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16. ABSTRACT

Maintenance and layover facilities are vital in operating and maintaining passenger rail systems. This research project is interested in the decision-making criteria for locating such facilities and how those criteria impact the performance of the rail system. This research project looks at the locations and the types of most recently-built rail maintenance and layover facilities in the United States. It also looks at the criteria that influenced construction in those locations. The research developed a list of location criteria and analyze which criteria influenced performance and how in those locations. Finally, the research project recommends location criteria based on the system's goals. These recommendations will influence future planning documents such as the California State Rail Plan and the Caltrans Rail Fleet Management Plan as well as location decisions.

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Locations for Future Intercity Passenger Rail Maintenance or Layover Facilities in CA

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EXECUTIVE SUMMARY

Rail transportation is vital for the economic growth of California and facilitates movement of people (and goods) on a regional scale. Rail maintenance and layover facilities are required for timely operations of the transit service if they are optimally located. There are few studies that provide a framework in determining the optimal facility location from among several locations available. Further, studies also show that determining an optimal location for a rail maintenance or a layover facility in a region is often a challenging task, limited by the constraints that drive the choice. If these constraints include considerations for soil conditions, costs, seismicity, fire, noise etc., the choice of an optimal location of a facility become even more complex and difficult.

Sustainable construction practices often govern the location considerations. For example, use of "just-in-time" transportation and construction methods. Other considerations for an optimal location could be provisions for an efficient waste management practices, use of methods to share maintenance needs with other facilities nearby, and opportunities to use renewable energy sources such as solar devices. Other factors that are to be considered for identifying location of a rail maintenance and layover facility could include structure's dimensional needs, capacity constraints for individual elements – such as locomotives, cars, storage etc.

This research provides guidance in determining key factors to be considered in determining future location of a rail maintenance and layover facility in California. Further, this research also explores innovative state-of-the-art technologies that can be used to enhance operations of an existing or a future intercity rail maintenance and layover facility in California. To fulfill the research objectives, site visits were carried out at four intercity passenger rail maintenance and layover facilities in California, Colorado and Florida. The following were the facilities that were visited:

A. Oakland Maintenance Facility (OMF) in California.
B. Stockton Altamont Corridor Express (ACE) Maintenance and Layover Facility in California.
C. Commuter Rail Maintenance Facility (CRMF) located in Denver, Colorado, and
D. West Palm Beach Brightline Layover and Maintenance Facility in Florida

The site visits to the facilities in Oakland and in Stockton were carried out the same day. The Oakland facility had sustainable measures in place, such as use of LED lights and reuse of water from train wash – however, the sustainability measures were limited when compared to the ACE in Stockton. For example, Stockton ACE had plenty of solar panels on its roof and the facility structure was recently constructed compared to the facility in Oakland. Diesel locomotives and cars were maintained at both the facilities. From among all the four sites, it was noted that the Oakland Maintenance Facility site comprised the most undesirable soil condition with geotechnical challenges. Oakland facility currently is constrained by any future expansion due to space limited in its surroundings, while Stockton ACE is planning an expansion of its current facility due to availability of land.

The Denver CRMF facility received a Leadership in Energy and Environmental Design (LEED) Gold Certification and carries out the maintenance of multiple-unit (EMU) cars in a sustainable and efficient manner. Based on further study of the facility and site visit to Denver CRMF, it was learnt that the facility was restructured and built from a previously existing yard at the location. However, like the Oakland facility, the facility does not have space for expansion in future to its neighboring space.

The West Palm Beach Brightline Layover and Maintenance Facility runs on the principle of a for-profit company and carries out most of its maintenance activities of its diesel operated locomotives and cars using mobile tools and machineries. Although Brightline facility in West Palm Beach Orlando has a good solar potential, solar power was not used for any lighting needs. Harmful emissions by diesel loco were treated using a converter before being released into the atmosphere.

All four sites of OMF, Stockton ACE, Denver CRMF, and Brightline West Palm Beach were closely connected to one or more transit stations along a prominent intercity passenger rail line. Based on the site visits and literature reviews, eight objective functions and constraints were identified that could govern the location for a future intercity passenger rail maintenance and layover facility in California. The objective functions are as follows:

1. Maximizing opportunities for state-of-the-art application of technologies – i.e. technologies that will increase maintenance/operational efficiencies, space utilization etc.
2. Maximizing building/structural/operational sustainability
3. Minimizing risks associated due to geotechnical issues and seismicity
4. Maximizing service/building/structural/operational resiliency (i.e. minimizing operational downtime incurred by service or design load effects)
5. Minimizing risks associated due to fire
6. Minimizing the total setup cost
7. Minimizing average time/distance traveled from the existing facilities and stations
8. Minimize risks due to flood and tsunami hazards

The constraints are:

- Limitations in availability of clean (alternative) sources of energy
- Water conservation and waste management (sustainability)
- Structures dimensional needs, space for expansion, capacity constraints for individual elements – such as materials, locomotives, cars, storage, workforce etc.

A list of candidate locations (with latitudes and longitudes) were shortlisted from among existing yard locations in California - with the assumption that an existing yard could save time and cost involved in land acquisition and other location-specific advantages could also be known in advance and leveraged. Further, these candidate locations were selected based on the proximity to the existing intercity passenger railroad line in California as well as proximity to at least one station within a ten-mile radius around each location. This would ensure quick dispatch of trains for operation after maintenance. With the knowledge that majority of workforce in California are concentrated within 10-mile radius around a job site, a candidate location should have a high concentration of rail-maintenance-related workforce around 10-mile radius of the location. Using these assumptions, there were seventeen candidate facilities (as yard-station systems) identified as a potential future location in California.

Each yard-station system is located within a mile distance from the intercity passenger railroad line and has at least one rail station within couple miles radius surrounding it. A future facility in California should be located within a 10-mile radius of a finally determined yard-station system. The 17 yard-station system identified as candidate for future facility location were: One Coaster Way, Sand Canyon, Southern California Regional Rail Authority, Keller Yard, Terminal Tower LAUS, Los Angeles Union Station (LAUS), Los Angeles Maintenance Facility, Metrolink Central Maintenance Facility (CMF), Metrolink Moorpark Crew Base, Montalvo, Centralized Equipment Maintenance and Operations Facility, Hayward Shop, Oakland Shop, Oakland Maintenance Facility, Richmond Shop, Concord Shop, and Stockton ACE.

A weighted preference value (score) for each yard-station system location was developed. The preference value is developed based on all the eight objective functions and constraints. The weighted preference value calculated for Stockton ACE was the highest among all the locations. Thus, indicating that area within 10-mile radius of Stockton ACE should be considered as the future location for rail maintenance and layover facility in California.

Various state-of-the-art technologies exist that can be used to overcome a location's disadvantage. This research also documents specific technologies to fulfil sustainability, geotechnical, operational resiliency, fire, and flood and tsunami hazards' protection needs of an existing or a future intercity passenger rail maintenance and layover facility in California.

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INTRODUCTION

Rail transportation is vital for the economic growth of California and facilitates movement of people (and goods) on a regional scale. Rail maintenance and layover facilities are required for timely operations of the transit service if they are optimally located. There are few studies that provide a framework for determining the optimal facility location from among several locations available ([1]). Further, studies also show that determining an optimal location for a rail maintenance or a layover facility in a region is often a challenging task, limited by the constraints that drive the choice. If these constraints include considerations for soil conditions, costs, seismicity, fire, noise etc., the choice of an optimal location of a facility become even more complex and difficult.

Sustainable construction practices often govern the location considerations. For example, use of “just-in-time” transportation and construction methods. Other considerations for an optimal location could be provisions for an efficient waste management practices, use of methods to share maintenance needs with other facilities nearby, and opportunities to use renewable energy sources such as solar devices. Other factors that are to be considered for identifying location of a rail maintenance and layover facility could include structure’s dimensional needs, capacity constraints for individual elements – such as locomotives, cars, storage etc. Other factors could include structure’s dimensional needs, capacity constraints for individual elements – such as locomotives, cars, storage etc.

This research provides guidance in identification of key factors and goals (objectives) that need to be considered in determining a future intercity rail maintenance and/or layover facility in California.

LITERATURE REVIEW

Based on the literature reviews, description of key elements considered important in engineering design and construction technologies for determining optimal locations for future intercity passenger rail maintenance or layover facilities are as follows:

Geotechnical and Structural Considerations

- Geotechnical investigations including the sub-surface exploration and soil classification: In order to estimate soil’s bearing capacity, test results from site’s borehole testing should be available. This data includes soil grain-size distribution, soil density, soil plastic limit, etc. A location with higher soil bearing capacity and lower potential settlement will result in smaller foundation size and foundation depth and consequently, lower construction cost (NAVFAC 7.1[2] & 7.2[3]).

- Ground Water Table: The higher the ground water table is (i.e., the closer to the ground surface), the lower the soil bearing capacity will be, which results in higher construction costs. In addition, soil excavation at sites with near surface water is challenging and incurs higher construction costs. Stabilizing surrounding soil cuts and watertight the

[1] Tönissen, D. D., Arts, J. J., & Shen, Z. J. (2019). Maintenance location routing for rolling stock under line and fleet planning uncertainty. Transportation Science, 53(5), 1252-1270.

[2] Naval Facilities Engineering Command, Design Manual 7.1: Soil Mechanics, 1986.

[3] Naval Facilities Engineering Command, Design Manual 7.2: Foundations and Earth Structures, 1986.

walls against seepage would be lengthy and costly. Examples of techniques for excavation at the presence of water include watertight driven sheet piles, Jet-grouting, and deep-soil mixing.

- Construction near or on a slope: Soil bearing capacity on a slope is considered smaller than that of a level surface. In addition, the site needs to be graded and the stability of the slope to be studied[4].

- Excessive total and Differential Settlements: At sites with organic and/or saturated clayey soil, a long-term *Consolidation* and *Plastic* settlement of the foundation is expected. In these sites, usually, it is the foundation settlement that governs the design for foundation size and depth. The higher the potential settlement, the larger the size of foundation and cost. In order to ensure continuous operation, the tolerance for *differential settlement* of a rail maintenance facility should be very small (relative to typical residential or commercial warehouses). Therefore, potential foundation settlement should be a crucial factor in the site selection process. At an additional cost to the project, various techniques for soil improvement (e.g., soil cementation, soil compaction, etc.) can be employed to control foundation settlement.

- Site-specific seismicity: It is noteworthy that seismic ground shakings can exacerbate potential geotechnical issues (e.g., excessive settlement) for a building. California is among the zones in the world with high seismic hazard. However, the hazard can vary depending on the location of the site within the state. Figure 1 presents a map of potential earthquake shaking for the state of California. Factors such as the distance of the site to an active fault and the soil condition (e.g., liquefaction hazard where layers of saturated sand are present) can contribute to the structural seismic demand and the total incurred construction cost[5].

[4] Naval Facilities Engineering Command, Design Manual 7.2: Foundations and Earth Structures, 1986.
[5] Caltrans seismic design criteria: http://www.dot.ca.gov/des/techpubs/sdc.html

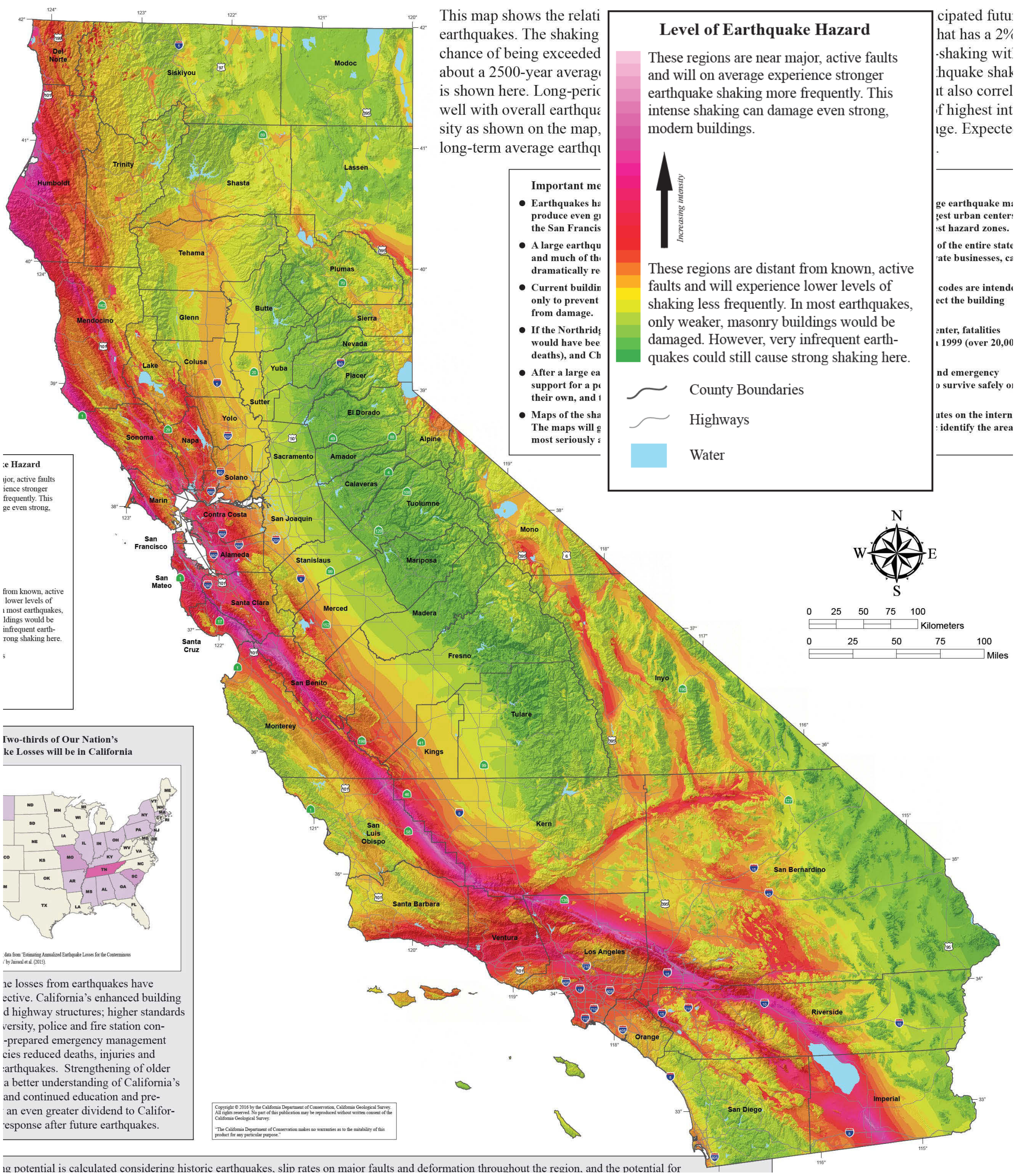


Figure 1: Earthquake shaking potential for California

(Source: California Geological Survey, www.conservation.ca.gov/cgs)

- Structural/Building Costs: Heavy panels in building/facility require adherence to seismic codes and pose challenge during transportation to the site location for construction – as these are prefabricated. Constraints such as transportation costs, the costs associated with casting, handling and erection of panels are high for construction of buildings/facilities in seismic zones -which will in-turn govern the location choice for a facility – to ensure seismic hazards and the costs of transportation of facility components and materials are minimal.

- Foundation Type, e.g., steel driven piles, concrete drilled piles, etc.: By analyzing the seismic and gravity load effects on the facility's foundation, the critical load demands on the soil will be determined. A cost-effective foundation type can be selected based on the load demand and soil condition. Caltrans' *Foundation Manual* (2015)[6] can be used for foundation selection and design. Cost of construction can be estimated via historic Caltrans construction cost data portal[7].

Fire Hazard

Optimal location of a future maintenance and operations facility should adhere to standards and design as per the latest California Fire Code Standards – acknowledging that the building and fire codes vary across the nation. The map in Figure 2 shows the spatial distribution of fire hazard severity zones in California and any future location should account for the level of severity the facility is prone to on a – moderate, high or very high scale. The following fire hazard related building requirements could govern the cost of construction, engineering design and subsequently, the choice of the location of a new facility:

- Construction type, building height, and footprint
- Exposures/separation requirements
- Type of material for load bearing components
- Fire ratings
- Interior finish
- Exit enclosure
- Fire alert system
- Fireproofing and firestopping, among others.

[6] Caltrans Foundation Manual: http://www.dot.ca.gov/hq/esc/construction/manuals/OSCCompleteManuals/Foundation.pdf

[7] Historic bid data for Caltrans construction cost data portal: http://sv08data.dot.ca.gov/contractcost/

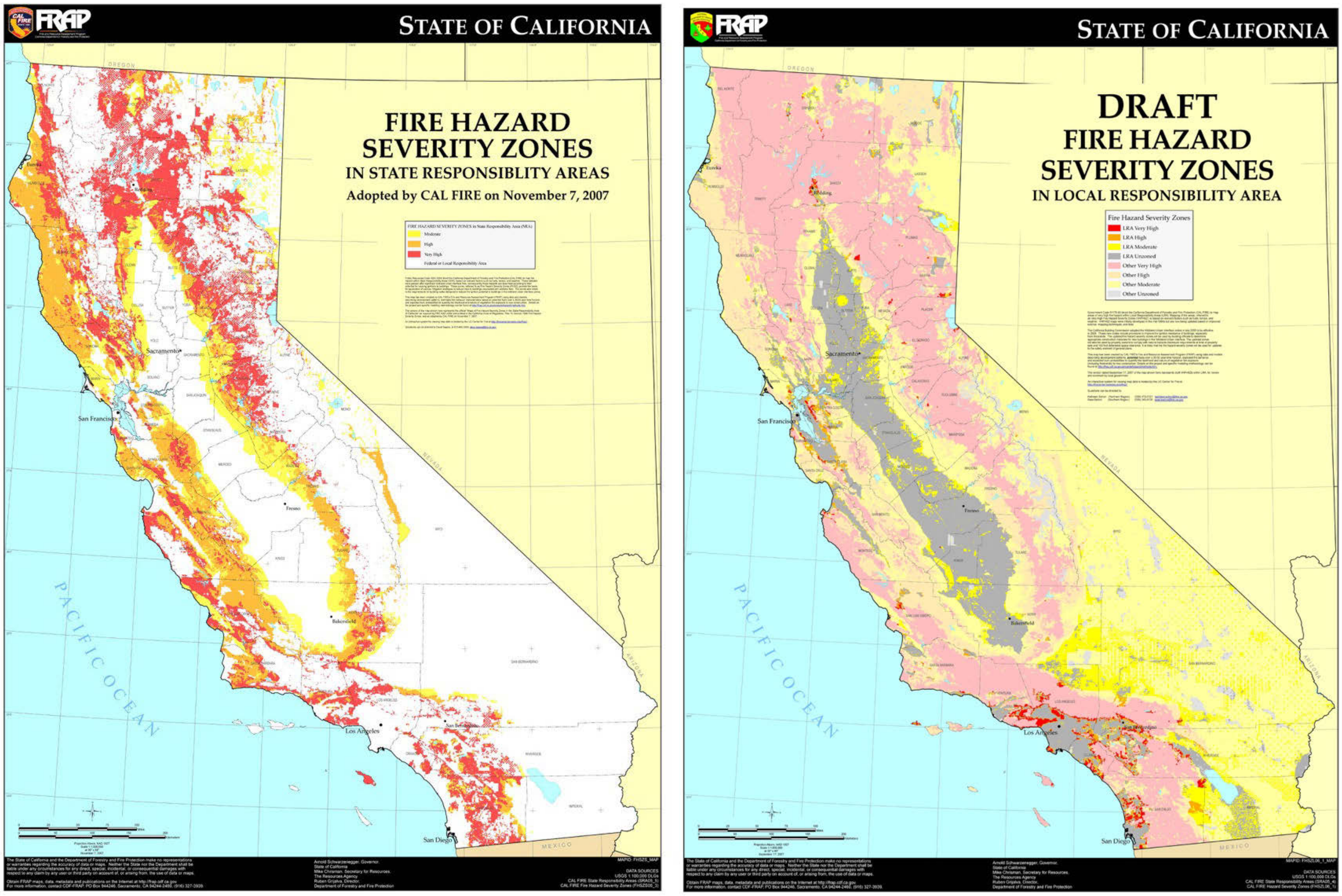


Figure 2:California fire hazard severity zones, state and local responsibility areas

(Source: Cal Fire, 2019[8])

[8] Cal Fire, accessed on August 22, 2019. https://frap.fire.ca.gov/frap-projects/fire-perimeters/

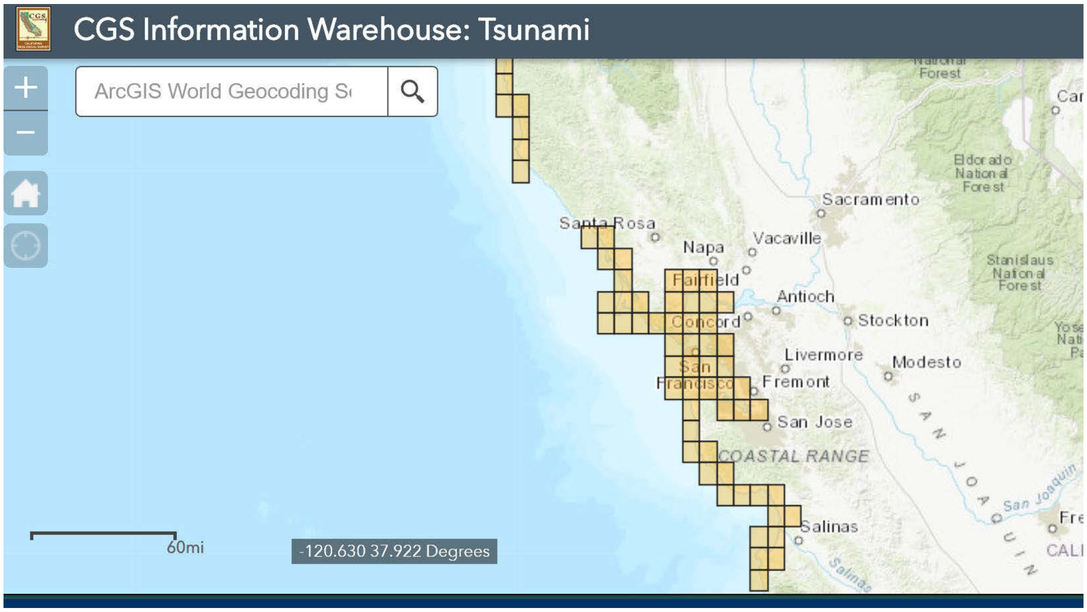
Weather/Climate Considerations for Flood, Wind etc.

Flood: The following are important considerations for designing and determining locations of a facility that could be flood prone:

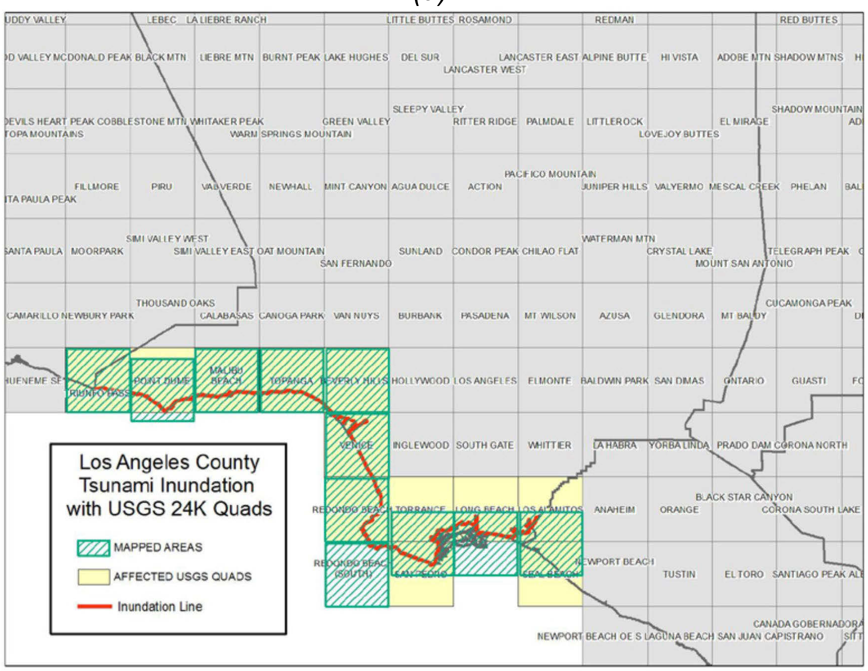
- source of flooding
- flood depth
- flood velocity
- flood duration
- rate of rise and fall
- wave effects
- flood-borne debris
- scour and erosion

Potential location choice of a facility should be governed based on the proper identification of flood hazard and regulations by the National Flood Insurance Program (NFIP) - Flood Hazard Mapping by FEMA.

Tsunami: Tsunami hazard should be considered for sites close to the coast. An interactive map of tsunami hazard in California is presented in Figure 3 (available via California Geological Survey website). The map provides an induction border for affected area by the tsunami raised water.



(a)



(b)

Figure 3:Tsunami map, a) Interactive Tsunami map for California b) Los Angeles Tsunami induction line

(Source: California Geological Survey, 2019[9]),

[9] California Geological Survey, accessed on June 21, 2019. https://www.conservation.ca.gov/cgs/maps-data

Wind: The windstorm types common in west coast states, especially California, are straight-line winds which blow in a straight line with speeds ranging up to 110 miles/hr (3-second gust speed at 33 feet height per ASCE7-10) for majority of locations in California and up to 130 miles/hr for *special* wind regions as prescribed by the code. A map of design wind load and special wind regions for the state of California is presented in Figure 4.

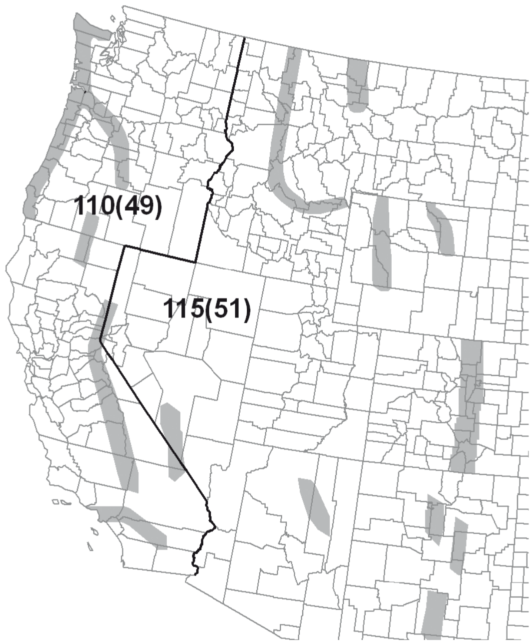


Figure 4: Design wind speed and special wind regions (in grey) for the state of California

(Source: ASCE7[10])

Sustainability Considerations in Site Selection

A. Sustainable construction practices involve the following ([11]):
   - (i) use of "just-in-time" transportation and construction methods – for precast concrete members,
   - (ii) use of minimal equipment
   - (iii) lower traffic levels,
   - (iv) minimize air pollution due to dust and have feasibility and use of zero emission multiple unit trains (DMUs).

B. Location should
   - (i) provide easy elimination and reuse of waste on construction projects,

[10] Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-16)
[11] Field Guide for Sustainable Construction by the Pentagon Renovation and Construction Program Office, Department of Defense. 2004.

(ii) use methods to share equipment such as crane, lifts etc. with other nearby construction projects,
(iii) provide suitability of soil to use trenchless technology for installing and rehabilitating underground utility systems.
(iv) have opportunities to use renewable energy sources - especially incorporate renewable energy,
(v) have potential for use of solar devices.

C. Construction technologies at site could consist of use of the following:
(i) GPS-based earthmoving system
(ii) automation in material handling processes
(iii) visualization with BIM (Building Information Modeling)
(iv) prefabrications
(v) use of unmanned aerial systems (UAS)
(vi) safe excavation technology devices
(vii) soil stiffness gauge for soil compaction control
(viii) Concrete Encounter for measuring concrete moisture
(ix) digital subsurface imaging technology
(x) new steel erection technology
(xi) use of 4D CAD model
(xii) use of digital photos with real time GPS information
(xiii) use of cool roof calculator, and
(xiv) wireless calling systems and Bluetooth technology
(xv) use of pre-cast structural components
(xvi) concrete post-tensioning techniques
(xvii) use of composite materials

General Capacity Needs (as constraints)

Location selection of a facility will be governed by various components of a facility such as - Locomotives, Cars, Service & Inspection, Equipment Storage Facilities, and Material Warehouse and Delivery. Table 1 identifies these capacity and dimensional needs in brief.

Table 1: General capacity and dimensional needs of operations and maintenance facility (OMF) elements

Elements	**Governing capacities and dimensional needs**
Locomotives	▪ Gantry cranes (such as bridge cranes, gantry cranes, monorail cranes, jib cranes, workstation cranes etc.) - Up to 16 ft in height for a 10-ton gantry crane. ▪ Predictive Maintenance (PM) Tracks ▪ Raised Rail ▪ Inspection Pits ▪ Scaffolding ▪ Ramps; Heavy repair and modification spot ▪ Truck/wheel drop table

	▪ Wheel truing machine; ▪ Track capacity for 8 locomotives each; ▪ New/Used Oil storage tanks
Cars	▪ Gantry crane ▪ Track with adequate car capacity PM line; ▪ Spot inside inspection pit; ▪ HVAC/Chiller repair shop
Service & Inspection	▪ Bay- for locomotive servicing spots ▪ Fuel/Oil/Sand Stations ▪ Inspection Pits and Scaffolding ▪ Car inspection tracks (one has full length inspection pit) ▪ Single axle split rail drop table ▪ Automated train washing facility ▪ Fuel storage tanks ▪ Waste pump truck discharge station
Equipment Storage Facilities	▪ Track for car storage capacity ▪ Ground power stations ▪ Utilities (Electricity, Water, Air and LED Lights)
Material Warehouse and Delivery	▪ Inside and outside storage ▪ Bay loading dock/ramp

Summary of Factors for Location Consideration

Key factors that should be considered for determining location of a future intercity rail maintenance and/or layover facility in California are summarized in Table 2.

Table 2: List of key factors that could govern locations for future facilities in CA

Cost Factors	Risk Factors	Coverage	Service-related	Accessibility	Sustainability
Sales Tax	Seismic Hazard	Distance	Maintenance Frequency	Resources	Energy Efficiency
Transportation Cost	Flood	Time	Reliability	Utility Lines	Recycled Water
Installation Cost	Fire	Population	Maintenance Time	Workforce	Emissions
Environmental Cost	Waste disposal or treatment risk	Equity		Connectivity to existing corridors	Noise
Waste Disposal Cost	Geotechnical Hazard/Foundation Settlement				
Service Cost	Transportation Risk				
Energy Cost					

SITE VISITS

Introduction

Site visits were carried out at four rail maintenance and layover facilities, as follows –

1. Oakland Maintenance Facility in California.
2. Stockton Altamont Corridor Express (ACE) Maintenance and Layover Facility in California.
3. Commuter Rail Maintenance Facility (CRMF) located in Denver, Colorado, and
4. West Palm Beach Brightline Layover and Maintenance Facility in Florida.

The detailed findings from the four site visits are presented below:

Oakland Maintenance Facility

Overview

The site visit was conducted on February 1, 2019 at the facility located in Oakland. The purpose of the site visit to the Oakland Maintenance Facility (OMF) was to gather information on the building facility components and factors that could become critical for identifying a future location in California. The map in Figure 5 shows the location of the facility in Oakland (and Stockton ACE, discussed later) in California.

Site-specific Details

Soil Condition and Geotechnical Challenges

OMF site's Geotechnical Investigation report[12] dated November 25, 1998 has been reviewed, and the main findings are discussed in this section. The maintenance facility's site comprises two main soil types underlain by the bedrock. The surface layer consisting of fully saturated clay and silty clay soil (also known as *Bay Mud*) and the historic alluvial deposits beneath carried to the site from the adjacent hills. The Bay Mud is dredged from the bay water and deposited at the site. It typically contains organic soil (e.g., peat). Two main disadvantages of the Bay Mud for construction purposes are their low shear capacity and their high potential settlement (compressibility). Such layers tend to lose water and compress significantly under surcharge loads exerted by superstructures. One of the main challenges at the site was an unconsolidated Bay Mud layer causing long term large building settlement. As a result, the soil settlement was the main geotechnical concern for this site which governed foundation selection. There exists a manmade fill with thickness ranging between 4.5 to 11 feet throughout the site, mainly consisting of poorly graded granular soil. In addition to the Bay Mud's consolidation settlement, the saturated manmade fill and the Bay Mud are highly susceptible to liquefaction-induced settlement.

The soil layers' thicknesses and their densities vary throughout the site; therefore, for each structure, different foundation systems were proposed. The Service and

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[12] Geotechnical Investigation Report, Proposed Amtrak Maintenance Facility Third Street and Union Street Oakland California, prepared by Kleinfelder Inc., November 25, 1998.

Inspection building and the Maintenance building were identified to have the largest expected differential settlement. Two main foundation systems recommended for these buildings were: 1) Shallow foundation combined with a soil surcharge program, or 2) Driven precast concrete piles transferring the superstructures'' load to the denser alluvial layer beneath. In the former method, the surcharging program does not address the liquefaction potential of the weak layers. It also requires about one year to be completed (if not expedited using drain holes). The pile foundations have been recommended as the performance-effective method to pursue.

Groundwater was generally encountered from 2.5-4.5 feet below ground. Such a relatively high water would require temporary dewatering of excavated area during foundation construction. The expected excavations are estimated to be 22 to 25 feet in depth. This dewatering can become challenging and could incur project delay and additional costs. Typical challenge includes increased water seepage into excavated area due to poor water-stopping techniques at the sheet or soldier piles' vertical joints.

As discussed in the literature review chapter, the geotechnical challenges could result in higher construction and maintenance costs. These challenges could cause long repair downtime to the facility operations. According to lessons learnt from this site, for selection of future maintenance facility locations, we must avoid, if at all possible, the following geotechnical challenges (i.e., undesirable soil conditions):

- Undrained and unconsolidated clayey soil with large potential settlement
- Soil with highly compressible organic soil content
- Poorly graded and saturated granular soil or saturated sandy soil with high potential of liquefaction induced settlement
- High water table wherever foundation excavation is required
- High variation in the soil profile across the site and the building, such as soil composition and layers' thicknesses (this consideration would increase damaging differential settlement across the building)

Site-Specific Seismicity

The Oakland Maintenance Facility site is at the proximity of several active faults in the San Francisco Bay area. These faults are located about 5 to 16 miles from the site, including the San Andres fault and the Hayward fault. The former is well-known for potential of triggering very strong ground shaking at the site. In addition, the Hayward fault is located approximately 5 miles from the site. Such a close distance could cause *near fault* shaking at the site, which is very damaging to buildings. The site is not located within a California Alquist-Priolo Earthquake Zone, and no mapped fault traces cross through site. Therefore, there is no risk of ground rupture within the limits of the site.

