APPENDIX F

Draft Rail Transit Concepts Initial Feasibility Study

Little Cottonwood Canyon ENVIRONMENTAL IMPACT STATEMENT
S.R. 210 | Wasatch Blvd. to Alta

Draft Rail Transit Concepts Initial Feasibility Study

Little Cottonwood Canyon Environmental Impact Statement S.R. 210 - Wasatch Boulevard to Alta

Lead agency:
Utah Department of Transportation

April 3, 2020

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1.0 Introduction

The purpose of this report is to summarize the Utah Department of Transportation's (UDOT) evaluation of constructing and operating a conceptual rail transit system as part of the Little Cottonwood Canyon Project. This report provides information that UDOT will use during the alternatives development and screening process for the Little Cottonwood Canyon Environmental Impact Statement (EIS), which will evaluate how well the rail transit concepts described in this report would satisfy the purpose of and need for the Little Cottonwood Canyon Project.

What is the purpose of this report?

The purpose of this report is to summarize UDOT's evaluation of constructing and operating a conceptual rail transit system as part of the Little Cottonwood Canyon Project.

The goal of this report is to define the rail technology that is most feasible for the needs of Little Cottonwood Canyon. The report also presents approximate travel times and costs for different rail alignment concepts to address future mobility needs of visitors to Little Cottonwood Canyon. The information in this report will be used to compare the most feasible rail technology and conceptual alignments with other mobility modes (aerial transit, buses, and/or roadway improvements) that are being considered to address the purpose of the project.

1.1 Description of the Study Area

Little Cottonwood Canyon is in the Uinta-Wasatch-Cache National Forest, which is on the eastern edge of the Salt Lake City metropolitan area located in Salt Lake County. Salt Lake County has a population of about 1.12 million. The canyon is home to two internationally recognized ski resorts, Snowbird Resort and Alta Ski Area, and includes parts of two National Wilderness Areas: Twin Peaks Wilderness to the north and Lone Peak Wilderness to the south. Winter recreation activities include skiing at the resorts, backcountry skiing, snowshoeing, and ice climbing. In the summer, the resorts offer abundant recreation opportunities, and land administered by the U.S. Department of Agriculture Forest Service is used extensively for hiking, cycling, rock climbing, fishing, camping, and picnicking.

The EIS study area used for the Little Cottonwood Canyon Project extends along State Route (S.R.) 210 from its intersection with S.R. 190/Fort Union Boulevard in Cottonwood Heights, Utah, to its terminus in the town of Alta, Utah, and includes the Bypass Road. UDOT developed the study area to include an area that is influenced by the transportation operations in Little Cottonwood Canyon. Traffic south of this intersection is mostly related to trips into and out of Little Cottonwood Canyon and commuter traffic on Wasatch Boulevard.

Through EIS study area, S.R. 210 is designated with different street names. For clarity in the EIS process, the following segments of S.R. 210 use the following naming conventions (shown in Figure 1):

- **Wasatch Boulevard** – S.R. 210 from Fort Union Boulevard to North Little Cottonwood Road
- **North Little Cottonwood Road** – S.R. 210 from Wasatch Boulevard to the intersection with S.R. 209
- **Little Cottonwood Canyon Road** – S.R. 210 from the intersection of North Little Cottonwood Road and S.R. 209 through the town of Alta, including the Bypass Road up to but not including Albion Basin Road

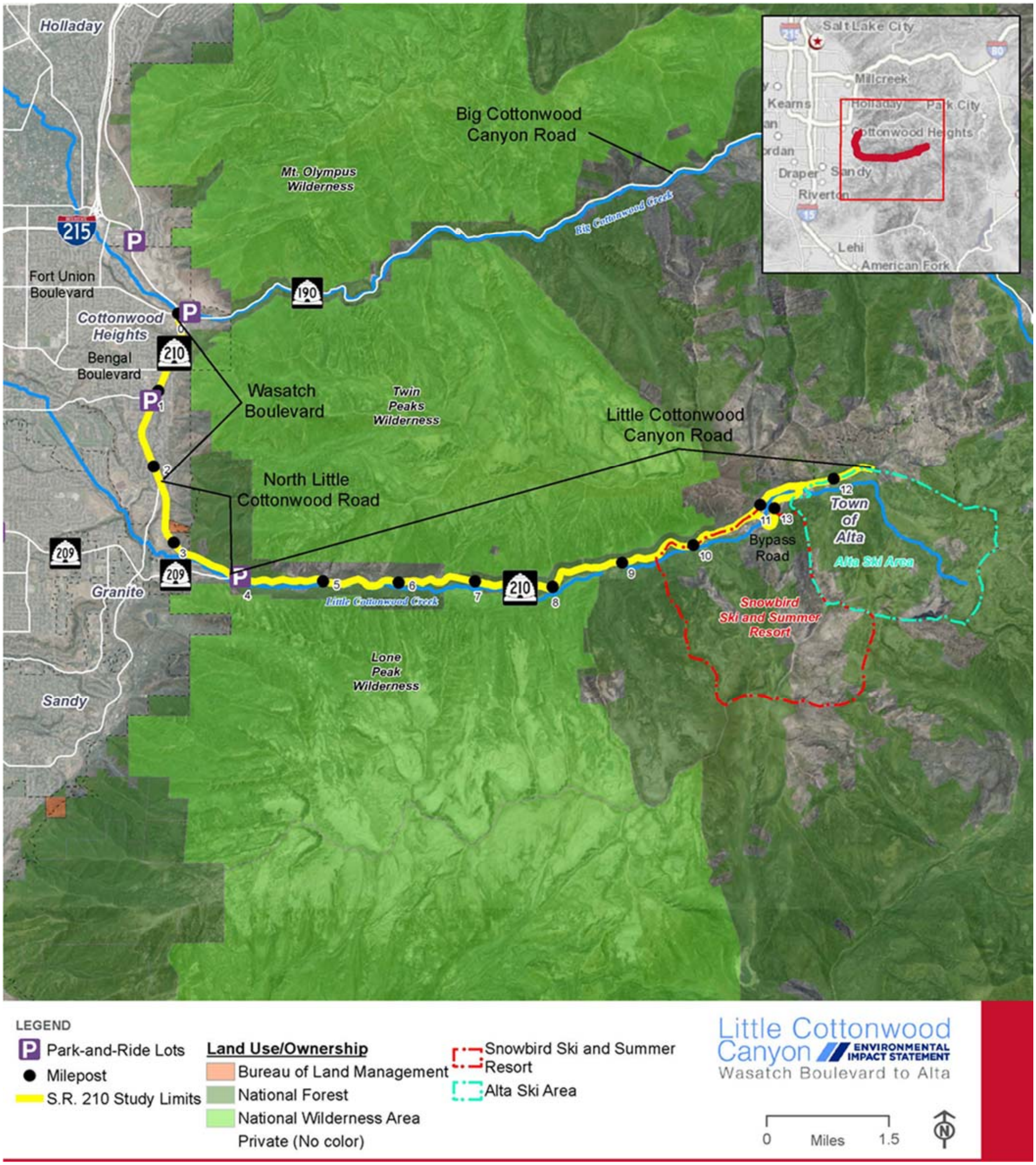
In the EIS, mobility modes are being evaluated to address skier use in winter and the related traffic congestion on North Little Cottonwood Road and Little Cottonwood Canyon Road. For this rail transit feasibility analysis only, the study area also includes S.R. 209 (9400 South and 9000 South) in Sandy, Utah. The S.R. 209 travel corridor is another potential route for a rail line into Little Cottonwood Canyon.

1.2 Previous Analysis

Several previous studies have analyzed the current and future transportation needs for Big and Little Cottonwood Canyons. In 2012, Salt Lake County and its study partners—UDOT, the Utah Transit Authority (UTA), Salt Lake City, the Wasatch Front Regional Council, and the U.S. Department of Agriculture Forest Service—developed a range of potential short- and long-term transportation solutions. The *Mountain Transportation Study* (Fehr and Peers 2012) recommended evaluating a range of different alternatives in an EIS.

In the years before the current EIS process was initiated, UDOT, UTA, and other agencies and planning organizations conducted studies of congestion, parking, transit use, and avalanche impacts in Little Cottonwood Canyon and on S.R. 210. Numerous studies were conducted as part of a process known as the Mountain Accord (Mountain Accord 2017). The Mountain Accord developed a plan for preserving the central Wasatch Mountains (which include Little Cottonwood Canyon) including short- and long-term transportation options. Both of these studies (the *Mountain Transportation Study* and the Mountain Accord) identified rail transit as one of many potential mobility concepts that should be explored, in greater detail, under an EIS framework.

Figure 1. Study Area for the Little Cottonwood Canyon EIS



2.0 Types of Rail Transit Systems

There are several different types of rail transit technologies, each of which has unique characteristics in terms of its passenger capacity, maximum operating speed, and engineering standards. The feasibility of each type depends on the specific application for which it is being evaluated. This section describes the types of rail transit concepts evaluated: heavy rail/commuter rail, light rail, cog rail, monorail, maglev, SkyTran, and funiculars.

2.1 Heavy Rail/Commuter Rail

Heavy rail/commuter rail generally consists of electric or self-propelled diesel locomotives pulling passenger cars. They usually operate in a densely developed urban environment or between major metropolitan areas. In dense urban environments, this type of rail service is often associated with subways, although many rail lines may be at-grade or elevated. In most instances, tracks run in dedicated corridors, without many grade crossings and physically isolated from adjacent properties by fences or other barriers. Stations are usually large to accommodate the large number of riders. Long spacing between stations and short dwell times (stops at stations) are desirable to minimize overall trip times and reduce fleet size. UTA's FrontRunner is an example of commuter rail.

To minimize capital costs, commuter rail is often operated over tracks that are part of the general freight rail system. For this reason, the rolling stock, signal equipment, and operating practices must be in accordance with all applicable government (for example, state and Federal Railroad Administration) regulations and standards developed by the American Railway Engineering and Maintenance-of-Way Association (AREMA) and the Association of American Railroads. Commuter rail operations, including associated terminals and operations and maintenance facilities (OMF), therefore require railroad-type rolling stock, larger curve radii, low maximum grades (less than about 4% is preferred), and signaling systems compatible with mainline railroad practice.

Heavy rail is not feasible for Little Cottonwood Canyon. Typical locomotive power (diesel-electric locomotives) is not adequate to climb the steep grades in the canyon, which are over 10%.

2.2 Light Rail

Light rail transit is a mode of transit service that is a successor to streetcars, tramways, and trolleys. It operates passenger rail vehicles individually (or in short, usually two- or three-vehicle trains) on fixed rails in right-of-way that is often separated from other traffic for much of its alignment. Light rail vehicles are typically driven electrically with power being drawn from an overhead electric line (overhead contact system, or OCS) via a pantograph. Running speeds are up to about 55 miles per hour (mph) depending on the alignment. UTA's TRAX is an example of light rail.

The key characteristic of light rail transit is its ability to operate on city streets without large station facilities and in mixed traffic (that is, within the same alignment as automobiles). Desirable maximum grades are also about 4%, though absolute maximum grades for ballast track of about 6% are acceptable for short distances. This flat vertical grade is needed because light rail transit (similar to commuter rail) typically uses an adhesion rail system in which power is applied by the electric motors to steel wheels to steel rails and the frictional forces drive the train forward. Adhesion is the most common type of rail system in the United States.

Light rail is not feasible for Little Cottonwood Canyon because more traction would be needed to navigate grades steeper than 6%. Little Cottonwood Canyon has grades over 10% in many sections of the canyon.

2.3 Cog Rail

Cog rail, also called rack rail or mountain rail, is a type of light rail. Cog rail uses a third rail that is toothed or racked. Train vehicles are fitted with a cog wheel (also called a pinion wheel) that meshes with the third rail to provide additional traction. This additional traction is needed primarily for downhill travel where the added stopping power of the cog wheel is needed in addition to the adhesion forces. This design allows a train vehicle to operate on steeper grades, around 10% to 15%. Maximum running speeds are similar to light rail (55 mph) when the cog is not engaged. However, in alignments with many curves or where vehicles operate in mixed traffic, slower speeds are used. In addition, when descending steep grades and the cog wheel is engaged, slower speeds (18 to 20 mph) are required for safe operation.

Cog rail vehicles are electric and powered by an OCS using catenary wire and a pantograph on the vehicle. Just like light rail, power collected by the pantograph is conveyed to electric motors on each set of trucks (or "bogies") on a vehicle so that traction power can be distributed over the rail vehicle or train. See Figure 5 on page 18.

2.4 Monorail

Monorail is an above-ground, fixed-guideway transit system with vehicles similar to those in a light rail system. Monorail can provide an hourly capacity at 5,000 persons and can travel at speeds greater than 50 mph. With few exceptions, monorail systems use rubber tires for traction. Aside from the elevated guideway, this is the main technological difference between monorail and traditional rail. Although rubber traction on steel rails is used on at least one monorail system (Aerobus), most systems with rubber tires run on concrete surfaces. In this regard, most monorail vehicles run more like road vehicles than railway trains. Theoretically, rubber-tired traction can overcome gradients of more than 15%, but currently the steepest gradient on which a monorail is operating is 10% in Japan (Atkins 2015).

A monorail system would operate similarly to the train concept being considered for Little Cottonwood Canyon but would have the primary disadvantage of not being compatible with the existing transit network, whereas a cog rail system could operate on the existing light rail transit network and use the same maintenance facilities. For the monorail to work in Little Cottonwood Canyon, it would require two fixed guideways to meet the per-person hourly capacity requirements and would require a separate maintenance facility. The required footprint would be similar to a cog rail system since it would require a separate structure for each guideway to provide safety redundancy if the support structure is struck by a major avalanche or canyon rock slide. Additionally, the monorail could not operate during active avalanche-mitigation periods because of the potential for an avalanche powder blast or an avalanche to damage the system. Because the monorail is elevated, it would be difficult to place the monorail track inside a snow shed. The columns to support an elevated track could be hardened to allow the main avalanche slide should go underneath the monorail system.

The monorail system would operate similarly to a cog rail system for moving people and would require a similar footprint to operate but would not be compatible with the existing light rail network to provide regionally connectivity, and would not be able to operate during avalanche mitigation. Therefore, UDOT decided not to evaluate the monorail further but to evaluate the cog rail system as a similar concept.

2.5 Maglev

Maglev (derived from *magnetic levitation*) is a type of monorail system that uses two sets of magnets or electromagnets—one set to repel and push the train up off the track, and another set to move the “floating train” ahead at high speed, taking advantage of the lack of friction. The goal of maglev is to obtain high train speeds. Along certain medium-range routes (usually 200 to 400 miles), maglev can compete favorably with high-speed rail and airplanes (Wikipedia 2019).

At the high, desirable speeds, the maglev track should have few horizontal and vertical curves. Maglev technology is not as feasible as other rail types for steep grades and sharp curves, such as those in Little Cottonwood Canyon. The minimum radius of curvature for high-speed operation is 5 to 10 miles, and the maximum grade is about 4% (USDOT and FRA 2018). Therefore, maglev is not recommended for further study in this report.

2.6 SkyTran

UDOT received a comment during the project scoping period to consider SkyTran as a solution for Little Cottonwood Canyon. According to the information provided to UDOT, SkyTran appears to be similar to maglev; it uses “magnetic wings” and a “spiral drive” to propel individual cars, which hold one to two people.[1] The individual SkyTran vehicles run along a main, elevated track and then diverge from the main track to a parallel track to access small stations that can be chosen by the rider. Individual vehicles can, therefore, bypass stops if riders do not need to board or disembark. When leaving a station, the vehicle would re-enter the main track where there is a gap between other vehicles, similar to ramp metering on a freeway.

What is scoping?

Scoping is an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.

No technical information was provided to UDOT regarding the levitation or propulsion system or regarding the control technology needed to meter vehicles into the main-track traffic, and no test facility has been constructed. UDOT considers this technology theoretical and therefore not feasible for Little Cottonwood Canyon.

2.7 Funiculars

Funicular railways typically use two rail vehicles that rest on tracks and are pulled up a steep slope by a cable-wench system. The vehicles are permanently attached to the cables. They move synchronously—while one vehicle is ascending, the other is descending on the track to provide a counterbalance and to help lift the other vehicle. They have capacity limitations (in terms of passengers per hour) for long distances because one vehicle would need to make a complete round trip before it could pick up more passengers.

This technology is not feasible to handle the high hourly rider demands in Little Cottonwood Canyon and is therefore not evaluated further in this report.

[1] The commenter directed UDOT to review the technology on two websites: https://vimeo.com/253517920 and https://www.skytran.com/system.

3.0 Selection of the Most Feasible Rail Technology and Track Configuration

> **What is the most technically feasible rail technology for Little Cottonwood Canyon?**
>
> A cog rail system is the most technically feasible rail transit technology for the canyon.

Because the grades in Little Cottonwood Canyon average 10% to 12%, and because a canyon alignment would have tight curves, a cog rail system is the most technically feasible fixed-rail transit concept for Little Cottonwood Canyon.

Previous studies (Fehr and Peers 2012; Mountain Accord 2017) concluded that a cog rail line in the canyon would likely follow the existing Little Cottonwood Canyon Road because the wilderness areas[2] and Little Cottonwood Creek[3] (an important water source to Salt Lake City) constrain alignments outside the existing road corridor. Alternative alignments might exist, but, for this preliminary evaluation, UDOT assumes that the cog rail line would run along the north side of Little Cottonwood Canyon Road. Figure 2 presents a conceptual cross-section of Little Cottonwood Canyon Road.

Figure 2. Conceptual Cross-section for a Cog Rail Line along Little Cottonwood Canyon Road

[2] The Wilderness Act states there shall be no commercial enterprise and no permanent road within any Wilderness Area designated by the Act and, except as necessary to meet minimum requirements for the administration of the area for the purpose of the Act (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area

[3] The 2003 *Revised Forest Plan Wasatch-Cache National Forest* notes that because of streams and riparian areas relatively high value and small proportion of the landscape, development outside already developed areas within these prescription is to be avoided by 300 feet on either side.

4.0 General Considerations for Implementing a Cog Rail System

This section presents some of the fundamental engineering and operational assumptions of a conceptual cog rail system for Little Cottonwood Canyon as well as considerations for parking at a rail base station. UDOT will compare the selected rail concept(s) to other mobility concepts (aerial transit, bus, and/or roadway expansion) in a separate report or in the EIS.

4.1 Operational Capacity and Demand

What is travel demand?

Travel demand is the expected number of transportation trips in an area. Travel demand can be met by various modes of travel, such as automobile, bus, rail, carpooling, bicycling, aerial transit, or a combination of modes.

The expected peak period of travel demand on S.R. 210 in 2050, as measured by the number of cars currently using the road, is between 7:00 AM and 10:00 AM. The current free-flow capacity of the road is about 1,100 cars per hour. Transportation analysts often look at the 30th-busiest hour on a road over the course of a year when determining the future travel demand on the road. For S.R. 210 in 2050, the 30th-busiest-hour roadway demand would be about 1,555 vehicles or about 3,200 people per hour. For a rail system to accommodate this high level of hourly demand (3,200 people), rail vehicles would need to arrive very frequently. Assuming a maximum capacity of 253 people[4] per rail vehicle and about 10 rail vehicles per hour, or a 5-minute frequency (or "headway") would be required to meet this demand. If rail vehicles could be connected to form a two-vehicle, 506-passenger train "consist," about 5 trains per hour (10-minute headways) would be required.

The actual number of riders per hour would vary from the maximum operational capacity during various times of the day and seasonally. The actual anticipated ridership depends on many factors, and a detailed demand analysis was outside the scope of the initial rail feasibility evaluation presented in this report. The maximum hourly demands occur during the winter months and on weekends (Friday, Saturday, and Sunday) when skiers and snowboarders are traveling to the resorts at the top of Little Cottonwood Canyon. This initial feasibility analysis used a peak-hour ridership of about 1,000 people. This hourly capacity was used to compare other transit concepts (gondola and bus) for Little Cottonwood Canyon. The peak daily ridership of about 5,200 people was used to estimate the required parking structure size, which is about 2,500 cars.

With the assumed travel demand of 1,000 people per hour, at 15-minute headways (4 vehicles per hour), and one cog-rail vehicle (253 passengers per vehicle), the hourly capacity would be about 1,012 people. The actual capacity per rail vehicle might be lower considering that train riders would be carrying gear (skis or snowboards, helmets, boots, and extra clothing). The capital cost estimates presented later in this report vary the per-vehicle capacity to determine a range of potentially required cog rail vehicles that would be needed to accommodate the peak-hour demand. The total number of cog rail vehicles needed to serve the

[4] Maximum capacity of Stadler 129829 cog rail vehicle with 106 seated passengers and assuming 147 standees. Email November 4, 2019. The number of standees is based on four riders per square meter of floor space, or one person in a 19-by-19-inch-square space.

hourly demands is also function of the round-trip travel times (which depends on the length of track and the assumed travel speed). These factors are described in Section 5.0, Rail Concepts Evaluation, for the various rail alignment concepts.

4.2 Connectivity with the Existing Light Rail System

One key consideration for a cog rail system serving Little Cottonwood Canyon is whether to connect it to UTA's existing TRAX light rail system or build a separate cog rail system to serve the canyon exclusively. With a connection to the existing TRAX system, passengers could embark from dispersed origins such as existing TRAX stations (with existing surface parking areas) or from the Salt Lake City International Airport, downtown Salt Lake City, or other commercial or residential areas (where there are stations but not dedicated park-and-ride lots).

4.2.1 Considerations for Parking

Parking might need be expanded at one or more of the existing TRAX stations to accommodate peak winter rider demands. However, this initial concept feasibility report does not analyze the parking availability at existing TRAX station park-and-ride lots during times of peak travel demand in Little Cottonwood Canyon (winter weekends, Fridays, Saturdays, and Sundays). The result of connecting a cog rail system to the existing TRAX system would be longer rail infrastructure and more cog rail vehicles to serve the peak-hour demands at acceptable headways.

The other general option would be to construct a cog rail line to serve users of Little Cottonwood Canyon only. This would require building a large parking area near the same location as the rail base station (the train station at the base of the canyon). UDOT's feasibility evaluations of other transit concepts (expanded bus and gondola aerial transit) have assumed that a large, 2,500-car parking structure would be located at a new "mobility hub" constructed at one of three locations: (1) at the mouth of the canyon, (2) at the gravel pit at the intersection of Wasatch Boulevard and Fort Union Boulevard near the mouth of Big Cottonwood Canyon, or (3) near the existing park-and-ride lot at the intersection of 9400 South and Highland Drive.

Section 4.2.4, Rail Base Station, Parking Options, and Resulting Rail Alignment, describes the concepts for either connecting a cog rail system to the existing TRAX system or building a dedicated rail base station with its required parking and operation and maintenance facility.

4.2.2 Operations and Maintenance Facility

If the cog rail system serving Little Cottonwood Canyon were not connected to UTA's existing TRAX system, a stand-alone cog rail operation and maintenance facility (OMF) would be required somewhere near the cog rail alignment. The OMF would be needed to operate the new rail system. The OMF would include the communications systems, train control rooms, areas to store track and right-of-way maintenance equipment, rail vehicle storage areas, and maintenance garages, as well as the necessary employee support facilities (offices, conference rooms, and restrooms). The preliminary estimate for the site size for OMF buildings, rail and support vehicle maneuvering and storage, onsite parking, and roads is about 10½ acres.[5] If the Little

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5 The preliminary OMF size is based on the building needs to operate the system and support staff and the site needs to maneuver, store, and maintain about 14 new cog rail vehicles.

Cottonwood Canyon rail system were to connect to UTA's existing TRAX system, UTA might also need to expand UTA's existing OMF to accommodate the addition of cog rail vehicles to UTA's fleet. A lower level of capital costs is assumed for this option.

4.2.3 Operating Assumptions

UDOT assumes that the cog rail system would provide 12 hours per day of winter service to the resorts in Little Cottonwood Canyon. Summer service is not required to meet the mobility requirements evaluated in the EIS and therefore was not evaluated in this preliminary feasibility study. In urban areas, UTA could use the track alignment to operate a light rail system year-round for weekday commuters. However, addressing weekday commuter demand on all of S.R. 209 and S.R. 210 is not part of the purpose of and need for the Little Cottonwood Canyon Project, and these corridors are outside the EIS study area. Rail transit along these routes are being evaluated in this report only as a way to provide potential connection points for a cog rail concept for Little Cottonwood Canyon. According to the Wasatch Front Regional Council's (WFRC) *Wasatch Front Regional Transportation Plan* (RTP) for 2019–2050, the potential transit ridership in these corridors does not justify transit investments at the level that can be provided by light-rail-type modes.

Table 1 presents the schedule assumptions for about 1,000 people per hour peak capacity and scaled back at other times during the winter season. This service schedule is considered in the annual operating cost estimates for each concept in Section 5.0, Rail Concepts Evaluation.

Table 1. Operating Schedule

Schedule	Schedule Details	Hours of Operation (hours)	Headway (minutes)	Trips per Hour	Maximum Hourly Capacity (passengers)
Winter peak days, peak hours	Friday–Sunday (7:00–10:00 AM and 3:00–6:00 PM)	6	15	4	1,012
Winter peak days, off-peak hours	Friday–Sunday (10:00 AM–3:00 PM and 6:00–7:00 PM)	6	30	2	506
Winter weekdays	Monday–Thursday (7:00 AM–7:00 PM)	12	30	2	506

4.2.4 Rail Base Station, Parking Options, and Resulting Rail Alignment

If a cog rail system is not connected to the existing TRAX system, a 2,500 stall parking area would be needed near the rail base station. General parking location options are presented in this report because the location of the parking area and rail base station is a fundamental consideration for the resulting alignment and the feasibility of a cog rail concept for Little Cottonwood Canyon.

Currently, the existing park-and-ride lots near the mouths of Big and Little Cottonwood Canyons are heavily used, especially during the winter. These lots operate at capacity most winter weekend days. There is parking away from the mouths of the canyons along the existing ski bus routes; however, these park-and-ride lots are heavily utilized during periods of peak winter demand. Because canyon users typically want the shortest travel time, transit riders tend to drive to the mouth of a canyon and take the ski bus up the canyon for the last segment of their trip However, when the existing park-and-ride lots reach capacity, some *potential* transit users bypass the lots and drive their vehicle up the canyons. Other canyon users will consider a shift in travel modes (from car to transit) as less desirable for various reasons and would rather drive their vehicle up the canyon.

Several parking locations have been explored by UDOT in this report to help expand ridership. The combination of the base parking lot and rail base station (or existing TRAX connection) and the resulting cog rail alignment define the following concepts evaluated in this report:

- **Concept 1** – Expanded parking and a rail base station at the mouth of Little Cottonwood Canyon. The resulting cog rail concept would run for about **8 miles** up the Little Cottonwood Canyon Road segment of the study area. UDOT assumes stations, in addition to the rail base station, at Snowbird Resort and Alta Ski Area. Preliminary design plans for Concept 1 are included in Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood Canyon.
- **Concept 2** – Expanded parking and a rail base station at a mobility hub located at the gravel pit (near Wasatch Boulevard and Fort Union Boulevard). UDOT assumes two train stations in the canyon (at Snowbird Resort and Alta Ski Area). This concept would have a cog rail alignment of about **12.2 miles**. Preliminary design plans for the canyon segment of Concept 2 are included in Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood Canyon. Preliminary design plans for the Wasatch Boulevard segment of Concept 2 are included in Appendix B2, Preliminary Design Plans for Segment 2 – Gravel Pit to Mouth of Little Cottonwood Canyon.
- **Concept 3** – Expanded parking and a rail base station at a mobility hub near 9400 South (S.R. 209) and Highland Drive. UDOT assumes two train stations in the canyon (at Snowbird Resort and Alta Ski Area). This concept would have a cog rail alignment of about **11.5 miles**. Preliminary design plans for the canyon segment of Concept 3 are included in Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood Canyon. Preliminary design plans for the segment of Concept 3 outside the canyon are included in Appendix B3, Preliminary Design Plans for Segment 3 – 9400 South and Highland Drive to Mouth of Little Cottonwood Canyon.
- **Concept 4** – UDOT also evaluated two options to connect to the existing TRAX system and avoid having to construct a large rail base station at a mobility hub with a 2,500-car parking structure and a large stand-alone OMF near the alignment. The two options for Concept 4 are:
    - **Concept 4, Option A** – This option would connect a cog rail system to the existing TRAX system at the Midvale Fort Union TRAX Station. The resulting cog rail concept would run east along Fort Union Boulevard (S.R. 190 and 7200 South) for about 5.9 miles to Wasatch Boulevard. The alignment would then run south along Wasatch Boulevard and North Little Cottonwood Road (S.R. 210) for about 4.2 miles to the mouth of Little Cottonwood Canyon. UDOT assumes three intermediate train stations along Fort Union Boulevard and one intermediate train stations along Wasatch Boulevard. Adding the 8-mile canyon alignment, the total length of this option is about **18.1 miles**. Preliminary design plans for the canyon segment of Concept 4A are included in Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood Canyon. Preliminary design plans for the segment of Concept 4A from the gravel pit to the mouth of the canyon are provided in Appendix B2, Preliminary Design Plans for Segment 2 – Gravel Pit to Mouth of Little Cottonwood Canyon. No conceptual design plans were prepared

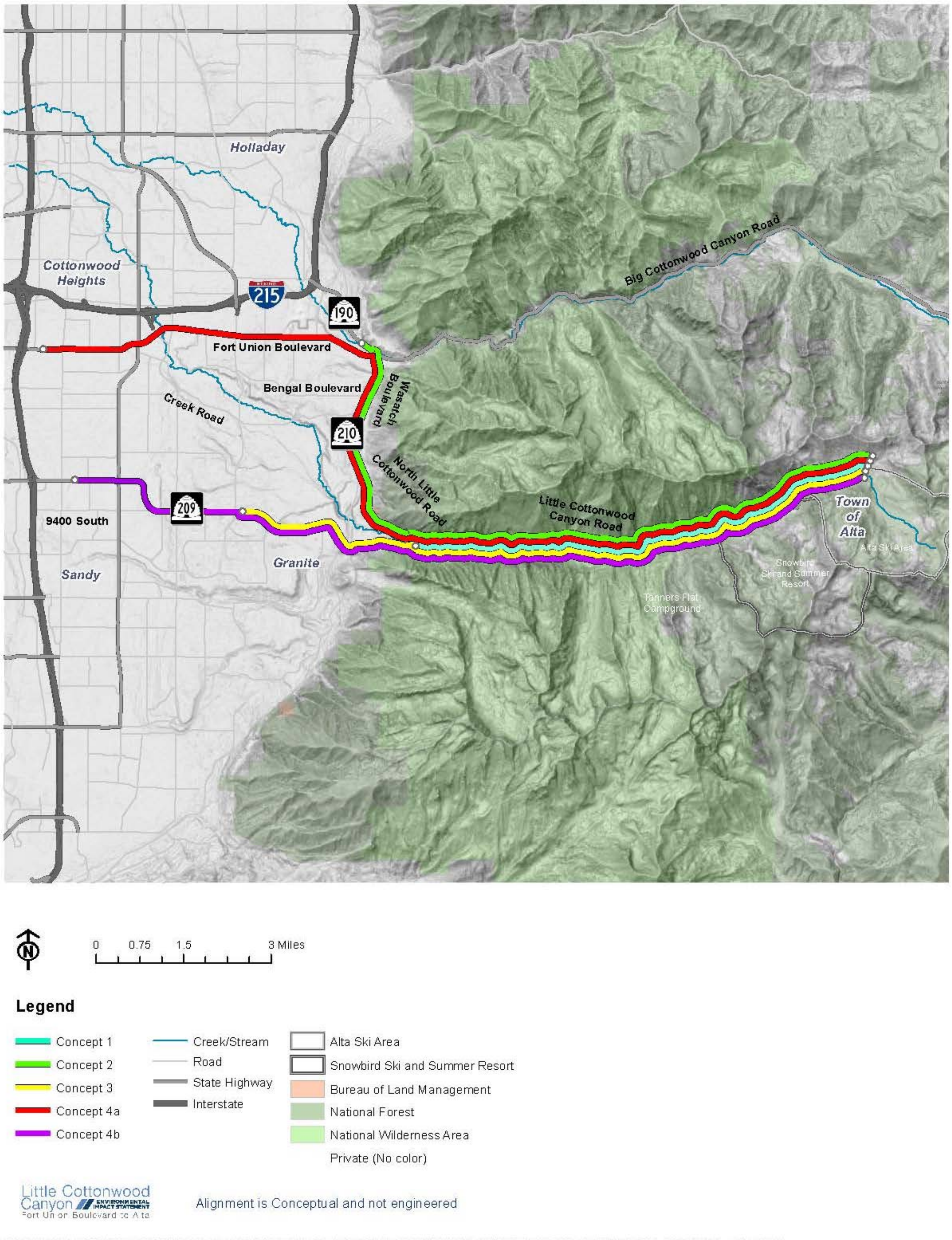
for this initial feasibility study for the segment of this concept between the Midvale Fort Union TRAX Station and the gravel pit mobility hub.

- **Concept 4, Option B** – This option would connect a cog rail system to the existing TRAX system at the Historic Sandy TRAX Station (at 9000 South and about 150 East). The resulting cog rail alignment would run east along 9000 South and 9400 South (S.R. 209) for about 6.3 miles to the mouth of Little Cottonwood Canyon. UDOT assumes three intermediate train stations somewhere along S.R. 209.[6] Adding the 8-mile canyon alignment, the total length of this option is about **14.3 miles**. Preliminary design plans for the canyon segment of Concept 4B are included in Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood Canyon. Preliminary design plans for the segment of Concept 4A outside the canyon are included in Appendix B3, Preliminary Design Plans for Segment 3 – 9400 South and Highland Drive to Mouth of Little Cottonwood Canyon, and Appendix B4, Preliminary Design Plans for Segment 4 – Historic Sandy TRAX Station 9400 South and Highland Drive.

Figure 3 shows the routes of these concepts. For details, see Section 5.0, Rail Concepts Evaluation.

[6] The assumed intermediate train stations are for travel time calculations only. UDOT's conceptual design for Concept 4A and 4B did not determine locations for these stations.

Figure 3. Rail Concept Overview



4.3 Right-of-way Considerations

The *Manual on Uniform Traffic Control Devices*, published by the Federal Highway Administration, defines the standards used by road managers nationwide to install and maintain traffic-control devices on all public streets, highways, bikeways, and private roads open to public travel. This manual groups rail transit right-of-way (ROW) into the following three types (FHWA 2009).

- **Exclusive rail ROW.** An exclusive ROW is completely grade-separated and protected by a fence or other traffic barrier. Motor vehicles, pedestrians, and bicycles are physically prohibited within the entire length of the ROW. The existing UTA TRAX system does not have any completely exclusive alignments because most street crossings are at grade. If a third rail at ground level is used to supply power to electric cars, a completely exclusive ROW is required.[7] (For more information, see Section 4.4, Typical Cross-section.) In general, higher rail speeds can be achieved when the ROW is totally protected from vehicle and pedestrian access.
- **Semi-exclusive ROW.** Semi-exclusive alignments are in a separate ROW or along a street or railroad right-of-way where motor vehicles, pedestrians, and bicycles have limited access and are directed to cross at designated locations only. Most of UTA's TRAX system is along semi-exclusive alignments with mostly at-grade street crossings. With semi-exclusive ROW, overhead contact wire systems (catenary) are required to prevent pedestrians or trespassers from contacting an electrified wire.[8]
- **Non-exclusive (mixed-use) ROW.** A mixed-use ROW is an alignment in which rail operates in mixed traffic with all types of road users (cars and pedestrians). This type includes streets, transit malls, and pedestrian malls where the ROW is shared with other uses. UTA's TRAX system from 1200 South to 900 South and along North Temple in Salt Lake City are examples of a mixed-use alignment. These use overhead contact systems and, because they operate in mixed traffic, the rail vehicles travel at slower speeds than they could in exclusive or semi-exclusive ROWs.

A cog rail system for Little Cottonwood Canyon would use a semi-exclusive ROW. More-detailed engineering design and analysis would be needed to determine which type of ROW is needed in various segments of an alignment as well as any ROW protection measures that should be implemented.

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7 AREMA Section 2.6.11, *Electric Traction Characteristics*

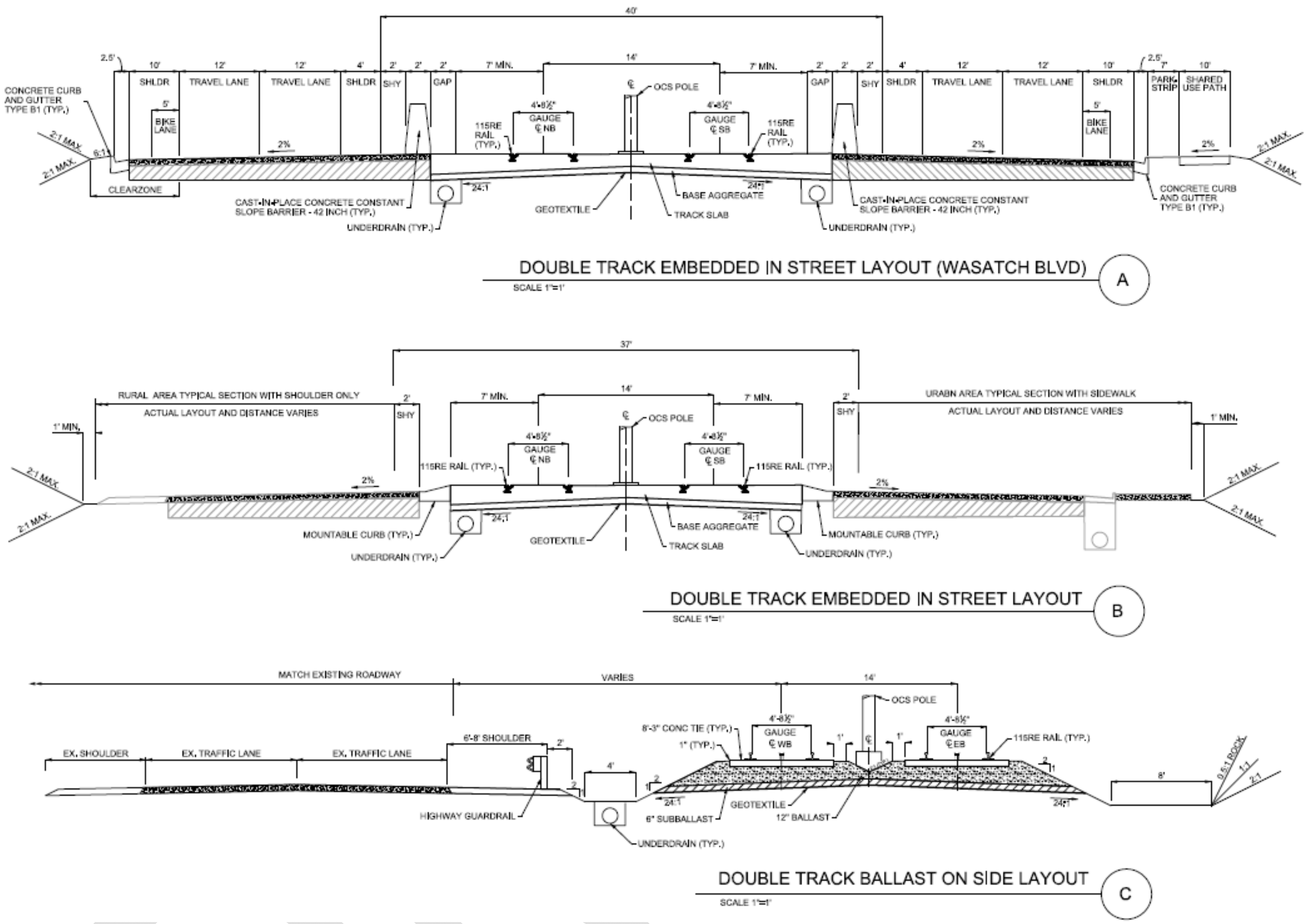
8 AREMA Section 2.6.10.2, *Dedicated Grade-level Right-of-Way*

4.4 Typical Cross-section

Figure 4 presents typical cross-sections for a conceptual cog rail alignments serving Little Cottonwood Canyon. These typical sections are generally categorized as one of two types: embedded track and ballasted track.

- **Embedded Track.** Typical Sections A and B in Figure 4 show the rail alignment in semi-exclusive ROW where the track would be embedded in pavement and running down the center of a street. This section would be used for cog rail segments outside the canyon. As shown for Typical Sections A and B, the center-running rail would be about 37 to 40 feet wide, and roadway widening would be required. Typical Section A shows a barrier between the travel lanes and the cog rail tracks. This typical section would be used in areas where there are higher road speed limits. Typical Section A would likely be used for Concept 2 along Wasatch Boulevard. Where slower speeds allow a more compact rail cross-section, Typical Section B could be used. Because the 9400 South segment between Highland Drive and S.R. 210 has a narrow, two-lane ROW and because several homes abut the street, Concept 3 uses Typical Section B, and this section was assumed for the entire length of this concept as well as for Concept 4B. More design would be needed to define areas where these or other cross-sections are applicable.
- **Ballasted Track.** Typical Section C in Figure 4 shows the rail on ballasted track in semi-exclusive ROW running adjacent to the road. This cross-section would be used in the canyon. The space between the tracks and the roadway would vary depending on the location of the tracks relative to the roadway. Cog rail alignments require greater minimum curve radius, which is a function of design speeds, compared to the roadway curves in Little Cottonwood Canyon. Therefore, the cog rail alignment would not exactly parallel the existing roadway alignment, and the separation distance would vary in different segments of the canyon as the rail alignment diverges from the road. An 8-foot-wide ditch between the rail ballast and the mountain side is included to manage stormwater runoff from the mountains side, to allow space to store snow removed from the tracks, and to collect fallen rocks.

Figure 4. Typical Cross-sections



4.5 Traction Power

Electric vehicles are the current industry and UTA standard. Power for vehicles can be provided via OCS or a third rail. A third rail would require an exclusive ROW to protect the public from the electrical hazard. An exclusive ROW could be achieved with fences, elevating the rail line on a structure, or placing it inside an enclosure or tunnel. National Fire Protection Association standards would apply to fixed-guideway transit and passenger rail systems.[9] If the track is elevated or in a tunnel, additional fire and life safety design criteria would apply; these ventilation or emergency egress elements are not considered in this report.

What is a third rail?

A third rail is an electrified rail adjacent to tracks at the same elevation as the tracks.

For this initial evaluation, UDOT assumes that traction power would be provided to the rail with an OCS, as with the existing TRAX system. An electrified third rail was eliminated because the need to totally enclose the ROW would limit pedestrian and wildlife access across the tracks in Little Cottonwood Canyon, affecting recreation and wildlife corridors. As a basic description of OCS, an electrical wire is suspended between OCS support poles, which forms the catenary. A pantograph, which is mounted on the top of the cars, collects the current and distributes it to the electric motor. Figure 5 shows the OCS poles between two sets of track and the pantograph on top of the light rail vehicle.

Figure 5. Example OCS and Pantograph

Substations would be needed to convert grid power, which is alternating current (AC), to the direct current (DC)-powered traction motors. The capacity of the existing, buried power line along Little Cottonwood

[9] NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*, 2017

Canyon Road was not evaluated. UDOT assumes that a separate, dedicated power system would be needed for a Little Cottonwood Canyon cog rail concept. The proposed cog rail system would need about 24 megawatts of power from the utility network. UDOT also did not investigate the existing power capacity in the area for this initial feasibility report.

4.6 Avalanche Protections

One primary objective for the Little Cottonwood Canyon EIS is to address the reliability of the Little Cottonwood Canyon Road corridor and substantially reduce the number of days and hours that the canyon is closed for avalanche mitigation and incidents. With the use of an OCS and an alignment along the north side of Little Cottonwood Canyon Road, UDOT assumes that the electrical components and the cog rail line would need to be protected by running the rail inside snow sheds through some of the more critical avalanche paths at a minimum. In order to more completely define cog rail concepts, and to generate rough-order-of-magnitude cost ranges, UDOT estimated potential snow shed lengths to protect the rail line and passengers in the canyon segments for all concepts

Dynamic Avalanche Consulting, LLC (Dynamic), assessed the avalanche hazards in Little Cottonwood Canyon in 2018. Dynamic's evaluation defined risks (based on traffic) and return periods (annual, 3-year, 10-year, and 30-year, for example) and then ranked avalanche paths that warrant mitigation to reduce risks and maintain mobility in the canyon. The top-ranked paths, in terms of risk,[10] are White Pine, Superior, Little Superior, White Pine Chutes 1, Little Pine, White Pine Chutes 2 and 4, East Hellgate, and White Pines Chutes 3 (Dynamic 2019).

What is return frequency?

Return frequency is average time, in years, between avalanches, whether triggered naturally or artificially through active mitigation, that have reached the road in each avalanche path.

Using these nine paths as a baseline, UDOT evaluated the approximate return frequency of adjacent paths to determine the preliminary lengths of snow sheds that would be needed to protect the cog rail OCS and track from avalanches. Longer snow sheds might be needed, compared to snow sheds for the road, because the effects of an avalanche (main slide and powder blast) on a cog rail line's power system would be greater than the effects of an avalanche on the road. The road would simply be covered by snow and could be cleared relatively easy, whereas it might take crews more time (possibly days) to repair or reconstruct the cog rail's power-delivery system.

Table 2 presents the conceptual lengths of snow shed that would be needed to protect a cog rail system. UDOT estimated the minimum mid-canyon and upper canyon snow sheds lengths by assuming that continuous snow sheds are needed to protect the rail line through the most significant, higher-return-period, avalanche paths. UDOT also extended these minimum snow shed lengths to cover more paths, pending more-detailed risk analysis, in order to determine a rough order-of-magnitude cost range for an added level of protection. For example, at a minimum, the mid-canyon segment has six of the top risk-ranked paths where a cog rail would need to include snow sheds (see the first column of Table 2). A snow shed that is at least 0.91 mile long would be required in this location. The Little Pine East avalanche path, which has a 10-year return period, is east of these six paths, and the Maybird path, which also has a 10-year return period, is west of these six paths. If additional protection is required, the mid-canyon snow shed would be extended

[10] Risks were assessed using Avalanche Hazard Index methods that considers all avalanche paths, frequency of events, and the anticipated traffic on S.R. 210 in Little Cottonwood Canyon.

(see the second column of Table 2). Under an extended mid-canyon snow sheds scenario, UDOT estimates that a continuous, 2.11-mile-long snow shed could be needed to protect the rail line in this section of the canyon. Similarly, between 1.23 and 1.73 miles of snow shed might be needed to protect the cog rail system in the upper portions of the canyon (see the third and fourth columns of Table 2).

Table 2. Assumed Minimum and Extended Snow Sheds

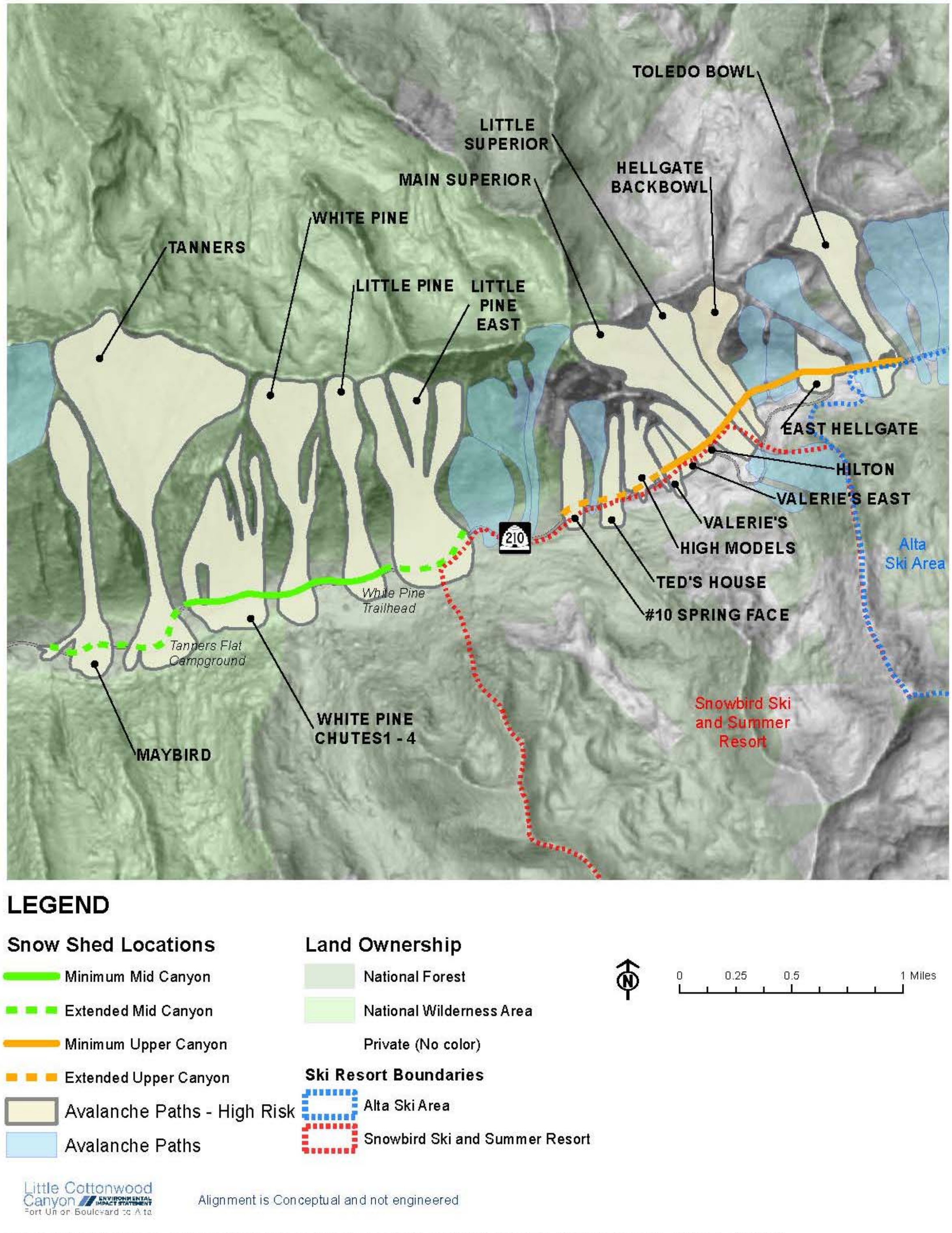
Minimum Mid-Canyon Snow Shed	Extended Mid-Canyon Snow Shed	Minimum Upper Canyon Snow Shed	Extended Upper Canyon Snow Shed
	Little Pine East	Toledo Bowl/Reds	Toledo Bowl/Reds
Little Pine	Little Pine	East Hell Gate	East Hell Gate
White Pine	White Pine	Little Superior	Little Superior
White Pine Chutes 1	White Pine Chutes 1	Superior	Superior
White Pine Chutes 2	White Pine Chutes 2	Hilton	Hilton
White Pine Chutes 3	White Pine Chutes 3	Valarie's East	Valarie's East
White Pine Chutes 4	White Pine Chutes 4	Valarie's	Valarie's
	Tanners		High Models
	Maybird		Ted's House
			#10 Springs Face
Length 0.91 mile	**Length 2.11 miles**	**Length 1.23 miles**	**Length 1.73 miles**
		Minimum length for mid- and upper-canyon snow sheds[a]	**2.14 miles**
		Extended length for mid- and upper-canyon snow sheds[b]	**3.84 miles**
		Maximum conceptual length[c]	**7.50 miles**

[a] Sum of minimum mid-canyon and minimum upper-canyon snow sheds.
[b] Sum of extended mid-canyon and extended upper-canyon snow sheds.
[c] Maximum theoretical length of snow shed to cover a cog rail line from Mormon Slide to Toledo Bowl avalanche paths.

Figure 6 shows the approximate limits of the minimum and extended mid-canyon and upper canyon snow sheds. For a low-end range, UDOT estimates that about 2.14 miles of snow shed would be needed (0.91 mile in the mid-canyon section and 1.23 miles in the upper-canyon segment) to protect the cog rail infrastructure. If more of the cog rail line needs to be protected below some of the other higher-frequency avalanche paths, UDOT estimates that about 3.84 miles (2.11 miles in the mid-canyon section plus 1.73 miles in the upper-canyon section) of snow shed would be needed. If, based on more thorough risk and cost-benefit analysis, complete protection for the cog rail line is necessary, up to about 7.5 miles of snow shed could be needed. A more thorough risk analysis would be needed to fully define the necessary protections. See Section 5.0, Rail Concepts Evaluation for capital costs.

UDOT conducted a risk analysis (measured as the Avalanche Hazard Index, or AHI) for Little Cottonwood Canyon Road for the current (2018) and 2050 roadway traffic conditions. Incorporating a fixed-rail-transit concept would result a different AHI (considering both the road and rail). However, this preliminary analysis did not include AHI calculations for a rail line nor required, or feasible, mitigation needed to adequately reduce the AHI (if the AHI is high) with changes in the transportation system.

Figure 6. Potential Cog Rail Snow Sheds



4.7 Travel Time Assumptions

Travel time is a function of track length and average train speed. The maximum grade, track curvature, and ROW type all affect the maximum train speeds in various segments of the cog rail line. For this initial analysis, UDOT assumes an average speed of 25 mph for all rail segments (both cog and adhesion).

Without a direct transit connection, the cog rail concept would require a large parking area where riders would park their personal vehicles, walk to the train-loading platform, and wait for and board a train. These transfers take time. If parking is separated from the base rail station, additional walking time or some form of transit (people-mover or buses) would be needed to transport passengers from the parking area to the rail base station. In the travel time calculations that follow, UDOT added 12 minutes to the travel time to account for this transfer.[11]

Dwell time is the time during which a train is stopped at a station to allow passengers to embark and disembark the rail vehicles. UDOT assumes a 2-minute dwell time at each station. These times are considered in Section 5.0, Rail Concepts Evaluation, which explores approximate travel times for different parking and rail base station concepts.

5.0 Rail Concepts Evaluation

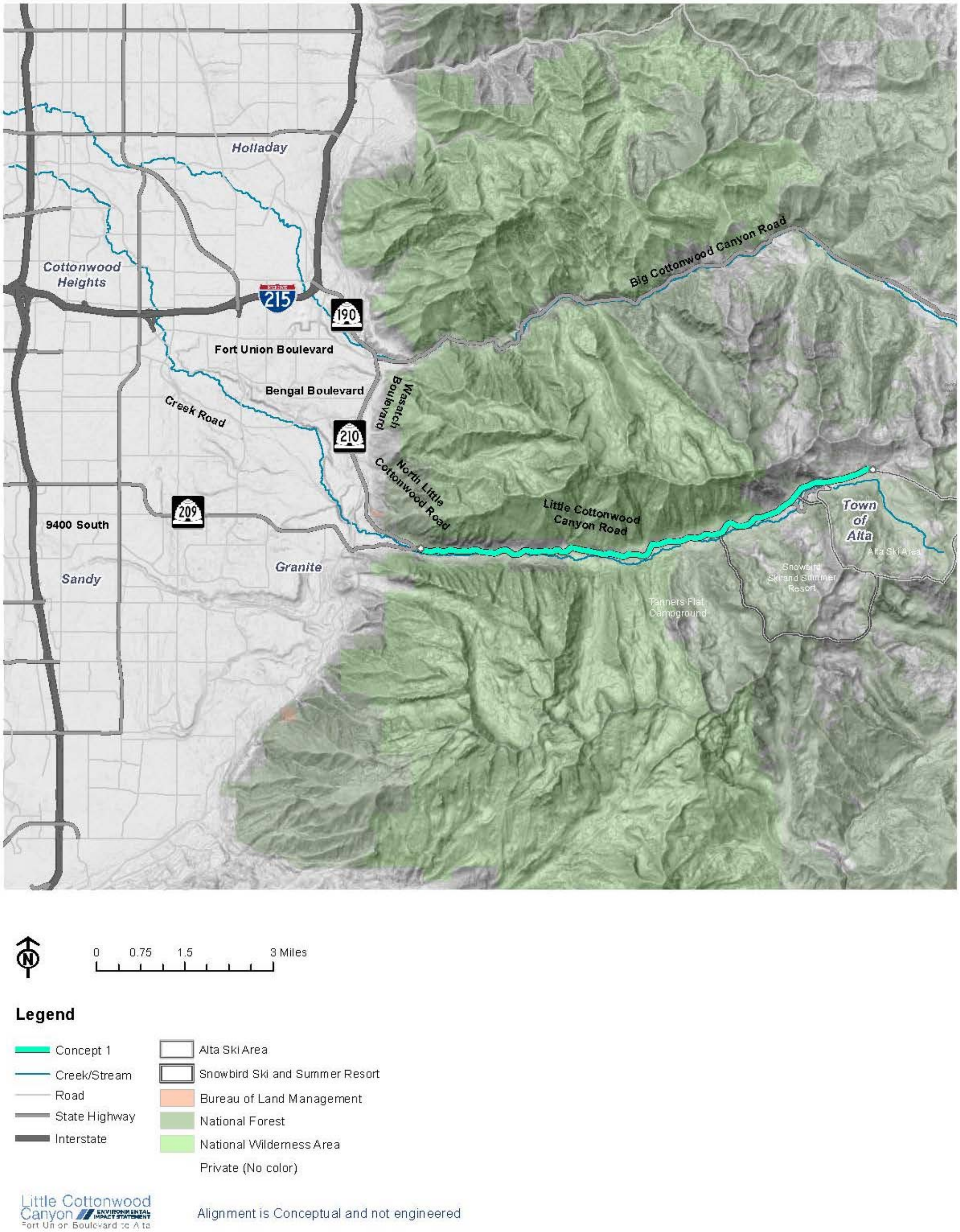
5.1 Concept 1 – Expanded Parking and Rail Base Station at the Mouth of Little Cottonwood Canyon

There is an existing park-and-ride lot at the mouth of Little Cottonwood Canyon at the intersection of S.R. 210 and S.R. 209. The existing lot has about 160 spaces. An expanded parking lot at or near this location, which could accommodate the assumed ridership, would require a large, multilevel parking structure. In order to compare transit concepts (bus, gondola, and train) equally, UDOT assumed a similar peak-hour ridership of about 1,000 people and a peak daily ridership of about 5,200. This level of ridership for Little Cottonwood Canyon would require a parking structure of about 2,500 cars.

