BLUFF RETREAT EVALUATION REPORT

PRC 421 DECOMMISSIONING PROJECT
GOLETA, SANTA BARBARA COUNTY, CALIFORNIA

Project No. 2102-0251

Prepared for:
California State Lands Commission
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AUGUST 2021

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ENGINEERS, GEOLOGISTS &
ENVIRONMENTAL SCIENTISTS

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INTRODUCTION

The following Bluff Retreat Evaluation Report (Report) has been prepared in support of the proposed PRC 421 Decommissioning Project (Project). The coastal bluffs evaluated in this report are located at existing facilities on the former State Oil and Gas Lease PRC 421 (that include two caissons and piers referred to as Pier 421-1 and Pier 421-2) on State of California tide and submerged lands below the bluffs, delineating the southern limit of the Sandpiper Golf Course in the City of Goleta, California (Project Site). In order to provide a comparison of retreat rates of armored versus unarmored coastal bluffs, the Study Area was extended beyond the Project Site: west to The Ritz-Carlton Bacara Resort and east to where the Sand Piper Golf Course borders the Ellwood Bluffs. The Project Site and Study Area locations are shown on Plate 1 - Site Location Map.

PROJECT UNDERSTANDING

The Project Site is located at the base of the coastal bluffs that comprise the southeastern property boundary of the adjacent Sandpiper Golf Course in the City of Goleta. The PRC 421 Decommissioning Project (Project) consists of two primary components:

- Component 1 of the Project decommissioning includes the complete demolition and removal of the 421-1 and 421-2 caissons and associated piers back to the existing wooden seawall; removal of both well casings and capping the well down to the bedrock; and the decommissioning of two pipelines through the golf course to the Ellwood Onshore Facility (EOF).
- Component 2 involves the decommissioning and removal of the two pipelines that extend from the pier areas beneath the access road, abandonment in-place of production pipelines through the golf course to the EOF, and the subsequent removal of the pier abutments, supporting rock revetment and wooden seawall beneath the access road along the bluff.

The purpose of this study is to: 1) estimate annual retreat rates at various locations along the coastal bluffs to aide in planning for the PRC 421 Decommissioning Project at the Project Site; and 2) provide an opinion regarding how the removal of the rock revetment and wooden seawall armoring the access road will affect bluff retreat. For the purposes of this study, a coastal bluff will be defined as the seacliff. The bluff retreat rates contained in this study were estimated separately for the retreat of the crest and toe of the coastal bluff.

WORK PERFORMED

The services provided by Padre included the following tasks for this study:

- Review of available historical: geologic reports and maps relevant to the Project Site; documented local retreat rates; aerial photography; elevation data (i.e., light detection and range [LiDAR]); and groundwater data;
- Mapping of historical crest and toe of coastal bluff and armament of toe;
- Estimating an average annual retreat rate for edge and toe of coastal bluff at various locations along the study area; and
- Preparation of this report presenting our data and findings.

FINDINGS

SITE CONDITIONS

Existing Land Uses

The Project Site is located within the City of Goleta within an area that has been historically utilized for oil and gas development support activities. The land is zoned for coastal industrial purposes and primarily consists of an access road along the toe of the coastal bluff, oil well piers, and staging areas that support the EOF operations. The Sandpiper Golf Course property is located atop the coastal bluff which forms the border of the Project Site to the east. The land use of adjacent parcels is primarily limited to commercial and public recreational uses: The Ritz-Carlton Bacara Resort to the west and the Ellwood Bluffs open space to the east, respectively.

Topography and Drainage Conditions

Ground surface elevations at the Project Site range from approximately 5 to 110 feet above mean sea level (ft AMSL). The southwest sloping coastal bluffs make up the Project Site and are bounded by a parallel access road which originates at the EOF; continues through the Sandpiper Golf Course; and terminates at the eastern most caisson. The road is retained along the bluff base by a wooden retaining wall and associated rock revetment. Below the access road is a gradual sloping alluvial sand beach that is bounded to the west and east by ephemeral wetlands that drain to the Pacific Ocean. Surface water run-off drains down the face of the coastal bluffs and flows in sheets off the access road that bisects the Project Site.

