# Exhibit H
# Geological Hazards and Soil Stability

# Boardman to Hemingway Transmission Line Project

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*Amended Preliminary Application for Site Certificate*

*June 2017*

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| Amended Project Order | First Amended Project Order, Regarding Statutes, Administrative Rules and Other Requirements Applicable to the Proposed Boardman to Hemingway Transmission Line (December 22, 2014) |
| ASC | Application for Site Certificate |
| ASCE | American Society of Civil Engineers |
| ASTM | ASTM International (formerly known as American Society for Testing and Materials) |
| BMP | best management practice |
| CSZ | Cascadia Subduction Zone |
| DOGAMI | Oregon Department of Geology and Mineral Industries |
| EFSC or Council | Energy Facility Siting Council |
| ESCP | Erosion and Sediment Control Plan |
| FEMA | Federal Emergency Management Agency |
| IBC | International Building Code |
| IPC | Idaho Power Company |
| km | kilometer |
| kV | kilovolt |
| LiDAR | light detection and ranging |
| MCE | maximum credible earthquake |
| MConE | Maximum Considered Earthquake ground motions |
| MMI | Modified Mercalli Intensity |
| MOP | Manual of Practice |
| MP | milepost |
| MPE | maximum probable earthquake |
| NESC | National Electrical Safety Code |
| NGDC | National Geophysical Data Center |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| OAR | Oregon Administrative Rule |
| ODOE | Oregon Department of Energy |
| OPS | U.S. Department of Transportation, Office of Pipeline Safety |
| OSSC | Oregon Structural Specialty Code |
| PGA | peak ground acceleration |
| Project | Boardman to Hemingway Transmission Line Project |
| SLIDO | Statewide Landslide Inventory Database for Oregon |
| STATSGO | State Soil Geographic Database |
| U.S. | United States |
| USACE | U.S. Army Corps of Engineers |
| USFS | United States Forest Service |
| USGS | U.S. Geological Survey |

# Exhibit H
# Geological Hazards and Soil Stability

## 1.0 INTRODUCTION

Exhibit H provides information regarding the geological and soil stability within the Site Boundary for the Boardman to Hemingway Transmission Line Project (Project). The information provided in Exhibit H shows that Idaho Power Company (IPC) has adequately characterized the site and potential geological and soils hazards, and that the Project can be designed, engineered, and constructed to avoid dangers to human safety presented by seismic, geological, and soil hazards.

## 2.0 APPLICABLE RULES AND AMENDED PROJECT ORDER PROVISIONS

### 2.1 General Standards for Siting Facilities

The Structural Standard set forth at Oregon Administrative Rule (OAR) 345-022-0020 provides, in relevant part:

> *(1) Except for facilities described in sections (2) and (3), to issue a site certificate, the Council must find that:*
>
> > *(a) The applicant, through appropriate site-specific study, has adequately characterized the site as to the Maximum Considered Earthquake Ground Motion as shown for the site in the 2009 International Building Code and maximum probable ground motion, taking into account ground failure and amplification for the site specific soil profile under the maximum credible and maximum probable seismic events; and*
> >
> > *(b) The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by seismic hazards affecting the site that are expected to result from maximum probable ground motion events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, liquefaction, lateral spreading, tsunami inundation, fault displacement, and subsidence;*
> >
> > *(c) The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggravated by, the construction and operation of the proposed facility; and*
> >
> > *(d) The applicant can design, engineer and construct the facility to avoid dangers to human safety presented by the hazards identified in subsection (c).*
>
> *. . . .*[1]

[1] Section (2) and Section (3) of OAR 345-022-0020 apply to energy generation facilities and special criteria facilities, respectively. Here, the Project is neither an energy generation facility nor a special criteria facility. Therefore, Section (2) and Section (3) of OAR 345-022-0020 do not apply to the Project.

## 2.2 Site Certificate Application Requirements

OAR 345-021-0010(1)(h) provides Exhibit H must include the following Information regarding the geological and soil stability within the Site Boundary:

> *(A) A geologic report meeting the guidance in Oregon Department of Geology and Mineral Industries open file report 00-04 "Guidelines for Engineering Geologic reports and Site-Specific Seismic Hazard Reports."*
>
> *(B) A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions.*
>
> *(C) Evidence of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate site-specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete.*
>
> *(D) For all transmission lines, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead ends, corners, and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction.*
>
> *(E) For all pipelines that would carry explosive, flammable or hazardous materials, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings and portions of the proposed alignment where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction.*
>
> *(F) An assessment of seismic hazards. For the purposes of this assessment, the maximum probable earthquake (MPE) is the maximum earthquake that could occur under the known tectonic framework with a 10 percent chance of being exceeded in a 50 year period. If seismic sources are not mapped sufficiently to identify the ground motions above, the applicant shall provide a probabilistic seismic hazard analysis to identify the peak ground accelerations expected at the site for a 500 year recurrence interval and a 5000 year recurrence interval. In the assessment, the applicant shall include:*
>
>> *(i) Identification of the Maximum Considered Earthquake Ground Motion as shown for the site under the 2009 International Building Code.*
>>
>> *(ii) Identification and characterization of all earthquake sources capable of generating median peak ground accelerations greater than 0.05g on rock at the site. For each earthquake source, the applicant shall assess the magnitude and minimum epicentral distance of the maximum credible earthquake (MCE).*
>>
>> *(iii) A description of any recorded earthquakes within 50 miles of the site and of recorded earthquakes greater than 50 miles from the site that caused ground shaking at the site more intense than the Modified Mercalli III intensity. The applicant shall include the date of occurrence and a description of the earthquake that includes its magnitude and highest intensity and its epicenter location or region of highest intensity.*

*(iv) Assessment of the median ground response spectrum from the MCE and the MPE and identification of the spectral accelerations greater than the design spectrum provided in the 2010 Oregon Structural Specialty Code. The applicant shall include a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic or subsurface conditions that could result in expected ground motions greater than those characteristic of the Maximum Considered Earthquake Ground Motion identified above.*

*(v) An assessment of seismic hazards expected to result from reasonably probable seismic events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence.*

*(G) An assessment of soil-related hazards such as landslides, flooding and erosion which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility.*

*(H) An explanation of how the applicant will design, engineer and construct the facility to avoid dangers to human safety from the seismic hazards identified in paragraph (F). The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring for seismic hazards.*

*(I) An explanation of how the applicant will design, engineer and construct the facility to adequately avoid dangers to human safety presented by the hazards identified in paragraph (G).*

## 2.3 Amended Project Order Provisions

The Amended Project Order includes the following discussion regarding Exhibit H:

*The Department understands that detailed site-specific geotechnical investigation for the entire site boundary is not practical in advance of completing the final facility design and obtaining full site access. However, OAR 345-021-0010(h) requires evidence of consultation with the Oregon Department of Geology and Mineral Industries (DOGAMI) prior to submitting the application if the applicant proposes to base Exhibit H on limited pre-application geotechnical work. Exhibit H shall include written evidence of consultation with DOGAMI regarding the level of geologic and geotechnical investigation determined to be practical for the application submittal.*

*Any geotechnical reports included in Exhibit H as supporting evidence that the proposed facility will meet the Council's structural standard should follow the guidelines of DOGAMI's "Open File Report 00-04 "Guidelines for Engineering Geologic Reports and Site Specific Seismic Hazard Reports."*

*Note that OAR 345-021-0010(1)(h), paragraphs (A), (F)(i), and (F)(iv) contain references to outdated guidelines and codes. Although the Council rules are currently applicable, before the B2H application process is concluded, the department intends to engage in rulemaking and will be seeking EFSC approval of updated rules that reflect currently applicable guidelines and codes. The department anticipates the requirements of OAR 345-021-0010(1)(h) will be modified to require compliance with the rules that became effective July 1, 2014. In anticipation of that rulemaking, the department recommends that the applicant consult directly with DOGAMI regarding the current DOGAMI requirements.*

(Amended Project Order, Section III(h))

# 3.0 ANALYSIS

## 3.1 Analysis Area

The analysis area for Exhibit H includes all areas within the Site Boundary, which is defined as "the perimeter of the site of a proposed energy facility, its related or supporting facilities, all temporary laydown and staging areas, and all corridors and micrositing corridors proposed by the applicant" (OAR 345-001-0010(55)). The Site Boundary encompasses the following facilities in Oregon:

- The Proposed Route, consisting of 270.8 miles of new 500-kilovolt (kV) electric transmission line, removal of 12 miles of existing 69-kV transmission line, rebuilding of 0.9 mile of a 230-kV transmission line, and rebuilding of 1.1 miles of an existing 138-kV transmission line;
- Four alternatives that each could replace a portion of the Proposed Route, including the West of Bombing Range Road Alternative 1 (3.7 miles), West of Bombing Range Road Alternative 2 (3.7 miles), Morgan Lake Alternative (18.5 miles), and Double Mountain Alternative (7.4 miles);
- One proposed 20-acre station (Longhorn Station);
- Ten communication station sites of less than ¼-acre each and two alternative communication station sites;
- Permanent access roads for the Proposed Route, including 206.3 miles of new roads and 223.2 miles of existing roads requiring substantial modification, and for the Alternative Routes including 30.2 miles of new roads and 22.7 miles of existing roads requiring substantial modification; and
- Thirty-one temporary multi-use areas and 299 pulling and tensioning sites of which four will have light-duty fly yards within the pulling and tensioning sites.

The Project features are fully described in Exhibit B and the Site Boundary for each Project feature is described in Exhibit C, Table C-24. The location of the Project features and the Site Boundary is outlined in Exhibit C.

## 3.2 Methods

Consistent with direction in the Amended Project Order, IPC will complete the studies necessary to generate the detailed information required by OAR 345-0210-0010(1)(h) in two phases. IPC has already completed Phase 1 of its Exhibit H Geological Hazards and Soil Stability studies. Exhibit H relies on published data, and also field and literature information compiled by IPC's geotechnical consultants. The Engineering and Seismic Hazards Supplement (Attachment H-1) presents the regional geologic and tectonic setting, seismic hazards, and non-seismic geologic hazards that could affect the Project. The Engineering Geology and Seismic Hazards Supplement was based on review of literature and existing mapping, referenced throughout Attachment H-1 and in Attachment H-1, Section 9 – References.

The Engineering and Seismic Hazards Supplement describes a reconnaissance-level survey that examined the proposed transmission line route from its starting point at Longhorn Station, near Boardman, Oregon, to its end point at the Hemingway Substation in Owyhee County, Idaho. IPC recognizes that any desktop analysis or regional study is generally useful for regional applications and should not be used as an alternative to site-specific studies in critical areas.

As described further in Section 3 of Attachment H-1, IPC proposes to conduct a Phase 2 site-specific geotechnical investigation, which will be conducted prior to final design and construction. Phase 2 will support final design, engineering, and construction specifications and will be used to avoid or mitigate site-specific geologic hazards. Following completion of Phase 2, IPC will develop a Phase 2 Site-Specific Geotechnical Report following the 2014 Guidelines for Preparing Engineering Geological Reports (OSBGE 2014). IPC will submit the Phase 2 Site-Specific Geotechnical Report to the DOGAMI and the Oregon Department of Energy (ODOE) prior to construction.

Also, since the issuance of the Project Order, the Energy Facility Siting Council (EFSC or Council) has revised the references to the guidelines and codes in OAR 345-021-0010(1)(h). Consistent with these revisions and consistent with the direction provided by DOGAMI, the most up-to-date building and structural codes that apply to transmission line projects will be used during the final design and construction of the Project. Current codes will be used to meet reliability standards and other external regulations. It is specifically assumed that current requirements embedded in structural, electrical building, and other codes meet or exceed the requirements of prior codes.

## 3.3 Geologic Report

> OAR 345-021-0010(1)(h): Information from reasonably available sources regarding the geological and soil stability within the analysis area, providing evidence to support findings by the Council as required by OAR 345-022-0020, including: (A) A geologic report meeting the guidance in Oregon Department of Geology and Mineral Industries open file report 00-04 “Guidelines for Engineering Geologic reports and Site-Specific Seismic Hazard Reports.”

OAR 345-021-0010(1)(h)(A) requires submission of a geological report meeting the standards of DOGAMI’s *Guidelines for Engineering Geologic Reports* (DOGAMI Guidelines). The DOGAMI Guidelines provide general guidance for completing engineering geology reports in Oregon. Adopted by the Oregon State Board of Geologist Examiners in 2004, it contains a suggested guide for the preparation of engineering geologic reports in Oregon. The DOGAMI Guidelines state that “the engineering geologic report should include sufficient facts and interpretation of the suitability of the site for the proposed use. Because of the wide variation in size and complexity of projects and scope of work, the guidelines are intended to be flexible and should be tailored to the specific project.” As such, the guidelines do not provide rigid requirements for every engineering geologic report.

The DOGAMI Guidelines include general types of information that may be considered in an engineering geology report. All of these may or may not be included, depending on the Project, or additional information may be necessary not mentioned in the DOGAMI Guidelines. General project information may include client, supervising geologist, project location and setting, purpose of report, topography, earth materials present, reference sources, geologic hazards, locations of test holes and excavations, field and laboratory test methods, statement of geologist’s financial information if applicable, and signature and seal of certified engineering geologist. Geologic maps and cross-sections may be necessary to define the geologic conditions present. Geologic descriptions are typically found in an engineering report including bedrock rock types, relative age or formation names, distribution and thickness, and physical characteristics, structural features, surficial deposits, surface and subsurface hydrologic conditions, and seismic considerations. The geologic factors observed are typically discussed in the context of suitability for proposed land use to identify geologic conditions that may result in risk to land use, recommendations for site grading, drainage considerations, and limitations of study. Recommendations for additional investigations or hazard mitigations are also a part of typical engineering geology and seismic hazard reports.

Attachment H-1 includes an introduction, summary of topographical and geological features, general description of the scope of the proposed site-specific investigation, and summaries and mitigation strategies for seismic and non-seismic hazards. In turn, Exhibit H supplements the data contained in Attachment H-1 in a format that closely matches the requirements of OAR 345-021-0010(1)(h)(A).

To support the detailed design, IPC will carry out the Phase 2 program of site-specific geological and geotechnical work to investigate subsurface soil and geologic conditions following site certificate approval and apply site-specific geotechnical design recommendations. The geotechnical investigation will emphasize areas that require engineering design and areas identified as potential geologic hazards in the Engineering Geology and Seismic Hazards Supplement, including seismicity, slope failure, liquefaction, and subsidence. The site-specific geotechnical investigation will be performed prior to final design and construction.

Using the results of the geotechnical investigation, IPC will prepare a final engineering geologic report, the Phase 2 Site-Specific Geotechnical Report, prior to final design and construction to assess site-specific hazards in conformance with the DOGAMI Guidelines. As described in the DOGAMI Guidelines, the Phase 2 Site-Specific Geotechnical Report will include additional facts and site-specific interpretation regarding geologic materials, processes, and history to allow evaluation of the suitability of specific affected sites for the proposed Project uses.

IPC has responded to many portions of the DOGAMI Guidelines in Exhibit H and Exhibit I, and will respond to the remaining applicable guidelines in the Phase 2 Site-Specific Geotechnical Report and related studies.

## 3.4 Site-specific Geotechnical Work

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|---|
| OAR 345-021-0010(1)(h)(B): A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions. |

OAR 345-021-0010(1)(h)(B) requires a description and schedule of pre-construction geotechnical work. Here, site-specific geologic and geotechnical investigations will include more detailed geologic field reconnaissance to identify faults and landslides and geologic data acquisition for soil, seismic, slope stability, and flood analyses.

Based on the geologic reconnaissance performed to date, IPC's geotechnical engineers have identified approximately 469 initial geotechnical boring locations for the Proposed Route (see Attachment H-1, Section 3.0 and Appendix C of Attachment H-1). Appendix A of Attachment H-1 includes maps of these proposed borehole locations. Section 3 of the Attachment H-1 provides an overview of the proposed site-specific geotechnical work, including right-of-way considerations, access and disturbance, and exploration methods.

Boring locations will occur at a maximum spacing of approximately 1 mile along the alignments, including at:

- dead-end structures;
- any corners or changes in alignment heading (angles);
- crossings of highways, major roads, rivers, railroads, and utilities such as power transmission lines, natural gas pipelines, and canals; and

- locations necessary to verify lithologic changes and/or geologic hazards such as landslides, steep slopes, or soft soil areas.

Reconnaissance and test borings, trenching techniques, and collection of rock and soil samples will be employed to help assess subsurface conditions. Collected rock and soil samples will be field classified and tested to determine geotechnical behaviors. Upon completion of soil and rock sampling, further laboratory tests will be conducted to measure physical and engineering properties of the soil and rock. Laboratory tests may include natural water content, particle size analysis, liquid and plastic limits, and moisture-density relationship. All testing will be performed in accordance with ASTM International (ASTM) or U.S. Army Corps of Engineers (USACE) testing requirements for consistency. Depending upon the materials encountered, additional testing in general accordance with ASTM or USACE testing procedures may be required to evaluate swell or settlement potential, direct shear, unconfined compressive strength, specific gravity and corrosion.

The results of the initial geotechnical investigation may identify data gaps that could result in additional investigation until sufficient information is received to ensure that the Project can be designed, engineered, and constructed. As detailed in Attachment H-1, it is anticipated that boring depths will generally be no more than 50 feet below the designed finish grade of the transmission center line. Subsurface investigation will be accomplished by hollow-stem auger in unconsolidated areas above the groundwater level and by mud rotary methods below groundwater level. In areas where rock is encountered, the rock will be cored using HQ triple-tube rock-coring techniques. Soil and bedrock samples will be collected for analysis of geotechnical properties. Rock-coring methods will be used in an attempt to obtain continuous samples of rock, where encountered during drilling. Other standard sample collection methods are described in Attachment H-1.

Depth to groundwater will also be measured in the borings. If seasonal high groundwater is anticipated to interact with foundations, piezometers may be installed to assess groundwater fluctuations.

For proposed structures (such as stations or communication stations) near identified faults or within historical and pre-historic landslide areas, additional geotechnical investigation will be conducted to acquire necessary data for seismic and slope stability analysis. The degree of analysis will be contingent on hazard present, facility to be constructed, and potential danger to human safety and infrastructure.

IPC will obtain the necessary detailed information through invasive field and laboratory studies essential for the design, engineering, and constructing of the proposed facilities. When appropriate, IPC may use geophysical methods to investigate the underlying soils and rock. Typical indirect methods would include, but not be limited to, seismic refraction and resistivity methods.

Based on the results of the geotechnical field work, other studies employing alternative investigation methods may be required to expand design knowledge necessary to assess seismic hazards and failure-prone slopes. For example, preliminary seismic sources and maximum probable ground shaking were analyzed and are presented in Attachment H-1. However, during the field investigation, faults that cross the Project will be evaluated to confirm location and assess activity. Additional investigative methods may include field geomorphic and geologic investigation, followed by trenching where towers would need to be relocated to avoid active faults.

In known landslide-prone areas, steep slopes will also be evaluated to examine the potential for slope failure. Subsurface investigations will examine soil/rock properties, depth to slide planes, groundwater depths, groundwater fluctuations, or depth to bedrock or specific soil horizons. Investigation methods may include borings, trenches, geophysical surveys, inclinometer installation and monitoring, and laboratory testing of soil/rock. Site modifications and mitigation strategies will be developed and implemented for each unstable area as required. IPC's preferred mitigation strategy will be to construct towers in stable locations and avoid unstable areas.

Geotechnical field investigations will commence when IPC obtains access and permission to proposed field investigation sites. The results will inform the final design and siting of the transmission line and related and supporting facilities: station, fly yards, stream crossings, roadway intersections, laydown yards, and multi-use yards. Table H-1 describes the general timeframe for detailed geotechnical work by facility and location. IPC will submit the results of the site-specific geotechnical investigation in the Phase 2 Site-Specific Geotechnical Report, which will be provided to DOGAMI and ODOE prior to construction.

**Table H-1. Schedule of Site-Specific Geotechnical Work**

| Facility | Location | General Timeframe |
|---|---|---|
| Station | Morrow County | Summer and Fall 2020[1] |
| Transmission Line Spread 1 | Morrow, Umatilla, and Union counties | Summer and Fall 2020[1] |
| Transmission Line Spread 2 | Baker and Malheur counties | Summer and Fall 2020[1] |

[1] Actual schedule will depend upon federal access approvals to conduct geotechnical investigations.

## 3.5 Consultation with DOGAMI

> OAR 345-021-0010(1)(h)(C): Evidence of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate site-specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete.

OAR 345-021-0010(1)(h)(C) requires consultation with DOGAMI on the geotechnical work. Regarding the Project, DOGAMI and the ODOE were consulted at an in-person meeting on April 4, 2011, in Portland, Oregon. Based upon comments made during this meeting by Mr. Bill Burns, Engineering Geologist for DOGAMI, IPC responded with a letter to DOGAMI (Attachment H-2). Excerpts from the letter are as follows:

1) *The SLIDO (Statewide Landslide Inventory Database for Oregon) was being updated based on new LIDAR data, and you requested that the updated SLIDO 2 data should be incorporated into the geotechnical hazard assessment and engineering design prior to construction.*

2) *Geological and soil hazard analysis is not required at each tower location. The degree of investigation should be contingent on the type of hazards present, facility to be constructed, and potential danger to human safety. The degree of analysis will vary across the Project corridor.*

3) *The most recent IBC and Oregon Structural Specialty Code (OSSC) requirements should be used although current Oregon Administrative Rules reference historical IBC requirements.*

4) *You were aware that in transmission line construction, design for wind and ice forces is more than sufficient to account for typical seismic forces.*

*5) A detailed geotechnical plan may be submitted concurrently with the Application for Site Certification (ASC) and the Engineering Geologic Report for the Project may be submitted after filing the ASC.*

*6) Exhibit H should contain as much detail as possible. DOGAMI will only review Exhibit H and its Attachment so reference should not be made to other documents.*

*7) You indicated that the April 2011 meeting would satisfy the requirements of DOGAMI consultation.*

Attachment H-2 contains a letter to DOGAMI, confirming DOGAMI's acknowledgement of the bulleted items listed above. The Engineering Geology and Seismic Hazards Supplement was attached to the letter to DOGAMI for the agency's review and evaluation.

## 3.6 Locations of Geotechnical Work

> OAR 345-021-0010(1)(h)(D): For all transmission lines, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead ends, corners, and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction.

OAR 345-021-0010(1)(h)(D) requires identification of geotechnical investigation sites. Here, sites for geotechnical investigation shall include indicative tower or substation locations and the following:

- dead-end structures;
- any corners or changes in alignment heading (angles);
- crossings of highways, major roads, rivers, railroads, and utilities such as power transmission lines, natural gas pipelines, and canals; and
- locations necessary to verify lithologic changes and/or geologic hazards such as landslides, steep slopes, or soft soil areas.

Attachment H-1, Appendix C presents a summary table with the approximate locations and rationale for the proposed boring locations. Additional borings may be necessary to fill data gaps from the initial drilling program. Appendix A of Attachment H-1 presents a series of geologic maps, showing the transmission line indicative alignment, and geologic features.

## 3.7 Pipelines

> OAR 345-021-0010(1)(h)(E): For all pipelines that would carry explosive, flammable or hazardous materials, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings and portions of the proposed alignment where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction.

OAR 345-021-0010(1)(h)(E) applies to pipelines. This subpart of the regulations does not apply to the Project, because the Project includes no pipelines.

## 3.8 Earthquakes and Seismic Hazards

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|---|
| OAR 345-021-0010(1)(h)(F): An assessment of seismic hazards. For the purposes of this assessment, the maximum probable earthquake (MPE) is the maximum earthquake that could occur under the known tectonic framework with a 10 percent chance of being exceeded in a 50 year period. If seismic sources are not mapped sufficiently to identify the ground motions above, the applicant shall provide a probabilistic seismic hazard analysis to identify the peak ground accelerations expected at the site for a 500 year recurrence interval and a 5000 year recurrence interval. . . . |

OAR 345-021-0010(1)(h)(F) requires an assessment of seismic hazards. The detailed seismic evaluation is presented in Attachment H-1. IPC is governed by the National Electric Safety Code (NESC) and is required to apply various weather-related structural loading cases while designing transmission lines. IPC will apply all NESC-required, weather-related loading cases as well as additional cases identified to be important to the integrity of the lines.

Notably, NESC Section 250.A.4 indicates that by designing for the required line and tower loading cases, nothing further is required to resist earthquake loads. It states, “The structural capacity provided by meeting the loading and strength requirements of Sections 25 (Loadings for Grades B and C) and 26 (Strength Requirements) provides sufficient capability to resist earthquake ground motions.”

Additionally, the American Society of Civil Engineers (ASCE) *Guidelines for Electrical Transmission Line Structural Loading* (Wong and Miller 2010) states the following:

> *Transmission structures need not be designed for ground-induced vibrations caused by earthquake motion because, historically, transmission structures have performed well under earthquake events, and transmission structure loadings caused by wind/ice combinations and broken wire forces exceed earthquake loads. This may not be the case if the transmission structure is partially erected or if the foundations fail due to earth fracture or liquefaction.*

> *Transmission structures are designed to resist large, horizontal loads of wind blowing on the wires and structures. These loads and the resulting strengths provide ample resistance to the largely transverse motions of the majority of earthquakes. Decades of experience with lines of all sizes has shown that very infrequent line damages have resulted from soil liquefaction or when earth failures affect the structural capacity of the foundation.*

Generally, NESC-mandated combined ice and loading cases have been determined by the industry to be sufficient to address seismic hazards from earthquakes.

Although seismic design criteria do not apply to transmission structures, seismic hazards must be evaluated in accordance with the OAR. The detailed seismic hazards evaluation is presented in Attachment H-1. For the purposes of this preliminary evaluation, the seismic sources are not mapped sufficiently to perform a deterministic evaluation of ground motions along a several-hundred-mile-long powerline alignment. Therefore, probabilistic peak ground acceleration (PGA) estimates for a 500- and 5,000-year return period have been included in this evaluation and are shown in Attachment H-1.

### *3.8.1 Maximum Considered Earthquake Ground Motion*

> OAR 345-021-0010(1)(h)(F): . . . In the assessment, the applicant shall include: (i) Identification of the Maximum Considered Earthquake Ground Motion under the 2009 International Building Code.

Seismic hazards will be evaluated according to the International Building Code (IBC). This evaluation provides PGA, short- and long-period (0.2 and 1.0 second) spectral accelerations. The OAR specifies use of IBC 2009 for design, however we assume the most recent version of IBC will be used during final design. As requested by ODOE and DOGAMI, both OAR-referenced building codes in addition to the current building codes were considered as discussed in Attachment H-1. The 2012 IBC provides Maximum Considered Earthquake ground motions (MConE) that correspond to a 2 percent probability of exceedance in 50 years, or a 2,500-year return period. The PGA, short- and long-period (0.2 and 1.0 second) spectral accelerations are shown in Attachment H-1.

### *3.8.2 Earthquake Sources*

> OAR 345-021-0010(1)(h)(F)(ii): Identification and characterization of all earthquake sources capable of generating median peak ground accelerations greater than 0.05g on rock at the site. For each earthquake source, the applicant shall assess the magnitude and minimum epicentral distance of the maximum credible earthquake (MCE).

Evaluation of source specific probabilistic ground motions along the 272.8-mile alignment has been provided using U.S. Geological Survey (USGS) 2002 and 2014 PGA and spectral accelerations on rock. Site class determinations and site specific hazard evaluations for structure locations will be determined during geotechnical design studies.

The four sources of earthquakes and seismic activity in Oregon are crustal, interplate, intraplate, and volcanic (DOGAMI 2010). The Project is not located on a plate boundary and the nearest is over 80 miles from the Project. However the Project may experience ground shaking from any of the earthquake types. The most significant earthquake sources near the Project are intraplate or crustal earthquakes; however, intraplate earthquakes may rarely occur and are located hundreds of miles from the Project.

- **Crustal earthquakes** are generally shallow (<30 kilometers [km] depth), resulting from active faulting in the upper North American Plate. Crustal earthquakes typically have a maximum magnitude near 7.0, and recurrence intervals are dependent on stress accumulation and release but can range from tens to hundreds of years.
- **Interplate earthquakes** are those that occur between two plate boundaries. Interplate seismicity in Oregon is generated from the convergence of the Juan de Fuca Plate and the North American Plate at the Cascadia Subduction Zone (CSZ) just off the coast of Washington and Oregon (USGS 2009a). These plates converge at a rate of 1 to 2 inches per year and accumulate large amounts of stress that are released abruptly in earthquake events. The CSZ and similar plate boundaries are capable of producing large, 9.0 magnitude subduction zone earthquakes. Recurrence intervals are typically on the order of 300 to 500 years.
- **Deep Intraplate earthquakes** occur deep (50-70 km depth) in the CSZ and have a maximum magnitude potential near 7.0. Recurrence intervals for deep intraplate earthquakes are generally between 500 to 600 years.

Because of their proximity, crustal faults represent the most significant seismic hazard to the proposed transmission alignment. A map of Quaternary faults is presented in Attachment H-1, Appendix D, Figure D9. The map presents the locations of known and inferred faults.

Table H-2 is a summary table of significant faults considered capable of generating a large earthquake within 5 miles of the Proposed Route and Alternative Route by county. These faults are potentially capable of producing a PGA greater than 0.05 g along the Proposed Route and Alternative Route. Of the youthful Quaternary faults identified by USGS (Table H-2), faults less than 15,000 years old are recent by geologic standards and likely pose the greatest potential for future earthquakes. These faults are assumed to be active.

**Table H-2. USGS Quaternary Faults within 5 Miles of Project by County**

| County | Fault Name | Approximate Milepost | Age (years) | Active? |
|---|---|---|---|---|
| Morrow | None | N/A | N/A | N/A |
| Umatilla | Hite Fault System, Thorne Hollow Section[1] | 80[1] | <130,000 | No |
| | Hite Fault System, Agency Section | 63.5 | <1,600,000 | No |
| Union | West Grande Ronde Valley Fault Zone (includes Mount Emily, La Grande, and Craig Mountain Sections)[2] | 89–119.5[2] | <15,000 | Yes |
| | South Grande Ronde Valley Fault Zone[1] | 115-126[1] | <750,000 | No |
| Baker | Unnamed East Baker Valley Faults[2] | 140–148[2] | <750,000 | No |
| | West Baker Valley Faults[2] | 149.5-152.5[2] | <130,000 | No |
| Malheur | Cottonwood Mountain Fault | 224.5 | <15,000 | Yes |
| | Faults Near Owyhee Dam[1] | 246–258.5[1] | <1,600,000 Class B[3] | No |

[1] Faults do not intersect the Project centerline; milepost (MP) reflects its closest location to the Project centerline.

[2] The West Grande Ronde Valley Fault Zone intersects the Project centerline near approximately MP 109. The Unnamed East Baker Valley Faults intersect the Project centerline at multiple locations near approximately MPs 141, 143, and 148. The West Baker Valley Fault intersects the Project centerline at multiple locations near approximately MPs 150, 151, and 152.

[3] Class B Faults are faults of uncertain origin that may be older than Quaternary.

### *3.8.3 Recorded Earthquakes*

> OAR 345-021-0010(1)(h)(F)(iii): A description of any recorded earthquakes within 50 miles of the site and of recorded earthquakes greater than 50 miles from the site that caused ground shaking at the site more intense than the Modified Mercalli III intensity. The applicant shall include the date of occurrence and a description of the earthquake that includes its magnitude and highest intensity and its epicenter location or region of highest intensity.

Due to the large areas of impact from earthquakes, the analysis area for recorded earthquakes was larger than the Site Boundary, and chosen by a variable buffer distance around epicenters, or groups of epicenters, of historical earthquakes. The seismology department at University of Nevada at Reno states that earthquakes of Richter magnitude 6.1 to 6.9 may affect areas up to 100 km from the epicenter (UNR 1996). Given that estimate, an analysis area radius of 25 miles was selected for earthquakes less than magnitude 6. A radius of 50 miles was assumed for earthquakes of magnitude 6 to less than 7, and the analysis area was extended out to 100 miles for earthquakes of magnitude 7 or greater. The distance of 100 miles was chosen because, above that distance, the effect on the proposed transmission line from even the strongest recorded past earthquakes would be minimal. The locations of historical earthquake epicenters were also reviewed relative to the Proposed Route and Alternative Routes. Earthquake data for Idaho and Oregon were obtained from the applicable state geologic survey departments. None of the recorded earthquakes within the Site Boundary exceeded Richter magnitude 6.0. The recommended design earthquake magnitudes of 6.0 to 6.2 appear realistic, given the maximum magnitude of historic earthquakes.

Historical earthquakes recorded by the USGS Earthquake Search Database (USGS 2016), the National Geophysical Data Center (NGDC 1985), and the Pacific Northwest Seismic Network (2008) are presented in Appendix D of Attachment H-1. A map of recorded earthquakes with magnitudes of 2 or greater within 50 miles of the Project is shown as Attachment H-1, Appendix D, Figure D10.

The NGDC reports 40 records of earthquakes measured at Modified Mercalli Intensity (MMI) III or greater within 50 miles of the Project. MMI values within the 50-mile route ranged from IV to VII. Attachment H-1, Appendix D, Table D2 lists these earthquakes, the date of occurrence, the earthquake magnitude, the MMI, and the city where it was felt. For earthquakes that were reported in terms of magnitude only, a MMI was estimated. The USGS (2009) provides the following descriptions of MMI values (abbreviated from the 12 levels of MMI):

> *III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.*
>
> *IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.*
>
> *V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.*
>
> *VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.*
>
> *VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.*

Based on the number of historical earthquakes that have occurred within 50 miles of the Project, it is assumed that earthquakes will occur during the life of the Project. However, the Project will be designed to withstand weather-related forces; according to the NESC, the structural capacity provided by meeting the loading and strength requirements for weather-related stresses provide sufficient capability to resist earthquake ground motions.

### *3.8.4 Median Ground Response, MCE and MPE*

> OAR 345-021-0010(1)(h)(F)(iv): Assessment of the median ground response spectrum from the MCE and the MPE and identification of the spectral accelerations greater than the design spectrum provided in the Oregon Structural Specialty Code (2010 edition). The applicant shall include a description of the probable behavior of the subsurface materials and amplification by the subsurface materials and any topographic or subsurface conditions that

> could result in expected ground motions greater than those characteristic of the Maximum Considered Earthquake Ground Motion identified above.

The MPE is the largest earthquake that a fault is predicted capable of generating under the known tectonic framework within a 500-year return period while the MCE is the largest earthquake that an active or potentially active fault is capable of generating. For this preliminary evaluation, the seismic sources are not mapped sufficiently to perform deterministic evaluations of ground motions along a several hundred-mile-long power line alignment. The location, length, and age of offset for credible fault ruptures are not sufficiently documented to determine magnitude and minimum epicentral distance. Therefore, as discussed in Attachment H-1, Section 4.1, probabilistic PGAs for a 500- and 5,000-year return period have been evaluated.

The ground motions provided in Attachment H-1 correspond to a Site Class B/C (soft rock) soil profile. The OAR requires "assessment of the median ground response spectrum" and "a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic of subsurface conditions that could result in expected ground motions greater than those characteristic of the MConE." To develop ground motions that correspond to other Site Class types, Site Coefficients that consider site soil type and level of ground shaking are required. The Site Class definitions and Site Coefficients can be obtained from ASCE 7-10. Subsurface explorations along the alignment have not been performed. Therefore, site-specific design criteria for structures will be prepared upon completion of the geotechnical investigations program.

### *3.8.5 Seismic Hazards Resulting from Seismic Events*

> OAR 345-021-0010(1)(h)(F)(v): An assessment of the seismic hazards expected to result from reasonably probable seismic events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence.

The Project may be subject to ground shaking, ground failure, landslides, liquefaction, fault displacement, and subsidence from reasonably probable seismic events. The Project is well above sea level and far from the Pacific Coast; therefore, tsunami inundation was not considered.

Interplate events occur between two tectonic plates, such as the CSZ where the Juan de Fuca Plate subducts beneath the North American Plate. Interplate events include subduction earthquakes that have the potential to be the largest earthquakes that may occur in the Pacific Northwest. Intraplate events are seismic events that occur within a tectonic plate. The Nisqually earthquake of 2001 was identified as an intraplate seismic event. Crustal earthquakes typically occur within 10 miles of the surface along shallow faults and are considered the most likely source to impact the Project. IPC identified known significant faults near the facility (see Attachment H-1, Section 4.2).

#### *Ground Motion or Seismic Shaking*

Ground shaking will be evaluated after subsurface explorations are performed and soil site classes can be determined. IPC's engineers have relied on the seismic results from Attachment H-1 to perform initial designs, and as additional information is collected during the site-specific geotechnical investigation, designs will be modified if necessary to construct facilities to avoid dangers to human safety presented by seismic hazards.

### *Ground Failure*

Ground failure and fault displacement can occur from fault rupture in an active fault zone. Known Quaternary faults located within 5 miles of the Proposed Route that could be considered active include the Cottonwood Mountain fault and segments of the West Grande Ronde Valley fault zone (see Table H-2). Of these active faults, the Hite Fault System, Agency Section, West Grande Ronde Valley Fault Zone, Unnamed East Baker Valley Faults, West Baker Valley Fault, and the Cottonwood Mountain fault crosses the Proposed Route and should be considered during final design. Ground failure including landslide, lateral spreading, liquefaction, and surface rupture or settlement will be evaluated once ground accelerations and subsurface conditions are known.

A preliminary seismic risk assessment was conducted from a review of earthquake hazard zones included in Federal Emergency Management Agency (FEMA) data, prepared for the U.S. Department of Transportation, Office of Pipeline Safety (OPS, 1996). The OPS data provide earthquake hazard rankings for the United States, including those portions of Idaho and Oregon near the proposed transmission lines. The OPS report utilized information from the USGS National Earthquake Hazards Reduction Program. The USGS compiled a large database of past earthquake magnitudes and locations. Based on those data, earthquake hazards were assigned to all parts of the country. Based on historical earthquake magnitudes and locations, geographic areas were assigned an earthquake hazard ranking, ranging from zero (no earthquake hazard) to 100 (highest earthquake hazard). For this earthquake hazard assessment, a high earthquake hazard was assigned for areas with earthquake hazard rankings of 85 to 100. Locations with earthquake hazard rankings between 70 and 84 were considered as medium risk, and rankings less than 70 were considered low risk. To identify existing earthquake conditions the mileage crossed for each earthquake hazard risk (low, medium, or high) was mapped and expressed as a percent for each county. To disclose overall hazard risk, the mileage crossed by the Proposed Route and alternative route in each county was identified.

Table H-3 presents the percent of low, medium, and high earthquake risk (in miles) along the Proposed Route and alternative routes by county. The OPS data indicate that earthquake risk is greatest in the northern portion of the Proposed Route, with all 82 percent of Morrow County in medium earthquake risk. The OPS data indicate the remainder of the Proposed Route contains low risk of earthquakes. The West of Bombing Range Road Alternatives 1 and 2 contains medium risk. The Morgan Lake and Double Mountain Alternatives contain a low risk of earthquakes.

**Table H-3. OPS Earthquake Hazard Risk – Proposed Route and Alternative Route**

| Facility | County | Miles Crossed[1] | Earthquake Hazard Risk by Centerline Miles Crossed/Percent of Miles Crossed – Proposed Route and Alternative Route | | |
|---|---|---|---|---|---|
| | | | **Low < 70** | **Medium 70 to 85** | **High 85 to 100** |
| Proposed Route | Morrow | 47.5 | 8.5/18 | 39.0/82 | 0 |
| | Umatilla | 40.9 | 40.9/100 | 0 | 0 |
| | Union | 39.9 | 39.9/100 | 0 | 0 |
| | Baker | 69.2 | 69.2/100 | 0 | 0 |
| | Malheur | 75.2 | 75.2/100 | 0 | 0 |
| ***Total Proposed Route*** | | ***272.8*** | ***257.5/87*** | ***39.0/13*** | 0 |
| **Alternative Routes** | | | | | |

| Facility | County | Miles Crossed[1] | Earthquake Hazard Risk by Centerline Miles Crossed/Percent of Miles Crossed – Proposed Route and Alternative Route | | |
|---|---|---|---|---|---|
| | | | Low < 70 | Medium 70 to 85 | High 85 to 100 |
| West of Bombing Range Road Alt. 1 | Morrow | 3.7 | 0 | 3.7/100 | 0 |
| West of Bombing Range Road Alt. 2 | Morrow | 3.7 | 0 | 3.7/100 | 0 |
| Morgan Lake | Union | 18.5 | 18.5/100 | 0 | 0 |
| Double Mountain | Malheur | 7.4 | 7.4/100 | 0 | 0 |

[1] Column may not sum exactly due to rounding.

### *Landslides*

Appendix E of Attachment H-1 contains a summary of each landslide that was identified along the Proposed Route and alternative routes that could potentially affect the stability of proposed tower foundations or associated work areas. The review includes site photographs and preliminary maps of unstable or landslide surfaces. Appendix E of Attachment H-1 was compiled through review of the DOGAMI 2014 SLIDO, version 3.2 database, published geologic maps, aerial imagery, Digital Terrain Model data, DOGAMI light detection and ranging (LiDAR) data, and limited site reconnaissance. The data were used to map landslides within 1 mile of the Proposed Route. IPC's engineers will collect Project-specific LiDAR data prior to final design and will use it to identify historic and prehistoric landslides, as possible. IPC's engineers will include the areas of soil instabilities in the site-specific geotechnical analysis.

### *Liquefaction*

Liquefaction is a phenomenon in which saturated, primarily cohesionless soils temporarily lose their strength when subjected to dynamic forces such as intense and prolonged ground shaking and seismic activity. All portions of the Site Boundary have the potential for ground shaking from earthquakes. Areas that are most susceptible to liquefaction have a combination of thick unconsolidated sediments, and a shallow water table (within 50 feet of the surface). Because the majority of the transmission line crosses relatively stable terrain with shallow bedrock and deep groundwater, the majority of the Site Boundary has a low susceptibility to liquefaction.

Prior to the development of final engineering design, liquefaction studies will be conducted for susceptible areas, including areas that cross or approach rivers and areas where thick unconsolidated sediments are encountered in the field. Additional evaluation of liquefaction also may be needed as the final alignment and tower locations are chosen. The geotechnical engineer will recommend additional exploration and/or analysis as applicable to assess liquefaction hazards in the geotechnical design report for the transmission line.

### *Subsidence*

Subsidence is the sinking or the gradual downward settlement of the land surface, and is often related to groundwater drawdown, compaction, tectonic movements, mining, or explosive activity. Seismic activity in the area could lead to the settling of sediment and could also exacerbate potential subsidence associated with groundwater withdrawal in more populous regions. No historical cases of subsidence in the Site Boundary have been identified, and the majority of the site has a low susceptibility to subsidence. At this time, there are no specific locations where subsidence studies will be performed. However, if subsidence-prone areas are identified during the Phase 2 geotechnical investigation, the transmission line will be designed and located to avoid subsidence hazards.

#### *Lateral Spreading*

Lateral spreading is the permanent horizontal movement of a liquefiable soil deposit due to the presence of initial shear stresses on horizontal planes within the soil during a seismic event. It occurs predominantly within gradual slopes or on flat sites situated near riverbanks, shorelines, bulkheads, or wharves. For locations where liquefaction poses a risk, an assessment will be made to determine if lateral spreading would be an additional hazard.

## 3.9 Soil-Related and Geologic Hazards

> OAR 345-021-0010(1)(h)(G): An assessment of soil-related hazards such as landslides, flooding, and erosion which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility.

### *3.9.1 Mass Wasting and Landslides*

Mass wasting is a generic term for landslides, rockslides, rockfall, debris flows, soil creep, and other processes that include the downslope movement of masses of soil and rock. Mass wasting can be initiated by precipitation events, sometimes in conjunction with land use. Slope stability is a function of moisture content, slope gradient, rock and soil type, slope aspect, vegetation, seismic conditions and ground-disturbing activities. Appendix E Attachment H-1 contains a detailed reconnaissance of the Site Boundary showing the locations of known landslides and soil instabilities. Additional information will be collected on unstable areas during the site-specific, Phase 2 geotechnical investigation. Those data will assist in design of a transmission line that either avoids unstable areas or is built to withstand the effects of land movements to avoid dangers to human safety.

### *3.9.2 Flooding*

Floodplain maps published by FEMA were reviewed to evaluate flooding potential within the Site Boundary. Because FEMA floodplain maps typically provide coverage for use by insurers in populated areas, and FEMA data are scarce away from populated areas, more comprehensive data also were evaluated. To evaluate flood hazards, DOGAMI Statewide Flood Hazard Database for Oregon – FEMA Flood Insurance Study inundation zones (2015) were compared to the temporary and permanent disturbance areas associated with the preliminary design (Table H-4). Project work areas, which include multi-use areas, pulling and tensioning sites, and structure work areas, would be temporary features and have temporary impacts in flood zones. Temporary flood zone impacts would occur in Morrow County (4.8 acres), in Baker County (30.3 acres), and in Malheur County (10 acres). Work areas for alternative routes would be the same as those for the Proposed Route.

Project roads would be permanent features and have permanent impacts in the flood zones. Permanent impacts would occur where access roads cross flood zones in Morrow County (0.5 miles) and Malheur County (0.8 mile). Access roads for alternative routes would cross flood zones in Morrow County (0.1 mile) and Malheur County (0.2 mile). See Exhibit K, Figures K-19 and K-20 for Morrow County locations, Figure K-62 for Union County locations, and Figure K-75 for Malheur County locations.

**Table H-4. Flood Zone Impacts for Work Areas[1] and Access Roads[2] – Proposed Route and Alternative Routes**

| Facility | County | 100-year Flood Zone Crossed | |
|---|---|---|---|
| | | Temporary Work Areas[1] (acres) | Permanent Roads[2] (miles) |
| Proposed Route | Morrow | 4.8 | 0.5 |
| | Umatilla | 0 | 0 |
| | Union | 0 | 0 |
| | Baker | 30.3 | 0 |
| | Malheur | 10.0 | 0.8 |
| ***Total Proposed Route*** | | ***45.1*** | ***1.3*** |
| **Alternative Routes** | | | |
| West of Bombing Range Road Alternative 1 | Morrow | 0 | 0.1 |
| West of Bombing Range Road Alternative 2 | Morrow | 0 | 0.1 |
| Morgan Lake | Union | 0 | 0 |
| Double Mountain | Malheur | 0 | 0.2 |

[1] Work Areas include multi-use areas, pulling and tensioning sites, and structure work areas. Work areas for Alternative Routes would be the same as those for the Proposed Route.
[2] Access Roads are existing roads with improvements and new roads.
Source: Oregon Spatial Data Library (DOGAMI 2015)

### *3.9.3 Erosion*

Erosion is a continuing natural process that can be accelerated by human disturbances. Factors that influence soil erosion include soil texture, structure, length and slope steepness, vegetative cover density, and rainfall or wind intensity. Soils most susceptible to erosion by wind and water are typically non-cohesive soils with low infiltration rates, residing on moderate to steep and sparsely vegetated slopes. Non-cohesive soils include silty, sandy, or gravelly soils, with little to no clay-sized particles. Wind erosion processes are less affected by slope angles but highly influenced by wind intensity. The potential for soil erosion within the Site Boundary varies based on the erosion mechanism and soil characteristics.

The erosion potential was analyzed using three factors: soil K factor, wind erodibility, and slope. The Phase 2 geotechnical analysis will provide further evaluation of soil erosion potential, based on both additional review of soil properties and laboratory testing of soil samples collected during geotechnical drilling. Soil erodibility will be considered in design of the Project to avoid dangers to human safety.

#### *Soil K Factor*

Soil erosion hazards were mapped throughout the Site Boundary based on the soil's K factor, the soil-erodibility factor. The standard measurement condition is the unit plot. The unit plot is 72.6 feet (22.1 meters) long on a 9 percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the surface of the soil. The plots are plowed, disked, and cultivated the same for a row crop of corn or soybeans except that no crop is grown on the plot.

Soils high in clay have low K values, because they are resistant to detachment. Coarse-textured soils, such as sandy soils, have low K values, because of low runoff even though these soils are easily detached. Medium-textured soils, such as the silt loam soils, have a moderate K values, because they are moderately susceptible to detachment and they produce moderate runoff.

Soils having a high silt content are the most erodible of all soils. They are easily detached, tend to crust, and produce high rates of runoff.

The State Soil Geographic (STATSGO) database was used to characterize soil erosion factors. The U.S. Department of Energy, Pacific Northwest National Laboratory website (DOE 2003) guideline was used to segregate the mapped soils into low, moderate, or high K Factor soils. Low K values ranged from 0.05 to 0.15, moderate K values were from 0.25 to 0.4, and high K values were greater than 0.4. However, the closest category in the Natural Resources Conservation Service (NRCS) geographic information system data file to 0.4 was 0.37. As such, a K factor of 0.37 was used to define soils mostly likely to erode. Appendix B of Attachment H-1 presents further information concerning soil erosion potential. Areas of soils with high K factor that could be affected during construction and operations are contained in Exhibit I, Table I-5 and Table I-9.

#### *Wind Erosion*

The potential for soil erosion by wind was evaluated using NRCS wind erodibility group data, which are based on the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion. Project construction activities that could expose soils particularly erodible to wind erosion include any surface disturbance (e.g., road construction and improvements, vegetation clearing).

#### *Slope*

In general, steep slopes possess a greater potential for erosion by water or mass movements than flat areas. Areas containing greater than 25 percent slope were considered to have greater erosion potential.

## 3.10 Geologic Hazard Mitigation

The following section discusses anticipated Project design, engineering, and construction measures to avoid or mitigate dangers to human safety resulting from the geologic hazards described above.

### *3.10.1 Seismic Hazard Mitigation*

> OAR 345-021-0010(1)(h)(H): An explanation of how the applicant will design, engineer and construct the facility to avoid dangers to human safety from the seismic hazards identified in paragraph (F). The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring for seismic hazards.

In general, transmission towers are designed for large wind and tension loads, which results in ample capacity to resist seismic loads. Towers will be designed in accordance with the NESC C2 (IEEE 2006), ASCE Standard 10-97 (ASCE 1997), ASCE Standard 7, Chapters 13 and 16 (ASCE 2013), and ASCE Manual of Practice (MOP)-74 (Wong and Miller 2010). Substation structures will be designed in accordance with applicable portions of the Oregon Structural Specialty Code (OSSC; ICC 2014).

All towers and facilities for the Project will be designed to meet or exceed the 2014 OSSC. The codebook contains the amendments to the 2015 IBC as adopted by the State of Oregon and local agencies. A qualified engineer will assess and review the seismic, geologic, and soil hazards associated with the construction of the towers and facilities. The Project will be designed to withstand wind and ice loads, which are greater than typical seismic forces. All designs and subsequent construction requirements may be modified based on the site-specific characterization of seismic, geologic and soil hazards. By following the appropriate codes; NESC C-2, OSSC Section 1604, 2015 IBC, ASCE 10-97, ASCE 7-13, ASCE 7-16, and ASCE MOP-74, the Project will be designed, engineered, and constructed to adequately avoid potential dangers to human safety presented by seismic hazards.

The Project facilities are generally unmanned and located in sparsely populated areas. Therefore, the risks to human safety due to seismic hazards are minimal due to the low probability of human presence. All Project facilities will be constructed in accordance with the 2014 OSSC and 2015 IBC, or the more recent standards applicable at the time of detailed design. To ensure compliance with the relevant building codes, IPC proposes that the Council include the following condition in the site certificate providing for the same:

> ***Structural Standard Condition 2:*** *During construction, the site certificate holder shall construct the facility in accordance with the versions of the International Building Code, Oregon Structural Specialty Code, and building codes adopted by the State of Oregon.*

Additional work will be necessary to complete the final seismic hazard assessment and identify all the areas that will require mitigation due to seismic hazards. As discussed in Attachment H-1, this will include the geotechnical field exploration program, laboratory testing, and detailed site reconnaissance. A qualified engineer will assess the seismic, geologic, and soil hazards associated with the construction of each tower and each facility. The Project will be designed to withstand wind and ice loads, which are typically greater than seismic loads from ground shaking. All designs and subsequent construction requirements will be modified based on the site-specific characterization of seismic, geologic, and soil hazards. Some specific mitigation techniques for earthquake-induced landslide and liquefaction hazards are presented below. The principal mitigation strategy for surface rupture hazards is modification of structure locations. Additional mitigation strategies will be developed and refined following completion of future geotechnical investigations. To ensure IPC conducts the additional geological and geotechnical investigations and develops any necessary mitigation, IPC proposes that the Council include the following condition in the site certificate providing for the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *a. Subsurface soil and geologic conditions within the site boundary;*
> *b. Geotechnical design criteria and data for the facility's project features;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

#### *3.10.1.1 Earthquake-Induced Landslide Mitigation*

Hazards and mitigation measures related to landslides in general are discussed in Section 3.10.2 under Mitigation of Slope Instability. To the extent landslides may be triggered by earthquakes in particular, IPC will investigate active faults within the Site Boundary as part of the Site-Specific Geological and Geotechnical Report and will propose mitigation measures specific to earthquake-induced landslides, if necessary. To ensure IPC conducts landslide potential investigations and develops any necessary mitigation, IPC proposes that the Council include the following condition in the site certificate providing for the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *c. Description of potentially active faults that may affect the facility and their potential risk to the facility;*
> *d. LiDAR or field survey investigation of the site boundary to assess the potential for slope instability and landslide hazards;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

#### *3.10.1.2 Liquefaction Mitigation*

For structures or towers that are located in areas with a risk of liquefaction, a number of methods are available to either adequately reduce the risk of liquefaction or improve the performance of the structure (or improve resiliency), if liquefaction were to occur. Specific methods to reduce the liquefaction potential are ground densification to increase the soil's natural resistance to liquefaction, installation of drains to prevent excess ground water pore pressure build-up during a seismic event, and installation of soil-cement shear cells which reduce the seismic shearing demands on the soil. As an alternative, the structure foundations can be designed to account for a layer of soil that may liquefy—e.g., deep foundations can be designed to bypass the liquefiable layer, being founded on deeper layers. IPC proposes that the Council include the following conditions in the site certificate providing that the Site-Specific Geological and Geotechnical Report addresses liquefaction potential and any necessary mitigation measures regarding the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *e. Evaluation of potential liquefaction hazards;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

### *3.10.2 Soil-Related Hazard Mitigation*

| |
|---|
| OAR 345-021-0010(1)(h)(I): An explanation of how the applicant will design, engineer and construct the facility to adequately avoid dangers to human safety presented by the hazards identified in paragraph (G). |

#### *3.10.2.1 Mitigation of Slope Instability*

Slope instability hazards should be thoroughly evaluated to assess the potential for failure. At locations where landslides, debris flows, or marginally stable slopes are identified, the hazard will be mapped and adequately characterized during the field exploration. All roads and transmission facilities will be designed to meet structural and zoning requirements. Structural requirements should adhere to soil lateral load requirements in the 2014 OSSC (Section 1610).

In general, structures should be located to avoid potential slope instability hazards wherever possible, and newly constructed slopes should be designed with an adequate safety factor against failure. Appropriate mitigation methods should be selected based on site characteristics and the structure to be constructed. If feasible, structures should be located with sufficient setback from slopes to mitigate the potential for slope instability during construction and operation. Where structures cannot be moved or realigned, slope instability mitigation techniques may include modification of slope geometry, hydrogeological mitigation, and slope reinforcement methods.

Slope geometry may be altered by grading or removing soil in order to provide a sufficient factor of safety. Hydrogeological mitigation may include surface drainage, shallow drainage, and deep drainage. These drainage mechanisms vary in intensity; however, all mechanisms attempt to reduce the soil's water content. This decreases both the soil's pore pressures and the overall driving force, thereby decreasing landslide risk. Types of drains may include trench drains, horizontal drain wells, siphon drains, or micro drains.

Reinforcement measures may be implemented when geometric slope modifications or drainage improvements are not sufficient or practical. Reinforcement modifications can involve the use of anchors or tieback systems, geofabric installation, buttressing, and cellular and crib face installation.

The use of vegetation may also be combined with the methods described above to help prevent shallow slides by intercepting rainfall, decreasing runoff, and providing root stabilization.

To ensure IPC conducts slope stability investigations and develops any necessary mitigation, IPC proposes that the Council include the following condition in the site certificate providing for the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *c. Description of potentially active faults that may affect the facility and their potential risk to the facility;*
> *d. LiDAR or field survey investigation of the site boundary to assess the potential for slope instability and landslide hazards;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

#### *3.10.2.2 Mitigation of Erosion*

A desktop analysis of soil conditions was conducted prior to initial Project siting (Shaw 2012). This analysis incorporated data from many sources as previously described. The transmission line siting was based partly on engineering constraints related to known geologic hazards, soil stability, water crossings, and areas of steep topography. By considering soil and slope conditions throughout the siting and design process, IPC has avoided soil impacts to the extent possible.

The Project will use existing roads to access Project sites to the extent practicable. Where needed, existing roads will be improved to reduce sediment generation and minimize impacts to soils. Results of further engineering evaluations will be used to provide micrositing and design of Project structures that protect the public and minimize construction on unstable soil surfaces. Additional soil data will be collected during the site-specific geotechnical evaluation to further evaluate soil conditions and to assist in preparing detailed foundation designs and erosion and sediment control measures.

Localized impacts to soils at and around tower locations, access roads, light-duty fly yards, and facility footprints in the temporary disturbance area will be minimized though the use of best management practices (BMP) and restoration efforts to restore soil surfaces and vegetation following disturbances.

Impacts to soils at and around tower locations, access roads, and facility footprints will be avoided or minimized through the use of BMPs and restoration measures to restore soil surfaces and vegetation following disturbances. IPC will meet design standards for new roads as required by the Bureau of Land Management, United States Forest Service (USFS), and Oregon Department of Transportation and will implement BMPs described below and in the Erosion and Sediment Control Plan (ESCP) and National Pollutant Discharge Elimination System (NPDES) permits to reduce potential soil erosion during the construction process. Construction of roads, facilities, and towers will be regulated by the NPDES 1200-C Stormwater Construction Permit and the associated ESCP. To minimize soil erosion, where practical IPC will implement revegetation procedures, such as recontouring, scarification, soil replacement, seedbed preparation, fertilization, seed mixtures, seeding timing, seeding methods, supplemental wetland and riparian plantings, and supplemental forest plantings.

Once the roads, towers, and other facilities have been constructed to the designed specifications, operations will have minimal potential for soil erosion. Slopes and cut banks will be stabilized with riprap and/or planted or seeded with vegetation as practical, and Project facilities will be maintained as required to prevent erosion. Temporary access road sites and other compacted soils will be mechanically loosened where necessary, and where required previously salvaged topsoil will be replaced and non-cropped areas will be revegetated.

Vegetation management methods employed during maintenance operations will not result in soil erosion.

### *Mitigation for Soil Erosion by Water*

Erosion control measures will be designed with attention to the mapped soil erosion hazards described above, with particular attention to areas with medium and high hazard ratings. Work on access roads will include grading and re-graveling of existing roads and construction of new roads. Soil erosion will be minimized by constraining traffic, heavy equipment and construction to existing roads where possible. Where new road construction is required, road widths will be limited to the width necessary to accommodate construction equipment. New roads will be located to avoid steep areas as much as possible.

Areas affected by construction will be reseeded with vegetation to minimize future erosion and to restore the systems to their natural state. Erosion and sediment control measures will be designed to remain intact until natural vegetation is sufficient to protect against erosion. The station operational footprint areas will be graveled to prevent erosion. The area outside the station fence may also be graveled where practical to prevent soil erosion during operations.

The Project has applied for and will obtain a 1200-C permit (see Exhibit I, Attachment I-3). Specific erosion and sediment control measures and BMPs to be implemented during the project construction and operations include the following BMPs:

- Avoid Highly Erodible Areas: Initial mitigation measures should include avoiding highly erodible areas, such as steep slopes, where possible, and rerouting impacted drainages to natural drainages to minimize erosion and sedimentation from runoff. Areas impacted by construction should be reseeded and sediment fences, check dams, and other BMPs will remain in place until impacted areas are well vegetated and the risk of erosion has subsided.

- Stabilize Road Entrance/Exit: A stabilized construction entrance/exit should be installed at locations where dirt (exposed, disturbed land) or newly constructed roads intersect existing paved roads. Stabilized entrances should also be installed at the construction laydown areas. The stabilized construction entrance/exits should be inspected and maintained for the duration of the Project life.
- Preserve/Restore Vegetation: To the extent practicable, existing vegetation should be preserved. In the event that vegetation is destroyed in temporary road locations or laydown areas, stockpiled topsoils should be replaced and recontoured. Vegetation should be reseeded to prevent erosion using an approved seed mixture specified by the NRCS or the USFS as being capable of surviving in local conditions (see the Vegetation Management Plan attached to Exhibit P1, Attachment P1-4).
- Control Dust: Dust should be controlled during construction through water application to the disturbed grounds and access roads where necessary. Application of excess water that could lead to erosion or sedimentation should be avoided. Other methods of dust control may include the use of poly sheeting, vegetation, or mulching. Speed limits should be kept to a minimum to prevent pulverization of road substrate.
- Install Silt Fencing: Silt fencing or an equivalent control measure should be installed at various locations along the transmission line. The fencing should be installed on contours downgradient of excavations, fill areas, or graded areas where necessary. Silt fencing or an equivalent control measure should be installed around the perimeters of material stockpiles and construction laydown areas.
- Install Straw Wattles: Straw wattles should be installed to decrease the velocity of sheet flow from stormwater. The wattles should be used along the downgradient edge of access roads adjacent to slopes or sensitive areas.
- Apply Gravel and Mulching: Gravel should be used where soil becomes wet or muddy to prevent erosion and working of the soil. Mulch should be provided to immediately stabilize soil exposed as a result of land disturbing activities. The mulch reduces the potential for wind and raindrop erosion.
- Install Stabilization Matting: Jute mesh, straw matting, or turf reinforcement matting should be used to stabilize slopes that could become exposed during installation of access roads, during rainfall events, or to stabilize intermittent streams disturbed during construction of road crossings. Erosion control matting should be combined with revegetation techniques.
- Control Concrete Washout Area: Concrete washout should be appropriately managed to prevent concrete washout water from impacting soils, water bodies, or wetlands.
- Manage Stockpiles: Soils excavated may be temporarily stockpiled. While the material is stockpiled, perimeter controls should be established and the stockpiled material should be covered as necessary with mulch, plastic sheeting, and/or other appropriate means to prevent erosion and sedimentation.
- Install Check Dams, Sediment Traps, and Sediment Basins: Check dams and sediment traps should be used during construction near tributaries and existing drainages. The check dams and sediment traps will minimize downstream disturbances and sedimentation of creeks. A sediment basin is a constructed temporary pond, built to

capture eroded soils that wash off from larger construction sites during rain storms. The sediment-laden soil settles in the pond before the runoff is discharged.

To ensure the protective measures set forth in the draft ESCP are incorporated into the final ESCP and to ensure compliance with the final ESCP, IPC proposes that the Council include the following conditions in the site certificate providing for the same:

> ***Soil Protection Condition 3:*** *Prior to construction, the site certificate holder shall submit to the department a copy of an ODEQ-approved construction-related final Erosion and Sediment Control Plan (ESCP). The protective measures described in the draft ESCP Plan in ASC Exhibit I, Attachment I-3, shall be included as part of the construction-related final ESCP, unless otherwise approved by the department.*

> ***Soil Protection Condition 6:*** *During construction, the site certificate holder shall conduct all work in compliance with the final ESCP referenced in Soil Protection Condition 3.*

### *Mitigation for Soil Erosion by Wind*

To mitigate the risk of accelerating soil erosion by wind in areas rated with wind erodibility groups 1 through 4, IPC will implement reseeding efforts, apply mulch, and use water for dust control. Areas that are susceptible to aeolian processes that will be disturbed by construction activities and not permanently covered by aboveground facilities will be vegetated using a seed mixture specified by the applicable agencies as being capable of surviving in local conditions, and withstanding burial and deflation from aeolian processes. Disturbed areas susceptible to wind erosion may be hydroseeded when temperatures and moisture levels are conducive to seed germination. Vegetation protection actions and activities will be presented as part of the Project’s Vegetation Management Plan (see Exhibit P1, Attachment P1-4). To ensure the protective measures set forth in the draft Vegetation Management Plan are incorporated into the final Vegetation Management Plan and to ensure compliance with the final Vegetation Management Plan, IPC proposes that the Council include the following conditions in the site certificate providing for the same:

> ***Fish and Wildlife Condition 5:*** *Prior to construction, the site certificate holder shall finalize, and submit to the department for its approval, a final Vegetation Management Plan. The protective measures described in the draft Vegetation Management Plan in ASC Exhibit P1, Attachment P1-4, shall be included as part of the final Vegetation Management Plan, unless otherwise approved by the department.*

> ***Fish and Wildlife Condition 18:*** *During construction, the site certificate holder shall conduct all work in compliance with the final Vegetation Management Plan referenced in Fish and Wildlife Condition 5.*

> ***Fish and Wildlife Condition 28:*** *During operation, the site certificate holder shall conduct all work in compliance with the final Vegetation Management Plan referenced in Fish and Wildlife Condition 5.*

### *3.10.2.3 Mitigation of Expansive Soils*

Expansive soils swell when exposed to moisture and shrink when dried. This change in volume can be detrimental to structure foundations. The selection of appropriate mitigation techniques will depend on the specific properties of site soils and foundation requirements of proposed structures. In general, mitigation techniques for expansive soils include removal, bypass, isolation, and treatment. If only a thin layer of expansive soil is present at a site, it may be feasible to strip and remove it. For thicker layers of expansive soil, it is common practice to extend foundations deep enough to effectively bypass the zone where moisture content is likely to change. Another mitigation alternative is to isolate the soil from changes in moisture content, through the use of enhanced drainage and/or coverings. Where only shallow foundations are practical, another mitigation alternative is to treat the expansive soils with lime or some other material that reduces their expansive properties. IPC proposes that the Council include the following condition in the site certificate providing that the Site-Specific Geological and Geotechnical Report addresses the potential of expansive soil impacts and any necessary mitigation measures regarding the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *f. Evaluation of potential soil expansion hazards;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

#### *3.10.2.4 Mitigation of Groundwater*

The first step in mitigation of hazards posed by groundwater is to understand where and when it is present. Groundwater levels can vary significantly from one location to another and from one season to another. The geotechnical investigation will help to determine where groundwater will be relevant along the proposed alignments. Where groundwater plays a role in slope instability, the hydrogeological mitigation measures discussed in above should be considered. As discussed in Attachment H-1, groundwater can also complicate construction, particularly where excavations extend below the water table. This will most likely be applicable to the proposed alignment where drilled shafts are required for tower foundations. If a shaft is excavated in good quality rock or firm fine-grained soils below the water table, groundwater may not be a significant concern. However, if shaft foundations extend below the water table in granular soils, casing and/or slurry may be necessary to prevent soil heave and maintain shaft integrity. IPC proposes that the Council include the following condition in the site certificate providing that the Site-Specific Geological and Geotechnical Report addresses affected groundwater and any necessary mitigation measures regarding the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *g. Description of groundwater detections and any related potential risk to the facility;*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

### *3.10.2.5 Mitigation of Corrosive Subsurface Conditions*

Where soil conditions are identified that may be corrosive to metals, potential mitigation alternatives may include application of protective coatings, such as coal tar enamel. Another mitigation alternative is to increase the metal thickness to provide a "sacrificial" layer that is thick enough to manage the amount of corrosion anticipated to occur over the structure's design life. Where sulfates are present and corrosion of concrete is a concern, mitigation alternatives may include use of sulfate-resistant cement, such as type II low-alkali cement, coating the concrete with an asphalt emulsion, or reducing the water-cement ratio to reduce the hydraulic conductivity of the concrete and slow the reaction processes. IPC proposes that the Council include the following condition in the site certificate providing that the Site-Specific Geological and Geotechnical Report addresses corrosive soils and any necessary mitigation measures regarding the same:

> ***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*
> *. . .*
> *h. Description of corrosive soils detections and any related potential risk to the facility; …*
> *. . .*
> *j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

### *3.10.2.6 Flood Mitigation*

Flood hazard mitigation goals are to avoid and reduce damage to constructed tower and facility locations, prevent construction that could exacerbate flooding, minimize economic losses associated with repair of structures influenced by flooding hazards and avoid dangers to human safety. Federal and state policies related to development in flood-prone areas were developed according to FEMA requirements and guidelines. These policies include zoning ordinances found in local regulations and building code ordinances in the OSSC Section 1612. This code establishes flood protection standards for all construction, including criteria to ensure that the foundation will withstand flood forces.

There are very few miles of access roads (permanent Project features) within the 100-year flood zone within the Site Boundary. Results of further engineering evaluations will be used to provide micrositing and design of Project structures that protect the public and minimize construction in flood zone areas. To reduce flood hazards, Project structures and towers will be set back from areas of high flood risks during final design. Where structures cannot be set back, a site-specific structural and erosion hazard assessment will be conducted to determine mitigation requirements.

Standards for protecting foundations against flood damage include requirements for soil testing and prepared fill. Building code provisions impose conditions to ensure that structures built in flood zones meet minimum standards. The primary structural code in Oregon is the OSSC, Section 1612 (ICC 2014). This code establishes flood protection standards for all construction, including criteria to ensure that the foundation will withstand flood forces and that all portions of the structures subject to damage are above, or otherwise protected from, flooding. IPC proposes that the Council include the following condition in the site certificate providing that the Site-Specific Geological and Geotechnical Report addresses flood hazards and any necessary mitigation measures regarding the same:

***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*

*. . .*

*i. Description of Project features within the 100-year flood zone and any related potential risk to the facility; and*

*j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

# 4.0 IDAHO POWER'S PROPOSED SITE CERTIFICATE CONDITIONS

IPC proposes the following site certificate conditions to ensure compliance with the relevant EFSC standards:

***Prior to Construction***

***Structural Standard Condition 1:*** *Prior to construction, the site certificate holder shall conduct a site-specific geological and geotechnical investigation, and shall submit to the department for its approval a Site-Specific Geological and Geotechnical Report. The investigation and/or report shall address the following:*

*a. Subsurface soil and geologic conditions within the site boundary;*

*b. Geotechnical design criteria and data for the facility's project features;*

*c. Description of potentially active faults that may affect the facility and their potential risk to the facility;*

*d. LiDAR or field survey investigation of the site boundary to assess the potential for slope instability and landslide hazards;*

*e. Evaluation of potential liquefaction hazards;*

*f. Evaluation of potential soil expansion hazards;*

*g. Description of groundwater detections and any related potential risk to the facility;*

*h. Description of corrosive soils detections and any related potential risk to the facility;*

*i. Description of Project features within the 100-year flood zone and any related potential risk to the facility; and*

*j. Define and delineate geological and geotechnical hazards to the facility, and means to mitigate the identified hazards.*

***Soil Protection Condition 3:*** *Prior to construction, the site certificate holder shall submit to the department a copy of an ODEQ-approved construction-related final Erosion and Sediment Control Plan (ESCP). The protective measures described in the draft ESCP in ASC Exhibit I, Attachment I-3, shall be included as part of the construction-related final ESCP Plan, unless otherwise approved by the department.*

***Fish and Wildlife Condition 5:*** *Prior to construction, the site certificate holder shall finalize, and submit to the department for its approval, a final Vegetation Management Plan. The protective measures described in the draft Vegetation Management Plan in ASC Exhibit P1, Attachment P1-4, shall be included as part of the final Vegetation Management Plan, unless otherwise approved by the department.*

***During Construction***

> ***Structural Standard Condition 2:*** *During construction, the site certificate holder shall construct the facility in accordance with the versions of the International Building Code, Oregon Structural Specialty Code, and building codes adopted by the State of Oregon.*

> ***Soil Protection Condition 6:*** *During construction, the site certificate holder shall conduct all work in compliance with the final ESCP referenced in Soil Protection Condition 3.*

> ***Fish and Wildlife Condition 18:*** *During construction, the site certificate holder shall conduct all work in compliance with the final Vegetation Management Plan referenced in Fish and Wildlife Condition 5.*

***During Operation***

> ***Fish and Wildlife Condition 28:*** *During operation, the site certificate holder shall conduct all work in compliance with the final Vegetation Management Plan referenced in Fish and Wildlife Condition 5.*

# 5.0 CONCLUSIONS

Exhibit H includes the application information provided for in OAR 345-021-0010(1)(h). Further, the evidence set forth in Exhibit H shows the Project will meet the Structural Standard at OAR 345-022-0020.

# 6.0 COMPLIANCE CROSS-REFERENCES

Table H-5 identifies the location within the application for site certificate of the information responsive to the application submittal requirements in OAR 345-021-0010(1)(h), the Structural Standard at OAR 345-022-0020, and the relevant Amended Project Order provisions.

**Table H-5. Compliance Requirements and Relevant Cross-References**

| Requirement | Location |
|---|---|
| **OAR 345-021-0010(1)(h)** | |
| (h) Exhibit H. Information from reasonably available sources regarding the geological and soil stability within the analysis area, providing evidence to support findings by the Council as required by OAR 345-022-0020, including: | |
| (A) A geologic report meeting the guidance in Oregon Department of Geology and Mineral Industries open file report 00-04 "Guidelines for Engineering Geologic reports and Site-Specific Seismic Hazard Reports." | Exhibit H, Section 3.3 and Attachment H-1 |
| (B) A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions. | Exhibit H, Section 3.4 and Attachment H-1 |
| (C) Evidence of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate site specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete. | Exhibit H, Section 3.5 and Attachment H-2 |

| Requirement | Location |
|---|---|
| (D) For all transmission lines, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead-ends, corners, and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction. | Exhibit H, Section 3.6 and Attachment H-1 |
| (E) For all pipelines that would carry explosive, flammable or hazardous materials, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings and portions of the proposed alignment where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction. | Exhibit H, Section 3.7. Not Applicable because the Project does not contain pipelines. |
| (F) An assessment of seismic hazards. For the purposes of this assessment, the maximum probable earthquake (MPE) is the maximum earthquake that could occur under the known tectonic framework with a 10 percent chance of being exceeded in a 50 year period. If seismic sources are not mapped sufficiently to identify the ground motions above, the applicant shall provide a probabilistic seismic hazard analysis to identify the peak ground accelerations expected at the site for a 500 year recurrence interval and a 5000 year recurrence interval. In the assessment, the applicant shall include: | Exhibit H, Section 3.8 |
| (i) Identification of the Maximum Considered Earthquake Ground Motion under the 2009 International Building Code. | Exhibit H, Section 3.8.1 and Attachment H-1 |
| (ii) Identification and characterization of all earthquake sources capable of generating median peak ground accelerations greater than 0.05g on rock at the site. For each earthquake source, the applicant shall assess the magnitude and minimum epicentral distance of the maximum credible earthquake (MCE). | Exhibit H, Section 3.8.2 and Attachment H-1 |
| (iii) A description of any recorded earthquakes within 50 miles of the site and of recorded earthquakes greater than 50 miles from the site that caused ground shaking at the site more intense than the Modified Mercalli III intensity. The applicant shall include the date of occurrence and a description of the earthquake that includes its magnitude and highest intensity and its epicenter location or region of highest intensity. | Exhibit H, Section 3.8.3 and Attachment H-1 |
| (iv) Assessment of the median ground response spectrum from the MCE and the MPE and identification of the spectral accelerations greater than the design spectrum provided in the 2010 Oregon Structural Specialty Code. The applicant shall include a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic or subsurface conditions that could result in expected ground motions greater than those characteristic of the Maximum Considered Earthquake Ground Motion identified above. | Exhibit H, Section 3.8.4 |
| (v) An assessment of seismic hazards expected to result from reasonably probable seismic events. As used in this rule “seismic hazard” includes ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence. | Exhibit H, Section 3.8.5 |

| Requirement | Location |
|---|---|
| (G) An assessment of soil-related hazards such as landslides, flooding and erosion which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility. | Exhibit H, Section 3.9 and Attachment H-1 |
| (H) An explanation of how the applicant will design, engineer and construct the facility to avoid dangers to human safety from the seismic hazards identified in paragraph (F). The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring for seismic hazards. | Exhibit H, Section 3.10.1 and Attachment H-1 |
| (I) An explanation of how the applicant will design, engineer and construct the facility to adequately avoid dangers to human safety presented by the hazards identified in paragraph (G). | Exhibit H, Section 3.10.2 |
| **OAR 345-022-0020** | |
| To issue the requested Site Certificate, the Council must find that:<br>(a) The applicant, through appropriate site-specific study, has adequately characterized the site as to the Maximum Considered Earthquake Ground Motion as shown for the site in the 2009 International Building Code and maximum probable ground motion, taking into account ground failure and amplification for the site specific soil profile under the maximum credible and maximum probable seismic events; and | Exhibit H, Section 3.8.1 through Section 3.8.4, and Attachment H-1 |
| (b) The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by seismic hazards affecting the site that are expected to result from maximum probable ground motion events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, liquefaction, lateral spreading, tsunami inundation, fault displacement, and subsidence; | Exhibit H, Section 3.8 and Section 3.10.1 |
| (c) The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggravated by, the construction and operation of the proposed facility; and | Exhibit H, Section 3.9 and Section 3.10.2 |
| (d) The applicant can design, engineer and construct the facility to avoid dangers to human safety presented by the hazards identified in subsection (c). | Exhibit H, Section 3.8, Section 3.10.1, and Section 3.10.2 |
| **Amended Project Order Provisions** | |
| The Department understands that detailed site-specific geotechnical investigation for the entire site boundary is not practical in advance of completing the final facility design and obtaining full site access. However, the rule requires evidence of consultation with the Oregon Department of Geology and Mineral Industries (DOGAMI) prior to submitting the application if the applicant proposes to base Exhibit H on limited pre-application geotechnical work. Exhibit H should include written evidence of consultation with DOGAMI regarding the level of geologic and geotechnical investigation determined to be practical for the application submittal. | Exhibit H, Section 3.5 and Attachment H-2 |
| Any geotechnical reports included in Exhibit H as supporting evidence that the proposed facility will meet the Council's structural standard should follow the guidelines of DOGAMI's "Open File Report 00-04 "Guidelines for Engineering Geologic Reports and Site Specific Seismic Hazard Reports." | Exhibit H, Section 3.3 and Attachment H-1 |

| Requirement | Location |
|---|---|
| Note that OAR 345-021-0010(1)(h), paragraphs (A), (F)(i), and (F)(iv) contain references to outdated guidelines and codes. Until such time that the Council rules can be revised to reflect current standards, the Department requests that applicants consult directly with DOGAMI, determine the most current structural standards that apply to its facility, then use those codes to prepare Exhibit H. The application should clearly note which codes and guidelines were used to prepare the information in Exhibit H. Exhibit H should also provide evidence that the current codes are equivalent to or more stringent than those cited in the Council's rules, and that the applicant agrees to construct the facility in accordance with the current codes and guidelines. | Exhibit H, Section 3.2 and Attachment H-1 |

# 7.0 RESPONSE TO PUBLIC COMMENTS

Table H-6 identifies the location within the application for site certificate of the information responsive to the public comments cited in the Amended Project Order.

**Table H-6. Public Comments**

| Requirements | Location |
|---|---|
| Geological hazards, including seismic hazards, steep terrain, and landslides, should be addressed in Exhibit H. | See Exhibit H, Section 3.3 |
| A commenter expressed concern about "thermal vents" on Lindsey Mountain—if the proposed route is in the area and might be impacted by such vents, it should be addressed in Exhibit H. | The Project is not in the vicinity of Lindsey Mountain. |
| A commenter expressed concern about "27 recognized fault lines" present in the John Day Valley. The applicant should address identified fault lines in Exhibit H. | The Project is not in the vicinity of the John Day Valley. |

# 8.0 REFERENCES


ASCE (American Society of Civil Engineers). 1997. Design of Latticed Steel Transmission Structures (ASCE Standard 10-97). Reston, VA, 71pp.

ASCE. 2013. Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE Standard 7). Reston, VA, 593pp.

Burns, Bill. 2011. DOGAMI staff member discussions during meeting of April 4, 2011.

DOGAMI (Oregon Department of Geology and Mineral Industries). 2010. Oregon's Earthquake Risk and Resiliency. *Cascadia Newsletter*. Winter.

DOGAMI. 2015. Statewide Flood Hazard Database for Oregon – FEMA Flood Insurance Study inundation zones. Available online at: http://spatialdata.oregonexplorer.info/geoportal/catalog/search/resource/details.page?uuid=%7BF2CC36DE-1F0A-42D2-9B8D-FDD71721A7D3%7D (accessed December 2016).

DOE (Department of Energy, Pacific Northwest National Laboratory). 2003. 5.3.2 Soil Erodibility Factor. Available online at: http://mepas.pnl.gov/mepas/formulations/source_term/5_0/5_32/5_32.html (accessed April 2011).

ICC (International Code Council). 2014. 2014 Oregon Structural Specialty Code: Chapter 16 Structural Design. May. ISBN: 978-1-60983-517-0.

IEEE (Institute of Electrical and Electronics Engineers). 2006. NESC National Electrical Safety Code C2-2007.

NGDC (National Geophysical Data Center). 1985. Earthquake Intensity Database Search, 1683 – 1985, NOAA Satellite and Information Service. Available online at: http://www.ngdc.noaa.gov/cgi-bin/hazard/util/ffq_result.pl (Accessed February 2011).

OPS (Office of Pipeline Safety). 1996. National Pipeline Mapping System, 1996, U.S. DOT Pipeline Safety. Available online at: https://www.npms.phmsa.dot.gov/ (Accessed March 2016).

OSBGE (Oregon State Board of Geologist Examiners). 2014. Guideline for Preparing Engineering Geologic Reports, Second Edition, May 30, 2014. Available online at: https://www.oregon.gov/osbge/pdfs/Publications/EngineeringGeologicReports_5.2014.pdf.Pacific Northwest Seismic Network. 2008. Earthquake Catalogs and Data. Available online at http://www.pnsn.org/HIST_CAT/catalog.html (Accessed February 2001).

Shaw (Shaw Environmental & Infrastructure, Inc.). 2012. Desktop Geotechnical Report, Proposed 500kV Transmission Line, Boardman, Oregon to Hemingway, Idaho. January.

UNR (University of Nevada, Reno, Nevada Seismological Laboratory). 1996. What is Richter Magnitude? Available online at: http://www.bing.com/search?q=UNR%2C+earthquake+magnitude&FORM=LENIE. (Accessed April 2011).

USGS (U.S. Geological Survey). 2009. The Modified Mercalli Intensity Scale. Available online at http://earthquake.usgs.gov/learn/topics/mercalli.php (Accessed December 2016).

Wong, C.J., and M.D. Miller, eds. 2010. Guidelines for Electrical Transmission Line Structural Loading (ASCE Manual of Practice MOP-74). ISBN-10: 0784410356. ASCE. Reston, VA.

# ATTACHMENT H-1
# ENGINEERING GEOLOGY AND SEISMIC HAZARDS SUPPLEMENT

**Attachment H-1 Engineering Geology and Seismic Hazards Supplement to Exhibit H**
**Boardman to Hemingway**
**500kV Transmission Line Project**
**Boardman, Oregon, to**
**Hemingway, Idaho**

December 7, 2016

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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24-1-03820-005

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## 1.0 INTRODUCTION

### 1.1 General

The intent of this report is to supplement Exhibit H of the Idaho Power Company (IPC) Application for Site Certificate (Oregon Administrative Rule (OAR) 345-021-0000) to the Energy Facility Siting Council (EFSC) for the Boardman to Hemingway 500kV Transmission Line Project. The project location is shown on the Vicinity Map, Figure 1. The basis for Exhibit H is OAR 345-021-0010(1)(h) and OAR 345-022-0020. With this document, Shannon & Wilson, Inc., will present information regarding geological and soil stability, as required by EFSC Exhibit H, along the proposed alignments of the Boardman to Hemingway 500kV Transmission Line. The following sections present the requirements outlined in OAR 345-022-0020(1), which generally states that the applicant must provide evidence that they can design, engineer, and construct the proposed facility in such a way as to avoid danger to human safety. Specifically, OAR 345-022-0020(1) states that the applicant must be able to demonstrate the following:

a) *The applicant, through appropriate site-specific study, has adequately characterized the site as to the Maximum Considered Earthquake Ground Motion as shown for the site in the 2009 International Building Code and maximum probable ground motion, taking into account ground failure and amplification for the site specific soil profile under the maximum credible and maximum probable seismic events; and*

b) *The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by seismic hazards affecting the site that are expected to result from maximum probable ground motion events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, liquefaction, lateral spreading, tsunami inundation, fault displacement, and subsidence;*

c) *The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggravated by, the construction and operation of the proposed facility; and*

d) *The applicant can design, engineer, and construct the facility to avoid dangers to human safety presented by the hazards identified in subsection (c).*

The following information is in accordance with OAR 345-021-0010(1)(h) and is intended to provide evidence of compliance to OAR 345-022-0020.

# 2.0 TOPOGRAPHIC AND GEOLOGIC FEATURES

The document OAR 345-021-0010(1)(h)(A) requires *"A geologic report meeting the guidance in Oregon Department of Geology and Mineral Industries open file report 00-04 'Guidelines for Engineering Geologic Reports and Site-Specific Seismic Hazards Reports.'"* This section presents the overall topographic and geologic framework for the proposed transmission alignments. Subsequent sections discuss potential geologic hazards within these geomorphic regions and categorization of these conditions/hazards for preliminary geotechnical design purposes.

Topographic and geologic information provided in this section is based on readily available reports and maps from the Oregon Department of Geology and Mineral Industries, geographic information system (GIS)-based maps, Idaho Department of Water Resources (IDWR) GIS-based maps, and other geologic literature, including reports from the U.S. Geological Survey, as listed in the references section of this report.

The proposed transmission alignments are located within four general physiographic provinces. From north to south along the alignment, the provinces are the Deschutes-Columbia Plateau, the Blue Mountains, the Owyhee Plateau, and the Snake River Plain (refer to Figure 2, Physiographic Province Page Index). The following discussion presents a brief description of the topographic characteristics of each province, major stream drainage systems (with an emphasis on those streams that will be crossed by the proposed transmission alignments), a description of the general geologic environment, and a brief description of surface soils mantling the bedrock units in each province.

## 2.1 Deschutes-Columbia Plateau

### 2.1.1 Topography

The northernmost portion of the IPC Proposed Route and the entirety of the West of Bombing Range Road Alternatives 1 and 2 are located within the Deschutes-Columbia Plateau province. The Deschutes-Columbia Plateau is predominantly a volcanic province covering approximately 63,000 square miles in Oregon, Washington, and Idaho. The plateau is surrounded on all sides by mountains. For the purpose of this study, we will describe only the portion of the province that lies in Oregon.

The Deschutes-Columbia Plateau is located in the northern portion of Oregon, and, for the purposes of this study, the province is bounded on the west by the Cascade Range, on the southwest by the High Lava Plains, on the south and east by the Blue Mountains, and artificially on the north by the Columbia River. The northernmost portion of the IPC Proposed Route and the entirety of the West of Bombing Range Road Alternatives 1 and 2 cross the Deschutes-Columbia Plateau as shown on Figure 2 and on Figure 3, Deschutes-Columbia Plateau Topography and Drainage. The region of the Deschutes-Columbia Plateau crossed by the alignments is known as the Umatilla Basin and slopes gently northward toward the Columbia River, with elevations up to 3,000 feet along the southern margins and elevations as low as a few hundred feet along the river.

#### 2.1.2 Drainage

Primary rivers within the province that are near the project area include the west-flowing Columbia River and its tributaries, the Umatilla River, and Willow Creek. McKay Creek and Butter Creek are major tributaries of Umatilla River. These streams have cut intricate, deep canyons across the plateau, but broad, flat plains remain between them within the Umatilla Basin. The IPC Proposed Route crosses the North Fork of Butter Creek three times, and the south Fork of Butter Creek once. In the foothills of the adjacent Blue Mountains province, the route also crosses McKay Creek and several smaller tributaries of the Umatilla River.

#### 2.1.3 Geologic Overview

The Deschutes-Columbia Plateau province was created on a grand scale. Its formation has been described by Orr and Orr (2000), and is summarized in the following paragraphs. Immense outpourings of lavas during the Miocene epoch created one of the largest flood basalt provinces in the world, second only to the Deccan Plateau in India. Erupting from multiple fissures in central and northeast Oregon as well as in southeast Washington and northwest Idaho, flow after flow of basalt lava filled a gradually subsiding basin, creating a broad, featureless plateau.

Even as the lavas were still erupting, regional stresses in the earth's crust began to warp the basalt surface into a complicated pattern of folds and faults. The Umatilla Basin is a down–warp or depression in the basalt surface. Upper Miocene to Pliocene age sediments eroded from the geologically older Blue Mountains province were deposited into this depression (refer to Figure 4, Deschutes-Columbia Plateau Geology, for province-wide general geology and Appendix A for geologic strip maps and rock unit descriptions). These sediments consist of partly indurated cobble-gravel and tuffaceous sand and silt, which now form terraces and alluvial fan deposits that lie between the basin floor and the basalt highlands along the southern margin of the basin. In the early Pleistocene, wind-blown silt called "loess" was deposited across the basalt uplands around the margins of the Umatilla Basin.

During the ice ages of the late Pleistocene, numerous lakes developed behind ice dams in northern Washington and western Montana. The largest of these, Glacial Lake Missoula, occupied the Clark Fork River Valley and much of western Montana. Glacial Lake Missoula grew steadily deeper until the ice dam failed and the lake emptied catastrophically. Once the lake had drained, the ice slowly reoccupied its position across the valley and the lake developed anew. This process of filling and emptying catastrophically was repeated numerous times. The resulting floods overpowered the landscape, eroding soil and scouring bedrock surfaces across southeastern Washington and through the Columbia River Gorge. The deluge back-flooded up stream valleys tributary to the Columbia River, including the Umatilla River, where the floodwater became temporarily impounded in the Umatilla Basin, forming a short-lived lake known as Lake Condon. As the energy of the flood waters dissipated in the area of Lake Condon, its sediment load, consisting of silt, sand, cobble-gravel, and boulders, was deposited across the floor of the basin. The geology of the Deschutes-Columbia Plateau Province is shown in Figure 4; strip maps and rock unit descriptions from the area are included in Appendix A.

#### 2.1.4 Soils

Soils data have been compiled by the National Resources Conservation Service (NRCS) in a series of county-wide reports. The following summary of soil conditions is discussed similarly by county from north to south along the IPC Proposed Route. Soil data tables and strip maps of soil units within a one-half mile radius of the IPC Proposed Route, rebuild sections, the alternative alignments, and associated multi-use areas are provided for reference in Appendix B, Soils Data Tables and Maps.

Morrow County soils, from the substation at the northern end of the alignment to approximately milepost 12 (MP12), are largely derived from sediments deposited during the late Pleistocene in former Lake Condon, which temporarily occupied the Umatilla Basin during the periods of catastrophic flooding from Glacial Lake Missoula. These soils are relatively uniform, consisting of well-drained silt loam to fine sandy loam with rare gravelly silt loam. The sandy soils are generally greater than 5 feet thick over the underling basalt bedrock; they are well drained, and have a moderate to severe erosion potential. A few sand dunes are present between MP7 and MP12.

South of MP12, the land surface begins to rise gradually in elevation and the sandy water deposited soils are replaced by wind-blown silt, or "loess." The loess is thickest on broad uplands. On narrow ridges, steep slopes, and along streams, such as Butter Creek, the loessal soils are subject to erosion and are often mixed with stony colluvium derived from the underlying basalt bedrock. A few isolated rock outcrops are present along Butter Creek where the soils have been eroded along the stream channel. Scattered rock outcrops and silt loam soils mixed with stony colluvium and residuum are common south of MP27 and on into Umatilla County.