Some members of the public are opposed to expanding the parking at this location because vehicle traffic during peak times creates traffic congestion in the area and restricts residents' mobility. A large parking structure at the base of the canyon would not help relieve congestion on S.R. 210 and S.R. 209 during peak arrival times. The congestion would be similar to the current conditions with traffic trying to enter the canyon. One of the purposes of the Little Cottonwood Canyon Project is to reduce congestion-related access issues for residents who live at the base on the canyon (that is, not being able to arrive at or leave their neighborhoods on peak ski days). However, this location for expanded parking and a rail base station has benefits with respect to the resulting rail alignment. The length of a cog rail line would be about 6.5 miles to Snowbird and another 1.5 miles to Alta, or about 8 miles total (Figure 7). UDOT prepared a preliminary design for Concept 1 (see Appendix B1, Preliminary Design Plan for Segment 1 – Little Cottonwood Canyon). The preliminary design used Typical Section C from Figure 4. The preliminary design plans do not include the snow sheds.

[11] These additional 12 minutes consist of the following times and activities: 0.5 minute to wait in the line of vehicles at the parking garage, 1 minute to find a parking spot, 4 minutes to unload gear, 3.5 minutes to walk to the train platform (assumed to be a 900-foot distance at a 3-mph pace), 1 minute to pay for a fare, and 2 minutes waiting in line to board the train.

Figure 7. Concept 1 Alignment



5.1.1 Travel Times

The travel time for Concept 1 includes personal vehicle travel time from Fort Union Boulevard to the mouth of Little Cottonwood Canyon; the time for a rider to park a vehicle, unload gear, walk to the loading platform, pay for a fare, board the train, and depart the rail base station; and the travel time from the rail base station to the resorts.

The estimated personal vehicle travel time along Wasatch Boulevard in 2050 is about 8 minutes from Fort Union Boulevard to the mouth of Little Cottonwood Canyon. This travel time assumes that Wasatch Boulevard has been expanded to accommodate the projected travel demand in 2050. With about 1,500 vehicles per hour trying to park at the expanded park-and-ride structure at the intersection of S.R. 209 and S.R. 210 during the peak hours, there could likely be some congestion at the intersection. However, this preliminary analysis assumes that the intersection of S.R. 210 and S.R. 209 can be improved such that vehicles can access the parking structure efficiently and that vehicles would not back up onto S.R. 210 or neighborhood streets.

UDOT added 12 minutes to the initial segment time to account for the time to park a personal vehicle, unload gear, walk to the train loading area, pay for a fare, board the train, and depart the rail base station. At an average speed of 25 miles per hour, the travel time to Snowbird would be about 16 minutes. With a 2-minute dwell time at a Snowbird station and a 1.5-mile, 4-minute train ride, the travel time to Alta would be another 6 minutes. The total travel time for Concept 1 would be about **36 minutes to Snowbird** and about **42 minutes to Alta** (Table 3).

Table 3. Travel Times for Concept 1

Segment Start	Segment End	Travel Mode	Rail Segment Length (miles)	Time, One-Way (minutes, rounded)
Fort Union Boulevard	Parking lot at rail base station	Drive	—	8
Parking lot	Departure from rail base station	Walk	—	12
Rail base station	Snowbird station	Rail	6.5	16
Snowbird station	Alta station	Rail	1.5	6
Total			**8.0**	**42**

5.1.2 Costs

Capital Cost

Capital costs include rolling stock (rail vehicles), track infrastructure (guideway, embedded track or ballast track and switches), civil site work (cuts and fills, structures, retaining walls, and storm drains), OCS, traction-power substations, station platforms, and utility relocations.[12] Costs in each segment of the cog rail concept would vary depending on the need for ROW, earthwork quantities, and the need for structural support elements (retaining walls or bridges). UDOT prepared preliminary engineering plans to conceptually define the cog rail Concept 1. ROW are not included.

Table 4 presents a rough order-of-magnitude cost for a cog rail line running about 8 miles from the mouth of Little Cottonwood Canyon to Alta. A cost range is presented by adjusting the number of rail vehicles that would be needed to serve the peak hour (5 to 8 vehicles), by providing a range of costs for a stand-alone OMF (variable size and location), and by assuming different lengths of snow sheds (2.14 to 3.84 miles).

Table 4. Concept 1, Capital Cost Range

	Component Cost ($million, 2019$)	
Element	Low Range	High Range
Guideway and track elements	130.0	130.0
Stations and terminals (base, Snowbird, Alta)	4.2	4.2
Site work (utilities and roadways)	15.1	15.1
Systems (controls, communications, and power supply/distribution)	202.5	202.5
Professional services (engineering, construction admin., legal, startup)	236.3	236.3
Contingencies (about 20%)	150.8	150.8
Cog rail vehicles [a]	55.6	88.8
Cog rail subtotal	**794.5**	**827.7**
Operation and maintenance facility [b]	60.0	75.3
Parking structure [c]	52.0	52.0
Snow sheds [d]	282.5	506.9
Total	**1,189**	**1,461.9**

[a] Five (low range) to eight (high range) cog rail vehicles would be needed for this concept depending on the actual per-vehicle capacity. A per-vehicle cost of about $11.1 million (2019$, Stadler 2019) was used in the estimate.

[b] Initial OMF sized to operate and maintain up to 14 cog rail vehicles at an estimated cost of about $75.3 million. The OMF cost was scaled for the low range to account for the potential for building a smaller OMF with this concept.

[c] Assumed parking structure sized for 2,500 cars for both the high and low ranges.

[d] Snow shed lengths of 2.14 miles (low range) and 3.84 miles (high range) were used. Snow shed unit cost is about $25,000 per linear foot based on a conceptually designed three-travel-lane snow shed.

[12] Not an exhaustive list.

The total estimated cost range for the design and construction of the cog rail system for Little Cottonwood Canyon only (Concept 1) would be about $795 million to $828 million. The approximately 10.5-acre OMF would cost about $60 million to $75.3 million. Assuming a 2,500-car parking structure at about $20,800 per parking space, the parking structure would cost about $52 million.[13] Snow sheds would cost about 25,000 per linear foot of snow shed or about $282.5 million to $506.9 million total, depending on the final snow shed lengths needed. A capital cost summary for Concept 1 is included in Appendix A. **The total estimated cost range for cog rail Concept 1 is about $1.19 billion to $1.46 billion.**

O&M Cost

To estimate operation and maintenance (O&M) costs, UDOT used a cost-per-mile methodology. UDOT assumes that cog rail train operations could be adjusted to more closely match actual expected ridership demands, which would vary by time of day and day of the week in the winter and seasonally. Operating assumptions are described in Section 4.2.3, Operating Assumptions. With those operating assumptions, UDOT estimated the total number of train trips per year and total number of miles traveled by rail vehicles. Table 5 presents the estimated total number of train trips (4,080) into Little Cottonwood Canyon per year under the assumed operating schedule.

Table 5. Number of Train Trips per Year into Little Cottonwood Canyon

Schedule	Hours of Operation	Trips per Hour[a]	Trips per Day	Days of Operation	Total Trips per Year
Winter peak hours	6	4	24	60	1,440
Winter off-peak hours	6	2	12	60	720
Winter weekdays	12	2	24	80	1,920
Total					**4,080**

Given the 8-mile one-way distance and the 16-mile round trip from the mouth of Little Cottonwood Canyon to Alta, the total miles traveled by cog rail vehicles would be about 65,280 miles annually. At $9.61 per vehicle revenue-mile (UTA 2018, p. 120), the total estimated annual O&M cost for Concept 1 is about **$628,000**.

[13] The per-parking-spot, planning-level capital cost estimate for a parking structure was provided to UDOT by its parking consultant, DESMAN Corporation.

5.2 Concept 2 – Expanded Parking and Rail Base Station at a Gravel Pit Mobility Hub

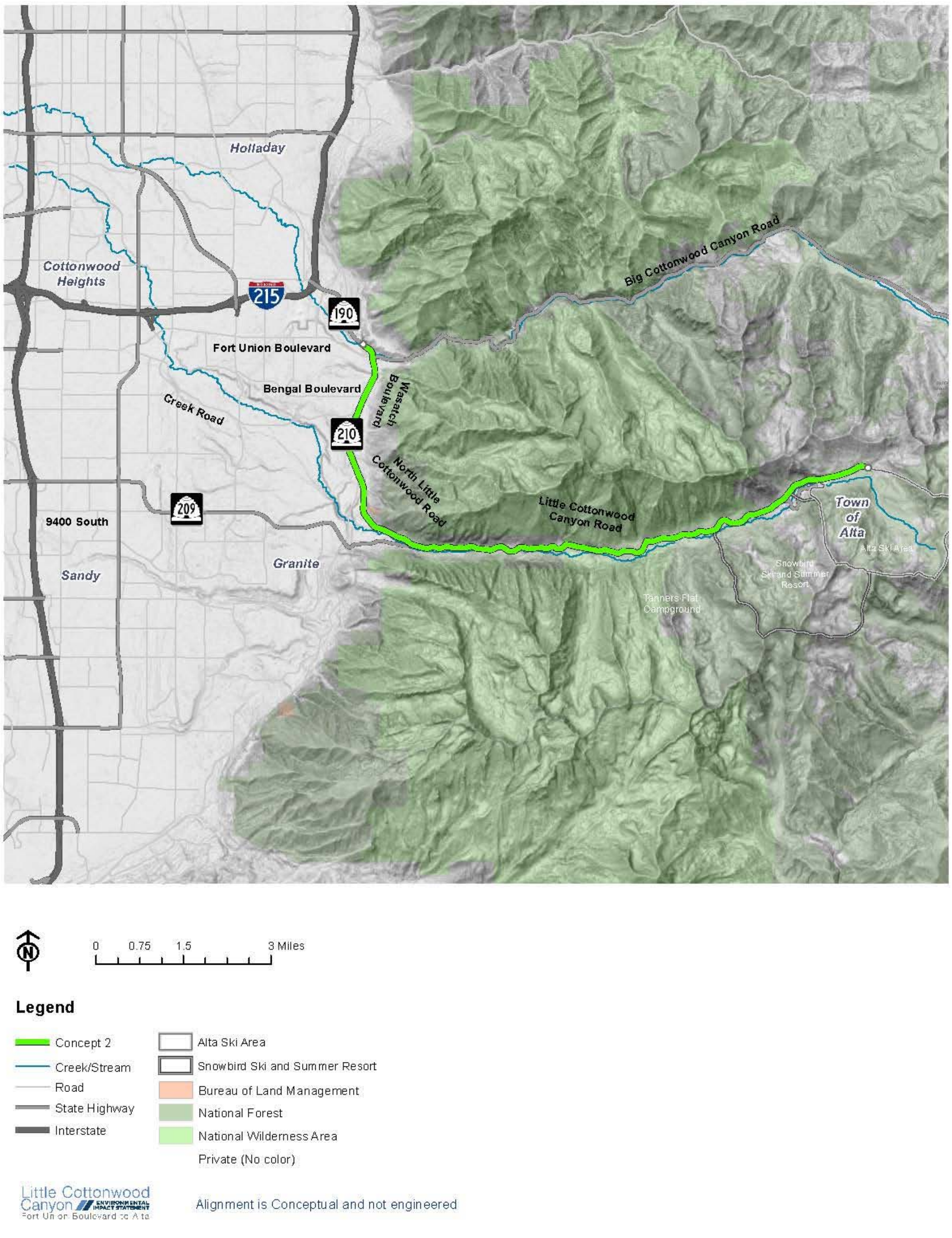
Because of the public opposition to an expanded parking lot and a parking structure in the residential areas around the mouth of Little Cottonwood Canyon, UDOT explored options to construct a large parking structure away from the mouth of the canyon. One option would place a large parking structure at a site of an aggregate (gravel) mining operation located just east of Wasatch Boulevard and north of Fort Union Boulevard near the mouth of Big Cottonwood Canyon. The parking structure would allow this location to function as a “mobility hub” from which users could take various transit options.

A main benefit of this location is that it would take cars away from the mouth of Little Cottonwood Canyon, which is where S.R. 210 and S.R. 209 merge and where traffic congestion is heavy during the current winter morning peak period. This location is near Interstate 215 (I-215) and would not add traffic to a residential area. Another benefit of this location as a mobility hub is that it could serve transit users traveling to either Big Cottonwood Canyon or Little Cottonwood Canyon, as well as serve weekday commuters in the future as UTA and UDOT explore long-term transit options for this part of the Salt Lake Valley. Parking could also be developed in conjunction with a future commercial or mixed-use development in the area.

For canyon users originating from the north part of the Salt Lake Valley (north of Fort Union Boulevard), this mobility hub would be on their route. However, canyon users who originate from south of 9400 South (S.R. 209) would need to bypass Little Cottonwood Canyon and drive about 3 more miles north to this mobility hub before boarding a cog rail vehicle.

See Figure 8 for the general route of Concept 2. The resulting train alignment would be about 12.2 miles. UDOT assumes that the double-track cog line would follow the same general alignment as S.R. 210—running in the center of Wasatch Boulevard, turning onto North Little Cottonwood Road, and then running along the north side of Little Cottonwood Canyon Road to the ski resorts. Conceptual design plans are shown in Appendix B2, Preliminary Plans for Segment 1 – Little Cottonwood Canyon, and Appendix B2, Preliminary Plans for Segment 2 – Gravel Pit to Mouth of Little Cottonwood Canyon.

Figure 8. Concept 2 Alignment



5.2.1 Travel Times

The urban segments of this concept alignment have flatter grades and wider curves than in Little Cottonwood Canyon. However, UDOT assumes that the maximum 25-mph speed in the canyon dictates the travel speed of cog rail vehicles along all segments of the route and in all directions for this concept. Note that the travel time begins at the gravel pit mobility hub near Fort Union Boulevard.

Table 6 presents the travel time for each segment and the total travel time for Concept 2. The total travel time is about **38 minutes to Snowbird** and about **44 minutes to Alta**. Note that, besides the base, Snowbird, and Alta stations, no intermediate train stations are assumed with this concept.

Table 6. Travel Times for Concept 2

Segment Start	Segment End	Travel Mode	Rail Segment Length (miles)	Time, One-Way (minutes, rounded)
Fort Union Boulevard	Parking lot at the rail base station at gravel pit mobility hub	Drive	—	Not applicable
Parking lot	Departure from rail base station	Walk	—	12
Rail base station	Mouth of Little Cottonwood Canyon	Rail	4.2	10
Mouth of Little Cottonwood Canyon	Snowbird station	Rail	6.5	16
Snowbird station	Alta station	Rail	1.5	6
Total			**12.2**	**44**

5.2.2 Costs

Capital Cost

Table 7 presents a rough order-of-magnitude cost for Concept 2, a cog rail line running about 12 miles from the gravel pit mobility hub at the intersection of Fort Union Boulevard and Wasatch Boulevard to Alta. The cost estimate for Concept 2 includes the planned roadway improvements to Wasatch Boulevard as well as a new bridge over Big Cottonwood Canyon creek. A cost range is presented by adjusting the number of rail vehicles that might be needed to serve the peak hour (6 to 9 vehicles), by providing a range of costs for a stand-alone OMF ($60 million to $75 million), and by assuming different lengths of snow sheds (2.14 to 3.84 miles).

Table 7. Concept 2, Capital Cost Range

Element	Component Cost ($million, 2019$) Low Range	High Range
Guideway and track elements	167.4	167.4
Stations and terminals	4.2	4.2
Site work (utilities and roadways)	233.2	233.2
Systems (controls, communications, and power supply/distribution)	319.7	319.7
Professional Services (engineering, construction admin., legal, startup)	261.2	261.2
Contingencies (about 20%)	233.1	233.1
Cog rail vehicles [a]	66.7	100.0
Cog rail subtotal	**1,285.5**	**1,318.8**
Operation and maintenance facility [b]	60.0	75.3
Parking structure [c]	52.0	52.0
Snow sheds [d]	282.5	506.9
Total	**1,680.0**	**1,953.0**

[a] Six (low range) to nine (high range) cog rail vehicles would be needed for this concept depending on the actual per-vehicle capacity. A per-vehicle cost of about $11.1 million (Stadler 2019) was used in the estimate.

[b] Initial OMF sized to operate and maintain up to 14 cog rail vehicles at an estimated cost of about $75.3 million. The OMF cost was scaled for the low range to account for the potential for building a smaller OMF with this concept.

[c] Assumed parking structure sized for 2,500 cars for both the high and low ranges.

[d] Snow shed lengths of 2.14 miles (low range) and 3.84 miles (high range) were used. Snow shed unit cost is about $25,000 per linear foot based on a conceptually designed three-travel-lane snow shed.

The total estimated cost range for the design and construction of the cog rail system with a parking structure at the gravel pit mobility hub and tracks running in the center of Wasatch Boulevard and into Little Cottonwood Canyon (Concept 2) would be about $1,285 million to $1,319 million. The approximately 10.5-acre OMF would cost about $60 million to $75.3 million. Assuming a 2,500-car parking structure at about $20,800 per parking space, the parking structure would cost about $52 million. Snow sheds, if needed to protect the cog rail OCS, would cost about 25,000 per linear foot of snow shed or about $282.5 million to $506.9 million total, depending on the final snow shed lengths needed. A capital cost summary for Concept 2 is included in Appendix A. **The total estimated cost range for cog rail Concept 2 is about $1.68 billion to $1.95 billion.**

O&M Cost

Concept 2 would have the same schedule and annual number of trips into Little Cottonwood Canyon as would Concept 1 (4,080 trips per year). Because Concept 2 is longer (24.4 miles round trip) than Concept 1 (16 miles round trip), the cog rail vehicle fleet would travel more miles per year with Concept 2. The total miles traveled by cog rail cars would be about 99,552 miles. At $9.61 per vehicle revenue-mile, the total estimated annual O&M cost for Concept 2 is about **$957,000**.

5.3 Concept 3 – Expanded Parking and Rail Base Station at a 9400 South and Highland Mobility Hub

Another concept would be to place a large parking structure near an existing park-and-ride lot at 9400 South and Highland Drive. The parking structure would allow this location to function as a mobility hub. This concept would also benefit mobility by removing cars from the mouth of Little Cottonwood Canyon, which is where S.R. 210 and S.R. 209 merge and where traffic congestion is heavy during the current winter morning peak period. UDOT assumes that a rail alignment can follow 9400 South to the mouth of Little Cottonwood Canyon and the north side of Little Cottonwood Canyon Road. See Figure 9 for the general route of Concept 3. The resulting cog rail alignment would be about 11.5 miles long. UDOT assumes that this concept would also require a double-track line for all segments. See Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood, and Appendix B3, Preliminary Design Plans for Segment 3 – 9400 South and Highland Drive to Mouth of Little Cottonwood Canyon, for the preliminary design plans for the canyon segment and the segment between 9400 South and Highland and the mouth of Little Cottonwood Canyon, respectively.

5.3.1 Travel Times

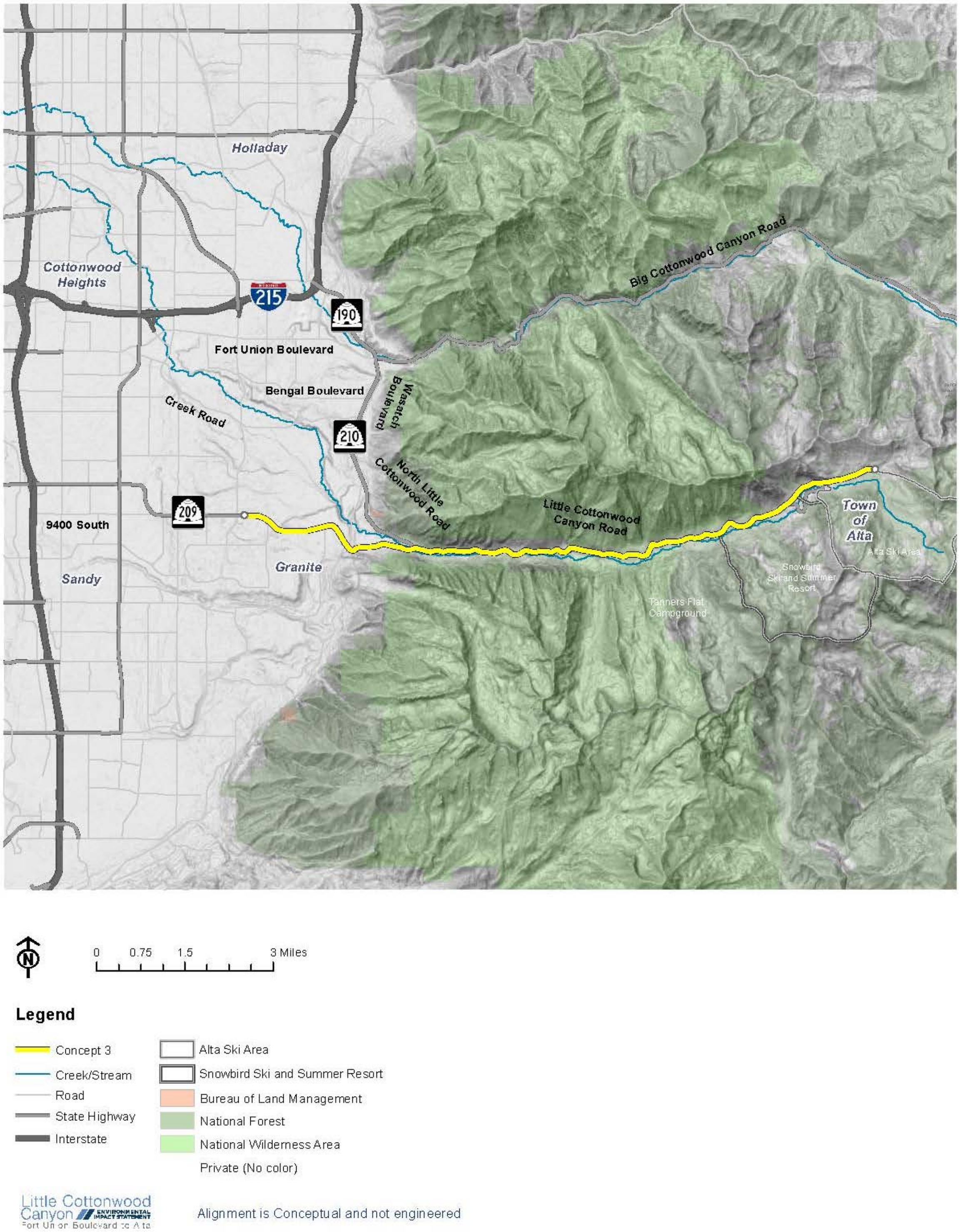
For Concept 3, the travel time in a cog rail train would be about **36 minutes to Snowbird** and about **42 minutes to Alta**. Note that, besides the base, Snowbird, and Alta stations, no intermediate train stations are assumed with this initial concept. Table 8 presents the travel time for each segment and the total travel time for Concept 3.

Table 8. Travel Times for Concept 3

Segment Start	Segment End	Travel Mode	Rail Segment Length (miles)	Time, One-Way (minutes, rounded)
Fort Union Boulevard	Parking lot at rail base station at 9400 South and Highland Drive mobility hub	Drive	—	Not applicable
Parking lot	Departure from rail base station	Walk	—	12
Rail base station	Mouth of Little Cottonwood Canyon	Rail	3.5	8
Mouth of Little Cottonwood Canyon	Snowbird station	Rail	6.5	16
Snowbird station	Alta station	Rail	1.5	6
Total			**11.5**	**42**

Note that the drive time in a personal vehicle from Fort Union Boulevard along Wasatch Boulevard was not included in the travel time for this concept. With this concept, UDOT assumes that some train riders would adjust their route to use Interstate 15 (I-15) and S.R. 209 (9000/9400 South) as opposed to I-215 and Wasatch Boulevard. Therefore, Wasatch Boulevard might not be the predominant route for transit riders to this mobility hub serving Little Cottonwood Canyon under Concept 3.

Figure 9. Concept 3 Alignment



5.3.2 Costs

Capital Cost

Table 9 presents a rough order-of-magnitude cost for Concept 3, a cog rail line running about 11.5 miles from 9400 South and Highland Drive mobility hub to Alta. A cost range is presented by adjusting the number of rail vehicles that might be needed to serve the peak hour (6 to 9 vehicles), by providing a range of costs for a stand-alone OMF, and by assuming different lengths of snow sheds (2.14 to 3.84 miles).

Table 9. Concept 3, Capital Cost Range

Element	Component Cost ($million, 2019$)	
	Low Range	High Range
Guideway and track elements	157.4	157.4
Stations and terminals	4.2	4.2
Site work (utilities and roadways)	40.8	40.8
Systems (controls, communications, and power supply/distribution)	280.2	280.2
Professional services (engineering, construction admin., legal, startup)	236.3	236.3
Contingencies (about 20%)	178.8	178.8
Cog rail vehicles [a]	66.7	100.0
Cog rail subtotal	**964.4**	**997.7**
Operation and maintenance facility [b]	60.0	75.3
Parking structure [c]	52	52
Snow sheds [d]	282.5	506.9
Total	**1,358.9**	**1,631.9**

[a] Six (low range) to nine (high range) cog rail vehicles would be needed for this concept depending on the actual per-vehicle capacity. A per-vehicle cost of about $11.1 million (Stadler 2019) was used in the estimate.

[b] Initial OMF sized to operate and maintain up to 14 cog rail vehicles at an estimated cost of about $75.3 million. The OMF cost was scaled for the low range to account for the potential for building a smaller OMF with this concept.

[c] Assumed parking structure sized for 2,500 cars for both the high and low ranges.

[d] Snow shed lengths of 2.14 miles (low range) and 3.84 miles (high range) were used. Snow shed unit cost is about $25,000 per linear foot based on a conceptually designed three-travel-lane snow shed.

The total estimated cost range for the design and construction of the cog rail system with a parking structure at a 9400 South and Highland Drive mobility hub and tracks running in the center of S.R. 210 and into Little Cottonwood Canyon (Concept 3) would be about $964 million to $998 million. The approximately 10.5-acre OMF would cost about $60 million to $75.3 million. Assuming a 2,500-car parking structure at about $20,800 per parking space, the parking structure would cost about $52 million. Snow sheds, if needed to protect the cog rail OCS, would cost about 25,000 per linear foot of snow shed or about $282.5 million to $506.9 million total, depending on the final snow shed lengths needed. A capital cost summary for Concept 3 is included in Appendix A. **The total estimated cost range for cog rail Concept 3 is about $1.36 billion to $1.63 billion.**

O&M Cost

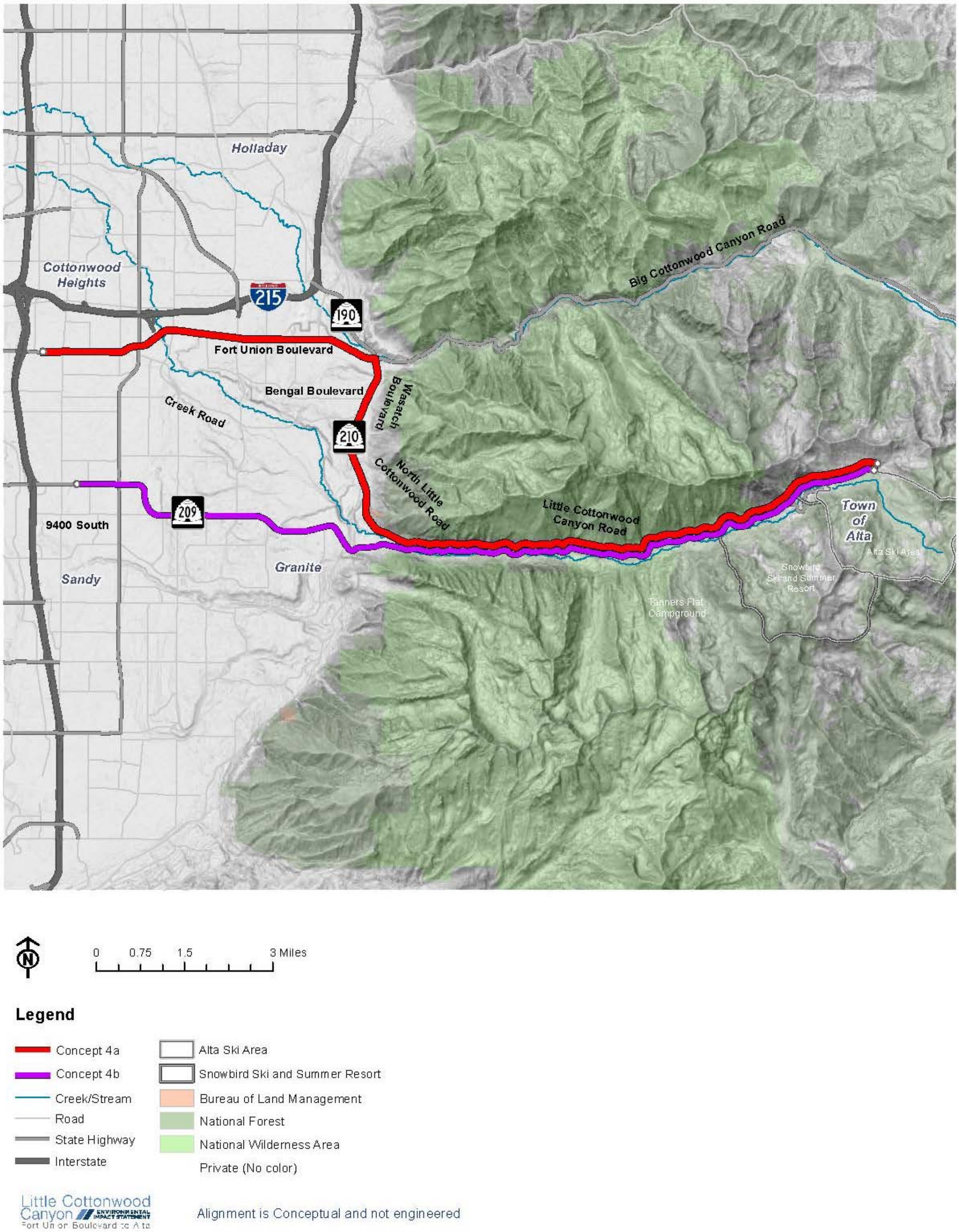
Concept 3 would have the same schedule and annual number of trips into Little Cottonwood Canyon as would Concept 1 (4,080 trips per year). With Concept 3, the total miles traveled by cog rail cars would be about 93,840 miles. At $9.61 per vehicle revenue-mile, the total estimated annual O&M cost for Concept 3 is about **$902,000**.

5.4 Concept 4 – Connection to the Existing TRAX System

UDOT evaluated two options to connect a Little Cottonwood Canyon cog rail line to UTA's existing TRAX system (see Figure 10). These options were consider to avoid the need to construct a large parking structure and reduced the need for a large (10.5-acre) stand-alone OMF to operate and service rail vehicles.

- **Concept 4, Option A** would connect to the existing TRAX system at the Midvale Fort Union TRAX Station near I-15 and Fort Union Boulevard (7200 South). The resulting conceptual rail alignment would run for about 5.9 miles east along Fort Union Boulevard to Wasatch Boulevard and then turn south and run for about 4.2 miles along Wasatch Boulevard to the mouth of Little Cottonwood Canyon. Adding the 8-mile segment in Little Cottonwood Canyon, the total length of this option would be about **18.1 miles**. See Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood, and Appendix B2, Preliminary Design Plans for Segment 2 – Gravel Pit to Mouth of Little Cottonwood Canyon, for the preliminary design plans for the canyon segment and segment between the gravel pit and the mouth of Little Cottonwood Canyon, respectively, which make up Concept 4A. No preliminary design plans were prepared for the Concept 4A segment between the Fort Union Boulevard TRAX Station and the gravel pit.
- **Concept 4, Option B** would connect to the existing TRAX system at the Historic Sandy Station near about 150 East and 9000 South. From the Historic Sandy TRAX Station, the resulting conceptual rail alignment would east run for about 6.3 miles along S.R. 209 (9000 south and 9400 South) to the mouth of Little Cottonwood Canyon. Adding the 8-mile segment in Little Cottonwood Canyon, the total length of this option would be about **14.3 miles**. See Appendix B1, Preliminary Design Plans for Segment 1 – Little Cottonwood, Appendix B3, Preliminary Design Plans for Segment 3 – 9400 South and Highland Drive to Mouth of Little Cottonwood Canyon, and Appendix B4, Preliminary Design Plans for Segment 4 – Historic Sandy TRAX Station 9400 South and Highland Drive, for the preliminary design plans for Concept 4B.

Figure 10. Concept 4A and 4B Alignments



5.4.1 Travel Times

Concept 4A – TRAX Connection at Midvale Fort Union Station

As described in Section 4.2.3, Operating Assumptions, connecting a Little Cottonwood Canyon cog rail line to UTA's existing TRAX system could also serve weekday commuter traffic. Although this is not part of the purpose of and need for the Little Cottonwood Canyon Project, if such a rail line were constructed to serve the needs of Little Cottonwood Canyon, it could also serve weekday commuters.

For travel time calculations, UDOT assumes that four intermediate stations would be built somewhere along the alignment of Concept 4A: three stations along Fort Union Boulevard and one station along Wasatch Boulevard. No specific station locations were identified for this preliminary feasibility study. A station dwell time of 2 minutes was assigned to each of these stations. UDOT also assumed that the TRAX vehicles could be equipped to use the cog rail line, so riders would not need to transfer at the mouth of the canyon. Note that driving or parking times were not included in the travel time calculations for Concept 4A.

Table 10 presents the travel time for Concept 4A, which is an 18.1-mile-long line. UDOT used the 25-mile-per-hour cog rail speed for all segments. Assuming that a rider embarks at the TRAX Midvale Fort Union TRAX Station, the total travel time would be about **48 minutes to Snowbird** and about **54 minutes to Alta**.

Table 10. Travel Times for Concept 4A

Segment Start	Segment End	Travel Mode	Rail Segment Length (miles)	Time, One-Way (minutes, rounded)
Midvale Fort Union TRAX Station	Wasatch Boulevard and Fort Union Boulevard	Rail	5.9	20
Wasatch Boulevard and Fort Union Boulevard	Mouth of Little Cottonwood Canyon	Rail	4.2	12
Mouth of Little Cottonwood Canyon	Snowbird station	Rail	6.5	16
Snowbird station	Alta station	Rail	1.5	6
Total			**18.1**	**54**

Concept 4B – TRAX Connection at Historic Sandy Station

UDOT assumed that Concept 4B would include three intermediate stations somewhere along 9000 South and 9400 South (S.R. 209). Table 11 presents the travel time for Scenario 4B, which is a 14.3-mile-long rail line. UDOT used the 25-mile-per-hour speed for all segments and a 2-minute dwell time at each station. UDOT also assumed that riders would not need to transfer to a cog rail vehicle at mouth of the canyon. Note that driving or parking times were not included in the travel time calculations for Concept 4B. Travel times for passengers that start at the Historic Sandy TRAX Station would be about **37 minutes to Snowbird** and about **43 minutes to Alta**.

Table 11. Travel Times for Concept 4B

Segment Start	Segment End	Travel Mode	Rail Segment Length (miles)	Time, One-Way (minutes, rounded)
Historic Sandy TRAX Station	Mouth of Little Cottonwood Canyon	Rail	6.3	21
Mouth of Little Cottonwood Canyon	Snowbird station	Rail	6.5	16
Snowbird station	Alta station	Rail	1.5	6
Total			**14.3**	**43**

5.4.2 Costs

Capital Cost

In order to generate conceptual construction quantities and rough order-of-magnitude cost estimates, UDOT prepare conceptual design plans for cog rail Concept 4B. Concept 4B, which would include a new rail line down S.R. 209, would be the shortest connection (about 3.8 miles shorter than Concept 4A) to the existing UTA light rail system. It would also have faster travel times (11 minutes faster) as measured from the connection points (either Midvale Fort Union or Historic Sandy TRAX Stations). The total cost for the urban segment of Concept 4A from UTA's Midvale Fort Union TRAX Station to the gravel pit mobility hub were estimated by applying a per-mile cost ($85 million to $100 million per mile) to the additional length, and adding that cost to the cost of Concept 2 (gravel pit mobility hub to Alta). A cost summary for Concept 2 is included in Appendix A.

Table 12 presents rough order-of-magnitude capital cost estimates for Concept 4A.

Table 12. Concept 4A, Capital Cost Range

Element	Component Cost ($million, 2019$)	
	Low Range	High Range
Concept 2 cost estimate range	1,284.6	1,317.9
5.9 miles of rail in urban setting ($85 million to $100 million per mile)	501.5	590.0
Cog rail subtotal	**1,786.1**	**1,907.9**
Operation and maintenance facility [b]	25.1	25.1
Parking structure [c]	0	0
Snow sheds [d]	282.5	506.9
Total	**2,093.7**	**2,439.9**

[a] Nine (low range) to 12 (high range) cog rail vehicles would be needed depending on the actual per-vehicle capacity. A per-vehicle cost of about $11.1 million (Stadler 2019) was used in the estimate.

[b] Because the cog rail system would connect to the existing UTA light rail system, a stand-alone OMF would not be needed for this concept. An allocation of $25.1 million is included in the cost estimate to account for expanding the existing OMF.

[c] A large parking structure would not be needed for this concept.

[d] Snow shed lengths of 2.14 miles (low range) and 3.84 miles (high range) were used. Snow shed unit cost is about $25,000 per linear foot based on a conceptually designed three-travel-lane snow shed.

The total estimated cost range for designing and constructing a cog rail system that connects to the Midvale Fort Union TRAX Station and runs about 18.1 miles to Alta is about $1.8 million to $1.9 billion. This cost does not include any parking structures or expanding existing park-and-ride lots. UDOT allocated $25.1 million for expanding UTA's existing OMF to accommodate the 9 to 12 additional cog rail vehicles needed for this concept. Snow sheds would cost about $282.5 million to $506.9 million total, depending on the final snow shed lengths needed. **The total estimated cost range for cog rail Concept 4A is about $2.09 billion to $2.44 billion.**

As mentioned in Section 5.4, Concept 4 – Connection to the Existing TRAX System, UDOT prepared a concept deign for Concept 4B. Table 13 presents rough order-of-magnitude capital cost estimates for Concept 4B.

Table 13. Concept 4B, Capital Cost Range

Element	Component Cost ($million, 2019$) Low Range	High Range
Guideway and track elements	180.6	180.6
Stations and terminals	4.2	4.2
Site work (utilities and roadways)	67.7	67.7
Systems (controls, communications, and power supply/distribution)	369.8	369.8
Professional services (engineering, construction admin., legal, startup)	236.3	236.3
Contingencies (about 20%)	203.4	203.4
Cog rail vehicles [a]	100.0	133.3
Cog rail subtotal	**1,162.0**	**1,195.3**
Operation and maintenance facility [b]	25.1	25.1
Parking structure [c]	—	—
Snow sheds [d]	282.5	506.9
Total	**1,469.6**	**1,727.3**

[a] Nine (low range) to 12 (high range) cog rail vehicles would be needed depending on the actual per-vehicle capacity. A per-vehicle cost of about $11.1 million (Stadler 2019) was used in the estimate.

[b] Because the cog rail system would connect to the existing UTA light rail system, a stand-alone OMF would not be needed for this concept. An allocation of $25.1 million is included in the cost estimate to account for expanding the existing OMF.

[c] A large parking structure would not be needed for this concept.

[d] Snow shed lengths of 2.14 miles (low range) and 3.84 miles (high range) were used. Snow shed unit cost is about $25,000 per linear foot based on a conceptually designed three-travel-lane snow shed.

The total estimated cost range for designing and constructing a rail system that connects to the Historic Sandy TRAX Station and runs for about 14.3 miles to Alta is about $1.21 million to $1.24 billion. This cost does not include any parking structures or expanding existing park-and-ride lots. UDOT allocated $25.1 million for expanding UTA's existing OMF to accommodate the 9 to 12 additional cog rail vehicles needed for this concept. Snow sheds would cost about $282.5 million to $506.9 million total, depending on the final snow shed lengths needed. A capital cost summary for Concept 4B is included in Appendix A. **The total estimated cost range for cog rail Concept 4B is about $1.74 billion to $1.77 billion.**

O&M Cost

Given the 36.2-mile round trip with Concept 4A and the 28.6-mile round trip with Concept 4B, the total miles traveled by cog rail vehicles would be 147,696 miles with Concept 4A and 116,688 miles with Concept 4B. At $9.61 per vehicle revenue-mile, the total estimated annual O&M costs would be about **$1,420,000** for Concept 4A and about **$1,122,000** for Concept 4B.

6.0 Comparison of Cog Rail Concepts

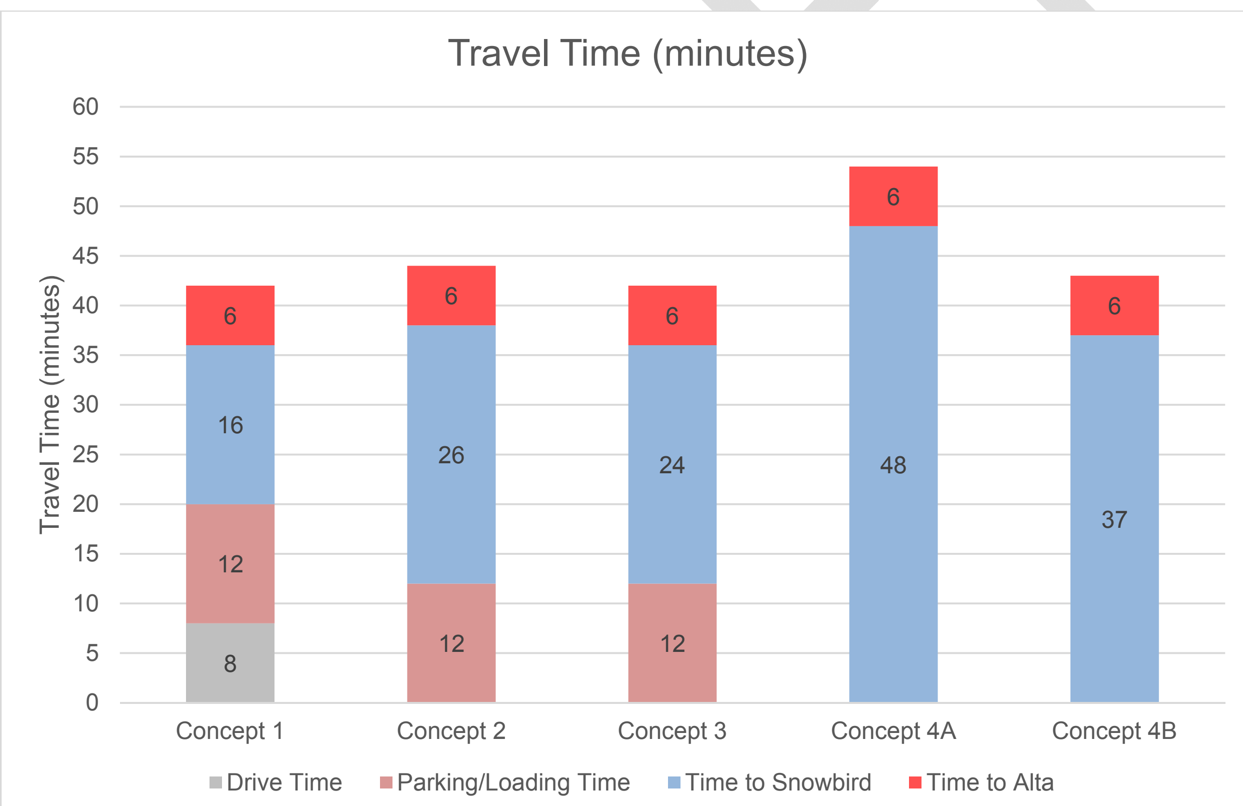
Taking into account the details of each scenario as described in Section 5.0, Rail Concepts Evaluation, UDOT compared the scenarios using the major initial feasibility criteria of travel time and capital and O&M costs. UDOT also compared the scenarios using the additional feasibility criterion of the purpose of the Little Cottonwood Canyon Project as well as specific considerations that apply to implementation of cog rail.

6.1 Rail Concept Comparisons Using the Major Feasibility Criteria

6.1.1 Travel Times

Figure 11 compares the estimated travel times for the rail concepts evaluated in this preliminary rail feasibility study.

Figure 11. Travel Time Comparisons



With the assumptions used in this initial feasibility study, the fastest overall travel times to the resorts in a cog rail train would occur with an expanded parking area and rail base station near the mouth of Little Cottonwood Canyon (Concept 1 with a travel time of about 42 minutes). Concept 1 includes 8 minutes of travel time in personal vehicle, which is the modeled travel time along Wasatch Boulevard with planned roadway improvements from Fort Union Boulevard to the base train station. Moving the parking away from the canyon, to Wasatch Boulevard and Fort Union Boulevard or to 9400 South and Highland Drive mobility hubs, would have similar total travel times (44 minutes for Concept 2 and 42 minutes for Concept 3). The 8-minute car ride with Concept 1 would be replaced with a 10-minute train ride with Concept 2. Note that the drive time in a personal vehicle was not included in Concept 3 since train riders' initial travel patterns could shift away from Wasatch Boulevard.

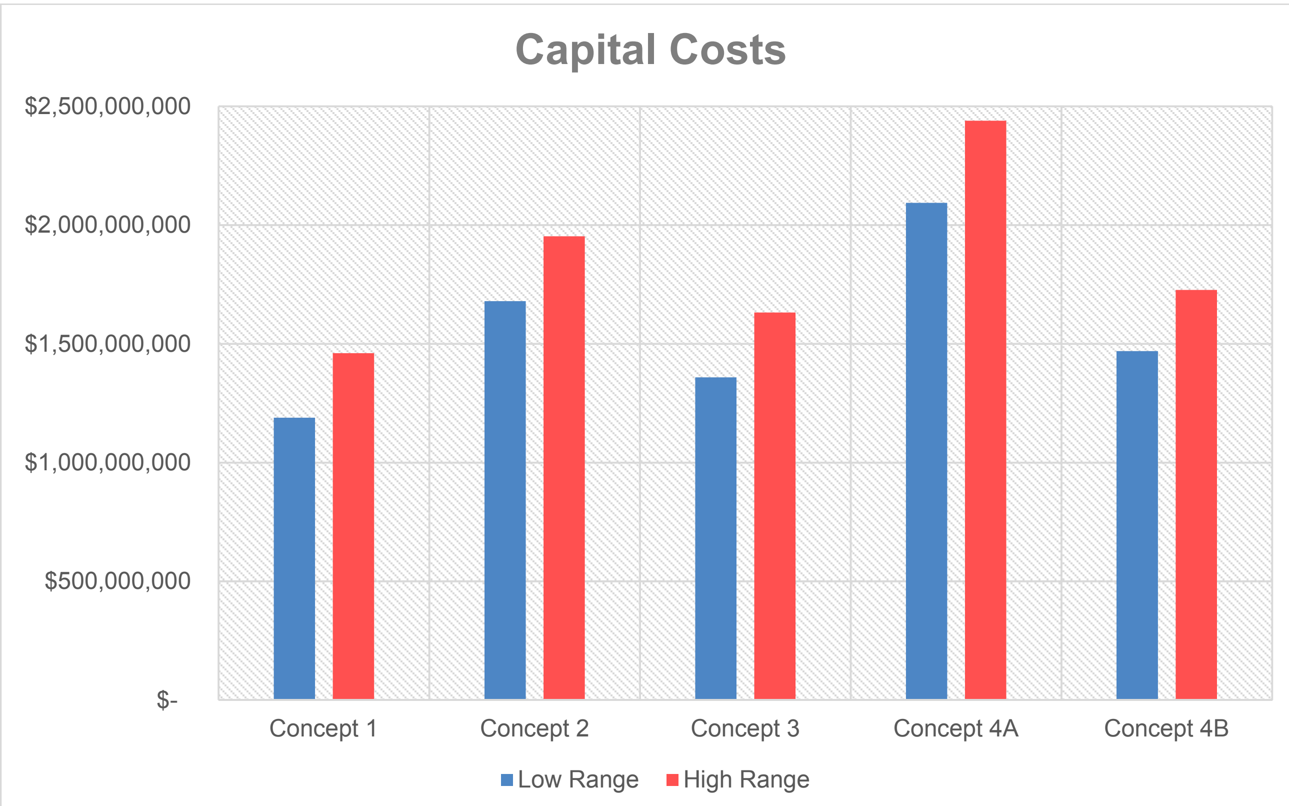
Connecting a Little Cottonwood Canyon cog rail to the existing TRAX system would result in travel times of 43 to 54 minutes from the assumed connection points (Historic Sandy or Midvale Fort Union TRAX Stations). These concepts would be 2 to 12 minutes longer than Concept 1. However, the travel times for Concepts 4A and 4B do not include any personal vehicle travel time nor any parking and loading times. With the concepts that connect to the existing light rail systems, travel times would be longer for riders embarking from TRAX stations located north or south of these connection points. Passengers embarking from intermediate stations along the Little Cottonwood Canyon cog rail line between the connection point and the mouth of Little Cottonwood Canyon would experience shorter travel times.

6.1.2 Capital and O&M Costs

Capital Costs

Figure 12 compares the estimated low- and high-range, capital costs for the cog rail concepts evaluated in this initial feasibility report.

Figure 12. Capital Cost Comparison



The least expensive concept, Concept 1 with a parking structure and a base rail station at the mouth of Little Cottonwood Canyon, would cost about $1.19 billion to about $1.46 billion. In addition to the track, power systems, rail vehicles, parking, and OMF, a major capital cost consideration is the need for snow sheds to protect the cog rail track and OCS from avalanches. Because an electrified third rail at ground level is not feasible, OCS would be needed, and the OCS would need to be protected to avoid long shut-down periods and to maintain reliable operations. These snow sheds, however, add considerable capital cost (an additional $300 million to $500 million total) from what might be typical for a new light rail or cog rail system.

Using a mobility hub that is located away from the mouth of the Little Cottonwood Canyon would require more infrastructure and more cog rail vehicles to serve peak-hour users. Capital costs for Concepts 2 and 3 are estimated to be between about $1.36 billion (low range for Concept 3) and about $1.95 billion (high range for Concept 2), or $170 million to $490 million more than Concept 1. Note that the capital cost for

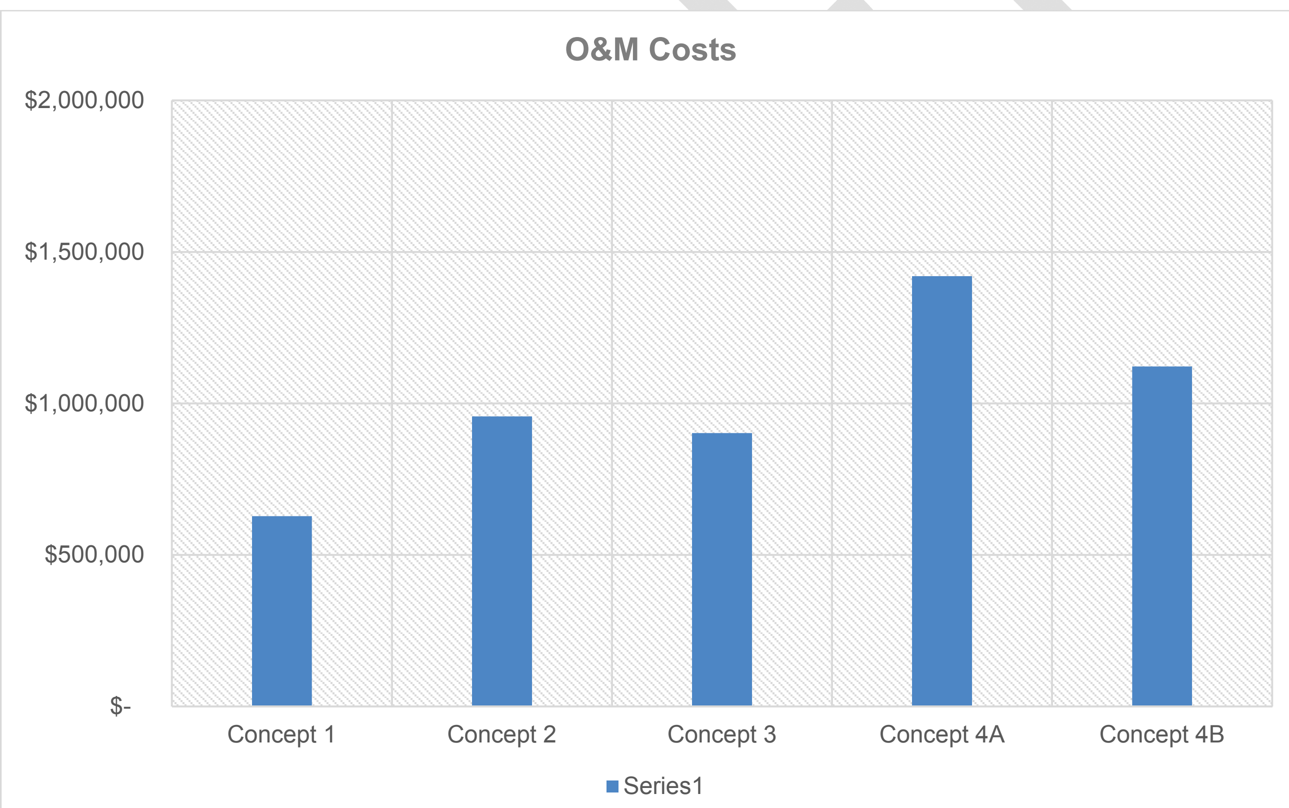
Concept 2 accounts for the planned roadway improvements to Wasatch Boulevard, which are needed to serve projected weekday commuter traffic.

The estimated cost of light rail line in an urban environment is about $100 million per mile. The per-mile cost offsets the avoided cost of a large parking structure ($52 million) and a large stand-alone OMF ($60 million to $75 million), which would not be required for Concepts 4A and 4B. Connecting a Little Cottonwood Canyon cog rail line to the existing TRAX system would cost about $1.7 billion to $2.4 billion (high range), or at least $260 million to more than $978 million more than Concept 1.

O&M Costs

O&M cost was determined by calculating the total miles travel annually by the cog rail vehicles and applying a per-mile unit operating cost. Figure 13 shows the approximate O&M costs for the cog rail concepts evaluated in this report. O&M costs would range from about $0.63 million to $1.4 million annually for winter service for the various concepts evaluated in this report.