GEOLOGIC CONDITIONS

Regional Setting

The Project Site is located along the south margin of the Transverse Ranges Geomorphic Province. These mountains represent a large east-west-trending anticline that has been complexly folded and faulted. The Santa Ynez Mountains and adjacent coastal lowlands, on which the Project Site is situated, are composed of sedimentary rocks ranging in age from Eocene to Holocene (Minor et al, 2009; Plate 3). The coastal bluffs at the Project Site are the product of uplifting and erosion that have shaped the Santa Barbara County coastline (Minor et al, 2009). During the Pleistocene, high rates of tectonic uplift in the Santa Barbara Basin created the marine terraces along the Goleta coastline. These wave-cut terraces are comprised of un-lithified gravels and finer-grained deposits (Rockwell et. al., 1992). Evidence of the continual active and spatially heterogeneous uplift along the coastline is reflected in terraces of the same age at different elevations (Norris, 2003; Keller and DeVecchio, 2012).

Local Geology

The coastal bluffs at the Project Site and Study Area are composed of three geologic formations: Quaternary Marine Terrace Deposits that overly the early Pliocene to late Miocene Sisquoc and the late Miocene Monterey Formations. Quaternary Marine Terrace Deposits consist primarily of loosely compacted, fine-grained silty and sandy clays. This unit is intensely to heavily vegetated with coastal scrubs, grasses, and trees. The porous nature of the marine terrace unit allows water runoff to seep through the deposits and weather the shale beds below.

The Sisquoc Formation is only observed at the western most end of the Project Site. The Sisquoc is primarily composed of diatomaceous mudstone and shale, with diatoms creating thinly bedded clay, shale, or laminated diatomite beds (Norris, 2003). The presence of diatomite indicates that deposition occurred in quiet, deep marine environments during a time of high sea level (Norris, 2003). Locally, the Sisquoc is known to be weak, extensively fractured, and easily eroded (Dibblee, 1988; Griggs and Savoy, 1985).

The remainder of the coastal bluffs included in the Study Area are composed of the Monterey Formation, which is divided into the Upper Siliceous, Middle Shale, and Lower Calcareous units within the Project Site and Study Area. The Upper Siliceous unit is described as marine and diatomaceous with cherty siliceous shale, calcareous mudstone, and subordinate dolomite and porcelanite. The Middle Shale unit is composed mainly of shale, mudstone, dolomite, porcelanite, phosphorite, and subordinate tuff. The Lower Calcareous unit is a marine mudstone and shale that contains subordinate dolomite, porcelanite, breccia, sandstone, and tuff. Similar to the Sisquoc formation, the Monterey is weak, extensively fractured, and easily eroded; however, unlike the Sisquoc, some sections of the Monterey are thinly bedded, hard, brittle, and cherty. The regional structure of the Monterey Formation in this area is complex with a series of northeast-southwest trending folds and east-west trending faults mapped through the coastal bluffs west and east of the Project Site. (Johnson et al, 2014; Minor et al, 2009).

GROUNDWATER CONDITIONS

Site Specific Hydrogeology

Quaternary Marine Terrace Deposits (silty and sandy clays to coarse-grained sands) that facilitate the surface water infiltration underlie the Sandpiper Golf Course to depths of approximately 10 to 20 ft below ground surface (bgs); based on visual field observations of the exposed face of the coastal bluff). These materials overlie the non-water bearing Sisquoc

Formation in the western corner of the project site where the EOF access road meets the beach. The remainder of the Project Site consists of non-water bearing Monterey Formation overlain by Terrace Deposits.

METHODS

LIDAR DATA ANALYSIS

Light-detection and range (LiDAR) elevation data was obtained for the years of 2018, 2009, and 1997 (Table 1). The LiDAR data was collected via aircraft using laser scanning technology to capture coordinate location data (northing, easting, and elevation data) as a point cloud. The point cloud data was interpolated by the data collection agencies and provided to Padre as polyline feature contour data delineating the coastal bluff at the Project Site. The crest and toes of bluff were delineated in geographic information systems (GIS) software from the contour LiDAR data for each data set (Plate 4).

Table 1. Summary of LiDAR Data Sources

Year	Source
2018	NOAA USGS LiDAR: Southern CA Wildfires (Job642765_ca2018_wildfires)
2009	NOAA USGS LiDAR: 2009 USACE Topobathy LiDAR: California (Job642767_usace2009_ca)
1997	1997 Fall West Coast NOAA/USGS/NASA Airborne LiDAR Assessment of Coastal Erosion (ALACE) Project for the UC Coastline (Job642766_1997_FallWC)

HISTORICAL AERIAL PHOTOGRAPH ANALYSIS

Historical aerial photographs corresponding to the years of LiDAR data were used to fine tune the delineation of the crest and toe of the coastal bluff (Table 2). Aerial photographs were viewed in two-dimension (2D or planar view) and in three-dimension (3D) in computer programs ArcMap and Google Earth Pro, respectively. Oblique historical aerial photographs available on the California Coast Records Project website were also reviewed.