Due to the high seismic hazard at the site, the seismic load demand for structural design purposes would be very large. These large loads result in large structural sections and larger foundation system and consequently, higher construction costs. Given the importance of these facility structures, it is desired to select the future location for a rail maintenance facility where:

- The seismic hazard and seismic design loads are lower

- The site is situated at a large distance from active faults. This is to avoid any near fault loading on the structure
- The California Alquist-Priolo Fault Zoning Act's map must be investigated to ensure that the future facility location is not located in an earthquake fault zone and no mapped fault transverses through the site causing site surface rupture. Figure 6 presents a screenshot of the California Geological Survey (CGS) Earthquake Hazards Zone Application ([13]) which helps identify the faults zones and fault traces in any location in California

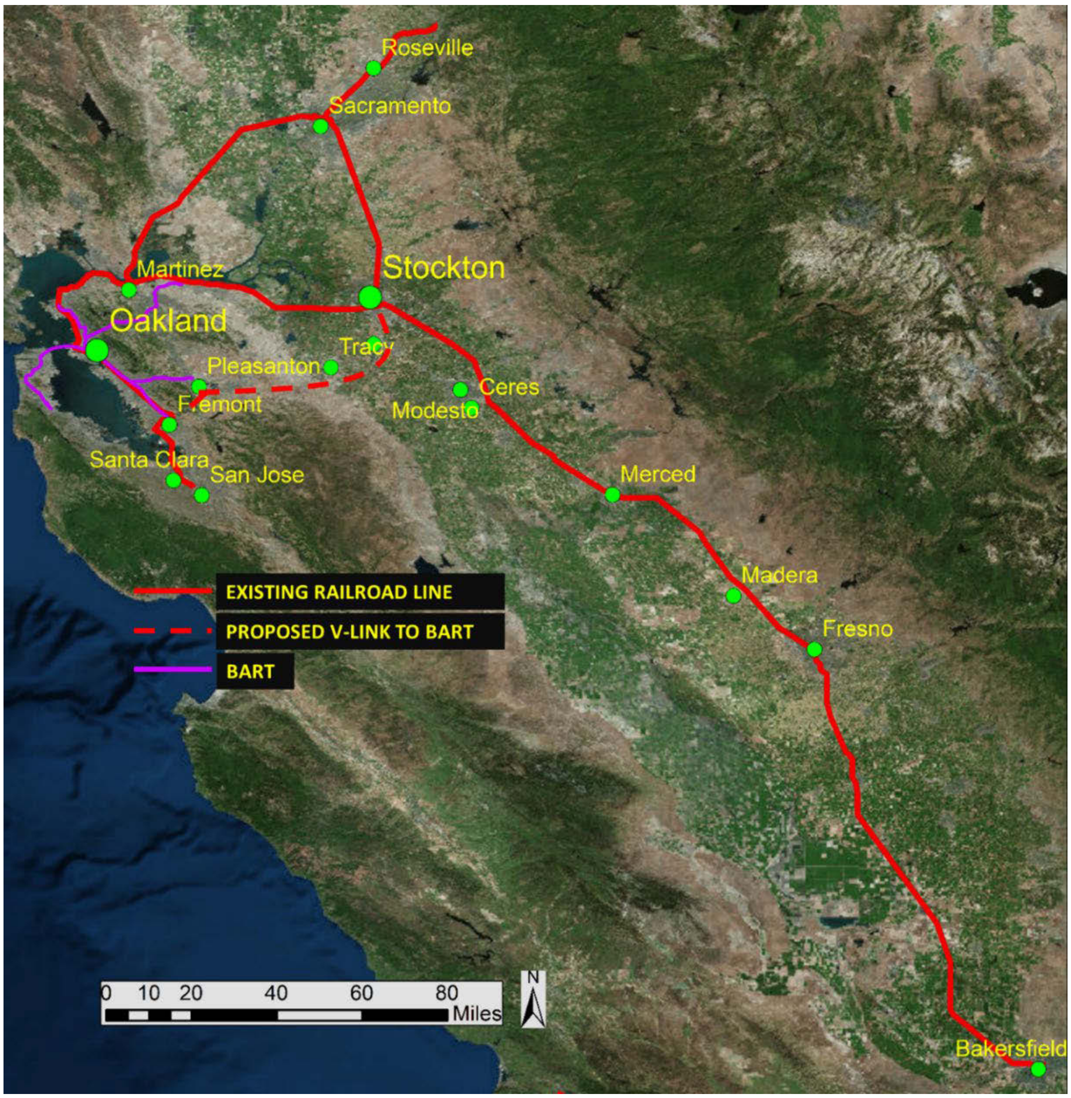

Figure 5: Geographical location of Oakland and Stockton facilities visited

[13] California Geological Survey, accessed on April 11, 2019. https://www.conservation.ca.gov/cgs/geohazards/eq-zapp

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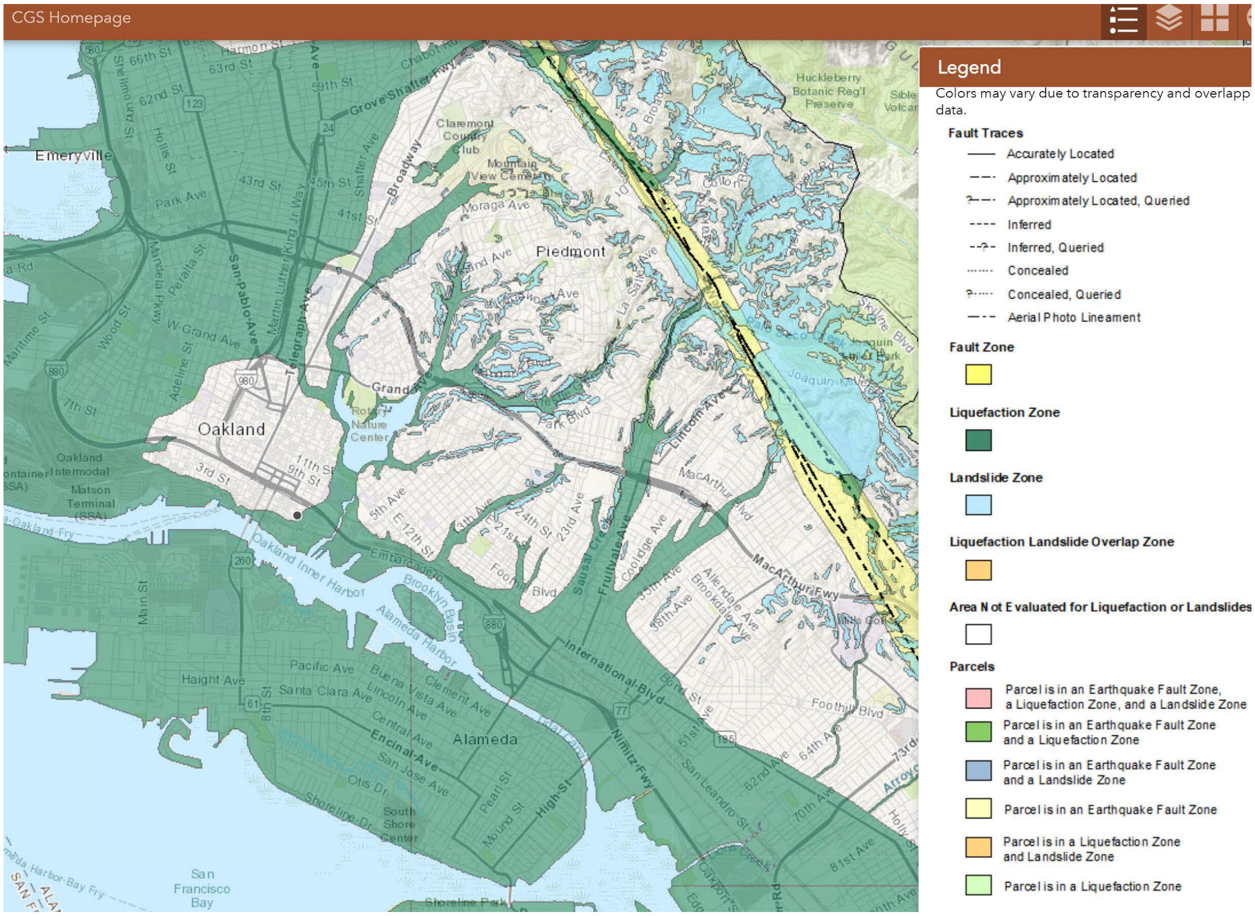


Figure 6: A screenshot of California Geological Survey (CGS) Earthquake Hazards Zone Application

(The map in Figure 6 is used for identifying fault zones and fault traces in any location in California. This Figure demonstrates earthquake fault zones and liquefaction zones at and around the Oakland Maintenance Facility)

Facility Components

Construction of the facility structures started in 2002 and the operation started in 2004. There are total of 14 tracks that are in the facility location and has the following buildings as summarized below:

1. Preventive Maintenance Building – This building is centrally located, which includes the following key machine, equipment and parts serving the maintenance needs:
    - Machine shop

- Locomotive repair shop
- Gantry cranes
- Tracks
- Wheel truing pit
- Drop table
- Material storage and control Issue room
- Vending machine placed just outside the building
- Storage room
- Break room
- Main office
- Boiler room
- Electrical room

2. Service & Inspection Building: The following key service-related equipment were in-housed in this building:
    a. HVAC shop
    b. Inspection pits
    c. Bay for locomotive servicing spots
    d. Fuel, oil and sanding area
    e. Tracks for car inspection
    f. Fuel storage tanks
    g. Automated train washing facility
    h. Waste pump truck discharge station

3. Train Wash Building: The building has a tank room, an electrical room and a load test room.
4. Storage: The storage consists of primarily scrap metal and oil waste bins, a scrap wheel garden, and good wheel storage.
5. Locomotive Fuel Rack and Sanding Area

Building Description

The Oakland Maintenance Facility building located at junction of 3rd and Adeline streets in Oakland, California. The facility includes two building structures including an *indoor* heavy maintenance facility and an *outdoor* light maintenance facility. The facility buildings consist of a single-story warehouse type structure comprising bays of steel portal frames. The indoor facility is enclosed by a reinforced concrete masonry units (CMU) structure, windows and composite siding sheets at the upper part. Figure 7 shows the property location on a vicinity map and Figure 8 shows a bird's eye view of the two buildings. The indoor facility building has a rectangular shape with approximate dimensions of 300 feet by 170 feet. The outdoor layover facility is a relatively long structure with a footprint of 1000 feet by 65 feet. On the northside of the structures, there are detached management offices. The indoor facility building houses both car and locomotive maintenance equipment as well as a material storage department on the east side.

The steel portal frames are constructed of I-shape built-up steel sections. The perimeter columns of the portal frames are encased in concrete at their base. The frame and the concrete encasement are shown in Figure 9. The CMU walls are 10 feet tall on the north and south sides of the building (as shown in Figure 9). There are windows and composite sidings on the upper part of the side walls. The height of the CMU walls varies up to 20 feet in the east and west sides by the building entrances. The roof structure is comprised of steel purlins spanning between steel rafters of the steel portal frames. The roof is clad by corrugated metal sheeting. Additional steel beams are mounted on the interior columns supporting a 30-ton overhead crane system. Figure 10 presents the roof and the crane system. On the north side of the building, a raised track and a raised floor is constructed for easing locomotives' light and heavy maintenance operations. Figure 11 shows the raised steel deck flooring on steel hollow structural section (HSS) columns and the raised track supported on H-shape steel piers.

The building's structural drawings were not available for review. The constructed foundation system, among those recommended in the geotechnical report, is not known. However, it is likely that the buildings' foundation is continuous strip footings under the CMU walls and driven piles and pile caps under the steel columns. The building's ground floor is a concrete slab-on-ground. The outdoor facility consists of similar structural framing and roof system with no walls and no overhead crane system. Figure 12 shows the steel portal frame and maintenance pit for the light outdoor facility.

Figure 7: Vicinity Map – Oakland Maintenance Facility

(Source: Google Maps)

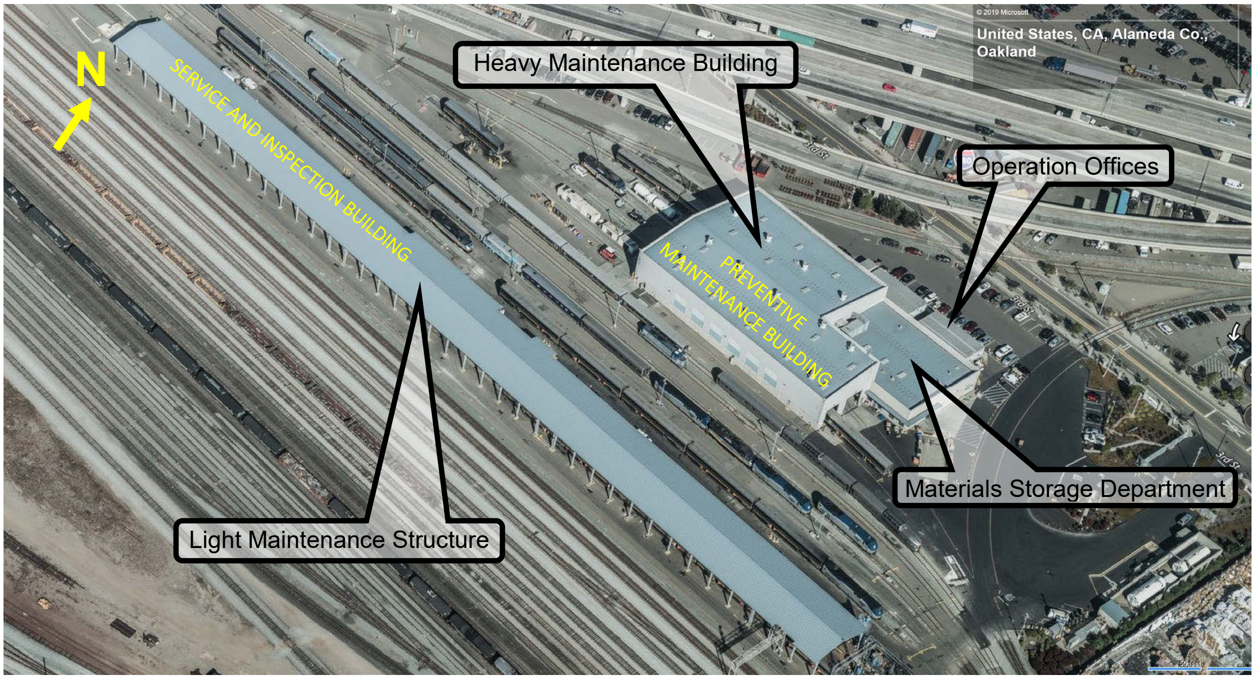


Figure 8: Bird's Eye view of the Oakland Maintenance Facility

(Source: Bing Maps)

Figure 9: Building structural components, steel portal frame, column's concrete encasement, and CMU walls

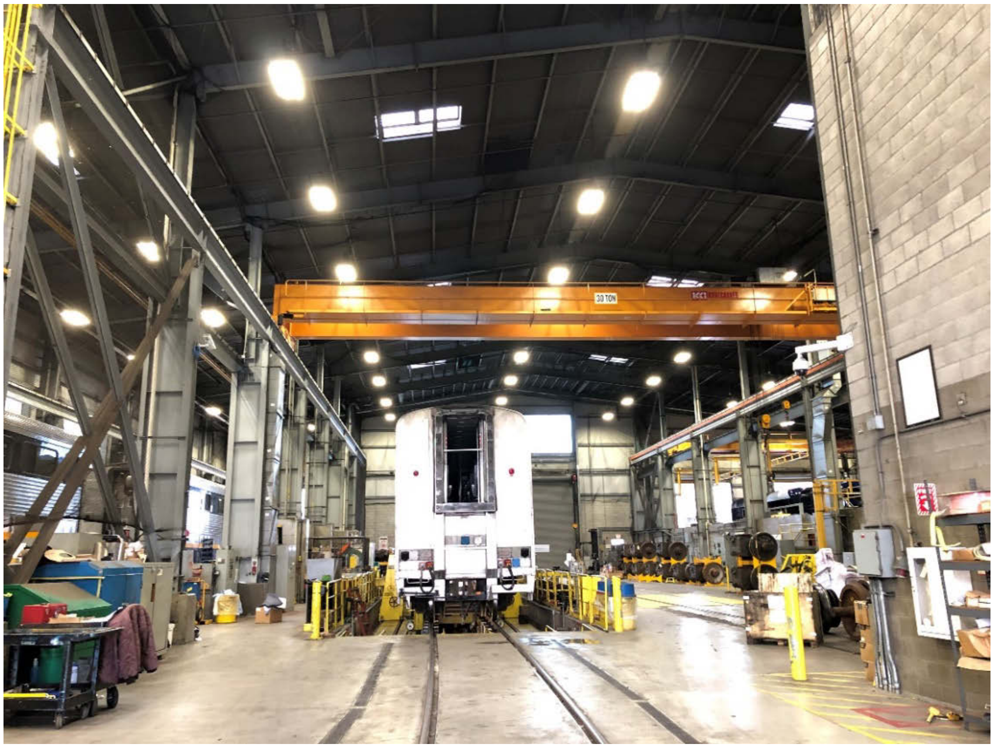


Figure 10: Building structural components, roof framings and overhead crane system

Figure 11: Raised steel deck flooring on steel HSS columns and the raised track supported on H-shape steel piers

Figure 12: Structural components of the outdoor light facility: Steel portal frame and roof system and maintenance pit

Stockton Altamont Corridor Express (ACE) - Maintenance and Layover Facility

Overview

The Stockton Altamont Commuter Express (ACE) site visit was conducted on February 1, 2019. The Stockton ACE facility construction started in 2012 and began operations in 2015, spread on almost 64-acres, with the location connected mainly through the BNSF and Union Pacific Railroad lines. The purpose of the site visit was primarily to compare the findings on the building facility components and factors with the facility in Oakland. The map in Figure 13 shows the location of the Stockton ACE.

Site-specific Details

The ACE maintenance facility was to be constructed by the San Joaquin Regional Rail Commission (SJRRC) in Stockton adjacent to the former Western Pacific (WP) and former Southern Pacific (SP) rail lines, west of West Lane and south of East Alpine Avenue[14]. The determination was that "although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the Project have been made by or agreed to by the applicant." SJRRC proposed to construct a new maintenance facility on the 64-acre site and make modifications to the rail line within a 9-acre Union Pacific Railroad (UPRR) parcel. The construction and operation of the project would affect approximately 73-acres.

[14] Altamont Commuter Express Maintenance Facility Project, Initial Study/Mitigated Negative Declaration, September 3, 2008.

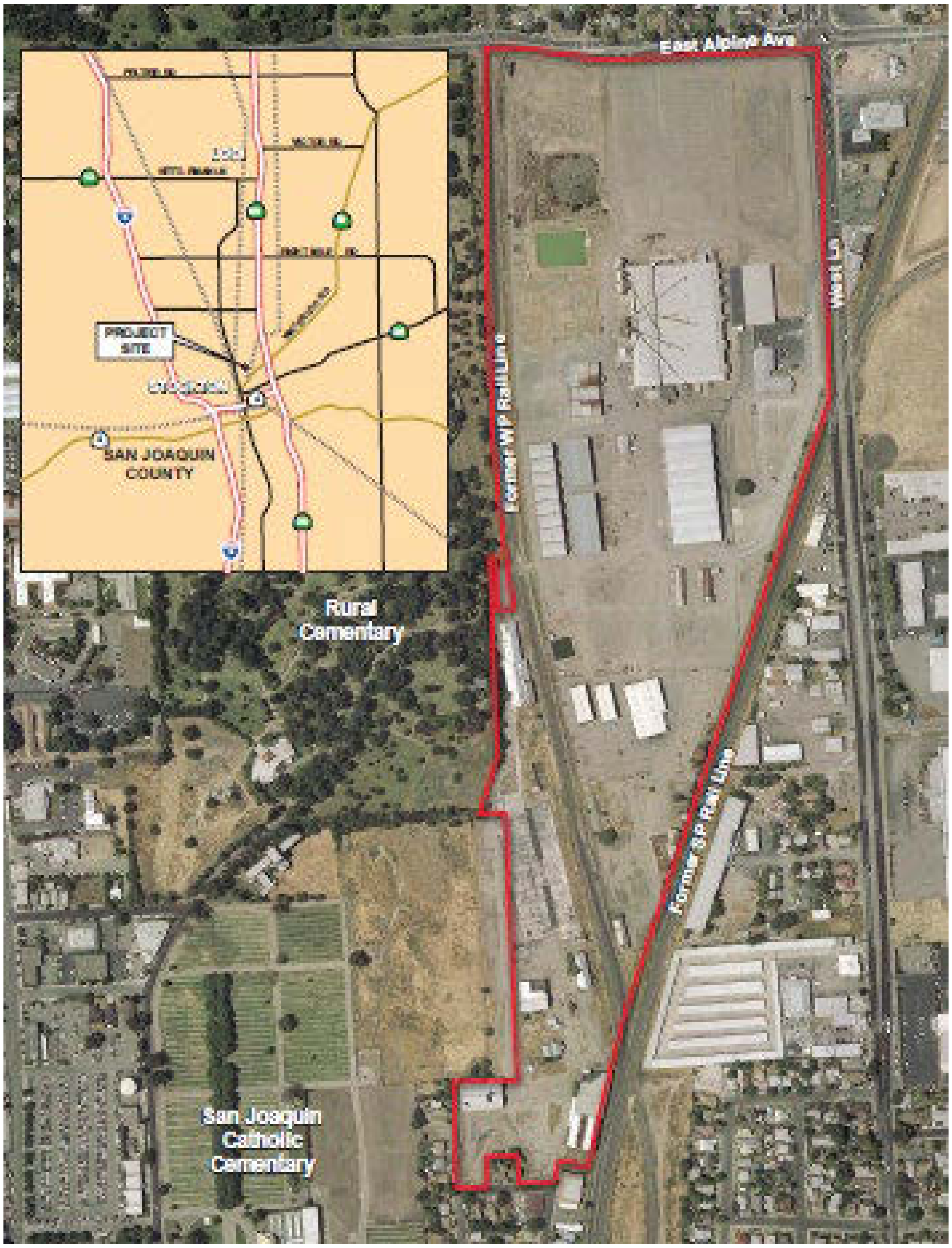


Figure 13: Proposed site location

Land Acquisition Challenges

The main challenge was the annexation of 27 parcels to obtain the entirety of the project area desired, which is 32 parcels (see Figure 13). If annexation of the entire 32-parcel island area cannot be achieved, SJRRC could pursue two options: (1) annexation of the East, Northeast, and Project Annexation parcels; or (2) pursue development of the Proposed Project within San Joaquin County and request an out-of-service agreement for the maintenance facility. The Project was subject to the California Environmental Quality Act (CEQA).

Impact on Agricultural and Scenic Resources

Aesthetics were considered first. It was determined that the project had no impact on the scenic vista or on scenic resources including trees, rock outcroppings and historic buildings along a scenic highway. It was determined that the project had less than significant impacts on existing visual character or quality of site and its surrounds and creating a new source of substantial light or glare that would adversely affect daytime or nighttime views in the area.

Agricultural Resources were considered next. There was no impact on converting farmland as per the Farmland Mapping and Monitoring Program of the California Resources Agency. This project did not conflict with existing zoning for agricultural use or conflict with a Williamson Act contract. Also, this project did not involve other changes in the existing environment that could result in the conversion of farmland to non-agricultural use.

Impact on Air Quality and Biological Resources

This project was considered to have a less than significant impact on air quality because “within the project area, air quality is monitored, evaluated, and regulated by federal, state, regional, and local regulatory agencies and jurisdictions, including the United States Environmental Protection Agency (EPA), the California Air Resources Board (CARB), and the San Joaquin Valley Air Pollution Control District (SJVAPCD).”

It was determined that this project would require mitigation for biological resources. BIO-1 and BIO-2 were required to be implemented for the loss of the Swainson’s hawk foraging habitat. This included ensuring that “an appropriate number of acres (as approved by CDFG) or agricultural land, annual grasslands, or other suitable raptor foraging habitat are preserved off site at a habitat preservation bank within San Joaquin County at a 1 to 0.5 (habitat lost to preserved) ratio.” Also, “a qualified biologist [shall] conduct nest surveys no more than 30 days prior to any demolition/construction or ground disturbing activities that are within 500 feet of potential nest trees or suitable nesting habitat (i.e., trees, grassland).” And if any active nests were found within the project site, the construction activities should only occur outside of a determined buffer zone. If the protected birds are disturbed, biologists shall consult and perform necessary salvage measures. “The project applicant will be required to fund the full costs of the salvage measures.”

Other Impact Measures and Mitigations

Mitigation for hazardous materials (HAZ-1) was required for this site due to its history. Mitigation for hydrology and water quality HYD-1, 2, and 3 were required. This required the fuel supplies and hazardous materials to be stored within confines of a designated construction staging area, preparing a Spill Prevention Control and Countermeasures (SPCC) plan, and a designed stormwater quality system to detail stormwater flows post construction.

Land use was considered less than significant without the need for mitigation. Mineral resources, noise, population and housing, public services, and recreation were also considered, and this project was considered to have no impact to a less than significant impact and did not require mitigation.

Transportation/Traffic required mitigation measures were required to control plan for project specific off-site improvements and repair the roads nearby as needed in order to reduce potential roadway damage impacts. It is also to be noted that at the Stockton ACE facility, the Burrowing Owl, White-tailed kite, and Swainson's Hawk were all to be affected by this development and required prerequisite mitigation.

Soil Condition and Geotechnical Challenges

The ACE maintenance facility project *Initial Study* report[15] prepared by PBS&J and dated September 3, 2008, has been reviewed and its main findings are discussed in this section. While the scope of the Initial Study report was not to provide detailed geotechnical exploration and soil testing results, some comments about geotechnical related risks were provided. Key findings noted in the report as well as important information available from the Soil Survey of San Joaquin County[16] (prepared for the US Department of Agriculture) and California Geological Survey webpage[17] are as follows.

- Per the Soil Survey of San Joaquin County, the facility site comprises two dominant soil categories. The northern portion of the site is located on *Stockton silty clay loam* and the southern portion is located on *Jacktone-Urban land complex*. Both soil types are described to have high shrink-swell potential as well as slow permeability.
- The fine-grained clayey soil condition at the site, if saturated, is susceptible to consolidation settlement. In addition, there is a probability of soil liquefaction and liquefaction induced settlement if the soil block is subjected to intense ground shaking. The site is expected to experience a low to moderate ground shaking during the next major earthquake in the Bay Area. Therefore, the probability of soil liquefaction and liquefaction induced settlement remain low to moderate.
- The low to moderate probability of the soil instability at the site could be addressed using available soil improvement techniques and/or using deep foundations (e.g., driven or cast-in-place piles) to support the superstructure. The site geotechnical report and construction drawings of the facility are not available for review.
- Figure 14 presents a screenshot of the CGS' Earthquake Hazards Zone Application which helps identify soil liquefaction potential at the site.
- The ACE facility site is located at area where there is no risk of *landslides*.

[15] Initial Study/Mitigated Negative Declaration, California, prepared by Kleinfelder Inc., November 25, 1998.
[16] Soil Survey of San Joaquin County: https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/california/CA077/0/san%20joaquin.pdf
[17] https://www.conservation.ca.gov/cgs/geohazards/eq-zapp

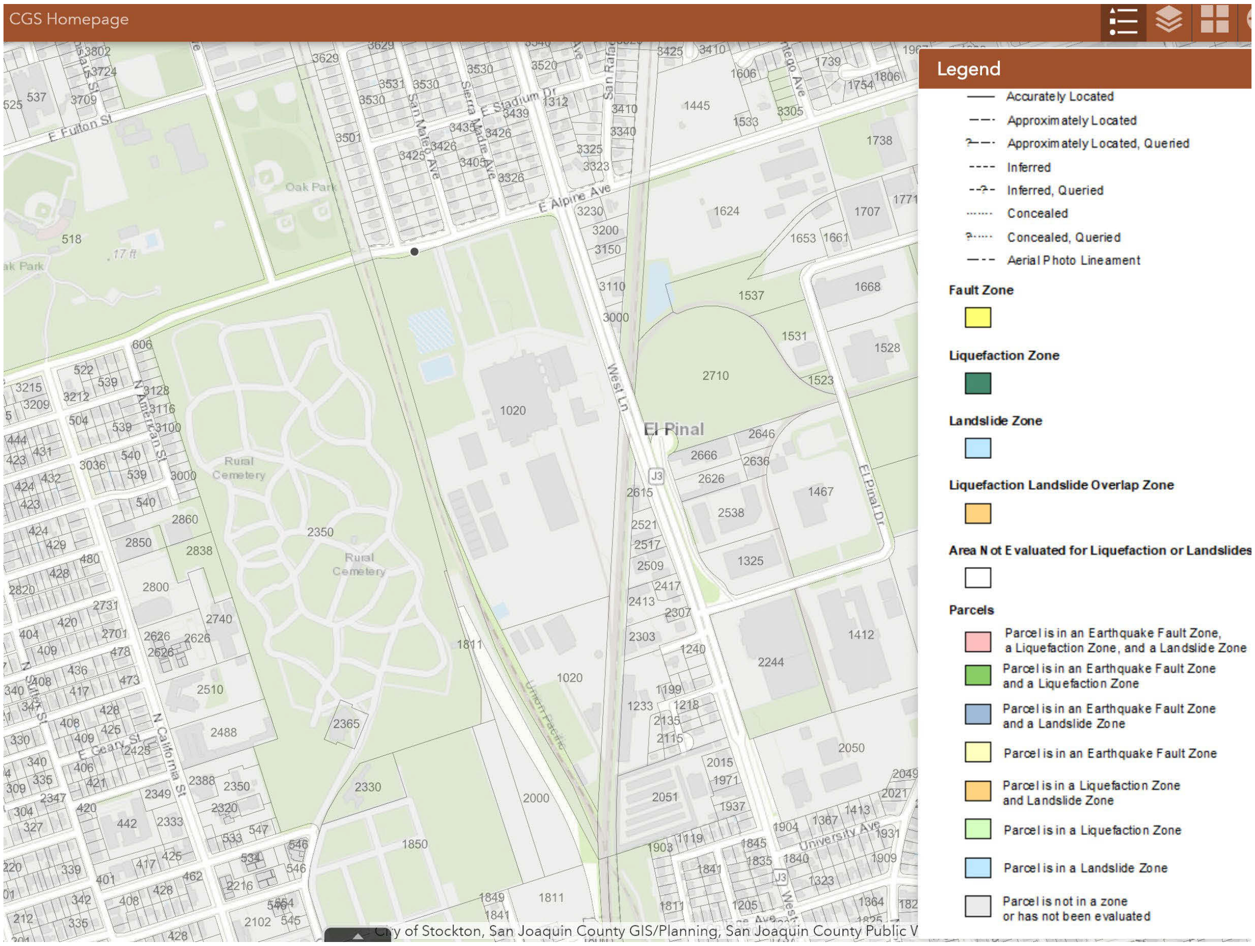


Figure 14: A screenshot of CGS' Earthquake Hazards Zone Application. This Figure demonstrates fault zones, landslide zones and liquefaction zones at and around the ACE Maintenance Facility site

Site-Specific Seismicity

There is no Alquist-Priolo Earthquake Fault Zone mapped within the city of Stockton. Therefore, there is no potential fault surface rupture within the facility site and its nearby lands. In addition, the Greenville fault, located approximately 21 miles west of the city of Stockton, is the closest active fault to the facility site. The San Andres fault with potential of triggering major earthquakes is located approximately 60 miles to the west of the site. As a result, the seismic hazards at the Stockton facility site are lower than the Bay Area and particularly the Oakland Maintenance Facility site. It is expected that during the next damaging earthquake in the Bay Area, the facility site at the city of Stockton will experience a low to moderate ground shaking (Seismic Risk Zone 3, per ASCE7-16[18]). For this lower seismic demand, facility structures that

[18] ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, 2016. https://www.asce.org/structural-engineering/asce-7-and-sei-standards/

are constructed according to the California Building Code's Seismic Design Criteria[19], will sustain less than moderate damage which ensures safety and minimum downtime to the facility's operation.

Building Description

The Altamont Corridor Express (ACE) maintenance facility building located at 1020 E Alpine Avenue in Stockton, California. The facility includes three building structures attached on their long side including a two-story admin office building, an *indoor* and an outdoor maintenance facility. The maintenance on cars is performed on the southern area of the facility while the locomotives' repair and maintenance are performed on the northern area of the building.

The facility buildings consist of a single-story warehouse type structure comprising bays of steel portal frames. The indoor facility is enclosed by 10-feet tall reinforced concrete masonry units (CMU) walls and composite siding sheets at the upper part. Figure 15 shows the facility location on a vicinity map and Figure 16 shows a bird's eye view of the two buildings. The entire facility buildings have a rectangular footprint of approximately 630 feet by 275 feet. On the northside of the structures, there are detached management offices. Material storage department is located on the north-east corner of the facility.

The steel portal frames are constructed of wide-flange steel sections. The perimeter columns of the portal frames are laterally supported by steel bracing at some bays. The frame, the steel bracings and the perimeter CMU walls are shown in Figure 17. The CMU walls and the sidings are presented in Figure 18. The roof system has a saw-tooth shape comprising of steel purlins spanning between steel rafters of the steel portal frames. The roof is clad by corrugated metal sheeting, skylights and windows at the teeth. Additional steel beams are mounted on the interior columns supporting an overhead crane system (Figure 17). On the south side of the building, a raised track and a raised steel deck flooring are constructed for easing locomotives' light and heavy maintenance operations. Figure 19 shows the raised steel deck flooring mounted on steel HSS columns and the raised track supported on H-shape steel piers.

The building's structural drawings and geotechnical report were not available for review. However, it is likely that the buildings' foundation is continuous strip footings under the CMU walls and isolated pad footings on piles under the steel columns. The building's ground floor is a concrete slab-on-ground.

The outdoor facility consists of two separate steel columns and cantilevered beam systems along the track. A similar roof system with no walls and no overhead crane system can be seen at the outdoor structure. Figure 20 shows the steel structural frame and maintenance pit for the outdoor facility.

