 20-year period of analysis and is consistent with USDOT guidance.

Over the 20-year period of analysis, the Oquirrh Connection is expected to result in total travel time savings of about $172 million for its highway users (undiscounted). The net present value of the travel time savings are estimated to be about $78.7 million using a 7 percent discount rate and approximately $120 million using a 3 percent discount rate.

5.2.4 Air Quality

Shorter distance and less travel time result in less fuel consumption, which reduces air emissions that would otherwise occur under the No Build Alternative. The amount of air emissions emitted depends on the quantity of fuel consumed, the emission profile of the vehicle, and the vehicle's fuel efficiency. Air emissions considered include carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM), sulfur oxides (SO_x), and volatile organic compounds (VOCs). Criteria air pollutants (CAPs) include NO_x, PM, SO_x and VOCs and greenhouse gas (GHG) emissions includes only CO_2 emissions.

Emission factors for automobiles were obtained from the Environmental Protection Agency (EPA, 2008a and 2008b) and used to quantify the Project's expected future air emission impacts. These factors (measured in pounds per gallon of fuel) were applied to the total gallons of gasoline fuel reductions calculated for the vehicle operating savings to estimate the total metric tons of emission reductions for each air pollutant.

5.2.4.1 Criteria Air Pollutants

The monetary values for the reduced emissions used in the BCA are based on USDOT guidance (2016b) and adjusted into 2017 dollar terms. Annual values of CAPs were discounted at 7 percent and 3 percent rates. The value of CO_2 reductions are discussed separately as GHG emissions.

Greenhouse Gas Emissions

The GHG emission values are based on the Social Cost of Carbon (SCC) developed by the Federal Interagency Working Group on Social Cost of Carbon and suggested by TIGER guidance (USDOT, 2016b). SCC values were inflated to 2017 dollars.

Federal SCC guidance recommends that GHG emissions are valued with a lower discount rate than other benefits because carbon dioxide emissions are long-lived and subsequent damages persist over many years. A 3 percent discount rate was selected as a central value that reflects the after-tax riskless interest rate and is consistent with OMB's Circular A-4 guidance for the consumptive rate of interest.

The GHG emissions value was calculated by multiplying the quantity in metric tons of carbon dioxide by the appropriate SCC value in that same year. The GHG benefits were discounted at 3 percent, irrespective of the discount rate otherwise selected for the BCA, to obtain the net present value.

Estimated Air Quality Benefits

The amount of emission reductions was based on the gallons of gasoline that would be saved as the result of the Project. Over the 20-year period of analysis, the Oquirrh Connection is expected to result in more than 35 million gallons of fuel saved. The resulting net reductions in emissions in metric tons are presented in **Table 18: Net Reduction in Emissions.**

Table 18: Net Reduction in Emissions

Emission Source	Net Reduction in Metric Tons (2034 – 2053)
Carbon Dioxide	366,239
Volatile Organic Compounds	938
Nitrogen Oxides	682
Particulate Matter	4
Sulfur Oxides	1

Note: Values were rounded to the nearest whole number.

The total GHG emission benefit over the period of analysis is nearly $27 million (undiscounted) and the CAP benefit is over $9 million (undiscounted). The net present value of the Oquirrh Connection's emission reduction benefits were estimated to be $30.9 million using a 7 percent discount rate and $24.4 million using a 3 percent discount rate.

5.2.5 Benefits Not Included in the BCA

The Project is expected to produce additional benefits that could not be adequately quantified for inclusion in BCA. The BCA excludes a number of societal or user benefits because they are difficult to measure given the currently available information. Inclusion of these additional benefits would increase the overall benefit-cost ratio.

5.2.5.1 Livability

Livability is a measure of all the factors that contribute to a community's quality of life. The Oquirrh Connection will directly improve residents' ability to travel both for work and leisure to destinations in other cities. With the Project, residents may have greater access to affordable housing options and high quality employment. New trailheads, bike facilities, and bike paths increase mobility, safety, and provide more recreation opportunities.

Transportation studies have attempted to develop estimates of the real estate price appreciation for areas with improved livability, but the causal relationships are weak and most studies have imputed very limited housing price benefits. Consequently, no livability benefits are included in the BCA.

5.2.5.2 Bicycle Facility Benefits

The new roadway is proposed to have 10-foot shoulders that could be jointly used for roadside parking and bicycling. For non-motorized traffic, a tunnel bypass would be provided. The bypass would connect in Butterfield Canyon in Salt Lake County before the tunnel by creating a new paved trail, approximately ¼ mile in length, from the preferred roadway alignment to the existing Butterfield Canyon Road. The existing road would remain in its current condition and used by local traffic and cyclists that choose to not use the new on-street bicycle facility. At the top where Butterfield and Middle Canyon meet, the road would be paved to trail width (10 to 14-feet) for approximately 1.5 miles, down Middle Canyon until it meets the western tunnel end. The separated multi-use paved path would also link to the Kennecott Canyon overlook road.

Although the new roadway would have a shoulder large enough for a designated bike lane, the Oquirrh Connection does not currently include this type of facility. The new roadway would include bicycle signage to indicate that cyclists would be sharing the roadway, and signs to direct cyclists to parallel pathways for certain areas (like the tunnel) where it would be safer for cyclists to be separated from the roadway.

If the Project added a designated bike lane to the new roadway connecting Tooele and Herriman, it would increase mobility for commuters, expand recreation options, and would result in health benefits to new cyclists. It is possible that a portion of these benefits would be realized without bicycle lane striping and symbols, however, studies have shown that a cyclist's perceived level of comfort is higher when a striped area is provided and unmarked lanes would not adequately serve the needs of the majority of cyclists (FHWA, 2013).

To evaluate the benefits of a potential new bicycling facility, first the demand was assessed. It is likely that a new bicycling facility would be used by many people who do not live near it and some local residents may ride, but not on the facility. The estimated demand provides the number of cyclists in the immediate area of the facility and how the presence of a new facility might impact that number. Guidance from the Transportation Research Board (TRB) National Cooperative Highway Research Program asserts that "a large portion of total bicycling is done by a small fraction of cyclists who ride frequently, and that many of those frequent riders are bike commuters" (TRB, 2006). Therefore, the number of people that commute to work by bicycle was used as a leading indicator of all types of cycling.

The daily average number of adult cyclists from the area around the facility was based on observed relationships from around the nation and adheres to the methodology outlined in TRB guidance. People are more likely to ride a bicycle if they live within 1.5 miles of a facility than if they lived outside that distance, and the likelihood of cycling increases the closer people are to the bicycle facility (TRB, 2006).

In the area of Herriman where the new roadway would begin, less than 5 percent of workers work outside of Salt Lake County, whereas nearly 43 percent of workers living in Tooele work outside of Tooele County (ACS, 2016). From this information, it is inferred that the majority of bicycle commuters would originate from Tooele. Moreover, in the Herriman Census tract that surrounds the beginning of the new roadway, no workers claimed commuting to work by bicycle (ACS, 2016). Since the demand is based on the number of existing commuting cyclists, demand was estimated only using Tooele information. This underestimates the total benefits as it is expected that there would be recreational use of the facility from Herriman residents as well as Tooele residents.

Although bicycle demand was estimated annually for the entire period of analysis, **Table 19: Tooele Bicycling Demand for 2034 and 2053** only displays a summary of the bicycle demand values for each category for years 2034 and 2053. Existing cyclists are the baseline conditions and new cyclists are estimated to be induced by a new bicycle facility. The total and new daily cyclist values include the number of bicycle commuters. A new bicycle facility is estimated to induce between 22 and 94 new cyclists in 2034 and between 34 and 144 new cyclists in 2053. The most likely values (57 new cyclists annually, on average) were used to estimate mobility, health, and recreation user benefits.

Table 19: Tooele Bicycling Demand for 2034 and 2053

Year	2034	2053
Daily Existing Bicycle Commuters	26	39
New Daily Commuters	9	14
Total Daily Existing Adult Cyclists - Low	63	96
Total Daily Existing Adult Cyclists - Most Likely	126	193
Total Daily Existing Adult Cyclists - High	265	405
New Daily Adult Cyclists - Low	22	34
New Daily Adult Cyclists - Most Likely	45	69
New Daily Adult Cyclists - High	94	144

Mobility

A dedicated bike lane improves movement and safety for cyclists. People are willing to travel additional time for improved bicycle facilities. For an off-street bike facility, individuals would be willing to travel an additional 20.38 minutes per trip and an additional 18.02 minutes for an on-street bicycle lane (TRB, 2006).

Although the new bike facility would include an off-street trail portion around the tunnel, the majority of the proposed bike lane would be on-street; therefore, the value for an on-street bicycle lane was used to estimate the mobility benefit. The analysis uses the intercity value of travel time for all purposes of $21.02 per hour in 2017 dollars (USDOT, 2016c). The value per trip is estimated to be $6.31 for cyclists that would be commuting to work.

The per-trip benefit was multiplied by the annual number of existing and new commuting cyclists. The annual value assumes commuters bike roundtrip, 5 days a week, for 42 weeks of the year (adjusted from the TRB assumption of 47 weeks per year after considering the average annual number of days that the Salt Lake and Tooele Valleys have snowstorms). The number of annual trips ranges from 14,685 in 2034 to 22,465 in 2053. The total undiscounted benefit over the 20-year period is estimated to be over $2.3 million.

Recreation

A new bicycle facility is expected to encourage more recreational cyclists. Different economic methods used to estimate the value of recreational activities generated a typical value of $51.13 per day in 2017 dollars, which is an estimate of the net benefit above and beyond the value of the time taken by the activity itself (TRB, 2006). Assuming a day of recreation would be about 4 hours and that recreation via biking would average one hour per trip, the value per recreational cycling trip, per day would be $12.78 for induced cyclists. The recreational benefits do not include a health benefit.

The number of new daily commuters was subtracted from the total number of new daily cyclists to obtain the number of new daily recreational cyclists. To annualize the number of recreational cyclists, the number of daily recreational cyclists was multiplied by the net daily benefit and 126 days. The annual value assumes recreational cyclist ride 42 weeks of the year and 3 days per week. The number of annual recreation hours ranges from 4,496 in 2034 to 6,879 in 2053. The total undiscounted benefit over the 20-year period is estimated to be nearly $1.5 million.

Health

Benefits of physical activity include weight loss, reduced risk of chronic diseases, and a longer lifespan. User health benefits were monetized by applying the healthcare cost savings that would be realized by increasing physical activity. Annual per capita healthcare cost savings vary between $23 and $1,410 with a median value of $154 in 2017 dollars (TRB, 2006). The median value of $154 per person, per year, was used to estimate the healthcare cost saving for the induced cyclists.

The annual health benefit was applied to the total number of new recreational cyclists that were estimated to be induced by a new bicycle facility (not including commuting cyclists). The annual health benefit ranges from about $6,900 in 2034 to $10,500 in 2053. Using the most likely demand value, the total undiscounted benefit over the 20-year period is estimated to be over $174,000.

Combined Bicycle Facility Benefits

Combining mobility, recreation, and health benefits results in total bicycle facility benefits of nearly $4 million over the 20-year period of analysis (undiscounted). The net present value of the total bicycle facility benefits are estimated to be $1.75 million using a 7 percent discount rate and $2.7 million using a 3 percent discount rate.

5.2.5.3 Other Recreation

Existing recreational pull outs have been identified along the length of the preferred alignment. Currently, there are more than 40 locations where vehicles may leave the existing Middle Canyon Road. The majority of these access points are located along the Middle Canyon alignment in Tooele County, where current recreational use is most prevalent. Some of these recreational access points include picnic sites and improved camping locations.

Consolidating access points into areas that would have parking and signage indicating trailheads would increase safety and enhance the recreation experience. Recreation can be improved further with the introduction of permanent campgrounds or day use areas and side access roads to keep slow moving recreational vehicles off of the main road.

As part of a new roadway facility, designated parking and access areas would be constructed or set aside for future construction by Salt Lake and Tooele Counties or the Bureau of Land Management, as appropriate. Signage for existing recreation trails and sites would be included as part of the new roadway.

The BCA does not include the additional recreation benefits from improving the existing recreation facilities.

5.2.5.4 Induced Trips

Creating a new connection between Tooele County and Salt Lake and Utah Counties expands opportunities for employment and housing among these areas. As a result of this new access, more people may move to Tooele County and commute to the southern Salt Lake County or northern Utah County. Additionally, the improved travel time and reduced distance between Tooele and Herriman can be expected to attract some drivers who would otherwise not take a trip.

Table 20: Number of Induced Trips by Year, provides a description of trips induced by the Oquirrh Connection that were generated using the Utah Statewide Travel Model. Some trips would occur without the Project in northern Salt Lake County, but with the Project they transfer to the new roadway. Other trips are completely new trips that occur because there would be a shorter and faster route from Tooele to the Wasatch Front. It is uncertain what proportion of the induced trips would occur without the Project in other areas of northern Salt Lake County and the details of those trips; therefore, benefits and costs from induced trips were not included in the BCA.

Table 20: Number of Induced Trips by Year

Description	2034	2050
Daily induced trips transferring from northern Salt lake County to the new road	2,200	2,600
Daily induced trips from Tooele to the Wasatch Front	4,200	5,000

Note: Number of induced trips were rounded to the nearest hundred.

5.2.5.5 Safety

Although vehicles can currently travel through Middle Canyon and Butterfield Canyon, the road is narrow, winding, and steep with unpaved sections through Middle Canyon. The currently configured route poses safety concerns and is closed to traffic during the winter. The new route between Tooele and Herriman would include the following safety improvements:

- widening and paving the existing road,
- joint use parking/bicycling shoulder,
- limiting the grade to a maximum of 6 percent.

These safety improvements are expected to reduce accidents and accident-related costs. Accident costs avoided would include fatalities, injuries, property damage (to vehicles and structures), and emergency services. The BCA includes safety benefits from the reduced VMT expected from the Oquirrh Connection but does not include the additional safety benefits that would accrue from improving the existing road.

5.2.5.6 Construction Delays

All Project-related construction activity would be performed during off-peak traffic periods. Consequently, traffic impacts during construction periods are expected to be limited with few, if any delays to roadway users. Therefore, in the absence of any projected congestion and significant increase in vehicle hours traveled, no economic costs (negative benefits) from construction-related delays and inconvenience to roadway users are included in the BCA.

5.3 Cost Analysis

For the BCA, the term ‘cost’ refers to the additional resources or expenditures required to implement, perpetuate, and maintain the investments associated with the Project. The BCA uses Project costs that have been estimated on an annual basis. All costs are shown in real 2017 dollars.

5.3.1 Capital Costs

Without discounting, the total capital costs were estimated to be $328.7 million, including a 25 percent contingency. Spending for capital costs was expected to begin in 2031 and continue until the completion of construction activities in 2033. The period for construction would be about 30 months. Without a detailed cost schedule, it was assumed that 20 percent of the capital costs would be spent in 2031 and 40 percent would be spent in both 2032 and 2033. The present value of the Project’s capital costs were estimated to be $303.4 million using a 7 percent discount rate and $317.3 million using a 3 percent discount rate.

5.3.2 Maintenance Costs

The new roadway and infrastructure would require ongoing annual upkeep to the lane lines, barriers, and pavement as well as snow removal. Maintenance costs per lane-mile ranges from $3,400 to $4,500 (in 2017 dollars) based on a review of UDOT documents (UDOT, 2013, 2014, and 2015). The product of the highest estimated maintenance cost per lane-mile and the number of lane-miles for the new roadway (46 lane-miles) results in an annual maintenance cost of about $208,000.

The operation and maintenance costs were assumed to begin in 2034, when the Project is expected to be complete. The estimated future total annual operation and maintenance cost for the Oquirrh Connection is estimated to be $1.9 million using a 7 percent discount rate and $2.9 million using a 3 percent discount rate.

5.4 Benefit-Cost Analysis Findings

5.4.1 Metrics

Four key metrics are commonly used to represent and evaluate BCA results: the net present value (NPV), the benefit-cost ratio (BCR), the economic rate of return (ERR), and the return on investment (ROI).

NPV is the present value of all costs subtracted from the present value of all benefits. Projects with values greater than zero are considered economically beneficial. The NPV is a useful way to compare the overall dollar value of a Project's expected future net benefits.

The **BCR** is the present value of all Project benefits divided by the present value of all costs. The ratio measures the factor by which benefits exceed (or are below) costs. A Project with a ratio value greater than 1.0 is considered economically feasible. The BCR is a useful way to compare the relative benefits of Projects that may differ in schedule and/or scale.

The **ERR** is the discount rate at which the benefits and costs of a Project over the entire evaluation period are equal. ERR is a useful way to compare Projects with different evaluation periods and costs. In this situation, the social benefits are considered the cash flows used to calculate the ERR.

The **ROI** is a traditional financial metric used to describe future cash flows in relation to the initial capital investment. ROI is used to evaluate the efficiency of an investment and is calculated by dividing the net benefits by the initial investment cost. The net benefits are considered the benefits to society; however, typically ROI would be calculated using only the financial benefits.

5.4.2 Results

The BCA estimates that the Project will generate $867.9 million in undiscounted benefits at an undiscounted total cost of $332.8 million over the entire 23-year period of analysis, resulting in net benefits of $535 million. **Table 21: Benefit-Cost Analysis Results by Year (in millions of 2017 dollars)** shows a summary of BCA results on an annual basis in millions of 2017 dollars. Projects expecting to use federal funding are required to use a 7 percent discount rate; however, given the interest rates of the recent years, the results are also shown with a 3 percent discount rate.

Table 21: Benefit-Cost Analysis Results by Year (in millions of 2017 dollars)

Project Year	Calendar Year	Project Costs	Vehicle Operating Savings	Safety Benefits	Travel Time Savings	Air Quality	Net Benefits	Discounted Net Benefits	
								7% Discount Rate	3% Discount Rate
0	2031	$65.7					-$65.7	-$65.7	-$65.7
1	2032	$131.5					-$131.5	-$122.9	-$127.6
2	2033	$131.5					-$131.5	-$114.8	-$123.9
3	2034	$0.2	$13.2	$9.7	$8.2	$1.2	$32.2	$26.4	$29.4
4	2035	$0.2	$13.8	$10.1	$8.2	$1.3	$33.2	$25.6	$29.5
5	2036	$0.2	$14.6	$10.4	$8.3	$1.3	$34.4	$24.8	$29.7
6	2037	$0.2	$15.2	$10.8	$8.3	$1.4	$35.4	$23.9	$29.7
7	2038	$0.2	$15.8	$11.1	$8.4	$1.5	$36.5	$23.2	$29.7
8	2039	$0.2	$16.6	$11.5	$8.4	$1.5	$37.8	$22.4	$29.8
9	2040	$0.2	$17.3	$11.8	$8.4	$1.6	$38.9	$21.7	$29.8
10	2041	$0.2	$18.0	$12.1	$8.5	$1.6	$40.0	$21.0	$29.8
11	2042	$0.2	$18.7	$12.5	$8.5	$1.7	$41.2	$20.2	$29.8
12	2043	$0.2	$19.4	$12.8	$8.6	$1.8	$42.4	$19.6	$29.7
13	2044	$0.2	$20.2	$13.2	$8.6	$1.8	$43.6	$18.9	$29.7
14	2045	$0.2	$20.9	$13.5	$8.7	$1.9	$44.8	$18.2	$29.6
15	2046	$0.2	$21.7	$13.9	$8.7	$1.9	$46.1	$17.6	$29.6
16	2047	$0.2	$22.6	$14.2	$8.8	$2.0	$47.4	$17.1	$29.5
17	2048	$0.2	$23.4	$14.6	$8.8	$2.1	$48.6	$16.5	$29.4
18	2049	$0.2	$24.3	$14.9	$8.9	$2.2	$50.0	$16.0	$29.4
19	2050	$0.2	$25.1	$15.2	$8.9	$2.2	$51.3	$15.4	$29.2
20	2051	$0.2	$25.7	$15.6	$9.0	$2.3	$52.3	$14.8	$28.9
21	2052	$0.2	$26.2	$15.9	$9.0	$2.3	$53.3	$14.2	$28.6
22	2053	$0.2	$26.8	$16.3	$9.0	$2.4	$54.3	$13.7	$28.3
TOTALS		**$332.8**	**$399.6**	**$260.2**	**$172.1**	**$36.0**	**$535.1**	**$87.7**	**$272.1**

The distribution of benefits is depicted in **Figure 27: Benefit-Cost Analysis Benefits**. Vehicle operating savings have the greatest share of the benefits (46 percent), followed by safety benefits (30 percent), travel time savings (20 percent), and air quality (4 percent).

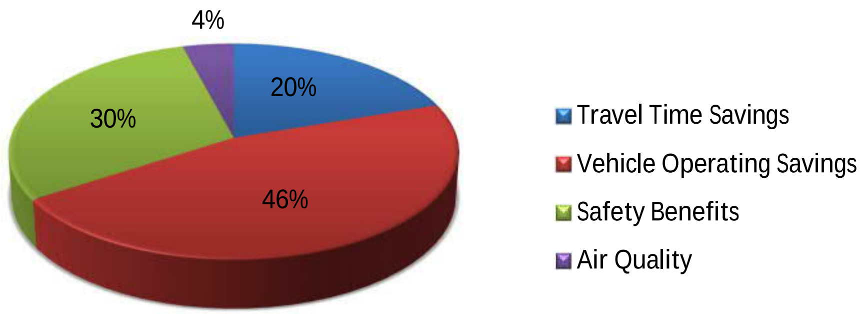


Figure 27: Benefit-Cost Analysis Benefits

Table 22: Benefit-Cost Analysis Results shows the overall BCA results for the Project. BCA metrics are presented with both a 7 percent discount rate and 3 percent discount rate. The proposed Oquirrh Connection has a positive BCR and NPV under both discount rates. The ERR and ROI are also favorable for both discount rates.

At a 7 percent real discount rate, the Project generates a net present value of $87.7 million, a BCR of 1.3, ERR of 14 percent, and ROI of 27 percent. At a 3 percent real discount rate, the Project generates a net present value of $272 million, BCR of 1.8, ERR of 14 percent, and ROI of 83 percent.

Table 22: Benefit-Cost Analysis Results

Metric	7% Discount Rate	3% Discount Rate
Net Present Value (NPV) (2017$)	$87,716,000	$272,052,000
Benefit-Cost Ratio (BCR)	1.3	1.8
Economic Rate of Return (ERR)	14%	14%
Return on Investment (ROI)	27%	83%
Note: NPV was rounded to the nearest thousand.		

6.0 CONCLUSION AND NEXT STEPS

From an engineering standpoint, it is feasible to construct a road through the Oquirrh Mountains. Out of the three corridors analyzed, the Butterfield Canyon to Middle Canyon route is the most feasible. Preliminary findings show that the preferred route provides benefits to the traveling public as well as to the communities it links. Construction of a road of this magnitude through mountainous terrain will present challenges but these are not insurmountable. The findings presented in this feasibility report are preliminary and are intended for planning purposes only, further study and analysis will be required.

Next steps in this process will include field investigations and surveys to better identify the alignment and existing conditions as well as potential impacts from the new roadway. Field investigations should include but not be limited to geologic and soil conditions, hydrologic conditions including water quality, environmental conditions (natural resources such as wildlife, wetlands), and weather related conditions such as snow avalanches. Right-of-way will also be a challenge as the proposed alignment in Butterfield Canyon and at the mouth of Middle Canyon do not follow existing roadways.

The Oquirrh Connection stakholders should continue to partner with large landowners such as the BLM and Kennecott as well as the Utah Department of Transportation and local communities to maintain interest and identify future funding for the project.

