APPENDIX A2 *Summary of Phase 1 Geotechnical Investigation* (Caltrans DES-OGDW, 2018)

Borings were originally logged by Caltrans and have been updated for consistency with Phase 2B geologic terminology (see Appendix A6).

State of California
DEPARTMENT OF TRANSPORTATION

California State Transportation Agency

M e m o r a n d u m

Making Conservation
A California Way of Life

To: Jaime Matteoli
Project Manager

Date: May 17, 2018

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From: **DEPARTMENT OF TRANSPORTATION**
DIVISION OF ENGINEERING SERVICES
GEOTECHNICAL SERVICES

Subject: **Summary of Phase 1 Geotechnical Investigation**

1.0 INTRODUCTION

The Office of Geotechnical Design West (OGDW) has prepared this memorandum summarizing the activities performed and preliminary findings of the first phase of the geotechnical investigation to support the planning, evaluation, and design of the alternative alignments that are being considered to bypass State Route 101 between post mile 13.5 and 16.0 in Del Norte County, California (see Figure 1 – Site Vicinity Map). A map showing the proposed alternative alignments is presented in Figure 2 – Site Plan. Descriptions, plan maps, and typical cross sections of the alternative alignments are provided in the Expert-Based Risk Assessment (https://lastchancegrade.com/files/managed/Document/293/Last_Chance_Grade_Expert-Based_Risk_Assessment_Final.pdf).

2.0 SCOPE OF WORK

This memorandum presents a summary of the work conducted as part of the Phase 1 geotechnical investigation to support the evaluation of the alternative alignments. This first phase explores a series of eight sites along the A-Alignment between Station 0+00 and 140+00 chosen for relatively simple permitting and access constraints (see Figure 2 – Site Plan). The purpose of the Phase 1 geotechnical investigation is to begin characterizing the subsurface conditions and landslide features identified in the vicinity of the of the proposed alternative alignments.

The following summary describes the work conducted and findings of this first phase of the geotechnical investigation.

- **Literature Review** – Existing reports, published geologic literature and maps were reviewed and incorporated into a site geologic model.
- **Aerial Photograph and LiDAR Raster Review and Desk-top Mapping -** Historic aerial photographs were reviewed to evaluated historic land use practices and past slope instability. High resolution topographic maps, as well as hill-shade and percent slope images, were generated using available LiDAR data sets. These were examined, and the landforms interpreted to assess potential slope instability features. To improve the efficiently of field mapping specific areas were identified during our review as targets for further evaluation.
- **Field Mapping and Ground-Truthing –** Reconnaissance level field review of the study area was conducted between February 5, and 23, 2018. During this reconnaissance we visited each of the targets identified during our desk-top study, as well as walking, and driving much of the network of roads and skid-trails crossing the study area. During this reconnaissance we mapped, seepage patterns, as well as the distribution of different soil and bedrock materials exposed in natural outcrops and road cut exposures and evaluated their impact on slope stability. In addition, we field-verified desktop mapped features, mapped recent slope failures, evaluated landforms, and observed tilting and bowing of trees.
- **Phase 1 Geotechnical Drilling -** A total of 13 borings were advanced at eight key locations along the A alignment. In general, each boring location was chosen to provide information needed to evaluate the proposed alignment or to confirm the presence or activity of landslides identified in previous steps.
- **Instrumentation and Monitoring** - Stand-pipe monitoring wells were constructed in eight of the 13 borings and vibrating wire piezometers and data loggers installed in these wells to continuously monitor changes in groundwater levels. Slope inclinometers were installed in 5 of the 13 borings to measure ground displacement in suspected landslide features.
- **Phase 1 Seismic Refraction Surveys** - A series of eight seismic refraction surveys were conducted at key locations along the alignment. The purpose of the surveys was to; image subsurface structures such as landslides; to aid in the lateral correlation of geotechnical borings; and to provide data to aid the evaluation of engineering characteristics of rock and soil along the alignment.

3.0 PROJECT DESCRIPTION

A series of different alternative highway alignments have been proposed in order to avoid an active landslide complex impacting the existing alignment between approximately post mile 13.5 and 15.6. The preliminary investigation described in this memo is designed to evaluate two alternatives, designated A1, and A2, which redirect Route 101 inland and up to three quarters of a mile east of the present alignment. The southern 2.4 miles of these two alignments coincide, but to the north they diverge to rejoin the existing highway alignment via different routes. The layout of these proposed alignments has been presented on Figure 2 – Site Plan. The proposed alignments cross heavily vegetated and often steep terrain and a number of different landforms, rock types, and landslide features, which may affect the viability, and design of these alignments.