[19] California Code of Regulations - Title 24: California Building Code
https://codes.iccsafe.org/content/CBC2018V2/toc

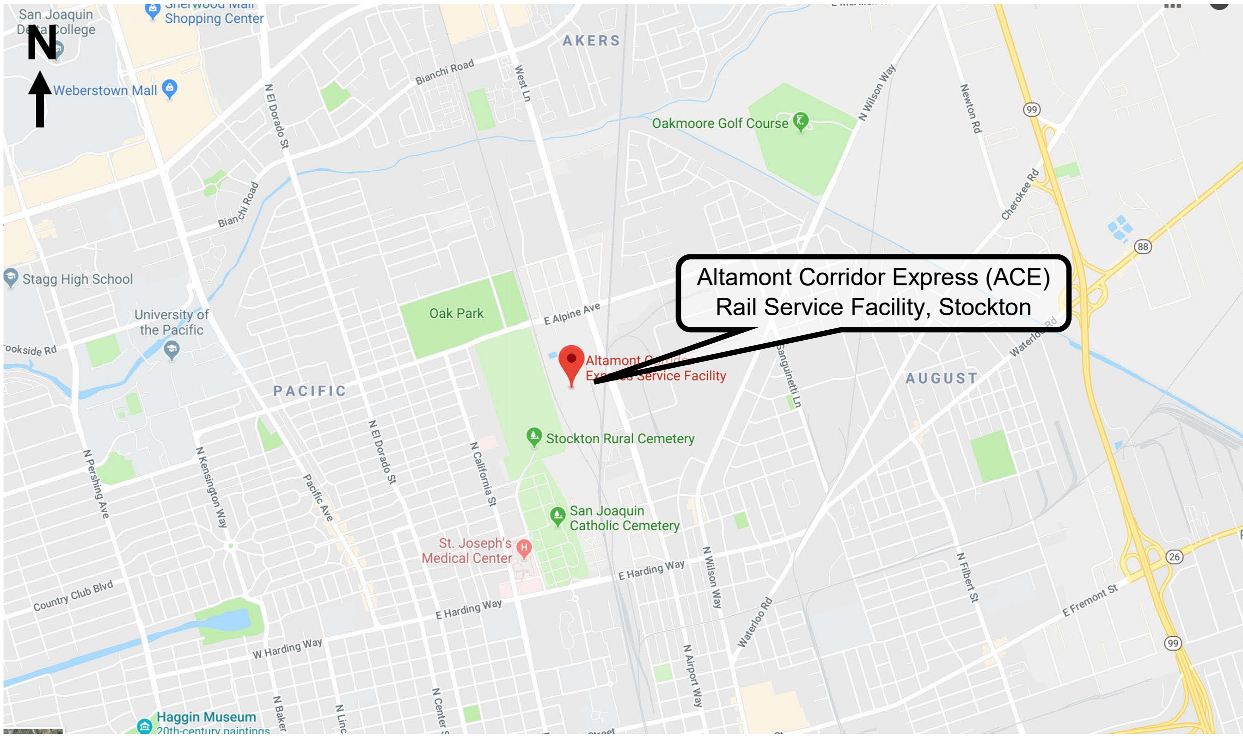


Figure 15: Vicinity Map – Altamont Corridor Express (ACE) Rail Service Facility

(Source: Google Maps)

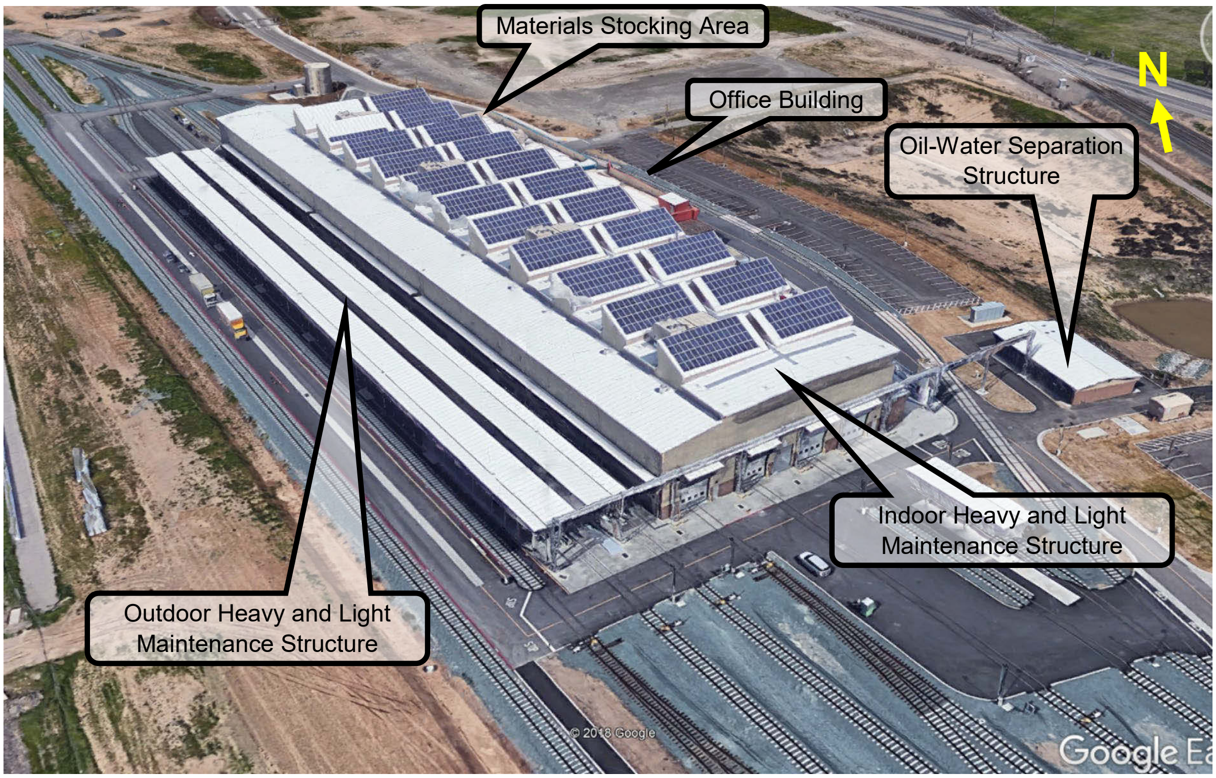


Figure 16: Bird's Eye view of the ACE Rail Service Facility

(Source: Google Earth)

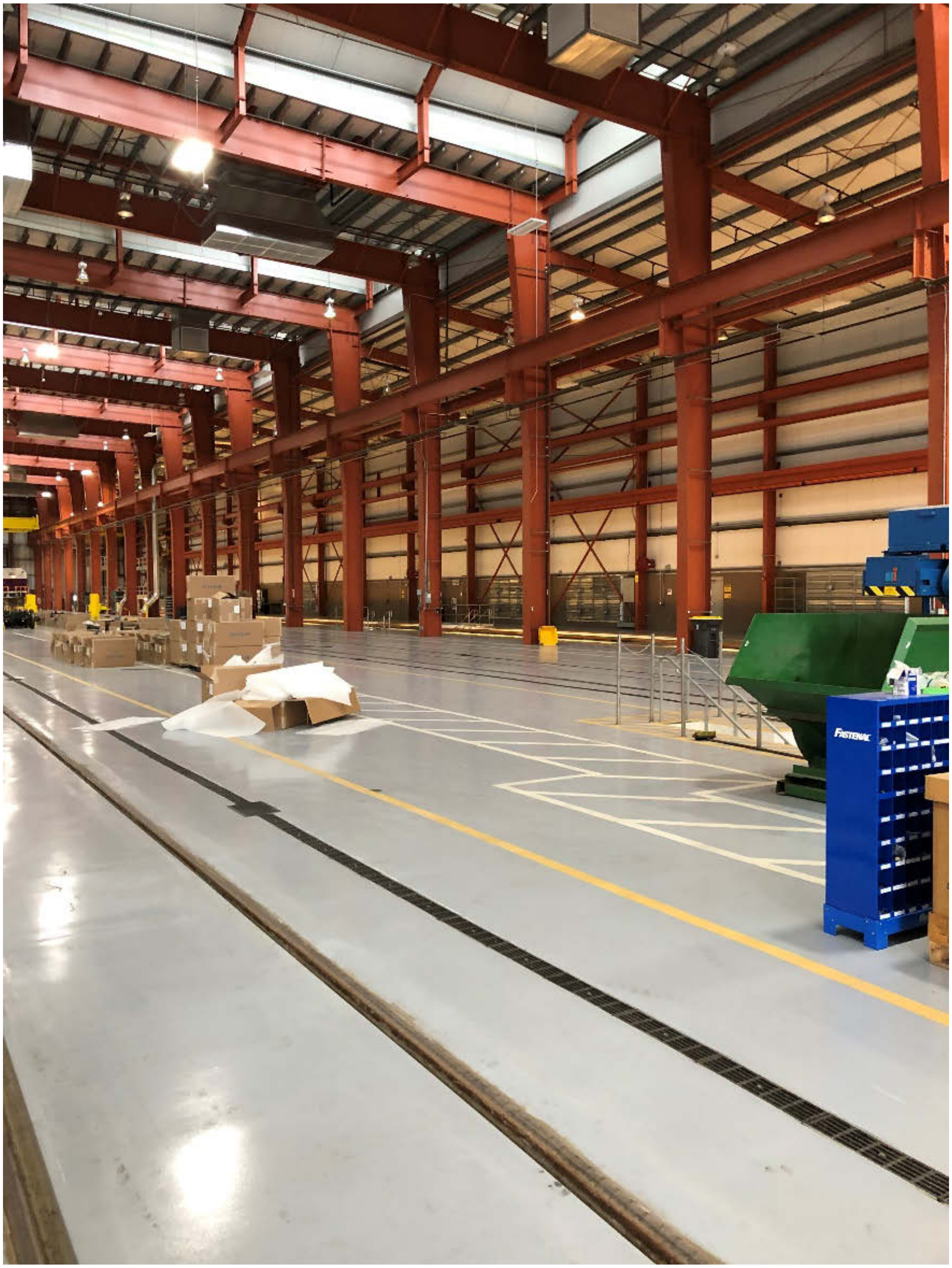


Figure 17: Building structural components, steel portal frame, steel bracing, and perimeter CMU walls

Figure 18: Building components: perimeter CMU walls and composite sidings

Figure 19: Raised steel deck flooring seated on steel HSS columns and the raised track supported on H-shape steel piers

Figure 20: Steel structural framing and maintenance pit for the outdoor facility structure

Denver Commuter Rail Maintenance Facility (CRMF)

Overview

The site visit to Denver CRMF was conducted on February 22, 2019 in Denver, Colorado. The facility is both a layover and a maintenance facility for commuter rails. This report presents information on facility location and the building components as observed at the site and through interview questions and answers summarized in the end. The map in Figure 21 shows the location of the Denver CRMF. The CRMF is located at 5151 Fox St., just north of I-70 and west of I-25.

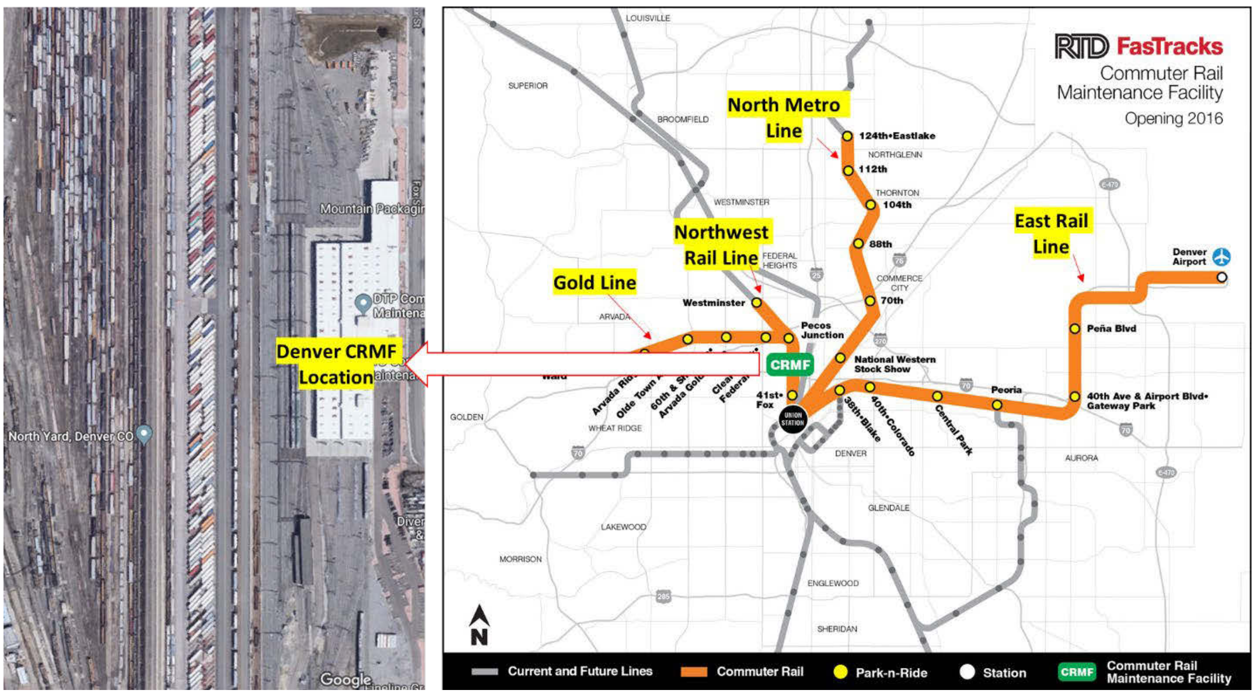


Figure 21: Geographical Location of Denver Commuter Rail Maintenance Facility

Site-specific Details

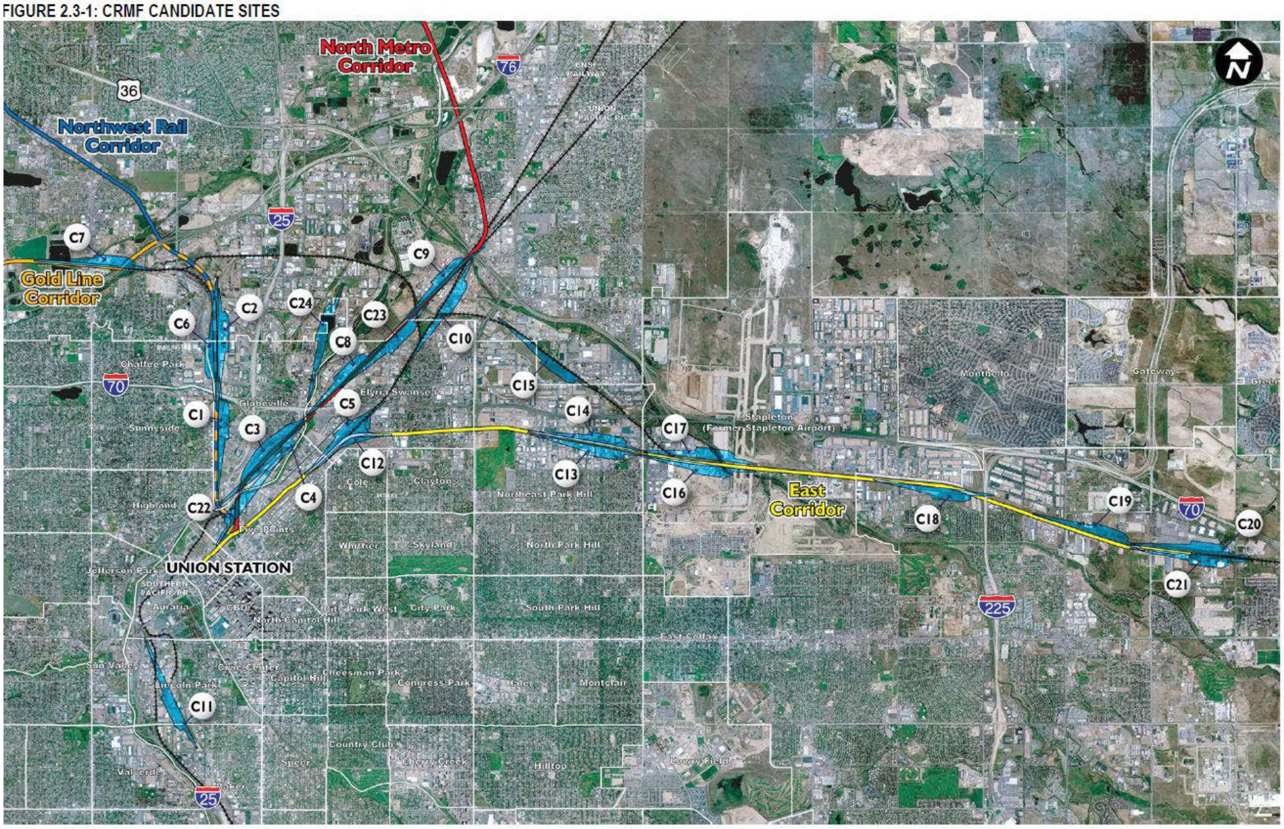
Site-specific challenges were in determining an ideal site location[20]. The largest issue that arose were potential need for property acquisitions and cost of those property acquisitions. Other considerations were proximity to rail (within 5 miles of Denver Union Station or end of line terminal station), rail access elevation, any conflicts with existing transportation means (roadways or freight rail), environmental consideration (wetlands,

[20] Commuter Rail Maintenance Facility Supplemental Environmental Assessment (SEA) Environmental Resources Technical Memorandum Supplement to FasTracks Commuter Rail Environmental Documents Incorporated by Reference Prepared by: CH2M HILL for the Federal Transit Administration (FTA) and the Regional Transportation District (RTD), April 2009.

parkland, or substantial impacts), type of facility allowed (double-ended yard and shop or stub-ended facility (unideal)) and other transit-oriented development (TOD) planning considerations. The next level of screening took into consideration existing property owners' ability to be relocated, rail and vehicle access, any significant environmental issues, minimal railroad crossings into the site, and minimal vehicle traffic impacts. Lastly, environmental resource impacts and benefits were considered.

Some 24 locations were considered as potential locations in 2005-2006 (see Figure 22 below). The above considerations were taken for each site and noted on which levels the project location passed. This was used as a screening process and resulted in only one location passing three screening levels. This location (C5) was modified to include additional property to the east as it was desired for the site to accommodate the four commuter rail corridors (see Figure 22). This modification eliminated the site as a possibility due to the high acquisition costs of the additional property.

FIGURE 2.3-1: CRMF CANDIDATE SITES



Source: URS, 2006.

Figure 22: Locations of potential sites for maintenance facility

(Source: COMMUTER RAIL MAINTENANCE FACILITY SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT[21])

[21] COMMUTER RAIL MAINTENANCE FACILITY SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT, Alternatives Considered, accessed on August 22, 2019, http://www.rtd-fastracks.com/media/uploads/mf/CRMF_SEA_2of2_Ch2-Ch8_figures_and_tables_updated-42009.pdf)

The previously eliminated alternatives that passed the second-level screening were reintroduced as potential locations in 2007. Only one site passed this reevaluation, RTD District Shops/Platte Facility (C4 in Figure 22). This property was selected because the majority of the site was owned by RTD and acquisition costs fell within the RTD budget. There was also potential to resolve land use conflicts with extensive coordination efforts versus other properties that would require purchase and relocation of land and potentially end in an unideal building format (stub-ended site).

Another remedy was to consult the public on potential locations. This was performed via voter approval from 2004-2006 and in 2008 there were meetings held with the public. Conversations with the public in 2008 caused reconsiderations in 2008-2009. This resulted in a new site being selected due to “strong public opposition.” This site (C1 in Figure 22) was modified from the original proposal and selected due to “substantial cost savings to taxpayers to keep bus maintenance facility in current location,” which was valued at $100 million. Also, the impacts to property owners already occurred under the Northwest Rail and Gold Line projects. Lastly, there was public preference for the CRMF in vicinity of this site.

Facility Details

Denver CRMF became operational in 2014 and was built by expanding the modified BNSF trailer on flat (TOFC) facility that existed there till 2009. The location of the CRMF is close to the Pecos Junction Station in the north and the 41st/Fox Station in the south – both within a mile distance from the CRMF. The CRMF serves to repair, maintain, clean and store the commuter rail for the four FasTracks commuter rail corridors: Gold Line, East Rail Line, Northwest Rail and North Metro (see Figure 21).

The location of the CRMF is very strategic and close to the BNSF and UP railroad freight lines (see Figure 23). Denver Transit Partners (DTP) acquired electric multiple-unit (EMU) cars for the commuter rail and are being maintained at the facility. Various facility components as shown in Figure 23 are interconnected. The facility is currently servicing 66 cars and can service up to 80 electric rail cars. The facility is spread over an area of 230,000-square-foot and is equipped with state-of-the-art training and conference rooms, staff break room and lockers. The facility buildings at Denver CRMF has LEED[22] Gold Certification.

[22] Leadership in Energy and Environmental Design - the most widely used green building rating system in the world.

Figure 23: Bird's Eye view of the RTD Commuter Rail Maintenance Facility (by Google Earth) from the South Side

Various building components in the layout of Figure 23 is summarized below:

1. Maintenance-of-way Building – This building is centrally located, which includes the following key maintenance, equipment and parts serving the daily maintenance needs:
    - Locomotive and car repair shop
    - Six tracks (three tracks for car inspection and maintenance with non-powered overhead power lines, and three for locomotive with overhead power lines)
    - Wheel truing pit
    - Shop lift table
    - Vending machine for small parts
    - Tool storage and check-out rooms

- Two gantry cranes (one 15-ton and another 3-ton capacities)

2. Machine Shop Building: This building contained key service-related facilities such as room for battery wash, welding room, machine shop and ultrasonic wash for parts cleaning.

3. Train Wash Facility: This is a fully automated facility located outside the building premise.

4. Warehouse/Storage Building: The storage location utilized four fully automated vertical lift machines (VLMs) to cater to everyday needs of parts of a rail car. The VLMs were operated using a computerized system and could fetch a required part using a laser-guided mechanism for all practical sizes and weights. The warehouse had stacks of materials used for general repair and maintenance, and the forklift was used to arrange or draw any needed parts that were heavy and required for maintenance. The warehouse was fully air-conditioned.

Building Description

The CRMF facility includes a main building structure and an outdoor car-wash structure. Figure 24 shows the property location on a vicinity map and Figure 23 shows a bird's-eye-view of the two structures. The main building includes an indoor maintenance facility, admin offices, small shop rooms, and the material storage warehouse. The facility building has an overall footprint of approximately 600 feet by 260 feet. The building has a rectangular shape with the eastern wing shifted about 200 feet toward north (see Figure 25). The eastern wing of the building includes a three-story structure which houses the shop rooms (e.g., weld shop, machine shop, battery shop, air brake shop, etc.) on the ground level and office spaces on the second and the third floor. Figure 26 presents the three-story structure at the east wing of the building. The maintenance work is performed on the central and western area of the facility including three regular and three powered tracks, respectively. In addition, there are six outdoor *staging* tracks along the west side of the building laid north-south. Construction of the facility structures started in 2012, and the facility operation started in 2014. The facility structure consists of a single-story warehouse-type structure comprising steel columns, steel girders and truss joist spanning east-west. To increase use of air space and for easing the maintenance work, there are multiple mezzanine levels throughout the main structure. Figure 27 and 28 show the structural components and the mezzanine levels. The mezzanines are constructed on cantilevered composite beams with concrete slabs on metal decks. In addition, for efficiency, the mezzanine levels provide additional areas for storing parts and for bench-testing of defective components. The facility includes 230,000 sq. ft of indoor area. The building is enclosed by 10-feet tall reinforced Concrete Masonry Unit (CMU) walls and corrugated metal sidings at the upper part.

Figure 26 shows the building enclosure on the north wall. Figures 27 to 20 show images of various structural components of the facility.

On the east wing, the three-story structure comprises steel columns, steel girders and concrete slabs on metal deck. Figures 30 and 31 show the elevated slab system at the machine shop. Additional overhead cranes have been deployed in each shop room to facilitate materials handling in the shops. Figure 31 shows the battery shop including an overhead crane where the crane rails are mounted on steel seats. It can be seen in Figure 32 that the steel beams in the battery shop, unlike the machine shop, are protected by fireproof coating for increasing the *fire rating*. Also, CMU wall in the battery shop partitions the room from the machine shop for potential containment of fire in the battery shop. Figure 33 presents a single-level mezzanine next to facility tracks. The facility includes four 3-ton and one 15-ton overhead cranes. The former is used for smaller components handling (e.g., HVAC units) and the latter is used for lifting cars' trucks. Figure 34 shows a two-level mezzanine floor for easing access next to a maintenance pit. The materials storage warehouse is located at the north-east area of the facility (see Figure 25).

The building's steel frames are constructed of both built-up sections and wide-flange steel sections. The columns are laterally supported by steel bracing at some bays (see Figure 26). The roof system comprises steel truss joists spanning east-west between the steel girders. The roof is clad by corrugated metal sheeting and skylights. The building's structural drawings and geotechnical report were not available for review. However, it is likely that the buildings' foundation comprises continuous strip footings under the CMU walls and isolated pad footings under the steel columns (i.e., shallow foundation system). The building's ground floor is a concrete slab-on-ground. The building has received a Gold LEED certificate for energy efficiency. The building enclosure comprises reflective windows for insulating heat and cold. Also, the building's heating system is embedded into ground floor's slab. Sensor-activated lights and several skylights throughout the building are deployed for reducing the energy consumption. Figure 35 shows the facility's doors. Aluminum roll-up doors are used for regular maintenance tracks whereas double-fold steel doors are used for powered tracks. Figures 36 to 29 show specific facility features.

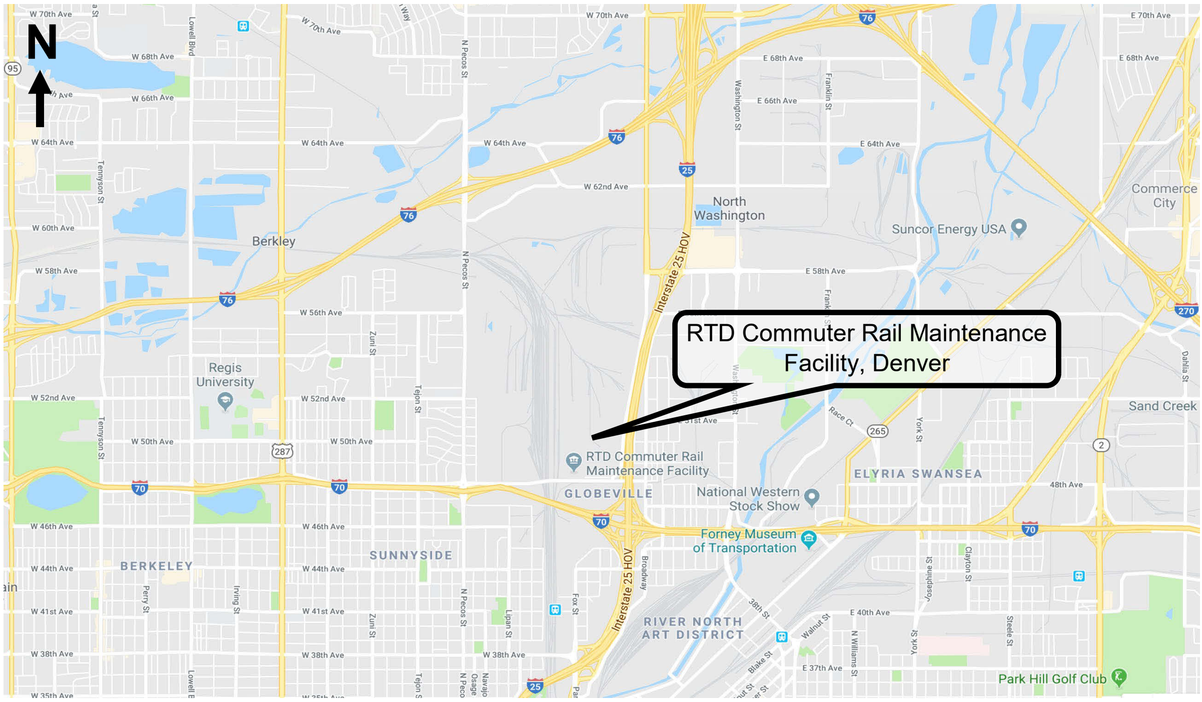


Figure 24: Vicinity Map – RTD Commuter Rail Maintenance Facility, Denver, Colorado

(Source: Google Maps)


Figure 25: Bird's Eye view of the RTD Commuter Rail Maintenance Facility (by Google Earth) from North Side

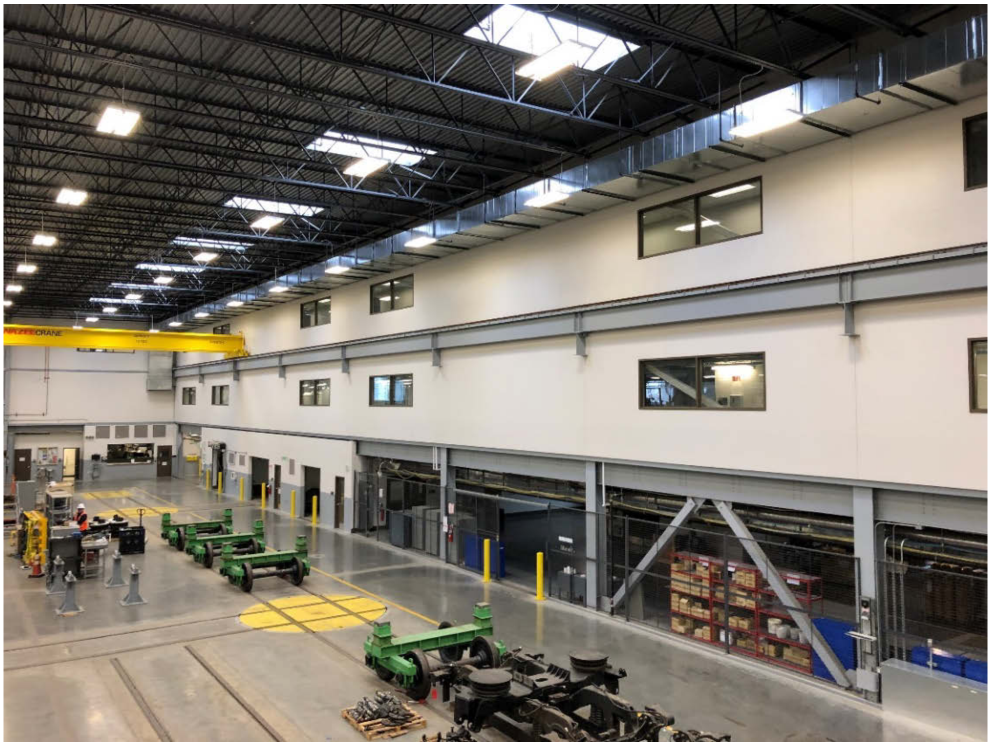


Figure 26: Three-story structure including shop spaces (on the ground level) and offices (on the second and third levels) at the east wing of the facility

Figure 27: Building's structural components: steel columns and beams and cantilevered mezzanine levels

Figure 28: Building's structural components: Steel columns and girders and roof truss-joists spanning east-west

Figure 29: The building enclosure comprising CMU walls and corrugated metal sidings

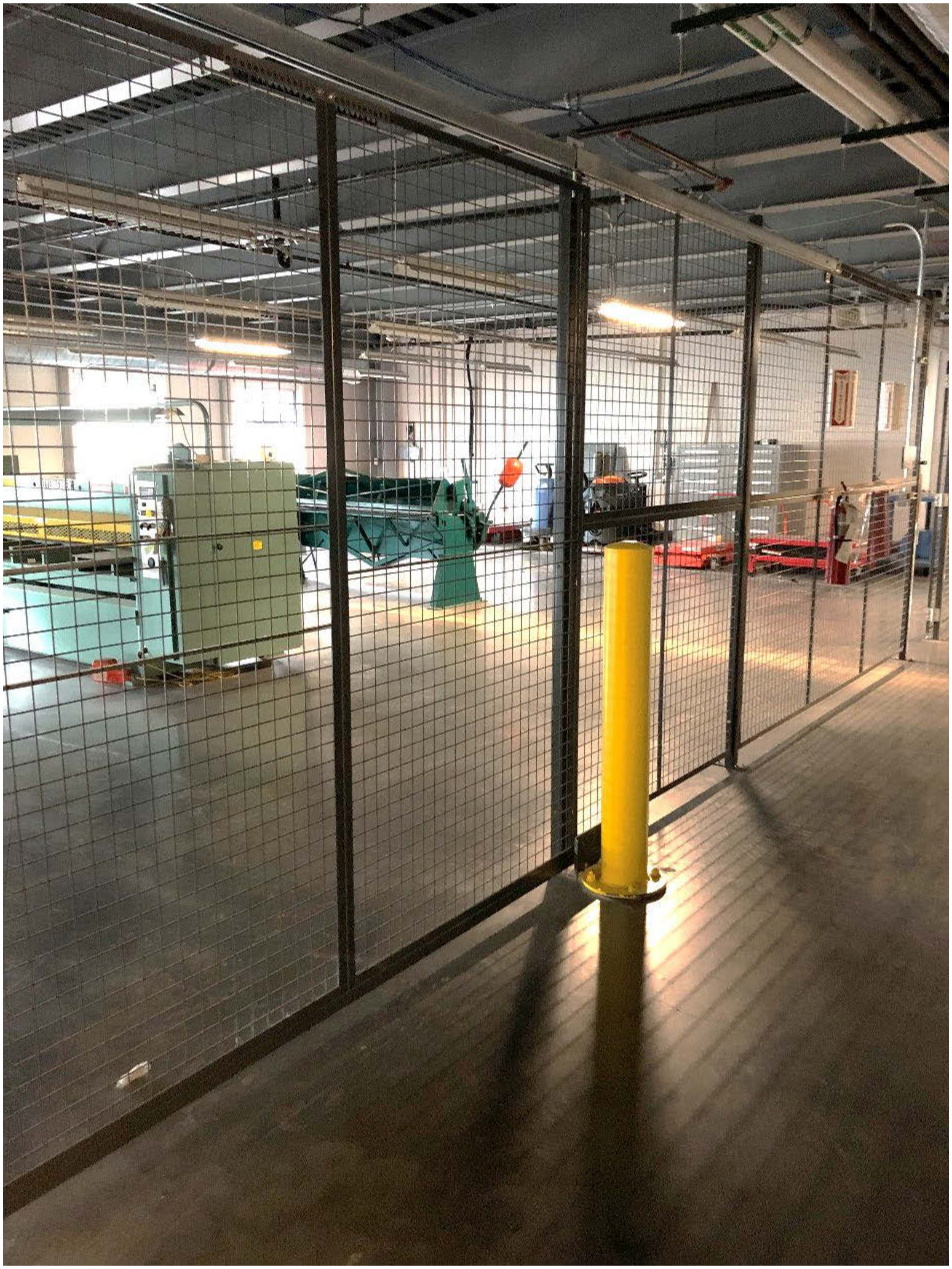


Figure 30: Machine shop and the second-floor structural system – Eastern wing of the building

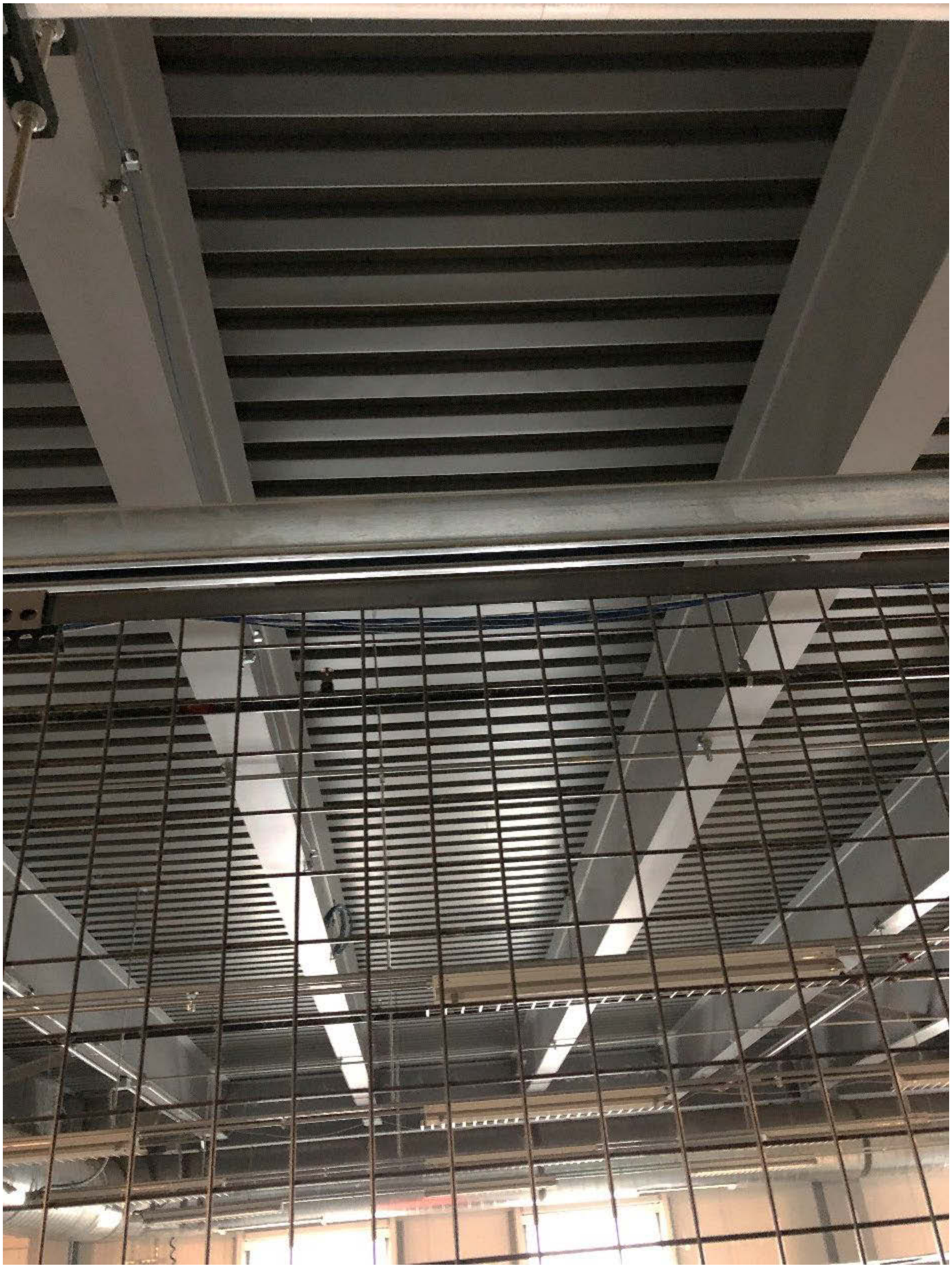


Figure 31: Second-floor elevated slab structural system – Eastern wing of the building

