EXHIBIT G

REFERENCE MATERIALS

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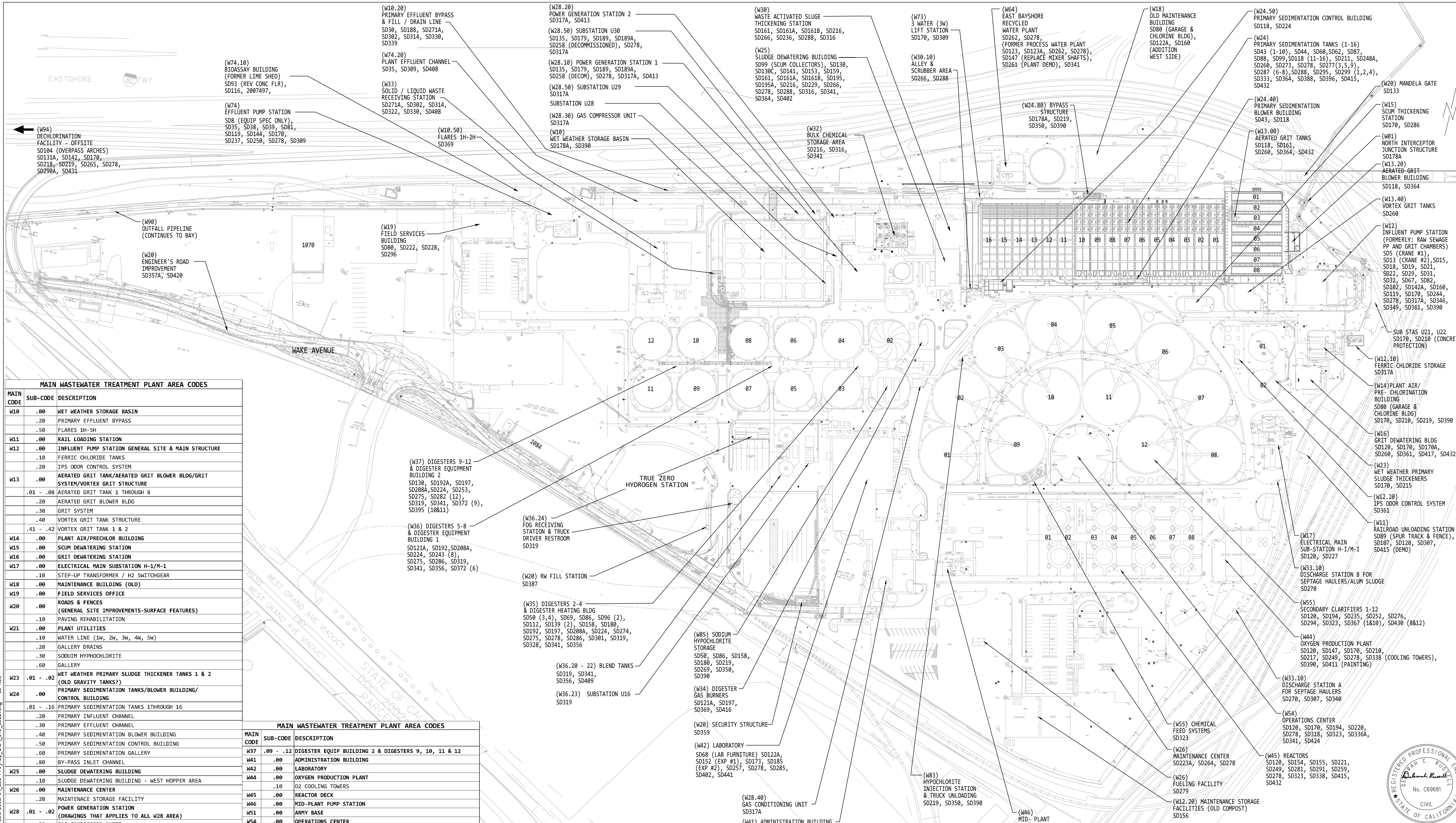

MAIN WASTEWATER TREATMENT PLANT AREA CODES		
MAIN CODE	SUB-CODE	DESCRIPTION
W10	.00	**WET WEATHER STORAGE BASIN**
	.20	PRIMARY EFFLUENT BYPASS
	.50	FLARES 1H-5H
W11	.00	**RAIL LOADING STATION**
W12	.00	**INFLUENT PUMP STATION GENERAL SITE & MAIN STRUCTURE**
	.10	FERRIC CHLORIDE TANKS
	.20	IPS ODOR CONTROL SYSTEM
W13	.00	**AERATED GRIT TANK/AERATED GRIT BLOWER BLDG/GRIT SYSTEM/VORTEX GRIT STRUCTURE**
	.01 - .08	AERATED GRIT TANK 1 THROUGH 8
	.20	AERATED GRIT BLOWER BLDG
	.30	GRIT SYSTEM
	.40	VORTEX GRIT TANK STRUCTURE
	.41 - .42	VORTEX GRIT TANK 1 & 2
W14	.00	**PLANT AIR/PRECHLOR BUILDING**
W15	.00	**SCUM DEWATERING STATION**
W16	.00	**GRIT DEWATERING STATION**
W17	.00	**ELECTRICAL MAIN SUBSTATION H-1/M-1**
	.10	STEP-UP TRANSFORMER / H2 SWITCHGEAR
W18	.00	**MAINTENANCE BUILDING (OLD)**
W19	.00	**FIELD SERVICES OFFICE**
W20	.00	**ROADS & FENCES (GENERAL SITE IMPROVEMENTS-SURFACE FEATURES)**
	.10	PAVING REHABILITATION
W21	.00	**PLANT UTILITIES**
	.10	WATER LINE (1W, 2W, 3W, 4W, 5W)
	.20	GALLERY DRAINS
	.30	SODUIM HYPHOCHLORITE
	.60	GALLERY
W23	.01 - .02	**WET WEATHER PRIMARY SLUDGE THICKENER TANKS 1 & 2 (OLD GRAVITY TANKS?)**
W24	.00	**PRIMARY SEDIMENTATION TANKS/BLOWER BUILDING/ CONTROL BUILDING**
	.01 - .16	PRIMARY SEDIMENTATION TANKS 1THROUGH 16
	.20	PRIMARY INFLUENT CHANNEL
	.30	PRIMARY EFFLUENT CHANNEL
	.40	PRIMARY SEDIMENTATION BLOWER BUILDING
	.50	PRIMARY SEDIMENTATION CONTROL BUILDING
	.60	PRIMARY SEDIMENTATION GALLERY
	.80	BY-PASS INLET CHANNEL
W25	.00	**SLUDGE DEWATERING BUILDING**
	.10	SLUDGE DEWATERING BUILDING - WEST HOPPER AREA
W26	.00	**MAINTENANCE CENTER**
	.20	MAINTENACE STORAGE FACILITY
W28	.01 - .02	**POWER GENERATION STATION (DRAWINGS THAT APPLIES TO ALL W28 AREA)**
	.30	GAS COMPRESSOR UNITS
	.40	GAS CONDITIONING UNITS
	.50	SUBSTATION U29 & U30
W30	.00	**WAS THICKENING STATION**
	.10	WAS THICKENING STATION - ALLEY & SCRUBBER AREA
W32	.00	**BULK CHEMICAL STORAGE AREA**
W33	.01 - .05	**LIQUID/SOLID (RESOURCE RECOVERY (R2) FACILITIES)**
	.10	DISCHARGE STATION
	.20	DEDICATED DIGESTER FOODWASTE & DEWATERING
	.30	FOODWASTE FERRIC FACILITY
W34	.00	**DIGESTER GAS BURNERS**
W35	.02 - .04	**DIGESTER HEATING BUILDING & DIGESTERS 2, 3 & 4**
W36	.05 - .08	**DIGESTER EQUIP BUILDING 1 & DIGESTERS 5, 6, 7 & 8**
	.20	BLEND TANKS

MAIN WASTEWATER TREATMENT PLANT AREA CODES		
MAIN CODE	SUB-CODE	DESCRIPTION
W37	.09 - .12	**DIGESTER EQUIP BUILDING 2 & DIGESTERS 9, 10, 11 & 12**
W41	.00	**ADMINISTRATION BUILDING**
W42	.00	**LABORATORY**
W44	.00	**OXYGEN PRODUCTION PLANT**
	.10	O2 COOLING TOWERS
W45	.00	**REACTOR DECK**
W46	.00	**MID-PLANT PUMP STATION**
W51	.00	**ARMY BASE**
W54	.00	**OPERATIONS CENTER**
W55	.01 - .12	**SECONDARY CLARIFIERS 1-12**
W64	.00	**EAST BAY SHORE RECYCLING FACILITY**
W73	.00	**3W LIFT STATION**
W74	.00	**EFFLUENT PUMP STATION**
	.10	BIOASSAY BLDG
	.20	PLANT EFFLUENT CHANNEL
W83	.00	**POST HYPOCHLORITE INJECTION STATION & TRUCK UNLOADING**
W85	.00	**HYPOCHLORITE STORAGE AREAS**
W90	.00	**OUTFALL**
W94	.00	**DECHLORINATION FACILITY (OFFSITE)**
	.10	CONTROL BLDG
	.20	INJECTOR BLDG
	.30	SODUIM BISULFITE STORAGE

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DESIGN	DESIGN BY:	J. TRAN
	DRAWN BY:	J. TANG
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STATE OF CALIFORNIA

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

WASTEWATER DEPARTMENT
MAIN WASTEWATER TREATMENT PLANT (MWWTP)

GENERAL

CONSTRUCTION CONTRACT SITE MAP
AREA CODE & LEGACY PROJECT NUMBERS

SCALE NTS
DATE 26JUN2026

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DRAWING NUMBER

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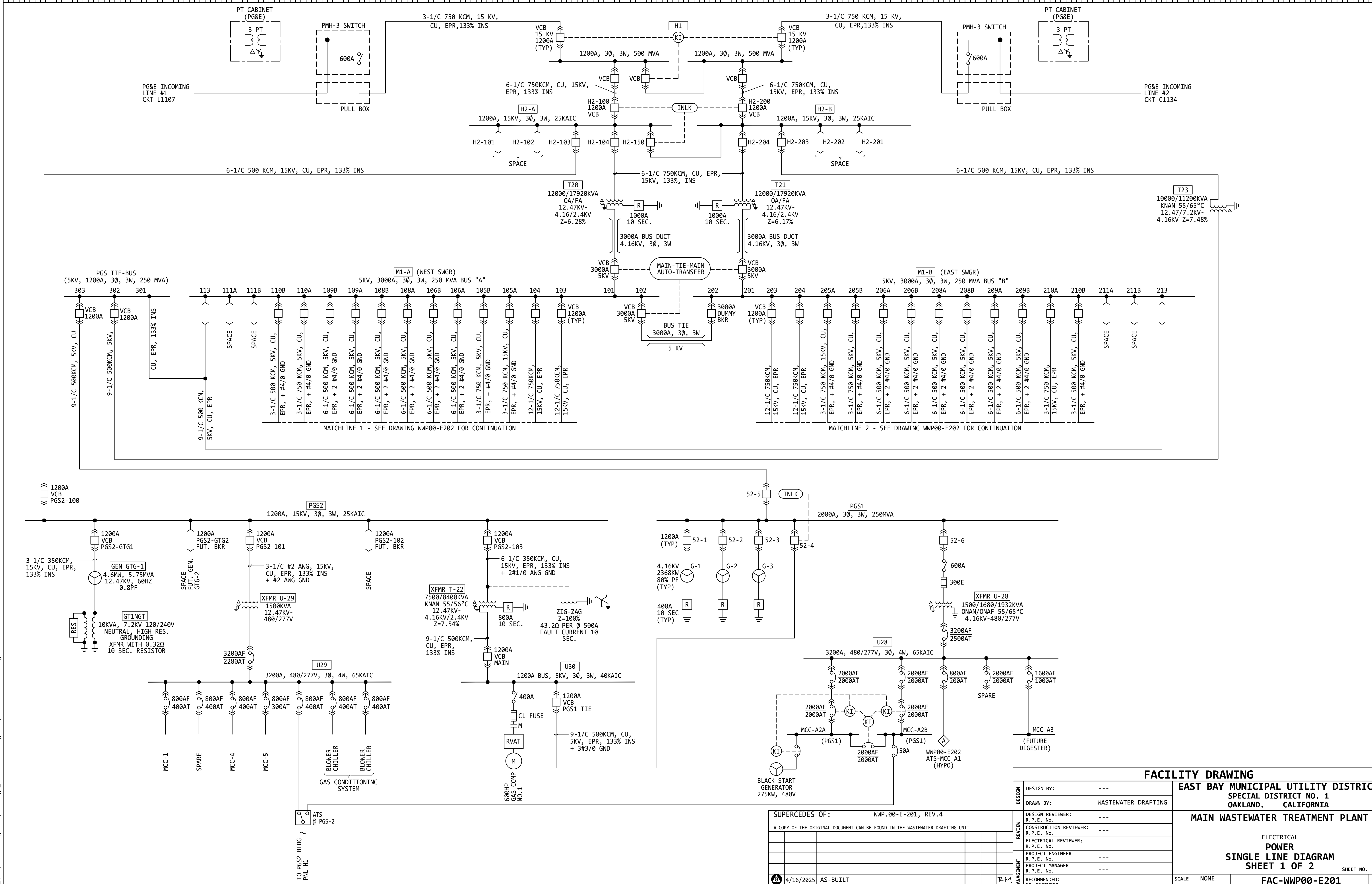

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EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT

ELECTRICAL
POWER
SINGLE LINE DIAGRAM
SHEET 1 OF 2

SHEET NO. 1

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DATE 04/16/2025

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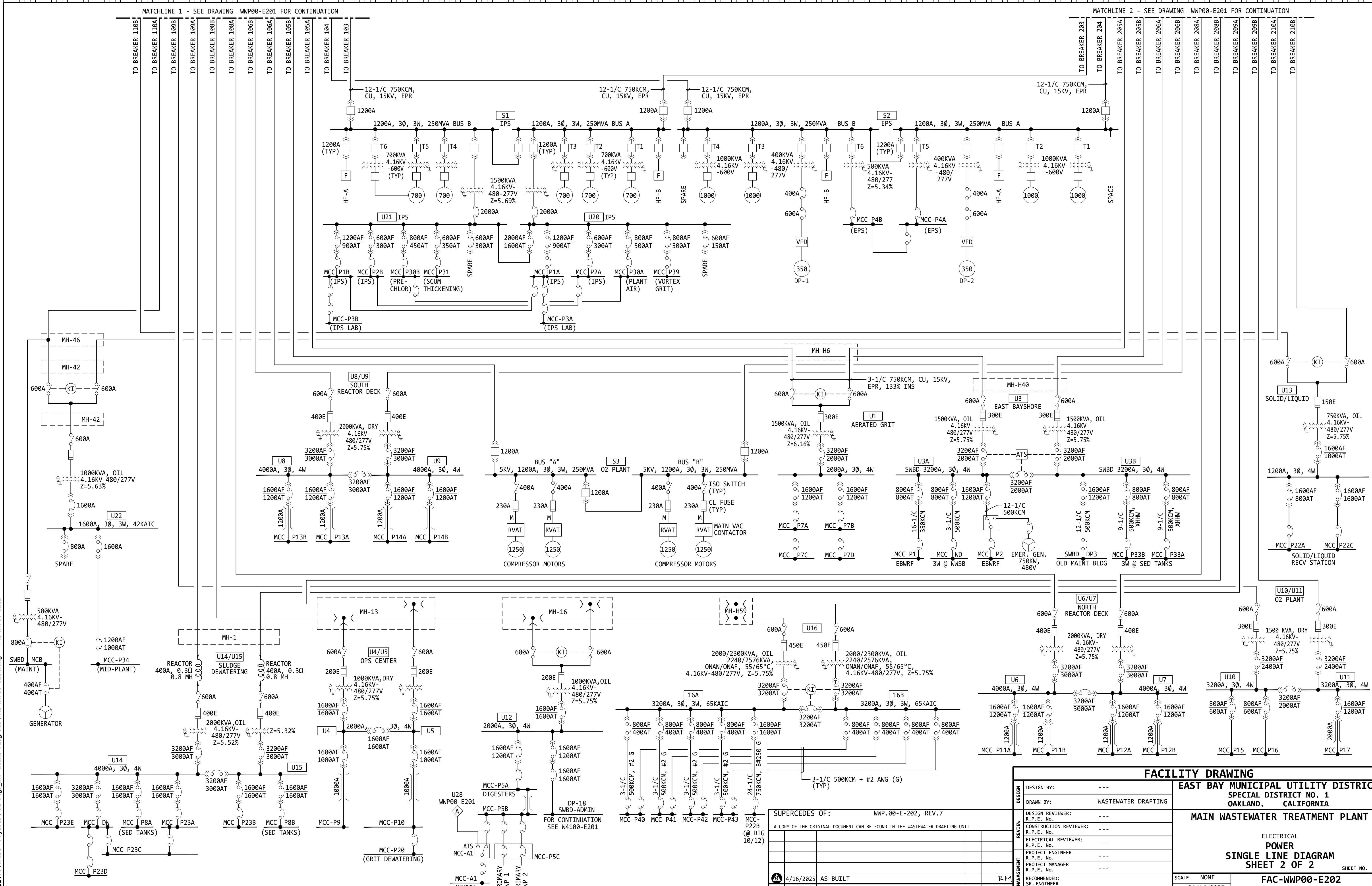

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FACILITY DRAWING

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

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	PROJECT MANAGER R.P.E. No.	---
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MAIN WASTEWATER TREATMENT PLANT

ELECTRICAL
POWER SINGLE LINE DIAGRAM SHEET 2 OF 2

SHEET NO. 2

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WASTEWATER ELECTRICAL RESILIENCY MASTER PLAN

Task 2 – TM1

Consequence of Failure Analysis

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Walnut Creek, CA 94596
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012241.00

East Bay Municipal Utility District

August 2024

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EXECUTIVE SUMMARY

The East Bay Municipal Utility District (EBMUD) would like to improve electrical resiliency at the Main Wastewater Treatment Plant (MWWTP) and has contracted with Woodard & Curran, Inc. (W&C) to analyze the system to identify failure vulnerabilities and consequences, develop and evaluate alternatives to enhance resilience, and ultimately provide a roadmap to greater resiliency. This TM (TM1) presents the results of the first task of the study.

Purpose of Scope

This TM assesses the resilience of power systems at the MWWTP and provides recommendations as appropriate to improve resilience.

The scope of the study included data review and site observations but did not include any field testing of equipment or conductors.

Findings

Table ES-1 summarizes key findings which are further described in Section 2

Table ES-1: Findings

Finding	Description
F-1	***No full power redundancy exists*** While the plant has four sources of power (two-line power feeds and two internal power generation stations (PGS's), no single source of power is sufficient for maximum load.
F-2	***Line power feeds are prone to common cause failure*** The plant's two-line power feeds (PG&E circuits L & C) are exposed to common-cause failure because they share a common alignment in the final approach to the plant: a single duct bank, vault, and aerial alignment.
F-3	***Various hazards threaten reliability of the line power*** Line power reliability has diminished in recent years and increased the plant's vulnerability.
F-4	***Load-shedding Controls are not protecting the plant from blackouts*** The plant's load-shedding system is not routinely enabled by plant staff, so the system affords minimal protection against loss of any of the plant's four power sources.

F-5	***Distribution System Topology*** The power distribution system within the MWWTP has evolved organically over the years, leading to complex routing and controls. This complexity magnifies the impact of individual component failures and has been a factor in some historic power outages. Component failures are attributed to wiring at the lower voltage levels that are not aligned with the same power bus (A or B) as the major equipment that they supplement, also described in this TM as commingling. Lack of redundancy in some portions of the power system Cabling systems including taps and splices in vaults that may contain water Aging distribution cable systems Lack of automated tie-breaker controls for motor control centers
F-6	***PGS black-start is slow*** PGS startup is slowed by the need to flare built-up biogas.
F-7	***Restoring utility power back to the plant is not efficient*** Bringing the plant back into service after a Direct Trip Transfer (DTT) requires District staff to come to the plant to reclose the breakers at H1 after PG&E provides approval. PG&E communication protocol is not efficient and the lack of appropriate training for District staff to restore power to the plant efficiently was compromised.

Analysis and Conclusions

Based on the findings listed above, W&C makes the following conclusions and further describes these conclusions in Section 3:

Table ES-2: Conclusions

Conclusions	Pertains to Finding(s)	Description
C-1	F-1, F-2, F-3	The plant's line power supplies should not be considered reliable, owing to lack of full redundancy to maintain plant operations during peak events and environmental exposure
C-2	F-4, F-6	The disablement of the SEL POWERMAX power control system poses a significant risk associated with power outages and maintaining PGS operation.
C-3	F-5	Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity.
C-4	F-5	Process trains and their ancillary devices are not wired to the same power bus which increases risk of non-operation when one of the two line circuits are not available and a tie breaker is not closed or if the load shed control system is enabled.
C-5	F-4, F-6	Biogas storage is not available to provide efficient and safe starting of engines during a black start.
C-6	F-5	Replacement or failure of some portions of the 12.47kV and 4160V distribution cable system require shutdowns of process systems or require temporary power.
C-7	F-7	Bringing the plant back into service after a DTT takes longer than expected due to operational procedures and communication protocol with PG&E.

Summary of Recommendations

W&C makes the following recommendations to improve the electrical resilience of the power distribution system at the MWWTP in the order of what W&C believes is the greatest contributor to a consequence of failure scenario that leaves the MWWTP without reliable power. These recommendations are further discussed in Section 4.

Table ES-3: Recommendations

Recommendations	Pertains to Conclusion(s)	Description
R-1	C-1	The plant's line power supply should not be considered reliable, owing to lack of full redundancy, and environmental exposure. Consider replacing one of the existing line circuits with a dedicated service with limited overhead distribution. Investigate option to obtain service from another provider (Port of Oakland)
R-2	C-2, C-5	The SEL POWERMAX system should be enabled at all times to maintain operation of PGS during utility outage and avoid black start.
R-3	C-2, C-4, C-5	Correct or consolidate low voltage wiring systems that are commingled between the different power buses (A versus B).
R-4	C-2	Revise load shed priority list based on criticality of processes and TTI.
R-5	C-7	Revise operational procedures to improve the time it takes to restore power to the plant.
R-6	C-1, C-3, C-5, C-6	Modify or add electrical equipment to provide full redundancy. Replace below grade cable connectors with above grade switchgear. Investigate modifications to the biogas system to provide storage to avoid flaring of gas during black start.

1. INTRODUCTION

1.1 Background

This TM is prepared as part of W&C's study of electrical resilience at MWWTP. There is a total of three TM's, with the first TM as the foundation for the second and third TM. The ultimate goal of the electrical resiliency study is to provide the District with a roadmap (TM3) of projects based on the findings (TM1) and alternatives selected (TM2).

1.2 Objective

The objective of this TM is to identify vulnerabilities within the power distribution system and operations at the MWWTP and then determine the consequence of failure and provide recommendations. To support the analysis W&C visited the site, met with District staff and reviewed the following data provided by the District:

- MWWTP Load Flow Study (May 2020)
- Map of Substations (Nov. 2016)
- Medium Voltage Single Line Diagram (May 2016)
- MWWTP Underground Electrical Facility Drawings (Dec. 2012)
- MWWTP Power Distribution System Replacement (SD 227, 1998)
- Standardized Maintenance Practice For Electrical Service Continuity Plan Standard Operating Procedure (SOP) for Main Service Power Restoration (Feb. 2023)
- PI Data Collected, 15 Min Intervals (2004 – 2022)

As part of this task, W&C visited the site visit on February 21, 2023, to observe the location and condition of existing equipment. With the exception of a few open vaults, underground systems such as duct banks, electrical handholes and vaults were not observed, and no vaults were entered. Switchgear and electrical panels were not opened due to safety concerns; however, the exterior and age of the panels were noted along with comments from District Operations staff regarding functionality and reliability concerns.

1.3 Scope

This TM is based on site observations, meetings with District Operations staff, review of documentation, historical data, etc. The findings and conclusions are limited to areas which we were able to observe safely without having to open electrical panels with live parts or entering electrical vaults that require authorization from the plant's health and safety department. Investigation of power circuits Line L and C entry into the MWWTP was restricted to observation of overhead lines, Google Earth, and as-built construction drawings. Routing offsite is being confirmed by PG&E and has not been verified as of the date of this TM. The data collected was then analyzed for potential failure and its consequences. Workshops and virtual meetings were held to document methods of operations and protocols when power to the plant is lost and is restored. The following components were considered most valuable to the power system during analysis:

- Pacific Gas & Electric (circuit lines L & C)
- Power Generation System (PGS-1 and PGS-2)
- System Topology
- Power Distribution Equipment and Cabling
- Power System Controls
- System capacity

- Restoring Power

1.4 Organization of this TM

Section 2 of this TM presents W&C's findings related to the power systems. This section includes an overview of the system's topology, its key components, its dependencies, and historical observations. Key findings, i.e., those that impinge on power system resilience, are numbered for easy reference.

Section 3 presents the analysis and conclusions W&C has drawn from the presented findings. Those conclusions represent W&C's synthesis of the various findings based on professional judgment.

Section 4 of this TM presents W&C's recommendations.

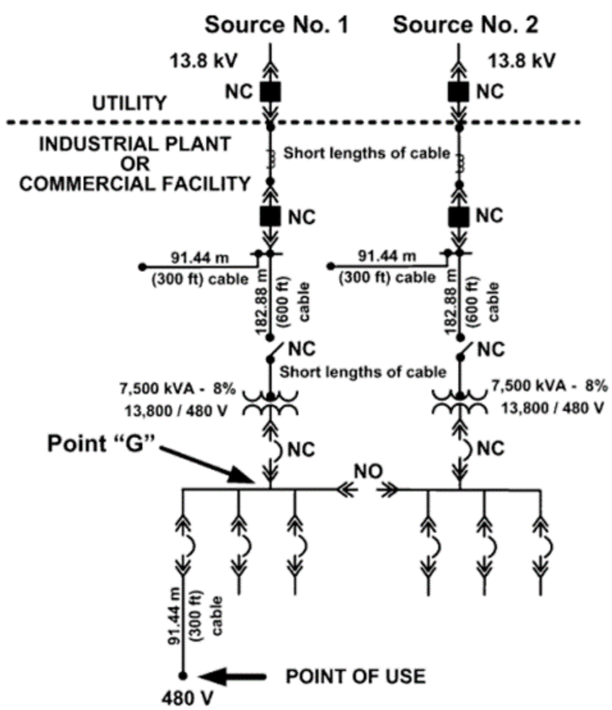
2. FINDINGS

2.1 Existing Plant Power System

2.1.1 System Topology

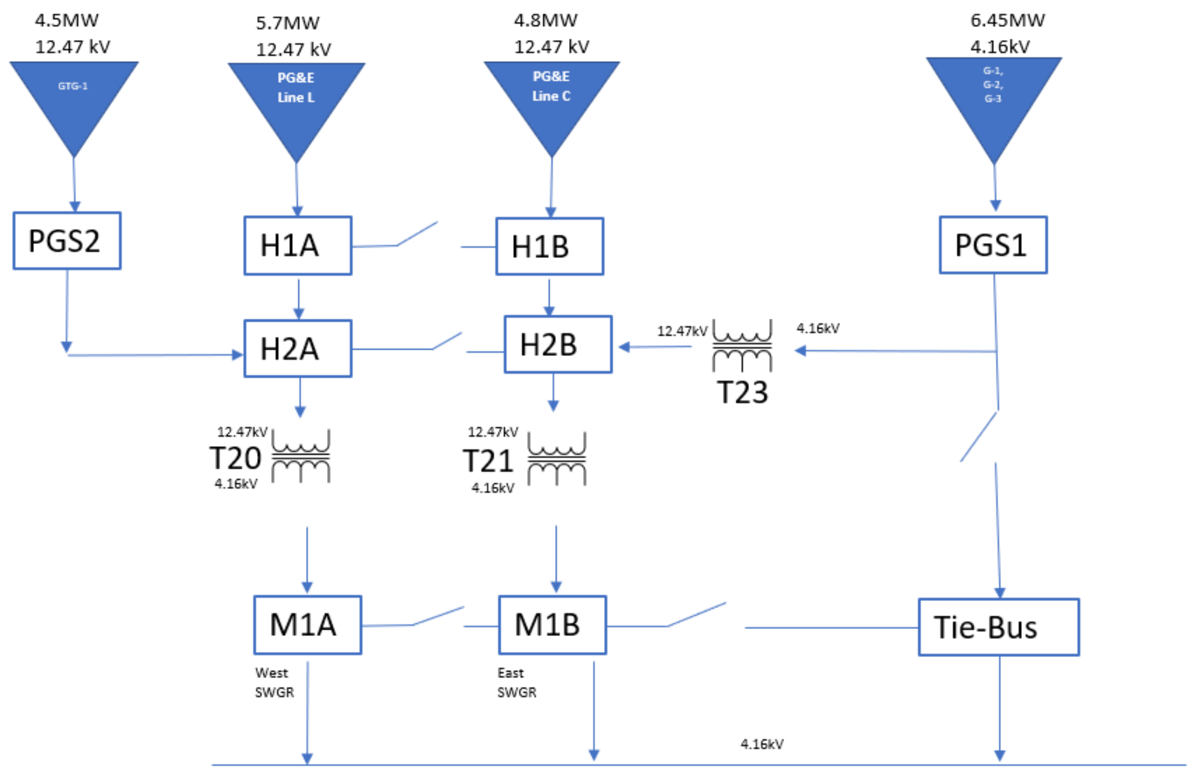
The line power at MWWTP was originally designed as a "secondary-selective system" as defined in IEEE 493 (IEEE). Such a system provides two separate line power sources in lieu of relying upon engine generators to provide standby power to meet federal standards for backup power. This configuration is responsive to federal standard EPA 430-99-74-001 (USEPA) which requires "Two separate and independent sources of electric power shall be provided to the works from either two separate utility substations or from a single substation and a works-based generator." Figure 2-1 shows a typical configuration.

Figure 2-1: Typical Secondary-Selective System



To implement the secondary-selective system, MWWTP receives distribution power from two 12.47 kV circuits: Line L1107 (Line "L") and Line C1134 (Line "C"), served by PG&E substations L and C, respectively. In addition to the two line power feeds, the MWWTP receives power from two internal power generation stations (PGS's) that produce electricity from biogas: PGS-1, a three-engine station, and PGS-2, a single-turbine station. two-liner power sources and their capacities are shown in Figure 2-2 below. Based on input from the District, the MWWTP is not on PG&E's Block 50 meaning that the plant is subject to rotating outages.

Figure 2-2: MWWTP Simplified Single Line Diagram



Finding F-1: No full power redundancy exists

Observation of the two independent electric power sources indicated in Figure 2-1 that comply with the foundation requirements of EPA for a reliable source of electric power is not enough to meet the load requirements as described in Section 2.1.2 Plant Load Data. It should also be noted that both Lines C and L are not dedicated lines, meaning that other PG&E customers are also connected to these circuit lines, which limits the available capacity for each line.

2.1.2 Plant Load Data

The District uses Plant Information (PI) software (by OSIsoft) to store historical process data from the DCS system. W&C studied historical PI data from 2004 to 2022 to assist with the understanding of minimum and maximum loads including wet and dry seasons. The data include high flow days, correlated with power monitoring data at individual locations throughout the plant. Power consumption data were collected at the meters located on the line side of the incoming transformers T-20 and T-21, denoted in the PI data as "Main Trans 1" (OT20) and "Main Trans 2" (OT21). The maximum peak demand and average values are noted in Table 1 below. As of the date of this TM, the maximum load demand is still recorded at 10.65MW.

Table 1: Recorded Maximum and Average Values (MW)

Season[1]	Maximum/Peak[2]	Average[3]
Wet	10.65 MW	4.78MW
Dry	7.53 MW	4.47MW

Notes:
1. Wet season is defined as October 1st thru April 15th per District.
2. Peak wet weather was recorded on 12/11/14 and peak dry weather was recorded on 6/4/11.
3. Average is based on a 10 year period from 2012 to 2022.

W&C reviewed the PI data and determined that most of the time the plant was a net power exporter. A histogram was developed from the PI data depicting the percentage of time power demand and is provided in Appendix A. The histogram illustrates that for less than 1% of the time the facility requires greater than 8MW indicating that rarely does the power demand exceed this value except for 1% of the time in both average and maximum. However, a recent power outage event that occurred on March 21, 2023, indicated that the power demand just prior to plant shutdown was approximately 6.9MW. Based on this data, and the data indicated in Table 1 it can be determined that consideration for increasing reliability and resiliency should be heavily focused on a minimum of greater than 4.47MW with a maximum of 10.65MW and up to 12MW (margin added for future and unforeseen historical events) for wet weather peak events.

Finding F-1: No full power redundancy exists

Comparing the load data with the power feed capacities (MW) shown in Figure 2-2, it is evident that neither of the two power feeds are sufficient on their own to meet maximum loads during any season; and when combined, their capacities are barely sufficient to meet maximum wet-weather loads. Thus, the current system's loads are inconsistent with the assumed design intent of full compliance with EPA standards for backup power.

2.1.3 Distribution and Utilization Voltage

The plant accepts both PG&E circuits at 12.47kV at switchgear H1, where revenue meters and the direct transfer trip system are located. Switchgear H2 is the distribution switchgear for the plant and is also where PGS2 is connected for distribution and export. PGS1 is downstream of H1 because its voltage is 4.16kV, rather than the 12kV at H2.

H2 provides the primary power to feed transformers T-20 and T-21 that step from 12.47kV down to 4160V for load centers located throughout the plant facility. The load centers are fed from the 4160V switchgear M1A (West SWGR) and M1B (EAST SWGR) and are connected via a normally open (NO) tie breaker. The load centers then step the 4160V down to 480V for Utilization via motor control centers or switchboards.

The motor control centers and Medium Voltage (MV) switchgear are all set up with main-tie-main systems to increase redundancy and reliability. There is an Auto Transfer Controller to operate the tie-breaker between M1-A and M1-B. The tie-breaker in this case closes when one of the incoming sources is not available either due to equipment failure or a PG&E outage in either service circuit. Additionally, all medium voltage breakers located within M1 and H2 can be remotely tripped and closed back in, allowing for load shedding in the event of an outage. Throughout the MWWTP, MV breakers configured with a main-tie-main have either mechanical or electrical interlocks to ensure the two incoming sources cannot be paralleled at any time.

Additionally, according to the District's SOP, most of the plant loads are powered from PG&E utility line L at 12kV which is paralleled with PGS2 (gas turbine generator). Minor loads are carried on PG&E utility Line C which is paralleled with PGS1 (the engine generators). By aligning equipment loads with Line L and PGS2, the majority of the plant critical loads are connected to the more reliable utility line with PGS2 considered as a second source of power. The utility Line C is reserved for less critical loads, as well as the primary export sales of power from PGS1. The equipment is fed as indicated, based upon the PI data provided and the power distribution single line provided.

2.1.4 Utility Service Routing

W&C reviewed existing electrical site plans from the Power Distribution Replacement Project (SD- 227), with particular attention to the PG&E incoming feeds. Circuit L is shown in the same duct bank with circuit C, as shown in Appendix B. Both circuits share the same electrical vault and the same duct bank and are routed northeast past the Grit Building and appear to go under the train tracks to a pole on Wood Street and 34th Street. Refer to Figure 2-3 for an aerial view of the plant with assumed routing of the PG&E duct bank and to Figure 2-4 where the riser pole for both circuits is assumed. Figure 2-5 indicates the locations of both substations that provide power for circuits L and C, respectively. It is not known if the overhead circuits on Wood Street and 34th Street go below grade or remain routed overhead.

W&C asked PG&E to confirm the routing of circuits L and C and determine the provenance of the unknown power pole on the north side of the plant shown in Figure 2-3. PG&E's response indicated that a field survey on Wood Street and 34th Street by PG&E is required for these items. As of the date of this TM, a field survey has not been completed to confirm our assumptions.

Finding F-2: Line power feeds are prone to common cause failure

The common routing and shared vaults of circuits L and C pose a risk to the reliability of the electrical service. Various hazards that might affect one of these circuits, for example, fires or short circuits in the vault, would likely damage both circuits.

Finding F-3 Various hazards threaten reliability of the line power

W&C also observed that the duct bank containing the PG&E circuits runs below a railroad track. Given the year of installation (1989), the duct bank may not meet modern standards.

After crossing the tracks, the utility services share a common aerial routing for some distance until they split to their respective substations. That aerial route is not in a highly secure area, exposing the circuits to damage.

Figure 2-3: Aerial View of Line C and L Routing

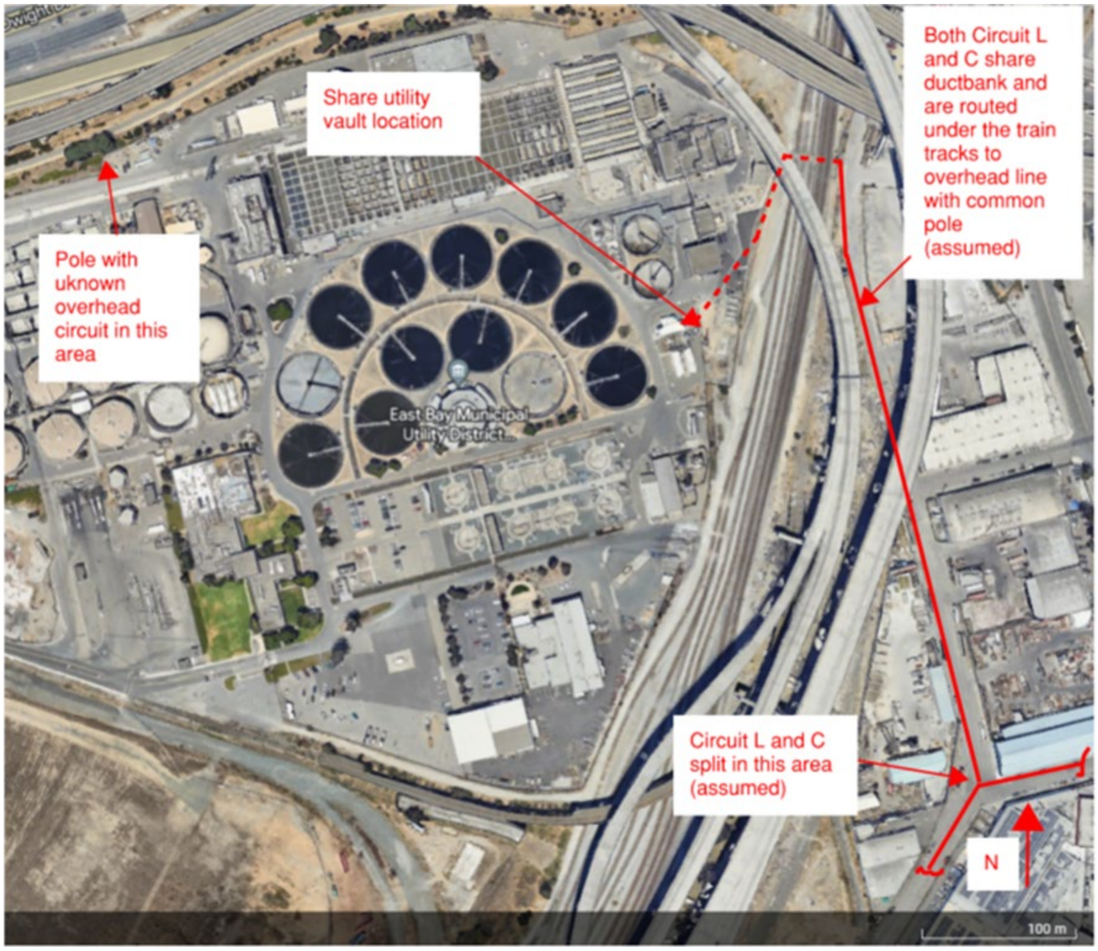


Figure 2-4: Pole Riser

Figure 2-5: Line Power Routing

2.1.5 Power Distribution Cables and Splices

2.1.5.1 Cables

When reviewing cable schedules from Project SD-227 and the Underground Electrical Facility Drawings, it appears that sections of cables were replaced as needed to accommodate the installation of the new M1 and H1 switchgear, as well as additional work at the unit substations across the facility. The cable schedules in the Underground Electrical Facility Drawings do not have an extensive list of the existing cables and their original installation date which would then aid in when they should be replaced (30 year life expectancy is customary).

Finding F-5: Aging distribution power cables may pose a threat to reliability.

2.1.5.2 Taps and Splices

Three underground tap (elbow connector) locations were identified as potential vulnerabilities. The existing system has MV taps accomplished with “T” body elbows and “L” body elbows. These tap connections, while reliable and rated for underground installation in a vault, must be disassembled to be disconnected. This requires the entire circuit to be de-energized, causing additional outages to interconnected buildings on that same circuit. An issue with The Operations Center feeder circuits from Substation U4 would require the de-energization of Substation U12 (Digester Building) as well as Substation U16 (Digester Feed Pumps), and an issue with the U12 feeder circuits would require a similar outage. Entering the vaults requires the District’s Health and Safety Department approval for entering a Confined Space prior to doing any work inside of the vault. This step while being vital to staff safety is required because it is a Confined Space and requires qualified staff to enter it. That said, this process adds time to obtaining entry to the vault. The locations are identified in Table 2-1 below, along with a description of the process equipment directly affected by a potential outage.

Table 2-1: Taps and Splice Vault Locations

Location of Connection	Connection Type	Connected Substations/Processes
MH-13	Tap	U4/U5: Operations Building, Grit Handling, RAS/WAS
MH-16	Tap	U12: Digester Building and Digester Ancillaries
MH-40	Splice	U3: East Bayshore, 3W Water Lift Station, Distribution Pumping, Chlorination, Wet Weather Storage, Bisulfite Addition
MH-46	Tap	Maintenance Building: Motor testing and repair shop

Finding F-5: Taps and splices create potential points of failure in the power distribution system, especially when subjected to moisture or water infiltration in the electrical vaults.

2.1.6 Power Distribution Equipment

2.1.6.1 Tie-Breaker Configuration and Operation

All the load centers fed from switchgear M1, whether from Bus A or from Bus B (M1-A and M1-B in Figure 2-2), have two independent feeder circuits. Those two feeds are meant to be used in a split-bus configuration (except where there is a single substation transformer), in which the two feeds come into two mains, and the bus tie breaker is normally open. Load Center S2, which supports the Effluent Pumping Station, is also configured in this manner. This setup reduces the immediate impact of an outage, since in the event of an outage on one side of the switchgear, loads can still be satisfied. It allows loads on one half of the bus to be satisfied even if an outage were to occur on to either side. It also provides some level of redundancy and resilience in the event of an outage, as half the loads would be active on one half of the bus even if an outage were to occur on either side of the M1 Switchgear.

However, downstream of switchgear M1, the system lacks the ability to automatically close the tie breaker for bus A and bus B. This could leave critical loads without power until staff could assess and manually operate the tie breaker. Doing so requires significant expertise. Potential to modernize the existing MCC's downstream with Main-Open Tie-Main automatic transfer functionality exists and would greatly increase the resilience of key facilities without operator intervention. Below are examples list in Table 2-2 of locations that could potentially benefit from Main-Open Tie-Main auto transfer configurations.

Table 2-2: Load Center Auto Transfer Tie Breaker Candidates

Substation ID/MCC	Process Purpose	Current Configuration
U20, U21/P1, P2	Influent Pump Station	Backfeed, Kirk Key Interlock
S2, MCC P4	Effluent Pump Station	Backfeed, Kirk Key Interlock
U4, U5/P9, P10	Ops Building	Single Feed, No Interlock

A Kirk Key is a safety mechanism to prevent simultaneous operation of multiple circuit breakers. It involves a key that locks or unlocks specific breakers to ensure that only one source can feed the load at a time.

Finding F-5: Lack of automatic controls for motor control center tie-breakers in specific areas will increase recovery times in the event of an outage.

2.1.6.2 Low Voltage Wiring

Discussions with operations staff and review of documentation indicate that some process trains are not fully functional during a partial power outage because their supplemental devices are wired to a different power source or bus than the bus that has available power. For example, the S1 Load Center, which supports the Influent Pumping Station, is fed from bus A and B of M1 Switchgear with a tie-breaker connecting both buses. The main breaker connected to the B bus is normally closed with the A bus main breaker normally open and the bus tie breaker normally closed. This is not a typical configuration for most plant systems when both A bus and B bus feeders are reliable. This is due to a commingling of power circuits within the IPS. In the case of an outage in one side of the M1 Switchgear, it is possible for pumps on one side of the S1 Switchgear to be energized but nonfunctional due to a lack of power to the ancillary devices.

Finding F-5: Some major equipment processes have supplemental devices that are not wired to the correct power bus (A or B) by which reliance on both sides of a dual-power system increases the risk of a process, or components of a process, going offline.

2.1.6.3 Reliability of Key Components

W&C observed that many components, while performing well, are obsolete. For example, the downstream switchgear at S1 and S2 are old 1980s vintage General Electric PowerVac equipment, which utilize induction disk protection relays. These pieces of switchgear are considered obsolete, although induction disk relay technology is still reliable if maintained properly. This switchgear will be replaced as part of the IPS Modifications Project.

Finding F-5: Aging equipment poses a high maintenance burden on staff to maintain adequate reliability and obtain spare parts.

2.1.6.4 Redundancy of Key Components

At many of the most critical unit processes, dual feeds are provided; each with its own transformer. This arrangement provides full redundancy in the event of an up-stream failure. Each feed and transformer is sized for the full load of the equipment; however, some motor control centers at the MWWTP are equipped with only a single feed and/or single transformer. As a result, the failure of either the feed or transformer would result in a power loss to the entire area of the MWWTP served by that transformer. Additionally, maintenance on the transformer is complicated by the need to provide temporary power during the maintenance activity. Examples of this arrangement include the Digester gas conditioning system, as well as the Digester Building. Table2-3 below indicates the substations that do not provide full redundancy:

Table 2-3: Substations without Full Redundancy

Substation No.	Process
U22	Mid-Plant
U16	Digesters
U1	Aerated Grit
U13	Solid/Liquid Receiving Station

Finding F-5: Lack of equipment redundancy at key locations increases the risk of a process shutdown and increases the difficulty of performing maintenance.

2.1.7 Power System Controls

The MWWTP power system employs a Schweitzer Engineering Laboratories (SEL) POWERMAX power management and control system (PMCS) that offers remote control of all MV breakers from a human machine interface (HMI). This system was installed around 2010 and updated in 2021. The POWERMAX system includes adaptive high-speed load shedding and generation shedding to preserve on-site generation during loss of utility. The POWERMAX system leverages the protective relays that are necessary for generator/bus/feeder protection and power quality meters to obtain real-time breaker status, alarms, event reports, sequential event reports (SER), and metering. This data is streamed to the Emerson Ovation Distributed Control System (DCS) and historized in the OSIsoft PI database. The POWERMAX system includes auto-synchronization to connect back when utility is restored. Lastly, the POWERMAX system includes an automatic switching system at Switchgear M1 that will open an M1 main breaker upon loss of source and close the M1 tie breaker to restore power to all process substation loads. The existing prioritization of loads is shown in Table 2-4 below:

Table 2-4: Existing Load Priority for SEL POWERMAX Control System

Priority	Breakers	Substation	Process Area
1	103, 203	S1	Influent Pump Station
2	104, 204	S2	Effluent Pump Station
3	110B, 210B	U13	Digester
4	109B, 209B	U10/U11	Oxygen Production Plant
5	108B, 208B	U4/U5/U12/U16	Operations Center, Lab, Admin Bldg, Digesters
6	108A, 208A	U6/U7	North Reactor Deck
7	106B, 206B	U8/U9	South Reactor Deck
8	106A, 206A	S3	Oxygen Compressors
9	105B, 205B	U3	Process Water (3W)
10	109A, 209A	U14/U15	Sludge Dewatering/Thickening
11	105A, 205A	U1	Grit Handling
12	110A, 210A	U22	Mid Plant

The POWERMAX system was installed in response to the December 2005 plantwide blackout event. The POWERMAX system is designed to be continuously enabled to instantly respond to the loss of a power source by shedding loads as needed to balance loads with supply, and routing power to critical loads. For example, if line power is lost, the system is designed to automatically separate from line power and run as two islanded power systems: 1) A-Bus or PGS2 Turbine Island, and 2) B-Bus or PGS1 Engine Island. Upon restoration of utility power, the POWERMAX system, if enabled, would auto-synchronize the islands back to line power without de-energizing any generator.

When the POWERMAX system is turned off, load shedding and islanding do not work, and loss of a single utility feed could result in a plant-wide power outage and a need to black-start power generation.

Based on conversations with District operations they prefer to leave the POWERMAX system disabled (turned off) because of the cross mixing or comingling of low voltage wires between the major equipment and their supplemental components. For example, when POWERMAX is enabled and line L and C is not available, the load shed controls will shed loads as necessary to maintain the priority loads as indicated in Table 2-2. The IPS pump motors require 3W for the pump seals to maintain the pump motor temperature. The 3W system is fed from Substation U3 which is further down in the priority list. If U3 does not have power, then the seal water system is not working and the pumps will not start or if they are running, will shut down. Other similar wiring issues or load shed priority inconsistencies were noted, such as the Cryogenic Plant should be moved up higher on the load shed priority list. A power shutdown to EPS creates a channel backup and over-chlorination then occurs. Adding more controls to the low voltage systems for specific processes will make the control system more complex. Consideration should be made to alignment of process trains and their ancillary systems, with high priority on load shedding schemes in coordination with power system controls.

Finding F-4: The routine disabling of automated load-shedding systems increases the risk of full-plant power outages.

2.1.8 Power Generation and Fueling

The MWWTP includes on-site power generation stations: PGS-1 is an older station with three multi-fuel engines, and PGS-2 has a single turbine; the topology and capacities of the stations are shown in Figure 2-2.

During normal operation, one or two of the 2.15 MW engines at PGS-1 run to offset the power demand from the electrical utility services. At any given time, one of the three engines is down for maintenance.

PGS-2, with its single turbine, produces about 4.5 MW of energy, so typically, the MWWTP has approximately 9 MW of gross on-site power generation capability. While this capacity is not sufficient to power the MWWTP during peak flow events (10.65MW as indicated in Section 2.1.2), it is more than sufficient to power the MWWTP during dry season average flows, where the power demand is approximately 4.5 MW. PGS-2 requires significant maintenance and lacks internal redundancy, so the 9 MW of power generation capability is not viewed as a firm or reliable capacity.

During prior blackouts (i.e., loss of line power), the turbine and generators will typically trip due to under- or over-voltage. To restore operation of this equipment, District operations staff will manually re-start the turbine and generators. Due to the fact that the MWWTP does not have sufficient storage capacity for biogas that is constantly being produced by the wastewater treatment process, operators must first flare off any excess biogas to reduce pressure prior to starting the turbine or engines. It was noted during a workshop meeting that the older flare system does not function properly, and the newer flare has limited operation. Depending on available biogas and demand needs during blackout, starting the turbine or engines could take anywhere from 30 mins up to 6 hours. Furthermore, it was noted that two operators are preferred during a blackout start; however, depending on staffing levels there might be only one PGS operator available.

Finding F-6: Lack of capacity for biogas storage requires operators to flare off gas after an unplanned outage of the power generation stations, resulting in delays in restoring power during an outage.

2.1.9 Communications During a Direct Trip Transfer (DTT)

When PG&E wants to isolate the MWWTP power (line L and C) from their grid (because of a line issue upstream), they send a signal to DTT the main breakers at H1. A DTT from PG&E triggers a lockout relay to trip the H1 main breakers that require a manual reset by District staff. Prior to the reset, the District staff must contact PG&E to confirm it is okay and safe to come back online. The purpose of the DTT is to ensure the H1 breakers trip when PG&E trips so that District staff cannot inadvertently back feed PG&E and create a hazardous condition for a Lineman.

Contacting PG&E using the "877" number can sometimes take extra time. When calling the 877 number, District staff would have to listen to the machine and follow instructions to press additional number(s) to reach the appropriate group. District staff is concerned that when a live person is not reached, they may not immediately be given a DTT clear/reset. Also, a recent email received from PG&E states that when PG&E receives a call from District staff, PG&E will send out their telephone technician to the substation to confirm the DTT trip is not a nuisance phone trip. The District is concerned that this PG&E procedure will delay the process of power restoration and will not work effectively for EBMUD.

District staff had a meeting with PG&E in April 2023 to determine how to improve communications and decrease the amount of time necessary to bring the plant back online. PG&E is going to provide a procedure to the District that is agreed upon by both parties to try and minimize time it takes to reset the H1 breakers.

During the outage that occurred on March 21, 2023, it took over an hour to bring the plant back online. Additionally, District staff was unable to reset the lockout relay (after approval from PG&E) and had to contact District Engineering Staff to come and help reset the lockout relay. This process took longer than anticipated due to lack of PG&E direct contact person during a DTT and lack of training District staff to execute the procedure of bringing the plant back online efficiently.

