IMPORTANT:

The Engineering Standards (Design Criteria, Standard Drawings and Standard Specifications) are currently being updated.

If access is needed to the 2011 Standards, please email Caltrain Engineering at engineeringstandards@samtrans.com and include why the Standards are required and your contact information.
CALTRAIN STANDARD CRITERIA
SECOND EDITION
SEPTEMBER 30, 2011

These Caltrain Standard drawings supersede Standards dated April 15, 2007.

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

Caltrain Standards consist of:

1. Design Criteria
2. Standard Drawings
3. Standard Specifications
4. Standards for Design and Maintenance of Structures
5. Engineering Standards for Excavation Support Systems
6. CADD Manual

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Engineering Manager  
Deputy Director of Engineering

SEPTEMBER 30, 2011
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CHAPTER I

DESIGN GUIDELINES

A. PURPOSE

The Design Criteria (Document) establishes the uniform and minimum standards for planning, design, and construction as well as maintenance of Peninsula Corridor Joint Powers Board (PCJ PB or JPB) facilities. This document is developed based on best industry standards and accepted practices for Commuter/Class 1 railroads and equals or exceeds applicable regulatory requirements.

PCJ PB and JPB are used interchangeably to mean agency. The name of the commuter service, Caltrain is often used in this document in the capacity as the agency because of the familiarity of the public with the name and associating it as the agency.

The Design Criteria (Criteria) is intended to cover the majority of Caltrain's current and future improvements. The Criteria does not attempt nor is it practical or feasible to cover all situations that might be encountered or requested throughout a project's life. Future large projects such as Electrification, and Dumbarton Rail Corridor (DRC) will develop their own Criteria and Standards on an as-needed basis.

Other projects by other various such as the Downtown Extension (DTX) and the Transbay Terminal Center (TTC) by the Transbay Joint Powers Authority (TJPA), and the California High Speed Train (HST) by the California High Speed Rail Authority (CHSRA) will have their own Criteria and Standards. The DTX project includes sharing of underground multi-modal stations, tunneling, etc. Part of the CHSR 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, namely Standard Drawings, and Standard Specifications supersedes the first issue (April 2007). The other three (3) other documents listed below issued separately which collectively form Caltrain Engineering Standards, or Caltrain Standards.


c. CADD Manual (“Drafting Standard”)
All these documents, including any changes made to them are available online on the Caltrain website (caltrain.com).

References on regulatory bodies and industry standards are included in the APPENDIX.

In the event of conflict between the Criteria, Specifications and Standard Drawings, and the industry standards such as AREMA, Federal Railroad Administration (FRA), California Public Utilities Commission (CPUC), and 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 life and controlled document. Users may forward any proposed changes or suggestions for consideration through the website. The criteria in this document will be updated on a continual basis to reflect regulatory changes and changes in Caltrain and industry practices. These updates will be posted on the website. 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 ('shall') means required, no exception. Guidance ('should') means recommended, involving engineering judgment. Option ('may') means permission. Support is informational statement. Any deviations from all 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 can not be used for future variance request. Any 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 is intended to provide the designer with flexibility while ensuring that the functionality, goals and objectives of Caltrain are met. The Design 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 (QA) process to provide some level of independent verification. The designers are ultimately responsible for every aspect and the overall integrity of the design.

B. PENINSULA CORRIDOR JOINT POWERS BOARD (PCJPB)

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 Peninsula Corridor Joint Powers Board (PCJPB or JPB).

The Peninsula Corridor Joint Powers Board is a state-authorized joint powers authority comprised of the three counties where Caltrain operates: San Francisco, San Mateo, and Santa Clara Counties. PCJPB owns approximately 52-route miles of rail corridor between San Francisco and San Jose, and an additional approximately 25 miles of trackage rights from San Jose to Gilroy. San Mateo County Transit District (SamTrans) provides administrative and staff support for PCJPB. See FIGURE 1-1 CALTRAIN SYSTEM MAP.

After about 20 years as Caltrain’s Contract Operator, Amtrak (National Railroad Passenger Corporation) is being replaced by TASI (Transit American Services, Incorporated), a subsidiary of Herzog in 2011. Being the Operating Railroad of Record (ORR) the Contract Operator 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 ROW maintenance), and inspections of bridge structures.

Additionally, the Contract Operator also on an as-needed basis provides supports of construction activities (capital, maintenance, and third-party work) in the form of Roadway Worker Protection (RWP) as well as signal maintainers, track inspectors, and communications system technicians. The Contract Operator performs the services of certifying the conditions of track and signaling and communications systems for return to safe and functional train revenue service following the completion of construction work.

1.0 CALTRAIN MISSION

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

The principal objectives of Caltrain commuter system are:

a. A safe, reliable and cost effective service

b. Contribution and support of regional air quality goals
FIGURE 1-1 CALTRAIN SYSTEM MAP

Caltrain corridor

UPRR corridor (trackage rights)
c. Working in partnership with regional plans and policies, and communities and other stakeholders for a balanced transportation system and potential economic enhancement.

d. Integration with other transit modes

e. An infrastructure that will sustain future regional growth

2.0 CALTRAIN CORRIDOR ASSETS

Current Caltrain corridor assets can be found in Caltrain Track Charts, Right-of-Way and Rail Corridor Infrastructure Assets.

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. Majority of the cargo is typically lumber, rock aggregates and some scrap metal. Freight traffic, about 3 or 4 trains daily, is typically moved at night.

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.

The UPRR and the PCJPB have joint facility arrangements in a number of locations. The PCJPB has the responsibility of maintaining a freight yard in South San Francisco and all industrial tracks that are within the Caltrain right-of-way (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, this typically being VTA (Santa Clara Valley Transportation Authority) for improvements within the Santa Clara County. Some Cities have sponsored and managed for improvements through their cities.

Construction contracts are typically DBB (Design Bid Build) on the basis of a competitive bid similar to any public works contracts. Other project delivery methods may be by the procurement process, for long delivery items, and for other supply contracts for materials such as ballast. Caltrain will consider, on a case by case basis, Design-build delivery method if the projects are relatively large (dollar and duration) and complex. Caltrain has not implemented this delivery method.

C. PLANNING AND DESIGN CONSIDERATIONS

For a successful implementation of 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.

Caltrain capital projects fall into the categories of safety improvements; state of good repair; operational enhancements and new initiatives. Safety improvements are developed through state and federal mandates and/or conditional assessments. State of good repair projects are to sustain the current system and operation taking into consideration of current conditions and remaining useful life of the asset. Operational enhancements are projects which improve throughput and reliability while new initiatives address long range planning efforts and future needs.

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 next design level. Each level shall be accompanied by an updated schedule, cost estimate, specifications, constructibility analysis, and Caltrain’s Safety and Security Certification.

During planning phase, considerations include Operations planning and Environmental planning. This will involve identifying stakeholders, such as the local agencies (cities, counties), communities (residents and businesses), PCJ PB partners, Caltrain riders, etc. 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 the Operations are essential. Examples of such inputs include the following:

a. Capacity and throughput improvements
b. Electrification (Future)
c. Infrastructure changes to enhance train performance
d. Track speed increase to accommodate future operations
e. Train service levels increase
f. Trip/travel time reduction
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 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 below.

a. CEQA (California Environmental Quality Act) guidelines

b. NEPA (National Environmental Policy Act) requirements

Project sites with historical resources such as station buildings (depots) and historical districts listed on the National Register of Historic Places (NRHP) are under the purview of the State Historical Preservation Officer (SHPO). The South Bay Historical Railroad Society (SBHRS) has an agreement with 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 station building at Atherton Station, shall be given proper consideration.

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

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

3.0 DESIGN LIFE

The design life for both permanent and temporary facilities are described below. While this determination is typical for railroad environment the Designers shall use it as a 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
b. Signaling System: 25 years, except noted otherwise

Signaling system is a most mission critical component of a commuter operations. The system, in concert with track system and train control communication system governs the operations of railroad. It includes the following:
   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 noted otherwise

The system, working in concert with the signaling system is part of communication for train operations:
   i. Communication tower
   ii. Data or Radio system, including fiber optic

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

The facilities are typically station related and generally contained within the limits of the stations:
   i. Station platforms
   ii. Station amenities (shelters, benches, bike racks, 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 system subject to dynamic and continuous enhancement in technology. Including in these are:
   i. VMS (Variable Message Sign)
   ii. PA (Public Address) system
   iii. TVM (Ticket Vending Machine)
   iv. CCTV (Closed Circuit Television) cameras

f. Major Civil Structures: 100 years

Major civil structures are part of the railroad infrastructure as follows:
   i. Bridges
   ii. Grade separation structures (vehicular)
   iii. Grade separation structures (pedestrian underpasses and overpasses)
   iv. Retaining walls

g. Others:

Other civil engineering components include the following:
   i. Grade Crossings (non-signal): 25 years
ii. Drainage System:
   1. Storm Water 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 five (5) years. They are typically required to facilitate
construction, or for interim improvement prior to construction of permanent facilities.
Examples of these facilities include the following:

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
time for materials, equipment and components.