Figure 32: Small capacity overhead cranes installed in the shop rooms

(Figure 32 shows example of battery shop. Concrete masonry block walls used to separate the battery shop from other areas. The steel beams are protected using fireproof coating)

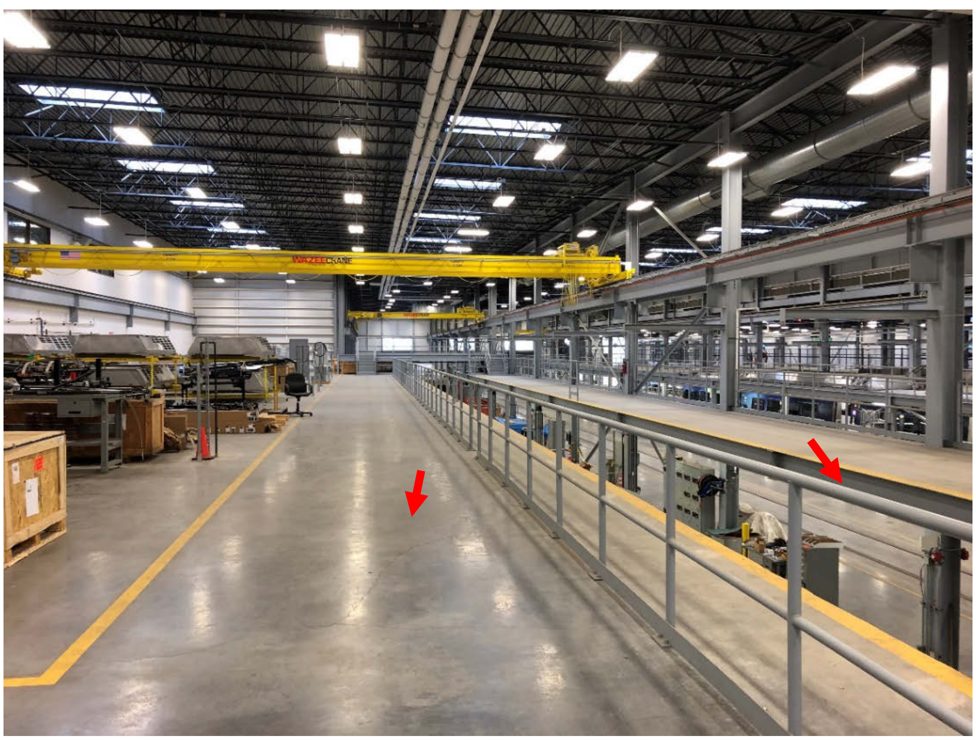


Figure 33: Single-level mezzanine area with two 3-ton overhead cranes

Figure 34: Two-level mezzanine floors next to a drop pit for easing access during maintenance and increasing efficiency

Figure 35: The facility's doors – Roll-up aluminum doors for regular tracks and tall double-fold steel doors for powered tracks

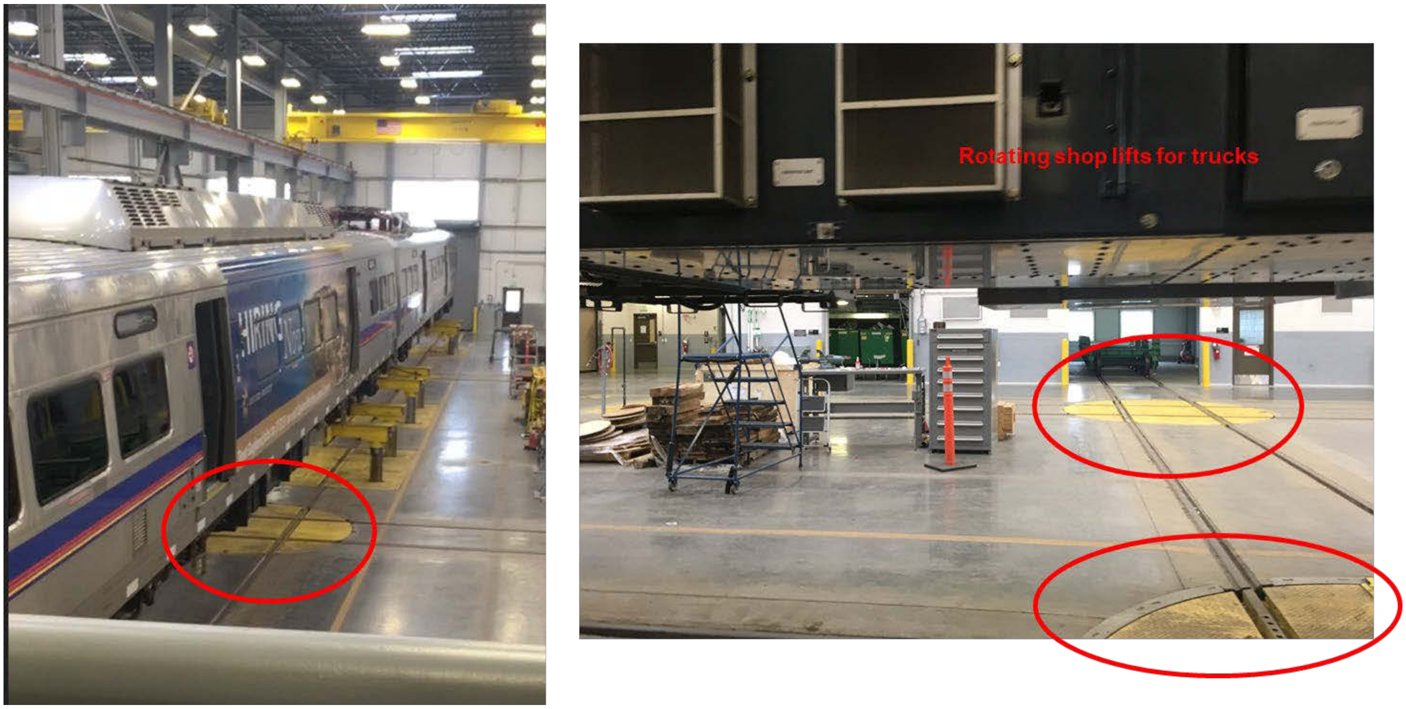


Figure 36: Rotating shop-lifts for trucks

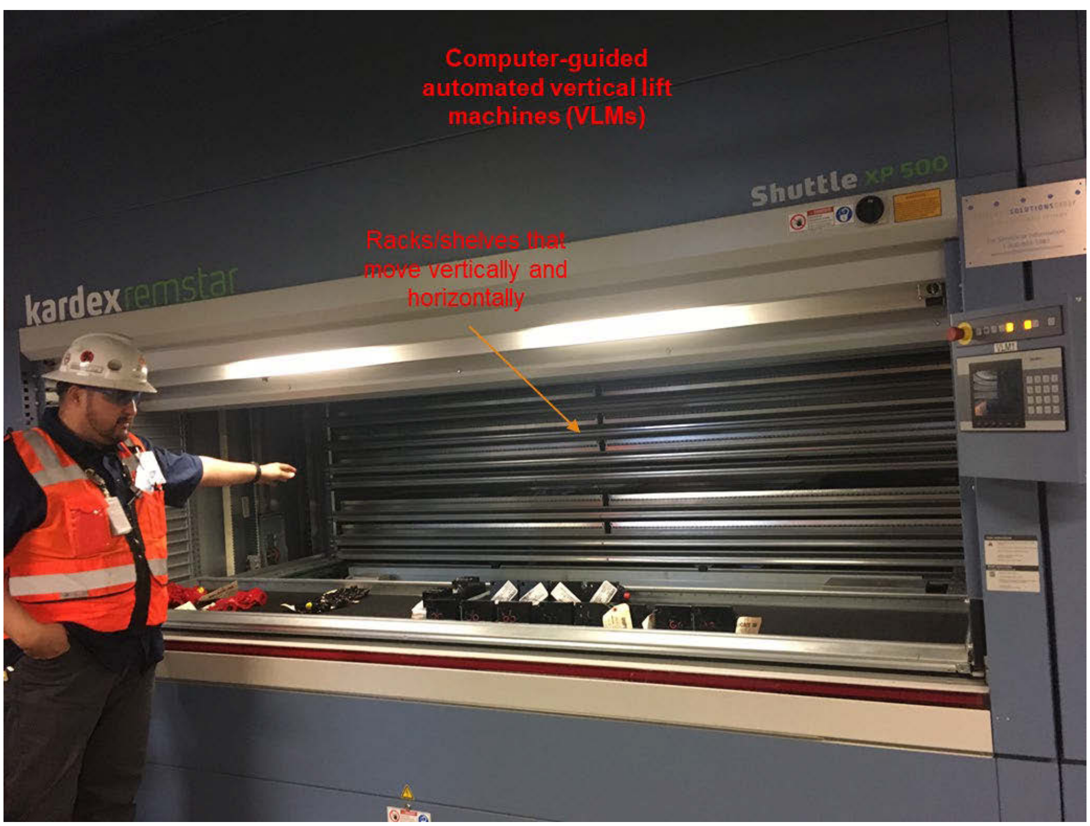


Figure 37: Vertical lift machines (VLMs)

Figure 38: Double-fold entrance door with high intensity air blowing exhaust fans

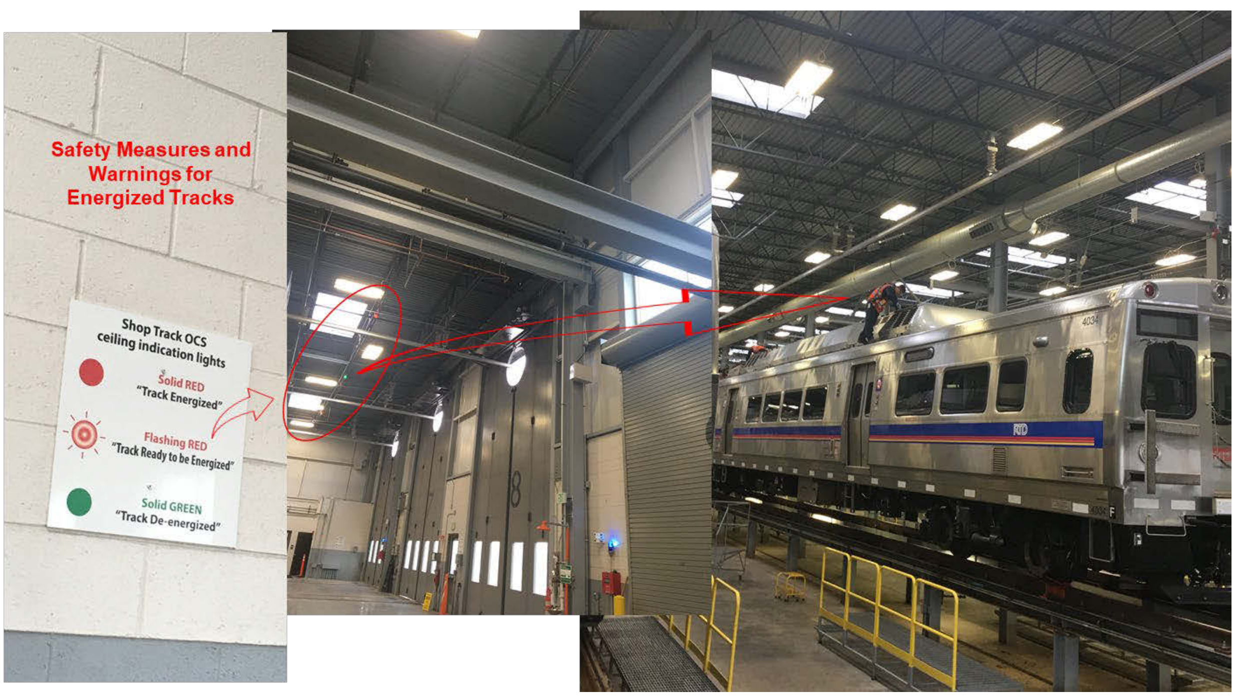


Figure 39: Safety measures for energized tracks

West Palm Beach Brightline Layover and Maintenance Facility

Overview

The Brightline[23] intercity rail maintenance and layover facility site visit was conducted on February 25, 2019. The facility is in West Palm Beach, Florida. The purpose of the site visit was to gather information on the building components, planning details, and factors identified with inputs gathered from the interview that could become critical for identifying a future location in California. The goal of the site visit was also to document any related information on Brightline's Orlando facility construction, which is almost complete. Figure 40 shows the location of the maintenance/layover facility in West Palm Beach in Florida.

Brightline Rail Line from West Palm Beach to Miami

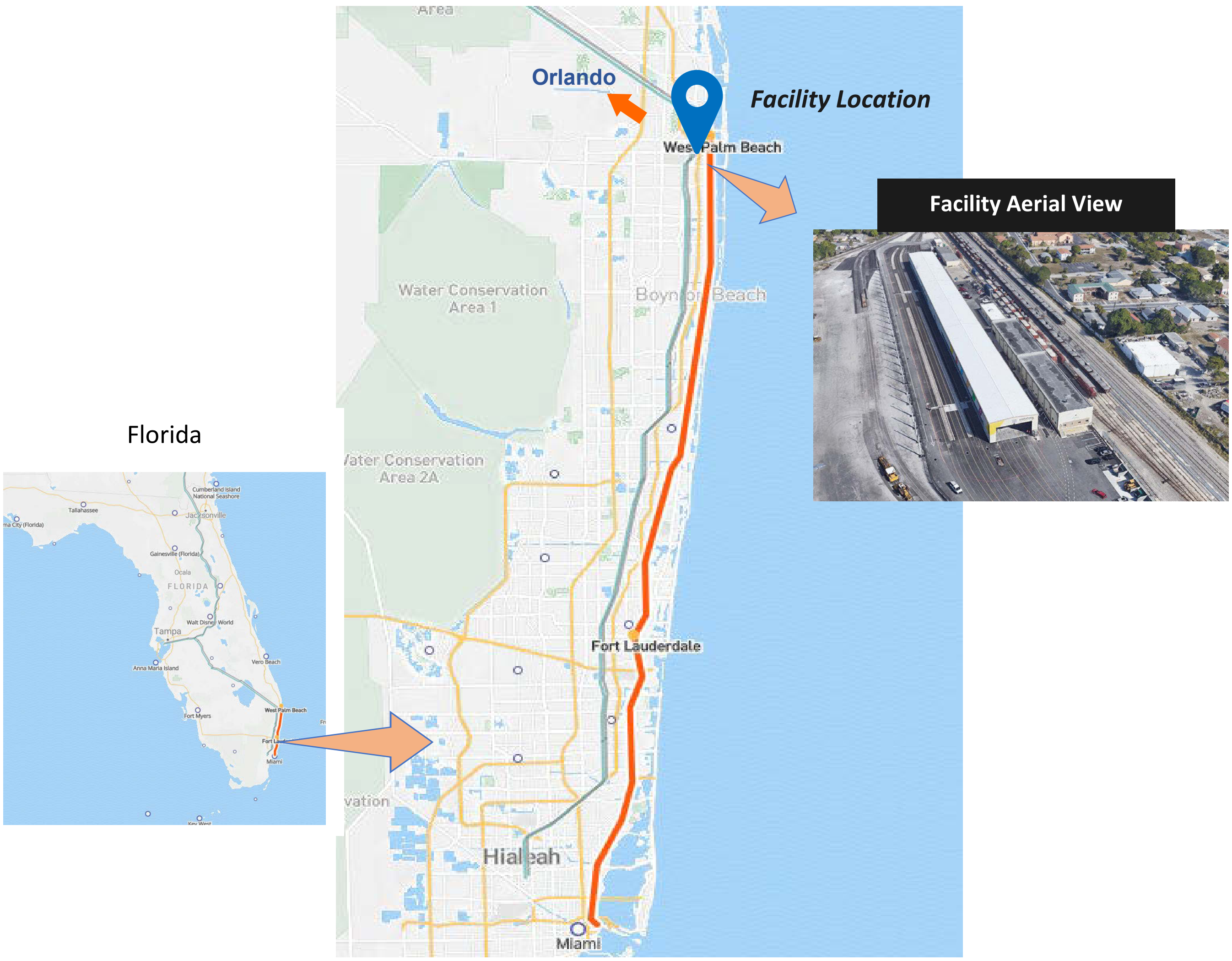


Figure 40: Geographical Location of Brightline Facility in West Palm Beach

[23] Note that the Brightline is soon going to change its name to Virgin Rail with investment from Virgin Rail Group.

Site-specific Details

One of the major criteria that were considered for site location was the cheaper price of the land at the location and the workforce needed for special skills (such as janitors and cleaners) was also easily available from the area. Although the majority of the land in Florida is marshy, the land on which the facility is located is much more stable and conducive as compared to the one in Orlando. The land in Orlando facility has a sinkhole. Some $50 million will be spent to fix the sinkhole at that facility before it becomes fully operational for rail maintenance. The facility in Orlando is very close to the airport, and real estate value has increased significantly in the surrounding area due to the new Brightline station. Further, it is expected that monetary gains with the new Orlando facility and Brightline station in the airport region will outweigh the expenditure incurred in getting the groundwork ready – such as fixing the sinkhole.

The West Palm Beach facility location had to be identified in proximity to the nearby station (West Palm Beach Station) to reduce non-revenue miles. At present the West Palm Beach Station is just 1-mile distance south of the facility.

Facility Details

Construction of the facility structures at West Palm Beach facility began in 2015, and the facility became operational in 2017. The rail services began in 2018 from Fort Lauderdale to West Palm Beach. Currently, the service is fully operational between Miami and West Palm Beach with a stop at Fort Lauderdale.

Rolling stock consists of five Siemens trainsets with four passenger coaches. Each train has a capacity of 240 passengers. The maintenance of these trainsets is carried out by Siemens. A trainset is powered by 4000 hp diesel locomotives each at the two ends of the four passenger cars.

Current expansion plans of Brightline is underway to connect Orlando north-west of West Palm Beach (see in Figure 40). The Brightline facility is located 1 mile from the West Palm Beach station. All trainsets are required to be at the facility for maintenance during the night before being dispatched for service in the morning.

1. Workshop – The buildings at this facility are called the 'workshops' where managerial and maintenance activities are carried out. The image in Figure 42 shows the two workshops side-by-side. These two workshop buildings are centrally located. The first workshop is an open area maintenance facility for rail, which includes the following key machines, equipment and parts serving the maintenance needs:

    - Mobile cranes for lifting. (Note there were no overhead gantry cranes used at the workshop)
    - Four tracks (two tracks are inside and two are outside the workshop area)
    - Wheel truing pit
    - Mobile van for washing and drying trains (manually operated)

- Mobile ladder for inspecting locomotives and cars
- Electrical room
- Storage (for 2-wheel sets and trucks)
- Mobile sanding van

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2. Office Building – The office building includes space for staff, break rooms and a conference room. There are no onsite commissaries at this facility location.

3. Storage Room: The storage room is connected to the main office building; however, the entrance is from the outside of the office building and does not have air-conditioning. Lack of air-conditioning prevents long term storage of items made of materials such as rubber. There is an interior/cleaning supplies adjacent to the storage room.

   Storage building includes QR-code for each material type stored at a shelf. The items stored comprise spare car wheels, car seats, metallic car body parts, and other part materials for rail maintenance purposes. QR- codes are used to access any material needed from the shelf using a reader. The shelfs have a maximum capacity of holding 7050 lbs with per upright capacity of 17,700 lbs. The materials used are branded by Siemens. There are no overhead cranes to move the materials within the storage. Access to items on a shelf is achieved using a mobile vehicle with forklift.

Building Description

The Brightline Rail maintenance facility building is located at 601 15th Street in West Palm Beach, Florida. The complex includes two detached long rectangular buildings with their long side positioned in the north-south direction including a main maintenance facility building (on the west side of the property) and an admin office building (on the east side of the property). At the north half of the office building, there is a material storage warehouse and a machine shop. Construction of the facility structures started in 2015, and the facility operation started in 2017. The maintenance facility building consists of a single-story warehouse type structure comprising bays of steel portal frames. The majority of lower half of the building's perimeter is open for easing access to any location of the facility. Figure 41 shows the property location on a vicinity map, and Figure 42 shows a bird's-eye- view of the two buildings. The office and material warehouse structure were preexisting structures at the site, which used to be a transfer warehouse for freight rail on the east side of the property. The office building comprises steel columns and roof truss system enclosed by unreinforced masonry brick walls. The maintenance facility buildings have a rectangular footprint of approximately 830 feet by 70 feet. The facility structure also includes two maintenance tracks one with a maintenance pit.

The steel portal frames are constructed of wide-flange steel sections. The perimeter columns of the portal frames are laterally braced by horizontal wide-flange steel sections. Figure 43 and Figure 44 show the facility building's structural system. Most of the lower half of the building perimeter is open up to 10 feet, while the upper half is clad by corrugated metal sheets attached to the columns and the horizontal steel bracings. The building enclosure including the steel framings and the metal sheets are presented in Figure 45 and Figure 46. Located in a zone with high speed gust and hurricane hazard, the open perimeter of the building helps with reducing the induced wind load on the structure through the windward and leeward faces of the building. The roof system comprises of steel purlins spanning north-south between steel rafters of the steel portal frames. The roof is clad by corrugated metal sheeting along with thermal insulator sheets. The structure does not include any overhead crane. The building's structural drawings and geotechnical report were not available for review. However, it is likely that the facility buildings' foundation is isolated pad footings on pile under the steel columns. The building's ground floor is a concrete slab-on-ground.

It is expected that the preexisting office and materials warehouse building was built in the 70's. The building comprises steel columns and, roof truss and steel beams. The building is enclosed at its perimeter by double-width unreinforced masonry brick walls. Figure 47 shows the building's walls and roof system. The building's structure has been slightly modified to accommodate current facility's need. For instance, a mezzanine level has been added at the machine shop in between the offices and the materials warehouse. Also, some of the building's openings have been covered by CMU walls. Figure 48 shows a closer view of the steel columns and the perimeter masonry walls. The roof system includes a two-way truss-joists supporting roof steel beams. The roof is clad by flat steel sheets and bituminous roofing pads. Figure 49 presents an interior view of the roof structural system.

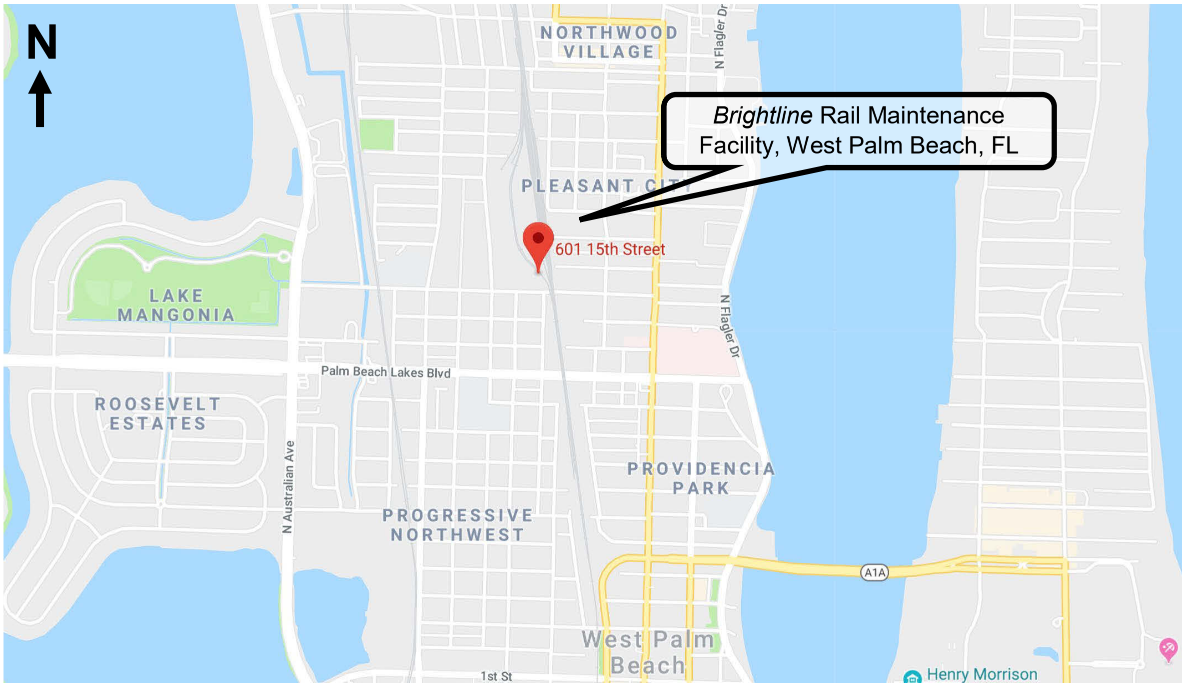

Figure 41: Vicinity Map – Brightline Rail Maintenance Facility
(Source: Google Maps)

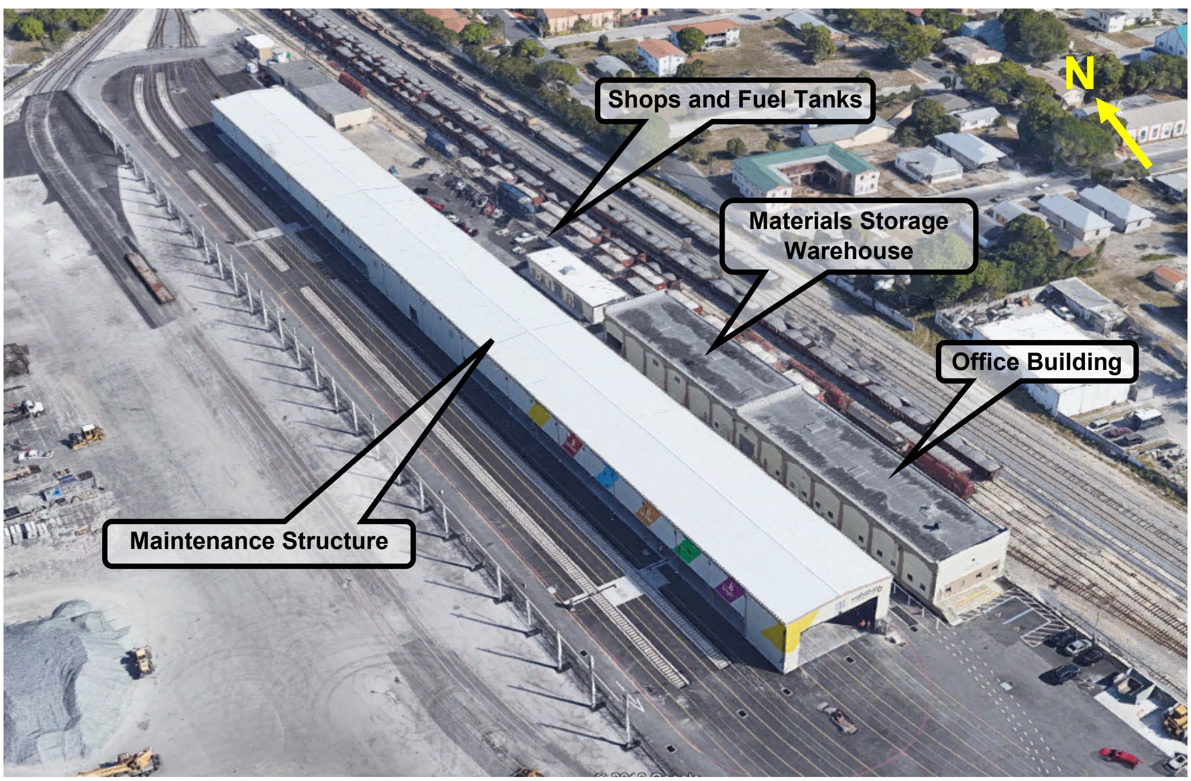

Figure 42: Bird's Eye view of the Brightline Rail Maintenance Facility
(Source: Google Earth)

Figure 43: Building structural components: steel portal frame and horizontal steel bracings, and open perimeter

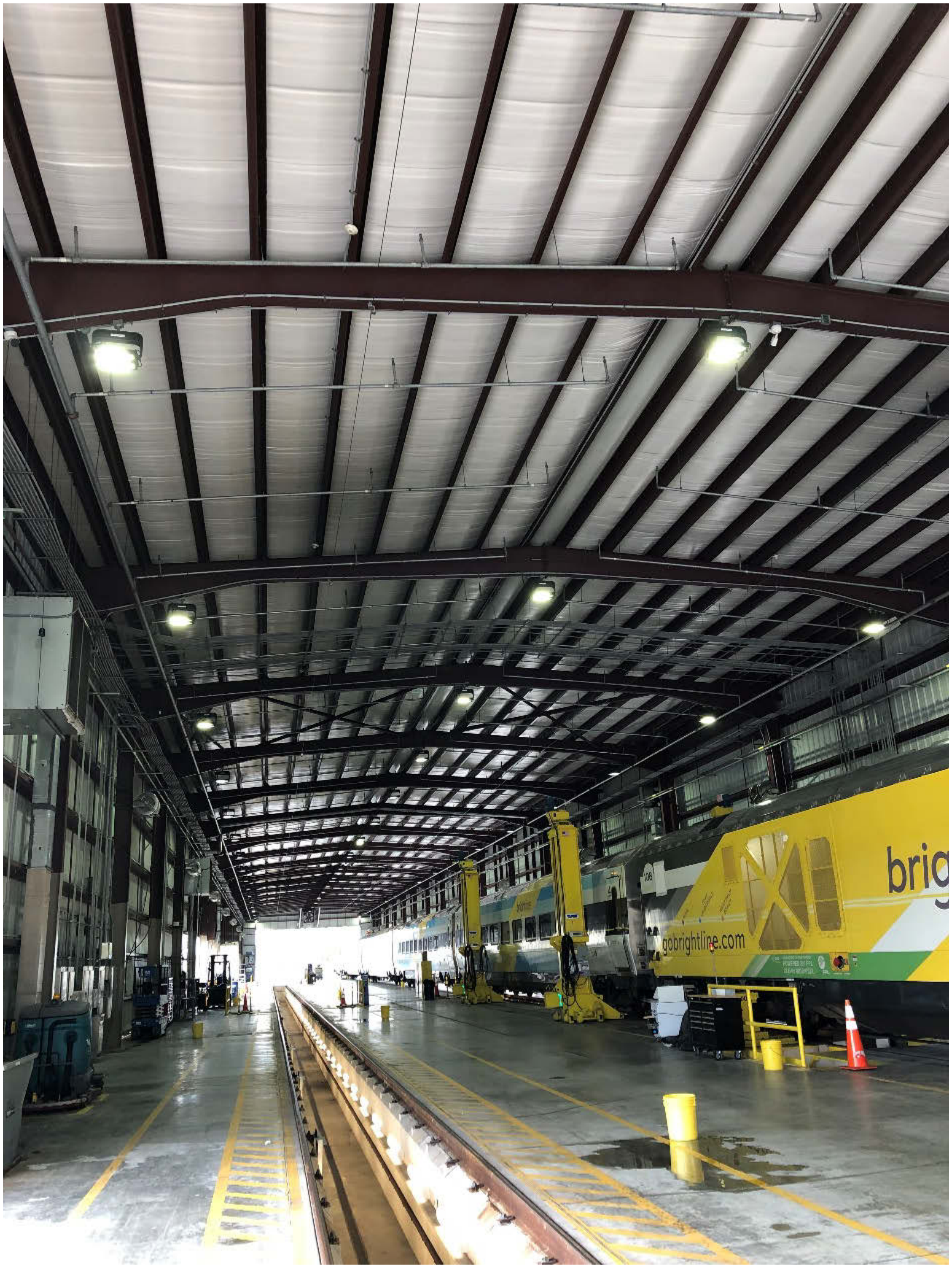

Figure 44: Building structural components: steel portal frame, concrete slab on grade, and the maintenance pit

Figure 45: Maintenance building’s perimeter enclosure: horizontal steel braces and vertical studs and attached corrugated metal sheets

Figure 46: A close view of the facility enclosure: The horizontal steel braces and the attached metal sheets

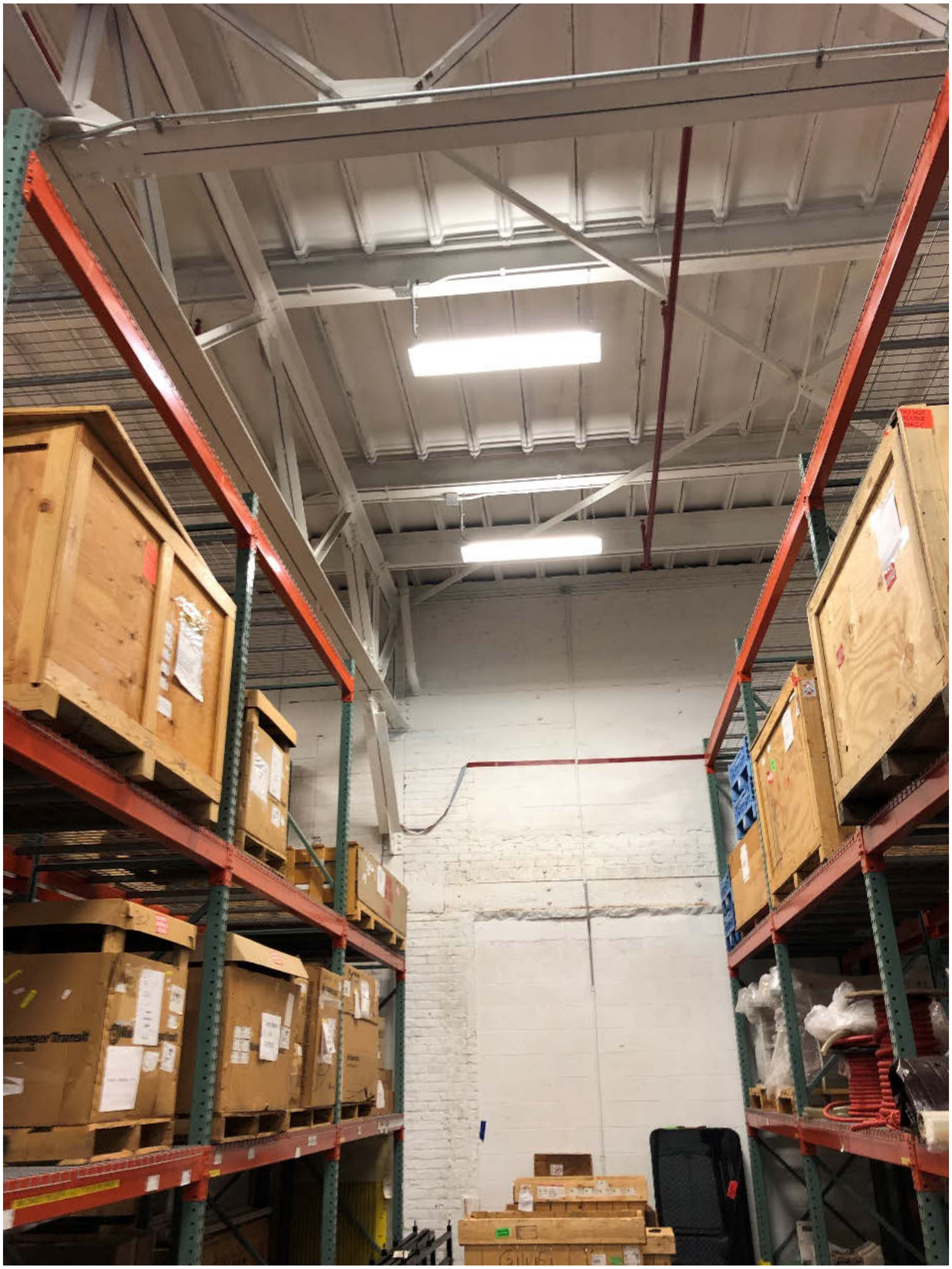

Figure 47: Materials storage building's walls and roof system

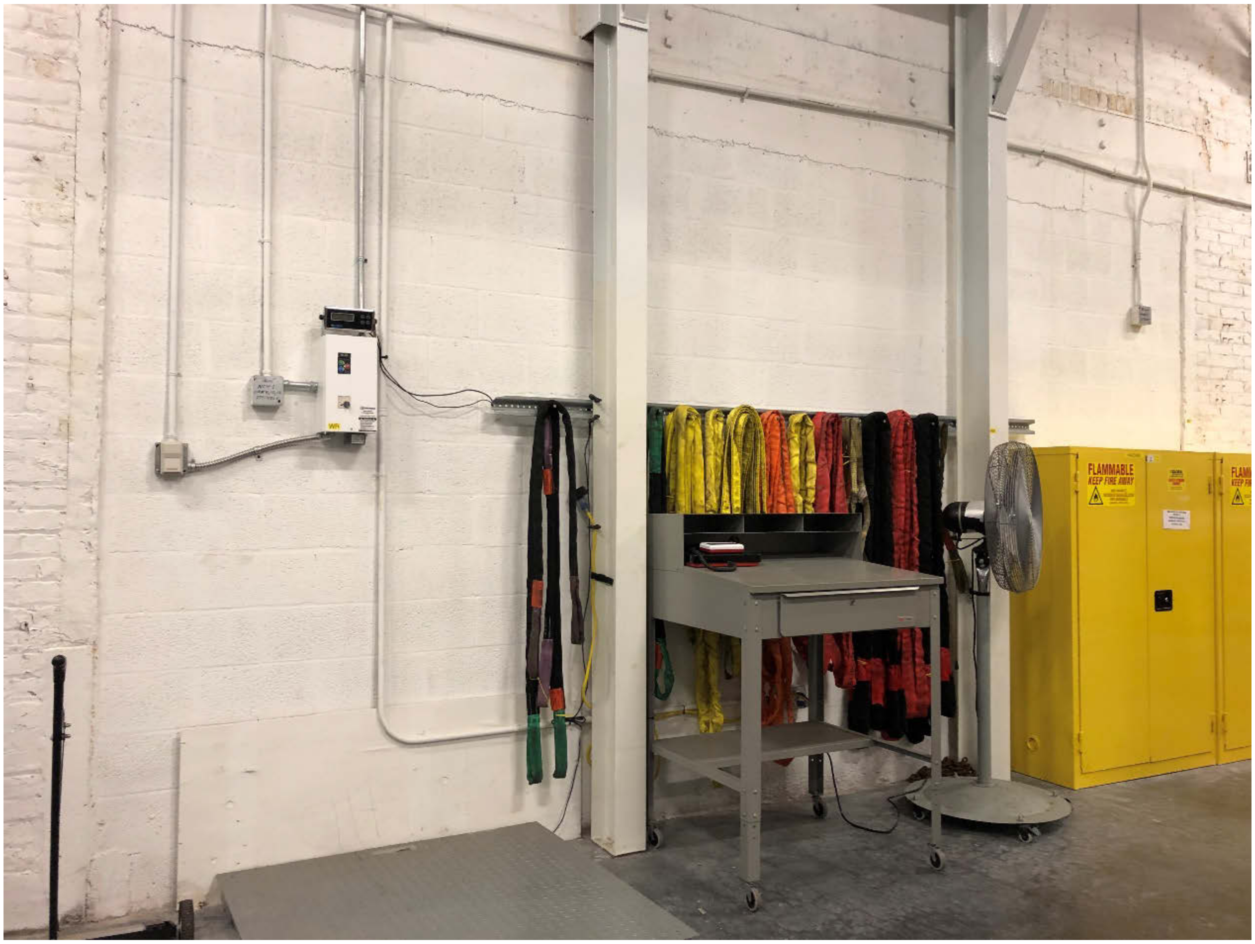

Figure 48: Materials storage building's steel framings and the perimeter masonry walls

Figure 49: Two-way truss-joists supporting roof steel beams – Materials storage building

DETERMINING CANDIDATE FACILITY SITE LOCATIONS

Background

The first step towards determining a future rail maintenance and layover facility in California consists of preparing a candidate list of options for such locations (with latitudes and longitudes). Therefore, a list of such locations is prepared keeping in mind that the future location should be the closest to the railroad line. Statistics from the Longitudinal Employer-Household Dynamics, Center of Economic Studies (US Census Bureau), show that majority of the workforce in California reside within 10-mile distance around employment centers and job sites. Thus, a candidate location should be identified such that it has a high concentration of rail maintenance-related workforce around 10-mile radius of the location.