Finding F-6: Lack of PG&E direct contact person and staff not appropriately trained for bringing the plant back online after a DTT has increased the amount of time necessary to bring restore utility power to the plant.

3. ANALYSIS AND CONCLUSION

This section first analyses the risk posed to plant operations caused by power outages of various duration, based on the relative importance of different unit processes and their power requirements.

The risk analysis is then supplemented with a consideration of "Time To Impact" or TTI, which is an estimate of the time with limited power before critical plant operations are impacted. The TTI analysis can provide insight into the ability of the MWWTP to function during a blackout if onsite generation can be maintained during the blackout.

The analysis concludes with a discussion of key considerations that impact the plant's ability to function. These considerations flow directly from the findings presented in Section 2, with an emphasis on findings based on the degree of risk they pose to plant operations.

3.1 Risk Analysis

3.1.1 Risk Criteria

The Consequence of Failure (CoF) analysis included in this study is intended to provide a high-level analysis of the existing infrastructure at the MWWTP. This project does not include a condition assessment or Likelihood of Failure analysis. In its evaluation of the criticality of the various components of electrical infrastructure, W&C first considered any safety concerns related to various equipment on site. Failure of any equipment that increases the possibility of injury to staff was most critical. Beyond safety concerns, the next highest priority was continued compliance with the MWWTP's discharge permit – any equipment failure which would result in the release of untreated, or partially treated wastewater was considered highest priority. Finally, equipment which is required for typical daily operations, but is not required for treatment or restoration of operations after a loss of power was considered the lowest priority.

The "time to impact (TTI)" analysis presented below builds upon these initial rankings by also including the time component in the analysis. Depending on process layout, redundancy, and other factors, certain treatment processes at the MWWTP can withstand power interruption for longer than other processes before serious consequences ensue. Although all equipment at the MWWTP serves a purpose and would eventually cause impacts if without power for an extended period (greater than 1 day), some processes can be lost for a period of several hours without major impacts, while other areas of the facility see impacts almost immediately (less than 1 hour) upon loss of power. Given that many utility outages are of limited duration, TTI is a useful concept to provide insight into the viability of different options for risk reduction.

3.1.2 Consequence of Failure (CoF) Rankings

The scope of work for this project included development of Consequence of Failure (CoF) rankings for the electrical system components at the MWWTP. These rankings are used to determine the most critical electrical equipment associated with the most critical processes at the MWWTP and to prioritize them based on the analysis. During the information gathering stage of the project, EBMUD project management team identified a previous Consequence of Failure Analysis which was performed in 2017 as part of a facility-wide study of seismic vulnerabilities and recommended that W&C review and compare this data with the risk analysis. The analysis done by W&C used these seismic study CoF rankings and supplemented them with the TTI analysis to reflect the differing time scales between seismic damage restoration versus restoration of line power after a blackout.

The CoF rankings from the EBMUD seismic study have been summarized and are presented below Table 3-1. While these rankings largely mirror the existing rankings of the existing load shedding program, there are some differences. Where "tie" is indicated, they match the existing load shedding priority list.

Table 3-1: Summary of CoF Rankings from Seismic Study

Priority	Substation	Process Area
1 (tie)	S1	Influent Pump Station
1 (tie)	U16	Digester 9-12, Feed System
1 (tie)	U14/U15	Sludge Dewatering Building, Sludge Thickening
4 (tie)	U6/U7	North Reactor Deck
4 (tie)	U8/U9	South Reactor Deck
6 (tie)	U4/U5	Grit Building, Operations Center
6 (tie)	U28	PGS1, Hypochlorite Area
6 (tie)	U29/U30	PGS2
9	U3	Process Water (3W)
10	U13	Digester Building
11	S2	Effluent Pump Station
12	EF4	Maintenance Building
13	U12	Lab/Admin Area, Digesters
14	E19	Substation at Dechlorination
15	U1	Aerated Grit

Both the load shedding program and the seismic study CoF analysis have the IPS & Reactor Decks as high priority areas, the Process Water (3W) as a medium priority, and Aerated Grit as a low priority. There are significant differences in rankings of other areas, such as the sludge dewatering area, and the Effluent Pump Station. Another major finding (not summarized in the table above) is that the 2017 seismic analysis did not differentiate between the Oxygen Production Facility (substation U10/U11) and the Oxygen Facility Compressors (substation S3). The oxygen facility compressors have the highest peak electrical demand of any substation at the MWWTP, and therefore should be considered separately from the relatively small load associated with the remainder of the facility.

To further evaluate the rankings, W&C reviewed the PI data to identify the relative size of each load that is connected to M1. This will allow consideration of the demand in comparison to the load shed rankings. If alternative methods of operation could re-rank significant loads to lower priority of the load shedding program, it would be a benefit to the District by allowing significant power loads to be shifted to other areas of the facility in order to match the available power. The results of this review are presented in Figure 3-1 and Figure 3-2 below for both maximum and average demand based on the PI data provided:

Figure 3-1: Load Percentage Maximum

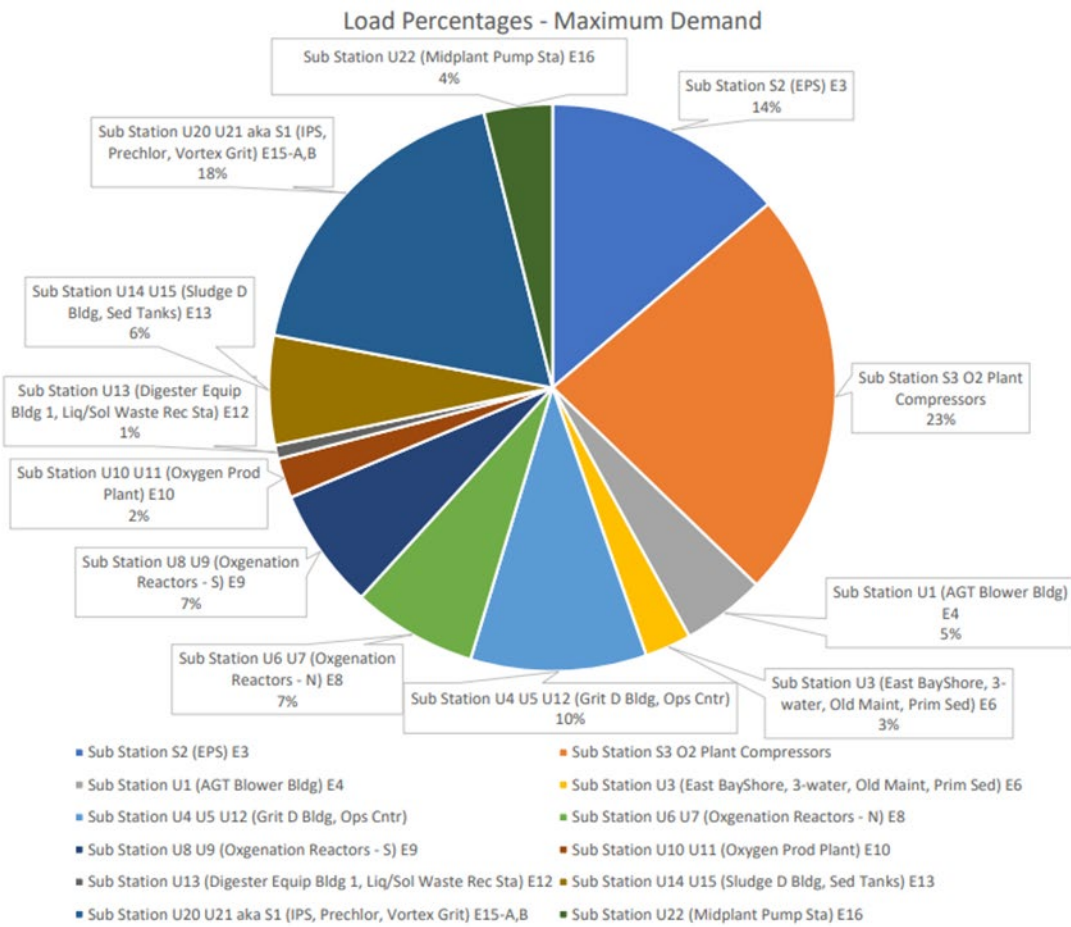
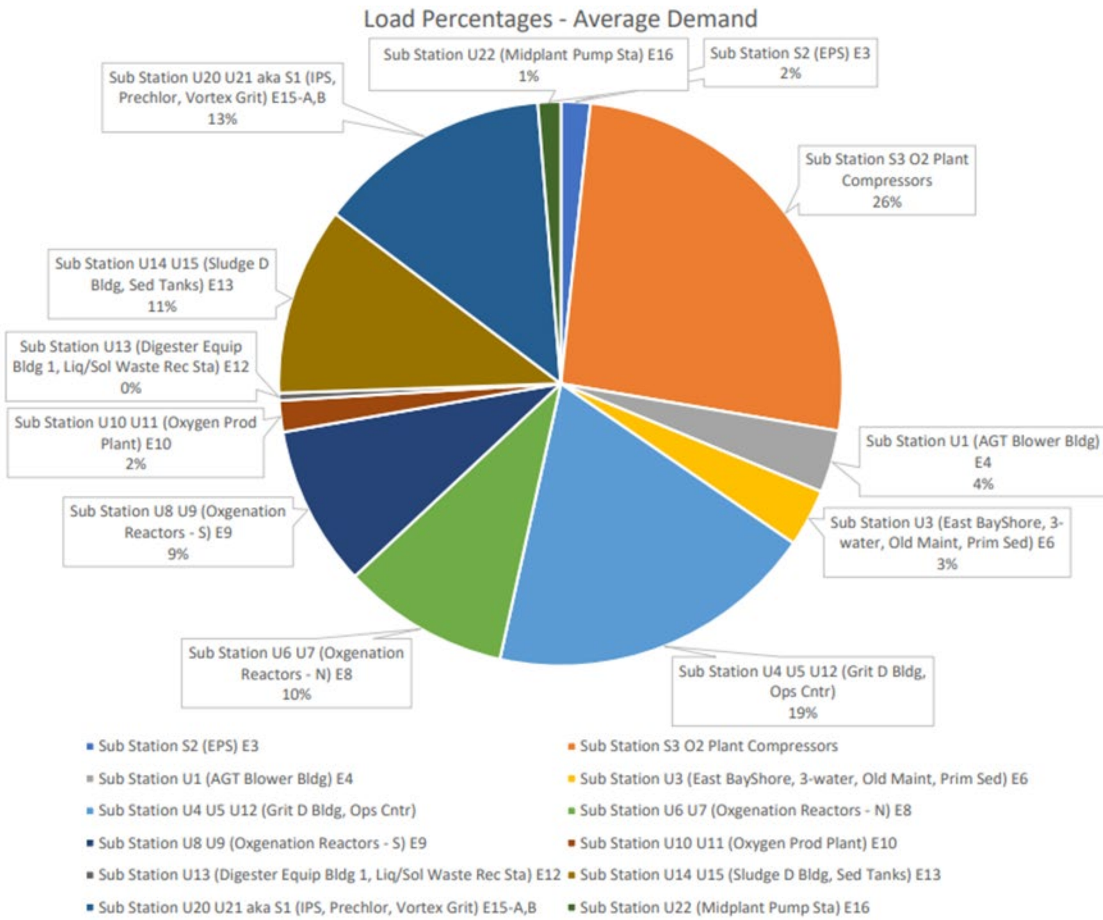


Figure 3-2: Load Percentage Average



As shown in Figure 3-1, Substation S1, which includes the IPS, is a significant portion of the overall facility demand (18% at peak, and 13% on average). W&C has concluded that this load is critical to the overall operation of the facility, so the IPS should be continued as a high priority.

These data, along with discussions with District staff, allowed us to perform the “Time to Impact” analysis to determine how long a process could be without power before impacting the process as described in the next Section.

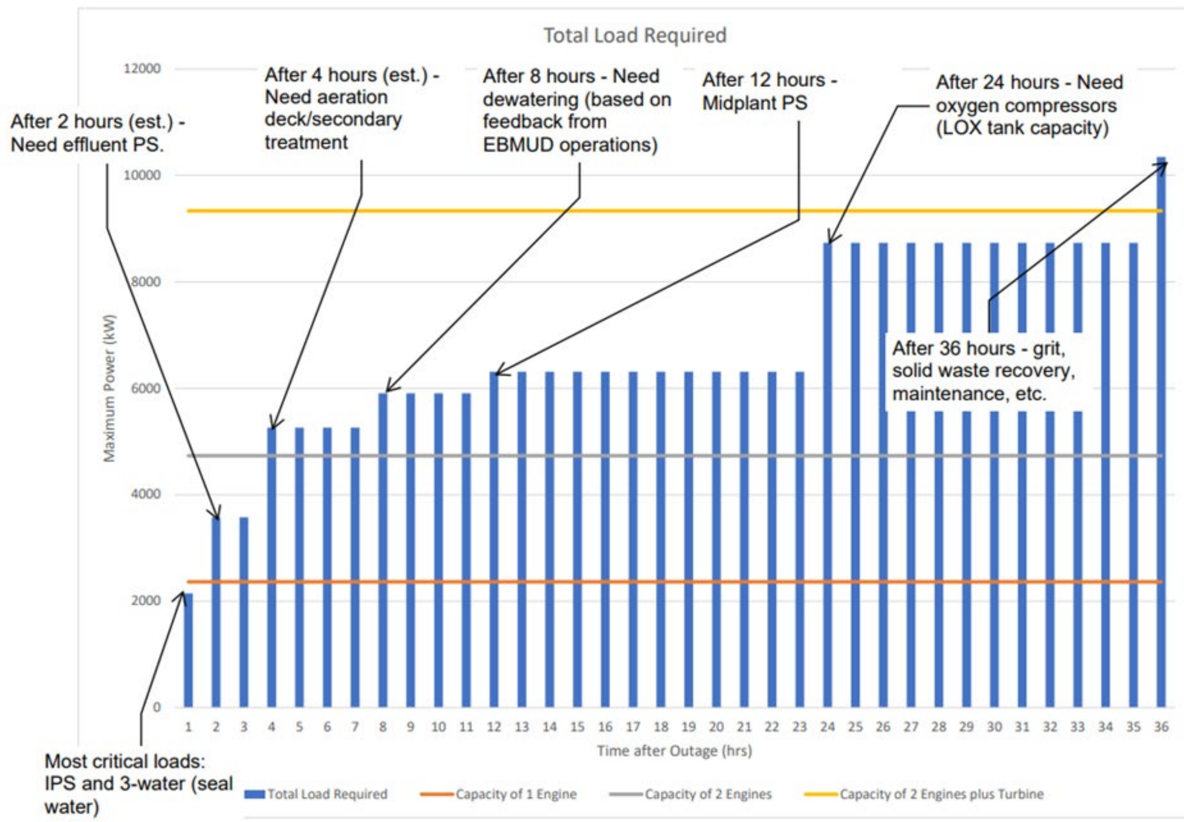
3.2 Time to Impact (TTI) Analysis

Using the historical electrical usage data (maximum draw, average draw) provided by EBMUD, W&C developed figures showing the required power at the MWWTP as a function of time after loss of utility power or the PGS’s. This can be used to prioritize various substations for restoration of power. Figure 3-4 also shows the same impacts, but during average flow and power consumption conditions.

3.2.1 Maximum Load Conditions

Figure 3-3 shows impacts based on maximum historical loads and correlates to a wet weather/high flow event. The graphic shown below also depicts the ***most impactful consequence of failure to the least impactful consequence based on time*** without an available power source.

Figure 3-3: Time to Impact Under Maximum Load Conditions



As indicated in the figure, The TTI analysis for maximum loads shows that the MWWTP should be able to provide power to its most critical loads (IPS, EPS) for approximately three hours if two of the three on-site engine generators are operating. If the turbine is also operating, the facility should be able to prioritize loads to the most critical and operate with minimal process impacts for up to 36 hours. This analysis assumes that there is no loss in turbine or engine service upon loss of utility power; that assumption is more likely to be borne out if the POWERMAX system is enabled at the time of the outage. If the POWERMAX system is not enabled, then both the turbine and engines will go offline and will have to be black started within one hour before impacting the IPS facility and the remainder of the plant.

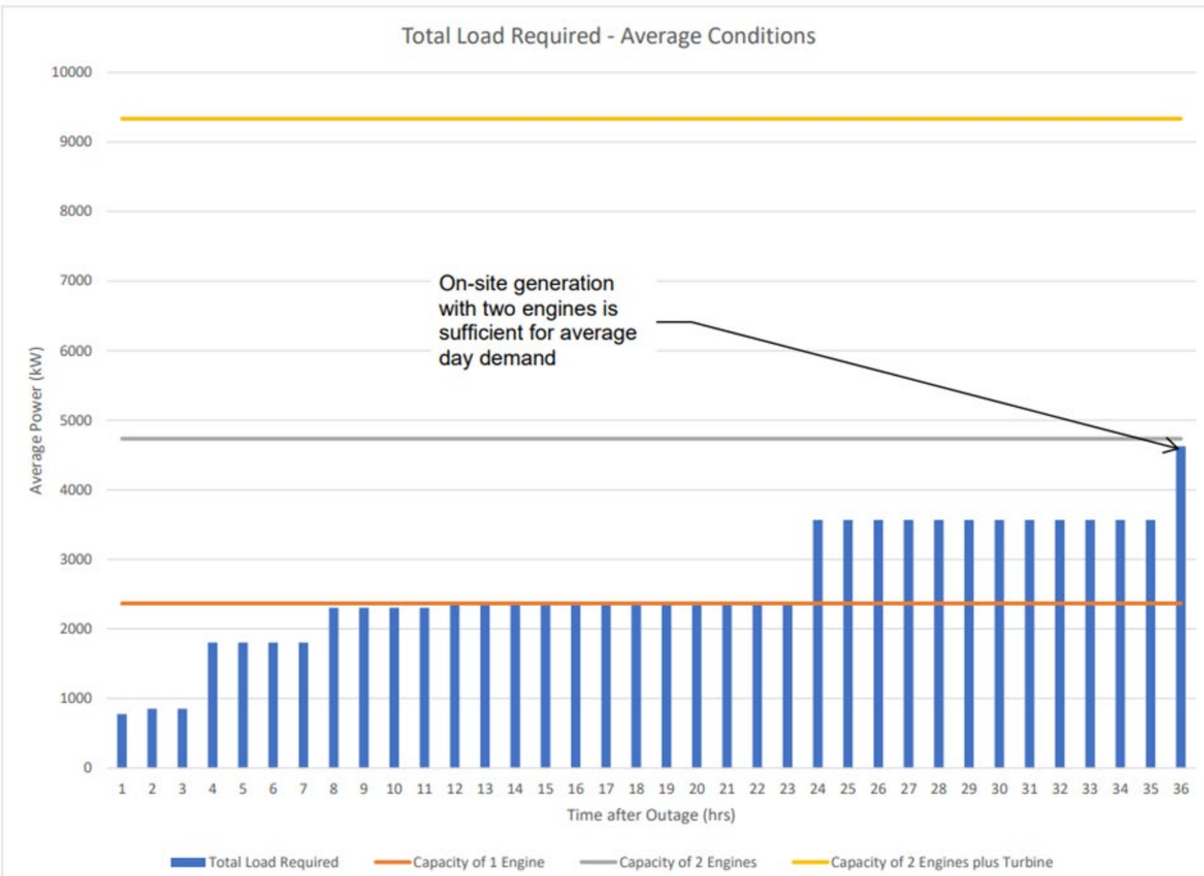
3.2.2 Normal Load Conditions

Figure 3-4 shows TTI under normal, i.e., average, load conditions.

As shown in Figure 3-4 below, two of the three generators at PGS-1 can provide all of the power needed to operate the MWWTP, even if PGS-2 (the turbine) is out of service. As for the maximum-load scenario, this analysis assumes that the POWERMAX system is enabled to prevent shutdown of the PGS upon loss of utility power.

The sufficiency of onsite generation is consistent with PI data, which show that under normal conditions the MWWTP is normally exporting power.

Figure 3-4: Time to Impact Average



The figure also shows that even one engine can stave off impacts for up to 23 hours.

3.3 Conclusions

This section presents several conclusions that synthesize the Findings in Section 2 considering the analyses presented earlier in the Executive Summary.

C-1 Existing Utility Feeds Are Not a Reliable Power Source

As outlined in Section 2, the existing utility lines C and L suffer from a host of problems:

- Neither service has sufficient capacity to power the entire MWWTP. As a result, the facility uses dual feeds, which complicates operations during the loss of a single feed. Although the automatic tie-breaker at the incoming switchgear M1 allows continuity of power for average loads during the dry season, if one line is lost and power demand exceeds the capacity of the remaining feed, the tie-breaker position will not prevent further loss of power to the facility.

- The two lines as routed are vulnerable to common-cause failure since they share at least one vault, duct bank, and possible aerial route.
- The physical routing of the incoming feeds exposes them to multiple hazards, including vehicular damage or high wind damage to the overhead section, and impaired access for maintenance or repair along much of the alignment.
- Reliability of power provided by PG&E has been limited in the past and is likely to deteriorate further as demand for electricity increases, while threats to reliability such as wildfire continue.
- Communications with, and responsiveness of PG&E during an outage event has proven to be a challenge including confirmation of existing underground and overhead locations.

C-2 The PGS's As Currently Configured Do Not Provide a Reliable Backup to Line Power

PGS-2 has several characteristics that make it an unsuitable source of backup power:

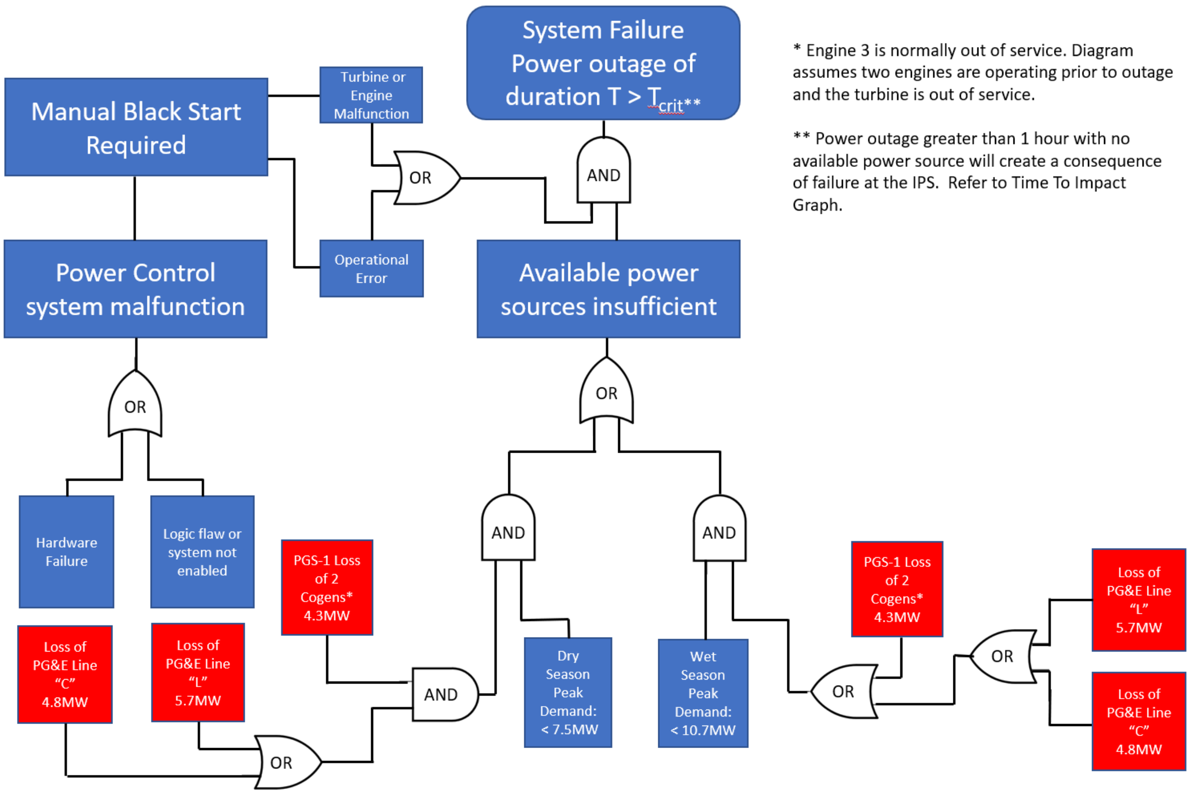
- With only a single turbine the station lacks internal redundancy
- The PGS is prone to extensive maintenance outages.
- The PGS has minimum time-to-restart criteria that impinge on its utility as a backup power source. PGS-1, with three conventional multi-fuel engines, is more robust. However, the PGS still cannot be considered an adequate backup power supply, for two key reasons:
- The plant (with two of three engines running) is inadequate to meet maximum loads for an extended period.
- The plant is currently configured to shut down on loss of line power, and its restart is a lengthy process.

C-3 Enablement of the POWERMAX system would reduce risk

The rationale for POWERMAX being disabled is that, if enabled, the system might cut power to critical unit processes as part of its load shedding, because some key power feeds are "commingled." For example, a unit process might be prioritized to remain online during load-shedding, but its control system power might have been inadvertently wired to a power source that was not prioritized by the POWERMAX system.

While this is a valid concern, on balance W&C believes that overall risk could be lowered by enabling POWERMAX. Figure 3-5 illustrates the factors that can contribute to extended downtime of the IPS due to power loss. This diagram uses Boolean logic to indicate scenarios that when combined result in the IPS going offline. As noted in the diagram, whether the load shedding program is activated or not is a key contributor to the MWWTP's ability to withstand the loss of both PG&E circuits.

Figure 3-5: Risk Analysis Diagram



* Engine 3 is normally out of service. Diagram assumes two engines are operating prior to outage and the turbine is out of service.

** Power outage greater than 1 hour with no available power source will create a consequence of failure at the IPS. Refer to Time To Impact Graph.

Enabling POWERMAX absent other actions would create a new risk, that of POWERMAX cutting power to a load that was intended to be prioritized to remain online, due to the commingling of wiring problem discussed above. This risk could be mitigated by implementing one or more of these actions, which are further outlined in the Recommendations section:

- In the short to medium term, by adding local UPS's for key control systems that are fed by commingled power sources
- In the longer-term, eliminating commingled power feeds to promote more effective load shedding
- Training staff in the use and limitations of POWERMAX to maximize its potential value by reducing risk

4. RECOMMENDATIONS

The recommendations in this section are relatively general in nature and will be further examined by W&C in the Alternative Analysis TM 2. Some of the recommendations, such as consideration of new line power feeds, will be subject to alternatives analysis to identify a specific scope that addresses the findings of this TM, and also aligns with EBMUD's long-term electrical roadmap.

4.1 Summary of Recommendations

The recommendations are also listed in the Executive Summary and briefly described below:

1. **Recommendation R-1:** *Replace PG&E line circuits L and C with circuits that each have a minimum capacity of 12MW.* The reliability and available capacity of the existing PG&E circuits has been identified as a major vulnerability for EBMUD. While additional onsite generation could also in theory address the need for higher-reliability power, new power feeds appear to be more responsive to EBMUD's needs given that they are not only unreliable but undersized.

2. **Recommendation R-2:** *Enable the SEL POWERMAX system to maintain operation of PGS's during utility outages, thus reducing the risk of cascading failures, and avoiding the need for manual black start of the turbine and engines.* It is recognized that enabling POWERMAX, absent other measures, would create a new risk due to the current issue of commingling of power sources as discussed in Finding F-5. Therefore, implementing this recommendation should be done in concert with other recommendations described below which are aimed at mitigating the problem of commingled power feeds.

3. **Recommendation R-3:** *Correct or consolidate low voltage wiring systems that are commingled between the different power buses (A versus B).* For the near term, consider local UPS's to provide short-term mitigation of commingled power systems, i.e., situations where critical control signals for a unit process are fed on a different bus as power for the unit process, thus undermining automatic load shedding. In the long term, consolidate power feeds for each unit process so that specific unit processes can be prioritized by the POWERMAX system without fear that power for a critical system is intertwined with the power for a less-critical system that is the target of load shedding.

4. **Recommendation R-4:** *Revise load shed priority list based on CoF rankings, TTI and revised wiring configurations as recommended in R-3.* It was found in this analysis that some process systems should be moved up in the priority list because of their association with critical equipment that if not operating creates a chain of events that ultimately shutdowns an entire process. Ancillary systems that support critical equipment will be moved up in their rankings in the load shed priority list. Other process systems will be looked at more closely and considered for higher priority listing during the next phase of work.

5 **Recommendation R-5:** *Improve restoration of power processes by modifying operational procedures and develop a PG&E approved communication protocol when a DTT occurs. Provide training that is focused on restoring power to the plant safely and more efficiently.* The District has recently discussed with PG&E to develop a protocol that both entities could agree upon to increase the time it takes to restore power to the plant. This includes identifying who the point of contact at PG&E would be

versus an automated calling center with longer wait times. Additionally, District staff should align their SOP with PG&E to improve communications during a DTT and determine appropriate qualified District staff for "On Call" duty during off hours and weekends.

6. **Recommendation R-6:** *Modify infrastructure and process systems to improve redundancy including the addition of equipment (substations, biogas storage, etc.) and replacement of aging equipment to increase reliability. Replace systems that are in areas (below grade) to above grade to increase safety and reduce downtime during replacement of damaged equipment.* W&C will evaluate equipment replacement and alternatives in more detail in the next phase of work, TM2 - Alternatives Analysis.

Next Steps

Based on the research performed to date and the findings presented in this TM, we have begun work on the next phase of this project – Alternatives Analysis. In this phase, we will identify specific projects which could potentially be undertaken by EBMUD to improve the resiliency of the electrical infrastructure at the MWWTP. The projects presented will be evaluated on the four Master Plan guiding principles: technical, environmental, social, and financial. Following preparation of the draft Technical Report #2, we will conduct a workshop with District staff to refine the evaluation of the potential alternatives, to develop a Road Map for EBMUD to implement, with the goal of improving the overall resiliency of the electrical infrastructure.

5. REFERENCES

EBMUD: Luong, Syndi. *Main Wastewater Treatment Plant Load Study*. Study. Oakland, 2020.

IEEE. "493- 2007, Design of Reliable Industrial and Commercial Power Systems." 2007.

USEPA. "EPA-430-99-74-001, Design Criteria for Mechanical, Electric, and Fluid Systems Component Reliability for Wastewater Treatment Facilities." 1999.

6. ABBREVIATIONS

MV: Medium Voltage (either 5kV or 15kV)

NC: Normally Closed

NO: Normally Open

PG&E: Pacific Gas & Electric

PGS: Power Generation Station

PI: Plant Information (OSIsoft PI database is the DCS historian. PI is used by EBMUD for data collected by the OSIsoft and sent to DCS.)

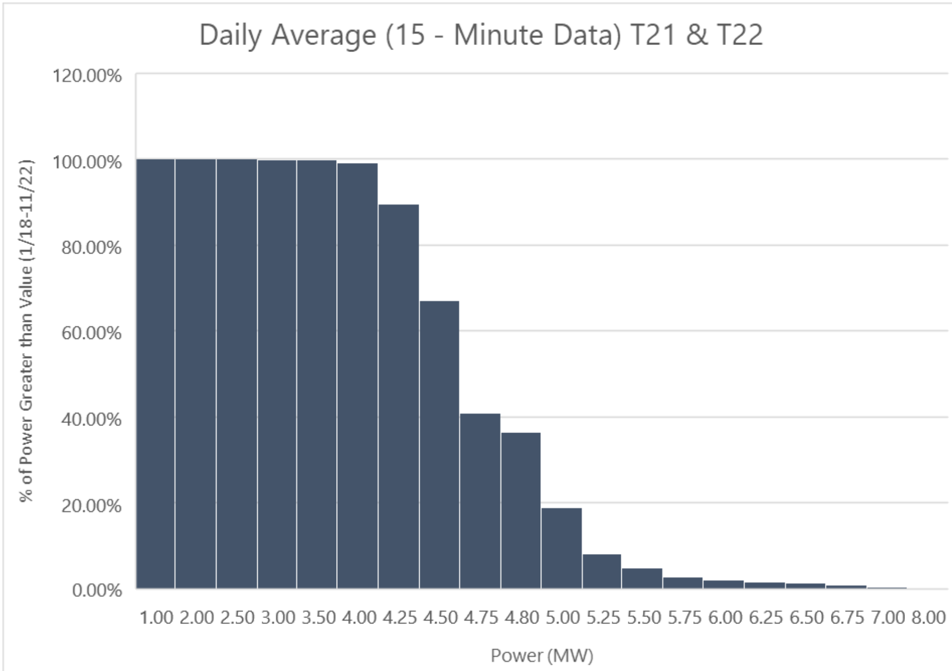
SOP: Standard Operating Procedure

APPENDIX A: HISTORICAL POWER CONSUMPTION

Appendix A: Historical Power Consumption

Demand Power (MW)	Percentage of Time Power Demand			
	Daily Average (15 Minute Data)	Daily Maximum (15 Minute Data)	Daily Overall (15 Minute Data)	Daily Average (Daily Data)
1.00	100.%	100%	100%	100%
2.00	100.%	100%	100%	100%
2.50	100.%	100%	100%	100%
3.00	99%	100%	100%	100%
3.50	99%	100%	100%	100%
4.00	99%	100%	98.%	99%
4.25	89%	99%	88%	89%
4.50	67%	89%	66%	67%
4.75	41%	66%	41%	41%
4.80	36%	62%	37%	36%
5.00	19%	44%	20%	19%
5.25	8%	24%	9%	8%
5.50	5%	13%	5%	5%
5.75	3%	8%	3%	3%
6.00	2%	5%	2%	2%
6.25	2%	4%	2%	2%
6.50	1%	3%	1%	1%
6.75	1%	2%	1%	1%
7.00	1%	2%	1%	1%
8.00	1%	1%	1%	1%

Daily Average (15 – Minute Data)



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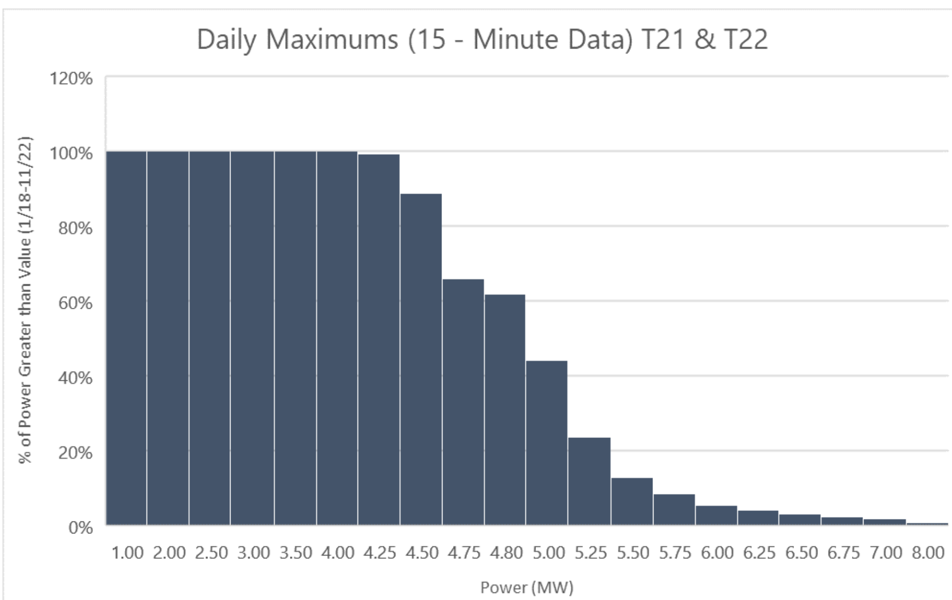

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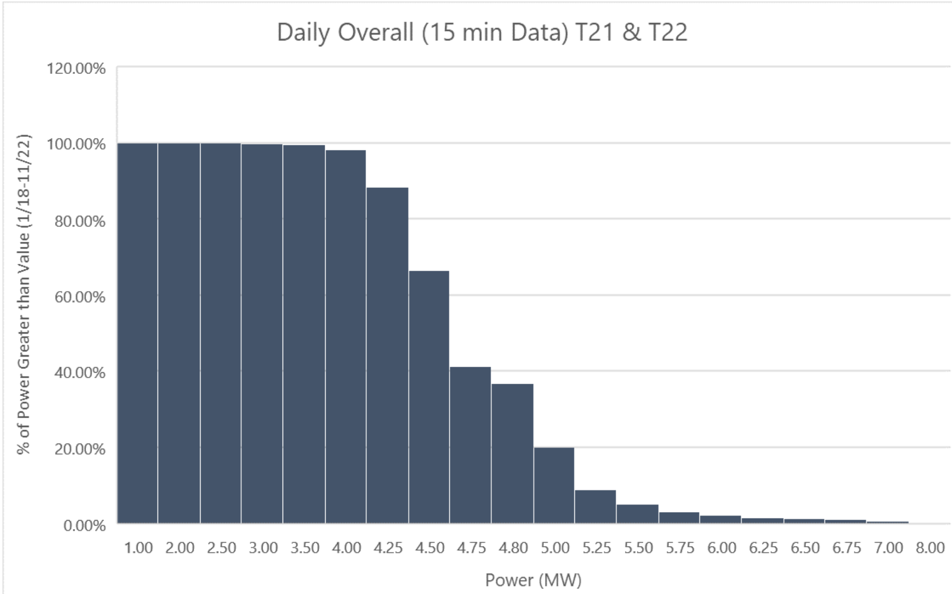

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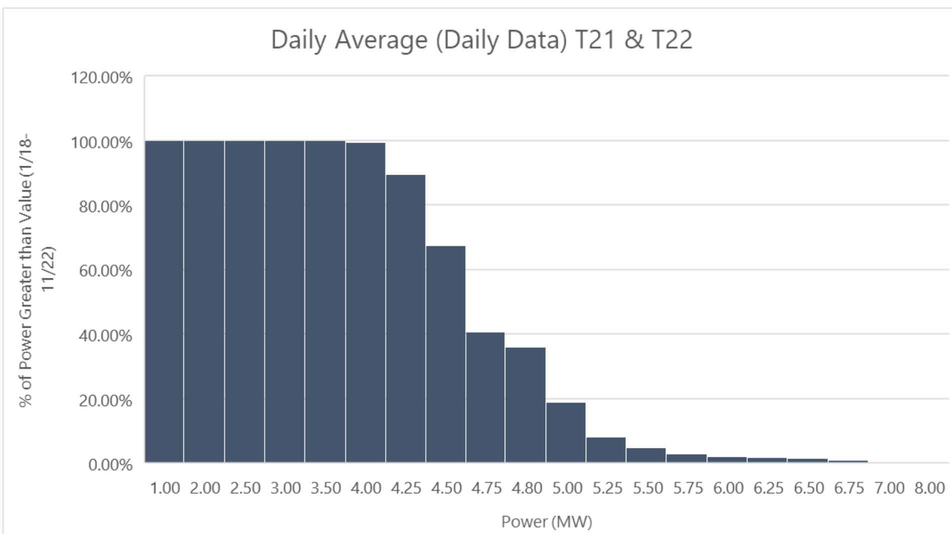
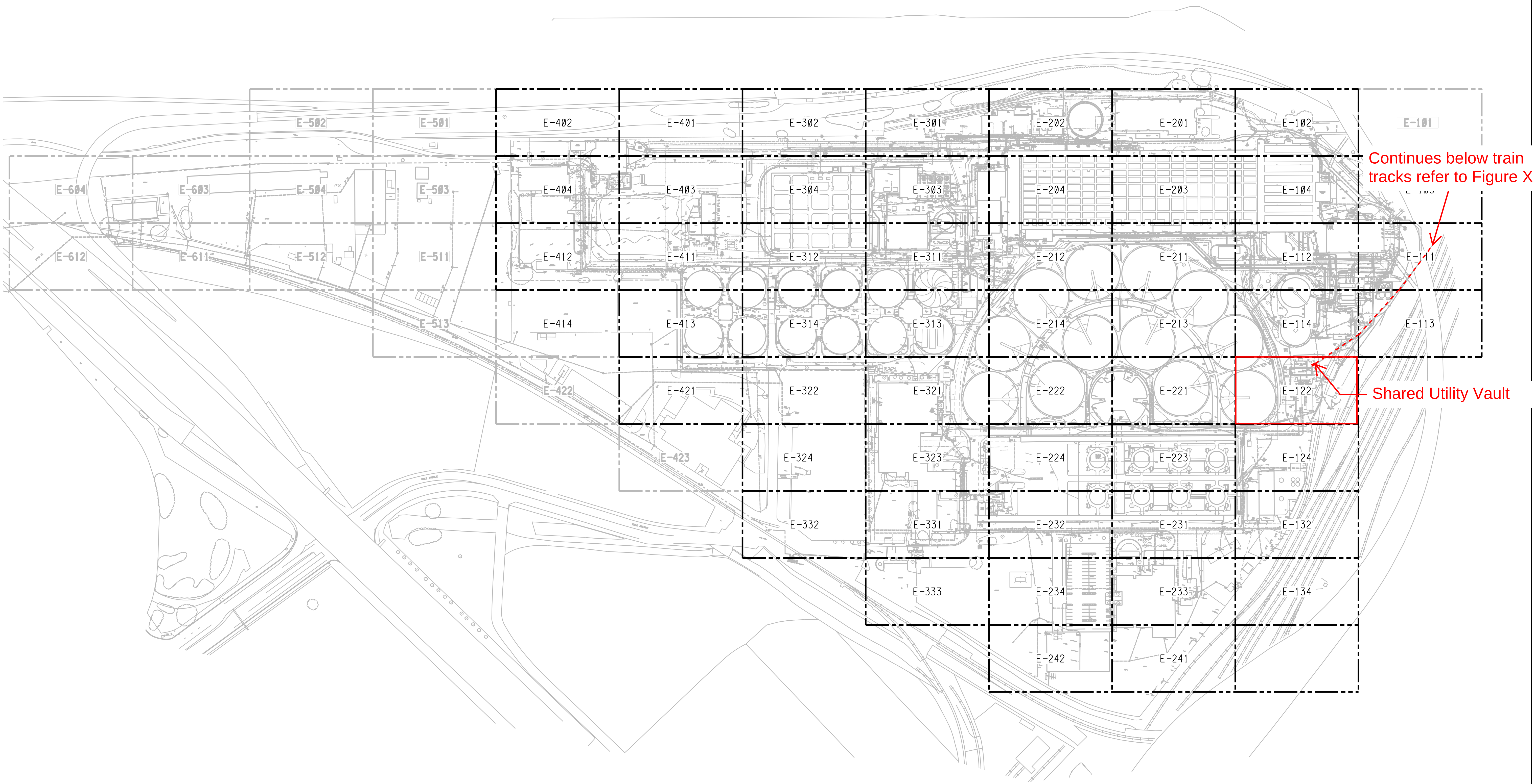


APPENDIX B: SITE PLANS



APPENDIX B-1

GENERAL NOTES

1. FOR CONDUIT SCHEDULES, SEE W21.00-E-800 SERIES DRAWINGS.

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DRAWN BY:	WASTEWATER DRAFTING
DESIGN CHECKED BY: R.P.E. No.	---
CONSTRUCTABILITY CHECKED BY:	---
ELECTRICAL CHECKED BY: R.P.E. No. E15544	MICHAEL T NAKAMURA
PROJECT ENGINEER R.P.E. No.	---
PROJECT MANAGER R.P.E. No.	---
RECOMMENDED: SR. ENGINEER R.P.E. No. E15544	MICHAEL T NAKAMURA

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT
UNDERGROUND UTILITY
ELECTRICAL
GENERAL SITE
KEY PLAN

SCALE 1"=125'
DATE 20SEP2010

W21.00-E-040
DRAWING NUMBER

1
REV.

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REF 8:
REF 9:

REF 4:
REF 5:
REF 6:

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REF 2: J:\W21\w2100xutil.mst
REF 3: J:\w21\w2100bdr.mst

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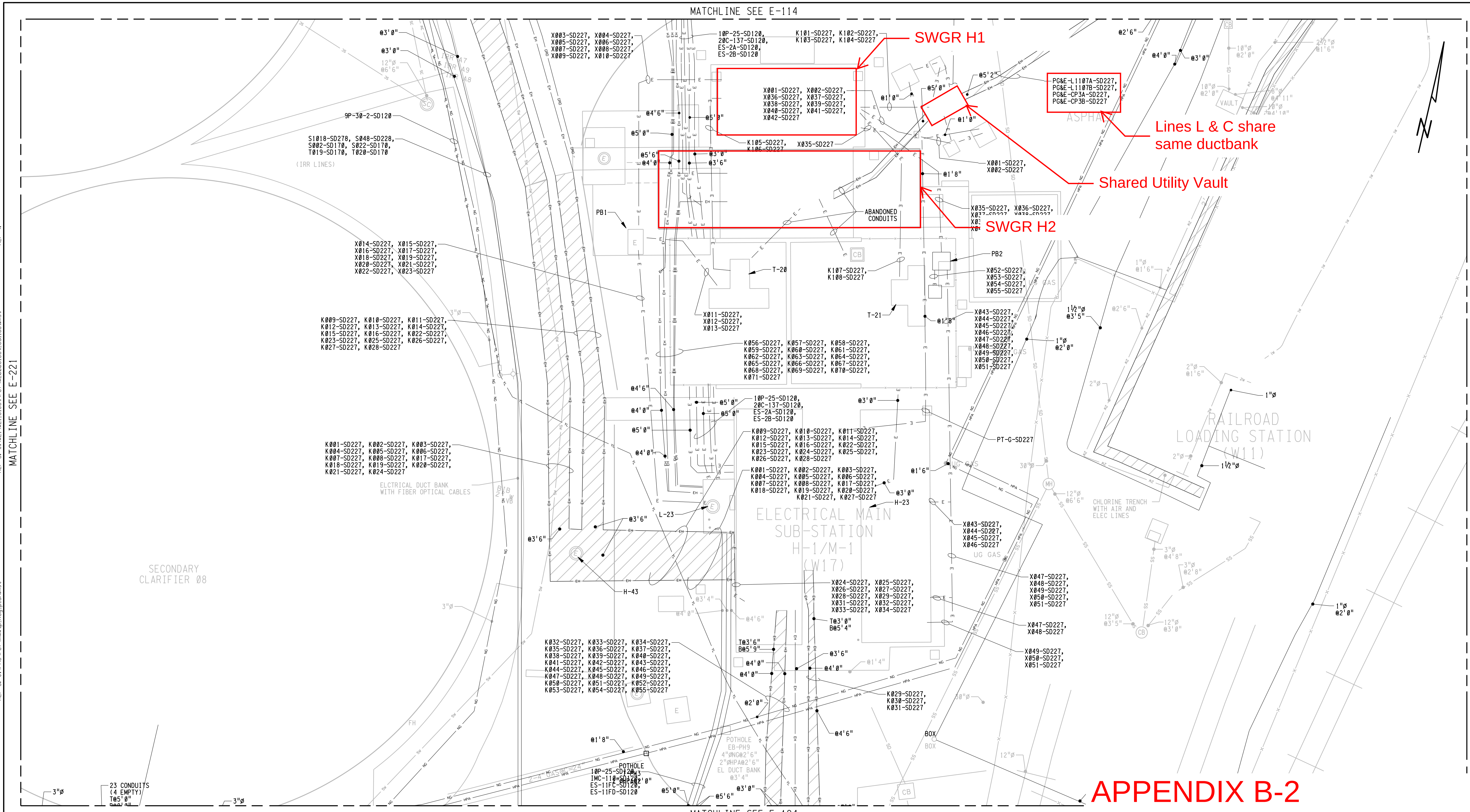

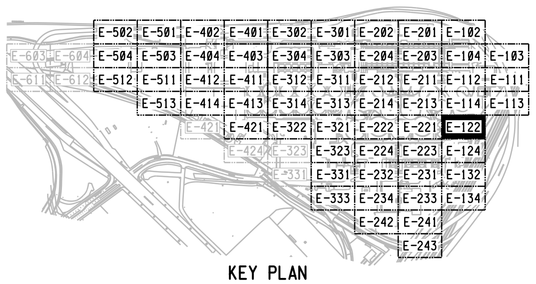

SUPERSEDES: W21.00-E-121, REV0

A COPY OF THE ORIGINAL DRAWING CAN BE FOUND IN THE WASTEWATER DRAFTING UNIT

NO.	DATE	REVISION	BY	REC.	APP.
1	20DEC2012	UPDATED EXST SITE & UNDERGROUND UTILTY DWG AND RENUMBERED 1"=10' SCALE DRAWINGS			

3" ON ORIGINAL DOCUMENT

DESIGN BY: M. KAGUCHIA
DRAWN BY: WASTEWATER DRAFTING
DESIGN CHECKED BY: R.P.E. No. ---
CONSTRUCTABILITY CHECKED BY: ---
ELECTRICAL CHECKED BY: R.P.E. No. E15544 MICHAEL NAKAMURA
PROJECT ENGINEER R.P.E. No. ---
PROJECT MANAGER R.P.E. No. ---
RECOMMENDED: SR. ENGINEER R.P.E. No. E15544 MICHAEL NAKAMURA

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND, CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT
UNDERGROUND UTILITY
ELECTRICAL
PARTIAL SITE PLAN

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DRAWING NUMBER
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Woodard & Curran

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WASTEWATER ELECTRICAL RESILIENCY MASTER PLAN

Task 3 – Technical Memorandum 2

Road Map Projects Alternatives Analysis

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East Bay Municipal Utility District

August 2024

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EXECUTIVE SUMMARY

The East Bay Municipal Utility District (EBMUD) would like to improve electrical resiliency at the Main Wastewater Treatment Plant (MWWTP). EBMUD has contracted Woodard & Curran, Inc. (Woodard & Curran) to identify failure vulnerabilities and consequences, develop and evaluate alternatives to enhance resilience, and ultimately provide a roadmap to greater electrical resiliency. The first task of the study, to identify failure vulnerabilities and consequences, has been completed. Those findings are summarized in Technical Memorandum 1 (TM 1).

This TM focuses on the development and evaluation of Road Map Project alternatives that might resolve the vulnerabilities identified in TM 1, and applies insights gained in TM 1 as a basis for understanding. Road Map Projects are evaluated here using master planning criteria and are compared using qualitative rankings. Ultimately, the Projects evaluated in this TM will be packaged into a collection of recommended upgrades aimed at improving the EBMUD MWWTP electrical resiliency. Final recommendations will be presented in the next TM.

Purpose and Scope

This TM defines and evaluates projects that aim to resolve the electrical vulnerabilities previously identified. The projects are termed "Road Map Projects" to reflect the planning approach, which is one of phased, flexible implementation of potentially multiple projects over time. Following an introduction in Section 1, Section 2 identifies and defines the following master planning criteria that are used to evaluate each Road Map Project:

- Operational Simplicity
- Maintainability
- Cost-Effectiveness
- Reliability and Effectiveness
- Ease of Implementation
- Flexibility for Future Process Changes or Increased Demand
- Low Greenhouse Gas (GHG) Emissions

Section 3 develops a comprehensive project summary for each Project at the planning level and includes the following:

- Impacts to operations
- Work triggers and project alignment with the EBMUD Integrated Master Plan for the MWWTP
- Proposed project location
- Planning-level cost estimates are developed for each Project alternative.

Section 4 evaluates each Project presented in Section 3 using the criteria developed in Section 2. Any vulnerabilities identified in TM 1 that are resolved by the Projects are presented here. The Woodard &

Curran team evaluated the Projects on their performance relative to each criterion using a "high-neutral-low" basis. Woodard & Curran then assessed the Projects relative to other Road Map Projects evaluated within this memo. The most beneficial projects for EBMUD MWWTP will receive a majority of "high" ratings.

Section 5 presents interim conclusions based on the evaluations completed in this TM. This Section highlights trends and takeaways observed in the consideration of Road Map Projects.

In the next TM, Woodard & Curran will make final recommendations based on the evaluations developed in this TM.

Conclusions

Based on the Project evaluations undertaken in Section 4, Woodard & Curran has made several high-level conclusions:

- While being very flexible, the EBMUD electrical system is very complex, which hinders operability and maintainability, and increases the risk of unplanned downtime. The completion of multiple Road Map Projects will likely be required to simplify the system and introduce needed resiliency.
- Coupling short-term, targeted projects with larger scope upgrades may provide the most efficient path to improved reliability. Layering these projects together can also add resiliency.
  - Several short-term projects could provide outsize impacts to electrical resiliency at the EBMUD MWWTP. Projects that improve operability of the Power Generation Stations (PGS) systems during a utility power outage without compromising performance of critical treatment operations should be prioritized. While these projects by themselves would not provide full redundancy, they would reduce overall risk significantly and complement longer-term electrical upgrades.
  - Much of the system complexity stems from the fact that two utility feeds currently must be operable to meet peak power demand. EBMUD should give priority consideration to obtaining a utility feed that can meet peak demands by itself, in order to improve reliability and reduce complexity.
- While full power redundancy with a generator bank would provide value, it would pose high capital and operating costs. A smaller generator bank that powers the most important loads (i.e., IPS) would be less expensive and provide substantial benefit. That project could also be designed to permit future buildout to a full-plant backup should that be warranted in the future and allows the District time to further define backup power needs.
- Operator and staff training will be needed to support the existing electrical system and future upgrades to that system. An area of emphasis for training should be load shed controls and their critical importance to the resiliency of the plant. Because the MWWTP exports and imports power from multiple sources it functions as a Microgrid and has commensurate training needs. As utility grids become more unstable and the District continues to produce renewable energy, the value of this type of training will only increase. Specifically, additional periodic training in Standard Operating Procedures for "black starts" of the PGSs will help speed up the process of restoring power to the MWWTP and increase the knowledge base for new operators.