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

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., which have been
reviewed and approved by Caltrain Deputy Director of Engineering. The DBM shall
include all assumptions, Records of all Requests for design exceptions, a thorough
analysis for 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 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 specific design checklist to meet the needs and objectives, in order to facilitate the quality control process. The objective shall include establishing sustainability goals in general accordance with the State Building Code, in particular Green Building Standards Code (or CalGreen). Below are examples of design considerations that the checklists should incorporate for various design disciplines.

1.0 CONSTRUCTION IMPACTS

It is imperative that during design that construction phasing or staging for any project which intrudes on or has the potential to intrude on rail operations shall be planned in such a way as to mitigate any impact on Caltrain train operations. Further, the design review process shall clearly identify the resources required from Caltrain, and all impacts to operations, including when and for how long as well all mitigation measures. All must be collaborated and approved in advance by Caltrain Rail Operations.

The following may be used as a guidance for planning construction phasing and staging:

a. Double track closure is not permitted during regular scheduled services. Double track closure may be permitted but limited to the short off-peak service hours and only on weekends.

b. Single track closure may be allowed during weekends.

c. Speed of temporary tracks shall typically be maintained at existing speed, but in general not less than 65 MPH.

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

e. Station closure shall not be contemplated.

2.0 OPERATING SAFETY CLEARANCES

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 with full track element “footprints” for special trackwork elements to check and assure 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. Embankment and drainage design shall include footprints for signals, signal enclosures, and signal and communications vaults, manholes, pull boxes, and conduit runs.

a. Constructability
b. CPUC requirements
c. Safety of freight operations
d. Drainage and grading of trackway
e. Horizontal track alignment and vertical track profile requirements
f. Locations of special trackwork includes signal components
g. Locations of related track and signal components
h. Sections typical to trackway
i. Spacing and clearances of track
j. Design speed and maximum authorized speed

4.0 STATIONS AND FACILITIES

Stations shall be designed to provide safety, and accessibility to all users, including bicyclists and mobility impaired persons. The resulting stations shall be convenient, functional and attractive. Safety is paramount of all. 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, incorporating local elements.

5.0 STATION COMMUNICATIONS SYSTEM

This communications system include three (3) components, namely passenger information system (Visual Message signs or VMS, and Public Announcements or PA), fare collection (TVM or Ticket Vending Machine, and Clipper or regional pay system), and safety and security system.

Passenger information system is controlled from the CCF (Central Control Facility) at CEMOF (Centralized Equipment Maintenance and Operations 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 or MTA.

6.0 SIGNALS

This is a mission critical component of the Caltrain commuter system. Design of 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 joints 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

As with Signaling system, this is a mission critical component of the Caltrain commuter system, among others providing interaction among the train dispatchers and field personnel. The system is integrated to 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

8.0 AT-GRADE CROSSINGS

Design of grade crossing shall result in a safe, convenient, and functional passage for trains and all users, including motorists, and non-motorists (pedestrians, mobility impaired persons, bicyclists). The vehicular crossings where there are adjacent 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 a high pedestrian traffic.

The design shall meet the requirements of the ADA accessibility, Federal Railroad Administration (FRA), Federal Highway Administration (FHWA), the CPUC 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 in the corridor in order to effectively maintain Caltrain infrastructure. During design and construction, the considerations shall include impacts to adjacent properties to Caltrain, impacts to operations and maintenance, including site access. The drainage shall improve the existing conditions and proposed improvements.

Fencing, railing and walkways are a critical safety component 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 Standards for Design and Maintenance of Structures”, and “PCJPB Engineering Standards for Excavation Support Systems”.

9.3 Utilities

Close coordination is required with all utility owners. It is most important to perform utility survey consisting of a records survey to identify and verify the utilities, potholing and other field survey. Coordinate with the owners for adequacy of
protection, and design of replacement, or relocation of impacted utilities. Consider impacts during construction to the utility owners and users. All utilities shall be underground.

10.0 MECHANICAL, ELECTRICAL AND PLUMBING

The mechanical, electrical and plumbing (MEP) consists of the following components:

a. Conduit and cable schedules
b. Electrical service
c. Emergency back up systems
d. Fire protection
e. Lighting
f. Mechanical systems
g. Plumbing

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 conflicts can be minimized to the greatest extent possible during construction. This in turn will lead to a smoother system commissioning and 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 all design solutions are compatible with each other. The designers shall communicate to Caltrain and other stakeholders of proposed resolution to each design interface issues.

The optimum design of a complete facility must often reconcile the 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.

F. SAFETY AND SECURITY CERTIFICATION

Caltrain implements a Safety and Security Certification Program. The purpose of the Safety and Security Certification is to ensure that new infrastructure, facilities,
equipment, rules, procedures, manuals, and training and their operation, including interface with the existing rail system, are viewed as, and are actually determined to be safe and secure.

The Safety and Security Certification process is generally applied to projects with a construction/acquisition budget of $1 Million or greater, or, will be applied as determined by the Caltrain Safety and Security Certification Policy Committee. The designers shall refer to the Safety and Security Certification Program Plan for their roles and responsibilities.

G. VALUE ENGINEERING

Value engineering involves detailed identification of alternatives and evaluation of each for the purpose of improving the performance, ease of maintenance and economy and safety. Value engineering shall typically be performed during the design phase on projects with construction value over $25 million. Timeline for value engineering shall be determined in the Design Basis Memorandum. In summary, the Value engineering shall:

a. Identify and develop alternatives to improve construction, operation, and maintenance of the system wide facilities.

b. Evaluate implementation costs to maximize cost savings for construction, operations, and maintenance.

c. Design for safety, operating efficiency, and ease of maintenance.

d. Design with consideration for future access to facilities for maintenance and repair.

e. Study the long range use of the improved facilities.

When alternatives derived from value engineering are implemented, they shall not compromise life cycle cost of the project.

END OF CHAPTER
CHAPTER 2

TRACK

A. GENERAL

This Chapter includes criteria and standards for the planning, design, construction, and maintenance as well as materials of Caltrain trackwork. The term track or trackwork includes 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 in several main sections, namely track structure and their materials including civil engineering, track geometry design, and special trackwork. Performance charts of Caltrain rolling stock are also included at the end of this Chapter.

The primary considerations of track design are safety, economy, ease of maintenance, ride comfort, and constructability. Factors that affect the track system such as safety, ride comfort, design speed, noise and vibration, and other factors, such as constructability, maintainability, reliability and track component standardization which have major impacts to capital and maintenance costs, 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, minimal maintenance requirements, and construction of which with minimal impact to normal revenue operations.

Because of the complexity of the track system and its close integration with 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 non-revenue tracks. All Caltrain tracks are ballasted tracks. No direct fixation is allowed. The revenue tracks, carrying passengers, include main tracks, sidings, station tracks, and temporary (or shoofly) tracks. Union Pacific Railroad (UP) also operates freight service on all these tracks.

The non-revenue 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 seldom used except in emergency or other unusual situations shall be constructed as non-revenue tracks, regardless of whether passengers may be carried on the cars or not.
1.0 REGULATORY AND INDUSTRY STANDARDS

Track construction and maintenance shall conform to general requirements as described in CHAPTER 1 – DESIGN GUIDELINES, and all required codes and regulations, and standard industry practices and recommendations in the APPENDIX, specifically the following:

a. Federal Railroad Administration (FRA)
   Title 49 Code of Federal Regulation (CFR)
   Part 213, Track Safety Standards for Class 5 Track

b. California Public Utilities Commission (CPUC)
   Applicable General Orders

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

The designer shall use this 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 five (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. Familiar with the federal (FRA) and state (CPUC) regulatory standards, as well as the industry standards and practices such as UPRR, High Speed Rail and AREMA.

b. 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. Knowledge of signal system and operation (commuter and freight) requirements and how they impact design speed.

d. Good understanding of the principles of track geometry, such as design of curves (simple, compound and spiral) and relationship between horizontal and vertical curves, as well as relationship between curves and superelevations. 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, track crossings). General knowledge in fabrication and inspection in the fabrication yard, or field construction and assemble 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. Have experience in track construction sequencing and track construction under active conditions or tight windows. 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 electrical conductive medium for transmitting.

Caltrain track consists of both concrete and timber ties on primarily 136 pounds continuous welded rail (CWR). Only concrete ties and 136 pounds CWR using fast clips as fastening system are used for new construction. This fastening system shall be used for standardization and for the purpose of maintaining the state of good repair system. Maintenance activities include welding to eliminate the remaining rail joints. For industry, yard and temporary tracks (shoofly), the track may be constructed of track panels of timber ties using only screw spikes.

The subballast is either an earth compacted underlayment or a Hot Mix Asphalt Concrete (HMAC) layer. HMAC is used to minimize local settlement due to difference in track modulus. Its general applications include bridge approaches, 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 three most essential elements for a sustainable stability of track structure are drainage, drainage, drainage. An effective and efficient drainage keeps the track well drained and hence in relatively moisture free environment.

