Remedial Action Plan

Brisbane Parcel B
3775 Bayshore Blvd
Brisbane, California

Prepared for:

Univar Solutions

Prepared by:

EHS Support℠

September 2022

REMEDIAL ACTION PLAN

PARCEL B
3775 BAYSHORE BLVD
BRISBANE, CALIFORNIA

September 2022

Presented herein is a Remedial Action Plan (RAP) prepared on behalf of Univar Solutions USA Inc. and VWR International, LLC (Univar/VWR) for proposed final remediation activities at 3775 Bayshore Boulevard in Brisbane, California (Parcel B). Parcel B is adjacent to a former VWR facility located at 3745 Bayshore Boulevard (Parcel A). The purpose of this document is to propose a final remedy and provide the remedial design basis.

PROFESSIONAL GEOLOGIST
GREGORY CHRISTOPHER WHITE
No. 8415
June 30, 2024
STATE OF CALIFORNIA

Greg White, PG
EHS Support LLC
Senior Project Manager
California Professional Geologist No. 8415

Table of Contents

List of In-Text Tables

List of Attached Tables

List of In-Text Figures

List of Attached Figures

List of Appendices

Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
%v	percent by volume
µS/cm	microsiemens per centimeter
AS	air sparging
BAAQMD	Bay Area Air Quality Management District
bgs	below ground surface
CalEPA	California Environmental Protection Agency
CEQA	California Environmental Quality Act
DNAPL	dense non-aqueous phase liquid
DQO	data quality objective
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources
EC	engineering control
ESL	Environmental Screening Level
ft	feet or foot
GRA	general remedial action
HSU	hydrostratigraphic unit of interest
HVAC	heating, ventilation, and air conditioning
IC	institutional control
LEL	lower explosive limit
LNAPL	light non-aqueous phase liquid
NAD83	North American Datum 1983
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum 1988
O&M	operation and maintenance
PDI	pre-design investigation
PID	photoionization detector
PVC	polyvinyl chloride
RAO	remedial action objective
RAP	Remedial Action Plan
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RWQCB	Regional Water Quality Control Board
SIM	selected ion monitoring
SMCEHD	San Mateo County Environmental Health Department
SMP	soil management plan

SSDS	sub-slab depressurization system
SSVP	sub-slab vapor probe
SVE	soil vapor extraction
SWRCB	State Water Resources Control Board
TCH	thermal conductive heating
TMP	temperature monitoring probe
TOC	top of casing
TPH	total petroleum hydrocarbons
UCL	upper confidence limit
USA	Underground Service Alert
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VGAC	vapor-phase granular activated carbon
VI	vapor intrusion
VOC	volatile organic compound
yr	year

1. Introduction

On behalf of Univar Solutions USA Inc. and VWR International, LLC (collectively, "Univar/VWR"), EHS Support LLC ("EHS Support") is submitting this Remedial Action Plan ("RAP") for remediation activities proposed at 3775 Bayshore Boulevard in Brisbane, California (Parcel B). Parcel B is adjacent to a former VWR facility located at 3745 Bayshore Boulevard ("Parcel A"). In this RAP, Parcel B is referred to as the "Site" (**Figure 1**).

Since 2013, Univar/VWR have performed voluntary environmental investigation and remediation activities at the Site with regulatory oversight provided by the California Regional Water Quality Control Board, San Francisco Bay Region (RWQCB). Investigations identified soil, groundwater, and soil vapor impacts at the Site in the vicinity of the former chemical tank farm, along the former rail spur located east of the building, and at the southern end of the building near the loading dock. Organic compounds have been identified in soil, groundwater, and sub-slab soil vapor samples collected from these areas, as reported in the *On-Site Remedial Investigation Data Summary Report* (ERM, 2015a) and *Data Gaps Investigation Report* (EHS Support, 2018). Narrative remedial action objectives (RAOs) and numeric cleanup levels ("Cleanup Levels") were developed in the *Remedial Action Objectives and Cleanup Levels Proposal* (EHS Support, 2020), approved by RWQCB in March 2021.

To facilitate remedy selection and remedial design, additional data collection was undertaken in July and August 2021 to determine the lateral and vertical extent of soil subject to remediation and characterize pre-remediation baseline conditions in soil vapor and groundwater. These data collection activities are reported in the *Pre-Design Investigation Report* (PDI Report; EHS Support, 2022a), approved by RWCQB in April 2022. The lateral extent of contamination subject to active remediation in depth intervals 0 to 5 feet below ground surface [ft bgs], 5 to 15 ft bgs, and 15 to 55 ft bgs are shown on **Figure 2**, **Figure 3,** and **Figure 4**, respectively.

In discussions with the property owner, it is the joint opinion of Univar/VWR and the property owner that cleanup be undertaken to achieve RAOs, close the Site under an industrial/commercial use scenario, and limit the need for long-term post-remediation monitoring. Given that the Site is currently vacant, Univar/VWR performed interim measures excavation work proposed in the *Interim Remedy Implementation Plan* (Appendix G of the *Pre-Design Investigation Report*; EHS Support, 2022a) to remove the source mass underlying the parking area south of the warehouse to support re-lease efforts while the final remedy for the remainder of the Site is developed (**Figure 5**). Interim measures excavation activities were completed between May and July 2022.

Given the successful implementation of interim measures, the focus of this RAP is on the remaining areas requiring active remediation and complementary engineering controls (ECs), institutional controls (ICs), and monitoring necessary to achieve regulatory Site closure under an industrial/commercial use scenario or a low-threat closure scenario.

1.1. Purpose of Plan

The purpose of this RAP is to evaluate remedial alternatives, propose final remedial actions, provide the remedial design basis, and provide RWQCB with sufficient information to readily approve the final remedy for implementation at the Site.

1.2. Project Goals

Overarching project goal: The goal of this project is to implement a remedy that is protective of public health and the environment and enables continued industrial/commercial Site use, consistent with the goals of the RWQCB Brownfields Program.

Remediation goals:

- Address residual sources of organic contamination present as non-aqueous phase liquid (NAPL) and in soil (sorbed-phase contamination).
- Enable attainment of RAOs through effective source removal, ongoing natural degradation processes, and protective ECs and ICs.
- Achieve RWQCB closure.

1.3. Document Organization

The structure of this RAP is as follows:

- **Section 2**: Site Background. Provides the history of Site operations and an overview of the hydrogeologic setting.
- **Section 3**: Remedial Action Objectives and Cleanup Levels. Discusses the RAOs and the Cleanup Levels for soil, groundwater, and soil vapor.
- **Section 4**: Identification of Remedial Alternatives. Outlines the remedial alternatives.
- **Section 5:** Remedial Alternatives Screening. Evaluates the remedial alternatives consistent with applicable provisions of SWRCB Resolution No. 92-49 and the California Environmental Quality Act (CEQA).
- **Section 6:** Proposed Remedy. Describes the proposed remedy and evaluates the ability of the proposed remedy to satisfy the RAOs.
- **Section 7**: Performance Monitoring Program. Discusses the three monitoring periods (i.e., baseline monitoring, operational monitoring, and remedy verification monitoring) and associated requirements.
- **Section 8**: References. Lists the documents cited in this report.

2. Site Background

2.1. Property Description

The Property consists of three contiguous parcels of property located at 3745 and 3775 Bayshore Boulevard, totaling 15.2 acres: (1) APN 007-150-030 ("Parcel A"); (2) APN 007-150-040 ("Parcel B"); and (3) APN 007-150-070 ("Parcel C"). The Property and all three parcels are shown on **Figure 6**. Spear Street Associates, L.P. and its predecessors owned the Property from 1978 through March 2016. M & L Associates acquired the Property on April 1, 2016. As discussed in **Section 1**, Parcel B is the subject of this RAP.

The Property is relatively flat, almost completely covered by hardstand areas (e.g., buildings with concrete slab floors, asphalt/concrete parking areas), and has a nominal surface elevation of 10 feet (ft) above mean sea level. According to the City of Brisbane zoning map, the Property is zoned TC-2 (within the Southeast Bayshore Commercial District).[1] According to the Association of Bay Area Governments Resilience Program, the Property is located in a very high liquefaction susceptibility hazard area, a violent shaking hazard area (based on a magnitude 7.8 earthquake along the San Andreas Fault) [2], and a minimal flood hazard area (between 0.2 and 1 percent annual chance of flood) (Federal Emergency Management Agency flood zone X).

Adjoining the eastern side of the Property is the Caltrain right-of-way that runs northwest to southeast. Approximately 20 ft east of the Caltrain right-of-way is the Brisbane Lagoon, which is to the north and east of the Property. Brisbane Lagoon is a remnant of the San Francisco Bay ("Bay") created during the construction of U.S. Highway 101 in the 1950s. Brisbane Lagoon is connected to the Bay through a series of channels that cross under U.S. Highway 101 at the northeastern end of the lagoon at the Brisbane Lagoon Fisherman's Park. Land to the south is open space surrounding a freeway overpass and the convergence of Bayshore Boulevard and U.S. Highway 101. Land use to the west across Bayshore Boulevard includes residential and commercial/light-industrial developments. The Property is at the base of San Bruno Mountain; the elevation of Bayshore Boulevard immediately west of the Property is generally at least 30 ft higher.

Parcel A is improved with an approximately 225,000-square-foot concrete warehouse, as well as office buildings constructed in the early 1960s (**Figure 7**). Parcel B is improved with an approximately 80,000-square-foot concrete tilt-up building, constructed in 1980, with two adjacent tenant spaces (northern and southern), each of which is comprised of two smaller warehouse areas (**Figure 8**). Parcel C is a small contiguous parcel to Parcel B, known as the Tunnel Property, where an old rail line used to run through San Bruno Mountain. The parcel is improved with a paved parking area and fencing; there are no buildings on Parcel C (**Figure 9**).

2.2. Property History and Operations

According to the Brownfields application (VWR, 2014), the Property has been in commercial use since the early 1960s and served as a chemical distribution facility for 15 years (approximately 1962 to 1977).

[1] https://www.brisbaneca.org/cd/page/zoning-information
[2] http://resilience.abag.ca.gov/earthquakes/sanmateo/

Parcel A was historically used for warehousing and distribution of general scientific supplies and chemicals. Administrative operations were also conducted at Parcel A. The Parcel A warehouse building was cleaned and decommissioned from January 2013 to December 2014 as part of the facility closure. The closure work was overseen by San Mateo County Environmental Health Department (SMCEHD) and was conducted in accordance with Title 22 of the California Code of Regulations, Sections 66265.111 and 66265.114, which require the decontamination and closure of facilities that have handled hazardous materials and wastes. Closure activities were documented in the *Facility Closure Report* (ERM, 2015b), approved by SMCEHD in March 2015 (SMCEHD, 2015). The Parcel A warehouse is currently vacant and is planned to be re-leased for commercial freight forwarding operations beginning in 2022.

Parcel B was historically used for storage of pure-phase chemicals and blended product in aboveground storage tanks; presumably transferred to/from a bulk loading/unloading area via rail and truck. Based on a review of aerial photographs, aboveground storage tanks and associated piping and appurtenances were removed between 1975 and 1980, before the construction of the existing warehouse building in 1980. The Parcel B warehouse is currently vacant and is planned to be re-leased for commercial freight forwarding operations following the completion of planned remediation activities.

Univar/VWR did not use Parcel C for historical operations, Parcel C is not listed in the Brownfields application that requested agency oversight of investigation and remediation at Parcel A and Parcel B, and investigation data collected at Parcel B confirmed that organic contamination subject to remediation at Parcel B has not migrated to Parcel C. Based on a review of aerial photographs, Parcel C was undeveloped, vacant land prior to 1946. By 1950, an old rail line was constructed which ran across the parcel and through San Bruno Mountain. By 1968, the old rail line was removed, and the parcel appeared to be used as an unpaved parking area. By 2005, the parking area was paved and appeared similar to its current configuration.

2.3. Hydrogeologic Setting

The hydrostratigraphic units of interest (HSUs) at the Site are described below. The groundwater monitoring network is shown on **Figure 10** and the sub-slab soil vapor monitoring network is shown on **Figure 11**.

- **Shallow Fill**: The Shallow Fill represents the unsaturated soils (approximately 0 to 5 ft bgs based on the nominal depth to groundwater) and the uppermost saturated zone (approximately 5 to 10 ft bgs; inclusive of the zone of historical water table fluctuations) within the Fill. The Fill (inclusive of the Shallow and Deep Fill) ranges in thickness from approximately 1 to 36 ft with the thickest Fill underlying the current building footprint. The composition of the Fill exhibits local variability, but overall is comprised of two dominant soil types: (1) silt and clay; and (2) a sand/silt/clay mixture. While there are local areas of coarse-grained soils, the pore spaces are predominantly infilled with fine-grained soils. Accessory materials present in the Fill include bricks, glass, asphalt, concrete fragments, and angular gravel and rock fragments of varying composition. The Shallow Fill well network includes 10 monitoring wells and 1 extraction well that are screened at or across the water table.
- **Deep Fill**: The Deep Fill represents saturated soils within the Fill (at depths greater than 10 ft bgs). Due to the depression in the Young Bay Mud surface, the Deep Fill HSU is only present in areas where the Fill-Young Bay Mud contact is deeper than 10 ft bgs. In areas where the Fill extends to less than 10 ft bgs, the Deep Fill is absent, and the Shallow Fill is underlain directly by

the Young Bay Mud. The Deep Fill monitoring network includes six wells that are screened at the Fill/Young Bay Mud contact (and are fully saturated).

- **Upper Young Bay Mud**: The Upper Young Bay Mud underlies the Fill, is comprised almost entirely of silt/clay, and is fully saturated. The surface of the Young Bay Mud is deepest in the center of the Site below the former tank farm forming a trough feature that is oriented southwest to northeast. The Young Bay Mud (inclusive of the Upper and Lower Young Bay Mud) ranges in thickness from approximately 17 to 50 ft. The Upper Young Bay Mud represents the organic-rich, low density (less dense than water), and poorly compacted deposits within the upper 10 ft of the Young Bay Mud. One monitoring well is screened within the Upper Young Bay Mud.
- **Lower Young Bay Mud**: The Lower Young Bay Mud underlies the Upper Young Bay Mud, is similarly comprised almost entirely of silt/clay, and is fully saturated. The Lower Young Bay Mud represents soils that are lower in organic content, higher in density, and more compact compared to the overlying Upper Young Bay Mud soils. The Lower Young Bay Mud extends from approximately 10 ft below the Fill/Young Bay Mud contact to the Old Bay Mud surface. The Lower Young Bay Mud monitoring network includes three wells that are screened at the Lower Young Bay Mud/Old Bay Mud contact.
- **Old Bay Mud**: The Old Bay Mud underlies the Lower Young Bay Mud, is similarly comprised almost entirely of silt/clay, and is fully saturated. The Old Bay Mud exhibits higher bulk density, lower water content, lower organic carbon content, and lower effective porosity than the Young Bay Mud and is considered a lower confining unit underlying the Young Bay Mud. As discussed in the *Data Gaps Investigation Report* (EHS Support, 2018), the Old Bay Mud is present at depths ranging from 44 ft to 65 ft bgs. No wells are installed within the Old Bay Mud.

Groundwater beneath the Brisbane Property is encountered at approximately 5 ft bgs and generally flows to the east or northeast towards the Brisbane Lagoon. Calculated groundwater seepage velocities are on the order of 100 ft per year (ft/yr) in the Fill and 2 ft/yr in the Young Bay Mud. Groundwater is saline[3] and is not suitable for drinking water purposes, consistent with State Water Resources Control Board (SWRCB) Resolution No. 88-63. Pump testing indicated a sustained yield of 12.7 gallons per minute in the Fill at 90 days of pumping, but only if recharge is constant. Pump testing also indicated that, should long-term pumping be undertaken, local heterogeneity and boundary conditions in the Fill may lead to differential drawdown and dewatering and the Young Bay Mud is unlikely to respond to hydraulic stresses in the Fill.

2.4. Perceived Release Conceptualization

Based on the nature of historical operations and the distribution of NAPL and associated soil, groundwater, and soil vapor contamination, three distinct areas with different potential release mechanisms were identified at Parcel B (**Figure 12**):

- Former Chemical Tank Farm Area
- Former Railspur
- Former Catch Basin

Site investigations confirmed that sufficient NAPL mass was released within the Former Chemical Tank Farm Area to facilitate downward NAPL migration through the Fill and Young Bay Mud to the Old Bay

[3] Average electrical conductivity values are approximately 5,800 microsiemens per centimeter (µS/cm) for the Shallow Fill, 25,000 µS/cm for the Deep Fill, and 38,000 µS/cm for the Young Bay Mud.

Mud contact (at a depth of approximately 55 ft bgs), but insufficient mass was released to facilitate pooling at these contacts. While NAPL was historically mobile, through a combination of natural mass loss mechanisms and limiting geologic factors, the remaining NAPL mass is predominantly immobile, concentrated at the Fill and Young Bay Mud contact, and present as small droplets or groups of droplets in isolated pore spaces. Further, the investigations indicate that the areas of NAPL impacts are localized, and the extent of impacts is confined to Parcel B.

Historical releases along the Former Railspur and in the Former Catch Basin were likely attributable to point sources that were surficial. NAPL in these areas is limited predominantly to the Fill and, to a limited extent, the Upper Young Bay Mud. Consistent with the findings in the Former Chemical Tank Farm Area, NAPL is predominantly immobile in these areas.

Most of the constituent mass is present as NAPL with approximately 90 percent of NAPL mass within the Former Chemical Tank Farm Area. Vertically, most of the mass is present at the Fill/Young Bay Mud contact (at depths ranging from approximately 10 to 35 ft bgs) in the Former Chemical Tank Farm Area and the Fill in all other areas (at depths ranging from approximately 0 to 15 ft bgs).

Soil impacts are generally limited to the vicinity of NAPL impacts. Groundwater impacts attenuate rapidly downgradient of these areas. Natural degradation is contributing to constituent mass destruction at the Site.

Site investigations have indicated the following organic constituents for soil and groundwater in Parcel B that require remediation:

- Petroleum hydrocarbons
- Chlorinated volatile organic compounds (VOCs)
- 1,4-dioxane

Based on the Site characterization (EHS Support, 2018), development of Cleanup Levels (EHS Support, 2020), PDI activities (EHS Support, 2022a), and completion of interim measures excavation, the remaining extent of contamination subject to active remediation is shown on **Figure 13**.

3. Remedial Action Objectives and Cleanup Levels

A Conceptual Site Exposure Model was presented in the *Data Gaps Investigation Report* (EHS Support, 2018) and updated in the *Remedial Action Objectives and Cleanup Levels Proposal* ("Proposal"; EHS Support, 2020) to identify potential exposure pathways and receptors that may be exposed to constituents detected in environmental media. Constituents, environmental fate and transport mechanisms, Site hydrogeology, current and potential future land uses, and Site and vicinity populations were considered in the development of the RAOs and Cleanup Levels (EHS Support, 2020).

This section provides the narrative RAOs and numeric Cleanup Levels for soil, groundwater, and soil vapor developed in the RWQCB-approved Proposal. The Cleanup Levels approved as part of the RAOs and Cleanup Levels Proposal (EHS Support, 2020) for soil, groundwater, and soil vapor are included in **Table 1**, **Table 2**, and **Table 3**, respectively. Given the successful removal of contamination located south of the Parcel B warehouse via the interim measures excavation, the remaining extent of contamination subject to active remediation is shown on **Figure 13**.

3.1. Soil

RAO #1: Prevent further degradation of groundwater via leaching of constituents exceeding Non-Degradation Soil Cleanup Levels (**Table 1**) from on-site, vadose zone soil (0 to 5 ft bgs) into groundwater.

RAO #2: Prevent potential future exposure of on-site commercial/industrial workers and/or trespassers, general construction workers, trench workers, and excavation workers to constituents exceeding Human Health Soil Cleanup Levels (**Table 1**) in on-site vadose zone soil (0 to 5 ft bgs) and saturated soil (5 to 15 ft bgs).

3.2. Groundwater

RAO #3: Reduce on-site groundwater concentrations within the Fill and Young Bay Mud to below the Non-Degradation Groundwater Cleanup Levels (**Table 2**) to the extent technically and/or economically feasible.

RAO #4: Prevent potential future exposure of potential aquatic receptors in Brisbane Lagoon to constituents in off-site, downgradient groundwater exceeding Aquatic Receptor Health Groundwater Cleanup Levels (**Table 2**).

RAO #5: Prevent potential future exposure of on-site trench workers to constituents exceeding Human Health Groundwater Cleanup Levels (**Table 2**) in shallow groundwater (0 to 15 ft bgs).

3.3. Soil Vapor

RAO #6: Prevent potential future exposure of on-site, indoor commercial/industrial workers to constituents in soil vapor exceeding Human Health Soil Vapor Cleanup Levels (**Table 3**).

4. Identification of Remedial Alternatives

As described in the RWQCB-approved Proposal (EHS Support, 2020), general remedial actions (GRAs) considered for the Site include:

- Removal – Physical removal of soil, liquids, or vapors; treatment on- or off-site; and disposal.
- *In situ* Treatment – In-place treatment of contaminants through injection or emplacement of a variety of chemical amendments.
- Containment – Physical containment of contaminants on-site in a manner that is protective of human health and the environment.
- Natural degradation – In-place treatment of contaminants through existing biological, geochemical, and/or physical means.
- Controls – Application of a broad range of ECs and ICs that prevent unacceptable exposure to contaminants.

As discussed in **Section 1**, both Univar/VWR and the property owner are interested in selecting a final remedy that achieves RAOs, closes the Site under an industrial/commercial use scenario, and limits the need for long-term post-remediation monitoring. Given that the Parcel B warehouse is planned to be re-leased for commercial freight forwarding operations following the completion of planned remediation activities, remedial options are inherently limited to those that enable near-term Site use.

In addition to future Site use considerations, the following key technical challenges limit the GRAs that are potentially viable for the Site:

- **Geologic** – The geotechnical properties of the Young Bay Mud are poor and physical disturbance and/or dewatering of the Young Bay Mud could lead to settlement and destabilization of the existing building. As such, remedies that minimize the potential for settlement and/or impact to existing structures will be preferable over alternatives that do not.
- **Hydrogeologic and Hydrogeochemical** – The pumping yield within the Fill is low, and within the Young Bay Mud is essentially nil, inherently limiting the effectiveness of potential groundwater extraction and injection technologies. The heterogeneous nature of the Fill may also lead to differential dewatering. In addition, groundwater is saline in nature and thus impacts potential treatment and disposal options.
- **Nature and Extent** – The presence of low viscosity NAPL at depth (extending to 55 ft bgs), within saturated fine-grained soils, beneath the existing building footprint (greater than 85 percent of the final remedial extent is located beneath the existing warehouse building), and at low saturations below mobility thresholds presents challenges to achieving RAOs in the short-term and further limits potential removal- and injection-based options. The presence of metals in soil and groundwater (attributed to the Fill and Young Bay Mud and not historical operations) poses potential unacceptable risks that may not be mitigated by the same remedial technologies that would achieve RAOs for organic constituents.

Given these Site use considerations and technical challenges, two remedial alternatives have been identified as potentially suitable for the Site:

- **Risk-based remediation alternative** is suitable to achieve the goals of the RWQCB Brownfields Program and SWRCB Resolution Nos. 68-16, 88-63, and 92-49.
- **Removal-based remediation alternative** is intended to provide greater certainty with respect to attainment of RAOs and Cleanup Levels and limit the duration of remediation activities, while also achieving risk-based requirements.

These alternatives include a combination of potentially viable GRAs identified earlier in this section. These alternatives are summarized in **Table 4-1** and are described further in **Section 4.1** through **Section 4.3**, along with the evaluation of the baseline "no-action" remediation alternative.

Table 4-1 Remediation Alternatives

Risk-Based Remediation Alternative	Removal-Based Remediation Alternative
1. Soil vapor extraction and air sparging within the top 15 feet of the Fill (unsaturated and saturated) beneath the existing warehouse. 2. Excavation of residual impacts within the top 15 feet of Fill and Young Bay Mud along the eastern property boundary. 3. Establishment of a containment zone in accordance with SWRCB Resolution No. 92-49 for impacts within the Young Bay Mud underlying the warehouse. 4. Execution of a long-term groundwater monitoring program to evaluate natural degradation processes and assess remaining contaminant concentrations. 5. ECs in the form of maintenance of slab and other hardstand areas and a sub-slab depressurization system. 6. ICs in the form of an environmental restrictive covenant(s) and SMP.	1. TCH of final remedial extents beneath warehouse and along eastern property boundary. 2. Completion of short-term post-remediation soil, groundwater, and vapor monitoring. 3. ECs in the form of maintenance of slab and other hardstand areas and a sub-slab depressurization system, if needed, based on post-remediation monitoring data. 4. ICs in the form of an environmental restrictive covenant(s) and SMP.

EC = engineering control
IC = institutional control
SMP = soil management plan
SWRCB = State Water Resources Control Board
TCH = thermal conductive heating

RWQCB previously indicated that a soil management plan (SMP) and an environmental restrictive covenant are required as a condition of approving regulatory closure for the Property under an industrial/commercial use scenario or a low-threat closure scenario. As such, an SMP was submitted to, and approved by, RWQCB for the Property in July 2022 (EHS Support, 2022b) and an environmental restrictive covenant for the Site is in place and has been recorded against the Property. The restrictions identified in the covenant are summarized as follows:

- The Property shall not be used for housing, residences, hospitals, schools for persons under the age of 21, daycare facilities, or hospices.
- Groundwater underneath the Property shall not be used for municipal or domestic water supply purposes but may be used for any other purpose authorized by the RWQCB and consistent with the approved remedy.

The RWQCB has indicated that, in addition to these restrictions, a land use covenant must be recorded against the Property that obligates the property owner to comply with the SMP of record. The future final land use restrictions will likely take the form of one or more new environmental covenants, following a template approved by the RWQCB, that supersede the existing environmental restrictive covenants. Given these RWQCB requirements, ICs are incorporated in the three remediation alternatives and are not discussed separately in the following sections, which provide a description of each remedial alternative.

In addition, natural degradation has been demonstrated to be a significant contaminant mass destruction mechanism at the Site as documented in the *Prospect for Natural Degradation* (Appendix F of the PDI Report [EHS Support, 2022a]). Therefore, all remedies assume that natural degradation processes will continue and will potentially be enhanced by the remediation alternatives described in **Section 4.1** through **Section 4.3**.

4.1. Risk-Based Remediation Alternative

The risk-based remedial approach at the Site would comprise the following:

Air sparging and soil vapor extraction: Install an air sparging and soil vapor extraction (AS/SVE) system beneath the warehouse in the Shallow Fill/Deep Fill units to remove contaminant mass from the shallow groundwater and unsaturated zone to mitigate potential vapor intrusion (VI) risks and create a clean water lens to limit and/or prevent re-contamination of the vadose zone following system operation. Horizontal AS/SVE wells would be installed from the east side of the property using directional drilling techniques and extend beneath the warehouse. The remedy assumes monthly operation and maintenance (O&M) services on the AS/SVE system for an operating period of 3 years followed by post-treatment monitoring of groundwater (8 wells) and sub-slab vapor (23 probes) within the Fill zone annually for 3 years.

Excavation: As part of AS/SVE installation it is conceptualized that soils exceeding Cleanup Levels along the eastern side of the property (outside of the warehouse along the former railspur) would be excavated to a depth of 15 ft bgs. Areas would be backfilled with clean fill (following AS/SVE well installations) and surfaces would be restored to pre-excavation conditions. It is also assumed that the remediation compound would be built on the east side of the property to minimize disturbance to tenants.

Containment Zone: Establish a Containment Zone in accordance with SWRCB Resolution No. 92-49 for impacts within the Young Bay Mud underlying the warehouse given the technical challenges in remediation dense non-aqueous phase liquid (DNAPL) source zones within fine-grained soils at depth below the existing warehouse. Establishment of a Containment Zone would require demonstration of plume stability (i.e., confinement of impacts above Cleanup Levels within the designated Containment Zone), completion of an application to the RWQCB, review by the SWRCB (initial and periodic reviews and reimbursement of review costs), development of a groundwater monitoring program, and execution of a cleanup and abatement order. Following approval, no further active remediation within the Containment Zone would be required.

Long-term monitoring: Develop a groundwater monitoring program to evaluate natural contaminant mass losses in the Young Bay Mud (leveraging the conclusions provided in the *Prospect for Natural Degradation* [Appendix F of the PDI Report {EHS Support, 2022a}]), demonstrate Containment Zone compliance, and progress towards achieving groundwater Cleanup Levels within the Young Bay Mud. Assume monitoring will occur every 5 years for a period of 30 years at three existing Young Bay Mud wells and five new Young Bay Mud wells, which will serve as Containment Zone sentinel wells (eight total wells). The monitoring frequency is based on the low groundwater seepage velocity within the Young Bay Mud (approximately 2 feet per year) and the 30-year duration is consistent with the United States Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) requirements for post-closure care at hazardous waste facilities. The compliance monitoring program would also include a contingency plan to address changes in conditions that could affect Containment Zone compliance.

Engineering controls: Provisions for including ECs reflect likely treatment limitations for AS/SVE beneath the building given the approved Cleanup Levels. ECs, including maintenance of slabs and installation and operation of a sub-slab depressurization system (SSDS), are assumed to be components of the remedy.

4.2. Removal-Based Remediation Alternative

The removal-based remedial approach at the Site would comprise the following:

Thermal Conductive Heating (TCH): Implement TCH in the final remedial extents beneath the warehouse (21,000 cubic yards) and to the east of the warehouse (757 cubic yards). TCH is expected to take approximately 1.5 years (mobilization through demobilization and decommissioning).

Post-remediation monitoring: Post-remediation monitoring assumes short-term monitoring of soil, groundwater, and vapor following completion of the TCH. Details for each monitoring program are described below:

- Soil samples will be collected from a number of locations/depth intervals throughout the TCH treatment areas before system shut down. Requirements for continued system operation, should the soil samples remain above soil treatment standards, would be addressed via a performance monitoring program requiring continued operation until the treatment standards are met. No post-operation soil sampling is assumed. Soil concentrations that are below treatment standards but remain above applicable Cleanup Levels will be used to determine the areas of the warehouse that will require ECs such as maintenance of hardstand surfaces, if necessary.
- Post-remediation groundwater sampling: Post-remediation groundwater monitoring at six downgradient wells will compare groundwater concentrations to applicable Cleanup Levels downgradient of the treatment areas. Groundwater monitoring is assumed to be quarterly for one year (with a contingency plan for additional monitoring should Cleanup Levels not be achieved).
- Post-remediation sub-slab vapor sampling: Post-remediation sub-slab soil vapor monitoring at 21 locations will compare sub-slab soil vapor concentrations to applicable Cleanup Levels beneath the building. The results of the sub-slab soil vapor sampling will be used to determine the areas of the warehouse that will require a contingent SSDS (if any). Sub-slab soil vapor monitoring is assumed to be two events.
- Post-remediation indoor air sampling: To confirm that future workers will not be exposed to VOCs above Cleanup Levels or methane above explosion risk thresholds due to VI, two post-treatment indoor air sampling events are proposed to be collected from 14 locations within the warehouse.

Engineering controls: Similar to the risk-based remediation approach, provisions for including ECs reflect likely treatment limitations via TCH beneath the building given the approved Cleanup Levels. ECs, including maintenance of slabs and installation and operation of an SSDS, are contingent components of the remedy based on post-remediation monitoring data.

4.3. No Active Remediation Alternative

The no active remediation alternative will result in the attainment of Site RAOs and Cleanup Levels via long-term natural degradation of contaminants. This alternative assumes that the existing and required ICs will remain, but no additional ICs, ECs, monitoring, or active treatment would be implemented to reduce contaminant concentrations or ensure that there are no unacceptable risks to human health or the environment in the future.

5. Remedial Alternatives Screening

Screening of remedial alternatives is performed consistent with applicable provisions of SWRCB Resolution No. 92-49 and CEQA. Screening criteria for remedial technology alternatives comprise:

- **Effectiveness** – Evaluates the expected short-term and long-term performance of a potential remedy during and after implementation to achieve RAOs and Cleanup Levels. Short-term effectiveness includes an evaluation of the potential short-term adverse environmental impacts and human exposures during the construction and/or implementation of a potential remedy. These impacts include potential changes to geochemical conditions, nuisance conditions or potential exposures resulting in increased solubility of chemical constituents, increased production of volatile byproducts, increased traffic, detours, loss of use of or access to a property, odors, vapors, dust, habitat disturbance, run-off, and noise. Long-term effectiveness evaluates the impact of remaining contamination (if present) on receptors and the environment after implementation.
- **Implementability** – Evaluates the technical and administrative feasibility of a potential remedy. Technical feasibility includes challenges associated with construction and execution of a potential remedy and the ability to monitor remedy effectiveness. Administrative feasibility includes the availability of the necessary personnel and material, and the potential difficulties in obtaining specific operating approval and/or access for construction.
- **Relative cost** – Evaluates the benefit of attaining further reductions in constituent concentrations compared with the cost of achieving those reductions for a potential remedy. Evaluates current and future use and socioeconomic impacts to the surrounding community.
- **Net environmental impact** – Evaluates the likely environmental impacts associated with construction, execution, and operation of a potential remedy.

Details of the evaluation process are provided in **Table 4** and summarized below for the following candidate remedial alternatives:

- Alternative 1 – Risk-based remediation
- Alternative 2 – Removal-based remediation
- Alternative 3 – No active remediation

Based on the evaluation provided in **Table 4**, Alternative 2 was determined to be the best remedial approach. As described in **Section 1.2**, the goals of this project are to implement a remedy that is protective of public health and the environment and enables continued industrial/commercial land use.

Alternative 2 (removal-based remediation) has been identified for the following reasons:

- Tenant vacancy provides a near-term window of opportunity to gain access to the Site for remediation and will minimize disruption to Site operations. Alternative 2 remediation timeframes are generally short (on the order of one to two years) and require fewer long-term operations, maintenance, and monitoring than Alternative 1 and Alternative 3.
- Alternative 2 is most capable of reducing contaminant mass in the Young Bay Mud given the Site hydrogeology and the presence of contamination in the low permeability Young Bay Mud (extending to 55 ft bgs) beneath the warehouse. Alternative 1 and Alternative 3 leave significant contamination in place.
- Alternative 2 is most capable of reducing contaminant mass in all phases given that the dissolved-phase and vapor-phase concentrations decrease significantly with distance from NAPL and soil source areas (i.e., there is not a long plume emanating from the source areas).

- Alternative 2 enables verification of remedy effectiveness through a short-term, post-remediation monitoring program. Conversely, Alternative 1 would require long-term monitoring and access to the Site and Alternative 3 provides no path to removing contamination or achieving regulatory closure.
- Alternative 2 is reasonably expected to achieve the RWQCB-approved RAOs and Cleanup Levels assuming that the implementability and effectiveness challenges associated with operating the remedy within the existing building can be overcome. Alternative 1 may be able to achieve RWQCB-approved RAOs and Cleanup Levels, but there are some significant concerns around the implementability of Alternative 1 given the thickness of the vadose zone and challenges in installing the horizontal well network. Alternative 3 provides no path to removing contamination or achieving regulatory closure.
- Alternative 1 and Alternative 2 align with the Brownfields program goals by enabling continued Site use as an industrial/commercial property following remediation. However, Alternative 2 is preferred over Alternative 1 given that the timeframe for remediation and monitoring are shorter for Alternative 2.
- Alternative 2 aligns with the Property owner and stakeholder goals of remediating the Site for near-term Site use as a commercial property. Alternative 1 would reduce the ability to use the Site for a longer period and Alternative 3 provides no path for confidently eliminating potential risks and enabling long-term Site use.
- All the alternatives address the presence of metals within Site soils (that are not associated with historical operations) through ICs.
- Alternative 2 is the most expensive remedial option, but the benefit-to-cost ratio is perceived to be greater than for Alternative 1 and Alternative 3 given the high level of confidence afforded by Alternative 2 of achieving contaminant mass removal within the shortest timeframe.
- Alternative 1 and Alternative 2 carry some environmental impacts associated with the construction and operation of their remedy components, but their impacts are outweighed by the net benefit in removing contamination and providing for future beneficial uses of groundwater. Alternative 2 is preferred over Alternative 1 because of the shorter timeframe to restore beneficial uses of groundwater. Alternative 3 has no impacts on the environment via construction or operation impacts but it does not provide a means of reducing the contamination, and therefore, does not provide a net benefit to the environment.

6. Proposed Remedy

This section describes the proposed removal-based remedy, Alternative 2, and evaluates the ability of the proposed remedy to satisfy the RAOs.

6.1. Proposed Remedial Alternative

Informed by **Section 4** and **Section 5**, stakeholders decided that Alternative 2 is the best remedy to achieve the project goals (**Section 1.2**). TCH is a proven source removal technology for remediating NAPL and sorbed-phase contamination at depth and within fine-grained soils. TCH aligns with the stakeholders' goal to remediate the Site to enable near-term commercial use.

The key challenges associated with Alternative 2 are (1) effective design of the TCH system within the confines of the existing warehouse, and (2) ensuring that the remedy does not cause irreparable damage to the warehouse building. Given these challenges, Univar/VWR and the Property owner have collaborated with structural and geotechnical engineering firms to identify the potential risks associated with thermal remediation and develop a risk management program to eliminate or reduce potential risks to an acceptable level. The culmination of these efforts is documented in WJE's *Limited Geotechnical and Structural Study to Support Remedial Decision Making* (WJE, 2022; **Appendix A**).

Given the goal to complete remediation at the Site and enable near-term commercial use, TerraTherm, Inc. was contracted to develop a *Remedial Action Work Plan* (RAWP; TerraTherm, 2022; **Appendix B**). The RAWP provides the design basis for constructing, operating, and monitoring the TCH remedy. Where applicable, recommendations provided in WJE's structural study report (**Appendix A**) have been incorporated into the RAWP including safe setback distances between heaters and structural building elements and utilities. In addition, WJE recommends a range of data collection and monitoring activities before, during, and after remediation to assess the building condition and make any repairs that may be required following completion of the remediation. These recommendations have been incorporated into the performance monitoring program described in **Section 7**. The TCH remedy component of Alternative 2 is summarized below and described in detail in the RAWP (**Appendix B**).

The total areal treatment extent for TCH is approximately 23,500 square feet (0.54 acres). Greater than 85 percent of the total treatment area is located beneath the existing warehouse building (**Figure 14**). Vertical extraction wells (co-located in boreholes with heater wells) will be used to remove the vaporized contaminants and steam. Most of the equipment (e.g., heater cans and conveyance piping) will be located inside the existing warehouse building with a few heater cans located outside, east of the warehouse building. The TCH remedy's thermal oxidizer will be located in the southern parking lot. The thermal oxidizer consists of a discharge stack that will be 2 feet in diameter and 45 feet above ground surface.

Thermal Conductive Heating Approach:

- TCH is proposed to remove organic contamination from the subsurface at the Site from depths ranging from 0 to 55 ft bgs via thermal desorption and vaporization of contaminants by heating the subsurface to approximately 100 degrees Celsius (°C). Most of the contaminant mass is located beneath the water table at the Fill/Young Bay Mud contact.
- The TCH design indicates a heater spacing of approximately 15 feet to heat groundwater within the treatment areas to its boiling point.

- Vertical extraction wells (co-located in boreholes with heater wells) will be used to remove the vaporized contaminants and steam, and to maintain pneumatic and hydraulic control.

Vapor and Liquid Treatment Approach:

- Extracted vapor will be treated using a thermal oxidizer permitted through the Bay Area Air Quality Management District (BAAQMD). In the event of a potential outage of the thermal oxidizer, a backup vapor treatment system will be constructed before startup. The backup vapor treatment system includes a process vacuum blower, three vapor-phase granular activated carbon (VGAC) vessels in series followed by one potassium permanganate vessel.
- Liquid condensate is separated from vapor in moisture separators and pumped through an oil-water separator, bag filters, and two liquid-phase granular activated carbon vessels in series.

Monitoring:

- The temperature will be monitored throughout the TCH operation to track subsurface heating.
- Vapor and liquid treatment systems will be monitored for mass removal and discharge compliance.

Treatment will occur under the air and water discharge permit provisions. Treated effluent will be discharged to the publicly owned treatment works in accordance with applicable San Francisco Public Utilities Commission permit requirements. EHS Support will continue to work closely with the BAAQMD to ensure effluent vapors from the thermal oxidizer are below applicable quality standards. The Air Permit (application number 31446) for the Site was approved by the BAAQMD on August 10, 2022 pursuant to the Bay Area 2017 Clean Air Plan, which is the applicable plan for San Mateo County. Grading and drilling permits will be obtained, as required, by the City of Brisbane and San Mateo County, respectively.

The TCH remedy is anticipated to take approximately 1.5 years (mobilization through demobilization and decommissioing). Pending the requisite approvals and issuance of permits, mobilization for drilling and well installation is anticipated to begin in November 2022. The following are the key components of the proposed remedy:

- Work Plan and Permitting
- Premobilization / Procurement
- Mobilization and Setup
- Drilling, Well Installation, and Abandonment of Existing Wells and Probes
- Cover Installation
- Well Field Piping
- Electrical Installation
- Treatment System Installation
- Install Monitoring and Instrumentation
- Pre-Startup and Shakedown
- Operation
- Decommissioning
- Remove Heaters/Wells/Cover
- Site Clearance and Demobilization
- Final Report

Monitoring required before, during, and after remediation will be conducted in accordance with the performance monitoring program (**Section 7**). It is unreasonable to expect TCH, a contaminant source removal remedy, alone to immediately achieve all Cleanup Levels for soil, groundwater, and soil vapor (**Table 1**, **Table 2**, and **Table 3**, respectively). Technical limitations of TCH performance include occurrence of contaminants with a wide range of boiling points and the limitations imposed on the heating temperatures and heater spacing to ensure that there are no irreparable impacts to the building structure as a result of heating. In addition, there are practical limitations associated with turning the TCH system back on if Cleanup Levels are not achieved (i.e., the system cannot be re-heated following cool-down without significant additional heating time). Further there are safety challenges in collecting representative soil vapor and groundwater samples from hot media; therefore, confirmation samples collected before system cessation are limited to soil samples (i.e., groundwater and soil vapor sampling are not recommended while the TCH remedy is operating).

Given these challenges, EHS Support has worked closely with TerraTherm to develop a set of soil treatment standards that serve as target endpoints for completion of active TCH operations. EC and IC remedy components intend to protect against potential risks associated with any contamination remaining above their applicable Cleanup Levels based on post-remediation monitoring data.

The following are the key steps used to develop target endpoints for active TCH in the form of soil treatment standards as calculated equivalent soil concentrations for each constituent:

1. Convert Human Health Groundwater Cleanup Levels into equivalent soil concentrations using soil-water equilibrium principles and the soil-water partitioning equation (**Table 5**).
2. Use RWQCB Soil Saturation Limits as a surrogate for Non-Degradation Groundwater Cleanup Levels on the basis that both values are representative of concentrations at which NAPL is likely to be present (**Table 6**).
3. Evaluate soil Cleanup Levels and equivalent soil concentrations (for groundwater Cleanup Levels) considering treatment technology limitations (**Table 6**).
4. Develop appropriate soil treatment standards (**Table 7**).

As shown in **Table 5**, equivalent soil concentrations were developed using Site data and literature values. Equivalent soil concentrations were developed for the Fill and Young Bay Mud and the more stringent of the two values was carried into **Table 6**. As shown in **Table 6**, TCH will achieve most of the Site's constituent Cleanup Levels when TCH is operated to completion, as measured by achieving their respective soil treatment standards. However, given the stringent Non-degradation Soil Cleanup Levels (based on potential leaching from the vadose zone to groundwater) and Human Health Cleanup Levels, Alternative 2 includes both ICs and ECs to address potential risks associated with concentrations remaining above Cleanup Levels given that TCH is a source removal technology and is not an efficient polishing technology. The scope and extent of ECs, if needed, will be evaluated based on the post-treatment monitoring data. Execution of the ICs is currently underway.

In addition to treatment limitations based on stringent Cleanup Levels for some constituent compounds, it is noted that no treatment standards are developed for 1,4-dioxane and 2,4-dimethlyphenol. No soil treatment standards have been developed for these constituents because concentrations for these constituents are already below applicable Cleanup Levels in most treatment areas and their physiochemical properties pose challenges to TCH remediation given the limitations associated with the heating temperature and the desire to limit pore water reductions and associated potential settlement. Therefore, further reductions of these constituents are not critical to the success of the remedy given that potential future risks can be mitigated through ICs and ECs as planned. The resulting TCH soil treatment standards for all constituents are summarized in **Table 7** and are incorporated in the performance monitoring program (**Section 7**) and the RAWP (**Appendix B**).

6.2. Comparison to RAOs

This section provides an evaluation of the proposed remedy, Alternative 2, and its ability to achieve the RAOs for the Site. For reference, Alternative 2 includes the following key components:

1. TCH of final remedial extents beneath warehouse and along eastern property boundary
2. Completion of short-term post-remediation soil, groundwater, and vapor monitoring
3. ECs in the form of maintenance of slab and other hardstand areas and a sub-slab depressurization system, as needed, based on post-remediation monitoring data
4. ICs in the form of an environmental restrictive covenant and SMP

In addition, natural degradation processes are expected to be enhanced in areas proximal to the heating as discussed in the *Prospect for Natural Degradation* (Appendix F of the PDI Report [EHS Support, 2022a]); therefore, it serves as a complementary mass reduction polishing mechanism for TCH.

The logic explaining how the various remedy components that comprise Alternative 2 will collectively achieve the RAOs is discussed in **Section 6.2.1** through **Section 6.2.3** and summarized in **Table 6-1**.

Table 6-1 Achievement of RAOs via Implementation of Alternative 2

Depth Interval (ft bgs) or Location	Media	Cleanup Level Type		
		Non-Degradation	Human Health	Aquatic Receptor Health
0 to 5	Soil	TCH and ECs	TCH and ICs	--
	Soil Vapor	--	TCH and ECs	--
5 to 15	Soil	--	TCH and ICs	--
	Groundwater	TCH and ICs	TCH and ICs	--
15 to 55	Soil	--	--	--
	Groundwater	TCH and ICs	--	--
Eastern Property Line	Groundwater			TCH and Natural Degradation

-- = Not applicable
ECs = engineering controls
ft bgs = feet below ground surface
ICs = institutional controls
RAO = remedial action objective
TCH = thermal conductive heating

6.2.1. Soil

RAO #1: Prevent further degradation of groundwater via leaching of constituents exceeding Non-Degradation Soil Cleanup Levels from on-site, vadose zone soil (0 to 5 ft bgs) into groundwater.

Alternative 2 will achieve RAO #1 through TCH and ECs such as maintenance of hardstand surfaces. Areas subject to ECs will be based on the comparison of confirmation soil samples (collected before cessation of the TCH system) to Non-Degradation Soil Cleanup Levels. Areas exceeding Cleanup Levels will be subject to ECs.

RAO #2: Prevent potential future exposure of on-site commercial/industrial workers and/or trespassers, general construction workers, trench workers, and excavation workers to constituents exceeding Human Health Soil Cleanup Levels in on-site vadose zone soil (0 to 5 ft bgs) and saturated soil (5 to 15 ft bgs).

Alternative 2 will achieve RAO #2 through TCH and ICs. Achievement will be demonstrated via the comparison of confirmation soil samples (collected before cessation of the TCH system) to Human Health Soil Cleanup Levels. Areas exceeding Cleanup Levels will be subject to ICs.

6.2.2. Groundwater

RAO #3: Reduce on-site groundwater concentrations within the Fill and Young Bay Mud to below the Non-Degradation Groundwater Cleanup Levels to the extent technically and/or economically feasible.

Alternative 2 will achieve RAO #3 through TCH and ICs. Achievement will be demonstrated via comparison of confirmation soil samples (collected before cessation of the TCH system) to soil concentrations that are equivalent to Non-Degradation Groundwater Cleanup Levels using RWQCB soil saturation limit values. Areas exceeding Cleanup Levels will be subject to ICs.

RAO #4: Prevent potential future exposure of potential aquatic receptors in Brisbane Lagoon to constituents in off-site, downgradient groundwater exceeding Aquatic Receptor Health Groundwater Cleanup Levels.

Alternative 2 will achieve RAO #4 through TCH and complementary natural degradation processes. Achievement will be demonstrated via the comparison of confirmation groundwater samples at downgradient monitoring wells (collected following cessation of the TCH system) to Aquatic Receptor Heath Groundwater Cleanup levels.

RAO #5: Prevent potential future exposure of on-site trench workers to constituents exceeding Human Health Groundwater Cleanup Levels in shallow groundwater (0 to 15 ft bgs).

Alternative 2 will achieve RAO #5 through TCH and ICs such as an environmental restrictive covenant and SMP. Areas subject to ICs will be based on a comparison of confirmation soil samples (collected before cessation of the TCH system) to calculated soil concentrations that are equivalent to Groundwater Human Health Cleanup Levels using the equilibrium partitioning equation.

6.2.3. Soil Vapor

RAO #6: Prevent potential future exposure of on-site, indoor commercial/industrial workers to constituents in soil vapor exceeding Human Health Soil Vapor Cleanup Levels.

Alternative 2 will achieve RAO #6 through TCH and ECs such as an SSDS. Areas subject to ECs will be based on the comparison of confirmation sub-slab soil vapor samples (collected following cessation of the TCH system) to Human Health Soil Vapor Cleanup Levels.

7. Performance Monitoring Program

The performance monitoring program for the Site comprises monitoring during three key periods associated with final remedy implementation:

- Baseline monitoring (before remediation)
- Operational monitoring (during remediation)
- Remedy verification monitoring (near the completion of, or after, remediation)

The monitoring requirements during each of these periods are discussed in **Section 7.1** through **Section 7.3** and include the following general types of monitoring activities:

- Environmental monitoring
- Building condition monitoring
- System operations monitoring

7.1. Baseline Monitoring

Baseline monitoring includes environmental monitoring and building condition monitoring and is intended to provide a pre-remediation dataset that is adequate to compare future data against to evaluate changes that are a result of remedy implementation.

7.1.1. Environmental Monitoring

Environmental baseline monitoring was largely completed in July and August 2021 as part of the PDI activities (EHS Support, 2022a) and included soil, sub-slab vapor, and groundwater sampling. Soil sampling was completed to determine the extent of the contaminated areas subject to active remediation (**Figure 13**). Groundwater and soil vapor sampling were completed from the existing well and vapor probe networks (**Figure 10** and **Figure 11**, respectively) to verify the current Site conditions and contaminant concentrations.

Additional soil vapor baseline monitoring will be completed before initiation of Site remediation to assess the soil vapor conditions between the Parcel A and Parcel B warehouses given that TCH conducted beneath the Parcel B warehouse has the potential to affect soil vapor conditions beneath the adjacent Parcel A warehouse. According to the Department of Toxic Substances Control's (DTSC) *Supplemental Guidance: Screening and Evaluating Vapor Intrusion* (DTSC, 2020), soil gas samples should be collected between the building (Parcel A warehouse) and the release area (Parcel B warehouse) as close to the building (Parcel A) as possible, preferably within 10 lateral feet of the building (Parcel A). EHS Support proposes to install three soil vapor probes between the existing Parcel B warehouse and existing Parcel A warehouse (**Figure 15**). The field investigation procedures will follow protocols established by *Advisory – Active Soil Gas Investigations* ("DTSC guidance") (DTSC, 2015).

A drilling permit is not required from SMCEHSD as the soil borings will not reach groundwater or extend to 10 feet bgs. Drilling will be completed via hand auger methods to a depth of approximately 3 ft bgs to place the probe screen above the seasonal and tidal high-water table. Soil cuttings will be logged by a field geologist using the Unified Soil Classification System (USCS). Recovered soil samples will be screened in the field for VOCs using a hand-held photoionization detector (PID). The PID response will be obtained by placing the soil sample in a sealable plastic bag (i.e., zip lock) and allowing vapors to equilibrate for approximately 15 minutes. The soil headspace will be measured by inserting the tip of the PID into the plastic bag. Soil descriptions and PID results will be recorded and included in a field book or on soil boring log forms.

Soil vapor probe construction will be consistent with DTSC guidance and will consist of a stainless-steel implant filter, ¼-inch outer diameter Nylaflow tubing, and a valve at the termination. The probe will be set within 12 inches of sand pack, with a minimum of 6 inches of dry bentonite immediately above the sand pack, followed by hydrated bentonite grout. The soil vapor probe locations will be completed with a flush-mounted traffic-rated well cover.

Baseline soil vapor samples will be collected a minimum of 48 hours following installation to allow the probes to come into equilibrium with the Site vapor conditions. Samples will be collected per DTSC guidance using 1-liter or 6-liter SUMMA canisters for laboratory analysis. Vapor samples will be collected and analyzed for methane and Site-related constituents (**Table 3**) using USEPA Methods TO-15, TO-3, and TO-17.

7.1.2. Building Condition Monitoring

Given the challenge of operating the TCH system within the existing warehouse, WJE's *Limited Geotechnical and Structural Study to Support Remedial Decision Making* (WJE, 2022; **Appendix A**) provides a risk assessment matrix (Appendix V of the WJE report) that outlines the recommended management steps that should be taken before remediation to reduce risks and mitigate effects of TCH on the building structure. Where applicable, these mitigation measures have already been incorporated into the remedial design (RAWP; **Appendix B**). Pre-remediation monitoring and assessment activities identified in the risk assessment matrix include:

1. Relative elevation survey and condition assessment of the existing slab.
2. Visual condition assessment of precast walls and connections near the treatment area.
3. Concrete testing on small diameter cores at perimeter piles for concrete composition and susceptibility to thermal damage.
4. Extraction of existing concrete samples and laboratory analysis for concrete composition, susceptibility to thermal damage, and mechanical properties to establish pre-treatment properties.
5. Review of as-built utility plans from relevant agencies and confirmation of utilities by private utility locator subcontractor.

Univar/VWR will work collaboratively with WJE, TerraTherm, and the property owner to complete these monitoring and assessment activities. Items 1 through 4 will be described in detail in a future implementation plan developed by WJE and item 5 has already been incorporated into the RAWP (TerraTherm, 2022; **Appendix B**).

7.2. Operational Monitoring

Operational monitoring includes environmental monitoring, building condition monitoring, and system operations monitoring. Operational monitoring is conducted to ensure that the remedy is operating as intended and is not contributing to unacceptable risks to human health or the structure of the Parcel B building.

7.2.1. Environmental Monitoring

Environmental monitoring is intended to assess the potential for soil vapor to migrate beyond the subsurface vapor collection infrastructure of the TCH treatment area towards the Parcel A warehouse. Soil vapor monitoring will be completed at the three soil vapor probes proposed to be installed between the existing Parcel A warehouse and existing Parcel B warehouse (**Figure 15**). Samples will be collected quarterly (starting one month after system operation begins) throughout the duration of the TCH system operation. Samples will be collected via the same methods and for the same set of analytes as described in **Section 7.1.1**.

As an early indicator of potential VI issues at Parcel A arising as a result of the Parcel B TCH remediation, soil vapor concentrations for Site-related constituents will be compared to 10 times the RWQCB Commercial Environmental Screening Levels (ESLs) for soil vapor, and methane concentrations will be compared to a screening value of 1.25 percent by volume (%v). Should concentrations exceed these screening levels, a plan will be developed to conduct a VI assessment through indoor air, ambient air, and sub-slab sampling at Parcel A as appropriate under the latest VI DTSC guidance.

7.2.2. Building Condition Monitoring

Based on the pre-remediation building condition assessment and monitoring activities outlined in **Section 7.1.2**, and consistent with the recommendations provided in the risk matrix (Appendix V of WJE's *Limited Geotechnical and Structural Study to Support Remedial Decision Making* [WJE, 2022; **Appendix A**]), the following conditions will be monitored and assessed during remediation:

1. Changes in levelness of slab
2. Expansion of slab
3. Temperatures near heater borings, multiple representative piles, and at various depths throughout the treatment area (including in-slab)

Univar/VWR will work collaboratively with WJE, TerraTherm, and the property owner to complete these monitoring and assessment activities. Items 1 and 2 will be detailed in a future implementation plan developed by WJE. Note that item 3 has already been incorporated into the RAWP (TerraTherm, 2022; **Appendix B**).

7.2.3. System Operations Monitoring

System operations monitoring includes tasks that will be performed by TerraTherm personnel during the startup and full operational phases of treatment. System monitoring requirements are summarized in this section and discussed in further detail in the RAWP (**Appendix B**; TerraTherm, 2022). Operational monitoring procedures will be further described in a future O&M Plan developed by TerraTherm.

Given the methane concentrations observed during the PDI activities in groundwater and soil vapor (EHS Support, 2022a), TerraTherm will initiate wellfield extraction during startup in a controlled manner by introducing dilution air to reduce methane concentrations, as required. The following additional monitoring procedures will be implemented during startup at the Site:

- Real-time lower explosive limit (LEL) monitoring will be performed via a permanent meter located upstream of the thermal oxidizer. During startup, Site operators will check the LEL meter

for spikes in concentration as extraction is initiated in different sections of the wellfield. The LEL meter will be equipped with warnings/alarms when safety limits are reached.
- Manual LEL monitoring via a hand-held landfill gas/multi-gas meter (e.g., LANDTEC GEM5000 or equivalent unit set to monitor methane) will be performed to screen the thermal oxidizer vapor influent samples for methane. The unit may be used for wellfield vapor sampling as needed to pinpoint areas of the wellfield where methane buildup is suspected.
- Vapor sampling of methane will be conducted during the first two sampling events to confirm meter readings.

After the first two weeks of operations, and based on observed methane concentrations and project team consensus, methane sampling will end. LEL monitoring will continue during operations with the real-time LEL meter.

Operational monitoring will be completed to track remediation progress and compare it to predicted performance so that appropriate operational adjustments can be made. Remote monitoring will be conducted using a programmable logic controller that will monitor and record selected system operating data including relevant temperatures, pressures, and flows through the aboveground treatment equipment, as well as the position of safety sensors and controls. Wellfield temperature data from the field thermocouples will be collected and logged by a separate temperature data collection system.

Manual monitoring of Site-related constituents in the vapor phase will be performed regularly, typically 3 to 5 times a week, using a hand-held PID at the influent to the treatment system (inlet to the thermal oxidizer), intermediate locations in between VGAC vessels, and discharge location (effluent stack). Grab vapor, condensate, and NAPL samples will also be collected periodically for laboratory analysis. Operational data will be used to provide estimates for the following:
- Mass removed in the vapor state measured at the inlet to the vapor treatment system
- Mass removed in dissolved state (i.e., condensate)
- Mass removed as NAPL as measured in the light non-aqueous phase liquid (LNAPL)/DNAPL storage tanks
- Destruction removal efficiency of the vapor treatment system (determined by comparing influent and effluent samples)
- Liquid and vapor discharge compliance with applicable permit and local municipalities' monitoring requirements

Manually collected data will also include:
- Power usage = reading of totalizing meters.
- Liquid flows = reading of totalizing flow meters inserted in the treatment system transfer lines.
- Temperature and pressure readings = gauge readings for the treatment system.
- Wellfield pressure readings = gauges placed in the wellfield.

Energy balance will be periodically calculated for the Site at a network of temperature monitoring probes (TMPs) to verify that the thermocouples are providing accurate representation of conditions throughout the treatment area and to assess the progress of heating. The thermocouple data will be evaluated to provide detailed information on the heat-up of the subsurface. These data will be used to determine the amount of energy stored in the subsurface and to adjust heater temperatures, if necessary. At a minimum, the following data representations are used:
- Individual borehole vertical temperature profiles using multi-depth TMPs

- Plots of temperature versus time for all TMPs
- Average lateral temperature profiles at various depth zones across the treatment area

As described in the RAWP (**Appendix B**; TerraTherm, 2022), performance standards have been set to ensure that the system will operate as intended for the modeled treatment timeframe and will ultimately result in achieving soil treatment standards (**Table 7**) before system cessation. The performance standards are summarized as follows and described in further detail in **Appendix B**:

- Heater Operation – The heaters shall have a minimum of 95 percent operational efficiency (aka "up time").
- Extraction and Treatment System Operation – The extraction and treatment system shall maintain greater than 95 percent uptime for the duration of thermal treatment.
- Treatment Temperature Attainment – Nominal temperatures of 100°C are achieved and maintained within all of the treatment areas and depth zones for the duration of boiling and drying.
- Soil Treatment Standards Attainment – Soil treatment standards (**Table 7**) are achieved and approved by the RWQCB.

While soil treatment standards attainment is part of the performance standards for the successful operation of the TCH remedy, the soil sampling approach is described in **Section 7.3**, given that the soil sampling data serves as the final verification step in assuring that the TCH remedy is complete and system operations can cease (following RWQCB concurrence with soil treatment standard attainment).

7.3. Remedy Verification Monitoring

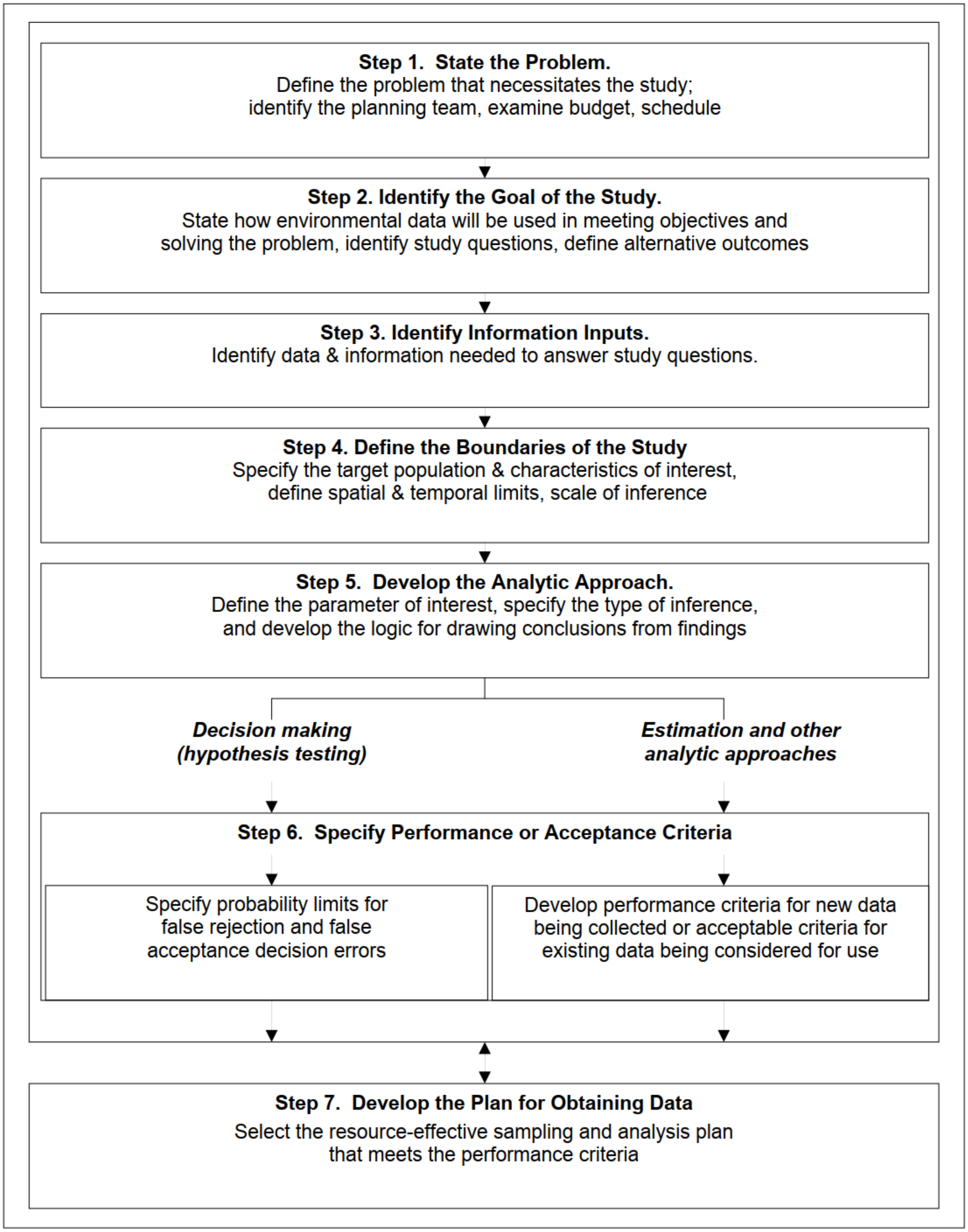
Remedy verification monitoring includes environmental monitoring and building condition monitoring. Environmental monitoring is intended to verify that TCH is an effective source removal remedy, determine the scope and extent of ECs (if required), and ensure that RAOs will be achieved. Building condition monitoring is intended to assess post-remediation warehouse conditions and identify the scope and extent of building repairs (if required).

7.3.1. Environmental Monitoring

7.3.1.1. Soil

As discussed in **Section 7.2.3**, after the heater operation, extraction and treatment system, and temperature performance standards are achieved, soil samples will be collected from the treatment area before system decommissioning to verify that the TCH remedy is complete and system operations can cease (following RWQCB concurrence with soil treatment standard attainment).

The remedy verification soil sampling approach was developed using the *Guidance on Systematic Planning Using the Data Quality Objective Process* (USEPA, 2006). The general data quality objective (DQO) process (Figure 2 from USEPA, 2006) is depicted in **Figure 7-1**. A summary of the DQO process as it applies to the Site is provided following the figure.



Source: Figure 2, USEPA, 2006

Figure 7-1 Data Quality Objective Process

Step 1 – State the Problem: Determine if the TCH remedy is complete and system operations can cease.

Step 2 – Identify the Goal of the Study: Determine if soil concentrations within a given treatment area meet the soil treatment standards. Depending on soil concentrations, options include continued system operation or system cessation.

Step 3 – Identify Information Inputs: Soil samples will be collected from within the final remediation extent and analyzed for Site-related constituents (**Table 1**).

Step 4 – Define the Boundaries of the Study: The target population consists of all remedy verification soil samples collected after heater operation, extraction and treatment system, and temperature performance standards are achieved within the spatial boundaries of the final remediation extent for the 0 to 5 ft bgs, 5 to 15 ft bgs, and 15 to 55 ft bgs depth intervals (**Figure 13**). "Decision units" correspond to the vertical treatment intervals depicted on **Figure 7-2**:

- 0 to 5 ft bgs (orange)
- 5 to 15 ft bgs (blue)
- 15 to 55 ft bgs (magenta)

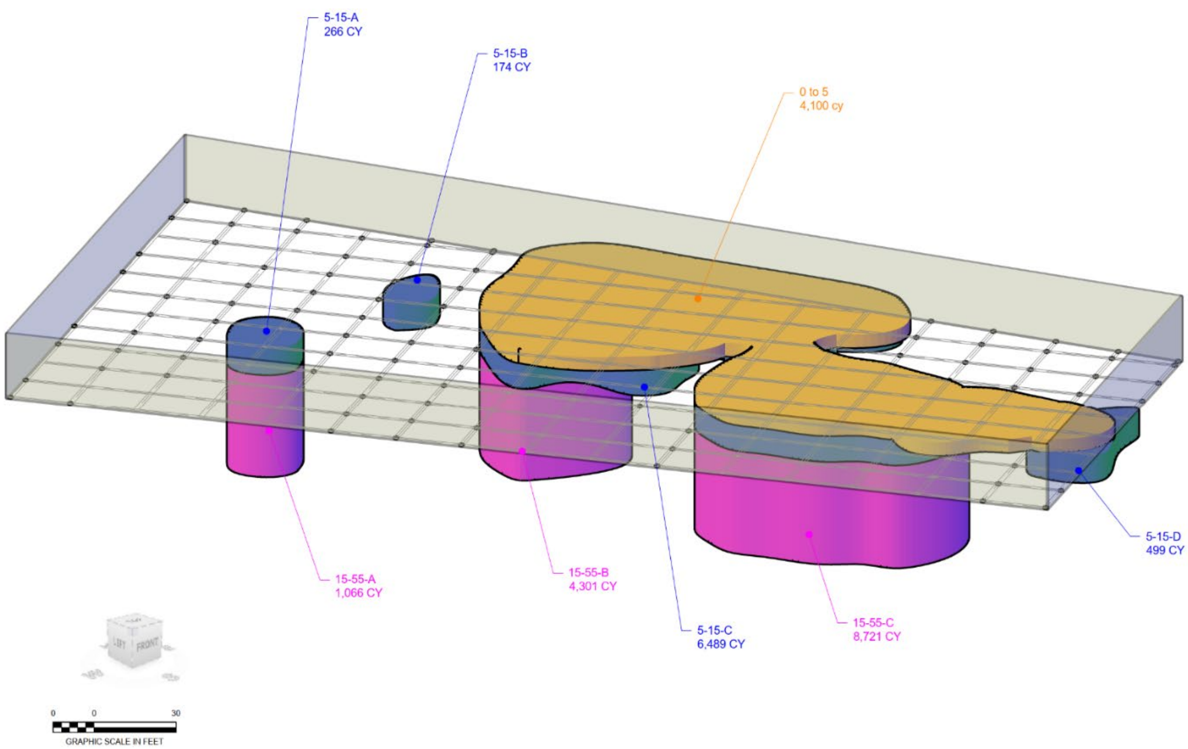


Figure 7-2 Remedy Verification Soil Sampling Decision Units

Step 5 – Develop the Analytic Approach: Soil samples will be analyzed by the following analytical methods:

- VOCs by Method 8260B
- Total petroleum hydrocarbons (TPH) by Method 8015B
- 1,4-Dioxane by Method 8260 Selected Ion Monitoring (SIM)

The mean soil concentration for each constituent will be calculated using all soil samples collected within each decision unit. The resulting mean soil concentrations for each constituent and decision unit will be evaluated using the following decision rule: If the mean concentration for all constituents within each decision unit is less than the soil treatment standard for all constituents, and no individual constituent concentration exceeds the soil saturation limit (**Table 7**), then TCH for that decision unit can cease following RWQCB concurrence, else TCH will continue in that decision unit.

Step 6 – Specify Performance or Acceptance Criteria: Soil within the decision units prior to TCH are assumed to be contaminated above the soil treatment standards established for the Site. Therefore, the baseline condition is, “the soil exceeds the soil treatment standards” and the alternative condition is “the soil meets or is lower than the soil treatment standards.” The consequence of making a false acceptance decision error is the expense of continuing TCH for soils, that in fact, meet the soil treatment standards. The consequence of making a false rejection decision error is that TCH will be stopped before meeting the soil treatment standards for a decision unit. The false acceptance decision error is mitigated through the collection of data during previous investigation efforts that culminated in the delineation of the areas subject to active remediation. The false rejection hypothesis is mitigated through the achievement of the other performance standards (**Section 7.2.3**) (i.e., heater operation, extraction and treatment system, and temperature performance standards) before remedy verification soil sampling.

Step 7 – Develop the Plan for Obtaining the Data: The lateral extent and treatment volume of each decision unit (0 to 5 ft bgs, 5 to 15 ft bgs, and 15 to 55 ft bgs) were used to develop a soil sampling design and sampling density plan. Given that the potential risk of exposure to soil exceeding the treatment standards diminishes with depth, the sampling density is highest in the 0 to 5 ft bgs decision unit and lowest in the 15 to 55 ft bgs decision unit. The total volume of the 0 to 5 ft bgs decision unit is approximately 4,093 cubic yards with a sampling density of 140 cubic yards per sample, for a total of 30 soil samples. The total volume of the 5 to 15 ft bgs decision unit is approximately 7,428 cubic yards with a sampling density of 250 cubic yards per sample, for a total of 30 soil samples. The total volume of the 15 to 55 ft bgs decision unit is approximately 14,088 cubic yards with a sampling density of 470 cubic yards per sample, for a total of 31 soil samples. In total, 91 confirmation soil samples are proposed from 17 boring locations. The sampling plan is summarized by decision unit on **Table 7-1** and the soil boring locations are shown on **Figure 14**.

Table 7-1 Soil Remedy Verification Sampling Plan

	Decision Unit			
	0 to 5 ft bgs	**5 to 15 ft bgs**	**15 to 55 ft bgs**	**Total**
Square feet	22,101	20,057	9,510	51,668
Cubic yards	4,093	7,428	14,088	25,609
# Samples	30	30	31	91
# Borings	15	16	6	17
Cubic Yards/Sample	140	250	450	280

ft bgs = feet below ground surface

The soil sampling methodology, summarized as follows, will be conducted in general accordance with TerraTherm's SOP-SA-100 *Hot Soil Sampling for Organic Compounds* (TerraTherm, 2017; **Appendix C**). Heaters near the proposed soil sampling locations will be turned off immediately before the start of sampling. The energy input may be decreased or entirely shut off up to one day in advance of drilling to limit the risk of live steam in the subsurface. To maintain steam capture in the subsurface, the vapor recovery system will remain on during drilling activities to prevent the steam from traveling up the boreholes. Once sampling is complete, the energy input to the heaters will be increased back to operating levels until RWQCB concurs with the attainment of the soil treatment standards and approves the system shutdown.

Before boring advancement, a drilling permit will be obtained from the SMCEHSD. Boring locations will be reviewed before conducting work to ensure appropriate coverage of wiring and cables within the wellfield to allow for drill rig access and to ensure boring locations are positioned to avoid known utilities and/or obstructions. Borehole clearance will be performed at all boring locations to evaluate the presence of utilities and/or obstructions. Public utility clearance will be conducted through Underground Service Alert (USA) of Northern California. A geophysical contractor will also be mobilized to the Site to determine the location of underground public, private, and unknown utilities and/or obstructions. Borings will be manually cleared to a depth of 4 feet below the bottom of the impervious surface (e.g., concrete, asphalt) and a diameter at least as large as the drill tooling at each location. A drilling subcontractor will be retained to advance the proposed 17 soil borings via direct-push or sonic drilling technologies.

As described in TerraTherm's SOP-SA-100 *Hot Soil Sampling for Organic Compounds* (TerraTherm, 2017; **Appendix C**), prior to sample collection, the sealed soil cores will be placed in an ice bath to cool the cores down and limit potential volatile losses. Discrete samples will be collected once the temperature has cooled to at least 50 degrees Fahrenheit (°F). PID readings will be collected at 6-inch intervals. Discrete samples will be collected at each boring (**Figure 7-3**) at the frequency detailed in **Table 8** and collected at the interval(s) with the highest PID reading, or if all PID readings are the same, at the depth of the pre-remediation sample collected nearest to the confirmation sample location.

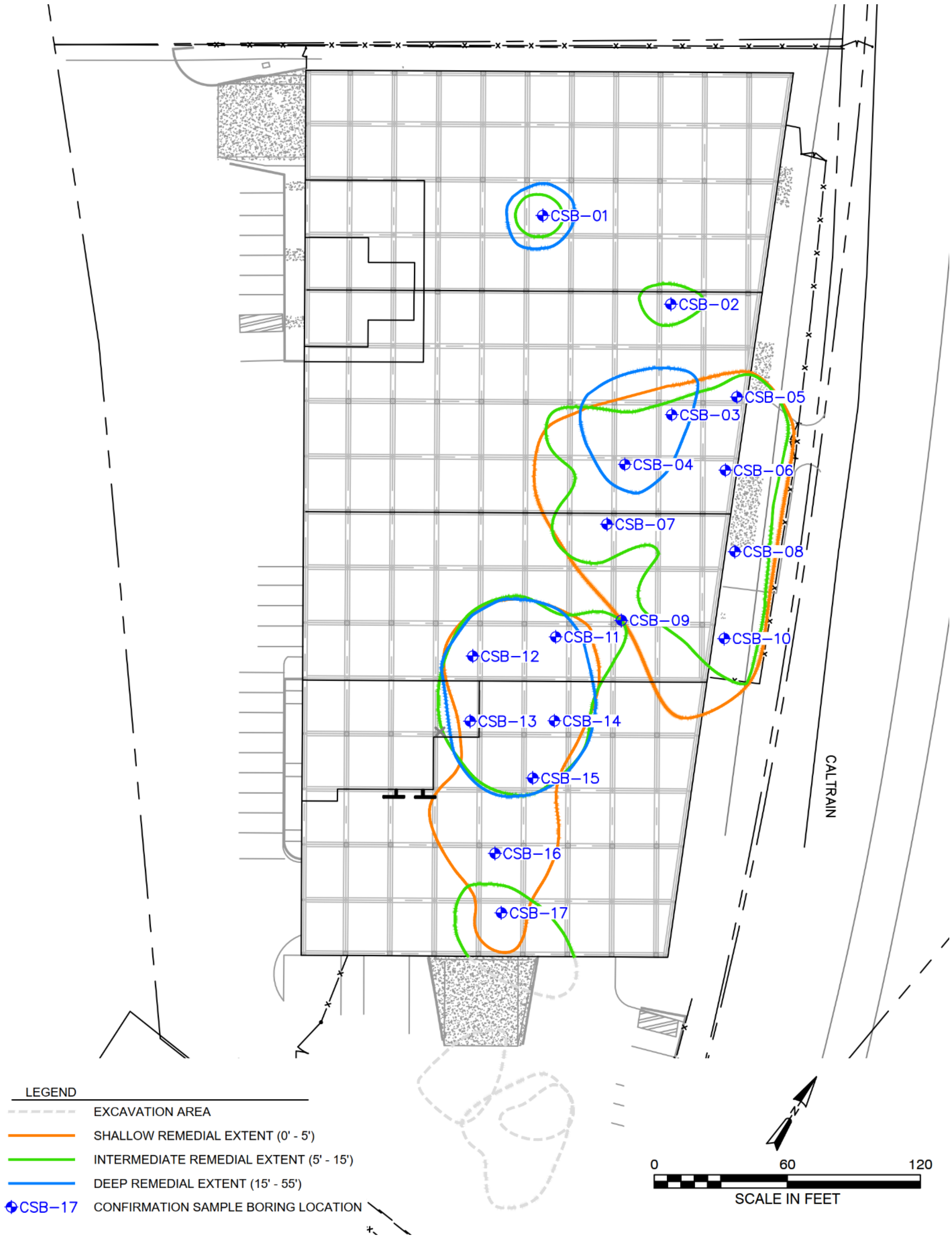


Figure 7-3 Remedy Verification Soil Sampling Boring Locations

As described earlier, soil samples will be analyzed by the following analytical methods:

- VOCs by Method 8260B
- TPH by Method 8015B
- 1,4-Dioxane by Method 8260 SIM

Following the completion of soil sampling, all boreholes will be destroyed via pressure grouting with cement/bentonite grout (mixture containing approximately 6 percent bentonite by weight) placed from the total depth of the borehole in accordance with permit requirements. The boring pavement surface will then be restored to match the existing grade.

Following RWQCB concurrence with soil treatment standard attainment, the heaters will be shut down and vapor extraction will continue for 14 days for an initial cool-down period. Once the initial cool-down period is complete, the extraction and treatment system will be shut down.

As described in **Section 6.2**, soil samples within areas that attain soil treatment standards but exceed Cleanup Levels will be subject to ECs and/or ICs.

7.3.1.2. Groundwater

Remedy verification groundwater monitoring will be conducted to ensure protection of potential aquatic receptors in Brisbane Lagoon (RAO #4) (**Section 6.2**). The remedy verification groundwater monitoring network will consist of six downgradient monitoring wells: two existing monitoring wells (MW-5 and MW-9) and four replacement monitoring wells that require abandonment before TCH implementation (MW-1A-R, MW-1B-R, MW-2A-R, and MW-2B-R) (**Figure 16**). Discussed herein are the drilling, installation, and sampling methodologies. Well destruction before TCH is discussed in the RAWP (**Appendix B**; TerraTherm, 2022).

Permitting

Before soil borehole advancement, subsurface drilling permits will be obtained from the SMCEHSD.

Well Installation

Borehole clearance will be performed at all boring locations to evaluate the presence of utilities and/or obstructions. Public utility clearance will be conducted through USA of Northern California. A geophysical contractor has also been mobilized to the Site to determine the location of underground public, private, and unknown utilities and/or obstructions. Borings will be manually cleared to a depth of 4 feet below the bottom of the impervious surface (e.g., concrete, asphalt) and a diameter at least as large as the drill tooling at each location.

The drilling subcontractor will be retained to advance the proposed four replacement monitoring wells (MW-1A-R, MW-1B-R, MW-2A-R, MW-2B-R) (**Figure 16**). Borings will be advanced to total depths similar to their original locations: MW-1A-R to a total depth of approximately 7 ft bgs, MW-1B-R to a total depth of approximately 18 ft bgs, MW-2A-R to a total depth of approximately 8 ft bgs, and MW-2B-R to a total depth of approximately 18 ft bgs.

Soil cuttings will be logged at approximately 5-foot intervals by a field geologist using the USCS and measured for VOC headspace vapors using a PID.

Following soil boring activities, the replacement monitoring wells will be installed in accordance with the California Department of Water Resources (DWR) *Bulletin 74: California Well Standards* (California DWR, 1991). The replacement monitoring wells will be constructed similar to their original locations with a 2-inch, schedule 40 polyvinyl chloride (PVC) well casing with an approximate 5-foot length schedule 40 PVC 0.020-inch slotted screen across the target interval.

No sooner than 72 hours following grout placement to allow sufficient curing, the monitoring well will be developed. The development process includes surging and bailing the well. Before development, the depth to the bottom of the well will be measured and compared to the well completion log, thereby determining the amount of sediment in the well. The well will be developed until the amount of sediment recovered decreases to asymptotic levels. After well development has been completed, the depth to the bottom of the well will be verified with a water level probe.

Surveying

Newly installed groundwater monitoring wells will be surveyed by a California-licensed surveyor following completion of the drilling program. Survey data will be provided in a report or summary from the licensed surveyor. The wells will be surveyed for horizontal and vertical controls to the following datums:

- Horizontal: California State Plane Coordinate System, North American Datum 1983 (NAD83)
- Vertical: Top of the well casing and ground surface elevation to the nearest 0.01-foot relative to the North American Vertical Datum 1988 (NAVD88)

Sampling

Groundwater sampling will be completed quarterly for four quarters. Remedy verification groundwater monitoring shall begin when groundwater temperature levels return to their pre-heating equilibrium condition as measured by water temperature levels in all six wells. The proposed target groundwater temperature level that enables inception of the remedy verification groundwater monitoring initiative is less than or equal to 24°C (recorded July 2021 at MW-07A). This maximum temperature concentration is based on the shallow groundwater temperature level record for July 2021.

All six wells will be gauged to measure water levels and total well depth. The depth to groundwater will be measured in each well to the nearest 0.01 foot to the top of casing (TOC). The measurements will be recorded in a field book or on field forms. All measurements will be conducted within 8 hours.

Following well gauging, all monitoring wells will be purged and sampled via low-flow procedures. Groundwater will be purged from wells using the general guidelines provided in *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures* (USEPA, 1996). Low-flow purging will be conducted using disposable tubing and a pump, with the tubing or pump intake lowered into position near the center of the screen. During low-flow purging, the water level in each well will be measured periodically to monitor drawdown. Pumping rates will be adjusted to achieve a stabilized drawdown no greater than 0.33 feet. In addition to monitoring the water level at each well during low-flow sampling, parameters such as temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity of the groundwater will be monitored using an in-line flow-through cell and multi-parameter device. During purging, these parameter readings will be recorded every 3 to 5 minutes until the parameters stabilize.

After stabilization (or if parameters do not stabilize after one hour), the flow-through cell will be detached from the pump and tubing assembly. Groundwater samples will be collected directly from the pump tubing within laboratory-supplied glassware and properly preserved. Samples containers will be properly labeled, placed directly on ice, and shipped under chain of custody to a California-certified laboratory.

Groundwater samples will be analyzed for Site-related constituents and compared against the Aquatic Receptor Health Groundwater Cleanup Levels.

7.3.1.3. Soil Vapor

Remedy verification sub-slab soil vapor monitoring will be conducted to ensure protection of potential human health receptors within the warehouse (RAO #6) (**Section 6.2**). The remedy verification sub-slab vapor probe (SSVP) monitoring network will mirror the pre-remediation SSVP network of 21 SSVPs (**Figure 11**). The Vapor Pin® system will be used to construct the SSVP adjacent to their previous original locations (required to be abandoned to facilitate the TCH remedy as described in the RAWP [**Appendix B**; TerraTherm, 2022]). Sub-slab vapor samples will be collected twice, 6 months apart during seasonal extremes (i.e., winter and late summer/early autumn), and compared to RWQCB-approved Cleanup Levels.

Remedy verification sub-slab soil vapor monitoring shall begin when sub-slab vapor temperatures reach the Site's normal ambient sub-slab soil vapor temperature. The proposed target sub-slab vapor temperature that enables inception of the remedy verification sub-slab soil vapor monitoring initiative is less than or equal to 24°C. This maximum 24-degree metric is based on the shallow groundwater temperature record for July 2021 where groundwater near overlying vadose zone occupied with soil gas ranged from 20°C to 24°C. Soil gas temperatures will be monitored in the 21 SSVPs (**Figure 11**) upon discontinuation of heating. A mean (average) temperature of less than or equal to 24°C will be used to qualify for inception of the remedy verification sub-slab soil vapor monitoring initiative.

The reasonable expectation for cool-down of the sub-slab soil vapors to less than 24°C is three to six months. This estimation is based on review of TCH case studies and various guidance on the use of TCH such as USEPA Engineering Paper entitled *In Situ Thermal Treatment Technologies: Lessons Learned* (USEPA, 2014) where it gives a rule of thumb that, ". . . sites generally cool at a rate of approximately 1◦C/day" but that, "Cooling rates at some sites have been considerably slower than this rule of thumb" where groundwater flow rates are low. It is reasonable to anticipate that cooling will be more rapid in the near-surface shallow fill where groundwater flow beneath the sub-slab vapor horizon groundwater is relatively high (compared to the groundwater velocity through the underlying Young Bay Mud).

The sub-slab vapor sampling program was developed in accordance with the 2011 California Environmental Protection Agency (CalEPA), DTSC *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* ("Vapor Intrusion Guidance" [DTSC, 2011]); the CalEPA DTSC *Advisory – Active Soil Gas Investigation* (DTSC, 2015); and the 2020 DRAFT *Supplemental Guidance: Screening and Evaluating Vapor Intrusion* (DTSC, 2020).

In accordance with the DTSC Vapor Intrusion Guidance (DTSC, 2011), a pre-sampling Site inspection and materials inventory will be conducted within the Parcel B Building before sampling. The pre-sampling inspection will be focused on documenting the current layout and conditions for sampling sub-slab locations. Foundation boundaries and areas that may be under the influence of the heating, ventilation, and air conditioning (HVAC) system will be noted.

Monitoring the meteorological conditions near the project will be conducted by obtaining data from the National Weather Service weather station, or similar, during soil vapor sampling activities. The data will include mean temperature, barometric pressure, average humidity, precipitation, and average wind speed and direction. Soil vapor sampling will not take place during or within five days of a significant rain event (i.e., ½ inch or more during a 24-hour period), except under buildings or high-integrity pavement, or while a frontal system is passing through the area.

A “shut-in” test will be applied to all aboveground sampling equipment. A vacuum of 100 inches of water will be applied to the aboveground sampling train. The vacuum will be monitored for approximately one minute. If the vacuum dissipates during the shut-in test, all aboveground fittings will be tightened, and the test will be repeated until the sampling equipment holds a vacuum.

A leak test will be conducted during sampling at each soil vapor probe location. A shroud filled with approximately 10 to 30 percent helium will be placed over the probe and all aboveground sampling equipment during purging. The concentration of helium in the shroud will be measured using a hand-held field helium detector and recorded on field sampling forms. The final 200 milliliters of purged soil vapor will be collected in a Tedlar® bag using a lung box, and the concentration of helium in the Tedlar bag will be measured with a field helium detector. If the concentration of helium is greater than 0.5 percent (or greater than 5 percent of the minimum concentration in the shroud) then the surface of the sample probe will be resealed, and all aboveground fittings will be tightened. Soil vapor will be purged again, and another leak test will be conducted. Otherwise, soil vapor sample collection will proceed. As an additional quality control measure, a minimum of 10 percent of the soil vapor samples collected via SUMMA canisters will be analyzed for helium by the analytical laboratory.

Before sampling, a volume of air will be purged from the probe to avoid sampling stagnant or ambient air. Purge volumes will be calculated in the field based on the volume of the void space in the tubing.

At each probe, three purge volumes of soil vapor will be removed from the probe before sampling. The total volume of purged soil vapor at each location will be recorded on field forms. Soil vapor will be purged from each probe using a flow rate between 100 and 200 milliliters per minute to prevent ambient air intrusion. A consistent, low rate will be used at each sampling location to limit stripping VOCs that may be adsorbed to soil. Additionally, the vacuum during sampling will be maintained at less than 100 inches of water (approximately 7 inches of mercury) during purging and sampling. The vacuum will be measured using an in-line gauge during purging. The soil vapor samples will be collected in 1-liter SUMMA canisters. After the samples are collected, the SUMMA canisters will be closed and secured pending shipment to the analytical laboratory under chain of custody procedures.

Data pertaining to the purging and sampling of the SSVPs will be recorded in the field on the sub-slab vapor sampling field form. Information on the field form includes sample number, sample collection time, location, volume purged, purge time and flow rate, type of probe, and other pertinent Site-specific observations.

Following the pre-sample purge and leak test, soil gas samples will be collected in stainless-steel SUMMA canisters with dedicated flow controllers that are pre-set by the laboratory to collect the soil gas sample over a 30-minute period. Each canister will be labeled with the sample name, location, time and date of sample collection, analytical method, and flow controller serial number.

Samples will be submitted to a California-certified laboratory and analyzed for Site-related constituents (**Table 3**) and methane. Site-related constituent concentrations will be compared to Human Health Soil Vapor Cleanup Levels (**Table 3**). Methane concentrations will be compared to a screening value of 1.25 %v. Samples will be analyzed by analytical methods TO-15, TO-3, and TO-17.

As described in **Section 6.2**, soil vapor samples that exceed Cleanup Levels will be subject to ECs, as required, following completion of the two sampling events.

7.3.1.4. Indoor & Outdoor Air

Indoor and outdoor air monitoring will be conducted post-remediation to ensure protection of human health receptors within the Parcel B building. The indoor air samples will be collected from the same locations as previously collected from 2013 to 2016 (EHS Support, 2017). Three outdoor air samples will be collected in accordance with the *Supplemental Guidance: Screening and Evaluating Vapor Intrusion* (DTSC, 2020) and in accordance with DTSC's Vapor Intrusion Guidance (DTSC, 2011). Indoor air samples are designed to evaluate potential exposures to commercial occupants of Parcel B and assess seasonal changes in indoor air concentrations. Outdoor air samples will be collected simultaneously with indoor air sampling to assess ambient air conditions outside the building for comparison purposes. Ambient air samples will also be collected during the same field mobilization and at the same frequency and duration of sub-slab vapor samples (i.e., two events, 6 months apart during seasonal extremes) and compared to RWQCB Indoor Air ESLs.

The proposed indoor and outdoor air sampling event includes 17 locations shown on **Figure 17** and described below. In addition to the primary samples, one duplicate sample will be collected and one trip blank (using a clean SUMMA canister) will accompany the shipment of samples submitted to the lab.

A total of 14 indoor air samples will be collected within the Parcel B Building (IA-01B to IA-14B):

- Eight samples (IA-02B, IA-06B, IA-07B, IA-11B, IA-12B, IA13B, IA14B) from open warehouse locations
- Four samples (IA-01B, IA-03B, IA-04B, IA-09B) from ground floor office spaces
- One sample (IA-10B) from an upstairs office space
- One sample (IA-08B) from ground floor lunchroom, located above a common sewer trench that could serve as a preferential pathway for vapor migration

Three outdoor ambient air samples (OA-01B to OA-03B) will be collected at the same time as the indoor air sampling:

- One sample (OA-2B) from the western side of the Parcel B Building
- One sample (OA-1B) from the eastern side of the Parcel B Building
- One sample (OA-3B) from the northern side of the Parcel B Building

In accordance with the DTSC Vapor Intrusion Guidance (DTSC, 2011), a pre-sampling Site inspection and materials inventory will be conducted within the Parcel B Building before sampling. The pre-sampling inspection and materials inventory will document whether materials are present in the Parcel B Building, as well as the building construction and the condition of the concrete slab.

At the time of indoor air sampling, documentation of building conditions and information during air sampling in the Parcel B Building, as recommended in the DTSC Vapor Intrusion Guidance (DTSC, 2011), will be noted on field forms to identify potential background sources of VOCs.

Samples will be collected in 6-liter SUMMA canisters that are equipped with dedicated flow controllers and pre-set by the laboratory to collect the air sample over the sampling period.

Before sampling, the SUMMA canisters will be checked and verified to have sufficient vacuum for the test. The sampling devices will be located in the breathing zone, approximately 3 to 5 feet off the ground surface. As per the DTSC Vapor Intrusion Guidance (DTSC, 2011), the HVAC systems will be operated normally for the season and time of day. During the colder months, the heating systems should be operating for at least 24 hours before the scheduled sampling event to maintain normal indoor temperatures above 65°F before and during sampling. During indoor air sampling, in accordance with DTSC Vapor Intrusion Guidance (DTSC, 2011), the building windows should remain closed and ingress and egress should be minimized.

The sample collection will be implemented by opening the SUMMA canister flow controller. The guidance recommends that sampling events should be conducted to produce representative concentrations of the monitored compounds over the anticipated daily exposure period for building occupants. An 8-hour test is appropriate to assess the potential daily exposure from a commercial/industrial worker exposure scenario. Applicable sampling information will be recorded on air sampling logs.

Upon completion of the 8-hour test period, the flow controller valve on the canisters will be closed and the canister will be labeled with the sample name, location, time and date of sample collection, analytical method, and flow controller serial number.

Samples will be submitted to a California-certified laboratory and analyzed for Site-related constituents (**Table 3**).

7.3.2. Building Condition Monitoring

Using information from the pre-remediation building condition assessment, building condition assessment during operations, and monitoring activities outlined in **Section 7.1.2** and **Section 7.2.2**, and consistent with the recommendations provided in the risk matrix (Appendix V of WJE's *Limited Geotechnical and Structural Study to Support Remedial Decision Making* [WJE, 2022; **Appendix A**]), the following monitoring and assessment activities will be completed post-remediation:

- Relative elevation survey and condition assessment of the post-treatment slab.
- Concrete testing consistent with pre-remediation testing program.
- Visual condition assessment and survey and relative elevation survey of slab surface near the treatment area.
- Concrete sample extraction and laboratory analysis.
- Visual condition assessment of precast walls and connections in the vicinity of the treatment area.
- Visual condition assessment of existing partitions.
- Scope and verification of the utility function, if utility is within 15 feet of the treatment area.

Additional data collection may be undertaken based on the results of the data collected during operations. Univar/VWR will work collaboratively with WJE and the property owner to complete these monitoring and assessment activities. Monitoring and assessment activities will be described in detail in a future implementation plan developed by WJE. Should repairs be necessary post-remediation, Univar/VWR will work with the property owner to complete repairs.

7.4. Contingency Plan

The remedy, as proposed, is designed to limit the need for contingent actions beyond those contemplated as part of the proposed remedy (comprised of TCH, ECs, ICs, and monitoring). Remedy verification soil and sub-slab soil vapor concentrations that remain above applicable Cleanup Levels will be subject to ECs and ICs as necessary to achieve RAOs and support a closure determination for the Site. Therefore, the following contingency plan is focused on defining actions that may be taken if remedy verification groundwater concentrations remain above Aquatic Receptor Health Groundwater Cleanup Levels (**Table 2**) at one or more wells at the end of the prescribed monitoring period of four quarters:

1. Calculate the 95% Upper Confidence Limit (UCL) for the constituent(s) exceeding the respective Cleanup Level.
   - If 95%UCL is below the Cleanup Level, no further action is required.
   - If 95%UCL is above the Cleanup Level, proceed to next step.
2. Model the concentration at the potential downgradient receptor point (i.e., Brisbane Lagoon) using Biochlor (or other appropriate modeling tool) and calculate the Mann-Kendall trend.
   - If modeled concentration at the potential downgradient receptor point is below the Cleanup Level and trend is stable or decreasing, no further action is required and monitoring can cease.
   - If modeled concentration at the potential downgradient receptor point is above the Cleanup Level and trend is stable or decreasing, continue sampling for up to four additional quarters to strengthen statistical dataset and review future data against Cleanup Levels and this contingency plan (starting at step 1). If this condition is observed after four additional quarters (i.e., eight total monitoring events), proceed to next step.
   - If modeled concentration at the potential downgradient receptor point is below the Cleanup Level and trend is increasing, continue sampling for up to four additional quarters to strengthen the statistical dataset and review future data against Cleanup Levels and this contingency plan (starting at step 1). If this condition is observed after four additional quarters (i.e., eight total monitoring events), proceed to next step.
   - If modeled concentration at the potential downgradient receptor point is above the Cleanup Level and trend is increasing, proceed to next step.
3. Collect downgradient groundwater sample and compare the results to the applicable Aquatic Receptor Health Groundwater Cleanup Level.
   - If concentration is below the Cleanup Level and trend (from Step 2) is stable or decreasing, no further action is required and monitoring can stop.
   - If concentration is above or below the Cleanup Level and trend (from Step 2) is increasing, sample downgradient groundwater for up to seven additional quarters and work through previous steps.
   - If concentration at downgradient sampling location is above the Cleanup Level after working through the previous steps, proceed to the next step.
4. Complete additional investigation, risk assessment, and/or remedial action, as required, to mitigate the risk in coordination with RWQCB.

7.5. Site Management and Closure

7.5.1. Land Use Covenant and Site Management Plan

As discussed in **Section 4**, RWQCB has previously indicated that an SMP and an environmental restrictive covenant are required as a condition of approving regulatory closure for the Property under an industrial/commercial use scenario or a low-threat closure scenario. As such, an SMP was submitted to, and approved by, RWQCB for the Property in July 2022 (EHS Support, 2022b) and an environmental restrictive covenant for the Site is in place and has been recorded against the Property. The restrictions identified in the covenant are summarized as follows:

- The Property shall not be used for housing, residences, hospitals, schools for persons under the age of 21, daycare facilities, or hospices.
- Groundwater underneath the Property shall not be used for municipal or domestic water supply purposes but may be used for any other purpose authorized by the RWQCB and consistent with the approved remedy.

The RWQCB has indicated that, in addition to these restrictions, a land use covenant must be recorded against the Property that obligates the property owner to comply with the SMP of record. The future final land use restrictions will likely take the form of one or more new environmental covenants, following a template approved by the RWQCB, that supersede the existing environmental restrictive covenants.

7.5.2. Site Closure

Following completion of TCH and post-remediation monitoring, ECs will be installed, as required, to ensure long-term projection to human health and the environment. Following installation of any required ECs, Univar/VWR will request that RWQCB make a determination that no further action is required to facilitate closure for industrial/commercial land use.

8. Schedule

The estimated schedule to implement the proposed remedy, Alternative 2, consisting of TCH, ICs, ECs, and monitoring is provided below. A detailed schedule will be provided following receipt of requisite agency approvals.

- Premobilization and baseline monitoring: 3 months
- Mobilization, Site setup, and construction for TCH remedy: 6 months
- Operation of TCH remedy and operational monitoring: 8 months
- Demobilization and decommissioning: 4 months
- Post-remediation soil vapor and groundwater sampling and installation of ECs (as required): 12 months

9. References

California Department of Water Resources (DWR). 1991. Bulletin 74: California Well Standards.

Department of Toxic Substances Control (DTSC), California Environmental Protection Agency. 2011. *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* (Vapor Intrusion Guidance). October.

DTSC, California Environmental Protection Agency. 2015. *Advisory – Active Soil Gas Investigations*. July.

DTSC, California Environmental Protection Agency. 2020. Supplemental Guidance: Screening and Evaluating Vapor Intrusion. February.

EHS Support. 2017. Indoor Air Sampling Report (Warehouses #1 and #2). December 19.

EHS Support. 2018. Data Gaps Investigation Report. May.

EHS Support. 2020. Remedial Action Objectives and Cleanup Levels Proposal. December.

EHS Support. 2022a. Pre-Design Investigation Report. February.

EHS Support. 2022b. Soil Management Plan. July.

ERM. 2015a. On-Site Remedial Investigation Data Summary Report.