4.0 FIELD INVESTIGATION

The project engineering geologist performed a site reconnaissance and engineering geologic mapping of the site between February 5, and 23, 2018.

A subsurface exploration was performed between July 10, and September 27, 2018 and included the excavation, logging and sampling of 13 mud-rotary borings, RC-18-001 through RC-18-013, at eight locations to a maximum depth of 100 feet. The location of each boring has been included in Figure 2.

Slope inclinometers (SI) were installed in five of the borings, RC-18-002, RC-18-005, RC-18-007, RC-18-009, and RC-18-011. Piezometers were installed in eight of the borings, RC-18-001, RC-19-003, RC-18-004, RC-18-006, RC-18-008, RC-18-010, RC-18-012, RC-18-013. On December 4, 2018 vibrating wire piezometer probes linked to data loggers were installed in each of the monitoring wells. The data loggers were set to take and record groundwater measurements every 24 hours. On October 2, 2018 initial, baseline readings were performed on each of the five SI's. A second set of readings were performed on December 4th. Ongoing SI readings are scheduled to be conducted approximately four times a year.

Between September 16, and 25, 2018 a series of eight seismic refraction surveys were conducted by a Caltrans Geophysics crew at key locations along the alignment presented in Figure 2. At the time this report was drafted the report presenting the results of these surveys was still pending.

5.0 SITE GEOLOGIC & SUBSURFACE CONDITIONS

5.1 Geologic & Topographic Setting

Preliminary information regarding the site characteristics was obtained from published geologic maps and previous geotechnical investigations and from subsurface exploration and mapping .

The project involves an approximately 2.8-mile long section of Route 101 that extends up the western flanks of a south trending ridgeline which descends between Damnation Creek to the north and Wilson Creek to the south. The steep western slopes of this ridgeline traversed by the Highway descends to the Pacific Ocean. The more gently sloping eastern flanks of the ridge is dissected by a series of un-named drainages, tributaries to Wilson Creek to the east.

Repeated and ongoing landslide activity has impacted the current alignment since shortly after the route was completed in the 1920s. The entire slope between the ridge top and the ocean between post mile 12 and 15.6 is mapped as a large landslide complex.

The site is located within the Coast Ranges geomorphic province of California. According to published geologic maps of the area (Wills, 2000) the site is underlain by formations of the Cretaceous Franciscan Complex including the Mélange and Broken Formation. The Mélange is described as dark grey, highly sheared siltstone and shale containing isolated intact blocks of greywacke, greenstone, chert, and serpentinite. The Broken Formation is described as composed mainly of gray, thickly bedded sandstone with siltstone and shale interbeds. The mélange forms an approximately north-south trending belt within the Broken Formation. The current alignment is mapped as underlain by mélange lithologies between Wilson Creek and PM 14.45, and by Broken Formation between PM 14.45 and 15.6. All but the northernmost portions of the A-alignments where they rejoin the existing alignment are mapped as underlain by Mélange. The relevant portion of this map has been included in Figure 3 – Regional Geologic Map.

5.2 Desk-Top & Field Mapping

As indicated above, the study area encompasses approximately 2,000 acres of often steep and heavily vegetated terrain. To aid the efficient evaluation of such a large area, a combination of aerial photography and LiDAR bare-earth imagery was used to generate a preliminary desktop map of topographic features related to landsliding. This map was then used to focus field mapping efforts and modified by the resulting findings. The finalized landslide map is presented as Figure 4 – Landslide Map. Landslides identified by the mapping were classified based on their activity, confidence of identification, and dominant type of movement. This classification was abbreviated into a three digit numbering system applied to each landslide feature presented in Figure 4.

During our review of aerial photography and LiDAR imagery and later mapping of the site we observed evidence for widespread active landsliding in the vicinity of the existing alignment, as well as the proposed L-Alignment and X-Alignments. The entire western flank of the south trending ridgeline between Wilson Creek to the south to a point approximately 0.6 miles south of Damnation Creek appears to be a massive landslide complex. This landslide complex is made up of many nested slides of different types and activity levels (see Figure 4).