It should be noted that a 1997 aerial photograph of sufficient quality for analysis was unavailable for use at the time of this study; however, a 1994 aerial photograph was available from Google Earth Pro that generally agreed with the geometry of the 1997 crest and toe of coastal bluff; it was used as background imagery for display purposes (Plate 4).

Table 2. Summary of Historical Aerial Photographs

Year(s)	Source
2018	NAIP Imagery
2009	Google Earth Pro Image
1994	Google Earth Pro Image
2019, 2015, 2013, 2010, 2008, 2006, 2005, 2004, 2002, 1993, 1989, 1986, 1987, 1986, 1979, and 1972	California Coastal Records Project: Bacara Resort, Ellwood; Ellwood Pier, Goleta; and Sand Piper Golf Course, Goleta.
1930s	UCSB Collection

ESTIMATED ANNUAL RETREAT RATES

Annual retreat rates for the coastal bluff at the Project Site were estimated at seven points along the crest and seven points along the toe (fourteen points total) that were selected based on proximity to the proposed PRC 421 Decommissioning Project (Plate 5). Additionally, retreat rates were estimated at fifteen points along the crest and fourteen points along the toe that are outside of the Project Site but within the Study Area along the southwest facing Miocene shale coastal bluffs. In an effort to capture the varying rates at which the bluff retreats differently along the coastline, locations were chosen along the bluff where retreat was identified by the historical LiDAR data and aerial photographs. These locations were categorized as high, low, or negligible based on the results of the comparison of retreat rates. These variations at the selected points reflect local factors (i.e. armament or lack thereof, run-off, etc.) affecting each particular location (Plates 2 and 5).

Estimated annual retreat rates shown on Plate 5 were calculated using the change in distance of the 2018 and 1997 LiDAR defined crest and toe of bluff divided by the 21 years separating the collection of the data sets. Estimated retreat rates along the bluff crest ranged from 10 to 63 centimeters per year (cm/yr). Retreat rates along the toe of bluff were estimated at 7 to 61 cm/yr where the toe is not armored by rock revetment, compared to 0 cm/yr where the toe of the coastal bluff is armored by rock revetment (Plate 5).

DISCUSSION

The coastal bluff Study Area is composed of non-water bearing Sisquoc and Monterey Shale that is continually exposed to the effects of coastal processes contributing to weathering and erosion of the bluff. Whereas the Sisquoc and Monterey Formations are non-water bearing, groundwater does not influence the internal weathering of the shale unit. Therefore, wave action is the primary hydraulic weathering process affecting the coastal bluff at the Study Area, with the changing tides and wave action saturating and expanding existing fractures and joints to loosen material that is eroded away.

Large winter storm events are the primary source of bluff erosion and generally remove enough material in one or two events to equal the estimated average annual erosion rate. Bluff erosion and retreat generally do not take place as incremental events happening over the course of the year, but rather the result of one or two major events (von Thury, 2013). It should be noted that major erosional events may not occur annually.

The retreat rates estimated in this study are based on LiDAR data collected in the most recent 24 years and aerial photographs for approximately the last 90 years; If LiDAR and aerial photographs were available over a larger geologic time period, the rates calculated in this study may vary. Rainfall and associated runoff are not considered to be major factors contributing to bluff erosion and retreat at the Project Site. Ephemeral wetlands and drainages present at the Project Site and Study Area likely contribute to weathering and erosional processes leading to heightened bluff erosion and retreat rates immediately adjacent to natural drainage outlets that contribute to outlier retreat rates of greater than 60 cm/yr. For example, heightened bluff erosion of 62 cm/yr is taking place at the eastern end of the Project Site between Wells 421-1 and 421-2 (Plate 5). The heighted erosion rates are likely due to runoff from the golf course. A potential deep-seated landslide at the western end of the Project Site (approximately 800 feet west of 421-1) appears to also be the cause for the outlier retreat rate of 63 cm/yr (Plate 5). Although, vegetation removal or tree falls and anthropogenic installations such as drainage outfalls and irrigation can contribute to weathering and erosional processes, they are not considered to be major factors contributing to bluff erosion and retreat at the Project Site.