Figure 13. O&M Cost Comparison



Concepts with parking near the mouth of Little Cottonwood Canyon or at mobility hubs would cost about $0.63 million to more than $0.96 million annually to operate rail vehicles and maintain the rolling stock and infrastructure. Annual O&M costs for concepts that connect to the existing light rail system would be $1.12 million to $1.42 million. Because it is shortest route, Concept 1 would have the lowest O&M cost.

6.1.3 Comparison of Major Feasibility Criteria

Table 14 compares the major feasibility criteria for the cog rail concepts evaluated in this initial feasibility report.

Table 14. Cog Rail Capital Cost, O&M Cost, and Travel Time Comparison

Concept	Capital Cost (billion $)	Annual O&M Cost (million $)	Total Travel Time to Alta (minutes)
1	1.19 to 1.46	0.63	42
2	1.68 to 1.95	0.96	44
3	1.36 to 1.63	0.90	42 [a]
4A	2.09 to 2.44	1.42	54 [a,b]
4B	1.47 to 1.73	1.12	43 [a,b]

[a] Total travel times does not include any personal vehicle travel time.
[b] Total travel time does not include parking and loading times

6.2 Rail Concept Comparisons Using Additional Feasibility Criteria

In addition to comparing the scenarios in terms of their travel time and capital and O&M costs (Section 6.1, Rail Concept Comparisons Using the Major Feasibility Criteria), UDOT compared the rail concepts in terms of additional feasibility criteria pertaining to the purpose of the Little Cottonwood Canyon Project (improved mobility and improved neighborhood access or reduced congestion). UDOT included additional criteria pertaining to transportation reliability and changes to travel patterns, which are considerations that apply to rail transit in an urban environment. Other environmental impacts would be addressed in the EIS if a cog rail concept is selected for detailed analysis. These additional feasibility criteria are described below, and the scenarios' ratings for these criteria are summarized in Section 6.2.6, Summary of Rail Concept Comparisons Using Additional Feasibility Criteria.

6.2.1 Impacts to Congestion

There is an existing park-and-ride lot at the mouth of Little Cottonwood Canyon at the intersection of S.R. 210 and S.R. 209. The existing lot has about 160 spaces. An expanded parking lot at or near this location, which could accommodate the assumed cog rail ridership, would require a large, multilevel parking structure. UDOT initially assumes that a 2,500-car parking structure would be required to meet the daily demand for the number transit riders entering the canyon.

Some members of the public are strongly opposed to expanding the parking lot at this location because traffic during peak times creates traffic congestion in the area and restricts residents' mobility. A large parking structure at the base of the canyon, which would be needed with Concept 1, would not help relieve congestion on S.R. 210 and S.R. 209 during peak arrival times. The congestion would be similar to the current conditions with traffic trying to enter the canyon. One of the purposes of the Little Cottonwood Canyon Project is to reduce congestion-related access issues for residents who live at the base on the canyon (not being able to arrive at or leave their neighborhoods on peak ski days). Therefore, Concept 1 would have a high impact under this criterion.

Moving the parking and rail base station to a mobility hub located away from the mouth of the canyon (Concepts 2 and 3) would benefit residents' mobility by removing some cars from the residential area. Concept 2, which places the parking structure at the gravel pit and therefore closer to an interstate freeway (I-215) is better than Concept 3, which is about miles from 3 miles from I-15. With Concept 2, personal vehicles would travel past more residential areas to access the parking structure at the 9400 South and Highland Drive mobility hub. For train riders using their personal vehicle for the initial stages of their trip, parking for Concept 4 could be more dispersed, and Concept 4 would not concentrate traffic to just one parking area.

6.2.2 Needed Roadway Improvements and Impacts to Travel Patterns

Implementing a cog rail line outside Little Cottonwood Canyon would require major roadway infrastructure improvements and would change travel patterns on the existing roadway network. There are many residential areas adjacent to the rail alignments outside Little Cottonwood Canyon. A center-running rail line would limit left turns out of these neighborhoods. Drivers who want to make a left-hand turn would be required to turn right, travel to a signalized intersection, and make a left U-turn or make a loop along other routes. The complicated details of the changed travel patterns through all cog rail concepts segments was not evaluated in this initial feasibility report. In general, cog rail concepts that run down the center of S.R. 210 (Wasatch Boulevard), S.R. 209 (9400/9000 South), and S.R. 190 (Fort Union Boulevard) would require extensive roadway widening, would have high impacts to the existing utility infrastructure, and would substantially change the travel patterns to and from residential and commercial areas that abut these arterial roads. Concept 1 would rank as low, Concepts 2 and 3 as medium, and Concepts 4A and 4B as high under this criterion.

6.2.3 Potential Residential Impacts

Concept 1, which runs on the north side S.R. 210, would require the acquisition of a few homes that are located in the upper portions of the canyon. Compared to other concepts, Concept 1 would score low on the residential impacts criterion. Several residential areas surround the mouth of Little Cottonwood Canyon. Cog rail concepts outside the canyon have a high potential to affect residents and will result in several property acquisitions. The preliminary design for Concept 2 assumes a wider typical cross-section because the concept includes improvements to Wasatch Boulevard. Concept 2 (and 4A, which has the same Wasatch Boulevard segment as Concept 2) has a higher potential for property acquisitions. The design for Concepts 3 and 4B would reconstruct the same number of travel lanes as exist now. These concepts have a medium rank for the potential to affect residential areas.

6.2.4 Improving Mobility and Maximizing Transit Ridership

One way to improve mobility is by providing additional transportation modes. A cog rail line would address wintertime mobility primarily by shifting a substantial portion of the future travel demand to mass transit and possibly would avoid the need to add automobile capacity in the canyon. As described in this report, UDOT's initial evaluation assumes that a percentage of the peak hourly demand could be accommodated by a cog rail system, and that all rail concepts are essentially equal in this regard. The actual expected ridership would be based on many factors including travel time benefits and pricing, which was not estimated in this conceptual feasibility report.

In general, a "one-seat ride" (either vehicle or transit) is most preferable to users. One mode shift, or a "two-seat ride," is less desirable but is still acceptable to many users as evidenced by the use of the existing park-and-ride lots and the popularity of ski bus service. If a Little Cottonwood Canyon cog rail line were connected to UTA's existing, and expansive, light rail network, there would be more potential riders in proximity to the existing park-and-ride lots, and this might make the transit portion of the trip attractive to more users. However, until all rail vehicles become equipped with cog equipment, riders would need to shift travel modes from standard light rail vehicles that operate over the existing network to a cog rail vehicles that can navigate the grades in the canyon. Shifting travel modes twice (from car to light rail to cog rail), or a "three-seat ride," would likely be unpopular but could be acceptable to some users if the travel time were shorter than with other available options or if it were less expensive. If resort parking becomes more limited in the future, or if future policy decisions limit automobile use in the canyon, a longer train ride could be a reasonable scenario.

The annual transit ridership, measured as a percentage of total trips in the canyon, would be low without other traffic demand management tools (such as tolling) or an overall policy to substantially restrict personal vehicles in the canyon. The resulting fare needed to pay back a portion of the cog rail's capital cost and help fund operating expenses was not determined for this initial feasibility study. UDOT is conducting an analysis to understand canyon users' willingness to pay for transit service versus the value of their time ("ridership elasticity") and will apply those findings in the ongoing alternatives-evaluation process for the EIS. The biggest cost driver is the length of the rail infrastructure, which affects both initial capital costs and annual O&M costs. Moving the rail base station to mobility hubs located away from the mouth of Little Cottonwood Canyon (Concepts 2 and 3, which would cost between $1.95 billion and $1.6 billion, respectively) would cost about $170 million to $492 million more (up to about 34% more) than would a rail base station at the mouth of the canyon (Concept 1, which would cost about $1.18 billion to 1.46 billion). The additional infrastructure would tend to increase the fare required to pay back the initial capital cost, if the intent is to require users to pay back some of the costs.

6.2.5 Avalanche Closure Risks

An additional mobility consideration is the reliability of the transportation system given the unique characteristics of the Little Cottonwood Canyon transportation corridor. The current avalanche-control program in Little Cottonwood Canyon causes the road to be closed periodically for avalanche control and can cause 2-to-4-hour travel delays or longer. This causes traffic to back up in the neighborhoods at the entrance of the canyon.

As described in Section 4.6, Avalanche Protections, UDOT initially assumes that snow sheds in would be needed for cog rail concepts as passive avalanche-control measures. UDOT estimated that between 2.14 and 3.84 miles of snow sheds would be needed to protect the track and OCS from avalanches with all concepts. If the entire cog rail OCS needs to be protected in all avalanche paths in the canyon, up to 7.5 miles of snow sheds might be required. Placing snow sheds in these paths to protect the cog rail track and OCS from avalanches would also make a cog rail system reliable compared to the existing road and could significantly reduce closure times (currently about 56.3 hours of road closure per year), which are needed for the active avalanche-control measures (primarily artillery) currently being used. However, these come at a high cost, as explained in Section 5.0, Rail Concept Evaluation. All cog rail concepts are equivalent for this criterion.

6.2.6 Summary of Rail Concept Comparisons Using Additional Feasibility Criteria

Table 15 shows a comparison of evaluation criteria presented in this initial feasibility report.

Table 15. Comparison of Costs, Travel Times, and Additional Feasibility Criteria

Concept	Capital Cost (billion $)	Annual O&M (million $)	Travel Time to Alta (minutes)	Impacts to Traffic Congestion	Roadway Improvements and Impacts on Existing Travel Patterns	Potential Residential Impacts	Expected Ridership
1	1.19 to 1.46	0.63	42	High	Low	Low	High
2	1.68 to 1.95	0.96	44	Low	Medium	High	High
3	1.36 to 1.63	0.90	42	Medium	Medium	Medium	High
4A	2.09 to 2.44	1.42	54	Low	High	High	Medium
4B	1.47 to 1.73	1.12	43	Low	High	Medium	Medium

Comparing these rankings, Concept 1 has the lowest costs, fastest travel times, lowest impacts to the existing roadway network, no impacts to existing travel patterns outside Little Cottonwood Canyon, and the least amount of residential impacts. However, Concept 1 does not relieve congestion to residential areas at the mouth of the canyon during times of peak winter demand. Relieving congestion by moving the parking and base cog rail station from the mouth of the canyon comes at a high cost due to the additional rail infrastructure and the need for roadway reconstruction. Moving the parking also introduces other impacts; the impacts to residential areas increase, and the cog rail line running in the center of travel lanes would change area travel patterns.

UDOT will use this information during the alternatives development and screening process for the Little Cottonwood Canyon EIS, which will evaluate how well the rail transit concepts described in this report would satisfy the purpose of and need for the Little Cottonwood Canyon Project. The information in this report will be used to compare the most feasible rail technology and conceptual alignments with other mobility modes (aerial transit, buses, and/or roadway improvements) that are being considered to address the purpose of the project. UDOT would prepared more-refined engineering design for the rail concept(s) if one or more are carried forward for a detailed analysis in the EIS. After that more-refined engineering design is complete, more-accurate costs and impact estimates could be provided.

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APPENDIX A

Cost Estimates

			LCC - Cog Rail Concept Concept 1 - LCC Mouth to Alta		
SCC	SCC Sub	Item #	Item Description	YoE	Subtotal YoE
10			GUIDEWAY & TRACK ELEMENTS (Route Miles)		$129,953,623
	10.05		Guideway: Earthwork		$99,113,043
	10.10		Track: Embedded		$0
	10.11		Track: Ballasted		$28,521,739
	10.12		Track: Special (switches, turnouts)		$2,318,841
20			STATIONS, STOPS, TERMINALS, INTERMODAL (number)		$4,173,913
	20.01		At-grade station, stop, shelter, mall, terminal, platform		$4,173,913
	20.06		Automobile parking multi-story structure		$0
30			SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS		$75,362,319
	30.03		Heavy Maintenance Facility		$75,362,319
40			SITEWORK & SPECIAL CONDITIONS		$15,055,652
	40.01		Demolition, Clearing, Earthwork		$2,747,826
	40.02		Site Utilities, Utility Relocation		$7,327,536
	40.03		Additional Projects / Locations		$0
	40.04		Environmental mitigation, e.g. wetlands, historic/archeologic, parks		$1,831,884
	40.05		Curb, Sidewalk, Guardrail		$1,188,406
	40.06		Pedestrian / bike access and accommodation, landscaping		$686,957
	40.07		Roadway Work		$1,273,043
	40.08		Temporary Facilities and other indirect costs during construction		$0
50			SYSTEMS		$202,453,426
	50.01		Train control and signals		$16,115,942
	50.02		Traffic signals and crossing protection		$765,217
	50.03		Traction power supply: substations		$153,977,322
	50.04		Traction power distribution: catenary system		$16,864,510
	50.05		Communications		$8,701,449
	50.06		Fare collection system and equipment		$231,884
	50.07		Central Control		$5,797,101
60			ROW, LAND, EXISTING IMPROVEMENTS		$0
	60.01		Purchase or lease of real estate		$0
	60.02		Relocation of existing households and businesses		$0
70			VEHICLES (number)		$88,888,889
	70.01		Cog Rail Vehicles		$88,888,889
80			PROFESSIONAL SERVICES (applies to Cats. 10-50)		$236,302,244
	80.01		Preliminary Engineering		$22,867,287
	80.02		Final Design		$60,979,433
	80.03		Project Management for Design and Construction		$45,734,575
	80.04		Construction Administration & Management		$48,992,020
	80.05		Professional Liability and other Non-Construction Insurance		$8,165,337
	80.06		Legal; Permits; Review Fees by other agencies, cities, etc.		$16,330,673
	80.07		Surveys, Testing, Investigation, Inspection		$16,330,673
	80.08		Start up		$16,902,247
90			UNALLOCATED CONTINGENCY		$150,438,013
100			FINANCE CHARGES		*YoE Total*
	Segment Totals (10-100)				$902,628,080

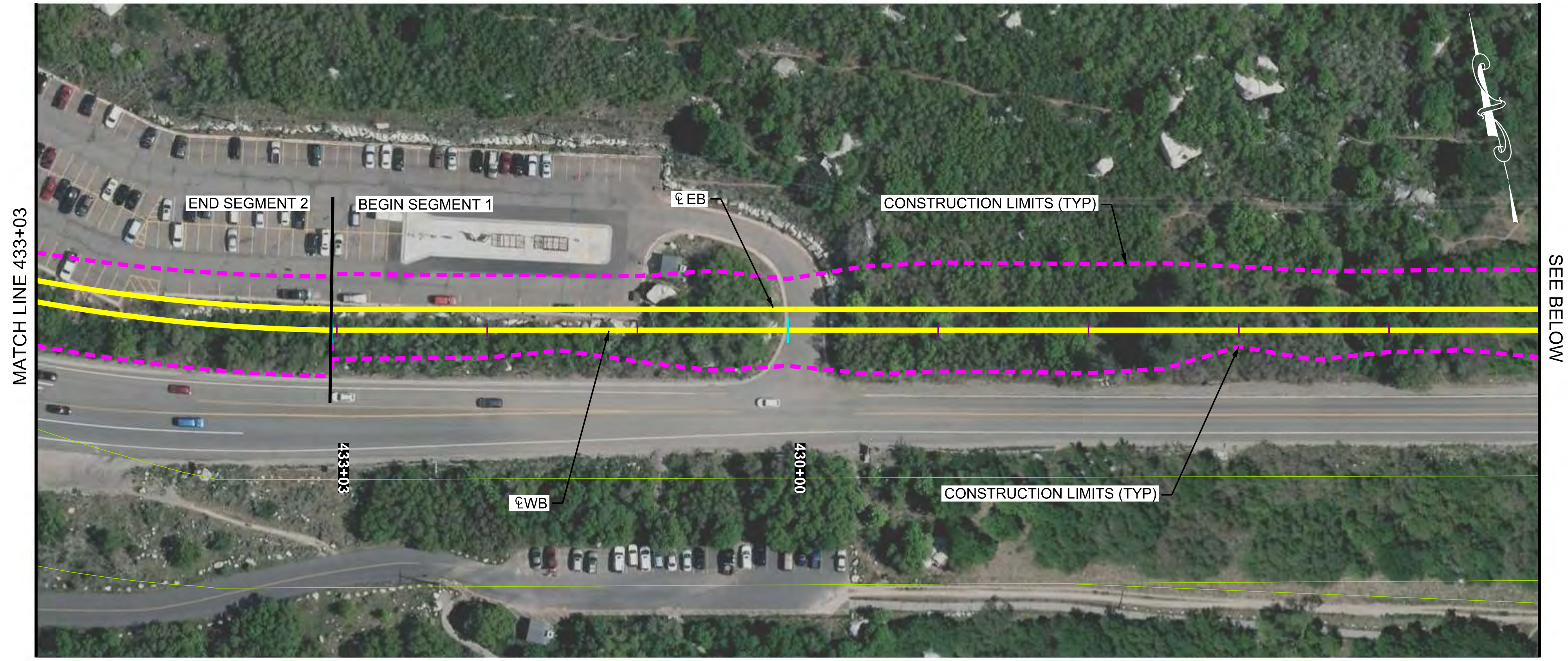
			LCC - Cog Rail Concept Concept 2 - Gravel Pit to Alta		
SCC	SCC Sub	Item #	Item Description	YoE	Subtotal YoE
10			GUIDEWAY & TRACK ELEMENTS (Route Miles)		$167,411,710
	10.05		Guideway: Earthwork		$99,576,812
	10.10		Track: Embedded		$36,414,609
	10.11		Track: Ballasted		$28,521,739
	10.12		Track: Special (switches, turnouts)		$2,898,551
20			STATIONS, STOPS, TERMINALS, INTERMODAL (number)		$4,173,913
	20.01		At-grade station, stop, shelter, mall, terminal, platform		$4,173,913
	20.06		Automobile parking multi-story structure		$0
30			SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS		$75,362,319
	30.03		Heavy Maintenance Facility		$75,362,319
40			SITEWORK & SPECIAL CONDITIONS		$233,155,100
	40.01		Demolition, Clearing, Earthwork		$8,255,072
	40.02		Site Utilities, Utility Relocation		$27,617,391
	40.03		Additional Projects / Locations		$0
	40.04		Environmental mitigation, e.g. wetlands, historic/archeologic, parks		$2,991,304
	40.05		Curb, Sidewalk, Guardrail		$10,985,863
	40.06		Pedestrian / bike access and accommodation, landscaping		$1,846,377
	40.07		Roadway Work		$77,787,729
	40.08		Temporary Facilities and other indirect costs during construction		$103,671,363
50			SYSTEMS		$319,716,586
	50.01		Train control and signals		$25,043,478
	50.02		Traffic signals and crossing protection		$3,826,087
	50.03		Traction power supply: substations		$239,937,623
	50.04		Traction power distribution: catenary system		$30,671,716
	50.05		Communications		$14,208,696
	50.06		Fare collection system and equipment		$231,884
	50.07		Central Control		$5,797,101
60			ROW, LAND, EXISTING IMPROVEMENTS		$0
	60.01		Purchase or lease of real estate		$0
	60.02		Relocation of existing households and businesses		$0
70			VEHICLES (number)		$100,000,000
	70.01		Cog Rail Vehicles		$100,000,000
80			PROFESSIONAL SERVICES (applies to Cats. 10-50)		$261,185,696
	80.01		Preliminary Engineering		$25,275,293
	80.02		Final Design		$67,400,780
	80.03		Project Management for Design and Construction		$50,550,585
	80.04		Construction Administration & Management		$54,151,051
	80.05		Professional Liability and other Non-Construction Insurance		$9,025,175
	80.06		Legal; Permits; Review Fees by other agencies, cities, etc.		$18,050,350
	80.07		Surveys, Testing, Investigation, Inspection		$18,050,350
	80.08		Start up		$18,682,112
90			UNALLOCATED CONTINGENCY		$232,201,065
100			FINANCE CHARGES		*YoE Total*
	Segment Totals (10-100)				$1,393,206,389

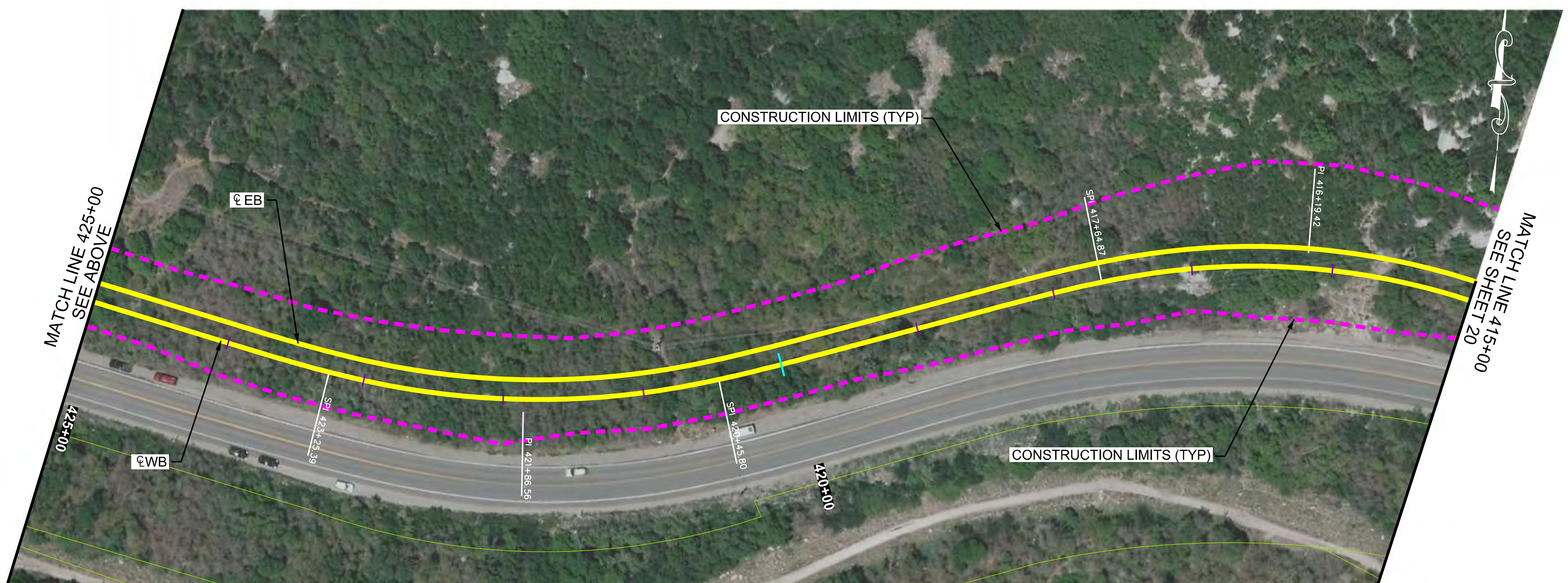
			LCC - Cog Rail Concept Concept 3 - 9400/Highland to Alta		
SCC	SCC Sub	Item #	Item Description	YoE	Subtotal YoE
10			**GUIDEWAY & TRACK ELEMENTS (Route Miles)**		**$157,431,884**
	10.05		Guideway: Earthwork		**$99,576,812**
	10.10		Track: Embedded		**$26,434,783**
	10.11		Track: Ballasted		**$28,521,739**
	10.12		Track: Special (switches, turnouts)		**$2,898,551**
20			**STATIONS, STOPS, TERMINALS, INTERMODAL (number)**		**$4,173,913**
	20.01		At-grade station, stop, shelter, mall, terminal, platform		**$4,173,913**
	20.06		Automobile parking multi-story structure		**$0**
30			**SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS**		**$75,362,319**
	30.03		Heavy Maintenance Facility		**$75,362,319**
40			**SITEWORK & SPECIAL CONDITIONS**		**$40,879,305**
	40.01		Demolition, Clearing, Earthwork		**$6,602,899**
	40.02		Site Utilities, Utility Relocation		**$15,849,275**
	40.03		Additional Projects / Locations		**$0**
	40.04		Environmental mitigation, e.g. wetlands, historic/archeologic, parks		**$2,643,478**
	40.05		Curb, Sidewalk, Guardrail		**$1,985,971**
	40.06		Pedestrian / bike access and accommodation, landscaping		**$1,701,449**
	40.07		Roadway Work		**$12,096,232**
	40.08		Temporary Facilities and other indirect costs during construction		**$0**
50			**SYSTEMS**		**$280,195,525**
	50.01		Train control and signals		**$25,043,478**
	50.02		Traffic signals and crossing protection		**$3,849,275**
	50.03		Traction power supply: substations		**$205,939,757**
	50.04		Traction power distribution: catenary system		**$26,777,507**
	50.05		Communications		**$12,556,522**
	50.06		Fare collection system and equipment		**$231,884**
	50.07		Central Control		**$5,797,101**
60			**ROW, LAND, EXISTING IMPROVEMENTS**		**$0**
	60.01		Purchase or lease of real estate		**$0**
	60.02		Relocation of existing households and businesses		**$0**
70			**VEHICLES (number)**		**$100,000,000**
	70.01		Cog Rail Vehicles		**$100,000,000**
80			**PROFESSIONAL SERVICES (applies to Cats. 10-50)**		**$236,302,244**
	80.01		Preliminary Engineering		**$22,867,287**
	80.02		Final Design		**$60,979,433**
	80.03		Project Management for Design and Construction		**$45,734,575**
	80.04		Construction Administration & Management		**$48,992,020**
	80.05		Professional Liability and other Non-Construction Insurance		**$8,165,337**
	80.06		Legal; Permits; Review Fees by other agencies, cities, etc.		**$16,330,673**
	80.07		Surveys, Testing, Investigation, Inspection		**$16,330,673**
	80.08		Start up		**$16,902,247**
90			**UNALLOCATED CONTINGENCY**		**$178,869,038**
100			**FINANCE CHARGES**		***YoE Total***
	Segment Totals (10-100)				**$1,073,214,227**

			LCC - Cog Rail Concept		
			Concept 4B - Sandy Trax to Alta		
SCC	SCC Sub	Item #	Item Description	YoE	Subtotal YoE
10			GUIDEWAY & TRACK ELEMENTS (Route Miles)		$180,620,290
	10.05		Guideway: Earthwork		$100,040,580
	10.10		Track: Embedded		$48,000,000
	10.11		Track: Ballasted		$28,521,739
	10.12		Track: Special (switches, turnouts)		$4,057,971
20			STATIONS, STOPS, TERMINALS, INTERMODAL (number)		$4,173,913
	20.01		At-grade station, stop, shelter, mall, terminal, platform		$4,173,913
	20.06		Automobile parking multi-story structure		$0
30			SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS		$25,120,773
	30.03		Heavy Maintenance Facility		$25,120,773
40			SITEWORK & SPECIAL CONDITIONS		$67,678,145
	40.01		Demolition, Clearing, Earthwork		$9,797,101
	40.02		Site Utilities, Utility Relocation		$22,910,145
	40.03		Additional Projects / Locations		$0
	40.04		Environmental mitigation, e.g. wetlands, historic/archeologic, parks		$3,315,942
	40.05		Curb, Sidewalk, Guardrail		$3,670,029
	40.06		Pedestrian / bike access and accommodation, landscaping		$2,542,029
	40.07		Roadway Work		$25,442,899
	40.08		Temporary Facilities and other indirect costs during construction		$0
50			SYSTEMS		$369,873,310
	50.01		Train control and signals		$32,869,565
	50.02		Traffic signals and crossing protection		$6,168,116
	50.03		Traction power supply: substations		$273,925,194
	50.04		Traction power distribution: catenary system		$35,130,725
	50.05		Communications		$15,750,725
	50.06		Fare collection system and equipment		$231,884
	50.07		Central Control		$5,797,101
60			ROW, LAND, EXISTING IMPROVEMENTS		$0
	60.01		Purchase or lease of real estate		$0
	60.02		Relocation of existing households and businesses		$0
70			VEHICLES (number)		$133,333,333
	70.01		Cog Rail Vehicles		$133,333,333
80			PROFESSIONAL SERVICES (applies to Cats. 10-50)		$236,302,244
	80.01		Preliminary Engineering		$22,867,287
	80.02		Final Design		$60,979,433
	80.03		Project Management for Design and Construction		$45,734,575
	80.04		Construction Administration & Management		$48,992,020
	80.05		Professional Liability and other Non-Construction Insurance		$8,165,337
	80.06		Legal; Permits; Review Fees by other agencies, cities, etc.		$16,330,673
	80.07		Surveys, Testing, Investigation, Inspection		$16,330,673
	80.08		Start up		$16,902,247
90			UNALLOCATED CONTINGENCY		$203,420,402
100			FINANCE CHARGES		*YoE Total*
	Segment Totals (10-100)				$1,220,522,410

APPENDIX B1

Preliminary Design Plans for Segment 1 – Little Cottonwood





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PIN 16092

PROJECT NUMBER XXXX

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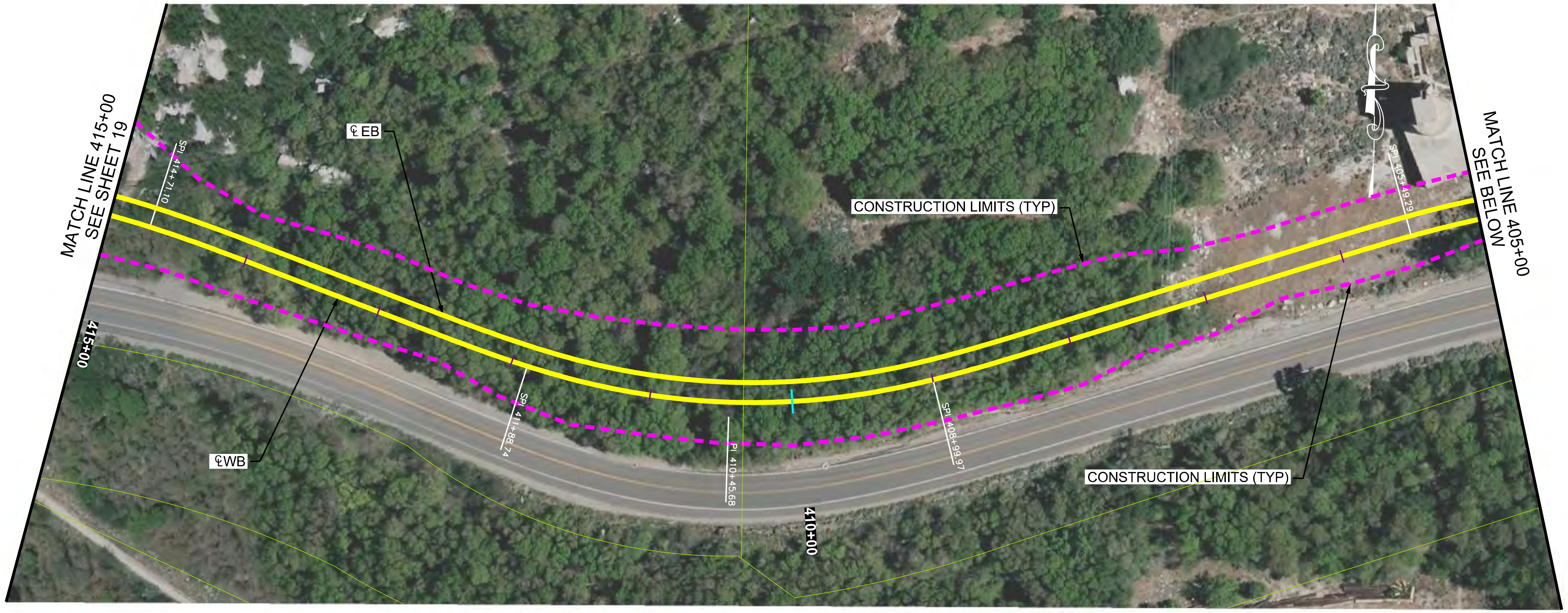

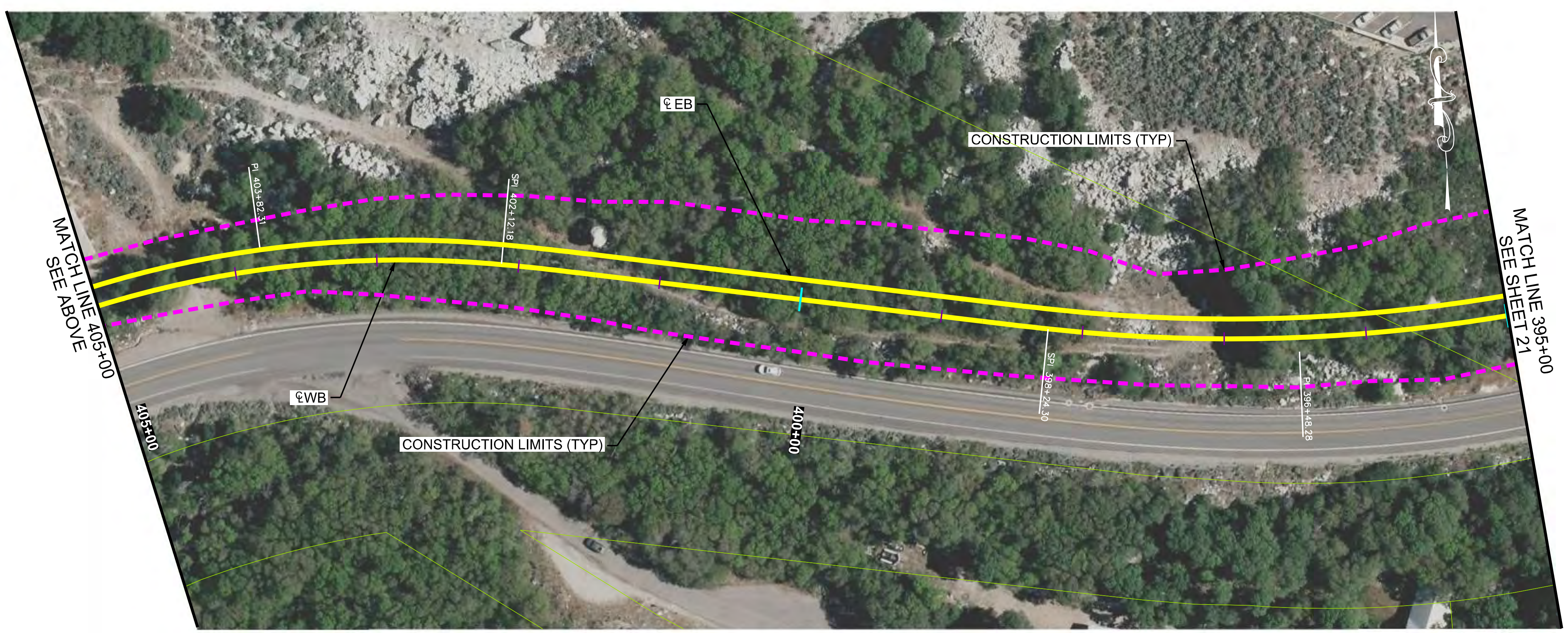

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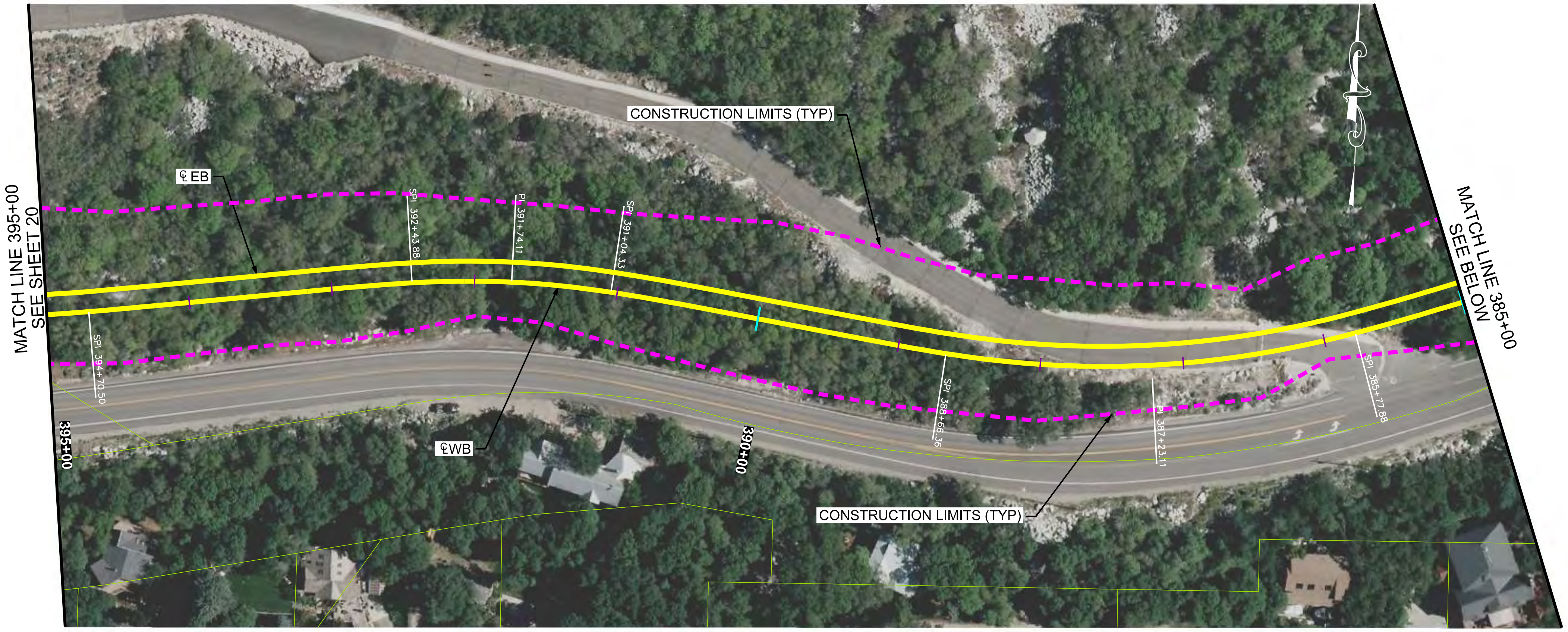

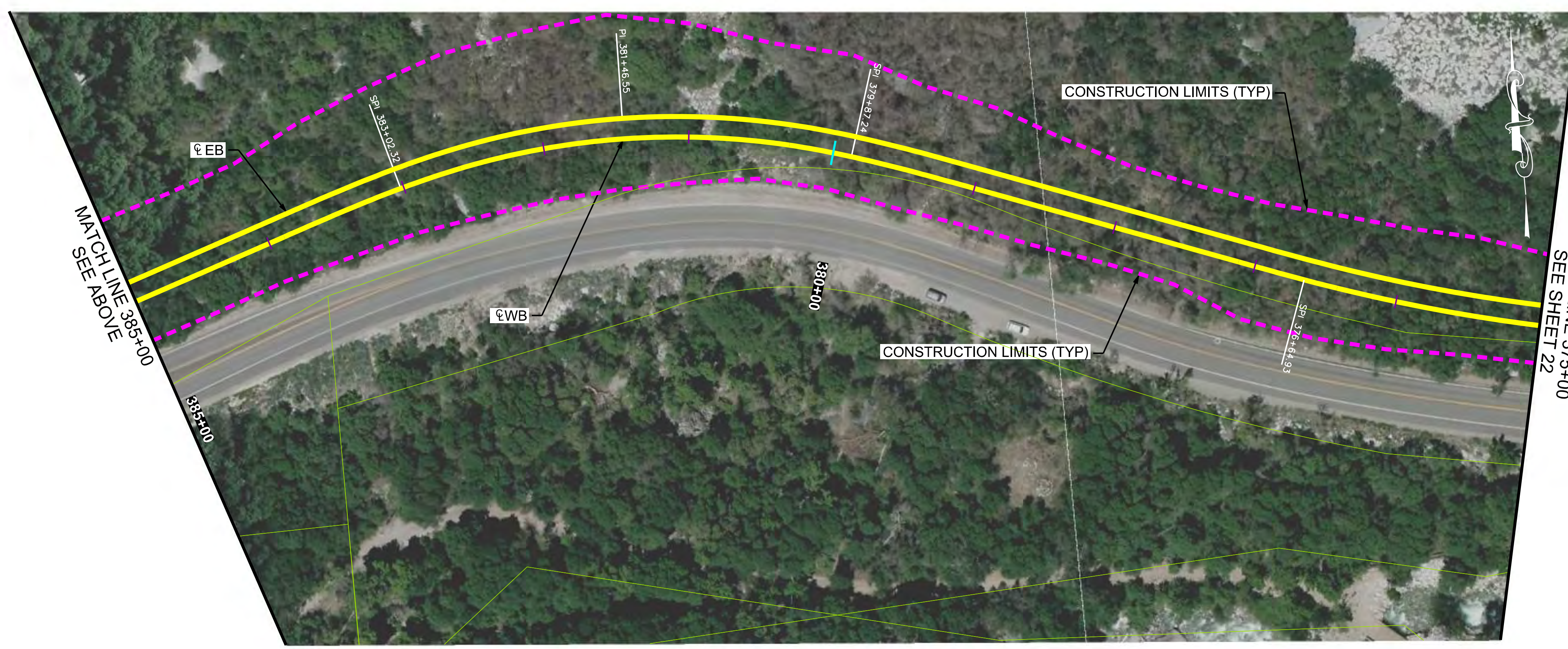

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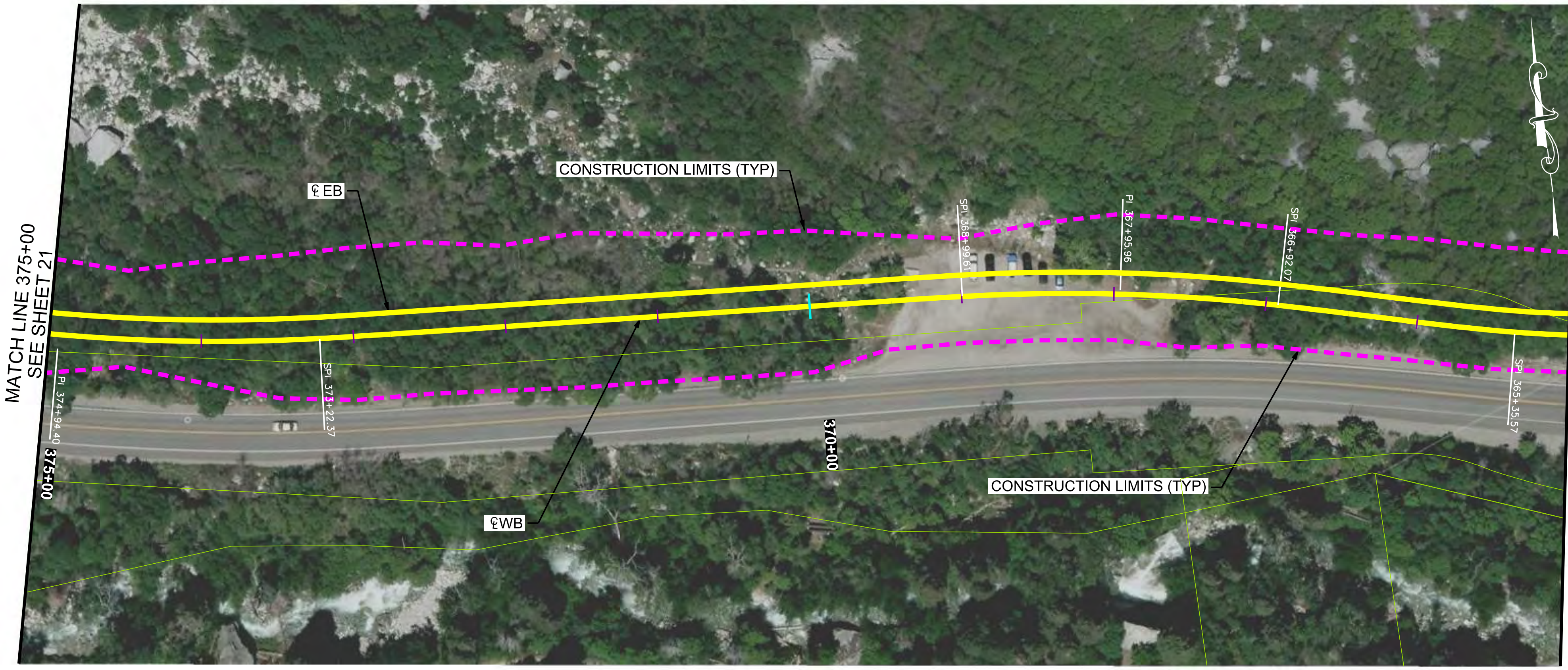

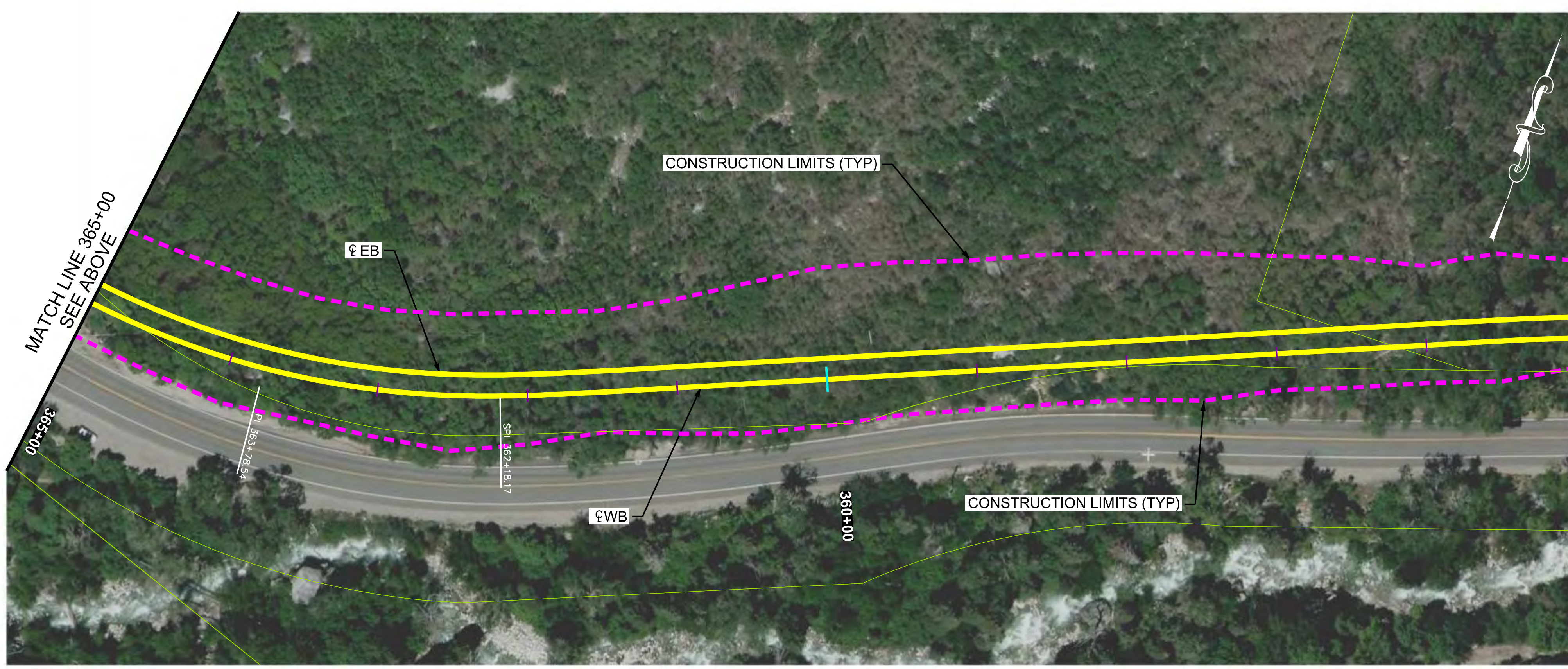

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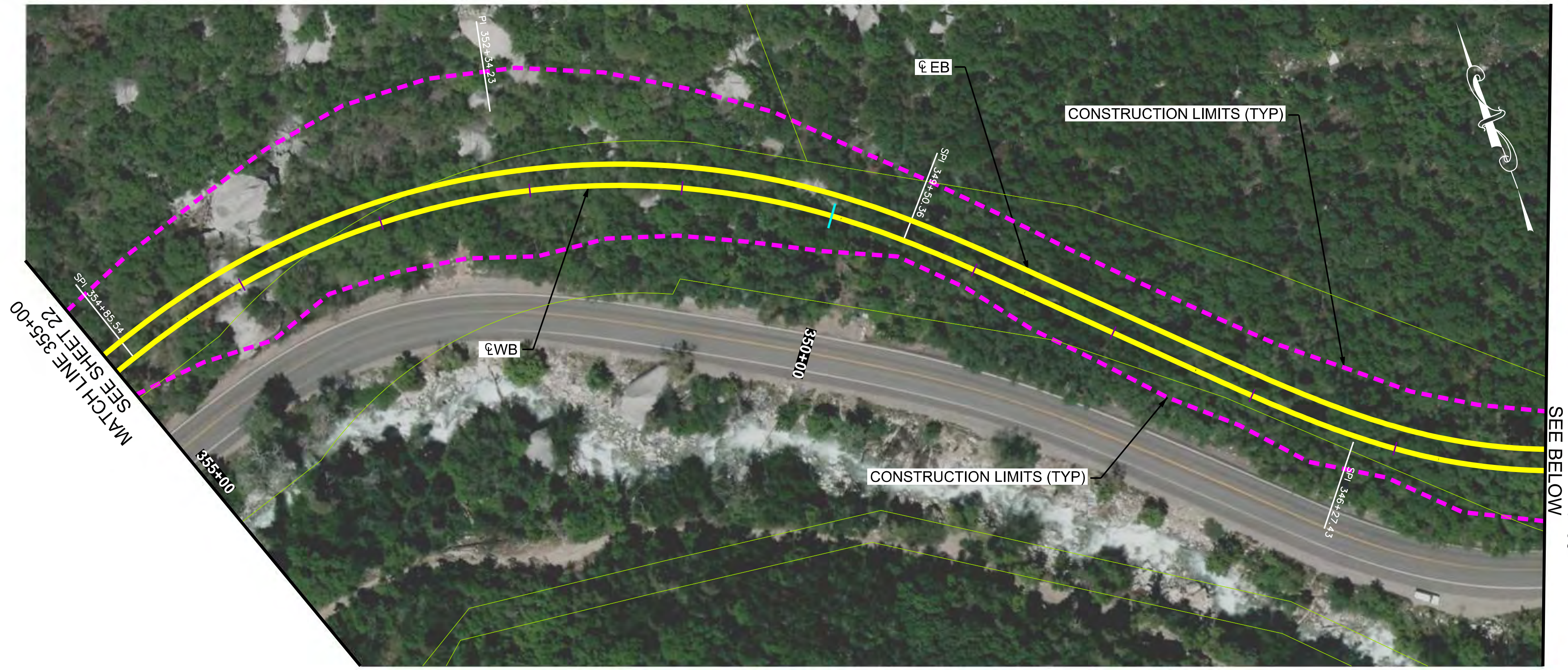

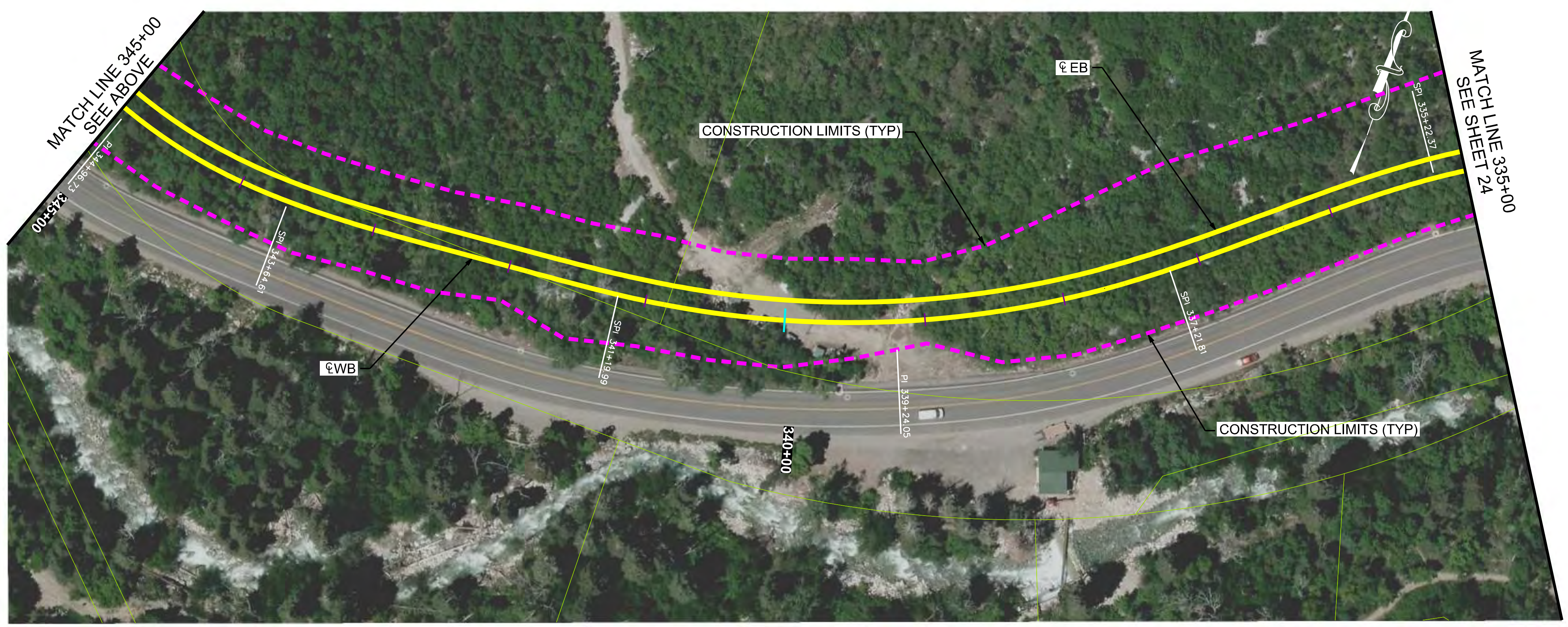

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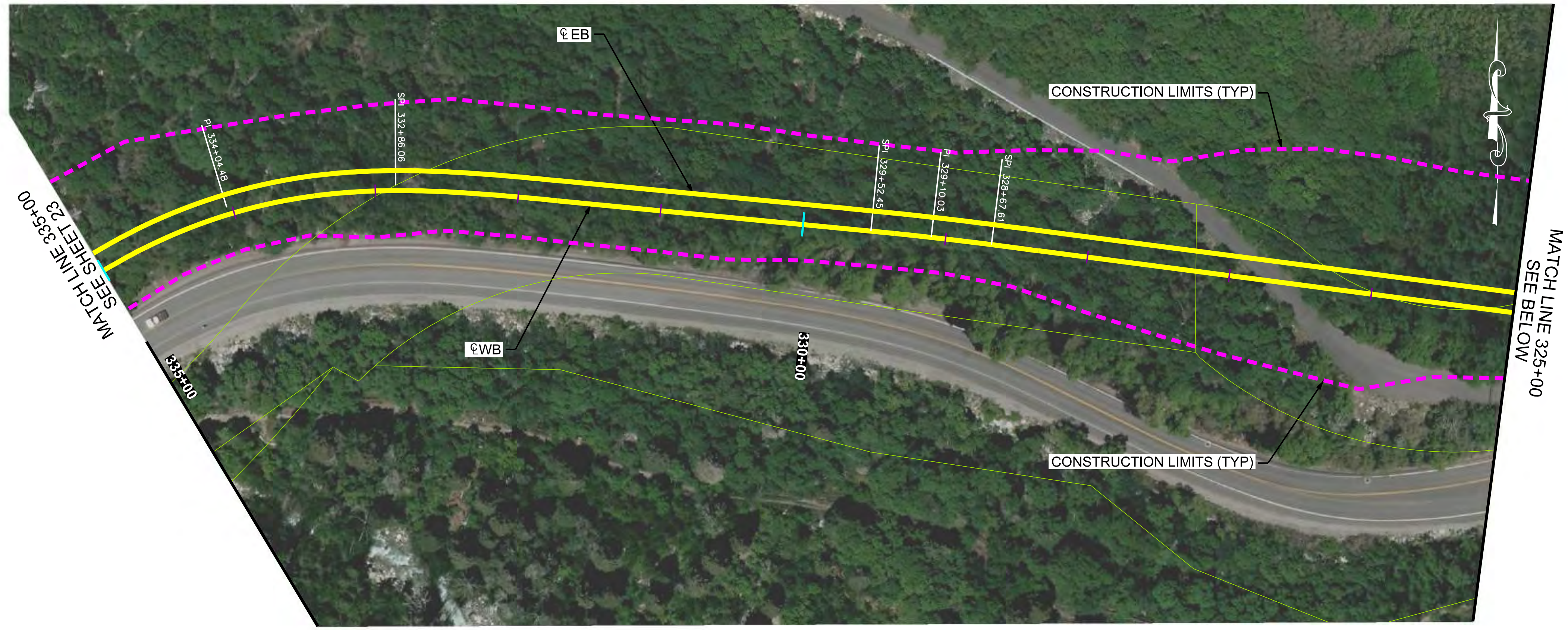

