**Peninsula Corridor Joint Powers Board**
1250 San Carlos Avenue
San Carlos, California 94070-1306


# DESIGN CRITERIA

**FIFTH EDITION**

**January 1, 2026**

# CALTRAIN DESIGN CRITERIA
# FIFTH EDITION
# JANUARY 1, 2026

These Caltrain Design Criteria supersede Design Criteria dated January 1, 2024.

Check for any updates online as well as send any suggestions or changes through www.Caltrain.com.

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# CHAPTER 1

# DESIGN GUIDELINES

## A. PURPOSE

This document establishes minimum standards for planning, designing, constructing, and maintaining Caltrain (Peninsula Corridor Joint Powers Board, or PCJPB, or JPB) facilities. It is based on industry best practices for commuter/Class 1 railroads and meets or exceeds applicable regulatory requirements.

PCJPB and JPB are used interchangeably to refer to the agency. The name of the commuter service, Caltrain, is also often used in this Document to refer to the agency because the public is familiar with this name and associates it with the agency.

The Design Criteria (Criteria) are intended to cover the majority of Caltrain's current and future improvements, while not precluding a blended and shared corridor, including California High Speed Rail (CHSR) and Union Pacific freight service. The Criteria do not attempt to cover all situations that might arise throughout a project's life, nor is it practical or feasible to do so. Large capital projects and programs may develop their own criteria and standards on an as-needed basis.

Projects managed and delivered by other agencies, such as the Portal/Downtown Extension (DTX) project by the Transbay Joint Powers Authority and the CHSR project by the California High Speed Rail Authority, will have their own criteria and standards. The DTX project includes shared underground multi-modal stations, tunnels, etc. Part of the HSR is planned to share Caltrain corridor, which will involve shared use of certain stations and facilities.

## 1.0 CALTRAIN STANDARDS

The Caltrain Design Criteria, together with the following documents, form the Caltrain Engineering Standards, or Caltrain Standards:

a. Standard Drawings

b. Standard Specifications

c. Standards for Design and Maintenance of Structures ("Structures Manual")

d. Engineering Standards for Excavation Support Systems ("Shoring Manual")

e. Computer-Aided Design and Drafting Manual ("Drafting Standard")

f. Electrification Standards

All these documents are available online on the Caltrain website (caltrain.com).

References for regulatory bodies and industry standards are included in Appendix C.

In case of conflict between Caltrain standards and applicable codes or regulations (e.g., AREMA, FRA, CPUC GOs), the more stringent requirement shall take precedence. Caltrain will determine the prevailing standard in case of ambiguity.

## 1.1 UPDATES AND REVISIONS

As with any Standards, this is a live and controlled document. Users may forward any proposed changes or suggestions for consideration through the website. This Document will be updated on a continual basis to reflect regulatory changes and changes in Caltrain and industry practices. Periodically, Caltrain will issue revised documents to replace the existing documents.

It is the responsibility of the designers and other users to use the latest applicable updates and revisions.

## 1.2 DESIGN VARIANCES

In this Document and all other Caltrain Standard Documents, “standard” is defined as a course of action that is required, with no exception, and is referred to using the verb “shall”; “guidance” is defined as a course of action that is recommended, involving engineering judgment, and is referred to using the verb “should”; “option” is defined as a course of action that is permissible but not required, and is referred to using the verb “may”; and “support” refers to an informational statement. Any deviations from these Criteria must be approved via Caltrain’s Standard Procedure for Design Variances (G-24).

It shall be noted that variances or deviations are not for convenience. They shall be very rare, and only as a last resource and only after exhaustive analysis. Designers or other Project personnel shall not request a variance based on precedence. To request a variance, designers shall prepare written justifications documenting the reasons and justifications as outlined in the Caltrain Standard Procedure for Design Variances. If approved, the variance is only valid for the specific location of the project. This variance cannot be used for future variance requests. Design variances shall never be less than the regulatory standards and shall not introduce unacceptable safety and functionality of the railroad.

## 2.0 DESIGNER ROLES AND RESPONSIBILITIES

The Criteria contained in this Document are intended to ensure that the functionality, goals, and objectives of Caltrain are met. The Criteria shall be used in conjunction with sound engineering judgment, experience, and standard industry practices. This Document in no way replaces the individual designer’s adherence to the profession’s “standard of care” in design.

Designers are ultimately responsible for every aspect of the design, and its overall integrity to professional standards of care. Caltrain reviews are for quality assurance but do not relieve the designer of accountability and are intended to provide some level of independent verification. Reference the Caltrain Quality Management Plan (Manual Number M-4) for additional detail.

## B. PENINSULA CORRIDOR JOINT POWERS BOARD

Caltrain is a commuter rail service operating on a 77-mile corridor between the cities of San Francisco and Gilroy. Caltrain is owned and governed by the PCJPB.

The PCJPB is a state-authorized joint powers authority comprising the three counties where Caltrain operates: San Francisco, San Mateo, and Santa Clara. PCJPB owns approximately 52 route miles of rail corridor between San Francisco and San Jose, and approximately 25 additional miles of trackage rights from San Jose to Gilroy (see Figure 1-1, Caltrain System Map).

Caltrain Operations and Maintenance services are performed through the use of a Contract Operator who operates the trains and performs the state of good repair (SOGR) maintenance of the infrastructure (track, signal, OCS/traction power, stations, structures, and other facilities, as well as right-of-way [ROW] maintenance).

The Contract Operator also provides support of construction activities (capital, maintenance, and third-party work) on an as-needed basis, in the form of Roadway Worker Protection, as well as providing signal and traction electrification system maintainers, track inspectors, and communications system technicians. The contract operator also performs the return to service inspections following the completion of Capital and third party projects prior to returning the railroad track, structures, signal system, communication system, and overhead contact system to service, insuring the system is safe and functional.

## 1.0 CALTRAIN MISSION

Caltrain is a customer-focused rail system offering safe, reliable, accessible, and sustainable transportation service that enhances quality of life for all. Caltrain strives to be a vital link in the statewide rail network by improving connectivity to other transit systems, contributing to the region's economic vitality, and partnering with local communities to ensure that diverse constituencies receive a world-class travel experience.

The principal objectives of the Caltrain commuter system are:

a. Providing a safe, reliable, and cost-effective service

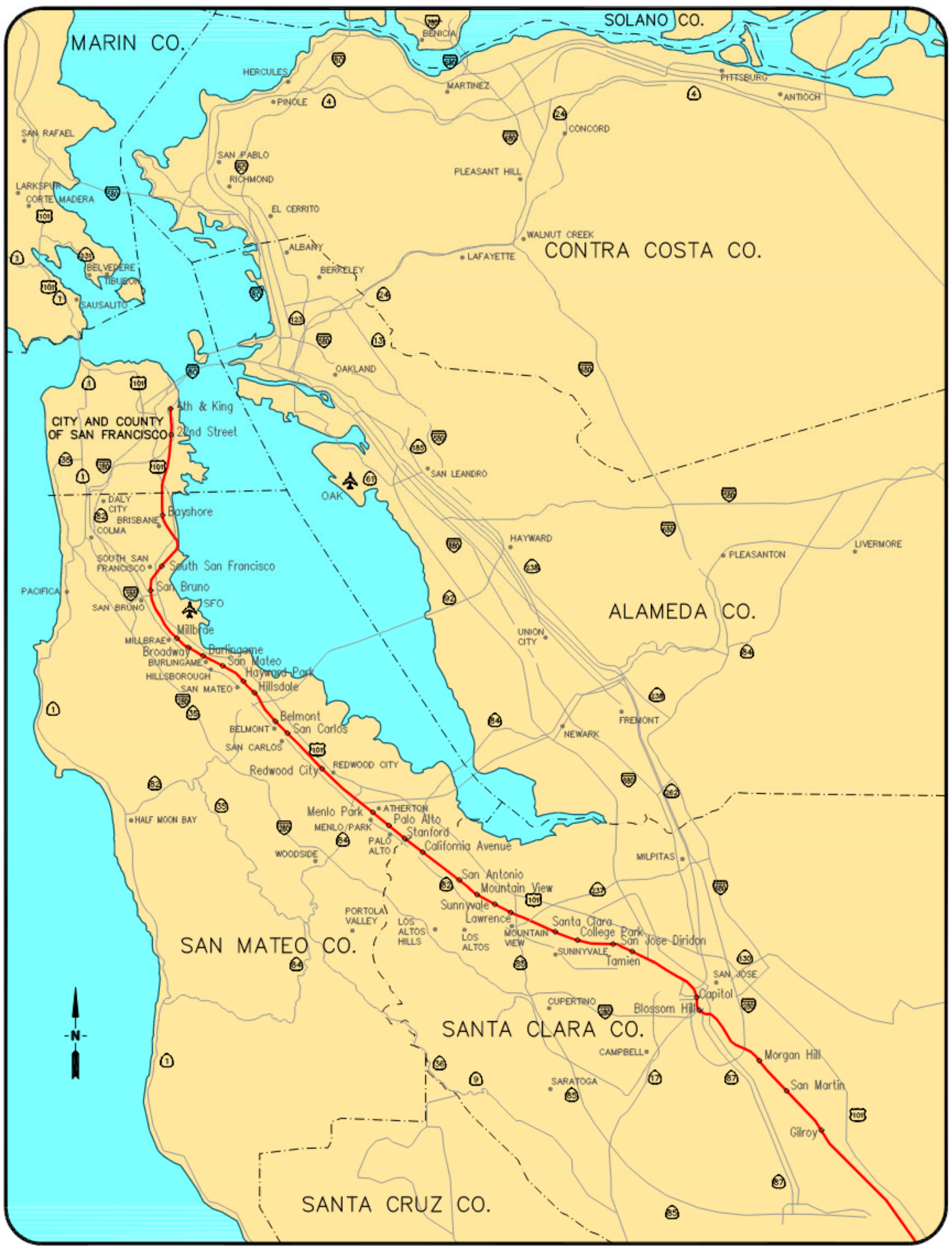
b. Contribution and support of regional air quality goals

c. Working in partnership, in accordance with regional plans and policies, with communities and other stakeholders, to achieve a balanced transportation system and potential economic enhancement

d. Seamless integration with other transit modes

e. Providing an infrastructure that will sustain future regional growth

**SAN FRANCISCO BAY AREA**




**Caltrain corridor**

**Figure 1-1: Caltrain System Map**

## 2.0 CALTRAIN CORRIDOR ASSETS

Current Caltrain corridor assets can be found in *Caltrain Track Charts*.

## 3.0 UNION PACIFIC RAILROAD

The Union Pacific Railroad (UPRR or UP) has the trackage right to operate local freight service on the Caltrain corridor. The trackage right requires that at least one main track is always available for freight service between midnight and 5 a.m., and that PCJPB provides at least one 30-minute headway window in each direction between 10 a.m. and 3 p.m. The UPRR owns, maintains, and controls Track No. 1 from CP Coast (Santa Clara) to CP Lick (San Jose), and all tracks from CP Lick to Gilroy. PCJPB has trackage rights from CP Lick to Gilroy.

In practice today, freight commonly runs between 7 a.m. and 3 a.m. Caltrain's 2025 dispatch data for freight operations indicate that there are four round trips per day, on average, along the Caltrain corridor. Typical freight train movements are as follows:

- South San Francisco freight yard to Redwood City freight yard – one round trip daily during daytime ("South City" Local)
- South Terminal Area (South of CP Coast) – one round trip daily during daytime ("Salinas")
- South Terminal Area (South of CP Coast) to Redwood City freight yard and South San Francisco freight yard – one round trip daily during nighttime ("Mission Bay")
- South Terminal Area (South of CP Coast) to Redwood City freight yard – one round trip daily during nighttime ("Rock Job")

The UPRR and the PCJPB also have joint facility arrangements in a number of locations.

## 4.0 PROJECT DELIVERY METHODS

Caltrain generally develops and manages its own capital and maintenance projects entirely from conception to completion, through all typical major project delivery phases such as planning, design, and construction.

Caltrain typically uses design-bid-build and awards on the basis of a competitive bid, consistent with public works contracts. Caltrain may also consider, on a case-by-case basis, alternative delivery methods such as design-build or construction manager/general contractor (CM/GC) if the projects are relatively large (in dollar amount and duration) and complex, such as grade separation projects. Advance procurement contracts may be considered to procure equipment and materials requiring long-lead items, such as ballast, track turnouts, and large signal houses.

## C. PLANNING AND DESIGN CONSIDERATIONS

To successfully implement a project, especially during the conceptual and preliminary design stages, the designers must have a good understanding of the current and future needs of the system, and the design parameters that may impact the design. The purpose of this section is to outline the considerations that require analysis and review in the planning process, such as Operational Analysis establishing service assumptions, projections, and operating criteria to be used in determining the magnitude of the proposed infrastructure improvements.

Caltrain capital projects fall into the following categories: ensuring a safe and secure railroad; maintaining core services (including State of Good Repair, or SOGR); enhancing service and customer experience; delivering the long-range service vision; and fulfilling mandates, compliance requirements, and emergency needs. Safety and security improvements are typically developed based on condition assessments. SOGR projects support the existing system and operations, taking into consideration current conditions and the remaining useful life of the asset. Projects that enhance service and customer experience aim to improve system performance, elevate customer experience, and enable operational efficiencies. Projects that deliver the long-range service vision allow for implementing increased service - up to eight trains per hour per direction during peak periods. Mandate, compliance, and emergency projects are developed based on mandates by regulatory agencies or state and/or federal law. Planning stage shall consider operations and service, community considerations, environmental considerations, and standardization of equipment and materials.

Mission-critical components are defined as those that have a direct impact on the system safety, security, and operations. For the mission-critical components, the designer shall provide in-depth technical analysis and develop alternatives for Caltrain review. Operationally, the performance of each alternative should be measured in throughput, reliability, capacity, and functionality.

Each design level needs to be thoroughly reviewed prior to the beginning of the next design level. Each level shall be accompanied by updated versions of applicable documents (such as schedule, cost estimate, specifications, constructability analysis, and Caltrain's Safety and Security Certification.)

During the planning phase, considerations include both operations planning and environmental planning. This involves identifying stakeholders, such as government regulatory agencies, the local agencies (cities, counties), communities (residents and businesses), PCJPB partners, and Caltrain riders. Designers shall closely collaborate with Caltrain to solicit and evaluate inputs from the stakeholders, and set and manage expectations.

## 1.0 OPERATIONAL PLANNING

Early in the planning phase, inputs from Caltrain Rail Operations are essential. Examples of such inputs include:

a. Capacity and throughput improvements

b. Infrastructure changes to enhance train performance

c. Increases of track speeds to accommodate future operations

d. Increases of train service levels

e. Reductions in trip/travel time

f. Safe and timely interchange of passengers and information among various local and regional modes of transportation

## 2.0 ENVIRONMENTAL PLANNING

For projects that require environmental clearance and are subject to permitting requirements, the environmental process shall be initiated during the project planning phase.

The following key environmental permits and clearances are typically required for Caltrain projects:

- California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) environmental clearances and associated mitigation measures and Best Management Practices. Federal and state environmental review processes require CEQA documentation. If the project is receiving federal funding NEPA clearance is also required.

- Migratory Bird Treaty Act (MBTA), (16 USC § 703–711, 50 CFR 10) and California Fish & Game Code §§ 3503, 3513, and 3800 protect migratory and nongame birds, their nests and eggs. Protects nesting birds. Work within bird nesting season (Feb–Aug) may require pre-construction surveys and exclusion measures.

- National Pollution Discharge Elimination System (NPDES)

- Archaeological Resources Protection Act (ARPA)

- Code of Federal Regulations (CFR): Title 36, Part 800 – Protection of Historic Properties

- Tree Removal Permits (as required by each City)

In addition, the following permits are required on Caltrain projects with construction activities occurring within creeks, streams, or rivers:

- Clean Water Act (CWA) Section 401, Water Quality Certification issued by the Regional Water Quality Control Board (RWQCB).

- Clean Water Act (CWA) Section 404, Nationwide Permit 14, as verified by the US Army Corps of Engineers (USACE).

- California Fish and Game Code Section 1600 Lake and Streambed Alteration Agreement issued by the California Department of Fish and Wildlife (CDFW).
- Endangered Species Act (ESA) Section 7 Biological Opinion

Each project will be assigned an Environmental Project Manager who is responsible for managing applicable regulations, clearances, permit conditions, and mitigation measures for the project. Designers shall coordinate closely with the Environmental Project Manager.

Project sites with historical resources such as legacy station buildings (depots) and historical districts listed on the National Register of Historic Places are under the purview of the State Historic Preservation Officer (SHPO). The South Bay Historical Railroad Society has an agreement with the SHPO as the custodian of all historical depot buildings owned by Caltrain. Additionally, local historical resources designated by the cities and local governments shall be also given proper consideration.

The environmental studies are normally conducted with engineering design and analysis progressing in concert to support the studies. The studies involve identifying and verifying any potential impacts and, if any such impacts are identified, developing the corresponding proposed mitigations. Examples of these activities include impacts to adjacent properties, historic preservation need, visual interest, noise mitigation, aesthetic improvements, and traffic analysis.

The planning process also includes identifying any possible ROW acquisitions, as either permanent acquisitions or temporary construction easements.

## 3.0 DESIGN LIFE

The design lives of both permanent and temporary facilities are described below. Although this determination is typical for the railroad environment, the designers shall use it as guidance, subject to site-specific conditions and circumstances, as well as time.

## 3.1 PERMANENT SYSTEM-WIDE FACILITIES

Permanent facilities shall generally be designed for a minimum life as follows:

a. Track System: 50 years

This system, commonly referred to as track structure for both track and special trackwork, includes the following components:

i. Rail

ii. Fastening System

iii. Ties

iv. Ballast

v. Subballast

vi. Subgrade

vii. Slab or Direct Fixation

b. Signaling System: 25 years, except when noted otherwise

The signaling system is a mission-critical component of a typical commuter rail operation. The system, in concert with the track system and train control communication system, governs the operations of a railroad. It includes the following major system components:

i. Signal houses

ii. Signal equipment/computers: 10 years

iii. Signal software system: updated as provided by the manufacturer

c. Train Control Communication System: 10 years, except when noted otherwise

This system, working in concert with the signaling system, is part of communication and dispatch control for train operations. Portions of the system are technology-driven and subject to ongoing enhancement in technology typically subject to a 3-year minor technology refresh and a 6-year major technology refresh. It includes:

i. Communication tower

ii. Data or radio system, including fiber optic infrastructure

iii. Computer Aided Dispatch (CAD) System, commonly referred to as the Rail Operations Control System (ROCS)

d. Stations and Facilities: 50 years, except when noted otherwise

The facilities are typically station-related and generally contained within the limits of the stations. They include:

i. Station platforms

ii. Station amenities (shelters, benches, bike racks, and bike lockers): 15 years

iii. Electrical system: 30 years

iv. Station buildings

v. Parking structures

vi. Surface parking: 20 years

e. Station Communications: 10 years. Portions of the system are technology-driven and subject to ongoing enhancement in technology typically subject to a 3-year minor technology refresh and a 6-year major technology refresh. They include:

i. Passenger Information System (PIS), commonly referred to as Predictive Arrival Departure System (PADS)

ii. Variable Message Sign (VMS)

iii. Digital information displays including Platform End Displays (PED) and Train Schedule Displays (TSD).

iv. Public Address (PA) system

v. Ticket Vending Machine (TVM)

vi. Closed-Circuit television (CCTV) cameras

f. Major Civil Structures: 100 years

Major civil structures are an important part of the railroad infrastructure, which include:

i. Bridges

ii. Grade-separation structures (vehicular)

iii. Grade-separation structures (pedestrian underpasses and overhead)

iv. Retaining walls

g. Positive Train Control (PTC): 5 years, except when noted otherwise

h. Traction Power and Overhead Contact System components – refer to Caltrain Electrification Standards

i. Others:

Other civil engineering components include:

i. Grade Crossings (non-signal): 25 years

ii. Drainage System:

1. Stormwater lift station: 50 years

2. Culverts (large, crossing tracks): 50 years

3. Track-side ditches: 10 years

iii. Landscaping and irrigation system: 15 years

### 3.2 TEMPORARY SYSTEM-WIDE FACILITIES

These facilities accommodate construction of permanent systems and shall be designed for a period up to 5 years. They are typically required to facilitate construction, or for interim improvement prior to construction of permanent facilities. Examples of these facilities include:

a. Shoofly (temporary tracks)

b. Temporary station and related facilities during construction

c. Temporary signal and communications facilities

### 4.0 SYSTEM RESILIENCY AND SUSTAINABILITY

Design of the Caltrain system shall consider the system resiliency and sustainability. Project specific measures, consistent with Caltrain's policies and objectives, shall be developed during each project's initial phase. The latest version of the California State Hazard Mitigation Plan published by the Governor's Office of Emergency Services offers an exhaustive compilation of relevant natural hazards and corresponding mitigation strategies, which may serve as a foundation for developing these measures. Guidance on resiliency and sustainability issued by the local jurisdiction in which the project is situated shall be reviewed for adoption in the formulation of project specific measures.

### 5.0 STANDARDIZATION OF EQUIPMENT AND MATERIALS

Design must include the use of standardized equipment and materials wherever possible. Standardization ensures ease of procurement and inventory management; minimizes staff training; optimizes maintenance; and avoids long lead times for materials, equipment, and components.

Major equipment and materials shall meet industry standards, be available off the shelf, and be supplied by established manufacturers that have a well-documented product quality and a history of furnishing to Commuter or Class 1 railroads that have service experience and operating conditions similar to those of the Caltrain system. When selecting equipment and materials, consideration shall be given to long-term costs, ease of construction and maintenance, and readily available technical support.

## D. GENERAL DESIGN CONSIDERATIONS

In the early phase of the design, designers shall prepare a Design Basis Memorandum (DBM), summarizing the project description, limits, scope, technical criteria, any design variances, key specifications, and etc. The DBM shall be reviewed and approved by the Caltrain Director of Engineering and shall include all assumptions, records of design variance requests, and a thorough analysis of justifications. The DBM shall then be used as a basis for the detailed design and design review.

Prior to each design submittal to Caltrain, designers shall verify that all design documents are complete, accurate, and conform to Caltrain design criteria and standards, and consistent with the best and accepted industry standards and practices. Designers are responsible for and shall perform a thorough quality control review in accordance with the established procedures on all project deliverables before their release.

As part of the early project delivery, the designers shall develop a set of project-specific design checklists to demonstrate that the design meets the project's needs and objectives, and to facilitate the quality control and quality assurance process. The following sections provide examples of design considerations that the checklists should incorporate for various design disciplines. Such checklists shall also include regulatory requirements such as Americans with Disabilities Act (ADA) compliance, stormwater management, and sustainability design.

## 1.0 CONSTRUCTION IMPACTS

For any project that may intrude on rail operations, a proper construction phasing or staging plan shall be developed during design to maintain continuous operation of the railroad. Temporary track closures and associated isolations of the overhead contact system for limited work windows may be allowed with approval from Caltrain Rail Operations. For each construction phase, the plan shall identify all impacts to rail operations, and the associated mitigation measures required. For each construction activity requiring temporary track closure, the plan shall clearly identify the tracks to be impacted, and the length of the work window required. The construction phasing or staging plan must be designed in close collaboration with Caltrain Rail Operations. Approval from Caltrain Rail Operation is required before the plan is finalized. During construction, the Contractor shall submit Site Specific Work Plans (SSWPs) incorporating the phasing accepted during the design phase.

The following information should be used for planning construction phasing and staging:

a. Double-track closure is not permitted during regular scheduled services. Double-track closure may be permitted only on weekends if absolutely necessary, with advanced approval from Caltrain Rail Operations.

b. Single-track closure may be allowed during weekends and short off-peak hours during weekdays when appropriate.

c. Temporary tracks shall be designed to meet existing operating speeds of the particular track segment

d. Caltrain operates additional services for special events that are not in the passenger timetable.

e. Station closure shall not be contemplated.

## 2.0 OPERATING SAFETY CLEARANCES

Adequate clearance is required to ensure the safety of the rail operations. The design of railroad infrastructure shall comply with Caltrain standards and take into account the following considerations:

a. Locomotives and rail cars (dimensions, weight, clearance envelope, capacity, etc.)

b. Horizontal and vertical clearances for permanent and temporary features and structures

c. Horizontal and vertical clearances for construction and maintenance equipment

d. CPUC requirements

e. Clearance from OCS and traction power wires and equipment

f. Sight lines of train engineers

## 3.0 TRACK SYSTEM

Track design drawings shall be checked against the full track structure "footprints," including special trackwork elements, to ensure that switch machines, headblocks, insulated joints (temporary and permanent), walkways, drainage channels or side ditches, and signal foundations and all related appurtenances can be constructed without interference. Before commencement of design work, key members of the design team shall conduct a thorough walkthrough within project limits to identify any site specific conditions that may potentially impact the project design. Embankment and drainage design shall include footprints for OCS poles, signals, signal enclosures, signal and communications vaults, manholes, pull boxes, and conduit runs. Other important aspects of the design include:

a. Constructability

b. CPUC requirements

c. FRA Regulations

d. AREMA Standards

e. Safety of freight operations

f. Drainage and grading of trackway

g. Horizontal track alignment and vertical track profile requirements

h. Locations of special trackwork, including signal components

i. Locations of related track and signal components

j. Sections typical to trackway

k. Spacing and clearances of track

l. Design speed and maximum authorized speed

## 4.0 STATIONS AND FACILITIES

Safety is paramount. Stations shall be designed to provide safety, sustainability, and accessibility to all users, including bicyclists and mobility-impaired persons. When constructed, the stations shall be safe, convenient, functional, and attractive. The station design shall include platforms, access to platforms, platform crossings (if applicable), station furniture and amenities, and parking. The stations shall be functional for passengers, integrating other existing modes of local and regional transportation systems. To the extent possible, the stations shall be as attractive as possible, and incorporate local elements.

## 5.0 STATION COMMUNICATIONS SYSTEM

The station communications system includes three components: passenger information system (VMS, PA, and other digital signs), fare collection (TVM and Clipper or regional transit payment system), and safety and security systems (CCTV).

The passenger information system is controlled from both the Menlo Park and San Jose Central Control Facilities. The CCTV and fare collection systems are controlled at Caltrain headquarters, except for Clipper, which is managed by the San Francisco Bay Area Metropolitan Transportation Commission.

## 6.0 SIGNALS

This is a mission-critical component of the Caltrain commuter system. Design of the signaling system shall incorporate the following checklist:

a. Aspect strings

b. Cable, conduits, and pull boxes, including schedules

c. Electrical and communication services requirements

d. FRA/CPUC/AREMA requirements

e. Frequency compatibility

f. Grade-crossing warning system controls

g. Grade-crossing warning system devices (including pedestrian)

h. Grade-crossing warning system times

i. Locking times

j. Power switch machines, hand-throw switches, electric locks, and derails

k. Signaling equipment clearances, including signal houses and grade-crossing warning system devices

l. Signal headways

m. Signal houses, signals, impedance bond, and insulation joint locations

n. Signal sight distance requirements

o. Signal stopping distance requirements

p. Signal types and sizes

q. Station stop locations (present and future)

r. Track Circuits

s. Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)

t. Grounding and Bonding requirements

## 7.0 TRAIN CONTROL SYSTEM

Like the signaling system, this is a mission-critical component of the Caltrain commuter system, providing, among other functions, interaction between the train dispatchers and field personnel. The train control system is integrated with the train signals system. Train control communication consists of the following components:

a. Computer Aided Dispatch (CAD) System and Traction Power Supervisory Control and Data Acquisition (SCADA) system, typically referred to as the Rail Operations Control System (ROCS)

b. Base stations and antenna towers

c. Data radio system

d. Voice radio system

e. 220 megahertz PTC radio system

f. Fiber optic communications network

## 8.0 AT-GRADE CROSSINGS

Designer shall look into the elimination and closure of railroad crossings by performing a study of each particular crossing within the proposed project limits and if justifiable the closure of the road crossing shall be incorporated into the design.

Design of grade crossings shall result in a safe, convenient, and functional passage for trains and all users, including motorists and non-motorists (pedestrians, mobility-impaired persons, or bicyclists). Vehicular crossings adjacent to roadway intersections shall be thoroughly analyzed, using a “Diagnostic Team” approach involving the local agency (cities, counties) as well as the CPUC and FRA. Additionally, a risk analysis shall be performed on vehicular crossings with high pedestrian traffic.

The design shall meet the requirements of ADA accessibility, FRA, Federal Highway Administration, the CPUC, Caltrain Engineering Standard Drawings and Specifications, CA MUTCD, and local agencies, where applicable.

## 9.0 GENERAL CIVIL DESIGN

Civil design includes drainage, utilities, structures and bridges, walkways, and fencing and railing. Landscape and irrigation improve the aesthetic aspects of the stations.

## 9.1 GENERAL CIVIL WORK

General civil work includes grading and drainage, fencing, railing, walkways, landscape, and irrigation.

Drainage is a critical component to effectively maintain Caltrain infrastructure in the corridor. During design and construction, considerations shall include impacts to properties adjacent to Caltrain; and impacts to operations and maintenance, including site access. The drainage shall improve the existing conditions and proposed improvements.

Fencing, railing, and walkways are critical safety components used to promote crossing at designated locations, as well as to discourage general access to the Caltrain ROW.

## 9.2 STRUCTURES AND BRIDGES

Design of structures and bridges shall conform to Caltrain’s standards, as contained in the PCJPB Structures Manual and the PCJPB Shoring Manual.

## 9.3 UTILITIES

Close coordination with all utility owners is required. Designers shall obtain and become familiar with all utility easements within the project limits that may be affected. It is essential to perform comprehensive utility surveys, including records research, potholing, and other field investigations, to identify and verify existing utilities. Utility owners shall be consulted and involved in evaluating the adequacy of protection measures, and the design of any utility replacements or relocations. During the design phase, consideration shall be given to the potential impacts on the utility owners and users from construction activities. Unless otherwise approved, all utilities shall be placed underground.

## 10.0 MECHANICAL, ELECTRICAL, AND PLUMBING

Mechanical, electrical, and plumbing components include:

a. Electrical service

b. Emergency back-up systems

c. Fire protection

d. Lighting

e. Mechanical systems

f. Plumbing

## 11.0 TRACTION ELECTRIFICATION SYSTEM

Caltrain completed electrification of the railroad between San Francisco Station and Tamien Station in San Jose in 2024. The 2 × 25 kilovolt (kV) alternating current traction electrification system (TES) is the combination of the traction power system, the overhead catenary system (OCS), and the traction power return system, together with appropriate interfaces to the TES-related Supervisory Control and Data Acquisition system.

The OCS supplies power to the electrically powered rail vehicles at 25 kV, which uses a catenary configuration consisting of an energized, current-carrying messenger wire to support a contact wire by means of in-span wire hangers. Because the electrified railroad is in non-dedicated ROWs with public highway-rail at-grade crossings and in which freight operations may occur, the electrification design satisfies single point of failure requirements and includes a shunt cable at utility crossings.

The traction power return system consists of the running rails, impedance bonds, return cables, and static or ground wires. The principal return path is through the running rails and static or ground wires. Due to the resistance of the rails, and static or ground wires, some residual current will flow through the earth back to the substation. In a 2 × 25 kV negative (autotransformer) feed system, because of the configuration and electrical connectivity arrangement of the autotransformers, the autotransformer feeders also form part of the return system.

Refer to the Caltrain Electrification Standards for design criteria related to the traction electrification system.

## 12.0 POSITIVE TRAIN CONTROL

Caltrain has implemented a PTC system as required by the Rail Safety Improvement Act of 2008. This system relies on accurate mapping of critical features including wayside track and signal GPS data points that make up the rail network in the PTC database. Any changes to wayside track and signal features along the Caltrain corridor will affect the PTC database. As a result, all changes along the Caltrain corridor must be appropriately reported to ensure that the changes are incorporated in the PTC database.

The designer shall coordinate with Caltrain Engineering on all design elements that have the potential to affect the PTC system.

### 12.1 FIBER OPTIC CABLE COMMUNICATIONS BACKBONE

A fiber optic cable communications backbone has been installed for the length of the Caltrain ROW from San Francisco to San Jose. For any design that may impact the fiber optic cable or may require relocation of the cable, the designer shall coordinate with Caltrain Engineering prior to design to select a method that minimizes signal loss in the fiber optic cable.

### 13.0 RAIL NETWORK (OPERATIONS TECHNOLOGY NETWORK)

Caltrain Rail Network or Operations Technology (OT) network encompasses all ancillary equipment, computers, firewalls, routers, switches, servers, that supports the networking of Caltrain's communication systems, operations, signals, to facilitate Caltrain's revenue service. OT network also encompasses the logical network configurations including firmware and software programming to ensure proper network operation. Designers shall work closely with Caltrain Engineering to maintain compliance with design criteria and standards.

## E. SYSTEMS INTEGRATION

System integration is an essential function in the planning and design process. The goal of system integration is to resolve all interdisciplinary design conflicts during the planning and design process, so that conflicts can be minimized to the greatest extent possible during construction. This in turn will lead to smoother system commissioning, cutover, and transition to operations.

The designers of each design discipline shall identify all relevant interface issues and potential design conflicts, and communicate with each other to ensure that all design solutions are compatible with each other. The designers shall communicate to Caltrain and other stakeholders regarding proposed resolutions for each design interface issue.

The optimum design of a complete facility must often reconcile competing design elements from various disciplines participating in a project. During concept development and preliminary engineering, the design and construction impacts of each discipline on the others must be checked, discussed, and adjusted to avoid a final design that fails to achieve the project goals.

## END OF CHAPTER

# CHAPTER 2

# TRACK

## A. GENERAL

This chapter includes criteria and standards for the planning, design, construction, maintenance, and materials of Caltrain trackwork. The terms “track” or “trackwork” include special trackwork and its interface with other components of the rail system. The trackwork is generally defined as from the subgrade (or roadbed or trackbed) to the top of rail and is commonly referred to in this document as track structure.

This chapter is organized into several main sections, which discuss track structure, materials, and civil engineering; track geometry design; special trackwork; and performance charts of Caltrain rolling stock.

The primary considerations of track design are safety, economy, ease of maintenance, ride quality, constructability, and capacity to meet both current and future operational needs, including integration with California High-Speed Rail (CAHSR). Factors that affect the track system such as safety, ride comfort, design speed, and noise and vibration, and other factors that have major impacts to capital and maintenance costs, such as constructability, maintainability, reliability, and standardization of track components must be addressed early during the planning and design phases. It shall be the objective and responsibility of the designer to design a functional track system that meets Caltrain’s current and future needs with a high degree of reliability and minimal maintenance requirements, and whose construction will have minimal impact to normal revenue operations.

Because of the complexity of the track system and its close integration with the signaling system, it is essential that the design and construction of trackwork, signal, and other corridor-wide improvements be integrated and analyzed as a system approach, so that the interactions among these elements are identified and properly coordinated.

The Caltrain commuter rail system consists of revenue and nonrevenue tracks. All Caltrain main tracks are ballasted. Direct fixation track may be used where required, subject to approval by the Caltrain Director of Engineering. Revenue tracks include mainline, siding, station, and temporary tracks used for passenger service. Union Pacific Railroad (UPRR) operates freight service within the corridor, and future California High-Speed Rail (CAHSR) passenger service is planned within the blended corridor.

The nonrevenue tracks include yard, emergency set-out, MOW, and storage tracks that are constructed for the purpose of switching, storing, or maintaining rolling stock or other MOW cars and on-track equipment not in revenue service.

## 1.0 REGULATORY AND INDUSTRY STANDARDS

Track construction and maintenance shall conform to the general requirements described in **Chapter 1, Design Guidelines**, and all applicable codes and regulations, and recognized industry standards. These include but are not limited to the following:

a. Federal Railroad Administration (FRA), Title 49 Code of Federal Regulation (CFR), Part 213, Track Safety Standards

b. California Public Utilities Commission (CPUC) General Orders (GO 26-D, GO 118, GO 75-D, GO 143-B where applicable)

c. American Railway Engineering and Maintenance-of-Way Association (AREMA), Manual for Railway Engineering (current edition)

d. Design shall not preclude CAHSR

e. Caltrain Standard Plans, Drawings, and Specifications

## 2.0 DESIGNERS' QUALIFICATIONS

The design of track construction and maintenance shall be conducted by qualified professionals with the necessary expertise to ensure compliance with industry and regulatory standards. Designers may be licensed Professional Engineers (PE) in the relevant disciplines; such licensing is preferred but not required, such as civil or structural engineering, where applicable.

Designers shall have a minimum of 5 years of experience as the lead designer of railroad track systems, including main line and yard applications. Possession of registration as a civil engineer, though not required, is highly desirable. Specifically, designers shall have the following qualifications.

a. Lead Track Design Engineer: Minimum 10 years of experience in railroad track design, construction, and maintenance. Must demonstrate experience applying FRA, CPUC, and AREMA standards. PE license is preferred.

b. Senior Track Engineer/Project Manager: Minimum 7 years of experience in railway engineering and design. Should be familiar with AREMA Chapter 5 (Track) and FRA Part 213 (Track Safety Standards). Strong background in track alignment, subgrade, and ballast design.

c. Design Engineers & Analysts: Minimum 5 years of experience in railway track engineering. Proficiency in rail design software (e.g., Bentley Rail Track, OpenRail, Civil 3D, or similar tools) is required. Familiarity with UPRR, FRA, CPUC, and Caltrain-specific standards is expected.

d. Design Integration Specialist (if applicable): For projects involving complex system interfaces (signals, electrification, and structures), an integration specialist with minimum 5 years of interdisciplinary coordination experience is required.

e. Quality Assurance & Compliance Specialists: Minimum 5 years of experience in railway safety and compliance verification. Knowledge of FRA safety regulations and CPUC General Orders (GO 26-D, GO 75-D, etc.) is necessary.

f. The designers shall be familiar with Caltrain Engineering Standards, Design Criteria, and the current federal (FRA) and state (CPUC) regulatory standards, as well as the industry standards and practices for class 1 freight and commuter rail.

g. The designers shall have a good understanding of track structure, and its components, and general civil engineering principles pertaining to subgrade or trackbed and drainage requirements.

h. The designers shall have knowledge of signal system and operation (commuter and freight) requirements and how they impact design speed.

i. The designers shall have a good understanding of the principles of track geometry, such as design of curves (simple, compound, and spiral) and the relationship between horizontal and vertical curves, as well as relationship between curves and superelevation. They shall also have knowledge of spiral length requirements for commuter, freight, and high-speed rail systems.

j. For special trackwork the designers shall have experience in designing special trackwork track geometry. General knowledge in fabrication and inspection in the fabrication yard, or field construction and assembly or fabrication of the special trackwork is required. Special trackwork designers shall be familiar with the standard industry practices generally provided by the special trackwork vendors.

k. The designer shall have experience in track construction sequencing and track construction under active railroad or tight windows and shall understand specifications and related bid items for track construction.

## B. TRACK STRUCTURE

The track structure consists of subgrade, subballast, ballast, ties, rail, fastening system, other track materials (OTM), special trackwork, and other elements for signals. These trackwork elements are interconnected to provide a continuous surface for running trains and an electrically conductive medium for transmitting.

Caltrain track consists of both concrete and timber ties with primarily 136-pound continuous welded rail (CWR). Concrete ties with fastclips and new 136-pound CWR shall be used in the design of new construction. Industry and MOW setout tracks may utilize wood ties with screw spikes and elastic fasteners(e-clips)This fastening system shall be used for standardization and for the purpose of maintaining the track structure in a state of good repair. In track, rail joints shall be eliminated or minimized – use of factory bonded insulation joints, flush-butt welding and thermite welding shall be utilized in the elimination of rail joints. Factory manufactured transition rails shall be used when joining rail of different sizes, compromised welds shall not be used. Temporary tracks or shoofly tracks used to facilitate construction and planned to be used for revenue service operations may be designed utilizing wood ties with screw spikes, elastic fastener and 136 pound CWR.

Each of the components of the track structure is briefly described below.

## 1.0 DRAINAGE

Drainage is a critical component for ensuring long-term track stability and performance. Effective and efficient drainage keeps the track well drained and hence in a relatively moisture free environment.

The track structure must include a well-designed drainage system to maintain a dry and stable subgrade, which is essential for preventing pumping, settlement, and signal system failures. A well-drained and stable subgrade ensures the absence of standing water, thereby preventing pumping phenomena. Any standing water may shunt the signal circuits, causing signal failures.

Appropriate drainage is an integral part of trackwork design. Provisions shall be made for ditches, underdrains (at train stations), and other drain features, as necessary to maintain a stable roadbed, refer to chapter 8, Civil Design, Part C, and Drainage for additional details. The collected water shall eventually discharge into the adjacent public storm drainage infrastructure. The drainage system shall be protected from erosion. Ditches (longitudinal and side ditches) and any direct discharge to them shall be protected with erosion control measures such as riprap, aprons, erosion control blanket, and permanent vegetation. The longitudinal alignment of the drainage system shall be as straight as possible and with as little curve as possible. When curves are not avoidable, they shall be as flat as possible; if necessary, provide an appropriate holding inlet and/or ditch slope protection.

At bridge approaches, positive drainage shall be provided, sloping away from the abutments and toward the embankment sides. Side slopes shall be protected with appropriate erosion control measures (e.g., riprap) in accordance with AREMA Chapter 1 (applicable sections) or Caltrans erosion control standards, depending on location and application. The drainage and erosion control basis of design shall be submitted to Caltrain for review and approval.

## 2.0 SUBGRADE

Subgrade, commonly referred to as the “roadbed” or “trackbed,” supports the railroad loads transmitted through the rails, ties, ballast, and subballast. The subgrade shall provide sufficient width for track structure and adjacent walkways or service roads, as required by Caltrain and AREMA standards.

The top of subgrade must be graded so that there is a minimum 2 percent cross slope toward the adjacent ditch or embankment slope, or to another longitudinal drainage system. Where existing right-of-way (ROW) or other restrictions do not allow the construction of side ditches, the designer shall propose another suitable gravity drainage system for consideration.

Subgrade design shall be consistent with Caltrain Standard Drawings Track Sections for ballasted track and AREMA Manual of Railway Engineering, Chapter 1, Roadway and Ballast. The ultimate stability of the roadbed will be governed by the engineering characteristics and suitability of the subgrade soils. To define these parameters, an adequate exploration program should be developed, with the assistance of a qualified geotechnical engineer. The designer shall also analyze the existing subgrade and determine whether the material is considered suitable for the subgrade. If the existing subgrade is unsuitable, it shall be removed and replaced with approved backfill and shall be compacted in accordance with Caltrain Standard Specifications. Alternatively, a geogrid or filter fabric, or HMAC may be used. HMAC will be further discussed below.

The geotechnical report must define the allowable bearing capacity, potential settlement, and subgrade treatment recommendations (e.g., overexcavation, stabilization, use of filter fabric or geogrid). Subgrade shall be compacted to 95% relative compaction per ASTM D1557.

## 3.0 SUBBALLAST

Subballast is a uniform, approved, compacted layer placed over the full width of the track subgrade, in accordance with Caltrain Standard Drawings for ballasted track and applicable AREMA provisions. Subballast shall be provided when the subgrade has poor drainage, marginal materials, or is subject to seasonally high or perched groundwater.

Subballast shall be placed with a minimum 2 percent cross slope toward side ditches, embankment slopes, or other longitudinal drainage systems. Unless noted otherwise, provide a uniform minimum 6-inch-thick layer of base material. Where a service road is adjacent to the track, extend the subballast across the full road width.

To increase track performance and reliability, provide biaxial geogrid within the subballast section, unless the subgrade has an R-value > 40 or is to be stabilized with lime or cement. Where subgrade is soft or drainage is poor, increase subballast to 12 inches over geofabric, or provide a minimum 8-inch HMAC layer over geofabric.

For yard, nonrevenue, and temporary tracks, subballast requirements shall match those of revenue main tracks; deviations shall be submitted to the Caltrain Director of Engineering for approval during preliminary design.

Subballast may consist of either compacted granular material or hot-mix asphalt concrete (HMAC). HMAC is typically used to minimize differential settlement and track modulus changes, especially at bridge approaches, turnouts, crossovers, stations, and at-grade crossings. Refer to Caltrain Standard Drawings for typical track structure sections.

## 4.0 HOT-MIXED ASPHALT CONCRETE UNDERLAYMENT

HMAC is a dense, graded asphalt concrete of maximum 1- to 1.5-inch aggregates. It is commonly used in highway applications to provide support where roadbed conditions are poor and unstable, and to facilitate drainage. The benefits of HMAC to the track structure include:

a. Improve load distribution to the subgrade

b. Waterproof and confine the subgrade; waterproofing eliminates subgrade moisture fluctuations, which effectively improves and maintains the underlying support

c. Confine the ballast, thus providing consistent load-carrying capability

HMAC provides a positive separation of ballast from the subgrade. It eliminates pumping without substantially increasing the stiffness of the trackbed. It increases operating efficiency by decreasing maintenance costs, thereby providing a long-term benefit.

HMAC shall be 8–inch-thick, graded, with positive drainage through a minimum 2 percent cross slope toward the side ditch or underdrain. HMAC on approaches to bridge decks shall be 12 inches thick. Details of this application are available in the Caltrain Standard Drawings. The HMAC layer shall be used at the following locations:

a. All at-grade crossings (vehicular or pedestrian crossings)

b. Within limits of special trackwork

c. Within limits of station platforms

d. At bridge approaches (transition zones) where track modulus changes.

e. Including and extending all transition Zones.

The track hump that commonly exists at the bridge approaches severely degrades ride quality and increases maintenance (track surfacing) and wear and tear to both the rolling stock and the rail. The HMAC underlayment shall be graded with a positive slope away from the bridge abutments, and toward each side of the track embankment. A minimum length of 50 feet is specified in the Caltrain Standard Drawings.

It should be noted that the thickness of the ballast at the bridge approaches shall be 9 inches. Ballast thickness less than the standard shall be submitted and approved by Caltrain. Thickness greater than 12 inches will not be allowed. The risk of development of track hump increases with thicker ballast sections, which are associated with increases in ballast consolidation or breakdown.

## 5.0 BALLAST

Ballast is placed above the subballast, or HMAC. The ballast plays a critical role in providing support for the rail and ties, distributing railroad loads uniformly through the subballast over the subgrade, maintaining proper track horizontal alignment, vertical profiles, superelevation on curves and lateral resistance in addition to facilitating track maintenance.

Ballast shall consist of durable, angular, crushed rock conforming to Caltrain Standard Specifications. Ballast must be sourced from Caltrain-approved quarries and free of deleterious materials. Ballast shall be AREMA Grade Size 4A for mainline track and AREMA Grade Size 5 for walkways. The reuse of subballast must meet Caltrain gradation and be approved in advance.

For tangent main tracks, the minimum ballast depth shall be 9” for wood tie track and 12” for concrete tie track, and 9” on bridges (regardless of type of ties) measured from the bottom of the tie.

For superelevated track, ballast depth below the tie shall not exceed 12 inches plus the design superelevation. Total depth shall not exceed 18 inches without written approval from the Caltrain Director of Engineering.

The ballast depth outside these limits must be approved by the Caltrain Director of Engineering. Where thicker ballast sections result in settlement from ballast consolidation, the maintenance costs are increased due to the greater frequency or need for track surfacing. Track structure over embankments is particularly prone to this phenomenon because the ballast is not being contained.

For yard tracks and industrial tracks, the minimum ballast depth shall be 6 inches if constructed with wood ties, and 8 inches. if constructed with concrete or steel ties. The maximum depth shall not exceed 12 inches without approval from the Caltrain Director of Engineering. Existing ballast salvaged during construction may be used for subballast provided it meets the standards.

## 6.0 TIES

Concrete ties shall be used for all new mainline and siding track construction. Temporary, Industry and MOW setout tracks may be constructed with wood ties per SD-2213, subject to Caltrain approval. 10-foot concrete or wood ties shall be installed at transitions zones as required between areas of different track modulus.

Rehabilitation of existing tracks shall use similar fastening systems as the track to be rehabilitated. If more than 50% rehabilitation is required on the segment of track or within the project limits, reconstruction of the entire track to meet Caltrain standards. Concrete ties are superior to timber ties in track gage maintenance. Concrete ties are engineered to maintain track gage under harsh weather conditions and over long periods of time. Tracks on concrete ties yield higher track modulus (stiffer track), which results in a stable though stiffer ride quality; and they reduce rolling resistance, which is particularly beneficial for long-haul operations. Concrete ties are more economical in production than the traditional timber ties, due to material shortage and the increasing cost of wood. With the fast-clip fastening system, track construction on concrete ties also requires less labor-intensive tasks.

Due to the improved design and fabrication of concrete ties and the overall deteriorating quality of timber, concrete ties outlast the timber ties. Furthermore, unlike timber ties that require the heavy use of the creosote treatment to prevent rotting and insect infestation, concrete ties do not require any additional chemical treatment and are therefore more environmentally friendly.

Although the material handling labor is less for the lighter timber ties, the number of ties per track mile required is less overall for concrete ties. One of the disadvantages of concrete ties is the extent of the damage to the ties in the event of derailment.

Standard concrete ties for main tracks, including at stations, shall be 8 feet 3 inches (minimum) to 8 feet 6 inches (maximum) long, spaced at 24 inches. Wood ties shall be 7x9x8'.6", spaced at 19.1/2". Spot tie, or production tie replacement shall be utilizing the same type of tie within the track segment, if the replacement will exceed 50% of tie replacement, construction to new standard concrete tie track shall be implemented 100% of the track segment.

Standard ties for at-grade crossings are concrete suitable for a moisture-prone environment. They are 10 feet long to accommodate concrete crossing panels, and to provide enhanced load distribution for additional vehicular traffic. The corresponding concrete tie clips shall be galvanized. Maintenance of at-grade crossings involves street closure, which requires the approval of the local agency.

Transition ties include approaches to turnouts, bridges and at-grade road crossings. 10' Timber wood ties shall be used within a standard timber tie track segment, and 10' concrete ties shall be used within a concrete tie segment. Transitions between wood and concrete tie segments shall use 10' wood ties as the transition tie, at all locations, including grade crossings, bridges, and turnouts -Per Caltrain Standard Drawings SD-2214 a & b for further details.

## 7.0 RAIL

The standard rail for all main tracks special trackwork is new 136-pound premium head-harden continuous welded rail (CWR), conforming to AREMA, installation shall be in accordance with the most current Caltrain Procedures for the Installation, Adjustment, Maintenance and Inspection of continuous Welded Rail, (Caltrain CWR Plan) . Temporary main line or shoofly tracks expected to be in service for less than 2 years may be constructed utilizing 136-pound Class 1 CWR rail as defined per AREMA standards, and rail shall be pre-tested and approved by Caltrain.

## 8.0 INNER GUARD RAIL

Inner guard rails consist of an additional rail (single guard) or rails (double guard) installed parallel to and between the running rails. They are installed on the approaches and through bridges, tunnels, aerial elevated structures, and at other critical locations to prevent or reduce the likelihood of derailed equipment from striking a bridge or other structure and to keep the derailed wheels and equipment on the ties within the running rails until the train comes to a stop.

Surfacing of the track by mechanical equipment can be reduced if inner guard rail is not installed properly, therefore an evaluation shall be performed of the MOW equipment used on Caltrain to ensure the installation of the inner guard rail will not interfere with the track surfacing equipment

A single guard rail is a continuous rail fastened to ties adjacent to the gage side of one running rail. A double guard rail consists of two such line rails, one adjacent to the gage side of each running rail

Inner guard rails shall be installed at the following locations unless waived by the Caltrain Director of Engineering:

a. Through truss bridges, and structures supported on piers or on bents that may be struck by derailed equipment that could result in possible failure of the structure

b. On bridges that have piers with considerable skew or that extend beyond the bridge trusses due to the angular crossing of a road, railroad or waterway

c. On all bridges where exposed structural steel is present above top of rail and is subject to structural damage by derailed equipment

d. Bridges where individual span is over 100’ in length

e. Structures over 800 feet in length

f. A structure that spans 150 feet over a waterway that normally contains 15’ or more water.

g. On aerial viaduct or elevated structures extending over or adjacent parallel waterways, interstate, or heavily traveled expressways / highways, as required by Director of Engineering.

h. Approaches to and through portals, and tunnels, and shall protect both ends of bridges, structures, or elevated segments.

i. In three or four track segments the inner guard rails are not required on the center track (s) Inner guard rails shall be installed at any other location as directed by the Director of Engineering.

Inner guard rails shall be installed uniform and parallel the running rails, at 18” from the gage of the running rail to the guard face of the guard rail, they shall be installed protecting train movements in both directions of the track, and extend through and 50’ beyond the bridge, or structure to be protected. The ends of the guard rails shall come to an end in the center of the track at a smooth and uniform transition, with ends beveled to prevent being caught by dragging equipment.

Inner guard rails are not required on pre-existing bridges, structures or elevated track segments until the bridge, structure or segment of track is replaced or rehabilitated, unless directed by the Director of Engineering.

In wood tie track segments, inner guard rails may be constructed using rails of the same size and weight as the running rails or a smaller / lighter rail, in no case shall the lighter rail be 17 lbs. lighter or 2” smaller in height (Top of rail) than the

running rails, the most common rail used on Caltrain is 136Lb, therefore 119Lb inner guard rail may be installed with 136Lb running rail.

Track constructed on concrete tie with CWR, the inner guard rail shall also be CWR of the same size and weight, secondhand rail may be used for inner guard rails.

On Concrete ties. Inner Guard Rails shall be fastened to each tie. On wood ties, Inner guard Rail shall be plated and spiked on every tie-on new installation.

In no case shall the guard rail be higher than the running rails.

### 9.0 RAIL FASTENING SYSTEM

OTM includes all materials to hold rails to the ties, and to connect between rails. Caltrain's standard fastening system includes rail clips and associated tie pads and insulators. Use of nonstandard fastening (e.g., cut spikes, screw spikes, track bolts, nuts, spring washers, tie plates, rail anchors, insulated joints, standard joint bars, and compromise bars) is permitted only for approved applications such as car and locomotive repair facilities, (elevated tracks, inspection pits, car wash tracks, etc.), and shall require approval from the Caltrain Director of Engineering.

Refer to Caltrain Standard Drawings and Standard Specifications for types of OTM and their applications, and for conformance to the Caltrain Specifications.

### 10.0 BUMPING POST

Tracks designated to be used by passenger equipment shall be equipped with hydraulic fixed or buffer typed bumping post. Bumping post shall be designed to safely arrest the movement of a 10-car trainset travelling at 20 mph. The bumping post type and model shall have documented dynamic performance testing and must be approved by Caltrain. Bumping posts shall be installed at the end of each stub-ended track. They shall be installed, at minimum, three ties before the end of track or in accordance with manufacturer's recommendations. The track is preferred to be on tangent within 100 feet ahead of the face of the bumping post, and from the face of the bumping post to the end of track.

## C. TRACK GEOMETRY

The primary goals of geometric criteria for Caltrain are to provide a safe, cost-effective, efficient, and comfortable ride, while maintaining adequate factors of safety with respect to overall operations, maintenance, and vehicle stability.

The geometric design criteria for trackwork have been developed using the best engineering practice and the experience of comparable operating commuters and Class 1 railroads. The designers need to strive for a balance among the following competing principles:

a. Consideration of Caltrain's overall system safety

b. Optimization of passenger comfort

c. Maximization of speed

d. Effectiveness of implementation costs

e. Ease and efficiency of maintenance

**Table 2-1** lists the general limiting factors that affect track geometry design. It is very important for the designers to understand these elements and provide the best track geometry based on the design criteria established in this chapter.

**Table 2-1: Limiting Design Elements**

| Design Elements | Major Limiting Factors |
|---|---|
| Minimum tangent length between curves | • Passenger comfort<br>• Vehicle truck/wheel forces |
| Horizontal curves<br>(maximum degree of curve – $D_c$) | • Design speed<br>• FRA curve speed<br>• Trackwork maintenance<br>• Vehicle truck/wheel forces |
| Compound and reverse curves | • Passenger comfort<br>• Vehicle suspension travel<br>• Trackwork maintenance |
| Length of spiral transition curve | • Passenger comfort<br>• Trackwork maintenance<br>• Vehicle suspension travel |
| Superelevation | • Passenger comfort<br>• Vehicle stability<br>• FRA 49 CFR § 213.57<br>• Freight Operations |
| Superelevation runoff rate | • Passenger comfort<br>• Vehicle suspension travel<br>• FRA 49 CFR § 213.59<br>• Freight Operations |
| Vertical tangent between vertical curves | • Passenger comfort<br>• Turnout locations<br>• Freight Operations<br>• Vehicle limitations |
| Vertical curve/grade<br>(maximum rate of change) | • Passenger comfort<br>• Vehicle suspension travel<br>• Slack action and train handling<br>• Horizontal and vertical tangents<br>• Freight Operations |
| Special trackwork | • Passenger comfort<br>• Design speed<br>• Diverging route design speed<br>• Trackwork maintenance |
| Station platforms | • Vehicle clearances<br>• Americans with Disabilities Act platform gap requirements<br>• Passenger train set configurations |

| Design Elements | Major Limiting Factors |
|---|---|
| Mixed use of commuter/freight railroads | • Vehicle clearance<br>• Trackwork maintenance<br>• Compatibility of operations |

## 1.0 GENERAL DESIGN REQUIREMENTS

Mainline and passing tracks shall be designed to support 110 mph passenger train operations (FRA Class 6) and 60 mph freight operations, unless otherwise approved. Temporary tracks (Shoofly tracks—temporary detour tracks during construction) must support the existing maximum authorized speed as a minimum. Curves shall be optimized for mixed traffic and long-term track geometry stability. Upon completion of the track construction, Caltrain will determine the appropriate operating speed.

The resulting track shall be with as few and as small curves as possible. However, small curves such as 30 minutes or less shall be discouraged, because they are impractical to construct or to maintain. Furthermore, over time, these small curves tend to lose their curvature, requiring increasing additional maintenance. If such small curves are not avoidable, they need to be at least 500 feet long for ease of construction and maintenance.

Designers shall strive for speeds in 5-mph increments, but other increments are permitted when practicable.

As part of the design, designers shall typically include the following information and data for Caltrain review, and for use during construction:

a. Track chart (existing and proposed), in a format consistent with Caltrain published track charts

b. Stationing continuously along the length of all main tracks, using Main Track MT-1 as a reference, including mile posts. Stationing shall be at 100’ intervals maximum

c. Track plan (on planimetric background) showing existing and proposed track, with mileposts, and containing the following information (left side of the page is railroad north, with an arrow pointing to actual north):

   i. Caltrain ROW lines and other surrounding property lines or constraints, street names, landmarks, etc.

   ii. Track information: curve numbers and turnouts with their corresponding stationing, and other turnouts points

   iii. Project-related features, such as (existing and proposed): underground utilities (communications, signal, drainage, sewers); other utilities (manholes, vaults, etc.); structures (signal houses and other structures), ditches, and drainage facilities

iv. Track drainage and other drainage (existing and proposed)

d. Track centers, every 500 feet, or when the track centers change at all change locations

e. Vertical profiles (existing and proposed), including slopes (in percent) developed for each track, in grid, with elevations in two decimals for key points, such as highs, lows, change of curve, or speed

f. Track plan and profile on the same sheet, with the same limits, with the plan on top of the page

g. Cross sections, every 50 feet, (toward increasing stations) showing existing and proposed, scaled appropriately, including any vertical clearances

h. Track geometry data in tabular form, with the following information: design speeds (current and proposed), curve data [curve number; corresponding stationing; curve characteristics (in degrees, minutes, and seconds); coordinates, both northing and easting], spiral length, superelevation (total, unbalance, actual)

## 2.0 CRITERIA LEVELS

In determining the track geometry, the following levels of criteria shall be considered for implementation:

a. Preferred Standard

This standard shall be applied to all new mainline and siding tracks, based on an evaluation of maximum passenger comfort, maximum speed, initial construction cost, and long-term maintenance considerations. The preferred standard shall be used wherever there are no significant physical constraints.

b. Minimum Standard

This standard shall be applied where and only when physical constraints prevent the use of the Preferred Standard. Minimum Standards are determined primarily by the rail car design and safety of operations, with passenger comfort as the secondary consideration. The design shall meet all applicable federal and state requirements and shall be approved by the Caltrain Director of Engineering. The use of Minimum Standard shall require a variance request and approval; the variance request shall include a documented design review and decision memo outlining:

- Cost/benefit analysis (note: cost alone shall not be the determining factor)
- Operational impacts
- Long-term maintenance implications
- Justification for deviation from the Preferred Standard geometry.

c. Nonrevenue Track Standard

Track design criteria shall be the same as for main track. The track geometry shall be based on class of track and track speed. All tracks shall meet Caltrain, FRA, and CPUC standards. This case shall be applied to nonmainline and nonrevenue tracks where low speed operations are in effect. These standards are determined primarily by the rail car design and safety of operations, with little or no consideration of passenger comfort.

The use of absolute minimum standards, particularly for horizontal alignment, has several potential impacts in terms of increased annual maintenance, noise, and rail car wheel wear, and shorter track component life. Their use shall be implemented with extreme caution and require approval from the Caltrain Director of Engineering. In no case shall the standards be allowed below the minimum standards mandated by federal and state regulations.

At locations where the existing alignment or other restrictions preclude this, the track shall accommodate train speeds equal to or exceed the existing speeds.

## 3.0 HORIZONTAL ALIGNMENT

The horizontal alignment consists of tangent segments joined by circular curves with transition spirals, as measured along the center line of track. Alignments shall optimize safety, ride quality, and maintainability. Spirals are required for most curves and are essential for transitioning superelevation smoothly. Track superelevation in curves is used to maximize train operating speeds wherever practicable. In yards and other nonrevenue tracks, spiral transition curves, and superelevation are rarely required.

Curvature and superelevation of track alignment are related to design speed and to the acceleration and deceleration characteristics of the rail cars and locomotives for that location. The design criteria for tangent, curve, design speed, superelevation, and spiral transition curve are described in the next few sections.

Design shall achieve highest possible passenger speeds through elimination of selected curves. Optimization of horizontal curve, implementation of higher actual superelevation (Ea) in curved track with longer transition spirals, and implementation of higher unbalance (Eu) acceptable for use with passenger trains on a mixed passenger and freight track operation.

## 3.1 HORIZONTAL ALIGNMENT CRITERIA

Horizontal alignments for Caltrain mainline tracks shall be stationed along the track centerlines of Main Track 1 from San Francisco (north) to San Jose or Gilroy (south), based on the Caltrain GIS alignment. Refer to Caltrain Track Charts for track and alignment information.

The following track center distances from the main track shall be applied along tangents.

- Main track: 15 feet minimum

- Yard track: 25 feet minimum
- Main track to switching leads: 25 feet minimum

On curves, to provide clearance between cars and locomotives equivalent to that obtained on adjacent tangent track, track centers shall be increased as follows:

a. A minimum of 1 inch for every 30 minutes of curvature where the amount of superelevation is the same on adjacent tracks or the superelevation of the inner track is greater than that of the outer track

b. A minimum of 1 inch for every 30 minutes of curvature, plus 3½ inches for every inch of difference in elevation between the two tracks where the superelevation of the outer track is greater than that of the inner track

## 3.2 TANGENT

Tangent lengths shall consider the longest rail car used in Caltrain service and provide adequate straight track for vehicle dynamics and rider comfort. Tangents between curves must provide a minimum of 3 seconds of vehicle travel time at design speed (L = 3V) and shall not be less than 100 feet unless otherwise approved. Tangents shall extend at least 100 feet beyond both ends of station platforms, and at-grade crossings.

The tangent length for mainline tracks shall be established as shown in **Table 2-2** below.

**Table 2-2: Tangent Length (Main Tracks)**

| Tangent Location on Mainline Tracks | Tangent Length (feet) | |
|---|---|---|
| | Preferred | Minimum** |
| Between reverse curves | 3V | 100 |
| Between point of switches (PS) of turnouts (TOs) | 3V | 100 |
| Between PS and curve | 100 | 100 |
| Between PS and platform | 100 | NA |
| Between PS and grade crossing | 250 | 100 |
| Between PS and last long tie of TO | 60 | NA |
| Between curve and platform | 100 | 30 |
| Between curve and grade crossing | 100 | 10 |

Notes

* Tangent length shall not be less than the length of stock rail projection.

** Use Minimum Standard will require to review Section 2.0b – Criteria Level

NA – Use Preferred.

V = design speed in the area, mph

The tangent length for yard and nonrevenue tracks shall be established as shown in **Table 2-3**:

**Table 2-3: Tangent Length (Yard and Nonrevenue Tracks)**

| Tangent Location on Yard and Nonrevenue Tracks | Tangent Length (feet) | |
|---|---|---|
| | Preferred | Minimum** |
| Between reverse curves | 60 | N/A |
| Between PS of TOs | 40 | 15* |

Notes:
*Tangent length shall not be less than the length of stock rail projection.

** Use Minimum Standard will require to review Section 2.0-b – Criteria Level

NA – Use Preferred.

## 3.3 HORIZONTAL CURVES

Horizontal curves shall be designed for the highest feasible design speed, considering future maximum authorized speed (MAS), passenger comfort, right-of-way, and maintenance. Minimum design speed shall not be lower than the existing MAS without written approval. Curve elimination or flattening should be evaluated as part of every major track realignment. The spiral length shall be sufficient to allow superelevation runoff for the future maximum operating speed even if the existing MAS is less than the future maximum speed.

Design speeds for passenger trains running through all curves shall be as shown in **Table 2-4**.

**Table 2-4: Design Speeds Through Curves**

| Track Type and Condition | Curve Design Speed (mph) | |
|---|---|---|
| | Preferred | Minimum** |
| Main track | 110 | Exceed MAS |
| Control siding with #20 TO | 50 | NA |
| Control siding with #14 TO | 35 | NA |
| Temporary main track | Existing MAS | N/A |
| Yard lead | 25 | 15 |
| Yard track | 15 | 10 |

Notes:
** Use Minimum Standard will require to review Section 2.0-b – Criteria Level
NA – Use Preferred.

