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

DESIGN CRITERIA

FOURTH EDITION

January 1, 2024

CALTRAIN DESIGN CRITERIA
FOURTH EDITION
JANUARY 1, 2024

These Caltrain Design Criteria supersede Design Criteria dated August 31, 2020.

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

Document Revision History

Date	Revision Description
April 15, 2007	First Edition
September 30, 2011	Second Edition
August 31, 2020	Third Edition
January 1, 2024	Fourth Edition

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CHAPTER 1

DESIGN GUIDELINES

A. PURPOSE

This Design Criteria Document (Document) establishes the uniform and minimum standards for planning, design, construction, and maintenance of Peninsula Corridor Joint Powers Board (PCJPB or JPB) facilities. This Document has been developed based on best industry standards and accepted practices for Commuter/Class 1 railroads and equals 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. The Criteria do not attempt to cover all situations that might be encountered or requested throughout a project's life, nor is it practical or feasible to do so. Large capital projects and programs such as Electrification and the Dumbarton Rail Corridor will develop their own criteria and standards on an as-needed basis.

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

1.0 CALTRAIN STANDARDS

This Document, together with two other documents (the Standard Drawings and Standard Specifications), supersede the previous issue (August 2020). The other three documents listed below were issued separately and collectively form Caltrain Engineering Standards, or Caltrain Standards.

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

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

c. Computer-Aided Design And Drafting Manual ("Drafting Standard")

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 the event that the Criteria, Standard Specifications, and Standard Drawings conflict with other standards, codes, and regulations, such as the American Railway Engineering and Maintenance-of-Way Association (AREMA), Federal Railroad Administration (FRA) regulations, California Public Utilities Commission (CPUC) General Orders, and codes of other state and local agencies—the most stringent requirements shall take precedence. Caltrain's determinations regarding conflicts shall be final.

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 shall receive prior approval by the Caltrain Deputy Director of Engineering.

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. 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 provide the designer with flexibility, while ensuring 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.

Review of the design by Caltrain is part of the Owner's Quality Assurance process, and is intended to provide some level of independent verification. The designers are ultimately responsible for every aspect of the design, and its overall integrity.

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. San Mateo County Transit District provides administrative and staff support for PCJPB (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, stations, structures, and other facilities, as well as right-of-way [ROW] maintenance), and inspections of bridge structures.

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 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 strives to provide a safe, convenient, reliable, and economical rail transportation system, offering minimum travel times to commuters in the San Francisco Bay Area. Caltrain is constantly seeking to provide new and improved services to meet the needs of the commuters, and to increase operational efficiency.

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   UPRR corridor (trackage rights)

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 8 p.m. and 5 a.m., with occasional daytime service. Caltrain's 2012 dispatch data for freight operations indicate that there are seven round trips per day, on average, along the Caltrain corridor. Typical freight train movements are as follows:

- San Francisco to South San Francisco freight yard – one round trip daily during daytime ("South City" Local)
- South San Francisco freight yard to Redwood City – one round trip daily during nighttime ("Broadway")
- South San Francisco freight yard to San Jose (Newhall Yard) – one round trip daily during nighttime ("Mission Bay")
- South Terminal Area (South of CP Coast) – four round trips daily ("Salinas," "Granite Rock 1," "Granite Rock 2," and "Permanente") and one one-way daily ("MRVSJ")

Over the past decade, about 60 to 80 freight rail cars per day, on average, have run between San Jose and San Francisco in each direction (once loaded, once empty). This translates to 20,000 to 30,000 loaded rail cars carrying 2 to 3 million tons of cargo on the Peninsula each year,

The UPRR and the PCJPB also have joint facility arrangements in a number of locations. The PCJPB is responsible for maintaining a freight yard in South San Francisco and all industrial tracks that are within the Caltrain ROW from San Francisco to CP Lick.

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. Some projects are sponsored and managed by other PCJPB partners. For example, the Santa Clara Valley Transportation Authority has previously sponsored and managed improvements in

Santa Clara County. Also, some cities have previously sponsored and managed improvements through their city limits.

Construction contracts are typically design-bid-build, and are awarded on the basis of a competitive bid, similar to any public works contracts. Advanced procurement contracts may be considered to procure equipment and materials requiring long delivery times, such as ballast, track turnouts, and large signal houses. Caltrain will consider, on a case-by-case basis, design-build delivery methods if the projects are relatively large (in dollar amount and duration) and complex, such as electrification and positive train control (PTC) projects.

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 categories of safety improvements, SOGR, operational enhancements, and new initiatives. Safety improvements are developed through state and federal mandates and/or conditional assessments. SOGR projects sustain the current system and operation, taking into consideration current conditions and the remaining useful life of the asset. Operational enhancements are projects that improve throughput and reliability, while new initiatives address long-range planning efforts and future needs. 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 an updated 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. Electrification

c. Infrastructure changes to enhance train performance

d. Increases of track speeds to accommodate future operations

e. Increases of train service levels

f. Reductions in trip/travel time

g. 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 will be conducted during the project planning phase in accordance with the guidelines and requirements of state and federal agencies listed below.

a. California Environmental Quality Act guidelines

b. National Environmental Policy Act requirements

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, such as the station building at Atherton Station, shall be 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: 20 years, except when noted otherwise

This system, working in concert with the signaling system, is part of communication for train operations. It includes:

i. Communication tower

ii. Data or radio system, including fiber optic

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

iv. Station buildings

v. Parking structures and surface parking

e. Station Communications: 10 years

These are technology-based systems, subject to dynamic and continuous enhancement in technology. They include:

i. Variable message sign (VMS)

ii. Public address (PA) system

iii. Ticket vending machine (TVM)

iv. 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. 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

4.0 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 and its limits, scope, technical criteria; any design variances; key specifications, etc. The DBM shall be reviewed and approved by the Caltrain Deputy Director of Engineering and shall include all assumptions, records of all requests for design exceptions, and a thorough analysis of justifications and their subsequent rejection or approval by Caltrain Deputy Director of Engineering. The DBM shall then be used as a basis for the detailed design and design review.

Prior to each design submittal to Caltrain, the designers shall check all design documents to ensure that the project deliverables are complete and accurate, conform to Caltrain design criteria and standards, and consistent to the best and accepted industry standards and practices. The 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 closure 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.

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. Speed of temporary tracks shall typically be maintained at existing speeds, but in general not less than 65 miles per hour.

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. Design of railroad infrastructure shall meet 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. 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 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, 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

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

The passenger information system is controlled from the Central Control Facility the Centralized Equipment Maintenance and Operations Facility and Backup Central Control Facility, at the Caltrain Construction Support Facility. The other two systems are controlled at Caltrain headquarters in San Carlos, except that Clipper 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 requirements

e. Frequency compatibility

f. Grade-crossing warning system controls

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

h. Grade-crossing warning system time

i. Locking times

j. Power switch machines

k. Signal clearances

l. Signal headways

m. Signal houses, signals, 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)

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. Base stations and antenna towers

b. Data radio system

c. Voice radio system

d. 220 megahertz PTC radio system

e. 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. 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 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 is required with all utility owners. Designer shall obtain and be familiar with all utility easements within the project limits that may be affected. It is most important to perform utility surveys, which consist of a records survey to identify and verify the utilities, potholing, and other field surveys. The owners shall be consulted and coordinated regarding the adequacy of protection, and the design of replacement or relocation of impacted utilities. In the design phase, consideration shall be given to potential impacts to the utility owners and users due to construction. With the exception of temporary overhead utility relocations to allow or facilitate construction of the proposed project, all permanent utilities shall be underground.

10.0 MECHANICAL, ELECTRICAL, AND PLUMBING

Mechanical, electrical, and plumbing components include:

a. Conduit and cable schedules

b. Electrical service

c. Emergency back-up systems

d. Fire protection

e. Lighting

f. Mechanical systems

g. Plumbing

11.0 TRACTION POWER

Caltrain is currently electrifying its railroad. The project will convert Caltrain from diesel-hauled passenger rail cars to Electric Multiple Unit trains for service between San Francisco Station and Tamien Station in San Jose. The 2 × 25 kilovolt (kV) alternating current traction power infrastructure to be installed consists of an overhead contact system (OCS), an autotransformer feed (ATF) system, and a Traction Power Turn System.

The OCS supplies power to the electrically powered rail vehicles at 25 kV, which will use 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 must satisfy single point of failure requirements and include a shunt cable at utility crossings.

The 2 × 25 kV ATF system arrangement reduces the need for traction power substations and would require the installation of only two traction power substations, spaced 36 miles apart. In addition, the system includes one switching station and seven paralleling stations at a spacing of approximately 5 miles. The paralleling stations provide additional power support to the power distribution system and permit increased spacing of the primary traction power substations. In addition to reducing the number of traction power substations—and thereby minimizing the introduction of new, large equipment installations into the corridor—the auto-transformer feed arrangement for implementation along the Caltrain corridor would help reduce electromagnetic fields (EMF) and electromagnetic interference (EMI), because the arrangement includes two parallel aerial feeders, one on each side of the alignment. The currents in the parallel feeders flow in the opposite direction to that in the main catenary conductors, reducing the EMF/EMI effects created by current flow in the OCS.

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.

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

12.0 POSITIVE TRAIN CONTROL

Caltrain is developing and implementing a PTC system as required by the Rail Safety Improvement Act of 2008. As part of the PTC project, the PTC team has completed the data collection of PTC critical features along the Caltrain corridor. These critical features include wayside track and signal GPS data points and 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

As part of the Caltrain PTC system, 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.

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 comfort, constructability, and current and future capacity. 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 track component standardization, must be recognized and implemented in the early phase of planning and design. 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 interaction of these elements are identified and accommodated.

The Caltrain commuter rail system consists of revenue tracks and nonrevenue tracks. All Caltrain main tracks are ballasted tracks. Direct fixation is allowed with the approval of the Caltrain Deputy Director of Engineering. The revenue tracks, carrying passengers, include main tracks, sidings, station tracks, and temporary (or shoofly) tracks. Union Pacific Railroad (UPRR) also operates freight service on all these tracks.

The nonrevenue tracks include yard, industrial, and other tracks that are constructed for the purpose of switching, storing, or maintaining rolling stock or other on-track equipment not in revenue service. Tracks that are for emergency set out, MoW equipment or rolling stock storage, or maintenance purposes shall be designed as non-revenue tracks.

1.0 REGULATORY AND INDUSTRY STANDARDS

Track construction and maintenance shall conform to the general requirements described in **Chapter 1, Design Guidelines**, and all required codes and regulations, and standard industry practices and recommendations in the **Appendices**, specifically 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) Applicable General Orders

c. American Railway Engineering and Maintenance-of-Way Association (AREMA)

The designer shall use these criteria in conjunction with other Caltrain Standards, namely Caltrain Standard Drawings (SD-2000 series) and Standard Technical Specifications (Division 20, Track).

2.0 DESIGNERS' QUALIFICATIONS

The designers shall have at least 5 years of experience as the lead designer of railroad track system, including main lines and yards. Possession of registration as a civil engineer, though not required, is highly desirable. Specifically, the designers shall have the following qualifications.

a. 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 such as UPRR, High Speed Rail and AREMA.

b. The designers shall have a good understanding of track structure and its components (joints, weld, compromise joints, and insulated joints), and general civil engineering principles pertaining to subgrade or trackbed and drainage requirements.

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

d. 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 superelevations. They shall also have knowledge of spiral length requirements for commuter, freight, and high-speed rail systems.

e. For special trackwork the designers shall have experience in designing special trackwork track geometry (turnouts or switches, crossovers, and track crossings). 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.

f. The designer shall have experience in track construction sequencing and track construction under active conditions 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 yard tracks may be designed and constructed utilizing wood ties, screw spikes and 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. Maintenance activities include welding to eliminate the remaining rail joints. 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. The subballast is either an earth-compacted underlayment or a hot-mixed asphalt concrete (HMAC) layer. HMAC is used to minimize local settlement due to differences in track modulus. Its general applications include bridge approaches, turnouts, crossovers, passenger stations, and at-grade crossings. Refer to Caltrain Standard Drawings for typical sections of track structure.

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

1.0 DRAINAGE

The most essential element for maintaining a stable track structure is drainage. Effective and efficient drainage keeps the track well drained and hence in a relatively moisture free environment.

The track structure requires an effective drainage system to keep the subgrade well drained and stable. 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 the trackwork design. Provisions shall be made for ditches, underdrains (at train stations), and other drain features, as necessary to maintain a stable roadbed. The collected water shall eventually discharge into the municipality drainage system. 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 the bridge approaches, positive drainage shall be provided, sloping away from the abutments as well as to the sides toward the embankment. Side slopes shall be protected with proper erosion control measures such as riprap.

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 have adequate width for walkways and a positive slope to either side of the track to keep the subgrade free of standing water.

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 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.

3.0 SUBBALLAST

Subballast is a uniform layer of approved backfill, placed and compacted over the entire width of the subgrade. Subballast shall always be considered when the subgrade has poor drainage, is of poor material, or is subject to a seasonally high or perched water table.

Similar to subgrade, subballast shall be consistent with Caltrain Standard Track Sections for ballasted track and AREMA. Subballast shall have a minimum 2 percent cross slope toward the side ditch or embankment slope, or another longitudinal drainage system. The subballast for all tracks shall consist of a uniform minimum 6-inch layer of base material. Where a service road is placed adjacent to the track, the subballast shall extend across the full width of the road section. To increase the performance life and reliability of the track structure, biaxial geogrid shall be included in the subballast design, unless the subgrade has an R-value greater than 40 or will be stabilized with lime or cement. Where the subgrade is soft or has relatively poor drainage, the subballast shall be increased to 12 inches over geofabric; or, if necessary, shall consist of at least 8–inch-thick HMAC over geofabric.

For yard, non-revenue, and temporary tracks, the sub-ballast requirements are the same as for revenue main tracks, exceptions will need to be submitted for approval to the Caltrain Deputy Director of Engineering in preliminary design stage.

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 the 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. 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

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 12 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 be crushed rock of acceptable parent material, conforming to Caltrain Standard Specifications, and shall be obtained from Caltrain-approved quarries. Ballast shall be AREMA Grade Size 4A for mainline track and AREMA Grade Size 5 for walkways.

For tangent main tracks, including bridges, the minimum ballast depth shall be 9" for wood tie track and 12" for concrete tie track, measured from the bottom of the tie. For a curve superelevated track, the maximum ballast shall not exceed 18" maximum at any point below bottom of tie. The ballast depth outside these limits must be approved by the Caltrain Deputy 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 Deputy 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 new construction of main tracks. Construction of temporary main tracks may use wood ties with lag screws and elastic fastener. Yard tracks can be constructed with timber ties (at 21-inch spacing), or on concrete ties that are specifically designed for yard tracks. 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; however, 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. Timber ties for main tracks shall be 7 inches by 9 inches by 9 feet long, spaced at 19½ inches.

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 shall be used in areas where track modulus changes significantly. These areas include approaches to bridges and to at-grade crossings. Ten-foot-long transition timber ties shall be used for standard timber tie track segments, and 10-foot-long transition concrete ties shall be used for standard concrete tie track segments. Refer to Caltrain Standard Drawings for further details.

7.0 RAIL

The standard rail for all main tracks, including the special trackwork, is New 136# Premium Head Harden rail. Temporary main line or shoofly tracks expected to be in service for less than 2 years may be constructed utilizing Class 1 rail (as defined by AREMA). Rail shall be pre-tested and approved 136# secondhand rail.

8.0 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. Nonstandard fastening systems include cut spikes, screw spikes, track bolts, nuts, spring washers, tie plates, rail anchors, insulated joints, standard joint bars, and compromise bars.

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

9.0 BUMPING POST

Tracks designated to be used by passenger equipment shall be equipped with hydraulic fixed or buffer typed bumping post. The bumping post shall be capable of stopping a 10-car train set travelling at 20 MPH. The bumping post shall be of a proven model and type used in similar passenger systems as Caltrain. The type and model and its test results shall be submitted to Caltrain for approval. 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 commuter 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 the 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 • Vehicle truck/wheel forces
Horizontal curves (maximum degree of curve – D_c)	• Design speed • FRA curve speed • Trackwork maintenance • Vehicle truck/wheel forces
Compound and reverse curves	• Passenger comfort • Vehicle suspension travel • Trackwork maintenance
Length of spiral transition curve	• Passenger comfort • Trackwork maintenance • Vehicle suspension travel
Superelevation	• Passenger comfort • Vehicle stability • FRA • Freight Operations
Superelevation runoff rate	• Passenger comfort

Design Elements	Major Limiting Factors
Superelevation runoff rate (cont.)	• Vehicle suspension travel • FRA • Freight Operations
Vertical tangent between vertical curves	• Passenger comfort • Turnout locations • Freight Operations • Vehicle limitations
Vertical curve/grade (maximum rate of change)	• Passenger comfort • Vehicle suspension travel • Slack action and train handling • Horizontal and vertical tangents • Freight Operations
Special trackwork	• Passenger comfort • Design speed • Diverging route design speed • Trackwork maintenance
Station platforms	• Vehicle clearances • Americans with Disabilities Act platform gap requirements • Passenger train set configurations
Mixed use of commuter/freight railroads	• Vehicle clearance • Trackwork maintenance • Compatibility of operations

1.0 GENERAL DESIGN REQUIREMENTS

Track alignment for main tracks and passing tracks shall be designed to 110 miles per hour (mph) and FRA Class 6 track standards, except for freight traffic, which shall be designed to 60 mph. Upon completion of the track construction, Caltrain will determine the appropriate operating speed. Shoofly tracks—temporary detour tracks during construction—shall be designed to match the current maximum authorized operating speeds as a minimum. Curves should be designed to the highest possible for mixed traffic based on the design criteria, train performance and local conditions.

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, superelevations (total, unbalance, actual)

2.0 CRITERIA LEVELS

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

a. Preferred Standards

This case shall be applied to main line and siding tracks, based on an evaluation of maximum passenger comfort, maximum speed, initial construction cost, and maintenance considerations. These standards shall be used where there are no significant physical restrictions or increases in construction cost. If there is a construction cost increase, a benefits cost analysis shall be provided showing the estimated cost increase and benefits of the proposed design.

b. Absolute Minimum Standards

This case shall be applied where physical restrictions prevent the use of the preferred standards. The absolute minimum standards are determined primarily by the rail car design and safety of operations, with passenger comfort as the secondary consideration. The standards shall meet federal and state minimum requirements and the approval of the Caltrain Deputy Director of Engineering.

c. Yard and Nonrevenue Track Standards

Track design criteria for rail shall be the same as for main track. The track geometry shall be based on class of track and track speed. All track 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 Deputy 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 exceeds the existing speeds.

3.0 HORIZONTAL ALIGNMENT

The horizontal alignment of track consists of a series of tangents joined to circular curves and spiral transition curves, as measured along the center line of track. 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: 20 feet minimum
- Main track to switching leads: 25' 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

Horizontal tangents shall be designed based on the longest rail car length for the rail corridor and ride comfort for the passengers. A formula for tangent length in feet ($L = 3V$), where V is the design speed (mph) for ride comfort is based on the rail car traveling at least 3 seconds on tangent track between two curves. Tangent shall extend at least 100 feet beyond both ends of station platforms, and at-grade crossings.

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

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

Tangent Location on Mainline Tracks	Minimum Tangent Length (feet)	
	Preferred	Absolute Minimum
Between reverse curves	3V	100
Between point of switches (PS) of turnouts (TOs)	50	20*
Between PS and curve	100	15*
Between PS and platform	100	60
Between PS and grade crossing	100	50
Between PS and last long tie of TO	60	15*
Between curve and platform	60	30
Between curve and grade crossing	50	10

Notes:
* Tangent length shall not be less than the length of stock rail projection.
V = design speed in the area, mph

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

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

Tangent Location on Yard and Nonrevenue Tracks	Minimum Tangent Length (feet)	
	Preferred	Absolute 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.

3.3 HORIZONTAL CURVES

Horizontal curves shall be designed for the maximum speeds possible above the existing maximum authorized speed (MAS) without being cost prohibitive (e.g., requiring additional ROW, or impacting existing improvements like buildings or flyover supports). The spiral length shall be sufficient to allow superelevation runoff for the future maximum design speed even if the existing MAS is less than the future maximum speed.