The track structure requires an effective drainage system in order to keep the subgrade well drained and stable. A well drained and stable subgrade means absence of standing water therefore preventing pumping phenomena. Additionally, 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 erosions. Ditches (longitudinal and side ditches), and any direct discharge to them shall be protected with such as riprap. Longitudinal drainage system alignment shall be as straight as possible with as little curve as possible.
When curves are not acceptable, they shall be as flat as possible, and if necessary, provide appropriate holding inlet and/or ditch slope protection.

At the bridge approaches, a positive drainage shall be provided sloping away from the abutments as well as to the sides towards the embankment. Side slopes shall be protected with 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 cross slope of two (2)% minimum towards the adjacent ditch or embankment slope, or to other longitudinal drainage system. Where existing right-of-way or other restrictions do not allow the construction of side ditches, designer shall propose other suitable gravity drainage system for consideration.

The designer shall 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, use geogrid or filter fabric, or HMAC (hot mixed asphalt concrete). 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, of poor material, or is subject to seasonal high or perched water table.

Similar to subgrade, subballast shall have a cross slope of two (2)% minimum towards the side ditch or embankment slope, or other longitudinal drainage system. The sub-ballast for all tracks shall consist of a uniform minimum six (6) inches 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. Where the subgrade is soft or with relatively poor drainage, the subballast shall be increased to 12 inches over geofabric, or if necessary, shall consist of at least eight (8) inches thick Hot Mixed Asphalt Concrete (HMAC) over geotextile fabric.

For yard tracks, the requirement for subballast is similar. Subballast may not be required for yard tracks and industrial tracks with the approval of the Caltrain Deputy Director of Engineering.
4.0 HOT MIXED ASPHALT CONCRETE (HMAC) UNDERLayment

HMAC, a dense graded asphalt concrete of maximum 1 to 1.5 inches aggregates common to highway applications to provide support where roadbed conditions are poor and unstable, and to facilitate drainage. The benefits of HMAC to the track structure are summarized as follows:

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 track bed. It increases the operating efficiency due to decreased maintenance costs, hence providing a long term benefit.

HMAC shall be (8) inch thick graded with positive drainage of a cross slope of two (2)% minimum toward side ditch or underdrain. The HMAC layer shall be used at all locations listed below. Details of this application are available in the Caltrain Standard Drawings.

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 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 towards each side of the track embankment. A minimum of 50 feet long is specified in the Caltrain Standard Drawings, however, longer transition shall be provided when possible within the time constraints of construction.

It should be noted that the thickness of the ballast at the bridge approaches shall be kept under 12 inches. The risk of development of track hump increases with thicker ballast section associated with increase in ballast consolidation or breakdown.

5.0 BALLAST

Ballast is placed above the subballast, or HMAC. The ballast plays a critical role by providing support for the rail and ties, distributing railroad loads uniformly through the
subballast over the subgrade, maintaining proper track alignment, and 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 Gradation Number 4A or AREMA Grade 4A.

For main tracks, including bridges, the minimum ballast depth shall be nine (9) inches, measured from the bottom of the tie. Larger ballast section (12 inches or more) is commonly used on freight main lines is not necessary because of the relatively low gross tonnage of freight operations by Union Pacific (UPRR) through Caltrain corridor.

Maximum ballast depth shall generally not exceed 18 inches. Ballast depth outside these limits must be approved by the Caltrain Deputy Director of Engineering. Thicker ballast section resulting in settlement from ballast consolidation increases the maintenance costs due to increase frequency or need for track surfacing. Track structure over embankment is particularly prone to this phenomenon because the ballast is not being contained.

For yard tracks and industrial tracks, the corresponding minimum depth of the ballast shall be six (6) inches, and 12 inches maximum. Existing ballast salvaged during construction may be used for subballast.

6.0 TIES

Only concrete ties shall be used for new construction of main tracks. Timber ties with Pandrol fastening systems shall only be used for the rehabilitation of existing timber tie tracks, construction of yard and industrial tracks, and construction of temporary main tracks. Yard tracks can be constructed on timber (at 21 inch spacing), or on concrete ties that are specifically designed for yard tracks. Longer 10 ft timber ties are installed at transition zones between areas of very different track modulus.

Concrete ties are superior over 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 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 compared to 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.

Improved design and fabrication of concrete ties and overall deteriorating quality of timber result in concrete ties outlasting 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, therefore are more environmentally friendly.
While the material handling labor is less for the lighter timber ties, overall the tracks on concrete ties are less per track mile. 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 x 9 inches x 9 feet long at 19-1/2 inches spacing.

Standard ties for at-grade crossings are concrete suitable for moisture prone environment. They are 10 feet long to accommodate concrete crossing panels, and for enhanced load distribution from 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 timber ties shall be 7 inches x 9 inches x 10 feet long and shall be used in areas of changing track modulus, between standard timber tie section and standard concrete tie section, at approaches to at-grade crossings, and at approaches to bridges. Refer to Caltrain Standard Drawings for further details.

7.0 RAIL

The standard rail for all main tracks, including the special trackwork is 136 RE. Temporary tracks during construction that will not be in service more than two (2) years may be of 132 HF rail. Other non-revenue tracks may be constructed using 119 RE rail, as available from Caltrain’s existing inventory.

8.0 RAIL FASTENING SYSTEM

Other track materials (OTM) include all materials to hold rails to the ties, and to connect between rails. Caltrain’s standard for fastening system which includes rail clips and associated tie pads and insulators. Non-standard fastening system includes 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.

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 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

<table>
<thead>
<tr>
<th>DESIGN ELEMENTS</th>
<th>MAJOR LIMITING FACTORS</th>
</tr>
</thead>
</table>
| Minimum 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 |
| Superelevation Runoff Rate | • Passenger comfort  
• Vehicle suspension travel |
| Vertical Tangent between Vertical Curves | • Passenger comfort  
• Turnout locations |
| Vertical Curve/Grade (Maximum Rate of Change) | • Passenger comfort  
• Vehicle suspension travel  
• Slack action and train handling  
• Horizontal and vertical tangents |
| Special Trackwork | • Passenger comfort  
• Design speed  
• Trackwork maintenance |
| Station Platforms | • Vehicle clearances  
• ADA platform gap requirements |
| Mixed use of Commuter/Freight RR | • Vehicle clearance  
• Trackwork maintenance  
• Compatibility of operations |
1.0 GENERAL DESIGN REQUIREMENTS

Track alignment, at a minimum, shall be designed to maximum authorized speed (MAS) of 90 mph and FRA Class 5 track standards. Upon completion of the track construction, Caltrain will determine the appropriate operating speed.

The resulting track shall be with as few curves and curves as small as possible. However, small curves such as 30 minutes or less shall be discouraged because they are impractical to construct or to maintain. Furthermore, with time these small curves tend to lose their curvature hence increasing additional maintenance. When such small curves are not avoidable, then the curves 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 during construction:

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

b. Stationing continuously along the length of all main tracks, using Main Track MT-1 as reference, including mile posts.

c. Track plan (on planimetric background) showing existing and proposed, with mileposts and shall contain the following information. Left side of page is railroad north, with arrow pointing 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, drainage facilities.

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

d. Track centers, every 500 feet, or when the track centers change by every 3 inches.

e. Vertical profiles (existing and proposed) including slopes (in percent) developed for each tracks 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 same limits with plan on top of the page.

g. Cross sections (toward increasing stations) showing existing and proposed, 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, coordinates (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 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 increase in construction cost.

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 with approval from the Caltrain Deputy Director of Engineering.

c. Yard and Non-Revenue Track Standards

This case shall be applied to non-mainline and non-revenue 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 existing alignment or other reductions 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 non-revenue tracks, spiral transition curves 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.