Additional factors such as coastal bluff aspect, tidal influence (discussed in a separate contemporaneous NV5 report, 2021), and rock strength also contribute to the range of the estimated 0 to 63 cm/yr retreat rates at the Project Site and Study Area (Plate 5). The retreat rates at the lower end of the range are found at locations where the bluff has been armored at the toe with riprap (large boulders) or behind uncompromised sections of the wooden seawall below the golf course. It should be noted that the access road that presently terminates at Well 421-2 originally continued east along the coastline toward the Ellwood Bluffs and was armored with a wooden seawall to prevent the road from washing out. The access road has been washed out and the toe of the coastal bluff has begun to retreat behind the wooden seawall in areas where the wooden seawall has been compromised. Retreat rates behind and immediately adjacent the compromised wooden seawall mapped on Plate 5 are greater than those of uncompromised sections. It should also be noted that the marine terrace deposits are loosely consolidated and are more susceptible to washing out and eroding the crest at a higher rate than the shale unit. In general, higher rates of retreat along the crest are associated with higher retreat rates along the unarmored toe, as evidenced along the coastal bluff near The Ritz-Carlton Bacara Resort.

In 2013, a University of California, Santa Barbara Master of Science Thesis, *Using Laser Scanning Technology to Monitor Coastal Erosion and Sea-Cliff Retreat in Southern Santa Barbara County, California*, estimated regional erosion rates for the crest of south facing coastal bluffs stretching from Point Conception to Coal Oil Point to range from 11 to 73 cm/yr (von Thury, 2013). The 2013 study calculated estimated annual erosion rates using 2010 vs. 1998 and 1997 NOAA LiDAR data. The 1997 NOAA LiDAR data set that was used in the 2013 study is the same elevation data set that was used in the current study conducted by Padre. The retreat rates estimated for both this study and the von Thury 2013 study generally agree with a 2005 study by

Gary Griggs et al that calculated retreat rates based on monument measurements at various locations in southern Santa Barbara County between Point Conception and Rincon Point to range from 8 to 30 cm/yr. It should be noted that the neither the 2013 nor 2005 studies calculated retreat rates for the section of coastline covered in our Study Area. The regional retreat rates calculated in the 2005 study were based on monument locations that were accessible to Griggs et al and were not spaced at a measured interval. In 2013, von Thury chose regional retreat locations proximal to where Griggs et al (2005) calculated retreat rates and added additional points of calculated retreat between the points chosen by Grigg et al (2005). Working with LiDAR, von Thury was not limited to only the locations that could be physically accessed and could instead calculate retreat rates for sections of coastline inaccessible to the public in GIS. It should also be noted that neither the 2013 nor the 2005 studies calculated the quantity of retreat rates within a concentrated area as was done in the study.

The methods used to quantify retreat rates have advanced technologically over the past two centuries from ground surveying the coastal bluffs with known monuments to aerial photography analysis to the use of laser scanning technology (von Thury, 2013; Hapke, 2004). Each of these methods has its own assumptions, limitations, and degree of both error and accuracy. Degrees of accuracy and error for each method should be taken into account when evaluating retreat rates. This applies to LiDAR and other laser scanning technologies because the quality of the data depends on the point spacing during collection and coverage. Point spacing is not the only factor affecting LiDAR survey quality, but it is the most significant for the results of the detail of the composite point cloud (Mitchell, 2013). The 2018, 2009, and 1997 LiDAR data sets obtained from NOAA contain varying degrees of point spacing and extent of coverage. The denser the points collected in a survey, the more accurate the terrain model that is built from the point cloud will be as a result of less interpolation between data points. Conversely, the less dense the points collected during the survey, the more interpolation is performed between data points. Early LiDAR surveys, like the 1997 data set, could have between 330 to 2,520 cm (3 to 25 meters) between each ground surface elevation, latitude, and longitude point (von Thury, 2013). According to the metadata provided by the National Oceanic and Atmospheric Administration (NOAA) Digital Coast: Data Access Viewer for the 2018, 2009, and 1997 LiDAR data sets used in this study, estimated point spacing for the data sets are 0.4 meter (m), 2 m, and 3 m, respectively (NOAA, 2021). LiDAR data collection has since increased in intensity and points can be collected every 2 to 8 cm or less. Advances in LiDAR technology over the years will lead to increased accuracy and confidence in calculated retreat rates (von Thury, 2013).