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APPENDIX A

Oquirrh Mountain Connection Travel Demand Estimation Memo

MEMO

TO: Jaime White, P.E. – AECOM
FROM: Kordel Braley, PE, PTOE, Austin Feula, PE
DATE: June 22, 2017
SUBJECT: Oquirrh Mountain Connection Travel Demand Estimation

1.0 INTRODUCTION

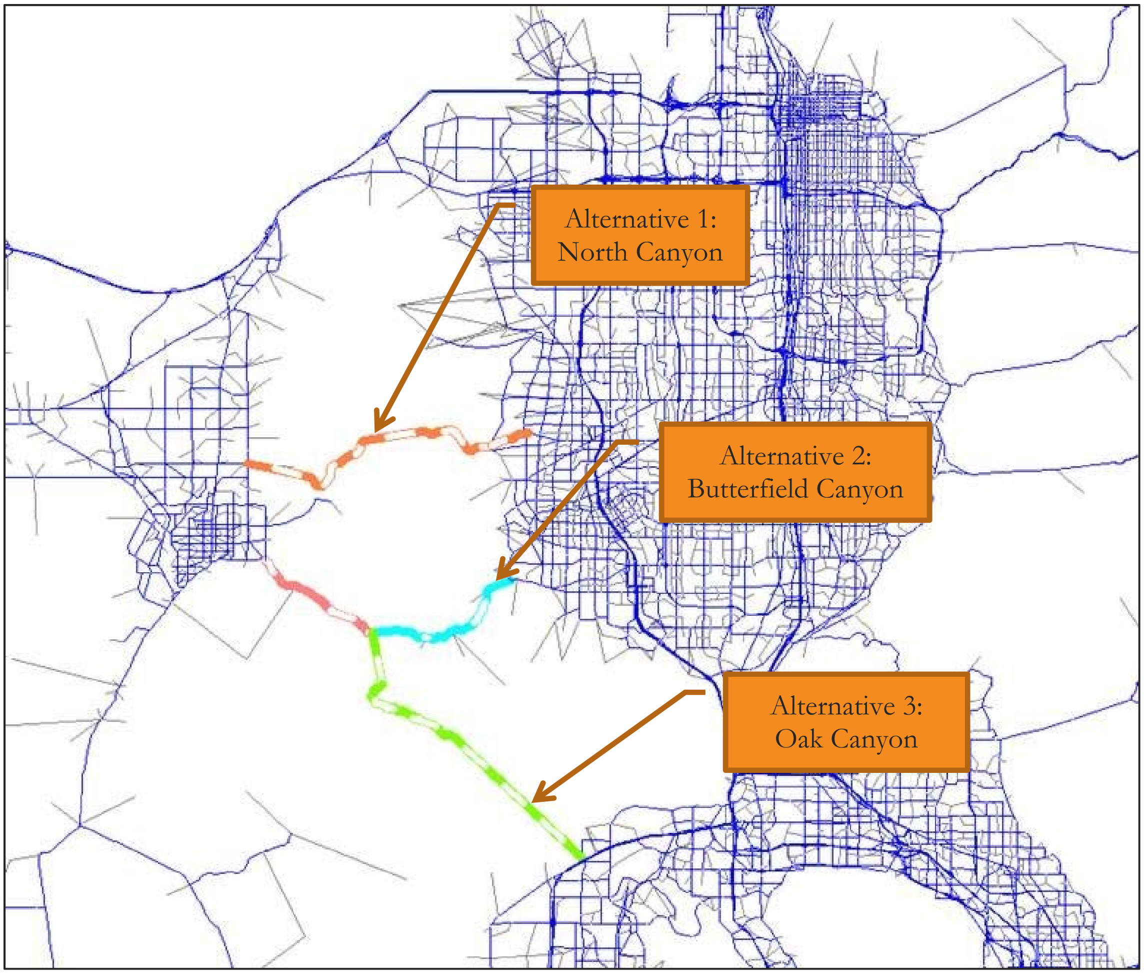
Planning-level demand analysis was examined for three alternatives through the Oquirrh Mountain Range between Tooele Valley and southwestern Salt Lake County/northwestern Utah County. This analysis provides decision-makers and the project team perspective on the need for this project and an idea of the magnitude of demand so an appropriately sized and designed facility can be considered.

The three alternatives are as follows (see also Figure 1):

- **Alternative 1**: North Canyon connection, north of Kennecott Mine. Connects into Tooele County via SR-36 just north of SR-112. Connects into Salt Lake County via Mountain View Corridor at approximately 9000 South.
- **Alternative 2**: Butterfield Canyon connection, south of Kennecott Mine. Connects into Tooele County at eastern extent of Vine Street. Connects into Salt Lake County at existing Butterfield Canyon entrance.
- **Alternative 3**: Oak Canyon connection into Utah County. Connects into Tooele County at same location as Alternative 2. Connects into Utah County via SR-73 at approximately the junction of Eagle Mountain Boulevard.

The Utah Statewide Travel Model (USTM) was used to understand each corridor's travel demand. Additional metrics, such as travel times and effects on traffic for downstream connections, were also estimated for Alternatives 2 and 3.

FIGURE 1: ALTERNATIVE ROUTES



2.0 BASE ROADWAY ASSUMPTIONS

Based on discussions with the project team, a list of assumptions for the three alternatives was developed to most accurately reflect what would realistically be built through the Oquirrh Mountain Range. These assumptions are provided below:

- Roadway geometry through the Oquirrh Mountain Range was provided by the project team.
- A base year of 2014 and a future year of 2050 were assumed for all alternatives.
- Connections on the Tooele Valley side were determined through discussions with Tooele City staff.
- The following assumptions were made in the modeling process for all three alternatives:
    - Speed: 45 MPH
    - USTM Functional Type: Principal Arterial
    - Cross-section: 4 lanes (2 lanes in each direction)
    - Although heavy and medium trucks would not be prohibited, the project team assumed that minimal trucks, if any, would use this road due to significant grades

and winding mountain roadways. Therefore, the model was set up to prevent trucks in these alternatives.

- Any necessary capacity improvements at connection points were made to not limit potential trips along the proposed connections. These capacity improvements are listed below:
  - Widen 1000 North east of SR-36 in Tooele to two lanes in each direction
  - Widen Herriman Highway east of proposed Alternative 2 connection to 5600 West to two lanes in each direction

3.0 MODELING

USTM version 1.3 was chosen as the starting point for developing the travel demand estimates for the three Oquirrh Mountain connection alternatives. USTM version 1.3 was used by UDOT in the development of the UDOT 2015 Long Range Transportation Plan. All travel demand modeling work was done in Citilabs Cube 6.4.2.

A 2050 scenario was added to the USTM version 1.3 model to evaluate the 2050 travel condition for this project. The 2050 scenario included the following land-use/socioeconomic data and transportation network assumptions:

- Wasatch Front Area:
  - Imported into USTM the Wasatch Front travel model version 8.2 zone structure and highway network. Wasatch Front version 8.2 was used for the Wasatch Front Central Corridor Study.
  - Imported into USTM the 2050 socioeconomic data used in the Wasatch Front Central Corridor Study base-case land use scenario. This socioeconomic dataset was developed using the MPO's Real Estimate Market Model (REMM). This dataset is believed to most closely resemble the 2050 socioeconomic dataset that will be used in the MPO's 2019 Regional Transportation Plan (RTP).
- USTM Model Outside Wasatch Front Area:
  - Used 2050 socioeconomic dataset and highway network developed for Envision Tomorrow's base-case scenario.

To be compatible with the 2050 scenario's highway and zone structure, the 2014 data from the Wasatch Front version 8.2 model was also brought into the USTM model.

The 2014 base year travel model commuting pattern between Tooele and Salt Lake/Utah counties were compared against the 2012 Utah Household Travel Survey. The model was found to be overestimating the number of trips between Tooele County and Salt Lake/Utah County in the base year. A 0.59 correction factor was applied for all alternatives evaluated to most accurately reflect real-world travel patterns between these counties.

4.0 RESULTS

4.1 | BASE RESULTS

As described in the introduction section, the base condition was modeled assuming a speed limit of 45 MPH, and a four-lane cross-section. A four-lane cross-section was assumed to not constrain traffic by causing drivers to re-route due to potential peak period congestion.

2050 AADT results for the three alternatives are presented below in Figure 2. AADT along all three alternatives range from 12,000 to 18,000 vehicles per day. Alternative 1 offers the most direct connection between major 2050 population centers, and thus is projected to have the highest AADT. Alternative 2, while offering a key connection between two major 2050 population centers, is not as direct as Alternative 1, thus is projected to have a slightly lower AADT. Alternative 3, while providing a direct connection for Utah County, does not offer as significant of a time savings to much of Salt Lake County, thus is projected to have the lowest AADT of the three alternatives.

FIGURE 2: 2050 ALTERNATIVE EVALUATION RESULTS

Alternative	AADT
1	18,000
2	15,000
3	12,000

Because the project team removed Alternative 1 from consideration fairly early in the study, additional analyses were only completed for Alternatives 2 and 3.

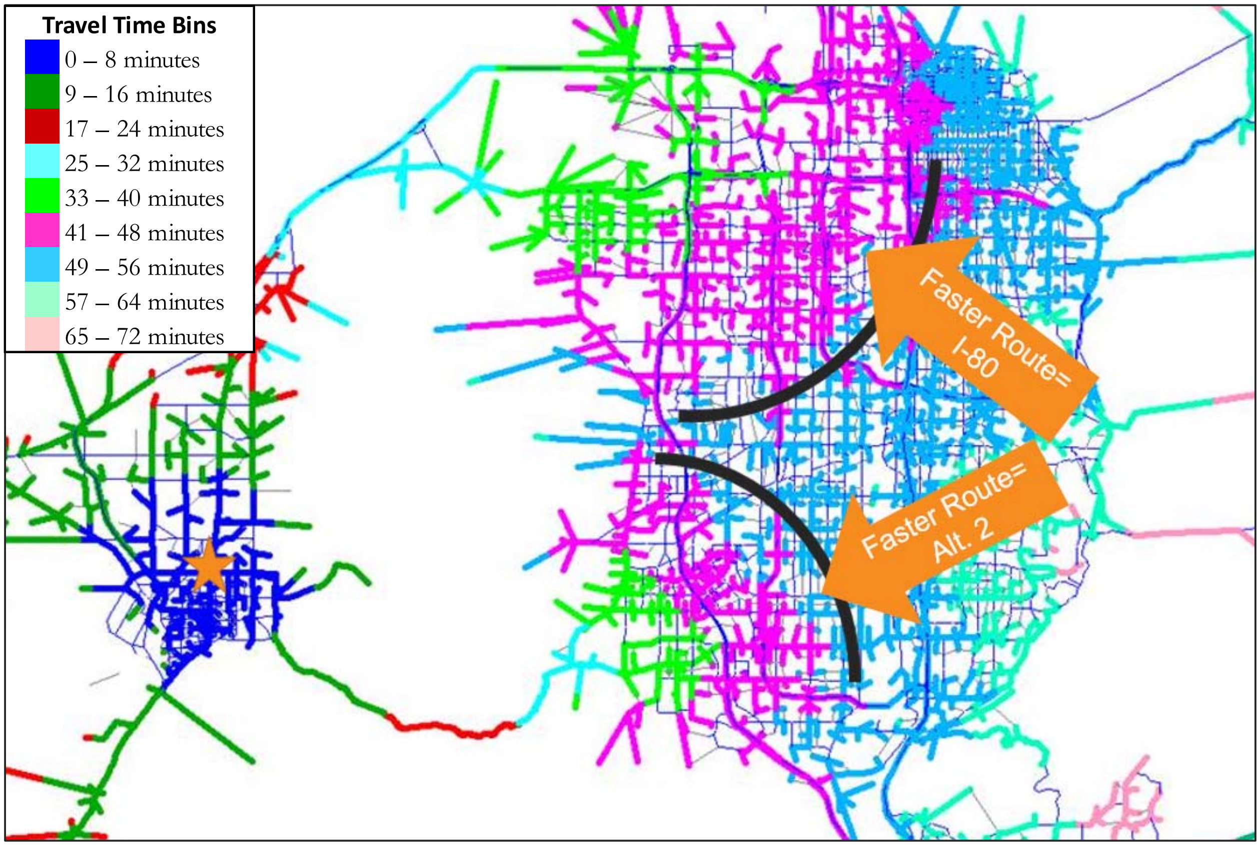
Travel times for Alternatives 2 and 3 were examined between significant locations on both sides of the Oquirrh Mountains. As shown in Figure 3, both Alternatives 2 and 3 offer significant time savings from Tooele to certain destinations as compared to the existing options of I-80 and SR-73.

Figure 4 presents these data by showing the specific regions in Salt Lake County where Alternative 2 offers a faster connection than I-80. I-80 is still a faster connection to much of northern Salt Lake County, Alternative 2 is a faster connection to the southwest corner of the valley, and both routes have fairly similar travel times to much of the central valley.

FIGURE 3: 2050 CONGESTED TRAVEL TIMES (MINUTES) BETWEEN TOOELE AND VARIOUS LOCATIONS IN SALT LAKE/UTAH COUNTY

	Alt 2	Alt 3	I-80	SR-73
Herriman	41	51	52	85
Draper Prison	50	54	58	88
Lehi TP	56	49	62	82
Eagle Mtn	57	34	67	69

FIGURE 4: 2050 CONGESTED TRAVEL TIMES (MINUTES) BETWEEN TOOELE AND SALT LAKE COUNTY



DOWNSTREAM VOLUMES

Congestion impacts of the proposed Alternative 2 connection on adjacent roadway tie-in points were examined. This was done to determine the downstream effects of adding a significant connection over the Oquirrh Mountains. For this, AADT with and without the Alternative 2 connection for roadways in Tooele and southwest Salt Lake County were examined.

Figure 5 and Figure 6 present this analysis in graphic and tabular form, respectively. Figure 5 and Figure 6 include all roadways anticipated to have an increase of at least 2,000 vehicles per day with Alternative 2 in place.

On the Tooele side of the proposed connection, 1000 North is projected to carry most the traffic with an estimated AADT of 7,000 vehicles per day. As shown in Figure 5, this is projected to serve most trips between the northwest side of Tooele and Alternative 2. Vine Street is projected to carry 5,000 vehicles per day. As shown in Figure 5, Vine Street will likely serve as the key connection between downtown Tooele and Alternative 2.

On the Salt Lake County side of the proposed connection, Herriman Highway is projected to carry most traffic to Mountain View Corridor. Additionally, traffic is also projected to use Bacchus Highway to travel north, 13400 South as a secondary connection to Mountain View Corridor, and 12600 South (east of Mountain View Corridor) to connect to Bangerter Highway. Traffic impacts on

Mountain View Corridor were disregarded, as this roadway is expected have significant capacity to handle increases from this proposed connection.

FIGURE 5: DOWNSTREAM TRAFFIC FLOWS (ALTERNATIVE 2 IN YEAR 2050)

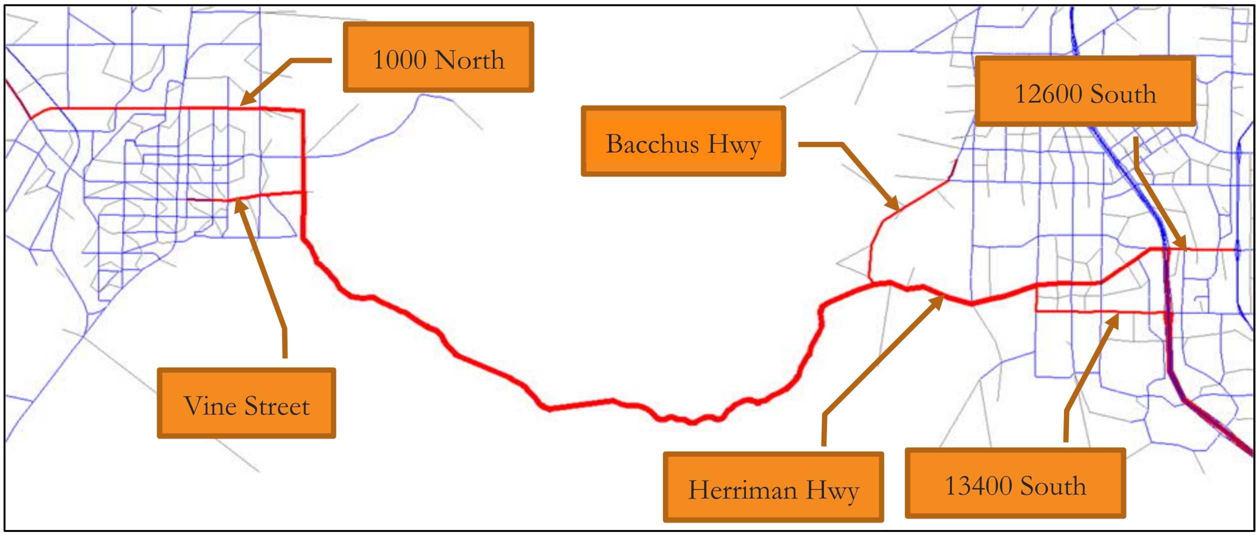


FIGURE 6: DOWNSTREAM TRAFFIC FLOWS (ALTERNATIVE 2 IN YEAR 2050)

	Route	Start	End	No Build	Alternative 2 Base	Alternative 2 New	Alternative 2 Total
SL Co	Bacchus Hwy	Just north of Alt 2		4,000	4,000	3,000	7,000
	Herriman Hwy	Canyon Exit	6400 W	11,000	10,000	11,000	21,000
	Herriman Hwy	6400 W	Mtn View/12600 S	19,000	17,000	7,000	24,000
	12600 S	Mtn View	Bangerter	73,000	71,000	3,000	74,000
	13400 S	Herriman Hwy	Mtn View	11,000	9,000	3,000	12,000
Tooele	Vine St			3,000	-	5,000	5,000
	1000 N	East of SR-36		7,000	6,000	7,000	13,000
	1000 N	West of SR-36		13,000	10,000	4,000	14,000

**No Build includes all downstream project improvements from Build Scenario*

As Alternative 3 has the same tie-in location as Alternative 2 on the Tooele side, and a lower estimated AADT, no additional analysis was performed at this location. On the Utah County side of the Alternative 3 connection, the roadway will join into a proposed freeway, thus any additional traffic volume will have a negligible effect on congestion.

I-80 AND SR-73 REROUTING

Trips using the proposed alternatives are comprised of three primary groups:

- **Re-Routed Trips**: Trips that are currently made between Tooele and Salt Lake or Utah counties and will re-route onto Alternative 2 as it offers a faster alternative to either SR-73 or I-80.
- **Transferred Trips**: Trips that are currently made between Tooele and Salt Lake or Utah counties that will now go to new destinations in Salt Lake or Utah counties that are quicker to get to using Alternative 2.

- **New Trips**: New trips that were not previously made between Tooele and Salt Lake or Utah counties but are now made between Tooele and Salt Lake or Utah counties.

Figure 7 shows the AADT expected for each of these three groups in 2034 and 2050. The horizon year 2034 was chosen as this corresponds to the end of the LRP Phase II, which was determined by the project team to be a reasonable assumption for construction of this facility. Approximately two-thirds of the trips using Alternative 2 are expected to be existing trips that are re-routed and no longer using I-80 or SR-73, while one-third of trips are expected to be new trips.

FIGURE 7: GROUPS OF ALTERNATIVE 2 TRIPS

Analysis Year	Re-Routed Trips	Transferred Trips	New Trips	Total Trips
2034	4,700	2,200	4,200	11,000
2050	7,400	2,600	5,000	15,000

4.2 | SENSITIVITY ANALYSIS – ROADWAY DESIGN

Additionally, a series of sensitivity analyses were performed to determine how significant of a role roadway design plays in the traffic volumes along Alternative 2. These sensitivity tests were all performed on Alternative 2, and adjust number of lanes, speed, and route distance to measure the effects of each design element on traffic volumes.

FIGURE 8: SENSITIVITY ANALYSIS- ROADWAY DESIGN

Test #	Lanes	Speed	Distance	AADT
1	2	35 MPH	+ 2.0 Miles	7,000
2	2	45 MPH	No change	15,000
Base	4	45 MPH	No change	15,000
3	4	55 MPH	- 0.2 Miles	18,000

As can be seen in Figure 8, changing just the number of lanes from the base condition has minimal effect on projected traffic volumes, while changing speed and distance has a major effect. By reducing the speed by 10 MPH and lengthening the route by 2 miles traffic volumes are projected to be less than half of the base condition. By increasing the speed by 10 MPH and shortening the route by 0.2 miles traffic volumes are projected to increase by 3,000 vehicles per day.

4.3 | SENSITIVITY ANALYSIS – LAND USE

Due to significant uncertainty when projecting land-use changes more than 30 years into the future, a secondary 2050 land-use scenario was evaluated. This was performed to determine how much effect variations in land-use would have on projected traffic along the proposed alternatives.

The secondary scenario evaluated was the 2050 land-use from the 2015 Regional Transportation Plan. The results of this sensitivity analysis are presented below in Figure 9.

FIGURE 9: SENSITIVITY ANALYSIS- LAND USE

Alternative	Base AADT	Sensitivity AADT
2	15,000	16,000
3	12,000	11,000

As can be seen in Figure 9, changes in land-use are not projected to have a major effect on traffic volumes on Alternatives 2 or 3. Even with the redevelopment of the Draper prison site assumed in the base condition, and not the secondary land-use scenario, traffic volumes are not expected to change much. Alternative 2 is slightly larger in the sensitivity scenario because more population in the southwest portions of Salt Lake County as compared to the base scenario. Alternative 3 is slightly higher in the base scenario because population is higher in the northwest portions of Utah County as compared to the sensitivity scenario.

4.4 | COMBINED ALTERNATIVES

As Alternatives 2 and 3 share the same route west of the Butterfield Canyon Pass, the option of building both alternatives together was evaluated. This resulted in an AADT of 18,000 vehicles per day on the west leg of the connection, which is 3,000 vehicles per day greater than Alternative 2 alone. These 18,000 vehicles per day are estimated to be split evenly (9,000 vehicles per day) between Alternative 2 and 3 east of Butterfield Canyon Pass. No vehicles are expected to use this route to connect southwest Salt Lake County to northwest Utah County.

4.5 | INTERMEDIATE YEARS

To estimate AADT along the proposed corridor before 2050, the connection was also analyzed with 2014 base year conditions. Linear interpolation was used to estimate travel along the proposed connection for intermediate years. Figure 10 presents Alternative 2 for 2014, 2050, and interpolated 2034 results.

FIGURE 10: ALTERNATIVE 2- INTERMEDIATE YEARS ANALYSIS

Year	AADT
2014	6,000
2034	11,000*
2050	15,000

*Interpolated between 2014 and 2050.

5.0 CONCLUSIONS

We offer the following summary of key findings based on the analysis presented in this report:

- USTM was used to understand each corridor's travel demand. Socioeconomic data, zone structure, and the highway network for the Wasatch Front area were imported into the statewide model from the Wasatch Front travel model.
- All USTM model AADT outputs were adjusted to match 2012 Utah Household Travel Diary Survey travel patterns.
- AADT along all three alternatives are as follows (assuming a base condition of 2 lanes in each direction and a speed of 45 MPH):
    - Alternative 1: 18,000
    - Alternative 2: 15,000
    - Alternative 3: 12,000
- Below a speed of 45 MPH a connection over the Oquirrh Mountain Range loses significant traffic flow as it would not be a viable alternative to I-80 for all but a small percentage of trips.
- Shifts in land-use, increase in speed, and decrease in number of lanes do not have a significant effect on projected traffic volumes.
- Some roadway widening could be required on downstream links such as 1000 North in Tooele (east of SR-36) and on Herriman Highway in Herriman (between U-111 and 5600 West).
- Approximately two-thirds of the trips using Alternative 2 are expected to be existing trips that are re-routed and no longer using I-80 or SR-73, while one-third of trips are expected to be new trips.

APPENDIX B

Oquirrh Connection Road & Tunnel Feasibility Study Preliminary Geotechnical Assessment Memo

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801 904 4100 fax

Memorandum

To	Jaime White, PE	Page	1
CC			
Subject	Oquirrh Connection Road & Tunnel Feasiblity Study Preliminary Geotechnical Assessment		
From	Matt Francis, PE; Curtis Tanner, PE; Randy Lentell, PG		
Date	June 22, 2017		

Purpose

This memo provides our desktop evalution of geotechnical and tunnel planning considerations and related recommendations for the Oquirrh Connection Feasibility Study.

Three initial corridors were selected for the alignment alternatives evaluation– North (Barney's Canyon), Middle (Butterfield and Middle Canyons), and South (Oak Canyon, Ophir). The three corridors were based on general topographical differences and possible populations served. Thenorth (Barney's Canyon) alignment alignment was eliminated due to conflicts with significant active mine operations and an EPA Superfund site in Tooele County. The south alignment was eliminated due to mountainous terrain and lack of connectivity to population centers.

The preferred alignment connects SR-36 in Tooele, through Middle Canyon to Butterfield Canyon, to SR-111 in southern Salt Lake County. There is also a future connection from middle Canyon to Oak Canyon and SR-73 in Utah County.
An overview of the project area and preferred alignment is attached as Figure 1.

Project Risks

Based upon our review and evaluations during this studyof the currently available geotechnical and geologic information and data, we are of the opinion that geotechnical risks for the alignment are relatively low and the preferred alignment and connections with currently proposed tunnel reaches are generally feasible for design and construction. Identified project risks center around normal, though not insignificant challenges associated with design and construction in mountainous terrain; i.e., stability, erosion, draingage, maintenance, safety and seasonal access limitations. We believe these can all be addressed effectively with proper geo-engineering best practices and understanding of local geology and ground behavior. Many of these practices were developed by AECOM (such as ASCE best practices for risk management of underground construction. Ref.ASCE 2007) and applied for the Upper Diamond Fork Tunnel, the most recent tunnel of comparable complexity in Utah for this project design. A risk register should be developed based upon field exploration findings, updated roadway design data and and geotechnical analysis, and refined through each phase of development including detailed analysis, design and in organizing the procurement methods, bid documents and contractor performance requirements, following the ASCE guidance.