ERM. 2015b. Facility Closure Report. February.

SMCEHD. 2015. VWR International LLC CAD043073964. March 27.

TerraTherm. 2017. Hot Soil Sampling for Organic Compounds. SOP-SA-100. October.

TerraTherm. 2022. Remedial Action Work Plan. September.

United States Environmental Protection Agency. 1996. Robert Puls and Michael Barcelona. Low-Flow (Minimal Drawdown) Ground-water Sampling Procedures. EPA/540/S-95/504. April.

United States Environmental Protection Agency. 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. EPA QA/G-4. February.

United States Environmental Protection Agency. 2014. In Situ Thermal Treatment Technologies: Lessons Learned. https://www.epa.gov/sites/default/files/2015-06/documents/istt_ll_issue_paper.pdf

VWR. 2014. Request for Agency Oversight of a Brownfield Site. May.

WJE. 2022. Limited Geotechnical and Structural Study to Support Remedial Decision Making. September.

Tables

Table 1
Final Soil Cleanup Levels
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	Final Soil Cleanup Levels		
	Non-Degradation Soil Cleanup Level for RAO#1 (0 to 5 ft) (mg/kg)	Human Health Shallow Soil Cleanup Level for RAO#2 (0 to 5 ft) (mg/kg)	Human Health Deep Soil Cleanup Level for RAO#2 (5 to 15 ft) (mg/kg)
CHLOROETHANES			
1,1,1-Trichloroethane (1,1,1-TCA)	7.0E+00	7.2E+03	2.1E+04
1,1-Dichloroethane (1,1-DCA)	3.1E-01	1.6E+01	1.1E+03
1,2-Dichloroethane (1,2-DCA)	3.1E-02	2.1E+00	1.3E+02
CHLOROETHENES			
Tetrachloroethylene (PCE)	8.0E-02	2.7E+00	9.5E+01
Trichloroethylene (TCE)	8.5E-02	6.1E+00	5.1E+01
1,1-Dichloroethene (1,1,-DCE)	4.2E+00	3.5E+02	1.0E+03
cis-1,2-Dichloroethylene (cis-1,2-DCE)	1.6E+00	7.8E+01	2.2E+02
trans-1,2-Dichloroethylene (trans-1,2-DCE)	1.4E+01	5.7E+02	1.6E+03
Vinyl Chloride	1.5E-03	1.5E-01	9.8E+00
PETROLEUM HYDROCARBONS			
C10-C24 (Petroleum - Diesel Range)	2.3E+03	1.1E+03	3.1E+03
C5-C12 (Petroleum - Gasoline)	1.0E+03	1.8E+03	5.2E+03
Benzene	2.5E-02	1.4E+00	9.4E+01
Ethylbenzene	4.3E-01	2.6E+01	1.5E+03
Styrene	1.0E+01	2.5E+04	7.0E+04
Toluene	1.0E+01	4.7E+03	1.4E+04
Xylenes	1.0E+01	2.4E+03	7.0E+03
Naphthalene	1.2E+00	1.7E+01	1.2E+03
OTHER ORGANIC COMPOUNDS			
1,4-Dioxane	8.4E-01	2.2E+01	6.1E+02
1,2-Dichlorobenzene	1.0E+00	7.8E+03	2.2E+04
2,4-Dimethylphenol	8.9E+00	7.1E+03	2.0E+04
Chlorobenzene	1.4E+00	1.3E+03	3.3E+03
Chloroform	2.3E-02	1.4E+00	9.7E+01
Hexachlorobutadiene	6.2E-02	5.3E+00	2.9E+02
Methyl Isobutyl Ketone (4-Methyl-2-Pentanone; MIK)	5.1E-01	1.4E+05	4.0E+05
Methylene Chloride	1.9E-01	2.5E+01	1.4E+03

Notes:
ft = feet
mg/kg = milligrams per kilogram
RAO = remedial action objective

Table 2
Final Groundwater Cleanup Levels
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	Final Groundwater Cleanup Levels		
	Non-Degradation Groundwater Cleanup Level for RAO#3 3) (any depth) (µg/L)	Aquatic Receptor Health Groundwater Cleanup Level for RAO#4 4) (any depth) (µg/L)	Human Health Groundwater Cleanup Level for RAO#5 5) (0 to 15 ft bgs) (µg/L)
CHLOROETHANES			
1,1,1-Trichloroethane (1,1,1-TCA)	5.0E+04	3.1E+03	3.1E+03
1,1-Dichloroethane (1,1-DCA)	5.0E+04	4.7E+01	2.5E+02
1,2-Dichloroethane (1,2-DCA)	5.0E+04	1.1E+04	1.6E+01
CHLOROETHENES			
Tetrachloroethylene (PCE)	5.0E+04	2.3E+02	4.1E+01
Trichloroethylene (TCE)	5.0E+04	2.0E+02	6.2E+00
1,1-Dichloroethene (1,1,-DCE)	5.0E+04	2.2E+04	3.9E+02
cis-1,2-Dichloroethylene (cis-1,2-DCE)	5.0E+04	2.2E+04	4.5E+01
trans-1,2-Dichloroethylene (trans-1,2-DCE)	5.0E+04	2.2E+04	4.5E+02
Vinyl Chloride	5.0E+04	7.8E+02	1.2E+02
PETROLEUM HYDROCARBONS			
C10-C24 (Petroleum - Diesel Range)	2.5E+03	6.4E+02	2.4E+03
C5-C12 (Petroleum - Gasoline)	5.0E+04	3.7E+03	3.5E+03
Benzene	5.0E+04	3.5E+02	1.2E+01
Ethylbenzene	5.0E+04	4.3E+01	1.6E+02
Styrene	5.0E+04	NA	5.9E+03
Toluene	5.0E+04	2.5E+03	1.6E+03
Xylenes	5.0E+04	1.0E+02	2.8E+02
Naphthalene	1.6E+04	1.5E+01	1.5E+01
OTHER ORGANIC COMPOUNDS			
1,4-Dioxane	5.0E+04	5.0E+05	6.3E+02
1,2-Dichlorobenzene	5.0E+04	6.5E+01	1.4E+03
2,4-Dimethylphenol	5.0E+04	1.1E+02	1.9E+04
Chlorobenzene	5.0E+04	6.5E+01	3.1E+02
Chloroform	5.0E+04	3.2E+03	1.9E+01
Hexachlorobutadiene	1.6E+03	3.2E+00	2.9E+01
Methyl Isobutyl Ketone (4-Methyl-2-Pentanone; MIK)	5.0E+04	1.7E+02	2.4E+04
Methylene Chloride	5.0E+04	3.2E+03	3.8E+02

Notes:
µg/L = micrograms per liter
ft = feet
bgs = below ground surface
NA = not applicable, no Cleanup Level developed.
RAO = remedial action objective

Table 3
Final Soil Vapor Cleanup Levels
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	Final Soil Vapor Cleanup Level
	Human Health Soil Vapor Cleanup Level for RAO#6 (µg/m^3)
CHLOROETHANES	
1,1,1-Trichloroethane (1,1,1-TCA)	4.4E+06
1,1-Dichloroethane (1,1-DCA)	7.7E+03
1,2-Dichloroethane (1,2-DCA)	4.7E+02
CHLOROETHENES	
Tetrachloroethylene (PCE)	2.0E+03
Trichloroethylene (TCE)	3.0E+03
1,1-Dichloroethene (1,1,-DCE)	3.1E+05
cis-1,2-Dichloroethylene (cis-1,2-DCE)	3.5E+04
trans-1,2-Dichloroethylene (trans-1,2-DCE)	3.5E+05
Vinyl Chloride	1.6E+02
PETROLEUM HYDROCARBONS	
C10-C24 (Petroleum - Diesel Range)	1.0E+06
C5-C12 (Petroleum - Gasoline)	1.0E+05
Benzene	4.2E+02
Ethylbenzene	4.9E+03
Styrene	1.4E+06
Toluene	1.3E+06
Xylenes	4.4E+05
Naphthalene	3.6E+02
OTHER ORGANIC COMPOUNDS	
1,4-Dioxane	1.6E+03
1,2-Dichlorobenzene	8.8E+05
2,4-Dimethylphenol	1.0E+03
Chlorobenzene	2.2E+05
Chloroform	5.3E+02
Hexachlorobutadiene	5.6E+02
Methyl Isobutyl Ketone (4-Methyl-2-Pentanone; MIK)	4.2E+05
Methylene Chloride	1.2E+04

Notes:
µg/m^3 = micrograms per meter cubed
RAO = remedial action objective

Table 4
Evaluation of Remedial Alternatives
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Alternatives	Effectiveness	Implementability	Relative Cost	Net environmental impact
1. Risk-Based Remediation 1) Soil vapor extraction and air sparging within the top 15 feet of the Fill (unsaturated and saturated) beneath the existing warehouse. 2) Excavation of residual impacts within the top 15 feet of Fill and Young Bay Mud along the eastern property boundary. 3) Establishment of a containment zone in accordance with SWRCB State Water Resources Control Board Resolution No. 92-49 for impacts within the Young Bay Mud underlying the warehouse. 4) Execution of a long-term groundwater monitoring program to evaluate natural degradation processes and assess remaining contaminant concentrations. 5) Engineering controls in the form of maintenance of slab and other hard stand areas and a sub-slab depressurization system. 6) Institutional controls in the form of an environmental restrictive covenant and soil management plan.	Both AS/SVE and excavation are assumed to be effective in removing contamination within the upper 15 feet of the Fill, although both the removal efficiency and timeframe associated with AS/SVE are uncertain given the appreciable amount of fines within the Fill and limited extent of the vadose zone (groundwater is nominally 5 ft bgs). These uncertainties could result in loss of, or extended limited use of, the Site (beyond the planned remediation timeframe). In addition, there is some uncertainty associated with the long-term performance of the AS/SVE remedy given the potential for recontamination of the upper 15 feet of soil given the contamination that would remain at depth within the Young Bay Mud. Excavation and AS/SVE are not expected to have a significant impact on the geochemical conditions, solubility of chemical constituents, or result in increased production of volatile byproducts after cessation of these remedial technologies. Ongoing natural degradation within the underlying Young Bay Mud is not expected to be affected by these remedial technologies. Establishing a containment zone to address the unremediated impacts within the Young Bay Mud at depths greater than 15 ft bgs is considered an effective method of addressing contamination that would remain in place. However, evaluating the long-term performance of the remedy would require long-term monitoring that would impact on future Site use and would not allow expeditious Site closure, a goal of both Univar/VWR and the Property owner. Engineering controls are expected to perform effectively in the short-term and long-term with minimal long-term monitoring requirements. Institutional controls are required by the RWQCB as a condition of closure and expected to be effective in the short-term and long-term given they will be tied to the deed for the Property. **Conclusion:** Might be effective	AS/SVE will require installation of a horizontal well network, electrical systems, recovery piping, and a vapor treatment system. The system can be built with standard equipment. However, AS/SVE may not be implementable given the depth of the structural beams beneath the warehouse (approximately 2 feet thick) and the depth to the water table (approximately 5 feet below ground surface). In other words, the vadose zone may not be thick enough to install horizontal SVE infrastructure beneath the building. In addition, installing the horizontal AS/SVE piping during excavation along the eastern property boundary has some limitations as well given the typical setback distance required to drill horizontally beneath the building and the limited distance between the warehouse and the eastern property boundary (approximately 50 ft). A discharge permit will be needed for the treated exhaust from the Bay Area Air Quality Management District. As the vapor treatment system removes contaminants below action levels, it is not expected that there will be any difficulty obtaining the air permit, although permitting timeframes could be extensive. A drilling permit from San Mateo County will also be required for well installation and is not expected to be difficult to obtain. Excavation immediately adjacent to the eastern wall of the building is expected to be readily implementable via standard techniques such as trench boxes or slide rail shoring to reach the full excavation depths. A grading permit will be required from the City of Brisbane for excavation and it is not expected that there will be any difficulty obtaining the grading permit. There are some implementability concerns with establishing a containment zone and executing the associated long-term monitoring program including whether or not the approach would garner agency approval and how feasible long-term access to monitoring infrastructure will be in the future, when the Site is expected to be back in operation. There are no implementability concerns with the engineering controls as the building slab is already in good condition and performs as an effective vapor barrier and a sub-slab depressurization system can be easily installed while the building is empty. Institutional controls are required by the RWQCB as a condition of closure and expected to be readily implementable given that Univar/VWR and the property owner are already working together to execute agency-required institutional controls. **Conclusion:** Might be implementable	The total estimated cost of the AS/SVE/excavation remedy is $5M and includes pre-construction (e.g., remedy design and structural/geotechnical analysis), construction (e.g., system installation), system operation and monitoring, long-term remediation monitoring, oversight, reporting, and project management. The cost of the remedy is considered significant given that it may leave approximately 58% of the contaminant mass in place given that the mass in all phases (NAPL, groundwater, soil) is predominantly located at a depth of greater than 15 ft bgs within the Deep Fill and Upper Young Bay Mud. In addition, the remedy would not achieve closure (i.e., the Site would remain open based on the containment zone designation). **Conclusion:** **High cost relative to reductions in contaminant mass, long-term protection of human health and the environment, and lack of regulatory closure.**	The likely environmental impacts associated with AS/SVE/excavation include increased truck traffic during construction, increased emissions (discharged via air permit), potential erosion of soils, and some vapor release to the atmosphere. The potential environmental impacts associated with operation of the sub-slab depressurization system include discharge of low, diminishing vapor concentrations below action limits. Given that the remedy would leave a significant amount of contamination in place, it would result in restoration of groundwater through natural means, but would likely take decades. Therefore, restoring the future potential beneficial uses of the aquifer would be realized eventually. **Conclusion:** **Net environmental benefit is moderate given the timeframe to restore potential future beneficial uses of the aquifer.**
2. Removal-Based Remediation 1) TCH of final remedial extents beneath the warehouse and along the eastern property boundary. 2) Completion of short-term post-remediation soil, groundwater, and vapor monitoring. 3) Engineering controls in the form of maintenance of slab and other hard stand areas and a sub-slab depressurization system. 4) Institutional controls in the form of an environmental restrictive covenant and soil management plan.	TCH is a proven technology for removing organic contaminant source material (i.e., NAPL) and sorbed-phase contamination within fine-grained soils at depth. While there are inherent challenges in effectively implementing the remedy beneath the existing warehouse, case studies indicate that TCH has been implemented effectively within buildings and structures, even when the buildings and structures remained occupied. The timeframe for remediation is relatively short-term (on the order of a year) and while there will be disruptions to Site operations during mobilization and demobilization, once constructed, the remedial operations will be contained within the building (which will be vacant during operations) and within a secured remediation treatment compound. Given that TCH will target the entire extent requiring active remediation (including the Young Bay Mud), there is limited potential for rebound and recontamination following cessation of active treatment. By design, TCH will have a short-term impact on the geochemical conditions, solubility of chemical constituents, and increased production of volatile byproducts, however, these short-term impacts are not expected to lead to detrimental long-term affects after cessation of the remedy. TCH will also enhance natural degradation processes beyond the active treatment areas via increasing the groundwater temperatures. Post-remediation monitoring is expected to be an effective means of evaluating remedy success, will be short-term in nature (less that two years), and will be focused in non-operational areas when possible to allow for Site use during monitoring. Engineering controls are expected to perform effectively in the short-term and long-term with minimal long-term monitoring requirements. Institutional controls are required by the RWQCB as a condition of closure and expected to be effective in the short-term and long-term given they will be tied to the deed for the Property. **Conclusion:** Reasonably expected to be effective	TCH will require installation of a vertical well network, electrical systems, recovery piping, and a liquid and vapor treatment system. The system can be built with standard equipment. A key implementability challenge associated with TCH is installing and operating the remedy within the existing warehouse given the potential for structural damage to the piles, grade beams, and/or slab as a result of heating. However, TCH has been successfully and safely implemented within buildings with similar structures and at sites underlain by similar soils (i.e., Young Bay Mud). Another implementability challenge is the need to upgrade the current utility services (gas and electrical) at the Site. Although it is expected that upgraded service can be obtained through PG&E, the timeframes associated with the upgrades are significant. A discharge permit will be needed for the treated exhaust from the Bay Area Air Quality Management District. As the vapor treatment system removes contaminants below action levels, it is not expected that there will be any difficulty obtaining the air permit, although permitting timeframes could be extensive. A drilling permit from San Mateo County will also be required for well installation and is not expected to be difficult to obtain. There are no implementability concerns with completing a short-term post-remediation monitoring program. There are no implementability concerns with the engineering controls as the building slab is already in good condition, performs as an effective vapor barrier, and can be repaired or resealed following TCH. A sub-slab depressurization system can be easily installed while the building is empty. Institutional controls are required by the RWQCB as a condition of closure and expected to be readily implementable given that Univar/VWR and the property owner are already working together to execute agency-required institutional controls. **Conclusion:** Might be implementable	The total estimated cost of the TCH remedy is $11.5M and includes pre-construction (e.g., remedy design and structural/geotechnical analysis), construction (e.g., system installation and utility upgrades), system operation and monitoring, post-remediation monitoring, oversight, reporting, and project management. The cost of the remedy is considered significant, however, approximately 99% of the contaminant mass is expected to be removed and the remedy provides a near-term path to achieve closure with limited post-remediation monitoring. **Conclusion:** **Cost is high, but the remedy provides a high degree of certainty that it will be protective of human health and the environment and that regulatory closure can be achieved near-term.**	The likely environmental impacts associated with TCH include increased truck traffic during construction, increased emissions (discharged via air permit), and increased utility usage via operation of the system to heat groundwater. The potential environmental impacts associated with operation of the SSDS system include discharge of low, diminishing vapor concentrations below action limits. Given that the remedy would result in removing approximately 99% of the contamination, it would result in near-term restoration of groundwater. Therefore, restoring the future potential beneficial uses of the aquifer would be realized on the order of years. **Conclusion:** **Net environmental benefit is high given the short timeframe to restore potential future beneficial uses of the aquifer and high certainty of contaminant removal.**
3. No Active Remediation Assumes no additional institutional controls, engineering controls, monitoring, or active treatment beyond the existing and RWQCB-required institutional controls.	No action is not expected to be effective given that it does not reduce contaminant mass or confidently protect human health and the environment. **Conclusion:** Not effective	No action is readily implementable given that it does not require any additional active remediation or controls beyond what is already in place or required. **Conclusion:** Readily implementable	No action would not incur additional costs, however, it provides no further reduction of contaminant mass beyond natural degradation and provides no path to regulatory closure. **Conclusion:** **Cost is negligible, but does not provide a path to closure or a plan to confidently mitigate potential future risks.**	No action would not result in any short-term environmental impacts due to construction, execution, and operation of a potential remedy. However, no action would also not result in an increased reduction in contaminant mass and therefore, does not provide a path to restoring potential future beneficial uses of groundwater and does not confidently remove potential future risks to environmental receptors. **Conclusion:** **No net environmental benefit.**

Notes:
AS = air sparging
bgs = below ground surface
ft = feet
NAPL = non-aqueous phase liquid
PG&E = Pacific Gas and Electric
RWQCB = Regional Water Quality Control Board
SVE = soil vapor extraction
SWRCB = State Water Resources Control Board
TCH = thermal conductive heating
VWR = VWR International, LLC

Table 5
Calculation of Equivalent Soil Concentrations
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	Human Health Groundwater Cleanup Level (5 to 15 ft) (mg/L)	Soil Organic Carbon/Water Partition Coefficient (L/kg)	Fill	Young Bay Mud
			Calculated Equivalent Soil Concentration for Human Health Groundwater Cleanup Level (5 to 15 ft) (mg/kg)	Calculated Equivalent Soil Concentration for Human Health Groundwater Cleanup Level (5 to 15 ft) (mg/kg)
Chloroethanes				
1,1,1-Trichloroethane	3.1	1.10E+02	4.07	6.22
1,1-Dichloroethane	0.25	3.16E+01	0.14	0.22
1,2-Dichloroethane	0.02	1.74E+01	0.01	0.01
Chloroethenes				
Tetrachloroethene	0.04	1.55E+02	0.07	0.11
Trichloroethene	0.01	1.66E+02	0.01	0.02
1,1-Dichloroethene	0.4	5.89E+01	0.32	0.49
cis-1,2-Dichloroethene	0.05	3.55E+01	0.03	0.04
trans-1,2-Dichloroethene	0.4	5.25E+01	0.34	0.52
Vinyl Chloride	0.1	1.86E+01	0.05	0.09
Petroleum Hydrocarbons				
C10-C24 (Petroleum - Diesel Range)*	2.4	1.50E+03	35.00	51.99
C5-C12 (Petroleum - Gasoline)*	3.5	1.30E+02	5.24	7.98
Benzene	0.01	5.89E+01	0.01	0.02
Ethylbenzene	0.2	3.63E+02	0.61	0.91
Styrene	5.9	7.76E+02	44.96	66.95
Toluene	1.6	1.82E+02	3.27	4.94
Xylenes	0.3	3.86E+02	1.11	1.66
Naphthalene	0.01	2.00E+03	0.28	0.42
Other Organic Compounds				
1,4-Dioxane***	0.6	1.70E+01	0.26	0.42
1,2-Dichlorobenzene	1.4	6.17E+02	8.63	12.87
2,4-Dimethlyphenol	18.9	2.09E+02	42.33	63.82
Chlorobenzene	0.3	2.19E+02	0.71	1.07
Chloroform	0.02	3.98E+01	0.01	0.02
Hexachlorobutadiene	0.029	5.37E+04	14.92	22.11
Methyl Isobutyl Ketone (MIK)**	24.1	7.00E+01	22.07	34.13
Methylene Chloride	0.4	1.17E+01	0.14	0.22

Notes:

*Soil Organic Carbon/Water Partition Coefficient from San Francisco Bay RWQCB 2019 Environmental Screening Levels
**Soil Organic Carbon/Water Partition Coefficient from Hazardous Substances Data Bank (HSDB)
***Soil Organic Carbon/Water Partition Coefficient from Schuurmann G et al; Environ Sci Technol 40: 7005-11 (2006), Supporting Information
kg = kilograms
L = liters
mg = milligrams
RWQCB = Regional Water Quality Control Board

Equation

Csoil = GWCL x (Kd + θg/ρw) [Simplified for saturated zone]

Where:	Fill	Young Bay Mud	Units	Notes
Csoil: Calculated Equivalent Soil Concentration	Calculated Above	Calculated Above	mg/kg	See equation above
GWCL: Groundwater Cleanup Level	Chemical Specific	Chemical Specific	mg/L	RWQCB-approved Groundwater Cleanup Level
Kd: Soil Distribution Coefficient	Chemical Specific	Chemical Specific	L/kg	Calculation: Kd = Koc x foc
Koc: Soil Organic Carbon/Water Partition Coefficient	Chemical Specific	Chemical Specific	L/kg	Literature Value
foc: Fraction Organic Carbon Content in Soil	0.00952	0.01410	Unitless mass ratio	Average values from 2017 data
θg: Moisture Content (Gravimetric Water Content)	0.25	0.43	Unitless mass ratio	Average values from 2017 data
ρw: Density of Water	1	1	kg/L	Value at 25 degrees Celsius

Table 6
Development of Soil Treatment Standards
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	0 to 5 foot interval			5-15 foot interval				15-55 foot interval	
	Soil Treatment Standard (0 to 5 ft bgs) (mg/kg)	Non-Degradation Soil Cleanup Level for RAO#1 (0 to 5 ft) (mg/kg)	Human Health Shallow Soil Cleanup Level for RAO#2 (0 to 5 ft) (mg/kg)	Soil Treatment Standard (5 to 15 ft bgs) (mg/kg)	Human Health Deep Soil Cleanup Level for RAO#2 (5 to 15 ft) (mg/kg)	Equivalent Soil Concentration for Non-Degradation Groundwater Cleanup Level (any depth) (mg/kg)	Calculated Equivalent Soil Concentration for Human Health Groundwater Cleanup Level (5 to 15 ft) (mg/kg)	Soil Treatment Standard (15 to 55 ft bgs) (mg/kg)	Equivalent Soil Concentration for Non-Degradation Groundwater Cleanup Level (any depth) (mg/kg)
1,1,1-Trichloroethane	1	7.0	7,214.5	1	20,734.3	650.0	4.1	1	650.0
1,1-Dichloroethane	1	0.3	15.7	1	1,057.9	1,700.0	0.1	1	1,700.0
1,2-Dichloroethane	1	0.03	2.1	1	130.5	3,000.0	0.01	1	3,000.0
Chloroethenes									
Tetrachloroethene	1	0.1	2.7	1	95.3	170.0	0.1	1	170.0
Trichloroethene	1	0.1	6.1	1	50.6	700.0	0.01	1	700.0
1,1-Dichloroethene	1	4.2	348.3	1	1,001.0	1,200.0	0.3	1	1,200.0
cis-1,2-Dichloroethene	1	1.6	78.3	1	224.9	2,400.0	0.03	1	2,400.0
trans-1,2-Dichloroethene	1	14.2	569.6	1	1,637.1	1,900.0	0.3	1	1,900.0
Vinyl Chloride	1	0.002	0.1	1	9.8	3,900.0	0.1	1	3,900.0
Petroleum Hydrocarbons									
C10-C24 (Petroleum - Diesel Range)	2000	2,286.0	1,083.6	2000	3,114.3	2,300.0	35.0	2000	2,300.0
C5-C12 (Petroleum - Gasoline)	300	1,000.0	1,818.0	300	5,224.8	1,000.0	5.2	300	1,000.0
Benzene	1	0.03	1.4	1	94.2	1,900.0	0.01	1	1,900.0
Ethylbenzene	1	0.4	25.9	1	1,545.4	490.0	0.6	1	490.0
Styrene	1	10.1	24,527.2	1	70,491.1	870.0	45.0	1	870.0
Toluene	1	10.3	4,698.8	1	13,504.2	810.0	3.3	1	810.0
Xylenes	5	10.4	2,427.2	5	6,975.6	270.0	1.1	5	270.0
Naphthalene	10	1.2	16.7	10	1,162.1	280.0	0.3	10	280.0
Other Organic Compounds									
1,4-Dioxane	No Standard	0.8	21.6	No Standard	613.3	120,000.0	0.3	No Standard	120,000.0
1,2-Dichlorobenzene	1	1.0	7,760.1	5	22,302.5	380.0	8.6	5	380.0
2,4-Dimethlyphenol	No Standard	8.9	7,078.8	No Standard	20,344.4	24,000.0	42.3	No Standard	24,000.0
Chlorobenzene	1	1.4	1,321.1	1	3,347.4	750.0	0.7	1	
Chloroform	1	0.02	1.4	1	97.3	2,600.0	0.01	1	
Hexachlorobutadiene	1	0.1	5.3	5	293.5	17.0	14.9	5	17.0
Methyl Isobutyl Ketone (MIK)	1	0.5	140,408.0	5	403,532.5	3,400.0	22.1	5	
Methylene Chloride	1	0.2		1	1,420.7	3,300.0		1	3,300.0

Notes:
RWQCB-Approved Cleanup Level for soil
Soil equivalent of RWQCB-Approved Cleanup Level for groundwater
Treatment Standard attains Cleanup Level
Treatment Standard does not attain Cleanup Level
Equivalent Soil Concentrations for Non-Degradation Groundwater Cleanup Level are the Soil Saturation Limit provided in the RWQCB Environmental Screening Level Workbook (January 2019)

bgs = below ground surface
ft = feet
kg = kilogram
mg = milligrams
RAO = remedial action objective
RWQCB = Regional Water Quality Control Board

Table 7
Summary of Soil Treatment Standards
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Constituent	0 to 5 foot interval	5 to 15 foot interval	15 to 55 foot interval	All Depth Intervals
	Soil Treatment Standard (0 to 5 ft bgs) (mg/kg)	Soil Treatment Standard (5 to 15 ft bgs) (mg/kg)	Soil Treatment Standard (15 to 55 ft bgs) (mg/kg)	Soil Saturation Limit (any depth) (mg/kg)
Chloroethanes				
1,1,1-Trichloroethane	1	1	1	650
1,1-Dichloroethane	1	1	1	1700
1,2-Dichloroethane	1	1	1	3000
Chloroethenes				
Tetrachloroethene	1	1	1	170
Trichloroethene	1	1	1	700
1,1-Dichloroethene	1	1	1	1200
cis-1,2-Dichloroethene	1	1	1	2400
trans-1,2-Dichloroethene	1	1	1	1900
Vinyl Chloride	1	1	1	3900
Petroleum Hydrocarbons				
C10-C24 (Petroleum - Diesel Range)	2000	2000	2000	2300
C5-C12 (Petroleum - Gasoline)	300	300	300	1000
Benzene	1	1	1	1900
Ethylbenzene	1	1	1	490
Styrene	1	1	1	870
Toluene	1	1	1	810
Xylenes	5	5	5	270
Naphthalene	10	10	10	280
Other Organic Compounds				
1,4-Dioxane	No Standard	No Standard	No Standard	120000
1,2-Dichlorobenzene	1	5	5	380
2,4-Dimethlyphenol	No Standard	No Standard	No Standard	24000
Chlorobenzene	1	1	1	750
Chloroform	1	1	1	2600
Hexachlorobutadiene	1	5	5	17
Methyl Isobutyl Ketone (MIK)	1	5	5	3400
Methylene Chloride	1	1	1	3300

Notes:
Soil Saturation Limit provided in the RWQCB Environmental Screening Level Workbook (January 2019).

bgs = below ground surface
ft = feet
kg = kilogram
mg = milligram
RWQCB = Regional Water Quality Control Board

EHS Support

Table 8
Confirmation Soil Samples
Remedial Action Plan
Brisbane Parcel B
3775 Bayshore Blvd., Brisbane, CA
Univar Solutions USA Inc.

Confirmation Sample Boring Decision Unit	Sample Depth Intervals (ft bgs)									
	0 to 5 (ft bgs)		5 to 15 (ft bgs)		15 to 55 (ft bgs)					
CSB-01	NS	NS	5-15	NS	15-28	28-42		42-55		
CSB-02	NS	NS	5-15	NS	NS	NS	NS	NS	NS	NS
CSB-03	0-2.5	2.5-5	5-10	10-15	15-23	23-31	31-39	39-47	47-55	NS
CSB-04	0-2.5	2.5-5	5-10	10-15	15-23	23-31	31-39	39-47	47-55	NS
CSB-05	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-06	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-07	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-08	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-09	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-10	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-11	0-2.5	2.5-5	5-10	10-15	15-22	22-28	28-35	35-42	42-48	48-55
CSB-12	0-2.5	2.5-5	5-10	10-15	15-22	22-28	28-35	35-42	42-48	48-55
CSB-13	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-14	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS
CSB-15	0-2.5	2.5-5	5-10	10-15	15-22	22-28	28-35	35-42	42-48	48-55
CSB-16	0-2.5	2.5-5	NS	NS	NS	NS	NS	NS	NS	NS
CSB-17	0-2.5	2.5-5	5-10	10-15	NS	NS	NS	NS	NS	NS

Notes:
ft bgs = feet below ground surface
NS = No Sample

Figures

EHS Support	3745 and 3775 Bayshore Blvd Brisbane, CA	PROPERTY LOCATION MAP	FIGURE 1

Remedial Extent - 0 to 5 ft Below Ground Surface:

Total Area:
22,790 ft^2

Area Underneath Existing Buildings:
16,583 ft^2 / 73%

Area Underneath Hardstand Surfaces:
4,174 ft^2 / 18%

Area Underneath No Hardstand Surfaces:
2,032 ft^2 / 9%

Total Volume:
113,949 ft^3 / 4,220 yd^3

Volume Within Fill:
78,142 ft^3 / 2,894 yd^3 / 69%

Volume Within Young Bay Mud:
35,806 ft^3 / 1,326 yd^3 / 31%

Volume Within Fill Beneath Buildings:
71,627 ft^3 / 2,653 yd^3 / 86%

Volume Within Fill Beneath Hardstand Surfaces:
1,969 ft^3 / 73 yd^3 / 9%

Volume Within Fill Beneath No Hardstand Surfaces:
4,546 ft^3 / 168 yd^3 / 45%

Volume Within Young Bay Mud Beneath Buildings:
11,290 ft^3 / 418 yd^3 / 14%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
18,903 ft^3 / 700 yd^3 / 91%

Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
5,613 ft^3 / 208 yd^3 / 55%

NOTES
ft^2 = square feet
ft^3 = cubic feet
yd^3 = cubic yard
MIP = membrane interface probe
NAPL = non-aqueous phase liquid

The delineation levels are the lowest of the Non-Degradation Soil Cleanup Levels and the Human Health Shallow Soil Cleanup Levels.

NAPL extents are approximated based on the following datasets collected throughout the investigative history for Parcel B: soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and/or MIP responses.

J:\EHS_GIS\C0165I_Brisbane01_ANALYSIS\20220511_SMP\Figs\Soil_Delineation_Figures.mxd

Printed 7/18/2022 11:19:23 AM by Kaitlyn.Buffington

Reviewed by:

EHS Support

3775 Bayshore Blvd
Brisbane, CA

PARCEL B FINAL REMEDIATION EXTENT 0-5 FT BGS

Figure 2

Remedial Extent - 5 to 15 ft Below Ground Surface:

Total Area:
19,174ft^2

Area Underneath Existing Buildings:
13,930 ft^2/ 73%

Area Underneath Hardstand Surfaces:
4,215 ft^2 / 22%

Area Underneath No Hardstand Surfaces:
1,029 ft^2 / 5%

Total Volume:
191,744 ft^3 / 7,120 yd^3

Volume Within Fill:
78,789 ft^3 / 2,918 yd^3 / 41%

Volume Within Young Bay Mud:
112,956 ft^3 / 4,184 yd^3/ 59%

Volume Within Fill Beneath Buildings:
77,212 ft^3 / 2,860 yd^3/ 55%

Volume Within Fill Beneath Hardstand Surfaces:
161 ft^3 / 6 yd^3/< 1%

Volume Within Fill Beneath No Hardstand Surfaces:
1,416 ft^3 / 52 yd^3/ 14%

Volume Within Young Bay Mud Beneath Buildings:
62.092 ft^3 / 2,300 yd^3/ 55%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
41,991 ft^3 / 1,555 yd^3/ > 99%

Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
8,872 ft^3 / 329 yd^3/ 86%

NOTES
ft^2 = square feet
ft^3 = cubic feet
yd^3 = cubic yard
MIP = membrane interface probe
NAPL = non-aqueous phase liquid

The delineation levels are the lowest of the Non-Degradation Soil Cleanup Levels and the Human Health Shallow Soil Cleanup Levels.

NAPL extents are approximated based on the following datasets collected throughout the investigative history for Parcel B: soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and/or MIP responses.

Reviewed by:

EHS Support

3775 Bayshore Blvd
Brisbane, CA

PARCEL B FINAL REMEDIATION EXTENT 5-15 FT BGS

Figure 3

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\2022\0511_SMPFigs\Soil_Delineation_Figures.mxd

Printed 7/18/2022 11:19:25 AM by Kaitlyn.Buffington

Remedial Extent - 15 to 55 ft Below Ground Surface:

Total Area:
7,762 ft^2

Area Underneath Existing Buildings:
7,762 ft^2 / 100%

Area Underneath Hardstand Surfaces:
0 ft^2 / 0%

Area Underneath No Hardstand Surfaces:
0 ft^2 / 0%

Total Volume:
310,496 ft^3 / 11,224 yd^3

Volume Within Fill:
7,439 ft^3 / 276 yd^3 / 4%

Volume Within Young Bay Mud:
303,057 ft^3 / 11,224 yd^3/ 98%

Volume Within Fill Beneath Buildings:
7,439 ft^3 / 276 yd^3/ 2%

Volume Within Fill Beneath Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Fill Beneath No Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Young Bay Mud Beneath Buildings:
303,057 ft^3 / 11,224 yd^3/ 98%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

NOTES
ft^2 = square feet
ft^3 = cubic feet
yd^3 = cubic yard
MIP = membrane interface probe
NAPL = non-aqueous phase liquid

The delineation levels are the lowest of the Non-Degradation Soil Cleanup Levels and the Human Health Shallow Soil Cleanup Levels.

NAPL extents are approximated based on the following datasets collected throughout the investigative history for Parcel B: soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and/or MIP responses.

Reviewed by:

EHS Support

3775 Bayshore Blvd
Brisbane, CA

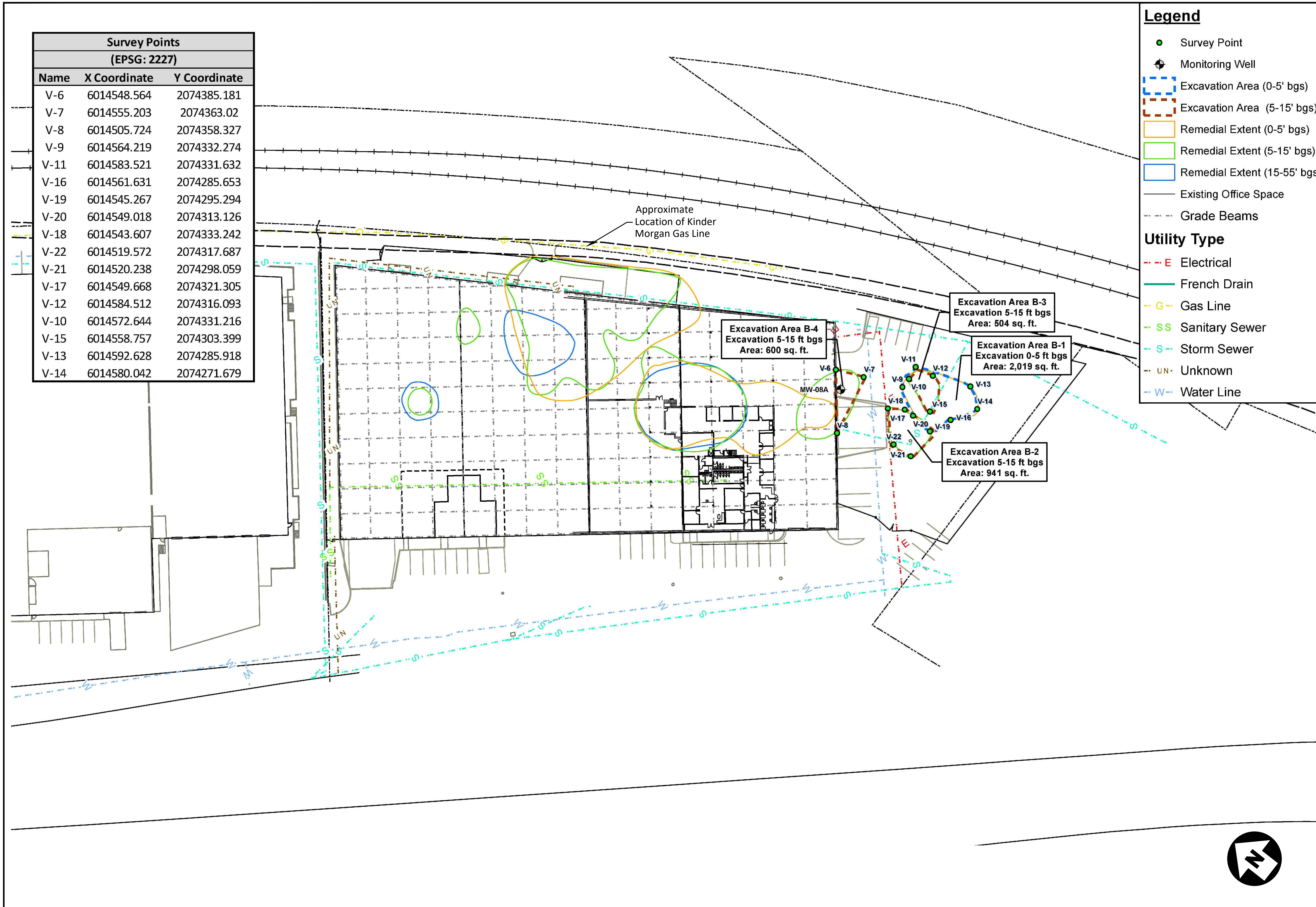
PARCEL B FINAL REMEDIATION EXTENT 15-55 FT BGS

Figure 4

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMPFigs\Soil_Delineation_Figures.mxd

Printed 7/18/2022 11:19:27 AM by Kaitlyn.Buffington

Survey Points		
(EPSG: 2227)		
Name	X Coordinate	Y Coordinate
V-6	6014548.564	2074385.181
V-7	6014555.203	2074363.02
V-8	6014505.724	2074358.327
V-9	6014564.219	2074332.274
V-11	6014583.521	2074331.632
V-16	6014561.631	2074285.653
V-19	6014545.267	2074295.294
V-20	6014549.018	2074313.126
V-18	6014543.607	2074333.242
V-22	6014519.572	2074317.687
V-21	6014520.238	2074298.059
V-17	6014549.668	2074321.305
V-12	6014584.512	2074316.093
V-10	6014572.644	2074331.216
V-15	6014558.757	2074303.399
V-13	6014592.628	2074285.918
V-14	6014580.042	2074271.679



Prepared By: EHS Support

For:

Doc ID:

3775 Bayshore Blvd.
Brisbane, California

Parcel B Excavation Areas
(0 - 15 FT BGS)

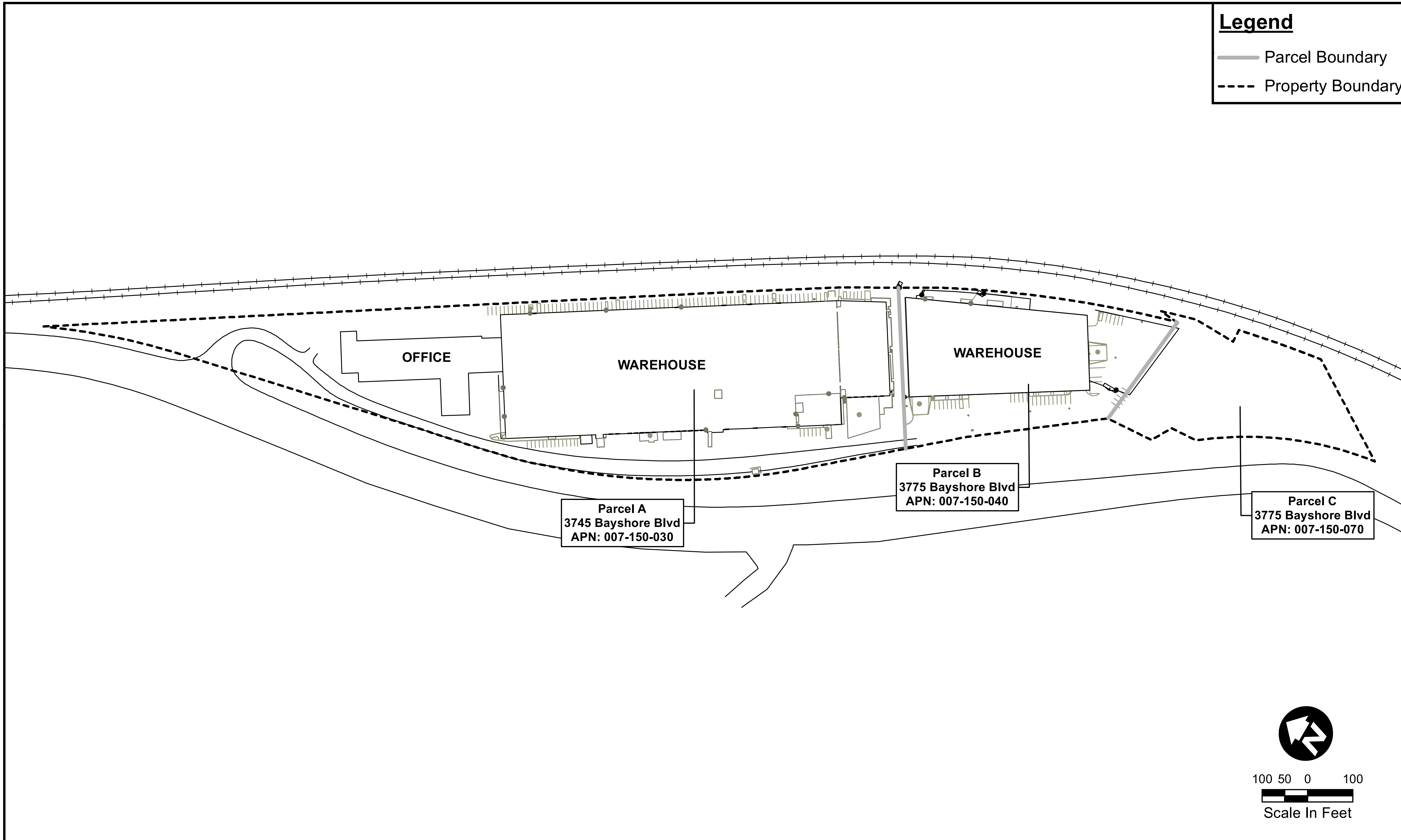
No.	Date	Revisions	By	CHKD
1	12/08/21	Updated Excavation Areas	MDO	JA

Project No.: C01959_2021

Date Drawn: 12/2021

Drawn By: MDO

Figure 5



EHS Support

3745 and 3775 Bayshore Blvd
Brisbane, CA

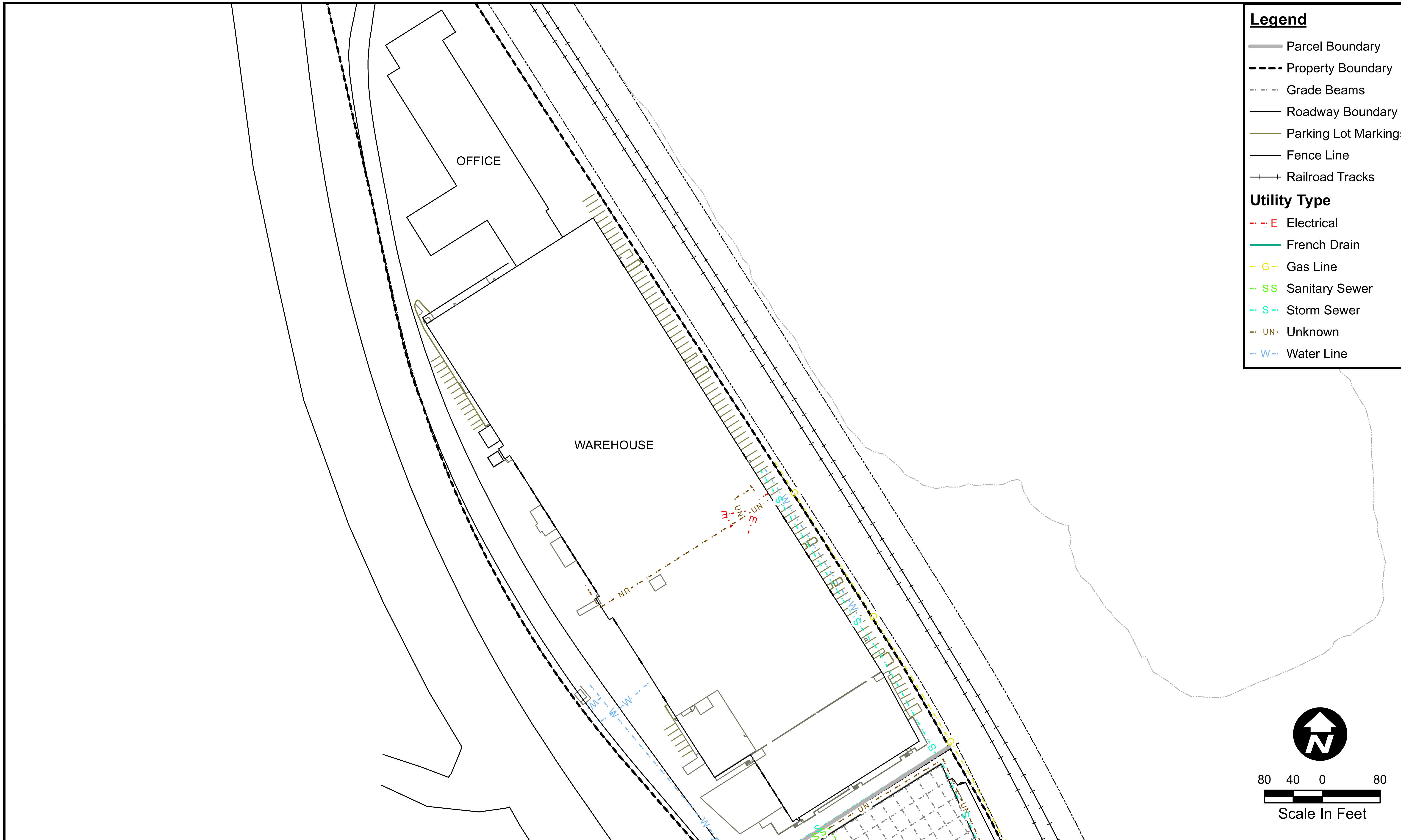
PROPERTY PLAN

FIGURE 6

Reviewed By:

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMPFigs\F002_SitePlan.mxd

Printed 7/18/2022 12:05:04 PM by Kaitlyn Buffington



Reviewed by:

EHS Support

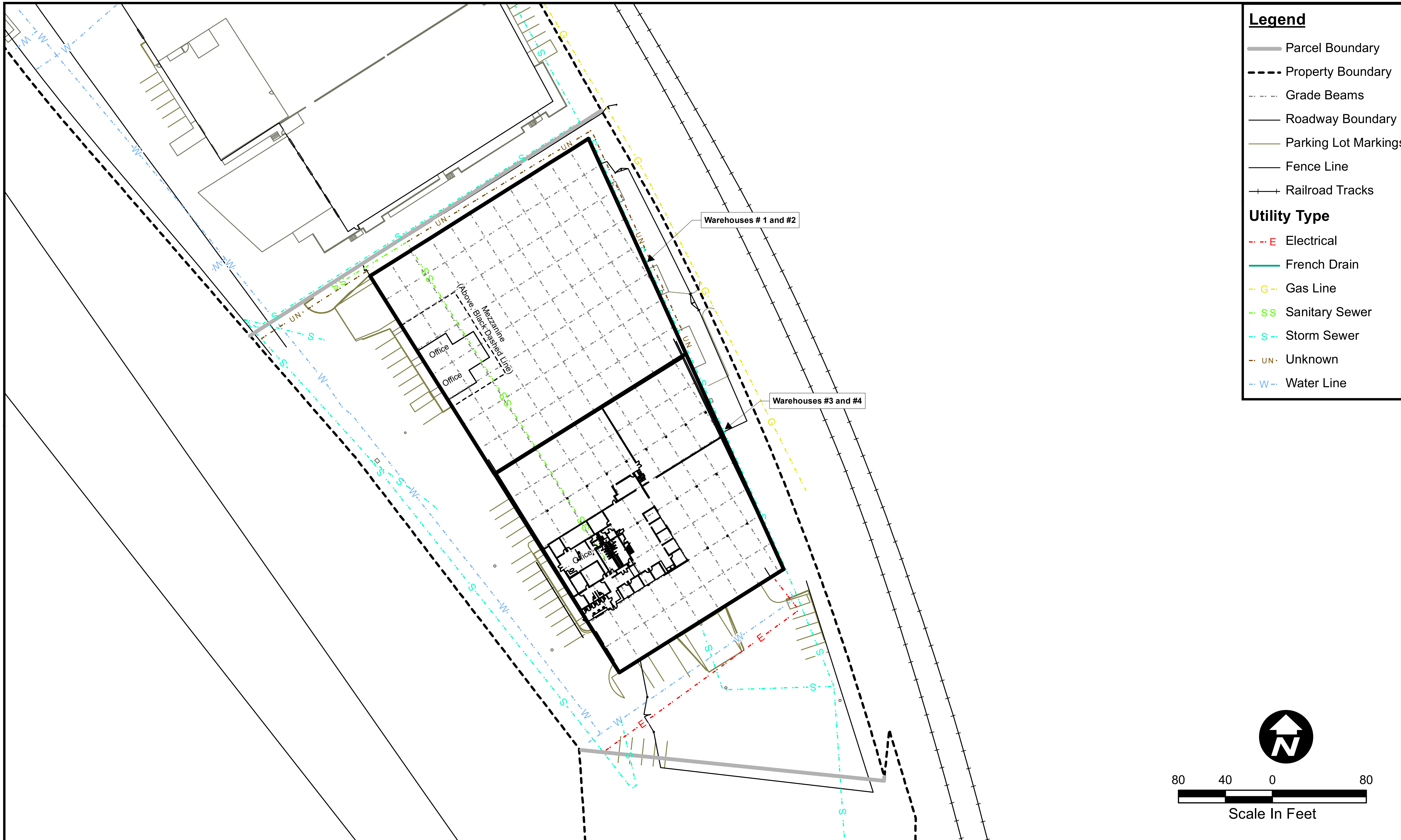
3745 Bayshore Blvd
Brisbane, CA

PARCEL A PLAN

FIGURE 7

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMPFigs\F003_SiteAPlan.mxd

Printed 7/18/2022 12:06:12 PM by Kaitlyn.Buffington



Reviewed by:

EHS Support

3775 Bayshore Blvd
Brisbane, CA

PARCEL B PLAN

FIGURE 8

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMPFigs\F004_SiteBPlan.mxd

Printed 7/18/2022 12:11:45 PM by Kaitlyn.Buffington

Reviewed by:

EHS Support

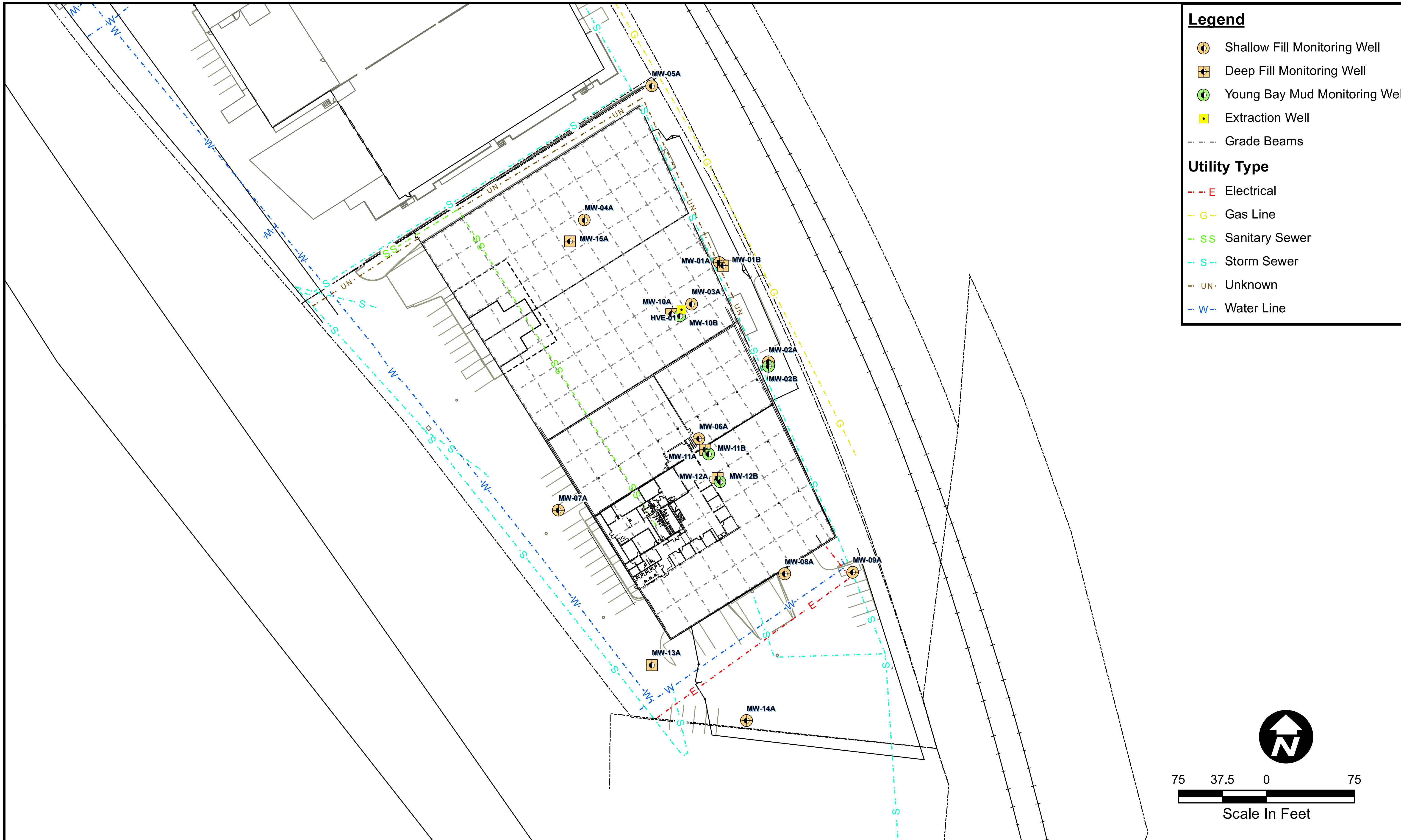
3775 Bayshore Blvd
Brisbane, CA

PARCEL C PLAN

FIGURE 9

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMPFigs\F005_SiteCPlan.mxd

Printed 7/18/2022 12:09:51 PM by Kaitlyn.Buffington



Reviewed by: G. White

EHS Support

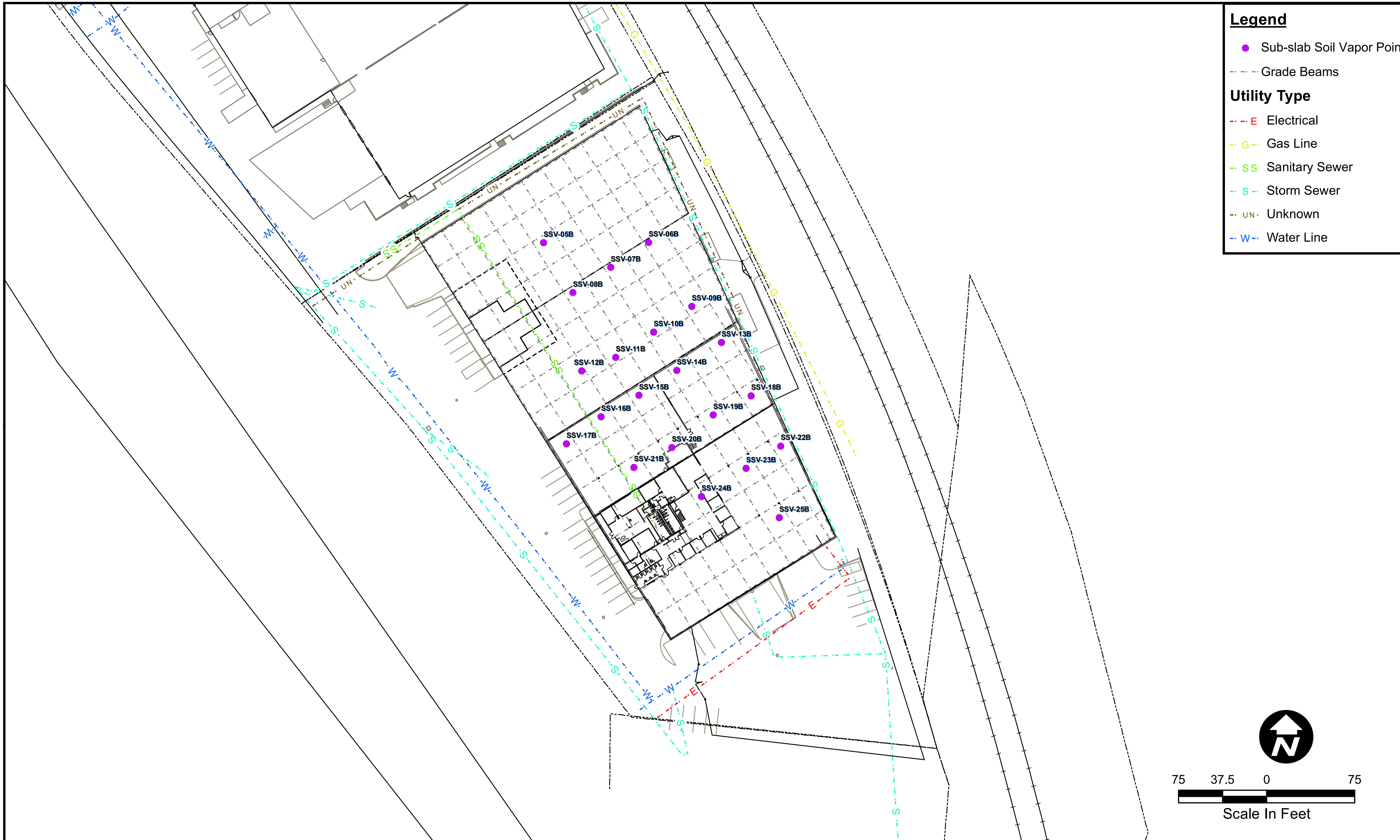
3775 Bayshore Blvd
Brisbane, CA

Groundwater Monitoring Network

FIGURE 10

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20210526_FigureRequest\MonitoringNetwork.mxd

Printed 7/18/2022 12:38:50 PM by Kaitlyn Buffington



Reviewed by: G. White

EHS Support

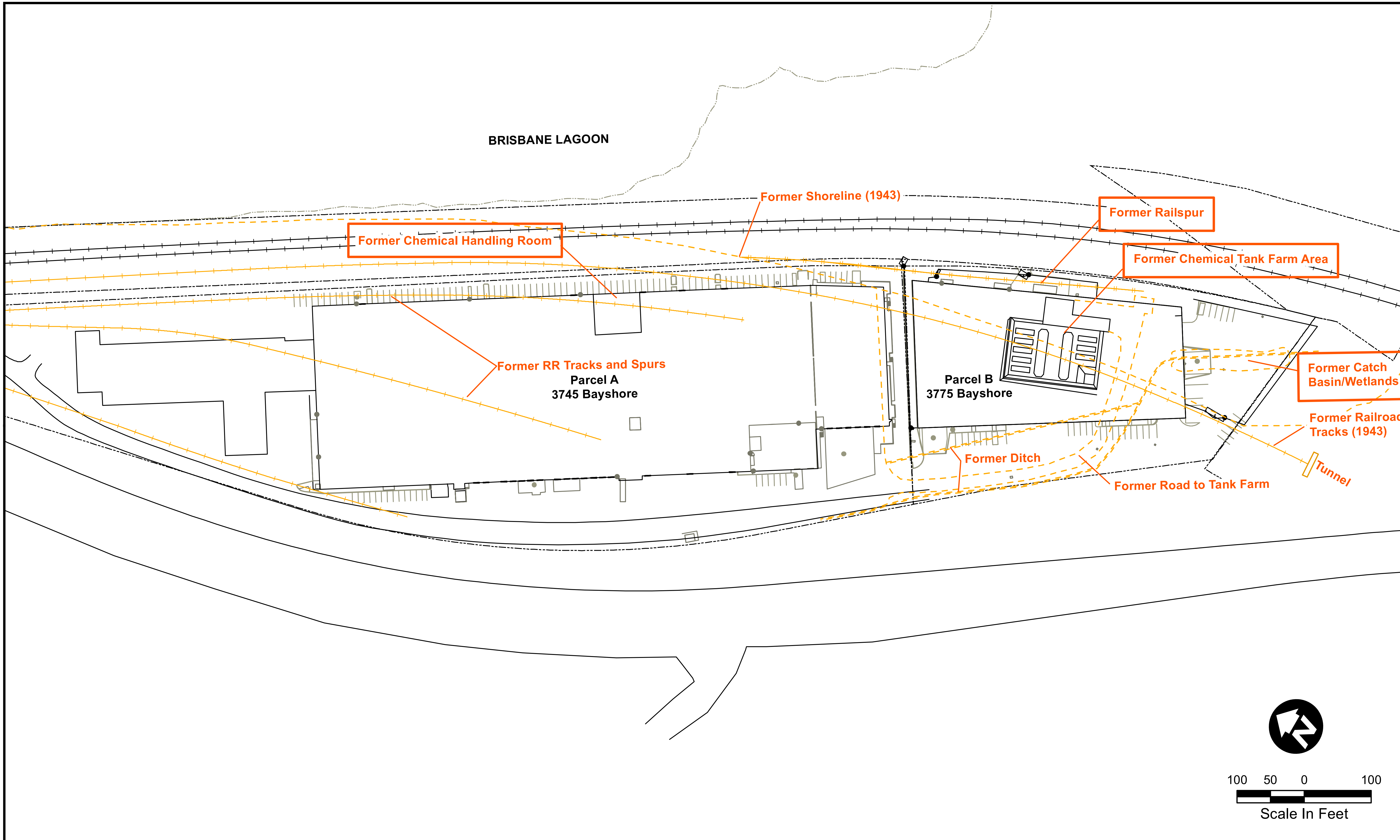
3775 Bayshore Blvd
Brisbane, CA

Sub-Slab Vapor Monitoring Network

FIGURE 11

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20210526_FigureRequest\MonitoringNetwork.mxd

Printed 7/18/2022 12:36:32 PM by Kaitlyn.Buffington



EHS Support

3745 and 3775 Bayshore Blvd
Brisbane, CA

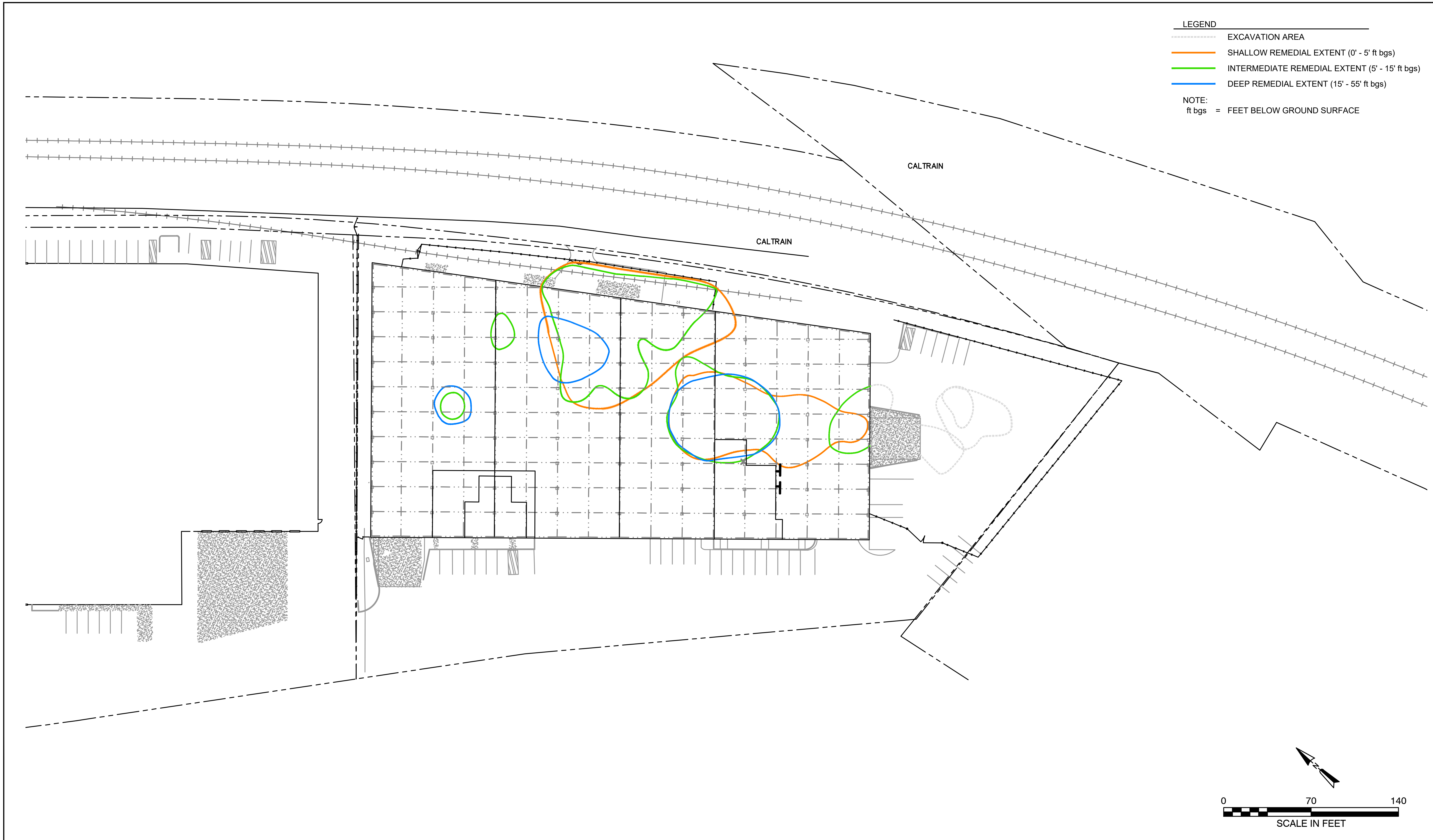
HISTORICAL PROPERTY FEATURES

FIGURE 12

Reviewed By:

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220511_SMP\Figs\F005_SitePlanHistFeats.mxd

Printed 7/18/2022 11:16:48 AM by Kaitlyn.Buffington



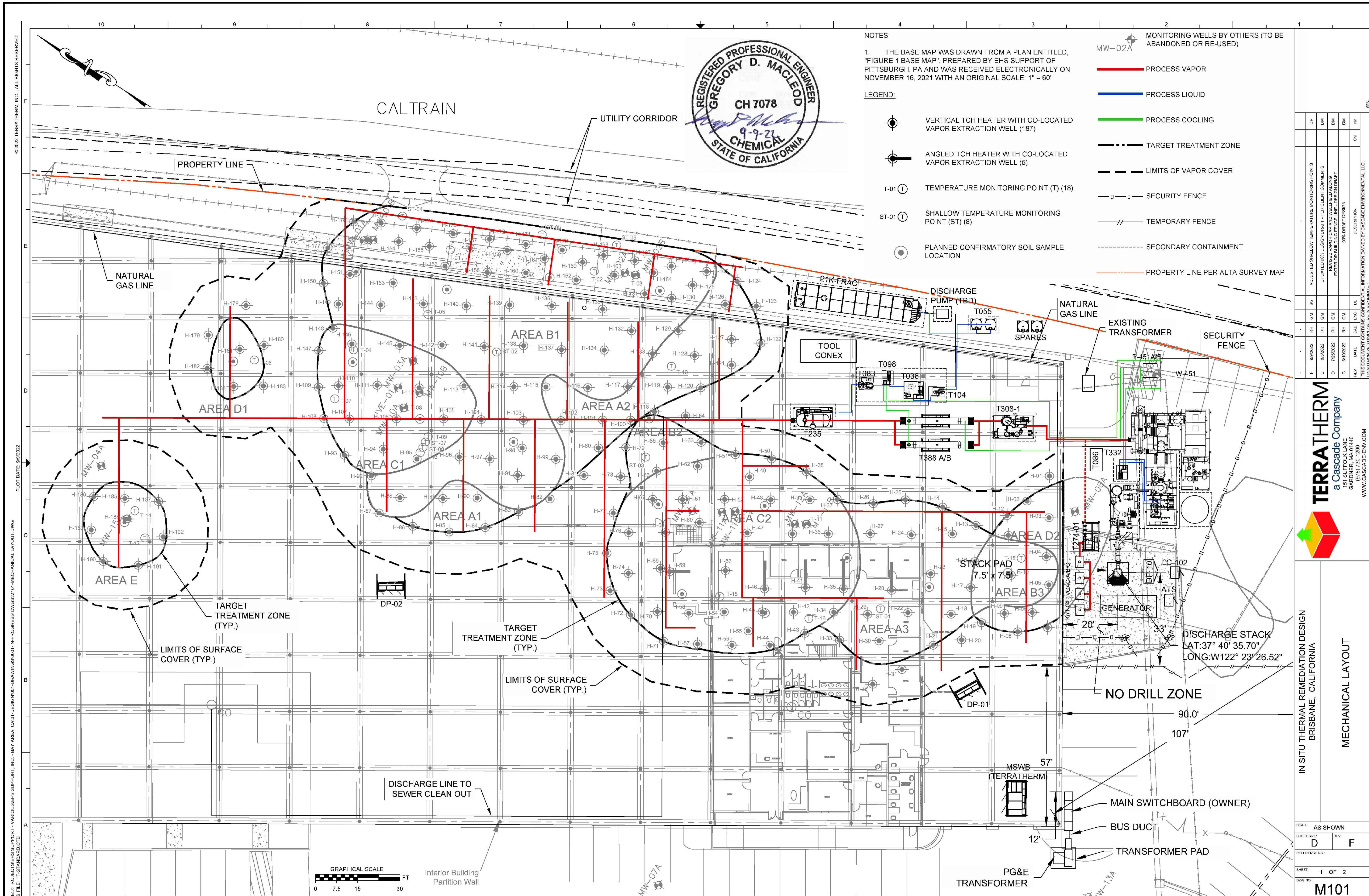
EHS Support

REVISIONS			
Rev.	By:	Disc.:	Date:
Rev.	By:	Disc.:	Date:
Rev.	By:	Disc.:	Date:
Rev.	By:	Disc.:	Date:

3775 BAYSHORE BLVD.
BRISBANE, CALIFORNIA

FIGURE 13
PARCEL B FINAL REMEDIATION EXTENTS 0' - 55'

Drawn By: MDO	Date Drawn: 07/2022
Reviewed By: AP	Date Reviewed: 07/2022
Scale: 1" = 70'	Plot Date: 07/2022
Project Number.: C01651	



Prepared By: EHS Support

For:

Doc ID:

3775 Bayshore Blvd.
Brisbane, California

Thermal Remedy System Layout

No.	Date	Revisions	By	CHKD

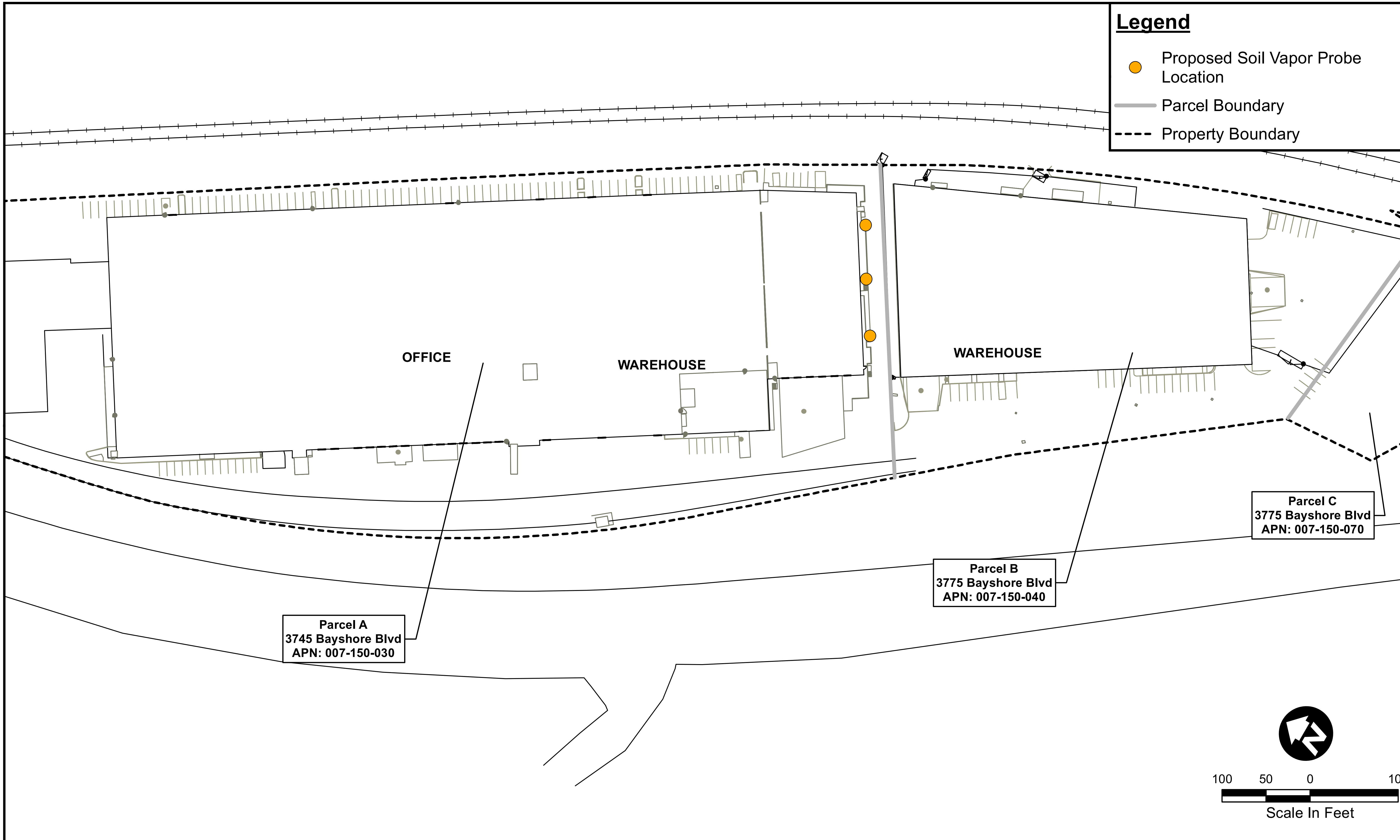
Project No.: C01959_2021

Date Drawn: 09/2022

Drawn By: MDO

Figure 14

Reference:
Figure based from TerraTherm Figure M101
Mechanical Layout, dated 9/9/2022



J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20220720_RAPFigs\SVPs.mxd

Printed 9/9/2022 9:22:01 AM by Mick.Osburn

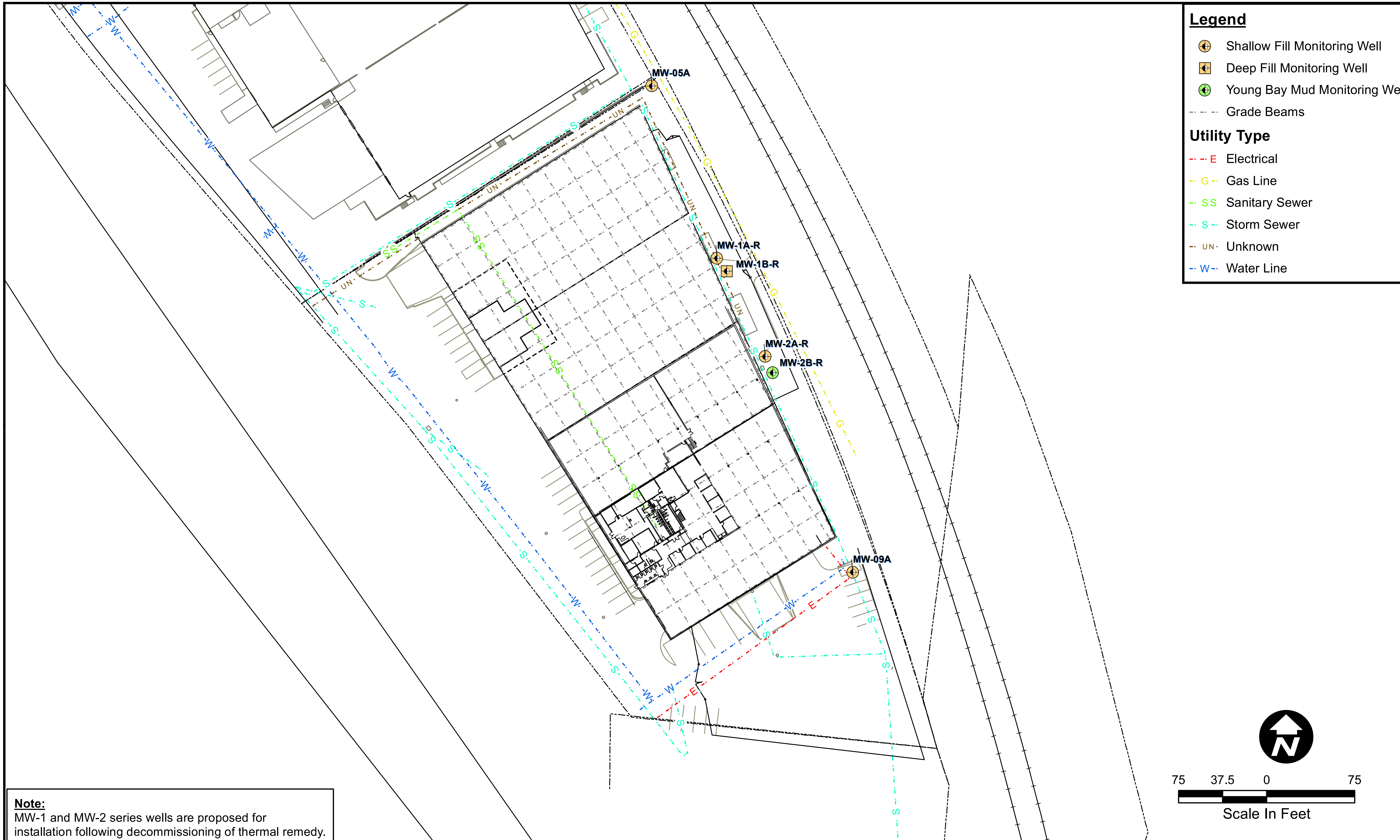
Reviewed By:

EHS Support

3745 and 3775 Bayshore Blvd
Brisbane, CA

SOIL VAPOR BASELINE AND OPERATIONAL MONITORING NETWORK

FIGURE 15



Note:
MW-1 and MW-2 series wells are proposed for installation following decommissioning of thermal remedy.

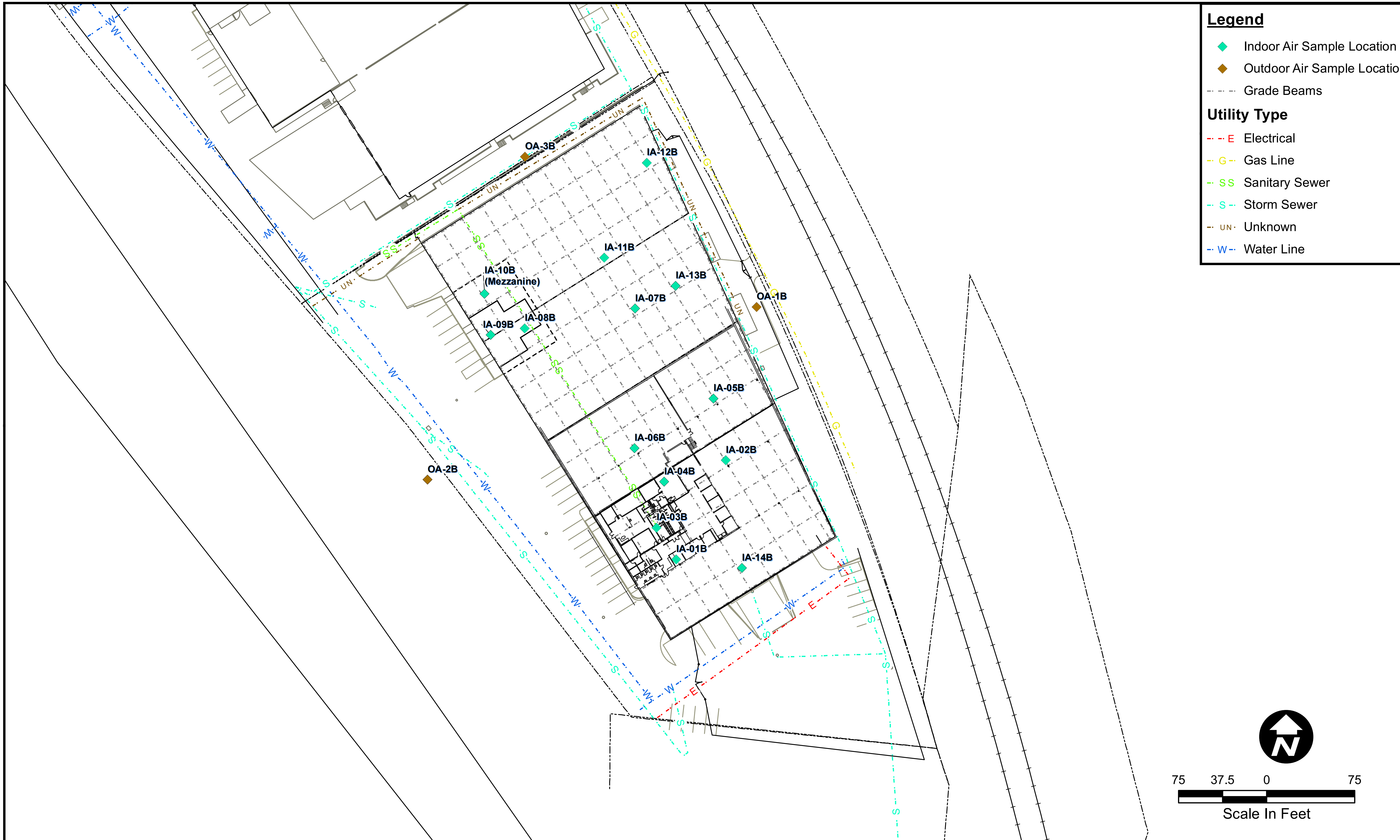
Reviewed by: G. White

EHS Support

3775 Bayshore Blvd
Brisbane, CA

REMEDY VERIFICATION GROUNDWATER MONITORING NETWORK

FIGURE 16



J:\EHSS_GIS\C0165\1_Brisbane\01_ANALYSIS\20220720_RAPFigs\AirSampleLocationsParcelB.mxd

Printed 9/9/2022 9:22:43 AM by Mick.Osburn

Reviewed by: G. White

EHS Support	3775 Bayshore Blvd Brisbane, CA	REMEDY VERIFICATION AMBIENT AIR MONITORING LOCATIONS	FIGURE 17

Appendix A Limited Geotechnical and Structural Study to Support Remedial Decision Making

WJE

FINAL REPORT

Limited Geotechnical and Structural Study to Support Remedial Decision Making

3775 Bayshore Boulevard, Brisbane, CA

Image dated 02/17/2014 provided through Pictometry subscription. Annotations by WJE.

FINAL REPORT

September 9, 2022

WJE No. 2020.1252

PREPARED FOR:

Michelle U. Rosenthal
Veris Law Group
1809 Seventh Avenue, Suite 1400
Seattle, Washington 98101

PREPARED BY:

Wiss, Janney, Elstner Associates, Inc.
2000 Powell Street, Suite 1650
Emeryville, California 94608
510.428.2907 tel

WJE

FINAL REPORT

Limited Geotechnical and Structural Study to Support Remedial Decision Making

3775 Bayshore Boulevard, Brisbane, CA

Michael W. West, P.G. 5947
Principal

Robert C. Kraus, P.E., S.E. 6789
Senior Associate and Unit Manager

Peter A. Stauffer, P.E. (CO, WY)
Principal

PROFESSIONAL GEOLOGIST
MICHAEL W. WEST
No. 5947
STATE OF CALIFORNIA

REGISTERED PROFESSIONAL ENGINEER
ROBERT C. KRAUS
No. S 6789
Exp. 03/31/23
STRUCTURAL
STATE OF CALIFORNIA

FINAL REPORT

September 9, 2022

WJE No. 2020.1252

PREPARED FOR:

Michelle U. Rosenthal
Veris Law Group
1809 Seventh Avenue, Suite 1400
Seattle, Washington 98101

PREPARED BY:

Wiss, Janney, Elstner Associates, Inc.

CONTENTS

EXECUTIVE SUMMARY

The Brisbane property is located at 3745 and 3775 Bayshore Boulevard in Brisbane, California. Parcel A occupies the north two-thirds of the property and Parcel B occupies the southern third. WJE was retained to assess certain engineering considerations for the Brisbane property focused on Parcel B. This report evaluates the potential for conceptual soil remediation activities to affect existing structures on Parcel B. Although this executive summary is provided for the convenience of the reader, it should be read in conjunction with the body of the report.

Subsurface conditions at Parcel B, from the ground surface to a depth of about 100 feet, consist of imported fill, Young Bay Mud (YBM), Old Bay Mud (OBM), and bedrock. The ground surface over much of Parcel B is at approximately Elevation ten feet above mean sea level (AMSL), and the existing groundwater table is about five feet below the ground surface (bgs). The warehouse at Parcel B is a one-story building that was constructed in 1980. The building has wood roof framing, precast concrete walls, and a reinforced concrete slab with grade beams that are supported by precast concrete piles.

WJE evaluated the effects on the structure from two conceptual soil remediation techniques: soil excavation and in-situ thermal heating. Soil excavation remediation would involve removal of fill materials and underlying YBM in two areas, one to the east of the Parcel B warehouse, and one to the south. In-situ thermal heating remediation would involve heating soils to at least 100°C in select areas below and near the Parcel B warehouse footprint. As of the date of this report, we understand that both the thermal remediation and excavation scenarios have been selected for further development and implementation at the site.

The potential for the soil remediation concepts to affect the structure varies. WJE performed geotechnical engineering calculations to estimate magnitudes of ground movement and resulting pile down-drag forces (i.e., downward forces acting on the piles that result from the settlement of the soil that surrounds the piles) associated with the remediation concepts, and the capacities and stiffnesses of the piles in resisting these down-drag forces and horizontal movement. WJE also developed a structural engineering analysis model of the slab and grade beam system to evaluate the effects of the in-situ thermal heating on the slab and grade beam structure. The effects on the above-slab structure and the site utilities were evaluated on an empirical basis.

Geotechnical and structural engineering evaluations provided in this report are based on preliminary design documents for these remediation scenarios, as listed in detail below. Where appropriate, reasonable and conservative assumptions have been incorporated in these analyses to address uncertainty associated with subsurface conditions and the existing warehouse structure.

Soil Excavation

Based on our evaluation, soil excavation activities should not result in significant ground settlement or downward movement of the piles near the excavations. Since negligible settlement is predicted as a result of potential soil excavation remediation activities, no meaningful flexural cracking or strength changes in the existing Parcel B warehouse would be expected.

<u>In-situ Thermal Heating</u>

In-situ thermal heating remediation could result in total settlements between 0.3 and 17 inches, and down-drag forces between 14 kips and 87 kips, depending on the depth of treatment at a given location. In-situ thermal remediation treatment would cause combined down-drag forces and thermal expansions of the piles, slab, and grade beams that would likely result in differential vertical and horizontal displacements. Slab cracking would likely occur, and the design strength of the slab and multiple piles would be exceeded, but these elements would likely not fail. Piles, and portions of the slab and grade beam close to the heating elements could potentially lose some strength, and most of the piles are likely to be cracked due to the horizontal thermal expansion of the slab. Evaluation of the adequacy of the post-remediation condition of the structure to resist future design loads would likely be appropriate. The settlements due to the in-situ thermal heating concepts would likely damage the various underground site utilities in close proximity to the thermal heating remediation areas.

To support the thermal remediation scenario, we recommend additional investigation work as well as various forms of data collection, sampling, and surveying be performed, prior to, during, and subsequent to the remediation. A schematic description of many of these recommendations can be found in Appendix V. Details of these recommendations will be provided in a separate implementation plan document at a later date for review and discussion among project stakeholders.

INTRODUCTION

The Brisbane property at 3745 and 3775 Bayshore Boulevard is located west of the southern end of Brisbane Lagoon, in Brisbane, California (Figure 1 and 2). The property is bounded by railroad tracks to the east, Bayshore Boulevard to the west and south, and the lagoon to the north. Parcel A occupies the north three-quarters of the property and Parcel B occupies the southern quarter. In the early 1960s, an approximately 225,000-square-feet concrete warehouse and several office buildings were constructed on Parcel A, and an above-ground tank farm and other ancillary facilities were constructed on Parcel B. In 1980, the tank farm and other facilities were removed and a one-story, approximately 80,000-square-feet warehouse was constructed on Parcel B.

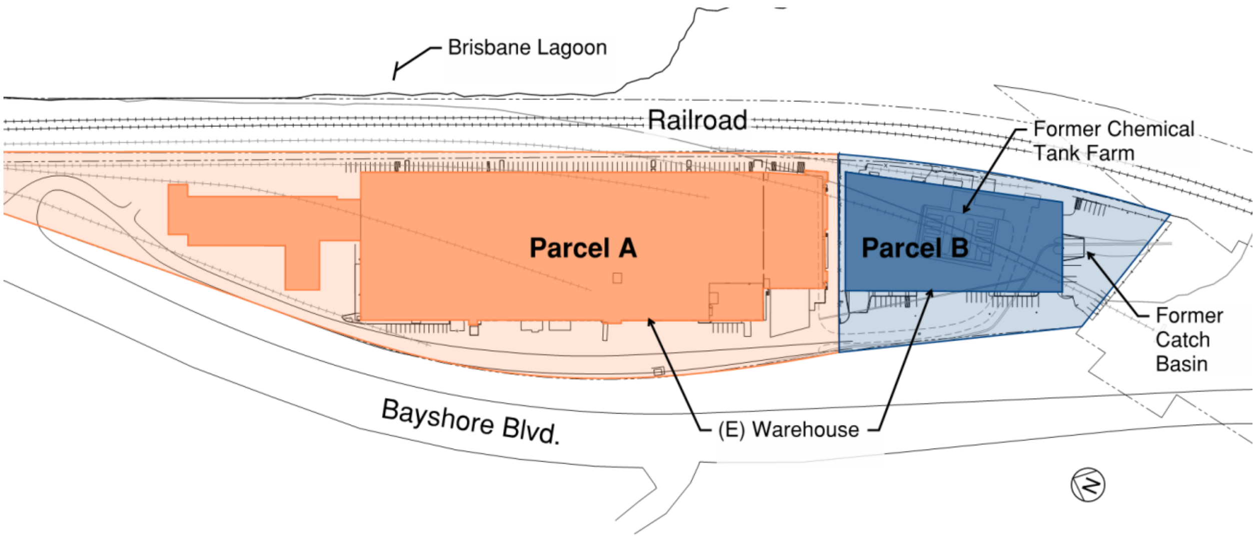


Figure 1. Brisbane property site plan.

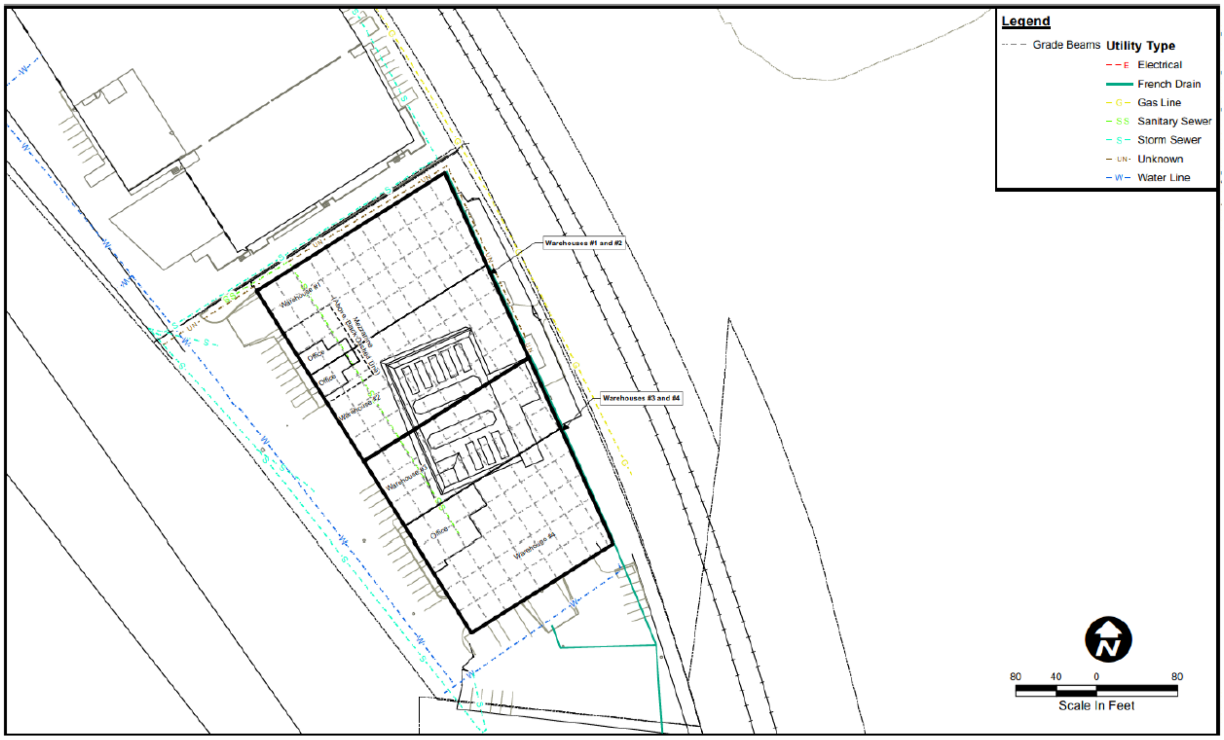


Figure 2. Parcel B site plan (Veris, February 17, 2020)

WJE was retained to assess certain engineering and redevelopment considerations related to two different conceptual soil remediation techniques that are being considered for the Brisbane property, soil excavation and in-situ thermal heating. Mr. Greg White, PG, with EHS Support (EHS) of Geneva, Illinois has provided input and support during our assessment.

This report evaluates the potential for conceptual soil remediation activities to affect the existing structure on Parcel B. The report provides a summary of documents reviewed, a brief description of the site conditions, a summary of the two conceptual remediation techniques being considered, followed by our engineering evaluation of the remediation techniques and how they could affect the Parcel B improvements. A risk assessment matrix summarizing the potential impacts of the thermal remediation scenario as well as recommended mitigation and data collection measures is also included as an appendix to this report.

DOCUMENT REVIEW

WJE reviewed the following documents provided by EHS:

- *Soil and Foundation Investigation, Brisbane Warehouse* by R.C. Harlan and Associates, dated September 7, 1979;
- *Report of Pile Installation* by R.C. Harlan and Associates, dated May 22, 1980;
- Portions of *Revised Draft On-Site RIDSR* by ERM, selected figures and tables, and Appendices A and B, Project 2015.11.05;

- Portions of *Data Gaps Investigation Report* by EHS: CPT Data, Figures, Tables, Appendix B - Boring Logs, Appendix D - High Resolution Site Characterization (HRSC) and Cone Penetration Testing (CPT) Investigation, Appendix J - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated July 5, 2017, Appendix K - Groundwater Step Test Analysis - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated July 25, 2017, and Appendix L - Constant Rate Pumping and Recovery - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated October 20, 2017;
- Figures 10, 11, and 12, 3775 Bayshore Blvd, Brisbane, CA, Estimated Remedial Extent for depth intervals of 0-5 ft bgs, 5-15 ft bgs, and 15-55 ft bgs, EHS, May 25, 2021.
- *Data Compilation Regarding Geotechnical and Structural Effects of Subsurface Heating* by TerraTherm®, July 1, 2010;
- *Removal of PCE DNAPL from Tight Clays Using In Situ Thermal Desorption*, Heron, G., Lachance, J., and Baker, R., Groundwater Monitoring & Remediation 33, Fall 2013;
- *Confidential Bay Area Site, Brisbane, CA, Preliminary Site Evaluation, Revision 5*, TerraTherm®, June 1, 2021.
- Six sheets of construction drawings of the Parcel B warehouse by E.L. Engineering, variously dated from February and March 1979;
- Two sheets of construction drawings of the Parcel B warehouse by E.L. Engineering, and stamped "approved" on December 4, 1979;
- Hand sketches of the slab-on-ground and grade beam system, on E.L. Engineering letterhead, dated August 15 and 16 (no year);
- Historical aerial photographs;
- Interior photographs of the Parcel A and Parcel B warehouses; and
- Additional pdf's containing various project related documents.

To supplement the information provided by EHS, WJE performed limited independent research to identify additional references related to site conditions as well as various aspects of the site remediation activities that are being considered for the Parcel B site. A list of additional references is provided at the end of this report.

PARCEL B SITE CONDITIONS

The site conditions described below are based on a document review leveraging geologic data garnered from previous environmental and geotechnical evaluations and available building plans. WJE visited the site on July 21, 2021, and briefly observed conditions in and around the warehouse. WJE returned to the site at various times since then to meet with EHS, observe the site conditions, and take core samples from exposed piles.