As mentioned, each Project has been singularly described and evaluated in this TM to provide a list of alternative Projects for consideration by the District. Because the electrical system is flexible and complex as indicated, looking at these alternative Projects discretely maybe not be the best approach and instead as alternative portfolios of Projects.

Cost Summary

The following Summary Table provides the cost for each Alternative Road Map Project. Refer to each individual Project description for more information and Appendix A for Project Cost Development Forms.

No.	Description	Cost
1	New Port of Oakland 12kV Connection	9,800,000
2	New PG&E 12kV Connection	12,300,000
3	New 115kV PG&E Connection	99,000,000
4	12MW Generator Bank	56,420,000
5	Generators Sized for IPS	23,000,000
6	POWERMAX System Upgrades	700,000
7	Best Practices	17,000,000

1. INTRODUCTION

This Section defines the purpose of the technical memorandum and describes its content and organization.

1.1 Purpose and Background

This alternatives analysis is prepared as a part of the Wastewater Electrical Resiliency Master Plan (WERMP) at East Bay Municipal Utility District (EBMUD) Main Wastewater Treatment Plant (MWWTP). The results of the risk analysis performed under Task 2 of the WERMP and summarized in TM 1 form the basis of understanding of the major systems being evaluated in this TM. The intent of this TM is to identify specific projects and evaluate those projects for master planning purposes to improve electrical resiliency at EBMUD's MWWTP.

This TM will:

- Briefly describe the recommendation identified in the TM 1 risk assessment,
- Identify Road Map Projects that address the recommended upgrades,
- Develop a planning-level cost estimate for each Road Map Project,
- Describe triggers for work and mechanisms for aligning each Road Map Project with the EBMUD Integrated Master Plan (May 2022)
- Establish ranking criteria for use in Road Map Project evaluation, and
- Rank the proposed Road Map Project alternatives using the established ranking system.

1.2 Memorandum Organization

- Section 1 – Introduces the intent and organization of this memorandum and describes the drivers of this analysis.
- Section 2– Develops the evaluation criteria which will be used to analyze Road Map Project alternatives.
- Section 3– Describes Road Map Project alternatives. Descriptions of the Road Map Projects include planning-level cost estimates, descriptions of work triggers and project alignment with the EBMUD Master Integration Plan, a proposed location for the Project, and a discussion of impacts to operations.
- Section 4– Evaluates Road Map Project alternatives using the Section 2 evaluation criteria.
- Section 5– Concludes the Road Map Projects alternatives analysis with a takeaway summary and highlights next steps to be addressed in TM 3.
- Section 6– Cites technical references leveraged for analyses presented herein.

1.3 Cost Estimates

Cost estimates have been developed in accordance with the Association for the Advancement of Cost Engineering (AACE) Cost Estimate Classification System Class 4 cost estimate. Consistent with a Class 4 cost estimate, costs are projected to be accurate within -15% to +50% of the total given.

Costs are developed based on the following and used for planning purposes:

- Raw equipment costs are based on budgetary quotes provided from vendors, recent quotes from similar projects or power utility company documentation provided to assist with new service and substation equipment. These costs are included for major equipment and systems only.
- Where applicable demolition work, civil, electrical, instrumentation, hazardous material and handling are included in the cost as a percentage of the raw equipment cost.
- Startup, construction sequencing, easements, general conditions, sales tax, and Contractor's O&P are a percentage of the construction cost.
- The total project cost includes planning, permitting, engineering and construction management and is a percentage of the construction cost.
- A 30% contingency is included for each project cost.

Refer to Appendix A for a breakdown of the major equipment and the percentages used for each project. Percentage of construction cost may vary depending on the type and complexity of the project.

2. EVALUATION CRITERIA

This Section develops the evaluation criteria used for evaluating the Road Map Project alternatives described in Sections 3 and 4 of this TM. The evaluation technique leveraged in this analysis is qualitative: benefits or performance improvements provided by Road Map Projects are considered relative to the existing process and evaluated to be "high," "neutral," or "low."

The analysis uses seven evaluation criteria to compare the Road Map Projects:

1. <u>Operability:</u> Increasing the resiliency and reliability of the power supply of the EBMUD MWWTP are the principal drivers for this analysis. EBMUD has identified operator experience and training as a challenge due to recent staff attrition. Therefore, the operational burden of each alternative must be considered. Projects which require significant operator commitment or have high operational complexity will be ranked lower than projects which require less active management by operations.

2. <u>Maintainability</u>: Reliable performance of process equipment requires routine maintenance. There is a driver to minimize additional burden on operators and maintenance staff for tasks such as equipment maintenance. Projects that accomplish resiliency goals without increasing maintenance burdens will be ranked higher than those that carry higher maintenance requirements.

3. <u>Cost-Effectiveness</u>: The relative cost of a project will be important in the evaluation of alternatives and in the development of the road map. Projects estimated with a higher relative cost will be ranked lower than more economical projects.

4. <u>Reliability and Effectiveness</u>: Vulnerabilities identified in TM 1 as part of the Consequence of Failure analysis were considered when developing the roadmap projects analyzed in this TM. The road map projects will be evaluated for both their effectiveness as well as their capacity to resolve the identified vulnerabilities.

5. <u>Ease of Implementation</u>: This criterion accounts for the complexity associated with developing operating agreements, acquiring property rights, and obtaining permits that may be required for some road map alternatives. Projects requiring more coordination or more time for implementation will be ranked lower than projects requiring less time or coordination.

6. <u>Flexibility for Future Process Changes or Increased Demand</u>: EBMUD has developed several planning studies in recent years to prepare the MWWTP for future flows, loads, and effluent regulations. Many of these potential future changes could impact electrical demand at the MWWTP. Future-ready projects that allow for greater electrical flexibility and spare capacity are ranked higher than those with less flexibility and spare capacity.

7. <u>Low Greenhouse Gas (GHG) Emissions</u>: EBMUD has identified the carbon footprint impact of future projects as a critical evaluation criterion. On-site backup generators are typically powered by fossil fuels such as diesel fuel or natural gas. Grid power by contrast is generated mostly by clean sources such as wind or solar. Due to the space limitations at the MWWTP, construction of larger on-site green energy sources is not feasible; therefore, the new projects will be evaluated in comparison to existing fuel sources in use at the MWWTP.

An evaluation table is produced for each Road Map Project alternative that is identified in Section 3. An example table is shown below.

TABLE 1: EVALUATION OF AN EXAMPLE PROJECT

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Neutral	
Cost-Effectiveness	High	
Reliability and Effectiveness	Low	
Ease of Implementation	Neutral	Requires a land purchase
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	Comparable to current operations

The tables summarize the performance of each Road Map Project for each of the evaluation criteria previously presented. Project-specific evaluations are presented in Section 4.

3. IDENTIFICATION OF ROAD MAP PROJECT ALTERNATIVES

Section 3 describes Road Map Project alternatives. Descriptions of the Road Map Projects include planning-level cost estimates, descriptions of triggers (i.e., future events that could drive the project timing or change the project approach) and project alignment with the EBMUD Integrated Master Plan where applicable, a proposed location for each project, and a discussion of impacts to operations.

The Road Map Projects discussed in this Section were identified based on the risk assessment of the power distribution system at the EBMUD MWWTP and summarized in TM 1. Broadly, the potential upgrades described in TM 1 can be grouped into three major categories: New Service Connections; Emergency Generators; and Redundancy Improvements. The Projects are presented here by category, but several within one category may be recommended in the overall Road Map. Final recommendations and development of the Project Road Map will be presented at the conclusion of this project and TM 3.

3.1 New Service Connections

The MWWTP currently has two PG&E 12 kiloVolt (kV) service connections, designated Line C and Line L. Unlike typical full-service power feeds for wastewater treatment facilities, these feeds are currently supply-limited, whereby neither Line C nor L can supply peak power demands alone or together.

The lack of a full-sized electrical service has been identified as a major contributor to historical power outages at the facility. Most outages have occurred during a peak demand period that requires both Line L and Line C to be available when PGS1 and PGS2 are not in operation. When one utility feed is lost, only selected (critical) processes are allowed to operate until another source of power is available. While both PGS1 (engines) and PGS2 (turbine) can provide a second source of power, the Load Shed Control System must be enabled to provide a seamless transfer of power during a partial or full utility outage. However, load shedding is not fully effective where process treatment trains have co-mingled power. "Co-mingled power" refers to situations in which key process equipment within each train are mixing power from two different sources. Loss of power from any given source will severely impact operations.

The complexity of the MWWTP's electrical distribution system would be reduced by utilizing a single dedicated power source sized to meet peak wet weather equipment power loads. This would increase the reliability and capacity of power to the plant during peak demand periods instead of relying on two separate services, neither of which is sufficient to meet peak loads.

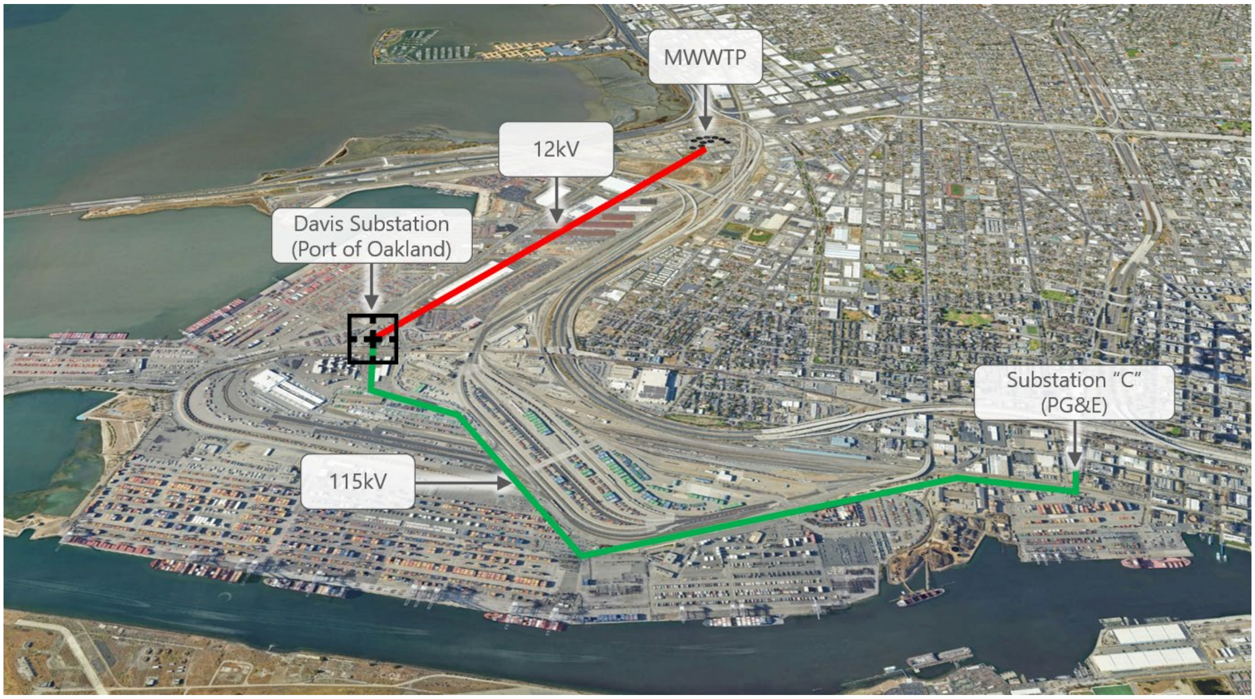
Woodard & Curran has identified three potential Road Map projects to provide a new power source with sufficient capacity for the entire MWWTP during a peak demand period. Based on the findings presented in TM 1, the new service connection would be a dedicated circuit that can provide a minimum capacity of 12 megawatts (MW) of power and up to 15 MW to account for future processes.

Any new service connection either at 115 kV or 12 kV will require a Preliminary Engineering Study (also known as a system impact study) to be completed by the power utility company. This is the first step when submitting an application for a new service and also initiates a Preliminary Engineering Study. The service application submitted to the power utility can identify a preferred substation and routing method upon which the study will either confirm or deny the request and offer another alternative for a new service. The costs included in this TM for new services are based on assumed locations; the final location will be determined based on the outcome of the Preliminary Engineering Study. The actual cost for a new service will not be determined until there is an agreement between the District and power utility company and the Preliminary Engineering Study has been finalized and the new service routing approved.

3.1.1 Road Map Project 1: New Port of Oakland 12 kV Connection

As part of this project, Woodard & Curran has contacted the Port of Oakland to learn more about their power supply capabilities. In these discussions, the Port of Oakland has informed us that there is a 115 kV power supply which is routed from PG&E's Substation C in South Oakland, near Jack London Square, to the Davis Substation. The Port of Oakland operates and owns this substation which steps power down from 115 kV to 12 kV for distribution to its customers. The Port of Oakland is currently in the process of designing replacements for the Davis substation (65% design) as well as the nearby substation SSR-14 (95% design). Neither of these substations includes provisions for large customer (agency) connections and instead considers only smaller customers (tenants). The Port of Oakland indicated that they receive their power from PG&E at 115kV and that providing a new dedicated 12 kV service for the MWWTP would require a Preliminary Engineering Study (System Impact Study) to be conducted by PG&E. At the time of this TM, the Port of Oakland could not confirm a dedicated 12 kV service would be available. Representatives from Port of Oakland highly recommended that EBMUD's General Manager have discussions with the Port of Oakland Executive leadership to discuss viable options for a new dedicated 12 kV service to the MWWTP. The benefits of this project include the reliability of the service, as the 115 kV connection is located closer to the MWWTP than the current PG&E connections, as well as its capacity. A dedicated 12 kV circuit would provide more reliability than the existing PG&E connections because the circuit from the Davis Substation would not have other tenants connected to the same line which could reduce capacity and potentially cause electrical transients. A conceptual routing for this new connection is presented in Figure 1.

FIGURE 1: PROJECT 1 – PORT OF OAKLAND POWER CONNECTION



Assuming the System Impact Study is favorable and successful negotiations with Port of Oakland are completed, it is estimated that the new service could be in place in 5-10 years. The MWWTP would continue to operate using the two existing PG&E Lines L and C in the interim. Then, one of the existing PG&E lines could be removed (Line C) with the other, more reliable Line L to remain as a partial "standby" source (Line L by itself cannot provide full redundancy). Since H1 (existing metering switchgear) is a utility-approved metering switchgear, the existing PG&E Line C breaker and controls could be removed and replaced with Port of Oakland breaker and controls without having to greatly modify H1 to integrate the new Port of Oakland service.

This alternative would increase the reliability of the utility power service during both normal and peak demand periods with the new connection considered as the "primary" circuit. The increase in reliability is due to a newer infrastructure system that Port of Oakland can provide, which includes newly replaced substations and a new overhead power line less vulnerable to damage than existing lines. The new service would be dedicated, i.e., not subject to reduction of capacity in the future. The new service contract between EBMUD and the Port of Oakland would have the potential to provide financially strengthened power sale agreements, since the Port of Oakland currently purchases power from EBMUD.

3.1.1.1 Cost Summary for Road Map Project 1: New Port of Oakland 12 kV Connection

It is expected that costs would include, at a minimum, a new breaker/switch at substation SSR-14, new overhead lines to the MWWTP, and other associated work such as property easements, City and County fees, and Port of Oakland fees for a new service connection.

TABLE 2: ROAD MAP PROJECT 1 – COST SUMMARY[1]

Description	Cost
Equipment	$2,600,000
Construction	$3,000,000
Engineering/Permitting	$1,900,000
Subtotal	$7,500,000
Contingency	$2,300,000
TOTAL	**$9,800,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.1.2 Road Map Project 2: New 12 kV PG&E Dedicated Connection

If EBMUD would like to move forward with a Preliminary Engineering Study with PG&E and the option to have a dedicated 12 kV service is probable based on favorable study results then it is anticipated that a new 12 kV dedicated service could be installed within 5-10 years after the study is completed (1 year). Given that the existing utility feeds are 12 kV, installation of a new 12 kV feed with higher capacity would have minimal impacts on the daily operations at the facility. Similar to the Port of Oakland alternative, due to the fact that the MWWTP would no longer be "split" and reliant on two separate feeds, it likely would simplify operations by reducing the complexity of the power distribution and control system. While a single dedicated full capacity 12 kV service would increase reliability relative to the status quo (two half-capacity feeds), per EPA guidelines a second reliable standby power source would still be recommended. This second power source would need to provide full capacity (during a peak event) should the dedicated 12 kV service not be available.

3.1.2.1 Cost Summary for Road Map Project 2: New PG&E 12 kV Dedicated Connection

The estimated cost is based on the assumption that a new dedicated 12 kV service would be provided from Station L and be terminated at H1 switchgear. Impacts to existing H1 switchgear would be minimal; however final routing of the new service below the railway tracks is not confirmed. The exact routing will not be determined until the Preliminary Engineering Study is completed and approved.

TABLE 3: ROAD MAP PROJECT 2 – COST SUMMARY[1]

Description	Cost
Equipment	$2,900,000
Construction	$4,100,000
Engineering/Permitting	$2,500,000
Subtotal	$9,500,000
Contingency	$2,800,000
TOTAL	**$12,300,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

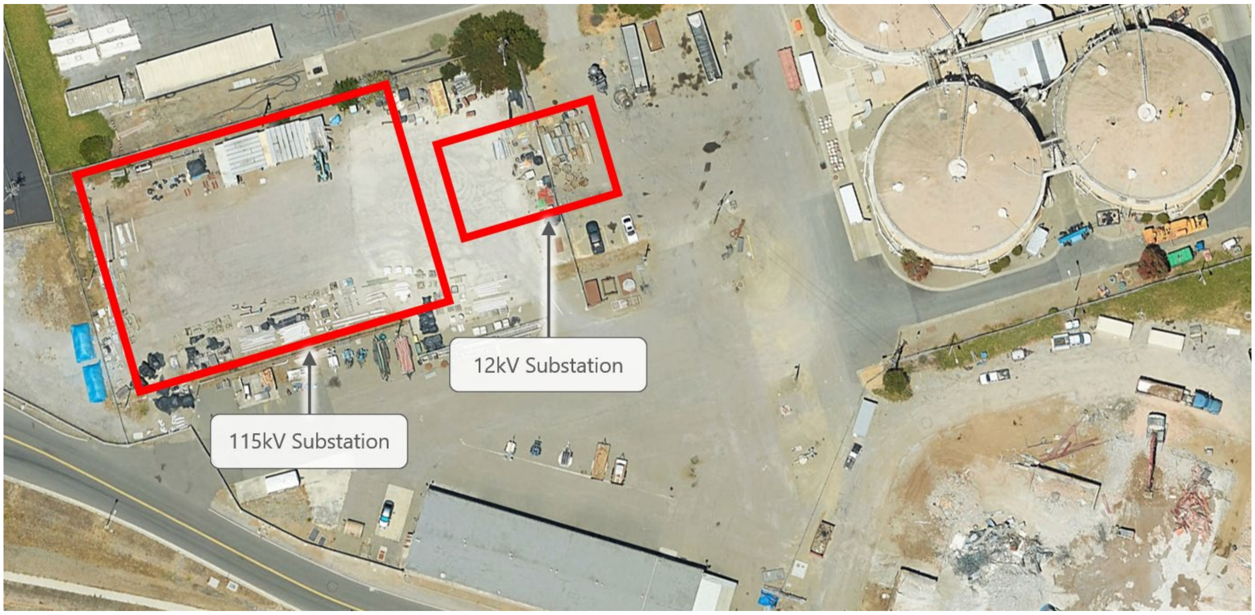
3.1.3 Road Map Project 3: New 115 kV Pacific Gas & Electric (PG&E) Connection

Woodard & Curran's scope of work included evaluation of a new high voltage (115 kV) connection sized to meet peak loads alone. The new 115 kV extension would start from the Davis Substation and be routed overhead to MWWTP. The routing is same as the Port of Oakland 12 kV connection as shown in Figure 1.

While PG&E may further evaluate this option, our preliminary review indicates that the space required to step down high voltage power from 115 kV and connect to the existing distribution system is prohibitive. Figure 2 below shows a hypothetical location that represents the estimated area needed for the needed 115 kV switchgear as well as a 12 kV transformer at approximately 28,500 sq ft. It does not show other gear which includes protective relays and current transformers. The figure is intended only to indicate the major needed space and it is not proposing a specific location for a new substation. In fact, no suitable space has been identified for a substation with this large footprint.

PG&E would own and maintain the high voltage (115 kV) switch yard including surge arresters, disconnectors, circuit breaker, etc. However, the District would own and maintain the substation transformer. Per ANSI and the NEC, the voltage classifications are as follows: High Voltage 115 kV up to 1,100 kV, Medium Voltage 2.4 kV to 69 kV and Low Voltage 240 V to 600 V. Since the MWWTP has both low and medium voltage systems it is assumed that District Staff is already trained for those voltage classes. To provide maintenance work on the substation transformer EBMUD would need to acquire the capability to maintain high voltage systems, whether with in-house staff or with contractors. The high voltage substation introduces new challenges to maintaining and owning the substation which impacts the District's standard training and operating programs and procedures. PG&E may require direct access to the substation therefore the District might need to provide a separate gate without requiring PG&E electricians to go through Security.

FIGURE 2: ROAD MAP PROJECT 2 EXAMPLE FOOTPRINT[1]



Note 1: Measurements are based on Google Earth Ruler (+/- 2.5 %)

A new service application to initiate a Preliminary Engineering Study would be required and could take up to two years for study results. A new service of this type could take up to 10 years from the date of service application. However, given the space constraints, we do not believe this option to be feasible at this time.

3.1.3.1 Cost Summary for Road Map Project 3: New 115 kV PG&E Connection

The estimated cost of the 115 kV transmission overhead service is based on previous conversations with PG&E regarding the relocation of an existing 115 kV transmission service for a proposed new conveyance pump station located near Patterson, California. The information for that project was based on a preliminary design done by Woodard & Curran in 2020 and has been adjusted for inflation for use in this TM. The substation equipment cost is based on PG&E's 2023 General Rate Case Exhibit (PG&E-4) Electric Distribution Workpapers Supporting Sections 14-23 Volume 2 of 2, Table 17-27.

TABLE 4: ROAD MAP PROJECT 3 – COST SUMMARY[1]

Description	Cost
Equipment	$27,000,000
Construction	$29,000,000
Engineering/Permitting	$20,000,000
Subtotal	$76,000,000
Contingency	$23,000,000
TOTAL	**$99,000,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.2 Emergency Standby Power Generators

While the projects described in Section 3.1 of the report would improve the electrical distribution system at the MWWTP by simplifying the incoming feeds, they do not address the need for on-site backup power generation in the event of loss of line power. In this section we present two options for new on-site power generation to improve resiliency and redundancy at the MWWTP: one to handle peak loads for the entire plant (12 MW), and one to handle peak loads for the single most critical system, the Influent Pump Station, approximately 6 MW. This section concludes with a discussion of potential load-shedding enhancements.

As indicated in this section, the cost and permitting difficulty for new generators could be formidable, particularly if the generator bank is sized for full-plant peak loads. Permitting difficulty might be eased if generators were combined with a Battery Energy Storage System (BESS) to reduce the run time of the generators by handling short-term outages without a generator start. This feature is not included with either Road Map Project 4 and 5 or included in the evaluations; however, it could be considered as part of either one of these Road Map Projects. BESSs are discussed further below.

Battery Energy Storage Systems (BESS)

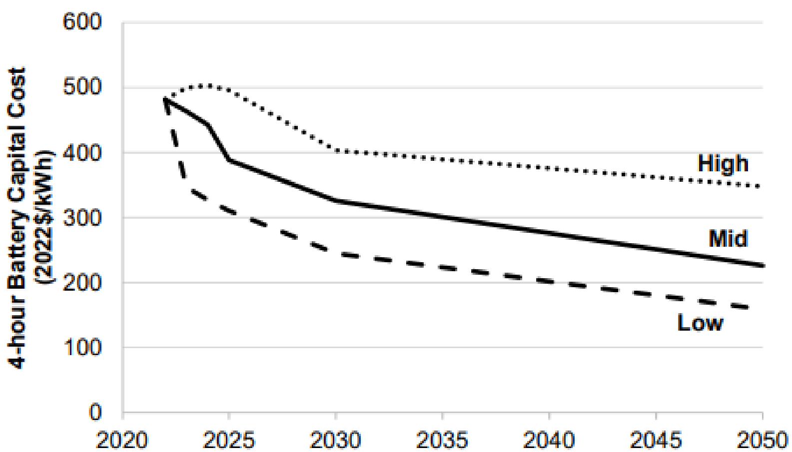
A BESS would complement conventional generators by allowing the MWWTP to sustain power transients and short duration outages (up to two minutes). For outages longer than two minutes, the standby generators would come online to carry the required load. The most common battery storage systems are based on lithium-ion power cells; however, other technologies are being introduced into the market such as sodium-ion which reduces risk of fires and overheating relative to lithium-ion but requires a larger footprint.

Based on discussions with a BESS manufacturer (aggreko®) nine 1.2-MWh battery banks (for a total of 10.8 MWh) would be required to supply the entire plant for two minutes. The size of the BESS in this case is governed not by runtime (two minutes) but by peak power output. The indicated size would provide about an hour of runtime. Figure 3 below shows one 1.2-MWh battery bank on the left and a DC-to-AC inverter on the right.

FIGURE 3: LITHIUM-ION BATTERY UNIT AND INVERTER

The projected cost of BESS is shown below in Figure 4 taken from National Renewable Energy Laboratory (NREL) 2023 Update.

FIGURE 4: PROJECTED COST FOR BATTERY STORAGE SYSTEMS



Based on this information: $\frac{\$500}{KWh} X\ 10{,}800KWh = \$5{,}400{,}000$

The figure shows only the BESS itself; additional costs include those for equipment such as inverters, switchgear modifications, integration into existing controls system (SEL POWERMAX), step-up transformers, etc. Inclusion of those costs would likely double the material cost to approximately $10.8M, implying a full construction cost of potentially $20M.

While a BESS would provide incremental reliability enhancements over generators for short-term power outages, its value for reducing overall generator runtime would be minimal given that power outages (of any duration) are infrequent compared to the required runtime every year for generator testing.

3.2.1 Road Map Project 4: 12 MW Generator Bank

Road Map Project 3 involves the installation of a bank of generators (4 – 3 MW units), controls, and on-site diesel fuel storage with a power generation capacity of 12 MW (as determined in TM 1). This capacity is sufficient to meet full-plant peak loads (max value documented is 10.6 MW) with spare capacity for future loads as well. The on-site diesel fuel storage would be sized to provide 72 hours supply of fuel at maximum load. Normal operations could continue for as long as fuel could be supplied during an outage.

Challenges associated with this project include the overall cost (to be presented below), space requirements, and permitting requirements. This project would also add to the complexity of the control system by adding another power generation source to the electrical distribution system.

Ideally, the new generators and paralleling switchgear would be rated for 12kV and be located in close proximity to the existing H2 switchgear (where the standby power connection would occur) to avoid long cable runs. However, space near the H2 switchgear is at a premium, with most of the area occupied by elements of the medium voltage power distribution system. Figure 5 below indicates a hypothetical location of the generator system and fuel storage area.

Air permitting with the Bay Area Air Quality Management District (BAAQMD) would be a significant issue related to this project. The MWWTP is in a designated priority community per AB 617, the Community Air Protection Program. It is expected that the BAAQMD will enforce strict emissions regulations requiring after-treatment technologies that meet EPA's current Tier 4 standards. The new generators would be installed with Best Available Control Technology (BACT), which will involve high costs and sensitive equipment. Generators would need to be run at full capacity at least once per month for testing. Currently the BAAQMD requires Tier 4 after-treatment technology for the types of generators proposed in this TM. Most recently the California Air Resources Board (CARB) is considering Tier 5 be implemented in 2030 after board approval in mid-2025. This type of variability of regulatory requirements can hinder design and permitting of generators delaying schedules and increasing cost.

FIGURE 5: ROAD MAP PROJECT 4 PROPOSED LOCATION ON SITE[1]

Note 1: Measurements are based on Google Earth Ruler (+/- 10 %).

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generators, controls, and fuel storage tanks could be constructed and tested offline from the remainder of the facility. There are spaces available at H2A and H2B to allow for two connections to the standby power system. The existing electrical interlock (INLK) at H2 would most likely require replacement with a larger and more sophisticated control system. The SEL POWERMAX control system currently used for load shed controls could be investigated as an option to control the breakers at H2 for standby power when utility power is not available. The SEL POWERMAX would allow ease of integration for the new standby generators and enable the ability to potentially parallel PGS1 and PGS2 with the standby generators. This feature would reduce demand on the generators during an outage and thus increase the refueling interval beyond 72 hours.

The many components comprising this project including not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, and spill containment would impose significant new maintenance needs. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored fuel which has a shelf-life of only 6-12 months.

The benefits of this project in terms of power reliability would need to be weighed against the substantial capital cost and O&M burden created by the project.

3.2.1.1 Cost Summary for Road Map Project 4: 12 MW Generator Bank

TABLE 5: ROAD MAP PROJECT 4 – COST SUMMARY[1]

Description	Cost
Equipment	$13,100,000
Construction	$19,050,000
Engineering/Permitting	$11,250,000
Subtotal	$43,400,000
Contingency	$13,020,000
TOTAL	**$56,420,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

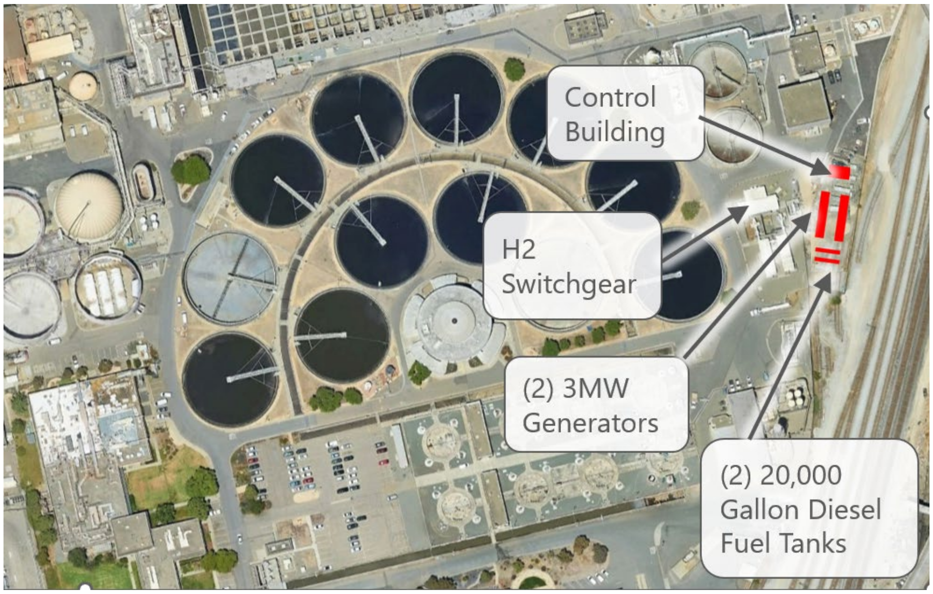
3.2.2 Road Map Project 5: Generators Sized for Influent Pump Station

Due to the capital cost, space requirements, and O&M burden of Road Map Project 3, Woodard & Curran also considered a smaller generator project to improve resiliency and address the immediate concerns at the Influent Pump Station (IPS). This would include the installation of two 12kV, 3 MW generators to serve the IPS via switchgear H2. These generators were sized based on powering the five influent pumps required to meet peak wet weather flows as determined by the District. Refer to Appendix B for generator sizing calculations which resulted in 2 – 2.5MW units for generators rated at 4160V (size for 12kV generators would be roughly the same). This TM is proposing 2 – 3MW to provide a margin for additional unknown loads. The actual size of the generators would be determined during a preliminary design phase.

The rationale for prioritizing the IPS is not only that the IPS performs a critical function (which it does). In addition, as presented in TM 1, the "time to impact" on plant operations should IPS suffer a power loss is the shortest among plant processes. While the precise time-to-impact depends on plant conditions at the moment of a power outage, it's often so short that impacts at IPS will be occurring before plant operators can restore operations at PGS-1 or PGS-2.

This project includes the installation of two 3 MW generators adjacent and connected to the H2 switchgear along with on-site fuel storage and a control building. Modifications would be necessary at H2 switchgear including improvements or replacement of the existing electrical interlocks with a more sophisticated control system. This project would restore power to the IPS within one minute upon a loss of utility power.

FIGURE 6: ROAD MAP PROJECT 5 PROPOSED LOCATION ON SITE[1]



Note 1: Measurements are based on Google Earth Ruler (+/- 2.5 %)

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generator, controls, and fuel storage tank could be constructed and tested offline from the remainder of the facility.

The many components comprising this project including not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, and spill containment would impose significant new maintenance needs, although to a lesser degree than the 12 MW Project 4. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored fuel which has a shelf-life of only 6-12 months.

This alternative could be built as an initial phase of Road Map Project 4. In that case, the project layout, and key components, would be sized for buildout to the capacities needed for Project 4, but only half of the full 12 MW capacity, and only half of the ultimate fuel storage, would be built initially. A second phase could follow at any time, e.g., five years after the initial phase, to add more generators and tanks, and adjust controls as needed. A benefit of phasing, beyond reducing immediate cash flow needs, is that the second phase could be designed with more precise knowledge of future loads. A downside of phasing is that the cost of the initial phase would be somewhat more than a "standalone" Project 5 because of the need to oversize some equipment for future loads.

3.2.2.1 Cost Estimate for Road Map Project 5: Generators sized for Influent Pump Station

The costs presented below assume that the project is not implemented as the initial phase which if it was, would add more to the project cost for the added infrastructure for final buildout of a 12MW generator bank.

TABLE 6: ROAD MAP PROJECT 5 – COST SUMMARY[1]

Description	Cost
Equipment	$5,900,000
Construction	$7,200,000
Engineering/Permitting	$4,600,000
Subtotal	$17,700,000
Contingency	$5,300,000
TOTAL	**$23,000,000**

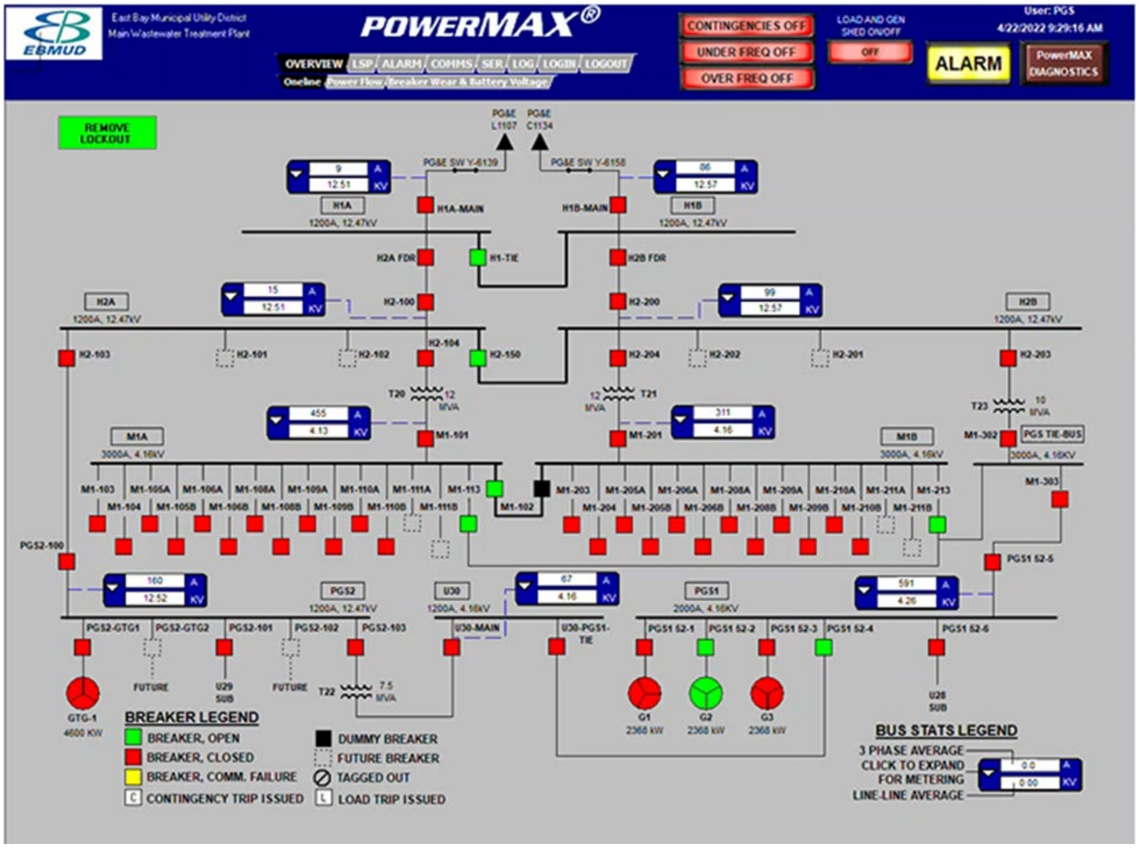
Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.2.3 Road Map Project 6: POWERMAX System Upgrades

Under normal EBMUD MWWTP operations, electrical power demand is met by a blend of utility power and onsite power, which is generated from biogas co-generation (co-gen). During a utility power outage, without the use of load shedding to reduce the load demand to match the power being generated, critical plant process will shut down.

As discussed in TM 1, EBMUD has invested in SEL POWERMAX load shedding system to monitor power and prioritize load distribution in the event of a utility outage. When implemented, the load shed system will increase the reliability of PGS-1 & 2 by reducing the likelihood of this equipment tripping due to over- or under-frequency. The load shedding system will also maintain power to processes identified by EBMUD as being the most critical. Figure 7 below is a screen shot of the SEL POWERMAX HMI.

FIGURE 7: SCREEN SHOT OF EXISTING LOAD SHED CONTROLS



Since EBMUD has already invested in the load shedding system, this project would simply activate the system already in place. TM 1 identified some adjustments that could be made to the software to re-prioritize the various treatment processes based on our Time to Impact analysis; however, these are minor programming changes that do not require significant capital investment.

EBMUD Operations staff has identified potential improvements to the load shedding program including the consideration of controlling breakers at the 480 V level (MCC main breakers). The goal of that would be to prioritize specific loads that might otherwise be subject to load shedding at the 12 kV level. Including the 480 V system in the load shedding logic has the potential to greatly increase system complexity and is impractical with the current load-shed system setup. An alternative approach would be examining high-priority 480 V loads on a case-by-case basis to identify options such as refeeding the load to a higher-priority 12 kV circuit or providing a dedicated UPS for small loads.

3.2.3.1 Cost Summary for Road Map Project 6: POWERMAX System Upgrades

The primary costs for this project are software license updates, programming changes, and training. Additionally, the cost below includes communication processor upgrades, which is recommended to be replaced as part of this work since the existing processors are nearing the end of their useful life.

TABLE 7: ROAD MAP PROJECT 6 – COST SUMMARY[1]

Description	Cost
Equipment	$300,000
Construction	$150,000
Engineering/Permitting	$50,000
Subtotal	$550,000
Contingency	$150,000
TOTAL	**$700,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance Tables. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.3 Infrastructure Improvements

As part of the investigations associated with this project, Woodard & Curran identified additional projects that would improve reliability by increasing the resiliency of existing systems at the MWWTP. Increasing resiliency as it relates to this TM means bolstering existing electrical systems and providing redundant equipment where it makes sense to keep the plant operating when energy sources are compromised. Some examples include replacement of aging cables, moving below grade elbow connectors to above grade for easier and safer access and the addition of substations to maintain operations during maintenance work.

3.3.1 Road Map Project 7: Best Practices

The seventh road map project identified creates a system of best practices for EBMUD to implement as part of Asset Management of their electrical infrastructure. Our scope of work is limited to desktop study and visual observations during a site visit and does not include evaluation of the infrastructure in detail. However, in discussions with EBMUD staff it is apparent that the existing infrastructure is aging and will require upgrades in the future simply to maintain existing capabilities.

The costs presented in this report assume that EBMUD would undertake all the identified improvements as part of a single capital project. However, EBMUD may wish to incorporate portions of these potential upgrades into smaller projects targeting specific areas of the MWWTP rather than perform a facility-wide project due to the scope and scale of these items. Some specific options include:

- Replacing below grade elbow connectors (in MH 13, 16, 40, 43) with above grade sectionalizing cabinet. Currently, cabling is connected in underground vaults. These confined spaces make inspection difficult and increase the risk of groundwater intrusion. Modern design standards call for such connections to be made at above-grade equipment to eliminate groundwater concerns. Figure 8 below is a picture of a proposed above grade sectionalizing cabinet; manufacturer is Eaton, SecTER Series.
- Documenting existing medium voltage (MV) cables, prioritizing testing based upon their age, putting older cables as high priority versus newer/tested cables. The older MV cables will likely need testing over the next 5-10 years.
- Increasing redundancy at the substations: While most switchgear have redundant feeders with redundant transformers, we have identified several gears with no redundancy, including U1

(Aerated Grit), U12 (Digester Building), U13 (Solid/Liquid Receiving Station), and U22 (Mid-Plant).

- Co-Mingling Wiring Issues – EBMUD Operations staff have noted several areas where components of a process train are powered from different sides of an open MCC tie breaker. For example, an Influent Pump may be powered from one side of the tie breaker, but the valves/gates associated with that pump are powered from the other side. Due to the dual feed from the utility, when one side of the MCC loses power, the manual tie breaker remains open and in effect, the entire treatment train loses power. Continued efforts by EBMUD to identify and remediate these conditions will increase resiliency.

FIGURE 8: ROAD MAP PROJECT 7 PROPOSED ABOVE GRADE SECTIONALIZING CABINET

This work can be fully aligned with EBMUD's Master Integration plan by incorporating these recommendations into capital projects, so they are addressed as various areas of the facility are upgraded. These modifications should reduce the burden on MWWTP operations staff by making the electrical infrastructure more resilient and reliable, reducing the need for hands-on service.

3.3.1.1 Cost Summary for Road Map Project 7: Best Practices

The total cost shown in the table below represents the cost for all of the equipment replacement cost and not for each individual type of equipment. For example, the District might want to implement the cable replacement only or address each substation transformer individually. Refer to Appendix A for the breakdown of each type of equipment for more details.

TABLE 8: ROAD MAP PROJECT 7 – COST SUMMARY[1]

Description	Cost
Equipment	$5,000,000
Construction	$4,700,000
Engineering/Permitting	$3,400,000
Subtotal	$13,100,000
Contingency	$3,900,000
TOTAL	**$17,000,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

4. EVALUATION OF ROAD MAP PROJECT ALTERNATIVES

This Section evaluates the Road Map Project alternatives presented in Section 3 using the evaluation criteria presented in Section 2. Many of the project alternatives are complementary rather than exclusive, so the final selection by EBMUD may well be a portfolio of projects implemented over time.

Each project description includes a reference to the conclusions and recommendations from TM 1. This summary will allow for more insight into the relative impact that each project may have on overall electrical resiliency at EBMUD MWWTP.

4.1 Project 1: New Port of Oakland 12 kV Connection

Like Projects 2 and 3, a new Port of Oakland connection addresses TM 1 recommendation R1: "Consider replacing one of the existing line circuits with a dedicated service with limited overhead distribution." This recommendation addresses TM 1 conclusion C1: "The Plant's line power supplies should not be considered reliable, owing to lack of full redundancy." Also, like Projects 2 and 3, this project alternative assumes that the new connection can meet peak plant loads on its own, and that one of the two existing PG&E lines would be removed. The remaining PG&E line service could be dedicated as standby power and when combined with PGS1 could provide redundancy as long as the load shedding control system is operable. Projects 1, 2 and 3 are thus directly comparable.

TABLE 9: EVALUATION OF PROJECT 1 – NEW PORT OF OAKLAND 12 KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 3
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.2 Project 2: New PG&E 12 kV Connection

A new 12 kV PG&E connection addresses the same TM 1 recommendations and conclusions as Projects 1 and 2. Project 3 differs from Project 1 in that it avoids the siting of 115 kV switchgear on EBMUD premises; a downside of that characteristic is that the 12 kV service is more prone to voltage sags.

TABLE 10: EVALUATION OF PROJECT 3 – NEW PG&E 12 KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 1
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.3 Project 3: New PG&E 115 kV Connection

As discussed, this Project, like Projects 1 and 3, addresses TM 1 conclusion C1: "The Plant's line power supplies should not be considered reliable, owing to lack of full redundancy." A distinguishing feature of this Project relative to Project 1 or 3 is that its service voltage of 115 kV would result in higher reliability due to higher voltage systems being able to withstand voltage transients and sags better than 12 kV systems. However, a new 115 kV substation would be required for which space does not appear to exist, thus rendering this option infeasible. If the project were feasible, it would require additional training and certification for District staff for high voltage systems and would incur extensive cost to construct new transmission towers and obtain right of way.

TABLE 11: EVALUATION OF PROJECT 2 – NEW PG&E 115KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Low	Requires high voltage class training and certification.
Cost Effectiveness	Low	A new transmission extension and substation will be costly.
Reliability and Effectiveness	High	
Ease of Implementation	Low	Appears to be infeasible due to space limits for 115 kV switchgear. Transmission line easement is larger than that for 12 kV transmission lines.
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.4 Project 4: 12 MW Generator Bank

Projects 1, 2 and 3 address TM 1 recommendation R1: " Consider replacing one of the existing line circuits with a dedicated service with limited overhead power distribution." however, they do not address federal standard EPA 430-99-74-001 as described in TM 1. The intent of this project is to combine it with a single, full capacity power utility circuit such that a second reliable standby power source is available when the power utility circuit is not available.

The critical assumptions made for consideration of this project are as follows: Project 4 assumes there is sufficient space to locate the generator bank and ancillary systems.

TABLE 12: EVALUATION OF PROJECT 4 – 12 MW GENERATOR BANK

Criteria	Performance/Benefit	Notes
Operability	Low	Adding another power generation source will add more complexity to the controls.
Maintainability	Low	Complex machinery to maintain, adding to operator burden.
Cost Effectiveness	Low	Generators, switchgear, ancillary systems, and infrastructure required will be costly.
Reliability and Effectiveness	High	Diesel engine generators used as a standby power source are considered quite reliable.
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. BAAQMD permitting regulations are fluid and represent potential stalls to project implementation. For example, California Air Resources Board (CARB) is considering Tier 5 be implemented in 2030 after board approval in mid-2025.
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.5 Project 5: Generator Sized for IPS

Two 3-MW generators would provide enough capacity to meet the power load demanded by the Influent Pump Station (IPS) which addresses parts of the TM 1 recommendation R-6: "Modify or add electrical equipment to provide full redundancy." The project is specifically pertinent to conclusions C-1 and C-3, which are as follows:

- C-1: "The plant's line power supplies should not be considered reliable, owing to lack of full redundancy to maintain plant operations during peak events and environmental exposure."

- C-3: "Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity."

TABLE 13: EVALUATION OF PROJECT 5 –GENERATOR SIZED FOR IPS

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Low	
Cost Effectiveness	High	
Reliability and Effectiveness	Neutral	Only provides power for initial unit processes
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. May be difficult to permit with BAAQMD. Rating of Low is based on ultimate build-out to 12 MW.
Flexibility for Future Process Changes or Increased Demand	High	Building as an initial phase with an option to add more generators provides flexibility to meet future needs.
Reduced GHG Emissions	Neutral	

Project 5 is valuable for its potential to generate an overall increase in electrical system resiliency if it were coupled with a larger Project, such as Project 1 or 2 or included in the Influent Pump Station Upgrades Project. This project could be employed on a shorter implementation schedule and result in added redundancies when layered with other, more complex upgrades.

4.6 Project 6: POWERMAX System Upgrades

Load-shed modifications address TM 1 recommendations R-2 and R-4 which are:

- R-2: "The SEL POWERMAX [load-shedding] system should be enabled at all times to maintain operation of PGS during utility outage and avoid black start."
- R-4: "Revise load shed priority list based on criticality of processes and [time to impact]."

The recommendations for this project primarily pertain to TM 1 conclusion C-2: "The disablement of the SEL POWERMAX power control system poses a significant risk associated with power outages and maintaining PGS operation."

The critical assumptions made for consideration of this project are as follows: It is assumed that the issues of co-mingling of wiring for process equipment trains and their associated systems as mentioned in Project 7 are addressed either prior to this work or in tandem. In addition, it is assumed that District Operations staff is properly trained in the use of SEL POWERMAX to further understand the benefits of the load shed controls for increased resiliency. Coupling this project with Project 7 with appropriate training appears to provide significant resiliency to MWWTP operations.

TABLE 14: EVALUATION OF PROJECT 6 – POWERMAX SYSTEM UPGRADES

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Neutral	
Cost Effectiveness	High	Implement existing systems
Reliability and Effectiveness	High	
Ease of Implementation	High	Modifications to a control system that is already in place.
Flexibility for Future Process Changes or Increased Demand	High	Major changes easily adapted to
Reduced GHG Emissions	Neutral	

4.7 Project 7: Best Practices Upgrades

Best practices upgrades include replacing below grade cable connectors with an above grade sectionalizing cabinet, taking inventory of, and replacing MV cables, adding redundancy to substations U1, U13, U16 and U22, and rewiring equipment trains that have co-mingled circuits. These upgrades address TM 1 recommendation R-3, and parts of R-6:

- R-3: "Correct or consolidate low voltage wiring systems that are co-mingled between the different power buses (A versus B)."
- R-6: "Modify or add electrical equipment to provide full redundancy. Replace below grade cable connectors with above grade switch gear."

These recommendations are pertinent to conclusions C-3, C-4:

- C-3: "Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity."
- C-4: "Process trains and their ancillary devices are not wired to the same power bus which increases risk of non-operation when one of the two line-circuits are not available, and a tie breaker is not closed or if the load shed control system is enabled."

The critical assumptions made for consideration of this project are as follows: The upgrades listed under this project are assumed to be part of capital improvement plans or maintenance programs. It is assumed that not all the best practice components would be completed simultaneously. Sub-projects, e.g., replacing MV cables, adding redundancy to substations U1, U13, U16 and U22, and rewiring equipment trains that have co-mingled circuits could be completed as smaller projects with short-turn implementation times and could be prioritized to maximally increase electrical resiliency at EBMUD MWWTP. For example, addressing the co-mingling issues alone will have an outsize impact on plant resiliency.

TABLE 15: EVALUATION OF PROJECT 7 – BEST PRACTICES UPGRADES

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	High	Compared to the generator, each of these sub-projects will provide resiliency at a fraction of the cost of other proposed projects.
Reliability and Effectiveness	High	Will improve redundancy and resiliency
Ease of Implementation	High	This project conglomerates several sub-projects. Some of these, such as addressing the co-mingling, adding resilient substations, and replacing MV cables are straightforward to implement, though they may be labor intensive. Projects could readily be added to ongoing Master Planning efforts.
Flexibility for Future Process Changes or Increased Demand	Neutral	Fixing existing issues does not increase capacity
Reduced GHG Emissions	Neutral	Fixing comingling issues could allow the re-prioritized SEL POWERMAX load shed to operate and existing PGSs to operate without relying on exterior power sources. Per discussions with EBMUD, the comingling issues are a reason why the load shed program was disabled.

5. CONCLUSIONS

This Section broadly summarizes the results of the alternatives analysis completed in Section 4. Conclusions presented herein are intended to highlight overarching trends and key observations about Road Map Projects without providing explicit recommendations. The selection of recommended Road Map Projects will be undertaken in TM 3.