Between Wilson Creek and approximately PM 14.45 the alignment appears to cross an area underlain by Mélange lithologies (KJFm). In this area the landslide complex is interpreted as an active earthflow, characterized by gently rolling irregular slopes averaging approximately 4:1. The existing alignment in this area has been subject to ongoing distress in the form of rolling gradual pavement deformation. Prior to this study little subsurface exploration had been conducted in this area as no structures have been required to mitigate this distress. The eastern edge of this slide is bordered by a prominent but subdued and well vegetated scarp. The western edge of the landslide is bordered by steeper slopes descending to the beach front. North of approximately PM 13.8 this beach appears to be actively eroding due to wave action resulting in a front of active debris flow style landslides (see Figure 4).

Between PM 14.45 and approximately PM 15.6, where the alignment turns east, crosses the ridge and heads inland, it appears to cross an area underlain by Broken Formation lithologies (KJFbf). In this area the landslide complex is dominated by a series of massive interconnected rock-slides. The slopes in this area are steep, averaging approximately 1½:1. The existing alignment in this area has been subject to ongoing distress in the form of dissection by scarps of significant offset. Numerous mitigation structures have been constructed along this portion of the alignment, mostly consisting of solider pile and ground anchor retaining walls. The eastern edge of this area is bordered by an anastomosing zone of steep scarps separating extensional blocks, often separated by gentile slopes or depressions. Review of aerial photography suggest that many of the swales extending down the slope below this area have been episodically stripped of vegetation by debris slides originating at these head scarps. The western edge of this slide is bordered by steeper slopes descending to the beach front. The slopes above the beach are lined by a series debris slides some of which extend a significant way up the slope towards the highway alignment. A number of nested rockslides extend up the slope between the alignment and this steepened beach front slope resulting in past bearing failure of the road surface.

The proposed A-Alignments leave the existing alignment at approximately PM 13.5 curving east and crossing the ridgeline at approximately Station (Sta.) 20+25. West of this point the alignments cross gently southwest sloping topography interpreted as active earthflow (Qls 112, see Figure 4).

Between Sta. 20+25 and approximately Sta. 55+ 15 the Alignment crosses a series of steep sided, south trending, bedrock spur-ridges and intervening drainages. We interpret this portion of the alignment as underlain by Broken Formation lithologies (KJFbf). Outcrop in this area; in drainages, on slopes, and in road cuts consisted of moderately to intensely weathered sandstone. Boring RC-18-013, excavated into the easternmost of these ridges encountered sandstone bedrock to the full depth explored. Other than a series of small rock and debris slides impacting cut-slopes associated with a logging road upslope of the alignment, we observe no evidence of slope instability in this area. Previous mapping (Wills, 2000) delineated a landslide, designated as a "probable, mature, rock slide", intersecting the alignment between Sta. 29+40 and 45+50. Based on our preliminary desk-top and field mapping we observed no evidence for this landslide. We recommend further evaluation of this feature.

Between Sta. 55+15 and approximately 120+40 the alignment crosses onto topography characterized by gently rolling irregular slopes averaging approximately 4:1. This topography is similar in slope and character to the active earthflow on the opposite side of the ridge, but is more deeply incised by drainages, and lacks a defined head-scarp along its upper margin. Based on borings this portion of the alignment is underlain by Mélange lithologies, often decomposed to a clayey soil in the upper 50-60 feet. The area is tentatively interpreted as a series of dormant earthflows, locally containing nested rock slides.

Between Sta. 120+40 and 140+00 the alignment crosses the crest and gently sloping eastern flanks of a north trending ridgeline. Two borings, RC-18-003 and RC-18-004 drilling along this portion of the alignment encountered predominantly Broken Formation lithologies, consisting of thickly interbedded siltstone and sandstone. However, Mélange lithologies were encountered in the lower 4 feet of RC-18-003, and in layers separating intact rock making up approximately half of the lower 50-feet of RC-18-004. We interpret this location as being close to the boundary between the north-south trending band of Mélange to the east and the Broken Formation to the west.