Subsurface conditions at Parcel B, from uppermost to lowermost, consist of imported fill that is approximately 5 to 35 feet thick; Young Bay Mud (YBM) ranging from approximately 25 to 45 feet thick, thickening to the northeast toward Brisbane Lagoon; Old Bay Mud (OBM); and bedrock. We understand that the ground surface over much of Parcel B is at approximately Elevation 10 feet AMSL, and the existing groundwater table is about five feet below the ground surface (bgs). We expect that the groundwater table will fluctuate with the tide and with the water level in Brisbane Lagoon. A summary of field and laboratory test results for subsurface materials encountered during the geotechnical investigation completed for the Parcel B warehouse (Harlan, 1979) is provided below.

Table 1 - Summary of Field and Laboratory Test Results - Harlan, 1979

Material	Statistic	SPT Blows/foot (corrected)	Moisture Content, %	Dry Density, pcf	Unconfined Compression Strength, psf	Undrained Unconsolidated Strength (Triaxial), psf
Fill	Average	23	17.1	105		2280
	Min	5	10.6	86		
	Max	50	25.5	117		
	St. Dev	15	5.7	12		
	No. of occurrence	11	5	5		1
Young Bay Mud	Average	7	58.1	67	443	
	Min	4	29.7	55	210	
	Max	13	77.5	90	860	
	St. Dev	3	18.0	13	359	
	No. of occurrence	5	6	6	4	
Old Bay Mud	Average	30	23.3	100	2340	
	Min	17	12.8	92	1360	
	Max	40	31.0	106	2850	
	St. Dev	8	6.8	6	601	
	No. of occurrence	11	9	9	5	
Sandstone	Average	>50	17.8	110		
	Min	50	9.1	98		
	Max	>50	26.4	121		
	St. Dev		12.2	16		
	No. of occurrence	5	2	2		

Notes

1. SPT blow counts presented represent "corrected" values to take into account the California Modified sampler used in the field.

2. One direct shear test was completed in the Old Bay mud in boring 11 at 65 feet bgs.

3. Three consolidation tests were completed in the Young Bay mud in boring 1 at 8 and 22 feet bgs and boring 2 at 24 feet bgs.

Available cone penetration test (CPT) results were also relied on to characterize the stratigraphy and engineering properties of subsurface materials. In general, the field and laboratory test results summarized in Table 1 are consistent with CPT results.

The imported fill materials are thickest in the area where the tank farm was previously located, in the central portion of the Parcel B warehouse. The fill appears to have been placed at different times during the development of the site and is variable in terms of its soil composition and relative consistency. In general, the fill is a dense-to-very-dense silty and clayey gravel and sand. The lower fill materials in some areas are mixed with the underlying YBM.

The YBM consists of soft, saturated sediments that were deposited in the San Francisco Bay estuary less than 10,000 years ago. YBM generally consists of light gray to black silty clay with interbeds of sand, shell, and peaty mud. Because of its consistency, YBM is known to flow laterally toward channels and sloughs, into excavations, and in some instances, toward gentle slopes where loads are placed unevenly (McDonald, Nichols, Wright, and Atwater, 1978). Typically, YBM will not liquefy during earthquakes, although thin sand layers within the YBM generally have a high potential for liquefaction (Youd et al., 1975).

The YBM is underlain by OBM, which is also composed of clay sediments, but with somewhat higher sand content than the YBM. The OBM has notably lower water content than the YBM, with a medium stiff to hard consistency. The concrete piles of the Parcel B warehouse were driven into the OBM to develop their load capacity.

Two of the geotechnical borings completed for the Parcel B warehouse geotechnical investigation encountered sandstone bedrock at about 85 feet deep (Harlan, 1979).

Below Parcel B, the potentiometric groundwater surface in the shallow fill typically ranges from about 7 to 4 feet above mean sea level, sloping from southwest to northeast toward the lagoon. The potentiometric groundwater surface in the YBM in the vicinity of the prior tank farm slopes down to the east (ERM, 2015).

PARCEL B STRUCTURE DESCRIPTION

The Parcel B warehouse is a one-story building constructed in 1980. The building is trapezoidal in plan, and extends approximately 400 feet north-south, 220 feet east-west at the north end, and 165 feet at the south end (Figure 3). Based on the limited information available, the building is approximately 28 feet tall. The structure consists of a wood-framed roof supported by interior tube-steel columns and precast concrete perimeter walls. The walls and columns are supported by a 12-inch-thick, reinforced concrete structural slab and a system of grade beams (18 inches wide by 30 inches deep north-south and 16 inches wide by 18 inches deep east-west) that are founded on 12-inch-square precast, prestressed, driven concrete piles. The typical building gridlines, with which most columns, roof framing, and walls are aligned, are spaced 20 feet apart east-west and 50 feet apart north-south. The grade beams are aligned with the gridlines. An additional line of north-south grade beams is present between each east-west gridline, such that the typical grade beam spacing is 20 feet east-west and 25 feet north-south. A single pile is typically located under each grade beam intersection. The building is divided into separate warehouse spaces by east-west tenant partition walls. At the west perimeter wall, there are office areas, and above each office space is a mezzanine with additional offices.

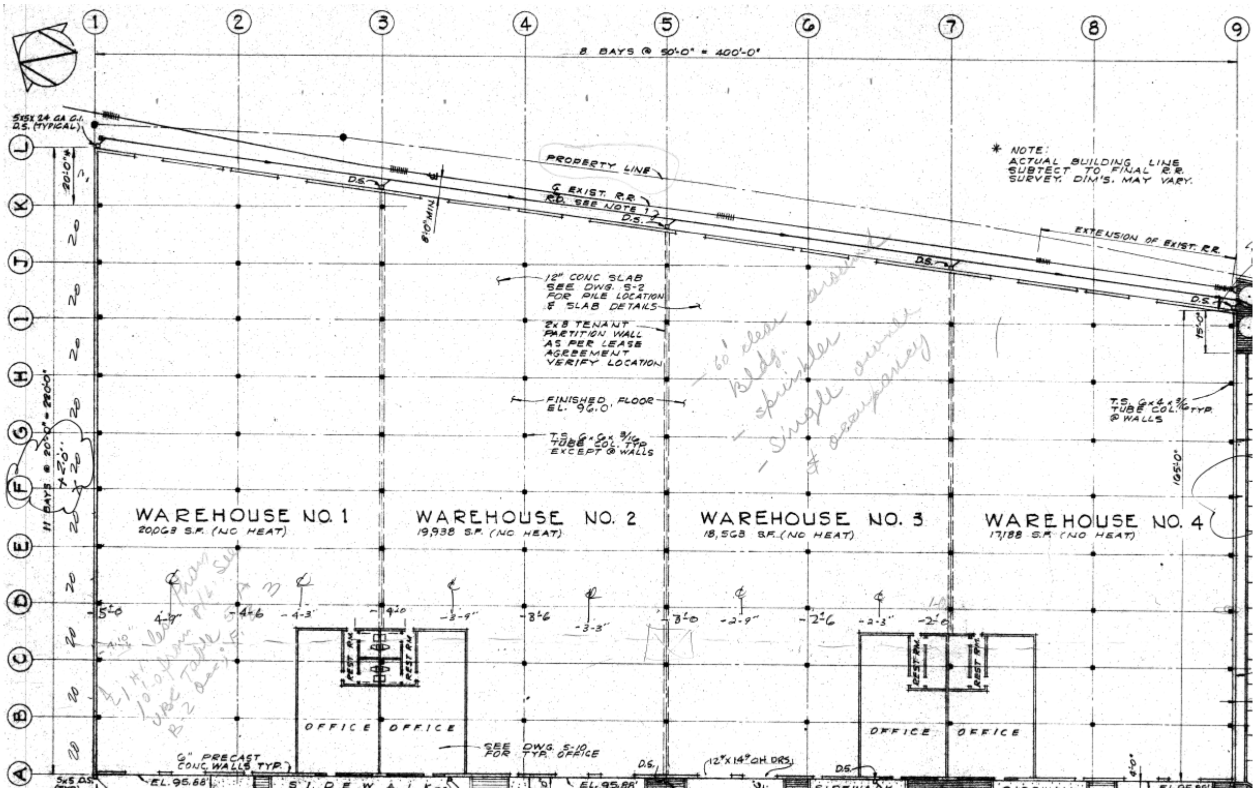


Figure 3. Plan view of Parcel B warehouse (from sheet S-3 of September 4, 1979 drawing by E.L. Engineering)

The structural information we reviewed included typical properties, such as slab thickness, select grade-beam dimensions, select longitudinal reinforcing bar sizes and distributions, pile sizes, allowable pile soil capacities, and number of as-built piles. During our evaluation of the two remediation scenarios, described below, the provided documents generally did not include concrete and reinforcement strength(s), wall or pile reinforcement information, roof framing sizes and layouts, structural detailing, or information regarding utility configuration beyond the horizontal layout of the utilities.

DESCRIPTION OF CONCEPTUAL REMEDIATION TECHNIQUES

The two conceptual remediation techniques that EHS selected for WJE to evaluate are described below. They were selected for analysis by EHS because of potential settlement and/or structural effects associated with them. We understand that other remediation techniques may be considered by EHS; however, they are not the focus of this evaluation. Additional details pertaining to these conceptual remediation scenarios for purposes of this analysis are provided in Appendix I. These conceptual remediation techniques may be implemented individually or in combination. The remedy assumptions provided in Appendix I and included in this section were relied upon for the purposes of the geotechnical and structural analyses of the given remediation scenarios. Should the final remediation technique differ significantly from these assumptions, the applicability of these evaluations should be reviewed.

- Soil Excavation. The soil excavation remediation scenario would involve removal of fill materials and underlying YBM in two areas, one to the east of the Parcel B warehouse and one to the south.

The conceptual excavation on the east side is rectangular and is approximately 4,000 square feet in plan area—extending approximately 135 feet along the central portion of the east side of the building and extending eastward 30 feet from the warehouse building (Appendix I). The conceptual excavation extends to within approximately 40 feet of the existing railroad lines that bound the east side of the property.

The conceptual excavation on the south side of the warehouse would be about 3,700 square feet in area—roughly 50 feet east-west and extending 75 feet from the south side of the building.

Both the east excavation and the south excavation would be approximately 15 feet deep, extending a maximum of approximately 10 feet into the underlying YBM. Fill materials would be dewatered during the excavation construction activities. Following completion of the excavations, the areas would be backfilled with engineered fill and construction dewatering would cease.

- In-Situ Thermal Heating. The in-situ thermal heating scenario, also referred to as in-situ thermal desorption, would involve heating subsurface soils to at least 100°C within the planned remedial treatment areas. We understand that the thermal conductive heating scenario has been selected for further development by TerraTherm. Heating elements would be placed in vertical borings throughout the treatment areas, spaced apart by about 10 to 15 feet. To attain the target soil temperature of 100°C and meet the treatment objectives, the soil temperatures in the immediate vicinity of the heating elements may be as high as 400°C. In the course of heating the soil, the warehouse slab, grade beams, and any piles within the heated zone would also be heated to similar temperatures. Steam created by the heating process would be removed using vacuum extraction wells. The depth of treatment would extend from 0 to 5 feet bgs throughout approximately 9,993 square feet, from 5 to 15 feet bgs throughout approximately 12,947 square feet, and from 15 to 55 feet bgs throughout approximately 7,846 square feet within and adjacent to the warehouse (Appendix I). We understand the in-situ thermal heating remediation treatment would be performed over a period of approximately 180 days followed by a 12- to 16-month cooling period before subsurface temperatures return to ambient conditions.

GEOTECHNICAL ENGINEERING EVALUATION METHOD

WJE performed geotechnical engineering calculations to estimate the magnitude of ground settlement, the resulting pile down-drag forces that result from downward skin friction forces mobilized during ground settlement (Figure 4), and the load capacity and stiffness of the piles in resisting down-drag forces and horizontal displacements, and to assess other impacts that could occur as a result of the two conceptual remediation techniques. Down-drag forces act on the piles and are created as a result of settlement of soil that surrounds the piles, the skin friction between the pile and the settling soil results in a downward force acting on the pile. A brief description of the calculation methods follows.

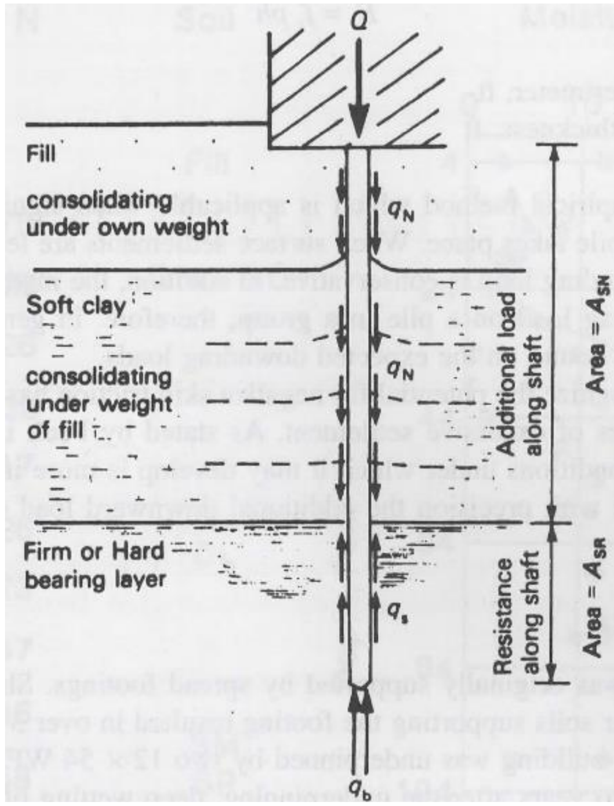


Figure 4. Excerpt from *R. Whitlow, Basic Soil Mechanics, Longman Scientific & Technical, Burnt Mill Harros* (1995)

Settlement of Fill

WJE estimated settlements in the fill resulting from in-situ thermal heating. Based on our review of field test results summarized below (Figure 5), we believe the fill materials would drain, and thereby settle relatively quickly for the in-situ thermal remediation scenario.

Soil Zones	No. of Wells	K ft/day	K gpd/ft²	K cm/sec
Median of Slug Test Results				
Shallow Fill	9	4.4	32.9	1.6E-03
Deep Fill	5	7.1	88.0	4.2E-03
Bay Mud	4	0.01	0.1	5.9E-06
All Wells	18	1.8	13.7	6.5E-04
Step Test Results				
Shallow Fill	2	4.4	33.0	1.6E-03
Constant-Rate Test Results				
Shallow Fill	5	8.7	64.6	3.0E-03
Deep Fill	5	12.6	94.0	4.4E-03
Consolidated	10	4.8	35.6	1.7E-03

Figure 5. Excerpt from *Constant Rate of Pumping and Recovery - Univar/Brisbane Aquifer Pumping Test* report (EHS, July 25, 2017)

The higher permeability (provided as "K" in Figure 5) of fill materials is consistent with the granular nature of the fill materials (sand and gravel) encountered in borings completed at the site.

In-situ thermal heating would reduce the pore water pressure in the existing fill materials, thereby resulting in an increase in the effective stress. An increase in effective stress would cause settlement. Settlement of the fill was estimated using the following relationship (Schmertmann, 1970):

$$\Delta H = \Delta q * \Sigma [(I_z * \Delta z) / E_s]$$

where:

ΔH = settlement

Δq = change in water pressure

I_z = Boussinesq coefficient: assumed to be 1.0, considering areal extent of dewatering

Δz = thickness of layer

E_s = deformation modulus estimated from N values obtained in the fill

The estimated magnitude of settlement will depend on how much the pore water pressure is reduced, and the thickness of the fill that is heated. Estimates of the ranges of settlements likely to occur were made based on the range of fill thicknesses indicated on the hydrogeological cross sections prepared by EHS (Appendix II).

Settlement of Young Bay Mud

We also evaluated the potential settlement effects of the YBM resulting from in-situ thermal treatment. Where the fill materials are treated by in-situ thermal heating, pore water pressures in the fill and at the top of the YBM would be reduced. This would effectively induce drainage of the upper YBM. Because of the limited duration of thermal treatments, settlement would be less than what would occur if the thermal heating were to continue for a longer period. WJE estimated the settlements that would occur in the YBM during the 180-day treatment period based on documented estimates of the settlement time for various thicknesses of YBM and for different drainage conditions (USACE, 2015).

A case study at a site near San Francisco where thermal conduction heating of YBM was implemented indicates that effective remediation was achieved without completely dewatering the subsurface clays (Heron et al., 2013). Applying this finding to conditions at Parcel B, we have estimated that the pore water pressures in the thermally treated YBM would be reduced to approximately one-half of the pre-treatment pore water pressures. The settlement that is induced in the YBM by the in-situ thermal heating of the YBM would occur as the pore water pressures are reduced during the approximate 180-day treatment period.

Reduction in the pore water pressure would increase the effective stress in the YBM. The settlement likely to occur in the YBM as a result of the change in effective stress was estimated using the following relationship:

$$S = \Sigma\ [C_c/(1+e_0)*H*LOG_{10}((\sigma_{vo}'+\Delta\sigma)/\sigma_{vo}')]$$

where:

S = settlement
C_c = compression index (Harlan, 1979)
e_0 = initial void ratio (Harlan, 1979)
H = thickness of layer
σ_{vo}' = initial effective stress
$\Delta\sigma$ = change in effective stress, change in water pressure that results from dewatering or in-situ thermal treatment

The amount of settlement would vary depending on the magnitude of the reduction in pore water pressures, and the thickness of the YBM within which water pressures are reduced. Settlement calculations were performed to estimate the ranges of settlements likely to occur considering our understanding of the subsurface conditions at the site and the conceptual remediation technique. Settlement calculations are presented in Appendix III.

Down-Drag Forces Acting on Piles

We evaluated the potential for settlement of the fill and YBM to cause down-drag forces acting on the Parcel B warehouse foundation piles. Settlement of soils surrounding a pile can generate down-drag forces, which can result in foundation movement. We have estimated the down-drag forces using a method based on soil shear strength and the shear stresses acting (as friction) on the sides of the piles. This method is similar to methods used to estimate pile load capacity. Down-drag forces were estimated using the API method for the portion of the pile within the fill, which is assumed to be cohesionless, and the α-method for the portion of the pile within the YBM, which is assumed to be cohesive. Subsurface material properties were developed from the original geotechnical study (Harlan, 1979), and subsurface investigations completed by EHS. Pile dimensions were obtained from the 1980 Harlan pile installation report.

The down-drag forces in the fill were estimated as (API method):

$$\text{Down-drag}_{(cohesionless)} = D*L*K_\delta*\sigma'_{vo}*\tan(\delta)$$

Where:

D=perimeter of pile

L=length of pile where settlement is to occur

K_δ =coefficient of lateral earth pressure

σ'_{vo}=vertical effective stress

δ=friction angle between the soil and pile wall

The down-drag forces in the YBM were estimated as (α-method):

$$\text{Down-drag}_{(cohesive)} = D*L*\alpha*S_u$$

Where:

D=perimeter of pile

L=length of pile where settlement is to occur

α=adhesion factor

S_u=undrained shear strength

The down-drag forces due to ground settlement would vary depending on the magnitude and location of settlement along the shaft. See the results section below for a summary of the estimated settlement values.

Pile Stiffness Estimate

To evaluate the structural response of the Parcel B warehouse, we evaluated the strength and stiffness of the existing piles and pile-soil interface. Deflection of the piles under loads imposed by ground movement (down-drag forces) is used in the structural engineering evaluation described later in this report. The preferred method for determining pile stiffness is a pile load test, typically performed prior to or during installation of service piles. It does not appear that pile load tests were performed for the Parcel B warehouse. Numerous methods have been developed to estimate load-deflection characteristics of piles from known soil and pile properties. Based on the available information, we used a method based on a hyperbolic equation derived from pile geometry and soil strength properties (Fleming, 1992).

Pile stiffness is dependent on many factors including the ultimate load capacity of the pile, live and dead loads acting on the pile, and the magnitude of the down-drag force. We estimated the ultimate load capacity from the pile installation records (Harlan, 1980), assuming a safety factor of two on the load capacities that were estimated by Harlan using the Engineering News Record Method 5 Formula (ENR, 1888). The estimated ultimate load capacity, the dead load acting on the pile, the down-drag force acting on the pile, and the load-deflection curve developed as described above, were used to estimate the stiffness of the soil supporting the pile. This stiffness is obtained from the slope of the load-deflection curve along the portion of the curve representing the application of the down-drag force to the pile that is supporting the estimated dead load. The elastic deformation of the pile was considered in the structural evaluation.

For the in-situ thermal heating remediation technique, the effects of lateral movement of the pile head associated with the thermal expansion of the grade beams and slab were evaluated using LPILE. Lateral deformations at the pile heads were estimated in the structural evaluation.

RESULTS OF GEOTECHNICAL ENGINEERING EVALUATION

The following is a brief summary of the results of our geotechnical evaluation for both of the remediation scenarios.

Soil Excavation Remediation Activities

Based on available subsurface information, we estimate that soil excavation would extend into the YBM by as much as 10 feet in portions of the two excavations. Considering the low undrained shear strength of the YBM and the tendency of YBM to flow toward excavations, excavation slopes would need to be very shallow and still might not be stable. We have assumed, therefore, that an excavation support system would be required for these excavations to minimize damage to adjacent structures and site features. One method of completing these excavations would involve use of a braced sheet pile excavation support system as conceptually shown in Figure 6. The sheet piles would be installed to depths well below the bottom of the excavation to maintain a stable excavation bottom and to prevent the flow of YBM into the excavation. We expect that the fill materials around the perimeter of the excavation and within the excavation may need to be dewatered to maintain a stable excavation and to facilitate excavation. We understand that an excavation support system consisting of a slot-cut excavation backfilled with flowable fill was used successfully in 2016 at Parcel A, and that this method is being considered to support these excavations.

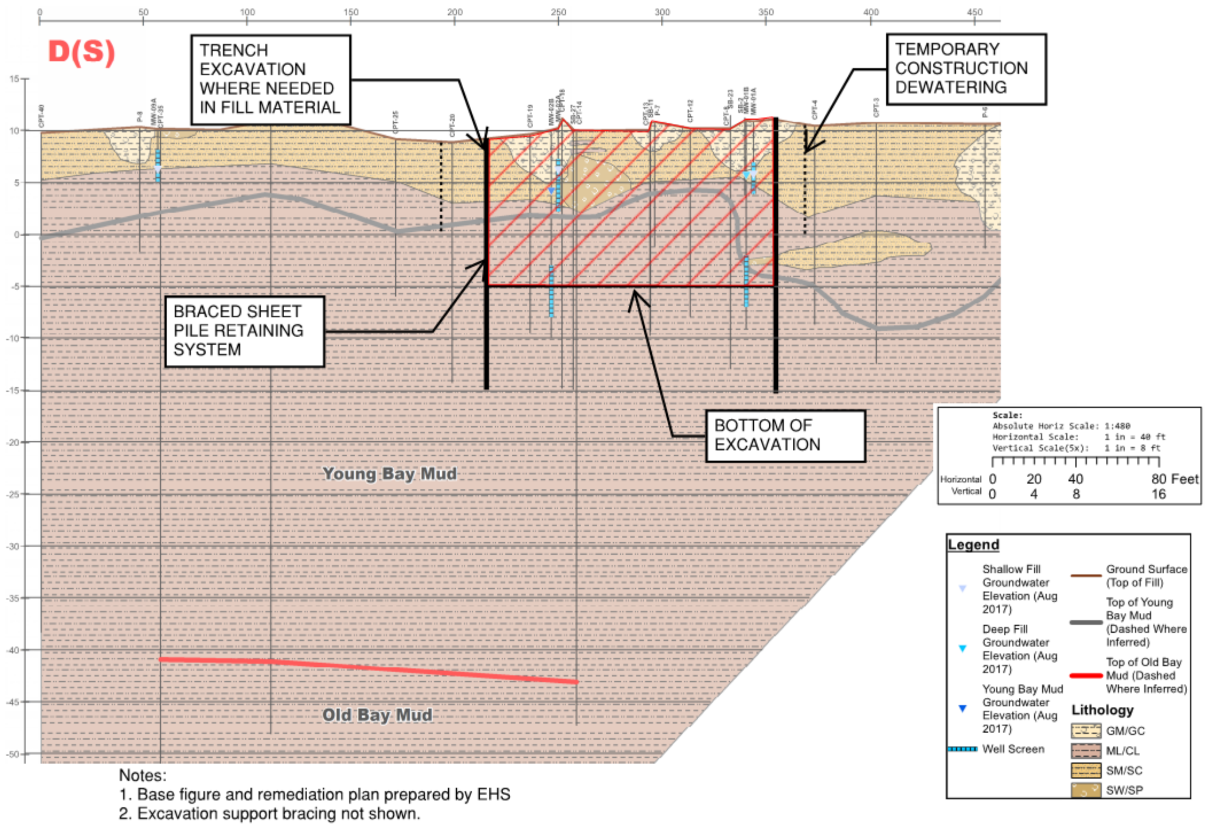


Figure 6. Conceptual excavation support plan (annotations by WJE).

Following completion of the excavation, the excavated area would be backfilled with engineered fill materials. Prior to backfilling, the bottom of the excavation may require placement of geogrid reinforcement and a layer of granular material to provide a stable surface for fill placement. We envision that the lower portion of the fill would consist of fine-grained materials placed at controlled moisture contents and densities to minimize future settlement. The upper several feet of fill would consist of granular soils, also placed at controlled moisture contents and densities, to provide a stable ground surface. We expect that the sheet piles would be removed during or soon after the backfill placement is completed.

Soil excavation and associated dewatering activities in the two areas adjacent to the Parcel B warehouse would likely result in a slight reduction in the horizontal stress acting on the upper 15 feet of the warehouse piles adjacent to the excavation. Provided the excavation support system is properly designed and constructed, we do not expect soil excavation activities to result in significant ground settlement or downward movement of the piles near the excavations.

Table 2 summarizes our estimated settlements and down-drag forces related to the soil excavation remediation.

Table 2. Conceptual Soil Excavation Remediation - Geotechnical Engineering Evaluation Summary

	5 Feet Thickness of Fill	15 Feet Thickness of Fill
Estimated Settlement in Fill	~ 0 inches	~ 0 inches
Estimated Settlement in YBM	~ 0 inches	~ 0 inches
Estimated Pile Down-drag Force	~ 0 kips	~ 0 kips
Other Effects: Possible lateral movement of the upper 15 feet of piles adjacent to the excavation areas. We have assumed that the excavation support system would be properly designed and constructed to minimize lateral movement of the earth support system so as to not significantly affect the existing warehouse foundation system or adjacent railroad tracks.		

In-Situ Thermal Heating Activities

Our estimates of settlement and pile down-drag force for the approximate depths of thermal treatment are summarized in Table 4 below. Calculation sheets for these estimates are provided in Appendix III.

Table 4. Conceptual In-Situ Thermal Heating Remediation - Geotechnical Engineering Evaluation Summary

	10 feet treatment depth	25 feet treatment depth	55 feet depth treatment
Estimated Settlement in Fill	0.2 inches	0.5 inches	0.5 inches
Estimated Settlement in YBM	0.3 inches	0.8 inches	16.6 inches
<u>Estimated Total Settlement</u>	<u>0.5 inches</u>	<u>1.3 inches</u>	<u>17.1 inches</u>
Estimated Down-drag Force	14 kips	46 kips	87 kips
Other Effects:	Significant differential settlement.		

The estimated settlement of 16.6 inches in the YBM for the 55-feet depth of thermal treatment assumes that the thermal treatment does not fully dewater the YBM clays. As discussed earlier, we have assumed the pore water pressures in the thermally treated YBM would be reduced by 50 percent. Because there is some uncertainty regarding the effect of thermal treatment on the YBM clays, the actual settlement could vary; however, the down-drag forces would not be expected to be significantly affected if the actual settlement varies from the estimated values.

Heating of the fill and YBM would likely result in some increase in volume of these materials due to thermal expansion. There is little information regarding this phenomenon in the literature. To the extent that thermal expansion of the fill and YBM occurs, we believe it would tend to reduce ground settlement and thereby potentially reduce pile down-drag. We have, therefore, conservatively neglected this phenomenon in developing the estimates of settlement and down-drag forces presented in Table 4.

Following completion of the conceptual in-situ thermal heating treatment, as the groundwater levels return to pre-treatment conditions, a portion of the fill settlement would likely be recovered quickly. In addition, a portion of the YBM settlement, particularly for the 55 feet depth of treatment case, would be recovered although this would occur over a much longer period of time, likely tens of years. The down-drag forces would likely diminish as the YBM settlement is recovered.

Effective Pile Stiffness

The estimated vertical pile-soil interface stiffness values are presented below in Table 5. These stiffness values are based on the down-drag forces estimated for the conceptual remediation scenarios and for the range of subsurface conditions. Since piles are stiffer when they experience relatively small changes in forces, the high-end pile stiffness values correspond to the low down-drag force cases, and the low-end pile stiffness values correspond to the high down-drag force cases.

Table 5 - Pile Stiffness Ranges

	Pile Stiffness	
	Low End	High End
Class A piles	5,700 kips/in.	6,800 kips/in.
Class B piles	4,000 kips/in.	5,200 kips/in.

Class A and Class B piles are of the same construction but differ according to how they were installed. According to the pile installation report (Harlan, 1980), the Class A piles have a structural design load capacity of 120 tons per pile and were installed to have a soils capacity of 150 tons to provide an allowance for down-drag. The Class B piles have a structural design load capacity of 99 tons per pile and were installed to have a soils capacity of 125 tons to provide an allowance for down-drag. The down-drag forces and pile stiffness values are incorporated in the structural analyses.

STRUCTURAL ENGINEERING EVALUATION

The conceptual soil remediation techniques have the potential to adversely affect the structure. The following is an assessment of the likely effects of the conceptual soil remediation techniques on the structure.

Structural Evaluation Method

WJE's structural evaluation of the existing site improvements focused on Parcel B, including the slab, grade beams, and piles of the existing warehouse. We also briefly considered the effects of the conceptual soil-remediation treatments on other improvements on Parcel B, including the above-ground precast concrete walls, wood roof framing, and steel pipe columns of the warehouse, and the buried site utilities.

Information about the existing Parcel B warehouse structure gleaned from our document review was used to develop an analysis model of the slab and grade beam system to evaluate the effects of remediation-related pile down-drag forces and thermal expansion. There was insufficient information to develop similar models for the above-slab structure or for the utilities; therefore, these elements were evaluated on an empirical basis.

WJE analyzed the slab and grade beams using the SAFE® 2016 analysis program by Computers & Structures, Inc. (SAFE). The model geometry was taken or inferred from the reviewed documents (Figure 7), and relevant material properties were estimated based on our experience with similar existing buildings. Illustrations of the model assignments can be found in Appendix IV. We directly or indirectly modeled the various structural elements with different elastic elements, as follows:

- The slab: elastic shell elements,
- The grade beams: elastic beam elements with offset centroids, and
- The piles: elastic link elements and vertical springs with stiffnesses developed using the geotechnical engineering results described above.

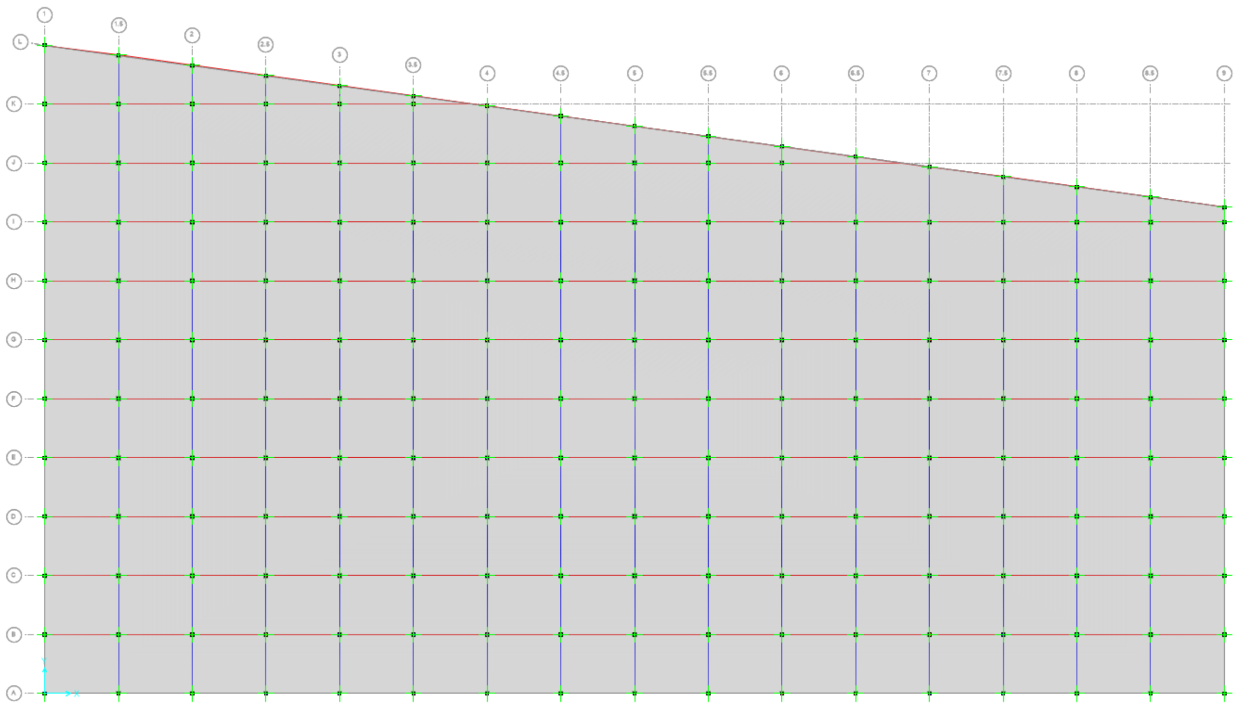


Figure 7. Plan view of the SAFE model of the slab (gray) and grade beams (blue and red lines).

Loads were applied to the SAFE model in various ways to approximate existing or proposed load conditions:

- Inherent self-weight (dead loads),
- Slab surface loads (live loads),
- Line loads (wall dead loads),
- Distributed temperature loads (slab thermal expansion),
- Point loads at columns (column loads),
- Point loads at pile locations (down-drag forces), and
- Vertical point-displacements at pile locations (pile thermal expansions).

Although likely originally cast directly against soil, the slab and grade beams appear to have been designed to act as an elevated framing system that spans between the piles at the grade beam intersections. This is a common design approach where long-term settlement of the underlying soil is expected to be significant. While the soil and piles would have initially restrained the shrinkage of the slab and grade beams, shrinkage stresses are expected to have largely dissipated due to long-term stress relaxation within the soil and the piles. We therefore assumed an unreduced modulus of rupture for existing uncracked concrete of the slab and grade beams.

Effects on the warehouse structure were not quantified for the excavation treatment option since the expected settlements would be negligible. Our analyses of the warehouse considered only the in-situ thermal heating scenario. Down-drag forces assigned at the individual pile locations were computed as a function of the conceptual remediation treatment areas, the thicknesses of the underlying fill and YBM soils, and the depths of the conceptual soil remediation. Thermal pile expansion displacements assigned at the appropriate pile locations were computed as a function of the depth of potential treatment, the inherent thermal expansion properties of the piles, and an assumed increase in the temperatures of the soil and piles. Thermal loads were applied to the slab throughout the conceptual remediation treatment areas. We understand that an insulating layer is likely to be laid on the top surface of the slab to control heat loss and have therefore assumed that the slab would be brought up to elevated temperatures gradually, and that there would be no significant thermal gradient through the slab thickness. In addition, we have assumed that there would be a horizontal thermal gradient outside the conceptual remediation treatment areas, with diminishing temperatures away from these extents.

A uniform live load of 200 pounds per square foot (psf), taken from the provided hand sketches of the slab and grade beam system, was applied to the slab, combined with the load effects of the conceptual in-situ thermal soil remediation scenario. We understand that during the in-situ thermal heating remediation the floor slab would be insulated, and the warehouse would not remain in use. At some point during the cool-down period, use of the warehouse could resume, and therefore the remediation-related demands (conservatively assumed to be the same as the full demands) and the live load demands would be additive.

Our empirical evaluation of the precast concrete walls, tube-steel columns, and wood-framed roof of the warehouse and the Parcel B utilities considered likely differential top-of-slab vertical and horizontal displacements caused by the thermal heating remediation scenario and the horizontal distances over which those differential displacements would occur. This measure, which for the purposes of this report we have called the “differential displacement slope,” was compared to empirically based limits for different types of construction subjected to differential displacements. These slopes are expressed in terms of differential displacement over distance; if this slope exceeds certain limits, damage may occur as discussed below. Based on studies of stiff construction types by Son and Cording (2005), differential slope limits of L/1000 vertically and L/2000 horizontally were conservatively set as the limits beyond which distress might manifest. For example, the limit of L/1000 corresponds to 0.3 inches of differential displacement separated by 25 feet. Because these limits were developed considering stiff structures similar to the precast concrete warehouse walls, more flexible elements, such as the tube-steel columns and wood-framed roof are expected to accommodate significantly greater differential displacement without experiencing damage.

Structural Evaluation Results and Discussion

We used the analysis results to characterize the effects of the conceptual thermal heating remediation scenario via two methods. The first method considered flexural cracking of the slab, comparing the demands due to the thermal heating scenario to both the assumed effective modulus-of-rupture and demands due to dead and live loads. The second method evaluated certain strength limit states of the slabs, grade beams, and piles, with respect to the relevant requirements of the 1976 *Uniform Building Code* (UBC), which was likely the building code used for the original design. Although the exact building code under which the building was designed is not known, the 1973 UBC and the 1979 UBC have reasonably similar requirements for gravity-load-resisting systems, and whichever code was used is unlikely to be substantively different from the 1976 UBC. Limit states were only evaluated for certain member actions, member types, and typical conditions due to the limited nature of the provided information.

The results for our analyses and discussions of those results, organized by conceptual remediation technique, are as follows. Our discussion of the effects of the remediation scenarios do not include discussion of the acceptability of these effects on the existing structure and site improvements. Selected analysis results are summarized in Appendix IV. A summary risk assessment matrix has been developed by WJE, in coordination with Univar, EHS, TerraTherm, Prologis, and Prologis' consultants, to support decision making and further development of the hypothetical thermal remediations scenario considered in WJE's analyses. This risk matrix enumerates a number of potential geotechnical and structural consequences of the thermal remediation scenario with approximate estimates of the likelihood of primary effects, the relative severity of these effects, as well as potential mitigation, data collection, and repair strategies where appropriate. This risk matrix is provided as Appendix V to this report.

<u>Soil Excavation</u>

Since little if any settlement is expected as a result of the conceptual soil excavation activities, no meaningful changes in the flexural cracking state or to the strength limit states of the slab, grade beams, and piles are expected. As a result, this scenario is also unlikely to meaningfully affect the precast concrete walls, tube-steel columns, and wood-framed roof of the warehouse. The conceptual excavations appear to overlap with the estimated locations of certain existing utilities: a water line at the south end of the warehouse, and a natural gas line, French drain, and a utility labeled "unknown" in the site plan at the east end of the warehouse. These utilities may require re-routing prior to excavation.

<u>In-Situ Thermal Heating</u>

We believe that the conceptual proposed in-situ thermal heating scenario would be likely to increase the flexural strains in the slab and grade beams near multiple piles and cause incremental flexural cracking.

The maximum demand-to-capacity ratios (DCRs) of the slab and grade beams would likely be increased by the in-situ thermal scenario and we believe that at certain locations near the deepest remediation treatment depths, the assumed design capacities of the slab would be exceeded. The piles are likely to also experience increases to their design DCRs, and we estimate that certain piles are likely to exceed their design capacities. We do not believe that the slab or piles would exceed their expected ultimate (rather than design) capacities, and therefore would not fail. These adverse load effects are generally for the elements located near what would be the areas of relatively deeper in-situ thermal heating because the thermal expansion-related pile displacements driving these effects are directly related to the depth of heating.

The horizontal thermal expansion of the slab would likely displace most pile heads horizontally enough to cause flexural cracking of the piles, except the piles closer to the center of the warehouse where anticipated horizontal movements are smallest; such cracking would not reduce the flexural capacity of the piles but would significantly reduce their flexural stiffness. The thermal expansion of the slab would also likely cause significant and widespread through-thickness radial cracking of the concrete outside the soil remediation areas due to the assumed horizontal temperature gradient. This thermal gradient would also likely cause substantial compressive stresses to develop in the slab and grade beams within the conceptual soil remediation areas. We believe that in some areas, these compressive stresses would be greater than or similar to the flexural slab tension stresses due to differential vertical displacements, which would potentially mitigate the likelihood of flexural tension-induced cracking of the slab in those areas.

The calculated maximum differential displacement slopes exceed the L/1000 vertical limit and L/2000 horizontal limits, which indicates that the precast concrete walls of the warehouse may experience some distress (e.g., cracking) particularly at edges and the corners of openings, and that the connections of the precast wall panels to the slab and to each other may experience cracking of concrete near these connections and potentially break-out failures of the connections' anchors. This distress will likely be more pronounced at remediation areas along the perimeter of the warehouse. The tube-steel columns and wood-framed roof of the warehouse are unlikely to experience damage because they are far more flexible than the precast walls and their connections. Site utilities, particularly those near the relatively deeper in-situ thermal treatment areas, are likely to be damaged due to ground settlement and thermal expansion.

The in-situ thermal heating scenario would also involve heating the slab, grade beams, and varying lengths of many of the piles to elevated temperatures for an extended period. For the purposes of our evaluation, we have assumed that elements in the remediation area would typically be exposed to uniform temperatures in the surrounding soil and that the sustained temperature would be approximately 100°C. The variation of concrete physical properties with temperature is complex and depends largely on the specific composition of the concrete (e.g., aggregate types, cement factor, water-cement ratio, etc.) - information that is currently unavailable for the Parcel B warehouse. The following temperature-related findings are those that we believe are generally true regardless of concrete composition. Reinforced concrete elements heated to 100°C would likely experience some minor softening of the concrete (American Concrete Institute, 2014).

We understand that the soil temperatures associated with the conceptual in-situ thermal heating scenario would be as high as 400°C close to the thermal heating units. Portions of the slab, grade beams, and piles near this elevated temperature zone would likely experience more advanced softening of the concrete, partial loss of concrete compressive strength, and partial loss of strength for reinforcing steel (American Concrete Institute, 2014; Naus, 2005; Thompson, 2015). In addition, prestressed piles near this elevated temperature zone would likely experience substantial loss of tensile strength of the steel prestressing strands and some prestress relaxation. Elements exposed to temperatures between 100°C and 400°C would likely experience these effects as gradual, but not linear, deterioration with increasing temperature.

The consequences of these structural responses vary depending on the type and degree of the response, as described below. Additional information characterizing the estimated consequences identified in WJE's analyses for this remediation scenario as well as recommended monitoring and measures to attempt to mitigate these consequences are provided in the risk assessment matrix included as Appendix V to this report.

- The heat-related softening and weakening of the reinforced concrete members within 2 to 3 feet of the heating elements would likely leave the post-remediation condition of those members substantially weaker than they were pre-remediation. The design of the thermal remediation system could prioritize maintaining sufficient clear distances between the thermal heating units and the building's structural elements (e.g., piles, pile caps, and grade beams) to mitigate the risks of direct thermal damage. Where such clear distances may not be achievable (e.g., where heating units penetrate through the slab), other methods of shielding or insulating structural elements from temperatures above 100°C could be investigated.

- The cracking of the slab due to its differential horizontal thermal expansion would result in a post-remediation condition likely including several large, through-thickness cracks that would not close all or most of the way, and yield slab and grade beam reinforcing steel. These conditions would need to be further evaluated to determine if these members would be adequate to resist future design demands. Absent structural performance issues arising from these conditions, the consequences would largely be aesthetic and serviceability related.
- The exceedances of strength limit states would not necessarily indicate that those sections of the slab had lost flexural strength, although a post-remediation condition survey could be performed to evaluate the slab for flexure-related distress, such as concrete cover spalling or bar buckling due to reversed displacements after yielding.
- The flexural cracking of the slab would slightly soften the out-of-plane flexural response of the slab, but the primary consequence would likely be aesthetic and serviceability-related.
- The cracking at the tilt-up walls due to differential vertical and horizontal movements would likely not impact the structural performance of these walls, but distress at the connections to the slab and adjacent wall panels could be evaluated to determine if these connections would be adequate to resist design demands.

The more significant impacts of the conceptual in-situ thermal heating scenario appear to be the result of localized treatment depths (Appendix I); the horizontal expansion of the slab; and the potential for exposure of the piles to temperatures significantly above 100°C. Scenarios that involve more evenly distributed treatment depths, heating throughout the warehouse footprint, and heating mechanisms located away from the piles would likely mitigate most of the impacts described above. The softening of the slab structure due to the cutting of cores for the heating elements and vacuum wells would marginally reduce the effects of the thermal expansion of these areas. Further softening of the slab by cutting additional cores, as well as isolation of these areas from the remaining slab areas not to be treated with a thermal expansion joint warrant consideration as mitigation measures in future studies. In addition, limiting the live loads imposed on the slab throughout the duration of the in-situ thermal heating and the cool-down period would reduce some of the effects on the existing structure that we initially and conservatively assumed to be additive.

The thermal displacements of the slab, grade beams, and piles are expected to be largely reversed after temperatures return to their pre-remediation levels. Most of the impacts discussed above, however, including slab, grade beam, and pile cracking, would remain after the thermal treatment is completed and the resulting displacements reverse. The risk assessment matrix in Appendix V includes additional discussion of potential consequences for this remediation scenario and recommends opportunities for mitigating or addressing their effects.

CONCLUSIONS

WJE evaluated two conceptual soil remediation scenarios provided by EHS for their potential effects on the site soils and the existing warehouse structure assuming, as a base case, that no mitigation measures are implemented. We have deferred to EHS and TerraTherm with respect to the environmental conditions at the site and the soil remediation scenarios. Based on our geotechnical and structural evaluations, we offer the following conclusions:

- Soil excavation remediation activities would not likely cause meaningful ground settlements or pile down-drag forces, and therefore are unlikely to meaningfully affect the existing warehouse structure.
- The in-situ thermal heating activities would likely have greater effects on the existing Parcel B improvements than soil excavation remediation activities, primarily due to the application of significant thermal loads to the piles, grade beams, and slab. Where the in-situ thermal treatment depth is 55 feet, the heating activities would likely cause large settlements in the fill and YBM soils, and large pile down-drag forces. The combined down-drag forces and thermal expansion of the piles would likely result in differential vertical displacements of the structure. Cracking would likely occur, and design limit states for the slab and multiple piles would be exceeded but would not exceed their ultimate capacities. Portions of the slab, grade beams, and piles close to the more highly heated soil could potentially lose strength. This scenario would also cause most of the piles to crack in flexure as portions of the grade beams and slab expand. Areas of the slab and grade beams that are heated less or unheated would resist this expansion, resulting in widespread cracking in these cooler portions of the concrete. Refer to the risk assessment matrix (Appendix V) for a more detailed evaluation of the potential effects of in-situ thermal remediation and recommended measures to attempt to mitigate these effects.

RECOMMENDATIONS

The geotechnical and structural engineering evaluations presented in this report are based on the information available at the time these evaluations were completed. These evaluations conservatively assume that no mitigation measures have been incorporated (i.e., this evaluation serves as a baseline evaluation of the remediation scenarios). Due to the significant uncertainty inherent in estimating ground movement and behavior and resulting structural responses, in particular related to in-situ thermal heating treatment, and the uncertainty related to the effects of this treatment scenario, the outcomes presented above may be exceeded if the remediation measures evaluated herein are implemented. The uncertainty inherent to these engineering evaluations has been estimated in our analyses by making conservative assumptions with regard to existing conditions and input parameters as appropriate.

Site investigation work to address some of these uncertainties is currently underway, and additional sampling, data collection, and laboratory testing recommendations will follow in a separate implementation plan for consideration among stakeholders. As outlined in Appendix V, this work should include documentation, sampling, and testing of the structural components to improve our understanding of the existing construction, structural components, and materials. Additional sampling and testing of site soils to improve our understanding of the expected geotechnical behavior of the subsurface strata may also be proposed.

In addition, it is important to understand that the remediation options presented above are schematic in nature. Prior to implementing any remediation, the selected methods need to be developed into formal procedures and validated, likely by collection of additional data on site. With respect to our findings, we believe that discussions regarding the impacts of the in-situ thermal remediation scenario and revisions to either the scenario itself, including potential mitigating actions, or the geotechnical and structural engineering assumptions we have made regarding the scenario would more significantly affect the results of our analysis than additional, increasingly sophisticated analyses. We reserve the right to modify our conclusions and opinions based on receipt and review of additional information as it becomes available.

We recommend that a pre-construction and post-construction condition survey be conducted to develop a comprehensive sense of the state of the building immediately prior to and following the remediation work. Many of these recommendations are schematically described in Appendix V. Detailed recommendations for the condition surveys of the building before and after construction, as well as recommendations for monitoring during remediation, will also be developed as part of a forthcoming implementation plan for the consideration of project stakeholders.

REFERENCES

American Concrete Institute, November 2014, ACI/TMS 216.1-14, Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies. Reported by ACI/TMS Committee 216, Farmington Hills, Michigan,

ERM, 2015, portions of *Revised Draft On-Site RIDSR*, selected figures and tables, and Appendices A and B, Project 2015.11.05

EHS, May 2018, portions of *Data Gaps Investigation Report*, CPT Data, Figures, Tables, Appendix B - Boring Logs, Appendix D - High Resolution Site Characterization (HRSC) and Cone Penetration Testing (CPT) Investigation, Appendix J - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated July 5, 2017, Appendix K - Groundwater Step Test Analysis - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated July 25, 2017, and Appendix L - Constant Rate Pumping and Recovery - Univar/Brisbane Aquifer Pumping Test prepared by EHS, dated October 20, 2017.

EHS, May 25, 2021, Figures 10, 11, and 12, 3775 Bayshore Blvd, Brisbane, CA, Estimated Remedial Extent for depth intervals of 0-5 ft bgs, 5-15 ft bgs, and 15-55 ft bgs.

E.L. Engineering, various dates from February and March 1979, Six sheets of construction drawings of the Parcel B warehouse.

E.L. Engineering, stamped "approved" on December 4, 1979, Two sheets of construction drawings of the Parcel B warehouse.

E.L. Engineering letterhead, dated August 15 and 16 (no year), Hand sketches of the slab-on-ground and grade beam system.

Engineering News-Record, December 1888, Formulas for the Safe Load of Bearing Piles: Method 5 - Steam Pile Drivers, Engineering News-Record.

Federal Highway Administration Manual, July 2016, Design and Construction of Drive Pile Foundations - Volume I, Publication No. FHWA-HNI-16-009.

Fleming, W.G.K., 1992, A New Method for Single Pile Settlement and Analysis, Geotechnique 42, No. 3.

Heron, G., Lachance, John, and Baker, Ralph, *Removal of PCE DNAPL from Tight Clays Using In Situ Therm Desorption*, Groundwater Monitoring & Remediation 33, No. 4, Fall 2013, pages 31-43.

McDonald, S.D, Nichols, D.R, Wright, N.A., and Atwater, B., 1978, Map Showing Thickness of Young Bay Mud, Southern San Francisco Bay, California, Miscellaneous Field Studies Map MF - 976.

Mitchell, J.K., 1963, *Engineering Properties and Problems of the San Francisco Bay Mud*, California Division Mines and Geology, Special Report 82.

Naus, D.J. November 2005, The Effect of Elevated Temperature on Concrete Materials and Structures - a Literature Review. Prepared for the U.S. Nuclear Regulatory Commission,

R.C. Harlan and Associates, September 7, 1979, *Soil and Foundation Investigation, Brisbane Warehouse*, Project 316.1.

Richard C. Harlan of R.C. Harlan and Associates, May 22, 1980, *Report of Pile Installation*, Project No. 350.1

Long, J.H., Hendrix, J., Jaromin, D., February 2009, Comparison of Five Different Methods for Determining Pile Bearing Capacities, University of Illinois at Urbana/Champaign.

Rodgers, R. and Majchrzak, M., June 1-4, 1993, *An Unsuccessful Urban Deep Excavation in Soft Soils*, Proceedings: Third International Conference on Case Histories in Geotechnical Engineering.

Schmertmann, J.H., 1970, Static Cone To Compute Static Settlement over Sand, Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers.

Son, M., Cording, E.J., February 2005. Estimation of Building Damage Due to Excavation-Induced Ground Movements, Journal of Geotechnical and Geoenvironmental Engineering, American Society of Civil Engineers.

TerraTherm®, July 1, 2010, *Data Compilation Regarding Geotechnical and Structural Effects of Subsurface Heating*.

TerraTherm®, June 1, 2021, *Confidential Bay Area Site, Brisbane, CA, Preliminary Site Evaluation, Revision 5*.

Thompson, C., August 2015, Mechanical Properties of Cold-Drawn Steel Strand at Elevated Temperatures. *Theses and Dissertations*, Lehigh University.

US Army Corps of Engineers San Francisco District, September 2015, *Appendix G - Geotechnical Engineering, South San Francisco Bay Shoreline Phase I Study*,

US Army Corps of Engineers, 28 August 2009, *Design: In Situ Thermal Remediation*, Engineer Manual, EM 1110-1-4015.

Whitlow, R., *Basic Soil Mechanics*, Longman Scientific & Technical, Burnt Mill Harrow, 1995.

Wilson, G. P., 2010, *The Behavior of a Deep Retained Excavation in Soft San Francisco Bay Mud*, 2010 Earth Retention Conference (ER2010).

Youd, T.L., Nichols, D.R., Helley, E.J., and Lajoie, K.R., 1975, Studies for Seismic Zonation of the San Francisco Bay Region, U.S. Geological Survey Professional Paper 941-A.

APPENDIX I - REMEDIATION ACTIVITIES

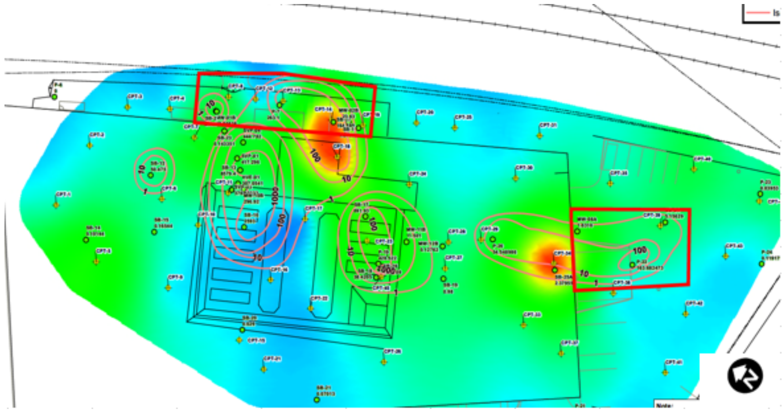


Figure 1 - Conceptual Soil Excavation Areas

Excavation			
East side of building	Bay Mud Depth ~	10	ft
(former railspur)	Water level ~	5	ft
	Areal extent of treatment - ~	3,983	sf
	Assume excavation depth	15	ft
	Assume short-term dewatering of fill		
	Assume current utilities configuration (shown on thermal figure)		
	Work will extend directly adjacent to warehouse wall		
	Soil properties:		
	Bulk density - 1.2gm/cc		
	Moisture content - 45% (weight)		
Excavation			
South side of building	Bay Mud Depth ~	10	ft
(former catch basin)	Water level ~	5	ft
	Areal extent of treatment - ~	3,749	sf
	Assume excavation depth	15	ft
	Assume removal/replacement of asphalt and concrete truck loading dock (conrete in green area; all remaining area asphalt)		
	Assume short-term dewatering of fill		
	Work will extend directly adjacent to warehouse wall		
	Assume work around water line (shown on thermal figure)		
	Soil properties:		
	Bulk density - 1.2gm/cc		
	Moisture content - 45% (weight)		

0 to 5 ft Below Ground Surface

Total Area:
9,993 ft^2

Area Underneath Existing Buildings:
6,624 ft^2 / 66%

Area Underneath Hardstand Surfaces:
2,617 ft^2 / 26%

Area Underneath No Hardstand Surfaces:
752ft^2 / 8%

Total Volume:
49,965 ft^3 / 1,851 yd^3

Volume Within Fill:
32,142 ft^3 / 1,190 yd^3 / 64%

Volume Within Young Bay Mud:
17,823 ft^3 / 660 yd^3/ 36%

Volume Within Fill Beneath Buildings:
30,219 ft^3 / 1,119 yd^3/ 60%

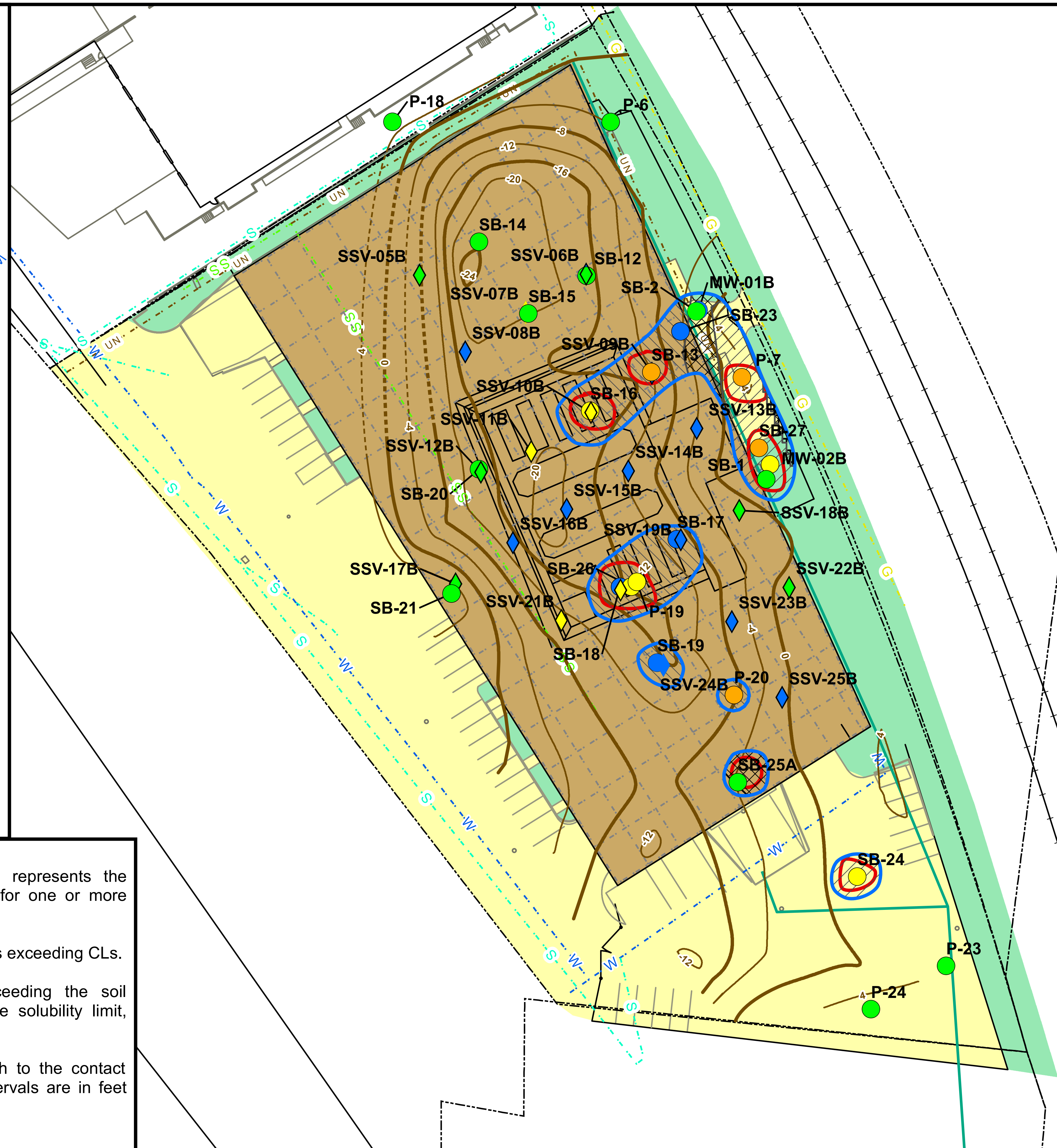
Volume Within Fill Beneath Hardstand Surfaces:
1,478 ft^3 / 55 yd^3/ 3%

Volume Within Fill Beneath No Hardstand Surfaces:
445 ft^3 / 16 yd^3/ 1%

Volume Within Young Bay Mud Beneath Buildings:
2,899 ft^3 / 107 yd^3/ 6%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
11,608 ft^3 / 430 yd^3/ 23%

Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
3,316 ft^3 / 123 yd^3/ 7%



Note:
The order of magnitude designation for each location represents the maximum order of magnitude above the Cleanup Level for one or more constituents and/or media

Remedial extent comprises all NAPL areas and soil samples exceeding CLs.

NAPL extent approximated based on soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and MIP responses.

Young Bay Mud contours based on the interpreted depth to the contact based on CPT and conventional boring logs. Contour intervals are in feet mean sea level (MSL).

Legend

RemedialExtent_Composition

Composition

- Fill
- Fill/Bay Mud
- Bay Mud
- NAPL Extent

Sample Type

- Soil Sample
- Subslab/soil vapor sample
- Bay Mud Contour (Index, 10ft)
- Bay Mud Contour (Intermediate, 2ft)

Order of Magnitude Designation

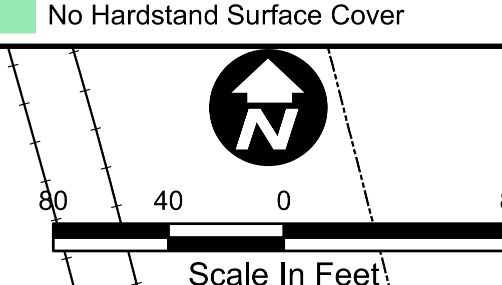
- Attains Cleanup Levels
- <1 order of magnitude above Cleanup Levels
- >1 to 2 order of magnitude above Cleanup Levels
- >2 to 3 orders of magnitude above Cleanup Levels
- >3 orders of magnitude above Cleanup Levels
- Remedial Extent
- Grade Beams

Utility Type

- Electrical
- French Drain
- Gas Line
- Sanitary Sewer
- Storm Sewer
- Unknown
- Water Line

Surface Type

- Building
- Parking and Hardstand
- No Hardstand Surface Cover



Reviewed by: G. White

EHS Support

3775 Bayshore Blvd
Brisbane, CA

Estimated Remedial Extent (0-5 ft bgs)

FIGURE 10
I-2

J:\EHSS_GIS\C0165_Brisbane01_ANALYSIS\20210524_EstRemedialExtent_NAPL_SOIFigRequest2_11.mxd

Printed 5/25/2021 1:25:52 PM by Paul Bendernagel

5 to 15 ft Below Ground Surface

Total Area:
12,947ft^2

Area Underneath Existing Buildings:
8,964 ft^2/ 69%

Area Underneath Hardstand Surfaces:
3,292 ft^2 / 25%

Area Underneath No Hardstand Surfaces:
692 ft^2 / 5%

Total Volume:
129,469 ft^3 / 4,795 yd^3

Volume Within Fill:
46,699 ft^3 / 1,730 yd^3 / 36%

Volume Within Young Bay Mud:
82,770 ft^3 / 3,066 yd^3/ 64%

Volume Within Fill Beneath Buildings:
46,494 ft^3 / 1,722 yd^3/ 36%

Volume Within Fill Beneath Hardstand Surfaces:
187 ft^3 / 7 yd^3/ < 1%

Volume Within Fill Beneath No Hardstand Surfaces:
18 ft^3 / 1 yd^3/< 1%

Volume Within Young Bay Mud Beneath Buildings:
43,142 ft^3 / 1,598 yd^3/ 33%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
32,730 ft^3 / 1,212 yd^3/ 25%

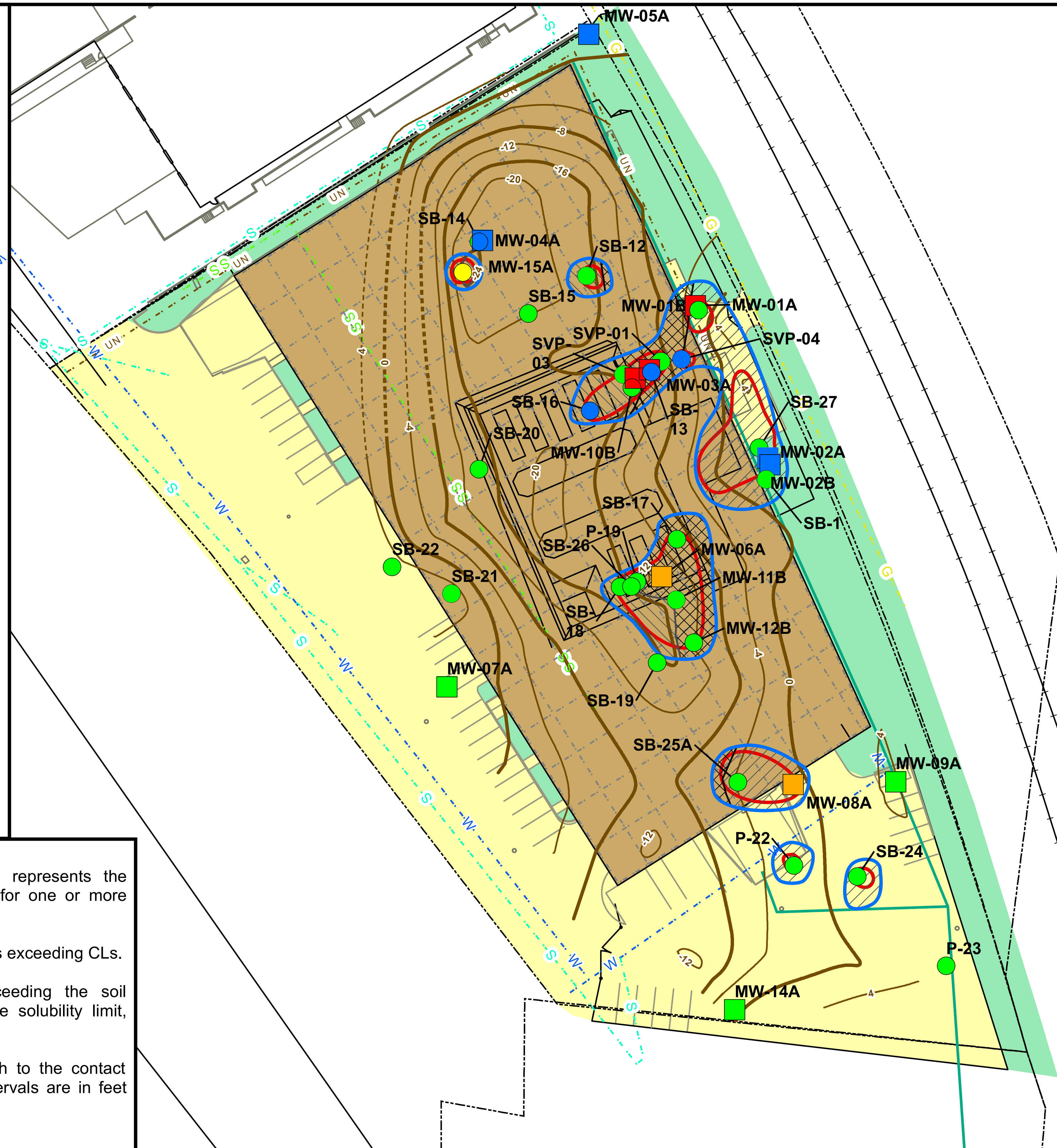
Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
6,897 ft^3 / 255 yd^3/ 5%

Note:
The order of magnitude designation for each location represents the maximum order of magnitude above the Cleanup Level for one or more constituents and/or media

Remedial extent comprises all NAPL areas and soil samples exceeding CLs.

NAPL extent approximated based on soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and MIP responses.

Young Bay Mud contours based on the interpreted depth to the contact based on CPT and conventional boring logs. Contour intervals are in feet mean sea level (MSL).



Legend

RemedialExtent_Composition

Composition
- Fill
- Fill/Bay Mud
- Bay Mud
- NAPL Extent

Sample Type
- Soil Sample
- Groundwater Sample
- Bay Mud Contour (Index, 10ft)
- Bay Mud Contour (Intermediate, 2ft)

Order of Magnitude Designation
- Attains Cleanup Levels
- <1 order of magnitude above Cleanup
- >1 to 2 order of magnitude above Cleanup
- >2 to 3 orders of magnitude above Cleanup Levels
- >3 orders of magnitude above Cleanup
- Remedial Extent
- Grade Beams

Utility Type
- E Electrical
- French Drain
- G Gas Line
- SS Sanitary Sewer
- S Storm Sewer
- UN Unknown
- W Water Line

Surface Type
- Building
- Parking and Hardstand
- No Hardstand Surface Cover

80 40 0 80
Scale In Feet

Reviewed by: G. White

EHS Support

3775 Bayshore Blvd
Brisbane, CA

Estimated Remedial Extent (5-15 ft bgs)

FIGURE 11
I-3

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20210524_EstRemedialExtent_NAPL_SOIFigRequest2_11.mxd

Printed 5/26/2021 1:29:24 PM by Paul.Bendernagel

<u>15 to 55 ft Below Ground Surface</u>

Total Area:
7,864 ft^2

Area Underneath Existing Buildings:
7,864 ft^2 / 100%

Area Underneath Hardstand Surfaces:
0 ft^2 / 0%

Area Underneath No Hardstand Surfaces:
0 ft^2 / 0%

Total Volume:
314,566 ft^3 / 11,651 yd^3

Volume Within Fill:
11,642 ft^3 / 431 yd^3 / 4%

Volume Within Young Bay Mud:
302,918h ft^3 / 11,219 yd^3/ 96%

Volume Within Fill Beneath Buildings:
11,642 ft^3 / 431 yd^3/ 4%

Volume Within Fill Beneath Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Fill Beneath No Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Young Bay Mud Beneath Buildings:
302,918 ft^3 / 11,219 yd^3/ 96%

Volume Within Young Bay Mud Beneath Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

Volume Within Young Bay Mud Beneath No Hardstand Surfaces:
0 ft^3 / 0 yd^3/ 0%

<u>Note:</u>
The order of magnitude designation for each location represents the maximum order of magnitude above the Cleanup Level for one or more constituents and/or media

Remedial extent comprises all NAPL areas.

NAPL extent approximated based on soil results exceeding the soil saturation limit, groundwater data exceeding the effective solubility limit, NAPL pore fluid saturation data, and MIP responses.

Young Bay Mud contours based on the interpreted depth to the contact based on CPT and conventional boring logs. Contour intervals are in feet mean sea level (MSL).

<u>Legend</u>

Sample type
-) Groundwater Sample

Order of Magnitude Designation
-) Attains Cleanup Levels
-) <1 order of magnitude above Cleanup Levels
-) >1 to 2 orders of magnitude above Cleanup Levels
-) >2 to 3 order og magnitude above Cleanup Levels
-) >3 orders of magnitude above Cleanup Levels

Composition
- Fill/Bay Mud
- Bay Mud
- Bay Mud Contour (Index, 10ft)
- Bay Mud Contour (Intermediate, 2ft)
- NAPL Extent
- Remedial Extent
- Grade Beams

Utility Type
- E Electrical
- French Drain
- G Gas Line
- SS Sanitary Sewer
- S Storm Sewer
- UN Unknown
- W Water Line

Surface Type
- Building
- Parking and Hardstand
- No Hardstand Surface Cover

Reviewed by: G. White

EHS Support

3775 Bayshore Blvd
Brisbane, CA

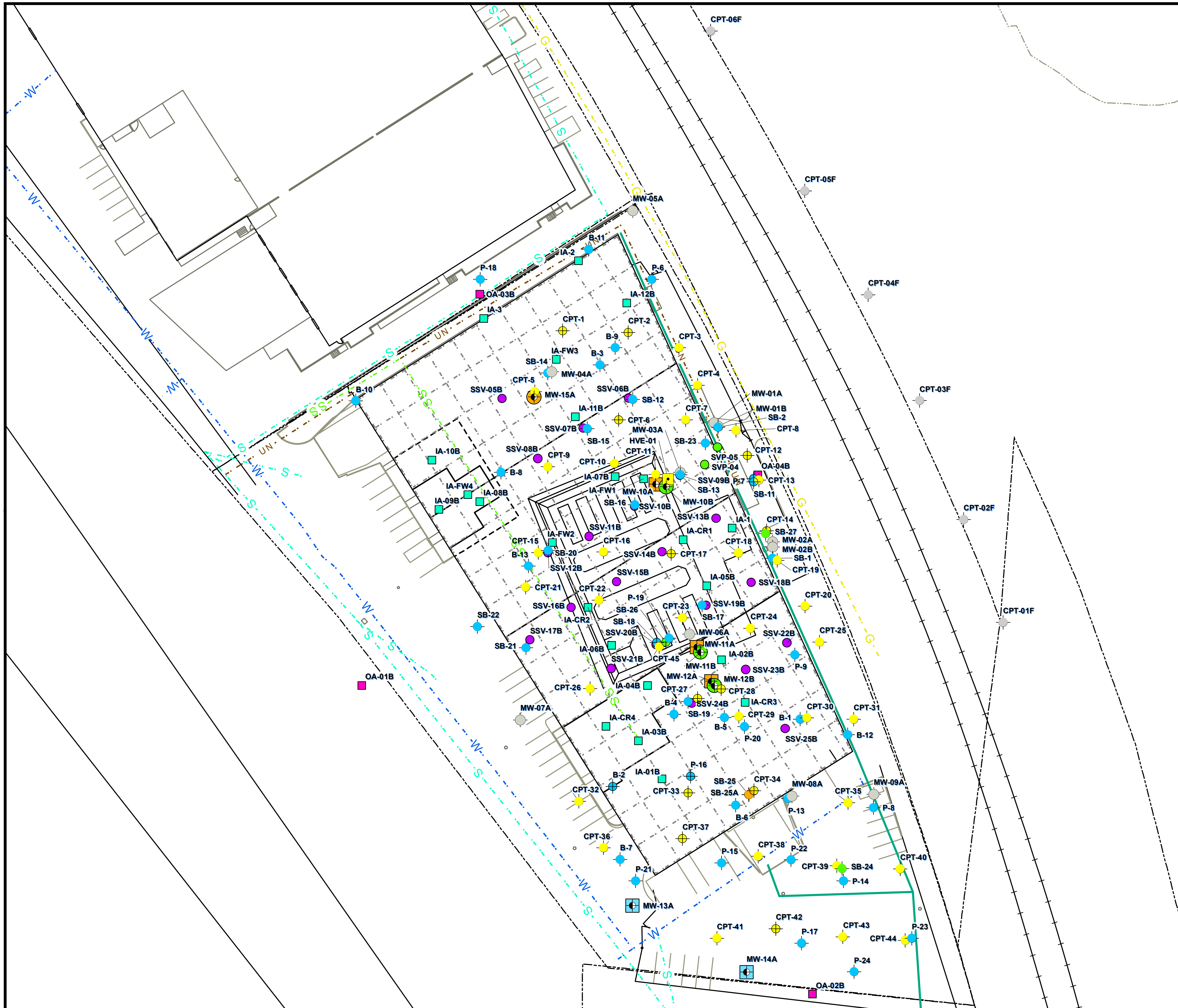
Estimated Remedial Extent (15-55 ft bgs)

FIGURE 12
I-4

J:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20210524_EstRemedialExtent_NAPL_SO\FigRequest2_12.mxd

Printed 5/25/2021 10:34:22 PM by Paul.Bendernagel

APPENDIX II - EHS SITE CHARACTERIZATION FIGURES



Legend

Data Gaps Investigation Locations

- CPT/MIP Location
- Soil Coring (Fill Zone Boring) Location
- Soil Coring (Bay Mud Zone Boring) Location
- Soil Coring (Fill Zone Groundwater Monitoring Well) Location
- Soil Coring (Bay Mud Groundwater Monitoring Well) Location
- Soil Screening (Fill Zone Groundwater Monitoring Well) Location
- Background Fill Zone Groundwater Monitoring Well Location

Existing Investigation Locations

- CPT/MIP Location (Offsite)
- Soil Boring Location
- Monitoring Well
- Extraction Well
- Soil Vapor Probe
- Subslab Soil Vapor Point
- Indoor Air Sampling
- Outdoor Air Sampling
- Grade Beams

Utility Type

- E Electrical
- French Drain
- G Gas Line
- SS Sanitary Sewer
- S Storm Sewer
- UN Unknown
- W Water Line

80 40 0 80

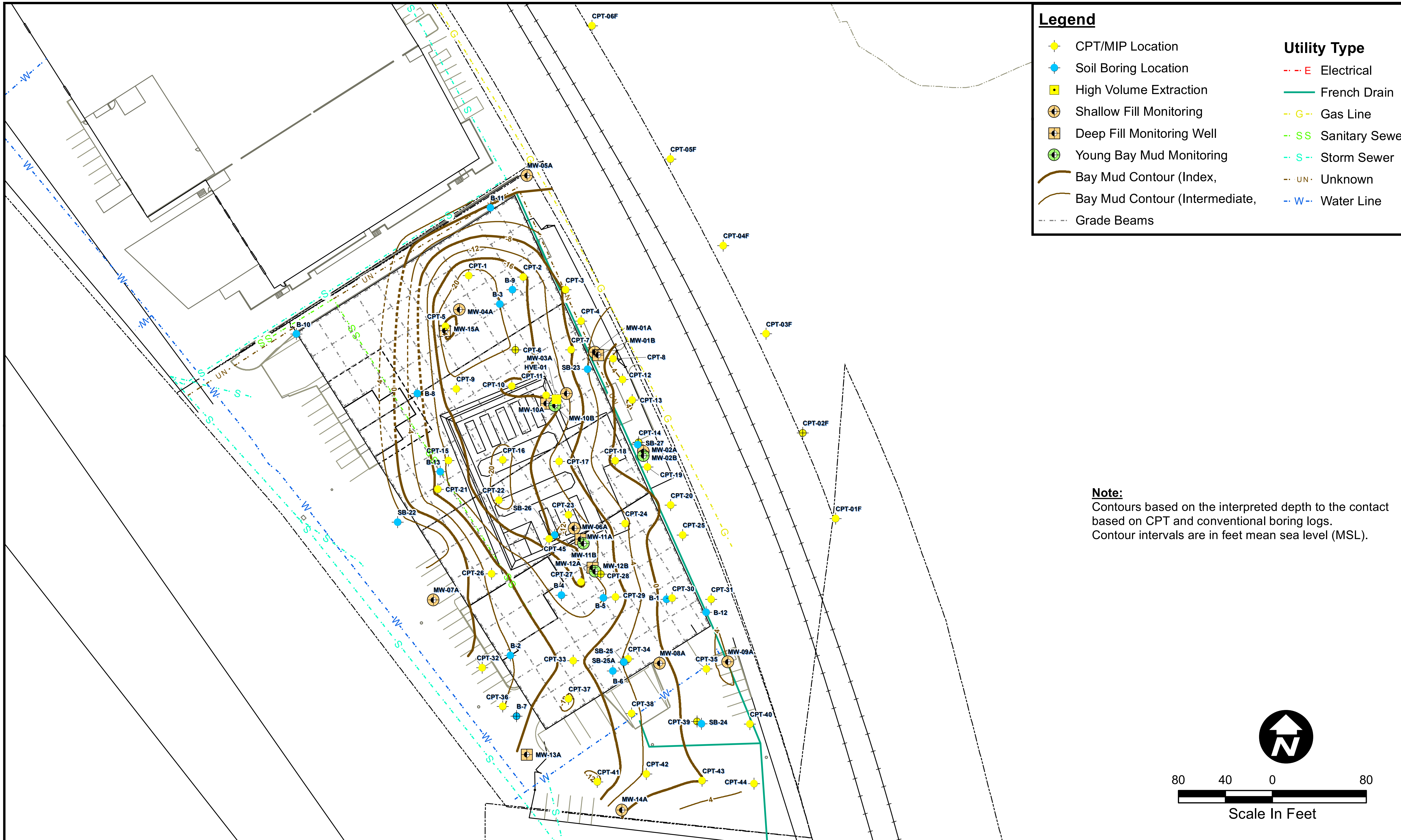
Scale In Feet

Reviewed by: G. White

EHS Support *consider it done*	3775 Bayshore Blvd Brisbane, CA	**Site Plan and Investigation Locations**	**Figure 3-1** II-1

D:\EHS_GIS\C01651_Brisbane\01_ANALYSIS\20170504_FigureRequest\SitePlan.mxd

Printed 12/13/2017 2:50:11 PM by ASmith



Reviewed by: G. White

D:\EHS_GIS\C01651_Brisbane\01_ANALYSIS\20170504_FigureRequest\SitePlan.mxd

Printed 12/13/2017 4:15:06 PM by ASmith

EHS Support *consider it done*

3775 Bayshore Blvd
Brisbane, CA

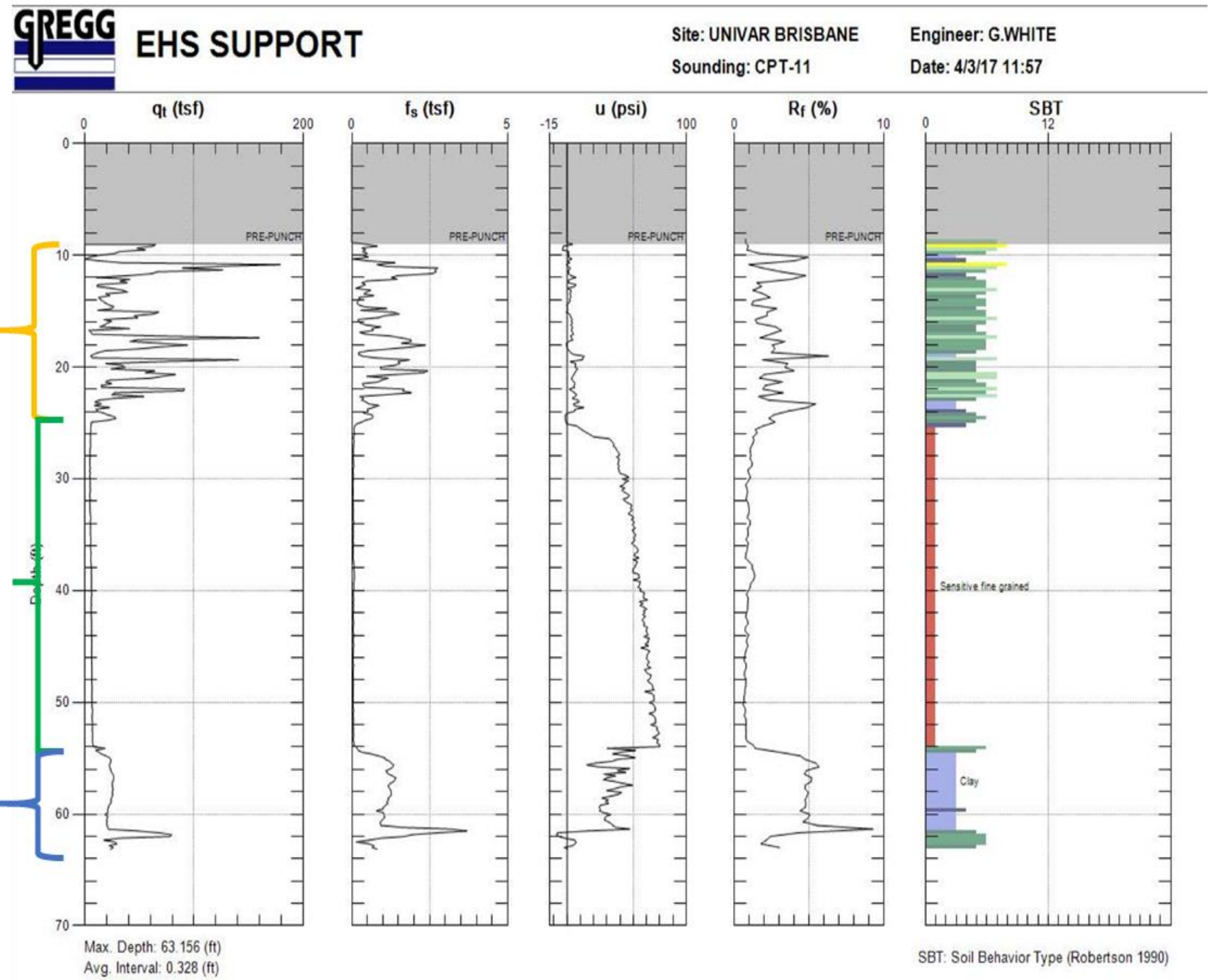
Site Plan and Young Bay Mud Contours

Figure 4-1
II-2

Fill:
Variable qt, fs, and resultant Rf and SBT. Fairly low u values.

Young Bay Mud:
Decreased and more consistent qt, fs, and resultant Rf. Fairly high u values as a function of fine-grained soils. Homogeneous SBT type.

Old Bay Mud:
Increased qt, fs, and resultant Rf compared to Young Bay Mud due to greater soil compaction. Rising u values with depth below contact. Fairly homogeneous SBT type.



ZONE		SBT
1		Sensitive, fine grained
2		Organic materials
3		Clay
4		Silty clay to clay
5		Clayey silt to silty clay
6		Sandy silt to clayey silt
7		Silty sand to sandy silt
8		Sand to silty sand
9		Sand
10		Gravely sand to sand
11		Very stiff fine grained*
12		Sand to clayey sand*

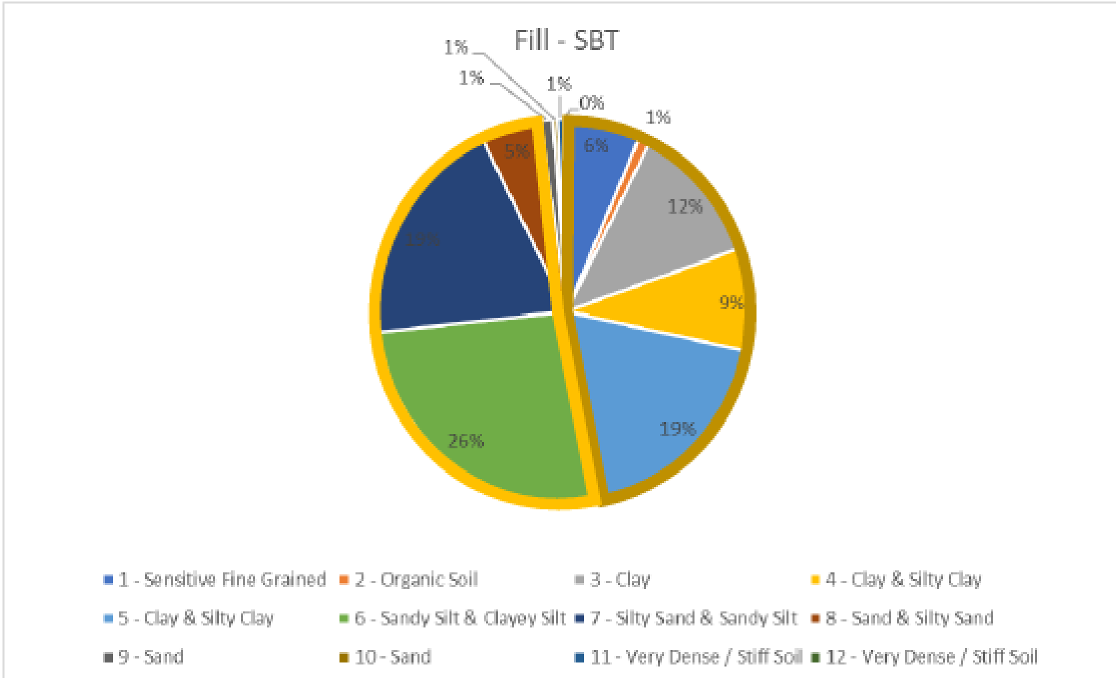
*over consolidated or cemented

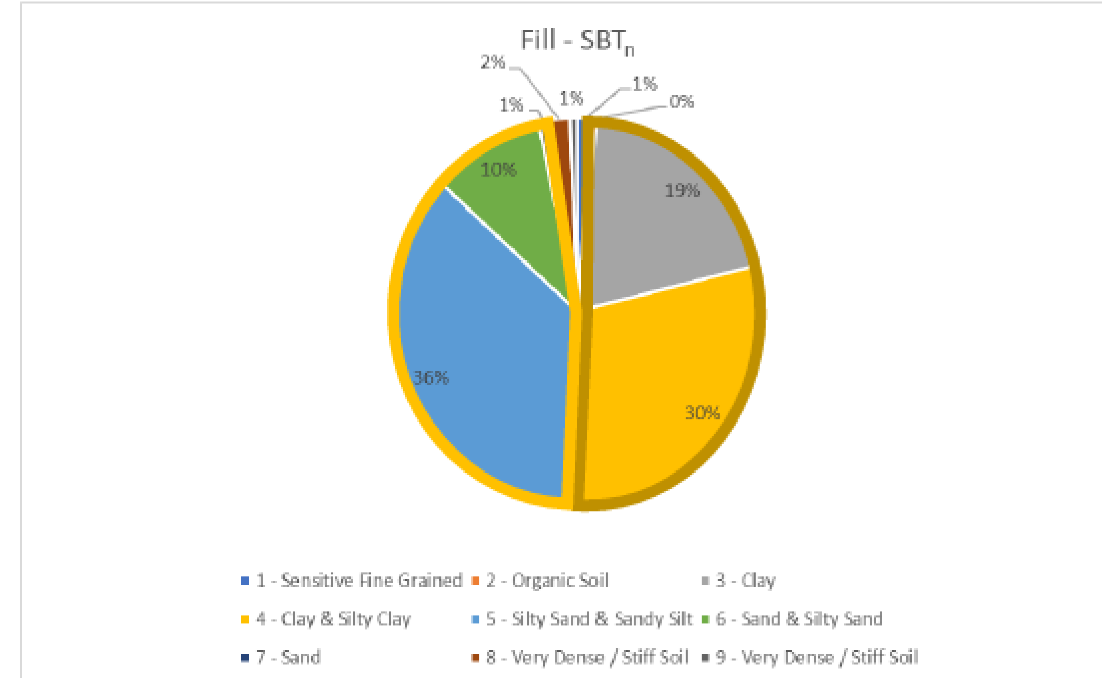
Where:
qt = total cone resistance
fs = sleeve friction
u = pore pressure
Rf = friction ratio [Rf = fs/qt x 100%]

EHS Support *consider it done*

FIGURE 4-2
EXAMPLE CPT LOG FROM CPT-11 WITH INTERPRETATION

PARCEL B 3775 BAYSHORE BLVD.
BRISBANE, CA





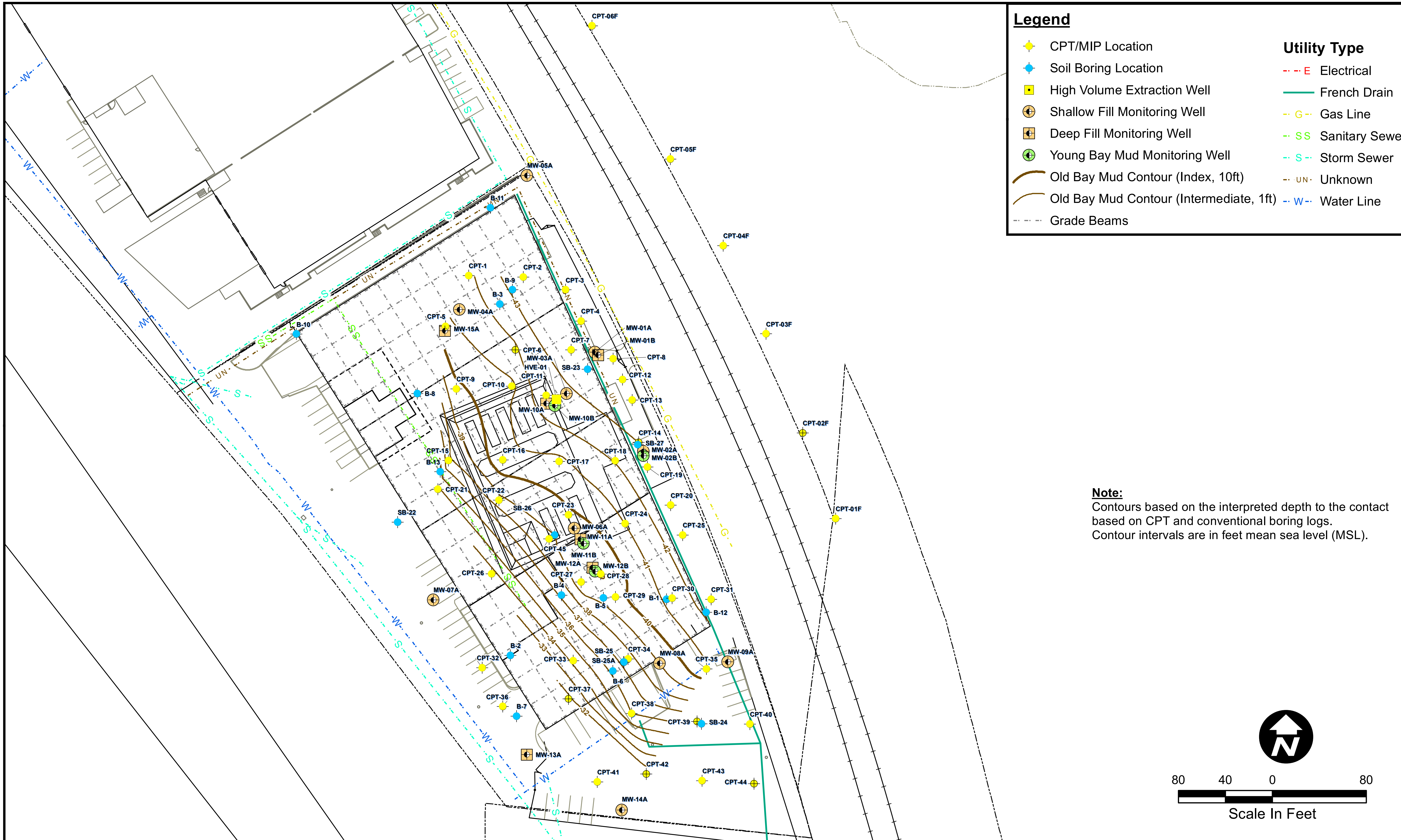
SBT Number	SBT Description	Fill Count	Fill %	Correlated USCS Identifier
1	1 - Sensitive Fine Grained	97	47%	ML/CL
2	2 - Organic Soil	15		
3	3 - Clay	184		
4	4 - Clay & Silty Clay	135		
5	5 - Clay & Silty Clay	283		
6	6 - Sandy Silt & Clayey Silt	398	51%	SM/SC
7	7 - Silty Sand & Sandy Silt	293		
8	8 - Sand & Silty Sand	78		
9	9 - Sand	16	1%	SW/SP
10	10 - Sand	6		
11	11 - Very Dense / Stiff Soil	8	1%	GM/GC
12	12 - Very Dense / Stiff Soil	4		

SBTn Number	SBTn Description	Fill Count	Fill %	Correlated USCS Identifier
1	1 - Sensitive Fine Grained	19	51%	ML/CL
2	2 - Organic Soil	6		
3	3 - Clay	294		
4	4 - Clay & Silty Clay	450		
5	5 - Silty Sand & Sandy Silt	549	46%	SM/SC
6	6 - Sand & Silty Sand	149		
7	7 - Sand	12	1%	SW/SP
8	8 - Very Dense / Stiff Soil	29	3%	GM/GC
9	9 - Very Dense / Stiff Soil	9		