5.1 Road Map Project Overarching Concerns

The team offers the following general conclusions that will help shape the future:

- The system complexity of the EBMUD electrical system is high. The completion of multiple Road Map Projects is likely required to simplify the system and introduce needed resiliency.
- Coupling short-term, targeted projects with larger scope upgrades may provide the most immediate path to improved reliability. Layering these projects together can also add resiliency.
  - Several short-term projects can provide outsize impacts to electrical resiliency at the EBMUD MWWTP. Projects that facilitate PGS system operability during utility outage, without compromising performance of critical treatment operations, would likely provide high value. Implementation of these projects would not provide full redundancy but would increase plant resiliency by strengthening the power system infrastructure. These projects could provide interim value and complement more comprehensive long-term electrical upgrades.
  - Much of the system complexity stems from the fact that two power utility feeds currently must be operable to meet peak power demands. EBMUD should give priority consideration to obtaining a power utility feed that can meet peak demands by itself, in order to improve reliability and reduce complexity.
  - While full power redundancy with a generator bank would provide value, it would pose high capital and operating costs. A smaller generator bank that powers the most important loads (i.e., IPS) would be less expensive and provide substantial benefit. That project could also be designed to permit future buildout to a full-plant backup should that be warranted in the future.
- Operator and staff training would provide high value to support existing and future electrical system upgrades including an enhanced understanding of load shed controls and their critical importance to the resiliency of the plant. Because the MWWTP exports and imports power from multiple sources it should be treated as a Microgrid, with commensurate training needs. As utility grids become more unstable and the District continues to lower GHG emissions utilizing renewable energy the need for this type of training becomes even more critical.
- The evaluation results for projects involving generators are not favorable when compared to new utility power connections. This is because implementation for generator systems includes uncertainty based on regulatory instability that is predicated on the requirements set forth by CARB and its impacts on technology that trickles down to manufacturing and regulatory enforcement. However, even with this in mind, the time to establish an agreement with a utility power company for a new service, planning, engineering, obtain easements and finally to construct the new connection service might require more time to implement than a generator bank. The evaluation results for new 12 kV connections indicate a High benefit since implementation is based on regulatory requirements that are considered less than generator systems and also power utility

connections require less maintenance. As the technology and dynamics of energy sources continue to evolve due to ever-changing policies it's possible that the performance/benefit could change for both alternatives. The approach to looking at the alternatives should be considered as alternative portfolio of projects so that a combination of projects will consider the variability of implementation and decrease the amount of time to the extent possible to address immediate resiliency and reliability issues.

5.2 Next Steps

The alternatives evaluation completed in this TM represents the technical basis of understanding for recommending Road Map Projects to EBMUD. A technical workshop will be conducted with District staff to review and refine the draft alternatives presented here. Insights arising from this workshop will be captured and integrated into the final Road Map Project recommendations. The summary of these recommendations, which will include prioritization of Projects, a description of their integration with EBMUD Integration Master Plan, and proposed timelines and implementation schedules, shall be presented in TM 3.

6. REFERENCES

Bredehoeft, P., Hollmann, J.K., Dysert, L.R., and Pickett, T.W., AACE International Recommended Practice No. 87R-14. TCM Framework 7.3 – Cost Estimating and Budgeting. "Cost Estimate Classification System – As Applied for the Petroleum Exploratory and Production Industry." August 7, 2020. Sample accessed online 12, 21, 2023 at www.web.aacei.org/docs/defailt-source/toc_87r-14.pdf.

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APPENDIX A: PROJECT COST DEVELOPMENT FORMS

Cost for Road Map Project 1: New Port of Oakland 12kV Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV Dedicated Overhead Line[1]	$220/Ft (7920ft)	$ 1,742,400.00
Modifications to H1 Switchgear		$ 500,000.00
Modifications to Power Controls		$ 100,000.00
New Breaker at Davis Substation		$ 250,000.00
Raw Equipment Cost "Line A"		$ 2,592,400.00
Miscellaneous Demolition	10% of "A"	$ 259,240.00
Civil	20% of "A"	$ 518,480.00
Electrical, Instrumentation and Controls	5% of "A"	$ 129,620.00
Hazardous Materials and Handling	5% of "A"	$ 129,620.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 129,620.00
Raw Construction Cost "Line B"		$ 3,758,980.00
Startup and Construction Sequencing	5% of "B"	$ 187,949.00
Construction Easements	10% of "B"	$ 375,898.00
General Conditions	10% of "B"	$ 375,898.00
Contractor O&P	5% of "B"	$ 187,949.00
Sales Tax	5% of "B"	$ 187,949.00
Construction Cost Subtotal "Line C"		$ 5,074,623.00
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 507,462.30
Total Construction Cost "Line D"		$ 5,582,085.30
Planning and Permitting	5% of Construction	$ 279,104.27
Engineering	15% of Construction	$ 837,312.80
Construction Management	15% of Construction	$ 837,312.80
Project Cost Subtotal "Line E"		$ 7,535,815.16
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 2,260,744.55
Total Project Cost		**$ 9,796,559.70**

Cost for Road Map Project 2: New PG&E 12 kV Dedicated Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV Dedicated Overhead Line[1]	$220/Ft (10,560ft)	$ 2,323,200.00
Modifications to H1 Switchgear		$ 500,000.00
Modifications to Power Controls		$ 100,000.00
Raw Equipment Cost "Line A"		$ 2,923,200.00
Miscellaneous Demolition	10% of "A"	$ 292,320.00
Civil	20% of "A"	$ 584,640.00
Electrical, Instrumentation and Controls	5% of "A"	$ 146,160.00
Hazardous Materials and Handling	5% of "A"	$ 146,160.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 146,160.00
Raw Construction Cost "Line B"		$ 4,238,640.00
Startup and Construction Sequencing	5% of "B"	$ 211,932.00
Construction Easements	20% of "B"	$ 847,728.00
General Conditions	10% of "B"	$ 423,864.00
Contractor O&P	5% of "B"	$ 211,932.00
Sales Tax	10.25% of "B"	$ 434,460.60
Construction Cost Subtotal "Line C"		$ 6,368,556.60
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 636,855.66
Total Construction Cost "Line D"		$ 7,005,412.26
Planning and Permitting	5% of Construction	$ 350,270.61
Engineering	15% of Construction	$ 1,050,811.84
Construction Management	15% of Construction	$ 1,050,811.84
Project Cost Subtotal "Line E"		$ 9,457,306.55
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 2,837,191.97
Total Project Cost		**$ 12,294,498.52**

Notes

1. Does not include poles, easement cost, right of way.

Cost for Road Map Project 3: New 115 kV Pacific Gas Electric (PG&E) Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
115kV Extension by PG&E		$ 4,853,456.00
115kV Substation Equipment		$ 2,300,000.00
115kV/12kV EBMUD Substation Transformer		$ 18,600,000.00
12kV EBMUD Substation Equipment		$ 1,400,000.00
Raw Equipment Cost "Line A"		$ 27,153,456.00
Miscellaneous Demolition	5% of "A"	$ 1,357,672.80
Civil	10% of "A"	$ 2,715,345.60
Electrical, Instrumentation and Controls	10% of "A"	$ 2,715,345.60
Hazardous Materials and Handling	5% of "A"	$ 1,357,672.80
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 1,357,672.80
Raw Construction Cost "Line B"		$ 36,657,165.60
Startup and Construction Sequencing	5% of "B"	$ 1,832,858.28
Construction Easements	15% of "B"	$ 5,498,574.84
General Conditions	10% of "B"	$ 3,665,716.56
Contractor O&P	5% of "B"	$ 1,832,858.28
Sales Tax	Oakl% of "B"	$ 3,757,359.47
Construction Cost Subtotal "Line C"		$ 53,244,533.03
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	5% of "A"+ Market Factor	$ 2,662,226.65
Total Construction Cost "Line D"		$ 55,906,759.69
Planning and Permitting	5% of Construction	$ 2,795,337.98
Engineering	15% of Construction	$ 8,386,013.95
Construction Management	15% of Construction	$ 8,386,013.95
Project Cost Subtotal "Line E"		$ 75,474,125.58
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 22,642,237.67
Total Project Cost		**$ 98,116,363.25**

Cost for Road Map Project 4: 12 MW Generator Bank

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV, 3 MW Standby Diesel Generator	$2,100,000/ea., 4x	$ 8,400,000.00
25000-gallon Diesel Fuel Tank	$90,000/ea., 3x	$ 270,000.00
Initial fueling	$6/gal., 75,000 gal	$ 450,000.00
5MW Load Bank		$ 475,000.00
Generator Control Building		$ 1,500,000.00
15KV Generator Switchgear	$200,000/ea., 6x	$ 1,200,000.00
Generator Protection and Control Panel	$125,000/ea., 4x	$ 500,000.00
SEL PowerMAX Modifications		$ 300,000.00
Raw Equipment Cost "Line A"		$ 13,095,000.00
Miscellaneous Demolition	5% of "A"	$ 654,750.00
Civil	30% of "A"	$ 3,928,500.00
Electrical, Instrumentation and Controls	20% of "A"	$ 2,619,000.00
Hazardous Materials and Handling	5% of "A"	$ 654,750.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 654,750.00
Raw Construction Cost "Line B"		$ 21,606,750.00
Startup and Construction Sequencing	5% of "B"	$ 1,080,337.50
Construction Easements	5% of "B"	$ 1,080,337.50
General Conditions	10% of "B"	$ 2,160,675.00
Contractor O&P	5% of "B"	$ 1,080,337.50
Sales Tax	10.25% of "B"	$ 2,214,691.88
Construction Cost Subtotal "Line C"		$ 29,223,129.38
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 2,922,312.94
Total Construction Cost "Line D"		$ 32,145,442.31
Planning and Permitting	5% of Construction	$ 1,607,272.12
Engineering	15% of Construction	$ 4,821,816.35
Construction Management	15% of Construction	$ 4,821,816.35
Project Cost Subtotal "Line E"		$ 43,396,347.12
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 13,018,904.14
Total Project Cost		**$ 56,415,251.26**

Cost for Road Map Project 5: Generators sized for Influent Pump Station

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV, 3MW Standby Diesel Generator	$2,100,000/ea., 2X	$ 4,200,000.00
20,000-gallon Diesel Fuel Tank	$80,000/ea., 2x	$ 160,000.00
Initial Fueling	$6/gal, 40,000 gal	$ 240,000.00
2MW Load Bank		$ 300,000.00
Generator Control Building		$ 250,000.00
15kV Generator Switchgear	$200,000/ea., 2x	$ 400,000.00
Generator Protection and Control Panel	$125,000/ea., 2x	$ 250,000.00
SEL PowerMAX Modifications		$ 50,000.00
Raw Equipment Cost "Line A"		$ 5,850,000.00
Miscellaneous Demolition	5% of "A"	$ 292,500.00
Civil	30% of "A"	$ 1,755,000.00
Electrical, Instrumentation and Controls	5% of "A"	$ 292,500.00
Hazardous Materials and Handling	5% of "A"	$ 292,500.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 292,500.00
Raw Construction Cost "Line B"		$ 8,775,000.00
Startup and Construction Sequencing	5% of "B"	$ 438,750.00
Construction Easements	5% of "B"	$ 438,750.00
General Conditions	10% of "B"	$ 877,500.00
Contractor O&P	5% of "B"	$ 438,750.00
Sales Tax	10.25% of "B"	$ 899,437.50
Construction Cost Subtotal "Line C"		$ 11,868,187.50
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 1,186,818.75
Total Construction Cost "Line D"		$ 13,055,006.25
Planning and Permitting	5% of Construction	$ 652,750.31
Engineering	15% of Construction	$ 1,958,250.94
Construction Management	15% of Construction	$ 1,958,250.94
Project Cost Subtotal "Line E"		$ 17,624,258.44
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 5,287,277.53
Total Project Costs		**$ 22,911,535.97**

Cost for Road Map Project 6: Load Shed Controls Modifications

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
SEL PowerMAX Communication Processor Upgrade	$20,000/ea., 15x	$ 300,000.00
Raw Equipment Cost "Line A"		$ 300,000.00
Electrical, Instrumentation and Controls	10% of "A"	$ 30,000.00
Raw Construction Cost "Line B"		$ 330,000.00
Startup and Construction Sequencing	5% of "B"	$ 16,500.00
Construction Easements	5% of "B"	$ 16,500.00
General Conditions	10% of "B"	$ 33,000.00
Contractor O&P	5% of "B"	$ 16,500.00
Sales Tax	10.25% of "B"	$ 33,825.00
Construction Cost Subtotal "Line C"		$ 446,325.00
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 44,632.50
Total Construction Cost "Line D"		$ 446,325.00
Planning and Permitting	0% of Construction	$ -
Engineering	5% of Construction	$ 22,316.25
Construction Management	5% of Construction	$ 22,316.25
Project Cost Subtotal "Line E"		$ 490,957.50
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 147,287.25
Total Project Costs		**$ 638,244.75**

Cost for Road Map Project 7: Best Practices

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Construction Cost		
Cable Replacement		$ 1,970,515.00
MV Elbow Replacement		$ 328,000.00
Influent Pump Station LV Commingled Power Investigation		$ 35,700.00
Cable Investigation and Testing		$ 125,000.00
Redundant Transformer at U1 (Aerated Grit)		$ 708,000.00
Redundant Transformer at U12 (Digester Building)		$ 648,000.00
Redundant Transformer at U13 (Solids/Liquid Recieving)		$ 515,000.00
Redundant Transformer at U22 (Mid-Plant)		$ 648,000.00
Raw Construction Cost "Line A"		$ 4,978,215.00
Miscellaneous Demolition	5% of "A"	$ 248,910.75
Civil	5% of "A"	$ 248,910.75
Electrical, Instrumentation and Controls	10% of "A"	$ 497,821.50
Hazardous Materials and Handling	5% of "A"	$ 248,910.75
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 248,910.75
Raw Construction Cost "Line B"		$ 6,471,679.50
Startup and Construction Sequencing	5% of "B"	$ 323,583.98
Construction Easements	5% of "B"	$ 323,583.98
General Conditions	10% of "B"	$ 647,167.95
Contractor O&P	5% of "B"	$ 323,583.98
Sales Tax	10.25% of "B"	$ 663,347.15
Construction Cost Subtotal "Line C"		$ 8,752,946.52
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 875,294.65
Total Construction Cost "Line D"		$ 9,628,241.18
Planning and Permitting	5% of "A"	$ 481,412.06
Engineering	15% of "A"	$ 1,444,236.18
Construction Management	15% of "A"	$ 1,444,236.18
Project Cost Subtotal "Line E"		$ 12,998,125.59
Estimating Contingency (includes market factor contingency	30% of "A"	$ 3,899,437.68
Total Project Cost		**$ 16,897,563.26**

APPENDIX B: GENERATOR SIZE CALCULATIONS

Cummins Power Generation

Recommended Generator Report - 2500DQKAN

Project - EBMUD IPS

Comments -

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 2
Duty	: Standby	**Site Altitude, ft(m)**	: 361(110)
Voltage	: 2400/4160, Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: No Preference		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 1450.5	**Max. Step kW**	: 1450.5 In Step 1	**Cumulative Step kW**	: 1450.5
Running kVA	: 1611.7	**Max. Step kVA**	: 1611.7 In Step 1	**Cumulative Step kVA**	: 1611.7
Running PF	: 0.9	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 1611.7	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 2901.08			**Pct Rated Capacity**	: 58.0

Total System Running Load and Step Load Requirements

Running kW	: 2901.0	**Max. Step kW**	: 2901.0	**Running NLL kVA**	: 3223.4
Running kVA	: 3223.4	**Max. Step kVA**	: 3223.4		

Generator Set Configuration

Alternator	: S9M1D-G4	**Engine**	: QSK60-G26
BCode	: B605	**Fuel**	: Diesel
Excitation	: PMG	**Displacement, cu in. (Litre)**	: 3672.0(60.2)
Voltage Range	: MV 4160	**Cylinders**	: 16
Number of Leads	: 6	**Altitude Knee, ft(m)**	: 984(300)
Reconnectable	: Yes	**Altitude Slope, % per 1000ft(304.8m)**	: 3
Full Single Phase Output	: No	**Temperature Knee, °F(°C)**	: 104(40)
Increased Motor Starting	: No	**Temperature Slope, % per 18°F(10.0°C)**	: 15
Extended Stack	: No	**Emissions**	: Tier 2
		Cooling Package	: High Ambient

Set Performance / Load Requirements

Set Performance		Load Requirements	
Running At	: 58.0% Rated Capacity		
Max. Step Voltage Dip, %	: 21	**Max. Allowed Step Voltage Dip**	: 35 In Step 1
Max. Step Frequency Dip, %	: 7	**Max. Allowed Step Frequency Dip**	: 10 In Step 1
Peak Voltage Dip, %	:	**Peak Voltage Dip Limit %**	: 35.0
Peak Frequency Dip, %	:	**Peak Frequency Dip Limit %**	: 10
Site Rated Standby kW/kVA	: 2500 / 3125	**Running kW**	: 1450.5
		Running kVA	: 1611.7
Site Rated Max. SkW	: 2639	**Effective Step kW**	: 1416.3
Max. SkVA	: 14835	**Effective Step kVA**	: 1611.7
Temp Rise at Full Load, °C	: 80	**Percent Non-Linear Load**	: 100.0
Voltage Distortion	: 9.3	**Voltage Distortion Limit**	: 10
Site Rated Max Step kW Limit	:	**Max Step kW**	:

*Note: Higher temperature rise at full rated load.
*Note: All generator set power derates are based on open generator sets.

Woodard & Curran

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WASTEWATER ELECTRICAL RESILIENCY MASTER PLAN

Task 4 – Technical Memo 3

Road Map

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East Bay Municipal Utility District

January 2025

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LIST OF ACRONYMS

AB	Assembly Bill
BAAQMD	Bay Area Air Quality Management District
BACT	Best Available Control Technology
BESS	Battery Energy Storage Systems
CARB	California Air resources Board
CEQA	California Environmental Quality Act
DTT	Direct Trip Transfer
EBMUD	East Bay Municipal Utility District
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
HRA	Health Risk Assessment
Ibank	California Infrastructure and Economic Development Bank
IMP	Integrated Master Plan
IPS	Influent Pump Station
IRA	Inflation Reduction Act
kV	Kilovolt
MCC	Motor Control Center
MV	Medium Voltage
MW	Megawatt
MWWTP	Main Wastewater Treatment Plant
PF	Power Factor
PG&E	Pacific Gas & Electric
PGS	Power Generation System
SEL	Schweitzer Engineering Laboratories
SOP	Standard Operating Procedure
TM	Technical Memoranda
UPS	Universal Power System
WERMP	Wastewater Electrical Resiliency Master Plan

EXECUTIVE SUMMARY

The East Bay Municipal Utility District (EBMUD) would like to improve electrical resiliency at the Main Wastewater Treatment Plant (MWWTP). EBMUD has contracted Woodard & Curran, Inc. (W&C) to identify failure vulnerabilities and consequences, develop and evaluate alternatives to enhance resilience, and ultimately provide a means in the form of a Road Map to greater electrical resiliency. The Road Map is described as a method used for planning purposes that outlines the projects to increase resiliency aligned with other ongoing projects and master plans and then provides offramps where decision points occur in the 10-year time frame. The goal of the study is to identify ways for EBMUD to improve resiliency, reduce potential for failure, facilitate the ability for potential expansion, and minimize upgrade costs. The first two tasks of the study (1) to identify failure vulnerabilities and consequences, and (2) to evaluate and rank Road Map Projects to address the identified failure vulnerabilities have been completed. Those findings are summarized in Technical Memoranda (TMs) 1 (**Appendix A)** and 2 (**Appendix B**).

This TM builds on the system understanding gained in the analyses completed in the previous two memoranda. The aim of this report is to simplify the consideration of multiple interlinked Road Map projects and understand their global impact on MWWTP electrical resilience so that EBMUD may implement projects in the most efficient and effective way. To accomplish that, this TM organizes recommended projects from TM2 into alternative portfolios of projects and overlays them on a ten-year planning timeline. Each portfolio is a set of complementary Road Map Projects that would increase the MWWTP electrical resiliency over a ten-year timeline, with decision points along the way to allow the timing and scale of projects to be adjusted, or even to transition to an alternative if future conditions warrant it. This report will also identify external drivers that are likely to impact the feasibility of the various projects and thus portfolios; those drivers include the available capacity of the electrical utility grid, negotiations with third parties such as the Port of Oakland, and permitting and operational considerations of the alternatives.

Purpose and Scope

This TM presents the approximate schedule to implement the Road Map Projects that were identified in TM2. Projects within a portfolio are grouped to complement each other and support the improvement of EBMUD MWWTP electrical resiliency. The projects are termed "Road Map Projects" to reflect the planning approach, which is one of phased, flexible implementation of potentially multiple projects over time with overlap to increase efficiency in implementation.

The TM is organized into six sections. Following an introduction in Section 1, Section 2 describes the consequence of failure analysis from TM1. Section 3 provides information on the projects that lead to the decision making behind Road Map development. Section 4 describes the Road Map in detail. Section 5 provides information on potential funding sources. Section 6 provides more detail on the conclusions.

Findings and Conclusions

TM2 identified seven potential projects, each of which could address one or more needs identified in TM1. Those potential projects are included in **Table 1-1** below and their associated costs:

TABLE 1-1: POTENTIAL ROAD MAP PROJECTS COSTS

Project	Description	Estimated Cost
1	New 12 kV feed from Port of Oakland	$9,800,000
2	New 12 kV feed from PG&E	$12,300,000
3	New 115 kV feed from PG&E	$99,000,000
4	Onsite generation to meet full-plant peak loads	$56,000,000
5	Onsite generation to meet critical peak loads	$23,000,000
6	Load shedding improvements	$1,500,000
7	Best-practices	$17,000,000

No single project is sufficient to provide the MWWTP with full resilience and reliability. Rather, projects must be integrated into portfolios of projects that combined can increase the resiliency and reliability of the electrical system at the MWWTP. W&C, in consultation with the District, developed four alternative project portfolios as summarized in **Table 1-2**. That table lists project portfolios in order from most preferred to least preferred, so Project Portfolio 1 is the recommended portfolio if it proves feasible.

The projects comprising a portfolio in many cases can be phased over time. This affords EBMUD the flexibility to right-size projects or otherwise adjust a portfolio based on external drivers that may change over time. Refer to Section 2.1 for the Summary of Recommendations.

TABLE 1-2: PROJECT PORTFOLIO ALTERNATIVES

Project Portfolio No.	Project Alternative No.s	Trigger
1	1 and 2 (two new 12 kV feeds) 6 (Load shed improvements) 7 (best practices)	Projects 1 and 2 (new 12kV services from the Port and PG&E respectively) are both feasible.
2	1 or 2 (one new 12 kV feed) 5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Only one of the two new 12kV services is feasible.
3	4/5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Neither 12kV line power project is feasible.
4	3 (new 115 kV feed) 5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Neither of the 12kV services is feasible nor is onsite generation for full peak loads practical, but a new 115 kV service (Project 3) *is* feasible.

A key early step is the initiation of the Preliminary Engineering Studies (), also known as System Impact Studies, to resolve basic feasibility questions for Projects 1, 2, and 3 (the line-power projects):

- Does Line L or C have the option for increased capacity?
- Can Port of Oakland provide and install a new dedicated full capacity 12kV circuit?
- Can PG&E provide and install a new dedicated full capacity 12kV circuit?
- Can PG&E provide and install a transmission line 115kV circuit to the MWWTP?

The outcome of the Preliminary Engineering Studies is crucial to determine which trigger criteria in **Table 1-2** are met, and thus which portfolios of projects are viable for further development.

Given that the Preliminary Engineering Studies are likely to take a year or more, studies to further vet and refine backup power options could be implemented in parallel with the Preliminary Engineering Studies. Robust onsite power generation is part of every long-term portfolio except Portfolio 1. Should Portfolio 1 (which does not include more onsite power generation) prove viable, enhanced onsite power generation could still provide interim benefits during the many years of implementing Portfolio 1. Studies to refine backup power options would incorporate the following assumptions:

- Power Generation System (PGS-1) has been modified to be more reliable; our understanding is that this is planned.
- The load shed system will be enabled.
- Comingling of wiring has been addressed, and correction will be made.

With these assumptions, a new diesel engine generator could be sized to initially meet only critical loads (i.e., Project 5), with space-planning to meet full plant loads if needed (Project 4) in the future – for example, if no line-power improvements prove feasible.

In summary, the recommended next step is to commission Preliminary Engineering Studies for the three potential line power projects, and simultaneously refine the scope and costs for onsite generation. When those steps are completed, a specific portfolio can be selected from **Table 1-2**.

1. INTRODUCTION

This Section defines the purpose of the technical memorandum and describes its content and organization.

1.1 Purpose and Background

This Road map was prepared as a part of the Wastewater Electrical Resiliency Master Plan (WERMP) at East Bay Municipal Utility District's (EBMUD or the District) Main Wastewater Treatment Plant (MWWTP). Alternatives developed as part of the work are organized into a road map over a 10-year period and are ranked in order of importance. The road map projects are aligned with the Integrated Master Plan Projects to the extent possible and/or where there is a fiscal advantage in leveraging civil and infrastructure work for electrical systems.

A presentation was made to the District on June 6, 2024, to discuss the ranking of projects and provide an overview of the road map projects. The District provided comments, and this memo is reflective of that input.

This TM will:

- Summarize Road Map project scope descriptions (for detailed cost for each alternative, see TM2)
- Provide site layouts
- Describe groupings of projects called "portfolios"
- Describe necessary infrastructure modifications
- Prioritize projects
- Provide a 10-year road map of the projects
- Identify implementation triggers
- Summarize potential funding opportunities

1.2 Memorandum Organization

The memo is organized into the following sections, which reflect our approach to the project scope:

- Section 1 – Introduction
- Section 2– Consequence of Failure Analysis
- Section 3– Project Identification and Decision Criteria
- Section 4- Road Map Strategy
- Section 5– Funding Sources
- Section 6- Conclusions

2. CONSEQUENCE OF FAILURE ANALYSIS

The first step in developing the road map was to assess the resiliency of power systems at the MWWTP and provide recommendations as appropriate to improve resilience. This work is detailed in TM1.

The objective of TM1 was to identify vulnerabilities within the power distribution system and operations at the MWWTP and then determine the consequence of failure and provide recommendations. To support the analysis W&C visited the site, met with District staff, and reviewed the following data provided by the District:

- MWWTP Load Flow Study (May 2020)
- Map of Substations (Nov. 2016)
- Medium Voltage Single Line Diagram (May 2016)
- MWWTP Underground Electrical Facility Drawings (Dec. 2012)
- MWWTP Power Distribution System Replacement (SD 227, 1998)
- Standardized Maintenance Practice For Electrical Service Continuity Plan Standard Operating Procedure (SOP) for Main Service Power Restoration (Feb. 2023)
- PI Data Collected, 15 Min Intervals (2004 – 2022)

As part of this task, W&C visited the site on February 21, 2023, to observe the location and condition of existing equipment. TM1 is based on site observations, meetings with District Operations staff, review of documentation, historical data, etc. The findings and conclusions are limited to areas which we were able to observe safely without having to open electrical panels with live parts or entering electrical vaults that require authorization from the plant's health and safety department. Investigation of power circuits Line L and C entry into the MWWTP was restricted to observation of overhead lines, Google Earth, and as-built construction drawings. Routing offsite is being confirmed by PG&E and has not been verified as of the date of this TM. The data collected were then analyzed for potential failure and its consequences. Workshops and virtual meetings were held to document methods of operations and protocols when power to the plant is lost and is restored. The following components were considered most important to the power system during analysis:

- Pacific Gas & Electric (circuit lines L & C)
- Power Generation System (PGS-1 and PGS-2)
- System Topology
- Power Distribution Equipment and Cabling
- Power System Controls
- System capacity
- Restoring Power

2.1 Summary of Recommendations

TM1 includes recommendations which are general in nature and were further examined by W&C in the Alternative Analysis TM2. The recommendations are briefly described below:

1. **Recommendation R-1**: Replace PG&E line circuits L and C with circuits that each have a minimum capacity of 12MW. The reliability and available capacity of the existing PG&E circuits have been identified as major vulnerabilities for EBMUD. While additional onsite generation could also in theory address the need for higher-reliability power, new power feeds appear to be more responsive to EBMUD's needs given that the existing feeds are not only unreliable but undersized. Replacing the existing power feeders in their entirety would improve reliability given that the existing system appears to be compromised due to the location and routing of the overhead lines.

2. **Recommendation R-2**: Enable the SEL PowerMax loadshed system to maintain operation of PGS's generators during utility outages, thus reducing the risk of cascading failures, and avoiding the need for immediate manual black start of the engines and subsequently the turbine. It is recognized that enabling PowerMax loadshed fully, absent other measures, would create a new risk due to the current issue of the commingling of power sources as discussed in Finding F-5. Therefore, implementing this recommendation should be done in concert with other recommendations described below which are aimed at mitigating the problem of commingled power feeds. The loadshed system could be partially implemented by enabling loads without commingling issues so that a marginal cascade failure risk reduction is obtained. However, it depends on the amount of plant load at any given point in time as to whether you can partially implement load shedding successfully.

3. **Recommendation R-3**: Correct or consolidate low voltage wiring systems in the IPS area that are commingled between the different power buses (A versus B). For the near term, consider local Uninterruptible Power Supplies (UPSs) to provide short-term mitigation of commingled power systems, i.e., situations where critical control signals for a unit process are fed on a different bus as power for the unit process, thus undermining automatic load shedding. In the long term, consolidated power feeds for each unit process so that specific unit processes can be prioritized by the PowerMax system without fear that power for a critical system is intertwined with the power for a less-critical system that is the target of load shedding.

4. **Recommendation R-4:** Revise load shed priority list based on Consequence of Failure rankings, Time to Impact and revised wiring configurations as recommended in R-3. It was found in this analysis that some process systems should be moved up in the priority list because of their association with critical equipment that if not operating creates a chain of events that ultimately shuts down an entire process. Ancillary systems that support critical equipment should be moved up in their rankings in the load shed priority list. Other process systems will be looked at more closely and considered for higher priority listing during the next phase of work.

5. **Recommendation R-5:** Improve restoration of power processes by modifying operational procedures and develop a PG&E approved communication protocol when a Direct Trip Transfer (DTT) occurs. Provide training and routinely perform live practice that is focused on restoring power to the plant safely and more efficiently. The District has recently discussed with PG&E the development of a protocol that both entities could agree upon to minimize the time to restore power to the plant. This includes identifying a point of contact at PG&E would be, to avoid the

delays of reliance on an automated calling center. Additionally, District staff should align their Standard Operating Procedure (SOP) with PG&E to improve communications during a DTT and determine appropriate qualified District staff for "On Call" duty during off hours and weekends.

6. **Recommendation R-6:** Modify infrastructure to improve redundancy including the addition of equipment (substations, tie breakers, cabling, etc.) and replacement of aging equipment to increase reliability. When practical, relocate equipment from below grade to above grade to increase safety and reduce downtime during replacement of damaged equipment. This type of work can be accomplished in the near future and does not require extensive engineering or planning. TM2 covers the equipment replacement alternatives in more detail. For aging critical equipment being replaced, the District should consider adding the new equipment to a Routine Preventative Maintenance program taking advantage of baseline test data. Routine Preventative Maintenance programs help reduce risk of failure, prolong useful life and provide early detection of equipment failure.

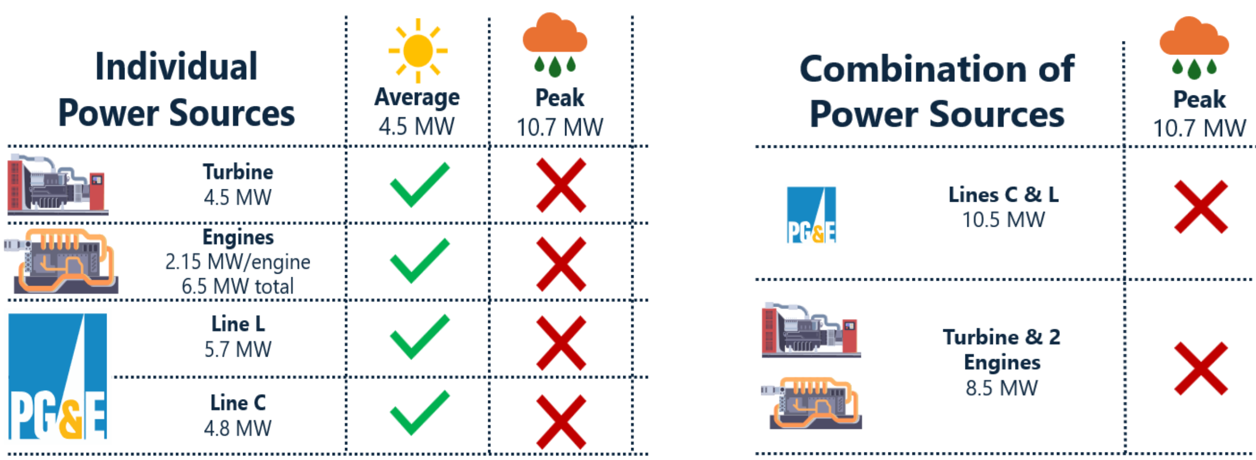
3. PROJECT IDENTIFICATION AND DECISION CRITERIA

The vision of this project is to create a road map to enhance electrical resiliency at the MWWTP, aligned with other planning efforts and phased for increased economy and flexibility. Therefore, the approach included the following steps:

1. Consequences of failure analysis: Analyzed existing conditions and major risk based on system topology, loads, and capabilities and identified potential strategies to address risk.
2. Alternatives analysis: Developed specific projects targeting risks, analyzed projects against performance criteria, and developed cost estimates.
3. Developed road map recommendations: Created portfolios of projects aligned with current and future needs and addressing risk to be implemented over time and to be adaptable to changing circumstance.

The existing power system supply is provided from four energy sources. At least two of the four sources must be online to meet peak wet weather demand (10.7 MW per TM1). All the sources have suffered outages in the past, including the cogeneration engines (PGS-1) and turbine (PGS-2) as well as both PG&E services. Refer to **Figure 3-1** below for individual and combination power source values.

FIGURE 3-1: POWER SOURCES



Additional concerns include:

- Complexity of the power system controls is high due to the multiple energy sources that must be combined to meet demand.
- There are commingled power circuits within Influent Pump Station (IPS) and other areas such that if one of the busses (Bus A or Bus B) fails and the tie breaker is open at Substation S1, the associated critical equipment will not be operational (such as a gate valve) so the entire process train becomes non-operational.
- As staff retire, institutional knowledge of the plant is being lost. Simplifying the power distribution system throughout the MWWTP will reduce the learning curve for new staff and increase the reliability of the system through ease of operation.
- Planning for future loads needs to be consistent with the Integrated Master Plan for the Main Wastewater Treatment Plant, May 2022.

Line Power Concerns

The lack of a full-sized electrical service has been identified as a major contributor to historical power outages at the facility. Most outages have occurred during a peak demand period that requires both Line L and Line C to be available when PGS-1 and PGS-2 are not in operation. When one utility feed is lost, only selected (critical) processes are allowed to operate until another source of power is available. While both PGS-1 (engines) and PGS-2 (turbine) can provide a second source of power, the Load Shed Control System must be enabled to provide a seamless transfer of power during a partial or full utility outage to prevent PGS-1 and PGS-2 from shutting down. However, load shedding is not fully effective where process treatment trains have commingled power to critical equipment that hinders the intended use of the load shed control system. This condition compromises the resiliency of the electrical system and requires correction to avoid shutdown of PGS-1 and PGS-2. Partial load shed enabling of un-commingled loads may help reduce the risk of cascading failures and keep PGS-1 and PGS-2 generators operational. However, it depends on the amount of plant load at any given point in time as to whether you can partially implement load shedding successfully.

The complexity of the MWWTP's electrical distribution system would be reduced by utilizing a single dedicated power source sized to meet peak wet weather equipment power loads. This would increase the reliability and capacity of power to the plant during peak demand periods instead of relying on two separate services, neither of which is sufficient to meet peak loads.

Any new service connection, whether at 115 kV or 12 kV, will require a PES, also known as a System Impact Study, to be completed by the power utility company. This is the first step when submitting an application for a new service, whether the new service is provided by PG&E or by the Port of Oakland. The service application submitted to the power utility can identify a preferred substation and routing method; the utility will either confirm the request or deny it and offer an alternative routing.

Specific outcomes of the studies include determination of whether Line L or Line C can increase the line ratings or ampere setpoint which are required to limit the import from the MWWTP and limit the export from the PGS systems. The MW values used in this TM (5.7MW Line L and 4.8MW Line C) are based on the setpoints provided by Pacific Gas & Electric (PG&E) in January of 2006 and assume 0.80 power factor (PF).

These ratings can change over time based on the available amperes in the circuit lines due to other customer demands or substation equipment. It should also be noted that when the PF is greater than 0.80PF, the capacity of the circuit increases. Higher power factors have been noted when the plant is operating at larger loads (~0.90PF). Further analysis of utilizing a power factor correction system could be considered once the results of the Preliminary Engineering Studies for Line L and Line C are available.

Standby Power Concerns

While the power projects described in Section 3.1 *et seq* of this TM would improve the electrical resiliency at the MWWTP, they do not fully address the need for on-site backup power generation in the event of loss of utility power per EPA design requirements.

The cost and permitting difficulty for new generators could be formidable, particularly if the standby power system is sized for full-plant peak loads. As noted by the District's air permitting coordinator, new diesel engine generators would appear to be permittable; however, the following would need to be considered:

1. The new generators would need to meet the EPA's Best Available Control Technology (BACT), which is currently Tier 4 (with plans for a Tier 5 in the future).
2. The District would need to purchase offsets for new emissions unless the District reduces emissions elsewhere.
3. The new source review process would include a health risk assessment (HRA); since the location of the MWWTP is located in an area that is part of the Community Air Protection Program per AB 617 this could pose permitting challenges.

The District should consider having the HRA done prior to purchasing a new generator in case it cannot pass or requires modifications. This can be accomplished by submitting the permit application early (before purchase) or hiring a Contractor (such as Yorke) to provide a permit review and HRA.

As part of the investigations associated with this project, W&C identified additional projects that would improve reliability by increasing the resiliency of existing systems at the MWWTP. Increasing resiliency as it relates to this TM means bolstering existing electrical systems and providing redundant equipment that could keep the plant operating when energy sources are compromised. Some examples include replacement of aging cables, moving below grade elbow connectors to above grade for easier and safer access, and the addition of secondary unit substations to maintain operations during maintenance work. Continue to routinely perform preventative maintenance on critical equipment.

Projects were identified to address the range of concerns outlined above. Each project is briefly described below; for details on each project, please see TM2.

3.1 Project 1: Port of Oakland 12 kV Connection

Project 1 includes a dedicated 12 kV circuit from the Port of Oakland's Davis Substation. This new circuit would provide more reliability than the existing PG&E connections because the circuit would not have other tenants connected to the same line, which could reduce capacity and potentially create interference on the distribution line. This line would also connect to EBMUD at the MWWTP through a less densely populated area with newer infrastructure (roads, street lighting, etc.) as compared to the existing utility lines routed through older roads that lack good maintenance access.

A proposed layout for Road Map Project 1 is shown in **Figure 3-2** below:

FIGURE 3-2: PROJECT 1 - PORT OF OAKLAND POWER CONNECTION

The Port of Oakland is currently in the process of designing replacements for its Davis substation (65% design July 2023) as well as substation SSR-14 (95% design July 2023). Neither of these substation designs include provisions for large customer (agency) connections such as those for the MWWTP. The Port of Oakland indicated that the provision of a new dedicated 12 kV service for the MWWTP would hinge on a favorable PES that would be conducted by PG&E. Should the PES reach a favorable outcome, design changes would need to be made to one of the pending substation projects. Therefore, representatives from Port of Oakland highly recommended that EBMUD's General Manager have discussions with the Port of Oakland Executive leadership to discuss a viable path forward for a new dedicated 12 kV service to the MWWTP. From a construction perspective and power system topology simplification perspective, replacing either Line L or Line C with the Port of Oakland connection makes sense based on the outcome of the Preliminary Engineering Studies.

Table 3-1 below describes Project 1's performance against criteria, as described in TM2.

TABLE 3-1: PROJECT 1 – EVALUATION AGAINST CRITERIA

Criterion	Performance/ Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 2
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

3.2 Project 2: PG&E 12 kV Connection

This project consists of a new PG&E 12kV service to replace one of the two existing circuits, Line L or C. The routing would depend upon the outcome of a PES, which would be initiated by PG&E if requested by the District. The PES itself would likely take one year. If the PES results were acceptable, it is anticipated that a new 12 kV dedicated service could be installed within 5-10 years afterward.

Given that the existing utility feeds are 12 kV, installation of a new 12 kV feed with higher capacity would have minimal impacts on the daily operations at the facility. Similar to the Port of Oakland alternative, due to the fact that the MWWTP would no longer be "split" and reliant on two separate feeds, this Project would simplify operations by reducing the complexity of the power distribution and control system. While a single dedicated full capacity 12 kV service would increase reliability relative to the status quo (two half-capacity feeds), per EPA guidelines a second reliable standby power source would still be recommended in order to provide peak capacity during a line power outage.

Table 3-2 below describes the criteria considered for Project 2, as described in TM2.

TABLE 3-2: PROJECT 2 – EVALUATION AGAINST CRITERIA

Criterion	Performance/ Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 1
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

3.3 Project 3: PG&E 115 kV Connection

This Project consists of a new 115 kV extension from the Port of Oakland Davis Substation on the PG&E side of the substation running overhead to MWWTP where a new 115kV/12kV substation and switchgear yard would reside (see **Figure 3-2**). The substation including transformers would be owned by EBMUD whereas PG&E would own and operate the transmission line and high voltage side of the switchyard including circuit protection and surge arresters.

While PG&E may further evaluate this option, our preliminary review indicates that the space required to step down high voltage power from 115 kV to 12KV and connect to the existing distribution system is prohibitive. The estimated area needed for the 115 kV/12kV substation is approximately 28,500 sq ft. No suitable space has been identified for a substation with this large footprint. The layout shown in **Figure 3-3** below is hypothetical and intended to show the area necessary for a switchyard and substation. Further planning and investigation will be required to locate the switchyard and substation if EBMUD decides to move forward with a 115kV connection from PG&E.

While the MWWTP already has both low and medium voltage systems, the introduction of a 115 kV transformer would trigger the need for additional training for District Staff to maintain that equipment, or use of contractors.

FIGURE 3-3: 115KV SWITCHYARD AND 12KV SUBSTATION

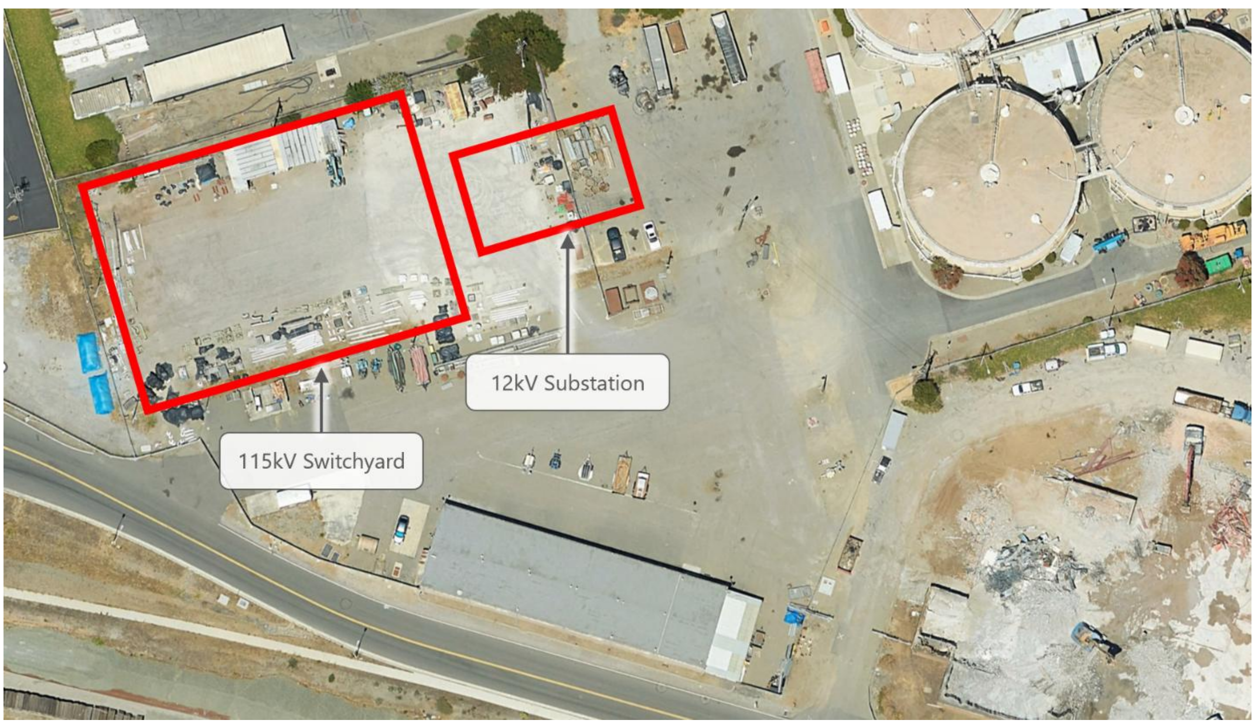


Table 3-3 below describes the criteria considered for Project 3, as described in TM2.

TABLE 3-3: PROJECT 3 – EVALUATION AGAINST CRITERIA

Criterion	Performance/ Benefit	Notes
Operability	High	
Maintainability	Low	Requires high voltage class training and certification.
Cost Effectiveness	Low	A new transmission extension and substation would be costly.
Reliability and Effectiveness	High	
Ease of Implementation	Low	Appears to be infeasible due to space limits for 115 kV switchgear. Transmission line easement is larger than that for 12 kV transmission lines.
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

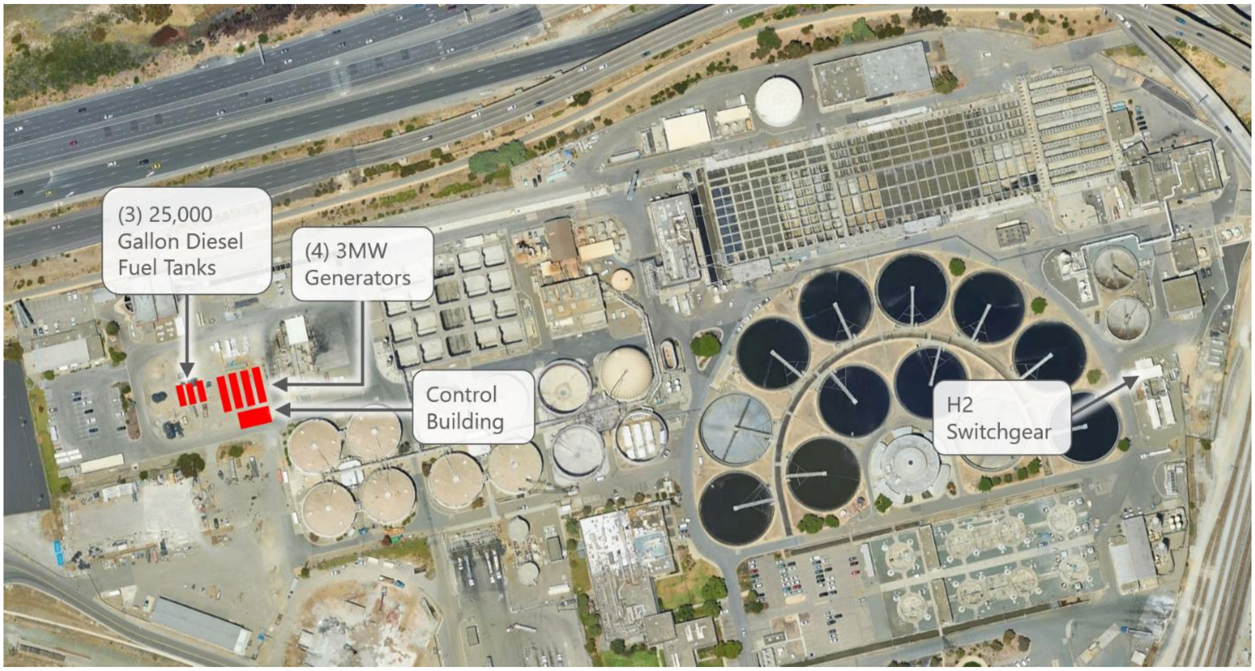
3.4 Project 4: 12 MW Generators

Road Map Project 4 involves the installation of a system of 12kV generators (4 – 3 MW units), controls, and on-site diesel fuel storage with a power generation capacity of 12 MW (as determined in TM1). This capacity is sufficient to meet full-plant peak loads (max value documented is 10.7 MW) with spare capacity for future loads as well. On-site diesel fuel storage would be sized to provide 72 hours supply of fuel at maximum load. Normal operations could continue for as long as fuel could be supplied during an outage. An aerial graphic showing the approximate area for a 12MW system of this type is included as **Figure 3-4** below.

Challenges associated with this project include high cost, space requirements, and permitting requirements. This project would also add to the complexity of the control system by adding another power generation source to the electrical distribution system in addition to the other existing power generation systems (PGS-1, PGS-2).

Ideally, the new generators and paralleling switchgear would be located in close proximity to the existing H2 switchgear (where the standby power connection would occur) to avoid long cable runs. However, space near the H2 switchgear is at a premium, with most of the area occupied by elements of the medium voltage power distribution system. **Figure 3-4** is intended to depict a hypothetical location to show the area required for the generators and for purposes of discussion in this TM.

FIGURE 3-4: PROJECT 4 - 12 MW GENERATOR



As previously mentioned in this TM and noted by District staff, air permitting with the Bay Area Air Quality Management District (BAAQMD) would be a significant issue related to this project since even absent a power outage, the generators would need to be tested monthly at full capacity. The MWWTP is in a designated priority community per AB 617, the Community Air Protection Program. Therefore, it is expected that the BAAQMD will enforce strict emissions regulations requiring after-treatment technologies that meet EPA's current Tier 4 standards, or a future Tier 5 as early as 2030. The new generators would be installed with Best Available Control Technology (BACT), which would involve high costs. An HRA would likely be required as mentioned earlier.

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generators, controls, and fuel storage tanks could be constructed and tested offline from the remainder of the facility. There are spaces available at H2A and H2B to allow for two connections to the standby power system. The existing electrical interlock at H2 would most likely require replacement with a larger and more sophisticated control system. The SEL PowerMax control system currently used for load shed controls could be investigated as an option to control the breakers at H2 for standby power when utility power is not available. The SEL PowerMax would allow ease of integration for the new standby generators and enable the ability to potentially parallel PGS-1 and PGS-2 with the standby generators. This feature would reduce demand on the generators during an outage and thus increase the refueling interval beyond 72 hours.

The many components comprising this project include not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, underground infrastructure, modification to existing infrastructure, and spill containment would impose significant new maintenance needs. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored fuel which has a shelf-life of only 6-12 months. While alternative fuels could be considered in lieu of diesel fuel, such as propane, that have virtually unlimited shelf life, however, have drawbacks such as lower energy density.

The benefits of this project in terms of power reliability would need to be weighed against the substantial capital cost and O&M burden created by the project.

Table 3-4 below describes the evaluation criteria considered for Project 4, as described in TM2.

TABLE 3-4: PROJECT 4 – EVALUATION AGAINST CRITERIA

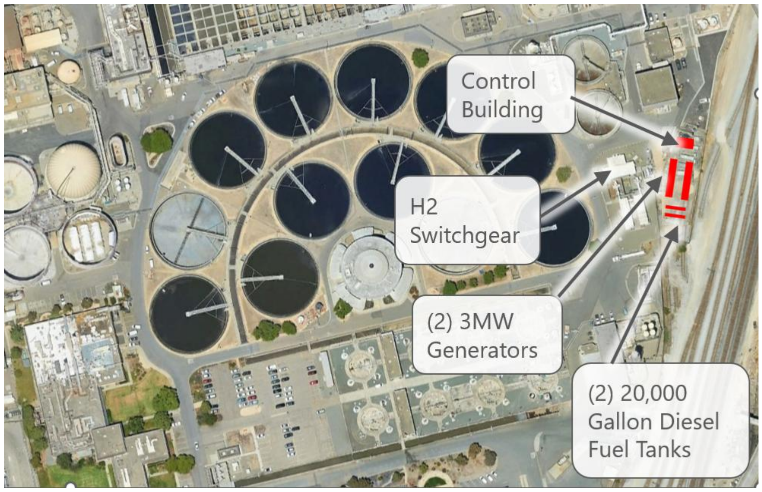
Criterion	Performance/ Benefit	Notes
Operability	Low	Adding another power generation source will add more complexity to the controls.
Maintainability	Low	Complex machinery to maintain, adding to operator burden.
Cost Effectiveness	Low	Generators, switchgear, ancillary systems, and infrastructure required will be costly.
Reliability and Effectiveness	High	Diesel engine generators used as a standby power source are considered quite reliable.
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. BAAQMD permitting regulations are fluid and represent potential delays to project implementation. For example, the California Air Resources Board (CARB) is considering Tier 5 be implemented in 2030 after board approval in mid-2025.
Reduced GHG Emissions	Neutral	

3.5 Project 5: 6 MW Generators

A smaller generator project to improve resiliency and address the immediate concerns at the IPS would include the installation of two 12kV, 3 MW generators near to and serving switchgear H2. W&C developed this smaller generator project as a way to avoid the large cost and space requirements of Road Map Project 4, while providing enough power to support the most critical loads, including IPS.