Potential for geotechnical and operational impacts to Rio Tinto Kennecott Copper (RTKC) have been minimized by selection of a preferred alignment which avoids RTKC property. No known conflicts have been identified, noting the proposed roadway could be used by RTKC at times to access upper portions of their property, and that cuts and improvements may result in some stress influence on RTKC property, though relatively remote proximity sets this a minor risk to be confirmed during design.

Topography

The topographic elevation map for the preferred alignment is attached as Figure 2. The maximum elevation for the alignment is about 7200 ft. The minimum elevations are at the valley floors which range from 5000 to 5400 ft. for Tooele, Utah County, and unicorporated Salt Lake County West of Herriman City. The alignment generally follows existing drainages—Middle Canyon in Tooele County, Butterfield Canyon in Salt Lake County, and Oak Canyon in Utah County to the south.

Cut and fill quantities and balance for the proposed alignment have yet to be identified. Cut and fill slope configurations along the alignment will need retaining wall design, drainage design, rock fall protection measures, settlement, and slope stability analyses.

There are two tunnels in the proposed alignments to avoid excessive slopes at the highest elevations of the alignments. One tunnel from Salt Lake County to Tooele County will be about 0.9 miles long, and a second tunnel from Utah County to Tooele County will be about 2.1 miles long. Both tunnels will be built at approximately 7200 ft elevation.

General Geology

The geologic map for the preferred alignment (Clark et al., 2012, Clark et al., 2016) is attached as Figure 3.

All of the routes will be underlain by the Paleozoic-aged Oquirrh Group. The Oquirrh Group is composed of three mappable lithologic units: a lower clastic limestone; a middle unit consisting of cyclically repeated limestone, shale, and sandstone; and an upper unit of interlayered thick beds of quartz sandstone and thin beds of carbonate sandstone. The Oquirrh Group consists of the following geologic formations in increasing age and depth: Bingham Mine Formation (limestone and quartzitic sandstone), Butterfield Peak Formation (cyclic shale, limestone and calcareous quartzite), "White Pine" Formation (cyclic shale, limestone and calcareous quartzite), and the Maple Formation (clastic limestone). The Oquirrh Group formations are underlain by the Manning Canyon Shale.

The uppermost elevations of all of the routes will be underlain by the Butterfield Peak Formation, with part of the east-west tunnel cutting through a lower member of the Bingham Mine Formation of the Oquirrh Group. Lower elevations of the alignments will be underlain by alluvial and colluvial deposits, crossing some older lahars and debris flows in Butterfield Canyon. The southernmost portion of the north-south tunnel and much of the Utah County alignment will be underlain by West Canyon Limestone of the Oquirrh Group. As the tunnel comes out of the canyon and turns southeast, the geology underlying the Utah County alignment is Manning Canyon Shale.

Surficial Geology

Shallow deposits overlying the geologic formations vary through the route. The soil map, which uses Natural Resources Conservation Service (NRCS) classification, is attached as Figure 4. ThMiddle Canyon lies on broad, moist - Reywat, moist - Rock outcrop association with 30 to 60 percent slopes and on Podmor, moist Datemark - Rock outcrop association. The last bit of Middle Canyon before and the first third of the east-west tunnel toward Butterfield Canyon lies on shallow Podmor - Datemark, moist – Rock outcrop association. This is also the shallow geology under the northern half of the north-south tunnel toward Utah County. There are darts of Podmor – Onaqui - Rock outcrop association that crosses both tunnels about mid-tunnel. The southern portion of the north-south tunnel and the route's subsequent curve to the southeast is underlain by Parkay - Rock outcrop complex. The rest of the Utah County route is underlain by surficial soils, in order, as follows: Lizzant very cobbly loam; Agassiz very stony loam; Lundy - Rock outcrop complex; and sloping Cumulic Haploxerolls. Butterfield Canyon lies mostly on Fitzgerald gravelly loam and Baird Hollow loam with some patches of Bradshaw-Agassiz Association at higher elevations and patches of Horrocks-Little Pole association crossing the lower elevations. As the Butterfield Canyon route enters the Salt Lake valley, the underlying soils consist of Henefer-Horrocks complex.

The majority of the surficial soils are granular and samples will be required for laboratory analyses for geo-engineering design. Particle size and texture will be used to design stable slopes, road base compaction and ground improvement requirements.

Geologic Hazards

As shown on the geologic map in Figure 3, the Oquirrh Connector routes will intersect one main thrust fault and parallel another thrust fault. The routes will also intersect secondary faults. The Middle Canyon Thurst Fault traverses under the north end of the north-south tunnel and crosses the Oak Canyon alignment at about Elevation +6200 ft. The Oak Canyon alignment parallels the West Canyon Thrust Fault, but lies entirely on the fault's foot wall. However, if the alignment moves to the southwest, the route may transverse this fault. There is an additional secondary strike/slip that crosses the Oak Canyon alignment. The Butterfield Canyon route traverses three or more secondary normal faults. There is also a buried fault under a portion of the Butterfield Canyon alignment.

Seismic studies will be required to identify fault age and recurrence interval to establish preliminary seismic design criteria.

Water Hazards and Erosion Control

Proximity to drainage channels increases the potential for hazards. Drainage channels of concern include perennial streams that flow during all of the year as well as ephemeral streams in subdrainages that flow only in response to spring snowmelt or precipitation events. Ponds, irrigation channels, and roadside ditches may also present hazards. Hazards associated with drainages include:

- Flooding and erosion
- Debris flows

- Slope instability triggered by streambank erosion at the toe of a slope
- Slope instability from loss of shear strength and softening caused by addition of moisture
- Frost heave and corrosion promoted by drainages
- Seismic liquefaction and lateral spreading of saturated sandy soils located near drainages

Because of these multiple hazards associated with drainages, detailed evaluation of these hazards at the planned alignments will be required. Construction will impact natural drainages, potentially concentrate runoff, and create cut and fill surfaces initially devoid of vegetation that may be subject to increased erosion. These issues will need to be addressed both during and after construction. Silt fencing, vegetative cover, erosion control blankets, filters, rip rap, drainage ditches, storm drains, or other appropriate measures will be required.

Slope Stability and Landslides

The slope stability considerations for this feasibility study are based on published regional literature, denoting historic landslides and unstable slope conditions. The regional studies, by nature are limited and incomplete, but they provide a good basis for planning detailed alignment-specific investigations and studies. Extensive geologic reconnaissance mapping, subsurface exploration, and slope stability analyses are required for a highway development of this scale.

A landslide risk map for the project area was composited from two UGS maps (Christensen and Shaw, 2008) (Elliott and Harty, 2010) and GIS data from the AGRC and NRCS data, The map is included as Figure 5. The composite map designates which areas require special landslide studies before development may begin on the land. The potential risk is generalized rather than detailed and criteria varies by county. Some of the mapped landslide risk for both Salt Lake and Tooele Counties is denoted as high solely based on existence of slopes greater than 30% grade according to available elevation data. The simplistic approach of determining landslide based upon slope grade does not include other significant factors including stratigraphy and variability of soil and rock strength, rock structure, erosion patterns, vegetation, groundwater conditions and precipitation. More detailed investigation of these hazards will be required for design. Published literature can be used for planning field and laboratory investigations, which should include geologic reconnaissance mapping, subsurface drilling and sampling, laboratory analyses, and slope stability analyses.

All mapped existing landslides are also denoted as high risk areas for re-mobilizing. The Butterfield Canyon alignment, approximately 0.7 miles to the west of the tunnel section, traverses a historic debris flow and will need additional investigation to characterize the soil and rock strength and develop a design approach to maintain adequate stability during construction and operations. Another mapped shallow landslide nearly a mile northwest of lower Butterfield Canyon is anticipated to have little or no affect on the proposed alignment. The limits of the identified shallow landslide will be defined during geologic reconnaissance. There are some observed landslides deposits about 200-600 feet west of the proposed Utah County alignment for nearly four miles, but they are not anticipated to affect the current alignment. The Oak Canyon alignment also traverses landslide deposits for 1000 feet immediately coming out of its tunnel. The current layout of the Utah County alignment also catches the edge of an area of unclassified landslide-type deposits for about 3500 feet at about three miles out of the southern mouth of the tunnel. The extent of these landslide deposits will be defined during geologic reconnaissance so that the final alignment or grade will not impede on these deposits.

Roadway Cuts, Fills, Retaining Walls

The lower portions of the planned alignments in Middle and Oak Canyon will likely have relatively minor cuts, fills, and retaining walls. However, due to the mountainous topography, substantial cuts, fills, and larger retaining walls will be required along significant portions of the alignments. The art of mountain road engineering is to balance the geometry and cut design to the limits of overburden resistance, and minimize creating erosion prone features.

Refer to Appendix A for examples of soil stabilization techniques.

Cuts

In general, the steeper the natural slope is, the shallower the soil cover will likely be. Rock cuts will be designed and constructed to be compatible with the intrinsic structure of the rock; i.e., the rock cuts will roughly parallel the strike and dip of the rock to the extent practical. We expect that cuts in the rock may be feasible at slopes around 0.75 Horizonal (H) to 1 Vertical (V) to 1 H to 1 V. The orientation and structure of the rock units will be mapped and analyzed during geologic reconnaissance. Depending on the height of the cut and the nature of the rock to be explored during design, persistent rock fall may be an issue in the upper reaches of the road and tunnel approach. They would require regular mainentenance and design of a catchment ditch and netting system for energy dissipation or to arrest rockfall debris. Cuts can be constructed steeper and rockfall potentially reduced or eliminated using soil nail walls with shotcrete facing or tensioned steel netting.

Cuts in soil overburden will likely have to be constructed at slopes of 1.5H to 1V, or flatter. The steeper the soil cut slope is, the greater will be the potential for erosion. Erosion control measures would include a broad range of best practices in conjuction with the site design including geotextile filters membranes, geosynthetic reinforcements, drainage and collections system, bio-retention and bio-stablization engineering with conventional mountain roadway features of reverse grading, storm drains, check dams, siltation basins and swales. Improved new products are also available for spray on erosion control vegetation seeding durable in rugged environments and permeable flowable fill for trenching and stabilization with integral drainage properties. An effective combination of these options would be developed during the design phase.

Fills

Unreinforced fills and embankents will likely have to be constructed at 2H to 1V slope or flatter per standard UDOT requirements. As with the cut slopes, the steeper the fill slope is, the greater will be the potential for erosion and the need for erosion control. Along portions of the alignments with flatter natural slopes, which are relatively small portions, standard mechanically stabilized earth (MSE) walls will likely be feasible. Along portions of the alignments with steeper slopes, wall systems with mechanical anchoring will likely be required. Susch systems might be tieback walls, hybrid MSE-tieback, soildier pile, and soldier pile with tieback, or other systems. These systems will require design with adequate corrosion protection and will have limited, planned design lifes (typically 75 years).

Bridges

On the Butterfirld Canyon alignment, several bridges would be required. Due to seismic demand and steep cross slopes, the design of abutment walls and support bents and foundations would present significant challenges. Challeges would include a change in height across the abutment or a rock cut, and a significant maximum height, and/or the design of tall and substantial support bents. Rock socketed shaft foundations or anchored spread footings would likely be required.

Tunneling

There are two proposed tunnels:

1) One east-west tunnel from Middle Canyon to Butterfield Canyon will be about 0.9 miles long
2) One north-south tunnel from Middle Canyon to Oak Canyon will be about 2.1 miles long

The required roadway width for 2 way traffic in a single tunnel is likely to be 28 - 34ft and with a minimum height over the roadway of 14ft and 16ft in the center.

Tunnel Geology

The tunnels will pass through the Oquirrh Group of rock units which consist of a lower clastic limestone; a middle unit consisting of cyclically repeated limestone, shale, and sandstone; and an upper unit of interlayered thick beds of quartz sandstone and thin beds of carbonate sandstone. The Oquirrh Group is a massive deposit of over 15,000 ft thick.

The east-west 0.9 mile tunnel running to Butterfield Canyon is likely to be excavated in the Butterfield Peaks Formation which consists of 60% silica cemented orthoquartzite and interbedded with 40% of cherty arenaceous and argillaceous fine grained limestone. The high-silica content rock is typically hard to very hard and exhibits medium to high compressive strengths (>8,000 psi) and is highly abrasive. Rock core will be drilled for laboratory testing of the core samples to define the range of unconfined compressive strengths and tensile strengths and petrographic analysis to define mineralogy. Point-load testing of the rock core will be performed in the field as the core is obtained to supplement laboratory strength data. Other laboratory testing will be performed to aid in selecting and designing rock excavation equipment, such as Schmidt Hammer, Cercher Abrasion, Slake Durability, Schore Sceleroscope, Taber Abrasion, NTNU Drillability and (Siever's J-Value Test).

The west portal of the proposed tunnel lies close to the middle canyon thrust fault and the tunnel passes through the Oak Springs Syncline that could bring the Bingham Mine Formation consisting of interbedded orthoquartzite and calcareous quartzite with limestone layers into the tunnel level. Geologic reconnaissance mapping will be performed to define the location and extent of faulted and folded rock structure and conditions and rock stratigraphy. A geological section will be developed along the the tunnel profile. The presence of faults and folded rock structure (i.e., syscline) will create potentially unstable conditions for rock tunneling and portal or shaft development. Fractured ground conditions, rock structure orientation and fracture infilling materials will be characterized to the extent possible during geologic reconnaissance mapping.

Permanent groundwater is not anticipated at a tunnel elevation of approximately +7200 ft, however perched water is possible. Groundwater will be primarily associated with secondary porosity of faulted and jointed rock. Folded rock units will also likely be water-bearing due to secondary porosity (i.e., fracturing). Water levels will be monitored in boreholes during the subsurface drilling investigation and borehole packer-permeability testing will be performed.

The north-south 2.1 mile long tunnel running from Middle Canyon to Oak Canyon will likely be constructed in the West Canyon Limestone. This formation consists mainly of interlayered clastic arenaceous limestone and dense cherty argillaceous crystalline limestone with some thin sandstone beds. The tunnel is likely to pass into the orthoquartzite and arenaceous/argillaceous limestones of the Butterfield Peaks Formation which is found at the north portal. The abrasive character of these formations is similar to that described above. Similar drilling, sampling and laboratory testing will be conducted along this tunnel alignment as above. This tunnel also passes through the Middle Canyon Thrust Zone, which is likely to provide blocky unstable fractured ground conditions and the existence of flowing water in this zone is a possibility.

Tunnel Constructability

The field and laboratory investigations will be planned, performed and reported in a manner to characterize the soil and rock conditions for design and construction planning and execution. Preliminary Geotechnical Data Reports and Geotechnical Baseline Reports will be prepared for the preferred alignment, including tunnel sections. Geotechnical data will be presented and anticipated soil and rock behavior, as well as anticipated groundwater conditions will be discussed. Feasible construction means and methods will be discussed and if certain methods should be precluded, they will be explained. Construction specifications will be prepared to match the appropriate ground conditions characterized in the geotechnical reports.

Based on the aniticpated geology the rock in the tunnel horizon is likely to be hard to very hard with UCS strength greater than 8,000 psi (greater than 55 MPa). Due to the prescense of sandstone, quartzite and arenaceous limestones the abrasivity is likely to be high, with tensile strengths moderate to high which will make liner design more efficient.

Careful characterization of soil and rock conditions and development of appropriate geologic interpretation by appropriate expertise during design, and the specification of performance criteria and equipment alternatives for construction is essential for complex configurations like this.The tunnel section will be determined by the lane width requirements to meet UDOT criteria and traffic flow demands. It will likely be a finished tunnel of some 30ft wide with single lanes in each direction, and with a minimum height over the lanes of 14ft (16ft in some cases).

Tunnel means and methods and constructability are based on the characterized ground conditions at the excavation face (to be confirmed during design), the required tunnel dimensions, support and stabilization requirements, and the required schedule. It is anticipated that conventional and machine mining methods will be appropriate for the anticipated conditions along the tunnel alignments. Conventional mining methods would include dynamic drill-and-blast methods or unilikely mechanical/chemical splitting methods. Machine-mining methods would include large-diameter tunnel boring machines (TBM) or rotary cutter boom-mining machines (such as roadheaders or alpine miners).

Conventional Drill-and-Blast methods might be performed with a variety of support measures, including *bald*-headed (with no support), light support with spot bolting as needed, moderate support with pattern bolting, heavy support with lattice girders or steel sets, or very heavy support with a combination of bolts and sets. A variation of conventional Drill-and-Blast is becoming more common and wide-spread, and is referred to as the Sequential Excavation Method (SEM). SEM is similar to what used to be referred to as the *New Austrian Tunnelling Method* (NATM). SEM consists of a combination of Drill-and-Blast methods and multiple layers of shotcrete in a sequence of excavations, such as top-heading and bench or multiple drifts. The SEM method can be executed with a variety of support measures in addition to the layered shotcrete, including rock bolts, lattice girders, and/or steel sets. Any tunnel configuration can be constructed, but horseshoe or modified horseshoe shapes are common. SEM or conventional Drill-and-Blast construction could be carried out at two or more faces, but the excavation time for the shorter east-west tunnel is likely to take about 2 – 3 years to mine from 2 faces, and 4- 5 years for the 2.1mile north–south tunnel.

Mobilization and execution of convention Drill-and-Blast methods or SEM methods are independent of mountainous remote terrains.

Roadheaders or Alpine Miners are relatively light-weight and more portable than large-diameter TBMs. They were developed for use in mountainous, remote regions and are suitable for mining rail or highway-sized tunnels. The newer, larger machines are capable of mining high- to very-high strength hard rock in excess of 16,000 psi unconfined strength. A large dual pick-type rotary-head roadheader was used to mine the new crossover tunnel for the Exchange Place Station for the PATH trains into the reconstructed World Trade Center Station in New York City. The rock was the hard Manhattan Schist with thick quartzite seams and pegmatite dikes (>5 ft thick). Roadheaders could prove to be feasible depending on the results of the field and laboratory investigations. Roadheaders are very suited to SEM mining methods, with the primary and permanent linings of layered shotcrete, bolts, and/or set.

A hard-rock disc-cutter TBM would appear feasible. However, if the investigation finds that the rock conditions exhibit a wide range of strengths and consistencies then a TBM fitted to cut variable rock conditions with a mix of disc, bull-point and/or spade cutters might be necessary for the variable conditions. This type of TBM would likely be feasible, as was used in the Upper Diamond Fork Tunnel. Depending on rock conditions, primary (initial) rock support could range from *bald*-headed (no support), to light spot bolting, to heavy support with pre-cast segmental concrete rings installed directly behind the cutter head as mining progresses, and serve as primary and permanent liner. Excavation with a TBM is likely to be faster with the shorter east west tunnel taking 1-1.5 years and the longer North south tunnel taking 2.5-3 years. This does not include the possible 10 -12 month delivery time for a new TBM. During this time the portals and a starter TBM launch tunnel could be excavated by Drill-and-Blast this would allow the TBM on arrival a faster start up.

The logistics of delivery of a TBM to the mountainous sites may be an issue as bridges and roads to the portals need to be suitable for very heavy loads of over 50 tons and access to heavy lift equipment. In addition adequate staging areas for assembly and excavation soil handing will be a significant site design consideration. If the rock conditions are favorable, then a large roadheader may be preferable to a TBM. Final design would also include liner requirements, roadway sections in the tunnel, pavements, lighting, ventilation and signage, with a robust O&M Plan.

Attachments:

Figure 1 Project Overview
Figure 2 Topographic Map
Figure 3 Geologic Map
Figure 4 Soils
Figure 5 Landslides

Appendix A: Sample Slope Stabilization Techniques

References:

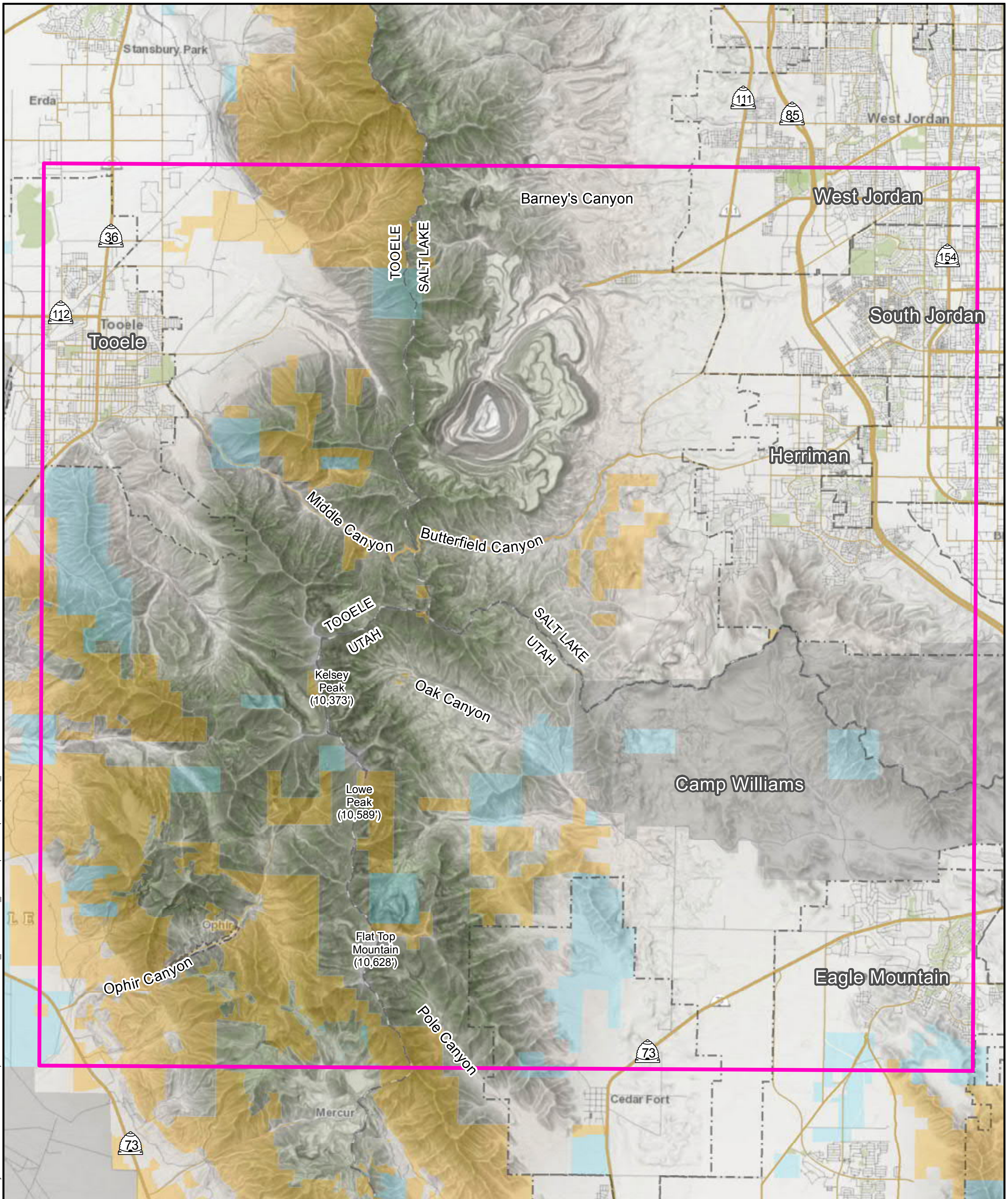
Christenson, G.E. and Shaw, L.M. 2008. *Geologic Map of Landslide Special Study Areas, Wasatch Front and Nearby Areas, Utah.* Supplement Map to Utah Geological Survey Map Circular 106, scale 1:200,000.

Clark, D.L., Kirby, S.M., Oviatt, C.G. 2012. *Interim Geologic Map of the Rush Valley 30' x 60' Quadrangle, Tooele, Utah, and Salt Lake Counties, Utah.* Utah Geological Survey Open-File Report 593, Plate 1, scale 1:62,500.

Clark, D.L., Oviatt, C.G., and Dinter, D.A. 2016. *Interim Geologic Map of Parts of the Tooele 30' x 60' Quadrangle, Tooele, Salt Lake, and Davis Counties, Utah, Year 3.* Utah Geological Survey Open-File Report 656, Plate 1, scale 1:62,500.

Elliott, A.H. and Harty, K.M. UGS. 2010. *Geologic Map of the Rush Valley 30' x 60' Quadrangle.* Utah Geological Survey Map 246DM, Landslide Maps of Utah, Plate 13 of 46, scale 1:100,000.

The American Society of Civil Engineers, 2007. Geotechnical Baseline Reports for Construction: Suggested Guidelines, Reston, VA.