EHS Support *consider it done*

FIGURE 4-3
FILL ZONE SOIL LITHOLOGY EVALUATION

PARCEL B 3775 BAYSHORE BLVD.
BRISBANE, CA



D:\EHS_GIS\C01651_Brisbane\01_ANALYSIS\20170504_FigureRequest\SitePlan.mxd

Printed 12/13/2017 4:15:08 PM by ASmith

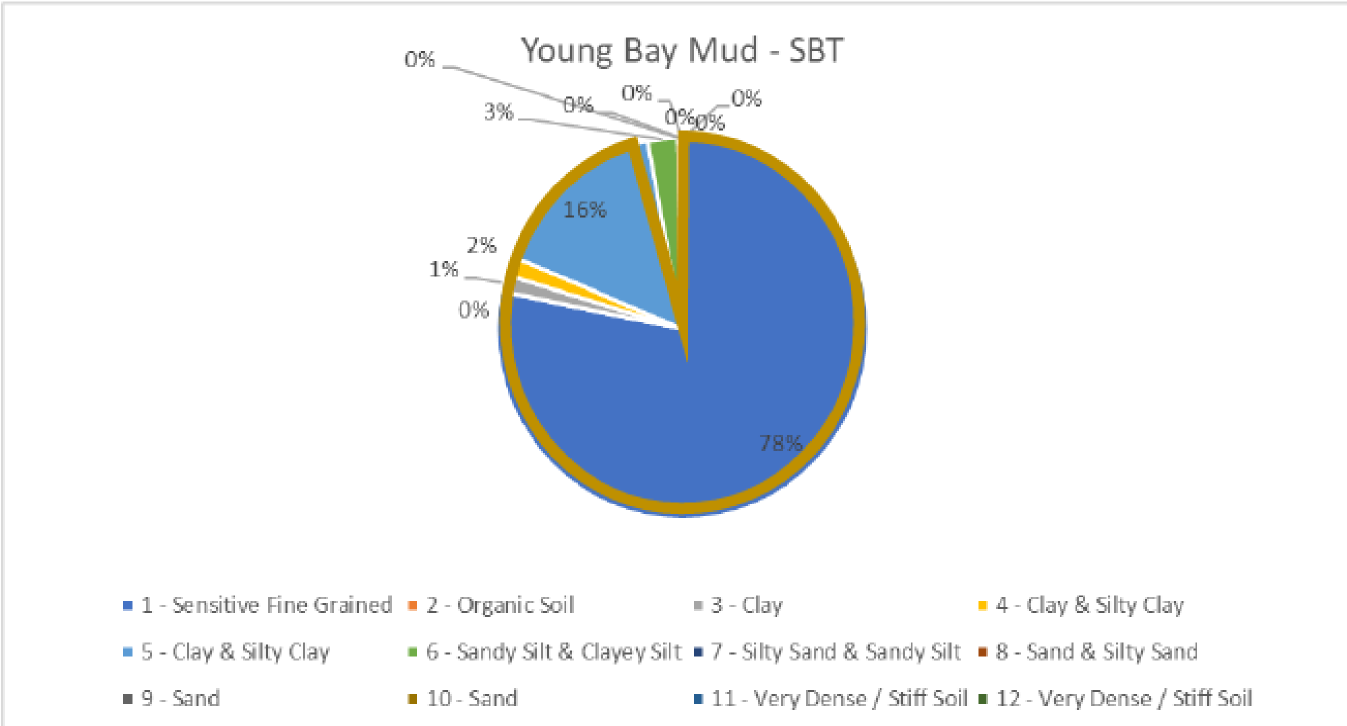
Reviewed by: G. White

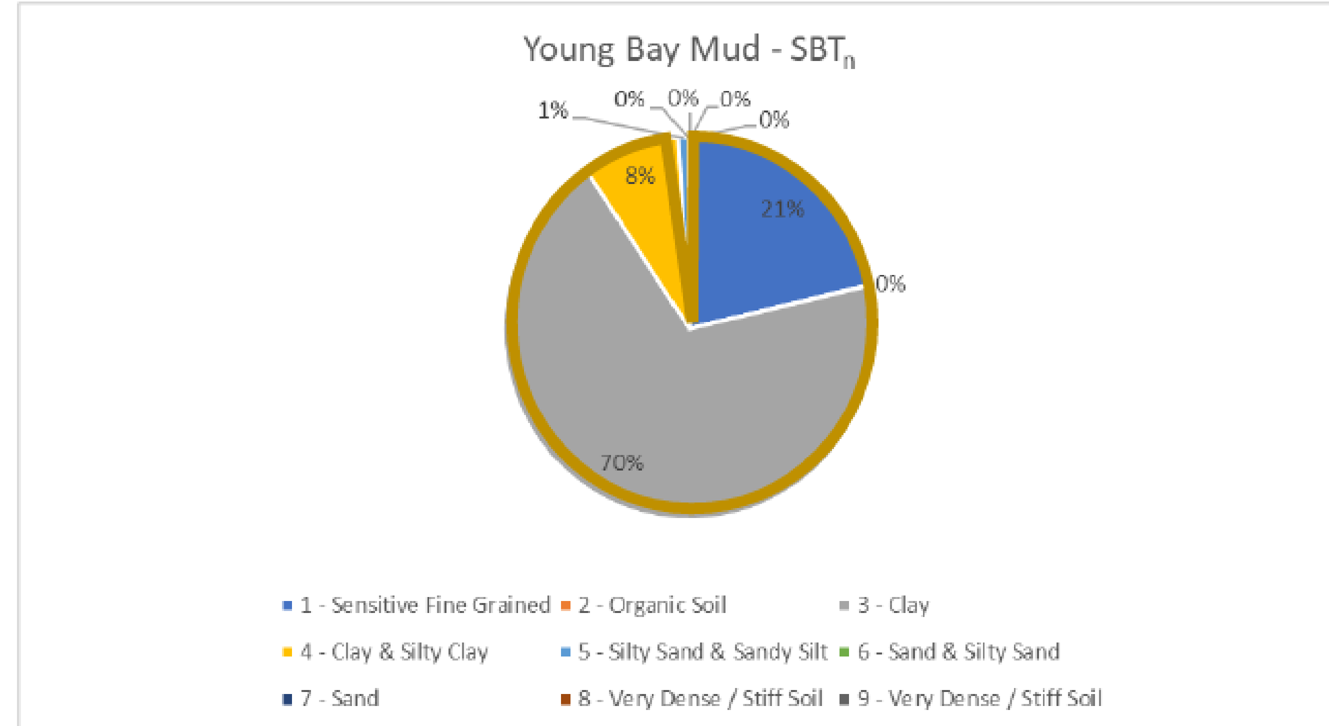
EHS Support *consider it done*

3775 Bayshore Blvd
Brisbane, CA

Site Plan and Old Bay Mud Contours

Figure 4-4





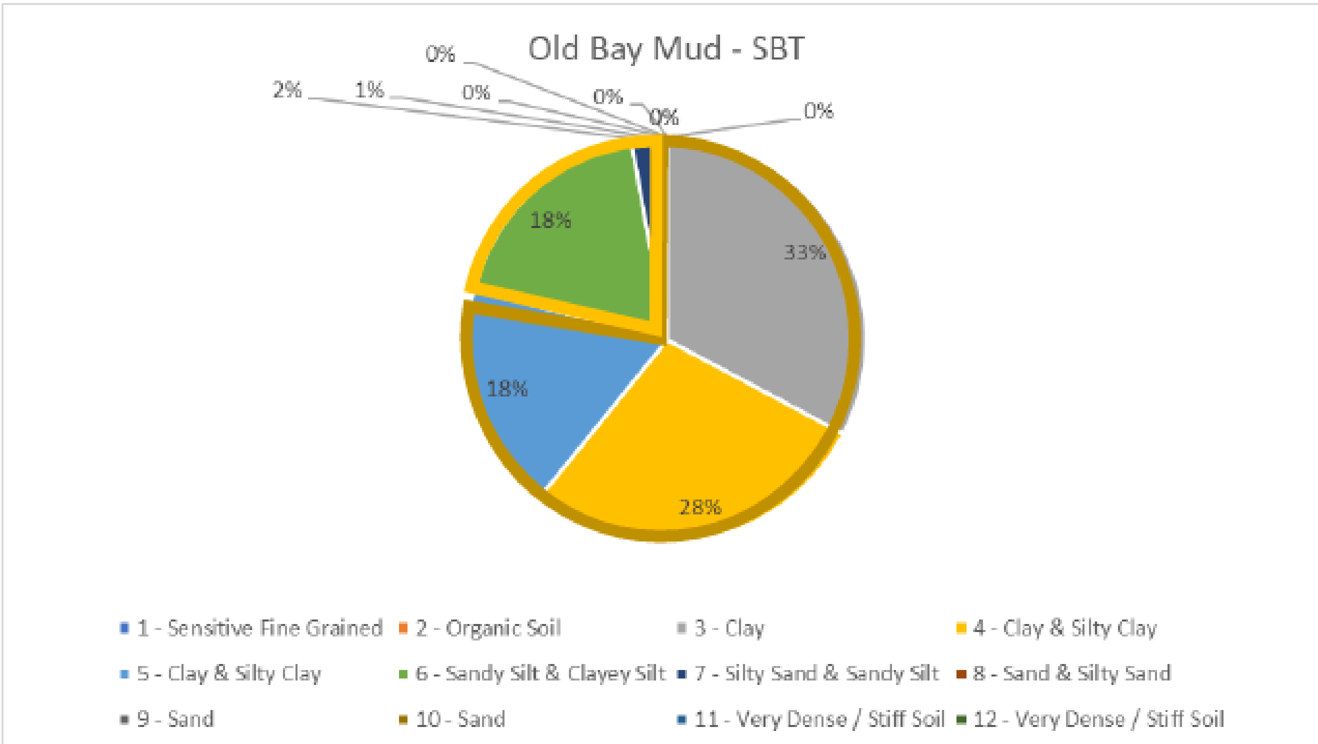
SBT Number	SBT Description	Young Bay Mud Count	Young Bay Mud %	Correlated USCS Identifier
1	1 - Sensitive Fine Grained	2205	97%	ML/CL
2	2 - Organic Soil	1		
3	3 - Clay	40		
4	4 - Clay & Silty Clay	47		
5	5 - Clay & Silty Clay	442		
6	6 - Sandy Silt & Clayey Silt	74	3%	SM/SC
7	7 - Silty Sand & Sandy Silt	6		
8	8 - Sand & Silty Sand	4		
9	9 - Sand	1	0%	SW/SP
10	10 - Sand	0		
11	11 - Very Dense / Stiff Soil	0	0%	GM/GC
12	12 - Very Dense / Stiff Soil	0		

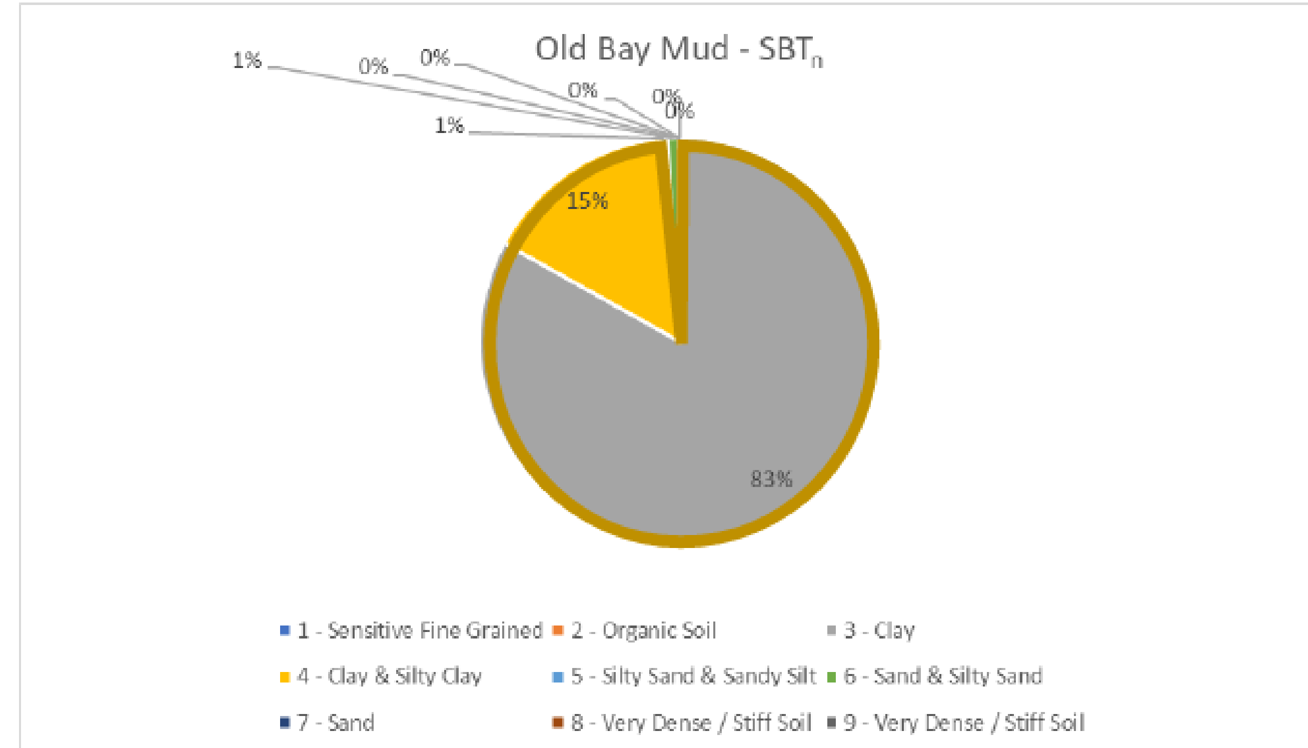
SBTn Number	SBTn Description	Young Bay Mud Count	Young Bay Mud %	Correlated USCS Identifier
1	1 - Sensitive Fine Grained	599	99%	ML/CL
2	2 - Organic Soil	2		
3	3 - Clay	1956		
4	4 - Clay & Silty Clay	235		
5	5 - Silty Sand & Sandy Silt	25	1%	SM/SC
6	6 - Sand & Silty Sand	3		
7	7 - Sand	0	0%	SW/SP
8	8 - Very Dense / Stiff Soil	0	0%	GM/GC
9	9 - Very Dense / Stiff Soil	0		

EHS Support
consider it done

FIGURE 4-5
YOUNG BAY MUD SOIL LITHOLOGY EVALUATION

PARCEL B 3775 BAYSHORE BLVD.
BRISBANE, CA





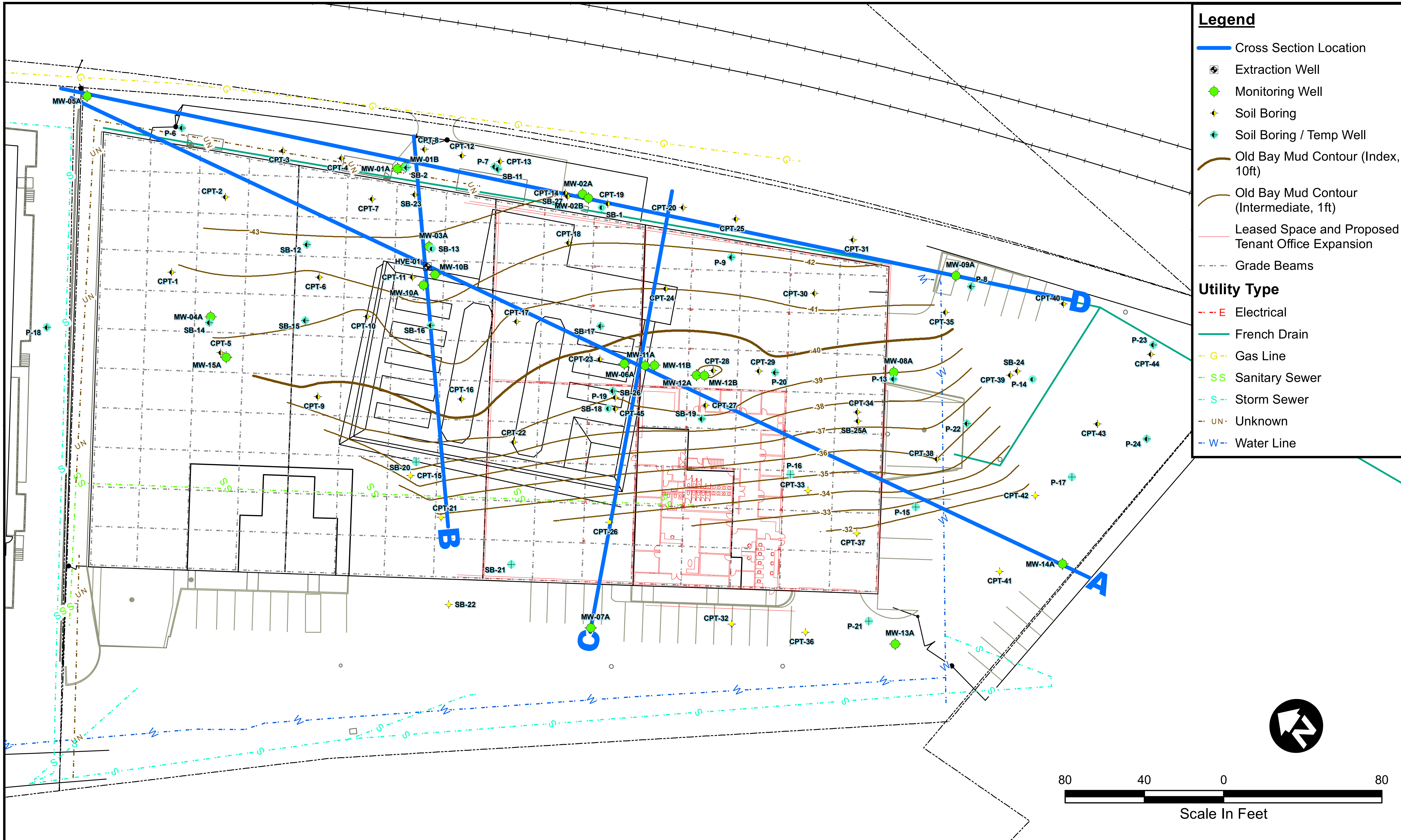
SBT Number	SBT Description	Old Bay Mud		Correlated USCS Identifier
		Count	%	
1	1 - Sensitive Fine Grained	0	79%	ML/CL
2	2 - Organic Soil	0		
3	3 - Clay	170		
4	4 - Clay & Silty Clay	147		
5	5 - Clay & Silty Clay	94		
6	6 - Sandy Silt & Clayey Silt	94	21%	SM/SC
7	7 - Silty Sand & Sandy Silt	9		
8	8 - Sand & Silty Sand	5		
9	9 - Sand	1	0%	SW/SP
10	10 - Sand	0		
11	11 - Very Dense / Stiff Soil	0	0%	GM/GC
12	12 - Very Dense / Stiff Soil	0		

SBTn Number	SBTn Description	Old Bay Mud		Correlated USCS Identifier
		Count	%	
1	1 - Sensitive Fine Grained	0	98%	ML/CL
2	2 - Organic Soil	0		
3	3 - Clay	425		
4	4 - Clay & Silty Clay	79		
5	5 - Silty Sand & Sandy Silt	3	2%	SM/SC
6	6 - Sand & Silty Sand	5		
7	7 - Sand	0	0%	SW/SP
8	8 - Very Dense / Stiff Soil	0	0%	GM/GC
9	9 - Very Dense / Stiff Soil	0		

EHS Support
consider it done

FIGURE 4-6
OLD BAY MUD SOIL LITHOLOGY EVALUATION

PARCEL B 3775 BAYSHORE BLVD.
BRISBANE, CA



Reviewed by: G. White

EHS Support
consider it done

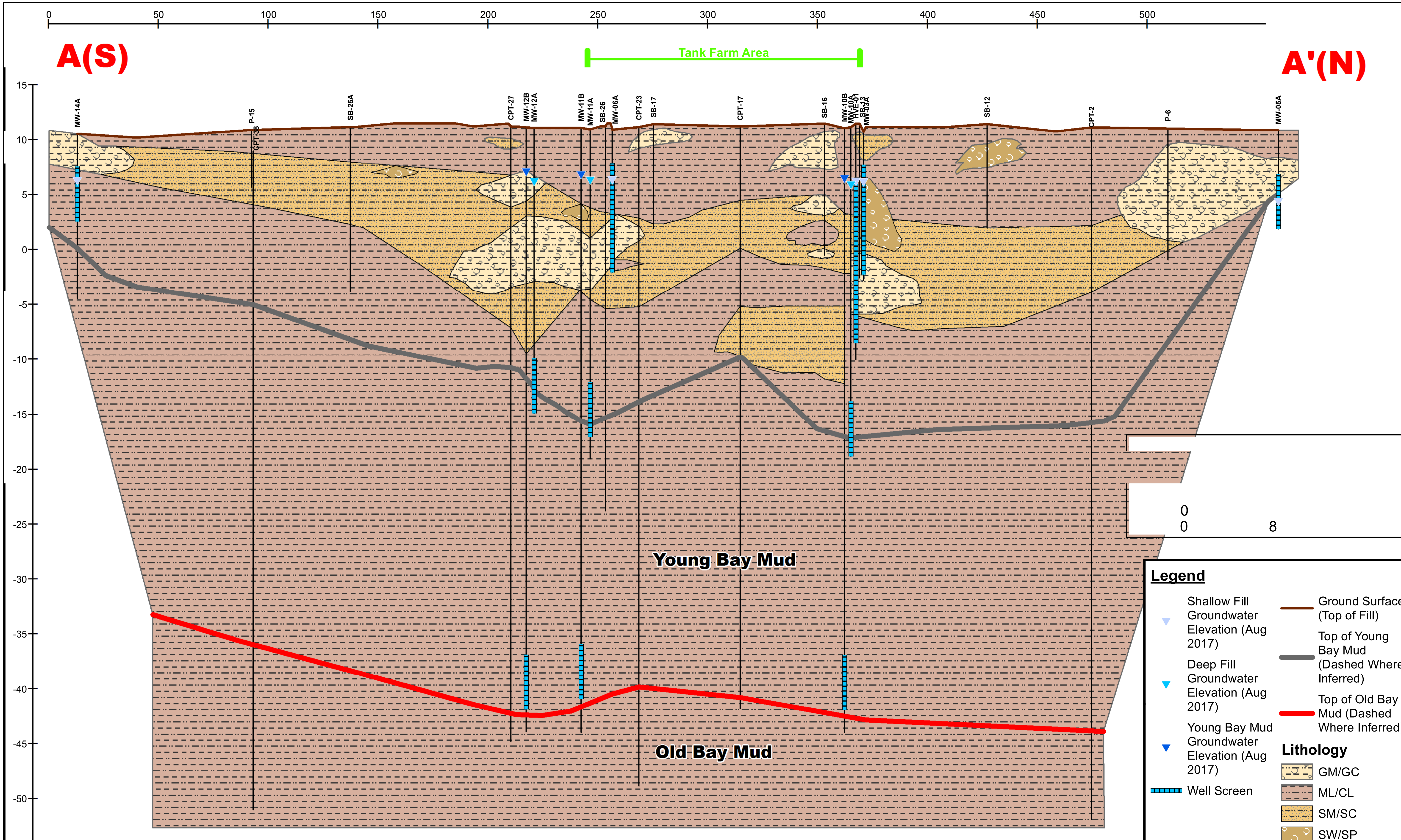
3775 Bayshore Blvd
Brisbane, CA

CROSS SECTION LOCATION MAP

FIGURE 4-7
II-8

D:\EHS_GIS\C01651_Brisbane\01_ANALYSIS\20170919_CrossSections\CSM.mxd

Printed 12/13/2017 2:49:12 PM by ASmith



Reviewed By: G. White

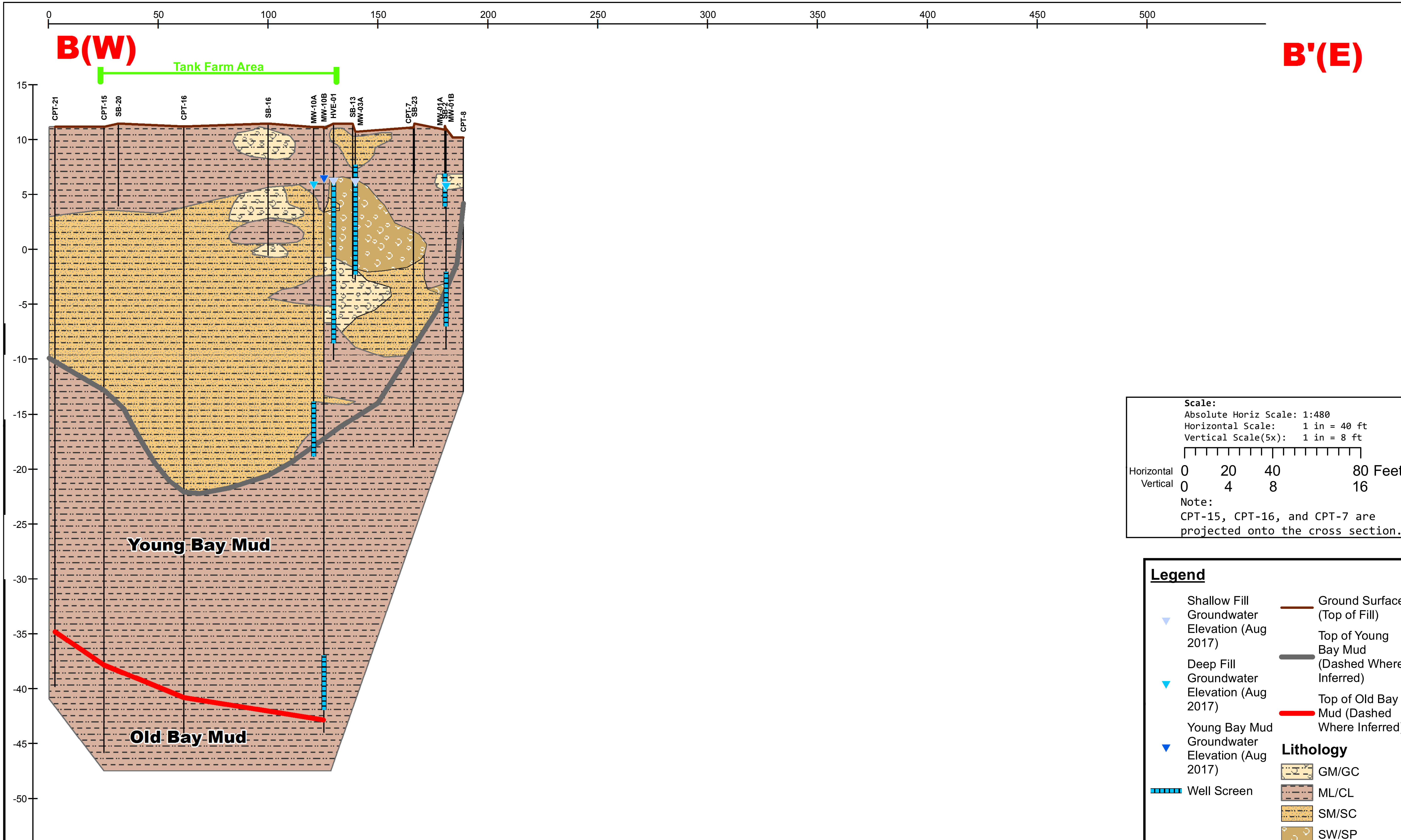
EHS Support consider it done

3775 Bayshore Blvd
Brisbane, CA

HYDROGEOLOGIC CROSS SECTION A-A'

Figure 4-8

Printed 12/13/2017 2:48:06 PM by ASmith



Reviewed By: G. White

EHS Support
consider it done

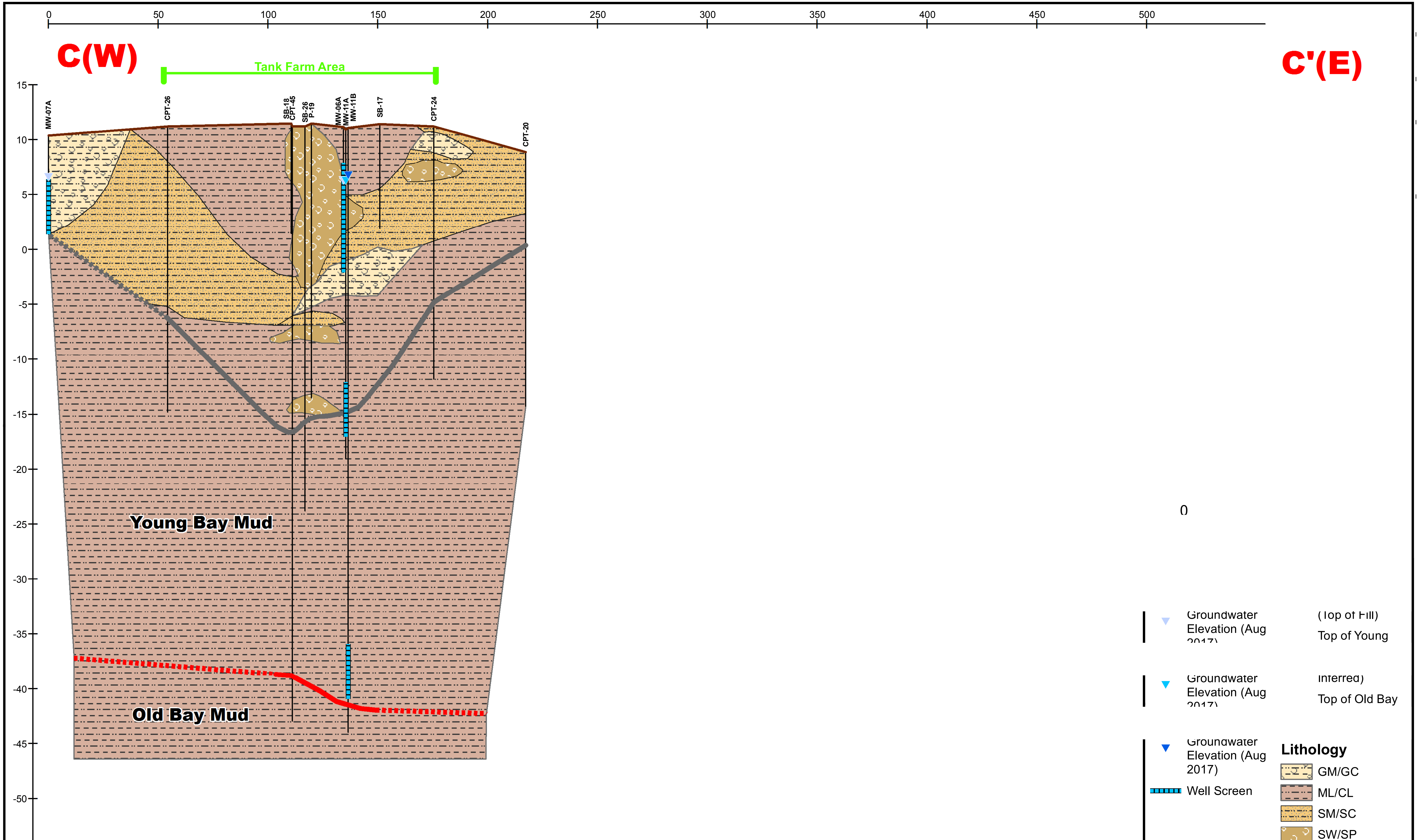
3775 Bayshore Blvd
Brisbane, CA

HYDROGEOLOGIC CROSS SECTION B-B'

Figure 4-9

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20170919_CrossSections\XsectSeries.mxd

Printed 12/13/2017 2:48:09 PM by ASmith



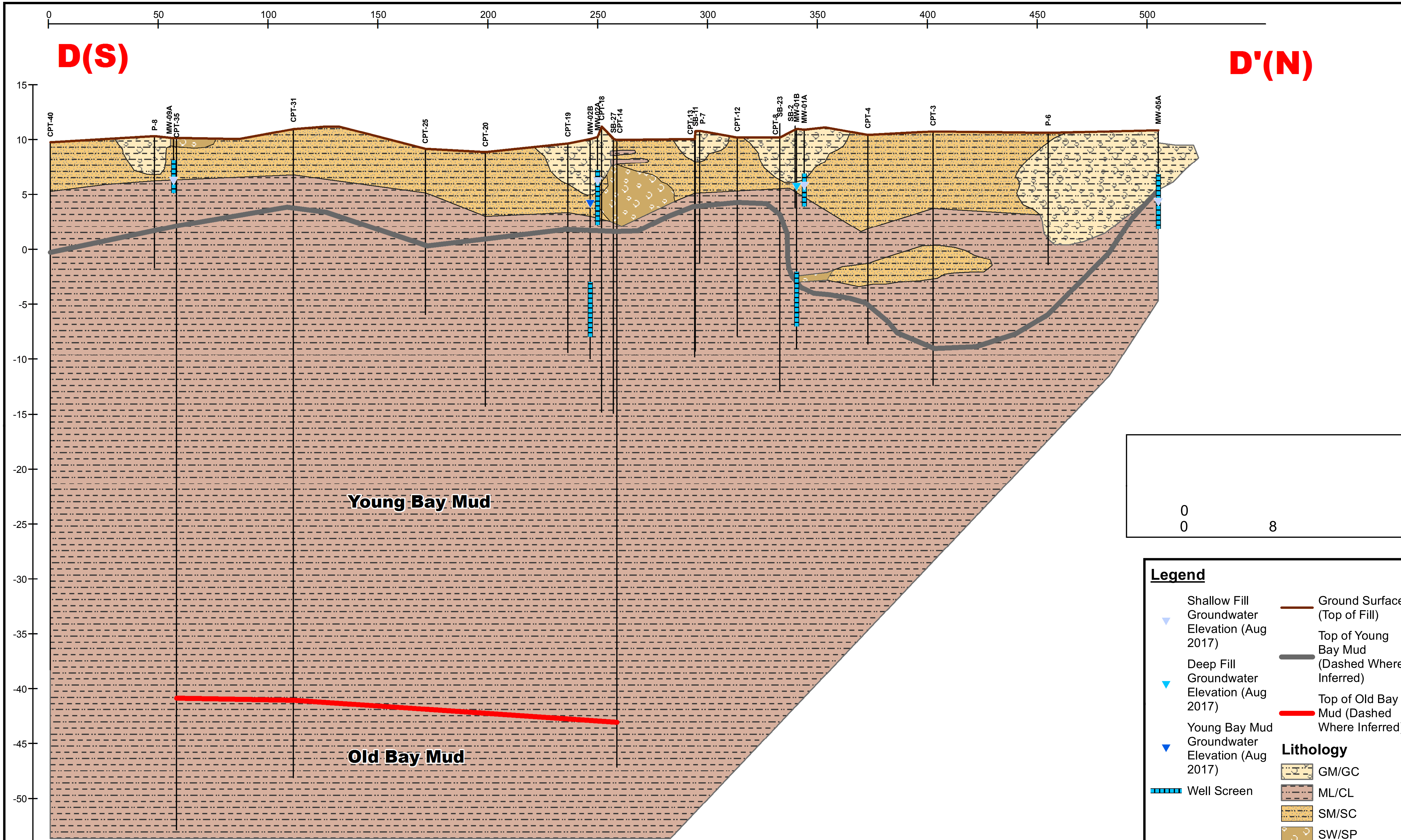
Reviewed By: G. White

EHS Support
consider it done

3775 Bayshore Blvd
Brisbane, CA

HYDROGEOLOGIC CROSS SECTION C-C'

Figure 4-10



Reviewed By: G. White

EHS Support *consider it done*

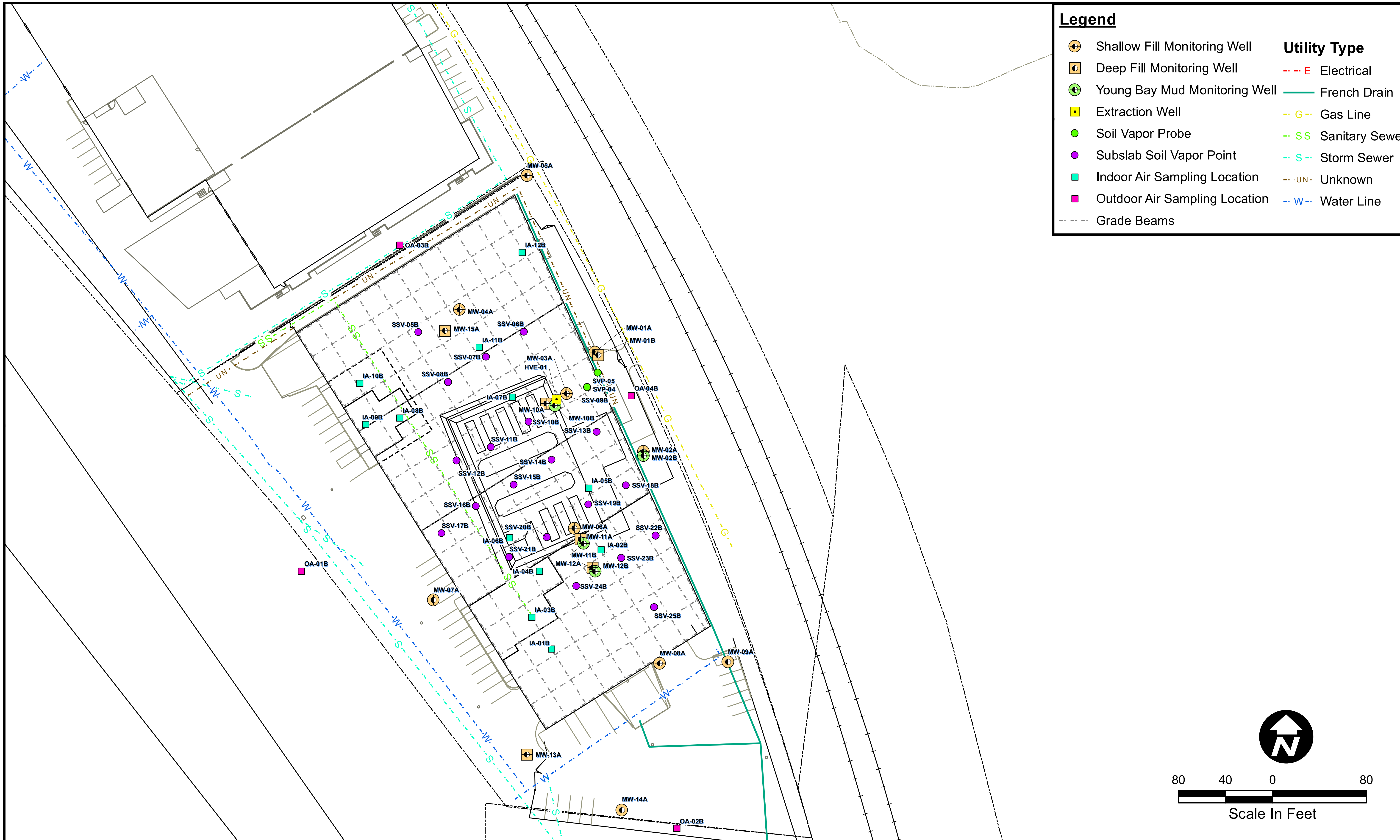
3775 Bayshore Blvd
Brisbane, CA

HYDROGEOLOGIC CROSS SECTION D-D'

Figure 4-11
II-12

D:\EHS_GIS\O01651_Brisbane\01_ANALYSIS\20170919_CrossSections\XsectSeries.mxd

Printed 12/13/2017 2:48:13 PM by ASmith



Reviewed by: G. White

EHS Support *consider it done*

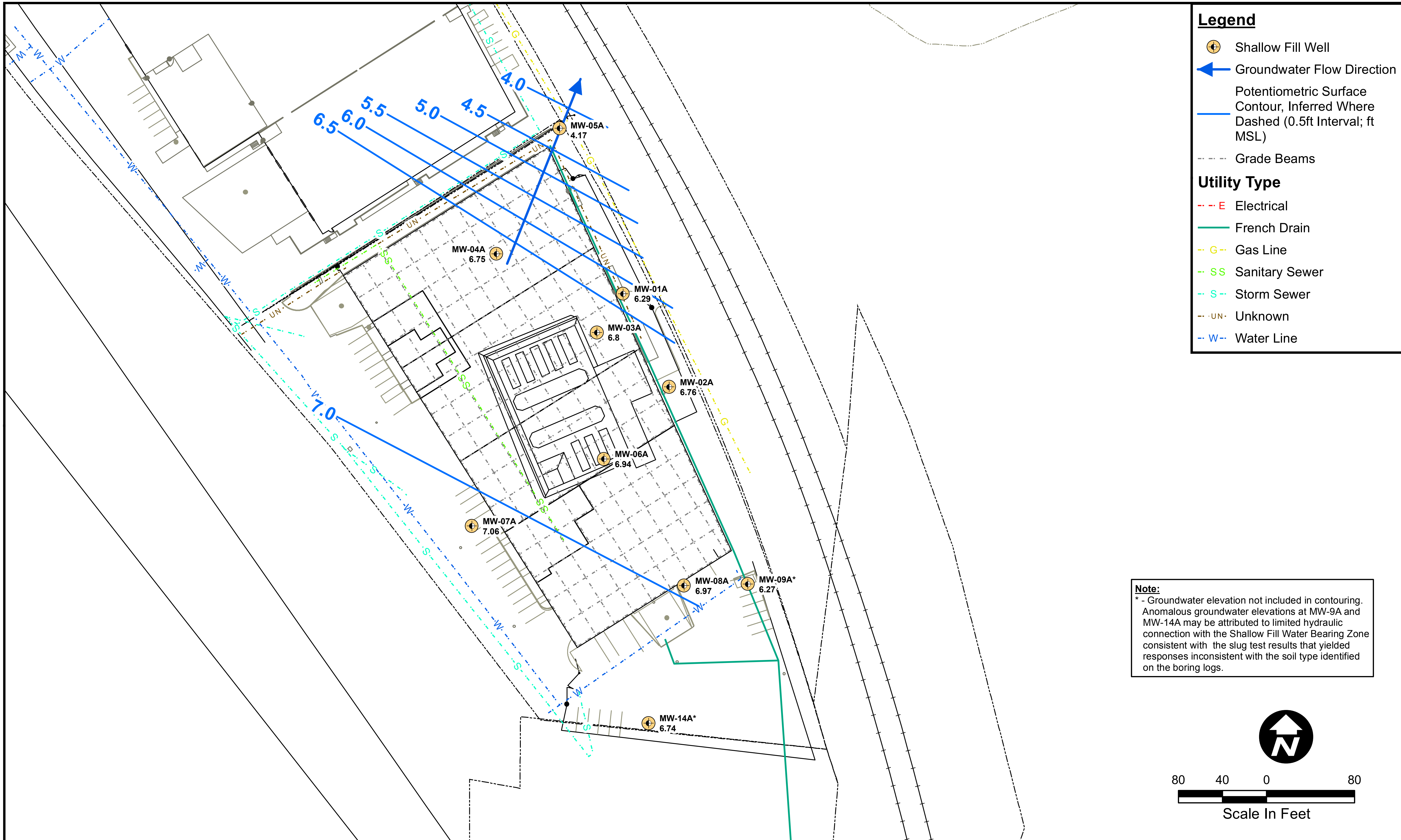
3775 Bayshore Blvd
Brisbane, CA

Site Monitoring Network

Figure 4-12
II-13

D:\EHS_GIS\C01651_Brisbane\01_ANALYSIS\2017\0504_FigureRequestSitePlan.mxd

Printed 12/13/2017 2:50:13 PM by ASmith



Reviewed by: G. White

EHS Support consider it done

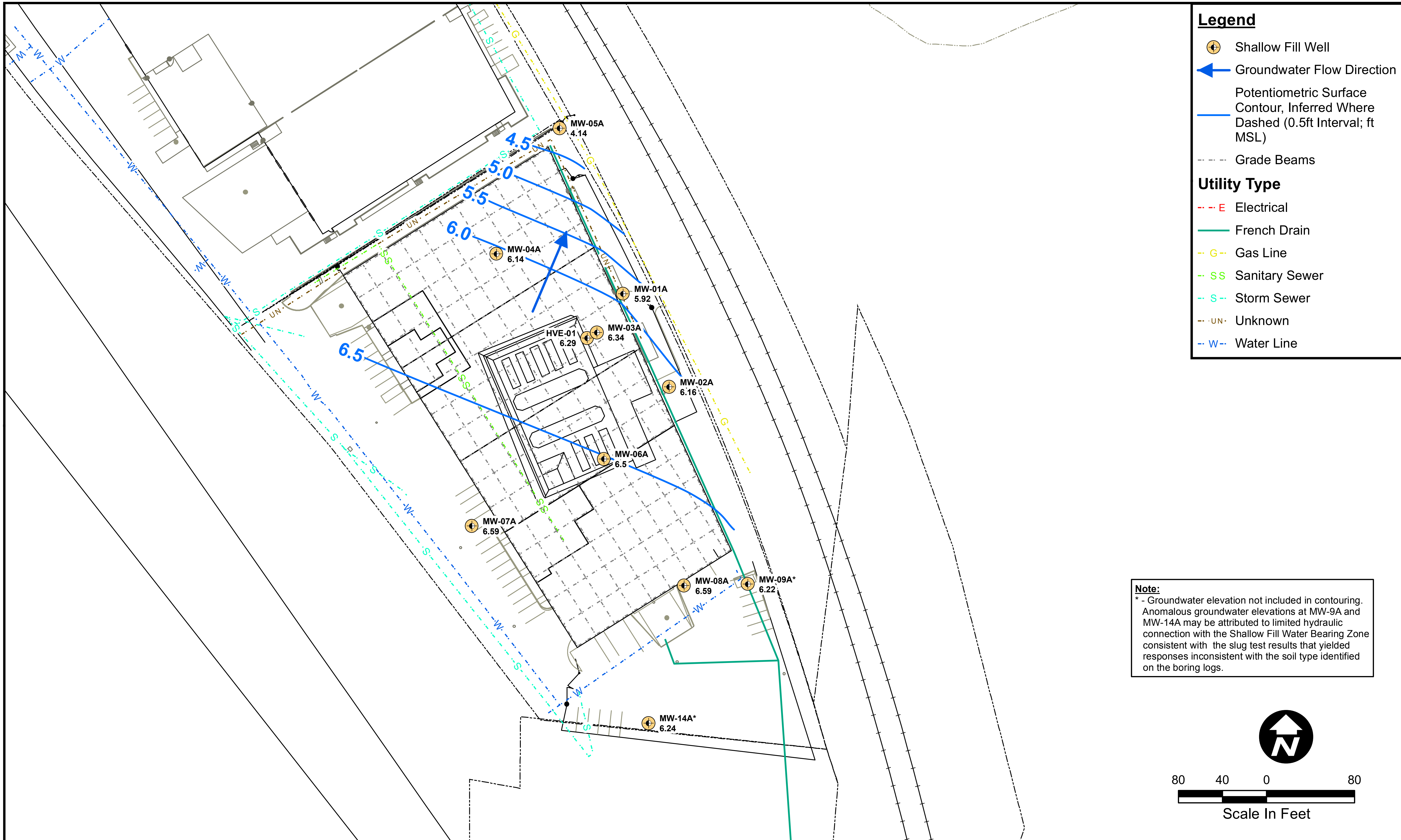
3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - SHALLOW FILL ZONE (APRIL 21, 2017)

Figure 4-13

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20170620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:46 PM by ASmith



Reviewed by: G. White

EHS Support *consider it done*

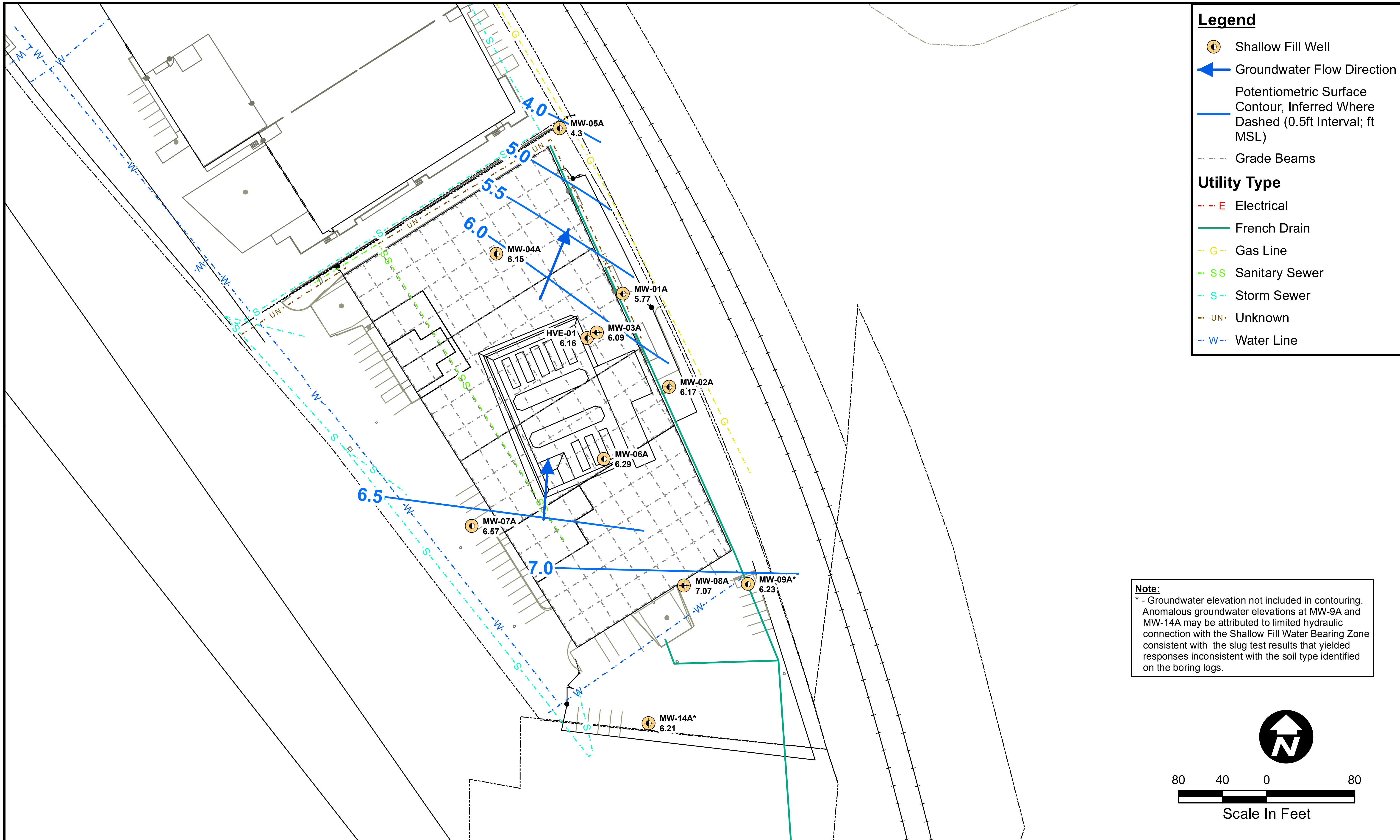
3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - SHALLOW FILL ZONE (JUNE 15, 2017)

Figure 4-14

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\2017\0620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:48 PM by ASmith



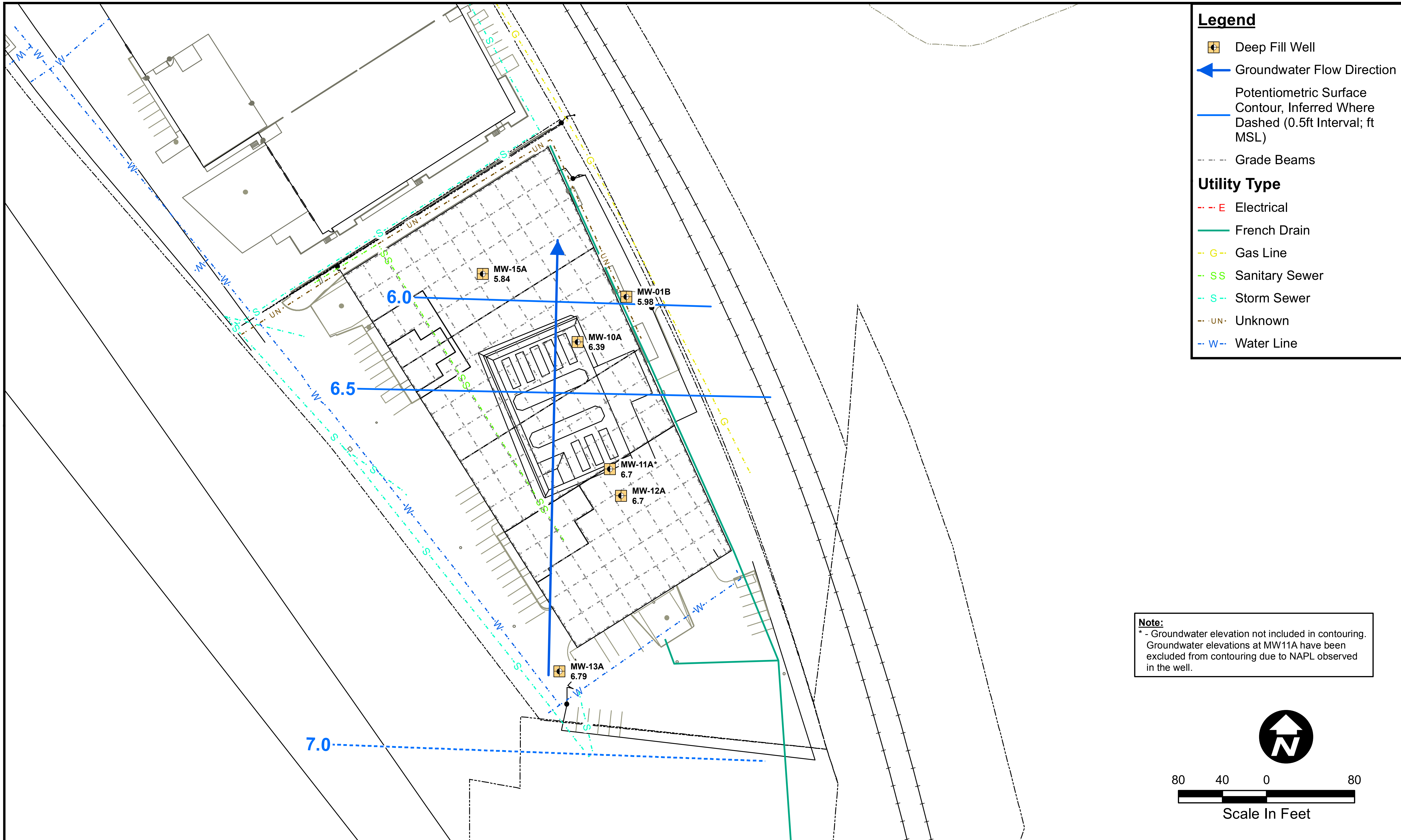
Reviewed by: G. White

EHS Support consider it done

3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - SHALLOW FILL ZONE (AUGUST 1, 2017)

Figure 4-15



Legend

Deep Fill Well
Groundwater Flow Direction
Potentiometric Surface Contour, Inferred Where Dashed (0.5ft Interval; ft MSL)
Grade Beams

Utility Type

E Electrical
French Drain
G Gas Line
SS Sanitary Sewer
S Storm Sewer
UN Unknown
W Water Line

Note:
* - Groundwater elevation not included in contouring. Groundwater elevations at MW11A have been excluded from contouring due to NAPL observed in the well.

80 40 0 80
Scale In Feet

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20170620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:51 PM by ASmith

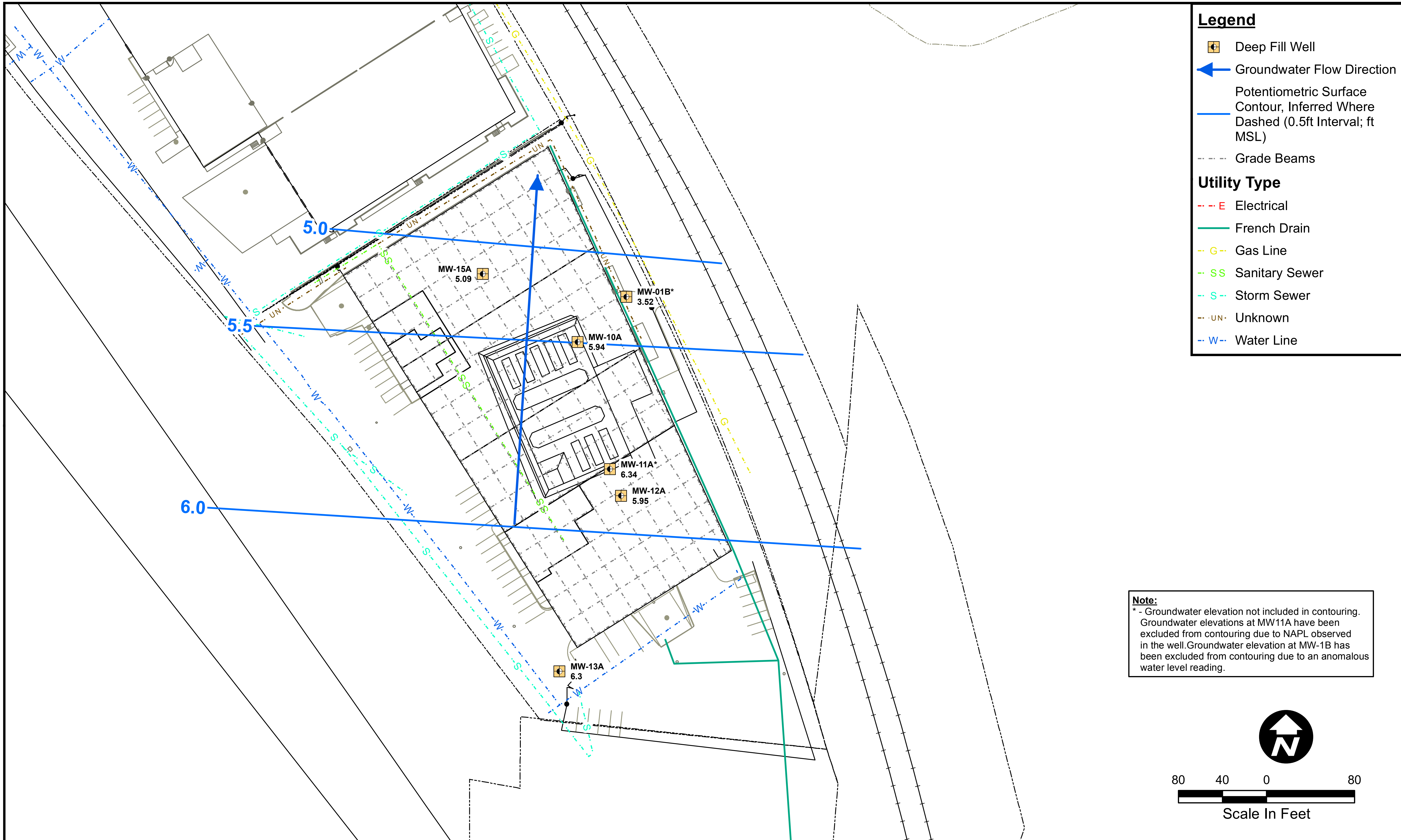
Reviewed by: G. White

EHS Support *consider it done*

3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - DEEP FILL ZONE (APRIL 21, 2017)

Figure 4-16



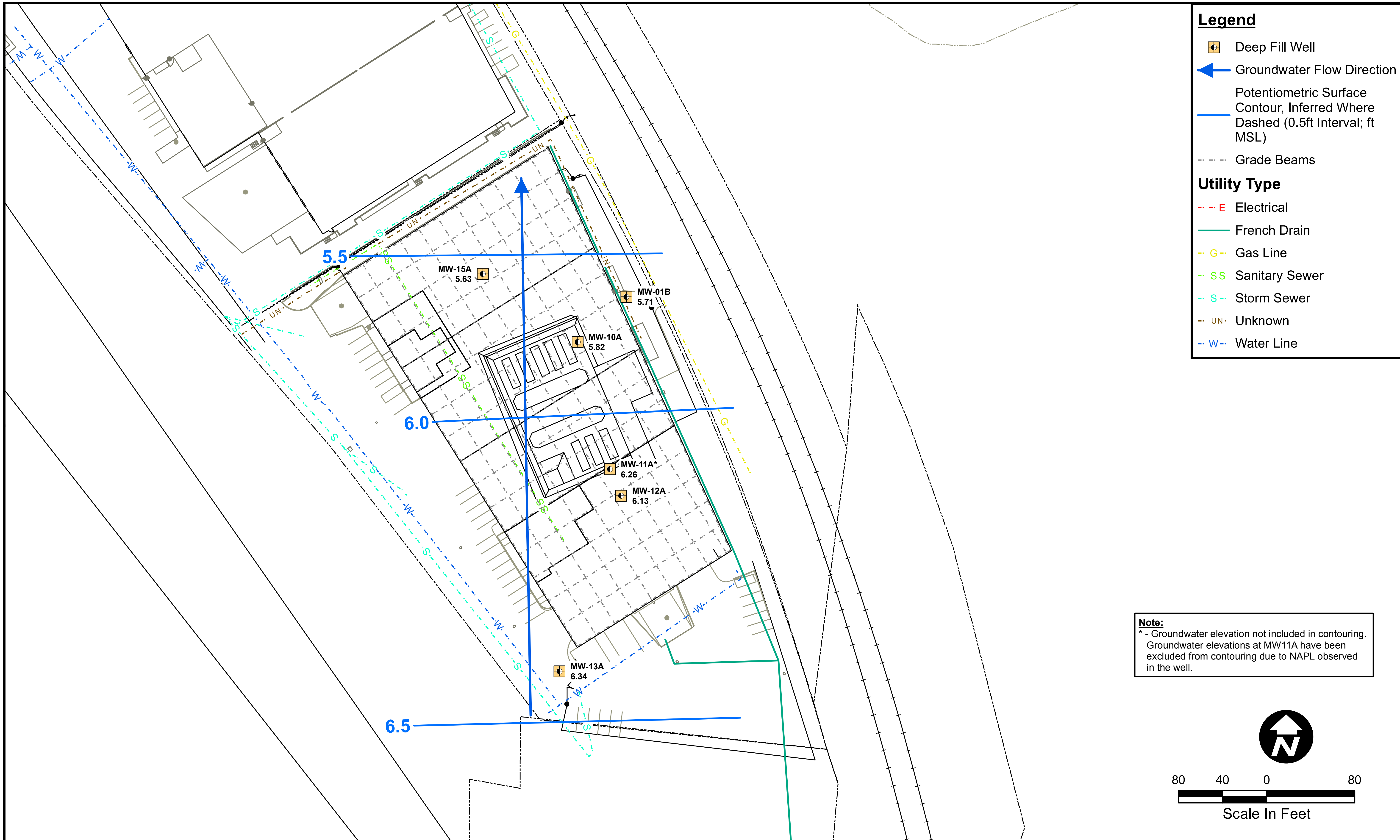
Reviewed by: G. White

EHS Support *consider it done*

3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - DEEP FILL ZONE (JUNE 15, 2017)

Figure 4-17



EHS Support consider it done

3775 Bayshore Blvd
Brisbane, CA

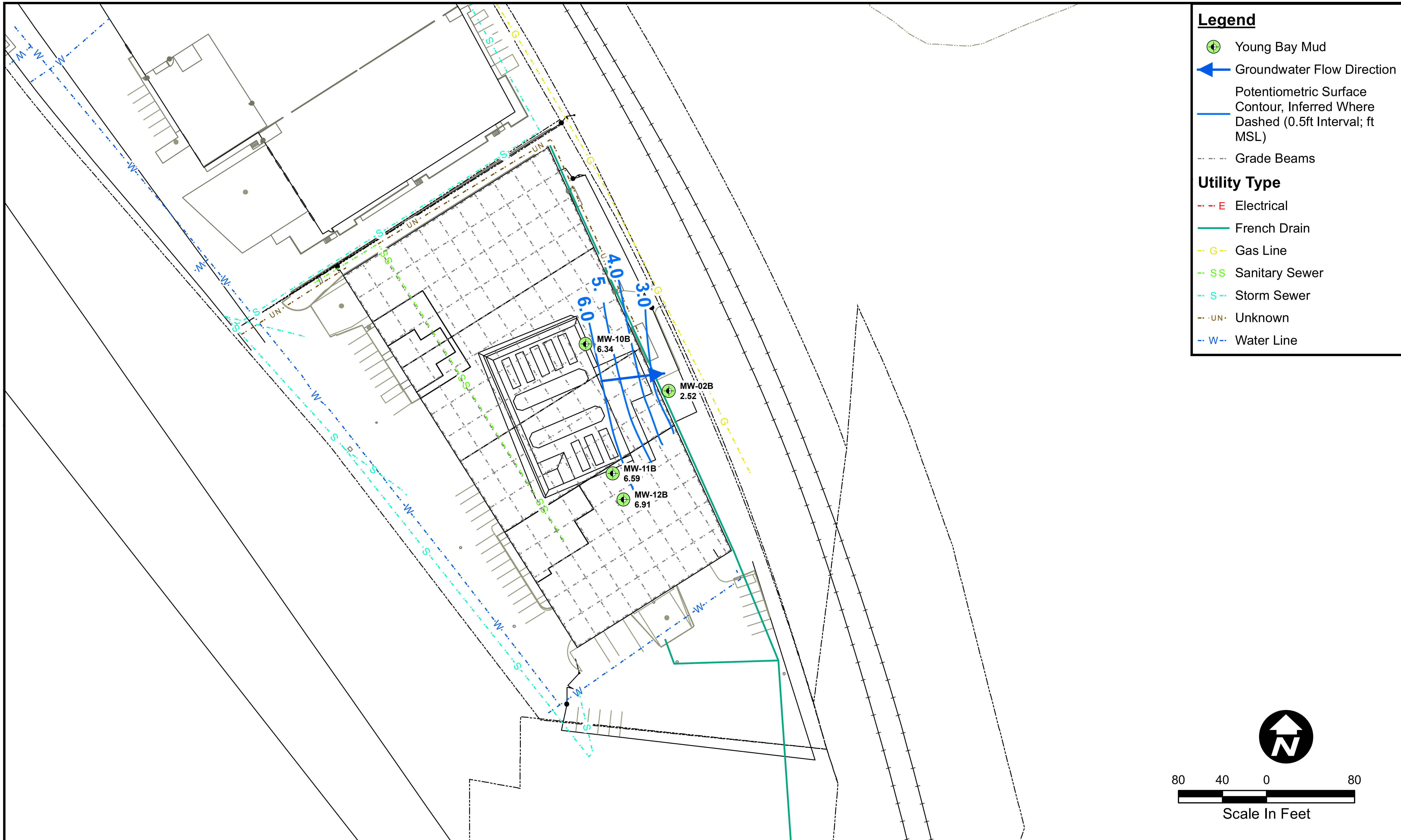
POTENTIOMETRIC SURFACE - DEEP FILL ZONE (AUGUST 1, 2017)

Figure 4-18

Reviewed by: G. White

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\2017\0620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:53 PM by ASmith



Reviewed by: G. White

EHS Support *consider it done*

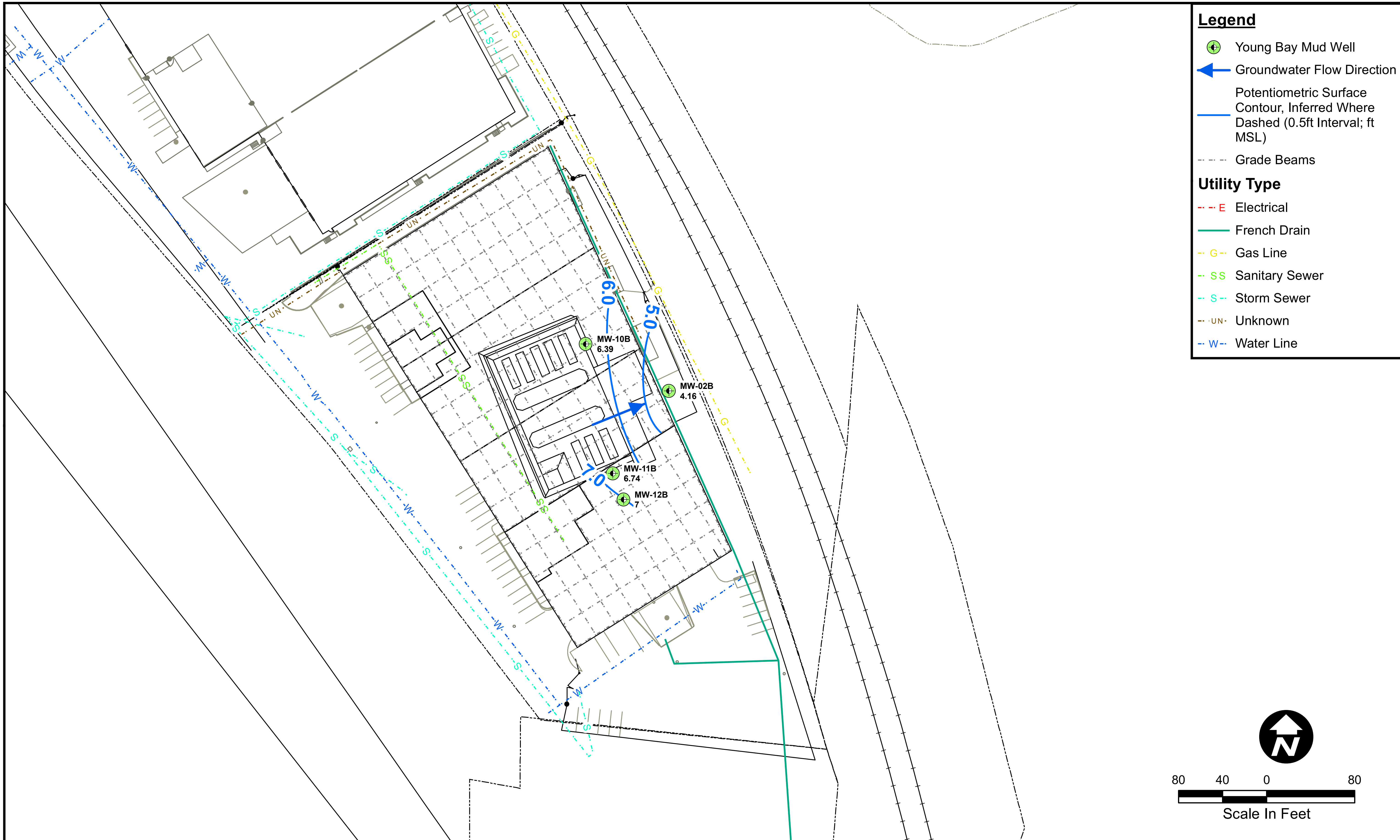
3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - YOUNG BAY MUD ZONE
(JUNE 15, 2017)

Figure 4-19
II-20

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\20170620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:54 PM by ASmith



EHS Support *consider it done*

3775 Bayshore Blvd
Brisbane, CA

POTENTIOMETRIC SURFACE - YOUNG BAY MUD ZONE
(AUGUST 1, 2017)

Figure 4-20

Reviewed by: G. White

D:\EHSS_GIS\C01651_Brisbane\01_ANALYSIS\2017\0620_PotSurfFigures\GWCON_Series.mxd

Printed 12/13/2017 2:55:56 PM by ASmith

APPENDIX III – GEOTECHNICAL CALCULATIONS

Immediate Settlement in Fill: In-Situ Thermal Treatment to 10 Feet Depth bgs

Inputs	
Reference Boring ID	Harlan
E_s Correlation Method	Menzenbach (1977)
γ, pcf	125
Heated Fill Thickness, ft	5
SPT Penetration (Fill), blows/ft	10
Es for N=10 blows/ft, ksf	626

Depth Interval			Δz, ft	N, blows per foot	E_s, ksf	Δq, ksf	Approx. Boussinesq I_z	Settlement (after Schmertmann, 1970)
Top, ft bgs	Bottom, ft bgs	Midpoint, ft bgs						$(I_z*\Delta z)/E_s$
5	7.5	6.25	2.5	10	626	0.078	1	0.0003
7.5	10	8.75	2.5	10	626	0.234	1	0.0009
10	12.5	11.25	2.5	10	626	0.312	1	0.0012
12.5	15	13.75	2.5	10	626	0.312	1	0.0012
15	17.5	16.25	2.5	10	626	0.312	1	0.0012
17.5	20	18.75	2.5	10	626	0.312	1	0.0012
20	22.5	21.25	2.5	10	626	0.312	1	0.0012
22.5	25	23.75	2.5	10	626	0.312	1	0.0012
25	27.5	26.25	2.5	10	626	0.312	1	0.0012
27.5	30	28.75	2.5	10	626	0.312	1	0.0012
30	32.5	31.25	2.5	10	626	0.312	1	0.0012
32.5	35	33.75	2.5	10	626	0.312	1	0.0012
							*ΔH, Δq * Σ [(Iz*Δz)/Es], ft =*	0.01
							*ΔH, Δq * Σ [(Iz*Δz)/Es], in. =*	**0.16**

Notes:

1. Settlement estimate to occur within fill.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -25 (EHS, Hydrogeologic Cross Section B-B', Figure 4-9)
3. Water will be boiled and removed to where u = 0 to 10 feet bgs.
4. Modulus calculated assuming N = 10, which corresponds approximately to the average minus one standard deviation.
5. Area of treatment large therefore Boussinesq I_z = 1.

WJE

Primary Consolidation Settlement Calculation: In-Situ Thermal Treatment to 10 Feet Depth bgs

General Properties	
Water Unit Weight, pcf	62.4
Initial Groundwater Level, ft	5
Depth to Thermal Treatment, ft	10

Soil Properties			
Fill		Young Bay mud	
Unit Weight, pcf	125	Unit Weight, pcf	105
Compression Index, Cc		Compression Index, Cc	0.74
Initial Void Ratio, e_0		Initial Void Ratio, e_0	1.5
OCR		OCR	1
0.5 yr. Consolidation (U), %	N/A	0.5 yr. Consolidation (U), %	7

Material	Layer Depth, ft		Layer Thickness, ft	Midpoint of Layer, ft	Overburden Stress, psf	Initial Porewater pressure, psf	Initial Effective Stress, psf	Final Porewater pressure, psf	Final Effective Stress, psf	Void Ratio, eo	Compression Index, Cc	Incremental Settlement, in.	Cumulative Settlement, in.
	From	To											
Fill	0	2	2	1	125	0	125	0	125	0.00	0.00	0.0	0.0
Fill	2	4	2	3	375	0	375	0	375	0.00	0.00	0.0	0.0
Fill	4	6	2	5	625	0	625	0	625	0.00	0.00	0.0	0.0
Fill	6	8	2	7	875	125	750	0	875	0.00	0.00	0.0	0.0
Fill	8	10	2	9	1125	250	875	0	1125	0.00	0.00	0.0	0.0
Fill	10	12	2	11	1375	374	1001	62	1313	0.00	0.00	0.0	0.0
Fill	12	14	2	13	1625	499	1126	187	1438	0.00	0.00	0.0	0.0
Fill	14	16	2	15	1875	624	1251	312	1563	0.00	0.00	0.0	0.0
Fill	16	18	2	17	2125	749	1376	437	1688	0.00	0.00	0.0	0.0
Fill	18	20	2	19	2375	874	1501	562	1813	0.00	0.00	0.0	0.0
Fill	20	22	2	21	2625	998	1627	686	1939	0.00	0.00	0.0	0.0
Fill	22	24	2	23	2875	1123	1752	811	2064	0.00	0.00	0.0	0.0
Fill	24	26	2	25	3125	1248	1877	936	2189	0.00	0.00	0.0	0.0
Young Bay mud	26	28	2	27	3335	1373	1962	936	2399	1.50	0.74	0.6	0.6
Young Bay mud	28	30	2	29	3545	1498	2047	1092	2453	1.50	0.74	0.6	1.2
Young Bay mud	30	32	2	31	3755	1622	2133	1248	2507	1.50	0.74	0.5	1.7
Young Bay mud	32	34	2	33	3965	1747	2218	1404	2561	1.50	0.74	0.4	2.1
Young Bay mud	34	36	2	35	4175	1872	2303	1560	2615	1.50	0.74	0.4	2.5
Young Bay mud	36	38	2	37	4385	1997	2388	1716	2669	1.50	0.74	0.3	2.9
Young Bay mud	38	40	2	39	4595	2122	2473	1872	2723	1.50	0.74	0.3	3.2
Young Bay mud	40	42	2	41	4805	2246	2559	2028	2777	1.50	0.74	0.3	3.4
Young Bay mud	42	44	2	43	5015	2371	2644	2184	2831	1.50	0.74	0.2	3.6
Young Bay mud	44	46	2	45	5225	2496	2729	2340	2885	1.50	0.74	0.2	3.8
Young Bay mud	46	48	2	47	5435	2621	2814	2496	2939	1.50	0.74	0.1	3.9
Young Bay mud	48	50	2	49	5645	2746	2899	2652	2993	1.50	0.74	0.1	4.0
Young Bay mud	50	52	2	51	5855	2870	2985	2808	3047	1.50	0.74	0.1	4.1
Young Bay mud	52	54	2	53	6065	2995	3070	2964	3101	1.50	0.74	0.0	4.1
Young Bay mud	54	56	2	55	6275	3120	3155	3120	3155	1.50	0.74	0.0	4.1

Total Settlement (S), in.	**4.1**
S, in. =Σ [Cc/(1+e_0)*H*LOG(σ_{vo}/σ_{vo}')]	
0.5 year Settlement (S@0.5yrs), in.	**0.3**
S@0.5yrs, in. =(S)*U	

Notes:

1. Settlement calculation to estimate the settlement expected to occur in YBM with in-situ thermal remediation to 10 feet depth.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -15 (EHS, Hydrogeologic Cross Section A-A', Figure 4-8)
3. Increase in effective stress resulting from in-situ thermal treatment equals change in water pressure. Settlement will occur during the treatment period.

Immediate Settlement in Fill: In-situ Thermal Treatment to 25 Feet Depth bgs

Inputs	
Reference Boring ID	Harlan
E_s Correlation Method	Menzenbach (1977)
ɣ, pcf	125
Heated Fill Thickness, ft	20
SPT Penetration (Fill), blows/ft	10
Es for N=10 blows/ft, ksf	626

Depth Interval			Δz, ft	N, blows per foot	E_s, ksf	Δq, ksf	Approx. Boussinesq I_z	Settlement (after Schmertmann, 1970) $(I_z*\Delta z)/E_s$
Top, ft bgs	Bottom, ft bgs	Midpoint, ft bgs						
5	7.5	6.25	2.5	10	626	0.078	1	0.0003
7.5	10	8.75	2.5	10	626	0.234	1	0.0009
10	12.5	11.25	2.5	10	626	0.39	1	0.0016
12.5	15	13.75	2.5	10	626	0.546	1	0.0022
15	17.5	16.25	2.5	10	626	0.702	1	0.0028
17.5	20	18.75	2.5	10	626	0.858	1	0.0034
20	22.5	21.25	2.5	10	626	1.014	1	0.0040
22.5	25	23.75	2.5	10	626	1.170	1	0.0047
25	27.5	26.25	2.5	10	626	1.248	1	0.0050
27.5	30	28.75	2.5	10	626	1.248	1	0.0050
30	32.5	31.25	2.5	10	626	1.248	1	0.0050
32.5	35	33.75	2.5	10	626	1.248	1	0.0050
							*ΔH, Δq * Σ [(Iz*Δz)/Es], ft =*	0.04
							*ΔH, Δq * Σ [(Iz*Δz)/Es], in. =*	**0.48**

Notes:

1. Settlement estimate to occur within fill.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -25 (EHS, Hydrogeologic Cross Section B-B', Figure 4-9)
3. Water will be boiled and removed to where u = 0 to 25 feet bgs.
4. Modulus calculated assuming N = 10, which corresponds approximately to the average minus one standard deviation.
5. Area of treatment large therefore Boussinesq I_z = 1.

WJE

Primary Consolidation Settlement Calculation: In-Situ Thermal Treatment to 25 Feet Depth bgs

General Properties	
Water Unit Weight, pcf	62.4
Initial Groundwater Level, ft	5

Soil Properties			
Fill		Young Bay mud	
Unit Weight, pcf	125	Unit Weight, pcf	105
Compression Index, Cc		Compression Index, Cc	0.74
Initial Void Ratio, e_0		Initial Void Ratio, e_0	1.5
OCR		OCR	1
0.5 yr. Consolidation (U), %	N/A	0.5 yr. Consolidation (U), %	7

Material	Layer Depth, ft		Layer Thickness, ft	Midpoint of Layer, ft	Overburden Stress, psf	Initial Porewater pressure, psf	Initial Effective Stress, psf	Final Porewater pressure, psf	Final Effective Stress, psf	Void Ratio, eo	Compression Index, Cc	Incremental Settlement, in.	Cumulative Settlement, in.
	From	To											
Fill	0	2	2	1	125	0	125	0	125	0.00	0.00	0.0	0.0
Fill	2	4	2	3	375	0	375	0	375	0.00	0.00	0.0	0.0
Fill	4	6	2	5	625	0	625	0	625	0.00	0.00	0.0	0.0
Fill	6	8	2	7	875	125	750	0	875	0.00	0.00	0.0	0.0
Fill	8	10	2	9	1125	250	875	0	1125	0.00	0.00	0.0	0.0
Fill	10	12	2	11	1375	374	1001	0	1375	0.00	0.00	0.0	0.0
Fill	12	14	2	13	1625	499	1126	0	1625	0.00	0.00	0.0	0.0
Fill	14	16	2	15	1875	624	1251	0	1875	0.00	0.00	0.0	0.0
Fill	16	18	2	17	2125	749	1376	0	2125	0.00	0.00	0.0	0.0
Fill	18	20	2	19	2375	874	1501	0	2375	0.00	0.00	0.0	0.0
Fill	20	22	2	21	2625	998	1627	0	2625	0.00	0.00	0.0	0.0
Fill	22	24	2	23	2875	1123	1752	0	2875	0.00	0.00	0.0	0.0
Fill	24	26	2	25	3125	1248	1877	0	3125	0.00	0.00	0.0	0.0
Young Bay mud	26	28	2	27	3335	1373	1962	0	3335	1.50	0.74	1.6	1.6
Young Bay mud	28	30	2	29	3545	1498	2047	223	3322	1.50	0.74	1.5	3.1
Young Bay mud	30	32	2	31	3755	1622	2133	446	3309	1.50	0.74	1.4	4.5
Young Bay mud	32	34	2	33	3965	1747	2218	669	3296	1.50	0.74	1.2	5.7
Young Bay mud	34	36	2	35	4175	1872	2303	891	3284	1.50	0.74	1.1	6.8
Young Bay mud	36	38	2	37	4385	1997	2388	1114	3271	1.50	0.74	1.0	7.8
Young Bay mud	38	40	2	39	4595	2122	2473	1337	3258	1.50	0.74	0.8	8.6
Young Bay mud	40	42	2	41	4805	2246	2559	1560	3245	1.50	0.74	0.7	9.4
Young Bay mud	42	44	2	43	5015	2371	2644	1783	3232	1.50	0.74	0.6	10.0
Young Bay mud	44	46	2	45	5225	2496	2729	2006	3219	1.50	0.74	0.5	10.5
Young Bay mud	46	48	2	47	5435	2621	2814	2229	3206	1.50	0.74	0.4	10.9
Young Bay mud	48	50	2	49	5645	2746	2899	2451	3194	1.50	0.74	0.3	11.2
Young Bay mud	50	52	2	51	5855	2870	2985	2674	3181	1.50	0.74	0.2	11.4
Young Bay mud	52	54	2	53	6065	2995	3070	2897	3168	1.50	0.74	0.1	11.5
Young Bay mud	54	56	2	55	6275	3120	3155	3120	3155	1.50	0.74	0.0	11.5

Total Settlement (S), in. **11.5**

S, in. =Σ [Cc/(1+e_0)*H*LOG(σ_{vo}/σ_{vo}')]

0.5 year Settlement (S@0.5yrs), in. **0.8**

S@0.5yrs, in. =(S)*U

Notes:

1. Settlement calculation to estimate the settlement expected to occur in YBM with in-situ thermal remediation to 25 feet depth.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -15 (EHS, Hydrogeologic Cross Section A-A', Figure 4-8)
3. Increase in effective stress resulting from in-situ thermal treatment equals change in water pressure. Settlement will occur during the treatment period.

Immediate Settlement in Fill: In-Situ Thermal Treatment to 55 Feet Depth bgs

Inputs	
Reference Boring ID	Harlan
E_s Correlation Method	Menzenbach (1977)
γ, pcf	125
Heated Fill Thickness, ft	30
SPT Penetration (Fill), blows/ft	10
Es for N=10 blows/ft, ksf	626

Depth Interval			Δz, ft	N, blows per foot	E_s, ksf	Δq, ksf	Approx. Boussinesq I_z	Settlement (after Schmertmann, 1970)
Top, ft bgs	Bottom, ft bgs	Midpoint, ft bgs						$(I_z*\Delta z)/E_s$
5	7.5	6.25	2.5	10	626	0.078	1	0.0003
7.5	10	8.75	2.5	10	626	0.234	1	0.0009
10	12.5	11.25	2.5	10	626	0.39	1	0.0016
12.5	15	13.75	2.5	10	626	0.546	1	0.0022
15	17.5	16.25	2.5	10	626	0.702	1	0.0028
17.5	20	18.75	2.5	10	626	0.858	1	0.0034
20	22.5	21.25	2.5	10	626	1.014	1	0.0040
22.5	25	23.75	2.5	10	626	1.17	1	0.0047
25	27.5	26.25	2.5	10	626	1.326	1	0.0053
27.5	30	28.75	2.5	10	626	1.482	1	0.0059
30	32.5	31.25	2.5	10	626	1.638	1	0.0065
32.5	35	33.75	2.5	10	626	1.794	1	0.0072
							*ΔH, Δq * Σ [(Iz*Δz)/Es], ft =*	0.04
							*ΔH, Δq * Σ [(Iz*Δz)/Es], in. =*	**0.54**

Notes:

1. Settlement estimate to occur within fill.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -25 (EHS, Hydrogeologic Cross Section B-B', Figure 4-9)
3. Water will be boiled and removed to where u = 0 in fill.
4. Modulus calculated assuming N = 10, which corresponds approximately to the average minus one standard deviation.
5. Area of treatment large therefore Boussinesq I_z = 1.

Primary Consolidation Settlement Calculation:In-Situ Thermal Treatment to 55 Feet Depth bgs

General Properties	
Water Unit Weight, pcf	62.4
Initial Groundwater Level, ft	5

Soil Properties			
Fill		Young Bay mud	
Unit Weight, pcf	125	Unit Weight, pcf	105
Compression Index, Cc		Compression Index, Cc	0.74
Initial Void Ratio, e_0		Initial Void Ratio, e_0	1.5
OCR		OCR	1

Material	Layer Depth, ft		Layer Thickness, ft	Midpoint of Layer, ft	Overburden Stress, psf	Initial Porewater pressure, psf	Initial Effective Stress, psf	Final Porewater pressure, psf	Final Effective Stress, psf	Void Ratio, eo	Compression Index, Cc	Incremental Settlement, in.	Cumulative Settlement, in.
	From	To											
Fill	0	2	2	1	125	0	125	0	125	0.00	0.00	0.0	0.0
Fill	2	4	2	3	375	0	375	0	375	0.00	0.00	0.0	0.0
Fill	4	6	2	5	625	0	625	0	625	0.00	0.00	0.0	0.0
Fill	6	8	2	7	875	125	750	0	875	0.00	0.00	0.0	0.0
Fill	8	10	2	9	1125	250	875	0	1125	0.00	0.00	0.0	0.0
Fill	10	12	2	11	1375	374	1001	0	1375	0.00	0.00	0.0	0.0
Fill	12	14	2	13	1625	499	1126	0	1625	0.00	0.00	0.0	0.0
Fill	14	16	2	15	1875	624	1251	0	1875	0.00	0.00	0.0	0.0
Fill	16	18	2	17	2125	749	1376	0	2125	0.00	0.00	0.0	0.0
Fill	18	20	2	19	2375	874	1501	0	2375	0.00	0.00	0.0	0.0
Fill	20	22	2	21	2625	998	1627	0	2625	0.00	0.00	0.0	0.0
Fill	22	24	2	23	2875	1123	1752	0	2875	0.00	0.00	0.0	0.0
Fill	24	26	2	25	3125	1248	1877	0	3125	0.00	0.00	0.0	0.0
Young Bay mud	26	28	2	27	3335	1373	1962	686	2649	1.50	0.74	0.9	0.9
Young Bay mud	28	30	2	29	3545	1498	2047	749	2796	1.50	0.74	1.0	1.9
Young Bay mud	30	32	2	31	3755	1622	2133	811	2944	1.50	0.74	1.0	2.9
Young Bay mud	32	34	2	33	3965	1747	2218	874	3091	1.50	0.74	1.0	3.9
Young Bay mud	34	36	2	35	4175	1872	2303	936	3239	1.50	0.74	1.1	5.0
Young Bay mud	36	38	2	37	4385	1997	2388	998	3387	1.50	0.74	1.1	6.0
Young Bay mud	38	40	2	39	4595	2122	2473	1061	3534	1.50	0.74	1.1	7.1
Young Bay mud	40	42	2	41	4805	2246	2559	1123	3682	1.50	0.74	1.1	8.3
Young Bay mud	42	44	2	43	5015	2371	2644	1186	3829	1.50	0.74	1.1	9.4
Young Bay mud	44	46	2	45	5225	2496	2729	1248	3977	1.50	0.74	1.2	10.6
Young Bay mud	46	48	2	47	5435	2621	2814	1310	4125	1.50	0.74	1.2	11.7
Young Bay mud	48	50	2	49	5645	2746	2899	1373	4272	1.50	0.74	1.2	12.9
Young Bay mud	50	52	2	51	5855	2870	2985	1435	4420	1.50	0.74	1.2	14.2
Young Bay mud	52	54	2	53	6065	2995	3070	1498	4567	1.50	0.74	1.2	15.4
Young Bay mud	54	56	2	55	6275	3120	3155	1560	4715	1.50	0.74	1.2	16.6

Total Settlement (S), in. **16.6**

S, in. =Σ [Cc/(1+e_0)*H*LOG(σ_{vo}/σ_{vo}')]

Notes:

1. Settlement calculation to estimate the settlement expected to occur in YBM with in-situ thermal remediation to 55 feet depth.
2. Fill assumed to extend from aproximately Elevation 10 to Elevation -15 (EHS, Hydrogeologic Cross Section A-A', Figure 4-8)
3. In-situ thermal heating to 100 ° C. Assume water pressure in Young Bay Mud goes to 50 percent of pre-treatement value.
4. Increase in effective stress resulting from in-situ thermal treatment equals change in water pressure. Settlement will occur during the treatment period.

Downdrag Calculations due to Thermal Treatment up to 25 feet - Fill 30 feet

Summary of Piles		
	Class A/B	
Pile shape	Square	
Material type	Prestressed Concrete	
Pile width A, ft	1	
Pile width B, ft	1	
Pile length, ft	95	
Pile perimeter, ft	4.0	
Pile base area, ft^2	1.0	
Driven Pile Method		
α-method (cohesive)		
API (cohesionless)		
Assumptions		
Downdrag acts on pile from 0 ft bgs to 25 feet bgs.		
Subsurface conditions based on section B-B' with pile length = to 70 feet.		
Fill was considered as cohesionless material.		
Subsurface conditions		
	Fill	**Young Bay mud**
From, ft	0	30
To, ft	30	50
Material thickness, ft	30	20
Alpha coefficient	-	1
Undrained shear strength, psf	-	400
Adhesion, psf	-	400
Soil-Pile friction angle	20	
Coefficient lateral earth pressure	1	
Effective overburden @15ft, psf	1251	
Cohesionless shaft resistance, psf	455	
Negative Load Resistance (Downdrag)		
	Class A/B	
Fill thickness, ft	25	
Young Bay mud thickness, ft	0	
Downdrag force, Qdowndrag, lbs	45533	

Downdrag Calculations due to Thermal Treatment up to 55 feet - Fill 30 feet

Summary of Piles		
	Class A/B	
Pile shape	Square	
Material type	Prestressed Concrete	
Pile width A, ft	1	
Pile width B, ft	1	
Pile length, ft	95	
Pile perimeter, ft	4.0	
Pile base area, ft^2	1.0	
Driven Pile Method		
α-method (cohesive)		
API (cohesionless)		
Assumptions		
Downdrag acts on pile from 0 ft bgs to 50 feet bgs.		
Subsurface conditions based on section B-B' with pile length = to 70 feet.		
Fill was considered as cohesionless material.		
Subsurface conditions		
	Fill	**Young Bay mud**
From, ft	0	30
To, ft	30	50
Material thickness, ft	30	20
Alpha coefficient	-	1
Undrained shear strength, psf	-	400
Adhesion, psf	-	400
Soil-Pile friction angle	20	
Coefficient lateral earth pressure	1	
Effective overburden @15ft, psf	1251	
Cohesionless shaft resistance, psf	455	
Negative Load Resistance (Downdrag)		
	Class A/B	
Fill thickness, ft	30	
Young Bay mud thickness, ft	20	
Downdrag force, Qdowndrag, lbs	86639	

APPENDIX IV – STRUCTURAL ANALYSIS SCREENSHOTS

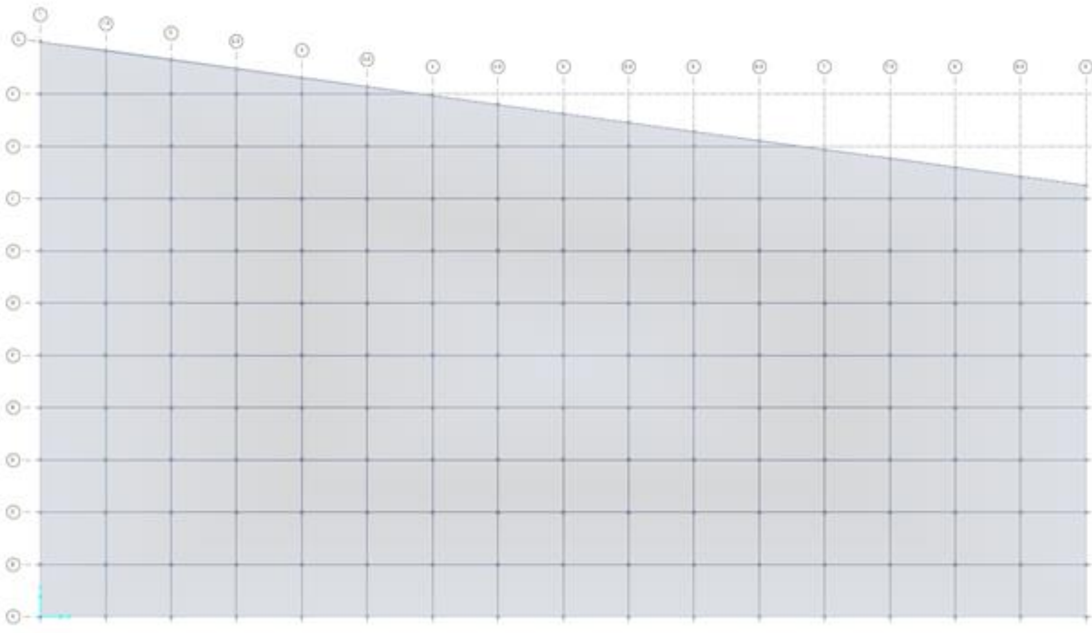


Figure 1. Slab model geometry in SAFE

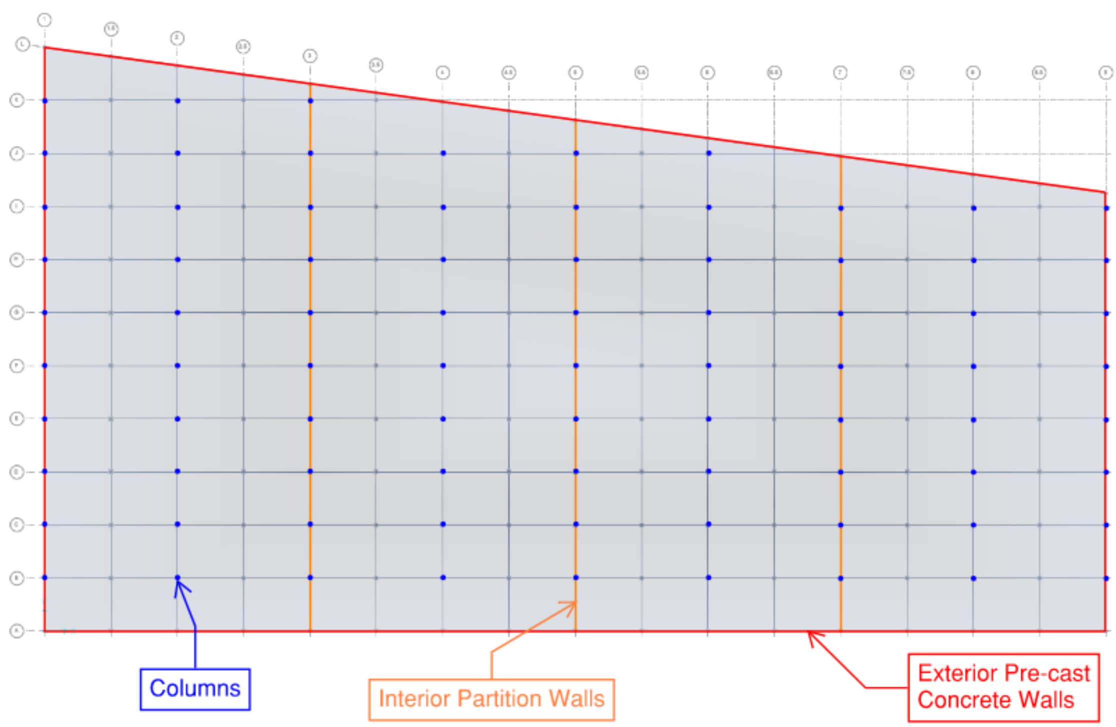


Figure 2. Slab model geometry with dead load source labels

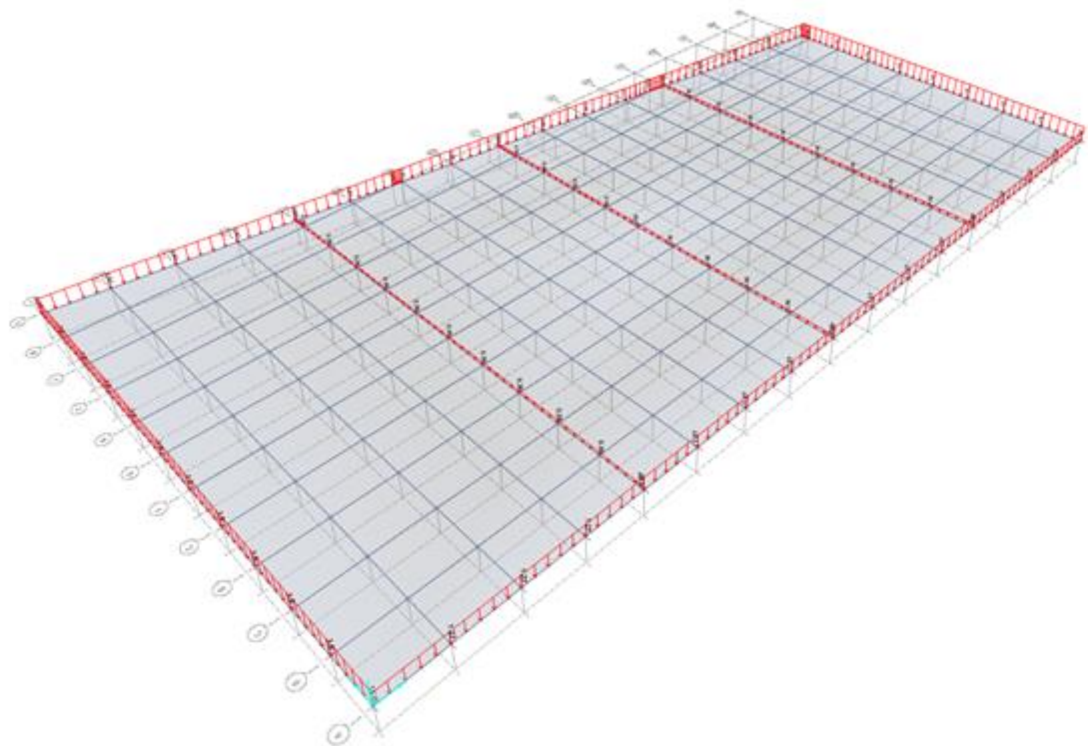


Figure 3. Wall dead loads applied in SAFE

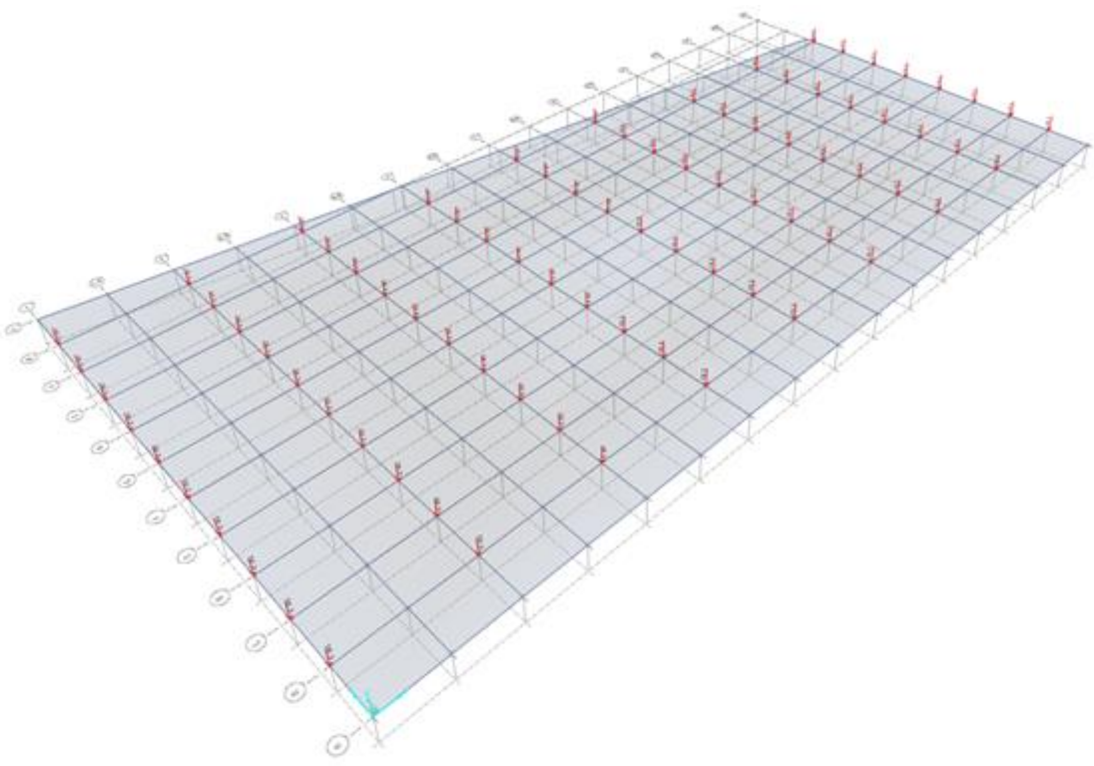


Figure 4. Column dead loads applied in SAFE

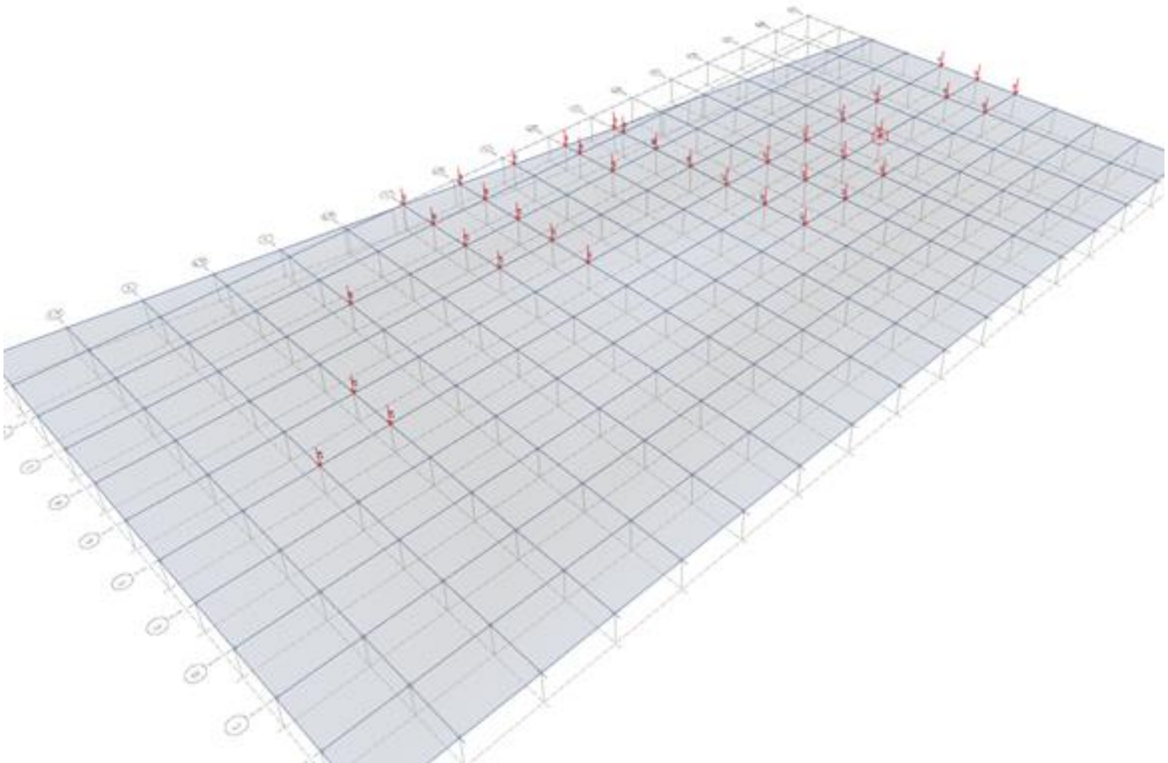


Figure 5. Thermal point loads applied in SAFE

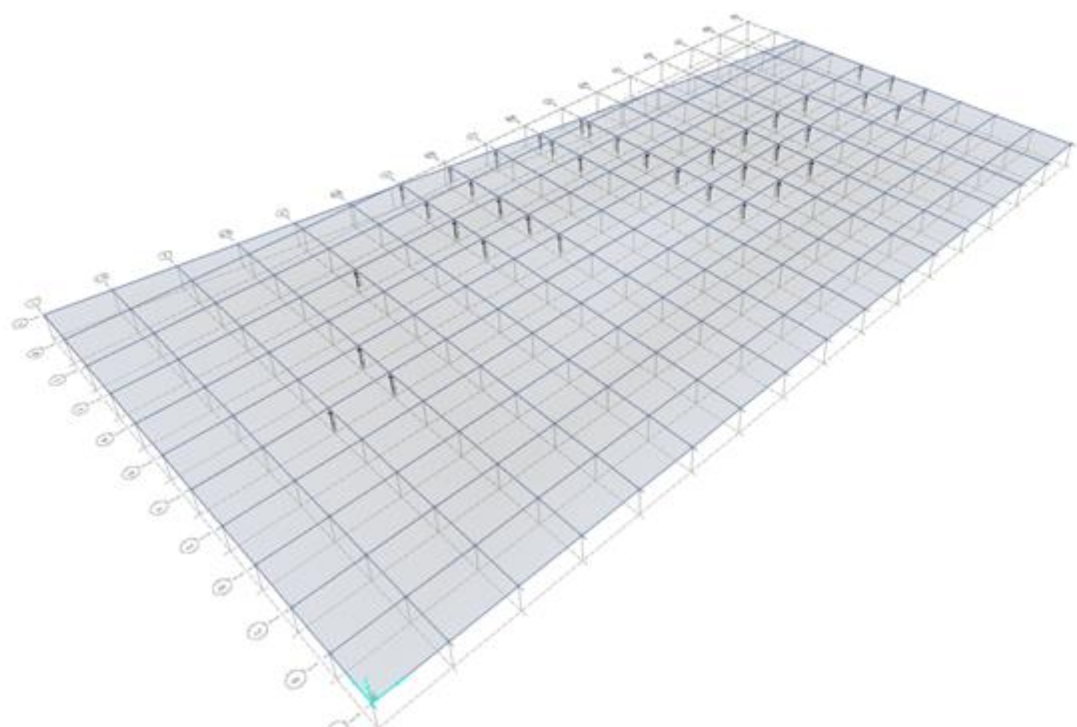


Figure 6. Thermal nodal displacements applied in SAFE

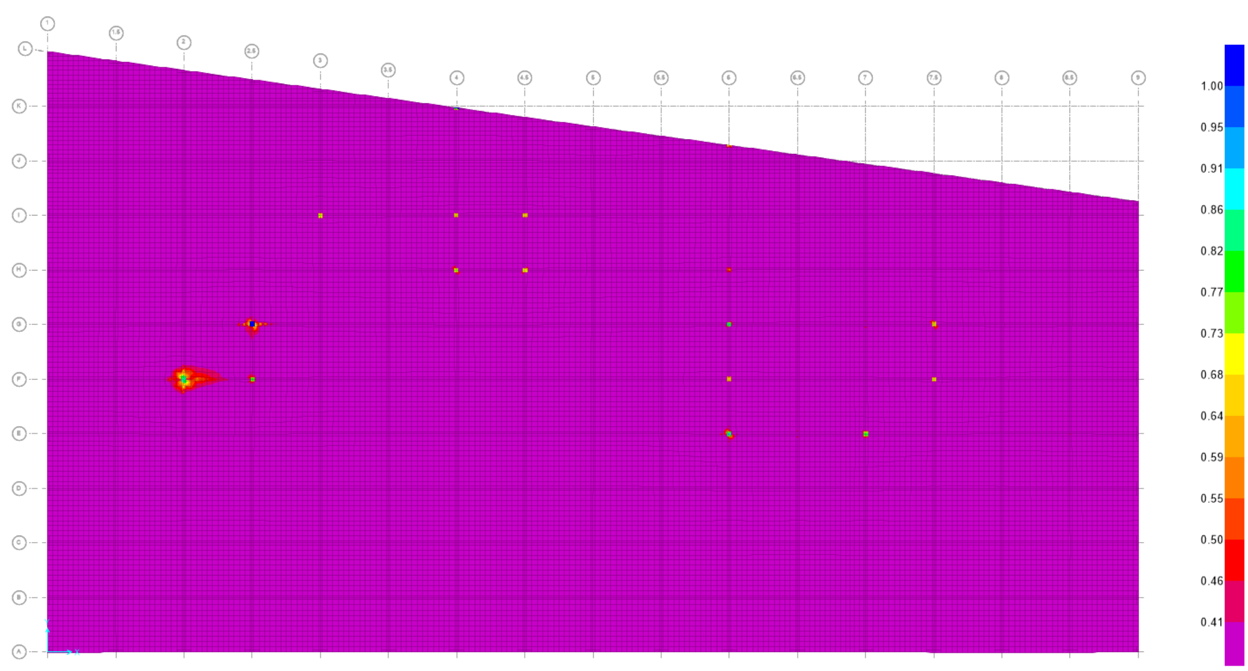


Figure 7. Top-of-slab tension stresses due to the thermal pile elongation load case (ksi). The stresses at the areas in purple are lower than the modulus of assumed rupture of the concrete, indicating lower potential for top-of-slab cracking.

