Cal Wave - Ocean Wave Energy and the Land Base Infrastructure

A Senior Project

presented to

the Faculty of the Architectural Engineering Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

BS Architectural Engineering

by

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June, 2016

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1.0 The Need for the Project

Development of wind and solar generation in the last decade has rapidly increased in popularity throughout Europe and in U.S. states like California and Texas. The cost of popular renewables has fallen significantly due to continuous improvements in technology, manufacturing, and the global economy. With international, national, state, and local policies insisting on increasingly lower carbon emission totals, today's citizens are considering the possibility that marine renewables may someday become an essential source of renewable electrical energy generation alongside and in combination with conventional wind and solar technologies.

The U.S. Department of Energy has made its objective to expediate the development of wave-energy technologies in the United States to construct a world-class National Wave Energy Testing Facility. The plan is to create this superior wave energy testing facility where technology manufacturers can pilot test their devices in a true marine setting. Cal Poly's Institute for Advanced Technology and Public Policy (IATPP) received a $750,000 grant, also known as Calwave I, from the Department of Energy to evaluate the feasibility of siting the planned National Wave Energy Test Facility in California. As part of the Feasibility Study, an Interdisciplinary Schematic Design Team for the Land Base Infrastructure which included an Electrical Engineer, an Architect, a Construction Manager, and a Structural Engineer, assessed preliminary facility design. This allocation of resources was utilized to determine which location along California's coast that has the most desirable characteristics to serve as the home of the National Wave Energy Testing Facility.

2.0 Proposed Site

For this project, the proposed site for the new ocean wave energy research facility is Vandenberg Air Force Base (VAFB), a United States Air Force Base located 9.2 miles northwest of Lompoc, California.

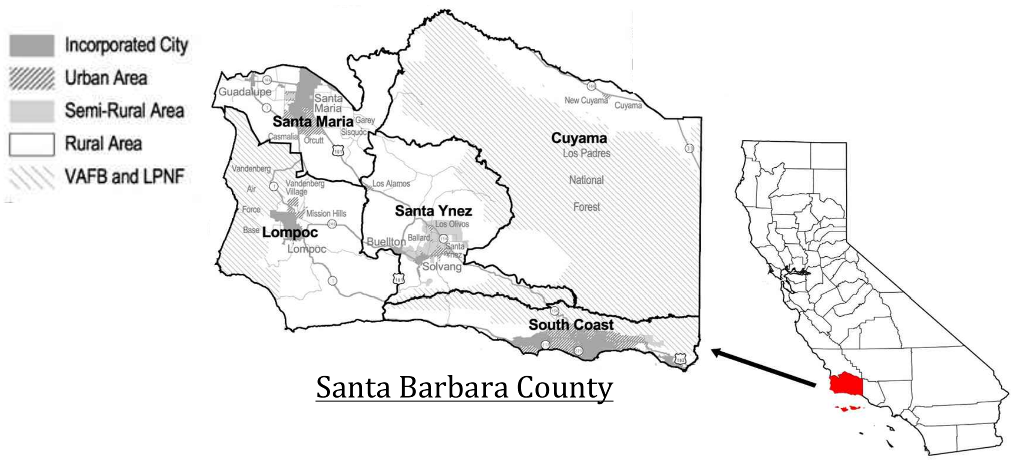

Figure 1: Location Map

The location of Vandenberg Air Force Base and the major cities within its vicinity, San Luis Obispo, Pismo Beach, Santa Maria, and Lompoc, can be viewed in Figure 2.

Figure 2: Vicinity Map

The specific site of the energy testing facility within VAFB is located at the Vandenberg Air Force Base Dock, located southern end as seen in Figure 2 and Figure 3.

Figure 3: Site Map 2

The electrical energy generated from the ocean is transmitted through cables beneath the ocean floor to the Shore Station. At the Shore Station, the electrical energy is conditioned to proper voltage for use at VAFB. The power must be transported through a new power line from the Shore Station to the VAFB power plant approximately four miles north of the site. The extent of the extension line route can be viewed above in Figure 3. From the VAFB power plant, the power then be used for grid distribution.

3.0 Disciplines

The Schematic Design feasibility study for the Land Base Infrastructure included:

- preliminary cost estimates
- conceptual site drawings
    - Shore Station plans
    - directional drilling plans
- Architectural History Study of VAFB Building

The Calwave I project personnel was organized with an overall project manager, Bill Toman for the Institute for Advanced Technology & Public Policy, as well as assistant project managers for each project focus: ocean station, land base infrastructure, and permitting. For the development of the preliminary shore station schematic design the land base infrastructure team consisted of an Electrical Engineer, an Architect, a Construction Manager, and a Structural Engineer was assembled. The electrical engineer from industry who offered his expertise was Larry Hollis, a Vice President at Rosendin Electric[1]. Dr. Dale Dolan and Rick Williams assisted with the construction management requirements for the projects. Additionally, Dr. Dale Dolan assisted with additional electrical engineering questions and Rick Williams offered experience and expertise regarding the architectural demands for the project. My particular role included incorporating all of these disciplines into a set of cohesive preliminary drawings, focusing particularly on the architectural and structural engineering.

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[1] CALIFORNIA - SAN JOSE
(CORPORATE HEADQUARTERS)
880 Mabury Road
San Jose, CA 95133
1.408.286.2800

3.1 Disciplines - Electrical

Larry Hollis at Resendin Electric participated as a consulting electrical engineer and person of expertise to communicate what equipment is necessary and its structural requirements. This included house keeping pads, trenches, underground vaults, cable trenches, step up transformers, switch gears, etc. Additionally, he assisted with preliminary cost estimate information for the equipment, which I included in my final cost estimates for the project.

Mr. Hollis also provided insight regarding the particular nature of the project and its relationship to Vandenberg Air Force Base. He recommended I investigate the following:

- specific costs associated with a remote, unihabited location
- security costs (due to the site being a government owned Air Force Base) and
- a badging process to get onto the site.

He also suggested I research whether potential additional costs could be associated with more stringent safety rules required to work on the Air Force Base. Finally, due to the proposed four mile extension power line, he recommended I investigate whether a permitting issue at the base could arise.

Our communication consisted primarily of phone meetings and email correspondence. Unfortunately, due to time conflicts and a limited availability for both parties, difficulties in scheduling arose. After two phone meetings, email became the primary form of communication, making follow up questions difficult to ask in a timely manner.

3.2 Disciplines – Construction Management

Dr. Dale Dolan and Rick Williams served as the electrical equipment experts for the project. Rick Williams confirmed the costs estimates I proposed and provided feedback regarding all deliverables. Preliminary schematics were provided by Dr. Dolan and Mr. Willliams. Below is an example of the typical hand drawings that had to be redrawn using REVIT.

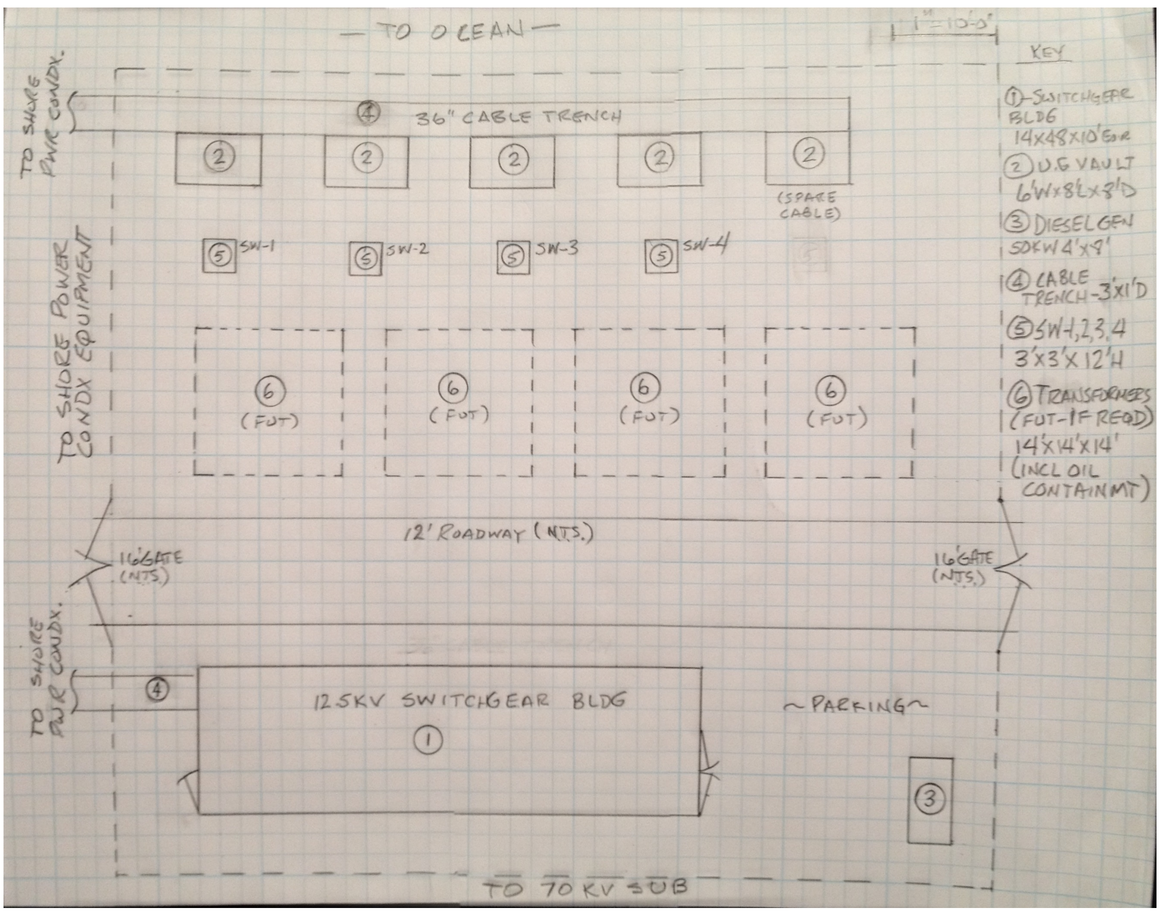


Figure 4: Sketch of Preliminary Layout

Through initial electrical power conditioning equipment sketches as seen in Figure 4, and communication with Dr. Dolan and Mr. Williams, I created the initial equipment layout.

3.3 Disciplines - Architectural

No criteria was given regarding the architectural requirements for the two prefabricated modular houses on the site. Initial research was on beach house architecture typical of central coast of California. On VAFB itself was a historic Boathouse. I opted for a structure reminiscent of a beach boathouse, citing Spooner Ranch as a precedent.

Figure 5: Architectural Influences

4.0 Personal Contribution

My specific work included understanding the roles of the construction manager, architect, and civil engineer and acting as an assistant to the experts on the project. I was in contact with Rick Williams regarding construction management and architecture, Dr. Dale Dolan regarding construction management of electrical equipment, Larry Hollis for electrical engineering expertise, and Bill Toman for project management and estimating.

Most of the communication with Vandenberg personnel, Rick Williams, Dr. Dale Dolan, and Bill Toman was relayed through my advisor Dr. Craig Baltimore. This communication consisted of drawing requirements, locations for specific equipment, and timeline criteria for my deliverables. I corresponded with Larry Hollis directly, discussing what was mentioned above. The communication between everyone involved in the project was essential for a cohesive design. Ultimately, the phone meetings proved to be most efficient and helpful for my contribution of the project. Additionally, the diagrams attached in the emails from Rick Williams and Dr. Dale Dolan assisted greatly in my understanding of what they were trying to convey in their emails. Because I was initially unfamiliar with most of the electrical jargon, the written emails proved to be the most cryptic and difficult to comprehend.

Furthermore, the process of working with the other disciplines closely mimicked how projects in the future will be approached and handled. For example, the numerous deadlines and revisions, constant communication, and involvement of many different disciplines was great experience before entering into the industry

4.1 Personal Contribution - Electrical

The marine life along certain parts of the central coast is preserved and therefore the seabed could not be disturbed through the construction of the wave energy research facility. Thus, horizontal directional drilling is required in order to drill through the cliffs and emerge off shore. Directional Drilling is controlled by the orientation of the drill-bit at the bottom of the hole. An example of directional drilling equipment is illustrated below.