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Land Ownership

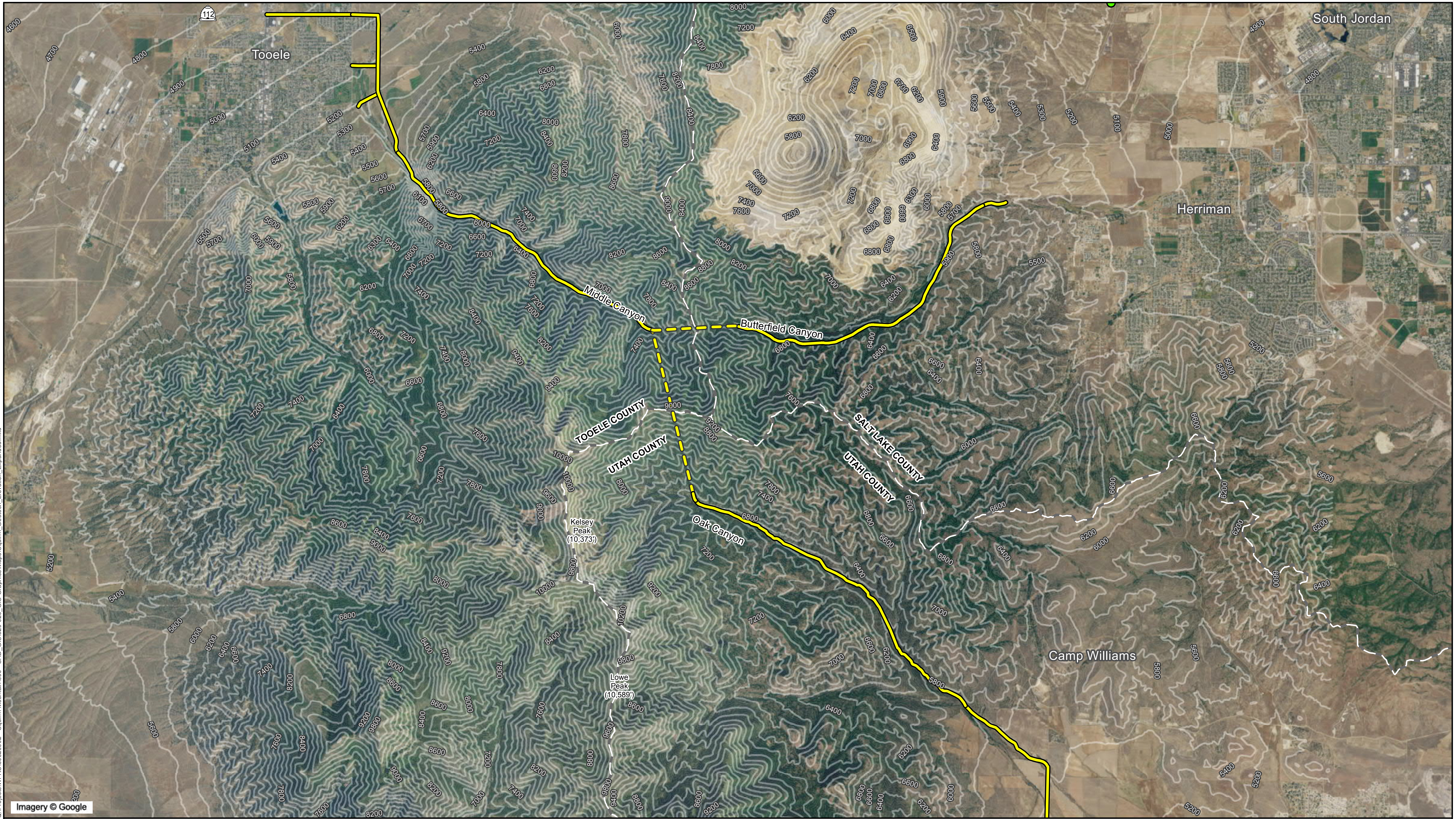
- Private (no color)
- BLM
- DOD
- SITLA

N E S W

0 1.75 3.5 Miles

Data Source: Utah AGRC

Oquirrh Connection
Figure 1
Project Overview



Proposed Road (55 mph Design)
Proposed Tunnel (55 mph Design)

N
W E
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0 5,000 10,000
Feet

Oquirrh Connection
Figure 2
Elevation Map

Data Source: Utah AGRC, NRCS

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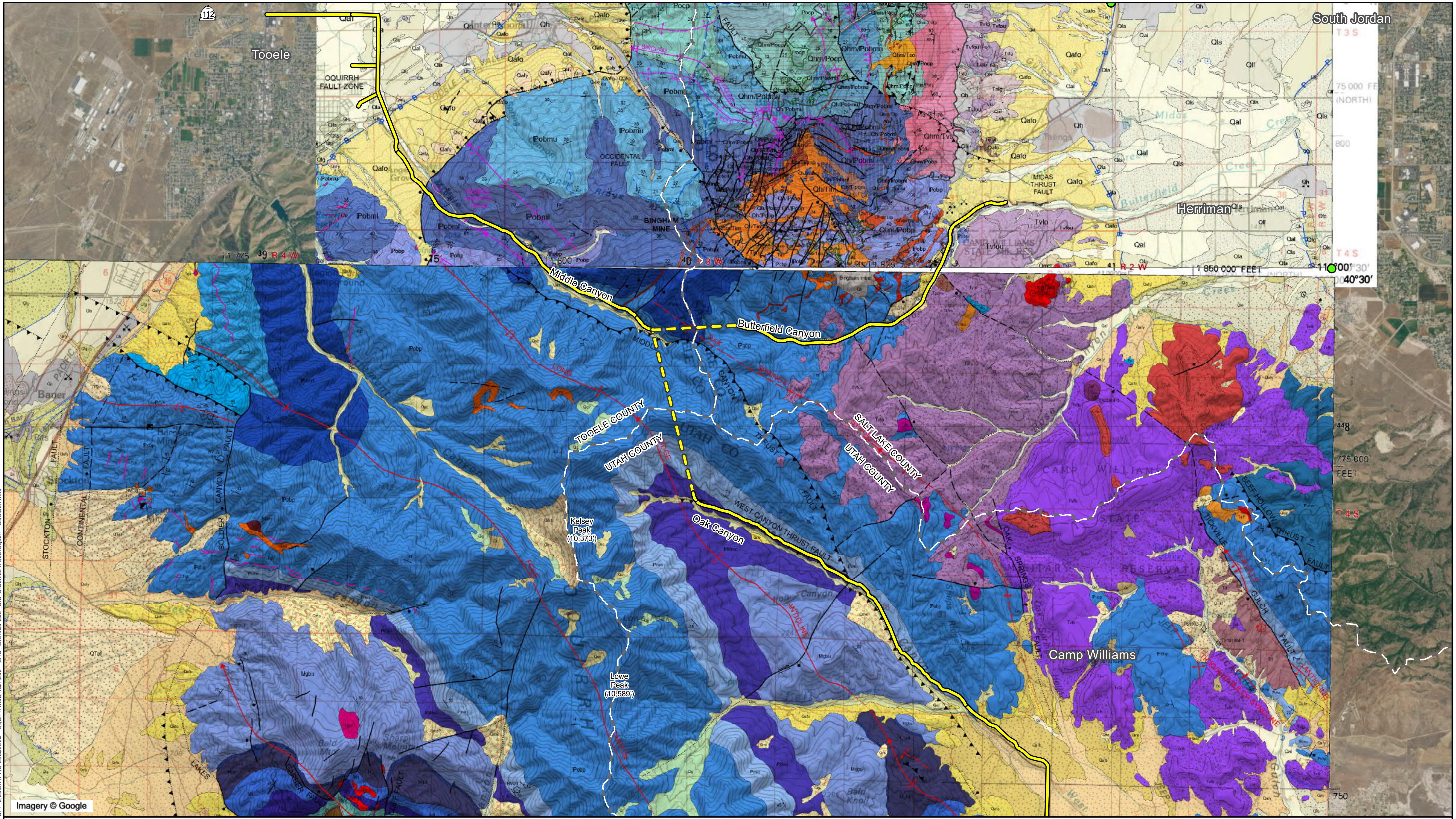

Proposed Road (55 mph Design)	
Proposed Tunnel (55 mph Design)	
Qac	Alluvial and colluvial deposits
Qg	Glacial deposits, undifferentiated
Qh	Human disturbance
IPobp	Oquirrh Group, Butterfield Peaks formation
IPobml	Oquirrh Group, Bingham Mine Formation, lower member
Tmi	Monzonite intrusions (also Tim)
Tvlo	Older lahars and debris flows
Tvfou	Older intermediate lava flows
Tl	Latite to dacite porphyry sills and dikes
	Normal fault - Dashed where approximately located, dotted where concealed; bar and ball on down-thrown side
	Fault of unknown geometry - Dashed where approximately located, dotted where concealed
	Thrust fault - Dashed where inferred, dotted where concealed; teeth on hanging wall
	Axial trace of anticline - Dashed where approximately located, dotted where concealed; arrow shows plunge
	Axial trace of syncline - Dashed where approximately located, dotted where concealed; arrow shows plunge
	Low-angle normal fault - Dotted where concealed; boxes on hanging wall

0 5,000 10,000 Feet

Data Source: Utah AGRC, Utah Geologic Survey (Rush Valley and Tooele Quads), NRCS

Oquirrh Connection
Figure 3
Geologic Map

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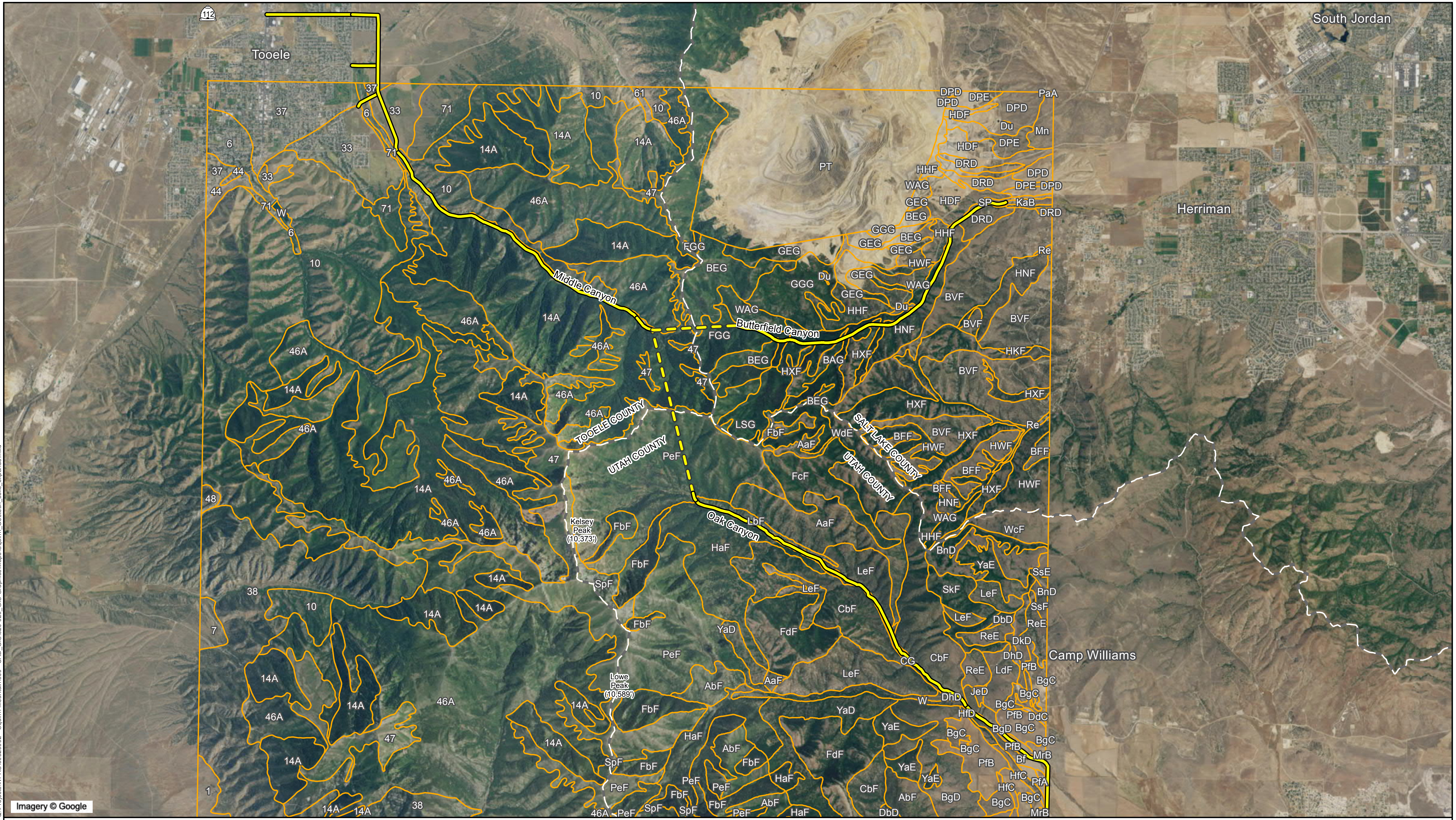

Proposed Road (55 mph Design)
Proposed Tunnel (55 mph Design)
NRCS Soils (see key)

Data Source: Utah AGRC, Utah Geologic Survey, NRCS

Soil Key

6: Birdow loam, 1 to 4 percent slopes
10: Broad, moist-Reywat, moist-Rock outcrop association, 30 to 60 percent slopes
14A: Datemark-Podmor, moist-Rock outcrop association, 30 to 70 percent slopes
33: Kapod gravelly loam, 2 to 10 percent slopes
46A: Podmor, moist Datemark-Rock outcrop assocation, 30 to 70 percent slopes
47: Podmor-Onaqui-Rock outcrop association, 20 to 60 percent slopes
AaF: Agassiz very stony loam, 30 to 70 percent slopes
BAG: Baird Hollow loam, 30 to 60 percent slopes
BEG: Bradshaw-Agassiz association, steep
BVF: Butterfield assocation, moderately steep
CbF: Calpac-Agassiz complex, 30 to 70 percent slopes
CG: Cumulic Haploxerolls, sloping
DhD: Dry Creek cobbly loam, 4 to 15 percent slopes
DRD: Dry Creek soils, 3 to 15 percent slopes
Du: Dumps
FGG: Fitzgerald gravelly loam, 40 to 70 percent slopes
GEG: Gappmayer very cobbly loam, 30 to 60 percent slopes
GGG: Gappmayer-Wallsburg association, very steep
HaF: Hamtah loam, 30 to 70 percent slopes
HHF: Harkers soils, 6 to 40 percent slopes
HNF: Henefer-Horrocks complex, 5 to 50 percent slopes
HXF: Horrocks-Little Pole association, steep
KaB: Kearns silt loam, 1 to 3 percent slopes
LbF: Lizzant very cobbly loam, 30 to 60 percent slopes
LeF: Lundy-Rock outcrop complex, 30 to 70 percent slopes
LSG: Lucky Star gravelly loam, 40 to 60 percent slopes
PeF: Parkay-Rock outcrop complex, 30 to 70 percent slopes
PT: Pits, mine
SP: Stony terrace escarpments
WAG: Wallsburg very cobbly loam, 30 to 70 percent slopes

N / S / E / W

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Oquirrh Connection
Figure 4
Soils

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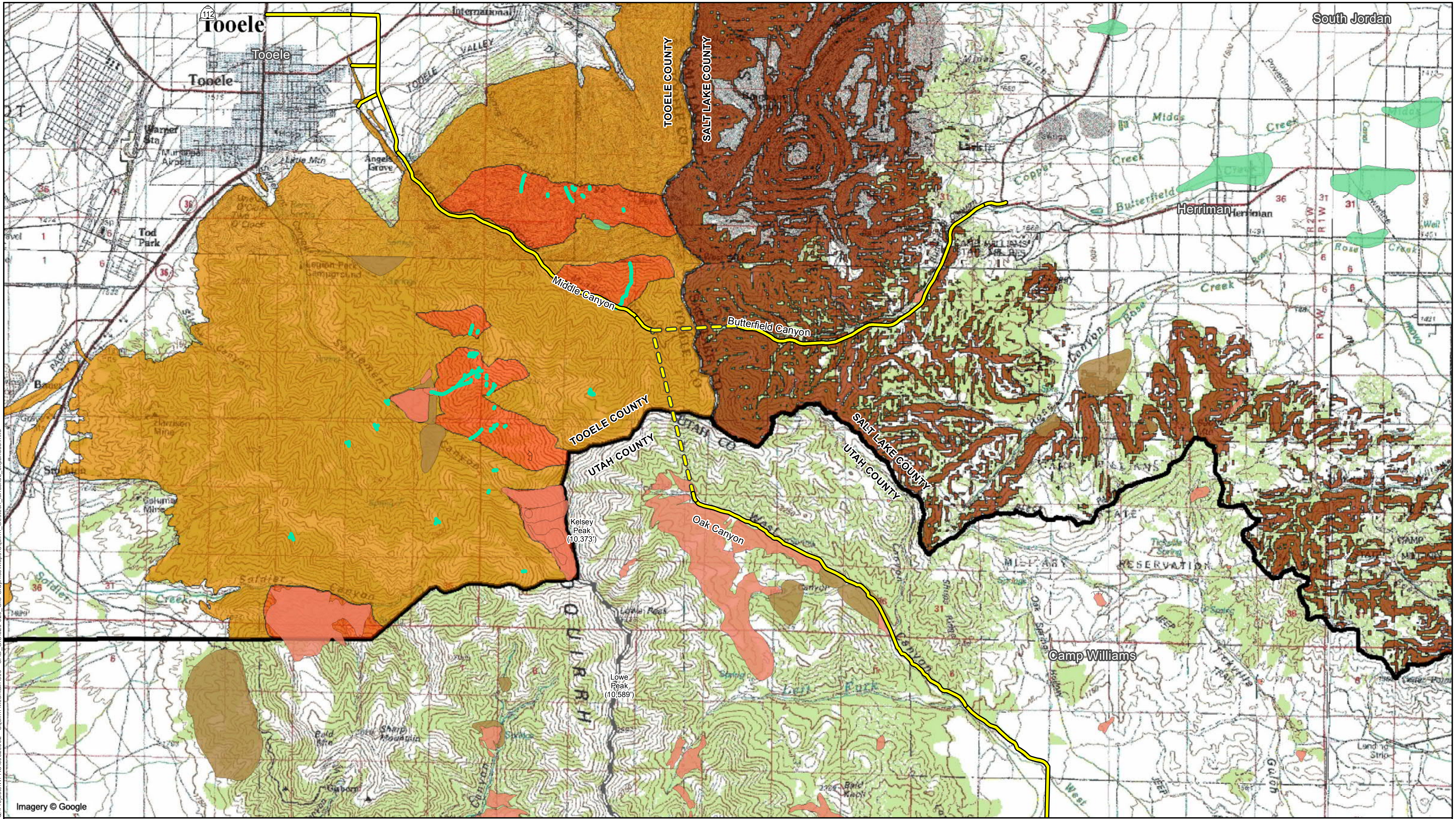

Proposed Road (55 mph Design)

Proposed Tunnel (55 mph Design)

Debris Flow Paths

Landslide Polygons

not classified

shallow landslide

Landslide Hazard

Moderate

High; includes all

Slopes greater than 30% not taken from original county maps.

0 5,000 10,000 Feet

Data Source: Utah AGRC, Utah Geologic Survey, NRCS

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Oquirrh Connection

Figure 5

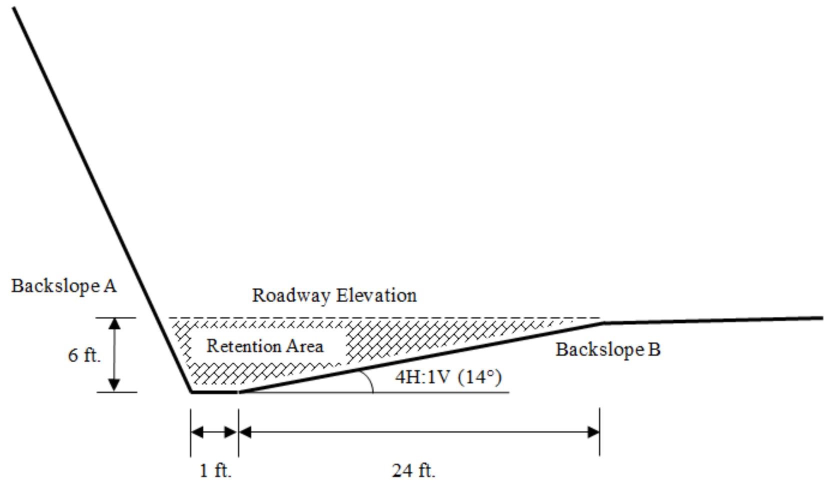
Landslides

Appendix A

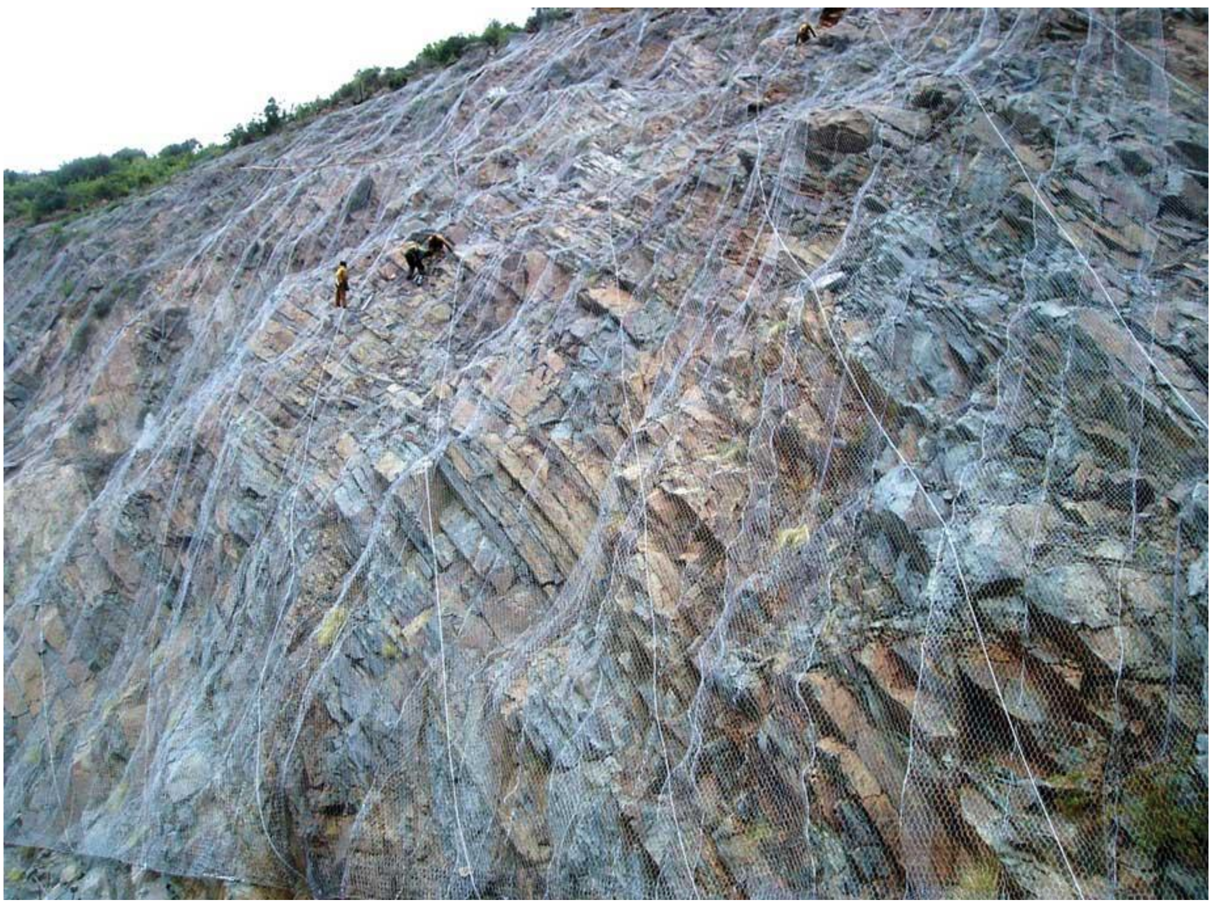
Sample Slope Stabilization Techniques

Soil Nail Wall Construction

Completed Soil Nail Wall

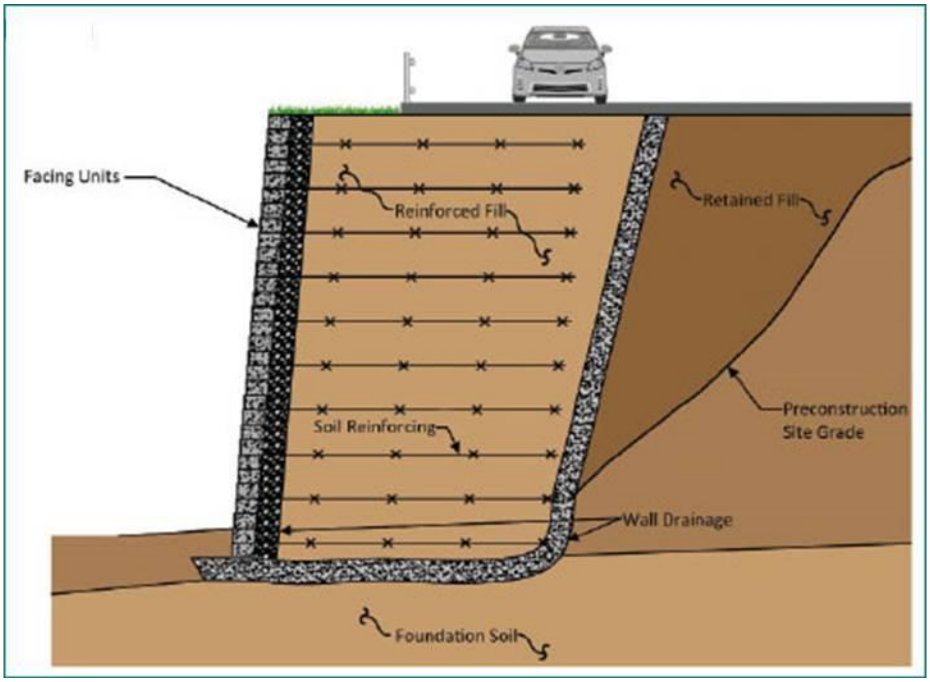


Rock Fall Catchment Ditch



Rock Fall Netting – May be designed to keep rock from falling or to allow rock to fall but minimize rollout.