Prior to the design of the track geometry, the designer shall consult with the Caltrain Director of Engineering to confirm the appropriate design speed(s), based on Caltrain's current and future requirements. Higher future design speed shall be considered where possible. Use of minimum design speed values shall be approved by Caltrain Director of Engineering.

### 3.3.1 Horizontal Curve

A horizontal curve is composed of a circular curve connected to tangent tracks on both ends with or without spirals. The circular curve body is defined by a constant radius. Spirals shall be clothoid, with a constant rate of change of curvature as defined by AREMA. The criteria for the designer shall be to eliminate any curve; or, if this is not feasible, to lessen the curvature. Implementation of curves of less than 30 minutes require approval from the Caltrain Director of Engineering. Curve data shall be provided in a table format with the following information:

a. Design speed (mph)

b. Stationing at P.C., P.T., T.S., S.C., C.S., and S.T.

c. Degree of curve (degrees, minutes, and seconds)

d. Length of curve, $L_c$

e. Amount of actual superelevation, $E_a$, (inches)

f. Amount of unbalance, $E_u$, (inches)

g. Length of spiral, $L_s$

Curve alignment through grade crossings shall be avoided when possible. If tracks are superelevated through the crossing, both the track and road profiles may need to be modified to provide a smooth road profile over the crossing.

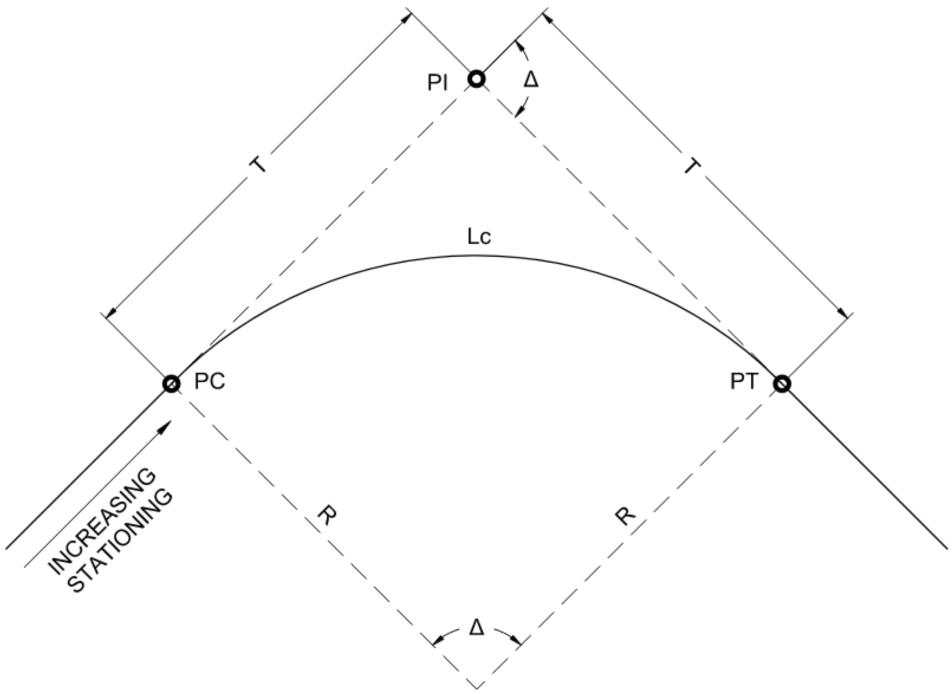
### 3.3.2 Circular Curve

The circular curve for the track geometry shall be defined by the chord definition and specified by its degree of curve ($D_c$). The degree of curve has been adopted as a unit of sharpness and is defined as the central angle subtended by a 100-foot-long chord for ease of field layout. The degree of a curve must be a whole number of degrees, minutes, and seconds. The practice of specifying a radius and then determining the resulting degrees, minutes, and seconds (and thereby creating fractional seconds) is not acceptable. Wherever possible, the minute and second of a curve should be rounded to the increment of five. The important relations of simple curves for the chord definition are as follows:

Radius, $R = 50/\sin(D_c/2)$
Length of curve, $L_c = 100\ (\Delta/D_c)$
Tangent distance, $T = R \tan(\Delta/2)$
where $\Delta$ = central angle

The minimum length of circular curve shall be 100 feet for mainline tracks and 50 feet for yard tracks.

See **Figure 2-1** for an illustration of the simple circular curve.




where:

| | |
|---|---|
| Δ | total intersection angle |
| $L_c$ | length of circular curve |
| PC | point of curve |
| PI | point of intersection of main tangents |
| PT | point of tangent |
| R | radius of curve |
| T | the tangent distance (semi-tangent) |

**Figure 2-1: Circular Curve**

## 4.0 SUPERELEVATION

Superelevation (Ea) is the vertical difference between the high (outside) and low (inside) rail. Superelevation is used to offset, or partially offset, the centrifugal force acting radially outward on a train when it is traveling along the curve. A state of equilibrium is reached when the centrifugal force acting on a train is equal to the counteracting force pulling on a train by gravity along the superelevated plane of the track.

The superelevation is applied to enhance ride quality, reduce rail/wheel wear, and enable higher speeds. Superelevation must be calculated using AREMA and FRA guidelines and applied in accordance with Caltrain's maximum limits.

The maximum actual superelevation (Ea) for Caltrain tracks is 5 inches. All curves with superelevation of 5 inches or more shall require the approval from the Caltrain Director of Engineering.

### 4.1 APPLICATION OF SUPERELEVATION

Actual superelevation shall be accomplished by maintaining the top of the inside (or low) rail at the “top of rail profile,” while raising the outside (or high) rail by an amount of the actual superelevation. The inside rail is designated as the “grade rail” (or profile rail) and the outside rail is designated as the “line rail.”

### 4.2 SUPERELEVATION EQUATION

Equilibrium superelevation shall be determined by the following equation:

$$\mathbf{e = 0.0007\ D_c V^2}$$

where:

$e$ = equilibrium superelevation, in inches.
$V$ = design speed through the curve, in mph
$D_c$ = degree of curvature, in degree

The total superelevation e is expressed as follows:

$$\mathbf{e = E_a + E_u}$$

where:

$E_a$ = actual superelevation that is applied to the curve
$E_u$ = unbalanced superelevation (amount of superelevation not applied to the curve)

The actual superelevation shall be rounded up to the nearest ¼ inch by the formulas above. For any curve, a minimum of ½ inch superelevation shall be specified.

Slower speed tracks, such as yard and nonrevenue tracks, and curves in special trackwork, shall not be superelevated.

Curves in station and grade crossings shall be avoided. They may be superelevated only with the approval of the Caltrain Director of Engineering.

The maximum unbalance superelevation shall not exceed 3 inches.

## 5.0 SPIRALS

Spirals (transition or easement curves) are defined as transition curves with a constantly decreasing or increasing radius proportional between either a tangent and a curve or between two curves with different radii (compound/intermediate spiral). More specifically, the spiral is a curve whose degree of curve increases directly as the distance along the curve from the point of spiral.

In other words, spirals provide a gradual change of curve and ride comfort from the tangent to full curvature. Spirals are a means of introducing a superelevation at a rate corresponding to the rate of increase in curvature, which permits a gradual increase to full lateral acceleration at a comfortable, and nondestructive rate. Within the length of a spiral, the actual superelevation should be applied linearly from zero at the Tangent to Spiral - TS to the superelevation at the spiral to curve.

For example, if the spiral is to change at the rate of 10 degrees per 100 feet, at 10 feet from the beginning of the spiral the curvature will be the same as that of a 1-degree curve; at 25 feet, it will be the same as that of a 2-degree, 30-minute curve; and at 60 feet, it will be the same as that of a 6-degree curve. Likewise, at 60 feet, the spiral may be compounded with a 6-degree curve; at 80 feet, with an 8-degree curve, etc.

## 5.1 APPLICATION OF SPIRALS

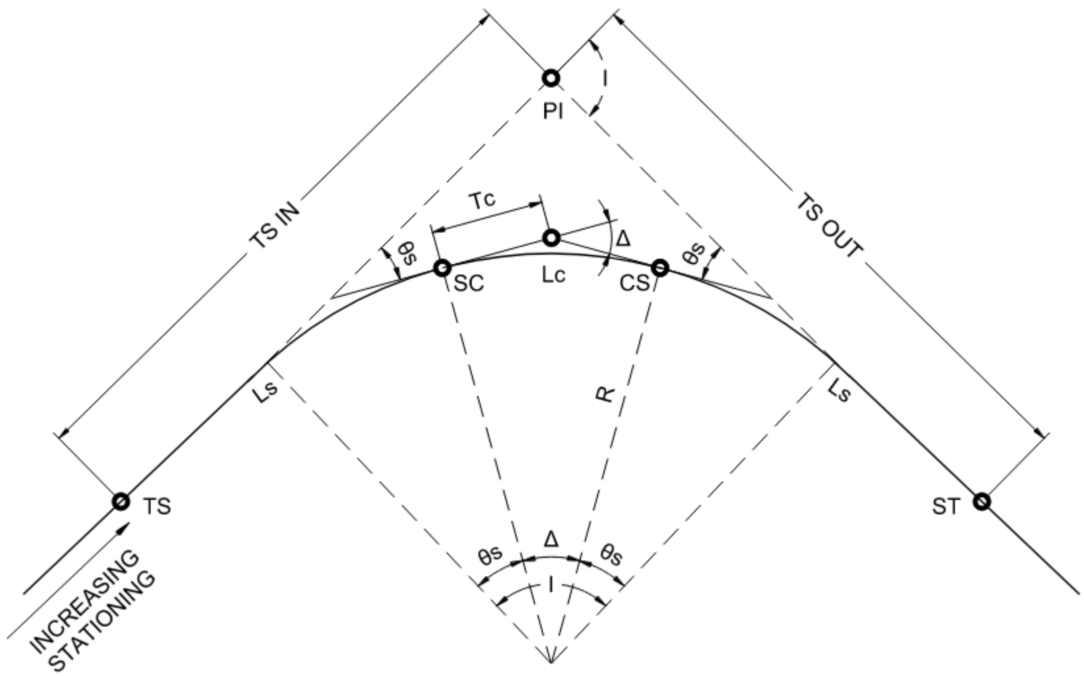
The spiral transition curves shall be provided between circular curves and horizontal tangents. The spiral transition curve shall be the “ten-chord spiral,” as defined by the AREMA Manual for Railway engineering; or the “clothoid spiral,” as defined by drafting software AutoCAD. See **Figure 2-2** for spiral and curve nomenclature.

Spirals are not required for curves less than 30 minutes with maximum authorized speeds of 20 mph or less, or on curves that is part of a turnout; however, a minimum curve length of 100 feet shall be implemented. Additionally, all curves that are not part of a turnout shall have a minimum of ½ -inch actual superelevation.

## 5.2 LENGTH OF SPIRALS

Spiral curve length and superelevation rate of change or runoff are directly related to passenger comfort. Although passenger comfort is a major consideration, the rate of change in superelevation in a spiral also affects the rail car bodies in terms of twisting, racking, or diagonal warp. According to AREMA, the superelevation differential between rail car truck centers should not exceed 1 inch. Therefore, based on an 85--foot long rail car with a truck center distance of 62 feet, the longitudinal slope of the outer rail with respect to the inner rail is limited to 1/744, or a rate of change of 1 inch per 62 feet in length, to avoid wheel lift. Because the Caltrain corridor will be a shared-use corridor with the California High-Speed Rail Authority (CHSRA), the rate of change also needs to meet CHSRA design requirement of ⅜ inch over 31 feet of track.

The length of the spiral can be determined by the following criteria, based on passenger comfort and operational safety.




where:

| | |
|---|---|
| $D_c$ | degree of curvature |
| I | total intersection angle |
| θs | spiral angle = $(L_s D_c) / 200$ |
| Δ | central angle of circular curve = I - 2 θs |
| R | radius of circular curve |
| Tc | tangent length of circular curve = R tan (Δ / 2) |
| $L_c$ | length of circular curve = (Δ / 180 ) R |
| $L_s$ | length of spiral |
| TS | tangent to spiral |
| SC | spiral to curve |
| CS | curve to spiral |
| ST | spiral to tangent |
| PI | point of intersection of main tangents |
| TS IN | tangent length of complete curve |
| TS OUT | tangent length of complete curve |

**Figure 2-2: Curves with Spiral Transition**

### 5.2.1 Spiral Length Requirements

Based on AREMA, Chapter 5, Section 3.1, the length of spiral shall be longest as determined from the formula in Table 2-5.

### Table 2-5: Length of Spiral

| Spiral Design Factor | Preferred | Minimum** |
|---|---|---|
| Superelevation | $L_s = 1.47E_aV$ | $L_s = 1.17E_aV$ |
| Unbalance | $L_s = 1.63E_uV$ | $L_s = 1.22E_uV$ |
| Twist | $L_s = 90Ea$ | $L_s = 75$ Ea. |
| Minimum Segment | $L_s = 2.64V$ | $L_s = 2.20V$ |

Notes:

** Use Minimum Standard will require to review Section 2.0-b – Criteria Level

where:

$E_a$ = actual superelevation that is applied to the curve
$E_u$ = unbalanced superelevation (amount of superelevation not applied to the curve)
V = design speed, mph

The spiral length shall generally be rounded to the nearest 5 feet.

The spiral lengths for the existing curves of the current Caltrain commuter corridor were determined based on the formula $L_s = 1.2E_aV$; this formula may therefore be used, as an exception, to establish the spiral length in areas with extreme site constraint, with the approval of the Caltrain Director of Engineering.

## 6.0 COMPOUND CIRCULAR CURVES

Compound circular curves may be used, if they are connected by an adequate spiral based on the difference between the required superelevation of the curves. The same speed shall be used to determine the spiral lengths and superelevation for the compound curves. The spiral lengths for compound curves shall be determined by the criteria previously described.

The minimum length of spiral between compound curves shall be 62 feet.

## 7.0 VERTICAL ALIGNMENT

The vertical alignment is defined by the profile grade along the top of low rail (grade rail). This profile governs drainage, train performance, ride quality, and coupler dynamics.

When the top of rail profile is given for one track only, the top of rail elevations of the other tracks are to be equal to the profile track at points radially and perpendicularly opposite. Gradients and lengths of vertical curves shall vary accordingly (slightly), to accommodate the differences in lengths through horizontal curves. All main tracks and sidings shall be designed to the same vertical profile. In multi-track territories where there are more than two tracks, the profile of the outside tracks may be lowered based on the cross slope of the roadbed, to minimize the need of increasing ballast depth. Avoid overlapping of vertical curves and horizontal curves when feasible without requiring ROW takes or significant increase of construction cost.

## 7.1 GRADES

The maximum preferred continuous grade for mainline track is 1 percent. Maximum design gradient, with curve compensation at 0.04 percent per degree of curve, if applicable, for grades up to 2 percent may be implemented for new construction projects with the approval of the Caltrain Director of Engineering. The resulting maximum gradient $G_c$ is generally expressed as follows:

$$G_C = G - 0.04D$$

where,

G = gradient before
D = degree of curve, in decimal.

Proposed track profile with grades greater than 1 percent requires a design exception, operational simulation, and justification. Track grades must be designed to support safe, efficient and cost-effective passenger service and freight operation. Potential operational issues are discussed below.

For passenger service, it is important to be able to maintain design speeds and to accelerate and brake safely at stations, signals, control points and speed change locations. The location of the proposed grade exception relative to these locations is an important consideration since, for example, it may impact safe braking distance. Other important operational considerations include reduced operating speed, and increased brake and rail wear. These factors can increase operating and maintenance costs. However, these impacts can be minimized if the length of the exception segment is relatively short.

In addition to maintaining operating speeds, the proper design of vertical curves relative to the adjacent grade is an important factor. This is due to the design of vehicle coupler units for safe operation.

An additional Caltrain consideration is how the exception may impact operations in unusual or emergency conditions. For example, can a train be towed in a rescue situation, and will there be sufficient power if a substation is down?

At station platforms, a constant gradient is required, with the maximum grade of 1 percent. At bridge structures, a minimum 0.4 percent grade shall be provided for drainage purposes. For yard tracks where cars are stored, a level gradient is preferred, but a maximum nonrolling track gradient of 0.2 percent is permitted.

For mainline track, the desired length of constant profile grade between vertical curves shall be determined by the following formula (but not less than 100 feet):

$$L = 3V$$

where:

L = minimum tangent length, feet
V = design speed in the area, mph

## 7.2 VERTICAL CURVES

Vertical curves for mainline and shoofly tracks shall be designed in accordance with the AREMA Manual for Railway Engineering shown in the following formula:

$$L = (D\,V^2 K)\,/A$$

where:

A = vertical acceleration, in feet per second squared (ft/sec$^2$)
D = absolute value of the difference in rates of grades expressed in decimal
K = 2.15, conversion factor to give L, in feet
L = length of vertical curve, in feet
V = speed of train, in mph

The recommended vertical accelerations (A) for passenger and freight trains for both sags and summits are as follows:

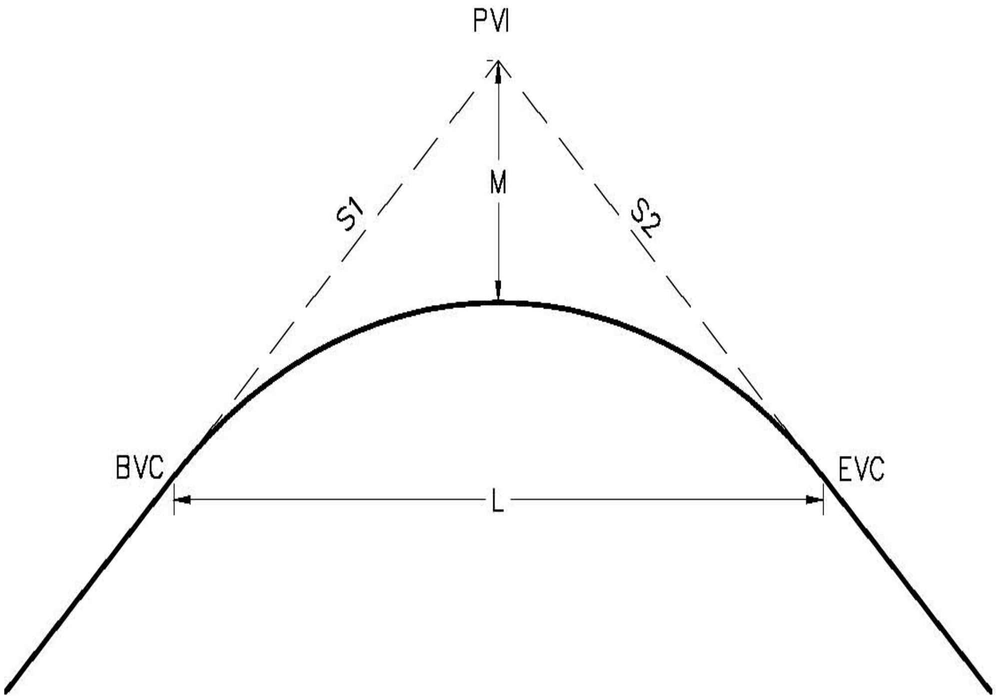
| Train Type | Recommended Vertical Acceleration (ft/sec$^2$) |
|---|---|
| Passenger Train | 0.60 (0.019 g) |
| Freight Train | 0.10 (0.003 g) |

The longer vertical curve based on the above recommended accelerations shall be used. Under no circumstances shall the length of vertical curve be less than 100 feet.

Station platform and special trackwork shall not be located within vertical curves. End of platform and PS shall be located at least 100 feet from the beginning and end points of the vertical curve. Avoid simultaneous horizontal and vertical curve overlapping unless justified.

In summit areas, locations of all signals shall be checked for visibility.

Complex profiles, such as those with more than three grade changes exceeding 1.0 percent each within 3,000 feet, may cause excessive dynamic forces and handling problems for trains. The Caltrain Director of Engineering may require train performance simulations to determine whether such profiles are acceptable for passenger and/or freight operations. See **Figure 2-3** for vertical curve nomenclature.




| | |
|---|---|
| BVC | beginning of vertical curve |
| EVC | end of vertical curve |
| PVI | point of intersection for vertical curve |
| S1 | slope of entering tangent in percent |
| S2 | slope of departing tangent in percent |
| L | length of vertical curve |
| M | correction in elevation at PVI |
| EL | elevation |

When the vertical curve is concave downward:

$$\mathbf{M = [(EL_{PVI} \times 2) - (EL_{BVC} + EL_{PVI})] / 4}$$

When the vertical curve is concave upward:

$$\mathbf{M = [(EL_{BVC} + EL_{EVC}) - (EL_{PVI} \times 2)] / 4}$$

**Figure 2-3: Vertical Curve**

# D. SPECIAL TRACKWORK

Special trackwork refers to trackwork units that are used for tracks to converge, diverge, or cross each other. Special trackwork includes turnouts, crossovers, and track crossings. All special trackwork designs shall be based on Caltrain Standard Drawings. In areas with real estate constraints, special trackwork designs for complex operational situations shall be submitted for approval.

## 1.0 TURNOUTS AND CROSSOVERS

Turnouts are used for tracks to diverge or converge from one track to another. **Turnouts** have different types and sizes (numbers). A turnout unit consists of a switch, a frog, and straight and curve stock rails, plus a means to throw the switch and secure it.

**Frog** is the portion of a turnout or track crossing where wheels cross from one track to another.

**Crossovers** are installed between two tracks for trains to move from one track to another adjacent track. A single crossover unit consists of two turnouts. A **universal crossover** unit consists of two continuous single crossovers installed in opposite directions.

**Lateral turnout** is a turnout in which the diversion due to the angle of the turnout is entirely on one side of the track from which the turnout is installed.

**Equilateral turnout** is a turnout in which the diversion due to the angle of the turnout is divided equally between the two tracks.

**Double slip switch (or puzzle switch)** is a special trackwork unit that allows two crossing tracks to diverge from one to another. With the approval of the Caltrain Director of Engineering this type of switch may be used at terminals, yards, or main tracks where the speeds will not exceed 25 MPH.

Double Slip Switches for higher speeds may be designed with the approval of the Director of Engineering.

**Turnout size or number** is the number corresponding to the frog number of the turnout. The frog number is equal to the cotangent of the frog angle. Cotangent is the inverse of tangent.

Special trackwork requires the corresponding switch machines (to throw the switches) that are integrated with signal work.

See **Figure 2-4** for layouts of various types of turnouts and crossovers.

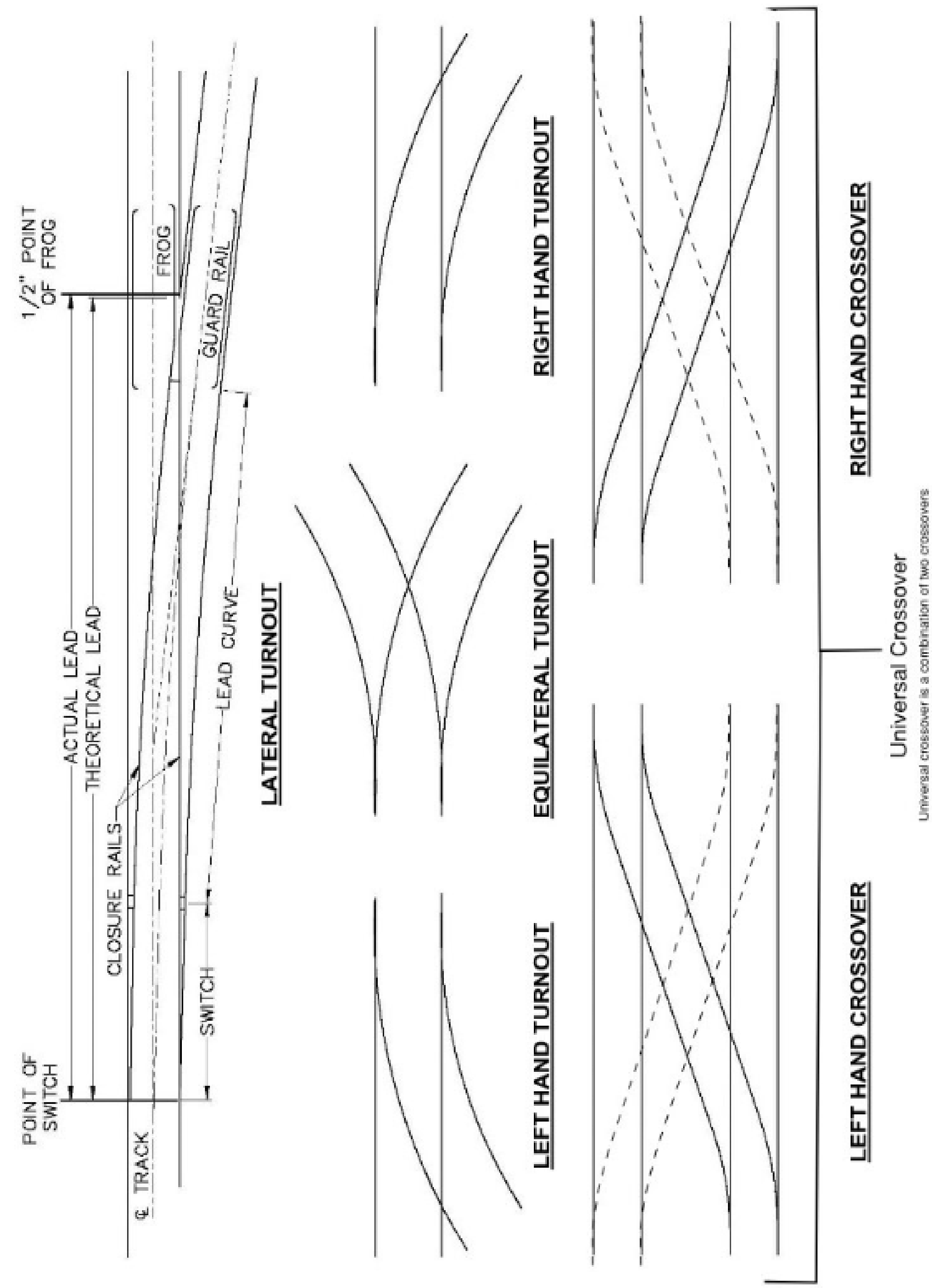



**Figure 2-4: Turnouts and Crossovers**

## 2.0 APPLICATION OF TURNOUTS AND CROSSOVERS

The following standard turnouts and crossovers shall be used according to the desired MAS for operations:

a. Lateral turnouts numbers 8 and 9 for yards

b. Lateral turnouts numbers 10, 14, and 20 for main line; No. 20 Turnout shall be used as a standard in locations where the operating speed of the main track exceeds 50 MPH

c. Number 9 or number 10 double-slip switches may be used in terminals

d. Turnouts with Hollow Steel Ties in accordance with Standard Drawings SD-2000 series shall be used for new constructions

The following information is required for the design of turnouts:

a. Turnout number

b. Stationing at the PS of the turnout

c. Stationing at the point of frog of the turnout

Detailed information on turnouts and crossovers is included in the Caltrain Standard Drawings.

## 2.1 SPEEDS THROUGH TURNOUTS AND CROSSOVERS

Passenger train design speeds for turnouts and crossovers are based on 3 inches of unbalanced superelevation for curves without spirals. Freight design speeds are for maximum of 2 inches unbalanced superelevation.

MAS through turnouts and crossover for passenger and freight trains are as follows:

a. 15/10 (passenger/freight) mph for number 8

b. 20/10 (passenger/freight) mph for turnouts number 9

c. 25/15 (passenger/freight) mph for turnout number 10

d. 35/25 (passenger/freight) mph for turnout number 14

e. 50/40 (passenger/freight) mph for turnout number 20

## 2.2 STANDARD TURNOUTS AND CROSSOVERS

Turnouts and crossovers shall be located to allow suitable placement of switch machines and/or switch stands to meet CPUC walkway requirements, with consideration of the placement and visibility of control signals, and with easy access for operation and maintenance.

Turnouts and crossovers shall be located on tangent tracks and shall meet the following requirements:

a. 100 feet minimum from PS to horizontal or vertical curves

b. Less than 100 feet from horizontal curves without superelevation with approval from the Caltrain Director of Engineering

c. 100 feet minimum from PS to the edge of road crossings (including sidewalks)

d. 50 feet minimum from PS to insulated joint

e. 100 feet minimum from PS to opposing PS

f. Crossovers shall be located in parallel tracks only

g. Standard crossovers shall be of 15 feet track center

## 2.3 NONSTANDARD TURNOUTS AND CROSSOVERS

Design of nonstandard turnouts and crossovers, such as equilateral turnouts and slip switches, shall require the approval of the Caltrain Director of Engineering. Design for conditions listed below shall require the approval of the Caltrain Director of Engineering.

d. Crossovers in nonparallel tracks

e. Crossovers with track center more than 15 feet

f. Turnouts in curves

g. Turnouts or crossovers on bridges or over underpasses

h. Turnouts or crossovers in paved areas

## 3.0 DERAILS

Derails are mechanical and/or electrical safety devices intentionally used to derail or divert uncontrolled movement of train, rail vehicles, or on-track equipment away from adjacent or connecting tracks without fouling the tracks. See Caltrain Standard Drawings for layouts and details. The designer shall closely coordinate with the signal designer for design and layout requirements.

Derails are required at all tracks connected to main line or siding tracks, regardless of grade. Derails shall be double point split switch derail per SD-2901. Derails are required on yard and industry tracks:

1. If track has a rolling grade and potential to foul other tracks.

2. Track where locomotives are stored.

3. Interchange tracks.

4. Where equipment movements are performed.

5. Tracks where cars or equipment is left unattended.

6. All track where storage, loading, and unloading of hazardous materials is performed (such tracks shall be also protected with derails against inbound movement, derail shall be installed not less than 50’ from near end of car.

7. Other locations designated by Caltrain.

Derails shall be located so that they derail equipment in a direction away from the main track. Derails shall be located beyond the clearance points of converging tracks. Double-point split-switch derails are installed at locations as required by Caltrain’s Operations and Engineering departments, including locations where operating locomotives are stored and where cars are moved or switched by nonrailroad personnel. All new main track turnouts and derails shall be power operated, referring to SD-2901.

Hinge or flop type derails may be used in yard and industry tracks for the protection of personnel fouling of non-main line or siding tracks where the grade does not exceed 1% and the speed of a rolling car does not exceed 5 mph.

Derails are connected to the signal system to indicate when they are lined for train movement. Derails installed to protect main tracks, controlled sidings or other controlled tracks shall be connected to the signal system.

Blue flag derails are required to protect workers on service tracks, in accordance with FRA Title 49 CFR Part 218; and to protect workers during the unloading of hazardous materials, in accordance with FRA Title 49 CFR Part 172.

## 4.0 RAILROAD TRACK CROSSINGS

Railroad track crossings are where tracks cross each other. Installation of railroad crossings shall require approval from the Caltrain Director of Engineering and shall take place only where there is no other economic option. If installed, crossings shall only be located on tangent tracks at standard skew angles, as recommended by AREMA. See AREMA Portfolio of Trackwork Plans for layouts and details of crossings for various skew angles.

## 5.0 SET-OUT TRACKS

All future setout tracks shall be equipped with a derail and have a minimum of 500 feet of clear storage capacity from edge of Hi-Rail Pad. The measurement length shall begin 25’ from edge of hi-rail pad and end of the bumping post. Maintenance of way (MOW) setout tracks shall be provided when existing MOW tracks are impacted by a project, or as required by Caltrain. - The setout area shall include a Hi-Rail set-on/set-off pad constructed with Hot Mix Asphalt (HMA). The pad must provide vehicle access ramps and be located at the nearest point of entrance to the main track. It shall begin 25 feet from the closest insulated joint and extend to a minimum of 60 feet in length, with a width matching the ties on the main track side.

Each setout track must also have roadway access suitable for a 40-foot-long rubber-tired truck trailer. Entrance and exit gates shall be installed at both ends of the setout track limits at a minimum. If access gates are placed beyond the track limits, a clear and unobstructed roadway must be provided between the access roadway and the nearest active track.

When relocating and/or removing a setout track, construction staging shall be implemented to always allow for MOW access to the setout track. All turnouts for new setout tracks shall be constructed using a #10 turnout with a jump frog. Track shall be spaced at a minimum distance of 25’ from adjacent siding or main track.

Setout tracks to be used for passenger train operations as determined by Caltrain shall have a minimum clear length of 950 feet and shall be electrified. All traction power elements shall be designed to meet the current Caltrain electrification standards. All new setout tracks shall be power operated switches, with double point power derails.

## E. TRAIN PERFORMANCE CHARTS

The MAS of the Caltrain system is 79 mph, which is based on FRA signal standards (49 CFR Part 236). To operate at speeds of 80 mph or higher, a supplemental signal system will be required. For a MAS of 79 mph, track conditions shall meet FRA Class 4 track standards.

The acceleration and deceleration charts for the current Caltrain consists of (**see Figure 2-5**) were developed by SYSTRA Consulting. They are taken from SYSTRA’s April 4, 2004 report, “Acceleration and Deceleration Performance of Caltrain’s FP40PH and MP36 Locomotive,” and the December 31, 2006 report, “Signal System Headway/Capacity Study.”

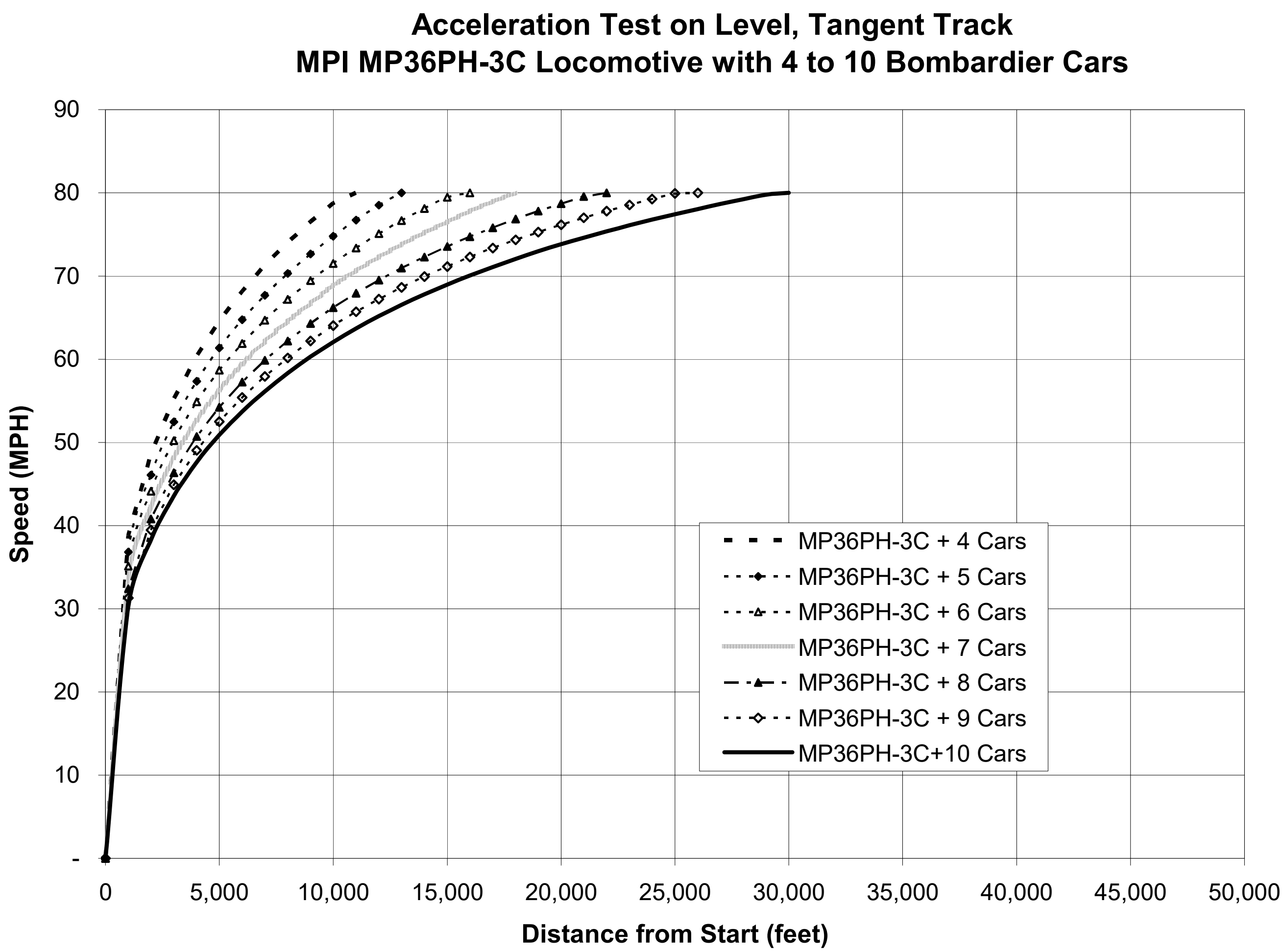



**Figure 2-5: Acceleration Chart for MPI MP36PH-3C Locomotive**

# END OF CHAPTER

# CHAPTER 3

# STATIONS AND FACILITIES

## A. GENERAL

The objective of this chapter is to provide designers with the minimum requirements for planning and designing new and temporary stations and their related facilities. These facilities include furniture, amenities, signage, fencing, railing, parking, lighting, and platform access. All station alterations shall follow the requirements in this chapter. Any deviations from these minimum requirements must be approved via Caltrain's Standard Procedure for Design Variances (G-24).

The design requirements for passenger information, fare collection or payment, regulatory and safety advisories, and security systems are covered in **Chapter 4, Communication & Passenger Information Systems**. The design requirements for the pedestrian at-grade crossings in stations and at vehicular crossings are contained in **Chapter 7, Grade Crossings**.

The design requirements in this chapter are generally for typical Caltrain stations**,** not for multi-modal stations. Multi-modal stations typically involve station buildings or structures, fare paid areas, and additional requirements on safety and security, access, and circulation. The stations may include vertical elements for circulation and egress, fire and safety considerations, ventilation requirements, and other requirements and elements associated with underground facilities. Project-specific design criteria shall be developed for a multi-modal station to meet all functional needs and applicable regulatory codes beyond the requirements in this document.

The design of stations and their facilities shall generally follow the principles of crime prevention through environmental design (CPTED). In particular, the design team shall include an appropriate CPTED-certified professional with responsibility for review of safety and security elements of the design from planning through final design.

Caltrain provides detailed standards (layout, location, design, and artwork template) for signage. In addition to the Caltrain-specific signage standards, each Caltrain station is subject to the San Francisco Bay Area Metropolitan Transportation Commission (MTC) Hub Signage Program (HSP). The HSP implementation requirements for each of the stations are defined in **Section H, Station Signage**.

Caltrain's stations shall be designed to promote and sustain ridership growth, enhance the aesthetics and connectivity of the neighborhood and community, and promote safety and security by maintaining station visibility to the public and local enforcement entities. To the extent possible, Caltrain stations shall also serve as gateways in and out of a community for the origin/destination of passenger traffic. Refer to Caltrain's Station Access Policy for additional information on Caltrain's goals for access to stations and the station Access Hierarchy. Specifically, Caltrain's stations shall:

a. Be a safe and comfortable area for passengers

b. Be functional, user-friendly, convenient, and accessible to all users

c. Provide transit information and schedule updates to passengers

d. Be attractive to passengers and community alike

A station shall be as pleasant as possible for passengers. It should, to the extent possible, provide safe, direct, and comfortable circulation space by minimizing overcrowding in certain areas and minimizing any obstructions or conflicts. Provide passenger orientation, information, physical barriers, and grade level changes where appropriate to enhance safety and a user-friendly experience.

## 1.0 DESIGN RATIONALE

Caltrain stations consist of site access, bicycle and car parking, platforms, buildings (at select locations), tracks, and all appurtenances necessary to provide a safe, functional, and user-friendly public transportation facility.

Stations, to a certain extent, are site-specific; however, the functionality and physical appearance of the stations shall be practical and, to the extent possible, consistent. The design shall incorporate a family of station parts and furnishings that are interchangeable. The station shall be a permanent, functional, and pleasant feature that integrates the character of the neighborhoods and community yet maintains an overall Caltrain system identity and recognition.

The station design shall be governed by the following criteria.

a. Demonstrated ridership demand projected to 20 years: Request the current and 20-year future ridership demand from Caltrain. Delineate the footprint for the expanded station and parking.

b. Effect on overall commuter system performance: Analyze how the changes will affect the performance of the Caltrain commuter system as a whole.

c. Safety and accessibility: Provide a safe, secure, friendly, and enjoyable transit experience that is easily accessible and complies with Americans with Disabilities Act (ADA) requirements.

d. Integration with other transit systems: Integrate Caltrain with other public transportation systems for the convenience of passengers and the promotion of ridership growth.

e. Joint development opportunity with local agency (future development): Provide an architectural and urban design framework that defines and encourages joint development opportunities.

f. Sustainability design requirements: Establish project-specific sustainability goals in accordance with the framework and mandatory requirements of the latest version of the California Green Building Standards Code (CALGreen), Title 24, Part 11.

## 2.0 CODES AND REGULATIONS

Station and facility design shall comply, unless noted otherwise, with the latest revision of the codes and regulations listed in Appendix C and the accompanying Caltrain Standard Drawings and Standard Specifications. Should there be conflicts between codes, the most restrictive code shall apply.

## 3.0 CALTRAIN STATIONS

**Table 3-1, Caltrain Stations**, provides classification and a relative ridership ranking for each Caltrain station. The purpose of this table is to provide design information, in particular for station signage design and environmental clearance.

The classification and ranking have been established based on ridership (relative rank) and connectivity to other transits (including shuttles). The ranking and hierarchy are based on current information and statistics, and their relative positions may change. The table also includes identification of the seven stations with historical resources, which are listed under the National Register of Historic Places.

**Table 3-1: Caltrain Stations**

| | Station Name | Ridership Rank | Transit Connections |
|---|---|---|---|
| | | **Multi-Modal Stations** | |
| 1 | 4th and King | 1 | Muni (bus and LRT) |
| 2 | **Palo Alto** | 2 | SamTrans, VTA (bus), shuttles, Dumbarton Express bus |
| 3 | Mountain View | 3 | VTA (bus and LRT), shuttles |
| 4 | **Diridon** | 4 | VTA (bus and LRT), ACE, Capitol Corridor, Amtrak, Santa Cruz Metro, Greyhound, FlixBus |
| 5 | **Millbrae** | 7 | SamTrans, BART |
| | | **Tier 1 Stations** | |
| 1 | Hillsdale | 8 | SamTrans, shuttles |
| 2 | **Menlo Park** | 13 | SamTrans, shuttles |
| 3 | Redwood City | 5 | SamTrans, shuttles |

| | Station Name | Ridership Rank | Transit Connections |
|---|---|---|---|
| 4 | **Santa Clara** | 11 | VTA (bus), ACE, Capitol Corridor |
| | **Tier 2 Stations** | | |
| 1 | San Mateo | 9 | SamTrans |
| 2 | **San Carlos** | 18 | SamTrans |
| 3 | Tamien | 22 | VTA (bus and LRT) |
| 4 | California Ave | 12 | VTA (bus) |
| 5 | **Burlingame** | 17 | SamTrans |
| 6 | Belmont | 19 | SamTrans, shuttles |
| 7 | Bayshore | 23 | Muni (bus and LRT), SamTrans, shuttles |
| 8 | Sunnyvale | 6 | VTA (bus) |
| | **Tier 3 Stations** | | |
| 1 | 22nd Street | 10 | Muni (bus) |
| 2 | San Antonio | 14 | VTA (bus) |
| 3 | Lawrence | 16 | N/A |
| 4 | San Bruno | 20 | SamTrans |
| 5 | South San Francisco | 15 | SamTrans, shuttles |
| 6 | Morgan Hill | 24 | VTA (bus) |
| 7 | Hayward Park | 21 | SamTrans |
| 8 | Gilroy | 25 | VTA (bus), MST, San Benito County Express, Greyhound |
| 9 | College Park | 28 | VTA (bus) |
| 10 | Blossom Hill | 26 | VTA (bus) |
| 11 | San Martin | 29 | VTA (bus) |
| 12 | Capitol | 27 | VTA (bus) |

Notes:

i. As part of the ADA requirements, FTA designated the following 10 stations to be key access stations: 4th and King, San Mateo, Hillsdale, Redwood City, Palo Alto, Mountain View, Sunnyvale, Santa Clara, Diridon, and Tamien. These stations are currently FTA-compliant.

ii. Station names in **bold** are listed on the NRHP.

iii. Only Palo Alto station is under the purview of SHPO, not SBHRS.

iv. Palo Alto station is owned by Stanford University.

v. Broadway and Stanford stations are not included in the table as they have limited operating hours.

ACE = Altamont Corridor Express
AC Transit = Alameda-Contra Costa Transit District
ADA = American with Disabilities Act
BART = Bay Area Rapid Transit
FTA = Federal Transit Administration
LRT = light-rail transit
MST = Monterey-Salinas Transit
Muni = San Francisco Municipal Railway
NRHP = National Register of Historic Places

SamTrans = San Mateo County Transit District
SBHRS = South Bay Historical Railroad Society
SHPO = State Historic Preservation Office
VTA = Santa Clara Valley Transportation Authority

## B. SITE CONSIDERATIONS

The development of new stations or the alteration of existing stations shall consider other stakeholders, such as local agencies (cities) and the community.

### 1.0 COMMUNITY INVOLVEMENT

Collaborate and/or partner with local agencies to obtain inputs, including the possible involvement of the community, to establish a sense of "place" at the station, to instill a sense of ownership by the community, and to make the station a recognizable feature along the corridor. The following key aspects shall be considered:

a. Station layout: Initiate and coordinate inputs from various stakeholders, including the community and local agency that will complement station development and increase ridership.

b. Station elements: Select design, types, and materials for canopies, fence, windscreens, and other elements in the station.

c. Neighborhood character: Preserve, maintain, and enhance existing qualities, characteristics, or architectural elements that are valued by the local community.

Station areas or structures designated by the State Historic Preservation Office (SHPO) as being of historical value shall be evaluated for potential applicability of requirements of the National Historic Preservation Act. As part of the environmental clearance process, designers shall collaborate with the South Bay Historical Railroad Society, representing SHPO, and its counterparts in the cities and counties, to identify and evaluate potential impacts as well as mitigation measures for historical areas or structures in station and site design.

### 2.0 JOINT DEVELOPMENT

Caltrain and community planners shall explore potential opportunities for transit-oriented development (TOD) adjacent to Caltrain stations. While TOD must be designed to balance the objectives of providing a convenient and pleasant experience for Caltrain passengers and providing opportunities for mixed-use development, designs must prioritize convenient access for Caltrain passengers.

For alterations of existing stations, the design should generally match the existing architectural elements. For construction of new stations, the design should follow the guidelines below:

a. Recognize emerging developments that can complement station development and increase ridership

b. Initiate and coordinate programs with the community that limit local traffic impacts and minimize disruption during and after the implementation phase

## C. CLEARANCES

All facilities adjacent to tracks shall meet the requirements of California Public Utilities Commission (CPUC) General Order 26-D for clearances. Caltrain has additional clearance requirements that are more stringent than CPUC requirements. Refer to **Figures 3-1** and **3-2** for Caltrain's minimum clearances (horizontal and vertical) for various elements at station platforms.

### 1.0 OBJECTIVES

The clearance requirements at Caltrain stations are safety-critical due to the current operational characteristics of Caltrain, namely express trains through most stations and the high frequency of train service. The horizontal clearances at the stations are established for the following passenger safety and operations requirements:

a. Passenger access and circulation

b. Special consideration for persons with mobility impairments, their space needs, and special boarding needs

c. Clear sight distance for passengers of the at-grade pedestrian crossing warning system, the visual message sign (VMS), and the approaching trains

d. Clear sight distance for passengers of station signage

e. Clear sight distance for train crew

f. Operational configuration: boarding assistance area (BAA) and mini-high platforms are on the northern third of the platforms. Bicycle cars are located at the third and sixth train cars from the north on a seven-car EMU consist.

g. Additional space anticipated to accommodate the needs of various types of passengers (persons with mobility impairments, bicyclists, and persons with luggage, children, and strollers)

### 2.0 HORIZONTAL AND VERTICAL CLEARANCES

### 2.1 HORIZONTAL CLEARANCES

The following minimum horizontal clearances from nearest track center shall be observed. Any deviation from these clearances must be approved via Caltrain's Standard Procedure for Design Variances. Refer to **Figures 3-1** and **3-2**. For mini-high platforms, see the Caltrain Standard Drawings.

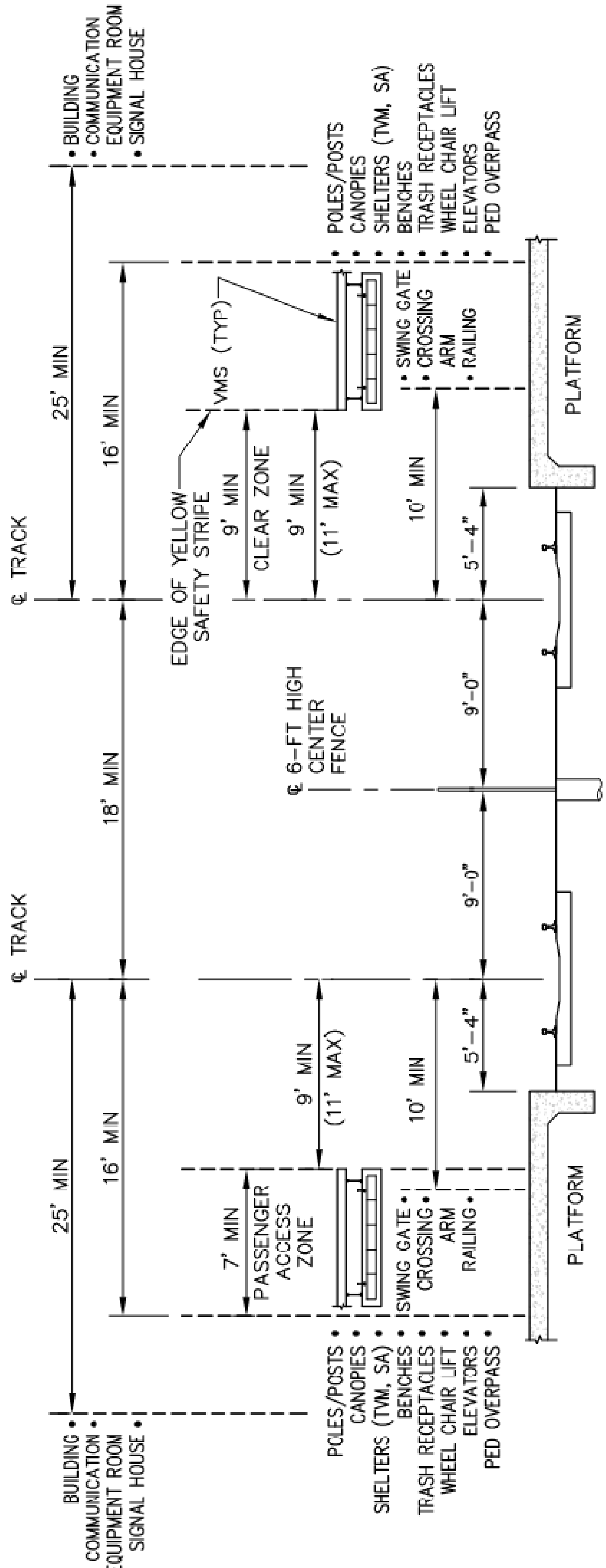
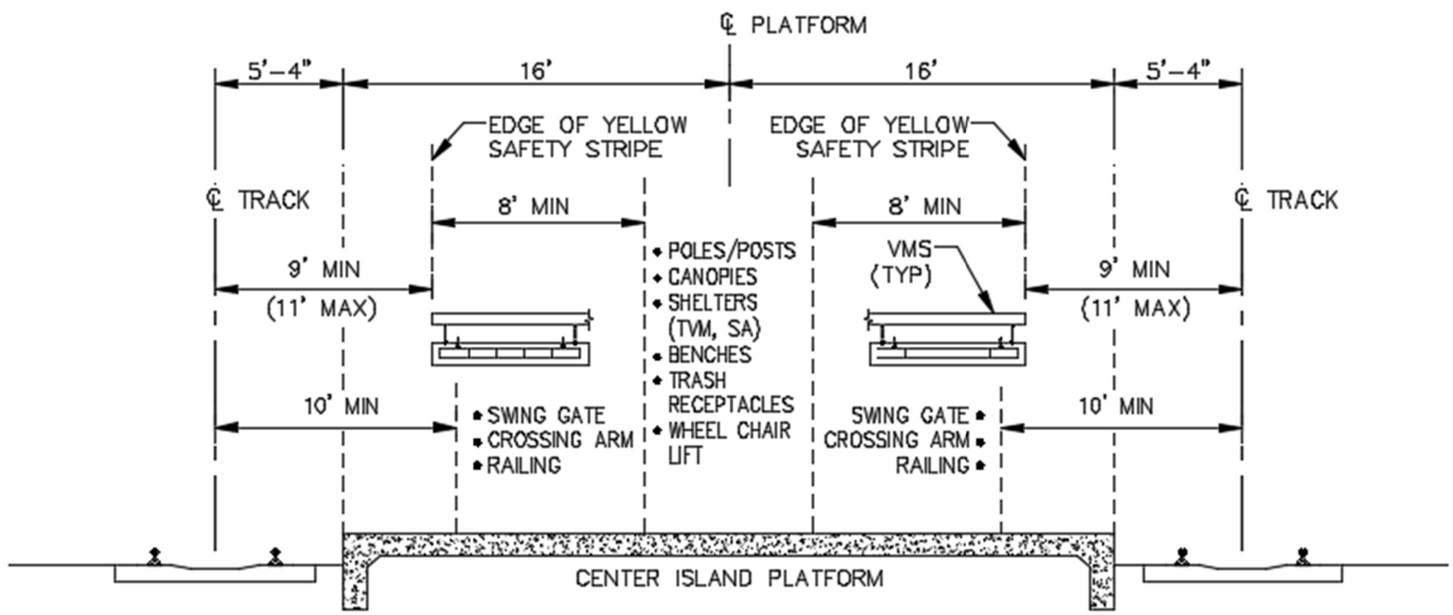



**Figure 3-1: Minimum Clearances at Station Platforms, Outboard Platform**




***Note:*** *Buildings, communications equipment room, signal house at 25' from the closest track centerline.*

**Figure 3-2: Minimum Clearances at Station Platforms, Center Island Platform**

a. Permanent Structures: 25 feet

Permanent structures include station buildings, the communications equipment room (CER), and trees (any size).

b. Minor Structures at Stations: 16 feet (Outboard platform)

17 feet (Center island platform)

Minor structures at stations include canopies, passenger shelters, ticket vending machine (TVM) shelters, light poles, OCS poles, signage and display case posts, benches, trash receptacles, BAA (bench and wheelchair lift), and landscaping. OCS pole foundations, including base plates and anchor bolt assemblies, at stations shall be fully buried below concrete platform finish surface to minimize impedance to passenger flow.

c. At-Grade Pedestrian Crossing: 10 feet

Crossing warning devices include swing gates, automatic pedestrian gate arms, railings, and associated signal apparatus.

d. Signal Houses: 16 feet, preferably 25 feet

Signal houses need to be located in such a way that they provide the sight view required for the signal maintainers. The houses shall be located as far away as possible from the tracks, but within the existing right-of-way (ROW).

e. Visual Message Signs: 9 feet

The edge of the panel board of the VMS shall be no closer than 9 feet from the nearest track center.

f. Return Fence at the Ends of a Station Platform: 9 feet

### 2.2 VERTICAL CLEARANCES

Any new overhead structures shall be designed with a minimum vertical clearance of 24 feet 6 inches from the top of rail. The overhead structures include bridges and overhead pedestrian crossings. Vertical clearances for overhead structures must also take into account the Overhead Contact System (OCS) wires. Refer to the Caltrain Electrification Standards for detailed requirements. No overhead utilities of any kind are allowed.

## D. STATION CONFIGURATION

Consideration shall be given in the design to possible track additions and possible extensions in the future for longer train consists. Station designers shall seek input from Caltrain in determining requirements for possible future station expansion.

The station layout shall include provisions for maintenance vehicles to access the tracks on both sides of the station. If this access is to be provided from the public parking or driveway areas, a locked gate shall be installed to keep unauthorized vehicles from entering the ROW.

## 1.0 BOARDING PLATFORMS

The standard for Caltrain station platforms is center island platform.

Center Island Platform: A center island platform is a single platform that services tracks on each side of the platform. The center island platform arrangement is considered to offer the most efficient use of platform space and furnishings.

See **Figures 3-3** and **3-4** for typical platform arrangements. See Caltrain Standard Drawings (SD 3000 series) for further details.

Use of the outboard platform (Figure 3-4) must be approved via Caltrain's Standard Procedure for Design Variances. Outboard platforms should only be considered when all other alternatives have been exhausted. Design information for outboard platforms is provided solely to guide the designer in the event that such a platform is required, not as an alternative for convenience.

Staggered platforms are outboard platforms where the platforms do not align. These platforms may sometimes stagger on two sides of a crossing street. These platforms are neither efficient nor convenient for passengers, and may only be used on a temporary basis, such as in a temporary station during construction.

Platforms, including potential extensions, will be located at least 100 feet from the nearest road crossing to prevent a stopped train from obstructing the crossing. If the location of the station causes train operations to be affected by the "Train Delayed within a Block" rule (GCOR 9.9), the station project shall include modifications to the signal system to avoid such delays. This is usually accomplished by adding or re-spacing automatic block signals.

## 1.1 PLATFORM DIMENSIONS

Platforms shall be at an elevation of 8 inches above the top of rail. The platform edge shall be 5 feet 4 inches from the centerline of the nearest track. Platforms are to be constructed of concrete with flush vertical wall on the track side. Designers shall seek input from Caltrain on the final profile and alignment for the tracks through the station area to establish the platform elevation.

The criteria for platform dimensions are presented in the following paragraphs. See Caltrain Standard Drawings for further details.

a. Platform length: The standard platform length shall be 875 feet to accommodate a 10-car EMU consist. See **Figure 3-5** for station "footprint" requirements and platform configurations. The potential for further platform lengthening should be considered in consultation with Caltrain Planning as platform redesigns are considered.

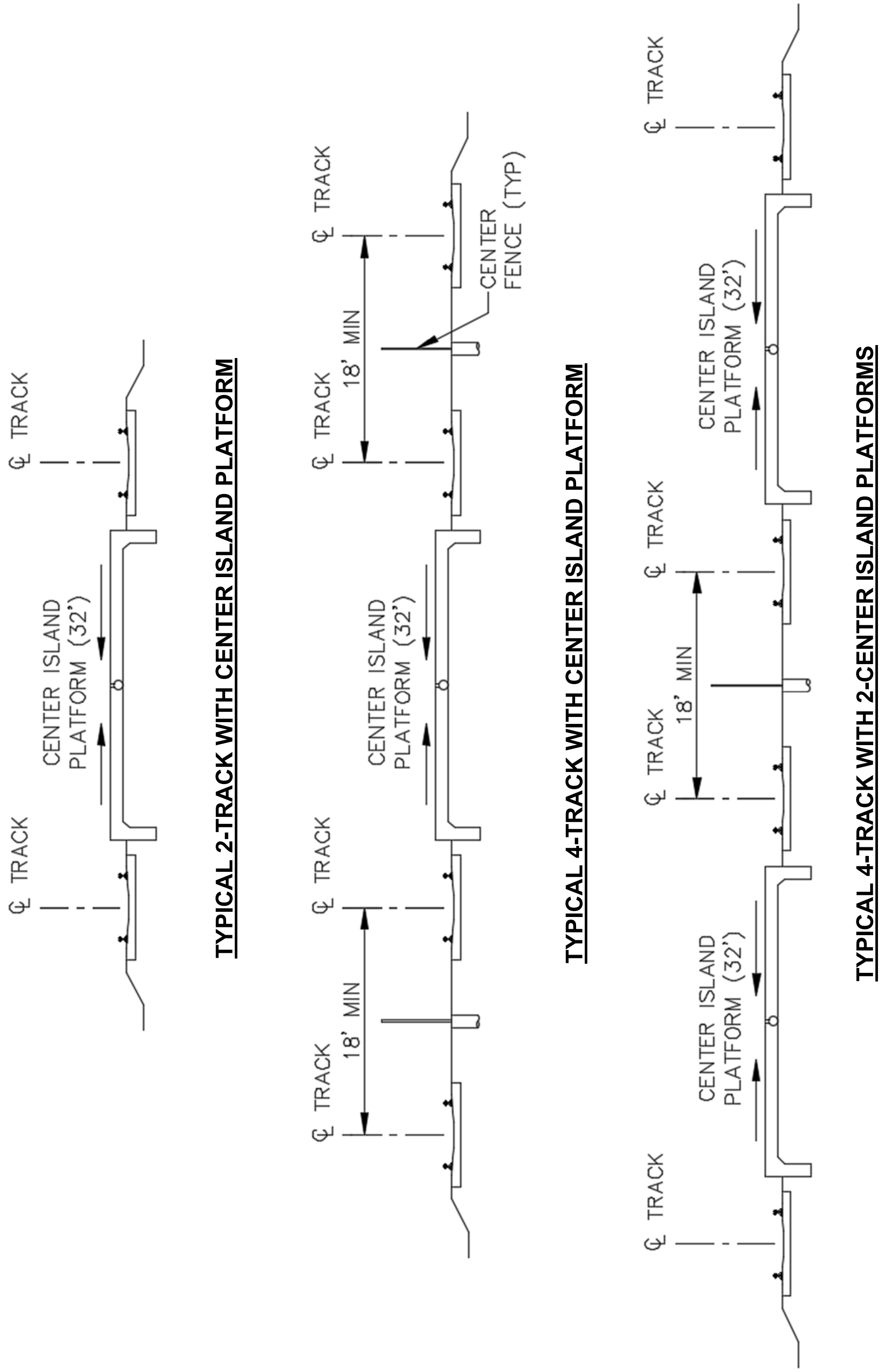



Figure 3-3: Typical Center Island Platform Arrangements

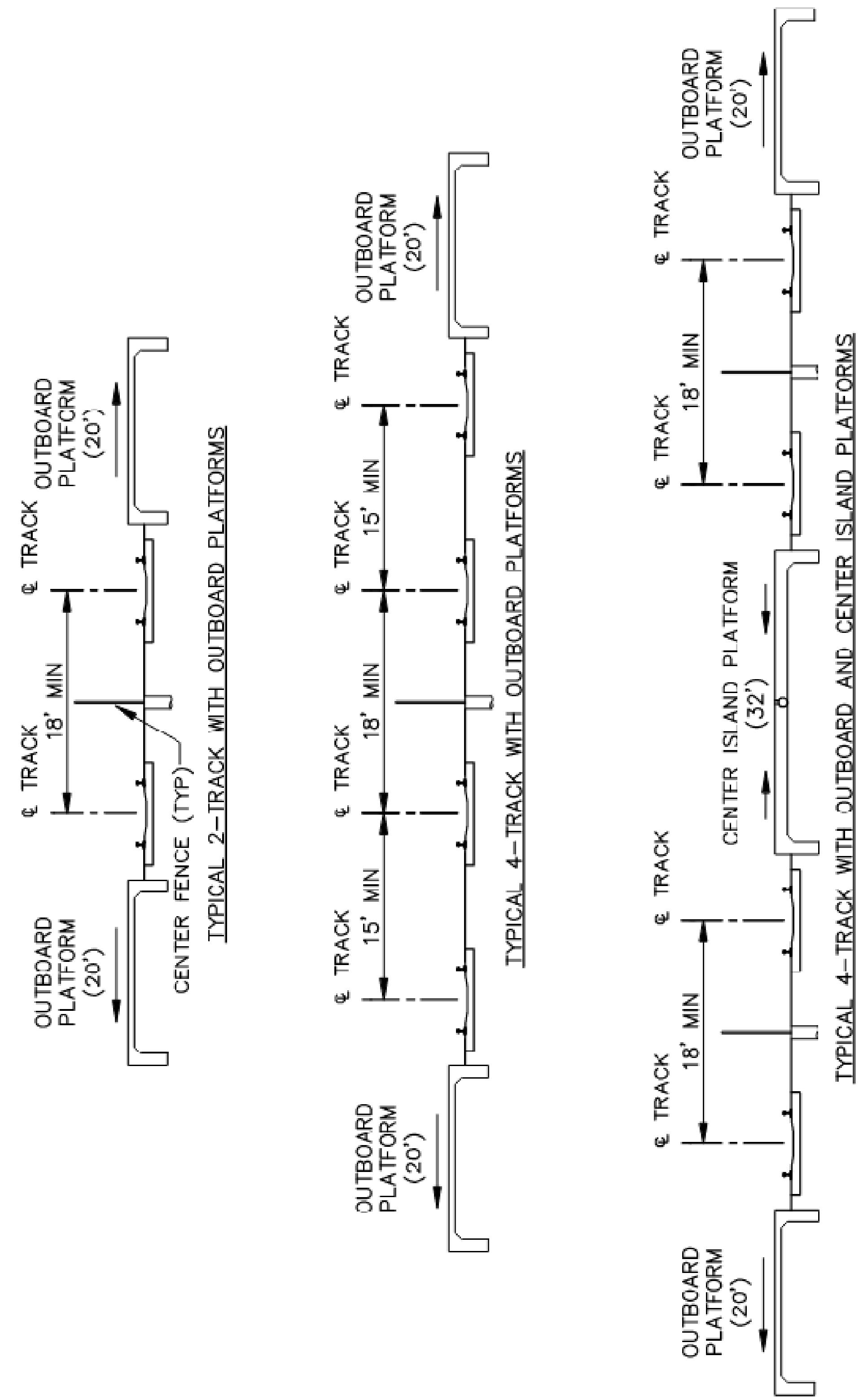



**Figure 3-4: Typical Outboard Platform Arrangements**

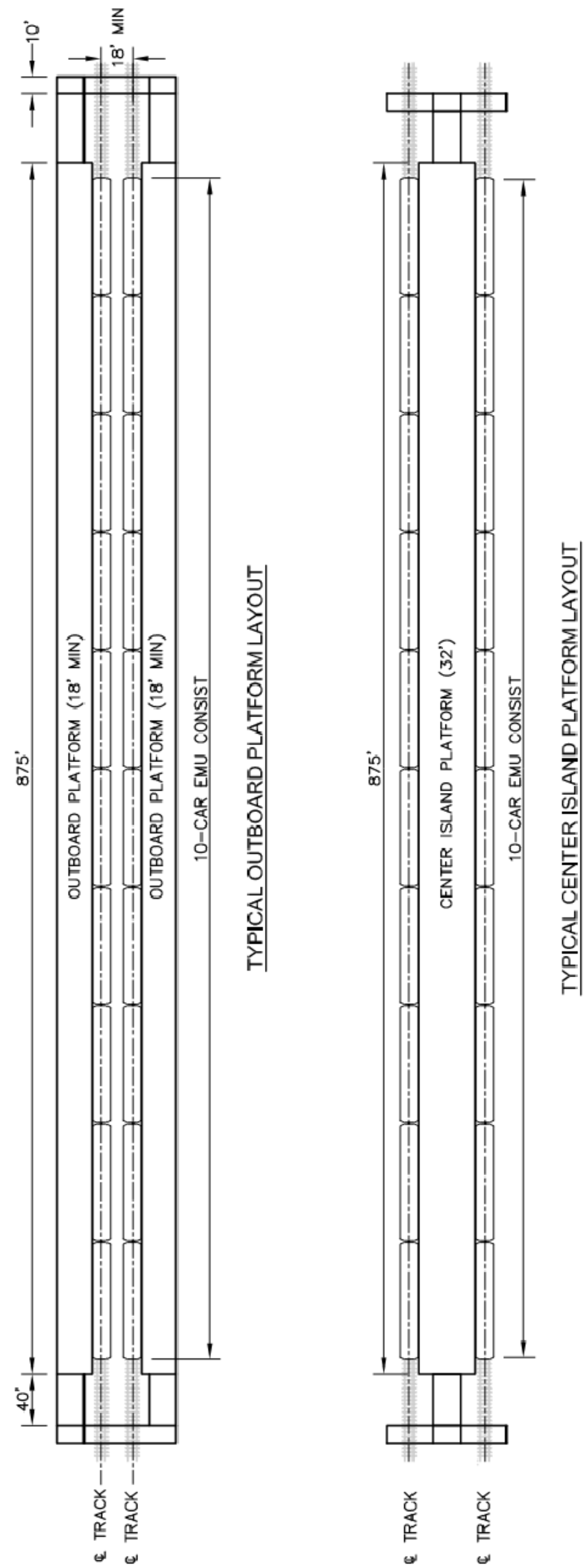



**Figure 3-5: Typical Platform Footprint Requirements**

b. Platform width: The platform shall be 20 feet wide for an outboard platform and 32 feet wide for a center island platform. The wider center platform is needed to accommodate stairways, ramps, and/or elevators, shelters, and passenger access and circulation safety. A minimum clear walkway width of 7 feet from the edge of the yellow safety stripe shall be maintained for the entire length of outboard platforms.