The generator system was sized based on powering the five existing influent pumps (700Hp) at IPS in order to meet peak wet weather flows, as determined by the District. The size of this generator system could change based on the preliminary design of the IPS currently in progress. An illustration of a potential layout for this option is included as **Figure 3-5** below, including onsite fuel storage and a control building.

FIGURE 3-5: PROJECT 5 - 6 MW GENERATORS



The rationale for prioritizing the IPS is not only that the IPS performs a critical function (which it does), but as presented in TM1, the "time to impact" on plant operations should IPS incur a power loss is only 1 hour. While the precise time-to-impact depends on plant conditions at the moment of a power outage, a black start of PGS-1 can take up to an hour, leaving no margin of safety.

This project includes the installation of two 12kV, 3 MW generators adjacent and connected to the H2 switchgear along with on-site fuel storage and a control building. Modifications would be necessary to the H2 switchgear including improvements or replacement of the existing electrical interlocks with a more sophisticated control system. This project would restore power to the IPS within one minute upon a loss of utility power.

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generator, controls, and fuel storage tank could be constructed and tested offline from the remainder of the facility.

The many components comprising this project include not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, protection barrier, and spill containment would impose significant new maintenance needs, although to a lesser degree than the Project 4 12 MW Generator system. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored diesel which has a shelf-life of only 6-12 months.

This alternative could be built as an initial phase of Road Map Project 4. In that case, the project layout, and key components, would be sized for buildout to the capacities needed for Project 4, but only half of the full 12 MW capacity, and only half of the ultimate fuel storage, would be built initially. A second phase could follow at any time, e.g., five years after the initial phase, to add more generators and tanks, and adjust controls as needed. A benefit of phasing, beyond reducing immediate cash flow needs, is that the second phase could be designed with more precise knowledge of future loads. A downside of phasing is that the cost of the initial phase would be more than a "standalone" Project 5 because of the need to oversize some equipment for future loads.

Table 3-5 below summarizes the project's evaluation against criteria, as further described in TM2.

TABLE 3-5: PROJECT 5 – EVALUATION AGAINST CRITERIA

Criteria	Performance/ Benefit	Notes
Operability	High	
Maintainability	Low	
Cost Effectiveness	High	
Reliability and Effectiveness	Neutral	Only provides power for critical unit processes, e.g., IPS.
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. May be difficult to permit with BAAQMD as mentioned for Project 4. Rating of Low is based on ultimate build-out to 12 MW.
Flexibility for Future Process Changes or Increased Demand	High	Building as an initial phase with an option to add more generators provides flexibility to meet future needs.
Reduced GHG Emissions	Neutral	

3.6 Project 6: Load Shed Modifications

This project consists of modifications to EBMUD's load shed system to increase the reliability of PGS-1 & 2.

Under normal operations, electrical power demand is met by a blend of utility power and onsite power, which is generated from biogas utilizing co-generation (co-gen) engines and turbines. During a utility power outage, without the use of load shedding to reduce the load demand to match the power being generated, the PGS systems will shut down.

As discussed in TM1, EBMUD has invested in a SEL PowerMax load shedding system to monitor power and prioritize load distribution in the event of a utility outage. If modified under this Project, the load shed system would increase the reliability of PGS-1 & 2 by reducing the likelihood of this equipment tripping due to over- or under-frequency. The load shedding system would also maintain power to processes identified by EBMUD as being the most critical.

Since EBMUD has already invested in the load shedding system, this project would simply activate the system already in place. TM1 identified some adjustments that could be made to the software to re-prioritize the various treatment processes based on our Time to Impact analysis; however, these are minor programming changes that do not require significant capital investment.

EBMUD Operations staff has identified potential improvements to the load shedding program including the consideration of controlling breakers at the 480 V level (MCC main breakers). The goal would be to prioritize specific loads that might otherwise be subject to load shedding at the 4.16 kV level. Including the 480 V system in the load shedding logic has the potential to greatly increase system complexity and increase cost greatly. An alternative approach would be examining high-priority 480 V loads on a case-by-case basis to identify options such as refeeding the load to a higher-priority 4.16 kV circuit or providing a dedicated UPS for small 480V loads.

Table 3-6 below describes the project's evaluation against criteria, as described in TM2.

TABLE 3-6: PROJECT 6 – EVALUATION AGAINST CRITERIA

Criteria	Performance/ Benefit	Notes
Operability	High	
Maintainability	Neutral	
Cost Effectiveness	High	Implement existing systems.
Reliability and Effectiveness	High	
Ease of Implementation	High	Modifications to a control system that is already in place.
Flexibility for Future Process Changes or Increased Demand	High	Major changes easily adapted to.
Reduced GHG Emissions	Neutral	

3.7 Project 7: Best Practices

The seventh road map project identified creates a system of best practices for EBMUD to implement as part of Asset Management of their electrical infrastructure such as replacing parts, documenting system conditions, increasing redundancy, and correcting wiring issues. W&C's scope of work was limited to desktop study and visual observations during a site visit and did not include evaluation of the infrastructure in detail. However, in discussions with EBMUD staff it is apparent that the existing infrastructure is aging and will require upgrades in the future simply to maintain existing capabilities.

The costs presented in this report assume that EBMUD would undertake all the identified improvements as part of a single capital project. However, EBMUD may wish to incorporate portions of these potential upgrades into smaller projects targeting specific areas of the MWWTP rather than perform a facility-wide project due to the scope and scale of these items.

Table 3-7 below describes the project's evaluation against criteria, as described in TM2.

TABLE 3-7: PROJECT 7 – EVALUATION AGAINST CRITERIA

Criteria	Performance/ Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	High	Compared to the generator, each of these sub-projects will provide resiliency at a fraction of the cost of other proposed projects.
Reliability and Effectiveness	High	Will improve redundancy and resiliency.
Ease of Implementation	High	This project conglomerates several sub-projects. Some of these, such as addressing the co-mingling, adding resilient substations, and replacing MV cables are straightforward to implement, though they may be labor intensive. Projects could readily be added to ongoing Master Planning efforts.
Flexibility for Future Process Changes or Increased Demand	Neutral	Fixing existing issues does not increase capacity.
Reduced GHG Emissions	Neutral	Fixing comingling issues could allow the re-prioritized SEL PowerMax load shed to operate and existing PGSs to operate without relying on exterior power sources.

For detailed information on these projects and project cost estimates, see TM2.

3.8 Project Refinement

Developing the road map projects included a number of conversations and workshops with EBMUD staff, regulatory agencies, the Port of Oakland, and PG&E. Each of these conversations, as well as energy resilience research provided structure around the development of the road map. This section describes some of the refinements that have resulted from those conversations.

3.8.1 Refinement of Projects 4 and 5

The District has provided additional input since the completion of TM2 regarding the addition of diesel engine generators (either 6MW or the full 12MW) as a secondary source of reliable standby power. In order for the District to respond to the immediate need of providing a reliable standby power source for critical equipment such as the IPS, the District has requested consideration of the following approach for incorporation of standby generators:

1. Consider PGS-1 engines as standby power source since these engines can also operate using diesel fuel if biogas is not an option. There is also existing diesel fuel storage onsite that can be refilled as required. The engine generators can be considered a reliable backup power source because they can be black started, they have a fast restart time after shutdown, and they can run on biogas,

natural gas, or diesel. The fuel diversity is a plus for the engines, however the natural gas line is capped off. The key drawback to relying on the engines is that the system is aged, and staff - knowledge is not consistent (but this can be fixed with formal and on-the-job training). It was also noted by Operations that they can only run up to approximately 1.5MW per engine on diesel, and to go higher it must be on methane (because the engines are tuned differently for methane).

2. Consider sizing new diesel generators for the remaining plant load after accounting for up to two PGS-1 engines being online to help carry the full load (either 6 MW for critical peak loads or 12 MW for full-plant peak loads).

3. Continue to refine and program the PGS-1 controls, instruments, and scenario testing to make PGS-1 work more reliably in a blackout situation.

Currently, the District is performing upgrades and improvements to PGS-1 to increase resiliency; the scope includes new voltage regulators, devices for auto-tuning capabilities, and more equipment status visibility via additional network connectivity's between engines, gas compressors, voltage regulators, and DCS. This refinement alternative provides an opportunity for the District to "double down" on what they currently have for generating reliable power.

The inclusion of PGS-1 in the assumed firm standby power would reduce generator projects 4 and 5 by about 3 MW, i.e., to 9 MW and 3 MW, respectively. The feasibility of this approach should be investigated in more detail and only implemented after considering the increased complexity of the power control system (PowerMax) that would result from splitting emergency power among multiple sources.

3.9 Decision Points

The following summarizes the key decision points based on the research described above in the context of developing the Road Map. These points were considered when looking at the system comprehensively to address the District's needs.

1. IPS is the most critical load and a top priority for enhanced standby power.

2. Full redundancy would be optimal, involving two power sources, each of which can meet peak loads on its own.

3. Some projects provide increased resiliency in the short term (less than 3 years), e.g., onsite generators. 6 MW would address the dominant risk at a reasonable cost and could be scaled out in the future.

4. Adding a more reliable utility power feed will likely take longer than 3 years, and the precise path is uncertain. Regardless of that uncertainty, a vital first step is submission of service applications to PG&E and Port of Oakland.

4. ROAD MAP STRATEGY

The decision points above lead to a strategy around project development. As no single project can provide full energy redundancy, and some projects are expected to require several years to implement, the road map involves a series of implementation steps occurring simultaneously with key decision points. By beginning work on different aspects of the projects simultaneously, the District can make progress on multiple projects which will lead to an electrical infrastructure system able to meet both average and peak demand, with reliable backup power available in the event of a utility line outage. Coupling short-term, targeted projects with larger scope upgrades will provide the most immediate path to improved reliability. These short-term projects allow EBMUD to be nimble in their approach to attending to immediate power needs meanwhile navigating through planning, permitting, and engineering studies that may take longer than expected.

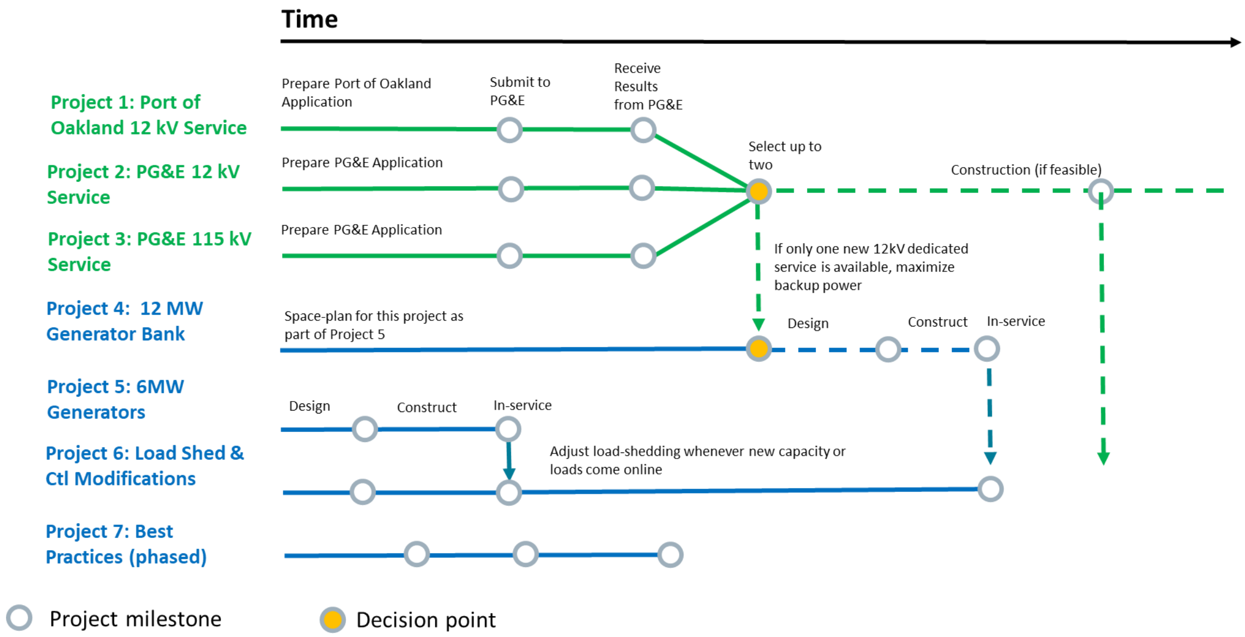
Several short-term projects can provide outsize impacts to electrical resiliency at the EBMUD MWWTP. Projects that facilitate PGS system operability during utility outage, without compromising performance of critical treatment operations, would likely provide high value. Implementation of these projects would not provide full redundancy but would increase plant resiliency by strengthening the associated power system infrastructure. Project 6, Load shedding improvements, in concert with upgrades planned for PGS-1, will allow the most critical process (IPS) to run during a blackout. These projects would complement more comprehensive long-term electrical upgrades.

Additionally, the best practices (Project 7) including operator and staff training would provide high value to support existing and future electrical system upgrades including an enhanced understanding of load shed controls and their critical importance to the resiliency of the plant.

4.1 Preliminary Road Map

A visual representation of the project road map is included in **Figure 4-1** below and was presented to the District in a workshop in June 2024.

FIGURE 4-1: WORKSHOP 3 ROAD MAP



Projects 1, 2, and 3 involve new utility services with significant uncertainty as to the feasibility, cost, and schedule of each. Therefore, W&C recommends that the early stages of all three of these projects be started with preparation of service applications to the Port of Oakland (Project 1) or PG&E (Projects 2 and 3). That will allow the necessary Preliminary Engineering Studies to be performed by PG&E, a process that is expected to take about one year. Based on the results of Preliminary Engineering Studies, the District may select the most promising option(s) for further development.

At the same time, Project 4 can begin with analysis of potential space, which will be important to Project 5.

Projects 5 and 6 can kick off design simultaneously, allowing them to move into construction, and into service as Projects 1, 2, and 3 are still in the planning stages.

Project 7 can begin immediately as a capital improvement project which can be phased as best fits the District's needs.

4.2 Refinements

Since the development of TM2, the District has decided to take a different approach to the use of diesel engine generators, as outlined in Section 3.4 For Projects 4 and 5, EBMUD would use generators sized to fill the remainder of power required in addition to the upgraded PGS-1 to provide a total "on-site" power generation capacity of either 6MW or 12MW for these scenarios.

This approach would reduce reliance on new diesel generators, thereby saving capital cost and space. A drawback to this approach is the reliance of multiple power sources throughout the MWWTP, which means that EBMUD will continue to have a complex power distribution system that is more difficult to maintain and train staff. There is also some risk that PGS-1 may not be as reliable as a new, modern diesel generator, given PGS-1's history of outages.

Projects 4 and 5 could be refined to include Battery Energy Storage Systems (BESS) technology. A BESS would complement on-site generators by allowing the MWWTP to sustain power transients and short duration outages of up to two minutes. A BESS system would increase the physical footprint of the on-site power generation system. The BESS could be used with the generators and combination of PGS-1, however, the SEL PowerMax will need to include the Microgrid features to facilitate the starting/stopping/paralleling with the various energy sources. BESS systems are emerging technology which may see significant improvements in capital cost and/or physical size over the 10-year planning horizon of the project. We recommend that any future projects associated with electrical resiliency include evaluation of a BESS as a potential add-on to the project. While BESS is relatively costly today, technology could reduce the size and space of battery systems in the future.

4.3 Power Management System

The combination of many projects in the portfolios, or even subsets of portfolios, will allow for redundancy and reliability for the District but will require modifications to the existing power management system (PowerMax). The PowerMax control system can be enabled to accept and control multiple energy sources similar to a microgrid and when configured properly will give the District a scalable means to integrate energy resources as they come online throughout the road map process.

A key component in this effort will be control systems that allow for load shedding, circuit protection, and The District's use of SEL PowerMax centralized controls can be reconfigured to allow for operations such as automatic decoupling and load shedding.

This self-dependency and ability to pivot based on available power sources will allow EBMUD to operate in "island mode" where the District can continue operations within its systems without the use of external sources.

Additional training of staff will be necessary on a continuous basis, with upgrades to software packages as required to meet industry trends and maintain the security and operations of the electrical system at the MWWTP. If training staff on a continuous basis is not an option, there are maintenance programs offered by third party firms or by the manufacturer (SEL).

4.4 Implementation Triggers

The primary trigger for selection of a specific portfolio is completion of preliminary studies of line power Projects 1, 2 and 3, since those studies will verify feasibility of the various line power projects and provide better cost and schedule information. Additional potential triggers, i.e., factors that could drive the timing or sizing of projects, include:

1. Third Party Factors/Decisions
2. Regulatory changes that favor one approach over another
3. Changes in system demands.
4. Permitting timelines

5. Changes in technology, for example battery technology

While the projects involving generators face significant regulatory requirements that impact cost, schedule and even feasibility, the projects involving new line power also face uncertainty regarding feasibility, cost, and schedule. These factors could alter the benefits or costs of one or more projects. Therefore, the District should be ready to pivot or adjust based on changing conditions. Implementing early stages of a combination of projects allows for the needed flexibility. The sections below describe the major implementation triggers for each group of projects identified.

4.4.1 Utility Power (Projects 1, 2, and 3)

Projects 1, 2, and 3 all involve new electrical utility feeds to provide power to the MWWTP. The requested new feeds should each have a capacity of at least 12MW in order to simplify the MWWTP electrical distribution system. Currently, EBMUD is reliant on multiple sources of power to operate the MWWTP, which results in a complex power distribution system involving split MCC buses, many of which require manual operation. If the MWWTP had an incoming utility source with 12MW capacity, all equipment could be supplied power via this single source, which would greatly simplify the operations of the distribution system and increase resiliency.

The implementation triggers related to these projects are largely external. Each of these potential projects must complete a PG&E PES to verify the technical feasibility of the project. We recommend that EBMUD commission a PES for each of these projects to obtain a complete understanding of the District's available options for upgraded electrical utility services. The information gained upon completion of these studies - specifically, which ones and how many of these three projects are feasible given the Port of Oakland and PG&E's available capacity and infrastructure will have a major impact on the overall road map.

If more than one of these projects is determined to be feasible, it would raise additional decision points for consideration by EBMUD. Projects 1 and 2 both involve a new 12kV utility service. The difference between the two projects is related to the billing entity that EBMUD would negotiate rates with for Project 1, EBMUD would need to negotiate an agreement with Port of Oakland. For Project 2, EBMUD would be negotiating with PG&E. The outcome of the negotiation terms of each utility potential could determine the preferred utility company.

Project 3, if determined via the PES to be technically feasible, would have a number of other external factors to consider prior to implementation including: the feasibility of routing high voltage transmission lines through areas of the community surrounding the MWWTP (easements/permitting); the physical space required for the on-site substation transformers and switchgear needed to implement this project (operational); need to hire or train EBMUD staff qualified to work on high-voltage electrical equipment (operational); as well as the high capital cost of this option (financial).

Further discussion of the relative desirability of each of these three projects continues during discussion of the available project portfolios below.

4.4.2 On-Site Power Generation (Projects 4 and 5)

Projects 4 and 5 include the implementation of on-site diesel generators to provide standby power. The goal of both projects is to provide EBMUD with a reliable standby power supply in the event of an outage of PG&E power. In order for the MWWTP to have full redundancy of its electrical power supply, it must have at least 12 MW of backup power, independent from the primary source.

The amount of on-site standby power required for the MWWTP to have full redundancy is dependent on a number of factors. These include:

- Results of the PG&E Preliminary Engineering Studies described above: Depending on the results of these studies, the overall amount of required on-site power generation could range from 0 to 12 MW.
- Evaluation/Rehabilitation of PGS-1: Incorporation of PGS-1 as a backup power source, based on successful reliability improvements, could reduce remaining backup power needs by about 3 MW.

Beyond the capacity of the on-site generation system, the complexity of the distribution of power sources should be a consideration. While providing backup on-site power from multiple sources is feasible, it increases the complexity of the electrical distribution system (similar to that of the MWWTP's existing grid power system). However, a distributed system of multiple on-site power systems would likely be a lower capital cost, which may outweigh the operational concerns.

4.4.3 Load Shed Controls and Best Practices

Projects 6 and 7 have no implementation triggers – these should be implemented by EBMUD.

Project 6 (Load Shed Controls) is the "lowest hanging fruit" in order for EBMUD to increase resiliency at the MWWTP. These controls were implemented specifically to increase electrical resiliency and should be re-implemented immediately. The fact that these controls were offline during recent utility power outages likely contributed to increased downtime for treatment processes. TM 1 identified some adjustments that could be made to the controls to better prioritize unit processes, and it is recommended that EBMUD continue to "fine tune" the load shed controls after future utility outages rather than to deactivate the entire system.

Project 7 (Best Practices) includes the development of a capital improvement plan to replace aging infrastructure at the MWWTP. Like many municipal wastewater facilities that were constructed in the 1970s, the MWWTP still relies on some critical equipment which is nearing or at the end of its useful life. TM 2 identified several areas of focus for EBMUD to replace this aging infrastructure with updated equipment which meets modern design standards. Implementation of these improvements will be important for EBMUD to maintain and improve its electrical resilience, regardless of the other capital projects identified in this report.

4.5 Available Project Portfolios

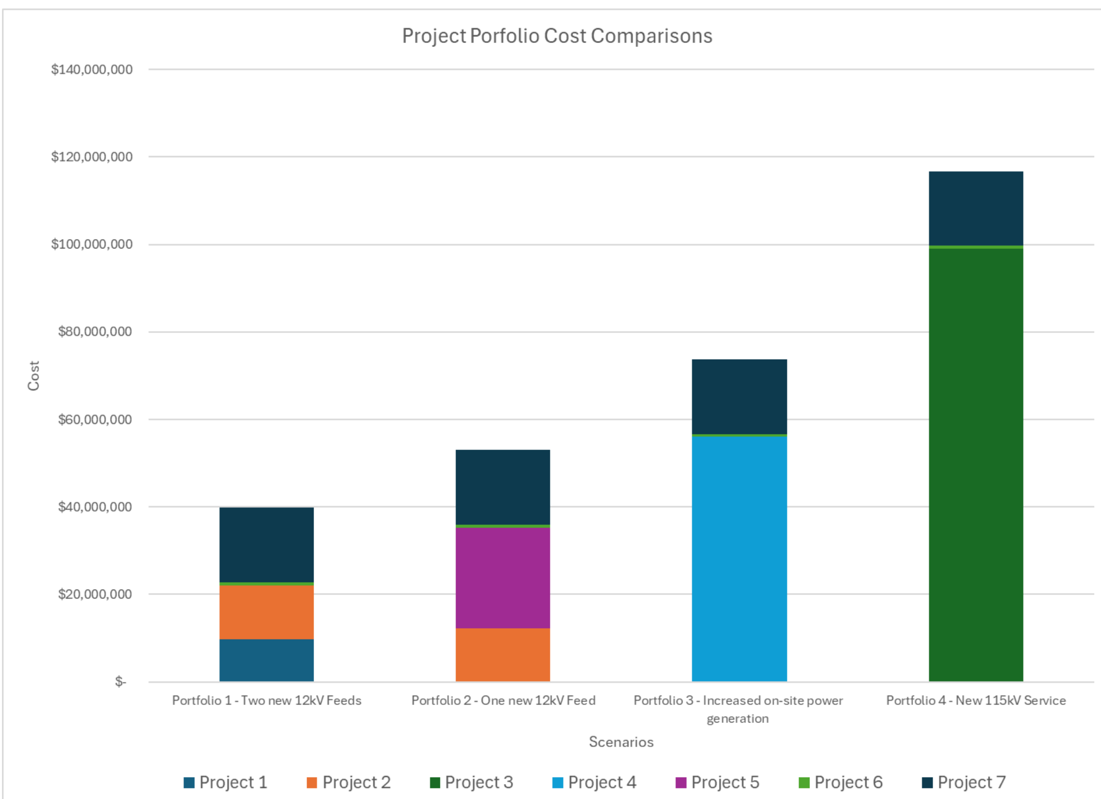
No individual project alternative as described in this TM will completely address the resiliency and reliability concerns noted and expressed by the District. Thus, while developing the road map W&C felt that a combination of the project alternatives into project "portfolios" would best describe the road map projects and how they could be implemented. Below, we outline several "portfolios" – combinations of projects which would allow the MWWTP to achieve full redundancy and compliance with EPA guidelines. The portfolios are ordered from the most desirable outcome to the least desirable. The availability of each portfolio will be dependent on the implementation triggers identified above. **Table 4-1** summarizes the project portfolios with details of each portfolio provided in the paragraphs below.

TABLE 4-1: SUMMARY OF PROJECT PORTFOLIOS

Project Portfolio No.	Project Alternative No.s	Trigger
1	1 and 2 (two new 12 kV feeds) 6 (Load shed improvements) 7 (best practices)	Projects 1 and 2 (new 12kV services from the Port and PG&E respectively) are both feasible.
2	1 or 2 (one new 12 kV feed) 5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Only one of the two new 12kV services is feasible.
3	4/5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Neither 12kV line power project is feasible.
4	3 (new 115 kV feed) 5 (onsite generation) 6 (Load shed improvements) 7 (best practices)	Neither of the 12kV services is feasible nor is onsite generation for full peak loads practical, but a new 115 kV service (Project 3) *is* feasible.

Figure 4-2 shows the estimated cost of each portfolio.

FIGURE 4-2: PROJECT PORTFOLIO COST COMPARISONS



4.5.1 Project Portfolio 1

This portfolio would provide the most robust power solution, but hinges on the determination, via the utility Preliminary Engineering Studies and favorable contract agreements, that both Projects 1 and 2 are attainable. This would allow EBMUD to operate using a single power source during normal operations. Upon loss of the primary power source, the power supply would automatically shift to the secondary utility line.

It should be noted that for the secondary power source to be considered reliable, that power supply must be routed through a different substation than that of the primary feed in other words, having two dedicated utility sources with each fed from existing substation L would not be considered reliable, as an outage of that substation would eliminate both power sources.

If both projects 1 and 2 were found to be feasible, EBMUD would need to enter into negotiations with Port of Oakland and PG&E to determine the terms for any capital and operating expenses of the new utility lines. The outcome of these negotiations would determine whether the Port of Oakland line or the PG&E line would be the primary source of power.

This portfolio would greatly simplify the electrical distribution system at the MWWTP, because all equipment would receive power from the same source, rather than the current arrangement whereby equipment in the same area may receive power from different sources. In this portfolio, PGS-1 could continue to operate, allowing EBMUD to continue to receive beneficial use of the biogas produced on site; however, PGS-1 would be a tertiary backup – the MWWTP would only be dependent on PGS-1 upon a loss of both utility sources. Additional negotiations with either utility would be required to agree on the export of power from both PGS-1 and PGS-2.

Project 6 (load shed improvements) is part of this (and every) portfolio. While the load shed system would be less critical upon completion of this project portfolio, Project 6 has a relatively low cost and would increase MWWTP's electrical resilience while the work is being completed.

Project 7 (best practices) would be implemented in this (and every) portfolio since under all conditions EBMUD would benefit by developing an ongoing maintenance routine to replace aging infrastructure.

4.5.2 Project Portfolio 2

The second project portfolio would be implemented under a scenario in which *either* Project 1 *or* Project 2 is feasible, but not both. EBMUD would implement the available feasible project to obtain a single source of power with sufficient capacity to power the entire MWWTP. Emphasis should be on replacing the lower capacity and less reliable C-1134 line, assuming it would be fed from a source other than PG&E Substation L (to maintain separate PG&E feeds). Similar to the results of Project Portfolio 1, this would simplify the electrical distribution system under normal conditions. However, in this scenario, a secondary power source would need to be supplied by a combination of sources this could include either existing Line L or C (assuming they can remain in service), an upgraded PGS-1 (if improvements can make this source more reliable), or new diesel generators installed on site.

Common to all portfolios, Projects 6 and 7 would be implemented.

4.5.3 Project Portfolio 3

Project Portfolio 3 is focused on providing onsite power generation for peak full-plant loads, based on neither of the 12 kV projects (Projects 1 and 2) being feasible. The total power requirement would be about 12 MW, which could be reduced by about 3MW if PGS-1 is made sufficiently reliable.

Common to all portfolios, Projects 6 and 7 would be implemented.

4.5.4 Project Portfolio 4

Project Portfolio 4 consists of Projects 3 (new 115 kV feed), as well as Project 5 (onsite power generation for a portion of plant loads). This portfolio would be selected if other less costly portfolios were determined to be infeasible, but Project 4 (i.e., a 115kV feed) proved feasible. In this context, the determination of "feasible" means not only technically feasible within a reasonable timeframe, but also economically feasible a new 115kV feed currently estimated at $99M. In this portfolio, the scope of Project 5 (onsite generation) would be adjusted, or even eliminated, depending upon the availability of the now-existing line power feeds C and L, and upon the status of PGS-1.

Common to all portfolios, Projects 6 and 7 would be implemented.

4.6 Key triggers

Project Portfolio 1 is significantly more desirable than the other portfolios, as it provides a high level of resilience without reliance on onsite generation. However, the feasibility of implementing that preferred portfolio, or any portfolio, is unknown at this time. Below, we discuss some of the key triggers which will help EBMUD ascertain the feasibility of each project portfolio, to properly navigate the electrical resiliency road map.

- **Results of PG&E Studies** – Completion of the Preliminary Engineering Studies to determine the feasibility of Projects 1, 2, and 3 is a key next step. We recommend that EBMUD pursue these studies concurrently in the near future, since they will likely take 12 months.

- **Negotiations with Port of Oakland** – EBMUD maintains a power sharing agreement with Port of Oakland. Relying on Port of Oakland for primary utility service would be a significant shift and would require updates to the governing agreement. We recommend that EBMUD have preliminary discussions with Port of Oakland in the near term to begin negotiations for an expanded agreement between the two agencies. Once the results of the PES for Project 1 are known, negotiations could be finalized and the agreement executed.

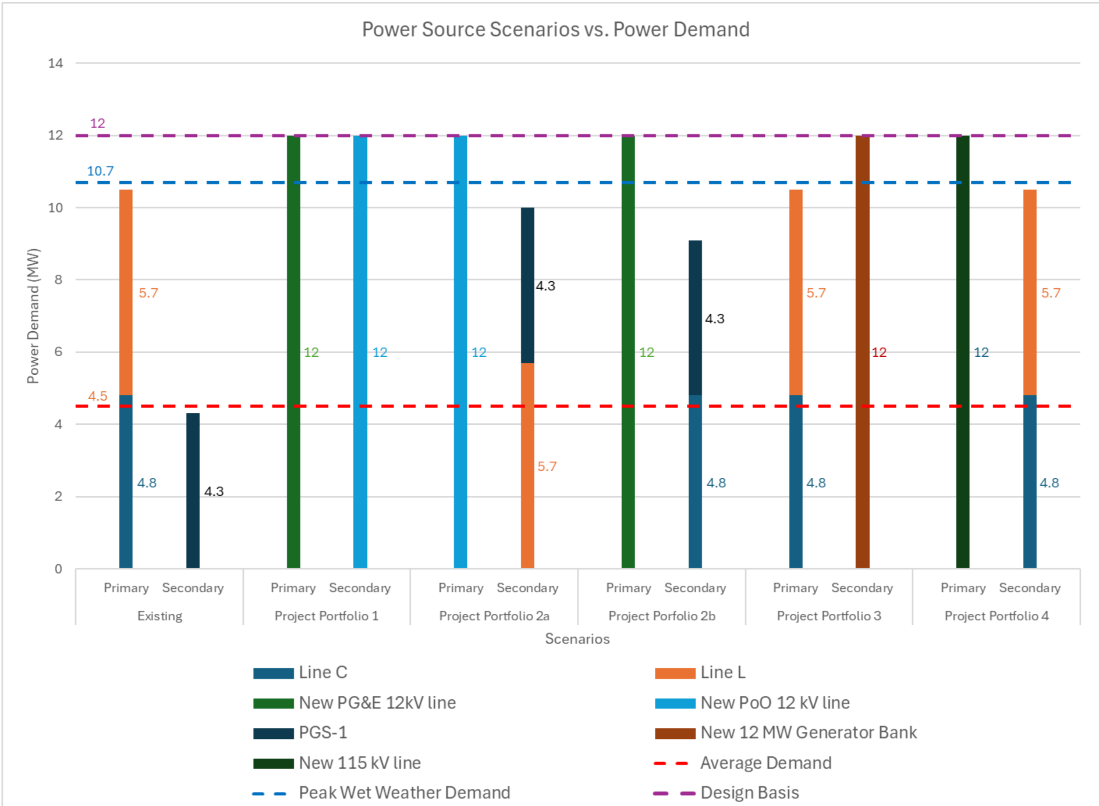
- **PGS-1 Evaluation** – We understand that the District is working on improvements to the PGS-1 engines that will improve their reliability after loss of utility power. Historically, PGS-1 has not been reliable during a loss of utility power; however, if the improvements planned by EBMUD can make the PGS-1 system more reliable, it would likely result in significant capital savings by reducing the number of new backup generators included in Projects 4 and 5.

4.7 Potential Power Sources

To provide true redundancy and comply with EPA guidelines, the MWWTP should have **both** a primary and secondary independent power source of power, **each** totaling at least 12 MW. Below is a discussion of the source of power in each project portfolio as a consideration. The makeup of the sources of power under each scenario are also shown graphically in **Figure 4-3**.

- Portfolio 1 – Provides a primary (PG&E) and secondary (Port of Oakland) new 12kV circuit. PGS-1 is a tertiary backup to the two new lines.
- Portfolio 2a – A new Port of Oakland connection would be fed from the Davis Substation as the primary 12kV circuit. The secondary power source could be a combination of Line C and PGS-1 and then assuming ideally existing Line C could remain as a partial power source. If PGS-1 can be considered reliable after the upgrades, the existing Line C plus PGS-1 provide 12.2 MW of power as a secondary source. No further on-site generation needed.
- Portfolio 2b – Assuming a new PG&E connection would be fed from Substation L as the primary circuit, ideally Line C could remain as a partial power source. If PGS-1 can be considered reliable after the upgrades, the existing Line C plus PGS-1 provides 11.3 MW of power which is just under the recommended maximum capacity. The remaining power requirement could be closed with a 1MW diesel generator or could be added later.
- Portfolio 3 –12 MW of total on-site generation is required in this scenario as the secondary power source. If PGS-1 can be considered reliable, it could reduce the required capacity of new generators by about 3 MW, i.e., from 12 MW to 9 MW.
- Portfolio 4 – The new 115kV service stepped down to 12kV would be the primary source. While Project 5 is part of the portfolio, it could potentially be eliminated if Lines L and Line C could both be retained as backup lines.

FIGURE 4-3 POWER SOURCE SCENARIOS VS. POWER DEMAND[1]



1. It was determined in TM1 that the turbine (PGS-2) was not a reliable source of power and therefore not included in Figure 4-3.

4.8 Road Map

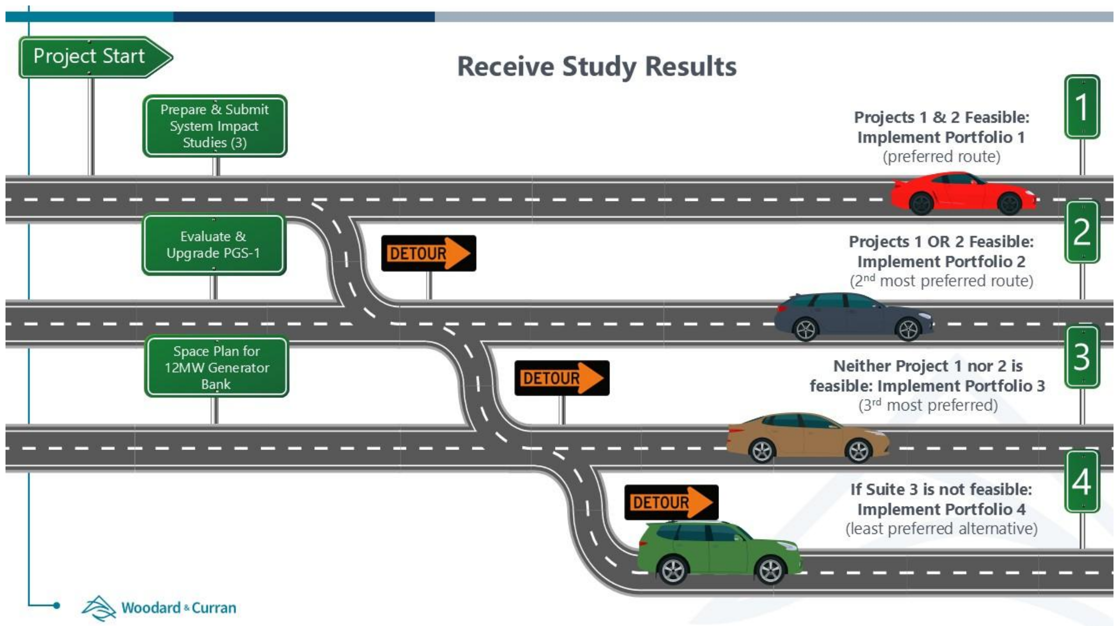
We recommend that EBMUD follow the road map included as **Figure 4-4** to increase the overall resiliency of the electrical system at the MWWTP. In order to determine which of the roads are "open" and available for EBMUD to utilize, the following tasks should take place in parallel the near term (over the next 12-18 months).

- PES for Projects 1, 2, and 3: As noted above, these studies will allow EBMUD to learn the feasibility of each project, which will dictate which project portfolios are available to the District.
- Evaluation and upgrades to PGS-1: Historically, PGS-1 has not been able to supply the MWWTP with backup power during a loss of utility power for a variety of reasons. EBMUD is currently evaluating improvements to this system to make PGS-1 more reliable. If these improvements can be implemented, it would reduce the cost and physical space requirements for any on-site backup power options.
- Space-plan for Project 4: In the event that PGS-1 still is not a reliable source of backup power in the future, EBMUD should allocate space for a 12MW generator bank. Although this project may not be needed, depending on the results of the System Impact Studies and PGS-1 upgrades, we recommend that EBMUD plan for this scenario in the meantime.

- Project 6 – Load Shed Modifications: We recommend that EBMUD implement the load shed modifications discussed in this report and previous Technical Memoranda. This project is the "lowest hanging fruit" for increased electrical resiliency in terms of capital cost and schedule to implement.

- Project 7 – Best Practices: Much of the infrastructure at the MWWTP is original and is nearing the end of its useful life. Furthermore, some antiquated equipment does not meet current-day design standards. We recommend that EBMUD implement an ongoing program to replace aging components of the electrical infrastructure and actively perform recommended routine preventative maintenance on critical equipment.

FIGURE 4-4: ROAD MAP



5. FUNDING SOURCES

A variety of state and federal funding opportunities exist or will come into effect that support the work described in this plan. Funding is often set aside for specific components of projects, such as design or construction, and is often allowable for specific timelines of work, with completion deadlines. Therefore, it is important to keep abreast of opportunities as projects progress.

This section describes examples of available funding that should be monitored for eligibility and evaluation criteria.

5.1 Inflation Reduction Act of 2022

The Inflation Reduction Act of 2022 (IRA) provides opportunities for water, clean energy, climate mitigation and resilience, agricultural, and conservation-related investment programs and tax incentives.

The IRA creates several new programs to reduce air pollution including greenhouse gases, with a particular focus on communities that carry a disproportionate pollution burden. These include:

- Greenhouse Gas Reduction Fund
- Environmental and Climate Justice Community Change Grant Programs
- Neighborhood Access and Equity Grant Program
- Low Emissions Electricity Program

Additionally, the IRA includes loans for energy projects. The IRA will provide $40 billion in loan authority for eligible projects. Project eligibility is still being determined at the time of the TM.

5.2 Infrastructure Investment and Jobs Act

Though the Infrastructure Investment and Jobs Act included $60 billion in clean energy, which was administered through the Department of Energy, very little of it is applicable to the projects described above and EBMUD is not eligible for most of the programs, therefore this is unlikely to be a useful source of funding.

5.3 California IBank Climate Financing

The California Infrastructure and Economic Development Bank ("IBank") and the State Treasurer's Office jointly serve as California's "Green Bank" and have proposed loans to offer in California's market for climate infrastructure including:

- Climate Loan Guarantee Program
- Climate Loan Participation Program
- Climate Incentives Bridge Loan

While these programs are not grants, but loans, they offer competitive interest rates which may be beneficial to EBMUD in securing funding for the projects.

5.4 California Energy Commission Funding Programs

The California Energy Commission has a variety of funding programs currently open, however many favor new, innovative technology as research projects that support the needs of the Commission. The following programs have potential in supporting the Road map Projects:

- GFO-23-317 - Energy Storage Innovations to Support Grid Reliability
- GFO-23-315 - Clean, Dispatchable Generation (for Cogen)

6. CONCLUSION

The scope of work required that this TM develop the road map in alignment with the Integrated Master Plan (IMP) for the Main Wastewater Treatment Plant (May 2022) to the extent possible. That Plan's project to replace or rehabilitate the Influent Pump Station (IPS) is clearly an opportunity to increase resiliency by incorporation as appropriate measures discussed in this TM such as addressing the current commingling of power and modifying the existing switchgear to include an automatic transfer switch.

The IMP also suggests topics that should be considered as drivers for the prioritization of projects in the road map. This section summarizes relevant portions of the IMP to verify alignment of the road map projects outlined in this TM. Key IMP topics are summarized below.

Renewable Energy Category:

- The PGS systems will remain in place for the near term, although future regulations or incentives may militate against it in the long term.
- As PGS-1 ages and other alternatives are considered for biogas (such as diverting to a post-digestion facility) the dependance on utility power will increase.

Climate Change Resiliency Category:

- Elimination of fossil fuel diesel use and switching to 100% renewable fuel could exclude the use of PGS-1 for diesel. The Plan also calls for consideration of eliminating natural gas supplies at the plant, which would further limit the versatility of PGS-1, effectively making it a single-fuel system.
- Elimination of natural gas, e.g., electrification of building heating and water, would increase demands for electricity.

Power Capacity Category:

- Projected increase in power demand:
    - 1MW in 2030
    - 2.1MW in 2040
    - 2.7MW in 2050

These observations and the intent to align the road map with the IMP strengthens the primacy of Project Portfolio 1 (service applications to utility companies) as the preferred portfolio, since that portfolio is not sensitive to the drivers identified by the IMP. For example, the fate of PGS-1, or biogas handling in general, does not impact the viability of Portfolio 1.

Throughout the discussion in the TMs, the value of 12MW was used as the basis for a reliable secondary power source and is based on the peak demand value noted of 10.7MW on 12/11/14 from the Main Wastewater Treatment Plant Load Study (May 2020). This value is an estimate based on data provided and information in the IMP and is within a +/- 10% margin. The applications for a new service should request up to 15MW of capacity to handle future loads. Utility distribution lines at 12kV typically can provide up to

15MW dedicated capacity. For greater than 15MW, a transmission service might be required. For example, in 2040 the IMP is estimating an additional 2.1MW, when added to the peak value of 10.7MW, the peak demand could be as high as 12.8MW. These values are an estimate only and can fluctuate and should be further refined during detailed load studies and design.

In conclusion, the road map proposes a series of early steps that will address short-term needs for power resilience while informing the long-term portfolio selection. Key early steps include beginning the PES process for all three utility line-power projects and further refining onsite generation projects to account for PGS-1.

APPENDIX A: TECHINCAL MEMORANDUM 1: CONSEQUENCE OF FAILURE ANALYSIS

WASTEWATER ELECTRICAL RESILIENCY MASTER PLAN

Task 2 – TM1

Consequence of Failure Analysis

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East Bay Municipal Utility District
August 2024

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EXECUTIVE SUMMARY

The East Bay Municipal Utility District (EBMUD) would like to improve electrical resiliency at the Main Wastewater Treatment Plant (MWWTP) and has contracted with Woodard & Curran, Inc. (W&C) to analyze the system to identify failure vulnerabilities and consequences, develop and evaluate alternatives to enhance resilience, and ultimately provide a roadmap to greater resiliency. This TM (TM1) presents the results of the first task of the study.

Purpose of Scope

This TM assesses the resilience of power systems at the MWWTP and provides recommendations as appropriate to improve resilience.

The scope of the study included data review and site observations but did not include any field testing of equipment or conductors.

Findings

Table ES-1 summarizes key findings which are further described in Section 2

Table ES-1: Findings

Finding	Description
F-1	***No full power redundancy exists*** While the plant has four sources of power (two-line power feeds and two internal power generation stations (PGS's), no single source of power is sufficient for maximum load.
F-2	***Line power feeds are prone to common cause failure*** The plant's two-line power feeds (PG&E circuits L & C) are exposed to common-cause failure because they share a common alignment in the final approach to the plant: a single duct bank, vault, and aerial alignment.
F-3	***Various hazards threaten reliability of the line power*** Line power reliability has diminished in recent years and increased the plant's vulnerability.
F-4	***Load-shedding Controls are not protecting the plant from blackouts*** The plant's load-shedding system is not routinely enabled by plant staff, so the system affords minimal protection against loss of any of the plant's four power sources.

F-5	***Distribution System Topology*** The power distribution system within the MWWTP has evolved organically over the years, leading to complex routing and controls. This complexity magnifies the impact of individual component failures and has been a factor in some historic power outages. Component failures are attributed to wiring at the lower voltage levels that are not aligned with the same power bus (A or B) as the major equipment that they supplement, also described in this TM as commingling. Lack of redundancy in some portions of the power system Cabling systems including taps and splices in vaults that may contain water Aging distribution cable systems Lack of automated tie-breaker controls for motor control centers
F-6	***PGS black-start is slow*** PGS startup is slowed by the need to flare built-up biogas.
F-7	***Restoring utility power back to the plant is not efficient*** Bringing the plant back into service after a Direct Trip Transfer (DTT) requires District staff to come to the plant to reclose the breakers at H1 after PG&E provides approval. PG&E communication protocol is not efficient and the lack of appropriate training for District staff to restore power to the plant efficiently was compromised.

Analysis and Conclusions

Based on the findings listed above, W&C makes the following conclusions and further describes these conclusions in Section 3:

Table ES-2: Conclusions

Conclusions	Pertains to Finding(s)	Description
C-1	F-1, F-2, F-3	The plant's line power supplies should not be considered reliable, owing to lack of full redundancy to maintain plant operations during peak events and environmental exposure
C-2	F-4, F-6	The disablement of the SEL POWERMAX power control system poses a significant risk associated with power outages and maintaining PGS operation.
C-3	F-5	Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity.
C-4	F-5	Process trains and their ancillary devices are not wired to the same power bus which increases risk of non-operation when one of the two line circuits are not available and a tie breaker is not closed or if the load shed control system is enabled.
C-5	F-4, F-6	Biogas storage is not available to provide efficient and safe starting of engines during a black start.
C-6	F-5	Replacement or failure of some portions of the 12.47kV and 4160V distribution cable system require shutdowns of process systems or require temporary power.
C-7	F-7	Bringing the plant back into service after a DTT takes longer than expected due to operational procedures and communication protocol with PG&E.

Summary of Recommendations

W&C makes the following recommendations to improve the electrical resilience of the power distribution system at the MWWTP in the order of what W&C believes is the greatest contributor to a consequence of failure scenario that leaves the MWWTP without reliable power. These recommendations are further discussed in Section 4.

Table ES-3: Recommendations

Recommendations	Pertains to Conclusion(s)	Description
R-1	C-1	The plant's line power supply should not be considered reliable, owing to lack of full redundancy, and environmental exposure. Consider replacing one of the existing line circuits with a dedicated service with limited overhead distribution. Investigate option to obtain service from another provider (Port of Oakland)
R-2	C-2, C-5	The SEL POWERMAX system should be enabled at all times to maintain operation of PGS during utility outage and avoid black start.
R-3	C-2, C-4, C-5	Correct or consolidate low voltage wiring systems that are commingled between the different power buses (A versus B).
R-4	C-2	Revise load shed priority list based on criticality of processes and TTI.
R-5	C-7	Revise operational procedures to improve the time it takes to restore power to the plant.
R-6	C-1, C-3, C-5, C-6	Modify or add electrical equipment to provide full redundancy. Replace below grade cable connectors with above grade switchgear. Investigate modifications to the biogas system to provide storage to avoid flaring of gas during black start.

1. INTRODUCTION

1.1 Background

This TM is prepared as part of W&C's study of electrical resilience at MWWTP. There is a total of three TM's, with the first TM as the foundation for the second and third TM. The ultimate goal of the electrical resiliency study is to provide the District with a roadmap (TM3) of projects based on the findings (TM1) and alternatives selected (TM2).

1.2 Objective

The objective of this TM is to identify vulnerabilities within the power distribution system and operations at the MWWTP and then determine the consequence of failure and provide recommendations. To support the analysis W&C visited the site, met with District staff and reviewed the following data provided by the District:

- MWWTP Load Flow Study (May 2020)
- Map of Substations (Nov. 2016)
- Medium Voltage Single Line Diagram (May 2016)
- MWWTP Underground Electrical Facility Drawings (Dec. 2012)
- MWWTP Power Distribution System Replacement (SD 227, 1998)
- Standardized Maintenance Practice For Electrical Service Continuity Plan Standard Operating Procedure (SOP) for Main Service Power Restoration (Feb. 2023)
- PI Data Collected, 15 Min Intervals (2004 – 2022)

As part of this task, W&C visited the site visit on February 21, 2023, to observe the location and condition of existing equipment. With the exception of a few open vaults, underground systems such as duct banks, electrical handholes and vaults were not observed, and no vaults were entered. Switchgear and electrical panels were not opened due to safety concerns; however, the exterior and age of the panels were noted along with comments from District Operations staff regarding functionality and reliability concerns.

1.3 Scope

This TM is based on site observations, meetings with District Operations staff, review of documentation, historical data, etc. The findings and conclusions are limited to areas which we were able to observe safely without having to open electrical panels with live parts or entering electrical vaults that require authorization from the plant's health and safety department. Investigation of power circuits Line L and C entry into the MWWTP was restricted to observation of overhead lines, Google Earth, and as-built construction drawings. Routing offsite is being confirmed by PG&E and has not been verified as of the date of this TM. The data collected was then analyzed for potential failure and its consequences. Workshops and virtual meetings were held to document methods of operations and protocols when power to the plant is lost and is restored. The following components were considered most valuable to the power system during analysis:

- Pacific Gas & Electric (circuit lines L & C)
- Power Generation System (PGS-1 and PGS-2)
- System Topology
- Power Distribution Equipment and Cabling
- Power System Controls
- System capacity

- Restoring Power

1.4 Organization of this TM

Section 2 of this TM presents W&C's findings related to the power systems. This section includes an overview of the system's topology, its key components, its dependencies, and historical observations. Key findings, i.e., those that impinge on power system resilience, are numbered for easy reference.

Section 3 presents the analysis and conclusions W&C has drawn from the presented findings. Those conclusions represent W&C's synthesis of the various findings based on professional judgment.

Section 4 of this TM presents W&C's recommendations.