CONCLUSIONS

Based on the retreat rates estimated in this report within the Project Site and Study Area, Padre is of the opinion that the rock revetment within the Project Site is effectively armoring the access road and preventing the road from washing out. Removal of the caissons and piers will create points of vulnerability along the wooden seawall below the piers that are not reinforced with rock revetment. If the wooden seawall behind the removed piers and caissons were to become compromised as the wooden seawall east of 421-2 has, then the access road will eventually wash out and cliff retreat behind the seawall will occur. This is already occurring in the eastern half of the Study Area, where the wooden seawall has been compromised and the bluff is retreating behind the compromised wooden armament. Retreat rates behind the wooden seawall are lower in sections where the wooden seawall is relatively uncompromised, compared to the bluff retreat experienced at or immediately adjacent locations where the seawall has been fully compromised.

The section of bluff within the Project Site that is armored by the rock revetment shows negligible signs of retreat. Any implied retreat by the LiDAR data was attributed to a lack of a data point or significant coverage that was resolved with historical aerial photograph coverage of the constant location of the access road at the toe of bluff. If the rock revetment and wooden seawall armoring the toe of bluff within the Project Site were removed, then it is likely that the coastal bluff would retreat at rates similar to those calculated at the western end of the Study Area in the vicinity of The Ritz-Carlton Bacara where the coastal bluff is not armored.

CLOSURE AND LIMITATIONS

Padre prepared the findings and data presented herein in accordance with generally accepted geologic and geotechnical engineering practices at the time and location that this report was prepared. No other warranty, express or implied, is made.

Soil and rock materials are typically not homogenous in type, strength, and other geotechnical properties and can vary between points of observation and exploration. In addition, groundwater and soil moisture conditions can vary seasonally and for other reasons. Padre does not and cannot have a complete knowledge of the subsurface conditions underlying a site. The data presented in this report are based upon the findings at the points of interpolation and extrapolation of information between and beyond those points of analysis.

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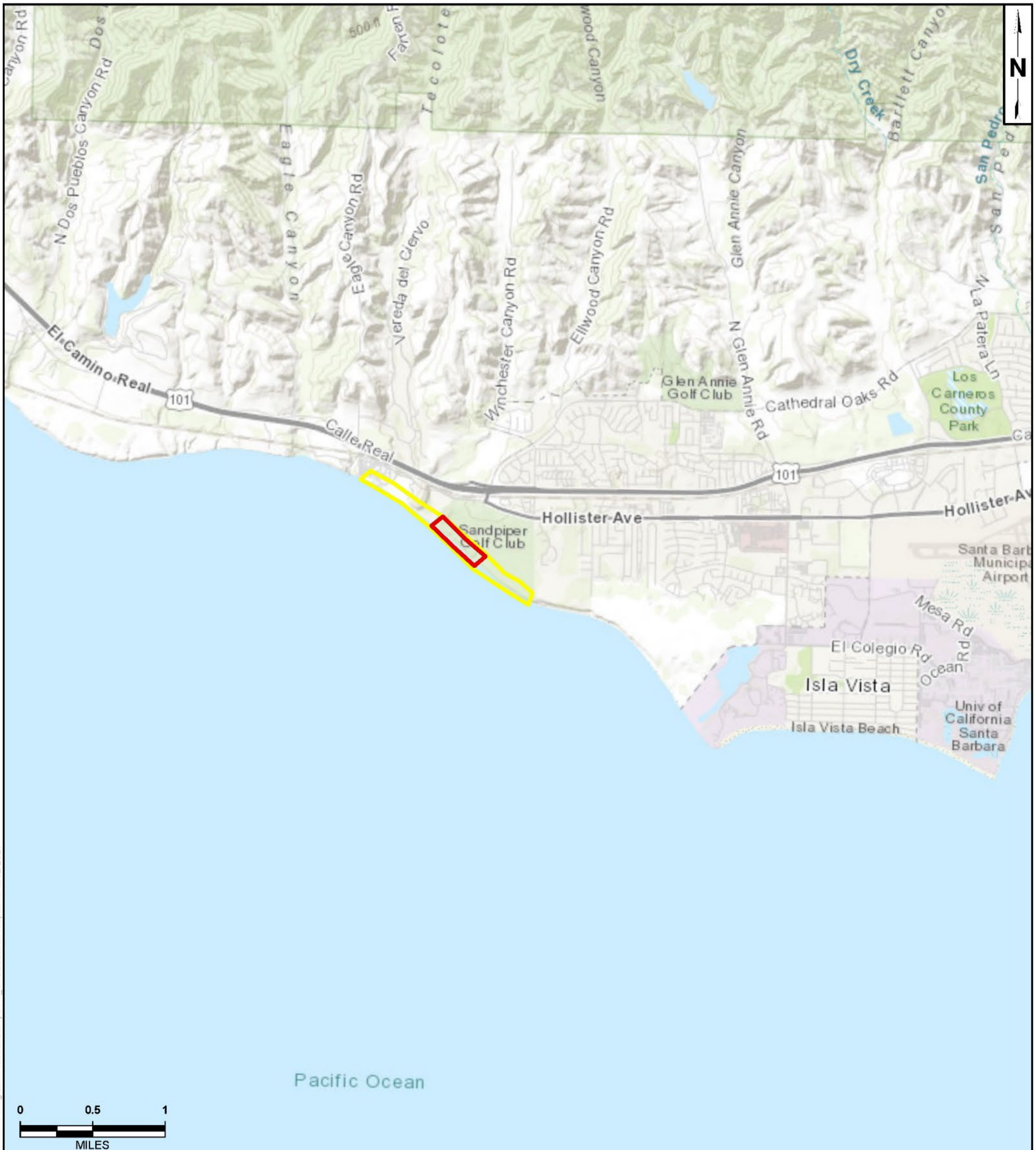
PLATES