   However, for center island platform, the clear walkway width shall be increased to a minimum 8 feet from the edge of the yellow safety stripe to the platform structures (stairways, elevators).

c. Platform longitudinal slope: The station platforms shall be on a track segment that is tangent, on level surface, and have the same grades as the tracks served. Track grades through a station of more than 1 percent shall not be considered.

d. Platform cross slope: This slope is required for drainage purposes. The slope shall generally be 1 percent (2 percent maximum, in accordance with ADA Standards) and shall slope away from the tracks to minimize the risk of wheelchairs naturally rolling toward the tracks. This will also aid in track drainage, by directing the surface water away from the track structure. At center island platforms, an underdrain shall be provided at the center of the platform width.

e. Platform curve: Curved track through the station, whether horizontally or vertically curved, shall be avoided. If unavoidable, the curve shall be as shallow a curve as possible, to no more than 0 degrees and 50 minutes, and at either end of the platforms. Platforms on curves shall require prior approval from the Caltrain Director of Engineering.

f. Track centers: Track centers at outboard station platforms shall be expanded to a minimum of 18 feet to accommodate center fencing, so that the fence is at least 9 feet clear from the track center. The center fence shall extend a minimum of 100 feet beyond the ends of the platforms. If there are at-grade pedestrian crossings at the stations, then the fence shall continue to the edge of the crossings, and extend a minimum of 100 feet beyond the at-grade pedestrian crossings.

## 1.2 TEMPORARY STATION

To allow continued passenger service at the station during construction activities, a temporary station shall be constructed as part of the construction staging. Requirements of temporary station platforms are generally the same as for permanent stations, with the following exceptions:

a. The minimum platform length is 615 feet, with a minimum platform width of 12 feet for an outboard platform. This platform length allows for the functional operation of a seven-car EMU consist. Additional platform length shall be confirmed with Caltrain Engineering if typical operational consists have been modified from this baseline.

b. The platform may be constructed of asphalt concrete to expedite construction. ADA-compliant detectable warning surface is required at the boarding edge of a platform, except at a holdout rule station. The selected detectable warning material shall be compatible with the material used for platform construction.

## 2.0 ADA REQUIREMENTS

Access to Caltrain stations shall conform to the requirements of the ADA, Section 504 of the Rehabilitation Act of 1973, as amended, and the United States Department of Transportation's implementing regulations at 49 Code of Federal Regulations (CFR) Parts 27, 37, 38, and 39. Since passage of the ADA in 1990, transit agencies have worked to make America's public transit system accessible for people with disabilities. As transit agencies continue to improve accessibility, many generate questions or receive public inquiries about complying with the comprehensive ADA regulations. To help transit system leadership and staff, the Federal Transit Administration (FTA) published detailed guidance in a user-friendly, one-stop resource describing ADA requirements and how to implement them in ADA Circular C 4710.1. This circular provides a full spectrum of design checklists to assist designers in ADA compliance verification of various design elements. Designers shall complete all applicable checklists to demonstrate that their designs meet ADA requirements.

At least one accessible route shall be provided at the site from accessible parking spaces and accessible passenger loading zones; public streets and sidewalks; and public transportation stops to the accessible building or facility entrance they serve. All platform and parking lot facilities must comply with the referenced codes.

Refer to Caltrain Standard Drawings for further details regarding each of the elements discussed below.

## 2.1 DETECTABLE WARNING SURFACE

Detectable warning surfaces are an ADA required safety feature consisting of a band of contrasting color and texture used to help persons with visual impairments identify the safe setback from moving trains and to warn of the platform edge and drop-off to the track. At at-grade pedestrian platform crossings, the detectable warning surfaces also identifies track crossings and signifies clear points of crossing.

The detectable warning surfaces shall be ADA-compliant with a truncated dome design and installed at the following locations:

a. Platform edge on the track side: The detectable warning surfaces shall be 2 feet wide along the entire length of the platform, and 3 feet wide at the returns at each end of the platforms.

b. Edge of the mini-high platforms facing the track: The detectable warning surfaces shall be 2 feet wide along the edge of the mini-high platforms.

c. Station at-grade pedestrian crossings: The detectable warning surfaces shall be 3 feet wide and placed in front of the crossing gates.

See Caltrain Standard Drawings (SD-3000 series) for further details.

## 2.2 YELLOW SAFETY STRIPE

A 6-inch-wide yellow stripe (federal yellow) shall be painted behind the detectable warning surfaces. The far side of the stripe shall mark a distance of 9 feet from the center of the track. Six–inch-high letters reading "**WAIT BEHIND YELLOW LINE**" shall be painted behind the stripe to indicate where passengers shall stand. The marking shall line up with the car doors. Refer to Caltrain Standard Drawings for dimensional information.

## 2.3 DETECTABLE DIRECTIONAL DETECTABLE WARNING SURFACE

Platforms shall be treated with directional and guide detectable warning surfaces to assist persons with visual impairments in locating the persons needing assistance (PNA) shelter and one of the TVMs at each platform. The detectable warning surface shall also be installed to identify the limits of the mini-high platforms. For users with visual impairments, consistency in directional detectable warning surface design makes Caltrain station access more predictable and easier to navigate. Complex directional detectable warning surface systems are not encouraged. Additionally, directional detectable warning surfaces other than those described must be approved via Caltrain's Standard Procedure for Design Variances. See Caltrain Standard Drawings (SD-3000 series) for further details.

## 2.4 MINI-HIGH PLATFORM

Mini-high platforms shall be installed to assist with boarding of persons with mobility impairments. The mini-high platform shall be aligned with the second train car from the north. See Caltrain Standard Drawings for details of the design of the mini-high platform.

## 2.5 BOARDING ASSISTANCE AREA

A Boarding Assistance Area (BAA) shall be provided on each platform. The BAA shall be aligned with the second train car from the north. The area shall be marked "**BOARDING ASSISTANCE AREA,**" and must include a shelter dedicated for use by persons with mobility impairments.

## 2.6 WHEELCHAIR LIFT

All stations shall be equipped with a manually operated wheelchair lift. The lift shall be adjacent to the shelter at the BAA. The lift shall be secured inside a lockable metal shed accessible only to train operations personnel. Refer to Caltrain Standard Specifications and Drawings for the technical requirements for the lift and shed.

## 2.7 LEVEL BOARDING

CFR Title 49, Part 37.42 requires that the operator of a commuter, intercity, or high-speed rail system must ensure that all new or altered stations meet the performance standard that all individuals with disabilities, including individuals who use wheelchairs, must have access to all accessible cars available to passengers without disabilities.

For a new or altered station, in which no track passing through the station and adjacent to platforms is shared with existing freight rail operations, the performance standard cited above must be met by providing level-entry boarding to all accessible cars in each train that serves the station.

For a new or altered station, in which track passing through the station and adjacent to platforms is shared with existing freight rail operations, the railroad operator may comply with the performance standard cited above by using one or more of the following means:

a. Level-entry boarding

b. Car-borne lifts

c. Bridge plates, ramps, or other appropriate devices

d. Mini-high platforms, with multiple mini-high platforms or multiple train stops, as needed, to permit access to all accessible cars available at that station

e. Station-based lifts

Before constructing or altering a platform at a station at which a railroad proposes to use a means other than level-entry boarding, the railroad operator must submit a plan to the Federal Railroad Administration (FRA) and/or FTA, describing the means proposed to meet the performance standard at that station. The plan must demonstrate how boarding equipment or platforms would be deployed, maintained, and operated; and how personnel would be trained and deployed to ensure that service to individuals with disabilities is provided in an integrated, safe, timely, and reliable manner.

If the means of meeting the performance standard is not using car-borne lifts, the railroad operator must perform a comparison of the costs (capital, operating, and life-cycle costs) of car-borne lifts and the means chosen, as well as a comparison of the relative ability of each of these alternatives to provide service to individuals with disabilities in an integrated, safe, timely, and reliable manner. This analysis shall be included in the plan submitted to FTA and/or FRA for approval.

Union Pacific Railroad (UPRR) possesses a perpetual and exclusive easement to operate freight train service on the Caltrain corridor, as delineated in the "Trackage Rights Agreement – Peninsula Main Line and Santa Clara/Lick Line" (Agreement) dated December 20, 1991. All Caltrain main line tracks are shared with UPRR freight trains. In addition, all existing Caltrain platforms are at 8 inches above the top of rail. Therefore, before a system-wide level boarding update is implemented, new station platforms shall be designed to 8 inches above top of rail if approved by FRA and FTA. Designers shall prepare a boarding access plan as described above, and submit it to FTA and FRA for approval. However, design consideration shall be given to allow for easy modification, to accommodate higher platform elevations for future level boarding. One such example is to extend the ramps to station at-grade pedestrian crossings to 40 feet long to allow for higher boarding level in the future.

### 3.0 UTILITIES

The platform surface shall be as smooth and uniform as possible. The utility duct bank shall be located so that utility access covers such as vaults, pull boxes, handholes, and maintenance holes are not in the main pedestrian walkways or passenger circulation areas. For center island platforms, the duct bank shall be offset from the platform centerline to avoid conflicts with features such as light pole foundations, stairs, and ramps. The access covers shall be flush with the platform surface.

### 4.0 DRAINAGE

Positive drainage away from the walkways, tracks, and platforms shall be provided. The entire station site and contiguous railroad ROW shall be drained.

All station platform surfaces shall slope at 1 percent (2 percent maximum, in accordance with ADA requirements) away from the track. Such a slope down and away from the track will both address a safety consideration by eliminating the rolling tendency of wheelchairs toward the tracks and drain platform runoff water away from the tracks to avoid overtaxing the track structure underdrain system.

For center island platforms, the platform drain shall be at the center of the platform, with area drains such as trench drains for discharge to the nearest municipal drainage collection system.

To enhance the effectiveness of the drainage at the station area, the subballast of the track structure shall be constructed with 8-inch-thick hot-mix asphalt concrete (HMAC). The HMAC shall extend 10 feet beyond the limits of the platforms, or 10 feet beyond the at-grade pedestrian crossings, if such exist. Six-inch polyvinyl chloride (PVC) perforated underdrain pipe shall be installed between the tracks to collect and carry the water to the municipal stormwater system. Track structure drainage shall be provided with a 2 percent slope toward the underdrain.

Pedestrian underpass drains shall discharge to the appropriate municipal collection system.

Drainage design shall be in accordance with the standards and practices of the site-specific local jurisdictions. In cases where the local jurisdictions have no codes or standards, Caltrans standards and/or Caltrain standards shall be followed. Caltrain drainage requirements are covered in **Chapter 8, Civil Design**.

## E. ACCESS AND CIRCULATION

Caltrain passengers access the stations by bus, automobile, motorcycle, bicycle, on foot, and other transit systems (SamTrans, Muni, VTA, Amtrak, BART, ACE, Capitol Corridor, etc.) To promote the use of the stations and to reduce dependence on the automobile, Caltrain encourages provision of intermodal connections at its stations. The overall station layout shall afford the following:

a. Operational efficiencies that simplify modal interchange and passenger processing

b. A safe, efficient, and convenient configuration for intermodal transfer at the station

c. Clear and easily understood transit information that can be referenced quickly and that minimizes disorientation

Good pedestrian access and circulation to and from station entrances and parking, and across train platforms, are essential for the smooth and safe operation of stations. Access and circulation patterns should be as simple, obvious, and comfortable as possible.

## 1.0 PRACTICAL DESIGN CONSIDERATIONS

The following are the major points that warrant careful review for applicability and consideration in achieving good pedestrian access and circulation:

a. Avoid unnecessary turns and dead ends. Pedestrian access from bus, kiss-and-ride, and park-and ride areas shall be as clear and as simple as possible.

b. Use color, texture, and sight distances to increase visual pleasure, guidance, patron safety, and security at all circulation elements.

c. Provide adequate space to avoid bottlenecks.

d. Avoid cross-circulation at fare collection and decision points. Generally provide right-hand circulation.

e. Provide adequate space so that queues at fare collection areas do not block the pedestrian traffic.

f. Locate passageways, shelters, and stairways to encourage balanced train loading and unloading.

g. Minimize grade changes. Where necessary, grade changes shall conform to ADA accessibility requirements.

h. Cross flows, dead ends, and turns greater than 90 degrees are undesirable for both patron security and circulation.

i. Design circulation to provide ample space adjacent to, but out of the main stream of, pedestrian flow. This will accommodate disabled, infrequent, or waiting patrons.

j. Provide surge and queuing spaces ahead of every barrier and change in circulation, direction, or mode.

k. Avoid obstructions such as pylons, advertising displays, concessions, seating, or maps in the pedestrian through zone.

l. Avoid locating platform components such as railings, windbreaks, or other obstructions that would impact the locomotive engineer’s line of sight as the train approaches or leaves the station.

m. Provide a minimum of two points of access/egress from the platform that meet the requirements of National Fire Protection Association 130.

## 2.0 ACCESS MODES TO STATIONS

On Foot: Provide the shortest travel path from station entrances to the platforms. All access paths shall be ADA-compliant, and without interference from other access modes.

Bicyclists: Space shall be provided for bicycle lockers and racks at every station, but not on boarding platforms. These facilities shall be located to minimize conflicts with pedestrian and vehicular traffic, make the most effective use of roadways and curb cuts, and reduce the need for special graphics.

Automobiles: Automobile access shall be provided in a manner that meets all state and local codes. To the extent practical, provide a “Kiss-and-Ride” or automobile drop-off area near a platform access as part of the parking area layout. Depending on the need and ridership of the station, a taxi waiting area may also be provided as part of the parking area layout. Provide adequate ADA parking stalls near the primary platform entrances, with accessible routes clearly delineated by markings and signage.

Public Transit: Passengers transferring from other public transit services require high-quality connections to Caltrain. The design of these connections should minimize travel distance and provide wayfinding signage and information to maximize customer convenience.

## 3.0 STATION CIRCULATION

Safety is the most important design consideration regarding passenger circulation on platforms. A minimum 7-foot-wide (for outboard platforms; 8-foot for center island platforms) passenger circulation path from the edge of the yellow safety stripe shall be provided along the entire length of the platform to promote a clear line of sight or visibility of approaching trains. There shall be no columns, posts, or other structures in this path. This will allow sufficient width for the passing of two wheelchairs side by side, or four persons side by side. This will also allow for ease of boarding and alighting of passengers, movement of passengers with carry-on items (luggage, strollers, etc.) or bicycles, and operation of a wheelchair lift.

## 3.1 PEDESTRIAN CROSSINGS

Pedestrian crossings include pedestrian overhead, underpasses, and at-grade crossings. The preferred design shall have completely grade-separated pedestrian access to the platform(s), with a center fence between the tracks where applicable to prevent persons from crossing between platforms at grade. Pedestrian underpasses are preferred to overheads because they have much shorter travel distances. If designed attractively, underpasses enhance usage.

For new stations, pedestrian at-grade crossings shall only be used when grade separated crossings are not feasible. New station at-grade crossings, if used, are intended for station circulation only, and are generally not a part of an overall circulation for the public at large. All new at-grade pedestrian crossings require a formal CPUC application process.

An emergency service crossing is typically for the use of maintenance vehicles, and may also be included in the stations with pedestrian underpasses or overhead for emergency egress, to reduce costs for constructing a second underpass or overhead. Designers shall consult with Caltrain regarding the applicability of this service crossing.

Structural design of pedestrian overhead and underpasses shall be in accordance with *Peninsula Corridor Joint Powers Board Standards for Design and Maintenance of Structures.*

### 3.1.1 Pedestrian Overhead

A pedestrian overhead is typically considered where the track is below natural grade. The overhead span shall be a minimum of 24 feet 6 inches clear above the top of rail while maintaining sufficient clearance from elements of the overhead contact system, and shall be a minimum of 12 feet wide. The overhead can be served by stairs, ramps, or elevators complying with ADA requirements. A stair and ramp design is preferred.

The overhead tower structure shall be a minimum of 16 feet clear from the centerline of the track. Overheads with open sides shall have protective railings and shall be equipped with security screens for the full height of the sides to prevent the dropping of objects from the overhead. Particular attention must be paid to the wayside signal line of sight when an overhead is constructed.

### 3.1.2 Pedestrian Underpass

A pedestrian underpass is generally preferred to an overhead where the track is at grade or elevated on an embankment. Underpasses shall be straight runs, without corners or curves, to provide through visibility. The underpass at stations shall be at least 16 feet wide and 10 feet high at the crown (9 feet at the side walls), creating an arch to soften the passage perception. The underpass shall be located where it is most convenient to the users.

For underpasses where there is considerable use by the public at large (pedestrians, bicycles, etc.) and as part of the local planning, the width should be increased to 20 feet, 12 feet high (crown), and 10 feet (side). ADA-compliant access must be provided in a manner similar to that discussed above for overheads. Closed-circuit television (CCTV) cameras shall be installed at all pedestrian underpasses. Electrical and communications conduits should be installed at each end of an underpass to support electronic signage and CCTV.

### 3.1.3 At-Grade Pedestrian Crossings

At-grade crossings are clearly-defined crossings for pedestrians where the surface of the crossing is level with the top of rails and the surrounding area. At-grade crossings at stations shall be constructed at the end(s) of the platforms, which eliminates blockage of the crossing by a standing train. All at-grade pedestrian crossings shall be equipped with automatic warning devices. Crossing surfaces shall be a minimum of 10 feet wide with end ramps of HMAC at 1:8 slopes (maximum).

If there is an existing roadway crossing equipped with automatic warning devices directly adjacent to a station, it may be an acceptable at-grade passenger/pedestrian crossing. It is preferable to use an existing crossing rather than to add an additional at-grade crossing. The station designer shall seek input from Caltrain and evaluate the existing crossing to determine whether improvements are necessary.

At-grade crossings are described in more detail in **Chapter 7, Grade Crossings**.

## 3.2 WALKWAYS

Walkways shall be 8 feet wide to allow for passage between pedestrians and bicyclists, except that walkways at crossings shall be 10 feet wide. Adequate sight distance and visibility shall be provided along pedestrian routes. Pedestrian walkways shall be well lit. Refer to **Section I** of this chapter for lighting requirements.

## 3.3 VERTICAL CIRCULATION

Provide stairs and ramps if required. Elevators and escalators are not preferred due to maintenance requirements and costs. Site selection, however, should serve to eliminate the need for vertical circulation. All vertical circulation elements shall conform to all building code requirements and accessibility standards per ADA Accessibility Guidelines and California Code of Regulations (CCR), Title 24.

### 3.3.1 Stairs and Ramps

Stairs and ramps shall be provided where grade changes make vertical access to platforms a necessity. Exterior stairs at Caltrain stations are cast-in-place concrete. Use of precast concrete or steel stairs is discouraged. Design of new stairs and ramps should take into consideration future platform height changes associated with the implementation of level boarding.

### 3.3.2 Elevators

Elevators may be considered for platform access only where vertical distance makes ramps impractical, which is generally defined as a vertical rise greater than 12 feet. Elevators shall be installed only with the approval of the Caltrain Director of Engineering. Elevators should be adjacent to the main access point of platforms.

Because elevators are highly maintenance-intensive for functional and general upkeep, they are generally economically unfavorable. Permitting by the state requires that the machinery undergo mandatory regular safety inspections.

### 3.3.3 Escalators

Escalators may be considered for platform access where stair rise exceeds 24 feet in height and where justified by passenger volume, and only with the approval of the Caltrain Director of Engineering. Escalators serving platforms shall be fully enclosed in weather-tight structures, and enclosed landings shall be provided at the platform level.

### 4.0 PARKING

Parking lots/structures are elements that are determined by ridership and available land use and ownership. Caltrain will coordinate with local jurisdictions for parking lot requirements. Parking structures shall be addressed on a project-specific basis.

The size and shape of the site are the principal determinants in designing the most efficient parking lot layout, with positive drainage away from the tracks. Parking layout should minimize the length of the accessible route to the platforms. Whenever the site permits, parking lot aisles should be oriented and located perpendicular to the platforms to facilitate access to and from the platform, and to avoid the need for passengers to walk between parked cars.

The required number of parking spaces shall be based on ridership and will be provided by Caltrain. Allowances shall be made for accessible spaces, bicycle lockers, and potential van and carpool spaces. Loading and unloading areas for buses, minibuses, vanpools, and cars shall be provided as appropriate for the anticipated vehicle population.

ROW availability may constrain the provision of the minimum required spaces. Designer shall seek input from Caltrain on a case-by-case basis in determining the minimum required spaces.

Parking lot walkways shall have a minimum 8-foot clear path of travel. Vehicles shall not encroach on the path of travel.

Parking areas adjacent to the Caltrain ROW shall be fenced in accordance with **Section G** of this chapter.

## F. FURNISHINGS AND AMENITIES

All station platform furnishings and amenities shall be standardized to provide familiarity to the users and to provide a uniform appearance. The standardization also facilitates ease of maintenance and replacement. Station furnishings include shelters, bicycle lockers, bicycle racks, benches, news racks, and trash receptacles. Station amenities include a passenger information system and a fare payment system.

The principles of CPTED shall be applied to all furnishings and amenities. To prevent vandalism, each of the furnishings and amenities shall be securely fastened to the platform, and those secured on poles or posts shall be at adequate height.

Caltrain Standard Drawings provide general layouts and design requirements for each of the furnishings and amenities.

## 1.0 FURNISHINGS

Station furnishings include all furniture located on the platforms and in the station buildings for the comfort and convenience of passengers. For placement of furniture and signs on the platforms, see Caltrain Standard Drawings. As a minimum, the station furnishings shall include shelters (including those for persons with mobility impairments), benches, and trash receptacles. The minimum amenities shall include a passenger information system—including a public information display case and an electronic messaging system (VMS and public address [PA] system)—and a fare payment system.

## 1.1 SHELTERS

A shelter is a metal-roofed, free-standing structure intended to provide passengers with comfort and for protection from weather. All shelters shall conform to the requirements of the ADA, Title II, and California accessibility regulations, Title 24.

The shelters shall be nominally 7 feet deep and 18 feet wide for outboard platforms. The shelters shall be 8 feet deep for center island platforms. See Caltrain Standard Drawings for design requirements of these shelters.

Shelter posts or columns shall be clear a minimum of 16 feet from the centerline of the track. Shelter elements shall have sufficient transparency to provide adequate visual surveillance of the station area, to discourage vandalism and enhance the safety of users. Shelters should not create hiding areas. Shelter materials shall be vandal-resistant. Other than TVM shelters, each shelter shall have a bench that is secured to the shelter structure or the platform slab.

The clear height of passenger shelters shall be a minimum of 6 feet 8 inches and a maximum of 8 feet above the top of the platform.

Each shelter shall be illuminated. Illumination requirements for platforms and other station areas are contained in **Section I, Electrical Systems**.

There are two types of shelters for different uses, namely TVM shelters and passenger shelters including shelters for passengers with mobility impairments. Each of these is described in the following sections.

### 1.1.1 Passenger Shelters

The shelters shall be as shown on the Caltrain Standard Drawings. Additional shelters may be required to accommodate longer train sets if service level is increased in the future. The shelters shall be 18 feet wide; vandal-resistant; and furnished with two light fixtures at opposite ends of the shelter, and a bench.

A smaller shelter shall be provided, one per platform, for the use of persons with mobility-impairments. This shelter shall be located in the BAA.

#### 1.1.2 Ticket Vending Machine Shelters

Shelters shall be provided for the TVMs. These shelters shall be of a design similar to those for passengers, but configured for adequate space (width and depth) for wheelchair maneuvering, as shown on the Caltrain Standard Drawings. The shelter posts shall also be configured to accommodate wheelchair access to the TVM units. There shall be no bench inside these shelters, to maximize space for queuing and circulation.

### 1.2 BENCHES

Benches shall be located along the platform. Because the benches are exposed to an outdoor environment (not inside shelters), they shall be heavy-duty, scratch- and vandal-resistant, and secured to the platform. The benches shall have an armrest in the middle to discourage people from sleeping on them or using them as skateboard ramps. Benches shall be placed to line up with each car. Refer to Caltrain Standard Drawings.

### 1.3 TRASH RECEPTACLES

Trash receptacles shall be provided on each platform at the following locations:

a. At each side of the passenger shelter and TVM shelter

b. At each bench

c. At or near platform entrances

d. At parking areas near the stairways and ramps

Trash receptacles shall be of concrete construction with a lockable side service door. Trash receptacles openings shall have minimal exposure to wind and rain. At certain high-volume and key stations, recycling receptacles shall be provided. Trash receptacles shall not interrupt passenger flow and shall be placed in visible locations that are accessible to cleaning crews. See Caltrain Standard Drawings.

### 1.4 BICYCLE LOCKERS AND RACKS

The following provides a general rule for the number of bike racks, shared micromobility parking (combination of bike racks for dockless devices and docks for docked devices), and secure bike parking spaces (combination of electronic lockers and shared access bike rooms) needed at stations. Generally the standards are 1.2 racks, 1.8 micromobility spaces, and 6 secure spaces for every 100 passengers of the average weekday ridership counts per Caltrain's Annual Ridership Survey. Additional areas that can be easily converted to bike parking shall be reserved to meet the projected ridership counts in 2027, when approximately 100,000 daily riders are anticipated. For design purposes, the 2027 projected passenger counts may be calculated by multiplying the 2018 passenger counts by 1.5. The 1.5 factor may be adjusted due to local demand and other station-specific factors. The reserved areas may be used for hardscape or vehicle parking purposes in the interim.

Bike parking shall be located in well-lit areas in highly visible locations within view of the public and police patrols. It should be located in areas with convenient access to station platforms, with options on both sides of the tracks for side boarding stations and near stairs and/or ramps for center boarding stations while not impeding passenger circulation. Bicycle racks or lockers shall not be located on the platforms. A minimum of six (6) feet shall be maintained around bike racks and the doors of bike lockers and bike rooms. Clear signs shall be provided directing users to them. Priority shall be given to bike parking over general car parking when space at a station is limited since several customers with bikes can be served in the same space as one customer with a car.

Bike racks shall be an inverted ‘U’ shape with square tubing, two points of contact for each bike, and space so there is the ability to park 2 bikes at each rack. Bike lockers should be on-demand electronic lockers. Shared access bike rooms should have double height bike racks with lift assist technology for users of the top racks. The shared access rooms can be a part of a station building or modular units designed for parking bicycles.

## 1.5 NEWSPAPER RACKS AND VENDING MACHINES

Newspaper racks and vending machines shall not be allowed on platforms. This is to avoid unnecessary congestion to passenger access and circulation. The racks and machines may be placed inside the station concourse or passenger waiting area. If the station does not have a waiting area, then the racks and machines may be placed on the sidewalks near the station entrances.

Food and beverage concessions shall not be allowed on the platforms. Trash that inadvertently lands on tracks is not only a maintenance issue but also is potentially hazardous to passengers and the public at large on passing trains.

## 2.0 STATION AMENITIES

Station amenities generally refer to the passenger information system, fare collection system, and security system. Communication with passengers is through the Caltrain Central Control Facilities in San Jose and Menlo Park. The remaining subsystems (fare collection and security cameras) are connected to Caltrain headquarters.

All station amenities shall be securely fastened to the platform or poles/posts, as applicable. For placement of station amenities on the platforms, see Caltrain Standard Drawings. For technical details, refer to **Chapter 4, Communication & Passenger Information Systems**.

## 2.1 PASSENGER INFORMATION SYSTEM

The information system provided to the passengers shall consist of VMS, a PA system, and public information cases. Each of these is described below.

### 2.1.1 Visual Message Sign

The VMS is an electronic messaging system designed as one of the means to communicate with passengers. The VMS is also required by ADA to augment and complement audio PA messaging for the benefit of persons with hearing impairments.

Each VMS unit shall have two identical sides to display identical messages, capable of streaming two parallel lines. A minimum of two VMS boards per boarding platform shall be provided for viewing convenience and for redundancy. The VMS board shall be approximately one-third of the platform distance from each platform end. Minimum vertical clearance from the platform floor to the message board shall be 8 feet 2 inches, and maximum clearance shall be 9 feet. The edge of the VMS board shall not be closer than 9 feet from the track center, but for maximum visibility, shall not be more than 11 feet from the track center.

For elevated or below-grade stations, additional VMS units shall be placed in concourse areas and major decision points of passenger circulation paths, such as underpasses and/or overheads.

#### 2.1.2 Public Address System

The PA system provides clear, audible communication to passengers waiting at a station. The PA system augments and complements the VMS system.

The PA system shall consist of speakers along boarding platforms. A pair of PA speakers shall be mounted on every other light pole, beginning at the second light pole on the north end of the platforms. The speakers shall be mounted at such a height as to provide the optimum broadcasting and to prevent vandalism.

For elevated or below-grade stations, additional PA speakers shall be placed in concourse areas and major decision points of passenger circulation paths, such as underpasses and/or overheads.

#### 2.1.3 Public Information Case

Public information cases shall be designed to post the schedule, system map, “You Are Here” map, and advisory bulletins. Public information cases shall be provided as close to platform entrances and TVMs as possible. Provide one display case adjacent to the TVM shelter and additional display cases as shown on Caltrain Standard Drawings.

Public information cases shall be lockable, with multiple lock points. Cases shall be provided with vent holes to reduce the collection of moisture inside the case and minimize fogging on the glass. Public information cases shall be heavy-duty and suitable for an exterior environment. Detailed design of public information cases is provided in the Caltrain Standard Drawings.

For elevated or below-grade stations, additional cases shall be placed in concourse areas and major decision points of passenger circulation paths, such as underpasses and/or overheads.

### 2.2 FARE COLLECTION SYSTEM

The fare collection system consists of TVMs for train ticket purchase and parking fees, and card readers for Clipper, the regional smart card system. Both the TVMs and Clipper card readers shall be located on the platforms in well-lighted areas.

#### 2.2.1 Ticket Vending Machines

The TVM is for ticket purchase and for payment of parking. There shall be a minimum of two units or a pair of TVMs per platform area. The two TVMs shall be housed inside a shelter. The shelter shall be situated so that passengers using the equipment do not cause platform congestion. The TVMs shall be situated and housed approximately 220 feet from the northern edge of the platform. The proposed layout is shown in more detail in the Caltrain Standard Drawings. In general, TVMs shall not face the tracks to avoid waiting queues impeding platform passenger circulation. Consideration shall be given to minimize sun glare before finalizing the orientation of a TVM.

#### 2.2.2 Clipper

The MTC, comprising nine counties in the San Francisco Bay Area, implements Clipper, a smart card fare payment technology. Clipper allows public transit riders to use Bay Area public transit regardless of the varying fare structures on different transit systems, and without having to carry cash, ticket books, or passes. Caltrain utilizes this program, which is managed by MTC.

As part of the Clipper system, a card reader called a card interface device (CID) shall be installed on the platforms and concourse area. The number and locations of the CIDs to be installed at a station shall be determined based on the ridership and passenger circulation of the station. Provide an adequate number of CIDs to serve the ridership level of a station. CIDs should be located in proximity to station entrances/exits. Consideration should be given to minimize the impact on passenger flow due to queuing patrons waiting to use a CID and to maximize the convenience for patrons with mobility challenges. As a minimum, three CIDs shall be provided on each platform: one toward the center of the platform, preferably near a TVM shelter; the remaining two toward opposite ends of the platform near platform entrances/exits. When appropriate, place additional CIDs at major decision points of passenger circulation paths beyond station platforms, such as major underpasses and/or overheads.

## G. SAFETY AND SECURITY

The principles of CPTED shall be applied to safety and security. The design, from preliminary to final, shall be reviewed by a CPTED-certified professional. Designers shall submit a CPTED report to Caltrain for review before completion of design.

Detectable warning surfaces, yellow safety stripe, and directional detectable warning surfaces described earlier in the chapter also function as enhancements to safety.

## 1.0 LIGHTING

Lighting shall be provided at all station and parking areas and shall eliminate dark spots. Refer to **Section I, Electrical Systems**, for details of illumination level of lighting.

## 2.0 HANDRAILS AND GUARDRAILS

Guardrails (3 feet 6 inches high) with base curb plates shall generally be provided at the back side of platform where there is a grade drop of 6 inches or more for fall protection purposes. Handrails and guardrails shall also be provided in all appropriate locations and shall conform to all building code requirements and the accessibility standards of the ADA Accessibility Guidelines and CCR, Title 24. Guardrails shall not have ornamental patterns that would provide a ladder effect.

## 3.0 FENCING

### 3.1 CENTER FENCE

Where two or more tracks serve an outboard station, a center fence shall be provided for the full length of the platforms and to the at-grade pedestrian crossings, and at least 100 feet further beyond the crossings. The fence shall be 6 feet in height from top of tie, to act as a deterrent to climbing and to prevent passing through the fence, as well as to indirectly guide passengers to the pedestrian crossings. The fence design shall be in accordance with the Caltrain Standard Drawings. The design shall balance aesthetic appearance with the structural sturdiness and strength necessary to withstand vandalism and to allow for hanging and mounting of station signage. The centerline of the fence shall be a minimum of 9 feet clear from the centerline of the track, as shown in **Figure 3-1**.

### 3.2 RIGHT-OF-WAY FENCING

In the vicinity of a station, the ROW fencing shall be installed to prevent any unsafe shortcut to the platform and to guide the passengers to the designated platform entrances.

Fencing shall be installed along the entire length of all parking areas adjacent to the Caltrain ROW. Fences adjacent to roadways and parking lots should be set back and protected by curbing to allow for vehicular overhangs. The fencing outside of the station area shall generally be 8-foot-high ROW fencing and installed at 6 inches away from ROW lines within JPB property. ROW fencing includes access gates for maintenance personnel.

## 4.0 CLOSED-CIRCUIT TELEVISION CAMERAS

Closed-Circuit Television (CCTV) cameras will be installed on platforms at multi-modal stations, and as directed by Caltrain. If CCTVs are installed in the parking area at multi-modal stations, Caltrain will coordinate with the local enforcement agency for possible monitoring. CCTVs shall be installed in pedestrian underpasses and underneath bridges where stations are located. Caltrain will coordinate with the local enforcement agency regarding possible monitoring and logistical requirements or preferences. Effective use of the cameras at night will depend on the level of illumination at the camera locations. This shall be determined by CPTED-certified personnel in collaboration with Caltrain.

## H. STATION SIGNAGE

Caltrain station signage includes sign panels and platform markings, collectively referred to as signs. The signage serves to provide clear directions and information to passengers without additional assistance. Some of the signs are required by law, such as ADA-related signs, while others are safety and other regulatory advisories. Signs shall be placed at sufficiently frequent intervals and at visible locations, and generally, to the extent possible, in well-lighted areas.

Caltrain Signage Standards are contained in the Caltrain Standard Drawings under Stations and Facilities. The signs are grouped into different types based on their functionality. Each sign is labeled and numbered sequentially, with the initial letter identifying its type. The Caltrain Signage Standards also include dimensions and specifications regarding the panel material, the graphic, and applicable mounting details. To ensure a high level of consistency and uniformity of the sign products, Caltrain will provide the artwork of these signs to the sign vendor. The artwork does not include markings, municipal traffic signs, or standard regulatory signs such as railroad signs.

As part of the station design, the designer shall prepare a sign schedule specific to the station. The schedule shall include the sign type, sign number, description, quantity, locations, and additional mounting details, consistent with what is shown in the Caltrain Standard Drawings. In addition to Caltrain standard signs, designers shall identify and provide any additional signs such as wayfinding signs that may be required for the station. Design of the signage shall conform to the goals and purpose of the MTC's HSP. Further details about the Caltrain signage and the HSP is provided in the following sections.

### 1.0 CALTRAIN SIGNAGE

Caltrain signs are static. The signage, including wayfinding signage, is for placement on the platforms as well as in parking lots. Dynamic signs are typically provided only at multimodal stations, in accordance with the MTC's HSP.

### 1.1 SIGNAGE TYPES

There are nine different sign types, with distinct functions and purposes, as described in the following paragraphs. See Caltrain Standard Drawings (SD 3000 series) for further details.

Type 1 – Station Identifier

These signs include the station name or station identification, with the station name mounted on the light poles, and Caltrain corporate logo on the shelters.

Type 2 – Operations Signs

These signs provide information for both passengers and train operations crew. They include Spot cabs and public information cases.

Type 3 – Boarding Assistance Signs

These signs provide information to assist PNAs. They include BAA signs on PNA shelters, and bench cards.

Type 4 – Station Directional Signs

These signs show the train service direction so that passengers can determine whether they are on the correct platform. These signs are mounted on the center fence (for outboard platforms) or at the center of the platform (for center island platforms).

Type 5 – Regulatory and Warning Signs

These are safety advisory (regulation and warning) signs posted at various locations. They include No Fun signs (No Smoking, No Skateboarding), Keep Right/Keep Left signs (mounted on return fences at the limits of the platforms), and Look Before Crossing and Trespassing/Suicide Hotline signs (at the at-grade pedestrian crossings).

Type 6 – Proof of Payment

These signs provide fare collection or ticketing advisory.

Type 7 – Wayfinding Signs

These signs provide various kinds of information, mainly around the station area.

Type 8 – Parking Signs

These signs provide general parking and ticketing information and include restricted parking as well as general parking signs (No Parking, ADA Parking, etc.). These signs are provided at the entrance to the parking area.

Type 9 – Grade Crossing Signs

These are safety and warning signs mounted on the pedestrian exit gates at the pedestrian at-grade crossings.

## 1.2 WAYFINDING SIGNAGE

Additional wayfinding signs may be required and located well in advance of station destinations and in areas where there are no obstructions. Wayfinding signs shall be placed to provide directions from highways or major arterials.

## 1.3 SIGNAGE PLACEMENT

These signs are to be placed principally at three locations: on the platforms (including on the lighting poles), on the center fence, and in parking lots. The vast majority of the signs are mounted on the center fence (for outboard platforms) and on the ROW fence (for center island platforms). The signs on center fence provide a much higher level of visibility to the public, but at the same time minimize clutter on the platforms. Additional benefits include greatly reduced maintenance of these signs due to lower potential for vandalism.

### 1.4 STATION MARKINGS

Station markings are painted on the station platforms and mini-high platforms and are discussed in the following paragraphs. For longer performance, the markings shall be painted first with primer to seal the surface porosity, and have at least two finish coats.

a. Boarding Assistance Area:
This marking consists of an ADA logo and is painted on the platform toward the northern end of the platform designated as the BAA.

b. "Wait Behind Yellow Line"
The text "Wait Behind Yellow Line" advises passengers to wait behind the yellow safety stripe, which is behind the detectable warning surfaces. The edge of this line marks a distance of 9 feet from the track center.

c. "Wait Behind the Yellow Tiles"
This advisory note is a marking on the mini-high platform, cautioning passengers to stay behind the detectable warning surfaces on the mini-high platform.

d. "Danger Not a Waiting Area"
This text marking is on the station platform between the yellow safety line and the mini-high platform.

## 2.0 MTC HUB SIGNAGE PROGRAM

In 2010, the MTC implemented a HSP for all transit agencies in the Bay Area. Its purpose is to elevate the functionality of the transit center through streamlined and consistent wayfinding signage and consolidated schedule and fare information for transit passengers traveling throughout the Bay Area.

The MTC has identified 21 initial regional transit hubs in the Bay Area; five of these are Caltrain stations, identified because of their hierarchy as multimodal stations. These five stations are San Francisco (4th and King), Millbrae, Palo Alto, Mountain View, and San Jose (Diridon). MTC has implemented the HSP at all of these stations except Millbrae Station, which has been implemented by BART. The HSP implementation at the four other Caltrain stations was completed in 2011. See **Table 3-1, Caltrain Stations**.

### 2.1 HSP STANDARDS

The MTC has established technical standards for design elements and guidance on where such elements shall be located. The signs affected include directional signs, wayfinding kiosks, transit information displays, and real-time transit information displays.

When implementing the HSP, the designer shall consult the latest version of the MTC Standards and Guidance Document for further guidance on the content of signs and when, where, and how to install the signage types.

The HSP consists of the six types of signs listed below. Graphic examples and design details can be found in MTC's HSP Standards document.

- Type 1: Transit Center ID (static signs)
- Type 2: Wayfinding (static signs)
- Type 3: Information Cube (static signs)
- Type 4: Wayfinding Kiosk (static signs)
- Type 5: Transit Information Displays (static signs)
- Type 6: Real-Time Information Displays (dynamic signs)

### 3.0 CALTRAIN HSP IMPLEMENTATION

For stations other than the five multimodal stations, a tiered approach will be used to implement additional HSP sign types. During the planning process for any major alterations of stations, the designer shall collaborate, through Caltrain, with the MTC to ensure that the appropriate level of signage under the HSP is applied, and for any exception to the MTC Standards.

During design, it is also prudent to update the station ranking and hierarchy, because as density and transit access around stations increase, greater application of the HSP may be required at stations that may not trigger a significant level of wayfinding signage today. See **Table 3-1, Caltrain Stations**.

The final determination of signs shall take into account the need to maintain the familiarity and feel of Caltrain to which the public has become accustomed. As a general guidance, though, the HSP sign implementation may be as follows:

a. For Multimodal Stations: MTC HSP all six types

b. For Tier 1 stations: MTC HSP sign types 1, 2, 3, 4, and 5

c. For Tier 2 stations: MTC HSP sign types 1, 2, 3, and 5

d. For Tier 3 stations: MTC HSP sign types 2, 3, and 5

## I. ELECTRICAL SYSTEMS

The electrical systems shall be functional for the supply, control, and protection of all AC power electrical requirements. Loads at the station include the following:

a. Lighting (platforms, shelters, parking, access, etc.)

b. Fare collection equipment

c. Station communications devices such as VMS and PA

d. Safety and security devices such as CCTVs

e. Pedestrian crossing signal equipment (although the power is included in the signaling system)

f. Emergency lighting and power systems (if required)

g. Mechanical equipment (if applicable)

## 1.0 ELECTRICAL SERVICE

The electrical service shall consist of two separate systems. One service is for the mission-critical signaling system. The other service is for all other station needs, such as general lighting, communications devices, fare collection systems, and mechanical equipment. Designers shall coordinate with various engineering disciplines for load requirements and overall electrical system design. Designers shall coordinate with the applicable utility provider (e.g., PG&E, or municipal utilities) and prepare all service applications, drawings, and calculations required to obtain the new electrical services.

Platform power requirements typically shall have a 120/208-volt, 3-phase, 4-wire, 100-amp minimum capacity for general lighting. Power requirements for parking areas are dependent on the proposed power use. The power requirements for communications devices are included in **Chapter 4, Communication & Passenger Information Systems**, and the requirements for the signaling system are included in **Chapter 5, Signals**. All electrical services shall be sized to accommodate 20 percent future growth from the initial load.

Each station typically has a CER and other communication cabinets. The main electrical service drop will be co-located in the CER. The station shall also be provided with a generator receptacle and manual transfer switch to accommodate use of a portable generator during extended utility power outages. The electrical service drop for signal equipment will be located near the signal house(s). The CER also houses the electronic equipment for all station communication devices, such as fare collection systems (TVMs, Clipper), passenger information systems (VMS, PA systems), and possibly CCTV cameras. See **Chapter 4, Communication & Passenger Information Systems**, for further details.

Provide load and short-circuit calculations supporting the sizing of the service and associated distribution equipment.

## 2.0 CONDUIT AND CABLE SYSTEMS

Station platforms and facilities shall contain power and communications conduits and pull boxes required to support all Caltrain equipment, including TVMs, Clipper devices, PA speakers, VMS, and CCTV systems.

All conduit systems (electrical, communications, and signals) shall be located within the utility corridor to prevent platform closure in the event that there is a failure in the conduit system requiring excavation in the platform area. All conduit runs within the platform, except short laterals, shall have a minimum diameter of 2 inches. One empty spare conduit with a pull cord shall be provided for each conduit crossing beneath the tracks. Spare conduits shall be the same size as those installed. Exposed wiring or conduit serving passenger shelters, lighting, PA speakers, electronic message boards, ticket equipment and CCTV cameras is not permitted. Where exposed conduit cannot be avoided in public areas, it shall be painted to match the underlying surface.

The ROW is also used for fiber optic and signal lines that are buried in conduit systems in the ROW. To prevent platform closure and to allow excavation for these lines, Caltrain policy requires conduits to be installed for the full length of the platform as shown on the Standard Drawings, with 4–foot-square pull boxes. These conduits shall be installed in addition to any other conduit systems installed for the platform.

Power wiring shall be type THHN/THWN or XHHW for dry locations, and XHHW-2 for wet locations. All conductors shall be copper with 600 volt insulation and shall comply with the requirements of NFPA 130.

Branch circuit wiring shall be No. 12 AWG minimum. Conductors shall be sized to limit branch-circuit voltage drop to a maximum of 3 percent, and the total voltage drop on both feeders and branch circuits to 5 percent.

## 3.0 LIGHTING DESIGN REQUIREMENTS

### 3.1 GENERAL HARDWARE REQUIREMENTS

All luminaires shall be selected to provide design and perceptual unity and simplify maintenance requirements. The number of different fixture types used at a station shall be minimized to the extent feasible; emergency light fixtures with integral batteries shall be avoided where possible. All site lighting fixtures shall be waterproof, vandal-resistant, and equipped with tight gaskets to prevent dust infiltration. Luminaires shall function effectively for a minimum of 20 years, accounting for routine maintenance. Unless noted otherwise, all luminaires shall be light-emitting diode (LED) with a 4000K color temperature.

### 3.2 ILLUMINATION LEVELS

Illumination levels shall define and differentiate between task areas, decision and transition points, and areas of potential hazard. Passengers will perceive greater security when platforms, walkways, and parking lots are properly illuminated. Platform lighting is essential to the safety and security of station facilities and provides increased safety for the passengers as they board and alight trains.

In addition to quantity of light, it is essential that illumination be designed to minimize glare and provide a uniformity ratio of 3:1 (average to minimum) under normal conditions. Uniformity of emergency lighting shall conform to NFPA 101. Luminaires shall be selected, located, and aimed to accomplish their primary purpose while minimizing objectionable glare and interference with task accuracy, vehicular traffic, and neighboring areas.

The lighting design shall provide illumination levels per **Table 3-2, Illumination Levels**; significant over-lighting shall be avoided. All values shown in the table represent maintained illumination levels, calculated using a light loss factor of 0.8. Provide photometric calculations using AGI-32 software (or approved equivalent software).

**Table 3-2: Illumination Levels**

| Location | Illumination Level |
|---|---|
| Boarding platform and waiting areas | 5-foot candles – average |
| Communications Equipment Room | 50-foot candles – average |
| Elevator Machine Room | 50-foot candles – average |
| Emergency lighting: aerial (pedestrian overhead), underpasses, platforms, stairways, escalators, and elevators | 2-foot candles – minimum |
| Emergency lighting: parking garage | 1-foot candles – minimum |
| Escalators and elevators (including landings) | 10-foot candles – average |
| Shelters: passengers | 10-foot candles – minimum |
| Shelters: TVM | 15-foot candles – average |
| Parking lots | 2-foot candles – average |
| Parking garages | 5-foot candles – average |
| Pedestrian underpass | 10-foot candles – average |
| Signage (on platform - vertical illuminance on sign face) | 10-foot candles – average |
| Stairs and ramps | 10-foot candles – average |
| Station building: primary public entrances and exits | 10-foot candles – average |
| Walkways, entrances, and exits | 10-foot candles – average |
| Yard lighting | 5-foot candles – average |

**Notes:**
TVM = ticket vending machine

## 3.3 LIGHTING REQUIREMENTS

Station lighting includes internal site circulation areas and access routes to the station. The placement of luminaires shall not obstruct the movement of vehicles. Luminaire placement shall be coordinated with the landscape and site plan to protect light standards adjacent to roadways and to ensure that plantings do not obscure the lighting distribution pattern.

Vehicular access lighting shall provide a natural lead-in to the bus and Kiss-and-Ride areas. The illumination on all access and egress roads shall be graduated up or down to match the illumination level of the adjacent street or highway.

Pedestrian access lighting shall define pedestrian walkways, crosswalks, ramps, stairs, tunnels, and bridges.

Platform area lighting shall be provided as shown in Caltrain Standard Drawings. The lighting elements shall extend the entire length of the platform and shall demarcate the platform and emphasize the platform edge and vertical vehicle surfaces. Care shall be taken to avoid "blinding" train engineers or other vehicle drivers with excessive or misdirected lighting. Similarly, platform lighting shall not be directed to any adjacent residences. For placement of platform luminaires, see Caltrain Standard Drawings.

### 3.4 CONTROL OF LIGHTING SYSTEMS

Lighting control shall be designed to use energy efficiently. Automatic and manual control arrangements shall ensure efficient use of energy and ease of maintenance. With limited exceptions (i.e., tunnels requiring continuous illumination), lighting shall be turned on/off by a relay control panel via a photocell. A time clock connected to the control panel shall allow lighting to be dimmed (by an adjustable percentage) during periods of no train service at the station. Emergency lighting fixtures shall operate at full intensity (no dimming) when utility power is lost.

## J. LANDSCAPING AND IRRIGATION

### 1.0 LANDSCAPING

Landscaping shall be designed to enhance the overall aesthetic value of the station site. Landscaping shall, where practicable, define areas, direct pedestrian traffic, and provide shade and screening from adjacent properties. Landscaping shall also provide proper site drainage and stabilize slopes and embankments. Landscaping shall be low-maintenance and drought-tolerant.

Landscaping shall not impede visibility of platform areas or parking lots. The principles of CPTED shall be applied so as not to create hiding spaces, security barriers, or interfere with access to any facility for maintenance. Landscaping shall not obstruct electronic or static signage or impede the line of sight required for train operations. Landscaping shall not be included on the platform.

All landscaping shall maintain a minimum of 16-feet horizontal clearance from the centerline of track. Trees and shrubs shall be situated so that anticipated growth does not encroach closer than 16 feet to the centerline of the nearest track. No trees shall be planted closer than 25 feet from the centerline of track. Also, trees and shrubs shall not encroach on the electrical safety zone (ESZ), which is an area extending 10 feet from the closest electrified component of the overhead contact system. No trees shall be planted where mature tree height could result in contact with OCS lines or fall onto the track.

### 2.0 IRRIGATION

Landscaping design shall minimize the need for irrigation by using native and drought-tolerant plant species. Where irrigation is required, spray patterns and drainage shall be designed to maximize coverage, minimize overspray, and direct water away from tracks, platforms, and walkways. Drainage requirements are provided in **Chapter 8, Civil Design**.

## 3.0 PLATFORM WASHDOWN FACILITY

Platforms shall be provided with quick-connect hose couplers installed in recessed boxes. Couplers shall be at approximately 85 feet on center to allow full coverage with a 50-foot hose. Drainage requirements are provided in **Chapter 8, Civil Design**.

# END OF CHAPTER

# CHAPTER 4

# COMMUNICATION & PASSENGER INFORMATION SYSTEMS

## A. GENERAL

The term “Communication and Passenger Information Systems” refers to the collection, dissemination, and transmission of information to and from the field using electronic systems and methods. The field includes operation facilities, passenger stations, traction power facilities, and wayside signal locations. The purpose of these systems is to extend the physical reach of human operations, maintenance, and security, which will enable centralized operations and security, and provide maintenance personnel with additional data that will reduce the time required to repair equipment and systems in the field. Because these systems affect the traveling public, Caltrain operations and maintenance staff, and safety and security personnel, the general philosophy is to strive for a fully integrated, user-friendly system that presents timely and relevant information to its intended users in an easily intelligible manner.

### 1.0 SYSTEM WIDE COMMUNICATIONS

The design criteria presented in this chapter for communication systems define the technical requirements used for the development of specifications and the design of the radio systems supporting Advanced Train Control System (ATCS), the very high frequency (VHF) radio, and Positive Train Control (PTC) radio.

The ATCS data radio, the VHF voice radio, and the PTC Radio are all independent stand-alone communication systems that are each supported by backhaul communications through Caltrain-owned microwave radio network and fiber-optic plant. The design criteria define the requirements for these communication systems and subsystems to safely and efficiently fully support the Caltrain operations, as well as the requirements to expand these systems to support future Caltrain communication needs. The various radio systems shall interface with and support existing and future train operations, i.e., California High-Speed Rail (CHSR).

Communications with MPCCF, SJCCF, and CEN shall use the Caltrain-owned fiber optic cable plant installed from the San Francisco Terminal to CP Lick. Other forms of communications from the field to the office or dispatch use wireless communications, i.e., cellular or radio. In instances where normal Caltrain communication channels are not technically available the communications can be conducted over third party service providers’ channels such as AT&T. In general, communications between passenger stations and the office are provided over media such as Ethernet WAN and LAN networks provided by AT&T or other approved service providers. The Caltrain passenger stations include all stations from San Francisco to Tamien. Stations south of Tamien shall use third party communications services provided by the appropriate and approved service provider.

All network or IP-based communications are discussed in a dedicated Chapter 10, Rail Network. Design criteria for Caltrain's Rail Network and relevant IP technologies are found in Chapter 10.

The new equipment design and installations at the stations, however, shall account for communication system upgrades using the Caltrain-owned fiber optic cable plant. The fiber optic cable backbone provides for a fully redundant communication optical network, connecting Caltrain passenger stations, right-of-way (ROW) facilities, MPCCF, SJCCF, and CEN at the speeds between 1 Gigabits per second (Gbps) and 10 Gbps at optical nodes. Higher bandwidth can be designed for based on design criteria within Ch. 10 and approval from Caltrain Engineering.

## 2.0 PASSENGER INFORMATION SYSTEMS OVERVIEW

Passenger stations are the hubs of passenger activity on the Caltrain system. The primary function of passenger stations is the orderly boarding and alighting of passengers to and from the trains. Passengers arrive at stations in personal cars, in shared-ride vehicles, on bicycles, from other bus or rail transportation, and on foot. To support them in their journey, a number of passenger information systems are provided at stations, including ticket vending and add-value machines, digital passenger information signs such as Variable Message Signs (VMS), public address audio announcements, and even Closed-Circuit Television (CCTV) at some stations. At terminal stations such as Diridon and 4th and King, additional digital displays are provided such as Platform End Displays (PED) and Train Schedule Displays (TSD). Staff at terminal stations are available to answer questions, make local announcements, and resolve issues at stations.

However, the majority of stations are not staffed and dynamic and reliable messaging is needed to keep passengers informed. This systemwide communication system is provided from a primary headend location at the Menlo Park Central Control facility (MPCCF). The back-up San Jose Central Control facility (SJCCF) serves as secondary headend location that with most systems configured in a redundant and stretched virtualized environment that are active in parallel and/or can be activated as primary in the case where the primary headend location is inoperable. The Central Control Facility houses the train dispatchers. The SJCCF adjacent to the Centralized Equipment Maintenance and Operations Facility(CEMOF) is located in San Jose, and the MPCCF is located in Menlo Park.

Caltrain also uses an auxiliary headend facility at Caltrain headquarters (CEN) in San Carlos. The physical location of this facility is anticipated to change in 2026; the current location shall be as indicated in the Contract Documents. Nonetheless, the function of CEN will remain the same. This facility is mostly dedicated to Caltrain security/video surveillance and processing; and maintenance and monitoring of the Caltrain wide-area network (WAN)/local area network (LAN) and fare collection.

Information from the control facilities headend can be provided in real time, automated or in schedule mode, via both audible and visual subsystems. The objective is to provide passengers with scheduled and updated information and knowledge of the commuter system. Such information may include the following:

a. Safety and security advisories

b. Timetables listing departure times at scheduled stations

c. Commuter rail delays, status, or travel updates

d. Alternate service plan advisories

e. Advisories regarding construction activities and interruptions

f. Timekeeping or clocks

g. Station (local) announcements

In addition to supporting the orderly boarding and alighting of passengers, Caltrain endeavors to keep both passengers and property safe and vandal-free. To this end, closed-circuit television (CCTV) cameras are used in stations as the remote eyes of security and operations. Operational sensitive locations, such as train control, communications, and fare vending rooms or equipment, may also be remotely monitored from the Caltrain headend facility in San Carlos.

## 3.0 PASSENGER INFORMATION SUBSYSTEMS

There are three primary passenger information subsystems used to convey public information and support passenger station amenities. These include:

a. Audio Information Systems

   i. Public Address (PA) system

b. Visual Information Systems

   i. Digital displays including Variable message sign (VMS), Platform End Displays (PED) and Train Schedule Displays (TSD)

   ii. Passenger Information System (PIS) commonly referred to as Predictive Arrival Departure System (PADS)

   iii. Closed Circuit Television System (CCTV)

c. Fare Information Systems

   i. Ticket vending machines (TVM)

   ii. Clipper card interface devices (CID)

Passenger assistance telephones, such as Push-to-talk and emergency call box, are currently not provided.

Talking signs for visually impaired persons are available at the two terminal stations: San Francisco 4th and King and San Jose Diridon.

## B. DESIGN REQUIREMENTS

### 1.0 STANDARDS AND CODES

Communication and Passenger Information Systems design shall comply with the latest adopted editions, unless noted otherwise, of all applicable federal, state, and local codes and regulations, including the Americans with Disabilities Act (ADA), Cal/OSHA standards, CPUC Regulations, applicable Federal Railroad Administration (FRA) regulations, Federal Communications Commission (FCC) regulations, the California Building Standards Code, State of California Electrical Safety Orders, Title 8, CAC, Motorola R56 Grounding Standards, and the communications industry standards listed in **Appendix C**.

Communication and Passenger Information Systems design documents shall include the following, as applicable and at a minimum:

**System Description:** System description, at a minimum, shall include the subsystem description, detailed design and interface information, all performance, functionality and operational description, cutover information, and details such as the cable and equipment identification.

**Interface Requirements:** Interface requirements shall identify all required wired, optical, and wireless communication interfaces between systems and subsystems components, and between the field i.e. station main point of entry (MPOE) and MPCCF, SJCCF, and CEN. This shall include the following:

a. Interfaces between new work to be performed and existing communications systems and subsystems

b. Interfaces among the subsystems

c. Interfaces with Caltrain-owned fiber optic cable plant

d. Identification and description of any required hardware and software modifications or additions to existing subsystems equipment, including Supervisory Control and Data Acquisition (SCADA) software, MPCCF, SJCCF, CEN headend equipment, Alarm Point, and any other required interfaces

e. Identification of all external interfaces, including service points and those to facilities and equipment provided by others; interface examples include power, cable facilities, discrete signals, voice, and data

f. Interface information, including media type, communications protocols, and terminations information such as connector type and pin assignments

**Product Specifications:** The communications design documents shall include product specifications that meet or exceed the operational, functional, and performance required by the design. Products shall be in compliance with applicable Standards and Codes, shall have a life span of not less than 5 years, and shall have manufacturer's support available for 10 years after the product has reached its end of life. Product life span shall start from the anticipated construction period.

**Drawings:** Drawings shall include the cover sheet; complete drawing index; electrical; power distribution panels and circuit assignments; mechanical; conduit and cable layouts; conduit and cable schedule; wiring diagrams showing all interfaces; system block and functional diagrams with corresponding parts lists; equipment installation details; grounding details; and other details required by the design. All drawings shall be produced in compliance with the current Caltrain CADD Manual.

**Bill of Materials:** An equipment list (bill of materials) shall consist of a table or list of model and part numbers for all proposed equipment and materials to be used for individual subsystems. The table or list shall be grouped for each subsystem, with functional descriptions of equipment or material included. Quantities and locations shall be included.

**Calculations:** Calculations shall be included as outlined in the subject subsystem section.

**Cutover Plan:** Phasing and cutovers shall be included to identify all major system cutover events or integration activities and shall describe techniques, methods, duration, and procedures.

**Equipment and Cable Identifications and Symbols:** Cable and equipment identifications shall comply with Caltrain standard conventions for naming, abbreviating, and presenting equipment and cables in the design documents. An equipment label and nameplate schedule shall also be included.

**Installation and Test:** The design documents shall include installation methods and testing requirements, as applicable.

**End of Life and End of Support:** Submit documentation that proposed hardware and software are within the manufacturer's active support lifecycle, with a minimum of five to ten years of future availability. Provide product roadmaps, planned firmware or software updates, and backward compatibility assurances for technology products. Provide end-of-life (EOL) and end-of-support (EOS) dates, propose upgrade paths, and include lifecycle management plans.

The designer shall be responsible to produce the design documents in phases, which shall be submitted for designs involving radio systems. The 65% and 100% design shall, at a minimum, include the following documents:

(1) Radio coverage/link simulations

(2) Intermodulation studies

(3) Grounding and lightning protection

(4) Tower structural calculations for operation and licensing

During installation, the following documentation shall be provided as needed:

a. All deviations from the installation requirements specified in the contract documents shall first have the approval of the Engineer. The installer shall submit a Request for Information, explaining the reason(s) for any deviations and a description of the deviation itself to the Engineer for approval.

b. Prior to the start of any installation, the installer shall submit for the Engineer's approval catalog cut-sheets and other manufacturer literature describing the product being considered for installation.

c. At least 30 days prior to the start of the installation of any item, the installer shall submit for the Engineer's approval a set of installation drawings, code plugs, and software configuration management. The installation shall thereafter proceed only after written approval of the drawings by the Engineer.

d. Test plans and procedures shall be provided at least 90 days prior to the start of testing, Training and operations and maintenance manuals shall likewise be submitted at least 60 days prior to maintenance training; a list of recommended spare parts, test equipment and special tools, shall be submitted at least 60 days prior to the start of training.

## C. CALTRAIN COMMUNICATIONS NETWORK

Field locations and passenger stations within Caltrain's operating right-of-way from San Francisco to San Jose shall communicate with MPCCF, SJCCF, and Headquarters using Caltrain-owned fiber optic cable plant. The designer shall coordinate with JPB regarding the design requirements for new construction or rehabilitation projects.

Communication network connectivity between the CCFs, CEN, and the stations south of Tamien shall be based on utilizing Caltrain-owned communication utilities as the highest priority. In instances where Caltrain-owned utilities are not technically feasible then alternative communications are considered with close coordination and final approval from Caltrain. For new construction or major rehabilitation at stations south of Tamien, Caltrain communications channel shall be leased Ethernet based network from a Third Party Service Provider. Consideration shall be given to increasing carrier network capacity (bandwidth) by using Caltrain-owned fiber optic cable plant or backbone. The design objective then shall be to equal the network capacity (bandwidth) on both the carrier side and the subsystem distribution side of the station MPOE.