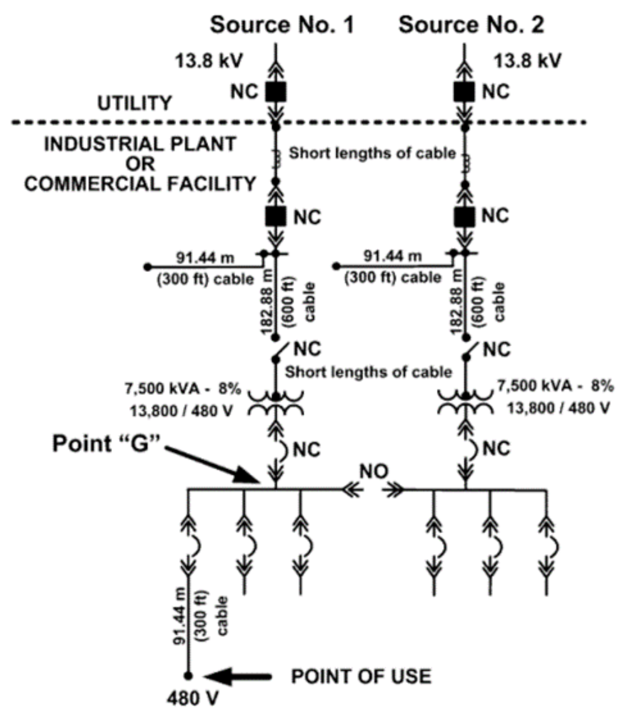
2. FINDINGS

2.1 Existing Plant Power System

2.1.1 System Topology

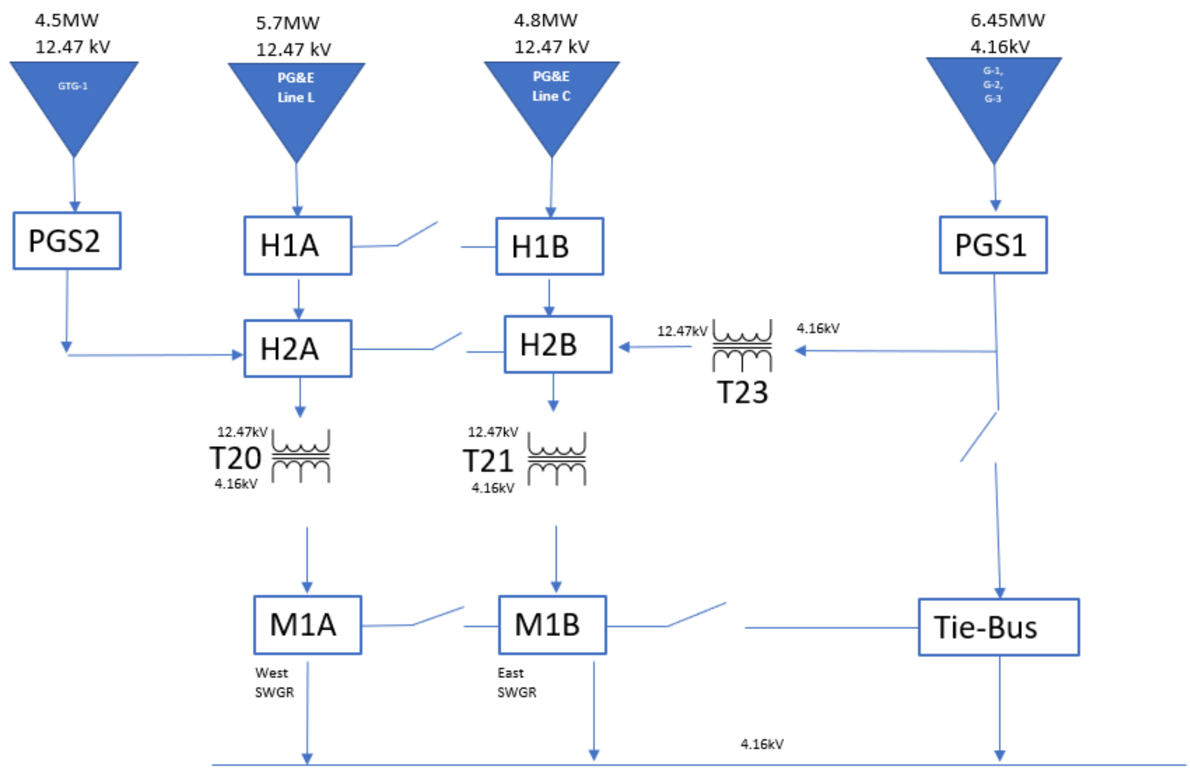
The line power at MWWTP was originally designed as a "secondary-selective system" as defined in IEEE 493 (IEEE). Such a system provides two separate line power sources in lieu of relying upon engine generators to provide standby power to meet federal standards for backup power. This configuration is responsive to federal standard EPA 430-99-74-001 (USEPA) which requires "Two separate and independent sources of electric power shall be provided to the works from either two separate utility substations or from a single substation and a works-based generator." Figure 2-1 shows a typical configuration.

Figure 2-1: Typical Secondary-Selective System



To implement the secondary-selective system, MWWTP receives distribution power from two 12.47 kV circuits: Line L1107 (Line "L") and Line C1134 (Line "C"), served by PG&E substations L and C, respectively. In addition to the two line power feeds, the MWWTP receives power from two internal power generation stations (PGS's) that produce electricity from biogas: PGS-1, a three-engine station, and PGS-2, a single-turbine station. two-liner power sources and their capacities are shown in Figure 2-2 below. Based on input from the District, the MWWTP is not on PG&E's Block 50 meaning that the plant is subject to rotating outages.

Figure 2-2: MWWTP Simplified Single Line Diagram



Finding F-1: No full power redundancy exists

Observation of the two independent electric power sources indicated in Figure 2-1 that comply with the foundation requirements of EPA for a reliable source of electric power is not enough to meet the load requirements as described in Section 2.1.2 Plant Load Data. It should also be noted that both Lines C and L are not dedicated lines, meaning that other PG&E customers are also connected to these circuit lines, which limits the available capacity for each line.

2.1.2 Plant Load Data

The District uses Plant Information (PI) software (by OSIsoft) to store historical process data from the DCS system. W&C studied historical PI data from 2004 to 2022 to assist with the understanding of minimum and maximum loads including wet and dry seasons. The data include high flow days, correlated with power monitoring data at individual locations throughout the plant. Power consumption data were collected at the meters located on the line side of the incoming transformers T-20 and T-21, denoted in the PI data as "Main Trans 1" (OT20) and "Main Trans 2" (OT21). The maximum peak demand and average values are noted in Table 1 below. As of the date of this TM, the maximum load demand is still recorded at 10.65MW.

Table 1: Recorded Maximum and Average Values (MW)

Season[1]	Maximum/Peak[2]	Average[3]
Wet	10.65 MW	4.78MW
Dry	7.53 MW	4.47MW

Notes:
1. Wet season is defined as October 1st thru April 15th per District.
2. Peak wet weather was recorded on 12/11/14 and peak dry weather was recorded on 6/4/11.
3. Average is based on a 10 year period from 2012 to 2022.

W&C reviewed the PI data and determined that most of the time the plant was a net power exporter. A histogram was developed from the PI data depicting the percentage of time power demand and is provided in Appendix A. The histogram illustrates that for less than 1% of the time the facility requires greater than 8MW indicating that rarely does the power demand exceed this value except for 1% of the time in both average and maximum. However, a recent power outage event that occurred on March 21, 2023, indicated that the power demand just prior to plant shutdown was approximately 6.9MW. Based on this data, and the data indicated in Table 1 it can be determined that consideration for increasing reliability and resiliency should be heavily focused on a minimum of greater than 4.47MW with a maximum of 10.65MW and up to 12MW (margin added for future and unforeseen historical events) for wet weather peak events.

Finding F-1: No full power redundancy exists

Comparing the load data with the power feed capacities (MW) shown in Figure 2-2, it is evident that neither of the two power feeds are sufficient on their own to meet maximum loads during any season; and when combined, their capacities are barely sufficient to meet maximum wet-weather loads. Thus, the current system's loads are inconsistent with the assumed design intent of full compliance with EPA standards for backup power.

2.1.3 Distribution and Utilization Voltage

The plant accepts both PG&E circuits at 12.47kV at switchgear H1, where revenue meters and the direct transfer trip system are located. Switchgear H2 is the distribution switchgear for the plant and is also where PGS2 is connected for distribution and export. PGS1 is downstream of H1 because its voltage is 4.16kV, rather than the 12kV at H2.

H2 provides the primary power to feed transformers T-20 and T-21 that step from 12.47kV down to 4160V for load centers located throughout the plant facility. The load centers are fed from the 4160V switchgear M1A (West SWGR) and M1B (EAST SWGR) and are connected via a normally open (NO) tie breaker. The load centers then step the 4160V down to 480V for Utilization via motor control centers or switchboards.

The motor control centers and Medium Voltage (MV) switchgear are all set up with main-tie-main systems to increase redundancy and reliability. There is an Auto Transfer Controller to operate the tie-breaker between M1-A and M1-B. The tie-breaker in this case closes when one of the incoming sources is not available either due to equipment failure or a PG&E outage in either service circuit. Additionally, all medium voltage breakers located within M1 and H2 can be remotely tripped and closed back in, allowing for load shedding in the event of an outage. Throughout the MWWTP, MV breakers configured with a main-tie-main have either mechanical or electrical interlocks to ensure the two incoming sources cannot be paralleled at any time.

Additionally, according to the District's SOP, most of the plant loads are powered from PG&E utility line L at 12kV which is paralleled with PGS2 (gas turbine generator). Minor loads are carried on PG&E utility Line C which is paralleled with PGS1 (the engine generators). By aligning equipment loads with Line L and PGS2, the majority of the plant critical loads are connected to the more reliable utility line with PGS2 considered as a second source of power. The utility Line C is reserved for less critical loads, as well as the primary export sales of power from PGS1. The equipment is fed as indicated, based upon the PI data provided and the power distribution single line provided.

2.1.4 Utility Service Routing

W&C reviewed existing electrical site plans from the Power Distribution Replacement Project (SD- 227), with particular attention to the PG&E incoming feeds. Circuit L is shown in the same duct bank with circuit C, as shown in Appendix B. Both circuits share the same electrical vault and the same duct bank and are routed northeast past the Grit Building and appear to go under the train tracks to a pole on Wood Street and 34th Street. Refer to Figure 2-3 for an aerial view of the plant with assumed routing of the PG&E duct bank and to Figure 2-4 where the riser pole for both circuits is assumed. Figure 2-5 indicates the locations of both substations that provide power for circuits L and C, respectively. It is not known if the overhead circuits on Wood Street and 34th Street go below grade or remain routed overhead.

W&C asked PG&E to confirm the routing of circuits L and C and determine the provenance of the unknown power pole on the north side of the plant shown in Figure 2-3. PG&E's response indicated that a field survey on Wood Street and 34th Street by PG&E is required for these items. As of the date of this TM, a field survey has not been completed to confirm our assumptions.

Finding F-2: Line power feeds are prone to common cause failure

The common routing and shared vaults of circuits L and C pose a risk to the reliability of the electrical service. Various hazards that might affect one of these circuits, for example, fires or short circuits in the vault, would likely damage both circuits.

Finding F-3 Various hazards threaten reliability of the line power

W&C also observed that the duct bank containing the PG&E circuits runs below a railroad track. Given the year of installation (1989), the duct bank may not meet modern standards.

After crossing the tracks, the utility services share a common aerial routing for some distance until they split to their respective substations. That aerial route is not in a highly secure area, exposing the circuits to damage.

Figure 2-3: Aerial View of Line C and L Routing

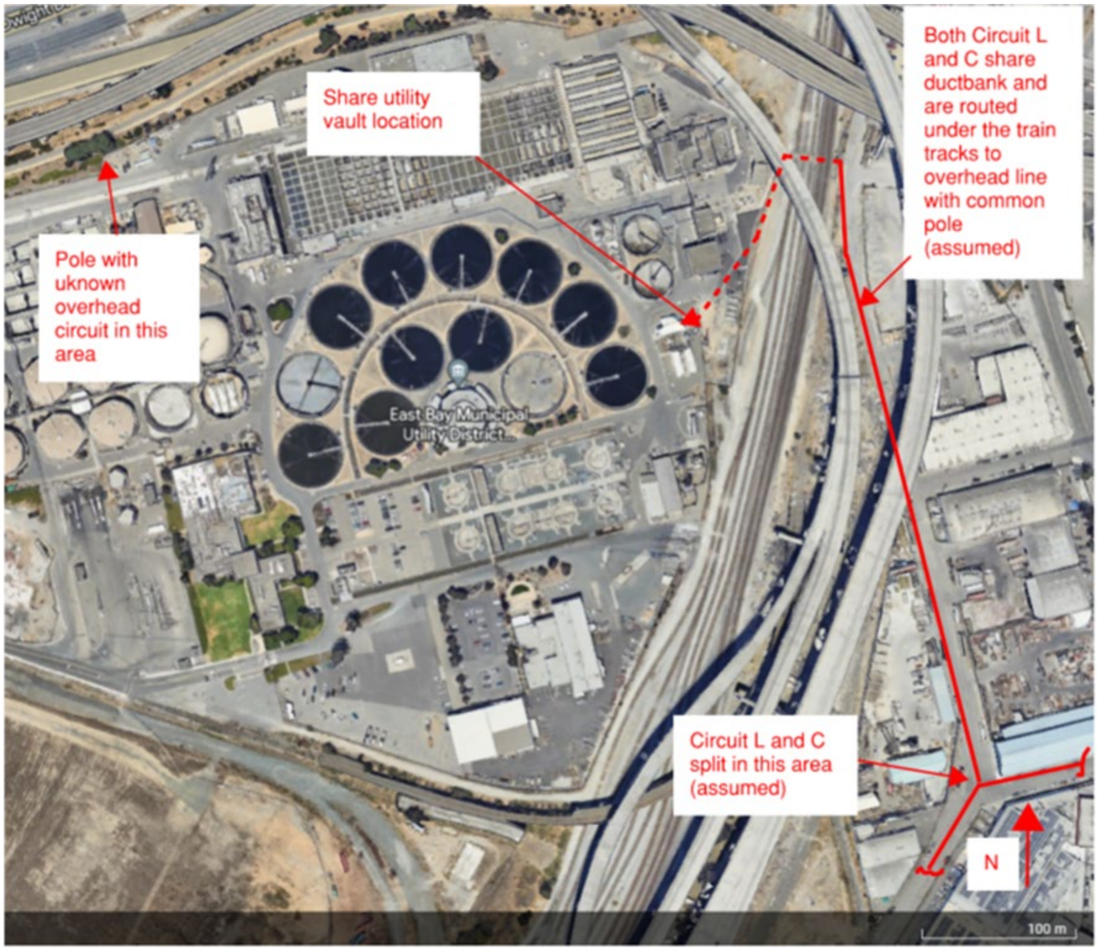


Figure 2-4: Pole Riser

Figure 2-5: Line Power Routing

2.1.5 Power Distribution Cables and Splices

2.1.5.1 Cables

When reviewing cable schedules from Project SD-227 and the Underground Electrical Facility Drawings, it appears that sections of cables were replaced as needed to accommodate the installation of the new M1 and H1 switchgear, as well as additional work at the unit substations across the facility. The cable schedules in the Underground Electrical Facility Drawings do not have an extensive list of the existing cables and their original installation date which would then aid in when they should be replaced (30 year life expectancy is customary).

Finding F-5: Aging distribution power cables may pose a threat to reliability.

2.1.5.2 Taps and Splices

Three underground tap (elbow connector) locations were identified as potential vulnerabilities. The existing system has MV taps accomplished with "T" body elbows and "L" body elbows. These tap connections, while reliable and rated for underground installation in a vault, must be disassembled to be disconnected. This requires the entire circuit to be de-energized, causing additional outages to interconnected buildings on that same circuit. An issue with The Operations Center feeder circuits from Substation U4 would require the de-energization of Substation U12 (Digester Building) as well as Substation U16 (Digester Feed Pumps), and an issue with the U12 feeder circuits would require a similar outage. Entering the vaults requires the District's Health and Safety Department approval for entering a Confined Space prior to doing any work inside of the vault. This step while being vital to staff safety is required because it is a Confined Space and requires qualified staff to enter it. That said, this process adds time to obtaining entry to the vault. The locations are identified in Table 2-1 below, along with a description of the process equipment directly affected by a potential outage.

Table 2-1: Taps and Splice Vault Locations

Location of Connection	Connection Type	Connected Substations/Processes
MH-13	Tap	U4/U5: Operations Building, Grit Handling, RAS/WAS
MH-16	Tap	U12: Digester Building and Digester Ancillaries
MH-40	Splice	U3: East Bayshore, 3W Water Lift Station, Distribution Pumping, Chlorination, Wet Weather Storage, Bisulfite Addition
MH-46	Tap	Maintenance Building: Motor testing and repair shop

Finding F-5: Taps and splices create potential points of failure in the power distribution system, especially when subjected to moisture or water infiltration in the electrical vaults.

2.1.6 Power Distribution Equipment

2.1.6.1 Tie-Breaker Configuration and Operation

All the load centers fed from switchgear M1, whether from Bus A or from Bus B (M1-A and M1-B in Figure 2-2), have two independent feeder circuits. Those two feeds are meant to be used in a split-bus configuration (except where there is a single substation transformer), in which the two feeds come into two mains, and the bus tie breaker is normally open. Load Center S2, which supports the Effluent Pumping Station, is also configured in this manner. This setup reduces the immediate impact of an outage, since in the event of an outage on one side of the switchgear, loads can still be satisfied. It allows loads on one half of the bus to be satisfied even if an outage were to occur on to either side. It also provides some level of redundancy and resilience in the event of an outage, as half the loads would be active on one half of the bus even if an outage were to occur on either side of the M1 Switchgear.

However, downstream of switchgear M1, the system lacks the ability to automatically close the tie breaker for bus A and bus B. This could leave critical loads without power until staff could assess and manually operate the tie breaker. Doing so requires significant expertise. Potential to modernize the existing MCC's downstream with Main-Open Tie-Main automatic transfer functionality exists and would greatly increase the resilience of key facilities without operator intervention. Below are examples list in Table 2-2 of locations that could potentially benefit from Main-Open Tie-Main auto transfer configurations.

Table 2-2: Load Center Auto Transfer Tie Breaker Candidates

Substation ID/MCC	Process Purpose	Current Configuration
U20, U21/P1, P2	Influent Pump Station	Backfeed, Kirk Key Interlock
S2, MCC P4	Effluent Pump Station	Backfeed, Kirk Key Interlock
U4, U5/P9, P10	Ops Building	Single Feed, No Interlock

A Kirk Key is a safety mechanism to prevent simultaneous operation of multiple circuit breakers. It involves a key that locks or unlocks specific breakers to ensure that only one source can feed the load at a time.

Finding F-5: Lack of automatic controls for motor control center tie-breakers in specific areas will increase recovery times in the event of an outage.

2.1.6.2 Low Voltage Wiring

Discussions with operations staff and review of documentation indicate that some process trains are not fully functional during a partial power outage because their supplemental devices are wired to a different power source or bus than the bus that has available power. For example, the S1 Load Center, which supports the Influent Pumping Station, is fed from bus A and B of M1 Switchgear with a tie-breaker connecting both buses. The main breaker connected to the B bus is normally closed with the A bus main breaker normally open and the bus tie breaker normally closed. This is not a typical configuration for most plant systems when both A bus and B bus feeders are reliable. This is due to a commingling of power circuits within the IPS. In the case of an outage in one side of the M1 Switchgear, it is possible for pumps on one side of the S1 Switchgear to be energized but nonfunctional due to a lack of power to the ancillary devices.

Finding F-5: Some major equipment processes have supplemental devices that are not wired to the correct power bus (A or B) by which reliance on both sides of a dual-power system increases the risk of a process, or components of a process, going offline.

2.1.6.3 Reliability of Key Components

W&C observed that many components, while performing well, are obsolete. For example, the downstream switchgear at S1 and S2 are old 1980s vintage General Electric PowerVac equipment, which utilize induction disk protection relays. These pieces of switchgear are considered obsolete, although induction disk relay technology is still reliable if maintained properly. This switchgear will be replaced as part of the IPS Modifications Project.

Finding F-5: Aging equipment poses a high maintenance burden on staff to maintain adequate reliability and obtain spare parts.

2.1.6.4 Redundancy of Key Components

At many of the most critical unit processes, dual feeds are provided; each with its own transformer. This arrangement provides full redundancy in the event of an up-stream failure. Each feed and transformer is sized for the full load of the equipment; however, some motor control centers at the MWWTP are equipped with only a single feed and/or single transformer. As a result, the failure of either the feed or transformer would result in a power loss to the entire area of the MWWTP served by that transformer. Additionally, maintenance on the transformer is complicated by the need to provide temporary power during the maintenance activity. Examples of this arrangement include the Digester gas conditioning system, as well as the Digester Building. Table2-3 below indicates the substations that do not provide full redundancy:

Table 2-3: Substations without Full Redundancy

Substation No.	Process
U22	Mid-Plant
U16	Digesters
U1	Aerated Grit
U13	Solid/Liquid Receiving Station

Finding F-5: Lack of equipment redundancy at key locations increases the risk of a process shutdown and increases the difficulty of performing maintenance.

2.1.7 Power System Controls

The MWWTP power system employs a Schweitzer Engineering Laboratories (SEL) POWERMAX power management and control system (PMCS) that offers remote control of all MV breakers from a human machine interface (HMI). This system was installed around 2010 and updated in 2021. The POWERMAX system includes adaptive high-speed load shedding and generation shedding to preserve on-site generation during loss of utility. The POWERMAX system leverages the protective relays that are necessary for generator/bus/feeder protection and power quality meters to obtain real-time breaker status, alarms, event reports, sequential event reports (SER), and metering. This data is streamed to the Emerson Ovation Distributed Control System (DCS) and historized in the OSIsoft PI database. The POWERMAX system includes auto-synchronization to connect back when utility is restored. Lastly, the POWERMAX system includes an automatic switching system at Switchgear M1 that will open an M1 main breaker upon loss of source and close the M1 tie breaker to restore power to all process substation loads. The existing prioritization of loads is shown in Table 2-4 below:

Table 2-4: Existing Load Priority for SEL POWERMAX Control System

Priority	Breakers	Substation	Process Area
1	103, 203	S1	Influent Pump Station
2	104, 204	S2	Effluent Pump Station
3	110B, 210B	U13	Digester
4	109B, 209B	U10/U11	Oxygen Production Plant
5	108B, 208B	U4/U5/U12/U16	Operations Center, Lab, Admin Bldg, Digesters
6	108A, 208A	U6/U7	North Reactor Deck
7	106B, 206B	U8/U9	South Reactor Deck
8	106A, 206A	S3	Oxygen Compressors
9	105B, 205B	U3	Process Water (3W)
10	109A, 209A	U14/U15	Sludge Dewatering/Thickening
11	105A, 205A	U1	Grit Handling
12	110A, 210A	U22	Mid Plant

The POWERMAX system was installed in response to the December 2005 plantwide blackout event. The POWERMAX system is designed to be continuously enabled to instantly respond to the loss of a power source by shedding loads as needed to balance loads with supply, and routing power to critical loads. For example, if line power is lost, the system is designed to automatically separate from line power and run as two islanded power systems: 1) A-Bus or PGS2 Turbine Island, and 2) B-Bus or PGS1 Engine Island. Upon restoration of utility power, the POWERMAX system, if enabled, would auto-synchronize the islands back to line power without de-energizing any generator.

When the POWERMAX system is turned off, load shedding and islanding do not work, and loss of a single utility feed could result in a plant-wide power outage and a need to black-start power generation.

Based on conversations with District operations they prefer to leave the POWERMAX system disabled (turned off) because of the cross mixing or comingling of low voltage wires between the major equipment and their supplemental components. For example, when POWERMAX is enabled and line L and C is not available, the load shed controls will shed loads as necessary to maintain the priority loads as indicated in Table 2-2. The IPS pump motors require 3W for the pump seals to maintain the pump motor temperature. The 3W system is fed from Substation U3 which is further down in the priority list. If U3 does not have power, then the seal water system is not working and the pumps will not start or if they are running, will shut down. Other similar wiring issues or load shed priority inconsistencies were noted, such as the Cryogenic Plant should be moved up higher on the load shed priority list. A power shutdown to EPS creates a channel backup and over-chlorination then occurs. Adding more controls to the low voltage systems for specific processes will make the control system more complex. Consideration should be made to alignment of process trains and their ancillary systems, with high priority on load shedding schemes in coordination with power system controls.

Finding F-4: The routine disabling of automated load-shedding systems increases the risk of full-plant power outages.

2.1.8 Power Generation and Fueling

The MWWTP includes on-site power generation stations: PGS-1 is an older station with three multi-fuel engines, and PGS-2 has a single turbine; the topology and capacities of the stations are shown in Figure 2-2.

During normal operation, one or two of the 2.15 MW engines at PGS-1 run to offset the power demand from the electrical utility services. At any given time, one of the three engines is down for maintenance.

PGS-2, with its single turbine, produces about 4.5 MW of energy, so typically, the MWWTP has approximately 9 MW of gross on-site power generation capability. While this capacity is not sufficient to power the MWWTP during peak flow events (10.65MW as indicated in Section 2.1.2), it is more than sufficient to power the MWWTP during dry season average flows, where the power demand is approximately 4.5 MW. PGS-2 requires significant maintenance and lacks internal redundancy, so the 9 MW of power generation capability is not viewed as a firm or reliable capacity.

During prior blackouts (i.e., loss of line power), the turbine and generators will typically trip due to under- or over-voltage. To restore operation of this equipment, District operations staff will manually re-start the turbine and generators. Due to the fact that the MWWTP does not have sufficient storage capacity for biogas that is constantly being produced by the wastewater treatment process, operators must first flare off any excess biogas to reduce pressure prior to starting the turbine or engines. It was noted during a workshop meeting that the older flare system does not function properly, and the newer flare has limited operation. Depending on available biogas and demand needs during blackout, starting the turbine or engines could take anywhere from 30 mins up to 6 hours. Furthermore, it was noted that two operators are preferred during a blackout start; however, depending on staffing levels there might be only one PGS operator available.

Finding F-6: Lack of capacity for biogas storage requires operators to flare off gas after an unplanned outage of the power generation stations, resulting in delays in restoring power during an outage.

2.1.9 Communications During a Direct Trip Transfer (DTT)

When PG&E wants to isolate the MWWTP power (line L and C) from their grid (because of a line issue upstream), they send a signal to DTT the main breakers at H1. A DTT from PG&E triggers a lockout relay to trip the H1 main breakers that require a manual reset by District staff. Prior to the reset, the District staff must contact PG&E to confirm it is okay and safe to come back online. The purpose of the DTT is to ensure the H1 breakers trip when PG&E trips so that District staff cannot inadvertently back feed PG&E and create a hazardous condition for a Lineman.

Contacting PG&E using the “877” number can sometimes take extra time. When calling the 877 number, District staff would have to listen to the machine and follow instructions to press additional number(s) to reach the appropriate group. District staff is concerned that when a live person is not reached, they may not immediately be given a DTT clear/reset. Also, a recent email received from PG&E states that when PG&E receives a call from District staff, PG&E will send out their telephone technician to the substation to confirm the DTT trip is not a nuisance phone trip. The District is concerned that this PG&E procedure will delay the process of power restoration and will not work effectively for EBMUD.

District staff had a meeting with PG&E in April 2023 to determine how to improve communications and decrease the amount of time necessary to bring the plant back online. PG&E is going to provide a procedure to the District that is agreed upon by both parties to try and minimize time it takes to reset the H1 breakers.

During the outage that occurred on March 21, 2023, it took over an hour to bring the plant back online. Additionally, District staff was unable to reset the lockout relay (after approval from PG&E) and had to contact District Engineering Staff to come and help reset the lockout relay. This process took longer than anticipated due to lack of PG&E direct contact person during a DTT and lack of training District staff to execute the procedure of bringing the plant back online efficiently.

Finding F-6: Lack of PG&E direct contact person and staff not appropriately trained for bringing the plant back online after a DTT has increased the amount of time necessary to bring restore utility power to the plant.

3. ANALYSIS AND CONCLUSION

This section first analyses the risk posed to plant operations caused by power outages of various duration, based on the relative importance of different unit processes and their power requirements.

The risk analysis is then supplemented with a consideration of "Time To Impact" or TTI, which is an estimate of the time with limited power before critical plant operations are impacted. The TTI analysis can provide insight into the ability of the MWWTP to function during a blackout if onsite generation can be maintained during the blackout.

The analysis concludes with a discussion of key considerations that impact the plant's ability to function. These considerations flow directly from the findings presented in Section 2, with an emphasis on findings based on the degree of risk they pose to plant operations.

3.1 Risk Analysis

3.1.1 Risk Criteria

The Consequence of Failure (CoF) analysis included in this study is intended to provide a high-level analysis of the existing infrastructure at the MWWTP. This project does not include a condition assessment or Likelihood of Failure analysis. In its evaluation of the criticality of the various components of electrical infrastructure, W&C first considered any safety concerns related to various equipment on site. Failure of any equipment that increases the possibility of injury to staff was most critical. Beyond safety concerns, the next highest priority was continued compliance with the MWWTP's discharge permit – any equipment failure which would result in the release of untreated, or partially treated wastewater was considered highest priority. Finally, equipment which is required for typical daily operations, but is not required for treatment or restoration of operations after a loss of power was considered the lowest priority.

The "time to impact (TTI)" analysis presented below builds upon these initial rankings by also including the time component in the analysis. Depending on process layout, redundancy, and other factors, certain treatment processes at the MWWTP can withstand power interruption for longer than other processes before serious consequences ensue. Although all equipment at the MWWTP serves a purpose and would eventually cause impacts if without power for an extended period (greater than 1 day), some processes can be lost for a period of several hours without major impacts, while other areas of the facility see impacts almost immediately (less than 1 hour) upon loss of power. Given that many utility outages are of limited duration, TTI is a useful concept to provide insight into the viability of different options for risk reduction.

3.1.2 Consequence of Failure (CoF) Rankings

The scope of work for this project included development of Consequence of Failure (CoF) rankings for the electrical system components at the MWWTP. These rankings are used to determine the most critical electrical equipment associated with the most critical processes at the MWWTP and to prioritize them based on the analysis. During the information gathering stage of the project, EBMUD project management team identified a previous Consequence of Failure Analysis which was performed in 2017 as part of a facility-wide study of seismic vulnerabilities and recommended that W&C review and compare this data with the risk analysis. The analysis done by W&C used these seismic study CoF rankings and supplemented them with the TTI analysis to reflect the differing time scales between seismic damage restoration versus restoration of line power after a blackout.

The CoF rankings from the EBMUD seismic study have been summarized and are presented below Table 3-1. While these rankings largely mirror the existing rankings of the existing load shedding program, there are some differences. Where "tie" is indicated, they match the existing load shedding priority list.

Table 3-1: Summary of CoF Rankings from Seismic Study

Priority	Substation	Process Area
1 (tie)	S1	Influent Pump Station
1 (tie)	U16	Digester 9-12, Feed System
1 (tie)	U14/U15	Sludge Dewatering Building, Sludge Thickening
4 (tie)	U6/U7	North Reactor Deck
4 (tie)	U8/U9	South Reactor Deck
6 (tie)	U4/U5	Grit Building, Operations Center
6 (tie)	U28	PGS1, Hypochlorite Area
6 (tie)	U29/U30	PGS2
9	U3	Process Water (3W)
10	U13	Digester Building
11	S2	Effluent Pump Station
12	EF4	Maintenance Building
13	U12	Lab/Admin Area, Digesters
14	E19	Substation at Dechlorination
15	U1	Aerated Grit

Both the load shedding program and the seismic study CoF analysis have the IPS & Reactor Decks as high priority areas, the Process Water (3W) as a medium priority, and Aerated Grit as a low priority. There are significant differences in rankings of other areas, such as the sludge dewatering area, and the Effluent Pump Station. Another major finding (not summarized in the table above) is that the 2017 seismic analysis did not differentiate between the Oxygen Production Facility (substation U10/U11) and the Oxygen Facility Compressors (substation S3). The oxygen facility compressors have the highest peak electrical demand of any substation at the MWWTP, and therefore should be considered separately from the relatively small load associated with the remainder of the facility.

To further evaluate the rankings, W&C reviewed the PI data to identify the relative size of each load that is connected to M1. This will allow consideration of the demand in comparison to the load shed rankings. If alternative methods of operation could re-rank significant loads to lower priority of the load shedding program, it would be a benefit to the District by allowing significant power loads to be shifted to other areas of the facility in order to match the available power. The results of this review are presented in Figure 3-1 and Figure 3-2 below for both maximum and average demand based on the PI data provided:

Figure 3-1: Load Percentage Maximum

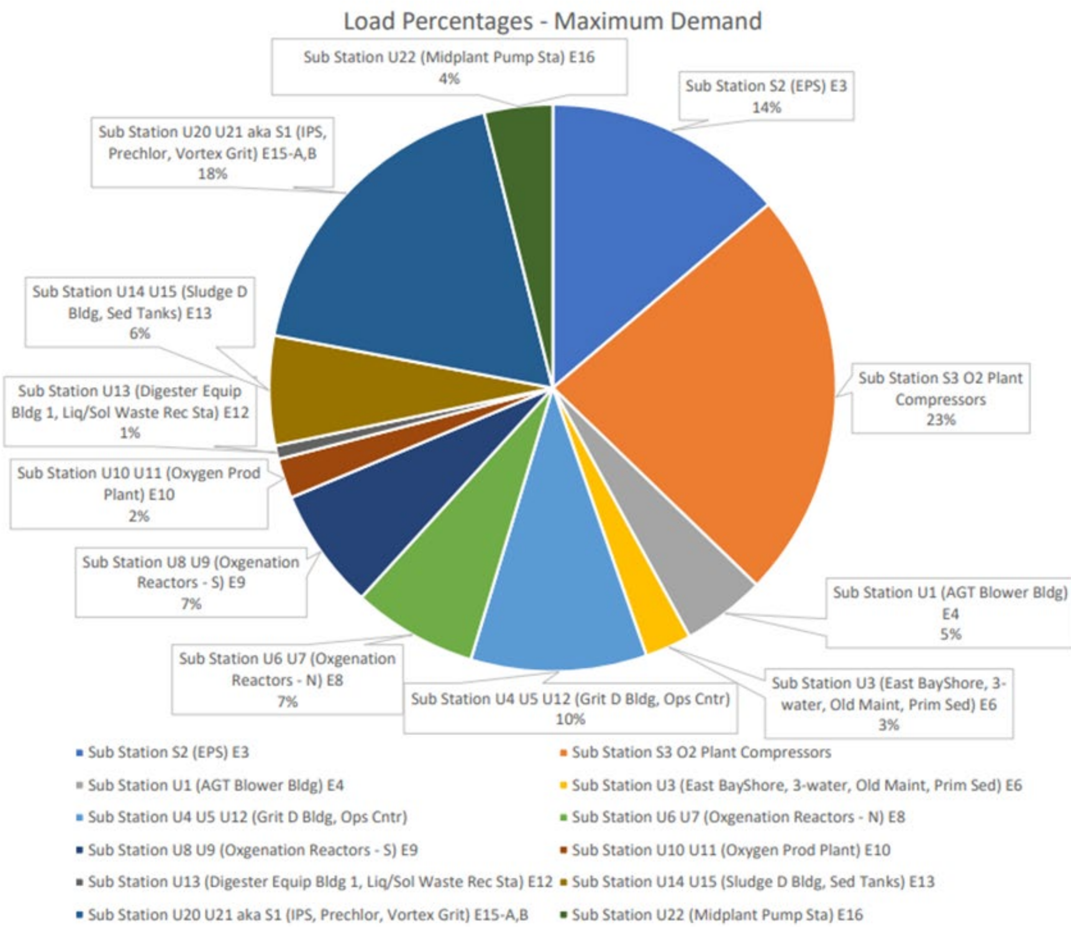
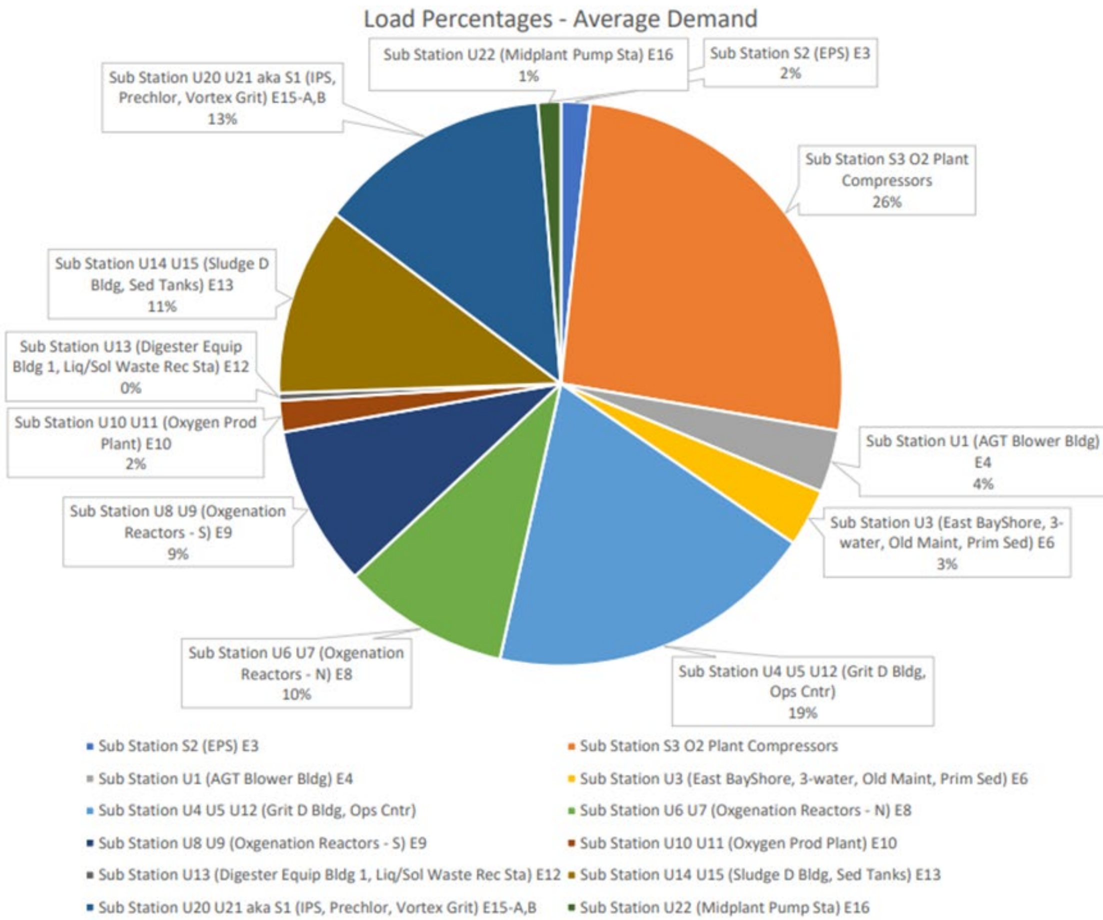


Figure 3-2: Load Percentage Average



As shown in Figure 3-1, Substation S1, which includes the IPS, is a significant portion of the overall facility demand (18% at peak, and 13% on average). W&C has concluded that this load is critical to the overall operation of the facility, so the IPS should be continued as a high priority.

These data, along with discussions with District staff, allowed us to perform the "Time to Impact" analysis to determine how long a process could be without power before impacting the process as described in the next Section.

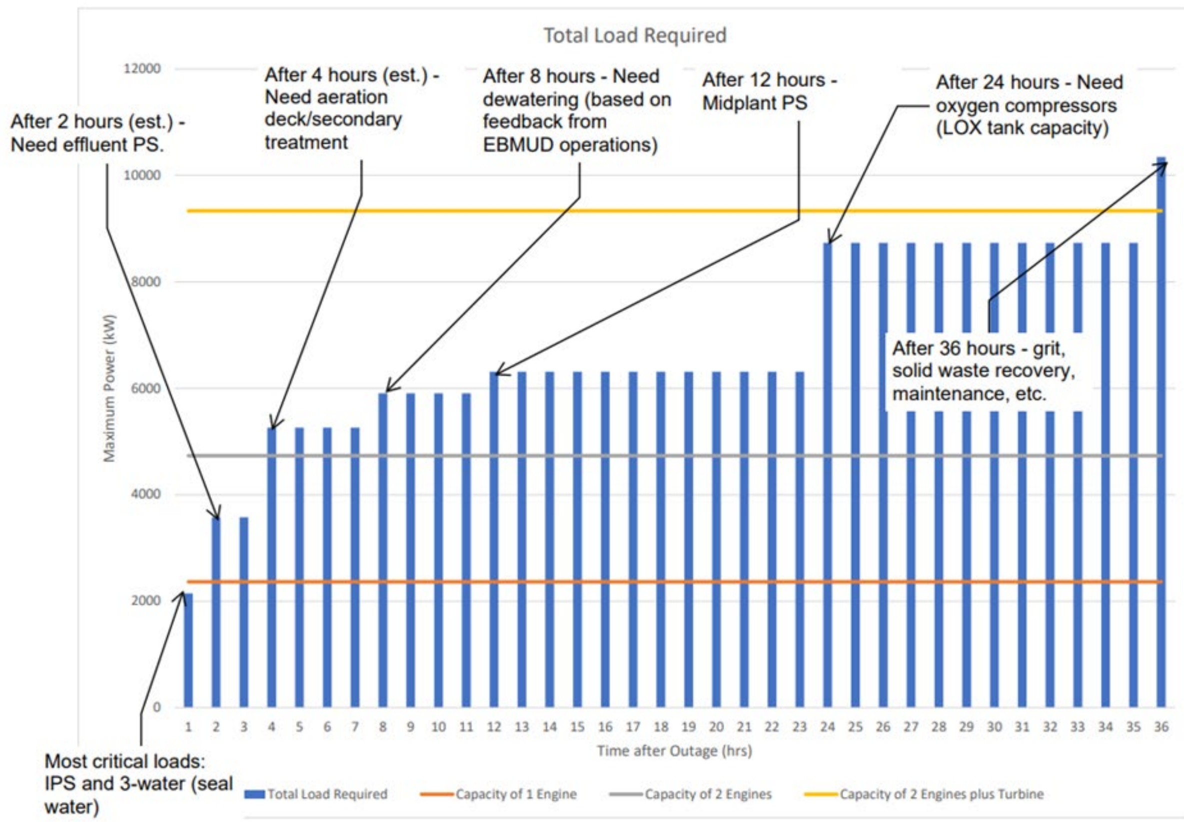
3.2 Time to Impact (TTI) Analysis

Using the historical electrical usage data (maximum draw, average draw) provided by EBMUD, W&C developed figures showing the required power at the MWWTP as a function of time after loss of utility power or the PGS's. This can be used to prioritize various substations for restoration of power. Figure 3-4 also shows the same impacts, but during average flow and power consumption conditions.

3.2.1 Maximum Load Conditions

Figure 3-3 shows impacts based on maximum historical loads and correlates to a wet weather/high flow event. The graphic shown below also depicts the ***most impactful consequence of failure to the least impactful consequence based on time*** without an available power source.

Figure 3-3: Time to Impact Under Maximum Load Conditions



As indicated in the figure, The TTI analysis for maximum loads shows that the MWWTP should be able to provide power to its most critical loads (IPS, EPS) for approximately three hours if two of the three on-site engine generators are operating. If the turbine is also operating, the facility should be able to prioritize loads to the most critical and operate with minimal process impacts for up to 36 hours. This analysis assumes that there is no loss in turbine or engine service upon loss of utility power; that assumption is more likely to be borne out if the POWERMAX system is enabled at the time of the outage. If the POWERMAX system is not enabled, then both the turbine and engines will go offline and will have to be black started within one hour before impacting the IPS facility and the remainder of the plant.

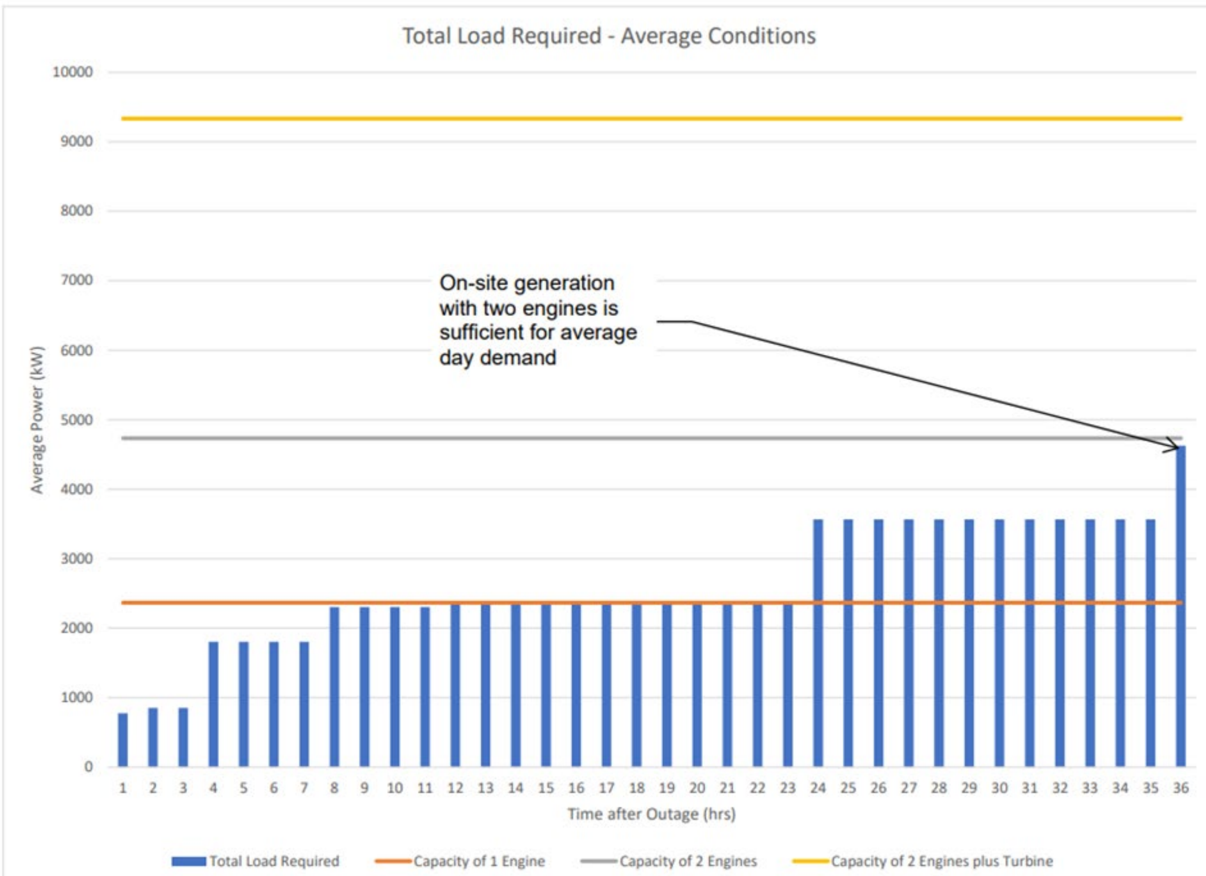
3.2.2 Normal Load Conditions

Figure 3-4 shows TTI under normal, i.e., average, load conditions.

As shown in Figure 3-4 below, two of the three generators at PGS-1 can provide all of the power needed to operate the MWWTP, even if PGS-2 (the turbine) is out of service. As for the maximum-load scenario, this analysis assumes that the POWERMAX system is enabled to prevent shutdown of the PGS upon loss of utility power.

The sufficiency of onsite generation is consistent with PI data, which show that under normal conditions the MWWTP is normally exporting power.

Figure 3-4: Time to Impact Average



The figure also shows that even one engine can stave off impacts for up to 23 hours.

3.3 Conclusions

This section presents several conclusions that synthesize the Findings in Section 2 considering the analyses presented earlier in the Executive Summary.

C-1 Existing Utility Feeds Are Not a Reliable Power Source

As outlined in Section 2, the existing utility lines C and L suffer from a host of problems:

- Neither service has sufficient capacity to power the entire MWWTP. As a result, the facility uses dual feeds, which complicates operations during the loss of a single feed. Although the automatic tie-breaker at the incoming switchgear M1 allows continuity of power for average loads during the dry season, if one line is lost and power demand exceeds the capacity of the remaining feed, the tie-breaker position will not prevent further loss of power to the facility.

- The two lines as routed are vulnerable to common-cause failure since they share at least one vault, duct bank, and possible aerial route.
- The physical routing of the incoming feeds exposes them to multiple hazards, including vehicular damage or high wind damage to the overhead section, and impaired access for maintenance or repair along much of the alignment.
- Reliability of power provided by PG&E has been limited in the past and is likely to deteriorate further as demand for electricity increases, while threats to reliability such as wildfire continue.
- Communications with, and responsiveness of PG&E during an outage event has proven to be a challenge including confirmation of existing underground and overhead locations.

C-2 The PGS's As Currently Configured Do Not Provide a Reliable Backup to Line Power

PGS-2 has several characteristics that make it an unsuitable source of backup power:

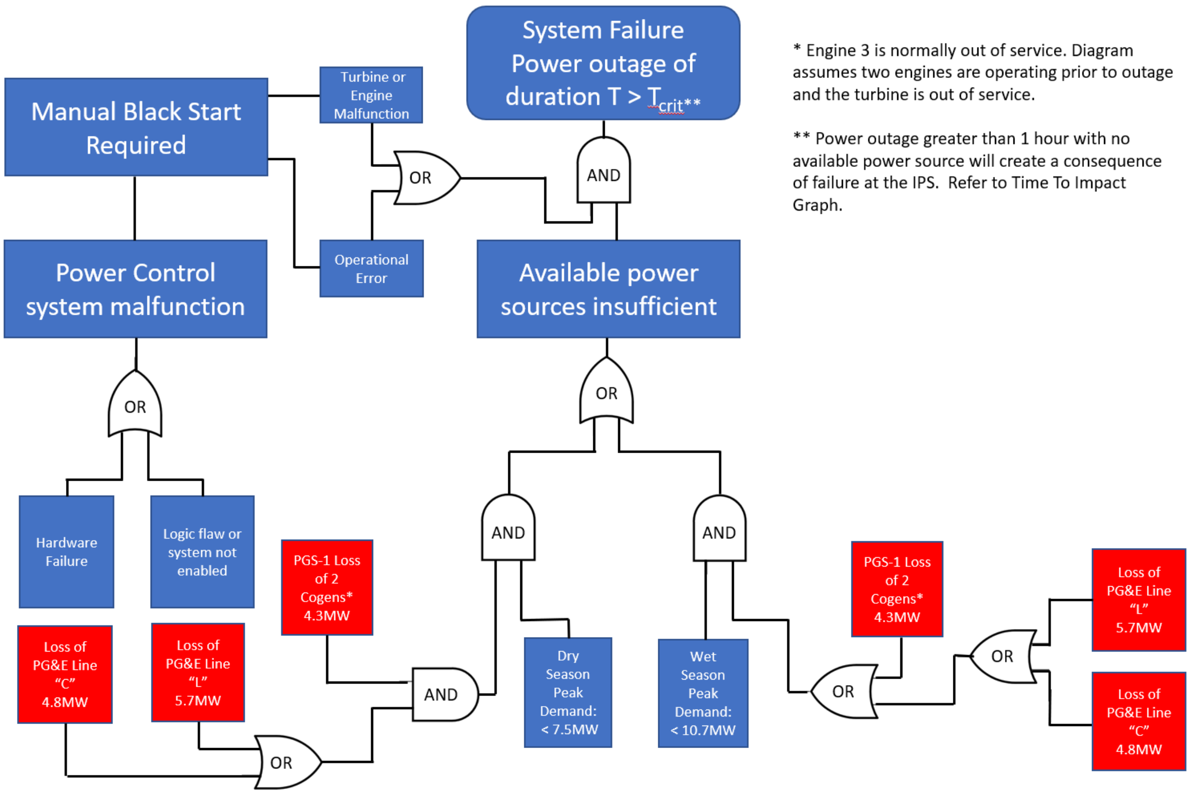
- With only a single turbine the station lacks internal redundancy
- The PGS is prone to extensive maintenance outages.
- The PGS has minimum time-to-restart criteria that impinge on its utility as a backup power source. PGS-1, with three conventional multi-fuel engines, is more robust. However, the PGS still cannot be considered an adequate backup power supply, for two key reasons:
- The plant (with two of three engines running) is inadequate to meet maximum loads for an extended period.
- The plant is currently configured to shut down on loss of line power, and its restart is a lengthy process.

C-3 Enablement of the POWERMAX system would reduce risk

The rationale for POWERMAX being disabled is that, if enabled, the system might cut power to critical unit processes as part of its load shedding, because some key power feeds are "commingled." For example, a unit process might be prioritized to remain online during load-shedding, but its control system power might have been inadvertently wired to a power source that was not prioritized by the POWERMAX system.

While this is a valid concern, on balance W&C believes that overall risk could be lowered by enabling POWERMAX. Figure 3-5 illustrates the factors that can contribute to extended downtime of the IPS due to power loss. This diagram uses Boolean logic to indicate scenarios that when combined result in the IPS going offline. As noted in the diagram, whether the load shedding program is activated or not is a key contributor to the MWWTP's ability to withstand the loss of both PG&E circuits.

Figure 3-5: Risk Analysis Diagram



* Engine 3 is normally out of service. Diagram assumes two engines are operating prior to outage and the turbine is out of service.

** Power outage greater than 1 hour with no available power source will create a consequence of failure at the IPS. Refer to Time To Impact Graph.

Enabling POWERMAX absent other actions would create a new risk, that of POWERMAX cutting power to a load that was intended to be prioritized to remain online, due to the commingling of wiring problem discussed above. This risk could be mitigated by implementing one or more of these actions, which are further outlined in the Recommendations section:

- In the short to medium term, by adding local UPS's for key control systems that are fed by commingled power sources
- In the longer-term, eliminating commingled power feeds to promote more effective load shedding
- Training staff in the use and limitations of POWERMAX to maximize its potential value by reducing risk

4. RECOMMENDATIONS

The recommendations in this section are relatively general in nature and will be further examined by W&C in the Alternative Analysis TM 2. Some of the recommendations, such as consideration of new line power feeds, will be subject to alternatives analysis to identify a specific scope that addresses the findings of this TM, and also aligns with EBMUD's long-term electrical roadmap.

4.1 Summary of Recommendations

The recommendations are also listed in the Executive Summary and briefly described below:

1. **Recommendation R-1:** *Replace PG&E line circuits L and C with circuits that each have a minimum capacity of 12MW.* The reliability and available capacity of the existing PG&E circuits has been identified as a major vulnerability for EBMUD. While additional onsite generation could also in theory address the need for higher-reliability power, new power feeds appear to be more responsive to EBMUD's needs given that they are not only unreliable but undersized.