Design speeds for passenger train 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	15
Yard lead	25	15
Yard track	15	10

Prior to the design of the track geometry, the designer shall consult with the Caltrain Deputy 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 Deputy 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 less than 30 minutes requires the approval from the Caltrain Deputy 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

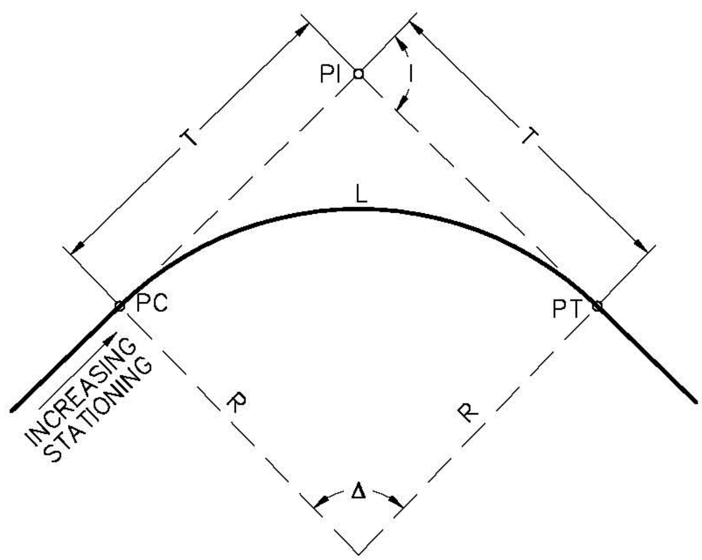
The circular or simple curve for the track geometry shall be defined by the chord definition and specified by its degree of curve (D_c). The degree of curve has been adopted as a unit of sharpness and is defined as the central angle subtended by a 100-foot-long chord for ease of field layout. The degree of a curve must be a whole numbers 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 Δ = central angle

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

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



where:

Δ	total intersection angle
L	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: Simple Circular Curve

4.0 SUPERELEVATION

Superelevation is the height difference in inches between the high (outside) and low (inside) rail. Superelevation is used to counteract, or partially counteract, 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 superelevated track results in improved ride quality and reduced wear on rail and rolling stock.

The maximum actual superelevation for Caltrain tracks is 5 inches. All curves with superelevation of 5 inches or more shall require the approval from the Caltrain Deputy 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 = total superelevation required for equilibrium, in inches.
pV = maximum 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 Deputy Director of Engineering.

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 (simple spiral) 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

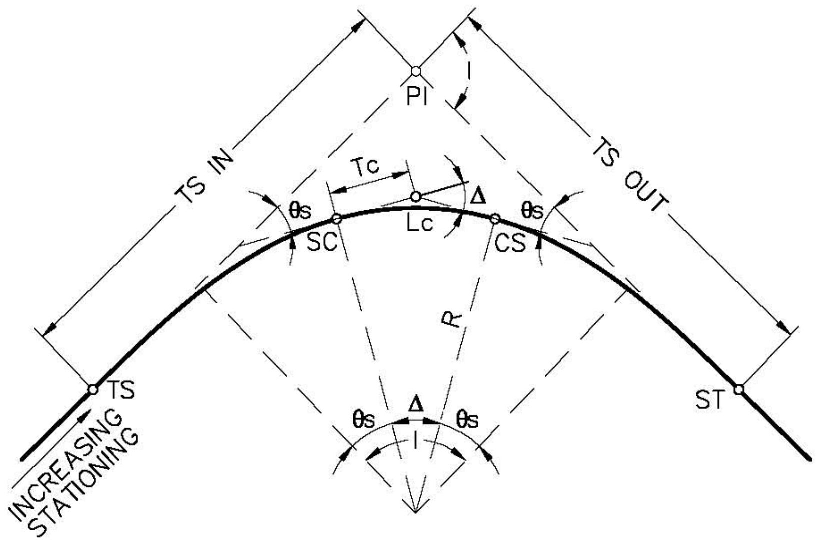
The spiral transition curves shall be provided between circular curves and horizontal tangents. The spiral transition curve shall be the “ten-chord spiral,” as defined by the AREMA Manual for Railway engineering; or the “clothoid spiral,” as defined by drafting software AutoCAD. See **Figure 2-2** for 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 curve 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, and CHSRA Design Criteria, 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	$L_s = 82E_a$	$L_s = 82E_a$
Minimum Segment	$L_s = 2.64V$	$L_s = 2.20V$

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 Deputy Director of Engineering.

6.0 COMPOUND CIRCULAR CURVES

Compound circular curves may be used, provided that they are connected by an adequate spiral based on the difference between the required superelevations of the curves. The same speed shall be used to determine the spiral lengths and superelevations 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 shall be defined by the profile grade represented by the top of rail elevation of the low rail. This low rail is the grade rail.

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 continuous main line grade along the Caltrain commuter corridor is 1 percent. The preferred maximum design gradient for long continuous grade shall be 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 Deputy 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. 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, higher fuel consumption 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 shall be designed in accordance with the requirements for high-speed main tracks and shooflies, as recommended in AREMA Manual for Railway Engineering shown in the following formula:

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

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:

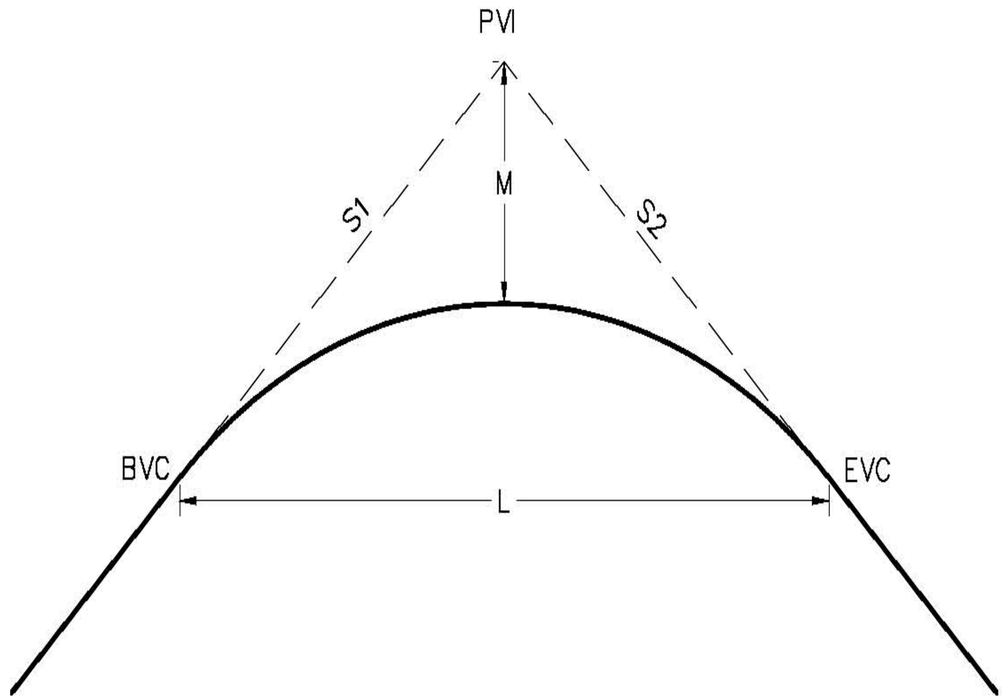
Train Type	Recommended Vertical Acceleration (ft/sec^2)
Passenger Train	0.60 (0.019 g)
Freight Train	0.10 (0.003 g)

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 inside vertical curves. End of platform and PS shall be located at least 100 feet from the beginning and end points of the vertical curve.

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 a distance of 3,000 feet, may cause excessive dynamic forces and handling problems for trains. The Caltrain Deputy 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:

M = [(EL @ PVI x 2) – (EL @ BVC + EL @ PVI)] / 4

When the vertical curve is concave upward:

M = [(EL @ BVC + EL @ EVC) - (EL @ PVI x 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 (or switches), crossovers, and track crossings. All special trackwork design 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 Deputy 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 switch) that are integrated with signal work.

See **Figure 2-4** for layouts of various types of 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:

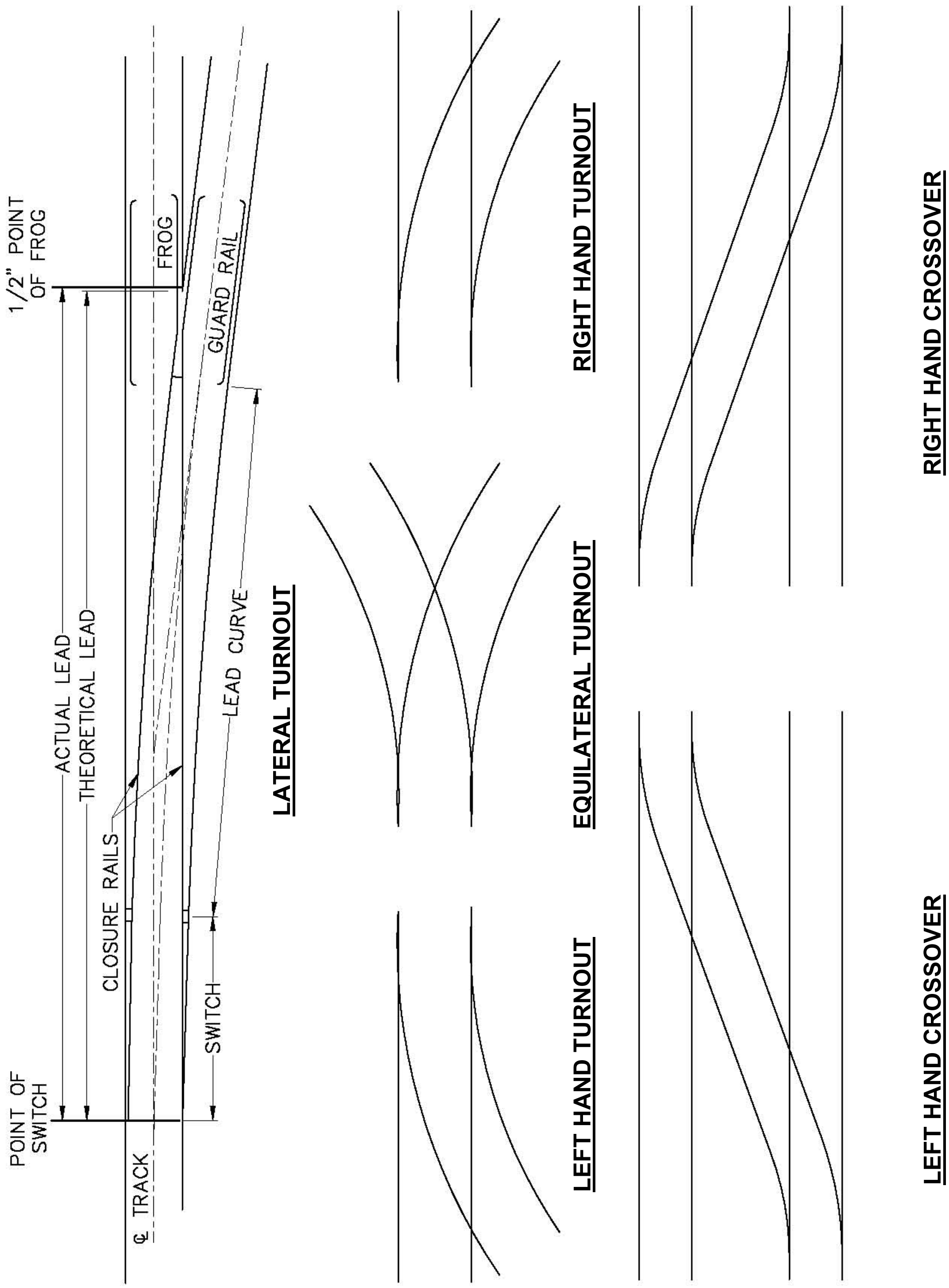


Figure 2-4: Turnouts and Crossovers

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

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

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

d. 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 Deputy 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. 50 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 Deputy Director of Engineering. Design for conditions listed below shall require the approval of the Caltrain Deputy 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. Double point split switch derails shall be power operated if the main line or controlled siding switch is power operated.

Hinge or flop type derails may be used in yard and industry tracks for the protection of personnel or to prevent fouling of non-main line or siding tracks.

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 CROSSINGS

Railroad crossings are where tracks cross each other. Installation of railroad crossings shall require approval from the Caltrain Deputy Director of Engineering and shall take place only where there is no other economical 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 to meet maintenance needs. The measurement length shall begin 25’ from the derail or 50 feet from the clear point if no derail is installed and end at 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. Each setout track shall include a mean of access for a 40-foot-long rubber tire truck trailer for deliveries and pickups. When relocating and/or removing a setout track, construction staging shall be implemented to allow for MOW access to the setout track at all times. All turnouts for new setout tracks shall be constructed using a #10 turnout with a jump frog. Track shall be spaced 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 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 following acceleration and deceleration charts for the current Caltrain consists (**Figures 2-5 through 2-7**) were developed by Systra Consulting. They were contained in their April 4, 2004, report titled "*Acceleration and Deceleration Performance of Caltrain's FP40PH and MP36 Locomotive,*" and their December 31, 2006, report *"Signal System Headway/Capacity Study."*