Station amenities shall account for Clipper network connectivity between Clipper Headquarters and the stations to serve station Clipper CIDs. This network is leased by Clipper from a service provider and is independent from the Caltrain WAN/LAN.

The network equipment chosen for each station that can be connected to the Caltrain-owned fiber optic cable plant shall be adaptable/scalable. The designer shall adhere to Design Criteria's Ch 10 Rail Network Design for network based technologies and coordinate with JPB Engineering regarding the network equipment selected for the project.

The existing network "carrier" and Caltrain fiber network will interface with the station LAN at the communications equipment room (CER). Note that, in the absence of a CER, some Caltrain stations use outdoor station communications cabinets (SCC), also sometimes referred to as communications interface cabinets (CIC). It is the intent of Caltrain to phase out the SCC/CIC and upgrade to the CER. For simplicity and unless specifically required, the terms "SCC" and "CIC" are omitted from this document; the term "CER" is used instead as a universal substitute for these various types of station central communications architecture.

A mixture of Caltrain-owned microwave radio and deployment of Caltrain-owned fiber optic based networks along the railroad ROW. Limited use of multi-protocol label switching, another leased but significantly more costly service, shall be considered where it provides the greatest cost/benefit. For PTC and CHSR related work, coordinate with JPB for design requirements because the design criteria are still not finalized yet at this time.

At this time, the predominant back-haul resource used for the communication systems/networks is the leased 4-wire telephone service. **Table 4-1** lists the current leased telephone infrastructure used by Caltrain to support the ATCS data radio and the VHF voice radio systems.

**Table 4-1: Communication Systems and Leased Telephone Infrastructure**

| Critical Systems | Circuits | Types | Office Pairs | Field Pairs |
|---|---|---|---|---|
| Visual Messaging System Lines | 1 | T1 frame relay | 1 | |
| | 1 | 4W ADM 8legs | 2 | |
| PA Lines | 1 | Fiber | 1 | |
| | 1 | Fiber | 1 | |
| ATCS Cellular as a secondary backup | 1 | Cellular Modem | 2 | 2 |
| | 1 | Cellular Modem | 1 | 1 |
| | 1 | Cellular Modem | 2 | 2 |
| | 1 | Cellular Modem | 1 | 1 |
| | 1 | Cellular Modem | 2 | 2 |
| | 1 | Cellular Modem | 1 | 1 |
| Control Points | 1 | 4W 5legs | 2 | |
| | NEW | 4W | | 2 |
| | NEW | 4W | | 2 |
| | NEW | 4W | | 2 |

| | | | | |
|---|---|---|---|---|
| | NEW | 4W | | 2 |
| | 1 | 4W digital | 2 | 2 |
| | 1 | 4W 4legs | 2 | |
| | | 4W | | 2 |
| | | 4W | | 2 |
| | | 4W | | 2 |
| | 1 | 4W 6legs | 2 | |
| | | 4W | | 2 |
| | | 4W | | 2 |
| | | 4W | | 2 |
| | | 4W | | 2 |
| | | 4W | | 2 |
| Tunnel Radio | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W PTP | 2 | 2 |
| Road Radio | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W PTP | 2 | 2 |
| | 1 | 4W twisted pair | 2 | N/A |
| UPRR Radio | 1 | 4W twisted pair | 2 | N/A |
| **Totals Circuits** | **26** | | **43** | **51** |

Notes:

ATCS = Advanced Train Control System
DSL = delivered audio quality
PA = public address
PTP = point-to-point
UPRR = Union Pacific Railroad

Legacy circuits T1 Frame Relay and variations of four wire (4W) are provided by service provider with the intent of replacement to digital circuits. The following two circuit types outside of cellular and fiber are predominantly used:

(1) 4-Wire PTP

A 4-wire PTP line is a leased 9,600-bit-per-second (bps) baud rate telephone circuit that is provisioned between two fixed locations. It provides a single telephone circuit with four wires, which enable it to support full-duplex telephone communication. This type of leased circuit was required between each of the 27 ATCS CP sites, the two mountaintop sites, and the CCF and BCCF.

(2) 4-Wire Digital

A 4-wire digital line is a leased telephone circuit that is provisioned between two fixed locations. It provides a faster (56K) single telephone circuit with four wires, which enables it to support full-duplex data communication. The quality of the line is enhanced to support the more demanding channel requirements for digital communications. This type of leased circuit was used between

CP Army and the CCF and BCCF to support data messages between the two sites.

For new or rehabilitation projects, the leased line circuits shall be replaced with Caltrain-owned fiber optic-based network or latest digital technology provided by local network service provider where possible. Coordinate with JPB to determine where these circuits are to remain active, to be removed, or to be used as communications back-up circuits.

## D. SUBSYSTEM NETWORK DISTRIBUTION

At each passenger station, the communications carrier network and/or Caltrain-owned Fiber Optic Backbone cable shall terminate into a flexible, scalable, and robust station network distribution system. This subsystem shall carry signals from all subsystems according to their particular configuration and need. The objective of this subsystem is to extend the capability of the main network throughout the station. Characteristics of this network distribution system should be as follows:

a. Distribution cabinets shall be optimized for communicating with field devices and the CER. Copper and fiber optic infrastructure shall be used, as applicable, for new construction or rehabilitation projects.

b. There shall be two sets of power wiring brought into each distribution cabinet:

    i. Essential Power: Battery-backed uninterruptible power supply (UPS) power system for essential communication equipment such as LAN switches, Media Converters, TVMs, CCTV, VMS, and Clipper CIDs shall be provided from the station's CER. Where CER cannot accommodate UPS system installation, a stand-alone UPS unit in each distribution cabinet shall be provided. The UPS shall be sized to satisfy the project requirements for future load and backup time as described in the "Power and Uninterruptible Power Supply" section of this Chapter.

    ii. Non-Essential Power (from the station distribution power panels): Power for non-essential devices such as fans, air conditioners, maintainer jacks, and cabinet lights.

c. Distribution cabinets shall contain the following:

    i. Dual Caltrain LAN switches: If there are more than one of each, TVM or VMS shall be wired to a distribution cabinet. For redundancy, they shall be divided into two groups: the first group will be served by one distribution switch, and the second group will be served by the second distribution switch.

    ii. CID Switch (where required): Provided by Clipper

    iii. Category 6A patch panel(s)

iv. Lightning/surge protection modules: For all copper LAN and other communication copper cabling coming into the cabinets from outdoors

v. Fiber patch panel

vi. Integrated cable management

vii. Power distribution equipment for essential power

viii. Convenience outlets and distribution equipment for essential power

ix. Convenience outlets and distribution equipment for non-essential power

x. Grounding equipment

xi. Adequate temperature-cooling equipment shall be provided for the distribution cabinet. Fans, heat exchangers, and air conditioning units shall be sized based on ambient temperature and heat dissipation in the cabinet.

xii. 24 volt direct current (VDC) power supply for CIDs (one power supply per two CIDs) (where required)

xiii. Stand-alone UPS with external batteries where essential power cannot be fed from CER.

xiv. Characteristics: National Electrical Manufacturers Association (NEMA) 4, vandal-resistant, lockable, etc.

d. Distribution switch(es) shall be as follows:

i. Capable of remote management

ii. Capable of forming redundant LAN configurations

iii. Having fiber and copper ports for device connectivity

iv. With fiber fed from the main switch

v. IEEE 802.3at or IEEE 802.3bt compliant (power-over-Ethernet [POE])

vi. Layer 2 switching capable

vii. Industrial rated (i.e., an operating temperature range of -10 degrees Celsius (°C) to at least +50°C; vibration tolerant, etc.)

viii. Sized to have 25 percent spare port capacity

e. A redundancy scheme shall be implemented such as redundant LAN configurations with the switchover based on rapid-spanning tree protocol (e.g., Ethernet Rings topology).

f. Distribution to and from individual field devices shall be via fiber optic and Category 6A cable, using POE where feasible. For cable runs longer than 300 feet (or if specifically required by the field device's design), a single-mode or multi-mode fiber connection shall be used.

## E. THIRD-PARTY TELECOMMUNICATIONS

Telecommunications are essential to the safe, reliable, and efficient operation of railroads across the San Francisco Bay Area. Caltrain depends on advanced communication networks to support train control, signaling, traction power, and passenger information systems. Much of this capability is supplemented through partnerships with third-party telecommunications service providers such as AT&T, Verizon, and Crown Castle.

Caltrain's electrified corridor includes third party networking, fiber-optic, and wireless technologies that connects control centers, substations, and wayside equipment. These systems enable real-time monitoring and train control, Supervisory Control and Data Acquisition (SCADA), and other mission-critical functions. Third-party telecom service providers often support as a secondary medium to Caltrain's communication infrastructure.

Beyond rail operations, commercial telecom partnerships also support Caltrain's public-facing services, including station passenger information systems, cellular connectivity for passengers, and extension of passenger information systems south of San Jose within Caltrain's ROW. Transit-oriented agencies providing amenities (i.e., Clipper) use third-party service providers for communication purposes and electronic delivery of services. These arrangements expand both public coverage and Caltrain's internal connectivity, while allow for potential non-fare revenue for the railroad.

As 5G and next-generation broadband networks continue to develop, collaboration with established telecommunications companies will become even more important. Shared infrastructure—leveraging the existing fiber backbone, electrical systems, and strategic ROW locations—offers a cost-effective way to enhance Caltrain's communications capacity while supporting regional digital equity and connectivity goals.

Through coordinated planning with third-party telecom providers, Caltrain can continue to strengthen its operational resilience, improve service reliability, and contribute to the region's modern telecommunications evolution.

# F. PASSENGER INFORMATION SYSTEMS

## 1.0 CLOSED-CIRCUIT TELEVISION CAMERAS

CCTV is used for video surveillance of the station platforms. At some stations, CCTV is also used for video surveillance of station indoors (station concourse), underpasses, station surrounding areas (e.g., the station plaza, parking lots, stairs and ramps, and bus stops), and other facilities (e.g., traction power facilities, operations control center, and maintenance yards). Outside of stations and facilities, highway grade crossings are another location type where CCTV is installed and will continue to be implemented in the future. The CCTV cameras can also be provided for coverage of locations where money is intended to be exchanged (e.g., fare collection). The quantity and location of cameras will depend on the type and size of station.

The CCTV project design (from concept to final stage), installation, and acceptance shall follow crime prevention through environmental design (CPTED) guidelines. The project design, installation, testing, and acceptance shall be approved and witnessed by Caltrain, including CPTED-certified personnel and the Safety and Risk Management.

The station CCTV system components shall be compatible with the Caltrain existing CCTV headend equipment installed at CEN, MPCCF, and SJCCF, provided by Verint Nextiva. The modifications to the existing Caltrain headend will be done by Caltrain personnel. The contractor shall facilitate integration of the new station CCTV equipment into the existing CCTV headend, and communicate with Caltrain personnel regarding the effects of the design, implementation, and testing details of the new equipment on the existing system.

All new CCTV installations shall use day/night Internet protocol (IP) cameras only. Whenever practical, the IP cameras shall be supplied with direct current (DC) power, using POE technology.

The station CCTV cameras shall provide 100 percent coverage for inside stations, station train platforms, pedestrian underpass, waiting areas, and stairs and ramps. This coverage shall be achieved by use of fixed cameras.

The design of the fixed cameras (placement, elevation, camera tilt, and vertical and horizontal fields of view) shall allow for the following resolution:

a. Forensic Detail: Priority targets (underpass, station platform, TVMs/CIDs, parking exit/entrance, and stairs and steps) require detailed coverage—at least 80 pixels per foot.

b. General Detail: The remaining station areas shall be covered by at least 20 to 40 pixels per foot.

The station CCTV system shall also include pan-tilt-zoom (PTZ) cameras, which shall provide for the following:

a. Redundancy of coverage

b. A means for Caltrain or local agency security personnel to zoom in on a crisis area in real time when a problem is reported from the field or a pre-determined alarm is triggered (i.e., TVM Intrusion Alarm)

PTZ cameras shall be provided at key locations including TVMs, station entrances, grade crossings and other locations as designated by Caltrain.

The design of corresponding station devices shall accommodate a means of passing the alarm information to the CCTV system.

The PTZ camera design shall include digital input/output (I/O) contacts and the ability to set pre-defined PTZ settings. When a digital alarm input is triggered by a station object, the associated predefined PTZ setting shall be invoked for the associated PTZ camera to automatically zoom in onto the alarmed object.

The design of the PTZ cameras' placement, elevation, and vertical and horizontal fields of view shall allow for resolution of at least 120 pixels per foot at maximum zoom-in for any location of the required area of coverage.

The requirements for CCTV design for these areas of video surveillance shall be determined based on the priorities input from the stakeholders and CPTED personnel.

As with all subsystem devices, video cameras shall be networked and assigned dedicated bandwidth. The network protocol shall be transmission control protocol (TCP)/IP for all subsystems.

The network video system (CCTV) shall be a fully digital system, transported over an IP-based network using TCP/IP Ethernet protocol. A CCTV virtual local area network (VLAN) shall be partitioned to dedicate bandwidth solely for the CCTV subsystem. Network cameras shall be equipped to interface directly with Category 6A cable installed to the assigned distribution cabinet and associated networking equipment.

At the station CER, the CCTV system shall use a dedicated station digital video recorder (DVR), which is a computer used for recording and storing the station CCTV video data. Station DVR shall use current Recorder Server CCTV management and recording software. The station CCTV PC hard drives shall record and store video information up to 14 days for all station cameras, and at the highest resolution and frame rates allowed by the design of each implemented camera and the DVR (including 50 percent additional spare storage for future growth).

The CCTV system design shall allow Caltrain personnel to retrieve recordings both locally and remotely. Additionally, the system shall support requests for remote monitoring by independent agencies (i.e., the local police department in whose jurisdiction the system is located).

To accommodate current low bandwidth limitations for links between the CCTV headend at CEN, MPCCF, SJCCF, and remote Caltrain stations, the station's DVR shall support downscaling of the video streams to low resolution (i.e., 1 to 4 CIF [Common Intermediate Format]) for remote “live” views. Note that downscaling will be used for a “live” view function only; the station DVR shall record video of the high-resolution cameras at their maximum resolution and frame rate. To facilitate this function, station DVR shall use Verint Media Gateway Server software or equivalent approved by Caltrain.

The station DVR shall support local and remote retrieval and download of recorded video. For local retrieval, the station DVR shall support export of the recorded video into DVD or external hard drive media. The remote retrieval of the stored video (recorded at its full resolution and frame rate) over Caltrain-owned fiber optic cable plant and leased network channel from the Caltrain CEN, MPCCF, and SJCCF is expected to be done during off-peak hours. Such download shall be configured as a low-priority function, which should not interfere with the performance of the remaining station subsystems.

All stored and retrieved video recordings shall provide evidence of authenticity (i.e., that no video tampering took place), so that it could be submitted in a court of law as evidence.

In accordance with stakeholder input, in non-critical areas with the least amount of human traffic, the use of motion and audio detection software is allowed; this could enable slowing down the recording speed when there is no motion (e.g., during off or night hours) and speeding up the recording when motion is detected. This can be used to minimize the storage capacity requirements.

The network camera system shall deploy management software to automatically find and set up IP addresses, show connection status, and configure and manage firmware upgrades for multiple camera locations. To optimize bandwidth and image quality, the network camera system shall have a wide range of compression features, enabling the system to view events at H.265/MPEG-4 compression while recording at Motion JPEG.

For enhanced security, network cameras shall be equipped with remote I/O ports for monitoring other security and alarm devices, such as door contacts, smoke detectors and temperature sensors, light or other switches, or alarm relays. Activation of these I/O devices will cause the network camera to stream full video and generate activity reports.

Use of 4K UHD or Full HD IP cameras is encouraged for the majority of the station video surveillance applications. Megapixel images provide for the desired pixel-per-foot resolutions, using fewer cameras. The designer shall produce storage design calculations showing that the capacity of video storage hard drives is adequate. Note that such calculations typically include a variety of cameras types, reflecting their specific frame rates, resolutions, and compression types. The compression types and rates typically depend on a particular CCTV software vendor, and the designer shall provide the corresponding DVR storage requirement calculation as part of their CCTV design submittal. Also, to support future growth, the performance and storage of the station DVR equipment shall be rated to handle an additional 50 percent of similar station CCTV equipment.

As part of the design submittals, the designer shall include camera installation and wiring details, shall provide Caltrain Engineering with all necessary calculations for performance and storage requirements of the CCTV system, and shall identify adequate and up-to-date equipment/software that is fully compatible with the existing CCTV headend in CEN, MPCCF, and SJCCF.

At a minimum, the station design shall provide for RAID 5 or 6 redundancy for the station DVR hard drives capable of recording and storing video information for 14 days (including additional 50 percent spare storage allocated for future needs).

A portion of the station LAN shall be partitioned for CCTV as CCTV VLAN. The designer shall produce calculations showing that allocated CCTV VLAN bandwidth is sufficient to serve all station CCTV system needs. This VLAN capability shall reside in the network switch hardware. Additional bandwidth shall be allocated depending on the station size and number of CCTV camera locations.

## 2.0 FARE COLLECTION

A minimum of two units of TVM per boarding platform shall be provided for redundancy, and to handle any peak usage.

Communication with the station fare collection devices shall be implemented in a redundant manner; there shall be at least two separate LAN distribution switches serving their corresponding TVM (and/or group of VMS signs). This way, if one of the switches fails, there will always be another functioning TVM (and/or group of VMS signs) connected to the remaining switch and available to serve passengers at the station.

Clipper is a regional system that is administered by the San Francisco Metropolitan Transportation Commission (MTC).

The Clipper CIDs are typically situated near the TVMs. The quantity of Clipper CIDs is typically three per platform; however, their exact quantity and placement shall be coordinated between the designer and Caltrain/Clipper.

Though not a TVM, Clipper CID uses the same station fiber physical network. However, the Clipper LAN is independent from Caltrain LAN, and their network devices shall never interface. The Clipper subsystem design shall use a station Clipper LAN IP-based network operating at 100 Mbps for field devices and 1 Gbps for the station backbone connection (between distribution cabinets and CER).

A CID card reader is installed on a dedicated pole, and requires a 24 VDC power. The corresponding 24 VDC rack-mounted power supplies are usually placed inside the closest CER or distribution cabinets.

Clipper provides and installs all station CID network equipment: CID Router, CID switches, and the end CID devices. The Clipper vendor also provides for a separate WAN connection (at MPOE).

For rehabilitation and new construction projects, coordinate with JPB and MTC regarding the use of Caltrain-owned fiber optic cable plant for Clipper WAN connectivity.

Caltrain is responsible for furnishing CID poles and temporary covers for the poles, and the contractor is responsible for their installation. The MTC is responsible for providing all interconnecting conduits and communication/power wiring, and for furnishing, installing, and terminating all necessary 24 VDC power supplies in distribution cabinets (one power supply per two CID devices).

For fiber cable connection, TVM shall house a single-mode fiber optic media converter and a compact single-mode fiber patch panel for connecting the TVM to the distribution network switch via single-mode fiber optic cable. The CID shall have dedicated Category 6A or single-mode fiber optic connectivity, depending on the distance to the distribution network switch. The cables shall be installed via dedicated conduit runs. The CID's Category 6A or the single-mode fiber optic cables shall also share the conduit with two #16 American wire gauge (AWG) minimum power wiring conductors (for 24 VDC power). Voltage drop calculations shall be provided to determine the required power conductors gauge. For single-mode fiber optic connectivity, provide 10/100 Mbps media converters.

Distribution cabinets shall house dual-network (aggregate) switches for Caltrain LAN and single CID switches for Clipper LAN. Each TVM device shall be assigned to a separate distribution switch for additional network reliability.

## 3.0 DIGITAL SIGNS AND DISPLAYS

### a. Variable Message Signs

VMS are required to augment and complement audio PA messaging for the benefit of hearing-impaired commuters, to satisfy ADA requirements for equivalent visual information. Visual messaging shall be both centrally controlled from the dispatch office and locally controlled by maintenance personnel.

VMS boards shall be digital and network-based control in nature and of a light-emitting diode (LED) type, shall support a wide range of variable character sizes, and colors, include configurable parameters including scrolling and flashing, and shall meet ADA requirements. This includes variable parameters to ensure character sizes can be adjusted to compensate for differing physical mounting positions.

The VMS dimensions for a typical single or dual-face display with a maximum of four lines shall not exceed 14.5 inches high by 52.53 inches wide by 13.75 inches deep. Single-face display depth is typically 8.5 inches and shall only be used in lieu of the dual-face sign at locations where patrons can view only one side.

The VMS communications interface shall be 10/100BASE-T or over a single-mode fiber optic cable. The designer shall coordinate with the owner and shall provide the most reliable and economical interface solution. The VMS shall be compatible with and integrate easily with the existing passenger information display system (PIDS) at CCF.

The VMS shall have a full-color RGB display with a pixel pitch not exceeding 0.25 inches, and be capable of displaying multiple text styles and sizes, graphics, and logos; suitable for outdoor installation; UL-listed; accessible for service; and provided with dimming control.

The designer shall place a minimum of two dual-sided units per platform for redundancy and passenger convenience. VMS design shall include a plan view depicting both the message sign and the support structure location in the station, including distances to platform edge, conduit size and route, and conduit pull box locations. For VMS installation and mounting requirements, refer to Standard Drawings SD-4901, SD-4903, SD-4904, and SD-4905.

This subsystem design shall use a VLAN IP-based network operating at minimum of 100 Mbps. An IP address will be assigned to all message signs in the network. Messaging shall be controlled at the CCFs. The CCF shall be able to message individual stations, message groups of stations, or broadcast messages to all stations as required.

Distribution cabinets shall house dual-network (aggregate) switches. Each VMS device shall be assigned to a separate distribution switch for additional network reliability.

For rehabilitation projects or new construction, the design shall incorporate connectivity of the VMS system with MPCC and SJCC via the JPB fiber optic cable plant.

The VMS system shall be powered by essential power (from CER station UPS).

The details of the VMS specifications are in Specification Section 27 42 10.

b. **Platform End Displays (PED)**

Platform End Displays are digital LCD flat-panel monitor type signs. They are utilized at the San Francisco 4th/King Station and San Jose Diridon Station tunnel to aid in passenger wayfinding, with potential future use at various other stations such as grade-separated platforms. They are high resolution and fully color capable, whose displayed content is fully controlled and configured by the head-end Passenger Information System (PIS) system. They are typically mounted in a portrait configuration and display critical train and departure information for the track is located, including color schemes, scheduled stopping pattern, destination, and messages pushed by the PIDS clerk operator.

The signs shall include a rugged computer, either attached or built-in, necessary and suitable to facilitate network connectivity, receive and interpret content data received from the head-end controlling system, and display the content on the monitor. The controlling computer shall also retain fault reporting and logging, and self-recovery capabilities. The computer shall also be rugged, and tamper resistant, including cybersecurity considerations for both wired or wireless connectivity access.

The screens shall be 50” LCD type monitors or similar, and be natively hardened or contained within a hardened enclosure to prevent vandalism and damage, and shall provide an appropriate IEC Ingress Protection (IP) rating suitable for the location in which it is mounted (e.g., outdoor vs. lobby) and its accessibility to the public.

c. **Train Schedule Displays (TSD)**

Train Schedule Displays are digital LCD flat-panel monitor type signs. They are utilized at the San Francisco 4th/King Station and San Jose Diridon Station to aid in passenger wayfinding, with potential future use at various other stations. They are high resolution and fully color capable, whose displayed content is fully controlled and configured by the head-end Passenger Information System (PIS) system. They are typically mounted in a landscape configuration and display schedule and track information for the trains and station for which the sign is located. Content includes the train departure schedule, destinations, real-time updates for track changes and on-time or delay status, stopping-pattern type, color schemes, and messages pushed by the PIDS clerk operator.

The signs shall include a rugged computer, either attached or built-in, necessary and suitable to facilitate network connectivity, receive and interpret content data received from the head-end controlling system, and display the content on the monitor. The controlling computer shall also retain fault reporting and logging, and self-recovery capabilities. The computer shall also be rugged and tamper resistant, including cybersecurity considerations for both wired or wireless connectivity access.

The screens shall be 50” LCD type monitors or similar, and be natively hardened or contained within a hardened enclosure depending on its mounting location to prevent vandalism and damage, and shall provide an appropriate IEC Ingress Protection (IP) rating suitable for the location in which it is mounted (e.g., outdoor vs. lobby) and its accessibility to the public.

## 4.0 PUBLIC ADDRESS SYSTEM

PA systems shall be designed for Caltrain staff to communicate with passengers, locally or from a remote location. Station public announcements shall be made in a clear, audible, and uniform manner to provide train and general information, as well as emergency and security announcements throughout the station facility.

The PA system shall consist of speakers along boarding platforms to provide clear, audible communication to commuters. Major Caltrain passenger stations also allow for inside and outside station announcements (e.g., station plaza or station concourse).

The PA system shall be able to initiate PA announcements either remotely or locally.

The remote announcements shall be initiated as follows:

Automated PA announcements from the MPCC and SJCC by the PA system headend equipment PA announcements over a phone line or cellular by Caltrain end users. Automated PA announcements from CCF are the primary use of the PA system and provide for Caltrain's train and general information. This includes the following:

a. Timetable, listing departure times at scheduled stations

b. Commuter rail delays, status, or travel updates

c. Alternate service plan advisories

d. General safety and security advisories

e. Advisories regarding construction activities and interruptions

Unplanned announcements such as emergency or security announcements and information related to local events are typically initiated by the centrally controlled head-end PIDS clerk from dispatch office or locally, using a paging microphone.

At Caltrain passenger stations where an agent office exists, provide means of a wireless paging via wireless communications that would allow the station agent to make PA announcements while walking along the station and guiding the patrons according to the situation taking place in the station area.

At multiplatform stations (with more than two platforms), a paging microphone for each platform shall be provided.

To ensure that various types of announcements do not overlap each other, the station PA control system shall support implementation of priority scheme. In-progress PA announcements shall be preempted according to the priority scheme defined below (Priority 1 being the highest; Priority 4 the lowest):

Priority 1: Automated PA announcements from CCF.

Priority 2: Local hard-wired paging microphone from the station PIDS clerk office (where applicable i.e. San Jose Diridon, 4th & King San Francisco).

Priority 3: Local paging microphones at the station platforms.

Priority 4: Remote PA announcements over a phone line or cellular by a Caltrain end-user.

For stations where the PIDS clerk office is implemented, the station PA system shall enable users to turn remote messaging off. This shall be done for special or emergency events, to prevent the PA system from announcing PA messages other than those related to the event.

Local announcements are expected to be of limited duration. The majority of the announcements are expected to be automated PA announcements from CCF. These are PA system pre-recorded voice announcements, which (for ADA compliance) shall be coordinated with stored, preset text messages for display on the VMS, also generated by the CCF.

The MPCC and SJCC can send messages to individual stations, send messages to groups of stations, or broadcast messages to all stations as required.

To prevent "prank-call" announcements, PA announcements over a phone line by Caltrain end-users shall use a phone access device, which can limit access to the PA system by requiring the phone user to enter an authorized access code.

Caltrain has introduced a new digital backhaul service for the PA system using IP addresses, but the audio amplifiers at the train stations are not IP-based. To bridge this gap, Caltrain uses a digital-to-analog (D/A) modem at each station for the new digital IP-based system until the entire PADS system is replaced with a fully digital audio system.

The networked signal processor shall be provided with analog and digital I/O terminations or cards accommodating all inputs and outputs from phone circuits, gateways, microphones and ambient noise sensors, and connections to the amplifiers, as needed in support of the station PA system; and, where necessary, digital inputs (e.g., on/off switches, multiple-position switches, or remote volume control devices). Networked audio cards compatible with the amplifier shall be provided for digital audio distribution where applicable.

The networked signal processor shall be of a modern type, with sophisticated software that allows programming and processing of the analog and digital inputs in support of the station's specific needs. It shall support PA zones and eliminate microphone feedback, any undesirable "clicking/snapping" sounds, and/or 50hertz (Hz) humming noise interference from power wiring; and its output shall be adjustable according to the ambient noise level. Its software shall support the ability to automatically adjust the output of the system to meet the daytime and nighttime noise abatement requirements of local municipalities.

Station amplifiers shall have a minimum of two input and two output channels. Each output channel shall be capable of providing 70-volt (V) operation. Amplifiers capable of operating on both 70V and 100V for high impedance application shall have each output independently configurable for low or high impedance application. The amplifier digital or networked audio capability shall be compatible with the networked signal processor.

The amplifier shall be configurable and shall have programmable I/O control ports in addition to monitoring and control capability over the network. Dry-contact alarms shall be reported via UPS digital input sensing where applicable. The amplifier shall have protection circuits against shorted outputs, mismatched loads, overheating, and over- and under-voltage.

Each station shall be provided with a minimum of two amplifiers configured in a redundant manner so that half of the speakers on each platform, concourse, waiting room at terminals, etc., remain operational if one amplifier fails. The station-networked signal processor, amplifiers, gateways, and other devices shall be installed inside the CER or the SCC. Amplifiers and networked signal processors shall be rack mounted.

PA system speakers shall be mounted on existing station structures, such as light poles, canopies, columns, walls, and ceilings, depending on the station architecture. Platform speakers shall be 40-watt speakers of constant directivity design with transformer and taps. Speakers installed in waiting rooms, concourses, and other areas other than platforms shall have power ratings as required by the design and shall have transformers and taps. The speaker shall be suitable for the environment and the location where they are installed. The PA speakers for a zone shall be connected so that odd-numbered speakers are wired to one output on one amplifier and even-numbered speakers are wired to one output on another amplifier. Refer to Standard Drawings SD-4110 and SD-4111 for the speakers physical wiring topology for speakers. The PA cable wire size shall be a minimum of 16 AWG for the speaker and a minimum of 18 AWG for the microphone.

To mitigate changes in volume of the ambient noise, the PA system shall use ambient noise sensors and adjust the PA output accordingly. There shall be one ambient noise sensor per zone (platform, concourse, waiting room, etc., as applicable). All ambient noise-sensing microphones shall be placed carefully, facing away from the PA system speakers; the goal is to sense the ambient audio levels, not the audio generated by the PA system.

Analog (voice) signals are required at distribution amplifiers to drive the PA speakers throughout the station.

The designer shall provide a detailed PA system design, including block diagrams, wiring and installation details, a bill of material listing, the calculation of standby and active power used by the amplifier, and the voltage drop and wire gauge sizing calculation for each chain of speakers terminated on the amplifier. Acoustical analysis shall also be provided, as described in the following section.

## 5.0 ACOUSTIC MODELING

For rehabilitation projects, the designer shall include in the design sound pressure level (SPL) calculations the number of speakers and the horizontal and vertical speaker orientations required to provide SPL at about 10 decibels (dB) above ambient.

For new construction and as requested by the owner, acoustical analysis using simulation software shall be used to meet the following requirements:

a. Because the goal for any PA system is speech intelligibility, designers shall ensure that following minimum values of the speech transmission index (STI) are met (measured at a height of 5 feet above the floor level):

   i. Station Platform: The desired STI should be a minimum of 0.6, measured at 95 percent of all station platform areas assigned to be covered by the PA system.

   ii. Inside Station Areas: The new PA system shall cover all publicly accessible areas in the station. For new stations, the desired STI shall be a minimum of 0.6, measured at 95 percent of all station indoor areas. For an existing station with challenging reflective materials and architectural design, the desired STI should be a minimum of 0.5, measured at 95 percent of all station indoor areas.

   iii. Outdoor Station Areas (including the station plaza): This is an open area where the designers can impose the list amount of control for the PA system design, and where the adjacent neighborhoods and street traffic represent a large concern. For these areas, the STI should be a minimum of 0.5 at 25 feet in the vicinity of the station doors; with a minimum of 0.5 STI and uniformity of 80 percent coverage in the station plaza areas.

b. For the preliminary analysis of the station PA system design, the following values should be used for ambient noise (the final design of the PA system shall be based on the tested values in the station environment):

   i. The station interior has been shown to have an ambient noise level averaging between 66 and 73 dB

   ii. Platforms with stopped trains with operating car air conditioning show an average ambient noise level of 80 dB to 85 dB

   iii. Platforms with stopped trains and measured near operating locomotives show an average ambient noise level of 85 dB to 95 dB

c. For the design of the station PA system's uniformity of coverage for the PA announcements, the values below shall be achieved in at least 95 percent of the station areas. The values are measured as SPL expressed in dB. The new PA system shall be capable of producing output sound levels of at least 12 dB higher than the measured ambient noise. The uniformity of the coverage shall be as follows:

   i. Complex Caltrain Station Layout – Minimum design goal: ±6 dB at the 1,000 Hz octave band. Typical Caltrain Station (one or two platforms) layout – Preferred design goal: ±3 dB at the 1,000 Hz octave band

d. A signal-to-noise ratio between 6 and 12 dB (depending on each station's particular environment) should be targeted for improving intelligibility.

Designers shall develop computerized acoustic models of indoor spaces to ensure that the STI values noted above are met with the appropriate ambient noise. Outdoor spaces that have little reverberation need not require modeling. However, outdoor stations in areas that have a density of buildings or platform shelters, etc., may need modeling to achieve the required STI performance levels.

## 6.0 PASSENGER ASSISTANCE AND EMERGENCY TELEPHONES

Talking signs for the visually impaired passengers are provided at the terminal stations in San Francisco (4th and King) and San Jose (Diridon). Emergency telephones are currently not provided at Caltrain stations.

## 7.0 CABLE AND RACEWAY

Cables and raceways in support of the station's communications equipment, devices, communications rooms, and facilities shall contain power and communications cables, conduits, conduit fittings, conduit supports, cable trays, pull boxes, junction boxes, identifications of cables, conduits, pull boxes and junction boxes, grounding components, innerducts, and other items as applicable for the design.

The cable and raceway design shall adhere to the latest adopted edition of the National Electrical Code (NEC) as enforced by the local authority having jurisdiction, including conduit fill, bends, ampacities, and grounding requirements.

The designer shall provide conduit and cable schedules, conduit fill percentage calculations, and calculations for the sizing of power cables.

## 8.0 FIBER OPTIC AND CATEGORY 6A CABLES

Single-mode fiber optic cable shall be used, as applicable to station design.

The design shall provide for single-mode fiber optic cable for backbone connectivity between the distribution cabinets and CER, as well as for device connectivity to the LAN distribution switch in the distribution cabinet.

The station aggregation switch shall be single-mode compatible and allow future fiber connectivity with the Caltrain-owned fiber optic cable plant. Where possible, the single-mode fiber optic cable network shall be provided in a physical dual-ring topology. Single-mode fiber optic cable shall be installed in separate conduits via color-coded innerducts to clearly identify single-mode fiber optic cable.

At the CER and distribution cabinets, all single-mode fiber optic cable shall be terminated on fiber optic patch panels provided with splice trays, connector panels, and other hardware for terminating all strands of the cable. Fiber connectors and patch cords shall be colored yellow. The preferred connector type for the patch panel is SC (Standard Connector). The preferred connector type for the network device side is LC (Lucent Connector).

Single-mode fiber optic cable between the distribution cabinet and a device such as TVM, VMS and CCTV shall be terminated on a compact patch panel or provided with a factory pre-terminated connector for ease of coupling to the compact fiber patch panel at the device end. The other end of the cable shall be terminated at the distribution cabinet, as described above.

Single-mode fiber optic cable shall be an all dielectric (no metallic components), loose-tube, gel-free cable.

Category 6A cables shall be used for device termination where the device is within 300 feet from the distribution cabinet LAN distribution switch. Category 6A cables shall terminate on Category 6A patch panels. Category 6A patch cables shall be used for termination on the LAN distribution switch.

## 9.0 PROTECTION TERMINAL BLOCKS

All outdoor copper cabling (e.g., Category 6A, PA, and microphone audio cables) shall be connected through the suitable protection type terminal blocks at the entry points of the distribution cabinet, SCC, and CER.

The protection equipment shall match the application type of each terminated cable, and shall be implemented according to the vendor recommendations.

## 10.0 CONDUIT RACEWAY SYSTEMS

When designing conduit raceway systems for station communications, the following shall be considered:

a. Where possible, the CER or distribution cabinet shall be centrally located in the station. Backbone cable and conduit shall extend from the main equipment throughout the station as required.

b. Backbone cable and conduit from the CER to each distribution cabinet and from distribution cabinet to distribution cabinet shall be designed for redundancy. The CER shall have at least two pathways to each distribution cabinet on a platform; refer to Standard Drawings SD-4830 and SD-4831. Providing pathway redundancy improves subsystem reliability by guarding against total subsystem failures due to conduit collapse, cable cuts, or other cable path problems.

c. Four-inch conduits shall be installed for backbone cables. American National Standards Institute (ANSI)/Telecommunications Industry Association (TIA) 569 shall govern the conduit pathway design, including pull boxes and cable routing, as applicable.

d. The conduit system shall be placed to avoid crossing other utilities. Where crossings cannot be avoided, adequate clearances must be adhered to when crossing either under or over another utility. Outside plant conduits will be spaced at least 12 inches from other paralleled utilities, and at least 6 inches of spacing when crossing perpendicular to other utilities. This space will allow work to be accomplished on either utility’s equipment at the point of intersection at any later date. Grade changes necessary to get under or over obstructions should be at an approximately 5-degree grade change. At no time should both utilities' equipment become encased in the same trench or concrete pour.

## 11.0 OUTDOOR, INDOOR AND UNDERGROUND CONDUITS

For outdoor installation and indoor installation susceptible to physical damage, galvanized steel rigid metal conduits (RMCs) shall be used. The minimum conduit trade size shall be ½ inch, and the maximum shall be 6 inches. Conduit supports, straps, bolts, screws, and so forth shall be of corrosion-resistant materials. Electrical metallic tubing (EMT) may be used for indoor installations not subject to physical damage.

Where RMC installation is not practical, and where installation conditions require flexibility and protection against liquid, liquid-tight flexible metal conduits (LFMCs) shall be used. The minimum trade size shall be ½ inch, and the maximum shall be 4 inches. The LFMC shall be securely fastened in place. For longer runs, LFMC shall be securely fastened within 1 foot of each termination point and at intervals not exceeding 4½ feet along the run. LFMC fittings and supports shall be of corrosion-resistant materials.

For underground installation and for concrete-encasement applications, rigid polyvinyl chloride (PVC) conduits, fittings, and factory elbows shall be used. Where transitioning from underground PVC to exposed RMCs, RMC fittings shall be installed. The minimum trade size for underground PVC installation in the design shall be 2 inches minimum, and the maximum trade size shall be 6 inches.

Schedule 40 PVC conduits shall be used for installation along the platform from pull box to pull box, and from pull box to equipment foundation.

Schedule 80 PVC conduits shall be used for under-track installation and shall be encased in concrete.

The following design criteria shall be followed:

a. Outside plant-rated hand-holes with covers marked "communications" shall have a highway rating of H-20.

b. Outside plant-rated conduits shall be trenched or buried to a minimum depth of 48 inches below grade to the top of the conduits. Where this depth requirement cannot be met, the conduits shall be concrete-encased.

c. Fiber optic conduit pathways installed below grade shall be concrete-encased when installed under rails.

d. Outside plant fiber optic cables and conduits shall be protected using detectable marking tape placed 12 inches below grade and over the area to be protected, in addition to above-grade visual markers.

e. Cable raceways shall be sized to carry Category 6A and fiber optic cable, in accordance with code and industry standards. The minimum conduit size used for Category 6A and fiber optic cable shall be 1 inch when running cables between station distribution cabinets and the subsystem device location. The minimum conduit size used for bundled fiber optic cable shall be 4 inches when running cables between the main equipment room and the station pull boxes or distribution cabinets. All conduit fittings shall be compression type (not mechanical). All conduit ends shall be reamed and bushed. All outside plant conduit openings shall be sealed after cable installations. All unused conduits shall have pull-strings placed.

f. Conduits shall enter the pull box from the side. Transition of the conduits to the side of the pull box shall be made at a point away from the pull box, and shall allow for the conduit's minimum bending radius requirements. The transition shall be "S"-shaped, as shown on Standard Drawing SD-4832.

## G. FIBER OPTIC OUTSIDE PLANT

Caltrain's Fiber Optic Outside Plant is designed to provide a resilient and scalable communications backbone supporting present and future railroad operations. The system incorporates two 288-strand loose tube single-mode fiber optic cables: Cable A, serving as the operational cable for Positive Train Control, signaling, traction power, dispatch, and electrification systems; and Cable B, maintained as dark fiber for redundancy or future commercial leasing. Both cables are installed in separate 1" HDPE innerducts within a shared 4" PVC conduit, with an additional spare 1" innerduct containing a tracer wire for maintenance purposes.

Future installations will standardize on 1.25" innerducts to enhance capacity and accessibility. Accessibility to the system is provided by a typical 4'x3'x2' fiberglass pull boxes spaced approximately every 1,000 feet, and splice closures installed roughly every 0.5 miles for structured connectivity.

Fiber nodes or field locations are connected in a collapsed ring configuration with 16 active rings, including a dedicated ring for critical radio systems such as Positive Train Control and dedicated rings for Traction Power Systems. The Passenger Wi-Fi system utilizes dedicated fiber rings as a backhaul to Caltrain's datacenter located at its CCF.

Wayside signal nodes are generally arranged such that a location skips the physical adjacent neighboring node and connects directly to the second location upstream and downstream. This type of connection enhances redundancy and minimize adjacent neighbor failures. This design supports operational reliability, system longevity, and adaptability to future technological demands.

In addition to the outside plant or field fiber optic cable infrastructure, Caltrain's fiber optic system runs into terminal points that also serve as Caltrain's authority limits. The fiber optic cables terminate at key endpoints in San Francisco at the 4th & King Station and in San Jose at CP Lick, forming the primary north–south communication pathway. Along this route, the fiber also terminates at Caltrain's Menlo Park and San Jose Control Center data centers, where vital operational systems and back-office functions are centralized. These facilities host network management equipment, dispatch communication systems, Positive Train Control servers, train control, and other mission-critical applications.

To ensure continuity, the end terminals are interconnected through third party telecom service providers, completing the fiber ring and reinforcing system redundancy. By consolidating communication at these strategic locations, Caltrain ensures reliable coordination of train operations, real-time data exchange, and secure management of railroad systems across the corridor.

Caltrain's Fiber Outside Plant provides the essential pathway linking field nodes to the central control facilities, ensuring seamless communication across the railroad. At each field location, a network switch and fiber patch panel interface with a typical 12-strand fiber cable that ties into Caltrain's 288 fiber backbone cable. This local cable is joined through a splice closure approximate to the backbone cable, creating the connection point into the larger physical network. When the backbone cable is near the control center, another lateral cable coming off another splice closure goes into the central control facility.

Inside the facility, a main fiber distribution patch panel organizes connections between the field nodes and fiber aggregation switches. Finally, the fiber transport links field data into back-office applications such as SCADA, enabling real-time monitoring and control of signaling, traction power, and other mission-critical railroad operations. This infrastructure ensures reliability, scalability, and operational continuity across Caltrain's network.

## H. WIRELESS SYSTEMS

### 1.0 LEASED CELLULAR SITES

The San Francisco Bay Area maintains one of the nation's most advanced wireless networks, featuring widespread 4G LTE coverage and ongoing 5G expansion by major carriers. However, service gaps remain due to the region's dense urban areas, varied topography, and high commuter traffic along key transportation corridors such as the Caltrain line on the San Francisco Peninsula. These factors drive demand for strategically located infrastructure to strengthen network reliability and capacity.
To meet this demand, carriers increasingly depend on leased assets—macro towers, rooftop sites, and small cell nodes—rather than building new, standalone structures. On the Peninsula, where space and permitting opportunities are limited, long-term site leases within established transportation corridors have become particularly valuable.

Caltrain currently leases portions of its right-of-way (ROW) for telecommunications infrastructure as part of its non-fare revenue program. Existing agreements include cell tower sites managed through third-party providers such as Crown Castle, which operate shared communications facilities supporting multiple carriers. Expanding this model to additional sites along the corridor would enhance wireless coverage for passengers and surrounding communities while providing Caltrain with a sustainable source of supplemental revenue.

As wireless technology continues to evolve and 5G deployment accelerates, Caltrain's electrified corridor offers an ideal, infrastructure-ready environment for future telecommunications partnerships that balance operational safety, public benefit, and financial return.

## 2.0 PASSENGER Wi-Fi

The new Wi-Fi network uses Blu Wireless's 60 GHz millimeter wave (mmWave) radio technology to provide passengers with high-speed, reliable connectivity while also

supporting train monitoring. Nomad Digital, an Alstom subsidiary specializing in transport connectivity, served as the system integrator for the project. Its key contributions included:

a. Deploying the network: Construction of a 51-mile trackside network with 64 radio sites and 9 edge switches.

b. Integrating technologies: Combining Blu Wireless's 60 GHz mmWave radios with onboard Wi-Fi to serve passengers inside the trains.

c. Ensuring cybersecurity: Protecting the system with the Nomad Secure intrusion detection solution.

## 3.0 DATA RADIO

### 3.1 ATCS CELL MODEM RADIO NETWORK

Currently Caltrain uses the ATCS 900 MHz band as a backup for WIU messaging. This 900 MHz band is owned by AAR which will be re-banded by the FCC in September 2025. AAR will not allow any railroads to use this new band for ATCS network. Caltrain is in the process of switching the ATCS network to a third-party wireless cell-modem private network (e.g., FirstNet) as a backup for WIU messages. This work includes installation of cell modems and antennas on the ATCS huts at 32 locations, along with installation of power and data cables to the new cell modems. The data network is implemented through Caltrain-owned fiber as the primary backhaul and a new cell-modem coverage as the secondary backhaul.

### 3.2 MICROWAVE RADIO NETWORK (EXPIRING)

The microwave network was originally implemented as the primary backhaul for ATCS protocols. When the PTC network was introduced to enhance operational safety, fiber was added to serve as the primary backhaul for both the PTC and ATCS networks. After the addition of the PTC network, the microwave network was repurposed as a backhaul for the 900 MHz radio network. Since the 900 MHz radio network will no longer be in use after September 2025, the microwave network is planned to be retired and removed from the system by mid-2026.

## 3.3 PTC RADIO

PTC serves as a redundancy that overlays with existing safety and signaling systems. It is intended to prevent train-to-train collisions, overspeed derailments, incursions into established work-zone limits, and the movement of a train through a mainline switch in the improper position.

Interoperable Train Control Messaging (ITCM) itself is a Meteorcomm product. ITCM is a Positive Train Control (PTC) communications system that enables applications in the back office, locomotives, and wayside to communicate with each other across railroad boundaries.

The Caltrain system is covered by fourteen (14) 220MHz base stations, five (5) of which are co-located. Additional coverage is provided by UP and BNSF stations. The design has been optimized to provide sufficient RF coverage and an appropriate level of RSSI per WSM. Tests show that coverage from San Francisco to Gilroy including the four (4) tunnels can sustain an RSSI of at least -94 dBm, considering a 5-mile radius around each base station.

## 3.4 VOICE RADIO

VHF voice radio system consisting of three distinct channels is currently used to support all operations along the Caltrain right-of-way (ROW). The three channels are: a road channel, used for train dispatch; a maintenance-of-way (MOW) channel, used to support operations and the mechanical department; and a yard (aka blue flag) channel.

New VHF sites are co-located with selected PTC sites, using the existing RuggedCom RS900 switch and existing fiber Ring 4, which is already terminated at the PTC base station locations, to provide VHF backhaul service.

The new VHF radios are installed at co-located sites in analog mode until the new digital system is implemented. At the MOW sites, and until the new digital system is implemented, the new radios shall remain in analog mode until all participating railroads agree to switch to the NXDN digital mode. The road channel is an analog, FM, narrowband (12.5 KHz) simplex channel operating on a frequency of 160.8150 MHz. The MOW channel is an analog, FM narrowband (12.5 KHz) full duplex channel operating on the frequency pair: 161.5050 MHz for base station transmit and 160.5750 MHz for base station receive. The yard channel is an analog, FM, narrowband (12.5 KHz) simplex channel, configured for independent local operation at the San Jose CEMOF and San Francisco 4th Street yards on a frequency of 161.0700 MHz. The road, MOW and blue flag channels are all managed and controlled from the voice radio dispatch consoles at the CEMOF control center. This dispatch console is a Safetran digital touch exchange. The road channel is provisioned along the entire ROW, through the use of aboveground as well as tunnel radio base stations. The yard channel is provisioned only within the confines of the two railroad yards at Fourth Street near downtown San Francisco and CEMOF in San Jose. The MOW channel is provisioned along the entire ROW, through the use of aboveground as well as tunnel radio base stations; it is further provisioned alongside streets and highways on most of the peninsula and the East Bay. The headend for railroad dispatch, operations, and maintenance is served by a radio dispatch system which is configured as follows: a total of two independent dispatch stations are located at the CEMOF. One of the two dispatch stations is responsible for supporting the northern portion of the railroad, between approximate mileposts (MPs) 0.0 and 44.0; the second station supports the southern portion of the railroad, between approximate MPs 44.0 and 52.0 on the road dispatch channel.

Between MP 52.0 and 71.0 Gilroy, the dispatch is performed by UPRR. Although capable of monitoring train movements on the UPRR tracks, Caltrain cannot perform any train dispatch on the UPRR tracks. Although the dispatch stations are stand-alone, each independent of the other, they are also fully redundant to each other, because they are individually capable of supporting rail vehicle movements for both the northern and southern regions of the railroad. The operation of the MOW channel at CEMOF is system-wide for both consoles and is therefore not restricted to these northern and southern limits.

The design for the radio dispatch at BCCF shall be duplicated to provide the same functions that exist at CEMOF.

Caltrain is moving towards digital radio system as discussed further in other sections.

a. BASE STATION SITES

Thirteen VHF voice radio base station sites currently exist to support the road channel. Of these, nine are above-grade radio base station sites along the ROW, each of them configured for carrier-squelch, simplex operation on the road channel (47) frequency of 160.8150 MHz. The remaining four base station sites are inside four railroad tunnels along the ROW. A second carrier-squelch, simplex channel, operating on a frequency of 161.0700 MHz, is used to support maintenance and yard operation, but is repeated only in the vicinity of the San Francisco and San Jose yards, using the Fourth Street and the San Jose base station towers, respectively.

Six VHF voice radio base station sites currently exist to support the MOW channel. Of these, four are co-located with the road channel at the four tunnel sites, and two are co-located at the mountaintop sites. This channel is configured for carrier-squelch, full duplex operation on the frequency pair: 161.5050 MHz for base station transmit and 160.5750 MHz for base station receive.

b. ABOVE-GROUND BASE STATION

Of the nine aboveground road base station sites, three are controlled by the northern territory dispatch and two by the southern territory dispatch. The two aboveground MOW base station sites are at San Bruno Mountain and Monument Peak; each is capable of providing radio coverage along the entire ROW and to most of the peninsula and surrounding areas. This ensures that a train engineer and signal maintainer can communicate with anyone else along the ROW, without the assistance of a third party such as the dispatcher.

To support this configuration, the maintenance base stations shall be configured as full duplex, carrier-squelch repeaters, with the receive audio from each site routed to the CCF for voting and steering of the transmit audio. The dispatcher shall have access to this channel using a push-to-talk foot pedal and shall therefore have the highest priority for use of the channel. The maintenance channel shall be capable of use as an emergency backup for the road channel.

**Table 4-2: Dispatch Base Station Sites**

| Site Name | VHF CH / Freq MHz | Azimuth | Latitude | Longitude |
|---|---|---|---|---|
| SF North Road 4747 | 47 / 160.815 | 40/40 | 37.7718 | -122.4006 |
| SF Mechanical 6464 | 64 / 161.070 | 40 | 37.7718 | -122.4006 |
| Tunnel 1 Road 4747 | 47 / 160.815 | TBD | 37.7583 | -122.3924 |
| Tunnel 1 MOW | 9331/161.050 Tx 160.575 Rx | TBD | 37.7583 | -122.3924 |
| Tunnel 2 Road 4747 | 47 / 160.815 | TBD | 37.7517 | -122.3930 |
| Tunnel 2 MOW | 9331/161.050 Tx 160.575 Rx | TBD | 37.7517 | -122.3930 |
| Tunnel 3 Road 4747 | 47 / 160.815 | TBD | 37.7298 | -122.3961 |
| Tunnel 3 MOW | 9331/161.050 Tx 160.575 Rx | TBD | 37.7298 | -122.3961 |
| Tunnel 4 Road 4747 | 47 / 160.815 | TBD | 37.7117 | -122.4014 |
| Tunnel 4 MOW | 9331/161.050 Tx 160.575 Rx | TBD | 37.7117 | -122.4014 |
| Brisbane Road 4747 | 51 / 160.815 | 320/220 | 37.6733 | -122.3894 |
| Millbrae Road 4747 | 52 / 160.815 | 310/130 | 37.5949 | -122.3804 |
| Hillsdale Road 4747 | 53 / 160.815 | 320/150 | 37.5424 | -122.3018 |
| RWC Road 4747 | 54 / 160.815 | 290/140 | 37.4746 | -122.2130 |
| Stanford Road 4747 | 55 / 160.815 | 340/160 | 37.4403 | -122.1597 |
| Sunnyvale Road 4747 | 56 / 160.815 | 300/110 | 37.3784 | -122.0297 |
| SJ North Road 4747 | 57 / 160.815 | 300 | 37.3389 | -121.9080 |
| South Road 9696 | 96 / 161.550 | 300/130 | 37.3389 | -121.9080 |
| CEMOF Yard 6464 | 64 / 161.070 | | 37.3389 | -121.9080 |
| UPRR 42 | 42 / 160.740 (Rx only) | | 37.3389 | -121.9080 |
| PCS 25 | 25 / 160.485 (Rx only) | | 37.3389 | -121.9080 |
| Tamien South 9696 | 96 / 161.550 | 300/140 | 37.3142 | -121.8857 |
| San Bruno Mountain MOW | 9331/161.050 Tx 160.575 Rx | 180 | 37.6873 | -122.4348 |
| Monument Peak MOW | 9331/161.050 Tx 160.575 Rx | 250 | 37.4848 | -121.8668 |

c. TUNNEL BASE STATION

Between the Fourth Street tower and Sign Hill base station sites, there are four railroad tunnels. Each tunnel is between 1,000 and 3,800 feet in length and is equipped, at its south entrance, with a small, stand-alone VHF radio base station configured for simplex, carrier squelch operations. Each of the four tunnel radio base stations is identical to the four above-grade radio base stations, except that each tunnel radio base station is connected to its own distributed antenna system; these antenna systems are installed in, and support radio communications in, the individual tunnels.

The recovered audio signal from each of the four-road channel tunnel radio subsystems is passed via 4wire leased lines to San Jose, where a voting comparator selects the best audio signal to present to the dispatcher. The voters, which are manufactured by JLP/Raytheon, shall be compatible with the Electronic Industry Alliance (EIA) signaling tones required to control the ICOM radio base station.

As Caltrain expands, it will become necessary to either build new railroad tunnels or to add new radio channels to the existing railroad tunnels. The following railroad tunnel radio criteria shall apply:

i. To provision radio coverage inside tunnels, trenches, and other subterranean areas, the designer shall use a distributed antenna system comprising radiating cable and low-profile antennas. Radiating cable shall be used to support radio coverage for all subterranean areas, except the large open areas where antennas can be used. The design of the base station, the donor antenna interface, and the distribution antenna shall be provided by Caltrain.

ii. The designer shall prepare a RF power budget, which shall depict the worst-case scenarios for the transmission and coupling of the RF signals along and from the radiating cables installed along the tunnels and trenches. The power budgets shall be prepared using a spreadsheet program such as Microsoft Excel, and shall prove the viability of the communication links.

iii. The designer shall perform an intermodulation study to determine what combination of frequencies is likely to create harmful intermodulation products inside the base station equipment. The designer shall use the results of the intermodulation study to fine-tune the design and installation to mitigate the creation of these harmful intermodulation products.

iv. The design shall guarantee radio coverage of 99 percent of the subterranean areas, with a reliability of 99 percent based on a signal quality of 20 dB signal in noise and distortion (SINAD). The designer shall be allowed to test the system based on the use of a circuit merit (CM), delivered audio quality (DAQ) or signal-level test, provided that the designer is able to first establish a correlation between a measured signal quality of 20 dB SINAD and the proposed CM, DAQ or signal-level tests.

d. DRAGGING EQUIPMENT DETECTOR

In addition to the four aboveground base station sites, there are three dragging equipment detectors (DEDs) along the ROW at MP 10.8 (between Millbrae and San Bruno; location being moved from MP 11.3 to MP 10.8), MP 28.2 (between Menlo Park and Atherton), and MP 42.0 (between Santa Clara and Lawrence). Each of these DED sites shall be equipped with a VHF voice radio, configured to report wayside status to the train engineer and the dispatch control center at CCF by transmitting this data on the same frequency as the road channel: 160.8150 MHz. More location details of the three DEDs are shown in **Table 4-3**.

**Table 4-3: Dragging Equipment Detection Sites**

| DED Name | GPS Coordinates | Site Elevation (Feet) | Antenna Azimuth |
|---|---|---|---|
| 10.8 | N 37º 37' 42.2"<br>W 122º 24' 37.0" | 15 | Rail transmitter, omni-directional<br>Gain 0 dBi |
| 28.2 | N 37º 27' 36.4"<br>W 122º 11' 25.9" | 36 | Rail transmitter, omni-directional<br>Gain 0 dBi |
| 42.2 | N37º 22' 11.5"<br>W121º 58' 27.6" | 44 | Rail transmitter, omni-directional<br>Gain 0 dBi |

Notes:
dBi = decibel (isotropic)
DED = dragging equipment detector
GPS = Global Positioning System

The DEDs are transmit-only devices, located along the ROW. They use a GE/Harmon Electronics (West Coast Operations) WCO46 "talker-system," which contains a discrete Motorola HT750 VHF voice radio connected to a small roof-mounted Sinclair low-profile, omni-directional railroad antenna.

The transmit power of each DED shall be reduced to provide an effective radiated power (ERP), dependent on the terrain in the immediate vicinity of the DED, that will restrict radio coverage to provide a receive intensity of ≥ 109 decibel-milliwatts within a ±3mile region of track. The transmit ERP required to achieve this shall be determined by the designer based on the use of radio coverage simulations and field tests. If limiting the DED radio coverage to ±3 miles result in a loss of a reliable link to at least one radio base station site, the DED messages shall be recorded locally; otherwise, all DED messages shall be recorded at the CCF.

**Table 4-4: Dragging Equipment Detector Radio Specifications**

| Specification | Description | Note |
|---|---|---|
| Model | Motorola VHF HT-750, analog, conventional transmitter | Narrow-band capable |
| Operation | Transmit only | |
| Power | 5 watts, adjustable | |

Note:
VHF = very high frequency

e. MOBILE & ONBOARD RADIO

Each locomotive and cab car operating in the ROW northbound through Gilroy will be equipped with a VHF-voice onboard radio. Each radio is programmable to all Association of American Railroads (AAR) frequencies, allowing it to be interoperable on any railroad. Each radio is programmed and configured to operate in carrier-squelch simplex mode on both the road and the yard (aka blue flag) channels. Likewise, all mobile and portable (handheld) radios used by Caltrain operations and maintenance personnel are programmed to operate on each of the two carrier-squelch simplex channels. Each radio is also programmed and configured to operate in carrier-squelched, half-duplex mode on the MOW channel.

The road channel is heavily used, particularly during the morning and evening rush hours. In addition to the locomotive, vehicle mobile, and portable radio users, the three DEDs add to radio traffic by broadcasting from the respective DED each time a train passes. They contend with the other users for road-channel air-time to access the four above-grade base station sites in order to communicate with the dispatcher. These users also contend with each other and with the three DEDs in order to communicate with each other (only when in close proximity) using the simplex radio-to-radio mode. Similar user contention for access to the four tunnel radio base stations occurs; but due to logistical reasons, no more than about six locomotives and a slightly greater number of mobiles and portables radios will be within range of these four tunnel base station sites.

Radio over fiber extension equipment shall be provided where applicable, similar to CP Sierra repeater site. The equipment shall consist of radio and antenna side units connected via fiber optic cable.

Flagman railroad personnel utilize North or South Channels of the voice radio sytem to communicates with dispatchers for safe work activities

The Caltrain EMU employs an onboard radio known as the Train Radio System TRS2090-D. It is a rolling stock system component that is able to provide the following features in analog mode:

i. Transparent data interconnection between core system components (TCMS) and TRS2090-D based on information middleware for fault management

ii. Digital inputs and outputs

iii. Voice communication from / to the train driver

iv. Voice announcements to the passengers via public address systems

The TRS2090-D has a digital system core-architecture and is currently configured for the use in the existing analog radio network of Caltrain at 12.5

kHz channel grid. When Caltrain switches to NXDN platform the radio needs to be upgraded by replacing the DMR module to the NXDN module.

## I. INSTALLATION REQUIREMENTS

Special instructions for the installation of portions of the voice radio and data radio systems are presented in the following sections.

### 1.0 BASE STATION

Base station antennas shall meet the technical requirements of **Table 4-2**. In particular, the horizontal and vertical beam-width shall be designed to support coverage. Gain shall be as required to meet the coverage requirements. Antenna may be custom-built if required to provide the necessary gain and beam-width.

Transmission line used shall be 50 ohm, flexible coaxial cable, and the size of the cable shall be as specified in the contract documents. Cable installations on towers shall be supported with hangers and clips as instructed by the manufacturer. The outer shield of the cable shall be grounded to the tower, using grounding kits, at the base of the tower, where the cable turns parallel to the ground.

Design of the installation of all base station towers shall be performed by a civil or structural engineer, licensed in the State of California. The engineer shall certify that the tower foundation, as well as the soil type at the installation site, meets the structural and wind loading requirements.

Base station radio equipment shall be installed in lockable enclosed cabinets, mounted inside air-conditioned rooms or enclosures. Base station towers, antennas, and equipment shall be grounded in accordance with Caltrain Standard Specifications.

### 2.0 ANTENNA AND ANTENNA MAST

Antennas shall be grounded through their tilt-down antenna masts. This shall be provisioned by ensuring a reliable electrical connection between each antenna and the supporting tilt-down mast.

### 3.0 GROUNDING AND LIGHTNING PROTECTION

Refer to the Caltrain grounding requirements for details of the requirements applicable to the Caltrain Standard Specifications.

### 4.0 SAFETY

The installer shall follow the written safety instructions provided by Alstom (GE/Harmon) or Safetran for the installation of the MCP, and, in particular, the written safety instructions provided by Western Towers for installation and operation of the tilt-down towers. All towers shall be installed in such a way that they tilt down PARALLEL to the tracks.

The installer shall coordinate with Caltrain to determine the minimum distance, on a case-by-case basis, of the foundation of each tilt-down tower from the center of the track. The installer shall take note of the locations of all spur tracks or intersecting tracks adjacent to the locations of the tilt-down tower installation to ensure that the minimum safety distances and orientations are maintained.

The installer shall make special note of the locations of overhead power and utility lines to ensure that they are beyond the path of any part of their tower as it tilts up and down.

All work shall be in accordance with the Caltrain Roadway Worker Protection training and manual.

## 5.0 VOICE RADIO OPERATIONAL REQUIREMENTS

The following are nonnegotiable operational requirements of the voice radio road channel. Any expansion of the voice radio system must also simultaneously preserve the following operational specifications:

(1) One simplex radio channel (the road channel) is used to coordinate all train movement. It is therefore repeated along the entire ROW. A second simplex channel, the yard channel, is used to support maintenance and yard-related activities and is only broadcast within the confines of the two specific yard locations.

(2) Each DED reports wayside status immediately after the passage of a train. This report must be made on the road channel, so that it can be heard by the train engineer, and in the event that there is a problem the train can be brought to a stop immediately. This will be configured to an exceptions-based reporting configuration. DEDs configured in this way will report only when they detect a problem, but must continually report their health status to the CCF.

(3) The report from each DED must be recorded, either at the CCF or locally at the site.

(4) All voice radio communications that require the use of a base station site must be recorded at the CCF, in accordance with Federal Railroad Administration regulations. However, because all voice radio communication (even those localized communications using the radio-to-radio mode) will be recovered by at least one base station site, all voice radio communication will, in effect, be recorded at the CCF.

(5) All Caltrain groups that must have a reliable and guaranteed communication link to other Caltrain groups, as defined by the matrix presented in **Table 4-5**, must also be preserved with the retrofits.

All voice radio communication along the ROW takes one of the following three modes: a) PTP global; b) PTP local; and c) point-to-space global. Every user on the road channel intending to speak to the dispatcher uses PTP global. When the dispatcher responds, point-to-space global is used to repeat the dispatcher's instruction to the "space" surrounding one or more base station sites. Finally, for localized communications such as between a locomotive and a roadway worker in charge, mode PTP local is used.

(6) **Table 4-5** presents a matrix showing all 10 users groups currently using the VHF voice radio system. The matrix defines which groups need to hear which other groups, and which communication links are guaranteed, system global and system localized.

## Table 4-5: Who Needs to Hear from Whom

| Transmit \ Receive | Control Center Recording Equipment | Dispatcher | Train Engr | Train Cndr | EIC | Maintainer (Mobiles) | Maintainer (Portables) | Yard | Terminal Manager | CEMOF |
|---|---|---|---|---|---|---|---|---|---|---|
| Dispatcher | √ G | N/A | √ L | √ L | √ L | √ L | √ L | √ L | √ L | √ L |
| Train engineer | √ G | √ G | N/A | √ L | √ L | √ L | √ L | √ L | √ L | √ L |
| Train conductor | √ G | √ G | √L | N/A | √L | √ L | √ L | √ L | √ L | √ L |
| EIC | √ G | √ G | √ L | √ L | N/A | √ L | √ L | √ L | √ L | √ L |
| Maintainer (mobiles) | √ G | √ G | √ L | √ L | √L | N/A | √ L | √ L | √ L | √ L |
| Maintainer (portables) | √ G | √ G | √ L | √ L | √L | √ L | N/A | √ L | √ L | √ L |
| Yard | √ G | √ G | √ L | √ L | √L | √ L | √ L | N/A | √PL | N/A |
| Terminal manager | √ G | √ G | √ L | √ L | √L | √ L | √ L | √PL | N/A | N/A |
| CEMOF | √ G | √ G | √ L | √ L | √L | √ L | √ L | N/A | N/A | N/A |
| DED | √ G | No | √PL | No | No | No | No | No | No | No |

Key:

G = **Global communication required.** This means that the identified radios must be capable of direct communications with each other **irrespective** of their relative position along the ROW. For example, each radio communication message from the train engineer must be heard by the dispatcher and the CCF recording equipment, irrespective of where the train (train engineer's radio) is along the ROW.