2. **Recommendation R-2:** *Enable the SEL POWERMAX system to maintain operation of PGS's during utility outages, thus reducing the risk of cascading failures, and avoiding the need for manual black start of the turbine and engines.* It is recognized that enabling POWERMAX, absent other measures, would create a new risk due to the current issue of commingling of power sources as discussed in Finding F-5. Therefore, implementing this recommendation should be done in concert with other recommendations described below which are aimed at mitigating the problem of commingled power feeds.

3. **Recommendation R-3:** *Correct or consolidate low voltage wiring systems that are commingled between the different power buses (A versus B).* For the near term, consider local UPS's to provide short-term mitigation of commingled power systems, i.e., situations where critical control signals for a unit process are fed on a different bus as power for the unit process, thus undermining automatic load shedding. In the long term, consolidate power feeds for each unit process so that specific unit processes can be prioritized by the POWERMAX system without fear that power for a critical system is intertwined with the power for a less-critical system that is the target of load shedding.

4. **Recommendation R-4:** *Revise load shed priority list based on CoF rankings, TTI and revised wiring configurations as recommended in R-3.* It was found in this analysis that some process systems should be moved up in the priority list because of their association with critical equipment that if not operating creates a chain of events that ultimately shutdowns an entire process. Ancillary systems that support critical equipment will be moved up in their rankings in the load shed priority list. Other process systems will be looked at more closely and considered for higher priority listing during the next phase of work.

5 **Recommendation R-5:** *Improve restoration of power processes by modifying operational procedures and develop a PG&E approved communication protocol when a DTT occurs. Provide training that is focused on restoring power to the plant safely and more efficiently.* The District has recently discussed with PG&E to develop a protocol that both entities could agree upon to increase the time it takes to restore power to the plant. This includes identifying who the point of contact at PG&E would be

versus an automated calling center with longer wait times. Additionally, District staff should align their SOP with PG&E to improve communications during a DTT and determine appropriate qualified District staff for "On Call" duty during off hours and weekends.

6. **Recommendation R-6:** *Modify infrastructure and process systems to improve redundancy including the addition of equipment (substations, biogas storage, etc.) and replacement of aging equipment to increase reliability. Replace systems that are in areas (below grade) to above grade to increase safety and reduce downtime during replacement of damaged equipment.* W&C will evaluate equipment replacement and alternatives in more detail in the next phase of work, TM2 - Alternatives Analysis.

Next Steps

Based on the research performed to date and the findings presented in this TM, we have begun work on the next phase of this project – Alternatives Analysis. In this phase, we will identify specific projects which could potentially be undertaken by EBMUD to improve the resiliency of the electrical infrastructure at the MWWTP. The projects presented will be evaluated on the four Master Plan guiding principles: technical, environmental, social, and financial. Following preparation of the draft Technical Report #2, we will conduct a workshop with District staff to refine the evaluation of the potential alternatives, to develop a Road Map for EBMUD to implement, with the goal of improving the overall resiliency of the electrical infrastructure.

5. REFERENCES

EBMUD: Luong, Syndi. *Main Wastewater Treatment Plant Load Study*. Study. Oakland, 2020.

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USEPA. "EPA-430-99-74-001, Design Criteria for Mechanical, Electric, and Fluid Systems Component Reliability for Wastewater Treatment Facilities." 1999.

6. ABBREVIATIONS

MV: Medium Voltage (either 5kV or 15kV)

NC: Normally Closed

NO: Normally Open

PG&E: Pacific Gas & Electric

PGS: Power Generation Station

PI: Plant Information (OSIsoft PI database is the DCS historian. PI is used by EBMUD for data collected by the OSIsoft and sent to DCS.)

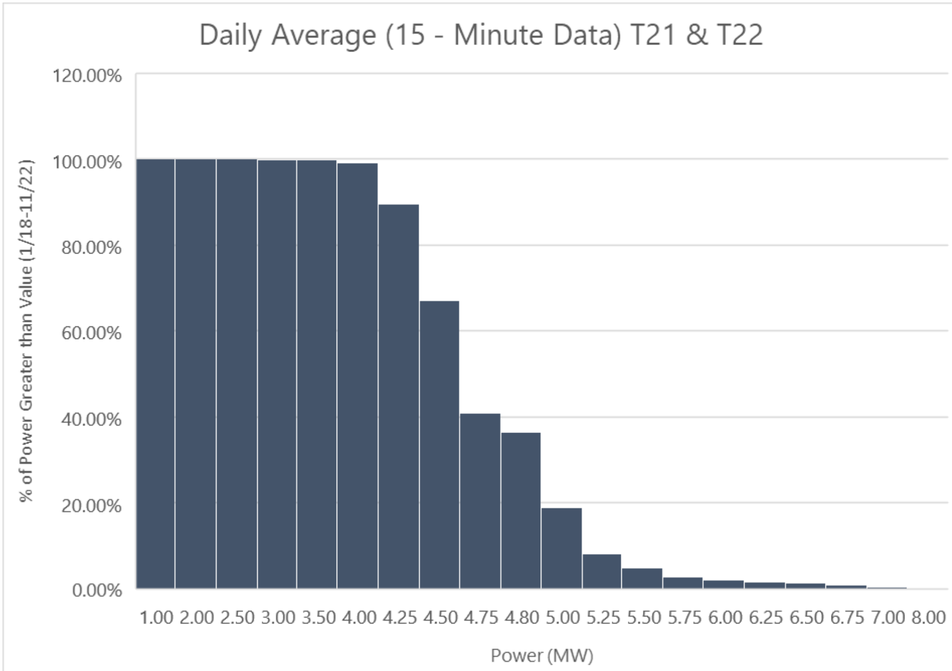
SOP: Standard Operating Procedure

APPENDIX A: HISTORICAL POWER CONSUMPTION

Appendix A: Historical Power Consumption

Demand Power (MW)	Percentage of Time Power Demand			
	Daily Average (15 Minute Data)	Daily Maximum (15 Minute Data)	Daily Overall (15 Minute Data)	Daily Average (Daily Data)
1.00	100.%	100%	100%	100%
2.00	100.%	100%	100%	100%
2.50	100.%	100%	100%	100%
3.00	99%	100%	100%	100%
3.50	99%	100%	100%	100%
4.00	99%	100%	98.%	99%
4.25	89%	99%	88%	89%
4.50	67%	89%	66%	67%
4.75	41%	66%	41%	41%
4.80	36%	62%	37%	36%
5.00	19%	44%	20%	19%
5.25	8%	24%	9%	8%
5.50	5%	13%	5%	5%
5.75	3%	8%	3%	3%
6.00	2%	5%	2%	2%
6.25	2%	4%	2%	2%
6.50	1%	3%	1%	1%
6.75	1%	2%	1%	1%
7.00	1%	2%	1%	1%
8.00	1%	1%	1%	1%

Daily Average (15 – Minute Data)



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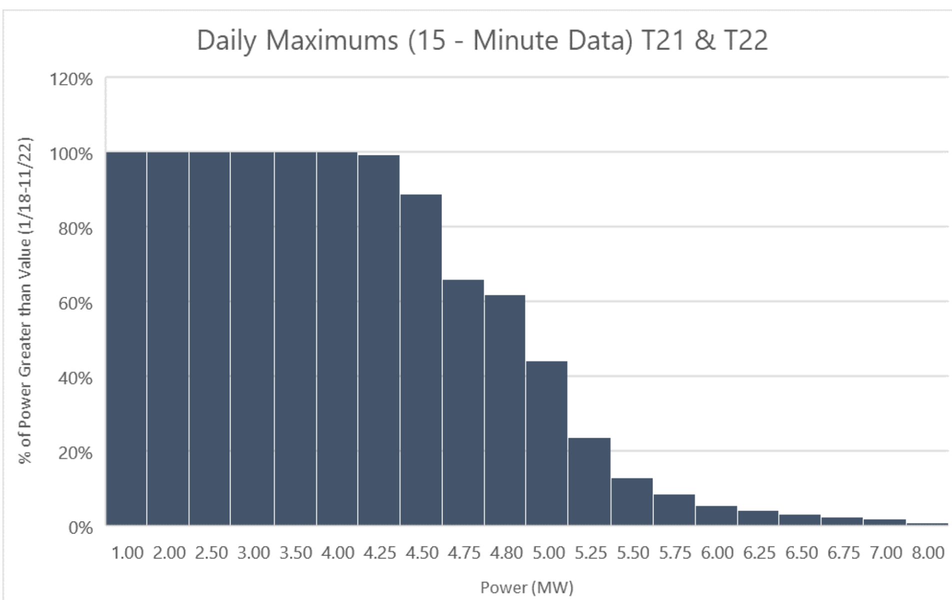

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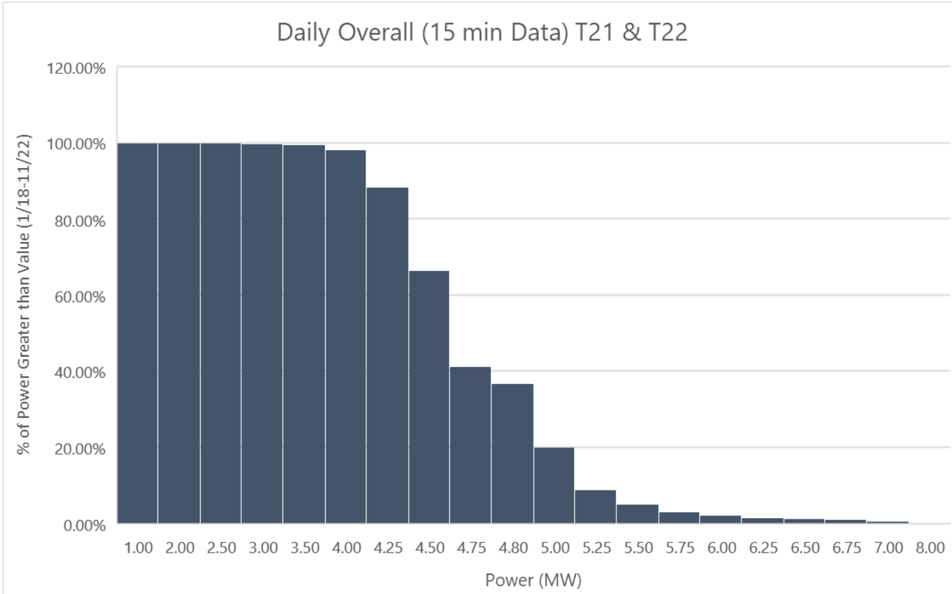

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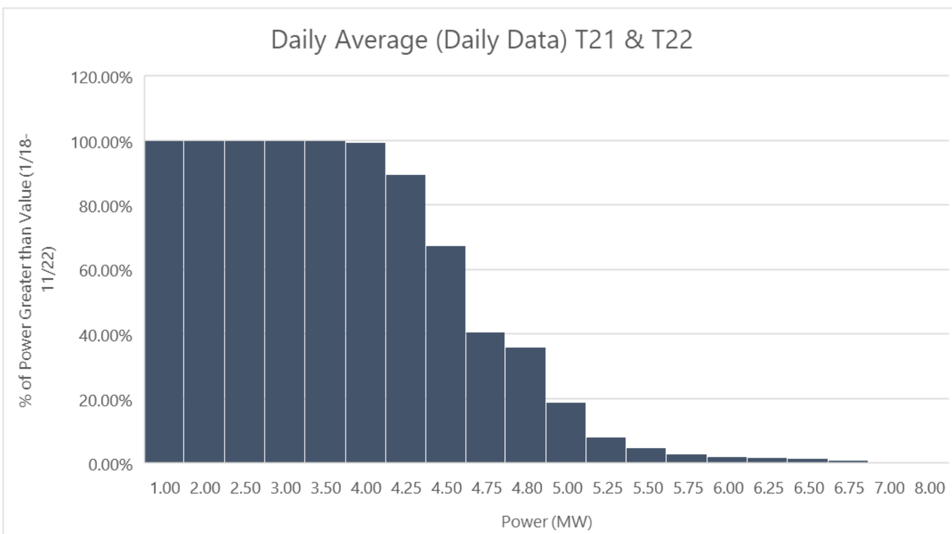
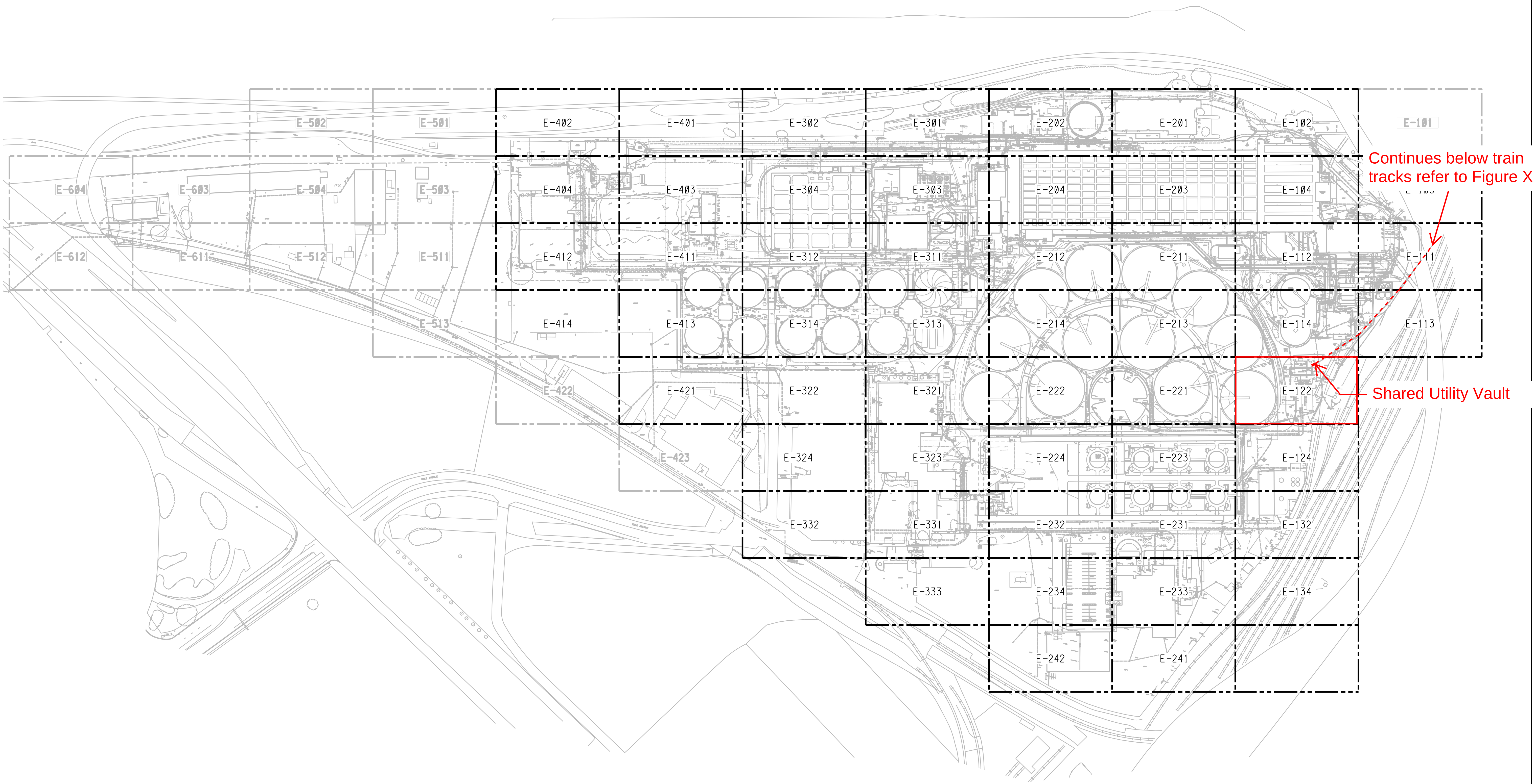


APPENDIX B: SITE PLANS



APPENDIX B-1

GENERAL NOTES

1. FOR CONDUIT SCHEDULES, SEE W21.00-E-800 SERIES DRAWINGS.

3" ON ORIGINAL DOCUMENT
0 1 2 3

NO.	DATE	REVISION	BY	REC.	APP.
1	20DEC2012	UPDATED EXST SITE & UNDERGROUND UTILTY DWG AND RENUMBERED 1"=10' SCALE DRAWINGS		MH	BL

DESIGN BY:	M. KAGUCHIA
DRAWN BY:	WASTEWATER DRAFTING
DESIGN CHECKED BY: R.P.E. No.	---
CONSTRUCTABILITY CHECKED BY:	---
ELECTRICAL CHECKED BY: R.P.E. No. E15544	MICHAEL T NAKAMURA
PROJECT ENGINEER R.P.E. No.	---
PROJECT MANAGER R.P.E. No.	---
RECOMMENDED: SR. ENGINEER R.P.E. No. E15544	MICHAEL T NAKAMURA

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND, CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT
UNDERGROUND UTILITY
ELECTRICAL
GENERAL SITE
KEY PLAN

SCALE 1"=125'
DATE 20SEP2010

W21.00-E-040
DRAWING NUMBER

REV. 1

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DATE: 27-DEC-2012 16:41
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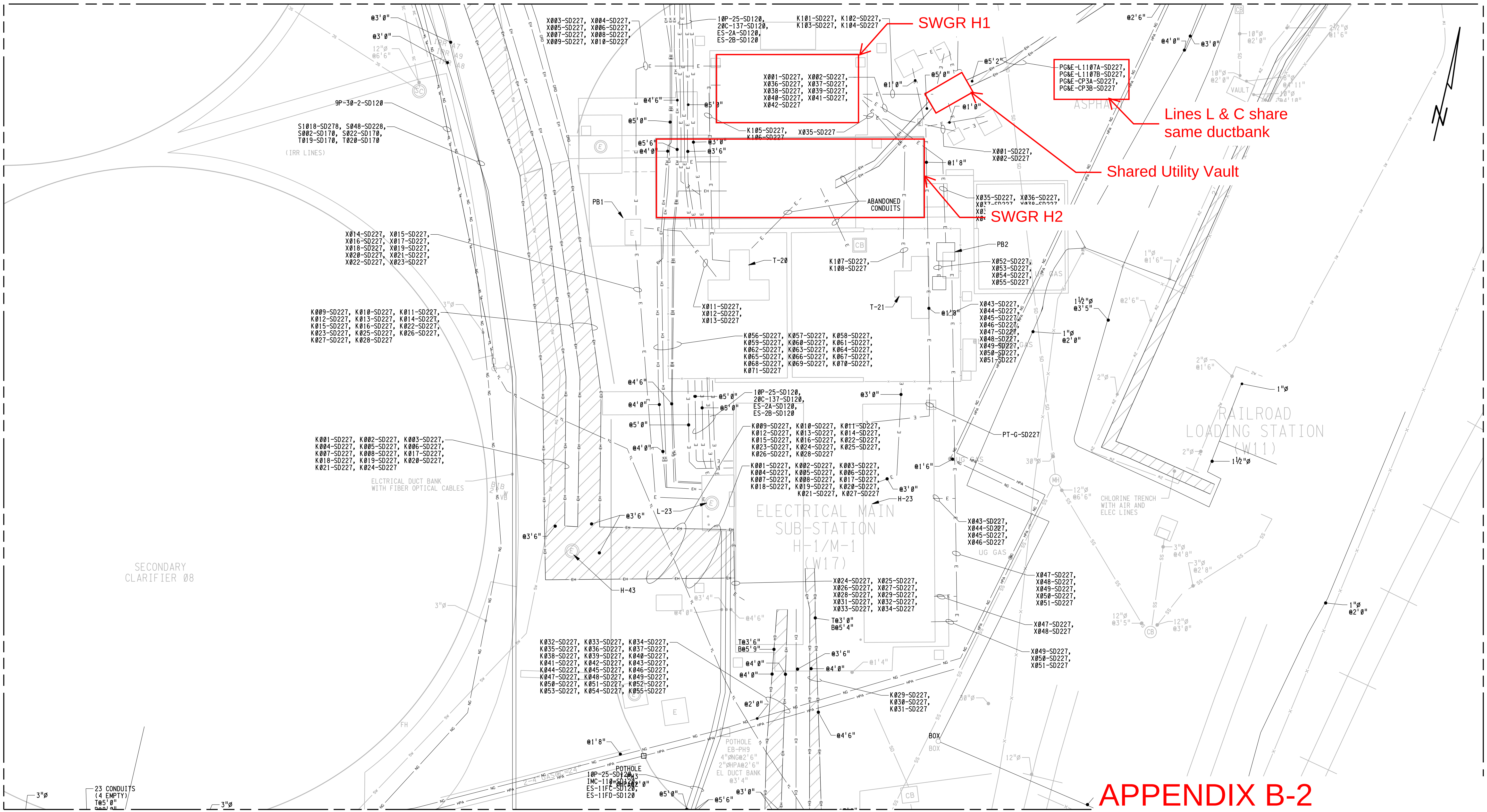
REF 9:

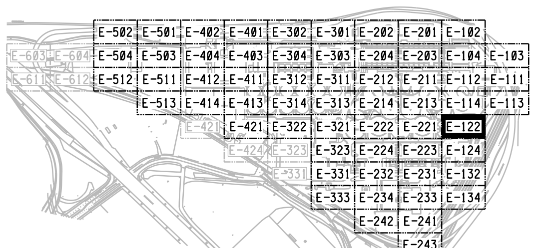
MATCHLINE SEE E-114



MATCHLINE SEE E-221

APPENDIX B-2

MATCHLINE SEE E-124



KEY PLAN

3" ON ORIGINAL DOCUMENT

SUPERSEDES: W21.00-E-121, REV0

A COPY OF THE ORIGINAL DRAWING CAN BE FOUND IN THE WASTEWATER DRAFTING UNIT

NO.	DATE	REVISION	BY	REC.	APP.
1	20DEC2012	UPDATED EXST SITE & UNDERGROUND UTILITY DWG AND RENUMBERED 1"=10' SCALE DRAWINGS	MW		

DESIGN	DESIGN BY:	M. KAGUCHIA
	DRAWN BY:	WASTEWATER DRAFTING
REVIEW	DESIGN CHECKED BY: R.P.E. No.	---
	CONSTRUCTABILITY CHECKED BY:	---
	ELECTRICAL CHECKED BY: R.P.E. No. E15544	MICHAEL NAKAMURA
	PROJECT ENGINEER R.P.E. No.	---
	PROJECT MANAGER R.P.E. No.	---
	RECOMMENDED: SR. ENGINEER R.P.E. No. E15544	MICHAEL NAKAMURA

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND, CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT
UNDERGROUND UTILITY
ELECTRICAL
PARTIAL SITE PLAN

SCALE 1"=10'
DATE 20SEP2010

W21.00-E-122
DRAWING NUMBER

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REV.

USER: amunoz
DATE: 27-DEC-2012 16:41
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PLOT SCALE: 20.000000:1

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& Curran

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APPENDIX B: TECHNICAL MEMORANDUM 2: ROAD MAP PROJECTS ALTERNATIVES ANALYSIS

WASTEWATER ELECTRICAL RESILIENCY MASTER PLAN

Task 3 – Technical Memorandum 2

Road Map Projects Alternatives Analysis

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012241.00

East Bay Municipal Utility District

August 2024

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EXECUTIVE SUMMARY

The East Bay Municipal Utility District (EBMUD) would like to improve electrical resiliency at the Main Wastewater Treatment Plant (MWWTP). EBMUD has contracted Woodard & Curran, Inc. (Woodard & Curran) to identify failure vulnerabilities and consequences, develop and evaluate alternatives to enhance resilience, and ultimately provide a roadmap to greater electrical resiliency. The first task of the study, to identify failure vulnerabilities and consequences, has been completed. Those findings are summarized in Technical Memorandum 1 (TM 1).

This TM focuses on the development and evaluation of Road Map Project alternatives that might resolve the vulnerabilities identified in TM 1, and applies insights gained in TM 1 as a basis for understanding. Road Map Projects are evaluated here using master planning criteria and are compared using qualitative rankings. Ultimately, the Projects evaluated in this TM will be packaged into a collection of recommended upgrades aimed at improving the EBMUD MWWTP electrical resiliency. Final recommendations will be presented in the next TM.

Purpose and Scope

This TM defines and evaluates projects that aim to resolve the electrical vulnerabilities previously identified. The projects are termed "Road Map Projects" to reflect the planning approach, which is one of phased, flexible implementation of potentially multiple projects over time. Following an introduction in Section 1, Section 2 identifies and defines the following master planning criteria that are used to evaluate each Road Map Project:

- Operational Simplicity
- Maintainability
- Cost-Effectiveness
- Reliability and Effectiveness
- Ease of Implementation
- Flexibility for Future Process Changes or Increased Demand
- Low Greenhouse Gas (GHG) Emissions

Section 3 develops a comprehensive project summary for each Project at the planning level and includes the following:

- Impacts to operations
- Work triggers and project alignment with the EBMUD Integrated Master Plan for the MWWTP
- Proposed project location
- Planning-level cost estimates are developed for each Project alternative.

Section 4 evaluates each Project presented in Section 3 using the criteria developed in Section 2. Any vulnerabilities identified in TM 1 that are resolved by the Projects are presented here. The Woodard &

Curran team evaluated the Projects on their performance relative to each criterion using a "high-neutral-low" basis. Woodard & Curran then assessed the Projects relative to other Road Map Projects evaluated within this memo. The most beneficial projects for EBMUD MWWTP will receive a majority of "high" ratings.

Section 5 presents interim conclusions based on the evaluations completed in this TM. This Section highlights trends and takeaways observed in the consideration of Road Map Projects.

In the next TM, Woodard & Curran will make final recommendations based on the evaluations developed in this TM.

Conclusions

Based on the Project evaluations undertaken in Section 4, Woodard & Curran has made several high-level conclusions:

- While being very flexible, the EBMUD electrical system is very complex, which hinders operability and maintainability, and increases the risk of unplanned downtime. The completion of multiple Road Map Projects will likely be required to simplify the system and introduce needed resiliency.
- Coupling short-term, targeted projects with larger scope upgrades may provide the most efficient path to improved reliability. Layering these projects together can also add resiliency.
    - Several short-term projects could provide outsize impacts to electrical resiliency at the EBMUD MWWTP. Projects that improve operability of the Power Generation Stations (PGS) systems during a utility power outage without compromising performance of critical treatment operations should be prioritized. While these projects by themselves would not provide full redundancy, they would reduce overall risk significantly and complement longer-term electrical upgrades.
    - Much of the system complexity stems from the fact that two utility feeds currently must be operable to meet peak power demand. EBMUD should give priority consideration to obtaining a utility feed that can meet peak demands by itself, in order to improve reliability and reduce complexity.
- While full power redundancy with a generator bank would provide value, it would pose high capital and operating costs. A smaller generator bank that powers the most important loads (i.e., IPS) would be less expensive and provide substantial benefit. That project could also be designed to permit future buildout to a full-plant backup should that be warranted in the future and allows the District time to further define backup power needs.
- Operator and staff training will be needed to support the existing electrical system and future upgrades to that system. An area of emphasis for training should be load shed controls and their critical importance to the resiliency of the plant. Because the MWWTP exports and imports power from multiple sources it functions as a Microgrid and has commensurate training needs. As utility grids become more unstable and the District continues to produce renewable energy, the value of this type of training will only increase. Specifically, additional periodic training in Standard Operating Procedures for "black starts" of the PGSs will help speed up the process of restoring power to the MWWTP and increase the knowledge base for new operators.

As mentioned, each Project has been singularly described and evaluated in this TM to provide a list of alternative Projects for consideration by the District. Because the electrical system is flexible and complex as indicated, looking at these alternative Projects discretely maybe not be the best approach and instead as alternative portfolios of Projects.

Cost Summary

The following Summary Table provides the cost for each Alternative Road Map Project. Refer to each individual Project description for more information and Appendix A for Project Cost Development Forms.

No.	Description	Cost
1	New Port of Oakland 12kV Connection	9,800,000
2	New PG&E 12kV Connection	12,300,000
3	New 115kV PG&E Connection	99,000,000
4	12MW Generator Bank	56,420,000
5	Generators Sized for IPS	23,000,000
6	POWERMAX System Upgrades	700,000
7	Best Practices	17,000,000

1. INTRODUCTION

This Section defines the purpose of the technical memorandum and describes its content and organization.

1.1 Purpose and Background

This alternatives analysis is prepared as a part of the Wastewater Electrical Resiliency Master Plan (WERMP) at East Bay Municipal Utility District (EBMUD) Main Wastewater Treatment Plant (MWWTP). The results of the risk analysis performed under Task 2 of the WERMP and summarized in TM 1 form the basis of understanding of the major systems being evaluated in this TM. The intent of this TM is to identify specific projects and evaluate those projects for master planning purposes to improve electrical resiliency at EBMUD's MWWTP.

This TM will:

- Briefly describe the recommendation identified in the TM 1 risk assessment,
- Identify Road Map Projects that address the recommended upgrades,
- Develop a planning-level cost estimate for each Road Map Project,
- Describe triggers for work and mechanisms for aligning each Road Map Project with the EBMUD Integrated Master Plan (May 2022)
- Establish ranking criteria for use in Road Map Project evaluation, and
- Rank the proposed Road Map Project alternatives using the established ranking system.

1.2 Memorandum Organization

- Section 1 – Introduces the intent and organization of this memorandum and describes the drivers of this analysis.
- Section 2– Develops the evaluation criteria which will be used to analyze Road Map Project alternatives.
- Section 3– Describes Road Map Project alternatives. Descriptions of the Road Map Projects include planning-level cost estimates, descriptions of work triggers and project alignment with the EBMUD Master Integration Plan, a proposed location for the Project, and a discussion of impacts to operations.
- Section 4– Evaluates Road Map Project alternatives using the Section 2 evaluation criteria.
- Section 5– Concludes the Road Map Projects alternatives analysis with a takeaway summary and highlights next steps to be addressed in TM 3.
- Section 6– Cites technical references leveraged for analyses presented herein.

1.3 Cost Estimates

Cost estimates have been developed in accordance with the Association for the Advancement of Cost Engineering (AACE) Cost Estimate Classification System Class 4 cost estimate. Consistent with a Class 4 cost estimate, costs are projected to be accurate within -15% to +50% of the total given.

Costs are developed based on the following and used for planning purposes:

- Raw equipment costs are based on budgetary quotes provided from vendors, recent quotes from similar projects or power utility company documentation provided to assist with new service and substation equipment. These costs are included for major equipment and systems only.
- Where applicable demolition work, civil, electrical, instrumentation, hazardous material and handling are included in the cost as a percentage of the raw equipment cost.
- Startup, construction sequencing, easements, general conditions, sales tax, and Contractor's O&P are a percentage of the construction cost.
- The total project cost includes planning, permitting, engineering and construction management and is a percentage of the construction cost.
- A 30% contingency is included for each project cost.

Refer to Appendix A for a breakdown of the major equipment and the percentages used for each project. Percentage of construction cost may vary depending on the type and complexity of the project.

2. EVALUATION CRITERIA

This Section develops the evaluation criteria used for evaluating the Road Map Project alternatives described in Sections 3 and 4 of this TM. The evaluation technique leveraged in this analysis is qualitative: benefits or performance improvements provided by Road Map Projects are considered relative to the existing process and evaluated to be "high," "neutral," or "low."

The analysis uses seven evaluation criteria to compare the Road Map Projects:

1. Operability: Increasing the resiliency and reliability of the power supply of the EBMUD MWWTP are the principal drivers for this analysis. EBMUD has identified operator experience and training as a challenge due to recent staff attrition. Therefore, the operational burden of each alternative must be considered. Projects which require significant operator commitment or have high operational complexity will be ranked lower than projects which require less active management by operations.

2. Maintainability: Reliable performance of process equipment requires routine maintenance. There is a driver to minimize additional burden on operators and maintenance staff for tasks such as equipment maintenance. Projects that accomplish resiliency goals without increasing maintenance burdens will be ranked higher than those that carry higher maintenance requirements.

3. Cost-Effectiveness: The relative cost of a project will be important in the evaluation of alternatives and in the development of the road map. Projects estimated with a higher relative cost will be ranked lower than more economical projects.

4. Reliability and Effectiveness: Vulnerabilities identified in TM 1 as part of the Consequence of Failure analysis were considered when developing the roadmap projects analyzed in this TM. The road map projects will be evaluated for both their effectiveness as well as their capacity to resolve the identified vulnerabilities.

5. Ease of Implementation: This criterion accounts for the complexity associated with developing operating agreements, acquiring property rights, and obtaining permits that may be required for some road map alternatives. Projects requiring more coordination or more time for implementation will be ranked lower than projects requiring less time or coordination.

6. Flexibility for Future Process Changes or Increased Demand: EBMUD has developed several planning studies in recent years to prepare the MWWTP for future flows, loads, and effluent regulations. Many of these potential future changes could impact electrical demand at the MWWTP. Future-ready projects that allow for greater electrical flexibility and spare capacity are ranked higher than those with less flexibility and spare capacity.

7. Low Greenhouse Gas (GHG) Emissions: EBMUD has identified the carbon footprint impact of future projects as a critical evaluation criterion. On-site backup generators are typically powered by fossil fuels such as diesel fuel or natural gas. Grid power by contrast is generated mostly by clean sources such as wind or solar. Due to the space limitations at the MWWTP, construction of larger on-site green energy sources is not feasible; therefore, the new projects will be evaluated in comparison to existing fuel sources in use at the MWWTP.

An evaluation table is produced for each Road Map Project alternative that is identified in Section 3. An example table is shown below.

TABLE 1: EVALUATION OF AN EXAMPLE PROJECT

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Neutral	
Cost-Effectiveness	High	
Reliability and Effectiveness	Low	
Ease of Implementation	Neutral	Requires a land purchase
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	Comparable to current operations

The tables summarize the performance of each Road Map Project for each of the evaluation criteria previously presented. Project-specific evaluations are presented in Section 4.

3. IDENTIFICATION OF ROAD MAP PROJECT ALTERNATIVES

Section 3 describes Road Map Project alternatives. Descriptions of the Road Map Projects include planning-level cost estimates, descriptions of triggers (i.e., future events that could drive the project timing or change the project approach) and project alignment with the EBMUD Integrated Master Plan where applicable, a proposed location for each project, and a discussion of impacts to operations.

The Road Map Projects discussed in this Section were identified based on the risk assessment of the power distribution system at the EBMUD MWWTP and summarized in TM 1. Broadly, the potential upgrades described in TM 1 can be grouped into three major categories: New Service Connections; Emergency Generators; and Redundancy Improvements. The Projects are presented here by category, but several within one category may be recommended in the overall Road Map. Final recommendations and development of the Project Road Map will be presented at the conclusion of this project and TM 3.

3.1 New Service Connections

The MWWTP currently has two PG&E 12 kiloVolt (kV) service connections, designated Line C and Line L. Unlike typical full-service power feeds for wastewater treatment facilities, these feeds are currently supply-limited, whereby neither Line C nor L can supply peak power demands alone or together.

The lack of a full-sized electrical service has been identified as a major contributor to historical power outages at the facility. Most outages have occurred during a peak demand period that requires both Line L and Line C to be available when PGS1 and PGS2 are not in operation. When one utility feed is lost, only selected (critical) processes are allowed to operate until another source of power is available. While both PGS1 (engines) and PGS2 (turbine) can provide a second source of power, the Load Shed Control System must be enabled to provide a seamless transfer of power during a partial or full utility outage. However, load shedding is not fully effective where process treatment trains have co-mingled power. "Co-mingled power" refers to situations in which key process equipment within each train are mixing power from two different sources. Loss of power from any given source will severely impact operations.

The complexity of the MWWTP's electrical distribution system would be reduced by utilizing a single dedicated power source sized to meet peak wet weather equipment power loads. This would increase the reliability and capacity of power to the plant during peak demand periods instead of relying on two separate services, neither of which is sufficient to meet peak loads.

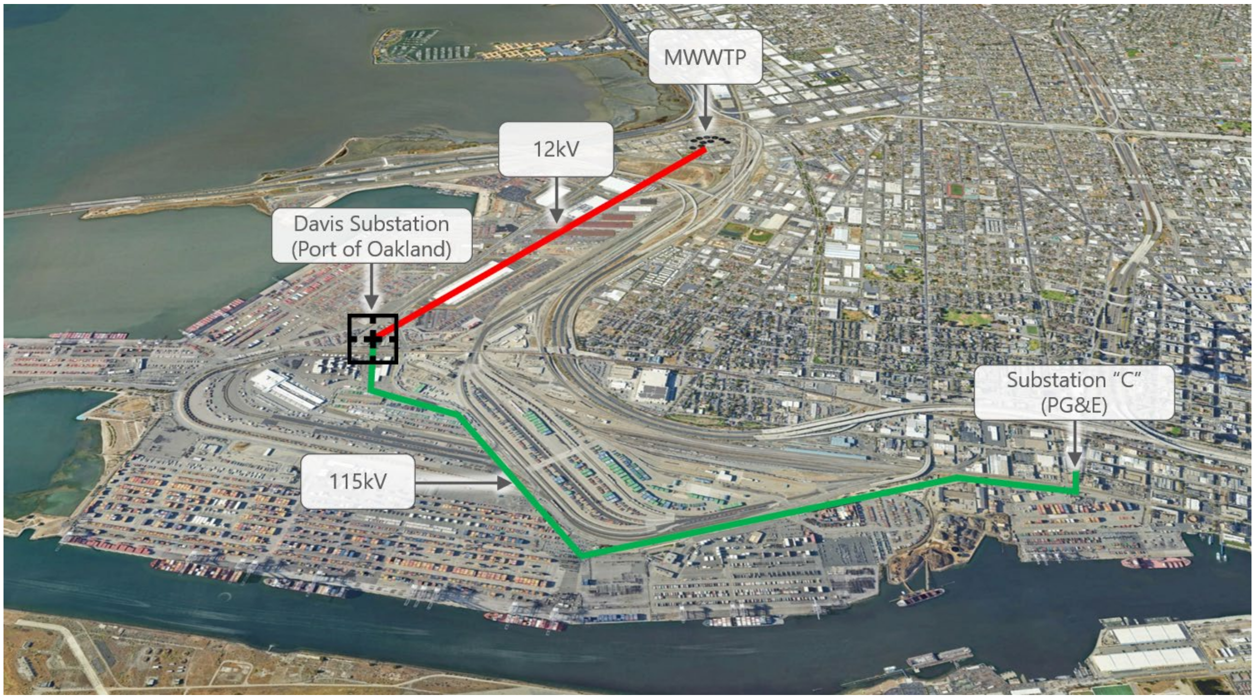
Woodard & Curran has identified three potential Road Map projects to provide a new power source with sufficient capacity for the entire MWWTP during a peak demand period. Based on the findings presented in TM 1, the new service connection would be a dedicated circuit that can provide a minimum capacity of 12 megawatts (MW) of power and up to 15 MW to account for future processes.

Any new service connection either at 115 kV or 12 kV will require a Preliminary Engineering Study (also known as a system impact study) to be completed by the power utility company. This is the first step when submitting an application for a new service and also initiates a Preliminary Engineering Study. The service application submitted to the power utility can identify a preferred substation and routing method upon which the study will either confirm or deny the request and offer another alternative for a new service. The costs included in this TM for new services are based on assumed locations; the final location will be determined based on the outcome of the Preliminary Engineering Study. The actual cost for a new service will not be determined until there is an agreement between the District and power utility company and the Preliminary Engineering Study has been finalized and the new service routing approved.

3.1.1 Road Map Project 1: New Port of Oakland 12 kV Connection

As part of this project, Woodard & Curran has contacted the Port of Oakland to learn more about their power supply capabilities. In these discussions, the Port of Oakland has informed us that there is a 115 kV power supply which is routed from PG&E's Substation C in South Oakland, near Jack London Square, to the Davis Substation. The Port of Oakland operates and owns this substation which steps power down from 115 kV to 12 kV for distribution to its customers. The Port of Oakland is currently in the process of designing replacements for the Davis substation (65% design) as well as the nearby substation SSR-14 (95% design). Neither of these substations includes provisions for large customer (agency) connections and instead considers only smaller customers (tenants). The Port of Oakland indicated that they receive their power from PG&E at 115kV and that providing a new dedicated 12 kV service for the MWWTP would require a Preliminary Engineering Study (System Impact Study) to be conducted by PG&E. At the time of this TM, the Port of Oakland could not confirm a dedicated 12 kV service would be available. Representatives from Port of Oakland highly recommended that EBMUD's General Manager have discussions with the Port of Oakland Executive leadership to discuss viable options for a new dedicated 12 kV service to the MWWTP. The benefits of this project include the reliability of the service, as the 115 kV connection is located closer to the MWWTP than the current PG&E connections, as well as its capacity. A dedicated 12 kV circuit would provide more reliability than the existing PG&E connections because the circuit from the Davis Substation would not have other tenants connected to the same line which could reduce capacity and potentially cause electrical transients. A conceptual routing for this new connection is presented in Figure 1.

FIGURE 1: PROJECT 1 – PORT OF OAKLAND POWER CONNECTION



Assuming the System Impact Study is favorable and successful negotiations with Port of Oakland are completed, it is estimated that the new service could be in place in 5-10 years. The MWWTP would continue to operate using the two existing PG&E Lines L and C in the interim. Then, one of the existing PG&E lines could be removed (Line C) with the other, more reliable Line L to remain as a partial "standby" source (Line L by itself cannot provide full redundancy). Since H1 (existing metering switchgear) is a utility-approved metering switchgear, the existing PG&E Line C breaker and controls could be removed and replaced with Port of Oakland breaker and controls without having to greatly modify H1 to integrate the new Port of Oakland service.

This alternative would increase the reliability of the utility power service during both normal and peak demand periods with the new connection considered as the "primary" circuit. The increase in reliability is due to a newer infrastructure system that Port of Oakland can provide, which includes newly replaced substations and a new overhead power line less vulnerable to damage than existing lines. The new service would be dedicated, i.e., not subject to reduction of capacity in the future. The new service contract between EBMUD and the Port of Oakland would have the potential to provide financially strengthened power sale agreements, since the Port of Oakland currently purchases power from EBMUD.

3.1.1.1 Cost Summary for Road Map Project 1: New Port of Oakland 12 kV Connection

It is expected that costs would include, at a minimum, a new breaker/switch at substation SSR-14, new overhead lines to the MWWTP, and other associated work such as property easements, City and County fees, and Port of Oakland fees for a new service connection.

TABLE 2: ROAD MAP PROJECT 1 – COST SUMMARY[1]

Description	Cost
Equipment	$2,600,000
Construction	$3,000,000
Engineering/Permitting	$1,900,000
Subtotal	$7,500,000
Contingency	$2,300,000
TOTAL	**$9,800,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.1.2 Road Map Project 2: New 12 kV PG&E Dedicated Connection

If EBMUD would like to move forward with a Preliminary Engineering Study with PG&E and the option to have a dedicated 12 kV service is probable based on favorable study results then it is anticipated that a new 12 kV dedicated service could be installed within 5-10 years after the study is completed (1 year). Given that the existing utility feeds are 12 kV, installation of a new 12 kV feed with higher capacity would have minimal impacts on the daily operations at the facility. Similar to the Port of Oakland alternative, due to the fact that the MWWTP would no longer be "split" and reliant on two separate feeds, it likely would simplify operations by reducing the complexity of the power distribution and control system. While a single dedicated full capacity 12 kV service would increase reliability relative to the status quo (two half-capacity feeds), per EPA guidelines a second reliable standby power source would still be recommended. This second power source would need to provide full capacity (during a peak event) should the dedicated 12 kV service not be available.

3.1.2.1 Cost Summary for Road Map Project 2: New PG&E 12 kV Dedicated Connection

The estimated cost is based on the assumption that a new dedicated 12 kV service would be provided from Station L and be terminated at H1 switchgear. Impacts to existing H1 switchgear would be minimal; however final routing of the new service below the railway tracks is not confirmed. The exact routing will not be determined until the Preliminary Engineering Study is completed and approved.

TABLE 3: ROAD MAP PROJECT 2 – COST SUMMARY[1]

Description	Cost
Equipment	$2,900,000
Construction	$4,100,000
Engineering/Permitting	$2,500,000
Subtotal	$9,500,000
Contingency	$2,800,000
TOTAL	**$12,300,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

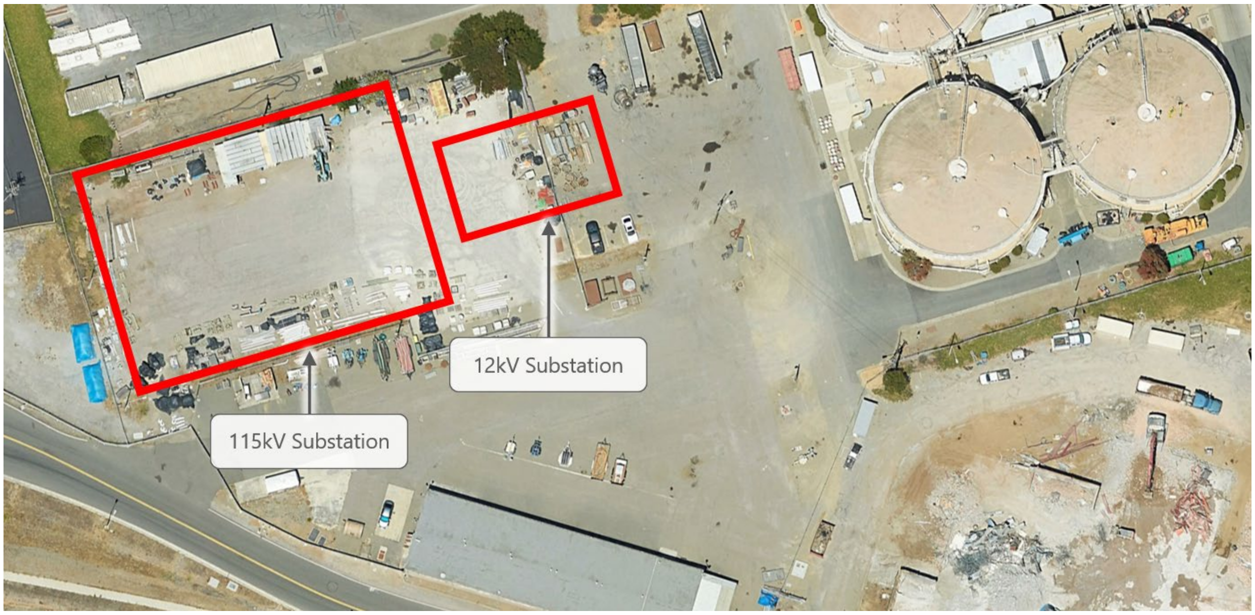
3.1.3 Road Map Project 3: New 115 kV Pacific Gas & Electric (PG&E) Connection

Woodard & Curran's scope of work included evaluation of a new high voltage (115 kV) connection sized to meet peak loads alone. The new 115 kV extension would start from the Davis Substation and be routed overhead to MWWTP. The routing is same as the Port of Oakland 12 kV connection as shown in Figure 1.

While PG&E may further evaluate this option, our preliminary review indicates that the space required to step down high voltage power from 115 kV and connect to the existing distribution system is prohibitive. Figure 2 below shows a hypothetical location that represents the estimated area needed for the needed 115 kV switchgear as well as a 12 kV transformer at approximately 28,500 sq ft. It does not show other gear which includes protective relays and current transformers. The figure is intended only to indicate the major needed space and it is not proposing a specific location for a new substation. In fact, no suitable space has been identified for a substation with this large footprint.

PG&E would own and maintain the high voltage (115 kV) switch yard including surge arresters, disconnectors, circuit breaker, etc. However, the District would own and maintain the substation transformer. Per ANSI and the NEC, the voltage classifications are as follows: High Voltage 115 kV up to 1,100 kV, Medium Voltage 2.4 kV to 69 kV and Low Voltage 240 V to 600 V. Since the MWWTP has both low and medium voltage systems it is assumed that District Staff is already trained for those voltage classes. To provide maintenance work on the substation transformer EBMUD would need to acquire the capability to maintain high voltage systems, whether with in-house staff or with contractors. The high voltage substation introduces new challenges to maintaining and owning the substation which impacts the District's standard training and operating programs and procedures. PG&E may require direct access to the substation therefore the District might need to provide a separate gate without requiring PG&E electricians to go through Security.

FIGURE 2: ROAD MAP PROJECT 2 EXAMPLE FOOTPRINT[1]



Note 1: Measurements are based on Google Earth Ruler (+/- 2.5 %)

A new service application to initiate a Preliminary Engineering Study would be required and could take up to two years for study results. A new service of this type could take up to 10 years from the date of service application. However, given the space constraints, we do not believe this option to be feasible at this time.

3.1.3.1 Cost Summary for Road Map Project 3: New 115 kV PG&E Connection

The estimated cost of the 115 kV transmission overhead service is based on previous conversations with PG&E regarding the relocation of an existing 115 kV transmission service for a proposed new conveyance pump station located near Patterson, California. The information for that project was based on a preliminary design done by Woodard & Curran in 2020 and has been adjusted for inflation for use in this TM. The substation equipment cost is based on PG&E's 2023 General Rate Case Exhibit (PG&E-4) Electric Distribution Workpapers Supporting Sections 14-23 Volume 2 of 2, Table 17-27.

TABLE 4: ROAD MAP PROJECT 3 – COST SUMMARY[1]

Description	Cost
Equipment	$27,000,000
Construction	$29,000,000
Engineering/Permitting	$20,000,000
Subtotal	$76,000,000
Contingency	$23,000,000
TOTAL	**$99,000,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.2 Emergency Standby Power Generators

While the projects described in Section 3.1 of the report would improve the electrical distribution system at the MWWTP by simplifying the incoming feeds, they do not address the need for on-site backup power generation in the event of loss of line power. In this section we present two options for new on-site power generation to improve resiliency and redundancy at the MWWTP: one to handle peak loads for the entire plant (12 MW), and one to handle peak loads for the single most critical system, the Influent Pump Station, approximately 6 MW. This section concludes with a discussion of potential load-shedding enhancements.

As indicated in this section, the cost and permitting difficulty for new generators could be formidable, particularly if the generator bank is sized for full-plant peak loads. Permitting difficulty might be eased if generators were combined with a Battery Energy Storage System (BESS) to reduce the run time of the generators by handling short-term outages without a generator start. This feature is not included with either Road Map Project 4 and 5 or included in the evaluations; however, it could be considered as part of either one of these Road Map Projects. BESSs are discussed further below.

Battery Energy Storage Systems (BESS)

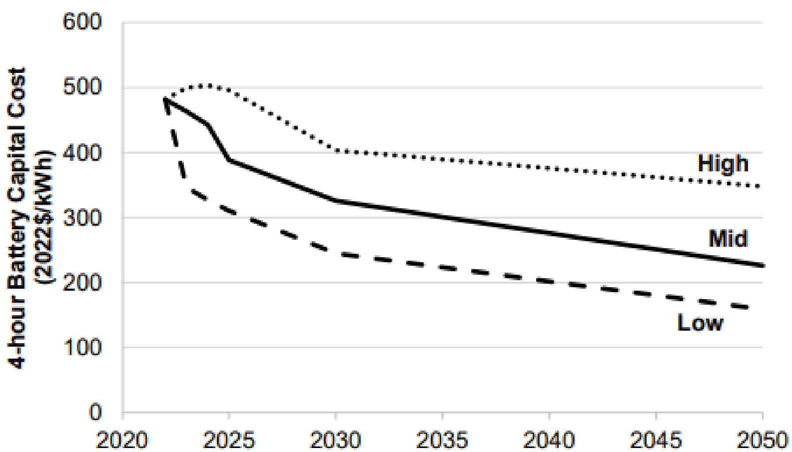
A BESS would complement conventional generators by allowing the MWWTP to sustain power transients and short duration outages (up to two minutes). For outages longer than two minutes, the standby generators would come online to carry the required load. The most common battery storage systems are based on lithium-ion power cells; however, other technologies are being introduced into the market such as sodium-ion which reduces risk of fires and overheating relative to lithium-ion but requires a larger footprint.

Based on discussions with a BESS manufacturer (aggreko®) nine 1.2-MWh battery banks (for a total of 10.8 MWh) would be required to supply the entire plant for two minutes. The size of the BESS in this case is governed not by runtime (two minutes) but by peak power output. The indicated size would provide about an hour of runtime. Figure 3 below shows one 1.2-MWh battery bank on the left and a DC-to-AC inverter on the right.

FIGURE 3: LITHIUM-ION BATTERY UNIT AND INVERTER

The projected cost of BESS is shown below in Figure 4 taken from National Renewable Energy Laboratory (NREL) 2023 Update.

FIGURE 4: PROJECTED COST FOR BATTERY STORAGE SYSTEMS



Based on this information: $\frac{\$500}{KWh}\ X\ 10{,}800KWh = \$5{,}400{,}000$

The figure shows only the BESS itself; additional costs include those for equipment such as inverters, switchgear modifications, integration into existing controls system (SEL POWERMAX), step-up transformers, etc. Inclusion of those costs would likely double the material cost to approximately $10.8M, implying a full construction cost of potentially $20M.