North of approximately Sta. 140+00 the A1 and A2-Alignments deviate and cross a steep sided gully on separate bridge footprints. As no borings were excavated north of RC-18-004 as part of Phase 1, we provide very preliminary opinions based on our interpretation of topographic expression, and mapping of limited outcrop and cut-slope exposures, below.

The A1 tunnel, extending between the western end of this bridge and the existing alignment will likely encounter Broken Formation lithologies and no discernable landsliding east of the main coastal side complex.

Between Sta. 148+00 and 164+50 the A2-Alignment crosses the gently east sloping end of an east trending ridgeline. Previous mapping (Wills, 2000) delineated this ridge end as consisting of two nested rock slides, the southern of which is designated as questionable and the northern of which is designated as probable. Based on our interpretation of LiDAR imagery we don't see evidence for these rockslides. However, the gentile slopes suggest the area is underlain by weak, probably Mélange rock.

North of approximately Sta. 161+70 the A2-Alignment crosses and east trending drainage on an approximately 1,100-foot long bridge before rejoining the existing alignment at approximately PM 16.0. Between approximately Sta. 175+00 and the intersection of the existing alignment the A2-Alignment crosses an area mapped as a probable, mature, rockslide, based on LiDAR imagery. Field truthing of this feature suggests that, if present, it must be quite old. The feature crosses the existing alignment, but no history of pavement distress is noted in this area. The feature is vegetated by old-growth redwood trees of significant size and age, which show no signs of past disturbance. The proximity of this feature to the northern abutment of the bridge makes further evaluation of the existence, activity, and lateral extent critical to the evaluation of the A2-Alignment.