Rock Fall Arrest System


Facing Units
Reinforced Fill
Retained Fill
Preconstruction
Site Grade
Soil Reinforcing
Wall Drainage
Foundation Soil

MSE Wall

Tieback Wall before shotcrete facing

APPENDIX C

Oquirrh Connection Land Use Impacts and Benefits Memo

1 OQUIRRH MOUNTAIN CONNECTION: CORRIDOR DESCRIPTION

The Butterfield-Middle Canyon Alignment option for the Oquirrh Mountain Connection is an approximately 14 mile long roadway that connects the communities of Tooele (Tooele County) and Herriman (Salt Lake County) in Utah. At its western termini, the alignment connects with 1000 North in the City of Tooele at its intersection with Droubay Road (about 1.2 miles east of Main Street). The alignment generally follows the Middle Canyon and Butterfield Canyon Roads through the Oquirrh Mountains. On the east, the alignment connects with 13055 South, just south of the Kennecott Copper Mine.

1.1 GENERAL PLANS AND LAND USE POLICY DOCUMENTS

The key community and county level general plans and land use policy documents were reviewed to establish a baseline for the future anticipated land use within the study area. Available population growth projections within the general plans have also been summarized in the following section.

1.1.1 Tooele County General Plan Update 2016

The Tooele County General Plan Update 2015 is intended to help understand the broad planning goals for the County, and to assist decision makers as they evaluate future development and growth. The 2016 update of the General Plan focused on land use and housing. According to population projections based on past trends, the population in Tooele County is projected to increase from 65,782 in 2015 to 127,340 by 2040, for an overall increase of 61,558. Eighty-six percent of this growth is anticipated to take place within the Tooele Valley, with the Tooele population increasing by 27,816, and the unincorporated Tooele Valley by 12,551. Table 1 summarizes the projected population change within Tooele County from 2015 to 2040. Figure 1 illustrates the projected population growth in Tooele County spatially.

Table 1: Population Change in Tooele County (2015-2040)

	2015	2020	2030	2040
Tooele Valley				
Grantsville	10,198	11,794	16,216	22,139
Lake Point	1,266	1,400	1,633	1,880
Stansbury Park	8,998	9,145	9,290	9,537
Stockton	622	691	838	996
Tooele City	35,367	39,839	49,855	63,183
Unincorporated Tooele Valley	4,712	6,507	11,312	17,263
Tooele Valley Total	61,163	69,376	89,144	114,998
Unincorporated County	4,619	5,506	7,777	1,2342
Tooele County Total	65,782	74,882	96,921	127,340

The highest population growth in the County is expected to occur immediately east of Tooele City limits, generally concentrated on the northeast and southeast sides of 1000 N and Droubay Roads. This location is part of the International Smelter and Refining (IS&R) Superfund Site (Atlantic Richfield Company). The IS&R site was placed on the Environmental Protection Agencies (EPA) National Priority List in July of 2000. The future land use of this area is expected to be rural residential, per Tooele County future land use map (see Figure 2).

Figure 1: Projected Population Change (2015-2040) by TAZ

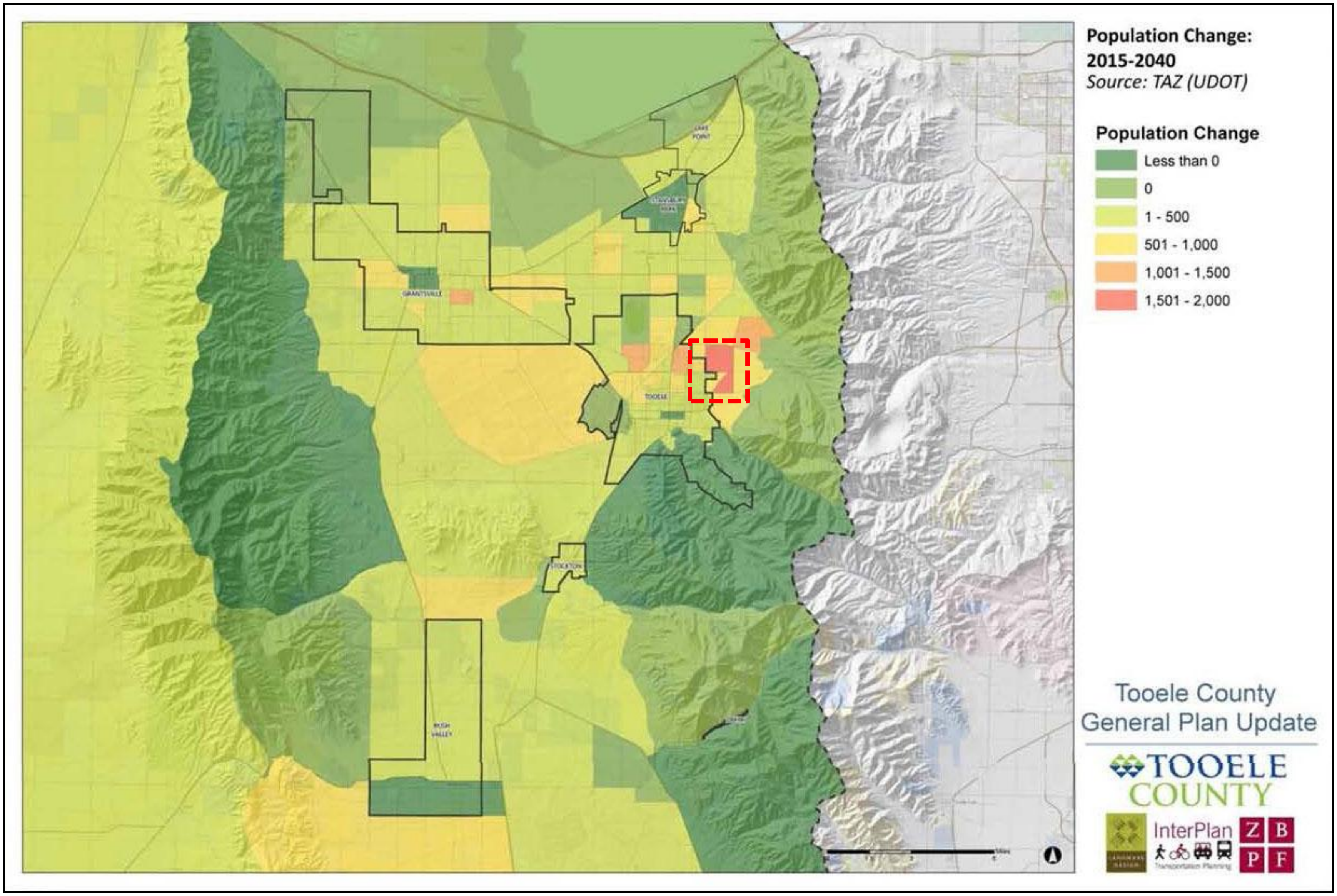
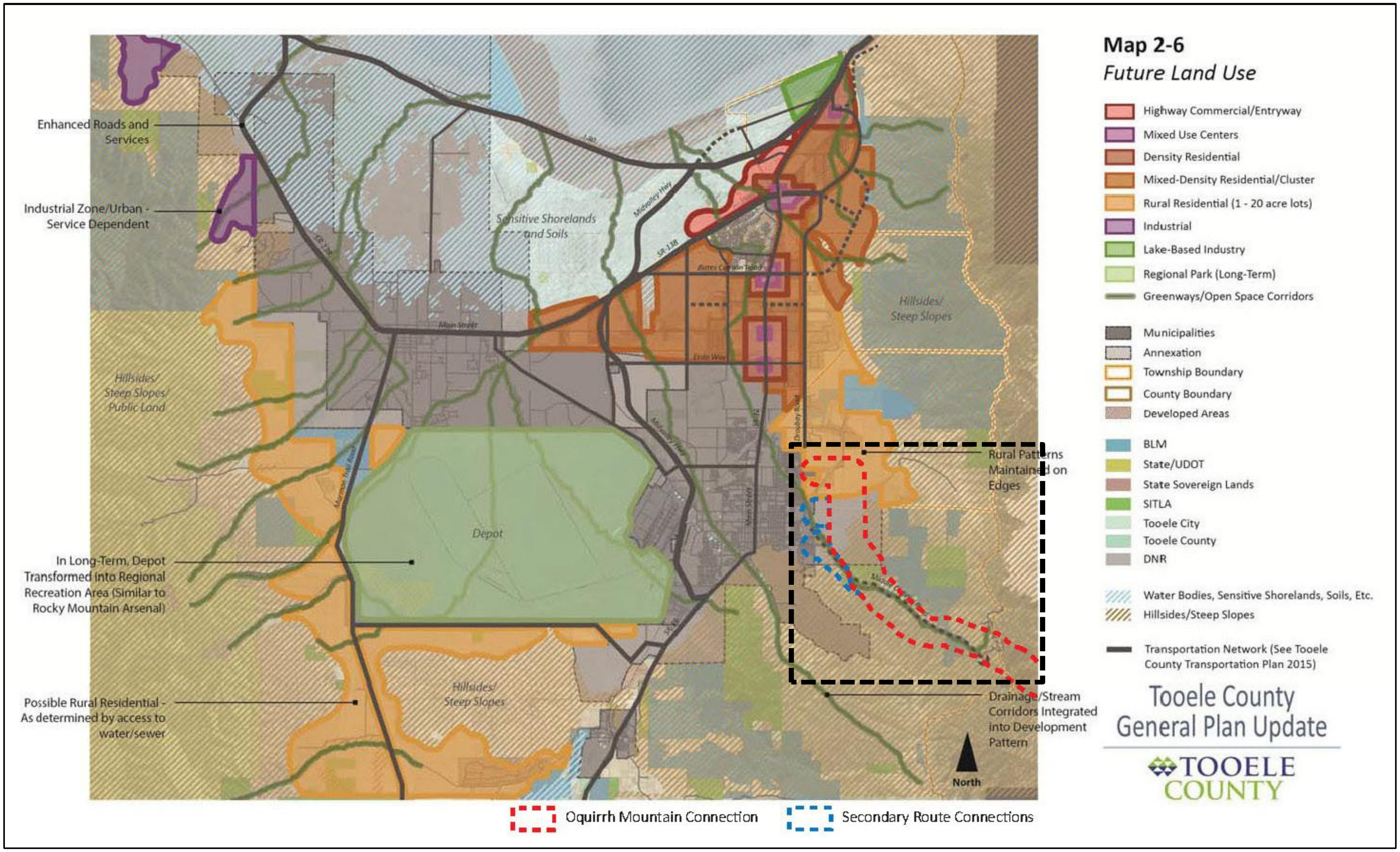
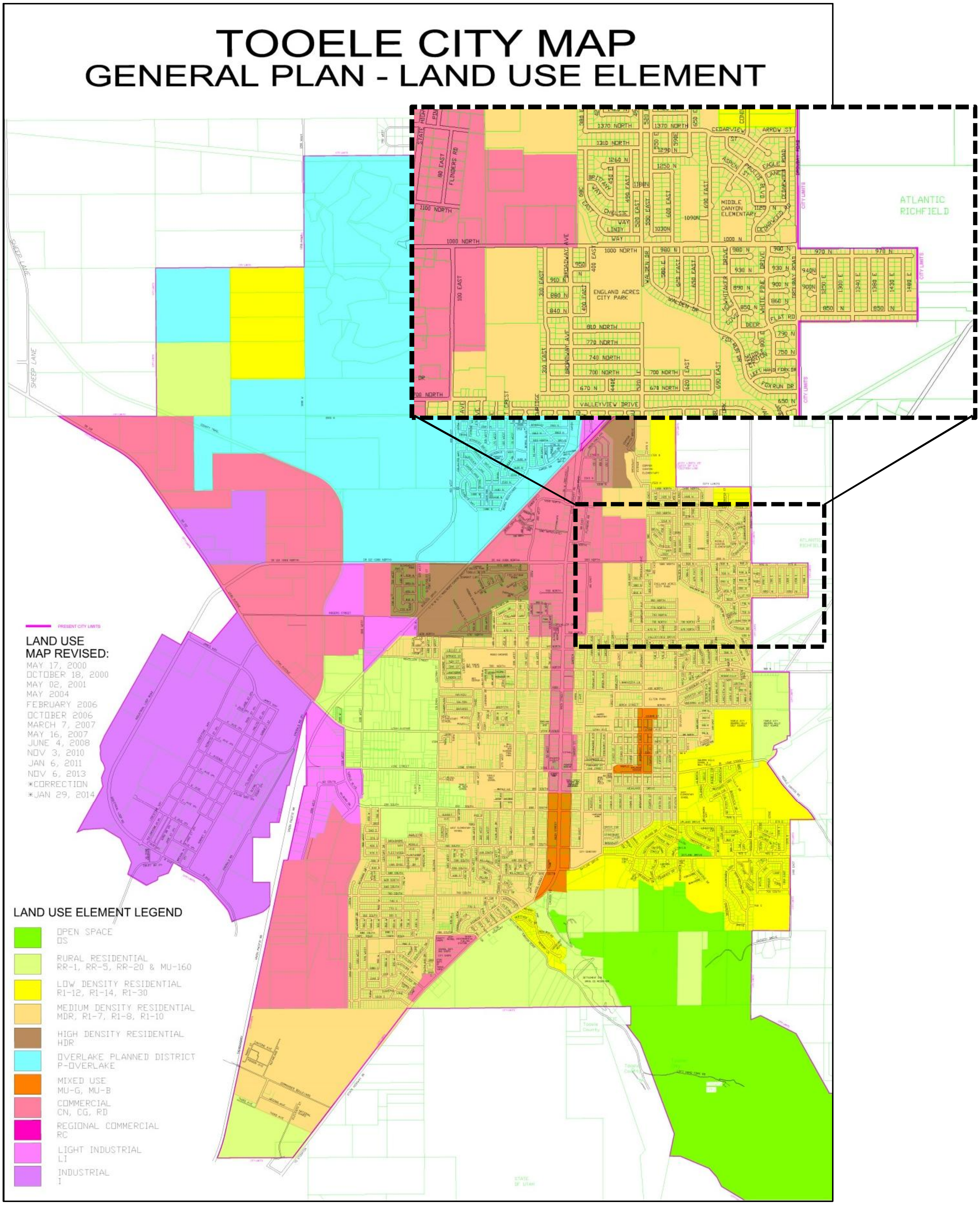


Figure 2: Tooele County Future Land Use



While the updated General Plan was prepared in concert with the updated Tooele County Transportation Plan 2015, there was no indication that a future Oquirrh Mountain Connection was considered during the preparation of the Future Land Use Plan. Within the Tooele City limits, the land use surrounding the western termini of the Oquirrh Mountain Connection selected alignment has been identified as medium density residential (see Figure 3).

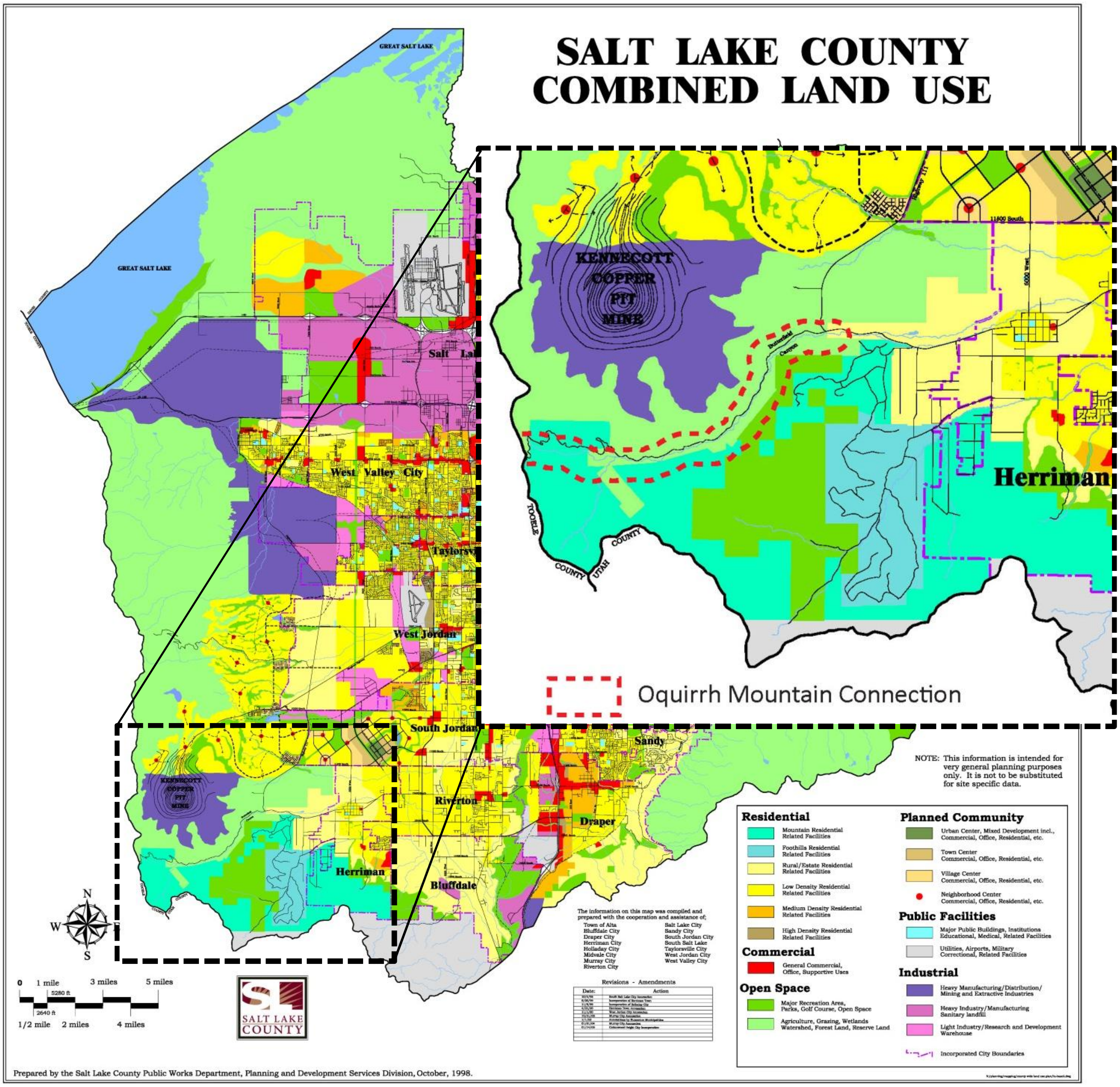
Figure 3: Tooele City Land Use Element



1.1.2 Salt Lake County Combined Land Use Map

The Salt Lake County's combined land use map identifies Mountain Residential (and related facilities), Open Space (agriculture, grazing, wetlands, watershed, Forest Land, Reserve Land), and Major Recreation Areas (Parks, Golf Courses, Open Space) as the primary land uses along the selected alignment of the Oquirrh Mountain Connection (see Figure 4).

Figure 4: Salt Lake County Combined Land Use Map



1.1.3 Herriman City 2025 General Plan Amendment

The 2025 General Plan Update envisions a community that is healthy, diverse and livable, and which has a unique and desirable “sense of place”. The plan identifies the southwest corner of the Salt Lake Valley as a very desirable location for real estate development. That will likely remain so for the coming decade as this is one of the last areas of the valley with new homes being built and has become one of the most desirable locations.

Recent Census estimates from 2012 put the City’s population at 24,433. Conservative estimates by the Governor’s Office of Planning and Budget (GOPB) project continued growth at the highest rate of any city in Salt Lake County (see Table 2).

Table 2: Salt Lake County Population Projections (Source: GOPB)

	2010	2020	2030	2040	2050	2060	Percentage Change (2010-2060)	Annual Growth Rate
Salt Lake County	118,554	140,950	179,643	218,527	259,050	302,619	155.26%	1.89%
Bluffdale	7,598	10,099	16,777	19,499	22,098	25,125	230.68%	2.42%
Herriman	21,785	27,003	38,458	50,114	64,896	81,310	273.24%	2.67%
Riverton	38,753	44,339	50,150	56,512	61,974	67,192	73.39%	1.11%
South Jordan	50,418	59,509	74,258	92,403	110,083	128,992	155.84%	1.90%

Within the Herriman City limits, the 2025 Future Land Use Map identified Medium Density Residential, Agriculture Residential, and Open Space as the key land uses in the vicinity of the eastern termini of the selected alignment of the Oquirrh Mountain Connection (See Figure 5).

1.1.4 Southwest Community Land Use Plan

The Southwest Community Land Use Plan, prepared by the Salt Lake County Planning and Development Services in 2008 mimics the land use shown in the Salt Lake County Combined Land Use Plan. The key land uses adjacent to the selected alignment of the Oquirrh Mountain Connection include Mountain Residential, Open Space, and Industrial Mining (see Figure 6).

In addition, the Wasatch Front Regional Council provided a property ownership map for the Butterfield Canyon Corridor (Salt Lake County line to Herriman) which identifies Herriman Irrigation Company, Salt Lake County, Kennecott Utah Copper, BLM, and The Last Holdout LLC as the main property owners along the corridor (see Figure 7).