As the IPC Proposed Route continues into Umatilla County, it crosses terraces south of the Umatilla Basin and then begins climbing the basalt highlands. Soils become gradually thinner, but are still composed largely of loess, which consist of fine sandy silt loam to silty fine sandy loam. The soils vary from about 20 to 40 inches deep and are commonly mixed with stony basalt colluvium and residuum or overlie cemented alluvial terrace deposits. The soils are generally well-drained and the erosion hazard remains moderate to severe.

## 2.2 Blue Mountains Province

### 2.2.1 Topography

The IPC Proposed Route continues toward the southeast through the Blue Mountains physiographic province. The Blue Mountains province is located largely in northeastern Oregon and is bounded on the east by the Snake River Canyon, the Columbia River Plateau, and an Accreted Terrane; on the north and west by the Deschutes-Columbia Plateau; and on the south by the High Lava Plains and the Owyhee Plateau provinces. The Blue Mountains province is made up of a cluster of smaller ranges of various orientations and relief. Their multiple origins are evident in the topography. The western portion of the province is part of a wide, uplifted plateau, while the Wallowa Mountains on the east contain a striking array of glacially sculpted mountain peaks, deep canyons, and broad valleys.

The IPC Proposed Route traverses the Blue Mountains just west of the Grande Ronde Valley, and then along the low hills that rise above the eastern margin of Baker Valley, which is drained by the Powder River (refer to Figure 5, Blue Mountains Topography and Drainage). The Morgan Lake Alternative parallels the IPC Proposed Route, farther west of the Grande Ronde Valley. The Proposed 230-kV Rebuild Route parallels the IPC Proposed Route northeast of Baker City. The alignments are generally situated between the Elkhorn Mountains, to the west, and the Wallowa Mountains, to the east.

The IPC Proposed Route continues in a southwesterly direction across relatively low rolling hills that form the southeastern margin of the Baker Valley, and then south over Lone Pine Mountain, until reaching the Sutton Creek Valley. The alignment then turns toward the southeast, up the Sutton Creek Valley, and in a direction that approximately parallels the Interstate 84 highway. Topography south of the Baker Valley consists of low, steep-sided mountains and ridges with narrow intervening valleys. Most valleys are either dry or occupied by small ephemeral streams. Small springs are often present at the heads of the valleys.

The IPC Proposed Route reaches a drainage divide near Pleasant Valley. From here, the route continues southeasterly down Alder Creek. Before it reaches Durkee Valley, it turns south, crosses Alder Creek, then crosses the foothills to the northwest of Durkee Valley. It continues across the Burnt River where it turns southeast along the mountains to the west of the Burnt River Canyon. At Dixie, the alignment begins to follow the canyon until Huntington. This canyon is narrow with rocky, steep-sided valley margins. Adjacent mountain ridges and peaks rise 2,000 feet or more above the valley floor.

About 4 miles south of Huntington, the Proposed 138-kV Rebuild parallels the IPC Proposed Route. Here, near its closest approach to the Snake River, the IPC Proposed Route turns south. The route then crosses the southeastern foothills of the Blue Mountains. Formed primarily of fine-grained sedimentary rocks, the peaks and ridges are lower in elevation, more rounded, and eroded by a more finely divided drainage network than the hard rock peaks along the Burnt River Canyon. Most canyons are dry or contain only small seasonal streams.

About 8 miles north of the town of Vale, Oregon, the route swings southwestward, then south again, crosses the Willow Creek Valley, then swings south again and crosses the Malheur River about 10 miles west-southwest of Vale. The valleys of Willow Creek and the Malheur River are intensely cultivated; vegetables and other crops are made possible in this area of sparse precipitation by extensive irrigation systems. In contrast to the green valley floors, the surrounding hills are dry, brown, and sparsely vegetated. After crossing the Malheur River, the Double Mountain Alternative provides an option to cut off a northward curve in the IPC Proposed Route, which then enters the Owyhee Plateau physiographic province.

### 2.2.2 Drainage

The Blue Mountain Range consists of several extensive watersheds, draining into rivers including the Grande Ronde, Imnaha, Wallowa, and John Day. The Grande Ronde River is the principal watershed of the Blue Mountain Range. With headwaters approximately 20 miles southwest of La Grande, the Grande Ronde River intersects the proposed alignment approximately 7 miles west of La Grande. The Grande Ronde River flows through the mountains, generally trending north until it passes La Grande and begins to trend northeast, meandering through the Grande Ronde Valley. Little Catherine Creek flows in a northwesterly direction, passes east of Union, and joins Grande Ronde River just east of La Grande. Continuing south and east through the Blue Mountains province, the IPC Proposed Route crosses through the semi-arid Powder Basin. The main streams of the Powder Basin are the Powder River and the Burnt River. The Powder River originates in the Elkhorn Mountains and trends to the north through the city of North Powder and then east to the Snake River. The Burnt River originates in the Blue Mountains (the east slope of the uplands between the Elkhorn Mountains and the Strawberry Range) from the confluence of North, West, Middle, and South Forks of Burnt River, which converge at Unity Lake. The Burnt River trends east to a confluence with the Snake River near Huntington. The Malheur River and its tributary Willow Creek drain the southeastern portion of the Blue Mountains Province; they flow eastward to the Snake River near Ontario.

### 2.2.3 Geologic Overview

The IPC Proposed Route runs through the central portion of the Blue Mountains Province, crossing the northern portion of the Elkhorn Mountains, and then continuing south through the Baker Valley. From there, the alignment generally run along a portion of the Burnt River Canyon, then southwest over the southeastern foothills, across the Willow Creek drainage basin, and finally southward across the Malheur Valley. This area through the Blue Mountain province contains some of the oldest rocks in Oregon. Permian, Triassic, and Jurassic rocks were scraped off of a subducting oceanic plate and accreted to the Mesozoic shoreline, which at that time was positioned near the present Idaho border with Washington and Oregon. Metamorphism, intrusion, and volcanic activity cemented these exotic blocks onto the North American continent, where they became the foundation of northeast Oregon (Orr and Orr, 2000).

The IPC Proposed Route crosses groups of rocks that have been designated as the Baker, Wallowa, and Olds Ferry Terranes. Within the Baker Terrane, the alignment encounters Burnt River Schist and Elkhorn Ridge Argillite. The Wallowa Terrane portion consists of igneous rocks including the Clover Creek Greenstone. The Olds Ferry Terrane consists primarily of sedimentary rocks, including those of the Weatherby Formation (Jet Creek Member). The southeastern foothills of the Blue Mountains Province (the areas drained by Willow Creek and Malheur River) are largely composed of Miocene- to Pliocene-age tuffs and tuffaceous sedimentary rocks. The geology of the Blue Mountains Province is shown in Figure 6, Blue

Mountains Geology; strip maps and rock unit descriptions from the area are included in Appendix A.

### 2.2.4 Soils

Beginning about 15 miles west of the Union County line, and just after crossing Birch Creek (near MP65), the IPC Proposed Route passes out of the Umatilla Basin and enters the Blue Mountains Province. Elevation continues to increase, and the predominantly loessal silt loam soils gradually grade to residual (developed in-place) silt loams and clay loams that are often mixed with volcanic ash and gravel- to cobble-sized rock clasts (colluvium) derived from the underlying basalt lava and andesitic tuff parent materials. The soils vary from a few inches to a few feet thick over weathered bedrock, are generally well drained, and are typically characterized as having a severe erosion hazard. Similar soil conditions are also present along the Morgan Lake Alternative. Soil data tables and strip maps of the soil units within a one-half mile radius of the IPC Proposed Route, rebuild sections, and the alternative alignments are provided for reference in Appendix B.

The IPC Proposed Route continues toward the southeast and passes through the Glass Hill area west of La Grande. The IPC Proposed Route traverses areas underlain by silt loam soils derived from a mixture of basalt colluvium and surficial deposits of loess and volcanic ash. These soils mantle ridge crests and mountain slopes and are often stony, i.e., they grade with depth to more rocky colluvial debris derived from the underlying basalt bedrock. Although bedrock exposures are rare, the soil cover is relatively thin, commonly less than five feet thick over weathered basalt bedrock. The soils are well-drained and are associated with a severe erosion hazard.

The IPC Proposed Route descends gradually in elevation toward the south and southeast, and then finally leaving the highlands, it crosses Powder River and enters Baker County and the northern portion of the Baker Valley southwest of Union, Oregon. Valley soils consist predominantly of silt loam soils developed from loess and volcanic ash that grade with depth to stony colluvium that was derived from residual soils weathered out of the underlying basalt and tuff parent materials. These soils are generally less than 10 feet thick over the underlying bedrock surface, moderately- to well-drained, and have a moderate to severe erosion hazard. Alluvial silt and sand with local accumulations of gravel and cobbles are present along stream channels and across adjacent floodplains.

The IPC Proposed Route continues southeastward and up onto the low range of hills that flank the eastern side of the Baker Valley. Soils continue to consist predominantly of silt loam derived from loess and volcanic ash, which overlie colluvial and/or residual soils derived from underlying basalt and tuffaceous volcanics as well as some, intrusive and metamorphic rocks. The route continues southeast past North Powder, Haines, and Baker City. The short Proposed 230-kV Rebuild section is included here, just east of Baker City and south of Highway 86. Stony silt loam colluvial soils developed on the underlying bedrock are mixed with loess, volcanic ash, alluvial and lacustrine sediments, and older alluvial terrace and alluvial fan deposits. These soils are generally well-drained silt loams, which often contain gravel and cobbles, and have a moderate to severe erosion hazard. Surface soils are generally less than five feet thick over the underlying consolidated parent materials.

Approximately 3 miles southeast of Baker City, the IPC Proposed Route approaches Sutton Creek and Interstate 84. At this point, the route turns southeastward and continues up Sutton Creek, crosses a drainage divide near Pleasant Valley, and then continues down Alder Creek, turning south about 6 miles from its confluence with Burnt River near Durkee. The route then continues southeastward following the western ridge of the Burnt River canyon. Although it crosses Alder Creek once, Burnt River once, and Dixie Creek once, the route generally keeps to steep slopes between hilltops and ridges above the valley floor. Soils in this section are stony to gravelly silt loams and gravelly clay loams mixed with colluvium derived from mixed alluvial and lacustrine sedimentary rocks, basalt, greenstone, argillite, schist, and metamorphosed volcanic rocks. These soils are present on hill slopes; they are well-drained, have a severe erosion hazard, and generally range between 5 and 10 feet thick over the underlying consolidated parent materials.

About 3 miles south of Huntington, the IPC Proposed Route crosses the Baker-Malheur County Line. Soils data in Malheur County is limited to areas along Willow Creek and Malheur River where the alluvial soils will support agricultural pursuits. However, geologic mapping is available (refer to Appendix A), and where soil data is unavailable, we have used the geologic mapping along with a comparison of similar rock types and associated soils in Baker County to infer generalized soil conditions that are likely to develop from the underlying bedrock parent materials.

From the Malheur County Line (near MP197), the IPC Proposed Route trends southwestward to the Willow Creek Valley, then turns southeastward. Between the Baker-Malheur County line and the Willow Creek Valley, the route crosses principally consolidated fine-grained tuffaceous sedimentary rock. We can infer that surface soils from near the County line to near Willow Creek will consist principally of silt loam to fine sandy loam; hill slopes might be stony. Soils will be thickest on lower slopes and across the intervening valleys, intermediate depth on hilltops and ridge crests, and thinnest on upper and middle slopes. These fine-grained soils will likely be well drained, except in the intervening valleys and in closed basins where excessive fines may be present. We would expect that soils are probably not more than 10 feet thick over consolidated materials, and the erosion hazard rating will likely be severe.

In the Willow Creek Valley, soils on the IPC Proposed Route are dominated by silt loam and fine sandy loam derived from alluvial parent materials, the erosion hazard is slight to moderate, and the soils are deep, i.e., exceeding 10 feet. After crossing the Willow Creek Valley, the route makes a large loop to the west, then south and east around Vale. After crossing the Malheur River, the Double Mountain Alternative would cut off a short northward curve in the IPC Proposed Route. No soils mapping is available in this area. These alignments cross a variety of geologic units including unconsolidated sediments, consolidated sedimentary rocks, and igneous rock. We infer that the soils are largely fine sandy to silty loams, locally stony or gravelly, and that the soils are generally well drained with a moderate to severe erosion hazard rating. Just south of the Malheur River Valley, the IPC Proposed Route crosses into the Owyhee Plateau province.

## 2.3 Owyhee Plateau

### 2.3.1 Topography

The Owyhee Plateau straddles the Oregon-Idaho border near the southeastern end of the IPC Proposed Route and extends southward into north-central Nevada. The Owyhee Plateau is a subset of the much larger Basin and Range province that is found extensively throughout Nevada and even in parts of California. The Owyhee Plateau differs from the rest of the Basin and Range in that it is a flat, deeply dissected plateau with little interior drainage, and its fault-block topography, which is a characteristic of the Basin and Range, is less pronounced. The Owyhee Plateau rises from about 2,100 feet above sea level, where the Malheur River enters the Snake River, to about 6,500 feet at the top of Mahogany Mountain. The Owyhee River, the Malheur River, and the Snake River, as well as many smaller creeks and streams, have cut deeply into the plateau surface. The topography and drainage of the Owyhee Plateau is shown in Figure 7.

### 2.3.2 Drainage

The drainage basin of the Owyhee River encompasses the southern portion of the IPC Proposed Route near Lake Owyhee. Due to steep gradients, the Owyhee River and its tributaries provide well-defined drainage patterns and deeply incised canyons, with intermittent small streams flowing in from the surrounding hills. The Owyhee River is a tributary of the Snake River. In addition to the Owyhee River, Succor Creek drains the last watershed in this province and also flows into the Snake River.

### 2.3.3 Geologic Overview

The IPC Proposed Route continues south and east from the Malheur Valley through the Owyhee Plateau physiographic province, crossing into Idaho about 32 miles south of Ontario, Oregon. Shortly after crossing into Idaho, the IPC Proposed Route leaves the Owyhee Plateau and passes into the Snake River Plain physiographic province. The Owyhee Plateau was formed by volcanic eruptions of ash and basalt lava beginning in the middle Miocene (about 15 million years ago). Much of the ash was eroded and re-deposited in stream valleys. The earlier ash and lava was covered over by additional periodic eruptions of lava. A period of erosion followed, as regional uplift began to raise the area into low mountains. Basaltic eruptions continued, and from late Miocene into the Pliocene epoch, fault blocks developed, creating basins where ash-rich sediments were deposited by streams. Alternating basalt flows, ash deposits, and stream sediments accumulated up to 2,000 feet in thickness (refer to Figure 8, Owyhee Plateau Geology and Appendix A for strip maps and rock unit descriptions). By the early Pliocene (about 4 to 3 million years ago), as the climate became dryer, the Owyhee River had established its present channel. Uplift of the region continued and the streams cut even deeper into their canyons (Orr and Orr, 2000).

### 2.3.4 Soils

The IPC Proposed Route enters the Owyhee Plateau geomorphic province near MP245. As stated earlier, soils data in Malheur County is limited to areas along major streams where the alluvial soils will support agricultural pursuits. The entire county is covered by geologic mapping (refer to Appendix A), however, and has been used to infer generalized soil conditions that are likely to develop from the underlying bedrock parent materials.

From near MP245 to near MP250, the IPC Proposed Route crosses primarily terraced alluvial gravel and fine grained lacustrine sedimentary deposits. These parent materials have developed silt loam to gravelly silt loam soils that range from about 4 to 10 feet thick, are well drained, and have a moderate to severe erosion hazard rating.

From about MP250 to MP255, the IPC Proposed Route crosses alternating areas underlain by lacustrine sedimentary deposits, described above, and basalt bedrock. The basalt parent materials are likely to have produced stony loam soils that are less than 5 feet thick and which are well drained with a moderate to slight erosion hazard rating. Bare rock outcrops may occur locally.

Local soils mapping is available near the IPC Proposed Route adjacent to the Owyhee River (refer to Appendix B for soil tables and maps). Soils adjacent to the river crossing (near MP255) are silt loam and gravelly silt loam developed on terraced fluvial and lacustrine sedimentary parent materials. These soils are relatively deep, i.e. greater than 5 feet and well drained with a moderate to severe erosion hazard rating.

After crossing the Owyhee River (between MP255 and MP256) the IPC Proposed Route continues toward the southeast as it gradually descends from the Owyhee Plateau to the Snake River Plain. At the ground surface, the eastern slope of the Owyhee Plateau is largely composed of tuffaceous lacustrine sediments, tuff, and ash flow deposits, but basalt rock protrudes through the fine grained materials locally. The area is intricately eroded, and alluvial deposits and associated terraced alluvium and alluvial fan deposits of sand and gravel are also present locally. Soils developed from the tuffaceous materials are silty to fine sandy loams; gravelly loams have developed over the alluvial materials. The fine-grained soils are generally greater than 5 feet thick, well drained, and have moderate to severe erosion hazard rating. Where basalt rock is exposed, stony loam soils have developed and may be mixed with or grade with depth to colluvium and residuum. These coarse soils tend to be greater than 5 feet thick and well to somewhat excessively drained with a moderate erosion hazard rating.

## 2.4 Snake River Plain

### 2.4.1 Topography

The IPC Proposed Route passes into the edge of the Snake River Plain physiographic province less than two miles after crossing the border into Idaho. The Snake River Plain is a broad, relatively flat, topographic depression that extends across southern Idaho. The proposed alignment follows the southwestern margin of the Snake River Plain all the way to the Hemingway Substation. As the alignment follows the border between the Snake River Plain and the Owyhee Plateau, it experiences variable topographic relief that reflects the transition between the two provinces. While the terrain is less rugged than what is typically in the deeply dissected Owyhee Plateau, there is greater relief than is found throughout most of the Snake River Plain. The topography and drainage of the Snake River Plain is shown in Figure 7, Owyhee Plateau Topography and Drainage.

#### 2.4.2 Drainage

The portion of the project area within the Snake River Plain generally drains to the northeast, toward the Snake River, which lies northeast of and sub-parallel to the IPC Proposed Route. In the vicinity of the project, the Snake River flows toward the northwest, turning north at the Oregon-Idaho border and joining with its tributary, the Boise River. The Snake River ultimately drains into the Columbia River, near Kennewick, Washington.

#### 2.4.3 Geologic Overview

While the entire Snake River Plain appears to be topographically continuous, there are significant geologic and structural differences between the eastern and western portions. The western Snake River Plain, where the IPC Proposed Route is located, is thought to be a northwest-trending, fault-bound graben. Surface topography and geologic strata in the region dip toward the axis or middle of the plain (Shervais, et al., 2005; Bonnichsen and Godchaux, 2002). Rocks of the western Snake River Plain include Miocene rhyolitic tuffs and ash flows of the Idavada Volcanic Group, as well as fluvial and lacustrine sediment interbedded with basalt flows of the Idaho Group (Pierce and Morgan, 1992; Bonnichsen and Godchaux, 2002). The geology of the Snake River Plain province is shown in Figure 8, Owyhee Plateau Geology; strip maps and rock unit descriptions from the area are included in Appendix A.

#### 2.4.4 Soils

About 15 miles east of the Owyhee River crossing (about MP271), the IPC Proposed Route crosses the Oregon-Idaho border and enters Owyhee County, Idaho. At approximately MP273, the route passes into the Snake River Plain physiographic province. Good soils mapping is available for Owyhee County, Idaho. From the state boundary, soils are principally silt loam with some fine sandy loam from mixed alluvial and lacustrine deposits, volcanic ash, residual and colluvial materials derived from welded tuff, basalt, and rhyolitic lavas. These soils occur on alluvial fans, alluvial terraces, valley floors, foothills, and hill slopes. They tend to be well-drained with a moderate to severe erosion hazard. These soils also tend to be relatively deep, varying from about 4 to more than 15 feet thick over the underlying consolidated materials.

## 3.0 PROPOSED SITE-SPECIFIC GEOTECHNICAL WORK

The document OAR 345-021-0010 requires the following:

OAR 345-021-0010(1)(h)(B) "*A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions.*"

OAR 345-021-0010(1)(h)(C) *"Evidence of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate site-specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete."*

OAR 345-021-0010(1)(h)(D): *"For all transmission lines, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead ends, corners, and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides or marginally stable slopes that could be made unstable by the planned construction."*

The following sections provide a generalized exploration program for the proposed alignments and describe proposed geotechnical exploration methods based on anticipated geologic conditions. The proposed schedule for site-specific geotechnical work (OAR 345-021-0010(1)(h)(B)) is provided in the main Exhibit H text, along with evidence of consultation with the Oregon Department of Geology and Mineral Industries (DOGAMI) regarding the appropriate site-specific geotechnical work, as required by OAR 345-021-0010(1)(h)(C).

### 3.1 Geotechnical Exploration Plan

Shannon & Wilson reviewed the proposed project alignments with respect to aerial photographs, topographic maps, existing geologic mapping, soil mapping, landslide mapping, and limited reconnaissance data (compiled by Shannon & Wilson and Shaw) to select proposed boring locations. Locations of the proposed borings are summarized in Table C1 in Appendix C. These locations are also shown on the geologic map sheets in Appendix A, and the Landslide Inventory maps in Appendix E. In general, for final design purposes, criteria for boring placement included borings at the following:

- A maximum spacing of approximately 1 mile along the alignments;
- Dead-end structures;
- Any corners or changes in alignment heading (angles);
- Crossings of highways, major roads, rivers, railroads, and utilities such as power transmission lines, natural gas pipelines, and canals; and
- Locations necessary to verify lithologic changes and/or geologic hazards such as landslides, steep slopes, or soft soil areas.

Based on Shannon & Wilson's review, placement of the borings based on the above criteria also provides adequate exploration coverage for areas with high erosion potential and areas near recent or active faults. Borings may be added or repositioned based on future site reconnaissance and conditions encountered as the exploration program is performed. The preliminary summary table provided in Appendix C presents 514 proposed boring locations as well as information regarding the anticipated subsurface geology, anticipated drilling rig type, and justification for each boring. This information will need to be verified during a detailed field reconnaissance of the entire alignment, to be performed prior to drilling. The proposed borings include 469 boreholes along the IPC Proposed Route, one borehole for the West of Bombing Road Alternative 1, six boreholes for the West of Bombing Road Alternative 2, 27 boreholes for the Morgan Lake Alternative, and 11 boreholes for the Double Mountain Alternative. Current borehole designations are preliminary, based on the designation of the nearest tower, and are subject to future revision.

The depth of each boring will generally be no more than 50 feet below the designed finish grade of the transmission line centerline. Depths for drilling into hard soil or competent rock will vary depending on the information needed for design. Borings may be terminated at shallower depths if the blow counts (the number of blows required to advance a split-spoon sampler 12-inches) in soil materials exceed 50 blows per foot for a minimum of three consecutive samples taken at 5-foot intervals (a total depth interval of 15 feet). Borings may also be terminated at less than 50 feet when they have been advanced 10 feet into unweathered, competent rock, as determined by a field representative from examination of the recovered rock core.

### 3.1.1 Geotechnical Drilling Methods

The purpose of the geotechnical drilling will be to evaluate the foundation conditions for the proposed transmission towers and substations. Geotechnical drilling will be accomplished using a variety of drilling methods, which will vary depending on the type of soil and rock expected within the anticipated completion depth of each boring. Some of the various methods anticipated to be implemented are discussed below.

#### 3.1.1.1 Hollow Stem Auger Drilling

Hollow Stem Auger (HSA) drilling consists of rotating and pushing into the subsurface a hollow drill stem with a continuous helical fin on the outside. The lead auger has a toothed bit at the bottom with a hole in the middle. During drilling, a center rod with a plug at the bottom is left inside the auger drill string to keep the center free of cuttings. The cuttings are brought to the surface on the outside of the augers by rotation of the helical fin. For sampling, the internal rod is withdrawn, the plug is removed from the end of the rod and replaced with a soil sampler. The sampler is then inserted through the hollow auger stem and placed at the bottom of the borehole.

HSA drilling does not require water or drilling mud, making it ideal for work in remote areas where available water is scarce. It is also easier to determine the depth to groundwater, if it is encountered, as compared with other drilling methods. Another advantage is that the hole is essentially cased during drilling, so loose or caving materials do not inhibit drilling progress or sample quality. Augers can be used as casing in combination with mud rotary drilling or rock coring to temporarily support a borehole across loose materials. The principal disadvantage of HSA drilling is the potential for soil heave into the augers and/or unreliable blow counts when sampling in soft or loose soils below the water table. Under such conditions, mud rotary drilling is preferable. HSA generally cannot penetrate large cobbles or hard rock.

#### 3.1.1.2 Mud Rotary Drilling

Mud rotary borings are typically advanced using a smooth-walled hollow drill stem and a tri-cone bit, through which a fluid bentonite drilling mud is pumped. The drilling mud serves to cool the bit, keep the borehole open, and flush the cuttings to the surface. Returning drilling mud is typically passed through a screen and into a tub over the borehole. The screen collects the cuttings and the tub collects the mud for recirculation back into the hole. If a borehole cannot be kept open using mud alone, casing such as hollow stem auger may be set to facilitate advancement of the hole. Mud rotary drilling requires a water source or a supply vehicle which may have difficulty accessing some boring locations. Also, due to the presence of drilling fluid, groundwater levels may be difficult to discern during drilling.

#### 3.1.1.3 Rock Coring

Rock core drilling is typically used to advance a borehole through rock and, at the same time, retrieve sample cores of the rock. This can be done using a conventional coring system, where the core barrel with a diamond-impregnated bit is attached to a string of smaller diameter drilling rods. To retrieve the core sample, the entire string of drill rods must be pulled from the borehole. Today, wireline systems are more commonly used for rock coring. The wireline system also advances a core barrel behind a diamond-impregnated bit, but differs from the convention system in that the drill rods have a larger inside diameter and the core barrel contains an inner barrel which is inserted and retracted through the string of drill rods using a winch and a wireline system, while the rods and outer core barrel remain in the borehole. Clean water or water mixed with polymer is used to lubricate the casing, cool the bit, and flush fine cuttings from the hole.

### 3.1.2 Types of Drill Rigs

The drilling techniques described above can be performed using rigs mounted on road-legal trucks, tracked vehicles, or mobile platforms. Truck-mounted drilling rigs will be used at all locations not inhibited by access restrictions. The other drilling rigs are proposed for areas where the truck-mounted drilling rigs cannot be used due to steep terrain and/or difficult access. Other vehicles and equipment may also be mobilized to each boring location and could include a water truck or support vehicle, an air compressor, the field representative's pickup truck or utility vehicle, and possibly another support pickup truck. In some areas, a dozer or grading equipment may be required to assist with access to boring locations.

#### 3.1.2.1 Truck-Mounted Drilling Rigs

Truck-mounted drilling rigs are road-legal, heavy trucks that require access to be relatively flat (5 percent grade or less). They travel on existing roadways and two-track trails as close as possible to boring locations, and then overland on firm ground. Truck rigs are typically 30 feet long, 8.5 feet wide, 12 feet high with mast down, and 25 to 35 feet high with the mast up. The gross vehicle weight of a truck rig is typically about 30,000 to 40,000 pounds.

#### 3.1.2.2 Track-Mounted Drilling Rigs

Track-mounted drilling rigs are another alternative drill rig type for borings where there are softer ground conditions and/or up to 20 percent grade. These rigs are approximately 8,000 to 15,000 pounds with rubber tracks, resulting in approximately 10 psi ground pressure. This type of rig yields the lowest relative ground disturbance for mobile rigs on soft ground. Tracked rigs are typically 12 to 24 feet long, 6 to 8 feet wide, and 12 to 28 feet high with mast up. They are transported as close as possible to exploration sites on low-boy trailers, using existing roadways and two-track trails. From there, they track overland to boring locations. While these rigs can traverse steeper terrain than truck rigs, most models still require a relatively flat area to set up for drilling. In some areas along the proposed alignment, this may require some minor grading and site preparation using an excavator or dozer. Some drilling contractors have track-mounted water haulers available, which facilitates mud rotary drilling and rock coring on track rigs in remote areas, away from water sources.

#### 3.1.2.3 Platform Drilling Rigs

Platform drilling rigs will be utilized to access areas that are too steep for the mobile drilling rigs (described above) to access. Platform rigs will generally be transported to the boring locations by helicopter, in 8 to 10 pieces, and assembled on site. Where tower sites are located high on steep slopes above existing roadways, platform drilling equipment can also be lifted into place using mobile cranes. Platform rigs are approximately 6,000 to 7,000 pounds when assembled, and up to 32 feet high with the mast up. They generally have base dimensions on the order of 8 to 15 feet by 6 feet and have roughly 5-foot-long stabilizer legs that extend from all sides of the base to level the platform on slopes. For helicopter transport, staging areas near existing roadways will be required to load the equipment to the helicopter. For crane transport, staging areas will be required along roadways adjacent to the slopes where the rigs will be placed. Traffic control may be required if shoulder widths are insufficient.

### 3.1.3 Sampling Methods

During drilling operations, samples will generally be taken at 2.5 to 5 foot depth intervals. Most soil sampling will be performed using split-spoon samplers. Thin-walled tubes may be used to sample fine-grained or cohesive soils. HQ or NQ core will generally be used to advance through and sample rock. These sampling methods are described further in the following subsections.

#### 3.1.3.1 Split-Spoon Sampling

Disturbed samples in borings are typically collected using a standard 2-inch outside diameter (O.D.) split spoon sampler in conjunction with Standard Penetration Testing. In a Standard Penetration Test (SPT), ASTM D1586, the sampler is driven 18 inches into the soil using a 140-pound hammer dropped 30 inches. The number of blows required to drive the sampler the last 12 inches is defined as the standard penetration resistance, or N-value. The SPT N-value provides a measure of in situ relative density of granular soils (silt, sand, and gravel), and the consistency of fine-grained or cohesive soils (silt and clay). All disturbed samples are visually identified and described in the field, sealed to retain moisture, and returned to the laboratory for additional examination and testing. In some cases, it may be necessary to use a larger sampler, such as a 3.25-inch O.D. Dames & Moore sampler, to collect a representative quantity of soil that contains coarse gravels.

#### 3.1.3.2 Thin-Walled Tubes

Relatively undisturbed samples of fine-grained and/or cohesive soils encountered in the borings may be obtained by pushing a 3-inch outside-diameter, thin-walled tube sampler (also known as Shelby tube sampler, ASTM D1587) a distance of approximately 2 feet into the bottom of the borehole using a hydraulic ram. After a thin-wall tube sample is recovered from the boring, it is sealed at both ends to prevent moisture loss and carefully transported back to the laboratory. Care is taken to keep the sample upright and to avoid dropping, jarring, or rough handling.

#### 3.1.3.3 Coring

HQ or NQ coring is typically used to advance through and sample rock. Core runs are typically 5 feet long. Core samples are photographed in a split tube immediately after extraction from the core barrel. The core is evaluated in the field to determine the percentage of the run recovered as well as the Rock Quality Designation (RQD), defined as the sum of the length of core pieces 4 inches or more in length and divided by the total length of the drilled core run. The degree of weathering, soundness, joints and structural discontinuities, and other rock characteristics are documented on the boring logs. Rock core samples which are sensitive to moisture loss may be individually wrapped in the field with plastic wrap. All core is stored in waxed cardboard or plastic corrugated boxes which are labeled with the boring designation and depth intervals.

### 3.1.4 Boring Logs

A field representative will be present during all drilling activities. The field representative will locate the boreholes, collect samples, and maintain logs of the materials encountered. The logs will include sample locations and types, sample descriptions, and notes regarding drilling methods, drill action, fluid loss, problems encountered during drilling, and the depth to groundwater (if observed). The boring logs will present a description of the soil and rock materials encountered at each boring and the approximate depths at which material changes were observed. Soil samples will be described and identified visually, in general accordance with ASTM D2488, the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

### 3.1.5 Laboratory Testing

Laboratory testing will be performed on soil and rock samples obtained from the borings to refine field descriptions and to provide index properties for use in engineering design. Laboratory tests for soils may include natural water content and density analyses, Atterberg Limits tests, particle-size analyses, and analytical testing for corrosivity potential. Testing on rock may include point load, unconfined compressive strength testing, and slake durability testing. All laboratory testing will be performed in accordance with applicable ASTM International (ASTM) or U.S. Army Corps of Engineers (USACE) standard test procedures.

### 3.1.6 Geophysical Surveys

In addition to geotechnical drilling, non-invasive geophysical surveys may be conducted at substation expansion areas and remote areas that cannot be accessed by the previously described drilling equipment. Geophysical survey techniques may include electrical resistivity testing for grounding design or seismic refraction surveys, often used to profile depths to bedrock contacts.

## 4.0 SEISMIC HAZARDS

The following section provides information and discussion to satisfy *OAR 345-021-0010(1)(h)(F)* which reads, *"An assessment of seismic hazards. For the purposes of this assessment, the maximum probable earthquake (MPE) is the maximum earthquake that could occur under the known tectonic framework with a 10 percent chance of being exceeded in a 50 year period. If seismic sources are not mapped sufficiently to identify the ground motions above, the applicant shall provide a probabilistic seismic hazard analysis to identify the peak ground accelerations expected at the site for a 500 year recurrence interval and a 5000 year recurrence interval. In the assessment, the applicant shall include:*

*(i) Identification of the Maximum Considered Earthquake Ground Motion as shown for the site under the 2009 International Building Code;*

*(ii) Identification and characterization of all earthquake sources capable of generating median peak ground accelerations greater than 0.05 g on rock at the site. For each earthquake source, the applicant shall assess the magnitude and minimum epicentral distance of the maximum credible earthquake (MCE);*

*(iii) A description of any recorded earthquakes within 50 miles of the site and of recorded earthquakes greater than 50 miles from the site that caused ground shaking at the site more intense than the Modified Mercalli III intensity. The applicant shall include the date of occurrence and a description of the earthquake that includes its magnitude and highest intensity and its epicenter location or region of highest intensity;*

*(iv) Assessment of the median ground response spectrum from the MCE and the MPE and identification of the spectral accelerations greater than the design spectrum provided in the 2010 Oregon Structural Specialty Code. The applicant shall include a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic or subsurface conditions that could result in expected ground motions greater than those characteristic of the Maximum Considered Earthquake Ground Motion identified above;*

*(v) An assessment of seismic hazards expected to result from reasonably probable seismic events. As used in this rule "seismic hazard" includes ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence."*

### 4.1 Earthquake Ground Motions

The Maximum Probable Earthquake (MPE) is the largest earthquake predicted under the known tectonic framework within a 500 year recurrence period (RP), while the Maximum Credible Earthquake (MCE) is the largest earthquake that an active or potentially active fault is capable of generating. For the purposes of this preliminary evaluation, the seismic sources are not mapped sufficiently to perform deterministic evaluations of ground motions along a several hundred-mile-long power line alignment. The location, length, and age of last offset for credible fault ruptures are not sufficiently documented to determine magnitude and minimum epicentral distance. Therefore, based on the OAR criteria above, probabilistic peak ground acceleration (PGA) for a 500-, 2,500- and 5,000-year return period have been evaluated. The probabilistic evaluation method considers multiple specific sources and regional seismicity to predict the probability of an earthquake of a given magnitude occurring anywhere along the alignment within a given return period, which in the case of the OAR is a 500-, 2,500-, or 5,000-year return period.

The OAR specifies use of Oregon Structural Specialty Code (OSSC) 2010 and International Building Code (IBC) 2009 for design. However, the OAR has not been updated in several years and references the building codes which were current at the time the OAR was last updated. We interpret that the intent of the OAR is to require the most current IBC and OSSC, which at the time of writing this report are IBC 2015 and OSSC 2014. As requested by the Oregon Department of Energy (ODOE) and DOGAMI, we have considered both OAR-referenced building codes in addition to the current building codes. Probabilistic ground motion parameters in this evaluation were obtained from the 2002 and 2014 United States Geologic Survey (USGS) Probabilistic Seismic Hazard Analyses (PSHAs). It should be noted that the response spectra parameters are provided for preliminary design only.

### 4.1.1 Ground Motions from 2002 USGS PSHA

The 2009 IBC, as amended by the 2010 OSSC, utilizes the uniform hazard ground motion values from the 2002 USGS PSHA. As required in the OAR above, the PGA that corresponds to a 500-year mean return period is shown in Figure D1 in Appendix D, which provides mapped contours of the 500-year PGA along the entire alignment. The PGA values are mapped assuming a shear wave velocity of 760 meters per second, which corresponds to the boundary between Site Class B and Site Class C (Site Class BC).

The 2009 IBC defines the maximum considered earthquake (MconE) as having a 2 percent probability of being exceeded in 50 years (i.e., 2500-year return period). Peak ground accelerations and short- and long-period (0.2 and 1.0 second) spectral accelerations for the 2002 USGS PSHA are provided in Figures D2 through D4. The acceleration values are mapped assuming a shear wave velocity of 760 meters per second (Site Class BC).

Data required to prepare 5,000-year return period PGA contour map from the 2002 USGS PSHA were not available. Therefore, the 5,000-year return period PGA has been calculated at seven points along the alignment using the 2002 USGS disaggregation tool (USGS, 2002). These points include six evenly spaced points (approximately every 60 miles) as well as one point where the alignment crosses the Cottonwood Mountain Fault, near MP223.5. The Cottonwood Mountain Fault is the only fault crossed by the alignment which was considered in the 2002 USGS PSHA. Peak ground accelerations for a 5,000-year return period at each of the seven selected points are provided in Table 1.

### 4.1.2 Ground Motions from 2014 USGS PSHA

The USGS publishes updated PSHA data every six years to incorporate the latest understanding of the seismic framework and seismic uncertainties. A significant change from the 2002 PSHA to the 2008 and 2014 PSHAs is the inclusion of uncertainty in seismic structural capacity (Luco, 2007). This resulted in a "risk targeted" maximum considered earthquake ($MconE_R$) rather than a uniform hazard maximum considered earthquake (MconE) provided in the 2002 USGS PSHA (IBC, 2009).

The 2015 IBC utilizes the risk targeted ground motion values from the 2008 USGS PSHA. However, in order to provide the most up-to-date data, we used the risk targeted ground motion values from the 2014 USGS PSHA for this report.

As required in the OAR, the PGA that corresponds to a 500-year mean return period is shown in Figure D5 in Appendix D, which provides mapped contours of the 500-year PGA along the entire alignment. The PGA values are mapped assuming a shear wave velocity of 760 meters per second (Site Class BC).

The 2015 IBC defines the risk targeted maximum considered earthquake ($MconE_R$) as having a 2 percent probability of being exceeded in 50 years (i.e. 2,500-year return period). Peak ground accelerations and short- and long-period (0.2 and 1.0 second) spectral accelerations from the 2014 USGS PSHA are provided in Figures D6 through D8. The acceleration values are mapped assuming a shear wave velocity of 760 meters per second (Site Class BC).

Data required to prepare 5,000-year return period PGA contour map from the 2014 USGS PSHA were not available. Therefore, the 5,000-year return period PGA has been calculated at seven points along the alignment using the uniform hazard curve data from the 2014 USGS PSHA (USGS, 2016c). Peak ground accelerations for a 5,000-year return period at each of the seven selected points are provided in Table 1.

#### 4.1.3 Comparison of 2002 and 2014 USGS Ground Motions

The 500-year return period PGA values for the 2002 and 2014 USGS PSHAs are shown on Figures D1 and D5. The PGA values from the 2002 PSHA range from 0.088g at the beginning of the alignment near Boardman, Oregon, to 0.053g at the end of the alignment near Hemingway, Idaho, with an average PGA of 0.066. The PGA values from the 2014 PSHA range from 0.074g at the beginning of the alignment, to 0.045g at the end of the alignment. The change in PGA values from the 2002 to the 2014 PSHA ranged from -0.014g (-19 percent) to -0.005g (-9 percent), with an average change of -0.010g (-15 percent).

The 2,500-year return period PGA values are shown on Figure D2 and D6. The PGA values from the 2002 PSHA range from 0.200g at the beginning of the alignment to 0.111g at the end of the alignment, with an average PGA of 0.147. The PGA values from the 2014 PSHA range from 0.185g at the beginning of the alignment to 0.117g at the end of the alignment, with a local maximum of 0.159g near the Cottonwood Mountain Fault, and an average PGA of 0.148g. The change in PGA values from the 2002 to the 2014 PSHA ranged from - 0.015g (-7 percent) to +0.019g (+14 percent), with an average change of +0.001g (+1 percent).

The 2,500-year short period (0.2 second) spectral response acceleration ($s_s$) values are shown on Figure D3 and D7. The $s_s$ values from the 2002 PSHA range from 0.467g at the beginning of the alignment to 0.111g at the end of the alignment, with local maxima of 0.366g and 0.372g at mile posts 80 and 150, respectively. The average $s_s$ from the 2002 PSHA is 0.147. The $s_s$ values from the 2014 PSHA range from 0.416g at the beginning of the alignment to 0.262g at the end of the alignment, with local maxima of 0.345g and 0.359g at mile posts 80 and 224 (near the Cottonwood Mountain Fault), respectively. The change in $s_s$ values from the 2002 to the 2014 PSHA range from -0.051g (-11 percent) to +0.023g (+7 percent), with an average change of -0.013g (-3 percent).

The 2,500-year long period (1.0 second) spectral response acceleration ($s_1$) values are shown on Figure D4 and D8. The $s_1$ values from the 2002 PSHA range from 0.144g at the beginning of the alignment to 0.091g at the end of the alignment, with an average $s_1$ of 0.112g. The $s_1$ values from the 2014 PSHA range from 0.137g at the beginning of the alignment to 0.082g at the end of the alignment, with an average $s_1$ of 0.105g. The change in $s_1$ values from the 2002 to the 2014 PSHA range from -0.012g (-11 percent) to 0.000g (0 percent), with an average change of -0.007g (-7 percent).

The 5000-year return period PGA values are provided in Table 1. The PGA values from the 2002 PSHA range from 0.271g at the beginning of the alignment to 0.154g at the end of the alignment, with a local maximum of 0.233g near the Cottonwood Mountain Fault. The average PGA from the 2002 PSHA is 0.147. The PGA values from the 2014 PSHA range from 0.259g the beginning of the alignment to 0.117g at the end of the alignment, with a local maximum of 0.263g near the Cottonwood Mountain Fault, and an average PGA of 0.220g. The change in PGA values from the 2002 to the 2014 PSHA ranged from - 0.012g (-4 percent) to +0.030g (+13 percent) with an average change of +0.009g (+5 percent).

### 4.2 Seismic Sources

Evaluation of source-specific probabilistic ground motions along the proposed 300-mile alignment has been provided herein using USGS 2002 and 2014 PGA and spectral accelerations. Site class determinations and specific hazard evaluations for each tower will be determined in future design studies. The magnitude and minimum epicentral distance of the MCE is not evaluated as part of this preliminary study. Specific faults in close proximity to the alignment will be further evaluated during final design.

Potential seismic hazards along the proposed alignments can result from any of three seismic sources: interplate, intraslab, and crustal events. Interplate sources are those which occur between two plate boundaries. The major interplate source for the alignment is the Cascadia Subduction Zone (CSZ), along which the Juan de Fuca, Gorda, and Explorer Plates are subducting beneath the overriding North American Plate. The CSZ extends about 750 miles from northern California to southern British Columbia. Collision of the tectonic plates generates uplift along the coast and volcanism in the Cascade Range. Although extremely large earthquakes are anticipated along the CSZ, the substantial distance from the proposed alignment (about 280 miles or more) would attenuate ground shaking, causing this source not to represent the most significant earthquake hazard.

Intraslab earthquakes originate from within the subducting oceanic plates as a result of down-dip tensional forces and bending caused by mineralogical and density changes in the plates at depth. These earthquakes typically occur 28 to 37 miles beneath the surface. An example of an intraslab earthquake that occurred in the Pacific Northwest is the 2001 moment magnitude 6.8 Nisqually earthquake. Although relatively common in Washington State, significant intraslab earthquakes are historically rare in Oregon.

Shallow crustal earthquakes within the North American Plate have historically occurred in a diffuse pattern in Oregon, typically within the upper 4 to 19 miles of the continental crust. Because of their proximity, crustal faults represent the most significant seismic hazard to the proposed alignment. In accordance with OAR 345-021-0010(1)(h)(F)(ii), known significant faults near the proposed alignments that are associated with crustal earthquakes are outlined in the following sections.

### 4.2.1 Quaternary Faults

Quaternary faults are faults that are thought to have been active within the last 2.6 million years. Quaternary faults mapped in the USGS Quaternary Fault and Fold Database (USGS, 2006) that are within a 50-mile-radius of the IPC Proposed Route are shown in Appendix D, Figure D9. These USGS-mapped Quaternary faults are also shown on the geologic maps in Appendix A as blue dashed lines. Older or inactive faults are shown on the geologic maps in Appendix A as black lines that are solid (for confident), dashed (for approximate), or dotted (for concealed). Descriptions of USGS-mapped Quaternary faults within an approximate 5-mile radius of the proposed alignments are provided in the following sections. In the following sections, the discussed faults have a numerical identifier, such as 845, which corresponds with the fault ID provided by the USGS fault database (USGS, 2006). These Quaternary faults within an approximate 5-mile radius of the proposed alignments are also summarized in Appendix D, Table D1. Quaternary faults in Oregon and Idaho have been subdivided by approximate age and include the following categories:

- Undifferentiated Quaternary – less than 1,600,000 years old

- Mid- to Late-Quaternary – less than 750,000 years old
- Late Quaternary – less than 130,000 years old
- Latest Quaternary – less than 15,000 years old
- Historic – less than 150 years old

### 4.2.2 Hite Fault System (845)

The Hite Fault System is a north-east trending system that runs parallel and to the west of the Blue Mountains. Total length of the Hite Fault System is about 87 miles, with an average dip direction of N70°W. The Hite Fault System is divided into four sections. However, only two of the sections are significant to the proposed transmission alignment (within 5 miles of proposed centerline): the Thorn Hollow section (845c) and the Agency section (845d).

#### 4.2.2.1 The Thorne Hollow Section (845c)

The Thorne Hollow section consists of 27 miles of complex faulting that is expressed as co-linear streams, saddles, and notches in ridges within the Columbia River Basalt Group (CRB), as well as shallow linear depressions south of the Umatilla River. Movement is suggested to have occurred in the Quaternary period within the southern portion of the section, and middle to late Quaternary movement within the northern portion of the section. The sense of movement along faults located within the Thorn Hollow section has been described as normal, left-lateral, and right-lateral strike-slip. The faults have an average strike direction of N10°E and a dip of 80° to 90° NW. Total displacements in the Miocene aged (~17 to 6 million-year old) CRB may be on the order of 260 to 1,500 feet (Personius and Lidke, 2003a).

#### 4.2.2.2 The Agency Section (845d)

The Agency section consists of 17 miles of faults creating offsets within the CRB. Movement is suggested to have occurred in the Quaternary period in CRB rocks. The sense of movement along faults located within the Agency section has been described as normal, left-lateral, and right-lateral strike-slip. The faults have an average strike direction of N6°E and a dip direction to the NW (Personius and Lidke, 2003b).

### 4.2.3 West Grande Ronde Valley Fault Zone (802)

The West Grande Ronde Valley Fault Zone is a north and north-west trending system forming the western margin which confines the Grande Ronde Valley. Total length of the fault zone is approximately 30 miles. The fault zone is divided into three sections, the Mt. Emily section (802a), the La Grande section (802b), and the Craig Mountain section (802c). Each of the sections are part of a large graben system and have formed steep echelon range fronts containing tonal contrasts, linear depressions, springs, and scarps. Fault systems within this zone offset Miocene rocks of the CRB and Powder River Volcanic field, as well as Quaternary surficial deposits.

#### 4.2.3.1 The Mt. Emily Section (802a)

The Mt. Emily section consists of 18 miles of fault, forming a steep range front from Thimbleberry Mountain to the mouth of the Grande Ronde River Canyon. Recent detailed mapping suggests the latest Quaternary displacement occurred on the southern half of the section. The sense of movement along the faults of this section has been described as normal and right-lateral. Faults located within the Mt. Emily section have an average strike direction of N2°W and an estimated dip of 60°E to 70°E. Vertical offsets of the Miocene CRB are estimated to be around 3,280 feet (Personius, 2002c).

#### 4.2.3.2 The La Grande Section (802b)

The La Grande section consists of 9 miles of fault, forming steep range front from the mouth of the Grande Ronde River Canyon to the mouth of Ladd Canyon. The La Grande Section consists of two primary fault strands, one adjacent to La Grande and one parallel to Foothill Road. The La Grande strand is identified by small fault scarps on late Quaternary alluvial deposits in the mouths of canyons, and larger scarps in older landslide debris near the southern end of the strand, forming a steep linear range front. The Foothill strand is identified by linear topographic benches, springs, and vegetation along the range. Offsets of alluvial deposits and landslide deposits near the southern end of the La Grande strand are estimated to be late Quaternary. Latest Quaternary displacement has been inferred by the presence of scarps on the La Grande section. The sense of movement along the faults of this section has been described as normal and right-lateral. Faults located within the La Grande section have an average strike of N30°W and an estimated dip of 60°NE to 70°NE. Displacement along the Miocene CRB and Powder River volcanic field is estimated to be around 1,400 to 2,300 feet (Personius, 2002d).

#### 4.2.3.3 The Craig Mountain Section (802c)

The Craig Mountain section consists of about 6 miles of fault, forming steep range front along the east flank of Craig Mountain. Craig Mountain is identified by linear fronts and numerous springs, with hot springs located at the northern end of the section. Latest Quaternary displacement has not been identified at this time; however, multiple landslide complexes located along the mountain front may be covering evidence of recent faulting. The sense of movement along the faults of this section has been described as normal and right-lateral.

Faults in the Craig Mountain section have an average strike of N49°W and an estimated dip of 60°NE to 70°NE. Vertical offsets of the Miocene CRB are estimated to be around 2,400 feet southeast of Hot Lake hot springs (Personius, 2002e).

#### 4.2.4 South Grande Ronde Valley Faults (709)

The South Grande Ronde Valley Faults bound several north-west trending fault blocks in Miocene volcanic rocks. The total length of the fault zone is 14 miles. Faults located within the fault zone have been described as high-angle normal faults, with an average strike of N39°W. Faults within this system offset Miocene volcanic rocks with escarpments up to 650 feet high. The most recent movement is suggested to be middle and late Quaternary. Total displacements of 295 to 1,510 feet have been described in the High Valley, Catherine Creek, and Pyle Canyon faults (Personius, 2002a).

#### 4.2.5 Unnamed East Baker Valley Faults (712)

The Unnamed East Baker Valley Faults are a northwest trending system that forms the eastern margin of Baker Valley. The total length of the fault zone is 17 miles. The sense of movement along the faults has been described as normal. The faults have an average strike of N40°W and dip to the SW. The faults juxtapose Miocene volcanic rocks, and Mesozoic and Paleozoic igneous and metamorphic rocks, against Quaternary alluvial deposits, forming escarpments less than 325 feet high. Late Quaternary displacement has been suggested on a small section of one of the faults, while Quaternary displacement has been described along the length of the faults. The most recent movement is suggested to be middle and late Quaternary (Personius, 2002b).

#### 4.2.6 West Baker Valley Faults (804)

The West Baker Valley Fault is a north-west trending, down-to-the-northeast system forming a large, steep range along the western margin of Baker Valley. The faults are identified by linear range fronts, faceted spurs, benches, springs, tonal and vegetation lineaments, scarps observed in late Quaternary alluvial-fan deposits, and the exposed Mesozoic and Paleozoic igneous and metamorphic rocks of the uplifted Elkhorn Ridge. Total length of the fault zone is about 21 miles. The sense of movement along the faults has been described as normal. The faults have an average strike of N54°W and a dip of 40°NE to 70°NE. Lack of offset in middle to late Holocene deposits, along with large scarps in older Quaternary deposits, indicate late Quaternary surface-faulting and recurrent displacement (Personius, 2002f).

#### 4.2.7 Cottonwood Mountain Fault (806)

The Cottonwood Mountain Fault is a north-west trending system located along the eastern margin of Cottonwood Mountain. The fault is approximately 26 miles long and identified by prominent fault scarps in the alluvial fans east of Cottonwood Mountain. The fault offsets Miocene and Pliocene ash-flow tuffs and tuffaceous lacustrine deposits. Small scarps on Holocene deposits and larger scarps in mid to late Pleistocene deposits indicate recurrent late Quaternary activity, at a recurrence rate of about 3,750 – 25,000 years. The sense of movement along the fault has been described as normal and left-lateral. The fault has an average strike of N33°W and an estimated dip of 40°NE to 70°NE (Personius, 2002g).

#### 4.2.8 Faults Near Owyhee Dam (808)

The faults near Owyhee Dam are in a structurally complex region between the Blue Mountains, the Owyhee Plateau, and the Snake River Plain provinces. The faults are generally north to northwest rending and are identified by vegetation lineaments, scarps, and springs in Miocene sedimentary and volcanic rocks. Fault activity has been mapped as active in the Quaternary, with some debate over evidence of mid to late Quaternary activity. The total length of these faults is 23 miles. The sense of movement along the faults has been described as normal. The faults have an average strike of N13°W and an estimated dip of 60° to 70°E/W (Personius, 2002h).

#### 4.2.9 Owyhee Mountain Faults (636)

The Owyhee Mountain Faults are northwest-trending faults that demarcate the border between the Owyhee Plateau and the Snake River Plain. The faults offset volcanic rocks of Miocene to Pliocene age, with the possibility of Quaternary activity. The majority of surficial faults are of undifferentiated Quaternary age, with the faults of the Halfway Gulch and Water Tank faults showing evidence of latest Quaternary activity. The total length of these faults is 128 miles. The sense of movement along the faults has been described as normal. The faults have an average strike of N50°W and an estimated dip of 65°NE to 70°NE.

### 4.3 Historical Earthquakes

The Advanced National Seismic System (ANSS) Comprehensive Catalog (ComCat) contains earthquake source parameters (e.g. hypocenters, magnitudes, phase picks, and amplitudes) and other products (e.g. moment tensor solutions, macroseismic information, tectonic summaries, maps) produced by contributing seismic networks. This comprehensive collection of seismic information will eventually replace the ANSS Composite Catalog currently being hosted by the Northern California Data Center. However, historic regional seismic network catalogs have not yet been fully loaded. Important digital catalogs of earthquake source parameters are currently being loaded into ComCat. New and updated data is added to the catalog dynamically as sources publish or update products, hence there is a need for searching multiple data sources. Currently, the most comprehensive source for northwest earthquake data is the USGS ANSS Database (USGS, 2016a). The best sources for historical northwest earthquake intensity data are the National Geophysical Data Center (NGDC, 1985) and Johnson and others (1994), although neither of these sources are current at the date of this report.

In accordance with OAR 345-021-0010(1)(h)(F) (iii), Shannon & Wilson reviewed historical earthquake data for recorded earthquakes from the USGS Earthquake Search Data Base (USGS, 2016), the National Geophysical Data Center (NGDC, 1985), and the Pacific Northwest Seismic Network (PNSN, 2008). Recorded earthquakes with magnitudes of 2 or greater, within a 50-mile radius of the proposed alignments are shown in Appendix D, Figure D10.

Shannon & Wilson also collected Pacific Northwest earthquake intensity data from three sources: National Geophysical Data Center (NGDC, 1985), Johnson and others (1994), and the Advanced National Seismic System Comprehensive Catalog (ANSS, 2016). The resulting data was processed by geographic information system software (ArcGIS) to remove data points greater than 50 miles from the IPC Proposed Route centerline. The data was then edited to remove redundant entries.

The categories of data present in the original sources varied between the three data catalogs, and some categories (e.g. number of stations reporting, distance to nearest station) were removed to provide a consistent data set. Intensity is recorded at the location (usually the nearest city or town) where the earthquake was felt, which could be up to 50 miles from the IPC Proposed Route centerline. The ANSS data set did not include intensity values. Earthquake events for which no intensity was recorded are presented in a separate table, which includes an estimated intensity based on the event magnitude. Times of the earthquake events are expressed in Coordinated Universal Time, which is converted to Pacific Standard Time by subtracting eight hours.

The resulting intensity data includes a total of 123 earthquake events which occurred between March 1893 and April 2015. The intensity data is included in Appendix D, Seismic Evaluation. Table D2, Earthquakes Reported to Cause Greater than Modified Mercalli Intensity (MMI) III lists 40 earthquake events with intensities ranging from IV to VII; Table D3 lists 83 earthquake events estimated to have been capable of generating an intensity of at least MMI III. Abbreviated descriptions of the MMI values (USGS, 2016b) are as follows:

- III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
- IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
- V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
- VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
- VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

## 4.4 Ground Response Spectra

*OAR 345-021-0010(1)(h)(F)(iv)* requires "*assessment of the median ground response spectrum*" and "*a description of the probable behavior of the subsurface materials and amplification by subsurface materials and any topographic of subsurface conditions that could result in expected ground motions greater than those characteristic of the MConE.*" The ground motion parameters shown on Figures D1 through D8 and on Table 1 correspond to a Site Class B/C (soft rock) soil profile. To develop ground motions that correspond to other Site Class types, Site Coefficients that consider site soil type and level of ground shaking are required. The Site Class definitions and Site Coefficients can be obtained from IBC 2015, but subsurface explorations along the alignment have not yet been performed. Site specific design criteria for structures will be developed during final design, upon completion of the subsurface exploration program.

## 4.5 Seismic Hazards from Probable Seismic Events

In *OAR 345-021-0010(1)(h)(F)(v)*, seismic hazards from a probable seismic event include *"ground shaking, ground failure, landslide, lateral spreading, liquefaction, tsunami inundation, fault displacement and subsidence."* Ground failure, including landslide, lateral spreading, liquefaction, and surface rupture or settlement, will be evaluated using site-specific bedrock ground accelerations and subsurface conditions defined through the planned geotechnical exploration program.

#### 4.5.1 Ground Shaking

The magnitude of expected ground shaking for various probabilities of exceedance are discussed above using a code-based approach in conjunction with the USGS hazard maps, assuming that the site class is borderline B/C. Once the subsurface exploration program is performed for final design, the site class should be evaluated at each tower and facility in order to select the appropriate site class and a code-based site specific seismic response spectrum can then be developed.

#### 4.5.2 Earthquake-Induced Landslides

Earthquake-induced landslides will be evaluated during final design on a case by case basis. Primarily, existing landslides will be reviewed as stated in Section 5.1.1, below, and will be reviewed for both static and seismic stability. Additionally, during detailed site reconnaissance, performed as part of the final design, existing or potential slope instabilities will be noted and studied. Slopes can be analyzed for seismic hazard by adding a pseudostatic force to standard slope stability analyses. This force represents the inertial force that would act on a soil wedge during an earthquake. If an existing or potential landslide is deemed to have an inadequate factor of safety, the project will either avoid or mitigate the hazard.

#### 4.5.3 Liquefaction and Lateral Spreading

Liquefaction is the sudden loss of shear strength in soil caused from a rapid generation of excess ground water pore pressure during repeated shearing of the soil during shaking. Liquefaction is most common in loose clean sands below the water table, but may also occur in saturated silts and gravels. Soils must be saturated, meaning they must be below the water table, for liquefaction to occur.

For many of the towers along the IPC Preferred Routes and alternative routes, the towers will be placed on ridges or slopes that border valleys. For these locations, it is assumed that there is little to no soil below the water table, therefore the liquefaction hazard will be negligible.

The towers and structures located in areas covered in recent (Holocene) alluvial deposits, for instance those which cross valley floors, should be considered to have a low risk of liquefaction. During the detailed site exploration program, borings will be sampled using the SPT method, as stated in Section 3.1.3.1, above. The N-values are required to perform liquefaction analysis of susceptible soils below the water table. Common analysis methods are proposed in Seed et al 2003, Youd et al 2001, and Idriss and Boulanger 2006.

Lateral spreading may occur if liquefaction is triggered and if there is a free face or sloping ground to allow any non-liquefied soil resting on the liquefied portion to flow. This causes significant ground displacement and severe cracking. For locations where liquefaction poses a risk, an assessment will be made to determine if lateral spreading would be an additional hazard.

Ground subsidence also may occur due to the densification of soils subjected to repeated cyclic shearing. In some cases, liquefaction is triggered which can exacerbate subsidence. Where there is a potential for ground subsidence that affects a structure, it will be evaluated and quantified. In some cases, mitigation may be required if it is not practical to move a structure or design it for this hazard.

### 4.5.4 Surface Rupture

The faults that are considered in this geologic and seismic hazard review are listed in Section 4.2 above. For faults that are directly crossed by the alignment, a detailed review of the fault location and characteristics may be necessary to accurately quantify this hazard during the detailed site reconnaissance for final design. If the associated risk from fault rupture is found to be too high for the project, the locations for some towers my need to be modified.

### 4.5.5 Tsunami Inundation / Seiche

The alignment is not in a mapped tsunami zone nor does it border any large lake or reservoir capable of producing a seiche. These hazards are considered negligible.

## 5.0 NON-SEISMIC HAZARDS

Regarding non-seismic geologic hazards, *OAR 345-021-0010(h)(G)* requires, *"An assessment of soil-related hazards such as landslides, flooding and erosion which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility."*

Five categories of potential geologic hazards were identified by this desktop study:

- Slope Instability
- Erosion

- Expansive Soil
- Groundwater
- Corrosion Potential

Descriptions of the potential hazards and the proposed hazard evaluation methods are discussed below. Future geologic reconnaissance and geotechnical investigations are planned to address these hazards on a site-specific basis.

## 5.1 Slope Instability

Slope instability is a generalized category of geologic hazards that includes landslides, debris flows, talus slopes, alluvial fans, and soil creep. The following sections discuss each of these subcategories.

### 5.1.1 Landslides

Landslides are mass movements with a distinct zone of weakness separating the slide material from the more stable underlying material. They occur either by translational movement of the landslide mass along a roughly planar surface or rotational movement in which the zone of weakness is curved concavely upward. Landslides are often identified by the presence of scarps at the top or head of the feature, topographic bulges at the bottom or toe, hummocky topography, and chaotic bedding attitudes. In some cases, changes in the type and orientation of trees and vegetation can also be indicative of landslide activity.

A landslide hazard assessment was conducted to support the development of this Application for Site Certificate. The landslide assessment is summarized in Appendix E, which presents site maps of each landslide that was identified along the proposed alignments and considered to potentially affect the stability of proposed tower locations or multi-use areas. Data sources for the assessment included the 2014 Statewide Landslide Information Database for Oregon (SLIDO), version 3.2, published geologic mapping, review of LiDAR data, review of aerial photographs, and limited site reconnaissance.

Where mapped landslides intersect or lay adjacent to proposed transmission line routes, the field exploration program will include field reconnaissance by a geotechnical engineer and/or engineering geologist. Where landslides are observed, the geotechnical team will evaluate the mechanics of why the landslide occurred and how stable these areas are expected to be in the future. For example, some landslide areas may have filled in a ravine in such a way as to rendering further movement unlikely. Some other landslide areas may be the result of recent sliding along a weak layer of soil or rock. Undercutting by erosion may cause additional mass sliding in the future and, therefore, may indicate against siting towers in these areas. Seismic triggering of slope failures may pose additional hazards, particularly for granular deposits in areas of historic slope failures.

### 5.1.2 Debris Flow and Talus

A debris flow is a form of mass movement that can contain a combination of water, loose soil, rock fragments, and organic debris. Debris flows are typically caused by intense surface-water flow eroding the ground surface and mobilizing loose soil or rock on steep slopes. Debris-flow source areas are often identified by the presence of debris fans at the mouths of gullies below them. Talus consists of broken, angular rock fragments accumulated at the base of crags, mountain cliffs, or valley shoulders. SLIDO data was used in GIS to overly areas where debris flows and talus occur along the alignment. These areas are shown using specific hatch patterns on maps in the Landslide Inventory, Appendix E. Within the SLIDO database, debris flows are grouped with landslides and talus is grouped with colluvium (mixed slope deposits).

Where mapped debris flows and talus slopes coincide with proposed transmission line routes, the field exploration program will include field reconnaissance by a geotechnical engineer and/or engineering geologist. Where debris flows or talus slopes are observed, the geotechnical team will evaluate the mechanics of how the deposits were emplaced, and how stable these areas are expected to be in the future. In areas prone to debris flows, intense surface-water flow caused by heavy precipitation or snow melt may lead to additional debris flows, and may indicate against siting transmission towers in these areas.

### 5.1.3 Alluvial Fans

Alluvial fans are fan-shaped accumulations of sediment at the downstream ends of natural drainages, such as canyons between mountain ridges. Alluvial fans may be considered geologic hazards if they are unconsolidated and or steeply sloping. Slope failures are common in alluvial fan deposits where transverse valley streams erode at the toe of the fan. Alluvial fans are also susceptible to ongoing erosion and periods of surface water flow. SLIDO data was used in GIS to identify areas where alluvial fans occur along the alignment. These areas are shown using specific hatch patterns on maps in the Landslide Inventory, Appendix E.

#### 5.1.4 Soil Creep

Soil creep is a slow, downslope movement of soil under the influence of gravity. It is typically a shallow phenomenon involving the upper few feet of a colluvial or alluvial deposit, and is exacerbated by seasonal fluctuations in water levels and temperature. Soil creep can be identified by curved tree trunks, bent or leaning fences, tilted poles, small soil ripples or ridges, and the presence of colluvium.

### 5.2 Erosion Potential

Erosion is the 'wearing away' of soil or rock by agents such as wind, water, or ice. Erosion of surface soils is influenced by factors such as climate (wind and rainfall), soil type, slopes, and land use. The National Soil Information System (NASIS) GIS-based information system provided soil maps for the proposed alignments. These maps were used to determine the near-surface soils which may be encountered in the top 60 to 80 inches of the existing ground surface, and if shallow rock can be expected within this depth. Major units of surficial soils have been grouped into map units, which are a combination of General Soil Units (GSU's) identified within the individual counties. These map units are based on information provided in the Soil Survey of each individual county. The relative erosion potential of soils encountered along the alignments is indicated in the soil description tables and mapping presented in Appendix B.

### 5.3 Expansive Soils

Expansive soils owe their characteristics to the presence of swelling clay minerals. When they are exposed to moisture, the clay minerals absorb water molecules and expand; conversely, they shrink as they dry, leaving voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with smectite clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Over time, the shrinking and swelling cycles can cause loss of foundation support.

Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity (generally those with liquid limits exceeding 50 percent and plasticity indices over 30) usually have high inherent swelling capacities. The levels of expansion in the soils are very site-specific and will be identified during the geotechnical investigation.

### 5.4 Groundwater

Groundwater can have dramatic implications on design, construction, and long-term performance of structure foundations. Groundwater must be considered in areas of steep terrain, where slope stability may be a hazard, and in loose alluvial deposits, where liquefaction may occur. The study of groundwater is essential for determining the best construction means and methods. Excavations that extend below the water table in granular soils may require specific construction techniques such as, casing, cut-off walls, or local dewatering to appropriately deal with groundwater. The depth to groundwater, including perched groundwater, will be identified wherever possible during the geotechnical exploration program.

### 5.5 Corrosion Potential

Corrosive soils can damage subsurface utilities and structures. There are several variables that have an influence on the corrosion rates in soils. The following laboratory testing will be performed to evaluate known risk factors for corrosion and develop recommendations regarding general soil corrosion potential:

- pH - Soils usually have a pH range of 5 to 8. In this range, pH is generally not considered to be the dominant variable affecting corrosion rates. More acidic soils present an elevated corrosion risk to common construction materials such as steel, cast iron, and zinc coatings. Soil acidity is produced by mineral leaching, decomposition of acidic plants (such as coniferous tree needles), industrial wastes, acid rain, and certain forms of micro-biological activity. Alkaline soils tend to have high sodium, potassium, magnesium, and calcium contents. The latter two elements tend to form calcareous deposits that protect buried structures against corrosion. The pH level can affect the solubility of corrosion-resistant products and also the nature of microbiological activity.
- Resistivity - Soil resistivity is a measure of the ground's capacity to pass an electrical current. Soil resistivity generally decreases with increasing water content and the concentration of ions. While resistivity testing has historically been used as a broad indicator of soil corrosivity, where lower resistivity is associated with higher rates of corrosion, it is also useful for designing grounding systems for transmission towers and substations. Grounding systems provide a safe connection between an electrical circuit and the ground and are used for dissipation of electrical faults, grounding of lightning strikes, and maintenance of electrical equipment.
- Chloride level - Chloride ions generally increase corrosion rates, as they participate directly in anodic dissolution reactions of metals and tend to decrease soil resistivity.
- Sulfate level - Compared to the corrosive effect of chloride ions, sulfates are generally considered to be more benign in their corrosive action towards metallic materials. Concrete, however, may be attacked as a result of high sulfate levels. Sulfates can react

with cement to form calcium sulfoaluminate crystals, which can crack and disintegrate concrete as they grow. The presence of sulfates also poses some risk for metallic materials in the sense that sulfates can be readily converted to highly corrosive sulfides by anaerobic sulfate-reducing bacteria.

Preliminary indications of soil corrosivity to concrete and steel were analyzed along the proposed alignment using SSURGO GIS data. Susceptibility of concrete to corrosion when in contact with the onsite surficial soils is expected to be low, with a few instances where moderate susceptibility is anticipated. Susceptibility of uncoated steel to corrosion when in contact with the onsite surficial soils is expected to be moderate to high.

Analytical testing of soils for corrosion potential will be conducted during the geotechnical investigation. Tests will be conducted on each soil type and throughout the proposed route corridor to evaluate potential corrosion impacts on concrete and steel.

## 6.0 MITIGATION OF SEISMIC HAZARDS

The document *OAR 345-021-0010(h)(H)* states specifically regarding designing for seismic hazards, *"An explanation of how the applicant will design, engineer and construct the facility to avoid dangers to human safety from the seismic hazards identified in paragraph (F). The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring for seismic hazards."*

The project facilities are generally unmanned and located in sparsely populated areas. Therefore, the risks to human safety due to seismic hazards are minimal due to the low probability of human presence. All project facilities will be constructed in accordance with the 2014 OSSC and 2015 IBC or more current standards applicable if available at the time of detailed design.

Additional work will be necessary to complete the final seismic hazard assessment and identify all the areas that will require mitigation due to seismic hazards. As discussed in previous sections, this will include the geotechnical field exploration program, laboratory testing, and detailed site reconnaissance. A qualified engineer will assess the seismic, geologic, and soil hazards associated with the construction of each tower and each facility. The project will be designed to withstand wind and ice loads, which are typically greater than seismic loads from ground shaking. All designs and subsequent construction requirements will be modified based on the site-specific characterization of seismic, geologic, and soil hazards. Some specific mitigation techniques for earthquake-induced landslide and liquefaction hazards are presented below. As discussed in Section 4.5.4, the principal mitigation strategy for surface rupture hazards is modification of structure locations. Additional mitigation strategies will be developed and refined following completion of future geotechnical investigations.

### 6.1 Earthquake-Induced Landslide Mitigation

Mitigation of earthquake-induced landslide would be the same techniques discussed in Section 7.1 below.

### 6.2 Liquefaction Mitigation

For structures or towers which are located in areas that have a risk of liquefaction, there are a number of methods available to either adequately reduce the risk of liquefaction or to improve the performance of the structure (or improve resiliency), if liquefaction were to occur. Specific methods to reduce the liquefaction potential are ground densification to increase the soil's natural resistance to liquefaction, installation of drains to prevent excess ground water pore pressure build-up during a seismic event, and installation of soil-cement shear cells which reduce the seismic shearing demands on the soil.

Alternative to the methods which improve the soils resistance to liquefaction described above, the foundations for structures may be designed to account for a layer of soil which may liquefy. Deep foundations can be designed to bypass the liquefiable layer, being founded on deeper layers.

## 7.0 MITIGATION OF NON-SEISMIC HAZARDS

The guidance documents requires mitigation for non-seismic hazards be considered. *OAR 345-021-0010(h)(I)* specifically states, *"An explanation of how the applicant will design, engineer and construct the facility to adequately avoid dangers to human safety presented by the hazards identified in paragraph (G)."*

Additional work during final design will be necessary to complete the non-seismic hazard assessment and identify areas that may require mitigation due to non-seismic hazards. As discussed in previous sections, this additional work will include geotechnical field explorations, laboratory testing, and detailed site reconnaissance. Generalized mitigation strategies for the identified non-seismic hazards are described below. Additional mitigation strategies will be developed following completion of future geotechnical investigation program.

### 7.1 Mitigation of Slope Instability

Slope instability hazards should be thoroughly evaluated to assess the potential for failure. At locations where landslides, debris flows, or marginally stable slopes are identified, the hazard will be mapped and adequately characterized during the field exploration. All roads and transmission facilities will be designed to meet structural and zoning requirements. Structural requirements should adhere to soil lateral load requirements in the OSSC (Section 1610).

In general, structures should be located to avoid potential slope instability hazards wherever possible, and newly constructed slopes should be designed with an adequate safety factor against failure. Appropriate mitigation methods should be selected based on site characteristics and the structure to be constructed. If feasible, structures should be located with sufficient setback from slopes to mitigate the potential for slope instability during construction and operation. Where structures cannot be moved or realigned, slope instability mitigation techniques may include modification of slope geometry, hydrogeological mitigation, and slope reinforcement methods.

Slope geometry may be altered by grading or removal of soil in order to provide a sufficient factor of safety. Hydrogeological mitigation may include surface drainage, shallow drainage, and deep drainage. These drainage mechanisms vary in intensity; however, all mechanisms attempt to reduce the soil's water content. This decreases both the soil's pore pressures and the overall driving force, thereby decreasing landslide risk. Types of drains may include trench drains, horizontal drain wells, siphon drains, or micro drains.

Reinforcement measures may be implemented when geometric slope modifications or drainage improvements are not sufficient or practical. Reinforcement modifications can involve the use of anchors or tieback systems, geofabric installation, buttressing, and cellular and crib face installation.

The use of vegetation may also be combined with the methods described above to help prevent shallow slides by intercepting rainfall, decreasing runoff, and providing root stabilization.

### 7.2 Mitigation of Erosion

A desktop analysis of soil conditions was conducted prior to initial project siting (Shaw, 2012). This analysis incorporated data from many sources as previously described. The transmission line siting was based partly on engineering constraints related to known geologic hazards, soil stability, water crossings, and areas of steep topography. By considering soil and slope conditions throughout the siting and design process, IPC has avoided soil impacts to the extent possible.

The project should use existing roads to access construction sites to the extent practicable. Where needed, existing roads should be improved to reduce sediment generation and minimize impacts to soils. Site impacts to soils at and around tower locations, access roads, and facility footprints should be avoided or minimized, through the use of best management practices (BMPs) and restoration measures, to restore soil surfaces and vegetation following disturbances. IPC should meet design standards for new roads as required by the Bureau of Land Management, U.S. Department of Agriculture Forest Service, and Oregon Department of Transportation and should implement BMPs described below to reduce potential soil erosion during the construction process. To minimize soil erosion, where practical, IPC should implement revegetation procedures, such as recontouring, scarification, soil replacement, seedbed preparation, fertilization, seed mixtures, seeding timing, seeding methods, supplemental wetland and riparian plantings, and supplemental forest plantings.

Once the roads, towers, and other facilities have been constructed to the designed specifications, operations will have minimal potential for soil erosion. Slopes and cut banks should be stabilized with riprap and/or planted or seeded with vegetation as practical, and project facilities should be maintained as required to prevent erosion. Where necessary, temporary access road sites and other compacted soils should be mechanically loosened. Previously salvaged topsoil should be replaced and non-cropped areas should be revegetated where required.

### 7.2.1 Mitigation for Soil Erosion by Water

Erosion control measures should be designed with attention to the mapped soil erosion hazards (described in Section 5.2), with particular attention to areas with medium and high hazard ratings. Work on access roads should include grading and re-graveling of existing roads and construction of new roads. Soil erosion should be minimized by constraining traffic, heavy equipment, and construction to existing roads, where possible. Where new road construction is required, road widths should be limited to the width necessary to accommodate construction equipment. New roads should be located to avoid steep areas as much as possible.

Areas affected by construction should be reseeded with vegetation to minimize future erosion and to restore them to their natural state. Erosion and sediment control measures should be designed to remain intact until natural vegetation is sufficient to protect against erosion. The station operational footprint areas should be graveled to prevent erosion. The area outside the station fence may also be graveled, where practical, to prevent soil erosion during operations.

Specific erosion and sediment control to be implemented during the project construction and operations may include the following BMPs:

**Avoid Highly Erodible Areas:** Initial mitigation measures should include avoiding highly erodible areas, such as steep slopes, where possible, and rerouting impacted drainages to natural drainages to minimize erosion and sedimentation from runoff. Areas impacted by construction should be reseeded and sediment fences, check dams, and other BMPs will remain in place until impacted areas are well vegetated and the risk of erosion has subsided.

**Stabilize Road Entrance/Exit:** A stabilized construction entrance/exit should be installed at locations where dirt (exposed, disturbed land) or newly constructed roads intersect existing paved roads. Stabilized entrances should also be installed at the construction laydown areas. The stabilized construction entrance/exits should be inspected and maintained for the duration of the project life.

**Preserve/Restore Vegetation:** To the extent practicable, existing vegetation should be preserved. In the event that vegetation is destroyed in temporary road locations or laydown areas, stockpiled topsoils should be replaced and recontoured. Vegetation should be reseeded to prevent erosion using an approved seed mixture specified by the NRCS or the USFS as being capable of surviving in local conditions (see Vegetation Management Plan attached to Exhibit P).

**Control Dust:** Dust should be controlled during construction through water application to the disturbed grounds and access roads where necessary. Application of excess water that could lead to erosion or sedimentation should be avoided. Other methods of dust control may include the use of poly sheeting, vegetation, or mulching. Speed limits should be kept to a minimum to prevent pulverization of road substrate.

**Install Silt Fencing:** Silt fencing or an equivalent control measure should be installed at various locations along the transmission line. The fencing should be installed on contours downgradient of excavations, fill areas, or graded areas where necessary. Silt fencing or an equivalent control measure should be installed around the perimeters of material stockpiles and construction laydown areas.

**Install Straw Wattles:** Straw wattles should be installed to decrease the velocity of sheet flow from stormwater. The wattles should be used along the downgradient edge of access roads adjacent to slopes or sensitive areas.

**Apply Gravel and Mulching:** Gravel should be used where soil becomes wet or muddy to prevent erosion and working of the soil. Mulch should be provided to immediately stabilize soil exposed as a result of land disturbing activities. The mulch reduces the potential for wind and raindrop erosion.

**Install Stabilization Matting:** Jute mesh, straw matting, or turf reinforcement matting should be used to stabilize slopes that could become exposed during installation of access roads, during rainfall events, or to stabilize intermittent streams disturbed during construction of road crossings. Erosion control matting should be combined with revegetation techniques.

**Control Concrete Washout Area:** Concrete washout should be appropriately managed to prevent concrete washout water from impacting soils, water bodies, or wetlands.

**Manage Stockpiles:** Soils excavated may be temporarily stockpiled. While the material is stockpiled, perimeter controls should be established and the stockpiled material should be covered as necessary with mulch, plastic sheeting, and/or other appropriate means to prevent erosion and sedimentation.

**Install Check Dams, Sediment Traps, and Sediment Basins:** Check dams and sediment traps should be used during construction near tributaries and existing drainages. The check dams and sediment traps will minimize downstream disturbances and sedimentation of creeks. A sediment basin is a constructed temporary pond, built to capture eroded soils that wash off from larger construction sites during rain storms. The sediment-laden soil settles in the pond before the runoff is discharged.

### 7.2.2 Mitigation of Soil Erosion by Wind

To mitigate the risk of accelerating soil erosion by wind in areas susceptible to wind erosion, IPC should implement reseeding efforts, apply mulch, and use water for dust control. Areas that are susceptible to eolian processes that will be disturbed by construction activities and not permanently covered by aboveground facilities should be vegetated using a seed mixture specified by the applicable agencies as being capable of surviving in local conditions, and withstanding burial and deflation from eolian processes. Disturbed areas susceptible to wind erosion may be hydroseeded when temperatures and moisture levels are conducive to seed germination.

## 7.3 Mitigation of Expansive Soils

Expansive soils swell when exposed to moisture and shrink when dried. This change in volume can be detrimental to structure foundations. The selection of appropriate mitigation techniques will depend on the specific properties of site soils and foundation requirements of proposed structures. In general, mitigation techniques for expansive soils include removal, bypass, isolation, and treatment. If only a thin layer of expansive soil is present at a site, it may be feasible to strip and remove it. For thicker layers of expansive soil, it is common practice to extend foundations deep enough to effectively bypass the zone where moisture content is likely to change. Another mitigation alternative is to isolate the soil from changes in moisture content, through the use of enhanced drainage and/or coverings. Where only shallow foundations are practical, another mitigation alternative is to treat the expansive soils with lime or some other material that reduces their expansive properties.

### 7.4 Mitigation of Groundwater

The first step in mitigation of hazards posed by groundwater is to understand where and when it is present. Groundwater levels can vary significantly from one location to another and from one season to another. The geotechnical investigation will help to determine where groundwater will be relevant along the proposed alignments. Where groundwater plays a role in slope instability, the hydrogeological mitigation measures discussed in Section 7.1 should be considered. As discussed in Section 5.4, groundwater can also complicate construction, particularly where excavations extend below the water table. This will most likely be applicable to the proposed alignment where drilled shafts are required for tower foundations. If a shaft is excavated in good quality rock or firm fine-grained soils below the water table, groundwater may not be a significant concern. However, if shaft foundations extend below the water table in granular soils, casing and/or slurry may be necessary to prevent soil heave and maintain shaft integrity.

### 7.5 Mitigation of Corrosive Subsurface Conditions

Where soil conditions are identified that may be corrosive to metals, potential mitigation alternatives may include application of protective coatings, such as coal tar enamel. Another mitigation alternative is to increase the metal thickness to provide a ‘sacrificial’ layer that is thick enough to manage the amount of corrosion anticipated to occur over the structure’s design life. Where sulfates are present and corrosion of concrete is a concern, mitigation alternatives may include use of sulfate-resistant cement, such as type II low-alkali cement, coating the concrete with an asphalt emulsion, or reducing the water-cement ratio to reduce the hydraulic conductivity of the concrete and slow the reaction processes.

## 8.0 LIMITATIONS

This report was prepared for the exclusive use of HDR, Inc. (HDR), and the Idaho Power Company (IPC) design team for the Boardman, Oregon to Hemingway, Idaho 500kV Transmission Line Project. This report represents preliminary design considerations consisting of generalized geology, geologic hazard characterization, and geotechnical considerations. The purpose for this report is to assist IPC and HDR in preparing exhibits required by the Oregon Energy Facility Siting Council (EFSC) prior to obtaining their approval to complete design and initiate construction of the Boardman to Hemingway Project. No final design geotechnical recommendations are included herein. Instead, the report presents an assessment of conditions and recommends further geotechnical investigations and design support as planning of the project proceeds. Within the limitations of scope, schedule, and budget, the conclusions, and recommendations presented herein were prepared in accordance with generally accepted professional engineering geology and geotechnical engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as described in the references cited herein.

The conclusions and recommendations contained in this report are based primarily on available published information, with very limited field reconnaissance. No subsurface explorations were conducted for this study. We have assumed that the referenced data is factual, accurate, and representative of conditions throughout the project alignments. This report is intended to assist in project planning, permitting and preliminary design. This report is not suitable for final design. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of separated portions of this report.

The scope of our present work did not include environmental assessments or evaluations regarding the presence or absence of wetlands, or hazardous or toxic substances in the soil, surface water, groundwater, or air, on or below or around this site, or for the evaluation or disposal of contaminated soils or groundwater should any be encountered.

Shannon & Wilson, Inc. has prepared and included in Appendix F, “Important Information About Your Geotechnical/Environmental Report,” to assist you and others in understanding the use and limitations of our reports.

**SHANNON & WILSON, INC.**

David J. Higgins, CEG
Associate | Engineering Geologist

Risheng (Park) Piao, PE, GE
Vice President | Geotechnical Engineer

## 9.0 REFERENCES


Advanced National Seismic System (ANSS), 2016, Composite Catalog: accessed November, 2016: Available: http://earthquake.usgs.gov/earthquakes/search/ and http://www.quake.geo.berkeley.edu/anss/catalog-search.html.

American Society of Civil Engineers (ASCE), 2010 with 2013 errata, Minimum Design Loads for Buildings and Other Structures (Standards ASCE/SEI 7-10): Reston, VA, ASCE, 636 p.

Ashley, R.P., 1966, Metamorphic Petrology and Structure of the Burnt River Canyon Area, northeastern Oregon: Palo Alto, California, Stanford University, Ph.D. dissertation, 236 p., scale 1:21,100.

Barrash, Warren, John G. Bond, John D. Kauffman, and Ramesh Venkatakrishnan, 1980, Geology of the La Grande Area, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 6.

Bela, J.L. (Compiler), 1982, Geologic and neotectonic evaluation of north-central Oregon: The Dalles $1^0$ x $2^0$ quadrangle: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-027, scale 1:250,000.

Bonnichsen, B., and Godchaux, M.M., 2002, Late Miocene, Pliocene, and Pleistocene Geology of Southwestern Idaho With Emphasis on Basalts in the Bruneau-Jarbidge, Twin Falls, and Western Snake River Plain Regions, *in* Bill Bonnichsen, C.M. White, and Michael McCurry, eds., Tectonic and Magmatic Evolution of the Snake River Plain Volcanic Province: Idaho Geological Survey Bulletin 30, p. 233-312.

Boore, D.M., Atkinson, G.M., 2008, Ground Motion Prediction Equations for the Average Horizontal Component of PGA, PGV, and 5%-Damped PSA at Spectral Periods between 0.01 s and 10.0 s: Earthquake Spectra, v. 24, p. 99-138.

Brooks, H.C., 2006, Geologic and mineral resources map of the Mormon Basin quadrangle, Baker and Malheur Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-2006-25, 25 p., scale 1:24,000.

Brooks, H.C., 1991, Geology and Mineral Resources Map of the Vines Hill Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries, Geologic Map Series, GMS-063, scale 1:24,000.

Brooks, H.C., 1979, Geologic Map of the Huntington and Part of the Olds Ferry Quadrangles, Baker and Malheur Counties, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-013, scale 1:62,500.

Brooks, H.C., McIntyre, J.R., and Walker, G.W., 1976, Geologic Map of the Oregon part of the Baker 1 degree by 2 degree Quadrangle: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-007, scale 1:250,000.

Burns, W.J., Mickelson, K.A., Saint-Pierre, E.C., 2011, SLIDO-2, Statewide Landslide Information Database for Oregon, Release 2; Oregon Department of Geology and Mineral Industries.

Busskohl, C., 2006, Land type associations of the Malheur, Umatilla, and Wallowa-Whitman National Forests: US. Department of Agriculture Forest Service, Pacific NW Region, scale 1:100,000.

Campbell, K.W., and Bozorgnia, Y., 2008, NGA Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01 s to 10 s: Earthquake Spectra, v. 24, p. 139-171.

Chiou, B.S-J., and Youngs, R.R., 2008, An NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra: Earthquake Spectra, v. 24, p. 173–215.

Ferns, M.L., McConnell, V.S., Madin, I.P., and Johnson, J.A., 2010, Geology of the Upper Grande Ronde Basin, Union County, Oregon; Oregon Department of Geology and Mineral Industries Bulletin 107, vector digital data, scale 1:100,000.

Ferns, M.L., McConnell, V.S., Madin, I.P., and Johnson, J.A., 2003, Geologic Map of the Upper Grande Ronde River Basin, Union County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-2003-11, 85 p., scale 1:125,000.

Ferns, M.L., Madin, I.P., and Taubeneck, W.H., 2001a, Reconnaissance geologic map of the La Grande 30' x 60' quadrangle, Baker, Grant, Umatilla, and Union Counties, Oregon: Oregon Department of Geology and Mineral Industries Recon. Map Series RMS-1, scale 1:100,000.

Ferns, M.L., Madin, I.P., McConnell, V.S., and Johnson, J.J., 2001b, Geology of the surface and subsurface of the southern Grande Ronde Valley and lower Catherine Creek drainage, Union County, Oregon: Oregon Department of Geology and Mineral Industries Open File Report O-2002-02, 54 p., 3 plates, vector digital data, scale 1:24000.

Ferns, M.L., Brooks, H.C., Evans, J.G., and Cummings, M.L., 1993a, Geologic map of the Vale 30' x 60' quadrangle, Malheur County, Oregon and Owyhee County, Idaho: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-77, scale 1:100,000.

Ferns, M.L., Evans, J.G., and Cummings, M.L., 1993b, Geologic map of the Mahogany Mountain 30' x 60' quadrangle, Malheur County, Oregon and Owyhee County, Idaho: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-78, scale 1:100,000.

Ferns, M.L., 1989, Geology and Mineral Resources Map of the Owyhee Dam Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-55, scale 1:24,000.

Idriss, I.M. and Boulanger, R.W., 2006, Semi-empirical procedures for evaluating liquefaction potential during earthquakes. Soil Dynamics and Earthquake Engineering, 26(2), pp.115-130.

IEEE Power Engineering Society and American Society of Civil Engineers, 2001, IEEE Guide for Transmission Structure Foundation Design and Testing: IEEE Standard 691, Published by the Institute of Electrical and Electronics Engineers.

IEEE Power Engineering Society, 2000, IEEE Guide for Safety in AC Substation Grounding: IEEE Standard 80, Published by the Institute of Electrical and Electronics Engineers.

IEEE Power Engineering Society and American Society of Civil Engineers, 1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System: IEEE Standard 81, Published by the Institute of Electrical and Electronics Engineers.

International Building Code, 2015, Published by the International Code Council.

International Building Code, 2009, Published by the International Code Council.

Idaho Power Corporation, 2016, Exhibit H of the Amended Preliminary Application for Site Certificate for the Boardman to Hemingway Transmission Line Project: Report Prepared by Idaho Power Corporation, Boise, Idaho.

Johnson, A.G., Scofield., D.H., and Madin, I.P., 1994, Earthquake Database for Oregon, 1833 through October 25, 1993: Oregon Department of Geology and Mineral Industries Open-File Report O-1994-04.

Kramer, Steven L., 1996, Geotechnical Earthquake Engineering: Pearson, 653 p.

Luco, Nicolas, 2007, Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States, *in* SEAOC 2007 Convention Proceedings.

Madin, I.P., and Geitgey, R.P., 2007, Preliminary geologic map of the Umatilla Basin, Morrow and Umatilla Counties, Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-2007-15, 19 p., scale 1:100,000.

Madin, I.P., and Mabey, M.A., 1996, Earthquake Hazard Map for Oregon, State of Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-100.

Madin, I.P., and Ferns, M.L., 1977, Geology of the Malheur Butte quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-1997-02, scale 1:24,000.

National Geophysical Data Center (NGDC), 1985, Earthquake Intensity Database Search, 1683 – 1985, NOAA Satellite and Information Service: accessed September, 2015: Available: http://www.ngdc.noaa.gov/hazard/earthqk.shtml.

Oregon Geologic Data Compilation (OGDC), 2015, Oregon Geologic Data Compilation DVD, Release 6, compiled by Smith, R.L., and Roe, Warren P., Oregon Department of Geology and Mineral Industries.

Oregon Structural Specialty Code (OSSC), 2010, Published by the International Code Council.

Orr, E.L. and Orr, W.N., 2000, Geology of Oregon, Fifth Ed., Kendall/Hunt Publishing Co., Dubuque, Iowa, 254 p.

Pacific Northwest Seismic Network (PNSN), 2008, Earthquake Catalogs and Data: accessed November, 2016: Available: http://www.pnsn.org/HIST_CAT/catalog.html.