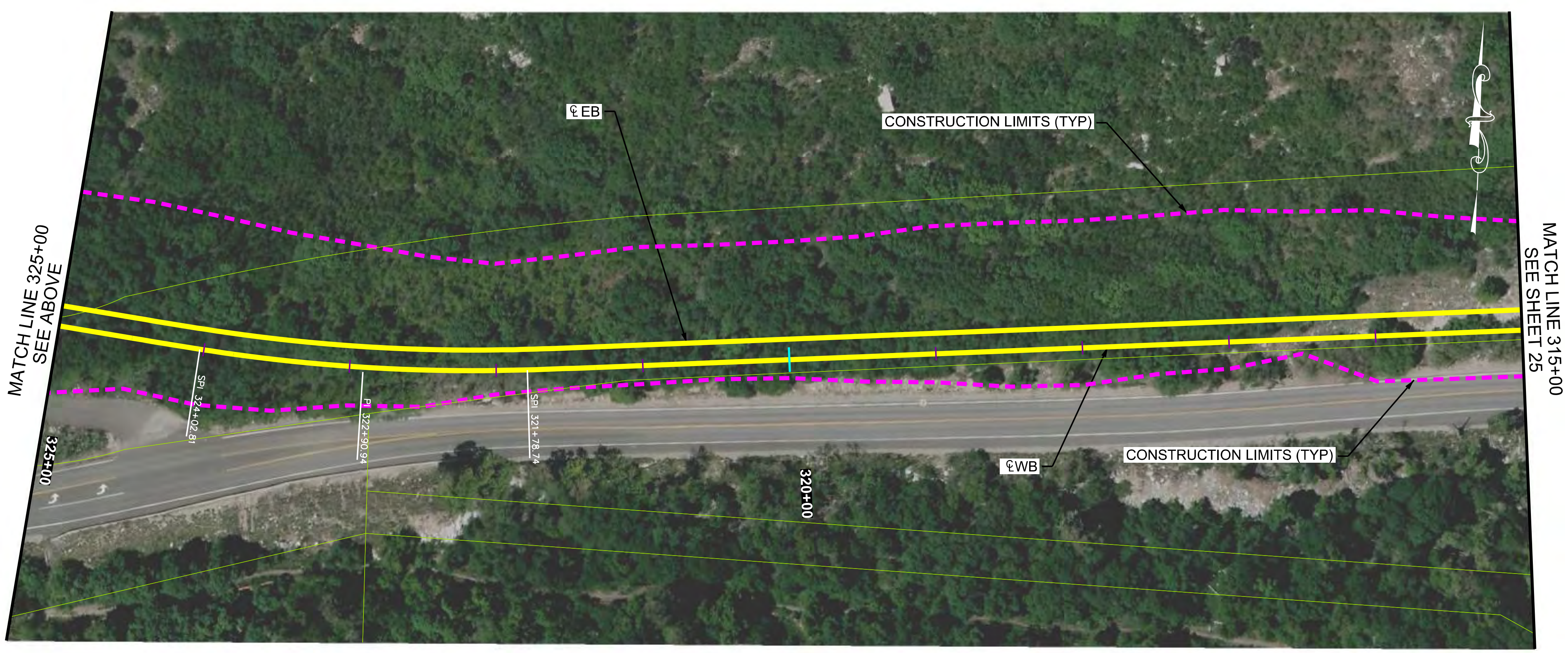

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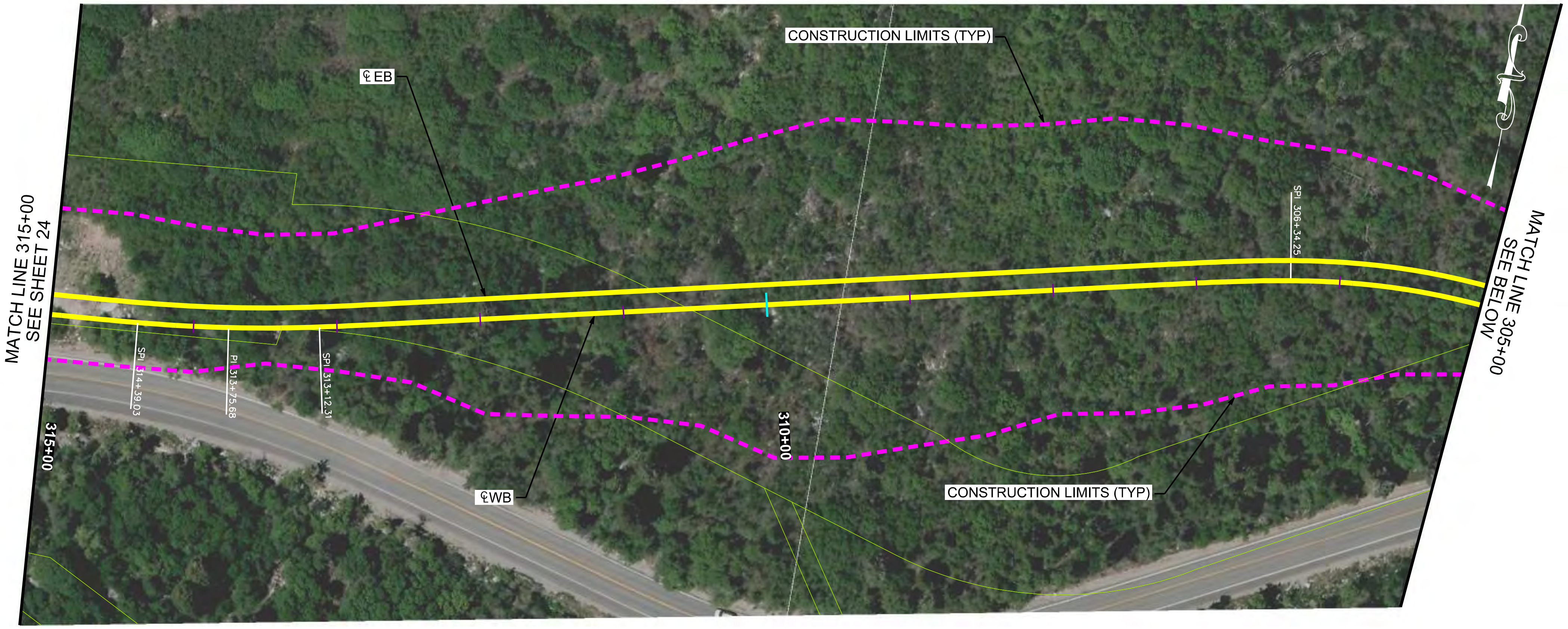

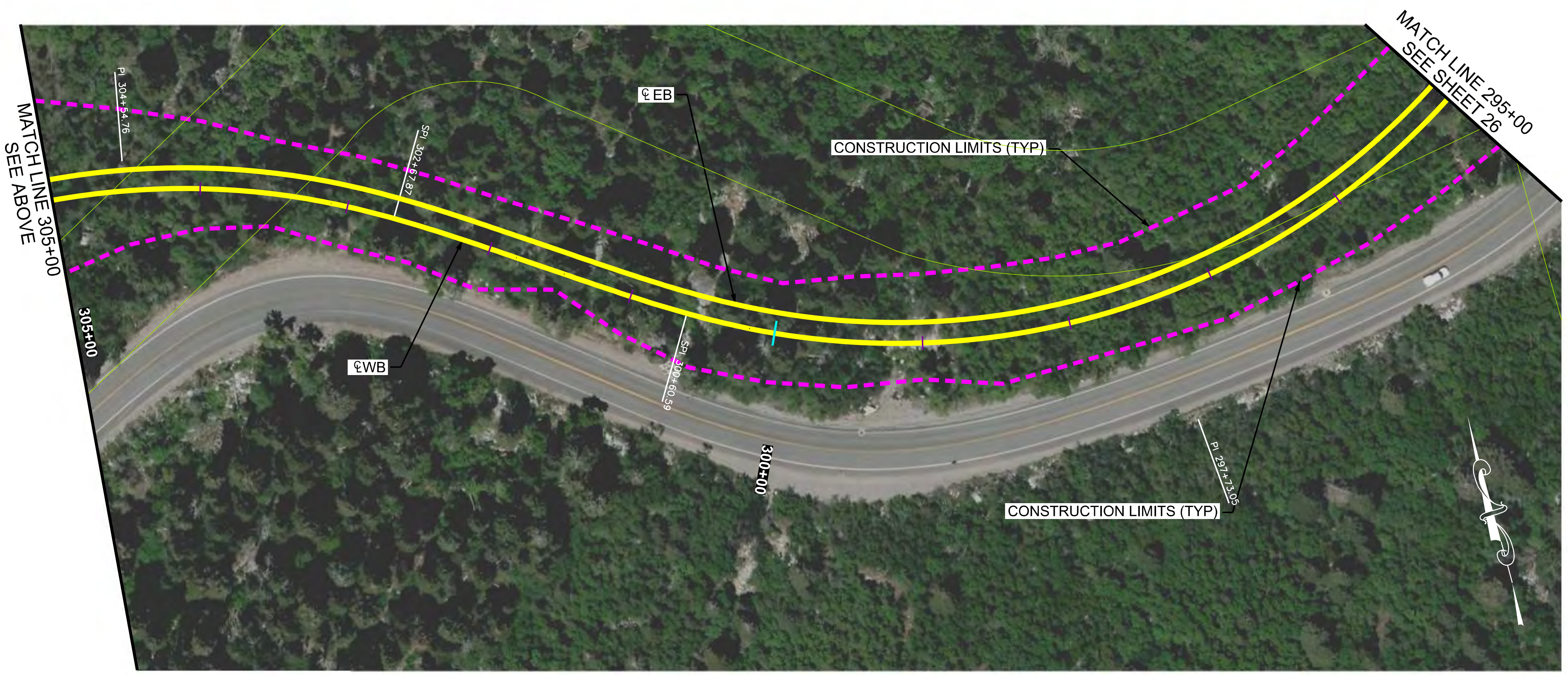

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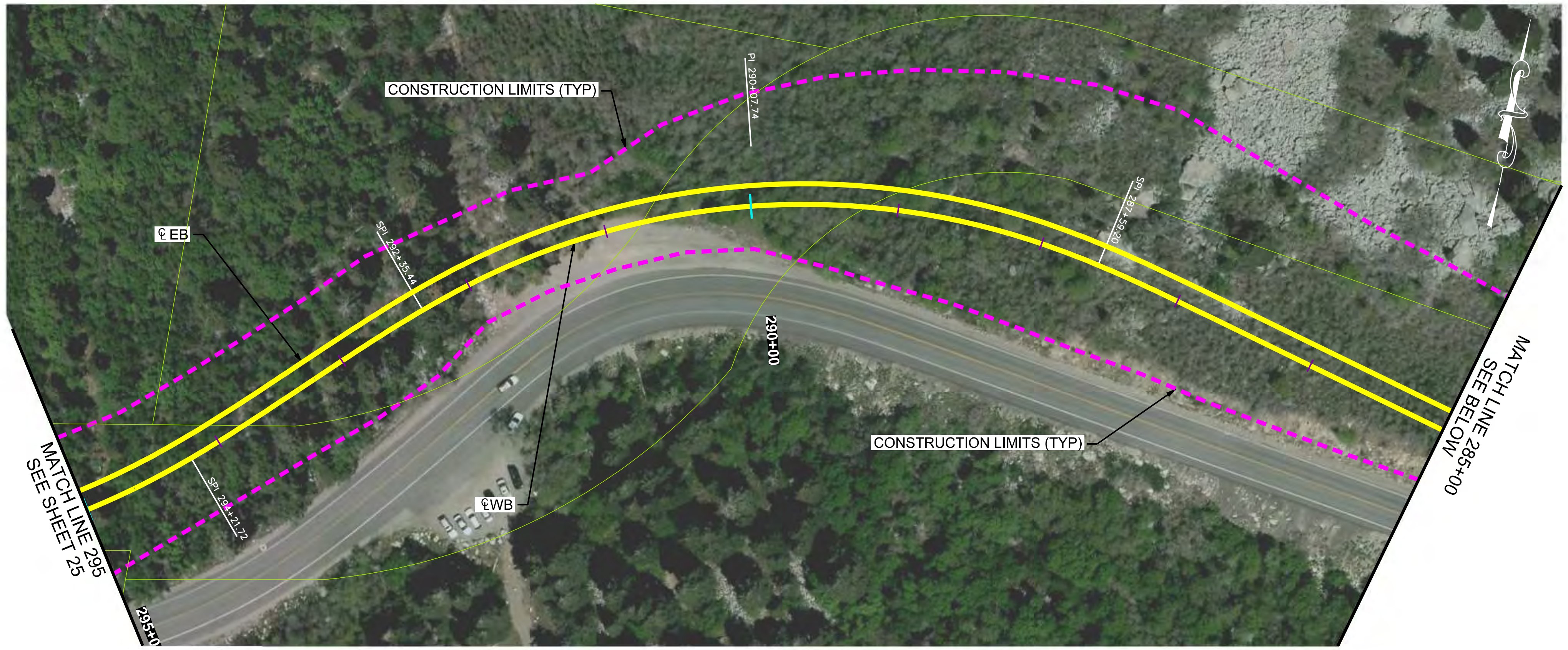

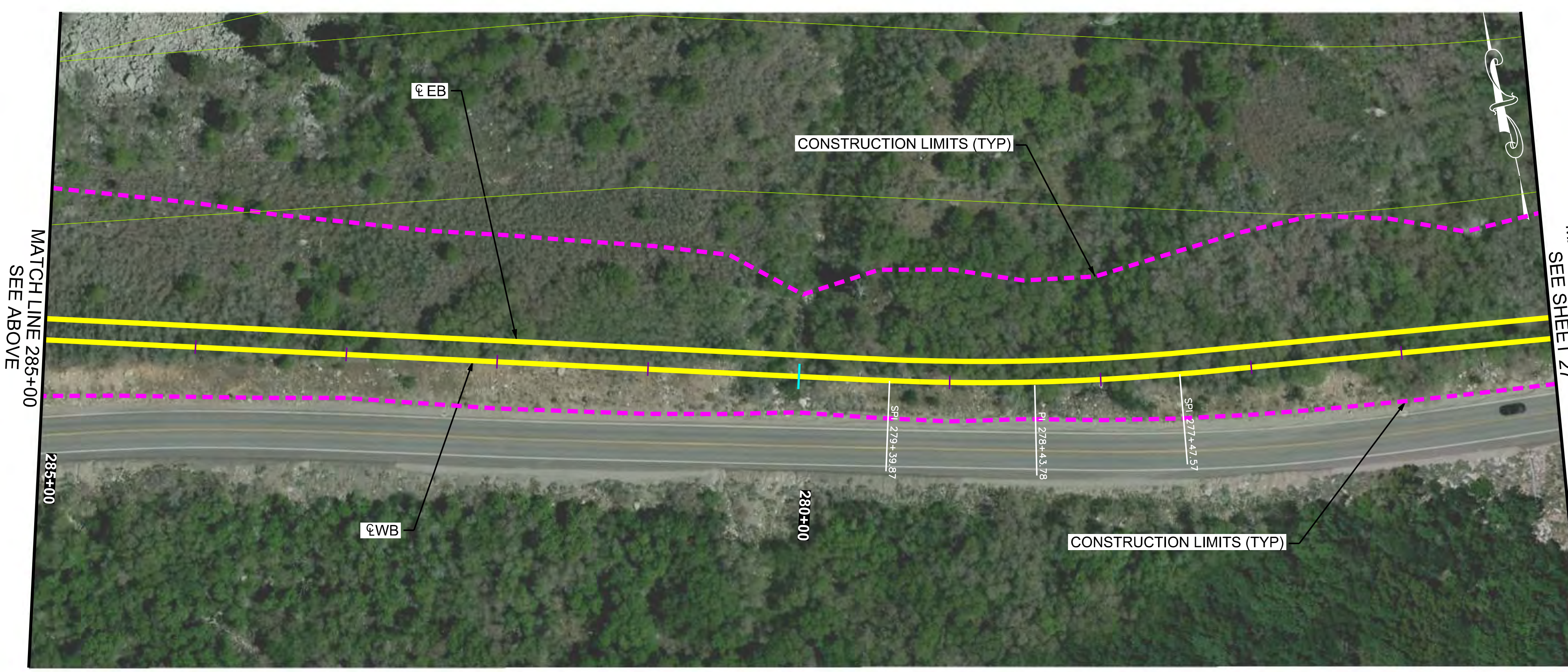

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COG RAIL SEGMENT 1

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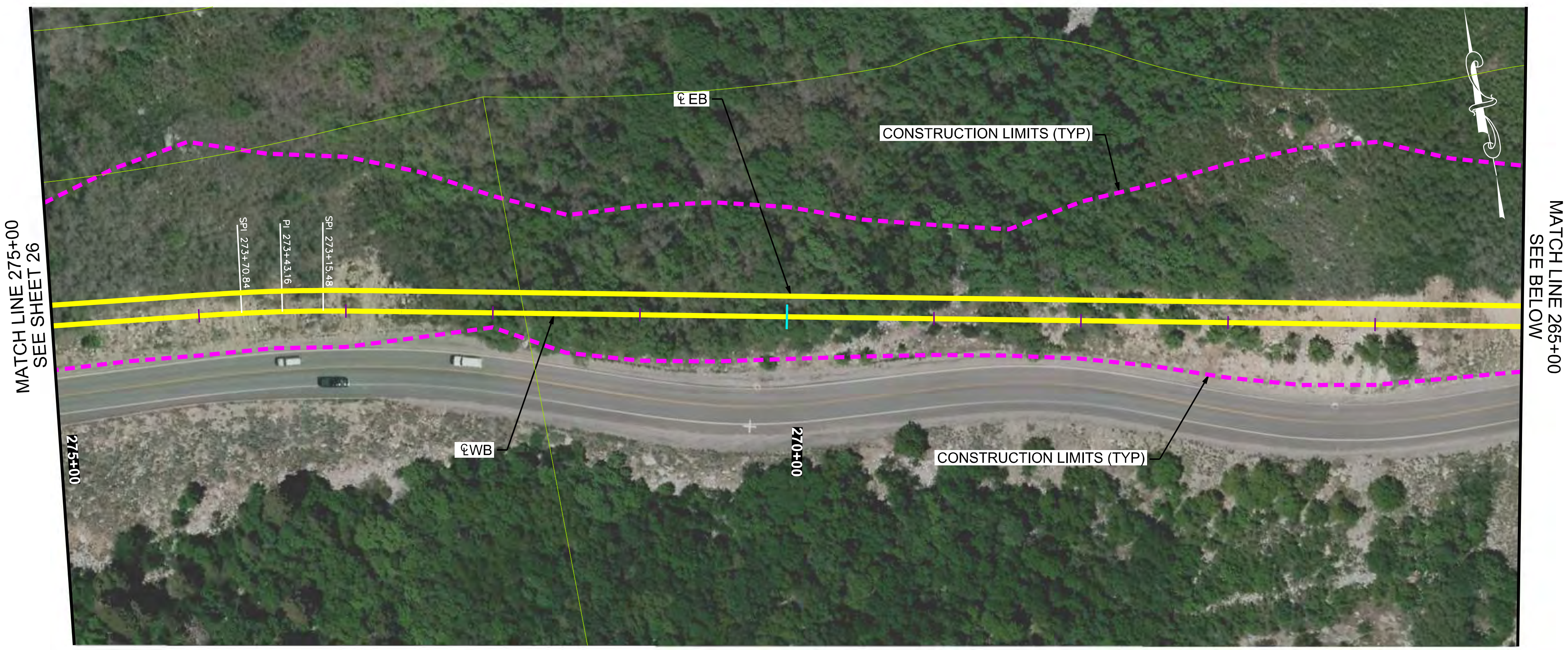

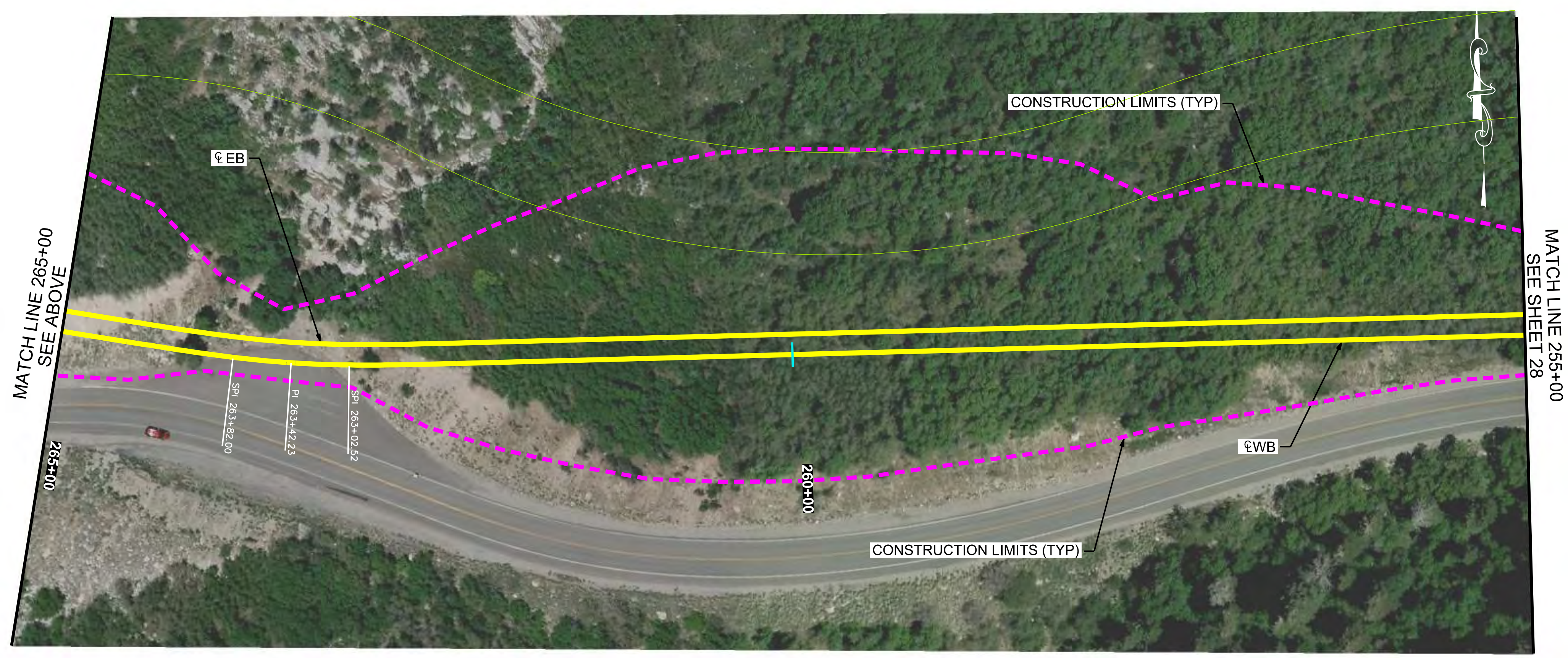

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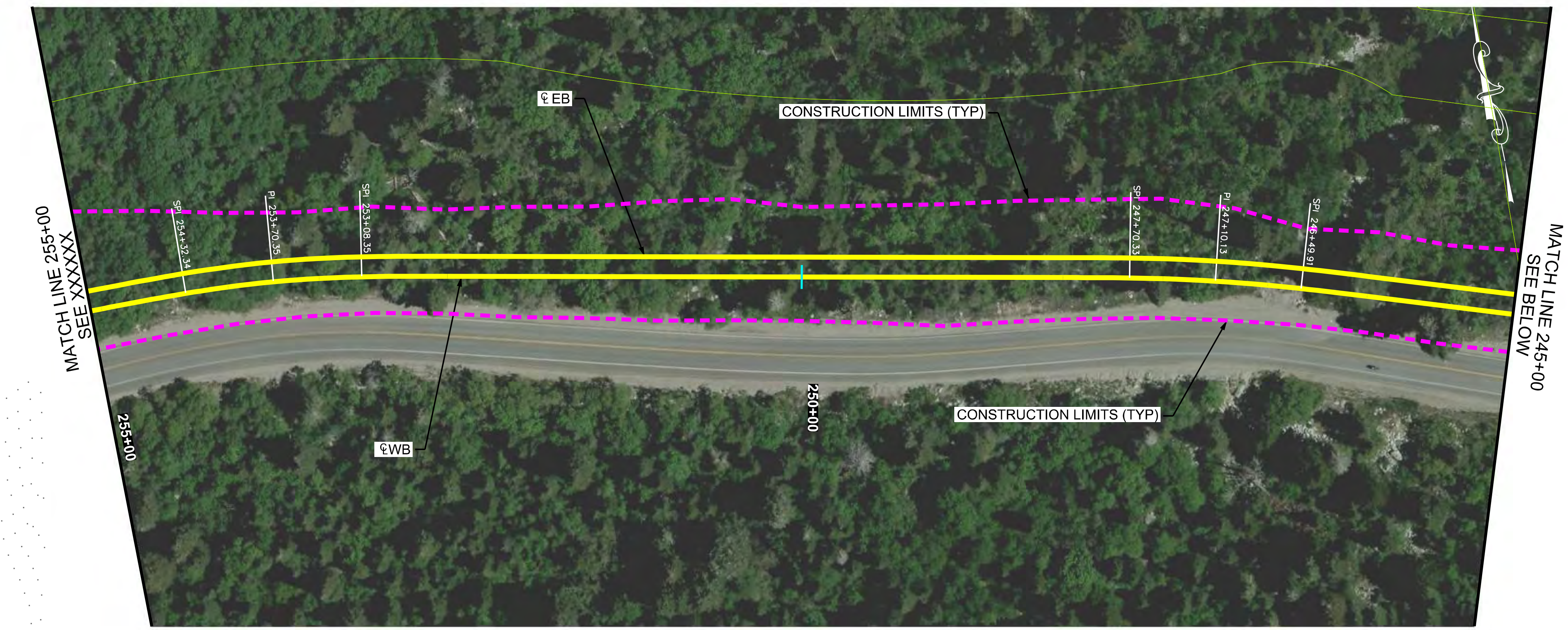

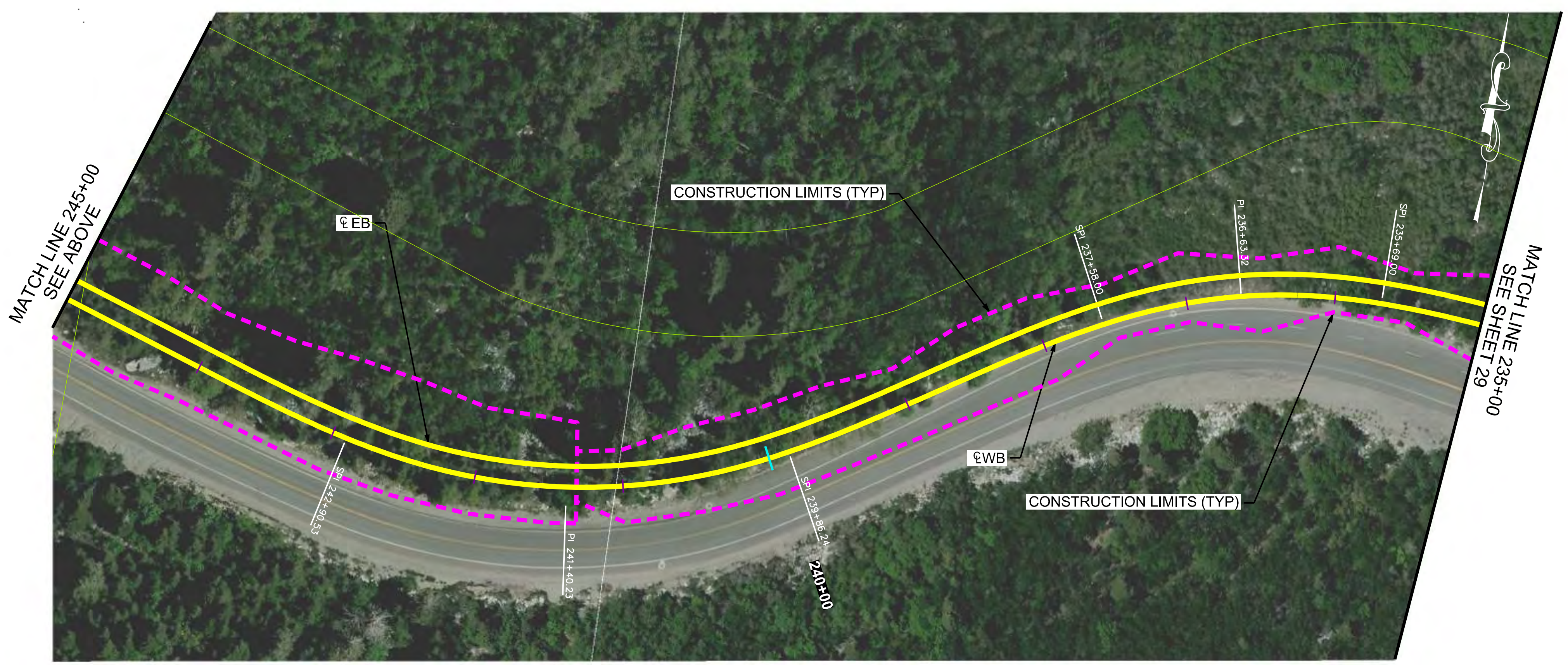

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COG RAIL SEGMENT 1

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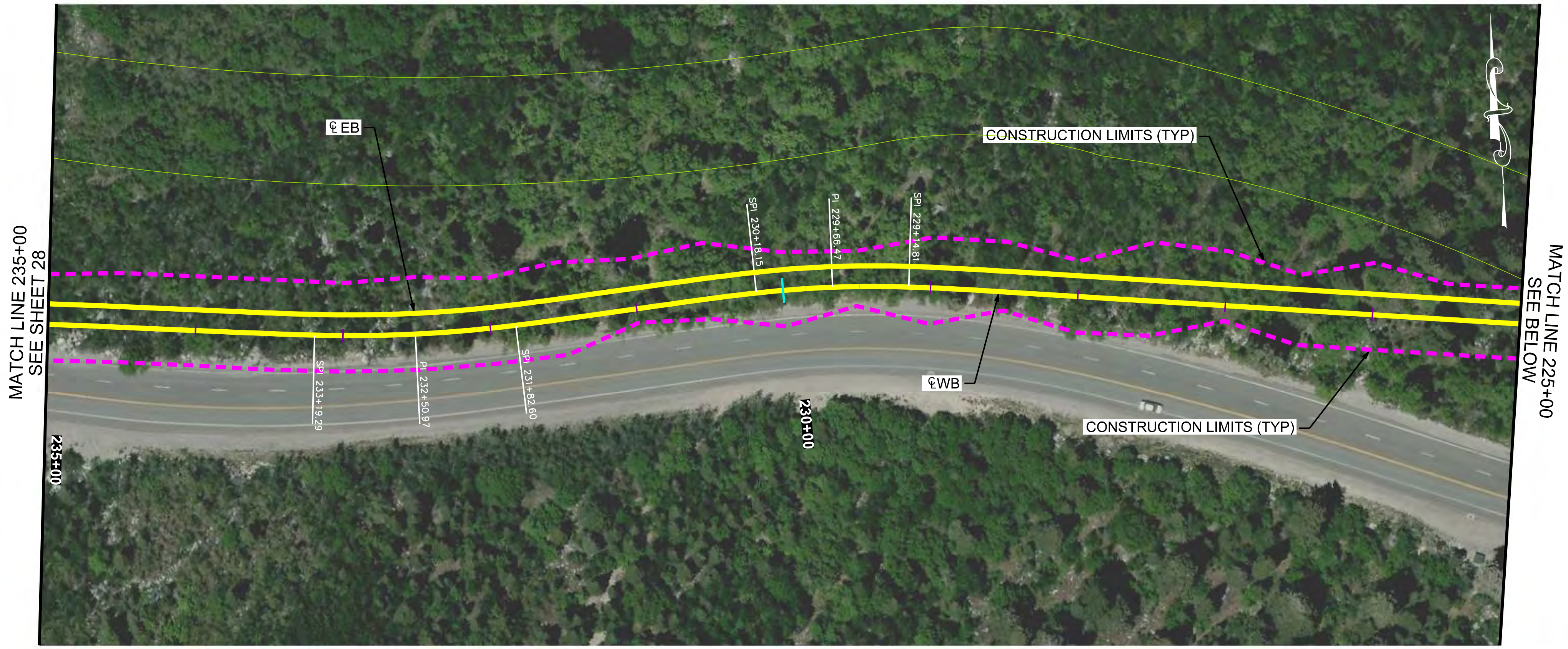

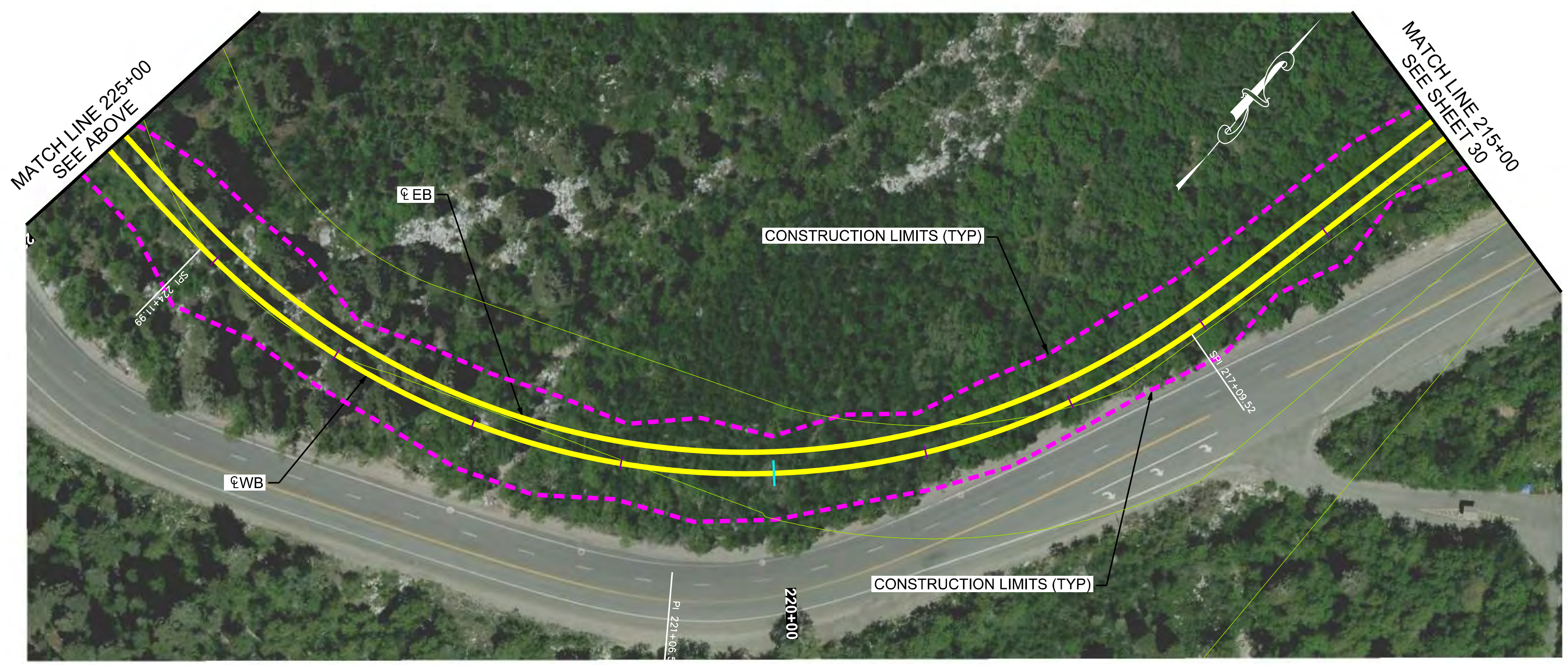

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COG RAIL SEGMENT 1

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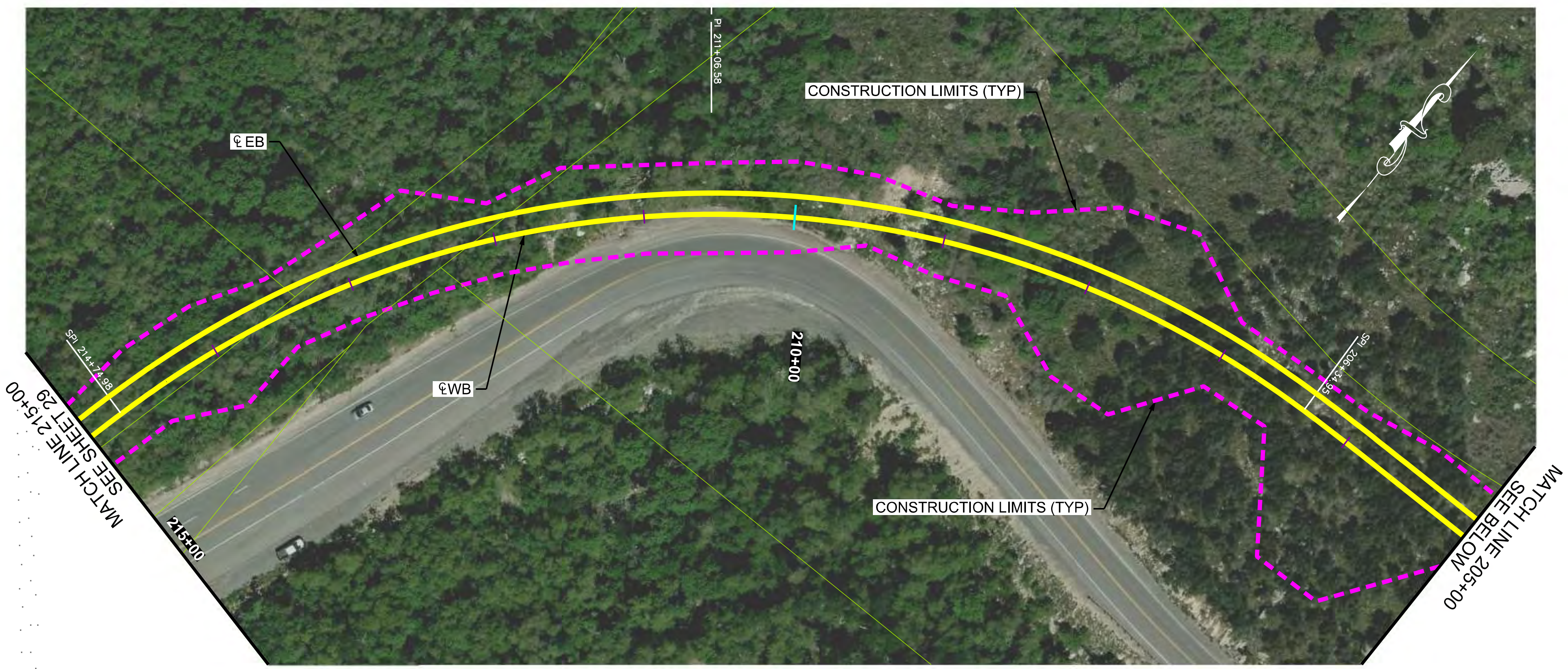

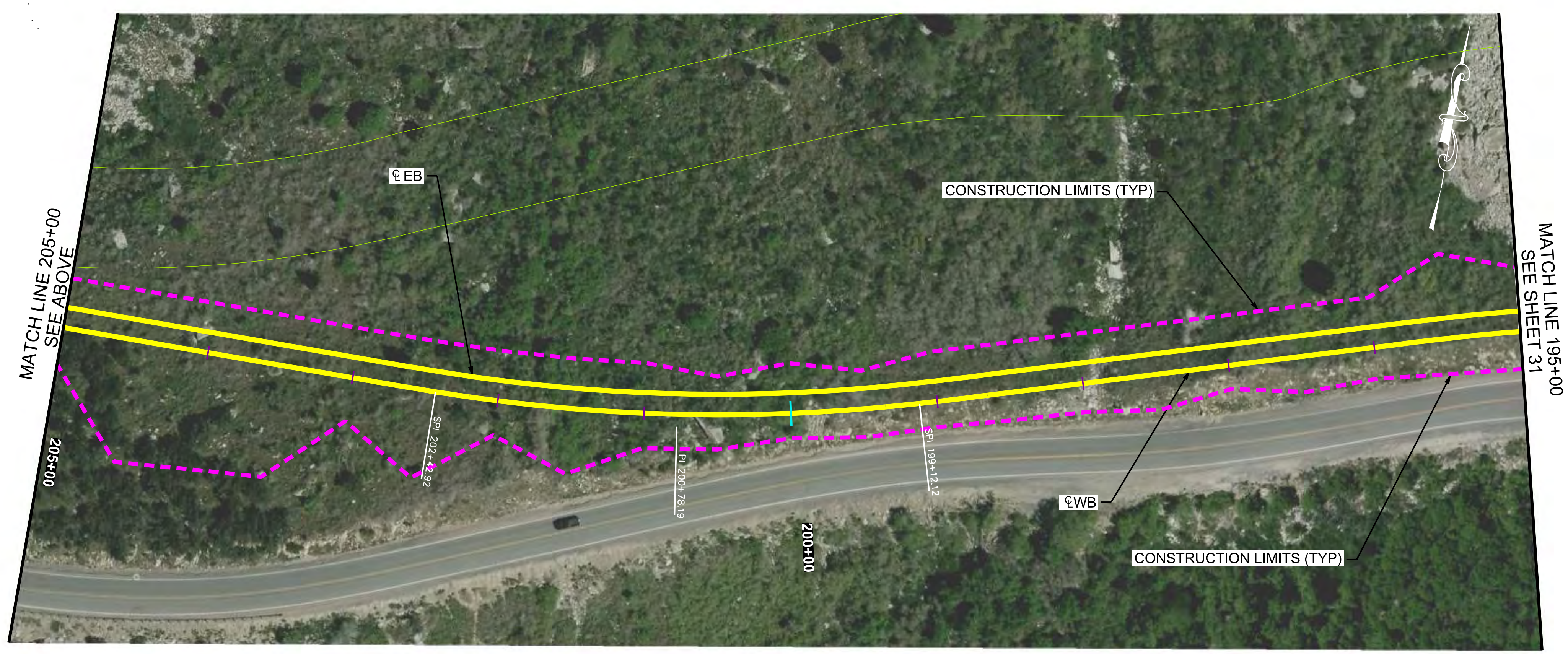

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PROJECT: LITTLE COTTONWOOD CANYON EIS

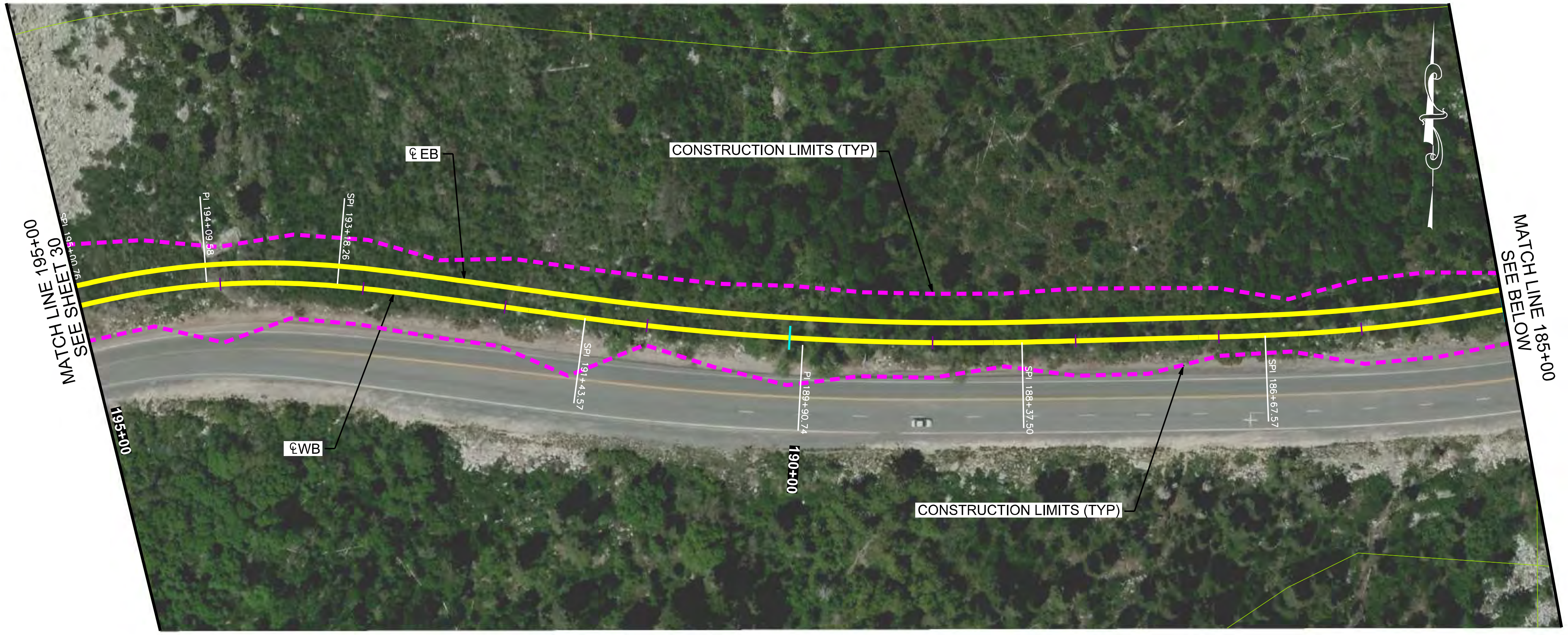
COG RAIL SEGMENT 1

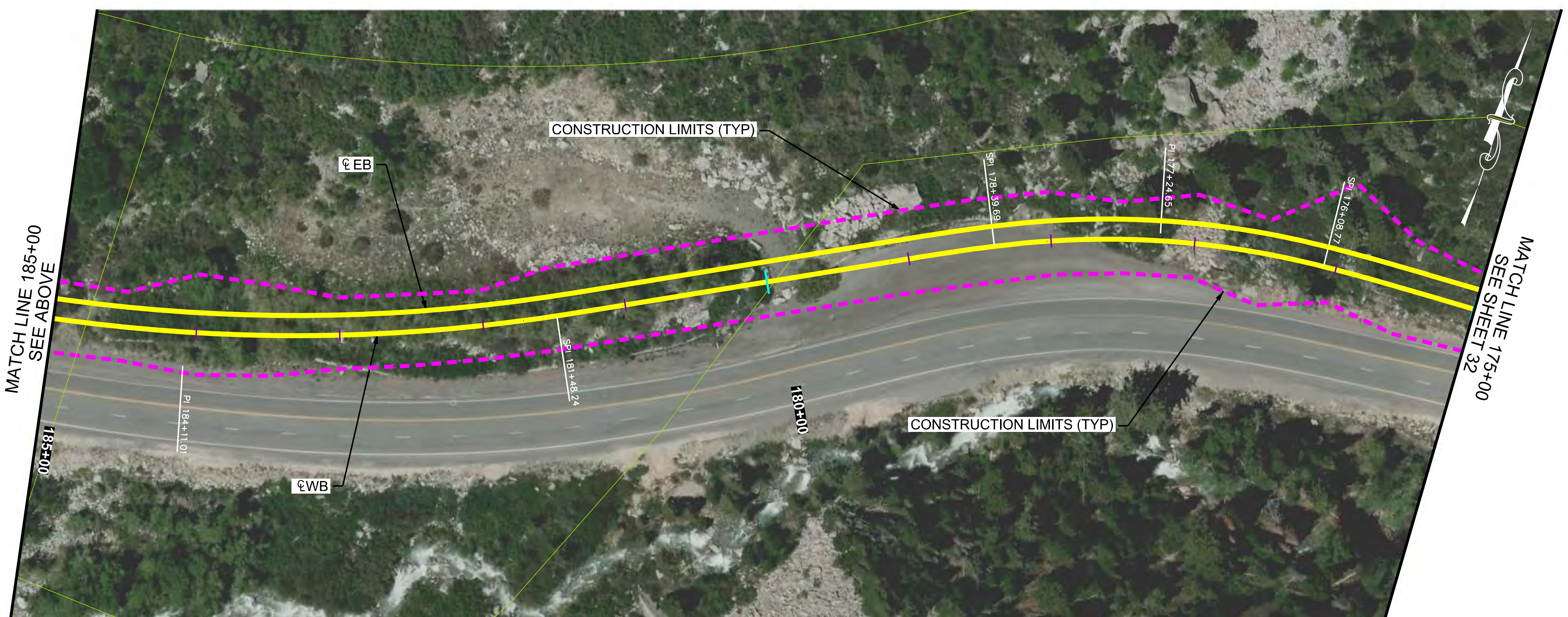
PROJECT NUMBER: XXXX

PIN: 16092

SHEET NO. 30

2/17/2020





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PROJECT: LITTLE COTTONWOOD CANYON EIS

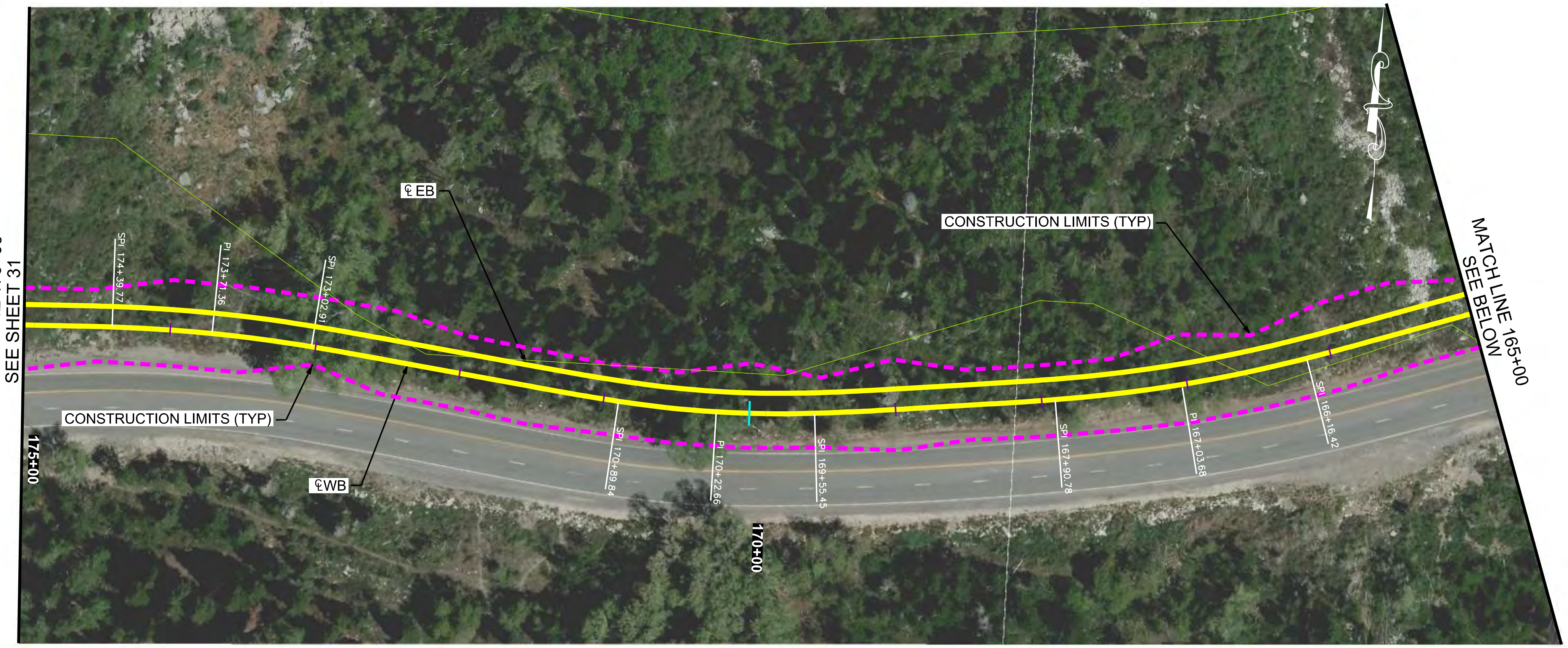
COG RAIL SEGMENT 1

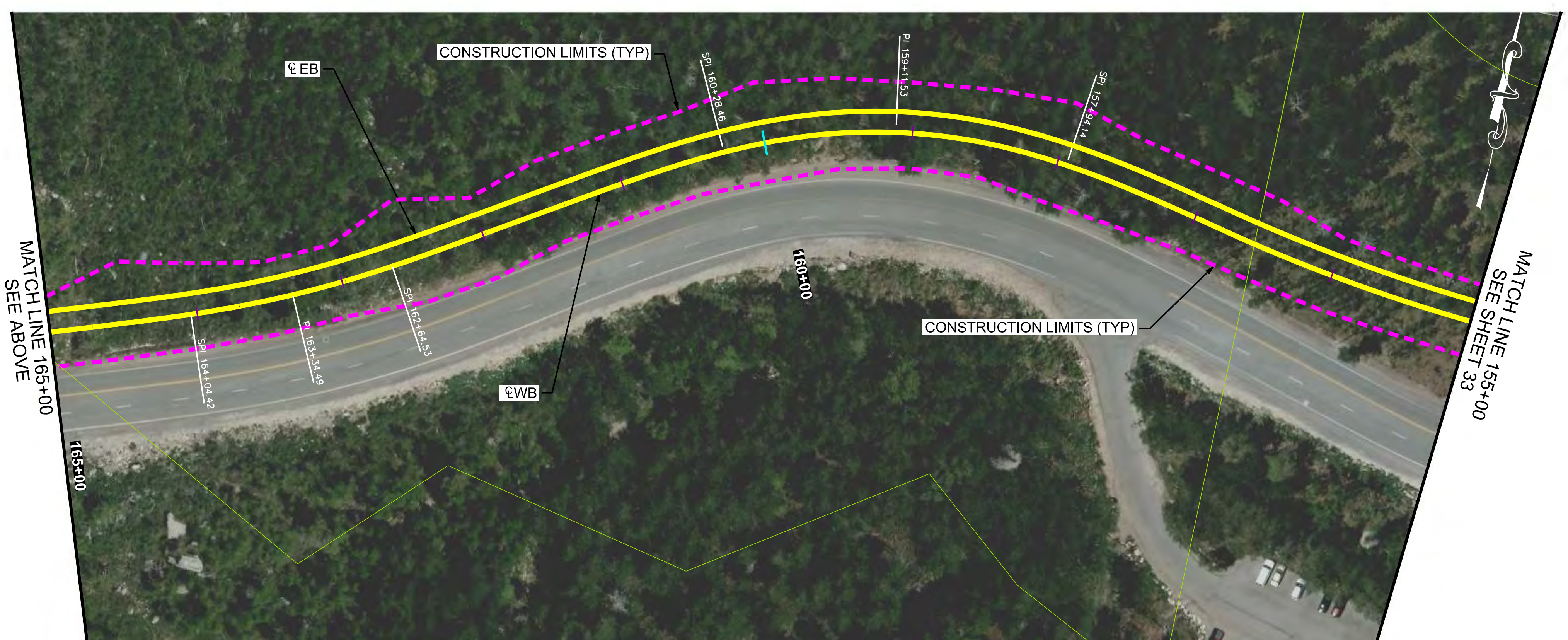
PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 31

2/17/2020





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PROJECT: LITTLE COTTONWOOD CANYON EIS