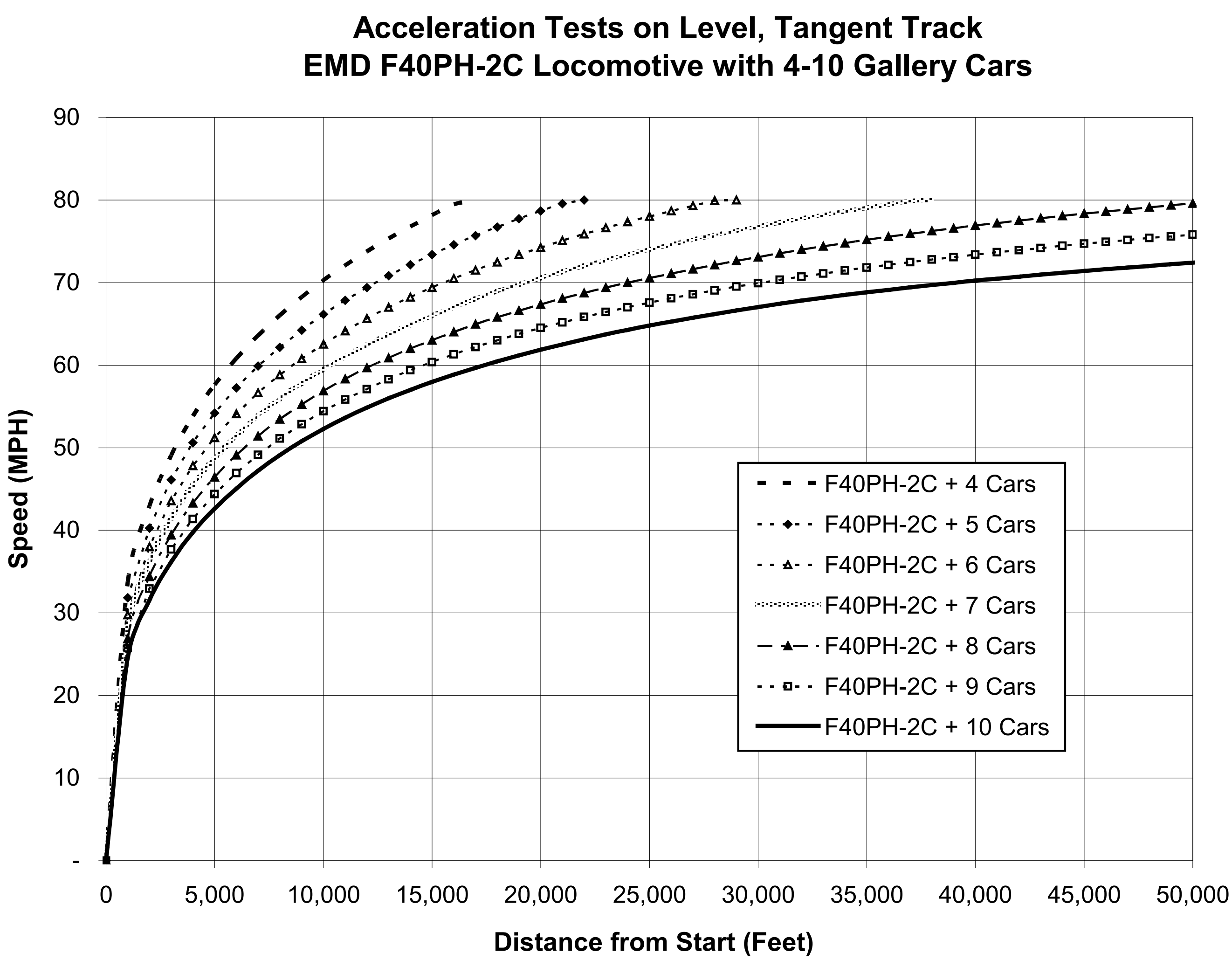


Figure 2-5: Acceleration Chart for EMD F40PH-2C Locomotive

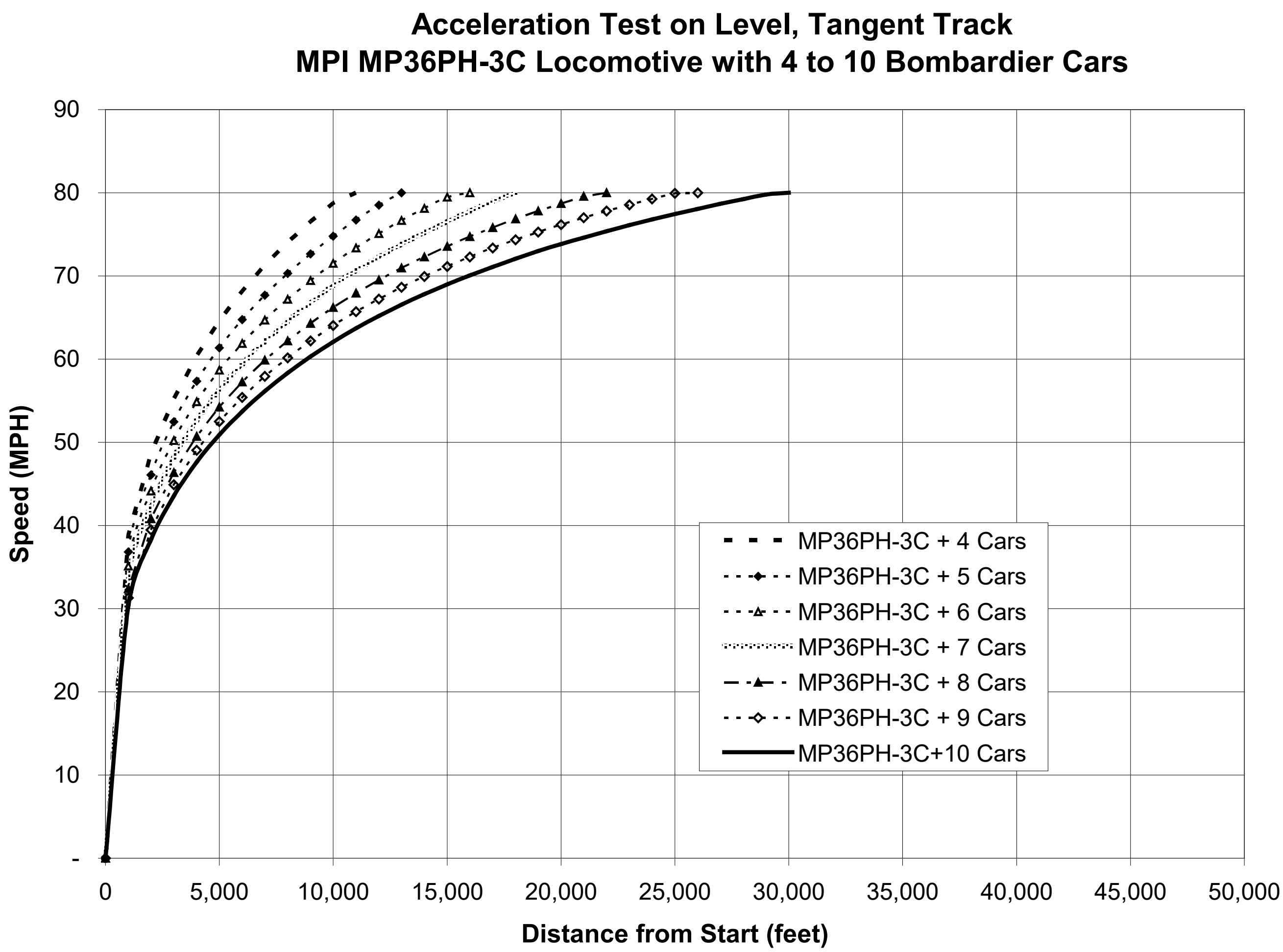


Figure 2-6: Acceleration Chart for MPI MP36PH-3C Locomotive

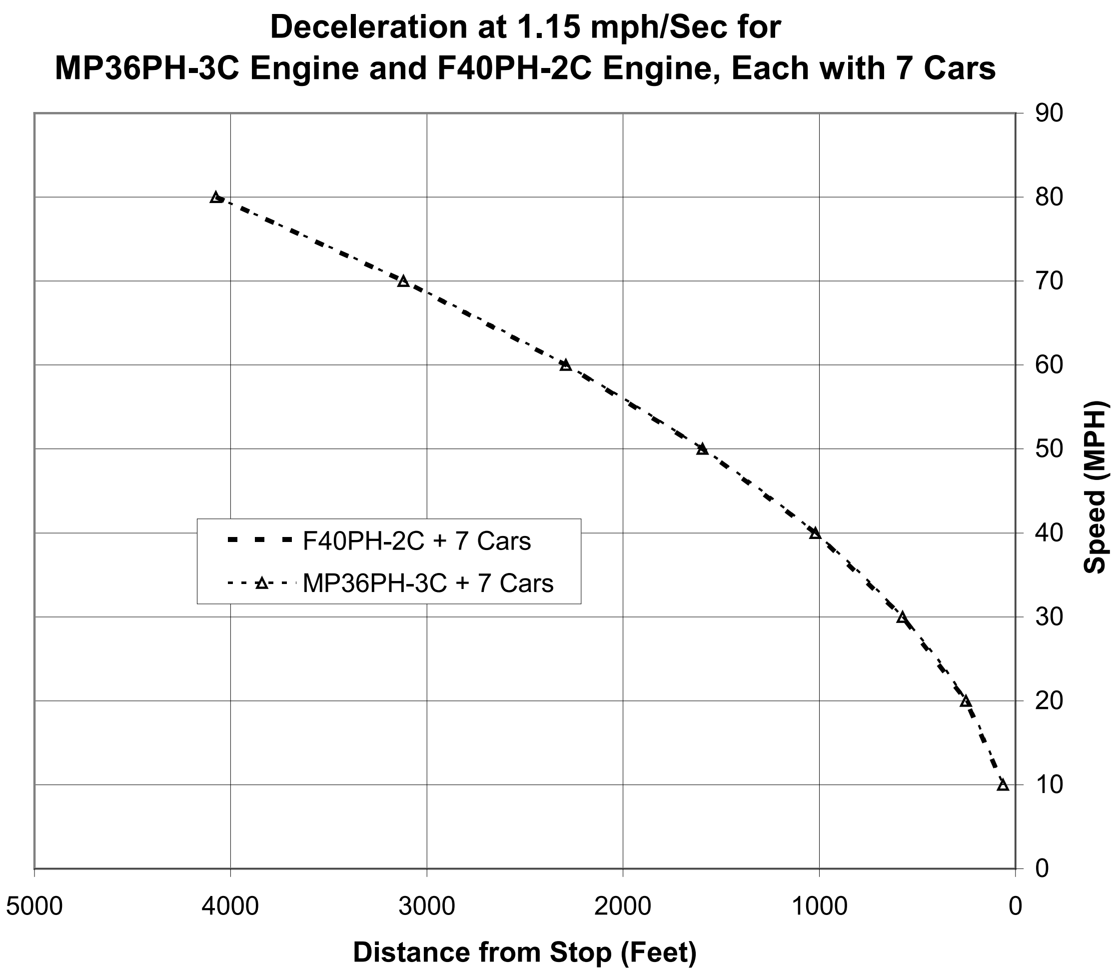


Figure 2-7: Deceleration Chart for MP36PH-3C Locomotive and F40PH-2C Locomotive

END OF CHAPTER

CHAPTER 3

STATIONS AND FACILITIES

A. GENERAL

The objective of this chapter is to provide the designers with the minimum requirements for planning and design of new and temporary stations and their related facilities. These facilities include furniture, amenities, signage, fencing, railing, parking, lighting, and platform access. All station rehabilitation shall follow the requirements in this chapter. Any deviations from these minimum requirements shall require a written approval from the Deputy Director of Engineering.

The design requirements for passenger information, fare collection or payment, and regulatory and safety advisories, as well as the security system are covered in **Chapter 4, Station Communications**. 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 Caltrain surface 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 safety and security elements of the design shall be reviewed by an appropriate CPTED-certified professional 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 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 source of passenger traffic. Specifically, Caltrain's stations shall:

a. Be a safe and comfortable area for passengers

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

c. Provide Caltrain transit information and schedule updates to passengers

d. Be attractive to passengers and community alike

A station shall be as pleasant as possible for the passengers. It should to the extent possible provide safe 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, parking, platforms, possible buildings, 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 station 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 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 bus service and other transit systems: Integrate Caltrain with other public transportation systems for the convenience of the 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 of the California Building Code, Part 11, Green Building Standards Code (CalGreen), in following aspects: materials efficiency, water efficiency and conservation, materials conservation and resource efficiency, energy efficiency, and environmental quality.

2.0 CODES AND REGULATIONS

Stations and facilities design shall comply with these Criteria and the accompanying Caltrain Standard Drawings and Standard Specifications. Stations and facilities design shall comply, unless noted otherwise, with the latest revision of the codes and regulations listed in the Appendix C. Should there be conflicts between codes, then 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)
3	Mountain View	4	VTA (bus and LRT)
4	**Diridon**	3	VTA (bus and LRT)
5	**Millbrae**	7	SamTrans, BART, connection to San Francisco International airport
Tier 1 Stations (minimum two connections)			
1	Hillsdale	8	SamTrans, AC Transit, shuttles
2	**Menlo Park**	11	SamTrans, shuttles
3	Redwood City	5	SamTrans, shuttles
4	**Santa Clara**	16	VTA, ACE, connection to San Jose airport

	Station Name	Ridership Rank	Transit Connections
Tier 2 Stations			
1	San Mateo	9	SamTrans
2	**San Carlos**	13	SamTrans, shuttles
3	Tamien	14	VTA (bus and LRT), Caltrain San Jose-Tamien shuttle
4	California Ave	12	VTA (bus), shuttles
5	**Burlingame**	15	SamTrans, shuttles
6	Belmont	19	SamTrans, shuttles
7	Bayshore	24	Muni (bus and LRT), SamTrans, shuttles
8	Sunnyvale	6	VTA (bus)
Tier 3 Stations			
1	22nd Street	10	Muni (bus)
2	San Antonio	18	VTA (bus), shuttles
3	Lawrence	17	Shuttles
4	San Bruno	20	SamTrans
5	South San Francisco	22	SamTrans, shuttles
6	Morgan Hill	25	VTA (bus), MST
7	Hayward Park	21	SamTrans, shuttles
8	Gilroy	23	VTA (bus), MST, Greyhound
9	College Park	27	VTA (bus)
10	Blossom Hill	26	VTA (bus), shuttles
11	San Martin	28	VTA (bus)
12	Capitol	29	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.

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 rehabilitation of existing stations shall consider other stakeholders, such as the 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" of 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 characters: 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 Historic Preservation Act. As part of the environmental clearance process, the 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 the 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. TOD, however, must be designed to balance between the objectives of providing a convenient and pleasant experience for Caltrain passengers and providing opportunities for mixed-use development.

For rehabilitation and renovation 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 development 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 track 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. 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 mobility-impaired persons, their space needs, and special boarding needs

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

d. Clear sight distance for passengers of station signage

e. Clear sight distance for train crew

f. Operations configuration: bicycle car, ADA-accessible car, boarding assistance area (BAA), and mini-high platforms are on the northern third of the platforms. This passenger circulation pattern will change after completion of Caltrain Electrification, because all electrical multiple unit (EMU) cars are ADA accessible and there are more bicycle cars in a typical train consist.

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

h. Uneven platform use: tendency of passengers to congregate on the northern third of the platform. This tendency will change after completion of Caltrain Electrification, due to passenger vehicle configuration change.

i. Bicycle users

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 by the Caltrain Deputy Director of Engineering. Refer to **Figures 3-1** and **3-2**. For mini-high platforms, see the Caltrain Standard Drawings.

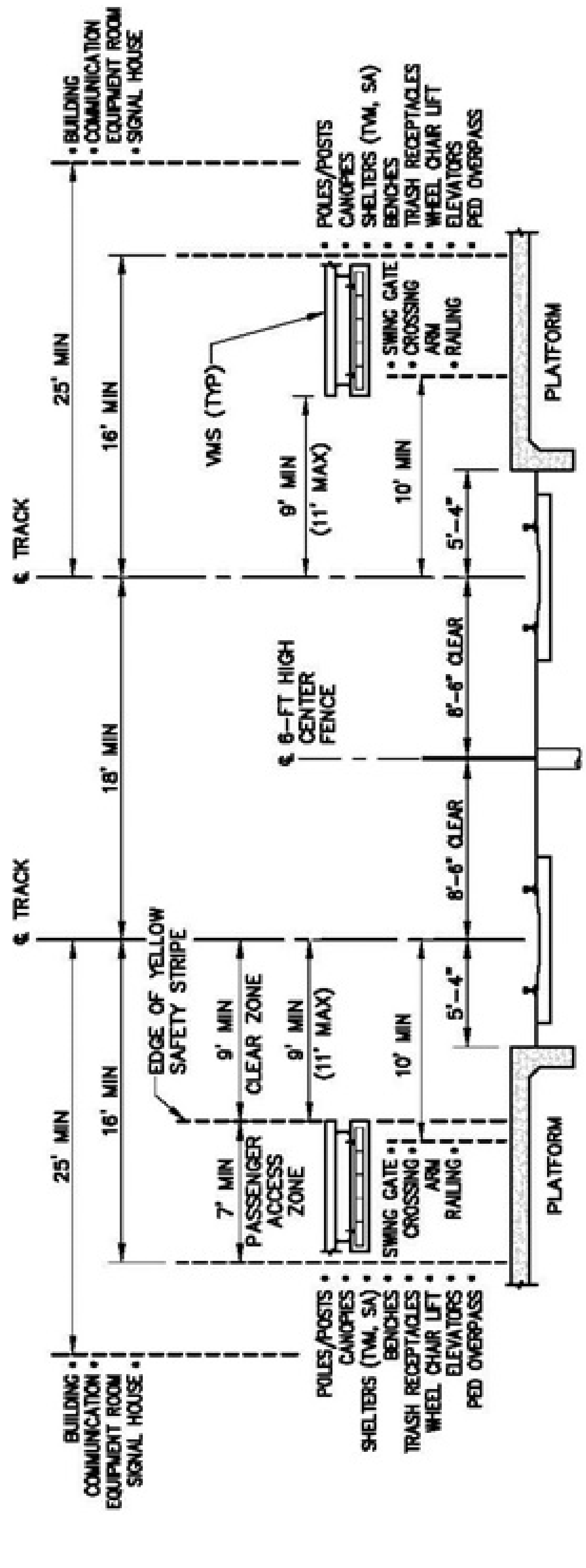
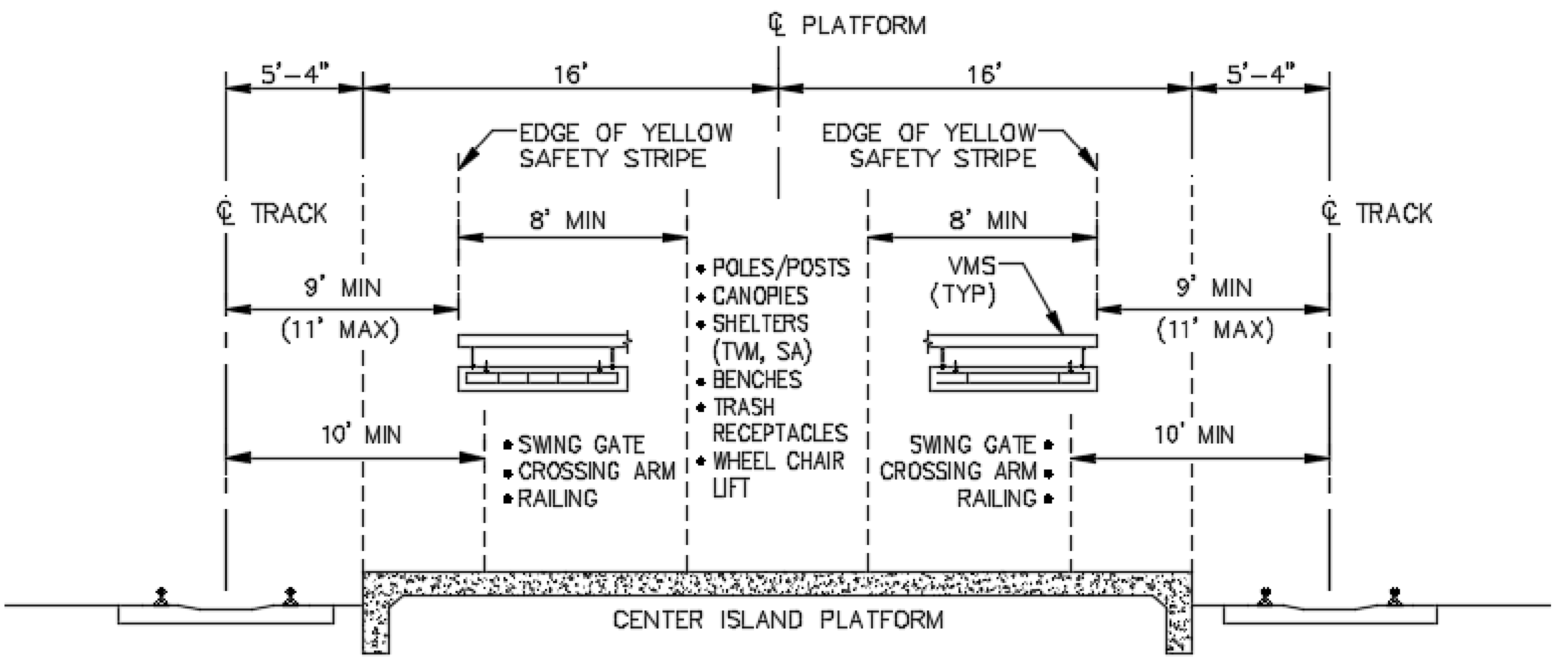


Figure 3-1: Minimum Clearances at Station Platforms, Outboard Platform



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 (Outbound platform)

17 feet (Center island platform)

Minor structures at stations include canopies, passenger and 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. Variable 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 the rail. The overhead structures include bridges and overhead pedestrian crossings. 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. The station designers shall seek input from Caltrain in determining requirements for possible future station expansion and provision for Electrification and Positive Train Control systems.

The station layout shall include provisions for roadway maintenance trucks 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: 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.

The outboard platform (Figure 3-4) must be approved by the Caltrain Deputy Director of Engineering.

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 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 the locomotive of 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 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 inputs 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.