Personius, S.F., and Lewis, R.S., compilers, 2003, Fault number 636, Owyhee Mountains fault system, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:19 PM.

Personius, S.F., compiler, 2002a, Fault number 709, South Grande Ronde Valley faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:22 PM.

Personius, S.F., compiler, 2002b, Fault number 712, Unnamed eastern Baker Valley faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:21 PM.

Personius, S.F., compiler, 2002c, Fault number 802a, West Grande Ronde Valley fault zone, Mount Emily section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:23 PM.

Personius, S.F., compiler, 2002d, Fault number 802b, West Grande Ronde Valley fault zone, La Grande section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:23 PM.

Personius, S.F., compiler, 2002e, Fault number 802c, West Grande Ronde Valley fault zone, Craig Mountain section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:22 PM.

Personius, S.F., compiler, 2002f, Fault number 804, West Baker Valley fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:21 PM.

Personius, S.F., compiler, 2002g, Fault number 806, Cottonwood Mountain fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:20 PM.

Personius, S.F., compiler, 2002h, Fault number 808, Faults near Owyhee Dam, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:19 PM.

Personius, S.F., and Lidke, D.J., compilers, 2003a, Fault number 845c, Hite fault system, Thorn Hollow section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:24 PM.

Personius, S.F., and Lidke, D.J., compilers, 2003b, Fault number 845d, Hite fault system, Agency section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 11/16/2016 06:23 PM.

Pierce, K. L., and Morgan, L. A., 1992, The track of the Yellowstone hot spot: Volcanism, faulting, and uplift, *in* Link, P. K., Kuntz, M. A., and Platt, L. B., eds., Regional Geology of Eastern Idaho and Western Wyoming: Geological Society of America Memoir 179, p. 1-53.

Prostka, H.J., 1967, Preliminary geologic map of the Durkee quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS- 003, 8 p., scale 1:62,500.

Prostka, H.J., 1962, Geology of the Sparta quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-001, 8 p., scale 1:62,500.

Shaw Environmental & Infrastructure, Inc., 2012, Desktop Geotechnical Report, Proposed 500kV Transmission Line, Boardman, Oregon to Hemingway, Idaho: Report Prepared by Shaw Environmental & Infrastructure Inc., Portland, Oregon, for Pike Energy Solutions, Portland, Oregon, 48 p.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Baker County, Oregon: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=OR.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Malheur County, Oregon: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=OR.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Morrow County, Oregon: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=OR.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Owyhee County, Idaho: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=ID

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Umatilla County, Oregon: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=OR.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database Union County, Oregon: Available: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=OR.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Dammerer, A.M., Wu, J., Pestana, J.M., Riemer, M.F., Sancio, R.B., Bray, J.D., Dayen, R.E., and Faris, A., 2003, Recent Advances in Soil Liquefaction Engineering – A Unified and Consistent Framework, 26th Annual ASCE Los Angeles Geotechnical Spring Seminar, Long Beack, California, April 30, 2003.

Shervais, J.W, Kauffman, J.D., Gillerman, V.S., Othberg, K.L., Vetter, S.K., Hobson, V.R., Zarnetske, M., Cooke, M.F., Mathews, S.H., and Hanan, B.B., 2005, Basaltic Volcanism of the Central and Western Snake River Plain: A Guide to Field Relations Between Twin

Falls and Mountain Home, Idaho, *in* Pederson, J., and Dehler, C.M., eds., Interior Western United States: Geological Society of America Field Guide 6, 26 p.

Swanson, D.A., Anderson, J.L., Camp, V.E., Hooper, P.R., Taubeneck, W.H., and Wright, T.L., 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, scale 1:250,000.

U.S. Geological Survey (USGS), 2002, Earthquake Hazards Program, 2002 interactive disaggregation tool: Available: https://geohazards.usgs.gov/deaggint/2002/.

U.S. Geological Survey (USGS), 2016a, Search Earthquake Catalog: accessed 11/16/16: Available: http://earthquake.usgs.gov/earthquakes/search/.

U.S. Geological Survey (USGS), 2016b, Earthquake Hazards Program, The Modified Mercalli Intensity Scale: accessed September, 2015: Available: http://earthquake.usgs.gov/learn/topics/mercalli.php.

U.S. Geological Survey (USGS), 2016c, Earthquake Hazards Program, 2014 uniform hazard curve data: Available: ftp://hazards.cr.usgs.gov/web/nshm/conterminous/2014/data/.

U.S. Geological Survey (USGS), 2006, Quaternary fault and fold database for the United States, accessed November, 2016: Available: http//earthquakes.usgs.gov/hazards/qfaults/.

Wald, D.J., Quitoriano, V., Heaton, T.H., and Kanamori, H., 1999, Relationship between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California: Earthquake Spectra, vol. 15, no. 3, p. 557-564.

Walker, G.W., Raines, G.L., and Connors, Katherine A., 2002, Spatial Digital Database for the Geologic Map of Oregon; U.S. Geological Survey Open File Report 03-67, scale 1:500,000.

Walker, G.W., 1979, Reconnaissance geologic map of the Oregon part of the Grangeville quadrangle, Baker, Union, Umatilla, and Wallowa Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Map I-1116, scale 1:250,000.

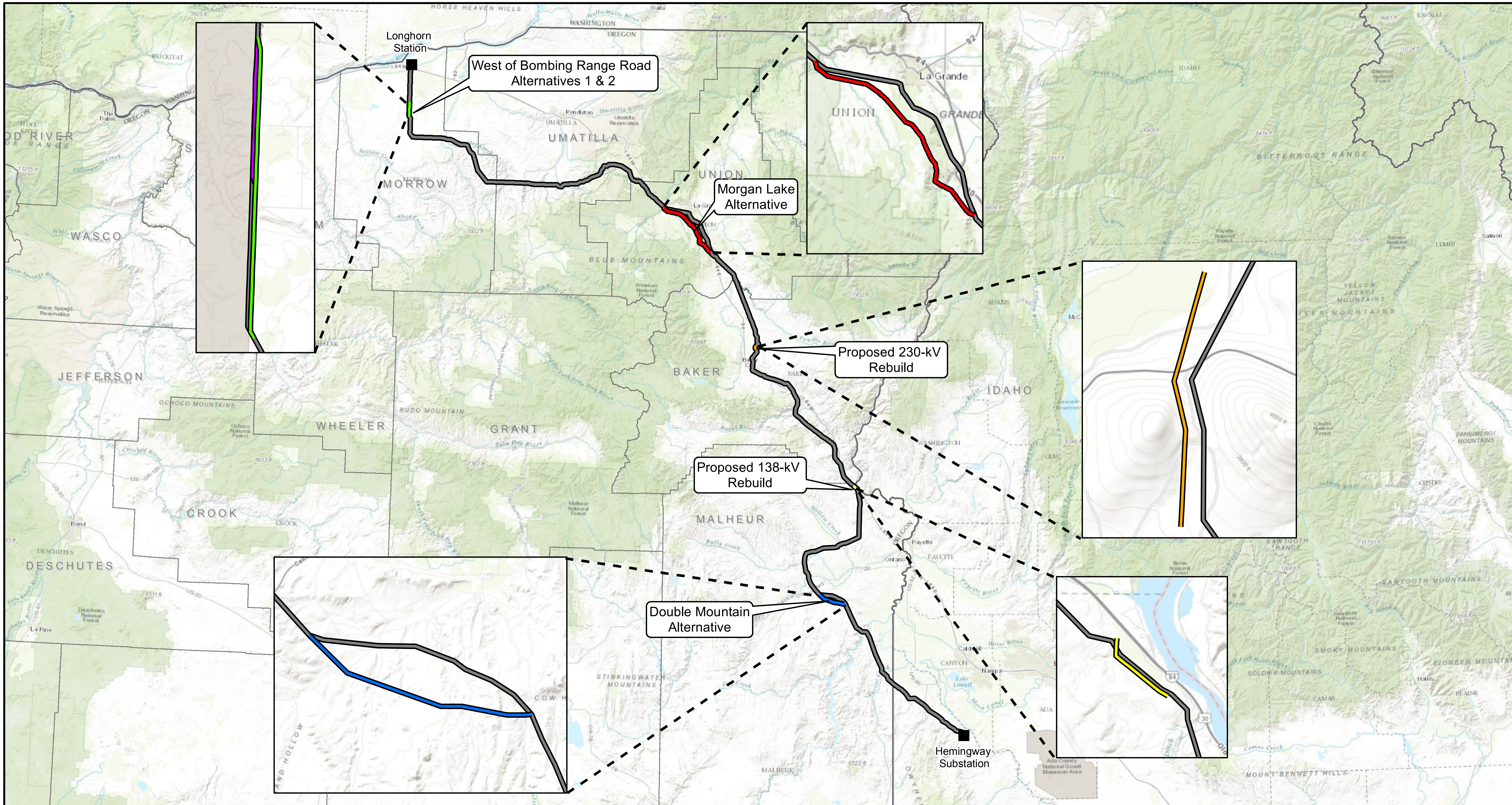
Walker, G.W., 1973, Reconnaissance Geologic map of the Pendleton Quadrangle, Oregon and Washington: U.S. Geological Survey Miscellaneous Investigations Map I-727, scale 1:250,000.

Youd, T. L., et al., 2001, Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils. Journal of geotechnical and geoenvironmental engineering 127.10: 817-833.

## TABLE 1: 5,000-YEAR RETURN PERIOD GROUND MOTION PARAMETERS

| Latitude | Longitude | Designation of Nearest Proposed Tower | 2002 USGS PSHA PGA (g) | 2014 USGS PSHA PGA (g) |
|---|---|---|---|---|
| 45.846 | -119.617 | 1/1 | 0.27 | 0.26 |
| 45.410 | -118.908 | 60/1 | 0.20 | 0.21 |
| 45.153 | -117.980 | 120/1 | 0.21 | 0.21 |
| 44.498 | -117.437 | 180/1 | 0.22 | 0.22 |
| 44.047 | -117.428 | 224/2 | 0.23 | 0.26 |
| 43.880 | -117.388 | 240/1 | 0.19 | 0.21 |
| 43.352 | -116.661 | 295/3 | 0.15 | 0.17 |

Notes
Ground motions were obtained from the 2002 and 2014 USGS Probabilistic Seismic Hazard Analysis (PSHA) and are provided for PGA at B/C boundary site conditions only. Directionality, risk coefficient, soil effects (other than B/C boundary), directivity effects, and basin effects are not included and should be added to the calculated value if necessary.




## LEGEND

| | |
|---|---|
| IPC Proposed Route | Proposed 230-kV Rebuild |
| West of Bombing Range Road - Alternative 1 | Proposed 138-kV Rebuild |
| West of Bombing Range Road - Alternative 2 | Double Mountain Alternative |
| Morgan Lake Alternative | Stations |

NOTE
Alignments provided by Idaho Power, dated 9/9/2016.

0 25 50 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**VICINITY MAP**

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**FIG. 1**

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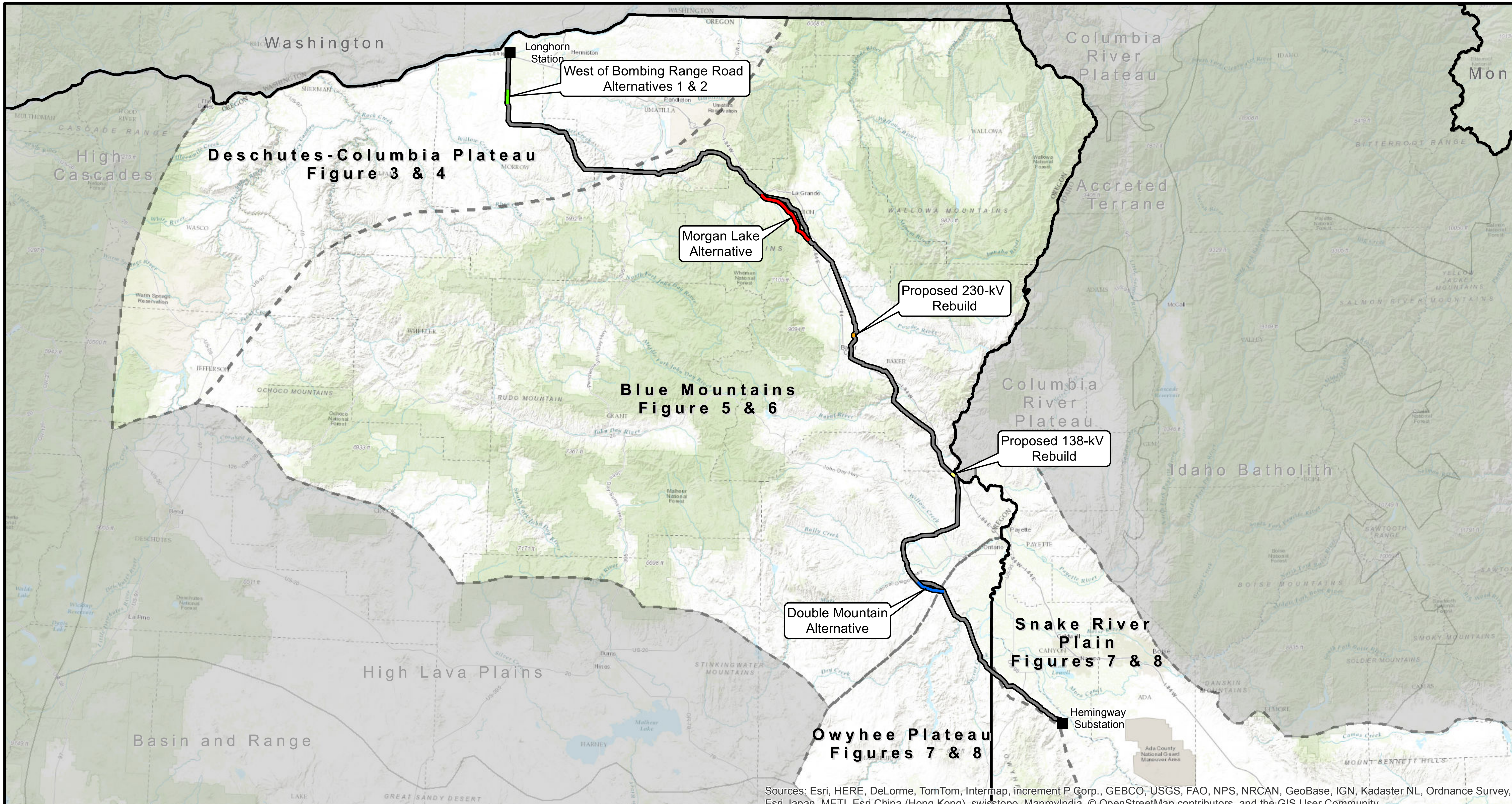


## LEGEND

- IPC Proposed Route
- West of Bombing Range Road - Alternative 1
- West of Bombing Range Road - Alternative 2
- Morgan Lake Alternative
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Stations
- Physiographic Province Boundaries (approximate)
- State Boundaries

NOTE
1. Alignments provided by Idaho Power, dated 9/9/2016.
2. Physiographic province boundaries are approximate.

0 25 50 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**PHYSIOGRAPHIC PROVINCE PAGE INDEX**

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**FIG. 2**

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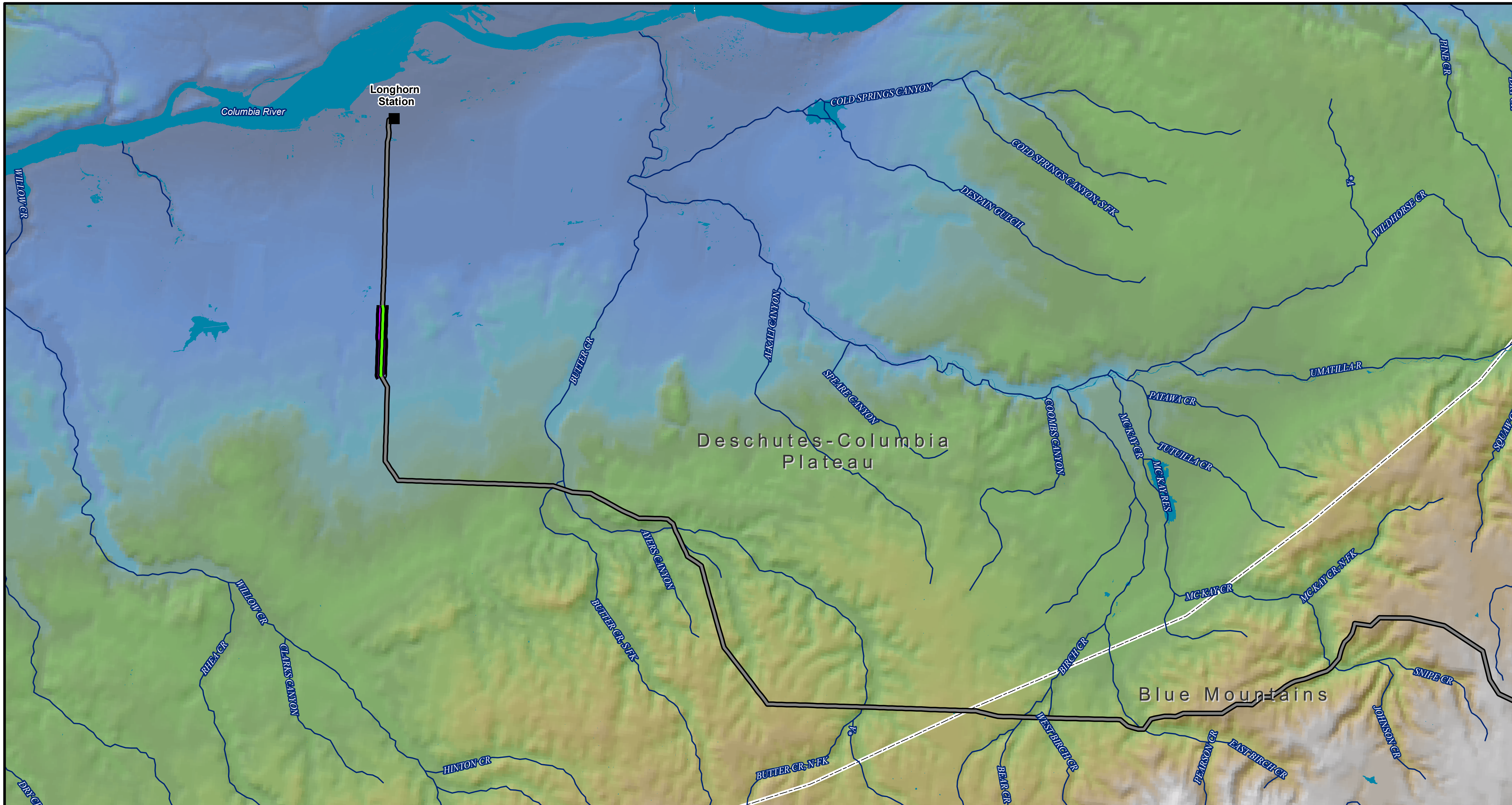


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## LEGEND

- IPC Proposed Route
- West of Bombing Range Road - Alternative 1
- West of Bombing Range Road - Alternative 2
- Physiographic Province Boundary
- Proposed Station
- Major Creeks and Rivers

ELEVATION (feet)

~5000 (ft)

0 (ft)

N S W E

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**DESCHUTES-COLUMBIA PLATEAU TOPOGRAPHY AND DRAINAGE**

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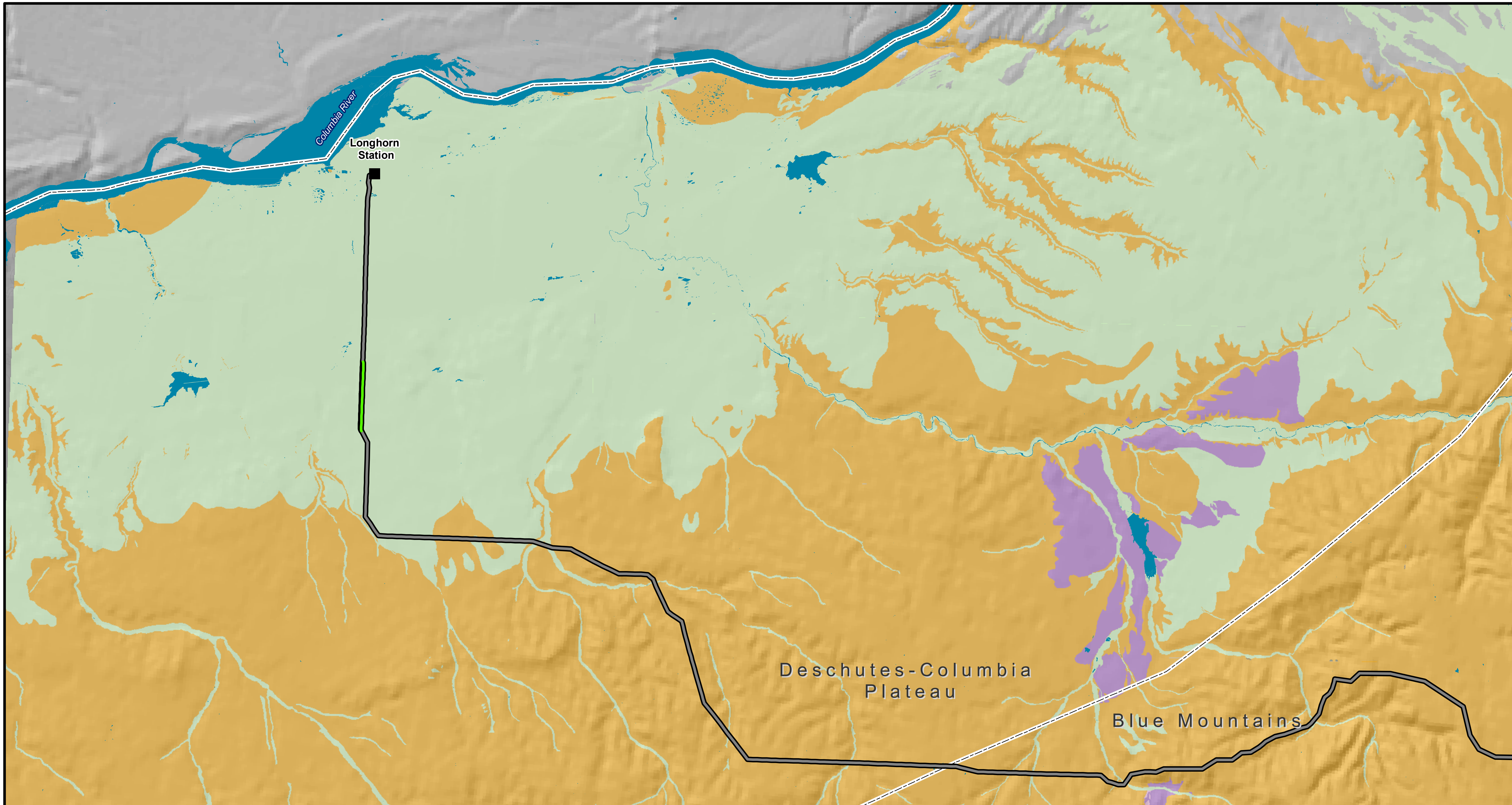
**FIG. 3**




## LEGEND

- IPC Proposed Route
- West of Bombing Range Road - Alternative 1
- West of Bombing Range Road - Alternative 2
- Proposed Station
- Physiographic Province Boundary (Approximate)

**SURFICIAL GEOLOGY**

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks
- Water

NOTES
1. Alignment(s) and station data provided by Idaho Power, dated 9/9/2016.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.
4. Oregon geology provided by DOGAMI, OGDC version 5 and 6.

0 5 10 Miles

N W E S

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**DESCHUTES-COLUMBIA PLATEAU GEOLOGY**

November 2016 24-1-03820-005

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**FIG. 4**

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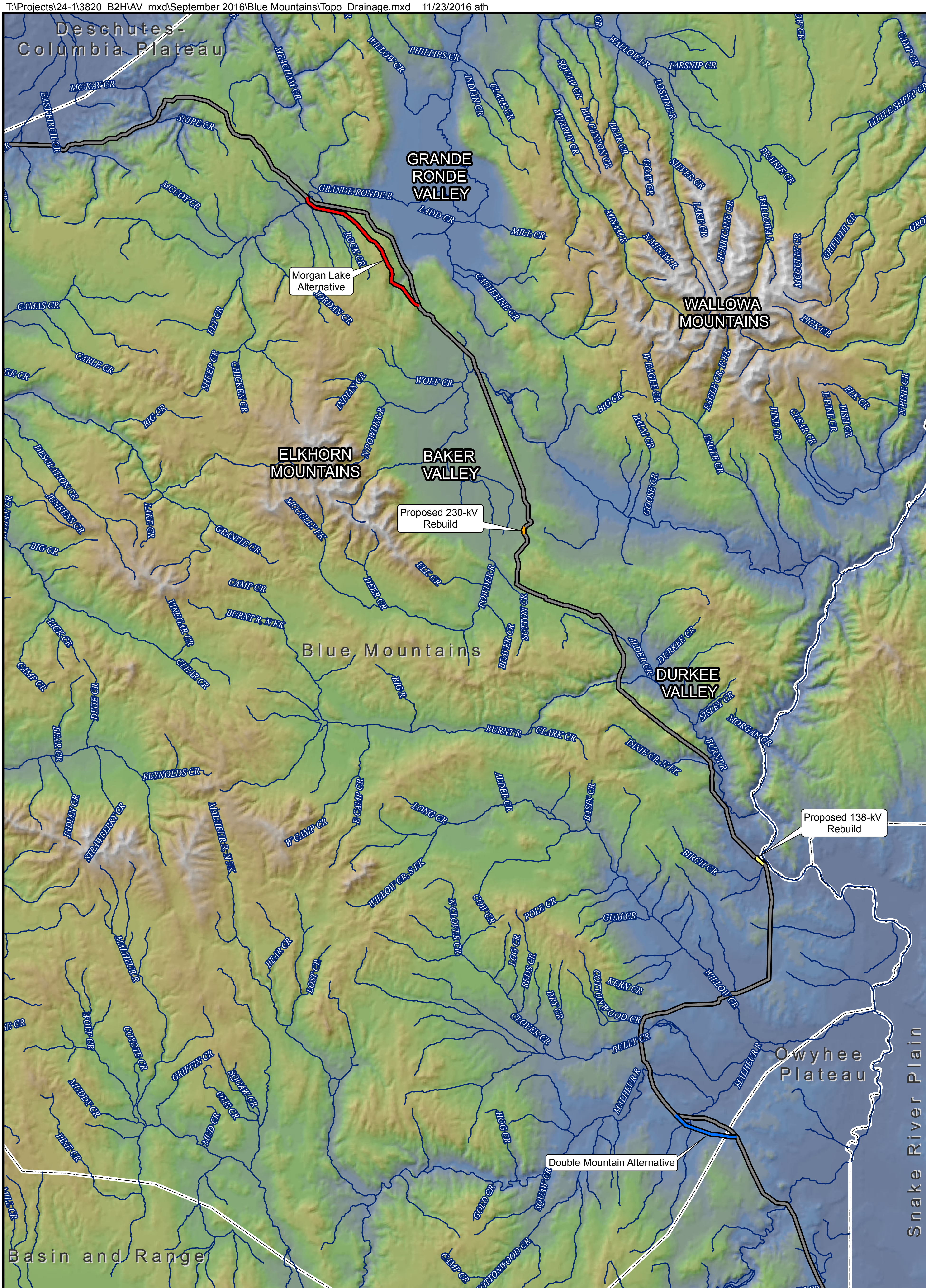
T:\Projects\24-1\3820_B2H\AV_mxd\September 2016\Blue Mountains\Topo_Drainage.mxd 11/23/2016 ath




LEGEND

- IPC Proposed Route
- Morgan Lake Alternative
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Physiographic Province Boundary (Approximate)
- Major Creeks and Rivers

ELEVATION (feet)
~9000 ft
0 ft

0 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**BLUE MOUNTAINS TOPOGRAPHY AND DRAINAGE**

November 2016 24-1-03820-005

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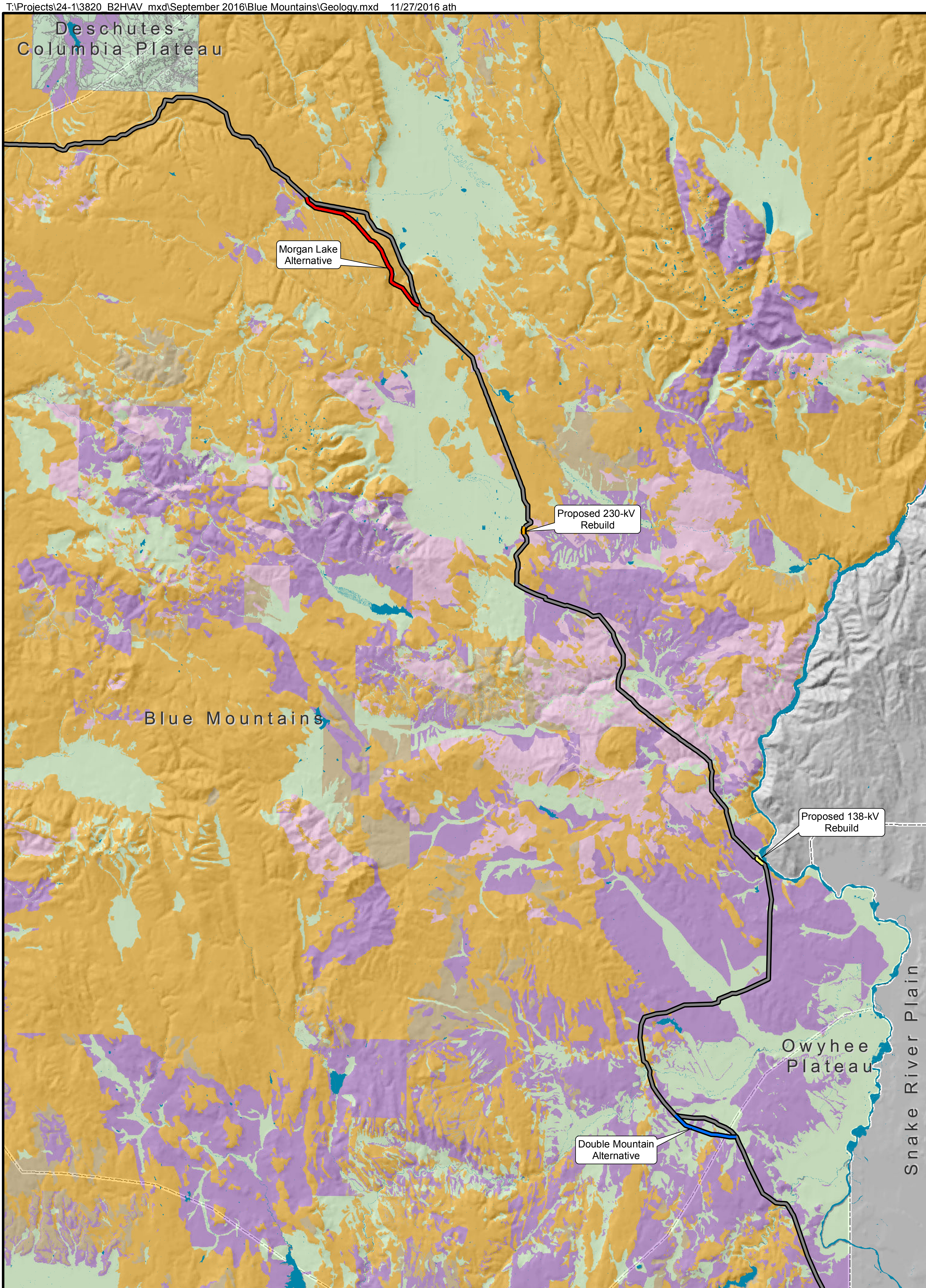
FIG. 5

T:\Projects\24-1\3820_B2H\AV_mxd\September 2016\Blue Mountains\Geology.mxd 11/27/2016 ath




LEGEND

- IPC Proposed Route
- Morgan Lake Alternative
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative

SURFICIAL GEOLOGY

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks
- Water

NOTES

1. Alignment(s) provided by Idaho Power, dated 9/9/2016.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.
4. Oregon geology provided by DOGAMI.

0 10 20 Miles

N W E S

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**BLUE MOUNTAINS GEOLOGY**

November 2016 24-1-03820-005

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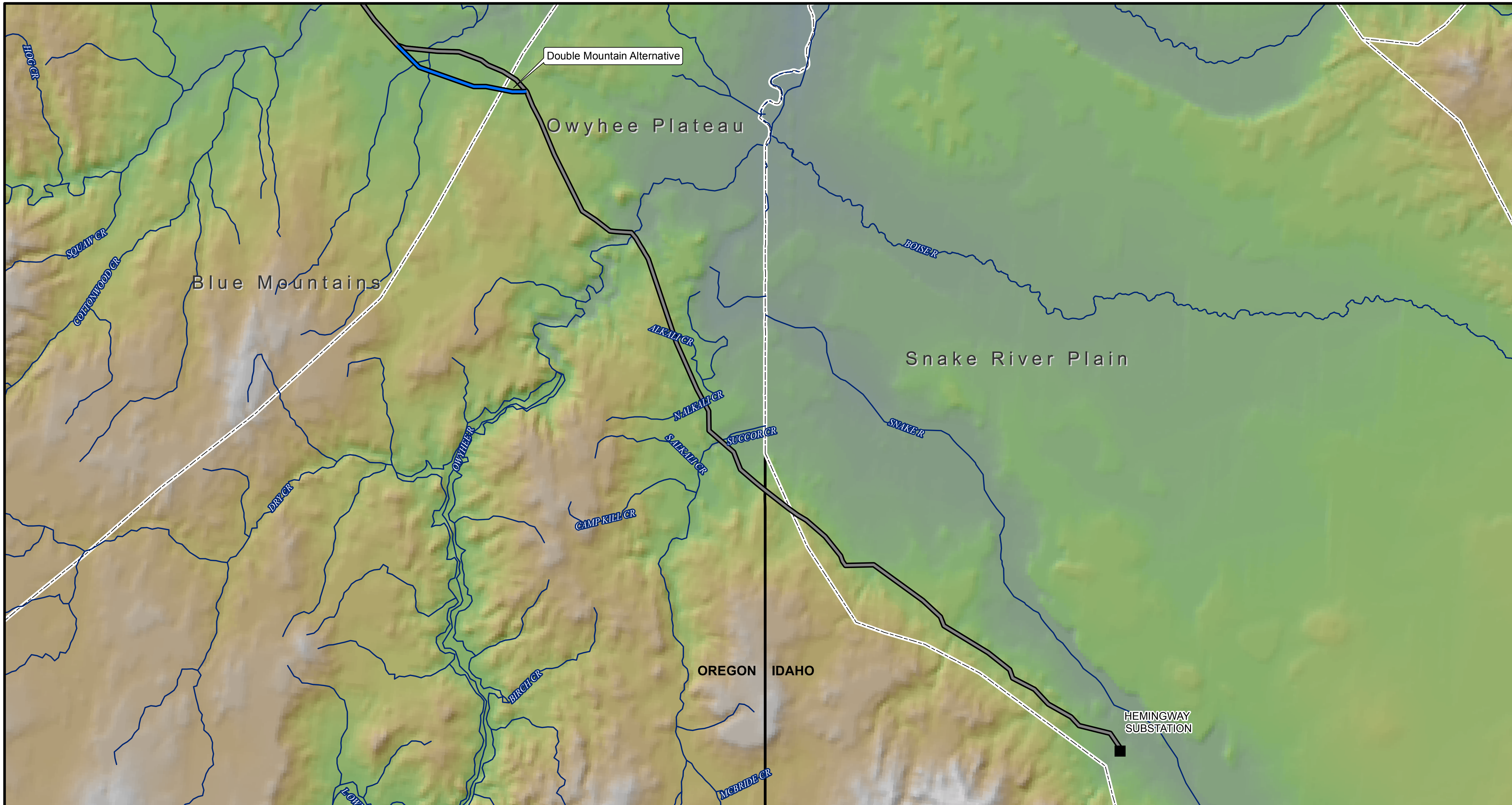
**FIG. 6**




LEGEND

- IPC Proposed Route
- Double Mountain Alternative
- Physiographic Province Boundary
- Major Creeks and Rivers
- Proposed Substation

ELEVATION (feet)
~6000 ft
0 ft

N E S W

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**OWYHEE PLATEAU TOPOGRAPHY AND DRAINAGE**

November 2016 24-1-03820-005

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**FIG. 7**

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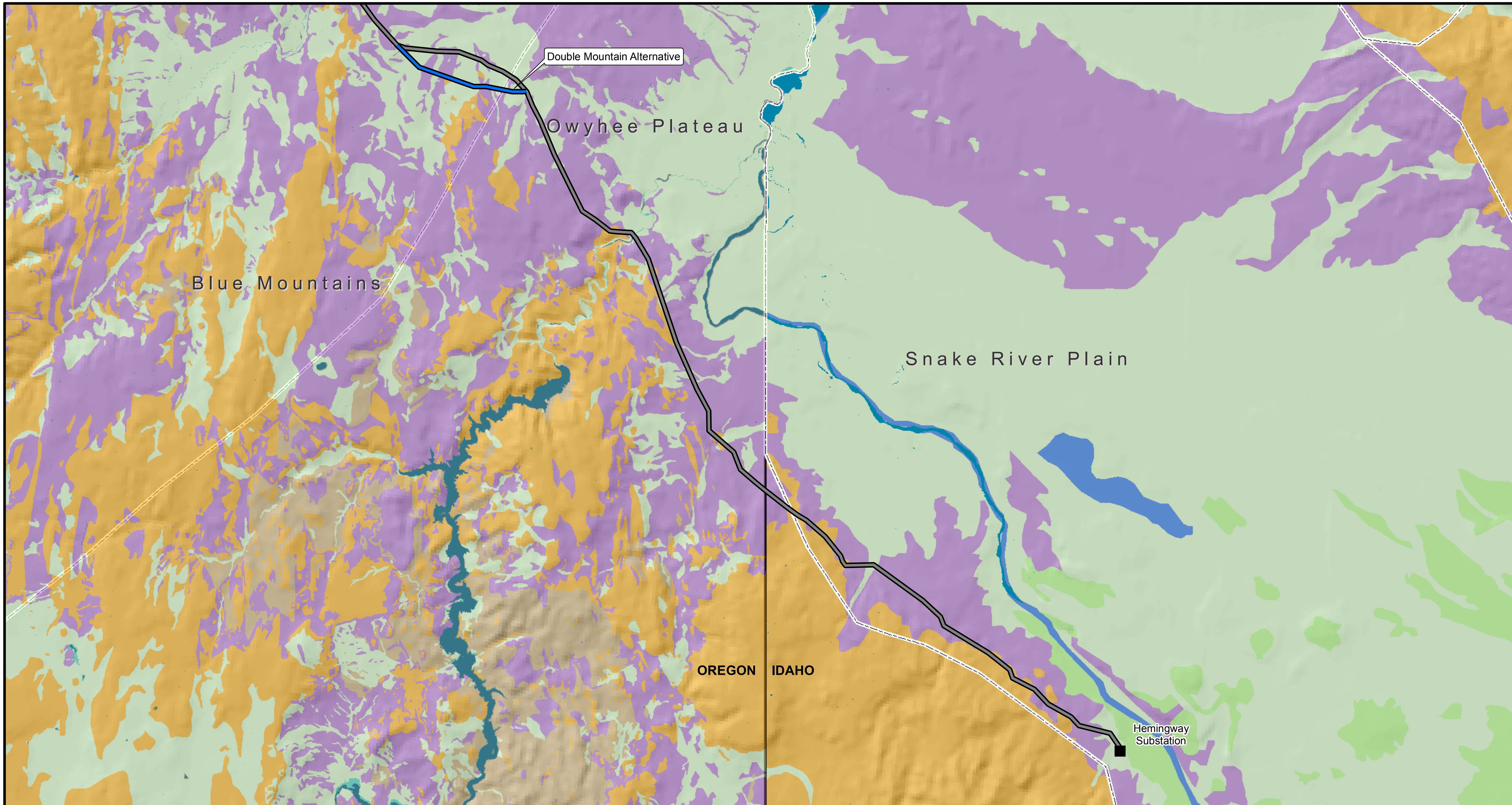


LEGEND

- IPC Proposed Route
- Double Mountain Alternative
- Physiographic Province Boundary
- Proposed Substation

SURFICIAL GEOLOGY

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks
- Water

NOTES

1. Alignments and substation data provided by Idaho Power, dated 9/9/2016.
2. Geologic province boundaries should be considered approximate.
3. For legend, see Fig. 9.
4. Oregon geology provided by DOGAMI. Idaho geology provided by USGS.

N W E S

0 5 10 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**OWYHEE PLATEAU GEOLOGY**

November 2016 24-1-03820-005

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**FIG. 8**

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# APPENDIX A

# GEOLOGIC MAPS AND UNIT DESCRIPTIONS

## TABLE OF CONTENTS



## TABLES



## FIGURES

# APPENDIX A

# GEOLOGIC MAPS AND UNIT DESCRIPTIONS

## A.1 INTRODUCTION

This appendix presents geologic maps that cover the IPC Proposed Route, Proposed 230 kV Rebuild, Proposed 138 kV Rebuild, West of Bombing Range Road Alternative 1, West of Bombing Range Road Alternative 2, Morgan Lake Alternative, and Double Mountain Alternative project alignments, as well as associated multi-use areas. Geologic maps along the majority of the alignment were originally created by Shaw Environmental & Infrastructure, Inc., and were first presented in their Desktop Geotechnical Report, dated January 19, 2012. Subsequent new alignments, as well as changes to the previous alignments, were evaluated by Shannon & Wilson, Inc. Maps from the Proposed 230 kV Rebuild, Proposed 138 kV Rebuild, West of Bombing Range Road Alternative 1, West of Bombing Range Road Alternative 2, Morgan Lake Alternative, and Double Mountain Alternative alignments, and associated multi-use areas, are integrated with the IPC Proposed Route in this appendix. The following sections describe how the maps were generated and the general characteristics of geologic units. Table A1 presents a Geologic Time Scale, for reference. Table A2 summarizes all surficial geologic units encountered within a 0.5-mile radius of the proposed alignments. Table A3 presents geologic unit data for multi-use areas located away from the alignment such that they fall outside the boundaries of the map sheets presented. Map Sheet 1 presents an index map for the geologic maps, and Sheets 2 through 114 present the geologic maps themselves.

## A.2 SURFICIAL GEOLOGIC MAPPING

GIS base files obtained for this study were compiled in the Oregon Geologic Data Compilation (OGDC) by the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Idaho Department of Water Resources (IDWR). The GIS data were then compared with geologic maps for those areas of Oregon and Idaho where the IPC Proposed Route, Proposed 230 kV Rebuild, Proposed 138 kV Rebuild, West of Bombing Range Road Alternative 1, West of Bombing Range Road Alternative 2, Morgan Lake Alternative, and Double Mountain Alternative alignments are proposed. The mapped geologic units and formations along these routes were generalized by this study into five lithologic categories and landslides (which frequently include many different lithologies). The lithologic categories are divided based on generalized geotechnical engineering properties.

The lithologic categories include the following:

- Unconsolidated sediments
- Landslide deposits
- Sedimentary rocks
- Volcaniclastic rocks
- Igneous rocks
- Metamorphic rocks

The categories allow for a better understanding of the general site geology and subsurface conditions, while allowing for variations in formation names and descriptions between different maps of the same area or maps of adjoining areas created by different authors. Prior to final design, site-specific geologic reconnaissance and geotechnical drilling will be performed to confirm the geology and engineering properties of subsurface materials at specific locations along the alignments. Proposed locations for geotechnical drilling are shown on the geologic map sheets in this Appendix. Additional information regarding the proposed explorations is presented in Appendix C, Summary of Proposed Boring Locations. The generalized lithologic categories and the major geologic units included in each category are described below. All surficial geologic formation and mapped subunits encountered within a 0.5-mile radius of the proposed alignments are summarized in Table A2, and geologic data for all multi-use areas located away from the alignment are summarized in Table A3.

### A.2.1 Unconsolidated Sediments

Unconsolidated sediments are found at various locations throughout the alignments and consist primarily of water-, wind-, and gravity-transported sediments including clay, silt, sand, gravel, cobbles and boulders, and minor ash. Included in this category are alluvium, fan deposits, terrace deposits, flood deposits, eolian deposits, and colluvium.

#### A.2.1.1 Alluvim

Alluvium (Qa, Qal, Qu) generally consists of quaternary age unconsolidated sediments deposited on active stream channels and floodplains. Deposits include clay; silt; sand; gravel; cobbles; boulders; and, in some areas, abundant organic material with thin peat beds. Fine-grained deposits are generally located along low terraces along river banks. Playa-lake deposits exist near the southern portion of the alignment, near Vale. Overbank silt deposits exist within the floodplains of the Owyhee, Malheur, and Snake Rivers (Ferns et al., 1993a). Overall, thicknesses of Alluvium deposits vary from approximately 10 feet to over 30 feet.

#### A.2.1.2 Fan and Terrace Deposits

Fan and terrace deposits are types of alluvium and, in many cases, are mapped together in the same units (Qas, Qas1, Qf, Qfd, Qtg). Alluvial fans consist of poorly sorted, unconsolidated to poorly consolidated boulder- to clay-size sediments deposited by streams, typically at the mouth of a drainage or canyon. Terrace deposits are typically composed of poorly sorted gravel and bouldery soils above modern stream channels. The terraces are formed when rivers and streams cut down through the sediments they previously deposited.

#### A.2.1.3 Missoula Flood Deposits

Missoula Flood deposits (Qmf) are the result of repeated glacial outburst floods, which occurred around 15,500 to 13,000 years ago due to rupture of ice dams that formed glacial Lake Missoula in modern-day Montana. The floods drained across the Idaho panhandle, through the Washington Scablands, and into the Columbia River. The deposits are generally mapped within the first 16 miles of the IPC Proposed Route, near the Columbia River. In the project area, this unit primarily includes unconsolidated silt, sand, gravel, and boulders. Thickness generally ranges from 15 to 50 feet with a maximum thickness of 150 feet (Madin and Geitgey, 2007).

#### A.2.1.4 Bonneville Flood Deposits

The Bonneville Flood deposits (Qpug, Qsbf, Qpa) are the result of a single catastrophic outburst flood that occurred around 14,500 years ago, due to rupture of a natural rock formation which had contained Lake Bonneville, which occupied the present-day basin of the Great Salt Lake. The flood waters washed across the Snake River Plain, through Hells Canyon, and ultimately out through the Columbia River. Deposits include unconsolidated silt, sand, and gravel and are found along IPC Proposed Route between milepost 255 (MP255) and MP256, and near the end, past MP294.

#### A.2.1.5 Aeolian Sand and Ash

Aeolian Sand and Ash (Qe) is a windblown deposit of quaternary age that is generally mapped within the first 16 miles of the IPC Proposed Route, near the Columbia River. This unit consists primarily of unconsolidated sands and silt from older Missoula Flood deposits and airfall volcanic ash deposits. Thickness ranges from a thin veneer just outside of the Missoula Flood deposits to approximately 3 feet thick in the highlands (Madin and Geitgey, 2007).

#### A.2.1.6 Colluvium

Colluvium (Qcf) includes mixed sedimentary deposits at the foot of a slope of a cliff, transported principally by gravity. Depending on the geology of the surrounding highlands, deposits of colluvium can range from mixtures of silt, sand, gravel, and cobbles, to clean accumulations of gravel- to boulder-sized rock fragments (talus). As many slopes contain at least a thin veneer of colluvium, it is likely that more colluvium exists along the alignment than is shown on the geologic maps, which tend to emphasize the underlying rock units.

### A.2.2 Landslide Deposits

Landslide Deposits (Qls, Qdf) are mapped at various locations throughout the alignments and result from the downslope movement of soil and/or rock masses. Landslides are generally differentiated from colluvium by the scale and rate of movement. Deposition of colluvium is typically a gradual process, whereas landslides occur as masses of soil or rock fail downslope, often along preexisting planes of weakness. Deposits may include large-scale rock-fall, mudflow, debris flow, scree, and talus deposits. The deposits may consist of unconsolidated, unsorted, chaotically mixed soil and/or rock debris. Landslide deposits can often be identified by hummocky topography, scarps, ponds, seeps, and tension cracks. If a landslide is active, or recently active, it may be identified by tilted trees and relatively fresh scarps. In the vicinity of the project alignment, failures often occur where basalt and/or other coherent rock units slide on top of weathered tuffaceous sedimentary rocks. Landslide deposits are discussed in further detail in Appendix E.

### A.2.3 Sedimentary Rocks

Sedimentary rocks form through consolidation and cementation of loose sediments, and are generally found in layers. The layers are formed by the sequential deposition of soil particles by features such as streams and lakes. The following sections describe sedimentary rock formations within the major terrane groups that may be encountered along the proposed alignments.

#### A.2.3.1 Sedimentary Rocks of the Baker Terrane Group

Formations of the Baker Terrane Group that fall within the category of sedimentary rocks include the Paleozoic to Mesozoic Elkhorn Ridge Argillite (Pe, TRPbe). These sedimentary rocks are generally located southeast of Baker City, between MP159 and MP188 of the IPC Proposed Route, and consist mainly of highly contorted fine-grained argillite, chert, and tuffaceous sediments that are believed to have been deposited in deepwater ocean-floor environments (OGDC, 2015). The argillite, chert, and tuff are interlayered with thin lenses of island arc volcanics, such as andesitic and basaltic lavas, as well as conglomerate beds, and pod-like limestone lenses which range from a few inches to many hundreds of feet thick (Prostka, 1967).

#### A.2.3.2 The Dalles Group

Sedimentary rocks of the Dalles Group that are mapped along the alignments consist primarily of the late Miocene and Pliocene Alkali Canyon Formation (Tac). These rocks are generally located between MP18 and MP89 along the IPC Proposed Route, and typically include interbedded fluvial and lacustrine (lake-deposited) sediments. The lower portion of the Tac generally consists of interbedded clay, silt, and conglomerate. The upper portion of the Tac generally consists of fine-grained deposits over conglomerate. Maximum thickness of the Tac is approximately 360 feet (Madin and Geitgey, 2007).

#### A.2.3.3 Sedimentary Rocks of the Idaho Group

The Idaho Group (Tic, Tig, Tpd) is from the late Miocene and Pliocene and includes mostly lacustrine sedimentary rocks associated with the large, ancient lake systems of western Idaho. These units are generally mapped along the IPC Proposed Route between MP234 and MP266 in Oregon, and between MP271 to MP293 in Idaho. They are also mapped along the Double Mountain Alternative. Sedimentary rocks in the Idaho Group consist mainly of well to poorly consolidated siltstone, fine-grained sandstone, mudstone, tuffaceous siltstone, limestone with thin beds of siltstone, pebble conglomerate, tuff, and tuffaceous sandstone. Encountered thicknesses of the Idaho Group are on the order of 350 feet to over 400 feet (Ferns et al., 1993a).

#### A.2.3.4 Neogene Sedimentary Rocks

A broadly named group of “Neogene Sedimentary Rocks” (Tms, Tst) are mapped along IPC Proposed Route around MP97 to MP99, and between MP153 to MP228. The rocks are generally from the Neogene period, specifically from the Miocene to late Miocene and Pliocene epochs. The units consist mainly of tuffaceous lacustrine and stream deposits, including poorly to moderately well-consolidated, bedded deposits of clay, siltstone, and sandstone, with intermixed ash and pumice, minor rhyolite flows, basalt flows, and mudflow deposits. The sedimentary rocks mainly overly basalt flows, but inter-finger with basalt in some locations. The units are up to 500 feet thick in the Durkee area (Prostka, 1967; Brooks et al., 1976; Brooks, 2006).

#### A.2.3.5 Sedimentary Rocks of the Olds Ferry Terrane

The Olds Ferry Terrane, which is composed of island arc volcanic and fore-arc marine deposits associated with the southernmost-northeast Oregon terranes, is mainly from the Jurassic period. Sedimentary rocks of the Olds Ferry Terrane include the Weatherby Formation's Jet Creek Member (Jwj), which is mapped along the IPC Proposed Route between MP188 and MP191. The Jet Creek Member consists mainly of cobble conglomerate, wacke, siltstone, massive and thinly bedded limestone, sandstone, and minor gypsum and anhydrite. Thickness of the overall unit may be over 1000 feet near Lime (Brooks, 1979).

#### A.2.3.6 Sedimentary Rocks of the Oregon-Idaho Graben

Rocks of the Oregon-Idaho Graben are of Miocene age and generally contain interbedded basalt, andesite, and dacite lava flows with small ash–flow tuffs, mafic hydrovolcanic deposits, tuffaceous sedimentary rocks, sandstone, and conglomerate. Sedimentary rock portions of this group (Tstl, Tstu) are mapped along the IPC Proposed Route between MP266 and MP271. These units consist primarily of tuffaceous siltstone and claystone, massive, well-indurated, moderately to well sorted, fine to medium-grained sandstone, and medium to coarse-grained conglomerate. Overall thicknesses range from 300 to greater than 650 feet (Ferns et al., 1993a).

### A.2.4 Igneous (Intrusive and Volcanic) and Volcaniclastic Rocks

Igneous rocks result from solidification of magma or lava upon cooling. Igneous rocks can either be intrusive (plutonic), formed as a result of the magma cooling very slowly below the surface, or extrusive (volcanic), formed above the ground surface as a result of a volcanic eruption. Volcaniclastic rocks are rocks that include volcanic rock fragments. They may include any portion of non-volcanic rock fragments and, depending on the geologic processes and depositional environment in which the rocks were formed, may be classified as either igneous or sedimentary.

#### A.2.4.1 Columbia River Basalt Group

The Columbia River Basalt Group (CRBG) is a series of voluminous basaltic lava flows that erupted from vents near the Oregon-Idaho-Washington borders during the Miocene epoch, between about 17 million and 6 million years ago. Units of the CRBG are mapped along several portions of the alignments, including MP18 to MP118, MP124 to MP126, MP151 to MP154, MP185 to MP194, and MP270 to MP271 of the IPC Proposed route, and along the

Morgan Lake Alternative. Major CRBG formations exposed along or near the alignment include Grande Ronde Basalt (Tcg, Tcgf, Tcgn1, Tcgn2, Tcgr2, Tg, Tgn2, Tgr2) and Wanapum Basalt (Tbf, Tcwf, Tf). These and other individual units have been defined on the basis of stratigraphic position, geochemistry, magnetic polarity, and petrography (Madin and Geitgey, 2007). CRBG flows generally occur sequential on top of one another, often with thin interbeds of sediment between them. Undifferentiated CRBG units on the geologic maps include Tb, Tbtv, Tcr, and Tm?b.

The Grande Ronde Basalt consists of fine-grained flow-on-flow sequences that comprise the thickest and most voluminous portion of the CRBG. This unit is described by Madin and Geitgey (2007) as "bluish-black aphyric to sparsely plagioclase phyric lava flows." The Frenchman Springs member of the Wanapum Basalt is a thick and widely distributed unit. Individual flows typically range from 3 to 100 feet, and the total thickness of rock encountered in wells ranges from 150 to 620 feet. Flows typically have rubbly flow tops; solid, jointed interiors; and are typically flow-on-flow basalts with little or no intervening sediments (Madin and Geitgey, 2007).

#### A.2.4.2 Idaho Batholith

The Idaho Batholith is a large igneous intrusion of Cretaceous to Eocene age that covers about 15,400 square miles in central Idaho. While most of the unit is located in central Idaho, smaller areas of the intrusion are also mapped south of the Snake River Plain, on the western side of the state. Mapped portions of the Idaho Batholith (Kii) intersect the IPC Proposed Route between MP290 and MP291. Rock types within the unit include granite and granodiorite.

#### A.2.4.3 Igneous Rocks of the Idaho Group

Igneous rocks of the Idaho Group include some olivine basalt flows of late Miocene age (Tbou). These flows are mainly black to greenish and grayish black basalt flows and flow breccias, interbedded with tuffaceous siltstones and claystones. Tbou is mapped along the IPC Proposed Route between MP250 and MP256. Thickness of the unit varies from 50 feet to more than 400 feet (Ferns et al., 1993a).

#### A.2.4.4 Idavada Volcanics

The Idavada Volcanics are a collection of Miocene to Pliocene-age silicic volcanic rocks that include rhyolite and pyroclastic flows of welded ash and vitric tuff. Mapped portions of the Idavada Volcanics (Tmf) intersect the IPC Proposed Route between MP272 and MP289.

#### A.2.4.5 Lake Owyhee Volcanic Field

Lake Owyhee Volcanic Field volcaniclastic rocks along the alignment are of Miocene age and include silicic welded and non-welded tuff (Twt), mapped intermittently between MP153 and MP180 of the IPC Proposed Route. Non-welded varieties of the tuff include ash-flow and air-fall tuff, some of which was water-lain. The unit also contains small patches of vitric welded tuff that are gradationally overlain by lake and stream sediments of the lower Pliocene (Brooks et al., 1976). Lesser amounts of rhyolite and andesite are mapped along the IPC Proposed Route between MP228 and MP229.

#### A.2.4.6 Nevadan Intrusives

The Nevadan Intrusives are Jurassic/Cretaceous plutons consisting primarily of quartz diorite and granodiorite (Brooks, et al., 1976; Prostka, 1967). Limited amounts of Nevadan Intrusives (KJi, kgd) are mapped along the IPC Proposed Route near MP147 and MP178.

#### A.2.4.7 Igneous Rocks of the Oregon-Idaho Graben

The Oregon-Idaho Graben is comprised of a series of interbedded olivine basalt, andesite, and dacite lava flows of Miocene age. Units of the Oregon-Idaho Graben are mapped along the IPC proposed Route between MP228 and MP266, and along the Double Mountain Alternative. Lower alkaline lava flows (Tbcl) are comprised mainly of dark gray to black, fine-grained platy lava flows and breccias that typically weather to brown. Upper alkaline lava flows (Tbcu) are comprised mainly of grayish black olivine basalt, basaltic andesite and andesite flows. Middle lava flows (Tbcm) consist of gray, vesicular, mainly basalt and basaltic andesite. Lower olivine-rich basalt flows (Tbol) are mainly black to dark-gray and vesicular. Upper calc-alkaline rhyolite and dacite flows and domes (Trcu) are dark-gray and gray rhyolite, rhyodacite, and dacite, which weather to various shades of red. Unit thickness is estimated to be over 300 feet thick in some locations. (Ferns et al., 1993a).

#### A.2.4.8 Powder River Volcanic Field

The Powder River Volcanic Field is comprised of a series of Miocene andesite, dacite, olivine-rich basalt, and basaltic lava flows resulting from multiple small volcanoes located between La Grande and Baker City. Units of the Powder River Volcanic Field are mapped along the IPC Proposed Route between MP100 and MP154, between MP185 and MP187, and along the Morgan Lake Alternative. Olivine basalt flows overlying ash-flows are from the earliest of eruptions. Major formations of the Powder River Volcanic Field include Andesite of Sawtooth Crater (Ta, Tan, Tpa), Basalt of Little Catherine Creek (Tb, Tb1, Tgo, Tob, Tpb, Tpgb, Tyb), and Dacite of Mt. Emily (Td, Tpd, Tpgd). The Andesite of Sawtooth Crater is typically fine-grained, plated andesite erupted from locations such as Sawtooth Ridge, located northeast of Baker City (Swanson, 1981). Basalt of Little Catherine Creek is commonly olivine basalt, and flows in the Baker Valley to Lower Powder Valley area are often severely faulted. The Dacite of Mt. Emily consists of a single lava flow with matrix–supported basal breccias and an upper massive, locally vesicular flow top. Cumulative dacite flows near Mt. Emily (Tpgd) are estimated to be more than 400 feet thick (Ferns et al., 2001b).

#### A.2.4.9 Igneous Rocks of the Wallowa Terrane

The Wallowa Terrane consists of Permian/Triassic island arc volcanic and shallow marine deposits associated with the northernmost of the northeast Oregon accreted terranes. Igneous rocks of the Wallowa Terrane (TRPv, TRqd) are mapped along the IPC Proposed Route between MP132 and MP137. TRPv rock types may include basaltic lava flows, flow breccias, and volcaniclastic rocks. TRqd rock types may include quartz diorite, diorite, and granite (Brooks et al., 1976).

### A.2.5 Metamorphic Rocks

Metamorphic rocks are igneous, sedimentary, or preexisting metamorphic rocks that have been physically and/or chemically altered over time by temperature, pressure, and/or circulation of hydrothermal fluids. Metamorphic rocks are included in the Baker Terrane, the Olds Ferry Terrane, and the Wallowa Terrane.

#### A.2.5.1 Metamorphic Rocks of the Baker Terrane

Metamorphic rocks of the Baker Terrane are Paleozoic to Mesozoic in age and include the Burnt River Schist (g, gb, m, mg/md, mqbd, p, q, TRgb, TRn, TRPbi) and the Elkhorn Ridge Argillite (MZPZa). Common rock types among the subunits include greenshchist, phyllite, quartzite, marble, and argillite (OGDC, 2015). Metamorphic Rocks of the Baker Terrane are generally mapped along the IPC Proposed Route between MP151 and MP152, and between miles MP161 and MP180.

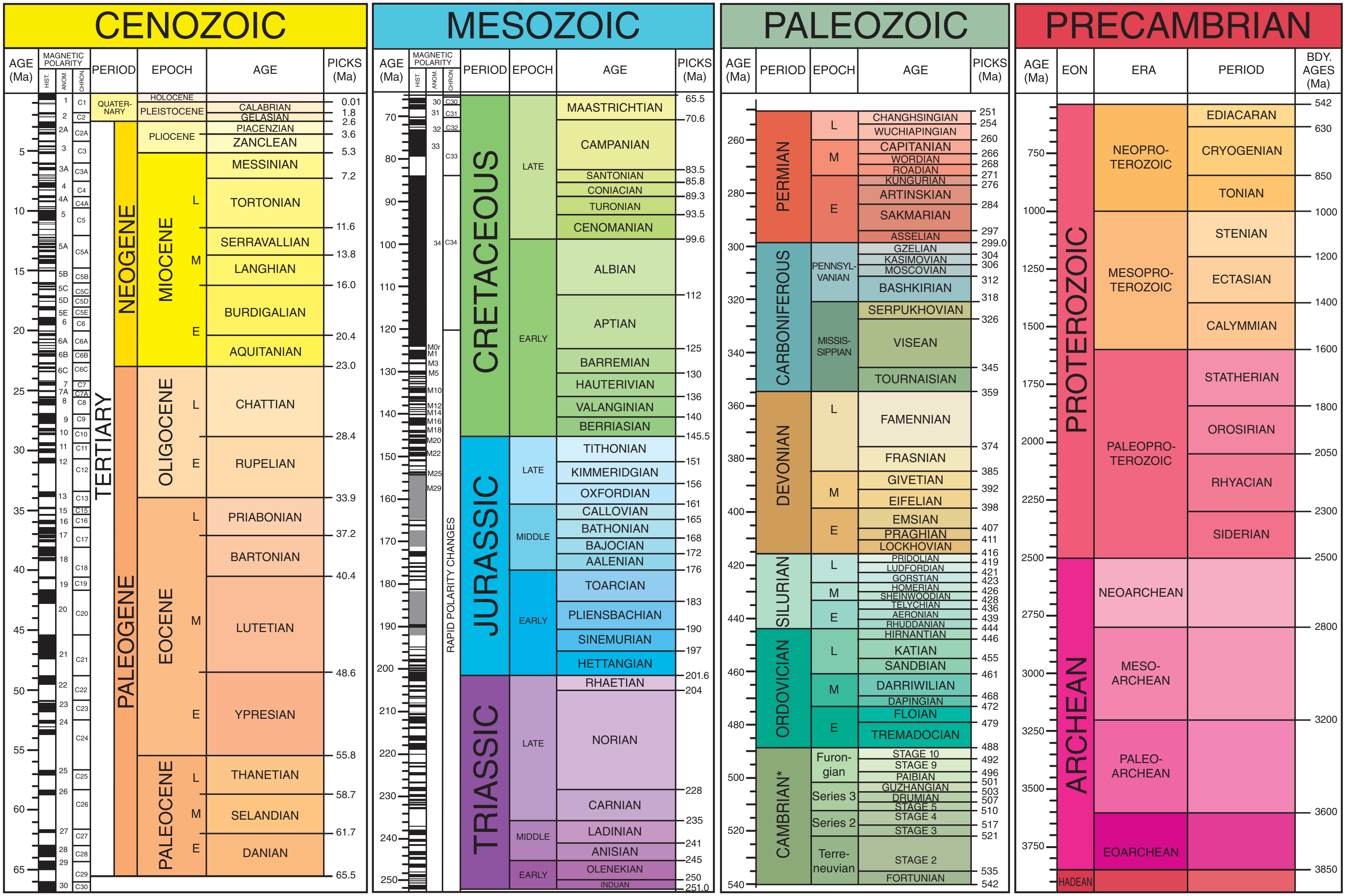
#### A.2.5.2 Metamorphic Rocks of the Olds Ferry Terrane

The Olds Ferry Terrane is composed of island arc volcanic and fore-arc marine deposits associated with the southernmost of the northeast Oregon terranes. Metamorphic rocks of the Olds Ferry Terrane include those in the Jurassic Weatherby Formation (Jw, TRg), which are generally mapped along the IPC Proposed Route between MP180 and MP190. Metamorphic rocks within the Weatherby Formation include gray phyllite, argillite, and slate. Overall unit thickness may be more than 1,000 feet (Brooks, 1979).

#### A.2.5.3 Metamorphic Rocks of the Wallowa Terrane

The Wallowa Terrane consists of Permian/Triassic island arc volcanic and shallow marine deposits associated with the northernmost of the northeast Oregon accreted terranes. Metamorphic rocks within the terrane group include the Clover Creek Greenstone (TRPwc, TRc) and other mafic metamorphic rocks (Tri), such as greenshcist (OGDC, 2015). Mapped portions of the unit intersect the IPC Proposed Route between MP126 to MP148.

# GEOLOGIC TIME SCALE




*International ages have not been fully established. These are current names as reported by the International Commission on Stratigraphy.

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Walker, J.D., and Geissman, J.W., compilers, 2009, Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C. ©2009 The Geological Society of America.

Sources for nomenclature and ages are primarily from Gradstein, F., Ogg, J., Smith, A., et al., 2004, A Geologic Time Scale 2004: Cambridge University Press, 589 p. Modifications to the Triassic after: Furin, S., Preto, N., Rigo, M., Roghi, G., Gianolla, P., Crowley, J.L., and Bowring, S.A., 2006, High-precision U-Pb zircon age from the Triassic of Italy: Implications for the Triassic time scale and the Carnian origin of calcareous nannoplankton and dinosaurs: Geology, v. 34, p. 1009–1012, doi: 10.1130/G22967A.1; and Kent, D.V., and Olsen, P.E., 2008, Early Jurassic magnetostratigraphy and paleolatitudes from the Hartford continental rift basin (eastern North America): Testing for polarity bias and abrupt polar wander in association with the central Atlantic magmatic province: Journal of Geophysical Research, v. 113, B06105, doi: 10.1029/2007JB005407.

TABLE A1

**TABLE A2: SUMMARY OF SURFICIAL GEOLOGIC MAP UNITS**

| Map Unit Label | State | Lithologic Category | Map Unit Name | Age | Terrane / Group | Formation | Member | Geologic Material Type |
|---|---|---|---|---|---|---|---|---|
| g | OR | Metamorphic Rocks | Greenstones and greenschists | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| gb | OR | Metamorphic Rocks | Gabbro and meta-gabbro | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| JKi | OR | Igneous Rocks | Quartz diorite | Jurassic/Cretaceous | Nevadan Intrusives | No data | No data | intermediate composition lithologies |
| JKqd | OR | Metamorphic Rocks | Quartz diorite | Jurassic/Cretaceous | Nevadan Intrusives | Pedro Mountain Stock | No data | intermediate composition lithologies |
| Jw | OR | Metamorphic Rocks | Weatherby Formation | Jurassic | Olds Ferry Terrane | Weatherby Formation | Jet Creek | mixed grained sediments |
| Jwj | OR | Sedimentary Rocks | Jet Creek member | Jurassic | Olds Ferry Terrane | Weatherby Formation | Jet Creek | mixed grained sediments |
| Jwjl | OR | Sedimentary Rocks | Jet Creek member limestone | Jurassic | Olds Ferry Terrane | Weatherby Formation | Jet Creek | limestone |
| kgd | OR | Igneous Rocks | Quartz diorite and granodiorite | Jurassic/Cretaceous | Nevadan Intrusives | No data | No data | intermediate composition lithologies |
| Kii | ID | Igneous Rocks | No data | Cretaceous to Eocene | Idaho Batholith | No data | No data | monzogranite |
| KJi | OR | Igneous Rocks | Upper Jurassic-lower Cretaceous plutons | Jurassic/Cretaceous | Nevadan Intrusives | No data | No data | intermediate composition lithologies |
| m | OR | Metamorphic Rocks | Marble | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | marble |
| mg/md | OR | Metamorphic Rocks | Metamorphosed intrusions | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| mqbd | OR | Metamorphic Rocks | Metamorphosed intrusions | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| mqd | OR | Metamorphic Rocks | Metamorphosed intrusions | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| mvc | OR | Metamorphic Rocks | Metavolcaniclastic rocks and greenstones | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | volcaniclastic rocks |
| MZPZa | OR | Metamorphic Rocks | Sedimentary and volcanic rocks | Paleozoic/Mesozoic | Baker Terrane | Elkhorn Ridge Argillite | No data | fine grained sediments |
| MZPZsv | OR | Metamorphic Rocks | Foliated sedimentary and volcanic rocks | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | mixed lithologies |
| p | OR | Metamorphic Rocks | Phyllitic rocks | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | sedimentary rocks |
| Pe | OR | Sedimentary Rocks | Elkhorn Ridge Argillite | Paleozoic/Mesozoic | Baker Terrane | Elkhorn Ridge Argillite | No data | fine grained sediments |
| q | OR | Metamorphic Rocks | Quartzite | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | chert |
| Qa | ID | Unconsolidated Sediments | No data | Quaternary | No data | No data | No data | gravel; floodplain, alluvial fan, colluvium |
| Qa | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Qal | OR | Unconsolidated Sediments | Stream alluvium and alluvial fans | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Qal | OR | Unconsolidated Sediments | Lacustrine and alluvial plain deposits | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | fine grained sediments |
| Qal | OR | Unconsolidated Sediments | Alluvium and colluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Qas | OR | Unconsolidated Sediments | Terrace gravels and alluvial fan deposits | Quaternary | Quaternary surficial deposits | Alluvial fan deposits | No data | mixed grained sediments |
| Qas1 | OR | Unconsolidated Sediments | Terrace gravels and alluvial fan deposits | Quaternary | Quaternary surficial deposits | Terrace deposits | No data | mixed grained sediments |
| Qcf | OR | Unconsolidated Sediments | Colluvium and talus deposits | Quaternary | Quaternary surficial deposits | Colluvial deposits | No data | mixed grained sediments |
| Qdf | OR | Landslide Deposits | Debris-avalanche and debris-flow deposits | Quaternary | Quaternary surficial deposits | Landslide deposits | No data | mixed grained sediments |
| Qe | OR | Unconsolidated Sediments | Eolian sand and ash | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Qf | OR | Unconsolidated Sediments | Alluvial fill | Quaternary | Quaternary surficial deposits | Terrace deposits | No data | mixed grained sediments |
| Qf | OR | Unconsolidated Sediments | Alluvial fan deposits | Quaternary | Quaternary surficial deposits | Alluvial fan deposits | No data | mixed grained sediments |
| Qfd | OR | Unconsolidated Sediments | Fluvial fan delta deposits | Quaternary | Quaternary surficial deposits | Fan delta deposits | No data | coarse grained sediments |
| Qls | OR | Landslide Deposits | Landslide debris | Quaternary | Quaternary surficial deposits | Landslide deposits | No data | mixed grained sediments |
| Qls | OR | Landslide Deposits | Landslides | Quaternary | Quaternary surficial deposits | Landslide deposits | No data | mixed grained sediments |
| Qls | OR | Landslide Deposits | Landslide deposits | Quaternary | Quaternary surficial deposits | Landslide deposits | No data | mixed grained sediments |
| Qmf | OR | Unconsolidated Sediments | Missoula Flood deposits | Quaternary | Quaternary surficial deposits | Missoula Flood deposits | No data | mixed grained sediments |
| Qpa | ID | Unconsolidated Sediments | No data | Late Pleistocene | No data | Caldwell Beds | No data | stratified glacial sediment |
| Qpug | ID | Unconsolidated Sediments | No data | Late Pleistocene | Lake Bonneville Flood Deposits and Snake River Group | Multiple | No data | sand and gravel |
| Qsbf | OR | Unconsolidated Sediments | Fluviatile sand, gravel, and silt | Quaternary | Quaternary surficial deposits | Bonneville Flood deposits | No data | fine grained sediments |
| Qtg | OR | Unconsolidated Sediments | Terrace and fan deposits | Quaternary | Quaternary surficial deposits | Terrace deposits | No data | mixed grained sediments |
| QTt | OR | Sedimentary Rocks | Terrace deposits | Tertiary/Quaternary | Neogene sedimentary rocks | Terrace deposits | No data | mixed grained sediments |

**TABLE A2: SUMMARY OF SURFICIAL GEOLOGIC MAP UNITS**

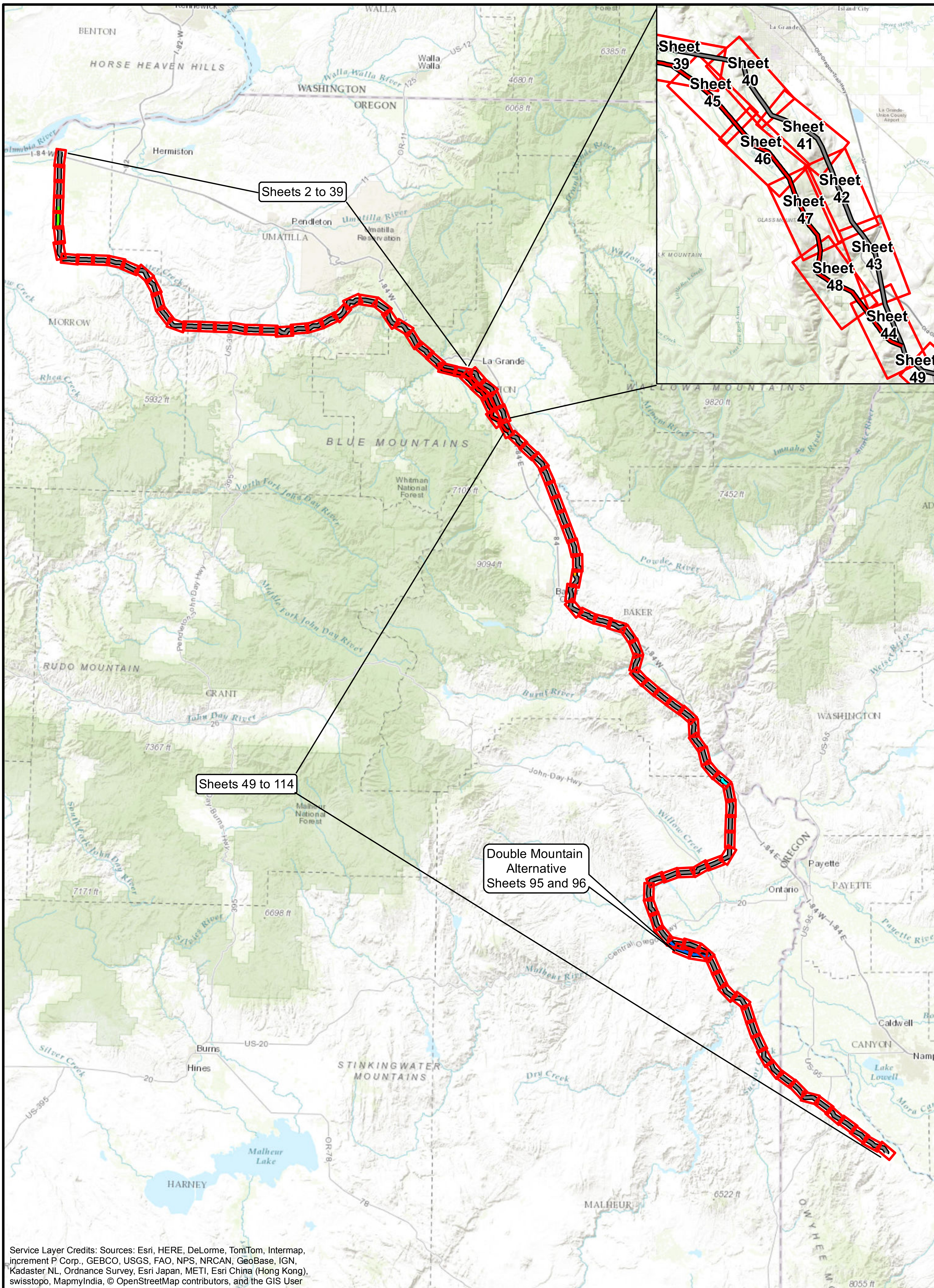
| Map Unit Label | State | Lithologic Category | Map Unit Name | Age | Terrane / Group | Formation | Member | Geologic Material Type |
|---|---|---|---|---|---|---|---|---|
| Qu | OR | Unconsolidated Sediments | Undifferentiated surficial deposits | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| Ta | OR | Igneous Rocks | Andesite flows and domes | Miocene | Powder River Volcanic Field | Andesite of Sawtooth Crater | No data | andesite |
| Tac | OR | Sedimentary Rocks | Alkali Canyon Formation | Miocene/Pliocene | Dalles Group | Alkali Canyon Formation | No data | mixed grained sediments |
| Tan | OR | Igneous Rocks | Andesite | Miocene | Powder River Volcanic Field | Andesite of Sawtooth Crater | No data | andesite |
| Tb | OR | Igneous Rocks | Basalt | Miocene | Columbia River Basalt Group | No data | No data | basalt |
| Tb | OR | Igneous Rocks | Porphyritic olivine basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tb | OR | Igneous Rocks | Basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tb | OR | Igneous Rocks | Basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tb1 | OR | Igneous Rocks | Basalt and andesite | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tbcl | OR | Igneous Rocks | Lower calc-alkaline lava flows | Miocene | Oregon-Idaho Graben | No data | No data | basalt |
| Tbcm | OR | Igneous Rocks | Middle calc-alkaline lava flows | Miocene | Oregon-Idaho Graben | No data | No data | basalt |
| Tbcu | OR | Igneous Rocks | Upper calc-alkaline lava flows | Miocene | Oregon-Idaho Graben | No data | No data | basalt |
| Tbf | OR | Igneous Rocks | Basalt | Miocene | Columbia River Basalt Group | Wanapum Basalt | No data | basalt |
| Tbf1 | OR | Igneous Rocks | Basalt | Miocene | Powder River Volcanic Field | Dacite of Mt. Emily | No data | dacite |
| Tbol | OR | Igneous Rocks | Lower olivine basalt flows | Miocene | Oregon-Idaho Graben | No data | No data | basalt |
| Tbou | OR | Igneous Rocks | Upper olivine basalt flows | Miocene | Idaho Group | No data | No data | basalt |
| Tbtv | OR | Igneous Rocks | Eastern tholeiitic lavas | Miocene | Columbia River Basalt Group | No data | No data | mixed lithologies |
| Tcg | OR | Igneous Rocks | Grande Ronde Basalt | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | No data | basalt |
| Tcgf | OR | Igneous Rocks | Ferroandesite of Fiddlers Hell | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Andesite of Fiddlers Hell | andesite |
| Tcgn1 | OR | Igneous Rocks | N1 Grande Ronde Basalt | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 1 | basalt |
| Tcgn2 | OR | Igneous Rocks | N2 Grande Ronde Basalt | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| Tcgn2 | OR | Igneous Rocks | N2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| Tcgr2 | OR | Igneous Rocks | R2 Grande Ronde Basalt | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Reversed mag. unit 2 | basalt |
| Tcr | OR | Igneous Rocks | Columbia River Basalt | Miocene | Columbia River Basalt Group | No data | No data | basalt |
| Tcwf | OR | Igneous Rocks | Frenchman Springs basalt | Miocene | Columbia River Basalt Group | Wanapum Basalt | Frenchman Springs Member | basalt |
| Td | OR | Igneous Rocks | Dacite flows and domes | Miocene | Powder River Volcanic Field | Dacite of Mt. Emily | No data | dacite |
| Tdr | OR | Volcaniclastic Rocks | Dooley rhyolite breccia | Miocene | Lake Owyhee Volcanic Field | Dooley Mountain Complex | No data | felsic composition lithologies |
| Tf | OR | Igneous Rocks | Undifferentiated Frenchman Springs flows | Miocene | Columbia River Basalt Group | Wanapum Basalt | Frenchman Springs Member | basalt |
| Tfls | OR | Sedimentary Rocks | Fluvial and lacustrine basinal sediments | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tfs | OR | Sedimentary Rocks | Fluvial and colluvial sediments | Paleocene/Eocene | Paleogene sedimentary rocks | No data | No data | mixed grained sediments |
| Tg | OR | Igneous Rocks | Grande Ronde Basalt, undivided | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | No data | basalt |
| Tgn2 | OR | Igneous Rocks | N2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| Tgo | OR | Igneous Rocks | Basalt of Powder River | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tgr2 | OR | Igneous Rocks | R2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Reversed mag. unit 2 | basalt |
| Th | OR | Sedimentary Rocks | Herren Formation | Paleocene/Eocene | Paleogene sedimentary rocks | Herren Formation | No data | mixed grained sediments |
| Tic | OR | Sedimentary Rocks | Lacustrine sediments | Miocene/Pliocene | Idaho Group | No data | No data | fine grained sediments |
| Tig | OR | Sedimentary Rocks | Lacustrine sediments | Miocene/Pliocene | Idaho Group | No data | No data | fine grained sediments |
| Tm?b | ID | Igneous Rocks | No data | Miocene | Columbia River Basalt Group | Multiple | No data | basalt |
| Tmd | ID | Volcaniclastic Rocks | No data | Miocene | No data | Payette Fm, Sucker Creek Fm, Latah Fm | No data | volcanic, pyroclastic, tuff |
| Tmf | ID | Igneous Rocks | No data | Miocene | Idavada Volcanics | Cougar Pt. Welded Tuff, Jenny Creek Tuff | No data | rhyolite, pyroclastic, ash-flow |
| Tms | OR | Sedimentary Rocks | Sedimentary rocks | Miocene/Pliocene | Neogene sedimentary rocks | No data | No data | mixed grained sediments |
| Tms | OR | Sedimentary Rocks | Sedimentary rocks | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tob | OR | Igneous Rocks | Olivine basalt sheet flows | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tob | OR | Igneous Rocks | Olivine basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |

# TABLE A2: SUMMARY OF SURFICIAL GEOLOGIC MAP UNITS

| Map Unit Label | State | Lithologic Category | Map Unit Name | Age | Terrane / Group | Formation | Member | Geologic Material Type |
|---|---|---|---|---|---|---|---|---|
| Tpa | OR | Igneous Rocks | Andesite and basaltic andesite | Miocene | Powder River Volcanic Field | Andesite of Sawtooth Crater | No data | andesite |
| Tpb | OR | Igneous Rocks | Basalt of Little Catherine Creek | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tpb1 | OR | Igneous Rocks | Basalt | Miocene | Kivett Volcanics | No data | No data | andesite |
| Tpbo | OR | Igneous Rocks | Basanite and trachybasalt | Miocene | Powder River Volcanic Field | Basanite of Horseshoe Basin | No data | basanite |
| Tpd | OR | Igneous Rocks | Dacite | Miocene | Powder River Volcanic Field | Dacite of Mt. Emily | No data | dacite |
| Tpd | ID | Sedimentary Rocks | No data | Pliocene | Idaho Group | Multiple | No data | sandstone |
| Tpgb | OR | Igneous Rocks | Olivine basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |
| Tpgd | OR | Igneous Rocks | Undifferentiated andesite and dacite | Miocene | Powder River Volcanic Field | Dacite of Mt. Emily | No data | dacite |
| Tr3 | OR | Igneous Rocks | Rhyolite and andesite | Miocene | Lake Owyhee Volcanic Field | Littlefield Rhyolite | No data | rhyolite |
| Trcu | OR | Igneous Rocks | Upper calc-alkaline rhyolite and dacite flows and domes | Miocene | Oregon-Idaho Graben | No data | No data | rhyolite |
| TRg | OR | Metamorphic Rocks | Gray phyllite | Jurassic | Olds Ferry Terrane | Weatherby Formation | Jet Creek | mixed grained sediments |
| TRg1 | OR | Metamorphic Rocks | Gray phyllite | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | sedimentary rocks |
| TRgb | OR | Metamorphic Rocks | Pre-upper Triassic intrusive complex | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| TRgb | OR | Metamorphic Rocks | Mafic and ultramafic rocks | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| TRgb2 | OR | Metamorphic Rocks | Pre-upper Triassic intrusive complex | Permian | Wallowa Terrane | No data | No data | mafic composition lithologies |
| TRh | OR | Volcaniclastic Rocks | Huntington Formation | Permian/Triassic | Olds Ferry Terrane | Huntington Volcanics | No data | mixed lithologies |
| TRi | OR | Metamorphic Rocks | Mafic intrusive rocks | Permian | Wallowa Terrane | No data | No data | mafic composition lithologies |
| TRn | OR | Metamorphic Rocks | Nelson marble | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | marble |
| TRPbe | OR | Sedimentary Rocks | Elkhorn Ridge Argillite | Paleozoic/Mesozoic | Baker Terrane | Elkhorn Ridge Argillite | No data | fine grained sediments |
| TRPbi | OR | Metamorphic Rocks | Pre-Tertiary rocks, undivided | Paleozoic/Mesozoic | Baker Terrane | Burnt River Schist | No data | greenstone |
| TRPms | OR | Metamorphic Rocks | Chlorite-mica schists of Pearson Creek | Paleozoic/Mesozoic | Mountain Home Complex | No data | No data | schist |
| TRPv | OR | Volcaniclastic Rocks | Volcanic and sedimentary rocks | Permian/Triassic | Wallowa Terrane | Clover Creek Greenstone | No data | greenstone |
| TRPwc | OR | Metamorphic Rocks | Clover Creek Greenstone | Permian/Triassic | Wallowa Terrane | Clover Creek Greenstone | No data | greenstone |
| TRqd | OR | Igneous Rocks | Pre-upper Triassic intrusive complex | Triassic | Wallowa Terrane | No data | No data | felsic composition lithologies |
| TRqd | OR | Igneous Rocks | Quartz diorite, diorite, and gabbro | Triassic | Wallowa Terrane | No data | No data | felsic composition lithologies |
| TRv | OR | Metamorphic Rocks | Volcanic and metavolcanic rocks | Permian/Triassic | Wallowa Terrane | Clover Creek Greenstone | No data | greenstone |
| Ts | OR | Sedimentary Rocks | Sedimentary rocks | Miocene/Pliocene | Neogene sedimentary rocks | No data | No data | mixed grained sediments |
| Tsal | OR | Sedimentary Rocks | Lower arkosic sandstone and conglomerate | Miocene | Oregon-Idaho Graben | No data | Lower member | coarse grained sediments |
| Tsau | OR | Sedimentary Rocks | Upper arkosic sandstone, conglomerate and tuffaceous siltstone | Miocene | Oregon-Idaho Graben | No data | Upper member | coarse grained sediments |
| Tst | OR | Sedimentary Rocks | Tuffaceous sedimentary rocks | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tst | OR | Sedimentary Rocks | Tuffaceous sedimentary rocks | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tst | OR | Sedimentary Rocks | Tuffaceous lacustrine and fluviatile sediments | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tst | OR | Sedimentary Rocks | Lacustrine and fluviatile deposits | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tst | OR | Sedimentary Rocks | Tuffaceous lake and stream deposits | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| Tstl | OR | Sedimentary Rocks | Lower tuffaceous sedimentary rocks | Miocene | Oregon-Idaho Graben | No data | Lower member | tuffaceous sedimentary rocks |
| Tstu | OR | Sedimentary Rocks | Tuffaceous siltstones, tuffs, and nonwelded ash-flow tuff | Miocene | Oregon-Idaho Graben | No data | Upper member | tuffaceous sedimentary rocks |
| Tt | OR | Volcaniclastic Rocks | Welded tuff | Miocene | Lake Owyhee Volcanic Field | No data | No data | welded tuff |
| Ttat | OR | Volcaniclastic Rocks | Welded ash-flow tuffs | Miocene | Lake Owyhee Volcanic Field | No data | No data | ash flow tuff |
| Twt | OR | Volcaniclastic Rocks | Silicic welded and non-welded tuff | Miocene | Lake Owyhee Volcanic Field | No data | No data | welded tuff |
| Tx | OR | Volcaniclastic Rocks | No name in explanation | Miocene | Neogene volcanic rocks | No data | No data | mixed lithologies |
| Tyb | OR | Igneous Rocks | Basalt | Miocene | Powder River Volcanic Field | No data | Little Catherine Creek | basalt |

**TABLE A3: SUMMARY OF GEOLOGIC INFORMATION FOR MULTI-USE AREAS AWAY FROM PROPOSED ALIGNMENT**

| Multi-Use Area | Northing (meters) | Easting (meters) | Map Unit Label | State | Lithologic Category | Map Unit Name | Age | Terrane / Group | Formation | Member | Geologic Material Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MU BA-02 | 4958846 | 436511 | Tst | OR | Sedimentary Rocks | Tuffaceous lacustrine and fluviatile sediments | Miocene | Neogene sedimentary rocks | No data | No data | fine grained sediments |
| MU BA-04 | 4936252 | 461150 | Qtg | OR | Unconsolidated Sediments | Terrace deposits | Quaternary | Quaternary surficial deposits | Terrace deposits | No data | mixed grained sediments |
| MU BA-06 | 4911097 | 478177 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU MA-03 | 4866475 | 469461 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU MA-07 | 4839634 | 492740 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU MA-07 | 4839634 | 492740 | Qsbf | OR | Unconsolidated Sediments | Fluviatile sand, gravel, and silt | Quaternary | Quaternary surficial deposits | Bonneville Flood deposits | No data | fine grained sediments |
| MU MA-08 | 4835510 | 492443 | Tic | OR | Sedimentary Rocks | Lacustrine sediments | Miocene/Pliocene | Idaho Group | No data | No data | fine grained sediments |
| MU MO-02 | 5051813 | 301969 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU MO-02 | 5051813 | 301969 | Tac | OR | Sedimentary Rocks | Alkali Canyon Formation | Miocene/Pliocene | Dalles Group | Alkali Canyon Formation | No data | mixed grained sediments |
| MU MO-05 | 5028732 | 329294 | Tgn2 | OR | Igneous Rocks | N2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| MU OW-1 | 4822912 | 498766 | Tpb | ID | Igneous Rocks | Basalt | Pliocene | No data | No data | No data | Basalt |
| MU OW-1 | 4822912 | 498766 | Tpd | ID | Sedimentary Rocks | Sandstone | Pliocene | No data | No data | No data | Sandstone Conglomerate |
| MU UM-01 | 5075048 | 315092 | Qmf | OR | Unconsolidated Sediments | Missoula Flood deposits | Quaternary | Quaternary surficial deposits | Missoula Flood deposits | No data | mixed grained sediments |
| MU UM-02 | 5043374 | 327250 | Tgn2 | OR | Igneous Rocks | N2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| MU UM-04 | 5033588 | 356470 | Tgn2 | OR | Igneous Rocks | N2 magnetostratigraphic unit | Miocene | Columbia River Basalt Group | Grande Ronde Basalt | Normal mag. unit 2 | basalt |
| MU UM-05 | 5028834 | 363663 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU UM-05 | 5028834 | 363663 | Th | OR | Sedimentary Rocks | Herren Formation | Paleocene/Eocene | Paleogene sedimentary rocks | Herren Formation | No data | mixed grained sediments |
| MU UN-01 | 5015809 | 420060 | Qal | OR | Unconsolidated Sediments | Lacustrine and alluvial plain deposits | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | fine grained sediments |
| MU UN-01 | 5015809 | 420060 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU UN-03 | 4993637 | 426871 | Qal | OR | Unconsolidated Sediments | Alluvium | Quaternary | Quaternary surficial deposits | Alluvial deposits | No data | mixed grained sediments |
| MU UN-03 | 4993637 | 426871 | Ts | OR | Sedimentary Rocks | Sedimentary rocks | Miocene/Pliocene | Neogene sedimentary rocks | No data | No data | mixed grained sediments |
| MU UN-04 | 4986206 | 426744 | Ts | OR | Sedimentary Rocks | Sedimentary rocks | Miocene/Pliocene | Neogene sedimentary rocks | No data | No data | mixed grained sediments |