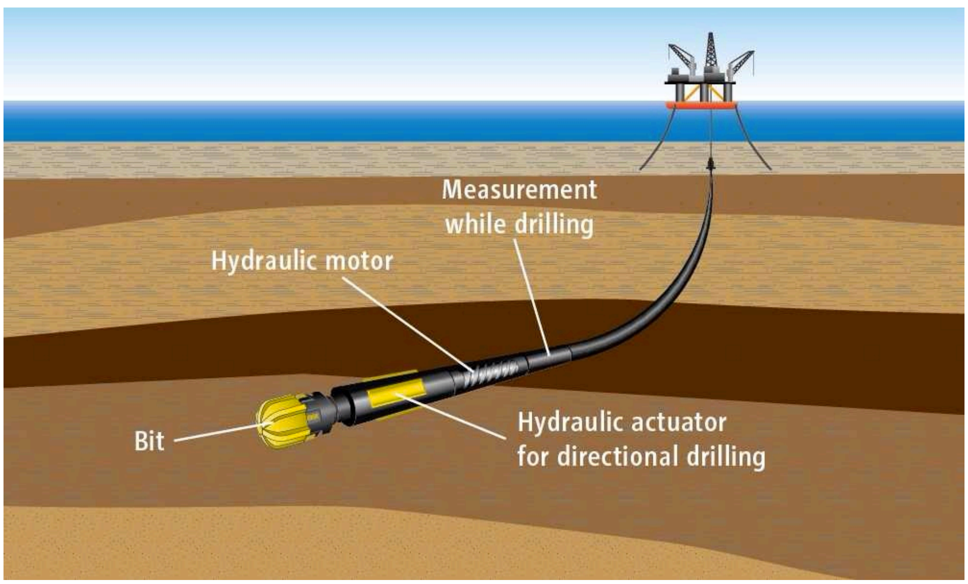


Figure 6: Directional Drilling Example

Under the advisement of Mr. Hollis, it was decided a specialty contractor would be required for the directional drilling of the submarine cables. He recommended that for the initial path of the cables, they should not cross the railroad if at all possible, which I incorporated into the design. Additionally, he advised me on the locations of each of the electrical components, their required size, and their connections.

Two preliminary designs were proposed: one a more direct route to the shore station where the steep angle of the directional drilling presents a problem at the shore station, and an alternate route located at a river stream with a more desirable slope angle.

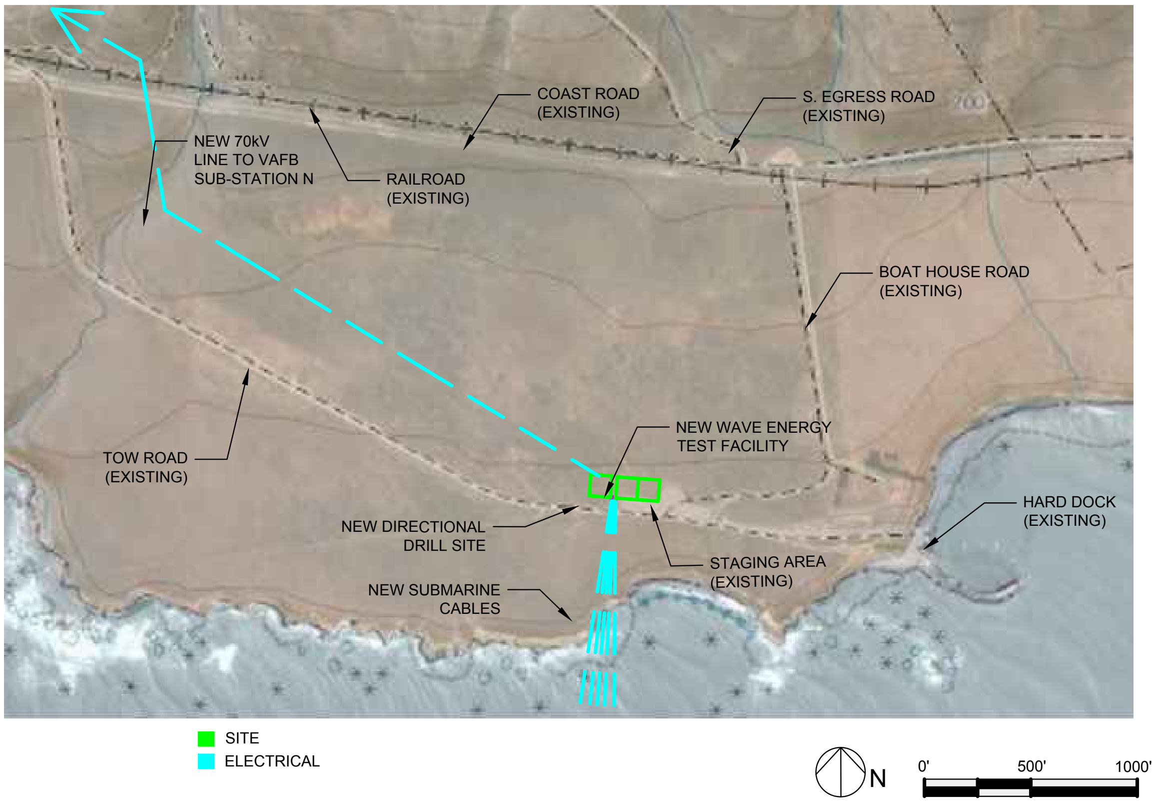


Figure 7: Preliminary Site Map

The preliminary site plan required minimal land based directional drilling. The major costs with the scheme in Figure 7 include the directional drilling at a steep angle. There is a significant cost difference (orders of magnitude) between land based and ocean based directional drilling.

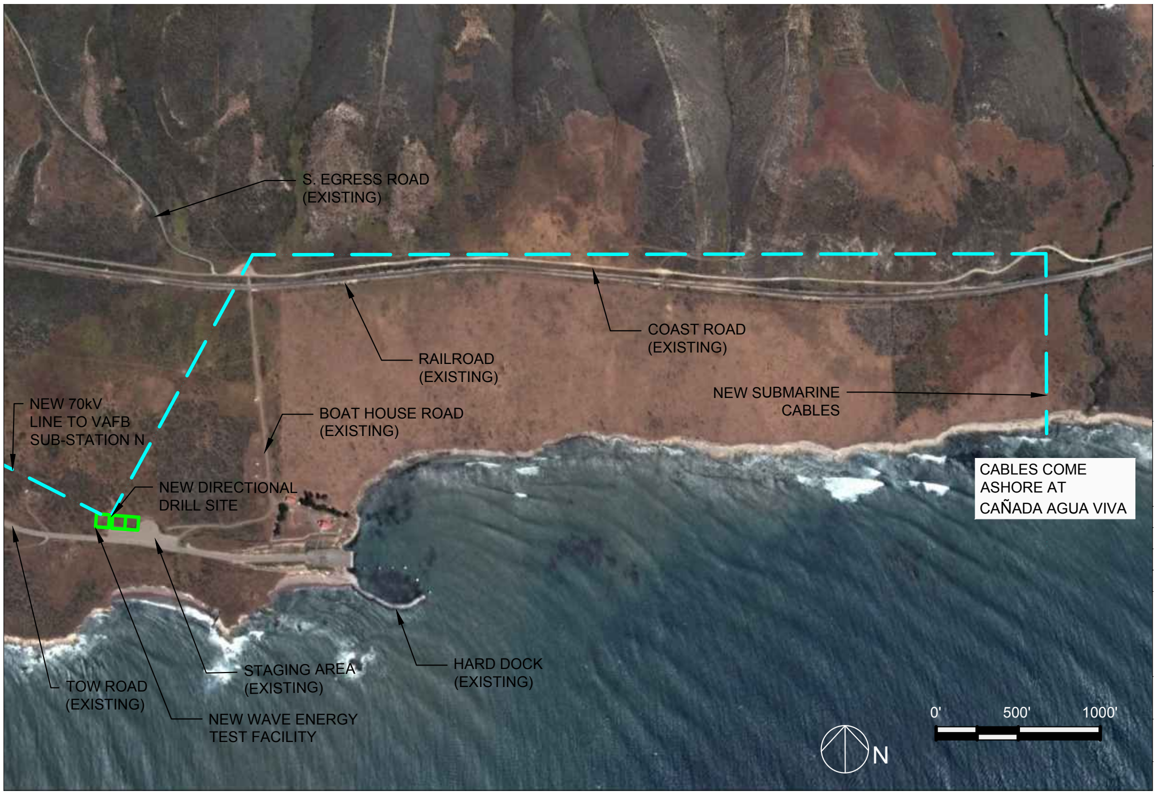


Figure 8: Alternative Site Map

The alternative proposal seen in Figure 8 required over a mile of land based drilling Though land based directional drilling is less far expensive than ocean, the additional drilling is still a significant cost. Directional drilling was a driving cost of the project, thus it was desired to limit the amount of drilling as much as possible, making the prosed site plan from Figure 7 the preferred choice.

4.2 Personal Contribution - Construction Management

The first site analysis I performed was an initial user-friendly topographic map, illustrating the gradual slope and eventually the cliffs that make this site ideal for this project. Because many people including political decision makers, permitting officials, etc., will be reviewing the report, it is essential to simplify the topographic details so the slope can be easily understood.

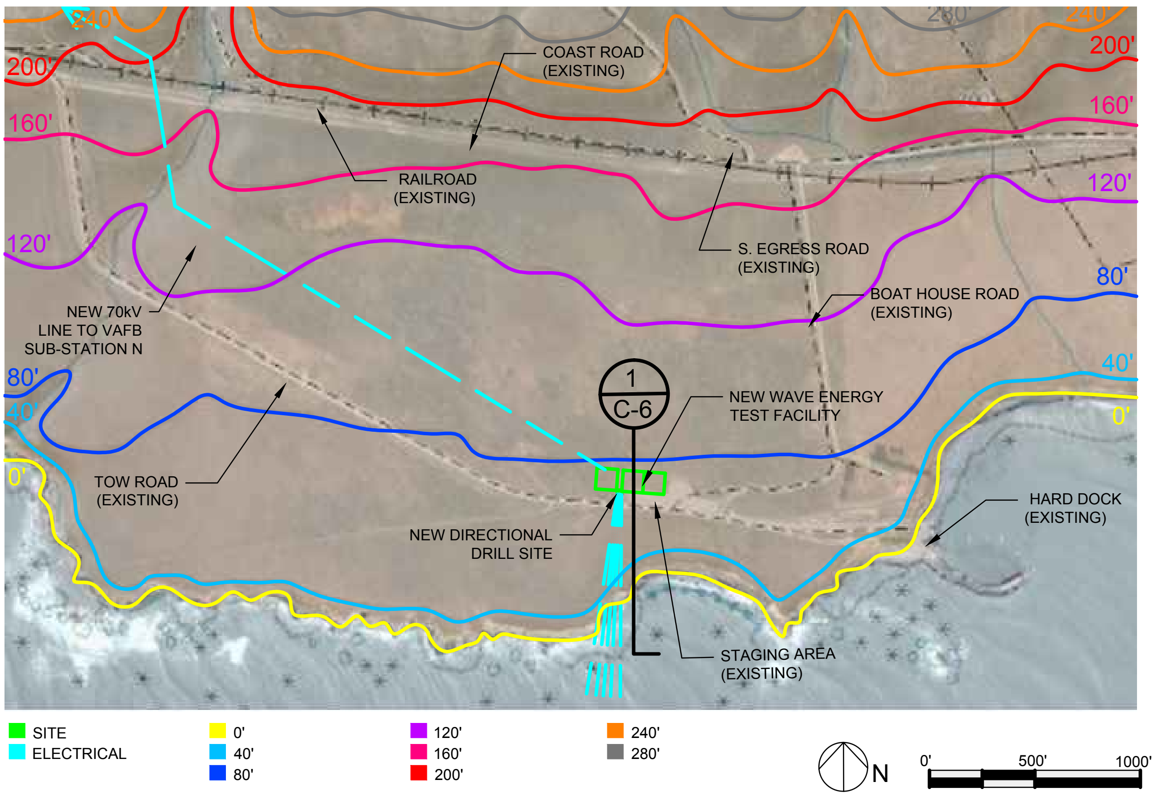


Figure 8: Topographic Site Map

The land base infrastructure will sit at the top of the cliff and the cables will be threaded through directionally drilled holes in the cliff to the wave energy equipment out in the ocean.