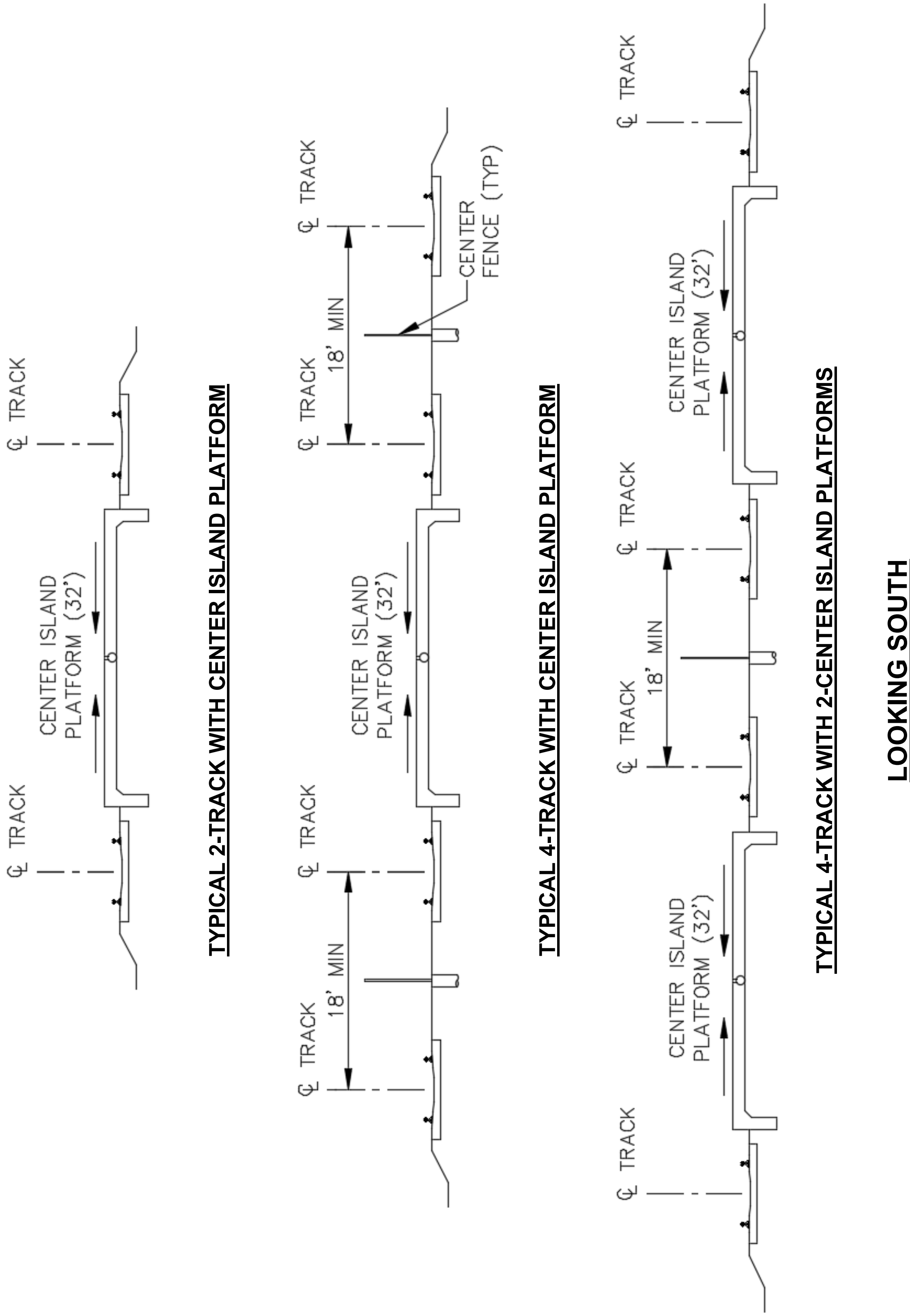


Figure 3-3: Typical Center Island Platform Arrangements

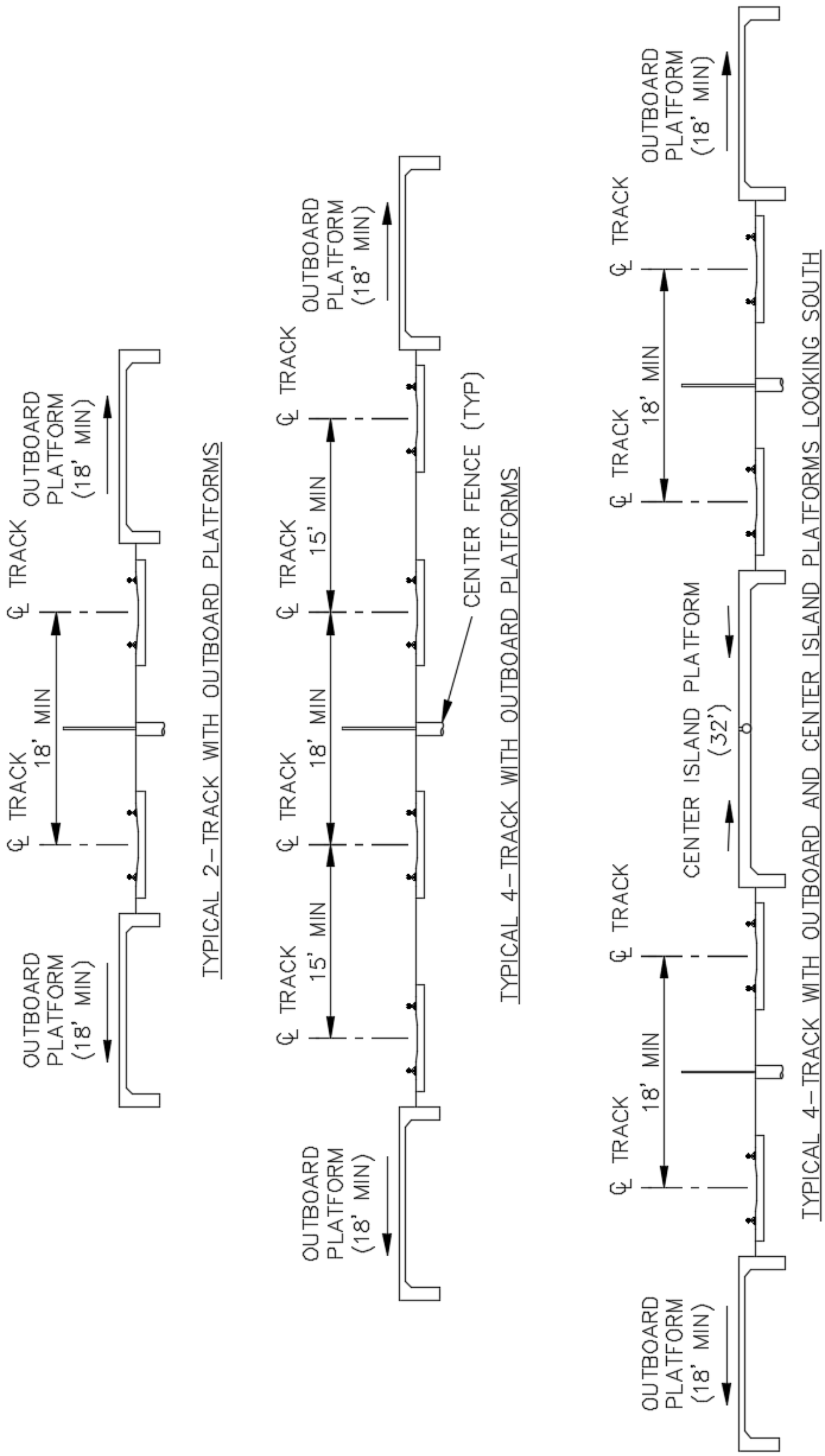


Figure 3-4: Typical Outboard Platform Arrangements

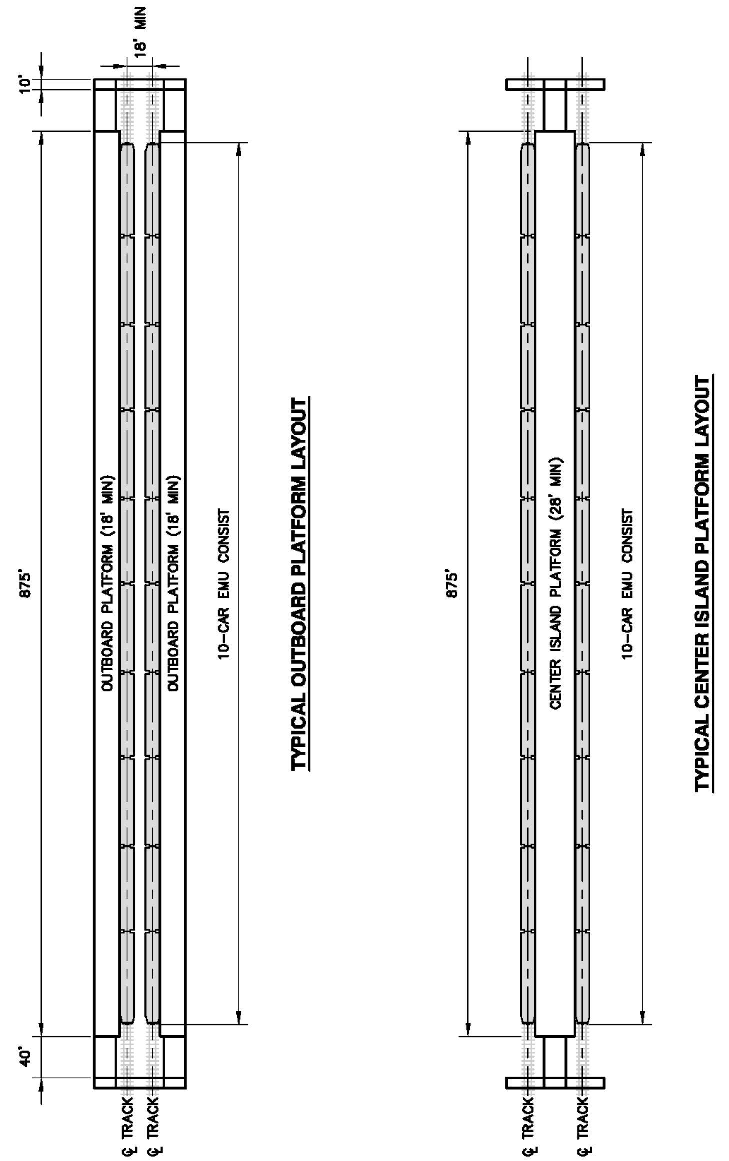


Figure 3-5: Typical Platform Footprint Requirements

b. Platform width: The platform shall be a minimum of 18 feet (20 feet preferred) wide for an outboard platform and 32 feet wide for a center island platform. The wider center platform is needed to accommodate stairway, ramps, and/or elevator, 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 the platform for 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 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 be sloped away from the tracks, to minimize the risk for persons in wheelchairs of natural rolling effects 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, either horizontally or vertically curved, shall be avoided. If unavoidable, the curve shall be as shallow a curve as possible, to no more than 1 degree and 30 minutes, and at either end of the platforms. Platforms on curves shall require prior approval from the Caltrain Deputy Director of Engineering.

f. Track centers: Track centers at station platforms shall be expanded to a minimum of 18 feet to accommodate center fencing, so that the fence is at least 8 feet 6 inches 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 platform are generally the same as for the permanent station, with the following exceptions:

a. The minimum platform length is 500 feet, with a minimum platform width of 12 feet. This platform length allows for the functional operation of a five-train consist. Additional platform length will be required to accommodate longer train sets when service level is increased in the future.

b. The platform may be constructed of asphalt concrete to expedite construction. ADA-compliant warning tactile is required at the boarding edge of a platform, except at a holdout rule station. The selected warning tactile 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 in 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 TACTILE

Detectable warning tactile is an ADA requirement safety feature consisting of a band of contrasting color and texture used to help sight-impaired persons demark 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 tactile also identifies track crossings and signifies clear points of crossing.

The tactile shall be ADA-compliant and installed at the following locations:

a. Platform edge on the track side: The tactile 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 tactile shall be 2 feet wide along the edge of the mini-high platforms.

c. Station at-grade pedestrian crossings: The tactile shall be 3 feet wide and placed in front of the crossing gates with an in-line dome design. This shall not be confused with the tactile at platform edges, which call for a staggered dome design.

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 tactile. 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 door.

2.3 DETECTABLE DIRECTIONAL TACTILE

Platforms shall be treated with directional and guide tactiles to assist sight-impaired persons in locating the persons needing assistance (PNA) shelter, and one of the TVMs at each platform. The tactile shall also be installed to identify the limits of the mini-high platforms. For sight-impaired users, consistency in directional tactile design makes Caltrain station access more predictable and easier to navigate. Complex directional tactile systems are not encouraged. Additionally, direction tactiles other than those described above shall require prior approval from the Caltrain Deputy Director of Engineering. See Caltrain Standard Drawings (SD-3000 series) for further details.

2.4 MINI-HIGH PLATFORM

Mini-high platforms, currently available at some stations, shall be installed to assist with boarding of mobility-impaired persons at all stations. The mini-high platform shall be in line 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 BAA shall be provided on each platform. The BAA shall be in line 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 mobility-impaired persons.

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 only accessible 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 utilities duct bank shall be located so that the utilities access covers such as vaults, pull boxes, handholes, and maintenance holes are not in the main pedestrian walkways or passenger circulation area. For center island platforms, the duct bank shall be offset from the platform centerline to avoid 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 positive rolling effect 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-mixed 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 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 need to 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 a case 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, foot, and other transit systems (SamTrans, AC Transit, Muni, VTA, Amtrak, BART, ACE, Capital Corridor, etc.) To promote the use of the station 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, 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. Passengers tend to congregate at the northern end of the platforms because Caltrain bicycle cars and ADA cars are the north first and second cars, and the TVMs are also near this end of the platform. This tendency will change after completion of Caltrain Electrification, due to passenger vehicle configuration change.

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 mainstream 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 telephone booths, pylons, advertising displays, coin changers, 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

Foot: Provide the shortest travel path from station entrance 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.

Motorcyclists: Motorcycle parking shall be considered, and separate provisions shall be made in the layout for secure and economical parking of motorcycles close to the platform in areas where automobile parking may not be possible.

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 passenger circulation path from the edge of the yellow safety stripe shall be provided along the entire length of the platform to promote a wide and clear line of sight or visibility of approaching trains. There shall be no columns, posts, and 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 separate platforms for each operating track, with a center fence between the tracks to prevent persons from crossing between platforms at grade. Pedestrian underpasses are preferred to overhead 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 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. Overhead 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 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 the 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 the overhead. 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 platform, 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 and with end ramps of HMAC at 1:8 slopes.

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 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. 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 changes in grade make vertical access to platforms a necessity. At locations where grade changes of 10 feet or more occur, for example at pedestrian overhead, elevators may be considered. Exterior stairs at Caltrain stations are cast-in-place concrete. Use of precast concrete or steel stairs is discouraged.

3.3.2 Elevators

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

Because elevators are typically prone to maintenance for functional and general upkeep, they are generally economically prohibitive. 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 approval of the Caltrain Deputy 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 through local jurisdiction 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 platform. 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, motorcycle parking, 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. The 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 F** 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 the poles or posts shall be at adequate height.

Caltrain Standard Drawings provide a general layout and the design requirements of 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 mobility-impaired persons), benches, and trash receptacles. The minimum amenities shall include a passenger information system—including a public information 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 mobility-impaired passengers. Each of these is described in the following sections.

1.1.1 Passenger Shelters

In general, one shelter per platform shall be provided for each car. The shelters shall line up with the car door, as shown in the Caltrain Standard Drawings. Additional shelters will be required to accommodate longer train sets when 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 mobility-impaired persons. This shelter shall be located in the BAA.

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.

1.1.2 Ticket Vending Machines 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. 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 the shelters), they shall be heavy-duty, scratch- and vandal-resistant, and secured to the platform. The benches shall have an arm rest 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 can receptacles shall be of concrete construction and a standardized top-loading heavy type as a deterrent to vandalism. Trash cans openings shall have minimal exposure to wind and rain. At certain high-volume and key stations, recycle 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 are not allowed to 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, spaces under elevated track supporting structures with sturdy fencing and a roof, 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 is potentially hazardous for 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 to passengers is through the Caltrain Central Control Facility in San Jose. The remaining subsystems (fare collection and security cameras) are connected to Caltrain headquarters in San Carlos.

All station amenities shall be securely fastened to the platform or pole/post, as applicable. For placement of station amenities on the platforms, see Caltrain Standard Drawings. For technical details, refer to **Chapter 4, Station Communications**.

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 Variable 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 hearing-impaired persons.

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. Typical 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 overhead.

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 overhead.

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 the 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 overhead.

2.1.4 Talking Signs

Talking signs for visually impaired persons are currently available at the Caltrain terminal stations at the San Francisco 4th and King Station and the San Jose Diridon Station. Talking signs are not an ADA requirement.

2.1.5 Public Pay Phones

Public pay phone if provided shall be accessible meeting ADA requirements.

2.2 FARE COLLECTION SYSTEM

The fare collection system consists of TVMs for train ticket purchase and parking fee; 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.

At stations with high ridership, a second pair of TVMs shall be provided per platform. The second TVM pair shall be not more than 300 feet from the other pair.

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 is implementing this program, which is designed, installed, and 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 adequate number of CIDs to serve the level of ridership of a station. CIDs should be located at the proximities of station entrances/exists. Consideration should be given to minimize the impact to passenger flow due to queuing patrons waiting to use a CID, and the convenience of mobility challenged patrons. 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 are toward opposite ends of the platform near platform entrances/exits. When appropriate, place additional CIDs in major decision points of passenger circulation paths beyond station platforms, such as major underpasses and/or overhead.

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 tactile, yellow safety stripe, and detectable directional tactile 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 any 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 plate shall generally be provided at the back side of the 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 an ornamental pattern that would provide a ladder effect.

3.0 FENCING

3.1 CENTER FENCE

Where two or more tracks serve a 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 prevent from 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 between the aesthetic look and the structural sturdiness and strength necessary to withstand vandalism, and to allow for hanging and mounting of the station signage. The centerline of the fence shall be 8 feet 6 inches minimum 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. The fencing shall be a minimum of 6 feet high.

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” away from ROW lines within JPB property. ROW fencing includes access gates for maintenance personnel.

4.0 CLOSED-CIRCUIT TELEVISION CAMERAS

CCTV cameras will be installed on the platforms at intermodal stations, and as directed by Caltrain. If CCTVs are installed in the parking area at intermodal stations, Caltrain will coordinate with the local enforcement agency for possible monitoring. CCTVs shall be installed in the pedestrian undercrossings and underneath the bridges where the 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 and 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 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 in detail 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 detail 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 multi-modal 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.

Type 5 – Regulatory and Warning Signs

These are safety advisory (regulations 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 include various kinds of information, mainly around the station area.

Type 8 – Parking Signs

These signs provide general and ticketing information for parking, 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 highway or major arteries.

1.3 SIGNAGE PLACEMENT

These signs are to be placed principally at three locations: on the platforms (including on the electrical 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 platform). 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 a much reduced maintenance of these signs due to less potential 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 warning tactile. 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 warning tactile on the mini-high platform.

d. "Danger Not a Waiting Area"
This text marking is on the station platform between the safety yellow 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 multi-modal 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 for Millbrae Station, which has been implemented by BART. The HSP implementation at the four other Caltrain stations was completed in 2001. 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: Wayfinding (static signs)
- Type 2: Transit Center ID (static signs)
- Type 3: Transit Information Displays – (static signs)
- Type 4: Wayfinding Kiosk (static signs)
- Type 5: Information "Flag" Sign (static signs)
- Type 6: Real-Time Information Displays (dynamic signs)

3.0 CALTRAIN HSP IMPLEMENTATION

For stations other than the five multi-modal stations, a tiered approach will be used to implement additional HSP sign types. During the planning process for any major rehabilitation 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 the design, it is also prudent to update the station ranking and hierarchy, because as density and transit access around stations increase, a 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 the signs shall take into account the need to maintain the familiarity and feel of Caltrain to which the public has been accustomed. As a general guidance, though, the HSP sign implementation may be as follows:

a. For Multi-Modal 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 1, 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 discipline users for load requirements and overall electrical system design. Designers shall additionally coordinate with Pacific Gas & Electric 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, Station Communications**, 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 communications devices, such as fare collection systems (TVMs, Clipper), passenger information systems (VMS, PA systems), and possibly CCTV cameras. See **Chapter 4, Station Communications**, 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, PA speakers, VMS, and CCTV.

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 in the platform other than short laterals shall be a minimum of 2 inches diameter. 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 and CCTV is not permitted. Where its use cannot be avoided, any exposed conduit in public areas 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 closure of the platform and to allow excavation for these lines, it is Caltrain's policy to provide at least four 4-inch-diameter conduits for the full length of the platform, with 4–foot-square pull boxes. These conduits will be installed in addition to any other conduit systems installed for the platform.

Power wiring must be THHN/THWN or XHHW for dry locations, and XHHW-2 for wet locations. All conductors must be copper with 600 volt insulation. Cabling in equipment rooms must be low smoke zero halogen type.

Branch circuit wiring must be #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 should be waterproof and vandal-resistant and should have tight gaskets to prevent infiltration of dust. Luminaires shall function effectively for a minimum of 20 years, allowing for routine maintenance. Unless noted otherwise, all luminaires shall be light emitting diode 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 will provide 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 level of 3:1 (average to minimum) under normal conditions. Uniformity of emergency lighting shall conform to NFPA 101. Luminaires shall be selected, located, and/or aimed to accomplish their primary purpose while producing a minimum of objectionable glare and/or interference with task accuracy, vehicular traffic, and neighboring areas.

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

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, platform, 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 and access 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 located adjacent to roadways, and to ensure that plantings will 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 the illumination level of the adjacent street or highway.

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

Platform area lighting shall be 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 also 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 that require illumination at all times), 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 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. Ideally, landscaping shall 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-resistant.

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

All landscaping shall be a minimum of 16 feet clear from the centerline of track. Trees and shrubs shall be situated so that the anticipated growth will 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 the electrification electrical safety zone (ESZ), which is an area extending 10 feet from the closest electrical conductor of the traction power system. No trees shall be planted at locations where the matured footprints will be within 20 feet of the ESZ.

2.0 IRRIGATION

Landscaping design shall minimize the need for irrigation by using native and drought-tolerant plants. Where irrigation is used, the water spray and drainage shall be designed to maximize coverage and reduce overspray, and shall be directed away from tracks, platforms, and walkways. Drainage requirements are covered in **Chapter 8, Civil Design**.

3.0 PLATFORM WASHDOWN FACILITY

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

END OF CHAPTER

CHAPTER 4

STATION COMMUNICATIONS

A. GENERAL

The term "Station Communications" refers to the collection, dissemination, and transmission of information to and from passenger stations using electronic systems and methods. 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 at the station. Because these systems affect the travelling 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 fashion.

1.0 STATION OPERATIONS 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 facilities are provided at stations, including rail-fare vending and add-value machines, passenger information signs, public announcements, payphones, and even concessions and restrooms at some stations. At terminal stations such as Diridon and 4th and King, train information display signs (TIDS) are also provided. 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 facility at the Caltrain Central Control Facility (CCF), and from the Back-Up Central Control Facility (BCCF) which also house the train dispatchers. The CCF is in the Centralized Equipment Maintenance and Operations Facility in San Jose, and the BCCF is in Menlo Park.

Caltrain also uses a secondary headend facility at Caltrain Headquarters in San Carlos. 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 CCF 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.

The Caltrain BCCF is in Menlo Park. This facility serves the stations' communication systems in the same manner as the CCF and Central Headquarters.

2.0 SYSTEM-WIDE COMMUNICATIONS TO/FROM STATIONS

Station communications with CCF, BCCF, and Central Headquarters 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 Caltrain WAN, based on the frame relay leased services.

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, CCF, BCCF, and Central Headquarters at the speeds between 1 Gigabits per second (Gbps) and 10 Gbps at optical nodes.

3.0 COMMUNICATIONS SUBSYSTEMS

There are three primary communication subsystems used to convey public information and three primary subsystems for fare collection and monitored security. These include:

a. Public address (PA) system

b. Variable message sign (VMS)

c. TIDS

d. Ticket vending machines (TVM)

e. Clipper card interface devices (CID)

f. Video security or CCTV

Telephones are provided for passengers' convenience. Passenger assistance telephones, such as Push-to-talk, 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.

4.0 STANDARDS AND CODES

Station communications design shall comply with the latest edition/revision, unless noted otherwise, of all applicable Federal and State Codes, Americans with Disabilities Act (ADA) requirements, applicable local codes, and the communications industry standards listed in **Appendix C**.

B. RAIL NETWORK

Caltrain Rail Network standards and design criteria are to be developed. Please contact Caltrain Systems Engineering if design criteria and standards are needed for the following elements of the Rail Network:

1. Data centers
   - Remote access (vendors and internal staff)
   - Railroad partners communication (Federated Links)
   - Physical requirements (power and power redundancy; cooling;)
   - Network segmentation (critical networks; administrative; CCTV)
2. LAN
3. WAN
4. Security
   - Cyber Security (Intrusion detection/Intrusion prevention)
   - Perimeter security
   - Physical security
5. GBN (ground-based network)
6. Data Radio system architecture
   - 220 MHz architecture
   - Onboard Communication package
   - Wayside Communication Package
   - Backhaul Communication package
7. WLAN Architecture
8. Telephony
9. Data back up and disaster recovery
10. Logging
11. System monitoring

12. Alerts system
13. Systems change management procedure
14. Network equipment technical support from the vendors (for example Cisco TAC)
15. Server infrastructure technical support (for example Dell)
16. Continuity plan
17. Emergency plan

C. 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 CCF, BCCF, and Central Headquarters. 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, CCF, BCCF, Central Headquarters 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 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 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.

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.