Figure 5: Herriman General Plan – 2025 Future Land Use

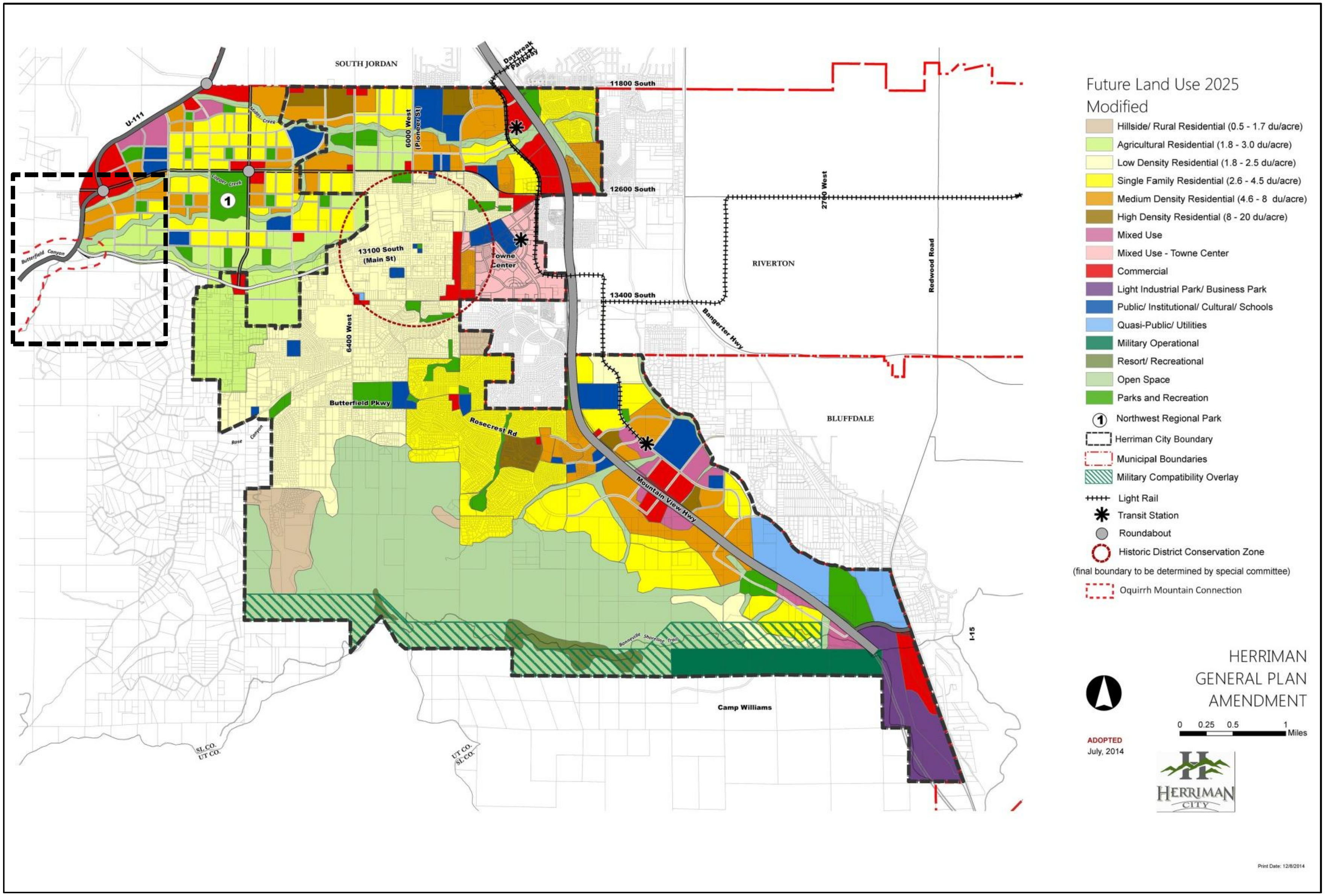


Figure 6: Southwest Community Land Use Plan

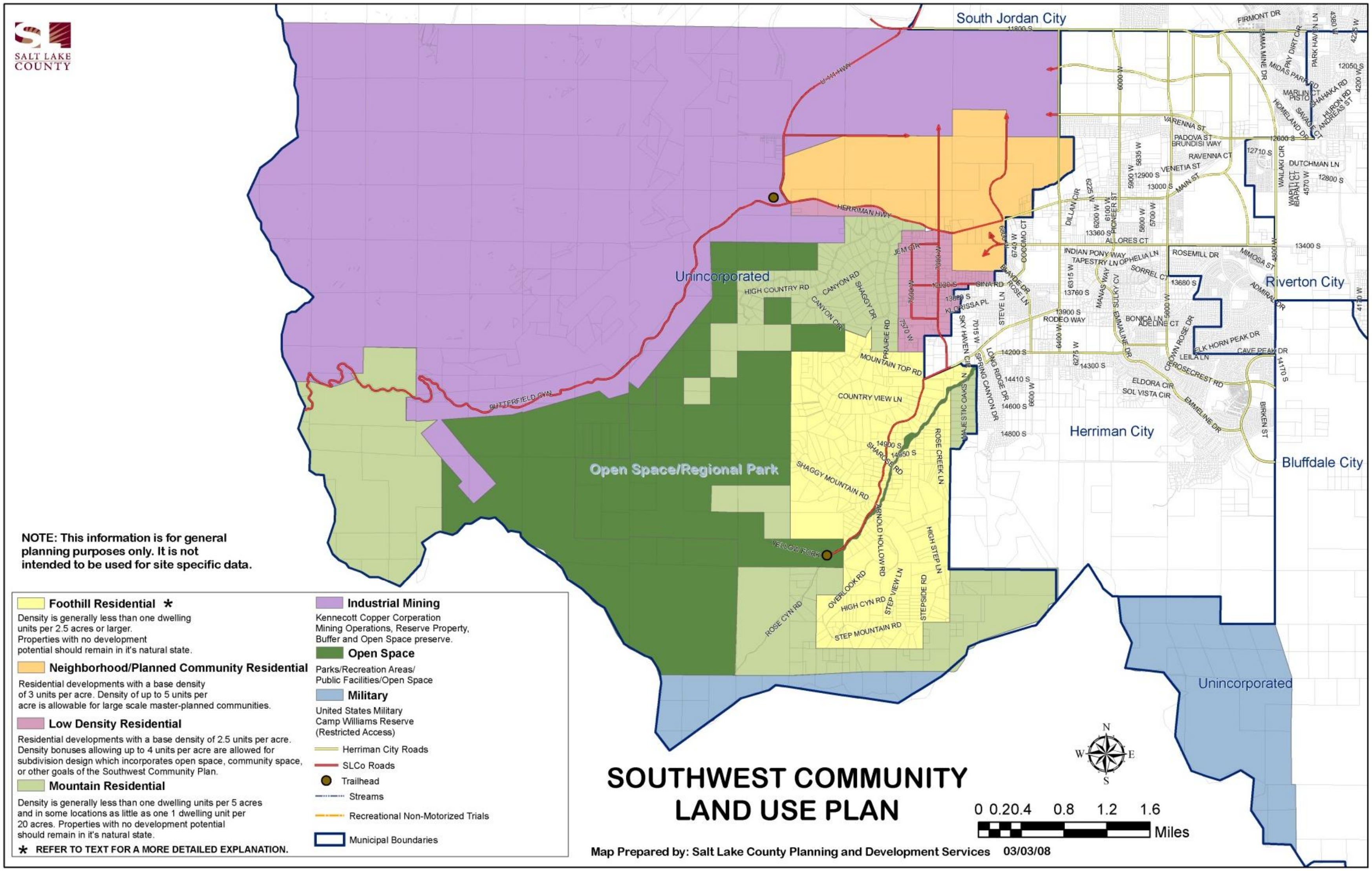
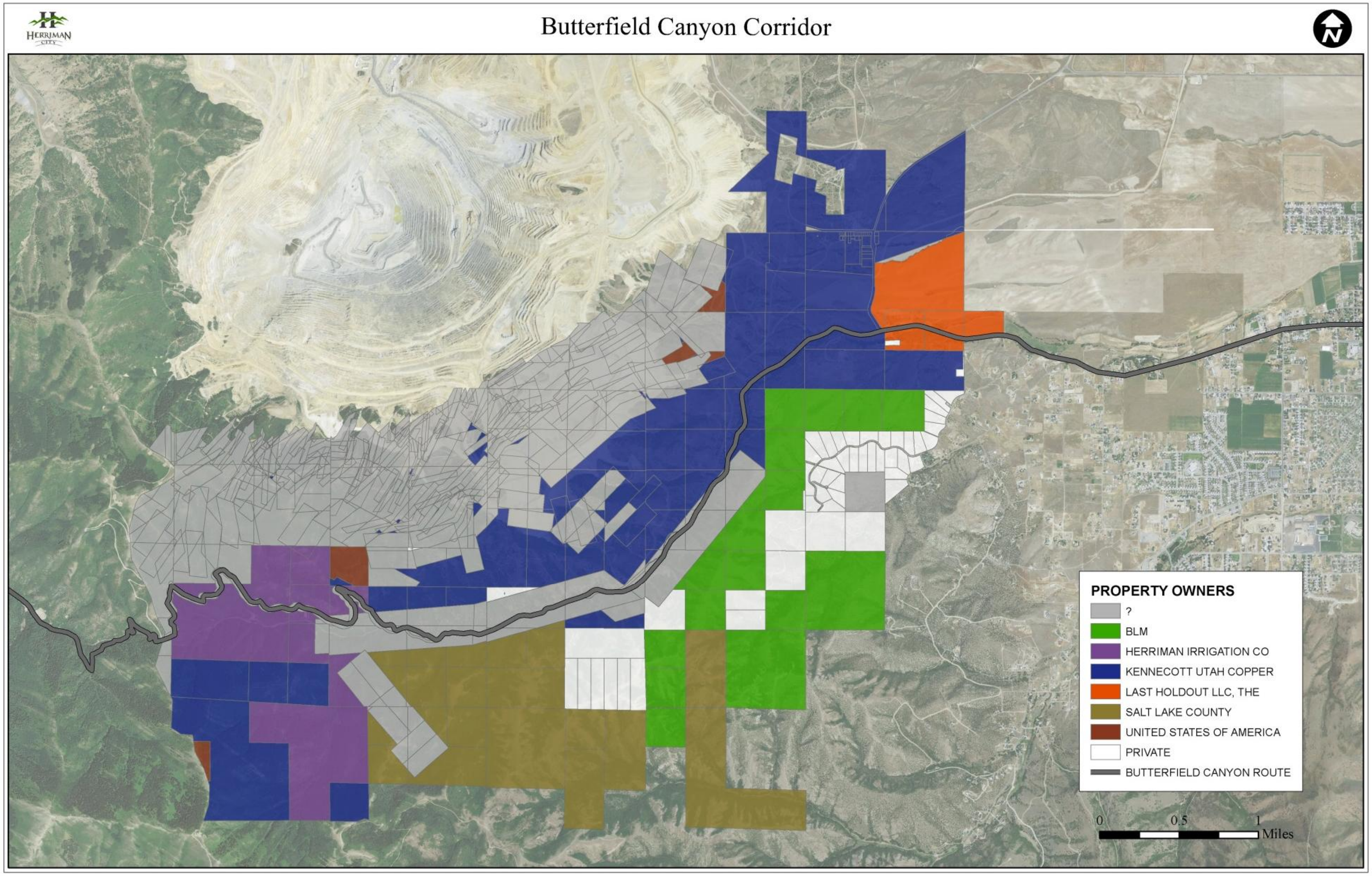


Figure 7: Property Ownership along Butterfield Canyon Corridor



1.2 ASSESSMENT OF POTENTIAL LAND USE IMPACTS

1.2.1 METHODOLOGY

For the purpose of assessing impacts to existing land uses, publicly-available parcel level use data for the Tooele and Salt Lake counties was utilized. GIS Shapefile data available on the Utah Automated Geographic Reference Center (AGRC) website was accessed and downloaded on March 22, 2017.

Available County-level parcel datasets include a "Property Class" attribute that identifies the existing use (e.g., residential, commercial, mixed-use, etc.) of each property. This attribute was utilized for assessing potential impacts to land uses within a 1/4-mile buffer of the Selected Oquirrh Mountain Connection Alternative.

1.2.2 POTENTIAL LAND USE IMPACTS IN TOOELE COUNTY

As mentioned earlier, a 1/4-mile buffer along the Selected Oquirrh Mountain Connection Alternative was created to identify the "Area of Potential Land Use Impacts" (see Figure 8). The key land uses identified along the selected alignment alternative include:

- An approximately 6-acre site of Middle Canyon Elementary School is within a 1/4-mile of the Oquirrh Connection's western termini where it connects with 1000 N at Droubay Road
- The following subdivisions fall within the area of land use impacts, in the vicinity of 1000 N and Droubay Road:
  - Cedarwood Estates
  - Carr Fork
  - Holt Meadows
  - North Fork
  - Middle Canyon Estates
- Agricultural land along the north and west side of selected alignment, north of Smelter Road
- Oquirrh Hills Golf Course located on the south-east corner of Smelter Road and Droubay Road
- Residential and Agricultural Land along Ericson Road, between Smelter Road and Anaconda Highway
- Agricultural Land (classified as Land Greenbelt or Agricultural) between Smelter Road and Oquirrh Mountain foothills
- Some of the parcels illustrated as 'Unclassified' are either BLM land, or State Trust land

Figure 8: Existing Land Use and Land Ownership along the Oquirrh Mountain Connection

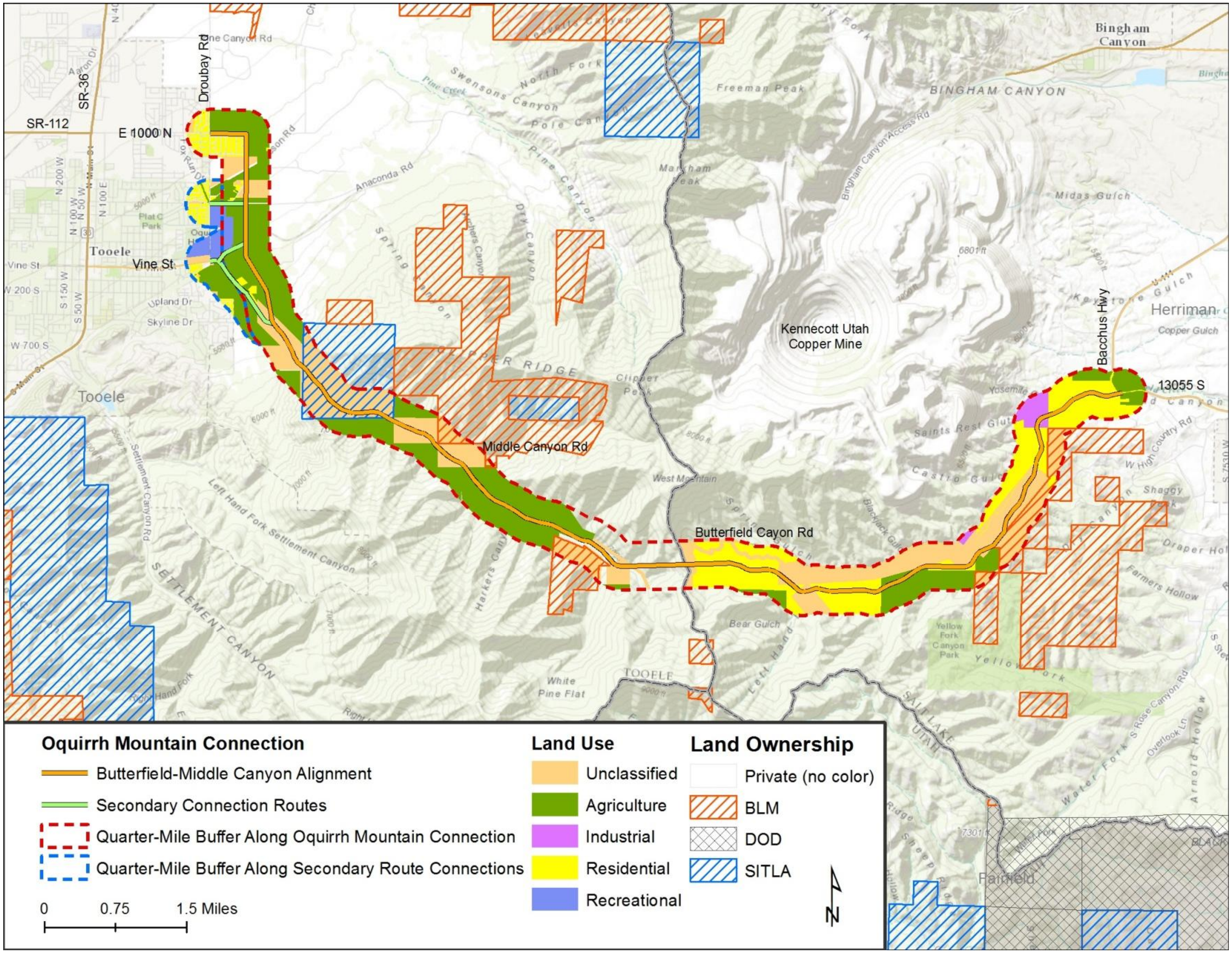


Table 3 below provides a summary of the land use impacts within Tooele County.

Table 3: Potential Land Use Impacts within Tooele County

Existing Land Use	Number of Properties Potentially Impacted	Land Area in Acres
Agriculture	62	1270.7
Residential	397	98.5
Recreational (Golf Course)	8	32.3
Other (Unclassified)	22	832.2

1.2.3 POTENTIAL LAND USE IMPACTS IN SALT LAKE COUNTY

The key land uses identified along the selected alignment alternative within Salt Lake County (see Figure 2) include:

- Land with "Residential" classification, east of the Tooele/Salt Lake County Line
- Agricultural land along the selected alignment
- Industrial parcels on the south and east of the Kennecott Copper Mine
- Residential land on the south and east of the Kennecott Copper Mine
- Residential and agricultural land at the eastern termini of the Oquirrh Mountain Connection selected alignment, where it connects with Bacchus Highway
- Some of the parcels illustrated as 'Unclassified' are State Trust land

Table 4 below provides a summary of the land use impacts within Salt Lake County.

Table 4: Potential Land Use Impacts within Salt Lake County

Existing Land Use	Number of Properties Potentially Impacted	Land Area in Acres
Agriculture	15	326.1
Residential	16	847.2
Industrial	4	74.1
Other (Unclassified)	53	718.9

1.2.4 POTENTIAL SECONDARY LAND USE IMPACTS IN TOOELE COUNTY

The primary land use impacts, discussed in the sections above, were identified within the Area of Potential Land Use Impacts along the Oquirrh Mountain Connection. In addition to the main alignment, additional routes in Tooele County will intersect with the selected alignment, and provide access to the Tooele community. These routes include:

1. Smelter Road (east-west connection to Droubay Road)
2. Middle Canyon Road (connection to Vine Street)
3. New Roadway Connection to Vine Street

Secondary land Use impacts have been identified along these routes, which include:

- Residential subdivisions within a quarter-mile of the intersection of Smelter and Droubay Roads:
    - Lakeview Heights

- Oquirrh Hills Estate
- Spring Meadows
- Chelsea Cove
- Middle Canyon Estates

· Agricultural land on the north east corner of Smelter and Droubay Roads
· Additional land underlying the Oquirrh Hills Golf Course
· Residential subdivisions within a 1/4-mile of the intersection of Vine Street and Droubay Road:
  - East Highlands
  - Vine Street Villas
  - Crestview Estates
· Loma Vista Subdivision on the east side of Middle Canyon Road
· Agricultural land along Middle Canyon Road

Table 5 below provides a summary of the secondary land use impacts along the additional route connections to Tooele City.

Table 5: Potential Land Use Impacts along Additional Route Connections in Tooele County

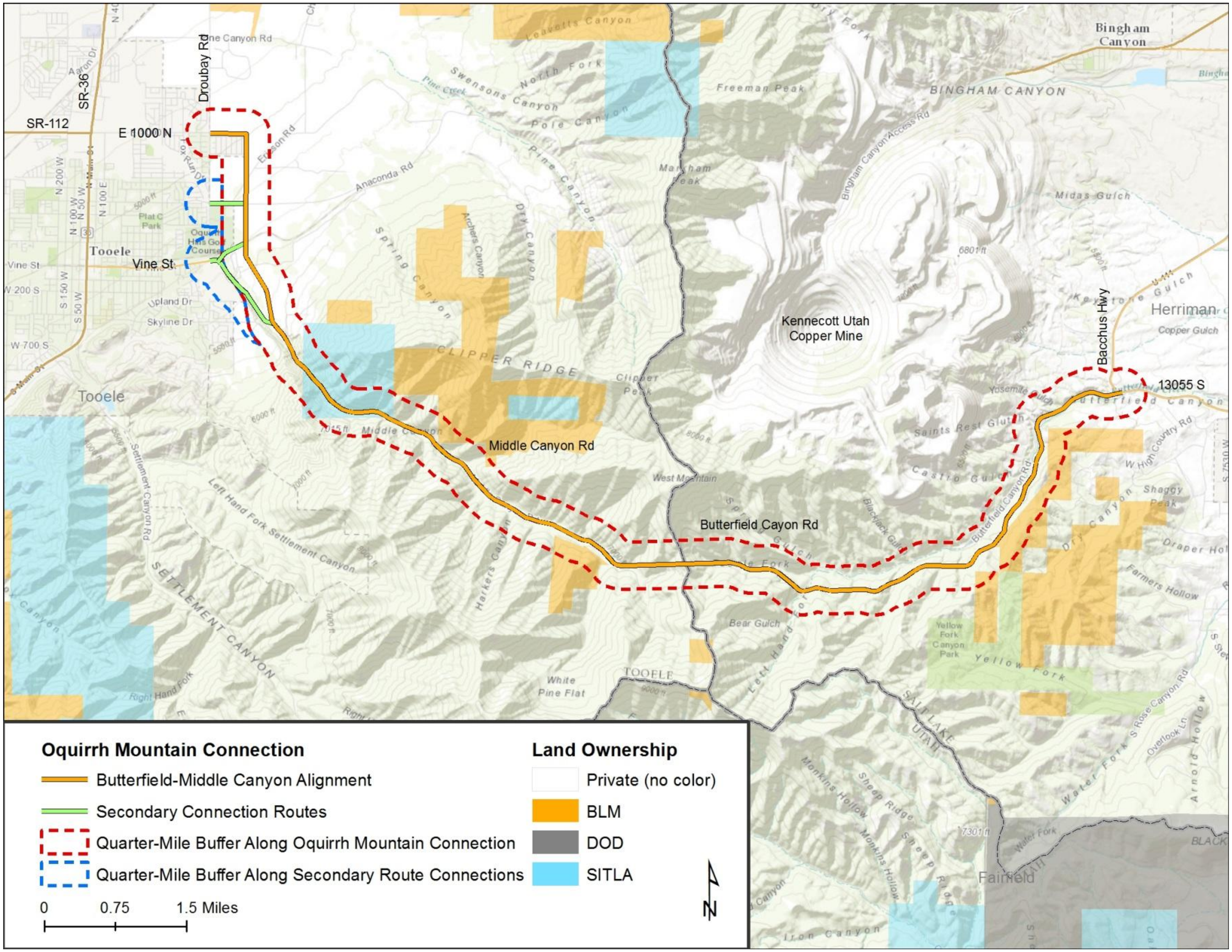
Existing Land Use	Number of Parcels Potentially Impacted	Land Area in Acres
Agriculture	22	114.5
Residential	316	58.1
Commercial	1	2.6
Recreational (Golf Course)	6	66.3
Other (Unclassified)	9	18.9

1.2.5 LAND OWNERSHIP

The selected alignment of the Oquirrh Mountain connection has proximity to the following land ownership, as illustrated in Figure 8 and Figure 9:

a. BLM Land (Tooele County)
b. State Trust Land (Tooele County)
c. BLM Land (Salt Lake County)
d. Private Land
   - Mountain Residential (Salt Lake County)
   - Major Recreation Area, Parks, Golf Course, Open Space
   - Agriculture, Grazing, Wetlands, Watershed, Forest Land, Reserve Land

Figure 9: Land Ownership – Tooele and Salt Lake Counties



1.3 LAND USE SUSCEPTIBILITY FOR CHANGE

Transportation investments have the ability to significantly alter development patterns. The susceptibility of land use for change is dependent on a variety of factors, which include:

- *Access to Transportation Corridors*
  In this case, the Oquirrh Mountain Connection could provide the transportation access necessary to facilitate development.
- *Availability of Land with Development or Redevelopment Potential*
  As illustrated in the Tooele County General Plan through extensive analysis of developable land, the majority of the growth is expected to occur around the eastern termini of the corridor where developable land is available. This area has a future land use designation of Rural Residential.
- *Proximity to Transportation Nodes*
  A total of four transportation nodes (key intersections) exist along the entire length of the corridor. These include:
  - 1000 N & Droubay Road (Tooele)
  - Smelter Road & Droubay Road (Tooele)
  - Vine Street & Middle Canyon Road (Tooele)
  - Bacchus Highway & 13055 South (Herriman)

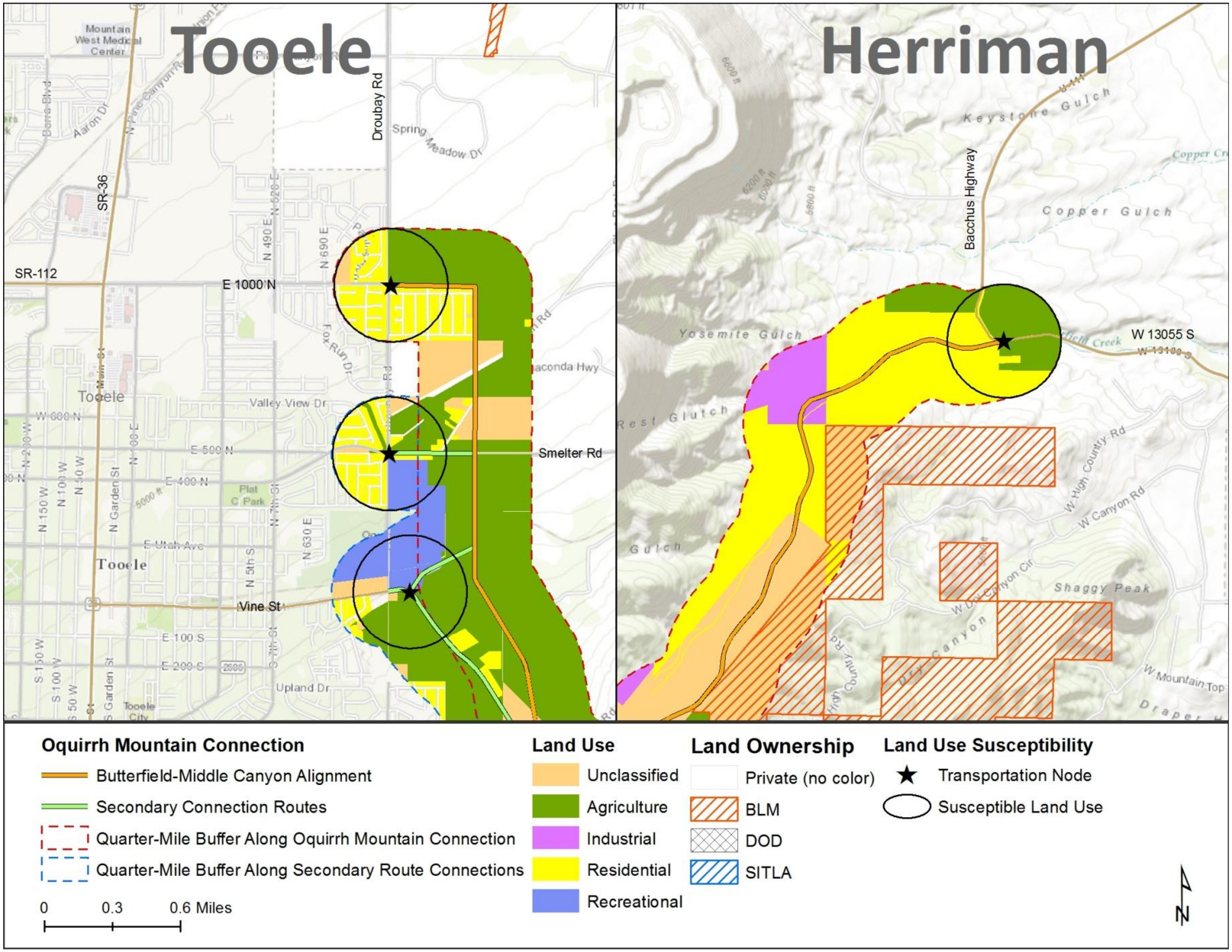
In the context of the Oquirrh Mountain Connection, a majority of the corridor follows the Middle Canyon Road and Butterfield Canyon Roads through agricultural land or open space, which includes mountain slopes and vegetation. In the absence of any major roadway nodes in the central part of the corridor, land use changes are not expected to occur between Tooele and Herriman.