LEGEND:

Project Site | Study Area

Source: Esri Online Topo Basemap, County of Santa Barbara
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Abbreviation: EIR = Environmental Impact Report
Notes: This map was created for informational and display purposes only.

MAP EXTENT:

padre associates, inc. ENGINEERS, GEOLOGISTS & ENVIRONMENTAL SCIENTISTS	PROJECT NAME: PRC 421 DECOMMISSIONING BLUFF RETREAT STUDY SANTA BARBARA COUNTY, CA		SITE LOCATION MAP	PLATE
	PROJECT NUMBER: 2102-0251	DATE: August 2021		1

Z:\GIS Projects\GIS Maps\Map Project\PRC 421 Decommissioning EIR\Retreat Study\Pl-1_Site Location Map.mxd 8/12/2021

LEGEND:

- Abandoned Oil Well
- Project Site
- Study Area

Source: NAIP Imagery 2018
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Abbreviation: EIR = Environmental Impact Report
Notes: This map was created for informational and display purposes only.

0 500 1,000
Feet

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PROJECT NAME: PRC 421 DECOMMISSIONING BLUFF RETREAT STUDY SANTA BARBARA COUNTY, CA		SITE VICINITY	PLATE 2
PROJECT NUMBER: 2102-0251	DATE: August 2021		

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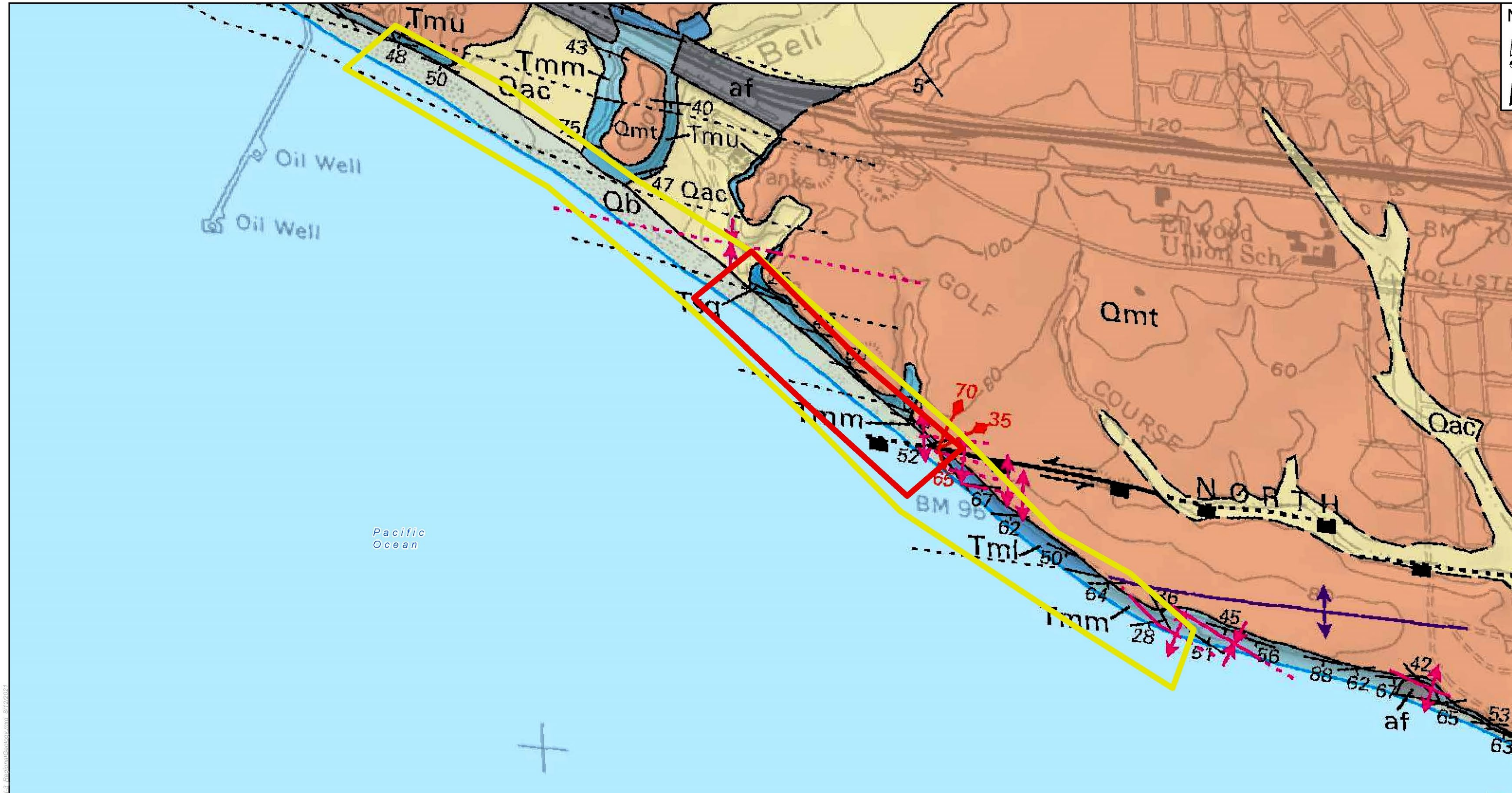