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

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 one (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 one (1) inch for every 30 minutes of curvature, plus 3-1/2 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 three (3) seconds on tangent track between two curves. Tangent shall extend at least 100 feet beyond both ends of the limits of the station platforms, and of 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)

<table>
<thead>
<tr>
<th>Tangent Location On Mainline Tracks</th>
<th>Minimum Tangent Length (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preferred</td>
</tr>
<tr>
<td>Between reverse curves</td>
<td>3V</td>
</tr>
<tr>
<td>Between Point of Switches of turnouts (TO’s)</td>
<td>50</td>
</tr>
<tr>
<td>Between PS and curve</td>
<td>100</td>
</tr>
<tr>
<td>Between PS and platform</td>
<td>100</td>
</tr>
<tr>
<td>Between PS and grade crossing</td>
<td>100</td>
</tr>
<tr>
<td>Between PS and last long tie of T.O.</td>
<td>60</td>
</tr>
<tr>
<td>Between curve and platform</td>
<td>60</td>
</tr>
<tr>
<td>Between curve and grade crossing</td>
<td>50</td>
</tr>
</tbody>
</table>

* 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 non-revenue tracks shall be established as per Table 2-3:

TABLE 2-3 MINIMUM TANGENT LENGTH (YARD AND NON-REVENUE TRACKS)

<table>
<thead>
<tr>
<th>Tangent Location On Yard and Non-Revenue Tracks</th>
<th>Minimum Tangent Length (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preferred</td>
</tr>
<tr>
<td>Between reverse curves</td>
<td>60</td>
</tr>
<tr>
<td>Between PS of T.O.’s</td>
<td>40</td>
</tr>
</tbody>
</table>

* 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 MAS without being cost prohibitive, i.e., requires additional right-of-way, impacting existing improvements like buildings, flyover supports, etc. 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 the following Table 2-4.
### TABLE 2-4 DESIGN SPEEDS THROUGH CURVES

<table>
<thead>
<tr>
<th>Track Type &amp; Condition</th>
<th>Curve Design Speed (MPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preferred</td>
</tr>
<tr>
<td>Main Track</td>
<td>90</td>
</tr>
<tr>
<td>Control Siding with #20 T.O.</td>
<td>50</td>
</tr>
<tr>
<td>Control Siding with #14 T.O.</td>
<td>35</td>
</tr>
<tr>
<td>Temporary Main Track</td>
<td>Existing MAS</td>
</tr>
<tr>
<td>Yard Lead</td>
<td>25</td>
</tr>
<tr>
<td>Yard Track</td>
<td>15</td>
</tr>
</tbody>
</table>

Prior to the design of the track geometry, the designer shall consult with 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.

#### 3.3.1 Horizontal Curve

The criteria for the designer shall be to eliminate any curve, and if this is not feasible, to lessen the curvature. Implementation of curves less than 30 minutes requires the approval from Caltrain Deputy Director of Engineering. Curve data shall be provided in a table format with the following information:

a. Design speed (MPH)
c. Degree of curve (degrees, minutes, and seconds)
d. Length of curve, $L_c$
e. Amount of actual superelevation, $E_a$, (inches)
g. Amount of unbalance, $E_u$, (inches)
h. 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 feet long chord for ease of field layout. The important relations of simple curves for the chord definition are as follows:

\[
\begin{align*}
R &= 50 / \sin(D_c/2) \\
L_c &= 100 \left( \frac{\Delta}{D_c} \right) \\
T &= R \tan\left(\frac{\Delta}{2}\right)
\end{align*}
\]

where \( \Delta = \) central angle

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

See the following FIGURE 2-1 for illustration of the simple circular curve.

**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.

FRA currently has established the maximum unbalanced superelevation as three (3) inches, and the maximum actual superelevation as seven (7) inches for track Classes 3 through 5. The maximum actual superelevation for Caltrain tracks is five (5) inches. All curves with superelevation of five (5) inches or more shall require the approval from 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:

\[ e = 0.0007 \, D_c \, V^2 \]

where:

- \( e \) = total superelevation required for equilibrium, in inches.
- \( V \) = maximum design speed through the curve, in miles per hour (MPH)
- \( D_c \) = degree of curvature, in degree

The total superelevation \( e \) is expressed as follows:

\[ e = E_a + E_u \]

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 to the nearest 1/4 inch by the formulas above. For any curve, a 1/2 inch superelevation shall be specified.

Slower speed tracks, such as yard and non-revenue tracks, and curves within special trackwork shall not be superelevated. Curves within station and grade crossings shall be avoided. They may be superelevated only with the approval from 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 non-destructive rate.

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 an 1 degree curve; at 25 feet, as of a 2 degrees 30 minutes curve; at 60 feet, as of a 6 degrees curve. Like wise, at 60 feet, the spiral may be compounded with a 6 degree curve; at 80 feet, with an 8 degrees curve, etc.

The clothoid spiral is commonly used in most CADD design software. Since Caltrain adopted AutoCAD and its associated Civil Design Software in the design of track alignment, the clothoid spiral shall be used. The clothoid spiral is similar to the Talbot railway transition spiral which has been widely used in the railroad industry and is recognized by the AREMA.

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 2-5 that follows for spiral and curve nomenclature.

Spirals are not required for curves less than 30 minutes for MAS under 20 MPH or on curve that is part of a turnout, however, a minimum of curve length of 100 feet shall be implemented. Additionally, all curves including such curves shall have a minimum 1/2 inch actual superelevation.

5.2 Length of Spirals

Spiral curve length and superelevation rate of change or runoff are directly related to passenger comfort. While passenger comfort is a major consideration, the rate of change in superelevation in a spiral also affects the rail car bodies in term of twisting, racking or diagonal warp. According to AREMA, the superelevation differential between rail car truck centers should not exceed one (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 one (1) inch per 62 feet in length in order to avoid wheel lift.

The length of the spiral can be determined by the following three (3) criteria based on passenger comfort and operational safety.
where,

\[ D_c \] Degree of Curvature

\[ I \] Total Intersection Angle
\[ \theta_s \] Spiral Angle = \( \frac{L_s D_c}{200} \)
\[ \Delta \] Central Angle of Circular Curve = \( I - 2 \theta_s \)
\[ R \] Radius of Circular Curve
\[ T_c \] Tangent Length of Circular Curve = \( R \tan\left(\frac{\Delta}{2}\right) \)
\[ L_c \] Length of Circular Curve = \( \frac{\Delta}{180} R \)
\[ L_s \] 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
\[ TS \text{ IN} \] Tangent Length of Complete Curve
\[ TS \text{ OUT} \] Tangent Length of Complete Curve

**FIGURE 2–2 CURVES WITH SPIRAL TRANSITION**
Spiral Length Requirements

Based on sections AREMA Chapter 5, Section 3.1, the length of spiral shall be longest as determined from formulas:

1. \( L_s = 1.63E_u V \); or \( L_s = 1.22E_u V \) * Desirable

2. \( L_s = 1.2E_a V \) Minimum (upto 60 mph)

3. \( L_s = 62E_a \) Absolute Minimum (or Exception) upto 50 mph

* Use of Spiral length \( L_s = 1.22E_u V \) requires the approval of Caltrain Deputy Director of Engineering

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.

In determining spiral length for Caltrain’s current and future projects, cost of construction and space constraints must also be considered because of high labor and real estate costs in the San Francisco Bay Area. Longer or extremely long spirals always provide a higher level of comfort, and ease on rolling stock but they may be cost prohibitive to construct and maintain. As a result, the most economical approach using the above formulas is to determine the spiral length by balancing the actual and unbalanced superelevations based on the equilibrium superelevation. When the two formulas are balanced (formulas 1 and 2 above), the spiral length determined should satisfy the design requirements from either unbalanced or actual superelevation.

After the actual and unbalanced superelevations are balanced, the spiral lengths will be established and the longest spiral will be used.

Since the spiral lengths for the existing curves of the current Caltrain commuter corridor were determined based on the formula \( L_s=1.2E_a V \), as an exception, this formula may be used to establish the spiral length in areas with extreme site constraint with the approval of the Caltrain Deputy Director of Engineering. Examples for determining spiral lengths are in the APPENDIX.

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 (TOR) elevation of the low rail. This low rail is the grade rail.

When TOR profile is given for one track only, the TOR 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.

7.1 Grades

The maximum continuous main line grade along the Caltrain commuter corridor is one (1)%. The preferred maximum design gradient for long continuous grade shall be one (1)%. Maximum design gradient, with curve compensation at 0.04 percent per degree of curve if applicable, for grades up to two (2)% 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 \( G \) is the Gradient before, and \( D \) is the degree of curve, in decimal.

At station platforms, a level gradient is preferred with a maximum grade of up to one (1)% is permitted. For yard tracks, where cars are stored, a level gradient is preferred, but a maximum non-rolling track gradient of 0.2% 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 per the requirements for high-speed main tracks and shooflies as recommended in AREMA Manual for Railway Engineering shown in the following formula:

\[
L = (D V^2 K) / A
\]

where,
- \( A \) = vertical acceleration, in ft/sec²
- \( D \) = absolute value of the difference in rates of grades expressed in decimal
- \( K = 2.15 \) conversion factor to give \( L \), in feet
The recommended vertical accelerations (A) for passenger and freight trains for both sags and summits are as follows:

<table>
<thead>
<tr>
<th>Train Type</th>
<th>Recommended Vertical Acceleration (ft/sec^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Train</td>
<td>0.60 (0.02 g)</td>
</tr>
<tr>
<td>Freight Train</td>
<td>0.10</td>
</tr>
</tbody>
</table>

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 point of switch shall be located at least 100 feet from beginning and end points of 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% each within a distance of 3000 feet, may cause train excessive dynamic forces and handling problems. 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 the following FIGURE 2-3 for vertical curve nomenclature.
When vertical Curve is Concave Downward:

\[ M = \frac{[(EL @ PVI \times 2) - (EL @ BVC + EL @ PVI)]}{4} \]

When vertical Curve is Concave Upward:

\[ M = \frac{[(EL @ BVC + EL @ EVC) - (EL @ PVI \times 2)]}{4} \]

**FIGURE 2-3 VERTICAL CURVE**
D. SPECIAL TRACKWORK

Special trackwork refers to trackwork units that are used for tracks to converge, diverge, or cross each other. Special trackwork includes turnouts (or switches), crossovers, and track crossings. All special trackwork design shall be based on Caltrain Standard Drawings. In areas where with real estate constraints, special trackwork units may be designed with less than standards, with approval of the Deputy Director of Engineering.