Changes to land use may be expected on either end of the corridor where it connects with the communities of Tooele and Herriman. Figure 10 illustrates the four transportation nodes identified above, and the area around them within a half-mile radius that may be susceptible to change.

On the Tooele City side, the existing land uses within the susceptibility zone consist of agriculture, residential, and recreational. The agricultural areas in the vicinity of 1000 N and Droubay Road are classified as Rural Residential (very low density) in the future land use plan. These areas may evolve into slightly higher density residential, likely smaller lot higher-end housing. Some townhouse/rowhouse or apartment style housing may also evolve in this area, if demand warrants. The transportation nodes are also expected to attract convenience commercial development (e.g., convenience retail, neighborhood services, small professional offices, child care, shoe repair, dry-cleaning, etc.) immediately around the roadway intersections. Often times, transportation nodes similar to that described here could eventually develop with neighborhood-oriented commercial/services on two of the intersection corners and mid- to higher-density housing on the other two intersection corners.

On the Herriman City side, the area to the north and east of the Bacchus Highway/13055 S side is classified as Agricultural Residential and Medium Density Residential. This area may also see similar increase in density with higher-end slightly smaller lot housing development. Since this is the last transportation node out of Herriman towards Tooele City, greater intensity convenience-commercial development could also occur at this location.

Figure 10: Land Use Susceptibility for Change



APPENDIX D

Oquirrh Connection Feasibility Study Benefits-Cost Analysis Memo

OQUIRRH CONNECTION FEASIBILITY STUDY

BENEFIT-COST ANALYSIS

JUNE 12, 2017

1. INTRODUCTION

This Oquirrh Connection Feasibility Study evaluated three potential roadway connections and narrowed the selection to one preferred feasible alignment. Selection was based on meeting the following criteria:

- Maximum 6 percent grade
- Tunnels utilized to maintain 6 percent grade, otherwise alignment follows existing terrain as much as possible
- Design speeds: 25 - 35 mph, 45 mph, and 55 mph

The preferred alignment is a 23-mile roadway that connects the communities of Tooele (Tooele County) and Herriman (Salt Lake County) in Utah (hereafter referred to as the Project). There is a potential future alignment option (2050) from Tooele to Eagle Mountain, as displayed in **Figure 1**. Both alignments include tunneling through the mountain in order to maintain a 6 percent or less grade (depicted in red on **Figure 1**). At this time, only the preferred alignment through Middle Canyon and Butterfield Canyon was evaluated.

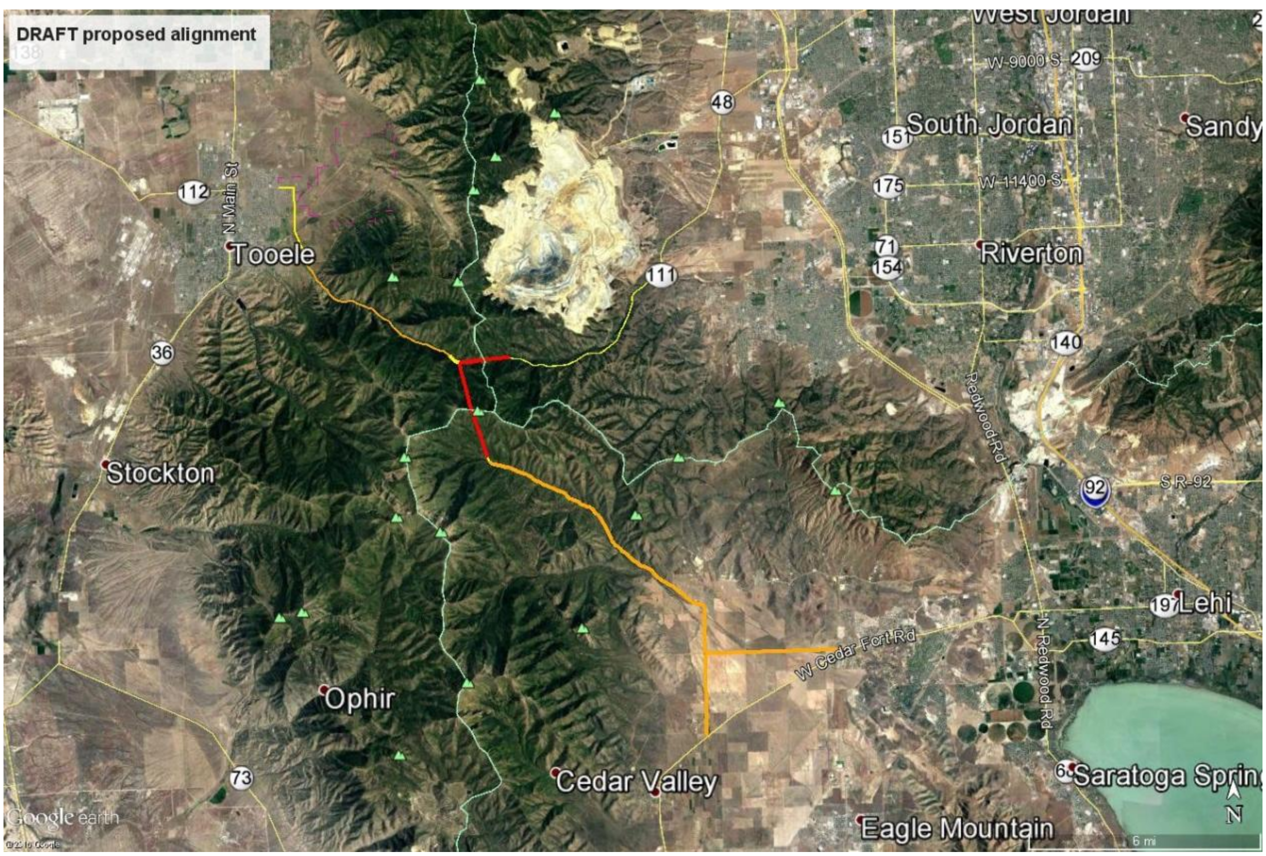


Figure 1: Proposed Project Alignments

The Project would construct a 23-mile two-lane roadway that would connect the communities of Tooele and Herriman via Butterfield-Middle Canyon. At its western termini, the alignment connects with 1000 North in the City of Tooele at its intersection with Droubay Road about 1.2 miles east of Main Street. The alignment generally follows the Middle Canyon and Butterfield Canyon Roads through the Oquirrh Mountains. On the east, the alignment connects with 13055 South, just south of the Kennecott Copper Mine.

Changes to land use may be expected on either end of the corridor where it connects with the communities of Tooele and Herriman; however, in the central section of the corridor, land use changes are not expected to occur.

Under current conditions, vehicles typically access Tooele via I-80 between the Great Salt Lake and the northern end of the Oquirrh Mountains, or around the southern end of the Oquirrh Mountains along Highway 73. Considering that the Project would connect Tooele and Herriman, traffic modeling was conducted from the intersection of SR-36 and SR-112 in Tooele to Herriman/Riverton at the intersection of the Mountain View Corridor and 12600 South.

The base case or No Build Alternative is the most likely scenario if the Project were not built. For the No Build Alternative, it is expected that I-80 and I-15 would be used to travel between Tooele, Salt Lake, and Utah counties. The Project is considered the Build Alternative and would provide a direct connection between Tooele and Herriman through the Oquirrh Mountains.

2. CONTEXT

According to CNBC, Utah was America's top state for business in 2016 based on more than 60 measures of competitiveness, such as workforce, cost of doing business, infrastructure, economy, quality of life, technology & innovation, education, and business friendliness. In eight of the past ten years, Utah has ranked in the top five on CNBC's Top States for Business (CNBC, 2016). Three Utah cities made Forbes top 10 Best Places for Business and Careers in 2016, and in 2015. Salt Lake City was named one of the best places to launch a startup outside of New York City and Silicon Valley (Forbes, 2015 and 2016). In fact, the corridor extending along the Wasatch Front from Ogden to Provo, with Salt Lake City in between, has been dubbed "Silicon Slopes" and has emerged as a hotbed for technology entrepreneurship.

Development potential in the Salt Lake Valley is constrained by the terrain north of Salt Lake City between the Great Salt Lake and the Wasatch Mountains and south of Salt Lake City where the Point of the Mountain nears Bluffdale and Lehi. The Project would connect the communities of Tooele and Herriman via Butterfield-Middle Canyon.

Lower land prices and newer housing options in Tooele County, located adjacent to Salt Lake County, have attracted home buyers from Salt Lake County that are willing to "drive 'til you qualify" for a home loan (meaning the farther from Salt Lake City, the more affordable homes become). According to the Tooele County Assessor's Office, 82 percent of the housing units in Tooele County are single-family homes. The median value of owner-occupied units for 2015 was

$177,700. More than half the homes (54 percent) have been built since 1990 and 33 percent of homes have been built since 2000 (ACS, 2016).

According to the 2016 General Plan Update, Tooele County is projected to increase to a population of over 127,000 by 2040, almost double the current population of nearly 65,000 (2016 estimate from the U.S. Census Bureau). These estimates consider the current growth constraints related to limited water resources and the lack of centralized sewer infrastructure. Actual numbers could be greater if technological advances resolve current growth constraints. Based on the average persons per household, about 20,000 additional households will be needed to accommodate the projected population growth (Tooele County General Plan, 2016).

At the other end of the Project, Herriman is one of the fastest growing cities in Utah. Similar to Tooele, this is a bedroom community with 86 percent of units categorized as single-family homes. In Herriman City, 92 percent of homes have been built since 1990 and 79 percent of homes have been built since 2000. The median value of owner-occupied units for 2015 was $293,400 (ACS, 2016). According to the Herriman City 2025 General Plan Amendment (2013), the population is projected to grow to over 100,000 by 2040 – an average of 769 new households per year.

In Herriman there are only 0.32 jobs per household in contrast to Salt Lake County where there are 1.72 jobs per household (Herriman City, 2013). The neighboring Riverton community has few jobs per household as well (0.81). This reflects that most citizens work outside of Herriman. There are few large employers in Herriman and none with more than 250 employees.

Creating new access through the Oquirrh Mountains is likely to encourage housing development in Tooele County and provide more affordable housing options for people working in southern Salt Lake County and Utah County. There is also potential for larger employers to consider locating in Tooele County.

3. BENEFIT-COST ANALYSIS FRAMEWORK

The Benefit-Cost Analysis (BCA) was conducted using the *TIGER Benefit-Cost Analysis Resource Guide* (USDOT, 2016b) for preferred methods and monetized values and follows the guidance from the U.S. Department of Transportation (USDOT, 2016a and 2003). A custom BCA model was developed to estimate the Project's future costs and benefits. Benefits were estimated over a 20-year period beginning in 2034 until 2053. The base year is when costs are expected to begin accruing (2031) and all values were discounted to the base year. It was assumed that 2034 would be the first year that the roadway would be open and benefits would begin accruing at the beginning of the year. All costs and benefits are in constant 2017 dollars.

The proposed Project is a 23-mile road that would connect Tooele and Herriman via Butterfield-Middle Canyon. The base case or No Build Alternative is the most likely scenario if the Project were not built. For the No Build Alternative, it is expected that I-80 and I-15 would be used to travel between Tooele, Salt Lake, and Utah counties. The Project is considered the Build Alternative and was compared to the No Build Alternative to identify incremental costs and benefits.

In accordance with United States Department of Transportation (USDOT) guidance (USDOT, 2015a), the BCA focuses on the system-wide traffic improvements resulting solely from the Project. In addition to reducing driving distance and travel times, the Project is expected to generate new trips between the three counties that would not occur under the No Build Alternative.

Although the average speed for the No Build Alternative is higher than the Build Alternative, creating a route that is less than half the distance of the No Build Alternative would result in travel time savings, vehicle operating cost savings, improved safety, and air quality benefits. The addition of a bike lane on the new roadway and an off-road paved trail to bypass the tunnel would create mobility, recreation, and health benefits.

The improved travel time and reduced distance between Tooele and Herriman can be expected to increase development in Tooele and attract some drivers who would otherwise not take a trip (induced trips). However, these induced trips were not included in the BCA and were assessed qualitatively in **Section 4.5**.

3.1. Benefit-Cost Analysis (BCA) Model

A custom BCA model was created to estimate the Project's total future benefits and costs over a 23-year lifecycle for the Project. Although benefits are expected to accrue after the 23-year period of analysis, residual value estimates for Project components that would continue to have any remaining period of useful operating life beyond the period of analysis were not included.

Generally, USDOT standard factors and prices were used for the BCA calculation except in cases where more Project-specific values or prices were available. In all such cases, modifications are noted and references are provided for data sources.

3.2. Key Assumptions

The key assumptions for the BCA are identified and discussed in the following sections, as well as assumptions applicable solely to specific benefits or costs and their respective quantification.

3.2.1 2017 Constant Dollars

The benefits and costs are expressed in constant dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The gross domestic product chained price index from the Office of Management and Budget was used to adjust past cost estimates or price values into 2017 dollar terms (OMB, 2017).

3.2.2 Real Discount Rate

The use of constant dollar values requires the use of a real discount rate for discounting to the present value. Future values were discounted using a 7 percent discount rate in accordance with both the USDOT guidance for the TIGER grant application and standard federal BCA methodology recommendations (USDOT, 2016a; OMB, 1992 and 2003). Results are also presented using a 3 percent real discount rate. All costs and benefits were discounted to 2031 (base year).

3.2.3 Period of Analysis

The analysis period for the BCA begins in 2031 and ends in 2053. Benefits are estimated over a 20-year period, assuming the roadway would open at the beginning of 2034.

4. BENEFIT ANALYSIS

All economic assumptions adhere to the *2016 Benefit-Cost Analysis Guidance for TIGER Grant Applicants* and the *TIGER Benefit-Cost Analysis Resource Guide* (USDOT, 2016a and 2016b). Values from other sources are specified. All benefits and costs are valued in 2017 dollars.

Five primary categories of user benefits were quantified: vehicle operating cost savings, safety benefits, travel time savings, air quality, and bicycle facility benefits. It is also expected that the Project would result in livability improvements; however, these benefits were not included in the BCA.

4.1. Vehicle Operating Cost Savings

The Project would connect Tooele and Herriman by building a new road via Butterfield-Middle Canyon. Compared with the current route to travel between Tooele, Salt Lake, and Utah counties using I-80 and I-15, the Project would reduce the travel distance to less than half of the No Build distance between Tooele and Herriman. Fewer vehicle miles traveled (VMT) reduces vehicle operating costs.

4.1.1 Reduced Fuel Use

The fuel savings for future highway users were valued using average annual gasoline and diesel prices from the Energy Information Administration's (EIA) 2017 Annual Energy Outlook "reference case" for projected fuel prices (EIA, 2017). Fuel price projections were adjusted to 2017 dollars. It was assumed that all vehicles would be passenger vehicles (autos) that use gasoline.

Average speeds from traffic modeling were compared with fuel consumption rates (gallons per mile) for automobiles (Cohn, et. al., 1992; AASHTO, 2010) to calculate the number of gallons consumed. The average fuel consumption by travel speed was based on the forecasts in **Table 4-1** that were generated using the Utah Statewide Travel Model.

Table 4-1: Projected Volume, Distance, and Average Speed Data (2034 and 2050)

Alternative	Volume (vehicles per day)	Distance (miles)	Average Speed (miles per hour)
2034 No Build	4,711	45.8	52.2
2034 Build	4,711	20.2	33.5
2050 No Build	7,367	45.8	52.7
2050 Build	7,367	20.2	29.8

Annual VMT was calculated as the product of the volume of vehicles per year (vehicles per day annualized using a conservative factor of 300) and distance. VMT for the period of analysis (2034 – 2053) was projected from this primary data using linear interpolation. The annual total value of the expected vehicle fuel cost savings was based on the vehicle type (passenger vehicle), annual VMT, the average travel speeds for each segment, and the corresponding value for fuel.

Over the 20-year period of analysis, the Project is expected to result in over 35 million gallons of fuel saved and more than $214 million (undiscounted) in fuel cost savings for its highway users. The net present value of the Project's expected fuel cost savings are estimated to be $89.3 million using a 7 percent discount rate and $143.7 million using a 3 percent discount rate.

4.1.2 Other Vehicle Cost Savings

Other non-fuel vehicle operating expenses include tire wear, maintenance, and depreciation. These costs are based on VMT changes between the No Build and Build Alternatives. The maintenance, depreciation, and tire costs per mile were obtained from the American Automobile Association (2016) and updated to 2017 dollars. The conservative estimate of $0.19 per VMT is the composite average marginal cost of tires, maintenance, and half of depreciation.

Over the 20-year period of analysis, the Project is expected to result in $185 million (undiscounted) in other vehicle cost savings (besides fuel) for its highway users. The net present value of the Project's expected other vehicle cost savings are estimated to be $80.7 million using a 7 percent discount rate and $126.4 million using a 3 percent discount rate.

4.1.3 Combined Vehicle Operating Cost Savings

Combining reduced fuel costs, less tire wear, lower maintenance costs, and depreciation results in a total vehicle operating cost savings of nearly $400 million over the 20-year period of analysis (undiscounted). The net present value of the Project's total vehicle operating cost savings are estimated to be $170 million using a 7 percent discount rate and over $270 million using a 3 percent discount rate.

4.2. Safety Benefits

Changes in VMT result in changes to the number of vehicle-related accidents. By reducing VMT, the Project is expected to reduce the number of future vehicle-related accidents. The safety benefits were derived from avoiding fatalities and reducing accident-related personal injuries and property damage from accidents (to vehicles and structures). When the number of accidents is reduced, emergency responder, time delay, emissions, and excess fuel burn costs would also be reduced; however, these additional benefits were not included in the BCA.

In the absence of specific accident rate information for the Project, national average accident rates were used to estimate the number of fatalities, injuries, and crashes based on changes to VMT. National average accident rates per 100 million vehicle-miles were obtained from the Bureau of Transportation Statistics. Preliminary estimates for 2015 are 1.13 fatalities, 79 injuries, and 203 crashes per 100 million vehicle-miles (BTS, 2015).

Safety benefits were calculated as the net difference between the accident costs of the Build and No Build alternatives. Accident costs were estimated from annual VMT, the type and severity of the accidents, and the unit costs of accidents. Methodologies in U.S. DOT guidance documents were followed to estimate the severity and cost of accidents using the accident rates per 100 million VMT (USDOT, 2016b). The accident cost was estimated to be $0.27 per VMT.

Over the 20-year period of analysis, the Project is expected to result in total safety benefits of over $260 million for its highway users (undiscounted). The net present value of the safety benefits are estimated to be $113.4 million using a 7 percent discount rate and $177.7 million using a 3 percent discount rate.

4.3. Travel Time Savings

The value of travel time savings depends on the characteristics of the travelling population, the mode, time, purpose of travel, and in some cases the location and/or availability of alternative transportation modes under the No Build and Build Alternatives. The value users assign to their travel time depends on their opportunity cost for that time. Travel time value varies by trip purpose: work travel time or personal time (which includes commuting).

Table 4-2 presents the volume per day and travel time for both the Build and No Build Alternatives for 2034 and 2050. These forecasts were generated using the Utah Statewide Travel Model. Vehicle hours travelled (VHT) for the period of analysis (2034 – 2053) was projected from this primary data using linear interpolation. The No Build Alternative was compared with the Build Alternative to calculate the hours saved by the Project.

Table 4-2: Projected Volume and Travel Time Data (2034 and 2050)

Alternative	2034 Volume (vehicles per day)	2050 Volume (vehicles per day)	2034 Travel Time (minutes)	2050 Travel Time (minutes)
No Build	4,711	7,367	52.6	52.2
Build	4,711	7,367	36.1	40.7

The annual total value of the expected VHT was calculated by multiplying the number of vehicles per day by the travel time and then annualized using a conservative factor of 300 to get the annual VHT estimate. VHT was annualized using a factor of 300 instead of 365 (days) because the Utah Statewide Travel Model does not differentiate well between weekday and weekend traffic at a localized level, so annualizing VHT using a factor of 300 instead of 365 (days) is expected to more accurately represent the data. The VHT savings is the difference between the VHT for the No Build and Build Alternatives. The travel time benefit is the net VHT savings multiplied by the corresponding value of time estimates.

Average vehicle occupancy varies by the time of day, location, and whether in the general purpose or express lanes. For simplicity, the travel time benefits in the BCA were conservatively estimated assuming that there is only one person per passenger vehicle even though vehicle occupancy rates are expected to be higher.

The proposed Project is estimated to initially result in nearly 389,000 hours of travel time saving in 2034 and over 430,000 hours by 2053. Over the 20-year period of analysis, the Project is expected to result in total time travel savings of nearly 8.2 million hours for future highway users. All traffic estimates are for passenger vehicles since it is unclear whether commercial trucks will use the new route created by the Project.

The analysis uses values of time following the US DOT's Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (2016c). The income data used in the US DOT guidance are derived from regularly updated public sources. Due to the unavailability of a breakdown of trip purposes, the intercity travel value of time for all purposes of travel was used and updated to 2017 dollars, resulting in an hourly value of $21.02 per person.

A future increase in wages greater than the rate of inflation would result in a real growth in the value of employees' wages, which would increase the value of time for future roadway users. However, the BCA conservatively assumes that the real value of current wage rates will remain constant over the 20-year period of analysis and is consistent with USDOT guidance.

Over the 20-year period of analysis, the Project is expected to result in total travel time savings of about $172 million for its highway users (undiscounted). The net present value of the travel time savings are estimated to be about $78.7 million using a 7 percent discount rate and approximately $120 million using a 3 percent discount rate.

4.4. Air Quality

A shorter distance and less travel time results in less fuel consumption, which reduces air emissions that would otherwise occur under the No Build Alternative. The amount of air emissions emitted depends on the quantity of fuel consumed, the emission profile of the vehicle, and the vehicle's fuel efficiency. Reducing fuel use decreases air emissions. Air emissions considered include carbon dioxide (CO_2), nitrogen oxides (NOx), particulate matter (PM), sulfur oxides (SOx), and volatile organic compounds (VOCs). Criteria air pollutants (CAPs) include NOx, PM, SOx and VOCs and greenhouse gas (GHG) emissions includes only CO_2 emissions.

Emission factors for automobiles were obtained from the Environmental Protection Agency (EPA, 2008a and 2008b) and used to quantify the Project's expected future air emission impacts. These factors (measured in pounds per gallon of fuel) were applied to the total gallons of gasoline fuel reductions calculated for the vehicle operating savings to estimate the total metric tons of emission reductions for each air pollutant.

4.4.1 Criteria Air Pollutants

The monetary values for the reduced emissions used in the BCA are based on USDOT guidance (2016b) and adjusted into 2017 dollar terms. Annual values of CAPs were discounted at 7 percent and 3 percent rates. The value of CO_2 reductions are discussed separately as GHG emissions.