1.0 COMMUNICATIONS NETWORK CARRIER

Stations from San Francisco to Tamien shall communicate with CCF, BCCF, and Central 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 CCF, Central Headquarters, and the stations south of Tamien shall be determined based on the best available technology and cost. This network shall be leased from a competitive local exchange carrier (CLEC).

For new construction or major rehabilitation at stations south of Tamien, Caltrain station WAN services shall be upgraded to a “full” T1 service, with serving speeds up to 1.544 megabits per second (Mbps). Many of the existing Caltrain stations use “partial T1” services, providing for typical serving speeds of 128, 256, 512, and 768 kilobits per second (Kbps). However, these speeds, in particular those in the lower range, are marginal for current needs and will not be adequate to support future needs. They should be upgraded to faster serving speeds of up to a “full” T1 (1.544 Mbps). If necessary, the existing MPOE should be upgraded at both ends: the existing station and the host end.

The leased T1 connectivity to the stations represents the network “carrier” side of the station design. 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 communications 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 CLEC 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 coordinate with JPB 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 absence of 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.

2.0 SUBSYSTEM NETWORK DISTRIBUTION

At each station, the communications carrier network 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 hub/switch throughout the station. Characteristics of this network distribution system should be as follows:

a. Distribution cabinets shall be optimized for communicating with devices and 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 splice/termination 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.af 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.

2.1 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., operations control center and maintenance yards). 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 Safety and Risk Management.

The station CCTV system components shall be compatible with the Caltrain existing CCTV headend equipment installed at the Central Headquarters, CCF, and BCCF, 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 following resolution:

a. Forensic Detail: Priority targets (underpass, station platform, TVMs/CIDs, parking exit/entrance, and stairs and steps) require detailed coverage—at least 40 pixels per foot.

b. General Detail: The remaining station areas shall be covered by at least 10 to 20 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, 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 evoked 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 40 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 Nextiva 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 San Carlos facility, CCF, BCCF, and remote Caltrain stations, the station's DVR shall support downscaling of the video streams to low resolution (i.e., 1 to 4 Common Intermediate Format [CIF]) 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.

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 from the Caltrain San Carlos facility, CCF, and BCCF 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/retrieved video recording shall provide for 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.264/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 Megapixel 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. Even though Megapixel cameras are typically more expensive than traditional (4 CIF) cameras, the reduction in the number of cameras will more than compensate.

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 San Carlos, CCF, and BCCF.

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.

2.2 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 designed and 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 a 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).

Each 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.

2.3 VARIABLE MESSAGE SIGNS

VMSs are required by ADA to augment and complement audio PA messaging for the benefit of hearing-impaired commuters. Visual messaging shall be both centrally and locally controlled.

VMS boards shall be of a light-emitting diode (LED) type, shall support a wide range of character sizes, and shall meet ADA requirements. The VMS dimensions for a single- or dual-face display with a maximum of four lines shall not exceed 16 inches high by 70 inches wide by 14 inches deep. Single-face display depth is typically half the depth of the dual face 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 wireless 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 display with a pixel pitch not exceeding 6 millimeters, 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 CCF. 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 CCF and BCCF 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 17750, Variable Messaging Signs.

2.4 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:

4.1 Automated PA announcements from the CCF and BCCF by the PA system headend equipment

4.2 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 locally, using local paging microphones.

At Caltrain passenger stations where an agent office exists, provide one wireless paging microphone 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 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 5 the lowest):

a. Priority 1: Automated PA announcements from CCF

b. Priority 2: Local wireless paging microphone from the station PIDS clerk office (where applicable)

c. Priority 3: Local hard-wired paging microphone from the station PIDS clerk office (where applicable)

d. Priority 4: Local paging microphones at the station platforms

e. Priority 5: 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 corresponding PA messaging shall be sent to the Caltrain stations over leased 4-wire E&M lines. The CCF has the ability to send messages to individual stations, send messages to groups of stations, or broadcast messages to all stations as required. The station PA system shall incorporate the corresponding E&M cards and the associated muting relays.

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.

For rehabilitation projects or new construction, the design shall include an all-Ethernet PA system using IP-to-Audio gateways. A cutover plan for switching to the new Ethernet PA system shall be provided and coordinated with the owner.

The PA system design shall consist of networked signal processors, amplifiers, speakers, ambient noise sensors, IP-to-Audio gateways, phone-interfaced devices, surge protection devices, and microphones.

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, E&M circuits, 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 50-hertz (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.

2.4.1 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 1,000 Hz Octave band

   ii. Typical Caltrain Station (One or Two Platforms) Layout – Maximum Design Goal: ±3 dB at 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.

As a rule, designers shall develop a computerized model 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.

2.5 PASSENGER ASSISTANCE AND EMERGENCY TELEPHONES

Talking signs 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.

3.0 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 revision of the National Electrical Code (NEC) for conduit fill percentages, conduit bends, power cable ampacities, grounding, and other recommendations applicable to the installation of cables and raceways.

The designer shall provide conduit and cable schedules, conduit fill percentage calculations, and calculations for the sizing of power cables.

3.1 FIBER OPTIC AND CATEGORY 6A CABLES

Single-mode and multi-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.

Multi-mode fiber optic cable shall be used if they exist at the station and if they have sufficient capacity to accommodate the design without requiring installation of new cables; otherwise, single-mode fiber optic cables shall be installed. Only single-mode fiber optic cables shall be used for station MPOE connectivity to the Caltrain-owned fiber optic cable plant.

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).

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 not equipped with fiber optic ports and 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.

3.2 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.

3.3 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 with pull boxes.

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.

3.4 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, the LFMC shall be securely fastened within 1 foot from the termination point and at intervals not exceeding 4½ feet. 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 42 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 6 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.

D. 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.

E. 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 a prefabricated steel construction structure. 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 CCF, BCCF, 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 a 56 Kbps service channel via the station/CCF carrier network shall be the preferred method.

F. 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.

G. 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 network 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 station communications 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. DC traction power system:

    i. Substation thyristor rectifier apparatus

    ii. DC power distribution to trains, via overhead power catenary circuits

    iii. On-board propulsion equipment, including solid-state chopper and motor circuits

    iv. DC 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 Federal Communications Commission, Code of Federal Regulations 47, Part 15, Over-Voltage Protection.

Over-voltage protection shall be provided for all outdoor PA, VMS, and CCTV equipment.

2.0 PROHIBITED MATERIALS AND METHODS

The station communications design shall ensure that the following materials and methods are excluded:

a. Flexible metal conduits and plastic tubing

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.

3.1 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

3.2 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/m^3

e. CO: 20 ppm, maximum

f. Chloride: 13.9 mg/m^3

g. Moisture Acidity: pH 4.41

3.3 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.

   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.

c. 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.

d. Intrusion protection shall meet IP65 standards for all device enclosures not rated NEMA 4X.

3.4 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.

3.5 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.

3.6 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.

3.7 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 CCF, 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

When the Southern Pacific Railroad owned and operated the Caltrain corridor, the signal system was designed based on the mixed operation of freight and passenger trains. The signal system spacing was based on single-direction running, with braking distances calculated for 80-ton per operative brake (TPOB) freight trains at 60 miles per hour (mph).

The Santa Clara, College Park, Fourth Street, and San Jose operators' positions were consolidated into a single dispatch center, with centralized traffic control (CTC) from Santa Clara (Control Point or CP Coast) to CP Tamien. San Francisco Control Points, namely Fourth Street, Potrero, Bayshore, and Brisbane were operated as Manual Interlockers under the control of the San Jose Dispatcher, with bi-directional automatic block signaling between Fourth Street and Potrero, and single direction running between control points from Potrero southward. After the California Department of Transportation completed the Interstate 280 retrofit, bi-directional CTC was in effect between Fourth Street and Bayshore.

Between 1992 and 1997, signal design was performed by various designers, as a byproduct of third-party contracts on the railroad. There was little consistency between projects, and little overview as to how the projects tied together and how they would fare with future projects. In 1997, the Caltrain's two signal engineering designers and the contract operator developed the Caltrain Signal Engineering Design Standards. The new standards have become one of migration.

1.0 SIGNAL SYSTEM MIGRATION

The migration of the Caltrain Signal System was defined as follows:

a. Replacement of Relay Based Systems with Microprocessor based systems: All areas outside the San Francisco and San Jose Terminals were completed in 2006

b. Replacement of telephone leased lines with Advanced Train Control System (ATCS) radio: ATCS radio is the primary medium of train control communication with Telco connectivity at 80 percent of the Control Points completed in 2003

c. Replacement of direct current (DC) track circuits and line circuits with Electronic Coded Track circuits: on station (OS) tracks remain DC, and there are some DC track circuits in locations where the coded track consists of on line circuits completed in 2003

d. Replacement of a system with single direction running ABS (automatic block system) with bi-directional running CTC: Completed in 2003 with the completion of construction for the Caltrain Express (CTX) projects

e. Installation of a positive train control (PTC) system

f. Implementation of a signal system that will also function in an electrified environment

g. Installation of a Fiber Optic Communications Network

By defining the path of migration, projects today will lay the groundwork for future projects. Because the railroad was originally defined as single direction running, many highway-grade crossings were designed for greatly reduced speeds in the reverse direction. In times where one track is removed from service due to construction or operational difficulties, the service disruption was magnified by the reduced speed required over these crossings.

Once the path of migration was defined as a bi-directional running railroad on both tracks, grade crossings were designed to accommodate the ultimate 79 mph operation on both tracks. Non-signaled moves are limited by Federal regulation to 59 mph. The crossings were designed to allow for 79 mph operation when the track became signaled in both directions. This approach avoided costly retrofit or replacement when the implementation of the signal migration for the whole corridor took place.

Caltrain has successfully migrated to CTC. With the construction of express tracks and a track structure of number 20 (Limited Speed), 14 (Medium Speed), and 10 (Slow Speed) powered turnouts, it became apparent that the Route Signal Aspects would not support the optimal operation. Speed Signaling was placed in service north of CP Coast. Speed Signaling alerts the train operator when the train is approaching a higher speed turnout. Different aspects are displayed for moves through number 20 turnouts, number 14 turnouts, and number 10 turnouts. In a Route Signal System, the train operator only knows to take a diverging route and must approach a control point prepared to take the turnout.

The original system was one of route signal aspects. After the system was upgraded to bi-directional CTC, the signal system aspects were converted to speed signal aspects north of CP Coast, to take advantage of the high-speed turnouts installed. Signal system logic was configured during the CTX projects to allow for the initial route signal aspects, and to convert to speed signal aspects with the minimum amount of change and retest.

Control Points have been designed to accommodate the currently funded projects; as much as possible, facilities were sized to allow for future projects. Currently, trains are governed by wayside signals. In the future, there will be some onboard enforcement of signal indications. With increased rail traffic, this important safety feature will be necessary. Express train operation may call for trains to operate at speeds greater than 79 mph. This too will require onboard control of locomotives by the signal system. The current system has been designed to allow for the addition of the new equipment.

The Caltrain Board of Directors has mandated future electrification of the Caltrain corridor. Equipment installed today must be sized to allow for the addition of necessary filtering and other equipment required for operation in a high-noise traction power environment. Funding guidelines prohibit purchasing equipment for projects other than those funded. However, an intelligent design with a defined path of migration allows for the future projects to build on the current projects, and for newly installed equipment to be reused as much as possible.

The migration path has been defined as moving the Caltrain signal system from a single-direction running automatic block between Control Points, to one of bi-directional CTC with express tracks. This has been accomplished. Relay logic is being replaced with programmable solid-state microprocessor-based logic. Leased telephone lines are being replaced with ATCS radios. The Caltrain signal system uses Electrode 4+ Code Rates to convey aspect and occupancy information. Although this is a system manufactured by Alstom, the code rate structure is an open architecture and can be emulated by competitive vendors. This equipment can be augmented to operate in an electrified environment, and it can support onboard train control equipment.

In addition to the large number of motor vehicles that cross the Caltrain tracks, a large number of pedestrians cross the Caltrain tracks. The safest for both pedestrians and motorists is one which is a grade-separated crossing, either over or under the tracks. The ideal scenario is to have no at-grade crossings. In the meantime, necessary crossing points for pedestrians are to be treated in the same manner as necessary crossings for motorists. These shall have microprocessor-based Constant Warning Time systems and pedestrian gates. When Caltrain is electrified, the Constant Warning Time devices of today will no longer be a viable option, and will need to be replaced as part of a program in conjunction with the electrification project. At stations and on sidewalks where major work is taking place, auxiliary sidewalk gate arms shall be added to the roadway gate, and a new gate assembly shall be installed in the off quadrant on the sidewalk for pedestrians.

This document incorporates many lessons learned from recent projects, reflects a commitment to the judicious use of public funds by defining the migration path, and recognizes the risk inherent to pedestrians and vehicles crossing the railroad at grade.

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.

Both the wayside signaling system and the crossing warning systems are present on the Caltrain tracks. Any modifications to the wayside signaling must consider any impact to the grade crossing warning systems. Design criteria for the grade crossing warning systems are covered in **Chapter 6, Grade Crossings**.

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. Refer to the "**Systra Signal System Capacity Study**" performed for Caltrain, which explains the methodology. Contact Caltrain Engineering for a copy of this study.

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.

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. 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 Deputy 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 ElectroLogIXS, or equivalent systems. Intermediate color-light signals shall use electronic coded track circuit systems such as Alstom ElectroLogIXS or equivalent systems, which will emulate the Electrocode 4 Plus rates and communicate through the rail with existing equipment. 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 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 Deputy 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. Any relay installations shall follow the same principles of application logic as microprocessor-based systems.

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 stored on a secure web site, as directed by Caltrain's Manager Engineering Signals and Crossings.

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.

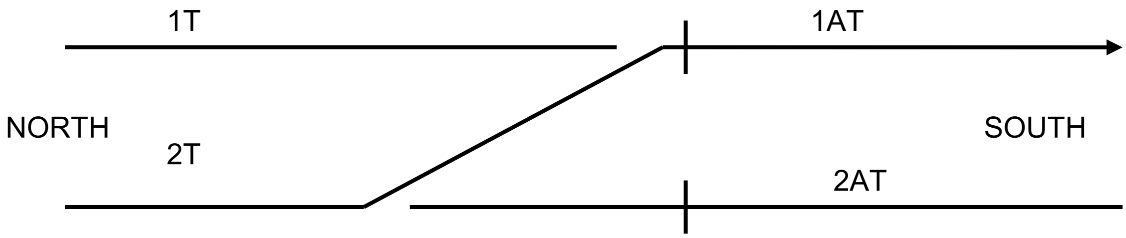


Figure 5-1 Interlocking Release (Switch Locking Released)

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.

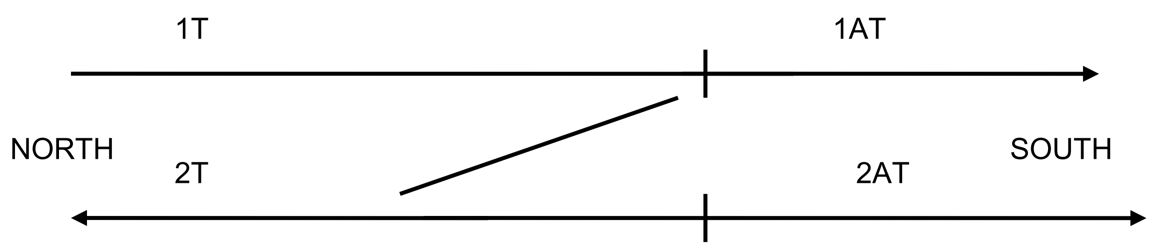


Figure 5-2 Interlocking Release (New Route Created)

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.

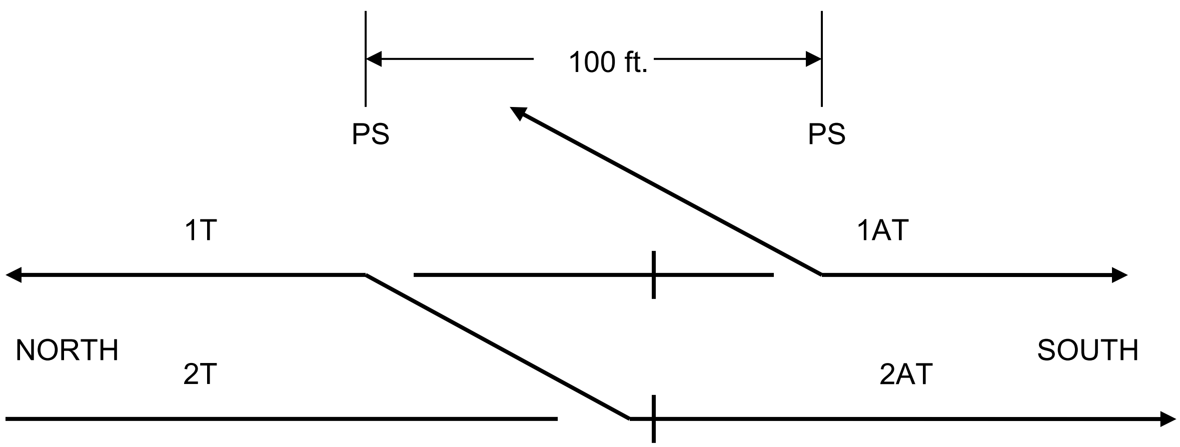


Figure 5-3 Parallel Routes

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. 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 6, 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.

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.

$$\mathbf{AG} = \frac{\mathbf{DG + DG + DG + DG + \ldots}}{\mathbf{TOTAL\ BLOCK\ LENGTH}}$$

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:

$$\frac{\text{(Actual Distance)} \times (6 + G)}{6}$$

Descending grades may be calculated by:

$$\frac{\text{(Actual Distance)} \times (4 - G)}{4}$$

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 the F40PH 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 Deputy 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 Deputy Director of Engineering or designee. Similarly, signal checkers who perform review of Caltrain signal circuitry design or programs must be approved by the Caltrain Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Deputy 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 Supervisory Control Office.

S. SIGNAL AND TRAIN CONTROL SYSTEM MIGRATION

The migration path has been defined as installing a PTC system overlay to the existing Caltrain signal and train control system, consisting of bi-directional CTC. The base safety system of wayside signals is in place. The Caltrain signal system uses Electrode 4 Plus Code Rates. Although this is a system manufactured by Alstom, the code rate structure is an open architecture and can be emulated by competitive vendors. The microprocessors at Control Points in most cases are the Alstom Vital Logic Controllers. This equipment is able to communicate from controller to controller and from controller to radio.

T. 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.

END OF CHAPTER

CHAPTER 6

TRAIN CONTROL COMMUNICATION

A. GENERAL

The design criteria presented in this chapter for mission or operations critical Train Control Communication defines the technical requirements used for the development of specifications and the design of the Advanced Train Control System (ATCS) Data Radio communication system, the various telephone interfaces, the very high frequency (VHF) voice radio communication system, and the positive train control (PTC) system.

The ATCS data radio, the VHF voice radio, and the PTC Radio are all independent stand-alone communication systems that are each supported by a Caltrain-owned microwave radio network and fiber-optic plant, and by various leased telephone subsystems, including T1, 4-wire (analog), 4-wire ear and mount (E&M) (analog), 4-wire (digital), 2-wire (analog), frame relay and digital subscriber line (DSL) for back-haul. 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 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 these three communications 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. Variable message sign

d. Fare collection system (ticket vending machine and Fastrak payment system or the “Clipper” card)

e. Train information display sign

The design criteria for these subsystems are addressed separately in **Chapter 4, Station Communications**.

The designer(s) of the train control system shall be qualified radio communications 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

All train movements on Caltrain tracks are managed and controlled by a non-vital supervisory control system (SCS). This SCS is implemented via a data radio network, which connects the train signaling Control Points (CPs) to the computer workstations, servers, and packet switches at the Central Control Facility (CCF) and at the Back-Up Central Control Facility (BCCF). The CCF is at the Caltrain Centralized Equipment, Maintenance, and Operations Facility (CEMOF) in San Jose, and the BCCF is in Menlo Park. A detailed description of each component of the data radio network and the CCF/BCCF headends interface is provided below. The data radio network is implemented through the use of ATCS channels 2 and 5. Each ATCS channel consists of a pair of multiple-addressing-scheme frequencies in the 900-megahertz (MHz) band (set aside by the Federal Communications Commission [FCC] for this application), which implements the ATCS protocol.

The ATCS protocol is central to the 900 MHz band radio frequency (RF) communication links 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 CCF and BCCF.