1.0 TURNOUTS AND CROSSOVERS

Turnouts are used for tracks to diverge or converge from one track to another track. 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 track.

Crossovers are installed between two (2) 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 (2) 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 which allows two crossing tracks to diverge from one to another. With the approval of the Caltrain Deputy Director of Engineering, this type of switch may be used at terminals and yards when the speeds will not exceed 15 MPH.

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 maximum authorized speeds (MAS) for operations:
FIGURE 2-4  TURNOUTS AND CROSSEOVERS
a. Lateral turnouts numbers 8 and 9 for yards

b. Lateral turnouts number 10, 14, and 20 for main line. Number 20 shall be used where there are no real estate constraints.

c. Number 9 double slip switches may be used in terminals.

d. Turnouts with Hollow Steel Ties (HST) per 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 point of switch (PS) of the turnout

c. Stationing at the point of frog (PF) 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 three (3) inches of unbalanced superelevation for curves without spirals. Freight design speeds are for maximum of two (2) inches unbalanced superelevation.

Maximum authorized speeds (MAS) through turnouts and crossovers for passenger and freight trains are as follows:

a. 10/10 MPH for turnouts number 9 for both passenger and freight

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 point of switch (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 point of switch 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 point of switch

f. Crossovers shall be located in parallel tracks only

g. Standard crossovers shall be of 15 feet track center

2.3 Non-Standard Turnouts and Crossovers

Design of non-standard 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.

a. Crossovers in non-parallel tracks

b. Crossovers with track center more than 15 feet

c. Turnouts in curves

d. 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 shall be installed on the downgrade end of yard and secondary track that is normally used for storage of unattended vehicles, if this track is directly connected to the main track, and if its prevailing grade is descending toward the main track. With approval from the Caltrain Deputy Director of Engineering, derails may be used at other track locations where cars are moved or locomotives are stored to prevent or minimize injury to passengers and personnel, and/or damage to equipment.

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 non-railroad personnel.
Derails are connected to the signal system to indicate when they are lined for train movement.

Blue Flag derails are required to protect workers on service tracks per FRA Title 49 CFR Part 218 and to protect workers during the unloading of hazardous materials per 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 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.

E. TRAIN PERFORMANCE CHARTS

The Maximum Authorized Speed (MAS) of the Caltrain system is 79 MPH, which is based on FRA signal standards (49 CFR Part 236). In order to operate at speeds of 80 MPH or higher, a supplemental signal system will be required. For MAS of 79 MPH, Class 4 track standards are the minimum requirements.

The following Acceleration and Deceleration Charts were developed (FIGURES 2-5 through 2-7, respectively) by Systra Consulting for Caltrain contained in their April 4, 2004 Report: “Acceleration and Deceleration Performance of Caltrain’s FP40PH and MP36 Locomotive”. Additional report “Signal System Headway / Capacity Study” (December 31, 2005, Revised February 10, 2006) in APPENDIX.
Acceleration Tests on Level, Tangent Track
EMD F40PH-2C Locomotive with 4-10 Gallery Cars

FIGURE 2-5 ACCELERATION CHART FOR EMD F40PH-2C LOCOMOTIVE
Acceleration Test on Level, Tangent Track
MPI MP36PH-3C Locomotive with 4 to 10 Bombardier Cars

FIGURE 2-6  ACCELERATION CHART FOR MPI MP36PH-3C LOCOMOTIVE
Deceleration at 1.15 mph/Sec for MP36PH-3C Engine and F40PH-2C Engine, Each with 7 Cars

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, platform access, etc. 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 for regulatory and safety advisories, as well as security system are covered in the CHAPTER 4 STATION COMMUNICATIONS. The design requirements for the pedestrian at-grade crossings within the stations, and at the 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.

The design of stations and their facilities shall generally follow the principles of the CPTED (Crime Prevention Through Environmental Design). In particular the safety and security elements of the design shall be reviewed by appropriate CPTED certified professional from planning through final design.

Caltrain provides detailed standards (layout, location, design, 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 it defined in Section H, STATION SIGNAGE.

Caltrain’s stations shall be designed to promote and sustain the 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, minimize any obstructions or conflicts. Provide passenger orientation, information, physical barriers, and level changes.

1.0 DESIGN RATIONALE

Caltrain stations consist of site access, parking, platforms, possible buildings, tracks and all appurtenances necessary to provide for public transportation, safety and information.

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:

a. Demonstrated demand projected to 20 years: Request the current and 20-year future ridership demand from Caltrain. Footprint for expanded station and parking shall be delineated.

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 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 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, and environmental quality.

2.0 CODES AND REGULATIONS

Stations and facilities design shall comply with this 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. Should there be conflicts between codes, then the most restrictive code shall apply.

3.0 CALTRAIN STATIONS

The following TABLE 3-1 CALTRAIN STATIONS provides classification and relative ranking of each Caltrain station. The purpose of this table is for 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 (7) stations with historical elements, which are listed under the National Register of Historic Places (NRHP).

B. SITE CONSIDERATIONS

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

1.0 COMMUNITY INVOLVEMENT

Collaborate and or partner with Local Agency to obtain inputs, including the possible involvement of the community, to establish a sense of “place” of the station and to instill a sense of ownership by the community and as a recognizable feature along the corridor. The following key aspects shall be considered:

a. Station layout: Initiate and coordinate inputs from various stakeholders from the community and Local Agency that will complement station development and increase ridership.

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

c. Neighborhood characters: Preserve, maintain and enhance existing qualities or characteristics or architectural elements which are valued.

Station areas or structures designated by the State Historic Preservation Office (SHPO) as of historical value shall address the potential applicability of requirements of the Historic Preservation Act. As part of the environmental clearance process, the
### TABLE 3-1 CALTRAIN STATIONS

<table>
<thead>
<tr>
<th>STATION CLASSIFICATION</th>
<th>RIDERSHIP RANK</th>
<th>TRANSIT CONNECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multi-Modal Stations:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 4ᵗʰ &amp; King</td>
<td>1</td>
<td>Muni (bus &amp; LRT)</td>
</tr>
<tr>
<td>2 Palo Alto</td>
<td>2</td>
<td>SamTrans, VTA (bus)</td>
</tr>
<tr>
<td>3 Mountain View</td>
<td>3</td>
<td>VTA (bus &amp; LRT)</td>
</tr>
<tr>
<td>4 Diridon</td>
<td>4</td>
<td>VTA (bus &amp; LRT)</td>
</tr>
<tr>
<td>5 Millbrae</td>
<td>5</td>
<td>SamTrans, BART, connection to SFO airport</td>
</tr>
<tr>
<td><strong>Tier 1 Stations:</strong> (minimum 2 connections)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Hillsdale</td>
<td>7</td>
<td>SamTrans, AC Transit, shuttles</td>
</tr>
<tr>
<td>2 Menlo Park</td>
<td>9</td>
<td>SamTrans, shuttles</td>
</tr>
<tr>
<td>3 Redwood City</td>
<td>6</td>
<td>SamTrans, shuttles</td>
</tr>
<tr>
<td>4 Santa Clara</td>
<td>15</td>
<td>VTA, ACE, connection to SJ airport</td>
</tr>
<tr>
<td><strong>Tier 2 Stations:</strong></td>
<td></td>
<td></td>
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<tr>
<td>1 San Mateo</td>
<td>10</td>
<td>SamTrans</td>
</tr>
<tr>
<td>2 San Carlos</td>
<td>13</td>
<td>SamTrans, shuttles</td>
</tr>
<tr>
<td>3 Tamien</td>
<td>16</td>
<td>VTA (bus &amp; LRT), Caltrain SJ-Tamien shuttle</td>
</tr>
<tr>
<td>4 California Ave</td>
<td>12</td>
<td>VTA (bus), shuttles</td>
</tr>
<tr>
<td>5 Burlingame</td>
<td>14</td>
<td>SamTrans, shuttles</td>
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<tr>
<td>6 Belmont</td>
<td>19</td>
<td>SamTrans, shuttles</td>
</tr>
<tr>
<td>7 Bayshore</td>
<td>23</td>
<td>Muni (bus &amp; LRT), SamTrans, shuttles</td>
</tr>
<tr>
<td>8 Sunnyvale</td>
<td>8</td>
<td>VTA (bus)</td>
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<td><strong>Tier 3 Stations:</strong></td>
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<td>1 22nd Street</td>
<td>11</td>
<td>Muni (bus)</td>
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<tr>
<td>2 San Antonio</td>
<td>18</td>
<td>VTA (bus), shuttles</td>
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<tr>
<td>3 Lawrence</td>
<td>17</td>
<td>Shuttles</td>
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<tr>
<td>4 San Bruno</td>
<td>20</td>
<td>SamTrans</td>
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<td>5 South San Francisco</td>
<td>21</td>
<td>SamTrans, shuttles</td>
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<tr>
<td>6 Morgan Hill</td>
<td>25</td>
<td>VTA (bus), MST</td>
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<td>7 Hayward Park</td>
<td>22</td>
<td>SamTrans, shuttles</td>
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<tr>
<td>8 Gilroy</td>
<td>24</td>
<td>VTA (bus), MST, Greyhound</td>
</tr>
<tr>
<td>9 College Park</td>
<td>26</td>
<td>VTA (bus)</td>
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<tr>
<td>10 Blossom Hill</td>
<td>27</td>
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<tr>
<td>11 San Martin</td>
<td>28</td>
<td>VTA (bus)</td>
</tr>
<tr>
<td>12 Capitol</td>
<td>29</td>
<td>VTA (bus)</td>
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**Notes:**

i. As part of the ADA requirements, FTA designated the following 10 stations to be key access stations: 4ᵗʰ & 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 National Register of Historic Places (NRHP).