Additionally, a site section was drawn to provide a clear image of where the site would be in reference to the ocean, and to indicate rough cut and fill potential.

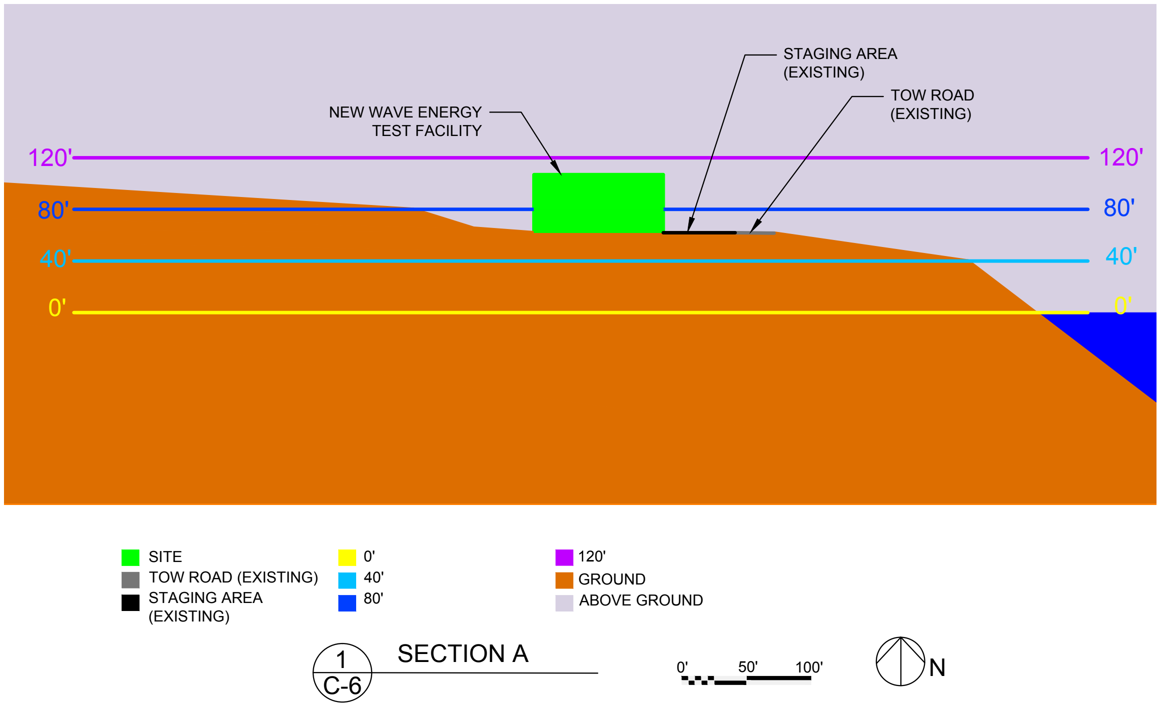


Figure 9: Site Elevation

These initial studies coupled with the recommendations of the experts involved, allowed me to develop initial plans of the site as well as the mapping of equipment within the site.

The surrounding development was documented as shown in Figure 10 below.

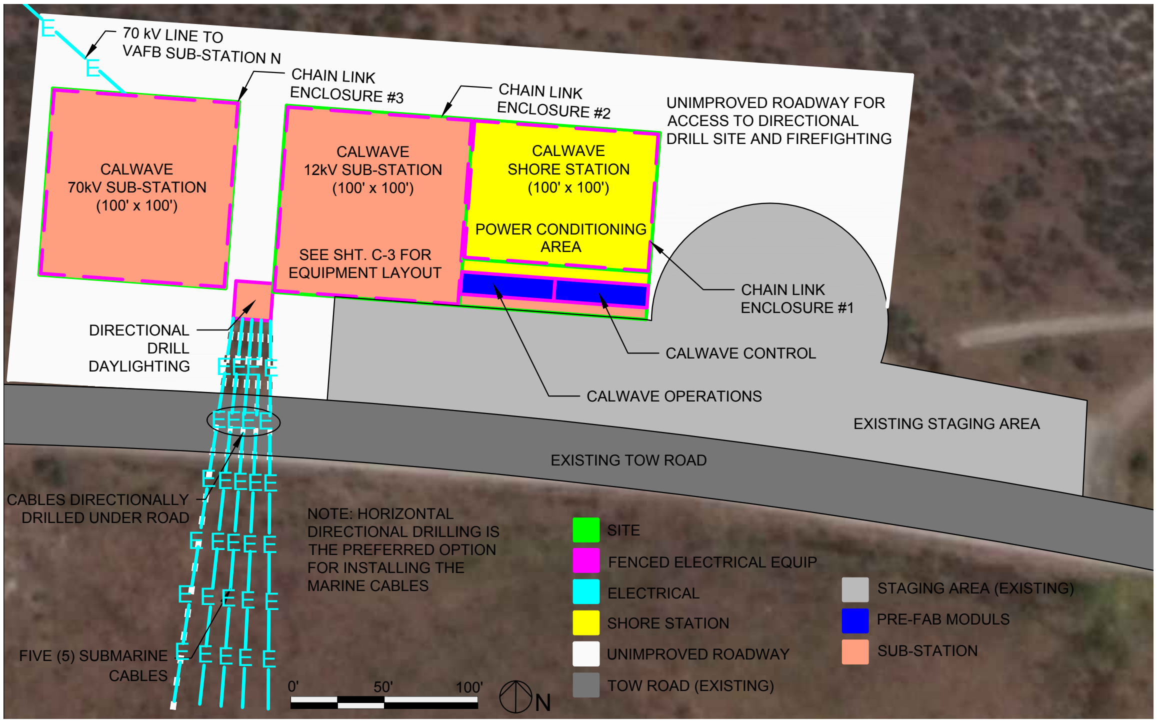


Figure 10: Site Map 3

Through the initial sketches and suggestions from Dr. Dolan and Mr. Williams, as well as the advice of Larry Hollis, I created the initial equipment layout.

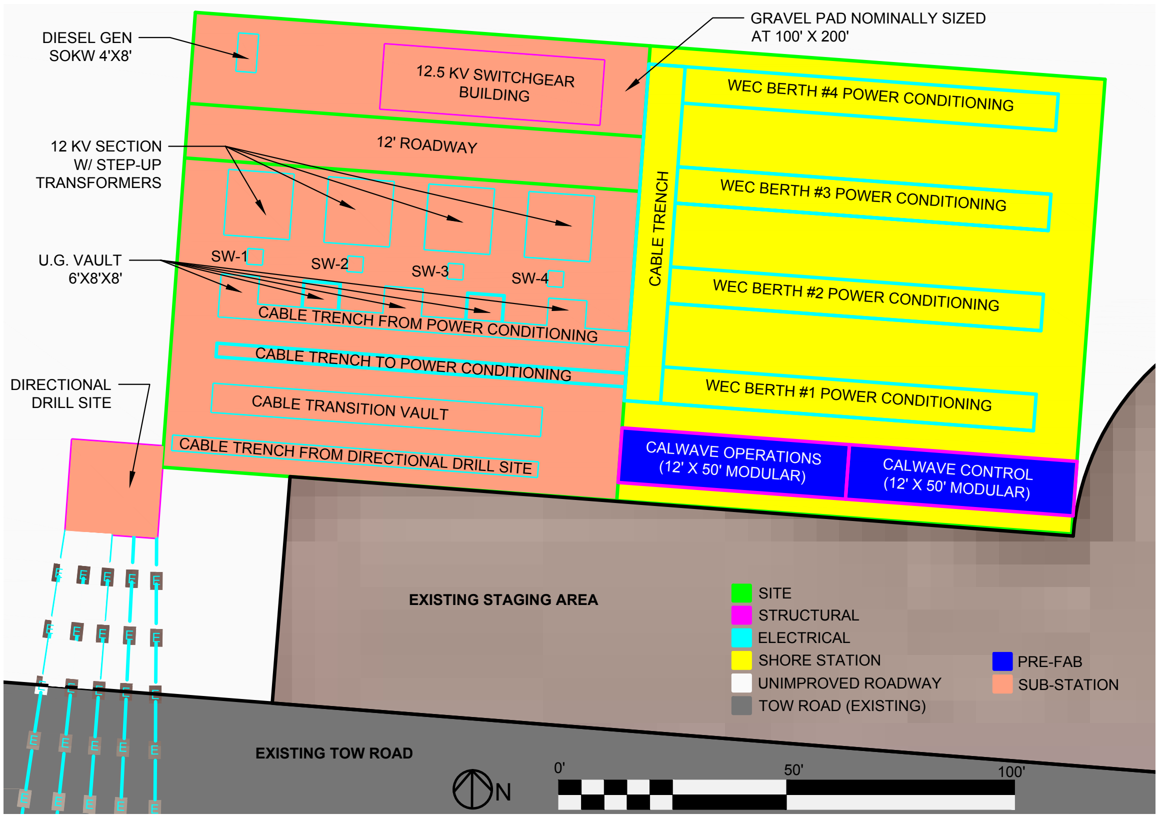


Figure 11: Site Map 4

Some added concerns arose when analyzing the feasibility of semi trucks entering and exiting the site, both during construction and after completion. The ASHTO document shown below illustrated the required turning radius or a vehicle 40 ft. long.

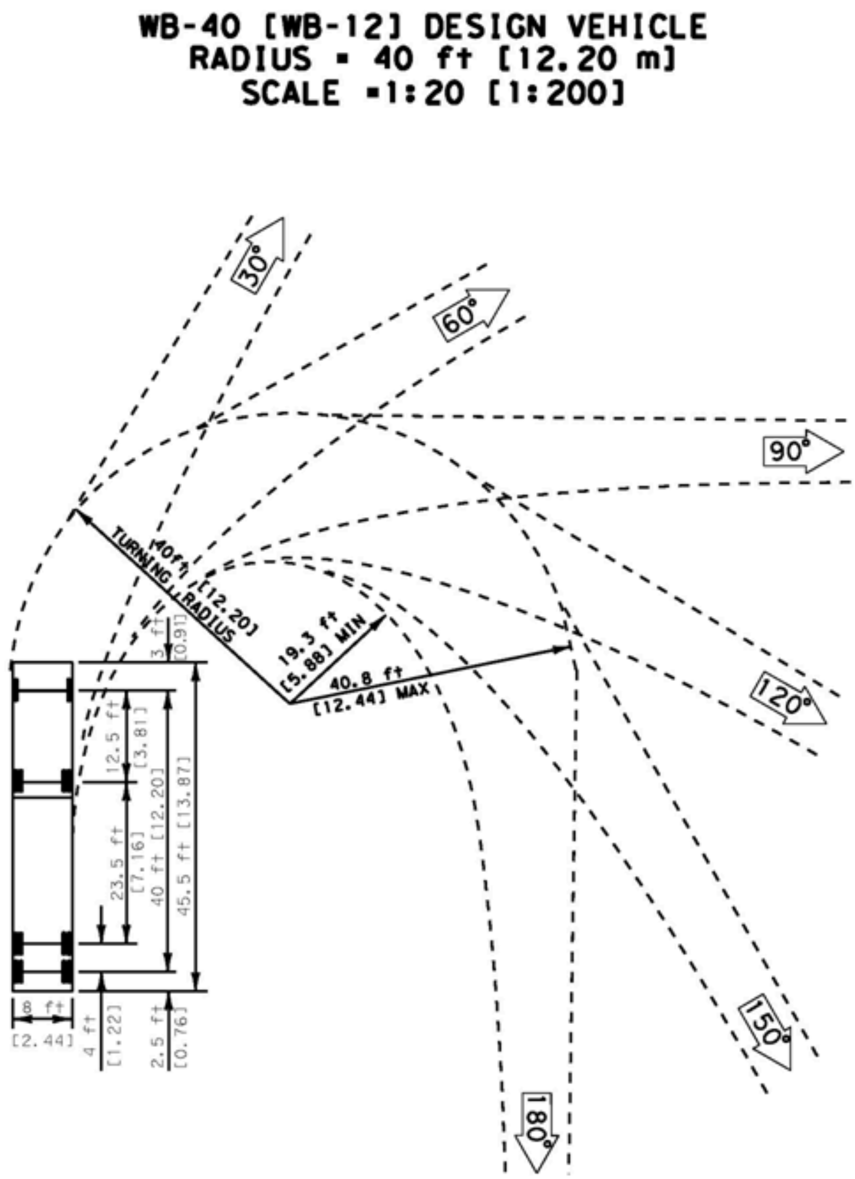


Figure 12: Turning Template for Semi-Trailer with 40 ft. Wheelbase

Using these parameters, the minimum radius was 19.3 feet and the maximum was 40.8 feet. These design considerations were incorporated into the final plans.