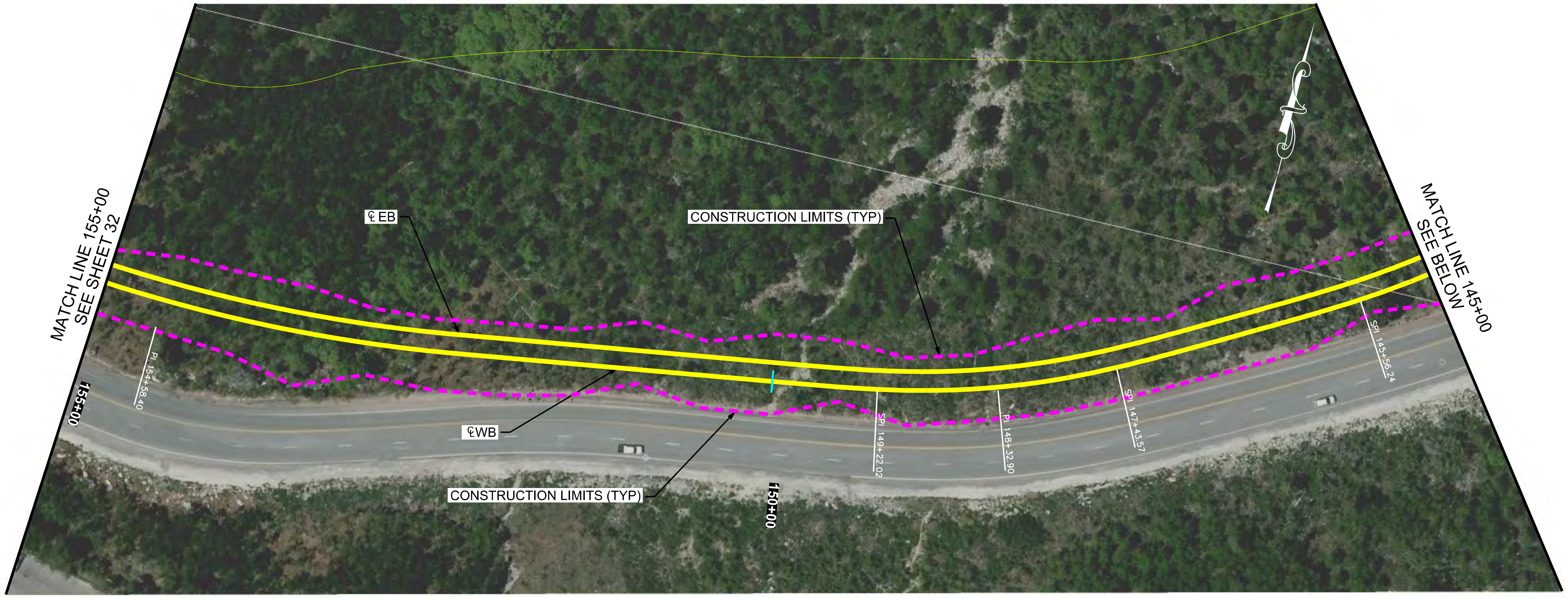
COG RAIL SEGMENT 1

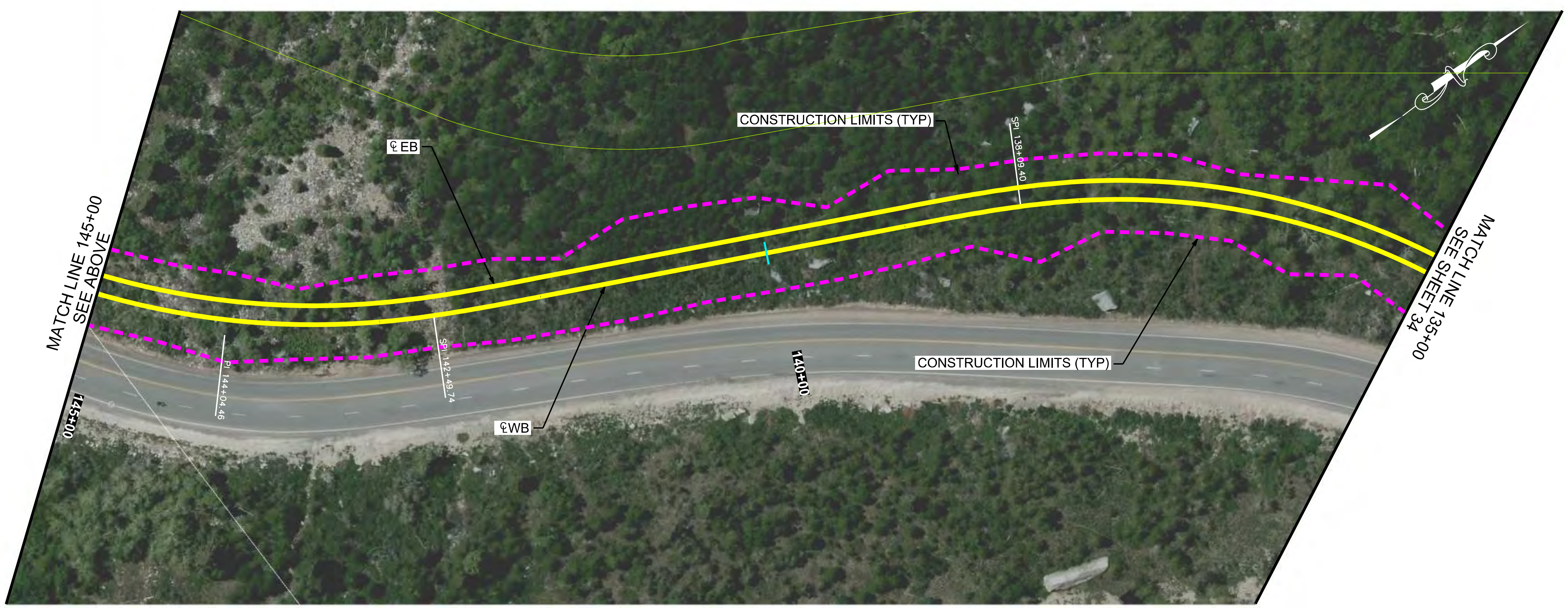
PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 32

2/17/2020





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COG RAIL SEGMENT 1

PIN 16092

PROJECT NUMBER XXXX

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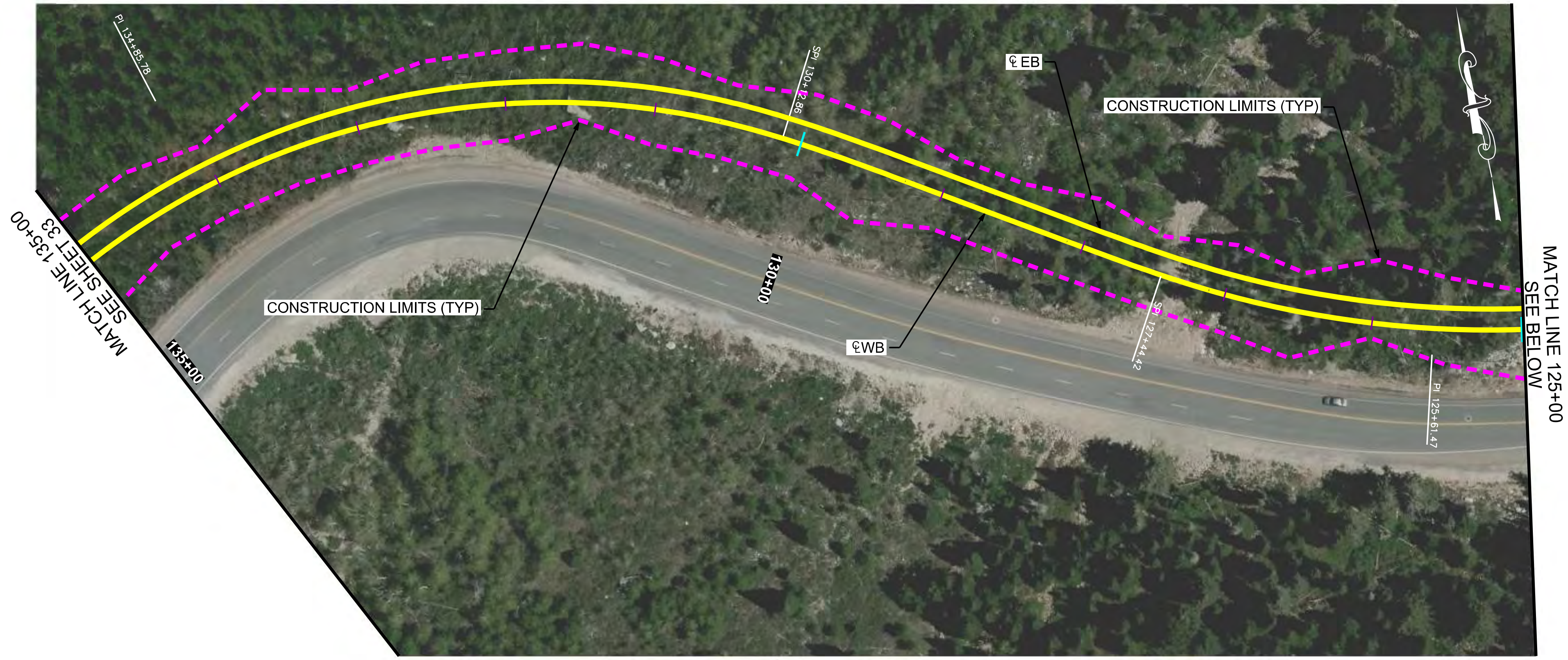
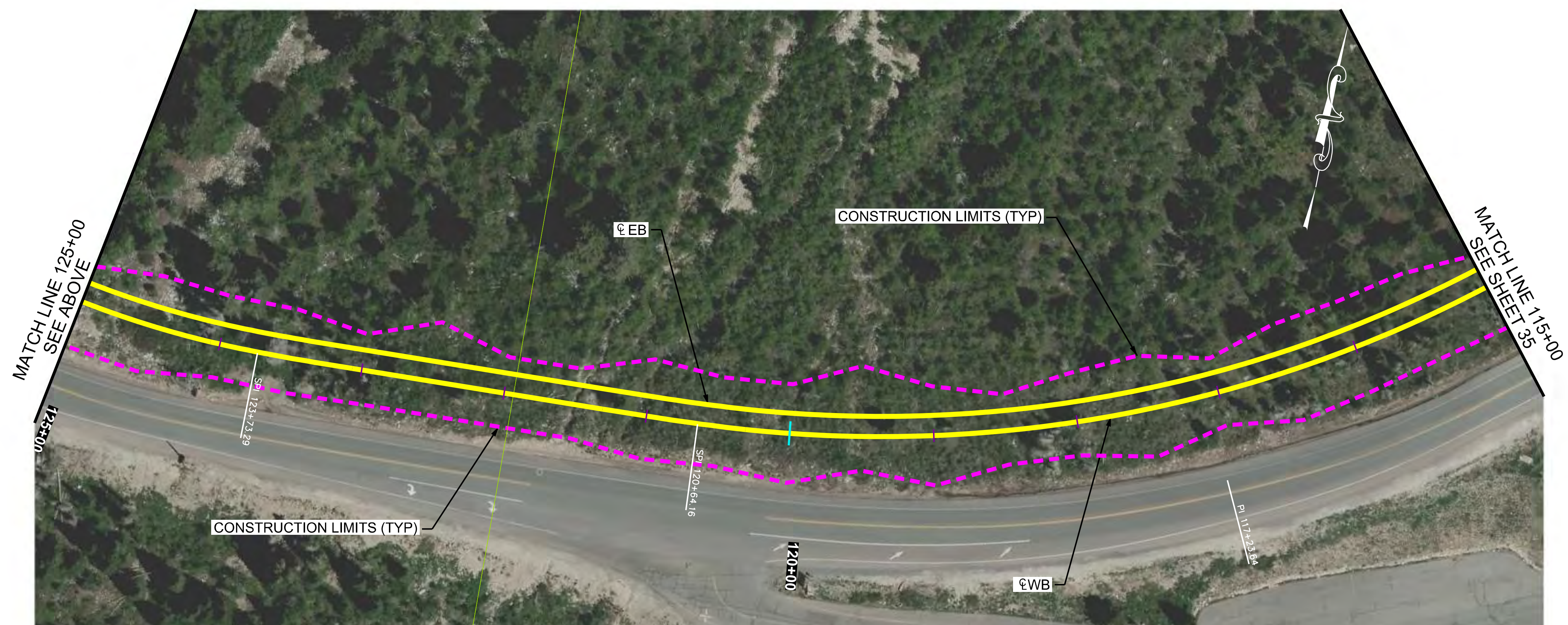
2/17/2020





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PROJECT: LITTLE COTTONWOOD CANYON EIS

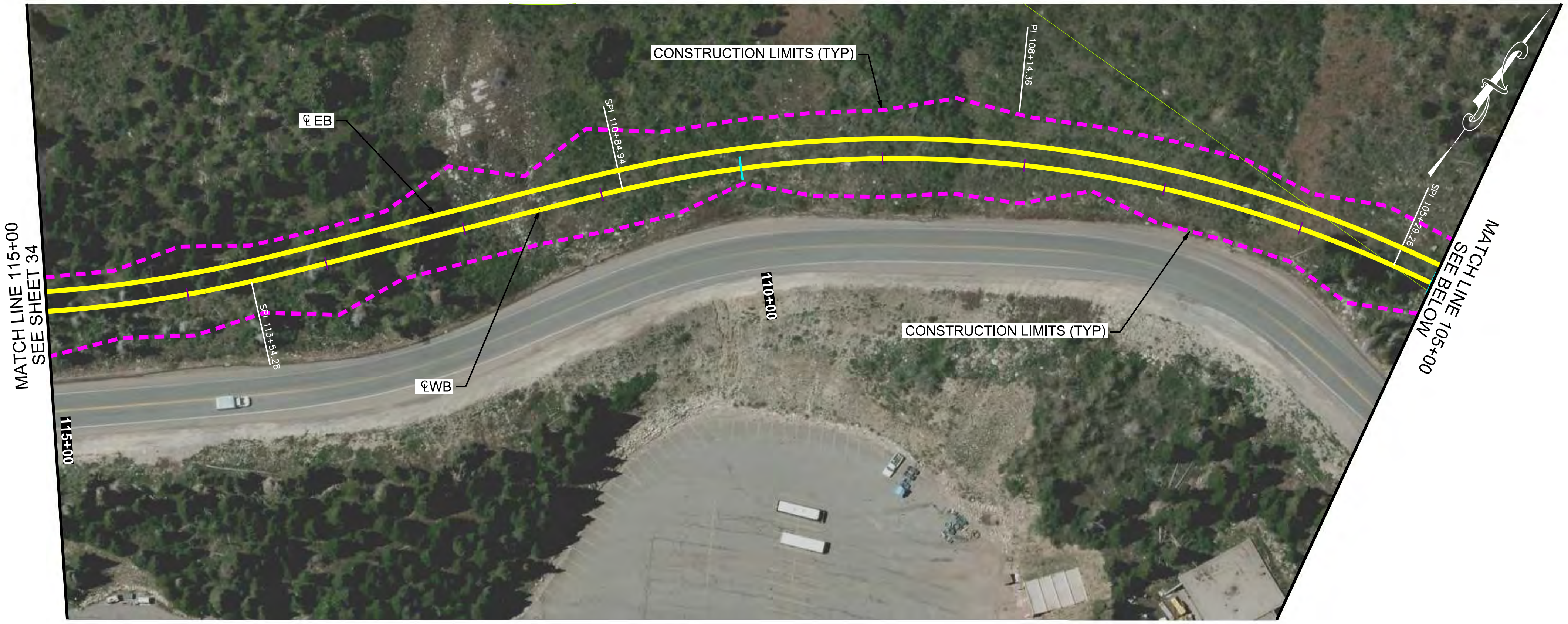
COG RAIL SEGMENT 1

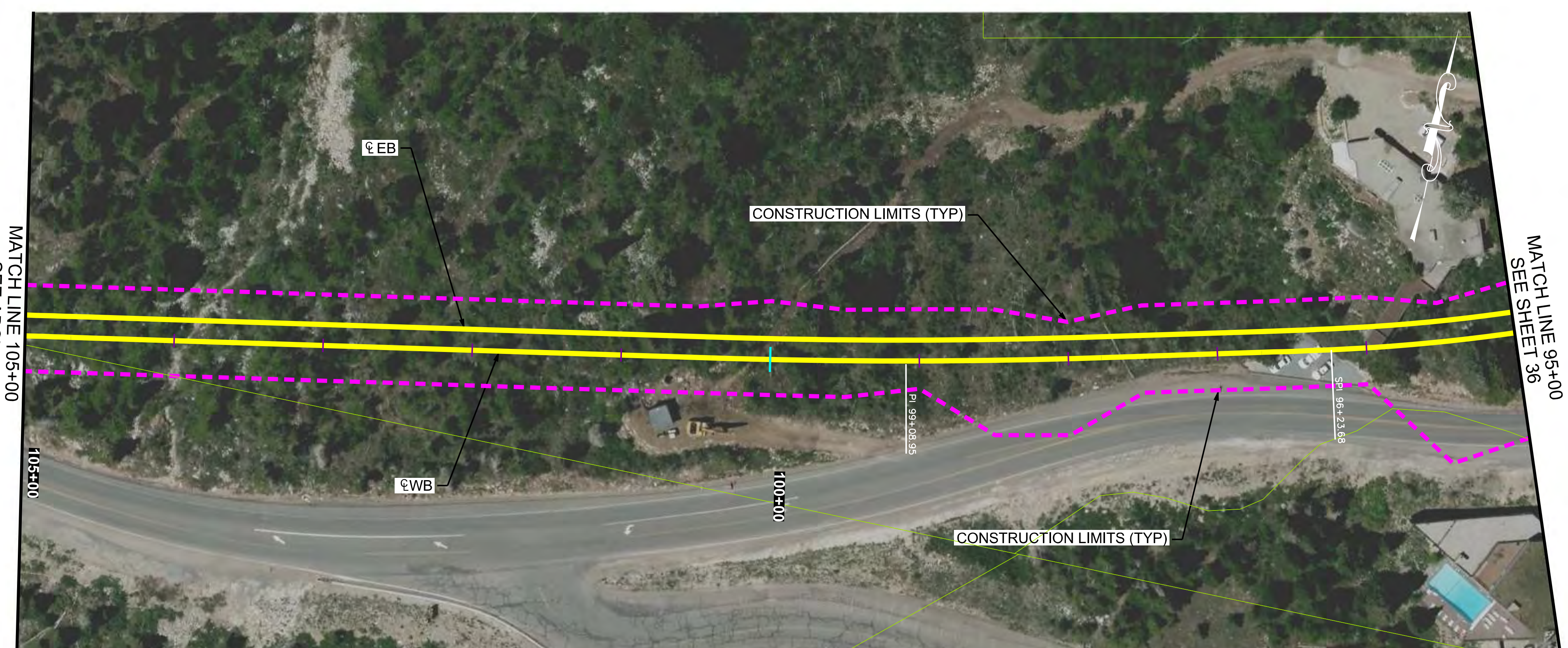
PIN: 16092

PROJECT NUMBER: XXXX

SHEET NO. 34

2/17/2020





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PROJECT: LITTLE COTTONWOOD CANYON EIS

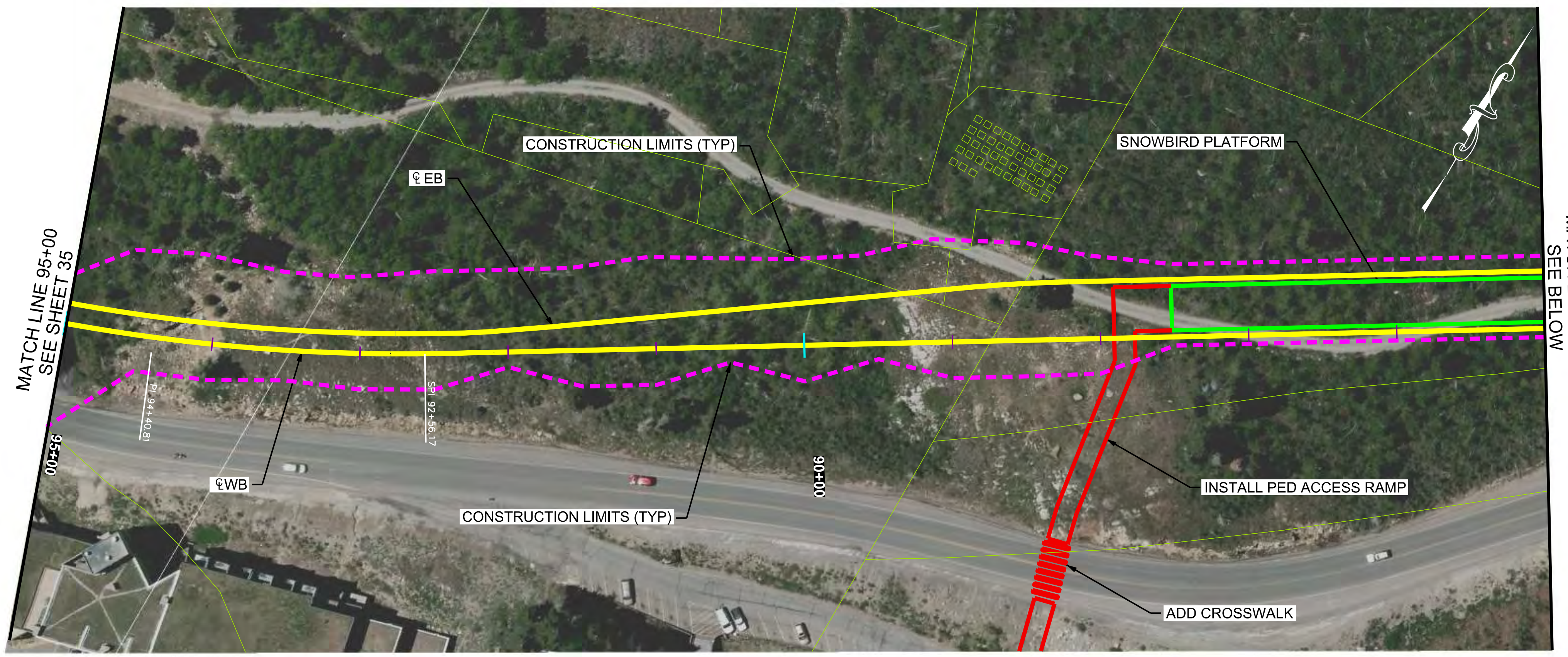
COG RAIL SEGMENT 1

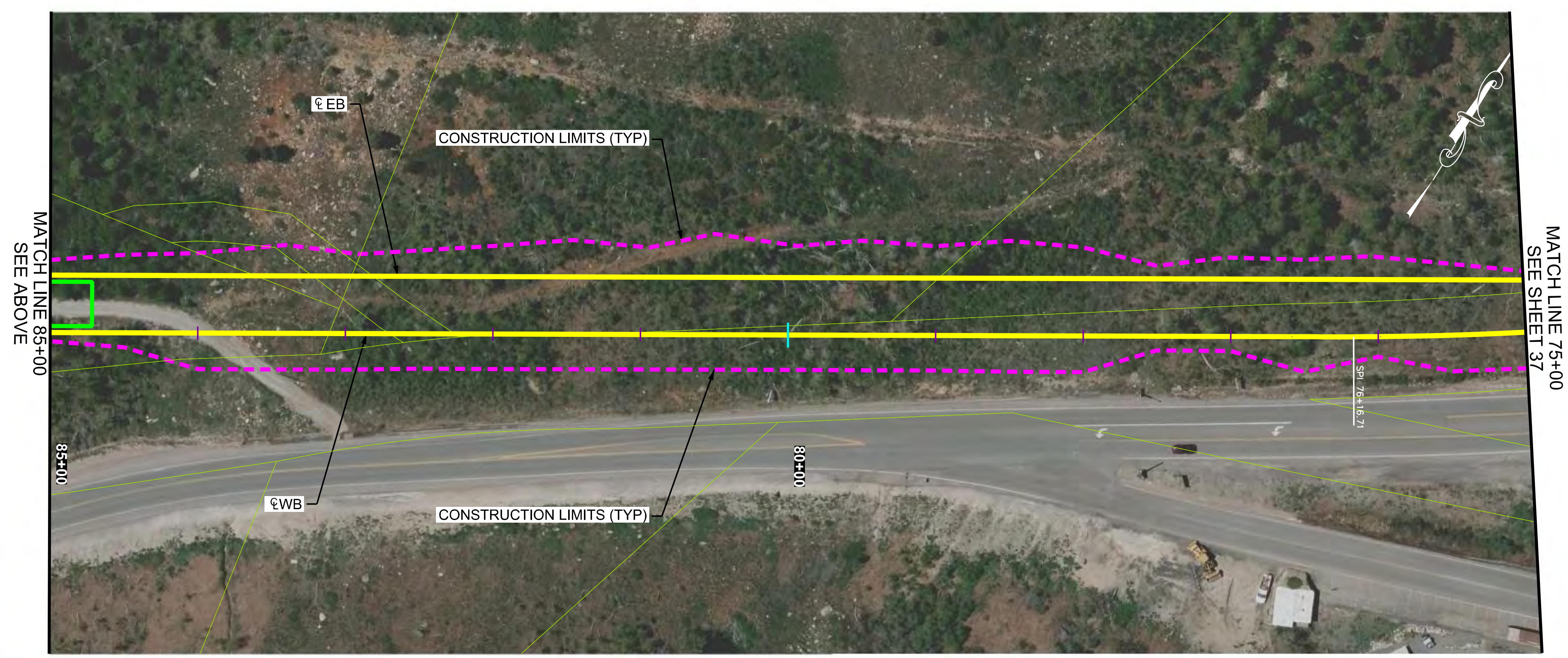
PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 35

2/17/2020





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PROJECT: LITTLE COTTONWOOD CANYON EIS

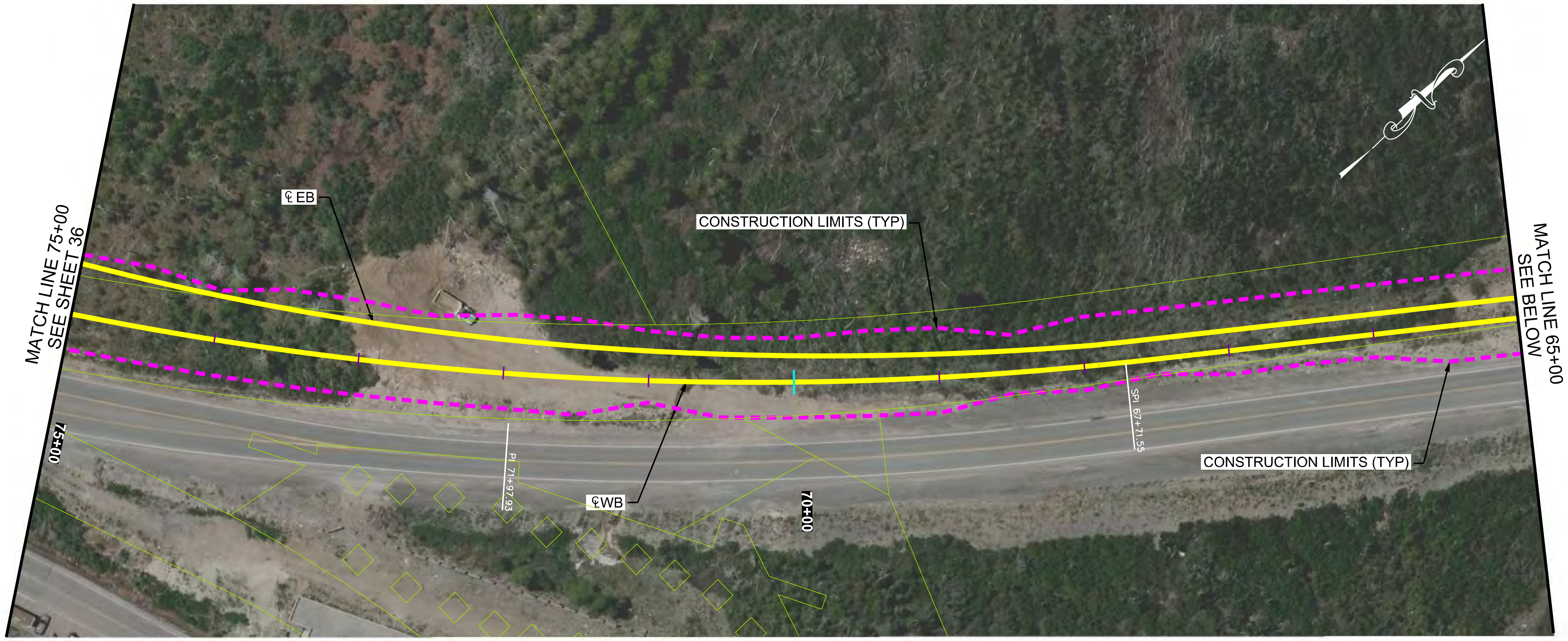
COG RAIL SEGMENT 1

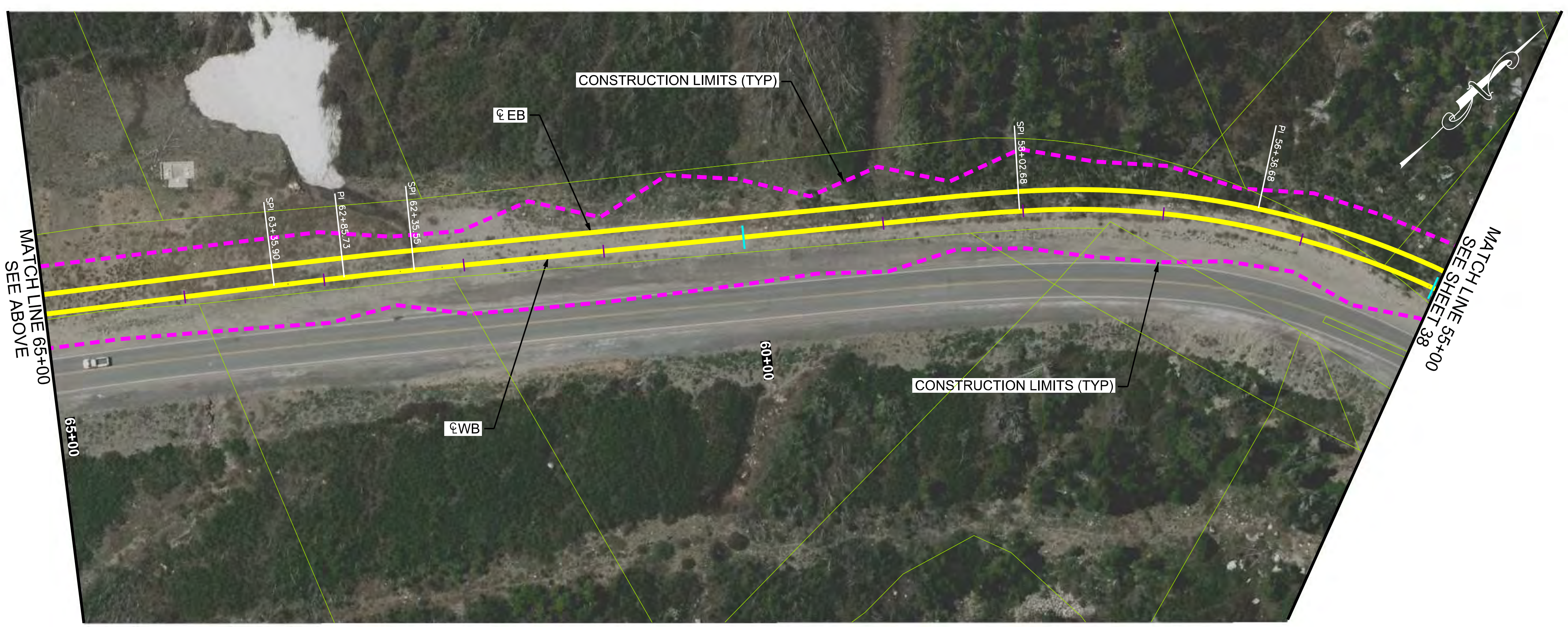
PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 36

2/17/2020





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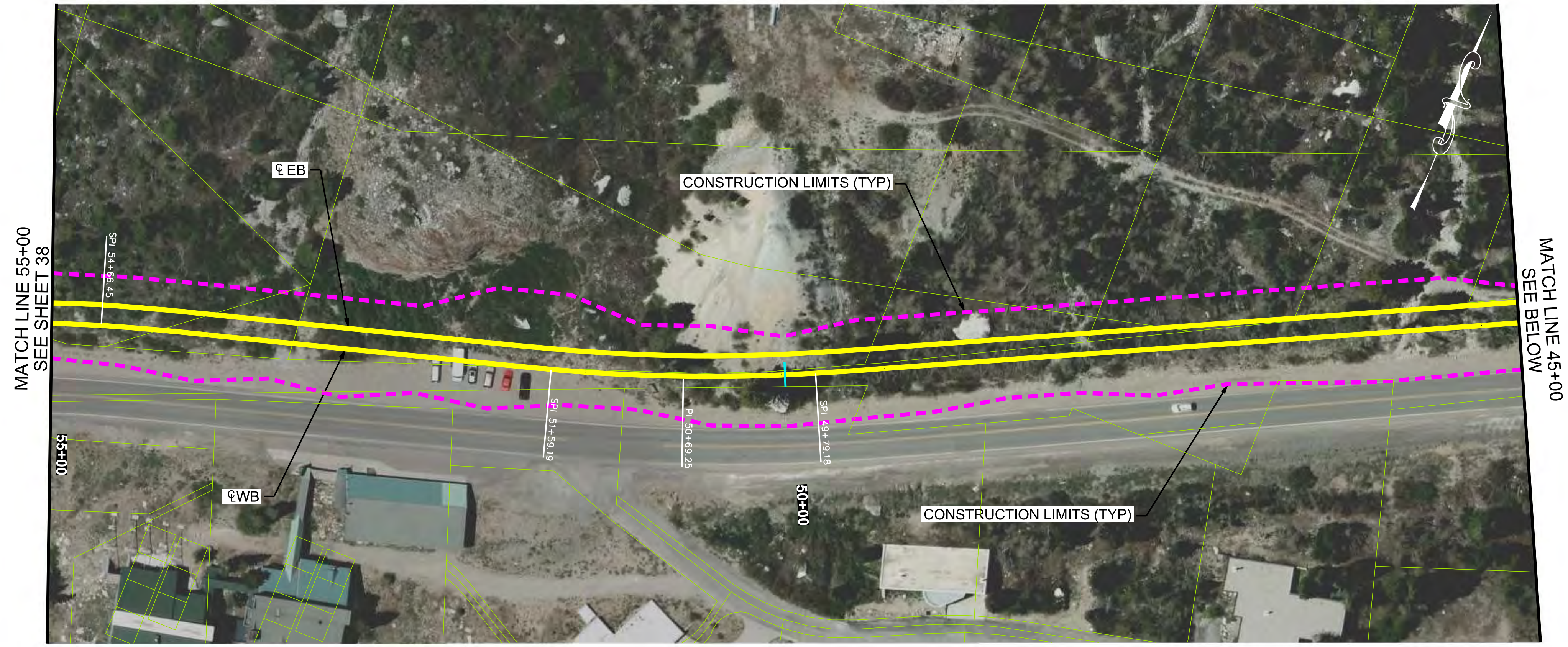
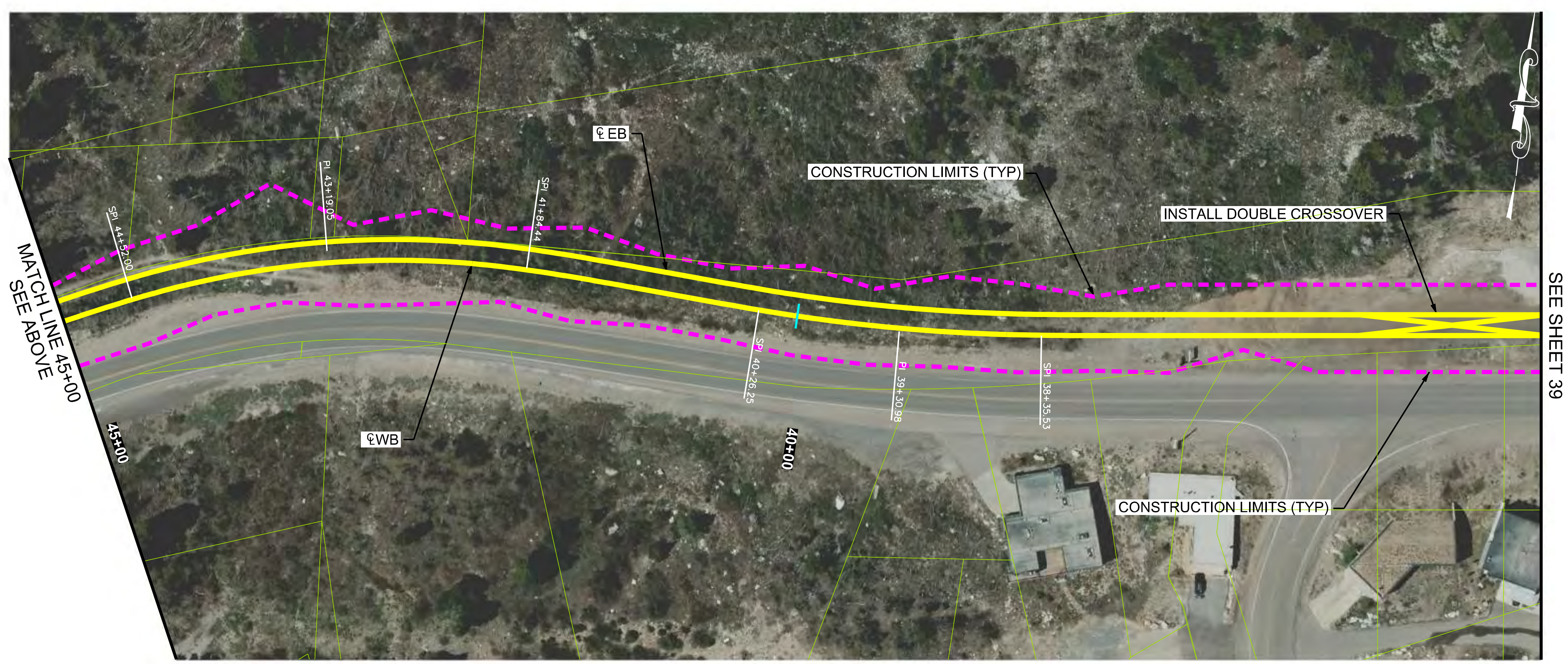
PROJECT	LITTLE COTTONWOOD CANYON EIS
	COG RAIL SEGMENT 1
PROJECT NUMBER	XXXX
PIN	16092

SHEET NO. 37





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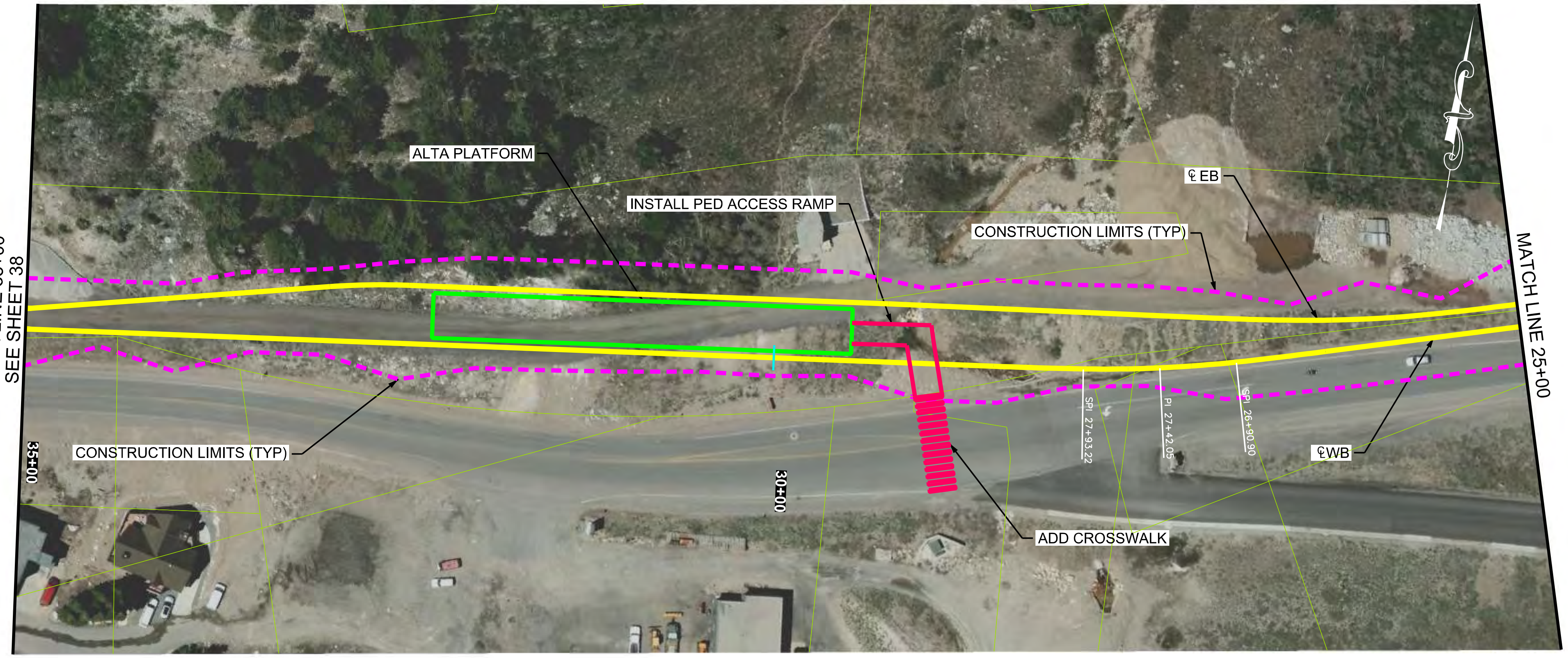
PROJECT: LITTLE COTTONWOOD CANYON EIS

COG RAIL SEGMENT 1

PIN: 16092

PROJECT NUMBER: XXXX

SHEET NO. 38



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NO.	DATE	APPROVED BY	REMARKS

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COG RAIL SEGMENT 1

PROJECT NUMBER: XXXX

PIN: 16092

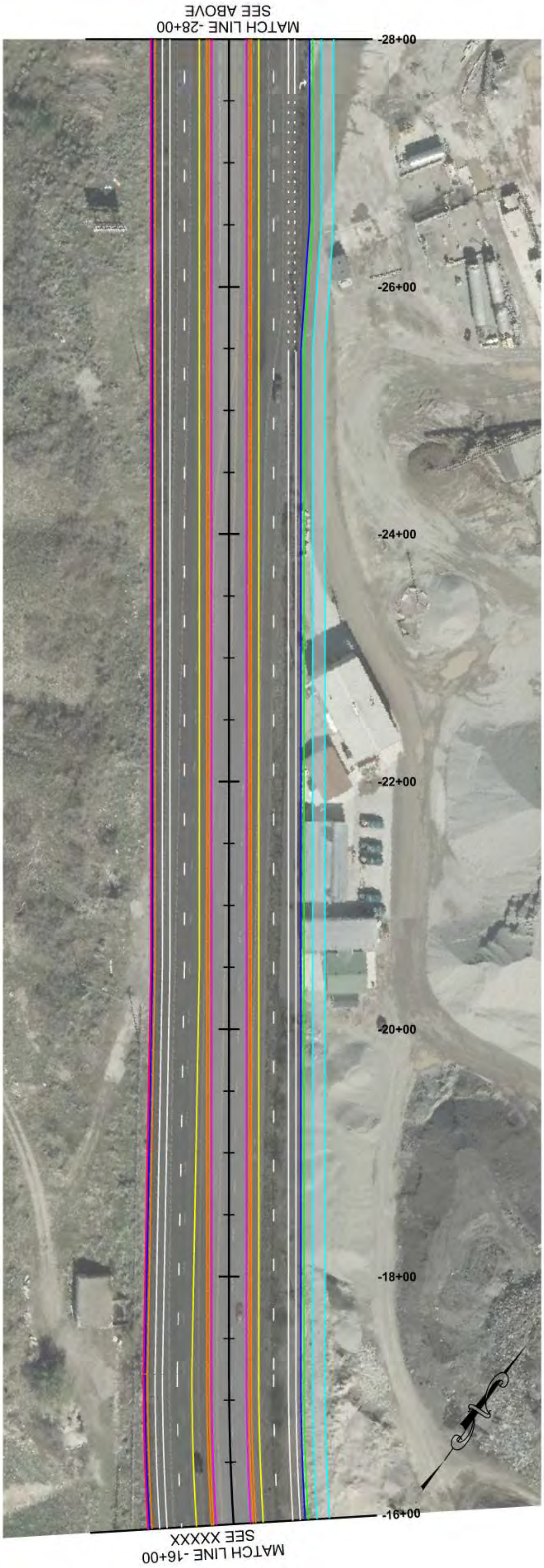
SHEET NO. 39

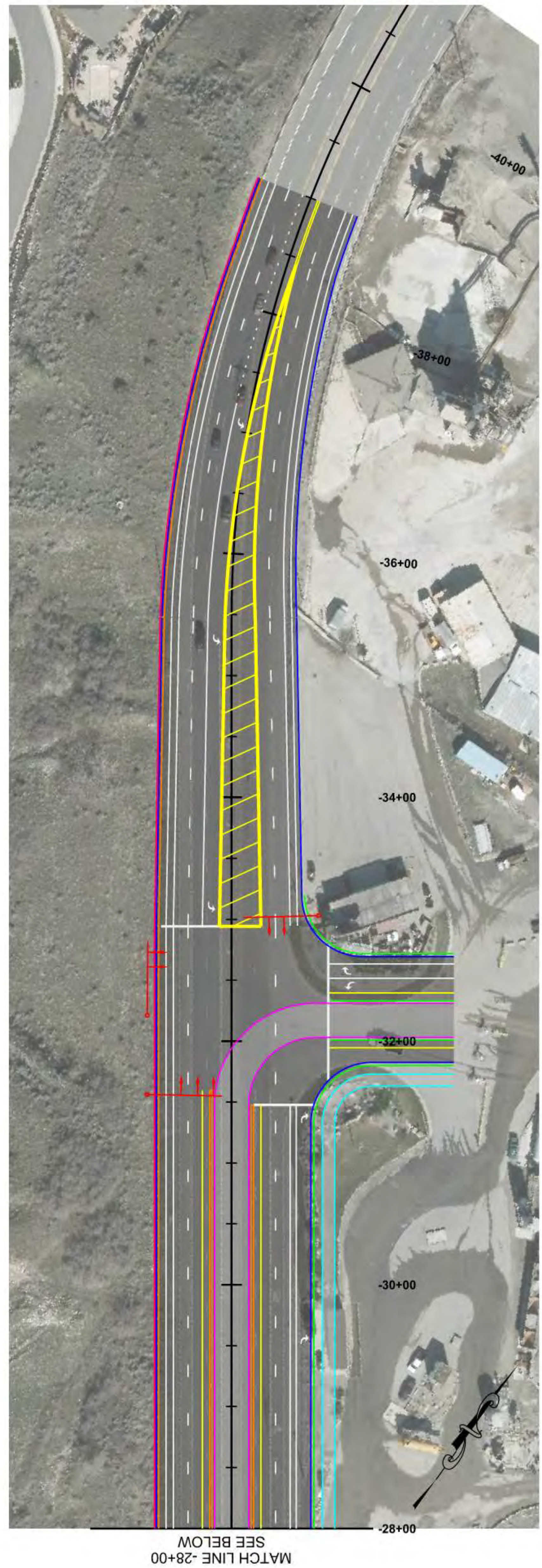
2/17/2020

APPENDIX B2

Preliminary Design Plans for Segment 2 – Gravel Pit to Mouth of Little Cottonwood Canyon

1/29/2020





PROJECT	LITTLE COTTONWOOD CANYON EIS	
	COG RAIL SEGMENT	
PROJECT NUMBER	XXXX	PIN 16092

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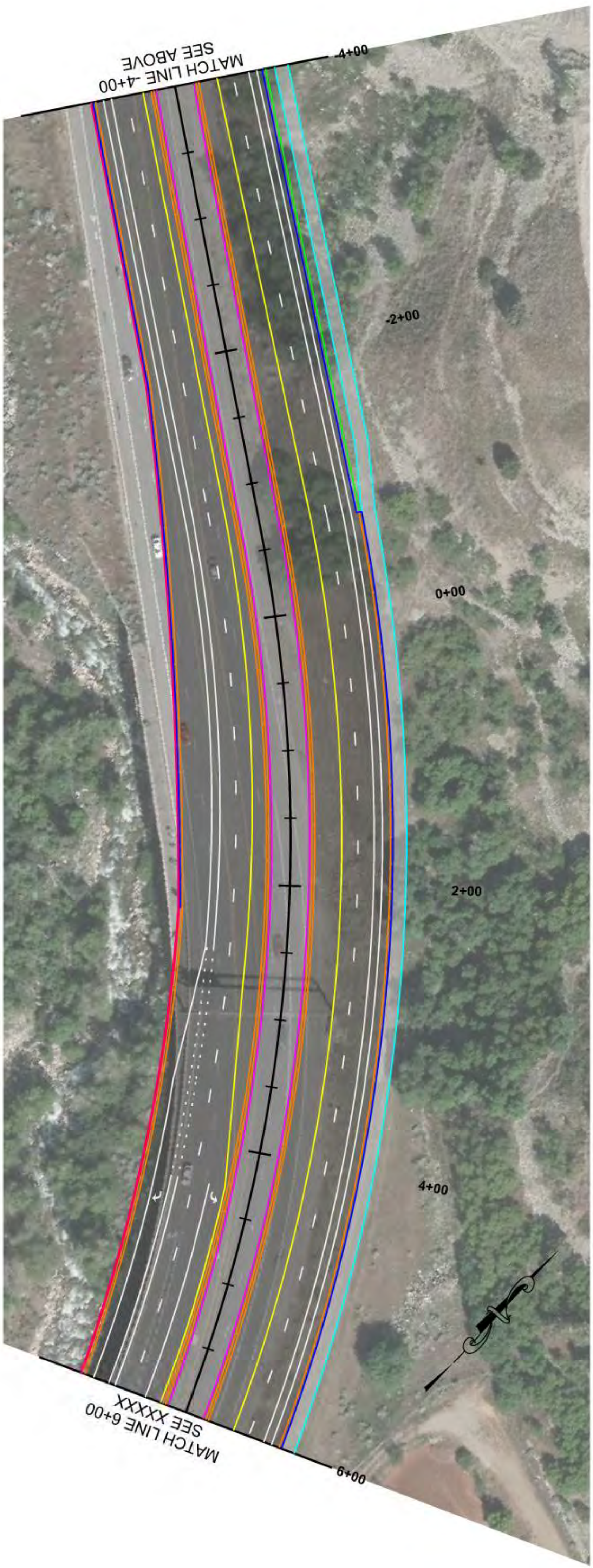

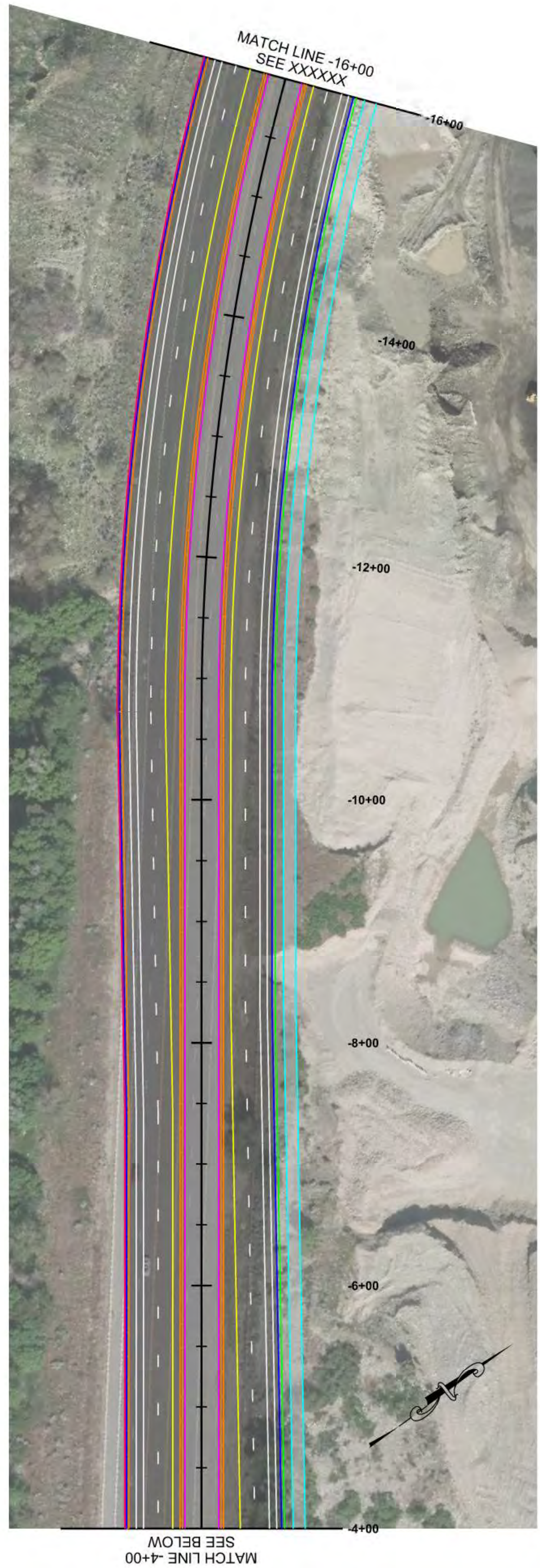

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PROJECT NUMBER	XXXX	PIN	16092	

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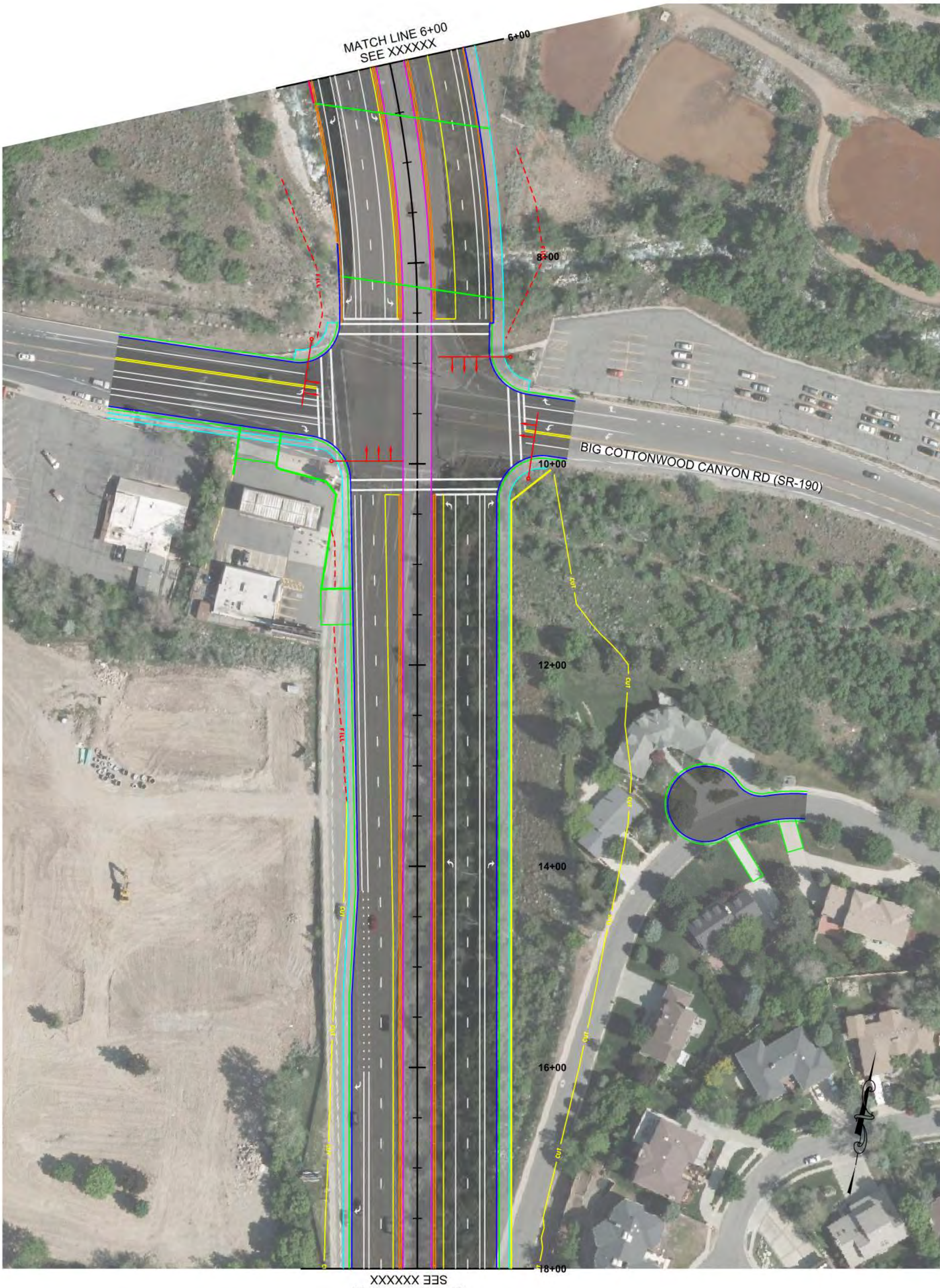

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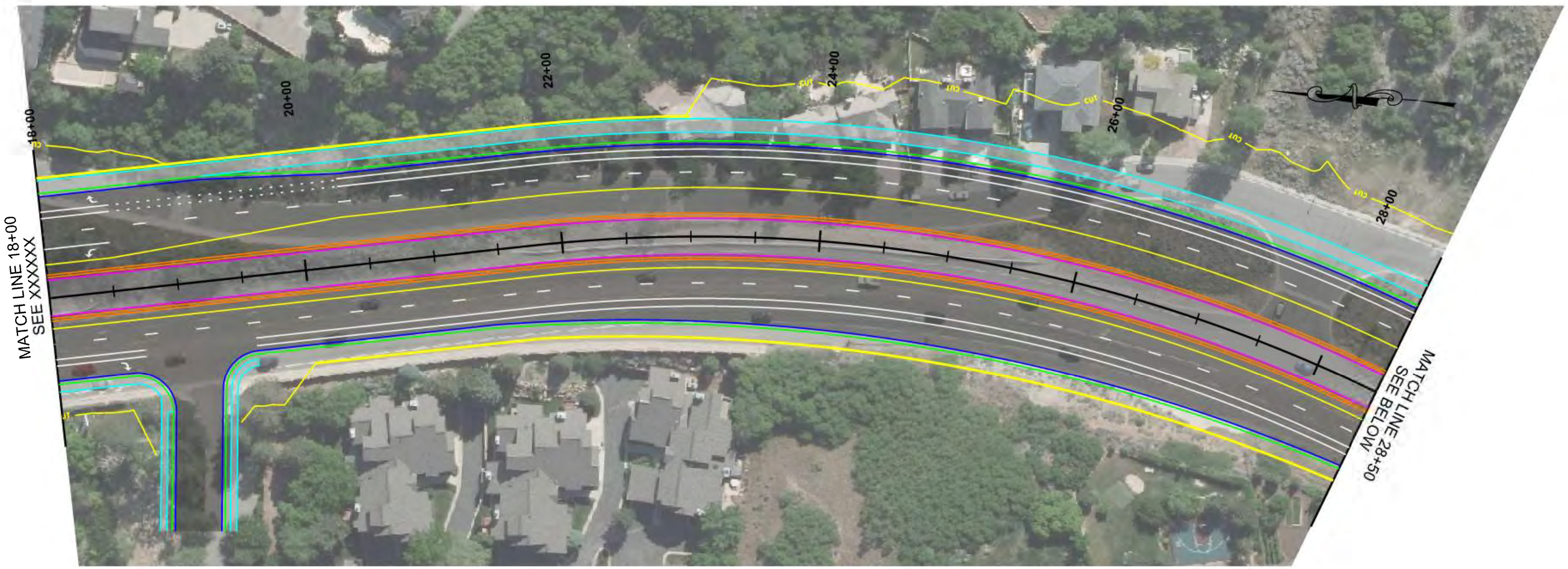

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PROJECT: LITTLE COTTONWOOD CANYON EIS

COG RAIL SEGMENT

PROJECT NUMBER: XXXX

PIN: 16092

SHEET NO.