## LEGEND

- IPC Proposed Route
- West Bombing Range Road Alternative 1
- West Bombing Range Road Alternative 2
- Morgan Lake Alternative
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Map Sheets

N E S W

0 16 32 Miles

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY INDEX MAP

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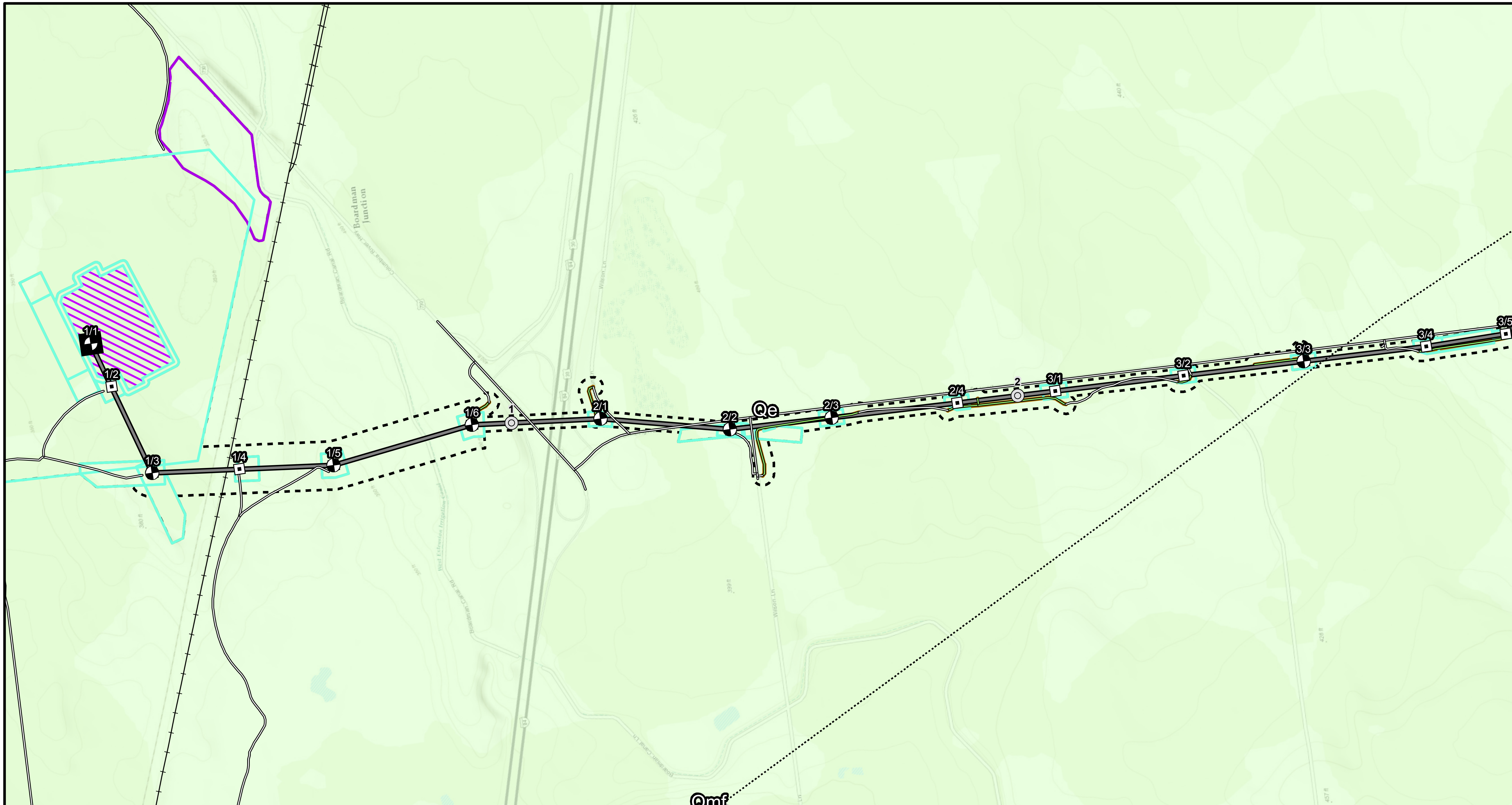


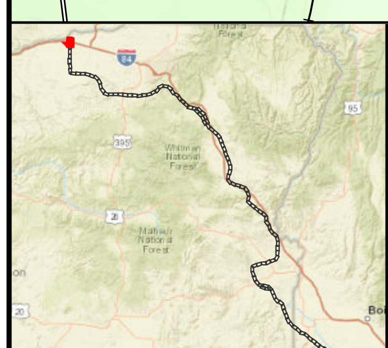

# LEGEND

TRANSMISSION FEATURES

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Morgan Lake Alternative
- West Bombing Range Road Alternative 1
- West Bombing Range Road Alternative 2
- Proposed Borings
- Towers
- Substation
- Mileposts
- Distribution Power Lines to Communication Station
- Construction Disturbance
- Operations Disturbance
- Multi-Use Areas
- Other Work Areas
- Site Boundary

SURFICIAL GEOLOGY

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

FAULTS

- Accurate
- Approximate
- Concealed
- Inferred
- USGS Mapped Fault
- No Data

ROADS

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

November 2016 24-1-03820-005

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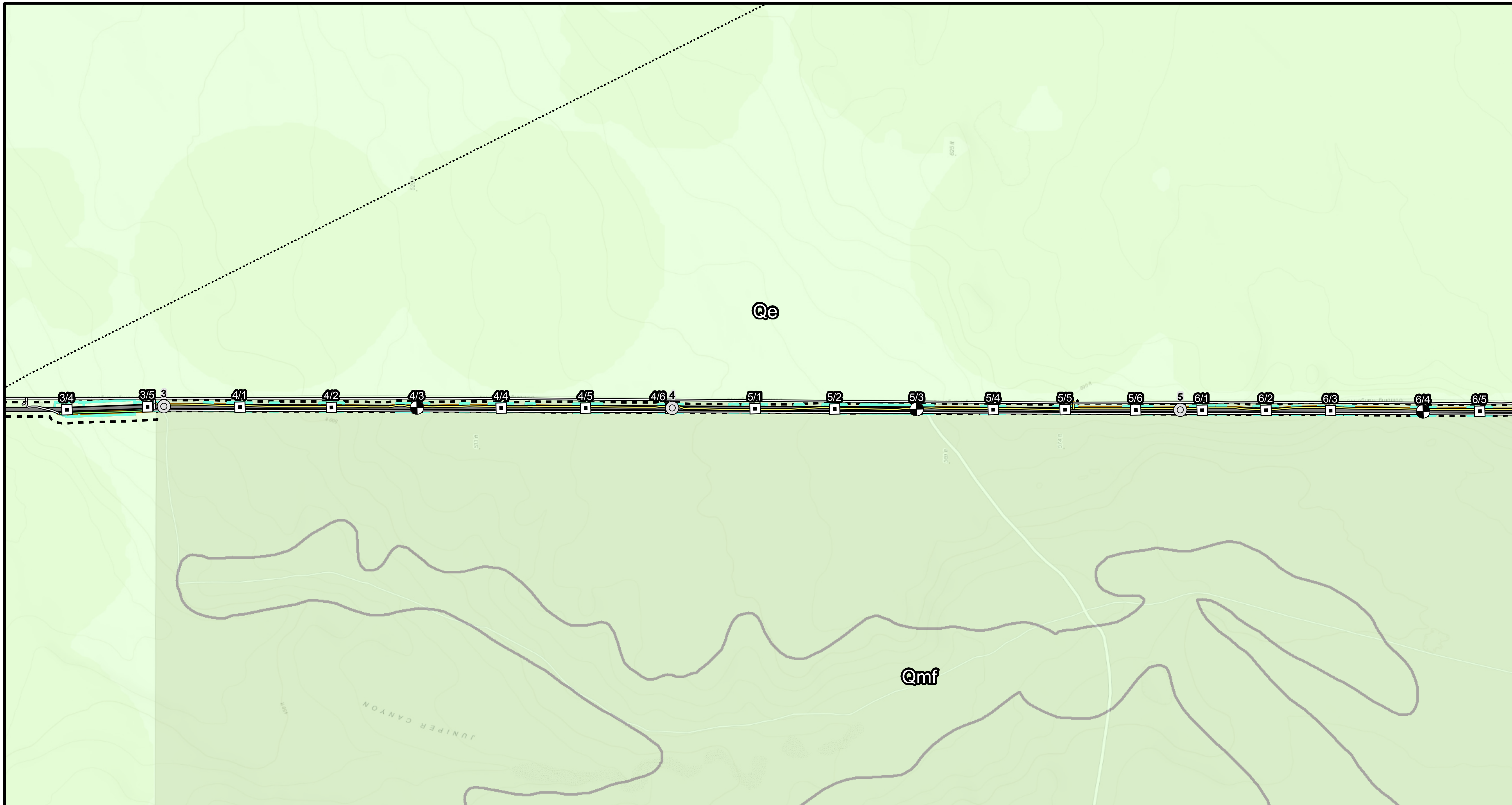


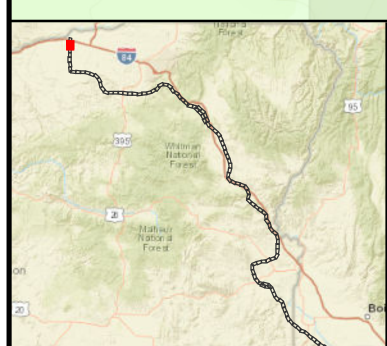

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
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**FAULTS**

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**ROADS**

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NOTE
For geologic unit descriptions see Table A-2

0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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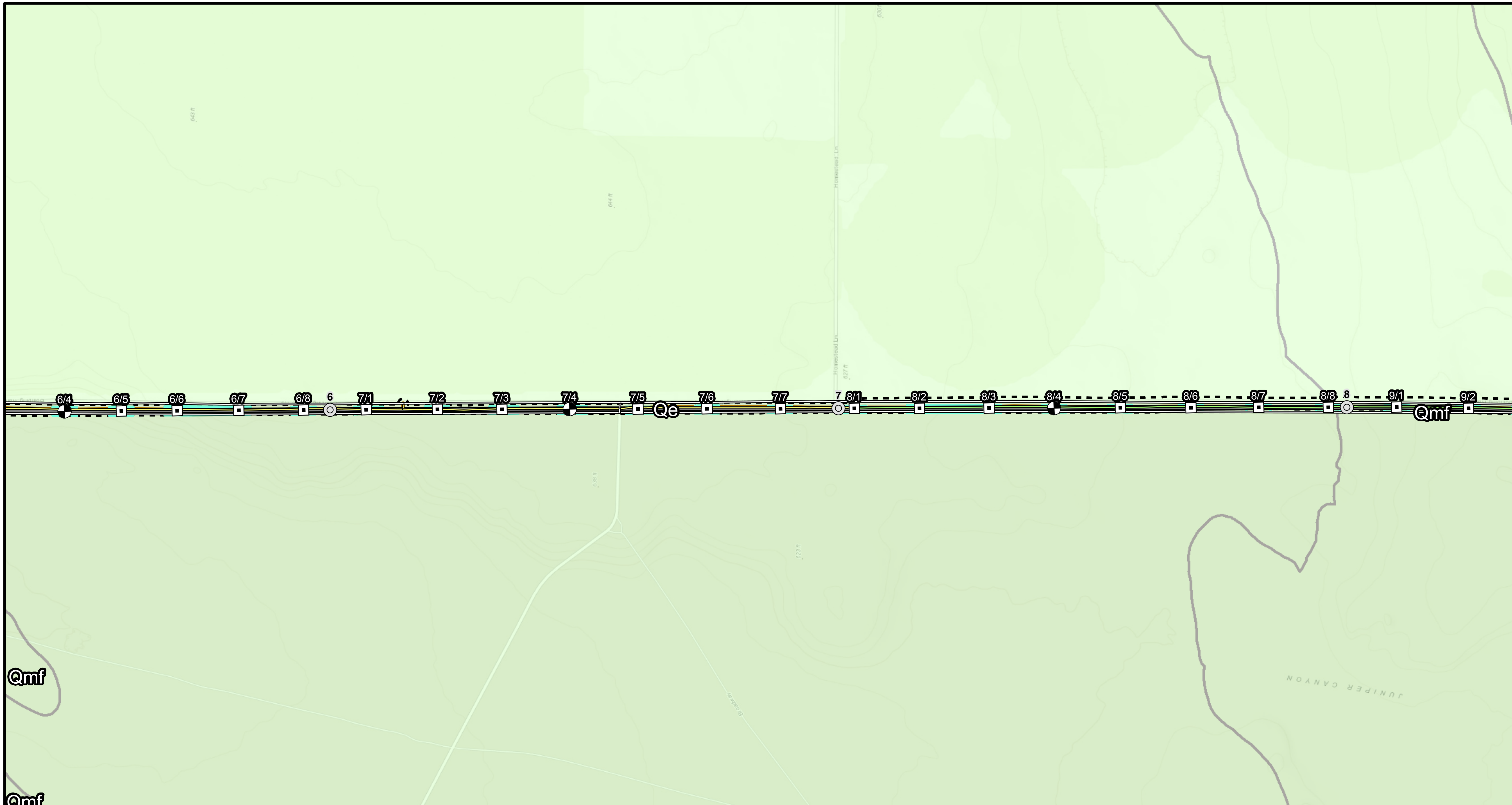


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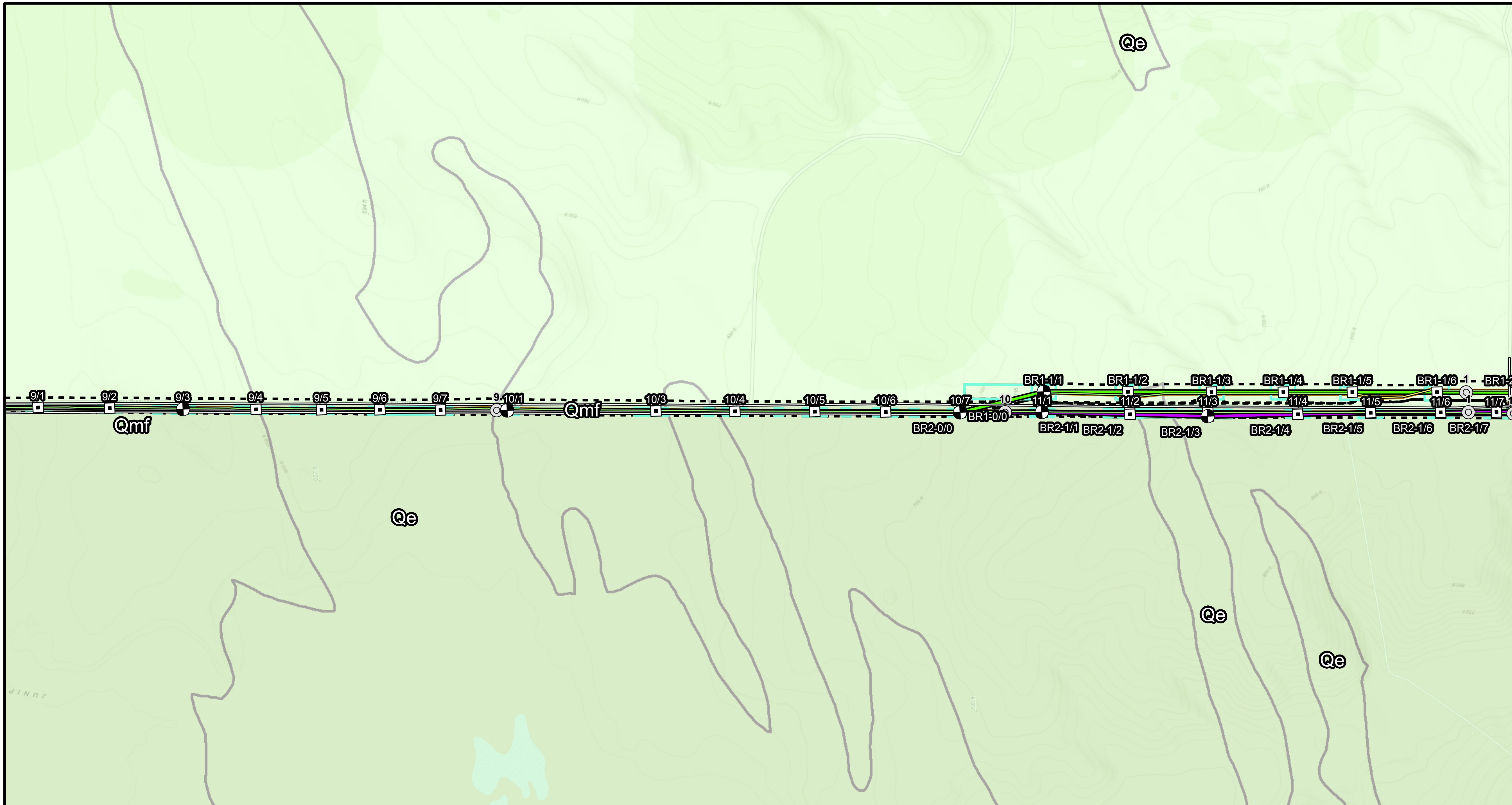


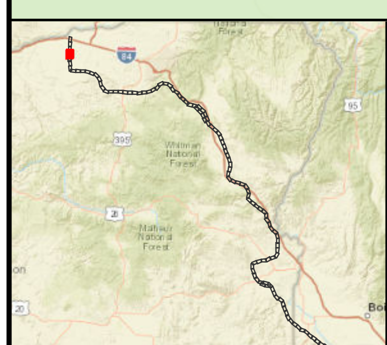

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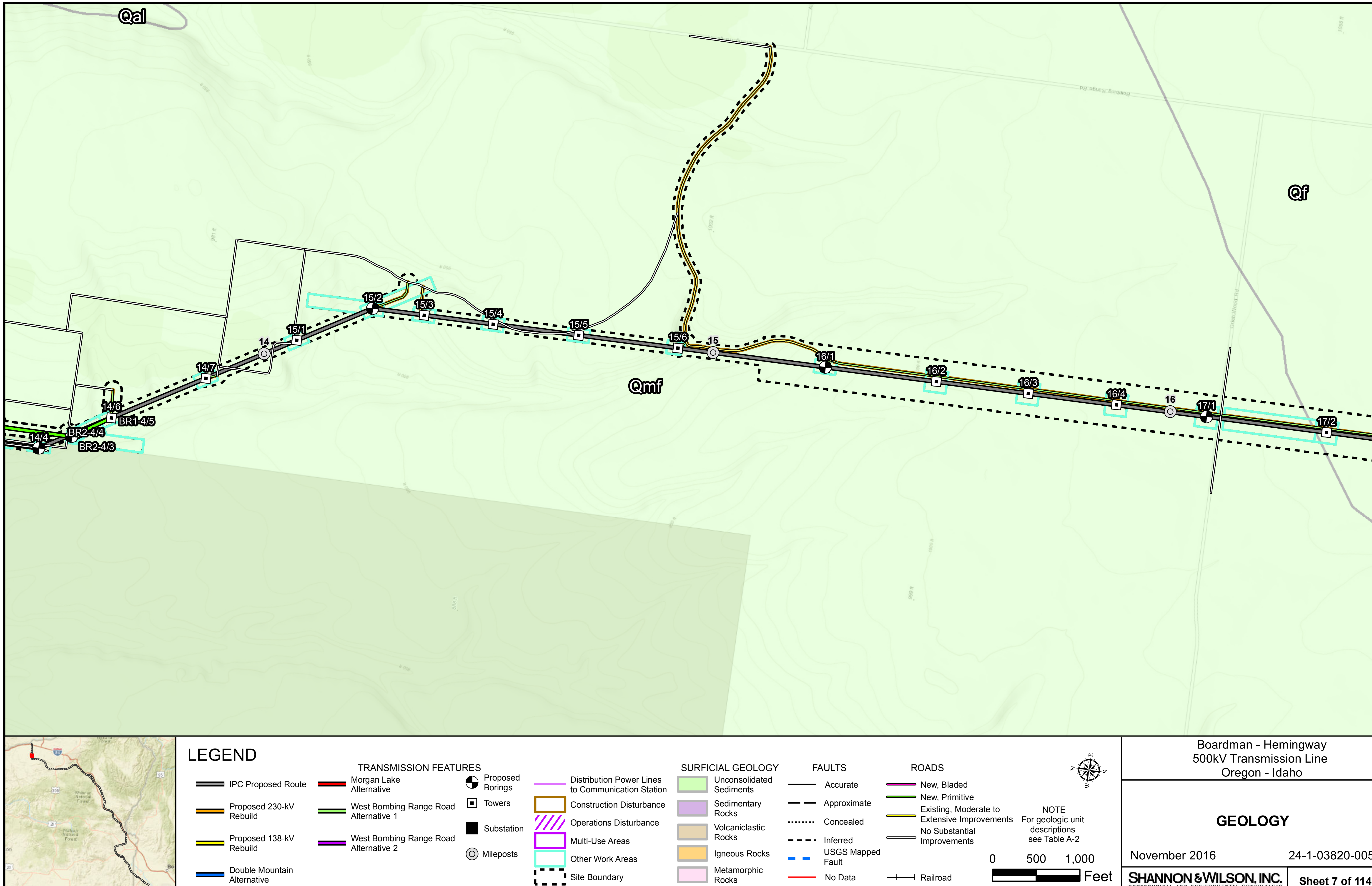


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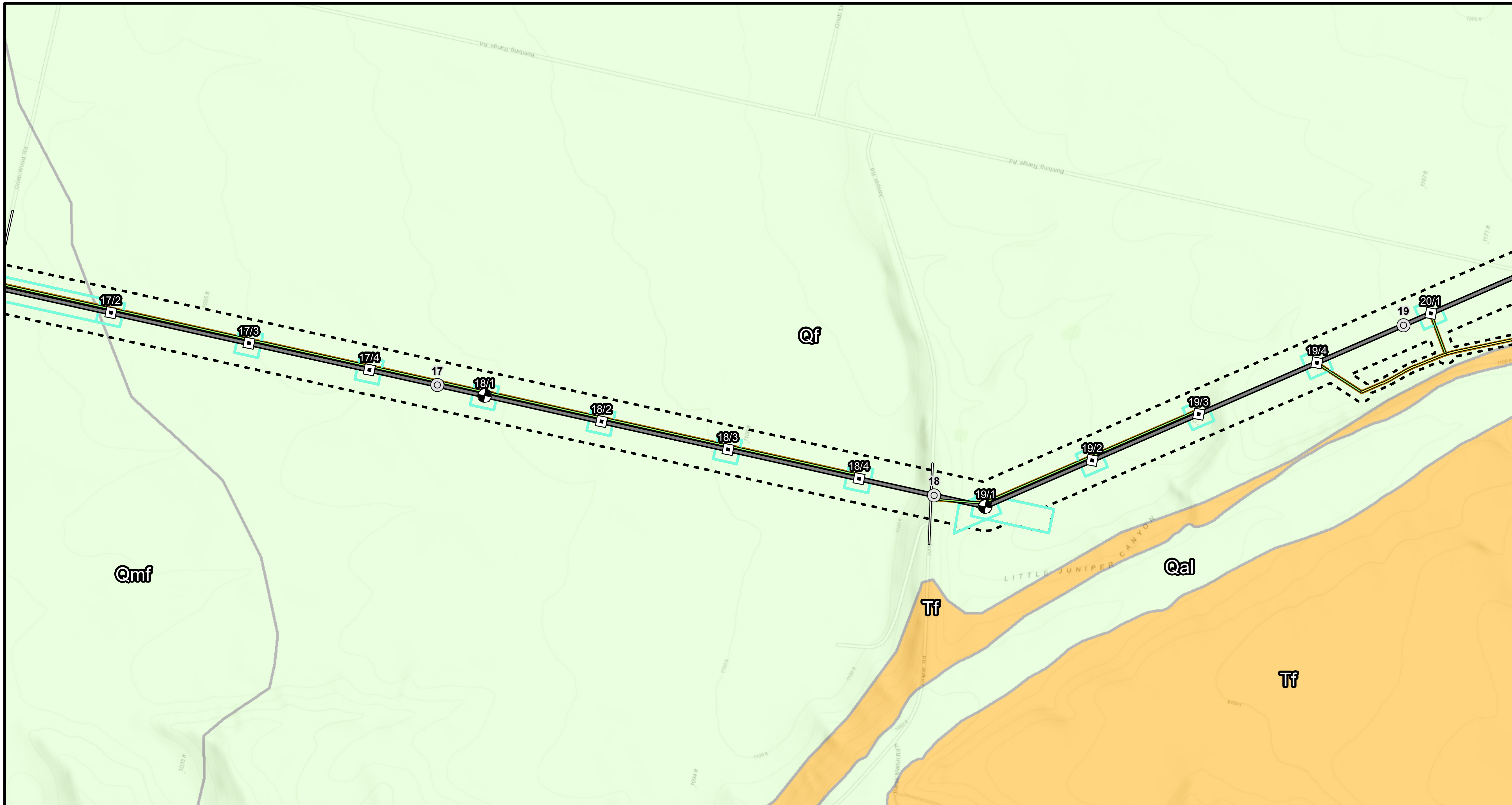


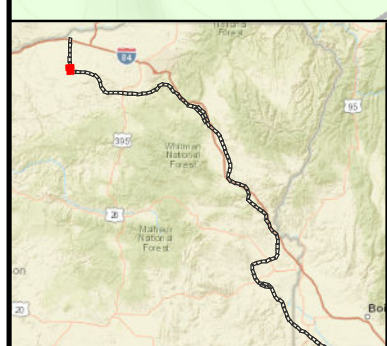

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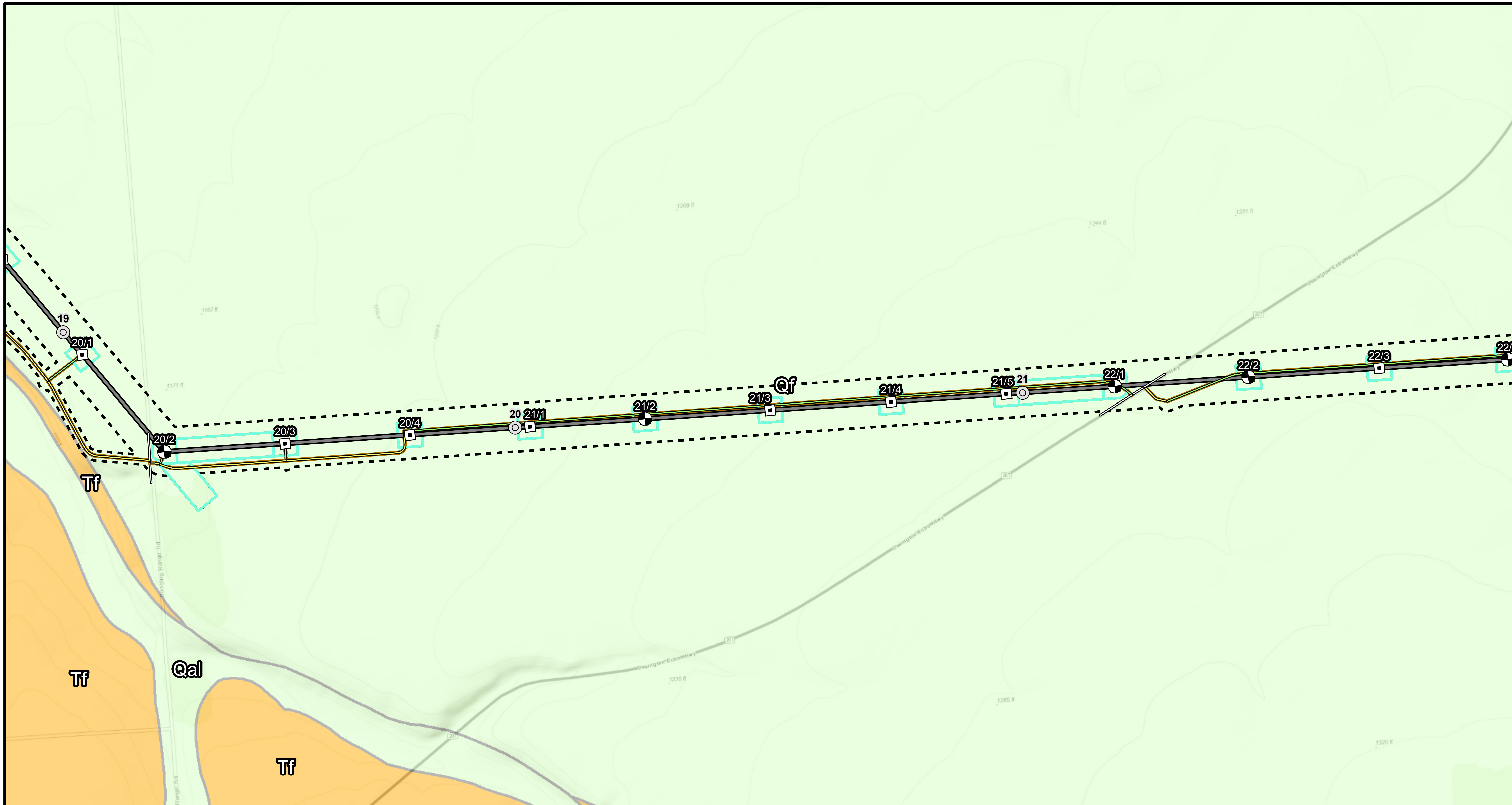


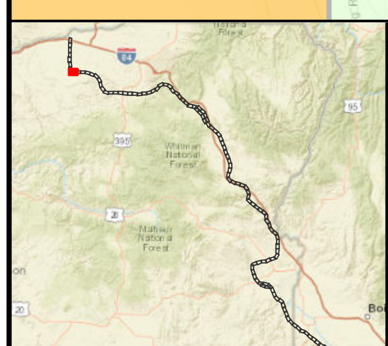

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# GEOLOGY

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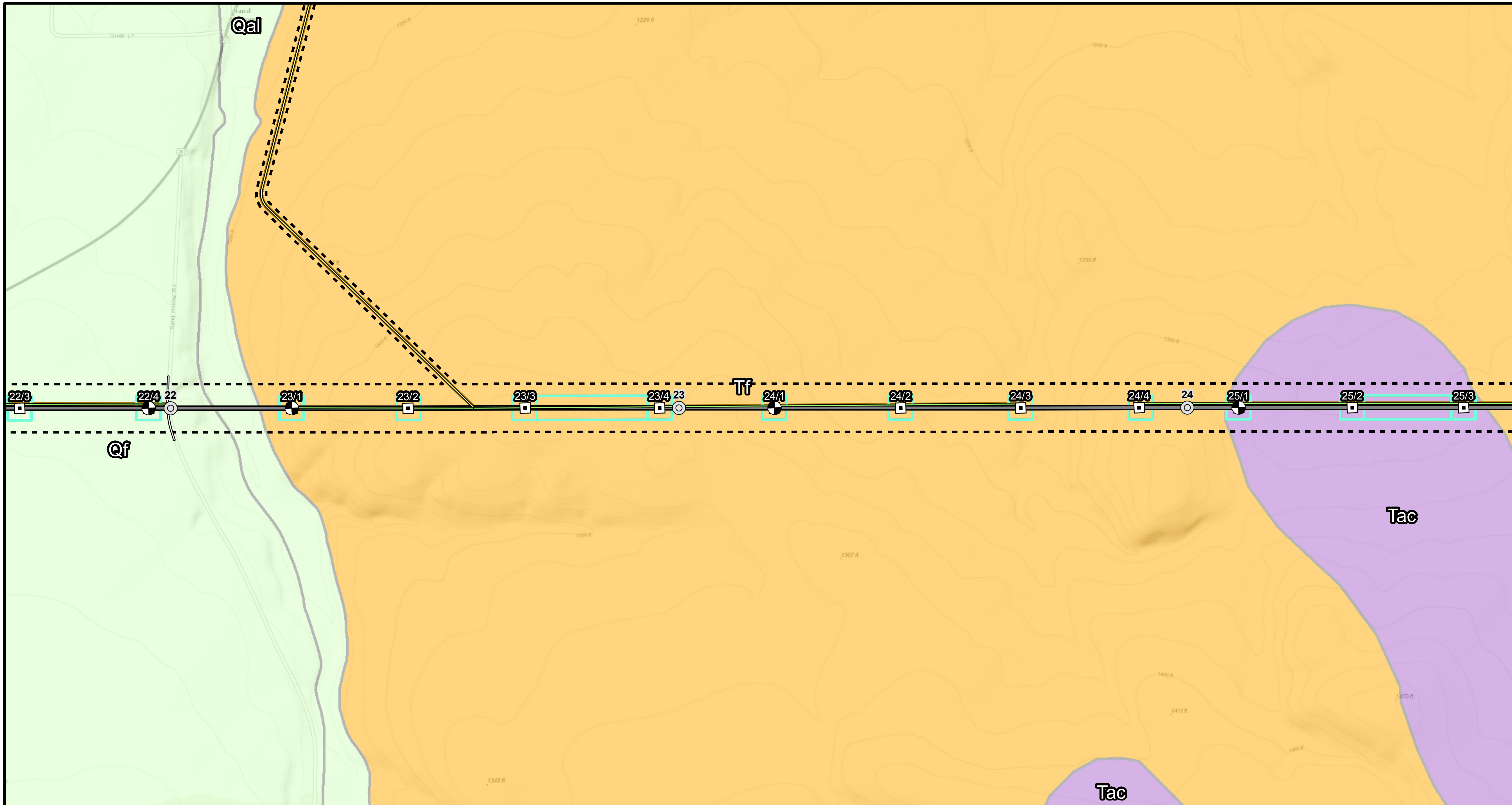


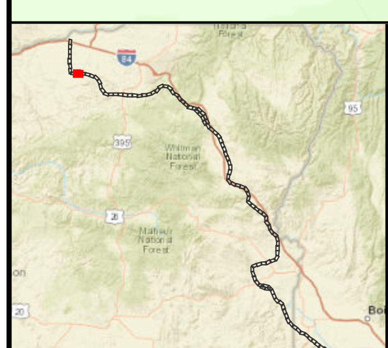

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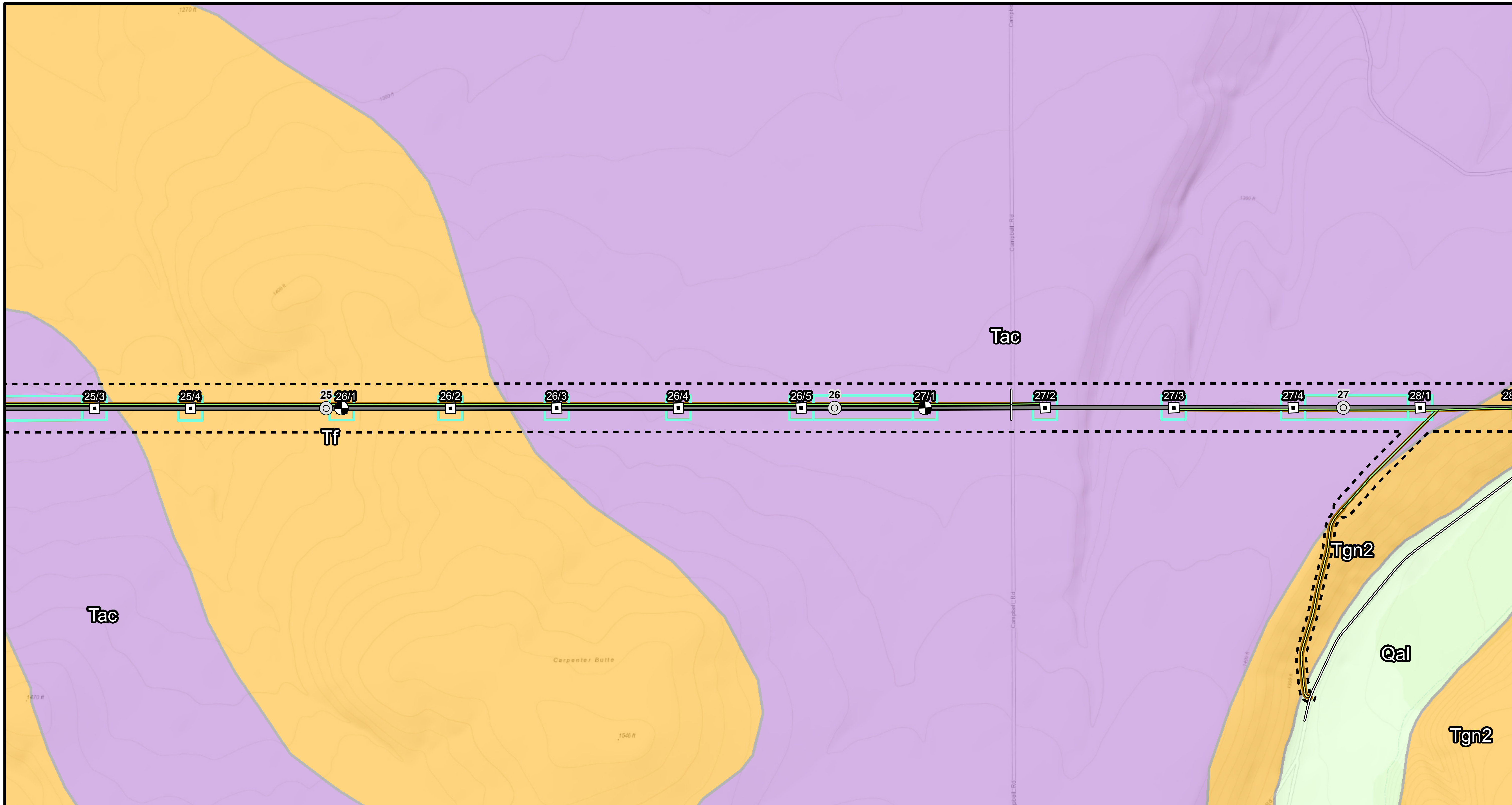


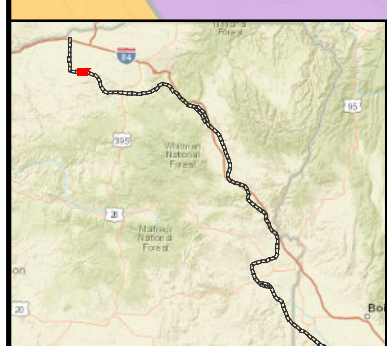

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# GEOLOGY

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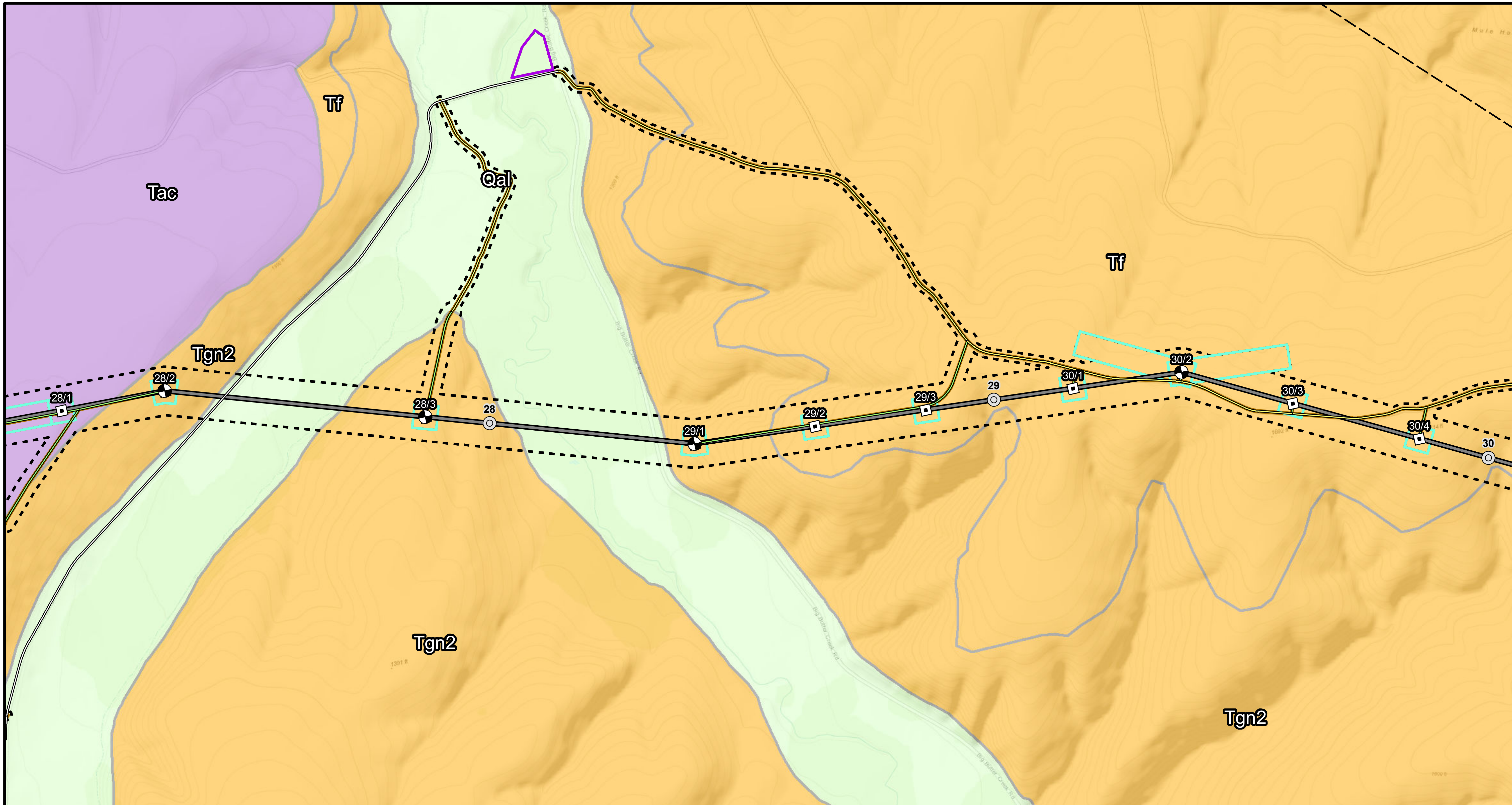


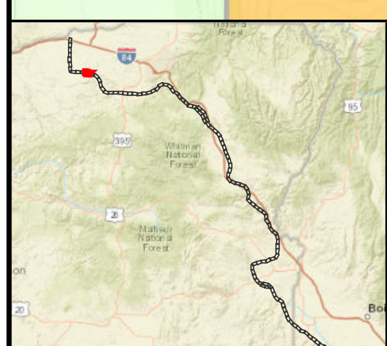

## LEGEND

**TRANSMISSION FEATURES**

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Oregon - Idaho

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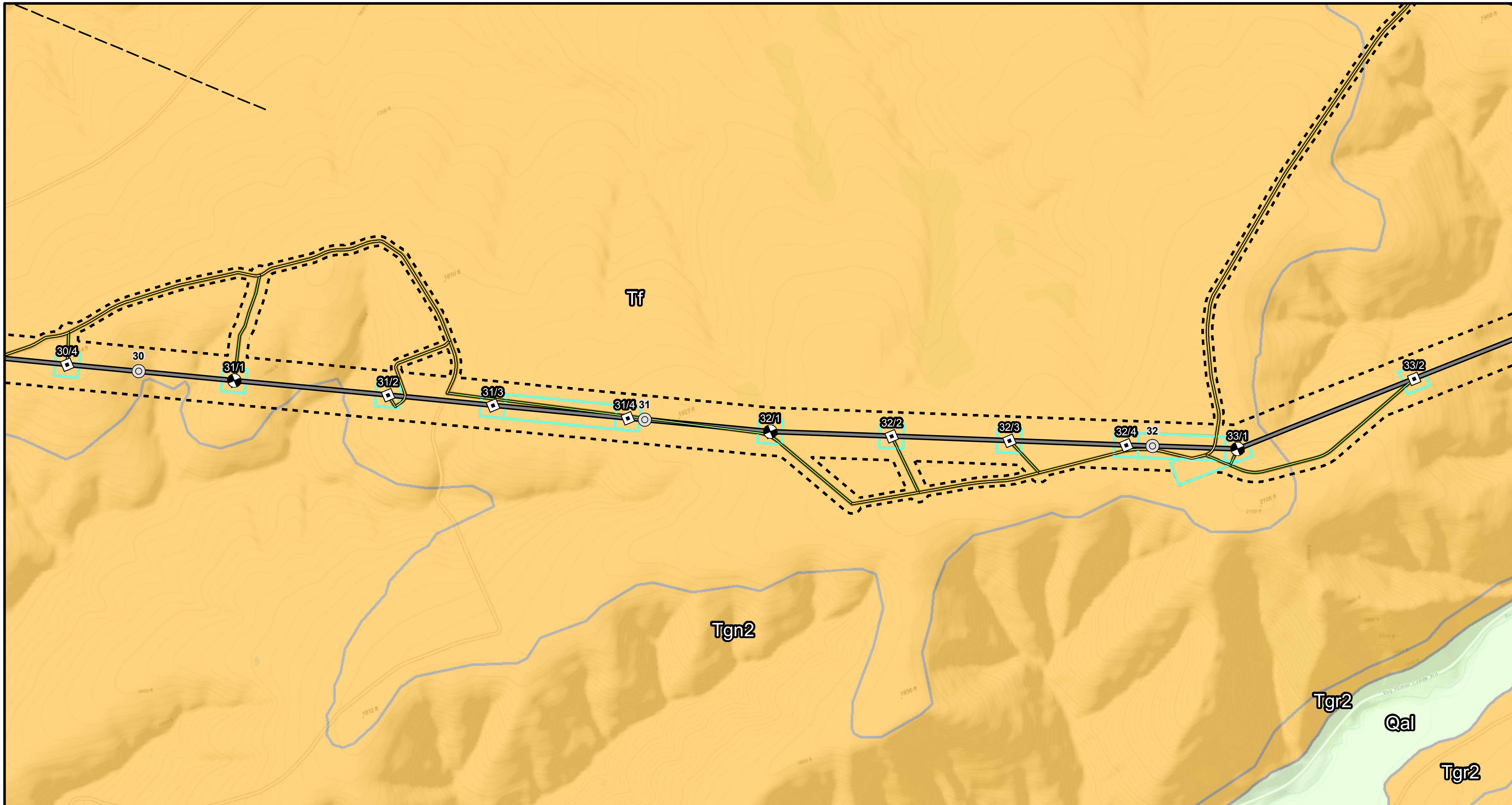


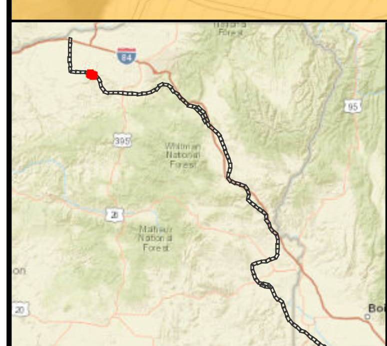

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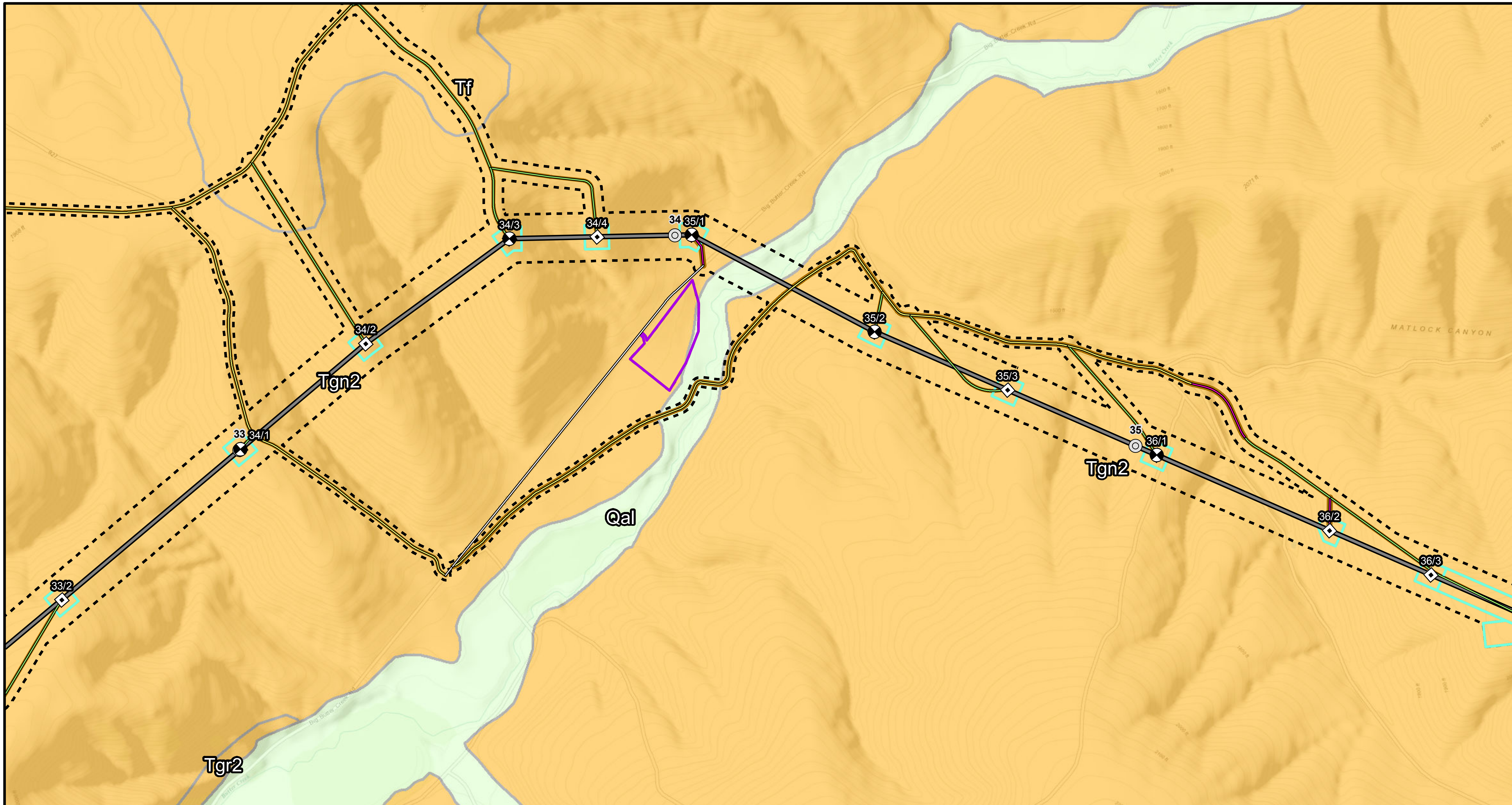


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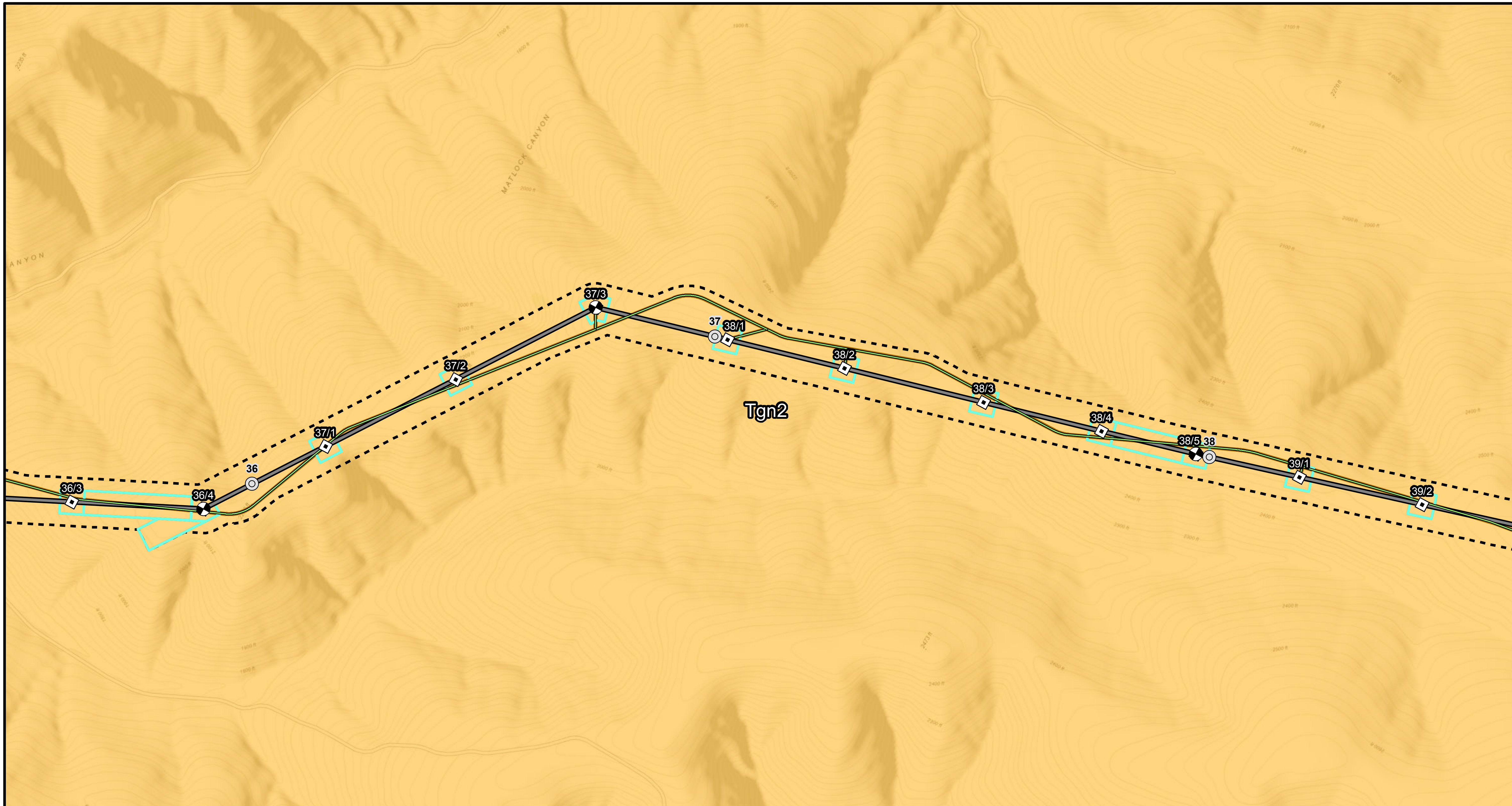


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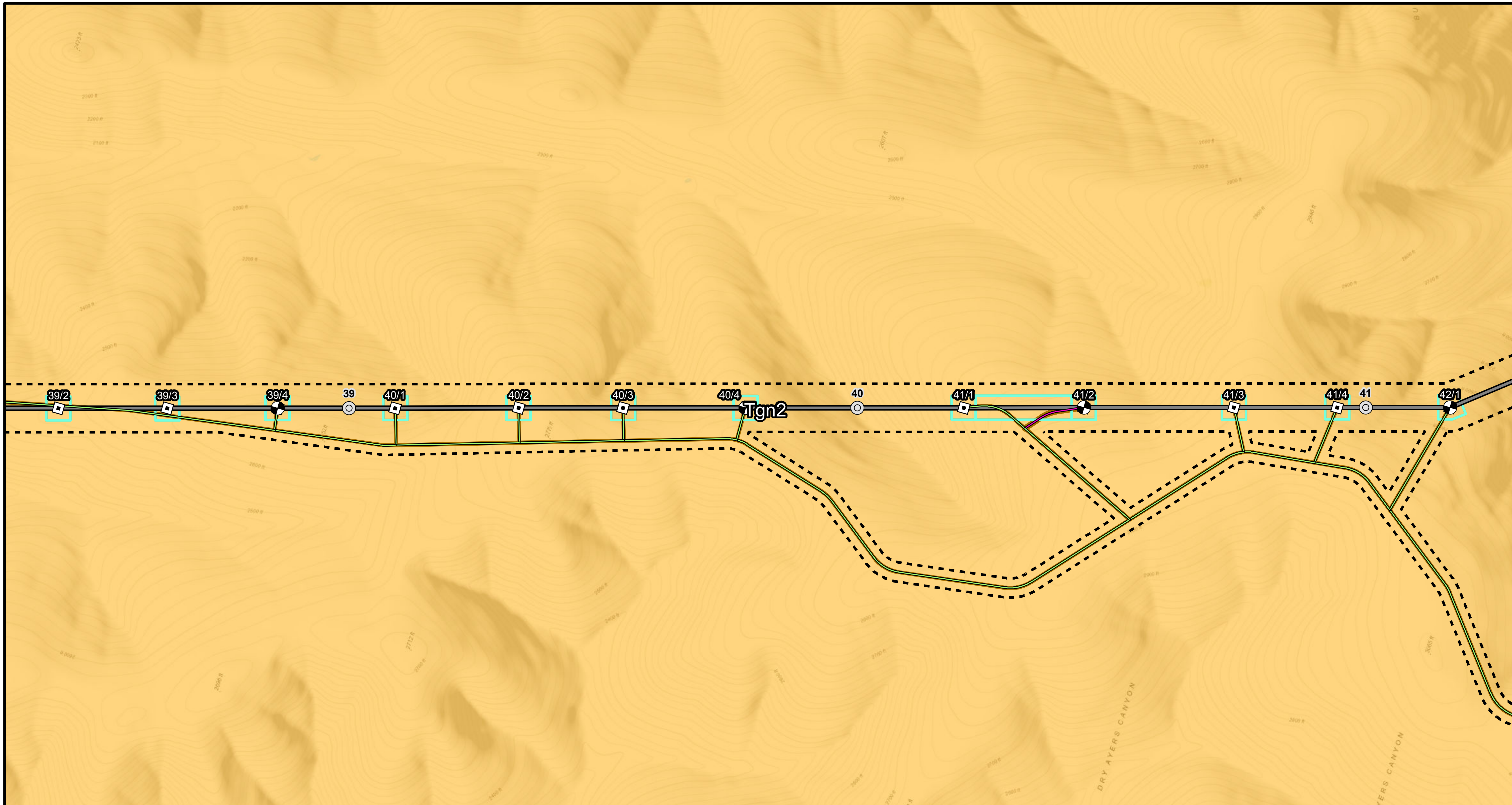


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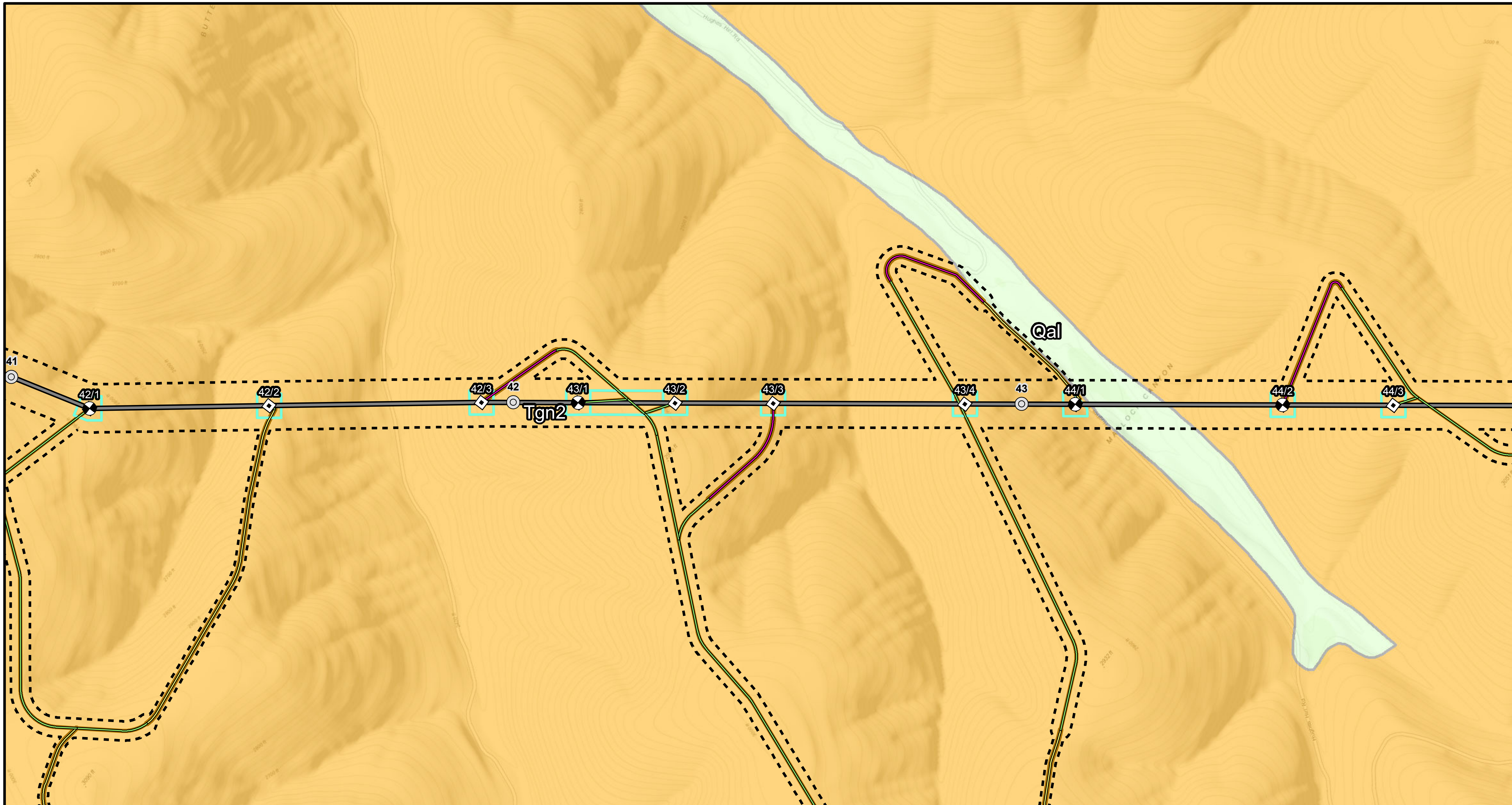


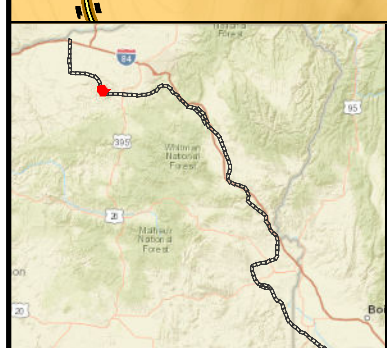

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Proposed 138-kV Rebuild
Double Mountain Alternative

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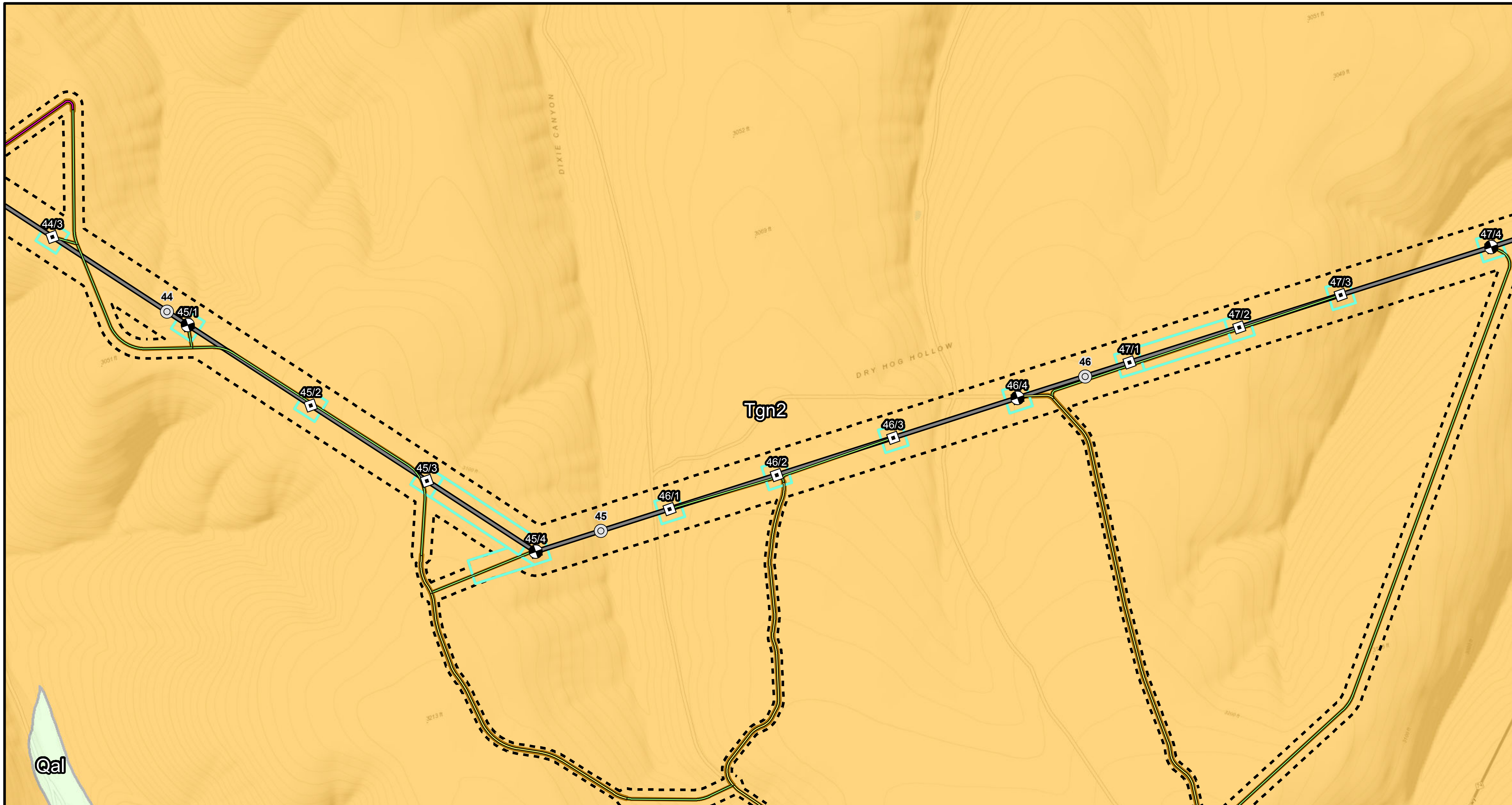


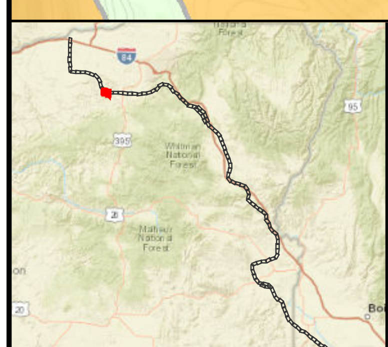

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Morgan Lake Alternative
- West Bombing Range Road Alternative 1
- West Bombing Range Road Alternative 2
- Proposed Borings
- Towers
- Substation
- Mileposts
- Distribution Power Lines to Communication Station
- Construction Disturbance
- Operations Disturbance
- Multi-Use Areas
- Other Work Areas
- Site Boundary

**SURFICIAL GEOLOGY**

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

**FAULTS**

- Accurate
- Approximate
- Concealed
- Inferred
- USGS Mapped Fault
- No Data

**ROADS**

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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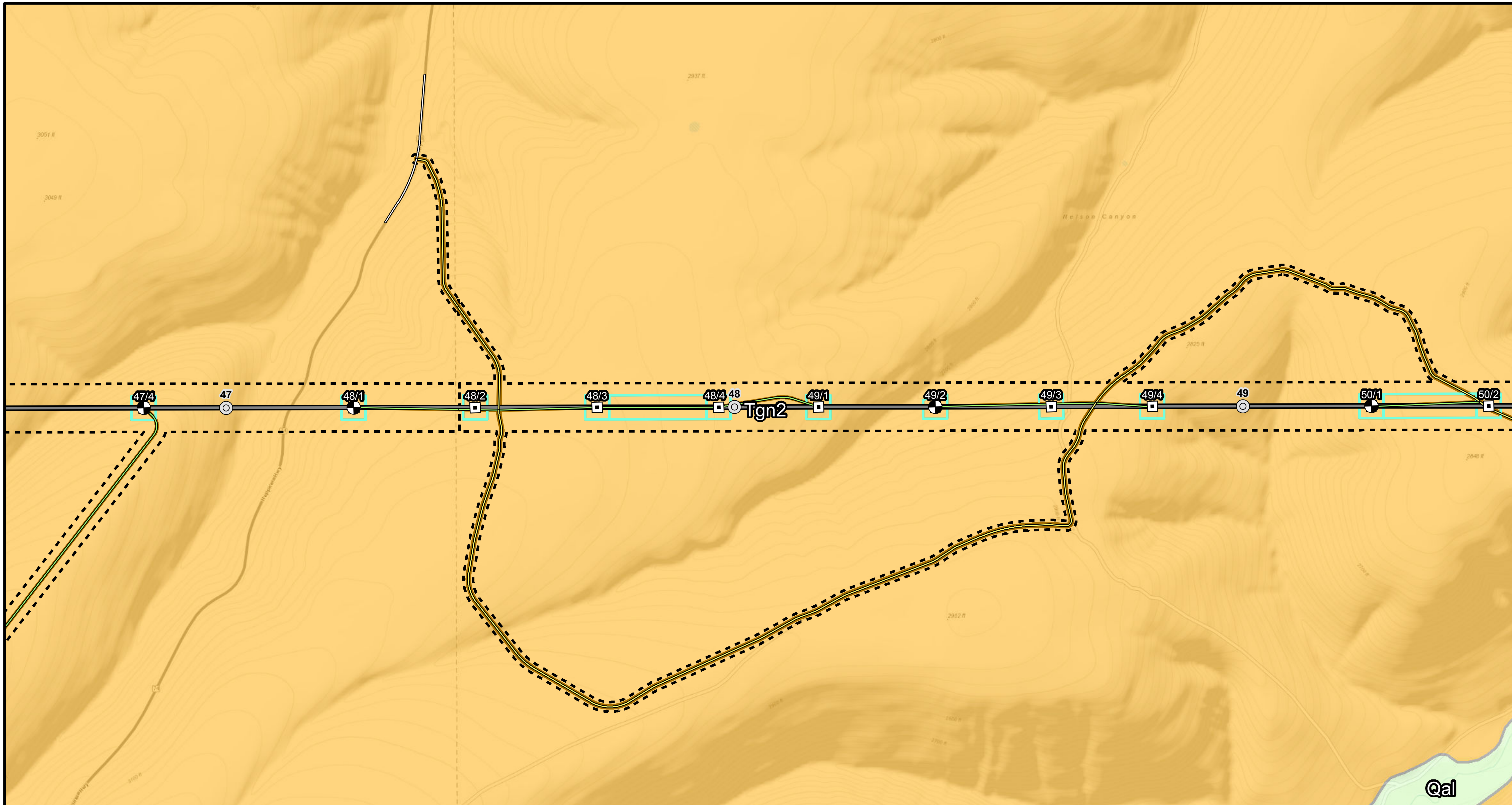


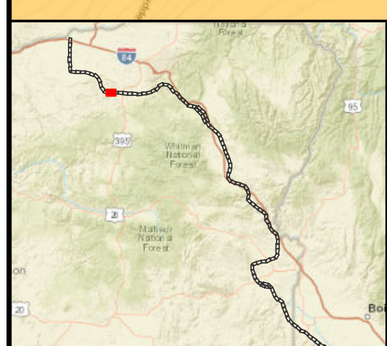

## LEGEND

**TRANSMISSION FEATURES**
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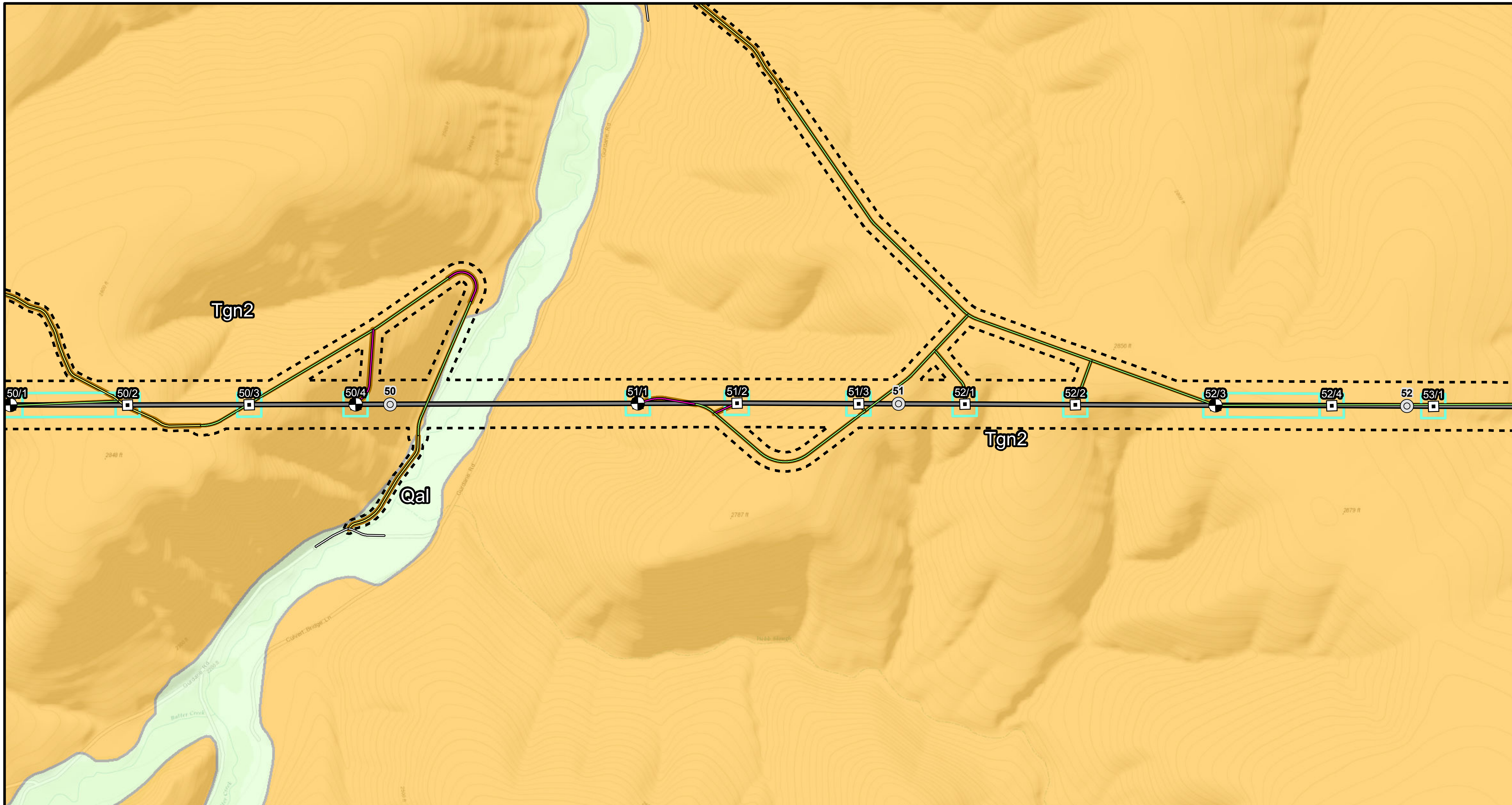


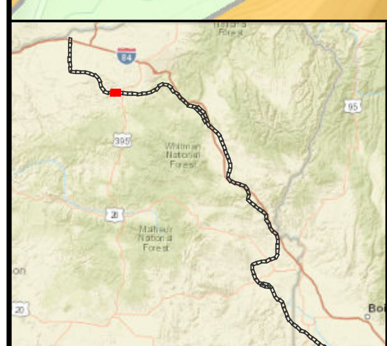

## LEGEND

**TRANSMISSION FEATURES**

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# GEOLOGY

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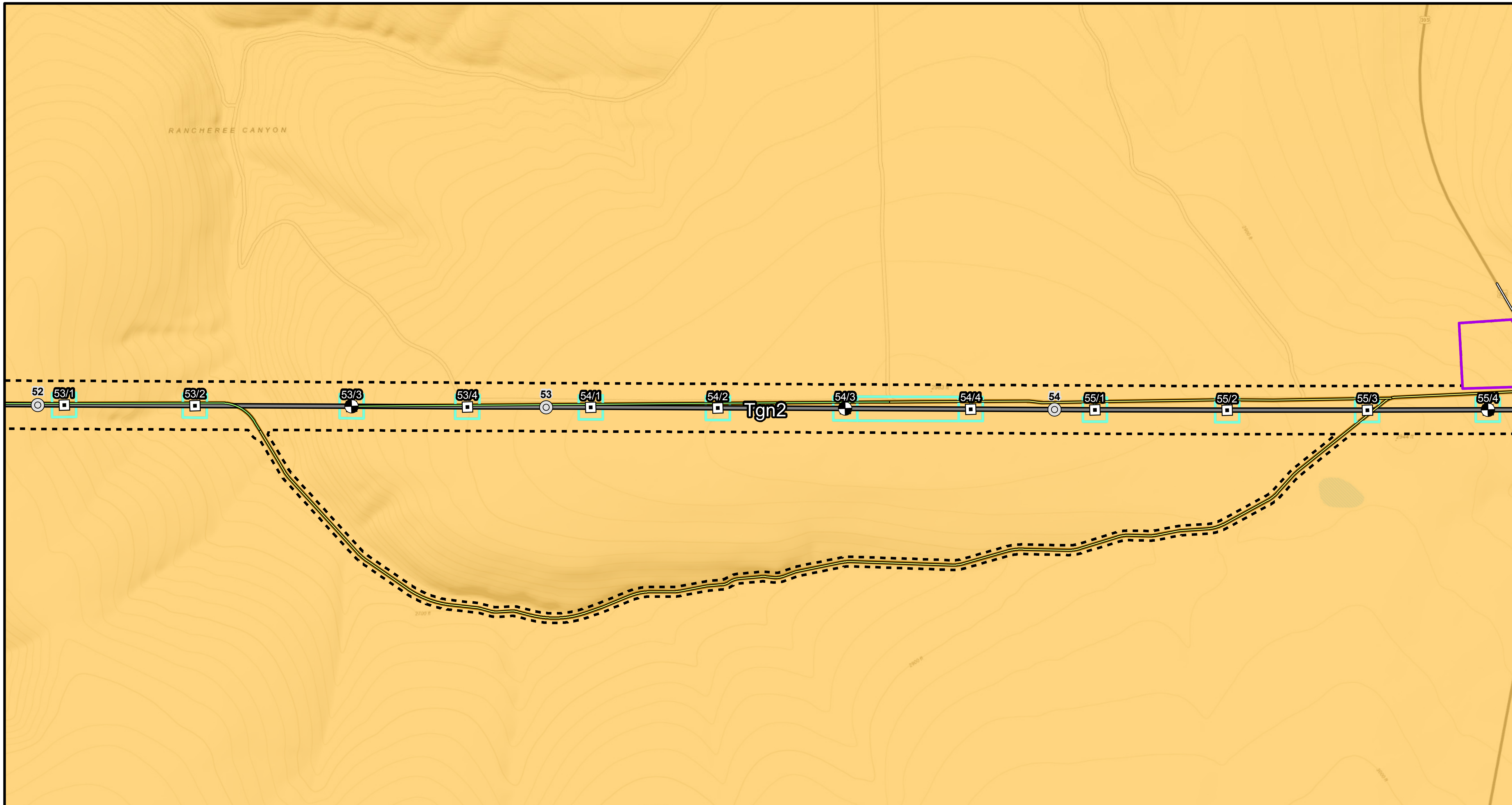


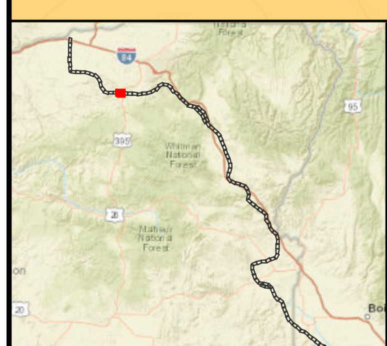

## LEGEND

**TRANSMISSION FEATURES**

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## GEOLOGY

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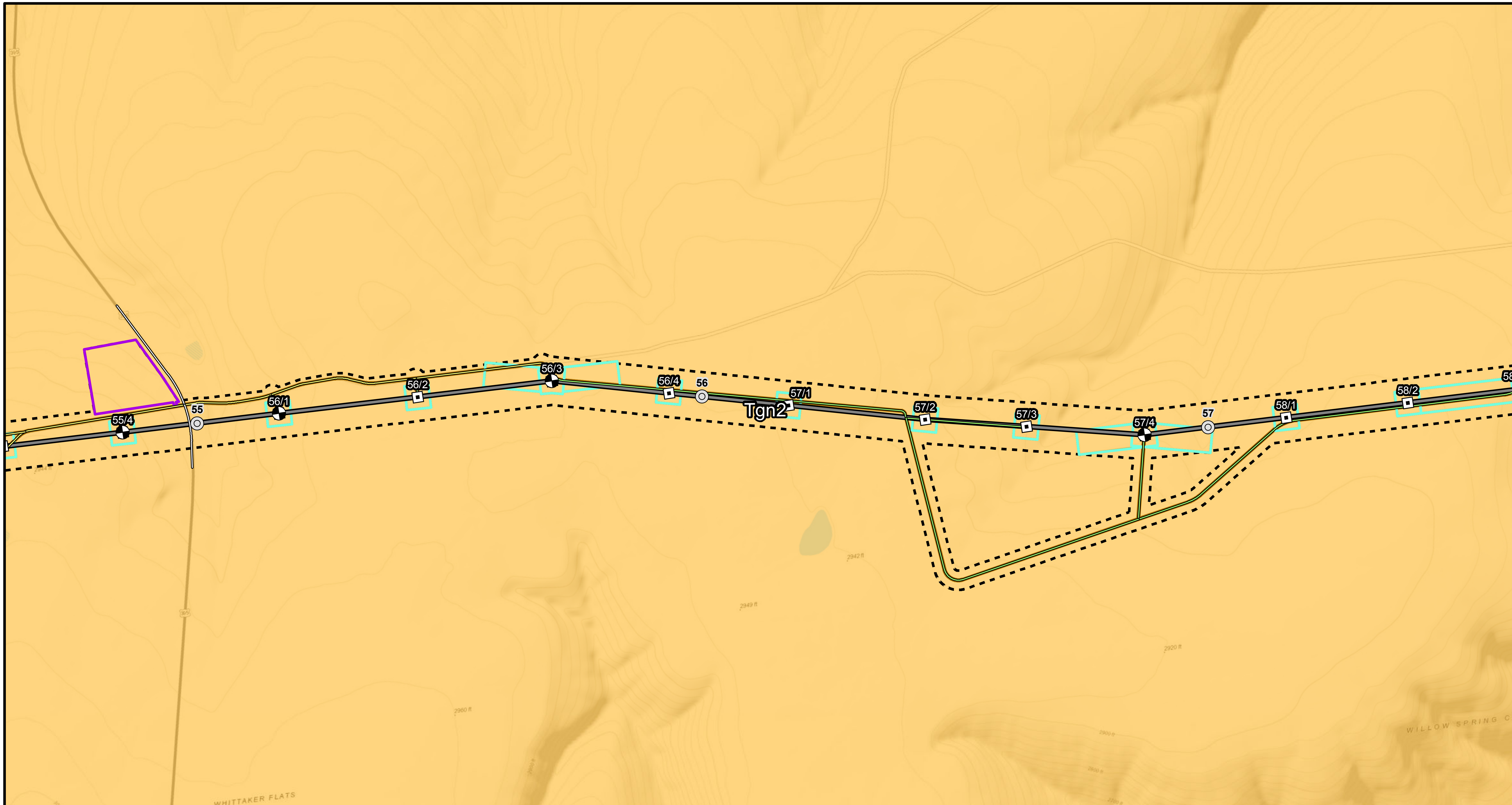


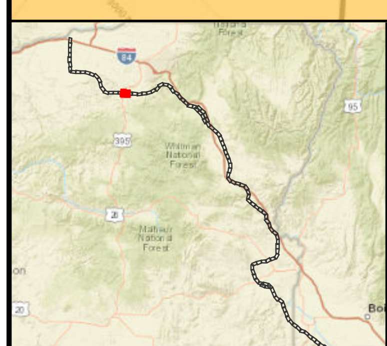

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# GEOLOGY

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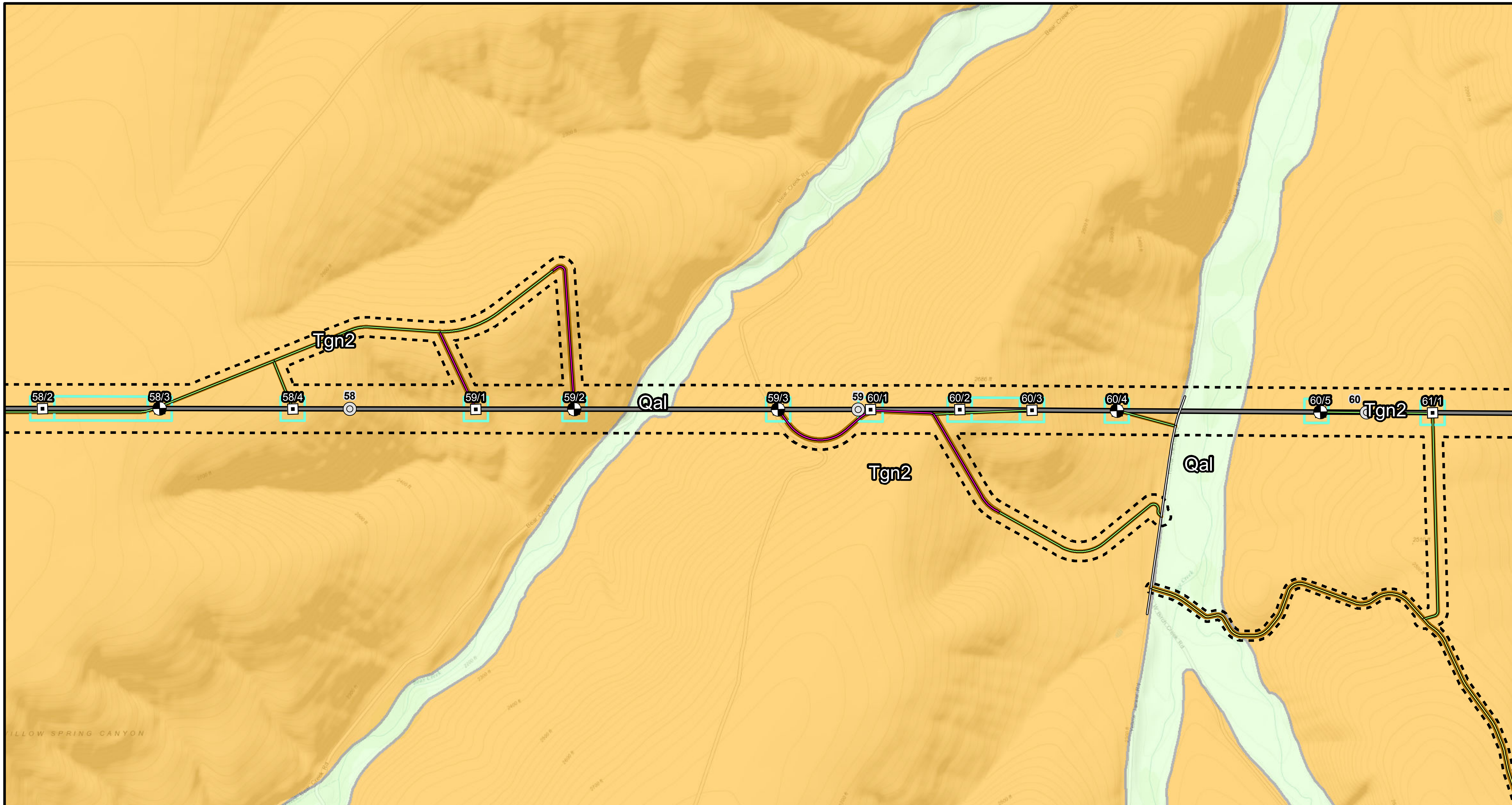


## LEGEND

TRANSMISSION FEATURES

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Oregon - Idaho

GEOLOGY

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS



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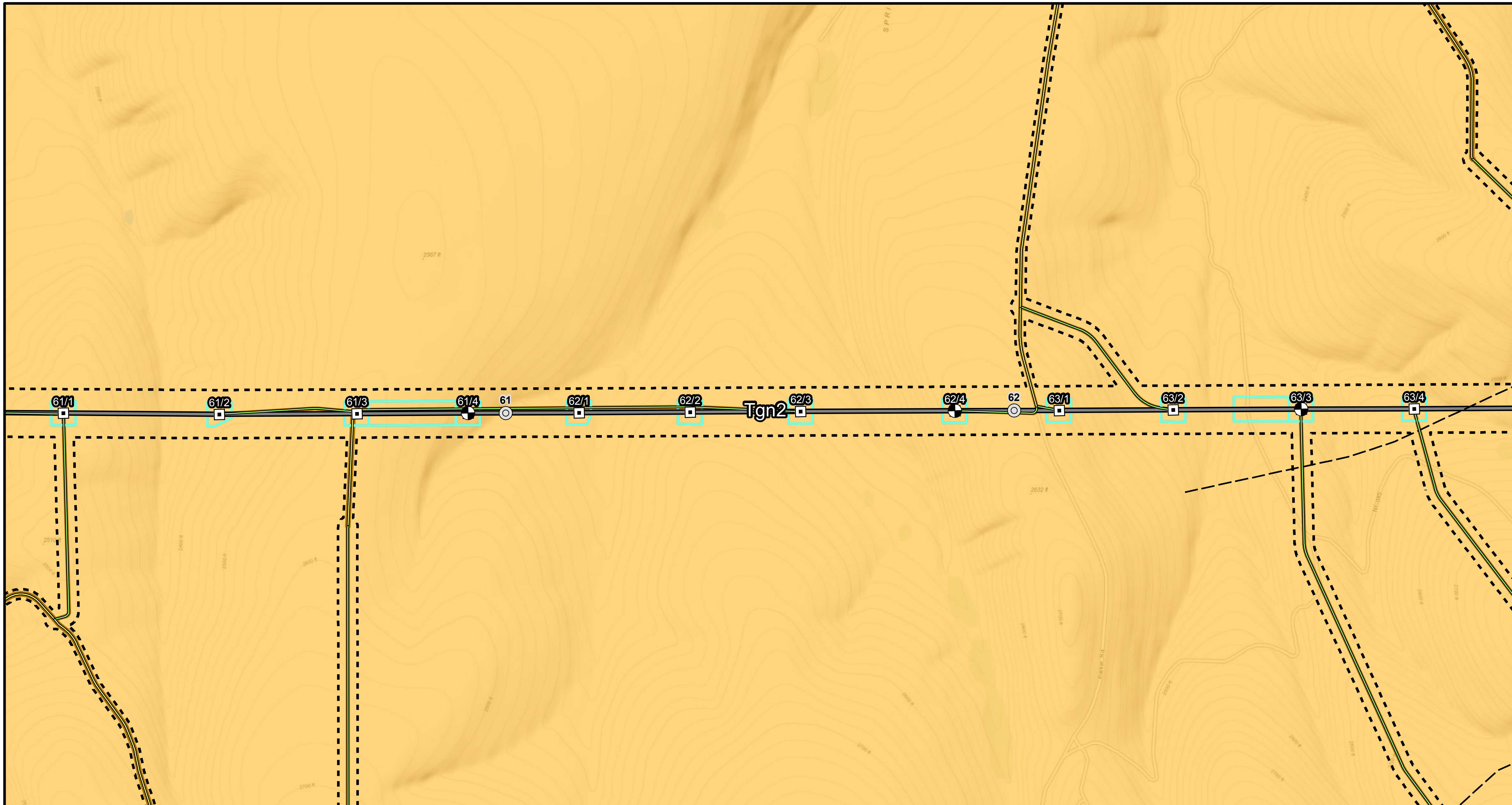