LEGEND:

- Project Site
- Study Area

Geologic Unit:

- Artificial Fill (af)
- Beach Deposits (Qb)
- Alluvium and Colluvium (Qac)
- Marine-Terrace Deposits (Qmt)
- Sisquoc Formation (Tsq)
- Monterey Formation - Upper Silicous Unit (Tmu)
- Monterey Formation, Middle Shale Unit (Tmm)
- Monterey Formation, Lower Calcareous Unit (Tml)

MAP EXTENT:

0 350 700
FEET

Source: Minor, S.A., et. al. (2009), Geologic map of the Santa Barbara Coastal Plain Area, Santa Barbara County, California.
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Notes: This map was created for informational and display purposes only.

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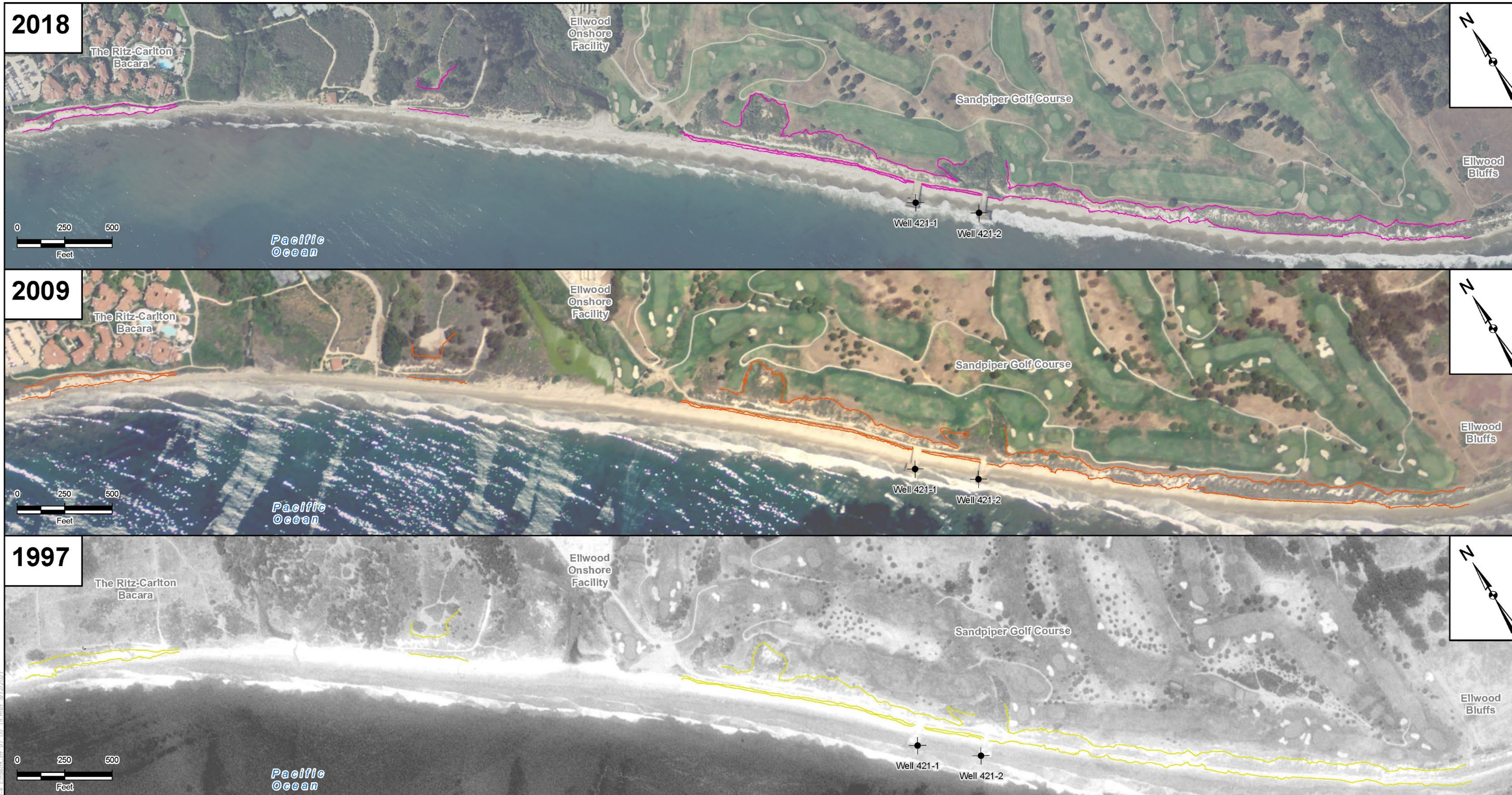
PROJECT NAME: PRC 421 DECOMMISSIONING BLUFF RETREAT STUDY SANTA BARBARA COUNTY, CA		REGIONAL GEOLOGY MAP	PLATE 3
PROJECT NUMBER: 2102-0251	DATE: August 2021		



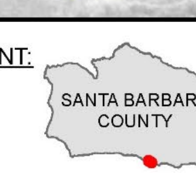
LEGEND:

Edge of Bluff Defined by LiDAR Contour Data

- Edge of Bluff 2018
- Edge of Bluff 2009
- Edge of Bluff 1997

Abandoned Oil Well

MAP EXTENT:



Source: 2018 Ca Wildfires;1998 Spring West Coast; NAIP Imagery 2018; 2009 and 1994 Google Pro Images.
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Abbreviations:cm/yr = centimeters per year
EIR = Environmental Impact Report
LiDAR = Light Detection and Range