Further, the following considerations are made for preparing the candidate locations around which a future location could be located: 1) proximity of the location to closest rail line, and 2) proximity to an existing yard and/or existing station for increasing service and operational efficiencies of the trains. The reasoning is based on the specific findings from site visits that were conducted at the facilities in Oakland, Stockton, Denver and West Palm Beach. These four facilities had the advantage of being located very close to the existing railroad lines at their respective sites. In addition, Denver CRMF was built as an expansion of an existing yard.

All four sites were located very close to one or more transit stations along the intercity passenger rail line. This also made sense as trains could be dispatched for service once preventive maintenance and inspection were completed. The new facility location in California can also serve as a layover facility for trains servicing passengers right from the nearest station. In the case of Denver CRMF, the location was an upgrade of an existing rail maintenance structure and was operating successfully for all maintenance needs of the rail line. Hence, a pre-existing site in California could also be a good candidate to be upgraded to an intercity passenger rail maintenance or layover facility.

Methodology

The methodology consists of identifying eight objective functions and constraints that will govern the location for a future intercity passenger rail maintenance and layover facility in California. The objective functions (and constraints), along with their level of importance, are presented in Table 3.

Table 3: Classification of level of importance of various objective functions and constraints for future facility location

<table>
<tr><th></th><th>Objective Function</th><th>Level of Importance</th></tr>
<tr><td>1</td><td>Maximizing opportunities for state-of-the-art application of technologies – i.e. technologies that will increase maintenance/operational efficiencies, space utilization etc.</td><td rowspan="4">Extremely Important</td></tr>
<tr><td>2</td><td>Maximizing building/structural/operational sustainability</td></tr>
<tr><td>3</td><td>Minimizing risks associated due to geotechnical issues and seismicity</td></tr>
<tr><td>4</td><td>Maximizing service/building/structural/operational resiliency (i.e. minimizing operational downtime incurred by service or design load effects)</td></tr>
<tr><td>5</td><td>Minimizing risks associated due to fire</td><td>Very Important</td></tr>
<tr><td>6</td><td>Minimizing the total setup cost</td><td>Very Important</td></tr>
<tr><td>7</td><td>Minimizing average time/distance traveled from the existing facilities and stations</td><td>Important</td></tr>
<tr><td>8</td><td>Minimize risks due to flood and tsunami hazards</td><td>Very Important</td></tr>
<tr><td></td><td>Constraints</td><td></td></tr>
<tr><td>1</td><td>Limitations in availability of clean (alternative) sources of energy</td><td rowspan="2">Extremely Important</td></tr>
<tr><td>2</td><td>Water conservation and waste management (sustainability)</td></tr>
<tr><td>3</td><td>Structures dimensional needs, space for expansion, capacity constraints for individual elements – such as materials, locomotives, cars, storage, workforce etc.</td><td>Very Important</td></tr>
</table>

Keeping the objective functions and constraints in mind, candidates for a future location of an intercity passenger rail maintenance and layover facility in California are determined using ‘spatial analysis’. The spatial analysis technique provides a very quick visualization of various candidate sites around yards/stations. Geographical maps have been developed with data collected from various sources in executing the spatial analysis technique.   The shapefile data on intercity passenger rail yards, lines, and stations have been obtained from the Caltrans GIS database library.

Candidate Locations

A future site location should also be very close to the rail line as well as to an endpoint station. Based on the employment concentration data of workers from the waste management industry[24], the commute distance for the workers should not exceed 10 miles from the existing yard locations. The workers employed in the waste management industry represent sustainability potential of a yard location.

The map in Figure 50 shows the spatial distribution of these 17 existing rail yards (relative to all the intercity passenger rail line stations), that have the potential to be upgraded to a future rail maintenance and layover facility in California.

It is observed that the following yards provide a more sustainable option for waste management if expanded as a future facility: Los Angeles Maintenance Facility, Keller Yard, Sand Canyon, Centralized Equipment Maintenance and Operations Facility and Daly City Shop.

A future facility location in California could leverage the existing proximity of stations and yards (mutually aligned along the rail line) to enhance resilience in operations, and maintenance and layover services, respectively. Resilience in rail maintenance can be provided by sharing maintenance loads and layover needs with one or more yards along the rail line. At the same time, passenger services could resume quickly starting with the nearby station after maintenance.

A list of these total 17 yards (as candidate locations) and 23 stations that lie spatially within proximity to each other have been presented in Table 4. The latitude and longitude locations are also noted for the existing yards.

[24] U.S. Census Bureau. (2019). LEHD Origin-Destination Employment Statistics (2002-2015). Washington, DC: U.S. Census Bureau, Longitudinal-Employer Household Dynamics Program, accessed on July 12, 2019 at https://onthemap.ces.census.gov.

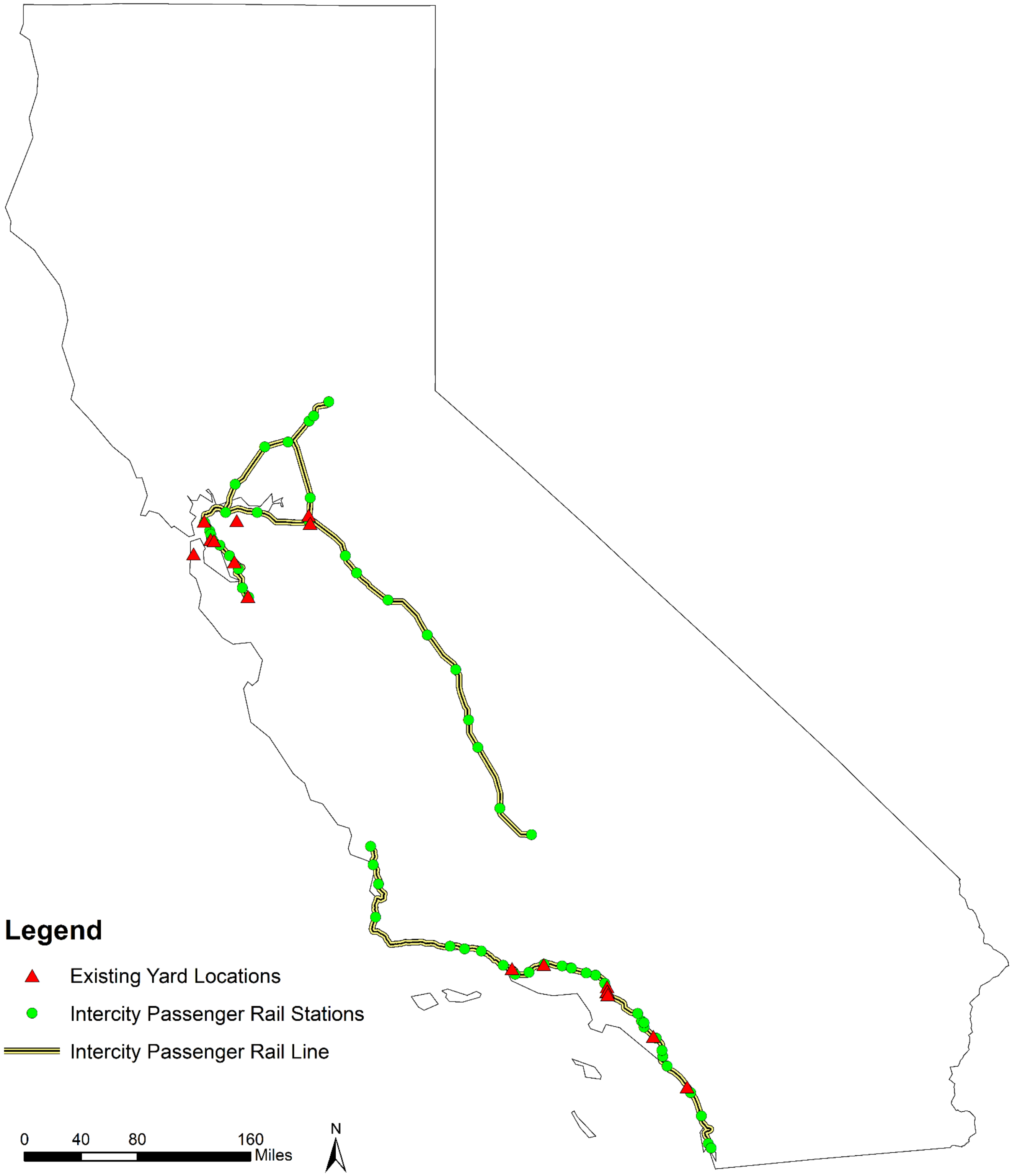

Figure 50: Spatial proximity of existing stations and rail yards along the intercity passenger rail lines in California

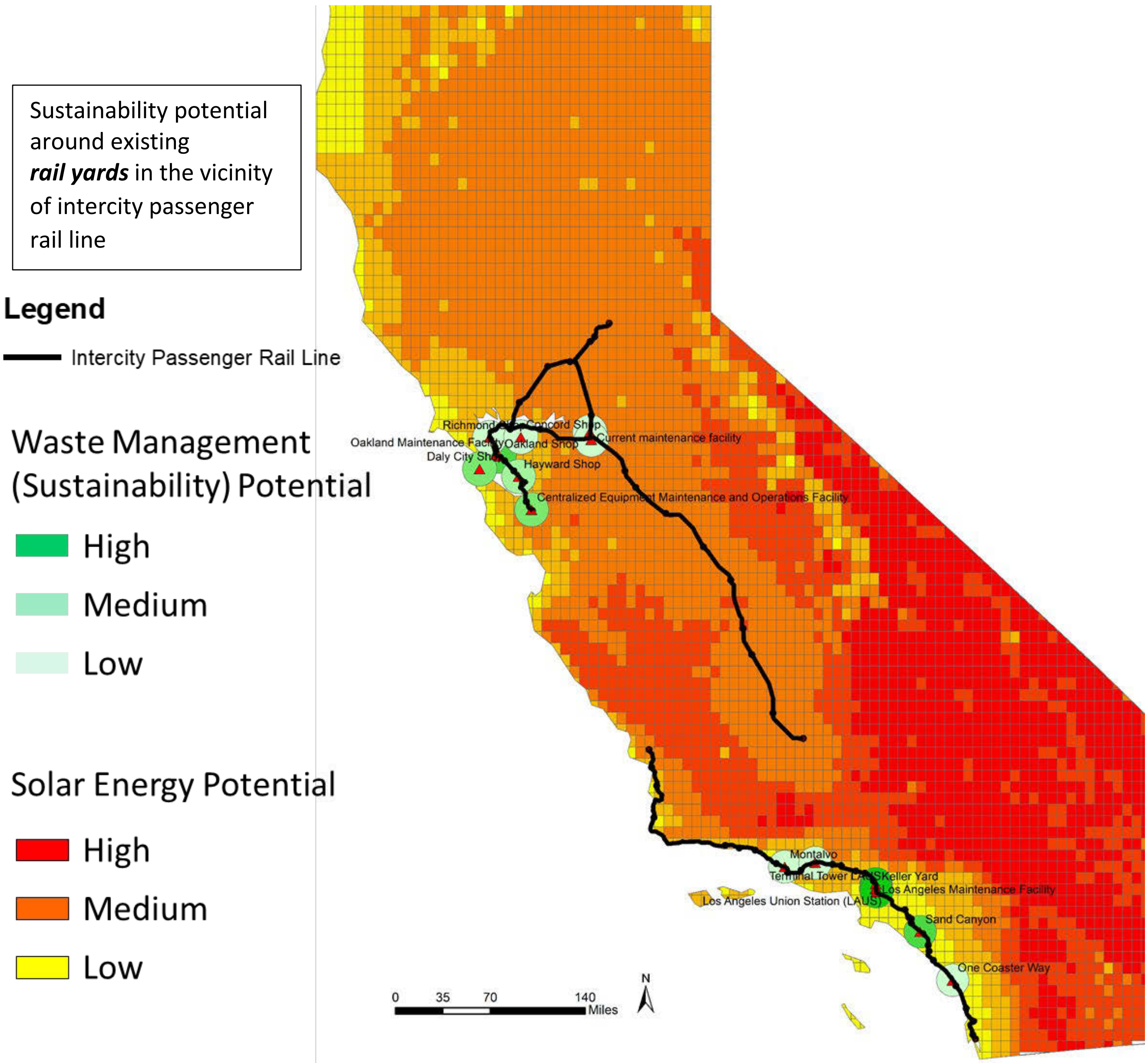

Figure 51: Sustainability potential (waste management and solar energy) surrounding existing rail yards close to rail line

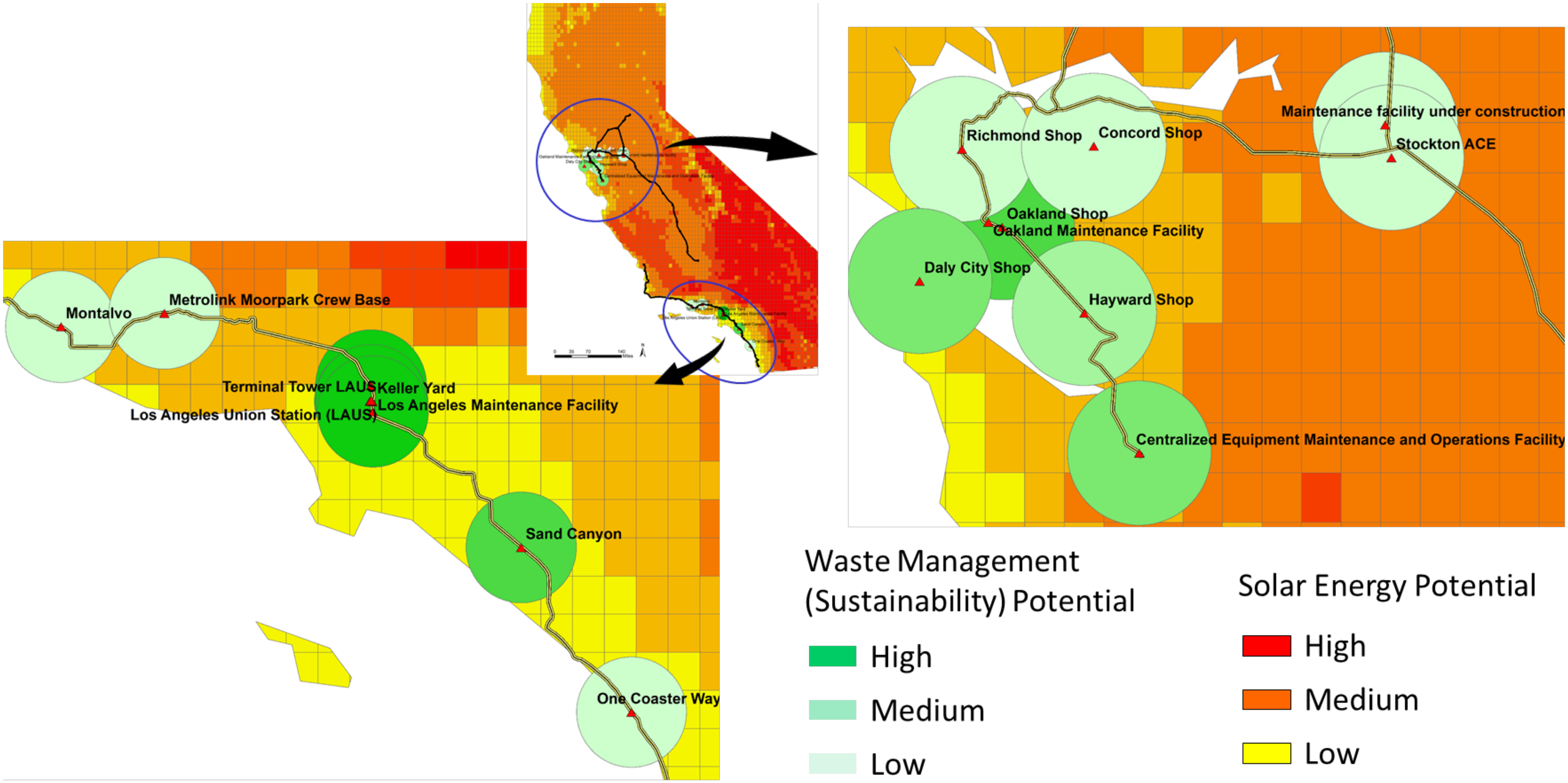

Figure 52: Enhanced spatial illustration of existing rail yards

(as shown in Fig. 51)

Table 4: List of existing intercity passenger rail stations and yards within 10-mile radius of each other in California

	YARD	OPERATOR	STATION	YARD COORDINATES[25]	
				LATITUDE	LONGITUDE
1	One Coaster Way	COASTER	Oceanside	33.2430	-117.4146
2	Sand Canyon	Metrolink	Orange	33.6748	-117.7612
			Santa Ana		
			Irvine		
			Laguna Niguel/ Mission Viejo		
3	Southern California Regional Rail Authority	Metrolink	Los Angeles	34.0564	-118.2331
			Glendale		
4	Keller Yard	Metrolink	Los Angeles	34.0550	-118.2284
			Glendale		
5	Terminal Tower LAUS	Metrolink	Los Angeles	34.0588	-118.2326
			Glendale		
6	Los Angeles Union Station (LAUS)	Metrolink	Los Angeles	34.0560	-118.2368
			Glendale		
7	Los Angeles Maintenance Facility	Amtrak	Los Angeles	34.0296	-118.2270

[25] Yard coordinates (latitudes and longitudes) provide point representation of yard location surrounding which 10-mile buffer circles are generated for a future facility location

			Glendale		
8	Metrolink Central Maintenance Facility (CMF)	Metrolink	Los Angeles	34.0972	-118.2329
			Glendale		
			Burbank		
9	Metrolink Moorpark Crew Base	Metrolink	Camarillo	34.2849	-118.8823
			Moorpark		
10	Montalvo	Metrolink	Oxnard	34.2501	-119.2067
			Ventura		
11	Centralized Equipment Maintenance and Operations Facility	CALTRAIN	San Jose	37.3393	-121.9100
			Santa Clara/Great America		
12	Hayward Shop	BART	Hayward	37.6198	-122.0488
			Fremont/Centerville		
13	Oakland Shop	BART	Berkeley	37.7914	-122.2565
			Emeryville		
			Oakland		
			Oakland Coliseum		
14	Oakland Maintenance Facility	Amtrak	Berkeley	37.8016	-122.2917

			Emeryville Oakland Oakland Coliseum		
15	Richmond Shop	BART	Richmond	37.9474	-122.3582
16	Concord Shop	BART	Martinez	37.9531	-122.0249
17	Stockton ACE	ACE	Stockton	37.9303	-121.2727

Spatial Analysis

The spatial analysis technique is used to evaluate the 17 yard-station systems (i.e. 17 existing rail yards and 23 stations) across the seven objective functions and constraints identified earlier in Table 3. The evaluation is carried out under each objective function, with the following discussion as follows:

1) **Maximizing opportunities for state-of-the-art application of technologies – i.e. technologies that will increase maintenance/operational efficiencies, space utilization etc.**

There are various state-of-the-art technologies that are being used for rail maintenance and layover facilities such as:

Vertical lift machine (VLM) – Warehouse/Storage Building: A vertical lift machine (VLM) operates using a computerized system and works like a vending machine using a laser-guided mechanism. VLM provides automated access to several rail parts needed for maintenance and can also serve as a storage system for just-in-time items which are replenished regularly in trains such as paper towels/napkins. VLMs were used extensively at Denver CRMF.

Wash Systems: A fully automated wash facility that uses waterless or 100% recycled water for various wash needs.

Turntable System: Car and wheelsets can be rotated using a turntable system where the space is a constraint. The system assists in improving the efficiency as these platforms can rotate horizontally, allowing workers to move and transfer a car or a wheelset to any workshop within the building and be fixed for expedited maintenance. Denver CRMF utilized similar state-of-the-art technology using a turntable system. In addition, state-of-the art technology such as the floor lifting system assists in vertical lifting of electric multiple units (EMUs) and other railway maintenance equipment. The system allows for utilization of vertical space in a building, and the technology is suited for locations that have limited space to expand.

Details of some of the state-of-the-art technologies applicable for a maintenance and layover facility have also been provided in the APPENDIX. These technologies are part of the additional information collected besides those noted from site visits to facilities in Oakland, Stockton ACE, Denver CRMF and Brightline West Palm Beach in Florida.

However, most of these technologies can be used to revamp an existing facility or be installed in a future facility. Therefore, all the 17 candidate locations would satisfy this objective function.

2) **Maximizing building/structural/operational sustainability**

A sustainable building/structure should be efficient in terms of both energy and use of other resources (such as water recycling and waste management) needed for the new maintenance facility to operate optimally. Thus, solar energy potential of a new facility should be high, as it is the most abundant renewable energy source in California. The map in Figures 51 show a very high solar energy potential for a future facility that is located along the north-central California's intercity passenger rail line ([26]).

Water recycling systems can be installed at any location and water reuse can be ensured.

Waste management can be tricky for a new facility as there has to be a proper mechanism to dispose waste generated at the facility. Skilled workers are often required for ensuring efficient waste management practices. Facilities often outsource their waste management needs. A location that is surrounded by a higher concentration of waste management employers and industries will be a preferred location in terms of operational sustainability. The maps in Figures 51 and 52 show the concentration of waste management activities within a 10-mile radius of existing rail yards in California. A future facility location could be set-up within proximity to these industry concentrations to leverage services from waste management firms for sustainability. The maps in Figures 51 and 52 show that a high waste management industry concentration exists within a 10-mile radius of the Los Angeles Maintenance Facility, Los Angeles Union Station, San Canyon, and most other yard-station systems in the Bay Area.

3) **Minimizing risks associated due to geotechnical issues and seismicity**

The map in Figures 53 and 54. provide information on soil texture and fault lines that exist across California. It is observed that the area around the yards of One Coaster Way and Sand Canyon stations in the Southern Californian Region would have lesser risks associated with geotechnical and seismic issues.

[26] Solar Energy Data, National Renewable Energy Laboratory for NREL, accessed on August 12, 2019. https://www.nrel.gov/gis/solar.html

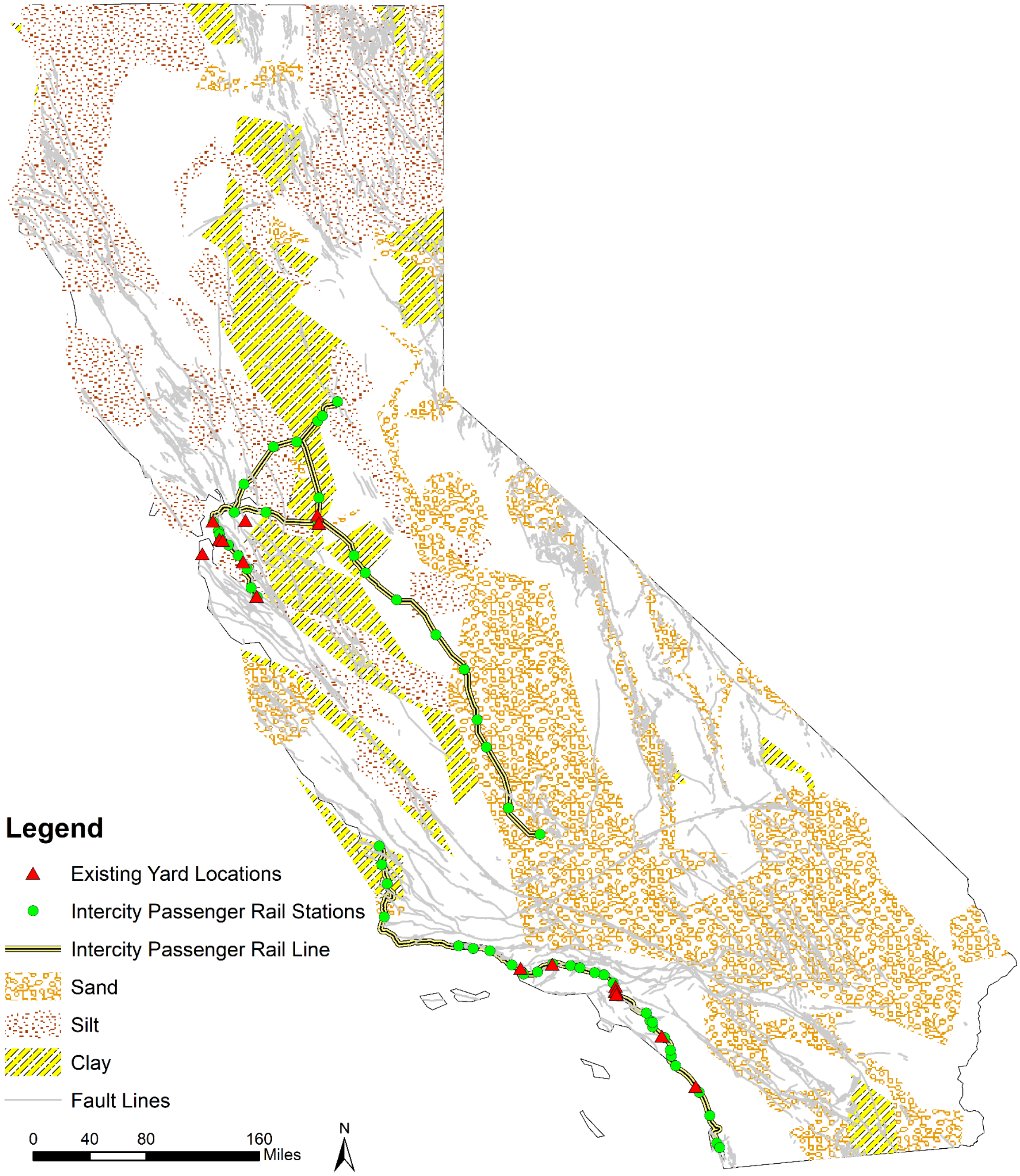

Figure 53: Spatial proximity of existing stations and rail yards along the intercity passenger rail lines in California

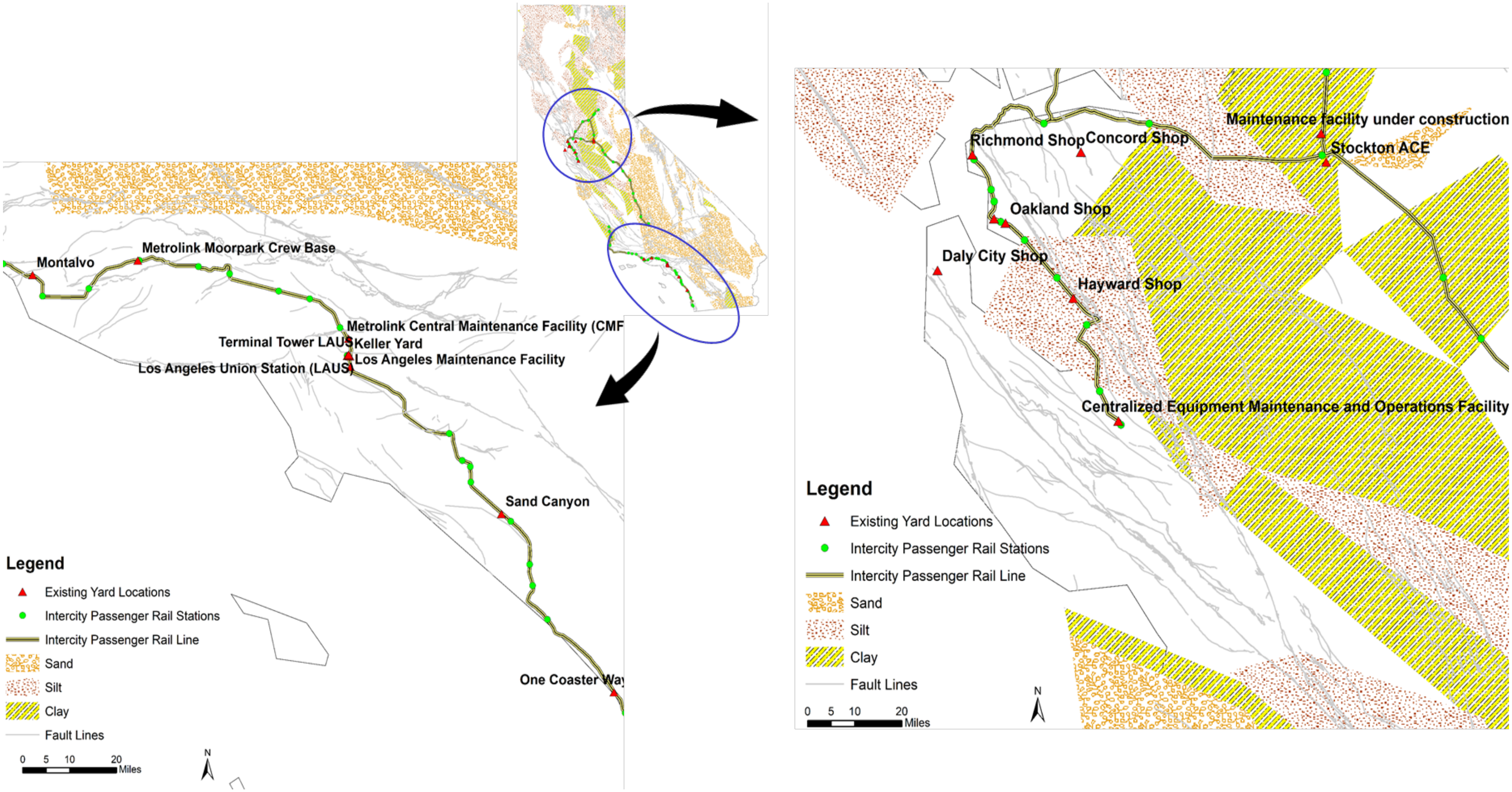

Figure 54: Enhanced spatial distribution of fault lines and soil texture across California

(as shown in Fig. 53)

4) Minimizing risks associated due to fire

The map in Figures 55 and 56 provide the information on fire perimeters, thus identifying fire prone regions in California. It is observed that the area around the yards in the Bay Area, Los Angeles and Stockton are safer from fire hazards.