While a BESS would provide incremental reliability enhancements over generators for short-term power outages, its value for reducing overall generator runtime would be minimal given that power outages (of any duration) are infrequent compared to the required runtime every year for generator testing.

3.2.1 Road Map Project 4: 12 MW Generator Bank

Road Map Project 3 involves the installation of a bank of generators (4 – 3 MW units), controls, and on-site diesel fuel storage with a power generation capacity of 12 MW (as determined in TM 1). This capacity is sufficient to meet full-plant peak loads (max value documented is 10.6 MW) with spare capacity for future loads as well. The on-site diesel fuel storage would be sized to provide 72 hours supply of fuel at maximum load. Normal operations could continue for as long as fuel could be supplied during an outage.

Challenges associated with this project include the overall cost (to be presented below), space requirements, and permitting requirements. This project would also add to the complexity of the control system by adding another power generation source to the electrical distribution system.

Ideally, the new generators and paralleling switchgear would be rated for 12kV and be located in close proximity to the existing H2 switchgear (where the standby power connection would occur) to avoid long cable runs. However, space near the H2 switchgear is at a premium, with most of the area occupied by elements of the medium voltage power distribution system. Figure 5 below indicates a hypothetical location of the generator system and fuel storage area.

Air permitting with the Bay Area Air Quality Management District (BAAQMD) would be a significant issue related to this project. The MWWTP is in a designated priority community per AB 617, the Community Air Protection Program. It is expected that the BAAQMD will enforce strict emissions regulations requiring after-treatment technologies that meet EPA's current Tier 4 standards. The new generators would be installed with Best Available Control Technology (BACT), which will involve high costs and sensitive equipment. Generators would need to be run at full capacity at least once per month for testing. Currently the BAAQMD requires Tier 4 after-treatment technology for the types of generators proposed in this TM. Most recently the California Air Resources Board (CARB) is considering Tier 5 be implemented in 2030 after board approval in mid-2025. This type of variability of regulatory requirements can hinder design and permitting of generators delaying schedules and increasing cost.

FIGURE 5: ROAD MAP PROJECT 4 PROPOSED LOCATION ON SITE[1]

Note 1: Measurements are based on Google Earth Ruler (+/- 10 %).

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generators, controls, and fuel storage tanks could be constructed and tested offline from the remainder of the facility. There are spaces available at H2A and H2B to allow for two connections to the standby power system. The existing electrical interlock (INLK) at H2 would most likely require replacement with a larger and more sophisticated control system. The SEL POWERMAX control system currently used for load shed controls could be investigated as an option to control the breakers at H2 for standby power when utility power is not available. The SEL POWERMAX would allow ease of integration for the new standby generators and enable the ability to potentially parallel PGS1 and PGS2 with the standby generators. This feature would reduce demand on the generators during an outage and thus increase the refueling interval beyond 72 hours.

The many components comprising this project including not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, and spill containment would impose significant new maintenance needs. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored fuel which has a shelf-life of only 6-12 months.

The benefits of this project in terms of power reliability would need to be weighed against the substantial capital cost and O&M burden created by the project.

3.2.1.1 Cost Summary for Road Map Project 4: 12 MW Generator Bank

TABLE 5: ROAD MAP PROJECT 4 – COST SUMMARY[1]

Description	Cost
Equipment	$13,100,000
Construction	$19,050,000
Engineering/Permitting	$11,250,000
Subtotal	$43,400,000
Contingency	$13,020,000
TOTAL	**$56,420,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

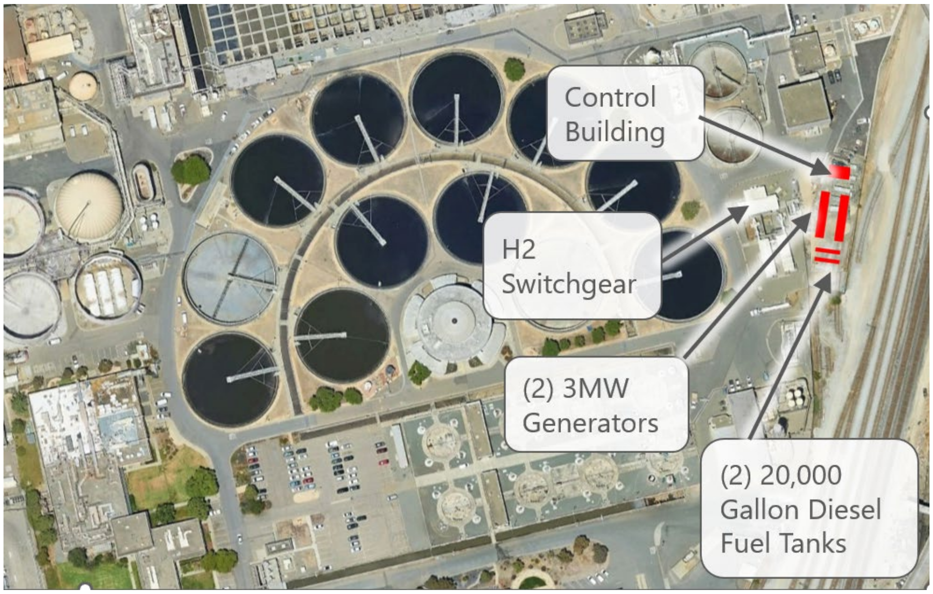
3.2.2 Road Map Project 5: Generators Sized for Influent Pump Station

Due to the capital cost, space requirements, and O&M burden of Road Map Project 3, Woodard & Curran also considered a smaller generator project to improve resiliency and address the immediate concerns at the Influent Pump Station (IPS). This would include the installation of two 12kV, 3 MW generators to serve the IPS via switchgear H2. These generators were sized based on powering the five influent pumps required to meet peak wet weather flows as determined by the District. Refer to Appendix B for generator sizing calculations which resulted in 2 – 2.5MW units for generators rated at 4160V (size for 12kV generators would be roughly the same). This TM is proposing 2 – 3MW to provide a margin for additional unknown loads. The actual size of the generators would be determined during a preliminary design phase.

The rationale for prioritizing the IPS is not only that the IPS performs a critical function (which it does). In addition, as presented in TM 1, the "time to impact" on plant operations should IPS suffer a power loss is the shortest among plant processes. While the precise time-to-impact depends on plant conditions at the moment of a power outage, it's often so short that impacts at IPS will be occurring before plant operators can restore operations at PGS-1 or PGS-2.

This project includes the installation of two 3 MW generators adjacent and connected to the H2 switchgear along with on-site fuel storage and a control building. Modifications would be necessary at H2 switchgear including improvements or replacement of the existing electrical interlocks with a more sophisticated control system. This project would restore power to the IPS within one minute upon a loss of utility power.

FIGURE 6: ROAD MAP PROJECT 5 PROPOSED LOCATION ON SITE[1]



Note 1: Measurements are based on Google Earth Ruler (+/- 2.5 %)

This project could be constructed "offline," meaning that it would have minimal impact on MWWTP operations. The generator, controls, and fuel storage tank could be constructed and tested offline from the remainder of the facility.

The many components comprising this project including not only the generators but also the associated switchgear, controls, building enclosure, fuel tanks, and spill containment would impose significant new maintenance needs, although to a lesser degree than the 12 MW Project 4. Among the maintenance items are monthly testing at full load, and fuel maintenance since the annual runtime would typically use only a small fraction of the stored fuel which has a shelf-life of only 6-12 months.

This alternative could be built as an initial phase of Road Map Project 4. In that case, the project layout, and key components, would be sized for buildout to the capacities needed for Project 4, but only half of the full 12 MW capacity, and only half of the ultimate fuel storage, would be built initially. A second phase could follow at any time, e.g., five years after the initial phase, to add more generators and tanks, and adjust controls as needed. A benefit of phasing, beyond reducing immediate cash flow needs, is that the second phase could be designed with more precise knowledge of future loads. A downside of phasing is that the cost of the initial phase would be somewhat more than a "standalone" Project 5 because of the need to oversize some equipment for future loads.

3.2.2.1 Cost Estimate for Road Map Project 5: Generators sized for Influent Pump Station

The costs presented below assume that the project is not implemented as the initial phase which if it was, would add more to the project cost for the added infrastructure for final buildout of a 12MW generator bank.

TABLE 6: ROAD MAP PROJECT 5 – COST SUMMARY[1]

Description	Cost
Equipment	$5,900,000
Construction	$7,200,000
Engineering/Permitting	$4,600,000
Subtotal	$17,700,000
Contingency	$5,300,000
TOTAL	**$23,000,000**

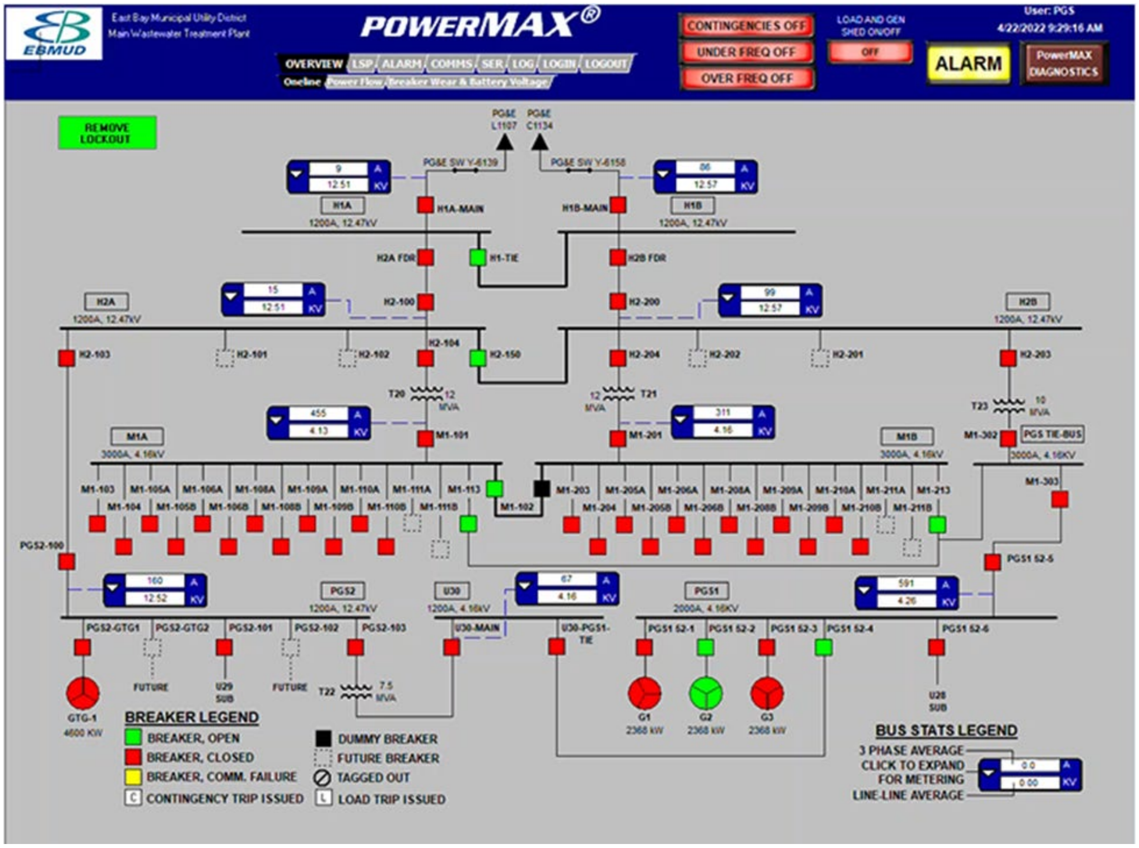
Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.2.3 Road Map Project 6: POWERMAX System Upgrades

Under normal EBMUD MWWTP operations, electrical power demand is met by a blend of utility power and onsite power, which is generated from biogas co-generation (co-gen). During a utility power outage, without the use of load shedding to reduce the load demand to match the power being generated, critical plant process will shut down.

As discussed in TM 1, EBMUD has invested in SEL POWERMAX load shedding system to monitor power and prioritize load distribution in the event of a utility outage. When implemented, the load shed system will increase the reliability of PGS-1 & 2 by reducing the likelihood of this equipment tripping due to over- or under-frequency. The load shedding system will also maintain power to processes identified by EBMUD as being the most critical. Figure 7 below is a screen shot of the SEL POWERMAX HMI.

FIGURE 7: SCREEN SHOT OF EXISTING LOAD SHED CONTROLS



Since EBMUD has already invested in the load shedding system, this project would simply activate the system already in place. TM 1 identified some adjustments that could be made to the software to re-prioritize the various treatment processes based on our Time to Impact analysis; however, these are minor programming changes that do not require significant capital investment.

EBMUD Operations staff has identified potential improvements to the load shedding program including the consideration of controlling breakers at the 480 V level (MCC main breakers). The goal of that would be to prioritize specific loads that might otherwise be subject to load shedding at the 12 kV level. Including the 480 V system in the load shedding logic has the potential to greatly increase system complexity and is impractical with the current load-shed system setup. An alternative approach would be examining high-priority 480 V loads on a case-by-case basis to identify options such as refeeding the load to a higher-priority 12 kV circuit or providing a dedicated UPS for small loads.

3.2.3.1 Cost Summary for Road Map Project 6: POWERMAX System Upgrades

The primary costs for this project are software license updates, programming changes, and training. Additionally, the cost below includes communication processor upgrades, which is recommended to be replaced as part of this work since the existing processors are nearing the end of their useful life.

TABLE 7: ROAD MAP PROJECT 6 – COST SUMMARY[1]

Description	Cost
Equipment	$300,000
Construction	$150,000
Engineering/Permitting	$50,000
Subtotal	$550,000
Contingency	$150,000
TOTAL	**$700,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance Tables. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

3.3 Infrastructure Improvements

As part of the investigations associated with this project, Woodard & Curran identified additional projects that would improve reliability by increasing the resiliency of existing systems at the MWWTP. Increasing resiliency as it relates to this TM means bolstering existing electrical systems and providing redundant equipment where it makes sense to keep the plant operating when energy sources are compromised. Some examples include replacement of aging cables, moving below grade elbow connectors to above grade for easier and safer access and the addition of substations to maintain operations during maintenance work.

3.3.1 Road Map Project 7: Best Practices

The seventh road map project identified creates a system of best practices for EBMUD to implement as part of Asset Management of their electrical infrastructure. Our scope of work is limited to desktop study and visual observations during a site visit and does not include evaluation of the infrastructure in detail. However, in discussions with EBMUD staff it is apparent that the existing infrastructure is aging and will require upgrades in the future simply to maintain existing capabilities.

The costs presented in this report assume that EBMUD would undertake all the identified improvements as part of a single capital project. However, EBMUD may wish to incorporate portions of these potential upgrades into smaller projects targeting specific areas of the MWWTP rather than perform a facility-wide project due to the scope and scale of these items. Some specific options include:

- Replacing below grade elbow connectors (in MH 13, 16, 40, 43) with above grade sectionalizing cabinet. Currently, cabling is connected in underground vaults. These confined spaces make inspection difficult and increase the risk of groundwater intrusion. Modern design standards call for such connections to be made at above-grade equipment to eliminate groundwater concerns. Figure 8 below is a picture of a proposed above grade sectionalizing cabinet; manufacturer is Eaton, SecTER Series.
- Documenting existing medium voltage (MV) cables, prioritizing testing based upon their age, putting older cables as high priority versus newer/tested cables. The older MV cables will likely need testing over the next 5-10 years.
- Increasing redundancy at the substations: While most switchgear have redundant feeders with redundant transformers, we have identified several gears with no redundancy, including U1

(Aerated Grit), U12 (Digester Building), U13 (Solid/Liquid Receiving Station), and U22 (Mid-Plant).

- Co-Mingling Wiring Issues – EBMUD Operations staff have noted several areas where components of a process train are powered from different sides of an open MCC tie breaker. For example, an Influent Pump may be powered from one side of the tie breaker, but the valves/gates associated with that pump are powered from the other side. Due to the dual feed from the utility, when one side of the MCC loses power, the manual tie breaker remains open and in effect, the entire treatment train loses power. Continued efforts by EBMUD to identify and remediate these conditions will increase resiliency.

FIGURE 8: ROAD MAP PROJECT 7 PROPOSED ABOVE GRADE SECTIONALIZING CABINET

This work can be fully aligned with EBMUD's Master Integration plan by incorporating these recommendations into capital projects, so they are addressed as various areas of the facility are upgraded. These modifications should reduce the burden on MWWTP operations staff by making the electrical infrastructure more resilient and reliable, reducing the need for hands-on service.

3.3.1.1 Cost Summary for Road Map Project 7: Best Practices

The total cost shown in the table below represents the cost for all of the equipment replacement cost and not for each individual type of equipment. For example, the District might want to implement the cable replacement only or address each substation transformer individually. Refer to Appendix A for the breakdown of each type of equipment for more details.

TABLE 8: ROAD MAP PROJECT 7 – COST SUMMARY[1]

Description	Cost
Equipment	$5,000,000
Construction	$4,700,000
Engineering/Permitting	$3,400,000
Subtotal	$13,100,000
Contingency	$3,900,000
TOTAL	**$17,000,000**

Note 1: Refer To Appendix A For Detailed Breakdown of Cost including Unit Cost and Allowance. All costs are in 2024 dollars and have been rounded up to the nearest 10^5.

4. EVALUATION OF ROAD MAP PROJECT ALTERNATIVES

This Section evaluates the Road Map Project alternatives presented in Section 3 using the evaluation criteria presented in Section 2. Many of the project alternatives are complementary rather than exclusive, so the final selection by EBMUD may well be a portfolio of projects implemented over time.

Each project description includes a reference to the conclusions and recommendations from TM 1. This summary will allow for more insight into the relative impact that each project may have on overall electrical resiliency at EBMUD MWWTP.

4.1 Project 1: New Port of Oakland 12 kV Connection

Like Projects 2 and 3, a new Port of Oakland connection addresses TM 1 recommendation R1: "Consider replacing one of the existing line circuits with a dedicated service with limited overhead distribution." This recommendation addresses TM 1 conclusion C1: "The Plant's line power supplies should not be considered reliable, owing to lack of full redundancy." Also, like Projects 2 and 3, this project alternative assumes that the new connection can meet peak plant loads on its own, and that one of the two existing PG&E lines would be removed. The remaining PG&E line service could be dedicated as standby power and when combined with PGS1 could provide redundancy as long as the load shedding control system is operable. Projects 1, 2 and 3 are thus directly comparable.

TABLE 9: EVALUATION OF PROJECT 1 – NEW PORT OF OAKLAND 12 KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 3
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.2 Project 2: New PG&E 12 kV Connection

A new 12 kV PG&E connection addresses the same TM 1 recommendations and conclusions as Projects 1 and 2. Project 3 differs from Project 1 in that it avoids the siting of 115 kV switchgear on EBMUD premises; a downside of that characteristic is that the 12 kV service is more prone to voltage sags.

TABLE 10: EVALUATION OF PROJECT 3 – NEW PG&E 12 KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	Neutral	Comparable to Project 1
Reliability and Effectiveness	High	
Ease of Implementation	High	
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.3 Project 3: New PG&E 115 kV Connection

As discussed, this Project, like Projects 1 and 3, addresses TM 1 conclusion C1: "The Plant's line power supplies should not be considered reliable, owing to lack of full redundancy." A distinguishing feature of this Project relative to Project 1 or 3 is that its service voltage of 115 kV would result in higher reliability due to higher voltage systems being able to withstand voltage transients and sags better than 12 kV systems. However, a new 115 kV substation would be required for which space does not appear to exist, thus rendering this option infeasible. If the project were feasible, it would require additional training and certification for District staff for high voltage systems and would incur extensive cost to construct new transmission towers and obtain right of way.

TABLE 11: EVALUATION OF PROJECT 2 – NEW PG&E 115KV CONNECTION

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Low	Requires high voltage class training and certification.
Cost Effectiveness	Low	A new transmission extension and substation will be costly.
Reliability and Effectiveness	High	
Ease of Implementation	Low	Appears to be infeasible due to space limits for 115 kV switchgear. Transmission line easement is larger than that for 12 kV transmission lines.
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.4 Project 4: 12 MW Generator Bank

Projects 1, 2 and 3 address TM 1 recommendation R1: " Consider replacing one of the existing line circuits with a dedicated service with limited overhead power distribution." however, they do not address federal standard EPA 430-99-74-001 as described in TM 1. The intent of this project is to combine it with a single, full capacity power utility circuit such that a second reliable standby power source is available when the power utility circuit is not available.

The critical assumptions made for consideration of this project are as follows: Project 4 assumes there is sufficient space to locate the generator bank and ancillary systems.

TABLE 12: EVALUATION OF PROJECT 4 – 12 MW GENERATOR BANK

Criteria	Performance/Benefit	Notes
Operability	Low	Adding another power generation source will add more complexity to the controls.
Maintainability	Low	Complex machinery to maintain, adding to operator burden.
Cost Effectiveness	Low	Generators, switchgear, ancillary systems, and infrastructure required will be costly.
Reliability and Effectiveness	High	Diesel engine generators used as a standby power source are considered quite reliable.
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. BAAQMD permitting regulations are fluid and represent potential stalls to project implementation. For example, California Air Resources Board (CARB) is considering Tier 5 be implemented in 2030 after board approval in mid-2025.
Flexibility for Future Process Changes or Increased Demand	High	
Reduced GHG Emissions	Neutral	

4.5 Project 5: Generator Sized for IPS

Two 3-MW generators would provide enough capacity to meet the power load demanded by the Influent Pump Station (IPS) which addresses parts of the TM 1 recommendation R-6: "Modify or add electrical equipment to provide full redundance." The project is specifically pertinent to conclusions C-1 and C-3, which are as follows:

- C-1: "The plant's line power supplies should not be considered reliable, owing to lack of full redundancy to maintain plant operations during peak events and environmental exposure."

- C-3: "Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity."

TABLE 13: EVALUATION OF PROJECT 5 –GENERATOR SIZED FOR IPS

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Low	
Cost Effectiveness	High	
Reliability and Effectiveness	Neutral	Only provides power for initial unit processes
Ease of Implementation	Low	Could be considered exempt from CEQA if not considered a significant impact to environment. May be difficult to permit with BAAQMD. Rating of Low is based on ultimate build-out to 12 MW.
Flexibility for Future Process Changes or Increased Demand	High	Building as an initial phase with an option to add more generators provides flexibility to meet future needs.
Reduced GHG Emissions	Neutral	

Project 5 is valuable for its potential to generate an overall increase in electrical system resiliency if it were coupled with a larger Project, such as Project 1 or 2 or included in the Influent Pump Station Upgrades Project. This project could be employed on a shorter implementation schedule and result in added redundancies when layered with other, more complex upgrades.

4.6 Project 6: POWERMAX System Upgrades

Load-shed modifications address TM 1 recommendations R-2 and R-4 which are:

- R-2: "The SEL POWERMAX [load-shedding] system should be enabled at all times to maintain operation of PGS during utility outage and avoid black start."

- R-4: "Revise load shed priority list based on criticality of processes and [time to impact]."

The recommendations for this project primarily pertain to TM 1 conclusion C-2: "The disablement of the SEL POWERMAX power control system poses a significant risk associated with power outages and maintaining PGS operation."

The critical assumptions made for consideration of this project are as follows: It is assumed that the issues of co-mingling of wiring for process equipment trains and their associated systems as mentioned in Project 7 are addressed either prior to this work or in tandem. In addition, it is assumed that District Operations staff is properly trained in the use of SEL POWERMAX to further understand the benefits of the load shed controls for increased resiliency. Coupling this project with Project 7 with appropriate training appears to provide significant resiliency to MWWTP operations.

TABLE 14: EVALUATION OF PROJECT 6 – POWERMAX SYSTEM UPGRADES

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	Neutral	
Cost Effectiveness	High	Implement existing systems
Reliability and Effectiveness	High	
Ease of Implementation	High	Modifications to a control system that is already in place.
Flexibility for Future Process Changes or Increased Demand	High	Major changes easily adapted to
Reduced GHG Emissions	Neutral	

4.7 Project 7: Best Practices Upgrades

Best practices upgrades include replacing below grade cable connectors with an above grade sectionalizing cabinet, taking inventory of, and replacing MV cables, adding redundancy to substations U1, U13, U16 and U22, and rewiring equipment trains that have co-mingled circuits. These upgrades address TM 1 recommendation R-3, and parts of R-6:

- R-3: "Correct or consolidate low voltage wiring systems that are co-mingled between the different power buses (A versus B)."
- R-6: "Modify or add electrical equipment to provide full redundancy. Replace below grade cable connectors with above grade switch gear."

These recommendations are pertinent to conclusions C-3, C-4:

- C-3: "Certain portions of the power system infrastructure lack equipment redundancy to provide 100% capacity."
- C-4: "Process trains and their ancillary devices are not wired to the same power bus which increases risk of non-operation when one of the two line-circuits are not available, and a tie breaker is not closed or if the load shed control system is enabled."

The critical assumptions made for consideration of this project are as follows: The upgrades listed under this project are assumed to be part of capital improvement plans or maintenance programs. It is assumed that not all the best practice components would be completed simultaneously. Sub-projects, e.g., replacing MV cables, adding redundancy to substations U1, U13, U16 and U22, and rewiring equipment trains that have co-mingled circuits could be completed as smaller projects with short-turn implementation times and could be prioritized to maximally increase electrical resiliency at EBMUD MWWTP. For example, addressing the co-mingling issues alone will have an outsize impact on plant resiliency.

TABLE 15: EVALUATION OF PROJECT 7 – BEST PRACTICES UPGRADES

Criteria	Performance/Benefit	Notes
Operability	High	
Maintainability	High	
Cost Effectiveness	High	Compared to the generator, each of these sub-projects will provide resiliency at a fraction of the cost of other proposed projects.
Reliability and Effectiveness	High	Will improve redundancy and resiliency
Ease of Implementation	High	This project conglomerates several sub-projects. Some of these, such as addressing the co-mingling, adding resilient substations, and replacing MV cables are straightforward to implement, though they may be labor intensive. Projects could readily be added to ongoing Master Planning efforts.
Flexibility for Future Process Changes or Increased Demand	Neutral	Fixing existing issues does not increase capacity
Reduced GHG Emissions	Neutral	Fixing comingling issues could allow the re-prioritized SEL POWERMAX load shed to operate and existing PGSs to operate without relying on exterior power sources. Per discussions with EBMUD, the comingling issues are a reason why the load shed program was disabled.

5. CONCLUSIONS

This Section broadly summarizes the results of the alternatives analysis completed in Section 4. Conclusions presented herein are intended to highlight overarching trends and key observations about Road Map Projects without providing explicit recommendations. The selection of recommended Road Map Projects will be undertaken in TM 3.

5.1 Road Map Project Overarching Concerns

The team offers the following general conclusions that will help shape the future:

- The system complexity of the EBMUD electrical system is high. The completion of multiple Road Map Projects is likely required to simplify the system and introduce needed resiliency.
- Coupling short-term, targeted projects with larger scope upgrades may provide the most immediate path to improved reliability. Layering these projects together can also add resiliency.
  - Several short-term projects can provide outsize impacts to electrical resiliency at the EBMUD MWWTP. Projects that facilitate PGS system operability during utility outage, without compromising performance of critical treatment operations, would likely provide high value. Implementation of these projects would not provide full redundancy but would increase plant resiliency by strengthening the power system infrastructure. These projects could provide interim value and complement more comprehensive long-term electrical upgrades.
  - Much of the system complexity stems from the fact that two power utility feeds currently must be operable to meet peak power demands. EBMUD should give priority consideration to obtaining a power utility feed that can meet peak demands by itself, in order to improve reliability and reduce complexity.
  - While full power redundancy with a generator bank would provide value, it would pose high capital and operating costs. A smaller generator bank that powers the most important loads (i.e., IPS) would be less expensive and provide substantial benefit. That project could also be designed to permit future buildout to a full-plant backup should that be warranted in the future.
- Operator and staff training would provide high value to support existing and future electrical system upgrades including an enhanced understanding of load shed controls and their critical importance to the resiliency of the plant. Because the MWWTP exports and imports power from multiple sources it should be treated as a Microgrid, with commensurate training needs. As utility grids become more unstable and the District continues to lower GHG emissions utilizing renewable energy the need for this type of training becomes even more critical.
- The evaluation results for projects involving generators are not favorable when compared to new utility power connections. This is because implementation for generator systems includes uncertainty based on regulatory instability that is predicated on the requirements set forth by CARB and its impacts on technology that trickles down to manufacturing and regulatory enforcement. However, even with this in mind, the time to establish an agreement with a utility power company for a new service, planning, engineering, obtain easements and finally to construct the new connection service might require more time to implement than a generator bank. The evaluation results for new 12 kV connections indicate a High benefit since implementation is based on regulatory requirements that are considered less than generator systems and also power utility

connections require less maintenance. As the technology and dynamics of energy sources continue to evolve due to ever-changing policies it's possible that the performance/benefit could change for both alternatives. The approach to looking at the alternatives should be considered as alternative portfolio of projects so that a combination of projects will consider the variability of implementation and decrease the amount of time to the extent possible to address immediate resiliency and reliability issues.

5.2 Next Steps

The alternatives evaluation completed in this TM represents the technical basis of understanding for recommending Road Map Projects to EBMUD. A technical workshop will be conducted with District staff to review and refine the draft alternatives presented here. Insights arising from this workshop will be captured and integrated into the final Road Map Project recommendations. The summary of these recommendations, which will include prioritization of Projects, a description of their integration with EBMUD Integration Master Plan, and proposed timelines and implementation schedules, shall be presented in TM 3.

6. REFERENCES

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APPENDIX A: PROJECT COST DEVELOPMENT FORMS

Cost for Road Map Project 1: New Port of Oakland 12kV Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV Dedicated Overhead Line[1]	$220/Ft (7920ft)	$ 1,742,400.00
Modifications to H1 Switchgear		$ 500,000.00
Modifications to Power Controls		$ 100,000.00
New Breaker at Davis Substation		$ 250,000.00
Raw Equipment Cost "Line A"		$ 2,592,400.00
Miscellaneous Demolition	10% of "A"	$ 259,240.00
Civil	20% of "A"	$ 518,480.00
Electrical, Instrumentation and Controls	5% of "A"	$ 129,620.00
Hazardous Materials and Handling	5% of "A"	$ 129,620.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 129,620.00
Raw Construction Cost "Line B"		$ 3,758,980.00
Startup and Construction Sequencing	5% of "B"	$ 187,949.00
Construction Easements	10% of "B"	$ 375,898.00
General Conditions	10% of "B"	$ 375,898.00
Contractor O&P	5% of "B"	$ 187,949.00
Sales Tax	5% of "B"	$ 187,949.00
Construction Cost Subtotal "Line C"		$ 5,074,623.00
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 507,462.30
Total Construction Cost "Line D"		$ 5,582,085.30
Planning and Permitting	5% of Construction	$ 279,104.27
Engineering	15% of Construction	$ 837,312.80
Construction Management	15% of Construction	$ 837,312.80
Project Cost Subtotal "Line E"		$ 7,535,815.16
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 2,260,744.55
Total Project Cost		**$ 9,796,559.70**

Cost for Road Map Project 2: New PG&E 12 kV Dedicated Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV Dedicated Overhead Line[1]	$220/Ft (10,560ft)	$ 2,323,200.00
Modifications to H1 Switchgear		$ 500,000.00
Modifications to Power Controls		$ 100,000.00
Raw Equipment Cost "Line A"		$ 2,923,200.00
Miscellaneous Demolition	10% of "A"	$ 292,320.00
Civil	20% of "A"	$ 584,640.00
Electrical, Instrumentation and Controls	5% of "A"	$ 146,160.00
Hazardous Materials and Handling	5% of "A"	$ 146,160.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 146,160.00
Raw Construction Cost "Line B"		$ 4,238,640.00
Startup and Construction Sequencing	5% of "B"	$ 211,932.00
Construction Easements	20% of "B"	$ 847,728.00
General Conditions	10% of "B"	$ 423,864.00
Contractor O&P	5% of "B"	$ 211,932.00
Sales Tax	10.25% of "B"	$ 434,460.60
Construction Cost Subtotal "Line C"		$ 6,368,556.60
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 636,855.66
Total Construction Cost "Line D"		$ 7,005,412.26
Planning and Permitting	5% of Construction	$ 350,270.61
Engineering	15% of Construction	$ 1,050,811.84
Construction Management	15% of Construction	$ 1,050,811.84
Project Cost Subtotal "Line E"		$ 9,457,306.55
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 2,837,191.97
Total Project Cost		**$ 12,294,498.52**

Notes

1. Does not include poles, easement cost, right of way.

Cost for Road Map Project 3: New 115 kV Pacific Gas Electric (PG&E) Connection

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
115kV Extension by PG&E		$ 4,853,456.00
115kV Substation Equipment		$ 2,300,000.00
115kV/12kV EBMUD Substation Transformer		$ 18,600,000.00
12kV EBMUD Substation Equipment		$ 1,400,000.00
Raw Equipment Cost "Line A"		$ 27,153,456.00
Miscellaneous Demolition	5% of "A"	$ 1,357,672.80
Civil	10% of "A"	$ 2,715,345.60
Electrical, Instrumentation and Controls	10% of "A"	$ 2,715,345.60
Hazardous Materials and Handling	5% of "A"	$ 1,357,672.80
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 1,357,672.80
Raw Construction Cost "Line B"		$ 36,657,165.60
Startup and Construction Sequencing	5% of "B"	$ 1,832,858.28
Construction Easements	15% of "B"	$ 5,498,574.84
General Conditions	10% of "B"	$ 3,665,716.56
Contractor O&P	5% of "B"	$ 1,832,858.28
Sales Tax	Oakl% of "B"	$ 3,757,359.47
Construction Cost Subtotal "Line C"		$ 53,244,533.03
Market Factor (accounted for in estimating contingency)	0% of "C"	
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	5% of "A"+ Market Factor	$ 2,662,226.65
Total Construction Cost "Line D"		$ 55,906,759.69
Planning and Permitting	5% of Construction	$ 2,795,337.98
Engineering	15% of Construction	$ 8,386,013.95
Construction Management	15% of Construction	$ 8,386,013.95
Project Cost Subtotal "Line E"		$ 75,474,125.58
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 22,642,237.67
Total Project Cost		**$ 98,116,363.25**

Cost for Road Map Project 4: 12 MW Generator Bank

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV, 3 MW Standby Diesel Generator	$2,100,000/ea., 4x	$ 8,400,000.00
25000-gallon Diesel Fuel Tank	$90,000/ea., 3x	$ 270,000.00
Initial fueling	$6/gal., 75,000 gal	$ 450,000.00
5MW Load Bank		$ 475,000.00
Generator Control Building		$ 1,500,000.00
15KV Generator Switchgear	$200,000/ea., 6x	$ 1,200,000.00
Generator Protection and Control Panel	$125,000/ea., 4x	$ 500,000.00
SEL PowerMAX Modifications		$ 300,000.00
Raw Equipment Cost "Line A"		$ 13,095,000.00
Miscellaneous Demolition	5% of "A"	$ 654,750.00
Civil	30% of "A"	$ 3,928,500.00
Electrical, Instrumentation and Controls	20% of "A"	$ 2,619,000.00
Hazardous Materials and Handling	5% of "A"	$ 654,750.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 654,750.00
Raw Construction Cost "Line B"		$ 21,606,750.00
Startup and Construction Sequencing	5% of "B"	$ 1,080,337.50
Construction Easements	5% of "B"	$ 1,080,337.50
General Conditions	10% of "B"	$ 2,160,675.00
Contractor O&P	5% of "B"	$ 1,080,337.50
Sales Tax	10.25% of "B"	$ 2,214,691.88
Construction Cost Subtotal "Line C"		$ 29,223,129.38
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 2,922,312.94
Total Construction Cost "Line D"		$ 32,145,442.31
Planning and Permitting	5% of Construction	$ 1,607,272.12
Engineering	15% of Construction	$ 4,821,816.35
Construction Management	15% of Construction	$ 4,821,816.35
Project Cost Subtotal "Line E"		$ 43,396,347.12
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 13,018,904.14
Total Project Cost		**$ 56,415,251.26**

Cost for Road Map Project 5: Generators sized for Influent Pump Station

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
12kV, 3MW Standby Diesel Generator	$2,100,000/ea., 2X	$ 4,200,000.00
20,000-gallon Diesel Fuel Tank	$80,000/ea., 2x	$ 160,000.00
Initial Fueling	$6/gal, 40,000 gal	$ 240,000.00
2MW Load Bank		$ 300,000.00
Generator Control Building		$ 250,000.00
15kV Generator Switchgear	$200,000/ea., 2x	$ 400,000.00
Generator Protection and Control Panel	$125,000/ea., 2x	$ 250,000.00
SEL PowerMAX Modifications		$ 50,000.00
Raw Equipment Cost "Line A"		$ 5,850,000.00
Miscellaneous Demolition	5% of "A"	$ 292,500.00
Civil	30% of "A"	$ 1,755,000.00
Electrical, Instrumentation and Controls	5% of "A"	$ 292,500.00
Hazardous Materials and Handling	5% of "A"	$ 292,500.00
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 292,500.00
Raw Construction Cost "Line B"		$ 8,775,000.00
Startup and Construction Sequencing	5% of "B"	$ 438,750.00
Construction Easements	5% of "B"	$ 438,750.00
General Conditions	10% of "B"	$ 877,500.00
Contractor O&P	5% of "B"	$ 438,750.00
Sales Tax	10.25% of "B"	$ 899,437.50
Construction Cost Subtotal "Line C"		$ 11,868,187.50
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 1,186,818.75
Total Construction Cost "Line D"		$ 13,055,006.25
Planning and Permitting	5% of Construction	$ 652,750.31
Engineering	15% of Construction	$ 1,958,250.94
Construction Management	15% of Construction	$ 1,958,250.94
Project Cost Subtotal "Line E"		$ 17,624,258.44
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 5,287,277.53
Total Project Costs		**$ 22,911,535.97**

Cost for Road Map Project 6: Load Shed Controls Modifications

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Equipment Cost		
SEL PowerMAX Communication Processor Upgrade	$20,000/ea., 15x	$ 300,000.00
Raw Equipment Cost "Line A"		$ 300,000.00
Electrical, Instrumentation and Controls	10% of "A"	$ 30,000.00
Raw Construction Cost "Line B"		$ 330,000.00
Startup and Construction Sequencing	5% of "B"	$ 16,500.00
Construction Easements	5% of "B"	$ 16,500.00
General Conditions	10% of "B"	$ 33,000.00
Contractor O&P	5% of "B"	$ 16,500.00
Sales Tax	10.25% of "B"	$ 33,825.00
Construction Cost Subtotal "Line C"		$ 446,325.00
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 44,632.50
Total Construction Cost "Line D"		$ 446,325.00
Planning and Permitting	0% of Construction	$ -
Engineering	5% of Construction	$ 22,316.25
Construction Management	5% of Construction	$ 22,316.25
Project Cost Subtotal "Line E"		$ 490,957.50
Estimating Contingency (includes market factor contingency	30% of Project Cost Subtotal	$ 147,287.25
Total Project Costs		**$ 638,244.75**

Cost for Road Map Project 7: Best Practices

Item	Unit Cost/ Allowance	Class 5 or 4 Total
Raw Construction Cost		
Cable Replacement		$ 1,970,515.00
MV Elbow Replacement		$ 328,000.00
Influent Pump Station LV Commingled Power Investigation		$ 35,700.00
Cable Investigation and Testing		$ 125,000.00
Redundant Transformer at U1 (Aerated Grit)		$ 708,000.00
Redundant Transformer at U12 (Digester Building)		$ 648,000.00
Redundant Transformer at U13 (Solids/Liquid Recieving)		$ 515,000.00
Redundant Transformer at U22 (Mid-Plant)		$ 648,000.00
Raw Construction Cost "Line A"		$ 4,978,215.00
Miscellaneous Demolition	5% of "A"	$ 248,910.75
Civil	5% of "A"	$ 248,910.75
Electrical, Instrumentation and Controls	10% of "A"	$ 497,821.50
Hazardous Materials and Handling	5% of "A"	$ 248,910.75
Excavated Soil Disposal (not deep or special excavation)	5% of "A"	$ 248,910.75
Raw Construction Cost "Line B"		$ 6,471,679.50
Startup and Construction Sequencing	5% of "B"	$ 323,583.98
Construction Easements	5% of "B"	$ 323,583.98
General Conditions	10% of "B"	$ 647,167.95
Contractor O&P	5% of "B"	$ 323,583.98
Sales Tax	10.25% of "B"	$ 663,347.15
Construction Cost Subtotal "Line C"		$ 8,752,946.52
Market Factor (accounted for in estimating contingency)	0% of "C"	$ -
Change order contingency (5% if greater than $50 million and 10% if less than $50 million	10% of "A"+ Market Factor	$ 875,294.65
Total Construction Cost "Line D"		$ 9,628,241.18
Planning and Permitting	5% of "A"	$ 481,412.06
Engineering	15% of "A"	$ 1,444,236.18
Construction Management	15% of "A"	$ 1,444,236.18
Project Cost Subtotal "Line E"		$ 12,998,125.59
Estimating Contingency (includes market factor contingency	30% of "A"	$ 3,899,437.68
Total Project Cost		**$ 16,897,563.26**

APPENDIX B: GENERATOR SIZE CALCULATIONS

Recommended Generator Report - 2500DQKAN

Project - EBMUD IPS

Comments -

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 2
Duty	: Standby	**Site Altitude, ft(m)**	: 361(110)
Voltage	: 2400/4160, Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: No Preference		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 1450.5	**Max. Step kW**	: 1450.5 In Step 1	**Cumulative Step kW**	: 1450.5
Running kVA	: 1611.7	**Max. Step kVA**	: 1611.7 In Step 1	**Cumulative Step kVA**	: 1611.7
Running PF	: 0.9	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 1611.7	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 2901.08			**Pct Rated Capacity**	: 58.0

Total System Running Load and Step Load Requirements

Running kW	: 2901.0	**Max. Step kW**	: 2901.0	**Running NLL kVA**	: 3223.4
Running kVA	: 3223.4	**Max. Step kVA**	: 3223.4		

Generator Set Configuration

Alternator	: S9M1D-G4	**Engine**	: QSK60-G26
BCode	: B605	**Fuel**	: Diesel
Excitation	: PMG	**Displacement, cu in. (Litre)**	: 3672.0(60.2)
Voltage Range	: MV 4160	**Cylinders**	: 16
Number of Leads	: 6	**Altitude Knee, ft(m)**	: 984(300)
Reconnectable	: Yes	**Altitude Slope, % per 1000ft(304.8m)**	: 3
Full Single Phase Output	: No	**Temperature Knee, °F(°C)**	: 104(40)
Increased Motor Starting	: No	**Temperature Slope, % per 18°F(10.0°C)**	: 15
Extended Stack	: No	**Emissions**	: Tier 2
		Cooling Package	: High Ambient

Set Performance / Load Requirements

Set Performance		Load Requirements	
Running At	: 58.0% Rated Capacity		
Max. Step Voltage Dip, %	: 21	**Max. Allowed Step Voltage Dip**	: 35 In Step 1
Max. Step Frequency Dip, %	: 7	**Max. Allowed Step Frequency Dip**	: 10 In Step 1
Peak Voltage Dip, %	:	**Peak Voltage Dip Limit %**	: 35.0
Peak Frequency Dip, %	:	**Peak Frequency Dip Limit %**	: 10
Site Rated Standby kW/kVA	: 2500 / 3125	**Running kW**	: 1450.5
		Running kVA	: 1611.7
Site Rated Max. SkW	: 2639	**Effective Step kW**	: 1416.3
Max. SkVA	: 14835	**Effective Step kVA**	: 1611.7
Temp Rise at Full Load, °C	: 80	**Percent Non-Linear Load**	: 100.0
Voltage Distortion	: 9.3	**Voltage Distortion Limit**	: 10
Site Rated Max Step kW Limit	:	**Max Step kW**	:

*Note: Higher temperature rise at full rated load.
*Note: All generator set power derates are based on open generator sets.

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ENGINEERING PROJECT
ENVIRONMENTAL, HEALTH, SAFETY AND SECURITY CHECKLIST

Spec Number/Project Name:	Click or tap here to enter text.
Project Engineer Name and Extension/Email:	Click or tap here to enter text.
Brief Summary of Project:	Click or tap here to enter text.

INSTRUCTIONS: This checklist is intended as an aid to engineering staff during the preliminary stages (before or at the 10% design milestone) of project development to ensure environmental, health, safety and security issues are addressed. For projects that may require significant planning and input from RCO, please obtain feedback and recommendations earlier in the planning phases. Please return this Checklist to Carla Cartagena, MS 704.

Coordination Meeting

A meeting is required with RCO in the early stage (by the 10% design milestone) of the project to discuss potential environmental, health, safety, and/or security issues and proposed mitigations. The meeting should be held when enough information is known about the project to address these issues, but early enough that changes can be made. Required attendees are the design PE, PM, WHS, ECS, and SEP. Has this meeting been scheduled? Yes ☐ No ☐

General Questions

1. Will any structures or buildings be demolished as part of this project? Yes ☐ No ☐ Unknown ☐

2. Will there be any removal or disturbance of materials with asbestos, lead, PCBs or any other known hazardous material? Yes ☐ No ☐ Unknown ☐

   If Yes or Unknown, please meet with WHS and ECS to coordinate a hazardous materials building survey. Please also review site history and past projects for sampling records and surveys and provide to RCO if available.

3. Has there been any prior contamination, abatement, or remediation of hazardous materials (asbestos, lead, PCBs, etc.) at the project site? Yes ☐ No ☐ Unknown ☐

   Please review site history and past projects and have records available for RCO review.

Workplace Health and Safety Issues

1. Will the project create or generate hazardous dust, fume, mist, gases, or vapors in any way that could expose workers: for example, Lead, Asbestos, Silica, PCB, or any other chemical substances? Yes ☐ No ☐ Unknown ☐

2. Will the project involve working at heights over six feet above or below grade? Yes ☐ No ☐ Unknown ☐

3. Will the project require trenching or excavating? Yes ☐ No ☐ Unknown ☐

4. Will any excavations or trenching exceed 20 feet in depth? Yes ☐ No ☐ Unknown ☐

5. Will any excavation or grading occur within an area that contains naturally occurring asbestos (NOA)? Yes ☐ No ☐ Unknown ☐

Note: NOA maps are available as a layer on the District B-Maps under the layer 'Environmental Areas of Concern.'

6. Will the total surface area of ground to be disturbed by the project, including by staging, trenching, excavation or grading, be1 acre or greater? Yes ☐ No ☐ Unknown ☐

7. Will personnel be required to enter confined spaces such as vaults, pipes, manholes, tanks, tunnels, trenches, etc.? Yes ☐ No ☐ Unknown ☐

8. Will the work involve the installation of electrical service over 600 volts? Yes ☐ No ☐ Unknown ☐

9. Will there be work that requires a diver for either inspection or construction? Yes ☐ No ☐ Unknown ☐

10. Will the work be located over a body of water such as a river or lake or bay? Yes ☐ No ☐ Unknown ☐

11. Will there be any tunneling or pipe jacking, or structural modification of existing tunnels or pipelines? Yes ☐ No ☐ Unknown ☐

12. Will there be any abrasive blasting of coatings or surfaces? Yes ☐ No ☐ Unknown ☐

13. Will there be any spray coating of surfaces? Yes ☐ No ☐ Unknown ☐

14. Will there be any work involving the draining, cleaning, purging, decontaminating, or demolition of systems or structures once used to store, process, or convey hazardous materials? Yes ☐ No ☐ Unknown ☐

15. Will any structures or buildings be constructed that will be two (2) or more stories, or 24 feet or more in height or depth? Yes ☐ No ☐ Unknown ☐

16. Have Prevention through Design (PtD) principles been applied to eliminate and/or reduce hazards at the source and increase safety for maintenance and operations workers? Yes ☐ No ☐ Unknown ☐

Note: This includes considerations for improving fall protection, confined space access, reducing noise exposure, etc.

Security Issues

1. Is the work being performed at a critical facility? Yes ☐ No ☐ Unknown ☐

2. Will the facility be in-service during construction? Yes ☐ No ☐ Unknown ☐

3. Are Contractor badges required during construction per the Construction Security Guidelines? Yes ☐ No ☐ Unknown ☐

4. Will guard services be required during construction? Yes ☐ No ☐ Unknown ☐

5. Have physical security improvements been integrated into design in accordance with Physical Security Design Guide: Yes ☐ No ☐ Unknown ☐

-Fencing and/or walls
-Physical barriers (bollards / K rail)
-Security keypads (C*Cure) and locks
-Video security systems
-Contact alarms

Environmental Issues

1. Is an environmental site assessment (phase I/phase II) required for the project? Yes ☐ No ☐ Unknown ☐

2. Will any water, wash water, or wastewater be disposed of to the storm sewer, sanitary sewer or receiving water (creek, stream, lake, bay, or other body of water) from this project during construction other than storm water runoff? Yes ☐ No ☐ Unknown ☐

3. Will any water, wash water, or wastewater be used for multiple uses, beneficial reuse (soil compaction, street sweeping, dust control, percolation, low-impact development features or irrigation)? Yes ☐ No ☐ Unknown ☐

4. Will any soil be off-hauled or beneficially reused from this project? Yes ☐ No ☐ Unknown ☐

5. Will any hazardous materials be stored at the project site during construction for more than 30 days (e.g., diesel tanks, temporary chemical tanks)? Yes ☐ No ☐ Unknown ☐

6. Will any known or suspected hazardous materials be removed and disposed of from this project (e.g., treated wood, chemical storage tank residue, PCB, mercury, or other process or lab chemicals)? Yes ☐ No ☐ Unknown ☐

7. Will any underground or aboveground tanks and/or associated piping be installed or removed during this project? Yes ☐ No ☐ Unknown ☐

8. Will any work be done in or adjacent to a stream, lake, river, or other water body? Yes ☐ No ☐ Unknown ☐

9. Does the project contain potential for erosion impacts to nearby water bodies during construction? Yes ☐ No ☐ Unknown ☐

10.Will monitoring wells be installed or removed under this project? Yes ☐ No ☐ Unknown ☐

11. Will construction result in land disturbance of one acre or more? Yes ☐ No ☐ Unknown ☐

12. Is there any known or suspected environmental (soil, soil gas or groundwater) contamination at or adjacent to this site? Yes ☐ No ☐ Unknown ☐

13. Will groundwater be encountered at any time during the project (e.g., excavation or trenching activities, dewatering, or work involving underground structures), regardless of whether contamination is known or suspected? Yes ☐ No ☐ Unknown ☐

If Yes or Unknown, coordinate with ECS to determine sampling, handling, and permitting requirements.

14. Are there any reports/ information available related to site history and potential contamination onsite? Yes ☐ No ☐ Unknown ☐

15. Is the project located adjacent to a freeway or highway? Yes ☐ No ☐ Unknown ☐

16. Is there residential property or sensitive receptors (e.g., schools, hospitals, nursing homes) adjacent to the site? Yes ☐ No ☐ Unknown ☐

17. Has a CEQA document been filed for the project? Yes ☐ No ☐ Unknown ☐

18.Will the project use architectural coatings or other VOC containing compounds, including aerosols, during construction? Yes ☐ No ☐ Unknown ☐

19. Will the project include installation of a boiler, generator, engine, or other equipment that combusts fuel (e.g., natural gas, diesel, gasoline, digester gas, propane)? Yes ☐ No ☐ Unknown ☐

20. Will the project include the installation of sources that can release volatile organic compounds (e.g., paint booth, parts cleaner, gasoline dispensing, other solvent usage)? Yes ☐ No ☐ Unknown ☐

21. Is the contractor planning to use portable generators to supply power during construction? Yes ☐ No ☐ Unknown ☐

22. Does the project require vegetation management or pesticide application? Yes ☐ No ☐ Unknown ☐

23. For wastewater projects: will this work be done on the west end property? Yes ☐ No ☐ Unknown ☐

Post-Construction Questions

1. Will hazardous substances (includes both hazardous materials and hazardous wastes) be stored at the newly constructed facility? Yes ☐ No ☐ Unknown ☐

2. Will the newly constructed facility discharge water, wash water or wastewater to a storm drain or receiving water (e.g., process streams, cooling water, vehicle wash water, sump water)? Yes ☐ No ☐ Unknown ☐

3. Will the newly constructed facility discharge water, wash water or wastewater (other than sanitary waste) to a sanitary sewer? Yes ☐ No ☐ Unknown ☐

4. Will the project include permanent installation of a boiler, generator, engine, or other equipment that combusts fuel (e.g., natural gas, diesel, gasoline, digester gas, propane)? Yes ☐ No ☐ Unknown ☐

5. Will the project include the permanent installation of sources that can release volatile organic compounds (e.g., paint booth, parts cleaner, gasoline dispensing, other solvent usage)? Yes ☐ No ☐ Unknown ☐

6. Will the project include permanent installation of any pressure vessels, including tanks used for the storage or accumulation of any gas or liquid under pressure? Yes ☐ No ☐ Unknown ☐