1.0 CODE SERVER

At the CCF and BCCF, the train dispatcher implements a route request by first inputting a control command into the code server. The code server decodes the command, and passes another encoded message to the packet switches, 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 the 900 MHz radios, 4-wire E&M circuits are used. The following ATCS protocols are implemented in the Caltrain system:

a. The SCS-128 protocol, developed by Safetran Systems (now part of Invensys), is used for all direct telephone line links between CPs and the CCF and BCCF, as well as for the links between the base station sites and the CCF and BCCF.

b. Internet protocol (IP)-based dispatch console/headends, called the Advance Information Management (AIM) dispatch headend console, are provided by AIRINC.

2.0 PACKET SWITCHES

The CCF and BCCF Packet Switches currently used in support of the ATCS data radio network are manufactured by Safetran Systems. They incorporate built-in hardware redundancy through the use of a dual packet-switch design in one box, one of which is redundant, and connected to the code server/front-end processor (FEP).

The packet switches are capable of performing a dual role, where required. They can perform protocol conversions, as needed, as well as received signal strength indicator (RSSI) selection. Because the AIRINC's 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 CCF and BCCF packet switches shall monitor the inbound signal quality RSSI from each of the three base station sites, corresponding to every transmission from a CP, to determine which base station site received the strongest signal from the CP. This RSSI information shall be used by the packet switches to determine, in real time, which base station site will be the most likely server, and shall route the next message from the code server to this base station site. Note that this RSSI result is not saved for general future routing of messages to base station sites, but shall only be used, in real time, for routing only the *next* message to the most-likely-server base station site.

3.0 NETWORK

The third major component of the non-vital SCS is the network of ATCS data radio base stations and 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 radio network.

Three base station sites are used to support all message transmissions between the CCF/BCCF and these CPs. The three base station sites used are at San Bruno Mountain in Daly City, Monument Peak in Milpitas, and at the CEMOF in San Jose.

The three base station sites are configured as redundant pairs on separate radio frequencies to the extent of their respective radio coverage footprints. The Monument Peak and San Bruno Mountain sites are each capable of providing ATCS data radio support to all of the northern CPs along the Caltrain Corridor. The CEMOF and Monument Peak sites provide full radio coverage and/or coverage redundancy for the southern CPs, with CP Michael as its southern limit and CP Mary as its northern limit.

Note that for a CP to be added to the ATCS data radio network, the design criteria is that it must receive full radio coverage, with an availability of at least 99 percent, from a minimum of two base station sites; otherwise, it shall be supported using leased telephone circuits. Because CP Lick, which is the southernmost CP along the railroad, is not controlled by Caltrain (it is controlled by Union Pacific Railroad [UPRR]), but simply monitored, this coverage criterion does not apply to it.

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:

a. 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 (DS0) channel between the base station sites and the packet switches. A thorough review of these parameters is required prior to the addition of additional CPs on the ATCS data network.

b. Where one or more base station sites have the geographical advantage, due to the terrain layout being capable of supporting much more than the maximum number of CPs for the designed speeds and headway, the use of a second FCC-licensed multiple-addressing-scheme frequency pair shall be investigated.

c. The ATCS data radio Channel shall be configured to provide full duplex data radio Operation between the CCF/BCCF and all CPs along the corridor. From the CCF/BCCF, the data radio messages shall be transmitted to each of the base station sites through the use of 2-Wire plain old telephone service (POTS) telephone circuits or microwave radio links (with a reliability of 99.999 percent or better). From the base station sites, the messages shall be transmitted to the CPs along the corridor via a pair of multiple-addressing-scheme frequencies licensed from the FCC, with a communications reliability of 99.0 percent or better, sufficient to ensure communications at 10 *E-7 bit error rate (BER)* without forward error correction (FEC) coding. A fade margin of 17 decibels (dB) shall be factored into the design to account for Rayleigh fading that will affect radio paths.

The CCF/BCCF 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.

d. The ATCS communications between the CCF/BCCF (code server) and the base station sites is based on a polling scheme. Each base station site shall be assigned to a unique code line on the code server, which shall poll each base station site in turn, to retrieve messages sent from the various CPs.

The ATCS communication between the base station sites and the CPs shall be based on a contention scheme. Two pairs of 900 MHz band ATCS frequencies configured for a multiple addressing scheme are used to implement the network. The frequencies listed in **Table 6-1** are currently used.

Table 6-1: ATCS Channel Frequencies

ATCS Channel	Frequency	Description
2	935.9375 MHz	Base station transmitting frequency
2	896.9375 MHz	Base station receiving frequency
5	936.9375 MHz	Base station transmitting frequency
5	897.9375 MHz	Base station receiving frequency

Notes:

ATCS = Advanced Train Control System
MHz = megahertz

Under this scheme, each CP that has a message to send to the CCF will contend for the radio channel with all other CPs. This will result in some RF-Network collisions, the number of which must be kept to a minimum to preserve the designed maximum speeds and minimum headways.

e. Data radio base station repeaters shall employ Gaussian minimum-shift keying (GMSK) direct frequency modulation (FM), configured for 12.5 kilohertz (KHz) channel spacing. base station antennas shall be directional, high-gain Yagi antennas with the horizontal and vertical beam widths and orientation that would allow them to establish point-to-point (PTP) radio links with each of the CPs with the required communication reliability and signal quality. The antennas used at CPs shall, however, be omni-directional, which allows for efficient expansion of the ATCS network. In special cases, a high-gain directional antenna may be required for certain CPs where the communication links will not meet the required reliability using the lower-gain omni-directional antennas.

The quantity of collisions is a direct function of the ratio of CPs to base stations; the higher this ratio, the greater the number of collisions. The larger the number of collisions, the lower the data throughput of the ATCS network will be. The reliability of the RF links is another factor that aggravates data throughput. As communication reliability falls below 99.0 percent, the number of communication re-tries increased, resulting in a longer time being required to send or receive a message.

The maximum railroad speeds and the minimum railroad headways are dependent on these design parameters. As the system expands, a thorough analysis of these parameters will be necessary to ensure reliable and efficient operations.

f. CPs may be connected to the leased 4-wire telephone circuit and to Caltrain-owned fiber-optic plant via the Ethernet switches that are present at each CP site. Except at CP Sierra and the two CPs at the terminal, the 4-wire leased telephone circuit connection acts as a secondary, cold-standby backup to the data radio network; in the event of a major radio outage, the CPs can be reconfigured to be controlled via the 4-wire telephone connections. This reconfiguration requires a maintainer to visit the affected site and load a new code plug that will support an ATCS over telephone interface.

C. VOICE RADIO

A 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.

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 55.0 on the road dispatch channel.

Between MP 55.0 and the southern end of the railroad, 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.

1.0 BASE STATION SITES

Nine VHF voice radio base station sites currently exist to support the road channel. Of these, five are above-grade radio base station sites along the ROW, each of them configured for carrier-squelch, simplex operation on the road channel 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 with the ATCS radio base stations. 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.

1.1 THE ABOVE-GROUND BASE STATION SITES

Of the five aboveground road base station sites, three are controlled by the northern territory dispatch, and one by the southern territory dispatch. Future voice radio base station sites operating on the road and yard channels shall be designed using the same configuration. For the road channel multiple low-level sites shall be used, each capable of providing radio coverage within a radius of 10 to 15 miles, to manage radio traffic congestion amongst the users in the field. For the yard channel, the coverage shall be similar, except localized to the vicinity of the respective railroad yards.

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.

The existing northern dispatch base station sites are listed in **Table 6-2**, along with their Global Positioning System (GPS) coordinates.

Table 6-2: Northern Dispatch Base Station Sites

Site Name	GPS Coordinates	Site Elevation (Feet)	Antenna Azimuth
Fourth Street Tower	N 37º 46' 28.8" W 122º 23' 50.2"	65 (55+10)	Omni-directional Gain 0 dBi
Sign Hill	N 37º 39' 53.8" W 122º 25' 14.1"	576 (561+15)	156º Gain 8 dBi
San Carlos	N37º 30' 23.4" W122º 15' 43.1"	106 (99+7)	140º Gain 8 dBi
CP Mary	To be provided	To be provided	To be provided

Notes:
CP = Control Point
dBi = decibel (isotropic)
GPS = Global Positioning System

The southern dispatch base station site is listed in **Table 6-3**, along with its GPS coordinates.

Table 6-3: Southern Dispatch Base Station Sites

Site Name	GPS Coordinates	Site Elevation (Feet)	Antenna Azimuth
CEMOF, San Jose	N 37º 20' 20.28" W 121º 54' 29.22"	138 (78+60)	314º/134º Dual Yagi Gain 10 dBi

Notes:
CEMOF = Centralized Equipment Maintenance and Operations Facility
dBi = decibel (isotropic)
GPS = Global Positioning System

1.2 THE TUNNEL RADIO BASE STATION SITES

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 4-wire 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 General Electric (GE) Mastr III base stations. Tunnel 4 radio base station is connected to the CP Sierra repeater site over Caltrain-owned fiber-optic cable. Radio over fiber-optic equipment exists at both locations.

The tunnel-repeater systems are in very hilly regions. The quality of radio coverage provided by the above-grade base stations is marginal in some spots near the tunnels; furthermore, the level of RF signals to/from the tunnels' distribution antenna system is insufficient to supplement any marginal coverage from the above-grade base station sites in these regions. As a result, the tunnel radio base station sites are equipped with an external antenna system extension. This external antenna extension is used on only one side of each tunnel (the southern end); the region outside the northern end of each tunnel is supported by the antenna extension of the next tunnel to its north. A high-gain directional antenna is used external to each tunnel to extend the radio coverage into the hilly regions adjacent to these tunnels.

The four MOW tunnel radio channels are voted and steered with the two MOW aboveground channels as a single system through a Motorola voter and transmitter steering audio matrix device.

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:

a. 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.

b. 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.

c. 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.

d. 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.

1.3 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 6-4**.

Table 6-4: Dragging Equipment Detection Sites

DED Name	GPS Coordinates	Site Elevation (Feet)	Antenna Azimuth
10.8	N 37º 37' 42.2" W 122º 24' 37.0"	15	Rail transmitter, omni-directional Gain 0 dBi
28.2	N 37º 27' 36.4" W 122º 11' 25.9"	36	Rail transmitter, omni-directional Gain 0 dBi
42.2	N37º 22' 11.5" W121º 58' 27.6"	44	Rail transmitter, omni-directional 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) WCO-46 "talker-system," which contains a discrete Motorola HT-750 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 ±3-mile 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 results 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.

1.4 VOICE RADIO FIELD EQUIPMENT

Each locomotive and cab car operating in the ROW northbound through Gilroy will be equipped with a VHF-voice mobile radio. Each radio is programmable to all automatic alternate routing (AAR) frequencies, allowing it to be interoperably used on any railroad. Each mobile 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 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.

2.0 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:

a. 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.

b. 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.

c. The report from each DED must be recorded, either at the CCF or locally at the site.

d. 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.

e. All Caltrain groups that must have a reliable and guaranteed communication link to other Caltrain groups, as defined by the matrix presented in **Table 6-5**, 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.

f. **Table 6-5** 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 6-5: 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

g. **Table 6-6** 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 6-6: 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

D. 220-MEGAHERTZ POSITIVE TRAIN CONTROL RADIO

For PTC-radio-related work, coordinate with JPB for design requirements because the design criteria are still not finalized yet at this time.

E. COMMUNICATIONS BACK-HAUL

A mixture of Caltrain-owned microwave radio and POTS 2-wire telephone circuits is currently used to support all communications back-haul for the train control communication systems. Safety enhancements of PTC and future CHSR will require significant expansions of the Caltrain-owned microwave radio network and/or the 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 6-7** lists the current leased telephone infrastructure used by Caltrain to support the ATCS data radio and the VHF voice radio systems.

Table 6-7: 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	
Digisign Line	1	DSL	1	
PA Lines	1	T1 MP in the CO	1	
	1	T1 MP in the CO	1	
ATCS Base Stations Lines	1	4W PTP	2	2
	1	2W audio	1	1
	1	4W PTP	2	2
	1	2W audio	1	1
	1	4W PTP	2	2
	1	2W audio	1	1
Digicon Net-Router	2	DSL	2	2
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

The following four circuit types are used:

a. 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.

b. 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.

c. 4-Wire E&M

A 4-wire E&M line is a 9,600 bps baud rate leased telephone circuit between two fixed locations. This type of circuit currently exists between base stations, CPs, passenger stations and CCF and BCCF.

For new or rehabilitation projects, the leased line circuits shall be replaced with Caltrain-owned fiber optic-based network 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.

F. REFERENCE STANDARDS

The installation of both data radio and voice radio communication systems shall only be performed by qualified radio communications technician(s). Each of the radio technicians shall be proposed to the engineer for approval. Technicians shall have an FCC license and a minimum of years of recent experience performing similar work.

1.0 ATCS DATA RADIO

All designs shall be in accordance with FCC rules and regulations and shall be coordinated via the AAR. All installations shall be in accordance with the following codes:

a. National Electrical Code (NEC)

b. American Railway Engineering and Maintenance-of-Way Association (AREMA) Communications and Signals (C&S) Manual

c. California Occupational Safety and Health Administration (Cal/OSHA) standards

d. California Public Utilities Commission (CPUC) regulations

e. State of California Electrical Safety Orders, Title 8, California Administrative Code (CAC)

f. FCC rules and regulations

g. The Motorola R56 grounding standard

2.0 TELCO INTERFACES

The telephone company shall perform all electrical work up to the main point of entry (MPOE). It shall be the responsibility of the installer to connect from the MPOE to the various equipment assemblies used by the Caltrain communication systems.

All installations shall be in accordance with the following codes:

a. NEC

b. AREMA C&S Manual

c. Cal/OSHA standards

d. CPUC Regulations

e. State of California Electrical Safety Orders, Title 8, CAC

f. Applicable Telecommunications Industry Association/EIA references

3.0 VOICE RADIO

All designs shall be in accordance with FCC rules and shall be coordinated via the AAR. All installations shall be in accordance with the following codes:

a. NEC

b. Cal/OSHA standards

c. CPUC Regulations

d. State of California Electrical Safety Orders, Title 8, CAC

e. FCC rules and regulations

f. The Motorola R56 grounding standard

G. DESIGN REQUIREMENTS

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

a. Radio coverage/link simulations

b. Intermodulation studies

c. Grounding and lightning protection

d. Tower structural calculations for operation and licensing

During installation, the following documentations 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.

H. PRODUCTS

1.0 ATCS DATA RADIO COMMUNICATION

Antenna towers shall be either 80-, 60-, or 40-foot, tilt-down towers from Western Towers or Caltrain Engineer approved equal. The designer shall determine the quantity of towers and their heights. The installer shall coordinate with Caltrain to verify the exact location for the installation of each tower. The mobile communications package (MCP) radios shall be from Safetran Systems (Invensys) or Harmon Industries (GE Transportation Systems).

The coaxial cable, CP antennas, Ethernet spread spectrum radios, 12 volt direct current (VDC) batteries and chargers, and other data radio products, where required, shall be procured from the sources listed in **Table 6-8**.

Table 6-8: Data Radio System Products and Equipment List

Item No	Equipment Description	Equipment Part No.	Manufacturer or Vendor
1	Spread spectrum (Ethernet) radio	A53325	Safetran (Invensys)
2	WCP ATCS radio MCP II	9011-53411-0205	Safetran or equal
3	Router	2811	Cisco Systems or equal
4	Ethernet switch	Part of #3	Cisco Systems or equal
5	WAG	A53457	Safetran
6	UPS	APC	SUA1500RM2U or equal
7	Batteries	SAFT	ED 240
8	Battery charger	NRS	ERB-C 12/201 C, ERB-C 12/401 C
9	DC/DC converter	Part of #2	Safetran or equal
10	2.4 GHz lightning arrestor	IS-MT50LN-MA	Polyphaser/Tessco
11	900 MHz lightning arrestor	DSXL-D-ME	Polyphaser/Tessco
12	Alarm relays/sensors	N/A	N/A
13	Spread spectrum 2.4 GHz antenna	As required	Maxrad/Tessco
14	ATCS 900 MHz antenna	As required	Maxrad/Tessco
15	Coaxial cables	LCFS114-50A or equal	Cellwave/Andrew
16	Coaxial cables	LCF78-50A LCF12-50A or equal	Cellwave/Andrew Cellwave/Andrew
17	Tilt-down antenna mast and installation accessories	N/A	Various
18	Miscellaneous accessories	N/A	Various

Notes:

ATCS = Advanced Train Control System
DC = direct current
GHz = gigahertz
MCP = mobile communications package
MHz = megahertz
UPS = uninterruptible power supply
WAG = wayside access gateway
WCP = wayside communications package

Tables 6-9 through **6-11** list specifications for the ATCS data radio equipment, which is based on the Safetran BCP and GE/Harmon MCP ATCS data radio transceivers.

Table 6-9: Base Station Data Radio Specifications

Description	Specifications
General	
FCC compliance	Parts 15, 90
Transmitter	
RF power output	25-75W Adjustable
Duty cycle	Continuous
Spurious emissions	-90 dBc
Harmonic emissions	-90 dBc
Audio response	+1/-3 dB per TIA-603
Hum and noise	-45 dB per TIA-603
Frequency spread	5 MHz
Frequency stability	0.1 ppm, -30°C to +60°C (-22°F to + 140°F)
RF Data Communication	
Frequency range	Transmit at 935 to 940 MHz, receive at 896 to 901 MHz
Number of channels	1 (synthesized, programmable)
Channel spacing	12.5 KHz
Channel resolution	12.5 KHz
Data modulation	GMSK, direct FM
RF bit rate	4,800 bits/sec
Error correction	Reed-Solomon (16,12) FEC and 16 bit CRC
Ground Network Port	
Port type	Sync./Async., EIA-232 with configurable port modem signaling
Baud rate	Up to 2.048 Mbit/second, 9,600 bit/second typical
Data link protocol	HDLC balanced, HDLC polled
Receiver	
Sensitivity 12 dB EIA SINAD	0.35 uV
20 dB quieting	0.50 uV
Adjacent channel rejection	-75 dB
Intermodulation rejection (EIA SINAD)	-75 dB
Spurious and image rejection	-90 dB

Table 6-9: Base Station Data Radio Specifications (Continued)

Description	Specifications
Audio squelch sensitivity	12 dB SINAD
Audio response	+1/-3 dB per TIA-603
Hum and noise ratio	-45 dB
Frequency spread	5 MHz
Frequency stability	+0.1 ppm, -30°C to + 60°C (-22°F to + 140°F)
Diagnostic Service Port	
Port type	Async. EIA-232
Baud rate	19,200 bit/sec typical
Data link protocol	ANSI, 8 Data bits. No Parity, 1 Stop bit
Electrical Requirements	
AC input voltage	120 to 240 VAC at 50 to 60 Hz
AC input current	0.4A (Standby at 117 VAC) 1.8A (transmit at 25W, at 117 VAC) 3.3A (transmit at 75W, at 117 VAC)
AC input power	47W (Standby), 211W (transmit at 25W), 390W (transmit at 75W)
DC Input Voltage	26.5 VDC
DC Input Current	6A (transmit at 25W), 11A (transmit at 75W)

Notes:

A = ampere
AC = alternating current
ANSI = American National Standards Institute
°C = degrees Celsius
CRC = cyclical redundancy check
dB = decibel
dBc = decibel (relative to carrier)
DC = direct current
EIA = Electronic Industry Alliance
°F = degrees Fahrenheit
FCC = Federal Communications Commission
FEC = forward error correction
FM = frequency modulation
GMSK = Gaussian minimum-shift keying
HDLC = high-level data link control
Hz = hertz
KHz = kilohertz
Mbit = megabit
MHz = megahertz
ppm = part per million
RF = radio frequency
SINAD = signal in noise and distortion
TIA = Telecommunications Industry Associates
uV = microvolts
VAC = volt alternating current
VDC = volt direct current
W = watt

Table 6-10: Control Point Data Radio Specifications

Description	Specifications
General	
Dimensions	5”HX10”WX10”L
Weight	16 pounds
FCC compliance	Parts 15, 90
Transmitter	
RF power output	30W Normal
Duty cycle	Per TIA-603
Spurious emissions	-65 dBc
Harmonic emissions	-65 dBc
Frequency stability	1.5 ppm, -30°C to 60°C (-22° to + 140°F)
RF Data Communications	
Frequency range	Receive at 935 to 941 MHz, Transmit at 896 to 902 MHz, Normal, Transmit at 935 to 941 MHz, T/A Mode
Number of channels	6 (synthesized, programmable)
Channel spacing	12.5 KHz
Channel resolution	12.5 KHz
Data modulation	GMSK, direct FM
RF bit rate	4,800 bits/sec
Error correction	Reed-Solomon (16, 12) FEC and 16 bit CRC
RF channel access	Data “Busy-Bit” protocol
Maximum frequency deviation	Adjust in accordance with the operations manual
Client Ports	
Types of ports	3 software configurable interfaces, 2 Sync./Async., EIA-422/EIA-232, 1 Sync./Async., EIA-422
Baud rate	9,600 bit/sec typical
Data link protocol	HDLC balanced (Sync. Or PPP Async.), HDLC polled (dial backup), others available
Alarm inputs	7 total
Receiver	
Sensitivity 12 dB EIA SINAD	0.35 uV
Selectivity	-70 dB
Intermodulation rejection (EIA SINAD)	-65 dB
Spurious and image rejection	-75 dB
Frequency stability	1.5 ppm, -30° to + 60°C(-22°F to + 140°F)
Input impedance	50 ohms

Table 6-10: Control Point Data Radio Specifications (Continued)

Description	Specifications
Diagnostic Service Port	
Port type	Async. EIA-RS-422
Baud rate	19,200 bit/second typical
Data link protocol	HDLC
Electrical Requirements	
DC input voltage	13.6 VDC, Negative Ground
DC input current	3A (receive), 14A (transmit)

Notes:

A = ampere
°C = degrees Celsius
CRC = cyclical redundancy check
dB = decibel
dBc = decibel (relative to carrier)
DC = direct current
EIA = Electronic Industry Alliance
°F = degrees Fahrenheit
FCC = Federal Communications Commission
FEC = forward error correction
FM = frequency modulation
GMSK = Gaussian minimum-shift keying
HDLC = high-level data link control
KHz = kilohertz
MHz = megahertz
ppm = part per million
RF = radio frequency
SINAD = signal in noise and distortion
TIA = Telecommunications Industry Associates
uV = microvolts
VDC = volt direct current
W = watt

Table 6-11: Base Station UHF Antenna Specifications

Description	Specifications
Frequency	890 to 940 MHz
Bandwidth for 1.5 to 1 VSWR	50 MHz
Horizontal beam width (1/2 power points)	As required
Vertical beam width (1/2 power points)	As required
Gain	As required
Antenna impedance	50 ohms
Front to back ratio	10 dB
Lightning protection (through support pipe)	DC Ground

Notes:

dB = decibel
DC = direct current
MHz = megahertz
VSWR = Voltage Standing Wave Ratio

2.0 TELEPHONE INTERFACES

Products should be in accordance with the existing agreements between Caltrain and the service providers.