Figure 55: Fire perimeters in California

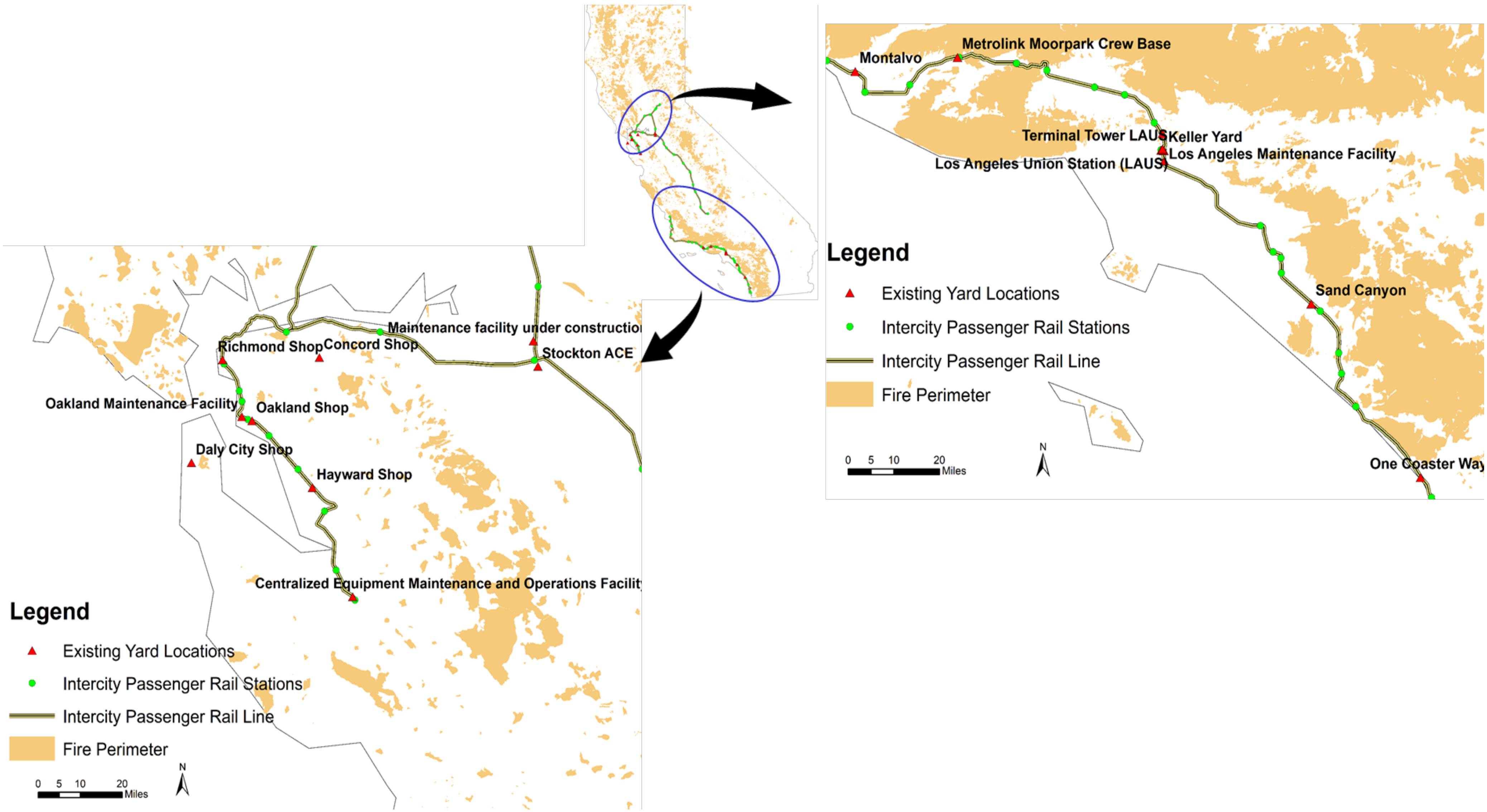

Figure 56: Enhanced map showing yards and fire perimeters in California

(as shown in Fig. 55)

5) **Maximizing service/building/structural/operational resiliency (i.e. minimizing operational downtime incurred by service or design load effects)**

Building/structural resilience of a facility can be increased by providing additional strength to the structure located anywhere in California. The strength would be as per building codes of a facility. This is provided that the cost in providing such structural strength is not a major constraint. Thus, a building at any location in California that can have a requisite structural strength as per the building codes would be preferred.

Service and operational resilience requires proper planning in the choice of location of a new facility. One of the ways service (and operational) resilience can be maximized is by locating the future facility close to an existing facility or a rail yard.

6) **Minimizing the total setup cost (including county-specific sales tax)**

The map shown in Figure 57 represents prevailing county sales tax (in percentage). These rates are in addition to the state tax of California ([27]). Sales tax can be considered an important present and future cost factor in determining the choice of a future facility location in California.

[27] California Department of Tax and Fee Administration, accessed on May 1, 2019. https://www.cdtfa.ca.gov/taxes-and-fees/sales-use-tax-rates.htm

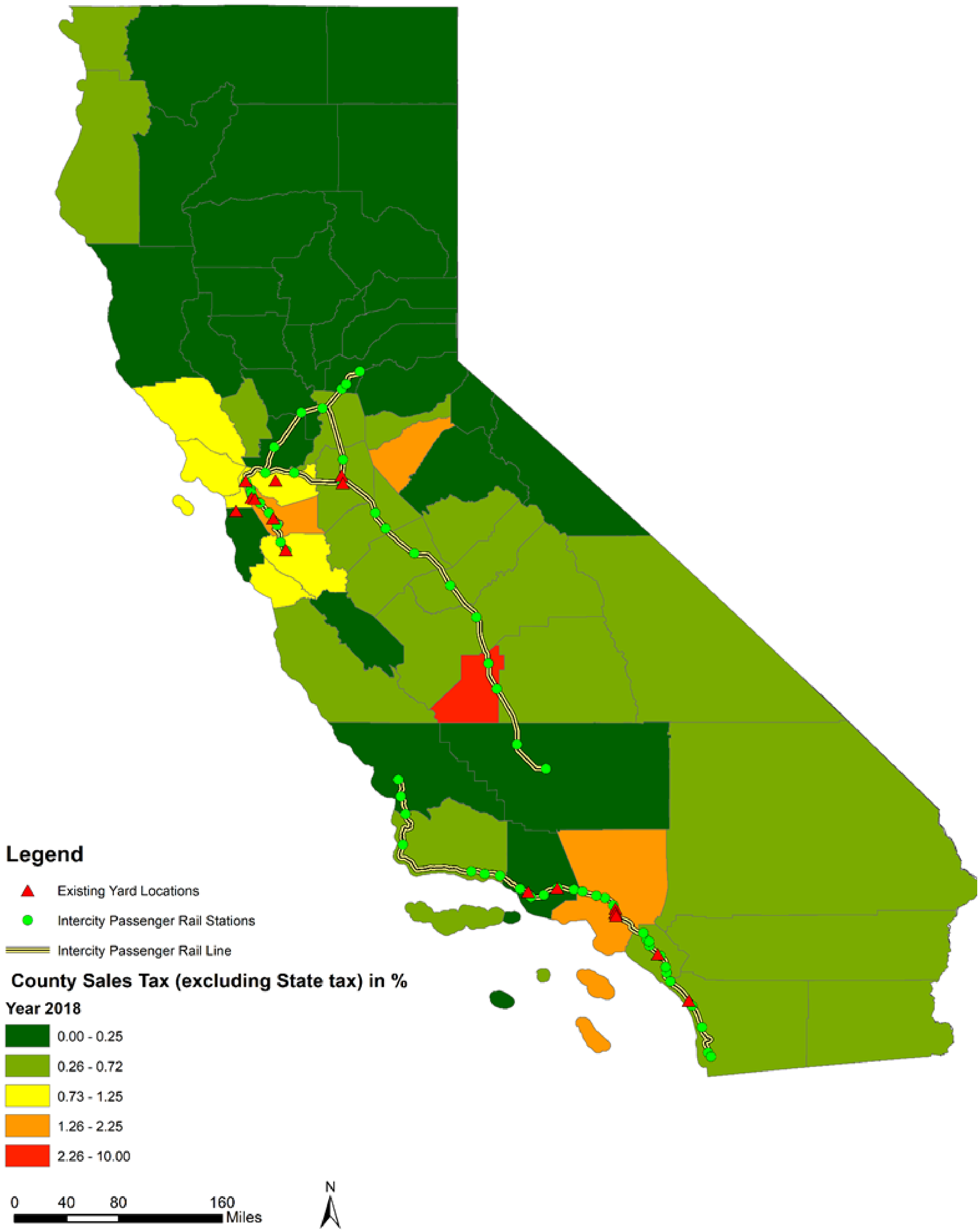

Figure 57: Distribution of sales tax across the counties in California

7) **Minimizing average time/distance traveled from the existing facilities and stations**

This objective function is fulfilled with the yards (and surrounding stations) that are close to the intercity passenger rail line in California.

Constraint Analysis

The following constraints serve as important inputs for facility location:

1. Limitations in availability of clean (alternative) sources of energy
2. Water conservation and waste management (sustainability)
3. Structures' dimensional needs, space for expansion, capacity constraints for individual elements – such as materials, locomotives, cars, storage, workforce etc.

The constraints are interchangeable with one or more of the listed objective functions identified in this study above. For example, constraints 1 and 2 are aligned with objective function on sustainability.

A rough estimate of space availability has been determined using visual analysis of land space availability in the surrounding 10-mile radius of rail yards shown in the maps of Figure 59. It is observed that the availability of land space surrounding Stockton, Metrolink Moorpark Crew Base, Montalvo and One Coaster Way rail maintenance facilities and yards appear to be higher than the rest of the other yards. Thus, based on the need for land space availability, any future rail maintenance and layover facility in California could be set-up within a 10-mile radius of either the Stockton or One Coaster Way yards.

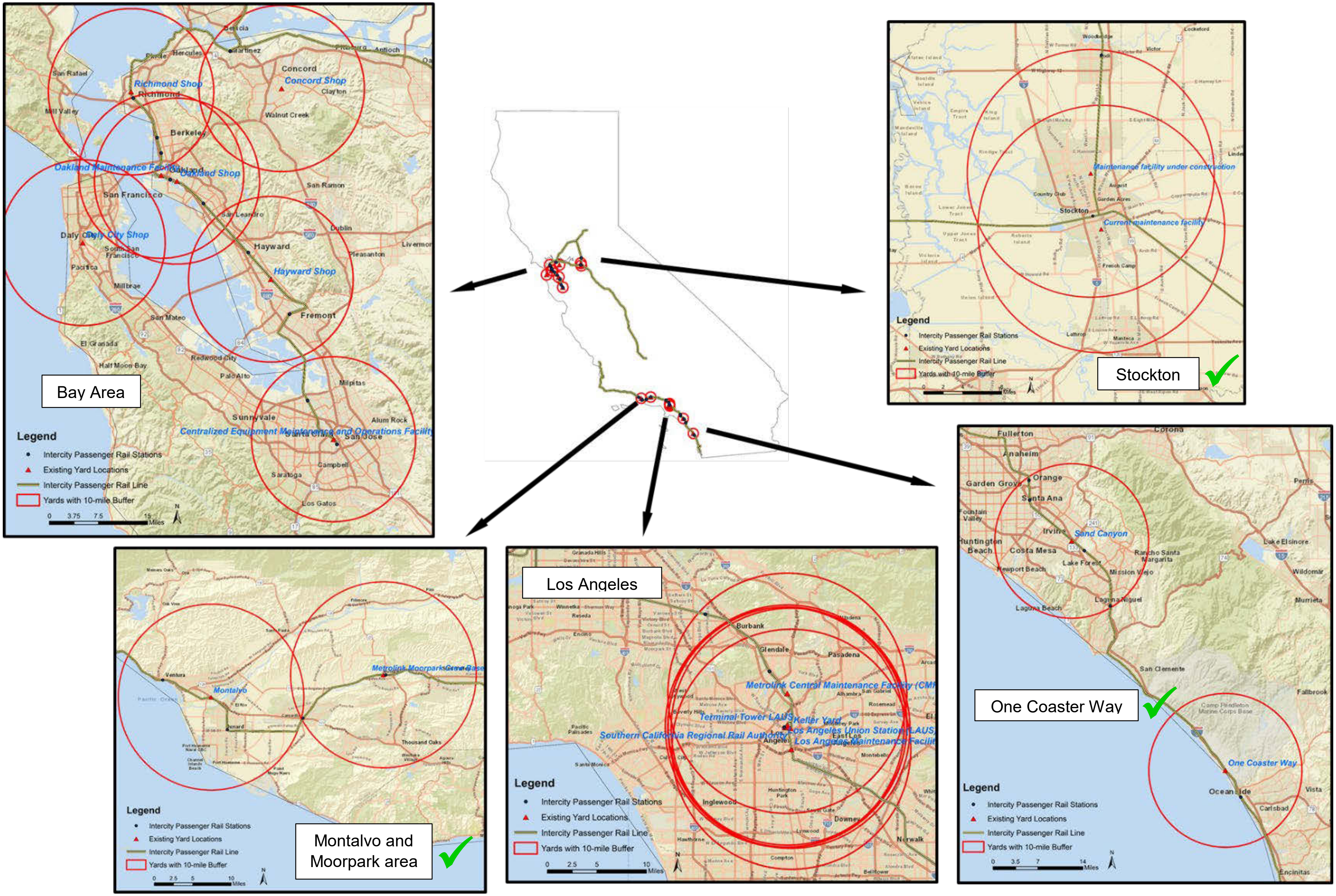

Figure 58: Land space availability of the surrounding 10-mile radius of each existing yard and station system in California.

8) Minimize risks due to flood and tsunami hazards

Each candidate location was assigned the level of risk to flood and tsunami hazards based on FEMA's National Flood Hazard Layer (NFHL) Viewer ([28]). A detailed information on each of the candidate locations is provided in the last section D of the APPENDIX.

Quantification of Preference for a Candidate Location

The area that lies within the 10-mile radius around a yard-station system can be the potential site for a future facility. Thus, the yard-station system identified earlier in Table 4 is quantitatively ranked in terms of level of satisfaction that can be achieved in fulfilling each of the seven objective functions (and three constraints). Table 5 presents the template that is populated based on the spatial analysis carried out in the Methodology section. A candidate location is assigned a preference score (level 10 to 1) depending on the spatial match for fulfilling each individual objective function. These scores are relative to the score that can be assigned to a location anywhere in California, and not just limited to the location of the 17 yard-station systems.

A preference level score (level of agreement) of 10 for a yard-system candidate location indicates that the location's relative preference for a future facility to be located within its 10-mile vicinity is the highest when compared to anywhere in California. A score of 1 indicates that the candidate location is not preferred due to any extreme disadvantage preventing a future facility to be located within its 10-mile vicinity. The choice of the numeral 10 to 1 is based on the schematic shown below:

Observing the scores in Table 5, all the candidate locations (yard-station systems) are assigned the highest possible score for the Objective Function 1 (*Maximizing opportunities for state-of-the-art application of technologies – i.e. technologies that will increase maintenance/operational efficiencies, space utilization etc.*), Objective Function 5 (*Maximizing service/building/structural/operational resiliency i.e. minimizing*

[28] FEMA's National Flood Hazard Layer (NFHL) Viewer, accessed on October 22, 2019. https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd&extent=-118.31250560885951,33.63618987121927,-117.64783275729789,33.92155559470369

operational downtime incurred by service or design load effects) and the Objective Function 7 (*Minimizing average time/distance traveled from the existing facilities and stations*). In order to fulfill Objective Function 4, any yard-station system candidate location is suitable because the application of most state-of-the-art of technologies are independent of a location if the cost of installation or application of any technology is not a major constraint at that location.

Table 5: Quantitative ranking for preference of each yard-station system across the objective functions

(Similar ranking can be established for constraints. However, the ranking would be redundant if constraints become same as one or more of the objective functions)

		Obj. Function 1	***Obj. Function 2***	***Obj. Function 3***	***Obj. Function 4***	***Obj. Function 5***	***Obj. Function 6***	***Obj. Function 7***	***Obj. Function 8***	***COORDINATE***	
	LIST OF CANDIDATE LOCATIONS (YARD-STATION SYSTEM)	*Maximizing opportunities for state-of-the-art application of technologies – i.e. technologies that will increase maintenance /operational efficiencies, space utilization etc.*	*Maximizing building/structural/operational sustainability*	*Minimizing risks associated due to geotechnical issues and seismicity*	*Minimizing risks associated due to fire*	*Maximizing service/building/structural/operational resiliency (i.e. minimizing operational downtime incurred by service or design load effects)*	*Minimizing the total setup cost (including county-specific sales tax)*	*Minimizing average time/distance traveled from the existing facilities and stations*	*Minimize risks due to flood and tsunami hazards*	*Lat.*	*Long.*
1	*One Coaster Way*	***10***	***4***	***8***	***4***	***10***	***8***	***10***	***4***	*33.2430*	*-117.4146*
2	*Sand Canyon*	***10***	***4***	***4***	***4***	***10***	***8***	***10***	***8***	*33.6748*	*-117.7612*
3	*Southern California Regional Rail Authority*	***10***	***8***	***4***	***10***	***10***	***4***	***10***	***8***	*34.0564*	*-118.2331*
4	*Keller Yard*	***10***	***4***	***4***	***10***	***10***	***4***	***10***	***4***	*34.0550*	*-118.2284*
5	*Terminal Tower LAUS*	***10***	***4***	***4***	***10***	***10***	***4***	***10***	***4***	*34.0588*	*-118.2326*
6	*Los Angeles Union Station (LAUS)*	***10***	***4***	***4***	***10***	***10***	***4***	***10***	***4***	*34.0560*	*-118.2368*
7	*Los Angeles Maintenance Facility*	***10***	***4***	***4***	***10***	***10***	***4***	***10***	***4***	*34.0296*	*-118.2270*

8	*Metrolink Central Maintenance Facility (CMF)*	***10***	***4***	***4***	***8***	***10***	***4***	***10***	***4***	*34.0972*	*-118.2329*
9	*Metrolink Moorpark Crew Base*	***10***	***8***	***4***	***4***	***10***	***10***	***10***	***8***	*34.2849*	*-118.8823*
10	*Montalvo*	***10***	***8***	***4***	***8***	***10***	***10***	***10***	***8***	*34.2501*	*-119.2067*
11	*Centralized Equipment Maintenance and Operations Facility*	***10***	***8***	***8***	***10***	***10***	***4***	***10***	***4***	*37.3393*	*-121.9100*
12	*Hayward Shop*	***10***	***8***	***8***	***10***	***10***	***4***	***10***	***8***	*37.6198*	*-122.0488*
13	*Oakland Shop*	***10***	***8***	***4***	***10***	***10***	***4***	***10***	***4***	*37.7914*	*-122.2565*
14	*Oakland Maintenance Facility*	***10***	***8***	***4***	***10***	***10***	***4***	***10***	***4***	*37.8016*	*-122.2917*
15	*Richmond Shop*	***10***	***8***	***4***	***10***	***10***	***4***	***10***	***8***	*37.9474*	*-122.3582*
16	*Concord Shop*	***10***	***8***	***4***	***10***	***10***	***4***	***10***	***4***	*37.9531*	*-122.0249*
17	*Stockton ACE*	***10***	***10***	***8***	***10***	***10***	***10***	***10***	***8***	*37.9303*	*-121.2727*

The compilation of quantitative scores for the 17 yard-station in Table 5 shows the distribution of preference level for each location. A future facility should be located within a 10-mile radius of one of these candidate locations for the Table 5 compilation to be valid and applicable. The most preferred candidate location will have the largest cumulative weighted score from all the objective functions presented in Table 5. Based on the relative importance of the objective functions presented earlier in Table 3, the final weights for each objective function are developed on a scale of 1 to 5. The distribution of these weights is as follows: 5 = *Extremely Important*, 4 = *Very Important*, 3 = *Important*, 2 = *Least Important*, 1 = *Not Important*. Thus, an objective function that is extremely important for a future facility's location consideration is assigned the score of 5, while an objective function that is not important is assigned a score of 1.

A weighted preference value ($\boldsymbol{P_{10\text{-mi, Loc}}}$) of a yard-station system location (***Loc***) is developed to rank each candidate location in terms of a future facility to be within its 10-mile radius. The expression for $\boldsymbol{P_{10\text{-mi, Loc}}}$ is as follows:

$$\boldsymbol{P_{10\text{-mi, Loc}} = w_1 \times Obj.\ Func1._{\text{QuantScore, Loc}} + w_2 \times Obj.\ Func2._{\text{QuantScore, Loc}} + w_3 \times Obj.\ Func3._{\text{QuantScore, Loc}} + w_4 \times Obj.\ Func4._{\text{QuantScore, Loc}} + w_5 \times Obj.\ Func5._{\text{QuantScore, Loc}} + w_6 \times Obj.\ Func6._{\text{QuantScore, Loc}} + w_7 \times Obj.\ Func7._{\text{QuantScore, Loc}} + w_8 \times Obj.\ Func8._{\text{QuantScore, Loc}}}$$

where,

w_1 = weight for *Objective Function 1* = **5** *(Extremely Important)*
w_2 = weight for *Objective Function 2* = **5** *(Extremely Important)*
w_3 = weight for *Objective Function 3* = **5** *(Extremely Important)*
w_4 = weight for *Objective Function 4* = **5** *(Extremely Important)*
w_5 = weight for *Objective Function 5* = **4** *(Very Important)*
w_6 = weight for *Objective Function 6* = **4** *(Very Important)*
w_7 = weight for *Objective Function 7* = **3** *(Important)*
w_8 = weight for *Objective Function 8* = **4** *(Very Important)*

Values (except for objective function 8) are determined based on inputs received from project panel

$Obj.\ Func1._{\text{QuantScore, Loc}}$ = *Objective Function 1 quantitative score for a location*
$Obj.\ Func2._{\text{QuantScore, Loc}}$ = *Objective Function 2 quantitative score for a location*
$Obj.\ Func3._{\text{QuantScore, Loc}}$ = *Objective Function 3 quantitative score for a location*
$Obj.\ Func4._{\text{QuantScore, Loc}}$ = *Objective Function 4 quantitative score for a location*
$Obj.\ Func5._{\text{QuantScore, Loc}}$ = *Objective Function 5 quantitative score for a location*
$Obj.\ Func6._{\text{QuantScore, Loc}}$ = *Objective Function 6 quantitative score for a location*
$Obj.\ Func7._{\text{QuantScore, Loc}}$ = *Objective Function 7 quantitative score for a location*
$Obj.\ Func8._{\text{QuantScore, Loc}}$ = *Objective Function 8 quantitative score for a location*

Values determined based on spatial analysis

RESULTS

Based on the quantified values for the expression for $P_{10\text{-mi, Loc}}$ for each candidate location, Table 6 is prepared for identifying the future facility location in California. The values indicate that Stockton ACE, which is already a fully operational maintenance and layover facility, has the highest $P_{10\text{-mi, Loc}}$ value and is the most preferred location for a future facility to be located within a 10-mile radius of the site. Other location, such as the Hayward Shop, has the second-highest score for $P_{10\text{-mi, Loc}}$. This location should be the next focus location for setting up a new future facility within the 10-mile radius around it. The third yard-station system for a future facility candidate location within the 10-mile radius is the Montalvo rail-yard system. The map in Figure 60 shows the spatial location of these top-three preferred locations for the future facility in California. Table 7 presents stations that are covered within a 10-mile buffer around the three preferred existing yards. It is to be noted that these preferences for the future location in California might change depending on the weights (level of importance) assigned to each objective function discussed earlier.

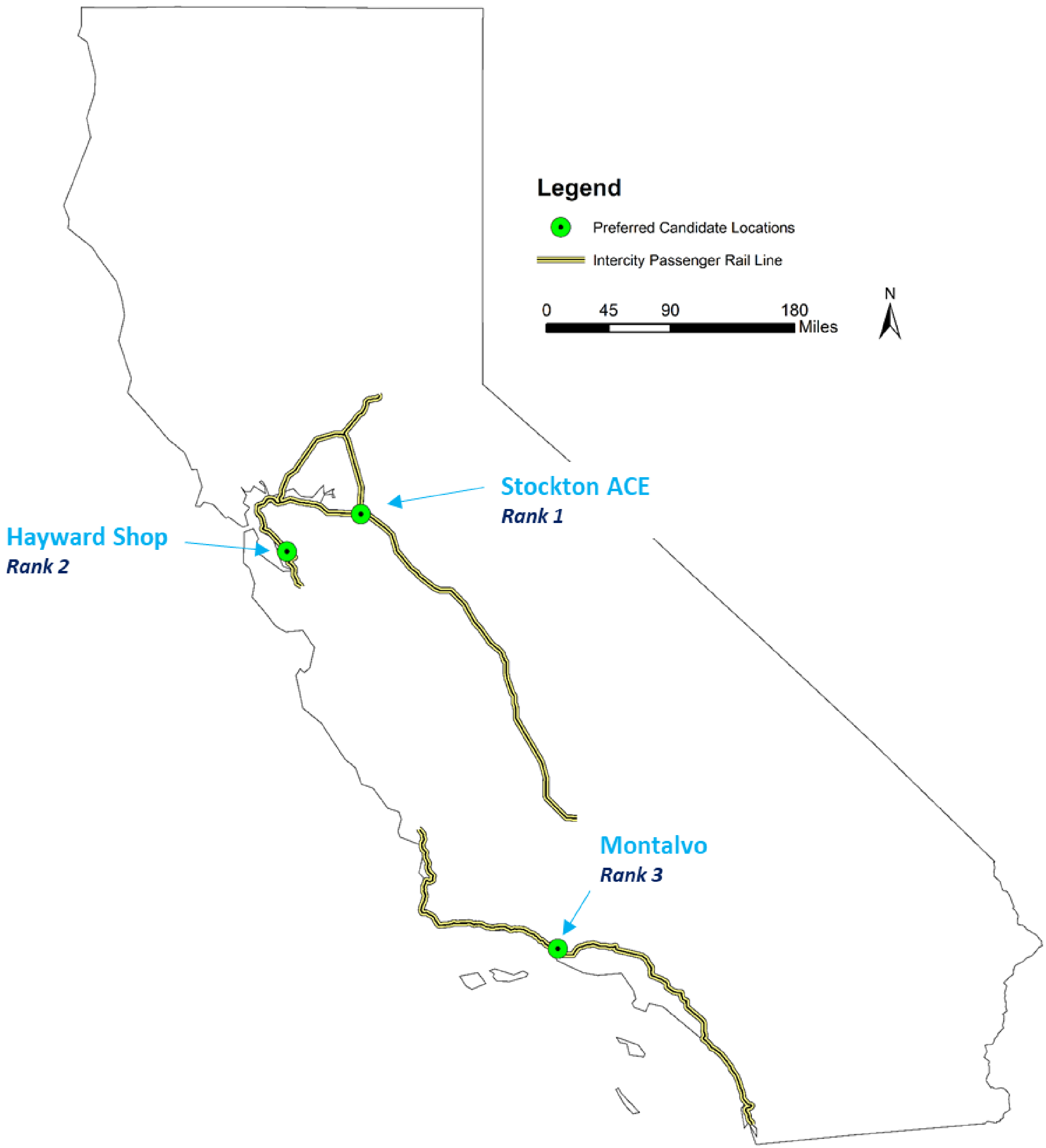

Figure 59: Spatial location of top five preferred location with 10-mile buffer for a future facility location in California

Table 6: Compilation of overall weighted preference score

	LIST OF CANDIDATE LOCATIONS (YARD-STATION SYSTEM)	**Weighted preference score ($P_{10\text{-mi, Loc}}$) for a location** (location with the largest score is the most preferred)	Coordinates	
			Latitude	**Longitude**
1	*One Coaster Way*	**248**	33.2430	-117.4146
2	*Sand Canyon*	**244**	33.6748	-117.7612
3	*Southern California Regional Rail Authority*	**278**	34.0564	-118.2331
4	*Keller Yard*	**242**	34.0550	-118.2284
5	*Terminal Tower LAUS*	**242**	34.0588	-118.2326
6	*Los Angeles Union Station (LAUS)*	**242**	34.0560	-118.2368
7	*Los Angeles Maintenance Facility*	**242**	34.0296	-118.2270
8	*Metrolink Central Maintenance Facility (CMF)*	**232**	34.0972	-118.2329
9	*Metrolink Moorpark Crew Base*	**272**	34.2849	-118.8823
10	*Montalvo*	**292**	34.2501	-119.2067
11	*Centralized Equipment Maintenance and Operations Facility*	**282**	37.3393	-121.9100
12	*Hayward Shop*	**298**	37.6198	-122.0488
13	*Oakland Shop*	**262**	37.7914	-122.2565
14	*Oakland Maintenance Facility*	**262**	37.8016	-122.2917
15	*Richmond Shop*	**278**	37.9474	-122.3582
16	*Concord Shop*	**262**	37.9531	-122.0249
17	*Stockton ACE*	**332**	37.9303	-121.2727

Table 7: Rail stations in the 10-mile-radius preferred rail-yard system

Preference Rank	**Yard as Candidate Location**	**OPERATOR**	**STATION**	**Yard Coordinates**	
				LATITUDE	**LONGITUDE**
1	Stockton ACE	ACE	Stockton	37.9303	-121.2727
2	Hayward Shop	BART	Hayward	37.6198	-122.0488
			Fremont/Centerville		
3	Montalvo	Metrolink	Oxnard	34.2501	-119.2067
			Ventura		

DISCUSSION AND CONCLUDING REMARKS

Site-specific challenges for Oakland facility included the structure's location on an unconsolidated bay mud layer. Remedies were to use surcharge and/or vertical drains to speed up consolidation of the layer. The recommendations beyond this were to use driven piles for a foundation. The lessons learnt for future site selection are to study the soil or research the area's history in order to predict the soil quality below the site. If a site with less than ideal soil is to be used, it is recommended to relocate the most critical building to an area with a more stable soil and less of a chance of settlement or at least differential settlement. Interviewing with the ACE Operations Superintendent, it was noted that the only drawback of the location was that it can only be expanded in length (with limits) to accommodate whole length of the train. The facility at ACE has future plans to expand and include a dry 4-acre pond area into its service needs. Currently, the facility operates only from Monday to Friday, unlike the Oakland OMF which operates on all the days of the week – this is due to higher number of rail services at Oakland serviced compared to ACE. The ACE facility is utilizing solar power for most of its lighting needs and has a high-speed door at the entrance and exit of the PM building with a strong exhaust and alarms to vent out smoke. The location of ACE is also not in a very active seismic zone. The seismicity of the area for location of Oakland OMF was also not brought out as a concern during our interviews and site visit. This could be due to the building codes and standards that were already followed for construction and maintenance of the two facilities.

Based on the Denver CRMF site visit, the lessons learnt for future site selection are to consider opportunity cost. In case of Denver CRMF, the consultations with the public brought attention to the possible savings of the rail maintenance facility remaining functional. This savings offset the cost of acquiring the land necessary for the determination of the final site. Additionally, this situation shows the importance of having a positive public opinion. Due to the relocation of this site, which was sparked by public opposition, the community was expected to be much more supportive of the work than previously.

The lessons learnt from West Palm Beach facility was to consider environmental costs before selecting a site. Thus, for future site selection, a thorough research on the area's history of land use and biological species should be known prior to purchase. For example, searching the California Nature Plant Society's Inventory of Rare and Endangered Plants would be a simple mitigation measure to perform prior to site location purchase.

All the four facilities in Oakland, Stockton, Denver and West Palm Beach were built close to an existing rail line. The facilities are also located very close to a transit station that is the end point of the line - either origin or destination. Thus, a future intercity rail maintenance and layover facility in California should be located at an optimal location to stations, railway corridor and possibility at the start or end point of the rail line.

All four facilities had some level of sustainability standards and practices in place. Denver CRMF had the highest level of sustainable measures compared to the other three facilities. ACE in Stockton utilized solar power for energy needs. Thus, a future location of a facility in California should provide good opportunity for tapping into the solar potential and other available natural resources of the location necessary for maintenance needs.   Although Brightline facilities in West Palm Beach and Orlando have a good solar potential, solar power was not used. The diesel emissions package is in line with the latest EPA standards.

A comparison of key location-specific findings from the in-person interviews conducted at the four sites is summarized in the Appendix of this draft report.

Each yard-station system is located within a mile distance from the intercity passenger railroad line and has at least one rail station within couple miles radius surrounding it. A future facility in California should be located within a 10-mile radius of a finally determined yard-station system. The 17 yard-station system identified as candidate for future facility location were: One Coaster Way, Sand Canyon, Southern California Regional Rail Authority, Keller Yard, Terminal Tower LAUS, Los Angeles Union Station (LAUS), Los Angeles Maintenance Facility, Metrolink Central Maintenance Facility (CMF), Metrolink Moorpark Crew Base, Montalvo, Centralized Equipment Maintenance and Operations Facility, Hayward Shop, Oakland Shop, Oakland Maintenance Facility, Richmond Shop, Concord Shop, and Stockton ACE.

A weighted preference value (score) for each yard-station system location was developed. The preference value is developed based on all the eight objective functions and constraints. The weighted preference value calculated for Stockton ACE was the highest among all the locations. Thus, indicating that area within 10-mile radius of Stockton ACE should be considered as the future location for rail maintenance and layover facility in California.

Recommended state-of-the-art technologies

Sustainability

1. Application of heliostat in interior sunlight illumination for large buildings
2. Photovoltaic air conditioner (PVAC)
3. Predictive Analytics: Predictive analytics involves condition-based maintenance with sensors installed on rail maintenance parts and equipment and is preferred over time-based maintenance or planned maintenance practices.
4. Distributed energy resources (DER)- Microturbines, Fuel Cells, Hybrid Systems (example, solid oxide fuel cell combined with a gas turbine)
5. Cogeneration - process in which electric power is generated at the facility where the waste heat is recovered to produce service hot water, process heat etc.
6. Permeable pavement, rain gardens, retention and detention basins, wells, rain barrels, wetlands, green roofs, R-tanks and biofiltration swales.
7. Stormwater control via biofiltration considers retention, detention and overflow
8. Plant, Soil and Permeable paving

9. Sustainable Urban Design System (SUDS), Water Sensitive Urban Design (WSUD), Low Impact Urban Design and Development (LIUDD)

Geotechnical issues and Seismicity

1. Predictive Analytics: Predictive analytics involves condition-based maintenance with sensors (e.g., strain gauges and tilt/settlement monitoring sensors) installed on structural components (e.g., foundations and columns/beams)
2. Three-dimensional engineering geological modeling
3. Bedrock confidence map for continuous monitoring of subgrade (e.g., using seismic wave method) to visualize variability in geologic materials and their physical properties
4. Soil improvement techniques such as Deep Soil Mixing (DSM) or Compaction Grouting to increase soil's bearing capacity and to reduce its settlement potential
5. Rapid driven deep foundations such as Micropiles or Helical piles
6. Soil Bio-Cementation or Microbially Induced Carbonate Precipitation (MICP) which help improve properties of sandy soil

Prevention and Protection Against Fire

1. Predictive Analytics: Predictive analytics involves condition-based maintenance with sensors installed on rail maintenance parts and equipment and is preferred over time-based maintenance or planned maintenance practices.
2. Sound Wave Fire Extinguisher at strategic locations
3. Water mist fire safety technology improves on typical sprinkler systems
4. Early Suppression Fast Response Fire Sprinkler Systems (ESFR) - ceiling-mounted, featuring high-pressure heads capable of producing a high volume of water.
5. Aspirating smoke detection (ASD) technology - the process draws in air samples through durable piping to detectors and tests it is using sophisticated laser-based technology, imaging, and photodiodes.

Efficiency Improvement

1. Predictive Analytics: Predictive analytics involves condition-based maintenance with sensors installed on rail maintenance parts and equipment and is preferred over time-based maintenance or planned maintenance practices.

2. Vertical lift machine (VLM) - operates using a computerized system and works like a vending machine using a laser-guided mechanism
3. Advanced Turntable Systems - assist in vertical lifting of electric multiple units (EMUs) and other railway maintenance equipment. This allows for utilization of vertical space in a building and the technology is suited for locations that have limited space to expand.

Protection Against Flooding

1. Floating building parts with air-filled concrete for greater buoyancy
2. Unmanned Aerial Vehicles equipped with GPS, cameras and remote control for image capturing was helpful to find drainage obstacles
3. Light-detection and ranging map (LIDAR) gives the elevation of a given area using laser technology
4. Breathability and vapor-permeable coatings

APPENDIX

A. Interview Notes - Denver CRMF (conducted on February 22, 2019)

Inputs obtained from interview with Mr. Carl Atencio (Chief Mechanical Officer, Denver Transit Operators) are summarized below.

Question	Notes
What were the constraints and barriers considered when siting the facility at this location?	A previous facility existed at the location in 2009, however, the plot size of the facility was not enough, and nearby land was purchased for the expansion and to construct CRMF.
What were the opportunities that were exploited in deciding to site at this location?	There was a pre-existing facility located at the site, and it was in close proximity to BNSF rail corridor. Other specific details can be obtained from Kevin Steele.
Who were the champions and sponsors of the facility: Local agency/ RTPA /MPO/ State DOT? How was the facility funded? With regards to funding and program mechanisms for Design / construction costs by initial Capital investments and recurrent annual Operating costs (how they relate to S & I and PM aspects)	The facility was designed and constructed under public-private partnership (P3) involving Denver Transit Constructors, Gannett Fleming and Fluor.
Any multimodal connectivity/innovative design that improves the operational and functional efficiencies, incorporated at this facility; wish list of improvements you could add to the facility if you had funds available to you.	The facility is located close to two stations in less than one-mile distance – Pecos Junction Station in the north and 41st/Fox St. Station in the south. The facility tracks run parallel to the BNSF and UP rail lines. Five of these facility tracks are outside the maintenance building and are primarily used for layover, while remaining six tracks are used for maintenance purposes indoors. Three of these six tracks are powered by overhead electric lines, while the remaining three are non-powered. There was no mention of anything that could be needed to improve the facility. The facility is well-maintained in-keeping with daily safety needs of its workers. Having to service only EMUs made the facility look clean and efficient.