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

iv. Palo Alto station is owned by Stanford University.
designers shall collaborate with the South Bay Historical Railroad Society (SBHRS), representing SHPO, and its counterparts within the Cities and Counties to identify and evaluate potential impacts as well as mitigation measures to the historical areas or structures in station and site design.

2.0 JOINT DEVELOPMENT

Caltrain and community planners shall explore potential opportunities to develop transit-oriented development (TOD) adjacent to Caltrain stations. TOD, however, needs to occur with a balance toward providing a convenient and pleasant experience for Caltrain passengers and providing opportunities for mixed use development.

For existing station rehabilitation and renovation, the design should generally match the existing architectural elements. On new station construction, the design should follow the guidelines below:

a. Recognize emerging development that can compliment 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) GO 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 horizontal clearances at the stations are established for the following passenger safety and operations requirements. The clearance requirements are safety critical due to the current operational characteristics of Caltrain, namely express trains through most stations and high frequency of train service.

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 at-grade pedestrian crossing warning system, the Visual Message Sign (VMS), and the approaching trains

d. Clear sight distance for passengers of the signage

e. Clear sight distance for train crew
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**
f. Operations configuration: bike car, ADA accessible car, Boarding Assistance Area, and mini-high platforms are located on the north third of platforms

g. Increasing amount of passengers requiring more space (mobility impaired persons, bicyclists, persons with luggages, children and strollers)

h. Uneven platform usage: tendency of passengers to congregate on the north third of platform

i. Bike 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 Caltrain Standard Drawings.

a. **Permanent Structures**: 25 feet

   Permanent structures include station buildings, Communications Equipment Room (CER), trees (any size), etc.

b. **Semi-permanent Structures**: 16 feet

   Semi-permanent structures include canopies, passenger and Ticket Vending Machines (TVM)/Stand Alone Validators (SAV) shelters, light poles, signage and display case posts, benches, trash receptacles, Boarding Assistance Area (bench and wheel chair lift), landscaping, etc.

c. **At-grade Pedestrian Crossing**: 10 feet

   Crossing closest structures include swing gate, tip of automatic pedestrian gate arm, railing, signal apparatus, etc.

d. **Signal Houses**: 16 feet, preferably 25 feet

   Signal houses need to be located such that they provide 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.

e. **Visual Message Signs**: 9 feet

   The edge of the panel board of the Visual Message Sign (VMS) shall be no closer than nine (9) feet from the nearest track center.

f. **Return Fence**: 9 feet
2.2 **Vertical Clearances**

Any new overhead structures shall be designed with a minimum vertical clearance shall be 24 feet 6 inches (24'-6") from top of rail. The overhead structures include bridges, overhead pedestrian crossings, signal bridges, etc. Overhead utilities of any kinds are not allowed.

D. **STATION CONFIGURATION**

Consideration shall be given to possible track additions and possible extensions in the future, for longer train consists. The station designers shall seek inputs from Caltrain in determining requirements for possible future station expansion and provision for future Electrification of the system.

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 right-of-way.

1.0 **BOARDING PLATFORMS**

The two preferred alternatives for Caltrain station platforms are as follows:

a. **Outboard Platforms:** Outboard platforms are side platforms located directly opposite one another, each servicing one mainline track.

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

The staggered platforms are outboard platforms where the platforms do not align, or are staggered either around or not around an adjacent street. These platforms are neither efficient nor convenient for passengers, and may be used on a temporary basis such as temporary station during construction. See **FIGURES 3-3 and 3-4** for typical platform arrangements. See Caltrain Standard Drawings (SD 3000 series) for further details.

Platforms including potential extensions will be located at least 100 feet from the nearest road crossing in order 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 a delay. This is usually accomplished by adding or re-spacing automatic block signals.
FIGURE 3-3   TYPICAL CENTER ISLAND PLATFORM ARRANGEMENTS

TYPICAL 2-TRACK WITH CENTER ISLAND PLATFORM

TYPICAL 4-TRACK WITH CENTER ISLAND PLATFORM

TYPICAL 4-TRACK WITH 2-CENTER ISLAND PLATFORMS

LOOKING SOUTH
FIGURE 3-4  TYPICAL OUTBOARD PLATFORM ARRANGEMENTS
1.1 Platform Dimensions

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

The following are criteria for platform dimensions. See Caltrain Standard Drawings for further details.

a. Platform length: Caltrain train consists are composed of different cars and locomotives necessitating additional platform lengths. The standard platform length shall be 700 feet to accommodate a six (6) car train consist. See FIGURE 3-5 for station “footprint” requirements and platform configurations. Platform design shall consider or not preclude a possible expansion of platform length to 1000 feet to accommodate an eight (8) car train consist. At the San Francisco and San Jose Diridon terminal stations, the station platforms shall be designed to accommodate two (2) 8-car trains.

b. Platform width: The platform shall be a minimum of 16 feet (20 feet preferred) wide for an outboard platform and a minimum of 28 feet (32 feet preferred) 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 seven (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 eight (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 and on level surface. Track grades through station of more than one (1) % shall not be considered.

d. Platform cross slope: This slope is required for drainage purposes. The slope shall generally be 1% (2% maximum per ADA Standards) and shall be sloped away from the tracks. The rationale for this is to minimize the risk of rolling effect of persons on wheel chairs by not providing the natural rolling effects toward the tracks. The other consideration is for track drainage by directing away the surface water away from track structure. At center island platforms an underdrain shall be provided at the center of the platform width.

e. Platform curve: Station through curved track, either horizontal or vertical curve shall be avoided. If unavoidable, the curve shall be as shallow a curve as possible to no more than one (1) degree and 30 minutes, and at either ends of the platforms. Platform located on the curve shall require prior approval from Caltrain Deputy Director of Engineering.
f. Track centers: Track centers at station platforms shall be expanded to 18 feet minimum to accommodate center fencing so that the fence is at least 8 feet six inches (8'-6") clear from the track center. The center fence shall extend 100 feet minimum 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 past 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. Minimum platform length is 500 feet with a minimum platform width of 12 feet. This platform length allows for a functional operations of a 5-train consist.

b. Platform may be constructed of asphalt concrete to expedite construction, however, the platform edge or platform surface to receive the warning tactile shall be of concrete. Asphalt concrete is not compatible to the installation of the warning tactile.

2.0 ADA REQUIREMENTS

Access to the station shall conform to the requirements of the Americans with Disabilities Act (ADA), Title II, and California accessibility regulations, CCR Title 24. At least one accessible route shall be provided within the site from accessible parking spaces and accessible passenger loading zones; public streets and sidewalks; 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 of each of the element below.

2.1 Detectable Warning Tactile

The tactile is an ADA requirement safety feature providing a band of contrasting color and texture for the sight impaired persons to demark the safe setback from moving trains and to warn of the platform edge and drop off to the track. And at at-grade pedestrian platform crossings, the tactile also identifies track crossings and to signify clear point of crossing.

The tactile shall be ADA compliant, and is of staggered dome design or configuration and is installed at the following locations:

a. Platform edge on the track side: 2-foot wide along the entire length of the platform, and 3-foot wide at the returns at each end of the platforms.

b. Edge of the mini-high platforms facing the track: 2-foot wide along the edge of the mini-high platforms.
c. Station at-grade pedestrian crossings: 3-foot wide placed in front of the crossing gates. This shall not be confused with the tactile at the vehicular crossings which calls for in-line dome design.

See Caltrain Standard Drawings (SD-2000 series) for further details.

2.2 Yellow Safety Stripe

A 6 inch wide yellow stripe (Federal yellow) shall be painted behind the tactile that the far side of the stripe marks a distance of 9 feet from the center of the track. Six (6) inch high letters “WAIT BEHIND YELLOW LINE” is painted behind the stripe to indicate where passengers shall stand. The marking shall line up with the car door. Mini-high platforms is also treated with similar 2 foot-wide tactile.