3.0 VOICE RADIO COMMUNICATIONS

The more significant characteristics of the technical specifications of the radio equipment and subsystems that shall be used to replace or retrofit the VHF voice radio are presented in **Tables 6-12** through **6-16**.

Table 6-12: Base Station Radio Specifications

Specification	Description	Note
Model	MASTR III VHF, analog, conventional base station	
Operation	Simplex/full duplex	
Squelch gate	Carrier only	
Power	10 to 110 watts, adjustable	
Channel spacing	12.5/25/30 KHz	Capable of 12.5 KHz
Sensitivity (EIA 12 dB SINAD)	-116 dBm	
Selectivity	90 dB	
Number of channels	1 transmit, 1 receive	

Notes:

dB = decibel
dBm = decibel-milliwatts
EIA = Electronic Industry Alliance
KHz = kilohertz
SINAD = signal in noise and distortion
VHF = very high frequency

Table 6-13: Locomotive/Cab Car Specifications

Specification	Description	Note
Model	VHF, analog, conventional mobile radio	
Operation	Simplex/half duplex	
Squelch gate	Carrier only	
Power	45 watts, adjustable	
Channel spacing	25/30 KHz	Capable of 12.5 KHz
Sensitivity (EIA 12 dB SINAD)	-116 dBm	
Selectivity	90 dB	
Number of channels	>90	

Notes:

dB = decibel
dBm = decibel-milliwatts
EIA = Electronic Industry Alliance
KHz = kilohertz
SINAD = signal in noise and distortion
VHF = very high frequency

Table 6-14: Mobile Radio Specifications

Specification	Description	Note
Model	VHF, analog, conventional mobile radio	
Operation	Simplex/half duplex	
Squelch gate	Carrier only	
Power	45 watts, adjustable	
Channel spacing	12.5/25/30 KHz	Capable of 12.5 KHz
Sensitivity (EIA 12 dB SINAD)	-116 dBm	
Selectivity	90 dB	
Number of channels	>90	

Notes:

dB = decibel
dBm = decibel-milliwatts
EIA = Electronic Industry Alliance
KHz = kilohertz
SINAD = signal in noise and distortion
VHF = very high frequency

Table 6-15: Portable Radio Specifications

Specification	Description	Note
Model	VHF, analog, conventional portable radio	
Operation	Simplex/half duplex	
Squelch gate	Carrier only	
Power	5 watts	
Channel spacing	12.5/25/30 KHz	Capable of 12.5 KHz
Sensitivity (EIA 12 dB SINAD)	-116 dBm	
Selectivity	90 dB	
Number of channels	>10	

Notes:

dB = decibel
dBm = decibel-milliwatts
EIA = Electronic Industry Alliance
KHz = kilohertz
SINAD = signal in noise and distortion
VHF = very high frequency

Table 6-16: 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

4.0 PTC RADIO COMMUNICATIONS

The designer shall coordinate with JPB in selecting the PTC radio communications products.

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 VHF AND ATCS BASE STATION

Base station antennas shall meet the technical requirements of **Table 6-11 and 6-12**. In particular, the horizontal and vertical beam-width shall be designed to support coverage to the range of CPs specified. 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.

1.1 ATCS DATA RADIO CONTROL POINT

One tilt-down antenna tower, one omni-directional antenna, one MCP radio, and associated batteries, battery chargers, direct current (DC)/DC converters, and lightning arrestors shall be required for each data radio CP site. The installer shall provide the tilt-down antenna tower, installation accessories, and the coaxial cables, and, in accordance with the contract documents, the required multi-strand and ground cables, connectors, and installation accessories.

The following equipment and material shall be required at each data radio CP site:

a. One MCP radio shall be provided for each data radio CP site, configured to communicate with the two base station sites. The radios shall be ATCS MCP data radios manufactured by either Safetran or GE/Harmon. The Safetran unit is preferred due to the remote diagnostic capabilities.

b. One omni-directional antenna shall be provided for each data radio CP site, equipped with a Type N female connector, and mounted to the top of each tilt-down tower using a 10- to 12-foot section of aluminum pipe, weighing no more than 16 pounds.

c. One 12 VDC battery plant shall be provided for each data radio CP site, (each plant comprising ten 1.2 VDC batteries), plus a 12 VDC battery charger, a DC/DC converter, and a lightning arrestor.

2.0 INSTALLATION INSTRUCTIONS

The designer shall coordinate with JPB regarding the installation requirements for the PTC radio communications system.

2.1 ATCS DATA RADIO CONTROL POINT

Installation of the antennas, tilt-down antenna towers, MCP radios, batteries, battery chargers, DC/DC converters, and lightning arrestors shall be performed in accordance with the manufacturer's written specifications. The manufacturer's written installation instructions shall be provided with the equipment.

3.0 RADIO PROGRAMMING AND CONFIGURATION

3.1 ATCS DATA RADIO MOBILE COMMUNICATIONS PACKAGE

MCP radios shall be configured for operation on either of two ATCS channels, based on the radio's area of operation. ATCS channel number 2 corresponds to an MCP transmit frequency of 896.9375 MHz and an MCP receive frequency of 935.9375 MHz. ATCS Channel number 5 corresponds to an MCP transmit frequency of 897.9375 MHz and an MCP receive frequency of 936.9375 MHz. Radios shall provide up to 30 watts of transmit power, and shall have a receiver sensitivity of 0.35 microvolt or better for 12 dB SINAD. The transmitter shall be aligned to ensure that it is operating on-frequency, with proper deviation and output power, into a 50-ohm load.

Additionally, the transmitter should be aligned to ensure that it produces the maximum frequency deviation allowed for its emission designation. The installer shall install and connect the MCP radios provided to the radio antenna system and to the DC power plant, as shown on the contract documents. The interface cable shall be provided by the contractor. The connection between the MCP radio and the Vital Logic Controller shall be performed by others. The MCP Radios provided shall be manufactured by either GE Harmon or by Safetran Systems. The installer shall follow the directions provided in of the grounding requirements provided with the contract documents to ensure the proper grounding of the MCP, antenna, tilt-down antenna tower, and other radio equipment.

4.0 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.

5.0 BATTERY PLANT

5.1 ATCS DATA RADIO

A battery bank and 12 VDC battery charger shall be installed at each CP. All radio equipment shall be powered directly by the batteries, which shall be configured to “float charge” so that momentary interruptions of alternating current (AC) power will not interrupt radio service. The design of the battery plant and charger shall be performed by others, to provide a minimum of 24 hours of battery backup at full load.

A DC/DC converter shall also be installed in series with the charger, as shown in the contract documents, to provide additional isolation. The installer shall install the lightning arrestor directly to the coaxial antenna cable, at the closest convenient location to the point of entry to the CP signal house. A 2/0 ground cable shall be installed between the lightning arrestor and the CP ground plate.

6.0 GROUNDING AND LIGHTNING PROTECTION

Refer to the Caltrain grounding requirements for details of the requirements applicable to the Caltrain Standard Specifications.

7.0 SAFETY

The installer shall follow the written safety instructions provided by 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.

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 Deputy 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.

Caltrain vehicular and pedestrian crossings use a track-circuit based device, 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. 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.

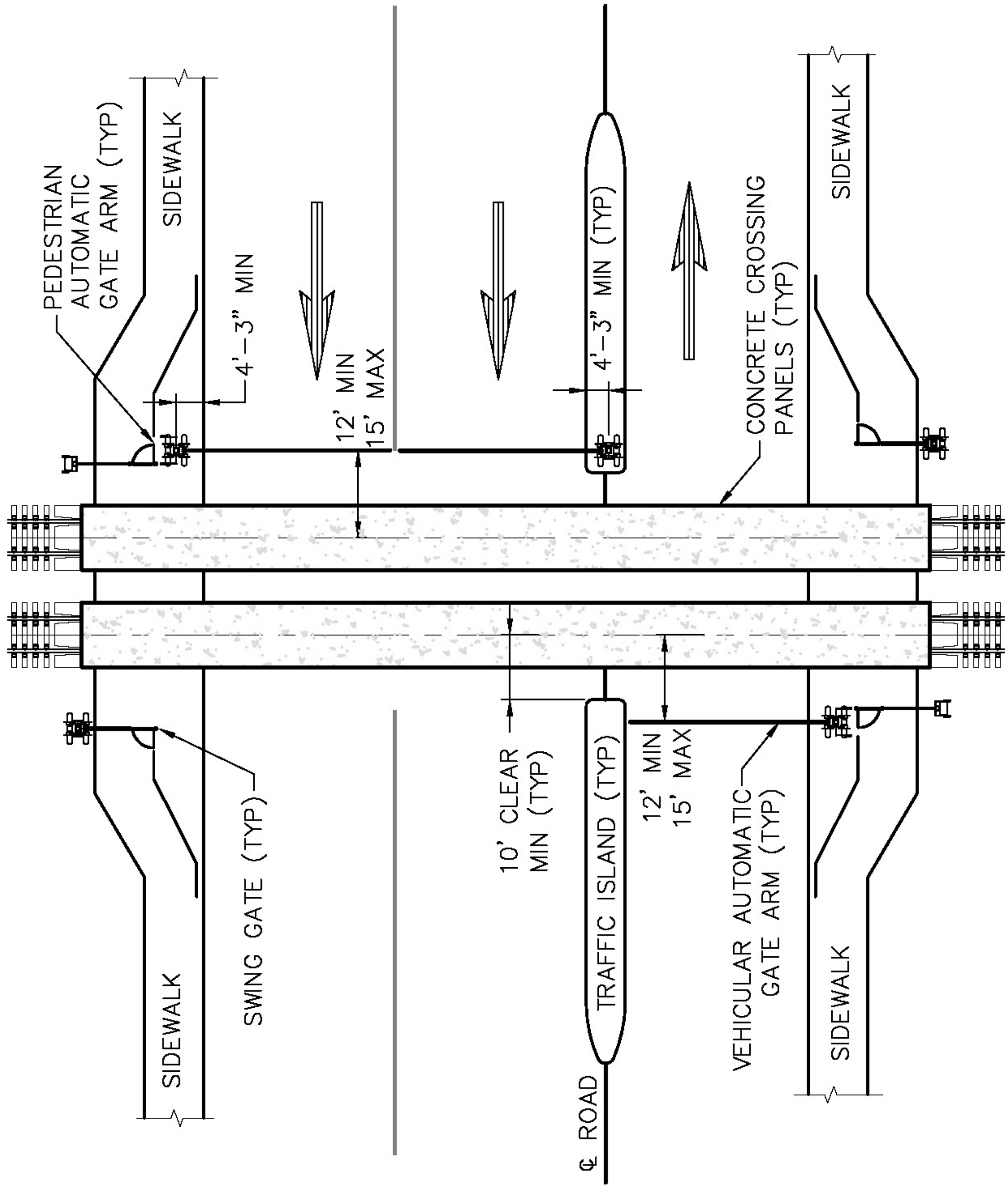


Figure 7-1: Typical Vehicular Crossing (Right-Angle Intersection)

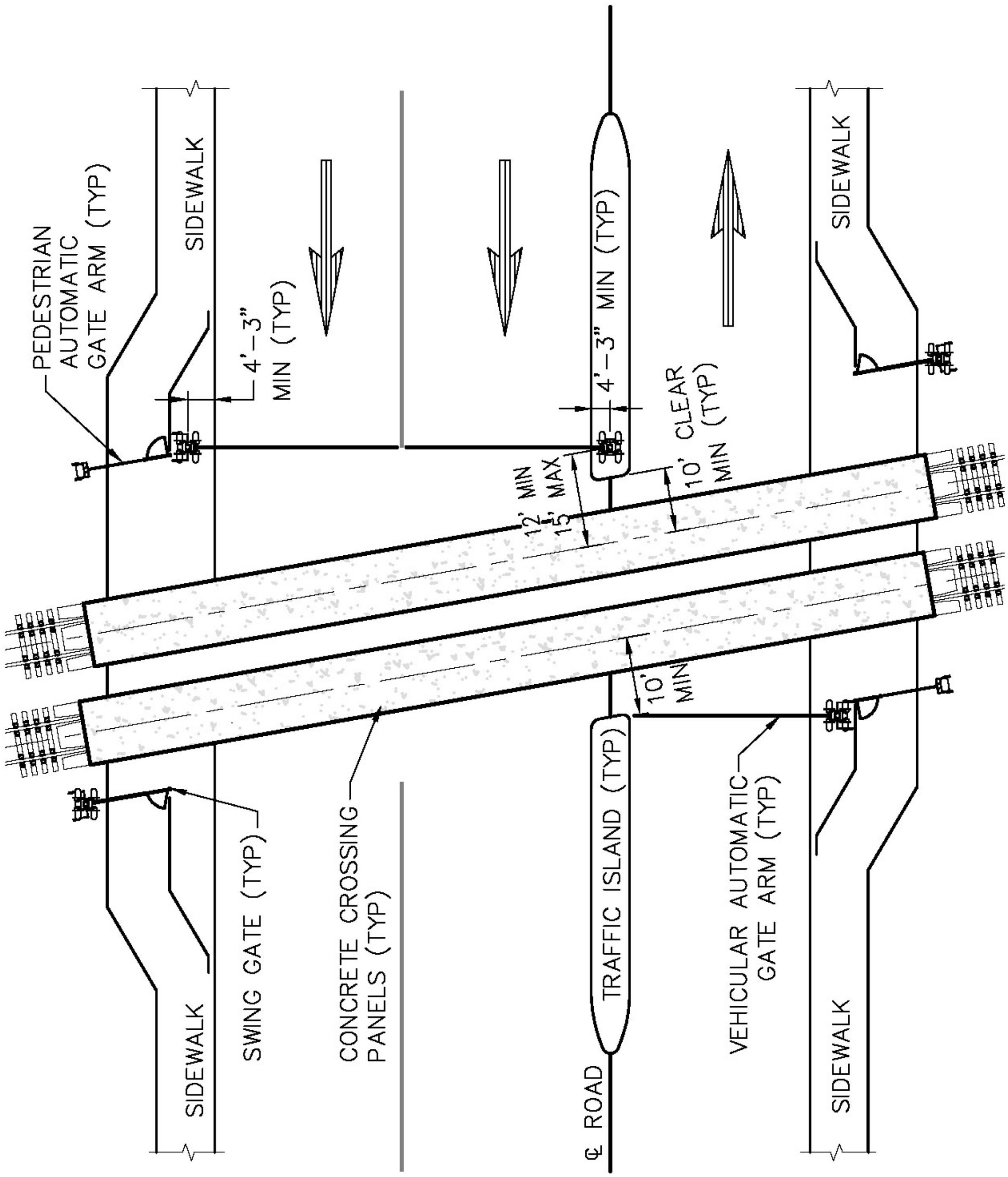


Figure 7-2: Typical Vehicular Crossing (Obtuse Intersection)

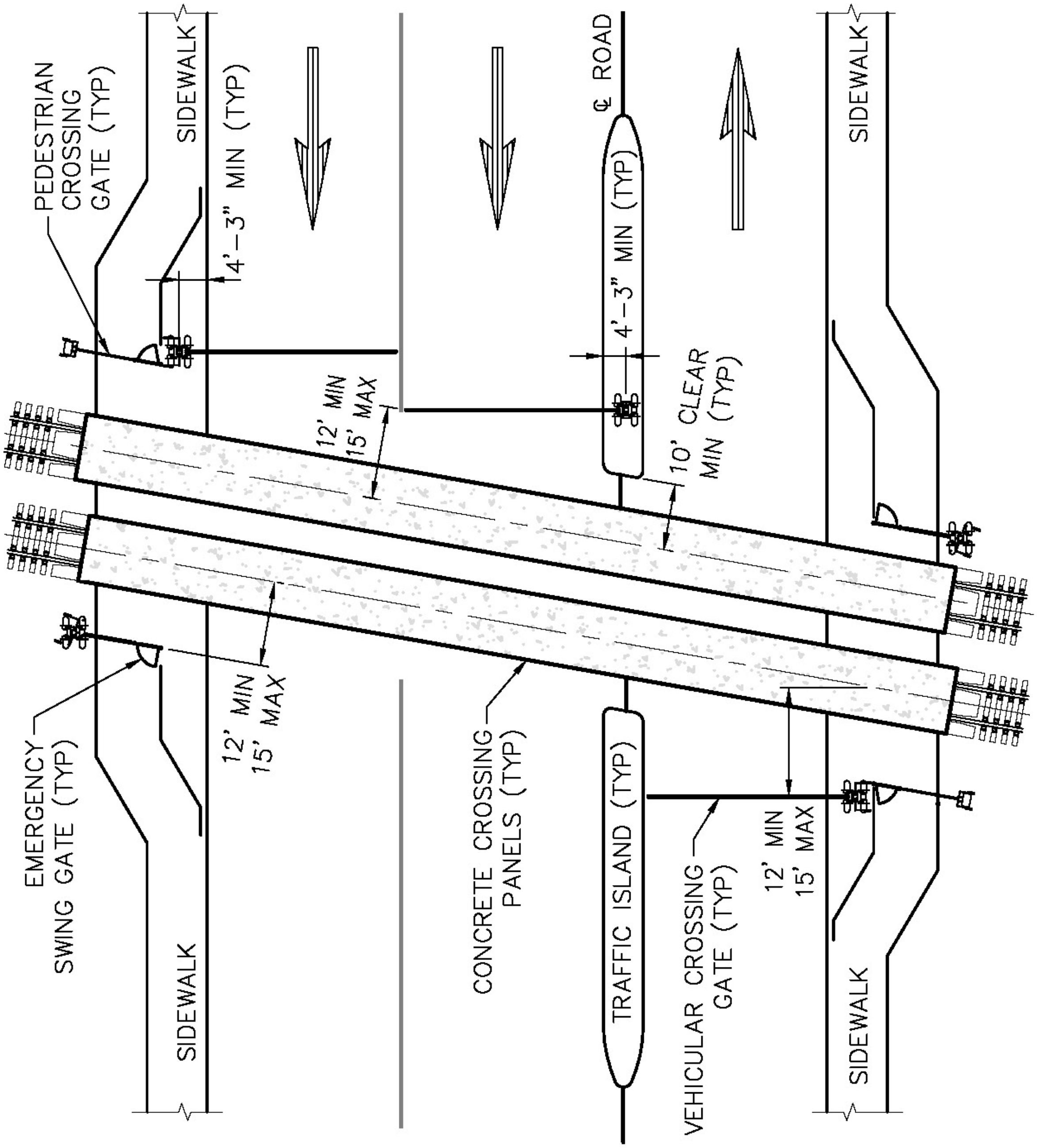


Figure 7-3: Typical Vehicular Crossing (Acute Intersection)

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. 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

1.2.2 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 be face the roadway(s) and be visible to incoming motorists, either on the crossing houses 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 Deputy 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.