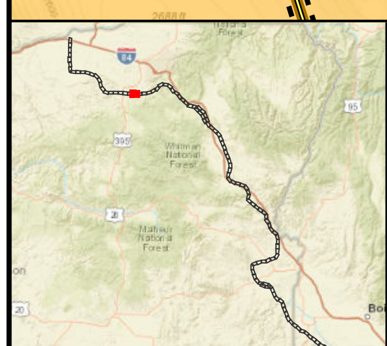

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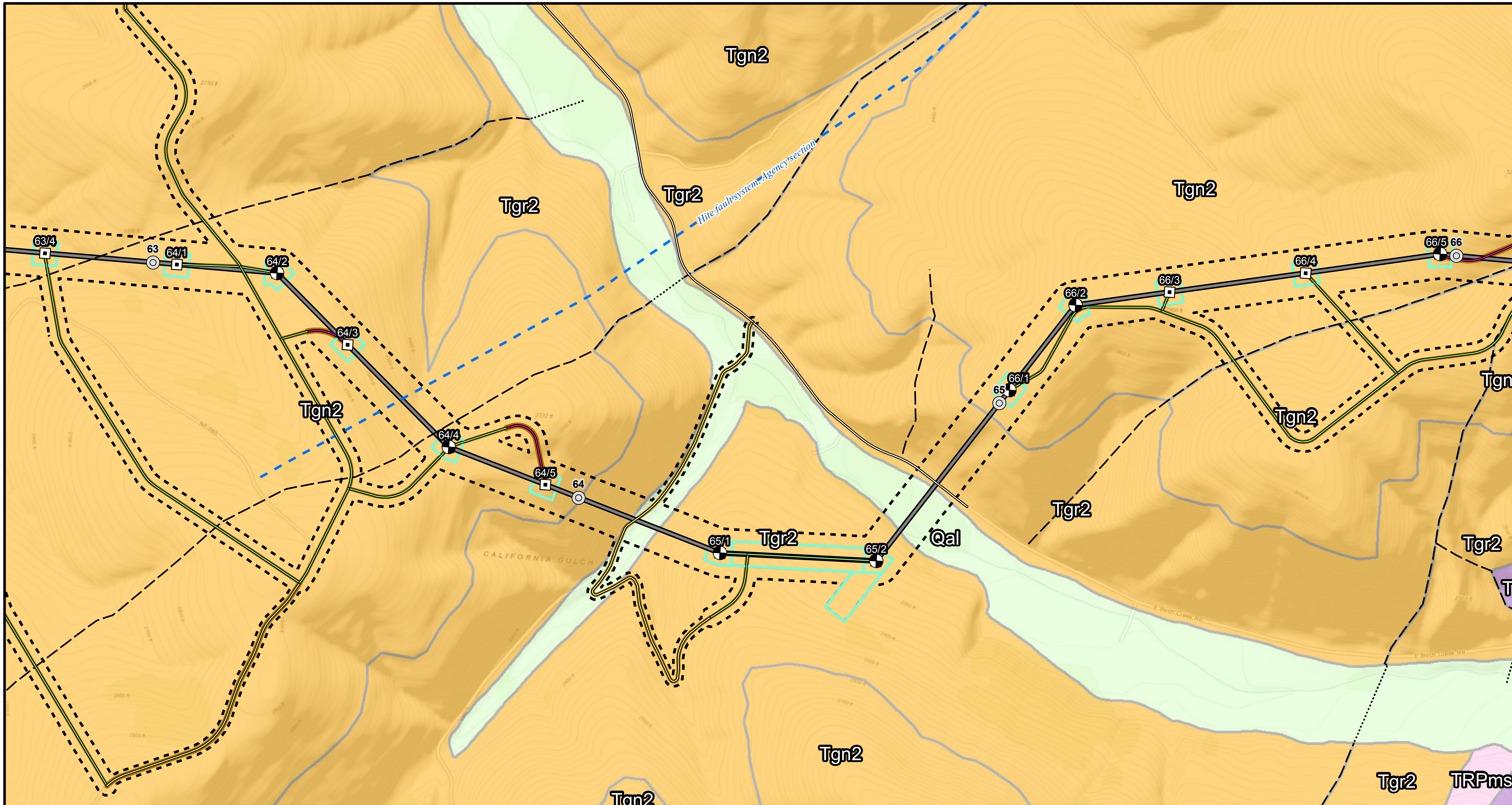


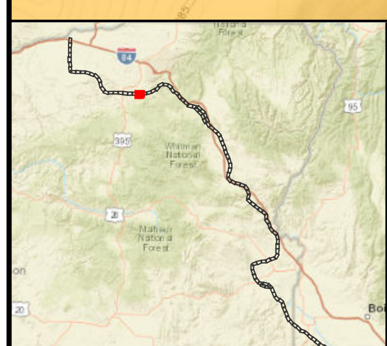

## LEGEND

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## GEOLOGY

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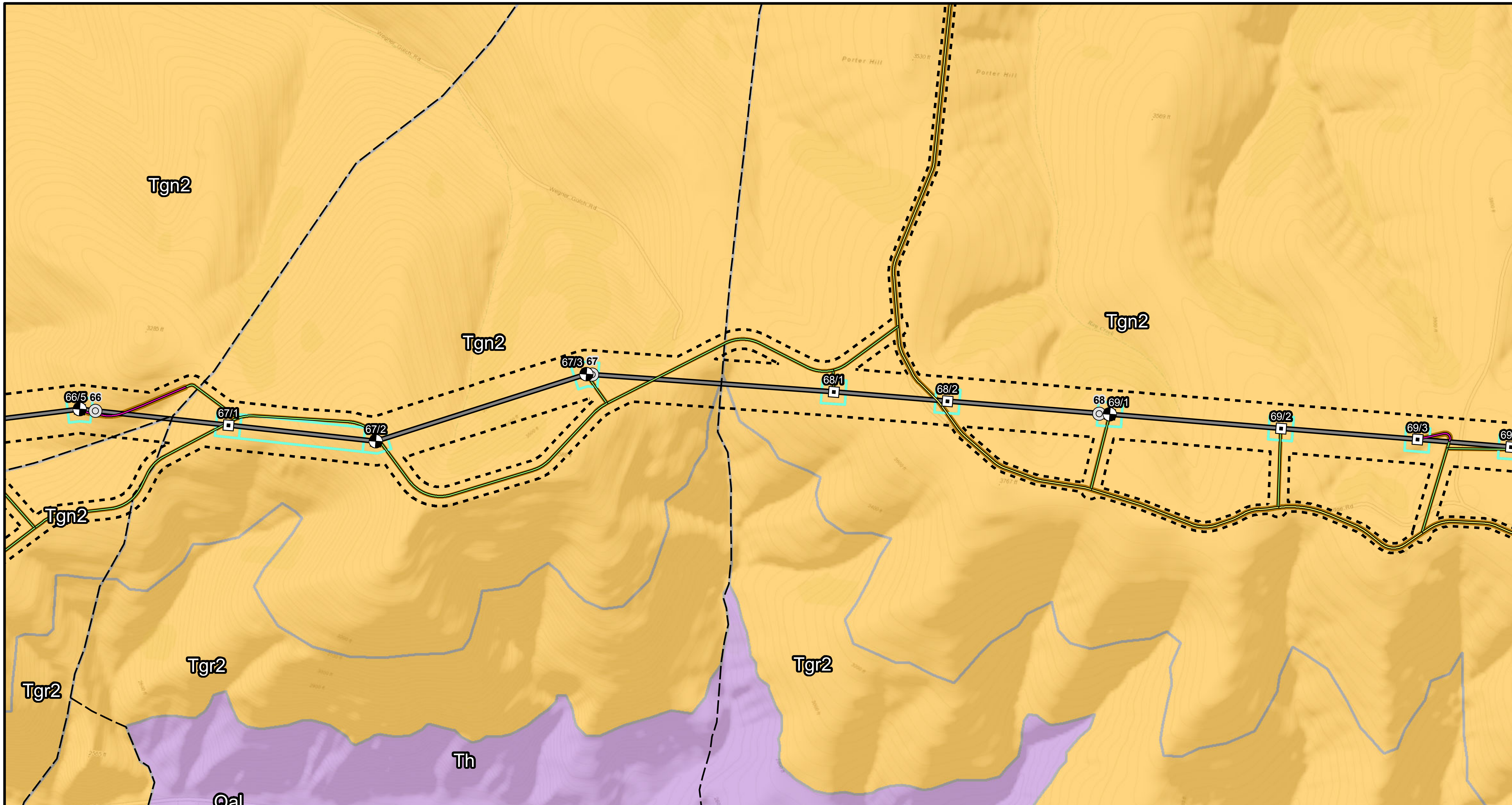


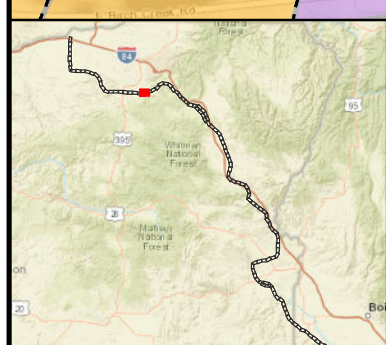

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## LEGEND

TRANSMISSION FEATURES
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Oregon - Idaho

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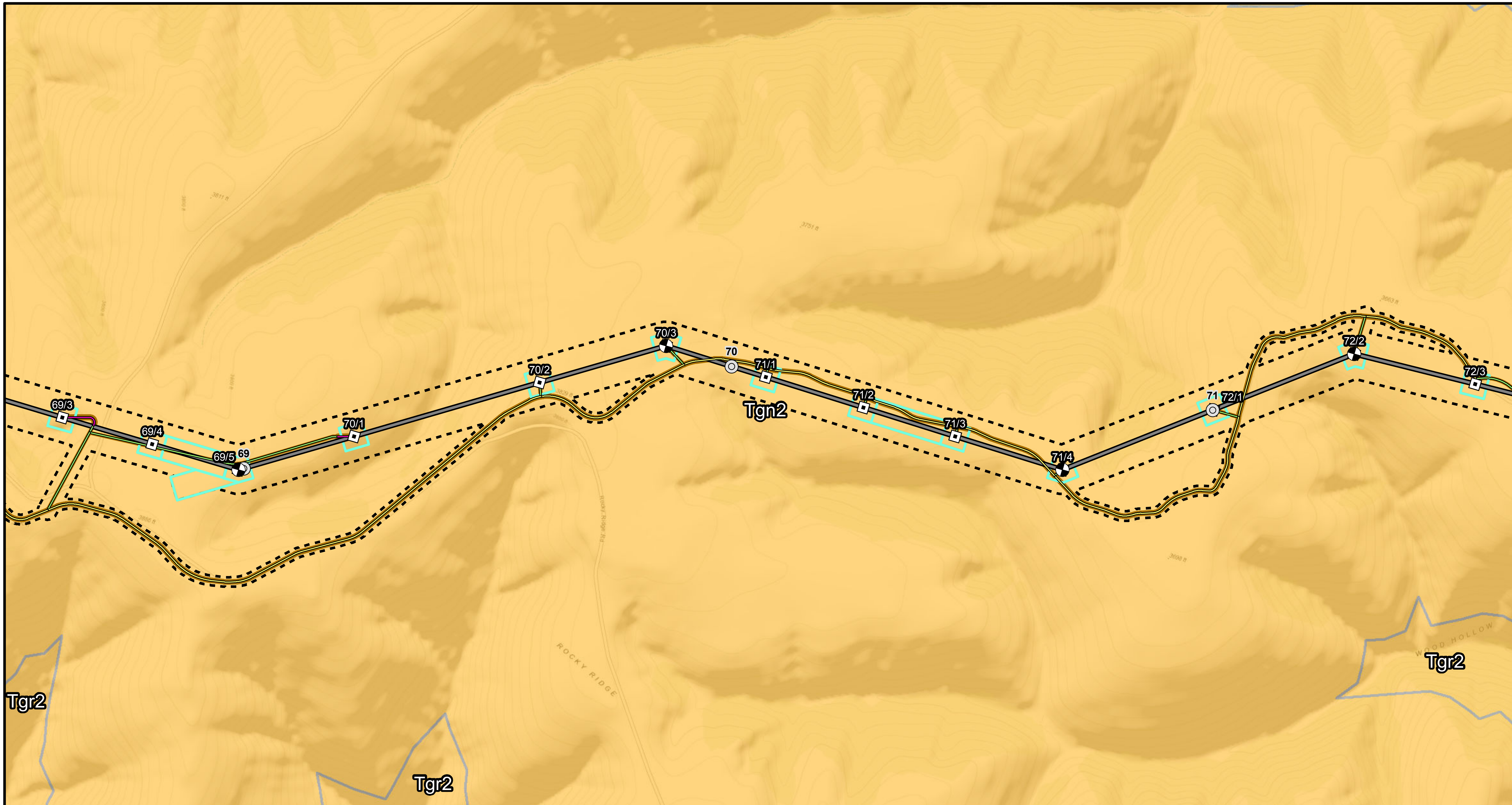


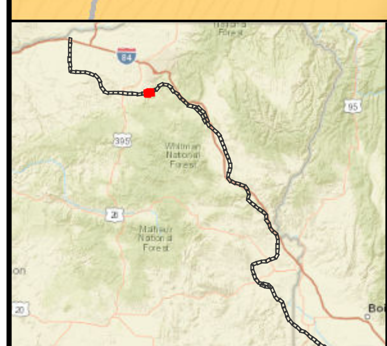

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Boardman - Hemingway
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Oregon - Idaho

**GEOLOGY**

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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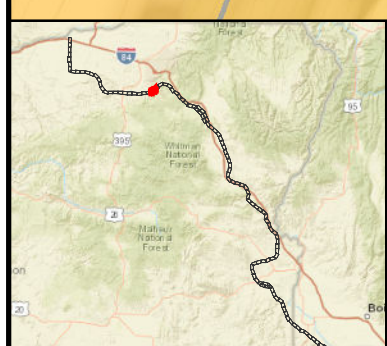

LEGEND

TRANSMISSION FEATURES

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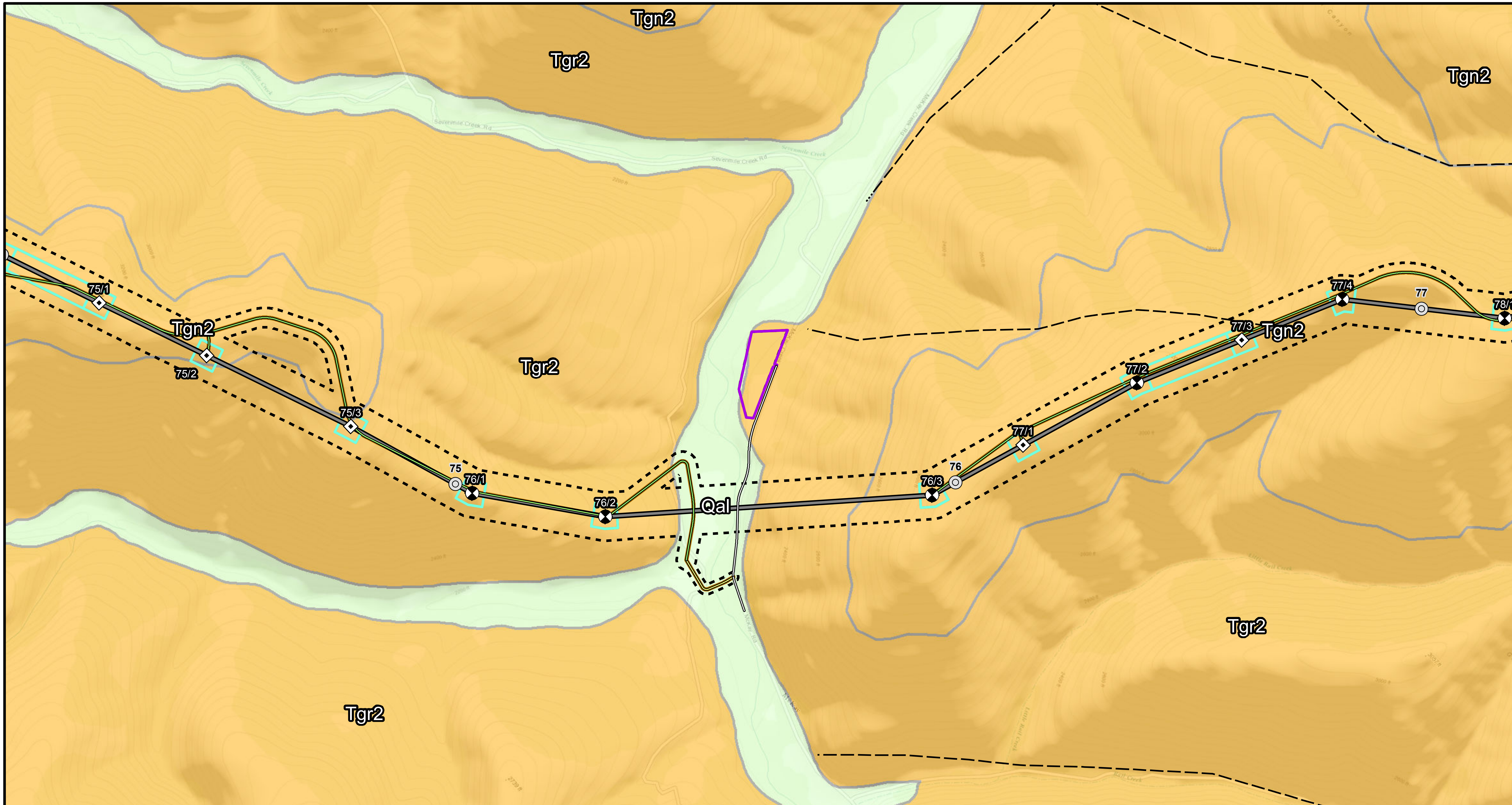


LEGEND

| IPC Proposed Route | TRANSMISSION FEATURES | | | SURFICIAL GEOLOGY | FAULTS | ROADS |
|---|---|---|---|---|---|---|
| IPC Proposed Route | Morgan Lake Alternative | Proposed Borings | Distribution Power Lines to Communication Station | Unconsolidated Sediments | Accurate | New, Bladed |
| Proposed 230-kV Rebuild | West Bombing Range Road Alternative 1 | Towers | Construction Disturbance | Sedimentary Rocks | Approximate | New, Primitive |
| Proposed 138-kV Rebuild | West Bombing Range Road Alternative 2 | Substation | Operations Disturbance | Volcaniclastic Rocks | Concealed | Existing, Moderate to Extensive Improvements |
| Double Mountain Alternative | | Mileposts | Multi-Use Areas | Igneous Rocks | Inferred | No Substantial Improvements |
| | | | Other Work Areas | Metamorphic Rocks | USGS Mapped Fault | Railroad |
| | | | Site Boundary | | No Data | |

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Oregon - Idaho

GEOLOGY

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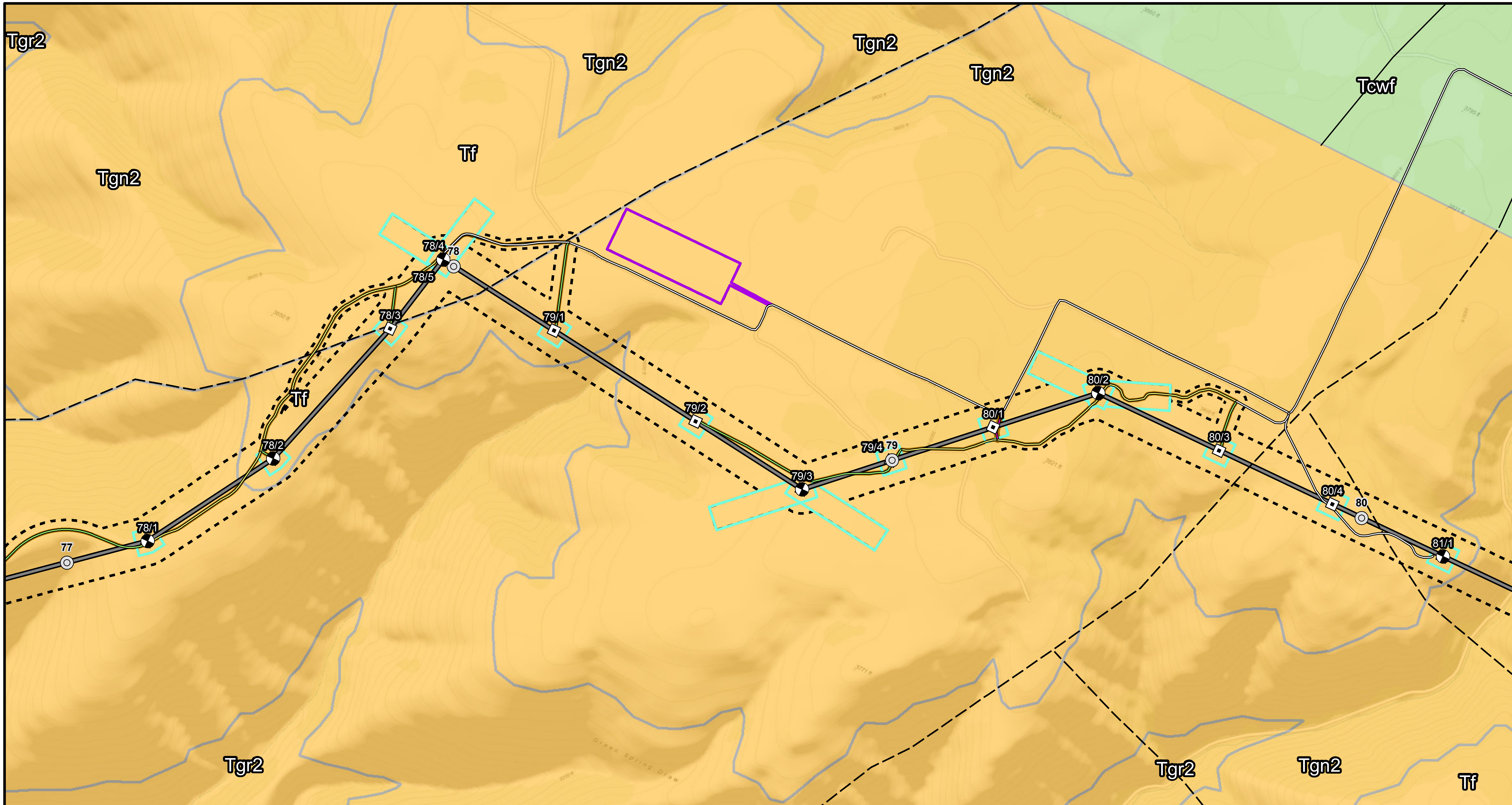


# LEGEND

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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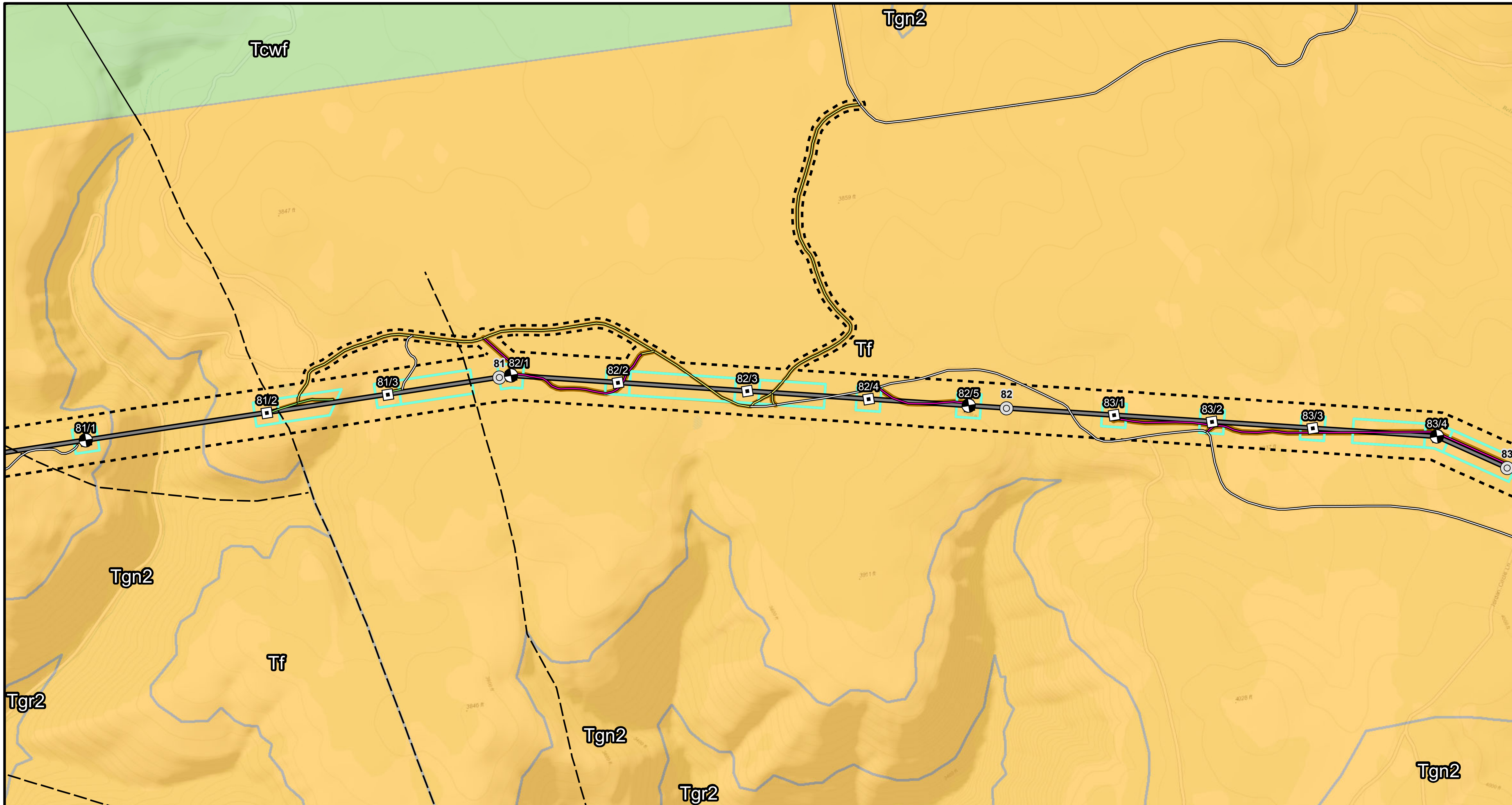


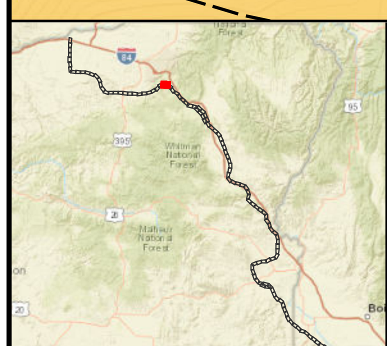

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- No Data

ROADS

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

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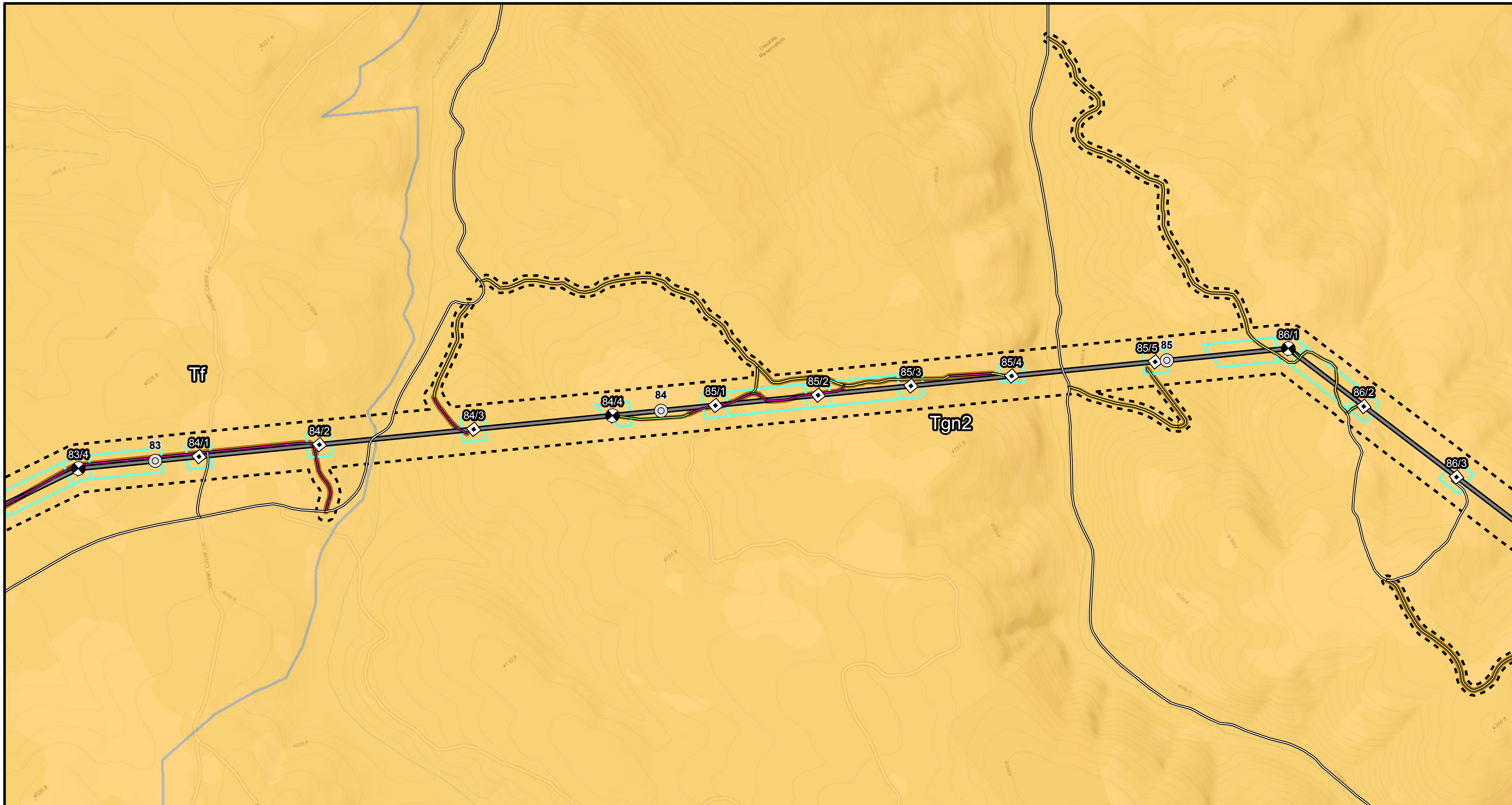


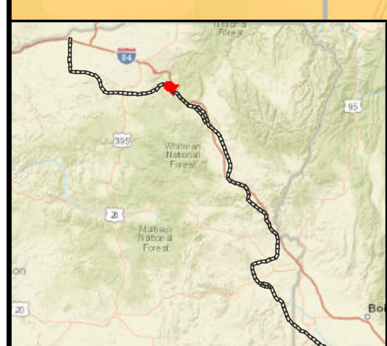

## LEGEND

**TRANSMISSION FEATURES**
- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
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- Distribution Power Lines to Communication Station
- Construction Disturbance
- Operations Disturbance
- Multi-Use Areas
- Other Work Areas
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**SURFICIAL GEOLOGY**
- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

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# GEOLOGY

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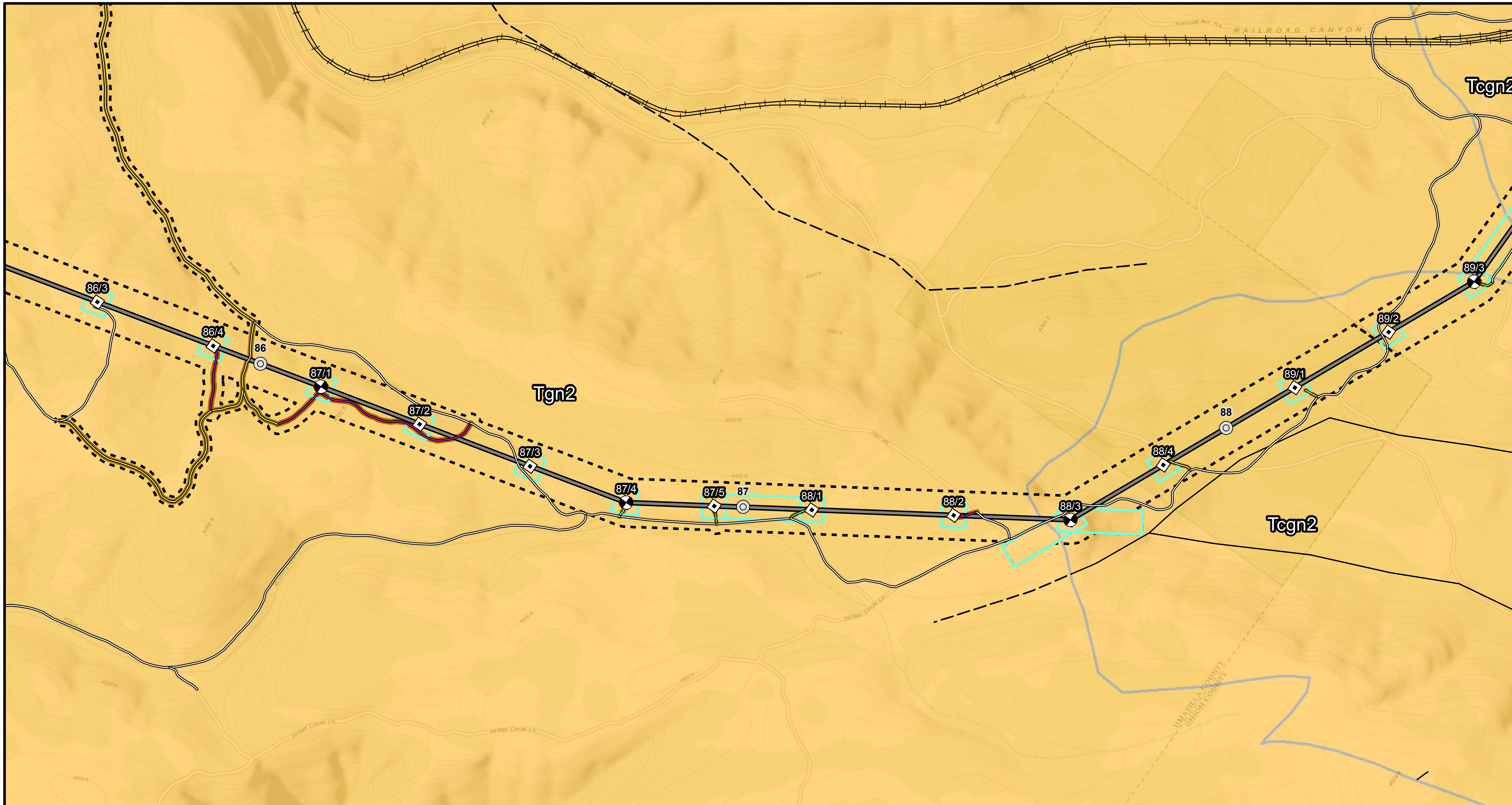


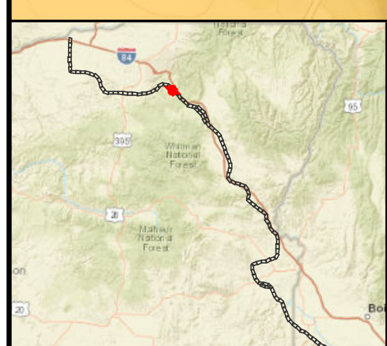

LEGEND

TRANSMISSION FEATURES

- IPC Proposed Route
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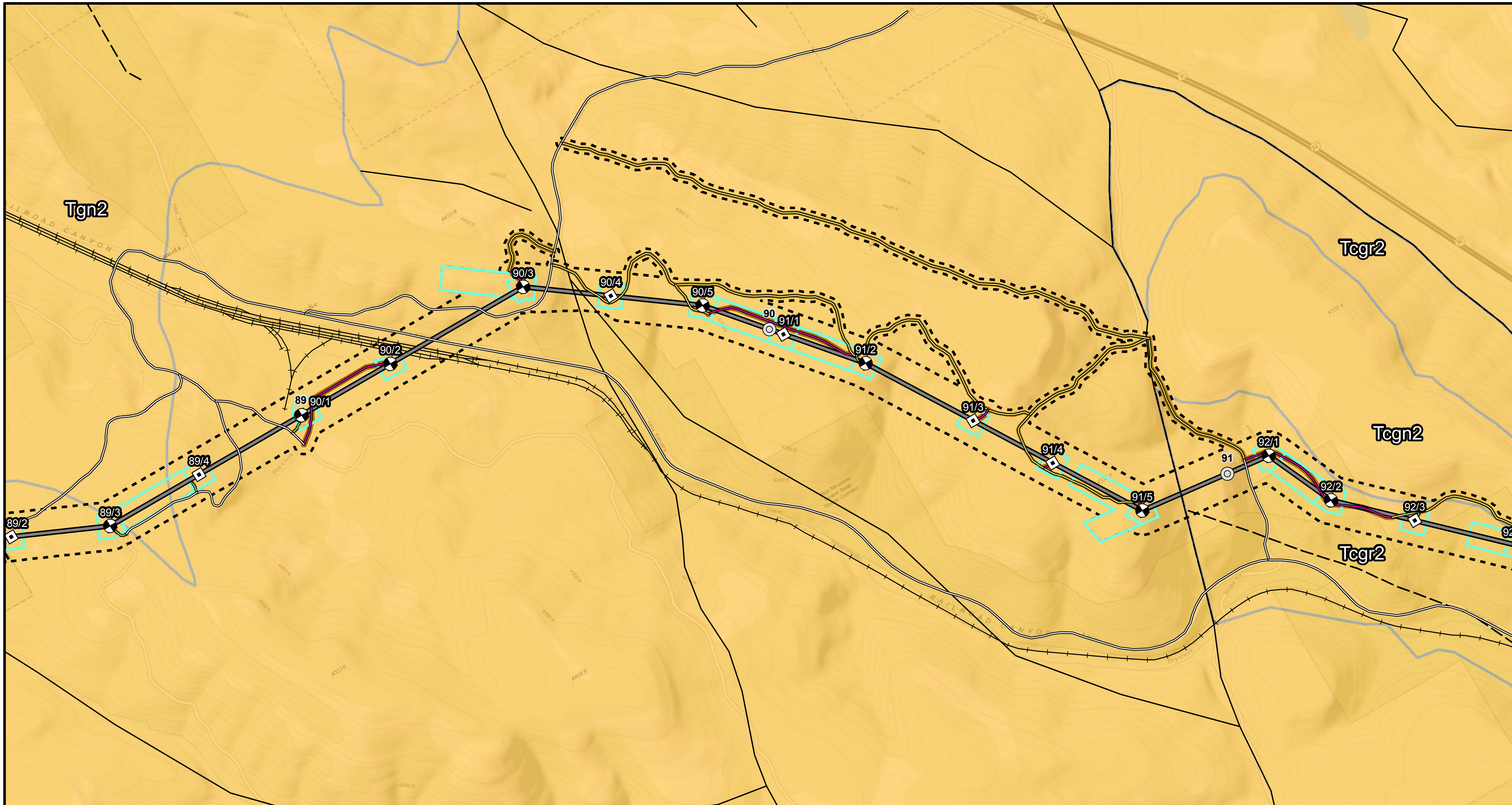


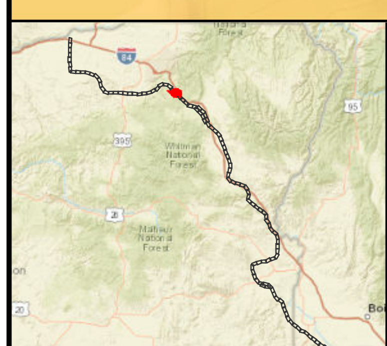

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**TRANSMISSION FEATURES**
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Oregon - Idaho

## GEOLOGY

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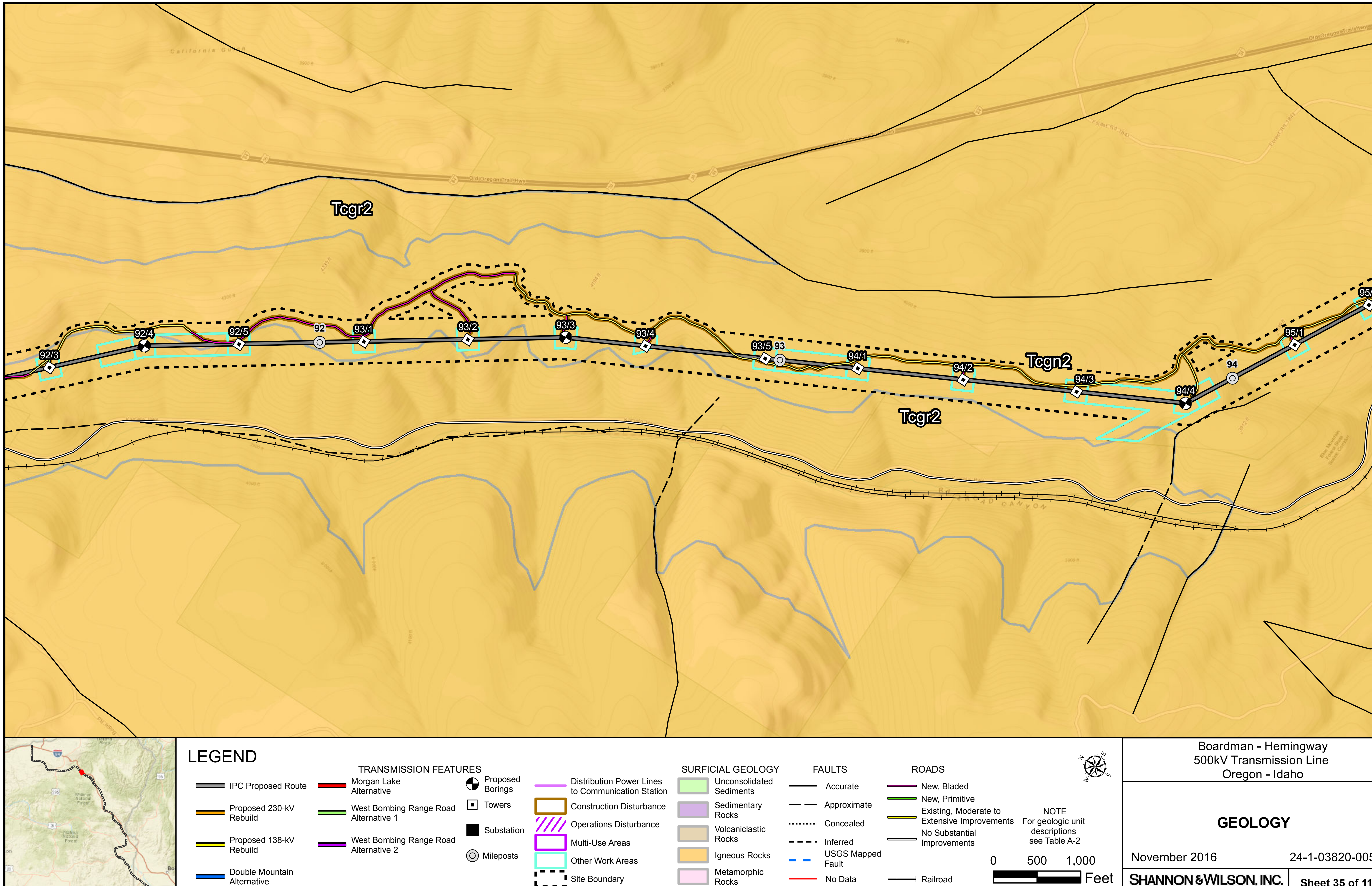


Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

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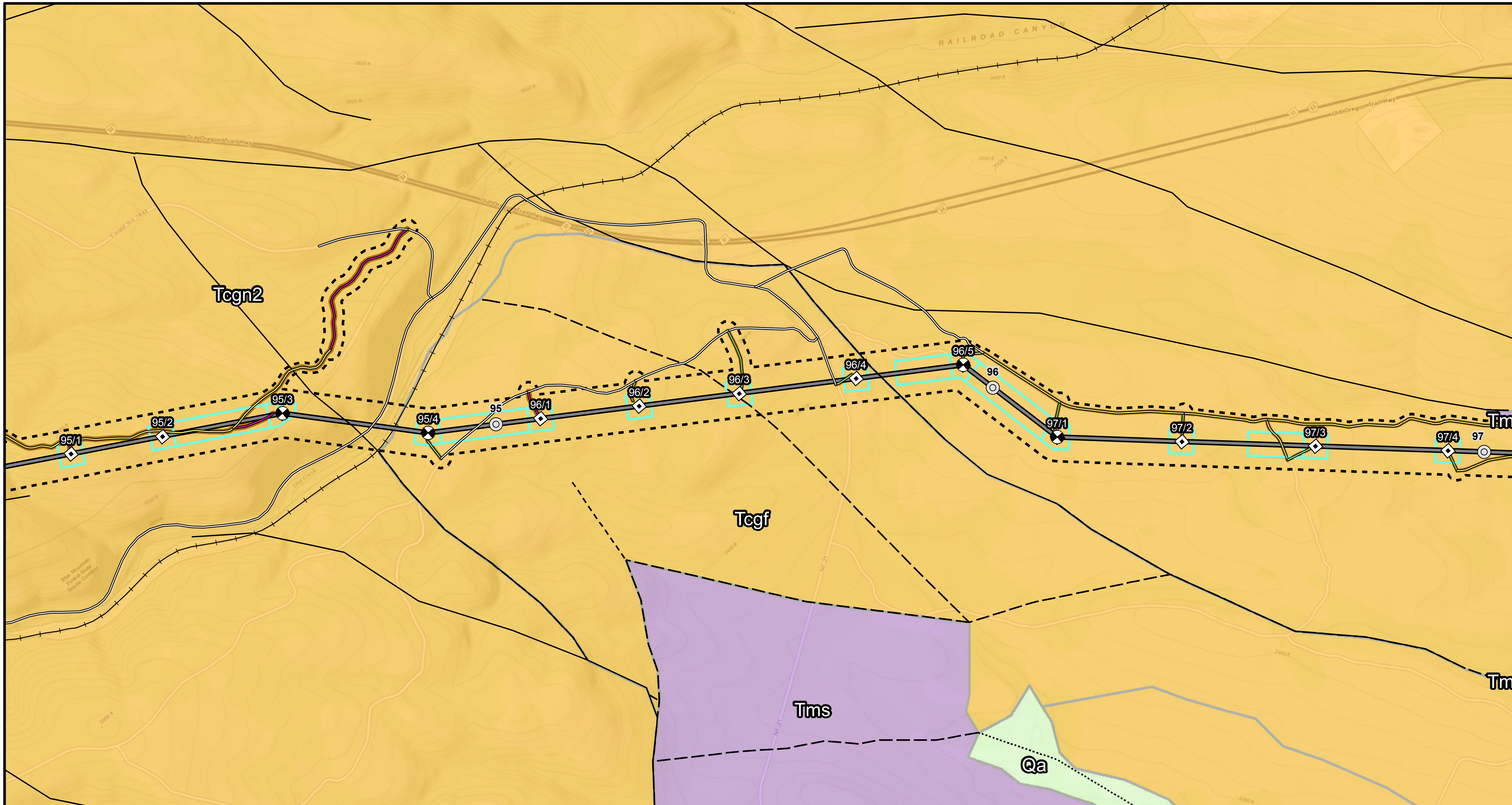


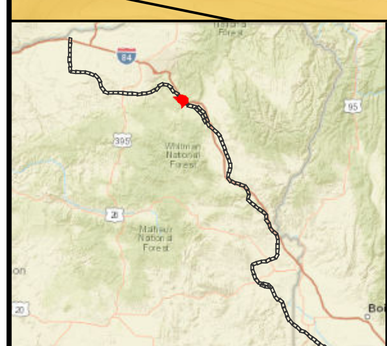

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
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- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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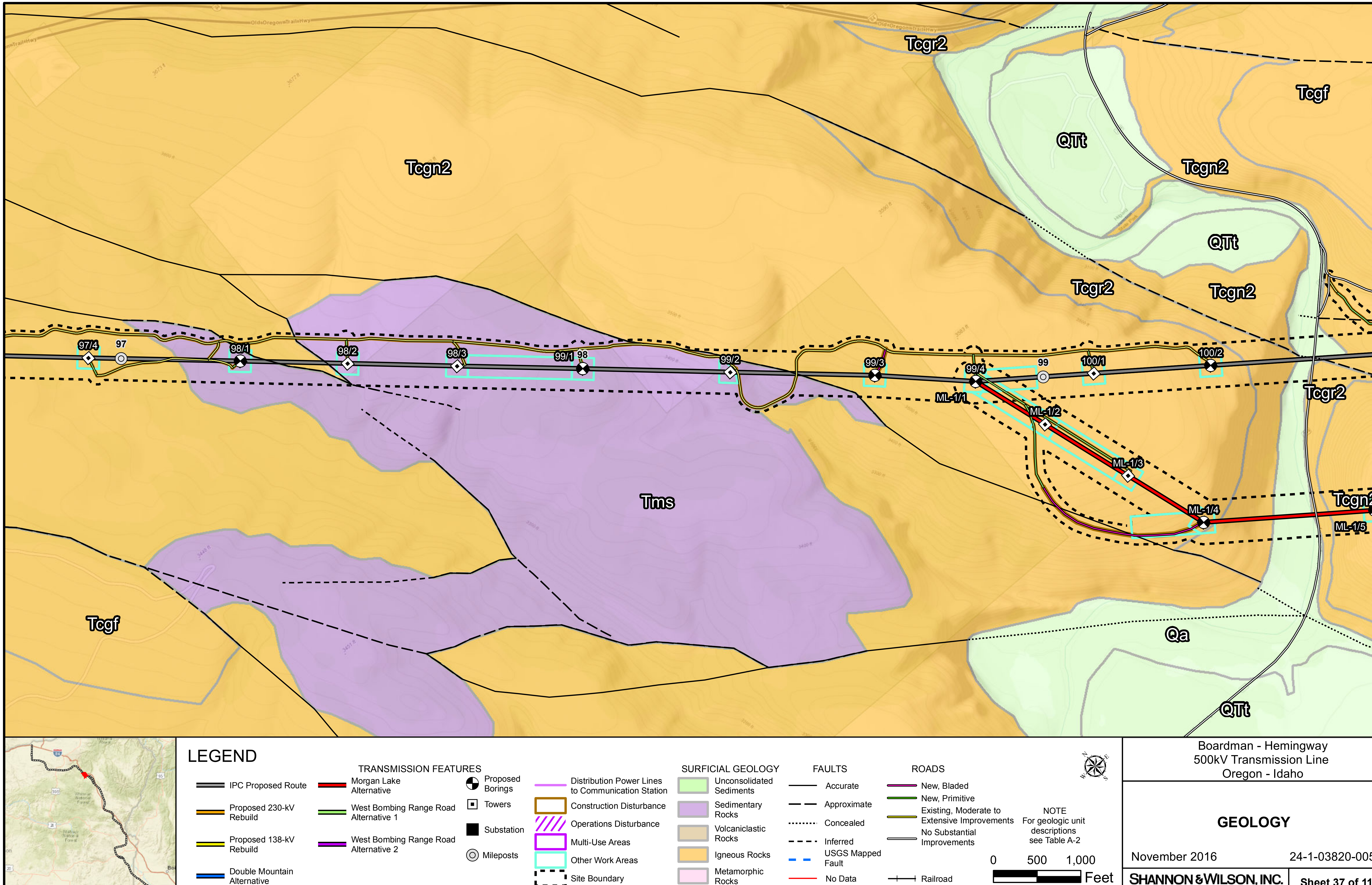




Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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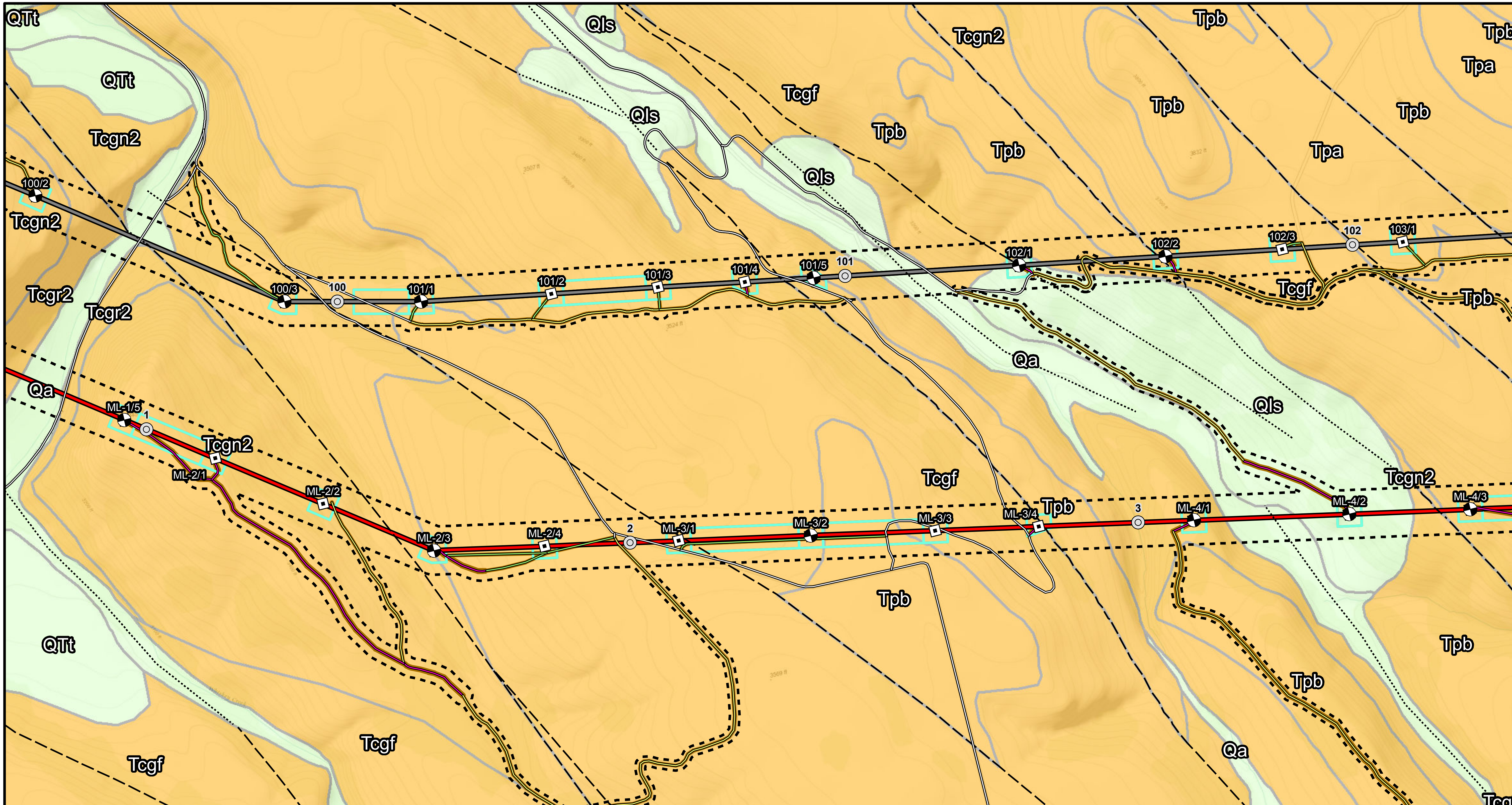


LEGEND

TRANSMISSION FEATURES
- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Morgan Lake Alternative
- West Bombing Range Road Alternative 1
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NOTE
For geologic unit descriptions see Table A-2

0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGY

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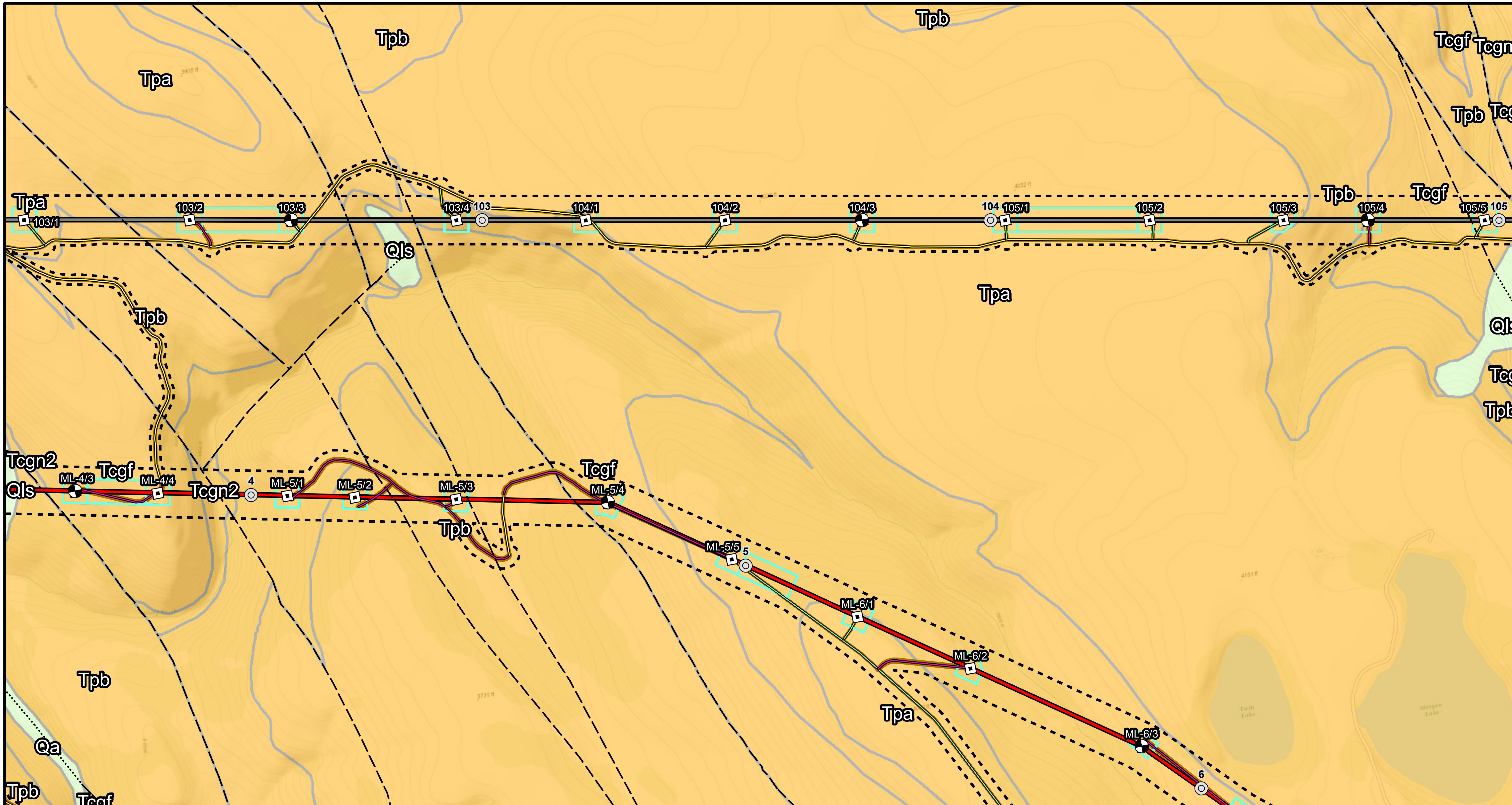


LEGEND

IPC Proposed Route
Proposed 230-kV Rebuild
Proposed 138-kV Rebuild
Double Mountain Alternative

TRANSMISSION FEATURES
Morgan Lake Alternative
West Bombing Range Road Alternative 1
West Bombing Range Road Alternative 2
Proposed Borings
Towers
Substation
Mileposts
Distribution Power Lines to Communication Station
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Unconsolidated Sediments
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Igneous Rocks
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USGS Mapped Fault
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ROADS
New, Bladed
New, Primitive
Existing, Moderate to Extensive Improvements
No Substantial Improvements
Railroad

NOTE
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0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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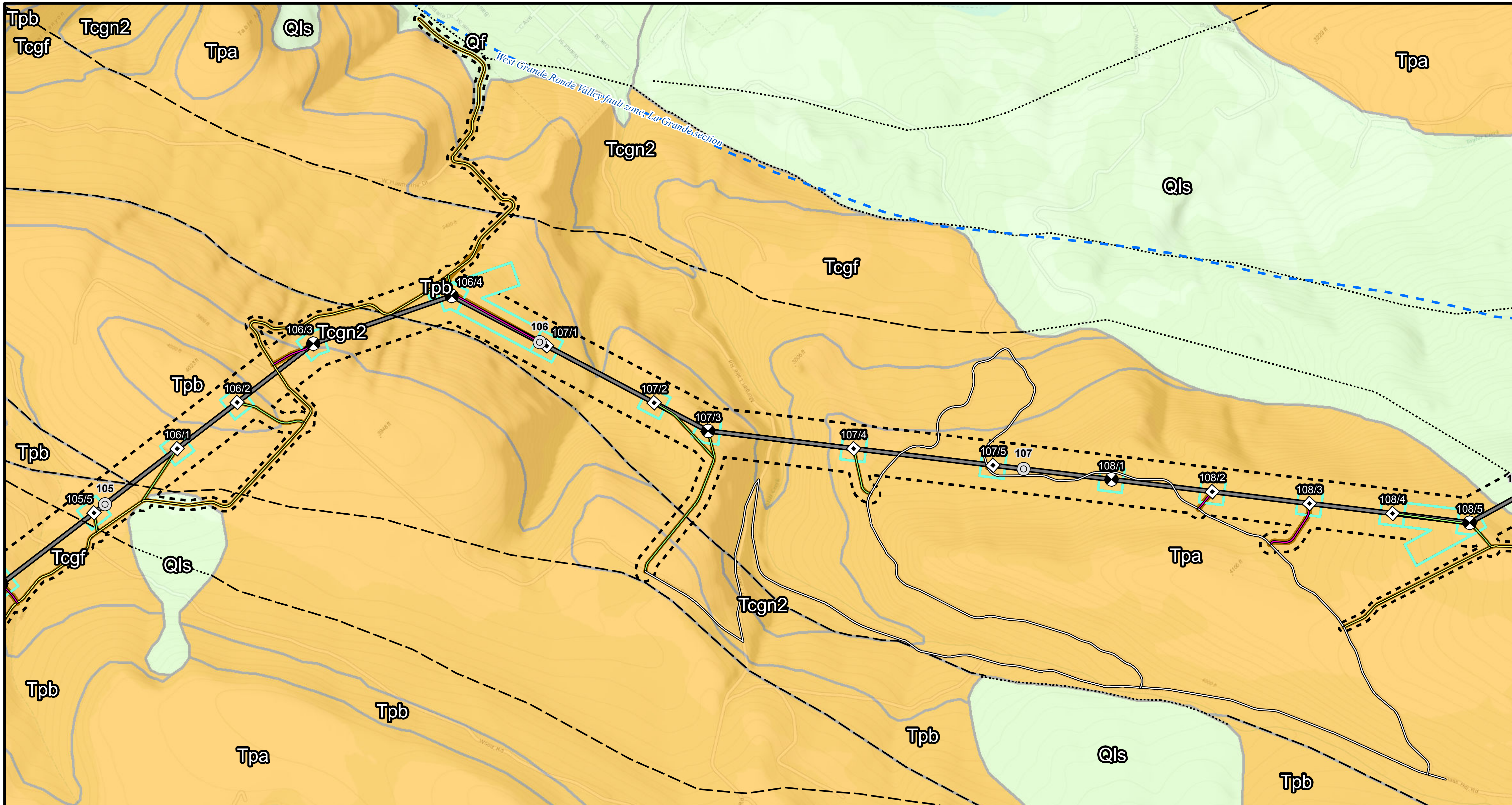


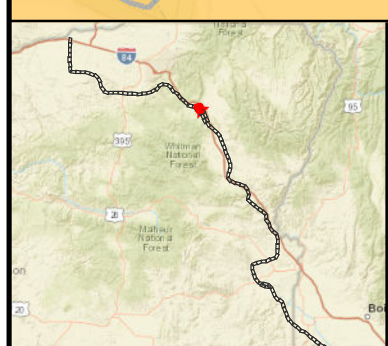

## LEGEND

**TRANSMISSION FEATURES**

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- Proposed 230-kV Rebuild
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0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY

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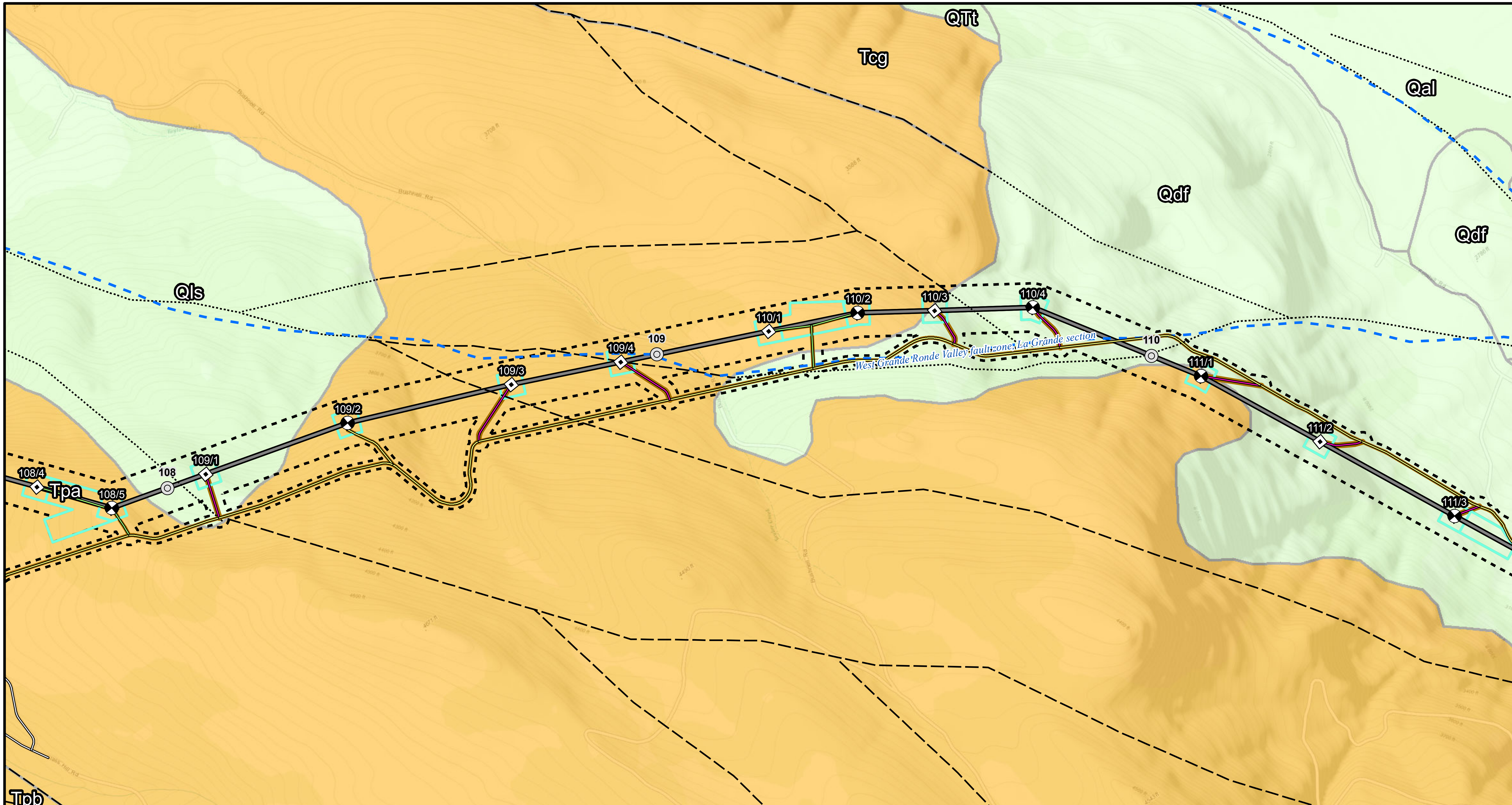


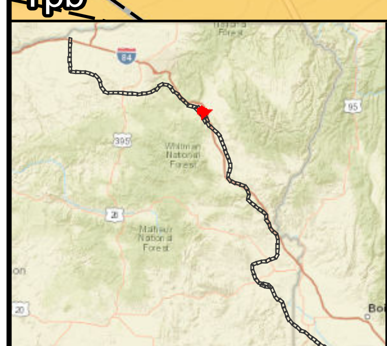

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## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
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0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY

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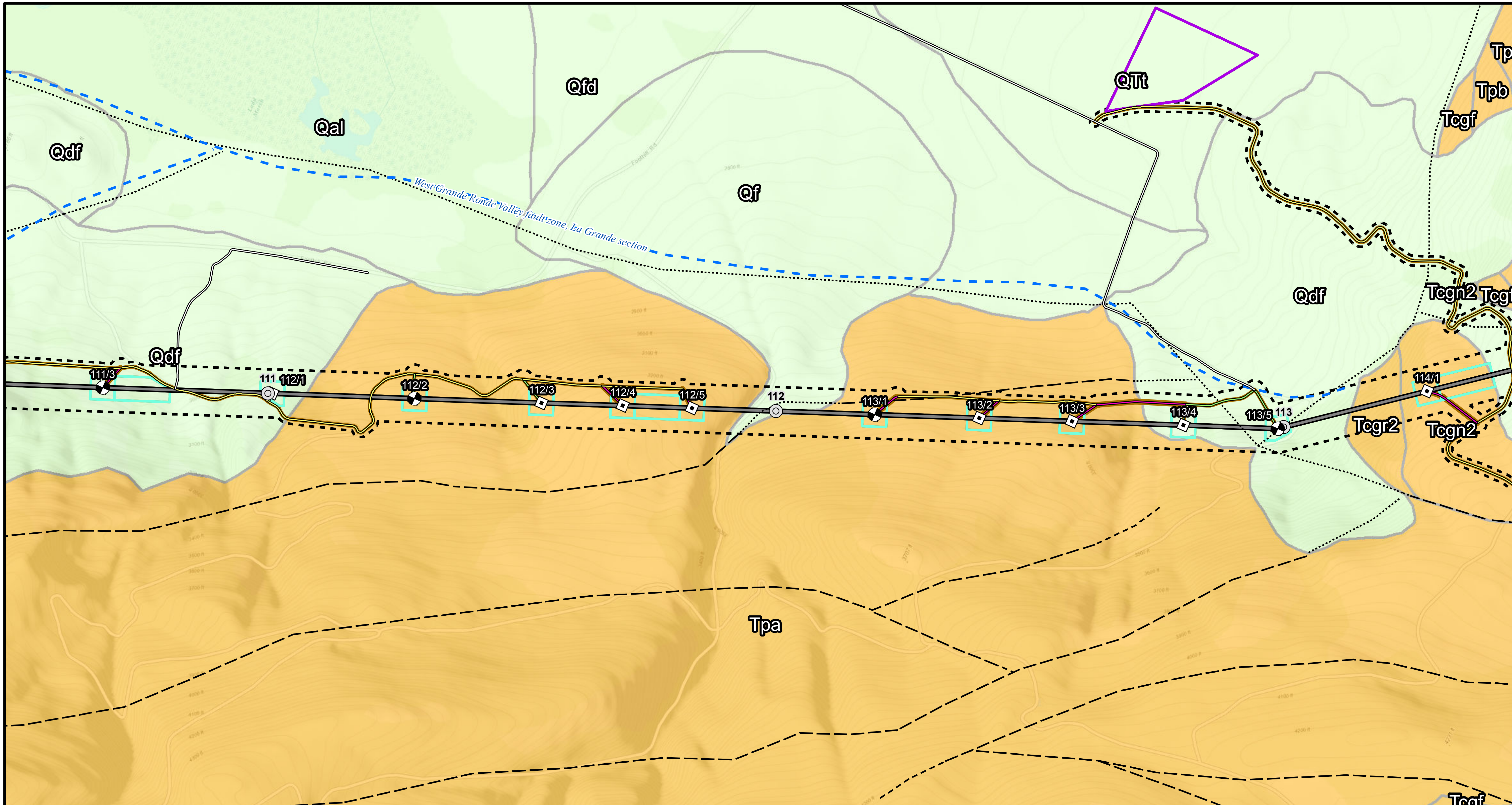


# LEGEND

**TRANSMISSION FEATURES**

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Boardman - Hemingway
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Oregon - Idaho

## GEOLOGY

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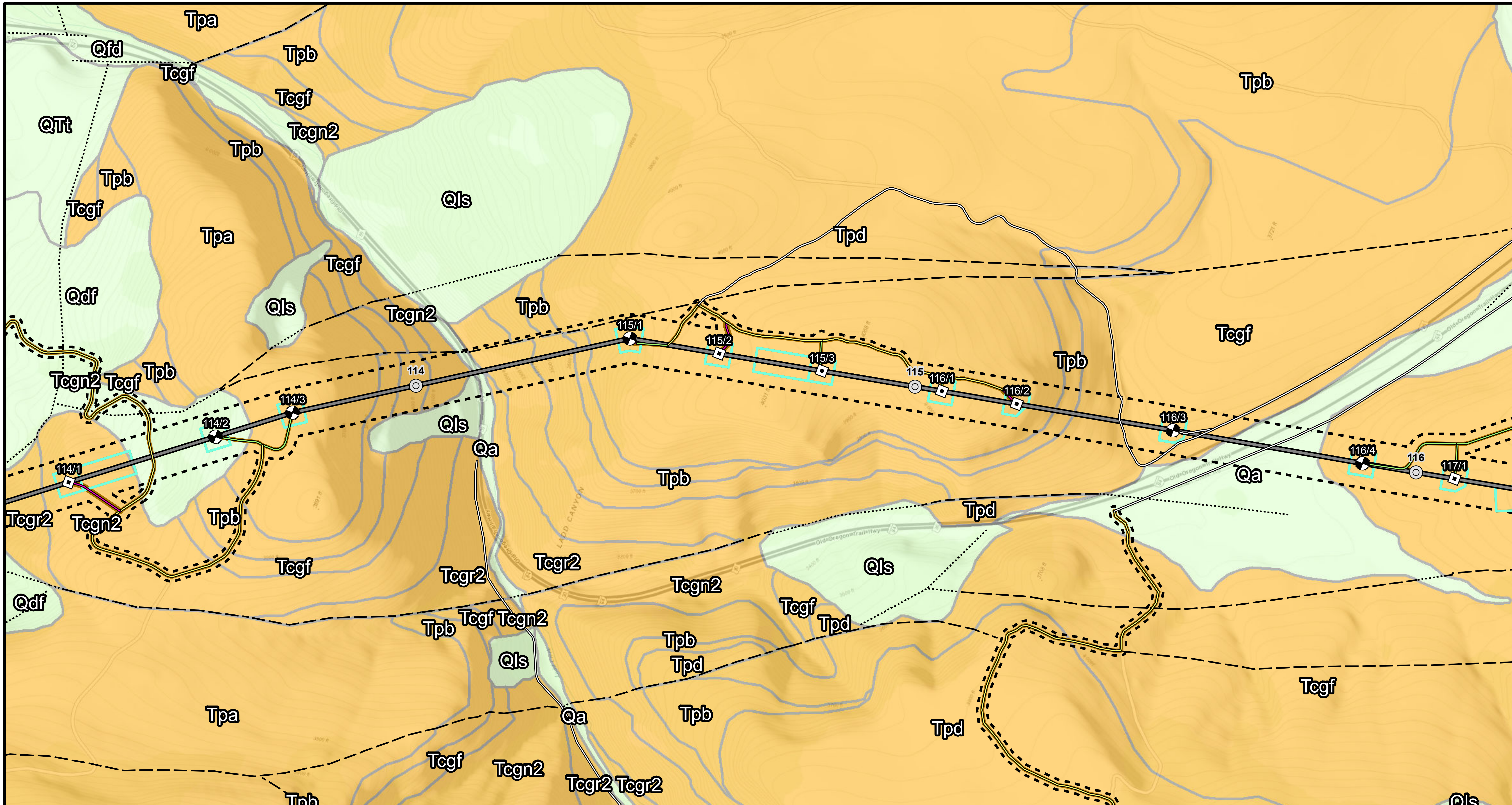


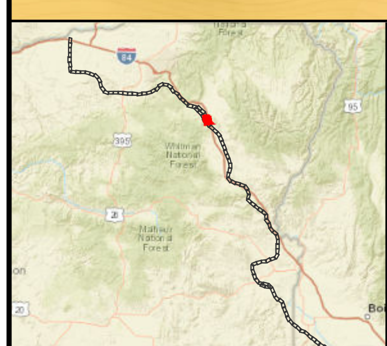

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Oregon - Idaho

## GEOLOGY

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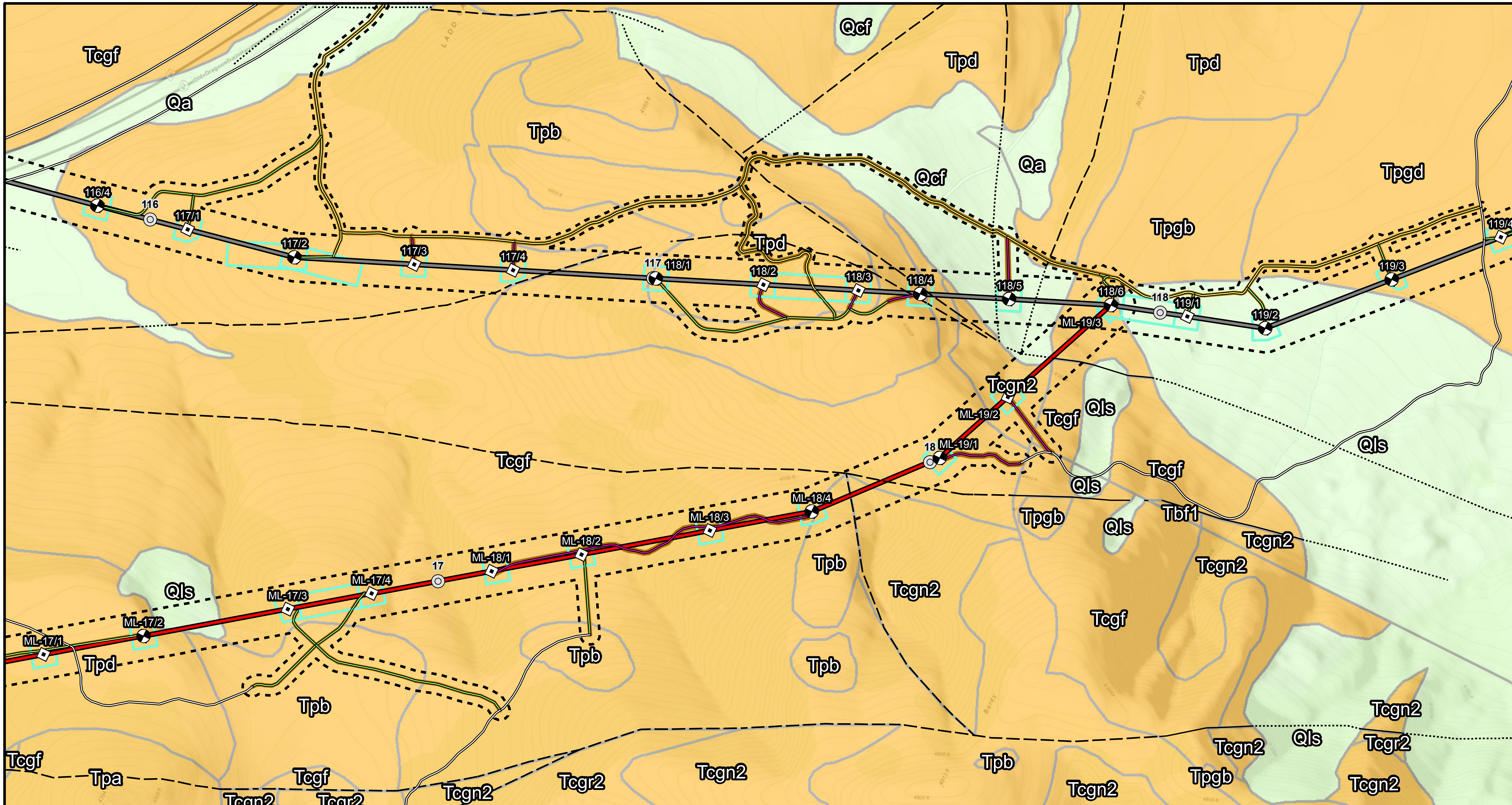
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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**GEOLOGY**

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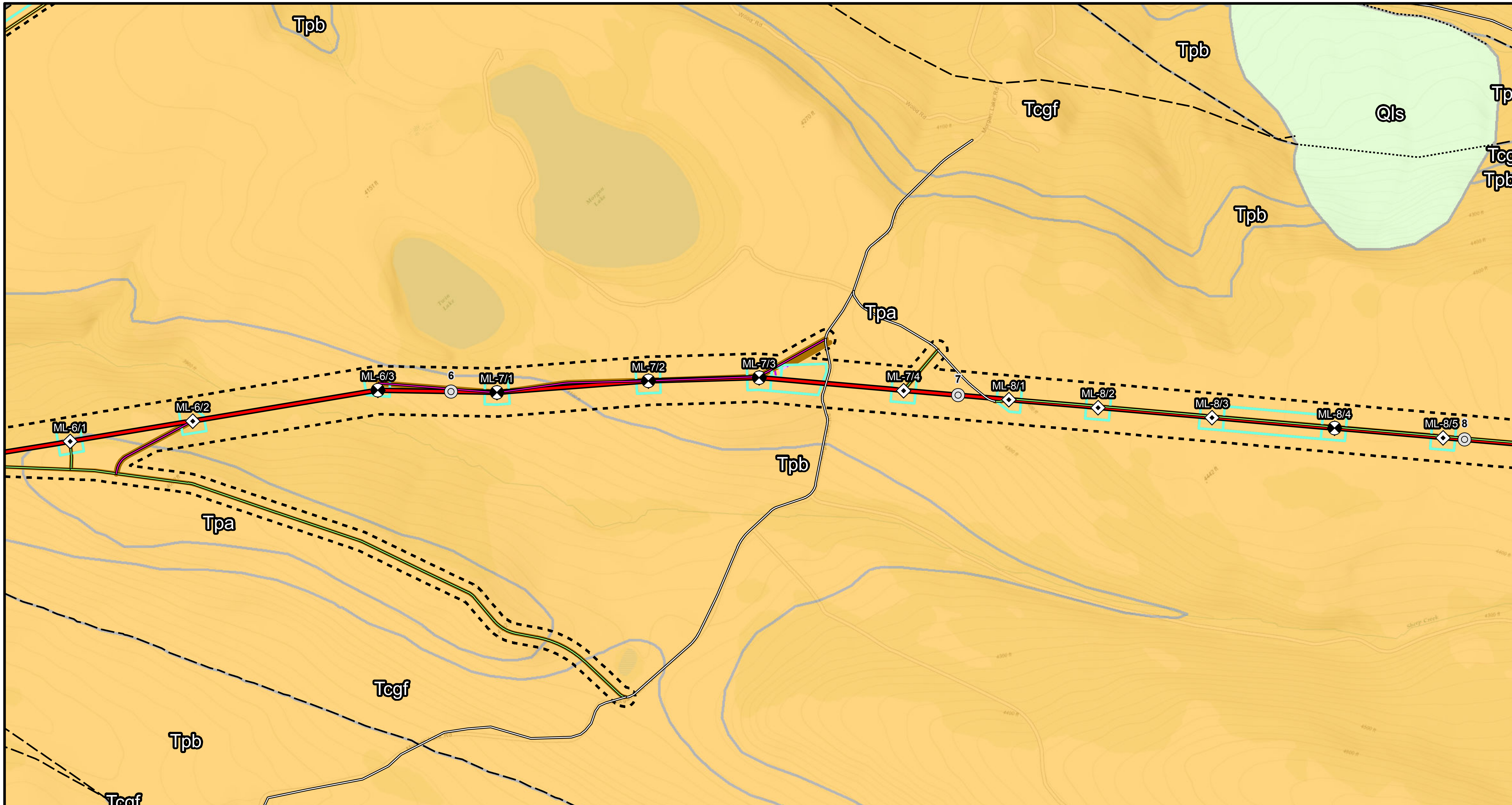


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November 2016 24-1-03820-005

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS



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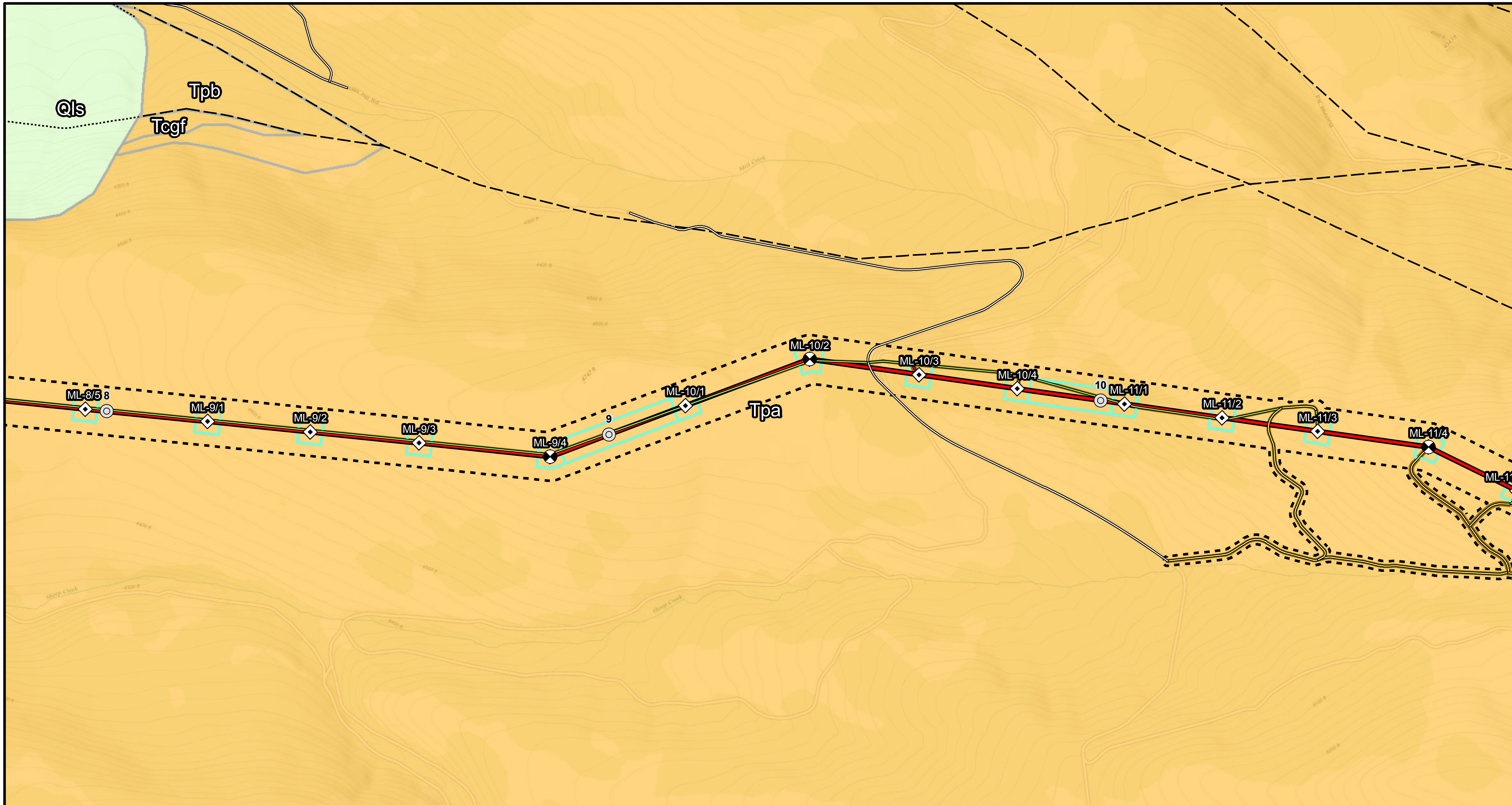