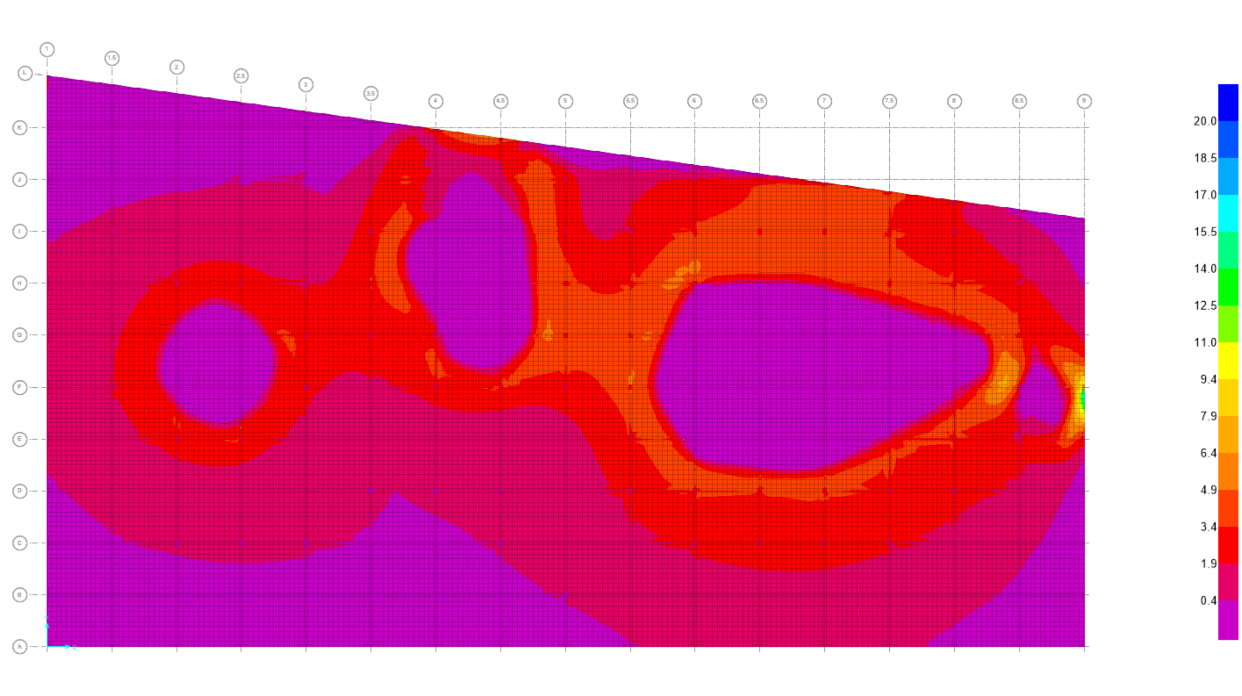


Figure 8. Mid-slab tension stresses due to the thermal slab expansion load case (ksi). The stress at the areas in purple are lower than the modulus of rupture of the concrete, indicating lower potential for slab cracking.

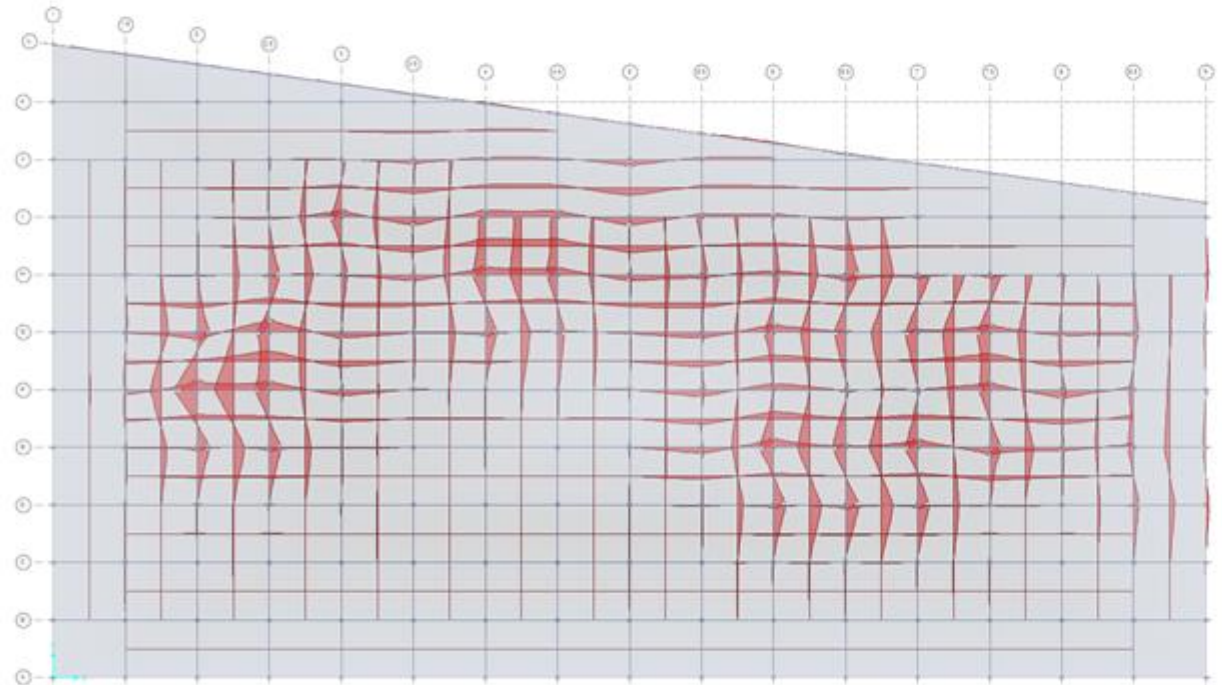


Figure 9. Change in slab moment due to the thermal pile elongation load case.

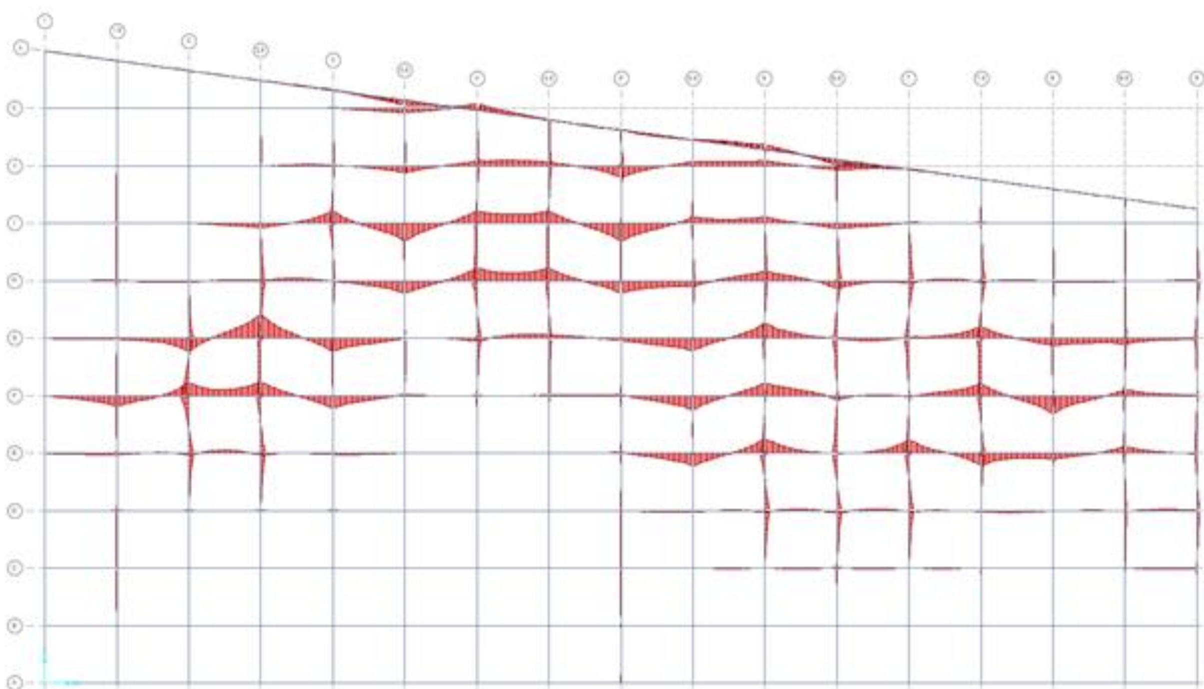


Figure 10. Change in beam moment due to the thermal pile elongation load case.

WJE

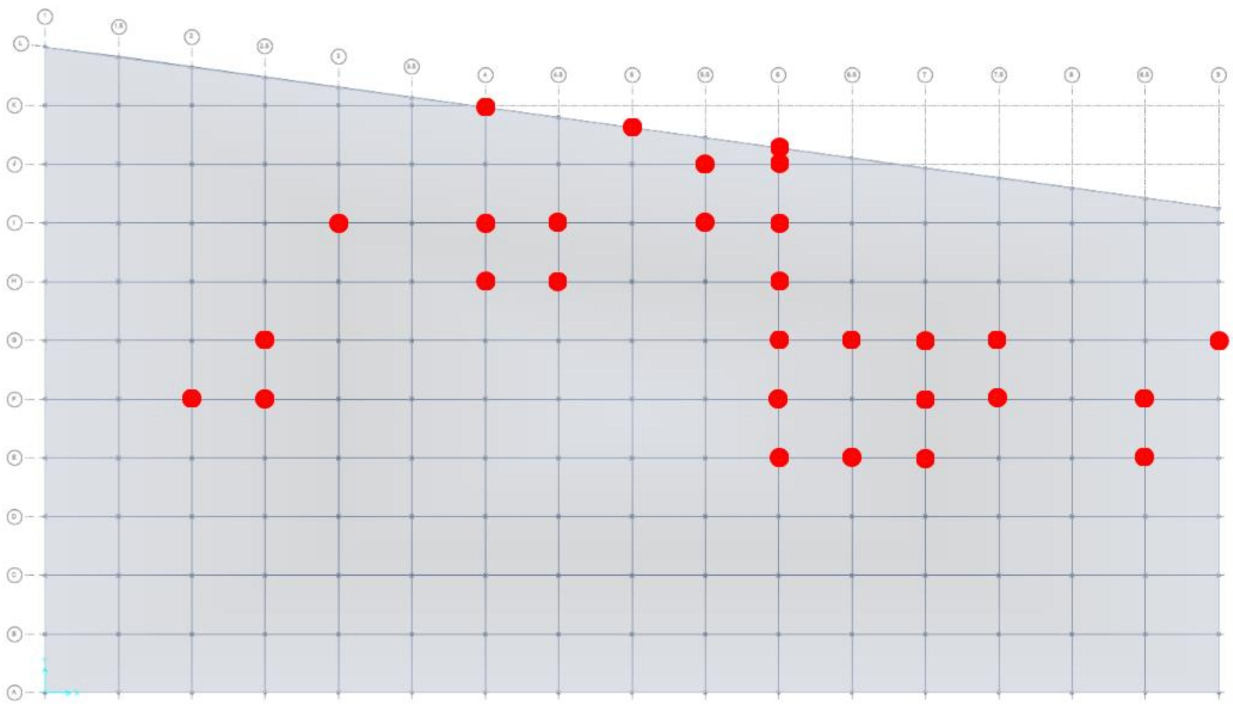


Figure 11. Piles with more than 50 kip increase in pile axial compression due to the thermal pile elongation load case.

APPENDIX V - RISK ASSESSMENT MATRIX

Overview of Risk Matrix Process

RISK MATRIX

Low	Medium	High	Severe	Extreme

CONSEQUENCE	LIKELIHOOD 5 HIGHLY UNLIKELY	4 UNLIKELY	3 POSSIBLE	2 LIKELY	1 HIGHLY LIKELY
5 Critical	MEDIUM	HIGH	SEVERE	SEVERE	EXTREME
4 Major	MEDIUM	MEDIUM	HIGH	SEVERE	SEVERE
3 Serious	MEDIUM	MEDIUM	MEDIUM	HIGH	SEVERE
2 Moderate	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH
1 Minor	LOW	LOW	MEDIUM	MEDIUM	MEDIUM

UNMITIGATED RISKS IDENTIFIED THROUGH GEOTECHNICAL AND STRUCTURAL ANALYSIS
(PRIOR TO IMPLEMENTATION OF RISK MANAGEMENT MEASURES)

RISK MANAGEMENT MEASURES

		DESCRIPTION OF POTENTIAL RISK			LIKELIHOOD		CONSEQUENCE (structural, serviceability, or health and safety)		RISK ASSESSMENT		RISK	PRIOR TO THERMAL REMEDIATION				DURING THERMAL REMEDIATION			AFTER THERMAL REMEDIATION		
EVENT	CATEGORY (subsurface structure, slab, above ground structure, utilities)	POTENTIAL EFFECT (undesirable effect potentially brought about by proposed thermal remediation in layperson's terms)	CAUSE	ADDITIONAL TECHNICAL DETAIL	RANKING (per drop down list)	BASIS	RANKING (per drop down list)	BASIS	LIKELIHOOD	CONSEQUENCE	ASSESSMENT	Is additional data collection warranted to refine risk ranking?	Can data be collected without intrusive or destructive means of investigation?	Can risk be mitigated through thermal remedial design process?	Can risk be mitigated through other engineering controls or changes to property/structure?	Is data collection warranted during thermal treatment?	Can data be collected without intrusive or destructive means of investigation?	If yes, what contingent actions could be considered depending on results?	Is data collection warranted after thermal treatment?	Can data be collected without intrusive or destructive means of investigation?	If risk is realized what can be done to address it?
1		Piles exceed their vertical design (nominal) capacity.	Downdrag forces and vertical expansion of piles during thermal treatment.	The thermal treatment causes settlement of the soil surrounding piles in the treatment areas - the skin friction between these settling soils and the piles imparts a downward, "downdrag", force on these piles. Increased temperatures of the piles in the thermal treatment areas causes these piles to expand; restraint of this vertical expansion due to the presence of the slab/grade beam structure imparts vertical forces on the piles.	LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion, In-Situ Thermal Heating sections) Our analyses show that piles within the deep thermal treatment areas experience relatively larger vertical force increases compared to shallow thermal treatment areas. Even with the conservative assumptions inherent in our analyses, we did not find exceedances of ultimate strength, so we believe this outcome is unlikely but we believe some exceedances of design capacity may be realized. Exceeding the vertical design capacity requires relatively less of a thermal treatment effect than exceeding the ultimate capacity; therefore, this event is relatively more likely.	MODERATE	These piles would not lose strength, but may have less of a factor of safety than design intended. The additional pile forces would diminish over time, but not to zero. Piles that have exceeded their design capacity but have not reached their ultimate capacity are not weakened. The design limit included a factor of safety relative to the ultimate capacity of the pile, though, so exceeding that limit reduces the residual capacity against failure relative to the design.	2	2	MEDIUM	Yes - complete relative elevation survey and condition assessment of the existing slab.	Yes	Not Likely	Not likely	Yes - monitor changes in levelness of slab	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - complete relative elevation survey and condition assessment of the post-treatment slab.	Yes	Placement of leveling compound at the slab surface where needed.
2		Piles exceed their vertical ultimate (actual) capacity.	Downdrag forces and vertical expansion of piles during thermal treatment.	The thermal treatment causes settlement of the soil surrounding piles in the treatment areas - the skin friction between these settling soils and the piles imparts a downward, "downdrag", force on these piles. Increased temperatures of the piles in the thermal treatment areas causes these piles to expand; restraint of this vertical expansion due to the presence of the slab/grade beam structure imparts vertical forces on the piles.	UNLIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion, In-Situ Thermal Heating sections) Our analyses show that piles within the deep thermal treatment areas experience relatively larger vertical force increases compared to shallow thermal treatment areas. Even with the conservative assumptions inherent in our analyses, we did not find exceedances of ultimate strength, so we believe this outcome is unlikely. Exceeding the vertical ultimate capacity requires relatively more of a thermal treatment effect than exceeding the design capacity; therefore, this event is relatively less likely.	SERIOUS	These piles would lose vertical strength and stiffness and displace downward. These piles would shed load to adjacent piles. The additional pile forces would diminish over time, but not to zero. The loss of pile strength would be permanent. Once the ultimate capacity is reached along the load-deformation curve, the pile/soil system experiences negative stiffness and loses strength. Piles loaded beyond their ultimate capacity would become relatively softer than other piles, likely causing load to migrate from the weakened/softened pile to others, potentially causing overload at those piles.	4	3	MEDIUM	Yes - complete relative elevation survey and condition assessment of the existing slab.	Yes	Not Likely	Not likely	Yes - monitor changes in levelness of slab	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - complete relative elevation survey and condition assessment of the post-treatment slab.	Yes	Placement of leveling compound at the slab surface where needed.
3		Piles crack in flexure.	Horizontal thermal expansion of the slab and grade beams during thermal treatment.	Increasing the temperature of the concrete slab and grade beams will cause those elements to expand. This expansion will be most noticeable and impactful horizontally, as the slab dilates and the thermal strains occur across distances on the order of 100 feet. Dilation of the slab will displace the heads of the piles horizontally - these displacements will be greatest near the periphery of the treatment areas and the slab. Horizontal displacement of pile heads will result in soil reactions near the top of the pile and flexural deformation of the pile. If the net tension stresses in a pile exceed its modulus of rupture, the pile will crack.	LIKELY	Structural and geotechnical analyses.(Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating section) Exceeding the cracking moment requires relatively less of a thermal treatment effect than exceeding the ultimate moment; therefore, this event is relatively more likely.	MINOR	These piles would lose flexural stiffness in the direction of displacement, but cracking is anticipated in the design of reinforced concrete elements and does not materially impact their structural performance. This cracking would not be recoverable (i.e., the crack would close but remain permanently when unloaded).	2	1	MEDIUM	No	No	Not Likely	Somewhat - treatment areas can be semi-isolated from the remainder of the slab to mitigate the thermal expansion strains	Yes - monitor expansion of slab	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area, and treatment areas potentially semi-isolated from remainder of slab.	No	No	Cracking does not materially impact the structural performance of the elements. No remediation measure proposed to address pile cracking.
4	Subsurface Structure	Piles fail in flexure.	Horizontal thermal expansion of the slab and grade beams during thermal treatment.	Increasing the temperature of the concrete slab and grade beams will cause those elements to expand. This expansion will be most noticeable and impactful horizontally, as the slab dilates and the thermal strains occur across distances on the order of 100 feet. Dilation of the slab will displace the heads of the piles horizontally - these displacements will be greatest near the periphery of the treatment areas and the slab. Horizontal displacement of pile heads will result in soil reactions near the top of the pile and flexural deformation of the pile. If the net tension stresses in a pile exceed its modulus of rupture, the pile will crack. Additional flexural deformations beyond cracking would result in yielding of reinforcing or compressive failures of a portion of pile concrete.	UNLIKELY	Structural and geotechnical analyses.(Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Evaluation Results and Discussion section - In-Situ Thermal Heating section) Exceeding the ultimate moment requires relatively more of a thermal treatment effect than exceeding the cracking moment; therefore, this event is relatively less likely.	SERIOUS	These piles would lose flexural strength and shed load to other elements. This failure would not be recoverable.	4	3	MEDIUM	No	No	Not Likely	Somewhat - treatment areas can be semi-isolated from the remainder of the slab to mitigate the thermal expansion strains	Yes - monitor expansion of slab. As initial threshold for further investigation, compare realized slab horizontal displacements during remediation with calculated displacement thresholds at which pile flexural failure is anticipated.	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area, and treatment areas potentially semi-isolated from remainder of slab.	Possibly, dependent on slab horizontal expansion data collected during thermal remediation	No	Installation of new, supplemental deep foundation element and integrate into grade-beam network.
5		Piles experience heat-related loss of strength and stiffness.	Deterioration of concrete at elevated temperatures during thermal treatment.	Subjecting concrete and reinforcing steel to elevated temperatures (100C to 400C) has the potential to diminish the physical properties of the concrete. The actual diminution of physical characteristics due to elevated temperature is heavily dependent on the temperature time history the materials are subjected to. The soil surround the piles within the thermal treatment areas will be heated to at least 100C and as much as 400C when closer to heating elements. Given the anticipated duration of the treatment, it is reasonable to assume that the full thickness of the piles will be elevated to the same temperature as the surrounding soil and experience physical characteristic deterioration as a result.	LIKELY	Uncertainty regarding heating element placement and profile of temperature near heating elements. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating section)	SERIOUS	The piles may lose strength and stiffness of the concrete, making the piles weaker as a whole in compression, tension, and flexure. This deterioration would not be recoverable.	2	3	HIGH	Yes - evaluation of piles will rely upon pre-remediation concrete testing on small diameter cores at perimeter piles for concrete composition and susceptibility to thermal damage	No	Yes - placement of heater borings a prescribed 3 ft safety distance from the piles.	Not likely	Yes - temperature monitoring near heater borings, near multiple representative piles, and at various depths throughout the treatment area.	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - evaluation of piles will rely upon post-remediation concrete testing consistent with pre-remediation testing program.	No	Engineering analysis to evaluate potential pile damage. Potential localized strengthening if necessary to restore pile strength and/or stiffness.
6		Soil heaving.	Thermal expansion of soils near the heating elements at the beginning of thermal treatment.	Concern raised by Langan.	POSSIBLE	From conversations with TerraTherm and our evaluation of the site soil, this phenomenon does not seem likely, but may be possible.	MINOR	The impact of potential heaving seems minor because of a) the possibility of an existing gap between the bottom of the slab and grade beam, b) the variability and compressibility of the upper soils indicated by subsurface investigations, and c) significant heave would be required to overcome the dead load forces in the slab, grade beam, and piles.	3	1	MEDIUM	Yes - complete relative elevation survey and condition assessment of the existing slab.	Yes	No	Not likely	No	N/A	N/A	Yes - complete relative elevation survey and condition assessment of the post-treatment slab.	Yes	Placement of leveling compound where needed. Need for placement of leveling compound related to soil heaving is highly unlikely.
7		Gaps around piles.	Development of gap (1) between pile and back-side soils as the pile head is displaced laterally during and after thermal treatment, or (2) due to shrinkage of soils.	Concern raised by Langan.	LIKELY	We understand that the soils near the tops of the piles (where lateral displacements due to thermal expansion of the slab will be greatest) are generally not cohesive, so we expect some gap to develop as the pile is deflected. Shrinkage of Young Bay Mud could occur in deep thermal treatment areas creating a gap around piles.	MODERATE	The displacement of the piles laterally will be greatest at the top of the pile, and then quickly diminish. Throughout these heights, the pile develops little-to-no skin friction. We believe that evaluation of the resulting "unbraced free height" of the pile adjacent to the gap is of concern to Langan. Such an evaluation would be unusual - we are unaware, for example, of evaluations of piles for their conditions AFTER an earthquake, considering the significant lateral displacement. In other words, we do not believe this phenomenon would be overly significant. We do not expect significant shrinkage of Young Bay Mud to occur except for zone immediately surrounding heating elements.	2	2	MEDIUM	No	No	Not Likely	Somewhat - treatment areas can be semi-isolated from the remainder of the slab to mitigate the thermal expansion strains	No	N/A	N/A	No	No	Engineering analysis to evaluate potential concerns. See Consequence - Basis.

UNMITIGATED RISKS IDENTIFIED THROUGH GEOTECHNICAL AND STRUCTURAL ANALYSIS (PRIOR TO IMPLEMENTATION OF RISK MANAGEMENT MEASURES)

EVENT	CATEGORY (subsurface structure, slab, above ground structure, utilities)	DESCRIPTION OF POTENTIAL RISK: POTENTIAL EFFECT (undesirable effect potentially brought about by proposed thermal remediation in layperson's terms)	DESCRIPTION OF POTENTIAL RISK: CAUSE	DESCRIPTION OF POTENTIAL RISK: ADDITIONAL TECHNICAL DETAIL	LIKELIHOOD: RANKING (per drop down list)	LIKELIHOOD: BASIS	CONSEQUENCE (structural, serviceability, or health and safety): RANKING (per drop down list)	CONSEQUENCE: BASIS	RISK ASSESSMENT: LIKELIHOOD	RISK ASSESSMENT: CONSEQUENCE	RISK ASSESSMENT
8		Top-of-slab surface becomes substantially out-of-level or out-of-flat.	Downdrag forces and vertical expansion of piles during thermal treatment.	The downdrag forces cause the pile heads to move down and the thermal expansion of the piles cause the pile heads to move up. Because the slab and grade beams are connected to the piles, they move up or down with the pile heads. The out-of-plane deformation of the slab will be greatest where the differential vertical pile head movements are greatest, which is likely near the boundaries of the thermal treatment areas.	POSSIBLE	Uncertainty regarding existing top-of-slab surface condition; structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections)	MAJOR	Undulations in the top-of-slab surface may impact tenant operations. These thermal-treatment-related undulations would likely diminish over time.	3	4	HIGH
9		Slab and grade beams crack in flexure.	Downdrag forces and vertical expansion of piles during thermal treatment.	The downdrag forces cause the pile heads to move down and the thermal expansion of the piles cause the pile heads to move up. Because the slab and grade beams are connected to the piles, they move up or down with the pile heads. The out-of-plane deformation of the slab will be greatest where the differential vertical pile head movements are greatest, which is likely near the boundaries of the thermal treatment areas.	LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections) Exceeding the cracking moment requires relatively less of a change than exceeding the ultimate moment; therefore, this event is relatively more likely.	MINOR	The slab and grade beams would soften in flexure locally and cracks at the top surface would present an aesthetic concern. This cracking would not be recoverable, but the cracks would likely close to some degree over time.	2	1	MEDIUM
10		Slab and grade beams exceed their flexural design (nominal) capacity.	Downdrag forces and vertical expansion of piles during thermal treatment.	The downdrag forces cause the pile heads to move down and the thermal expansion of the piles cause the pile heads to move up. Because the slab and grade beams are connected to the piles, they move up or down with the pile heads. The out-of-plane deformation of the slab will be greatest where the differential vertical pile head movements are greatest, which is likely near the boundaries of the thermal treatment areas.	POSSIBLE	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections) Exceeding the design moment requires relatively more of a change than exceeding the cracking moment and relatively less of a change than exceeding the ultimate moment; therefore, this event is relatively less likely than flexural cracking.	MODERATE	The slab and grade beams would not lose strength, but may have less of a factor of safety than the design intended. The additional flexural forces would diminish over time, but not to zero.	3	2	MEDIUM
11	Slab and Grade Beam Structure	Slab and grade beams exceed their flexural ultimate (actual) capacity.	Downdrag forces and vertical expansion of piles during thermal treatment.	The downdrag forces cause the pile heads to move down and the thermal expansion of the piles cause the pile heads to move up. Because the slab and grade beams are connected to the piles, they move up or down with the pile heads. The out-of-plane deformation of the slab will be greatest where the differential vertical pile head movements are greatest, which is likely near the boundaries of the thermal treatment areas.	UNLIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections) Exceeding the ultimate moment requires relatively move of a change than exceeding the design moment; therefore, this event is relatively less likely than flexural design overstress.	SERIOUS	The slab and grade beams would lose flexural strength and stiffness. The additional flexural forces would diminish over time, but not to zero. The loss of flexural strength would be permanent.	4	3	MEDIUM
12		Slab and grade beams crack in tension around thermal treatment areas.	Differential horizontal thermal expansion of the slab and grade beams during thermal treatment.	The temperature gradient in the slab and grade beams from the heated concrete within the thermal treatment areas and the unheated concrete outside the treatment areas will result in differential thermal strains. The slab and grade beams within the treatment areas will generally be in compression and those outside the treatment areas will generally be in tension. Because concrete is substantially weaker in tension, distress would first manifest itself in the form of radial (i.e., approximately perpendicular to the extents of the treatment areas) through cracks.	HIGHLY LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating section) Exceeding the cracking strain of concrete requires relatively less of a thermal treatment effect than exceeding the yielding strain of the steel reinforcing; therefore, this event is relatively more likely.	SERIOUS	Through cracks in the slab and grade beams would present an aesthetic, vapor barrier, and moisture barrier concern. This cracking would not be recoverable, but the cracks would likely close to some degree over time.	1	3	SEVERE
13		Slab and grade beam reinforcing steel yields in tension around thermal treatment areas.	Differential horizontal thermal expansion of the slab and grade beams during thermal treatment.	The temperature gradient in the slab and grade beams from the heated concrete within the thermal treatment areas and the unheated concrete outside the treatment areas will result in differential thermal strains. The slab and grade beams within the treatment areas will generally be in compression and those outside the treatment areas will generally be in tension. Because concrete is substantially weaker in tension, distress would first manifest itself in the form of radial (i.e., approximately perpendicular to the extents of the treatment areas) through cracks. As these differential thermal strains increase, the tensile strains in the reinforcing steel at the cracks would increase, and may yield (i.e., deform inelastically).	LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating section) Exceeding the yielding strain of the reinforcing steel requires relatively more of a thermal treatment effect than exceeding the cracking strain of concrete; therefore, this event is relatively less likely.	SERIOUS	Yielding of the reinforcing steel would lead to restraint to tension crack closure, and potentially buckling of the yielded bars. The cracks would present an aesthetic, vapor barrier, and moisture barrier concern. This yielding would not be recoverable.	2	3	HIGH
14		Slab and grade beams experience heat-related loss of strength and stiffness.	Deterioration of concrete at elevated temperatures during thermal treatment.	Subjecting concrete and reinforcing steel to elevated temperatures (100C to 400C) has the potential to diminish the physical properties of the concrete. The actual diminution of physical characteristics due to elevated temperature is heavily dependent on the temperature time history the materials are subjected to. We understand that an insulating blanket will cover the top of the slab and that the slab and grade beams will be brought up to the same temperature as the underlying soils within the thermal treatment areas. Moreover, direct proximity to the heating elements passing through the slab will potentially expose the slab and grade beams locally to the relatively higher temperatures closer to these heating elements.	HIGHLY LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating section)	MODERATE	The slab and grade beams would lose strength and stiffness of the concrete, making them weaker as a whole in flexure. This deterioration would not be recoverable.	1	2	HIGH

RISK MANAGEMENT MEASURES

EVENT	PRIOR TO THERMAL REMEDIATION: Is additional data collection warranted to refine risk ranking?	PRIOR: Can data be collected without intrusive or destructive means of investigation?	PRIOR: Can risk be mitigated through thermal remedial design process?	PRIOR: Can risk be mitigated through other engineering controls or changes to property/structure?	DURING THERMAL REMEDIATION: Is data collection warranted during thermal treatment?	DURING: Can data be collected without intrusive or destructive means of investigation?	DURING: If yes, what contingent actions could be considered depending on results?	AFTER THERMAL REMEDIATION: Is data collection warranted after thermal treatment?	AFTER: Can data be collected without intrusive or destructive means of investigation?	AFTER: If risk is realized what can be done to address it?
8	Yes - complete relative elevation survey and condition assessment of the existing slab.	Yes	Not Likely	Not likely	Yes - monitor changes in levelness of slab	No	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - complete relative elevation survey and condition assessment of the post-treatment slab.	Yes	Placement of leveling compound or slab overlay where needed.
9	Yes - Visual condition assessment and relative elevation survey of slab surface in treatment area	Yes	Not Likely	Not likely	No	N/A	N/A	Yes - Visual condition survey and relative elevation survey of slab surface in treatment area	Yes	Epoxy injection of open cracks where appropriate for slab serviceability and/or install new vapor barrier coating, cover, or seal as appropriate.
10	Yes - Visual condition assessment and relative elevation survey of slab surface in treatment area	Yes	Not Likely	Not likely	Yes - monitor changes in levelness of slab	Yes	No action necessary	Yes - Visual condition survey and relative elevation survey of slab surface in treatment area	Yes	Epoxy injection of open cracks where appropriate for slab serviceability and/or install new vapor barrier coating, cover, or seal as appropriate.
11	Yes - Visual condition assessment and relative elevation survey of slab surface in treatment area	Yes	Not Likely	Not likely	Yes - monitor changes in levelness of slab	Yes	No action necessary	Yes - Visual condition survey and relative elevation survey of slab surface in treatment area	Yes	Epoxy inject cracks and restore vapor barrier and/or install new vapor barrier coating, cover, or seal as appropriate. Chip out concrete and repair reinforcement locally.
12	Yes - condition assessment of the existing slab.	Yes	Yes - Heater boring placement 3-foot safety distance from all beams (and piles). Heater boring fitted with "cold-pin" for 12-inch safety distance below slab.	Yes - Oversized diamond coreholes through concrete to allow localized lateral expansion and installation of heater borings with co-located vapor extraction points. Insulated vapor cover (R-12 to R-15) extended minimum of 15 ft (typical only extended 8-10 ft) outside of treatment zone perimeter to limit the horizontal temperature gradient in concrete slab.	Yes - temperature monitoring near heater borings, near multiple representative piles, and at various depths throughout the treatment area (including in-slab).	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - condition assessment of the post-treatment slab.	Yes	Epoxy inject cracks to restore performance of existing vapor barrier and/or install new vapor barrier coating, cover, or seal as appropriate.
13	Yes - condition assessment of the existing slab.	Yes	Yes - Heater boring placement 3-foot safety distance from all beams (and piles). Heater boring fitted with "cold-pin" for 12-inch safety distance below slab.	Yes - Oversized diamond coreholes through concrete to allow localized lateral expansion and installation of heater borings with co-located vapor extraction points. Insulated vapor cover (R-12 to R-15) extended minimum of 15 ft (typical only extended 8-10 ft) outside of treatment zone perimeter to limit the horizontal temperature gradient in concrete slab.	Yes - temperature monitoring near heater borings, near multiple representative piles, and at various depths throughout the treatment area (including in-slab).	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - condition assessment of the post-treatment slab.	Yes	Epoxy inject cracks to restore performance of existing vapor barrier and/or install new vapor barrier coating, cover, or seal as appropriate. Chip out concrete and repair reinforcement locally.
14	Yes - extraction of existing concrete samples and laboratory analysis for concrete composition, susceptibility to thermal damage, and mechanical properties to establish pre-treatment properties.	No	Yes - Heater boring placement 3-foot safety distance from all beams (and piles). Heater boring fitted with "cold-pin" for 12-inch safety distance below slab.	Yes - Oversized diamond coreholes through concrete to allow localized lateral expansion and installation of heater borings with co-located vapor extraction points. Insulated vapor cover (R-12 to R-15) extended minimum of 15 ft (typical only extended 8-10 ft) outside of treatment zone perimeter to limit the horizontal temperature gradient in concrete slab.	Yes - temperature monitoring near heater borings, near multiple representative piles, and at various depths throughout the treatment area (including in-slab).	Yes	Temperature control (as needed) to maintain nominal 100°C throughout treatment area.	Yes - post-treatment coring and laboratory analysis of concrete.	No	Structural analysis; design and construction of localized strengthening if necessary to restore slab and/or grade beam strength and/or stiffness as required.

UNMITIGATED RISKS IDENTIFIED THROUGH GEOTECHNICAL AND STRUCTURAL ANALYSIS (PRIOR TO IMPLEMENTATION OF RISK MANAGEMENT MEASURES)

EVENT	CATEGORY (subsurface structure, slab, above ground structure, utilities)	DESCRIPTION OF POTENTIAL RISK: POTENTIAL EFFECT (undesirable effect potentially brought about by proposed thermal remediation in layperson's terms)	CAUSE	ADDITIONAL TECHNICAL DETAIL	LIKELIHOOD: RANKING (per drop down list)	LIKELIHOOD: BASIS	CONSEQUENCE (structural, serviceability, or health and safety): RANKING (per drop down list)	CONSEQUENCE: BASIS	RISK ASSESSMENT: LIKELIHOOD	RISK ASSESSMENT: CONSEQUENCE	RISK ASSESSMENT
15		Perimeter precast walls and connections crack.	Downdrag forces and vertical expansion of piles, and horizontal thermal expansion of the slab and grade beams during thermal treatment.		LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections) Exceeding the cracking capacity requires relatively less of an effect than exceeding the ultimate capacity; therefore, this event is relatively more likely.	MODERATE	The precast walls would lose stiffness and the cracks would present an aesthetic and moisture barrier concern. Cracking is anticipated in the design of reinforced concrete elements and does not materially impact their structural performance. This cracking would not be recoverable (i.e., the crack could close but will remain permanently when unloaded).	2	2	MEDIUM
16	Above Ground Structure	Perimeter precast walls and connections lose strength.	Downdrag forces and vertical expansion of piles, and horizontal thermal expansion of the slab and grade beams during thermal treatment.		POSSIBLE	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections) Exceeding the ultimate capacity requires relatively more of an effect than exceeding the cracking capacity; therefore, this event is relatively less likely.	SERIOUS	The precast walls would lose strength and connectivity in addition to the cracking. The strength loss would not be recoverable.	3	3	MEDIUM
17		Interior partition walls crack.	Downdrag forces and vertical expansion of piles, and horizontal thermal expansion of the slab and grade beams during thermal treatment.		HIGHLY LIKELY	Partition walls are as fragile or similarly fragile to the perimeter walls by inspection. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections)	MINOR	Cracking of the partition walls would present an aesthetic concern. This cracking would not be recoverable, but the cracks would likely close to some degree over time.	1	1	MEDIUM
18	Utilities	Utility conduits deform and impact function of utility.	Settlement of soils supporting utility during thermal treatment.		HIGHLY LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections). Proximity to thermal treatment areas significantly impacts likelihood.	SERIOUS	Utilities (i.e., sewers) that rely on gravity are more prone to loss-of-function due to settlement. All utilities are prone to loss-of-function where there is rupture of the utility conduit.	1	3	SEVERE
19		Utility conduits deteriorate and impact function of utility.	Deterioration of utility conduit materials at elevated temperatures during thermal treatment.		LIKELY	Structural and geotechnical analyses. (Limited Geotechnical and Structural Study to Support Remedial Decision Making, draft report dated August 24, 2021, Results of Geotechnical Engineering Evaluation - In-Situ Thermal Heating Activities and Structural Engineering Evaluation - Structural Evaluation Results and Discussion - In-Situ Thermal Heating sections). Proximity to thermal treatment areas and utility materials significantly impacts likelihood.	SERIOUS	Potential reduction of the structural integrity of the utility conduit, could result in failure of the conduit.	2	3	HIGH

RISK MANAGEMENT MEASURES

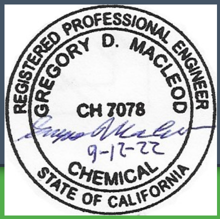
EVENT	PRIOR TO THERMAL REMEDIATION: Is additional data collection warranted to refine risk ranking?	PRIOR: Can data be collected without intrusive or destructive means of investigation?	PRIOR: Can risk be mitigated through thermal remedial design process?	PRIOR: Can risk be mitigated through other engineering controls or changes to property/structure?	DURING THERMAL REMEDIATION: Is data collection warranted during thermal treatment?	DURING: Can data be collected without intrusive or destructive means of investigation?	DURING: If yes, what contingent actions could be considered depending on results?	AFTER THERMAL REMEDIATION: Is data collection warranted after thermal treatment?	AFTER: Can data be collected without intrusive or destructive means of investigation?	AFTER: If risk is realized what can be done to address it?
15	Yes - Visual condition assessment of precast walls and connections in vicinity of treatment area.	Yes	Not likely	Not likely	Yes	Yes - relative displacement between panels could be monitored at pre-installed crack gauges.	N/A	Yes - Visual condition assessment of precast walls and connections in vicinity of treatment area.	Yes	Epoxy inject cracks to restore performance of walls as building enclosure system.
16	Yes - Visual condition assessment of precast walls and connections in vicinity of treatment area.	Yes	Not likely	Not likely	Yes	Yes - relative displacement between panels could be monitored at pre-installed crack gauges.	N/A	Yes - Visual condition assessment of precast walls and connections in vicinity of treatment area.	Yes	Epoxy inject cracks to restore performance of walls as building enclosure system Localized concrete repair in vicinity of connections/damage. Repair/supplementation of connections where necessary.
17	Yes - Visual condition assessment of existing partitions	Yes	Possible - observed partitions are rigidly connected to the slab and roof structures with little to no capacity for free movement. Glass is rigidly installed in site-built windows.These conditions could be retrofitted prior to remediation to mitigate some of the risk of damage.	Possible - observed partitions are rigidly connected to the slab and roof structures with little to no capacity for free movement. Glass is rigidly installed in site-built windows. These conditions could be retrofitted prior to remediation to mitigate some of the risk of damage.	No	N/A	N/A	Yes - Visual condition assessment of existing partitions	Yes	Cosmetic repairs to address damage to nonstructural finishes.
18	Yes - as-built utility plans from relevant agencies; confirmation by utility locate subcontractor	Yes	Yes - to some extent thermal design can attempt to place heater cans away from utilities	Yes - if utilities are located <15 ft from thermal treatment areas they will be protected, temporarily taken out of service, or removed.	No	N/A	N/A	Yes - scoping and verifying utility function if utility is within 15 ft of treatment area.	No	Repair utility
19	Yes - as-built utility plans from relevant agencies; confirmation by utility locate subcontractor	Yes	Yes - to some extent thermal design can attempt to place heater cans away from utilities	Yes - if utilities are located <15 ft from thermal treatment areas they will be protected, temporarily taken out of service, or removed.	No	N/A	N/A	Yes - scoping and verifying utility function if utility is within 15 ft of treatment area.	No	Repair utility

Assumptions:

Many of the effects of the thermal treatment will take months or years to diminish, including settlement of the soil and thermal elongation of the piles. This time dependency should be considered when evaluating the post-remediation condition of the structure and developing/implementing any repairs or alterations to the building.

Appendix B Remedial Action Work Plan

ADVISE | DESIGN | BUILD | OPERATE



TERRATHERM
a Cascade Company

In Situ Thermal Remedial Action Work Plan

In Situ Thermal Remediation

3775 Bayshore Boulevard

Brisbane, CA

September 2022

www.terratherm.com

TERRATHERM
a Cascade Company

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

TABLE OF CONTENTS

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

LIST OF FIGURES

LIST OF TABLES

ATTACHMENTS

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

ACRONYMS AND ABBREVIATIONS

°	Degrees
°C	Degrees Celsius
°F	Degrees Fahrenheit
"w.c.	Inches of Water Column
µg/L	Micrograms per Liter
A	Amp
ANSI	American National Standards Institute
COC	Contaminant of Concern
CS80	Carbon Steel Schedule 80
CVOC	Chlorinated Volatile Organic Compound
DNAPL	Dense Non-Aqueous Phase Liquid
ft	Feet
ft/day	Feet per Day
ft/ft	Feet per Foot
ft bgs	Feet Below Ground Surface
ft^2	Square Feet
gpm	Gallons per Minute
H_2O	Water
HCl	Hydrochloric Acid
IEEE	Institute of Electrical and Electronics Engineers
ID	Inner Diameter
in	Inch
ISTR	In Situ Thermal Remediation
kAIC	Kilo Ampere Interruption Capacity
$KMnO_4$	Potassium Permanganate
kVA	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt-Hour
lb	Pound
LEL	Lower Explosive Limit
LGAC	Liquid Granular Activated Carbon
LNAPL	Light Non-Aqueous Phase Liquid
mg/kg	Milligrams per Kilogram
NaCl	Sodium Chloride
NAPL	Non-Aqueous Phase Liquid
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
O&M	Operations and Monitoring
P&ID	Piping and Instrumentation Diagram

PCE	Tetrachloroethene
PFD	Process Flow Diagram
PID	Photoionization Detector
PLC	Programmable Logic Controller
RAWP	Remedial Action Work Plan
scfm	Standard Cubic Feet per Minute
SCR	Silicon Controlled Rectifier
SS	Stainless Steel
SVOC	Semi-Volatile Organic Compound
TCE	Trichloroethene
TCH	Thermal Conduction Heating
TMP	Temperature Monitoring Point
TTZ	Target Treatment Zone
V	Volt
VC	Vinyl Chloride
VEW	Vapor Extraction Well
VGAC	Vapor Phase Granular Activated Carbon
VOC	Volatile Organic Compound
yd^3	Cubic Yards

1 EXECUTIVE SUMMARY

This In Situ Thermal Remediation (ISTR) Remedial Action Work Plan (RAWP) presents TerraTherm, Inc.'s (TerraTherm's) approach for the ISTR treatment at 3775 Bayshore Boulevard, Brisbane, CA (the Site). TerraTherm is performing the design work under contract to EHS Support, LLC (EHS). The selected thermal remedy will consist of Thermal Conduction Heating (TCH) to treat the Target Treatment Zone (TTZ) to an average temperature of 100 degrees Celsius (°C). Unless noted otherwise, all activities noted in this RAWP are TerraTherm's responsibility

The TTZ is subdivided into eleven subareas based on different treatment zone locations and depths. The eleven areas have been defined as the zones where soil and groundwater are impacted by volatile organic compounds (VOCs). The treatment area is located both within and outside of an existing Site building. The target treatment depth varies depending on location, but generally begins either at the surface or five feet below ground surface (ft bgs), and extends to five, 15, or 55 ft bgs depending on its location.

The ISTR system to be installed at the Site includes 192 TCH borings with co-located vapor extraction wells (VEWs) to heat and extract vapors from the subsurface soil. Eighteen temperature monitoring points (TMPs) and eight shallow TMPs near building beams, between piles and heaters, and near a fuel line will collect temperature data to support and to track subsurface heating and monitor existing critical installations. The vapor and liquid treatment system consists of multiple sequential treatment components to condition extracted wellfield vapor before treatment through a thermal oxidizer, prior to discharge to the atmosphere. Back up vapor phase granular activated carbon (VGAC) adsorption including potassium permanganate ($KMnO_4$) impregnated zeolite media to remove vinyl chloride is available should the thermal oxidizer be offline. Condensed water from the vapor stream will be treated with liquid phase granular activated carbon (LGAC) treatment prior to discharge to the sanitary sewer.

The objective of the TCH system is to reduce concentrations of the site-related contaminants of concern (COCs), including chloroethanes, chloroethenes, petroleum hydrocarbons, and other VOCs in soil within the TTZ to the values shown in Table 2.1; the full list of Site COCs is also shown. The ISTR system will meet the performance standards described in Section 6.9 prior to shut down. The ISTR system will operate for a total of 232 days including a 28-day sampling and results evaluation period and 14 days for an initial post-treatment cool-down period. Once the initial cool-down period is complete, the ISTR system will be decontaminated and removed from the Site prior to Site restoration.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

2 SITE BACKGROUND AND REMEDIATION OBJECTIVES

This section summarizes Site information provided by EHS including the Site background, geology, and hydrogeology. It also defines the TTZ based on existing Site data and establishes remediation objectives that together serve as the basis of design for the project.

2.1 Objective

The objective of the TCH system is to reduce the concentrations of site-specific COCs within the TTZ to concentrations at or below the treatment standards and saturation limits in Table 2.1. There are different goals for each COC which are dependent on the treatment interval for each COC.

Table 2.1. Soil Treatment Standards

	0 to 5 foot interval	5-15 foot interval	15-55 foot interval	All Depth Intervals
Constituent	Soil Treatment Standard (0 to 5 ft bgs) (mg/kg)	Soil Treatment Standard (5 to 15 ft bgs) (mg/kg)	Soil Treatment Standard (15 to 55 ft bgs) (mg/kg)	Soil Saturation Limit (any depth) (mg/kg)
Chloroethanes				
1,1,1-Trichloroethane	1	1	1	650
1,1-Dichloroethane	1	1	1	1700
1,2-Dichloroethane	1	1	1	3000
Chloroethenes				
Tetrachloroethene	1	1	1	170
Trichloroethene	1	1	1	700
1,1-Dichloroethene	1	1	1	1200
cis-1,2-Dichloroethene	1	1	1	2400
trans-1,2-Dichloroethene	1	1	1	1900
Vinyl Chloride	1	1	1	3900
Petroleum Hydrocarbons				
C10-C24 (Petroleum - Diesel Range)	2000	2000	2000	2300
C5-C12 (Petroleum - Gasoline)	300	300	300	1000
Benzene	1	1	1	1900
Ethylbenzene	1	1	1	490
Styrene	1	1	1	870
Toluene	1	1	1	810
Xylenes	5	5	5	270
Naphthalene	10	10	10	280
Other Organic Compounds				
1,4-Dioxane	No Standard	No Standard	No Standard	120000
1,2-Dichlorobenzene	1	5	5	380
2,4-Dimethlyphenol	No Standard	No Standard	No Standard	24000
Chlorobenzene	1	1	1	750
Chloroform	1	1	1	2600
Hexachlorobutadiene	1	5	5	17
Methyl Isobutyl Ketone (MIK)	1	5	5	3400
Methylene Chloride	1	1	1	3300

Soil Saturation Limit provided in the RWQCB Environmental Screening Level Workbook (January 2019)

2.2 Site Background

The Site is located at 3775 Bayshore Boulevard, Brisbane, California. The TTZ is located both within and outside the footprint of an existing Site building. The TTZ located inside the building is covered by a concrete floor and contains a system of beams and piles for structure and support of the building. There are no known active subsurface utilities within the TTZ. The TTZ located outside of the building is presently covered by asphalt, concrete, and grass. Brief descriptions of the immediate Site surroundings are as follows:

- The Brisbane Lagoon, which is a body of water separated from the San Francisco Bay by the Bayshore Freeway, is located to the northeast of the Site;
- Bayshore Boulevard and a few commercial businesses are located to the west; and,
- A parking lot and vegetated hillside are located to the south of the Site.

A review of historical information indicates that the Site building was constructed between 1979 and 1980, along with the building piles and beams that support the building structure. The Site is currently owned by M&L Associates, and the building covering a portion of the TTZ will remain empty during ISTR implementation.

2.3 Target Treatment Zone

The TTZ has been defined as the zone where COC concentrations in soil have exceeded their respective clean up levels. The TTZ has been divided into 11 treatment subareas based on treatment depths and locations. A summary of the area dimensions is provided in Table 2.2 and a plan view showing the extent and name of each treatment area is shown in Figure 2.1.

Table 2.2. Treatment Subarea Definition Summary

Treatment Area	Area (square feet [ft^2])	Treatment Thickness	Geometrical Treatment Volume	Design Treatment Volume
		(ft bgs)	(Cubic Yards [yd^3])	[yd ^{3}]
A1, A2 and A3	5,048	5	935	
B1, B2 and B3	8,979	15	4,988	
C1 and C2	7,377	55	15,026	
D1 and D2	1,039	10	385	
E	712	50	1,318	
Total	**23,152**		**22,652**	**24,697**

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

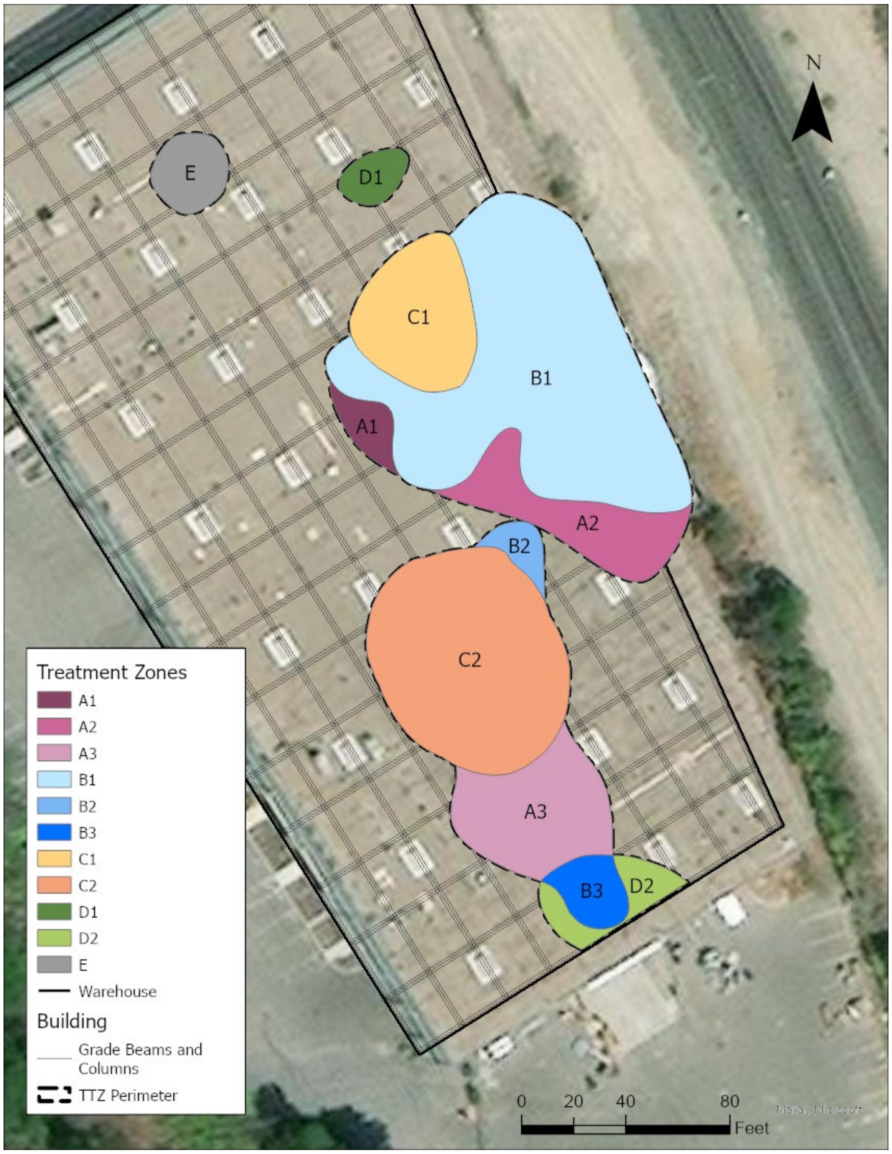


Figure 2.1. Treatment Areas

As summarized in Table 2.2, the total treatment area is 23,152 ft^2 and the total geometrical treatment volume is 22,652 yd^3. The actual volume that will be heated, the design treatment volume, is larger than the geometrical treatment volume because of heater boring placement restrictions (beams, piles, and existing walls) requiring that the ISTR system cover a slightly larger footprint than the geometrical footprint.

2.4 Geology and Hydrogeology

The geology within the TTZ at the Site has four main stratigraphic units consisting of shallow fill, deep fill, young bay mud, and old bay mud. A detailed description of each unit is provided below:

- Shallow Fill – The shallow fill generally consists of gravel-sand-silt mixtures, clayey gravel, silty clay, and mixtures of reworked native bay mud and artificial fill. The fill extends from the surface to approximately 15 ft bgs.
- Deep Fill – The deep fill underlies the shallow fill. The deep fill consists of material similar to the shallow fill and extends from approximately 5 to 36 ft bgs. The deep fill also varies significantly in thickness and composition. There is not a distinct lithologic contact marking the boundary between the shallow and deep fill with the designation primarily differentiated by the thickness of the vadose zone and vertical interval of water table fluctuations and screen intervals of the fill monitoring wells.
- Young Bay Mud – The young bay mud extends from approximately 10 to 54 ft bgs and is comprised of silt and clay and commonly containing shell fragments.
- Old Bay Mud – The old bay mud extends from approximately 54 and deeper and is comprised of silt and clay with some fine sand.

The water table at the Site is in the shallow fill layer, from five to seven ft bgs depending on location and flows to the east. The groundwater gradient in the shallow fill is approximately 0.009 feet per foot (ft/ft), in the deep fill is approximately 0.005 ft/ft, and in the young bay mud is 0.0095 ft/ft. The hydraulic conductivity of the shallow fill is 4.4 feet per day (ft/day), in the deep fill is 7.1 ft/day, and in the young bay mud is 0.01 ft/day.

2.5 Mass Estimate and Breakdown

EHS developed low and high COC mass estimates by multiplying NAPL pore fluid saturation (i.e, the fraction of the interconnected pore spaces filled with NAPL), density of the NAPL, effective porosity of the soil, and soil volume. All of these NAPL and soil input parameters were determined via laboratory testing of samples collected at the Site. Table 2.3 summarizes the mass estimate for the total organics under the building (interior TTZ), outside the building (exterior TTZ), and total (interior and exterior TTZ).

Table 2.3. Summary of COCs Mass Estimate

COCs	Mass Estimate [Low] (pounds [lbs])	Mass Estimate [High] (lbs)
Interior TTZ - Total VOCs	45,207	106,121
Exterior TTZ - Total VOCs	4,707	15,605
Total VOCs	49,914	121,726

3 THERMAL TECHNOLOGY BACKGROUND

3 THERMAL TECHNOLOGY BACKGROUND

3.1 Technology Overview

TCH will be implemented to remediate chlorinated volatile organic compound (CVOCs), petroleum hydrocarbons, and additional VOCs at the Site. A conceptual sketch of a TCH remediation process is shown below in Figure 3.1.

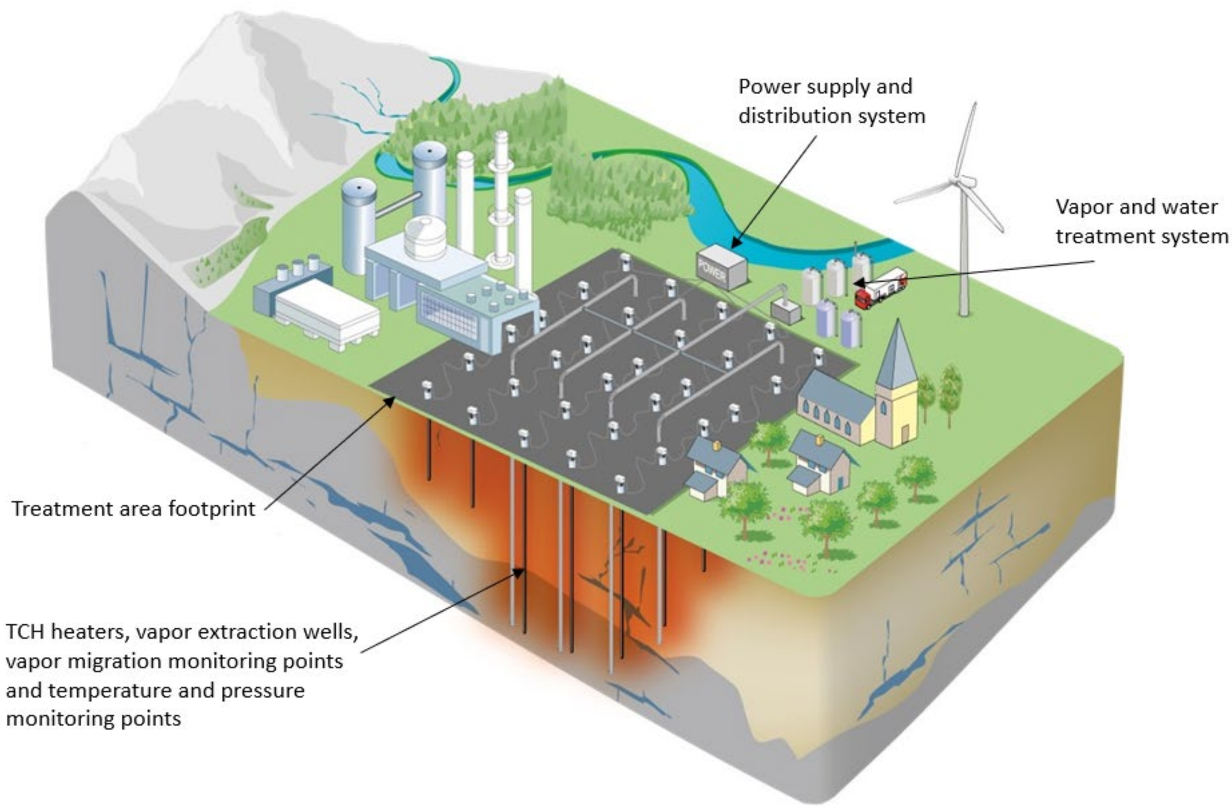


Figure 3.1. Example TCH Schematic (not specific to the Site)

The heating system is supported by an extraction and treatment system that includes:

- Co-located VEWs to extract vapors from soil;
- Conveyance pipe;
- Heat exchangers to cool recovered contaminant vapors;
- Liquid/vapor separator (knockout pot);
- Vacuum blower to transfer steam and vapors from the VEWs to the treatment system;
- Vapor treatment using a thermal oxidizer with backup VGAC in the event of thermal oxidizer downtime;
- Liquid treatment system (oil water separation, non-aqueous phase liquid [NAPL] storage);
- Liquid treatment using LGAC;

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

- Valves, gauges, and sensors to control and monitor recovery and treatment operations; and,
- Electrical power distribution equipment and infrastructure.

An existing office within the building will be used for housing data management computers and other monitoring equipment. The ISTR process is automated with a TerraTherm operator overseeing the system and collecting data and samples. As the Site is heated, fluids are extracted, cooled, separated, and treated. The subsurface process is monitored using temperature sensors and by the sampling and analysis of subsurface fluids.

3.2 In Situ Thermal Conduction Heating Background

TCH is a field-proven remediation technology that has been successfully used to remediate the full range of VOCs and semi-volatile organic compounds (SVOCs) (Stegemeier & Vinegar, 2001). TCH has been utilized at over 80 sites across the U.S. and worldwide and is a viable treatment technology for nearly all VOCs including CVOCs and petroleum hydrocarbons, which are present at the Site. TCH is particularly well suited for application in low permeability soils (including bay mud) because heat distribution is not affected by the low hydraulic conductivity of the soil. The TCH process is described as follows:

1. Thermal energy provided by vertical heater borings will heat the soil, water, and contaminants. The heating progresses by thermal conduction, as the heater wells are heated to temperatures around 500 to 600°C, creating significant temperature gradients in the formation around each heater. Thermal conductivity of soil materials varies over a very narrow range – only by a factor of three to five; therefore, TCH is very precise and predictable regardless of the permeability of the soil or its degree of heterogeneity. Concrete debris and structures that are known to be present at the Site will not pose any technical heating challenge for the TCH technology.
2. The heat front moves away from the TCH heaters through the soil by thermal conduction and convection, and the superposition of heat from the many heaters results in a temperature rise throughout the TTZ.
3. As soil temperatures increase, contaminants and water contained in the soil matrix are vaporized. While locations close to heaters (i.e., typically less than one foot) may achieve temperatures above the boiling point of water (100°C), locations in between heaters need only achieve temperatures near 100°C to accomplish steam distillation for effective removal of VOCs. Boiling off all the soil water is not necessary. Very high (>99%) removal results have been repeatedly measured for ISTR of VOCs.
4. The vacuum applied to the VEWs from the process system will draw the vapors through the soils and into the conveyance piping network for subsequent treatment.

The heater borings are 3-inch (in) inner-diameter (ID) schedule 80 (CS80) steel cased wells (3.5-in outer-diameter), equipped with a stainless-steel liner. Each of these contains a stainless-steel heater as shown in Figure 3.2.

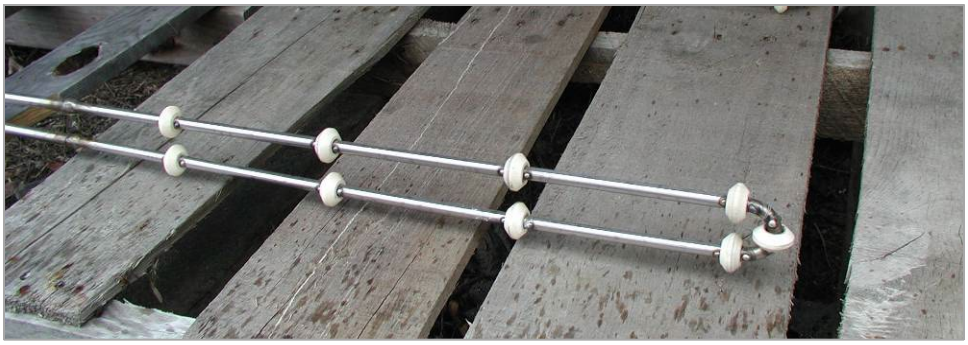


Figure 3.2. TerraTherm Heater Element

The metal rod of the heater has a diameter of approximately 0.5 in. The white beads are ceramic isolators. Electric power flows through the steel rod, causing it to heat resistively. Each heater is typically constructed of three parts – a cold pin (limiting energy output that will reduce heating of the existing building slab), a non-boosted heater section, and a boosted heater section. The cold pin is constructed of a more conductive metal and therefore only injects 15-20% of the energy delivered by other heater depths. The non-boosted heater section is designed to heat and target the TTZ while the boosted heater section is less conductive, delivering more heat in the heated zone to offset heat losses at the TTZ boundaries. Figure 3.3 shows an example of a full scale TCH wellfield. Each heater is connected by a heavy-duty portable power cord through an electrical junction box.

Figure 3.3. Example TCH Wellfield (not specific to actual site)

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

3.3 Remediation Mechanisms

3.3.1 Vaporization

The following describes how TCH will be used to treat COCs at the Site by heating the subsurface to near the boiling point of water (100°C). Heating the TTZ to the boiling point of water ensures that VOCs become volatile and partition into the vapor phase for extraction. The effectiveness of the TCH technology results from changes in the thermodynamic conditions in the subsurface during heating. The primary characteristic leading to effective thermal treatment is contaminant vaporization whereby a reduced boiling point is observed for NAPL/water mixtures of site contaminants in situ. Figure 3.4 illustrates changes to physical properties as temperatures increase (below for PCE and TCE), but similar trends are observed for the remaining Site COCs. As depicted, vapor pressure and Henry's Law constants increase dramatically as temperatures rise, allowing contaminants to vaporize below their characteristic boiling points.

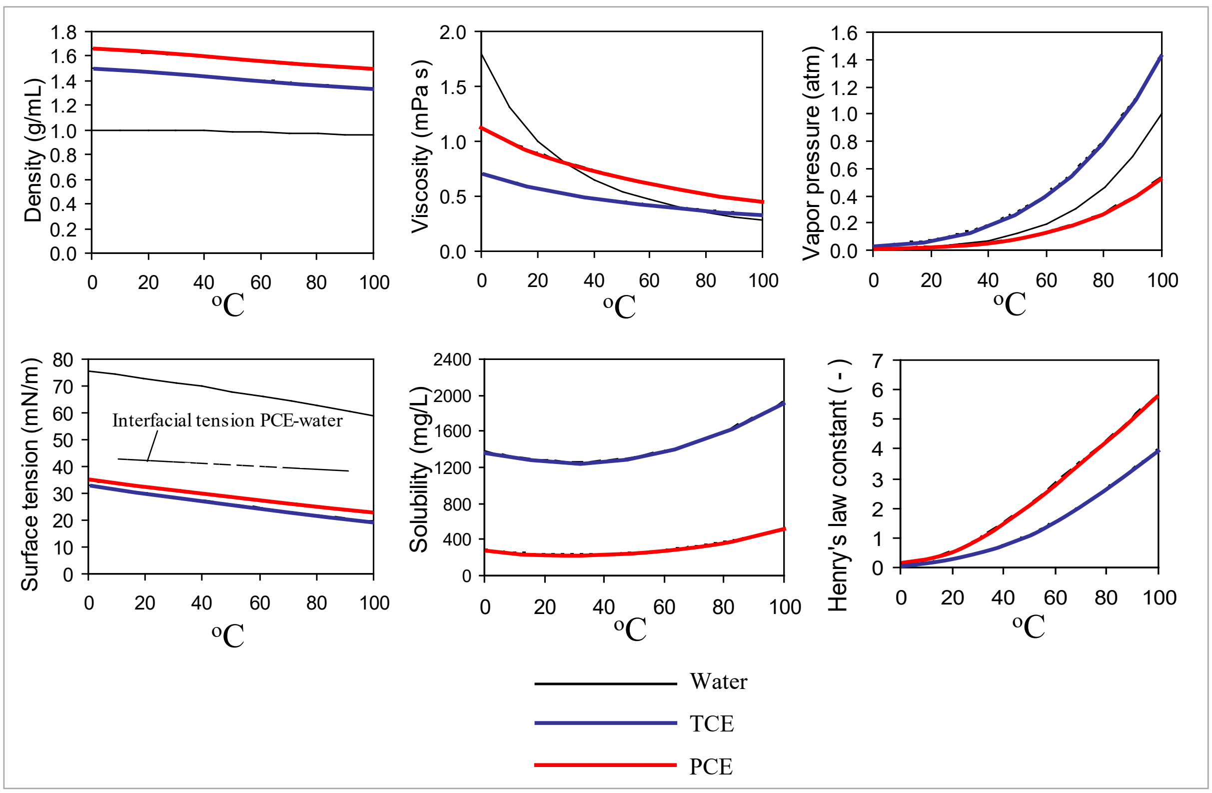


Figure 3.4. Physical Property Changes as a Function of Temperature (Heron, Baker, Bierschenk, & LaChance, 2006)

Vaporization is further illustrated in Figure 3.5, in which two images of the same porous medium show a comparison of heated and unheated pore water. The left image is at ambient temperature and the right image is at boiling temperature. Contaminant vaporization is illustrated by comparing the lighter areas (gases in the pore space) between the two pictures. The observed increase in gas volume as temperature is increased, demonstrates how boiling temperatures lead to steam formation. The continuous gas phase in the image to the right depicts the boiling of pore fluids and the creation of steam. The steam is rich in contaminant vapors, under pressure, and inclined to move out of the pore matrix toward the extraction locations.

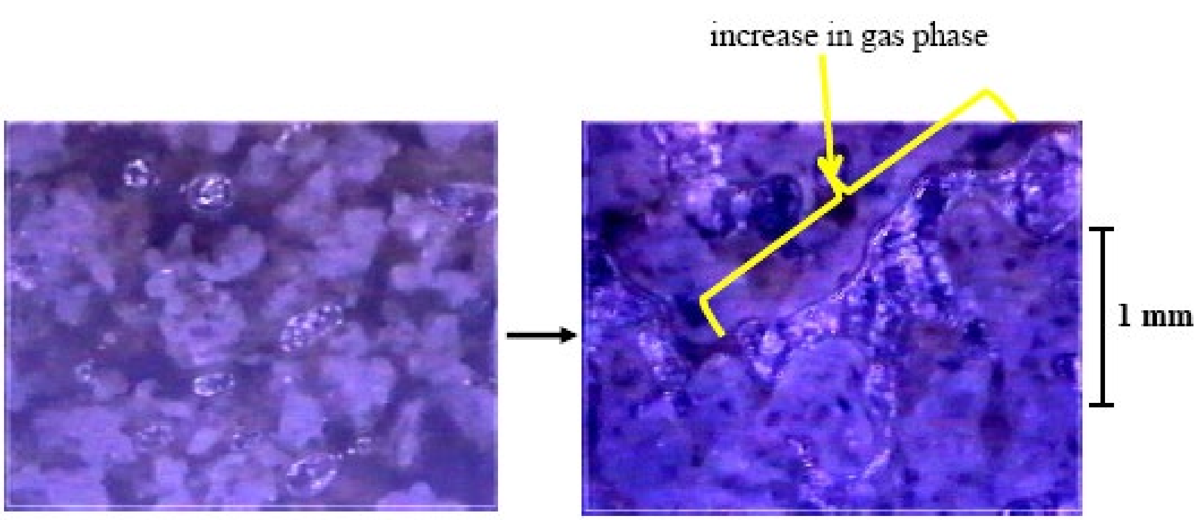


Figure 3.5. Ambient vs. Boiling Temperature Illustration, Pore-Scale

Similar mechanisms occur at NAPL-water interfaces where contaminant-rich steam is produced as a result of co-boiling and where the resulting buoyancy of the steam causes them to primarily migrate vertically to the vadose zone for removal. When heating the site COCs, the following occur:

- The vapor pressure of the COCs dramatically increases with temperature. As the subsurface is heated from ambient temperature to temperatures in the range of 100°C, the vapor pressure of the COCs will typically increase between 10- and 30-fold (Udell, 1996).
- Adsorption coefficients are reduced moderately during heating, leading to an increased rate of desorption of COCs from the soil (Heron, Van Zutphen, Christensen, & Enfield, 1998).
- Boiling of dense non-aqueous phase liquid (DNAPL) occurs at temperatures below the boiling point of water (DeVoe & Udell, 1998). Heating the subsurface to 100°C will make the DNAPL thermodynamically unstable, causing it to boil and convert to a vapor. The vaporized DNAPL components will be captured in the VEW system and be transported to the effluent treatment system prior to discharge.
- Fugitive emissions will be prevented by maintaining negative pressures at the wellheads and where possible across most of the TTZ through operation of the VEW system. In addition, all vapor collection piping will be operated under a net negative pressure. A

backup generator is included in the system design to operate the vapor extraction system in the event of a power outage.

Other remediation mechanisms that will be provided by the TCH approach include accelerated desorption from the solid phase, thermal destruction via in situ reactions near TCH heating elements, and microbial mineralization (Baker & Kuhlman, 2002).

4 THERMAL SYSTEM DESIGN

4.1 Overall Thermal Concept

The Site consists of multiple zones with different soil properties (porosity, saturation, groundwater flux). Numerical water and energy balance models have been developed by TerraTherm to simulate the addition, removal, and loss of energy in each layer of the Site separately with the layers exchanging both fluids (water and steam) and energy along their boundaries. The calculations also estimate heat losses along the top, sides, and bottom of the TTZ and the impact of groundwater flow into the treatment area, such that total energy demands, and the duration of thermal treatment can be estimated.

Numerical water and energy balance calculations were conducted to evaluate the best heating approach for the Site. The numerical calculations were performed to evaluate the effects of groundwater flux, TCH power input, heater design, and heating strategy. The water and energy balance calculations are referred to as the model. The basic model setup is described in the following sections.

4.2 Numerical Model

The model is based on simplified mass and energy balance principles relevant for TCH operation. The model can include up to twelve layers, each with different model input and derived parameters, and includes:

- Surface area;
- Depth;
- Area of perimeter;
- Porosity;
- Initial saturation;
- Initial bulk density;
- Initial heat capacity; and,
- Initial thermal conductivity.

During the simulations, parameters such as thermal conductivity and heat capacity are changed automatically as the water saturation changes based on published equations for these parameters. This means that as a zone is drying out due to boiling and steam removal, the water saturation is reduced. Therefore, both the heat capacity and thermal conductivity are reduced such that only the remaining water contributes to these parameters. This gives a more realistic heating prediction than if constant values are assumed.

The results of the numerical simulations have served as the basis for the design of the thermal treatment system at the Site. The model calculates the water mass balance for each layer. Water infiltration from the surface into the TTZ was assumed to be negligible for the Site.

Average total porosities were calculated for each soil unit from the porosity data table provided by EHS Support, resulting in total porosity values of 38% for the shallow fill, 35% for the deep fill, and 57% for the young bay mud. The model assumes heating starts at 0 ft bgs and extends to 5 ft below the bottom of the TTZ. Extending the heated zone below the TTZ helps to keep hot steam migrating upward and helps to offset heat losses towards the top and bottom of the TTZ.

Hydraulic conductivity values for each geologic layer used for this evaluation were provided by EHS. The hydraulic conductivity in the shallow fill is 4.4 ft/day, the deep fill is 7.1 ft/day, and the hydraulic conductivity in the young bay mud is 1.0×10^{-2} ft/day. The hydraulic gradient in the shallow fill is 0.009 ft/ft, 0.005 ft/ft in the deep fill, and 0.0095 ft/ft in the young bay mud.

The steam extraction rates were calculated based on the energy injected by the TCH system. The equation calculating the ratio between injected energy and extracted steam is derived based on observations made on several recent full-scale TCH projects. Cumulative energy added to the Site is calculated as a summation of enthalpy fluxes:

- Energy added by the TCH heaters;
- Energy extracted as steam in the vapor stream;
- Energy extracted in the entrained liquid stream (if any); and,
- Heat loss to the areas outside of the heated zone.

The energy removed as a non-condensable vapor at any given time is relatively small due to the low heat capacity of air in relation to steam and water and is therefore ignored in the calculations. The actual heat loss cannot be calculated accurately. An estimate can be made based on thermal profiles at the bottom and top of each layer and along the perimeter. For the heat loss through the top, bottom and sides, the temperature difference between the perimeter of the Site and the ambient soil is used to calculate the thermal gradient. For the calculations, it is assumed that the ambient soil surrounding the TTZ remains near ambient temperatures.

All heat migration through the sides and through the top and the bottom layer of the model are considered lost from the model domain. Heat migration from the bottom of a layer and into the top of the underlying layer remains as energy in the model if both layers are in the heated zone. The model calculates average layer temperatures based on the energy balance and the estimated heat capacity of each layer.

4.2.1 Simulation Assumptions

The modeling approach uses TerraTherm's layered box model that is finite difference numerical model. The separate areas (within different treatment depths) were aggregated into a single layered box model using average volumes, layer thicknesses, and hydrogeologic parameters to represent the entire treatment volume. Averages were calculated by the heater length in each zone rather than the zone geometry to provide more accurate and representative estimates of total heating requirements and energy demand.

Modeling the energy balance of each layer separately allows for better representation of Site heterogeneity than a single box model would provide. Energy transfer between layers is considered to get a better understanding of how the site is expected to heat with depth. If there is a layer with high groundwater flow in the middle of the TTZ, the energy lost to that groundwater flow in the layers above and below is captured whereas in a single box model that level of detail is lost. The porosity values included are averages calculated from the porosity data provided by EHS. The saturation was calculated based on the water table location.

Given that the layered box model is intended to be a representation of the entire treatment volume, the model output files (e.g., Figure 4.1) do not show the actual depth profiles for the Site, but instead show average temperature profiles. Layers two through seven represent the TTZ and while the average layer seven in the model represents the 24.0 to 28.8 ft bgs depth, it is also representative of the temperature prediction for the bottom layer in the actual Site configuration (for example, the layer at the bottom of the 55 ft treatment zones). Our numerical model has been utilized as the design basis for more than fifty field projects, and our model code is constantly validated and improved based on actual observations and data collected during operation.

4.2.2 Simulation Results

The Site definition and numerical modeling results are further described below and in more detail in the thermal model simulation report in Attachment B.

4.2.3 Temperature Progression and Duration

Figure 4.1 shows the predicted average temperature in the TTZ as a function of time. Based on the energy calculations, the predicted total duration of the remedy is estimated to be 232 days (inclusive of a 28-day soil sampling and results evaluation). Please note that the figure below represents the average Site temperature. During operation, while some TMPs are located within 5 ft of heaters and some closer to piles and beams, the majority of the Site temperature will be observed at the centroid locations between the heaters (i.e., the coolest locations). Thus, the observed temperature progression is expected to lag the modeled temperatures by up to 2-3 weeks.

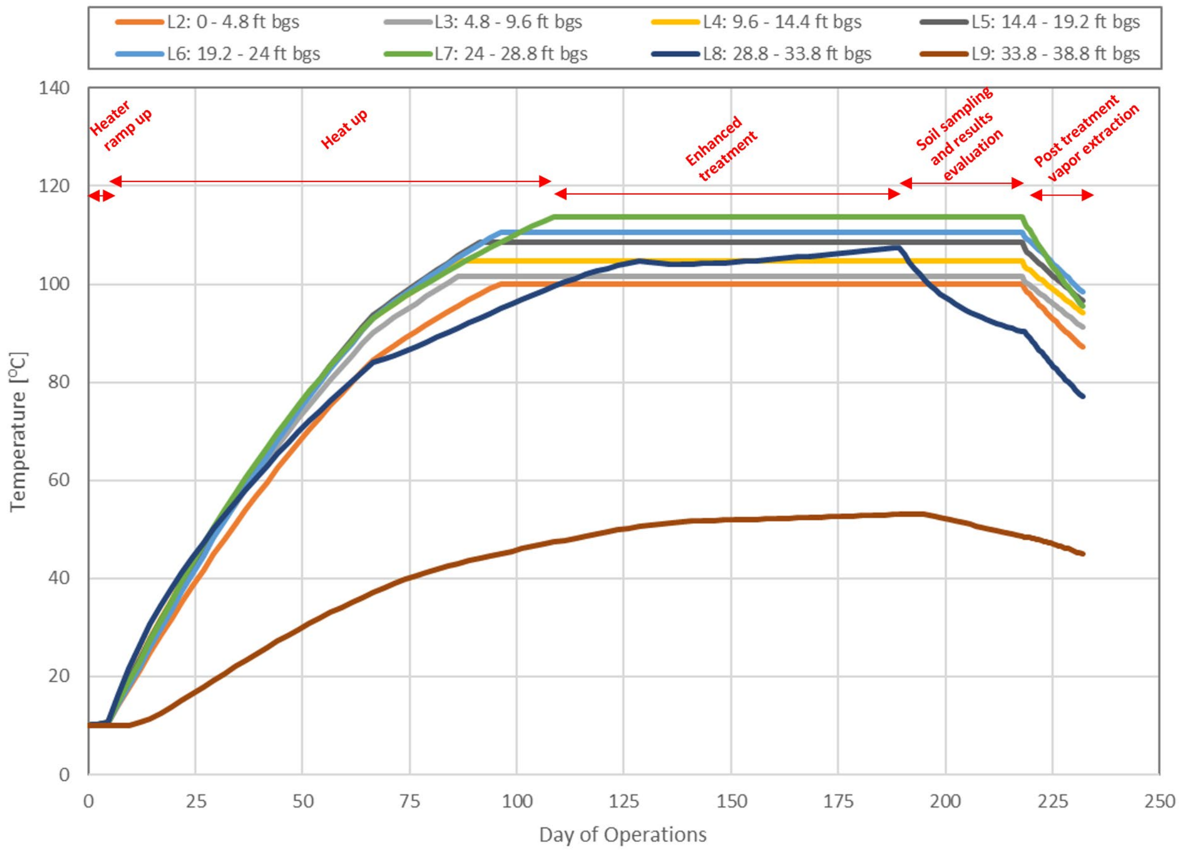


Figure 4.1. Modeled Average Temperature Curves (Layers 1 to 9) during Thermal Treatment[1]

The results of the simulation indicate that on average the TTZ (layers two through seven) reaches a temperature of the boiling point of water between days 90 to 120. As described above, there is a delay between the modeled average temperature and the temperature observed at the centroid locations. Thus, the boiling point is expected to be reached 110-140 days after startup of operation at the centroid locations, represented by the temperature monitoring points installed at the Site. The operational durations for the Site have been estimated based on the model calculations. The operational sequence and durations are shown in Table 4.1.

[1] Note: Layer 1 is above the TTZ, Layers 2-7 are within the TTZ and Layers 8 and 9 are below the TTZ. Please see further definition of the model treatment layers in the thermal model simulation report in Attachment B.

Table 4.1. Operational Phases and Durations

Operating Time	Number	Unit
Heater ramp up	2	Days
Heating to boiling and boiling*	188	Days
Soil sampling and results evaluation period	28	Days
Post treatment vapor extraction	14	Days
Total operating time	232	Days

**Note: These heating phases will occur simultaneously within different portions of the TTZ; this phase includes soil sampling and evaluation.*

The estimated total period of TCH operations is 232 days, including two days of heater ramp up, a 28 day soil sampling and results evaluation period, and 14 days of post-treatment vapor extraction and initial cool-down. During heat-up, the percentage of the TTZ that is boiling will progressively increase until the entire TTZ reaches the boiling point (90 to 120 days). Heating will continue until day 190, at which point a soil sampling and results evaluation period will be initiated. Once the performance standards defined in Section 6.9 have been achieved, the heating will be terminated, and the initial cool-down period will begin. During heat-up and the boiling period, steam and volatized COCs will be extracted from the TTZ and sent to the treatment system. The TCH system is operated with the objective of optimizing the subsurface heating and COC removal process. The operational plan is flexible, allowing for adjustments based on observed hydraulic responses, heating progression, and COC extraction rates.

4.2.4 Effluent Treatment System Design Parameters

The subsurface energy balance calculations in the numerical model are used to calculate values for the vapor extraction rates necessary to maintain capture and optimize the treatment. Table 4.2 presents the wellfield vapor and liquid design parameters resulting from the numerical model calculations. Based on the calculated values, the vapor treatment system has been designed to treat an influent wellfield flow rate of approximately 2,119 standard cubic feet per minute (scfm) (combined condensable and non-condensable flow). The liquid treatment system has been designed to treat a minimum of 6.5 gallons per minute (gpm) of condensate and 1.1 gpm of entrained wellfield water.

Table 4.2 Design Basis, Wellfield

Wellfield Vapor	Number	Units
Wellfield vapor extraction rate, max total	2,119	scfm
Wellfield non-condensable vapor, max	975	scfm
Wellfield condensable vapor (steam), max	1,144	scfm
Wellfield Liquid		
Wellfield steam extraction rate, when condensed, maximum	6.5	gpm
Wellfield water entrainment, maximum	1.1	gpm
Total liquid extraction rate, maximum	7.6	gpm

4.3 Wellfield Design and Installation

Heaters will extend 5 feet (ft) below the bottom of the TTZ to ensure target temperatures are reached throughout the TTZ. To limit any risk of condensation of mobilized COCs above the TTZ, heating will extend up to ground surface in outdoor areas and up to 12 inches below the bottom of the floor inside the building (including areas where the top of the TTZ is located 5 ft bgs). By doing so, a heated vadose zone is created at the top of the TTZ and above the water table, allowing for proper contaminant vapor capture.

The ISTR wellfield includes the following:

- Heaters spaced 13 - 14 ft apart along the perimeter of the Site. The interior heater spacing is 15 - 16 ft. A total of 192 heaters will be installed at the Site.
- Heaters installed a minimum of 3 ft away from the edge of all structural beams and /or piles.
- The heated depth begins minimum 12 in below the bottom of the floor inside the building. This safety distance will be used to limit the heating of the existing floor slab during operation.
- The heater can will be installed to 6-7 ft below the TTZ to allow for thorough heating across the bottom of the TTZ and thermal expansion of the heaters during the remedy.
- VEWs co-located to all TCH heaters to recover vapors and collect them in the vapor treatment system.
- Subsurface temperature monitored from 18 TMPs and eight shallow temperature monitoring points located near beams, between heaters and piles and along the eastern perimeter of the Site.

A summary of the quantities of borings by treatment area is included in Table 4.3.

Table 4.3. Boring Summary

Treatment Area	Vertical Heaters*	Angled Heaters*	TMPs	Shallow TMPs
A1, A2 and A3	26	1	1	1
B1, B2 and B3	75	0	5	2
C1 and C2	62	4	9	2
D1 and D2	16	0	1	0
E	8	0	2	0
Near fuel line (5 ft bgs)	-	-	-	3
Total	**187**	**5**	**18**	**8**

**Includes a co-located VEW (192 total VEWs)*

The boring types and functions are summarized below. The wellfield layout and well details are also shown in Drawings C102 and C103, respectively, in Attachment A.

- Vertical Heaters with Co-Located VEWs: These borings supply heat by thermal conduction and also serve as vapor recovery points. The heater borings consist of a 3-in ID CS80 welded heater can with a welded end cap. Additionally, each heater will have a 1-in co-located 0.010-slot, stainless steel (SS) screen and CS80 riser pipe installed in the same borehole. The screened segment of the co-located VEWs extends from 2-7 ft bgs. Selected heaters (54 in total) will also have a co-located TMP as shown on Drawing C104 in Attachment A. The heaters are installed vertically (90 degrees [°] from horizontal) using a minimum 7-in core barrel. The annular space of the heater boring will be filled with a high temperature grout plug of minimum four ft at the bottom to prevent a permeable pathway down below the TTZ. Sand will be backfilled on top of the grout to 1 ft bgs. High temperature grout will again be backfilled from one ft bgs to the surface, covering the sand pack.
- Angled Heaters with Co-Located VEWs: Construction of angled heaters with co-located VEWs is the same as for vertical heaters with co-located VEWs, except that they will be installed at an angle and the screened interval may differ from the vertical wells. As shown on drawing C103 in Attachment A, angled heaters will be installed at either 27°, 80° or 85° from horizontal.
- TMPs: These wells consist of a 1.5 in pipe instrumented with thermocouples every 3 ft in the vertical interval from the top to the bottom of the TTZ and enable monitoring of heating progression. The boring will be backfilled with high temperature grout to prevent any steam migration up along the monitoring point.

4.3.1 Vapor Cover

The top of treatment starts at ground surface in outdoor areas and a minimum of 12 inches below the bottom of the floor slab inside the building except in Subareas D and E, where the top of treatment is 5 ft bgs. Due to the shallow groundwater table present within the TTZ (i.e., 5-7 ft bgs), the upper 5 ft in Subareas D and E will also be treated to maintain a vadose zone above the water table where mobilized COCs can be captured by the extraction system. Because the system is heating within 1 ft of ground surface in all areas, an insulated vapor cover will also be constructed across the TTZ in all treatment areas. The insulated vapor cover will ensure that the 100°C target temperature is reached and maintained throughout the TTZ. Furthermore, the vapor cover will serve as a weather barrier in the eastern portion of Subarea B1, which is located outside of the building, and will prevent surface water from infiltrating into the TTZ during thermal operations. The vapor cover will have a minimum R-12 insulation value. High temperature insulation boards will provide the primary insulation for the cover.

The vapor cover will be constructed in the interior TTZ by using the existing concrete floor as the base layer. Three inches of insulating foam board will be placed on the existing concrete floor overlying the TTZ and extending a minimum of 15 ft outside of the TTZ perimeter. Plywood (or similar) will be placed over the foam board in high traffic areas to provide a suitable, durable walking surface and to ensure the boards are not damaged.

The vapor cover will be constructed in the exterior TTZ by pouring a three-to-four-inch layer of concrete over the existing ground surface within the TTZ and extending approximately 10 ft outside of the exterior TTZ perimeter. Three inches of insulating foam board (R-12 or greater) will then be placed over the concrete base layer. A three-inch layer of concrete will then be placed over the foam board to complete the cover and provide a suitable, durable walking surface. Vapor cover details are included in Drawing C103 in Attachment A.

4.3.2 Surveying

Prior to ISTR construction, TerraTherm will use a licensed California surveyor to survey and mark the locations of the ISTR wells. Previous surveying has been performed at the Site by a local surveyor but will be confirmed and updated prior to the start of construction.

4.3.3 Drilling and Well Installation Methods

Public and private utility locates will be completed prior to drilling activity. All ISTR borings will be installed by Rotosonic drilling methods. Sonic drilling is the preferred method to achieve optimal drilling production rates with sufficient power to install the wells to the required depths. This drilling approach greatly reduces the volume of cuttings generated as compared with hollow stem auger drilling and has been used successfully at other thermal remediation sites. TerraTherm will core a 12-inch hole in the existing floor slab for well installation inside of the building. After achieving the desired final borehole depth, the boring or monitoring point will be installed according to the design specifications for the particular type of boring (summarized on Drawing C103 in Attachment A) as the casing is withdrawn. This construction method was selected for three primary factors: 1) it minimizes the potential for contaminant migration within the borehole during well construction; 2) it minimizes waste; and 3) this method accelerates the drilling process, even at sites with difficult drilling conditions. Boreholes installed through the existing concrete slab are oversized to allow for localized expansion during the heating process. For selected heater borings in Subarea A3, including H-31 and H-32, hand auguring is considered due to these borings' shallow installation (11 ft bgs) and due to access limitations in this area of the building. Final drilling installation method for these borings will be determined during a drilling site walk conducted prior to startup of well installation.

4.3.4 Drilling Waste

Drill cuttings produced during installation of the wellfield components (heater borings with VEWs, and TMPs), will be collected and stored in covered roll-off containers until wellfield installation is complete. Approximately 74 yd^3 of drill cuttings are expected to be generated during the well installation process. Cuttings generated will be characterized and subsequently shipped off-site for appropriate disposal. EHS Support will be responsible for characterizing, profiling, and off-site disposal of drill cuttings.

4.3.5 Disposition of Existing Wells

The Site is known to have several existing sub slab soil vapor points and groundwater monitoring wells (MWs). The location of the wells are shown on Drawing C102. A total of 21 existing MWs have been identified at the Site of which 14 are within the TTZ. Table 4.4 outlines a suggested disposition and/or repurposing of the existing MWs within or near the TTZ. The final use will be at the discretion of EHS and will be confirmed by TerraTherm after verifying that the actual location will be suitable for the planned repurpose. In addition, a total of 20 vapor pins and five soil vapor probes will be abandoned. The vapor probes are included in the table below. The vapor pins are only installed through the concrete floor and are not included in Table 4.4.