4.3 Personal Contribution - Architectural

For the two modular buildings on site, I designed preliminary floor plans and sections. My education in architectural engineering and previous internship experience creating drawings allowed me to create clear and legible drawings.

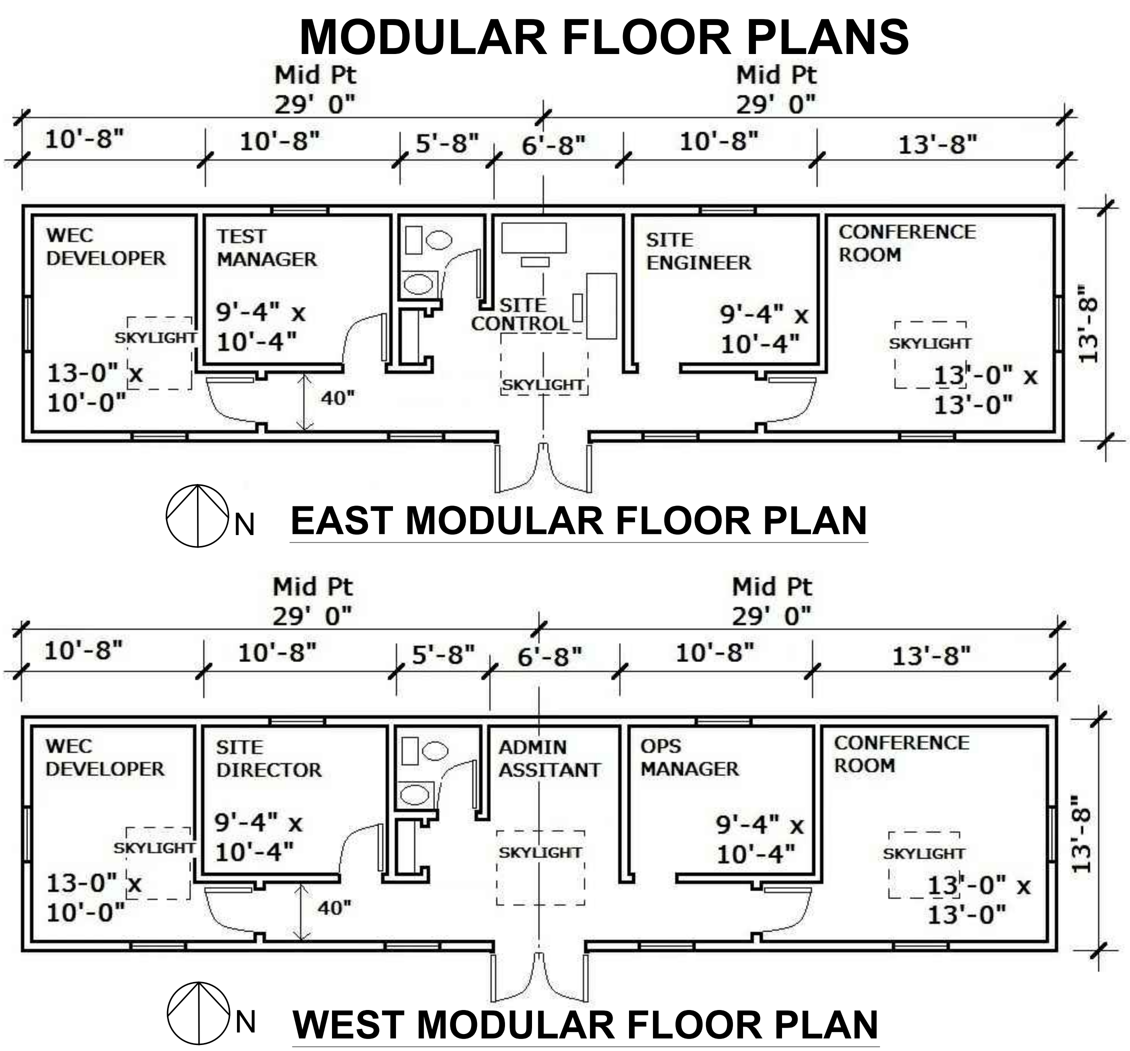


Figure 13: Floor Plans

The room use and layout was developed in consultation with Rick Williams.

Sections can be seen in Figure 14 below.

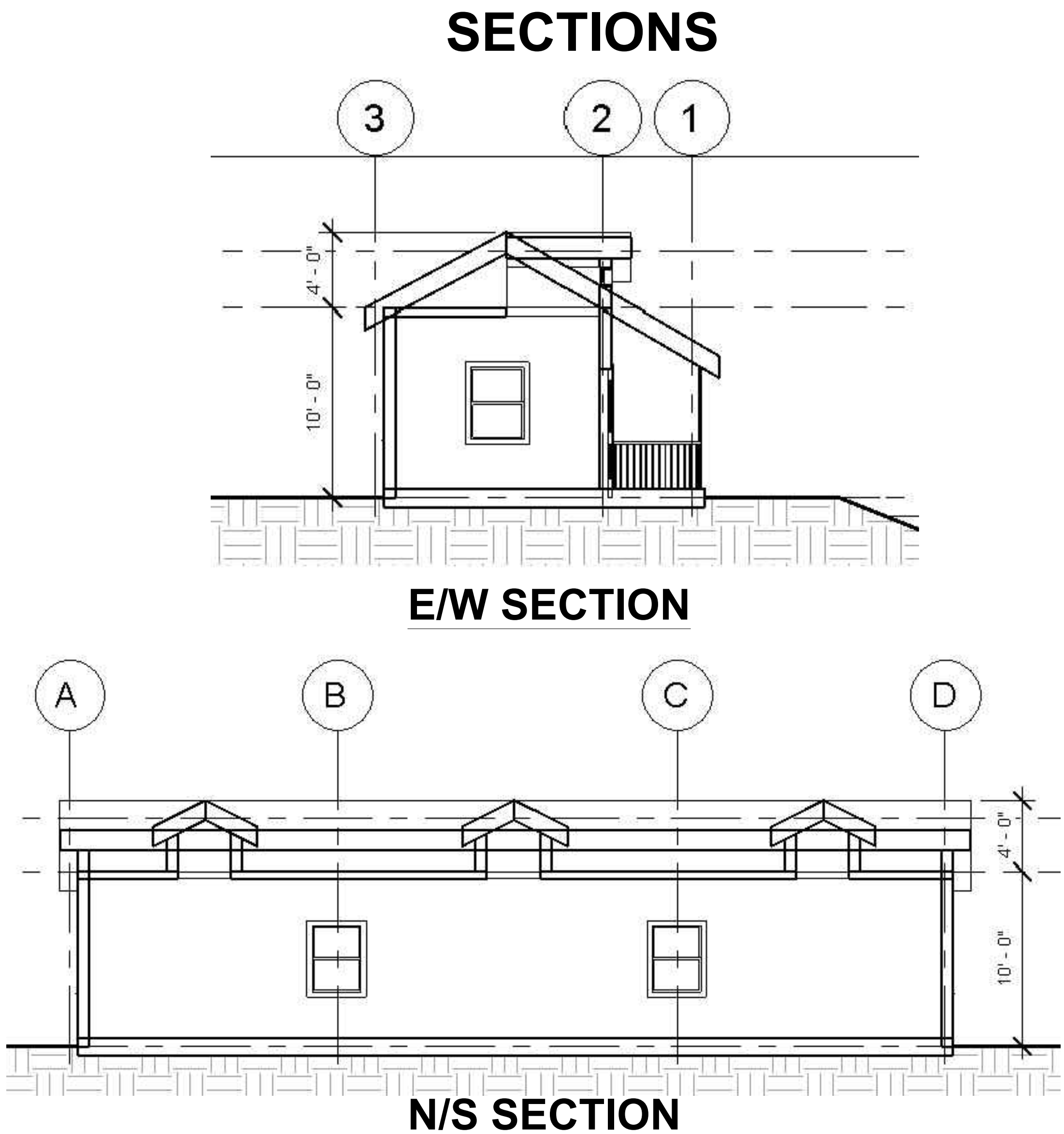


Figure 14: Sections

Finally, architectural façade renders were created using a Revit modeling program.

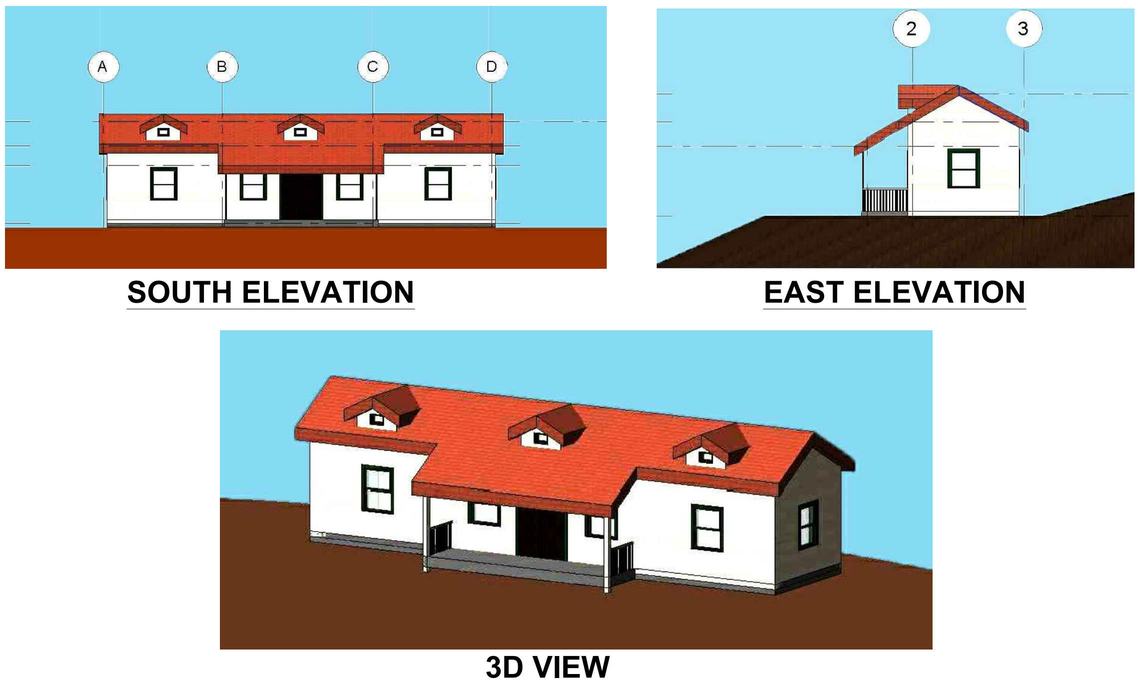


Figure 15: Architectural Renders

The final design incorporated Georgian style architecture including tall thin windows, symmetry, and a white color scheme.

5.0 Final Deliverables

The final deliverables were approved cost estimates and approved drawings. The final schematic design and architectural packages can be viewed in the appendix.

Ultimately, I discovered how difficult project coordination could be. The communication between everyone involved in the project was essential for a cohesive design. Incorporating all the details dictated by every assistant project manager as well as producing the best work possible was a difficult task. In order to appeal to each assistant project manager and properly integrate their specific disciples' requirements into the design demanded acute attention to detail. Additionally, in order for a continual production of work to occur, constant and daily communication between all involved was crucial to advance the project.