In addition to environmental costs and mitigation efforts, were there any equity and disadvantaged community considerations that dictated locating the facility at the current location.	The information will be obtained from Kevin Steele.
How does the agency pay for ongoing operations and maintenance of the facility?	Payments for operations and maintenance of the facility are done by Denver Transit Operators. Overall availability ratio (which measures rolling stock availability, on-time performance and station availability) is calculated every month and the ratio is used for payment when it is at least 97.7%. If the ratio is higher than 97.7%, the additional profit is made as bonus to the maintenance workers.
Details on the costs and constraints of different Local/ state / Federal permits and mandates governing the functioning and operations of the facility?	The information will be obtained from Kevin Steele.
What are the major cost components considered critical for regular operation and maintenance of the facility?	Exact cost estimates were not provided; however, a general idea was given about minimizing downtime costs by use of electrically powered gantry cranes for improved efficiencies, rotating shop lift table for trucks, indoor welding and battery wash facilities.
Information on spares/materials space management (Slow/ fast moving) Shop	Storage space, warehouse, battery wash and machine shops all were under one building – along with the administrative office. Shop lift table could rotate 360 degrees during maintenance of 42-ton cars and trucks to maximize space availability. Heavy maintenance of trucks typically took between 1 to 5 days at the facility.
Information on Spares Vending Machine new Tech?	Four computer and laser operated Vertical Lift Machines (VLM) were installed to expedite dispatch of spare parts in the warehouse. Parts with sizes up to 2 to 3 foot could be served using the VLMs. Each VLM has 1000 lbs. of capacity.

	The facility has been using two VLMs since the beginning but soon two more VLMs were purchased realizing their utility in improving efficiency. If the VLM did not have a particular spare part available, it sends a reminder to replenish its stock with that missing or diminishing part count.
How are the environmental costs measured?	Environmental costs are assessed by contracted them to outside firms and it's not done by the facility. The facility maintains Electric Multiple Units (EMUs) only and for 66 cars using a 25,000-volt main line. Proportion of this electric supply is used for auxiliary power and running heavy machines and equipment of the facility. The facility does not have any emission problems. Welding shop, which is indoors, is equipped with exhaust to drive out toxic air.
Risks and challenges faced for location choice – during engineering design and construction- and how were they overcome?	The location does not have any of these hazards and the facility is LEED Gold Certified
RTPA/ MPO/ state/ federal priorities and mandates	Suggested to contact Kevin Steele
Effective partnering and Contracting to pass the risk to Facility operating and maintenance contractors	Facility spends about 13-17% of its various contracts with small business enterprise (SBE) Denver Transit Operators (DTO) are entrusted for maintenance with SBE and facility risks are outsourced to contractors
One or more location advantages? Optimum facility space? Schedules, Routes current and future in long term rail planning documents/ Rail plans?	There is BNSF and UP yard located close to the facility. CRMF is located close to two stations within 1-mile distance. The RTD commuter rail serves 17,000 trips per day. Most of the facility elements are segregated under one building and are connected. Vertical spaces are optimally utilized using overhead gantry cranes. This assists in increasing the efficiency of workers at the facility.

	The facility has no space and hence no plans to expand The facility operates over 3 continuous shifts with 30 minutes overlap between any two shifts.
What are the best practices for maximizing train throughput and minimizing downtime during train maintenance? Current and future planned demand: Number of Daily Service & Inspections Pits needed? Preventive maintenance: Daily/ quarterly/ four yearly / mandated to keep in public service?	Vertical lift machines (VLMs) are used quick and automated. There are vending machines for tools to be checked out at multiple locations within the maintenance area. Every maintenance facility has gantry cranes to expedite work of the crew. Maintenance of locomotives and car are done daily. Maintenance of rail control parts as per FRA requirements of per 92-day and 184-day cycles. Spare parts of 3 car sets is always available at all times for maintenance needs. Truck wheel truing and similar wheel maintenance activities are done simultaneously at the same pit. There are no future plans for increasing the services and hence, current number of inspection pits are optimal. Maintenance work is carried out daily
Comment on accessibility of the facility location to resources to successfully achieve various operation, service and maintenance needs.	Location of the facility is close to BNSF and UP rail yards and the facility was reconstructed from a pre-existing facility. Workforce live and reside in the same city. The facility services only EMUs and is well connected to utility lines.
Innovations by current OMF and their wish lists / expansion plans	There was no wish list identified during the interview– the facility follows standard safety practices for all maintenance activities. For example, overhead green lighting system along the tracks indicate electric lines were not powered and the crew had a safety belt attached while climbing to the roof of the car or the locomotive for inspection.

Food commissary if needed - On site vs Off site	Facility has two break rooms and there is no food commissary inside the facility. However, food trucks are allowed inside the facility every two to three days of a week.
What are the best practices for achieving sustainability goals at the facility?	The Denver CRMF facility received a Leadership in Energy and Environmental Design (LEED) Gold Certification. Other important sustainable features of the CRMF include - efficient mechanics and lights for a 32 percent energy savings, water-efficient plumbing fixtures for a 39 percent reduction in water usage, radiant floor heating served by a 89 percent efficient water boiler and designed windows that prevent thermal transfer.

B. Interview Notes – West Palm Beach Brightline Facility (conducted on February 25, 2019)

Inputs obtained from interview with Mr. Tom Rutkowski (VP, Engineering & Chief Mechanical Officer, Brightline, West Palm Beach, FL) are summarized below.

Question	Notes
What were the constraints and barriers considered when siting the facility at this location?	The location was not attractive to Brightline because it was being opposed by local residents – mainly because they expected noise and pollution levels to increase due a facility being set-up in their neighborhood. In addition, locals had also thought that the facility workshops will not be aesthetically attractive in their residential neighborhood. Even to this day facility workers hear occasional gunshots at night.
What were the opportunities that were exploited in deciding to site at this location?	The facility runs on Florida East Coast Railway line and shares tracks with freight rail. Brightline is a 'for-profit' company and the facility location opened very recently in 2017. With only five trains that are maintained at the facility currently every night, most of the machines and equipment that are used for maintenance purposes are mobile or temporary. There was no air-conditioning at the workshops. One of the major criteria that were considered for site location was the cheaper price of the land at the location, workforce needed for special skill sets such as janitors and cleaners were also easily available from the area. Although majority area in Florida is marshy, the land on which the facility premises is located is much more stable and conducive as compared to the one in Orlando. The land in Orlando facility has a sinkhole and some $50 million will be spent to fix the sinkhole for the facility there before becoming fully operational for maintenance activities. The facility in Orlando is very close to the airport and real estate value has increased significantly in the surrounding area due to the new Brightline station. Further, it is expected that monetary gains with the new Orlando facility and Brightline station in the airport region will outweigh the expenditure incurred in getting the groundwork ready – such as fixing the sinkhole. The West Palm Beach facility location had to be identified in proximity to the nearby station (West Palm Beach Station) to

	reduce non-revenue miles. At present the West Palm Beach Station is just 1-mile distance south of the facility.
Who were the champions and sponsors of the facility: Local agency/ RTPA /MPO/ State DOT? How was the facility funded? With regards to funding and program mechanisms for Design / construction costs by initial Capital investments and recurrent annual Operating costs (how they relate to S & I and PM aspects)	Local authorities supported the establishment of the facility and with expectation that Brightline facility in West Palm Beach will provide full-time jobs to those needing regular jobs in the area and even some homeless were employed once the facility opened for maintenance. Local workforce was employed at the facility - such as those working in the wash facility. The facility after being established maintained quiet zones in the area- unlike most maintenance facilities that are noisy or create pollution from diesel engine emissions. Smoke from diesel engines were rendered harmless before being released by conversion with a converter inside the engine. Brightline trains also does not blow horns anywhere along its route or at railroad crossings along the tracks.
Any multimodal connectivity/innovative design that improves the operational and functional efficiencies, incorporated at this facility; wish list of improvements you could add to the facility if you had funds available to you.	The facility is open day and night and provides service throughout the week. The facility is connected to West Palm Beach Brightline station and Miami station is connected to Miami-Dade County light rail. The Brightline station at Miami is the last stop and is also close to Port Miami used for cruise ships. The facility also runs on tracks that is shared by freight rail in the region and is connected to the nearby port. There are future plans to set-up Brightline station at Fort Lauderdale Airport.
In addition to environmental costs and mitigation efforts, were there any equity and disadvantaged community considerations that dictated locating the facility at the current location.	Environmental costs of constructing and maintaining the facility has been huge – as hundreds of sea turtles which are protected species had to be transported to other locations. Existing rail line of Brightline has wildlife species and animal crossings points along its route– that is constantly monitored. Orlando facility avoided encroaching into American Eagle habitats. Brightline facility provided health benefits to locals who were employed and even some of them were homeless or did not have regular jobs were given regular source of income when the facility became operational.

How does the agency pay for ongoing operations and maintenance of the facility?	Brightline is a private firm and is a 'for-profit' company. There has been a recent investment from Virgin Rail Group and the plan is to change the name of Brightline rail.
Details on the costs and constraints of different Local/ state / Federal permits and mandates governing the functioning and operations of the facility?	Brightline believes in the attraction of the location where the facility is set-up. For example, the Orlando facility has already seen huge developments near the station with airport lounge-like looks and facilities for passengers. Brightline further brings in investors to open retail shops at all its stations to attract both passengers and non-passenger visitors from outside. All Brightline staffs are trained to greet station visitors nicely. The West Palm Beach facility, however, is not attractive since the people living in the surrounding area not economically well off. This prevents Brightline from investing on or expanding the facility or nearby areas of the West Palm Beach facility. Most of the focus of Brightline is to rather invest in the Orlando facility which is 3 hours north west from West Palm Beach facility.
Any risk factors?	Fast winds, floods and hurricanes are the main natural risks to the West Palm Beach facility. The buildings are designed to bear the loads from these risks.

C. Other state-of-the-art technologies for implementation at facilities

Details of some existing state-of-the-art technologies applicable for a maintenance and layover facility

1. Application of heliostat in interior sunlight illumination for large buildings - Song, et al. (2018)[29]

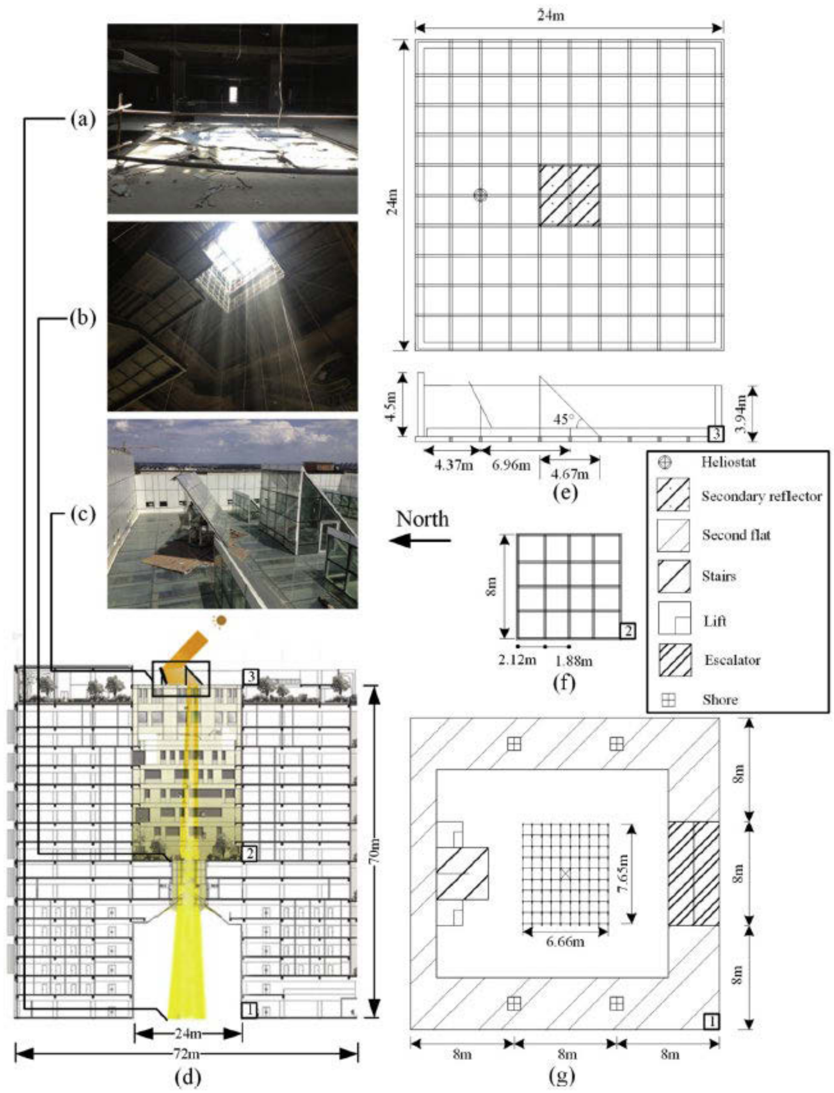

Figure A1 – Diagram of heliostat system

(a) daylighting on ground, (b) the 8th floor light path, (c) the roof-mounted heliostat and second reflector, (d) overall layout, (e) the beam net of the roof, (f) the beam geometry of the 8th floor, (g) the zone for daylighting on the ground.

[29] Song, J., Luo, G., Li, L., Tong, K., Yang, Y. and Zhao, J., 2018. Application of heliostat in interior sunlight illumination for large buildings. Renewable energy, 121, pp.19-27.

Technology Summary – See Figure A1 above, for a general layout. The structure, control module, secondary reflector and building structure. The heliostat is made from a collection of mirrors. The control module is made up of sensors, motors and reducers, controllers and a power supply. The secondary reflector is mounted at the center of the roof.

Specific applications – The experiments show that large-size heliostats can meet the demand for high flux (30 klux), long-distance (70m) interior daylighting in large buildings.

Advantages – The economic benefit of the equipment is converted according to the average light effect of a fluorescent lamp of 60 lm/W [37] and the price of 0.09 dollars/kWh. It takes 3.9 - 4.9 years to recover the cost of the equipment economically.

Limitations – The factors that affect the efficiency of light transmission are the reflectance of mirrors, the transmittance of glass, the coverage of steel beams in the system, and the sunshine area rate (SAR) of the heliostat mirror, which is defined as the ratio of the sunshine area on the mirror to the total area of the heliostat mirror.

Suitable for rail facility – This would be suitable for a rail facility as it would provide sufficient lighting in the facility for maintenance activities. For example, the luminous flux density (light density) projected by the heliostat (~30 klux) is far higher than that of traditional artificial lamps (~300 lux), such as LED.

2. Solar heating and cooling: Present and future development- Ge et al. (2018)[30]

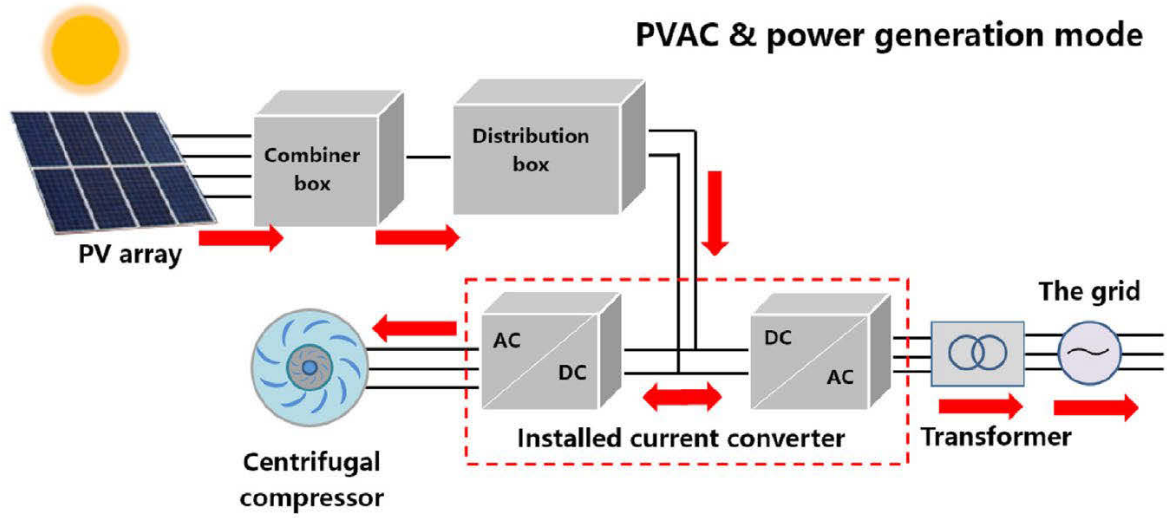

Figure A2: PVAC works in the PVAC & power consumption mode

Technology Summary – See Figure A2, above, for a general layout. Solar PV Cooling is when electricity produced by a photovoltaic (PV) system is used to power a conventional vapor compression refrigeration cycle. Experimental results and practical data proved that PVAC systems are high performance, save electricity, and have stable and reliable operation. The PVAC can be grid-connected or an off-grid system. The residual power from PV system can be sent to the grid when the PV power is more than what the unit needs; conversely, the power can be drawn from the grid to meet the gap when the PV power is less than the needs.

Specific applications – The DC-driven PVAC was recently commercialized by some companies in China and has been applied in many cases. The PV direct-driven inverter centrifugal chiller is used as an example. It is installed in an office building with a cooling load of 2790 kW in Zhuhai, China. During the cooling season from May to October, the monthly energy generation by PV system and power consumption by the chiller are tested. It is found that the total energy generation is 179MWh, which is 26.95% higher than the total energy consumption (141MWh), meaning the system provides "free" cooling for the building.

Advantages – A solar system has the merit of low operation cost using free renewable energy but high initial cost, and the payback period of solar heating and cooling system lies in the range of 3-15 years. This is highly related to the types of components, geographic location, and subsidy from government and can be optimized per project.

Limitations – The solar thermal cooling system is unfortunately not as well tested as the thermal heating system; however, there are expected to be further advancements in the

[30] Ge, T.S., Wang, R.Z., Xu, Z.Y., Pan, Q.W., Du, S., Chen, X.M., Ma, T., Wu, X.N., Sun, X.L. and Chen, J.F., 2018. Solar heating and cooling: Present and future development. Renewable Energy, 126, pp.1126-1140.

coming years. Novel concepts are proposed for future developments in this journal article.

Suitable for rail facility – This would be suitable for a rail facility if it were an enclosed rail facility, as heating and cooling costs for a large, long-term facility would be costly and potentially harmful to the environment. The installation of a PVAC system may be ideal when environmental and economic benefits are considered.

3. Life cycle cost of photovoltaic technologies in commercial buildings in Baja California, Mexico - Armendariz-Lopez et al. (2016)[31]

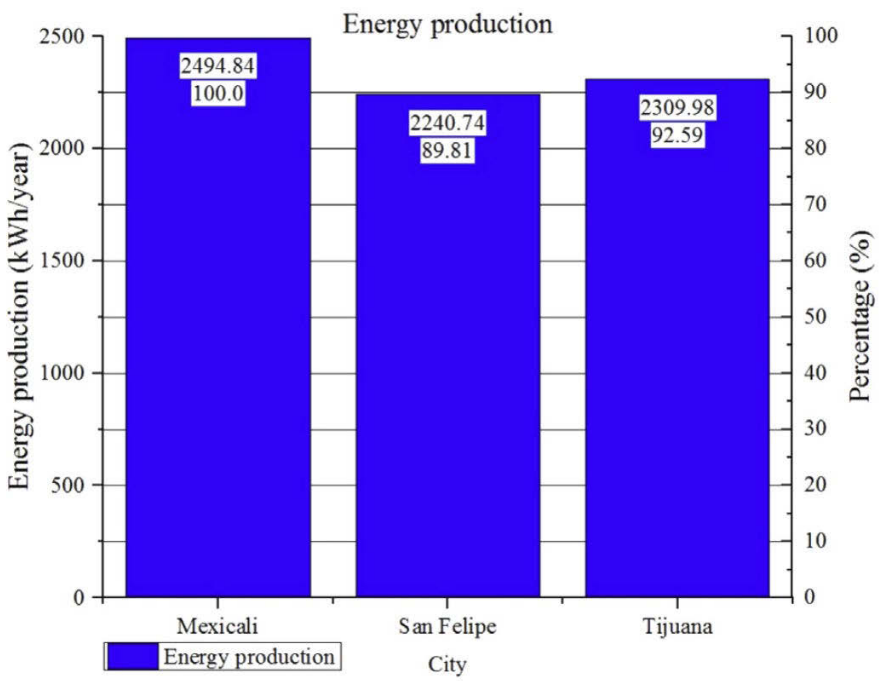

Figure A3: Energy production per installed multicrystalline kWp

Technology Summary – See Figure A2, above, for overview of potential energy production in Mexicali, San Felipe, and Tijuana, Mexico. The focus of this study was to analyze the photovoltaic (PV) module orientation for optimum power production and create a solar resource assessment for these three cities. This would create a template by which to identify the PV module's optimum orientation to utilize solar energy for a cleaner power source.

Specific applications – The analysis of electricity consumption in this research took into account the use of high-efficiency lamps, computers, printers and electronic devices for commercial use. The consumption of electricity by exterior lamps and air conditioning

[31] Armendariz-Lopez, J.F., Luna-Leon, A., Gonzalez-Trevizo, M.E., Arena-Granados, A.P. and Bojorquez-Morales, G., 2016. Life cycle cost of photovoltaic technologies in commercial buildings in Baja California, Mexico. Renewable Energy, 87, pp.564-571.

was variable in accordance with the sunlight and climate for each season in each location.

This journal article referenced Dong and Wiser (2013)[32] , which evaluated the economic impact of authorization processes from over 3,000 photovoltaic installations in 44 cities in California during 2011. Results indicated that best practices reduce costs between 4 and 12%, which meant $1,000 in savings for a 4 kW installation. [To be reviewed at a later date (article 6 in google drive)]

Advantages – The solar energy applications are suitable to supply electricity in the residential, commercial, or industrial sector. The potential of solar energy on earth surface is near 1.8 x 1,011 MW, which is 10,000 times greater than the global energy consumption.

Mexicali reached the shortest return on investment period: 13.02 years with an installed capacity of 4 kWp with the highest cost-benefit factor of 3.17. Solar resource was noted as the largest factor in how quickly a building in a given city would break even on their investment. Due to this factor, solar energy may be ideal for desert-like climates, which are not uncommon in California.

Limitations – It was noted that Japan requires less time to recover the investment of PV installation (7.70 years), than the UK (7.80 years) and Germany (12.32 years). This implies it is highly variable and will need to be verified in the US and California in particular.

Suitable for rail facility – This would be suitable for a rail facility as it would be a large, long-term facility. Considering environmental and economic benefits, installation of a PV system would prove a positive investment monetarily and environmentally.

4. *Predictive Analytics*: In order to enhance and improve operations and maintenance (O&M) activities at a rail maintenance facility, one of the state-of-the-art techniques involves predictive analytics using the industrial internet of things (IIoT). Predictive analytics involves condition-based maintenance with sensors installed on rail maintenance parts and equipment and is preferred over time-based maintenance or planned maintenance practices. Sensors provide predictive paradigm in which O&M teams get a week or even a month's notice in advance before assets fail. This allows the team to prepare schedules and resources to provide necessary maintenance without having to disrupt the service provided by the train. Predictive maintenance has proven to be one of the most effective and sustainable long-term solutions and is becoming a state-of-the-art practice in O&M services. Already these kinds of

[32] Dong, C. and Wiser, R., 2013. The impact of city-level permitting processes on residential photovoltaic installation prices and development times: An empirical analysis of solar systems in California cities. Energy Policy, 63, pp.531-542.

technologies are installed by agencies such as Palo Alto Research Center (PARC) in smart factories as well as critical aerospace and energy systems[33].

5. *Distributed energy resources (DER)*- DER refers to energy generation and storage systems placed at or near the point of use. DER technologies include the following (see Fig. A4 for details):
   i. ***Microturbines -*** small combustion turbines that produce between 25 kW and 500 kW of power.
   ii. ***Fuel Cells -*** Fuel cell power systems are quiet, clean, highly efficient on-site electrical generators
   iii. ***Hybrid Systems –*** example, solid oxide fuel cell combined with a gas turbine or microturbine or Wind turbines with battery storage and diesel backup generators.

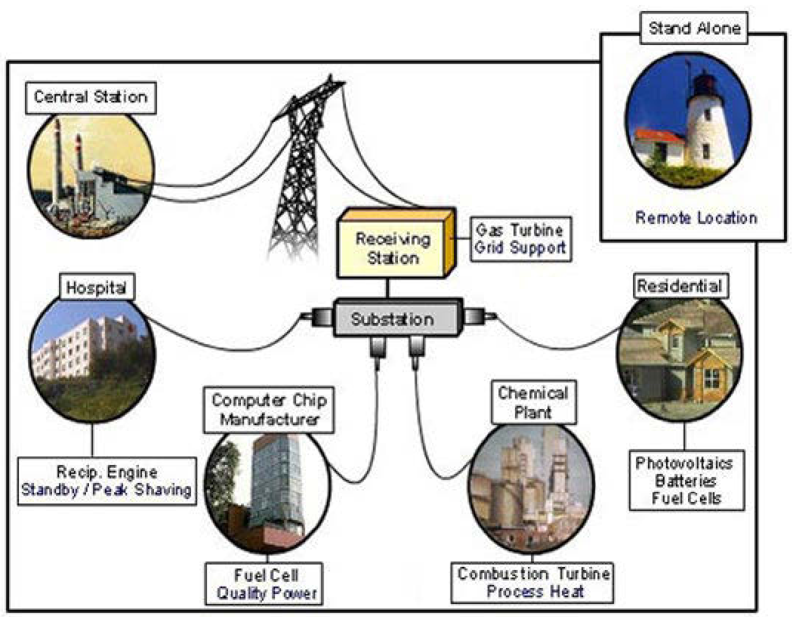

Figure A4: Examples of distributed energy resources

(Source: California Energy Commission and Capehart (2016)[34])

[33] Railway Technology, "Lines of data: using IIoT and AI to improve predictive rail maintenance", accessed on July 3, 2019. https://www.railway-technology.com/features/ai-and-iot-in-rail/

[34] Capehart, B., (2016). Distributed Energy Resources (DER), accessed on July 30, 2019. https://www.wbdg.org/resources/distributed-energy-resources-der

6. *Cogeneration* – is a process in which waste heat from running or operating electric power is utilized to produce service hot water[35].

7. Three-dimensional building energy performance measurement and modeling system - building-energy efficiency can be improved based on energy information, diagnosing a building and energy requirements[36].

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[35] Aldrich, R. (2016). Alternative Energy, accessed on July 30, 2019. http://www.wbdg.org/resources/alternative-energy

[36] Oh, T.K., Lee, D., Park, M., Cha, G. and Park, S., 2018. Three-Dimensional Visualization Solution to Building-Energy Diagnosis for Energy Feedback. Energies, 11(7), p.1736.

D. Flood Tsunami Hazard Report

National Flood Hazard Layer **One Coaster Way**

FEMA

33°14'39.04"N

117°25'11.29"W

117°24'33.83"W

33°14'8.96"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

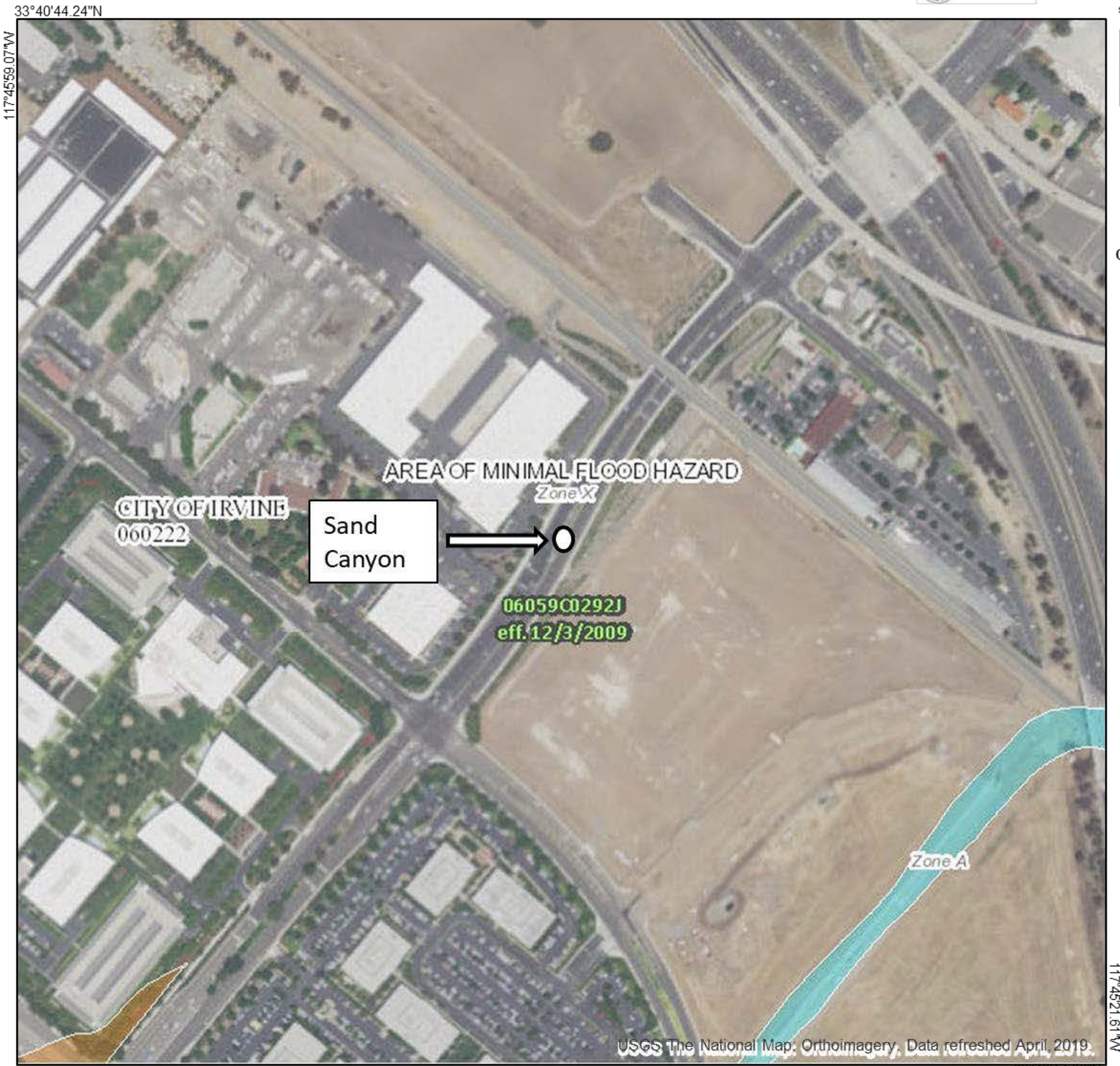
The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 3:30:35 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Sand Canyon**



Feet
0 250 500 1,000 1,500 2,000

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) Zone A, V, A99
- With BFE or Depth Zone AE, AO, AH, VE, AR
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes. Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map isan approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 5:02:53 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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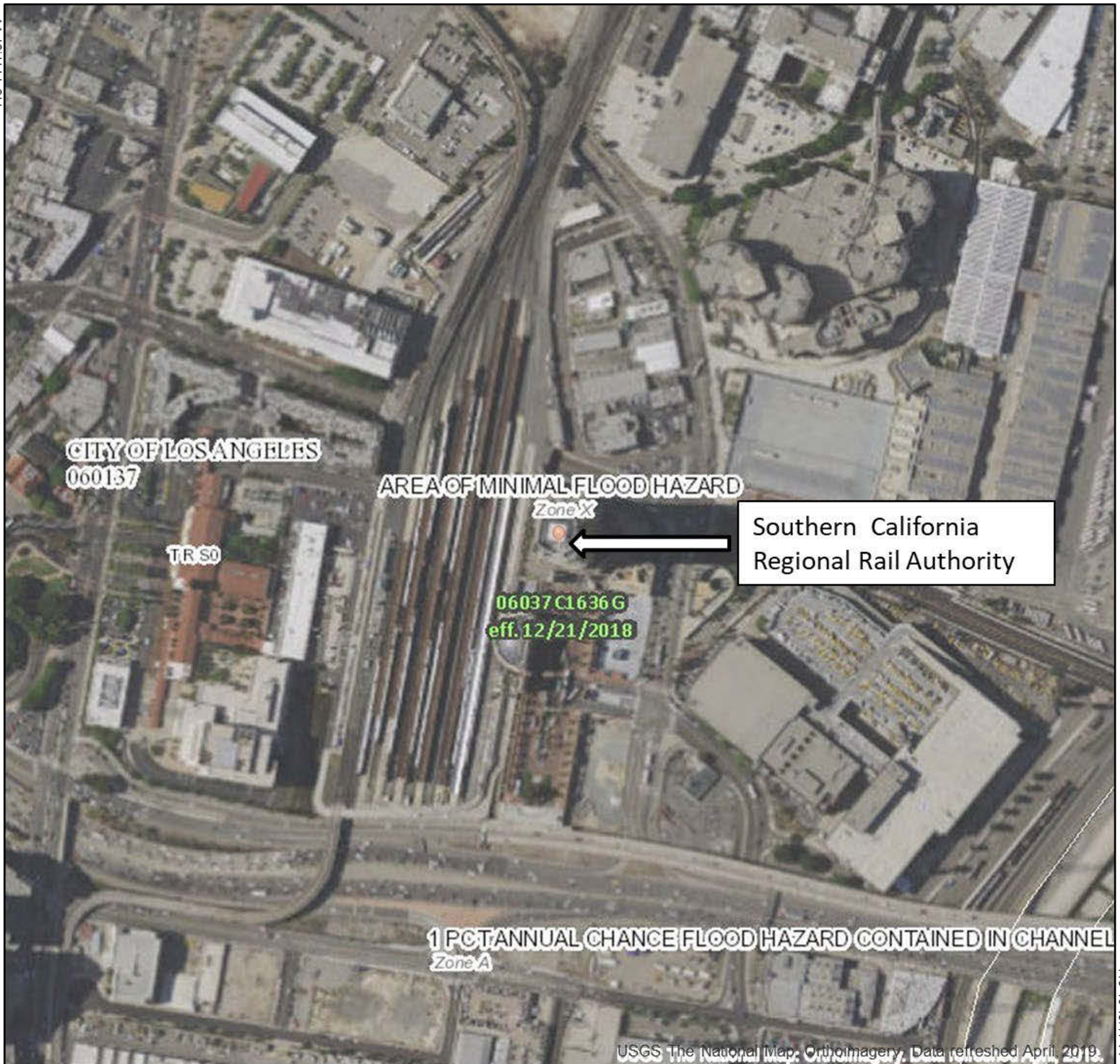
National Flood Hazard Layer **Southern California Regional Rail Authority**

34°3'37.94"N

118°14'17.87"W



118°13'40.41"W

34°3'8.14"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 3:50:47 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Keller Yard**