Table 4.4. Expected Future Uses for MWs

Monitoring Well	Water Bearing Zone	Diameter	Top of Screen	Bottom of Screen	Depth	Future Use
		[inches]	[ft bgs]	[ft bgs]	[ft bgs]	
MW-01A	Shallow Fill	8	4	7	7	To be abandoned
MW-02A	Shallow Fill	8	3	8	8	To be abandoned
MW-03A	Shallow Fill	8	3	13	13.5	To be abandoned
MW-04A	Shallow Fill	8	3	7	7	To be abandoned
MW-05A	Shallow Fill	8	4	9	9	Retained
MW-06A	Shallow Fill	8	3	13	13	To be abandoned
MW-07A	Shallow Fill	8	4	9	9	To be abandoned
MW-08A	Shallow Fill	8	4	9	10	Abandoned
MW-09A	Shallow Fill	8	2	5	5	Retained
MW-14A	Shallow Fill	8.25	3	8	15	To be abandoned
HVE-01	Shallow Fill	10	5	20	30	To be abandoned
MW-01B	Deep Fill	8	13	18	20	Over drilled; attempt to install H-152
MW-10A	Deep Fill	8.25	25	30	30	Over drilled; attempt to install T-08
MW-11A	Deep Fill	8.25	23	28	30	To be abandoned
MW-12A	Deep Fill	8.25	21	26	26	To be abandoned
MW-13A	Deep Fill	8.25	15	20	25	To be abandoned
MW-15A	Deep Fill	8.25	32	37	40	Over drilled; attempt to install H-188
MW-02B	Young Bay Mud	8	13	18	20	Over drilled; attempt to install T-03
MW-10B	Young Bay Mud	8.25	48	53	55	Over drilled; attempt to install H-112
MW-11B	Young Bay Mud	8.25	47	52	55	Over drilled; attempt to install T-12
MW-12B	Young Bay Mud	8.25	48	53	55	Over drilled; attempt to install T-11
SVP-01	Shallow Fill	10	4.25	5.0	5	To be abandoned
SVP-02	Shallow Fill	3.25	4.25		4.5	To be abandoned
SVP-03	Shallow Fill	3.25	4.25		4.5	To be abandoned
SVP-04	Shallow Fill	10	4.75		5	To be abandoned
SVP-05	Shallow Fill	3.25	3.33		3.67	To be abandoned

TERRATHERM
a Cascade Company

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

4.4 Methane

Methane is known to be present within the TTZ footprint in concentrations up to 9,300,000 micrograms per liter (ug/l). Methane is not considered to be attributed to methanogenesis but is instead likely a result of concomitant anaerobic petroleum hydrocarbon degradation in the source areas and dilute plume. The generation of methane in organic-rich young bay mud at the Site due to naturally occurring carbon sources may also be happening (EHS Support, Inc., 2022). Figure 4.2 below shows methane concentrations observed within the TTZ.

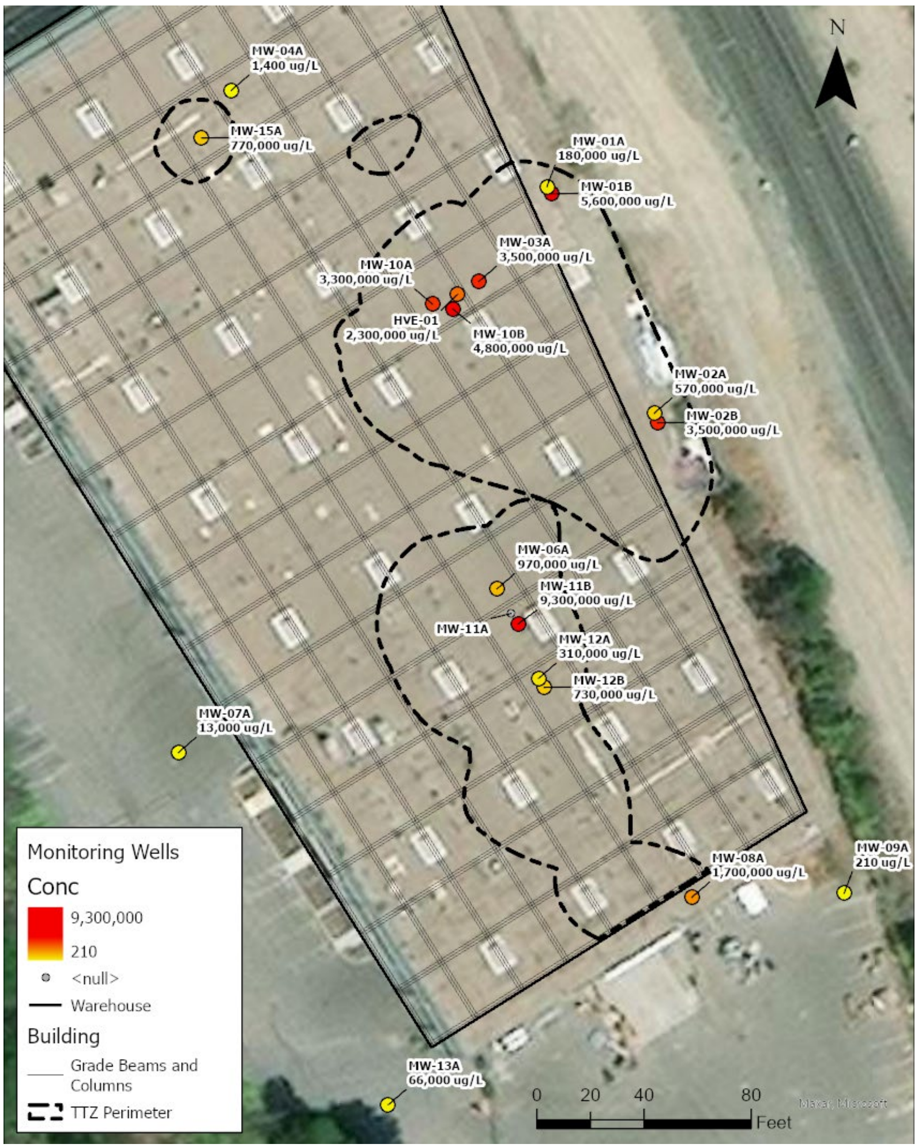


Figure 4.2. Methane Concentrations in TTZ

Given that the methane present at the Site is expected to be naturally occurring, production during thermal operations is expected to be limited. In TerraTherm's experience, methane is generally only a concern in the first few days/weeks of operation or until the subsurface at the Site has been flushed out through vapor extraction and the already present methane has been removed.

TerraTherm will initiate wellfield extraction in a controlled manner by implementing dilution air to reduce methane concentrations. The following additional monitoring procedures will be implemented at the Site and further described in the O&M Plan.

- A real time lower explosive limit (LEL) meter is present in the project design upstream of the thermal oxidizer. During startup, site operators will check the LEL meter for spikes in concentration as extraction is initiated in different sections of the wellfield. The LEL meter will be equipped with warnings/alarms when safety limits are reached.
- In addition, a handheld landfill gas/multigas meter (e.g., LANDTEC GEM5000 or equivalent unit set to monitor methane) will be used to screen the thermal oxidizer vapor influent samples for methane. The unit may be used for wellfield vapor sampling as needed to pinpoint areas of the wellfield where methane buildup is suspected.
- The first two vapor analytical sampling events will also analyze the thermal oxidizer vapor influent sample for methane. These analytical data will confirm onsite readings collected with the handheld meter.
- After the first two weeks of operations and low observed methane concentrations, and based on project team consensus, methane sampling will end. LEL monitoring will continue during operations with the real time LEL meter.

4.5 Mechanical and Electrical Installation

With the temporary nature of the ISTR system, the heaters and VEWs will be constructed as aboveground completions for ease of operation and maintenance. The proposed locations for mechanical and electric equipment are shown on the Mechanical Layout (M101) drawing in Attachment A. Vapor and liquid manifold piping will be installed on the ground and/or on unistrut (or similar) pipe stands. Vapor and liquid piping will consist of fiberglass and carbon steel pipe respectively. Connections to the individual wells will be made with flexible hose to allow for thermal expansion during operation. All hose will be adequately temperature and chemical rated for the expected service conditions.

The property owner will establish a temporary electric service with PG&E for power distribution to the TCH system. TerraTherm's subcontracted licensed electrician will obtain all necessary permits for the ISTR electrical system. TerraTherm will provide a skid-mounted portable switchboard with National Electrical Manufacturers Association (NEMA) 3R (outdoor, weatherproof) rated equipment to serve as the main electrical service connection point. The system will be designed and factory-tested in accordance with applicable American National Standards Institute (ANSI), NEMA, UL and Institute of Electrical and Electronics Engineers (IEEE) standards.

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

TerraTherm's subcontracted electrician will run secondary conductors from the 5,000 amp (A) main switchboard to downstream panel boards that feed the effluent treatment system components as shown on the Electrical One Line Drawing (E101) in Attachment A. The majority of the electrical panel boards and effluent treatment equipment proposed for use on this project are skid-mounted and portable. Due to the temporary nature of the project, most of the equipment connections will be made using extra heavy duty rated portable power cords (e.g., Type W cord, Type GGC cord, "mining cable") and other portable cords (e.g., Type SOW) suited for outdoor use in wet environments. All equipment will be installed, wired, and commissioned in accordance with the National Electrical Code (NEC).

4.6 Site Specific Considerations

4.6.1 Existing Infrastructure

An existing office area, shown in Figure 4.3, contains two half-walls that will be removed prior to ISTR well installation for drill rig access during construction of the wellfield. A wall constructed of metal studs and drywall running along the width of the building, from floor to ceiling, partitions the building into two halves, the North warehouse and South warehouse. Access ways will be cut into key locations to allow for proper routing of piping connected to the treatment system. In addition to these interior penetrations, perimeter penetrations to the exterior will be required in key locations to route vapor piping, liquid piping, and electrical conduit. As these exterior walls are masonry block construction, we will minimize the diameter and number of penetrations required. Penetrations will be sealed to minimize potential leak paths to prevent infiltration of water from the exterior into the building, and all perimeter penetrations will be properly filled at the conclusion of the project as part of the demobilization and site restoration phase of the project.

Figure 4.3. Existing Office Area

The exterior TTZ is generally flat, with an existing chain link fence approximately 25 ft to the east of the building, running parallel to the building. This fence will not be removed. At the southeast corner of the building there is a curb cut, which will remain to prevent vehicular access to the alleyway behind the building where the exterior TTZ is located. A hydrant along the curb will be used as a water source for the ISTR system.

Parking areas surrounding the Site will be used by personnel working in the adjacent parcel during operations. For this reason, any outdoor equipment will be secured on-site, either by fencing or other means, while construction and operations are underway. This includes both the process treatment equipment and any electrical gear which otherwise could potentially be accessed by unauthorized personnel. It is worth noting the proximity of the parking area, particularly those along the security fence, to the treatment system. Condensation of water vapor from either the cooling tower air exhaust and /or the discharge stack may impact these parking spaces, based on prevailing wind direction and weather conditions. This is a nuisance issue, as condensate is clean.

4.6.2 Temporary Facilities and Laydown Area

Temporary facilities and material laydown areas will be set up to support Site construction.

4.6.3 Utilities

Utilities required for the ISTR system include natural gas, electricity, makeup water, and sewer discharge. The electrical and natural gas utilities on Site will be provided by PG&E. Water will be provided by the city of Brisbane, and sanitary sewer discharge to the SFPUC Collection System. Required utility service ranges are shown in Table 4.6.

4.6.3.1 Fuel (Natural Gas)

The thermal oxidizer will run on natural gas provided by PG&E. An upgrade to the pressure regulator on the incoming gas line(s) to the building as well as the meter may be needed. The property owner will coordinate any incoming gas line upgrades with PG&E. Additional gas piping will be routed from the gas main, to the gas inlet, to the thermal oxidizer with the work being subcontracted by TerraTherm to a plumbing subcontractor. The gas line routing is shown on Drawing M101 in Attachment A.

4.6.3.2 Water

An existing hydrant is available at the Site and will be used as a water source for the initial equipment fill during system commissioning and as make up water during operation. Should a meter need to be installed to monitor water usage, TerraTherm will coordinate with the City of Brisbane.

4.6.3.3 Electric

ISTR system electricity will be provided by PG&E. A third-party contractor, Tri-Bay Electric, will oversee the supply and installation of the transformer, bus bar, and main switchboard required for ISTR operations under contract to Prologis.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

4.6.4 Wind and Seismic Considerations

Given the Site location, the process treatment equipment will be checked by a third-party engineer to ensure its adequacy for both wind and seismic loads. Particular attention will be given to the stack and its corresponding foundation. Wind and seismic calculations will be performed in accordance with ASCE-7 2016. Any equipment located within the building will not be subject to wind loading, only potential seismic force calculations.

4.7 Vapor and Liquid Treatment System

4.7.1 Process Flow Diagram and Piping and Instrumentation Diagram

A Process Flow Diagram (PFD) has been developed based on the system design and is included as Drawing P101 in Attachment A. The treatment equipment has been sized based on the heat capacity and energy balance data, as well as the thermal model output. Select mass and energy balance parameters are listed in Table 4.5.

Table 4.5. Selected Mass and Energy Balance Parameters

Parameter	Value
Expected wellfield vacuum, maximum	20 inches water column (" w.c.)
Expected vapor extraction temperature	Up to 100˚C
Anticipated vapor extraction flow rate (combined non-condensable and condensable vapor), maximum	2,119 scfm
Non-condensable Flow to thermal oxidizer	975 scfm
Total Flow at Stack	1,649 scfm
Collected condensed water from wellfield vapor stream, maximum	7.6 gpm

A Piping and Instrumentation Diagram (P&ID) has also been developed and is included as Drawing P102 in Attachment A. The P&ID depicts the major system components, valves, instruments and controls, alarms, and sample ports as well as the basic component sizing information, including pipe size and material of construction. Programmable Logic Controller (PLC)-based control panels will monitor and control the system components based on flow, temperature, pressure and level inputs from instruments and sensors on the process equipment skids. The local control panels will report to a main PLC via a Modbus network, where the main PLC will log the system data.

In the event of an alarm or upset condition, the PLC where the alarm occurs will take immediate action and report the alarm to the main PLC, which will in turn initiate any other required actions on the other local control panels. The main PLC is equipped with dial out alarm capability to notify the system operator in the event of an alarm or upset condition. An interlock table that defines the alarm schedule will be provided in TerraTherm's Operations and Maintenance (O&M) Plan prior to the start of operations.

4.7.2 Vapor Treatment System

The vapor treatment system consists of the following major items (the tag numbers refer to the equipment designations shown on Drawing P101 in Attachment A):

- Knock Out Tank / Moisture Separator (S-101) and Condensate Transfer Pumps (P-201 A/B)
- Vapor Heat Exchangers (E-101A/B)
- Moisture Separator (S-102) and Condensate Transfer Pumps (P-202 A/B)
- Thermal Oxidizer Package, consisting of:
  - Thermal Oxidizer (F-101)
  - Combustion Blowers (B-801 A/B)
  - Process Blowers (B-101 A/B)
  - Heat Recovery Heat Exchanger (E-102)
  - Caustic Supply System (T-301 and P-301A/B)

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

  - Quench/Scrubber (A-101)
- Bypass Process Blowers (B-102 A/B)
- Vapor Phase Carbon Vessels (VGAC-151/152/153)
- Potassium Permanganate Vessel (V-154)

4.7.2.1 Knock Out Tank / Moisture Separator (S-101)

The vapor extracted from the subsurface will be a mixture of non-condensable vapors (primarily air), steam, plus liberated COCs and extracted groundwater. As vapors flow from the wellfield to the process treatment system via the conveyance piping, some liquid may condense out due to both friction losses and heat losses. For this reason, a knockout tank is the first unit operation in the vapor treatment system. Consisting of a horizontal fiber reinforced plastic tank, any liquid that accumulates will be sent to the liquid treatment system for further disposition via the condensate transfer pumps (P-201 A/B). These air operated diaphragm pumps will run intermittently based on liquid level. Normally only one pump is running, with the other serving as a standby spare. The moisture separator and pumps will be skid mounted with instrumentation and level control.

4.7.2.2 Vapor Heat Exchangers (E-101 A/B)

After passing through the moisture separator (S-101), vapors flow through the heat exchanger(s) (E-101 A/B) to cool and condense the incoming steam to reduce the moisture content. During normal operation only one heat exchanger is running, with the other serving as a backup. Cooling water is supplied by a cooling tower (W-451). Each heat exchanger is designed to sufficiently reduce the temperature of the vapor stream to approximately 100 degrees Fahrenheit (°F). This allows for the bulk of the moisture to be removed from the wellfield vapors, making subsequent treatment easier.

Both the vapor stream and cooling fluid side of the heat exchangers are instrumented with temperature indicators to allow adjustment of the recirculation loop flow to maintain proper moisture removal. The heat exchangers selected are designed to operate with cooling water supply at the worst-case summer cooling water temperatures. Spare capacity is included in the heat exchanger design.

4.7.2.3 Moisture Separator (S-102)

A moisture separator (S-102) will immediately follow the heat exchangers (E-101 A/B) to separate the condensate from the vapor stream, which is subsequently sent to the thermal oxidizer. Condensate will be pumped via an air operated diaphragm pump (P-202 A/B) to the oil water separator (OWS-201) for further treatment. As with S-101, the pumps cycle on and off based on liquid level, and only one pump will be operating at a time. The moisture separator and pumps will be skid mounted.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

4.7.2.4 Thermal Oxidizer Package

The thermal oxidizer package consists of three main process skids: the oxidizer chamber, quench/scrubber, and exhaust blowers. The package also includes a recuperative heat exchanger for heat recovery and an exhaust stack. This package has been pre-engineered with interconnecting piping, valves, instrumentation, and controls.

The thermal oxidizer (F-101) is used to destroy and remove the COCs in a combustion process using air and natural gas to feed the burner. Within the reaction zone, the oxidizer destroys COC vapors, yielding carbon dioxide, water vapor, and acid vapors such as hydrochloric acid (HCl), which will be removed from the vapor stream in the downstream acid gas scrubber (A-101). The thermal oxidizer automatically maintains the temperature profile through a proportioning valve that adjusts the mixture of supplemental fuel (natural gas) to maintain the reaction zone temperature profile. The concentration of the acid vapors produced depends on the concentration of the CVOCs in the vapors entering the oxidizer. At peak conditions, it is anticipated that around 50 pounds per hour of acid gases will be generated. The thermal oxidizer exhaust vapors are processed through the exhaust side of the regenerative heat exchanger (E-102) for initial cooling and preheating of the thermal oxidizer influent vapor stream, prior to entering the quench and scrubber (A-101) system.

The vapors exiting the oxidizer chamber (F-101) will contain HCl, generated during the combustion of the chlorinated organics. Although the vapor will cool in the heat exchanger (E-102) it will still need to be quenched prior to scrubbing. The quench tower will cool the vapors to adiabatic saturation temperature, approximately 158°F. This cooled vapor will immediately flow to the scrubbing tower, which uses caustic to neutralize the HCl. The tower has been designed to remove 99.9% of the incoming HCl. Caustic is periodically added to the system using a chemical metering pump (P-301 A/B), and cycles on and off based on the pH of the scrubbing liquid. The caustic solution is recirculated back to the tower via recirculation pumps. Normally only one pump is running at a time. To avoid buildup of sodium chloride (NaCl) produced during the neutralization reaction (HCl + NaOH → NaCl + water [H_2O]), there will also be a small blowdown stream.

The quench and scrubber are skid mounted with the liquid recirculation pumps, caustic metering pumps, plus all valves, instruments, and controls. Because the scrubbing liquid will warm as it circulates, a plate and frame heat exchanger is included to cool the liquid before it is returned to the tower. This heat exchanger is a separate sub-skid and connected to the scrubber skid via flexible hosing.

Vapor is drawn through the oxidizer, quench, and scrubber via process blowers (B-101 A/B). Placed downstream to ensure they handle the cleanest vapor possible, these centrifugal blowers discharge to the exhaust stack. Each blower is connected to a variable frequency drive (VFD). Normally only one blower is running at a time, with the other serving as backup. As an added protection, a moisture separator is placed immediately ahead of these blowers. This separator vessel will knock out any entrained water to avoid damage to the blower impellers. The moisture separator and both blowers are skid mounted with piping, valves, instrumentation, and controls.

4.7.2.5 Bypass Process Blower (B-102)

In the event the thermal oxidizer package is taken offline for any reason, the bypass blower will be engaged. This blower will divert the vapors to an adsorbent (VGAC followed by $KMnO_4$]) which will serve as temporary vapor treatment until the oxidizer can be placed back into service. There is sufficient VGAC for approximately one week of operation before changeout is needed. The KMnO4 should not need to be changed out based on the expected vinyl chloride concentrations.

4.7.2.6 VGAC and $KMnO_4$ Vessels (VGAC-151, VGAC-152, VGAC-153, V-154)

Should the thermal oxidizer be offline, VGAC will be used as an alternative treatment mechanism (three vessels in series, each containing 5,000 lbs with a spare 5,000 lbs vessel to be used as needed). As vinyl chloride (VC) is known to be present, a single vessel (2,000 lbs) of $KMnO_4$ is included after the VGAC as a vapor polish.

4.7.3 Liquid Treatment System

The liquid treatment system will handle all liquids generated during ISTR operations. Treatment consists of a combination of filtering, cooling, gravity separation, and carbon adsorption. The liquid treatment system's components are mounted on skids with interconnecting piping. The system consists of the following major items:

- Bag Filters (FX-201A/B)
- Liquid Heat Exchanger (E-201)
- Oil/Water Separator (OWS-201)
    - DNAPL Storage Tank (T-351)
    - Light Non-Aqueous Phase Liquid (LNAPL) Storage Tank (T-352)
- Oil/Water Separator Transfer Pumps (P-203A/B)
- Bag Filters (FX-202A/B)
- LGAC (LGAC-151A/B)
- Discharge Tank (T-251) and Discharge Pumps (P-251A/B)

Final treated water will be transferred to a discharge tank (T-251) for temporary storage until discharge to the sanitary sewer has been approved.

4.7.3.1 Bag Filter (FX-201 A/B)

The liquid from the wellfield, including S-101, will be sent through a duplex bag filter assembly (FX-201A/B) to remove any coarse particles that may be present. Twenty-five micron bag filters will be installed initially and manually changed periodically as necessary.

4.7.3.2 Liquid Heat Exchanger (E-201)

The liquid treatment system will include a liquid heat exchanger (E-201) to cool the process liquid prior to delivery to the oil/water separator (OWS-201). The heat exchanger will receive condensate from bag filters FX-201A/B and cool the liquid to approximately 100°F. Cooling water for the liquid heat exchanger will be supplied by the cooling tower (W-451). The heat exchanger is fitted with pressure and temperature gauges to monitor the operating conditions of the heat exchanger.

4.7.3.3 Oil/Water Separator (OWS-201) and NAPL Storage Tanks (T-351 & T-352)

The oil/water separator (OWS-201) will separate the DNAPL and LNAPL from the remaining aqueous (water) phase. Internally, the separator is partitioned into separate LNAPL and DNAPL accumulation areas, delineated by a coalescing plate pack, an underflow weir, and an overflow weir. The separator is equipped with a vapor-tight cover and is vented to the vapor treatment system.

DNAPL will be pumped out of the bottom of its accumulation chamber periodically via air operated diaphragm pumps (P-301 A/B). One pump operates at a time with the second pump serving as a standby. Pump out is based on level control within the chamber. The oil/water separator will be skid mounted with the pumps, piping, valves, instruments, and controls. Separated NAPL will be stored in a DNAPL storage tank (T-351) and LNAPL storage tank (T-352) prior to off-site disposal. EHS Support will be responsible for characterization, profiling, and off-site disposal. Both NAPL storage tanks will be equipped with high level switches and secondary containment.

4.7.3.4 Oil/Water Separator Transfer Pumps (P-203 A/B)

A set of transfer pumps (P-203 A/B) evacuates the clear water (aqueous phase liquid) that accumulates in the clear water chamber of the oil/water separator. The transfer pumps are close-coupled, centrifugal type pumps. Only one pump operates at a time. The second, backup pump is provided in the event of the primary pump malfunction. Both pumps are integral to the oil/water separator skid (OWS-201).

4.7.3.5 Bag Filter Skid (FX-202 A/B)

The liquid from the oil/water separator clear well will be pumped through a duplex bag filter assembly (FX-202 A/B) to remove any fine particles before entering the LGAC vessels. Ten micron bag filters will be installed initially and manually changed as necessary.

4.7.3.6 Liquid Phase Carbon Vessels (LGAC-151)

A set of two LGAC vessels in series will be used as primary dissolved phase VOC treatment for the liquid stream. Each vessel will be charged with 2,000 lbs of LGAC media. The vessels will be plumbed in series and will be equipped with sample ports to monitor adsorption efficiency during operation. Connections between each vessel will be made with flexible hose to allow for easy

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

maneuvering during media changeouts. A total estimated 4,000 lbs of LGAC will be required during treatment.

4.7.3.7 Holding Tank (T-251) and Sanitary Sewer Discharge

A 21,000-gallon holding tank (T-251) will be provided for temporary water storage prior to being discharged to the sanitary sewer via access in an existing Site bathroom as shown on Drawing M101. Once approval is obtained from the SFPUC Collection System Division to directly discharge, we will pump the liquid from the frac tank to the point of discharge and control the flow based on level sensors in the holding tank. Continuous discharge will continue throughout ISTR operations.

4.7.4 Supplemental Equipment

4.7.4.1 Cooling Tower (W-451)

A cooling tower unit will be used to provide non-contact cooling water for the vapor and liquid heat exchangers. The cooling tower will have an expected 400 tons of cooling capacity. The cooling tower will be capable of maintaining 72°F cooling fluid at approximately 750 gpm. The cooling tower package includes a circulating pump capable of pumping a minimum of 1,100 gpm. Make-up water to the cooling tower will be drawn from an existing hydrant on the Site. All blowdown water will be pumped to the treated water holding tank prior to discharge.

4.7.4.2 Air Compressor (Z-501 A/B)

Two (one operating and one spare) sound-dampened rotary screw type air compressors will be installed at the Site. The compressors will be sized to provide compressed air for the process equipment transfer pumps. The compressors are equipped with a refrigerant-type aftercooler for moisture removal, a receiver tank, and filter/regulator assemblies. The compressors will be mounted in a weatherproof, ventilated, and sound-dampened enclosure. Each compressor is capable of 54 cubic feet per minute at 125 pounds per square inch gauge.

4.8 Utility Usage Estimates

Utility usage estimates and requirements are shown in Table 4.6.

Table 4.6. Utility Estimates and Requirements

Utility Estimates and Requirements	Estimated Average Rate	Estimated Total
Power usage, TCH	1,400 kilowatt (kW)	7,765,000 kilowatt hours (kWh)
Power usage, treatment system	225 kW	1,253,000 kWh
Power usage, total	1,620 kW	9,018,000 kWh
Wellfield liquid discharge, condensate plus entrained water	4.2 gpm	1,403,000 gallons
Cooling Tower Blowdown	4.9 gpm	1,620,000 gallons
Scrubber Tower Blowdown	6.2 gpm	2,071,000 gallons
Total Liquid Discharge	15.3 gpm	5,094,000 gallons
Cooling Tower Makeup Water	15.3 gpm	5,101,000 gallons
Scrubber Tower Makeup Water	9.46 gpm	3,160,000 gallons
Total water usage	24.76 gpm	8,261,000 gallons
Natural Gas Supply Pressure (measured at Oxidizer Fuel inlet)	5 psig (average) 7 psig (maximum)	N/A
Natural Gas Usage	2,030 cubic feet per hour	111,360 therms

A total of 7,765,000 kWh of energy will be added to the subsurface while the treatment system is expected to use 1,253,000 kWh for a total of 9,018,000 kWh. A total of 8,261,000 gallons of water is expected to be used during the remedy, while 5,094,000 gallons will be discharged to the sewer during operations. The thermal oxidizer is expected to use a total of 111,360 therms of natural gas.

4.9 Electrical Distribution Systems

The electrical power distribution system consists of the following major components:

- Primary Switchboard rated at 480 Y/277 Volt (V), 3 phase, 4 wire, 65 kilo ampere interruption capacity (kAIC). Additional details of this switchboard are as follows:
  - 5,000 A rated switchboard with a 100% neutral buss. Rated for Service Entrance use.
  - Skid mounted and rated for outdoor use (NEMA 3R). Switchboard is designed and factory-tested in accordance with applicable ANSI, NEMA, UL and IEEE standards.
  - 5,000 A Main Breaker, with adjustable trip settings (adjustable long time, short time, instantaneous and ground fault protection settings). The main breaker will be set to a trip value of approximately 4,000 A.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

    - Main Breaker is equipped with shunt trip such that an emergency stop will remove power to all ISTR system equipment.
    - Branch circuit breakers (minimum) with adjustable trip setting (adjustable long time, short time, and instantaneous protection). The branch breaker's rating plug is fully rated, and the breaker will be adjusted for the specific load.
- Secondary Switchboard 480 Y/277 V, 3 Phase, 4 Wire, 65 kAIC for power feed to process loads. Process Loads will be backed-up by a standby 350 kW (minimum) emergency generator and the power feed controlled by an automatic transfer switch. Generator is located outside, and is shown on Drawing M101 in Attachment A. Generator will be rented through a California industrial equipment supply company and will be compliant with California regulations.
- Locally mounted and wired 112.5 kilovolt-ampere 480-208/120 V three phase transformer and single phase 240/120 V load center. The panel will be used to supply power for controls and auxiliary components such as the auxiliary site lighting, emergency stop panels, ground fault circuit interrupter convenience receptacles, etc.

4.9.1 Instrumentation and DataCom Wiring

Installation practices for low voltage instrumentation and communications wiring in the field should provide that cabling is protected from excessive temperatures and mechanical abrasion. To the extent practicable, all instrumentation wiring will be kept separate from high voltage power cabling. Instrumentation wiring should never be bundled with or routed parallel with high voltage cabling. Where wiring must cross high voltage cabling, it should be at right angles and with as much physical separation as possible.

4.9.2 Backup Power

Backup power to operate the process treatment system is currently planned via an automatic transfer switch fed by a 350 kW (minimum) diesel-powered generator; however, backup power to operate the heaters is not included. A battery backup will maintain the main PLC in operation in the event of a power interruption. The thermal system operator will manually restart the thermal treatment system on generator power in the event of a loss of grid power.

4.9.3 Permitting

The following permits/applications are required for ISTR implementation:

- EHS will obtain an air discharge permit
- The following permits will be secured by TerraTherm:
    - A liquid discharge permit through the SFPUC Collection System Division;
    - An encroachment permit through the City of Brisbane;

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

- A building permit through the City of Brisbane (including plumbing and electrical); and,
- Drilling permits from San Mateo County.

5 THERMAL REMEDIATION OPERATIONS

5.1 Operational Sequence

The major phases of thermal field implementation and operations are shown below. Days in parentheses are the estimated durations of each phase. Please note that some phases may overlap based on observed temperatures and mass removal rates and trends.

- Heater ramp up (approximately two days of operation). The treatment system performance is verified prior to initiating heating.
- Heating to boiling (days 90 to 120 of operation). Continued heating and approaching of temperature targets in the TTZ.
- Final heating phase where vaporization is maximized by adjusting the TCH system with the objective of approaching diminishing mass removal returns (days 120 to 190 of operation).
- Confirmatory soil sampling, analysis, and results evaluation (days 190 to 218 of operation).
- Initial cool-down phase (14 days of operation). During this phase, extraction continues at near maximum rates.

The ISTR system is expected to operate for 232 days. More detail and discussion of criteria for starting and completing each phase will be presented in the O&M Plan to be prepared by TerraTherm prior to ISTR operations startup.

5.2 Description of Field Activities and Operations Phases

5.2.1 Commissioning

The purpose of the commissioning phase is to inspect, test, and calibrate the thermal treatment system including all materials and equipment in the wellfield and the process equipment. This phase is intended to locate and correct any problems or deficiencies in the system and will provide a smooth transition to full, normal operation. Clean water and air will be used to operate the system during commissioning. Data collection procedures will be tested and verified. The project-specific data website will be made operational at this time.

5.2.2 Startup

During the startup phase, power to the heaters is increased in a controlled manner and pneumatic control will be established by extraction of vapor from the co-located VEWs. Performance of the effluent treatment system for separation and treatment of vapors and liquids will be verified by process monitoring and sampling. Once it is documented that the treatment system meets the required criteria (flow rates and pressures), the TCH heaters will be brought online.

5.2.3 Heating

The heater operation will be controlled by the individual heater circuit Silicon Controlled Rectifiers (SCRs) and their individual temperature controllers. The SCR setpoints will be monitored throughout operations and adjustments made as needed. Adjustments to the system operation will be made in consultation with the TerraTherm Project Engineer and Technical Director. More detail and more specific criteria will be included in TerraTherm's O&M Plan.

5.2.4 Initial Cool-Down

Once it is determined that the performance standards defined in Section 6.9 have been achieved, the TCH heaters will be turned off. The extraction and treatment systems will continue to extract and treat vapors to allow for partial cool down and to capture steam and vapors still present in the subsurface. During this phase, the vapor system will operate, and the subsurface temperature monitoring will continue. Following the initial cool-down period, the system will be shut down and decommissioning will begin.

5.2.5 Decommissioning and Demobilization

Once operation is complete, TerraTherm will remove all wellheads and the heaters, liners, and TMP arrays from the subsurface. Borings will be abandoned in accordance with California Department of Water Resources and applicable county permit regulations. TerraTherm staff will decontaminate and remove the wellfield vapor and liquid lines, remove pipe stands and roll up cable. TerraTherm will decontaminate and decommission the vapor and liquid treatment equipment once as much decontamination water has been processed as possible. Waste and scrap materials will be loaded into dumpsters for off-site disposal. Equipment will be cleaned and packed for return shipment to TerraTherm's yard. Rented equipment and temporary facilities will be cleaned and demobilized from the Site.

5.3 Contingency Plan

The system has several areas of redundancy to ensure continual operation even if an unexpected condition arises. A VGAC treatment train is included should the oxidizer need to be taken offline for any reason. Additionally, process equipment has been designed for conditions in excess of what it is expected to be seen in normal operation, as shown in Table 5.1.

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

Table 5.1. Required and Design Capacity for Major Treatment System Components

Item	Tag Number	Capacity Needed	Design Capacity	Unit
Knockout Tank	S-101	2,123	3,000	scfm
Condensate Pumps	P-201 A/B	1.10	52.2	gpm
Vapor HX	E-101 A/B	808	1,001	ft^2
Moisture Separator	S-102	1,045	1500	scfm
Condensate Pumps	P-202 A/B	6.20	52.2	gpm
Thermal Oxidizer	F-101	1,224	1,500	scfm
Primary Blower	B-101 A/B	1,649	4,035	scfm
Backup Blower	B-102 A	1,044	1,300	scfm
VGAC	VGAC-151/-152/-153	1,834	3,000	scfm
Filter	FX-201	5.1	80	gpm
Liquid Heat Exchanger	E-201	6.4	8.1	ft^2
OWS Unit	OWS-201	8.7	15	gpm
Aqueous Pumps	P-203 A/B	10.4	18	gpm
NAPL Pumps	P-301 A/B	9.5	10.6	gpm
Filter	FX-202	10	80	gpm
LGAC	LGAC-251 A/B	9.5	25	gpm
Cooling Tower	W-451	252	400	cooling ton
Cooling Tower Pumps	P-451 A/B	1,198	1,622	gpm
Air Compressor	Z-501	88.5	108	scfm
LNAPL Tank	T-351	N/A	55	gallon
DNAPL TANK	T-352	N/A	55	gallon
Discharge Tank	T-251	N/A	21,000	gallon

All major equipment (vapor heat exchangers, liquid pumps, primary blowers, etc.) is provided in duplicate (A/B), the "A" unit being operative and the "B" unit serving as a backup should the primary unit fail for any reason. Finally, a redundant vapor heat exchanger (E-101B) also provides additional cooling capacity should more vapors be extracted than anticipated from the wellfield.

5.4 Site Restoration

After decommissioning and demobilization, TerraTherm will restore the Site to the pre-remediation conditions. Examples of restoration activities include:

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

- Repairing and sealing 12-inch core holes in the floor slab;
- Removing concrete vapor cover outside the building;
- Cleaning and restoring the parking area;
- Removing TerraTherm's electrical infrastructure that TerraTherm installed;
- Removing the temporary natural gas line plumbing to the treatment system;
- Cosmetic repairs;
- Repairing building wall penetrations; and,
- Reinstalling partitions and other office area features (as required).

TerraTherm is not responsible for structural building repairs arising out of the ISTR operations contemplated in WJE's "Limited Geotechnical and Structural Study to Support Remedial Decision Making."

5.5 Waste Management

TerraTherm will generate general construction refuse, spent bag filters, vapor carbon, liquid carbon, NAPL, personal protective equipment, soil, concrete, foam board, and other miscellaneous wastes. Estimated quantities have been added to Table 5.2. TerraTherm has assumed that the vapor and liquid carbon can be regenerated.

Table 5.2. Estimated Waste Types/Quantities

Waste Type	Waste Container	Estimated Quantity	UOM
Drill Cuttings	Roll off	75	yd^3
General Construction Debris	Roll off	80	yd^3
Drilling Water	Frac tank/sewer	15,200	gallons
Insulation Board	Roll off	350	yd^3
Concrete	Roll off	135	yd^3
VGAC	Super sac	20,000	1,000 lbs
LGAC	Super sac	4,000	1,000 lbs
$KMnO_4$	Drums	2,000	lbs
Liquid Discharge	Sewer	5,279,000	gallons
Bag Filters/Personal Protective Equipment	Drums	5	Drums
Well Abandonment Cuttings	Roll off	98	yd^3
Well Abandonment Water	Frac tank	20,000	gallons

6 TREATMENT PERFORMANCE EVALUATION

6.1 Principles of Monitoring and Sampling

Operational data will be collected and reviewed to track remediation progress and compare it to predicted performance so that appropriate operational adjustments can be made in a timely manner. A PLC will monitor and record selected system operating data including relevant temperatures, pressures, and flows through the aboveground treatment equipment, as well as the position of safety sensors and controls (e.g., pressure switches, level switches, and motor operated valves). Manual data checks/samples will be collected at a frequency of daily or weekly depending on the type of data. Data may also be collected on an as-needed basis for troubleshooting or system optimization. All data will flow through the project data manager and be subjected to review and quality control checks by the project team.

Manual monitoring of Site COCs in the vapor phase will be performed regularly in accordance with TerraTherm's O&M Plan, using a handheld photoionization detector (PID). PID readings will be taken as a total measure of VOCs. Calibration of the PID will be performed per the manufacturer's calibration procedures and TerraTherm's Vapor Sampling Standard Operating Procedure which will be included in TerraTherm's O&M Plan. Sample locations will be throughout the vapor treatment system such that removal efficiency of the vapor phase carbon beds can be monitored (if in use), and media can be changed out in a timely manner to maintain compliance with vapor emissions requirements. In addition to the PID readings, analytical laboratory samples will be collected at a frequency to be developed based on permit requirements.

6.2 Daily Operations Staffing Plan

An experienced TerraTherm Lead Operator, with engineering staff as needed, will be on-site during the testing and commissioning phase. As the system transitions into full operation mode, TerraTherm's Lead Operator will be at the Site for data collection, maintenance, and troubleshooting (typically weekdays). TerraTherm's Operator will also be available to respond to the Site during nights/weekends if the monitoring system detects any issues.

6.3 Remote Monitoring

The PLC will log selected system operating data including relevant temperatures, pressures, and flows through the aboveground vapor treatment equipment, as well as the position of safety sensors and controls (pressure switches, level switches, motor operated valves, etc.). Wellfield temperature data from the field thermocouples will be collected and logged by a separate temperature data collection system. The PLC and the temperature logging system will be accessible remotely through an internet connection, allowing TerraTherm engineering and project management staff in the office to access the PLC and observe the same operating information available to the field staff. Alarms and shut-down conditions will result in automatic notification of TerraTherm's Operator by cell phone.

6.4 Manual Process Data Collection

The manually collected data include:

- Power usage - Reading of totalizing meters;
- Liquid flows - Reading of totalizing flowmeters inserted in the treatment system transfer lines;
- Temperature and pressure readings - Gauge readings for the treatment system; and,
- Wellfield pressure readings - Gauges placed in the wellfield.

6.5 Screening Level Sampling

A handheld PID (MiniRae 3000, or similar) will be used to screen the vapor concentrations at different locations (typically 3-5 times a week, weekdays only):

- At the influent to the treatment system (i.e., inlet to the thermal oxidizer);
- At intermediate locations in between VGAC vessels (if in use); and,
- At the discharge location (effluent stack).

Vapor samples for screening will be collected in Tedlar™ bags. A humidity filter is typically required for the PID. The screening data will be included in the data collection sheet. TerraTherm may choose to collect additional vapor samples from individual wells or manifold sections to obtain information about the COC concentrations in vapors extracted across the Site.

6.6 Grab Samples

As all the extracted COCs flow through the vapor extraction manifold to the treatment system, tracking the mass removed from the remediation area is straightforward. Samples and process data from numerous locations will be used by TerraTherm to optimize the operation of the system, and to provide estimates for the following:

- Mass removed in the vapor state measured at the inlet to the vapor treatment system (EPA Method TO-15 analysis);
- Mass removed in dissolved state (i.e., condensate) (collected at the inlet to the LGAC vessels for EPA 8260C analysis);
- Liquid discharge compliance with the local municipalities monitoring requirements;
- Mass removed as NAPL as measured in the LNAPL/DNAPL storage tanks (if any produced for EPA 8260C analysis);

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

- Destruction removal efficiency of the vapor treatment system (determined by comparing influent samples described above, with effluent sample concentrations collected at the stack every for EPA Method TO-15 analysis for air permit equivalency compliance); and,
- VEWs as needed.

6.7 Energy Balance Calculations

An energy balance will be maintained throughout ISTR operations using the following data:

- TCH heater energy delivered by the TCH heaters;
- Energy removed in the form of condensable vapor;
- Energy removed in non-condensable air; and,
- Estimated heat losses.

The energy balance returns an average heating rate (in degrees per day) and an average TTZ temperature. These numbers are compared to the design numbers (energy delivery, average temperature) and the observed subsurface temperatures (from TMPs). An energy balance will be periodically calculated for the Site to verify that the thermocouples are providing accurate representation of conditions throughout the TTZ and to assess the progress of heating.

6.7.1 Energy Injected

The total energy delivered to the Site using the TCH heaters will be derived from wellfield electricity usage regulated by the SCRs. Power used for the process equipment will be measured or estimated separately.

6.7.2 Energy Removed

Energy will be removed from the Site in the form of hot water (i.e., condensate), steam and vapors. The water will be entrained with the extracted vapors from the co-located VEWs. The hot vapors from the co-located VEWs will consist of steam and air. For air and water, the energy fluxes are determined by multiplying the flow rate times a heat capacity times the fluid temperature. For steam, it is determined as a flow rate times the specific enthalpy of the steam (heat of condensation).

6.7.3 Energy Stored

The thermocouple data will be evaluated to provide detailed information on the heat-up of the subsurface. These data will be used to determine the amount of energy stored in the subsurface (e.g., energy stored in soil is equal to the soil temperature times the specific heat capacity of soil times the mass of soil).

6.8 Subsurface Temperatures

Data from the 18 TMPs, eight shallow TMPs, and 54 heater TMPs will be used to evaluate heating progress. The data will be collected and organized using a project webpage. At a minimum, the following data representations are used:

- Individual borehole temperature profiles of TMPs (18 total), shallow TMPs (eight total) and heater TMPs (54 total);
- Plots of temperature versus time for all sensors; and,
- Average temperatures at different depths from top to bottom of the TTZ.

6.9 Performance Standards

The following performance standards were developed to ensure that the ISTR remedy operates as intended. There are four components that make up the performance standards: (1) Heater Operation; (2) Extraction and Treatment System Operation; (3) Average Treatment Temperature Attainment; and (4) Soil Treatment Standard Attainment. Each of these components must be completed and/or achieved for project completion. Each component is identified and described in detail below. Further detail on operational monitoring and soil sampling procedures will be provided in TerraTherm's O&M Plan.

6.9.1 Heater Operation

a. Objective: The heaters shall have a minimum of 95% operational efficiency (aka "up time").

b. Measurement: Power input, cumulative energy densities, and heater operational time shall be measured by programmable logic controllers (PLCs), computers, or other electronic systems that monitor parameters such as current, voltage, and run condition of the heaters. "Uptime" is defined as when the heaters are delivering power into the subsurface. Once full-scale thermal operations begin (to be identified in the project schedule), the heaters shall operate 95% of the time (maintain 95% uptime) for the duration of thermal treatment (to be identified in the project schedule). Uptime shall be measured by evaluating the amount of heater operational time divided by the total time since full-scale thermal operations began. Planned maintenance (as specified in TerraTherm's O&M Plan), wellfield sampling activities that result in less than 8 hours of heater downtime within a 24-hour period, and any shutdown required for soil sampling will not be included in the uptime calculation. Unforeseen circumstances affecting heater operations that are not the fault of TerraTherm (or are required to manage heater temperatures for geotechnical or structural purposes) shall not be counted against the uptime objective (i.e., interruptions in the utility services).

c. Corrective Action: One-week before the termination of the heater operation pursuant to the project schedule, uptime shall be measured and if uptime is less than 95%, time shall be added to the project schedule to continue heater operations to such time as uptime meets or exceeds 95%.

6.9.2 Extraction and Treatment System Operation

a. Goals: The ISTR system will be designed, constructed, and operated in a manner that maximizes uptime of the extraction and treatment system. Uptime is defined when the extraction and treatment system are recovering vapors and liquids from actively heated portions of the treatment volume(s) and simultaneously treating the extracted fluid streams.

b. Measurement: Uptime shall be measured by programmable logic controller(s), computer(s), or other electronic systems that monitor extraction and treatment system parameters to show treatment system operation including runtime hours for the main or backup vacuum blowers, run condition, and blower speed. Backup observations of uptime will also be collected manually each weekday, excluding holidays. Compliance with emissions and/or discharge limits shall be measured by sampling and analyzing the process fluids streams (i) at the effluent stack of the vapor emissions control system, (ii) at the effluent line to the sewer, and (iii) at any other permit-required monitoring locations. The extraction and treatment system shall maintain greater than 95% uptime for the duration of thermal treatment (to be identified in the project schedule). Uptime shall be measured by evaluating the amount of extraction and treatment system operational time divided by the total time since full-scale extraction and treatment system operations began. Planned maintenance (as specified in TerraTherm's O&M), sampling activities that result in less than 8 hours of extraction and treatment system downtime within a 24-hour period, and any shutdown required for soil sampling will not be included in the uptime calculation. Unforeseen circumstances affecting extraction and treatment system operations that are not the fault of TerraTherm shall not be counted against the uptime objective (i.e., interruptions in the utility services).

c. Corrective Action: One-week before the termination of the extraction and treatment system pursuant to the project schedule, uptime shall be measured and if uptime is less than 95%, time shall be added to the project schedule to continue extraction and treatment system to such time as uptime meets or exceeds 95%.

6.9.3 Treatment Temperature Attainment

a. Goals: The ISTR system will be designed, constructed, and operated such that an average temperature of 100° Celsius (within the +/- 2°C range of accuracy as measured by the temperature monitoring system) is achieved and maintained within the treatment zone (Table 2.2) for the

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

duration of the boiling and drying operational period (excepting periods when the system will be shut down to allow for sampling activities).

b. Measurement: Temperatures will be measured at monitoring points equipped with multi-depth sensors located at least three feet away from heater cans within the treatment areas and depth zones. The temperature within the treatment zone must average at least 100° Celsius on a daily basis. The average daily temperature is calculated by taking an average of the highest daily temperature recorded at each sensor by day.

c. Corrective Action: If the ISTR system fails to achieve this performance standard, TerraTherm shall implement the appropriate remedial measures to meet the performance standard which may include increasing power output, installation of additional heaters, and/or other measures to achieve design temperatures.

6.9.4 Soil Treatment Standard Attainment

a. Goals: The ISTR system will operate until Soil Treatment Standards identified in Table 2.1 are achieved and sample results confirming the Treatment Standard attainment are approved by the RWQCB.

b. Measurement: 91 soil samples will be collected from 17 locations throughout the TTZ once asymptotic mass removal rates are achieved or the modeled boiling and drying time has elapsed, whichever occurs first. Asymptotic mass removal rates will be measured by vapor stream samples and flow rates from the main wellfield influent and/or specific area/zone influent. EHS will notify the RWQCB of planned confirmation soil sampling as soon as sampling conditions above are met to expedite the regulatory approval process for shut-down. Soil samples will be obtained via the methods as described in TerraTherm's O&M Plan. Direct push drilling will be completed by a TerraTherm subcontractor. Soil sampling and laboratory analysis will be EHS' responsibility. (Note: Up to 30 days for additional operations time has been allowed beyond the modeled boiling and drying period for sample collection, analyses, and regulatory review). Soil sample concentrations will be compared to the Soil Treatment Standards listed in Table 2.1. Mean concentrations of soil samples from each treatment area and depth zone shall meet the Soil Treatment Standards. In addition, no individual sample will exceed the soil saturation limit for any constituent (Table 2.1).

c. Corrective Action: If Soil Treatment Standards are not achieved, TerraTherm shall implement additional remedial actions including but not limited to additional soil sampling, extended system operation, installation of additional heaters, and/or other measures necessary to achieve the Soil Treatment Standards. If Soil Treatment Standards cannot be achieved after evaluating additional remedial actions, EHS and TerraTherm will critically evaluate the performance of the system, optimize operations to the maximum extent practicable, and/or evaluate alternative shutdown criteria, as applicable and approvable by RWQCB.

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

7 REPORTING

In general, project reporting includes the following:

- Monthly construction and demobilization progress reports documenting major Site activities;
- Automated reporting of the subsurface temperatures in a format available for review by the project team. If desired, the data can be remotely accessible to the project team;
- Monthly operational progress reports including average TTZ temperatures, simplified energy balance, estimates for mass removal to date, and performance of the effluent treatment system;
- Bi-monthly reporting including the following:
    - Total electrical use on a daily basis;
    - Energy input to the subsurface including voltage, current, and power on a daily basis;
    - Subsurface temperatures and pressures on a daily basis;
    - Vapor recovery, treatment system, and wellfield data (vacuum, flow rates) on a weekly basis (once the system operations are normalized);
    - Total gallons of condensate generated and treated and discharged on a weekly basis (once the system operations are normalized); and,
    - Caustic usage by the thermal oxidizer/scrubber system.
- Periodic project team conference calls may be arranged to review heating progress, discuss operational status and planning, discuss any issues, and identify any corrective measures that may need to be implemented; and;
- Final report with data package documenting the operational period.

8 REFERENCES

Baker, R. S., & Kuhlman, M. (2002, November 17-21). A Description of the Mechanisms of In-Situ Thermal Destruction (ISTD) Reactions. *Current Practices in Oxidation and Reduction Technologies for Soil and Groundwater, ORTs-2*. Toronto, Ontario, Canada: H. Al-Ekabi (Ed.).

DeVoe, C., & Udell, K. S. (1998, May 18-21). Thermodynamic and Hydrodynamic Behavior of Water and DNAPLs During Heating. *Proceedings from the First Conference on remediation of Chlorinated and Recalcitrant Compounds, 1*(2), 61-66.

EHS Support, Inc. (2022). *Technical Memo, Prospect for Natural Degradation, 3775 Bayshore Boulevard, Brisbane, California (Parcel B of Site).*

GHD Services Inc. (2020). *Remedial Action Work Plan - Former FMC Corporation.* North Wales: GHD Services Inc.

Heath, R. C. (2004). *Basic Ground-Water Hydrology.* Denver: U.S . Geological Survey, Information Services.

Heron, G., Baker, R., Bierschenk, J. M., & LaChance, J. C. (2006). Heat it All the Way - Mechanisms and Results Achieved using In-Situ Thermal Remediation. *Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds* (pp. F-13). Columbus: Battelle Press.

Heron, G., Van Zutphen, M., Christensen, T. H., & Enfield, C. G. (1998). Soil heating for enhanced remediation of chlorinated solvents: A laboratory study on resistive heating and vapor Extraction in a Silty, Low-permeable Soil Contaminated with Trichloroethylene. *Environmental Science and Technology, 32*(10), 1474-1481.

Stegemeier, G., & Vinegar, H. (2001). Thermal Conduction Heating for In-Situ Thermal Desorption of Soils. In C. H. Oh, *Hazardous and Radioactive Waste Treatment Technologies Handbook* (pp. 1-37). Boca Raton: CRC Press.

Udell, K. S. (1996). Heat and mass transfer in clean-up of underground toxic wastes. *Annual Reviews of Heat Transfer, 7*, 333-405.

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

Attachment A – ISTR Design Drawings

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

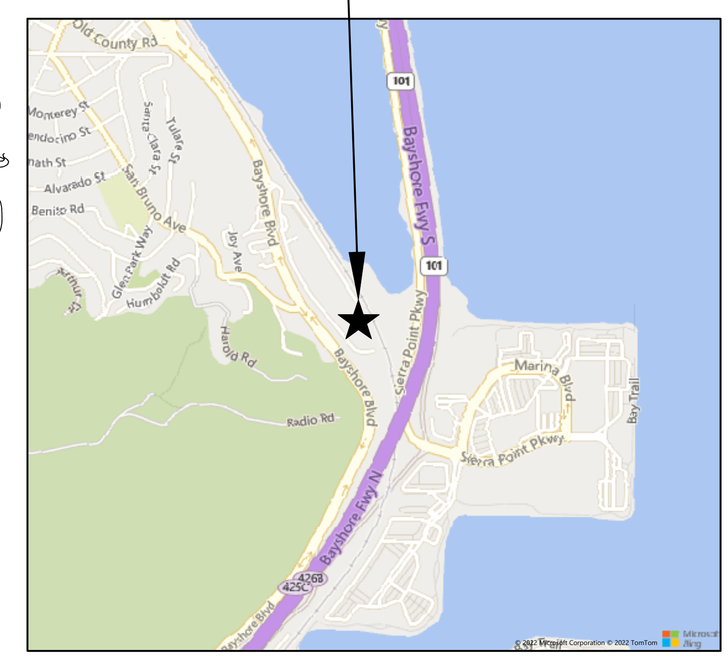
DRAWING INDEX

DRAWING NO.	DRAWING TITLE
TITLE SHEET	
C100	DRAWING INDEX & LOCATION MAP
CIVIL	
C101	EXISTING CONDITIONS PLAN
C102	WELLFIED LAYOUT WITH PLANNED CONFIRMATORY SOIL SAMPLE LOCATIONS
C103	TYPICAL WELL CONSTRUCTION DETAILS (2 SHEETS)
C104	TEMPERATURE MONITORING LAYOUT
ELECTRICAL	
E100	ELECTRICAL LEGEND
E101	ELECTRICAL ONE-LINE (3 SHEETS)
MECHANICAL	
M101	MECHANICAL LAYOUT (2 SHEETS)
M104	CONCRETE STACK PAD DETAIL 7.5 x 7.5
PROCESS	
P100	PROCESS LEGEND (4 SHEETS)
P101	PROCESS FLOW DIAGRAM + MASS AND ENERGY BALANCE (3 SHEETS)
P102	PIPING & INSTRUMENTATION DIAGRAM (8 SHEETS)

APPROXIMATE TREATMENT AREA

AERIAL VIEW - THERMAL REMEDIATION SITE

SITE



STREET MAP - THERMAL REMEDIATION SITE

REV	DATE	DESCRIPTION	CAD	ENG	PM
C	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	RH	AB	GM
B	6/10/2022	90% DESIGN DRAFT	RH	GM	SG
A	4/1/2022	60% DESIGN DRAFT	RH	AB	SG

THIS DOCUMENT CONTAINS CONFIDENTIAL INFORMATION OWNED BY TERRATHERM, INC. UNAUTHORIZED DISCLOSURE IS PROHIBITED

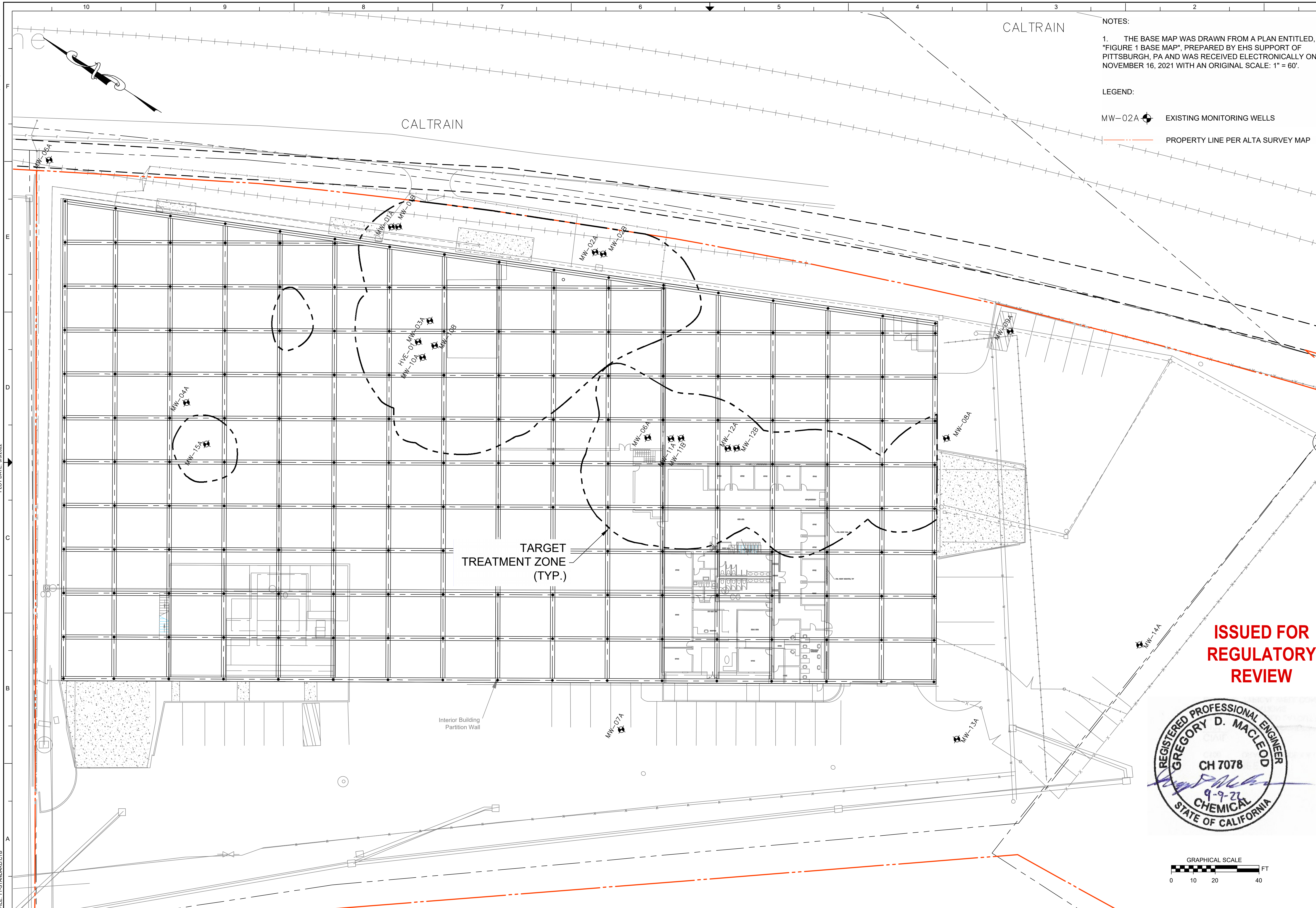
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

DRAWING INDEX AND LOCATION MAP

SCALE: AS SHOWN
SHEET SIZE: D REV: C
REFERENCE NO.: R21-103.00
SHEET: 1 OF 1
DWG NO.: C100

PLOT DATE: 9/9/2022



NOTES:

1. THE BASE MAP WAS DRAWN FROM A PLAN ENTITLED, "FIGURE 1 BASE MAP", PREPARED BY EHS SUPPORT OF PITTSBURGH, PA AND WAS RECEIVED ELECTRONICALLY ON NOVEMBER 16, 2021 WITH AN ORIGINAL SCALE: 1" = 60'.

LEGEND:

MW-02A — EXISTING MONITORING WELLS

PROPERTY LINE PER ALTA SURVEY MAP

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
.	.	.			-		
D	8/5/2022	RH	AB	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
C	6/10/2022	RH	SL	SG	90% DESIGN DRAFT		DP
B	4/1/2022	RH	AB	SG	60% DESIGN DRAFT		DP
A	11/12/2021	RH	JW	JW	DRAFT FOR AIR PERMITTING		SK

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

EXISTING CONDITIONS PLAN

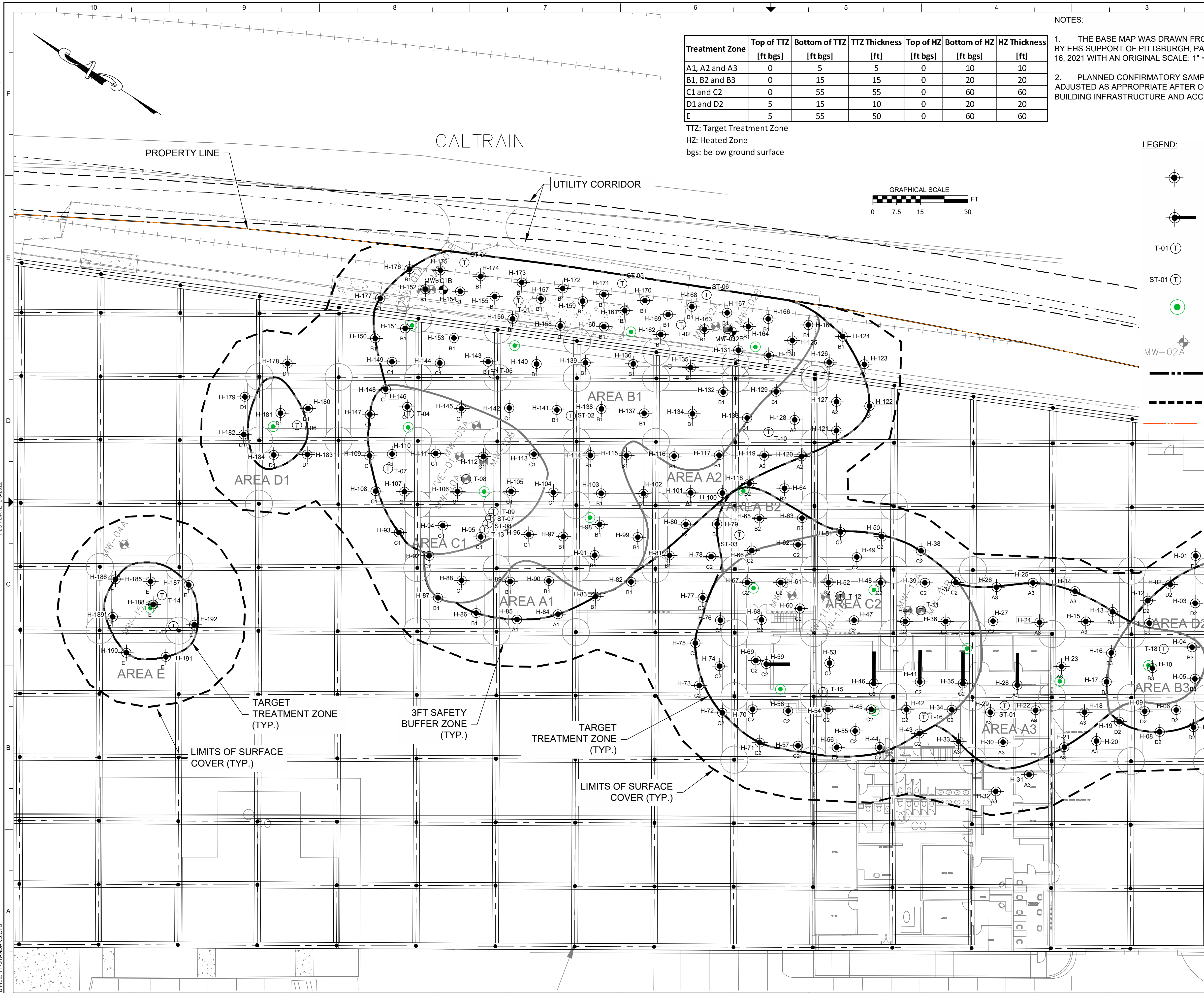
SCALE: AS SHOWN
SHEET SIZE: D
REV: D
REFERENCE NO.:
SHEET: 1 OF 1
DWG NO.: C101

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\01-DRAWINGS\001-IN-PROGRESS DWGS\C101-EXISTING CONDITIONS PLAN.DWG
CTB FILE: TT-STANDARD.CTB

Treatment Zone	Top of TTZ [ft bgs]	Bottom of TTZ [ft bgs]	TTZ Thickness [ft]	Top of HZ [ft bgs]	Bottom of HZ [ft bgs]	HZ Thickness [ft]
A1, A2 and A3	0	5	5	0	10	10
B1, B2 and B3	0	15	15	0	20	20
C1 and C2	0	55	55	0	60	60
D1 and D2	5	15	10	0	20	20
E	5	55	50	0	60	60

TTZ: Target Treatment Zone
HZ: Heated Zone
bgs: below ground surface



NOTES:

1. THE BASE MAP WAS DRAWN FROM A PLAN ENTITLED, "FIGURE 1 BASE MAP", PREPARED BY EHS SUPPORT OF PITTSBURGH, PA AND WAS RECEIVED ELECTRONICALLY ON NOVEMBER 16, 2021 WITH AN ORIGINAL SCALE: 1" = 60'.

2. PLANNED CONFIRMATORY SAMPLE LOCATIONS ARE PRELIMINARY. LOCATIONS WILL BE ADJUSTED AS APPROPRIATE AFTER CONSTRUCTION OF REMEDIAL SYSTEM TO ACCOUNT FOR BUILDING INFRASTRUCTURE AND ACCESS LIMITATIONS.

ISSUED FOR REGULATORY REVIEW

LEGEND:

- VERTICAL TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (187)
- ANGLED TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (5)
- T-01 TEMPERATURE MONITORING POINT (T) (18)
- ST-01 SHALLOW TEMPERATURE MONITORING POINT (ST) (8)
- PLANNED CONFIRMATORY SOIL SAMPLE LOCATIONS (17)
- MW-02A MONITORING WELLS BY OTHERS (TO BE ABANDONED OR RE-USED)
- TARGET TREATMENT ZONE
- LIMITS OF VAPOR COVER
- PROPERTY LINE PER ALTA SURVEY MAP

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 CHEMICAL STATE OF CALIFORNIA 9-9-22

REV	DATE	DESCRIPTION	CAD	ENG	CM	PM
F	9/9/2022	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS	RH	SL	SG	DP
E	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	RH	AB	GM	DP

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

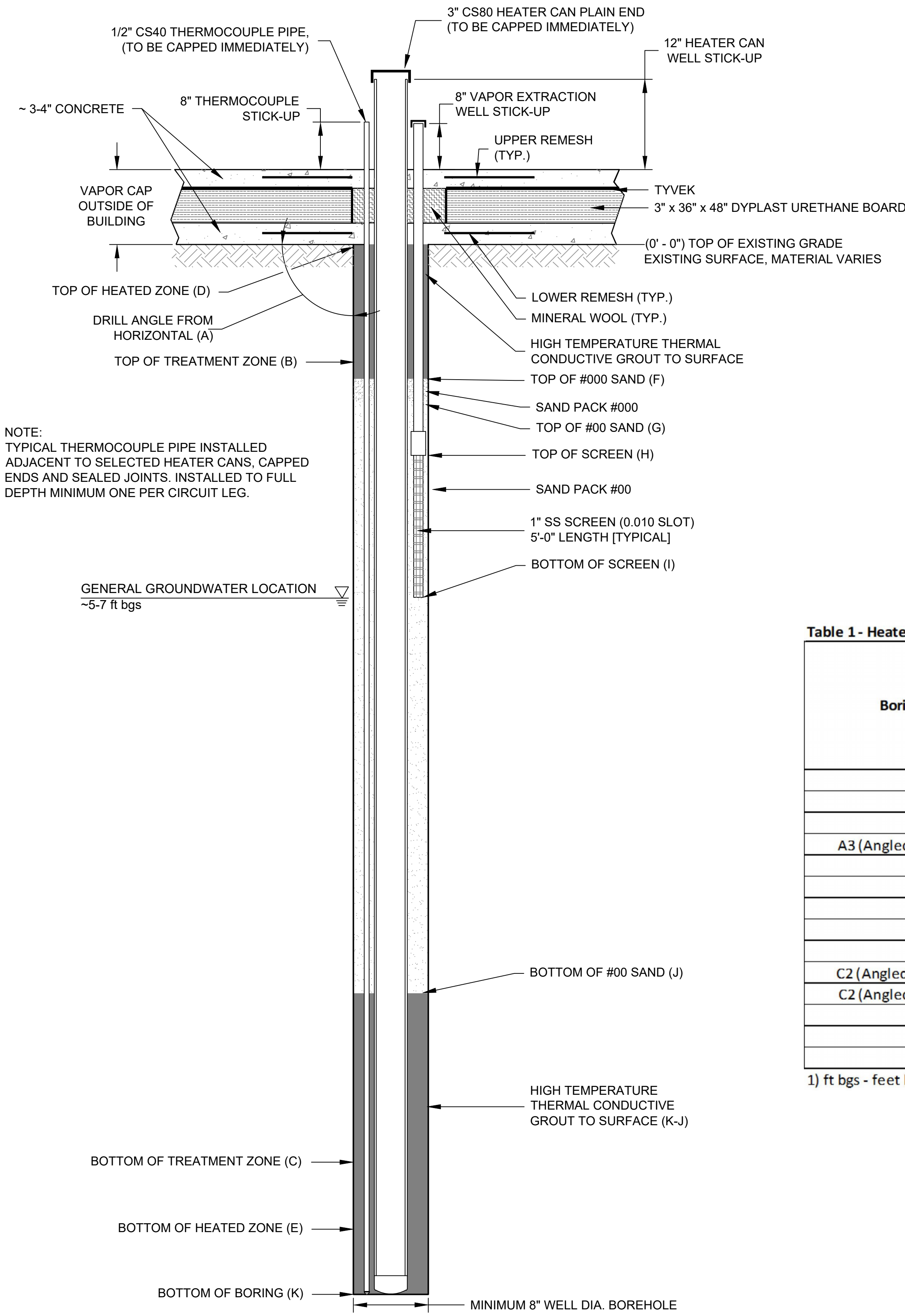
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

WELLFIED LAYOUT WITH PLANNED CONFIRMATORY SOIL SAMPLE LOCATIONS

SCALE: AS SHOWN
SHEET SIZE: D
REV: F
REFERENCE NO.:
SHEET: 1 OF 1
DWG NO.: C102

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\C102-WELLFIELD LAYOUT.DWG
CTB FILE: TT-STANDARD.CTB



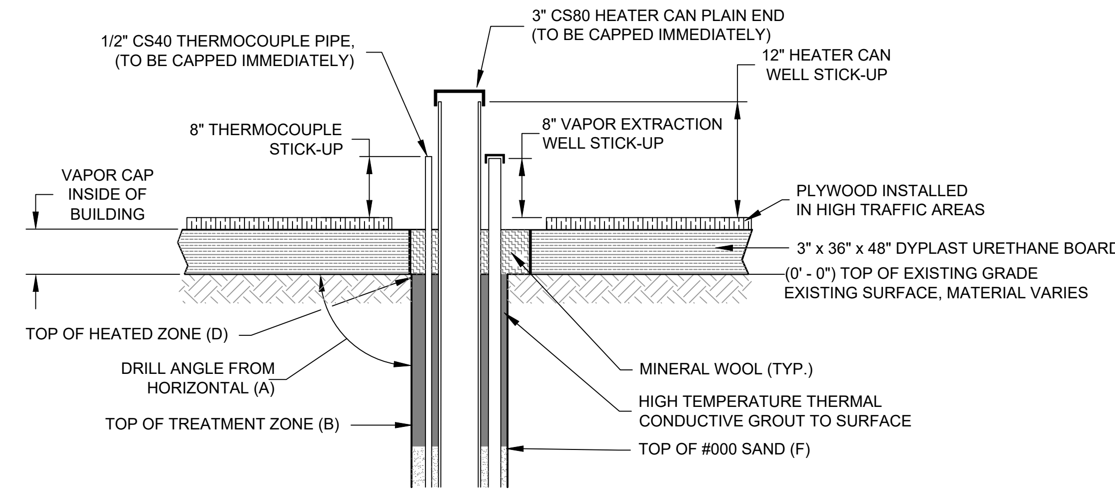
NOTE:
TYPICAL THERMOCOUPLE PIPE INSTALLED ADJACENT TO SELECTED HEATER CANS, CAPPED ENDS AND SEALED JOINTS. INSTALLED TO FULL DEPTH MINIMUM ONE PER CIRCUIT LEG.

HEATER CAN WITH CO-LOCATED VAPOR EXTRACTION TYPICAL DETAIL OUTSIDE BUILDING (H)

QTY (SEE TABLE 1) @ 3" CS80 PIPE
(I-H) L X 1 "SS WELL SCREEN, 0.010 SLOT, CS80 RISER

NOT TO SCALE

ANGLED BORING SHOWN VERTICAL FOR CLARITY



HEATER CAN WITH CO-LOCATED VAPOR EXTRACTION TYPICAL DETAIL INSIDE BUILDING (H)

QTY (SEE TABLE 1) @ 3" CS80 PIPE
(I-H) L X 1 "SS WELL SCREEN, 0.010 SLOT, CS80 RISER

NOT TO SCALE

NOTES:

1. DETAILS EXPRESSED IN UNITS OF FEET (FT) ARE TRAVEL LENGTHS ALONG THE BORING THAT ACCOUNT FOR THE DRILL ANGLE.
2. CENTRALIZERS WILL BE USED DURING WELL INSTALLATION TO ENSURE WELLS ARE CENTERED AND BACKFILL MATERIALS PROPERLY DISTRIBUTED AROUND THE WELLS.
3. BORE HOLES THRU BUILDING SLAB WILL BE OVER-DRILLED.
4. HEATERS INSTALLED INSIDE THE BUILDING WILL HAVE AN EXTENDED COLD PIN DOWN TO A MINIMUM OF 12 IN BELOW THE BOTTOM OF THE FLOOR TO LIMIT THE HEATING OF THE EXISTING FLOOR SLAB DURING OPERATION.

ISSUED FOR REGULATORY REVIEW

HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL SCHEDULE

Table 1 - Heater Boring with Co-Located Screen Detail

Boring Type	Quantity	Drill Angle from Horizontal (A)	Top of Treatment Zone (B) ft bgs	Bottom of Treatment Zone (C) ft bgs	Top of Heated Zone (D) ft bgs	Bottom of Heated Zone (E) ft bgs	Length to Top of #000 Sand (F) ft	Length to Top of #00 Sand (G) ft	Length to Top of Screen (H) ft	Length to Bottom of Screen (I) ft	Length to Bottom of #00 Sand (J) ft	Length to Bottom of Boring (K) ft
A1	2	90°	0.0	5.0	0.0	10.0	1.0	1.5	2.0	7.0	7.0	11.0
A2	9	90°	0.0	5.0	0.0	10.0	1.0	1.5	2.0	7.0	7.0	11.0
A3	15	90°	0.0	5.0	0.0	10.0	1.0	1.5	2.0	7.0	7.0	11.0
A3 (Angled - 10 ft Reach)	1	27°	0.0	5.0	0.0	10.0	2.0	2.5	7.0	12.0	12.0	23.0
B1	62	90°	0.0	15.0	0.0	20.0	1.0	1.5	2.0	7.0	15.0	21.0
B2	6	90°	0.0	15.0	0.0	20.0	1.0	1.5	2.0	7.0	15.0	21.0
B3	7	90°	0.0	15.0	0.0	20.0	1.0	1.5	2.0	7.0	15.0	21.0
C1	23	90°	0.0	55.0	0.0	60.0	1.0	1.5	2.0	7.0	55.0	62.0
C2	39	90°	0.0	55.0	0.0	60.0	1.0	1.5	2.0	7.0	55.0	62.0
C2 (Angled - 7.5 ft Reach)	1	85°	0.0	55.0	0.0	60.0	1.0	1.5	2.0	7.0	55.0	62.0
C2 (Angled - 10 ft Reach)	3	80°	0.0	55.0	0.0	60.0	1.0	1.5	2.0	7.0	56.0	63.0
D1	7	90°	5.0	15.0	0.0	20.0	1.0	1.5	2.0	7.0	15.0	21.0
D2	9	90°	5.0	15.0	0.0	20.0	1.0	1.5	2.0	7.0	15.0	21.0
E	8	90°	5.0	55.0	0.0	60.0	1.0	1.5	2.0	7.0	55.0	62.0

1) ft bgs - feet below existing ground surface (prior to adding vapor cap)

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

REV	DATE	CAD	ENG	DESCRIPTION	PM
D	9/9/2022	RH	SL	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS	DP
C	8/5/2022	RH	AB	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	DP
B	6/10/2022	RH	SL	90% DRAFT DESIGN	DP
A	4/1/2022	RH	SL	60% DESIGN DRAFT	DP

THIS DOCUMENT CONTAINS CONFIDENTIAL INFORMATION OWNED BY TERRATHERM, INC. UNAUTHORIZED DISCLOSURE IS PROHIBITED

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

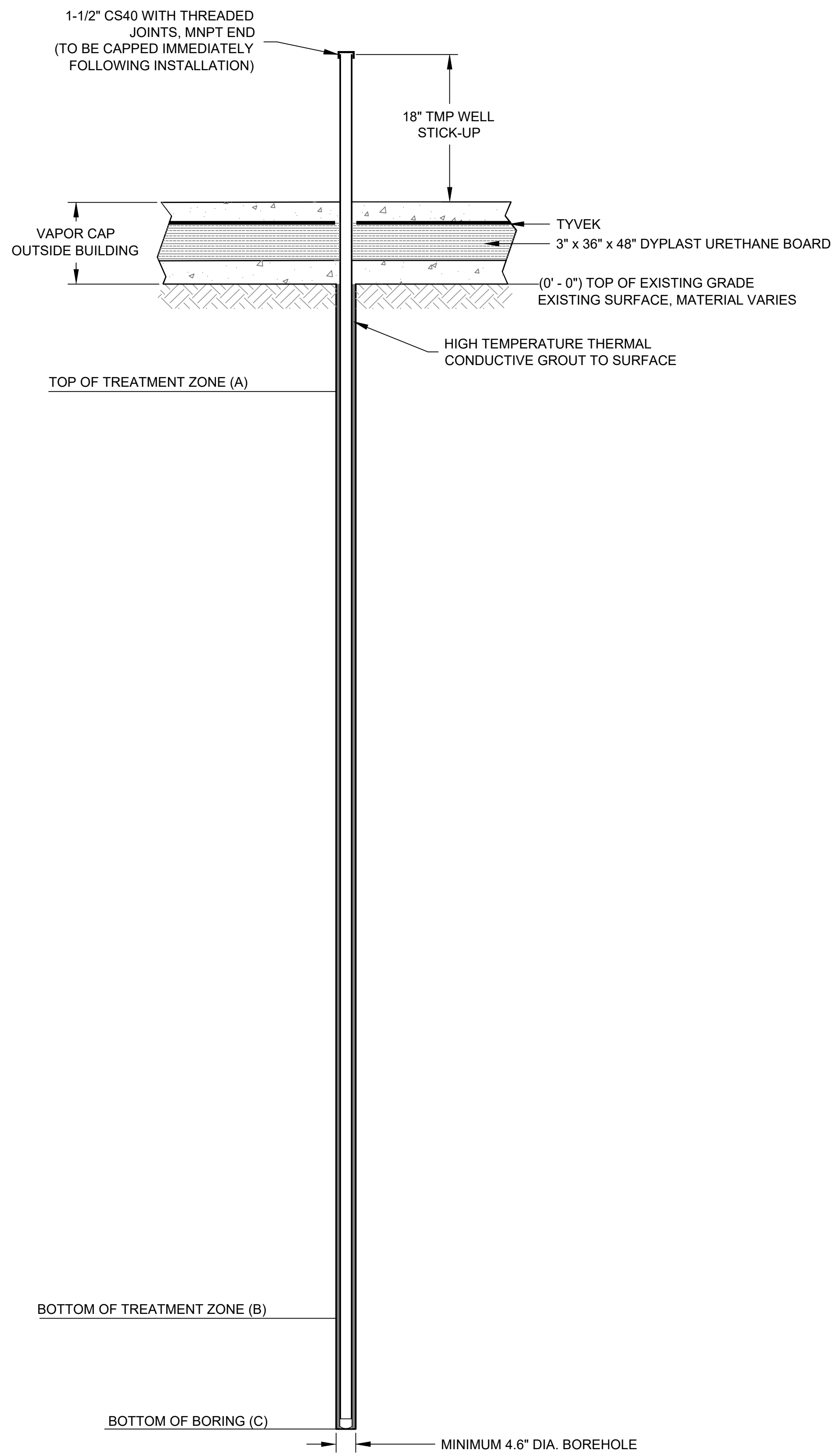
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

TYPICAL WELL CONSTRUCTION DETAILS

SCALE: NTS
SHEET SIZE: D
REV: D
REFERENCE NO.: R21-103.00
SHEET: 1 OF 2
DWG NO.: C103

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\C103-TYPICAL WELL DTLS.DWG
CTB FILE: TT-STANDARD.CTB



TEMPERATURE MONITORING POINT (TMP)

QTY (SEE TABLE 2) 1-1/2" CS40 PIPE

TEMPERATURE MONITORING SENSOR DEPTHS
(SEE TABLE 2)
NOT TO SCALE

TEMPERATURE MONITORING POINT SCHEDULE

Table 2 - Temperature Monitoring Point Detail

Boring Type	Quantity	TMP ID	Top of Treatment Zone (A) ft bgs	Bottom of Treatment Zone (B) ft bgs	Bottom of Boring (C) ft bgs	Temperature Sensor Locations ft bgs
A2	1	T-10	0.0	5.0	6.0	1', 4'
A3	1	ST-01	0.0	5.0	6.0	1', 4'
B1	5	T-01, T-02, T-03, T-05, ST-02	0.0	15.0	16.0	1', 4', 7', 10', 13'
B2	1	ST-03	0.0	15.0	16.0	1', 4', 7', 10', 13'
B3	1	T-18	0.0	15.0	16.0	1', 4', 7', 10', 13'
C1	5	T-04, T-07, T-08, T-09, T-13	0.0	55.0	56.0	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31', 34', 37', 40', 43', 46', 49', 52', 55'
C1	2	ST-07, ST-08	0.0	55.0	5.0	4'
C2	4	T-11, T-12, T-15, T-16	0.0	55.0	56.0	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31', 34', 37', 40', 43', 46', 49', 52', 55'
D1	1	T-06	5.0	15.0	16.0	1', 4', 7', 10', 13'
E	2	T-14, T-17	5.0	55.0	56.0	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31', 34', 37', 40', 43', 46', 49', 52', 55'
Outside	3	ST-04, ST-05, ST-06	N/A	N/A	5.0	4'

1) ft bgs - feet below existing ground surface (prior to adding vapor cap)

NOTES:

1. CENTRALIZERS WILL BE USED DURING WELL INSTALLATION TO ENSURE WELLS ARE CENTERED AND BACKFILL MATERIALS PROPERLY DISTRIBUTED AROUND THE WELLS.
2. BORE HOLES THRU BUILDING SLAB WILL BE OVER-DRILLED.

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 CHEMICAL STATE OF CALIFORNIA 9-9-22

REV	DATE	CAD	ENG		DESCRIPTION	CM	PM
D	9/9/2022	RH	SL	SG	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS		DP
C	8/5/2022	RH	AB	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	RH	SL	SG	90% DRAFT DESIGN		DP
A	4/1/2022	RH			60% DESIGN DRAFT		DP

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

TYPICAL WELL CONSTRUCTION DETAILS

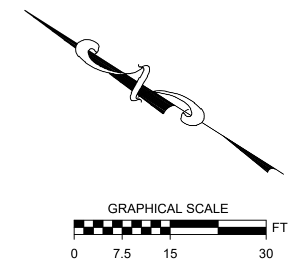
SCALE: NTS
SHEET SIZE: D
REV: D
REFERENCE NO.: R21-103.00
SHEET: 2 OF 2
DWG NO.: C103

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\C103-TYPICAL WELL DTLS.DWG
CTB FILE: TT-STANDARD.CTB

TMP ID	Area	Top of TTZ [ft bgs]	Bottom of TTZ [ft bgs]	Bottom of Boring [ft bgs]	Sensor Depths	Description
T-01	B.1	0	15	16	1', 4', 7', 10', 13'	Regular soil TMP
T-02	B.1	0	15	16	1', 4', 7', 10', 13'	
T-03	B.1	0	15	16	1', 4', 7', 10', 13'	
T-06	D.1	5	15	16	1', 4', 7', 10', 13'	
T-07	C.1	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-08	C.1	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-10	A.2	0	5	6	1', 4'	
T-11	C.2	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-12	C.2	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-14	E	5	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-16	C.2	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-18	B.3	0	15	16	1', 4', 7', 10', 13'	
T-04	C.1	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	TMP located 1 ft away from heater
T-13	C.1	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	TMP located 2.5 ft away from heater
T-15	C.2	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	TMP located 5 ft away from heater
T-05	B.1	0	15	16	1', 4', 7', 10', 13'	TMPs located near piles and beams
T-09	C.1	0	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
T-17	E	5	55	56	1', 4', 7', 10', 13', 16', 19', 22', 25', 28', 31' 34', 37', 40', 43', 46', 49', 52', 55'	
ST-01	A.3	0	5	6	1', 4'	Shallow TMPs located near beams
ST-02	B.1	0	15	16	1', 4', 7', 10', 13'	
ST-03	B.2	0	15	16	1', 4', 7', 10', 13'	
ST-04	Outside			5	4'	Shallow TMPs located near fuel line
ST-05	Outside			5	4'	
ST-06	Outside			5	4'	
ST-07	C.1	0	55	5	4'	TMP between heater and pile
ST-08	C.1	0	55	5	4'	TMP between heater and pile
Selected heaters					One sensor per location - flexible dep	Heater temperature TMP

TTZ: Target Treatment Zone
HZ: Heated Zone
bgs: below ground surface



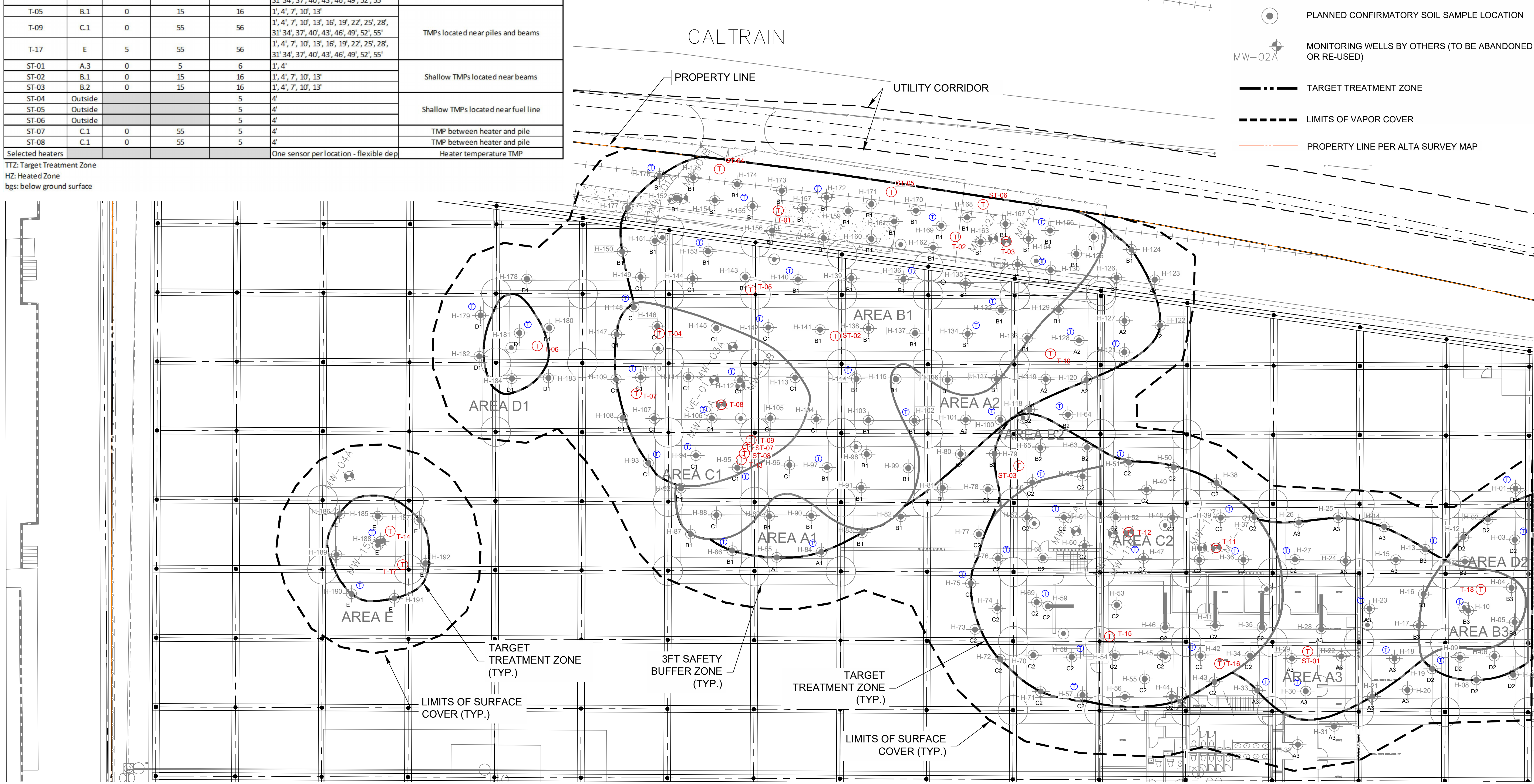
ISSUED FOR REGULATORY REVIEW

NOTES:

1. THE BASE MAP WAS DRAWN FROM A PLAN ENTITLED, "FIGURE 1 BASE MAP", PREPARED BY EHS SUPPORT OF PITTSBURGH, PA AND WAS RECEIVED ELECTRONICALLY ON NOVEMBER 16, 2021 WITH AN ORIGINAL SCALE: 1" = 60'.

LEGEND:

- VERTICAL TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (187)
- ANGLED TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (5)
- VERTICAL TCH HEATER WITH CO-LOCATED TEMPERATURE MONITORING POINT (54)
- T-01 TEMPERATURE MONITORING POINT (T) (18)
- ST-01 SHALLOW TEMPERATURE MONITORING POINT (ST) (8)
- PLANNED CONFIRMATORY SOIL SAMPLE LOCATION
- MW–02A MONITORING WELLS BY OTHERS (TO BE ABANDONED OR RE-USED)
- TARGET TREATMENT ZONE
- LIMITS OF VAPOR COVER
- PROPERTY LINE PER ALTA SURVEY MAP



REV	DATE	CAD	ENG		DESCRIPTION		
.	.	.			-		
.	.	.			-		
C	9/9/2022	RH	SL	SG	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS		DP
B	8/5/2022	RH	AB	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
A	6/10/2022	RH	SL	SG	90% DESIGN DRAFT		DP
REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

TEMPERATURE MONITORING WELL LAYOUT

SCALE: AS SHOWN
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 1 OF 1
DWG NO.: C104

FILE:J:\ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\C104-TEMPERATURE MONITORING LAYOUT.DWG
PLOT DATE: 9/9/2022
CTB FILE: TT-STANDARD.CTB

ELECTRICAL ONELINE LEGEND (SMART SYMBOL)

TERRATHERM FREQUENTLY USED TERMS AND SYMBOLS

A	- AMPERE
AMP	- AMPERE
ATS	- AUTOMATIC TRANSFER SWITCH
C.S.	- CARBON STEEL
DP	- DISTRIBUTION PANEL
FLA	- FULL LOAD AMPS. MOTOR FLA ARE SPECIFIED PER NEC 430.250
GFCI	- GROUND FAULT CIRCUIT INTERRUPTER
KVA	- KILOVOLT-AMPERE
KW	- KILOWATTS
KWHR	- KILOWATT-HOUR
LC	- LOAD CENTER
LCP	- LOCAL CONTROL PANEL
MSWB	- MAIN SWITCHBOARD
OWS	- OIL WATER SEPARATOR
SCR	- SILICON CONTROLLED RECTIFIER
T(XXX)	- TERRATHERM EQUIPMENT IDENTIFICATION NUMBER
V	- VOLTS
VFD	- VARIABLE FREQUENCY DRIVE

ELECTRICAL CONDUCTOR / WIRE

WIRE TERMINATION / CONNECTION POINT

SEMI-CONDUCTOR FUSE

X — ELECTRODE ELEMENT AS REPRESENTED IN ONELINE. LETTER IN HEXAGON DENOTES ELECTRODE TYPE.

HEAT TRACE FOR PIPING

XX — DISCONNECT SWITCH RATING AS NOTED

VFD — VARIABLE FREQUENCY DRIVE (VFD)

MS — MOTOR STARTER

XX, FLA XXX — MOTOR. HORSEPOWER AS INDICATED IN CIRCLE. FULL LOAD AMPS (FLA) AS NOTED PER APPLICABLE NEC TABLE.

XX KW — STANDBY GENERATOR. KW RATING AS NOTED.

XXX : XXX V — VOLTAGE TRANSFORMER, TYPICALLY USED FOR METERING. VOLTAGE RATIO AS NOTED.

XXX : 5 A — CURRENT TRANSFORMER, TYPICALLY USED FOR METERING. CURRENT TRANSFORMER RATIO AND POLARITY AS NOTED.

M~ — ENERGY METER (KWHR) MODEL AS NOTED

KVA PRI_VOLT : 480/277V %z — POWER TRANSFORMER WITH PRIMARY VOLTS, SECONDARY VOLTS, KVA RATINGS, AND % IMPEDANCE AS NOTED

EQUIPMENT SKID BOUNDARY

ATS-1 XXX A (N, E, L) — AUTOMATIC TRANSFER SWITCH. SWITCH AMP RATING AS NOTED

RATED HP @460V FLA X - X XX AMPS MAX — UL COMBINATION STARTER TYPE E, SELF-PROTECTED OR TYPE F. FULL LOAD AMP RATING ADJUSTABLE IN SPECIFIED RANGE.

ELECTRICAL ONELINE LEGEND (SMART SYMBOL - INTEGRATED EQUIPMENT)

CB # AMP 3 POLES — LOW VOLTAGE AIR CIRCUIT BREAKER WITH RATING AND NUMBER OF POLES AS NOTED. NON-ADJUSTABLE TYPE.

CB # XX AT XX AF 3 POLES — LOW VOLTAGE AIR CIRCUIT BREAKER WITH RATING AND NUMBER OF POLES AS NOTED. TRIP RATING ADJUSTABLE TYPE.

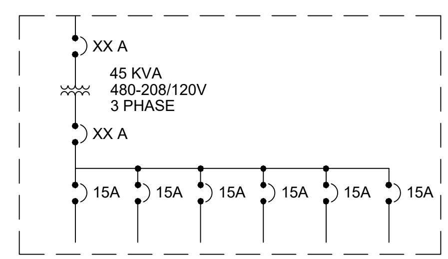
CB # XX AT XX AF 3 POLES LSIG — LOW VOLTAGE AIR CIRCUIT BREAKER WITH RATING AND NUMBER OF POLES AS NOTED. TRIP RATING ADJUSTABLE TYPE. PROTECTION TO BE SPECIFIED AS REQUIRED.

CB # XX AT XX AF 3 POLES LSIG — LOW VOLTAGE AIR CIRCUIT BREAKER WITH RATING AND NUMBER OF POLES AS NOTED. TRIP RATING ADJUSTABLE TYPE. PROTECTION TO BE SPECIFIED AS REQUIRED. DRAWOUT TYPE.

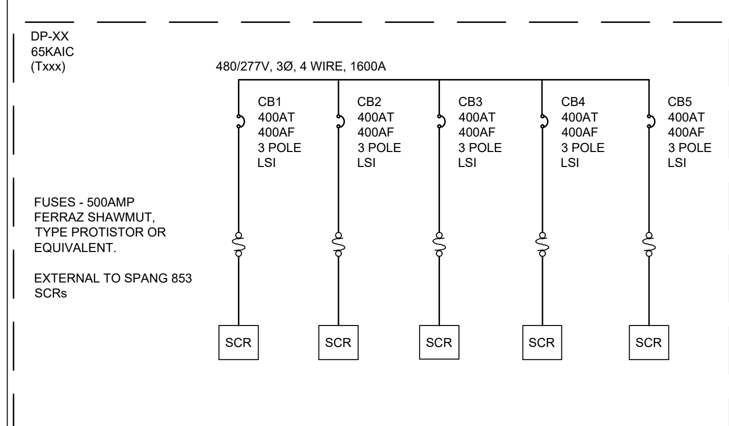
CB # XX AT XX AF 3 POLES LSIG — MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER WITH RATING AND NUMBER OF POLES AS NOTED. TRIP RATING ADJUSTABLE. PROTECTION TO BE SPECIFIED AS REQUIRED. DRAWOUT TYPE.

XXX AMP FUSE TYPE — FUSE RATING AND TYPE AS NOTED.

XXX A - SWITCH XXX AMP FUSE FUSE_TYPE — FUSED DISCONNECT SWITCH WITH SWITCH RATING, FUSE RATING AND TYPE AS NOTED.



INTEGRATED PANEL WITH TRANSFORMER ASSEMBLY. PRIMARY AND SECONDARY BREAKERS AS NOTED. DISTRIBUTION PANEL CONTAINS BREAKERS AS NOTED.

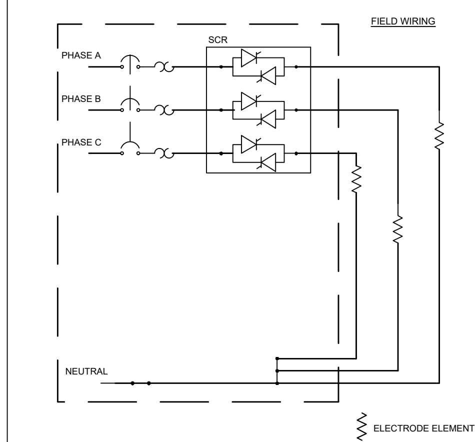


INTEGRATED DISTRIBUTION PANEL WITH BUILT-IN SCR CABINETS / ZONES. EACH ZONE HAS CUSTOMIZABLE PROTECTION FOR THE ELECTRODE CIRCUIT AND THE SCR.

SCR POWER WIRING SCHEMATICS

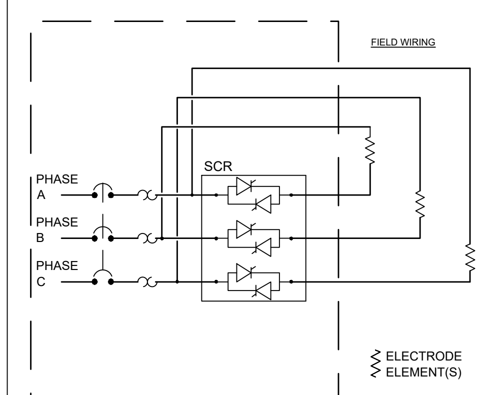
HEATER CIRCUIT - WYE CONFIGURED, 277V

HEATER CIRCUIT - WYE CONFIGURED, 277V, TYPICAL WIRING WITHIN INTEGRATED SCR CABINET



ELECTRODE CIRCUIT - INSIDE DELTA CONFIGURED, 480V

ELECTRODE CIRCUIT - DELTA CONFIGURED, 480V, TYPICAL WIRING WITHIN INTEGRATED SCR CABINET



ELECTRICAL WIRE LAYOUT SYMBOLS

GFCI — GROUND FAULT CIRCUIT INTERRUPTER (GFCI) DUPLEX OUTLET WITH WEATHERPROOF COVER.

ES — EMERGENCY STOP - PUSHBUTTON STATION

GFCI — OUTDOOR LIGHTING WITH GFCI DUPLEX RECEPTACLE IN WEATHERPROOF COVER

ES GFCI — OUTDOOR LIGHTING WITH GFCI DUPLEX RECEPTACLE AND E-STOP ON SHARED POLE

GENERAL NOTES

THE FOLLOWING NOTES ARE APPLICABLE TO ALL ELECTRICAL DRAWINGS, OR E-SERIES, UNLESS SPECIFICALLY STATED OTHERWISE ON THE SPECIFIC DRAWING. THE FOLLOWING IS NOT AN ALL-INCLUSIVE LIST OF RELEVANT CODE APPLICABLE TO THIS PROJECT BUT IS INTENDED TO HIGHLIGHT THE MAJOR SECTIONS ONLY.