L = **Local communication required.** This means that the identified radios shall expect to have reliable radio communication only when they are in the vicinity of each other. The exact range of this local communication is a function of the terrain, the height above average terrain of the two transmitters and the respective transmit powers. This communication is neither protected nor guaranteed, but occurs by the radio-to-radio mechanism with no assistance or intervention from the radio system (the base stations and CCF).

PL = **Protected local communication required.** This means that although the identified radios shall only be able to communicate via the radio-to-radio mechanism when they are in the vicinity of each other, this local communication capability is protected and guaranteed by the radio system design. In the case of the DED, this local communication capability is guaranteed for a distance of ±3 miles with respect to the DED along the track. In the case of the yard and terminal manager, this local communication capability is guaranteed within a circle of radius about 5 miles centered about the Fourth Street tower and about the CCF.

No = **No communication required.**

N/A = **Not applicable.**

Notes:

CCF = Central Control Facility
CEMOF = Centralized Equipment Maintenance and Operations Facility
DED = dragging equipment detector
EIC = employee in charge
ROW = right-of-way

(7) **Table 4-6** defines the extent and quality of the cumulative VHF voice radio coverage that shall be provided by the four aboveground and four tunnel radio base station sites. The radio coverage required from the DEDs shall be of the same quality, but limited to ±3 miles along ROW.

**Table 4-6: Radio Coverage Footprint and Quality**

| Location | Geographic Coverage (%) | Minimum EIA SINAD/CM/DAQ Level | % of Time Receive/Transmit Levels ≥ Minimum Levels | Comment |
|---|---|---|---|---|
| Along the ROW | 99 | 20/4/3.4 | 95/95 | To trains and trackside |
| Within 500 feet of trackside | 95 | 20/4/3.4 | 95/95 | To portable and mobile radios |
| Inside the tunnels | 99 | 20/4/3.4 | 95/95 | To trains and trackside |
| Around DEDs | 99 centered ±3 miles along ROW | 20/4/3.4 | 95/95 | ±3 miles along ROW |

Notes:

CM = circuit merit
DAQ = delivered audio quality
EIA = Electronic Industry Alliance
ROW = right-of-way
SINAD = signal in noise and distortion

## J. POWER AND UNINTERRUPTIBLE POWER SUPPLY

All station communications equipment and subsystem devices shall operate using a UPS with a battery reserve capable of sustaining the full equipment current load (plus an additional 50 percent for future growth) for a period of up to 90 minutes.

All UPS equipment shall be compatible with the existing Caltrain centralized UPS monitoring software (by APC) in the CCF facility. The new UPS shall be configured to report all types of alarms already defined by the existing Caltrain UPS monitoring software.

The UPS shall be also programmed for monitoring and reporting to CCF digital I/O alarms produced by other equipment (e.g., PA pre-mixer and amplifier(s) alarms). In the future, these alarms will be rewired to report to the future SCADA. UPS 120V alternating current (VAC) receptacles shall be orange, type NEMA L5-XX for identification.

The UPS load center shall be sized for the full complement of station subsystem devices, and breakers shall be dedicated by the subsystem as follows:

a. One 20 ampere (AMP), 120 VAC breaker per VMS

b. One 30 AMP, 120 VAC breaker per TVM

c. One 30 AMP, 120 VAC breaker per distribution cabinet

d. One 30 AMP, 120 VAC breaker per CER

The central UPS shall provide for essential power for all important communication devices in the station, such as the Caltrain WAN interface, CER communication devices, PA system equipment, LAN switches, media converters, TVMs, CCTV, VMS, and Clipper equipment. The essential power provided from the UPS system in the CER will necessitate the installation of an isolation transformer. Where the CER cannot accommodate the installation of a UPS system for providing essential power, the design shall allow for installing stand-alone UPS and backup batteries in each distribution cabinet. UPS load calculations shall be provided as described above.

Non-essential devices such as fans, air conditioners, cabinet lights, and maintenance outlets shall be powered directly from the Caltrain station distribution power panels.

The UPS design shall include a conduit structure separate from the fiber optic cable distribution. UPS power cabling shall not share the same conduit space with fiber optic or other communication cabling.

UPS distribution panels shall be housed in common service areas shared with other platform utilities, and not housed in communication distribution cabinets.

The 120/208 VAC UPS line side (input) shall be fed from the local alternating current (AC) electrical service on a dedicated and appropriately sized breaker. The 120 VAC UPS supply side (equipment side) shall have an adequate number of 120 VAC receptacles for equipment distribution. If required, AC service strips with surge protection shall be installed in the main equipment room and distribution cabinets to facilitate the number of required equipment receptacles.

## K. COMMUNICATIONS EQUIPMENT ROOM

The communications networking equipment shall be housed in the station and in the CER only accessible by authorized personnel. The CER is typically within the station building or structure. In rare instances if a station structure doesn't exist then a prefabricated steel construction structure can be proposed. All construction shall be in accordance with National Fire Protection Association (NFPA) 70 (NEC) and California Building Code (Title 24, Part 2).

Network electronics, termination panels, UPS, and other communications equipment shall be mounted in cabinets. Equipment cabinets shall be 84 inches tall, with 19 inches EIA standard mounting side channels, in accordance with EIA 310-D.

The CER shall also house the MPOE, which serves as the communication interface point between the station and MPCCF, SJCCF, and the Caltrain Headquarters.

The positioning of equipment racks shall allow adequate clearance for maintenance and safety, in accordance with NEC (NFPA 70). This requires at least 3 feet of space between live circuit components and walls or other obstructions.

The CER shall have an adequate grounding and bonding system. A single-point grounding scheme shall be used, and a single main ground bar shall be installed central to the room layout. Grounding design shall comply with ANSI/TIA 607.

The size of the CER will depend on the size of the station and assigned communications equipment, but shall be a minimum of 14 feet by 26 feet. The CER shall include separate electrical and communications rooms with separate doors. Unobstructed vertical space in the rooms shall be a minimum of 8 feet.

Equipment room lighting, environmental controls, floor loading, space planning, service entrances, and other design criteria will be in accordance with ANSI/TIA 569.

For security, a means to control access to any equipment room shall be provided. A state-of-the-art card reader/access system using the station/CCF carrier network shall be the preferred method.

## L. STATION COMMUNICATION CABINETS/COMMUNICATION INTERFACE CABINETS

The terms “SCC” and “CIC” can be used interchangeably. SCC is used in this document.

As mentioned above, for temporary stations, the designer may house the station-related communication equipment in these outdoor cabinets rather than in CERs.

SCCs are typically housed outside the station (or in station rooms, which do not have climate control) and are only accessible by authorized personnel.

Because of the variety and quantity of the equipment that needs to be placed into SCCs, the cabinets shall be at least 6 feet tall, 6 feet wide, and vandal-proof; furthermore, they will have two lockable doors, NEMA 3R cabinets, and 19-inch swing-out racks for ease of access for installation and maintenance.

For outdoor SCC installations, the designer shall incorporate all preventive measures to mitigate the effects of the outdoors:

a. The SCC cabinets shall be elevated (placed on a concrete pad).

b. Proper moisture protection and drainage shall be implemented.

c. The designer shall produce heat calculations for the worst-case scenario for the given equipment (including a provision for future 50 percent growth) and particulars of the location (e.g., officially recorded maximum outdoor temperatures). Based on these calculations, cooling means shall be provided, such as sun shields, painting of the cabinet, cooling fans, and, if necessary, a side-mounted air-conditioning unit.

d. Proper conduit entrances shall be provided.

e. Proper protection for lightning, protection terminal blocks, and an overall grounding scheme shall be provided.

The designer shall submit UPS calculations that provide for the UPS to support a typically 90-minute operation of the station's essential communication equipment, powered (either directly by SCC or via the distribution cabinets) by SCC UPS after loss of utility power.

The SCC shall include an intrusion alarm (and other equipment alarms, such as UPS loss of power) for connection to the future SCADA system. The SCC shall include proper lighting inside the cabinet and shall accommodate power outlets for ease of maintenance.

The designer shall determine the size and electric/thermal requirements of new SCCs, including sufficient space, cooling, and power to accommodate for 50 percent future growth. The contractor's thermal calculations shall be based on the temperatures for the given locale, and shall show that the chosen equipment can still operate in the enclosure without exceeding its temperature limits.

## M. OTHER DESIGN CONSIDERATIONS

### 1.0 ELECTROMAGNETIC INTERFERENCE

In addition to the industry design and equipment standards listed above, the following design criteria and considerations shall be adhered to for protection against electromagnetic interference (EMI).

Electrical, electronic, and communications systems design must perform in the Caltrain commuter system EMI environments with vehicles and other equipment without being functionally affected by them; and without affecting the system operation, safety, or other car-borne or wayside installations because of conducted, induced, or radiated emissions.

The design shall employ design techniques, construction methods, and whatever equipment is required to prevent interference caused by external and internal sources from affecting the proper operation of the equipment and systems specified herein. To contain EMI emissions wherever possible, the suppression of transients shall be at the source of the transient. The following design requirements shall be included in the design:

a. In addition to coordinating frequencies, the design shall provide required balancing, filtering, shielding, modulating techniques, and isolation to maintain the signal-to-noise ratio above the limits required to operate all equipment. Shielding, isolating, balancing, and grounding shall be used, as required, to reduce the undesirable effect of interference.

b. Electrostatic and magnetic shielding methods shall be employed to minimize the effect of stray signals and transient voltages on interconnecting cables.

c. Interconnecting power and signal cables shall be physically separated.

d. Equipment and facilities shall be located and arranged to minimize voltage induction into circuits due to future electrification, auxiliary power, and overhead catenary system current transients.

e. Suppressors shall be incorporated across inductive devices to minimize switching transients.

f. All relay coils and contactor coils shall have free-wheeling diode or metal oxide varistor transient suppression. The varistor is a surge protection device that is connected directly across the AC input. Other means of suppression or the absence of suppression for performance reasons shall be approved prior to use.

g. The number of suppression device types shall be kept to a minimum.

h. Equipment design and enclosures shall shield equipment from any effects resulting from the operation of any handheld transceiver when said transceiver is within 18 inches of the enclosure.

i. Equipment design and enclosures shall shield equipment from any effects resulting from the operation of cellular telephones, including when said telephones are operated in the vicinity of the equipment and on the passenger platforms.

Known EMI sources along the Caltrain ROW include but are not limited to the following major sources of interference that could affect operation of the system:

a. Medium- and low-voltage power circuits, including traction power AC source sub-transmission distribution systems operating at 60 Hz and carrying harmonics typical for the configuration and the loads served.

b. AC traction power system:

    i. Traction Power Substation

    ii. AC power distribution to trains, via overhead power catenary circuits

    iii. On-board propulsion equipment, including solid-state chopper and motor circuits

    iv. AC arcing, catenary to pantograph

    v. Temporary faults on the AC or DC power circuits

The train control signal system comprises a variety of discrete digital and digitally coded signal sources and receivers at the CCF, in signal houses, in wayside cables, in running rails, and in rail vehicles. Coded signal sources are in the DC to 20 kilohertz range.

The design shall provide surge arresters and other circuit-protection devices required to protect equipment from lightning currents and voltages. Related to emissions, the design shall ensure that its equipment does not electrically interfere with the proper operation of the future electrified rail cars or wayside equipment. Additionally, the equipment shall comply with applicable Federal Communications Commission, Code of Federal Regulations 47, Part 15, Over-Voltage Protection.

Over-voltage protection shall be provided for all outdoor communication systems including but not limited to PA, VMS, and CCTV equipment.

## 2.0 PROHIBITED MATERIALS AND METHODS

The communication and passenger information systems design shall ensure that the following materials and methods are excluded:

a. Flexible metal conduits and plastic tubing, except liquid-tight flexible metal conduit (LFMC) where specifically permitted in this Chapter.

b. Plastic conduit for interior electrical use, except that PVC conduit may be used for power circuits below basement concrete floors and for ground wire in any location. The transition from PVC to steel shall be made below the floor.

c. Aluminum wiring.

d. Incompatible Materials:

i. Aluminum fittings and boxes shall not be used with steel conduit.

ii. All materials in a raceway system shall be compatible.

iii. Dissimilar Metals:

(1) All dissimilar metals shall be properly insulated to prevent galvanic action.

(2) When bronze and aluminum components come into contact with dissimilar metals, surfaces shall be kept from direct contact by painting the dissimilar metal with a heavy coat of a proper primer or asphalt paint.

iv. When aluminum components come into contact with cement or lime mortar, exposed aluminum surfaces shall be painted with heavy bodied bituminous paint, water-white methacrylate lacquer, or zinc chromate.

v. Fasteners: All exposed fasteners shall be stainless steel.

vi. Multi-Use Suspension Systems: Piggy-back suspension systems for conduits and fixtures are prohibited. All suspensions shall be hung independently from structures, or, in limited cases, from trapeze suspension systems.

vii. Use of Wire Ties to Support Conduit: Splices shall not be used to join communications or electrical wiring in duct banks and raceways.

## 3.0 ENVIRONMENTAL

Communications equipment and material shall be designed for indoor and outdoor locations along the rail ROW, at elevations of approximately sea level to 1,000 feet above sea level, in a suburban environment. The areas adjacent to rail ROW are urban or suburban zones, some of which are occupied by industrial or commercial developments. Rail lines run parallel to major freeways along several lengthy sections.

Seismic 4 zone design requirements shall apply to all cabinets, racks, and devices mounted on or hung from elevated structures.

All outside plant cables shall be suitable for outdoor installations. All outdoor Category 6A cabling shall be installed in protective conduits.

## 4.0 CLIMATE CONDITIONS

The following particular climate conditions shall be used as design guidelines and shall be considered as operational requirements. Actual localized temperatures and conditions in spaces and enclosures may be more severe than the ambient climate conditions, and these factors shall be evaluated during the design effort. The design shall ensure that no equipment damage occurs during manufacture, storage, and shipment as a result of climate conditions that differ from those listed below:

a. Temperature and solar load:

   i. Minimum ambient air temperature external to equipment is 14 degrees Fahrenheit (°F)

   ii. Maximum ambient air temperature external to equipment is 120°F

   iii. Maximum solar radiation: 275 British Thermal units per hour per square foot

   iv. Maximum daily temperature range: 50°F

b. Precipitation:

   i. Maximum rainfall rate is 5 inches per hour; this rate may occur simultaneously with wind

   ii. Measurable quantities of ice infrequently occur

   iii. Average relative humidity is greater than 90 percent

## 5.0 AIR CONTAMINANTS

Related to air contamination, the equipment shall operate as specified in the atmosphere commonly found in rail vehicle environments and the San Francisco Bay Area. These include the following:

a. Enclosures particulates:

   i. Average: 0.175 milligrams per cubic meter ($mg/m^3$)

   ii. Maximum: 0.324 $mg/m^3$

b. Ozone: 0.200 parts per million (ppm), maximum

c. Naturally Occurring Asbestos: 0.25 ppm, maximum

d. Secondary Organic Aerosol: 0.262 mg/m3

e. CO: 20 ppm, maximum

f. Chloride: 13.9 mg/m3

g. Moisture Acidity: pH 4.41

## 6.0 OUTDOOR LOCATIONS

a. Equipment and enclosures installed in outdoor locations shall be designed to operate properly in the extremes of local weather conditions, including heavy winds, rain, hail, outside air temperatures, and relative humidity up to 100 percent.

b. Where equipment is installed in outdoor enclosures and subject to temperature extremes caused by exposure to direct sunlight plus heat from internal electrical losses, the enclosures shall be equipped with sun shields and convection vents so that maximum internal temperature rise above ambient air does not exceed 25°F. Equipment intended to be installed in outdoor enclosures shall be designed and tested for continuous service at 140°F.

c. The designer shall submit thermal calculations for each outdoor enclosure for each given equipment (the calculation shall include 50 percent growth for future equipment of a similar load) and environmental particulars of the given location. If use of fans appears to be insufficient, external air-conditioning cooling units shall be considered.

d. The design and construction of outdoor equipment enclosures shall include measures to protect against deterioration due to salt air, condensation, frost, and temperature extremes, including control of fungus growth and metal corrosion. Outdoor communication equipment enclosures shall comply with NEMA 4X or NEMA 3R and shall have a stainless steel finish.

e. Intrusion protection shall meet IP65 standards for all device enclosures not rated NEMA 4X.

f. Outdoor enclosures shall protect against damages as a result of environmental, infestation, and vandalism by designing secure solutions.

These solutions shall at minimum serve as deterrents to aforementioned causes of damages.

## 7.0 INDOOR LOCATIONS

Equipment and enclosures installed in indoor wayside locations shall be designed to operate continuously, properly, and safely in a temperature range of 32°F to 120°F, at relative humidity ranging up to 100 percent.

All cabling installed indoors shall be of low-smoke, fire-retardant design.

Indoor enclosures shall protect against damages as a result of environmental, infestation, and vandalism by designing secure solutions. These solutions shall at a minimum serve as deterrents to aforementioned causes of damages.

## 8.0 COOLING DEVICES

a. The designer shall provide cooling devices. Such devices shall be internal to the associated enclosures, and shall be included in the determination of conformance to reliability and maintainability requirements.

b. Unless otherwise specified, cooling devices shall be sized to maintain temperatures in enclosures between 60°F to 80°F while outside ambient temperatures are in the range specified previously.

c. More specific requirements for climate-controlled facilities may be found in the Standard Specifications.

## 9.0 HEATER DEVICES

a. The designer shall provide heater devices to remove condensation.

b. Such devices shall be internal to the associated enclosures, rooms, or houses, and shall be included in the determination of conformance to reliability and maintainability requirements. The requirements for heating devices are in the Caltrain Standard Specifications.

## 10.0 VIBRATION LIMITS

All equipment shall be designed to operate in an environment subject to the following vibration limits.

a. Wayside equipment:

   i. Equipment adjacent to track on direct fixation or tie and ballast sections, and mounted anywhere in the Caltrain ROW except as indicated herein below, shall be designed to operate in an environment subject to the following vibration levels: for all frequencies less than 12 Hz the peak-to-peak amplitude shall be 0.02 inch; for all frequencies from 12 Hz to 1,000 Hz, acceleration shall be 0.14 g peak or 0.1 root-mean-square acceleration (g rms).

ii. Equipment adjacent to and within 20 feet of special track work on direct fixation or tie-and-ballast construction shall be designed to operate in an environment subject to the following vibration levels: for all frequencies less than 12 Hz, the peak-to-peak amplitude shall be 0.2 inch; for all frequencies from 12 Hz to 1,000 Hz, acceleration shall be 1.4 g peak or 1.0 g rms.

b. Equipment situated in communications equipment spaces at the CCFs, CEN, distribution cabinets, other communications facilities, signal houses, or yards:

i. For all frequencies less than 12 Hz, the peak-to-peak amplitude shall be 0.02 inch

ii. For all frequencies from 12 Hz to 1,000 Hz: acceleration shall be 0.14 g peak or 0.1 g rms.

## END OF CHAPTER

# CHAPTER 5

# SIGNALS

## A. GENERAL

The purpose of this chapter is to provide guidelines for design or planning of Signal system.

## B. DESIGN GUIDELINES

The designer shall specify equipment and applications that will not only provide optimum safety but will maximize the efficiency and reliability of the commuter system. The design shall incorporate systems and equipment that have been proven to be reliable, durable, and effective on other rail networks. The design shall incorporate features that aid signal personnel in the inspection, testing, repair, and overall maintenance of the system. Application logic software shall be safe and conform to all applicable regulatory rules and regulations, but simple in form so as to be easily understood by personnel responsible for the maintenance and care of the system. As much as is practical, within the scope of a project, equipment to be installed shall be scalable for future expansion, and the signal houses shall be sized accordingly.

Where these criteria make reference to system logic and design criteria using vital relays, the same logic shall be applied to solid-state electronic interlocking application programs. All designs shall adhere to the rules and regulations contained in Title 49, Code of Federal Regulations (CFR), Parts 234, 235, and 236. Signal design criteria shall incorporate the rules and instructions contained in the most current issue of the California Public Utilities Commission's (CPUC's) General Orders; the General Code of Operating Rules (GCOR); Caltrain General Orders, Timetable, and Special Instructions; and American Railway Engineering and Maintenance-of-Way Association (AREMA) Communications and Signals Manual of Recommended Practices. Where the AREMA Manual is used, "may" and "should" are to be interpreted as "shall" unless in conflict with these standards or otherwise directed by Caltrain's Manager Engineering, Signals and Crossings. Note that the Caltrain General Orders, Timetable, and Special Instructions supersede the GCOR where they are in conflict with GCOR.

Systems present on the Caltrain tracks include a Traction Electrification System (TES) consisting of an Overhead Contact System (OCS), and Traction Power system (TPS), Wayside Signaling System and Crossing Warning Systems. There are portions of the system that are not electrified. Any modifications to the wayside signaling must consider any impact to the Grade Crossing Warning Systems, and Traction Electrification System where applicable. Design Criteria for the Grade Crossing Warning systems are covered in **Chapter 7, Grade Crossings**. Design Criteria for the

Overhead Contact System is **Electrification Standard Design Criteria Chapter 2, Traction Power System (TPS), Chapter 3, Overhead Contact System**, and **Chapter 4, Grounding and Bonding.**

### 1.0 STANDARDS, CODES, AND GUIDELINES

The latest editions of the following standards, codes, and guidelines shall be used, as applicable, for the design and implementation of the signal system.

a. Federal Railroad Administration (FRA), CFR; Title 49; Parts 234, 235, and 236

b. AREMA

c. CPUC

d. GCOR

e. General Orders

f. Timetable

g. Special Instructions

h. National Electrical Code (NEC)

i. Institute of Electrical and Electronics Engineers

j. American National Standards Institute

k. Electronic Industries Association

l. Federal Communications Commission

m. Caltrain Standard Drawings

## C. SAFE BRAKING CRITERIA

### 1.0 SIGNAL SPACING

Signal spacing shall consider all factors necessary to provide a safe and efficient operation. The signal block length should be a nominal 4,500 feet in length where possible. Such spacing allows passenger trains to operate with optimum headways, and use of "fourth aspect" (i.e. flashing yellow) signaling provides a safe braking distance for freight trains. Also, block spacing of this length can easily be incorporated in cab signal systems.

Braking criteria for 100 TPOB freight trains, operating at a maximum speed of 50 mph, and Passenger Train braking based on Amtrak's Braking Standards (CE-205 Standards) shall be used in calculating safe braking distance. The Caltrain Standard Drawings contain braking and deceleration tables for both types of consist. When manual calculations are used, the average grade (AG) shall be computed for each block for freight train braking, and Equivalent Level Track distances shall be computed for passenger trains to ensure safe braking distance is provided. Where short blocks are unavoidable and a safe braking distance cannot be achieved by using the flashing yellow aspect, the designer shall repeat the "yellow" aspect to a point where the flashing yellow aspect is applicable, as shown in the example below.

Computerized train performance programs are acceptable for calculating braking distances.

**EXAMPLE:**

**RED--------YELLOW--------YELLOW---------FL. YELLOW--------GREEN**
**+------------UNSAFE DISTANCE-------------+**
**+--------------------------SAFE DISTANCE-----------------------------+**

The signal system, although allowing for freight train braking, shall also be designed for the greatest possible passenger train efficiency. In some cases, an Approach Medium signal or an Approach Limited signal may provide a more efficient operation than an Advance Approach signal. Advance Approach signals should not be used where the approach block is less than 2,500 feet, or where the distance from the Advance Approach signal to the Stop signal provides stopping distance for less than timetable speed. Care should be exercised when the approach block is short.

With speed signals, the designer must ensure that the approach to a limited, medium, or slow speed signal provides sufficient stopping distance for both the passenger and freight train to attain the target speed at the point where a speed reduction or Stop is required. In other words, an Approach Limited signal up to a Limited Clear signal must provide sufficient braking for the train to be at Limited Speed signal at the Point of Switch. It is not necessary for the Approach Limited signal to provide braking distance to the Limited Clear signal.

### 2.0 SIGNAL SYSTEM HEADWAYS

The current signal system will generally support headways for local trains of 6 minutes, and for express trains at 5 minutes. Signal spacing must maintain or improve on these headways. The express train, for the purposes of calculating headways, makes no stops between San Jose and San Francisco and is followed by another express making no stops running on Green signal aspects. The headway for locals is calculated based on a local train making all stops, followed by a second local making all stops running on Flashing Yellow or better. Train Performance, station dwell, and signal system response and propagation times are part of the calculations. If a project requires changes to signal spacing contact the Caltrain Director of Engineering or designee for guidance on signal system headway methodology.

## D. SIGNAL PLACEMENT

Where possible, block signals shall be placed to the right of the track governed, with the exception of back-to-back ground signals, which shall be placed where practical to minimize the construction costs. Left-hand signals shall be placed where track centers do not accommodate right-hand placement. Bridge or cantilever signal structures shall be placed where more than two tracks must be signaled and where right-of-way constraints will not permit placement of ground signals. The use of dwarf signals is restricted to areas where trains operate at slow speeds or where high mast ground signals are not practical. Where practical, signals shall be placed in full view of station platforms so that the aspect displayed can be seen by the locomotive engineer when leaving the station.

Signals shall be placed and aligned to allow optimum viewing by the locomotive engineer. Where possible, signals shall be placed adjacent to tangent track. Where practical, the locomotive engineer shall be provided an unrestricted view of the signal for a minimum of 2,000 feet in the approach to the signal. Where conditions require placement in advance of, or within a curve, spread lenses shall be installed on the signal units to maximize the viewing area.

Signals shall not be placed within 2700’ of a Phase Break. Any new signal placement or modification to existing signal placement that does not meet this criterion requires review and approval by the Caltrain Director of Engineering or designee.

Each signal unit consists of three lamp units. The signal units shall be light-emitting diode (LED) in-line color-light, equipped with removable lamp units for ease of maintenance. Tri-Color LEDs signal units are also acceptable. Signal housing shall be designed to allow easy removal of lamp units from the rear of the housing. Each lamp unit shall be equipped with a LED assembly as described in AREMA Communications and Signals Manual Part 7.5.1. Unused Lamps shall be provided with Blank Cover Plates.

The designer shall make a thorough review of proposed signal locations to ensure that signals placed in accordance with Caltrain standards shall not be obstructed by vegetation, buildings, highway overhead, or other structures. Each location shall provide adequate space for each signal, signal house, and other apparatus, and be of sufficient size to provide ample walkways. Where signals are located on curves and adjacent tracks are present, signal height should be sufficient to ensure that signals can be viewed above standing rail cars. The designer should ensure that upper and lower signal units are visible.

Ground signals shall be approximately 22 feet high, measured from the base on the ground to the top of signal top. This height shall accommodate the placement of an upper and lower unit. Masts of this length will also provide adequate space for the addition of a lower unit to a single-headed signal. Signals are top justified.

In general, Absolute Signals at Control Points shall have three heads, Approach Signals to Control Points shall have two heads, and intermediate signals which do not serve as Approach Signals to Absolute Signals shall have one head.

Signal cantilever and signal bridge structures shall be installed with a clearance of 28 feet above top of rail, unless an exception is granted by the Caltrain Director of

Engineering or designee. This placement will accommodate future track elevation increases and electrification.

No portion of a dwarf signal shall be placed closer than 6 feet from centerline of any track. No portion of the dwarf signal shall be located higher than 34 inches above top of rail. (Note: Although the CPUC regulation allows placement of signal apparatus up to 36 inches above top of rail, the 2 inches variation should accommodate settling of the track, thus ensuring compliance with the regulation.)

Care shall be taken to ensure that signal lenses do not reflect light from adjacent structures, creating “phantom aspects.” Signal houses and cases shall be placed at a location where light cannot be reflected from the top or side of the housing. Where such placement cannot be avoided, the top of the housing shall be painted “flat black.” The use of lens screens or guards also help reduce such reflections.

Signals shall be placed so that a train leaving a station can see the signal before reaching 40 mph, so that no delay in the block shall occur. In some cases, it will be desirable to locate a signal at a grade crossing to eliminate additional insulated joints, and economize on equipment.

## E. SIGNAL SYSTEMS

Control Points shall use solid-state interlocking systems configured for use with LED in-line color-light signal units. Solid-state interlocking systems shall be Alstom shall be KB Signaling ElectroLogIXS, or approved equivalent. Additional wayside signal systems including, but not limited to Intermediate Color-light Signal, Regenerative Repeater, and Handthrow Switch applications shall utilize KB Signaling ElectroLogIXS, or approved equivalent.

To enhance system response time, transit rates shall be used, if possible. The use of vital relays shall be minimized where possible. All signal systems shall be equipped with integrated electronic data recorders that will record information useful in maintenance and repair of the system. Data recorders should be capable of storing a minimum of 300 train movements.

Electronic coded track circuits shall be used wherever practical to transmit and receive vital block signal data. Electrocode 4 Plus code rates shall be used. New application logic must be developed by the contractor and approved by the Caltrain Director of Engineering or designee. The Code Rates and Aspects shown in **Table 5-1** shall be used.

**Table 5-1: Code Rate and Aspect**

| Code Rate | Aspect |
|---|---|
| 7 | Clear |
| 4 | Advance approach |
| 3 | Approach limited |
| 8 | Approach medium |

| | |
|---|---|
| 2 | Approach |
| 9 | Approach slow |
| 6 | Accelerated tumble down |
| 5 | Non-Vital code indicating track occupancy, or a hand-throw switch in the block out of normal correspondence |
| M | Non-Vital code indicating power off in the block, or a lamp out condition in the block. Power Off shall indicate from the east end CP, lamp out from the west end CP |

"Light out" Application Logic shall incorporate aspect downgrades that minimize train delay. Under normal conditions, the upper and lower units of two and three-unit signals shall be illuminated. The principle can be summarized as follows: a Top Green will downgrade to a Flashing Yellow; all other Lamp-Outs will downgrade to a Restricting Aspect, unless the Dark Aspect does not affect safety. When elaborate Lamp-Out downgrade schemes are used, signals may not be reported until there are multiple lamps out.

The following typical downgrade logic shall be incorporated: Lamp-Out schemes should be shown on the circuit plans for each location. Refer to **Tables 5-2** through **5-7**.

**Table 5-2: One-Unit Signal, One Lamp-Out**

| | |
|---|---|
| **GREEN** lamp out | **FLASHING YELLOW** |
| **FLASHING YELLOW** lamp out | **FLASHING RED** |
| **YELLOW** lamp out | **FLASHING RED** |
| **RED** lamp out | **DARK** |

## Table 5-3: Two-Unit Signal, Top Unit Lamp Out

| | |
|---|---|
| **GREEN** over **RED** | **FLASHING YELLOW** over **RED** |
| **YELLOW** over **FLASHING GREEN** (for a Number Plated Signal) | **DARK** over **YELLOW** |
| **YELLOW** over **FLASHING GREEN** (for an Absolute Signal) | **FLASHING RED** over **RED** |
| **YELLOW** over **GREEN** (for a Number Plated Signal) | **DARK** over **YELLOW** |
| **YELLOW** over **GREEN** (for an Absolute Signal) | **FLASHING RED** over **RED** |
| **YELLOW** over **YELLOW** (for a Number Plated Signal) | **DARK** over **YELLOW** |
| **YELLOW** over **YELLOW** (for an Absolute Signal) | **FLASHING RED** over **RED** |
| **FLASHING YELLOW** over **RED** | **FLASHING RED** over **RED** |
| **YELLOW** over **RED** | **FLASHING RED** over **RED** |
| **FLASHING RED** over **RED** | **DARK** over **FLASHING RED** |
| **RED** over **GREEN** | **DARK** over **FLASHING RED** |
| **RED** over **FLASHING YELLOW** | **DARK** over **FLASHING RED** |
| **RED** over **YELLOW** | **DARK** over **FLASHING RED** |
| **RED** over **FLASHING RED** | **DARK** over **FLASHING RED** |
| **RED** over **RED** | **DARK** over **RED** |

## Table 5-4: Two-Unit Signal, Bottom Unit Lamp Out

| | |
|---|---|
| **GREEN** over **RED** | **GREEN** over **DARK** |
| **YELLOW** over **FLASHING GREEN** | **YELLOW** over **RED** |
| **YELLOW** over **GREEN** | **YELLOW** over **RED** |
| **YELLOW** over **YELLOW** | **YELLOW** over **RED** |
| **FLASHING YELLOW** over **RED** | **FLASHING YELLOW** over **DARK** |
| **YELLOW** over **RED** | **YELLOW** over **DARK** |
| **FLASHING RED** over **RED** | **FLASHING RED** over **DARK** |
| **RED** over **GREEN** | **RED** over **FLASHING RED** |
| **RED** over **FLASHING YELLOW** | **RED** over **FLASHING RED** |
| **RED** over **YELLOW** | **RED** over **FLASHING RED** |
| **RED** over **FLASHING RED** | **FLASHING RED** over **DARK** |
| **RED** over **RED** | **RED** over **DARK** |

## Table 5-5: Three-Unit Signal, Top Unit Lamp Out

| | |
|---|---|
| **GREEN** over **RED** over **RED** | **FLASHING YELLOW** over **RED** over **RED** |
| **YELLOW** over **FLASHING GREEN** over **RED** | **FLASHING RED** over **RED** over **RED** |
| **YELLOW** over **GREEN** over **RED** | **FLASHING RED** over **RED** over **RED** |
| **YELLOW** over **YELLOW** over **RED** | **FLASHING RED** over **RED** over **RED** |
| **FLASHING YELLOW** over **RED** over **RED** | **FLASHING RED** over **RED** over **RED** |
| **YELLOW** over **RED** over **RED** | **FLASHING RED** over **RED** over **RED** |
| **FLASHING RED** over **RED** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **FLASHING GREEN** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **GREEN** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **FLASHING YELLOW** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **GREEN** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **YELLOW** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **FLASHING RED** over **RED** | **DARK** over **FLASHING RED** over **RED** |
| **RED** over **RED** over **RED** | **DARK** over **RED** over **RED** |

**Table 5-6: Three-Unit Signal, Second Unit Lamp-Out**

| | |
|---|---|
| **GREEN** over **RED** over **RED** | **GREEN** over **DARK** over **RED** |
| **YELLOW** over **FLASHING GREEN** over **RED** | **YELLOW** over **RED** over **RED** |
| **YELLOW** over **GREEN** over **RED** | **YELLOW** over **RED** over **RED** |
| **YELLOW** over **YELLOW** over **RED** | **YELLOW** over **RED** over **RED** |
| **FLASHING YELLOW** over **RED** over **RED** | **FLASHING YELLOW** over **DARK** over **RED** |
| **YELLOW** over **RED** over **RED** | **YELLOW** over **DARK** over **RED** |
| **FLASHING RED** over **RED** over **RED** | **FLASHING RED** over **DARK** over **RED** |
| **RED** over **FLASHING GREEN** over **RED** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **GREEN** over **RED** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **FLASHING YELLOW** over **RED** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **GREEN** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **YELLOW** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **YELLOW** over **RED** | **RED** over **FLASHING RED** over **RED** |
| **RED** over **RED** over **GREEN** | **FLASHING RED** over **DARK** over **RED** |
| **RED** over **RED** over **FLASHING YELLOW** | **FLASHING RED** over **DARK** over **RED** |
| **RED** over **RED** over **YELLOW** | **FLASHING RED** over **DARK** over **RED** |
| **RED** over **FLASHING RED** over **RED** | **FLASHING RED** over **DARK** over **RED** |
| **RED** over **RED** over **RED** | **RED** over **DARK** over **RED** |

**Table 5-7: Three-Unit Signal, Third Unit Lamp-Out**

| | |
|---|---|
| **GREEN** over **RED** over **RED** | **GREEN** over **RED** over **DARK** |
| **YELLOW** over **FLASHING GREEN** over **RED** | **YELLOW** over **FLASHING GREEN** over **DARK** |
| **YELLOW** over **GREEN** over **RED** | **YELLOW** over **GREEN** over **DARK** |
| **YELLOW** over **YELLOW** over **RED** | **YELLOW** over **YELLOW** over **DARK** |
| **FLASHING YELLOW** over **RED** over **RED** | **FLASHING YELLOW** over **RED** over **DARK** |
| **YELLOW** over **RED** over **RED** | **YELLOW** over **RED** over **DARK** |
| **FLASHING RED** over **RED** over **RED** | **FLASHING RED** over **RED** over **DARK** |
| **RED** over **FLASHING GREEN** over **RED** | **RED** over **FLASHING GREEN** over **DARK** |
| **RED** over **GREEN** over **RED** | **RED** over **GREEN** over **DARK** |
| **RED** over **FLASHING YELLOW** over **RED** | **RED** over **FLASHING YELLOW** over **DARK** |
| **RED** over **YELLOW** over **GREEN** | **RED** over **YELLOW** over **RED** |
| **RED** over **YELLOW** over **YELLOW** | **RED** over **YELLOW** over **RED** |
| **RED** over **YELLOW** over **RED** | **RED** over **YELLOW** over **DARK** |
| **RED** over **RED** over **GREEN** | **RED** over **RED** over **FLASHING RED** |
| **RED** over **RED** over **FLASHING YELLOW** | **RED** over **RED** over **FLASHING RED** |
| **RED** over **RED** over **YELLOW** | **RED** over **RED** over **FLASHING RED** |
| **RED** over **FLASHING RED** over **RED** | **RED** over **FLASHING RED** over **DARK** |
| **RED** over **RED** over **RED** | **RED** over **DARK** over **RED** |

The applicable code transmitted from signals displaying the Lamp-Out condition indicated above shall also downgrade. Application Logic shall be configured to provide approach lighting of signals. Approach lighting may be accomplished by lighting the signal upon loss of a vital code on the approach to the signal, in the same fashion that Approach Locking is accomplished. Controlled signals shall light on approach, when a signal control bit is received from control station, and when a test clip or switch is closed (i.e. lamp test). Where multiple track operations are present, all signals on adjacent tracks governing movements in the same direction shall be illuminated where practical. Where a signal on one track is dark, the signal on the adjacent track(s) shall be put to Stop or Restricting aspect, and approaches shall be downgraded. Special lighting circuits should be incorporated to illuminate a signal displaying a Stop aspect where an approach lighting circuit is effective less than 2,500 feet in advance of the signal.

Although each design will provide for using approach lighting, Caltrain Operations will make the final determination regarding whether the feature will be applied. The designer shall evaluate each location to determine whether special circuits should be applied to ensure that aspects can be readily observed and acted upon by the train engineer.

## F. APPLICATION LOGIC

Application logic software shall conform to all regulatory requirements. Applicable Route Locking, Indication Locking, Time Locking, and Approach Locking shall be used. Route Locking shall be released using the first two consecutive track circuits. Sectional releasing shall be used wherever possible. New installations shall use Approach Locking. Separate timers shall be used on each signal in a pair where microprocessor systems are used. Program nomenclature shall follow Caltrain naming conventions. Program Logic shall follow the typical Caltrain Program Logic.

Companies providing Application Logic programs shall have a documented process of checking, computer simulating, and rack-testing all programs. All programs, upon being placed in service, shall be submitted to the Caltrain Director of Engineering or designee. Application Logic shall follow the sequence of activities for clearing a signal, as described below:

a. Request the signal and switch (Composite Delivery will be used)

b. Check the route – switches in position, opposing signals at stop and not in time, permissive codes received, detector tracks up, and any other applicable conditions

c. Apply the locking (Lock terms go false)

d. Tumble down to the adjoining Control Point

e. Upon verification of locking, (Lock terms false, Switch Motor Control Relays de-energized) clear the signal

f. Upon confirmation of signal aspects, upgrade the codes to the Approach signal to display the proper signal aspect

With no signals cleared, vital codes shall be transmitted in both directions on each track.

Where Sectional Releasing is used, the switch shall be allowed to change position as soon as the locking is released and applicable Loss of Shunt time runs. If a new route can be created which is protected from fouling by switch position, then a signal can be cleared even though the first train is still in the CP.

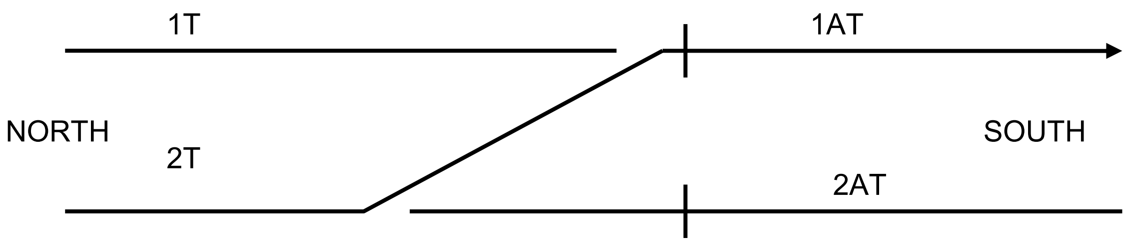



**Figure 5-1 Interlocking Release (Switch Locking Released)**

When the southbound train has crossed over and is occupying 1AT, as shown on **Figure 5-1**, the locking shall be released as soon as 1T completes Loss of Shunt time. At that moment, the crossover can be returned to the normal position, and a new route can be created as shown on **Figure 5-2**. Signals can be cleared on track two in either direction while the first train occupies the 1AT.

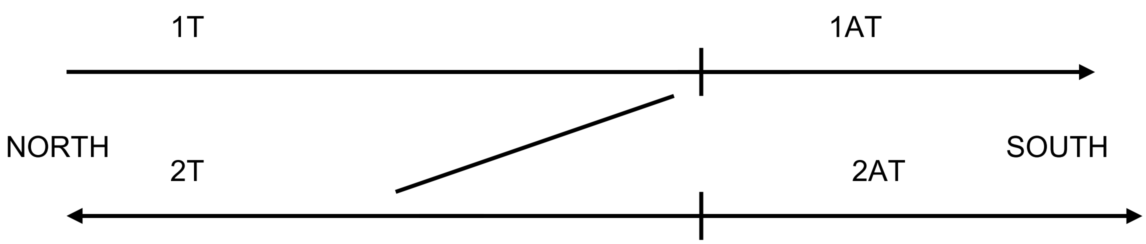



**Figure 5-2 Interlocking Release (New Route Created)**

In **Figure 5-2** above, if the southbound train was occupying the 2AT, the locking on the switch would release, and the switch could be reversed as shown on **Figure 5-1**; however, a new route would not be allowed, because the train in the 2AT could roll back and foul the 2T.

## G. SWITCH MACHINE

110 volt direct current (VDC) switch machines shall be used. Backup battery shall be provided by a separate 110 VDC supply. A National Railway Supply Model HF Max 130 V charger or approved equivalent shall be used. Overload timers in the Vital Program shall be used. The M23A is the preferred switch machine because the points are locked in hand operation. South of CP Bowers, only M23A machines should be installed. North of CP Bowers, in existing Control Points with Alstom Model 5F machines, Model 5F machines should be installed.

If in-tie switch machines are installed, they should be of a type that locks the points when in hand operation.

Turnouts #20 and greater require Push/Pull helper rod assemblies. Where clearance is a concern, the rotary helper assembly is acceptable.

Relays named NWR (Normal Switch Control Relay) and RWR (Reverse Switch Control Relay) will be used for switch control. The last called-for relay shall be held in the energized position until such time as locking is applied. The switch contact will be back-checked in the microprocessor program.

## H. REQUISITES FOR CENTRALIZED TRAFFIC CONTROL

The requisites for the CTC include the following:

a. Approach or Time Locking shall be applied to all approaches. Approach Locking is preferred, but Time Locking may be used when directed.

b. Indication Locking is required in connection with all electrically locked switches, movable-point frogs, or power derails at control points and interlockers.

c. Route Locking is required. Sectional Route Locking (Sectional Release) shall be used to facilitate the movement of trains.

d. Detector Loss of Shunt time shall be 5 seconds in terminal areas and lower speed areas. It shall be considered at Control Points in higher speed territories, but the designer must carefully evaluate the time of OS occupancy of short, fast trains in conjunction with the timing parameters of the wayside signal system, communications system, control office processing, and system loading, to ensure that there is no degradation of train tracking in the Caltrain control facility. The 10 second detector Loss of Shunt time should be used where train tracking is a concern, or where potential loss of shunt is possible due to rail conditions.

## I. TIME AND APPROACH LOCKING

Time Locking is provided in connection with existing signals. Approach locking shall be provided in connection with signals on routes where greater facility is required than is possible with Time Locking.

Time Locking is used to ensure that after a signal has been cleared, a conflicting or opposing signal cannot be cleared, or the position of a switch or derail in the established route cannot be changed until expiration of a predetermined time interval after the signal has been placed at stop, except when the locking is released by occupancy of two successive tracks in advance of the signal.

Approach Locking ensures that the time locking will not be effective if the track is unoccupied from a point at least 1,500 feet in approach to the approach signal to the controlled signal; or, in four-aspect signal territory, from a point at least 1,500 feet in approach of the first normally Restrictive signal approaching the control signal. In most cases, the requirement for Approach Locking is satisfied by checking that the same direction controlled signal at the Control Point in the rear is at Stop and not in time, and no intervening track circuits are occupied, as shown in the example below.

**EXAMPLES:**

!----------(adequate braking distance)--------!-------------1,500'---------------!
**RED------------------------------------------YELLOW----------------------------GREEN**
!--------------------------(Approach Locking limits)-------------------------------!

!--------------(adequate braking distance)-----------!----------1,500'------------!
**RED----------------YELLOW--------------FLASHING YELLOW-------------GREEN**
!----------------------------(Approach Locking limits)----------------- ------------!

Time or Approach Locking should be released by a train occupying two consecutive track circuits beyond the control signal. On low-speed routes, where a second track circuit is not available, one track circuit may be used to release Time and/or Approach Locking; however, two-track circuit releasing is preferred. Locking should also be released by a time element relay, or electronic timer, with automatic control.

Signal control circuits shall be so arranged that they cannot display "proceed" when the timing device is not normal.

Where the back contact of a detector section track relay or track relay repeater is used to release approach or time locking, the control circuit for the electric locking of the interlocked switches—or for the control circuits for the interlocked signals—shall be cut through the front contacts of the same relay whose back contact is used for releasing, or a repeater of that relay. Preferably, the control circuits for both the electric locking of the interlocked switches and the interlocked signals should be through front contacts of the same relay whose back contact is used for releasing, or a repeater of that relay.

## J. INDICATION LOCKING

Indication locking shall be provided in connection with all interlocking signals. Approach signals of the light type, controlled by independent two-wire circuits or by electronic track circuits, need not be checked in the interlocking signal indication circuits. Indication Locking does not apply to color-light signals. The principle of Indication Locking applies to mechanical devices such as searchlight signals and power switch machines.

## K. ROUTE LOCKING

Route Locking shall be provided in connection with all mechanical or power switches. Route Locking maintains the switch locking in front of the train after the signal has been passed, and the train is still in the route. This must be accomplished using a system of track circuits extending throughout the interlocking which control normal and reverse locks switches, derails, and movable point frogs.

Where there is more than one track circuit, a more complicated scheme of route locking may be necessary. In some cases, where there are a number of track sections in a route, it will be found convenient to use route locking relays to secure continuous switch protection throughout the route.

On interlocking plants where traffic is so heavy that maximum facility is needed, a system of sectional route locking shall be installed. This system shall provide for the release of switches behind a train as soon as the rear end of a train has reached a point sufficiently beyond clearance to ensure safety from conflicting moves. Sectional route locking shall be used in new design to facilitate train operations.

When parallel routes are proposed, the distance between the points of switch on the common track shall be sufficient to prevent either train from fouling the route of the other. In general, this is 100 feet from Point of Switch to Point of Switch, and minimum 13-foot track centers through the parallel portion of the route. Design of signaling for a parallel route must be closely coordinated with the track design.

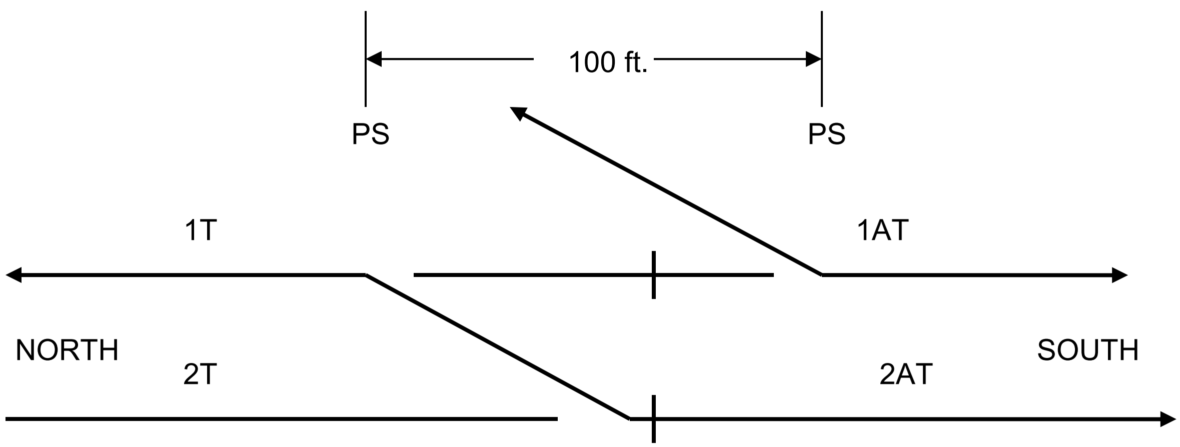



**Figure 5-3 Parallel Routes**

## L. POWER SYSTEMS FOR OTHER THAN VEHICULAR CROSSING LOCATIONS

Power to each location shall be provided from a commercial power system. Each location shall be evaluated, and the appropriate service connection provided. At a minimum, a 120/240 V alternating current, single-phase, 200-Amp service shall be provided at new locations. Where power is not readily available, an express cable shall be installed to the nearest power source. The size of the express cable conductor required shall be determined using NEC Standards. Each Control Point shall have an external plug connection for a generator to provide power to the house in the event of an extended outage.

Standby battery shall be provided at all locations. Chargers shall be equipped with temperature compensation devices. NRS HF-MAX model chargers or approved equivalent shall be used. All storage cells shall be valve-regulated lead acid style. EnerSys PowerSafe DDr50-17 batteries or approved equivalent shall be used. Batteries shall be of sufficient capacity to provide 24 hours of standby time under normal operating conditions, with 25 percent spare capacity for future use. “Normal operating conditions” are defined as “the signal system operating with all signals normally dark and power switches at rest and properly lined.” Battery capacity for highway crossings shall be as specified in **Chapter 7, Grade Crossings**.

## M. SIGNAL BLOCKS

Electrocode codes will be transmitted simultaneously in both directions throughout signal blocks. Turn of Traffic signaling shall not be used. Tumbledown shall take place after a signal has been requested into a block with vital codes being received.

As soon as the lead train enters the OS track, a Code 2 will be sent into the block so the Approach signal displays Yellow up to the Red Absolute.

Code 6 is used to accelerate the tumbledown. Code 6 shall be used when a signal is cleared into a block. Code 6 shall also be used as a Stick-Breaker at intermediate signals.

When a train is to enter a signal block between Control Points over a hand-operated switch, a comeout signal is preferred over an Electric Lock. In the case of a comeout signal or an Electric Lock, a short tumbledown timer shall run and Code 6 shall be transmitted in both directions. If vital codes are then received in both directions, the Lock shall release; in the case of a comeout signal, after the hand-operated switch is full reverse, the signal will clear. “Non-Clearing” hand-operated switch installations require approval by the Caltrain Director of Engineering or designee.

## N. THE AVERAGE GRADE

The following procedure or steps should be followed for calculating the AG of the block.

a. Using the engineer’s scale, measure the distance between all grade change points in the block. The sum of the distances is equal to the total block length.

b. Multiply each distance recorded by the grade indicated between each point. This is known as the distance grade (DG).

c. Sum the DGs and divide by the total block distance. This is the AG of the block.

$$AG = \frac{DG + DG + DG + DG + ....}{TOTAL\ BLOCK\ LENGTH}$$

For freight train braking, 6,000 feet in approach of the block must be used in averaging; unless the 6,000-foot approach grade is positive, in which case it shall not be factored.

For passenger train braking calculations, 1,000 feet in approach of the block must be used in averaging; unless the 1,000-foot approach grade is positive, in which case it shall not be factored. Braking distance may be calculated either by using the AG and the charts, or by converting the distance of the block to the equivalent distance of level track. Equivalent Distance may be calculated for ascending grades by the following:

$$\frac{(Actual\ Distance) \times (6 + G)}{6}$$

Descending grades may be calculated by:

$$\frac{(Actual\ Distance) \times (4 - G)}{4}$$

G is the AG of the block being equated, plus the approach specified above. Amtrak's Braking Curve CE-205 with a 25 percent safety factor, and 8 seconds free running will be used for all passenger trains in use on the corridor.

A commercially available train performance simulation program for calculating safe braking proposed for use must be approved by the Caltrain Director of Engineering or designee.

## O. QUALIFICATIONS OF DESIGNERS AND CHECKERS

Signal designers who perform signal design or programs for Caltrain must be approved by the Caltrain Director of Engineering or designee. Similarly, signal checkers who perform review of Caltrain signal circuitry design or programs must be approved by the Caltrain Director of Engineering or designee.

### 1.0 SIGNAL DESIGNERS

The classification Signal Designer is generic and refers to the responsible individual who produces signal circuitry design or programs. A company or third-party agency may classify this position as a Signal Engineer or other title. In general, a signal designer should have a minimum of 5 years of experience designing for a Class 1 or Commuter Railroad which operates under Sections 234, 235, and 236 of the FRA regulations.

The experience requirements for signal designers also apply to programmers of Vital Logic programs.

Designers may be called on to demonstrate their familiarity with applicable regulations, both state and federal, and their familiarity with traditional relay logic, ladder logic, and

Boolean Equations. Principles of railroad signaling, including automatic block signals, CTC, and interlocking, must be demonstrated to the satisfaction of the Caltrain Director of Engineering or designee. An understanding of train operations and the interaction with the signal system is required, as well as the abilities to analyze braking distances and calculate locking release times. In addition, knowledge of Highway-Grade Crossing Warning systems must be demonstrated.

At the discretion of the Caltrain Director of Engineering or designee, the designers may be interviewed. The interview may require a demonstration of circuit and program analysis.

### 2.0 SIGNAL CHECKERS

In general, a signal checker should have a minimum of 5 years of experience designing for a Class 1 or Commuter Railroad which operates under Sections 234, 235, and 236 of the FRA regulations, and an additional 5 years of experience checking signal designs and vital signal programs.

Signal checkers may be called on to demonstrate their familiarity with applicable regulations, both state and federal, and their familiarity with traditional relay logic, ladder logic, and Boolean Equations. Principles of railroad signaling, including automatic block signals, CTC, and interlocking, must be demonstrated to the satisfaction of the Caltrain Director of Engineering or designee. An understanding of train operations and the interaction with the signal system is required, as well as the abilities to analyze braking distances and calculate locking release times. In addition to this, knowledge of Highway-Grade Crossing Warning systems must be demonstrated.

The signal checker may be interviewed, at the discretion of the Caltrain Director of Engineering or designee. The interview may require a demonstration of circuitry design and program analysis.

## P. FINAL CHECK INSTRUCTIONS

To ensure the quality and integrity of the Caltrain Signal and Highway-Grade Crossing Warning system design, all designs shall receive a final check. The final check shall ensure that all designs meet the minimum requirements of CFR Title 49, Parts 234, 235, and 236. Designs shall also conform to Caltrain Communications and Signal Design Standards and applicable federal, state, and local regulations. All design applications shall adhere to the manufacturer’s minimum recommendations.

Signal designs shall be completed by a signal design firm authorized by Caltrain to provide such services. Upon completion of the design, two complete drawing sets shall be distributed to an outside firm authorized by Caltrain to perform final checks. Included with the drawing sets shall be any pertinent information that may aid the final checker in performing this work. Pertinent information shall include field surveys, service contracts, CPUC application documents, project correspondence, and calculations. Pertinent information shall include circuit design drawings of adjoining locations sufficient to check all circuits and controls in the affected case to both point of origination and termination.

The final checker shall review the drawings for adherence to the Caltrain standards, field survey requirements, service contracts agreements, CPUC application drawings, and circuit integrity. On one drawing set, the final checker shall indicate any corrections that are needed. Once completed, the marked-up drawing set shall be returned to the originating design firm for correction. Upon completing the revision, a corrected or revised copy shall be sent to the final checker for approval. Once approved, the design firm shall place the final checker's initials in the appropriate field in the "JBNOTE" cell and distribute the drawings for construction.

In instances where construction must immediately begin and sufficient time is not available to complete the final check procedure prior to distribution, the drawings shall be clearly marked **PRELIMINARY** and the checker's field in the JBNOTE cell shall be left blank. At the time of this preliminary distribution, two drawing sets shall be sent to a final checker. **Prior to placing the modifications in operation, a final check shall be completed.** Once the final check of the preliminary drawing set is completed and corrections have been made, a final drawing set shall be distributed. Prior to distribution, a new date shall be entered in the date field of the JBNOTE, with original date yellowed out. The transmittal letter shall reference the new drawing date, and a statement will be incorporated instructing construction forces to destroy the preliminary plan set in lieu of the final drawing set.

In an emergency situation, and only in such situations, modifications to the signal system may be made by field forces with the concurrence of the Caltrain Director of Engineering or designee. In such instances, the modifications shall be clearly marked on a drawing set and the modified drawing set delivered to a final checker as soon as possible. All field modifications shall be thoroughly tested to ensure the integrity and safety of the system.

## Q. CONFIGURATION MANAGEMENT

Part 236 Section 1 and Part 234 Section 201 of CFR 49 require that up-to-date and accurate signal drawings be kept at each location. Part 236 Section 18 requires a Software Management Control Plan for Vital Signal Application programs.

Signal drawings and signal programs are living documents that must be properly maintained to ensure the integrity of the signal system. Duplicate file copies increase the possibility of misleading or inaccurate drawings and programs being distributed to construction or maintenance forces. Files shall not be duplicated without the authority of the Caltrain Director of Engineering or designee.

To maintain control of Caltrain Signal Drawings and Application Logic Programs and to be compliant with federal regulations, the following checkout procedure shall be followed by all Signal Design Firms.

a. A general description of the project(s) shall be submitted to the Caltrain Director of Engineering or designee, along with specific milepost limits. The designer shall first request paper or PDF files of any locations within the project limits. Only files which the designer will need to modify for the project will be checked out to the design firm.

b. Upon completion of the design or program, the designer shall return the computer-aided design and drafting (CADD) files, application program files, an 11 × 17 hard copy of each drawing, and an 8½ × 11 copy of the program to the Caltrain Director of Engineering or designee. The designer shall include an itemized list of the files returned. The list shall categorize files as "new files," "modified files," and "deleted files."

c. The designer shall provide the Caltrain Director of Engineering or designee with CADD files of drawings that are distributed for construction, and then provide red-line as-installed PDF files of the construction plan set upon completion of the project. Caltrain's Signal and Crossings On-Call Services contractor shall perform all as-built work on CADD files for all Capital projects. Program files shall be furnished after the location is placed in service.

## R. SUPERVISORY CONTROL SYSTEM AND OFFICE TO FIELD COMMUNICATIONS

When a project requires the addition of a new Control Point(s), it is the responsibility of the designer to determine whether the additional Control Point(s) will require the addition of new codelines or additional regions to the Rail Operations Control System (ROCS).

Non-Control Point Wayside locations require office indications to be integrated with the ROCS for all new projects. It is the responsibility of the designer to determine the indications required which typically include, but not limited to: Track Circuit, Power Off, Signal Lamp Out, Ground Fault, Vital Link, Station Track Circuit and Processor Health statuses.

Indication Status are used by multiple sub systems and processes within the Caltrain Office and Back Office. All modifications and/or new additions require coordination with Caltrain Systems Engineering. Contact the Caltrain Director of Engineering or designee for guidance.

## S. FIBER OPTIC COMMUNICATION NETWORK

All wayside locations shall be integrated with Caltrain's Fiber Optic Communications Network (FOCN). The network is utilized to facilitate vital point to point communications between signal and crossing logic controllers. The network is also utilized to facilitate ATCS Communications, PTC Communications, TES Communications, Rail Operations Control System Communications, and other SCADA functions.

Design criteria for the Fiber Optic Communications Network are covered in **Chapter 6, Train Control Communication**.

## T. POSITIVE TRAIN CONTROL CONFIGURATION MANGEMENT

All Wayside signal equipment, programs, devices and components are critical components necessary for the safe and efficient operation of Caltrain's Positive Train Control System. It is the signal designer's responsibility to coordinate with Caltrain Systems Engineering when design changes impact the PTC system and ROCS. Contact the Caltrain Director of Engineering or designee for guidance.

### 1.0 WAYSIDE INTERFACE UNITS

Caltrain's PTC system requires switches, signals, and in certain cases, derails are required to be monitored. This is accomplished using Wayside Interface Units (WIUs) which are integrated into the wayside logic controllers installed on Caltrain. KB Signaling ElectroLogIXS or approved equivalent shall be used for Caltrain WIU applications.

### 2.0 SUBDIVISION FILE

Caltrain's PTC System's Track Database requires the location of field assets including (but not limited to) Switch Points, Signals, Track Centerline Data, Mile Post Signs, Phase Break Limits and Speed Restrictions. Any change needs to be coordinated with Caltrain's change management process to ensure safe and successful project deployment.

### 3.0 CHANGES TO PTC SYSTEM

Caltrain is solely responsible for modifying their PTC system. Projects and their designers shall provide necessary inputs for their projects such as track drawings, and PTC mapping files to the Caltrain Director of Engineering or designee. Any changes being proposed to wayside systems shall follow the change management process as defined in the Caltrain System Configuration Management Plan. Design Criteria for the Positive Train Control System are covered in **Chapter 6, Train Control** Communication

## U. TRACTION ELECTRIFICATION SYSTEM (TES)

The following subsections apply only to electrified tracks or on tracks impacted by the Overhead Contact Line Zone (OCLV). Traction Electrification System (TES) is the combination of the TPS, OCS, and the Traction Power Return System, together It forms a fully functional 2x25 kV, 60 Hz autotransformer power supply system. The Signal Design shall coordinate with other disciplines including OCS & TPS as required by the design work being performed. This includes but is not limited the modification or new installation of signal equipment, grade crossing equipment and track alignment changes to the Caltrain system.

### 1.0 IMPEDANCE BONDS AND BONDING CONFIGURATION

One Ohm and Four Ohm Noratel 300A ac Mini Impedance Bonds or approved equivalent shall be used.

Impedance bonds shall be provided where track circuits abut in order to provide a return path for traction current to the traction power facilities while maintaining the integrity of each track circuit. The neutral leads between adjacent impedance bonds shall be designed in a manner that will minimize the likelihood of theft. Impedance bond layouts shall be vandal proof.

Impedance bonds shall provide adequate impedance for the Control Point track circuits, the automatic block signal intermediate track circuits, regenerative repeater track circuits and any audio frequency track circuits that are located within the boundaries of the track circuit.

Impedance bonds shall be provided at the ends of track circuits leading from electrified tracks to nonelectrified tracks to bleed off the return current. The center tap of the impedance bond at the nonelectrified end shall be connected to the static wire or to the center of an impedance bond on the adjacent electrified track.

Impedance bonds are not required at insulated joints within crossovers or on track circuits that are wholly within non-electrified tracks. Where there are parallel non-electrified tracks that might be exposed to catenary/feeder strikes through conductive debris, connection to the return system (either through connection of both rails to the center tap of impedance bonds on adjacent tracks where the adjacent track has no track circuits, or through additional impedance bonds where the adjacent track has a track circuit) will be necessary. The signal designer shall include an explanation of such additional bonding, or lack thereof, with their design submittal, or in their Basis of Design Report (if applicable).

The signal designer shall coordinate with the OCS & TPS Designer in developing the cross-bonding scheme for traction power return conductors attached to impedance bonds. The Impedance Bond, Cross-Bonding and Neutral Return plans shall be provided by the signal designer.

See **Electrification Standard Design Criteria Chapter 2, Traction Power System (TPS), Chapter 3, Overhead Contact System**, and **Chapter 4, Grounding and Bonding** for further requirements and guidance.

## 2.0 GROUNDING AND BONDING

Grounding requirements for signal equipment, and Cross-bonding application requirements and guidelines are covered in **Electrification Standard Design Criteria Chapter 4, Grounding and Bonding**.

## 3.0 PHASE BREAKS

Grade Crossings, Station Platforms, or Signals shall not be closer than 2700’ unless approved by Caltrain Director of Engineering or designee. This distance gives the train approximately 600 feet after clearing a crossing or station stop to gain enough speed to coast through an upcoming phase break.

Three (3) phase breaks are located on the Caltrain ROW. They are located at TPS-1 (MP 9.0), SWS-1 (MP26.5) & TPS-2 (MP 45.2).

### 4.0 TRACK CIRCUITS

All coded and non-coded track circuits being installed on electrified track or on tracks impacted by the Overhead Contact Line Zone (OCLV) shall be compliable with the 25 kV 60 Hz Traction Power System. The number of track circuits in each interlocking shall be minimized, provided that sectional release requirements are fulfilled. For #20 switches, shunt fouling shall be used in lieu of additional track circuits within the crossovers. Double bonding of the rail within shunt fouling sections shall be provided.