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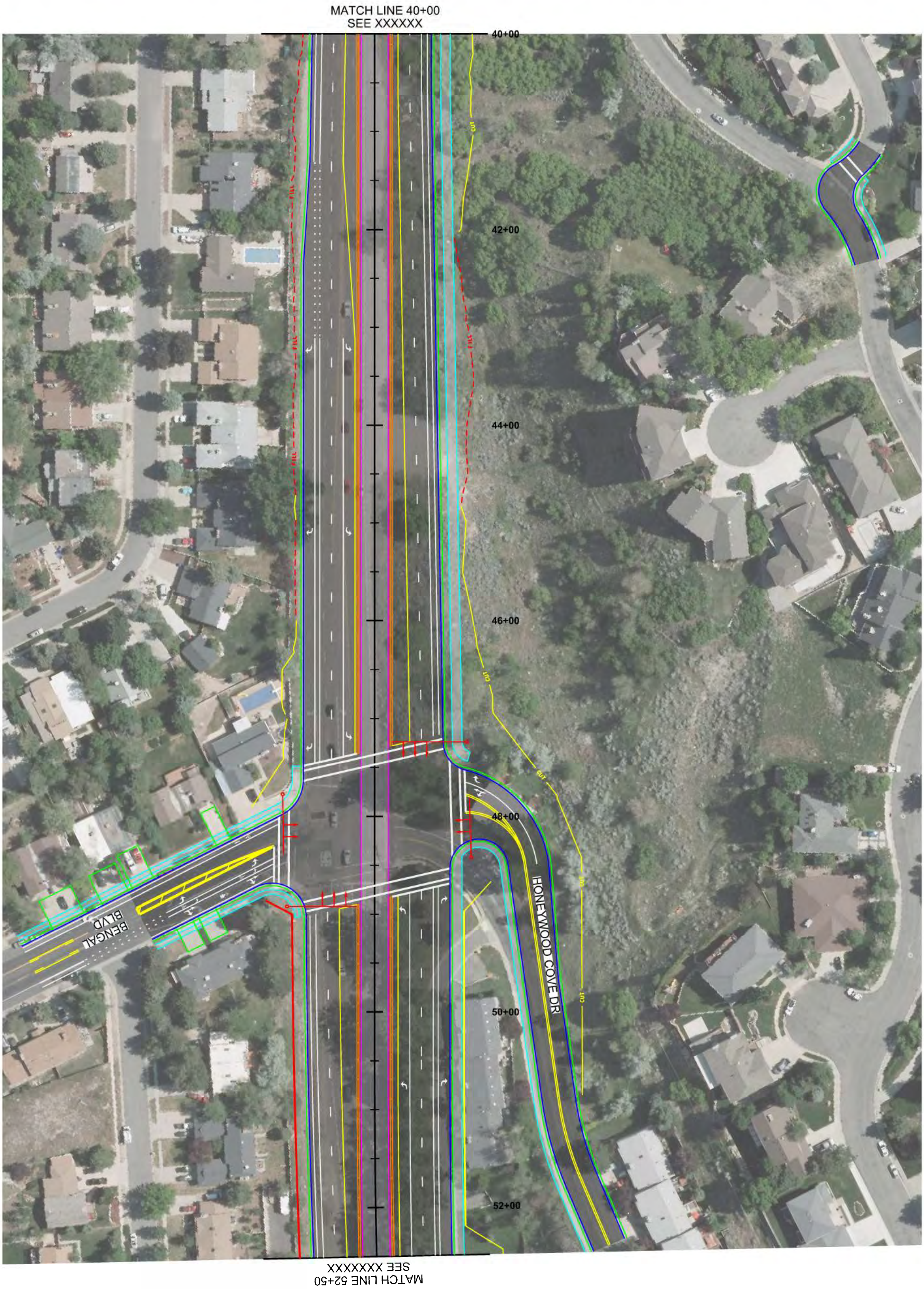

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PROJECT NUMBER	XXXX	PIN	16092

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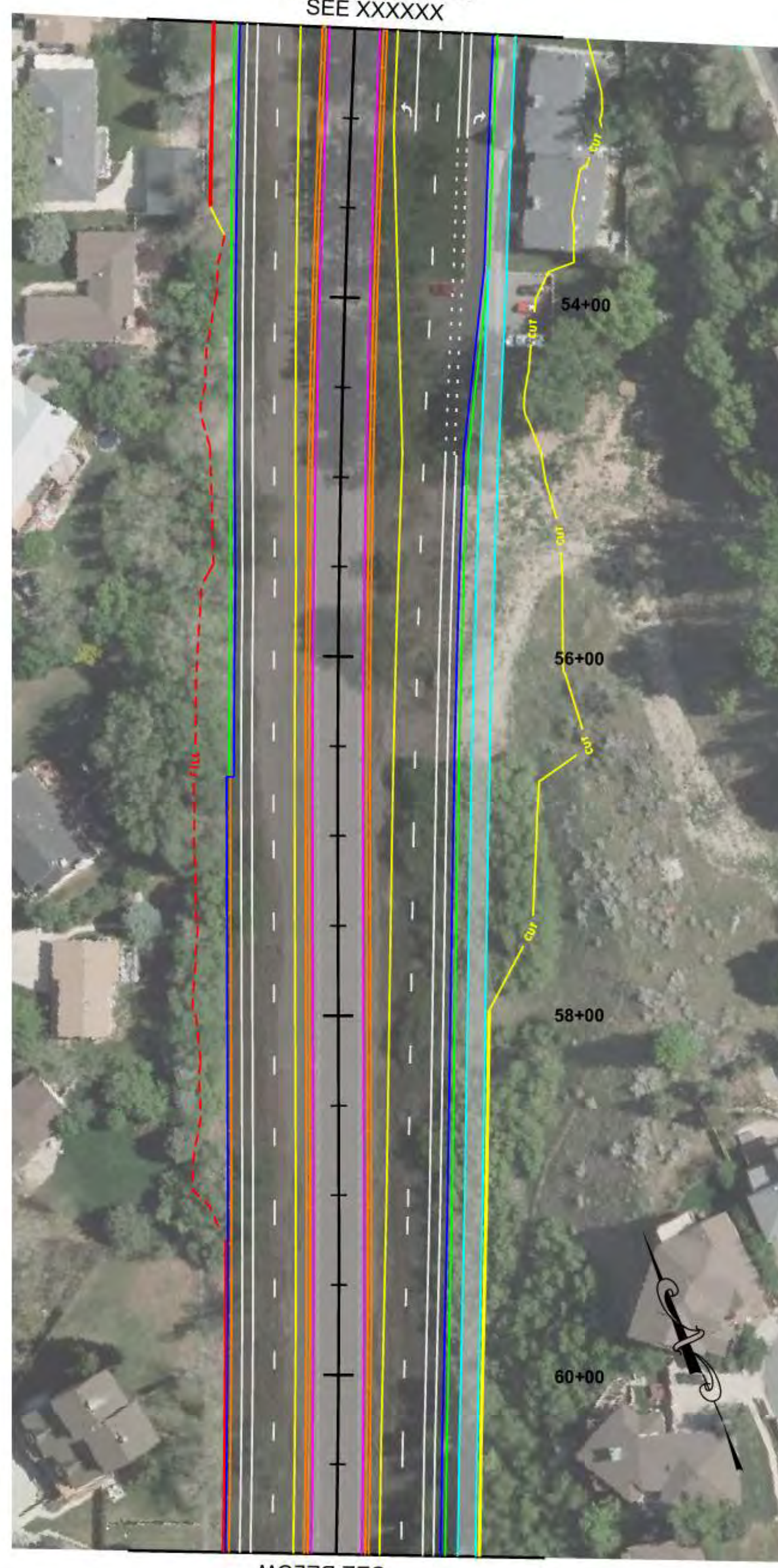

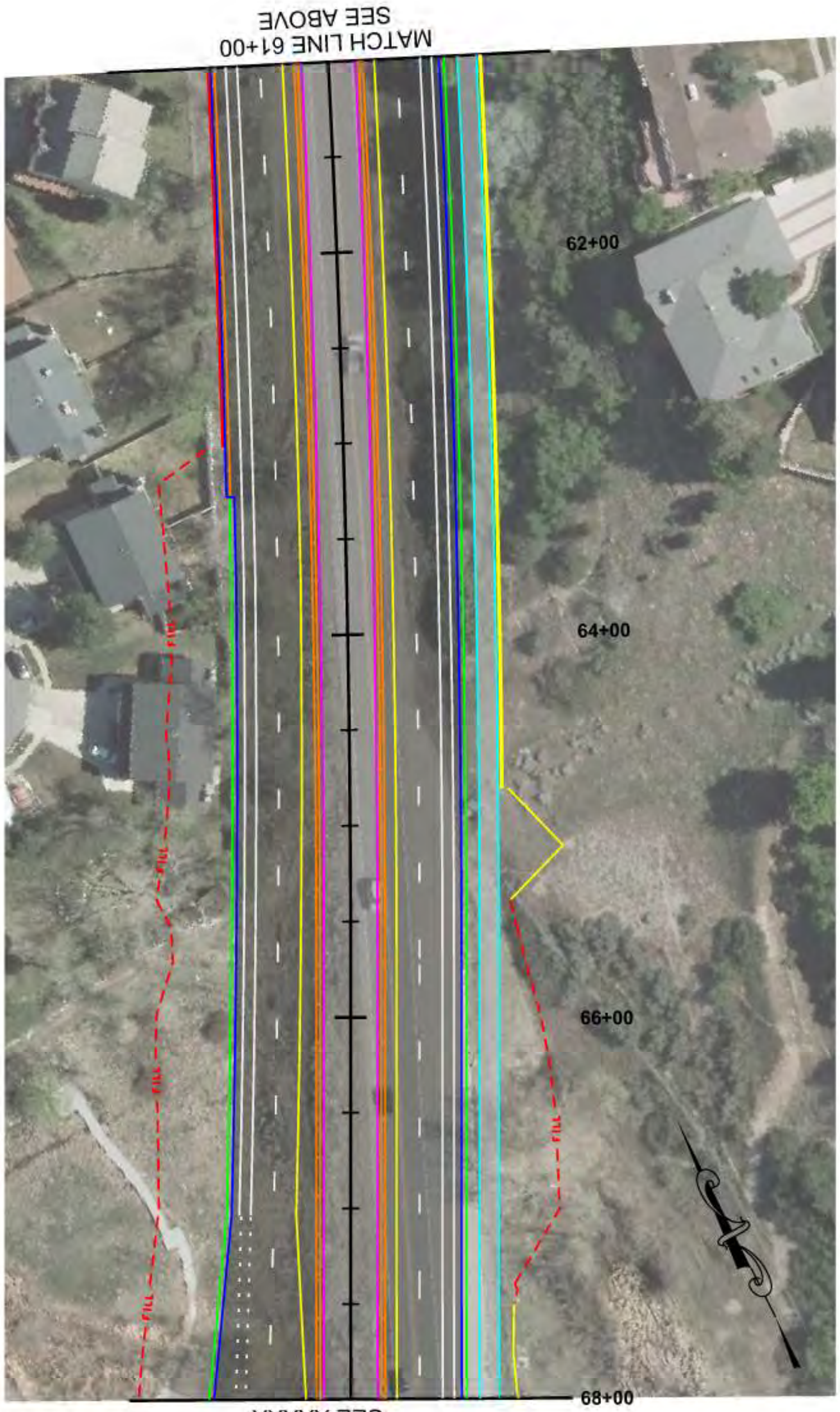

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PROJECT NUMBER	XXXX	PIN	16092

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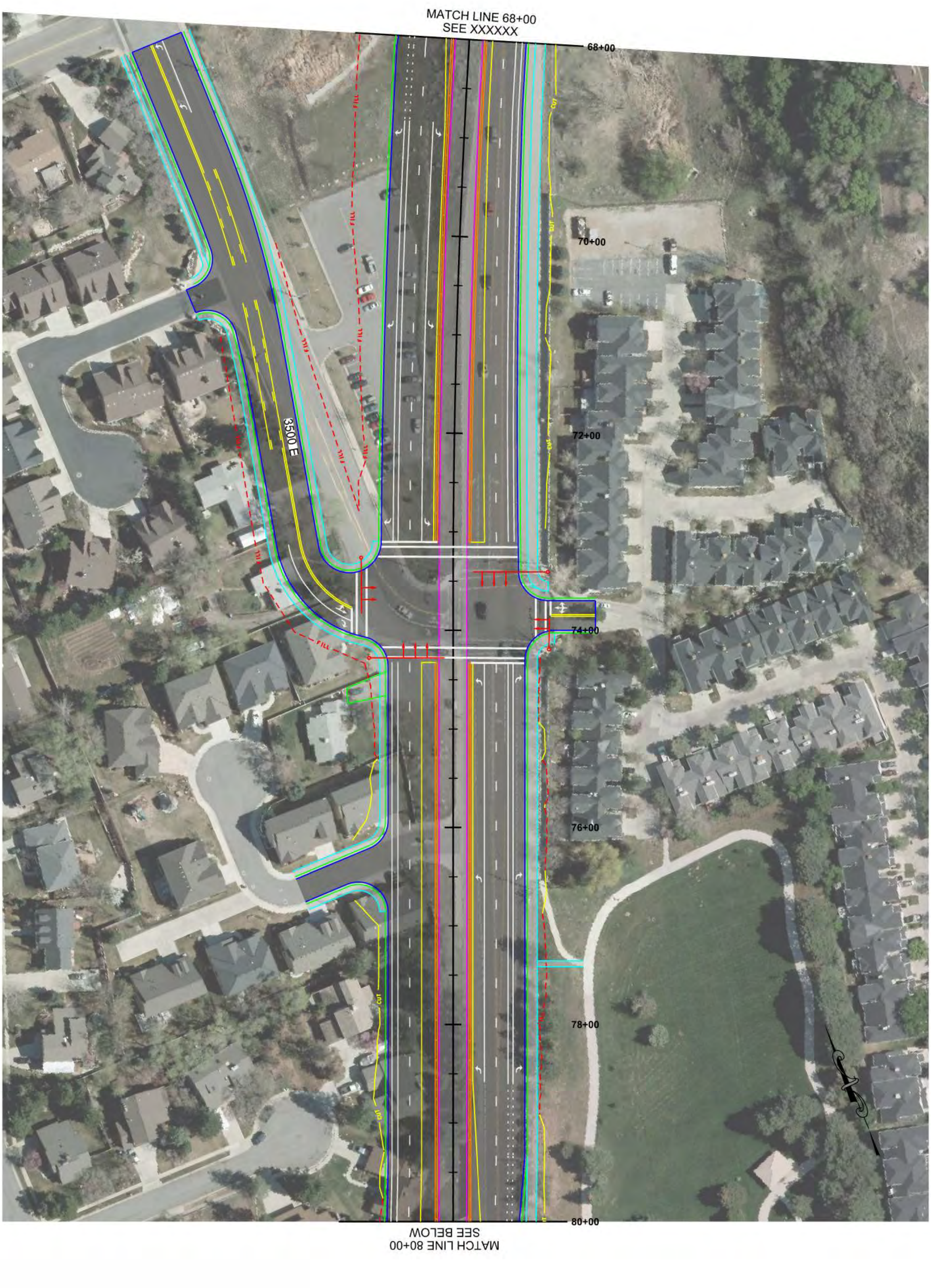

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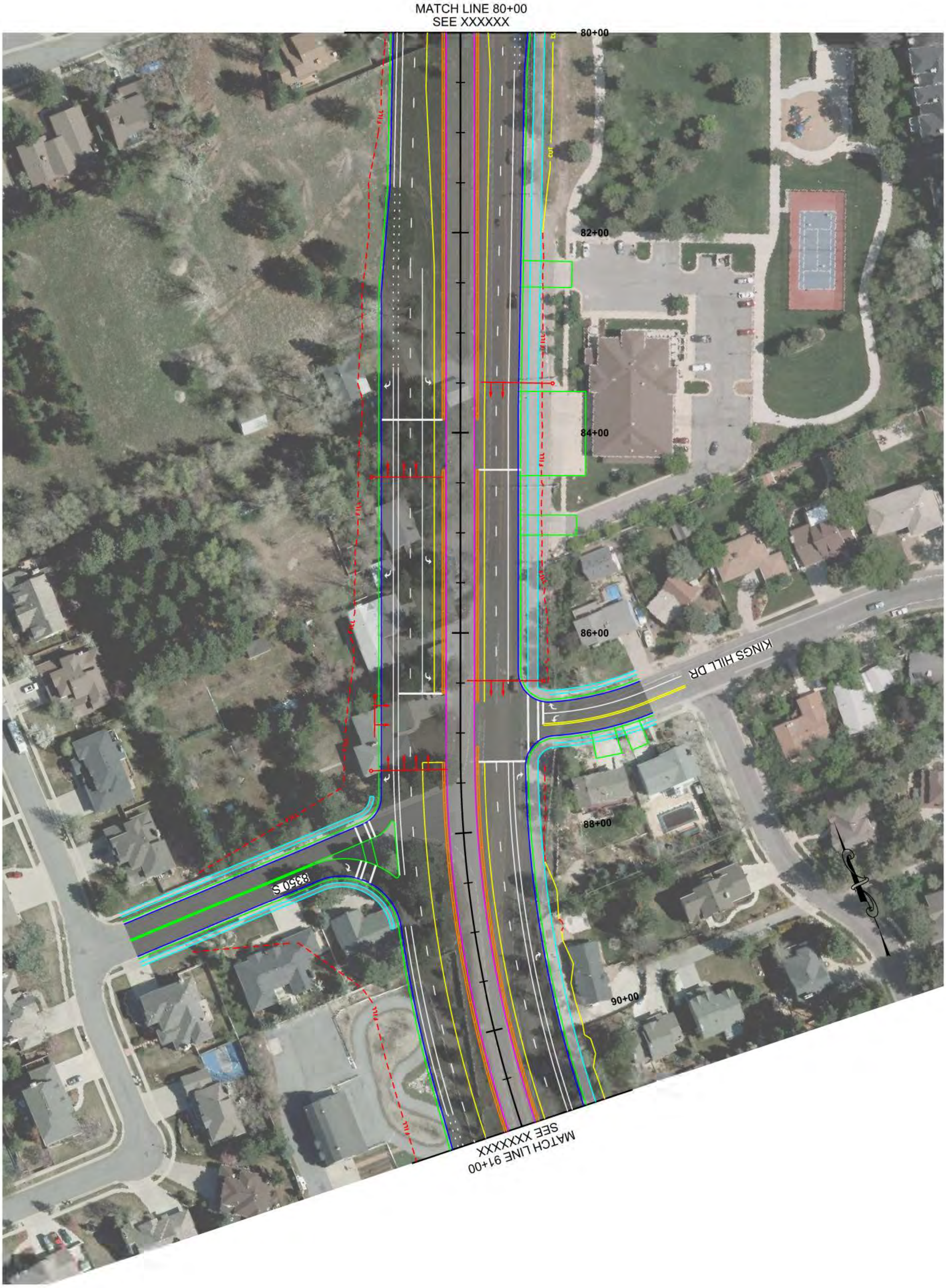
NO.	DATE	APPROVED BY	REMARKS



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PROJECT NUMBER	XXXX	PIN 16092	APPROVED PROFESSIONAL ENGINEER — DATE	DRAWN BY QC CHECKED BY

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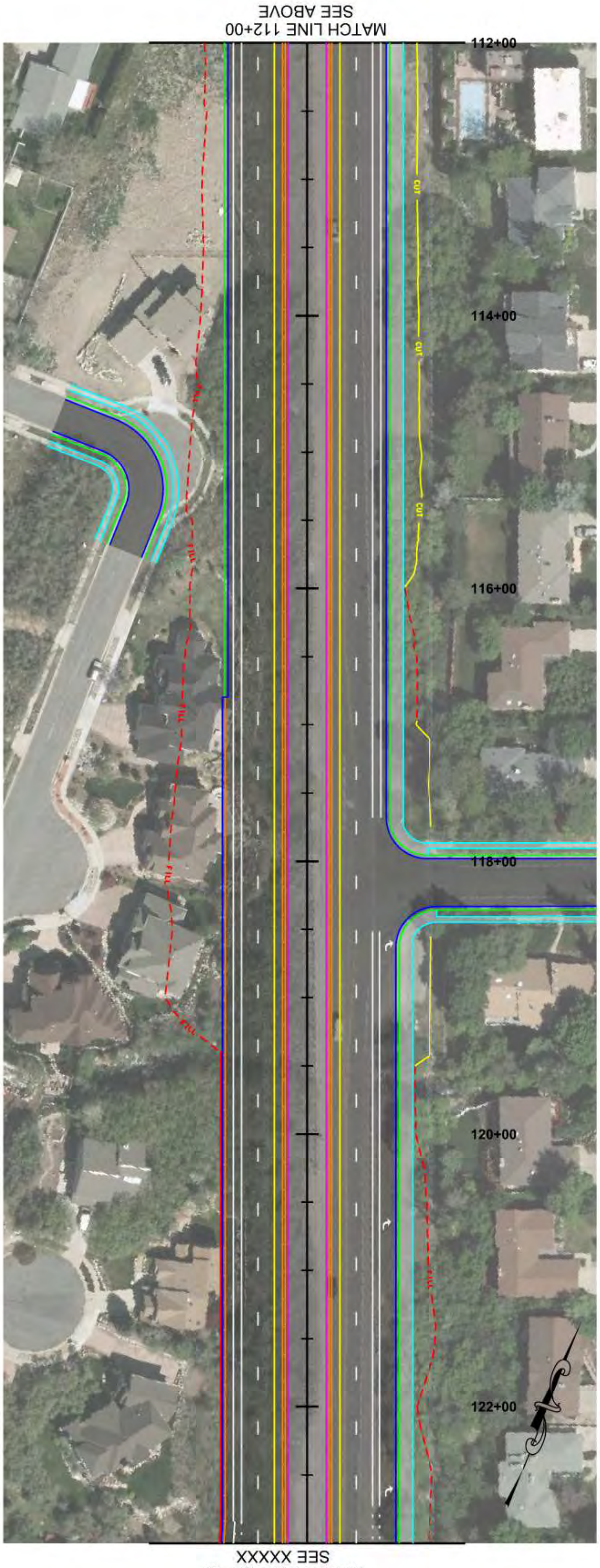

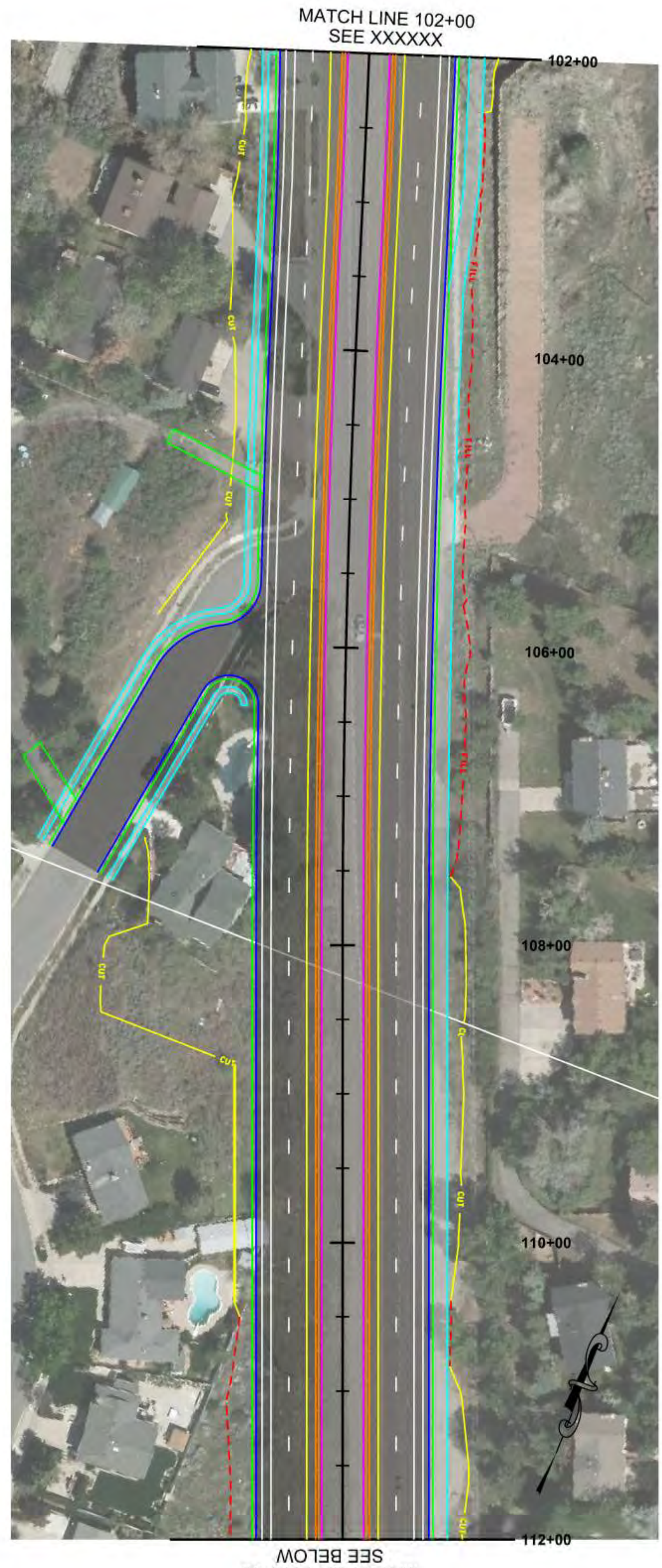

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PROJECT NUMBER	XXXX	PIN 16092

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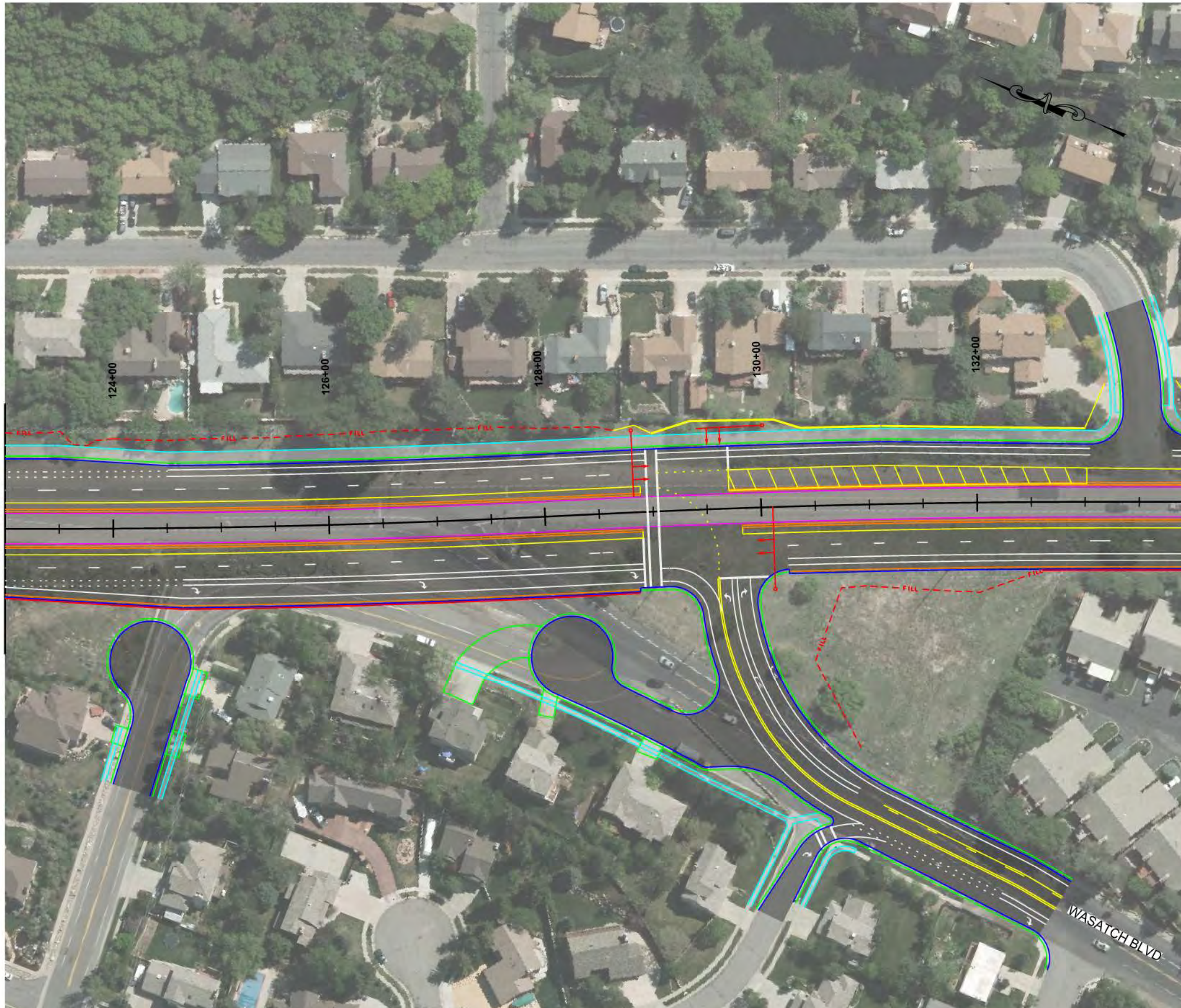

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COG RAIL SEGMENT

PIN 16092

PROJECT NUMBER XXXX

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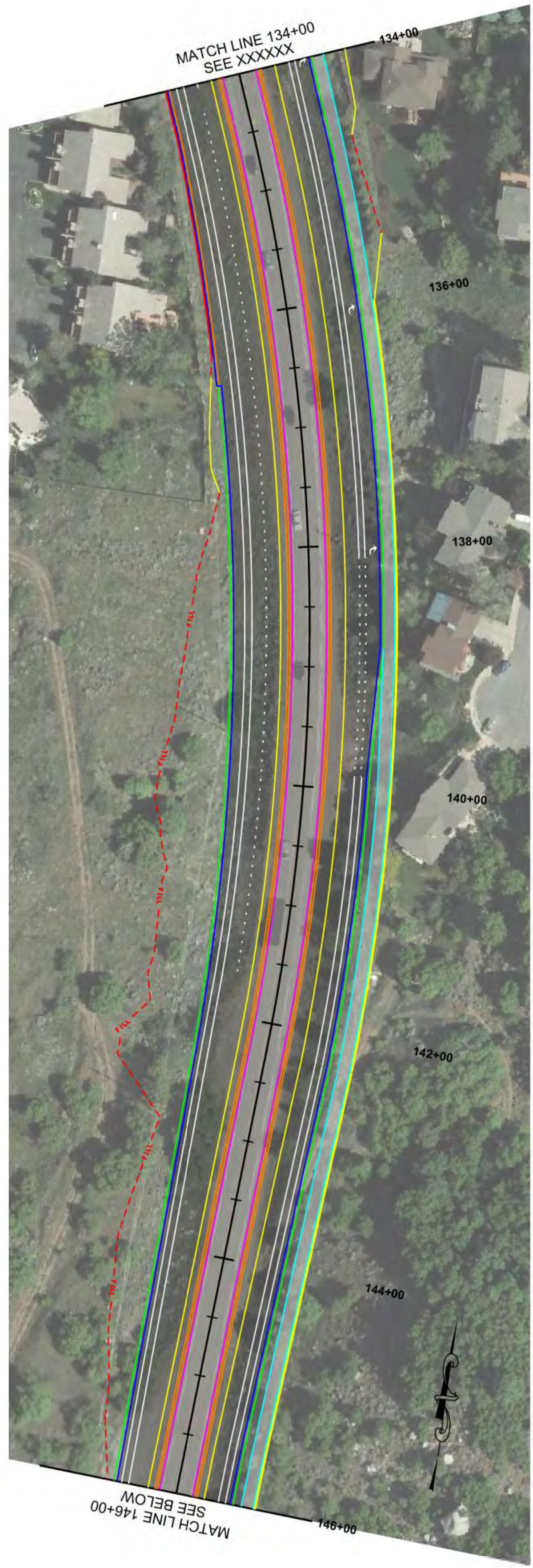
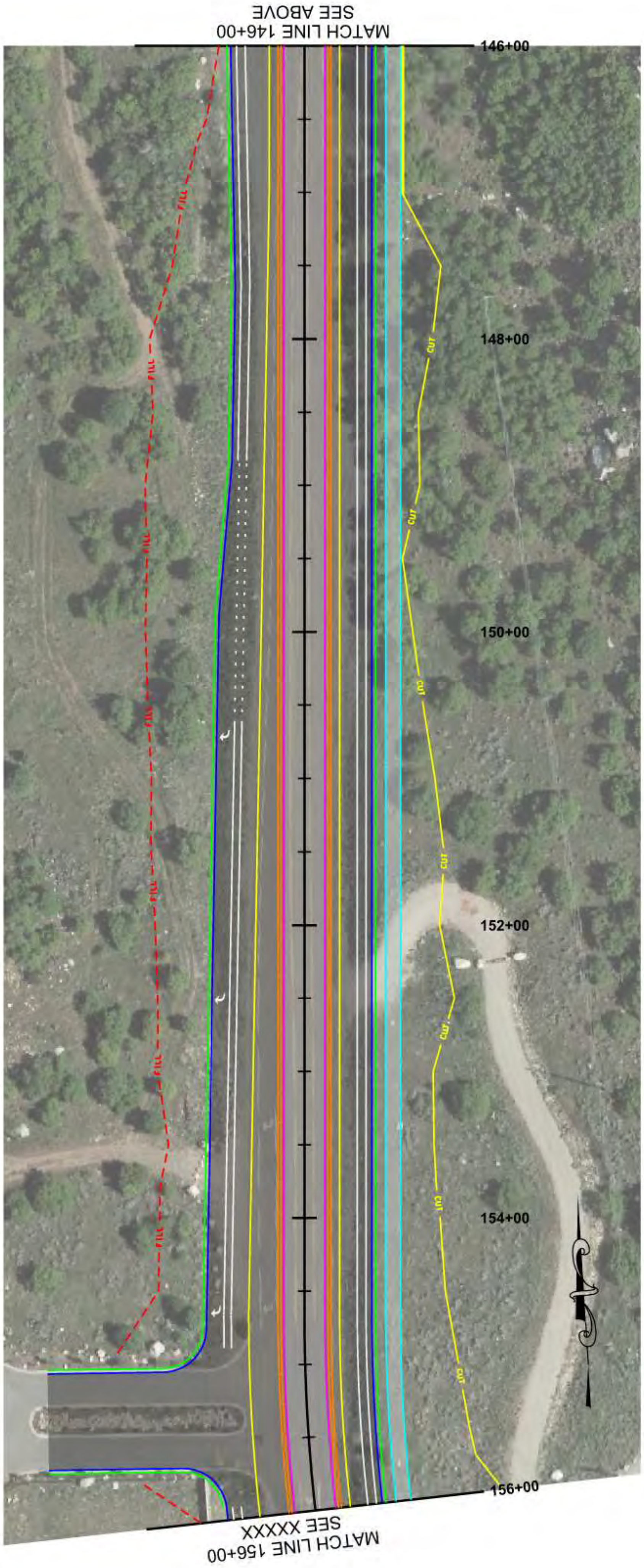
1/29/2020





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PROJECT NUMBER	XXXX	PIN	16092	APPROVED PROFESSIONAL ENGINEER — DATE
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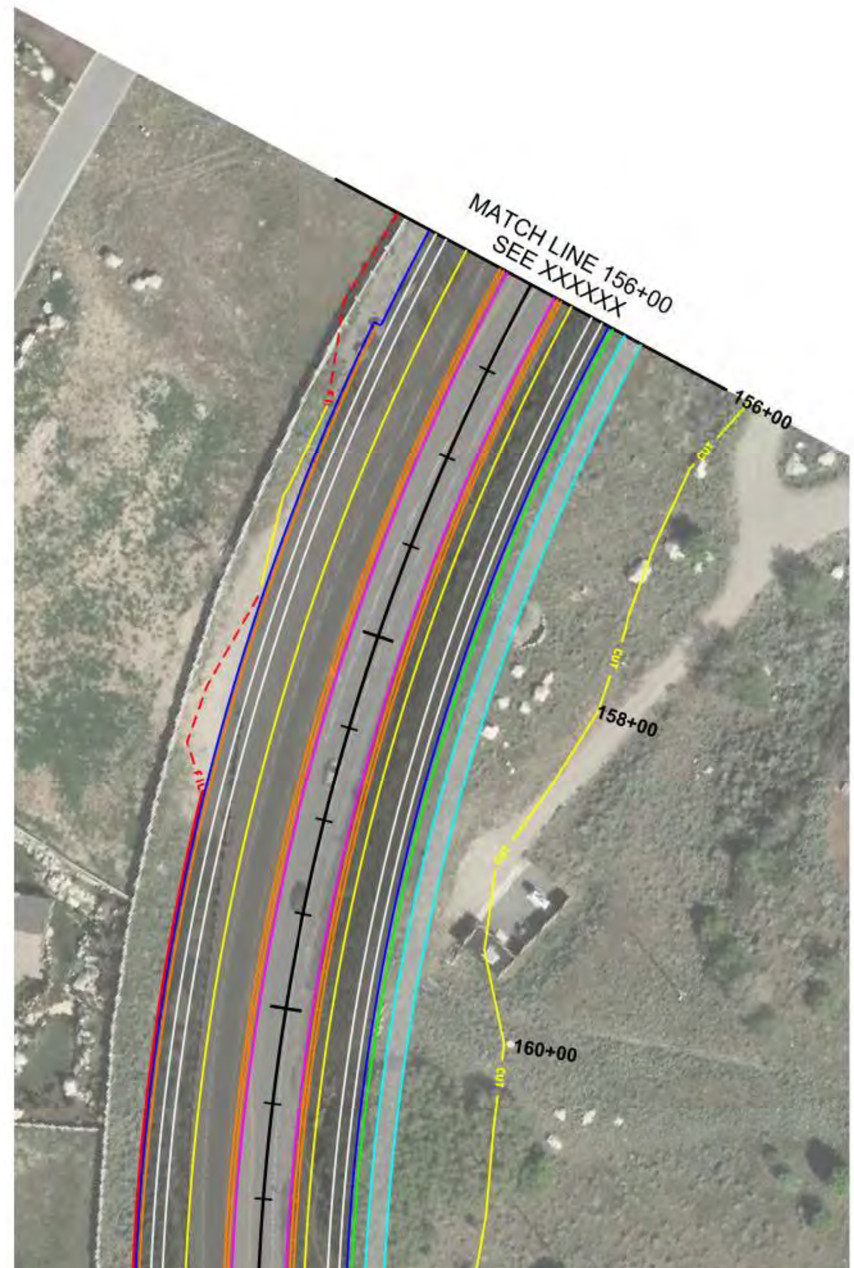

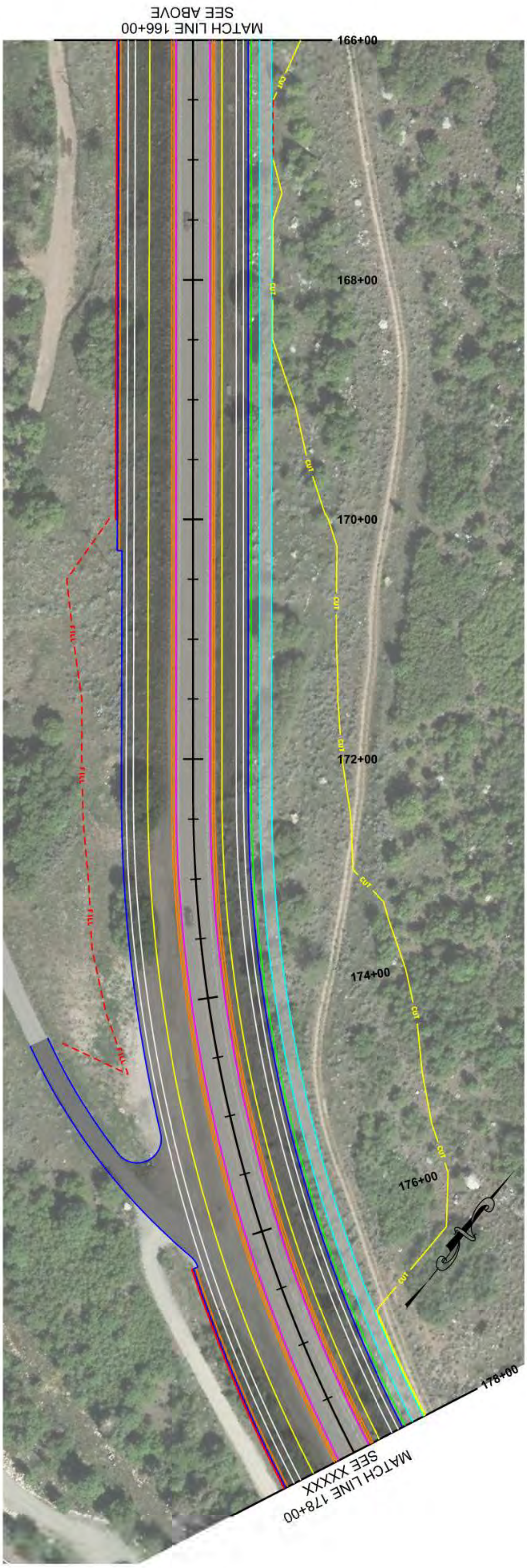

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PROJECT NUMBER	XXXX	PIN	16092

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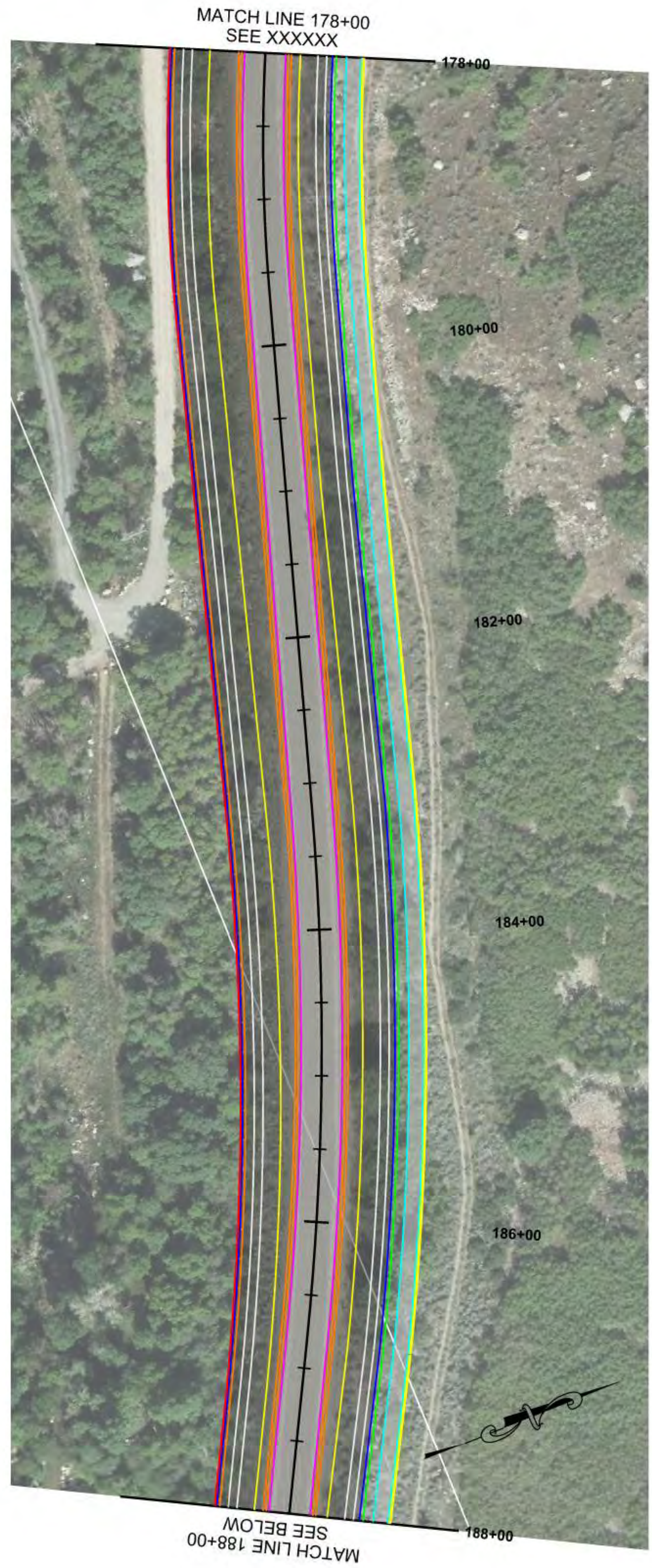
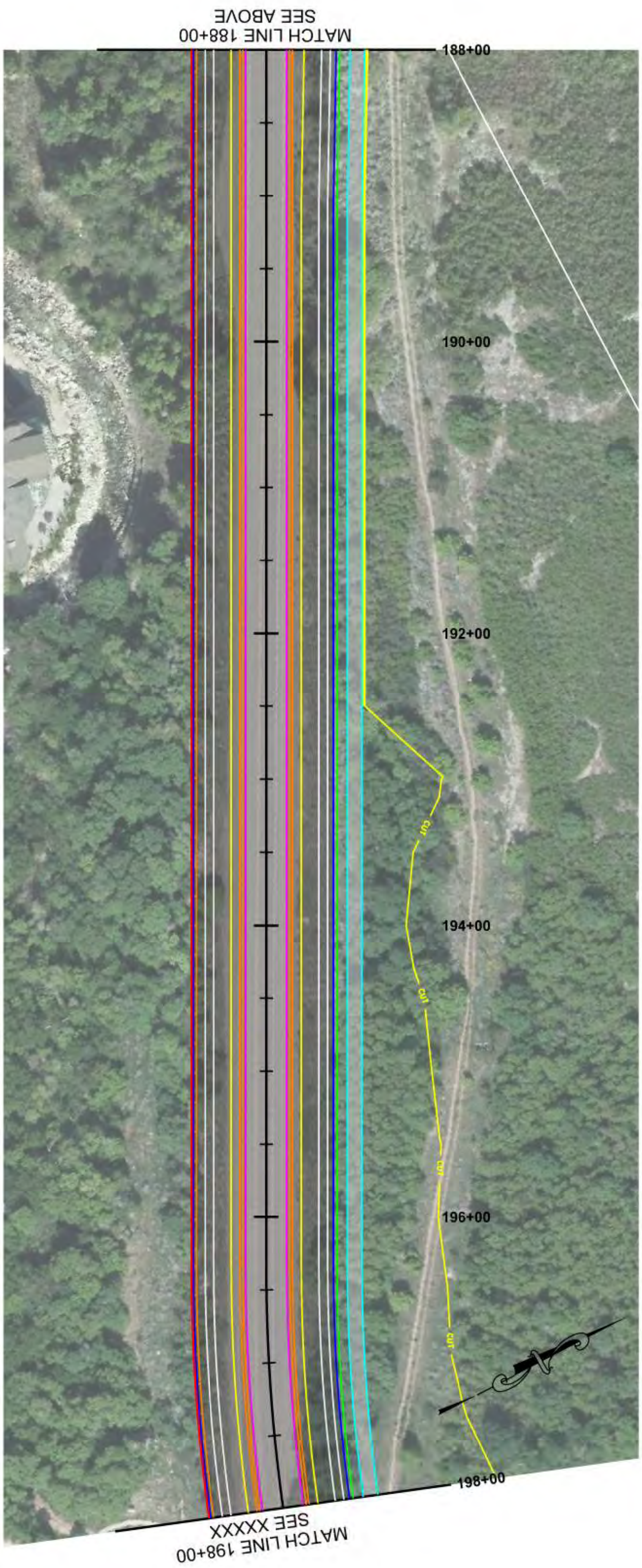
SHEET NO.