6.0 Acknowedgements

A special thanks to:

Dr. Dale Dolan

Department of Electrical Engineering

Faculty Scholar

Bill Toman - Calwave Project Manager

Institute for Advanced Technology & Public Policy

Rick Williams – Calwave Chief Engineer

Leidos Maritime Solutions

Larry Hollis

Vice President at Rosendin Electric

To Project Advisor Dr. Craig Baltimore for the feedback and helpful advice throughout this challenging project.

7.0 Works Cited

http://onlinemanuals.txdot.gov/txdotmanuals/rdw/minimum_designs_truck_bus_turns.htm

http://whitneyhafftartwork.com/works/1503712/spooner-ranch-house-2014

http://www.slb.com/resources/oilfield_review/~/media/Files/resources/oilfield_review/ors13/win13/defining_dir_drill.ashx

http://rebrn.com/re/how-do-extended-reach-oil-wells-change-direction-underground-136647/

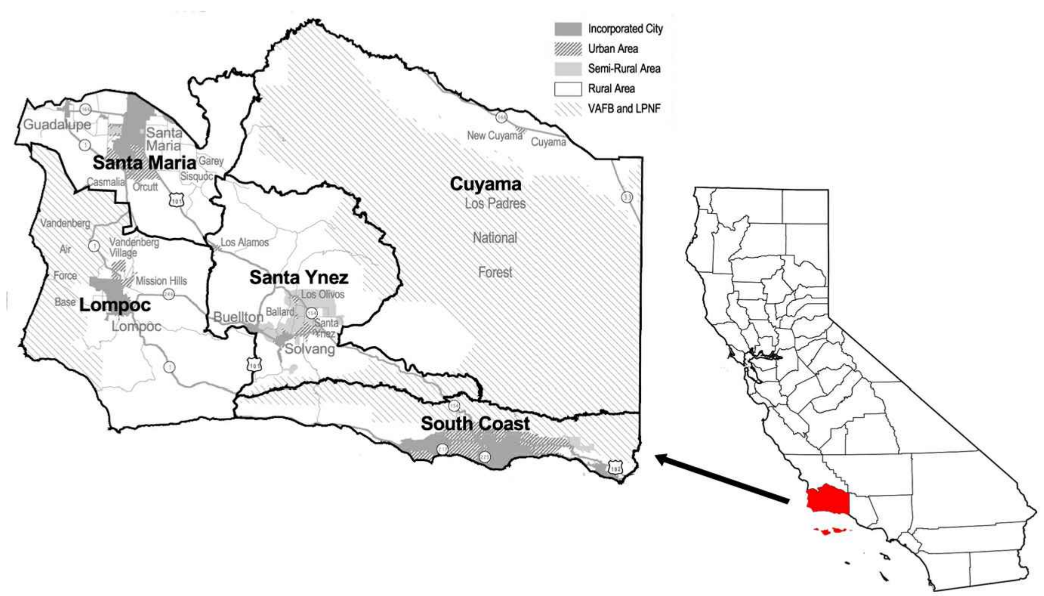
8.0 Appendix

See next page for Schematic Design and Architectural final packages as submitted to the Department of Energy.

Institute for Advanced Technology and Public Policy

NATIONAL WAVE ENERGY TEST FACILITY

June 2015



LOCATION MAP

VICINITY MAP

DRAWING INDEX

DESIGNATION	SHEET	DESCRIPTION
G-1	1 OF 8	COVER SHEET
C-1	2 OF 8	SITE PLAN 1
C-2	3 OF 8	SITE PLAN 2
C-3	4 OF 8	SITE PLAN 3
C-4	5 OF 8	SITE PLAN 4
C-5	6 OF 8	TOPO MAP
C-6	7 OF 8	SECTION
C-7	8 OF 8	ALT. DRILL SITE

THIS PROJECT REQUIRES A CLASS 'A'
GENERAL ENGINEERING CONTRACTORS LICENSE

FEASIBILITY STUDY
NOT FOR CONSTRUCTION

VANDENBERG AFB: CAL POLY CALWAVE PLANS

DRAWING TITLE:
COVER SHEET

REVISION DATES:

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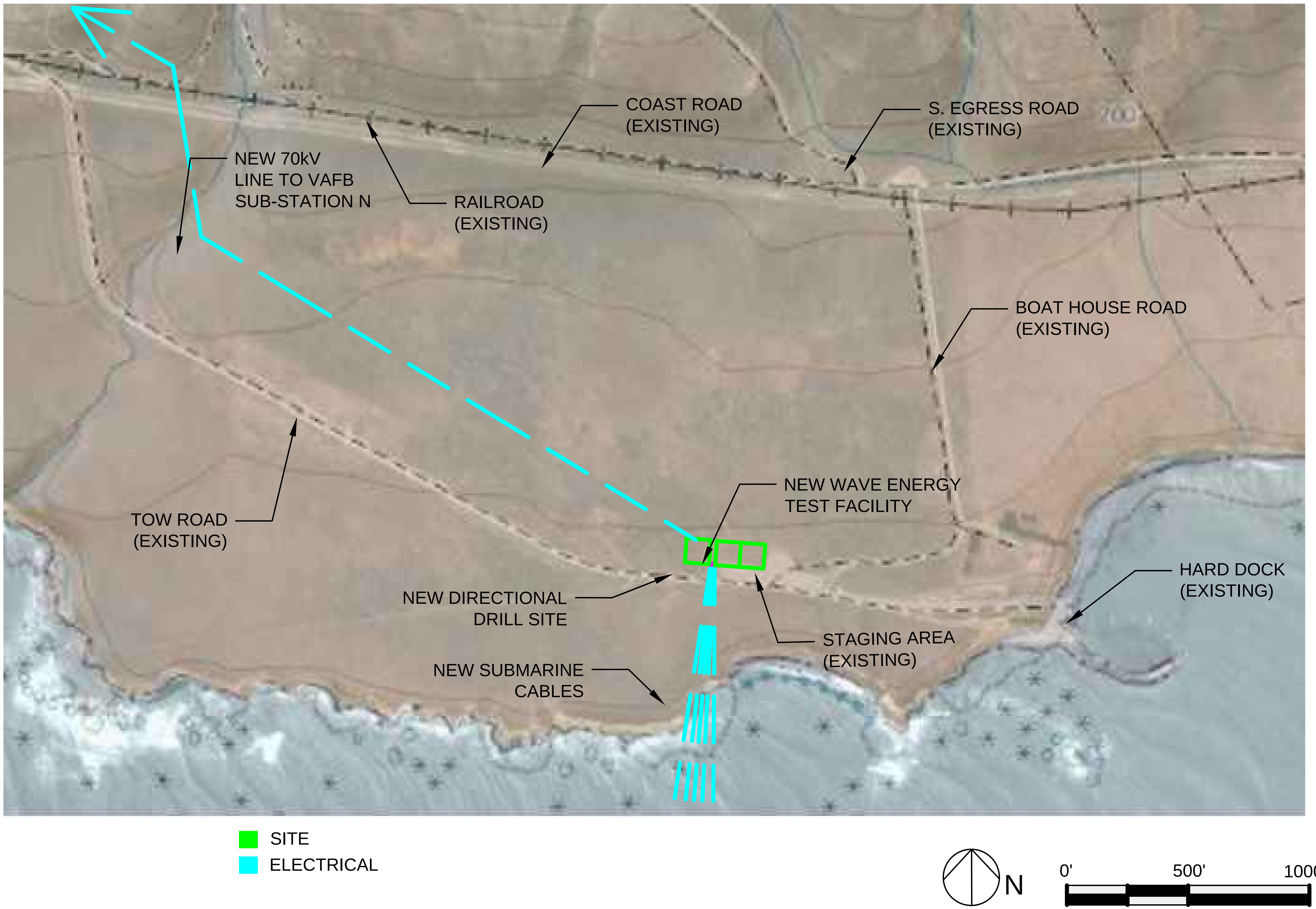
G-1

DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:



CAL WAVE
CAL POLY

VANDENBERG AFB: CAL POLY CALWAVE PLANS

DRAWING TITLE:
SITE MAP 1

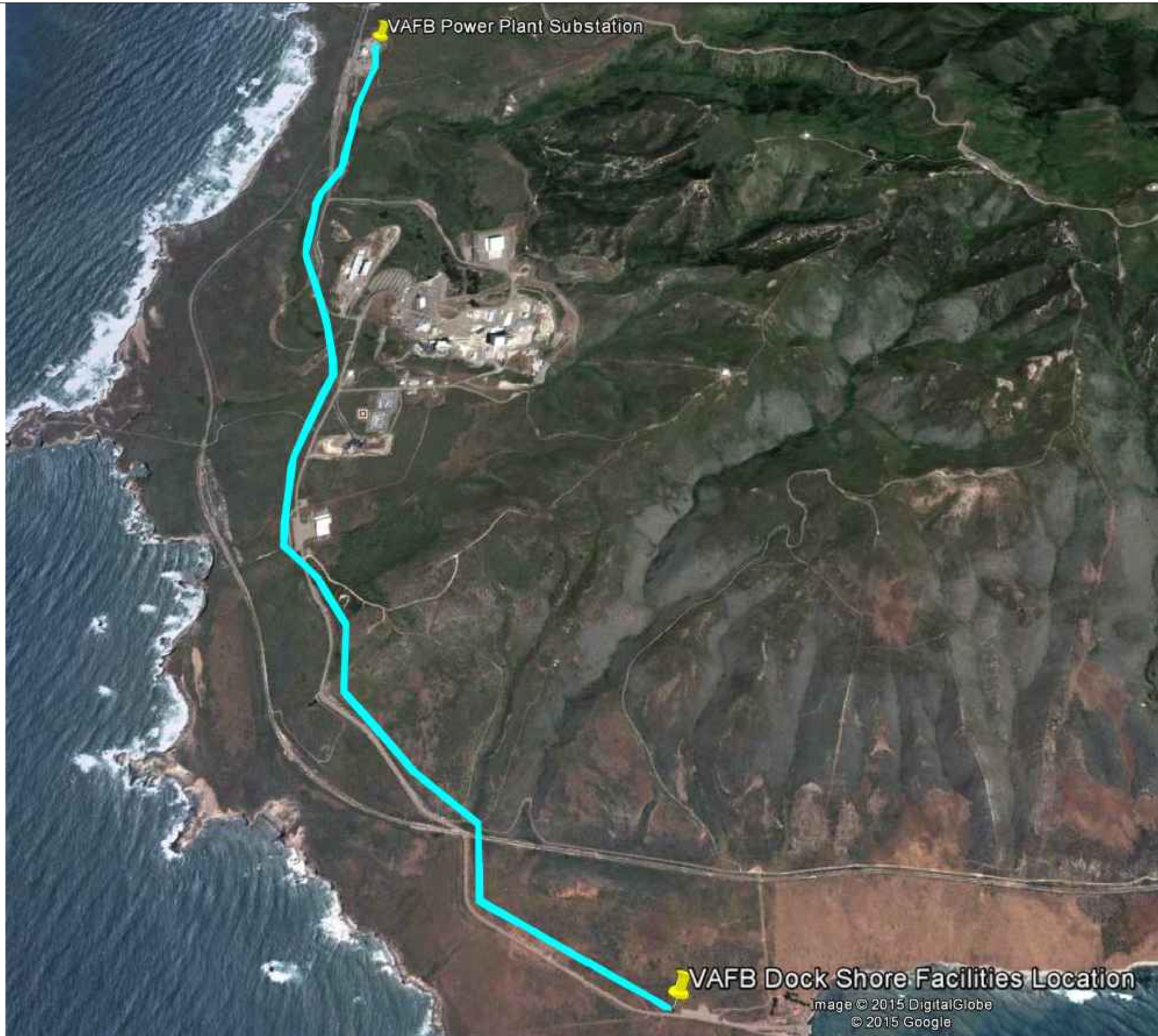
REVISION DATES:

SHEET NO.:
C-1

DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:
SEE MAP



DESCRIPTION:
NOTIONAL 70kV EXTENSION LINE ROUTE TO VAFB SUB-STATION N

APPROX. LENGTH OF EXTENSION LINE = 4 MILES

N

CALWAVE CAL POLY

VANDENBERG AFB: CAL POLY CALWAVE PLANS

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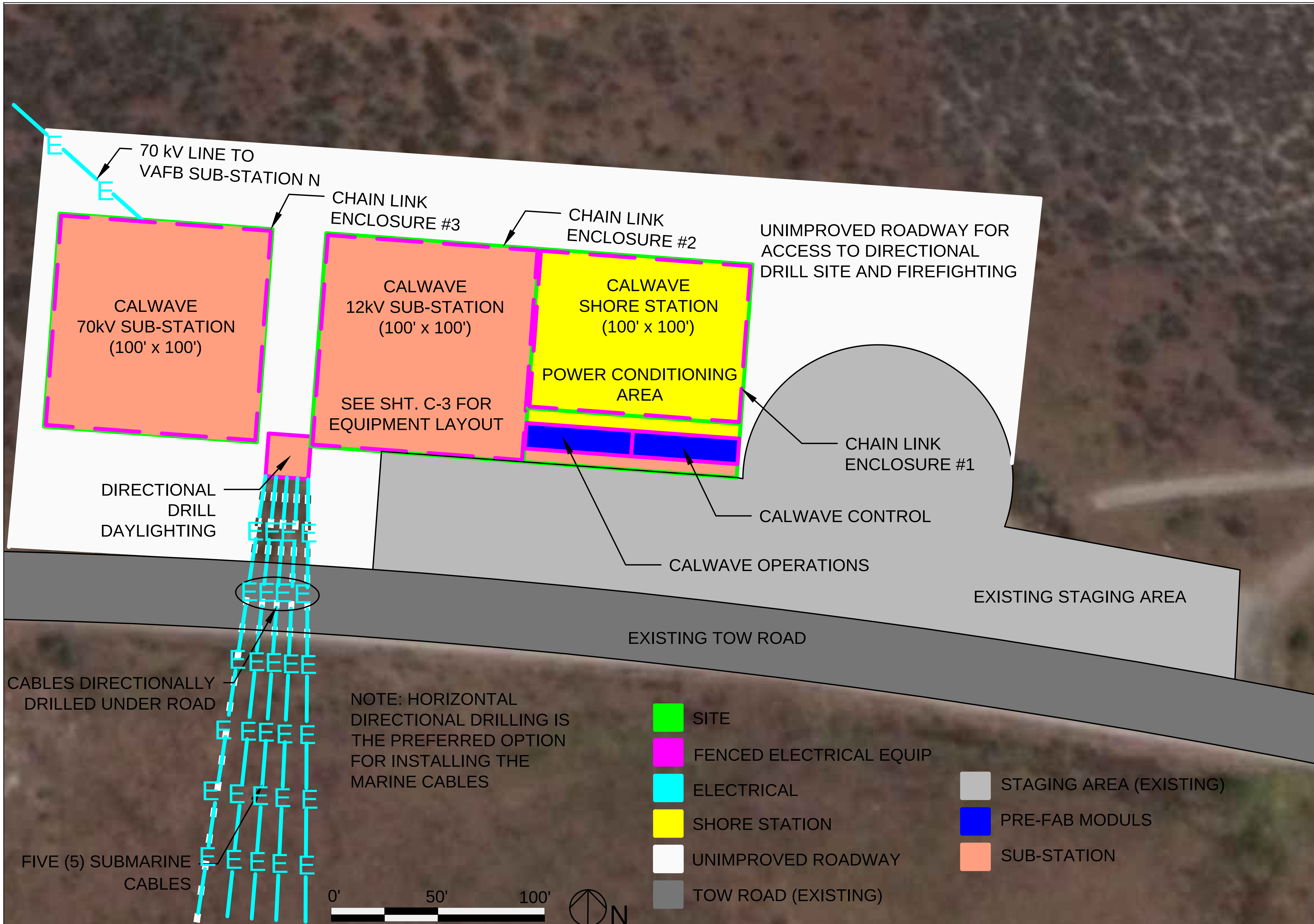
DRAWN BY:	KYLIN VAIL
DATE:	5/28/15
SCALE:	SEE MAP



CALWAVE CALPOLY

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SITE MAP 3

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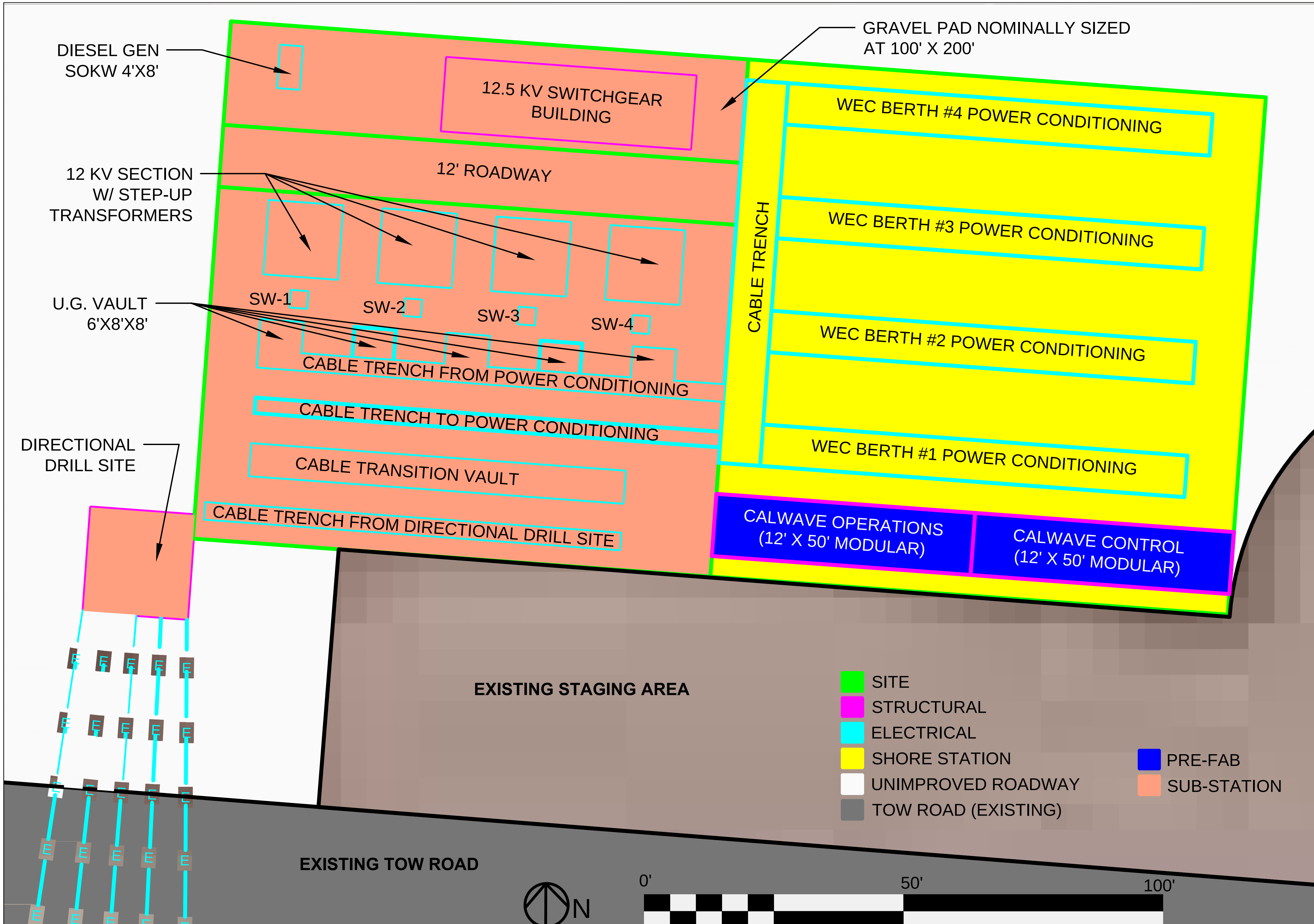
C-3

DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:
SEE MAP



CALWAVE CAL POLY

VANDENBERG AFB: CAL POLY CALWAVE PLANS

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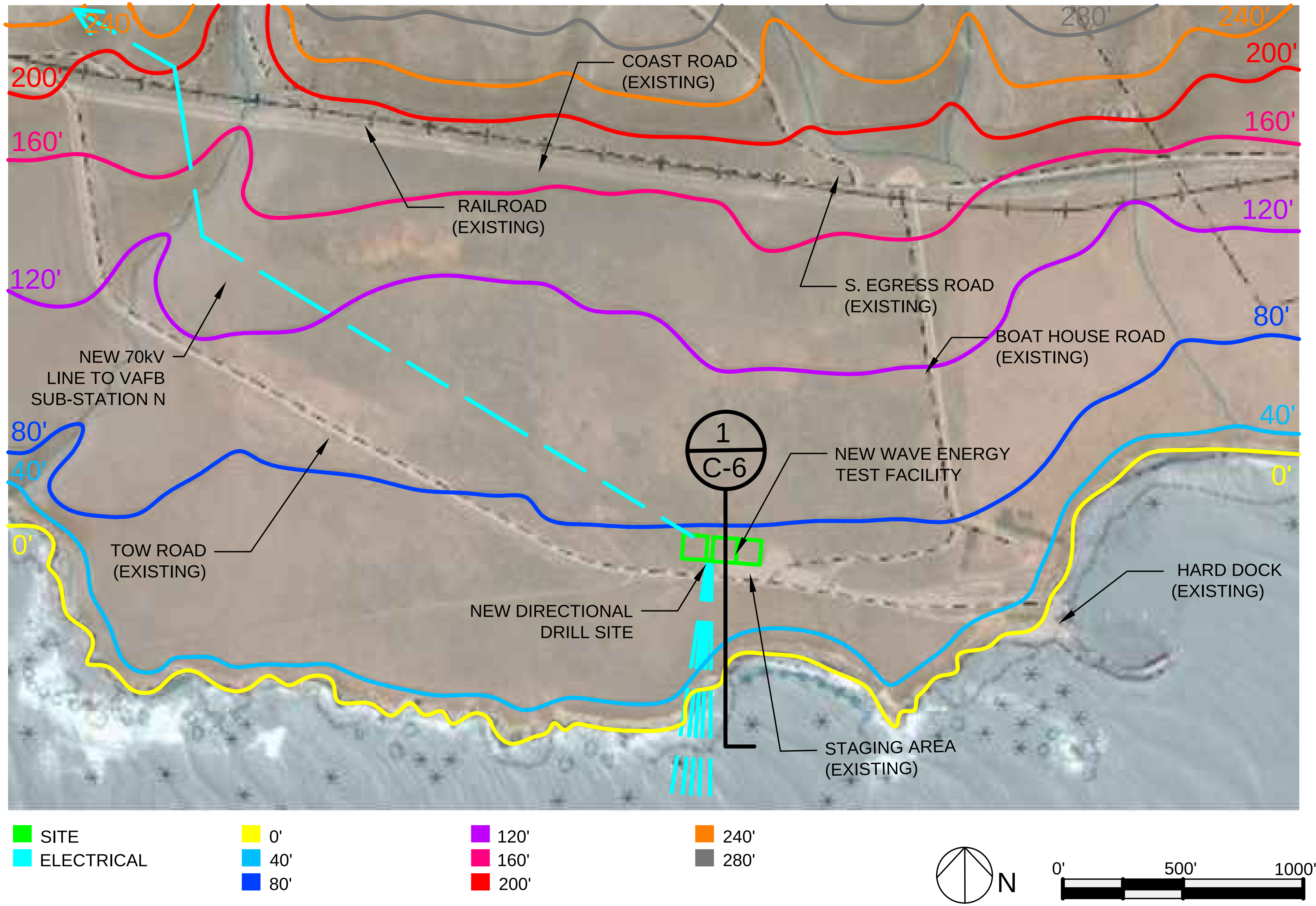