For stations with at-grade pedestrian crossings, similar tactile but 3 foot-wide is provided behind the crossing gate at the approach to the crossings. The wider tactile is required for approach to at-grade rail crossings.

2.3 Detectable Directional Tactile

Platforms shall be treated with directional and guide tactile to assist the sight impaired in locating the PNA shelter, and one of the TVMs at each platform. The tactile is also installed to identify the limits of the mini-high platforms. See Caltrain Standard Drawings (SD-2000 series) for further details.

2.4 Mini-High Platform

Mini-high platform, currently available at some stations is installed to assist with boarding of mobility impaired persons at all stations. The mini-high platform shall be located 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 boarding assistance area shall be provided on each platform. The boarding assistance area will be located 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 Wheel Chair Lift

All stations are equipped with a manually operated wheel chair lift. The lift is located adjacent to shelter at the Boarding Assistance Area. The lift shall be secured inside a lockable metal shed only accessible to the train operations personnel. Caltrain Standard Specifications for the technical requirements of the lift and shed.
2.7 Level Boarding

Level boarding platforms for the Caltrain will require extensive upgrade and are not planned at this time. However, the ramps to the at-grade pedestrian crossings shall be extended to 40 feet to allow for potential 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 at the back of the platforms 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. 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. Drain the entire station site and contiguous railroad right-of-way. For safety consideration, all platform surfaces shall slope at one (1)% (2% maximum per ADA) away from the track in order to eliminate the positive rolling effect of wheel chairs towards the tracks.

The other reason is for track drainage, i.e., by not draining water runoff (from rain and platform maintenance) unnecessarily to the track structure, which requires effective drainage. Less surface water runoff onto the tracks has the benefit of not unnecessarily taxing the track center 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 track structure, the subballast shall be constructed with eight (8) inches thick Hot Mixed Asphalt Concrete (HMAC). The HMAC shall extend 10 feet beyond the limits of the platforms or through the at-grade pedestrian crossing and 10 feet beyond. Six (6) inch PVC perforated underdrain pipe shall be installed between the tracks to collect and carry the water to the municipal storm water system. Track structure drainage shall be provided with a 2% slope towards 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, bike, 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 the 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 inter-modal 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 must 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 passage ways, shelters and stairways to encourage balanced train loading and unloading. Because Caltrain bike car and ADA car are the north first and second cars, and the TVMs are also located near the north end of the platforms, passengers tend to congregate at the north end of the platforms.
g. Minimize grade changes. Where necessary, grade changes shall conform to slope criteria for disabled access.
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 for 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 within the pedestrian through zone.

l. Avoid locating platform components such as railings or 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 (2) points of access/egress from the platform that meet the requirements of NFPA 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 distinctly not interfered by other access modes.

Bicyclists: Space shall be provided for bicycle lockers and racks at every station. 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: Auto access shall be provided in a manner that meets all state and local codes. To the extent practical, provide a “Kiss and Ride” or auto 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 need to be provided as part of the parking area layout. Provide adequate ADA parking stalls near to the primary platform entrances with accessible routes clearly delineated 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 car 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 way-finding signage and information to maximize customer convenience.
3.0 STATION CIRCULATION

Safety is the utmost important design consideration regarding passenger circulation on platforms. A minimum 7 feet 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 within this path. This will allow sufficient width for the passing of 2 wheel chairs side by side, or 4 person side by side. This will also allow for ease of boarding and alighting of passengers, passengers with carry on items (luggage, strollers, etc.), or bikes, and operation of wheel chair lift.

3.1 Pedestrian Crossings

Pedestrian crossings include pedestrian overpasses, 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 at-grade crossings are intended for station circulation only and are generally not a part of an overall circulation for public at large. All new at grade pedestrian crossings require a formal CPUC application process. Pedestrian underpass is preferred than the overpass because of its much shorter travel distance. If designed attractively, the underpass enhances usage.

An emergency service crossing is typically for use of maintenance vehicles, and may also be included in the stations with pedestrian underpasses or overpasses. Designers shall consult with Caltrain of applicability of this service crossing.

Structural design of pedestrian overpasses and underpasses shall be in accordance with PCJPB Standards for Design and Maintenance of Structures.

3.1.1 Pedestrian Overpass

A pedestrian overpass is typically considered where the track is below natural grade. The overpass span shall be a minimum of 24 feet six inches (24'-6") clear above top of rail and shall be a minimum of 12 feet wide. The overpass can be served by a stair, ramp or elevator system complying with ADA requirements. A stair and ramp design is preferred. A barrier system, such as a vertical rolling door, shall be installed at entrances to both ends of the overpass for security at night when Caltrain does not provide service.

The overpass tower structure shall be 16 feet minimum clear from the centerline of track. Overpasses 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 overpass. Particular attention must be paid to wayside signal line of sight when overpasses are constructed.
3.1.2 Pedestrian Underpass

The use of a pedestrian underpass is generally the preferable alternative to an overpass where the track is at a level 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 (nine (9) feet at the side walls), creating an arch to soften the passage perception. The underpass shall be located where it is most convenience to the users.

For underpasses where there is considerable use by public at large (pedestrians, bicycles, etc.) and as part of the local planning, the width should be increased to 20 feet and 12 feet high (crown) and 10 feet (side). ADA compliant access must be provided in a similar manner to the overpasses discussed above. CCTV 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. A barrier system, such as a vertical rolling door, shall be included at entrances to both ends of the underpass for security at night when Caltrain does not provide service.

3.1.3 At-Grade Crossings

At-grade crossings are clearly defined crossings whose surface is level with the top of rails and surrounding area for pedestrians. At-grade crossings at stations shall be constructed at the end(s) of the platform. This eliminates blockage of the crossing by a standing train, as opposed to having open crossings at the end of the platform where passengers can walk in front of a standing train when crossing warning devices have recovered. 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 hot mixed asphalt at 1:8 slope.

If an existing roadway crossing equipped with automatic warning devices exists directly adjacent to a station, it may be an acceptable at-grade passenger/pedestrian crossing. It is preferable to utilize 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 if improvements are necessary.

At-grade crossings are described in more details in CHAPTER 7 GRADE CROSSINGS.

3.2 Walkways

Walkways shall be 8 feet wide to allow for passage between pedestrians and bicyclists, except at crossing, the walkways shall be 10 feet wide. Provide adequate sight distance and visibility 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 American with Disabilities Act Accessibility Guidelines (ADAAG) 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 overpass, 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. Installation of elevators only with approval of Caltrain Deputy Director of Engineering. Elevators should be located adjacent to the main access point of platforms.

Elevators are typically prone to maintenance for functional and general upkeep, hence they are generally economically prohibitive. The machinery require mandatory regular safety inspections as part of permitting by the state.

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 Caltrain Deputy Director of Engineering. Escalators serving platforms shall be fully enclosed in weather-tight structures and enclosed landings shall be provided at 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/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, and 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.

Right-of-way availability may constrain the provision of the minimum required spaces. The designer shall seek inputs 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 right-of-way shall be fenced as per 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, bike lockers, bike racks, benches, news racks, trash receptacles. Station amenities includes passenger information system, and fare payment system.

The principles of Crime Prevention Through Environmental Design (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 design requirements of each of the furnishings and amenities.

1.0 FURNISHINGS

Station furnishings include all furniture located on the platforms and 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 the mobility impaired, benches, and trash receptacles. The minimum amenities shall include passenger information system, namely public information case, electronic messaging system (Visual Message Signs and Public Address System), and fare payment system.

1.1 Shelters

A shelter is a metal roofed, free-standing structure provided for the comfort of passengers and for protection from weather for passengers. All shelters shall conform to the requirements of the Americans with Disabilities Act (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 track. Shelter elements shall have sufficient transparency to provide adequate visual surveillance of the station area to discourage vandalism and enhance users safety. Shelters should not create hiding areas. Shelter materials shall be of vandal resistant. Each shelter shall have a bench that is integrated and secured to the shelter structure.

The clear height of passenger shelters shall be a minimum of 6 feet 8 inches (6'-8") and a maximum of 8 feet above top of platform.

Each shelter shall be illuminated. Illumination requirements for platforms and other station areas are contained in Section I ELECTRICAL SYSTEMS.

There are 2 types of shelters for different use, namely passenger shelters, including for the mobility impaired, and TVM shelters. Each of these is described below.

1.1.1 Passenger Shelters

In general one shelter per platform shall be provided for each car. The shelter shall line up with the car door, as shown in the Caltrain Standard Drawings. The shelters shall be 18 feet wide, vandal resistant, and furnished with two (2) lamps located at the opposite end of the shelter, and a bench.

A smaller shelter shall be provided one per platform for the use of the mobility impaired. This shelter shall be located in the Boarding Assistance Area (BAA).

The clear height of passenger shelters shall be a minimum of 6 feet 8 inches (6'-8") and a maximum of 8 feet above top of platform.

1.1.2 Ticket Vending Machines (TVM) Shelters

Shelters shall be provided for the Ticket Vending Machines (TVMs) and the public pay phone. These shelters are of similar design as those for passengers, but configured for adequate space (width and depth) for wheelchair maneuver. The shelter posts are also configured to accommodate wheelchair access to the TVM units. There will not any bench inside these shelters.