Notes: 1) 1997 edge of cliff overlay 1994 aerial photo due to poor image quality of 1997 aerial photograph.
2) This map was created for informational and display purposes only.

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PROJECT NAME: PRC 421 DECOMMISSIONING BLUFF RETREAT STUDY SANTA BARBARA COUNTY, CA		EDGE OF BLUFF 2018, 2009, AND 1997	PLATE 4
PROJECT NUMBER: 2102-0251	DATE: August 2021		

LEGEND:

Edge of Bluff Defined by LiDAR Contour Data
- Edge of Bluff 2018
- Edge of Bluff 2009
- Edge of Bluff 1997

Armament
- Approximate Extent of Rip-Rap
- Approximate Extent of Relatively Uncompromised Wooden Sea-Wall

- Abandoned Oil Well
- 28 Retreat Rate (cm/yr, 1997 - 2018)

- Project Site
- Study Area

MAP EXTENT:

SANTA BARBARA COUNTY

0 250 500
FEET

Source: NAIP Imagery 2018
Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Abbreviations: cm/yr = centimeters per year
EIR = Environmental Impact Report
LiDAR = Light Detection and Range
Notes: This map was created for informational and display purposes only.

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PROJECT NAME: PRC 421 DECOMMISSIONING
BLUFF RETREAT STUDY
SANTA BARBARA COUNTY, CA

PROJECT NUMBER: 2102-0251

DATE: August 2021

ESTIMATED BLUFF RETREAT

PLATE 5

roject\PRC 421 Decommissioning EIR\Retreat Study\Pl-5_RetreatRates.mxd 8/12/2021