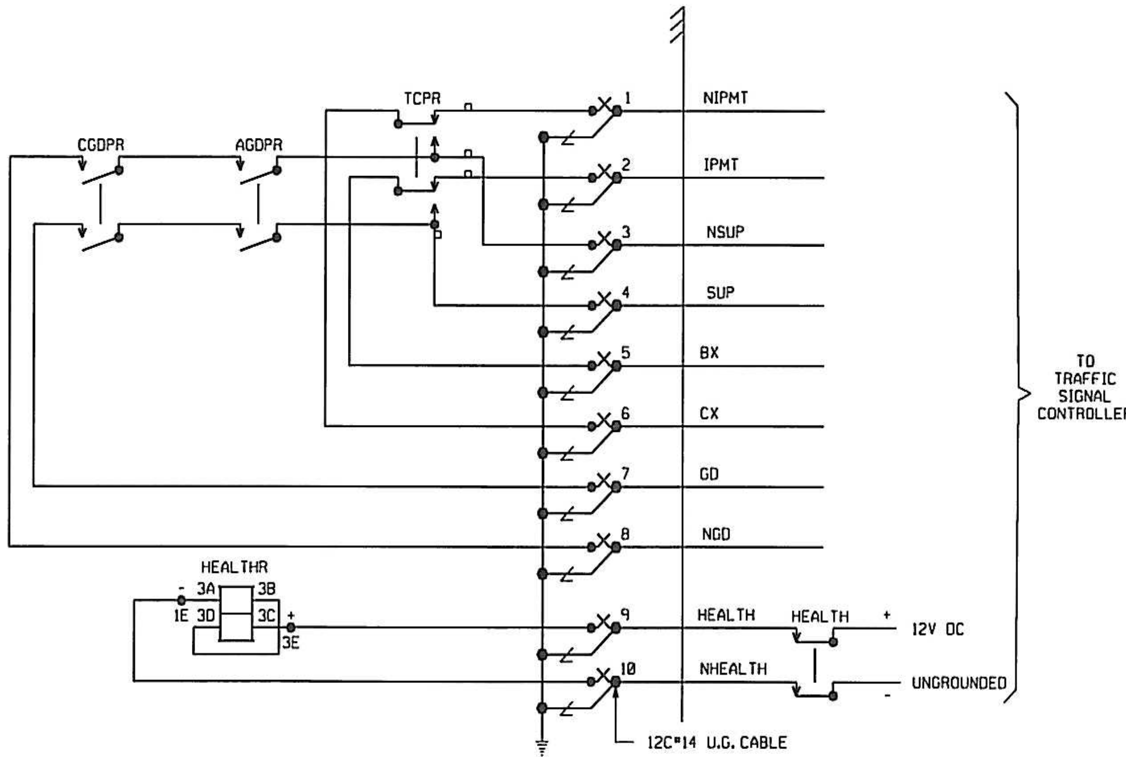


Figure 7-4: Interconnection Circuits with Supervision, Gate-Down Circuitry, and Health Circuit

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.

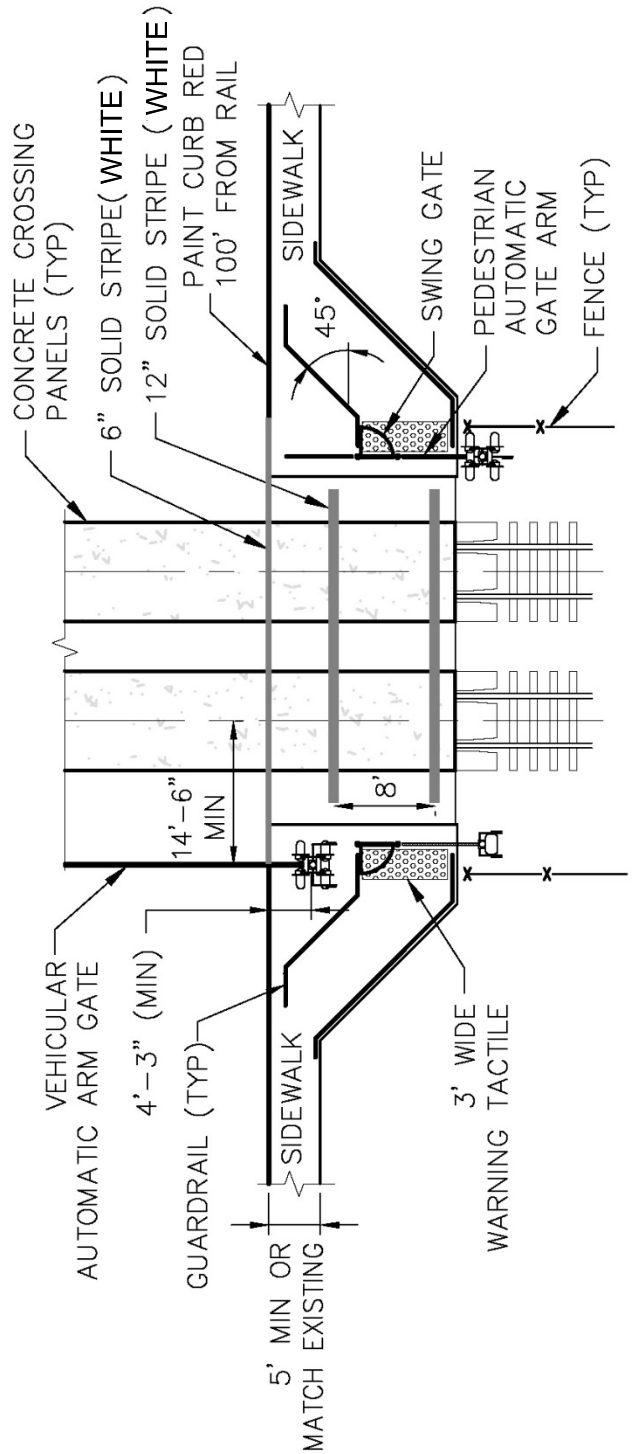


Figure 7-5: Typical Pedestrian Sidewalk at Vehicular Crossing

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.**

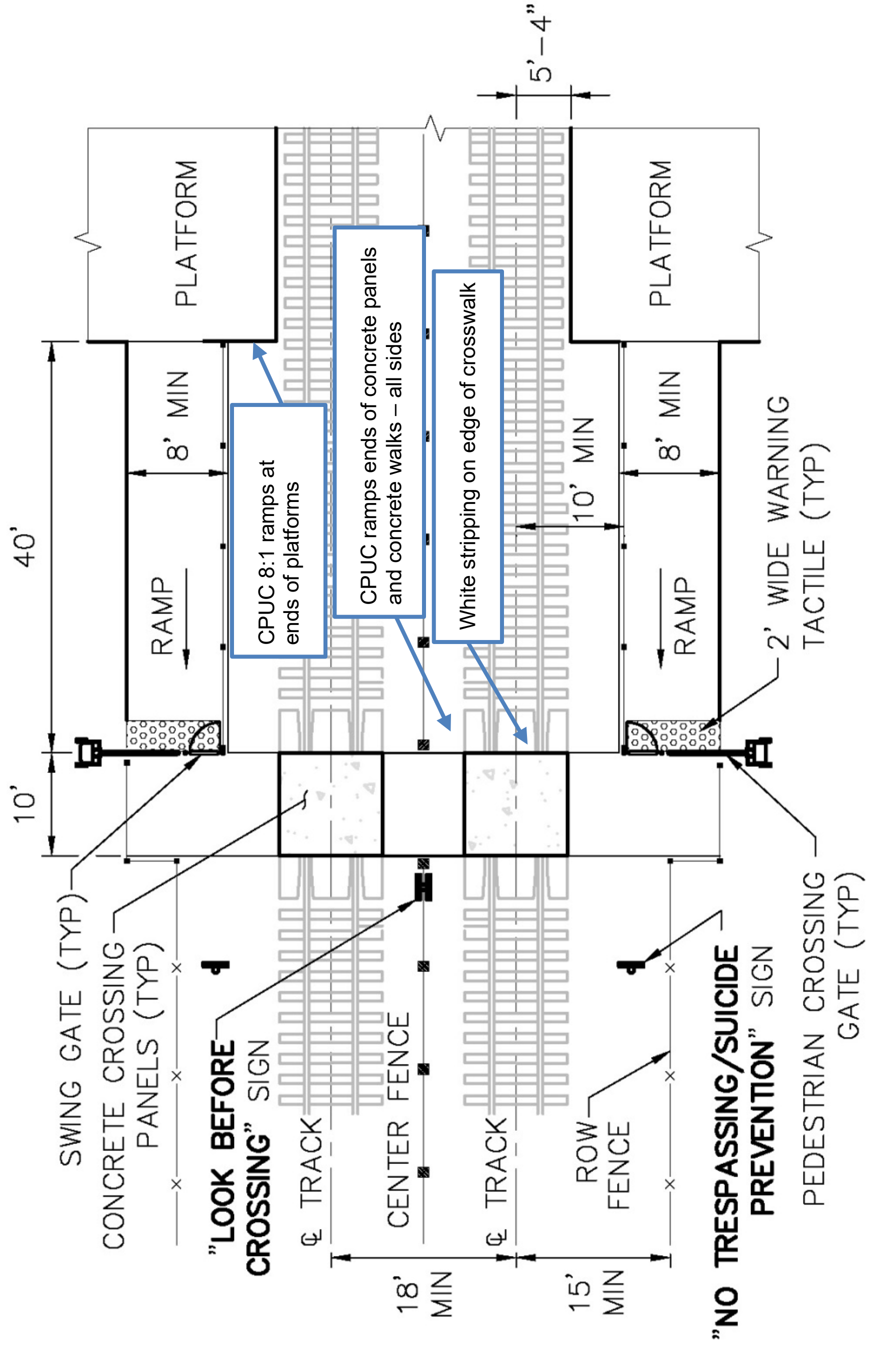


Figure 7-6: Typical Pedestrian Crossing at Stations

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.

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		CHECK IF LESS THAN ONE MOVEMENT PER DAY ☐		TYPE AND NUMBER OF TRACKS		
TOTAL				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? ☐ Yes ☐		
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 ☐ NO	☐ 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 are described and included as part of the criteria for the station facilities in **Chapter 3, Stations and Facilities**.

B. STRUCTURAL

Caltrain structures include bridges; grade separation structures, such as pedestrian underpasses and overhead, 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 with manufacturer-recommended foundation designs. The design of the structures follows Caltrain typical signal cantilevers, as specified in the Caltrain Standard Drawings for Signals. The foundation of signal cantilevers follows the manufacturer's recommendations. The foundation of signal bridges is provided in the Caltrain Standard Drawings. Signal foundation is typically of the gravity type.

The design of civil structures that are owned and/or maintained by Caltrain 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 shoring requirements shall follow the criteria of the *PCJPB Engineering Standards for Excavation Support Systems*.

Caltrain standards and requirements shall take precedence over other codes, such as 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. AREMA takes precedence over BDS for structures subject to railroad loading, and BDS takes precedence over CBC for structures subject to truck loading.

The design of structures that are owned or maintained by other agencies shall be in accordance with the standards of those agencies. These are either new construction, or rehabilitation, relocation, or modification of the 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 encountered that are not specifically covered in these criteria, a project-specific design criteria shall be submitted for the approval of the Caltrain Deputy 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 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.

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 from the bottom of ties. If the drainage system crosses the tracks, the system shall cross at a 90-degree angle to the center of tracks.

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, Caltrans’ guidelines shall be used.

1.1 HYDROLOGY

1.1.1 Storm Frequency

In general, a 50-year storm frequency shall be used for design of drainage ditches. However, the frequency may be modified to be in balance with the design life and damage potential of the structure or area to be protected.

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

The maximum expected discharge from drainage tributary areas shall be computed using the Rational Method. 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.

1.2 UNDERDRAIN PIPE

Underdrain pipe shall be minimum 6 inches in diameter at a minimum grade of 0.2 percent. 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 be wrapped in permeable geotextile. Underdrain cleanouts shall be installed every 300 feet.

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.

Manholes and inlets shall be spaced 500 feet apart, maximum, for manholes and inlets up to 30 inches in diameter; and 650 to 1,000 feet apart for manholes and inlets larger than 30 inches in diameter.

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 Water Quality Order No. 2013-0001-DWQ, National Pollutant Discharge Elimination System 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 is required to 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 on the certified lists published by the State Water Board on their Storm Water Trash Implementation Program webpage.

2.0 PUMP STATIONS

Caltrain pump stations are lift stations that may consist of a 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.

For reasons of economy of initial investment and maintenance, pump stations shall be avoided as much as possible. Where gravity systems are not practical, the pump stations shall require prior approval of the Caltrain Deputy Director of Engineering.

D. UTILITIES

This section covers design of underground utilities for new installation and for the relocation, adjustment, and/or abandonment of existing underground utilities, including those not owned and/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 Deputy 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 at a 90-degree angle to the track centerline.

c. Materials: Utilities shall be constructed with nonconductive materials.

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 at a minimum of 12 feet from the centerline of closest track. 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 be in conformance with the latest technical specifications and practices of the respective utility owner and Caltrain requirements.

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 to the information from the record survey.

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 of local fire marshal of fire protection provisions and access for emergency personnel and equipment. 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 walking surface; however, AC pavement surface is not required.

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 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 dispositions 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. Renew all existing leases only with the approval of the Caltrain Deputy Director of Engineering

c. Execute any new leases only with the approval of the Caltrain Deputy 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 a franchise right. Land can also be acquired when a railroad exercises its right 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 or 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. Literally, portions of the railroad property that were acquired through an easement are 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 presume sole right and ownership to the property. The grantee may extend the right to the property with 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 dispositions.

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 and permanent easements. 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 Deputy 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 principals 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.

After 2007, the National Geodetic Survey (NGS) will put all control under a new national control system known as the NAD 83 National Spatial Reference System. The NGS will combine all control points, both HARN and CORS points, under this one system. At that time, Caltrain will begin to use this new system.

1.1.2 Epochs

In 2012, the NGS published the NAD 83(2011) referenced as epoch 2010.00. Caltrain will be specifying 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 currently specifies the use of the current geoid (Geoid 03) 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 new or adjusted NGS NAVD 88 benchmarks only. 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 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 will 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 specification 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 will be subsequently adjusted using fully constrained adjustments in the current epoch to check the validity of the control work.

These baselines will 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 manmade 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 in 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 standard 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 in 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 perform testing to determine which of the 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 needs for the required output pixel resolution shall be established in the beginning.

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

CHAPTER 9 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 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 a man 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 or reversion such that should the subsequent owner violate the condition 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 the railroad has 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 easement 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 or ownership to the real property. When the real property is no longer in the use of the grantee, the original owner will presume sole right and ownership to 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 dispositions.

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 for renewal shall only be renewed after consultation with Caltrain Engineering. New leases shall not be executed without prior approval by Caltrain Deputy 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 is Caltrain specification. 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.

b. Minor Design Changes

When minor design adjustments are required, a meeting should occur between the Project Manager and the ROW Engineer.

2.2.2 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 the 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 the 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 the 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 the Caltrain as part of the purchase and sale agreement with the SP.

d. Secure all recorded or unrecorded deeds, rights or agreements inherited by the 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's 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 the Caltrain's in-house mapping records for original track alignment and parcel configuration information.

h. Research the 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.

2.2.3 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 on searching the 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

2.2.4 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 legals 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 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 the 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 the Caltrain.

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 the Caltrain, the use of bounds only descriptions is discouraged.

Plat Maps

A plat map as defined by the 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 the 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 or 8.5 by 14 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 principals of geodesy are of high precision and generally extend over large areas, such as 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 but 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 earths 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'Heuer terrestrial system of 1984 (BTS-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 BTS-84 system and based upon the GRS 80 ellipsoid.

Caltrain corridor control network is based upon NAD 83, and all geodetic surveying work performed for Caltrain shall adhere to this datum. State Code of the State 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. HARN's and CORS are from different adjustments and should not be used together in the same survey.

After 2007 the NGS will put all control under a new national control system known as the NAD 83 National Spatial Reference System. The NGS will be combining all control points, both HARN and CORS points under this one system. At that time, Caltrain will begin to use this new 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 the positions 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 will be specifying 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 on an ellipsoid which closely approximates the size and shape of the earth in the area of the survey. 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. Currently Caltrain is specifying the use of the current geoid (Geoid 03) be used 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 datum's, 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 will use new or adjusted NGS NAVD 88 bench marks only, 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 except control point data using elevation data derived from Real-Time Kinematics 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.

Baseline Adjustment using Least Square Adjustment

Baselines generated during geodetic surveys will be adjusted using a minimally constrained adjustment to check the measurement data and insure that the survey meets Federal Geodetic Control Subcommittee criteria and Caltrain specification 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 will be subsequently adjusted using fully constrained adjustments in the current epoch to check the validity of the control work.

These baselines will 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 is a coordinate system that 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 insure 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 the 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 in aerial mapping and photography except that any mapping 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' 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 is designed to give 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:foot	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 detail 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 method 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 manmade 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

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
APC	American Power Conversion
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 gage

- B -

BAA	boarding assistance area
BART	Bay Area Rapid Transit District
BCCF	Backup Central Control Facility
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
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
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
GE General Electric
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
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 Electric 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
PC	point of curve
PCJPB	Peninsula Corridor Joint Powers Board
PDF	Portable Document Format
PE	preliminary engineering
pH	Potential of Hydrogen
PI	point of intersection
PIDS	passenger information display 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
RF	radio frequency
RMC	rigid metal conduit
RMSE	root mean square error
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
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 Associates
TIDS	transit information display sign
TIN	triangulated irregular network
TO	turnout
TOD	transit-oriented development
TPOB	ton per operative brake
TS	tangent to spiral
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 Transportation Authority

- W -

W	watt
WAG	wayside access gateway
WAN	wild 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 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 Codes 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-D	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 the San Mateo County

D. Santa Clara County

E. Cities in the 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)

1. 455 Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers and Other Fiber Optic Components

2. 568 Commercial Building Telecommunications Cabling Standards

3. 569 Commercial Building Standard for Telecommunications Pathways and Spaces

4. 606 Administration Standard for Telecommunications Infrastructure

5. 607 Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises

F. American Railway Engineering and Maintenance-of-Way Association (AREMA)

1. Communications & Signals Manual of Recommended Practices

   a. Part 1.5.10 Recommended Instructions for Painting and Protective Coatings

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)

1. A48 Standard Specification for Gray Iron Castings

2. A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

3. B3 Standard Specification for Soft or Annealed Copper Wire

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)

1. 310 Cabinets, Racks, Panels, and Associated Equipment

N. Illuminating Engineering Society (IES)

O. International Building Code (IBC)

P. Institute of Electrical and Electronics Engineers (IEEE)

1. National Electrical Safety Code (NESC)

Q. Insulated Cable Engineers Association, Inc. (ICEA)

1. S-84-608 Telecommunications Cable Filled, Polyolefin Insulated, Copper Conductor Technical Requirements

R. Motorola R56 Standards and Guidelines for Communication Sites

S. National Electrical Manufacturers Association (NEMA)

1. WC 5 Thermoplastic-Insulated Wire & Cable for the Transmission & Distribution of Electrical Energy

2. WC 7 Cross-Linked-Thermosetting-Polyethylene-Insulated Wire & Cable for the Transmission &Distribution of Electric Energy

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)

1. 1581 Reference Standard for Electrical Wires, Cables, and Flexible Cords
2. 969 Marking and Labeling Systems
3. 444 Communications Cables
4. 1690 Data-Processing Cable