GENERAL NOTES:

1. TERRATHERM WILL PROVIDE ALL FLEXIBLE CORDS AND CONNECTORS FOR EQUIPMENT SHOWN ON DRAWING. CONTRACTOR MAY BE REQUESTED TO PROVIDE ADDITIONAL MATERIAL ON A T&M BASIS AS SITE CONDITION CHANGES.
2. TERRATHERM'S ELECTRICAL DESIGNS ARE BASED ON ARTICLE 590, TEMPORARY INSTALLATION, OF THE NATIONAL ELECTRIC CODE, 2017. ALL TEMPORARY WIRING AND EQUIPMENT WILL BE REMOVED AT THE CONCLUSION OF THE PROJECT. ALL CABLE SHALL BE LISTED FOR HARD OR EXTRA-HARD USAGE PER ARTICLE REQUIREMENT.
3. TYPE "W" AND TYPE "G-GC" ARE CLASSIFIED FOR EXTRA HARD USAGE PER NEC TABLE 400-4. TYPE "W" AND TYPE "G-GC" CABLE AMPACITY ARE SPECIFIED PER NEC ARTICLE 400-5(A)(2) USING 75 DEGREE C COLUMN F3 FOR THREE-CONDUCTOR (3/C) CABLES. COLUMN D1 IS USED FOR SINGLE-CONDUCTOR (1/C) WHERE THE CONDUCTOR IS NOT IN PHYSICAL CONTACT WITH EACH OTHER.
4. ALL CABLE SHALL BE BOTTOM ENTRY WHEREVER PRACTICAL. PER NEC 110.14, ALL TERMINALS OF EQUIPMENT >100A ARE ASSUMED TO BE 75C RATED UNLESS OTHERWISE NOTED.
5. GROUNDING SHALL BE INSTALLED PER NEC ARTICLE 250 - "GROUNDING AND BONDING FOR ALL EQUIPMENT". ROUTE ALL HEATER CIRCUIT EQUIPMENT GROUNDS WITH THE HEATER CIRCUIT CONDUCTORS TO EACH WELLHEAD. REFERENCE TYPICAL GROUNDING DETAILS FOR ADDITIONAL INFORMATION.
6. THE GROUNDING ELECTRODE CONDUCTOR FOR A SEPARATELY DERIVED SYSTEM (TRANSFORMER) SHALL BE INSTALLED AT THE FIRST DISCONNECTING MEAN PER NEC ARTICLE 250.30.
7. GENERATOR SHALL BE WIRED PER NEC ARTICLE 702, OPTIONAL STANDBY SYSTEMS. THE GENERATOR WILL BE WIRED TO A THREE (3) POLE TYPE AUTOMATIC TRANSFER SWITCH (ATS) AND SHOULD BE WIRED AS A NON-SEPARATELY DERIVED SYSTEM, I.E. DO NOT BOND NEUTRAL AT GENERATOR. WIRE EMERGENCY STOP SIGNAL TO PREVENT GENERATOR START DURING AN EMERGENCY. EMERGENCY STOP SIGNAL SHALL ALSO BE WIRED TO SHUNT TRIP THE MAIN BREAKER(S).
8. MAINTAIN WORKING CLEARANCE PER NEC ARTICLE 110.26 - "SPACES ABOUT ELECTRICAL EQUIPMENT".
9. ALL POWER DISTRIBUTION EQUIPMENT SHALL BE UL LISTED OR CERTIFIED BY A 3RD PARTY NRTL.
10. ALL PROCESS EQUIPMENT CONTROL PANELS SHALL BE BUILT TO APPLICABLE UL STANDARDS SUCH AS UL 508, UL 698. EQUIPMENT MAY BE FIELD EVALUATED BY A NRTL IF THE ABOVE STANDARD IS NOT AVAILABLE.
11. EQUIPMENT WITH "A" AND "B" TAG SUCH AS P-101A AND P-101B ARE NON-COINCIDENTAL LOADS.
12. USE THE FOLLOWING COLOR CODES FOR CONDUCTOR IDENTIFICATION:

	208Y / 120 VOLT	480 / 277 VOLT
PHASE A	BLACK	BROWN
PHASE B	RED	ORANGE
PHASE C	BLUE	YELLOW
NEUTRAL	WHITE	GRAY

13. ALL WORK SHALL CONFORM TO THE LATEST LOCAL, STATE AND FEDERAL REQUIREMENTS AS INTERPRETED BY THE AUTHORITY HAVING JURISDICTION

SITE SPECIFIC NOTES:

1. AMPACITIES OF CABLE ARE CORRECTED FOR AN MAX AMBIENT TEMPERATURE OF 91 DEGREE F
2. THE AVAILABLE FAULT CURRENT IS ASSUMED TO BE < 65KA. EXACT NUMBERS TO BE PROVIDED BY UTILITY

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 CHEMICAL STATE OF CALIFORNIA 9-9-22

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM	SF	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	MG	SF	90% DESIGN DRAFT		DP
A	4/1/2022	CN	MG	SF	60% DESIGN DRAFT		DP

TERRATHERM a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

ELECTRICAL LEGEND

SCALE: NTS
SHEET SIZE: D REV: C
REFERENCE NO.: -
SHEET: 1 OF 1
DWG NO.: E100

PLOT DATE: 8/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\E100-ELECTRICAL-LEGEND.DWG
CTB FILE: TT-STANDARD.CTB

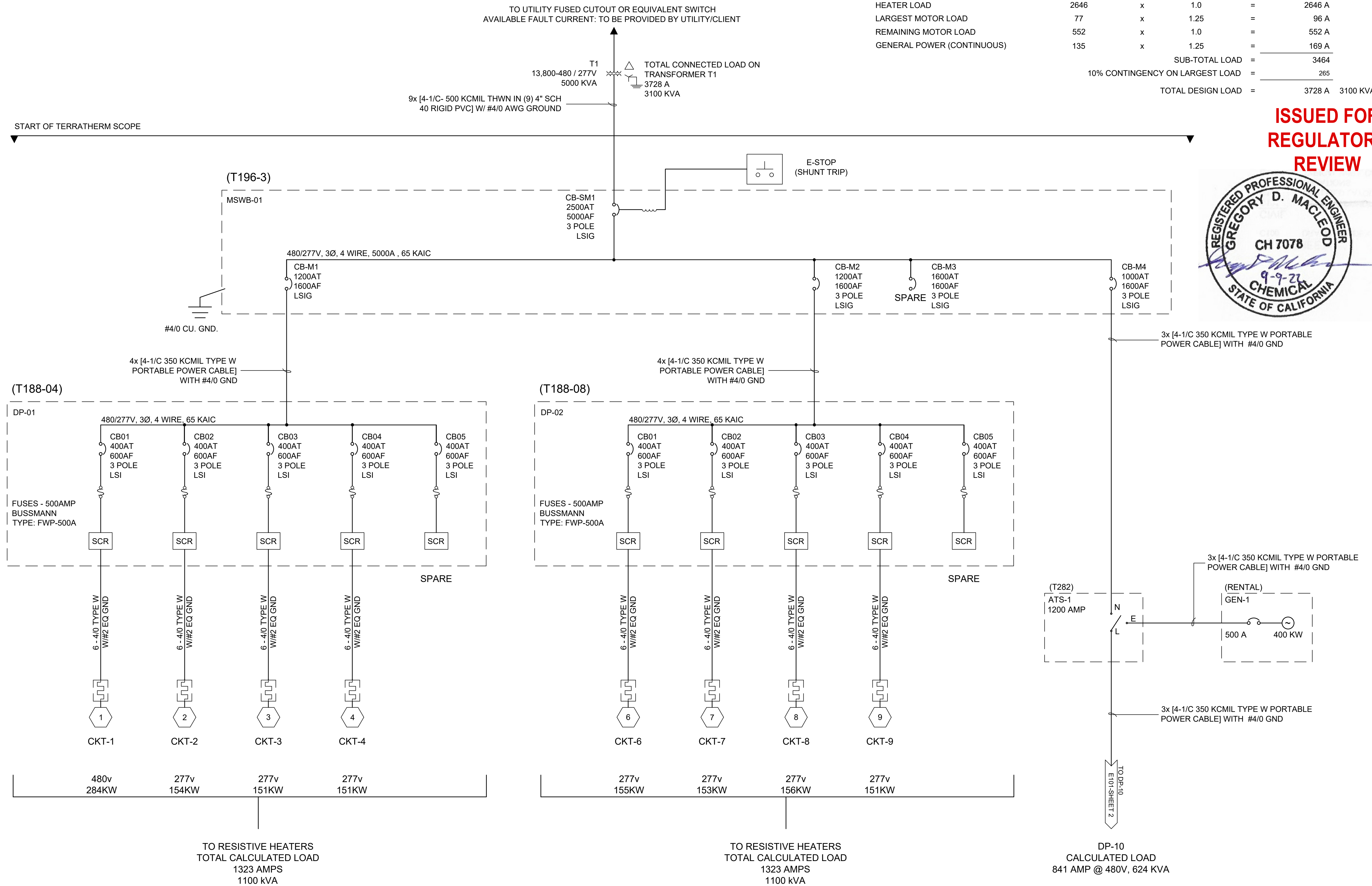
ELECTRICAL LOAD SUMMARY (480V)

CALCULATED PER 430.24. ROUNDING PER NEC 220.5(B)

	CONNECTED LOAD (A)		LOAD MULTIPLIER		DESIGN LOAD
HEATER LOAD	2646	x	1.0	=	2646 A
LARGEST MOTOR LOAD	77	x	1.25	=	96 A
REMAINING MOTOR LOAD	552	x	1.0	=	552 A
GENERAL POWER (CONTINUOUS)	135	x	1.25	=	169 A
			SUB-TOTAL LOAD	=	3464
			10% CONTINGENCY ON LARGEST LOAD	=	265
			TOTAL DESIGN LOAD	=	3728 A 3100 KVA

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-9-22 CHEMICAL STATE OF CALIFORNIA



REV	DATE	CAD	ENG		DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	MG	SF	90% DESIGN DRAFT		DP
A	4/1/2022	CN	MG	SF	60% DESIGN DRAFT		DP

DL

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

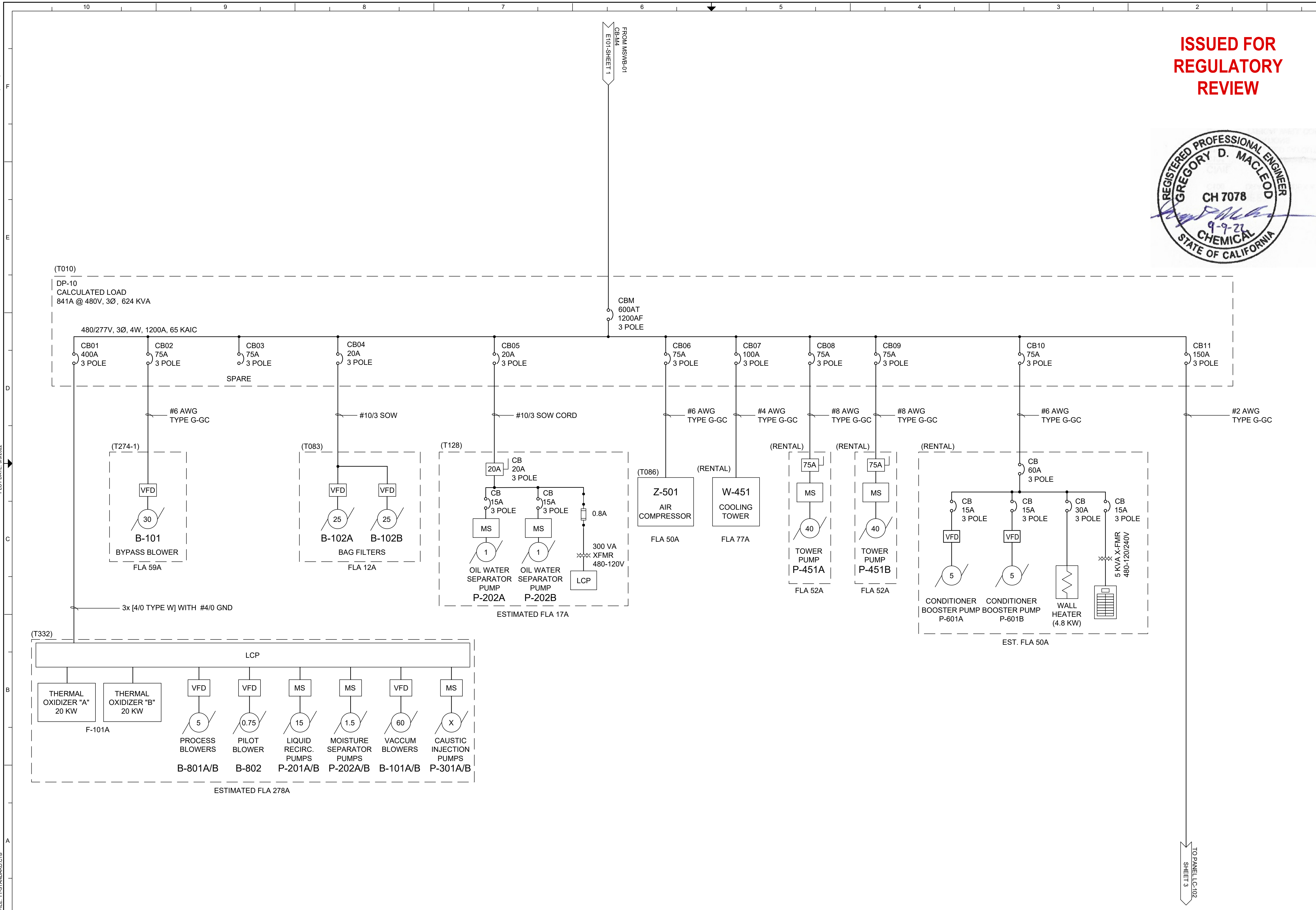
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

ELECTRICAL ONE LINE

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: --
SHEET: 1 OF 3
DWG NO.: E101

PLOT DATE: 9/9/2022

FILE: J:\...ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\E101-ELECTRICAL ONE LINE.DWG
CTB FILE: TT-STANDARD.CTB



REV	DATE	CAD	ENG	DL	DESCRIPTION
C	8/5/2022	CN	GM	DP	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS
B	6/10/2022	CN	MG	SF	90% DESIGN DRAFT
A	4/1/2022	CN	MG	SF	60% DESIGN DRAFT

CM PM

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

ELECTRICAL ONE LINE

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: --
SHEET: 2 OF 3
DWG NO.: E101

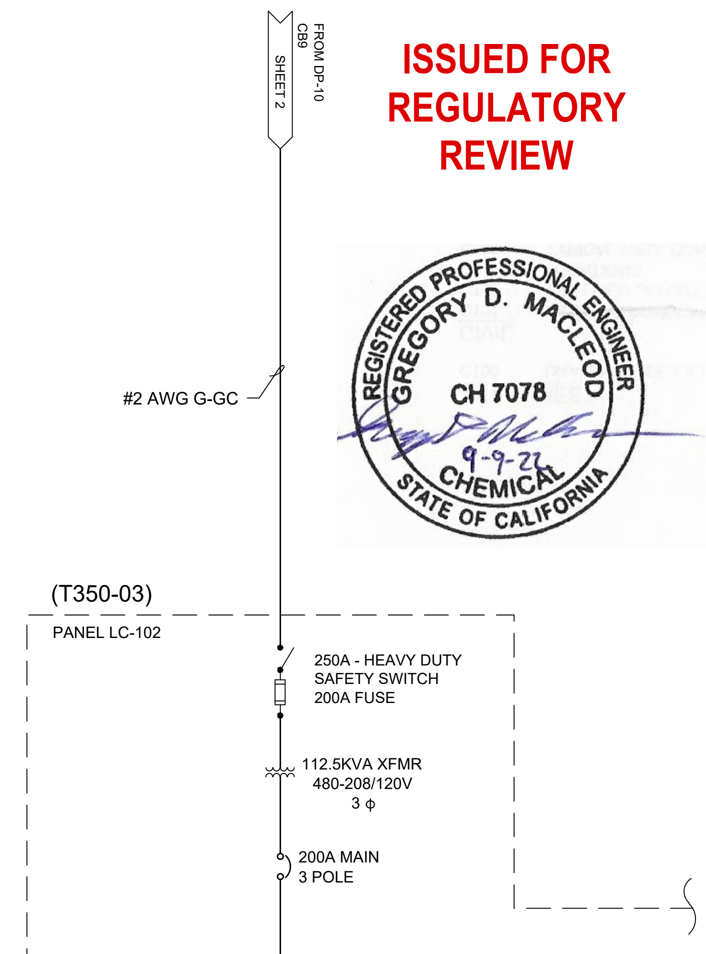
PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\E101-ELECTRICAL ONE LINE.DWG
CTB FILE: TT-STANDARD.CTB

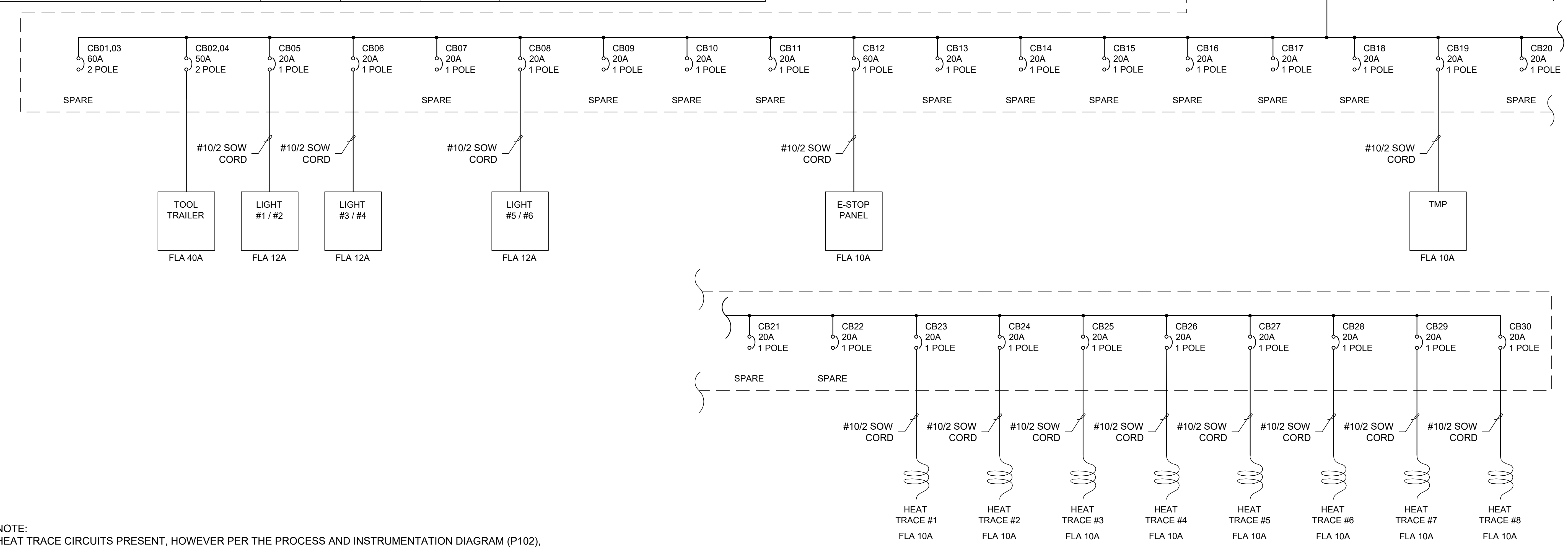
PANEL LC-102

TYPE: NEMA 3R	MAIN CB 200A	PANEL LOCATION: LC-102
SERVICE 120/240, 1PH, 3W	LOCATION: BOTTOM	SOURCE: DP-10
MFR: SQUARE D, QO	BUS RATING 150A	FEEDER: CB09

DESCRIPTION	CKT NO.	TRIP	⌒	LOADS (W) A		B		C		⌒	TRIP	CKT NO.	DESCRIPTION
OFFICE TRAILER	1	60	⌒	6000	4800					⌒	50	2	TOOL TRAILER
	3	60	⌒			6000	4800			⌒	50	4	
LIGHT #1 / #2	5	20	⌒					1200	1200	⌒	20	6	LIGHT #3 / #4
SPARE	7	20	⌒	0	1200					⌒	20	8	LIGHT #5 / #6
SPARE	9	20	⌒			0	0			⌒	20	10	SPARE
SPARE	11	20	⌒					0	1200	⌒	20	12	E-STOP PANEL
SPARE	13	20	⌒	0	0					⌒	20	14	SPARE
SPARE	15	20	⌒			0	0			⌒	20	16	SPARE
SPARE	17	20	⌒					0	0	⌒	20	18	SPARE
SPARE	19	20	⌒	0	1200					⌒	20	20	TMP
SPARE	21	20	⌒			0	0			⌒	20	22	SPARE
HEAT TRACE #1	23	20	⌒					1200	1200	⌒	20	24	HEAT TRACE #2
HEAT TRACE #3	25	20	⌒	1200	1200					⌒	20	26	HEAT TRACE #4
HEAT TRACE #5	27	20	⌒			1200	1200			⌒	20	28	HEAT TRACE #6
HEAT TRACE #7	29	20	⌒					1200	1200	⌒	20	30	HEAT TRACE #8
			TOTALS	15600		13200		8400		* GF TYPE BREAKER			



ISSUED FOR REGULATORY REVIEW



NOTE:
HEAT TRACE CIRCUITS PRESENT, HOWEVER PER THE PROCESS AND INSTRUMENTATION DIAGRAM (P102), HEAT TRACE IS NOT PLANED TO BE IN USE ON THIS PROJECT.

REV	DATE	CAD	ENG	DL	PM	DESCRIPTION
C	8/5/2022	CN	GM		DP	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS
B	6/10/2022	CN	MG	SF	DP	90% DESIGN DRAFT
A	4/1/2022	CN	MG	SF	DP	60% DESIGN DRAFT

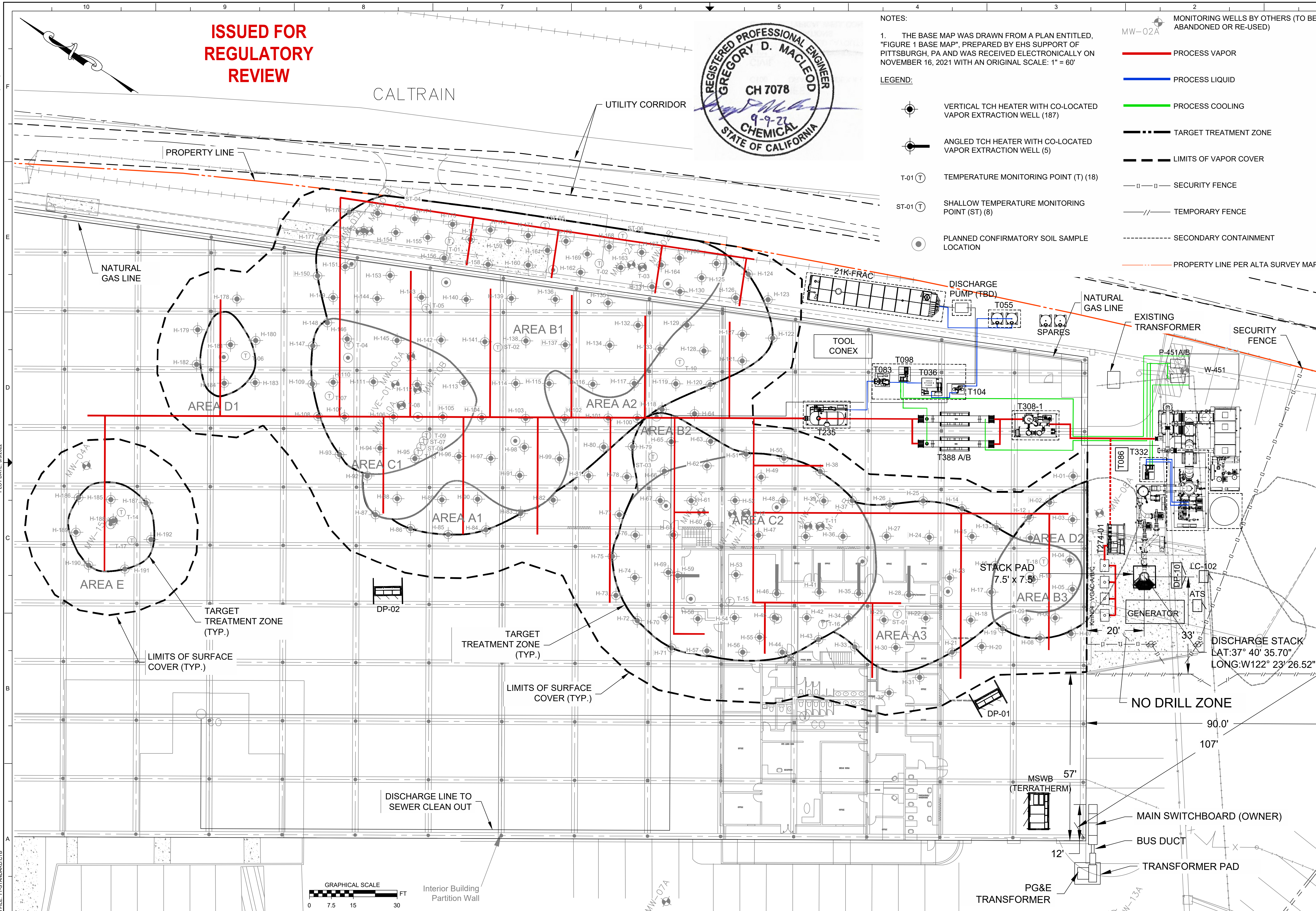
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

ELECTRICAL ONE LINE

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: --
SHEET: 3 OF 3
DWG NO.: E101

PLOT DATE: 9/9/2022
FILE: J:\...PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\E101-ELECTRICAL ONE LINE.DWG
CTB FILE: TT-STANDARD.CTB



REV	DATE	DESCRIPTION	CAD	ENG	DL
F	9/9/2022	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS	RH	GM	SG
E	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	RH	GM	
D	7/25/2022	REVISED VAPOR CAP AND WELLFIELD ALONG EXTERIOR BUILDING FENCE LINE - DESIGN DRAFT	RH	GM	
C	6/10/2022	90% DRAFT DESIGN	RH	GM	

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

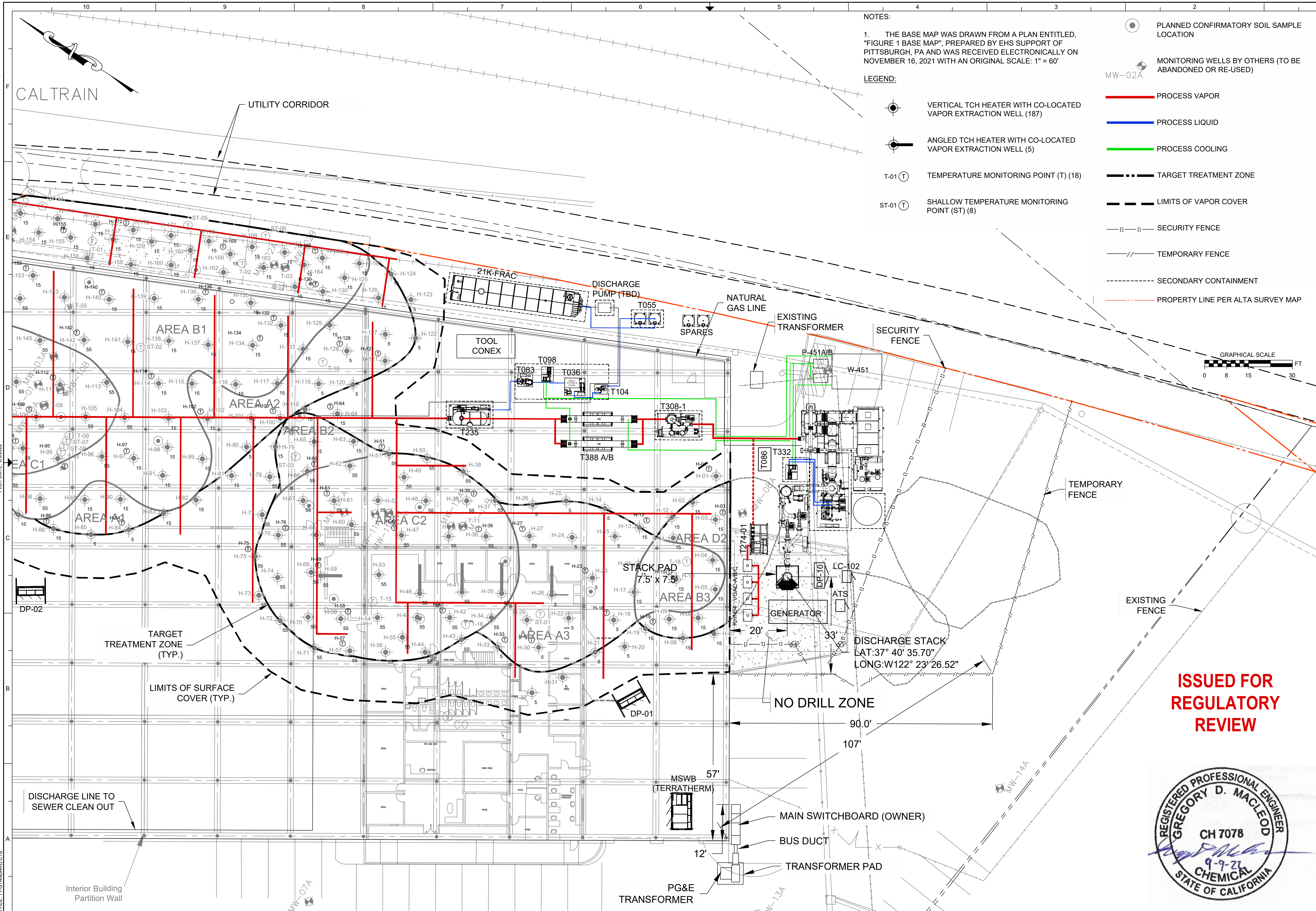
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

MECHANICAL LAYOUT

SCALE: AS SHOWN
SHEET SIZE: D
REV: F
REFERENCE NO.:
SHEET: 1 OF 2
DWG NO.: M101

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\M101-MECHANICAL LAYOUT.DWG
CTB FILE: TT-STANDARD.CTB



NOTES:

1. THE BASE MAP WAS DRAWN FROM A PLAN ENTITLED, "FIGURE 1 BASE MAP", PREPARED BY EHS SUPPORT OF PITTSBURGH, PA AND WAS RECEIVED ELECTRONICALLY ON NOVEMBER 16, 2021 WITH AN ORIGINAL SCALE: 1" = 60'

LEGEND:

- VERTICAL TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (187)
- ANGLED TCH HEATER WITH CO-LOCATED VAPOR EXTRACTION WELL (5)
- T-01 TEMPERATURE MONITORING POINT (T) (18)
- ST-01 SHALLOW TEMPERATURE MONITORING POINT (ST) (8)
- PLANNED CONFIRMATORY SOIL SAMPLE LOCATION
- MW-02A MONITORING WELLS BY OTHERS (TO BE ABANDONED OR RE-USED)
- PROCESS VAPOR
- PROCESS LIQUID
- PROCESS COOLING
- TARGET TREATMENT ZONE
- LIMITS OF VAPOR COVER
- SECURITY FENCE
- TEMPORARY FENCE
- SECONDARY CONTAINMENT
- PROPERTY LINE PER ALTA SURVEY MAP

ISSUED FOR REGULATORY REVIEW

REV	DATE	DESCRIPTION	CAD	ENG	DL
F	9/9/2022	ADJUSTED SHALLOW TEMPERATURE MONITORING POINTS	RH	GM	SG
E	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	RH	GM	DM
D	7/25/2022	REVISED VAPOR CAP AND WELLFIELD ALONG EXTERIOR BUILDING FENCE LINE - DESIGN DRAFT	RH	GM	DM
C	6/10/2022	90% DRAFT DESIGN	RH	GM	DM

TERRATHERM a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

MECHANICAL LAYOUT

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 CHEMICAL STATE OF CALIFORNIA 9-9-22

SCALE: AS SHOWN
SHEET SIZE: D
REV: F
REFERENCE NO.:
SHEET: 2 OF 2
DWG NO.: M101

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\M101-MECHANICAL LAYOUT.DWG
CTB FILE: TT-STANDARD.CTB

IDENTIFICATION LETTERS

SYMBOL	FIRST-LETTER: MEASURED VARIABLE (8)	FIRST-LETTER: VARIABLE MODIFIER (9)	SUCCEEDING-LETTERS: READOUT/PASSIVE FUNCTION (10)	SUCCEEDING-LETTERS: OUTPUT/ACTIVE FUNCTION (10)	SUCCEEDING-LETTERS: FUNCTION MODIFIER (11)
A	ANALYSIS (3)		ALARM		
B	BURNER, COMBUSTION				
C	CONDUCTIVITY (1)			CONTROL	CLOSE (3)
D	DENSITY (1)	DIFFERENTIAL			DEVIATION (3)
E	VOLTAGE		ELEMENT		
F	FLOW	RATIO			
G	PH (2)		GAUGE (5)		
H	HAND				HIGH
I	CURRENT		INDICATE (5)		MIDDLE
J	POWER		SCAN (3)		
K	TIME	DERIVATIVE with time		CONTROL STATION (3)	
L	LEVEL		LIGHT		LOW
M	MOISTURE (1)				
N	LEL (2)				
O			RESTRICTION		OPEN (3)
P	PRESSURE		POINT (TEST CONNECTION)		
Q	QUANTITY	INTEGRAL, TOTALIZE	INTEGRAL, TOTALIZE		
R	RADIATION (3)		RECORD		RUN (3)
S	SPEED, FREQUENCY	SAFETY (7)		SWITCH	STOP (3)
T	TEMPERATURE			TRANSMIT, TRANSMITTER	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	
V	VIBRATION (3)			VALVE, DAMPER, LOUVER	
W	WEIGHT (3)		WELL, PROBE		
X	DRAWING SPECIFIC (4)	DRAWING SPECIFIC (4), X-AXIS (3)		DRAWING SPECIFIC (4)	DRAWING SPECIFIC (4)
Y	EVENT, STATE	Y-AXIS (3)		AUXILIARY DEVICES	
Z	POSITION	SAFETY INSTRUMENTED SYSTEM (7)			

TYPICAL LETTER COMBINATIONS

SYMBOL	CONTROLLERS: RECORDING	CONTROLLERS: INDICATING	CONTROLLERS: BLIND	CONTROLLERS: SELF-ACTUATED CONTROL VALVES	READOUT DEVICES: RECORDING	READOUT DEVICES: INDICATING	SWITCHES AND ALARM DEVICES: HIGH	SWITCHES AND ALARM DEVICES: LOW	SWITCHES AND ALARM DEVICES: COMB	TRANSMITTERS: RECORDING	TRANSMITTERS: INDICATING	TRANSMITTERS: BLIND	SOLENOIDS, RELAYS, COMPUTING DEVICES	PRIMARY ELEMENT	TEST POINT	WELL OR PROBE	VIEWING DEVICE, GLASS	SAFETY DEVICE	FINAL ELEMENT
A	ARC	AIC	AC		AR	AI	ASH	ASL	ASHL	ART	AIT	AT	AY	AE	AP	AW			AV
B	BRC	BIC	BC		BR	BI	BSH	BSL	BSHL	BRT	BIT	BT	BY	BE		BW	BG		BZ
C	CRC	CIC	CC		CR	CI	CAH	CAL											
D																			
E	ERC	EIC	EC		ER	EI	ESH	ESL	ESHL	ERT	EIT	ET	EY	EE					EZ
F	FRC FQRC FFRC	FIC FQIC FFIC	FC FQC FFC	FCV, FICV	FR FQR FFR	FI FQI FFI	FSH FCSH FFSH	FSL FQSL FFSL	FSHL	FRT	FIT FQIT	FT FQT	FY FQY	FE FCE FFE	FP		FG		FV FQV FFV
G	GRC	GIC	GC		GR	GI	GSH	GSL	GSHL	GRT	GIT	GT		GE					
H		HIC	HC						HS										HV
I	IRC	IIC			IR	II	ISH	ISL	ISHL	IRT	IIT	IT	IY	IE					IZ
J	JRC	JIC			JR	JI	JSH	JSL	JSHL	JRT	JIT	JT	JY	JE					JV
K	KRC	KIC	KC	KCV	KR	KI	KSH	KSL	KSHL	KRT	KIT	KT	KY	KE					KV
L	LRC	LIC	LC	LCV	LR	LI	LSH	LSL	LSHL	LRT	LIT	LT	LY	LE		LW	LG		LV
M	MRC	MIC	MC		MR	MI	MSH	MSL	MSHL	MRT	MIT	MT		ME					
N	NRC	NIC	NC		NR	NI	NSH	NSL	NSHL	NRT	NIT	NT		NE					
O																			
P	PRC PDRC	PIC PDIC	PC PDIC	PCV PDCV	PR PDR	PI PDI	PSH PDSH	PSL PDSL	PSHL	PRT PDRT	PIT PDIT	PT PDT	PY PDY	PE PE	PP PP			PSV PSE	PV PDV
Q	QRC	QIC			QR	QI	QSH	QSL	QSHL	QRT	QIT	QT	QY	QE					QZ
R	RRC	RIC	RC		RR	RI	RSH	RSL	RSHL	RRT	RIT	RT	RY	RE		RW			RZ
S	SRC	SIC	SC	SCV	SR	SI	SSH	SSL	SSHL	SRT	SIT	ST	SY	SE					SV
T	TRC TDRC	TIC TDIC	TC TDC	TCV TDCV	TIR TDR	TI TDI	TSH TDSH	TSL TDSL	TSHL	TRT TDRT	TIT TDIT	TT TDT	TY TDY	TE TE	TP TP	TW TW		TSE	TV TDV
U					UR	UI							UY						UV
V					VR	VI	VSH	VSL	VSHL	VRT	VIT	VT	VY	VE					VZ
W	WRC WDRC	WIC WDIC	WC WDC	WCV WDCV	WR WDR	WI WDI	WSH WDSH	WSL WDSL	WSHL	WRT WDRT	WIT WDIT	WT WDT	WY WDY	WE WE					WZ WDZ
X																			
Y		YIC	YC		YR	YI	YSH	YSL				YT	YY	YE					YZ
Z	ZRC ZDRC	ZIC ZDIC	ZC ZDC	ZCV ZDCV	ZR ZDR	ZI ZDI	ZSH ZDSH	ZSL ZDSL	ZSHL	ZRT ZDRT	ZIT ZDIT	ZT ZDT	ZY ZDY	ZE ZDE					ZV ZDV

INSTRUMENT IDENTIFICATION

THIS INFORMATION IS BASED UPON ANSI/ISA-5.1-2009 INSTRUMENTATION SYMBOLS AND INDENTIIFICATION" AND ISA-5.3-1983 "GRAPHIC SYMBOLS FOR DISTRIBUTED CONTROL/SHARED DISPLAY INSTRUMENTATION, LOGIC AND COMPUTER SYSTEM. BOTH PUBLICATIONS ARE STANDARD OF ISA, INTERNATIONAL SOCIETY OF AUTOMATION.

EXPLANATORY NOTES FOR TABLE

1. TERRATHERM HAS CHOSEN THE SPECIFIC RECOMMENDED FIRST-LETTER LABELS FOR [C], [D] AND [M] PER THE STANDARD.
2. TERRATHERM HAS CHOSEN THE SPECIFIC LABEL FOR THE FIRST-LETTER [G] AS pH, AND [N] AS LEL.
3. LABELS ARE GIVEN PER THE STANDARD, BUT ARE UNCOMMON FOR TERRATHERM'S APPLICATIONS. THEIR USE SHOULD BE AVOIDED AND NO SUBSTITUTION FOR THEIR MEANINGS IS ALLOWED.
4. FIRST-LETTER OR SUCCEEDING-LETTER [X] IS USED AS "DRAWING SPECIFIC" AND IS TO BE DEFINED BY A NOTE ON THE DRAWING.
5. READOUT/PASSIVE FUNCTION LETTERS [G] AND [I] ARE DIFFERENTIATED BY A GAUGE READOUT HAVING ITS ELEMENT INTEGRAL TO THE INSTRUMENT AND AN INDICATION READOUT BEING SEPARATE FROM ITS ELEMENT.
6. READOUT/PASSIVE FUNCTION LETTER [L] INDICATED A LIGHT THAT IS INTENDED TO INDICATE OPERATING STATUS AND IS NOT INTENDED FOR ALARM INDICATION.
7. VARIABLE MODIFIER LETTERS [S] AND [Z] ARE DIFFERENTIATED RESPECTIVELY AS SAFETY VALVES WITH THE VARIABLE LETTERS [F] FLOW, [P] PRESSURE OR [T] TEMPERATURE; AND AS COMPONENTS OF A SAFETY INSTRUMENTED SYSTEM.
8. ALL INSTRUMENT LABELS MUST BEGIN WITH A LETTER FROM THE "MEASURED VARIABLE" COLUMN. NO OTHER LETTERS NOR MEANINGS ARE ALLOWED.
9. "VARIABLE MODIFIER" IS USED AS REQUIRED AS IN THE CASE OF A [DPS] DIFFERENTIAL PRESSURE SWITCH OR AS A [PSV] PRESSURE SAFETY VALVE.
10. "READOUT/PASSIVE FUNCTION" AND OUTPUT/ACTIVE FUNCTION" CAN BE USED CONSECUTIVELY, AS IN THE CASE OF A [PDIS] DIFFERENTIAL PRESSURE INDICATION SWITCH OR A [LIT] LEVEL INDICATION TRANSMITTER.
11. "FUNCTION MODIFIER" ARE USED TO DIFFERENTIATE THE RELATIVE POSITION OF SWITCHES AND ALARMS. THE COMBINATION OF [HH] HIGH-HIGH IS AN ACCEPTABLE PRACTICE.

HAND SWITCH DESIGNATIONS

E -EMERGENCY STOP

J -JOG

2PBL -2 PUSH BUTTONS (ON-OFF) MOMENTARY WITH BACK LIGHT(S)

2PB -2 MOMENTARY PUSH BUTTONS (ON-OFF)

JSR -JOG, STOP, RUN

HOA -HAND, OFF, AUTO

SS -START, STOP

OC -OPEN, CLOSE

OCA -OPEN, CLOSE, AUTO

MR -MANUAL, REMOTE

FOR -FORWARD, OFF, REVERSE

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

SEAL

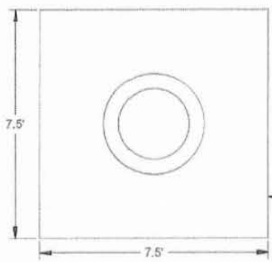
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

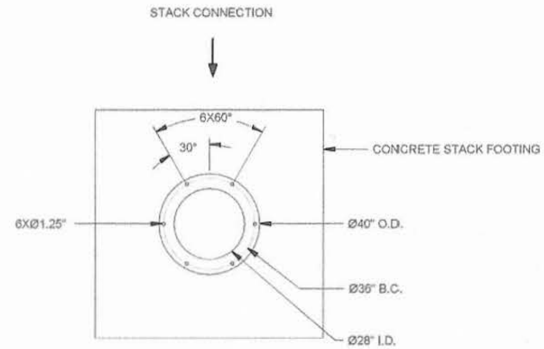
PROCESS LEGEND

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: -
SHEET: 1 OF 4
DWG NO.: P100

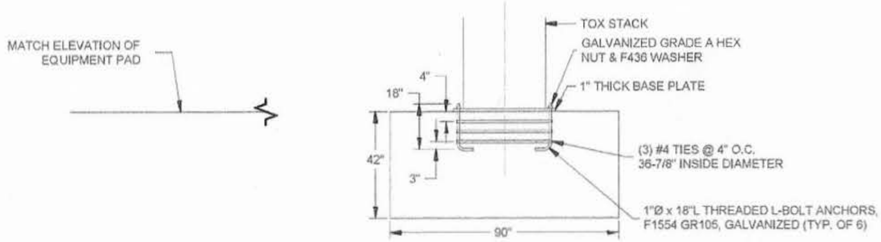
ISSUED FOR REGULATORY REVIEW



CONCRETE FOOTING DIMENSIONS



STACK BASE BOLT PATTERN



EQUIPMENT STACK PAD DETAILS 7.5' x 7.5'

NOTE:

1. CONCRETE COMPRESSIVE STRENGTH, f'c = 4,000 psi.
2. ANCHOR BOLT DESIGN BASED ACI 318-19 AND ASME STS-1 2016.
3. WIND AND SEISMIC DESIGN LOADS PER ASCE 7-16, RISK CATEGORY III, WIND EXPOSURE C, SEISMIC SIGHT CLASS D. USGS DATA FOR 3775 BAYSHORE BLVD. BRISBANE, CA.
4. DESIGN STACK HEIGHT 45 FT.

REGISTERED PROFESSIONAL ENGINEER RICHARD T HALLMAN 36872 MECHANICAL STATE OF CALIFORNIA

REV	DATE	CHD	ENG	DL	DESCRIPTION	DM	DP
1	[illegible]	GN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
0	[illegible]	RH	JW	JW	DRAFT FOR PROCUREMENT	DM	

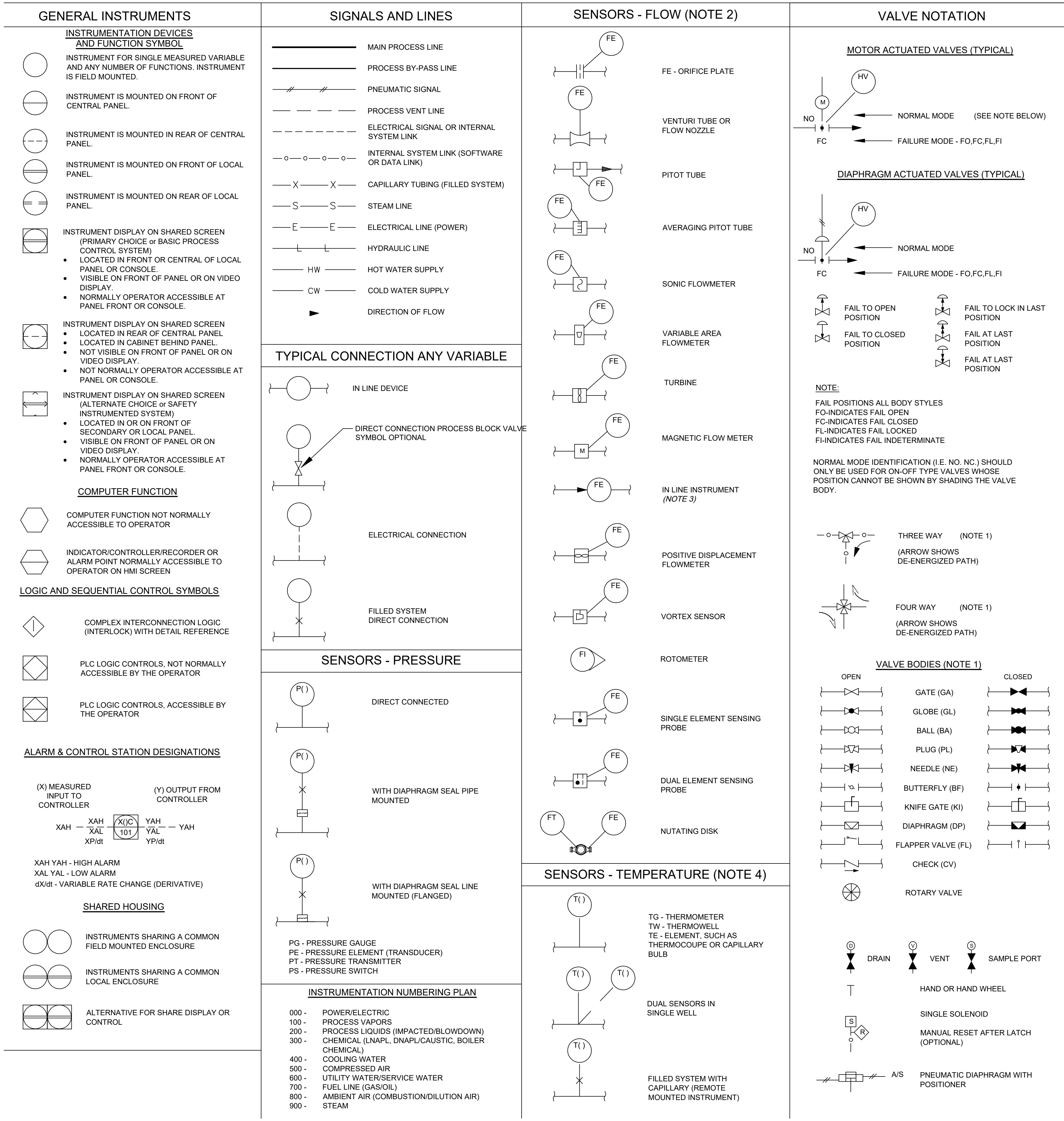
THIS DOCUMENT CONTAINS CONFIDENTIAL INFORMATION OWNED BY TERRATHERM, INC. UNAUTHORIZED DISCLOSURE IS PROHIBITED.

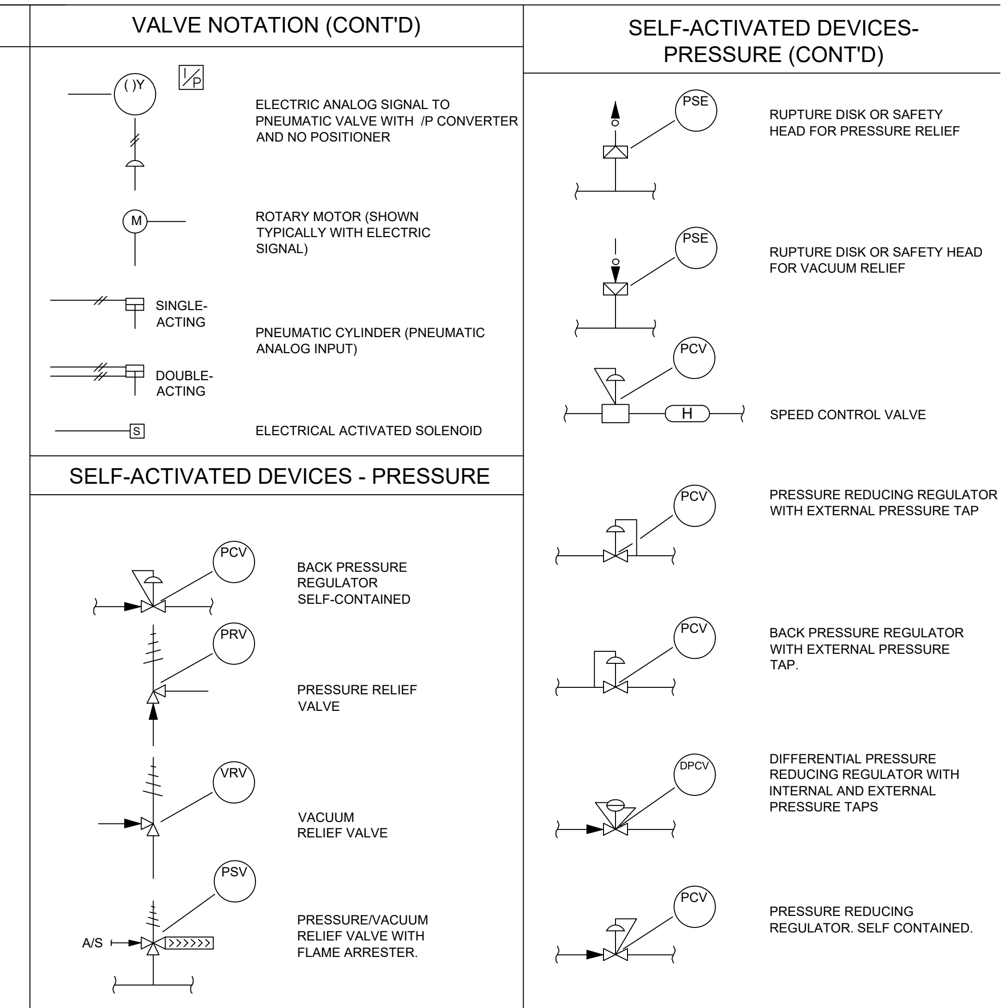
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

CONCRETE STACK PAD DETAIL 7.5 x 7.5

SCALE: NTS
SHEET SIZE: D
REV: 1
SHEET: 1 OF 1
DWG NO: M104





THIS INFORMATION IS BASED UPON ANSI/ISA-5.1-2009 INSTRUMENTATION SYMBOLS AND IDENTIFICATION" AND ISA-5.3-1983 "GRAPHIC SYMBOLS FOR DISTRIBUTED CONTROL/SHARED DISPLAY INSTRUMENTATION, LOGIC AND COMPUTER SYSTEM. BOTH PUBLICATIONS ARE STANDARDS OF ISA, INTERNATIONAL SOCIETY OF AUTOMATION.

NOTES:

1. VALVE-BODY PORTS THAT ARE CLOSED IN NORMAL OPERATION ARE BLACKENED. THE OPERATING CONDITION SHOWN FOR MAIN VALVE BODIES CORRESPONDS TO FULL-LOAD OR NORMAL OPERATION REGARDLESS OF THE TYPE OF ACTUATOR SOLENOID PILOT VALVE SHALL BE SHOWN IN THEIR DE-ENERGIZE POSITION.
2. IDENTIFY BOTH THE ACTUAL ELEMENT WHICH IS PLACED IN THE LINE AND THE INSTRUMENT UNLESS THE DEVICE IS ONE UNIT:
   FE ORIFICE PLATE: FT TRANSMITTER
   FT MAGNETIC FLOWMETER WITH INTEGRAL TRANSMITTER
3. THE TYPE OF FLOW INSTRUMENT IS USUALLY NAMED OUTSIDE THE INSTRUMENT CIRCLE E.G. MAGNETIC FLOWMETER, DISPLACEMENT METER, MASS FLOWMETER.
4. TAG THE THERMOWELL SEPARATELY IF IT IS REMOTE MOUNTED FROM THE INSTRUMENT:
   TW, TIC REMOTE CAPILLARY
   TI DIAL THERMOMETER
   TE, TT THERMOCOUPLE AND TRANSMITTER

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

REV	DATE	CAD	ENG	DESCRIPTION	
C	9/5/2022	CN	GM	DP	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT
A	4/1/2022	CN	GM	DL	60% DESIGN DRAFT

THIS DOCUMENT CONTAINS CONFIDENTIAL INFORMATION OWNED BY TERRATHERM, INC. UNAUTHORIZED DISCLOSURE IS PROHIBITED.

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

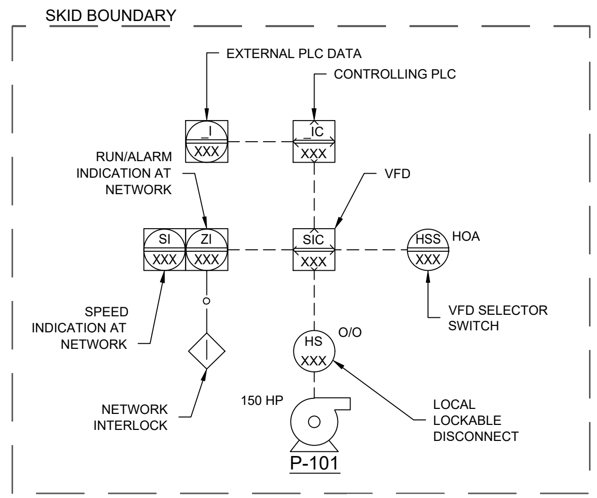
PROCESS LEGEND

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: -
SHEET: 2 OF 4
DWG NO.: P100

PLOT DATE: 9/9/2022
FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\100-PROCESS LEGEND.DWG
CTB FILE: TT-STANDARD.CTB

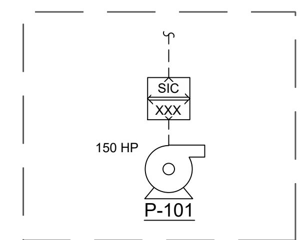
EXAMPLES

ISSUED FOR REGULATORY REVIEW



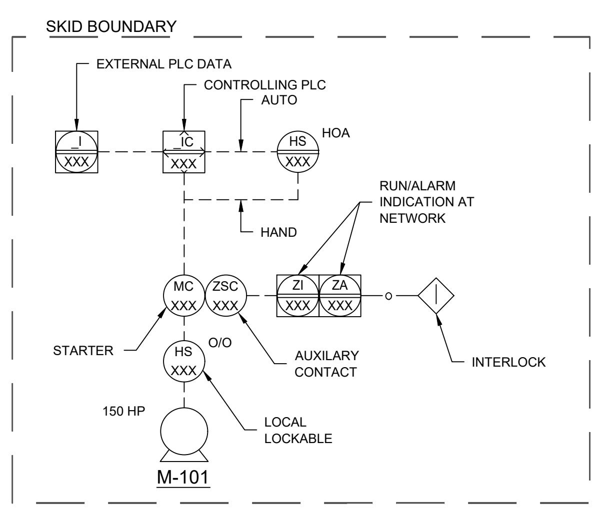
1 TYPICAL MOTOR SPEED (VFD) CONTROL LOOP DETAIL

NOT TO SCALE



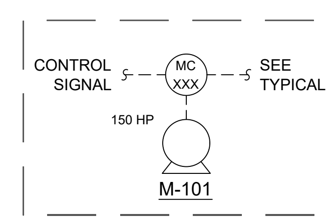
1 TYPICAL MOTOR SPEED CONTROL LOOP AS REPRESENTED IN P&ID

NOT TO SCALE



2 TYPICAL FIXED SPEED MOTOR CONTROL LOOP DETAIL

NOT TO SCALE



2 TYPICAL FIXED SPEED MOTOR CONTROL LOOP AS REPRESENTED IN P&ID

NOT TO SCALE

SEAL

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PROCESS LEGEND

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: -
SHEET: 3 OF 4
DWG NO.: P100

PLOT DATE: 9/9/2022

FILE: J:\...\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\100-PROCESS LEGEND.DWG
CTB FILE: TT-STANDARD.CTB

PROCESS LEGEND

GENERAL EQUIPMENT

- AGITATOR
- AIR COMPRESSOR
- AIR STRIPPER
- BLOWER, COMBUSTION
- BLOWER, ROTARY LOBE, VAPOR
- BLOWER, ROTARY VANE
- BATCH CENTRIFUGES
- CARBON VESSEL, LIQUID/VAPOR PHASE
- CENTRIFUGAL FAN
- CONTINUOUS CENTRIFUGES
- CLARIFIERS, THICKENERS
- DUST COLLECTORS, PRECIPITATORS
- FILTER, CARTRIDGE
- FILTER, BAG/SAND
- FILTERS, ROTARY VACUUM
- FIRED HEATERS

GENERAL EQUIPMENT (CONT'D)

- HEAT EXCHANGER
- PLATE & FRAME HEAT EXCHANGER
- HEAT RECOVERY HEAT EXCHANGER
- PUMP, SUMP
- PUMP, SUBMERSIBLE
- PUMP, VERTICAL
- PUMP, POSITIVE DISPLACEMENT
- PUMP, PROGRESSIVE CAVITY
- PUMP, CENTRIFUGAL
- PUMP, SUMP WITH MECHANICAL FLOAT SWITCH
- PUMP, GEAR
- PUMP, DOUBLE DIAPHRAGM
- PRESSURE VESSEL
- TRAY, DISC & DONUT, CASCADE
- PACKED DISTILLATION, ABSORBERS, ABSORBERS

GENERAL EQUIPMENT (CONT'D)

- PARTIAL CONDENSERS, TUBE SIDE
- PARTIAL CONDENSERS, SHELL SIDE
- OIL/WATER SEPARATOR
- QUENCH/SCRUBBER
- HEAD TANK/OPEN TANK
- TANK, CONE BOTTOM
- TANK W/CONE ROOF
- TANK, MOISTURE SEPARATOR
- TANK WITH SPILL TRAY
- 55 GAL. TANK

GENERAL EQUIPMENT (CONT'D)

- KILNS/DRYERS
- THERMAL OXIDIZER
- REVERSE OSMOSIS
- ROTARY, CENTRIFUGAL & WATER SEALED COMPRESSORS & VACUUM PUMPS
- TURBINES & EXPANDERS
- SCREW CONVEYOR
- STATIC MIXER
- STEAM BOILER
- COOLING TOWER
- WATER SOFTNER
- WATER SOFTNER WITH BRINE STORAGE

GENERAL PIPING

- DIRECTION OF FLOW
- CONCENTRIC REDUCER OR INCREASER
- ECCENTRIC REDUCER
- EXPANSION JOINT
- FLEXIBLE CONNECTION
- SCREWED CAP
- HOSE CONNECTION
- ATMOSPHERIC VENT
- CONSERVATION VENT
- QUICK CONNECT/DISCONNECT COUPLINGS W/FLEXIBLE HOSE
- WELDED CAP
- FLANGED JOINT
- PLUG
- DRAIN
- INSULATED LINE
- HEAT TRACING (E, S, HW)
- VENT FLAME ARRESTOR
- SIGHT GLASS
- UNION JOINT
- BLIND FLANGED LINE OR VALVE
- TRAP (T)
- LINE FILTER (F)
- SPRAY NOZZLE
- PUSH TO CONNECT FITTING
- LINE BREAK IDENTIFICATION (AS, CWS, CWR)
- STRAINER (STR-1)
- DUPLEX STRAINER (STR-2)
- WYE STRAINER (STR)
- VENTURI (EDUCTOR)
- BASKET STRAINER
- AIR TRAP

LINE IDENTIFICATION

8"–CS40–AS–CWR–105

- LINE NUMBER
- FLUID TYPE
- PIPE INSULATION
- PIPE SPECIFICATIONS
- NOMINAL PIPE DIAMETER

LINE SERVICE DESIGNATION

PIPE SPECIFICATIONS

- ABS: ACRYLONITRILE BUTADIENE STYRENE
- CA: CHEMAIRE TYPE ABS
- CPVC: CHLORINATED POLYVINYL CHLORIDE
- CS: CARBON STEEL
- FRP: FIBERGLASS-REINFORCED PLASTIC
- NT: NYLON TUBING
- PH: PETROLEUM HOSE
- PVC: RIGID POLY-VINYL-CHLORIDE
- RH: RUBBER HOSE
- SS: STAINLESS STEEL
- TT: TEFLON TUBING
- CU: COPPER

PIPE INSULATION TYPE

- AS: ANTI-SWEAT
- AU: ACOUSTIC
- IC: COLD (HEAT TRACE & INSULATE)
- IH: HOT
- IS: SAFETY
- PP: PERSONAL PROTECTION
- N: NONE

FLUID TYPE

- AA: AMBIENT AIR
- AS: COMPRESSED AIR
- CH: CHEMICAL FEED
- CW: COOLING WATER
- IA: INSTRUMENT AIR
- AS: NATURAL GAS
- PG: PROCESS GAS
- PL: PROCESS LIQUID
- PW: POTABLE WATER
- SL: SLUDGE
- ST: STEAM
- VE: VAPOR EXTRACTION
- VG: VENT GAS (OFFGAS)
- PV: PROCESS VAPOR
- UW: UTILITY WATER
- CWR: COLD WATER RETURN
- CWS: COLD WATER SUPPLY

ISSUED FOR REGULATORY REVIEW

REGISTERED PROFESSIONAL ENGINEER — GREGORY D. MACLEOD — CH 7078 — CHEMICAL — STATE OF CALIFORNIA — 9-9-22

EQUIPMENT NUMBER IDENTIFICATION

T – 101 A

- DUPLICATE OR SPARE
- SEQUENCE NUMBER
- EQUIPMENT LETTER (SEE BELOW)

A - AGITATOR
B - BLOWER
BN- BURNER NOZZLE
CP- CONTROL PANEL
C - CARBON MEDIA
D - DRIVE
E - HEAT EXCHANGER
F - FIRED EQUIPMENT
FX- FILTER
H - DUCT HEATER
M - MIXER, BLENDER
P - PUMP
PX- VENDOR PACKAGE SYSTEM
S - SEPARATOR
T - TANK
U - LUBRICATION PACKAGE
V - VESSEL
W - COOLING TOWER
WX- WEIRS
X - VENT STACKS
Y - MISCELLANEOUS
Z - MISCELLANEOUS EQUIPMENT
ZX- PIPING EXPANSION JOINT

MISCELLANEOUS

- ALARM HORN
- LINE BREAK OR RESUMPTION POINT (1ST, DWG.#)
- BATTERY LIMITS (B/L)
- FILLED LINE
- STEAM TRAP (T)
- PUMP W/LIQUID SEAL FLUSH
- PUMP W/INTERNAL SAFETY RELIEF
- SPECIALTY ITEM
- SPRAY NOZZLE OR SPARGER

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

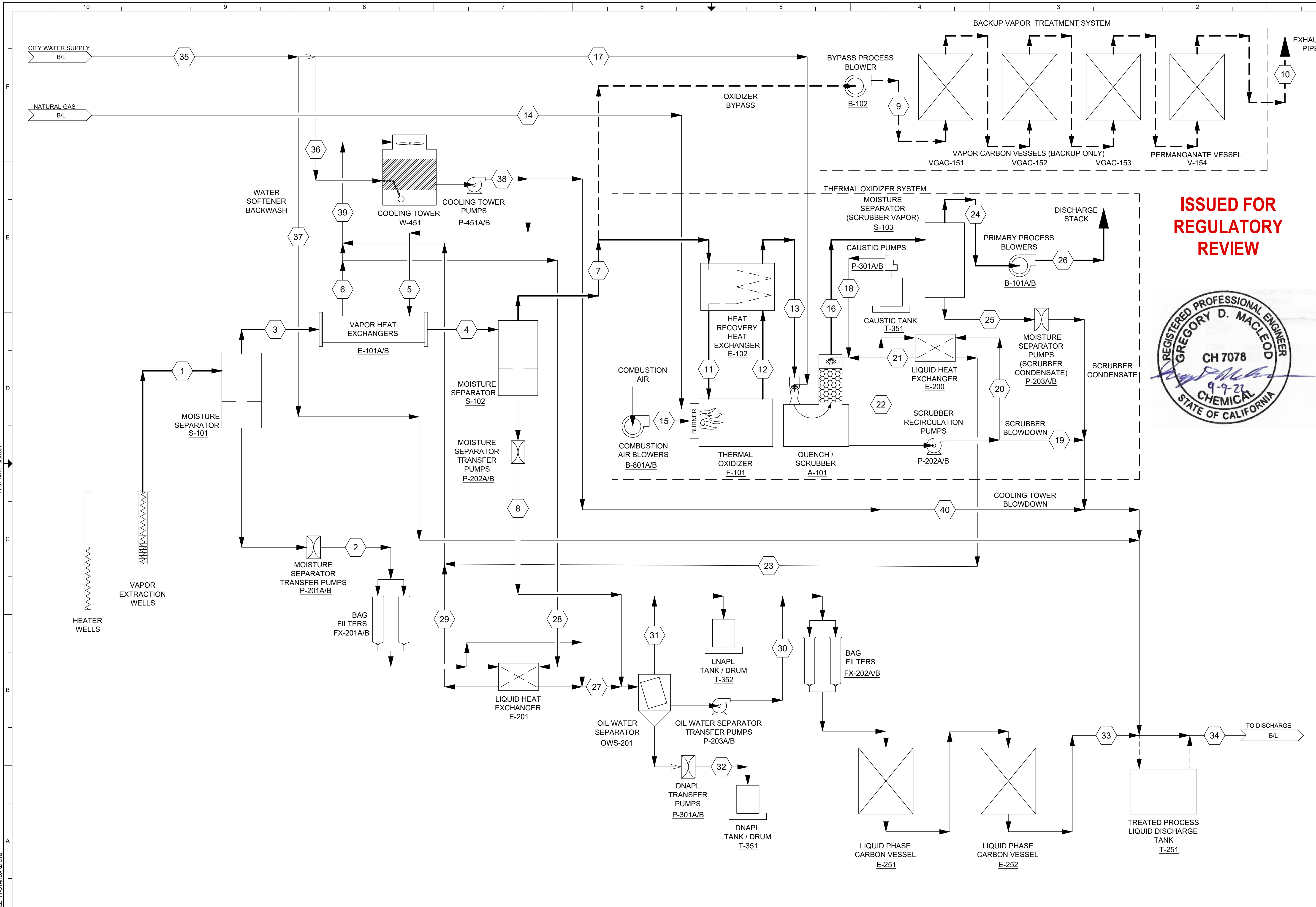
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PROCESS LEGEND

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.: -
SHEET: 4 OF 4
DWG NO.: P100

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\-100-PROCESS LEGEND.DWG
CTB FILE: TT-STANDARD.CTB



REV	DATE	CAD	ENG	DESCRIPTION	CM	PM
D	8/5/2022	CN	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
C	6/10/2022	CN	GM	90% DESIGN DRAFT	NH	DP
B	4/1/2022	CN	GM	60% DESIGN DRAFT		DP
A	11/12/2021	CN	JW	ISSUED FOR PERMITTING	GM	SK

SEAL

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PROCESS FLOW DIAGRAM
TOX BASED SYSTEM W/ FRONT END COOLING

SCALE: NTS
SHEET SIZE: D
REV: D
REFERENCE NO.:
SHEET: 1 OF 3
DWG NO.: P101

PLOT DATE: 9/9/2022

FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\101-PFD.DWG
CTB FILE: TT-STANDARD.CTB

STREAM NUMBER:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
STREAM ID:	WELLFIELD INFLUENT TO VAPOR TREATMENT	SEPARATOR S-101 CONDENSATE	HEX E-101A/B INLET	HEX E-101A/B OUTLET	COOLING WATER SUPPLY TO E-101A/B	COOLING WATER RETURN FROM E-101A/B	SEPARATOR S-102 OUTLET VAPOR	SEPARATOR S-102 CONDENSATE	VACUUM BLOWER B-101A/B OUTLET	STACK OUTLET VAPOR	THERMAL OXIDIZER INLET	THERMAL OXIDIZER OUTLET	SCRUBBER INLET VAPOR	OXIDIZER NATURAL GAS SUPPLY
Temperature (°F)	185	183	183	100	72	82	100	100	130	115	950	1,800	1,518	74
PressureVap (in wc ga)	-20		-28	-31			-34		20	-5	-30	-35	-40	139
PressureVap (in wc abs)	387		379	376			373		427	402	377	372	367	546
PressureLiq (psig)		59			40	30		52						
Relative Humidity														
Vapor														
Non-condensables														
Molar (lbmol/hr)	152		152	152			152		152	152	152	196	196	
Mass (lb/hr)	4,399		4,399	4,399			4,399		4,399	4,399	4,399	5,603	5,603	
SCFM (1 atm, 68°F)	975		975	975			975		975	975	975	1,256	1,256	
SCFM N2	770		770	770			770		770	770	770	1,054	1,054	
SCFM O2	205		205	205			205		205	205	205	201	201	
ACFM	1,253		1,275	1,119			1,128		1,039	1,075	2,812	5,883	5,220	
Volume %	46%		46%	93%			93%		93%	93%	93%	86%	86%	
Enthalpy (BTU/hr)	680,279		678,151	590,015			590,015		621,848	605,949	1,047,152	2,657,561	2,213,366	
Water														
Molar (lbmol/hr)	178		178	11			11		11	11	11	23	23	
Mass (lb/hr)	3,210		3,210	206			206		206	206	206	419	419	
SCFM (1 atm, 68°F)	1,144		1,144	73			73		73	73	73	149	149	
ACFM	1,470		1,496	84			85		78	81	212	700	621	
Volume %	54%		54%	7%			7%		7%	7%	7%	10%	10%	
Enthalpy (BTU/hr)	3,661,562		3,658,994	227,665			227,665		230,301	228,983	310,555	825,570	758,883	
COC														
Molar (lbmol/hr)	0.54		0.54	0.53			0.53		0.53	0.01	0.53	0.00	0.00	
Mass (lb/hr)	73.10		73.10	71.63			71.63		71.63	0.72	71.63	0.01	0.01	
SCFM (1 atm, 68°F)	3.45		3.45	3.39			3.39		3.39	0.03	3.39	0.00	0.00	
ACFM	4.44		4.52	3.89			3.92		3.61	0.04	9.76	0.00	0.00	
Volume %	0.16%		0.16%	0.32%			0.32%		0.32%	0.00%	0.32%	0.00%	0.00%	
Carbon Dioxide														
Molar (lbmol/hr)												6.93	6.93	
Mass (lb/hr)												304.78	304.78	
SCFM (1 atm, 68°F)												44.47	44.47	
ACFM												208.35	184.88	
Volume %												3.05%	3.05%	
Enthalpy (BTU/hr)												146,512	120,153	
Hydrogen Chloride														
Molar (lbmol/hr)												1.42	1.42	
Mass (lb/hr)												51.90	51.90	
SCFM (1 atm, 68°F)												9.14	9.14	
ACFM												42.82	38.00	
Volume %												0.63%	0.63%	
Enthalpy (BTU/hr)												17,806	15,021	
Natural Gas														
Molar (lbmol/hr)														5.34
Mass (lb/hr)														85.71
SCFM (1 atm, 68°F)														34.32
ACFM														25.90
Enthalpy (BTU/hr)														3,552
Total Vapor														
Molar (lbmol/hr)	331		331	164			164		164	163	164	227	227	5
Mass (lb/hr)	7,682		7,682	4,676			4,676		4,676	4,605	4,676	6,379	6,379	86
SCFM (1 atm, 68°F)	2,122		2,122	1,052			1,052		1,052	1,048	1,052	1,459	1,459	34
ACFM	2,727		2,776	1,207			1,217		1,120	1,156	3,033	6,834	6,064	26
Enthalpy (BTU/hr)	4,341,841		4,337,145	817,680			817,680		852,149	834,931	1,357,707	3,647,449	3,107,423	3,552
Liquid														
Water														
Molar (lbmol/hr)		0		167	18,407	18,407		167						
Mass (lb/hr)		0		3,004	331,693	331,693		3,004						
Volume (GPM)		0.00		6.00	662.86	662.86		6.00						
Enthalpy (BTU/hr)		0		204,523	13,301,230	16,616,172		204,523						
COC														
Mass (lb/hr)		0		1				1						
Concentration (mg/L)		0		486				486						
TDS														
Mass (lb/hr)														
mg/L														
NaOH														
Molar (lbmol/hr)														
Mass (lb/hr)														
mg/L														
Total Liquid (lb/hr)		0		3,006	331,693	331,693		3,006						

STREAM NUMBER:	15	16	17	18	19	20	21	22	23	24	25	26	27	28
STREAM ID:	COMBUSTION AIR TO THERMAL OXIDIZER	SCRUBBER DISCHARGE VAPOR	QUENCH WATER TO SCRUBBER	CAUSTIC SUPPLY TO SCRUBBER	SCRUBBER BLOWDOWN	SCRUBBER RECIRC TO E-200	SCRUBBER RECIRC FROM E-200	COOLING WATER SUPPLY TO E-200	COOLING WATER RETURN FROM E-200	SEPARATOR S-103 OUTLET VAPOR	SEPARATOR S-103 CONDENSATE	VAPOR DISCHARGE TO STACK	HEX E-201 OUTLET	COOLING WATER SUPPLY TO E-201
Temperature (°F)	74	168	55	95	105	105	95	72	112	163	163	188	100	82
PressureVap (in wc ga)	0	-44								-46		2		
PressureVap (in wc abs)	407	363								361		409		
PressureLiq (psig)			60		60	60	60	40	35		40		29	40
Relative Humidity														
Vapor														
Non-condensables														
Molar (lbmol/hr)	56	196								196		196		
Mass (lb/hr)	1,615	5,603								5,603		5,603		
SCFM (1 atm, 68°F)	360	1,256								1,256		1,256		
SCFM N2	284	1,054								1,054		1,054		
SCFM O2	75	201								201		201		
ACFM	364	1,676								1,672		1,535		
Volume %	98%	55%								59%		59%		
Enthalpy (BTU/hr)	206,532	230,239								223,347		257,838		
Water														
Molar (lbmol/hr)	1	153								127		127		
Mass (lb/hr)	21	2,762								2,283		2,283		
SCFM (1 atm, 68°F)	7	984								813		813		
ACFM	7	1,314								1,083		994		
Volume %	2%	43%								38%		38%		
Enthalpy (BTU/hr)	22,510	3,126,748								2,578,845		2,604,611		
COC														
Molar (lbmol/hr)		0.00								0.00		0.00		
Mass (lb/hr)		0.01								0.01		0.01		
SCFM (1 atm, 68°F)		0.00								0.00		0.00		
ACFM		0.00								0.00		0.00		
Volume %		0.00%								0.00%		0.00%		
Carbon Dioxide														
Molar (lbmol/hr)		6.93								6.93		6.93		
Mass (lb/hr)		304.78								304.78		304.78		
SCFM (1 atm, 68°F)		44.47								44.47		44.47		
ACFM		59.34								59.20		54.35		
Volume %		1.95%								2.10%		2.10%		
Enthalpy (BTU/hr)		10,727								10,397		12,055		
Hydrogen Chloride														
Molar (lbmol/hr)		0.01								0.01		0.01		
Mass (lb/hr)		0.52								0.52		0.52		
SCFM (1 atm, 68°F)		0.09								0.09		0.09		
ACFM		0.12								0.12		0.11		
Volume %		0.00%								0.00%		0.00%		
Enthalpy (BTU/hr)		17								16		19		
Natural Gas														
Molar (lbmol/hr)														
Mass (lb/hr)														
SCFM (1 atm, 68°F)														
ACFM														
Enthalpy (BTU/hr)														
Total Vapor														
Molar (lbmol/hr)	57	356								329		329		
Mass (lb/hr)	1,636	8,670								8,191		8,191		
SCFM (1 atm, 68°F)	367	2,285								2,114		2,114		
ACFM	371	3,049								2,814		2,583		
Enthalpy (BTU/hr)	229,042	3,367,731								2,812,606		2,874,523		
Liquid														
Water														
Molar (lbmol/hr)			260	9	172	2,083	2,083	500	500		27		31	260
Mass (lb/hr)			4,733	169	3,104	37,530	37,530	9,007	9,007		479		550	4,687
Volume (GPM)			9.46	0.34	6.20	75.00	75.00	18.00	18.00		0.96		1.10	9.37
Enthalpy (BTU/hr)			260,308	16,063	325,906	3,940,650	3,565,350	648,518	1,008,806		78,335		37,473	234,795
COC														
Mass (lb/hr)													2	
Concentration (mg/L)													3,557	
TDS														
Mass (lb/hr)					50									
mg/L					16,086									
NaOH														
Molar (lbmol/hr)				1										
Mass (lb/hr)				56										
mg/L				333,159										
Total Liquid (lb/hr)				225	3,154	37,530	37,530	9,007	9,007		479		552	4,687

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

ISSUED FOR REGULATORY REVIEW

REV	DATE	CAD	ENG		DESCRIPTION
D	8/5/2022	CN	GM	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENT
C	6/10/2022	CN	GM	NH	90% DESIGN DRAFT
B	4/1/2022	CN	GM		60% DESIGN DRAFT
A	11/12/2021	CN	JW	GM	ISSUED FOR PERMITTING

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

MASS & ENERGY BALANCE

SCALE: NTS
SHEET SIZE: D
REV: D
REFERENCE NO.:
SHEET: 2 OF 3
DWG NO.: P101

PLOT DATE: 9/9/2022
FILE: J:_PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS_101-PFD.DWG
CTB FILE: TT-STANDARD.CTB

STREAM NUMBER:	29	30	31	32	33	34	35	36	37	38	39	40
STREAM ID:	COOLING WATER RETURN FROM E-201	LIQUID CARBON LGAC-201-1/2 INLET	DISCHARGE TO LNAPL TANK	DISCHARGE TO DNAPL TANK	TREATED LIQUID TO DISCHARGE	TOTAL LIQUID DISCHARGE	TOTAL SITE MAKE UP WATER SUPPLY	MAKE UP WATER TO COOLING TOWER	WATER SOFTENER BACKWASH	TOTAL COOLING WATER SUPPLY	TOTAL COOLING WATER RETURN	COOLING TOWER BLOWDOWN (TO DISCHARGE)
Temperature (°F)	92	100	100	100	100	89	55	55	55	72	83	72
PressureVap (in wc ga)												
PressureVap (in wc abs)												
PressureLiq (psig)	35	37			13	8	60	60	60	40	35	40
Relative Humidity												
Vapor												
Non-condensables												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
SCFM N2												
SCFM O2												
ACFM												
Volume %												
Enthalpy (BTU/hr)												
Water												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Volume %												
Enthalpy (BTU/hr)												
COC												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Volume %												
Carbon Dioxide												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Volume %												
Enthalpy (BTU/hr)												
Hydrogen Chloride												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Volume %												
Enthalpy (BTU/hr)												
Natural Gas												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Enthalpy (BTU/hr)												
Total Vapor												
Molar (lbmol/hr)												
Mass (lb/hr)												
SCFM (1 atm, 68°F)												
ACFM												
Enthalpy (BTU/hr)												
Liquid												
Water												
Molar (lbmol/hr)	260	197			197	332	687	424	15	18,907	18,907	135
Mass (lb/hr)	4,687	3,555			3,555	9,840	12,374	7,641	275	340,700	340,700	2,427
Volume (GPM)	9.37	7.10			7.10	19.66	24.73	15.27	0.55	680.86	680.86	4.85
Enthalpy (BTU/hr)	281,628	241,996			241,996		285,697	176,419	6,355	13,662,427	17,408,088	
COC												
Mass (lb/hr)		3	0	0	0	0						
Concentration (mg/L)		962			10	3						
TDS												
Mass (lb/hr)						60			10			
mg/L						6,053			35,000			
NaOH												
Molar (lbmol/hr)						0						
Mass (lb/hr)						0						
mg/L						0						
Total Liquid (lb/hr)	4,687	3,558	0	0	3,555	9,900	12,374	7,641	285	340,700	340,700	2,427

ISSUED FOR REGULATORY REVIEW

SEAL

REV	DATE	CAD	ENG		DESCRIPTION	CM	PM
D	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
C	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
B	4/1/2022	CN	GM		60% DESIGN DRAFT		DP
A	11/12/2021	CN	JW	GM	ISSUED FOR PERMITTING		SK
				DL			

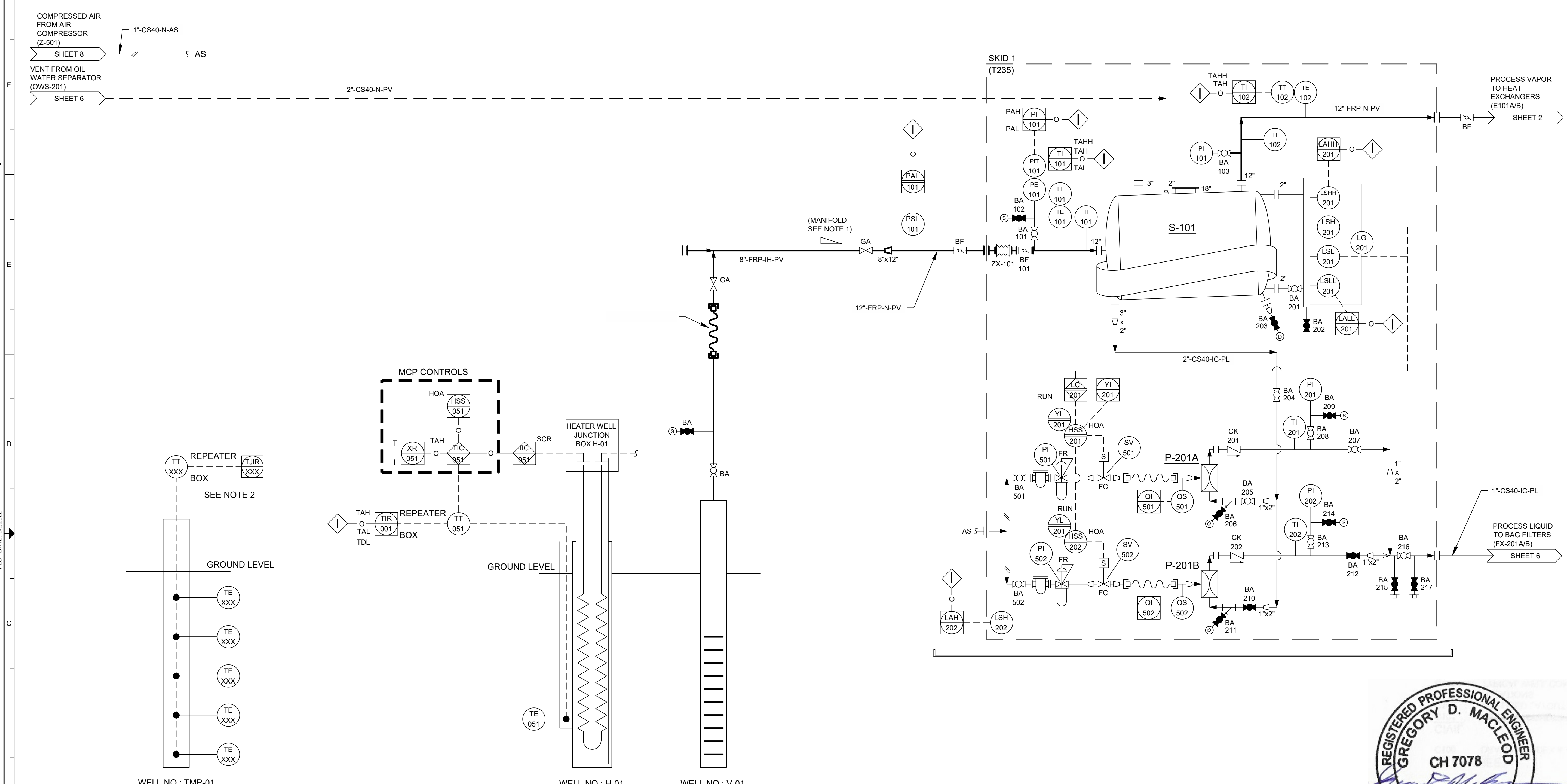
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.CASCADE-ENV.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

MASS & ENERGY BALANCE

SCALE: NTS
SHEET SIZE: D REV: D
REFERENCE NO.:
SHEET: 3 OF 3
DWG NO.: P101

PLOT DATE: 9/9/2022
FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\101-PFD.DWG
CTB FILE: TT-STANDARD.CTB



TYPICAL OF 18 TEMPERATURE MONITORING POINTS	
WELL NUMBER TAGS:	TMP-01 THRU TMP-18
REMOTE TERMINAL UNIT TAGS:	RTU-01 THRU RTU-18
NOTE: REFER TO CIVIL DRAWINGS FOR TE's DEPTHS.	

TYPICAL OF 8 SHALLOW TEMPERATURE MONITORING POINTS	
WELL NUMBER TAGS:	ST-01 THRU ST-08
REMOTE TERMINAL UNIT TAGS:	RTU-19 THRU RTU-26
NOTE: REFER TO CIVIL DRAWINGS FOR TE's DEPTHS.	

TYPICAL OF 192 HEATER BORINGS WITH CO-LOCATED VAPOR EXTRACTION WELLS	
HEATER BORING NUMBER TAGS:	H-01 THRU H-192
CO-LOCATED VAPOR EXTRACTION WELL NUMBER TAGS:	V-01 THRU V-192

NOTES:
1. TEMPERATURE ELEMENT (TE) IS INSTALLED ON ONE HEATER PER CIRCUIT LEG.
2. CO-LOCATED VAPOR EXTRACTION WELL NUMBERS CORRESPOND WITH HEATER WELL NUMBERS.