VANDENBERG AFB: CAL POLY CALWAVE PLANS

DRAWING TITLE:
TOPO MAP

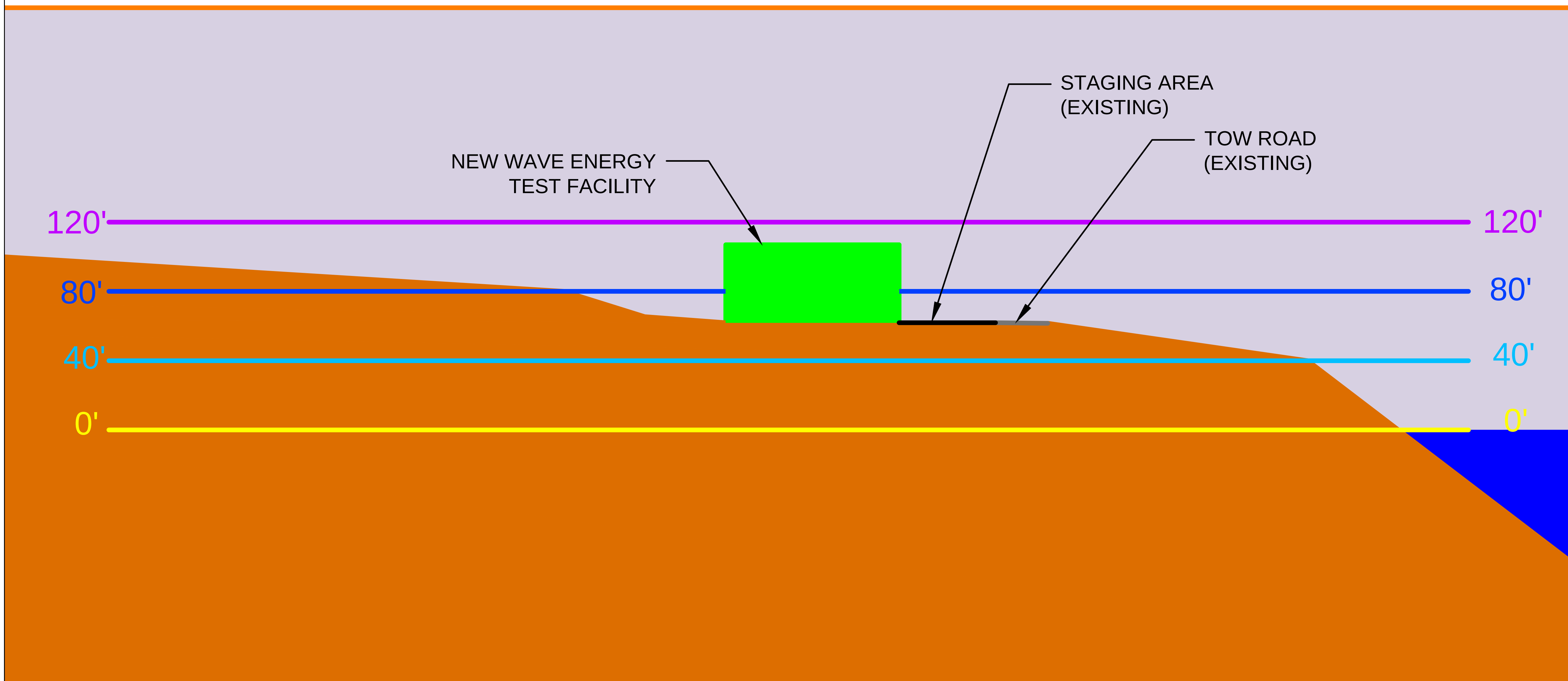
REVISION DATES:

SHEET NO.:
C-5

DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:
SEE MAP



- SITE
- TOW ROAD (EXISTING)
- STAGING AREA (EXISTING)
- 0'
- 40'
- 80'
- 120'
- GROUND
- ABOVE GROUND

1 / C-6 SECTION A

0' 50' 100'

N

VANDENBERG AFB: CAL POLY CALWAVE PLANS

DRAWING TITLE:
SECTION

REVISION DATES:

SHEET NO.:
C-6

DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:
SEE MAP

CALWAVE CAL POLY

VANDENBERG AFB: CAL POLY CALWAVE PLANS

DRAWING TITLE:
ALTERNATE DRILL SITE

REVISION DATES:

SHEET NO.:
C-7

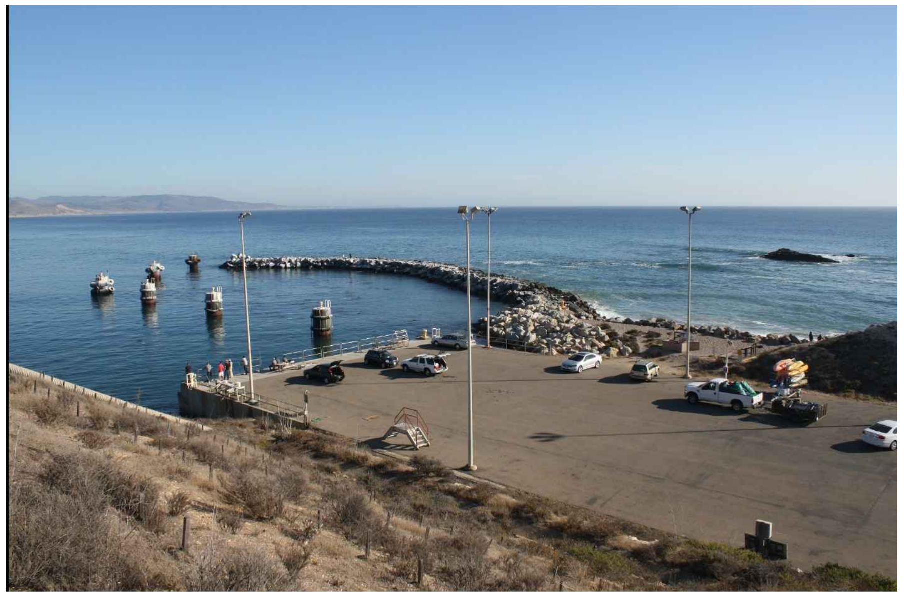
DRAWN BY:
KYLIN VAIL

DATE:
5/28/15

SCALE:
SEE MAP

VANDENBERG ARCHITECTURAL INFLUENCE

June 2015



MARINER MISSILE DOCK

SITE PLAN

MARINER MISSILE DOCK

HISTORICAL BOATHOUSE

HISTORICAL BOATHOUSE

HISTORICAL BOATHOUSE

CAL WAVE

CAL POLY

VANDENBERG AFB: CAL POLY CALWAVE ARCHITECTURE

DRAWING TITLE:	ARCH. FACADE
REVISION DATES:	
SHEET NO.:	A-1
DRAWN BY:	KYLIN VAIL
DATE:	6/15/15
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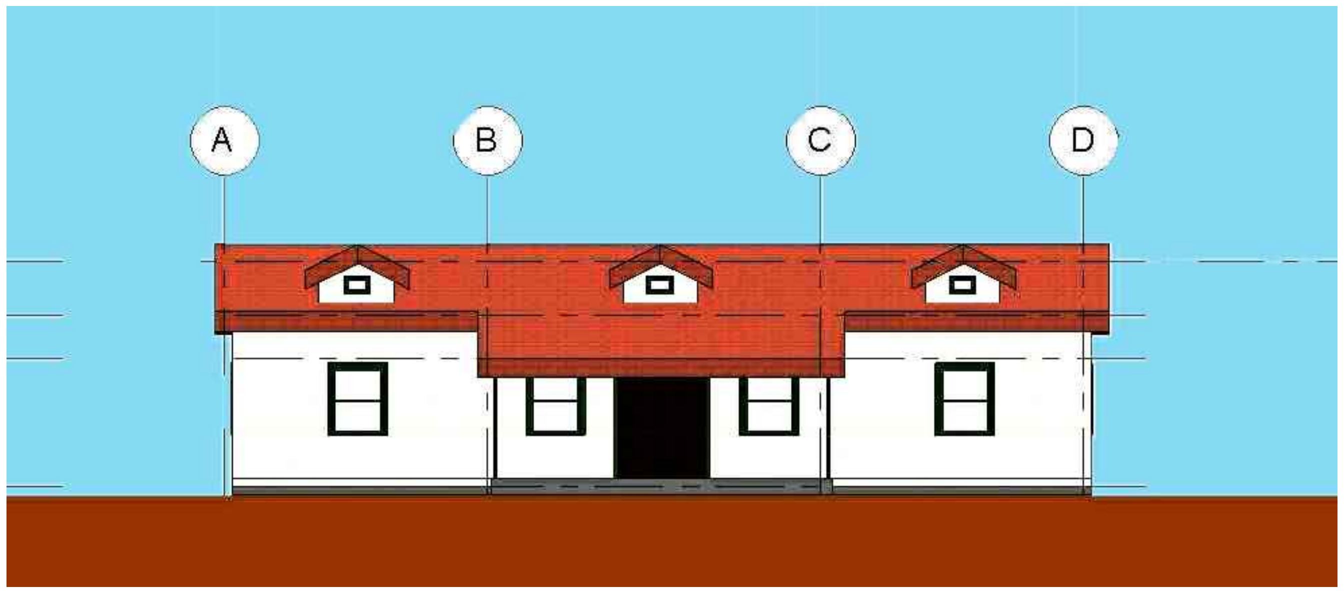
ARCHITECTURAL FAÇADE RENDERS

June 2015



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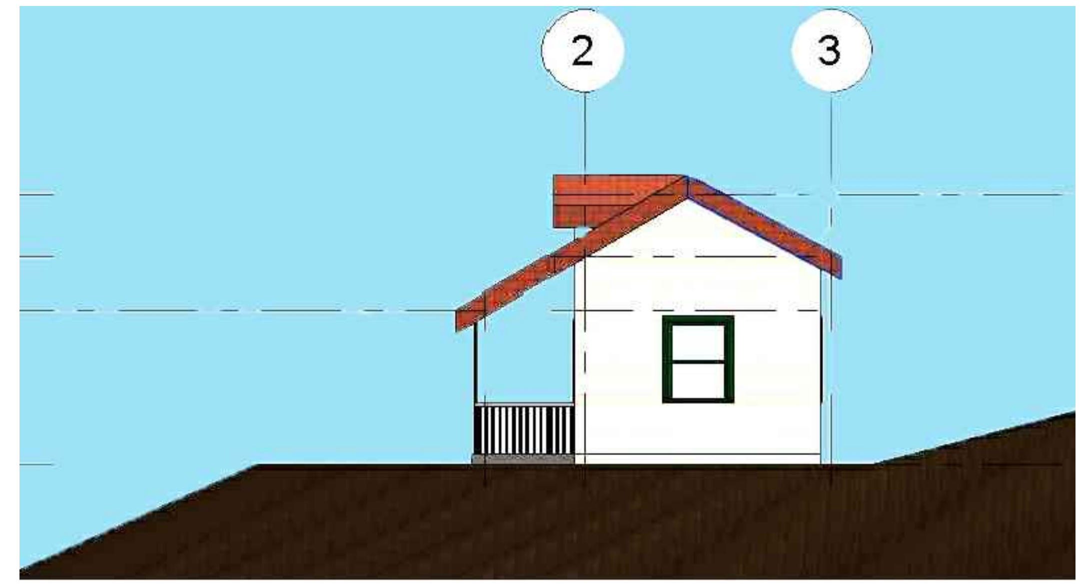

EAST ELEVATION

3D VIEW

VANDENBERG AFB: CAL POLY CALWAVE ARCHITECTURE

DRAWING TITLE:
ARCH. FACADE

REVISION DATES:

SHEET NO.:
A-2

DRAWN BY:
KYLIN VAIL

DATE:
6/15/15

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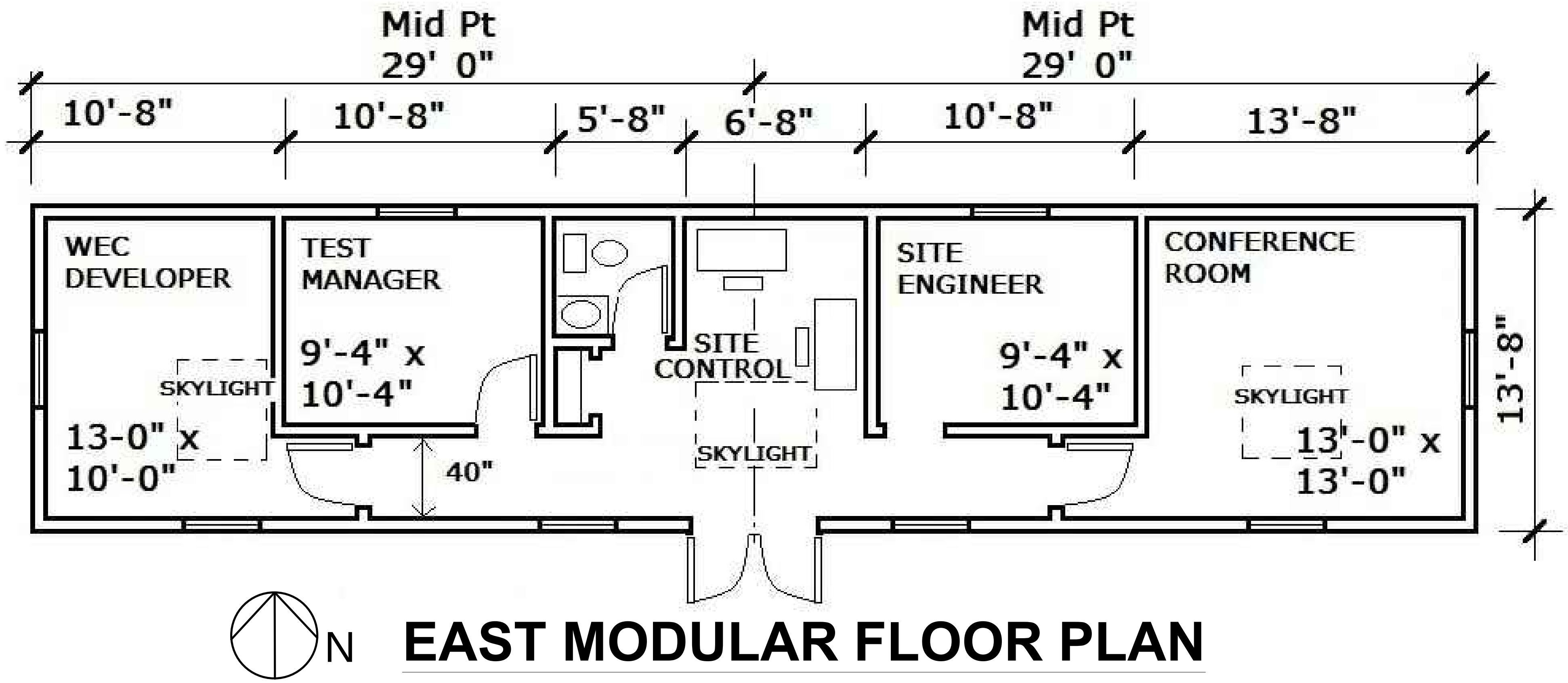
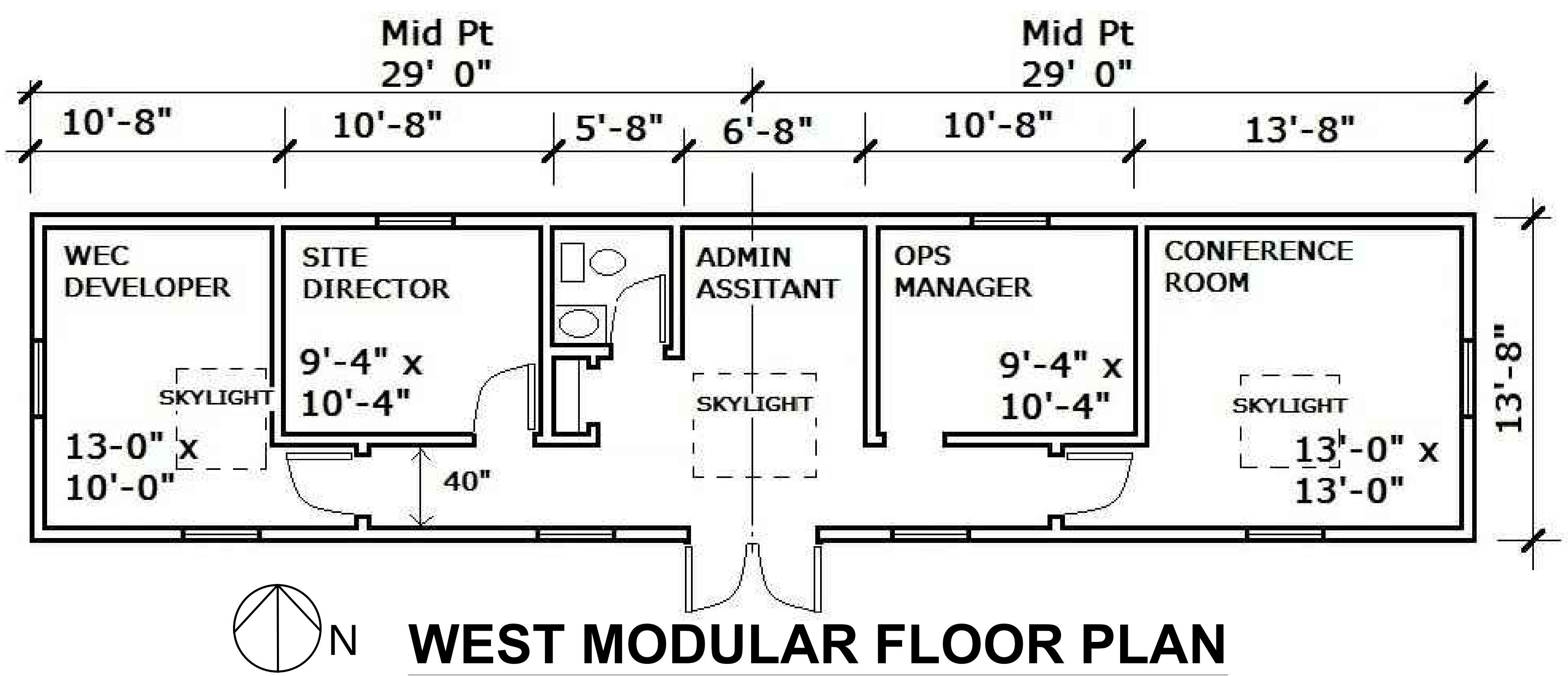
MODULAR FLOOR PLANS



EAST MODULAR FLOOR PLAN



WEST MODULAR FLOOR PLAN

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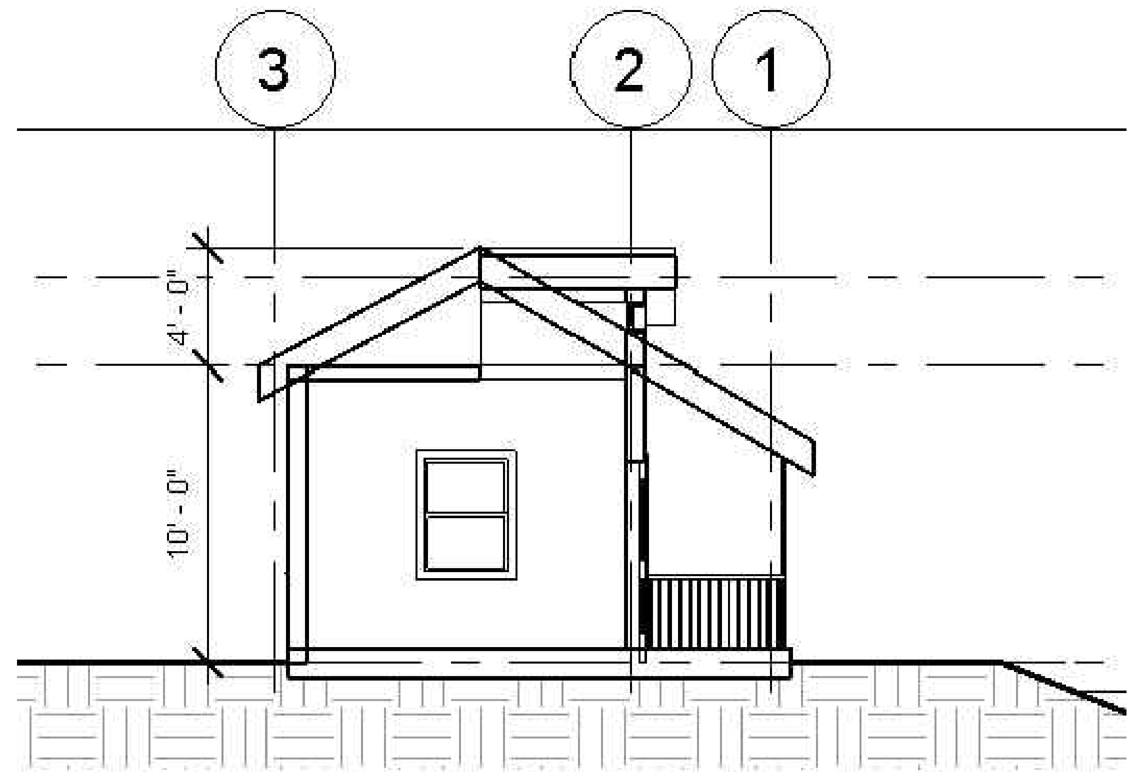
SECTIONS



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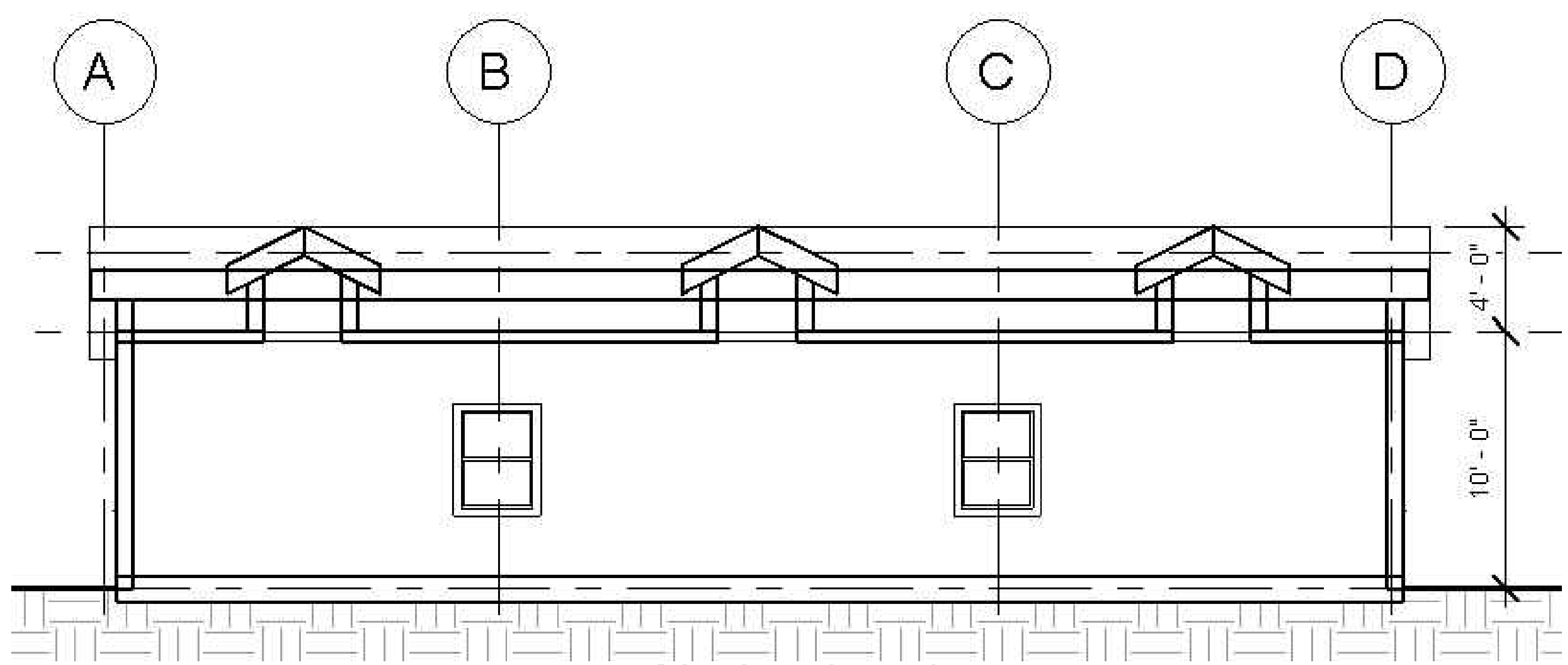

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