FEMA

34°3'32.90"N
118°14'0.96"W

118°13'23.50"W
34°3'3.09"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 3:59:04 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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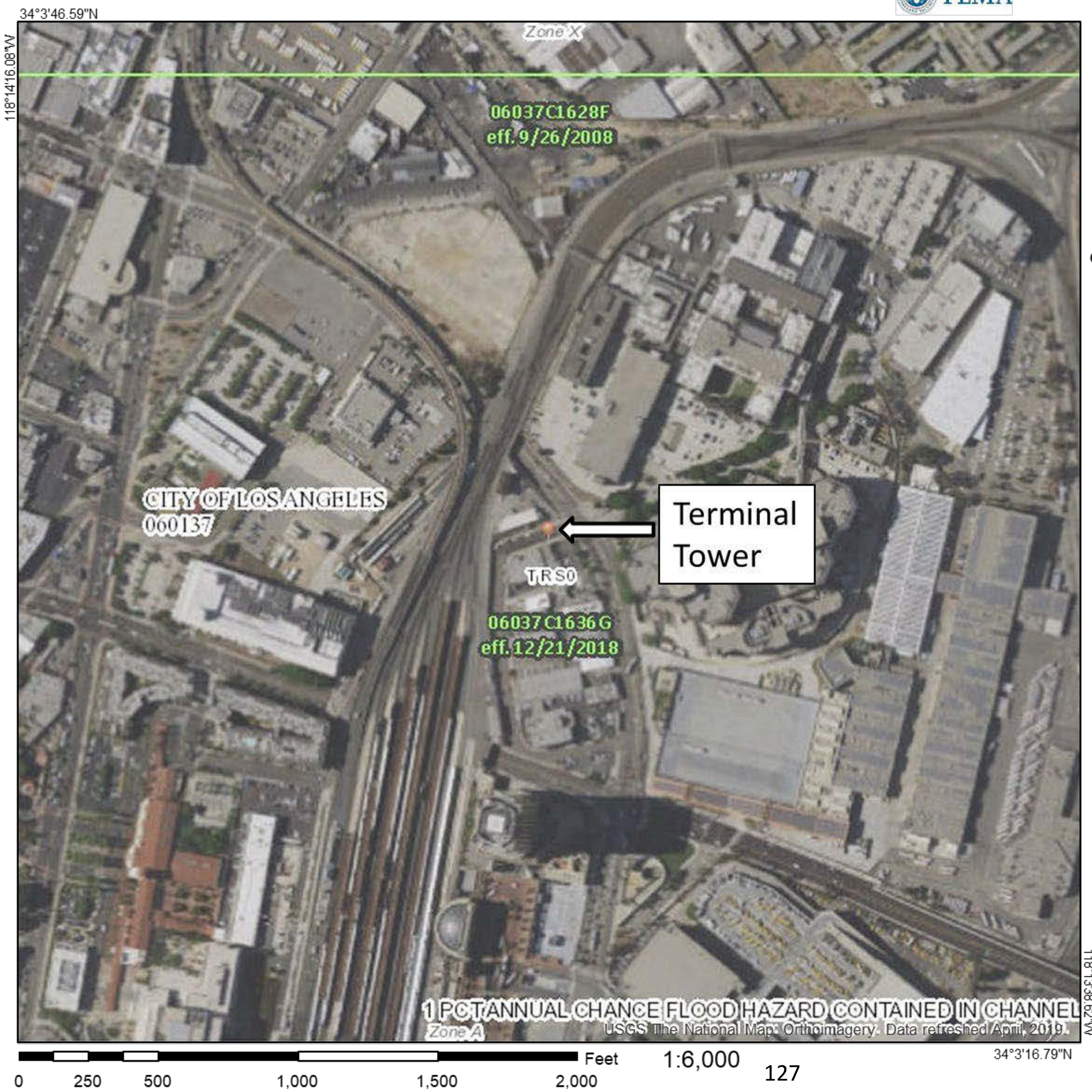
National Flood Hazard Layer **Terminal Tower**

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) Zone A, V, A99
- With BFE or Depth Zone AE, AO, AH, VE, AR
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes. Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:03:26 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

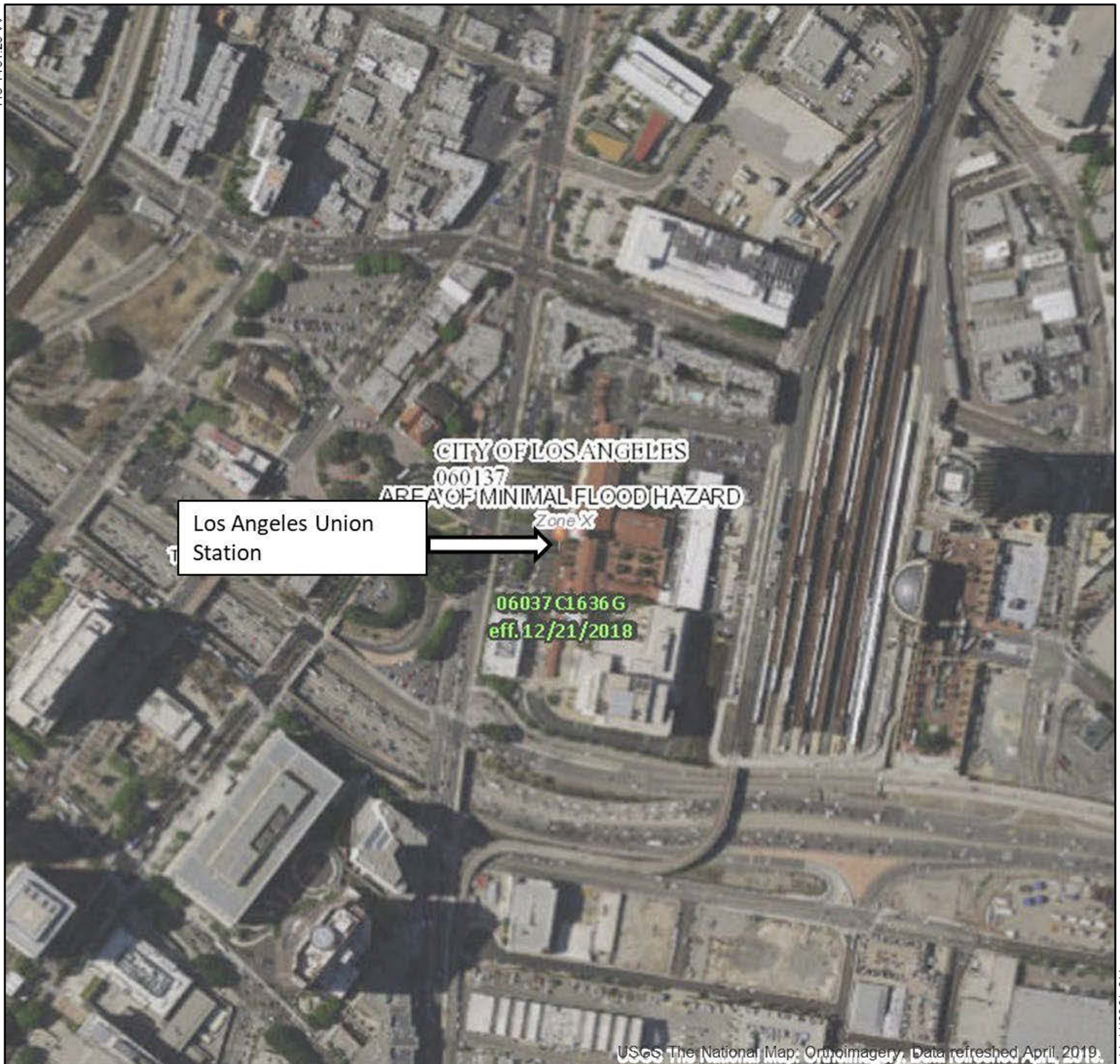
This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Los Angeles Union Station (LAUS)**

FEMA

34°3'36.51"N

118°14'31.23"W



118°13'53.77"W

34°3'6.70"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:08:44 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

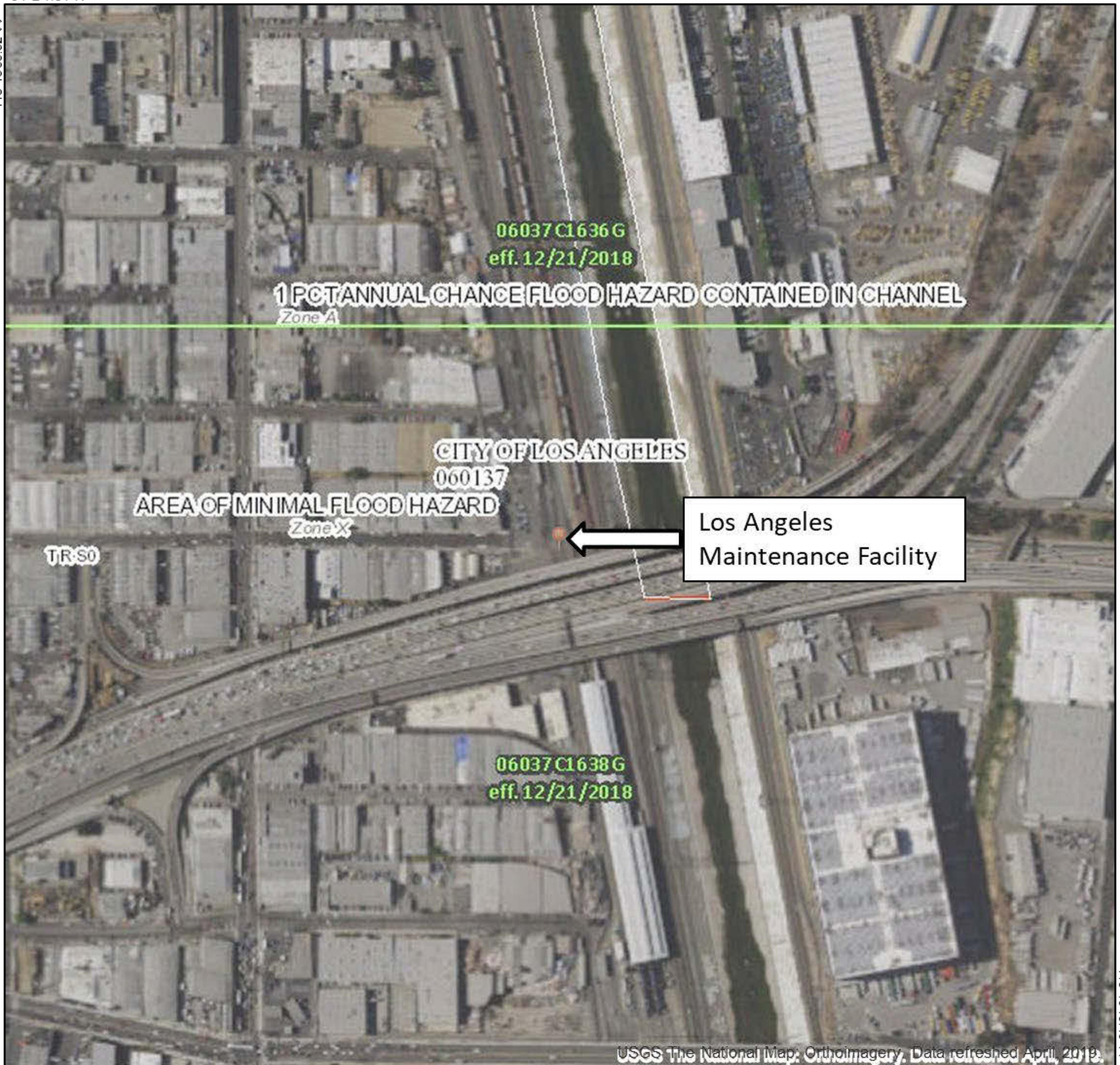
This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Los Angeles Maintenance Facility**

FEMA

34°2'1.51"N

118°13'55.92"W



118°13'18.46"W

34°1'31.69"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:11:45 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Metrolink Central Maintenance Facility (CMF)**

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) Zone A, V, A99
- With BFE or Depth Zone AE, AO, AH, VE, AR
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes. Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:15:52 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Metrolink Moorpark Crew Base**

FEMA

34°17'20.45"N

118°53'15.04"W

118°52'37.58"W

34°16'50.73"N

Feet 0 250 500 1,000 1,500 2,000

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:19:38 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

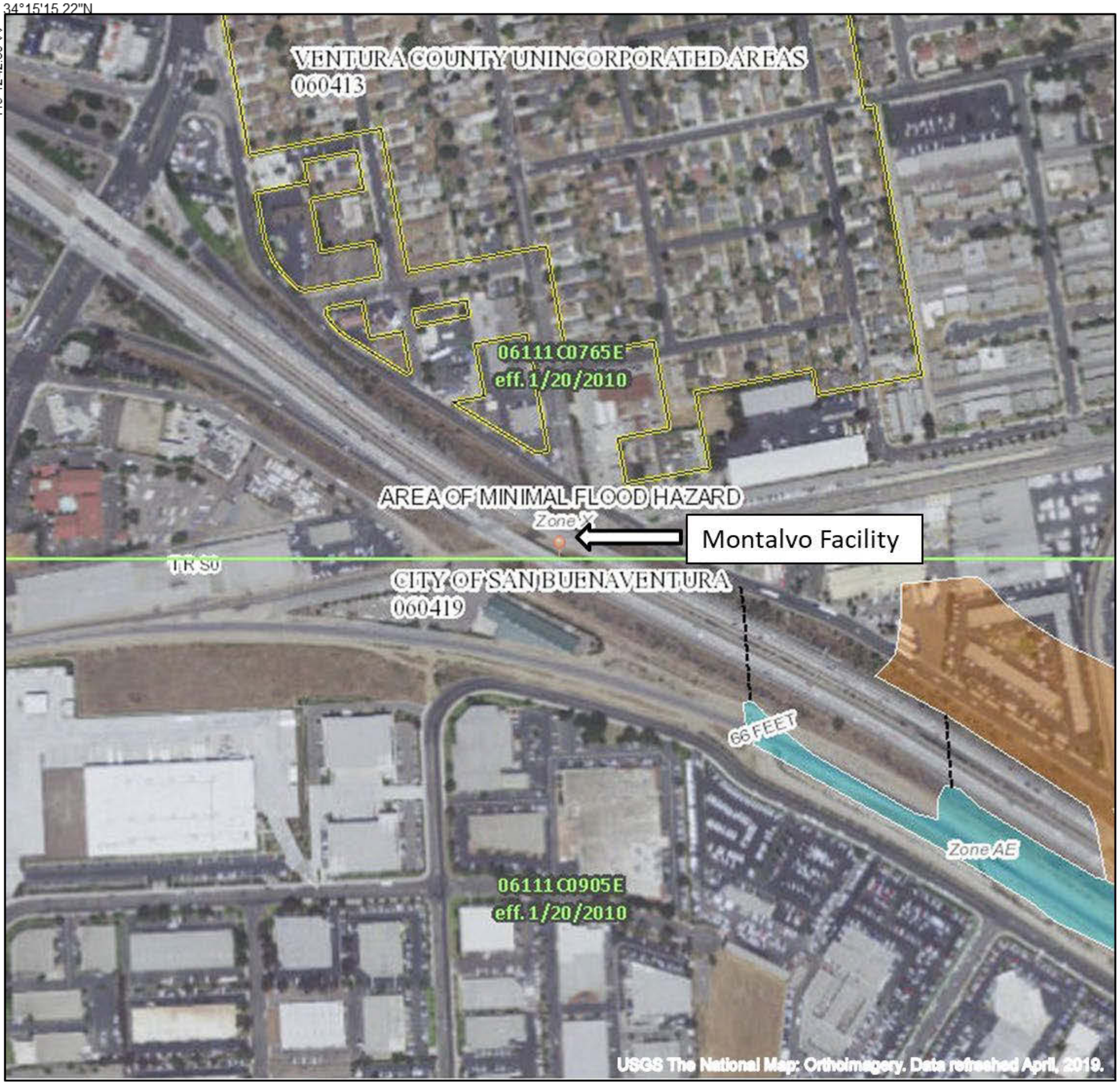
This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Montalvo**

FEMA

34°15'15.22"N

119°12'42.86"W



119°12'5

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) Zone A, V, A99
- With BFE or Depth Zone AE, AO, AH, VE, AR
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes. Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

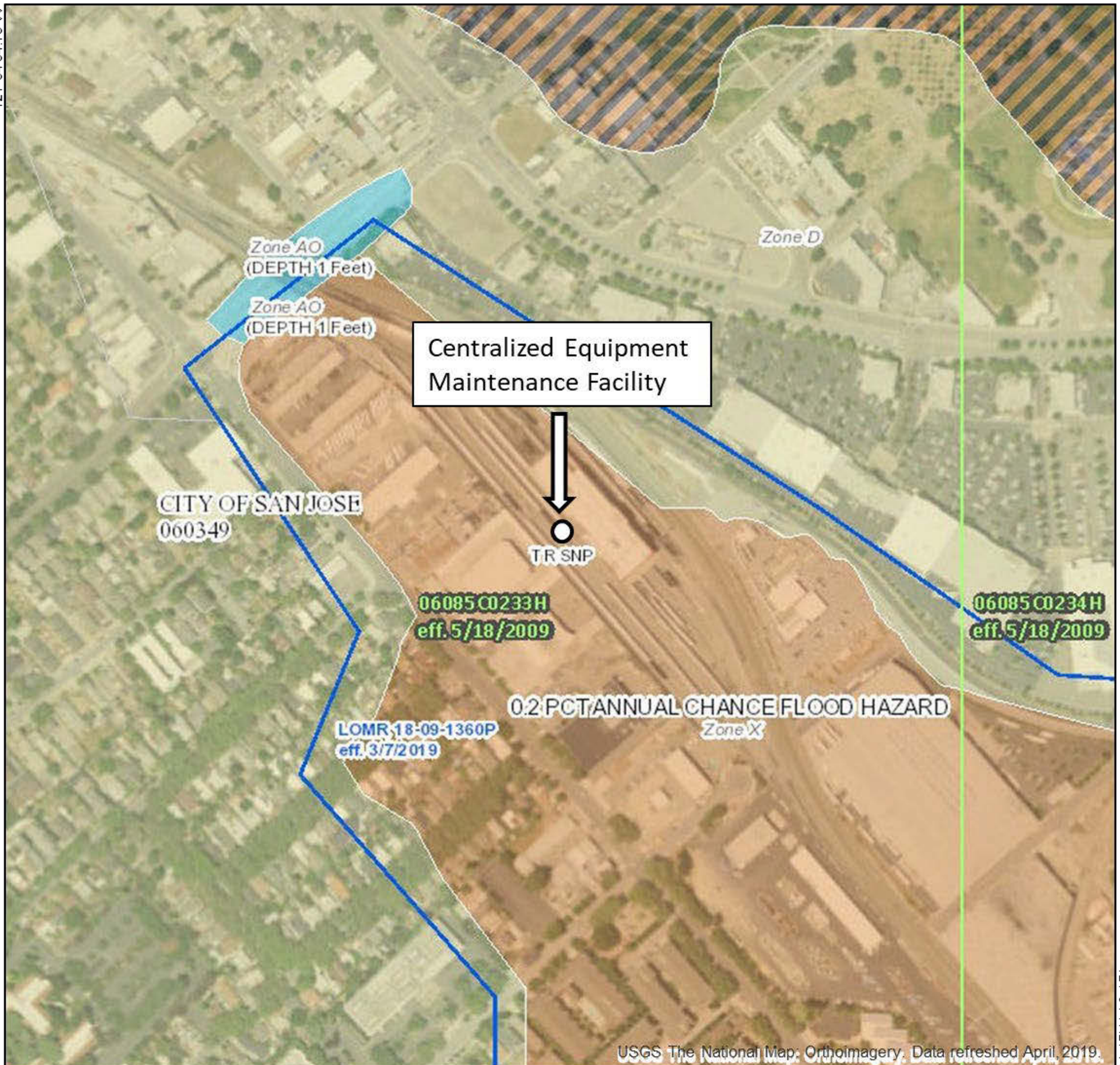
The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:22:48 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

National Flood Hazard Layer **Centralized Equipment Maintenance and Ops Facility**

FEMA

37°20'35.80"N

121°54'54.73"W



121°54'17.27"W

37°20'7.19"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:31:17 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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National Flood Hazard Layer **Hayward Shop**

FEMA

37°37'25.55"N

122°3'14.41"W

122°2'36.

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

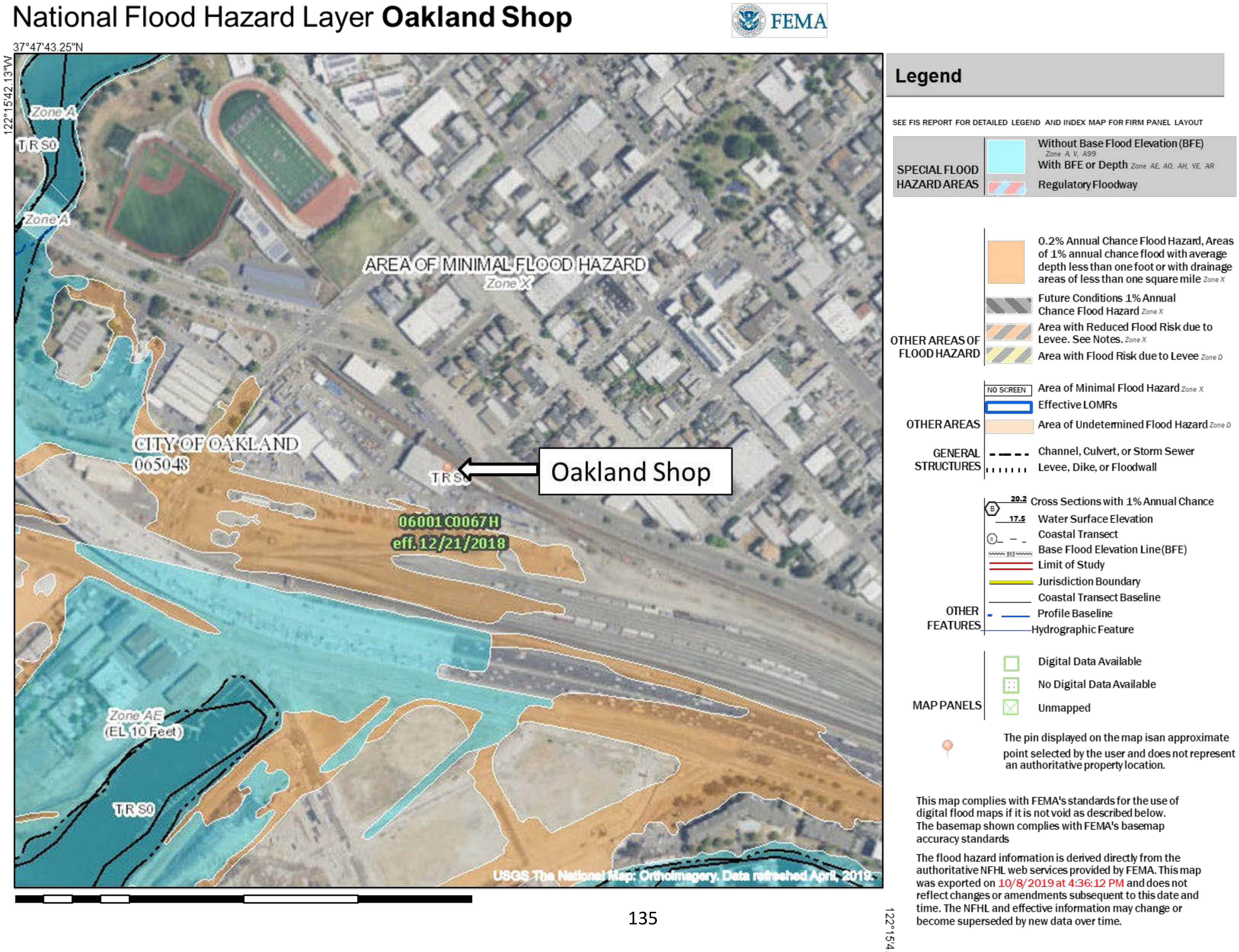
MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:34:00 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

National Flood Hazard Layer **Oakland Shop**



This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:36:12 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

National Flood Hazard Layer **Oakland Maintenace Facility**

FEMA

37°48'19.98"N

122°17'48.84"W

122°17'11.38"W

37°47'51.55"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map isan approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:43:10 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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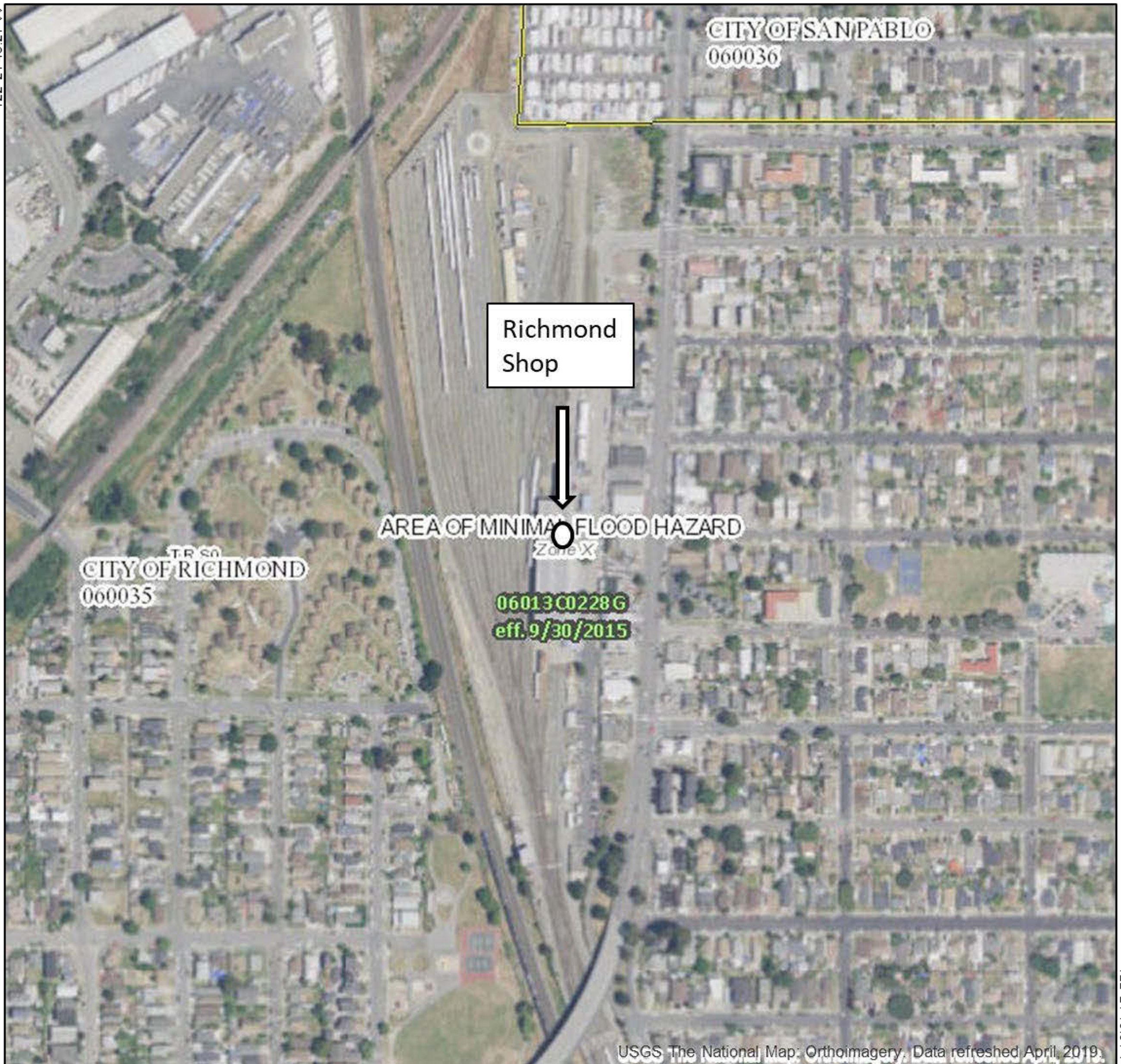
National Flood Hazard Layer **Richmond Shop**

FEMA

37°57'4.84"N

122°21'48.27"W



122°21'10.81"W

37°56'36.47"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map isan approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:48:59 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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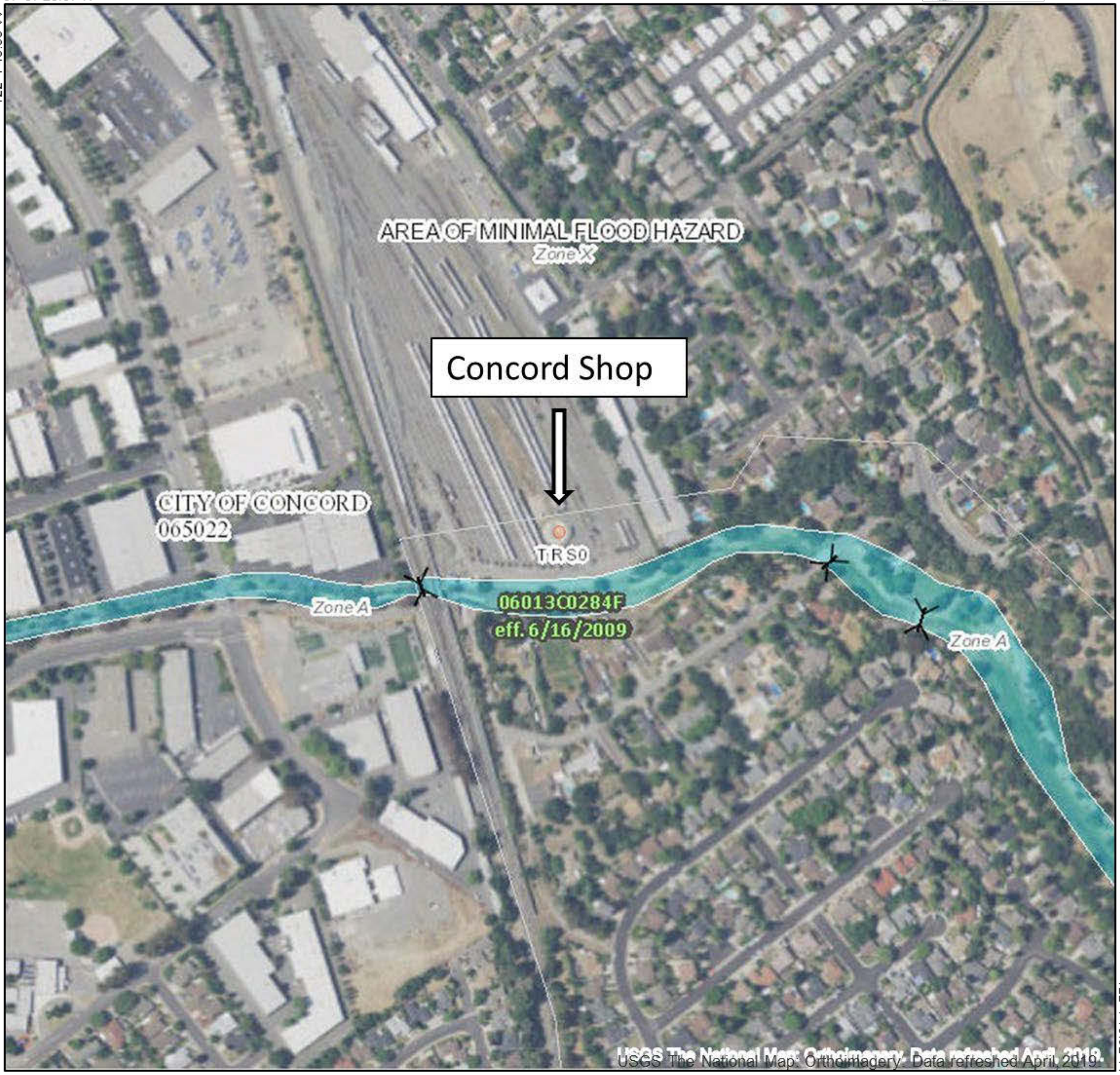
National Flood Hazard Layer **Concord Shop**

FEMA

37°57'25.37"N

122°1'48.38"W



122°1'10.92"W

37°56'57.00"N

Feet 1:6,000

0 250 500 1,000 1,500 2,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map isan approximate point selected by the user and does not represent an authoritative property location.

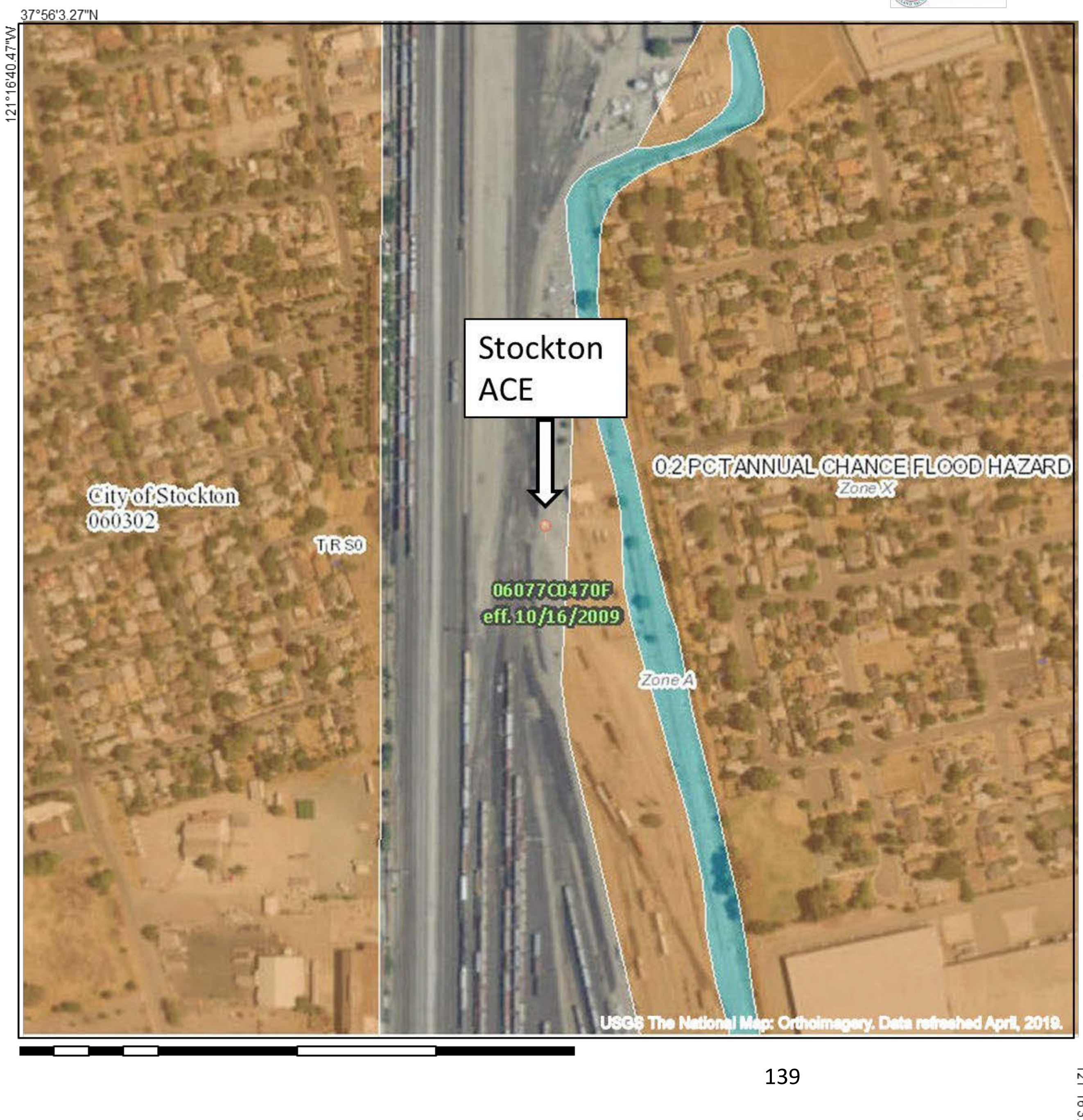
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:50:54 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer **Stockton ACE**

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/8/2019 at 4:56:35 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.