1/29/2020





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PROJECT NUMBER	XXXX	PIN	16092

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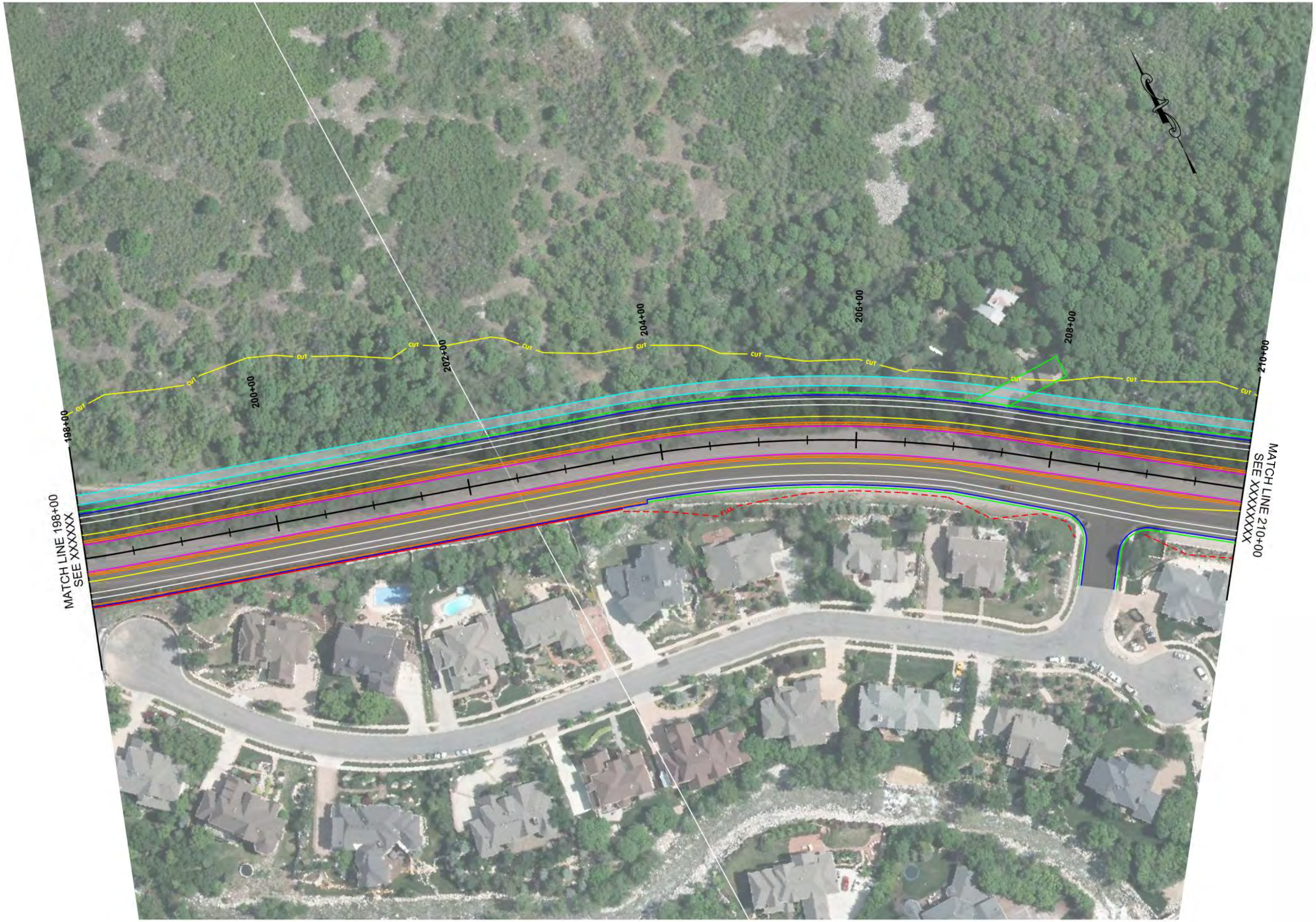

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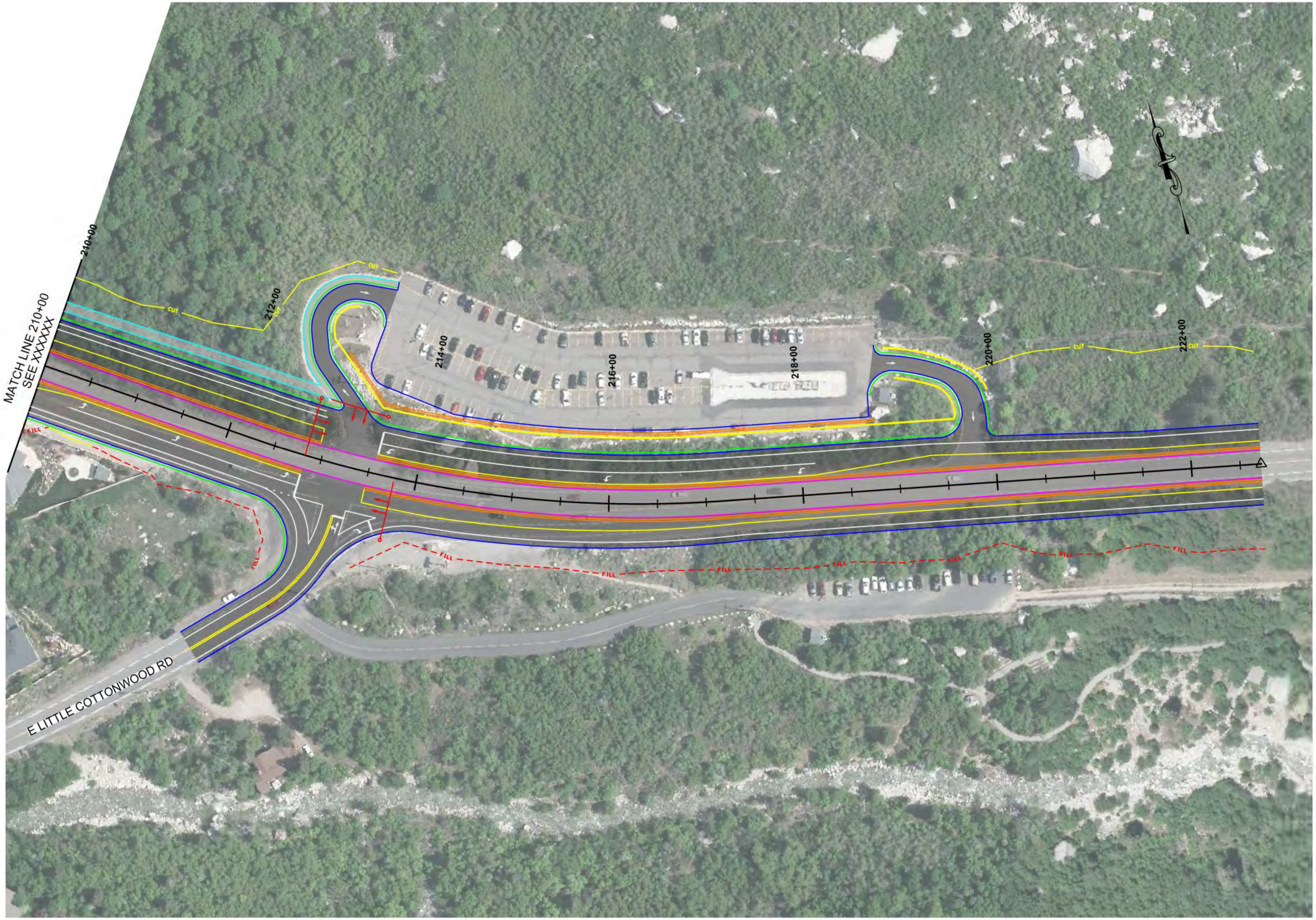

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PROJECT: LITTLE COTTONWOOD CANYON EIS

COG RAIL SEGMENT

PIN 16092

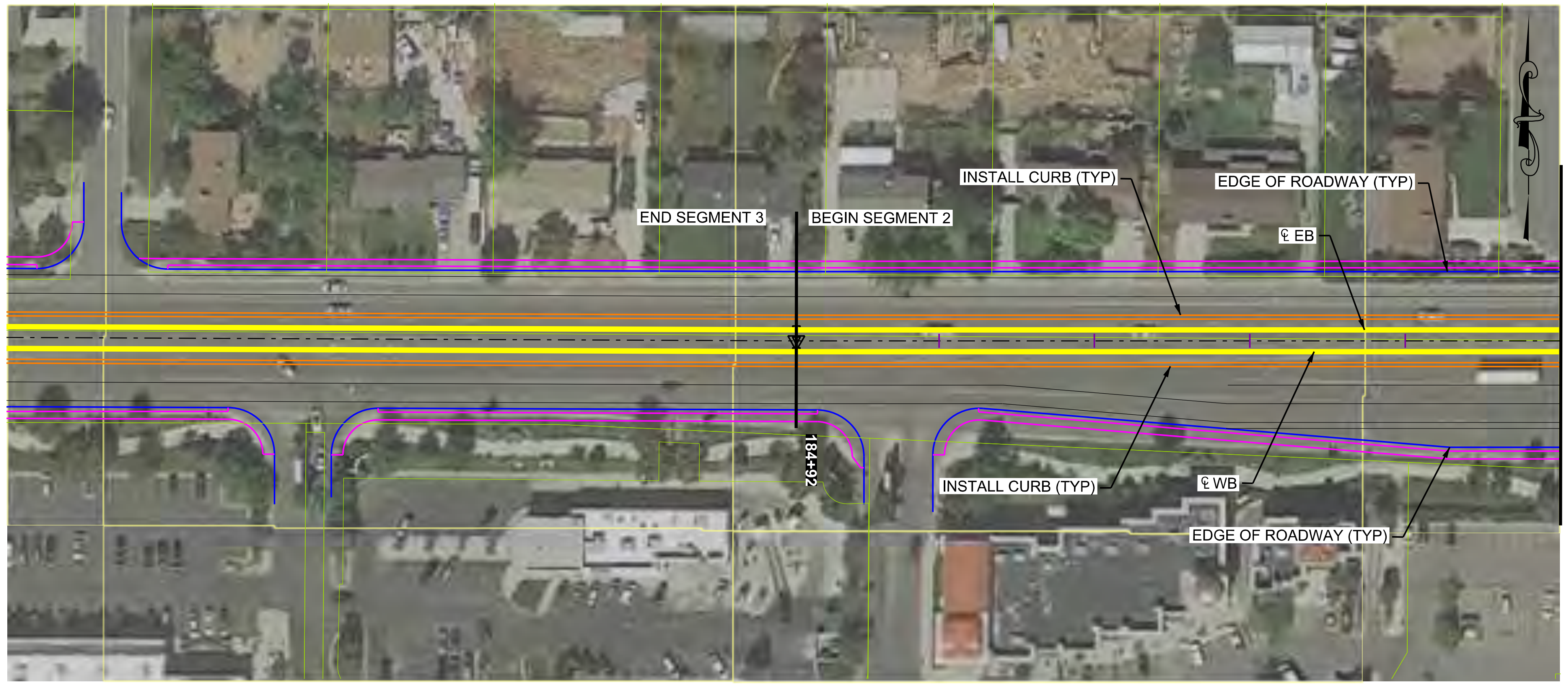
PROJECT NUMBER: XXXX

SHEET NO.

1/29/2020

APPENDIX B3

Preliminary Design Plans for Segment 3 – 9400 South and Highland Drive to Mouth of Little Cottonwood Canyon



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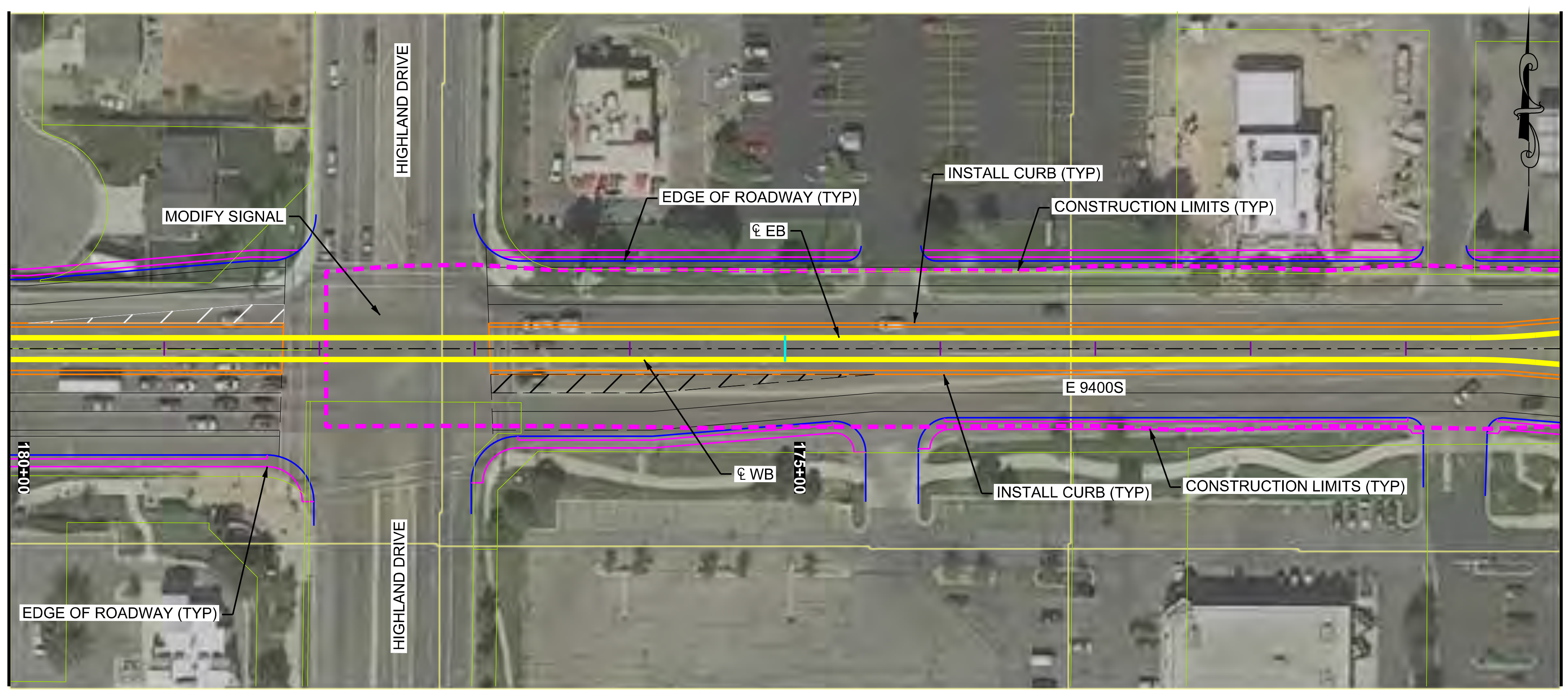

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PROJECT: LITTLE COTTONWOOD CANYON EIS
COG RAIL SEGMENT 2

PIN: 16092

PROJECT NUMBER: XXXX

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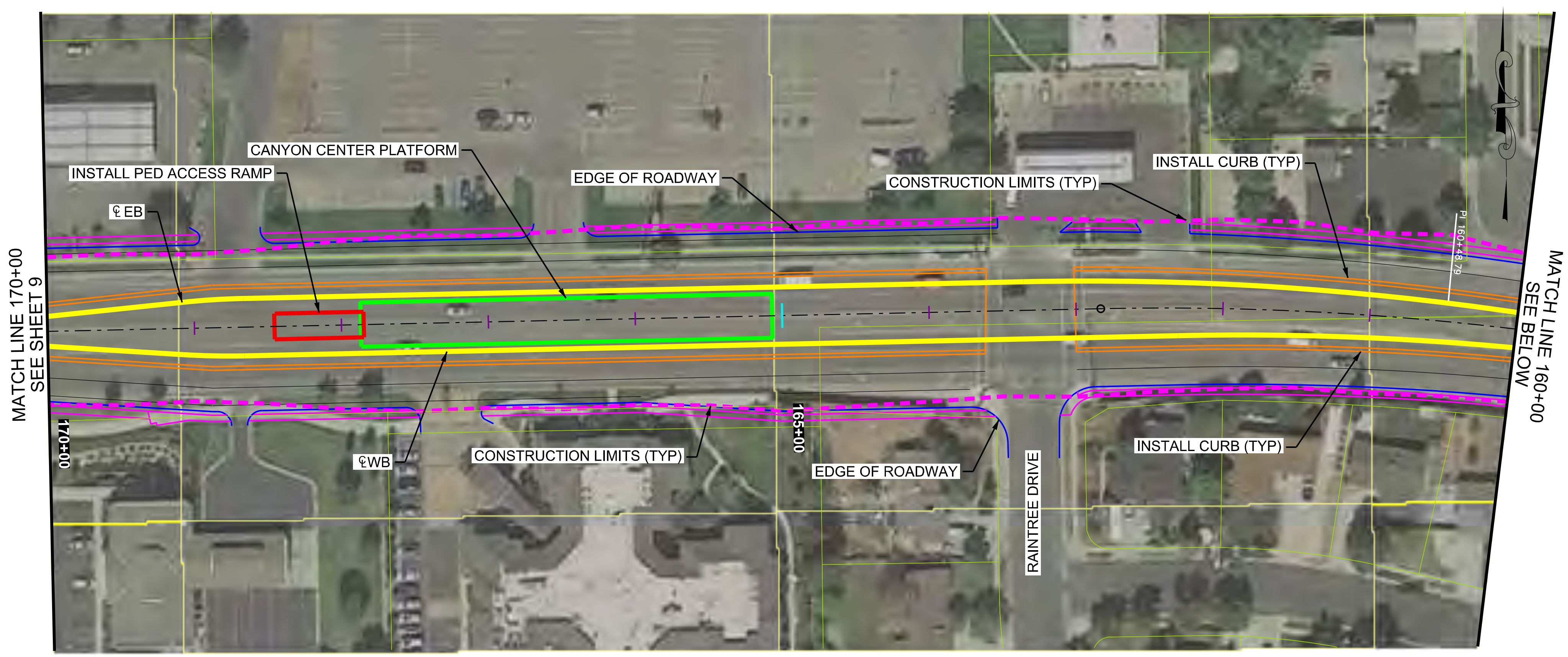

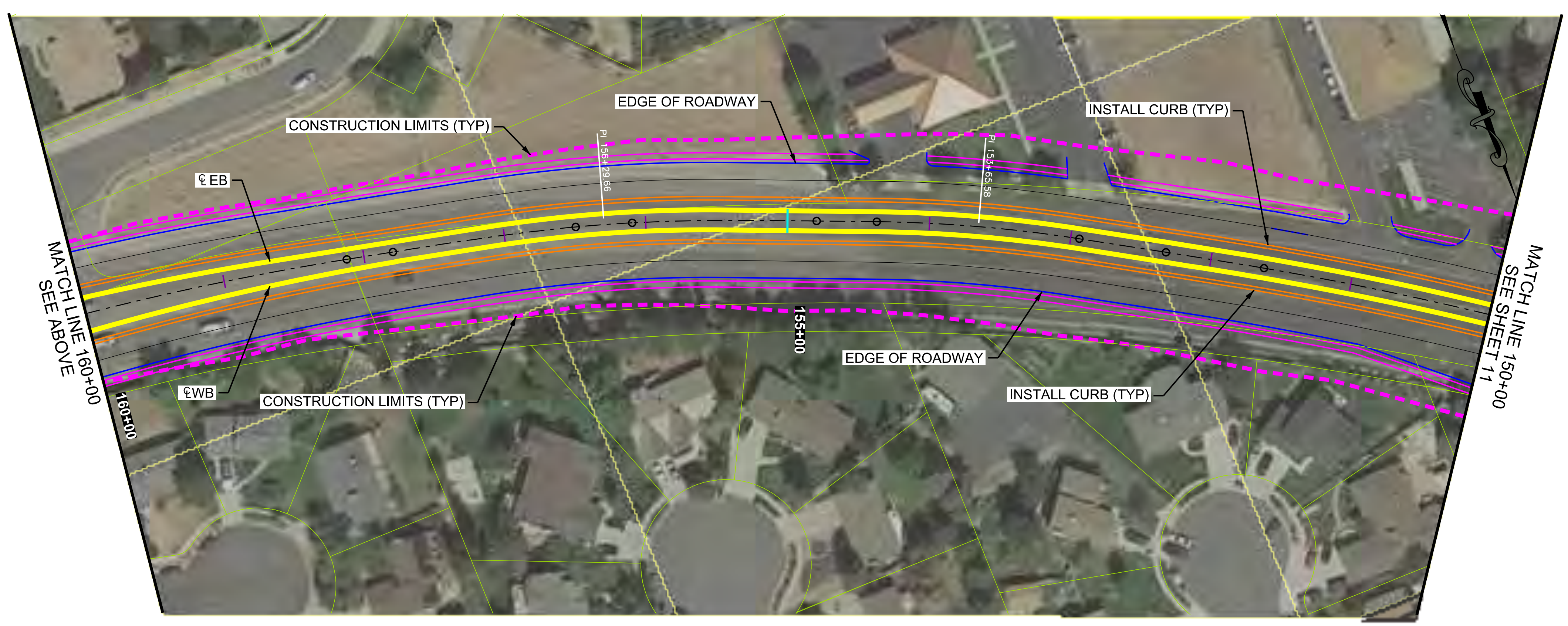

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NO.	DATE	APPROVED BY	REMARKS

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PROJECT: LITTLE COTTONWOOD CANYON EIS

COG RAIL SEGMENT 2

PIN 16092

PROJECT NUMBER XXXX

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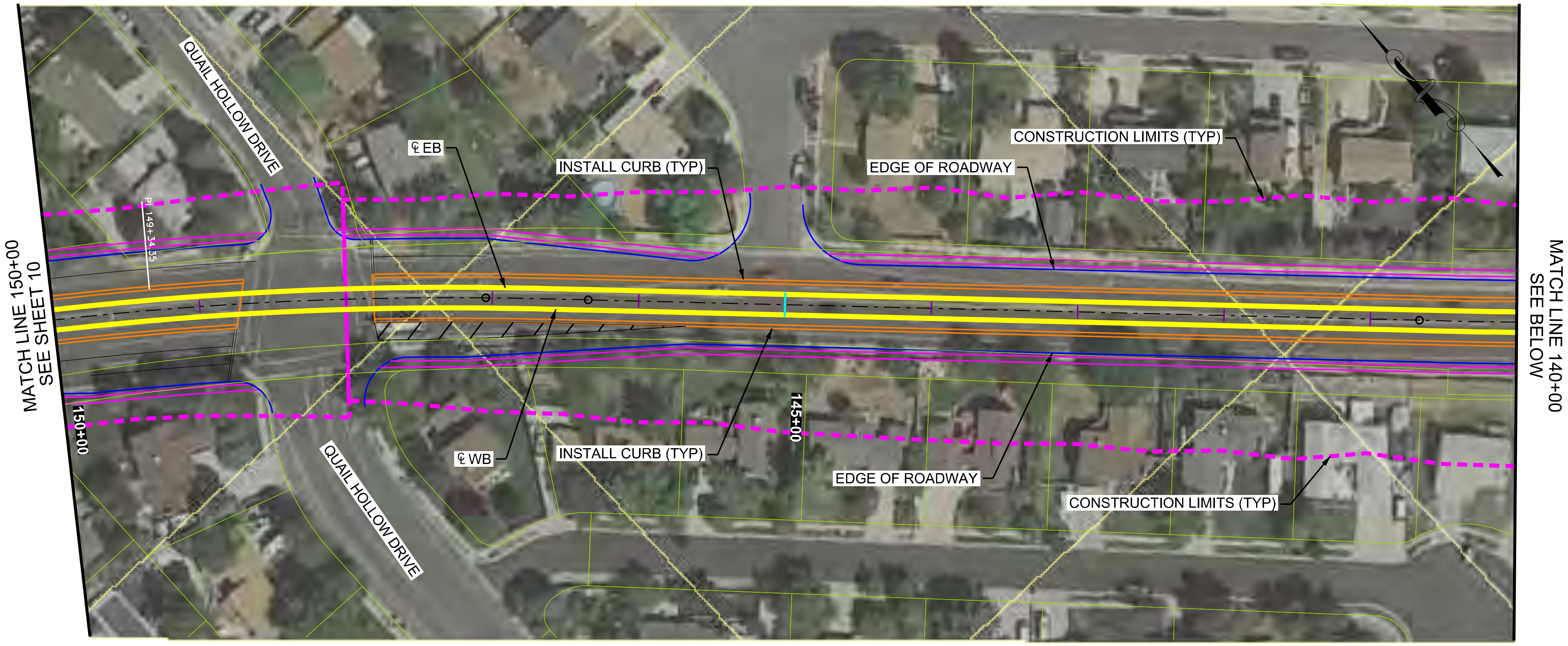
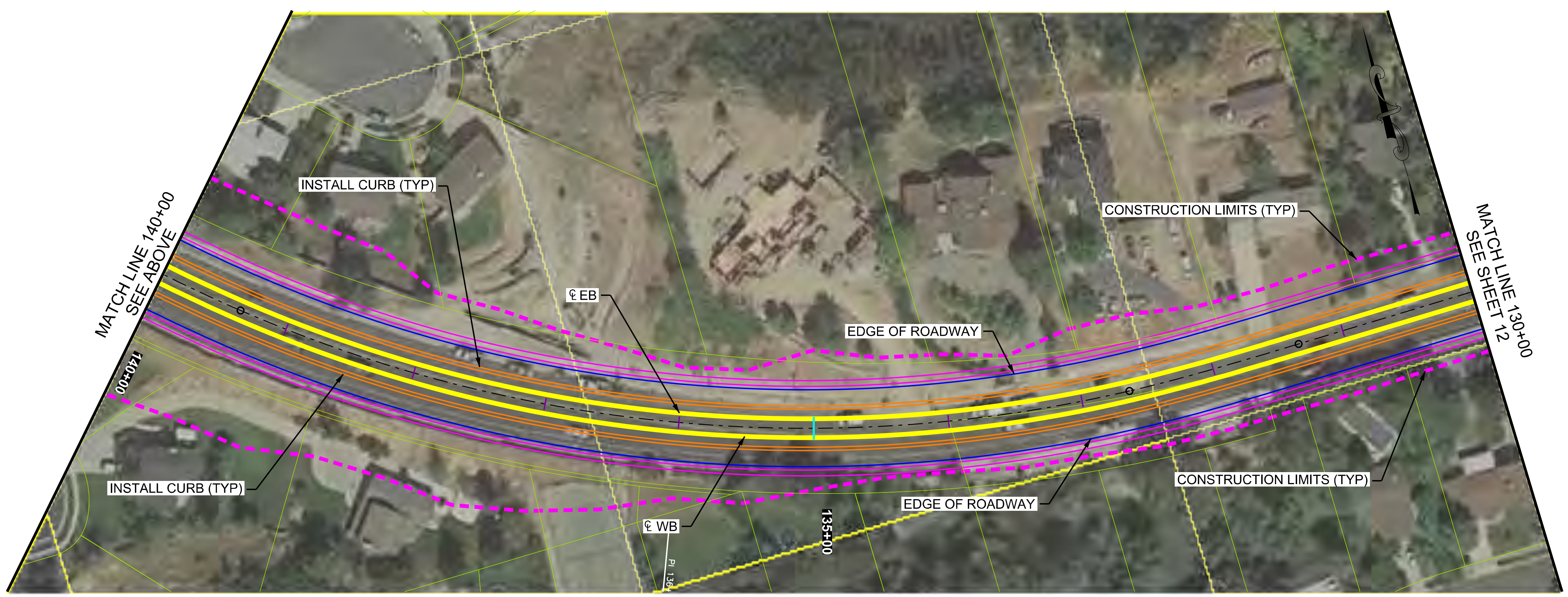
2/15/2020





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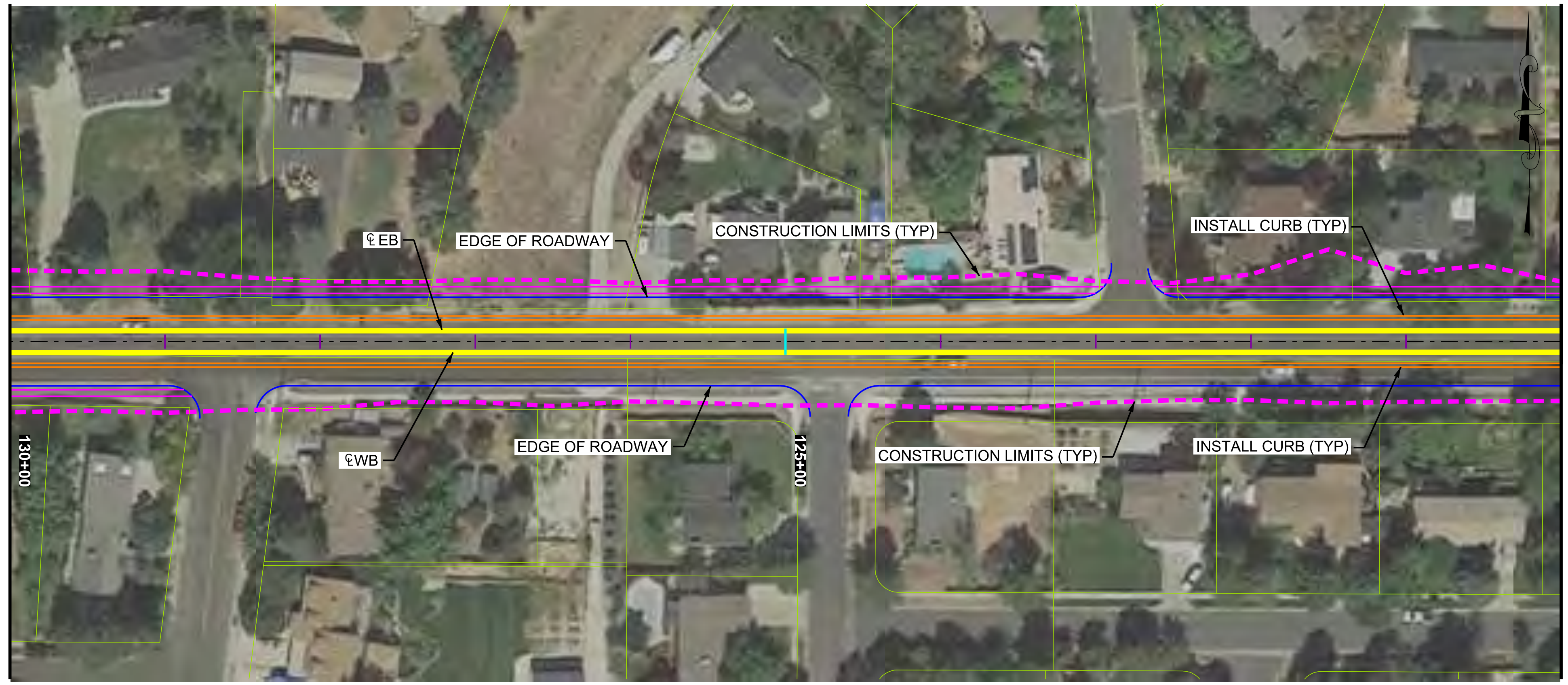
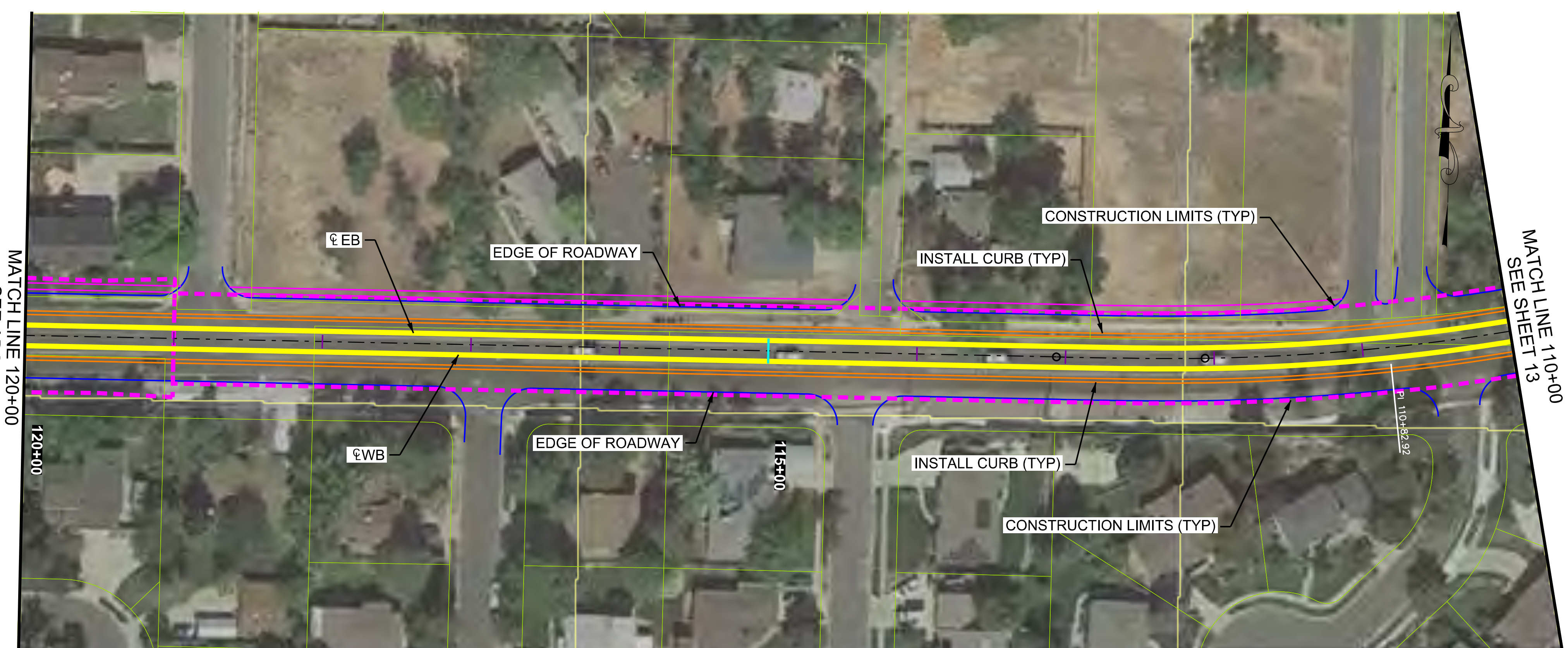
COG RAIL SEGMENT 2

PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 11





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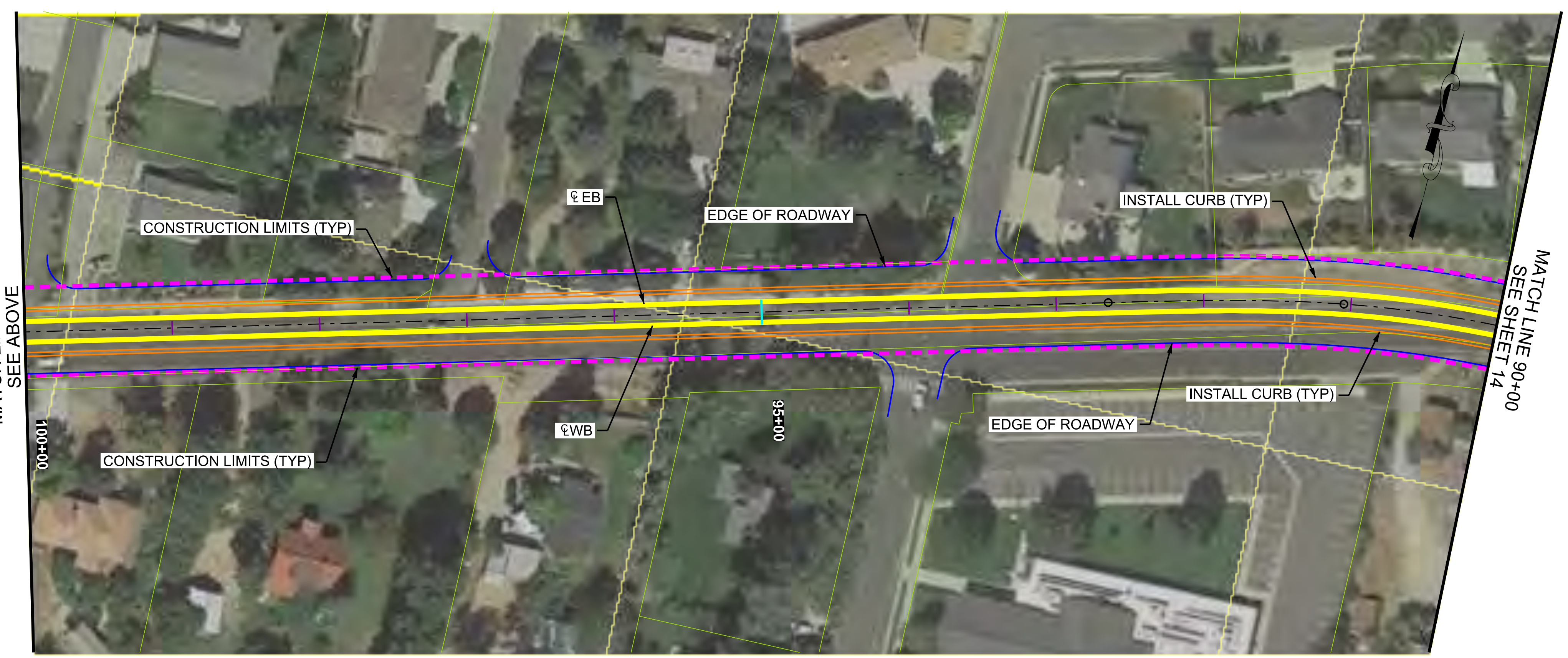
COG RAIL SEGMENT 2

PIN 16092

PROJECT NUMBER: XXXX

SHEET NO. 12



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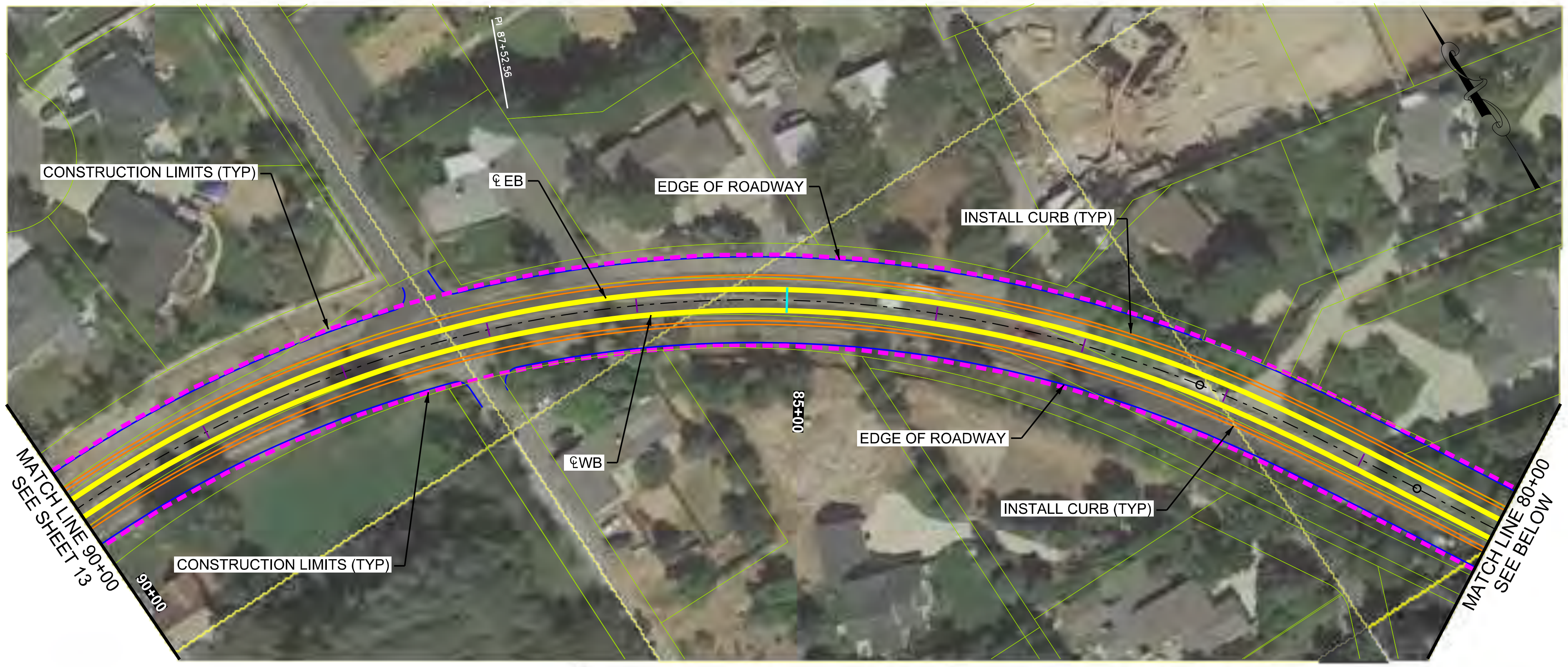
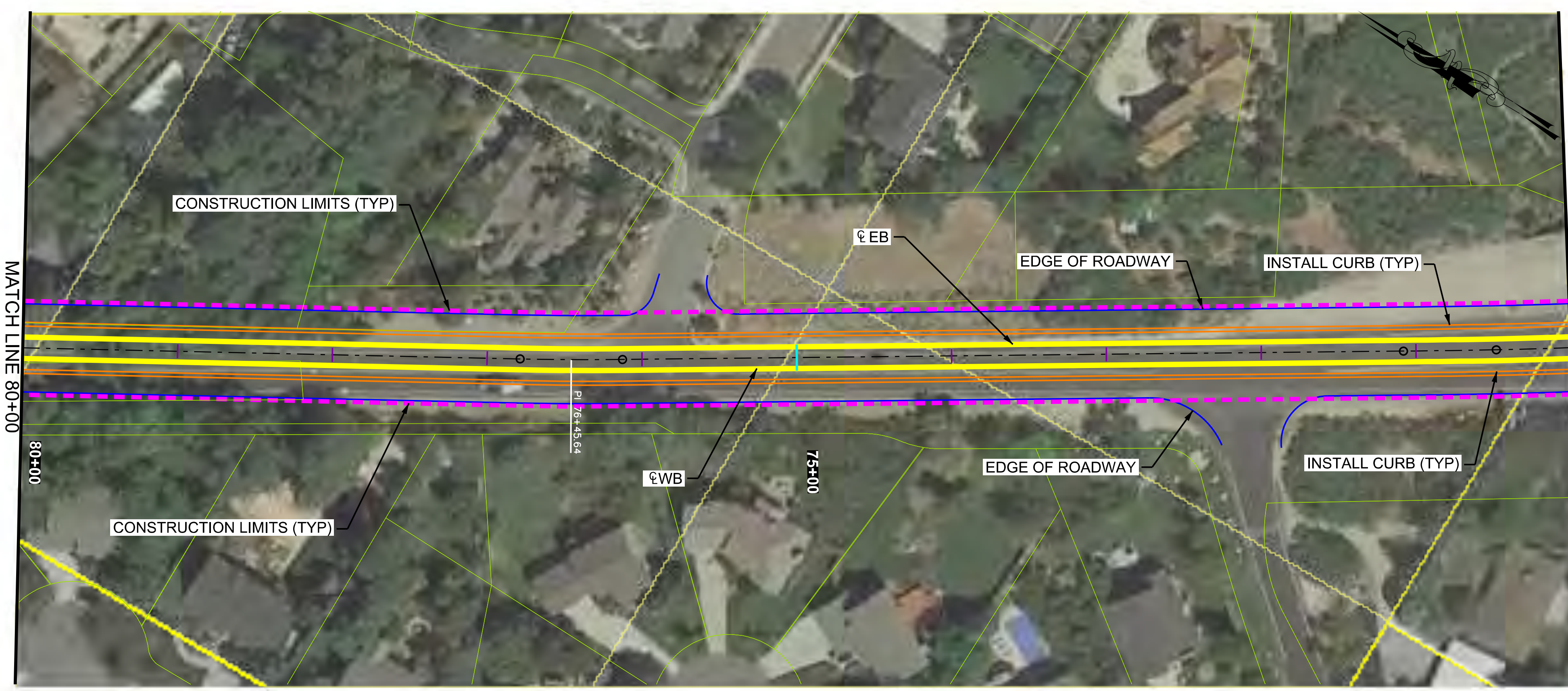
COG RAIL SEGMENT 2

PIN: 16092

PROJECT NUMBER: XXXX

SHEET NO. 13





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PROJECT NUMBER XXXX

SHEET NO. 14

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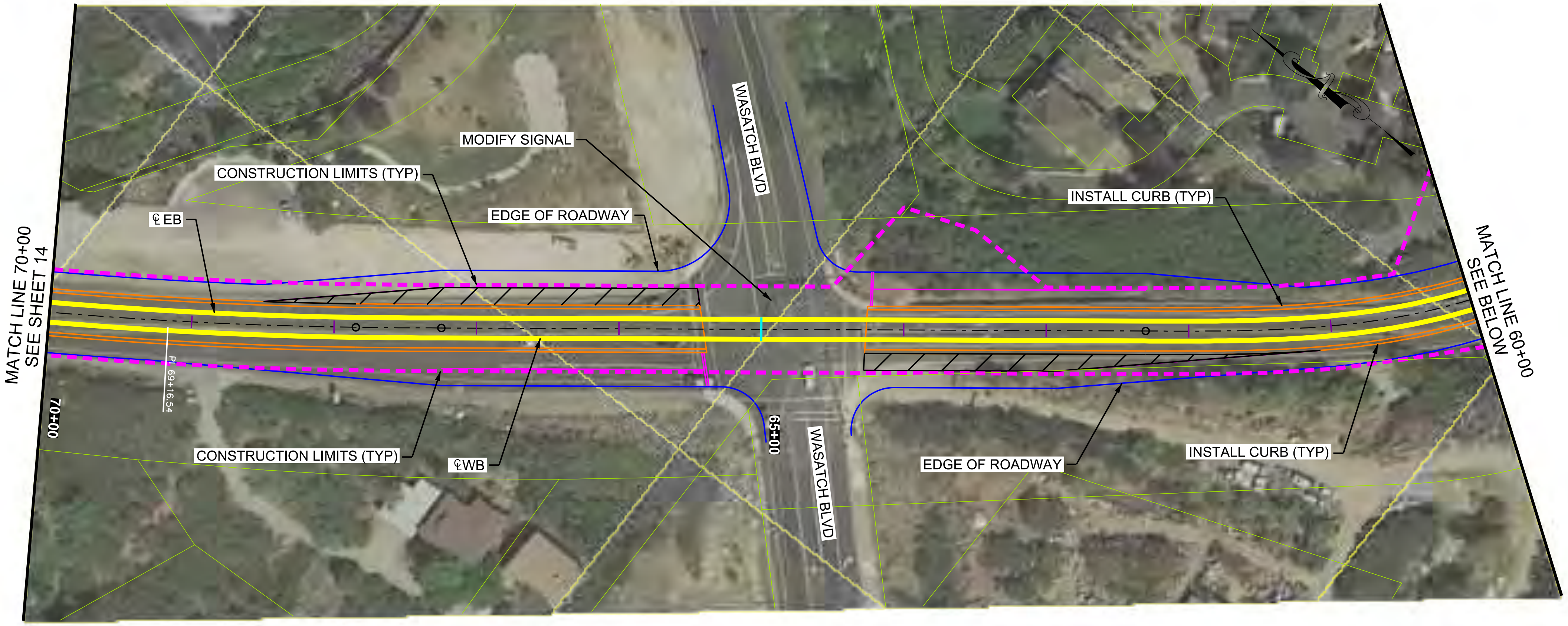

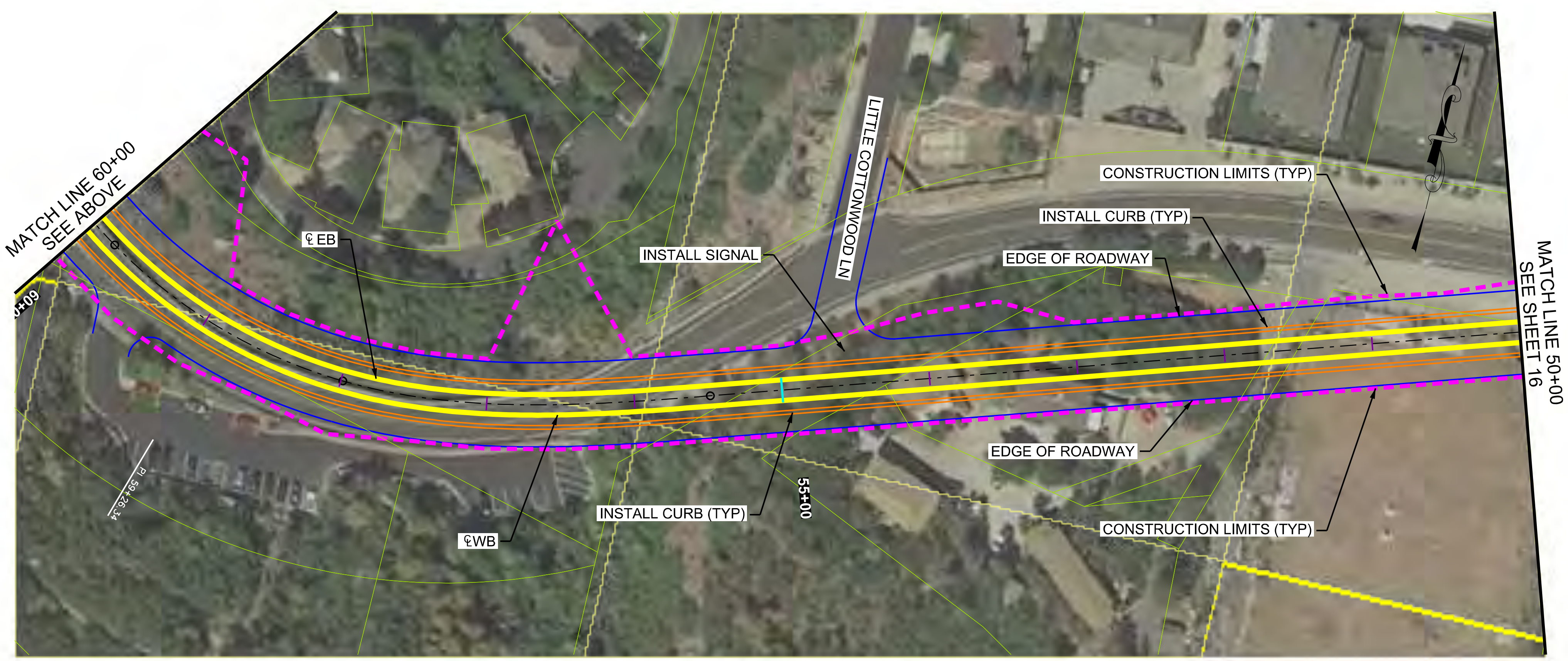

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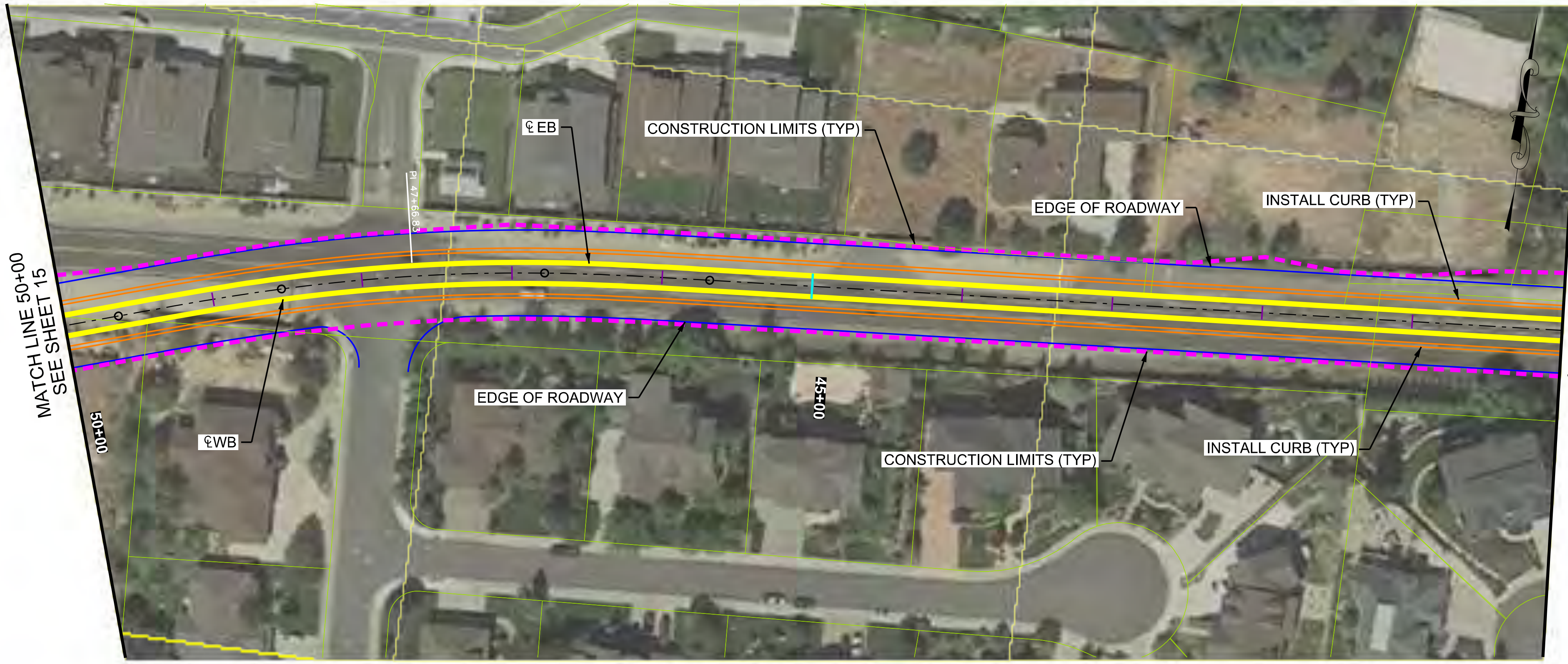
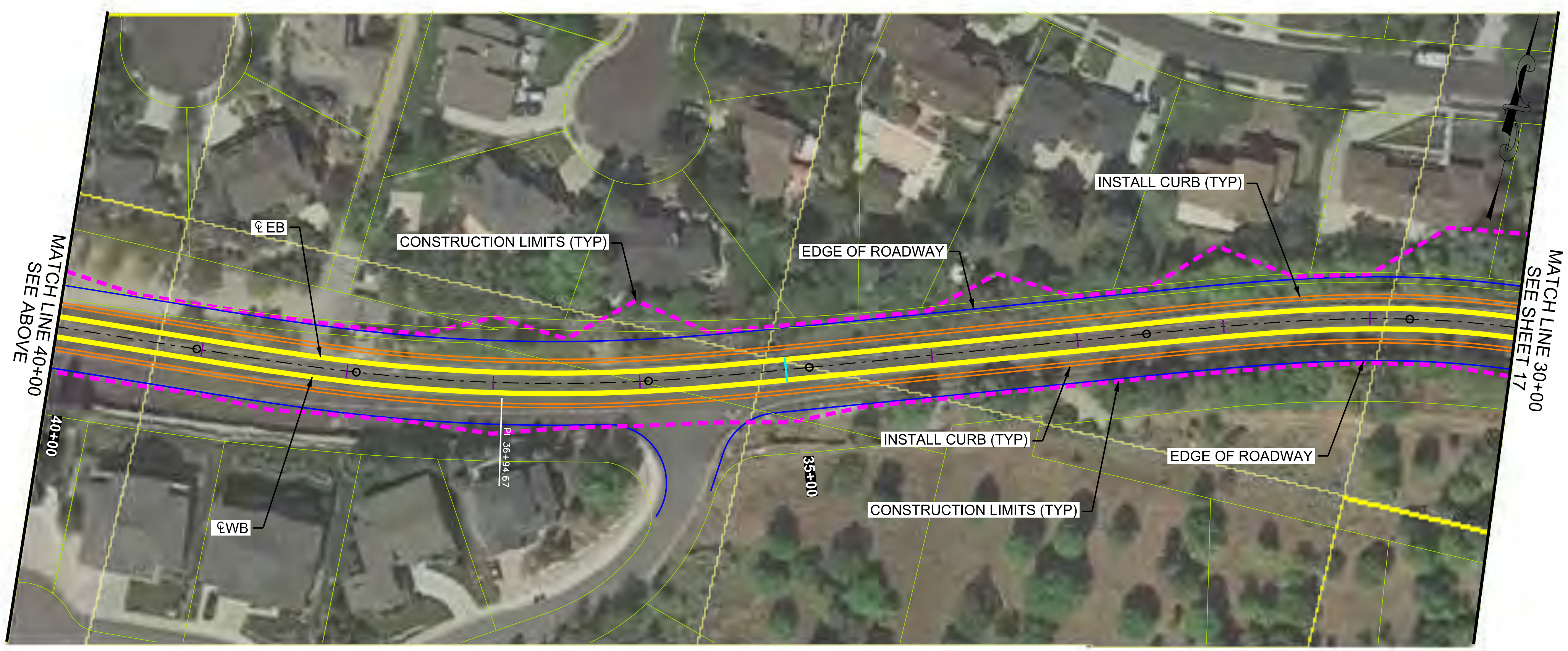
PROJECT NUMBER: XXXX

SHEET NO. 15

2/15/2020





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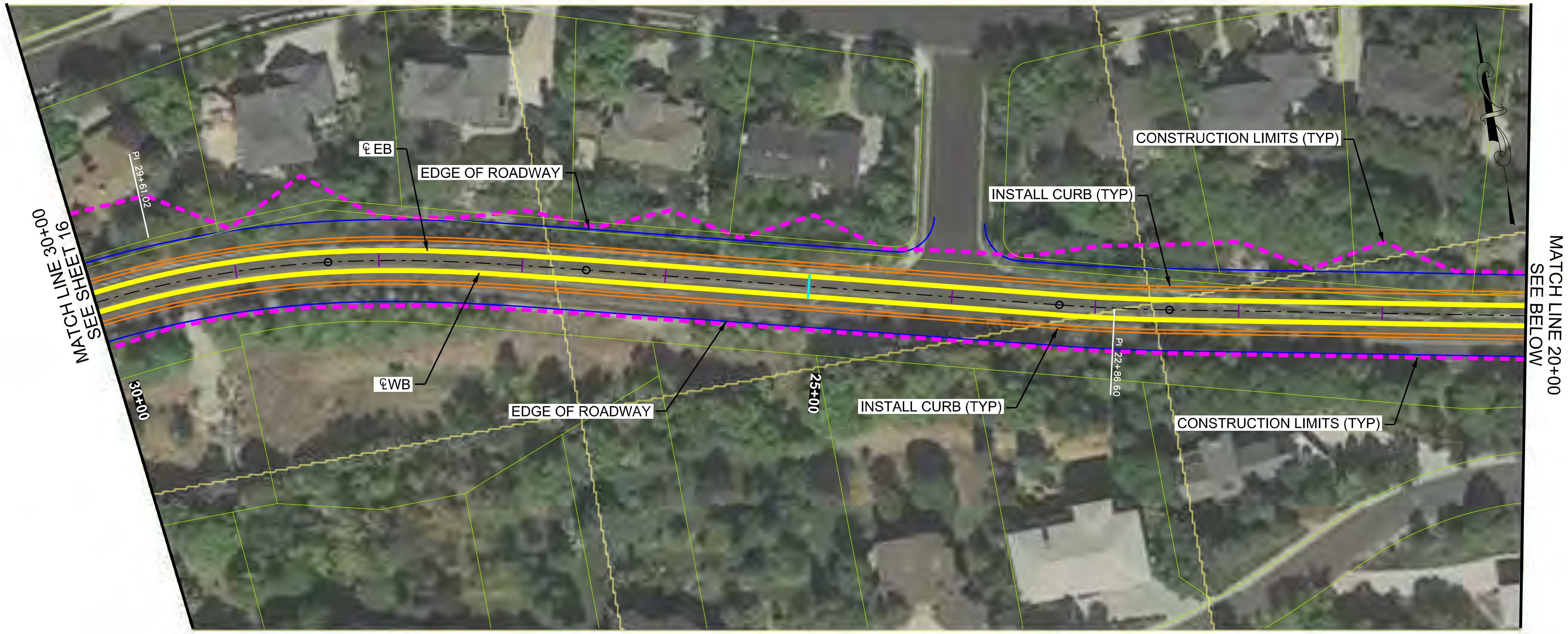
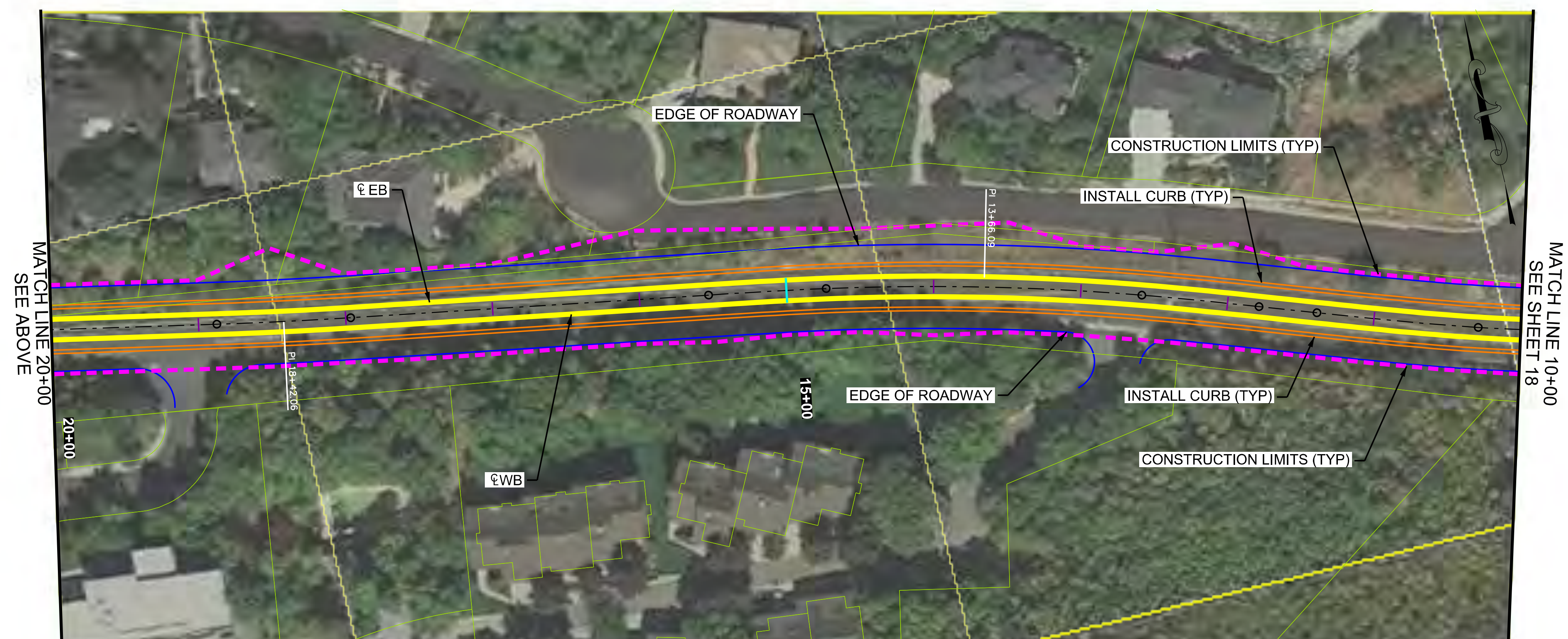
PROJECT NUMBER: XXXX