4.4.2 Greenhouse Gas Emissions

The GHG emission values are based on the Social Cost of Carbon (SCC) developed by the Federal Interagency Working Group on Social Cost of Carbon and suggested by TIGER guidance (USDOT, 2016b). SCC values were inflated to 2017 dollars.

Federal SCC guidance recommends that GHG emissions are valued with a lower discount rate than other benefits because carbon dioxide emissions are long-lived and subsequent damages persist over many years. A 3 percent discount rate was selected as a central value that reflects the after-tax riskless interest rate and is consistent with OMB's Circular A-4 guidance for the consumptive rate of interest.

The GHG emissions value was calculated by multiplying the quantity in metric tons of carbon dioxide by the appropriate SCC value in that same year. The GHG benefits were discounted at 3 percent, irrespective of the discount rate otherwise selected for the BCA, to obtain the net present value.

4.4.3 Estimated Air Quality Benefits

The amount of emission reductions was based on the gallons of gasoline that would be saved as the result of the Project. Over the 20-year period of analysis, the Project is expected to result in more than 35 million gallons of fuel saved. The resulting net reductions in emissions in metric tons are presented in **Table 4-3**

Table 4-3: Net Reduction in Emissions

Emission Source	Net Reduction in Metric Tons (2034 – 2053)
Carbon Dioxide	366,239
Volatile Organic Compounds	938
Nitrogen Oxides	682
Particulate Matter	4
Sulfur Oxides	1

Note: Values were rounded to the nearest whole number.

The total GHG emission benefit over the period of analysis is nearly $27 million (undiscounted) and the CAP benefit is over $9 million (undiscounted). The net present value of the Project's emission reduction benefits were estimated to be $30.9 million using a 7 percent discount rate and $24.4 million using a 3 percent discount rate.

4.5. Benefits Not Included in the BCA

The Project is expected to produce additional benefits that could not be adequately quantified for inclusion in BCA. The BCA excludes a number of societal or user benefits because they are difficult to measure given the currently available information. Inclusion of these additional benefits would increase the overall benefit-cost ratio.

4.5.1 Livability

Livability is a measure of all the factors that contribute to a community's quality of life. The Project will directly improve residents' ability to travel both for work and leisure to destinations in other cities. With the Project, residents may have greater access to affordable housing options and high quality employment. New trailheads, bike facilities, and bike paths increase mobility, safety, and provide more recreation opportunities.

Transportation studies have attempted to develop estimates of the real estate price appreciation for areas with improved livability, but the causal relationships are weak and most studies have imputed very limited housing price benefits. Consequently, no livability benefits are included in the BCA.

4.5.2 Bicycle Facility Benefits

The new 23-mile roadway is proposed to have 10-foot shoulders that could be jointly used for roadside parking and bicycling. For non-motorized traffic, a tunnel bypass would be provided. The bypass would connect in Butterfield Canyon in Salt Lake County before the tunnel by creating a new paved trail, approximately ¼ mile in length, from the preferred roadway alignment to the existing canyon road. The existing Butterfield Canyon Road would remain in its current condition and used by local traffic and cyclists that do not choose to use the new on-street bicycle facility. At the top where Butterfield and Middle Canyon meet, the road would be paved to trail width (10 to 14-feet) for approximately 1.5 miles, down Middle Canyon until it meets the western tunnel end. The separated multi-use paved path would also link to the Kennecott Canyon overlook road.

Although the new roadway would have a shoulder large enough for a designated bike lane, the Project does not currently include this type of facility. The new roadway would include bicycle signage to indicate that cyclists would be sharing the roadway, and signs to direct cyclists to parallel pathways for certain areas (like the tunnel) where it would be safer for cyclists to be separated from the roadway.

If the Project added a designated bike lane to the new roadway connecting Tooele and Herriman, it would increase mobility for commuters, expand recreation options, and would result in health benefits to new cyclists. It is possible that a portion of these benefits would be realized without bicycle lane striping and symbols, however, studies have shown that a cyclist's perceived level of comfort is higher when a striped area is provided and unmarked lanes would not adequately serve the needs of the majority of cyclists (FHWA, 2013).

To evaluate the benefits of a potential new bicycling facility, first the demand was assessed. It is likely that a new bicycling facility would be used by many people who do not live near it and some local residents may ride, but not on the facility. The estimated demand provides the number of cyclists in the immediate area of the facility and how the presence of a new facility might impact that number. Guidance from the Transportation Research Board (TRB) National Cooperative Highway Research Program asserts that "a large portion of total bicycling is done by a small fraction of cyclists who ride frequently, and that many of those frequent riders are bike commuters" (TRB, 2006). Therefore, the number of people that commute to work by bicycle was used as a leading indicator of all types of cycling.

The daily average number of adult cyclists from the area around the facility was based on observed relationships from around the nation and adheres to the methodology outlined in TRB guidance. Based on TRB research, people are more likely to ride a bicycle if they live within 1.5 miles of a facility than if they lived outside that distance and the likelihood of cycling increases within 1 mile and ½ mile of the bicycle facility (TRB, 2006).

In the area of Herriman where the new roadway would begin, less than 5 percent of workers work outside of Salt Lake County, whereas nearly 43 percent of workers living in Tooele work outside of Tooele County (ACS, 2016). From this information, it is inferred that the majority of bicycle commuters would originate from Tooele. Moreover, in the Herriman Census tract that surrounds the beginning of the new roadway, no workers claimed commuting to work by bicycle (ACS, 2016). Since the demand is based on the number of existing commuting cyclists, demand was estimated only using Tooele information. This underestimates the total benefits as it is expected that there would be recreational use of the facility from Herriman residents living within 1.5 miles of the entrance.

Population estimates were projected for the period of analysis based on 2015 Census data and the *Tooele County General Plan* (2016). Although the Project may increase population growth beyond current estimates, projections of population growth beyond that found in the *Tooele County General Plan* were not included. This results in a more conservative estimate of user benefits. Using these population projections, low, most likely, and high demand estimates were generated from 2030 until 2053 for the baseline conditions and with a new bicycle facility based on guidance from TRB and Census data within ½-mile, 1-mile, and 1.5-miles of the bicycle facility in Tooele.

Although bicycle demand was estimated annually for the entire period of analysis, **Table 4-4** only displays a summary of the bicycle demand values for each category for years 2034 and 2053. Existing cyclists are the baseline conditions and new cyclists are estimated to be induced by a new bicycle facility. The total and new daily cyclist values include the number of bicycle commuters. A new bicycle facility is estimated to induce between 22 and 94 new cyclists in 2034 and between 34 and 144 new cyclists in 2053. The most likely values (57 new cyclists annually, on average) were used to estimate mobility, health, and recreation user benefits.

Table 4-4: Tooele Bicycling Demand for 2034 and 2053

Year	2034	2053
Daily Existing Bicycle Commuters	26	39
New Daily Commuters	9	14
Total Daily Existing Adult Cyclists - Low	63	96
Total Daily Existing Adult Cyclists - Most Likely	126	193
Total Daily Existing Adult Cyclists - High	265	405
New Daily Adult Cyclists - Low	22	34
New Daily Adult Cyclists - Most Likely	45	69
New Daily Adult Cyclists - High	94	144

a. Mobility

A dedicated bike lane improves movement and safety for cyclists. People are willing to travel additional time for improved bicycle facilities. For an off-street bike facility, individuals would be willing to travel an additional 20.38 minutes per trip and an additional 18.02 minutes for an on-street bicycle lane (TRB, 2006). The added travel time is the price that individuals are willing to pay for the improved attributes of the on-street bike facility.

Although the new bike facility would include an off-street trail portion around the tunnel, the majority of the proposed bike lane would be on-street; therefore, the value for an on-street bicycle lane was used to estimate the mobility benefit. The analysis uses the intercity value of travel time for all purposes of $21.02 per hour in 2017 dollars (USDOT, 2016c). A future increase in wages greater than the rate of inflation would result in a real growth in the value of employees' wages, which would increase the value of time for future cyclists. However, it was conservatively assumed that the real value of current wage rates will remain constant over the period of analysis. The value per trip is estimated to be $6.31 for cyclists that would be commuting to work.

The per-trip benefit was multiplied by the annual number of existing and new commuting cyclists. The annual value assumes commuters bike roundtrip, 5 days a week, for 42 weeks of the year (adjusted from the TRB assumption of 47 weeks per year after considering the average annual number of days that the Salt Lake and Tooele Valleys have snowstorms). The number of annual trips ranges from 14,685 in 2034 to 22,465 in 2053. The total undiscounted benefit over the 20-year period is estimated to be over $2.3 million.

b. Recreation

A new bicycle facility is expected to encourage more recreational cyclists. Different economic methods used to estimate the value of recreational activities generated a typical value of $51.13 per day in 2017 dollars, which is an estimate of the net benefit above and beyond the value of the time taken by the activity itself (TRB, 2006). Assuming a day of recreation would be about 4 hours and that recreation via biking would average one hour per trip, the value per recreational cycling trip, per day would be $12.78 for induced cyclists. The recreational benefits do not include a health benefit.

The number of new daily commuters was subtracted from the total number of new daily cyclists to obtain the number of new daily recreational cyclists. To annualize the number of recreational cyclists, the number of daily recreational cyclists was multiplied by the net daily benefit and 126 days. The annual value assumes recreational cyclist ride 42 weeks of the year and 3 days per week. The number of annual recreation hours ranges from 4,496 in 2034 to 6,879 in 2053. The total undiscounted benefit over the 20-year period is estimated to be nearly $1.5 million.

c. Health

Benefits of physical activity include weight loss, reduced risk of chronic diseases, and a longer lifespan. User health benefits were monetized by applying the healthcare cost savings that would be realized by increasing physical activity. Annual per capita healthcare cost savings vary between $23 and $1,410 with a median value of $154 in 2017 dollars (TRB, 2006). The median value of $154 per person, per year, was used to estimate the healthcare cost saving for the induced cyclists.

The annual health benefit was applied to the total number of new recreational cyclists that were estimated to be induced by a new bicycle factility (not including commuting cyclists). The annual health benefit ranges from about $6,900 in 2034 to $10,500 in 2053. Using the most likely demand value, the total undiscounted benefit over the 20-year period is estimated to be over $174,000.

d. Combined Bicycle Facility Benefits

Combining mobility, recreation, and health benefits results in total bicycle facility benefits of nearly $4 million over the 20-year period of analysis (undiscounted). The net present value of the total bicycle facility benefits are estimated to be $1.75 million using a 7 percent discount rate and $2.7 million using a 3 percent discount rate.

4.5.1 Other Recreation

Existing recreational pull outs have been identified along the length of the preferred alignment. Currently, there are more than 40 locations where vehicles may leave the existing Middle Canyon Road. The majority of these access points are located along the Middle Canyon alignment in Tooele County, where current recreational use is most prevalent. Some of these recreational access points include picnic sites and improved camping locations.

Consolidating access points into areas that would have parking and signage indicating trailheads would increase safety and enhance the recreation experience. Recreation can be improved further with the introduction of permanent campgrounds or day use areas and side access roads to keep slow moving recreational vehicles off of the main road.

As part of a new roadway facility, designated parking and access areas would be constructed or set aside for future construction by Salt Lake and Tooele Counties or the Bureau of Land Management, as appropriate. Signage for existing recreation trails and sites would be included as part of the new roadway.

The BCA does not include the additional recreation benefits from improving the existing recreation facilities.

4.5.2 Induced Trips

Creating a new connection between Tooele County and Salt Lake and Utah Counties expands opportunities for employment and housing among these areas. As a result of this new access, more people may move to Tooele County and commute to the southern end of Salt Lake County or northern Utah County. Additionally, the improved travel time and reduced distance between Tooele and Herriman can be expected to attract some drivers who would otherwise not take a trip.

Table 4-5 provides a description of trips induced by the Project that were generated using the Utah Statewide Travel Model. Some trips would occur without the Project in northern Salt Lake County, but with the Project they transfer to the new roadway. Other trips are completely new trips that occur because there would be a shorter and faster route from Tooele to the Wasatch Front. It is uncertain what proportion of the induced trips would occur without the Project in other areas of northern Salt Lake County and the details of those trips; therefore, benefits and costs from induced trips were not included in the BCA.

Table 4-5: Number of Induced Trips by Year

Description	2034	2050
Daily induced trips transferring from northern Salt lake County to the new road	2,200	2,600
Daily induced trips from Tooele to the Wasatch Front	4,200	5,000

Note: Number of induced trips were rounded to the nearest hundred.

4.5.3 Safety

Although vehicles can currently travel through Middle Canyon and Butterfield Canyon, the road is narrow, winding, and steep with unpaved sections through Middle Canyon. The currently configured route poses safety concerns and is closed to traffic during the winter. The new route between Tooele and Herriman would include the following safety improvements:

- widening and paving the existing road,
- joint use parking/bicycling shoulder,
- limiting the grade to a maximum of 6 percent.

These safety improvements are expected to reduce accidents and accident-related costs. Accident costs avoided would include fatalities, injuries, property damage (to vehicles and structures), and emergency services. The BCA includes safety benefits from the reduced VMT expected from the Project but does not include the additional safety benefits that would accrue from improving the existing road.

4.5.4 Construction Delays

All Project-related construction activity would be performed during off-peak traffic periods. Consequently, traffic impacts during construction periods are expected to be limited with few, if any delays to roadway users. Therefore, in the absence of any projected congestion and significant increase in vehicle hours traveled, no economic costs (negative benefits) from construction-related delays and inconvenience to roadway users are included in the BCA.

5. COST ANALYSIS

For the BCA, the term ‘cost’ refers to the additional resources or expenditures required to implement, perpetuate, and maintain the investments associated with the Project. The BCA uses Project costs that have been estimated on an annual basis. All costs are shown in real 2017 dollars.

5.1. Capital Costs

Without discounting, the total capital costs were estimated to be $328.7 million, including a 25 percent contingency. Spending for capital costs was expected to begin in 2031 and continue until the completion of construction activities in 2033. The period for construction would be about 30 months. Without a detailed cost schedule, it was assumed that 20 percent of the capital costs would be spent in 2031 and 40 percent would be spent in both 2032 and 2033. The present value of the Project’s capital costs were estimated to be $303.4 million using a 7 percent discount rate and $317.3 million using a 3 percent discount rate.

5.2. Maintenance Costs

The new roadway and infrastructure would require ongoing annual upkeep to the lane lines, barriers, and pavement as well as snow removal. Maintenance costs per lane-mile ranges from $3,400 to $4,500 (in 2017 dollars) based on a review of Utah Department of Transportation documents (UDOT, 2013, 2014, and 2015). The product of the highest estimated maintenance cost per lane-mile and the number of lane-miles for the new roadway (46 lane-miles) results in an annual maintenance cost of about $208,000 annually.

The operation and maintenance costs were assumed to begin in 2034, when the Project is expected to be complete. The estimated future total annual operation and maintenance cost for the Project is estimated to be $1.9 million using a 7 percent discount rate and $2.9 million using a 3 percent discount rate.

6. BENEFIT-COST ANALYSIS FINDINGS

BCA is a widely used analysis tool for evaluating a Project's expected future economic performance. Extensive Federal and State guidance is available to assist in determining the appropriate approach for performing BCA analyses. Standard USDOT factors and values were used for the BCA calculation and references were provided for all data sources.

6.1. Metrics

Four key metrics are commonly used to represent and evaluate BCA results: the net present value (NPV), the benefit-cost ratio (BCR), the economic rate of return (ERR), and the return on investment (ROI).

NPV is the present value of all costs subtracted from the present value of all benefits. Projects with values greater than zero are considered economically beneficial. The NPV is a useful way to compare the overall dollar value of a Project's expected future net benefits.

The BCR is the present value of all Project benefits divided by the present value of all costs. The ratio measures the factor by which benefits exceed (or are below) costs. A Project with a ratio value greater than 1.0 is considered economically feasible. The BCR is a useful way to compare the relative benefits of Projects that may differ in schedule and/or scale.

The ERR is the discount rate at which the benefits and costs of a Project over the entire evaluation period are equal. ERR is a useful way to compare Projects with different evaluation periods and costs. In this situation, the social benefits are considered the cash flows used to calculate the ERR.

The ROI is a traditional financial metric used to describe future cash flows in relation to the initial capital investment. ROI is used to evaluate the efficiency of an investment and is calculated by dividing the net benefits by the initial investment cost. The net benefits are considered the benefits to society; however, typically ROI would be calculated using only the financial benefits.

6.2. Results

The BCA estimates that the Project will generate $867.9 million in undiscounted benefits at an undiscounted total cost of $332.8 million over the entire 23-year period of analysis, resulting in net benefits of $535 million. **Table 6-1** shows a summary of BCA results on an annual basis in millions of 2017 dollars. Projects expecting to use federal funding are required to use a 7 percent discount rate; however, given the interest rates of the recent years, the results are also shown with a 3 percent discount rate.

Table 6-1: Benefit-Cost Analysis Results by Year (in millions of 2017 dollars)

Project Year	Calendar Year	Project Costs	Vehicle Operating Savings	Safety Benefits	Travel Time Savings	Air Quality	Net Benefits	Discounted Net Benefits	
								7% Discount Rate	3% Discount Rate
0	2031	$65.7					-$65.7	-$65.7	-$65.7
1	2032	$131.5					-$131.5	-$122.9	-$127.6
2	2033	$131.5					-$131.5	-$114.8	-$123.9
3	2034	$0.2	$13.2	$9.7	$8.2	$1.2	$32.2	$26.4	$29.4
4	2035	$0.2	$13.8	$10.1	$8.2	$1.3	$33.2	$25.6	$29.5
5	2036	$0.2	$14.6	$10.4	$8.3	$1.3	$34.4	$24.8	$29.7
6	2037	$0.2	$15.2	$10.8	$8.3	$1.4	$35.4	$23.9	$29.7
7	2038	$0.2	$15.8	$11.1	$8.4	$1.5	$36.5	$23.2	$29.7
8	2039	$0.2	$16.6	$11.5	$8.4	$1.5	$37.8	$22.4	$29.8
9	2040	$0.2	$17.3	$11.8	$8.4	$1.6	$38.9	$21.7	$29.8
10	2041	$0.2	$18.0	$12.1	$8.5	$1.6	$40.0	$21.0	$29.8
11	2042	$0.2	$18.7	$12.5	$8.5	$1.7	$41.2	$20.2	$29.8
12	2043	$0.2	$19.4	$12.8	$8.6	$1.8	$42.4	$19.6	$29.7
13	2044	$0.2	$20.2	$13.2	$8.6	$1.8	$43.6	$18.9	$29.7
14	2045	$0.2	$20.9	$13.5	$8.7	$1.9	$44.8	$18.2	$29.6
15	2046	$0.2	$21.7	$13.9	$8.7	$1.9	$46.1	$17.6	$29.6
16	2047	$0.2	$22.6	$14.2	$8.8	$2.0	$47.4	$17.1	$29.5
17	2048	$0.2	$23.4	$14.6	$8.8	$2.1	$48.6	$16.5	$29.4
18	2049	$0.2	$24.3	$14.9	$8.9	$2.2	$50.0	$16.0	$29.4
19	2050	$0.2	$25.1	$15.2	$8.9	$2.2	$51.3	$15.4	$29.2
20	2051	$0.2	$25.7	$15.6	$9.0	$2.3	$52.3	$14.8	$28.9
21	2052	$0.2	$26.2	$15.9	$9.0	$2.3	$53.3	$14.2	$28.6
22	2053	$0.2	$26.8	$16.3	$9.0	$2.4	$54.3	$13.7	$28.3
TOTALS		**$332.8**	**$399.6**	**$260.2**	**$172.1**	**$36.0**	**$535.1**	**$87.7**	**$272.1**

The distribution of benefits is depicted in **Figure 2**. Vehicle operating savings have the greatest share of the benefits (46 percent), followed by safety benefits (30 percent), travel time savings (20 percent), and air quality (4 percent).

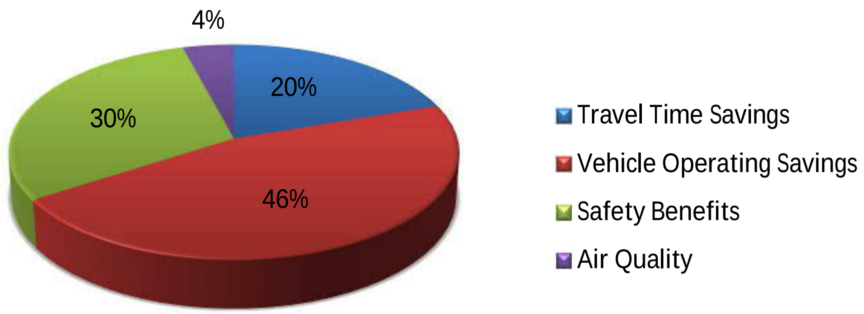


Figure 2: Benefit-Cost Analysis Benefits

Table 6-2 shows the overall BCA results for the Project. BCA metrics are presented with both a 7 percent discount rate and 3 percent discount rate. The proposed Project has a positive BCR and NPV under both discount rates. The ERR and ROI are also favorable for both discount rates.

At a 7 percent real discount rate, the Project generates a net present value of $87.7 million, a BCR of 1.3, ERR of 14 percent, and ROI of 27 percent. At a 3 percent real discount rate, the Project generates a net present value of $272 million, BCR of 1.8, ERR of 14 percent, and ROI of 83 percent.

Table 6-2: Benefit-Cost Analysis Results

Metric	7% Discount Rate	3% Discount Rate
Net Present Value (NPV) (2017$)	$87,716,000	$272,052,000
Benefit-Cost Ratio (BCR)	1.3	1.8
Economic Rate of Return (ERR)	14%	14%
Return on Investment (ROI)	27%	83%

Note: NPV was rounded to the nearest thousand.

7. REFERENCES

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APPENDIX E

Oquirrh Connection Year Round Roadway (Short-Term Recommendations) Memo

Year Round Roadway (Short-term Recommendations)

This preliminary effort evaluates the needs and improvements to the current roadway associated with creating year round access through Butterfield and Middle Canyons. Middle Canyon Road and Butterfield Canyon Road meet at an elevation of 7785 feet. The roadway has a typical width of 22 feet of asphalt in both canyons. Some areas of Butterfield canyon are narrower and concentrated on the western portion of the roadway near the top where the curves are most prevalent.

To operate and maintain this roadway as a year round connection between the Tooele Valley and the Salt Lake Valley the following improvements are recommended.

1. Place asphalt on the 7,900 ft. unpaved section in Middle Canyon.
2. Increase the width of the roadway from 22 feet to a nominal width of 24 feet.
    a. Will require some slopes cuts and walls to achieve the width
3. Evaluate and place guard rail to protect vehicles from steep slopes adjacent to the roadway.
4. Evaluate and place cross culverts to redirect drainage to protect the roadway.
5. Install appropriate signing to warn vehicles of geometric deficiencies (curves, steep grades)
6. Create vehicle turnouts that can be used for emergency turn arounds.
7. Winter maintenance activities and equipment
    a. 10 Wheel trucks for snow plowing
    b. Snow Blowers – truck mounted or self-propelled.
        i. Snow plowing may require use of a large vehicle mounted snow blower due to lack of shoulders for snow storage.
    c. Graders, Loaders, Pickups (4WD)
    d. Evaluate avalanche potential and mitigate as necessary

Equipment	Quantity	Units	Unit Cost	Low Cost	High Cost	Estimated Life (yrs.)	Low Annualized Cost	High Annualized Cost
10-wheeler (chained with 10-wheel drive)	1	Each	$230,000	$230,000	$253,000	15	$15,333	$16,867
Blower	1	Each	$500,000	$500,000	$550,000	25	$20,000	$22,000
Grader	1	Each	$280,000	$280,000	$308,000	20	$14,000	$15,400
Loader	1	Each	$160,000	$160,000	$176,000	20	$8,000	$8,800
Pickup (4WD)	1	Each	$30,000	$30,000	$33,000	5	$6,000	$6,600
Equipment Subtotal				$1,200,000	$1,320,000		$63,400	$69,700

8. Satellite County maintenance facility (shed and yard for materials) to serve Salt Lake and Tooele maintenance needs.
    a. Satellite snow shed would be needed somewhere near the roadway summit to store the equipment, materials, and salt. Sheds need to be located near roadway summits

so plowing can be performed downhill, due to the steep grades. Right-of-way may need to be purchased for the facility

Item	Quantity	Units	Unit Cost	Low Cost	High Cost
Satellite Facility (assumes 4-bay shed with 300 ton salt shed)	1	Lump	$1.75 million – $2 million	$1,750,000	$2,000,000
Contingency (20%)				$350,000	$400,000
Total				$2,100,000	$2,400,000

Costs for items 7 and 8 come from Winter Roadway Closure Study (UDOT June 2014) and costs for the other items are based on unit costs developed for the new alignments.