## V. SIGNAL DESIGN STAGES

The design cycle is an iterative process that may involve Railroad Operations, Finance, Contracts, and the other Railroad Engineering Disciplines.

### 1.0 CONCEPTUAL DESIGN LEVEL

The conceptual design level document may be produced by Caltrain or by the Signal Engineering design firm on behalf of Caltrain. It is a very basic document, intended to capture the rationale for the project. It may consist of the following:

a. A conceptual overview: a single line drawing identifying track configuration, signals and switches

b. A conceptual overview of alternate configurations, if any

c. A rough Order-of- Magnitude Budget estimate

### 2.0 35% DESIGN LEVEL

The 35% design level submittal builds on the conceptual design level. This document is suitable for review by all of the stakeholders. Upon completion of the 35% design level submittal and of Caltrain acceptance, the track configuration should be locked in. At this time, Operations may decide whether an additional crossover or turnout is required. The document generally consists of the following:

a. A preliminary scaled layout of the preferred alternative

b. Preliminary aspect charts

c. A Design Basis Report, when required, describing the reason for the project, and the operational benefits; a discussion of alternatives may be necessary

d. A preliminary Order-of- Magnitude Estimate

e. The preliminary materials list containing long lead time items may be required at this time, particularly with a grade-crossing project where an agreement is required with the public agency

## 3.0 65% DESIGN LEVEL

The 65% design level submittal is the evolving work in progress. It is essentially the final design that is not yet fully detailed. It should consist of the following:

a. Final scaled layouts and aspect charts

b. Preliminary materials list (long lead time items accurately depicted), which may include the final design for prewired signal houses; at this time, if deemed appropriate, a procurement package for the long lead items should proceed

c. Signal drawings that have signal house layouts and most equipment shown; the circuitry design is still in progress, but detailing is not complete

d. A Preliminary Engineer’s Estimate, developed to the same level of detail as that of the design

e. The technical specifications

## 4.0 95% DESIGN LEVEL

The 95% design level submittal should be the last review opportunity in the design cycle. It should consist of all of the following:

a. The final plans, transmitted to the checking firm for review

b. The final materials list

c. The final Engineer’s Estimate

d. The final technical specifications

## 5.0 FINAL DESIGN

The final design submittal is the Issued for Construction or Issued for Bid package. The design shall be complete, and the construction package shall be ready for distribution. The package should consist of the following.

a. Final design for distribution, incorporating any changes to the 95% document that may come out of the final check

b. An Issued for Bid package that includes plans, specifications, and an Engineering Estimate if it is a contract for third-party work

c. Software will be furnished for outside check after construction has begun, after the Issued for Construction drawings, and after or during initial construction

The design stages above are guidelines for the design cycle on Caltrain Signal projects. Caltrain may choose to combine stages, or introduce additional review cycles. For instance, if there are significant changes during the 35% review cycle, Caltrain may require a 40% iteration that reflects those changes. On a rehabilitation project, Caltrain may elect to go directly to the 95% design.

## W. SIGNAL EQUIPMENT NAMING CONVENTION

Reference designators are assigned to designate Signal system wayside facilities, equipment, and devices. Generally, these designators are formed using a combination of alpha and/or numeric characters as described herein. In cases where a naming convention is not given for certain facilities, Caltrain will provide the reference designators.

### 1.0 CONTROL POINTS

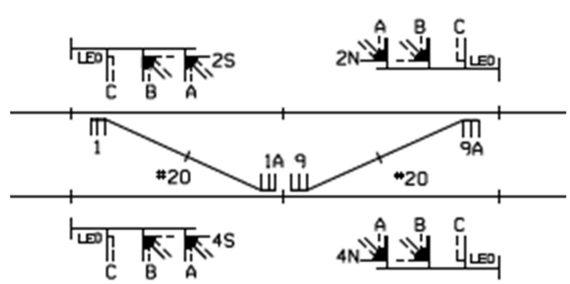
Control Points are identified by CP followed by the name of the nearest street.

### 2.0 SIGNALS

Home signals at control point locations are identified by one-digit number ‘2’ or ‘4’ followed by letter ‘S’ or ‘N’, for two mainline tracks M1 and M2. Number ‘2’ is designated for MT2, number ‘4’ is designated for MT1. Letter ‘S’ for southbound and letter ‘N’ for northbound.

Intermediate signals are identified by mileposts (odd numbers for northbound and even numbers for southbound) followed by hyphen with a number ‘1’ or ‘2’, ‘1’ for track MT1 and ‘2” for track ‘MT2”.

Color of signal light is identified by single letter ‘A’, ‘B’, ‘C’, ‘D’ etc.




### 3.0 SWITCHES

Switches are odd numbers.

Mainline switches are identified by one or two-digit number, with or without a letter ‘A’, designators.

Signaled Yard switches are identified by two-digit number designators.

## END OF CHAPTER

# CHAPTER 6

# TRAIN CONTROL SYSTEMS

## A. GENERAL

The design criteria presented in this chapter for mission or operations critical Train Control define the technical requirements used for the development of specifications and the design of the Rail Operation Control system and supplementary systems, i.e. the positive train control (PTC) system.

The Rail Operation Control system is supported by a Caltrain-owned microwave radio network and fiber-optic plant. The design criteria define the requirements for control systems and subsystems to safely, efficiently, and fully support the Caltrain operations. The ATCS data radio network shall interface to, and the voice radio system shall support, the PTC and the future California High Speed Rail (CHSR).

In addition to Caltrain's control systems/subsystems, there are several other communications subsystems that are used by Caltrain, as follows:

a. Public address (PA) system

b. Closed-circuit television

c. Digital station signs including Variable Message Sign (VMS), Platform End Displays (PED), and Train Schedule Displays (TSD).

d. Fare collection system (ticket vending machine and the "Clipper" card)

e. Data communications network

f. Fiber optic communications back backbone system

g. Wireless systems

The design criteria for these subsystems are addressed separately in **Chapter 4, Communication and Passenger Information Systems** and **Chapter 10, Rail Network**.

The designer(s) of the train control system shall be qualified electrical and electronics engineer(s), licensed in the State of California as professional electrical engineer(s). They shall have designed and integrated at least two similar projects in the last 5 years.

## B. ADVANCED TRAIN CONTROL SYSTEM DATA RADIO SYSTEM

Currently Caltrain uses the ATCS 900 MHz band as a backup for WIU messaging. This 900 MHz band is owned by AAR which will be re-banded by the FCC in September 2025. AAR will not allow any railroads to use this new band for ATCS network. Caltrain plans to switch the ATCS network with a third-party wireless cell modem network as a backup for WIU messages. installation of cell modems and antennas on the ATCS huts at 32 locations, along with the installation of power and data cables to the new cell modems.

All train movements on Caltrain tracks are managed and controlled by a non-vital supervisory control and data acquisition system (SCADA). This SCADA is implemented via a fiber optic network and data radio network, which connects the train signaling Control Points (CPs) to the computer workstations, servers, and packet switches at the Menlo Park Central Control facility (MPCC) and at the San Jose Central Control facility (SJCC). A detailed description of each component of the data radio network and the MPCC/SJCC headends interface is provided below. The data radio network is implemented through Caltrain own fiber as a primary for the back haul and a new cell modem coverage as secondary backhaul.

The ATCS protocol is central to the network communications over fiber between the network of CPs and Base Stations, as well as to the base-band (DS0) data links between these Base Stations and the packet switches at the MPCC and SJCC.

### 1.0 CENTRALIZED TRAFFIC CONTROL RELAY SERVICE (CTCRS)

At the MPCC and SJCC, the train dispatcher utilizing a Computer Aided Dispatch system implements a route request by first inputting a control command into the Front End Processor (FEP). The FEP decodes the command, and passes another encoded message to the Centralized Traffic Control Relay Service (CTCRS), which have the dual function of ensuring that the output protocol to the base station network is implementing the ATCS protocol (gateway function), and deciding which base station site will be the most likely server for the CP being commanded (router function).

As a backup to fiber backhaul the cell coverage provided by FirstNet.. The following ATCS protocols are implemented in the Caltrain system:

a. The SCS-128 protocol is used for all direct fiber between CPs and the MPCC and SJCC.

b. Internet protocol (IP)-based dispatch workstations, called the Advance Information Management (AIM) dispatch headend console, are provided by Wabtec (formerly ARINC).

### 2.0 FRONT END PROCESSOR (FEP) SERVER

The MPCC and SJCC FEP currently used in support of the ATCS data. They incorporate built-in hardware redundancy through the use of a dual code server/front-end processor (FEP).

The Wabtec AIM/FEPs use an ATCS over IP protocol; this protocol conversion feature of the packet switch is not required for the interface to the AIM/FEP. The ATCS over IP shall be the configuration used by the AIM system.

The MPCC and SJCC FEPs shall monitor the inbound messages from the CTCRS and decode messages for the AIM application to process for the train dispatcher.

### 3.0 NETWORK

The third major component of the non-vital SCADA is the network of ATCS CPs. The Caltrain railroad consists of approximately 78 miles of railroad tracks serving freight and passenger operations between San Francisco and Gilroy. Currently, 31 CPs are in operation, between CP Fourth Street in the north and CP Lick in the south, of which 27 are on the ATCS data network.

The ATCS network was designed to grow organically; however, to preserve system throughput and efficiency, the following parameters must be analyzed prior to adding new CPs or base stations:

For the efficient operation of Caltrain, the current maximum authorized speed is 79 miles per hour, and the minimum headway is 5 minutes. Given these requirements, empirical data suggest that no more than about 15 CPs shall be supported by a single base station. To increase maximum speeds or reduce headways further, it will be necessary to obtain additional efficiency improvements by reducing the coding or protocol conversion overhead, or increasing the data rate of the base-band The MPCC/SJCC shall receive from 100 percent of the CPs likewise with 99.0 percent or better, communication reliability, providing 10 E-7 BER without FEC coding. The data radios shall use specification-compliant ATCS communication protocol for communication between the CPs and the base station sites.

The ATCS communications between the MPCC/SJCC (code server) and the base station sites is based on a polling scheme.

## C. COMPUTER-AIDED DISPATCH SYSTEM (CAD) AND TRACTION POWER SCADA

The Computer-Aided Dispatch (CAD) system is commonly referred to as the Rail Operations Control System (ROCS), and serves a dual-role as the Traction Power SCADA (TP SCADA) central supervisory system. The in-service ROCS/TP SCADA is provided and supported by Wabtec, formerly ARINC, utilizing their AIMCore product platform.

These system(s) provide for the supervisory train dispatch and traffic control functions, and electrical traction power management respectively. They communicate to field signal devices utilizing ATCS and Genisys protocols, and SCADA-typical controllers, sensors, and Remote Terminal Units (RTUs) necessary to perform their functions over Caltrain’s communications and network infrastructure. These systems also integrate with each other and other external systems including the Passenger Information Display System (PIDS) – also referred to as the Predictive Arrival Departure System (PADS) – and Positive Train Control (PTC).

The functions of the CAD system must satisfy and provide functionality for:

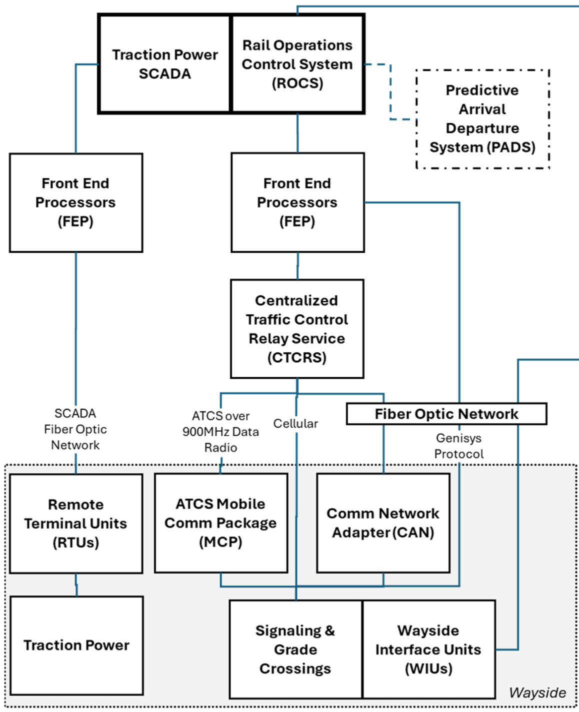
- Code Federal Regulations (CFR) 49 Chapter II Federal Railroad Administration (FRA), with a focus on Parts 218 and 236.
- Association of American Railroads (AAR) MSRP-K
- General Code of Operating Rules (GCOR)
- Caltrain System Special Instructions and Timetable
- Interfaces for adjacent or third-party systems (e.g. passenger information systems), as defined in system specifications.
- Positive Train Control (PTC), including but not limited to CAD-to-BOS Interface Control Document (ICD)
- Caltrain's datacenter and network architecture design practices
- Caltrain cybersecurity policies and design practices

All changes shall be compatible with the in-service system. All proposed modifications, software and material, are subject to coordination and approval by the Systems Engineering department and Caltrain's Change Control processes.

## D. POSITIVE TRAIN CONTROL (PTC) SYSTEM

The Positive Train Control (PTC) system shall be based on the Interoperable Electronic Train Management System (I-ETMS) architecture and solution, or of an acceptable compatible solution. The current in-service system is provided and supported by Wabtec, providing a full suite of subsystems spanning back office servers, communication and network systems, onboard communication and control systems, and interfaces to signaling systems necessary to achieve its required functions. They system supports a mixed vehicle fleet of diesel locomotives and electrified EMUs, with expandability for future vehicle types such as Battery powered EMUs (BEMU). The system therefore accounts for the diversity of these fleets' characteristics and dynamic performances, provides licensed features as applicable, and interoperability with Caltrain's tenant railroads. Lastly, the PTC system must integrate with and interface to all necessary secondary systems, such as the ROCS CAD system, signaling Wayside Interface Units (WIUs), etc., utilize and adhere to Interface Control Documents (ICD) where applicable including those control by ITC committee (e.g. CAD-to-BOS ICD, BOS-to-Onboard ICD, etc.).

The following diagram provides a high-level system functional diagram of the major components of the PTC system and major interfaces:




The PTC system must provide for, and adhere to, all necessary functions, interfaces, lawful regulations, and Interoperable Train Control (ITC) requirements, to include but not limited to:

- Code of Federal Regulations (CFR) 49 Chapter II Federal Railroad Administration (FRA), with a focus on Part 236.
- Association of American Railroads (AAR) MSRP-K
- General Code of Operating Rules (GCOR)
- Caltrain System Special Instructions and Timetable
- AAR/RailInc Interoperable Train Control (ITC) policies
- Caltrain PTC Safety Plan (PTCSP)
- Caltrain PTC Implementation Plan (PTCIP)
- Caltrain's datacenter and network architecture design practices
- Caltrain cybersecurity policies and design practices

All changes shall be compatible with the in-service system. All proposed modifications, software and material, are subject to coordination and approval by the Systems Engineering department and Caltrain's Change Control processes.

## E. REFERENCE STANDARDS

The following standards are relevant to devices and systems that will interface with the Traction Power SCADA:

a. Association of American Railroads Manual of Standards and Recommended Practices Section K-I through K-VI

b. IEEE 1815-2012 – Standard for Electric Power Systems Communications Distributed Network Protocol (DNP3)

c. IEC 61850 – Communication Networks and Systems for Power Utility Automation

## F. DESIGN REQUIREMENTS

The designer shall be responsible to produce the design documents in phases, Conceptual 5%, Preliminary 35%, Draft 65%, Final 100%. The 5% design shall, at a minimum, include the following documents:

a. A conceptual overview plan for function(s) and supplemental flowchart of workflows

b. High level gap analysis of existing business functions and modifications to functions

c. A rough Order of Magnitude Budget Estimate

d. A high-level design delivery schedule

Design for Preliminary, Draft, and Final phases will be based on acceptance and continuation into subsequent phases as defined by the Engineer.

## END OF CHAPTER

# CHAPTER 7

# GRADE CROSSINGS

## A. INTRODUCTION

The terms “grade crossings” or “crossings” in this document refer to all crossings at grade. Grade crossings are commonly referred to in the technical literature and government publications as “at-grade highway-rail crossings,” “highway-rail crossings,” or, more recently, “pathway grade crossings.” This chapter also covers pedestrian-only grade crossings.

Grade crossings are intersections where vehicles and/or pedestrians cross train tracks at the same elevation, and the train always has the right of way. By definition, an intersection is an area of potential conflict, i.e., two users cannot occupy the same space at the same time. The terms “motorized users” or “motorists” denote all types of vehicular drivers (automobiles, buses, trucks, motorcycles, etc.). The terms “non-motorized” users or “non-motorists” refer to all pedestrians, and include mobility-impaired persons, wheelchair occupants, and bicyclists.

Ideally, highway-rail grade crossings should not exist. For years, one of the goals of the Federal Railroad Administration (FRA) has been to eliminate all of the grade crossings. Because the large number of crossings makes this impossible, the more realistic goal is to have a grade crossing that affords a safe, comfortable, and convenient passageway for all users.

The grade crossing design consists of three essential elements: safety, accessibility, and functionality. To achieve these goals, the grade crossing requires a clearly defined and readily traversable pathway for both motorists and pedestrians. In addition to the defined pathway, the grade crossing limits need to be clearly delineated. That is, those areas where a pedestrian or motorist can safely wait for a train to pass, or where a pedestrian or motorist has passed beyond the area of potential conflict, must be readily apparent. One of the key considerations in the design is for the crossing to encourage lawful behavior.

Grade crossings may be either public or private. Public grade crossings are roadways that are under the jurisdiction of and maintained by a public authority. Private grade crossings are privately owned, often located in an industrial area, and are intended for use by the owner or by the owner’s licensees and invitees. Private grade crossings are not intended for public use and are not maintained by a public authority.

Grade crossing closures and/or replacement of grade crossings with grade separations will eliminate the majority of hazards. These two options can be difficult to achieve. Closure of a grade crossing requires collaboration and affirmation from both the local agency and the public, which is a challenging proposition. The grade separations are becoming more difficult to implement due to soaring costs, funding competition and limitations, and service impacts during construction.

## 1.0 CALTRAIN GENERAL POLICY

Caltrain has established a general policy in regard to vehicular grade crossings and pedestrian-only grade crossings, as well as the related quiet zones.

As a general policy, Caltrain actively promotes the following approaches on grade crossings:

a. Closure of underused existing crossings

b. Consolidation of existing grade crossings

c. Enhancement of safety, accessibility, and comfort of existing crossings

d. Grade separation of existing crossings

e. Adaptation of new technologies

New grade crossings are not permitted. The new crossing(s), if proposed, shall only be considered in conjunction with closure of adjacent crossing(s), and shall be approved by the Caltrain Director of Engineering.

Elimination of grade crossings is the safest approach to grade crossing enhancement and should be implemented as the preferred improvement for both vehicular and pedestrian crossings.

It is the policy of Caltrain to systematically improve all existing vehicular crossings by installing pedestrian gates in all four quadrants of the vehicular grade crossings to enhance pedestrian safety and accessibility.

It is Caltrain’s practice to closely collaborate with the California Public Utilities Commission (CPUC) and the local agencies having jurisdiction over the roadways to jointly evaluate and determine the improvements over Caltrain’s crossings. These three stakeholders form a diagnostic team comprising multiple disciplines in the areas of civil and traffic engineering, and railroad signal engineering. This is described more fully in **Section C, 5.0, Diagnostic Team**.

## 1.1 QUIET ZONES

“Quiet zones” refer to areas requiring the elimination of train horn sounding as the train approaches a grade crossing. The FRA, in its Rule on the Use of Locomotive Horns at Highway-Rail Grade Crossing, effective June 24, 2005, authorizes an option to maintain and/or establish quiet zones. Communities wishing to establish quiet zones must have in place supplemental or alternative safety measures to adequately compensate for the absence or reduction of train horn sounding.

Proposals for a quiet zone must take into account the fact that pedestrian crossings and vehicular crossings near Caltrain stations require sounding a train horn to reactivate the crossing active warning devices after a station stop. Any proposed alternative method of reactivating grade crossings due to a quiet zone will require new equipment on board all locomotives and cab cars, and will require conversion of all similar grade crossings.

## 2.0 CALTRAIN GRADE-CROSSING SYSTEM

Caltrain has three types of railroad grade crossings: vehicular grade crossings, pedestrian grade crossings, and emergency grade crossings. Emergency grade crossings provide access for Caltrain-approved maintenance vehicles, and passenger evacuation routes for revenue operations on an emergency basis, as well as for potential future operational needs. Emergency crossings are secured with gates and locks. They are not provided with active warning devices.

All vehicular grade crossings in the Caltrain corridor have pedestrian crossings on one or both sides of the crossings. Additionally, Caltrain also has pedestrian-only at-grade crossings. All but two of these crossings are located at passenger stations. As part of the effort to eliminate at-grade crossings, newer and reconstructed stations are designed without pedestrian at-grade crossings when it is feasible. These stations instead use pedestrian underpasses or overhead for passenger circulation.

All of the grade crossings on Caltrain are equipped with an active crossing warning system to provide notice that a train is approaching, with sufficient warning time for the motorist and pedestrian to stop short of the crossing; or, if they have already entered the crossing, to safely continue past the area of potential conflict.

Prior to the completion of Caltrain electrification, Caltrain vehicular and pedestrian crossings used a track-circuit based device, called predictor unit, which usually provides a constant warning time before the train reaches the crossing to activate bells, flashing lights, and automatic gate arms. The constant warning time devices control the flashing lights, automatic gates and bells, and the traffic preemption. All predictor units were replaced with Audio Frequency Overlay (AFO) circuits to be compatible with the electrification system under the PCEP (Peninsula Corridor Electrification Project) and the Crossing Optimization Project.

The Crossing Optimization Project implemented the 2-Speed Check (2SC) system and replaced all predictor unit computers with a track overlay-based system. 2SC System is the default Signal/Crossing System for Caltrain Electrification system. The 2SC system recognizes two train speeds (79mph and 40mph), provides fixed approach design with delay timers, and assigns corresponding crossing activation delay time with customized approach length. The Crossing Optimization Project also implemented Wireless Crossing system that unitizes the PTC system, provides Warning Time Activation performance similar to other Constant Warning Time technologies, crossings will only activate when train is departing the station and eliminates the one of two activations associated with a station stop train. The Crossing Optimization Project was completed in 2024.

Caltrain developed its own standard practices for pedestrian crossings, which have been in effect since 1999.

Caltrain constantly adapts to new technologies of railroad signaling, partners with the CPUC and the local agency on the preemption diagnostics, and evaluates current practices and improvements at grade crossings regarding traffic control devices.

Caltrain publishes the General Code of Operating Rules (GCOR), Caltrain General Orders (GO) Timetable, and Special Instructions which shall be considered in the design, installation, operations, and maintenance of Caltrain's crossings.

Typical vehicular grade crossings are illustrated in **Figure 7-1, 7-2, and 7-3** for right-angle, obtuse, and acute intersections, respectively.

## B. REGULATORY AUTHORITIES AND STANDARD PRACTICES

Grade crossings are regulated by the various federal and state government agencies; in California, it is the CPUC. In addition to these regulatory agencies, railroads collaborate with local agencies having jurisdiction over the roadway for traffic coordination. Caltrain has developed its own standard practices. The American Railway Engineering and Maintenance-of-Way Association (AREMA) and the Institute of Transportation Engineers (ITE) provide the industry standard practices and recommendations.

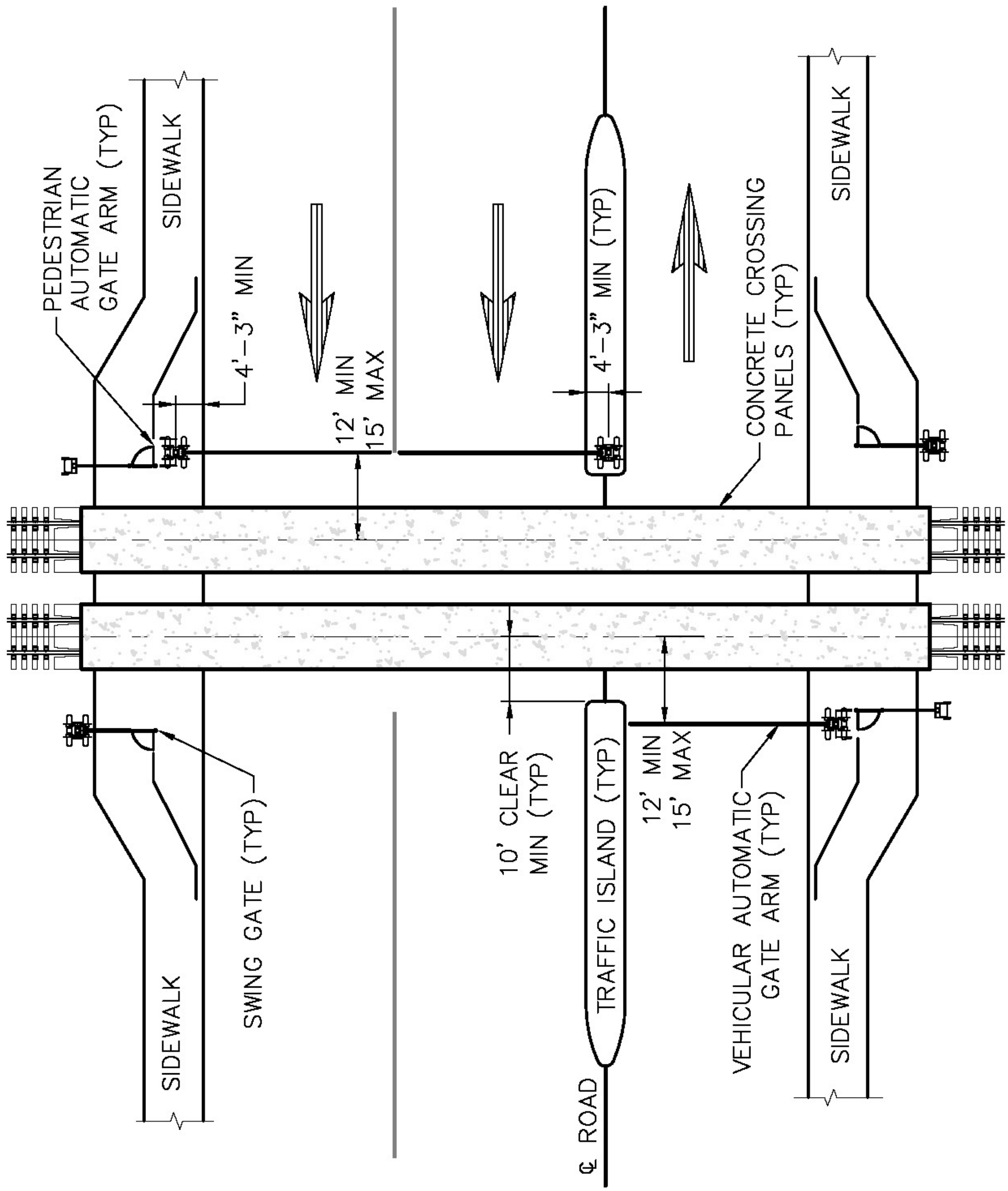



**Figure 7-1: Typical Vehicular Crossing (Right-Angle Intersection)**

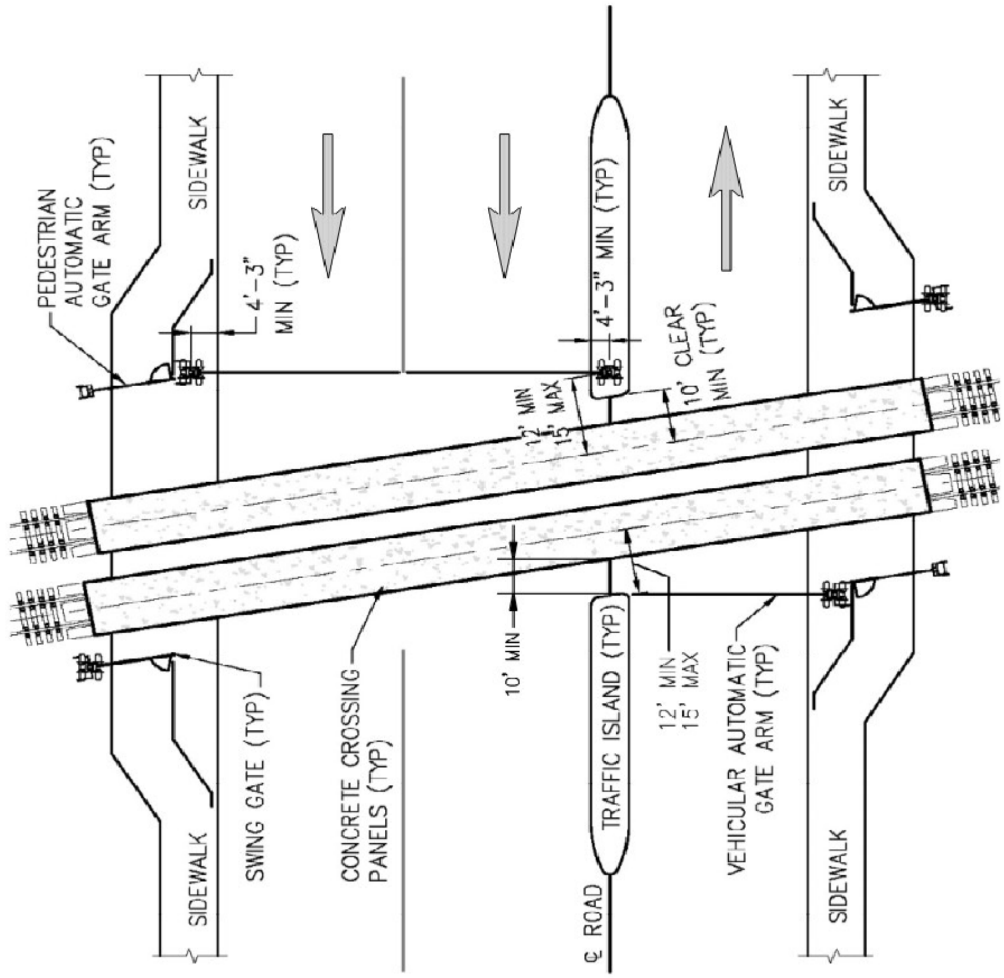



**Figure 7-2: Typical Vehicular Crossing (Obtuse Intersection)**

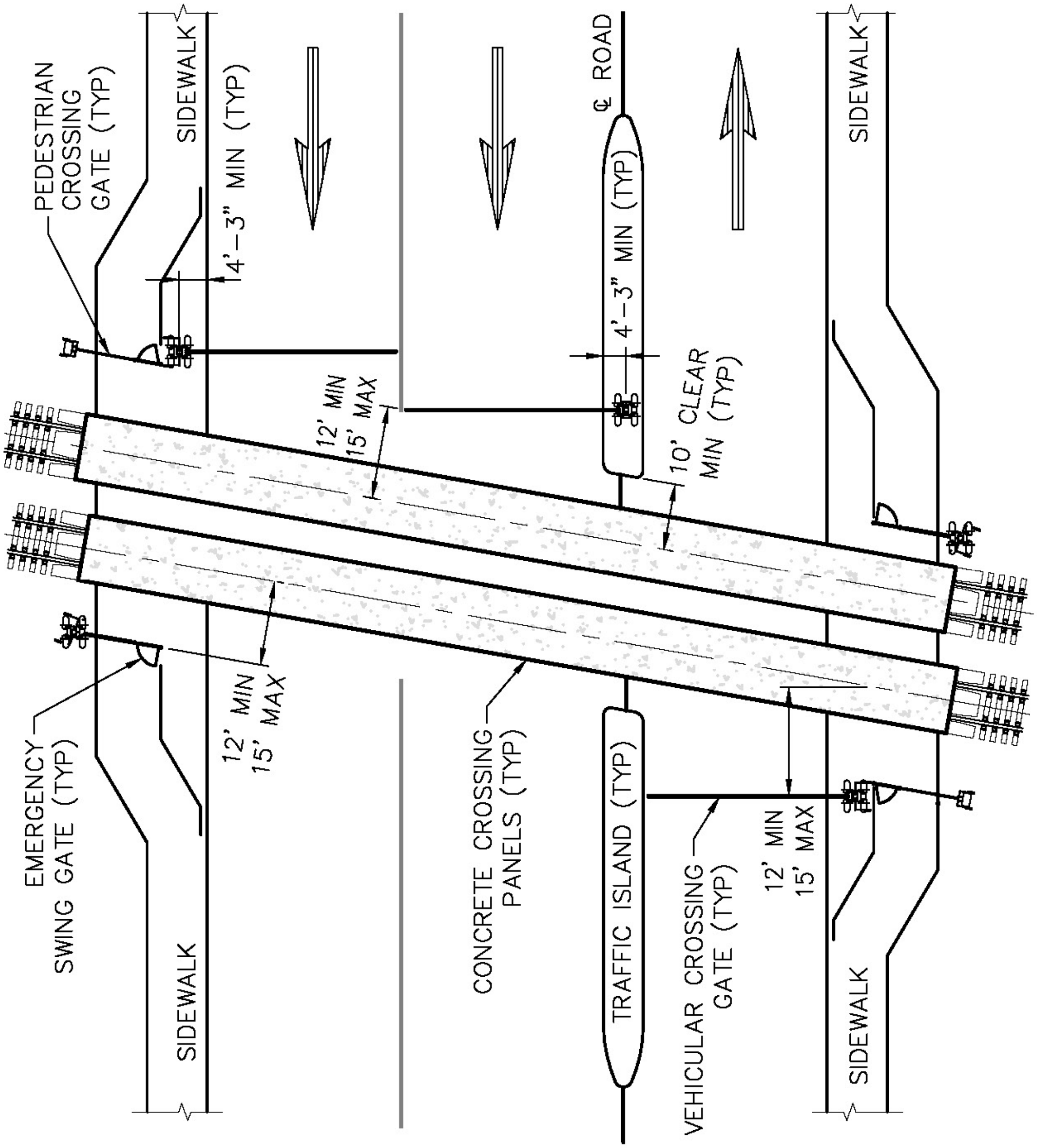



**Figure 7-3: Typical Vehicular Crossing (Acute Intersection)**

## 1.0 REGULATORY AUTHORITIES

Various federal agencies under the United States Department of Transportation (USDOT) have jurisdiction over the grade crossings. These include the FRA, Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and the National Transportation Safety Board (NTSB).

The United States Department of Justice (DOJ) has federal jurisdiction over accessibility for people with disabilities, and develops and publishes requirements for accessibility for people with disabilities as part of the Americans with Disabilities Act (ADA). USDOT has been designated to implement compliance procedures relating to transportation (highways, streets, and traffic management), with the FHWA overseeing the USDOT mandate in these areas.

In the State of California, the CPUC has the overall oversight of the grade crossings.

## 1.1 FEDERAL

USDOT has federal jurisdiction over grade crossings. Three DOJ agencies (FTA, FRA, and FHWA) oversee the rules and regulations at grade crossings and share the objective of reducing accidents at grade crossings. A fourth agency, NTSB, investigates transportation-related accidents, including those at crossings.

### 1.1.1 Federal Railroad Administration

FRA regulates and enforces aspects of grade crossing safety pertaining to railroads, such as track safety, train-activated warning devices, and train safety and conspicuity. It maintains a database of information on all railroad crossings in the country. FRA also regulates the type of lighting to be placed on a locomotive; the audibility of the bells; and the inspection, testing, and maintenance standards for active at-grade crossing signal system safety.

### 1.1.2 Federal Highway Administration

FHWA and FRA are jointly responsible for the safety at public vehicular grade crossings. FHWA provides guidelines and standards for the design of grade crossings, the assessment of at-grade crossings, and appropriate placement of traffic control devices at and on the approach to the crossings.

The FHWA publishes the following widely used documents:

a. Highway-Rail Grade Crossings Manual

b. Manual of Uniform Traffic Control Devices (MUTCD) – Guidance on the design and placement of passive and active traffic control devices

c. Railroad-Highway Grade Crossing Handbook – Guidance on grade-crossing design

d. Guidance on Traffic Control Devices at Highway-Rail Grade Crossings

### 1.1.3 Federal Transit Administration

FTA administers funding to support a variety of public transportation systems, including commuter rail. FTA has a policy statement that incorporates walking and bicycling facilities into all transportation projects, partly in response to public support for increased planning, funding, and implementation of sidewalks.

### 1.1.4 Americans with Disabilities Act

Federal agencies follow the ADA Accessibility Guidelines (ADAAG) for ADA compliance. However, these ADA standards for new construction and alterations promulgated (as guidelines) by the United States Access Board were principally developed for buildings and site work, and are not easily applicable to sidewalks, street crossings, and related pedestrian facilities in the public right-of-way (ROW).

In 1999, the Access Board started the rulemaking process for accessible pedestrian facilities in public ROW by convening a federal advisory committee of key stakeholders to develop recommendations that could supplement or replace the current standard. The Public Rights-of-Way Access Advisory Committee (PROWAAC) completed its initial work in 2000 and published its recommendations for new guidelines in a report, *Building a True Community*, which was presented at the 2001 Transportation Research Board Annual Meeting. On June 17, 2002, the Access Board issued a Notice of Availability of Draft Public Rights-of-Way Accessibility Guidelines (PROWAG), based on the PROWAAC report. Comments from consumers and design professionals led to the issuance of a second draft on November 23, 2005. A Notice of Proposed Rulemaking will follow, seeking public comment prior to publication of a final rule.

In the interim, jurisdictions must continue to design and construct new and altered pedestrian facilities that are accessible to and usable by people with disabilities. The 2005 draft PROWAG has been identified by USDOT as the current best practice in accessible pedestrian design under the FHWA's federal-aid (Section 504) regulation.

### 1.1.5 National Transportation Safety Board

NTSB investigates collisions at transportation facilities, including highway-rail grade crossings; promotes rail safety; encourages enforcement of compliance; and promotes technologies designed to improve safety.

NTSB initiates the Highway-Rail Crossing Safety and Trespass Prevention Program, whose objectives are to elevate the importance of grade crossing safety, and adopt a uniform strategy to deal with this critical issue. The program stresses the following nine initiatives:

a. To establish responsibility for safety at private crossings

b. To advance engineering standards and new technology

c. To expand educational outreach (help promote Operation Lifesaver, a nonprofit educational program about safety at grade crossings)

d. To energize enforcement

e. To close unneeded crossings

f. To improve data, analysis, and research

g. To complete deployment of emergency notification systems

h. To issue safety standards

i. To elevate current safety efforts for effectiveness

## 1.2 STATE OF CALIFORNIA

The State of California, through the CPUC, holds the ultimate authority over cross-jurisdictional grade crossings. CPUC is the state regulatory agency with statutory authority over the railroads and rail transit systems in the state. The CPUC has adopted the federal MUTCD; this modified and supplemented version of the document is commonly referred to as the California MUTCD (CA MUTCD).

The CPUC issues GOs pertaining to applicable requirements for the design and improvement of grade crossings. The current GO 75-D (protection of railroad grade crossings) covers grade crossing warning devices. CPUC authorization is required to modify an existing rail crossing. GO 88-B (modification of an existing rail crossing) provides a process for rail crossing modifications. Additionally, the CPUC distributes federal funds from the Railroad Highway Grade Crossing Program, also known as the Section 130 Program, (FHWA Section 130 funds for grade crossing improvement), and allocates state grade separation funding (Section 190) as well as warning device maintenance funding. The level of state funding has changed little since the program was established in the late 1950s.

The CPUC's Highway-Rail Crossing Safety Branch determines the need for improvements and what those improvements will be, as follows:

a. Reviews proposals for crossing improvements

b. Authorizes construction of new at-grade crossings

c. Investigates reported deficiencies of warning devices or other safety features at existing at-grade crossings

d. Recommends engineering improvements to prevent accidents

### 1.2.1 Emergency Notification Sign

CPUC also adopts the FHWA recent requirement for installation of notification signs at vehicular grade crossings. The signs are intended for callers to notify the railroad in case of emergency or problems at the grade crossings. The signs shall include the toll free phone number, information about the location (street name), and the USDOT crossing number. The signs shall face the roadway(s) and be visible to incoming motorists, either on the crossing signal masts or on stand-alone sign posts. Other details are described in the CA MUTCD.

### 1.3 LOCAL AGENCY

Local agencies (counties, cities, and towns) are key stakeholders and, together with the railroads and the CPUC, form a diagnostic team. In addition to the traffic control devices, improvements to grade crossings could include the traffic signal and preemption requirements. The traffic control devices are described in **Section D, Traffic Control Devices**. Traffic preemption is described in **Section E, Traffic Signal Preemption**.

### 2.0 INDUSTRY GUIDELINES

### 2.1 AMERICAN RAILWAY ENGINEERING AND MAINTENANCE-OF-WAY ASSOCIATION

AREMA publishes "*Communications and Signals Manual of Recommended Practices,"* which provides recommendations for design criteria and parameters, installation, inspection, testing, and maintenance of the signal at highway-rail grade crossings, including warning time calculations.

### 2.2 INSTITUTE OF TRANSPORTATION ENGINEERS

ITE publishes guidelines for preemption of traffic signals near railroad crossings.

## C. DESIGN OF GRADE CROSSING SYSTEMS

Because it is site-specific, each grade crossing is unique and complex. Each of the three different types of user groups (trains, vehicles, and pedestrians) has distinct characteristics in crossing behavior and limitations, and among users of the same group these differences vary widely. The system design needs to address the needs and capabilities of each of these user groups.

**Figures 7-1, 7-2, and 7-3** show the typical vehicular grade crossings for right-angle, obtuse, and acute intersections, respectively. **Figures 7-5 and 7-6** show the typical pedestrian grade crossings at vehicular crossings and passenger stations, respectively.

The underlying principle of grade crossing safety is to provide a defined path for safe passage across the tracks in an expeditious and efficient manner. Safety is enhanced by credible warning devices, which are appropriate to the different target users.

The crossing shall be designed to provide the required integration between the pedestrian grade crossing and the sidewalk. Ideally, there shall be adequate access in width to accommodate wheelchairs, in accordance with ADA requirements. In addition, the crossing shall transition smoothly, integrating with the surrounding footpath and road network. The design shall be clear of obstructions and provide adequate maneuvering space in a consistent manner for wheelchairs, strollers, and bicycles. If sidewalk is absent, a smooth transition shall be provided.

Any modifications to the existing grade crossings, whether rehabilitation or improvement, require an integrated effort among the civil and signal disciplines, as well as roadway traffic signaling. This will require the collaboration of all stakeholders: the railroad; the local agency, which has the authority of the roadway; and the CPUC, which has the overall oversight of the state grade crossings. This collaboration is in the form of a diagnostic team, which evaluates, assesses, analyzes, and jointly concurs on the optimum type, number, and placement of traffic control devices. Additionally, the team coordinates the requirements for traffic signal preemption and design of warning time. The diagnostic team is discussed in more detail in **Section C, 5.0, Diagnostic Team**.

## 1.0 GENERAL REQUIREMENTS

### 1.1 GEOMETRY

The geometric characteristics of a grade crossing directly impact the sight distance for the users. The sight distance is characterized by the horizontal and vertical alignment, transition from track to the roadway, and crossing surface. Vertical curves should be of sufficient length to ensure an adequate view of the crossing.

The grade through the crossing shall follow the track profile and grade, which shall generally be flat for crossings that are not on curves requiring rail super elevations. This will enhance the view of the crossing and, from the standpoint of sight distance, ride quality, braking, and acceleration distances.

Ideally, the roadway should intersect the tracks at a right angle and with no nearby intersections or driveways. When the right angle is not possible, the skew of the roadway should be reduced as much as possible to facilitate ease of crossing. For the motorists, this layout enhances the view of the crossing and tracks, and reduces conflicting vehicular movements from crossroads and driveways. To the extent practical, crossings should not be located on either roadway or track curves.

Skewed crossings are potential hazards for pedestrians. They lengthen the crossing and, because of the rail flangeway, increase the hazards to pedestrians, especially those on wheelchairs and strollers, or who are visually impaired.

### 1.2 VISIBILITY

The following objects are discouraged approaching crossings (within 150 feet) because they may interfere with the view of the warning devices: fences other than the center fence at stations higher than 4 feet; vegetation higher than 3 feet; signs not part of the passive traffic control devices; and cases, cabinets, or any equipment or structures or other physical sight obstructions.

### 1.3 ILLUMINATION

A well-lighted crossing will assist motorists, pedestrians, and bicyclists in assessing the conditions of the crossings, the crossing warning devices, and roadway conditions.

### 1.4 CROSSING SURFACE

The crossing surface requirements through grade crossings are dictated by the following requirements: drainage; access for maintenance; and the safety, accessibility, and comfort of users. Removable prefabricated concrete panels achieve these objectives.

Curb ramps shall be installed or tapered to daylight not closer than 6 feet from the nearest rail, with a 6-inch solid thermoplastic white line to connect the curb lines across. This line marks the edge of the roadway, to keep the motorists from entering into the tracks.

The crossing panels shall be extended by a minimum of 8 feet from the street side of the curb line. This 8-foot sidewalk extension provides a buffer zone between the vehicular lanes from the sidewalks, to accommodate uninterrupted passing. The buffer zone increases the comfort level and perceived safety of pedestrians.

The crossing cross slopes follow the track grade; because the track grade is typically 1 percent or less, the cross slopes will always be within ADA requirements. The rail flangeway between the rail and the crossing panels shall be treated with rubber filler to reduce the possibility of entrapment of wheelchairs, bicycles, feet, and strollers.

To eliminate tripping hazards, the lifting lugs of the crossing panels shall be filled flush with the manufacturer’s recommended filler. The hot-mixed asphalt concrete (HMAC) sections between the crossing panels and between the panels and the sidewalk shall always be maintained smooth to eliminate or minimize cracks, uneven surfaces, broken pavement, potholes, etc., so as not to increase travel time. This is critical especially for mobility-impaired people, the elderly, and people with strollers.

It is essential that the crossing be designed for ease of maintenance, to minimize the duration of maintenance that may cause train service interruptions and require lane or roadway closure.

Removable crossing panels will expedite maintenance work. The track structure within the grade and crossing and extending 40’ beyond the ends of the grade crossing shall be designed with a minimum of a 6” layer of HMAC. The finished grade all has a crown in the center and provide a 2% slope to either side. The track structure shall be placed on HMAC to accommodate the ever-increasing roadway traffic and to facilitate effective drainage, which reduces crossing settlement. Only concrete ties shall be used at the crossing. Timber ties shall not be used, because they deteriorate quickly under constant moisture conditions. There shall be no rail joints in the crossing or crossing island circuit. The crossing island circuit length is site-specific, but typically 50 feet past the edge of roadway. Other track details are contained in the Caltrain Standard Drawings.

## 1.5 DRAINAGE

Discontinuity or differences between the roadway surface and the rail present drainage and maintenance problems. Ideally, the rail crossing shall be at least equal to or slightly higher than the approaches, to alleviate drainage issues. Standing water may shunt the signal circuits, causing signal failures. An effective drainage system is required to intercept the surface and subsurface drainage and discharge it away from the crossing.

Design of drainage features at the grade crossing (e.g., culverts, ditches, or curb inlets) shall be coordinated with the local agency for discharge away and into the stormwater system of the local agency.

## 1.6 RIGHT-OF-WAY

ROW issues require long lead times to resolve. It is imperative that all ROW issues be identified at an early stage of the design and be resolved before completion of the design. Designers shall clearly delineate row lines and secure the necessary agreements or permits for any grade crossing improvement project.

## 2.0 LAND USE CONSIDERATIONS

Other improvements to enhance guidance and warning to crossing users include review of the land use adjacent to, at, and near the crossings.

The design team should identify any such hazards and work with CPUC, the local agency, and private property owners to mitigate such hazards. Mitigation may include medians, delineators, and signage.

## 2.1 ADJACENT INTERSECTIONS

Adjacent intersections include parallel roadways near the crossings, and frontage roads adjacent to the tracks.

Ideally, there should be sufficient distance between the tracks and the adjacent roadway intersections to enable roadway traffic in all directions to move expeditiously. Where physically restricted areas make it impossible to obtain adequate vehicle queuing distance between the tracks and an intersection, the following should be considered:

a. Interconnection of the roadway traffic signals with the grade-crossing signals to enable vehicles to clear the grade crossing when trains approach

b. Placement of “Do Not Stop on Track” signage on the roadway approach to the grade crossing

c. “No Left Turn” traffic signal or signage on the frontage roadways

When a roadway intersection is near a grade crossing that runs diagonally through the tracks; crosses one or two approaches; or crosses in the median of an intersection, special considerations should be considered in regard to roadway intersection geometry. The geometric design considerations include the following:

a. A minimum space of 75 feet is required between the grade crossing gate and the roadway intersection to prevent large trucks from being trapped on the tracks when advancing to the intersection;

b. Adequate space on the far side of any grade crossing for vehicles to escape if they become trapped on the crossing when a train is approaching

c. Raised median islands to prevent motorists from driving around the crossing gates

d. Evaluation of the appropriate length for left- and right-turn lanes to avoid blockage of adjacent through lanes when the crossing gate arms are lowered for passing trains

e. Determination of preemption time for both grade crossings; the preemption time may have to be substantially lengthened

The designers shall pay particular attention to parallel streets, especially to those allowing a left turn across the tracks.

### 2.2 ADJACENT DRIVEWAYS

Commercial or private driveways in the vicinity of a grade crossing are an area of concern. Large vehicles entering or leaving the driveway have the potential to trap vehicles on the railroad crossing. The hazard is magnified when vehicles back into or out of these driveways. Additionally, the entering and exiting vehicles may distract the motorists from the crossing ahead.

New driveways adjacent to crossings shall be discouraged. If this is not practical, the separation from tracks shall be a minimum of 75 feet.

### 2.3 STREET PARKING AND OFF-STREET PARKING

Parking within 75 feet from the crossing should be discouraged. Parked vehicles restrict the motorist's view of the crossing warning devices. The design shall incorporate a designated driveway and parking within the Caltrain right of way, for a pickup type vehicle, designated for signal maintenance vehicle.

### 2.4 STREET FURNITURE

Street furniture placed on the sidewalk by the local agency may include benches, roadway traffic control cabinets, parking meters, light poles, trash receptacles, or other sight-obstructing structures that have the potential to obstruct the view of the motorists and the view and access of pedestrians. They may also interfere with the access and maneuverability of pedestrians on wheelchairs and with strollers, as well as bicyclists. The furniture shall be placed not closer than 50 feet from the crossing.

### 2.5 TRAFFIC SIGNAGE

Traffic signage placed near the grade crossings shall only be those related to the crossings. Parking signs, street cleaning signs, etc., shall be placed at least 50 feet away from the crossings. Private billboard signs shall be not be allowed within 75 feet of the crossings.

## 3.0 GENERAL SIGNAL REQUIREMENTS

The designer shall specify equipment and applications that will not only provide optimum safety, but will maximize the efficiency and reliability of the commuter and freight train system. The design shall incorporate systems and equipment that have been proven to be reliable, durable, and effective on other rail networks and are in current use on Caltrain. Contact Deputy Director, Railroad Systems Engineering before commencement of any signal design work.

The design shall incorporate features that shall aid signal personnel in the inspection, testing, repair, and overall maintenance of the system. Any new test equipment or procedures required by new materials or methodologies must be identified and submitted to the Caltrain Director of Engineering for acceptance.

All designs shall adhere to the rules and regulations contained in Code of Federal Regulations (CFR) Title 49, Parts 234, 235, and 236. Grade crossing design criteria shall incorporate the rules and instructions contained in the most current issue of the Caltrain GCOR, Caltrain GOs, Caltrain Timetable, and Caltrain Special Instructions.

Any modifications to the grade crossing warning systems have the potential to necessitate changes to the system of wayside signaling. It should be noted that all changes to track structure including installation of insulated joints, imposition of audio frequencies on the rails, and any other changes need to be evaluated to determine the potential effect on the wayside signal system. Refer to **Chapter 5, Signals**, for wayside signal considerations and design criteria.

## 3.1 TRAIN DETECTION SYSTEM

Grade crossing cabins shall include in their design a radio dual-tone multi-frequency (DTMF) activator for the purposes of activating a grade crossing for maintenance activity. The Larry McGee Radio DTMF activator or approved equivalent shall be used. Contact Deputy Director, Railroad Systems Engineering before commencement of any signal design work.

## 3.2 FREQUENCY SELECTION AND APPLICATION

Contact Deputy Director, Railroad Systems Engineering before commencement of frequency selection.

## 3.3 POWER SUPPLIES

An independent battery set and charging circuit shall be furnished for the train detection equipment, and a separate battery set for standby power and charging circuit shall be used for the crossing warning devices. Chargers shall be equipped with temperature compensation devices. NRS HF-MAX model chargers or approved equivalent shall be used.

Where the total load of the crossing warning devices exceeds 60 amperes, a separate shelter with a charger and bank of batteries may be required. Battery capacity shall be sufficient to provide 12 hours standby, with the lights flashing and gate arms in the full horizontal position (gate battery). Battery capacity for the constant warning device shall be sufficient to provide a minimum of 24 hours of normal operation (equipment battery), with 25 percent spare capacity for future.

All storage cells shall be valve-regulated lead acid style. PowerSafe DDr50-17 batteries or approved equivalent shall be used. For the equipment battery, six cells shall be used. For the gate battery, seven cells shall be used.

Power calculations must be performed for all design modifications to ensure that battery backup remains compliant with these Design Criteria.

The manufacturers' recommended surge protection apparatus shall be incorporated into all grade crossing design. Surge protection units shall be installed on the alternating current supply source, battery supply, and track leads.

Terminals for direct current power input on battery surge suppressors should be connected directly to battery terminals. This will permit the battery to filter out small power surges from the battery charger before they enter the surge suppressor. Each vehicular crossing shall have an external plug connection for a generator, to provide power to the signal house in the event of an extended power outage.

Ground rods shall be installed at each corner of houses and on each end of cases. Ground rods shall be 10 feet in length, and connections to the rod shall be as direct as possible, with no short-radius bends (less than 18 inches) in ground leads. Resistance to ground shall be no more than 15 ohms.

## 3.4 WIRE AND CABLE

Grade-crossing design shall include proper sizing of all electrical wiring to ensure proper operation of the equipment, based on the equipment loads and the operating parameters determined by the equipment manufacturers. Minimum conductor sizes to be used shall be in accordance with **Table 7-1**.

**Table 7-1: Cable Size**

| Location | Cable Size |
|---|---|
| **Internal House/Case Wire** | |
| Battery chargers and feeds | #6-259 strand welders cable |
| Flasher lighting circuits | #10 strand |
| Track circuits | #10 strand |
| Loads in excess of 1 ampere | #10 strand |
| Loads less than 1 ampere | #14 strand |
| Loads less than 1 ampere (ElectroLogIXS) | #12 strand |
| **Flashing Light Signals/Gates** | |
| Light wires | #6 strand |
| Gate battery | #6 strand |
| All other circuits | #10 strand |
| **Cable** | |
| Flasher lighting circuits and gate feeds | #6 solid |
| All other circuits | #14 solid |

Grade crossing flasher lights must be provided a minimum of 8.5 volts direct current (VDC). Cable shall be sized to limit voltage drop to 3 VDC. Cable conductor sizes in **Table 7-1** shall be increased where needed to ensure these voltage levels.

Light-emitting diodes (LEDs) shall be installed on all new installations or significant upgrades to existing locations. Either relays or an approved solid-state crossing controller (SSCC) such as the SSCC IIIA or later model shall be installed when modifying a crossing. The SSCC IIIA is preferred. Where LED lamps are used, #10 strand wire may be used unless current requirements dictate the use of a larger gauge wire.

## 4.0 SELECTION OF WARNING TIME

The warning time at a grade crossing must be sufficient for both vehicles and pedestrians to clear the tracks. In general, the FRA requires a minimum warning time of 20 seconds to be provided for the crossing system. The design minimum on Caltrain is 25 seconds, based on a 20-second minimum warning time plus a 5-second buffer time. The actual warning may differ from the design minimum due to variations in train speed in the approach to the crossing. The only exception to the requirement for a 20-second minimum warning time occurs when a train stops in the approach to a grade crossing.

Guidelines for vehicular warning time are described in the AREMA *Communications and Signals Manual of Recommended Practices*, as well as the requirements in CFR Title 49, Part 234, but there are no comparable guidelines for pedestrians.

There are existing warning time guidelines for light rail systems under MUTCD Part 10, as well as standards for pedestrian crossings for roadways under MUTCD Part 4. These standards derive timing based on a walking speed of 4 feet per second (fps). ADAAG, however, recommends a 1.5-fps walking speed to allow for the mobility-impaired individuals.

Both roadway crossing signals and light-rail crossing signals can allow for motorists sight, reaction, and braking capabilities to mitigate a slower-moving individual in the crossing when the pedestrian phase ends. However, a Caltrain train traveling at 79 miles per hour (mph) requires more than a mile to stop. Obviously, a locomotive engineer cannot be relied on to see a pedestrian in time to stop.

## 4.1 HUMAN BEHAVIOR

Studies indicate that motorists sometimes choose to ignore the crossing signs or signals. This deliberate risk-taking behavior results in major risks, particularly where heavy, long, or slow vehicles are involved. Motorists and pedestrians are not always able to accurately estimate the speed of a train or its distance from a grade crossing, and are generally not aware of the distance it takes for a train to stop.

The FHWA Highway/Rail Grade Crossing Technical Group states in its report issued in November of 2002 on *Guidance on Traffic Control Devices at Highway Rail Grade Crossings*, that after 40 to 50 seconds motorists tend to become impatient and will attempt to drive around gates. The same amount of time can be attributed to pedestrians. Because the grade crossing is based on a 25-second warning time for a

79-mph train, a train approaching a station at speed and then decelerating for the station will have an increased warning time. Typically, this time is in the 40- to 50-second range. Extending the warning time to accommodate longer walk distances has the potential of increasing the warning time by more than 50 percent, thus increasing risk.

## 4.2 WARNING TIME

**Table 7-2** illustrates how each of these parameters relates to a grade crossing. The most current AREMA guidelines shall be followed in determining warning times.

### Table 7-2: Warning Time Parameters

<table>
<tr><td rowspan="6">Start of Crossing Approach</td><td colspan="8"><-----------------------------------------------Total Approach Time----------------------------------------------------------------------------></td><td rowspan="6">Crossing Threshold</td></tr>
<tr><td rowspan="5">Equipment Response</td><td rowspan="5">Advanced Preemption</td><td colspan="6"><--Lights Flashing-----------------------------------------------------------------------------------------></td></tr>
<tr><td colspan="5"><--Programmed Warning Time-------------------------------------------------------></td><td rowspan="4">Additional Gate Delay</td></tr>
<tr><td colspan="4"><--Prescribed Warning Time---------------------------------------------></td><td rowspan="3">Buffer Time</td></tr>
<tr><td colspan="3"><--20 Seconds Minimum Warning Time--></td><td rowspan="2">Clearance Time</td></tr>
<tr><td>Gate Delay</td><td>Gate Descent</td><td>Gate Horizontal</td></tr>
<tr><td></td><td colspan="8">Direction of Train Movement --></td><td></td></tr>
</table>

A wide track is a crossing that consists of more than one track, and is greater than 35 feet. Wide track is determined by measuring the distance parallel to the centerline of the roadway between the governing warning device and 6 feet beyond the furthermost rail on which trains operate. When this distance is greater than 35 feet, 1 second shall be added for each additional 10 feet, or fraction thereof.

Once the total time requirement is calculated, the designer shall determine the required approach circuit distance.

## 5.0 DIAGNOSTIC TEAM

Caltrain, the local agency, and CPUC, as the stakeholders of a vehicular grade crossing system, shall form a diagnostic team to jointly coordinate and share the responsibilities of the management of design, construction, and maintenance of the improvements for the operation of the grade crossing system. It is a multi-disciplinary team that requires a system approach. See Title 49 Subtitle B Chapter II Part 222 – Appendix F to Part 222 for additional information regarding a diagnostic team.

The local agency is responsible for providing a detailed written description of the roadway traffic signal operation, with the phasing and clearout times clearly indicated. The local agency is also responsible for the continuity of interconnection wire/cable (underground), traffic signal phasing and timing, and traffic signal enclosure and field equipment. Caltrain is responsible for the railroad equipment and its associated operation, and for providing the preemption call. Where a traffic preemption is requested by a local agency, a written agreement should be executed, indicating that any changes in the traffic signal operation or changes to the operation of the railroad warning devices will be communicated and jointly evaluated prior to implementation.

A Crossing Evaluation Report template for documenting diagnostic results is provided as a reference at the end of this chapter.

## 5.1 DESIGN PHASE

Communicate and coordinate design requirements and data to establish the interconnection design between Caltrain and the local agency, as follows:

a. Identify and agree on site-specific issues and requirements

b. Identify and agree on the regulatory, local agency, and Caltrain objectives and requirements

c. Maintain compliance with regulatory standards

d. Identify and agree on roles and responsibility between the two agencies

e. Considerations for enhancements to the operation of the crossing

The design requirements include the following:

**Specific Interface Requirements:**

a. Direction of travel

b. Signal island occupancy information

c. Station stop/meet

d. Track approach status

e. Track identification

f. Warning device status

**General Requirements:**

a. Adjacent crossings

b. Control points

c. Multiple track crossings

d. Passenger station in corridor

e. Train handling

f. Maximum authorized speed through the crossings

g. Warning time requirements and/or type of preemption (simultaneous or advanced preemption time)

h. Type of vehicles that must stop at all crossings, such as buses and trucks

### 5.2 MAINTENANCE AND OPERATIONAL RESPONSIBILITIES

Caltrain and the roadway authority shall jointly perform the following:

**a.** Testing and commissioning: Operational test and inspection of equipment and systems during the installation of the system

b. Diagnostics or trouble shooting: Operational test and inspection of equipment and systems to expedite rectification of the system

c. Maintenance: Operational test and inspection of equipment and systems as part of the routine maintenance

## D. TRAFFIC CONTROL DEVICES

Traffic control devices are devices that are intended to provide the required system integration, so that the grade crossing will function in a safe manner for the users. In other words, the devices regulate, guide, or warn traffic. Traffic control devices consist of active and passive devices. These grade-crossing control systems have evolved to enhance public safety and to provide more efficient train operations.

### 1.0 ACTIVE TRAFFIC CONTROL DEVICES

Approaching trains activate active railroad traffic control devices as well as the adjacent active roadway traffic control devices. The key component of the active railroad traffic control devices is the active warning devices described below, which provide users with crossing information regarding the approach of trains.

### 1.1 ACTIVE WARNING DEVICES

Active warning devices provide information about the approach of trains to motorists and pedestrians of the crossing, and consist of the following features:

a. Lights on gate arms and flashing lights on the signal mast

b. Audible active control devices (bells) on the signal mast

c. Vehicular and pedestrian gate arms as apparent barriers

If there are adjacent roadway intersections, the active warning devices should be interconnected to the roadway traffic controller to provide either simultaneous or advanced preemption to the roadway traffic signal system. This interconnection will be described in more detail under **Section E, Traffic Signal Preemption**.

The automatic gate arms are generally on a standalone signal mast. When automatic pedestrian gate arms are required on the pedestrian sidewalks, the pedestrian gate arms shall be a separate standalone signal mast. Attaching the pedestrian gate arm to the back of the vehicular gate arm is not recommended by the MUTCD.

On the other quadrants, the signal mast should generally be placed at the field side of the sidewalk. Space allowance must be made for movement of the gate counter weight, and for signal maintainer access to the gate mechanism. Due to space constraints, at times access to the mechanism will require rotating the gate mechanism on the mast.

At a pedestrian sidewalk that crosses the railroad, or at a sidewalk gate assembly, the warning flashing lights on the pedestrian signal mast shall be the conventional side-by-side arrangement. At station crossings that are only used by pedestrians, the flashing light signals shall be vertical. The design and installation shall allow an exit path and be mindful of the pedestrians who have already started crossing the tracks when activation occurs. This is provided by installing exit swing gates. The placement of the gate arm and the swing gate shall maximize effectiveness under space constraints, which typically occur on vehicular crossings.

## 2.0 PASSIVE TRAFFIC CONTROL DEVICES

Passive traffic control devices are traffic control devices that are not activated by the approaching trains. They are intended to provide warning and guide, channel, and control the passage through the crossings.

Passive traffic control consists of the followings:

a. Signage, including railroad signage

b. Pavement striping

c. Pavement markings

d. Pavement texturing

e. Channelization

f. Others

Signage, striping, and pavement markings provide visual warnings, and pavement texturing provide warnings for visually impaired persons. Signage and pavement markings shall follow the requirements defined in the CA MUTCD. Texturing is provided in the form of warning tactile, in accordance with the guidelines of the ADAAG.

Other devices may include raised median islands, delineators, and additional pavement markings, which require collaboration with the local agency.

## 2.1 RAILROAD SIGNAGE

Railroad signage includes crossbucks and number of tracks. The signage is mounted on the signal mast, which includes flashing light signals, bells, and gates.

### 2.1.1 Crossbuck Assembly

A grade-crossing crossbucks assembly shall consist of a Crossbuck sign, a Number of Tracks plaque (if two or more tracks are present), and either a Yield or a Stop sign installed on the same support. The crossbuck assembly shall be installed on the right-hand side of the highway on each approach to the highway-rail grade crossing.

A Yield sign shall be the default traffic control device for crossbuck assemblies on all approaches to passive grade crossings unless an engineering study performed by the regulatory agency or highway authority having jurisdiction over the roadway approach determines that a Stop sign is appropriate.

### 2.1.2 Advance Warning Signs

Advance warning signs shall be installed on each approach to a highway-rail grade crossing, in accordance with the requirements of the MUTCD.