S-101
CONDENSATE SUMP TANK (FRONT END)
54" Ø x 140" OAL
FRP
RATED: 203 inwc VAC @ 230°F

P-201A/B
CONDENSATE SUMP TRANSFER PUMP
AIR OPERATED DOUBLE DIAPHRAGM
MAX FLOW: 52 GPM
MAX PRESSURE: 120 PSIG

NOTES:
1. SEE CIVIL SHEETS FOR MANIFOLD DETAILS
2. SEE ELECTRICAL DRAWINGS FOR ELECTRICAL REQUIREMENTS

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 CHEMICAL STATE OF CALIFORNIA 9-9-22

ISSUED FOR REGULATORY REVIEW

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

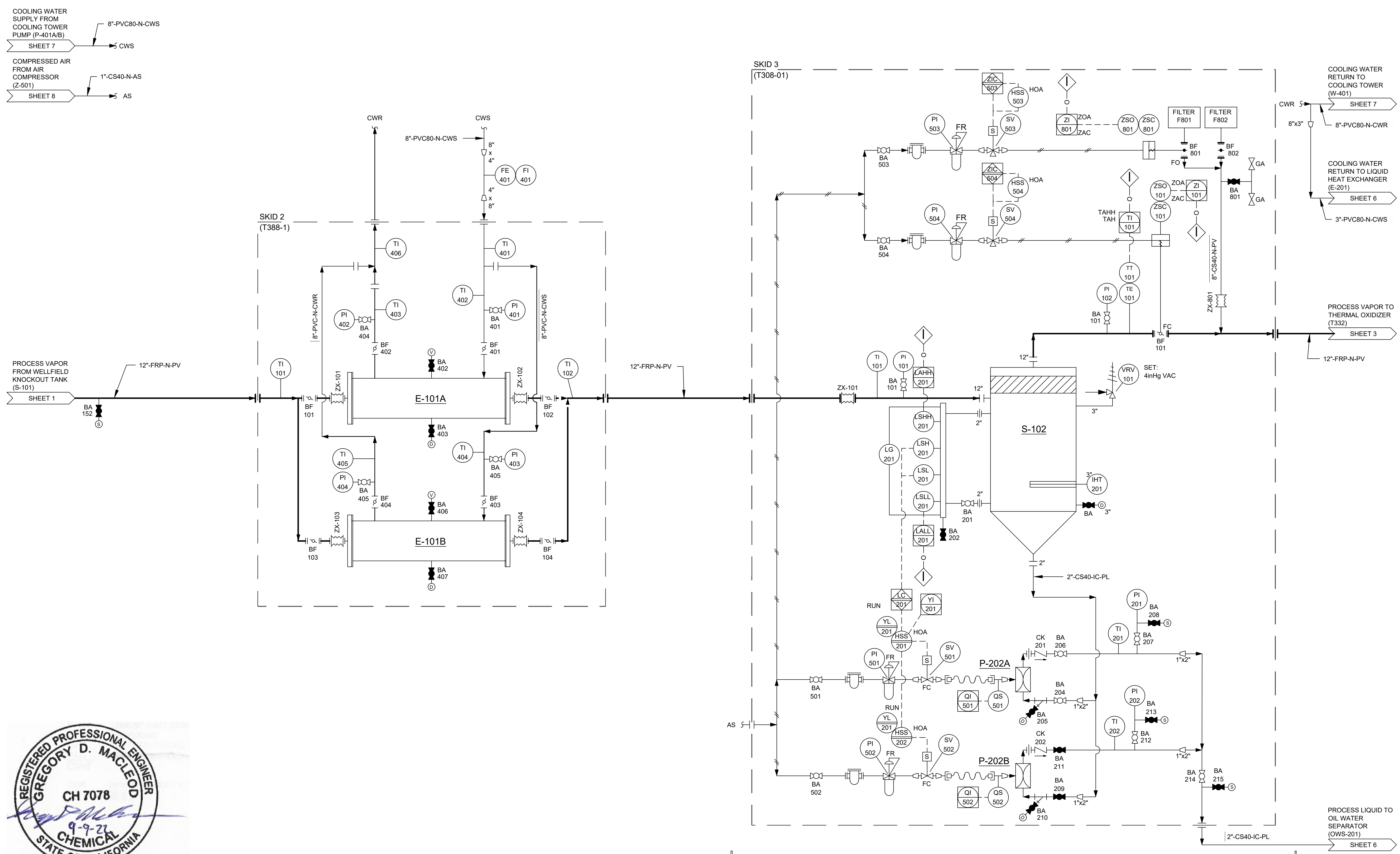
TERRATHERM a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 1 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\...\ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\...102-PNID.DWG
CTB FILE: TT-STANDARD.CTB



REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

ISSUED FOR REGULATORY REVIEW

E-101A/B
VAPOR HEAT EXCHANGER
CARBON STEEL SHELL & GRAPHITE TUBES
PRESSURE RATING: 75 PSIG/FV @ 340°F
(SHELL AND TUBE SIDES)
HEAT TRANSFER AREA: 983 FT ^{2}

S-102
MOISTURE SEPARATOR
FIBERGLASS VESSEL WITH DEMISTER PAD
3'-0" DIAMETER
PRESSURE RATING: -200" WC @ 230°F

P-202A/B
MOISTURE SEPARATOR PUMPS
DOUBLE DIAPHRAGM PUMP
52 GPM MAX, 120 PSIG MAX

REV	DATE	DESCRIPTION	CAD	ENG	CM	PM
C	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	CN	GM		DP
B	6/10/2022	90% DESIGN DRAFT	CN	GM	NH	DP
A	4/1/2022	60% DESIGN DRAFT	CN	GM		DP

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

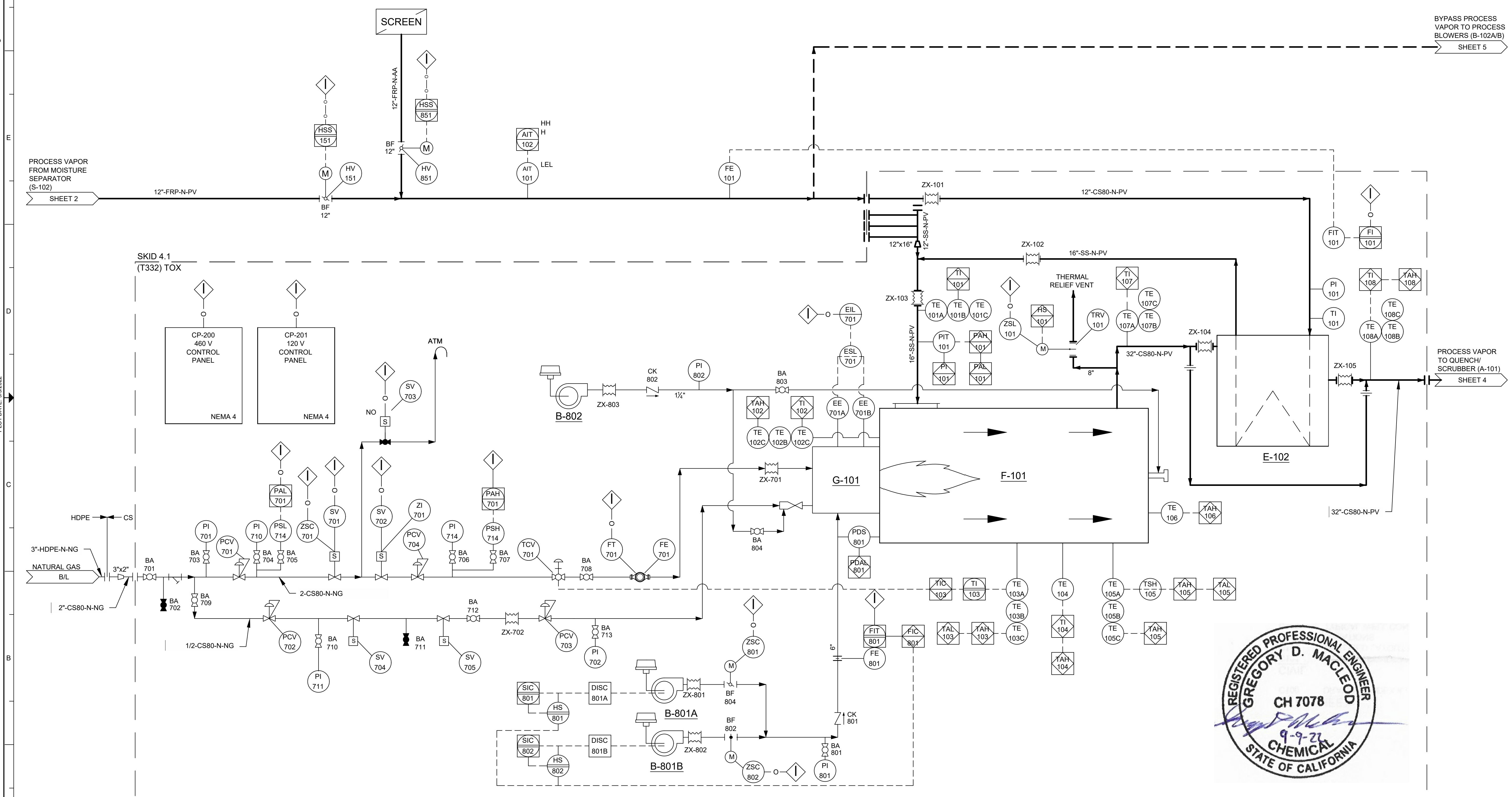
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
SHEET: 2 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

ISSUED FOR REGULATORY REVIEW



B-801A/B
COMBUSTION AIR BLOWER
5 HP, TEFC, FIX SPEED
460 VAC, 3 PHASE
500 SCFM @ 20IWC

B-802
PILOT AIR BLOWER
3/4 HP, TEFC, FIX SPEED
460 VAC, 3 PHASE

G-101
THERMAL OXIDIZER BURNER
NATURAL GAS
4.0 MM BTU/HR

F-101
THERMAL OXIDIZER
1,800° F OPERATING TEMP
1,500 SCFM DESIGN

E-102
HEAT RECOVERY HEAT EXCHANGER
310SS

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

REV	DATE	CAD	ENG	DESCRIPTION
C	8/5/2022	CN	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS
B	6/10/2022	CN	GM	90% DESIGN DRAFT
A	4/1/2022	CN	GM	60% DESIGN DRAFT

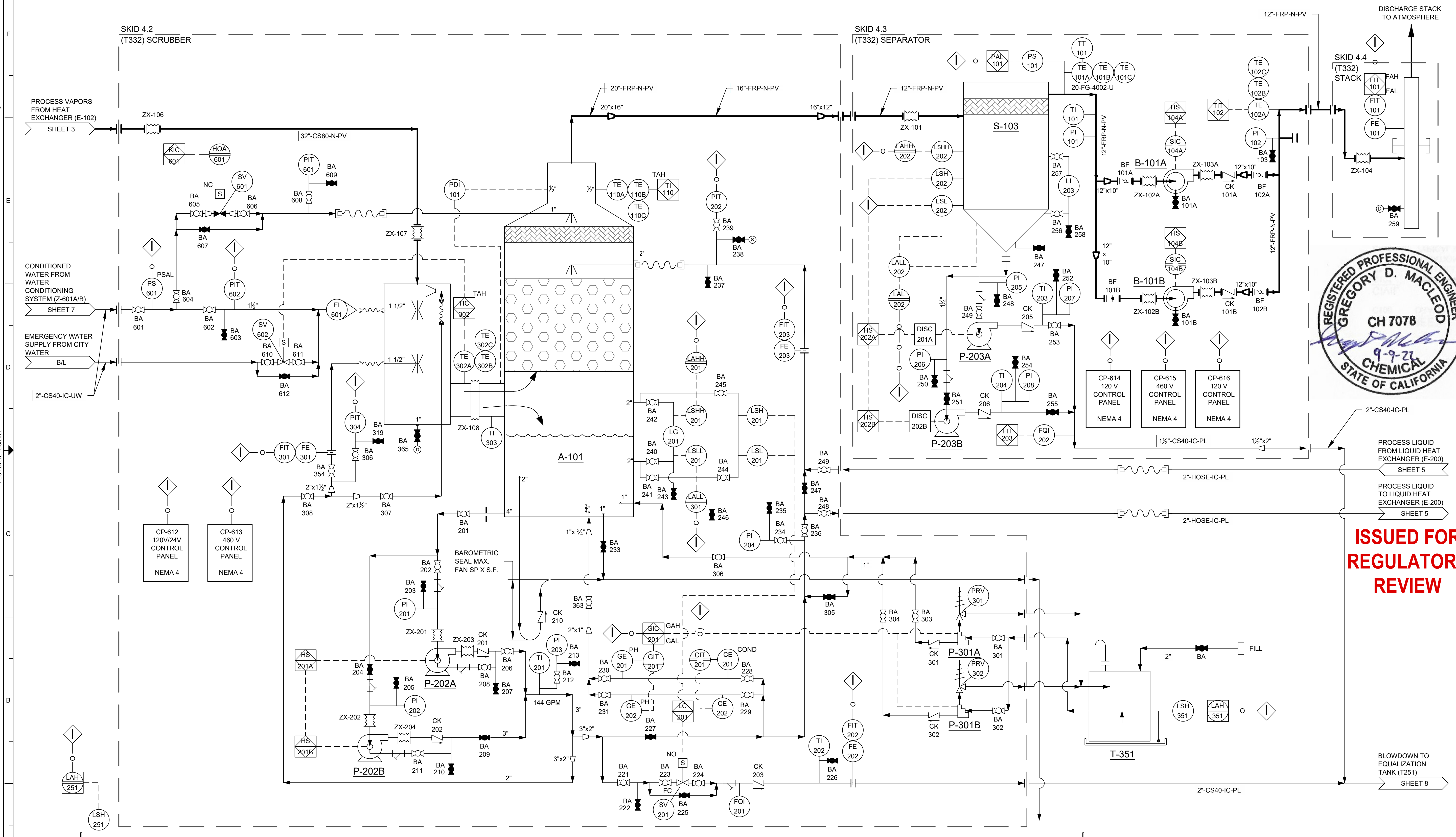
TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 3 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\...ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\...102-PNID.DWG
CTB FILE: TT-STANDARD.CTB



P-202A/B
SCRUBBER
RECIRC PUMP
15 HP, TEFC, FIXED SPEED
145 GPM @ 25 PSIG

A-101
QUENCH /
SCRUBBER
HASTELLOY C QUENCH
2'-6" ID, 15'-6" OAH
FRP SCRUBBER
4'-0" ID, 20'-11" OAH

S-103
MOISTURE
SEPARATOR 3
FIBERGLASS

P-203A/B
MOISTURE SEPARATOR
TRANSFER PUMPS
1.5HP, 460V, 3 PHASE
25 GPM @ 20 PSIG

P-301A/B
CAUSTIC
PUMPS
25 GPH @ 30 PSIG

T-351
CAUSTIC
TANK

B-101A/B
PRIMARY VACUUM
BLOWER
60 HP, TEFC, VARIABLE SPEED
460 VAC, 3 PHASE
4,035 ACFM @ 56 IWC SP

REV	DATE	DESCRIPTION	CAD	ENG	CM	PM
C	8/5/2022	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	CN	GM	DL	DP
B	6/10/2022	90% DESIGN DRAFT	CN	GM	NH	DP
A	4/1/2022	60% DESIGN DRAFT	CN	GM	GM	DP

THIS DOCUMENT CONTAINS CONFIDENTIAL INFORMATION OWNED BY TERRATHERM, INC. UNAUTHORIZED DISCLOSURE IS PROHIBITED

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-9-22
CHEMICAL
STATE OF CALIFORNIA

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

ISSUED FOR REGULATORY REVIEW

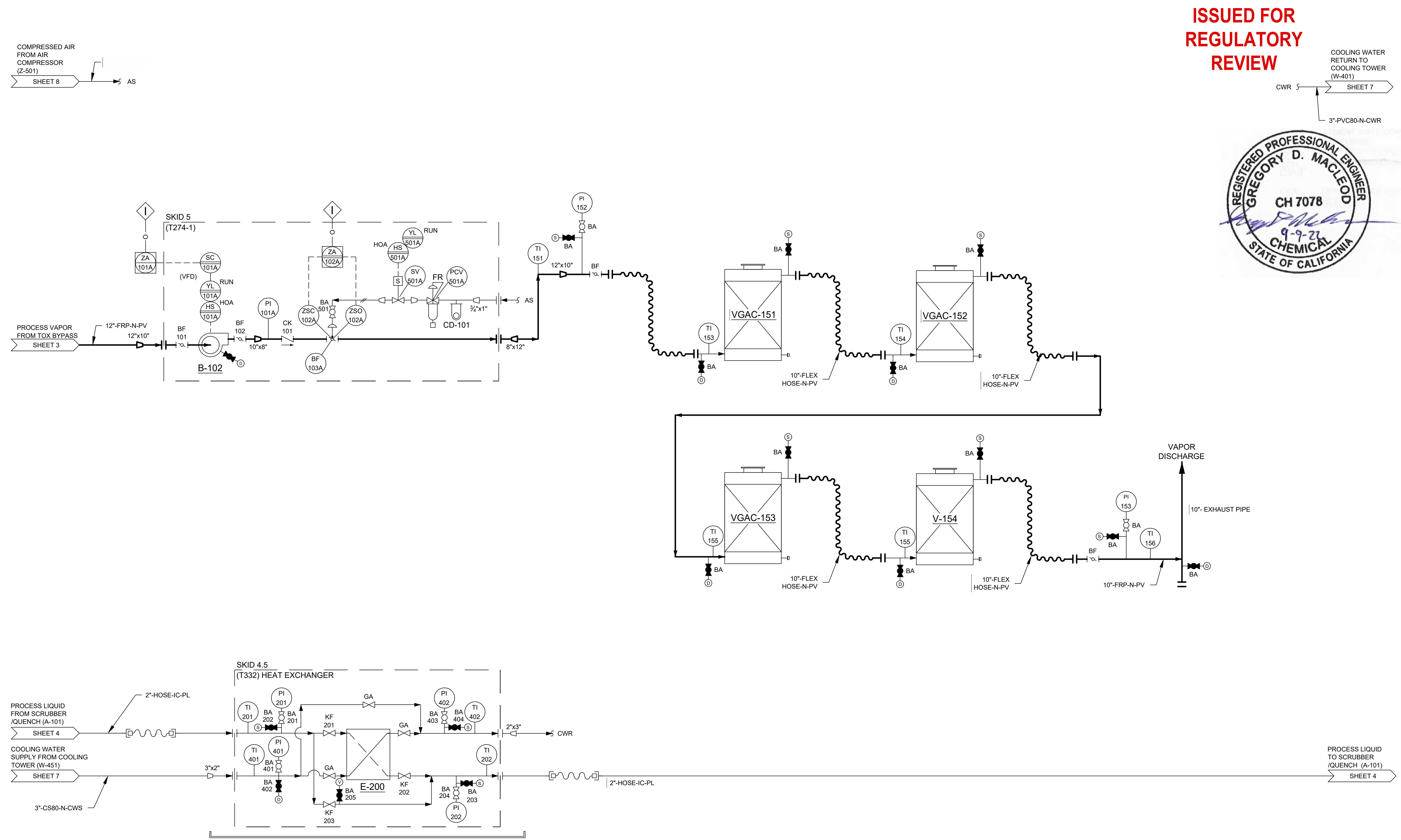
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 4 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\PROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

ISSUED FOR REGULATORY REVIEW



B-102
BYPASS PROCESS
BLOWER
30 HP, TEFC, VARIABLE SPEED
480 VAC, 3Ø

E-200
LIQUID HEAT
EXCHANGER
PLATE AND FRAME
316SS PLATES

VGAC-151/152/153
VAPOR PHASE
CARBON VESSELS
5000 LBS CARBON
CARBON STEEL VESSELS, SCH.40

V-154
PERMANGANATE
[$KMnO_4$] VESSEL
2000 LBS

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

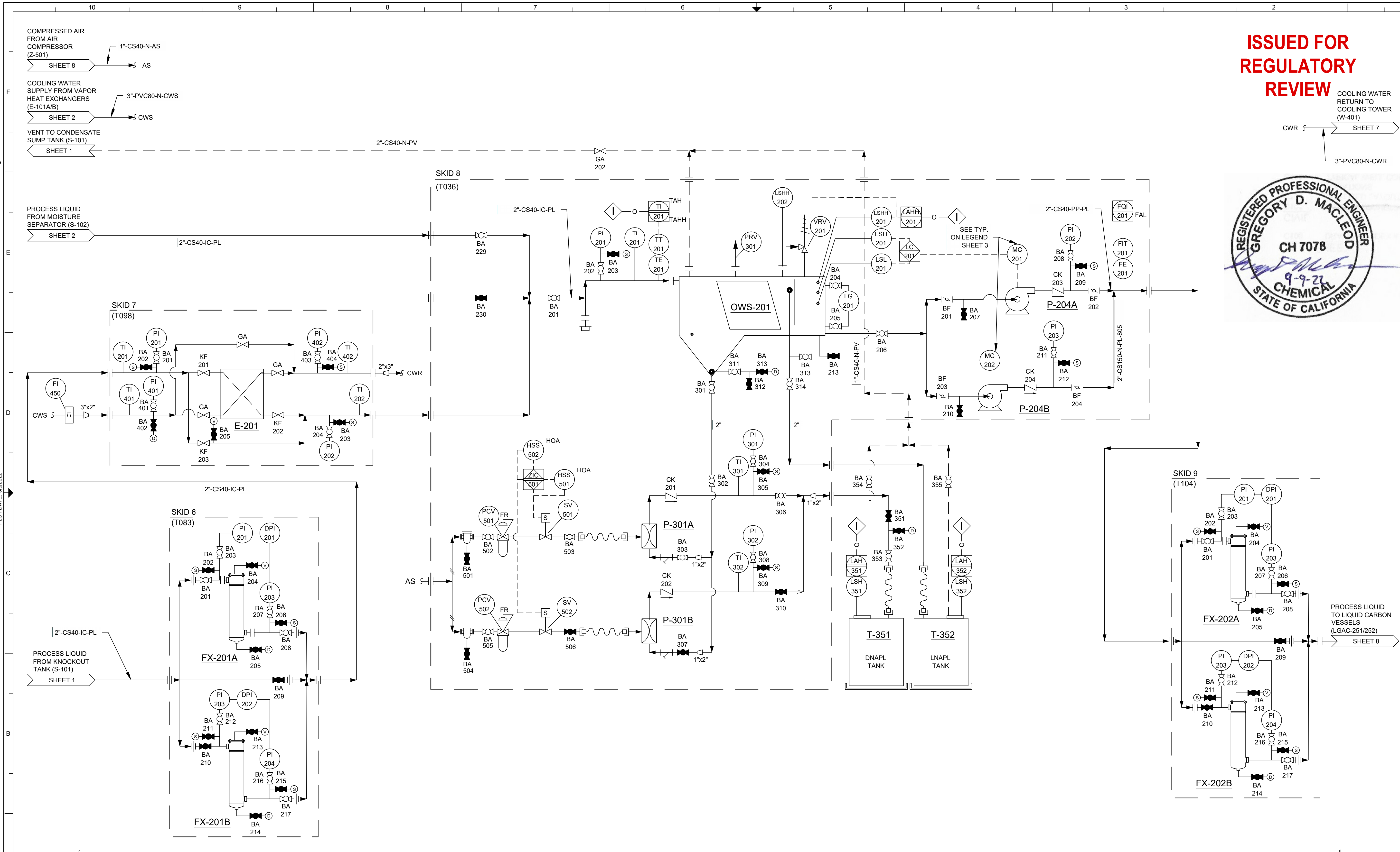
IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 5 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\...\ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS\...102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

ISSUED FOR REGULATORY REVIEW



FX-201A/B
BAG FILTERS
150 PSI MAX
80 GPM MAX
CARBON STEEL
30" (#2) BASKET
25 MICRONS

E-201
LIQUID HEAT EXCHANGERS
PLATE AND FRAME
316SS PLATES AND
VITON GASKETS

P-301A/B
DNAPL TRANSFER PUMPS
DOUBLE DIAPHRAM
100 PSIG MAX 10 GPM MAX

OWS-201
OIL WATER SEPARATOR
15 GPM CARBON STEEL 5' L X 3' W X 4'-10" H

P-203A/B
OIL/WATER SEPARATOR TRANSFER PUMPS
1.0 HP, TEFC, FIXED SPEED
460 VAC, 3 PHASE

T-351
DNAPL DRUM
55 GAL

T-352
LNAPL DRUM
55 GAL

FX-202A/B
BAG FILTERS
150 PSI MAX
80 GPM MAX
CARBON STEEL
30" (#2) BASKET
10 MICRONS

REV	DATE	CAD	ENG	DESCRIPTION		
C	8/5/2022	CN	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS	DP	
B	6/10/2022	CN	GM	90% DESIGN DRAFT	NH	DP
A	4/1/2022	CN	GM	60% DESIGN DRAFT	DP	

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

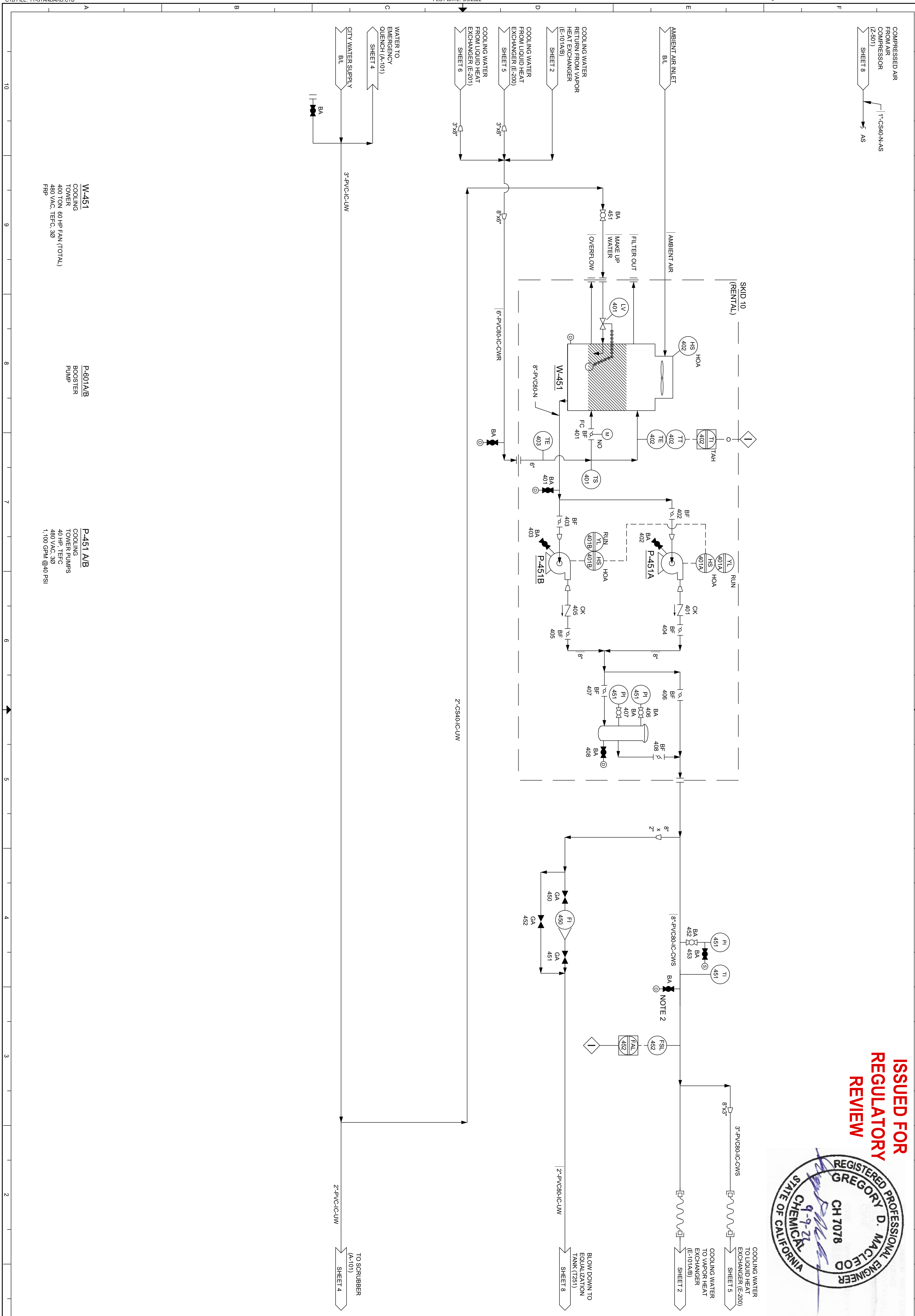
SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 6 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022

FILE: J:\...\ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS - 102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

FILE:J:□ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC. - BAY AREA, CA\01-DESIGN\001-DRAWINGS\0001-IN-PROGRESS DWGS□102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

PLOT DATE: 9/9/2022



IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

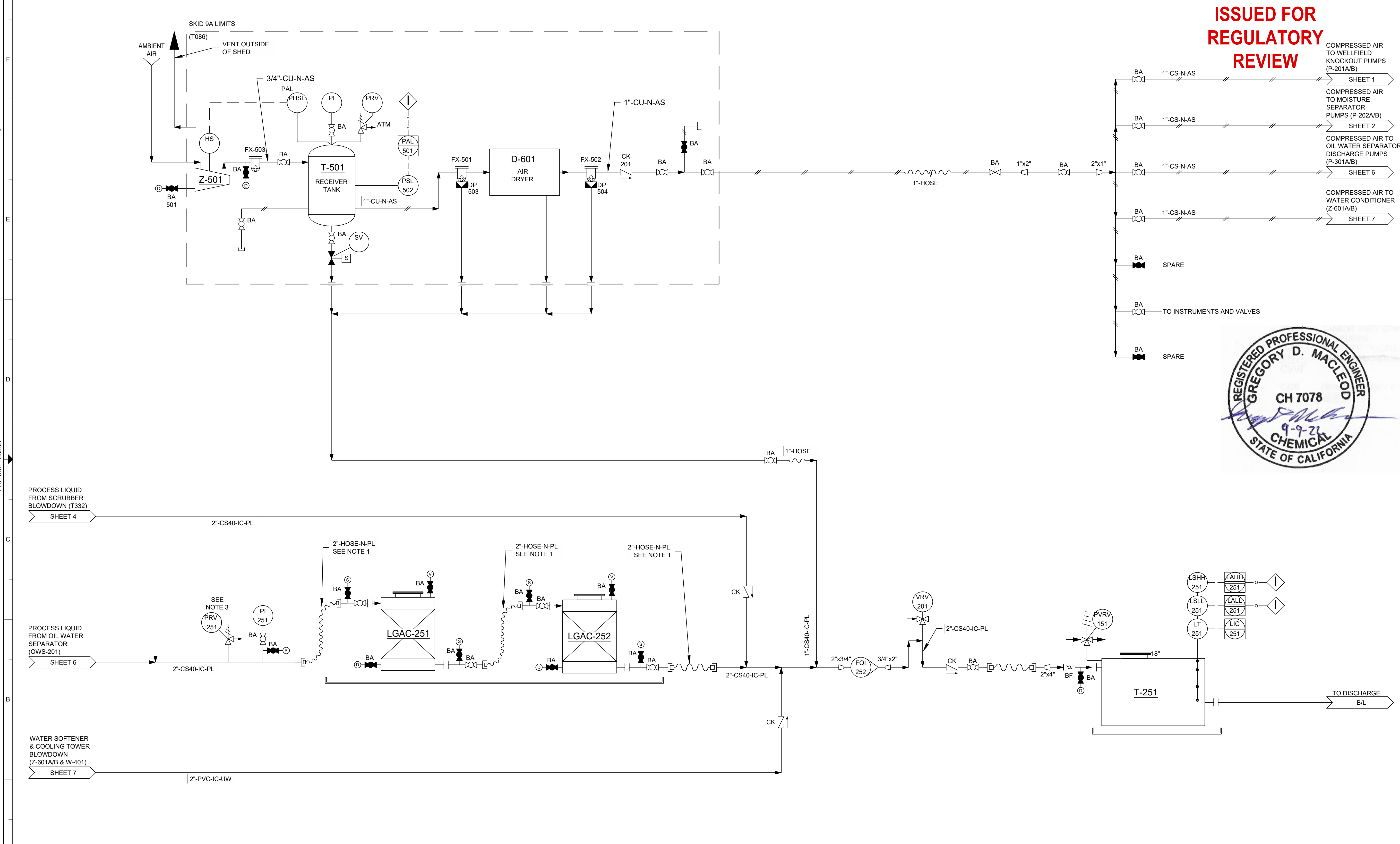
PIPING & INSTRUMENTATION DIAGRAM

SCALE: NTS
SHEET SIZE: D
REV: C
SHEET: 7 OF 8
DWG NO.: P102

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

REV	DATE	CAD	ENG	DL	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM		UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	NH	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM		60% DESIGN DRAFT		DP

SEAL



Z-501
AIR COMPRESSOR,
ROTARY SCREW
15 HP, TEFC
480 VAC, 3Ø
64 CFM @ 125 PSIG

T-501
AIR
RECEIVER

LGAC-251/252
LIQUID CARBON
VESSELS
250# CARBON 8x30 MESH
CARBON STEEL
2,000 LBS EACH

D-601
DRYER,
REFRIGERANT
125 SCFM @ 100°F

T-251
EQUALIZATION
TANK
21,000 GALLON
CARBON STEEL

NOTES:

1. HOSE LENGTH TO BE DETERMINED BY MAXIMUM DISTANCE BETWEEN VESSELS AT SWAPPED ORDER.
2. PUMP SUCTION NOZZLE TO BE ~2FT ABOVE TANK BOTTOM.
3. ROUTE RELIEF VALVE DISCHARGE TO BERM.

REV	DATE	CAD	ENG	DESCRIPTION	CM	PM
C	8/5/2022	CN	GM	UPDATED 90% DESIGN DRAFT - PER CLIENT COMMENTS		DP
B	6/10/2022	CN	GM	90% DESIGN DRAFT		DP
A	4/1/2022	CN	GM	60% DESIGN DRAFT		DP

TERRATHERM
a Cascade Company
151 SUFFOLK LANE
GARDNER, MA 01440
(978) 730-1200
WWW.TERRATHERM.COM

IN SITU THERMAL REMEDIATION DESIGN
BRISBANE, CALIFORNIA

PIPING & INSTRUMENTATION DIAGRAM

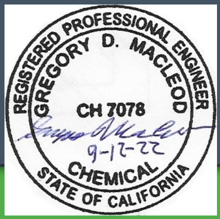
SCALE: NTS
SHEET SIZE: D
REV: C
REFERENCE NO.:
SHEET: 8 OF 8
DWG NO.: P102

PLOT DATE: 9/9/2022
FILE: J:\...ROJECTS\EHS SUPPORT - VARIOUS\EHS SUPPORT, INC - BAY AREA, CA\01-DESIGN\001-DRAWINGS\001-IN-PROGRESS DWGS\...102-PNID.DWG
CTB FILE: TT-STANDARD.CTB

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

Attachment B – Numerical Model Report

ADVISE | DESIGN | BUILD | OPERATE



TERRATHERM
a Cascade Company

Thermal Model Simulation Report

3775 Bayshore Boulevard, Brisbane, California

www.terratherm.com

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

TABLE OF CONTENTS

TABLES

FIGURES

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
BTU	British Thermal Unit
BTU/°F	British Thermal Units per Degree Fahrenheit
BTU/hr	British Thermal Units per Hour
cy	Cubic Yard
ft	Feet
ft bgs	Feet Below Ground Surface
ft^2	Square Feet
ft/ft	Feet per foot
gpm	Gallons per Minute
HZ	Heated Zone
ISTR	In Situ Thermal Remediation
kW	Kilowatt
kWh	Kilowatt-Hour
TCH	Thermal Conduction Heating
TTZ	Target Treatment Zone
VEW	Vapor Extraction Wells

1 INTRODUCTION

The warehouse facility located at 3775 Bayshore Boulevard in Brisbane, CA (the Site) consists of multiple zones with dimensions and surface areas, and thus so-called standard box models are not fully sufficient for estimating the heat progression; therefore, TerraTherm, Inc. (TerraTherm) has developed a water and energy balance code to simulate the addition, removal, and loss of energy in each layer of the Site separately, with the layers exchanging both fluids (water and steam) and energy along their boundaries. The calculations also estimate heat losses along the top, sides, and bottom of the treatment zone and the impact of groundwater flow into the treatment area, such that relatively accurate total energy demands are derived.

The water and energy balance calculations are referred to as “the model” in the following paragraphs. In the following sections the basic model setup is described, along with the specific goals expected to be derived based on the conducted water and energy balance calculations. The In Situ Thermal Remediation (ISTR) method to be used at the Site is Thermal Conduction Heating (TCH). Electrically powered TCH heaters will heat the Target Treatment Zone (TTZ).

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

2 SITE BACKGROUND

The model is based on simplified mass and energy balance principles relevant for thermal operation. The model can include up to 12 layers each with different model input and derived parameters including:

- Surface area
- Depth
- Area of perimeter
- Porosity
- Initial saturation
- Initial bulk density
- Initial heat capacity
- Initial thermal conductivity

During the simulations, parameters such as thermal conductivity and heat capacity of the soil are changed automatically as the water saturation changes, based on published equations for these parameters. This means, for instance, that as a zone is drying out due to boiling and steam removal, the water saturation is reduced, and therefore both the heat capacity and thermal conductivity are reduced, such that only the remaining water contributes to these parameters. This gives a more realistic heating prediction than if constant values are assumed. The results of the numerical simulations will serve as the basis for the design of the thermal treatment system at the Site.

The geology within the TTZ at the Site has four main stratigraphic units consisting of shallow fill, deep fill, young bay mud, and old bay mud. A detailed description of each unit is provided below:

- Shallow Fill – The shallow fill generally consists of gravel-sand-silt mixtures, clayey gravel, silty clay, and mixtures of reworked native bay mud and artificial fill. The fill extends from the surface to approximately 10 feet below ground surface (ft bgs).
- Deep Fill – Underlying the shallow fill is the deep fill which consists of similar material as the shallow fill and extends from about 5 to about 36 ft bgs. The deep fill also varies significantly in thickness and composition. There is not a distinct lithologic contact marking the boundary between the shallow fill and deep fill with the designation primarily differentiated by the thickness of the vadose zone and vertical interval of water table fluctuations and screen intervals of the fill monitoring wells.
- Young Bay Mud – The young bay mud extends from about 10 through about 54 ft bgs and is comprised predominantly of silt and clay and commonly contains shell fragments.
- Old Bay Mud – The old bay mud extends from about 54 ft bgs to depths greater than 55 ft bgs and is predominantly comprised of silt and clay with some find sand.

The water table at the Site is located in the shallow fill layer, generally from 5 – 7 ft bgs depending on location and flows to the west. The groundwater gradient in the shallow fill is approximately 0.009 feet per foot (ft/ft), in the deep fill is approximately 0.005 ft/ft, and in the young bay mud is 0.0095 ft/ft. The hydraulic conductivity of the shallow fill is 4.4 feet per day (ft/day), in the deep fill is 7.1 ft/day, and in the young bay mud is 0.01 ft/day.

Figure 2.1 shows the simplified layers of the TTZ at the Site that served as the basis for setting up the Site model. The bottom of the TTZ varies from 5 to 55 ft bgs. A weighted average TTZ thickness of 28.8 ft was calculated to estimate the bottom of the TTZ in the model.

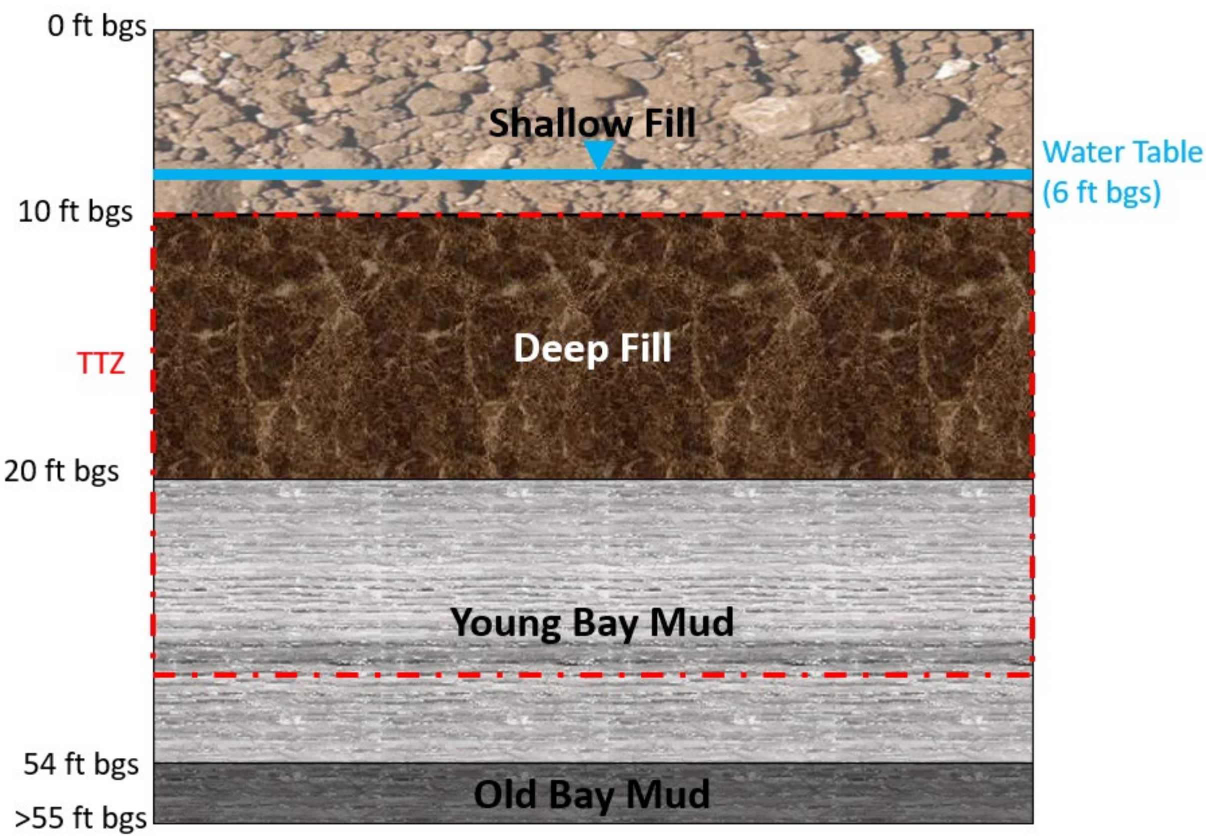


Figure 2.1. Schematic Showing the Conceptual Geology Assumed in the Treatment Area

For each layer, the water mass balance is calculated as follows:

$$M_{Net\ extraction} = M_{Out-Liquid} + M_{Out-Vapor} - M_{Injected} - M_{Inflow}$$

where M denotes cumulative water masses. Note that no fluids are injected when using the TCH technology. Exchange of fluids between the layers is estimated based on hydrogeologic parameters.

The mass removal in the liquid form is a simple summation of flow rate measurements:

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

$$M_{Out-Liquid} = \sum (m_{Liquid} \Delta t)$$

where the values for the flow rate m_{Liquid} are determined manually for each operational phase.

Hydraulic control will be maintained via steam generation and capture at the 192 vapor extraction wells (VEWs) co-located to the TCH heaters. TerraTherm estimates a total flow through the TTZ under natural gradients of 1.13 gallons per minute (gpm) and a total of 1.14 gpm in the model overall. Extracted steam and pumped water from the VEWs will remove energy from the TTZ.

The water mass removal in the form of vapor (steam, water vapor) is calculated as follows:

$$M_{Out-Vapor} = \sum (m_{steam} \Delta t) = \sum (m_{total\ vapor} - m_{non-cond}) \Delta t$$

where m_{steam} is the vapor flow rate made up of steam, m_{total} vapor is the total incoming vapor flow rate, and non-condensable mass, $m_{non-cond}$, is the vapor flow rate minus the steam component (air mostly).

For these simulations, the steam extraction rates are calculated based on the energy injected by the TCH system. The equation calculating the ratio between injected energy and extracted steam is derived based on observations made on several recent full-scale TCH projects. Figure 2.2 illustrates the streams that take part in the water mass balance within the heated zone (HZ).

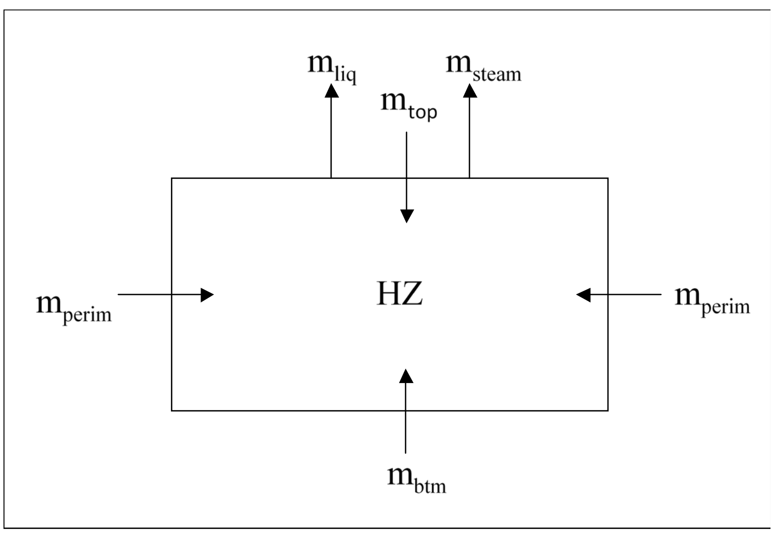


Figure 2.2. Mass Balance Principles for Water (One Layer Shown for Simplicity)

Total water extraction rates are estimated by the sum of the measured flows:

$$m_{extraction} = m_{liquid} + m_{steam}$$

The model keeps track of the volume or mass of water stored in each layer, based on extracted water, and estimates for the influx of water from the sides, bottom, and top by infiltration (the perimeter and bottom arrows shown on Figure 2.2).

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

$$M_{present,\, t1} = M_{present,\, t0} - M_{liquid} - M_{steam\ extr.} + M_{steam\ inject} + M_{bottom} + M_{perimeter}$$

where M denotes cumulative water masses.

The quantity of water removed from the subsurface is readily measured during operations; therefore, this quantity can be compared to a relatively accurate estimate of the pre-treatment quantity of water within each layer, based on values of porosity and saturation for the different zones in the model. For the Site it was assumed that infiltration into the TTZ from the top would be insignificant since the constructed vapor cover and the building above the treatment zone will prevent direct infiltration.

Cumulative energy (E) is calculated as a summation of enthalpy fluxes (Q):

$$E = \sum (Q\,\Delta t)$$

An estimated energy balance is maintained for each layer in the model based on energy delivered by the TCH heaters, energy extracted in the vapor and liquid streams, and heat loss to the areas outside of the HZ.

$$E_{in} = E_{out} + E_{storage} + E_{loss}$$

The energy fluxes are related for each time step as follows:

$$Q_{in} = Q_{out} + Q_{storage} + Q_{loss}$$

where Q denotes enthalpy flux (in British Thermal Units per hour [BTU/hr]). Figure 2.3 shows the schematic energy balance for one layer.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

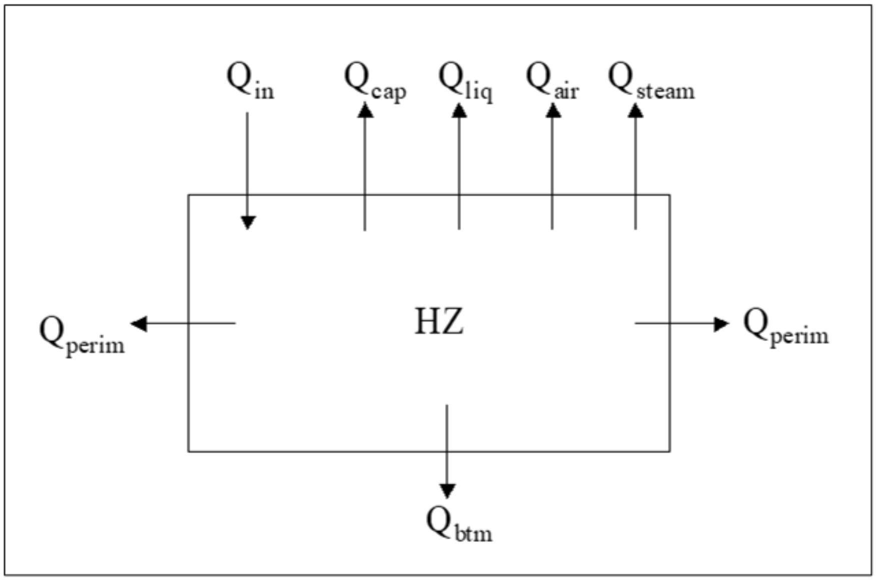


Figure 2.3. Energy Balance Schematic (One Layer Shown for Simplicity)

The estimate for Q_{in} will be based on the TCH energy input. The total energy removal from each layer is estimated as follows:

$$Q_{out} = Q_{liq} + Q_{non\ cond.\ gas} + Q_{steam\ out}$$

The energy flux in the extracted liquid is given by:

$$Q_{liq} = m_{liquid}\, c_{p,water}\left(T - T_0\right)$$

where c_p is heat capacity and T_0 is the ambient temperature.

For the extracted vapor stream, the energy flux in steam is estimated as follows:

$$Q_{steam\ out} = m_{condensate}\, \Delta H_{steam-ambient}$$

where m is mass flux and H is specific enthalpy (in BTU per pound). The enthalpy of the steam can be estimated from steam tables.

The energy removed as a non-condensable vapor at any given time is relatively small due to the low heat capacity of air in relation to steam and water and is therefore ignored in the calculations.

The actual heat loss cannot be calculated using accurate measures. An estimate can be made based on thermal profiles at the bottom and top of each layer, and along the perimeter, using the following calculations:

$$Q_{heat\ loss} = A K_T \frac{dT}{dz}$$

where A is the surface area through which energy is conducted, K_T is the thermal conductivity of the subsurface material, and dT/dz is the temperature gradient across the surface also expressed as $(T_1-T_2)/(z_1-z_2)$.

For the loss through the surface cover the temperature difference between the top and bottom of the upper layer in the model is used to calculate the temperature gradient. For the calculations, it is assumed that the ground surface remains near ambient temperatures due to a combination of wind cooling and simple heat radiation.

Heat loss calculations through the bottom and sides are accounted for in a similar manner. The layers exchange energy by thermal conduction such that energy leaves the warmer layer and enters the cooler layer.

All heat migration through the sides and through the top and the bottom layer of the model are considered lost from the model domain. Heat migration from the bottom of a layer and into the top of the underlying layer remains as energy in the model if both layers are in the HZ.

The model calculates average layer temperatures based on the energy balance and the estimated heat capacity of each layer. The stored energy is related to the HZ heat capacity and the average temperature as follows:

$$E_{storage} = C_{p,site}\left(T_{avg} - T_0\right) + m_{steam}\,\Delta_{steam-ambient}$$

where $C_{p,site}$ is the overall heat capacity of the heated layer, estimated from the volume, saturation, and specific heat capacity of the soil and water:

$$C_{p,site} = V_{soil}\,C_{p,site}\,V_{water}\,C_{p,water}$$

The steam energy stored as a non-condensable vapor at any given time is relatively small and will be neglected in the calculations. For comparison with the measured temperatures, the energy balance can be used to estimate the average temperature ($T_{energybal}$) of the heated volume:

$$T_{energybal} = T_0 + \frac{E_{storage}}{C_{p,site}} = T_0 + \frac{\left(E_{in} - E_{out} - E_{loss}\right)}{C_{p,site}}$$

Based on available data for the Site, a basic scenario was set up in the water and energy balance model and is presented further in the following sections.

3 DISCUSSION OF SIMULATION RESULTS

Results of the calculations indicate that the use of TCH will be a very effective means of heating the Site. The TTZ is shown in Figure 3.1. The heater spacing is approximately 15 ft in interior areas of the TTZ and approximately 13 ft along the perimeter.

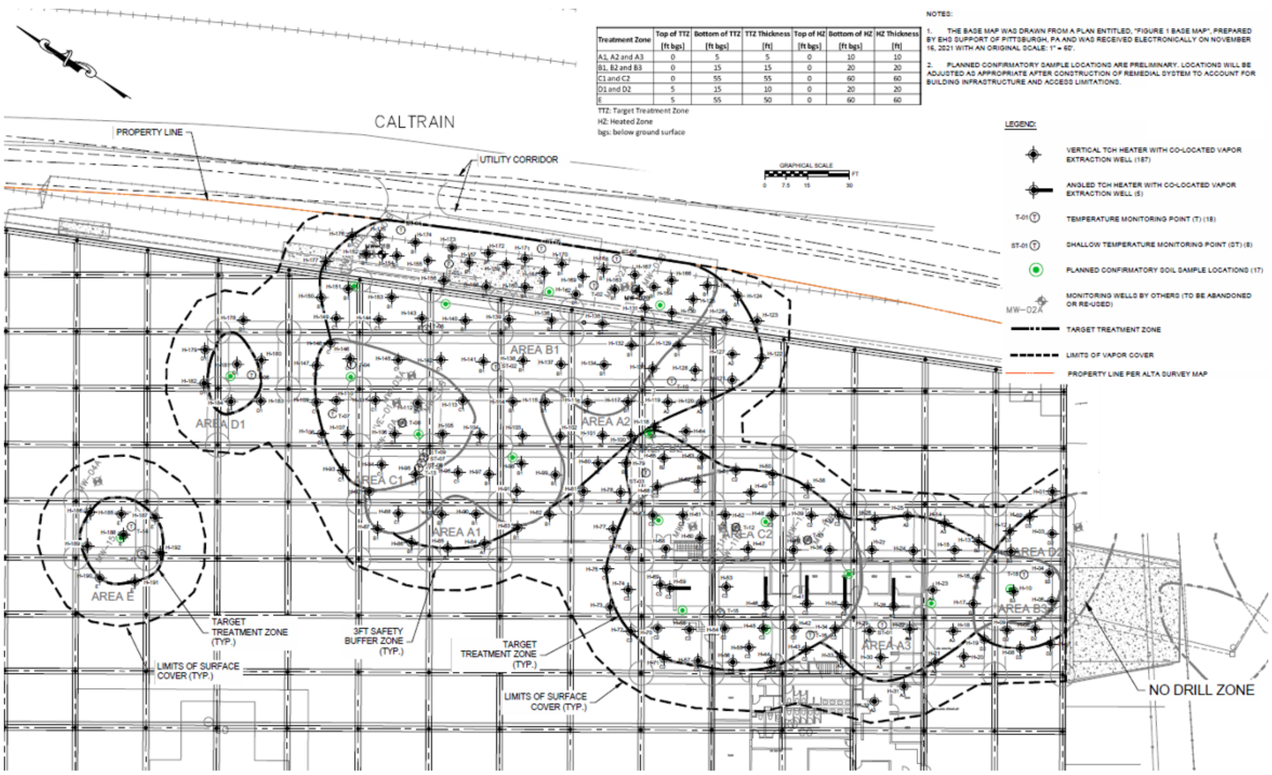


Figure 3.1. Thermal Treatment Area and Wellfield Layout

A total of 192 heaters will be used to treat the Site. The numerical model has been simplified to represent average conditions, based on overall heated thickness for the Site.

The average heated thickness is calculated using a weighted average based on the overall heated length. The heated thickness is calculated from the product of the number of heaters and the TTZ thickness. The average TTZ thickness is then calculated from the total heated length divided by the total number of heaters. Table 3.1 summarizes the heated thickness calculation for the Site. Accurate estimates of the power usage and heat-up curves require the model to reflect the average subsurface conditions of the Site as much as possible.

Table 3.1. Average HZ Thickness Calculation

Top of TTZ (ft bgs)	Bottom of TTZ (ft bgs)	Heater Quantity	Total Treatment Thickness (ft)
0	5	27	130
0	15	92	1,380
0	55	73	4,015
Total		**192**	**5,525**
Average			**28.8**

Based on a total treated volume of 24,697 cubic yard (cy) within a 23,152 square foot (ft^2) treatment area, the average treatment depth is approximately 28.8 ft. The HZ extends five ft below the bottom of the TTZ to offset the heat losses, meaning the average HZ depth is approximately 33.8 ft. The total modeled heated volume is 28,985 cy.

3.1 Numerical Calculations

The modeled volume was divided into nine layers based on the predominant geological properties present at the Site. Layers two through seven in the model are all within the TTZ, while the remaining layers are outside of the TTZ. Layers and geology defined in the numerical model are shown in Figure 3.2.

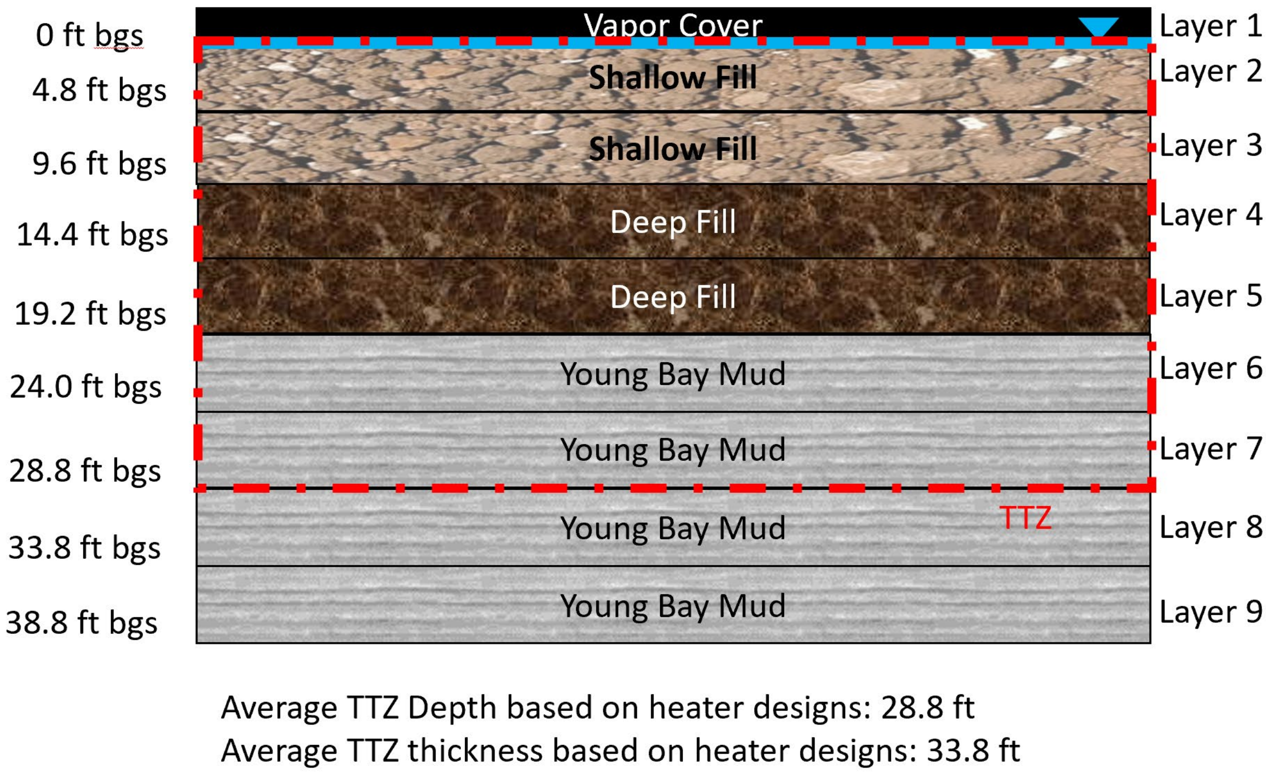


Figure 3.2. Numerical Model Layers

3.2 Input Parameters

Input values of porosity and initial saturation for the model layers appear in Table 3.2. These values serve as the starting basis for the energy balance calculations conducted in the model. The ambient starting temperature was conservatively estimated to be 10 degrees Celsius (°C).

Table 3.2. Porosity and Initial Saturation for Each Layer

Layer	Geology	Top (ft bgs)	Bottom (ft bgs)	Thickness (ft)	Porosity ( )	Initial Saturation ( )	Ambient Temperature (°C)
1	Vapor Cover	-1.00	0.00	1.00	0.01	0.10	10
2	Shallow Fill	0.00	4.80	4.80	0.38	0.98	10
3	Shallow Fill	4.80	9.60	4.80	0.38	1.00	10
4	Deep Fill	9.60	14.40	4.80	0.35	1.00	10
5	Deep Fill	14.40	19.20	4.80	0.35	1.00	10
6	Young Bay Mud	19.20	24.00	4.80	0.57	1.00	10
7	Young Bay Mud	24.00	28.80	4.80	0.57	1.00	10
8	Young Bay Mud	28.80	33.80	5.00	0.57	1.00	10
9	Young Bay Mud	33.80	38.40	5.00	0.57	1.00	10

3.3 Energy Balance

Tables 3.3 and 3.4 provide a summary of the heat capacity in the modeled zones and a summary of the model energy balance calculations.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

Table 3.3. Volume and Heat Capacity

Parameter	Value	Unit
Total volume, TTZ	24,697	cy
Total volume, HZ	28,985	cy
Solids volume, HZ	15,884	cy
Air volume, HZ	39	cy
Water volume, HZ	13,062	cy
Soil weight, HZ	70,947,000	lbs soil
Water weight, HZ	22,016,000	lbs water
Soil heat capacity, HZ	17,737,000	BTU/°F
Water heat capacity, HZ	22,016,000	BTU/°F
Total heat capacity, HZ	39,753,000	BTU/°F

The total volume of the TTZ is 24,697 cy, however the HZ includes five ft of stick-down and therefore a total volume of 28,985 cy. The total heat capacity of the heated volume is 39,753,000 British Thermal Units per degree Fahrenheit (BTU/°F).

Table 3.4 shows the energy added to the TTZ by the thermal conduction heaters, the energy removed from the TTZ as steam by the vapor extraction system, and the estimated energy losses through the top, bottom, and sides of the TTZ.

Table 3.4. Energy Balance (Average Values)

Parameter	Total (kilowatts [kW])
TCH power input rate, average	1,385
Steam energy removal, average	531
Heat loss top, average	23
Heat loss bottom, average	136
Heat loss sides, average	381
Net energy injection	315

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

3.4 Temperature Progression

Figure 3.3 shows the predicted average temperature in the TTZ as a function of time. Based on the energy calculations, the predicted total duration of the remedy is estimated to be 232 days, including a 28 days soil sampling and results evaluation period. Please note that the figure below represents the average Site temperature. During operation, the Site temperature will be observed at the centroid locations between the heaters (i.e., the coolest locations). Thus, the observed temperature progression is expected to be behind the modeled temperatures.

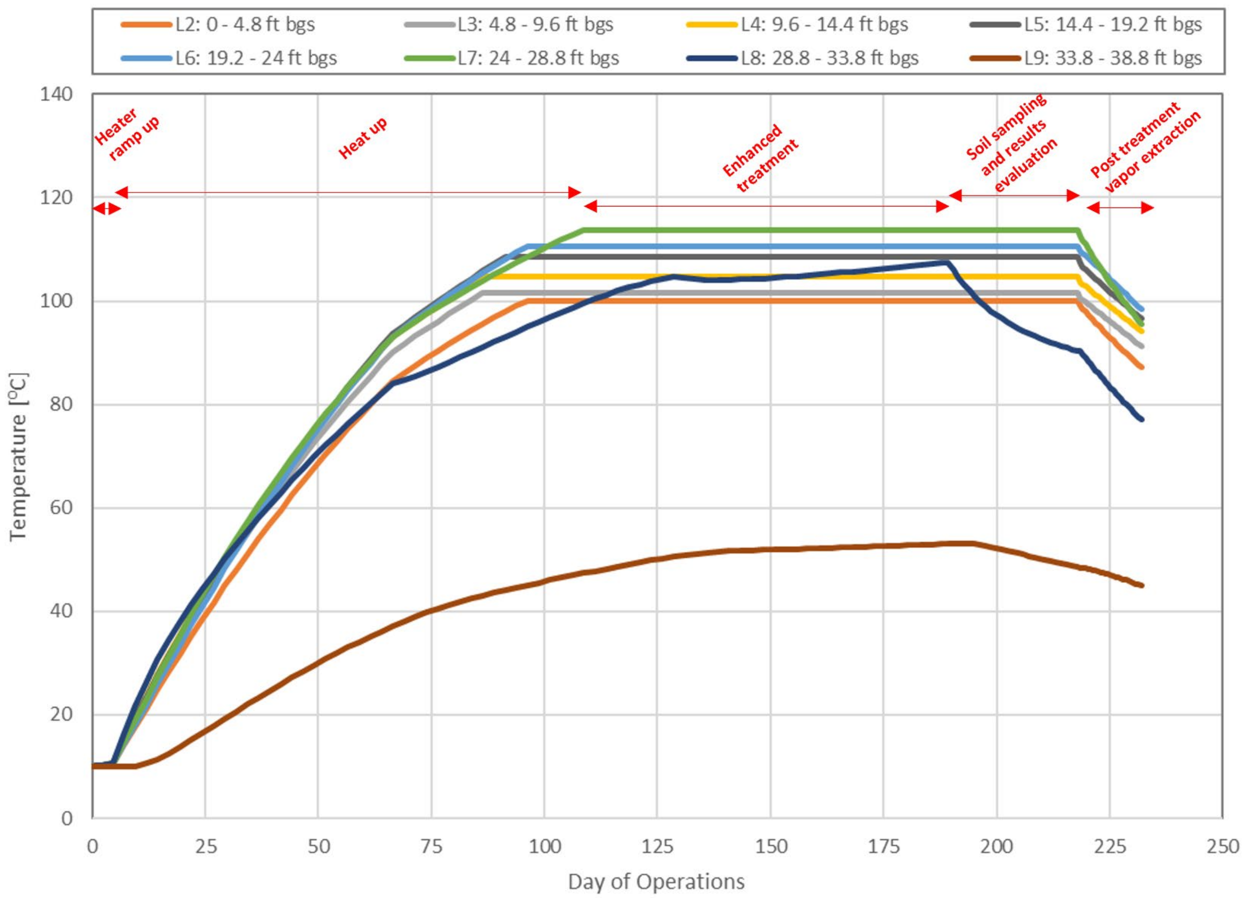


Figure 3.3. Average Temperature Curves for Layer 1 to Layer 9 during Thermal Treatment[1]

The results of the simulation indicate that on average the entire TTZ (layers two through seven) reaches a temperature of the boiling point of water between days 90 to 120 on average. In reality,

[1] Layers 2 through 7 are within the treatment zone, Layers 8 & 9 are below the treatment zone and Layer 1 is above the treatment zone.

REGISTERED PROFESSIONAL ENGINEER GREGORY D. MACLEOD CH 7078 9-12-22 CHEMICAL STATE OF CALIFORNIA

the boiling point is expected to be reached approximately 110-140 days after startup of operation at the centroid locations, represented by the temperature monitoring points installed at the Site.

Figure 3.4 shows the development of the temperature in depth profiles over the operational period. Note that the target treatment temperature is achieved between the 96 to 143 days lines. The uppermost point in the profiles represents the temperature in the vapor cover and is therefore not within the TTZ.

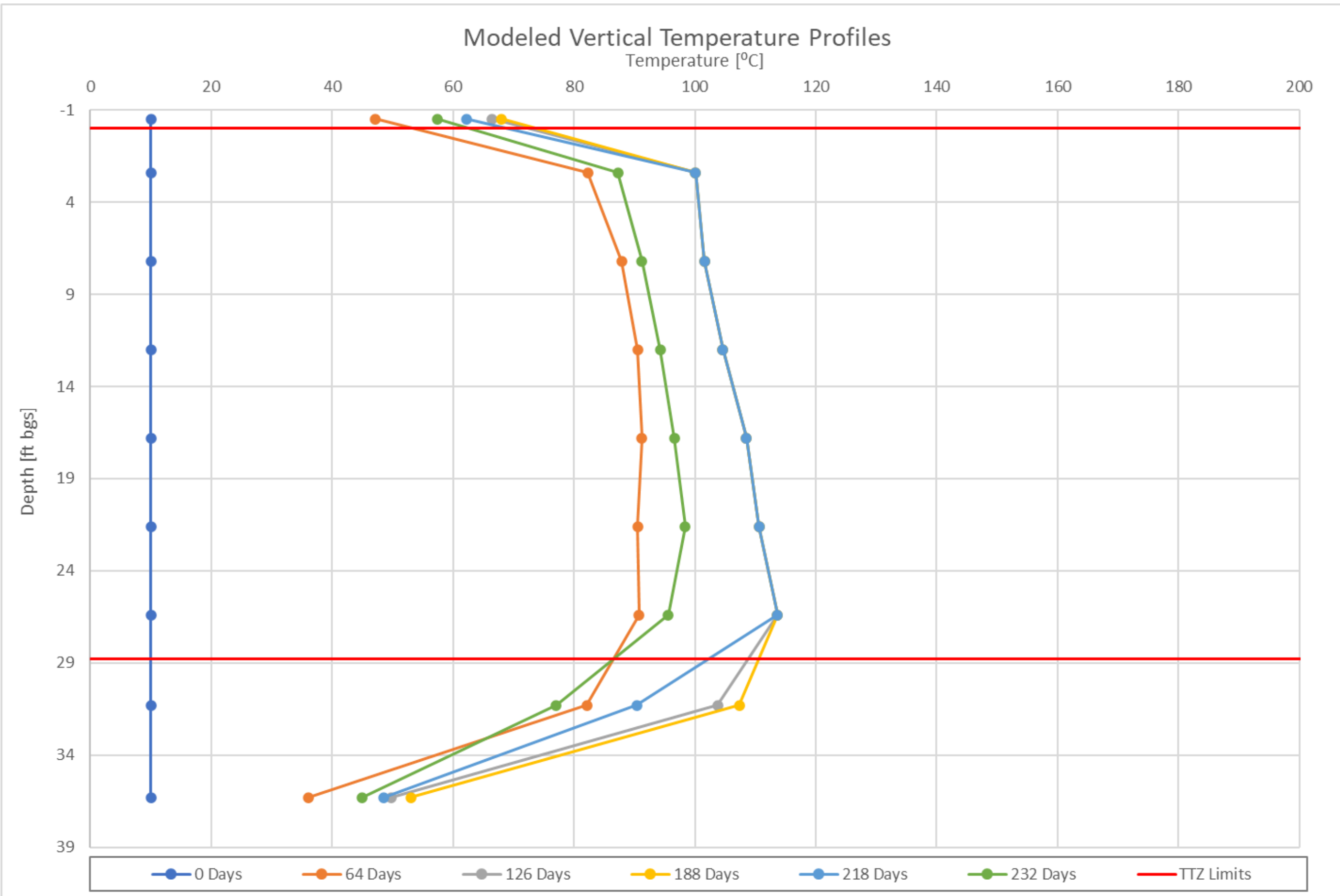


Figure 3.4. Predicted Vertical Temperature Profiles

3.5 Energy Demand

The numerical energy balance calculation accounts for the following:

- Energy input by the electrical heaters
- Delivery efficiency of the electrical heaters
- Heat losses to the surrounding areas (sides and through top and bottom of the TTZ)
- Removal of energy from the Site by extraction of heated air and steam

REGISTERED PROFESSIONAL ENGINEER
GREGORY D. MACLEOD
CH 7078
9-12-22
CHEMICAL
STATE OF CALIFORNIA

Table 3.5 summarizes the heating system's power usage throughout the duration of the thermal treatment system operation.

Table 3.5. Power Usage

Period	Duration (Days)	Subsurface Power Usage Kilowatt Hours (kWh)
Period 1	2	5,000
Period 2	62	2,581,000
Period 3	62	2,428,000
Period 4	62	2,305,000
Period 5	30	446,000
Period 6	14	0
Total	**232**	**7,765,000**

Based on the numerical calculations, it is estimated that a total of approximately 7.8 million kWh of electricity will be injected into the subsurface. The power demand of the effluent treatment system is in addition to this. The estimated total period of TCH operations is approximately 232 days including 14 days of post-treatment vapor extraction and initial cool-down. The operational plan is flexible, allowing for adjustments based on observed hydraulic responses, heating progression, and contaminant extraction rates.

Appendix C Hot Soil Sampling for Organic Compounds

1. PURPOSE AND APPLICABILITY

The purpose of this Standard Operating Procedure (SOP) is to ensure that TerraTherm, Inc. (TerraTherm) follows a consistent program in performance of hot soil sampling. This SOP applies to sampling of hot soils at any In Situ Thermal Remediation (ISTR) project to be submitted for volatile/semi-volatile organic compound (VOC/SVOC) and/or hydrocarbon analysis. Such soils are typically heated in excess of 100°C and this SOP establishes a set of procedures to ensure collection of soil samples that are representative of field conditions and to minimize the potential for loss of volatile organic compounds during sample collection.

TerraTherm is typically responsible for overseeing or performing a soil sampling program for each full-scale project. Hot soil sampling may be performed as progress sampling during ISTR operation or as confirmatory sampling at the conclusion of ISTR operation. This SOP outlines the methodology of such sampling, to help ensure consistency from one project to the next, and to ensure that sampling is performed in accordance with industry standard techniques (Gaberell *et al*., 2002) as well as US Environmental Protection Agency (EPA) methodology (US EPA, 2002). It is recognized, however, that project specific goals may differ, and that sampling methodologies may change accordingly to some degree. It is the ultimate responsibility of the Project Manager (PM) to ensure that the proposed sampling protocols meet both corporate and client requirements prior to sample collection.

This SOP applies to all applicable TerraTherm projects, and to personnel responsible for performing or overseeing soil sampling activities. All work must be done in accordance with the project specific work plan (WP), health and safety plan (HASP), sampling and analysis plan (SAP), and/or quality assurance project plan (QAPP) procedures.

2. RESPONSIBILITY

The Site Supervisor, or his designee, will conduct periodic inspections of the sampling procedures established by this SOP. The purpose of the inspection is to verify that the procedures and the requirements of the SOP are being followed. Any deviations or inadequacies that are identified during the inspection will be documented and immediately corrected.

It is also the responsibility of the party conducting the sampling to ensure appropriate coverage of wiring and cables within the wellfield to allow for drill rig access. It is required that plywood, or other appropriate form of protection, be placed over the wiring while the drill rig is moving to the specified drilling location. If covering the wires will not be sufficient to protect them from being damaged, a TerraTherm operator shall be asked to unplug any necessary cables while the drill rig is moving into place, and plug all wires back in once the drill rig is in place. No wires or cables shall be disconnected or reconnected by either the sampling party or the drill rig operators. Unless additional equipment will be installed, boreholes in the ground (and/or insulating cover) created during soil sampling should be backfilled after sample collection is complete (as specified in the drilling scope of work), as to minimize heat losses from the subsurface. This task is most often performed by the drilling team.

3. SAFETY

A TerraTherm operator or employee must be present at all times while the drill rig is moving within the wellfield. This ensures the safety of all project personnel and prevents damage to any equipment within the wellfield.

Exact safety procedures related to sampling in the wellfield is project specific and must be discussed with the Project Manager and/or TerraTherm's Health and Safety manager prior to all soil sampling activities.
All standard personal protective equipment (PPE) shall be worn by all personnel involved in the sampling process. Standard PPE and Modified Level "D" PPE includes, but is not limited to, the following:

- Hard hat
- Long sleeve shirt
- High Visibility Vest (or long sleeve shirt)
- Safety Glasses
- Steel-Toed Boots
- Temperature rated gloves (when handling hot materials)
- Full face shield (if directly involved with sample extraction from the boring where steam could be present)
- Hearing protection
- Inner latex and outer leather or cotton gloves

Drillers may be required to also wear the following PPE as necessary, depending on project circumstances:

- Hard hat with face shield
- Bib apron or Tyvek® suit
- High temperature rated gloves and/or sleeves

There are unique potential safety hazards associated with soil sampling at a Thermal site. These potential hazards include:

- Contact with hazardous voltages (electrical resistance heating sites only).
- Contact with steam, hot water, and hot soil.
- Contact with hot sampling tools.
- Exposure to hot hazardous chemicals.

These hazards can be mitigated through proper planning and the use of engineering controls. Proper planning includes strict adherence to the site-specific Health and Safety Plan (SSHP). Engineering controls include the use of the designated PPE.

All sampling tools that are inserted into the subsurface, and any material extracted from the subsurface, should be considered to be hot enough to burn unprotected skin. These items must be handled with proper care using the appropriate PPE.

It must be assumed that hot vapors or steam may exit the borehole at any time and that both steam and vapors may be under pressure. Avoid looking down a borehole, and never do so without safety glasses and a protective full-face shield.

Lockout/Tagout (LOTO):

Prior to performing any work below grade at an Electrical Resistance Heating (ERH) site, the Power Delivery System (PDS), must be turned off using the site-specific LOTO protocol. If more than one PDS is present on site, all PDS's will be turned off and locked out. Lockout tags shall not be removed until all subsurface work has been completed and field staff have exited all exclusion zones.

At thermal conductive heating (TCH) sites, prior to any sampling personnel or equipment entering the wellfield, or moving from one sampling location to another, a TerraTherm operator must shut down all active heater circuits in the vicinity of the sampling location, lockout and tagout all affected circuits, and verify that the heaters in those circuits are no longer live.

For sampling at both ERH and TCH sites, the energy input may be decreased or entirely shut off up to a day in advance of the drilling, to limit the risk of live steam in the subsurface. At SEE sites, steam has to be shut off several days in advance of the drilling, and it must be confirmed based on available data that no live steam is present in the subsurface at the drilling locations during sampling. Exact energy input strategies in advance of the drilling activities is site specific and will be communicated by the PM.

Refer to the project SAP and HASP for site-specific requirements and restrictions.

4. REQUIRED MATERIALS

TerraTherm has assembled a Soil Sampling Kit that contains the majority of the necessary materials listed below.

General:

- Alconox®, Simple Green, or other biodegradable soap for decontamination
- Distilled water
- Scrub brush(es) for decontamination of down-hole equipment
- Distilled water & large buckets for decontamination
- Nitrile Gloves
- Teflon tape and/or Aluminum Foil
- Thermometer(s)
- Ice bath (tub(s) with drain holes, dividers, ice), with secondary containment if needed*
- Stainless Steel Spoons / Spatulas
- Stainless Steel Sampling Bowls
- Field logbook
- Sample chain of custody form (typically provided by the laboratory)
- Laboratory sample bottleware/sampling kits (typically provided by the laboratory)

* If ice has not come in direct contact with contaminated materials, it may melt and drain to an appropriate location on site (e.g. grassy area). If the melted ice water contains contaminated materials from the subsurface (or if the site HASP or Operations & Monitoring Plan dictate), there should be secondary containment for the melted ice, and all water generated from this process should be re-introduced into the liquid treatment system.

Below is a list of sampling equipment that is generally provided by the driller.

Direct Push Method Sampling:

- Macro-Core® type soil sampler(s)—one for each rig plus extra(s)
- Sleeve liners, typically 6" long (stainless steel highly recommended)—enough for each boring. NOTE: these are often a special order/longer lead time item

- PVC end caps (red and black)—two caps for each sleeve insert, usually different colors to indicate top/bottom of each depth interval
- Extruder tool for GeoProbe (highly recommended)
- Material to backfill boreholes when sampling is complete, as specified in the drilling scope of work

Rotosonic Method Sampling:

- Standard sonic core barrel and associated drill tooling
- Polyethylene sample bags for sample cooling (e.g. Layflat tubing)
- Material to backfill boreholes when sampling is complete, as specified in the drilling scope of work

5. METHOD

Sampling Tool:

The length and diameter of the sampling tool may vary depending on the driller used to perform the work and the sampling tool selected. Different drilling techniques will have different sample collection systems. TerraTherm most often uses direct push technology (DPT, i.e. Geoprobe®) drilling with stainless steel liners in a Macro-Core® barrel. Figure 1 below outlines the direct push drilling material configuration.

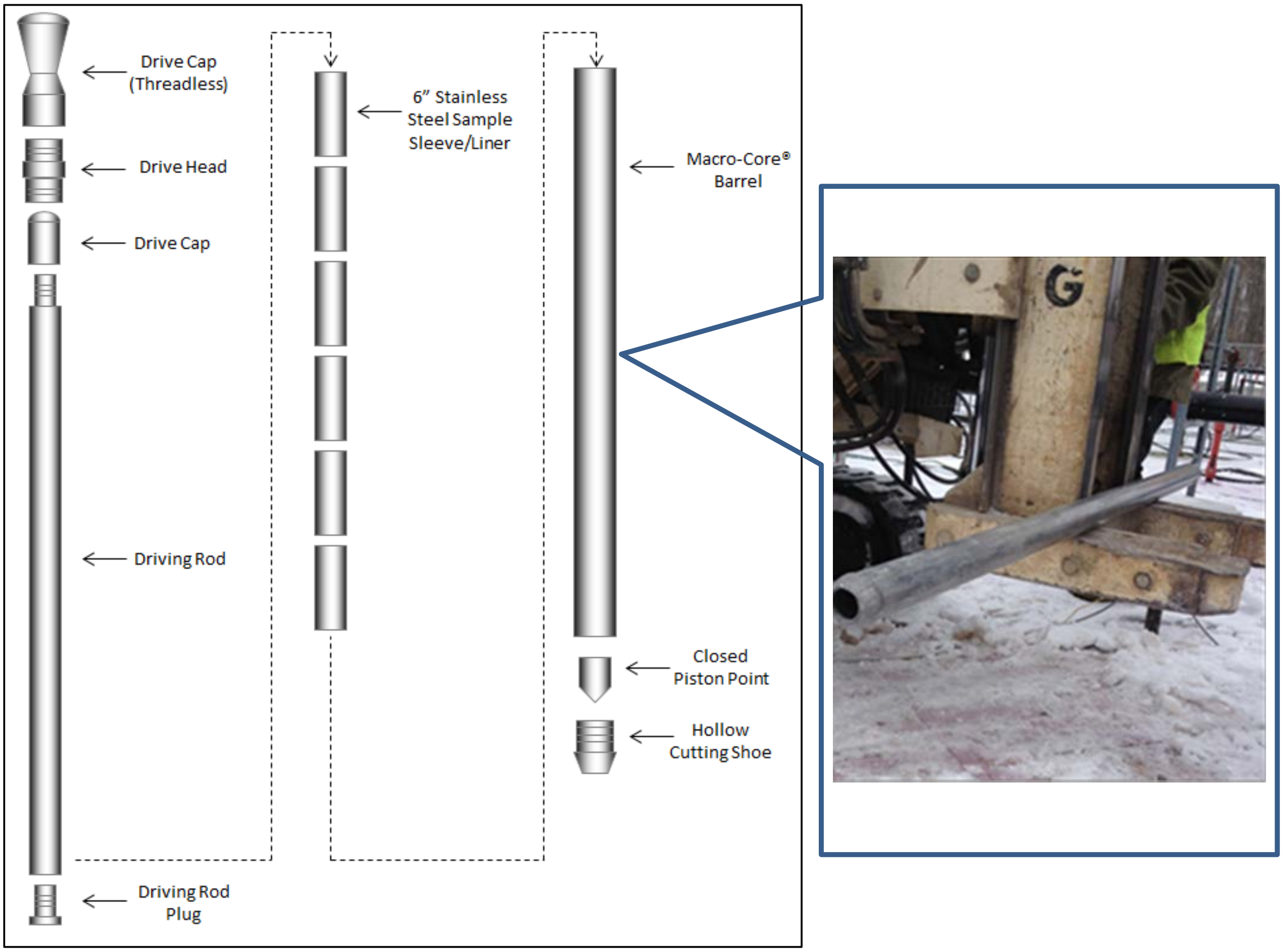


Figure 1. Direct Push Drilling Materials (inset shows 5-ft core barrel equipped with ten 6-inch sleeves)

Soil samples using the standard direct push method will be collected using a core barrel type sampler equipped with four to ten 6-inch stainless steel sleeves (exact number of sleeves depends on the total length of the core barrel). The stainless steel sleeves are also available in un-cut sections of varying lengths.

For direct push method sampling, TerraTherm highly recommends that the sleeves be supplied pre-cut into 6-inch intervals, so that each interval can be sampled individually and to reduce the possibility of cross contamination between cutting tools and the samples.

For some difficult geologic formations, rotosonic drilling may be used, which typically utilizes polyethylene ("plastic baggie") sleeves (example brand/trade name is LayFlat). The samples are collected using the rotosonic core barrel sampler and extracted into the polyethylene sleeves for cooling. For sites with temperatures in excess of 100 degrees C (or sites where plastic sleeves will not be effective), recently honed core barrels with five foot long aluminum inserts should be considered. Sonic "split barrels" may also be considered depending on the data objectives of the project. Figure 2 below outlines the rotosonic drilling material configuration.

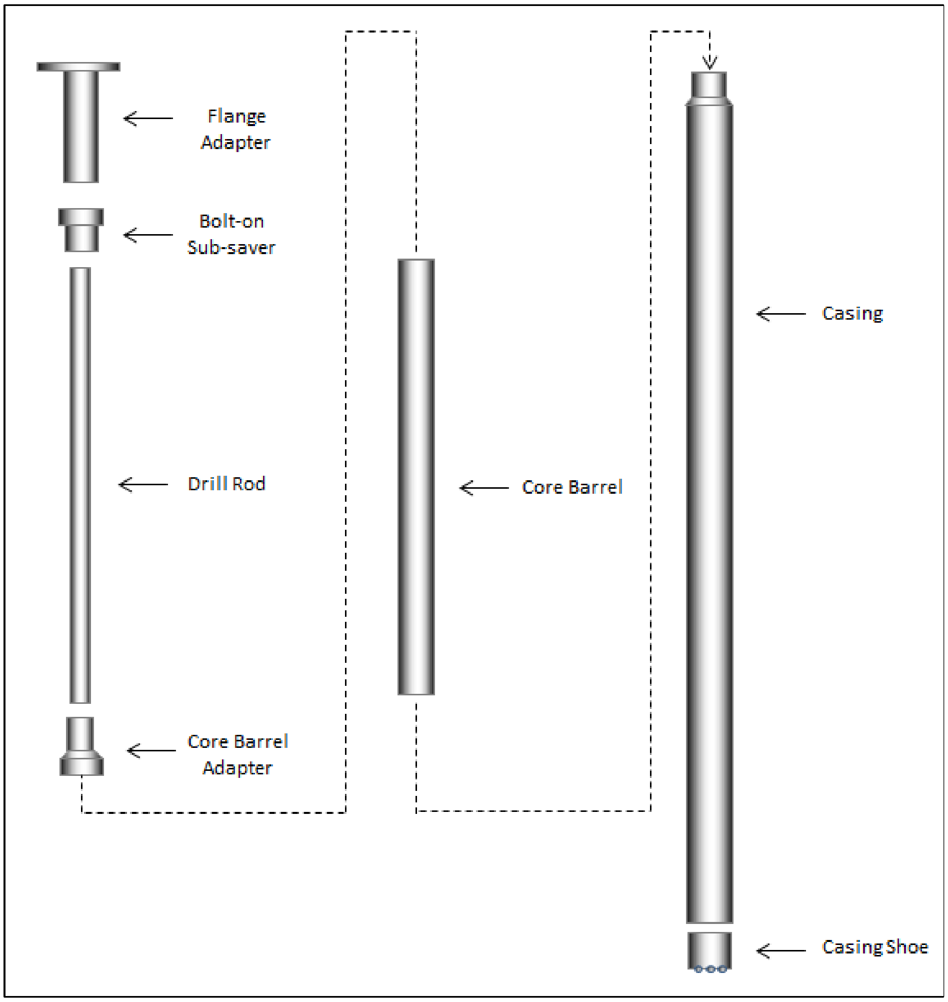


Figure 2. Rotosonic Drilling Materials

Decontamination:

All down-hole equipment (augers, core barrel, drive rods) must be decontaminated prior to use, between sampling locations, and at the end of each day. Sampling sleeves and end caps, which may be used more than once, must be decontaminated prior to each use. At a minimum, decontamination will consist of the following:

1. Removal of any gross contamination (e.g., wet soils stuck to the auger) by steam cleaning or other appropriate method;
2. Cleaning with a biodegradable soap (e.g., Alconox®) and water solution using a scrub brush;
3. Rinsing off the soapy solution with clean water; and,
4. Rinsing with distilled water.

Hot Soil Sampling Procedure:

Prior to mobilizing to the field, TerraTherm requires a planning conference call/meeting where the client, drilling team, and TerraTherm discuss the sampling goals and procedures. TerraTherm recommends sharing this SOP, as well as the attached one page summary "cheat sheets" to the drilling team when first contacting them about the sampling event. This will allow for them to plan properly in terms of personnel and PPE, as well as order any required supplies that are not typical stock items (e.g. stainless steel sleeves for direct push). Appendix 1 displays the one page "cheat sheets" for direct push and sonic drilling.

Interim and final soil sampling is best achieved using a direct push drilling technology such as Geoprobe®. The size of the Geoprobe® drill rig allows for easier maneuverability in a typical TerraTherm wellfield due to the often tightly spaced wells and manifolds. Occasionally rotosonic drilling is used for sites with tougher geology and/or greater spacing between wells and manifolds (e.g. steam enhanced extraction sites with wider well spacing). The first step of any soil sampling event, as described in Section 3 (Safety) is as follows:

- For Steam Enhanced Extraction (SEE) sites, steam injection should cease at least 3 days prior to the soil sampling event to allow for the subsurface to depressurize.

- For Electrical Resistance Heating (ERH) sites, every soil sampling event must start by turning off the Power Delivery Systems (PDS) and securing them using the site-specific lock-out, tag-out protocol. This will eliminate subsurface voltage. The energy input may be decreased or entirely shut off up to a day in advance of the drilling, to limit the risk of live steam in the subsurface.

- For Thermal Conductive Heating (TCH) sites, heaters in the area of soil sampling are turned off immediately before the start of sampling. Usually this is accomplished by turning off one complete circuit of heaters. The other circuits/heaters that are not in the immediate area of sampling or access are most often left in operations. The energy input may be decreased or entirely shut off up to a day in advance of the drilling, to limit the risk of live steam in the subsurface.

To maintain steam capture in the subsurface, the vapor recovery (VR) system must remain on during soil during invasive work. This will help prevent steam from traveling up sample boreholes and creating a hazardous work area.

All sampling tools that are inserted into the subsurface, and any material extracted from the subsurface, should be considered to be hot enough to burn unprotected skin. These items must be handled with proper care using the appropriate PPE.

It must be assumed that hot vapors or steam may exit the borehole at any time and that both steam and vapors may be under pressure. Avoid looking down a borehole, and never do so without safety glasses and a protective full-face shield.

There are two different basic methods described for sample collection below. The sample collection method shall be approved by the PM prior to sample collection to ensure that data results meet project goals.

Direct Push Sample Collection Method:

1. The decontaminated core barrel sampler and sample sleeve will be assembled and advanced to the desired depth. Once removed from the borehole, the core barrel will be disassembled, and the sample

sleeves will be removed sequentially, one-by-one. Temperature rated PPE (heat resistant gloves, sleeves, bib apron, hardhat with face shield) should be worn while handling hot materials.

2. The ends of each 6-inch sample sleeve will be immediately covered with sections of Teflon® tape or Aluminum Foil and then capped with PVC end caps (Figure 4).

3. Black and red endcaps are typically used to differentiate between the top and the bottom of each sample sleeve. The red endcap is typically labeled with the sampling depth interval (e.g., 1 ft to 1.5 ft).

4. At least one of the sleeves will be selected (from each boring), and a thermometer will be inserted through the end cap into the soil sample for temperature monitoring.

5. The capped and sealed sleeves will then be placed into an ice bath for cooling as shown in Figure 5. The ice bath will contain drain holes to allow melt water to freely drain rather than accumulate around the sample holder. Water shall be collected and containerized for proper disposal, as necessary. A picture of a typical ice bath used for direct push sampling is included as Figure 5. The sample identification (ID) information will be marked on each ice bath for reference (a dry erase board is helpful for keeping track of sample identification) when processing the cooled samples for labeling and shipping. The cooling process should take no longer than 2-3 hours, maximum. The sample should not be un-capped during the cooling period, as to prevent losses of volatile organic compounds. The sample cooling/processing area should protect the cores from direct sunlight, excessive ambient temperatures and rain.

6. Once the sample sleeve has cooled to a temperature below 50°F (10°C), sub-sampling methods may vary depending on the general purpose of the soil sampling event. For the purposes of this document the sampling methods will be divided into two categories: Interim and Confirmatory Sampling.

    a. Interim Soil Sampling – Interim soil sample depths are typically selected based on the highest headspace PID reading collected at each 6-inch sleeve. Boring locations and/or depths may also be pre-selected based on temperature monitoring during operations (i.e. select the worst case area for interim sampling; e.g. areas with difficult geology and/or areas with lagging temperatures). Once cooled to a temperature no higher than 50°F (10°C), remove the cap on one end, gently scoop out a small portion of soil into a bowl to expose fresh soil within the sleeve. Place the PID sample probe into the headspace within the sleeve and record the reading. Once the headspace PID reading has been taken, replace the endcap and return the sample sleeve to the ice bath while this is repeated for all sample sleeves for the selected interval. It is imperative that all spoons and spatulas be decontaminated prior to use and in between readings of each 6-inch sleeve.

       Alternately, a small amount of soil may be placed into a small glass container (e.g. mason jar), capped with aluminum foil, and the PID sample probe may poke a hole through the aluminum foil cap and read the sample headspace within the glass container.
       Once all of the PID readings have been collected, they are evaluated and, as a conservative approach, the depth intervals associated with the highest PID readings are generally selected for analytical sampling. The exact number of samples collected per boring will vary from project to project based on budget and overall project goals. Once depth intervals are selected, the cooled sleeves may be processed in the field by extruding the appropriate amount of soil from the middle of the sleeve, and placing the extruded soil directly into containers of the appropriate size and preservation, as dictated by the analytical laboratory and project sampling plan/quality assurance plan. Typically, for VOC samples, five grams of soil will be placed in pre-cleaned,

pre-preserved vials (preserved either with deionized water or sodium bisulfate for low level samples, or preserved with methanol for high level samples). The five grams of material are measured in a small bore sampler (often a small plastic syringe). Typically, for SVOC samples, a 2 oz. or 4 oz. unpreserved amber jar is filled with the extruded soil. Usually, a separate small plastic unpreserved container is also filled for the laboratory to determine the moisture content (for dry weight concentration reporting).

Alternately, if appropriate, volatile organic compounds may be collected in commercially available systems such as EnCore®. While most small-diameter core samplers can only be used for sampling and placement into the appropriate sample containers, only the EnCore® sampler can be used for sampling, storage and transportation of the sample to the lab. Please note that the EnCore® samples have a holding time of 48 hours from sample collection (i.e. the samples must arrive at the laboratory, and the laboratory must extract the material from the sampler and place into a preserved container within 48 hours). Figure 3 shows the typical EnCore® sampling technique (note that the sampling tee, used to hold the sampler, is not visible in the photo). Vials will be properly labeled and stored on ice in an insulated cooler. Usually, a separate small plastic unpreserved container is also filled for the laboratory to determine the moisture content (for dry weight concentration reporting). A helpful YouTube instructional video showing the EnCore® soil sampling technique is located online here: https://youtu.be/QUHiyHXzCn0 (last accessed 10/2017)

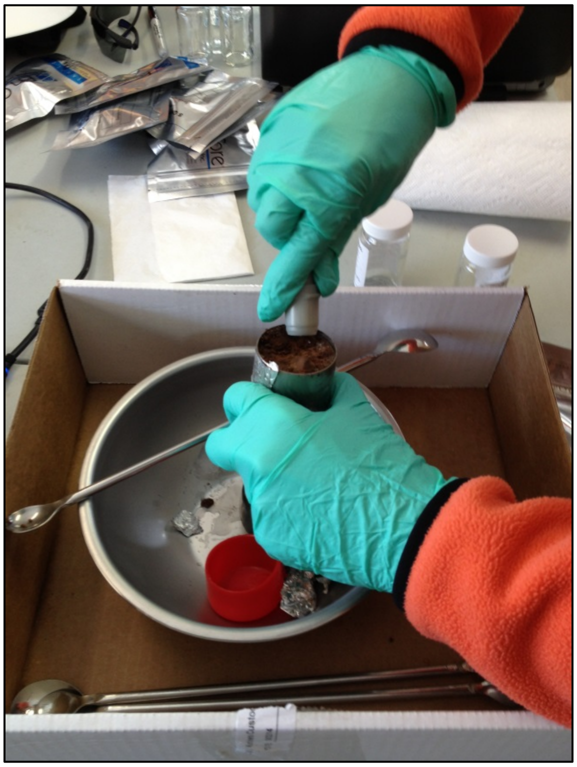


Figure 3. EnCore® Sampling Method (sample tee not shown)

b. Confirmatory Soil Sampling – Confirmatory sampling generally has discrete, pre-selected, and sometimes random sampling locations selected prior to the sampling event; therefore, sample locations are typically not dictated by the concentrations seen on the PID. However, headspace

PID readings, as described above, may be required for documentation purposes. Otherwise, once cooled to a temperature no higher than 50°F (10°C), the cooled sleeves may be processed as described above in section 6a.

7. If we are working with a more research oriented laboratory (e.g. University associated laboratory) that will accept core sleeves directly from the field, this procedure may be followed. Once cooled to a temperature below 50°F (10°C), sample sleeves are removed from the ice bath, labeled, and sealed tightly in a plastic bag for shipment to the laboratory on ice in an insulated cooler under the chain-of-custody documentation required by the site-specific SAP and QAPP. If these documents do not exist, at a minimum, industry standard chain-of-custody protocol will be followed. The research/University laboratory will open and extrude five grams of soil from the middle of each sample sleeve and place these sub-samples in pre-cleaned vials holding the appropriate preservatives for the selected analysis. Typically, this is deionized water or methanol.

8. The following information for each sample will be documented in a Field Logbook: brief soil description, depth interval of sample, headspace PID reading (if required), temperature of sample collected at time of collection, time and date of sample collection, name of sampler/s. A photographic record of each sample collected, with identification label, is desirable. Figure 6 shows an example setup for processing hot soil samples collected with direct push.

9. Investigation Derived Waste (IDW): Soil cuttings not consumed in the sampling process must be disposed of in accordance with Federal, State, and Local regulatory requirements. Refer to the project Waste Management Plan (WMP) for site-specific directions on how to handle, store, transport, and dispose of IDW.

10. Unless additional equipment will be installed, boreholes in the ground (and/or insulating cover) created during soil sampling should be backfilled after sample collection is complete, as to minimize heat losses from the subsurface.

Figure 4. Removal and Capping of Sleeved Samples

Figure 5. Ice Bath for Cooling Samples

Figure 6. Example Sample Processing Setup

Rotosonic Soil Sample Collection Method:

1. The decontaminated rotosonic core barrel ~~sampler~~ will be assembled and advanced to the desired depth. Once removed from the borehole and disassembled as necessary by the drill crew, the sample bag will be placed against the core barrel by the drilling team to ensure that the bag can withstand the hot soil temperatures (sonic soil sampling bags are most often made of 6-mil low density polyethylene [LDPE] which has an upper temperature limit of 93°C. Temperature rated PPE (heat resistant gloves, sleeves, bib apron, hardhat with face shield) should be worn while handling hot materials. For sites with greater temperatures, the split core barrel or aluminum liner insert are to be used.

2. Once it is confirmed that the sample bag can withstand the soil temperatures, the hot soil sample will be evacuated from the core barrel into the sample bag. Every effort possible will be made to minimize the time that the hot soil sample is exposed to ambient air during this process. See Figure 7 below.

Figure 7. Sonic Core Sampling Extraction (Boart Longyear, 2017)

3. The sample bag will then be immediately sealed on both ends by tying a knot with the plastic ends or fastening shut with tape. If the split barrel is used, the barrel will be capped at both ends with aluminum tape or properly-threaded caps. If the aluminum liner is used, the liner will be removed from the core barrel and sealed at both ends.

4. The entire sample bag (several feet long, depending on the depth of the boring) or aluminum liner will then be placed into an ice bath for cooling to a maximum of 50°F (10°C). Ice may be placed on all sides of the core. It is often helpful to place another plastic sheeting layer between the sample bag and the ice, such that melting water does not infiltrate the sample bag. For this procedure, cooling should ideally be completed in no more than 3-4 hours to prevent loss of volatiles. The ice bath will contain drain holes to allow melted water to freely drain rather than accumulate around the sample holder. Water shall be collected and containerized for proper disposal. The sample identification (ID) information will be marked on each ice bath for reference (again, dry erase boards are a good tool to use for this) when processing the cooled samples for labeling and shipping.

5. Sampling methods may vary depending on the general purpose of the soil sampling event. For the purposes of this document the sampling methods will be divided into two categories: Interim and Confirmatory Sampling.

    a. Interim Soil Sampling – Interim soil sample depths are typically selected based on the highest headspace PID reading collected at pre-determined intervals along each sample bag. Once cooled to a temperature no higher than 50°F (10°C) cut/rip a small hole in the sample bag at the desired depth interval location and place the PID sample probe into the headspace between the sample bag and the soil. Aluminum inserts should be cut to appropriate lengths once cooled to allow access to soil. Alternately, place a small amount of soil in a glass jar, cover the jar with aluminum foil, puncture the aluminum foil with the PID tip and screen the soil headspace in this manner. Once the headspace PID reading has been taken and recorded, cover the sample bag hole with tape and repeat at the next desired depth.

       It is imperative that all tools be decontaminated prior to use and in between readings of each sample interval.

       Once all of the PID readings have been collected and used to determine the ideal depth to sample, the cooled sample bags may be processed in the field by extruding the appropriate amount of soil from the hole in the sample bag, and placing the extruded soil directly into containers of the appropriate size and preservation, as dictated by the analytical laboratory and project sampling plan/quality assurance plan. Typically, for VOC samples, five grams of soil will be placed in pre-cleaned, pre-preserved vials (preserved either with deionized water or sodium bisulfate for low level samples, or preserved with methanol for high level samples). Typically, for SVOC samples, a 2 oz. or 4 oz. unpreserved amber jar is filled with the extruded soil. Alternately, if appropriate, volatile organic compounds may be collected in commercially available systems such as EnCore®.

    b. Confirmatory Soil Sampling – Confirmatory sampling generally has discrete sampling locations selected prior to the sampling event; however, headspace PID readings, as described above, may be required for documentation purposes. Otherwise, once cooled to a temperature no higher than 50°F (10°C), the cooled sample bags may be processed as described above in section 5a.

6. The following information for each sample will be documented in a Field Logbook: brief soil description, depth interval of sample, headspace PID reading (if required), temperature of sample collected at time of collection, time and date of sample collection, name of sampler/s. A photographic record of each sample collected, with identification label, is desirable.

7. Investigation Derived Waste (IDW): Soil cuttings not consumed in the sampling process must be disposed of in accordance with Federal, State, and Local regulatory requirements. Refer to the project Waste Management Plan (WMP) for site-specific directions on how to handle, store, transport, and dispose of IDW.

8. Unless additional equipment will be installed, boreholes in the ground (and/or insulating cover) created during soil sampling should be backfilled after sample collection is complete, as to minimize heat losses from the subsurface.

QA/QC Samples:

Trip blanks (applicable for volatile organic compound sampling only), equipment blanks (rinsate collected by rinsing sampling and/or handling equipment), field and/or blind duplicates and any other Quality Assurance/Quality Control (QA/QC) samples will be collected in accordance with the project SAP and Quality Assurance Project Plan (QAPP). Often, for interim soil sampling, QA/QC samples are less critical; during final confirmation sampling, QA/QC is typically more important.

Analytical Methods:

The analytical methods followed by the laboratory will vary depending on the contaminants of concern at the site, as well as the required detection limits and other data quality objectives. Examples of common volatile organic/semi-volatile organic analytical methods are shown in Table 1 below.

Table 1. Selected VOC/SVOC Analytical Methods

Analytical Method	Compounds of Interest	Notes
EPA SW-846 8260B	Volatile organic compounds (VOCs), including chlorinated VOCs	Options include: Requesting Tentatively Identified Compounds (TICs) for a library search of compounds, or Selected Ion Monitoring (SIM) for lower detection limits if needed
EPA SW-846 8270C	Semi-volatile organic compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs)	
EPA SW-846 8015	Total Petroleum Hydrocarbons (TPH) as Gasoline Range Organics (GRO)	Approximately C6-C12
EPA SW-846 8015	Total Petroleum Hydrocarbons (TPH) as Diesel Range Organics (DRO) / Oil Range Organics (ORO)	Approximately C10-C20 (DRO), C20-C34 (ORO)- actual ranges may vary between analytical labs

Other analytical methods (e.g. Polychlorinated Biphenyls/Pesticides, Dioxins, etc.) may apply on a project specific basis, as appropriate.

6. DOCUMENTATION

The following information for each sample will be documented in the Field Logbook:

- Name of site
- Date & time of sample collection
- Boring Location & depth interval of sample collection
- Brief description soil type, moisture content, and sample condition
- Temperature of sample at time of collection
- Name of sampler(s) and identification of drilling company
- Method of sample recovery (e.g. EnCore)
- If possible obtain a photograph of each sample collected with sample ID labels

Transfer of custody of the samples will be documented with a Chain of Custody (COC) form, provided by the laboratory.

7. REFERENCES

Boart Longyear. April 2017. Sonic Tooling Brochure. pp. 18. *Sonic Core Sampling Extraction.*

Gaberell, M., A. Gavaskar, E. Drescher, J. Sminchak, L. Cumming, W.-S. Yoon, and S. De Silva. 2002. "Soil Core Characterization Strategy at DNAPL Sites Subjected to Strong Thermal or Chemical Remediation." in: A.R. Gavaskar and A.S.C. Chen (Eds.), *Remediation of Chlorinated and Recalcitrant Compounds—2002*. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2002). ISBN 1-57477-132-9. Battelle Press, Columbus, OH.

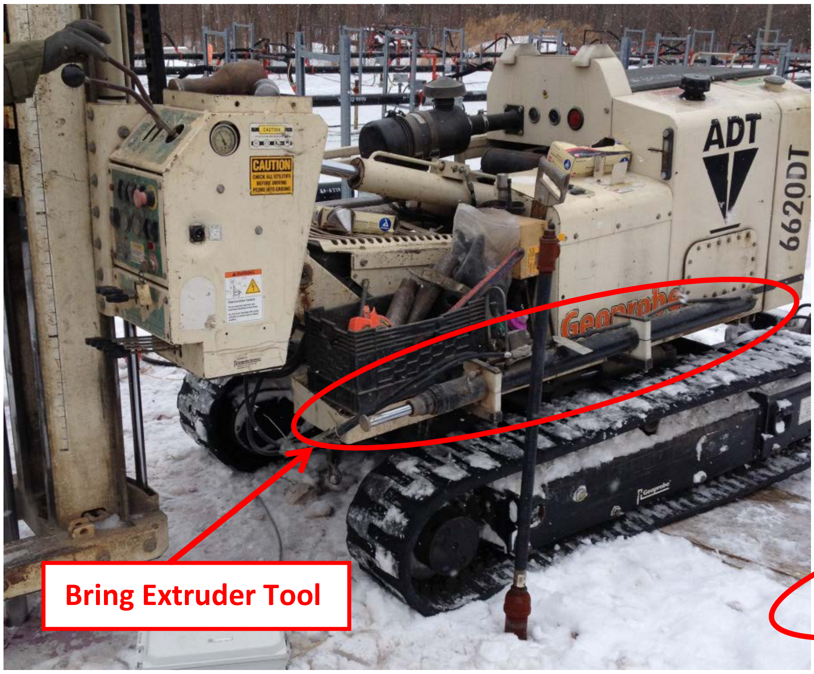
Gavaskar and A.S.C. Chen (Eds.), *Remediation of Chlorinated and Recalcitrant Compounds—2002. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds* (Monterey, CA; May 2002). ISBN 1-57477-132-9. Battelle Press, Columbus, OH.

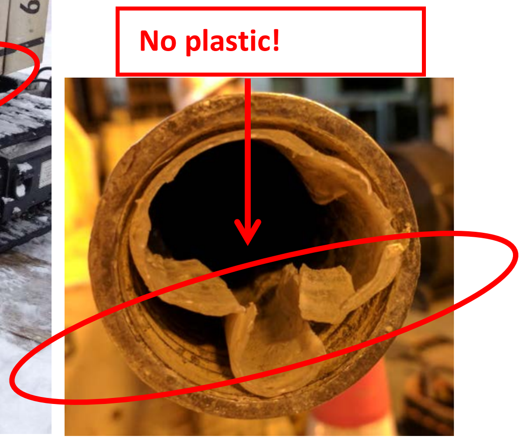
New Jersey Department of Environmental Protection. "Field Sampling Procedures Manual" August 2005. Available here: https://clu-in.org/download/char/passsamp/New-Jersey-Field-Sampling-Manualfsmp2005.pdf (last accessed 10/2017)

U.S. EPA Method *5035A, July2002,* Closed System Purge-And-Trap And Extraction For Volatile Organics In Soil And Waste Samples.

Hot Soil Sampling Checklist for Direct Push Technology (DPT) GeoProbe Drillers

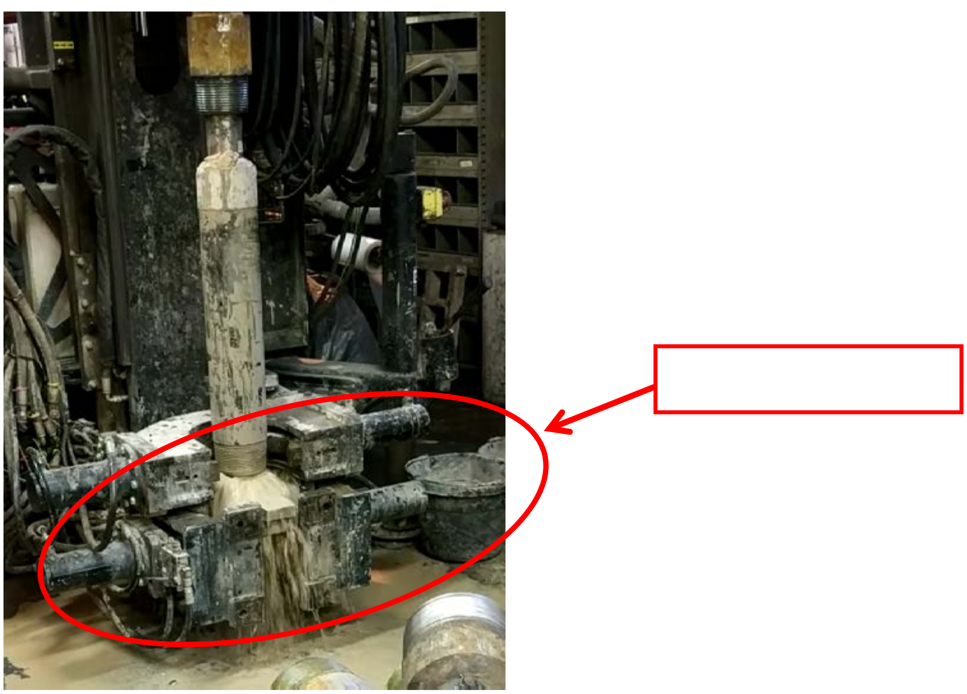
- High temperatures—expect at least 100°C (boiling) temperatures in the subsurface.
- Proper PPE required—HOT gloves (click here for example), faceshield, long sleeves, etc.
- Bring decon supplies to decon in between sample cores
- Do NOT use any poly/plastic or Teflon components for DPT (includes Teflon coated stainless steel)
- Use 6" stainless steel sleeves inside macrocore for DPT. Other lengths are acceptable with permission from TerraTherm.
- Bring red and black end caps for stainless steel sleeves
- Bring the extruder tool for DPT rigs.
- Bring 25-30% extra macrocores and extra sleeves, in case some get stuck/bent due to heat.
- Conference call/meeting required between drillers & TerraTherm before mobilizing to site.





Hot Soil Sampling Checklist for Sonic Drillers

- High temperatures—expect at least 100°C (boiling) temperatures in the subsurface.
- Proper PPE required—HOT gloves (click here for example), faceshield, long sleeves, etc.
- Bring decon supplies to decon in between sample cores
- Mini sonic rigs are the appropriate size for our application
- Low Density Poly Ethylene (LDPE) liners OK for 100°C sites—typically use 6 Mil Poly tubing (also called Layflat Tubing). Will need to check for melting of liner bag prior to putting soil in the liner. For sites with temperatures in excess of 100°C, aluminum liners with fully-cleaned/honed sonic core barrels or split core barrels should be considered or discussed.
- Either use no water in drilling process, or make sure to bring mudpan to catch water. Put bentonite clay around edge to contain water.
- <u>Conference call/meeting required between drillers & TerraTherm before mobilizing to site.</u>



TERRATHERM
a Cascade Company

TerraTherm, Inc.
151 Suffolk Lane
Gardner, MA 01440
978.730.1200

Procedure #	**SOG- SA-100**	**Revision #**	**3**
Review #1	Nikole Stone	**Review #2**	Alyson Fortune
Effective Date	**October 2017**	**Approved By:**	Stefan Griephe Nielsen