PIN: 16092

SHEET NO. 16

2/15/2020





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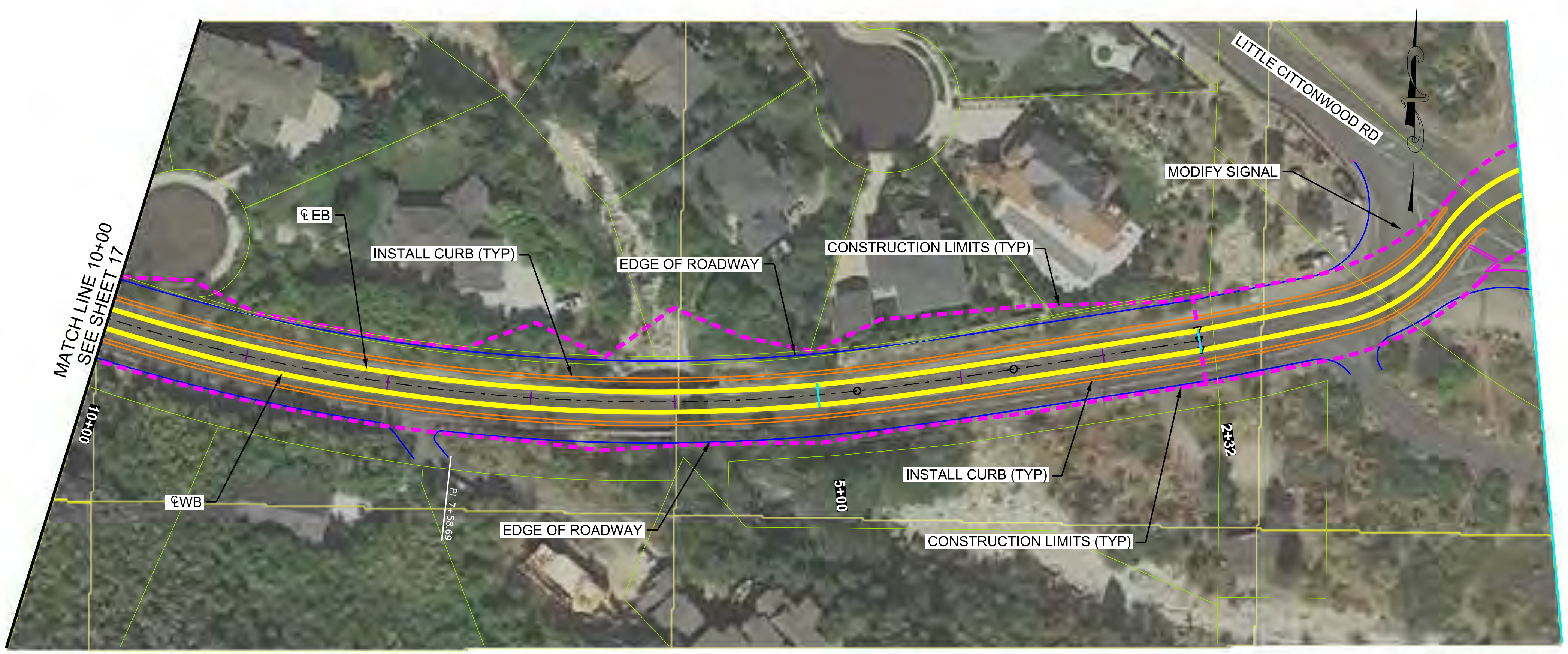
COG RAIL SEGMENT 2

PIN 16092

PROJECT NUMBER: XXXX

SHEET NO. 17

2/16/2020



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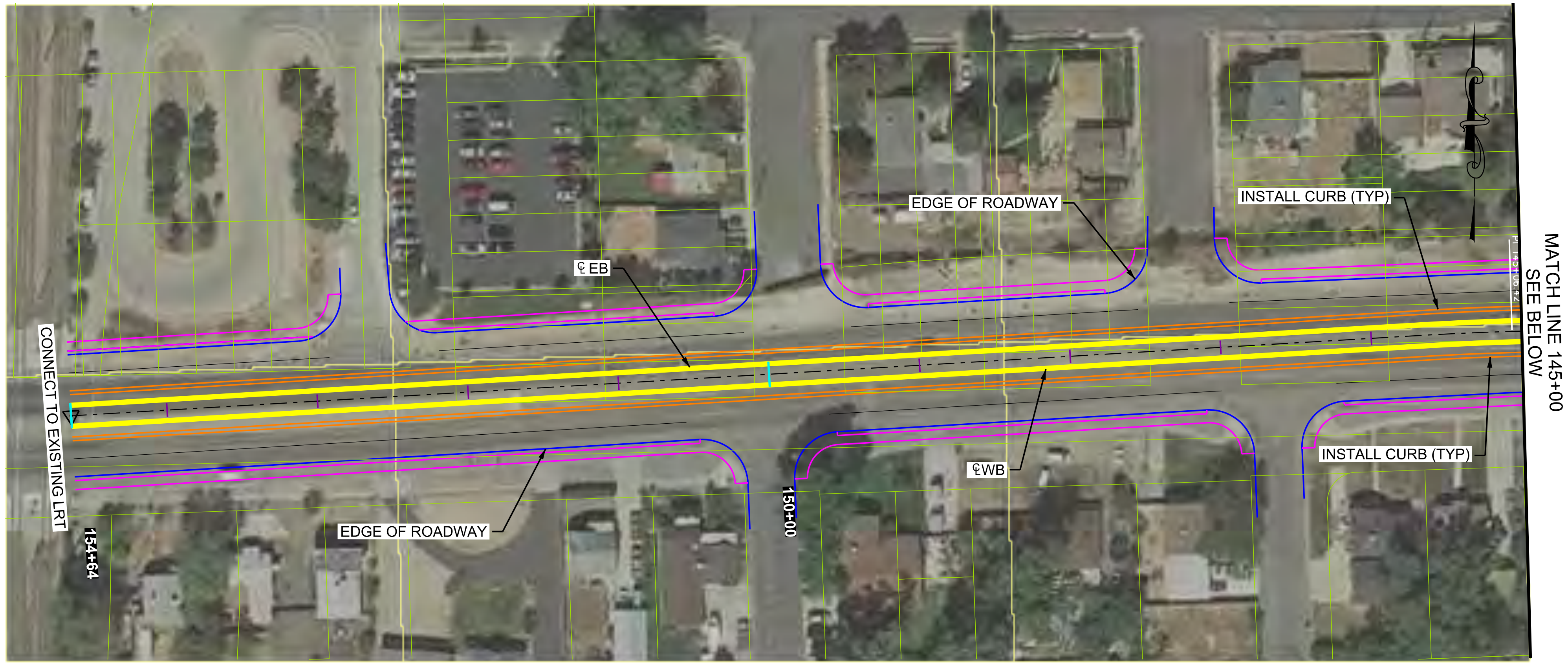
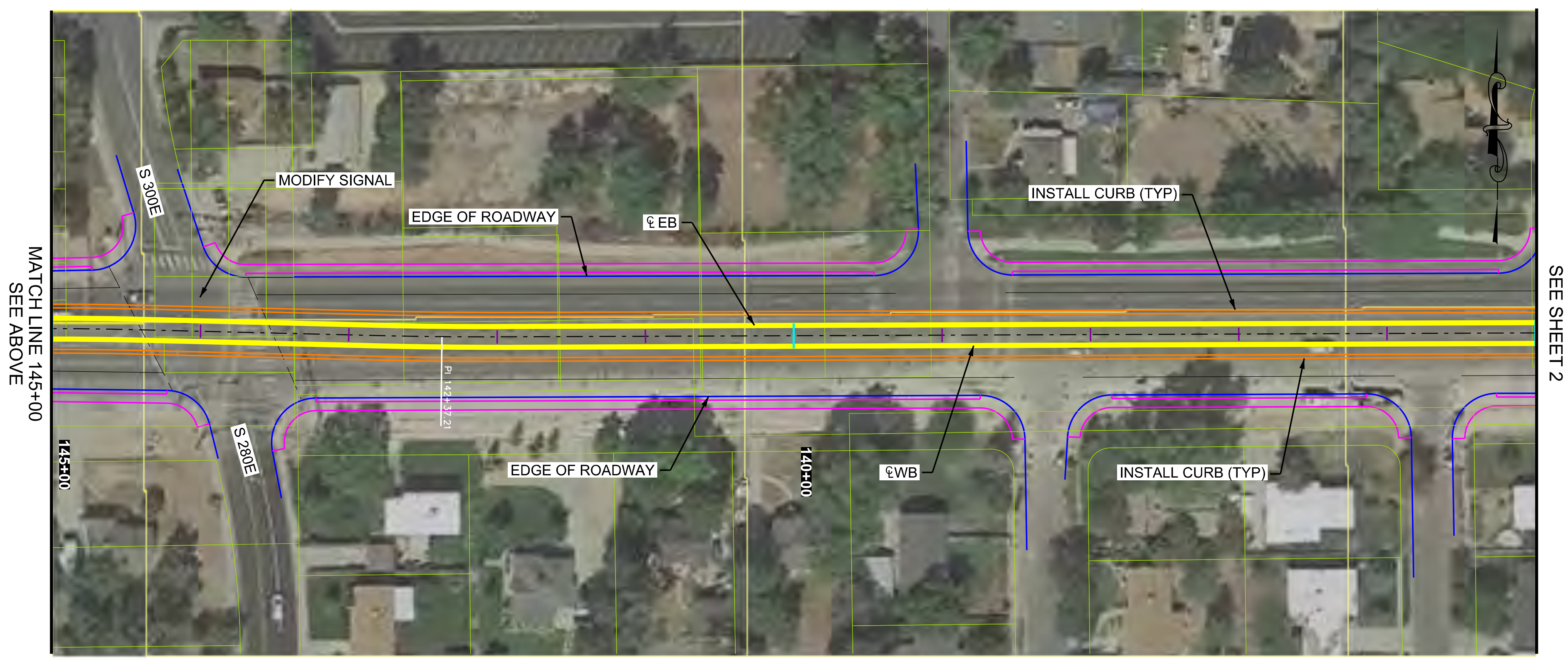
2/16/2020

APPENDIX B4

Preliminary Design Plans for Segment 4 – Historic Sandy TRAX Station 9400 South and Highland Drive





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COG RAIL SEGMENT 3

PROJECT NUMBER: XXXX

PIN: 16092

SHEET NO. 1

2/14/2020

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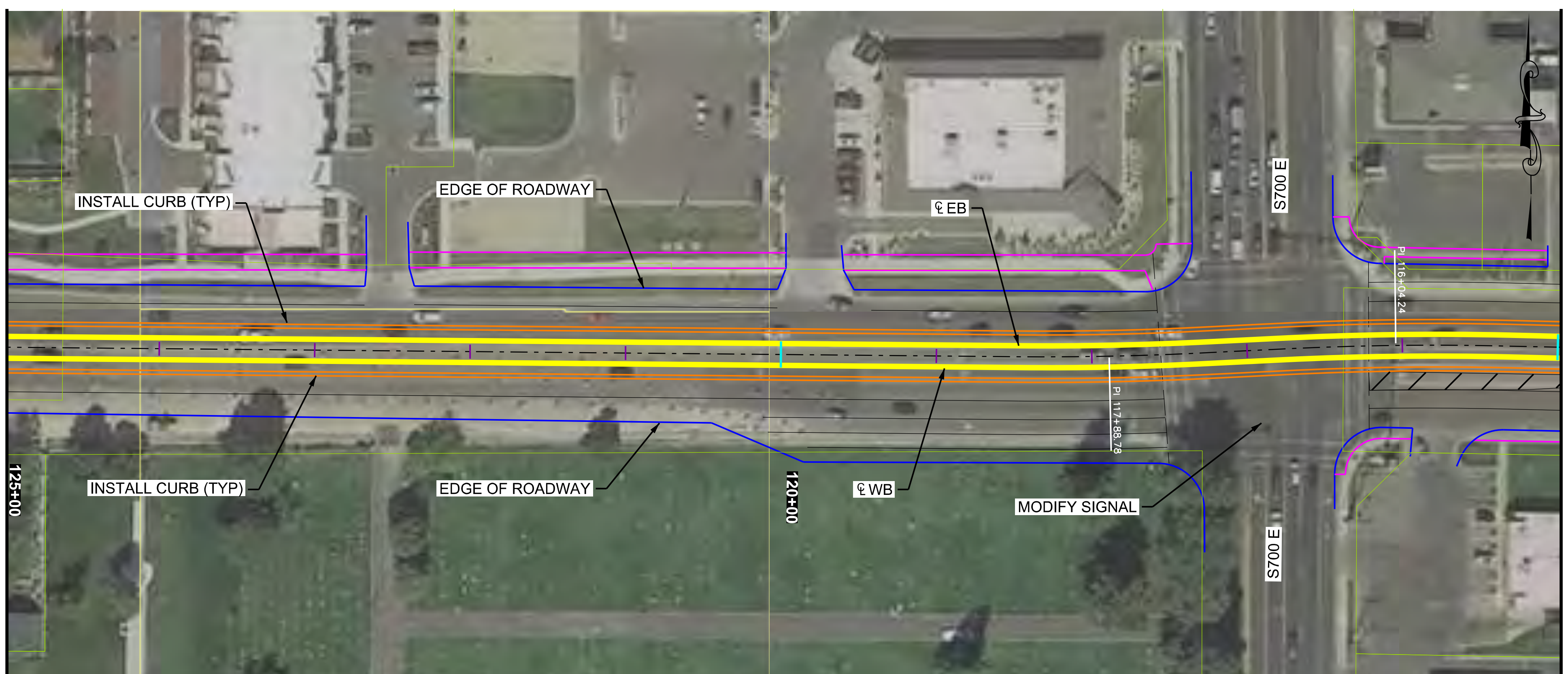

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COG RAIL SEGMENT 3

PROJECT NUMBER: XXXX
PIN: 16092

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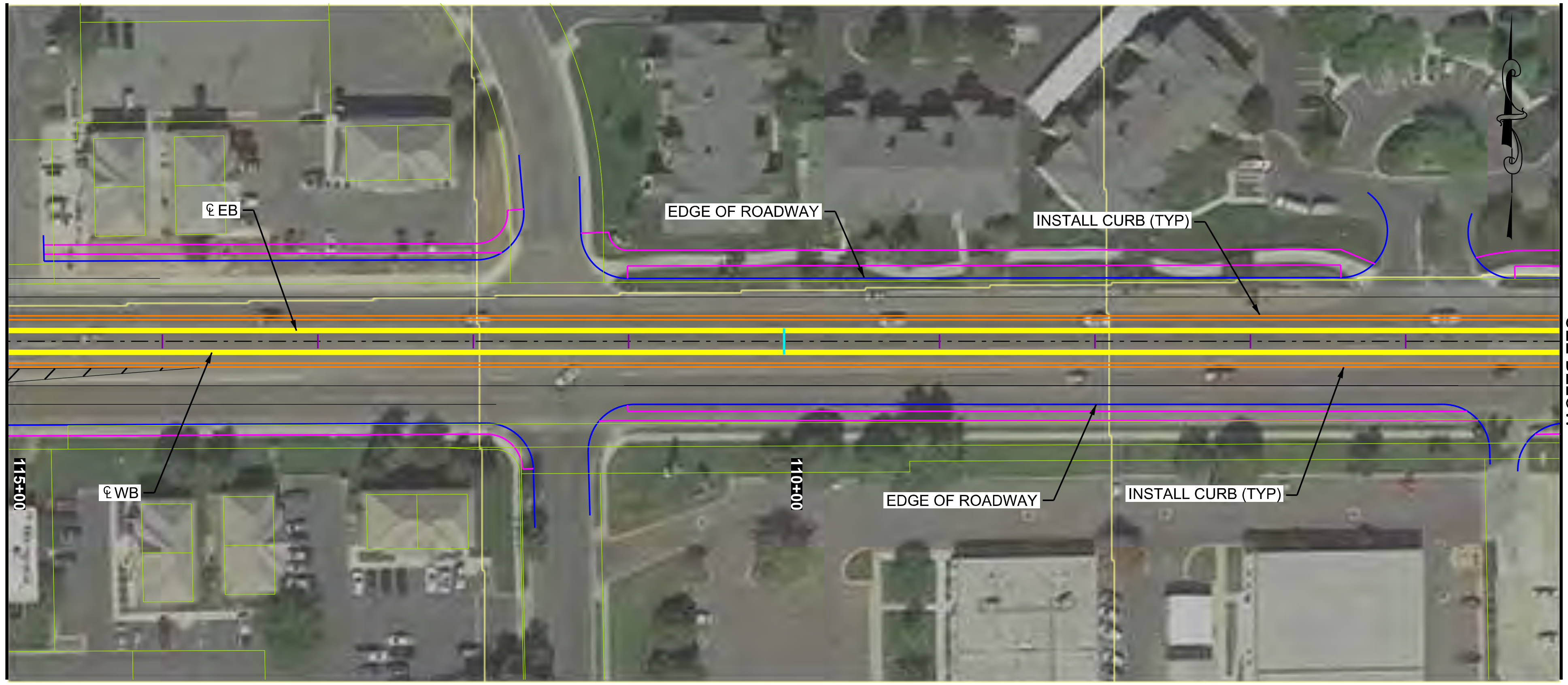
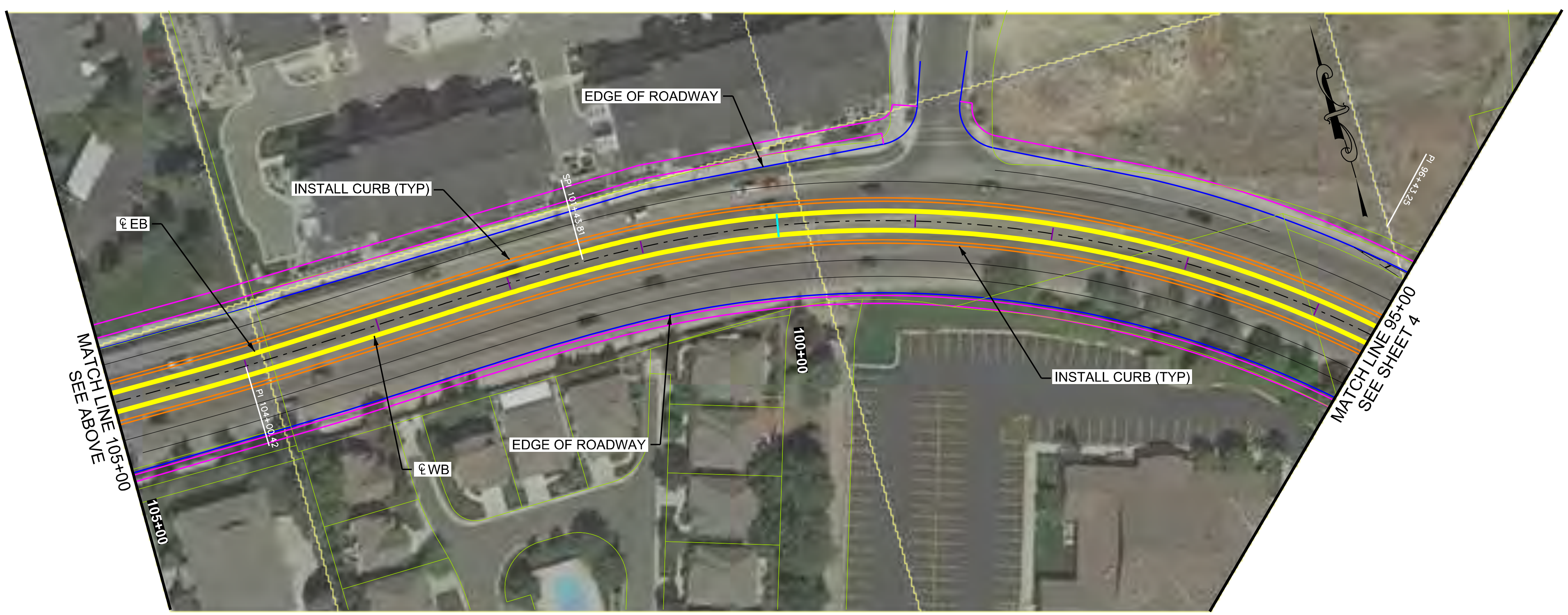
2/14/2020





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COG RAIL SEGMENT 3

PIN 16092

PROJECT NUMBER: XXXX

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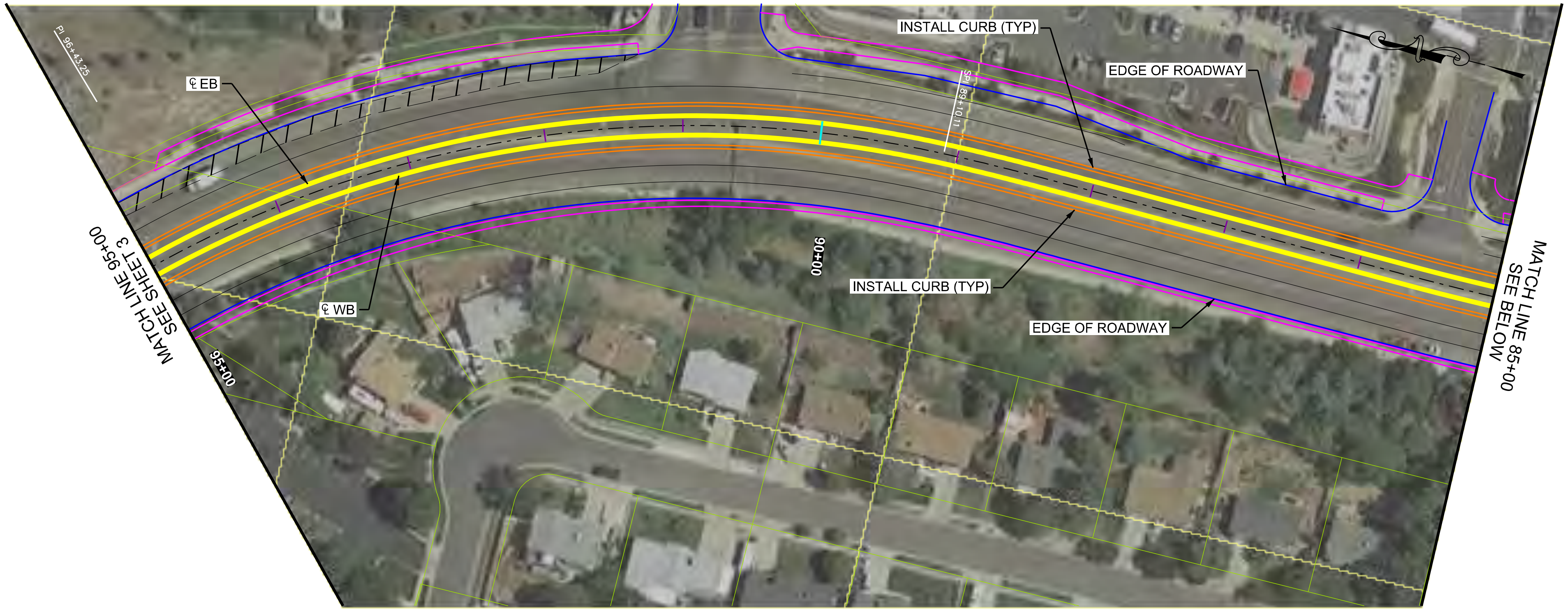
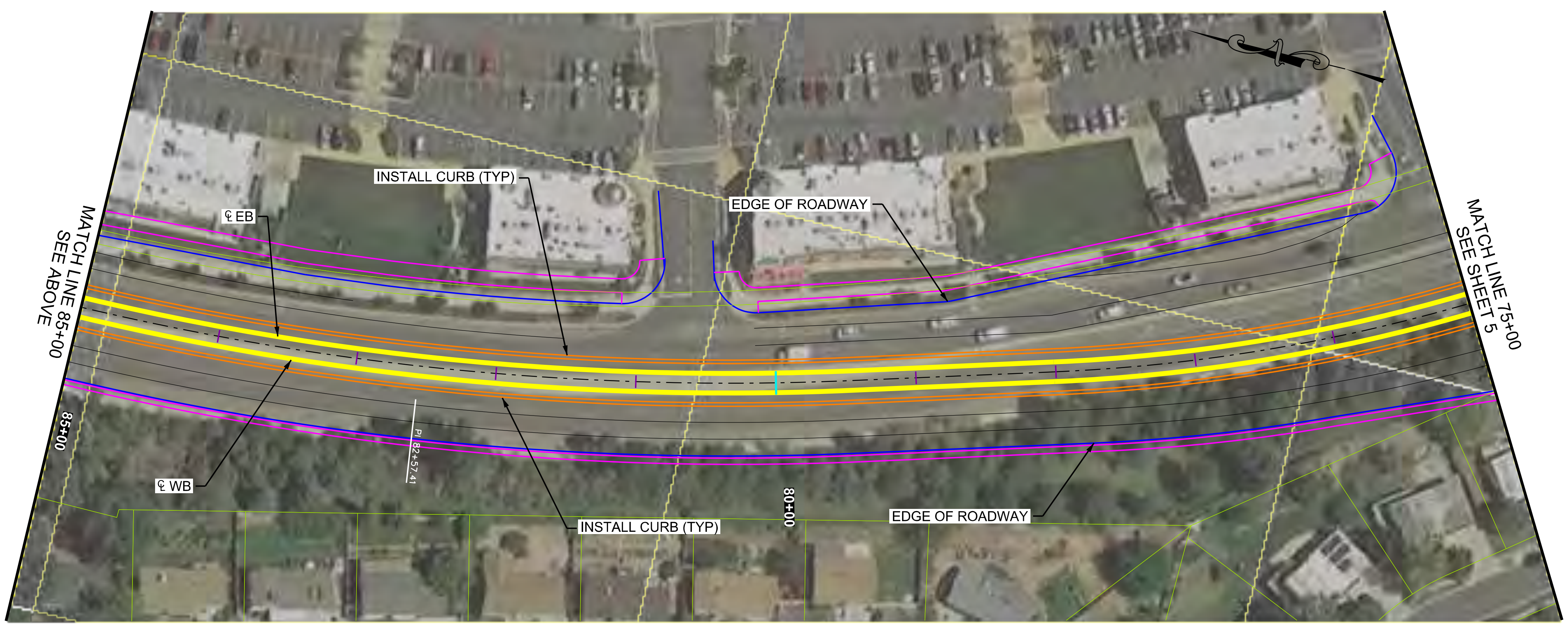
2/14/2020





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COG RAIL SEGMENT 3

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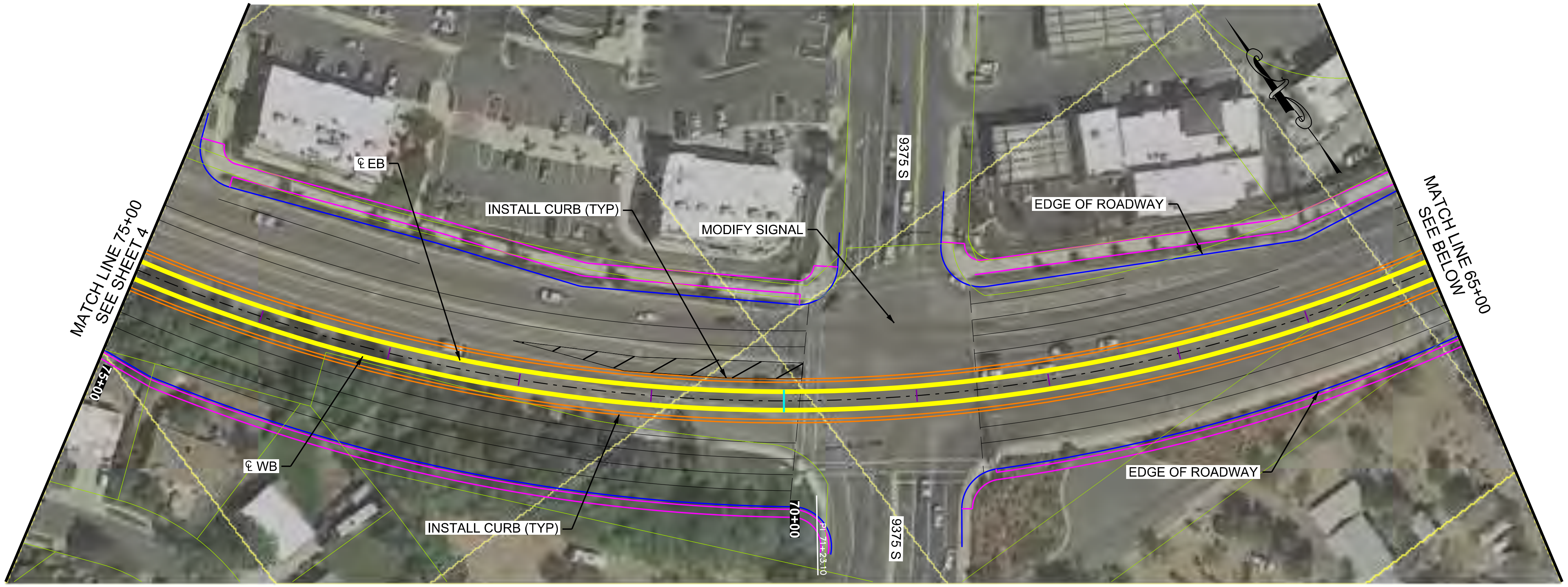
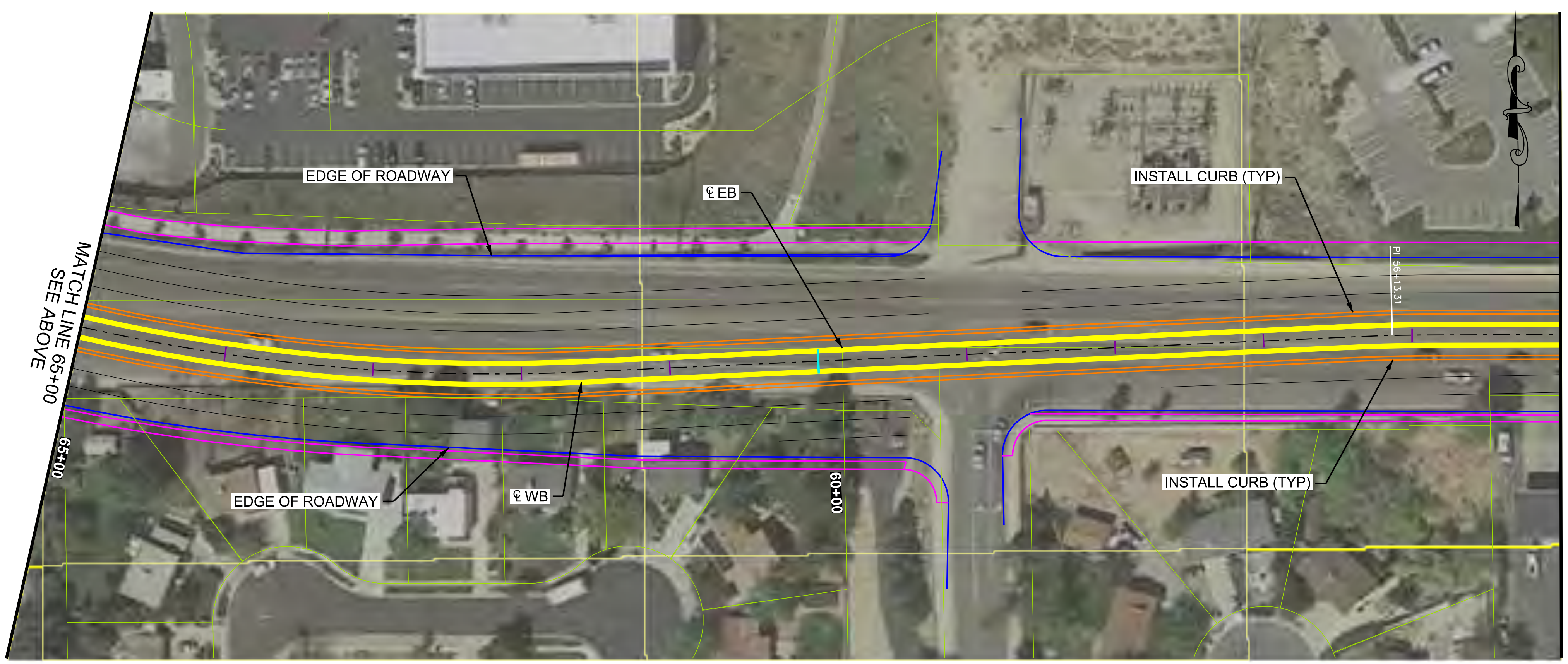
SHEET NO. 4

2/17/2020





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COG RAIL SEGMENT 3

PIN 16092

PROJECT NUMBER XXXX

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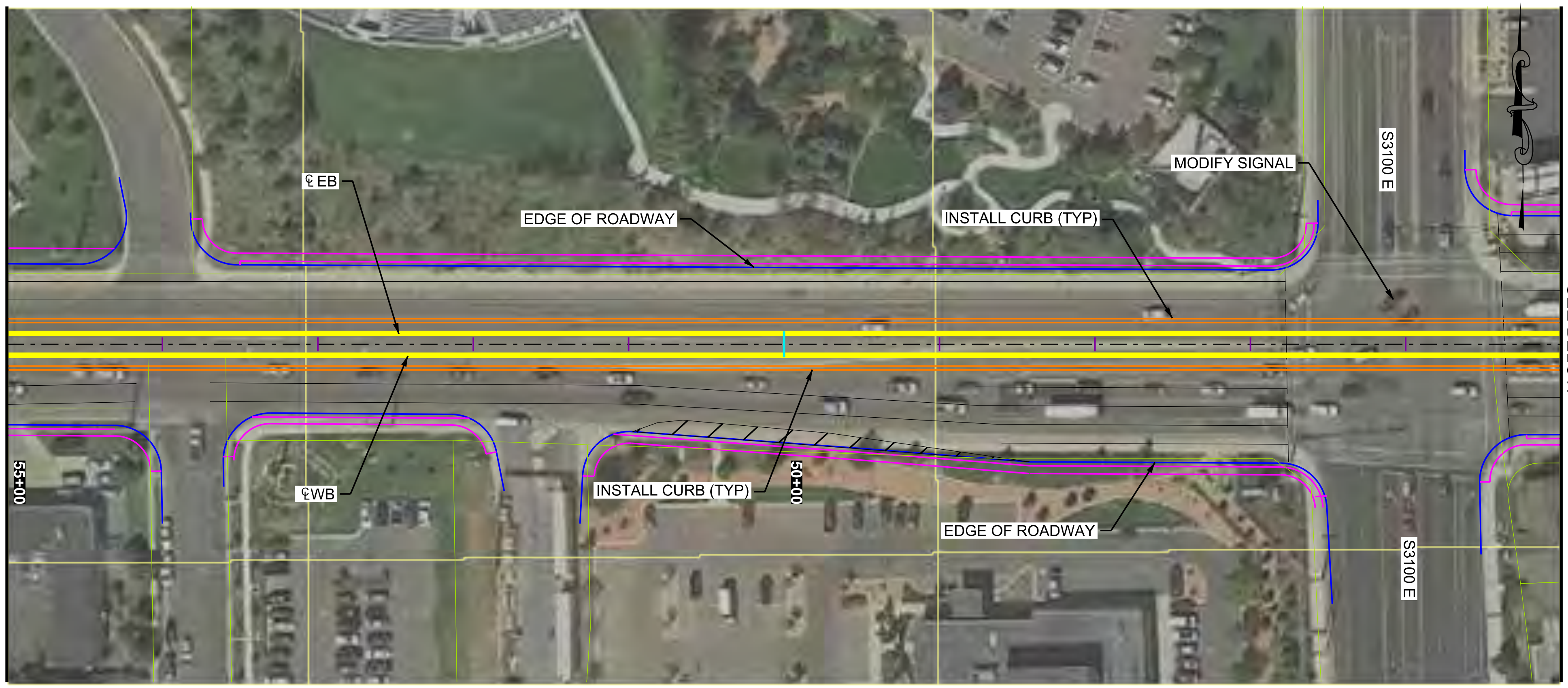

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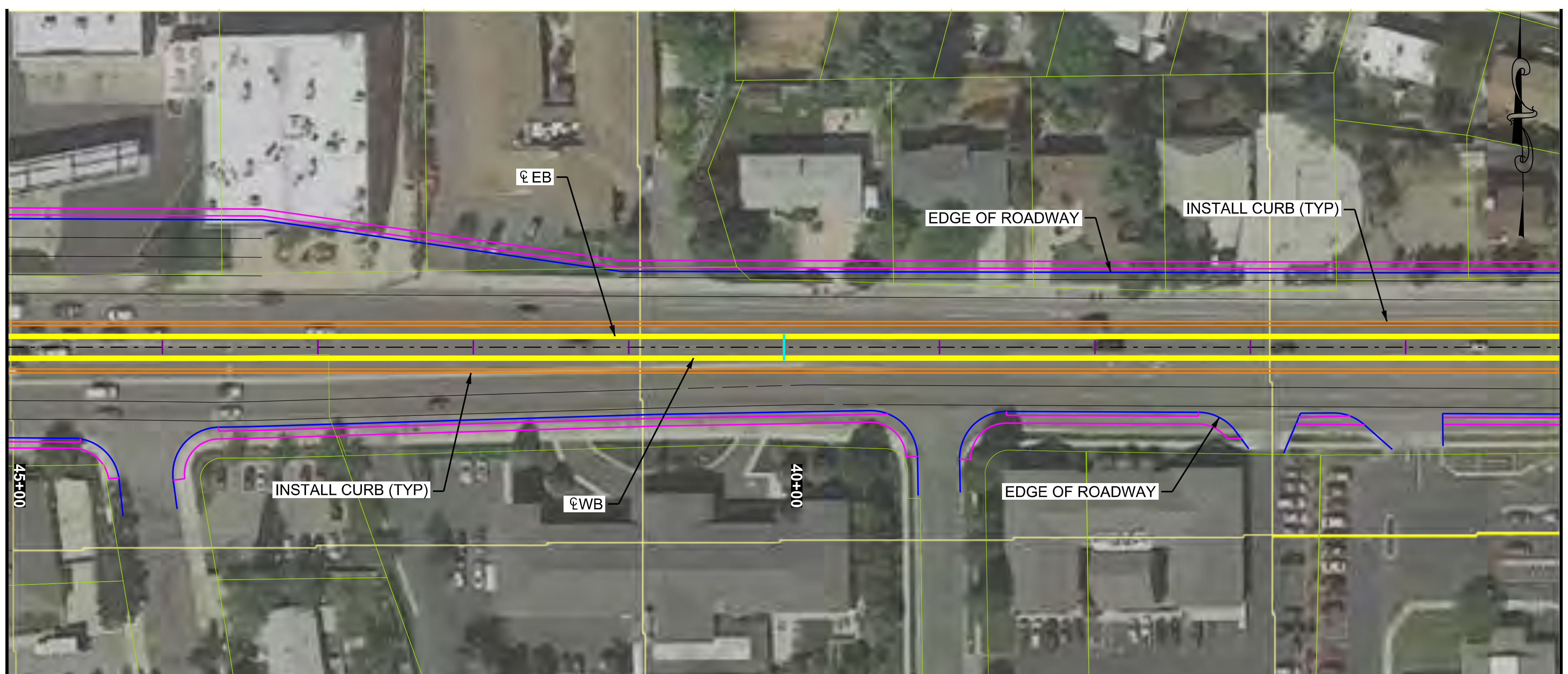

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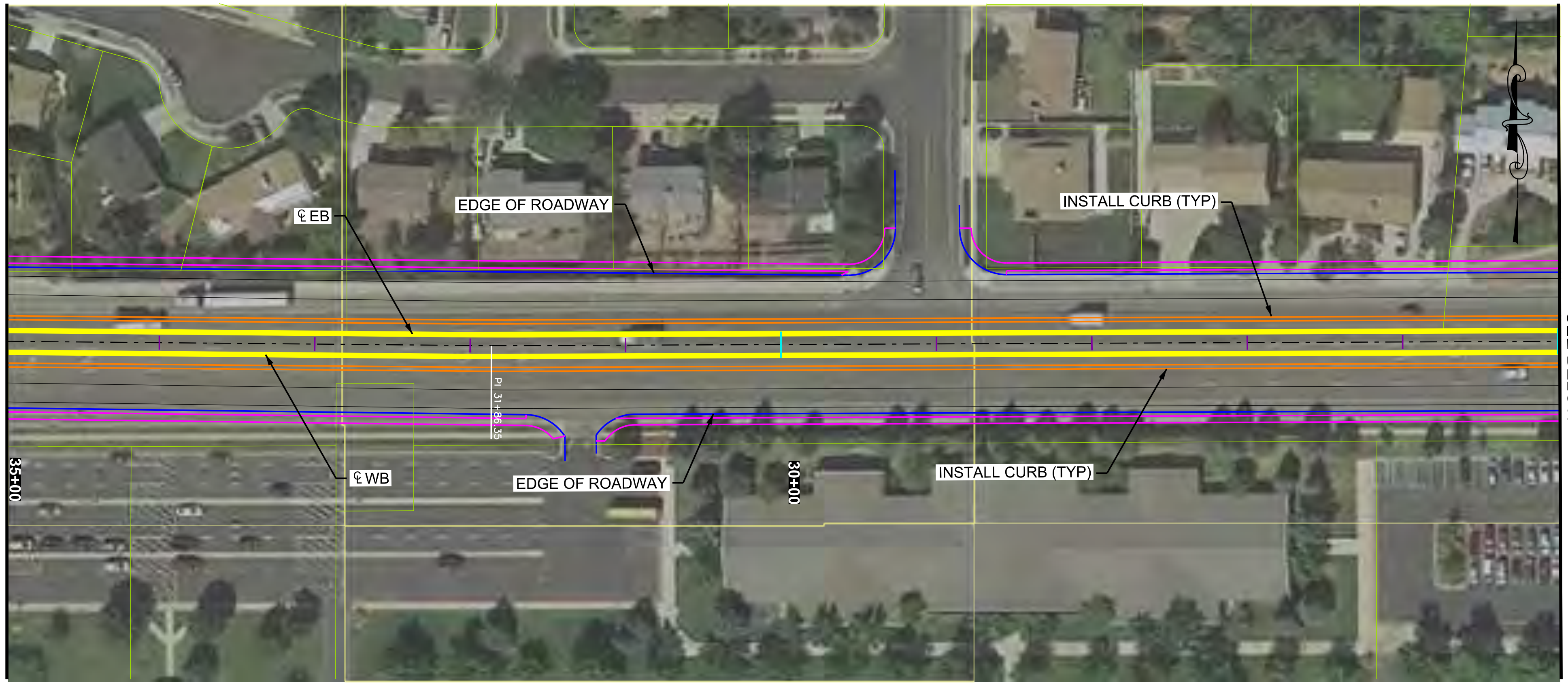
COG RAIL SEGMENT 3

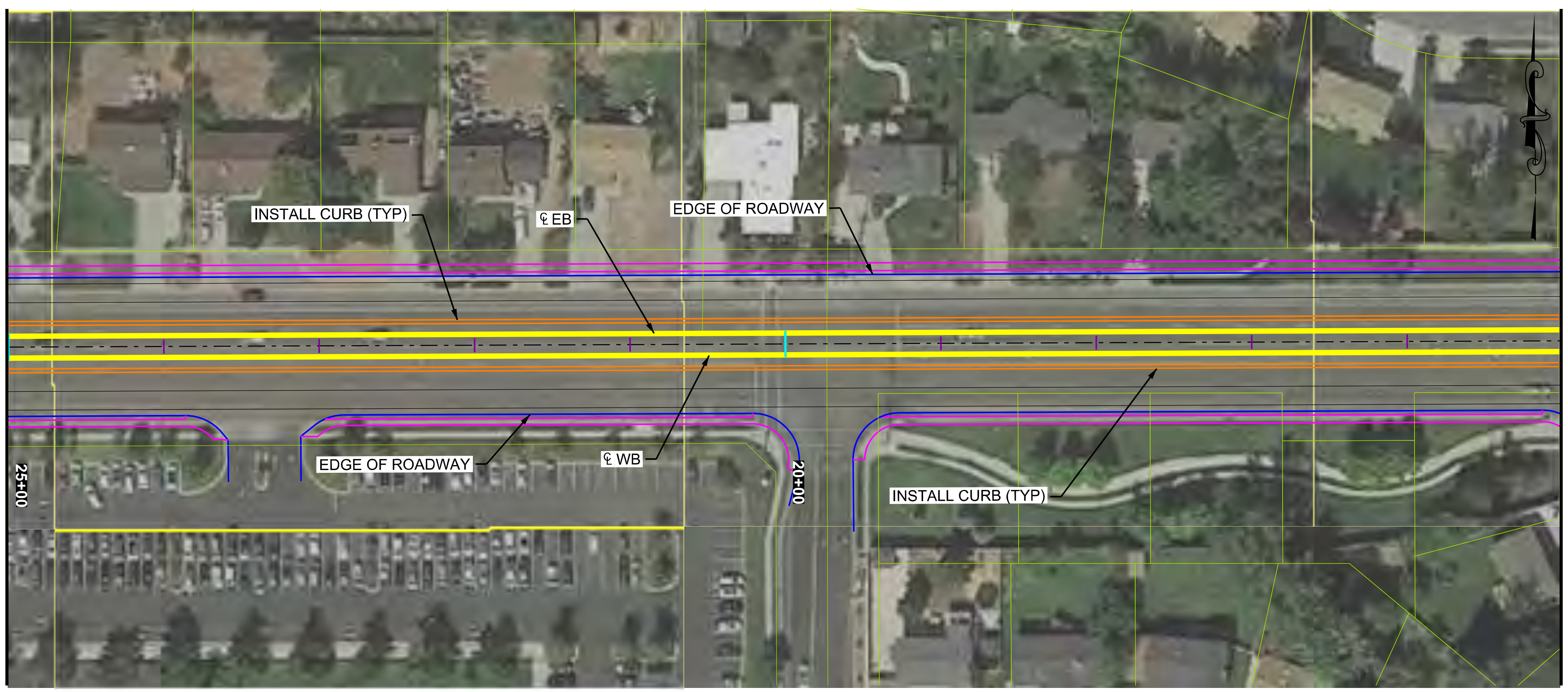
PIN 16092

PROJECT NUMBER XXXX

SHEET NO. 6

2/14/2020





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COG RAIL SEGMENT 3

PIN 16092

PROJECT NUMBER: XXXX

SHEET NO. 7

2/14/2020

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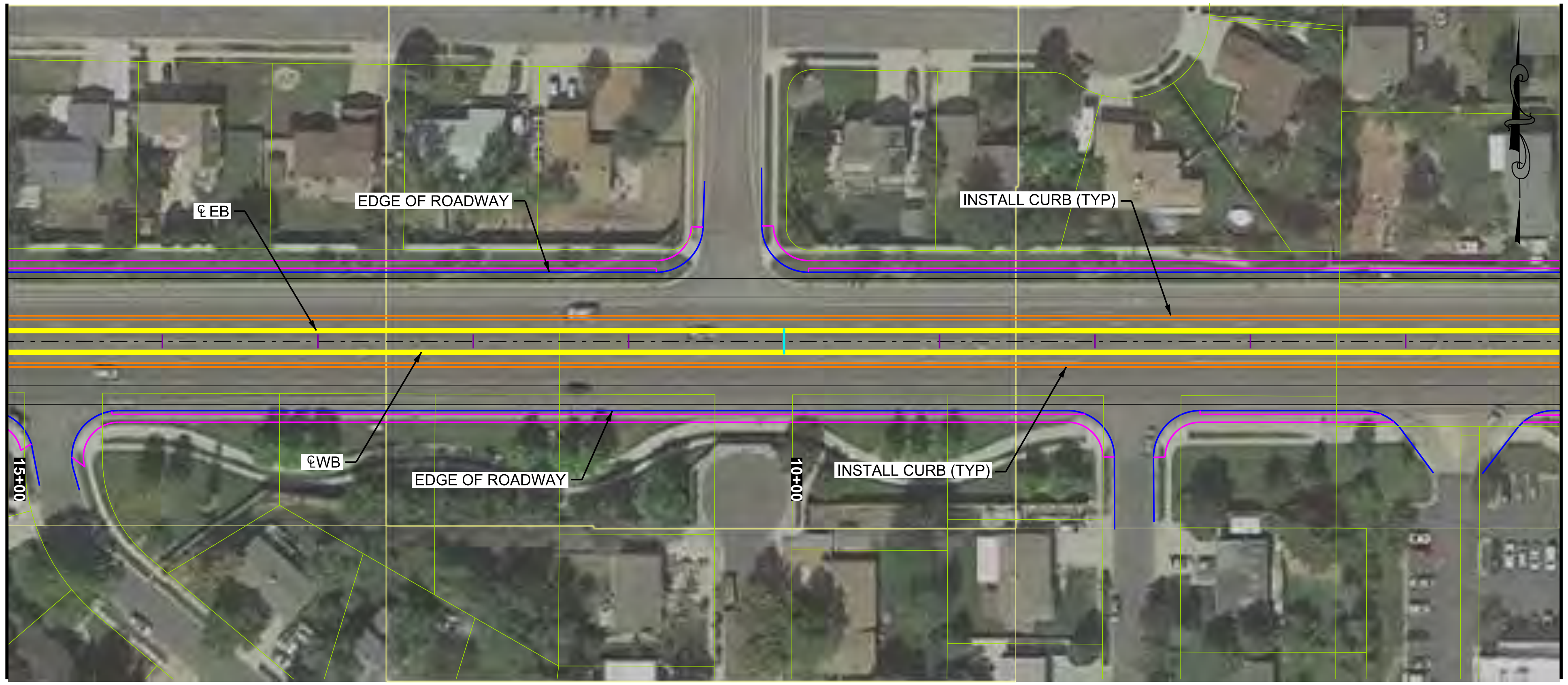

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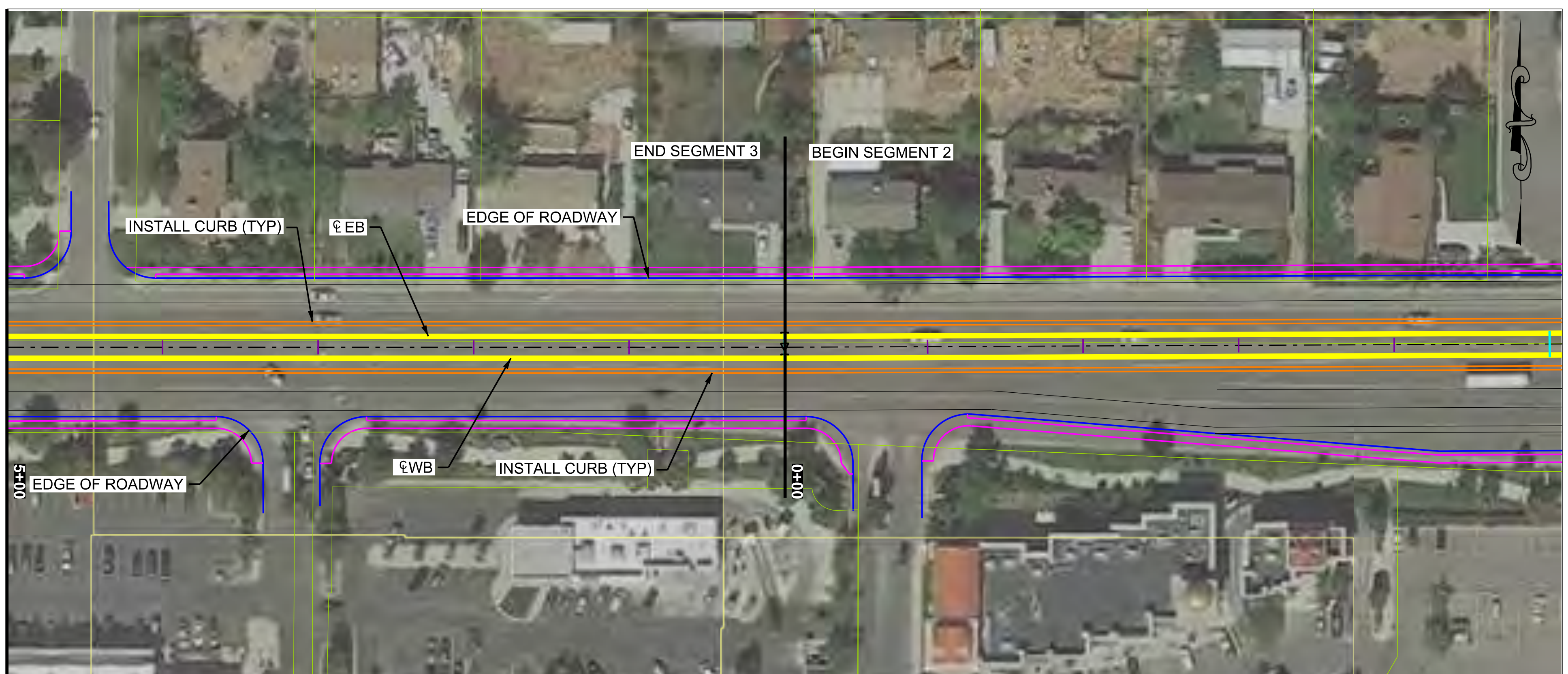

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COG RAIL SEGMENT 3

PIN: 16092
PROJECT NUMBER: XXXX

SHEET NO. 8

2/14/2020