### 2.1.3 Striping and Pavement Markings

A 6–inch-wide thermoplastic white striping indicating the curb lines shall be painted through the crossing. Double Yellow stripping between medians per Caltrans Detail 22 with raised pavement markers Type H shall be used.

The following markings on the pavement approaching the crossing are typically provided and maintained by the local agency:

a. Railroad crossing (RR Cross)

b. Stop bars

c. “KEEP CLEAR” markings

d. Other markings, such as curb painting (in red, designating no parking), directional arrows, or turning information.

## 2.2 RAISED MEDIAN ISLANDS

The installation of raised median islands on the roadway are extremely effective in reducing the opportunity to drive around lowered automatic gate arms. The design of the median islands shall follow the recommendations of CA MUTCD.

Median islands are critical in a multi-lane roadway with the increase in train services through the crossings; the high volume of the vehicular traffic; the roadway geometry with respect to approach characteristics; the relative skew of the roadway with respect to the crossing; and the existence of adjacent frontage roads and driveways.

Raised median islands are under the jurisdiction of the local agency. The designer shall clearly identify and justify the need for these islands, for review and approval by the local agency. If medians are not practical due to limited lane width, other traffic devices such as delineators and yellow pavement markings should be considered. Median islands and delineators are typically not popular with local agencies, or with property owners adjacent to the crossings. In many cases, the CPUC assistance will be required to facilitate gaining approval from private property owners and the local agency.

## 3.0 PEDESTRIAN TREATMENTS

In addition to pedestrian sidewalk gate arms, which include emergency swing gates, treatments for the pedestrians include passive traffic control devices such as signage, pavement markings and texturing, and channelization. Channelization includes guardrailing and fencing.

## 3.1 PAVEMENT TEXTURING

Pavement texturing shall be a 36-inch warning tactile panel with the Federal Standard truncated cones installed across the entire width of the sidewalk immediately in front of the pedestrian automatic gate arm, including the swing gates. The purpose of the tactile warning is to provide an indication to visually impaired persons of the limit to the tracks, as well as an indication to pedestrians of a safe stopping location and safe refuge area that is outside the rail dynamic envelope.

## 3.2 PAVEMENT MARKING

In the pedestrian crossing area, 12-inch-wide white striping (on both the vehicular side and the edge of the crossing) shall be provided to guide and mark the pedestrians-only area through the passageway.

## 3.3 CHANNELIZATION

The design of channelization is site-specific. Channelization should be provided where there is a high likelihood of unsafe behavior, and where the crossing has a significant skew.

The basic principle of channelization is to guide pedestrians, including bicycles, to cross the tracks where active warning devices are in place, and from where pedestrians are led to a crossing path through the designated crossing point. Channelization may include fencing, swing gates, median islands, and various passive traffic control devices.

### 3.3.1 Guardrailing

Guardrailing is railing installed at the approaches to the crossing to guide the users to the crossing points in front of the pedestrian sidewalk gate arm and the swing gate. This will guide visually impaired persons to the warning tactile through the railing and the kick plate.

### 3.3.2 Fencing

Fencing creates a physical barrier that prevents or discourages persons from taking shortcuts or from crossing the track in a risky or unauthorized manner. The fencing shall run for at least 20 feet leading to the tactile warning treatment. Fencing at the gates on the pedestrian sidewalk serves to channel the flow of pedestrians. Fencing along the Caltrain ROW provides a physical barrier to prevent motorists and pedestrians from entering the tracks near the grade crossings.

### 3.3.3 Exit Swing Gates

Exit swing gates should be installed where pedestrian sidewalk gate arms are installed. The swing gates are not electrically connected into approaching train or vehicular traffic signal systems. The purpose of the exit gate is to allow people who are in the crossing area (at the time an approaching train has activated and lowered the gate arms) to exit out of the crossing area through the exit gate to a clear point.

The swing gates must be ADA-compliant to allow pedestrians or persons in wheelchairs to exit the crossing by pushing the gate. Swing gates require regular maintenance to ensure proper operation.

## E. TRAFFIC SIGNAL PREEMPTION

The vehicular crossing consist of the railroad signal system and the roadway traffic signal system, which are required to function together effectively. The interconnection of the roadway traffic and railroad crossing signal system enables vehicles to clear the grade crossing when a train approaches. An effective interconnection system will:

a. Improve safety at crossing

b. Improve vehicular traffic through the crossing

c. Improve the planning and design of the railroad and roadway signal system

d. Expedite the diagnostics processing of both the railroad and roadway signal systems

Safety and operations through the vehicular crossing are the responsibility of both Caltrain and the local agency having jurisdiction of the roadway. Design and testing of traffic signal preemption interconnection circuits must be coordinated with the railroad and the agency having jurisdiction.

### 1.0 DESIGN CRITERIA

Prior to design of a traffic signal preemption circuit, the designer should review the latest guidelines regarding traffic signal preemption prepared by ITE, AREMA, MUTCD, CA MUTCD, CPUC, and other knowledgeable parties.

The approach of a train to a highway-rail grade crossing opens the electrical circuit, which in turn activates the traffic signal controller preemptor. This establishes and maintains the preemption condition during the time the highway-rail grade crossing warning system is activated.

A supervised double-break, double-wire circuit must be installed between the railroad and the traffic signal control system. To detect a shorted or open interconnection circuit, two additional wires will be used to provide a supervised circuit. The energy source originates at the traffic signal controller, and two wires provide a return path verifying that the railroad preemption control relay is energized and that there is no call for preemption. The two additional wires verify circuit integrity when the railroad issues a call for preemption. The circuitry design must be “Exclusive or logic” which is a logical operation that outputs true when inputs differ (one is true, the other is false). If both circuits are energized or both circuits are de-energized, it indicates a problem with the interconnect circuit; the traffic signal controller will assume a state known to be unsafe and issue a notification that there is a circuit deficiency.

**Table 7-3** identifies the number of wires and functions for the supervised interconnection circuitry for simultaneous and advance preemptions:

**Table 7-3: Wires and Functions for Preemptions**

| Wires | Simultaneous Preemption | Advance Preemption |
|---|---|---|
| 1 | Preempt relay negative (N1VPMT) | Source energy negative (N1VPMT) |
| 2 | Preempt relay positive (1VPMT) | Source energy positive (1VPMT) |
| 3 | Spare | Supervisor relay negative (NBVSUP) |
| 4 | Spare | Supervisor relay positive (BVSUP) |
| 5 | Source energy positive (BX 110) | Source energy positive (BX 110) |
| 6 | Source energy negative (CX 110) | Source energy negative (CX 110) |
| 7 | Spare | Gate down relay positive (GD) |
| 8 | Spare | Gate down relay negative (NGD) |
| 9 | Spare | Traffic signal health positive |
| 10 | Spare | Traffic signal health negative |
| 11 | Spare | Spare |
| 12 | Spare | Spare |

A preempt trap occurs when the traffic signals clear track green interval ends before the railroad signals start to flash and the crossing gates start to descend. A preempt trap can be avoided by using a “gate-down” circuit. The purpose of the gate-down circuit is to prevent the traffic signals from leaving the clear track green interval until it is determined that the gates controlling access over the tracks are fully horizontal. The traffic signal controller unit will change to the clear track green interval as usual, but will dwell in the clear track green interval until the gate-down confirmation is received, or until a user-defined maximum time has expired.

## 1.1 TRAFFIC SIGNAL HEALTH-CHECK CIRCUIT

A health-check circuit provides an indication to the railroad active warning system cabinet when the traffic signals are in dark or in All – Flash, such as when the controller is in failure. This health-check circuit will be a fail-safe design so there will be no case in which the circuit will remain energized while the traffic signals are dark or in All – Flash. This failed condition in the supervisory circuit will result in an unhealthy fault in the traffic signal controller, and will de-energize the output to the railroad health relay. Consideration should be given to roadway authority requirements for fault condition design.

## 1.2 INTERCONNECTION CIRCUITS

In **Figure 7-4**, energy (BX 110, CX 110) is supplied to the railroad from the traffic signal controller. The traffic control repeater relay (TCPR) provides the call to preempt. This relay is normally energized and returns energy to the inputs of the traffic signal controller. When a train is detected and the call for preemption is generated, the TCPR is de-energized and the energy is returned to the traffic signal controller on the wires labeled “BVSUP” and “NBVSUP.” This is the supervisory circuit. The supervisory circuit must be de-energized and the preemption circuit energized, or vice versa. This indicates the integrity of the interconnection circuitry to the traffic signal controller.

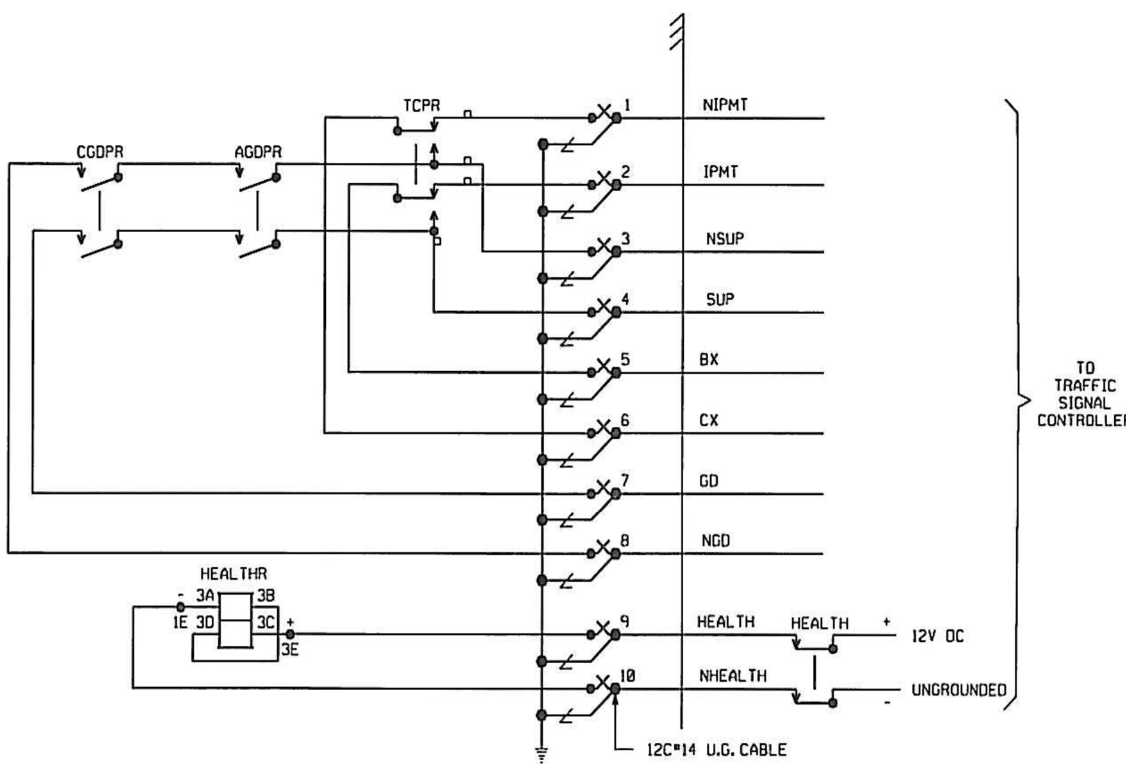



**Figure 7-4: Interconnection Circuits with Supervision, Gate-Down Circuitry, and Health Circuit**

The wires labeled “GD” and “NGD” are energized when the gates approaching the signalized intersection are down after a call to preempt. Upon receipt of these inputs, the traffic signal controller will terminate the traffic signal track clearance green (TCG) and transition to the phases allowed during preemption. These gate-down contacts may be bypassed by contacts of the island circuit so that TCG can terminate when the island is occupied in the event of a gate that does not fully lower.

The health of the traffic signal controller is communicated to the railroad via the health relay. If the traffic signal controller is not functioning or traffic signals are dark or in All – Flash, the health relay will be de-energized and the railroad grade crossing warning system may cause the gates to be down longer for an approaching train. The health of the traffic signal controller is communicated to the railroad via the health relay. If the traffic signal controller is not functioning or in All – Flash, the health relay will be de-energized. When the health relay is de-energized the grade crossing warning system will only provide simultaneous preemption.

When a serial connection is used, this information and more can be conveyed between the railroad control devices and the traffic signal control devices, and operation of both systems is enhanced.

### 1.3 SECOND-TRAIN LOGIC

Where there is more than one track, a second train can approach at any time. If there is an advanced preemption interconnection between the traffic signals and the railroad, the appearance of a second train can hold the traffic signals in preemption and the gates may rise momentarily, allowing vehicles to pull up on to the tracks. Where second-train logic is employed, if a second train is detected on the outer approach, the gates will remain down until after the second train passes. Second-train logic may be employed where no traffic signals are present, if circumstances warrant.

Where second-train logic is employed, exit gates or nonsurmountable medians shall be considered. Due to the increased amount of gate-down time where second-train logic is employed, it is possible that motorists may interpret the gates remaining down after a train has passed as a malfunction of the warning system. Exit gates discourage running around the entrance gates. This is especially critical where there is limited visibility on the approaches, or traffic is dense enough that the gates may be held down for three consecutive trains.

Excess warning time must be avoided as much as possible.

## F. VEHICULAR CROSSINGS DESIGN

All Caltrain vehicular grade crossings are designed with active traffic control devices, which include active warning devices and passive traffic control devices. Some of the vehicular grade crossings do not have sidewalks, and several are adjacent to passenger stations that function as pedestrian access between the two station platforms. Contact Deputy Director, Railroad Systems Engineering before commencement of vehicular grade crossing design.

### 1.0 DESIGN WARNING TIME

The Roadway Worker Protection Act defines “fouling a track” as the placement of an individual or an item of equipment in such proximity to a track that the individual or equipment could be struck by a moving train or on-track equipment, or in any case is within 4 feet of the field side of the nearest running rail.

Four feet from the nearest running rail is approximately 6 feet 6 inches from the track center. CPUC clearance is 8 feet 6 inches from the track center. The designer shall use the 8 feet 6 inches distance from the track center on both the entering and leaving side of the tracks to calculate the walking distance for the mobility-impaired individual.

Caltrain's current design warning time of 25 seconds is sufficient for pedestrians to cross a distance of up to 37 feet 6 inches, based on the ADAAG-recommended walking speed of 1.5 fps to allow for the mobility-impaired individuals. Contact Deputy Director, Railroad Systems Engineering before finalizing design warning time for a grade crossing.

Most of the Caltrain pedestrian crossings are less than 37 feet 6 inches in length, measured from the automatic gate arm to clear point. This distance is based on two tracks at 15-foot track centers, and a clear point of 8 feet 6 inches from the nearest track center. Where the crossing consists of three tracks, the design warning time shall be increased to account for the additional travel distance. Caltrain does not have and does not allow at-grade crossings where there are four tracks.

Crossings of a significant skew are of greater complexity, due to the increase in travel distance; the corresponding need for increased warning time in turn increases the likelihood of risky behavior. To mitigate this, channelization should be provided to direct the pedestrians to cross on a walkway that is as perpendicular as possible to the tracks.

## 2.0 VEHICULAR CROSSING WITH SIDEWALKS

Because Caltrain is located in a densely urbanized area with residential and commercial properties adjacent to the tracks, crossings are heavily used by pedestrians. Pedestrian sidewalks should therefore always be an integrated part of all of the vehicular grade crossings on the Caltrain corridor. Caltrain will collaborate with the local agency on installation of the appropriate fencing, guardrailing, and channelization to channel pedestrians to cross the tracks in appropriate crossing point at grade crossings with active warning devices.

See **Figure 7-5** for typical pedestrian sidewalk design at a vehicular crossing.

## 3.0 VEHICULAR CROSSING WITHOUT SIDEWALKS

Crossings without sidewalks should receive the same treatment as vehicular crossings with pedestrian sidewalks, and for the same rationale. Pedestrians will cross whether or not there is a sidewalk at the crossing. Providing crossings that pedestrians can cross safely, comfortably, and conveniently at all vehicular crossings is consistent with the general objective of Caltrain.

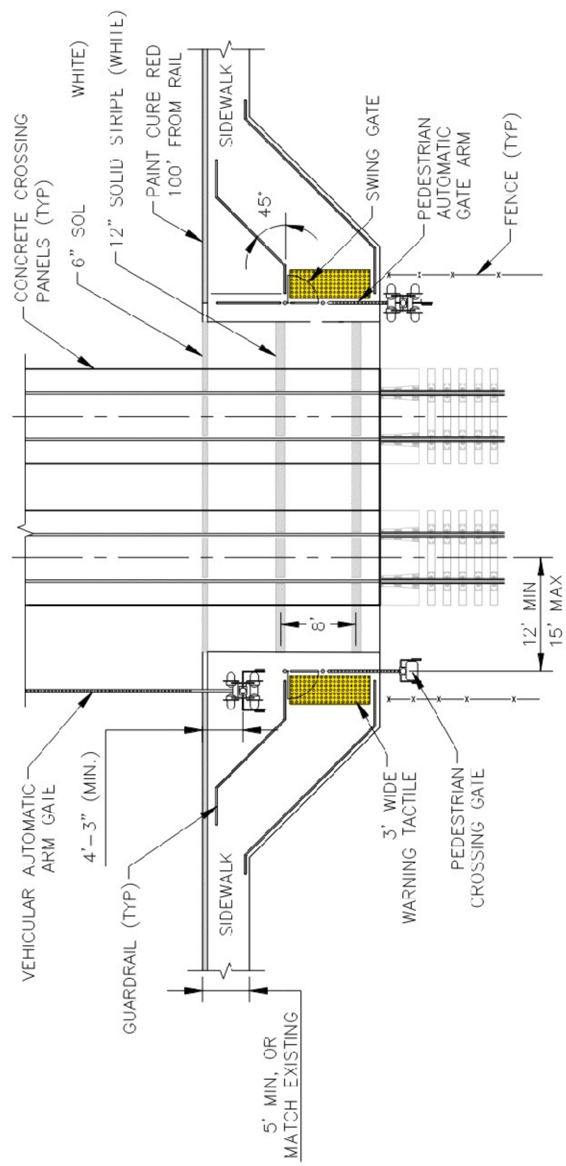



**Figure 7-5: Typical Pedestrian Sidewalk at Vehicular Crossing**

Over time and given increasing public awareness of the need, the local agency may provide sidewalks and the necessary transitions. Caltrain will take the initiative in collaborating with the local agency in providing pedestrian sidewalks connecting to the grade crossings.

## 4.0 PEDESTRIAN CROSSING SIDEWALK GATE ARMS

It is Caltrain’s general goal to install automatic pedestrian sidewalk gate arms and associated passive traffic control devices at all four quadrants of all vehicular crossings. The need for gates in all four quadrants is site-specific and should be evaluated based on risk assessment analysis when any, all, or any combination of the following crossing conditions exist:

a. Adjacent to a station

b. Adjacent to or near a school or senior center

c. Adjacent to or near dense residential centers or commercial attractions

d. High-volume pedestrian traffic

When automatic pedestrian sidewalk gate arms are required on pedestrian sidewalks, a standalone pedestrian signal mast shall be installed with pedestrian automatic sidewalk gate arms, swing gates, channelization, and other traffic control devices.

The signal mast configuration for the pedestrian sidewalk gate arms is as follows:

- Flashers configuration: horizontal
- Signal mast: on the far side of the curb
- Swing gates: on the curb side
- Crossing control: fencing and guardrailing
- Design warning time: 25 seconds minimum

## G. PEDESTRIAN CROSSINGS DESIGN

In addition to the sidewalks on the vehicular grade crossings, Caltrain has crossings that are only for the pedestrians. These crossings are referred to as “pedestrian crossings” and are located at stations and between roadway crossings.

Unlike vehicular crossings, there are no nationally or state recognized standards for the design of pedestrian crossing warning systems on railroads. As previously described, Caltrain has developed its own recommended practices for pedestrian grade-crossing configurations at stations, which it has implemented since 1999. These standard practices use active warning devices similar to those at vehicular crossings: signal equipment modified from that of vehicular crossings, crossing gate arms, and a crossing configuration that channels pedestrians.

### 1.0 DESIGN CRITERIA FOR PEDESTRIAN CROSSINGS

Normal operation is for the bells to activate, lights to flash, and, 3 seconds later, the gates to descend. The bells will continue to sound until the train has cleared the crossing island circuit and the gates have completed their ascent. Bells are considered pedestrian warning devices, and a grade crossing shall have enough bells to be heard in every quadrant. Soft tone bells are preferred except in an environment with high ambient noise levels. The bells shall all be electronic.

### 1.1 WARNING TIME

The ADAAG walking rate of 1.5 fps for a mobility-impaired person shall be used as the basis for calculating pedestrian warning times. The 1.5-fps walking rate allows sufficient time for a mobility-impaired person to safely travel across the crossing. Walking times are calculated for the mobility-impaired person from the start point to the clear point across the tracks.

## 1.2 CENTER FENCE

Track centers at stations with outboard platforms are widened to a minimum of 18 feet to accommodate a center track fence, which must be at 8 feet 6 inches clear from each track center.

The center fence will extend the length of the platform and beyond the crossing, and will channel the passengers to crossings at the end of the platforms. ADA-compliant ramps will be provided as a transition from platform height to rail-crossing height. Fencing or guardrailing will encompass the ramp through the gate arm and swing gate to the crossing clear point.

## 1.3 WARNING DEVICES

### 1.3.1 Gate Arms and Flashing Lights

Pedestrian warning devices shall be standard AREMA-compliant railroad gates and flashing lights that are commercially available. These devices are immediately recognizable to the public as a train approach warning system. A separate gate mechanism for sidewalks must be provided.

### 1.3.2 Swing Gates

At a crossing with pedestrian sidewalk gate arms, a person may have begun crossing the tracks when an approaching train activates the crossing. Such person may perceive that they are trapped by the horizontal gate arm, a swing gate is provided adjacent to the pedestrian gate arm so the pedestrian may continue crossing the tracks. This gate only swings away from the crossing and is marked "EXIT." The back side of the swing gate is marked "STOP," as a reminder to the pedestrians that the swing gate is only for one-way use.

## 1.4 SAFETY BUFFER ZONE

A pedestrian safety buffer zone is created on the level area between the clear point of the sidewalk gate arm and the swing gate. This allows a person to recognize the gate arm is positioned to provide adequate space for a group to stand in safety, or a wheelchair to maneuver. The perpendicular alignment of the gate to the tracks allows a maximum safety buffer zone. This is the preferred arrangement, but where insufficient space is available, a parallel alignment may be used.

A safety buffer zone also provides accommodation for the slower-moving individuals to turn back and take a place of safety if they have passed the gate arm and have seen and heard the crossing activation.

## 1.5 WARNING ASSEMBLIES

Pedestrian warning assemblies at stations will consist of lights arranged in a vertical configuration arrangement. The vertical configuration will take up less platform space. One pair of lights will be aimed down the platform and the other pair will be aimed across the tracks. If auxiliary lights are needed because of station entries perpendicular or parallel to the tracks, will be provided as needed.

## 1.6 GATE RECOVERY

After a train stops at the station, the gate arms will recover and passengers will be able to safely cross from one platform to the other while the train dwells at the station. If a second train approaches on the opposite track, the gates will reactivate or remain down.

## 2.0 PEDESTRIAN CROSSINGS AT STATIONS

Pedestrian crossings at stations are for pedestrians accessing the platforms, but the crossings are also used by the public to cross the tracks. Caltrain intends to eliminate all at-grade crossings and new stations or reconstructed stations will provide grade-separated pedestrian crossings for passenger circulation, if feasible without excessive ROW, construction cost, or other constraints.

Typical Caltrain at-grade pedestrian crossings at stations are located at each end of an outboard station platform. The advantage of having the crossings at the end of the platforms is that they facilitate channelization and they do not conflict with train operations. Crossings will be activated at the onset of approaching train. Gate arms will recover when the train stop at the station, but will stay down for approaching train on the other track.

An ADA-compliant ramp shall be provided at each end of a platform to transition the 8-inch elevation difference between the platform and the grade crossing. The ADA-compliant ramp will be 40 feet long to allow for future higher-level boarding platforms. See **Figure 7-6.**

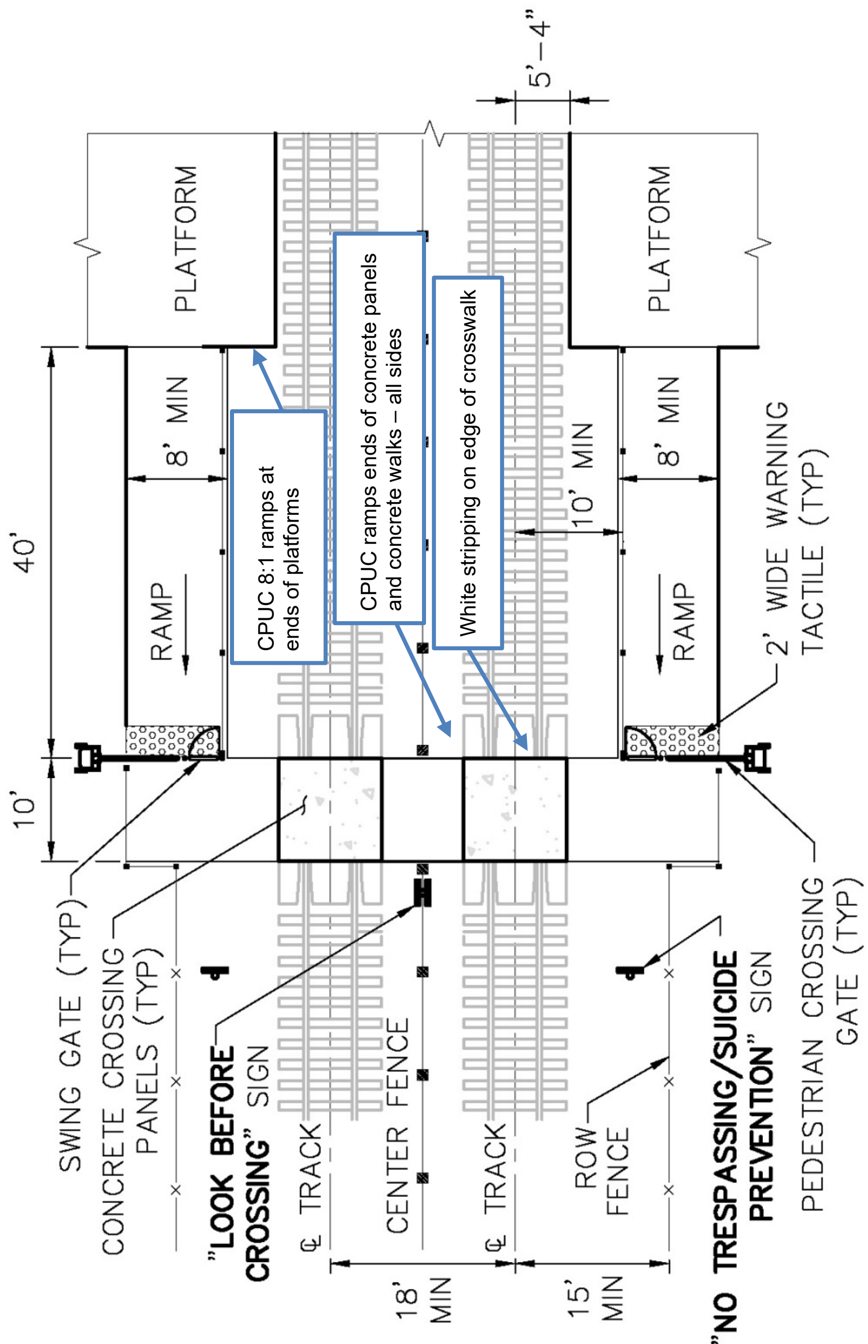



**Figure 7-6: Typical Pedestrian Crossing at Stations**

Caltrain has no standard at-grade crossing configuration for a center island platform. A design for a grade crossing warning system at a center island platform would require gates on the platform for each track, so that pedestrians on a platform would not exit the platform into the path of a second train. A center island platform with pedestrian gates should have a large safety buffer zone to accommodate potentially large numbers of pedestrians, because access to the platforms must be through the gated crossing only. Ideally, center island platforms should be grade-separated. Any installation of a center island platform with an at-grade crossing shall require a thorough analysis and the development of a site-specific design.

### 3.0 PEDESTRIAN CROSSINGS AT STATION AND ROADWAY

Some of the stations are adjacent to a street. At such locations, the station shall have a dedicated pedestrian crossing at one end of the platform, and the other crossing shares the street sidewalk. The pedestrian sidewalk will use active warning devices similar to those at vehicular crossings, including swing gates, pavement striping, markings, and texturing. If the station parking is on the street side, or if there are other considerations such as schools or other foot traffic generators near the station, then the treatment shall be evaluated based on risk for pedestrian gates on both sides of the street.

### 4.0 PEDESTRIAN CROSSINGS BETWEEN ROADWAY CROSSINGS

When the station is between two adjacent streets, both station pedestrian crossings share the sidewalks of the adjacent streets. Automatic pedestrian sidewalk gate arms will be required at the pedestrian sidewalk, and will use active warning devices similar to those at vehicular crossings including swing gates, pavement striping, markings, texturing, and appropriate channelization. Similarly, the need for sidewalk gates on both sides of the street will be evaluated.

Caltrain also has two pedestrian crossings for use by the public at large, located on the Caltrain ROW and not directly at a station. No new crossings of this type will be allowed.

## H. EXIT GATE SYSTEMS

Exit gate systems, formerly called four-quadrant gate systems, consist of the exit gate assembly (CPUC Standard 9 E); a vehicular intrusion detection system between the entrance gate and the exit gate; and the necessary safety critical logic equipment to control the operation of the exit gates and the vehicular intrusion detection system. Exit gates are installed to:

a. Enhance safety at crossings

b. Increase deterrence of vehicles driving around lowered entrance gates

c. Create an effectively sealed corridor for train travel

Safety and operations through the vehicular crossings are the responsibility of both Caltrain and the local agency having jurisdiction over the roadway. Installation of exit gates must be approved by CPUC. In general, the installation of exit gates will be recommended by a diagnostic team (CA MUTCD 8C). The diagnostic team shall perform a site-specific review which considers crossing attributes, roadway environment, and risk mitigation criteria.

## 1.0 DESIGN CRITERIA

The following are regulatory requirements for exit gates:

a. Exit gates shall be designed to fail in the raised position (CPUC GO 75-D, CA MUTCD 8C)

b. Entrance gates shall begin their descent before exit gates, and shall be horizontal before the exit gates are horizontal (CPUC GO 75-D)

c. A vehicle intrusion detection system shall be installed whenever exit gates are used (CPUC GO 75-D, CA MUTCD 8C)

d. At locations where gate arms are offset a sufficient distance for vehicles to drive between the entrance and exit gate arms, median islands shall be installed, in accordance with the needs established by an engineering study (CA MUTCD 8C)

e. Exit gate arm activation and downward motion shall be based on detection or timing requirements established by an engineering study of the individual site (CA MUTCD 8C)

The designer shall follow the latest standard practices and recommendations for exit gates contained in the AREMA Communications and Signals Manual of Recommended Practices and the latest recommendations of ITE.

Entrance gates are required to be fully horizontal 5 seconds prior to a train arriving at a crossing. This requirement does not apply to exit gates (CFR 49 Part 234, Section 223).

Where highway crossing warning systems on Caltrain require exit gates, a solid-state control system for the timing of the exit gate will be used, and this system will be integrated with the roadway vehicle detection system. The ElectroLogIXS XP-4, as currently manufactured by ALSTOM or equal, shall be used.

Radar-based vehicle detection shall be able to detect motor vehicles with a wheel base equal to or greater than 96 inches (8 feet), whether moving or stationary, in the roadway driving surface and within 20 degrees of the roadway axis, and between the entrance gates and the exit gates. The vehicle intrusion detection system shall be a microprocessor-based system of a safety-critical design, with necessary self-checking, such as that manufactured by Island Radar.

In general, the vehicle detection system shall hold up the exit gate based on the vehicle's direction of travel. The detection system shall be capable of detecting a roadway vehicle that is wholly within a single lane of travel for a given direction, and will not hold up exit gates for the adjacent travel lane due to a vehicle in the crossing.

The vehicle intrusion detection devices shall be able to handle the following functions:

a. Detect all motor vehicles, including all passenger motor vehicles, school buses, and trucks, but not including motorcycles and bicycles

b. Provide “occupied/not occupied” indications to railroad control circuits within 2 seconds of any state change

c. Verify, not less often than once each time the crossing gates are called down, that the vehicle intrusion detection devices are functioning and able to detect motor vehicle presence

d. Verify each time the crossing gates are called down that the occupied indication is working

e. Not generate false highway vehicle occupied indications more often than the minimum threshold values (to be determined by the engineering study)

f. Operate under battery back-up power or to default immediately to an occupied condition when external power is lost, based on the result of the engineering study

g. Meet the current applicable national and local standards

h. Provide, for each zone, individually isolated outputs that are energized to indicate “not occupied,” in such a manner that a failed output circuit or wiring fault will result in a de-energized state and “occupied indication”

i. Provide separate, individually isolated outputs for each loop that are energized to indicate “loop health,” in such a manner that a failed output circuit or wiring fault will result in a de-energized state and a “loop health failure” indication

j. Not generate or induce levels of energy into the rails or other railway communication medium of magnitudes that will cause false occupancy or false vacancy of trains under any normal or abnormal mode of operation

k. The radar detection system shall not be vulnerable to electromagnetic interference generated in the environment of an electrified railway under normal or fault conditions

l. When highway vehicular occupancy is not detected, the exit gate must be controlled to begin its descent within 1 second after the minimum highway vehicle clearance time expires and the detection loops indicate that the crossing is unoccupied; exit gates shall remain lowered until the train has completed its movement through the grade crossing; detection of occupancy will cause a descending exit gate to reverse direction and raise

m. The radar detection system shall not interpret a train movement through the crossing as vehicle occupancy

Systems having exit gate systems should have remote health monitoring systems capable of automatically notifying maintenance personnel when anomalies occur (CA MUTCD 8C).

Back lights directed toward the motorist shall not be installed on exit gates, to avoid the possibility of confusing a motorist crossing the tracks (Preemption of Traffic Signals near Railroad Crossings, a recommended practice of ITE, 2006).

Where pedestrian sidewalk gates are used, a separate gate mechanism shall be used in the quadrant containing the exit gate. Either the exit gate or the pedestrian sidewalk gate will have a bell. The pedestrian gate shall fail down even in the quadrant where the exit gate fails up.

Upon detection of an approaching train, the lights will begin to flash and the bells will begin to ring. A minimum of 3 seconds after the activation of the lights and bells, the entrance gates will begin their descent. If no vehicles are present in the crossing, the exit gates will begin their descent after the entrance gates. After the train has passed the crossing, the exit gates will begin their ascent. The entrance gates will begin their ascent after the exit gates have begun their ascent. The time differential between exit gate operation and entrance operation will be determined by the engineering study.

The need for exit gate clearance time will be evaluated based on the criteria in the AREMA Communications and Signals Manual of Recommended Practices. Warning times calculated at crossings with exit gates shall be calculated to the exit gate rather than to the point clear of the furthest rail.

## I. WIRELESS CROSSING SYSTEM

Wireless Crossing System is a PTC-based system. Design Criteria for the Positive Train Control System are covered in **Chapter 06, Train Control Communication**. When Wireless Crossing is enabled, a PTC equipped Locomotive sends messages to a crossing controller to facilitate constant warning times at crossing based on the trains GPS position and speed.

a. Onboard Components: On-Board Computer (OBC).

b. Wayside Components: Crossing WIU, PTC Radio and Antenna; Flashers, Gates and Control Equipment; and Island Detection.

## 1.0 LOCOMOTIVE SEGMENT

a. Software contains wireless crossing capability.

b. Communicates with Wayside Interface Unit (WIU).

c. Decides when to inhibit and activate warning devices.

d. Provides preemption call for interconnected grade crossings.

## 2.0 COMMUNICATIONS SEGMENT

a. Fiber optic cellular, and radio communications.

b. Facilitates messaging between train OBC and wayside WIU.

### 3.0 OFFICE SEGMENT

a. Schedule management support.

b. Track database management.

c. Management of locomotive type functionality.

### 4.0 WAYSIDE SEGMENT

a. Software contains wireless crossing capability.

b. Communicates with Wayside Interface Unit (WIU).

c. Decides when to inhibit and activate warning devices.

d. Provides preemption call for interconnected grade crossings.

## J. CROSSING WARNING EQUIPMENT NAMING CONVENTION

### 1.0 CROSSING GATES

The gate with no designation is the first gate followed by the gates that are identified by single letter 'A', 'B', 'C', 'D' etc.

## END OF CHAPTER

(Crossing Evaluation Report template form follows. Customize the form to meet Caltrain project-specific needs.)

| AAR/DOT No.: |
|---|
| Date of Diagnostic Review: |

DIAGNOSTIC TEAM

# Crossing Evaluation Report

## LOCATION DATA

| | | | |
|---|---|---|---|
| Railroad: | State: | County: | City: *(In or Near)* |
| R.R. Division: | Street/Road Name: | | |
| Nearest R.R. Timetable Station: | R.R. Milepost: | Branch/Line Name: | |

## DIAGNOSTIC REVIEW

| | | |
|---|---|---|
| Initiated By: | ☐ RAILROAD ☐ STATE ☐ LOCAL ☐ OTHER | Date Initiated: |

| DIAGNOSTIC TEAM | | NAME | AFFILIATION |
|---|---|---|---|
| | 1 | | |
| | 2 | | |
| | 3 | | |
| | 4 | | |
| | 5 | | |
| | 6 | | |
| | 7 | | |

## RAILROAD DATA

| DAILY TRAIN MOVEMENT | | CHECK IF LESS THAN ONE MOVEMENT PER DAY ☐ | | TYPE AND NUMBER OF TRACKS | | |
|---|---|---|---|---|---|---|
| TOTAL TRAINS | | | | MAIN | | If Other, Specify: |
| DAY THRU | | TRAIN MOVEMENTS PER DAY | | OTHER | | |
| NIGHT THRU | | **SPEED OF TRAIN** | | Can two trains occupy crossing at the same time? ☐ | | |
| DAY SWITCH | | Max. m.p.h. | | Can one vehicle block the another motorist's view of proposed warning devices? | ☐ YES ☐ NO | If Yes, explain: |
| NIGHT SWITCH | | Typical to m.p.h. | | | | |

| Crossing Surface | TRACK | TYPE | WIDTH | CONDITION |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| | |
|---|---|
| CROSSING ANGLE: | |
| COMMENTS | |

## ROADWAY DATA

| | | | | |
|---|---|---|---|---|
| Agency Having Jurisdiction: | ADT: | PERCENT TRUCKS | % | Roadway Surface: |

| Speed of Vehicle | School Bus Operation | Hazardous Materials | Pedestrians | Roadway Width: |
|---|---|---|---|---|
| Max. m.p.h. | ☐ YES ☐ | ☐ YES ☐ NO | ☐ YES ☐ NO | |
| Typical to m.p.h. | **No./Day** | **No./Day** | **Curb & Gutter** | Roadway Condition: |
| | | | ☐ YES ☐ NO | |

| | | | | |
|---|---|---|---|---|
| Shoulder: ☐ YES ☐ NO | If Yes, Width: | Is the Shoulder Surfaced? ☐ YES ☐ NO | If Yes, Width: | Is Sidewalk Present? ☐ YES ☐ NO |

Special Conditions Required as a Result of Nearby Highway Intersections:

Special Conditions required as a result of pedestrian traffic:

(Right of way fencing, channelization, pedestrian gates, exit swing gates)

Special Conditions required as a result of a station in the crossing approach:

(Restart Circuits required, timeouts)

AAR/DOT No.:

## EXISTING WARNING DEVICE

| Yes | No | Qty. | Type of Warning Device | |
|---|---|---|---|---|
| | | | Advance Warning Signs | Location: |
| | | | Stop Signs | Location: |
| | | | Stop Ahead Signs | Location: |
| | | | Pavement Markings | Location: |
| | | | Crossbucks | |
| | | | Number of Tracks Signs | |
| | | | Inventory Tags | |
| | | | Interconnected Highway Traffic Signals | |

| Yes | No | Qty. | LENSES 8” | LENSES 12” | Type of Warning Device | |
|---|---|---|---|---|---|---|
| | | | | | Mast Mounted Flashing Lights | |
| | | | | | Cantilever Flashing Lights | Length: |
| | | | | | Side Lights | |
| | | | | | Automatic Gates | Length: |
| | | | Bells | | | Length: |
| | | | Sidewalk Gates | | | |
| | | | Sidewalk Gate Arms | | | Length: |
| | | | “No Turn” Signs | | | |
| | | | Illumination | | | |
| | | | Other | Specify: | | |
| | | Is crossing flagged by train crew? | | | | |

### FIVE-YEAR ACCIDENT DATA

| | | | |
|---|---|---|---|
| **TOTAL ACCIDENTS** | | | Property |
| | | | Personal |
| | | | Fatal |
| **Number of Personal Injuries** | | **Number of Fatalities** | |

## TYPE OF DEVELOPMENT

☐ Open Space ☐ Residential ☐ Commercial

☐ Industrial ☐ Institutional

New developments that could affect ADT? ☐ Yes ☐ No

If Yes, Describe:

Location of Nearby Schools:

| ADJACENT CROSSINGS | | | |
|---|---|---|---|
| **DOT No.** | **Street/Road Name** | **Warning Device** | **ADT** |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| | | |
|---|---|---|
| Is there adequate access from this crossing to adjacent crossings? | ☐ Yes ☐ No | Sketch: |
| If yes, which crossing(s): | | |
| Can roadway realignment be accomplished to allow consolidation of crossings? If yes, provide sketch. | ☐ Yes ☐ No | |
| Impact of Closure: | | |

| RECOMMENDATIONS | | | |
|---|---|---|---|
| ARE IMPROVEMENTS TO THE CROSSING RECOMMENDED? | ☐ YES ☐ NO | | If No, Explain: |
| If Yes, what improvements? | | | |
| **Yes** | **No** | **Type of Improvement** | **Describe** |
| | | **Sight Improvement** | |
| | | **Crossing Surface** | |
| | | **Roadway Approaches** | |
| | | **Highway Traffic Signs** | |
| | | **Crossing Signals** | |
| | | **Crossing Closure** | |

| Prepared By: | Title: | Date: |
|---|---|---|
| | | |

Comments:

# CHAPTER 8

# CIVIL DESIGN

## A. GENERAL

This chapter includes standards and design considerations for civil engineering design in structural, drainage, and utilities work. Design considerations for electrical and mechanical work associated with station facilities are included in **Chapter 3, Stations and Facilities**.

## B. STRUCTURAL

Caltrain structures include bridges, grade separation structures, such as pedestrian underpasses and overhead crossings, tunnels, retaining walls, and culverts; and other structures, such as buildings, signal structures, and their related facilities.

Signal structures, including signal bridges and signal cantilevers, are typically specification-driven, manufactured products. The design and details of these structures shall follow the Caltrain Standard Drawings for Signals. The design of signal structures shall be in accordance with the criteria and requirements of the Peninsula Corridor Joint Powers Board (PCJPB) Standards for Design and Maintenance of Structures.

The design of civil structures owned and/or maintained by Caltrain shall be in accordance with the *PCJPB Standards for Design and Maintenance of Structures.* Shoring and excavation support systems shall conform to the *PCJPB Engineering Standards for Excavation Support Systems*.

Caltrain standards and requirements shall take precedence over other applicable codes, including the American Railway Engineering and Maintenance-of-Way Association (AREMA) and the California Department of Transportation's (Caltrans') Bridge Design Specifications Manual (BDS). The California Building Code (CBC) takes precedence over American Concrete Institute, American Institute of Steel Construction, and American Welding Society codes. For structures subject to railroad loading, AREMA governs over BDS, for structures subject primarily to highway or truck loading, BDS governs over CBC

Structures owned or maintained by other agencies shall be designed in accordance with the standards of those agencies. This applies to new construction and to rehabilitation, relocation, or modification of existing facilities. Even though these structures do not encroach into the Caltrain right-of-way (ROW), the facilities are close enough that they may impact Caltrain's current and future operations and maintenance. The proposed facilities, therefore, must be consistent with Caltrain operating and maintenance requirements, as well as future needs. The design parameters and the subsequent design shall be submitted to Caltrain for review.

Where special design cases are not specifically covered in these criteria, submit project-specific design criteria for approval by the Caltrain Director of Engineering.

## C. DRAINAGE

The drainage design criteria and requirements are intended to protect Caltrain's corridor and facilities from stormwater damage; to protect Caltrain from liability for damage to other property from stormwater flows caused by the construction of Caltrain improvements; and to provide Caltrain passengers and maintenance personnel with walking surfaces that are safe and free from ponding.

Caltrain drainage systems typically consist of the following:

a. Track drainage at stations, grade crossings, and ROWs

b. Station drainage (station platforms and parking)

c. Bridge deck drainage

d. Other drainage structures, such as storm drain pipes and culverts undercrossing the railroad.

e. Pump stations for pedestrian underpasses, tunnels, and other underground structures.

An effective drainage system is a critical element in the design of Caltrain facilities. Inadequately drained stormwater damages the infrastructure and other facilities. An effective system is required to:

a. Protect the track structure and other facilities from stormwater damage

b. Expedite drainage flow

c. Maintain access to pedestrians and maintenance personnel

d. Retard vegetation growth where it interferes with drainage or maintenance access.

e. Prevent stormwater runoff from entering adjacent properties, and vice versa

The design of drainage facilities belonging to another agency, that are relocated or modified because of Caltrain construction, and that do not encroach on the Caltrain ROW, shall conform to the design criteria and standards of that agency.

## 1.0 DESIGN REQUIREMENTS

Drainage facilities in the railroad zone of influence shall be designed in accordance with Caltrain railroad loadings. The criteria and requirements of the loadings in the zone of influence are contained in the *PCJPB Standards for Design and Maintenance of Structures*.

The design of any drainage facility shall take into account measures to reduce erosion and control sedimentation caused by the drainage facility or construction activities.

In general, relocation of existing drainage facilities shall be "replacement in kind" or "equal construction," unless conditions of flow, loading, or operation are altered. If conditions are altered, designs shall conform to the design criteria and the standards of the affected agencies.

The top of the drainage pipe, culvert, or structure shall be a minimum of 3 feet below the bottom of ties. Where drainage system crosses the tracks, they shall cross as near to 90-degrees to the track centerline as practicable.

Drainage from pedestrian underpasses shall be discharged to the municipal sewer system.

The design of drainage facilities that are owned and maintained by other agencies and are relocated or modified because of Caltrain construction, and that do not encroach on the Caltrain ROW, shall conform to the design criteria and standards of the local agency having jurisdiction over the area. In the absence of such criteria, use the latest Caltrans' guidelines, as applicable.

## 1.1 HYDROLOGY

### 1.1.1 Storm Frequency

In general, use a 50-year storm frequency for drainage ditches; select higher or lower frequencies where justified by facility importance, design life, or local agency requirements.

The peak runoff from a 100-year storm shall be used in the design of the following:

a. All facilities

b. Culverts crossing beneath at-grade track

c. Storm drain systems adjacent to tracks

d. Drainage systems crossing under bridge structures and on the ROW

e. Yard and station runoff collection systems (including those in streets and parking lots)

### 1.1.2 Design Discharge

Compute the design discharge using the Rational Method, unless the local agency having jurisdiction requires another hydrologic method (e.g., unit hydrograph or continuous simulation). For facilities that will be owned and/or maintained by the local agency, the design discharge shall be computed using other applicable procedures as required and approved by the local agency.

Precipitation, intensity, and duration data shall be based on the data either from San Francisco, San Mateo, or Santa Clara counties, depending on the project's location.

### 1.1.3 Design Sustainability

Caltrain structures and drainage facilities shall be designed with consideration to sustainability. Designers shall study a range of both current and future environmental impacts, including, but not limited to, erosion, stormwater, flooding, climate change, and future sea-level rise (where applicable). Designers shall incorporate measures for the Caltrain structures and drainage facilities to help mitigate these potential environmental impacts.

As part of the sustainability design criteria, Caltrain structures and drainage facilities shall be designed for a minimum life and able to withstand future storm events. Chapter 1, Section 3.0 provides the minimum requirements for design life of structures and facilities. Chapter 8, Section 1.1.1 outlines storm frequency requirements for the designer to incorporate into storm drainage design.

## 1.2 UNDERDRAIN PIPE

Underdrain pipe shall be a minimum inside diameter of 6 inches and a minimum slope of 0.2 percent to maintain positive drainage and prevent sediment accumulation. If the pipe is connected to the municipal system, it shall be compatible with the system of the local agency. For track drainage within the limits of the stations, and within the limits of grade crossings, use perforated Schedule 80 polyvinyl chloride (PVC) or high-density polyethylene (HDPE).

The underdrain pipe shall be bedded in aggregate filter material and the trench shall be wrapped in permeable geotextile. Provide underdrain cleanouts at intervals not exceeding 300 feet and at grade breaks and low points.

Use of perforated underdrain pipe shall be minimized to avoid the risk of clogging and difficult pipe access for maintenance. Where possible, use ditches instead of perforated pipe.

Pipe cover shall be a minimum of 48 inches below the top of rail for all pipes, including reinforced concrete pipe (RCP) and PVC and HDPE pipes.

Space manholes and inlets at a maximum of 500 feet for pipes up to 30 inches in diameter, and 650 to 1,000 feet for pipes larger than 30 inches, unless site conditions or agency standards requires closer spacing.

## 1.3 CULVERT

The minimum diameter for a storm drain pipe or culvert shall be 12 inches. For pipes directly under the track or within 15 feet from the centerline of the tracks, Caltrans Class V RCP shall be used, and the minimum diameter shall be 24 inches.

## 1.4 POST-CONSTRUCTION STORMWATER DESIGN CRITERIA

Caltrain, designated as a Non-Traditional Small Municipal Separate Storm Sewer System MS4 Permittee, shall comply with Section F of the State Water Resources Control Board (SWRCB) Water Quality Order No. 2013-0001-DWQ, as amended by subsequent reissuances and attachments, National Pollutant Discharge Elimination System (NPDES) General Permit No. CAS000004 Waste Discharge Requirements for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (the MS4 General Permit). All designs for projects involving creation and/or replacement of 2,500 to 5,000 square feet of impervious surface shall comply with Section F.5.g.1 (Site Design Measures) of the MS4 General Permit. All designs for projects involving creation and/or replacement of 5,000 square feet or more of impervious surface shall comply with Section F.5.g.2 (Low-Impact Development Design Standards) of the MS4 General Permit.

In addition, Caltrain shall comply with the *2015 Amendment to the Water Quality Control Plan for Ocean Waters of California to Control Trash* and *Part 1 Trash Provisions of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California* by the State of California Water Resources Control Board (collectively referred to as the Trash Provisions). All new projects shall include full capture systems for all storm drains that capture stormwater runoff from the project sites. As defined in the Trash Provisions, a full capture system is a treatment control or series of treatment controls, including, but not limited to, a multi-benefit project or a low-impact development control that traps all particles that are 5 millimeters or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate resulting from a 1-year, 1-hour, storm in the subdrainage area; or b) appropriately sized to, and designed to carry, at least the same flows as the corresponding storm drain. Designers shall select trash capture devices, plan the device layout across the project, and size the system as a whole to balance the cost of initial installation with the cost of routine maintenance of the system after installation. Reasonable efforts should be made to minimize routine maintenance costs after installation.

Designers are required to provide design documentation to demonstrate that their designs comply with the MS4 General Permit requirements and the Trash Provisions. Guidelines published by San Mateo County (titled “C.3 Stormwater Technical Guidance”) and Santa Clara County (titled “C.3 Stormwater Handbook”), or similar documents, may be used to prepare this design compliance documentation. The City and County of San Francisco does not have such a guidance document. The trash full capture systems employed in the design of a project, including treatment control devices and multi-benefit treatment systems, shall be selected from the current certified device lists of the State Water Board on the Storm Water Trash Implementation Program webpage.

### 2.0 PUMP STATIONS

Caltrain pump stations are lift stations that may consist of a single sump pump or a series of sump pumps. The lift station raises the hydraulic head of stormwater sufficiently to discharge by gravity to other drainage systems, such as ditches, the municipal stormwater system, or other lift stations.

To minimize initial and long-term maintenance costs, pump stations shall be avoided where feasible. Where gravity systems are not practical, the pump stations shall require prior approval of the Caltrain Director of Engineering.

## D. UTILITIES

This section covers the design of underground utilities for new installation and for the relocation, adjustment, or abandonment of existing underground utilities, including utilities not owned or maintained by Caltrain. The designer shall identify the utility envelope and coordinate the work with utility owners.

Caltrain prefers that combined system duct banks be installed wherever possible. The combined systems duct bank provides a common and coordinated underground structure for cables and wires for electrical, signals, positive train control, and communications systems along the corridor. At the stations, the duct bank will be located in the designated utility corridor.

Fiber optic carriers on the Caltrain corridor also prefer the combined system duct bank. This is preferred for economy and because of the space constraints in the corridor.

### 1.0 CALTRAIN UTILITIES

Utilities owned and maintained by Caltrain consist of wires and cables for signal, electrical, train control, communication, and piping for irrigation and drainage.

Utilities specifically designed for the Caltrain facilities at stations and ROW shall conform to the standards, codes, and requirements of the California Public Utilities Commission (CPUC) and the local jurisdiction within which the utilities are located, as appropriate. All design work shall be approved by the local jurisdictions and appropriate public utility agencies.

### 2.0 THIRD-PARTY UTILITIES

Third-party utilities owners include private owners, state, and municipal governments. Work shall be coordinated with and done in accordance with the standards of the utilities owner. Design and construction of third-party utilities within JPB ROW shall also meet the requirements in Caltrain Standard Drawings. Design, relocation, restoration, and construction shall be the responsibility of the facility owner.

Third-party utilities include natural gas, jet fuel, electrical facilities, telephone and television cable, fiber optic cable, fire protection, water, and sewers.

## 3.0 DESIGN GUIDELINES

### 3.1 REGULATIONS AND STANDARDS

a. Applicable standards and criteria established by the utility owners

b. CPUC General Order (GO) Number 95 (Overhead Electric Line Construction)

c. CPUC GO Number 128 (Construction of Underground Electric Supply and Communication System)

d. Standards and criteria of the jurisdictional agencies, as appropriate

### 3.2 NEW CONSTRUCTION

Replacements for any existing utilities, including municipal facilities, shall be designed to provide service equal to that offered by the existing installation. No betterment shall be included, unless specifically directed by the Caltrain Director of Engineering.

The following general design guidelines shall be followed for utility work:

a. Design Loading: All underground utilities shall be designed in accordance with Caltrain railroad loadings. This also applies to sleeves or encasement pipes.

b. Crossing Angle: Underground utilities shall cross the railroad ROW as close to 90 degrees to the track centerline as practicable.

c. Materials: Utilities installed within or crossing the railroad zone of influence shall be constructed with nonconductive materials, unless otherwise approved by Caltrain for specific operational needs.

d. Sleeves: Third-party utilities that cross tracks shall be sleeved for pipes carrying pressured and hazardous substances.

e. Future Ducts: Additional ducts shall be installed for future crossings whenever possible.

f. Horizontal Clearance: Utilities shall be located outside the zone of influence or, where this is not practicable, at a minimum horizontal offset of 12 feet from the centerline of the nearest track, unless otherwise approved by Caltrain. At the station area, the utilities shall be located in the designated utility corridor.

g. Vertical Clearance: Overhead wires and other utilities crossing the tracks are not allowed. They shall be located underground.

h. Vaults: Reconstruction, abandonment, or other work involving private vaults extending from adjoining buildings into public space shall be in accordance with the codes, standards, and practices of the responsible local jurisdiction.

i. Pipelines (water, oil, gas, or other highly flammable, volatile, or pressurized substances): The pipelines shall be encased in a larger casing pipe or conduit. Casing pipes shall be designed to withstand railroad loadings, and shall be coated with a suitable material to provide cathodic protection.

j. Utilities (electric power transmission lines, fiber optic cables, potable water, storm water, etc.): The utilities' owners shall be responsible for the relocation design of their facilities.

k. Fire Protection Facility: The relocation design shall be performed by Caltrain's design consultant and shall require the approval of the owner and appropriate fire agency.

## 3.3 GUIDELINES DURING CONSTRUCTION

New construction and the protection, support, restoration, and rearrangement of utilities shall conform to the latest technical specifications and practices of the respective utility owner and to Caltrain requirements; where conflicts occur, Caltrain requirements shall govern within Caltrain ROW.

Utilities encountered or located sufficiently close to be affected by the project construction shall be either:

a. Maintained in place and in operation during and after construction

b. Temporarily relocated and maintained in operation during and after construction

c. Temporarily relocated and maintained, then, upon completion of facilities, replaced by a new utility

d. Permanently relocated to a new location beyond the immediate limits of construction

e. Abandoned and/or removed

Additionally, utilities abutting Caltrain property shall not be interrupted and, if temporarily relocated, shall be restored upon completion of work.

## 4.0 UTILITY SURVEY

Utility surveys include record research, potholing, and/or field surveys. The utility surveys are used by Caltrain to locate existing utilities for the following purposes:

a. Basis for project planning and design

b. Relocations of impacted utilities

c. Acquisition for utility easements and/or ROW

d. Information for coordination and negotiation with utility companies

Utility potholing, complemented with field surveys, shall be conducted during design to develop a good understanding of the underground conditions, including confirming the record information obtained from utility maps and as-built drawings.

Survey limits and types of utilities to be located should be shown on a utility survey plan. The plan shall include all utility maps and drawings, as well as a utility information matrix showing ownership, contact information, measures necessary to facilitate the construction, and descriptions of easements required.

## E. MAINTENANCE OF WAY ACCESS

### 1.0 MAINTENANCE SHOP AND YARD

Maintenance shops, yards, and end-of-line storage tracks shall have a non-public maintenance service access road. The access road shall provide adequate access to all facilities within the yard and connect to public roadways. The main access roads in a shop and yard shall have a minimum width of 20 feet, and curves shall have a minimum outside radius of 60 feet. Obtain review and approval from the local fire marshal for fire protection provisions and for emergency access. For other maintenance service roads, the minimum width shall be 12 feet.

Main access roads within maintenance shops and yards shall be designed for a Traffic Index (TI) of 9.0 for adequate structural pavement section thickness for anticipated loads from equipment and trucks. For other maintenance service roads, a TI of 6.0 shall be used for pavement design.

Pavement shall be dense graded asphalt concrete consisting of PG64-10 asphalt binder and close graded mineral aggregates, Caltrans HMA Type A, unless otherwise required due to special conditions or use. Structural design of the pavement section shall be in accordance with the procedure for design of flexible pavements in the "California Department of Transportation Highway Design Manual", Chapter 630, Design of Structural Section.

The thickness of pavement section shall be determined using data shown in Caltrans 633.1 Empirical Method. Resistance (R) Value of the base material shall be determined based on soil tests conforming to California Test Method CT 301. Minimum asphalt concrete layer thickness shall be four inches for all pavement types. The additional gravel equivalent thickness for "Factor of Safety" shall be provided as prescribed in the Caltrans Highway Design Manual.

### 2.0 ACCESS TO WAYSIDE FACILITIES

For all Caltrain wayside facilities along the corridor, an access road shall be provided between a facility and the nearest public road in absence of a public access road. The minimum width of the access road shall be 12 feet. The access road shall have an even, stable walking surface; asphalt concrete (AC) paving is not required unless otherwise specified.

## END OF CHAPTER

# CHAPTER 9

# RIGHT-OF-WAY, SURVEYING AND MAPPING

## A. RIGHT-OF-WAY

The phrase “right-of-way” (ROW) generally refers to an easement, but railroads have adopted this phrase to describe their property.

The Caltrain ROW is made up of lengths of land of varying widths that usually increase at stations and yards to accommodate the increased real estate that these facilities require. The uniformity of the ROW is sometimes interrupted by the acquisition of private or public parcels of land that adjoin the original ROW.

### 1.0 CALTRAIN POLICY

The intent of Caltrain policy on ROW is to acquire and maintain the minimum ROW required to meet safety, maintenance, and operating needs. This policy eliminates or reduces unnecessary property acquisitions for proposed corridor improvements.

Caltrain general policy on ROWs is as follows:

a. Preserve the existing ROW for current and future Caltrain operations and maintenance needs

b. Renewal of all existing leases must be approved by the Caltrain Director of Engineering

c. Execution of any new leases must be approved by the Caltrain Director of Engineering

d. Acquire additional ROW for current and potential future uses

Caltrain may work on a partnership basis with local land use authorities in the early corridor planning phases to identify properties adjacent to the Caltrain corridor, and to explore all appropriate means for acquisition and preservation of those properties.

### 2.0 PROPERTY TRANSFERS

Land can be acquired by actual purchase (fee simple), or an easement or right of use. An easement may come in the form of an agreement with a local municipality, such as a franchise right. A railroad may purchase land from private owners through the use of eminent domain.

## 2.1 FEE SIMPLE

Fee simple or fee simple absolute is an estate where a right or rights to land exist without duration or limitations. This method of acquisition shall be proposed for the purchase of ROWs for the construction of permanent surface facilities.

## 2.2 FEE SIMPLE DETERMINABLE

Fee simple determinable is an estate where the creator or grantor retains a right of reversion allowing the estate to be terminated and recovered should the subsequent owner violate the conditions set out in the instrument that created it.

## 2.3 EASEMENT

An easement grants the right of use over the property to another party for a special purpose. Portions of the railroad property that were acquired through an easement are literally ROWs.

An easement may be acquired as a permanent or temporary easement. Permanent easements shall be proposed for utilities, maintenance accesses, and train control facilities. Temporary easements shall be proposed for construction access.

## 2.4 FRANCHISE RIGHT

A franchise right is a nontransferable privilege to use the property of another party. The grantee of the franchise right does not hold any interest in or ownership of the property. When the real property is no longer in the use of the grantee, the owner will resume sole right and ownership of the property. The grantee may extend the right to use the property upon payment of a fee.

## 3.0 RIGHT-OF-WAY REQUIREMENTS

Because ROW plans approved by Caltrain are used as a basis for acquisition of property, all interests and uses required shall be shown on the ROW drawings together with the detailed property descriptions.

The proposed ROW takes shall be based on the project footprint and are influenced by the track alignment, site topography, drainage improvements, structural improvements, service/access roads, utilities, and other required related Caltrain facilities.

## 3.1 PRELIMINARY RIGHT-OF-WAY ASSESSMENT

A Preliminary ROW Assessment is meant to be a tool for assessing property issues during the conceptual stage of proposed improvements. A Preliminary ROW Assessment process is not a boundary survey and is not designed to be used in replacement of, or in conflict with, State law and local law regarding boundary surveying. Detailed requirements for the Preliminary ROW Assessment are provided in the Reference at the end of this chapter.

### 3.2 RIGHT-OF-WAY BOUNDARY RESOLUTION

A ROW Boundary Resolution shall be performed at the final design stage for projects with definite ROW takes. Land acquisitions and permanent easements shall be referred to as a ROW take. Detailed requirements for the ROW Boundary Resolution are provided in the Reference at the end of this chapter.

#### 3.2.1 Legal Descriptions

Prior to the preparation of legal descriptions and plat maps, all proposed parcels for ROW takes shall be clearly identified in the ROW exhibit maps for the approval of the Caltrain Director of Engineering. The following documents shall be included in the maps.

a. ROW base maps of resolved ROWs

b. ROW exhibits clearly defining areas of ROW takes

c. ROW appraisal maps and record maps

A complete legal description shall consist of two parts: the legal description in writing and the plat map showing the area being described.

#### 3.2.2 Plat Maps

A plat map is a map or drawing of the land being described in the legal description. Plat maps shall be drawn to scale. Detailed requirements for plat maps are provided in the Reference at the end of this chapter.

## B. SURVEYING

Most Caltrain improvements involve rehabilitation and improvement of existing facilities.

Supplemental surveys shall be provided for planning and engineering when detailed topographic features are not available through aerial maps. The products resulting from supplemental surveys are generally topographic maps and digital terrain models (DTMs). Conventional (on-the-ground) surveying methods shall be used to gather data for supplemental surveys.

### 1.0 SURVEY CONTROL

Survey control establishes a common, consistent network of physical points for controlling the horizontal and vertical positions of a surveyed point. The survey control network ensures that adjacent projects have compatible control; in this way, it provides consistent and accurate horizontal and vertical control for all subsequent project surveys, including photogrammetric and mapping.

The following policies, standards, and procedures are applicable to all survey control work for all Caltrain improvement projects.

## 1.1 GEODETIC SURVEYING

Surveys employing the principles of geodesy are of high precision and generally extend over large areas, such as Caltrain's corridor. To perform geodetic surveys along the Caltrain corridor, surveyors must understand the elements that comprise geodetic surveys.

### 1.1.1 Horizontal Datums

The Caltrain corridor control network is based on the North American Datum of 1983 (NAD 83), and all geodetic surveying work performed for Caltrain shall adhere to this datum. The State Code of the State of California requires surveyors to use NAD 83 as the reference frame for geodetic surveys.

Caltrain allows Global Positioning System (GPS) software using the World Geodetic System of 1984 (WGS 84) because WGS 84 and Geodetic Reference System of 1980 ellipsoids are so close that the resulting computed data are correct.

Relative positioning data collected by surveyors can be tied to the NAD 83 datum using a state high-accuracy reference network (HARN) or the national continually operating referencing stations (CORS) network or calculated from either a HARN or CORS. HARNs and CORSs are from different adjustments and should not be used together in the same survey.

The National Geodetic Survey (NGS) has consolidated all control under the NAD 83 National Spatial Reference System, combining all control points, both HARN and CORS points, under this one system. Caltrain uses this system.