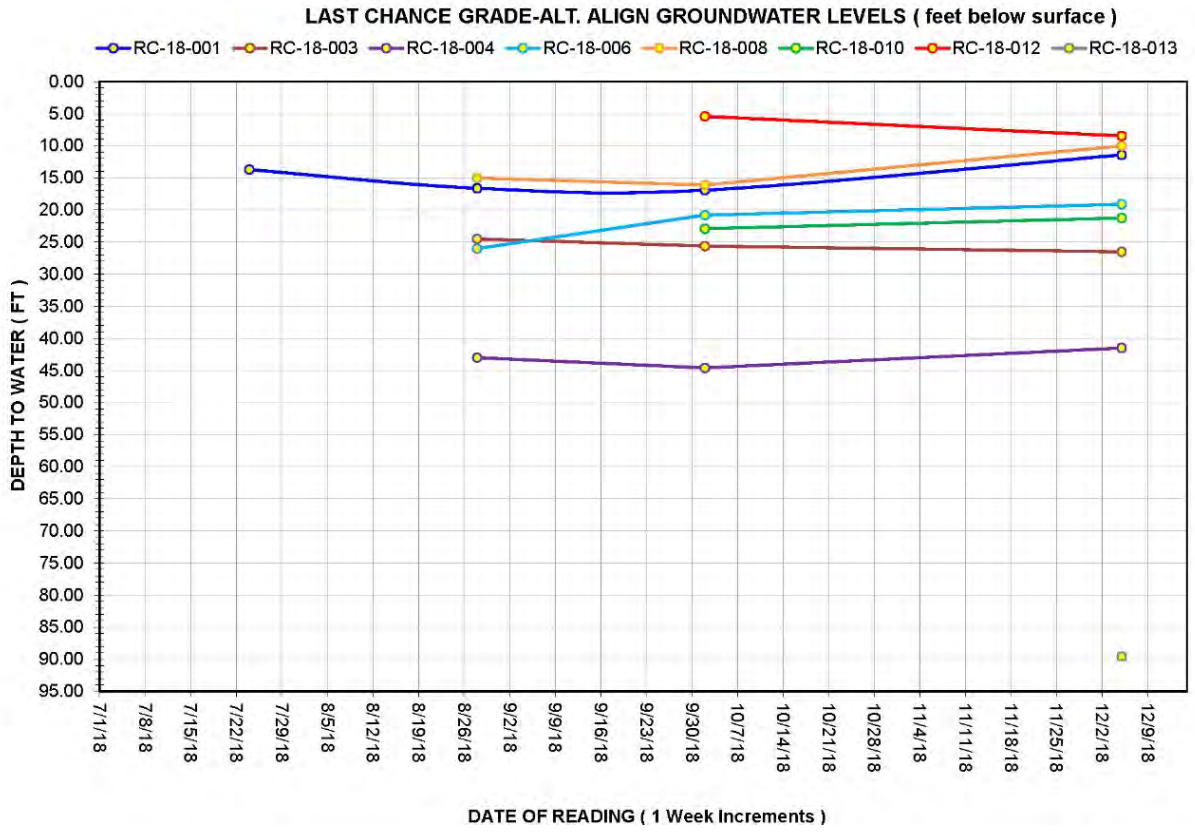
5.3 Subsurface Conditions

As indicated above, based on instrumentation needs, 13 borings were drilled at eight locations. The additional borings were drilled to allow both SI and Piezometers to be installed, in separate holes at five of the locations. Consequently, only eight of the borings conducted; RC-18-001, RC-18-003 through RC-18-005, RC-18-007, RC-18-009, RC-18-0011, and RC-18-013 were logged and sampled.

In general, each of the eight borings encountered a surficial layer of fill up to 10.5 feet in thickness, locally overlying colluvium, and residual soil, which in turn overlies Franciscan Formation rock which persisted to the maximum depth explored of 100 feet. Of the eight logged borings, all but RC-18-003, RC-18-004, and RC-18-013 encountered Mélange lithologies. RC-18-013 encountered massive greywacke sandstone to the full depth explored, grading from residual soil to moderately weathered, moderately hard, and moderately to intensely fractured at 100 feet. Although generally consisting of a pervasively sheared and foliated shale matrix containing fresh, hard, sandstone porphyroclasts between coarse sand and boulder sized, the consistency of the mélange was highly variable between borings. The mélange encountered in borings RC-18-001, RC-18-007, RC-18-009, RC-18-0011 was predominately decomposed to a clayey soil texture (CL, GC), while mélange encountered in borings RC-18-003, RC-18-004, and RC-18-005 while typically soft to moderately soft and very intensely fractured, retained a crushed rock fabric. Boring logs have been included as Attachment 1.

5.4 Groundwater

As indicated above eight piezometers were installed as part of our Phase 1 exploration. At the time this report was drafted vibrating wire piezometers and data loggers had only recently been installed in these monitoring wells, and the resulting high-density groundwater data had yet to be downloaded. Groundwater was manually measured several times prior to this installation. The results are presented in Chart 1 below. The groundwater varies widely between 89.6 feet bgs for RC-18-013 to 5.4 feet bgs for RC-18-012. In general, we observed that sites with more permeable soils such as fractured sandstone have deeper groundwater than sites with impermeable clayey soils. Additionally, sites located on ridgelines with little upslope catchment have deeper groundwater.



5.5 Slope Indicators

As indicated above five slope indicators were installed and initialized as part of our Phase 1 exploration. At the time this report was drafted no repeat measurements had been conducted, so no information on potential slope movement was available at these locations.

Any questions regarding the above recommendations should be directed to Eric A. Wilson (707) 441-5607.

Report by:

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Engineering Geologist
Office of Geotechnical Design-West

Figures:

Figure 1 – Site Vicinity Map
Figure 2 – Site Plan
Figure 3 – Regional Geologic Map
Figure 4 – Landslide Map