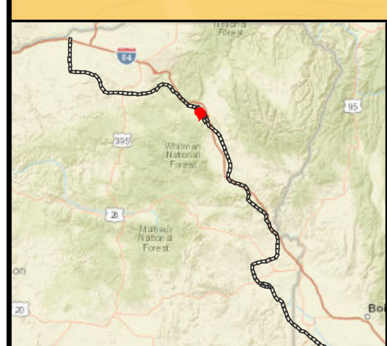

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY

November 2016 24-1-03820-005

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS



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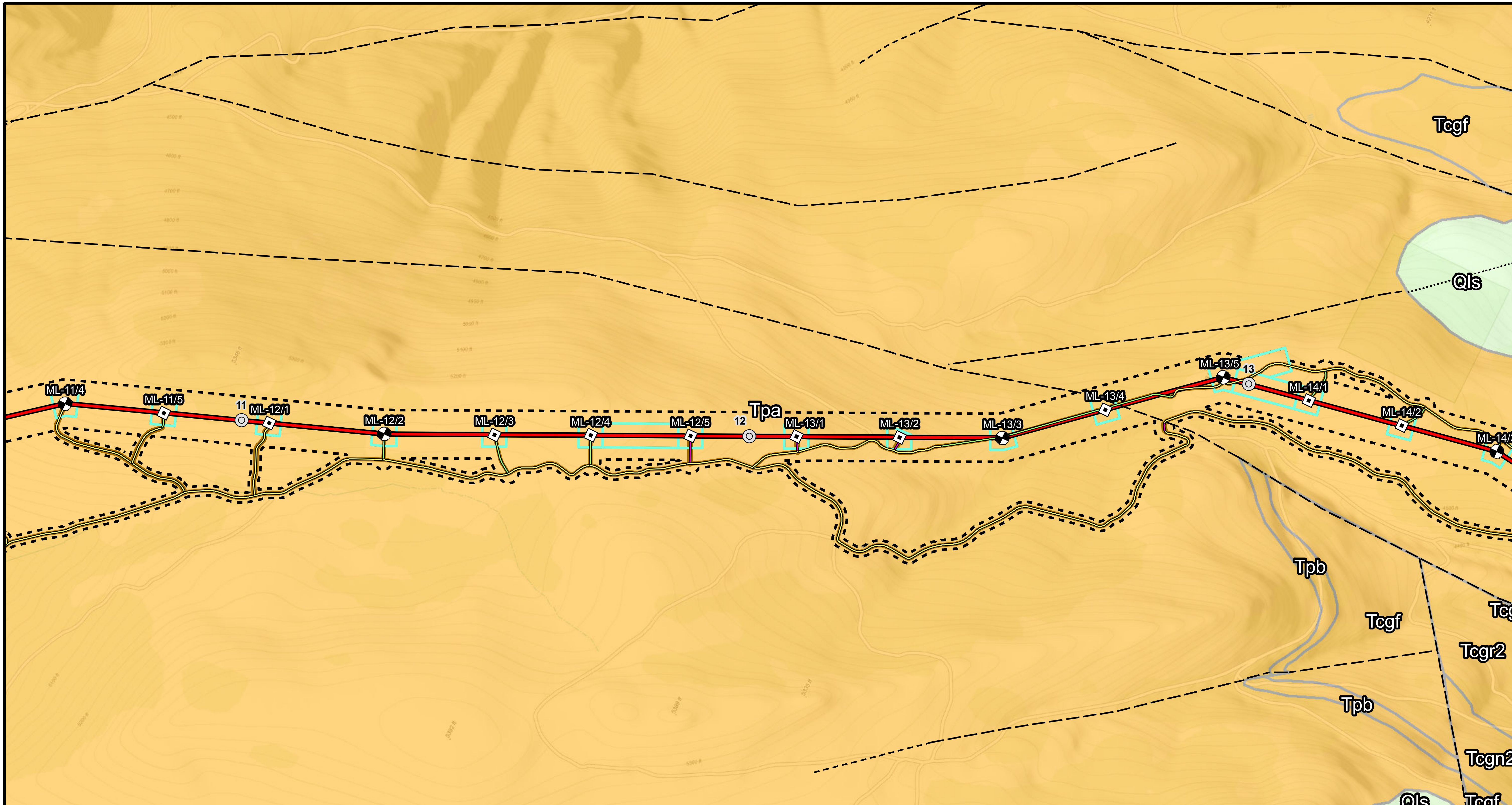


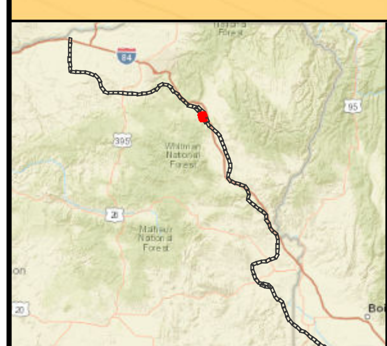

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
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**SURFICIAL GEOLOGY**

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

**FAULTS**

- Accurate
- Approximate
- Concealed
- Inferred
- USGS Mapped Fault
- No Data

**ROADS**

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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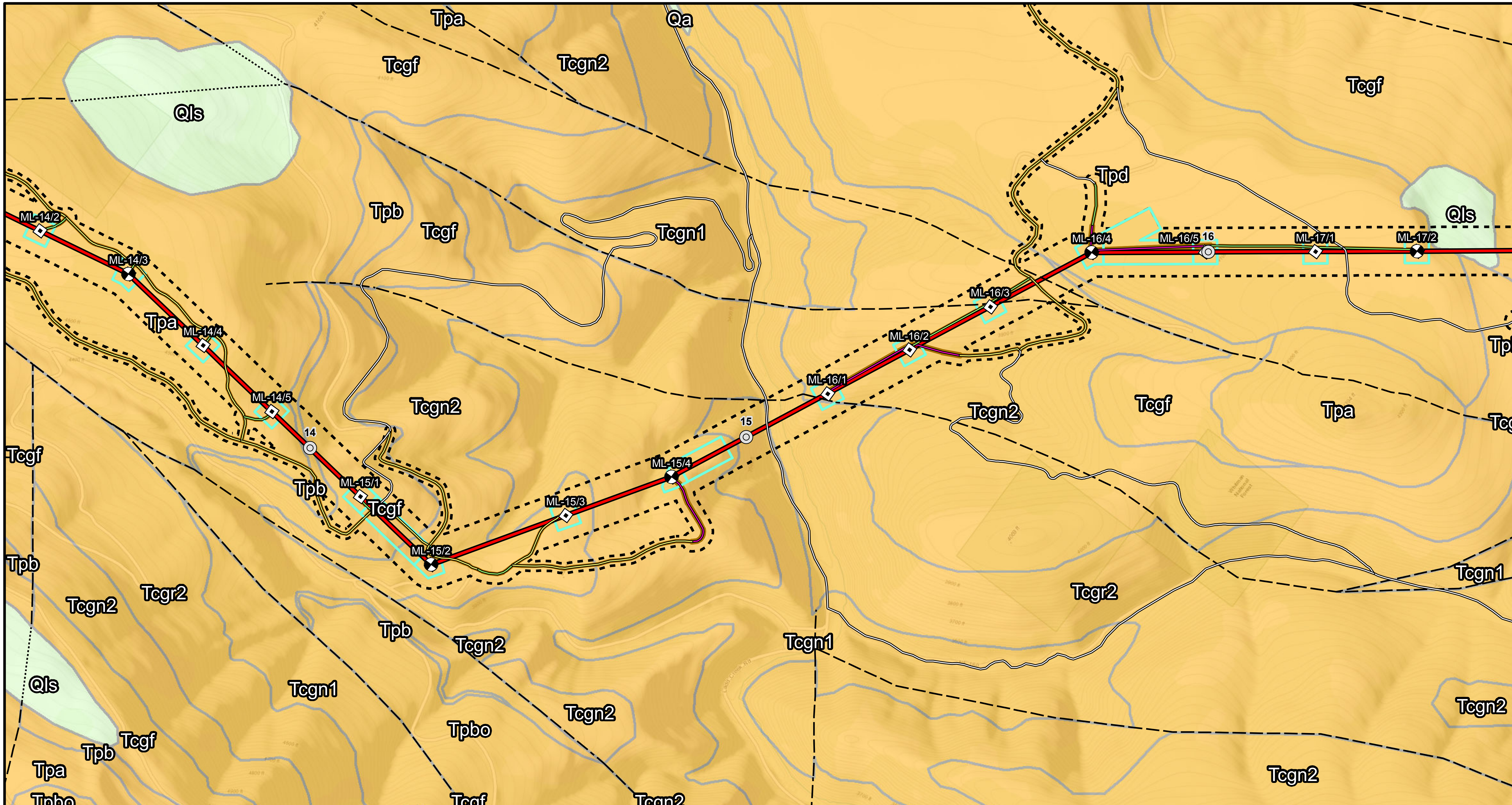


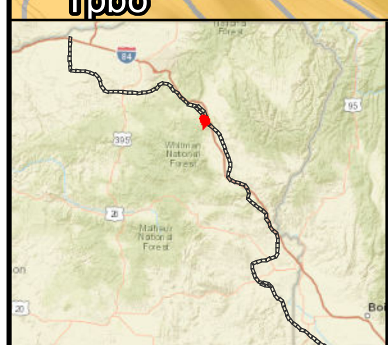

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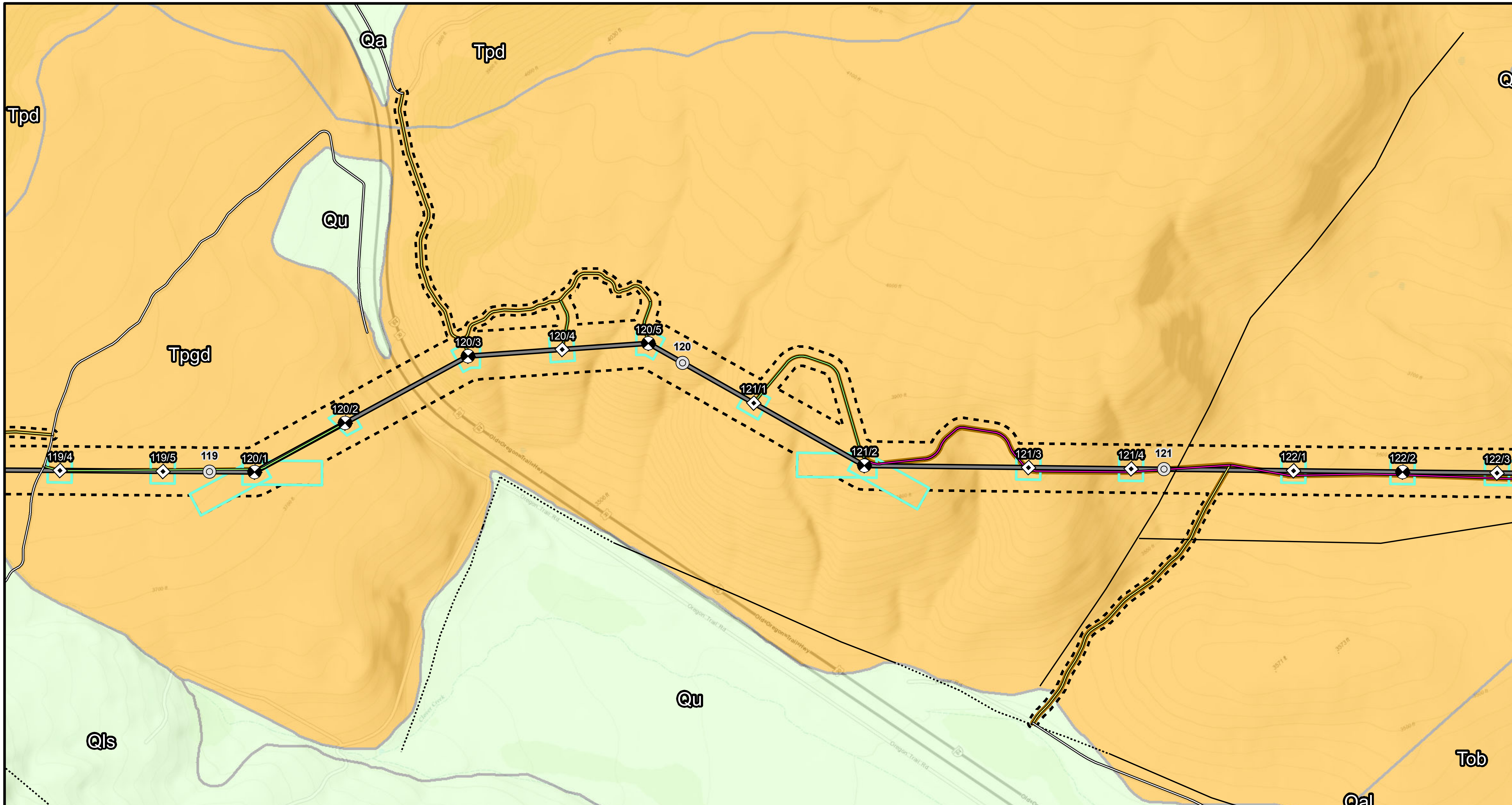


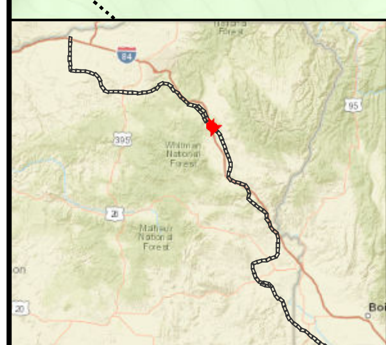

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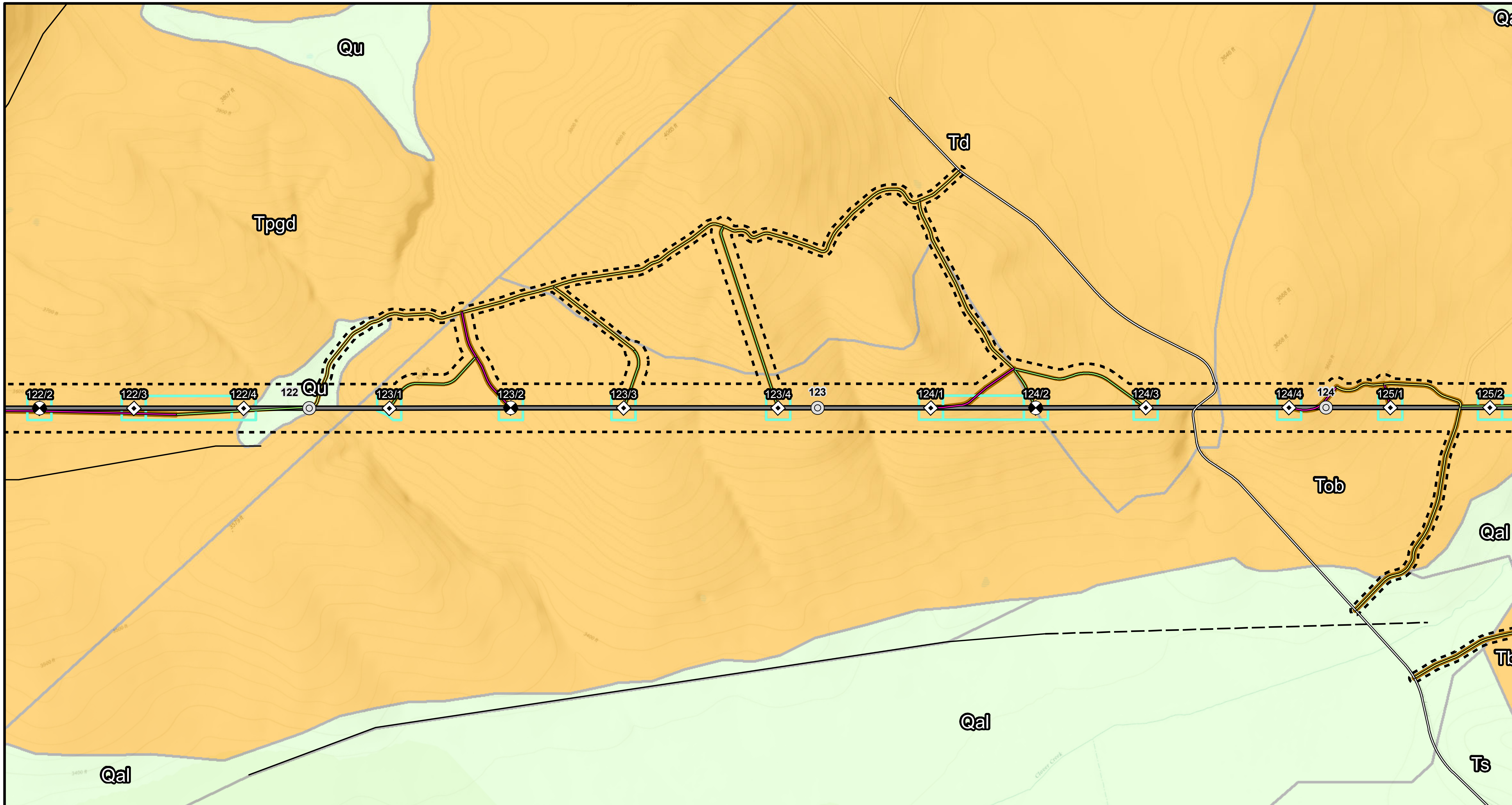


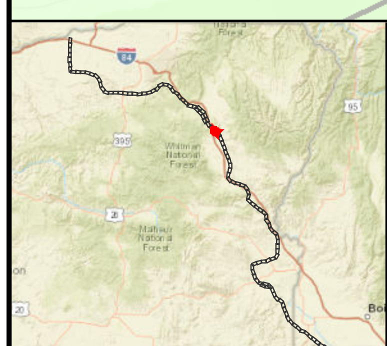

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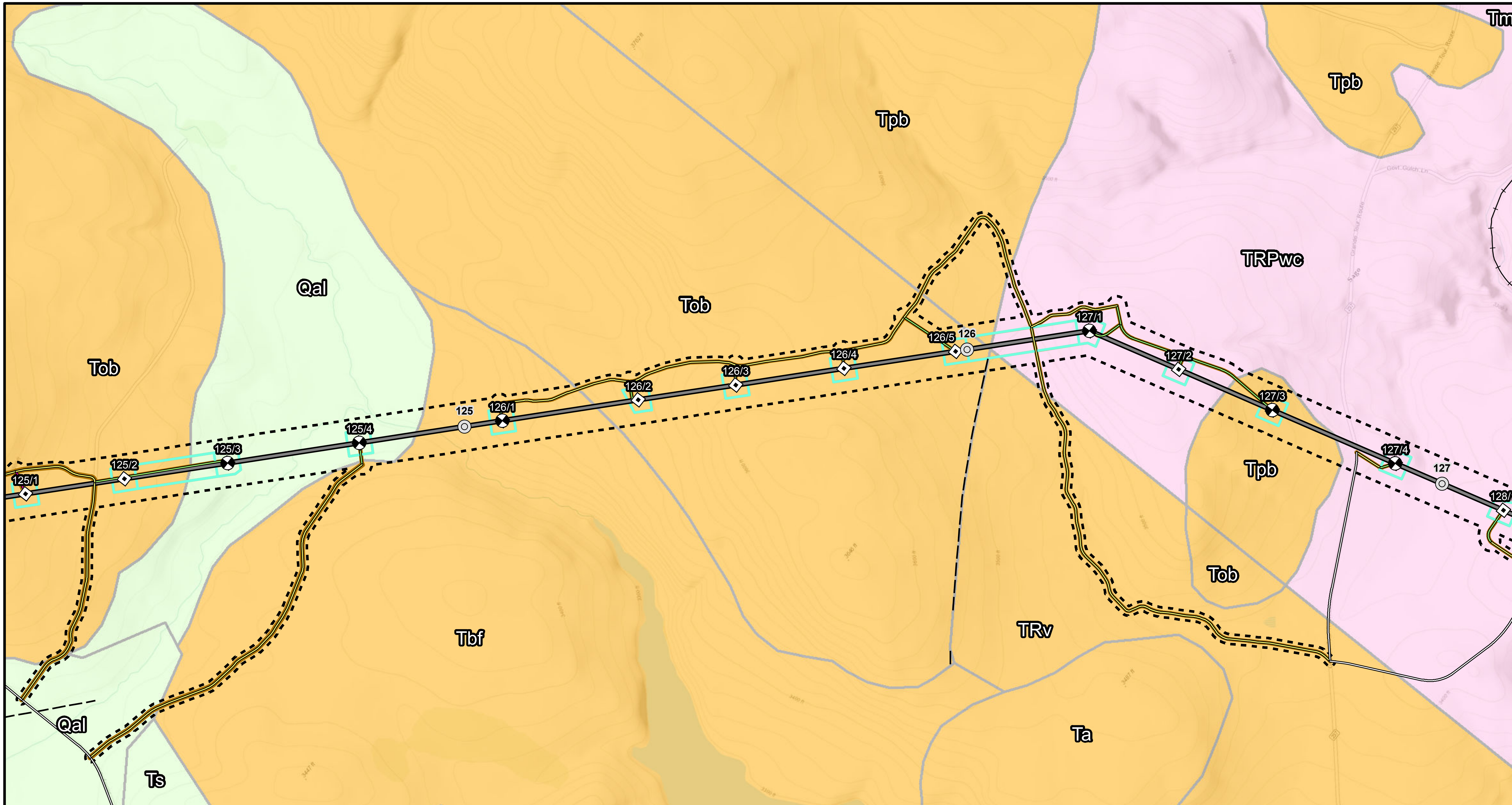


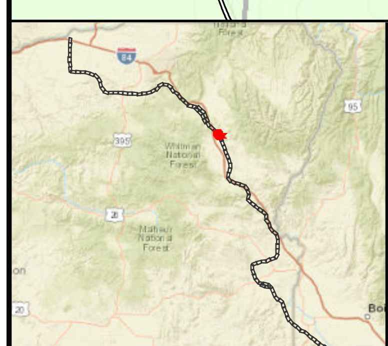

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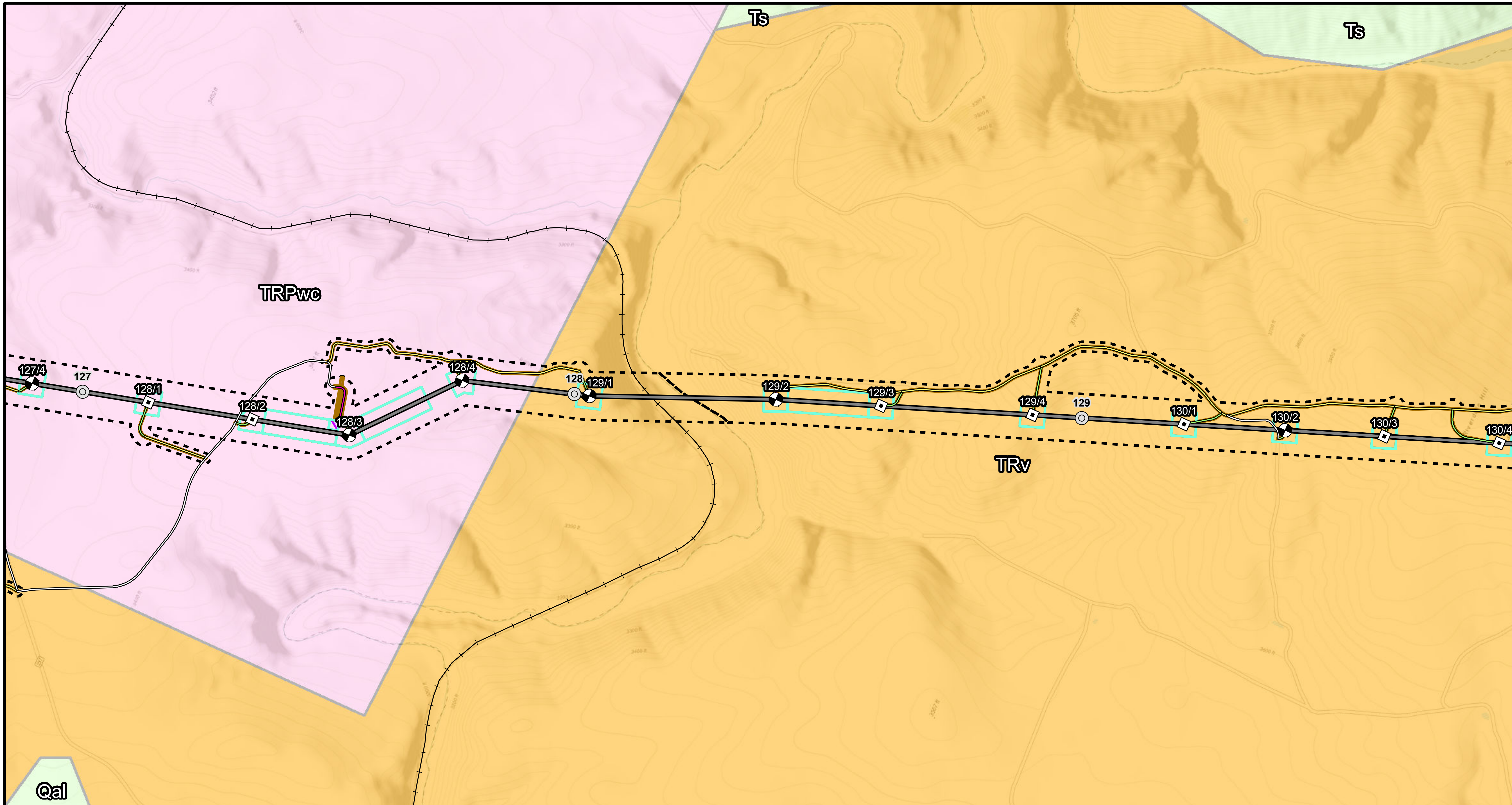


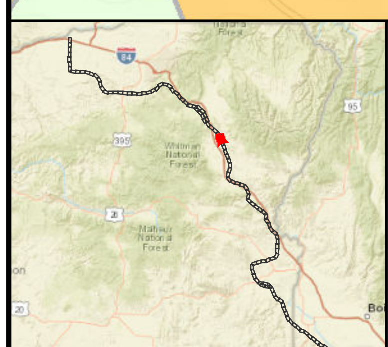

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## GEOLOGY

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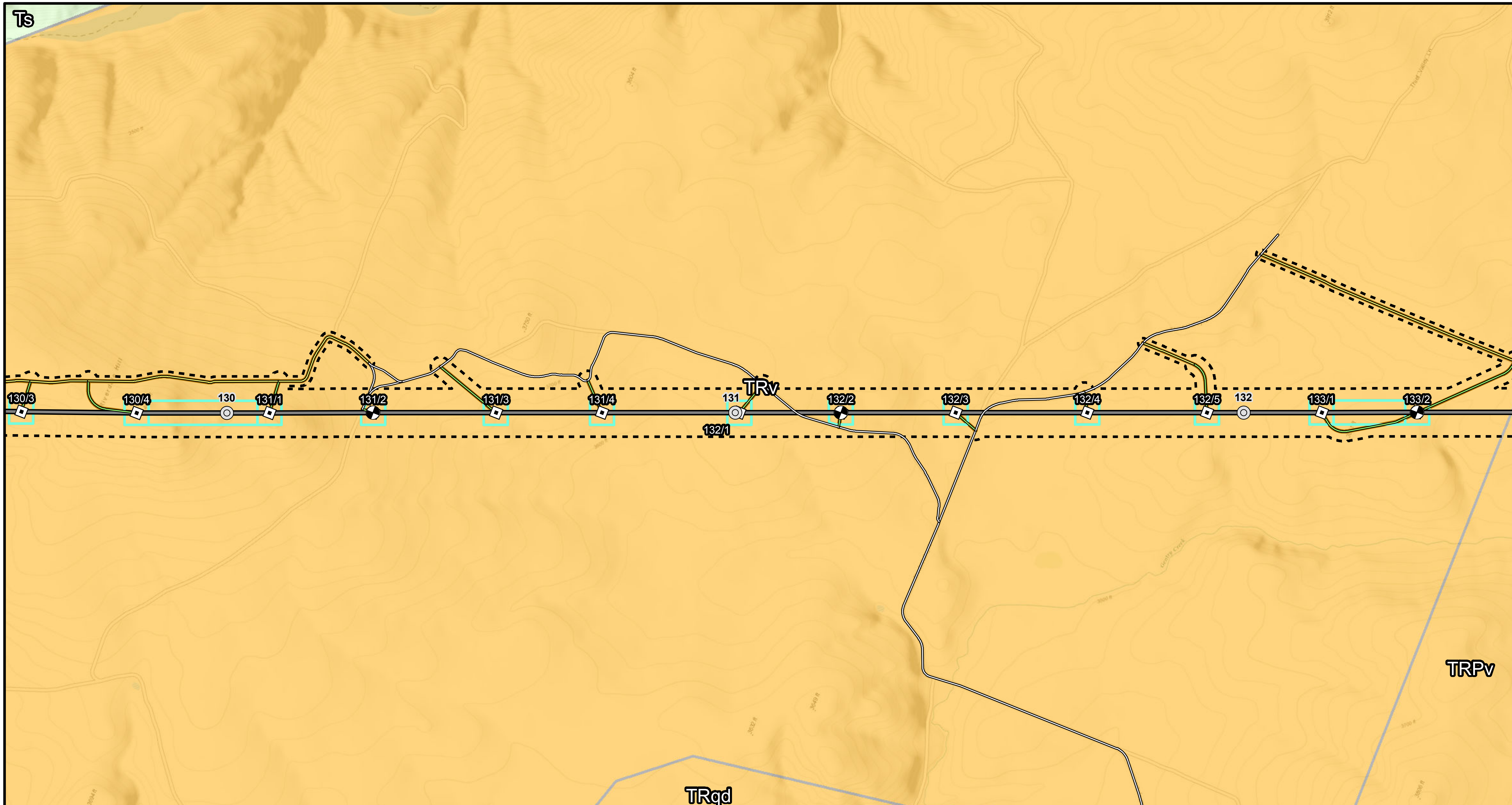


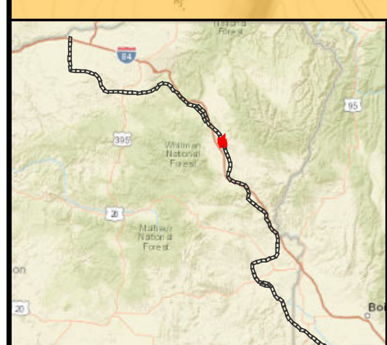

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Oregon - Idaho

**GEOLOGY**

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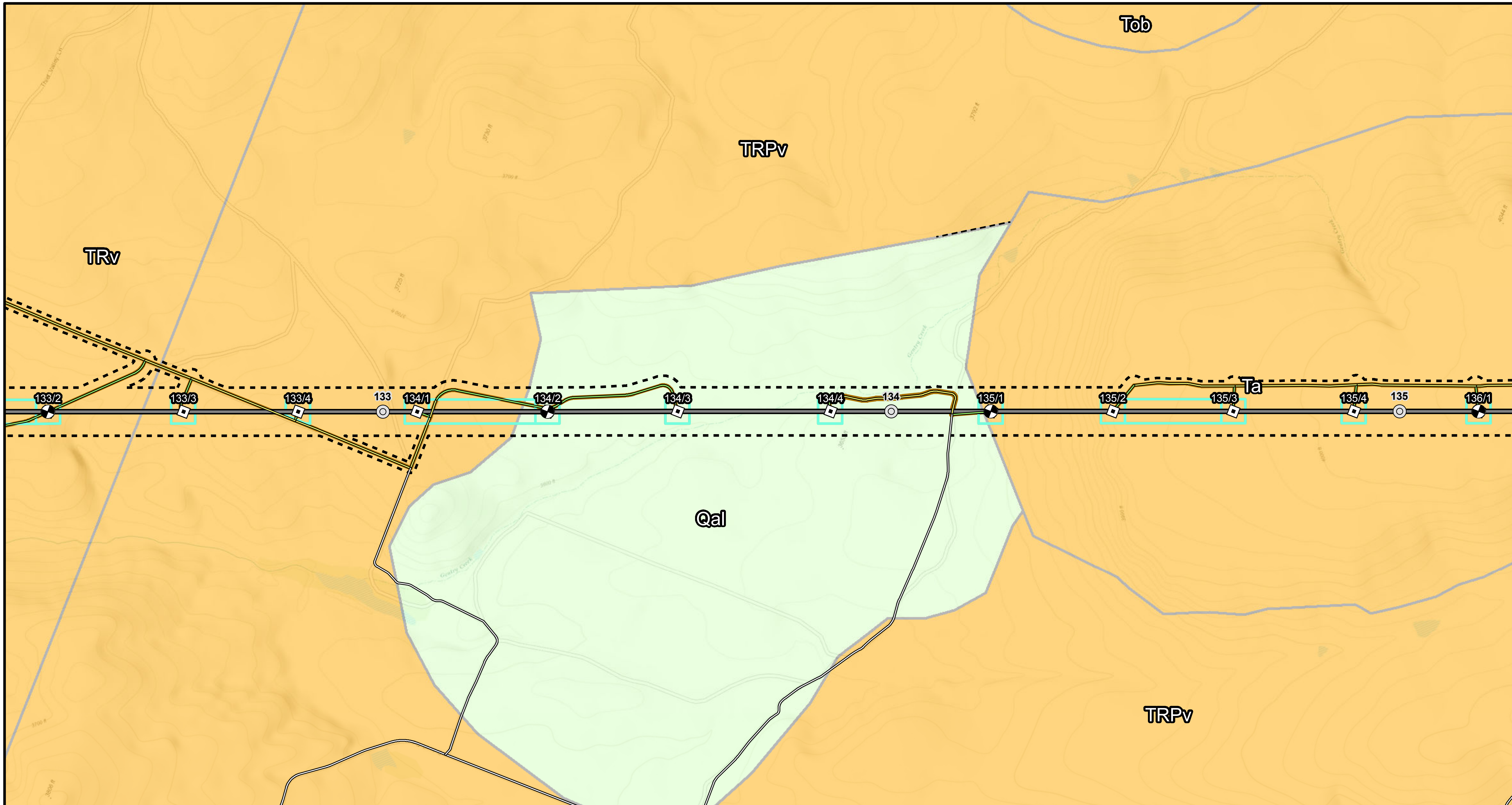


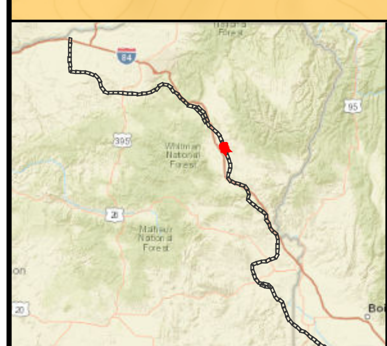

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Boardman - Hemingway
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Oregon - Idaho

# GEOLOGY

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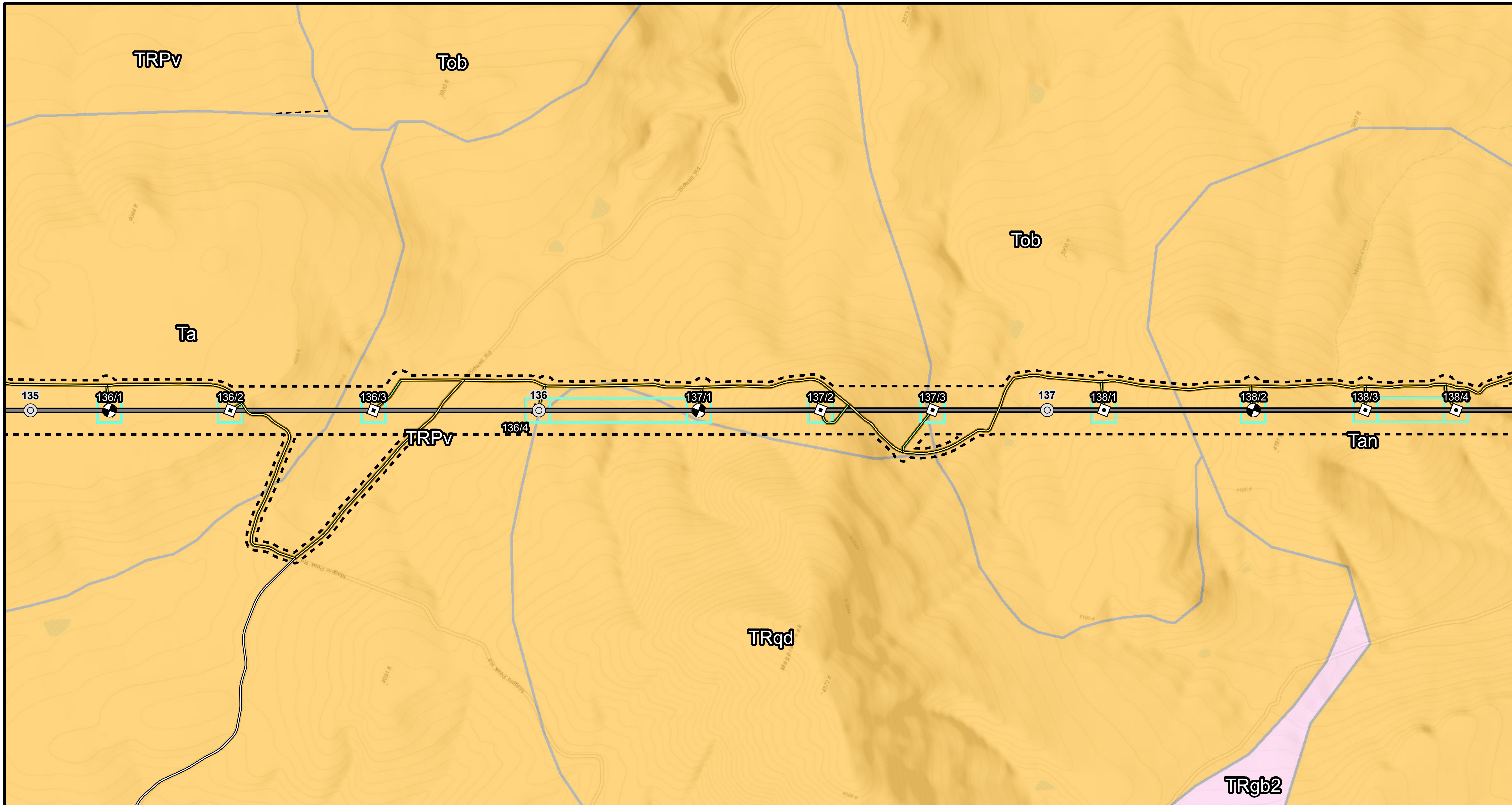


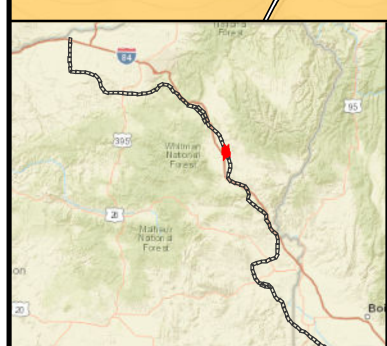

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Oregon - Idaho

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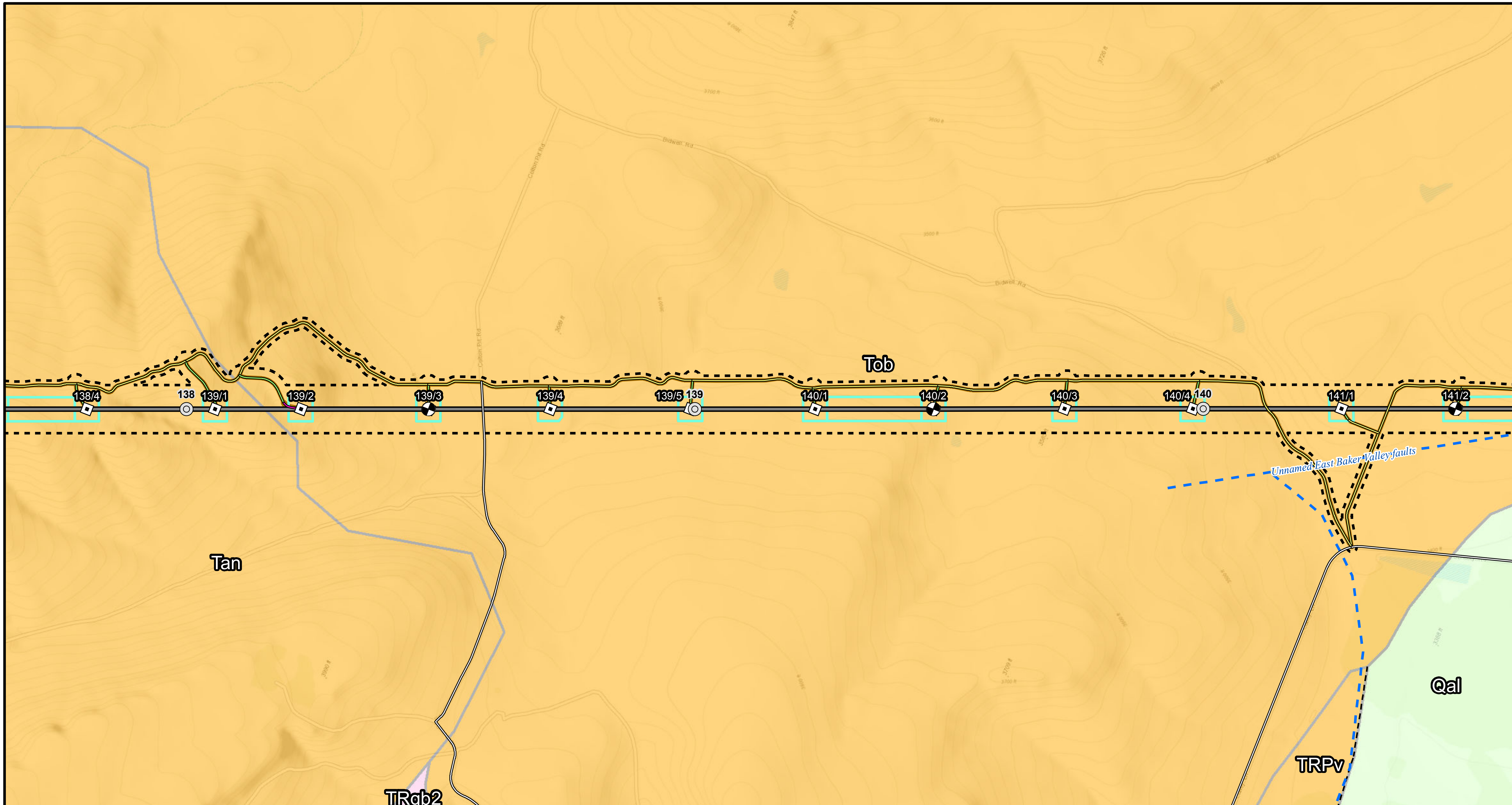


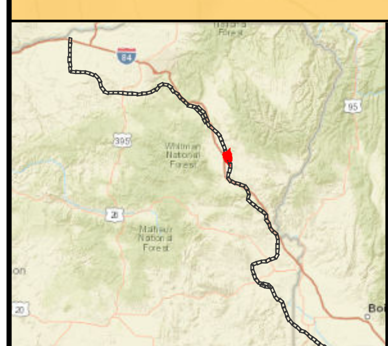

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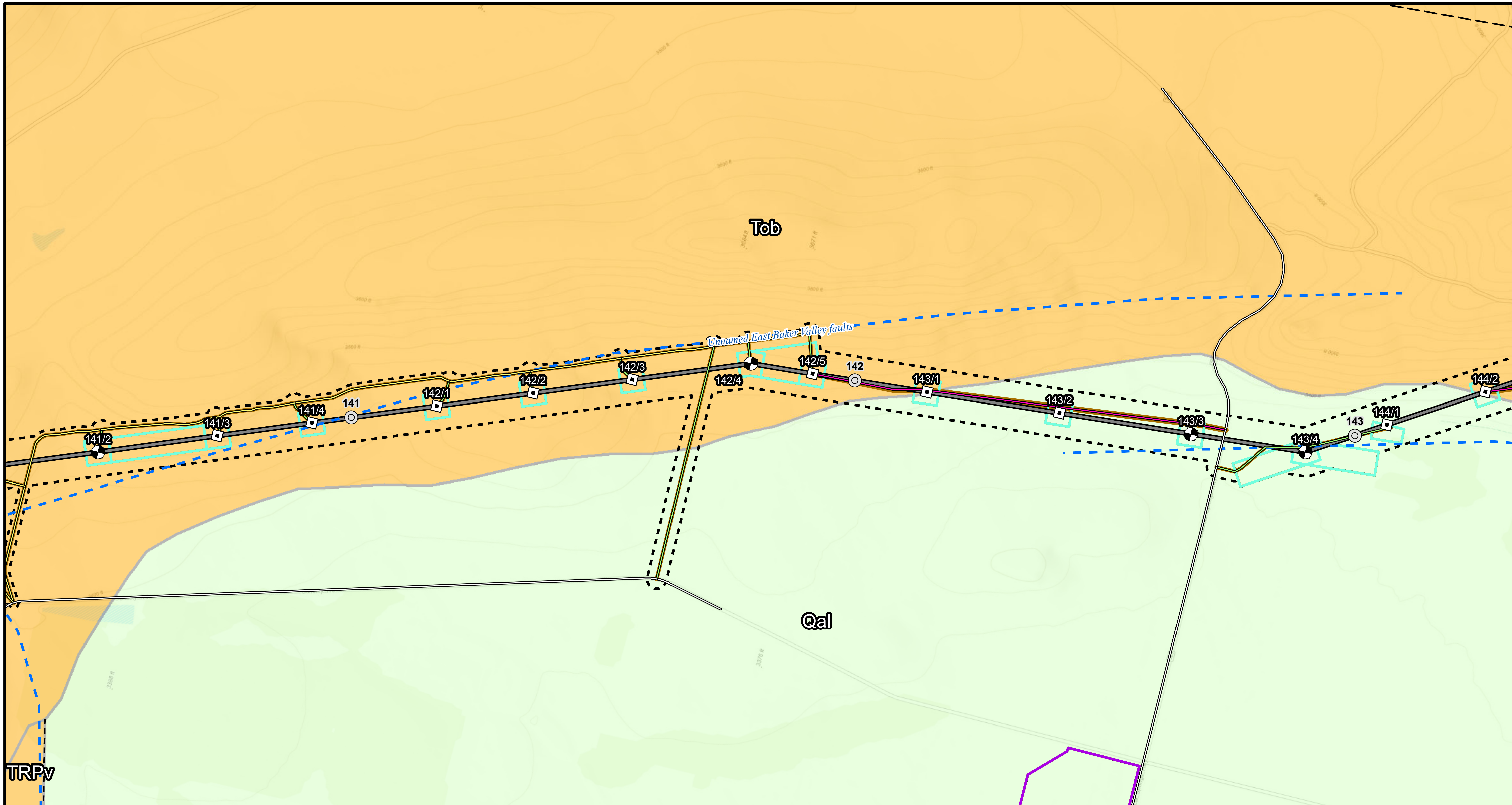


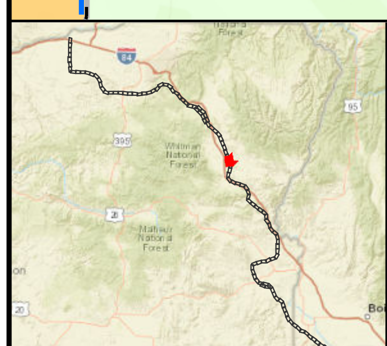

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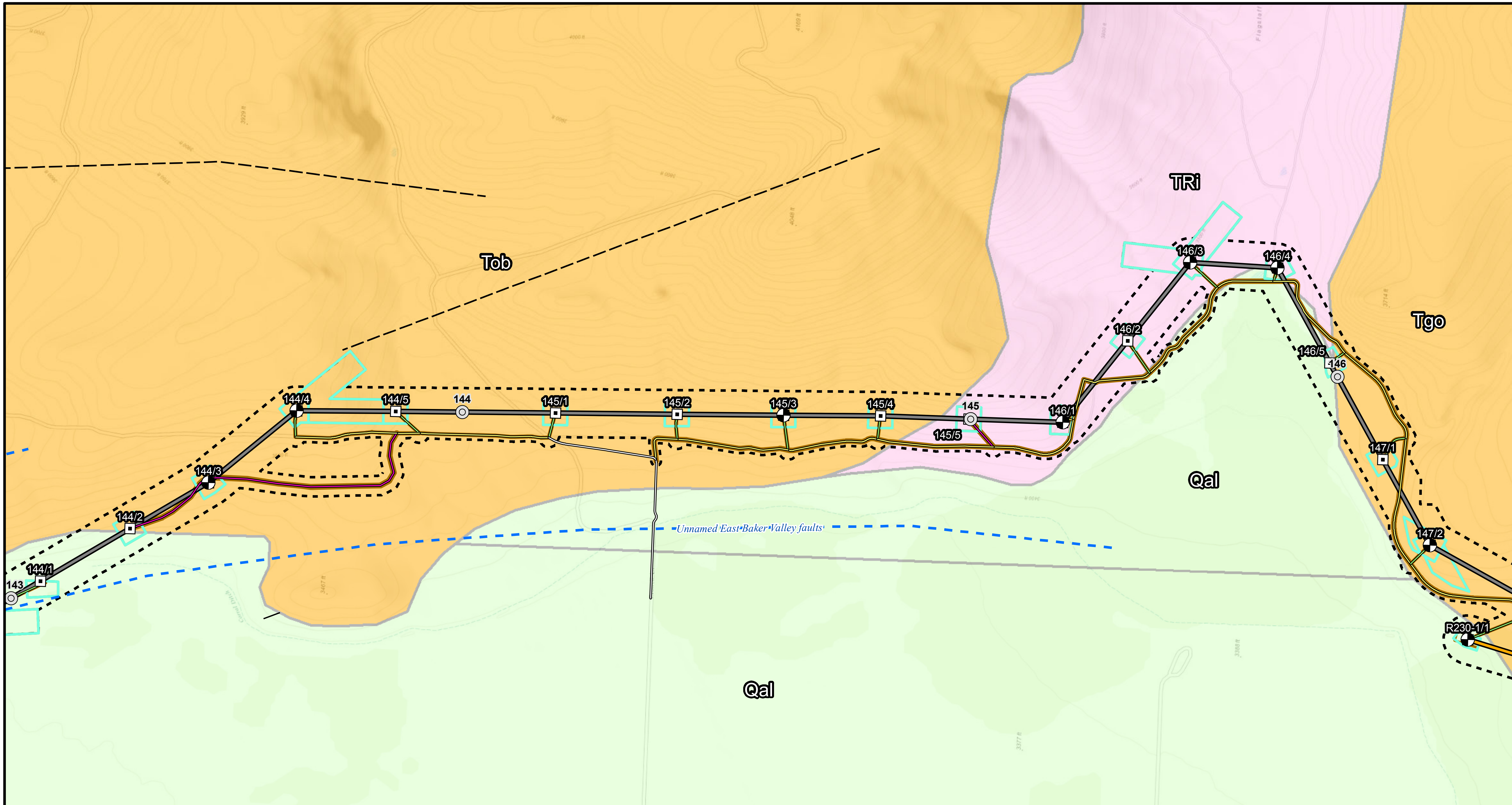


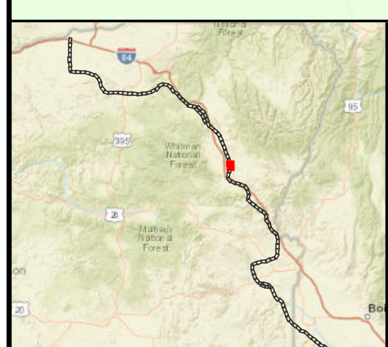

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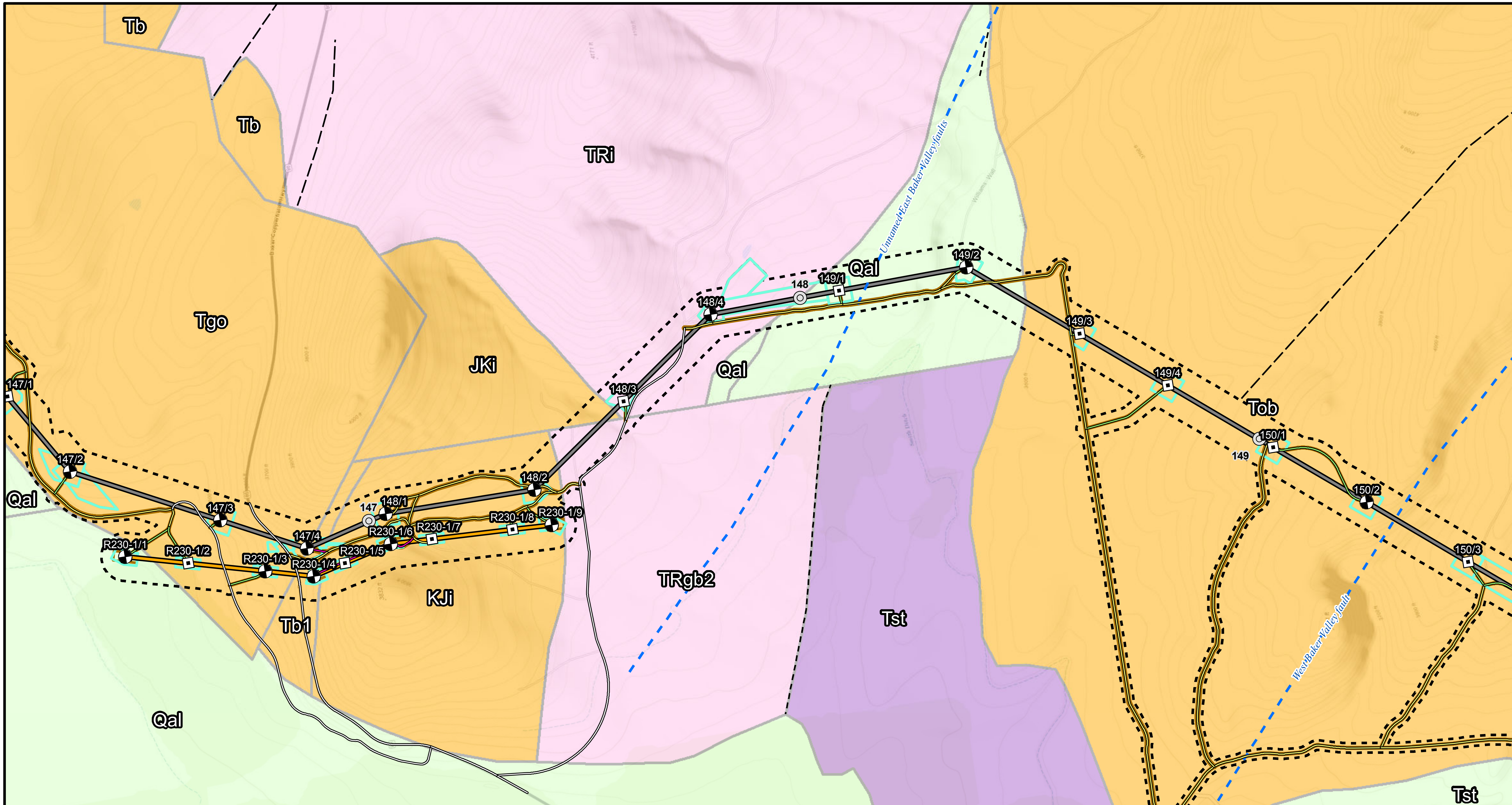


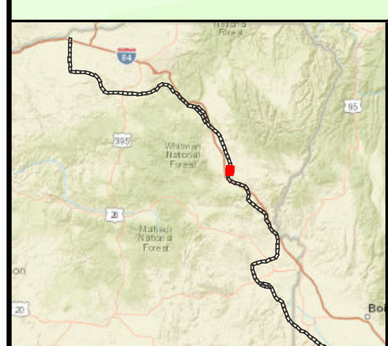

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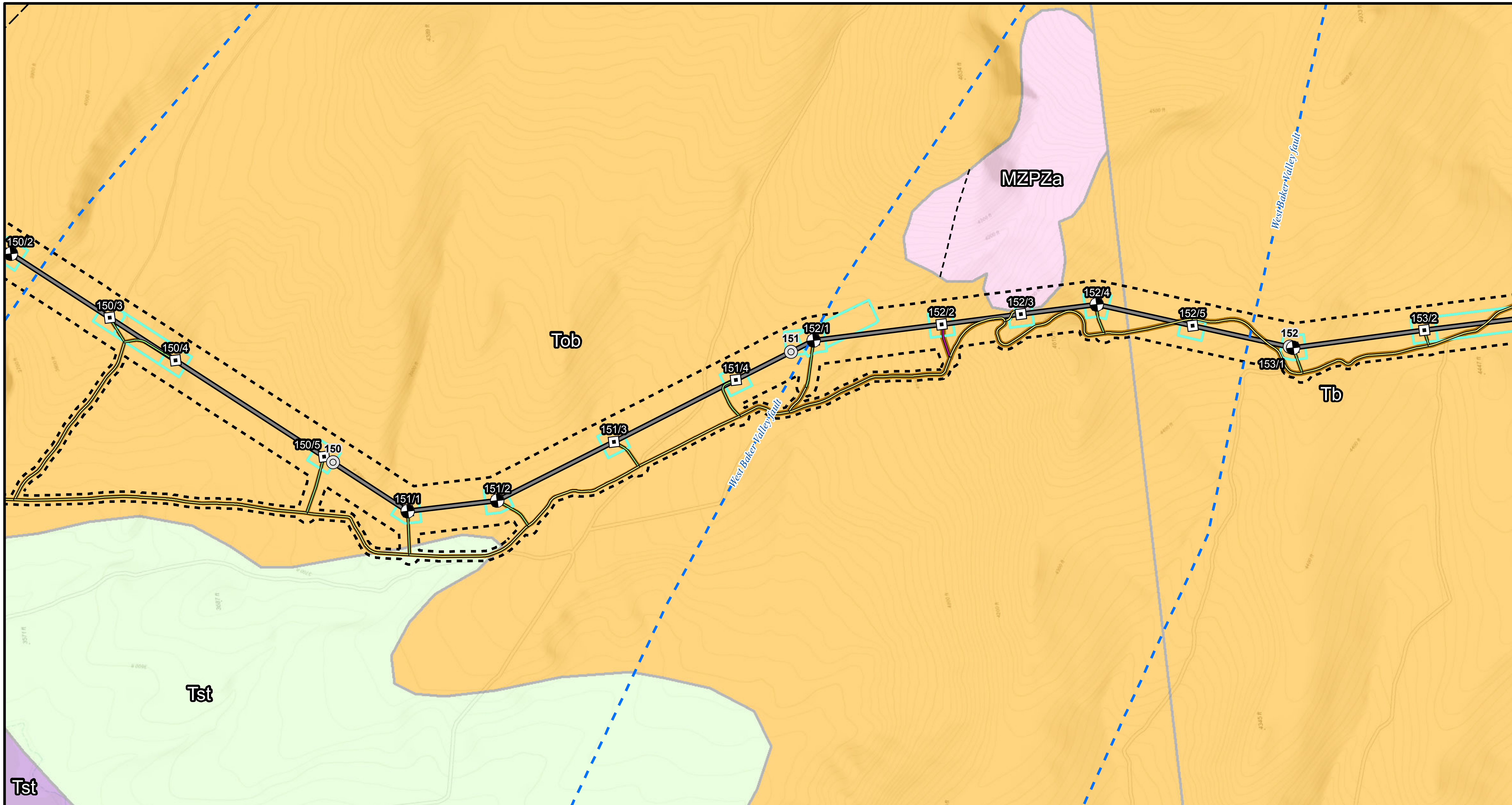


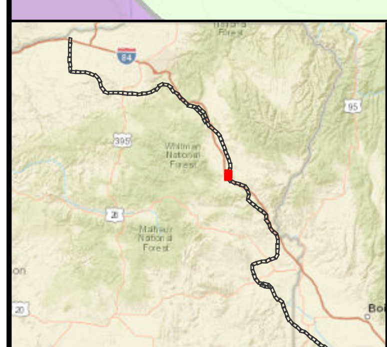

## LEGEND

**TRANSMISSION FEATURES**

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**FAULTS**

- Accurate
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- Concealed
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- USGS Mapped Fault
- No Data

**ROADS**

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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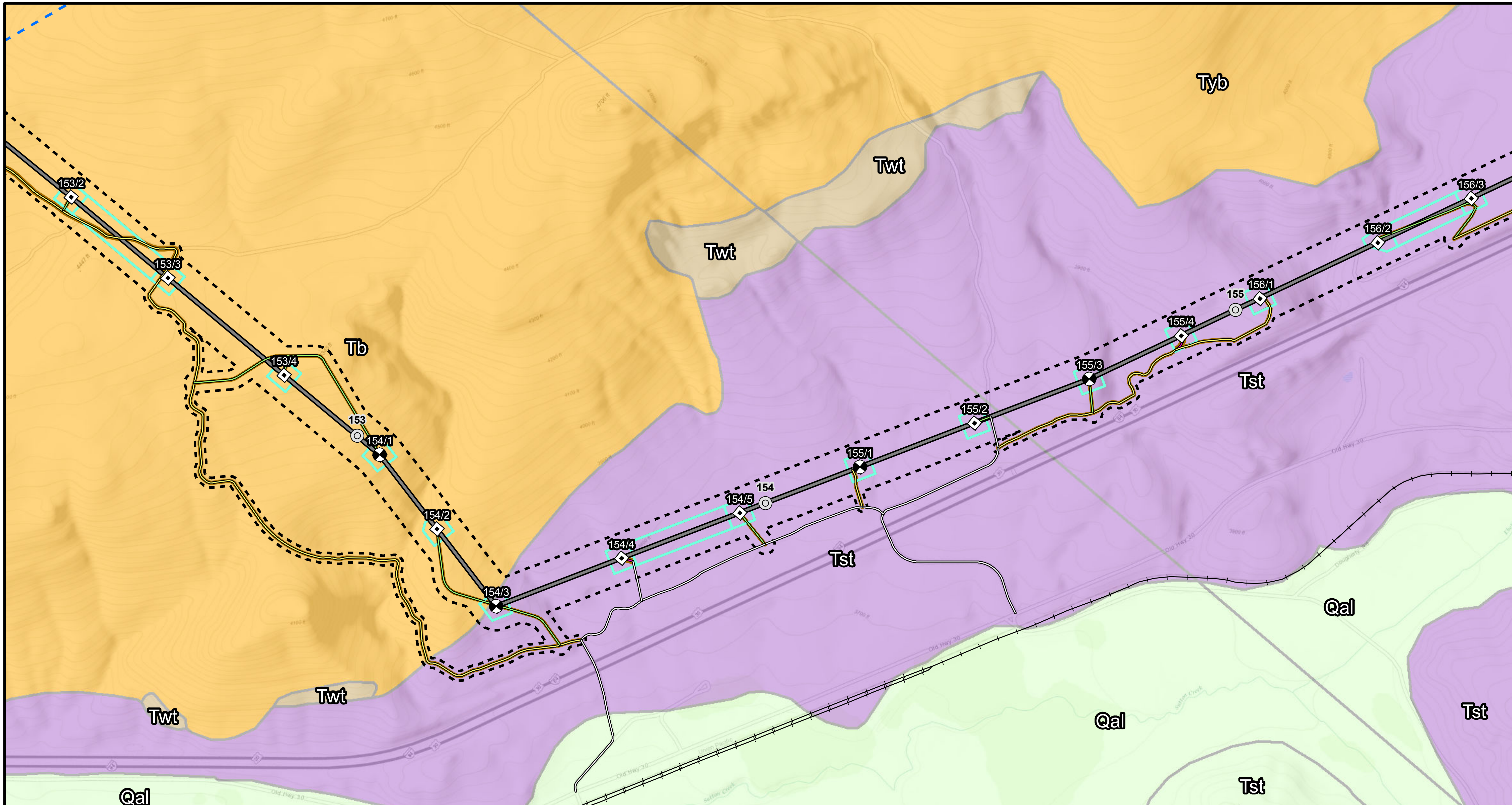


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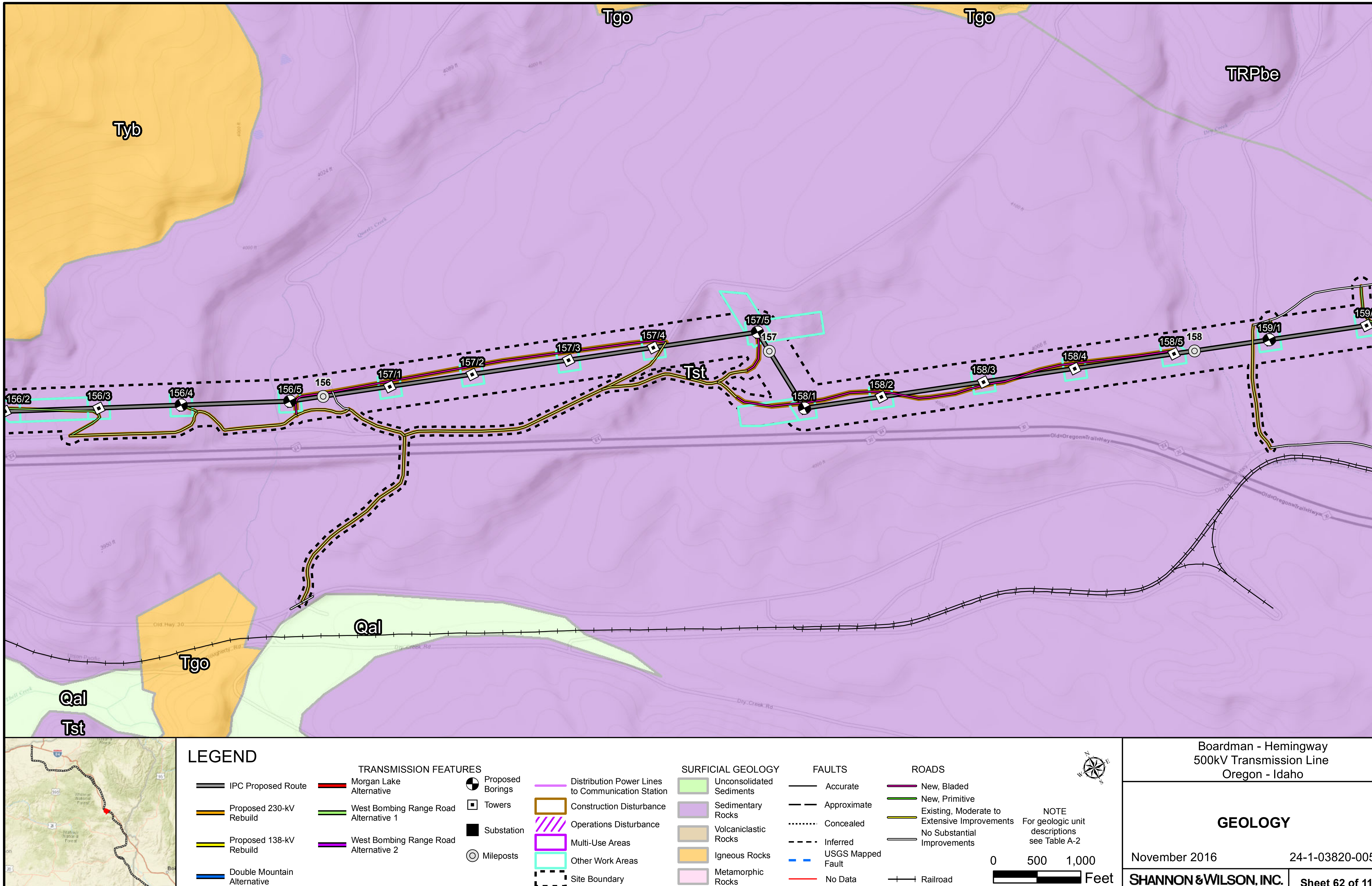


Boardman - Hemingway
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Oregon - Idaho

**GEOLOGY**

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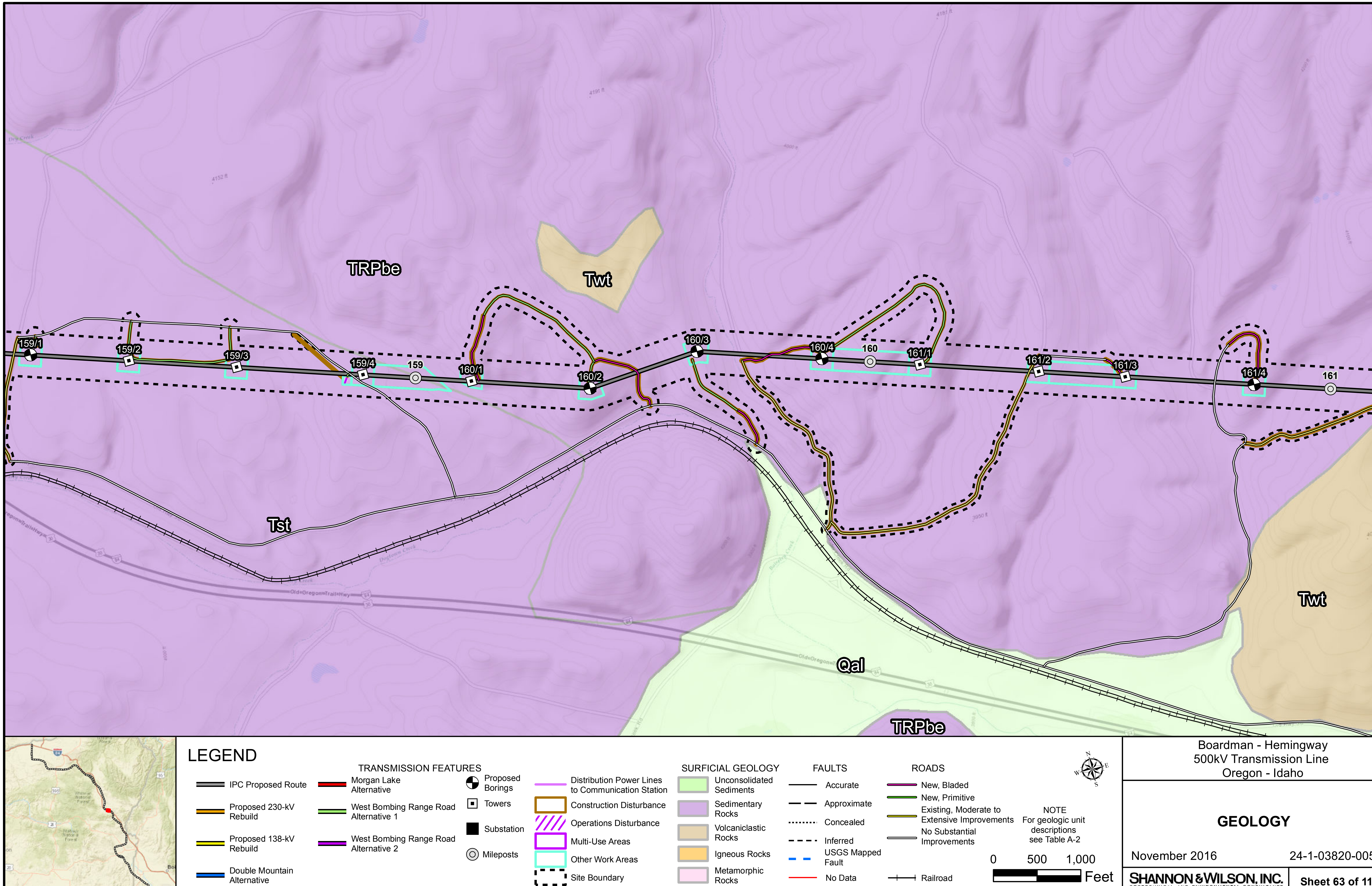


Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

**GEOLOGY**

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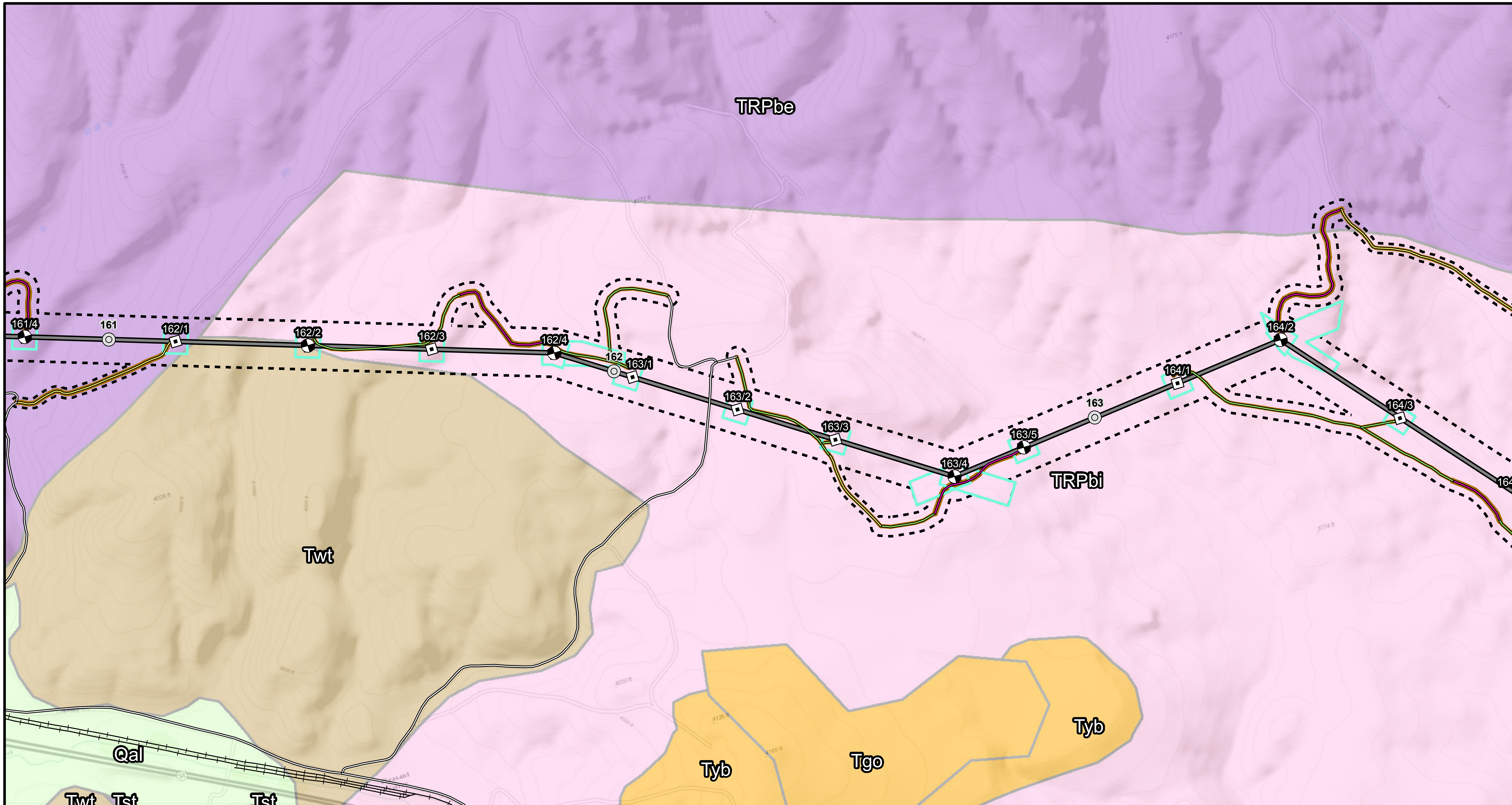


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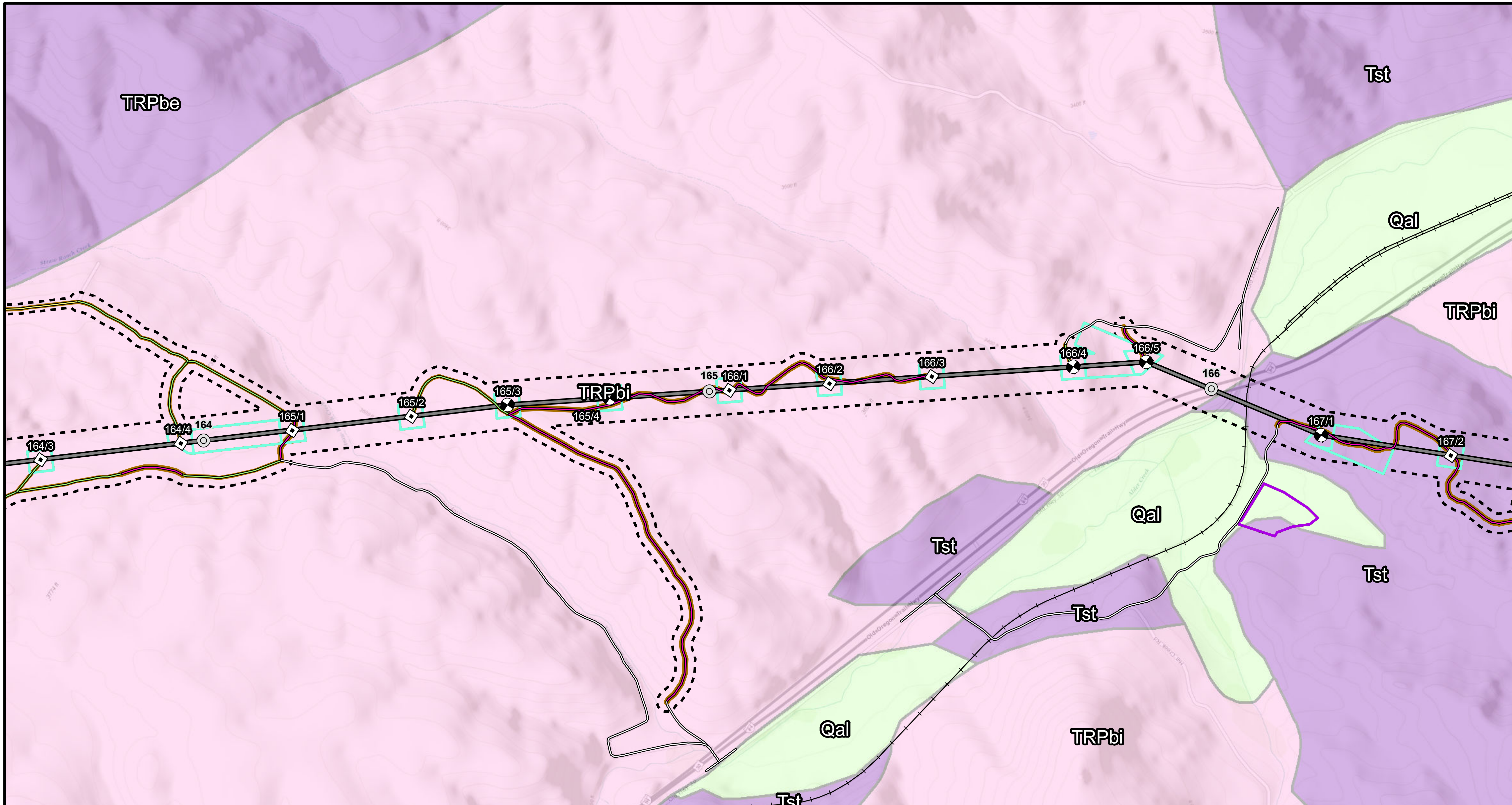


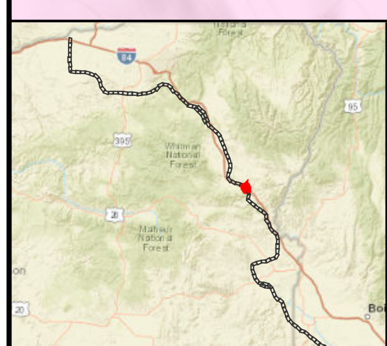

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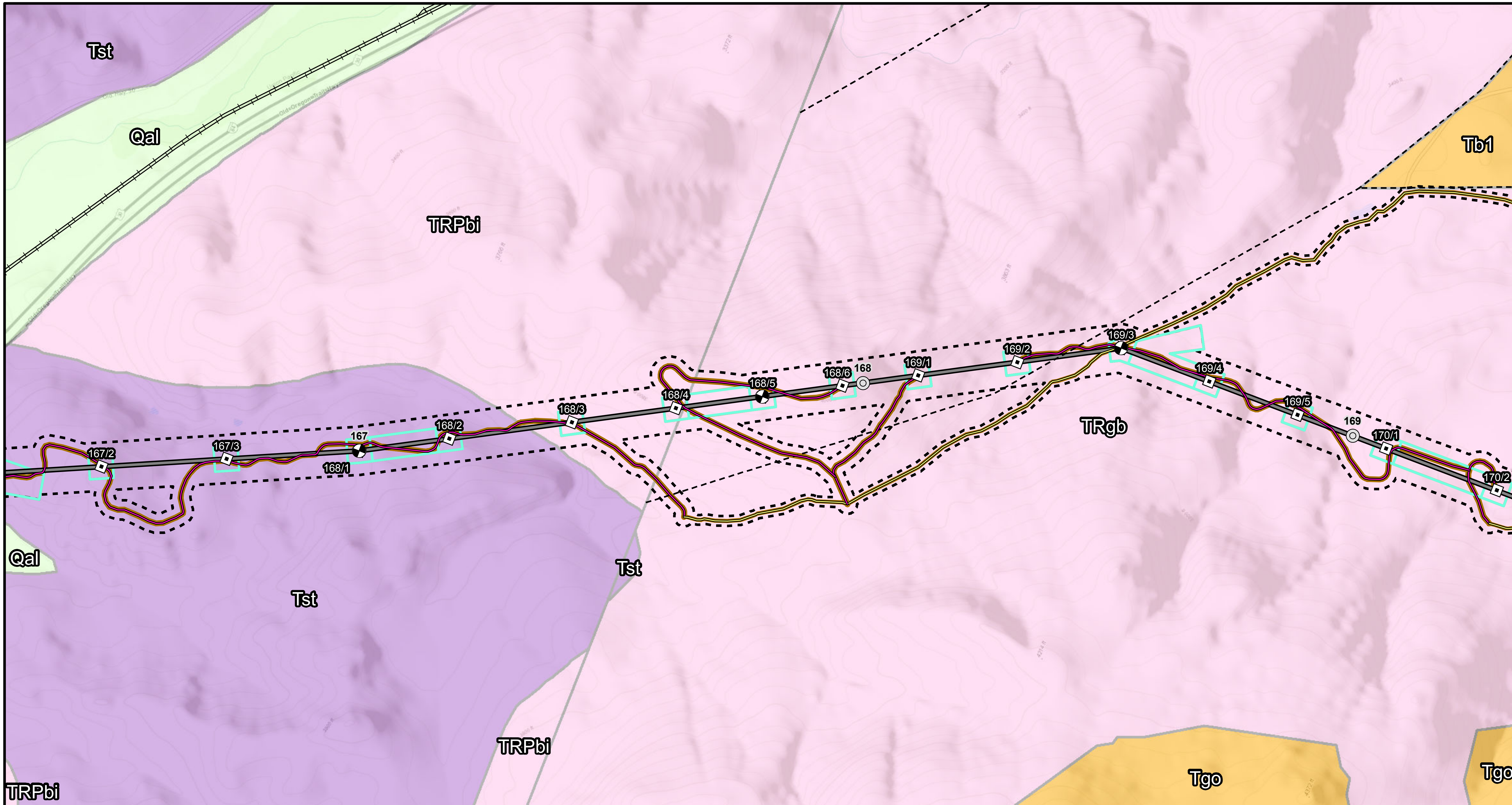


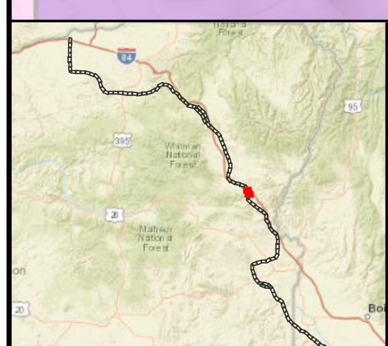

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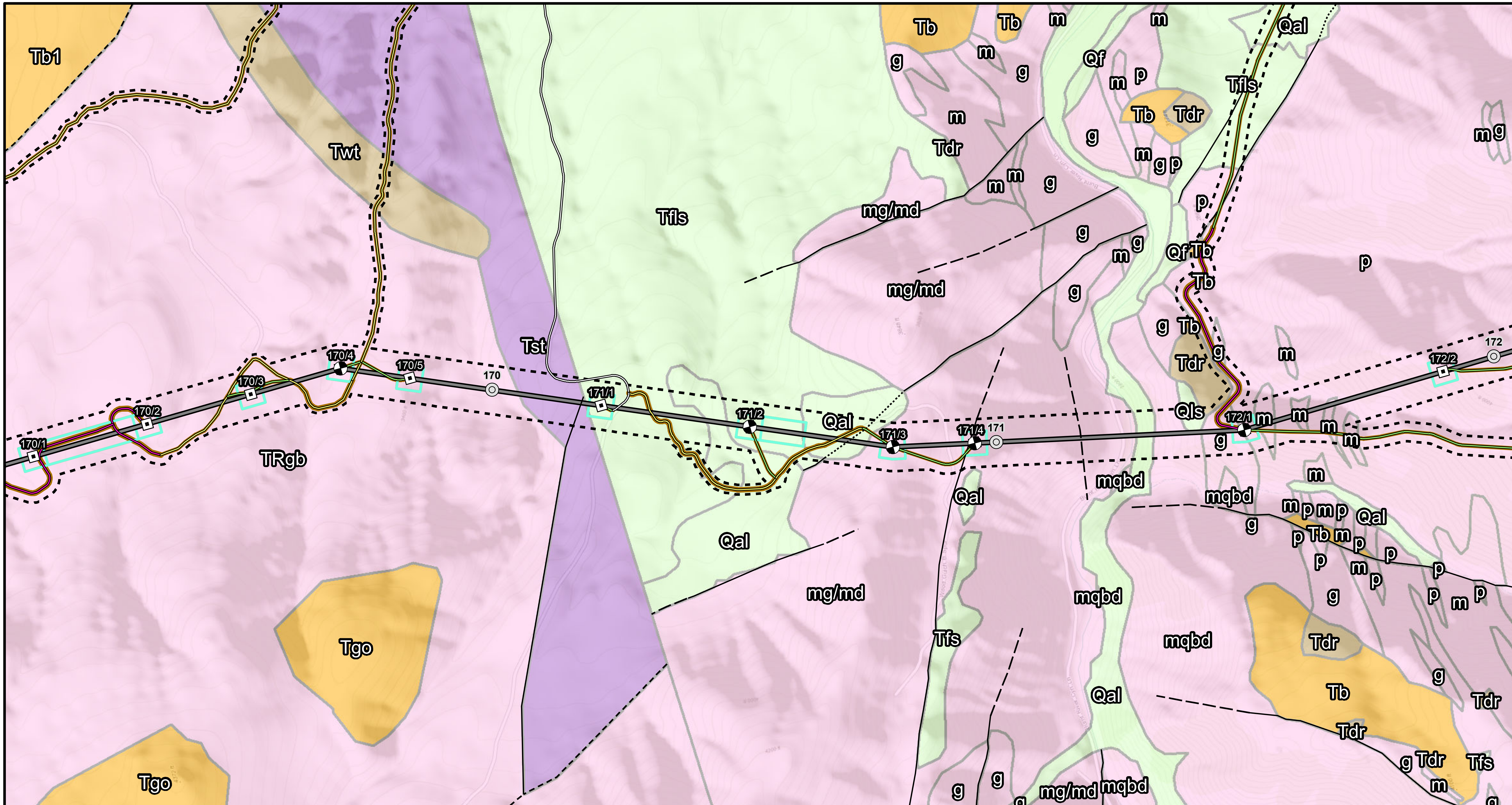


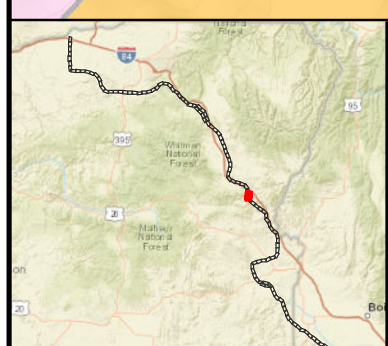

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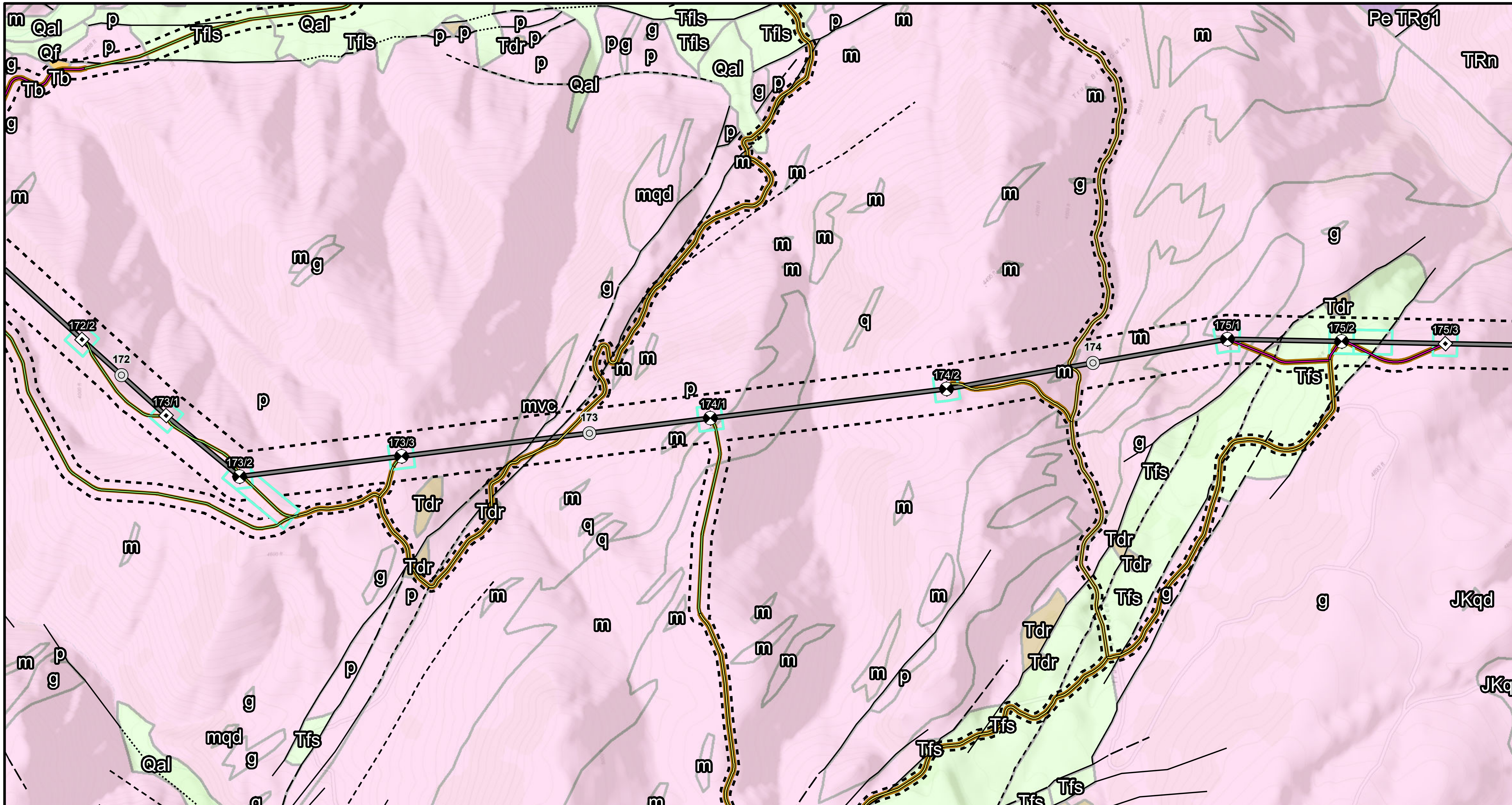