### 1.1.2 Epochs

In 2012, the NGS published the NAD 83(2011) referenced as epoch 2010.00. Caltrain specifies the California Coordinate System Zone III, NAD 83 epoch 2010.01, as the basis for all geodetic surveying performed on the ROW.

### 1.1.3 The Geoid

Caltrain specifies the use of the current geoid model in the processing and adjusting of geodetic survey data.

### 1.1.4 Vertical Datums

Elevations for engineering projects must be referenced to a single vertical datum so that various phases of a project, and contiguous projects, will conform.

The vertical datum for Caltrain shall be the North American Vertical Datum of 1988 (NAVD 88), as established by the NGS.

Control surveys shall use only new or adjusted NGS NAVD 88 benchmarks. NAVD 88 benchmarks whose elevations have been derived from a VERTCON shift of a National Geodetic Vertical Datum of 1929 (NGVD 29) benchmark shall not be used in primary and secondary vertical control networks as constraining elevation points, but may be used as a general vertical check. Caltrain will not accept control point data using elevation data derived from Real-Time Kinematic (RTK) or GPS.

A full report of the vertical control used to vertically constrain a control network is to be included in the deliverables of any control project performed for Caltrain.

Local cities or agencies may use still different vertical datums from the NGVD 29 or NAVD 88 vertical datums. These differences have to be taken into consideration when using as-built plans for work performed by others on adjacent projects, or on projects that are dated.

### 1.1.5 Least Square Adjustment

Baselines generated during geodetic surveys shall be adjusted using a minimally constrained adjustment to check the measurement data and ensure that the survey meets Federal Geodetic Control Subcommittee criteria and Caltrain's specifications for primary and secondary control networks. A full report of this minimally constrained adjustment will be included in the deliverables of any geodetic control project performed for Caltrain.

Minimally adjusted baselines meeting Caltrain standards shall be subsequently adjusted using fully constrained adjustments in the current epoch to check the validity of the control work.

These baselines shall then be adjusted using fully constrained adjustments in the correct epoch, if different from the Caltrain epoch and in the units required by Caltrain.

## 2.0 CALIFORNIA STATE PLANE COORDINATES

Surveys shall be performed on the California Coordinate System (CCS), in conformance with the California Public Resources Code. Surveyors shall be familiar with these codes, because they define the CCS and provide for its use.

The State of California comprises five zones. Zone III covers 15 counties, including San Francisco, San Mateo, and Santa Clara. All survey work performed for Caltrain shall be based on the California State Plane Coordinate System, Zone III.

## 3.0 TOPOGRAPHIC SURVEYS

Topographic surveys are used to determine the configuration of the ground surface and the locations of all natural and man-made objects and features. The resulting surveys include DTMs and topographic maps that are the basis for planning and engineering.

Elevations of existing topographic features—including top of rail, top of pavement, and utilities—are often required to develop accurate plans, specifications, and estimates. Surveyors need to carefully select methods and procedures for conducting the survey work to obtain accurate data.

The topographic surveys shall include the following items:

a. Track centerline and profile extending at least 200 feet beyond project limits

b. Roadway surveys extending at least 200 feet on each side of the proposed roadway ROW lines

c. Switch points, point of frogs, joints at project limits, joints at control points, signal facilities, communication line locations, etc.

## C. MAPPING

Caltrain does not have specific requirements for aerial mapping and photography, except that any mapping shall adhere to the National Map Accuracy Standards (NMAS), and that these accuracies are map-sheet-based.

The most commonly used data accuracy standards for municipal mapping applications are the American Society of Photogrammetry and Remote Sensing, Class I and II. Caltrain, along with an increasing number of municipalities, requests that mapping projects be compliant with the NMAS for large-scale mapping.

### 1.0 ACCURACIES

### 1.1 HORIZONTAL ACCURACY

**Table 9-1** shows the standards for some common map scales. Note that the conversion of paper maps into digital data usually creates additional error.

### 1.2 VERTICAL ACCURACY

Vertical accuracy as applied to contour maps shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown on it with corresponding positions determined by surveys of a higher accuracy. The designer shall determine which maps are to be tested, and the extent of the testing.

**Table 9-1: Map Scales**

| Horizontal Accuracy Examples | | |
|---|---|---|
| **Scale** | **Engineering Scale** | **National Map Accuracy Standard** |
| 1:480 | 1” = 40’ | ±1.33 feet |
| 1:600 | 1” = 50’ | ±1.67 feet |
| 1:1,200 | 1" = 100' | ±3.33 feet |

| | | |
|---|---|---|
| 1:2,400 | 1" = 200' | ±6.67 feet |
| 1:4,800 | 1" = 400' | ±13.33 feet |
| 1:9,600 | 1" = 800' | ±26.67 feet |
| 1:12,000 | 1" = 1,000' | ±33.33 feet |
| 1:24,000 | 1" = 2,000' | ±40.00 feet |

Only published maps meeting these accuracy requirements shall note this fact on their legends: "This map complies with National Map Accuracy Standards (NMAS)."

When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be so stated in the legend.

## 2.0 MAPPING SCALE AND APPLICATION

**Table 9-2** depicts various mapping scales and their applications.

**Table 9-2: Mapping Applications**

| Map Scale | Contour Interval | Mapping Application |
|---|---|---|
| 1" = 20' | 1-foot | Grade Crossing, Bridge, and Station Sites for Final Design |
| 1" = 40' | 2-foot | Standard Maps for Engineering Design (Preliminary Engineering and Plans, Specifications and Estimates) |
| 1" = 100' | 5-foot | Standard Maps for Environmental Studies, Feasibility Studies, Planning, and Conceptual Engineering |
| 1" = 200' | 10-foot | Corridor Studies |

## 3.0 ORTHOPHOTOGRAPHY

In digital orthophotography, pixel resolution correlates with map scale. **Table 9-3** provides typical correlations between pixel resolution and various map scales. The required output pixel resolution shall be established at the beginning of the project.

**Table 9-3: Pixel Resolution**

| Target Map Scale | | Orthophoto |
|---|---|---|
| **1 inch = x feet** | **Ratio (foot:feet)** | **Pixel Resolution (feet)** |
| 40 | 1:480 | 0.20 |
| 50 | 1:600 | 0.25 |
| 100 | 1:1,200 | 0.5 |
| 200 | 1:2,400 | 1.0 |
| 400 | 1:4,800 | 2.0 |

# REFERENCE FOLLOWS

# REFERENCE

## A. RIGHT-OF-WAY

### 1.0 GENERAL

The phrase "right-of-way" (ROW) as it pertains to a railroad, whether passenger or freight system, refers to the real estate or land on which the roadbed, track structure and facilities are built.

The width of a railroad ROW is dependent on many variables, and the determination of the ROW width at particular locations along a rail corridor can only occur after research into the history and chain of title that shaped that corridor. For example, a double track railroad's written acquisition deeds may be written in such a way that its ROW width is to be measured at right angles from a line running midway between the two tracks. But what if that same railroad was originally a single track system and the written acquisition deeds are written in such a way that its ROW width is to be measured at right angles from the centerline of the original track. Which track? And what if that original track location had undergone two or three line changes and curve revisions through its history, some of which are documented? And what if routine railroad maintenance has thrown the track centerline from its original or relocated position? These are the questions that any ROW Engineer working on a railroad ROW has to answer.

### 1.1 CALTRAIN RIGHT-OF-WAY

The Caltrain corridor is a ROW that was purchased largely from the Southern Pacific Railroad (SP), a double track system. Before the SP came along, a large part of what is now Caltrain's main line ROW was owned by the San Francisco and San Jose Railroad, a single track system. Several line changes and curve revisions have occurred along the ROW throughout its history, some of which have been documented, others that were not, and routine maintenance over the years has also worked to change the original geometry.

The Caltrain ROW is made up of lengths of land of varying widths that usually increase at stations and yards to accommodate the increased real estate that these facilities require. The uniformity of the ROW is sometimes interrupted by the acquisition of private or public parcels of land that adjoin the original ROW. Land can be acquired by actual purchase, in which the purchaser can acquire land in fee simple or they can acquire an easement or right of use. A right of use may come in the form of an agreement with a local municipality such as a franchise right. Land can also be acquired when the railroad exercises its right of eminent domain if it can be shown that it is in the public's interest.

ROW engineers work in conjunction with the Caltrain Real Estate Department and the Caltrain Engineering Department to determine existing ROW conditions and assess ROW needs. There is further discussion of this issue in sections below.

## 2.0 REAL PROPERTY DEFINED

## 2.1 TYPES OF REAL PROPERTY TRANSFER

Real property is the interest that an individual or entity has in lands, tenements, or hereditaments, and also things that are permanent, fixed, and immovable and which cannot be carried out of their places, as land or tenements. This definition pertains to the land but it also pertains to the rights arising out of or connected to the land.

The transfer of real property or conveyance of private lands between individuals, corporations, or other entities or, to or from city or county entities is accomplished by a document known as a deed. There are many different kinds of deeds such as grant deeds, quitclaim deeds, corporation deeds, warranty deeds, statutory deeds, etc. These deeds are made public by the filing of such instruments at the county recorder's office. The kinds of instruments used to convey real property to the Caltrain corridor are of the grant deed or quitclaim variety.

### 2.1.1 Fee Simple

Fee simple or fee simple absolute is an estate where a right or rights to land exist without duration or limitations. This method of acquisition shall be proposed for the purchase of ROW for the construction of permanent surface facilities.

### 2.1.2 Fee Simple Determinable

Fee simple determinable is an estate where the creator or grantor retains a right of reversion such that should the subsequent owner violate the conditions set out in the instrument that created it, the estate could be terminated and recovered.

### 2.1.3 Easement

An easement is the right of use over the real property of another. The right is often described as the right to use the land of another for a special purpose. The phrase "ROW" generally refers to an easement, but railroads have adopted this phrase to describe their property. So those portions of the railroad property that were acquired through an easement are quite literally ROW.

An easement may be acquired as a permanent or temporary easement. Permanent easements shall be proposed for utilities, maintenance accesses, and railroad signal facilities. Temporary easements shall be proposed for construction accesses.

### 2.1.4 Franchise Right

A franchise right is a nontransferable privilege to use the real property of another. The grantee of the franchise right does not hold any interest in or ownership of the real property. When the real property is no longer in the use of the grantee, the original owner will resume sole right and ownership of the property. The grantee may extend the right to the property with a fee. A franchise right does not require a conveyance to be created. For example, a municipal agency may grant a “franchise” to a railroad that will give them sole authority to cross a street.

## 2.2 RIGHT-OF-WAY REQUIREMENTS

ROW is the composite total requirement of all interests and uses of real property needed to construct, maintain, protect, and operate the commuter rail system. Some ROW requirements are temporary, while other ROW requirements are permanent as dictated by operating and maintenance needs. The intent is to acquire and maintain the minimum ROW required consistent with the operating requirements of the Caltrain system. Because ROW plans approved by the agency are used as a basis for acquisition of property, all interests and uses required shall be shown on the ROW plans together with the detailed property descriptions.

The proposed ROW takes shall be based on the project footprint and are influenced by the track alignment, site topography, drainage improvements, structural improvements, service/access roads, utilities, and other required related railroad facilities.

The existing ROW shall be preserved, and additional ROW acquired for potential uses in the future. All existing leases shall be renewed only after consultation with Caltrain Engineering. New leases shall not be executed without prior approval by the Caltrain Director of Engineering.

It is the responsibility of the ROW Engineer to coordinate ownership boundaries with new ROW requirements and to calculate areas of ownerships, ROW requirements, excesses, and remainders as a basis for all ROW maps and descriptions. Since Caltrain's survey control network and its railroad design criteria are based on the California Coordinate System (CCS), ROW calculations must also be based on the CCS. Products, deliverables and calculations having to do with ROW engineering will be based on the CCS, the North American Datum of 1983 (NAD 83) horizontal datum and the North American Vertical Datum of 1988 (NAVD 88) vertical datum as per Caltrain specifications. These datum specifications are described and discussed in detail in the Geodetic Surveying Section below.

a. Boundary Determination

Property boundaries are to be established on the same grid system as new ROW requirements (CCS) for:

i. Partial acquisition parcels.

ii. Total acquisitions with a boundary line coincident with the ROW line.

iii. Total acquisitions which include excess.

iv. Ownership boundaries shall be located from field survey data and record information in accordance with established legal principles.

v. The underlying fee in an abutting public road will be mapped as part of an ownership as defined above only when it is specifically included in the record description of the property.

### 2.2.1 Preliminary Right-of-Way Assessment

A Preliminary ROW Assessment is an elective in-house Caltrain process of examining available record property information and mapping in the area of a proposed improvement project. It is designed to produce an early assessment of the potential for property conflicts and the need for property acquisition in order to accommodate the needs of the proposed improvements. A Preliminary ROW Assessment, if requested by Caltrain, shall be performed at the preliminary engineering stage of all projects to identify ROW impacts. The preliminary ROW assessment shall include the following tasks.

a. Secure any title information and title reports as might be available in-house with Caltrain on the subject property.

b. Determine from available in-house recorded or unrecorded deed information, agreements, franchise rights, other rights, easements, or title that Caltrain has along that portion of the railroad corridor adjacent to or within the area of the proposed improvement project.

c. Secure all recorded or unrecorded deeds, rights or agreements inherited by Caltrain as part of the purchase and sale agreement with the SP.

d. Secure all recorded or unrecorded deeds, rights or agreements inherited by Caltrain as part of the purchase and sale agreement with the State of California.

e. Trace record property transfers to the Union Pacific Railroad as part of the merger with SP. This will require the assistance of a Title Company.

f. Research public records at the County of the subject property for recorded Parcel Maps, Subdivision Maps, Records of Survey, Monumentation Maps and ROW Mapping that may have been prepared in and around subject property, which may influence the location of subject property.

g. Gather all SP ROW and Track Mapping, Valuation Maps, and Station Maps, available within Caltrain's in-house mapping records for original track alignment and parcel configuration information.

h. Research Caltrain records for all ROW work previously performed in the area of the subject property.

i. Review available in-house Caltrain documentation on lease agreements.

j. Prepare a base map from all of the record information, topographic information and ROW mapping gathered and prepare an electronic file of this record ROW.

k. The base map and resulting ROW will be prepared from available record deeds and record mapping and available topographic information.

A Preliminary ROW Assessment is meant to be a tool for assessing property issues during the conceptual stage of an improvement project. A Preliminary ROW Assessment process is not a boundary survey and is not designed to be used in replacement of, or in conflict with, state law and local law regarding boundary surveying.

### 2.2.2 Right-of-Way Boundary Resolution

ROW boundary resolution shall be performed at the final design stage for projects with definite ROW takes and permanent easements. The ROW boundary resolution shall include the following tasks.

a. Perform field boundary evidence search and topographic survey of existing possession lines to determine location of written title documents and recorded maps of adjacent subdivisions and properties in the field.

b. Research available documentation including recorded maps, assessor's information and maps, available title information, recorded deeds, SP valuation maps, San Francisco and San Jose Railroad Route Maps, and Caltrain conveyance maps to formulate a boundary evidence search plan and subsequent boundary resolution and ROW check.

c. Review Preliminary Record of Survey Map of the Caltrain ROW, if available.

d. Review Preliminary Record of Survey Maps, if available.

e. Resolve geometry of original single track and/or subsequent double track alignments to reconcile calls to "centerline of track" in recorded deed documents and title reports.

f. Prepare ROW base maps.

g. Prepare land information packages to assist the Title Company in searching Caltrain's ownership rights and on any adjoining properties deemed necessary to assist in the resolution of the Caltrain ROW lines. This procedure assists the Title Company greatly and minimizes the cost of Preliminary Title Report preparation.

h. Field verification of records.

### 2.2.3 Legal Descriptions

The preparation of legal descriptions and plat maps for ROW acquisitions shall be coordinated closely with the project team and the Caltrain Real Estate Department. Prior to the preparation of legal descriptions and plat maps, all parcels for ROW takes shall be clearly identified in the ROW exhibit maps with approval from the Project

Manager and the Caltrain Real Estate Department. The following documents shall be submitted to the Caltrain Real Estate Department for approval.

a. ROW base maps of resolved ROW.

b. ROW exhibits clearly define areas of ROW takes.

c. ROW appraisal maps and record maps.

A legal description prepared for Caltrain will consist of two parts, the legal description in writing and the plat map showing the area being described. A legal description submitted without both parts will be considered incomplete unless otherwise agreed upon by Caltrain.

### 2.2.4 Describing Land

Metes Descriptions are perimeter descriptions described by measurement and direction of travel only and they have no bounds calls or calls to an adjoiner.

Bounds descriptions are perimeter descriptions based upon bounds calls only and have no measurement or direction of travel calls included.

Metes and bounds descriptions are perimeter descriptions that are described by measurements, direction of travel and by calls to adjoiners.

Strip descriptions are descriptions of property whose perimeter is described by widths from a given base line or centerline, say the centerline of a track, such as “30 feet on each side of the following described centerline.”

Descriptions by reference are descriptions of property by reference to some map or plat, such as “Lot 1, Block 49 of the University Subdivision.”

Descriptions by exception are descriptions of property which except out certain areas as a reservation from the conveyance such as “Lot 1, Block 49 of the University Subdivision, except the northerly 50 feet.”

There are many other ways to describe land but the type of legal description that one is likely to encounter on the Caltrain corridor will be of the Quasi-Metes and Bounds type. This is a description that uses both written instructions: measurements and direction of travel, and a call for a map. The other type of descriptions that one would encounter on this corridor is a combination bounds and strip description. When writing legal descriptions for Caltrain, the use of bounds only descriptions is discouraged.

### 2.2.5 Plat Maps

A plat map as defined by Caltrain is a map or drawing of the land being described in the legal description. The plat map is attached to, and made a part of, the legal description.

A plat map prepared for Caltrain shall be drawn to scale, and shall include, at a minimum, the following information:

a. North arrow

b. Legend

c. Point of beginning

d. Point of commencement if applicable

e. Thicker line indicating the land being described

f. Adjoiner record deed or map information

g. Relevant record deed or map data on the subject parcel of land

h. Adjacent street names, ROW lines and ROW widths

i. Distances and bearings of all lines along the land being described

j. Relevant bearings or distances to adjoiners

k. Area of described land

l. Stamp and signature of the licensed California land surveyor responsible for the map

m. Title block

n. Date

o. Scale

p. Title or name of the land being described

q. Assigned Caltrain Real Estate Department Parcel Number

r. Plat map prepared on an 8.5-by-11-inch or 8.5-by-14-inch format sheet of paper

## 2.3 RIGHT-OF-WAY PRESERVATION

Caltrain may work, on a partnership basis, with local land use authorities in early corridor planning phases to identify underutilized existing rail corridors or properties and to explore all appropriate means for acquisition and preservation of those corridors or properties. Preserving ROW for commuter rail use can be accomplished through various methods including:

a. Donations

b. Dedications

c. Transportation Impact Mitigations

d. Advance ROW Purchase

# B. SURVEYING AND MAPPING

## 1.0 SURVEY CONTROL

Survey control establishes a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of rail transportation improvement projects and facilities. The survey control network ensures that adjacent projects have compatible control. Furthermore, a precise control network provides consistent and accurate horizontal and vertical control for all subsequent project surveys including photogrammetric, mapping, planning, design, construction, and ROW.

The following policies, standards, and procedures are applicable to all survey control work for all Caltrain improvement projects. This includes surveys performed by Caltrain in-house survey staff, Consultants, local agencies, private developers and others.

## 1.1 GEODETIC SURVEYING

Surveys employing the principles of geodesy are of high precision and generally extend over large areas, such as the Caltrain railroad corridor, which runs from the City of San Francisco to the City of Gilroy and runs approximately 77 miles. It is important to understand the elements that comprise geodetic surveys to understand the Caltrain requirements for Geodetic Surveys along their corridor.

### 1.1.1 Horizontal Datums

A Horizontal Datum is generally defined by three basic requirements:

a. An ellipsoid

b. An origin

c. An orientation

The shape of the earth, although generally thought of as a sphere is really a sphere with flattening at the poles. This flattening at the poles creates what is known as an oblate spheroid. Geodetic Surveyors must take into account this true shape of the earth. Geodetic surveys establish control networks on a mathematical surface that most closely approximates the shape of the earth. This mathematical surface is known as the ellipsoid.

Although there are several mathematical surfaces or ellipsoids that have been developed over the years, the first reference spheroid used in North America was Clarke's Spheroid of 1866. Much of the California Department of Transportation's mapping is based upon this spheroid.

A Horizontal Datum is dependent upon the ellipsoid that is chosen to define its surface. For example, the North American Datum of 1927 (NAD 27), is based on Clarke's Spheroid of 1866. The origin of this datum is the triangulation station at Meade's Ranch in Kansas. The orientation was the geodetic azimuth from the Station at Meade's Ranch Kansas to the Station at Waldo in the town of Waldo, Kansas.

With the launching of satellites, the NAD 27 horizontal datum was rendered unusable. All near-earth satellites orbit around the center of the earth's mass, so an ellipsoid for satellite positioning had to have its origin at the center of mass. The Clarke Spheroid of 1866 had its center roughly 300 meters away from the center of the earth's mass.

In recent years, better mathematical models have been developed by the National Geodetic Survey (NGS) and the United States Department of Defense (DoD) and new reference spheroids have been developed that better approximate the actual shape of the earth. The latest ellipsoid developed by the DoD is the WGS84. The DoD uses an earth-centered, earth-referenced coordinate system or horizontal datum also called the World Geodetic System of 1984 (WGS 84) that is based on this ellipsoid. The latest ellipsoid developed by the NGS for civilian users is the Geodetic Reference System of 1980 (GRS 80) which has its origin positioned to be earth-centered and the orientation is that of the Bureau International de l'Heure terrestrial system of 1984 (BIH 84).

The NGS developed the NAD 83 to provide the survey community and other users with a reference system that was earth-centered, earth-fixed system, orientated to the BIH 84 system and based upon the GRS 80 ellipsoid.

The Caltrain corridor control network is based upon NAD 83, and all geodetic surveying work performed for Caltrain shall adhere to this datum. The State Code of California requires surveyors to use NAD 83 as the reference frame for geodetic surveys. In addition, all Plane Surveying performed on the Peninsula Corridor Joint Powers Board's (PCJPB's) rail corridor should be tied to this reference frame.

Global Positioning System (GPS) software using the WGS 84 system is permitted by Caltrain because the WGS 84 and GRS 80 ellipsoids are so close, that the resulting computed data is correct.

Relative positioning data collected by surveyors performing work along the corridor can be tied to the NAD 83 datum using a state high-accuracy reference network (HARN), the national continually operating referencing stations (CORS) network, or calculated from either a HARN or CORS. HARNs and CORS are from different adjustments and should not be used together in the same survey.

The NGS has consolidated all control under the NAD 83 National Spatial Reference System, combining all control points, both HARN and CORS points, under this one system. Caltrain uses this system.

### 1.1.2 Epochs

California survey control points, because of crustal motion between the Pacific and North American Plates, are subject to "shifting" positions on a constant basis. Depending on the type of seismic activity, great horizontal and vertical deformation can occur in monument positions. The published positions of points must be continually updated to account for these shifts or deformations. Depending on the kind of survey being performed and the time frame that it is performed within, some thought should be given to the epoch to use for the survey.

An epoch can be calculated for any given moment in time and is a “snapshot” in time of all the positions of the included monumentation. The first statewide epoch was the High Precision Geodetic Network that was published as the 1991.35 epoch. Later after the Northridge earthquake, a statewide epoch was recalculated and became known as the 1998.5 epoch. After the 2004 San Simeon earthquake, the NGS and the California Spatial Reference Center (CSRC) published the 2004.0 epoch. In 2012 an updated 2010.00 epoch was published.

Caltrain specifies California Coordinate System, Zone III, NAD 83 epoch 2010.01, as the basis for all geodetic surveying performed on its rail corridor.

### 1.1.3 The Geoid

Measurements are made on the apparent or topographic surface of the earth and computations are performed on an ellipsoid. One other surface is involved in geodetic measurement and that is known as the geoid. In geodetic surveying, the computations of the geodetic coordinates of points are performed in the area of the survey on an ellipsoid which closely approximates the size and shape of the earth. The actual measurements made on the surface of the earth with certain instruments are referred to as the geoid. The ellipsoid is the mathematically defined surface with specific dimensions but the geoid, coincides with that surface to which the oceans could conform over the entire earth if free to adjust to the combined effect of the earth’s mass attraction and the centrifugal force of the earth’s rotation.

The geoid is a surface along which the gravitational potential is everywhere equal and to which the direction of gravity is always perpendicular. This is significant because optical survey instruments containing leveling devices are commonly used to make geodetic measurements. When properly adjusted, the vertical axis of the instrument coincides with the direction of gravity and is therefore, perpendicular to the geoid.

Just as with ellipsoids, there are many definitions for the geoid that have been used over time in geodetic surveying. Caltrain specifies the use of the current geoid model in the processing and adjusting of geodetic survey data while performing geodetic surveys along its rail corridor. This geoid is available to users to download on the NGS website.

### 1.1.4 Vertical Datums

Elevations for engineering projects must be referenced to a single vertical datum so various phases of a project, and contiguous projects, will conform. Various organizations use datums that best serve their needs but these many different datums can cause confusion when trying to compare vertical data between projects performed by different agencies or private entities.

The NAVD 88 is a vertical network defined by one station, Father Point/Rimouski, which is an International Great Lakes Datum water-level station at the mouth of the St. Lawrence River in Quebec, Canada. This one station mean sea level elevation was held fixed in a minimally constrained least-squares adjustment performed by the NGS. Because only one station was held fixed, the network was not distorted due to constraints of different mean sea level elevations, unlike the National Geodetic Vertical Datum of 1929 (NGVD 29).

Both datums, NGVD 29 and NAVD 88 are orthometric elevations. An orthometric elevation or height of a point on the earth's surface is the distance from the reference surface (geoid) to the point, measured along the plumb line, normal to the geoid.

Local cities or agencies may use still different vertical datums that may be some variation from mean sea level or differ from that of the NGVD 29 or NAVD 88 vertical datums and these differences have to be taken into consideration when trying to use as-built plans on work performed by others on adjacent projects or on projects that are dated.

The vertical datum for Caltrain shall be the NAVD 88 as established by the NGS. All scope of services developed for Caltrain shall be specified as NAVD 88 vertical datum based projects.

Control surveys performed for Caltrain shall use only new or adjusted NGS NAVD 88 bench marks as the basis for their survey work. NAVD 88 bench marks whose elevations have been derived from a VERTCON shift of an NGVD 29 bench mark shall not be used in Primary and Secondary Vertical Control Networks as constraining elevation points but may be used as a general vertical check. These VERTCON elevations are generally only published to the tenth of a foot accuracy. Caltrain will not accept control point data using elevation data derived from Real-Time Kinematic (RTK) or GPS.

A full report of the vertical control used to vertically constrain a control network is to be included in the deliverables of any control project performed for Caltrain.

### 1.1.5 Baseline Adjustment using Least Square Adjustment

Baselines generated during geodetic surveys shall be adjusted using a minimally constrained adjustment to check the measurement data and ensure that the survey meets Federal Geodetic Control Subcommittee criteria and Caltrain specifications for primary and secondary control networks. A full report of this minimally constrained adjustment will be included in the deliverables of any geodetic control project performed for Caltrain.

Minimally adjusted baselines meeting Caltrain standards shall be subsequently adjusted using fully constrained adjustments in the current epoch to check the validity of the control work.

These baselines shall then be adjusted using fully constrained adjustments in the correct epoch, if different from the Caltrain epoch and in the units required by Caltrain.

## 2.0 CALIFORNIA STATE PLANE COORDINATES

The State Plane Coordinate System divides the United States into over 120 numbered zones. Three conformal projections were chosen:

a. Lambert Conformal Conic

b. Transverse Mercator

c. Oblique Mercator

To maintain an accuracy of one part in 10,000, it was necessary to divide many states into zones. Each zone has its own central meridian or standard parallels to maintain the desired level of accuracy. Zone boundaries follow county boundaries.

Surveys performed for Caltrain shall be on the CCS in conformance with the California Public Resources Code. Surveyors working on Caltrain corridor shall be familiar with these codes because they define the CCS and provide for its use.

A plane survey coordinate system is on a flat surface and therefore the geodetic positions of points must be projected from the curved surface of the spheroid to the flat surface to create flat plane coordinate positions. This is accomplished using a "projection." The CCS system is based upon the Lambert Conformal Conic Projection.

The State of California is comprised of five zones, all using the Lambert Conformal Conic Projection. Zone III covers the counties of Alameda, Calaveras, Contra Costa, Madera, Marin, Mariposa, Merced, Mono, San Francisco, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Stanislaus, and Tuolumne. The Caltrain railroad corridor lies entirely within San Francisco, San Mateo and Santa Clara counties, all lying within CCS, Zone III.

All survey work performed for Caltrain shall be based upon the California State Plane Coordinate System, Zone III.

## 3.0 AERIAL MAPPING AND PHOTOGRAMMETRY

Mapping prepared for Caltrain shall be in conformance with the National Map Accuracy Standards (NMAS). Caltrain may require a report of the checks that were made to ensure that the mapping is in compliance with these standards and this report may be requested at any time including as part of the deliverables.

## 3.1 HORIZONTAL ACCURACY

For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc.

In general, what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Therefore, although the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch.

Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

The table below shows the standard for some common map scales. Note that the conversion of paper maps into digital data usually creates additional error.

| HORIZONTAL ACCURACY EXAMPLES | | |
|---|---|---|
| Scale | Engineering Scale | National Map Accuracy Standard |
| 1:480 | 1”=40’ | +/- 1.33 feet |
| 1:600 | 1”=50’ | +/- 1.67 feet |
| 1:1,200 | 1"=100' | +/- 3.33 feet |
| 1:2,400 | 1"=200' | +/- 6.67 feet |
| 1:4,800 | 1"=400' | +/- 13.33 feet |
| 1:9,600 | 1"=800' | +/- 26.67 feet |
| 1:12,000 | 1"=1000' | +/- 33.33 feet |
| 1:24,000 | 1"=2000' | +/- 40.00 feet |

## 3.2 VERTICAL ACCURACY

Vertical accuracy as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing consultant or by Caltrain. Caltrain shall also determine which of the maps are to be tested, and the extent of the testing.

Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This map is an enlargement of a 1:24,000-scale published map."

## 3.3 AERIAL MAPPING AND PHOTOGRAPHY

Caltrain does not have specific requirements for aerial mapping and photography except that any mapping shall adhere to the NMAS, shown in detail above, but it understands that these accuracies are map sheet based. Caltrain understands that while it asks for adherence to these NMAS standards, often the interpretations of these standards are misunderstood and that the project manager should examine each potential consultant photogrammetrist's interpretation of the NMAS standards so that the expectations of the final mapping product are met. Also, accuracy standards vary in complexity and usability, and it is best that a discussion with the photogrammetrist take place regarding accuracy specification that would best suit the needs and budget of the project.

The most commonly used data accuracy standards for county and municipal mapping applications are the American Society of Photogrammetry and Remote Sensing (ASPRS) Class I and II. Additionally, more and more counties and municipalities, just as the PCJPB does, are requesting their mapping projects to be compliant with the NMAS for large-scale mapping.

ASPRS developed a new set of accuracy evaluation criteria. These accuracy standards for large-scale maps (generally 1" = 1000' and larger [i.e. 1" = 200', 1" = 100', etc.]) look at continuous datasets (not map sheet based) from a statistical perspective (the root mean square error [RMSE]) and therefore are considered more stringent. In terms of RMSE (like the ASPRS standards), NMAS generally equates to ASPRS Class 1.5.

## 3.4 MAPPING SCALE AND APPLICATION

The following table depicts various mapping scales and their applications.

| MAP SCALE | CONTOUR INTERVAL | MAPPING APPLICATION |
|---|---|---|
| 1” = 20’ | 1 foot | Grade Crossing, Bridge, and Station Sites for Final Design |
| 1” = 40’ | 2 foot | Standard Maps for Engineering Design (PE and PS&E) |
| 1” = 100’ | 5 foot | Standard Maps for Environmental Studies, Feasibility Studies, Planning, and Conceptual Engineering |
| 1” = 200’ | 10 foot | Corridor Studies |

Notes:

PE = preliminary engineering
PS&E = plans, specifications, and estimates

## 3.5 ORTHOPHOTOGRAPHY

In digital orthophotography, pixel resolution correlates with map scale. The table below provides a general idea of the pixel resolution as it correlates with various map scales. These correlations are typical and the needs of the project may dictate a higher or lower level of output pixel resolution.

| TARGET MAP SCALE | | ORTHOPHOTO |
|---|---|---|
| **1 inch = x feet** | **Ratio (foot:feet)** | **Pixel Res. (feet)** |
| 40 | 1:480 | 0.20 |
| 50 | 1:600 | 0.25 |
| 100 | 1:1,200 | 0.5 |
| 200 | 1:2,400 | 1.0 |
| 400 | 1:4,800 | 2.0 |

## 4.0 SUPPLEMENTAL ENGINEERING SURVEYS

Supplemental engineering surveys shall be provided for planning and engineering design when detailed topographic features are not available through aerial maps. The products resulting from supplemental engineering surveys are generally topographic maps and digital terrain models (DTMs). Conventional (on-the-ground) surveying methods shall be used to gather data for supplemental engineering surveys. This section provides standards, procedures, and general information for performing conventional engineering surveys using the Total Station Survey System, GPS, and differential leveling.

## 4.1 PLANNING

Planning begins with the meeting between the Project Surveyor and the Project Manager to discuss the proposed survey request. From a planning perspective, an important part of this meeting is obtaining information about anticipated future related survey requests for the project. Consideration of future ROW surveys and construction surveys should be part of the planning process so that the most efficient survey work plan for the overall project can be formulated.

A work plan for supplemental engineering surveys shall be prepared by the Project Surveyor. This work plan shall contain:

a. A survey request prepared by the Project Manager

b. A list of the required deliverables

c. A schedule for the requested project surveys, including critical milestones

## 4.2 TOPOGRAPHIC SURVEYS

Topographic surveys are used to determine the configuration of the surface of the project site and the locations of all natural and man-made objects and features. The deliverables of topographic surveys including DTMs and topographic maps are the basis for planning studies and engineering designs.

A DTM is a representation of the surface of the project site using a triangulated irregular network (TIN). The TIN models the surface with a series of triangular planes. Each of the vertices of an individual triangle is a coordinated (x, y, z) topographic data point. The triangles are formed from the data points by a computer program, which creates a seamless, triangulated surface without gaps or overlaps between triangles. The standard program for generating the DTM shall be AutoCAD Land Development Desktop Civil Design.

The topographic surveys shall include the following items along the railroad corridor:

a. Track centerline and profile shall include at least 200 feet beyond project limits.

b. Roadway surveys shall include at least 200 feet on each side of the proposed roadway ROW lines.

c. Switch points, point of frogs, joints at project limits, joints at control points, signal facilities, communication line locations, etc.

Most of Caltrain's projects involve rehabilitation and major improvements of existing facilities. For these projects, elevations of existing topographic features including top of rail, top of pavement, and utilities are often required to develop accurate plans, specifications, and estimates. As a result, surveyors need to carefully select methods and procedures for conducting the survey work to obtain accurate data.

## 4.3 UTILITY SURVEYS

Utility surveys are used to locate existing utilities for the following purposes:

a. Basis for planning and design

b. Relocations of impacted utilities

c. Acquisition for utility easements and/or ROW

d. Information for coordination and negotiation with utility companies

Survey limits and types of utilities to be located should be shown on the Survey Request and/or its attachments. The field survey file should include all utility maps and drawings and descriptions of easements.

It is important to locate all significant utility facilities. The following are lists of facilities and critical points to be located for various utilities. Potholing shall be considered to verify locations of critical utilities.

a. Oil and Gas Pipelines

   i. Intersection point with centerlines and/or ROW lines

   ii. For lines parallel to ROW: location ties necessary to show relationship to the ROW lines

   iii. Vents

   iv. Angle points

   v. Meter vaults, valve pits, etc.

b. Water and Sewer Lines

   i. Intersection point with centerlines and/or ROW lines

   ii. For lines parallel to ROW: location ties necessary to show relationship to the ROW lines

   iii. Manholes, valve boxes, meter pits, crosses, tees, bends, etc.

   iv. Elevation on waterlines, sewer inverts, and manhole rings

   v. Fire hydrants

   vi. Curb stops

c. Overhead Lines

   i. Supporting structures on each side of roadway with elevation of neutral or lowest conductor at each centerline crossing point

   ii. On lines parallel to roadway, supporting structures that may require relocation, including overhead guys, stubs, and anchors

d. Underground Lines

   i. Cables/lines (denote direct burial or conduit, if known), etc.

   ii. Manholes, pull boxes, and transformer pads

   iii. Crossing at centerline or ROW lines

   iv. For lines parallel to ROW: location ties as necessary to show relationship to the ROW lines

**END OF REFERENCE**

# END OF CHAPTER

# CHAPTER 10

# RAIL NETWORK

## A. OVERVIEW OF CALTRAIN RAIL NETWORK COMMUNICATIONS INFRASTRUCTURE

The Caltrain Rail Network or Operations Technology (OT) Network encompasses all ancillary equipment, computers, firewalls, routers, switches, servers, and infrastructure supporting Caltrain's communications, operations, and signaling systems to facilitate revenue service. The OT network also encompasses logical network configurations, firmware, and software programming to ensure proper and secure operation. Designers shall work closely with Systems Engineering to maintain compliance with design criteria, standards, and regulatory requirements.

### 1.0 DATA CENTERS

a. Locations: Menlo Park (MPCC), San Jose (SJCC), and Cloud – all shall meet high-availability standards.

b. Server Backoffice Systems: Configured for security and fault tolerance.

c. CCTV Network: Dedicated bandwidth and storage capabilities.

d. Network Management: Centralized tools for administration, monitoring, and troubleshooting.

e. Remote Access: Secure vendor and staff access through VPN, MFA, and RBAC.

f. Railroad Partner Communication: Federated links with interoperability per IETF guidelines for secure inter-domain communication.

g. Change Management: Standardized and documented update procedures.

h. Physical Requirements:
- Dual power feeds and UPS-backed redundant power.
- Adequate HVAC sized to maintain 64–75°F (18–24°C) and 40–60% RH per ASHRAE TC 9.9 for 24/7 uptime.

i. Network Segmentation:
- Tiered architecture.
- Critical operational networks.
- Administrative networks.
- CCTV networks.

## 2.0 LAN (LOCAL AREA NETWORK)

a. LAN transmission standards shall comply with IEEE 802.3.

b. Performance: Minimum 1 Gbps per endpoint, with upgrade path to 10 Gbps or higher.

c. VLAN Configurations for logical separation and efficiency.

d. Redundancy Architecture: Dual-stacked access switches, redundant uplinks, and failover links.

## 3.0 WAN (WIDE AREA NETWORK)

a. WAN transmission standards shall comply with IEEE 802.3 where Ethernet is deployed.

b. Performance: Baseline 1 Gbps, scalable to 10 Gbps or higher on backbone links.

c. QoS: Prioritization for operational, signaling, and voice traffic.

d. Redundancy Architecture: Geographically diverse fiber paths, automatic failover (e.g., BGP, MPLS, SD-WAN).

## 4.0 SECURITY

a. Cybersecurity:
   - Compliance with IEC 62443 and NIST SP 800-82.
   - Firewalls, intrusion detection/prevention, and segmentation by function.

b. Perimeter Security: Secure gateways with hardened configurations and role-based access.

c. Physical Security:
   - Restricted access with biometrics and surveillance.
   - Monitoring for tampering or intrusion.

d. Logging & SIEM:
   - Centralized log collection with 12-month minimum retention (90 days hot, 1 year cold).
   - Integration with Security Information and Event Management (SIEM) for threat detection and compliance reporting.

## 5.0 FIBER OPTIC BACKBONE COMMUNICATIONS SYSTEM

a. Medium: High-capacity fiber optic as the primary communication backbone.

b. DWDM support for scalable bandwidth.

c. Redundancy: Ring or mesh topologies with ≤50 ms recovery switching.

d. Compliance: Installed per TIA-568 and NECA standards with proper labeling and documentation.

e. Performance: Interfaces must support 10 GbE minimum, with 40 GbE uplinks for critical nodes.

f. Security: Tamper-proof, weather-rated enclosures; monitored access points.

## 6.0 DATA RADIO SYSTEM ARCHITECTURE

a. 220 MHz Architecture: FRA-compliant, interoperable with national PTC networks, encrypted low-latency exchange.

b. Onboard Packages: Ruggedized per EN 50155 standards.

c. Wayside Packages: Interfaces with sensors/signals, redundant links.

d. Backhaul Packages: Fiber, microwave, or LTE with QoS and redundancy.

e. Broadband / Wi-Fi:
   - Passenger Wi-Fi isolated from OT.
   - Internet access via 4G/5G/satellite with seamless failover.
   - Centralized management with content filtering.

## 7.0 WLAN ARCHITECTURE

a. High-speed, secure wireless networks.

b. Segregation of passenger and staff traffic.

c. Service-level compliance for performance and availability.

## 8.0 VOICE COMMUNICATION SYSTEM

a. VHF communication towers and onboard radios.

b. VoIP integration with legacy telephony.

c. Backhaul infrastructure redundancy.

d. High-availability, interference-resistant design.

## 9.0 DATA BACKUP & DISASTER RECOVERY

a. Scheduled data backups with defined RPO/RTO objectives.

b. Offsite replication and cold storage solutions.

c. Incident response and recovery playbooks.

## 10.0 LOGGING

a. Centralized log aggregation.

b. Retention and tiering as defined in Security section.

c. Compliance with FRA and cybersecurity standards.

## 11.0 SYSTEM MONITORING

a. Real-time monitoring with dashboards and alarms.

b. Automated remediation for predefined incidents.

## 12.0 ALERTING

a. Configurable thresholds for critical network events.

b. Tiered escalation and on-call notification procedures.

## 13.0 CHANGE MANAGEMENT

a. Version control, documentation, and approval workflows.

b. Pre-deployment lab testing and field acceptance testing (FAT).

## 14.0 NETWORK EQUIPMENT TECHNICAL SUPPORT

a. Vendor support contracts (e.g., Cisco TAC).

b. Scheduled firmware/patch updates and preventive maintenance.

## 15.0 SERVER INFRASTRUCTURE TECHNICAL SUPPORT

a. Vendor SLAs (e.g., Dell).

b. Preventive maintenance and lifecycle replacement.

## 16.0 CONTINUITY PLAN

a. Documented business continuity strategies.

b. Fully redundant critical systems for uninterrupted operations.

## 17.0 EMERGENCY PLAN

a. Defined failure response protocols.

b. Failover mechanisms for service continuity

## 18.0 STANDARDS AND COMPLIANCE

a. IEEE 802.3 – Ethernet LAN/WAN standards.

b. IETF – secure inter-domain communication guidelines.

c. TIA-568 – structured cabling standards.

d. IEC 62443 – OT cybersecurity standards.

e. NIST SP 800-82 – ICS/SCADA security best practices.

f. ASHRAE TC 9.9 – HVAC/operating conditions for data centers.

## 19.0 PERFORMANCE METRICS & SLAS

a. Uptime: ≥ 99.99% for critical systems.

b. Latency: < 50 ms round-trip for control/operational traffic.

c. Packet Loss: < 0.1% across backbone and WAN.

d. Jitter: ≤ 20 ms for voice/signaling.

e. Scalability: Support for growth in bandwidth and devices without redesign.

## B. SYSTEM-WIDE COMMUNICATIONS TO/FROM STATIONS

Station communications with MPCC, SJCC, SCHQ, and MLHQ shall use the Caltrain-owned fiber optic cable plant installed from the San Francisco Terminal to CP Lick, which includes all stations from San Francisco to Tamien. Stations south of Tamien shall use a public MPLS Ethernet service with a minimum bandwidth of 100 Mbps and latency equal to or less than 10 ms.

The new equipment design and installations at the stations, however, shall account for communication system upgrades using the Caltrain-owned fiber optic cable plant. Future upgrades shall not require major infrastructure rework and must support Caltrain's long-term fiber plan. The fiber optic cable backbone provides for a fully redundant communication optical network, connecting Caltrain passenger stations, right-of-way (ROW) facilities, MPCC, SJCC, SCHQ and MLHQ at the speeds between 1 Gigabits per second (Gbps) and 10 Gbps at optical nodes.

## C. STANDARDS AND CODES

a. ISO International Organization for Standardization OSI Model

b. TCP/IP Model IETF/US Department of Defense

c. IEEE 802.3 for Wired Ethernet

d. IEEE 802.11 for Wireless Ethernet

e. IETF Internet Engineering Task Force

f. IEC (International Electrotechnical Commission) 62443 for cybersecurity

g. TIA-942 for data center

h. NIST Cybersecurity Framework

i. AREMA for Communications and Signals Engineering

j. NFPA 70 for electrical safety

## D. DESIGN REQUIREMENTS

Station communications design documents shall include the following, as applicable and at a minimum:

**System Description:** System description, as a minimum, shall include the subsystem description, detailed design and interface information, all performance, functionality and operational description, cutover information, and details such as the cable and equipment identification.

**Interface Requirements:** Interface requirements shall identify all required wired, optical, and wireless communication interfaces between station systems and subsystems components, and between the station main point of entry (MPOE) and MPCC, SJCC, SCHQ and MLHQ. This shall include the following:

a. Interfaces between new work to be performed and existing communications systems and subsystems

b. Interfaces among the subsystems

c. Interfaces with Caltrain-owned fiber optic cable plant

d. Identification and description of any required hardware and software modifications or additions to existing subsystems equipment, including Supervisory Control and Data Acquisition (SCADA) software, MPCC, SJCC, SCHQ, and MLHQ headend equipment, Alarm Point, and any other required interfaces

e. Identification of all external interfaces, including service points and those to facilities and equipment provided by others; interface examples include power, cable facilities, discreet signals, voice, and data

f. Interface information, including media type, communications protocols, and terminations information such as connector type and pin assignments

**Product Specifications:** The station communications design documents shall include product specifications that meet or exceed the operational, functional, and performance required by the design. Products shall:

a. Be validated against the approved Caltrain Product List prior to acceptance.

b. Be in compliance with all applicable Standards and Codes, including FCC, UL, and ETL certifications.

c. Have a life span of not less than five (5) years, with the life span commencing at the anticipated construction period.

d. Have manufacturer's support available for ten (10) years after the product has reached its end of life.

**Drawings:** Drawings shall include the cover sheet; complete drawing index; electrical; power distribution panels and circuit assignments; mechanical; conduit and cable layouts; conduit and cable schedule; wiring diagrams showing all interfaces; system block and functional diagrams with corresponding parts lists; equipment installation details; grounding details; and other details required by the design. All drawings shall be produced in compliance with the current Caltrain CAD Manual.

**Bill of Materials:** An equipment list (bill of materials) shall consist of a table or list of model and part numbers for all proposed equipment and materials to be used for individual subsystems. The table or list shall be grouped for each subsystem, with functional descriptions of equipment or material included. Quantities and locations shall be included.

The bill of materials shall also include firmware and/or software version tracking for all applicable equipment to ensure consistency, compatibility, and maintainability across the system.

**Calculations:** Calculations shall be included as outlined in the subject subsystem section.

**Cutover Plan:** Phasing and cutovers shall be included to identify all major system cutover events or integration activities and shall describe techniques, methods, duration, and procedures. Coordination with the Caltrain Operations Control Center shall be required for all cutover activities to ensure operational awareness and safety. An outage mitigation strategy shall be developed and documented to minimize service disruptions and to provide contingency procedures in the event of unplanned impacts.

**Equipment and Cable Identifications and Symbols:** Cable and equipment identifications shall comply with Caltrain standard conventions for naming, abbreviating, and presenting equipment and cables in the design documents. An equipment label and nameplate schedule shall also be included.

**Installation and Test:** The design documents shall include installation methods and testing requirements, as applicable. Testing requirements shall include Factory Acceptance Test (FAT) procedures to verify compliance prior to shipment, and Site Acceptance Test (SAT) procedures to confirm proper installation, integration, and operation after deployment.

# END OF CHAPTER

# APPENDIX A

## ABBREVIATIONS

### - A -

**A** vertical acceleration
**A** ampere
**AAR** automatic alternate routing
**ABS** automatic block system
**AC** alternating current
**AC Transit** Alameda-Contra Costa Transit District
**ACE** Altamont Corridor Express
**ADA** Americans with Disabilities Act
**ADAAG** Americans with Disabilities Act Accessibility Guidelines
**AG** average grade
**AIM** Advance Information Management
**AMP** ampere
**ANSI** American National Standards Institute
**AREMA** American Railway Engineering and Maintenance-of-Way Association
**ASPRS** American Society of Photogrammetry and Remote Sensing
**ATCS** Advanced Train Control System
**ATF** autotransformer feed
**AWG** American wire gauge

### - B -

**BAA** boarding assistance area
**BART** Bay Area Rapid Transit District
**BCCF** Backup Central Control Facility (see also SJCC)
**BER** bit error rate
**BDS** (Caltrans) Bridge Design Specifications Manual
**bps** bit per second
**BTS-84** Bureau International de l'Heuer terrestrial system of 1984
**BVC** beginning of vertical curve

### - C -

**°C** degrees Celsius
**CAC** California Administrative Code
**CAD** Computer-Aided Dispatch (see also ROCS)
**CADD** computer-aided design and drafting
**Cal/OSHA** California Occupational Safety and Health Administration
**Caltrans** California Department of Transportation
**CA MUTCD** California Manual on Uniform Traffic Control Devices
**CBC** California Building Code
**CCF** Central Control Facility (see also MPCC)
**CCR** California Code of Regulations
**CCS** California Coordinate System
**CCTV** closed-circuit television
**CEMOF** Centralized Equipment Maintenance and Operations Facility
**CER** communications equipment room
**CFR** Code of Federal Regulations
**CHSR** California High Speed Rail
**CHSRA** California High Speed Rail Authority

| | |
|---|---|
| **CIC** | communication interface cabinet |
| **CID** | card interface device |
| **CIF** | Common Intermediate Format |
| **CLEC** | competitive local exchange carrier |
| **CM** | circuit merit |
| **CORS** | continually operating referencing stations |
| **CP** | Control Point |
| **CPTED** | crime prevention through environmental design |
| **CPUC** | California Public Utilities Commission |
| **CRC** | cyclical redundancy check |
| **CS** | curve to spiral |
| **C&S** | Communications and Signals |
| **CSRC** | California Spatial Reference Center |
| **CTC** | centralized traffic control |
| **CTX** | Caltrain Express |
| **CWR** | continuous welded rail |

**- D -**

| | |
|---|---|
| **D** | absolute value of the difference in rates of grades expressed in decimal |
| **Δ** | delta, total intersection angle |
| **DAQ** | delivered audio quality |
| **dB** | decibel |
| **dBc** | decibel (relative to carrier) |
| **dBi** | decibel (isotropic) |
| **dBm** | decibel-milliwatt |
| **DBM** | Design Basis Memorandum |
| **$D_c$** | degree of curve |
| **DC** | direct current |
| **DG** | distance grade |
| **DED** | dragging equipment detector |
| **DoD** | United States Department of Defense |
| **DOJ** | United States Department of Justice |
| **DS0** | base-band |
| **DSL** | digital subscriber line |
| **DTM** | digital terrain model |
| **DTMF** | dual-tone multi-frequency |
| **DTX** | Downtown Extension |
| **DVR** | digital video recorder |

**- E -**

| | |
|---|---|
| **e** | equilibrium superelevation |
| **$E_a$** | actual superelevation |
| **$E_u$** | unbalanced superelevation |
| **EIA** | Electronic Industry Alliance |
| **EIC** | employee in charge |
| **EL** | elevation |
| **E&M** | ear and mount |
| **EMF** | electromagnetic field |
| **EMI** | electromagnetic interference |
| **EMU** | electrical multiple unit |
| **ERP** | effective radiated power |
| **ESZ** | electrification electrical safety zone |
| **EVC** | end of vertical curve |

**- F -**

| | |
|---|---|
| **°F** | degrees Fahrenheit |
| **FCC** | Federal Communications Commission |
| **FEC** | Forward Error Correction |
| **FEP** | front-end processor |
| **FHWA** | Federal Highway Administration |
| **FM** | frequency modulation |
| **fps** | feet per second |
| **FRA** | Federal Railroad Administration |
| **FTA** | Federal Transit Administration |
| **$ft/sec^2$** | feet per second squared |

**- G -**

| | |
|---|---|
| **G** | gradient |

| | |
|---|---|
| **Gbps** | gigabit per second |
| **GCOR** | General Code of Operating Rules |
| **GHz** | gigahertz |
| **GIS** | Geographic Information System |
| **GMSK** | Gaussian minimum-shift keying |
| **GO** | General Order |
| **GPS** | Global Positioning System |
| **g rms** | g root-mean-square |
| **GRS 80** | Geodetic Reference System of 1980 |

**- H -**

| | |
|---|---|
| **HARN** | high-accuracy reference network |
| **HDLC** | high-level data link control |
| **HDPE** | high-density polyethylene |
| **HMAC** | hot-mixed asphalt concrete |
| **HSP** | Hub Signage Program |
| **HSR** | High Speed Rail |
| **Hz** | hertz |

**- I -**

| | |
|---|---|
| **I** | total intersection angle |
| **IEEE** | Institute of Electrical and Electronic Engineers |
| **I/O** | input/output |
| **IP** | Internet protocol |
| **ITE** | Institute of Transportation Engineers |

**- J -**

| | |
|---|---|
| **JPB** | Joint Powers Board |
| **JPEG** | Joint Photographic Experts Group |

**- K -**

| | |
|---|---|
| **K** | 2.15 conversion factor to give L, in feet, for a vertical curve |
| **Kbps** | kilobit per second |
| **KHz** | kilohertz |
| **kV** | kilovolt |

**- L -**

| | |
|---|---|
| **L** | length |
| **$L_c$** | length of curve |
| **$L_s$** | length of spiral |
| **LAN** | local area network |
| **LED** | light-emitting diode |
| **LFMC** | liquid-tight flexible metal conduit |
| **LRT** | light-rail transit |

**- M -**

| | |
|---|---|
| **M** | correction in elevation at PVI |
| **MAS** | maximum authorized speed |
| **Mbit** | megabit |
| **Mbps** | megabit per second |
| **MCP** | mobile communications package |
| **$mg/m^3$** | milligram per cubic meter |
| **MHz** | megahertz |
| **MOW** | maintenance of way |
| **MP** | milepost |
| **MPCC** | Menlo Park Control Center (see also CCF) |
| **MPEG** | Moving Pictures Expert Group |
| **mph** | mile per hour |
| **MPOE** | main point of entry |
| **MS4** | municipal separate storm sewer system |
| **MST** | Monterey-Salinas Transit |
| **MTC** | Metropolitan Transportation Commission |
| **Muni** | San Francisco Municipal Railway |
| **MUTCD** | Manual on Uniform Traffic Control Devices |

**- N -**

| | |
|---|---|
| **NAD 27** | North American Datum of 1927 |
| **NAD 83** | North American Datum of 1983 |

| | |
|---|---|
| **NAVD 88** | North American Vertical Datum of 1988 |
| **NEC** | National Electrical Code |
| **NEMA** | National Electrical Manufacturers Association |
| **NFPA** | National Fire Protection Agency |
| **NGS** | National Geodetic Survey |
| **NGVD 29** | National Geodetic Vertical Datum of 1929 |
| **NMAS** | National Map Accuracy Standards |
| **NRHP** | National Register of Historic Places |
| **NTSB** | National Transportation Safety Board |

**- O -**

| | |
|---|---|
| **OCS** | overhead contact system |
| **OS** | on station |
| **OTM** | other track materials |

**- P -**

| | |
|---|---|
| **PA** | Public Address |
| **PADS** | Predictive Arrival Departure System |
| **PC** | point of curve |
| **PCJPB** | Peninsula Corridor Joint Powers Board |
| **PDF** | Portable Document Format |
| **PE** | preliminary engineering |
| **PED** | Platform End Display |
| **pH** | Potential of Hydrogen |
| **PI** | point of intersection |
| **PIDS** | Passenger Information Display System |
| **PIS** | Passenger Information System |
| **PNA** | persons needing assistance |
| **POE** | power-over-Ethernet |
| **POTS** | plain old telephone service |
| **ppm** | part per million |
| **PROWAAC** | Public Rights-of-Way Access Advisory Committee |
| **PROWAG** | Public Rights-of-Way Accessibility Guidelines |
| **PS** | point of switch |
| **PS&E** | plans, specifications, and estimates |
| **PT** | point of tangent |
| **PTC** | Positive Train Control |
| **PTP** | point-to-point |
| **PTZ** | pan-tilt-zoom |
| **pV** | maximum design speed through the curve, in mph |
| **PVC** | polyvinyl chloride |
| **PVI** | point of intersection for vertical curve |

**- Q -**

**- R -**

| | |
|---|---|
| **R** | radius |
| **RCP** | reinforced concrete pipe |
| **RDS** | Radio Dispatch System |
| **RF** | radio frequency |
| **RMC** | rigid metal conduit |
| **RMSE** | root mean square error |
| **ROCS** | Rail Operations Control System |
| **ROW** | right-of-way |
| **RSSI** | received signal strength indicator |

**- S -**

| | |
|---|---|
| **S1** | slope of entering tangent in percent |
| **S2** | slope of departing tangent in percent |
| **SamTrans** | San Mateo County Transit District |
| **SBHRS** | South Bay Historical Railroad Society |
| **SC** | spiral to curve |

| | |
|---|---|
| **SCADA** | Supervisory Control And Data Acquisition |
| **SCC** | station communication cabinet |
| **SCS** | supervisory control system |
| **SD** | Standard Drawings |
| **SHPO** | State Historic Preservation Office |
| **SINAD** | signal in noise and distortion |
| **SJCC** | San Jose Control Center (see also BCCF) |
| **SOGR** | state of good repair |
| **SP** | Southern Pacific Railroad |
| **SPL** | sound pressure level |
| **ST** | spiral to tangent |
| **STI** | speech transmission index |
| **SSCC** | solid-state crossing controller |

**- T -**

| | |
|---|---|
| **T** | tangent distance (semi-tangent) |
| **θs** | spiral angle |
| **$T_c$** | tangent of circular curve |
| **TCG** | track clearance green |
| **TCP** | transmission control protocol |
| **TCPR** | traffic control repeater relay |
| **TIA** | Telecommunications Industry Association |
| **TIDS** | transit information display sign |
| **TIN** | triangulated irregular network |
| **TO** | turnout |
| **TOD** | transit-oriented development |
| **TPOB** | ton per operative brake |
| **TS** | tangent to spiral |
| **TSD** | Train Schedule Display |
| **TVM** | ticket vending machine |

**- U -**

| | |
|---|---|
| **UP** | Union Pacific Railroad |
| **UPRR** | Union Pacific Railroad |
| **UPS** | uninterruptible power supply |
| **USDOT** | United States Department of Transportation |
| **uV** | microvolt |

**- V -**

| | |
|---|---|
| **V** | design speed |
| **V** | volt |
| **VAC** | volt alternating current |
| **VDC** | volt direct current |
| **VHF** | very high frequency |
| **VLAN** | virtual local area network |
| **VMS** | Variable Message Sign |
| **VSWR** | Voltage Standing Wave Ratio |
| **VTA** | Santa Clara Valley Transportation Authority |

**- W -**

| | |
|---|---|
| **W** | watt |
| **WAG** | wayside access gateway |
| **WAN** | wide area network |
| **WCO** | West Coast Operations |
| **WCP** | wayside communications package |
| **WGS 84** | World Geodetic System of 1984 |

# APPENDIX B

## PCJPB/CALTRAIN STANDARDS AND REFERENCES

**1.0 Caltrain Design Criteria**

**2.0 Caltrain Standard Drawings**

**3.0 Caltrain Standard Specifications**

**4.0 PCJPB Standards for Design and Maintenance of Structures**

**5.0 PCJPB Engineering Standards for Excavation Support Systems**

**6.0 Caltrain CADD Manual**

**7.0 Caltrain Electrification Standards**

**8.0 Caltrain Track Charts, Right-of-Way, and Rail Corridor Infrastructure Assets**

# APPENDIX C

## REGULATORY AGENCIES AND INDUSTRY STANDARDS

### 1.0 APPLICABLE GOVERNMENT CODES AND REGULATIONS

All improvements of the facilities within the jurisdiction of the Peninsula Corridor Joint Powers Board shall be in strict conformance with government codes, regulations, laws, and standards where applicable, including but not limited to the codes, regulations, laws, and ordinances stated in sections and subsections below.

### 1.1 Federal

#### 1.1.1 Code of Federal Regulations (CFR) – Title 49, Transportation:

A. Part 37 Appendix A – Modifications to Standards for Accessible Transportation Facilities

B. Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards

C. Part 195 Transportation of Hazardous Liquids by Pipeline

D. Part 213 Track Safety Standards

E. Part 214 Railroad Workplace Safety

F. Part 234 Grade Crossing Safety

G. Part 235 Instructions Governing Applications for Approval of a Discontinuance or Material Modification of a Signal System or Relief from the Requirements of Part 236

H. Part 236 Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices, and Appliances

I. Part 237 Bridge Safety Standards

#### 1.1.2 Manual of Uniform Traffic Control Devices (MUTCD)

#### 1.1.3 Federal Transit Administration Circular C 4710.1 – Americans with Disabilities Act (ADA): Guidance

## 1.2 State

A. California Department of Transportation (Caltrans)

1. Highway Design Manual (HDM)
2. Standard Specifications
3. Standard Plans
4. Bridge Design Specifications

### 1.2.1 California Public Utility Commission General Order (CPUC G.O.):

| | | |
|---|---|---|
| A. | 26 | Clearances on railroads and street railroads as to side and overhead structures, parallel tracks and crossings |
| B. | 33 | Construction, reconstruction, maintenance and operation of interlocking plants of railroads |
| C. | 36 | Establishment or abolition of railroad agencies, sidings, spurs and other facilities and curtailment of agency service |
| D. | 72 | Standard types of pavement construction at railroad grade crossings |
| E. | 75 | Regulations Governing Standards for Warning Devices for At-Grade Highway-Rail Crossings |
| F. | 88 | Rules for Altering Public Highway-Rail Crossings |
| G. | 95 | Overhead electric line construction |
| H. | 112 | Design, construction, testing, maintenance and operation of utility gas gathering, transmission and distribution piping systems |
| I. | 118 | Construction, reconstruction and maintenance of walkways and control of vegetation adjacent to railroad tracks |
| J. | 128 | Construction of underground electric supply and communications systems |
| K. | Resolution SED-2 | Adopting Safety Requirements Governing the Design, Construction, Installation, Operation, and Maintenance of the 25 kV AC (Alternating Current) Railroad Electrification System of the Peninsula Corridor Joint Powers Board (Caltrain) on the San Francisco Peninsula Rail Corridor |

### 1.2.2 State of California Codes and Code of Regulations

A. Title 5, Division 1, Part 1, Chapter 5.5, The Elder California Pipeline Safety Act of 1981

B. Title 8, Division 1, Chapter 3.2 California Occupation Safety and Health Regulations (Cal/OSHA)

C. Title 24, Parts 1 to 10 and Part 12, California Building Standards Code

D. California Disabled Accessibility Guidebook (CalDAG)

### 1.2.3 California State Office of Historic Preservation

## 2.0 APPLICABLE ORDINANCES AND DESIGN CRITERIA

### 2.1 Cities and Counties

A. City and County of San Francisco

B. San Mateo County

C. Cities in San Mateo County

D. Santa Clara County

E. Cities in Santa Clara County

## 3.0 APPLICABLE GUIDELINES AND INDUSTRY STANDARDS

The design guidelines and criteria in this Criteria are based on the best industry practice. The following industry publications, standards, and design guidelines were used as references to develop this design criteria manual.

A. American Association of State Highway and Transportation Officials (AASHTO)

B. American Concrete Institute (ACI)

C. American Institute of Steel Construction (AISC)

D. American Iron and Steel Institute (AISI)

E. American National Standards Institute/Telecommunications Industry Association (ANSI/TIA)

F. American Railway Engineering and Maintenance-of-Way Association (AREMA)

1. Communications & Signals Manual of Recommended Practices

2. Manual for Railway Engineering

3. Portfolio of Trackwork Plans

G. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

H. ASTM International (ASTM)

I. American Welding Society (AWS)

J. Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities

K. BICSI Telecommunications Distribution Methods Manual

L. Crime Prevention Through Environmental Design (CPTED)

M. Electronic Industry Alliance (EIA)

N. Illuminating Engineering Society (IES)

O. International Building Code (IBC)

P. Institute of Electrical and Electronics Engineers (IEEE)

Q. Insulated Cable Engineers Association, Inc. (ICEA)

R. Motorola R56 Standards and Guidelines for Communication Sites

S. National Electrical Manufacturers Association (NEMA)

T. National Fire Protection Association (NFPA)

   1. 70 National Electrical Code (NEC)

   2. 70E Standard for Electrical Safety in the Workplace

   2. 71 Standard for the Installation, Maintenance and Use of Central Station Protective Signaling Systems for Watchman Fire Alarm and Supervisory Service

   3. 72 National Fire Alarm and Signaling Code

   4. 75 Standard for the Fire Protection of Information Technology Equipment

   5. 101 Life Safety Code

   6. 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

   7. 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces

   8. 1221 Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems

9. 780 Standard for the Installation of Lightning Protection Systems

U. Rural Utilities Service (RUS)

1. Specification for Filled Telephone Cables with Expanded Insulation (7 CFR 1755.890)

2. Standard for Acceptance Tests and Measurements of Telecommunications Plant (7 CFR 1755, Bulletin 1753F-201)

V. Safety Code for Mechanical Refrigeration

W. Southern California Public Works Handbook (Green Book)

X. UL Solutions (UL)