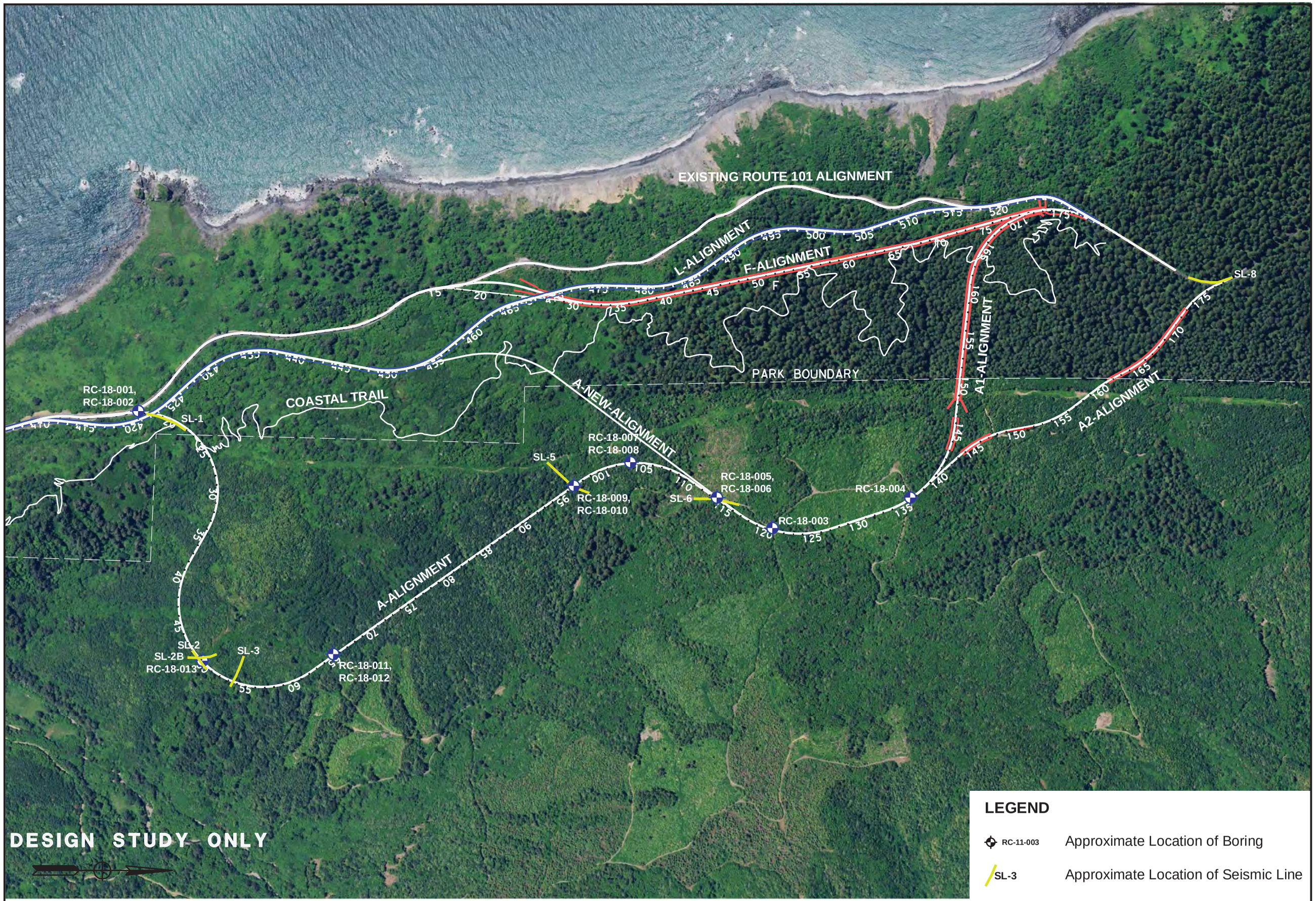
Attachments:

Attachment 1 – Boring Records

References:

Wills, C. J., 2000, Landslides in the Highway 101 Corridor Between Wilson Creek & Crescent City, Del Norte County, California, CGS Special Report 184.

Caltrans	**LAST CHANCE GRADE BYPASS** **HIGHWAY 101, POST MILE 13.4/16.0** **DEL NORTE COUNTY, CALIFORNIA**	**SITE VICINITY MAP**
	DECEMBER 2018	**FIGURE 1**