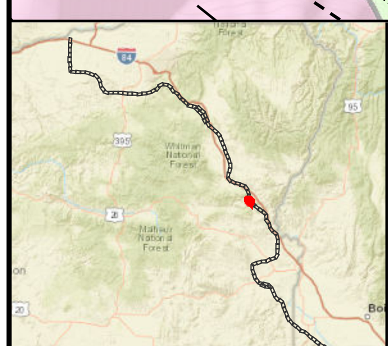

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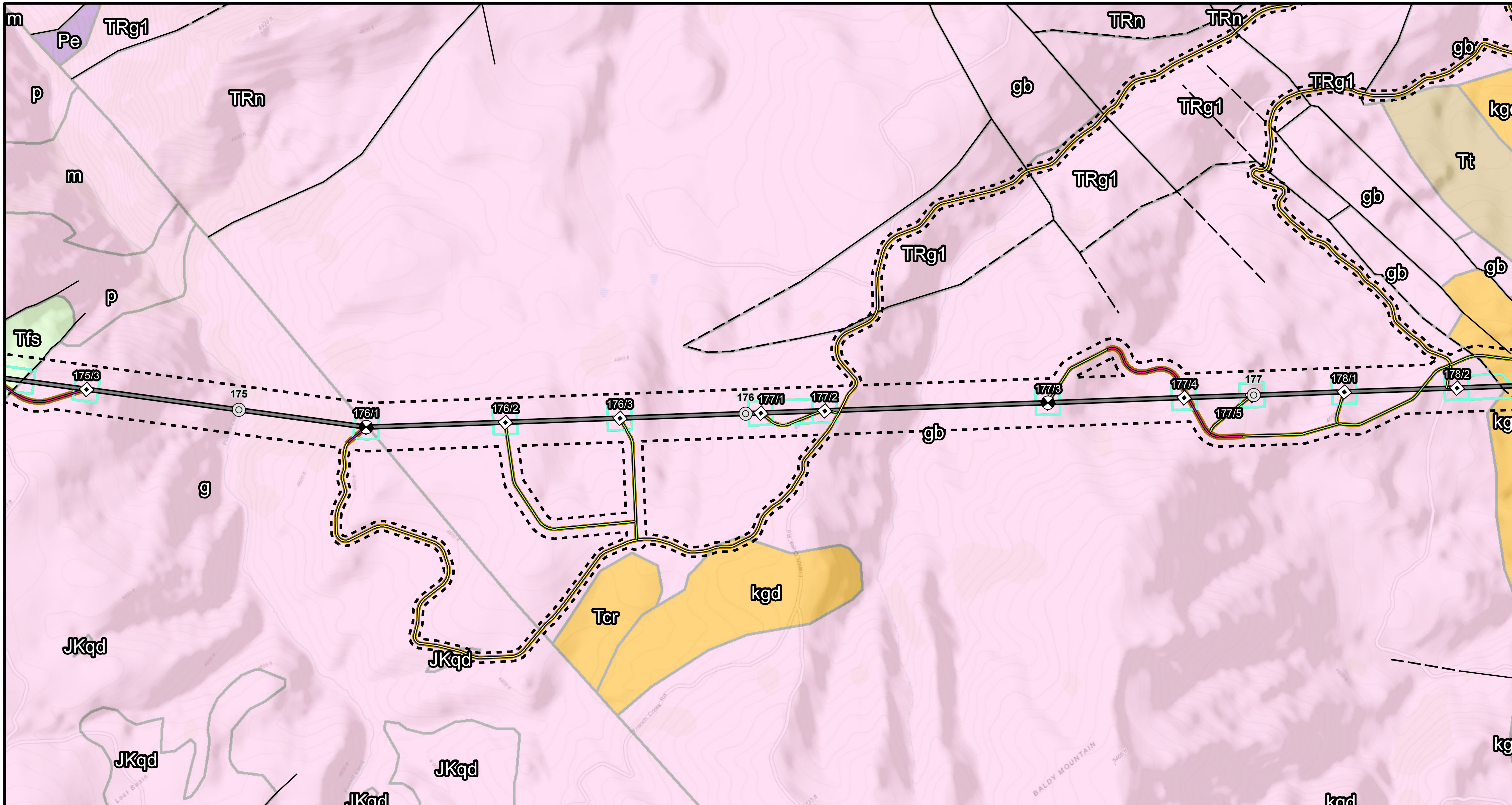


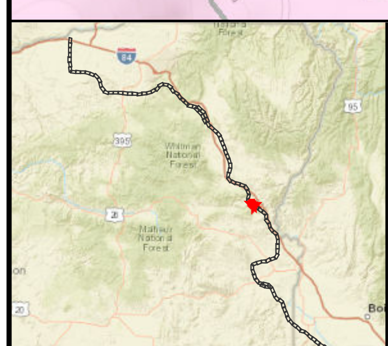

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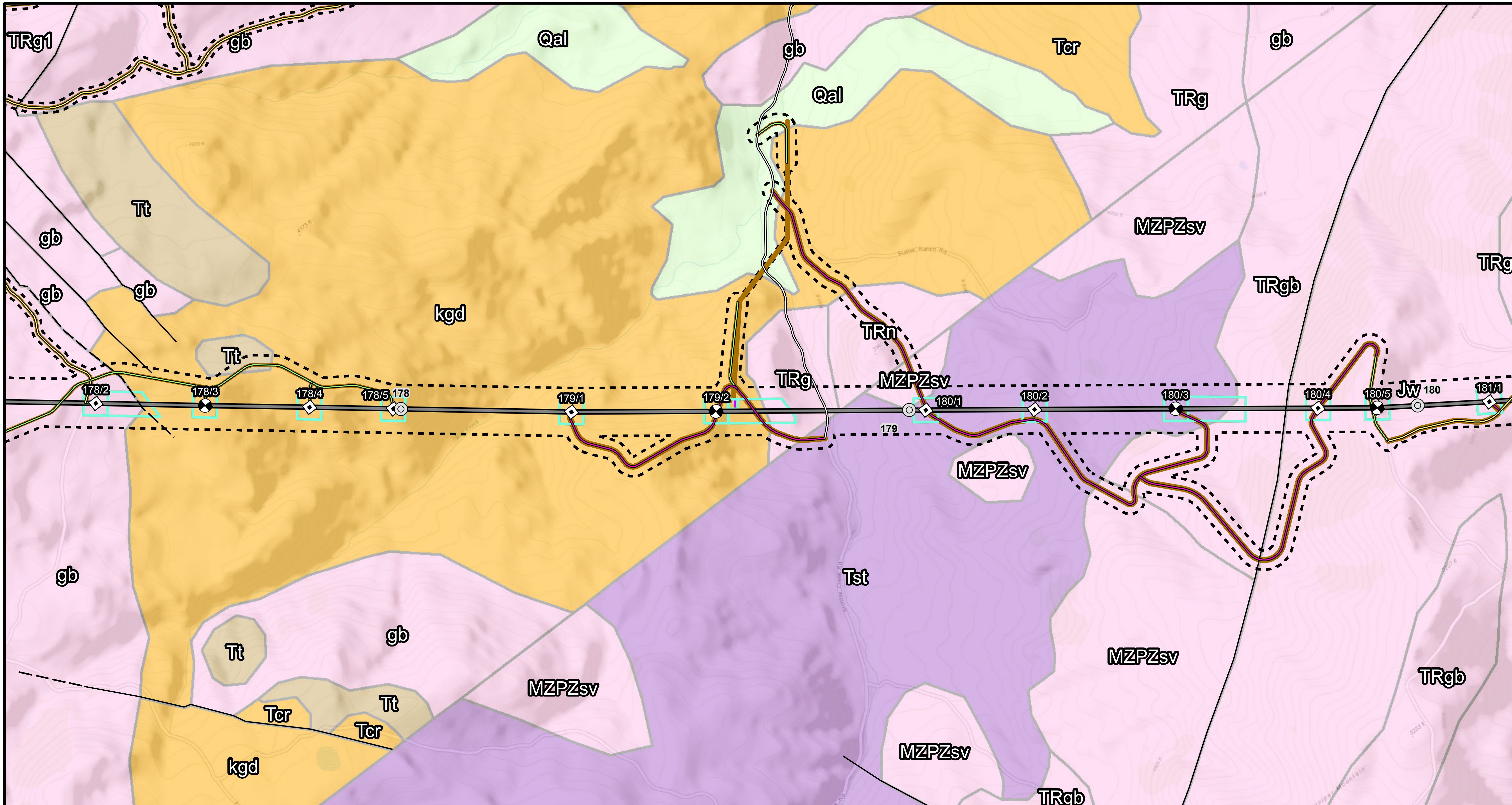


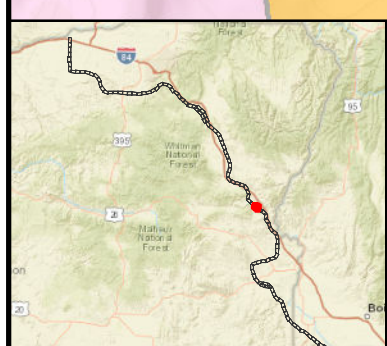

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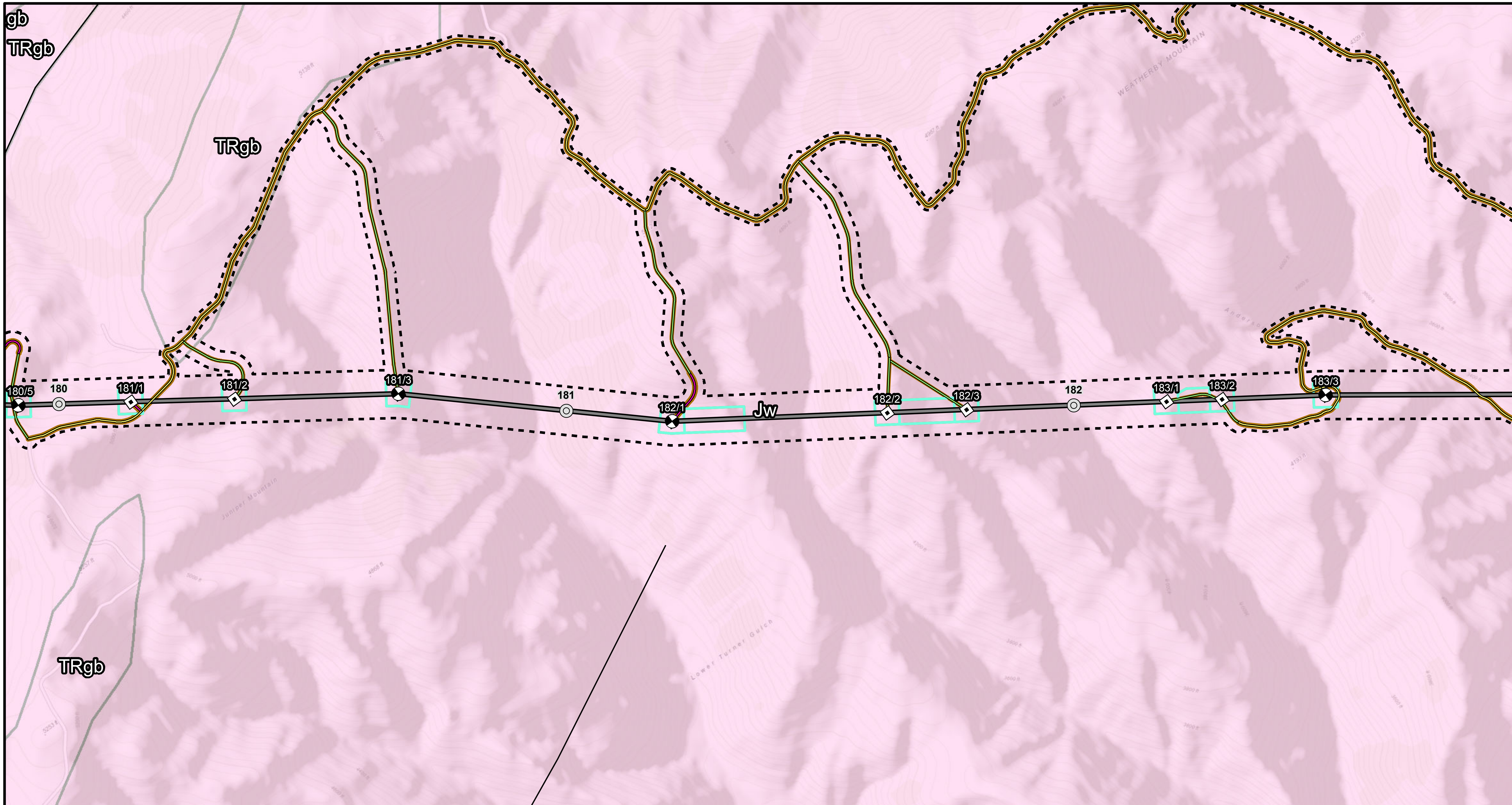


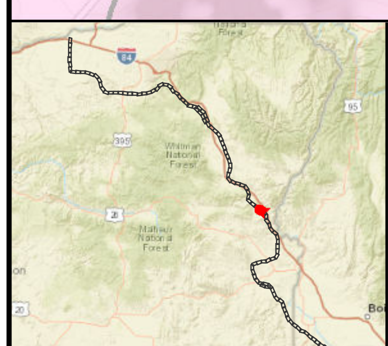

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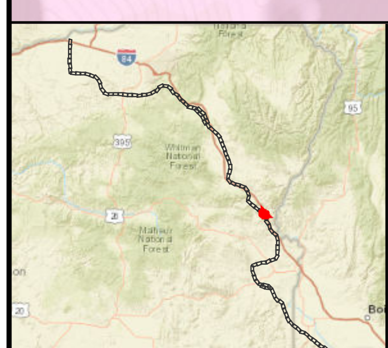

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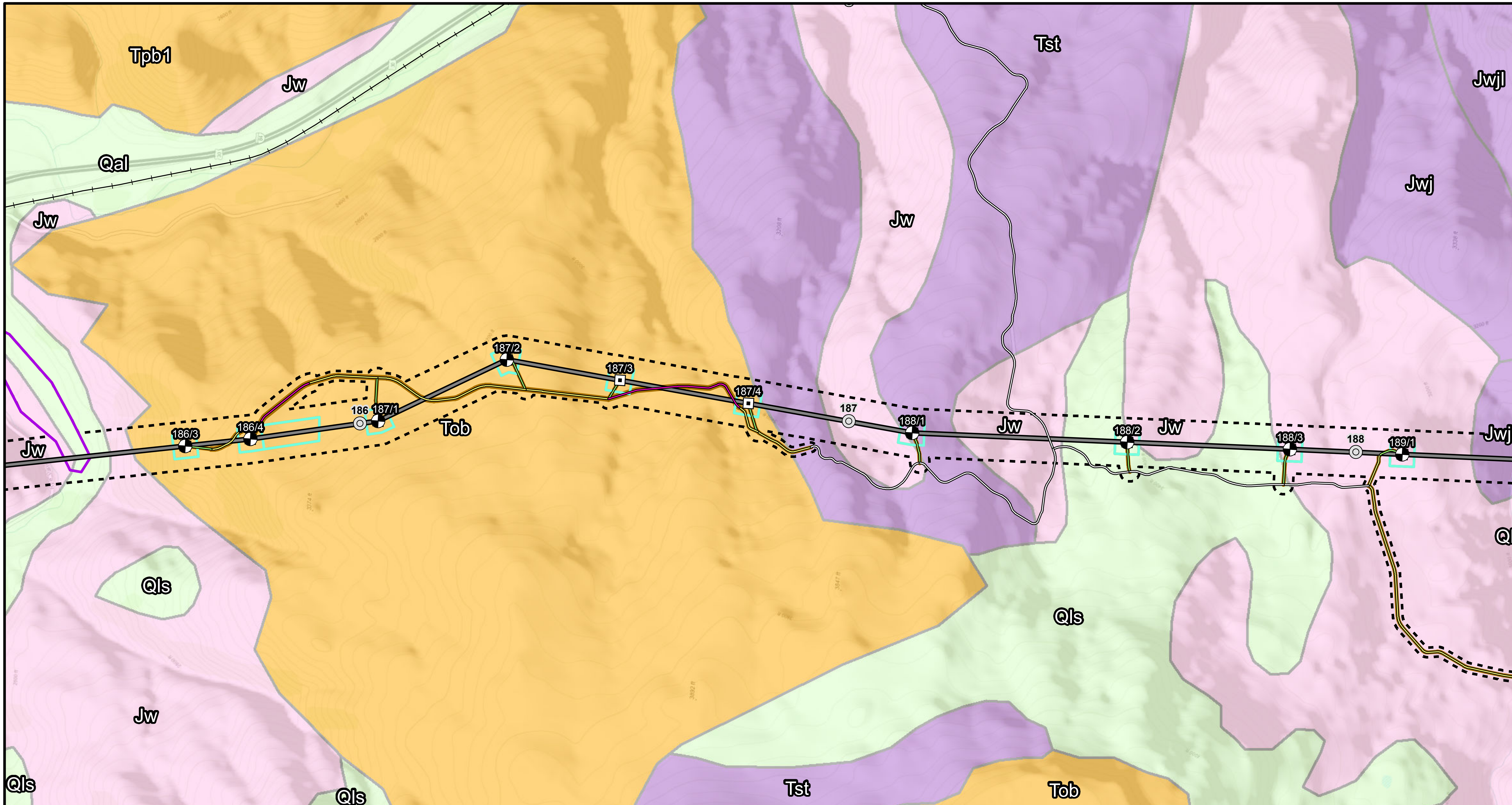


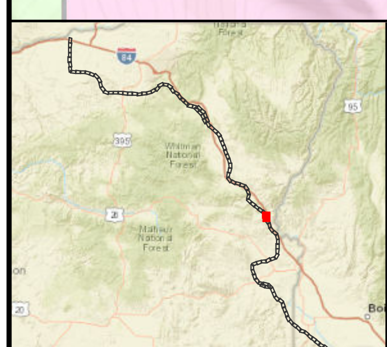

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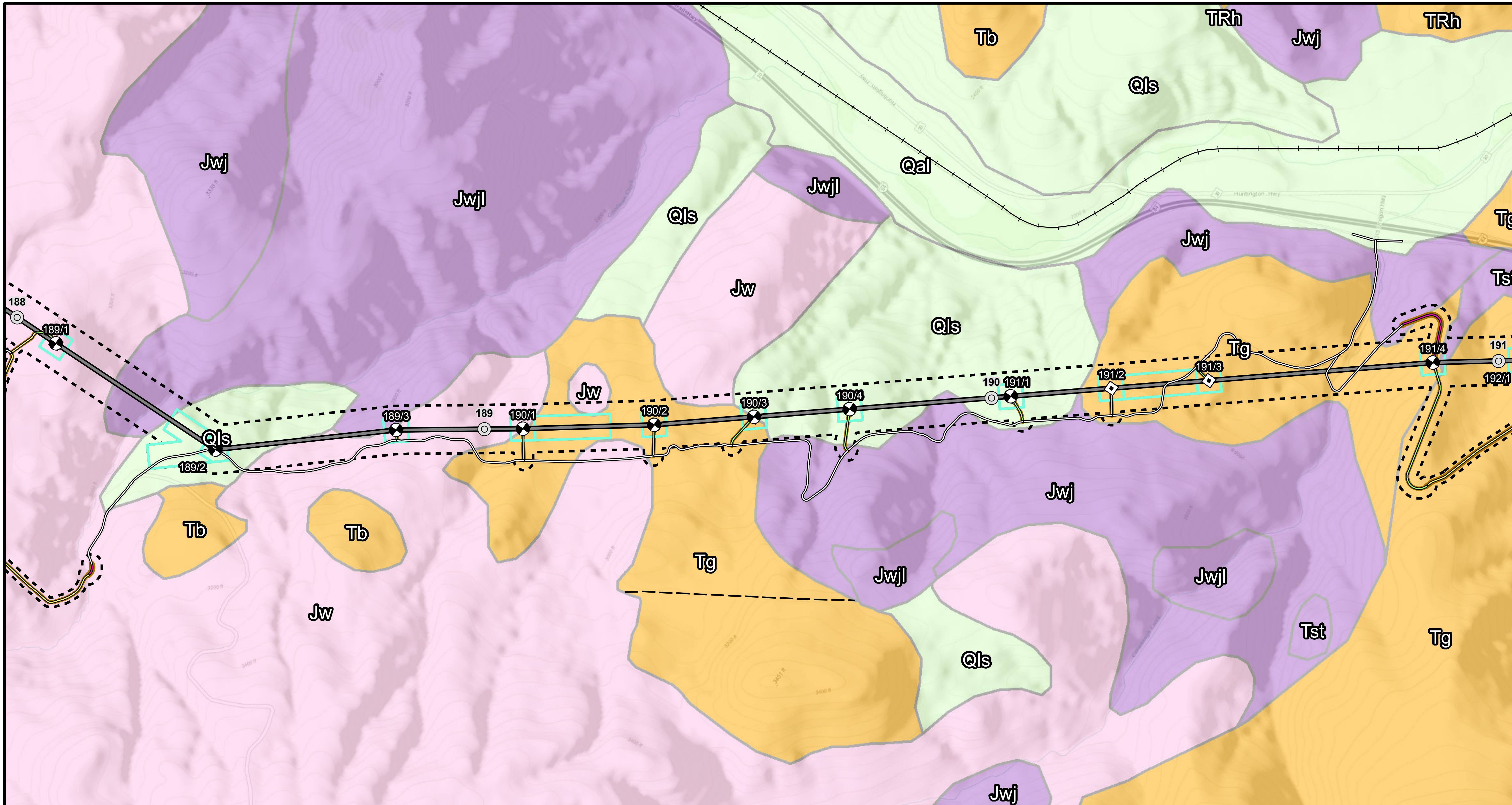


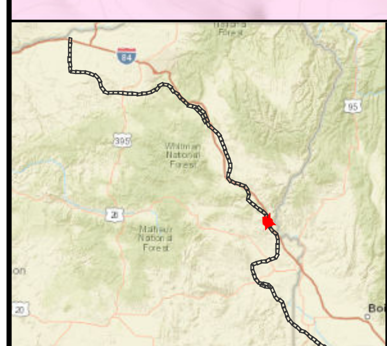

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

November 2016 24-1-03820-005

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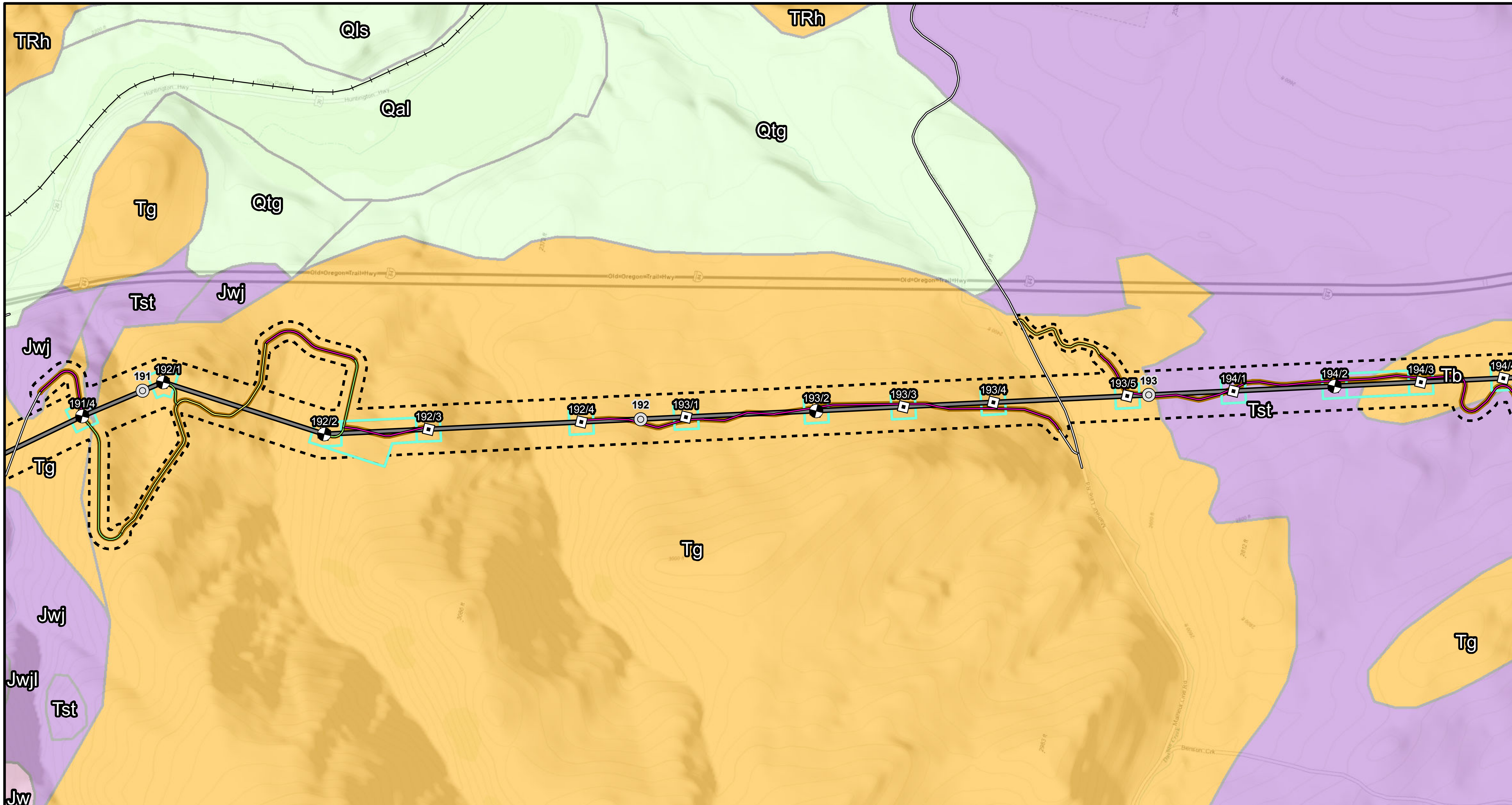


## LEGEND

**TRANSMISSION FEATURES**
- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
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- Operations Disturbance
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- Site Boundary

**SURFICIAL GEOLOGY**
- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
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**FAULTS**
- Accurate
- Approximate
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- USGS Mapped Fault
- No Data

**ROADS**
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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

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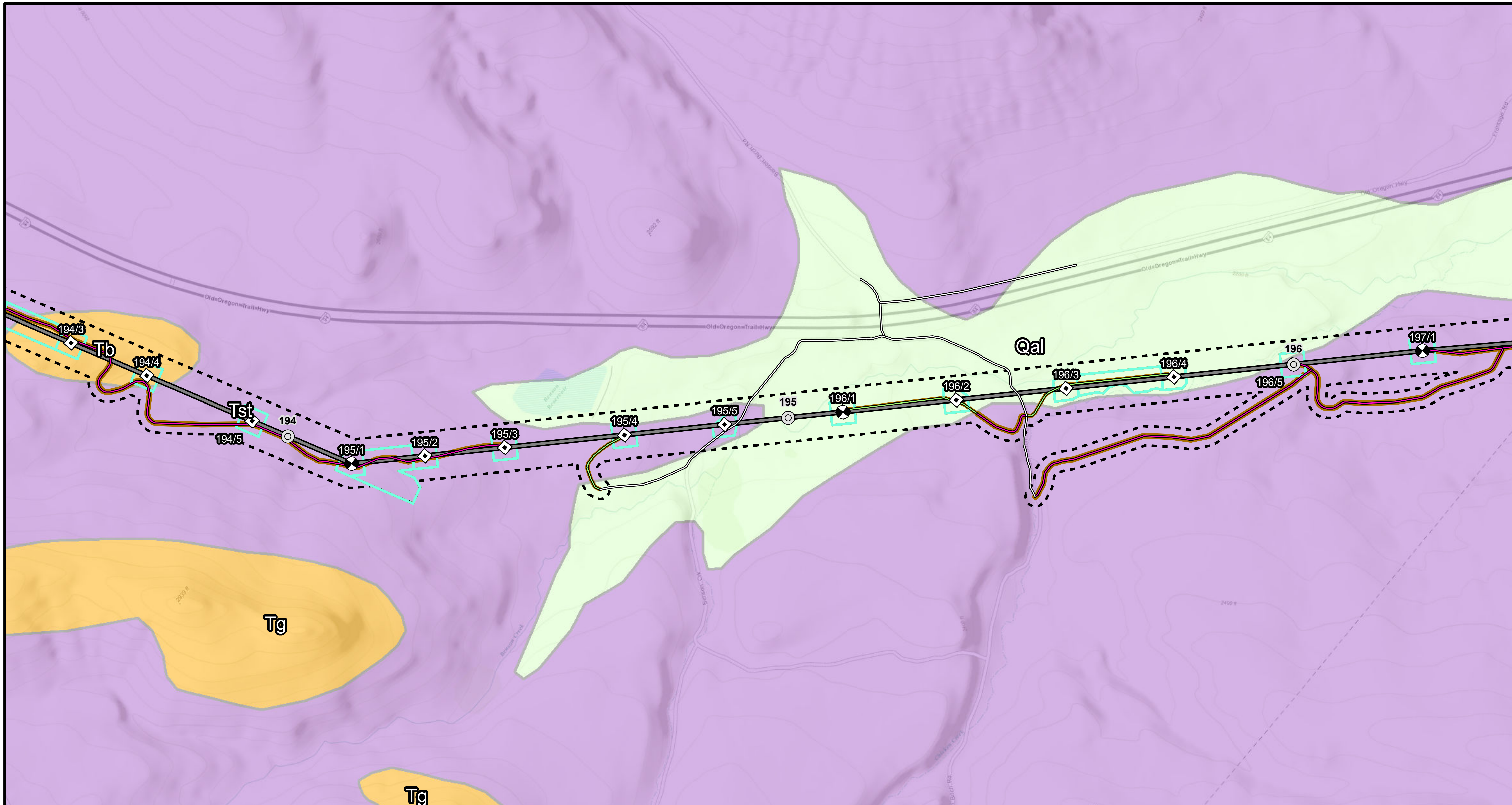


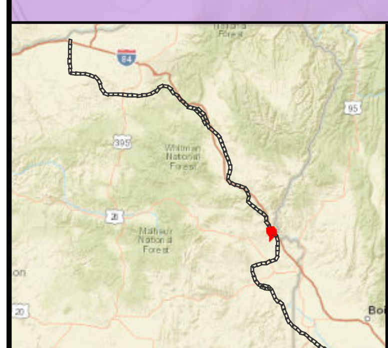

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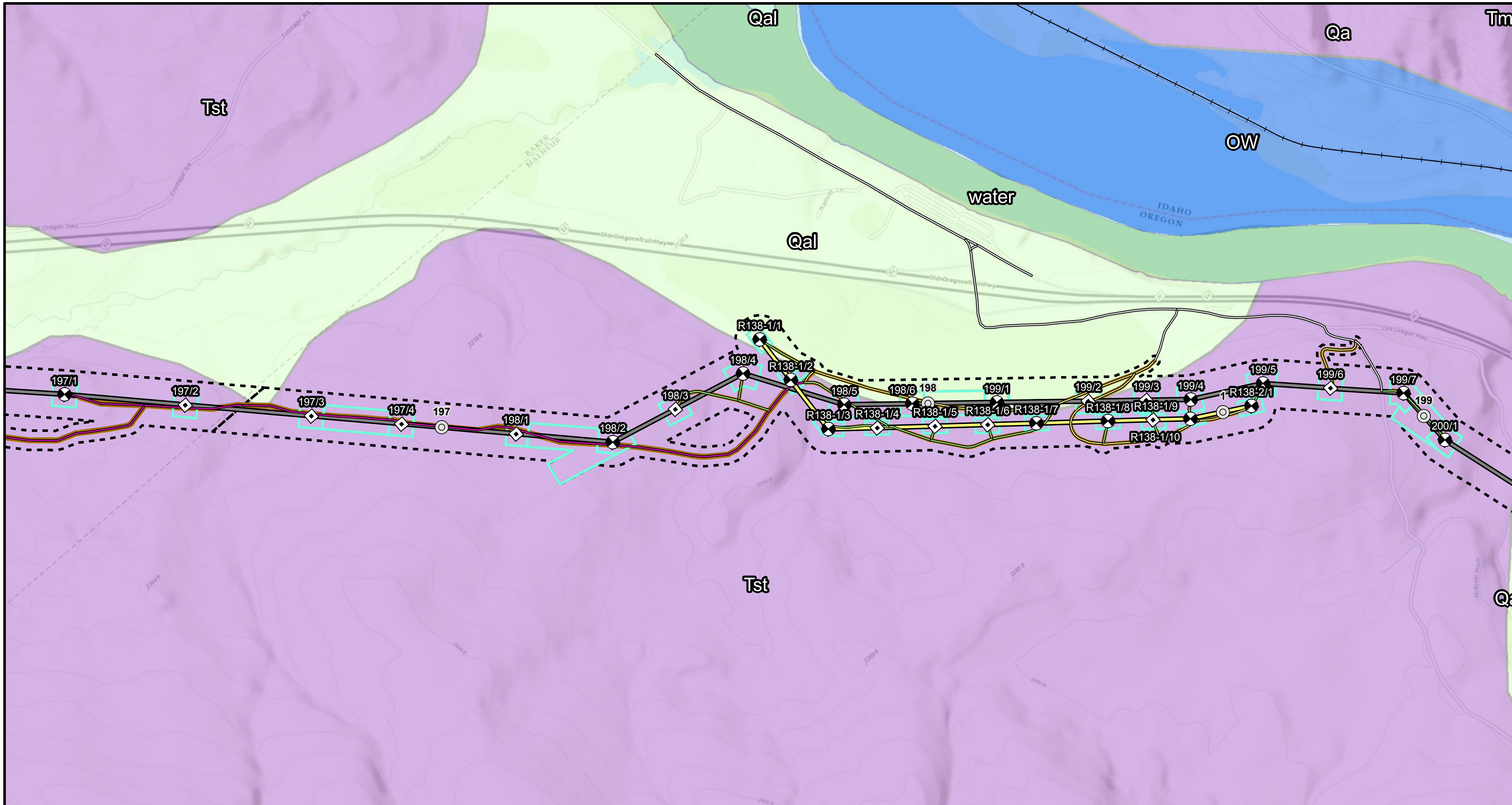


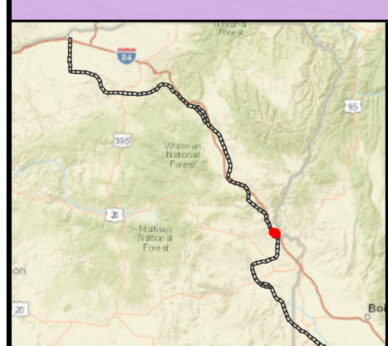

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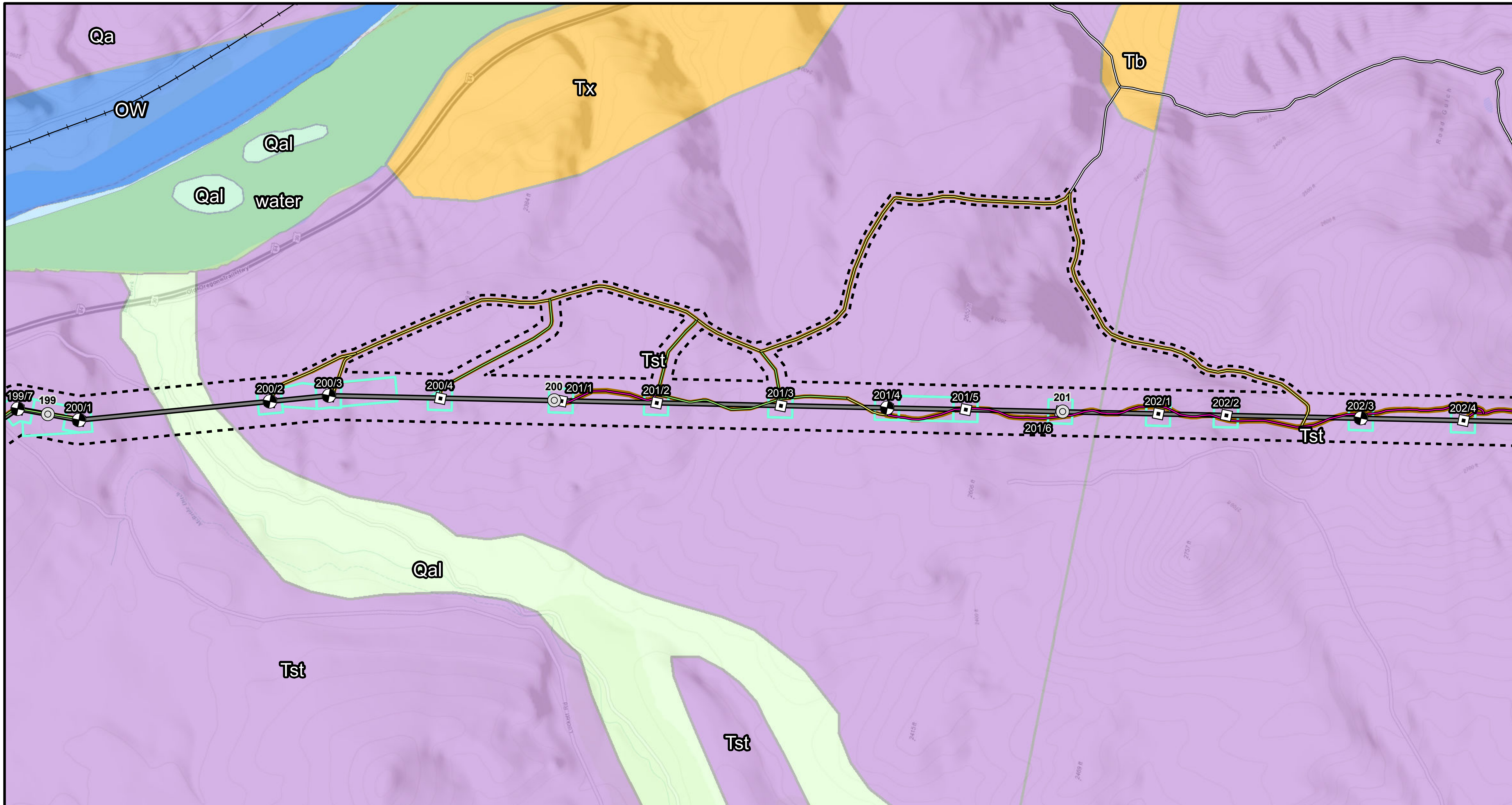


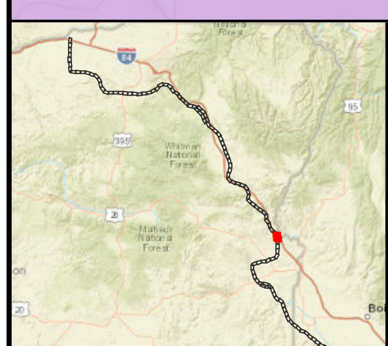

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500kV Transmission Line
Oregon - Idaho

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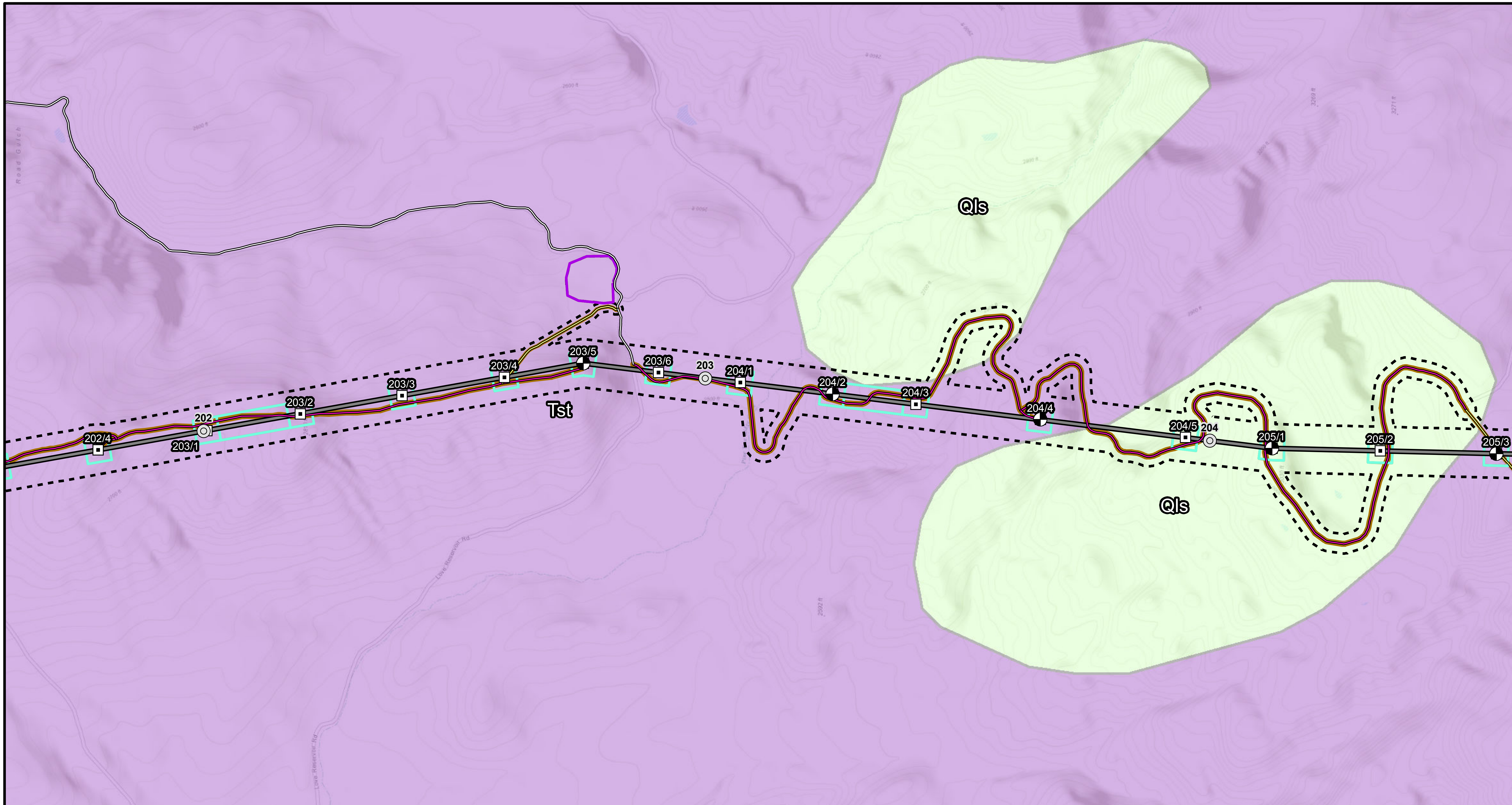


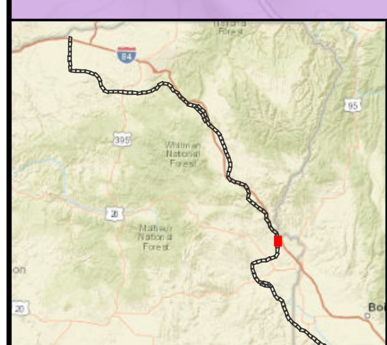

LEGEND

IPC Proposed Route
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Proposed 138-kV Rebuild
Double Mountain Alternative

TRANSMISSION FEATURES
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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGY

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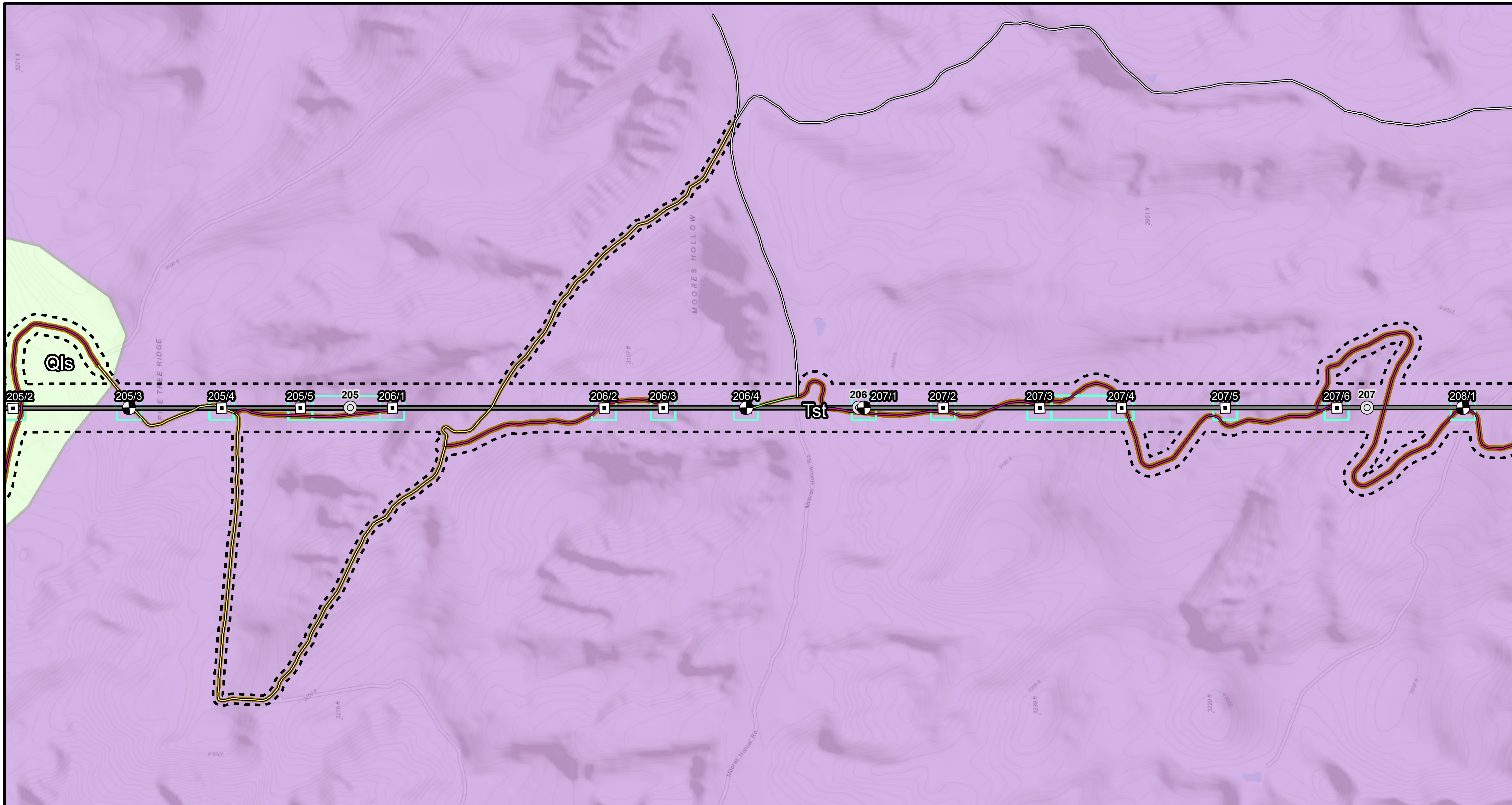


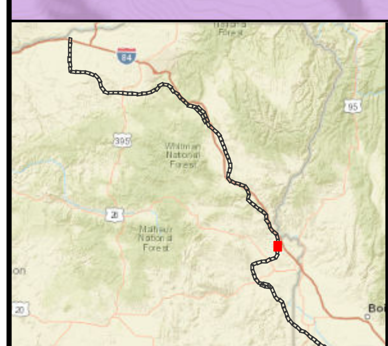

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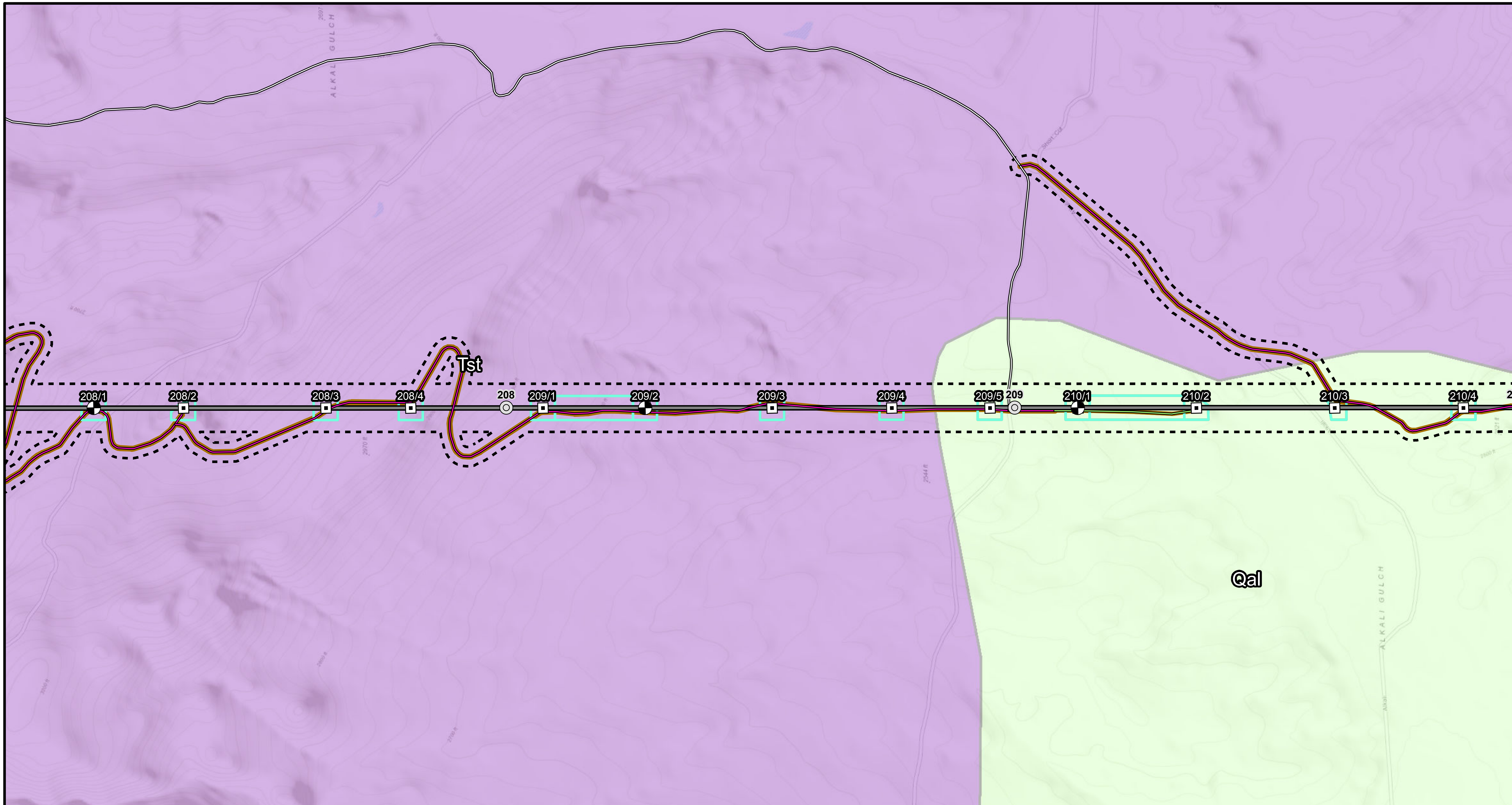


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Double Mountain Alternative

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGY

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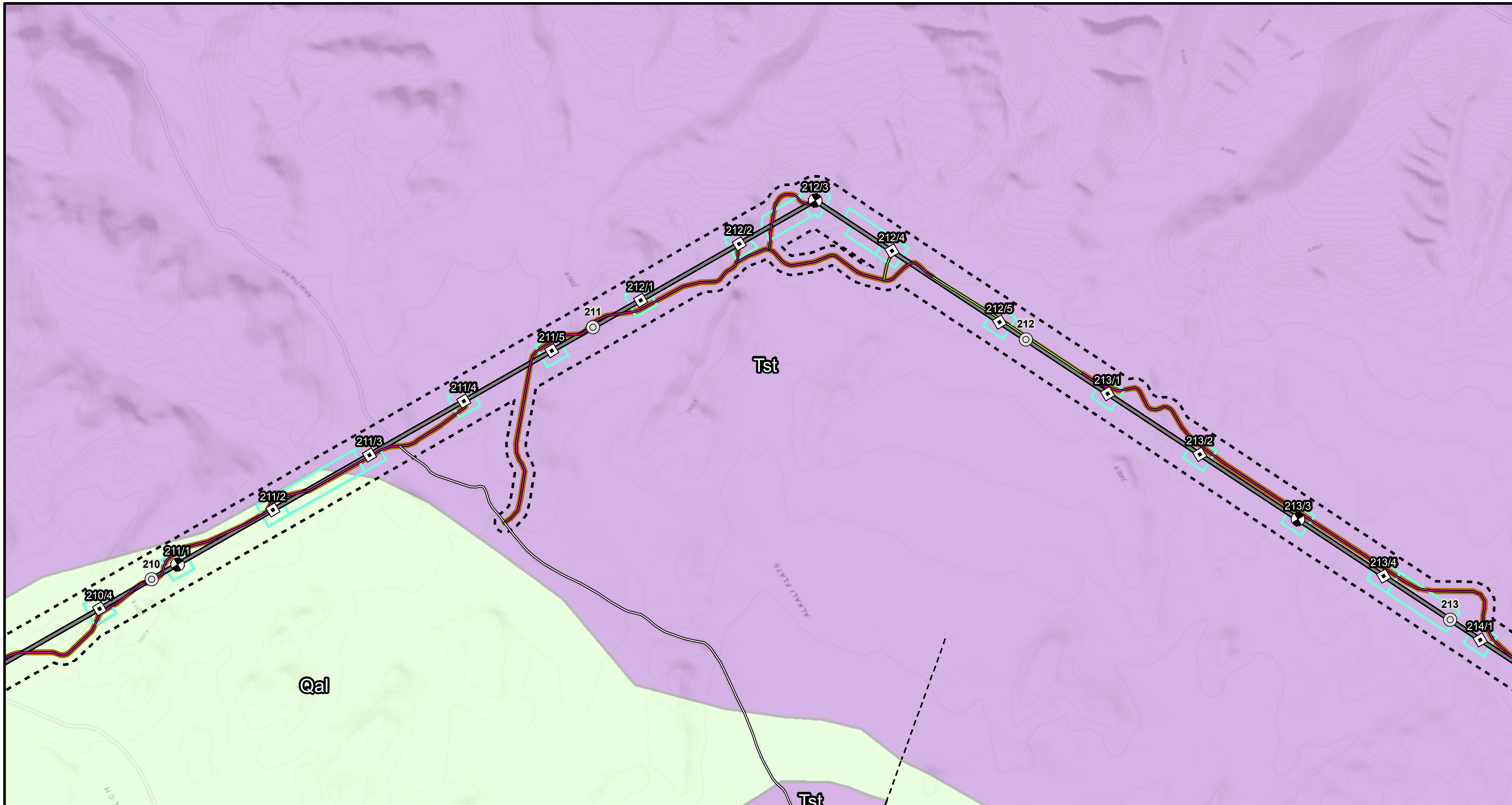


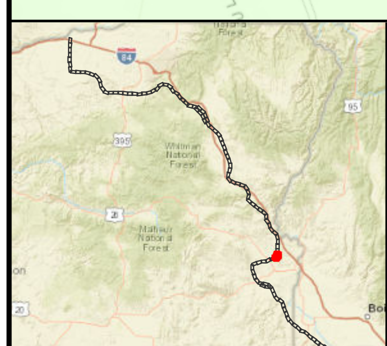

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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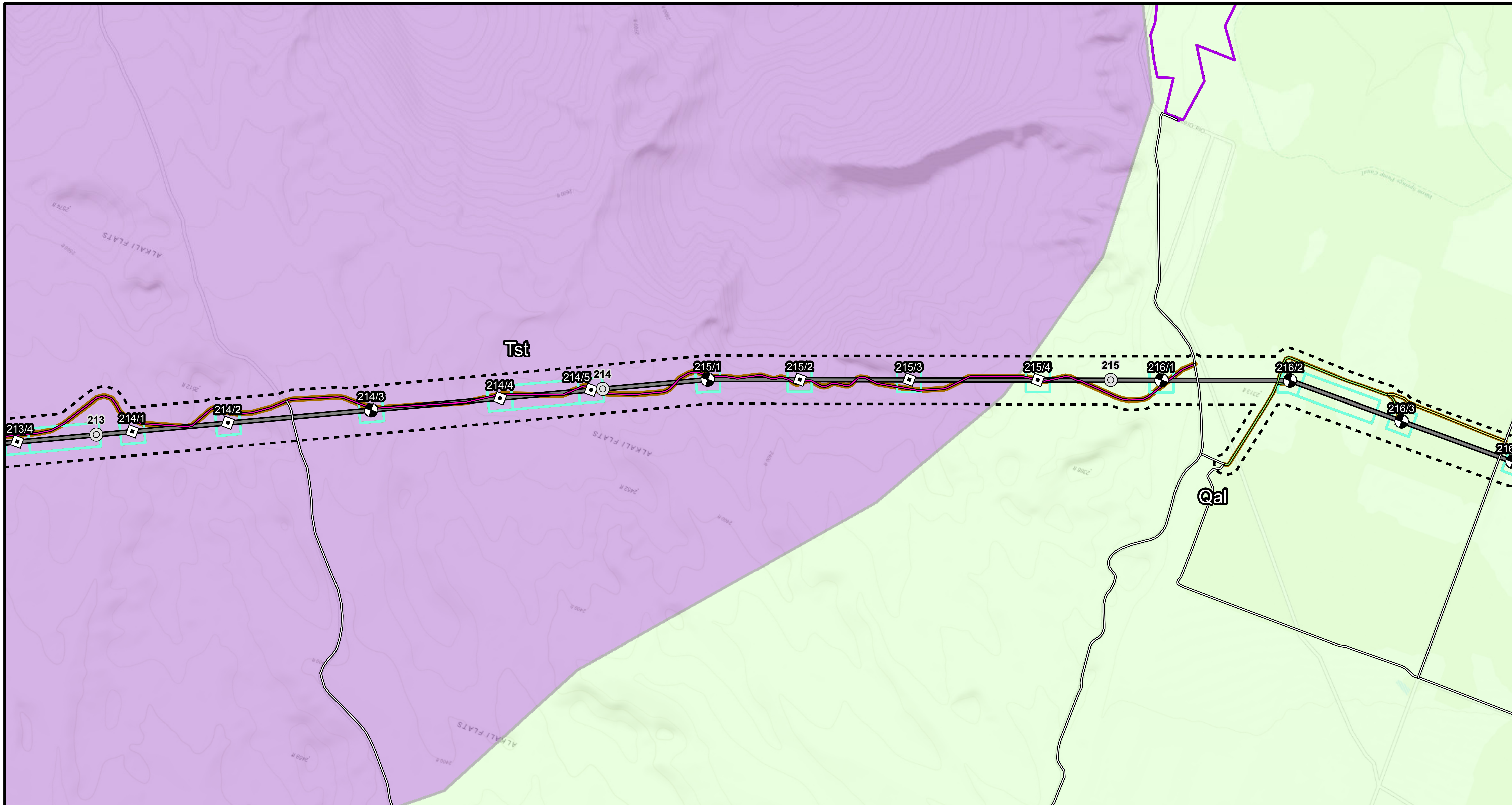


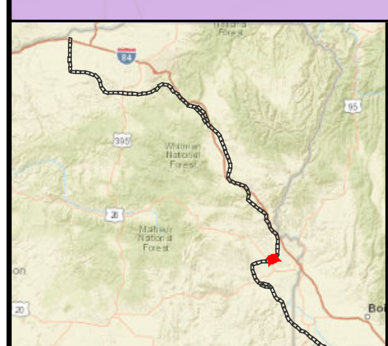

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Oregon - Idaho

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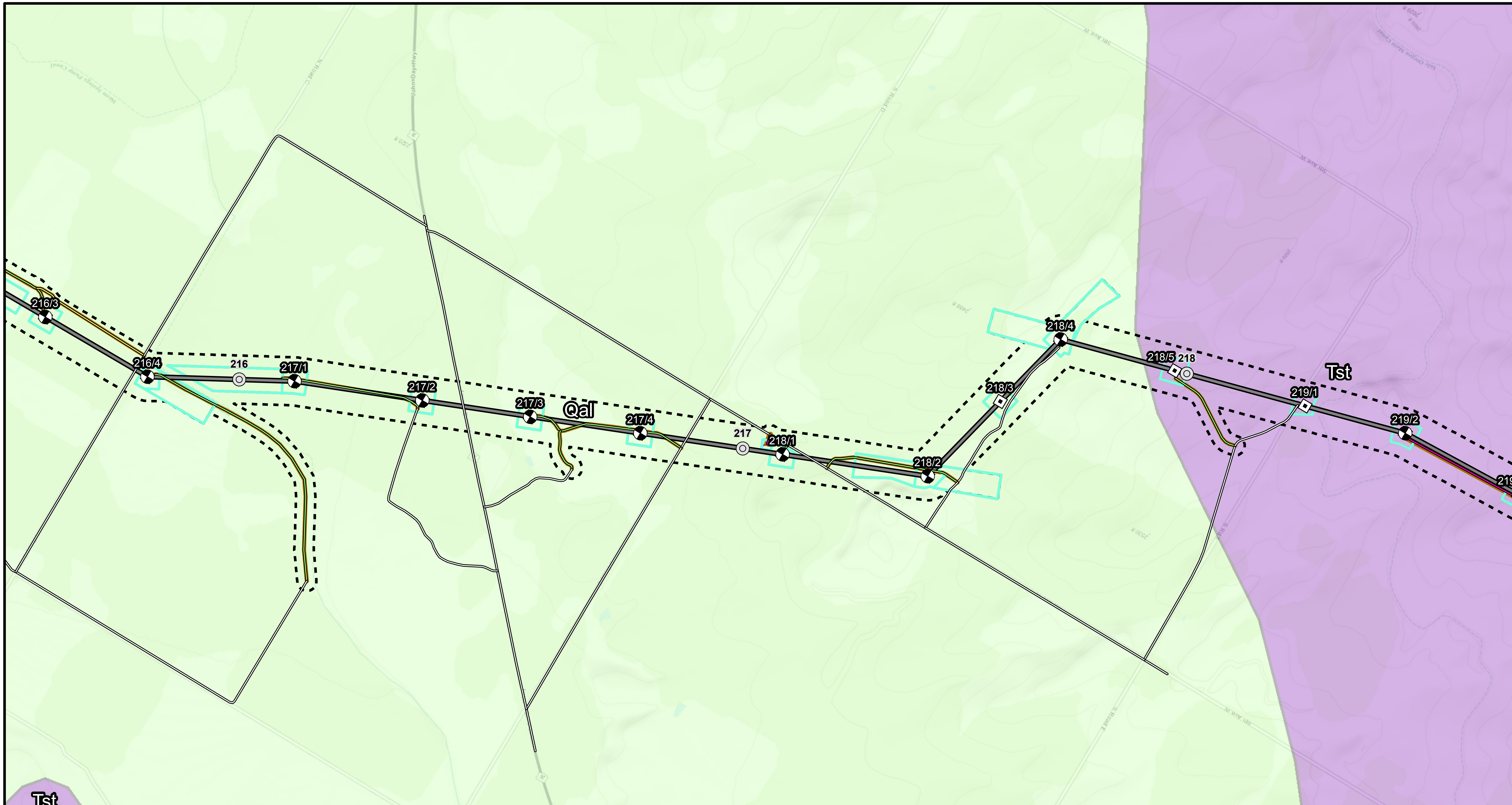


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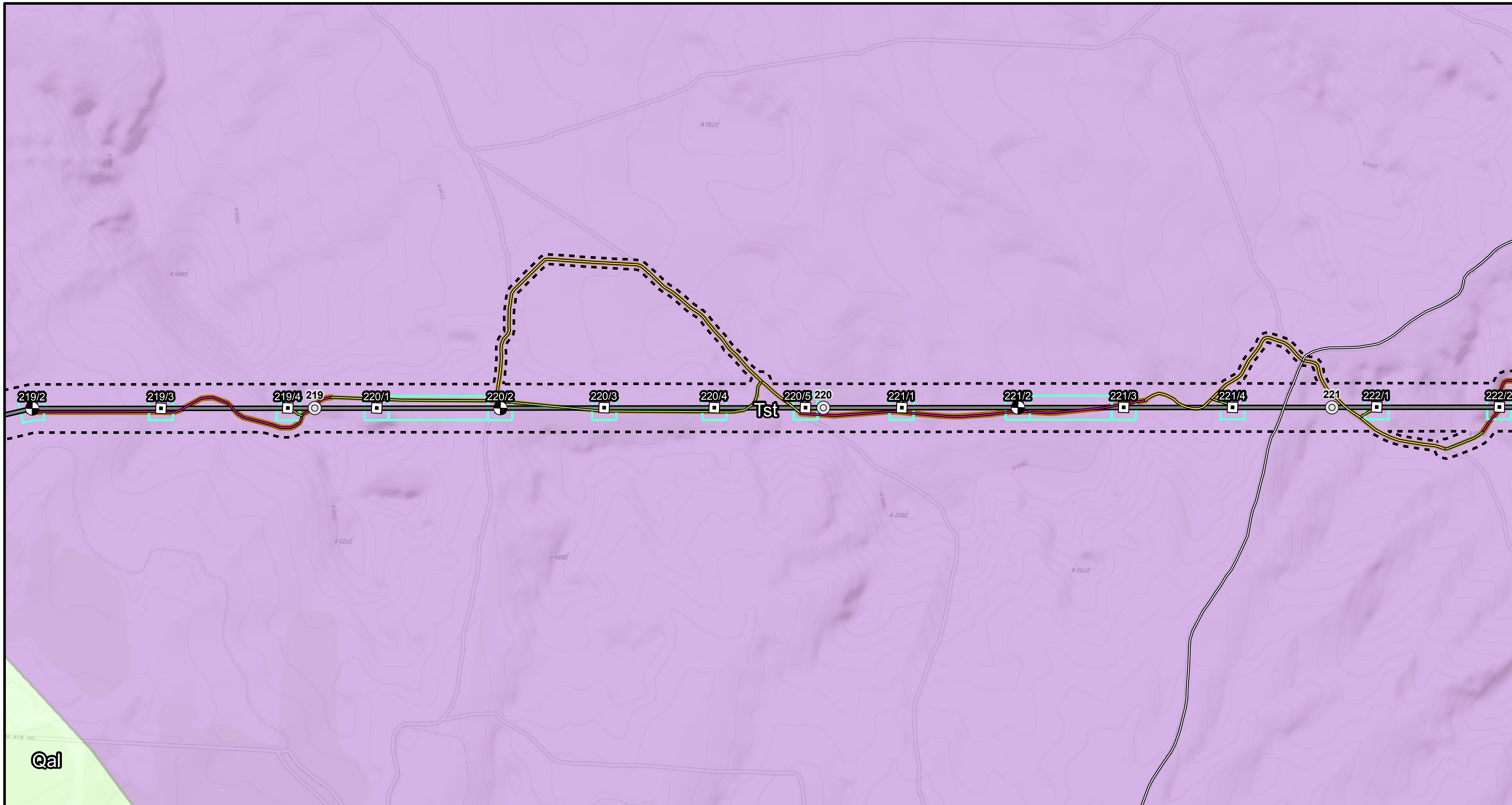


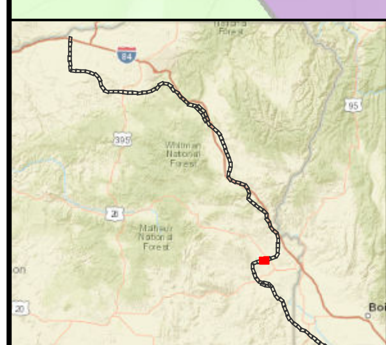

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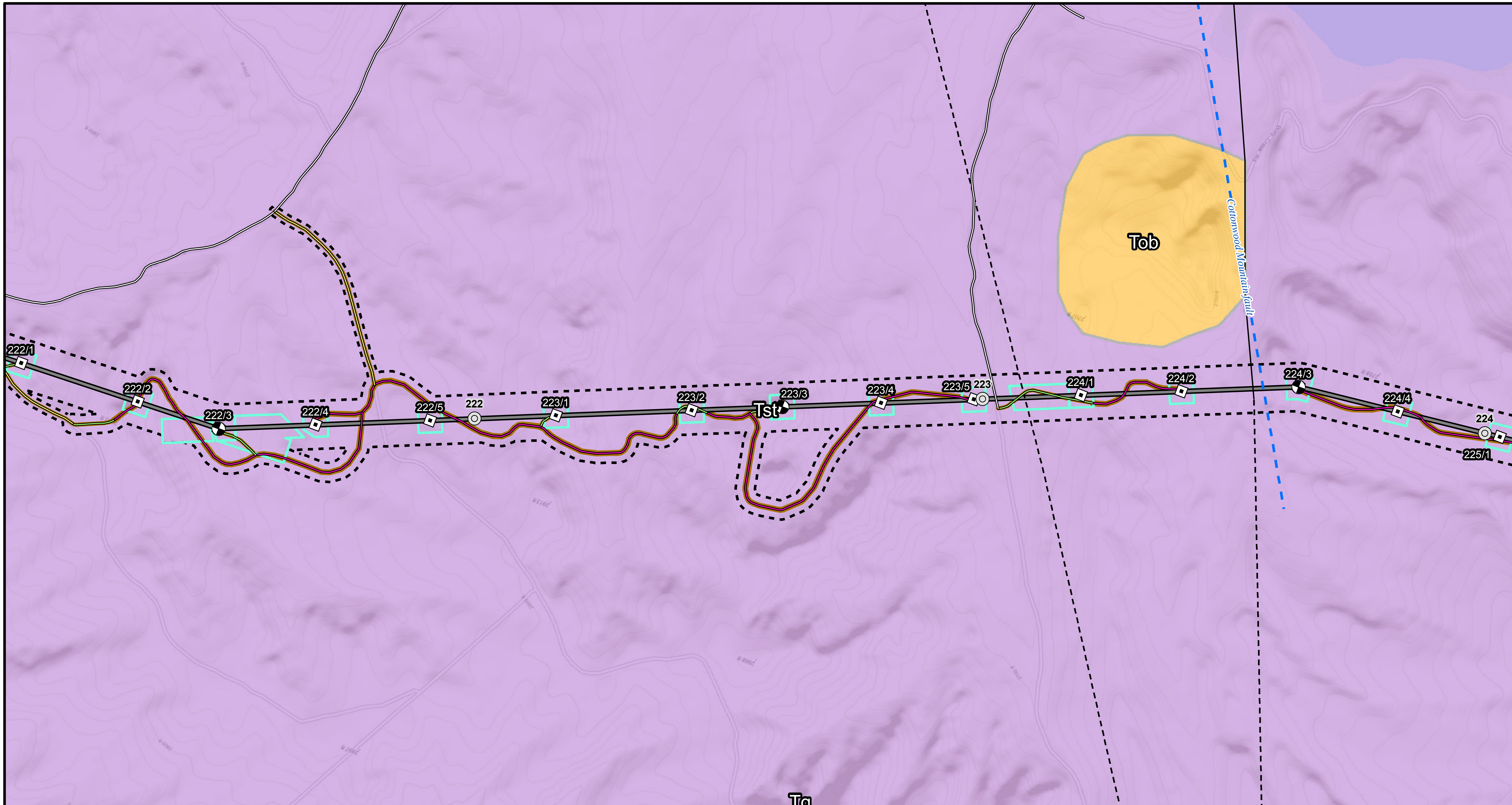


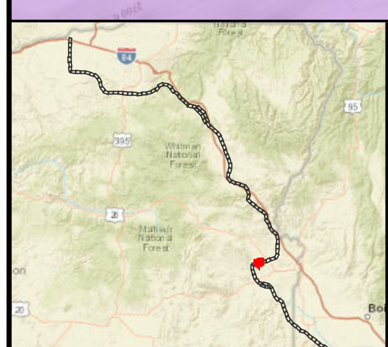

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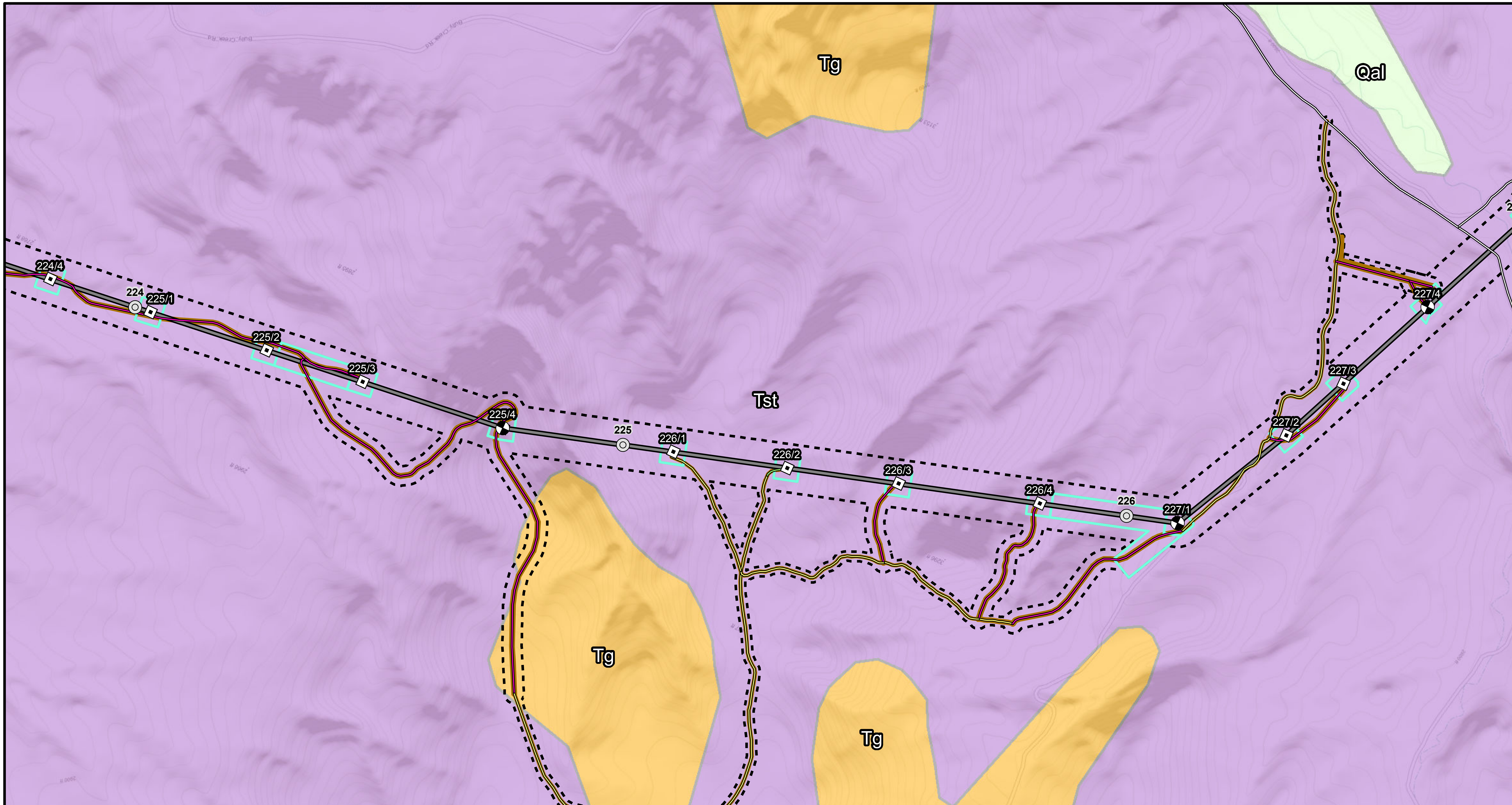


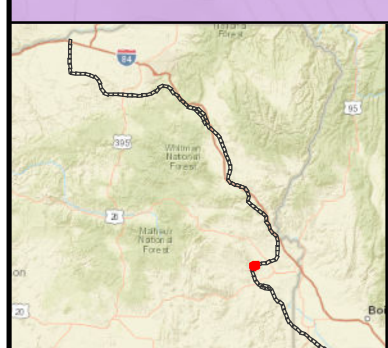

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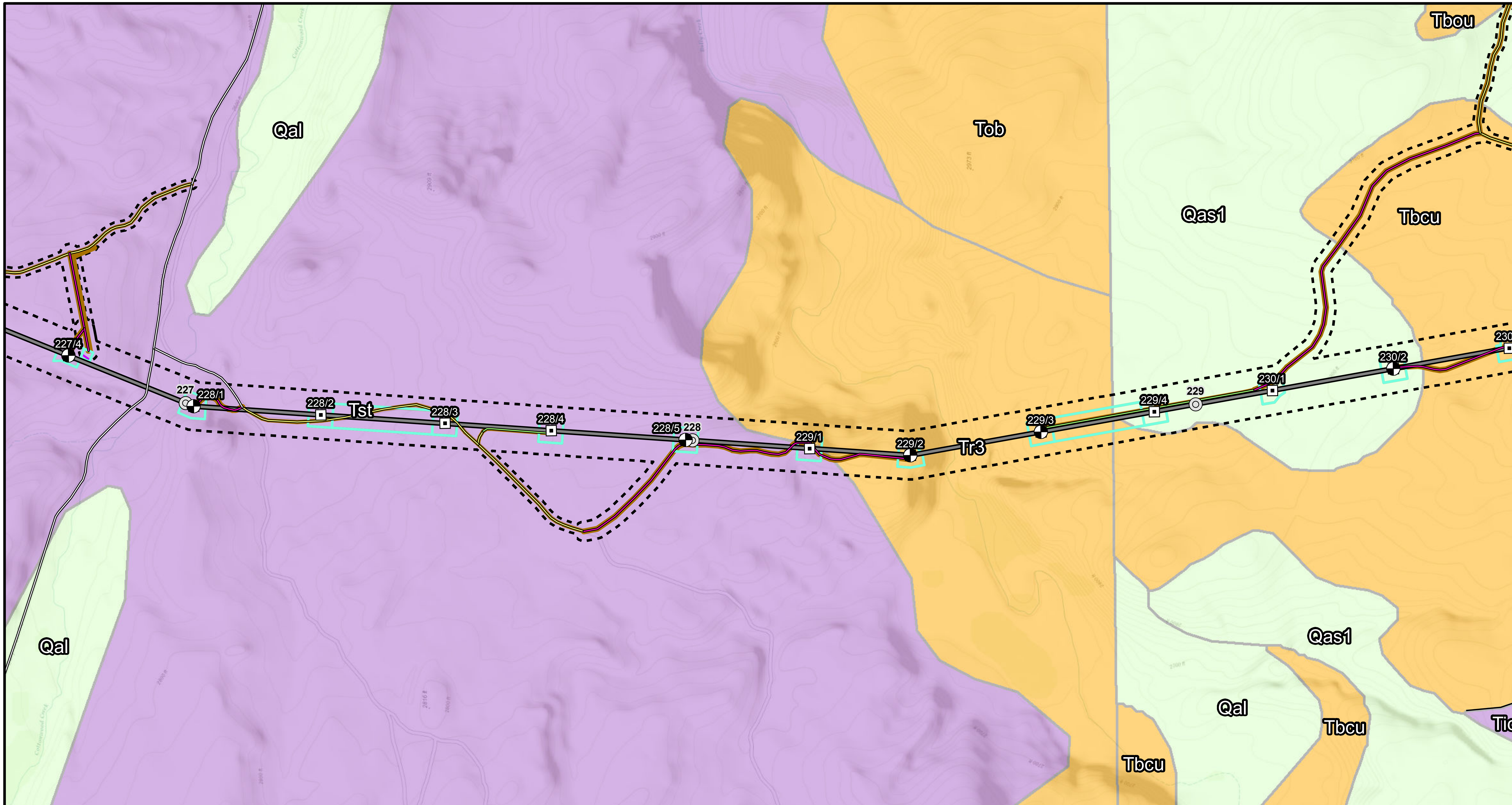


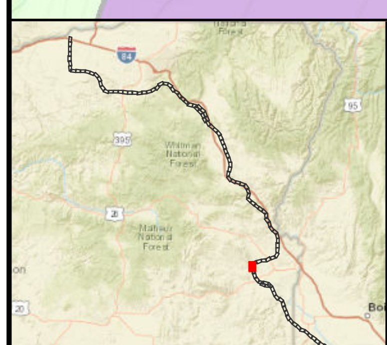

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- Site Boundary

**SURFICIAL GEOLOGY**

- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

**FAULTS**

- Accurate
- Approximate
- Concealed
- Inferred
- USGS Mapped Fault
- No Data

**ROADS**

- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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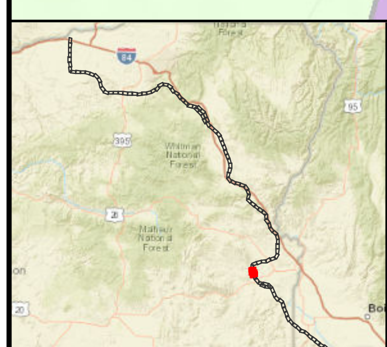

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Morgan Lake Alternative
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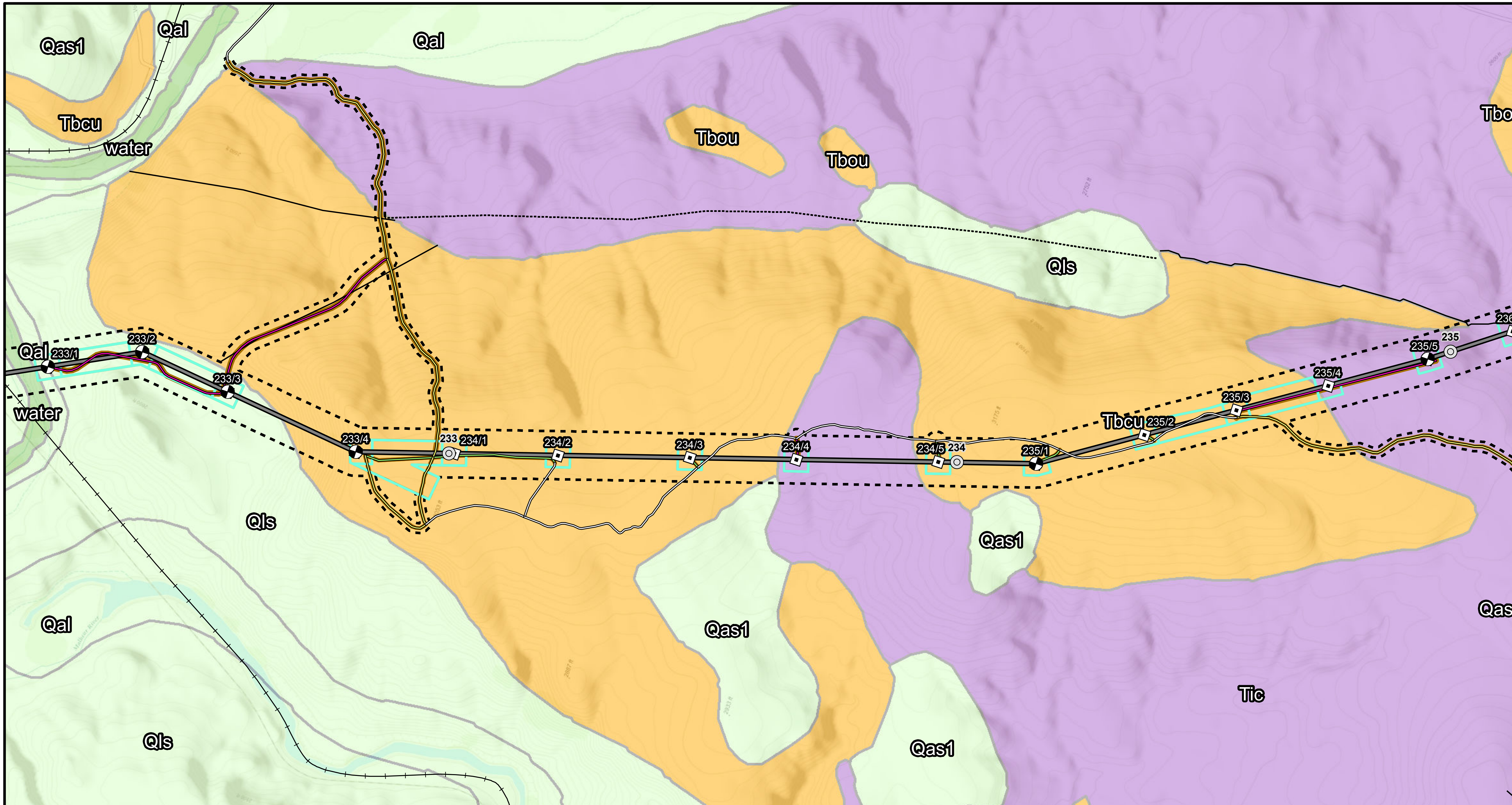


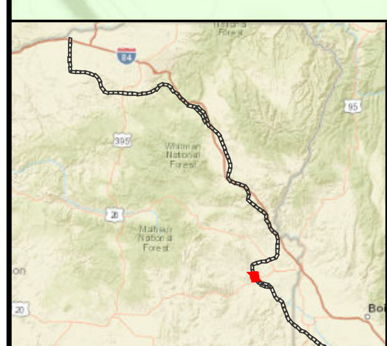

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**TRANSMISSION FEATURES**
- IPC Proposed Route
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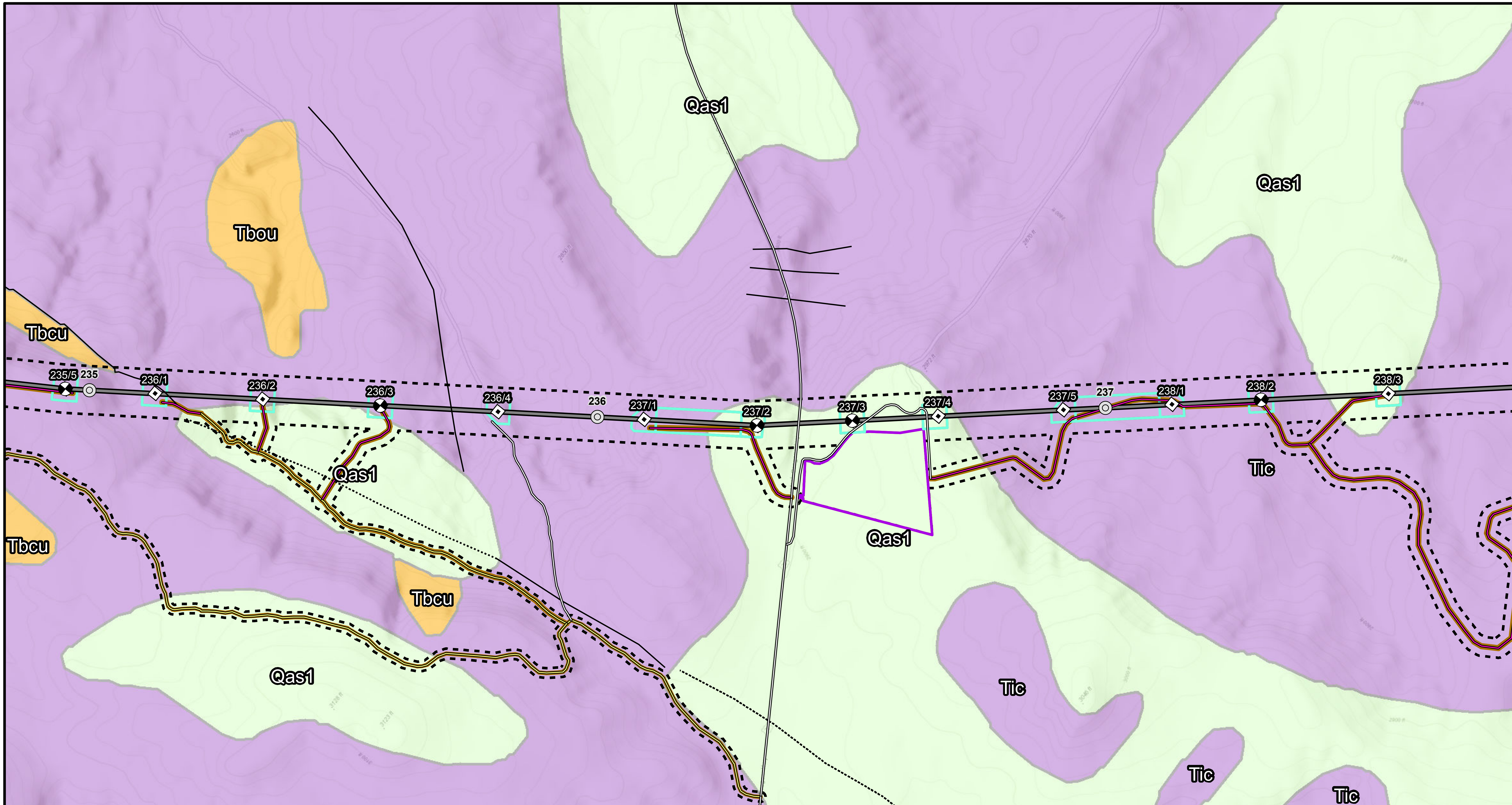


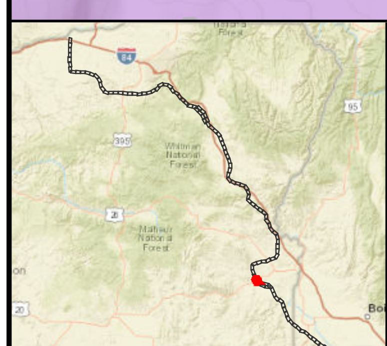

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**TRANSMISSION FEATURES**
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- Proposed 138-kV Rebuild
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Feet

Boardman - Hemingway
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Oregon - Idaho

**GEOLOGY**

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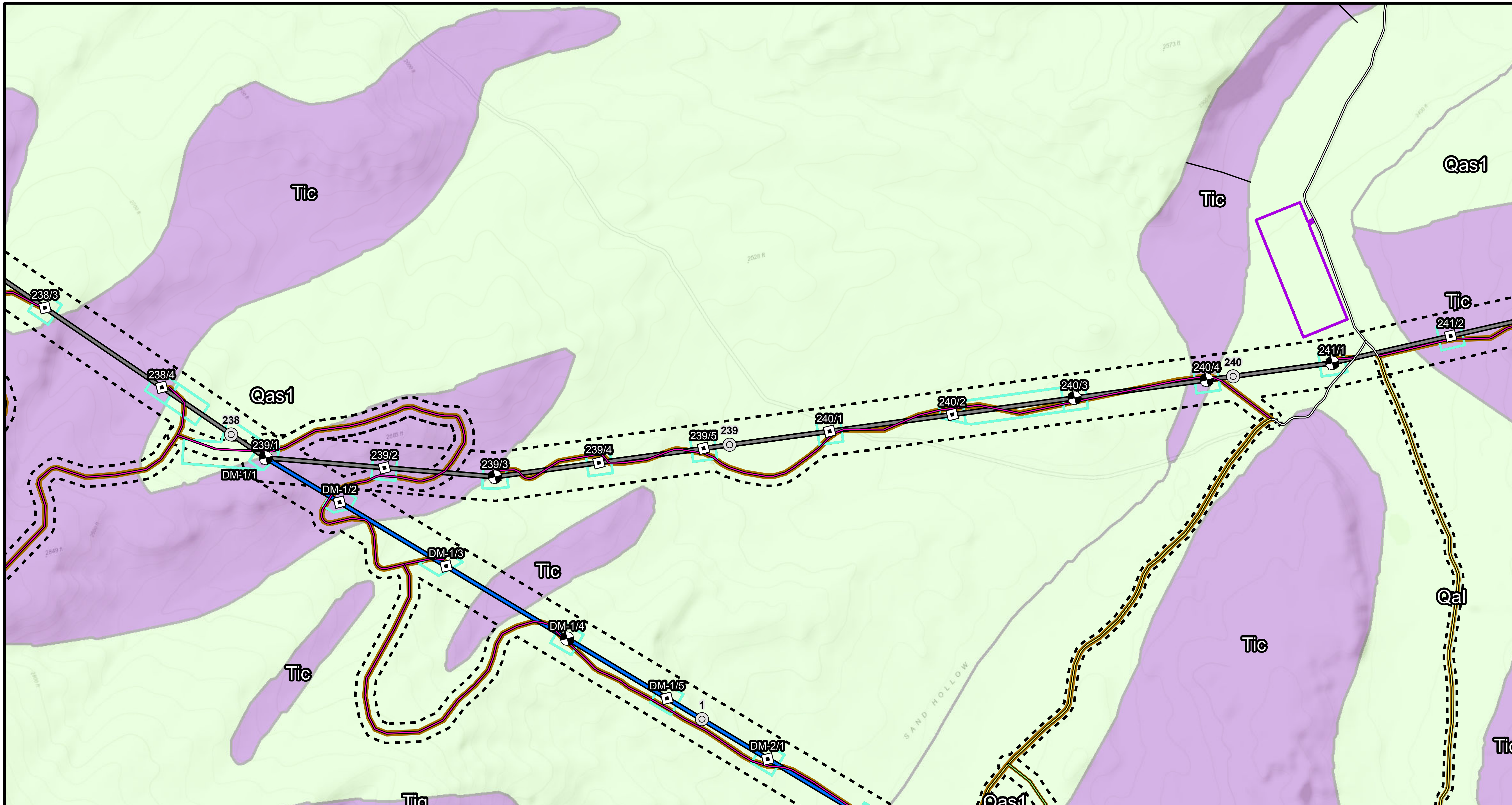