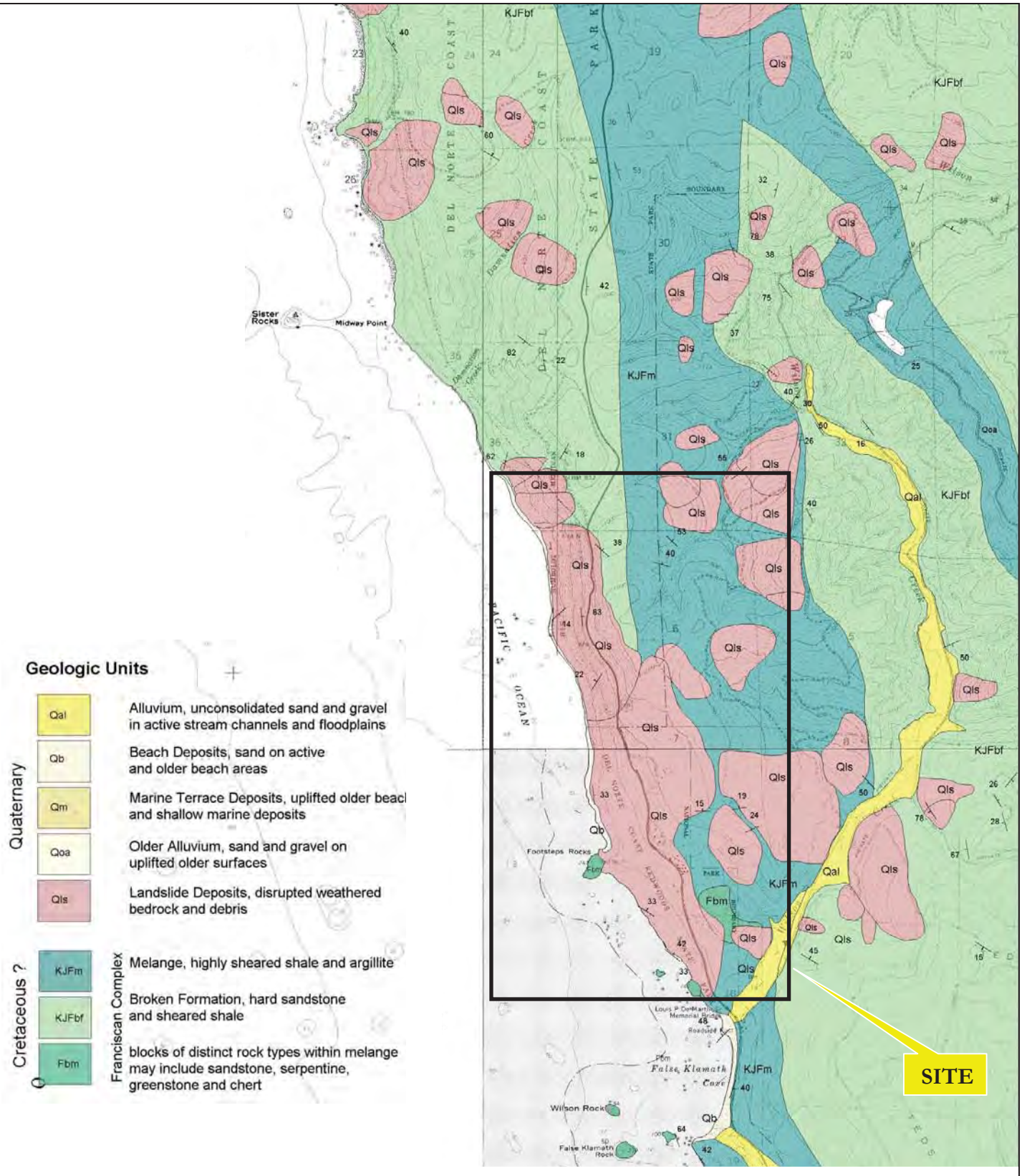


Caltrans

LAST CHANCE GRADE BYPASS
SITE PLAN

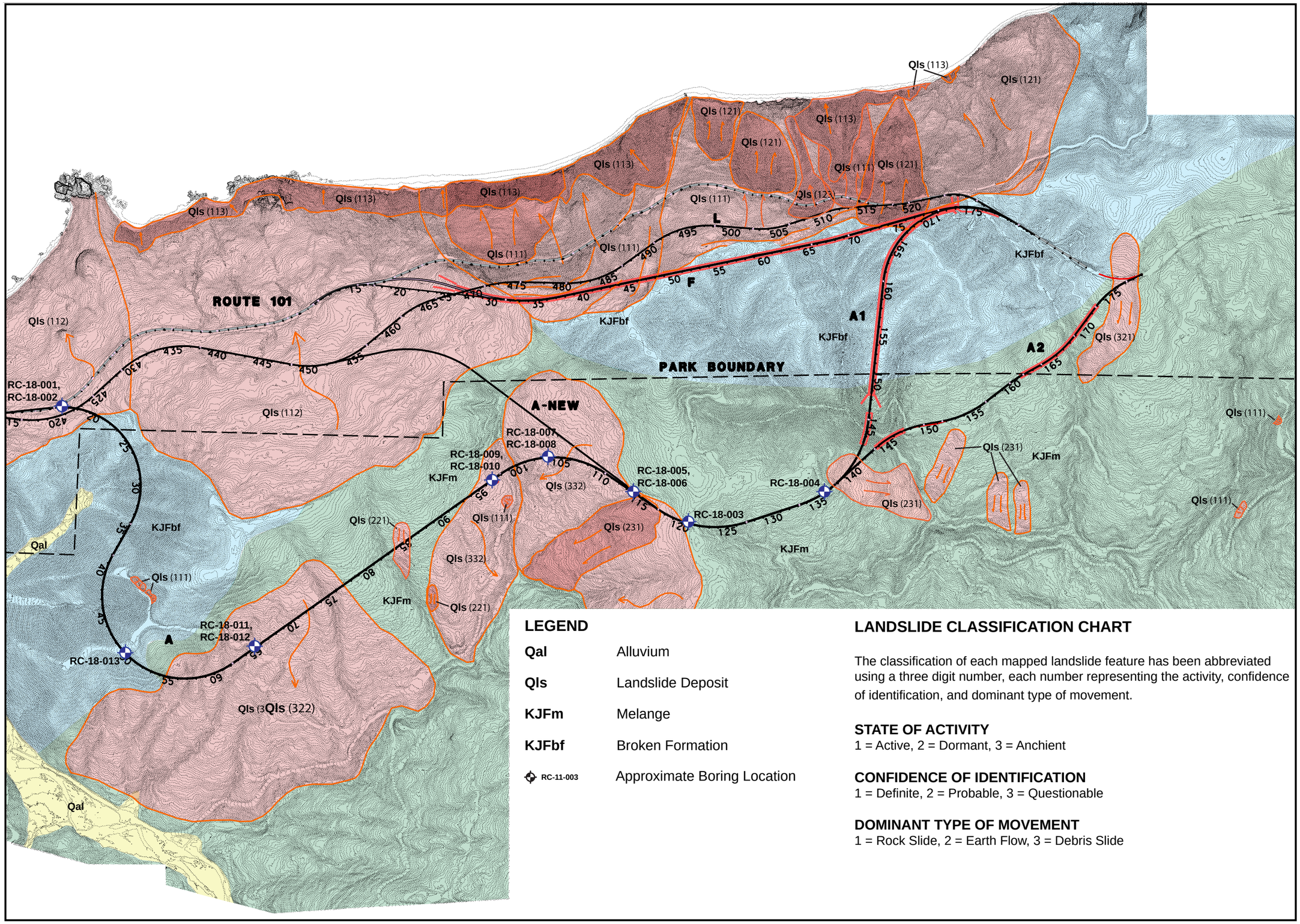
DEL NORTE COUNTY, CALIFORNA
HIGHWAY 101, POST MILE 13.4/16.0

DRAWN	EAW
CHECK	
APPROVED	EAW
DATE	Dec 2018
JOB NO.	01-0F280
FIGURE	2



Base: Landslides in the Highway 101 Corridor, Del Norte County, California: California Division of Mines and Geology, S[ecoa; Re[prt 184, C. J. Wills, 2000. Not to scale

Caltrans	LAST CHANCE GRADE BYPASS HIGHWAY 101, POST MILE 13.4/16.0 DEL NORTE COUNTY, CALIFORNIA	REGIONAL GEOLOGIC MAP
	DECEMBER 2018	FIGURE 3



LEGEND

Qal	Alluvium
Qls	Landslide Deposit
KJFm	Melange
KJFbf	Broken Formation
RC-11-003	Approximate Boring Location

LANDSLIDE CLASSIFICATION CHART

The classification of each mapped landslide feature has been abbreviated using a three digit number, each number representing the activity, confidence of identification, and dominant type of movement.

STATE OF ACTIVITY
1 = Active, 2 = Dormant, 3 = Anchient

CONFIDENCE OF IDENTIFICATION
1 = Definite, 2 = Probable, 3 = Questionable

DOMINANT TYPE OF MOVEMENT
1 = Rock Slide, 2 = Earth Flow, 3 = Debris Slide

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LAST CHANCE GRADE BYPASS
LANDSLIDE MAP

DEL NORTE COUNTY, CALIFORNA
HIGHWAY 101, POST MILE 13.4/16.0

DRAWN	EAW
CHECK	
APPROVED	EAW
DATE	Dec 2018
JOB NO.	01-0F280
FIGURE	4