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## LEGEND

IPC Proposed Route
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Proposed 138-kV Rebuild
Double Mountain Alternative

TRANSMISSION FEATURES
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Substation
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New, Primitive
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No Substantial Improvements
Railroad

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Oregon - Idaho

## GEOLOGY

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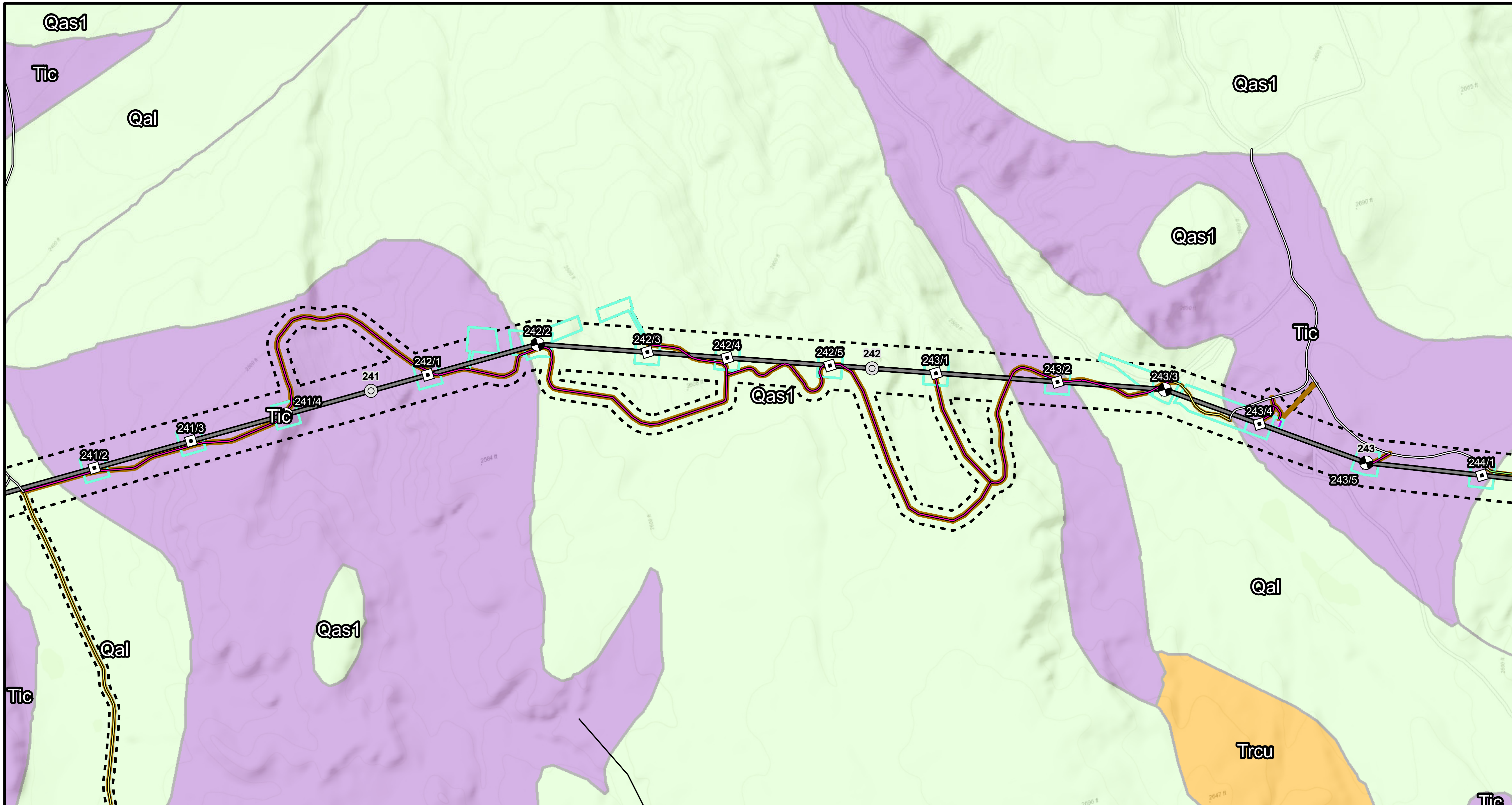


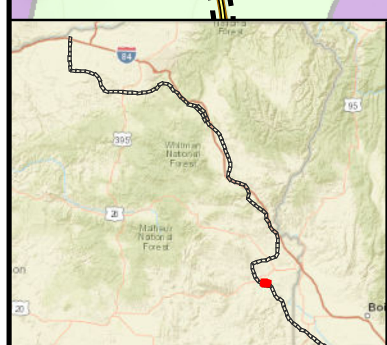

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Oregon - Idaho

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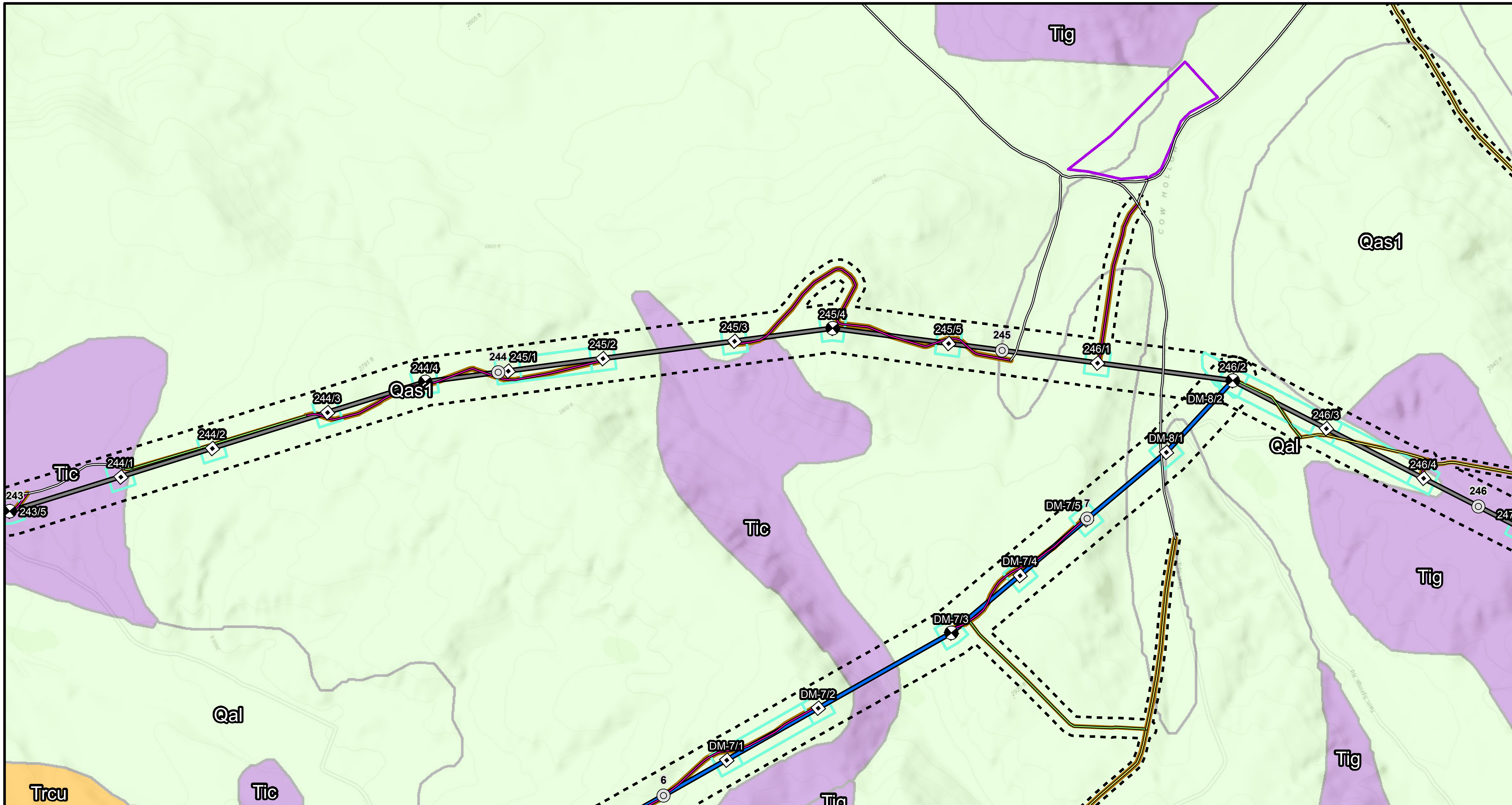


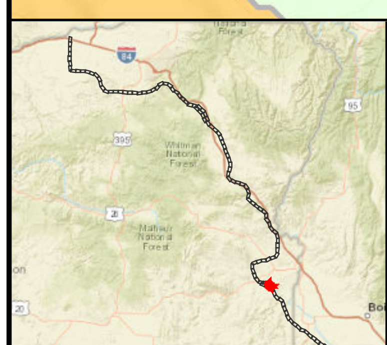

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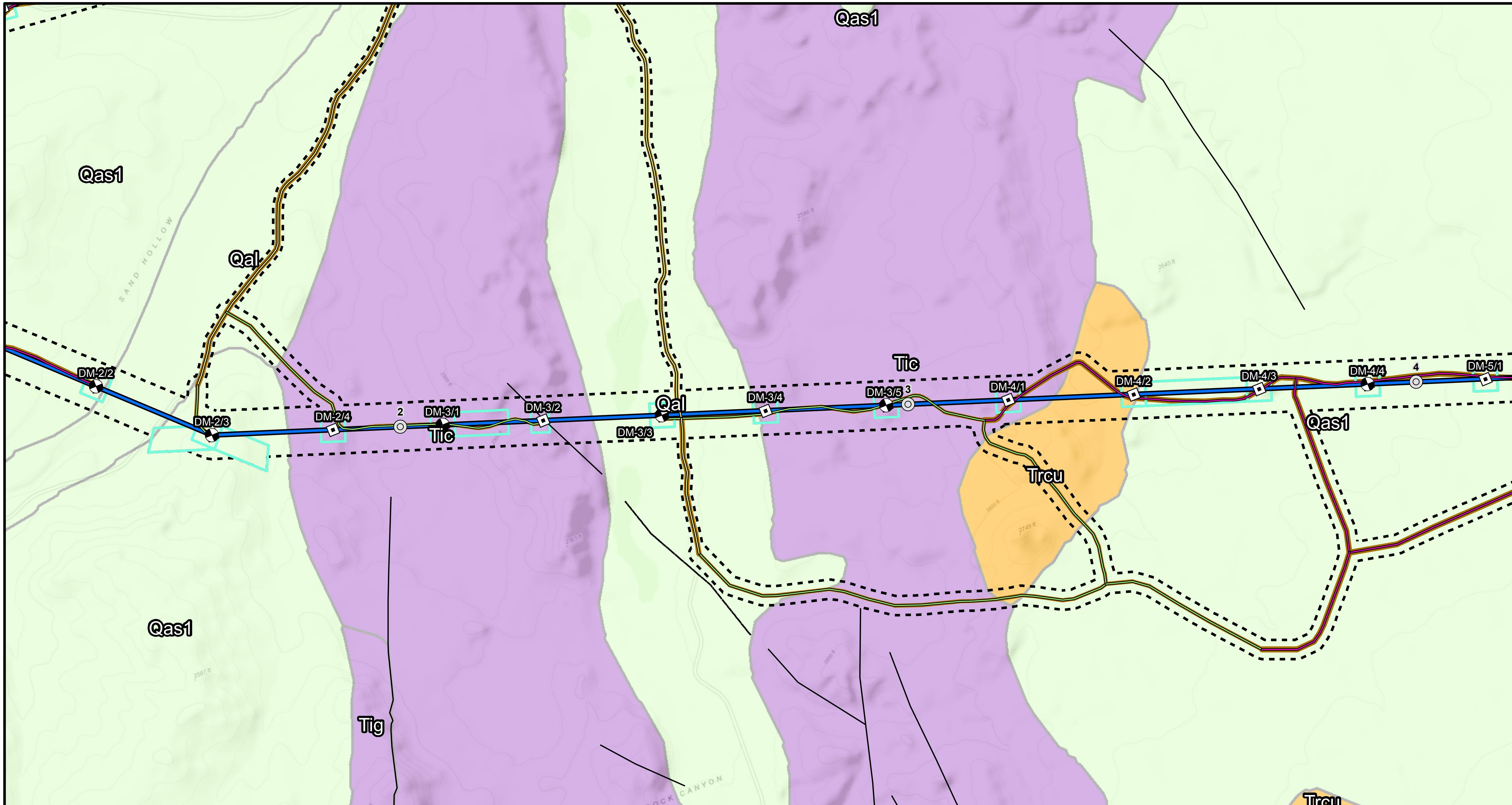


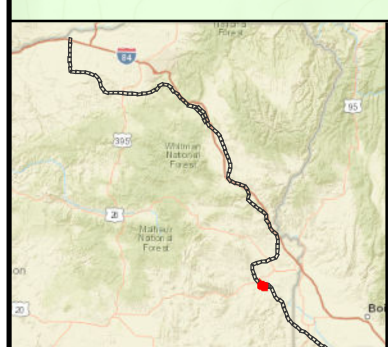

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Oregon - Idaho

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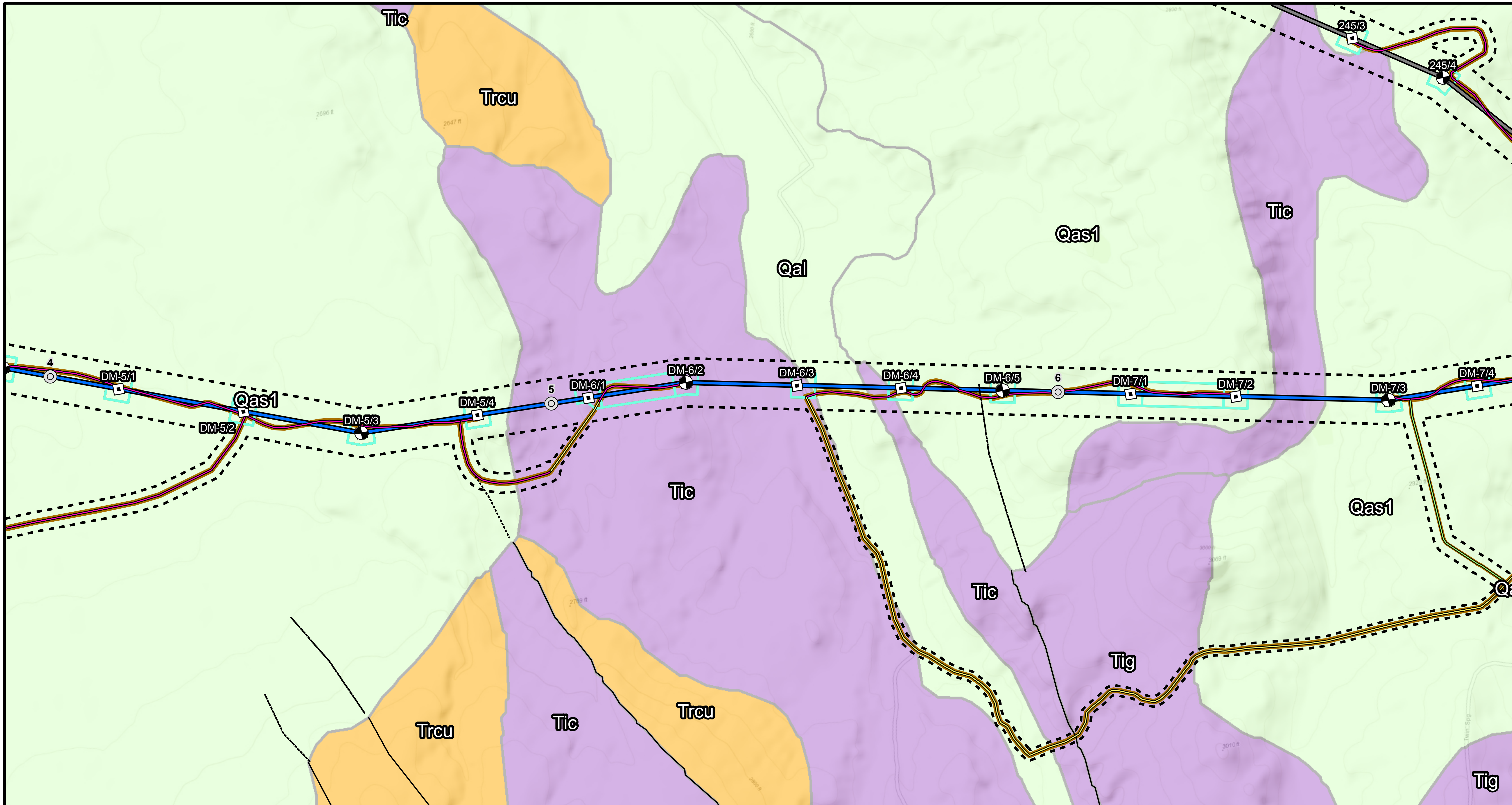


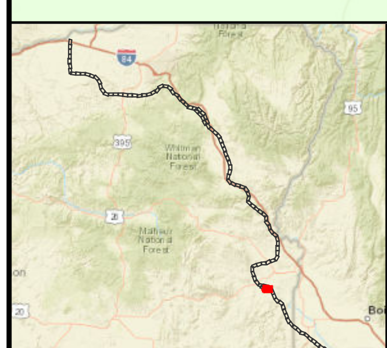

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LEGEND

| | |
|---|---|
| IPC Proposed Route | |
| Proposed 230-kV Rebuild | |
| Proposed 138-kV Rebuild | |
| Double Mountain Alternative | |

TRANSMISSION FEATURES

- Morgan Lake Alternative
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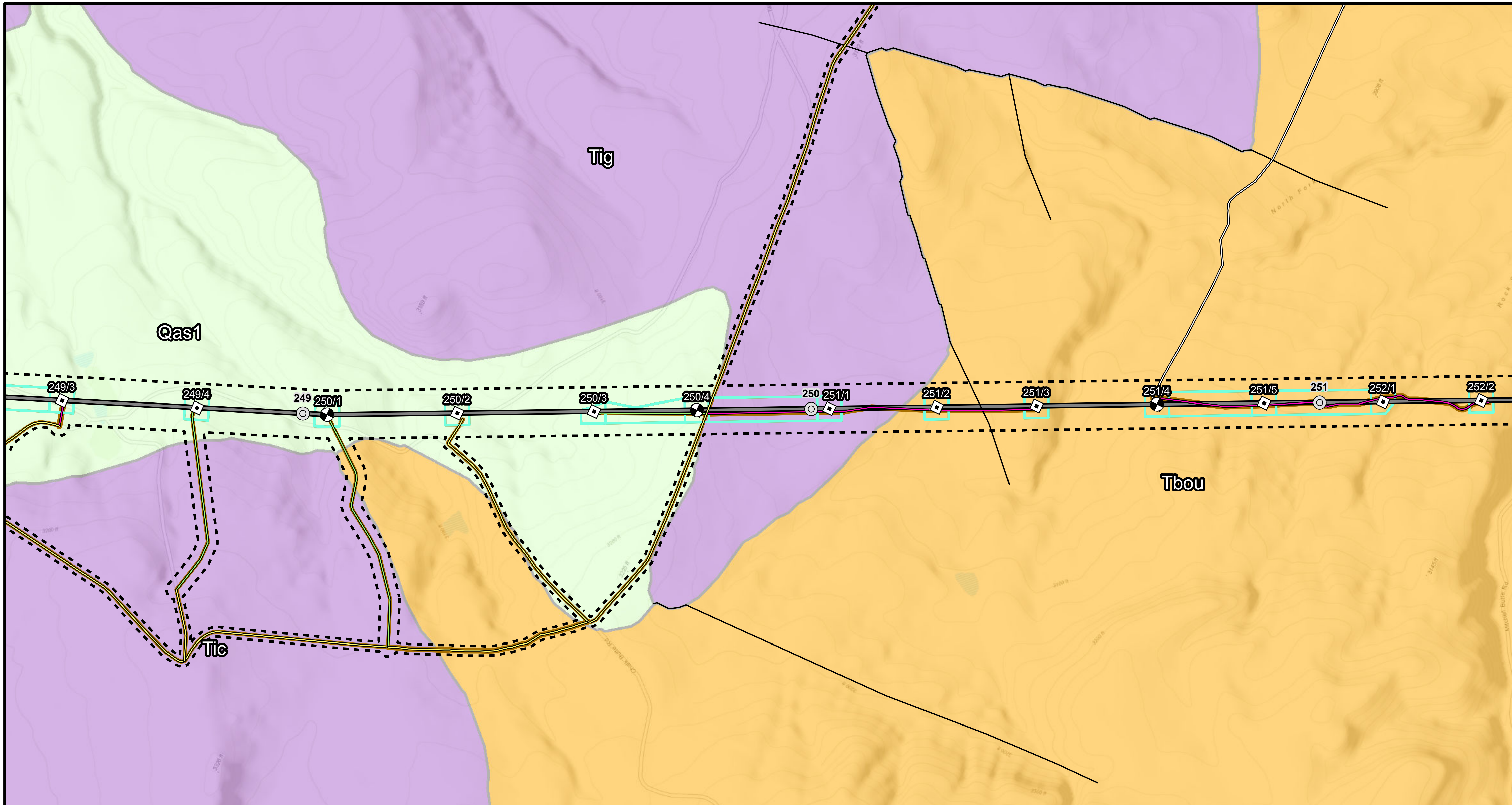


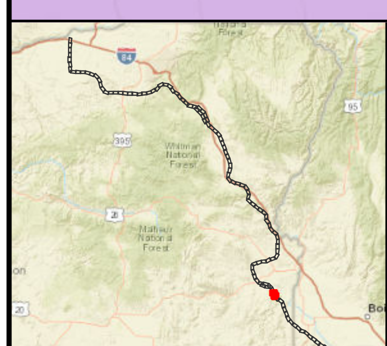

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## GEOLOGY

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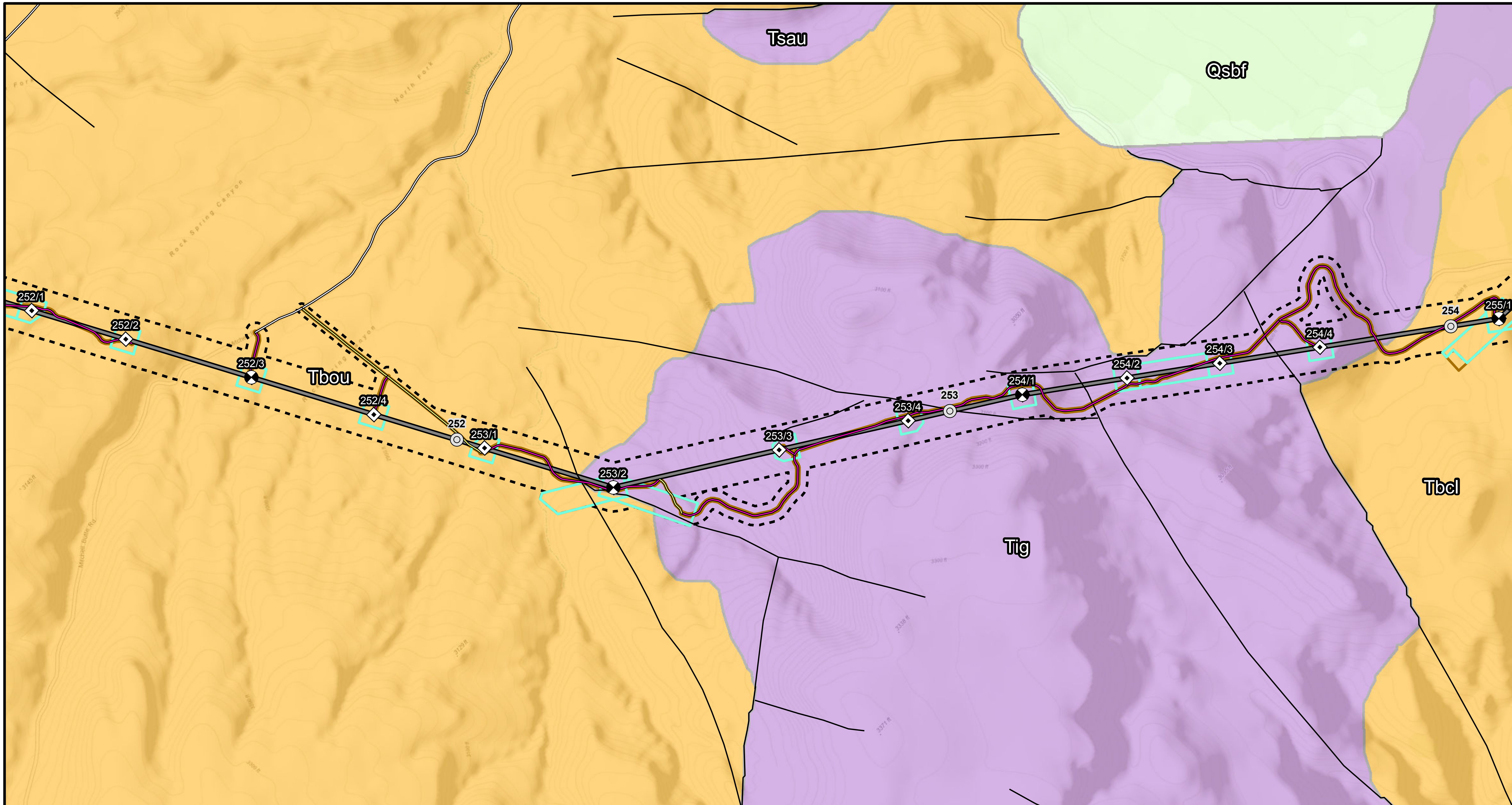


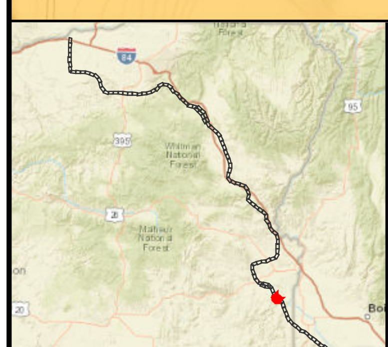

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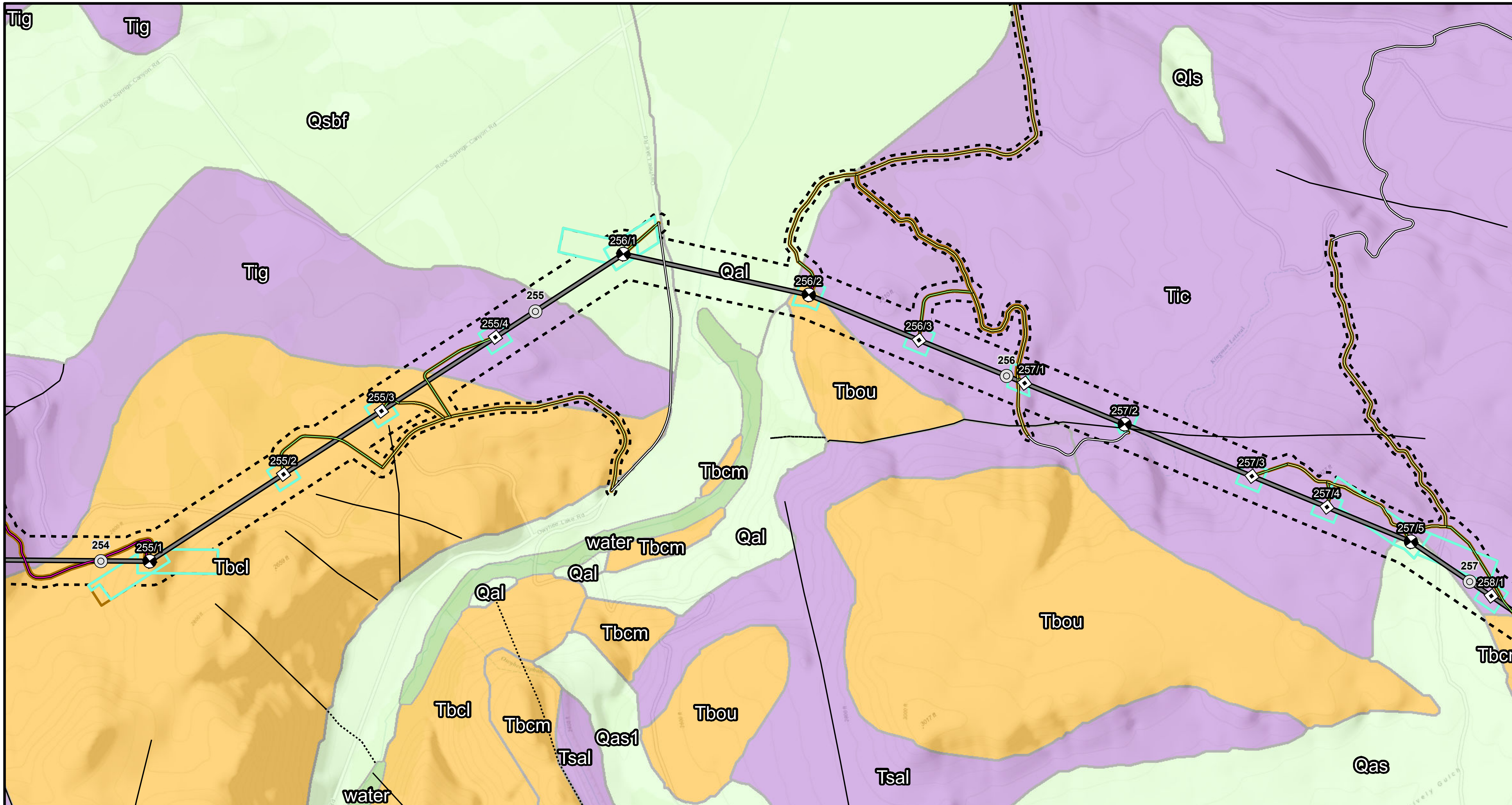


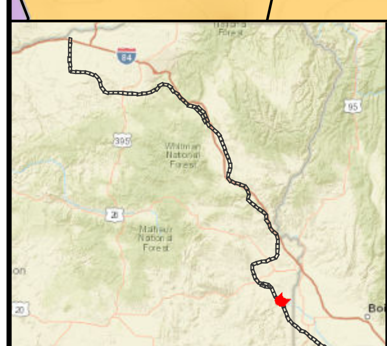

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November 2016 24-1-03820-005

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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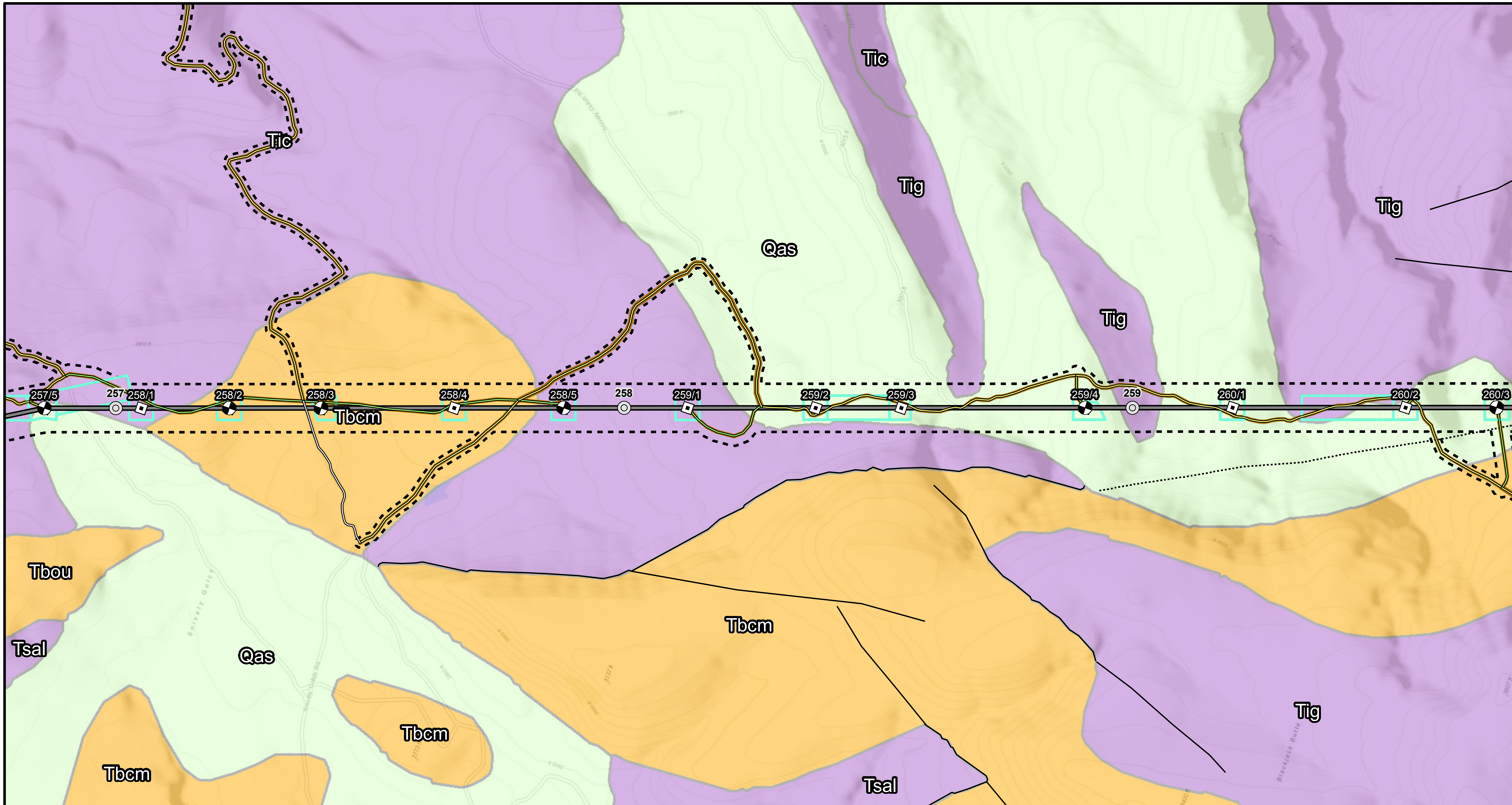


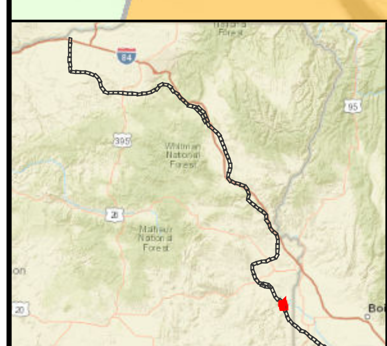

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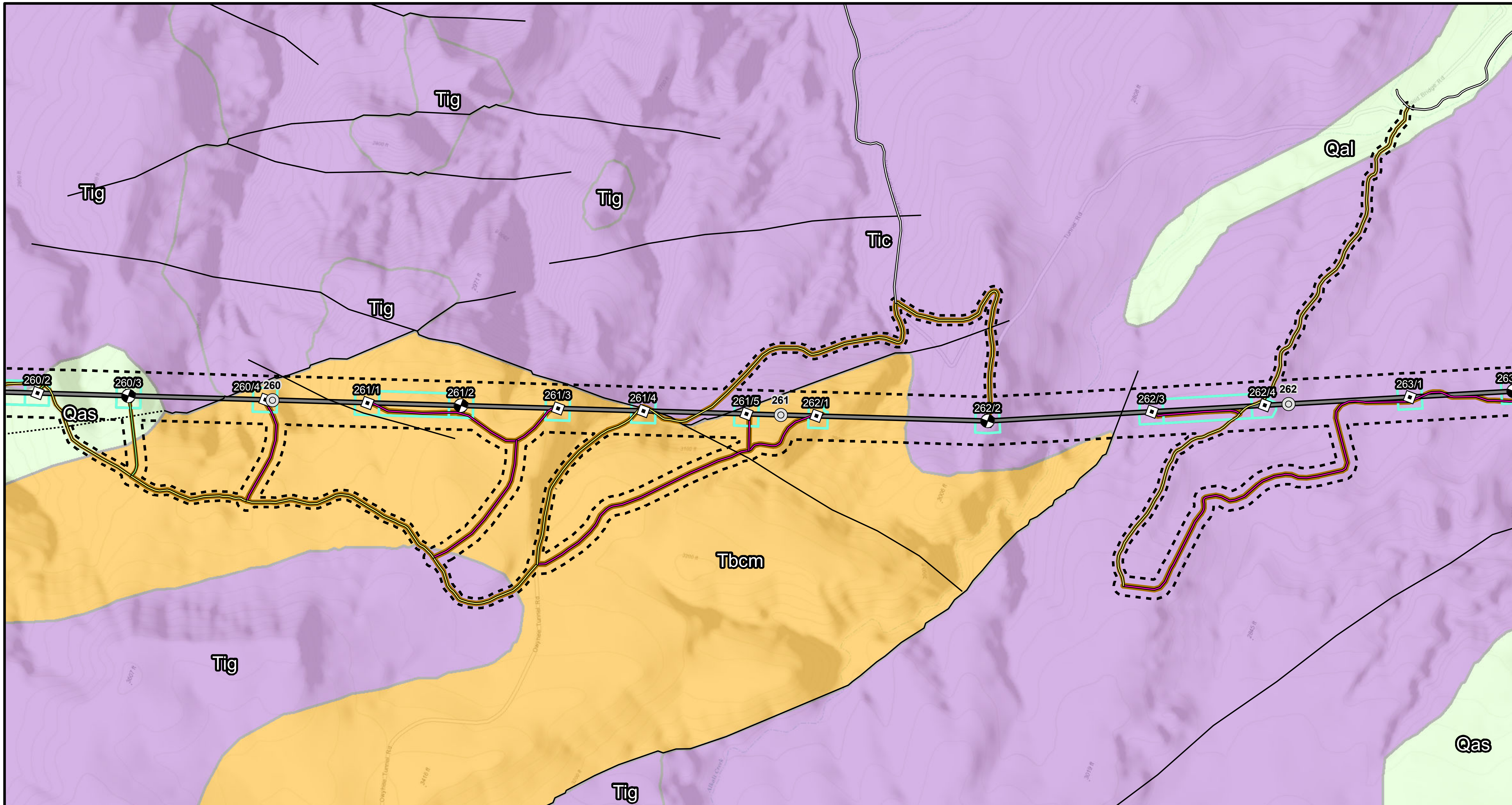


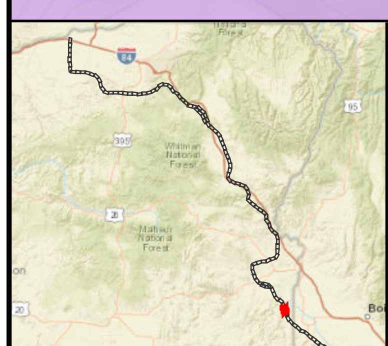

LEGEND

TRANSMISSION FEATURES
- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
- Double Mountain Alternative
- Morgan Lake Alternative
- West Bombing Range Road Alternative 1
- West Bombing Range Road Alternative 2
- Proposed Borings
- Towers
- Substation
- Mileposts
- Distribution Power Lines to Communication Station
- Construction Disturbance
- Operations Disturbance
- Multi-Use Areas
- Other Work Areas
- Site Boundary

SURFICIAL GEOLOGY
- Unconsolidated Sediments
- Sedimentary Rocks
- Volcaniclastic Rocks
- Igneous Rocks
- Metamorphic Rocks

FAULTS
- Accurate
- Approximate
- Concealed
- Inferred
- USGS Mapped Fault
- No Data

ROADS
- New, Bladed
- New, Primitive
- Existing, Moderate to Extensive Improvements
- No Substantial Improvements
- Railroad

NOTE
For geologic unit descriptions see Table A-2

0 500 1,000
Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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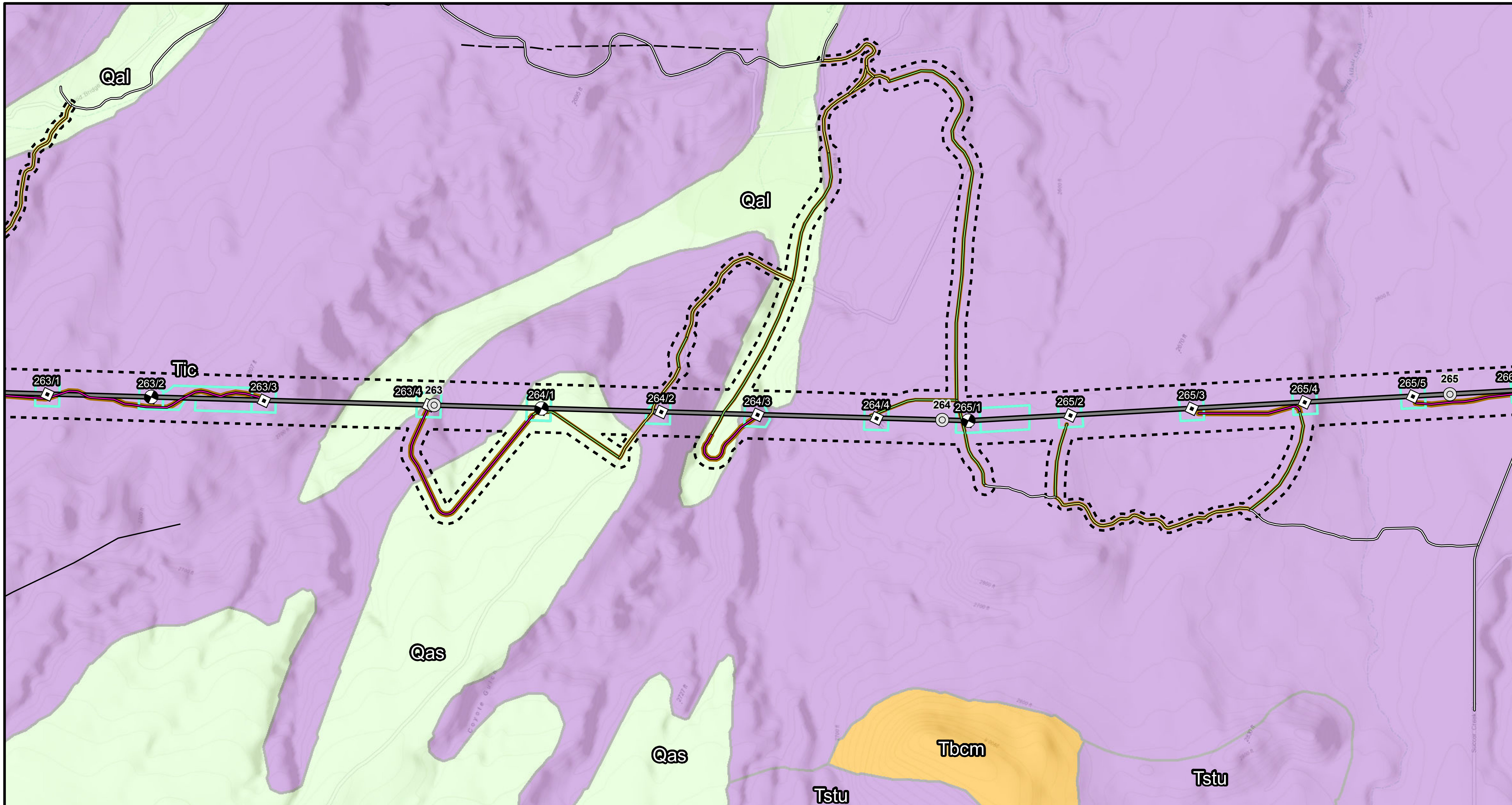


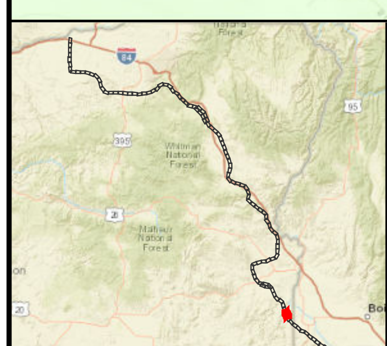

## LEGEND

IPC Proposed Route
Proposed 230-kV Rebuild
Proposed 138-kV Rebuild
Double Mountain Alternative

**TRANSMISSION FEATURES**

Morgan Lake Alternative
West Bombing Range Road Alternative 1
West Bombing Range Road Alternative 2
Proposed Borings
Towers
Substation
Mileposts
Distribution Power Lines to Communication Station
Construction Disturbance
Operations Disturbance
Multi-Use Areas
Other Work Areas
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**SURFICIAL GEOLOGY**

Unconsolidated Sediments
Sedimentary Rocks
Volcaniclastic Rocks
Igneous Rocks
Metamorphic Rocks

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**ROADS**

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New, Primitive
Existing, Moderate to Extensive Improvements
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Railroad

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0 500 1,000 Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY

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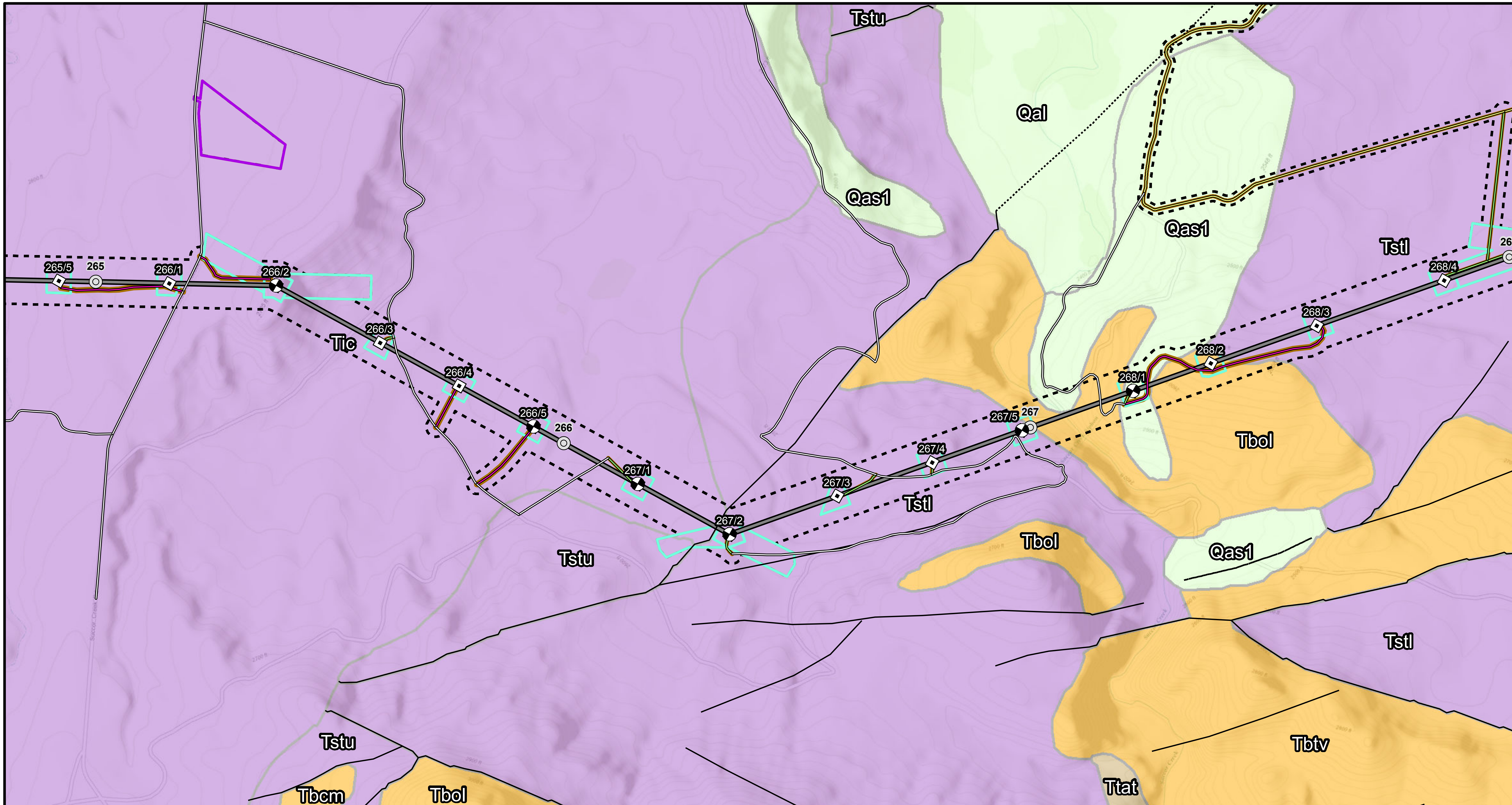


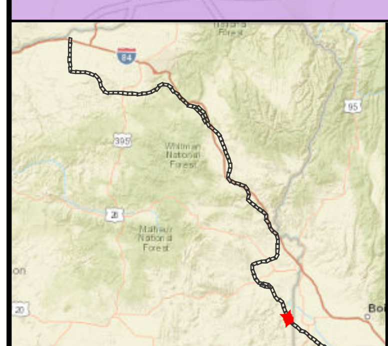

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TRANSMISSION FEATURES
- IPC Proposed Route
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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

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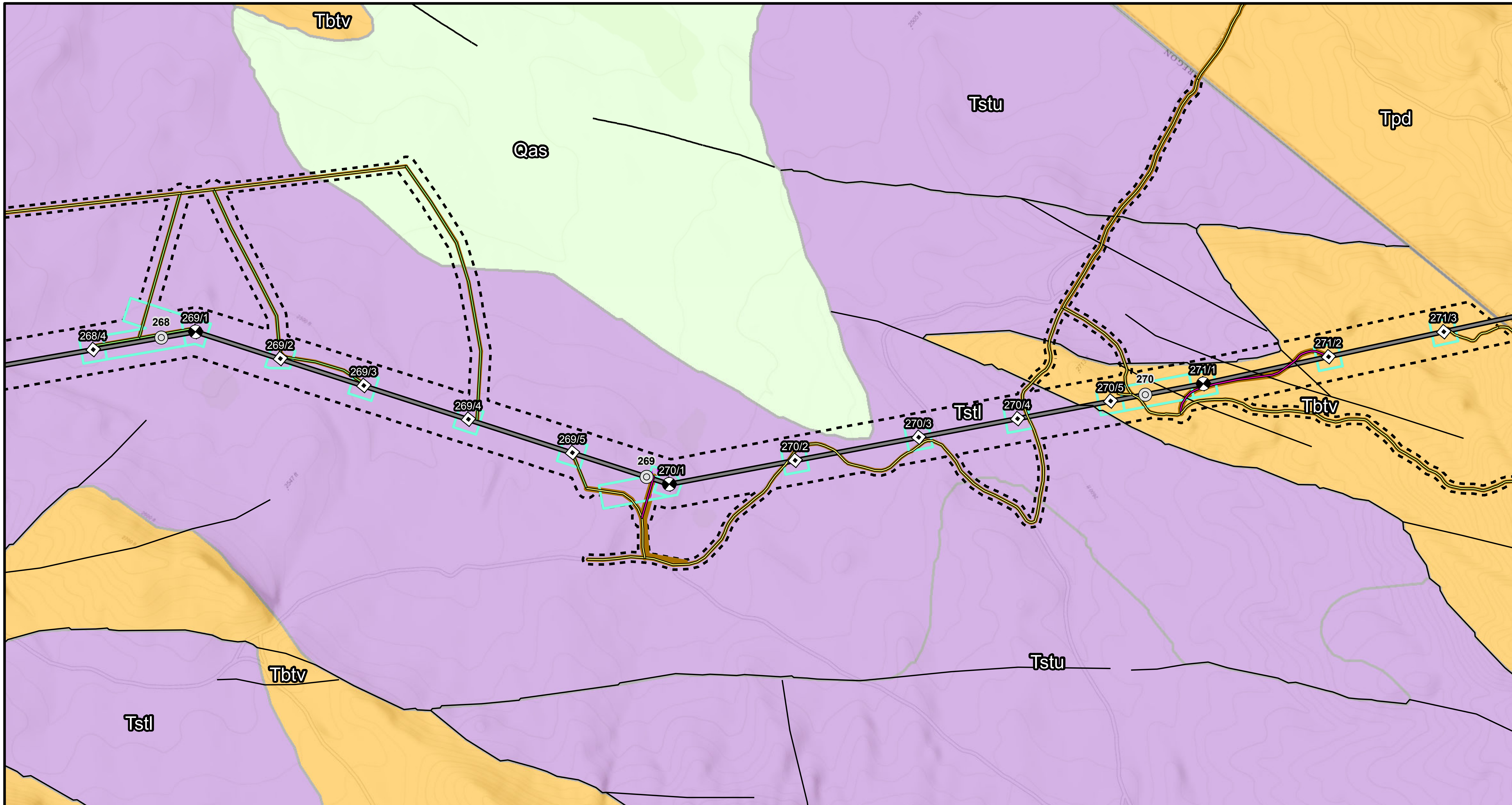


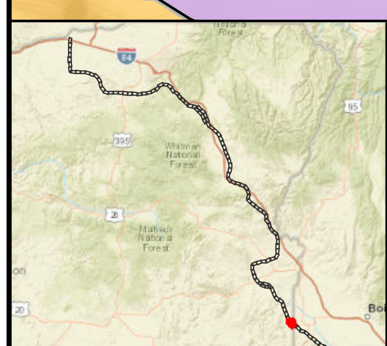

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**TRANSMISSION FEATURES**
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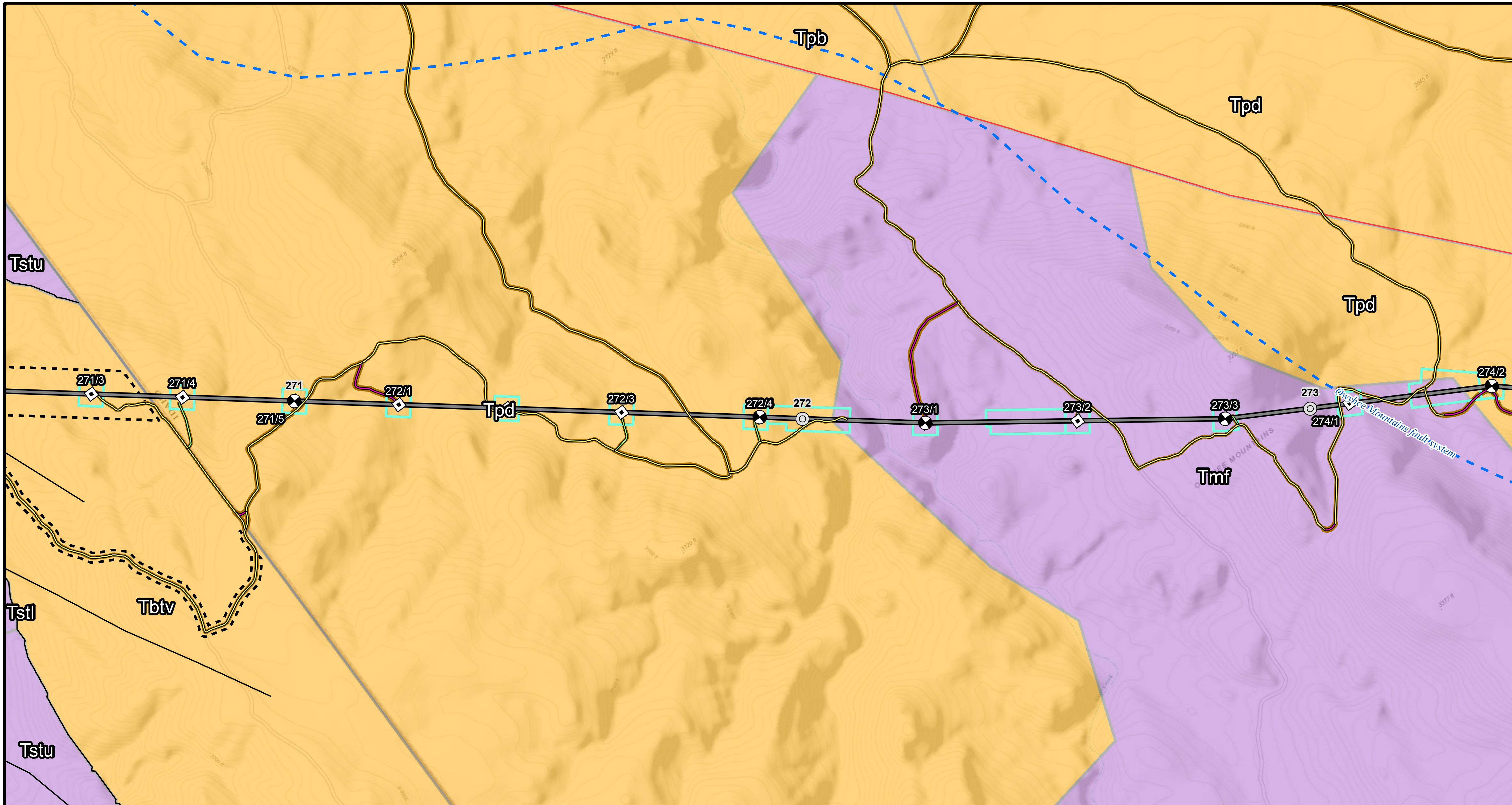


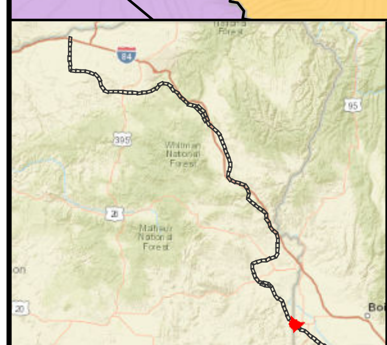

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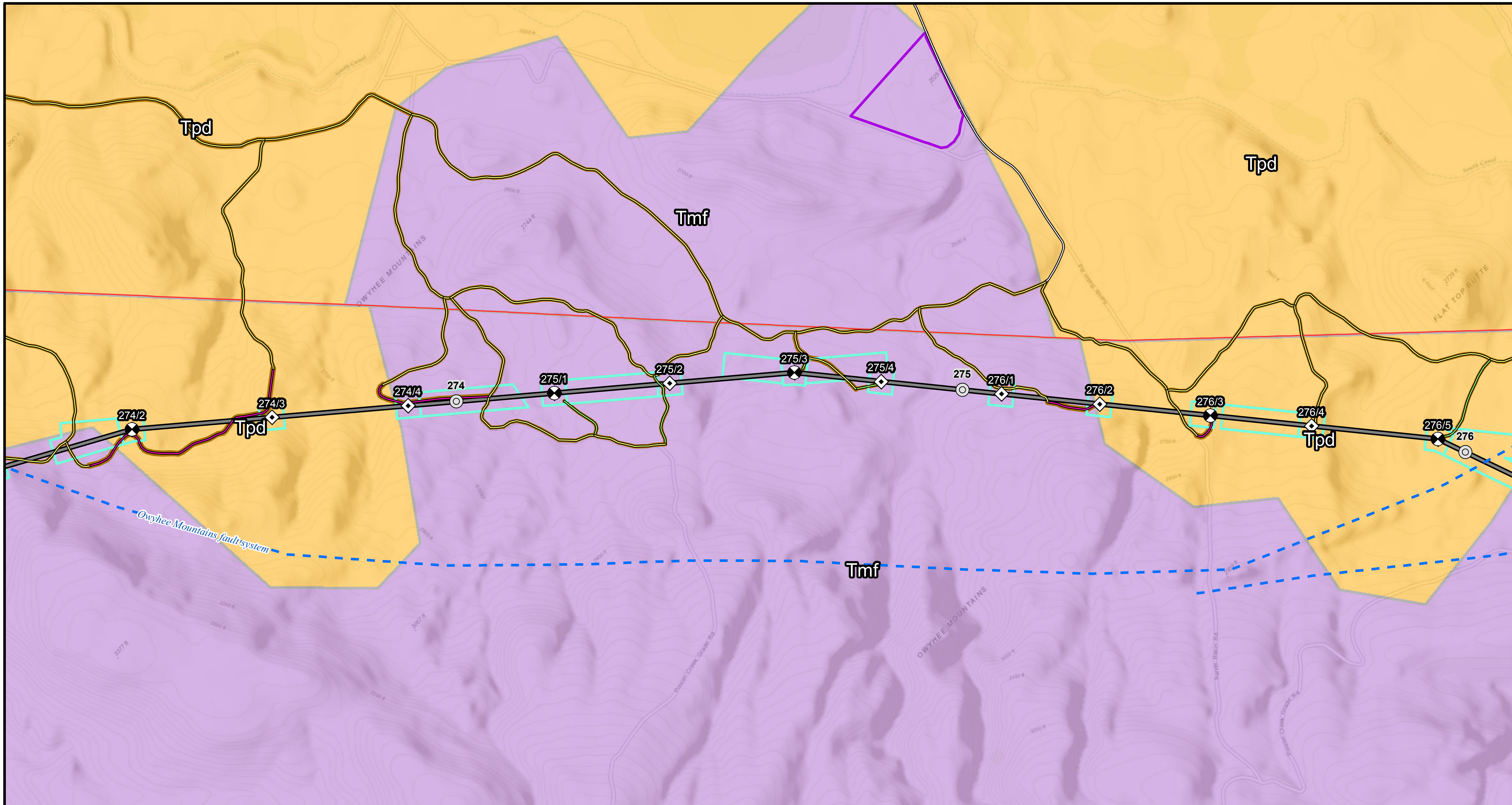


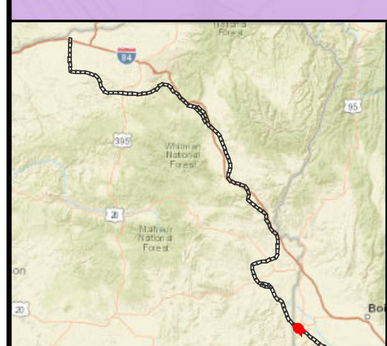

# LEGEND

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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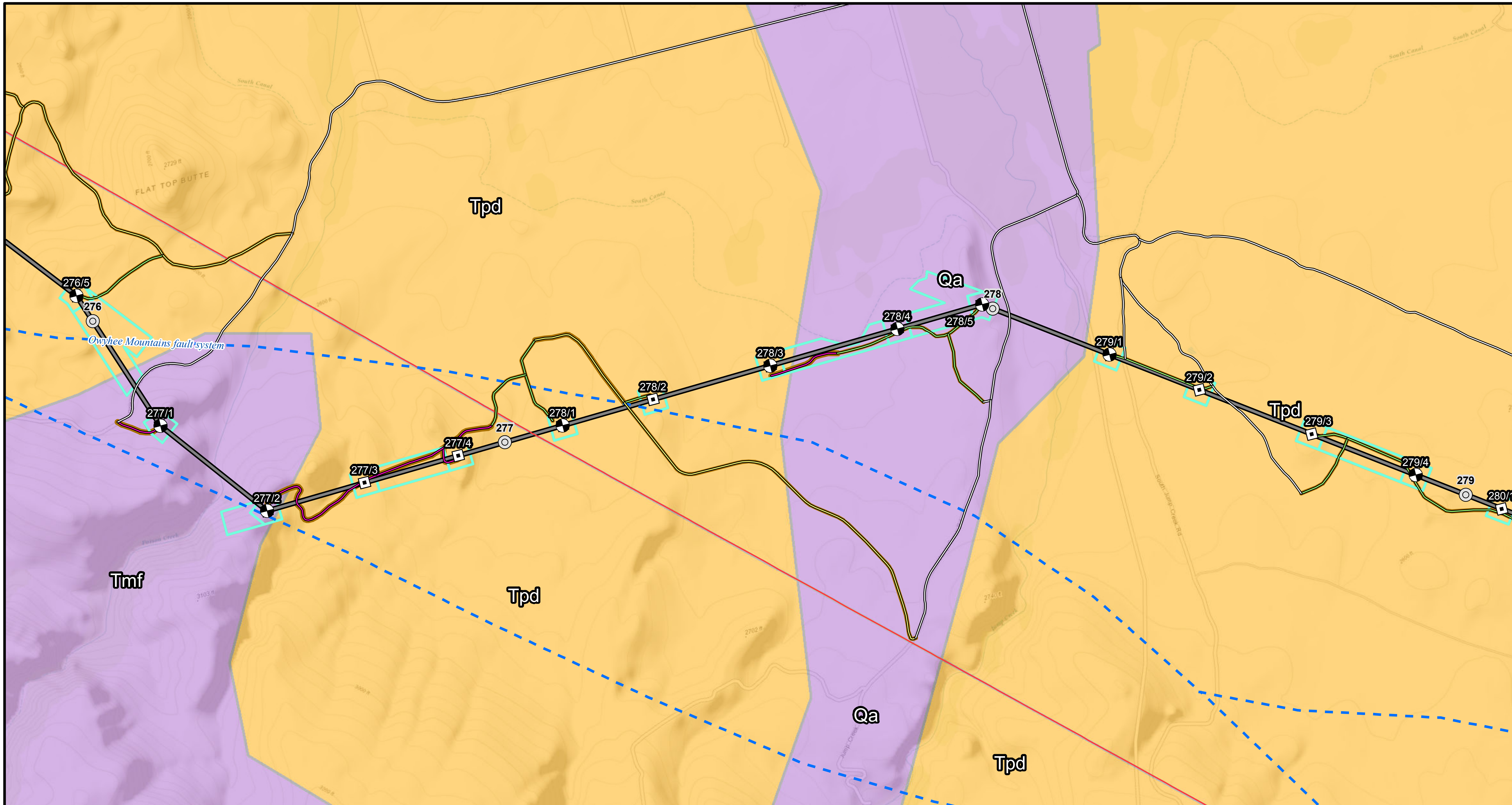


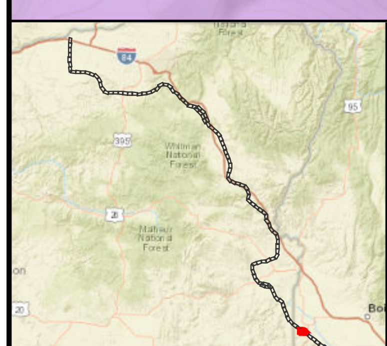

LEGEND

TRANSMISSION FEATURES

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Oregon - Idaho

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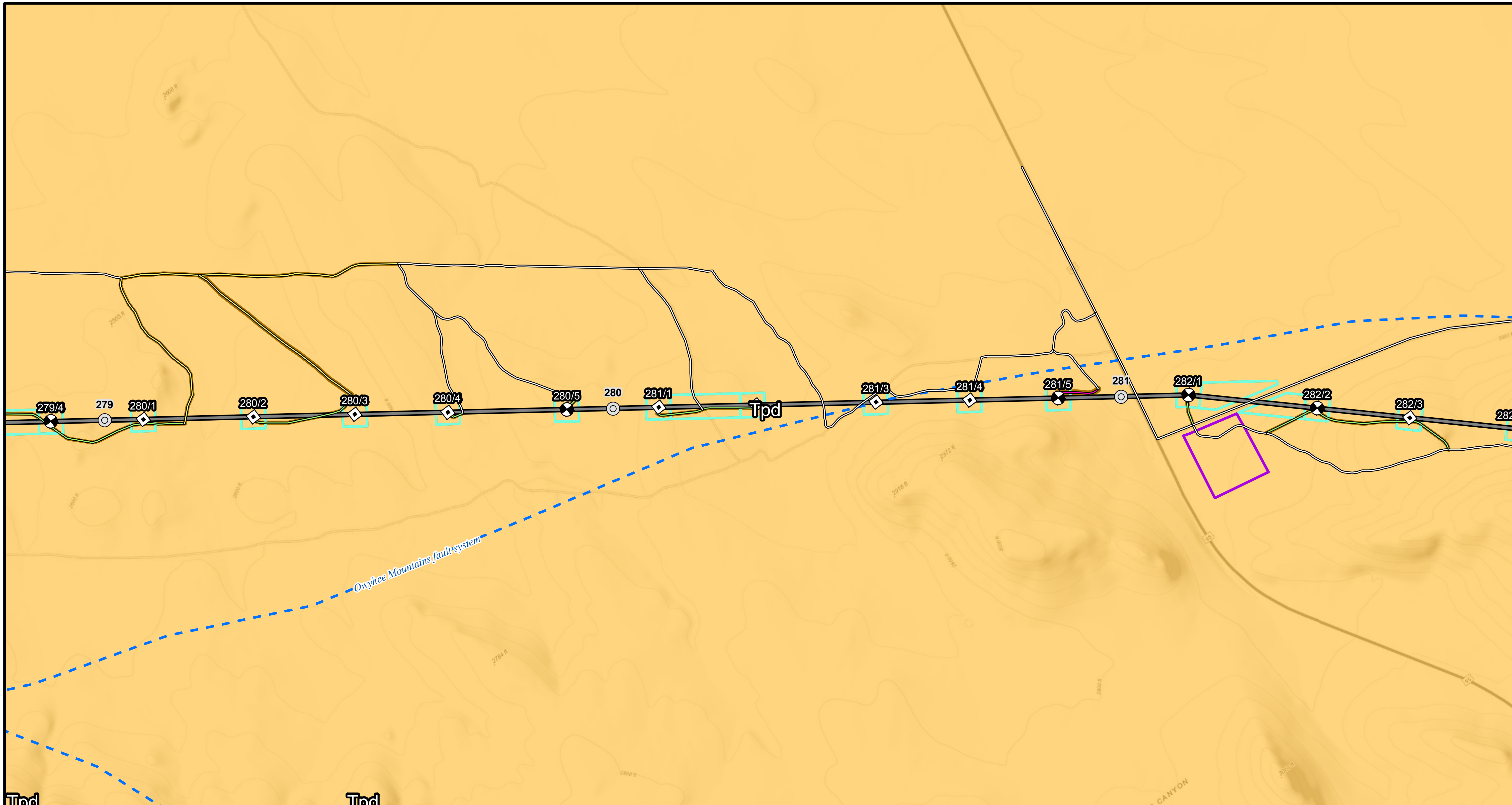


## LEGEND

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Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

## GEOLOGY

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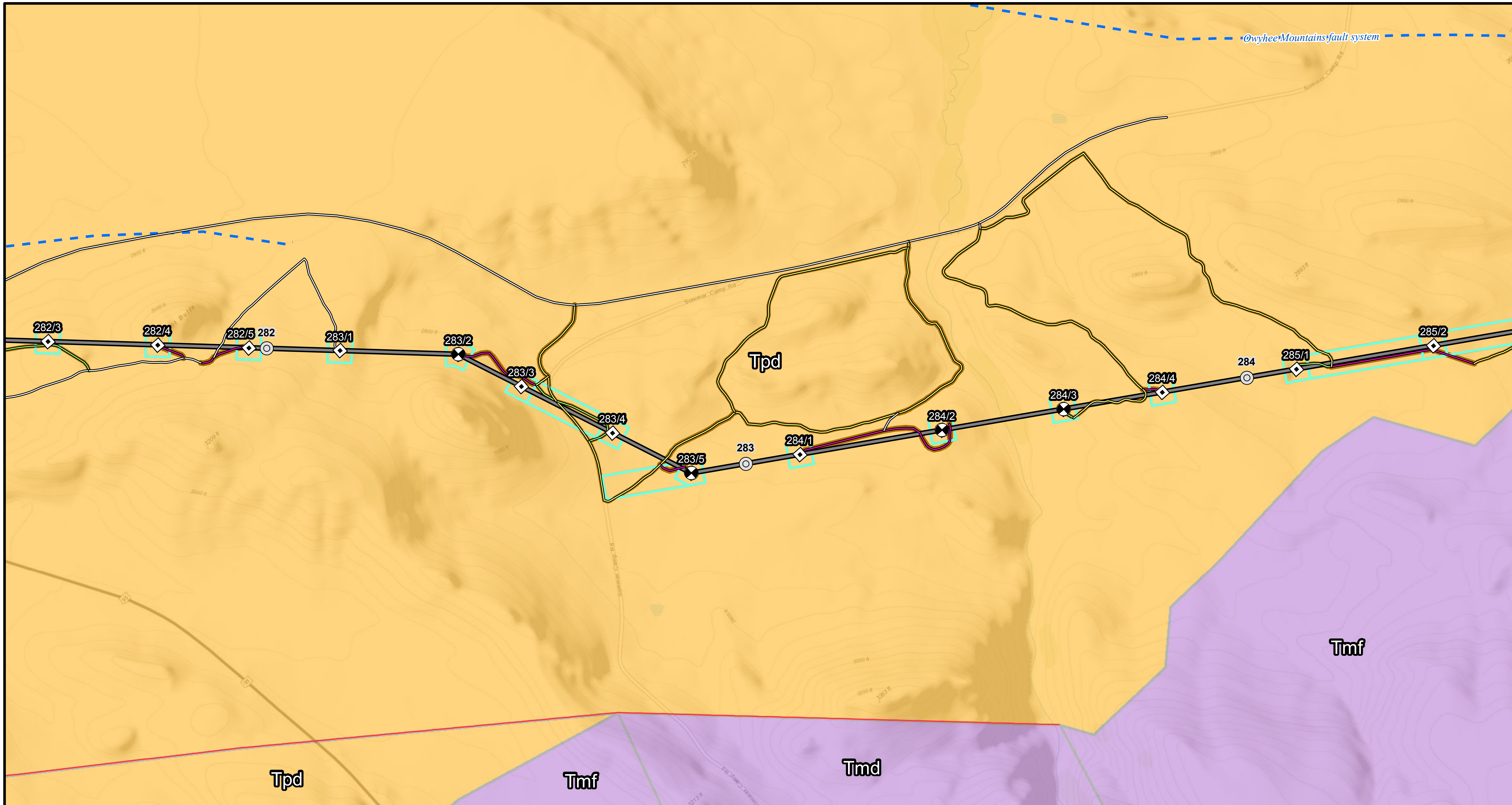


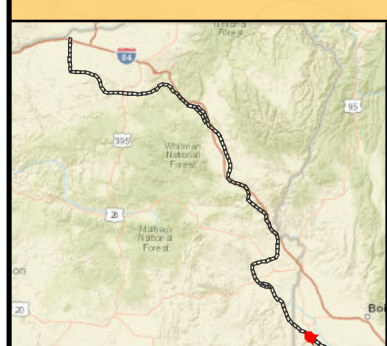

LEGEND

TRANSMISSION FEATURES

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
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Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

GEOLOGY

November 2016 24-1-03820-005

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS



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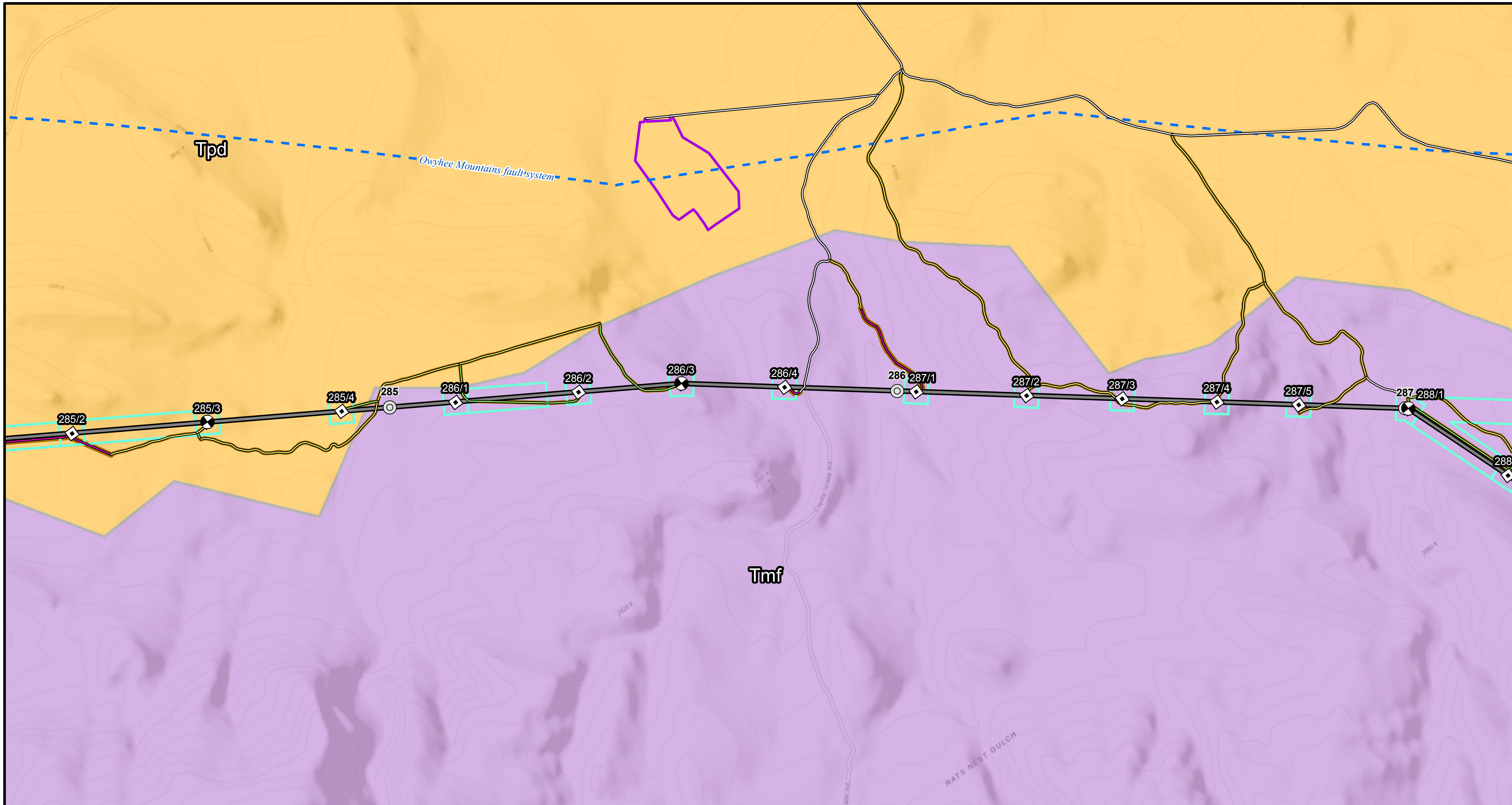


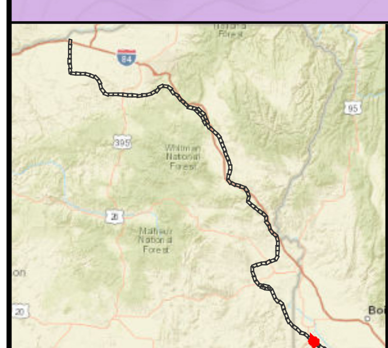

## LEGEND

**TRANSMISSION FEATURES**

- IPC Proposed Route
- Proposed 230-kV Rebuild
- Proposed 138-kV Rebuild
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Feet

Boardman - Hemingway
500kV Transmission Line
Oregon - Idaho

# GEOLOGY

November 2016 24-1-03820-005

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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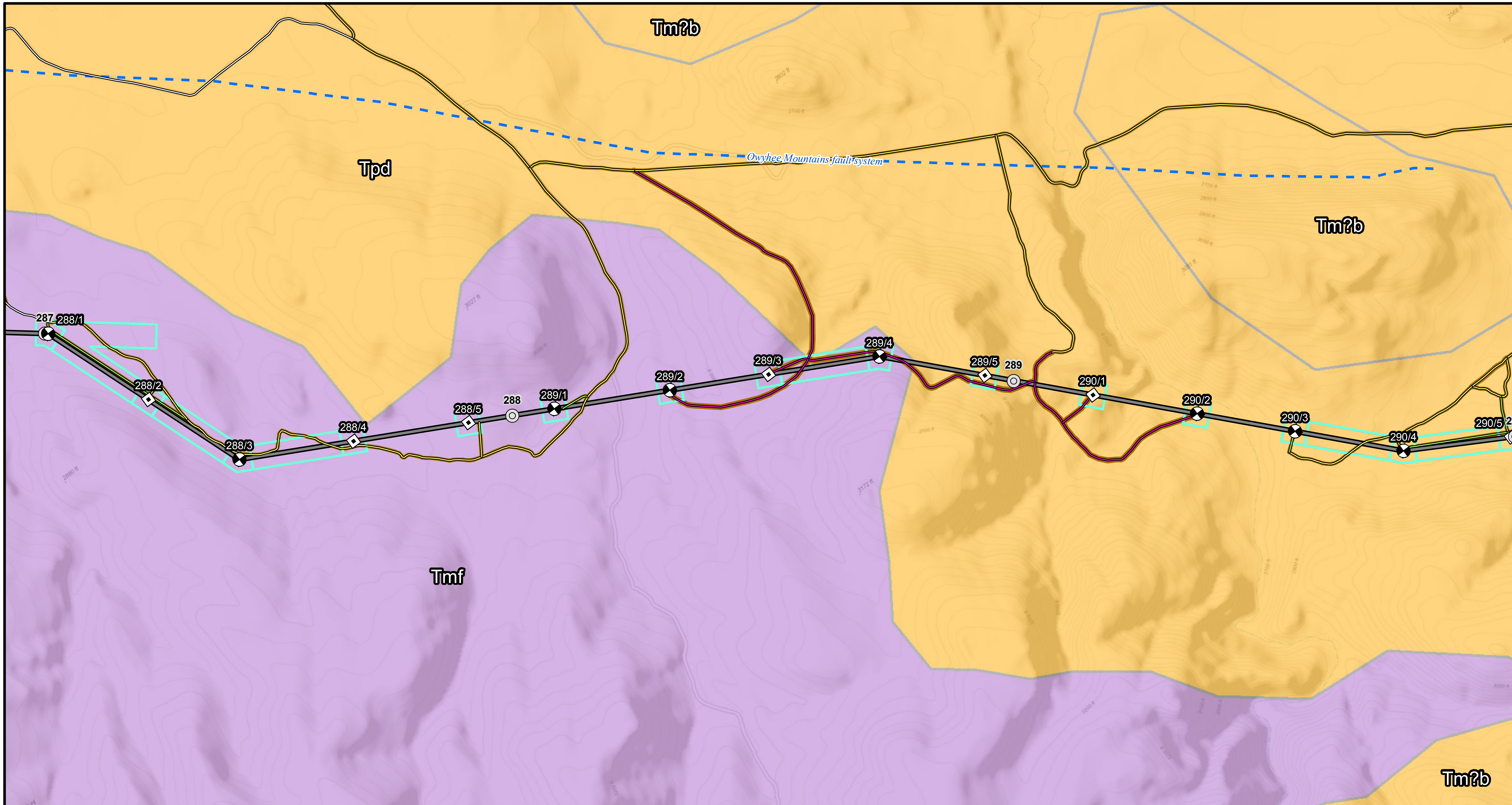


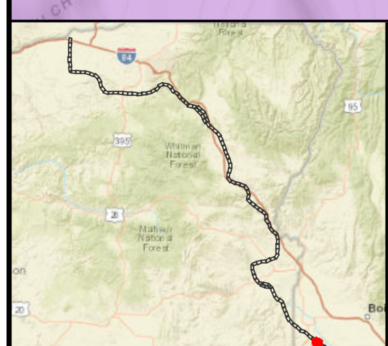

## LEGEND

**TRANSMISSION FEATURES**

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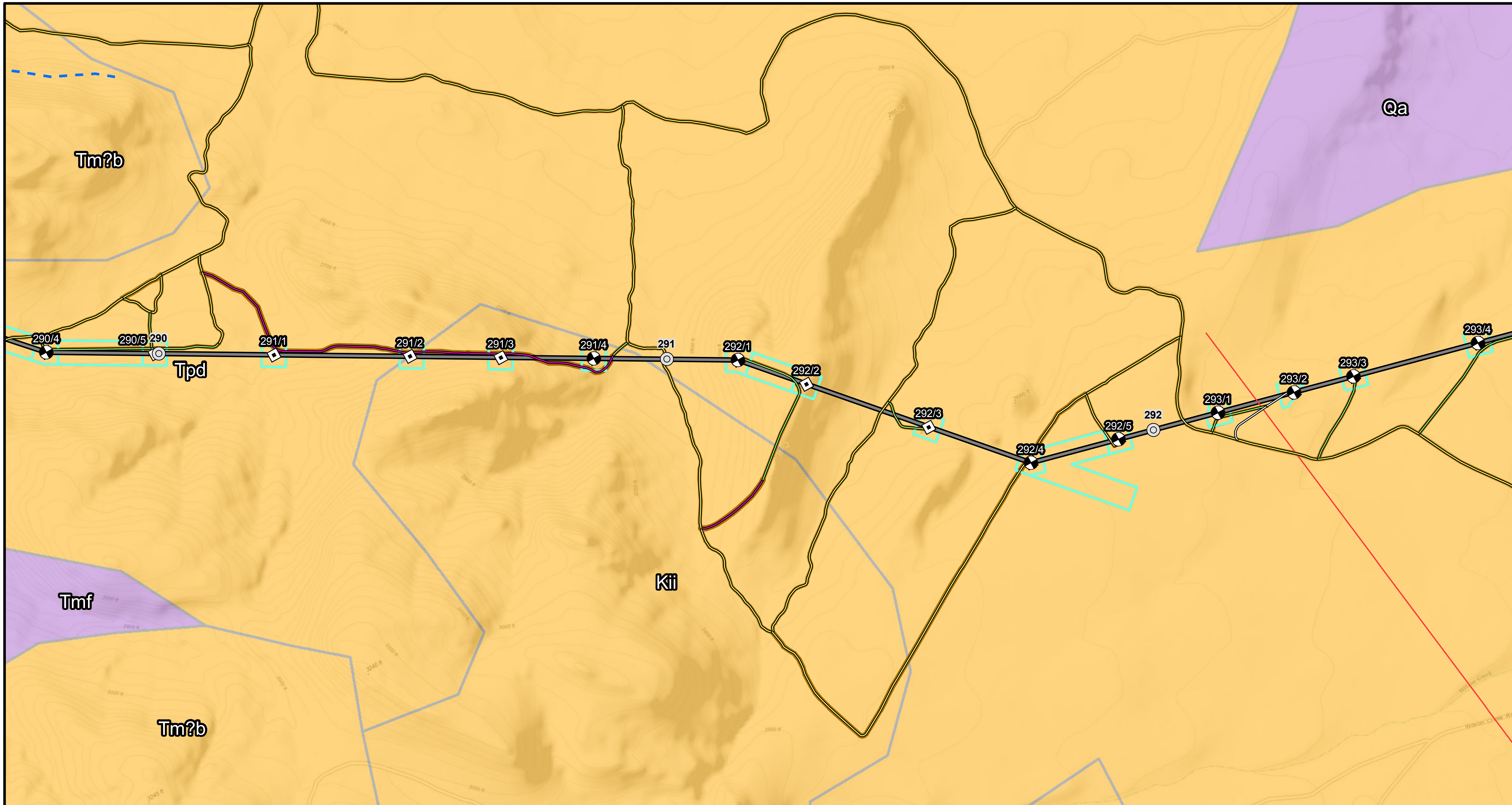


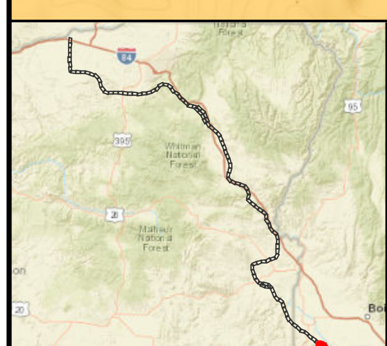

# LEGEND

**TRANSMISSION FEATURES**

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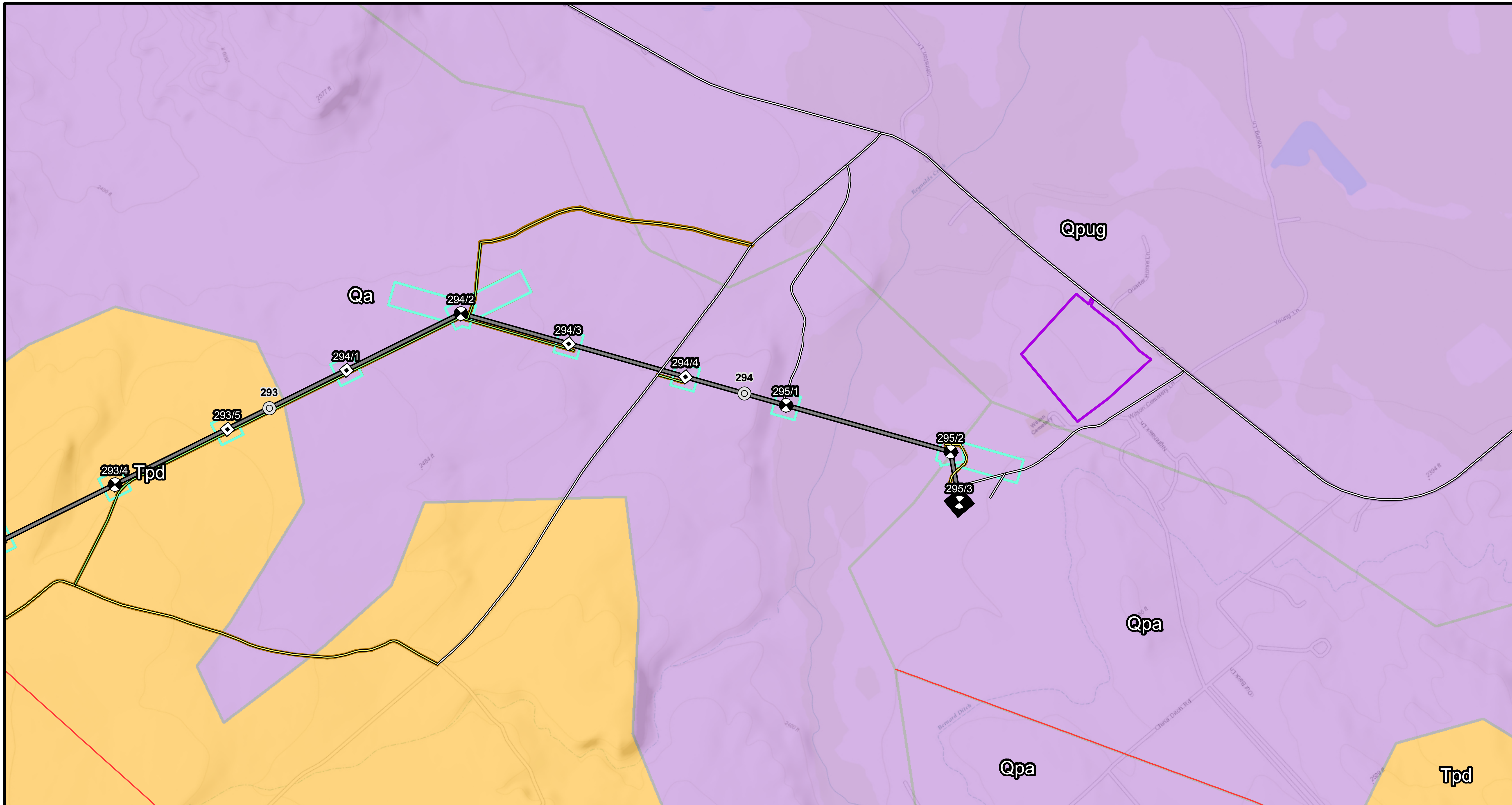


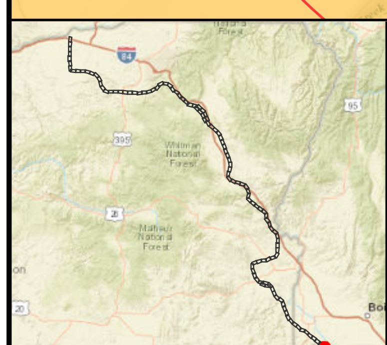

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