1.2 Benches

These benches are to be located along the platform. The benches are of outdoor environment (not inside the shelters) hence they shall be heavy duty, scratch and vandal resistant, and secured to the platform. The benches have arm rest in the middle to discourage sleeping on the benches and used 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 receptacle shall be of concrete construction and standardized top loading heavy type as a deterrent to vandalism. Trash cans shall have minimal exposure of opening 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 Bike Lockers and Racks

As a general rule, the number of bike lockers and bike racks shall generally be one (1) locker and six (6) bike racks for every 100 passengers. The amount may vary due to local demand and ridership which will be provided by Caltrain.

Bike lockers and racks shall not be located near the one third end of a platform north entrance. Instead they shall be located in a well lighted area and in a highly visible location within view of the public and police patrols. A minimum clear distance of six (6) feet shall be maintained around bike lockers and racks. Clear signage shall be provided directing users to them. Bike racks or lockers are not allowed to be located on the platform.

Bike lockers shall be secured modular units. Bike racks shall be square metal tubes that provide two points of contacts for each bike. See Caltrain Standard Drawings.

1.5 Newspaper Racks and Vending Machines

Newspaper Racks and Vending Machines are not 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 City’s sidewalks near the station entrances.

No food and beverages concessions are allowed on the platforms. Trash that inadvertently land on tracks are not only a maintenance issue, but is potentially hazardous for passengers and public at large upon passing trains.

2.0 STATION AMENITIES

Station amenities generally refer to passenger information system, fare collection system, and security system. Communication to the passengers is through the Caltrain Central Control Facility (CCF) 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

Information system provided to the passengers consists of Visual Message Sign (VMS), Public Address System (PAS) and Public Information Cases. Each of these is described below.

2.1.1 Visual Message Sign (VMS)

The Visual Message Sign (VMS) is an electronic messaging system designed as one of the means to communicate with the passengers. The VMS is also required by ADA to augment and complement audio public address messaging for the benefit of the hearing impaired.

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

2.1.2 Public Address System (PAS)

The Public Address System (PAS) provides clear, audible communication to passengers waiting at a station. The PAS augments and complements the VMS system.

The PAS consists of speakers located along boarding platforms. A pair of PAS 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 to provide the optimum broadcasting and to prevent vandalism.

2.1.3 Public Information Case

Public Information Case (Info Case) is designed to post schedule, system map, “You Are Here” map, and advisory bulletins. The Info Case shall be provided as close to the platform entrances and TVMs as possible. Provide one display case adjacent to the TVM shelter and other display case as shown on Caltrain Standard Drawings.

The Info Case shall be lockable with multiple lock points. The case shall be provided with vent holes to minimize fogging on the glass by reducing the collection of
moisture inside the case. The Info Case shall be heavy duty and suitable for exterior environment. Detailed design of this Info Case is provided in the Caltrain Standard Drawings.

2.1.4 Talking Signs

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

2.1.5 Public Pay Phones

One telephone per platform shall be provided to improve the sense of security and convenience, as most stations are not staffed. The phone shall be located inside the TVM shelter as indicated in the Caltrain Standard Drawings.

2.2 Fare Collection System

The Fare Collection System consists of Ticket Vending Machines (TVM) for train ticket purchase and parking fee, and for Clipper, the regional smart card system or Clipper. Both the TVMs and Clipper are located on the platforms and in a well lighted area during hours of darkness.

2.2.1 Ticket Vending Machines (TVM)

The TVM is for ticket purchase and for payment of parking. There shall be a minimum of two (2) units or a pair of TVMs per platform area. The two (2) TVMs and a public pay phone are housed inside a shelter. The location of this shelter shall be such so as not to cause congestion from passengers using the equipment. The TVMs shall be located and housed approximately 220 feet from the northern edge of the platform. The proposed layout is shown in more details in the Caltrain Standard Drawings.

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

2.2.2 Clipper

The Metropolitan Transportation Commission (MTC) comprising of nine (9) counties within 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, a device called Card Interface Device (CID) is installed on the platforms. A minimum of three (3) CIDs are provided on each platform: one is located toward the center of the platform preferably near a TVM shelter, and one each toward each end of the platform and near an entrance to the platform.
G. SAFETY AND SECURITY

The principles of Crime Prevention Through Environmental Design (CPTED) shall be applied to Safety and Security. The design from the preliminary to final shall be reviewed by a CPTED certified professional.

Detectable warning tactile, yellow safety stripe, and detectable directional tactile described earlier in the Chapter also function as enhancement to safety.

1.0 LIGHTING

Provide lighting at all station and parking areas, and 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 six (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 accessibility standards per ADAAG 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 (2) 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 further at least 100 feet beyond the crossings. The fence shall be six (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 indirectly guide passengers to the pedestrian crossings. The fence design shall be in accordance with the Caltrain Standard Drawings. The design is a balance between the aesthetic look and the structural sturdiness and strength in order to withstand vandalism and through express trains, and to allow for hanging of various station signage. Centerline of fence shall be 8 feet 6 inches (8'-6") minimum clear from centerline of track as per FIGURE 3-1.

The fence shall be sturdy to allow for mounting of the majority of station signage.

3.2 Right-of-Way Fencing

Within the vicinity of a station the right-of-way fencing shall be installed to prevent any unsafe short cut to the platform and to guide the passengers to the designated platform entrances. The fencing shall be a minimum of six (6) feet high.

Fencing shall be installed along the entire length of all parking areas adjacent to Caltrain right-of-way. 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 eight (8) feet high ROW fencing, and a
minimum of 10 feet from the nearest track center (more on curved tracks). Right-of-way fencing includes access gates for maintenance personnel.

4.0 CLOSED CIRCUIT TELEVISION (CCTV) CAMERAS

Closed Circuit Televisions 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 local enforcement agency for monitoring possibility and logistical requirements or preferences. Effective use of the cameras at night will be dependent upon the level of illumination at the camera locations. This shall be determined by the CPTED certified personnel in collaboration with Caltrain.

H. STATION SIGNAGE

Caltrain station signage include sign panels and platform markings, collectively referred as signs. The signage serves to provide clear directions and information to passengers without additional assistance. Some of the signs is 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 area.

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 Standards also includes dimensions and specifications of the panel material, the graphic, as well as 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, designer shall prepare a sign schedule specific to the station. The schedule shall include in details the sign type, sign number, description, quantity, locations, additional mounting details, etc. 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 (Hub Signage Program). More about this Program follows.

1.0 CALTRAIN SIGNAGE

Caltrain signs are static. The signage, including wayfinding signage are for placement on the platforms as well as in parking lots. Dynamic signs are provided typically at multi-modal stations in accordance with the MTC’s HSP (Hub Signage Program).
1.1 Signage Types

There are nine (9) different sign types based on their functions and purposes as follows. See Caltrain Standard Drawings (SD 3000 series) for further details.

Type 1 - Station Identifier
Station name or station identification. They include station name mounted on the light poles, and Caltrain corporate logo on the shelters.

Type 2 - Operations Signs
Information for both passengers and train operations crew. They include Spot cabs, and Information case.

Type 3 - Boarding Assistance Signs
Information to assist for Persons Needing Assistance (PNA). They include BAA signs on PNA shelters, and bench card.

Type 4 - Station Directional Signs
Information for passengers showing train service direction so they are on the correct platforms. These signs are mounted on the center fence.

Type 5 - Regulatory and Warning Signs
These signs are safety advisory (regulations and warning) signs located at various locations. They include No Fun signs (No Smoking, No Skateboarding, No Smoking), Keep Right/Keep Left signs (mounted on return fence at the limits of the platforms), Look Before Crossing and Trespassing/Suicide Hotline signs (at the at-grade pedestrian crossings).

Type 6 - Proof of Payment
Fare collection or ticketing advisory.

Type 7 - Wayfinding Signs
Include various information mainly around the station area.

Type 8 - Parking Signs
General and ticketing information for parking, and restricted parking information, 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
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 (3) 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 right-of-way fence (for center island platform). The signs on center fence provide a much higher level of feasibility to the public, while 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

The markings are painted on the station platforms and mini-high platforms consist of the following. For longer performance, the markings shall be painted first with primer to seal the surface porosity, and at least two coats.

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

b. “Wait Behind Yellow Line”
   The text “Wait Behind Yellow Line” advises waiting to be behind the yellow safety stripe which is behind the warning tactile. The edge of this line marks a distance of nine (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. “Warning. 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 Metropolitan Transportation Commission for the San Francisco Bay Area (MTC) implements a Hub Signage Program (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, 5 of which are Caltrain stations because of their hierarchy as multi-modal stations. These 5 stations are San Francisco (4th and King), Millbrae, Palo Alto, Mountain View, and San Jose (Diridon). Except for Millbrae, which will be implemented soon, the HSP implementation at all other Caltrain four (4) stations have recently been completed (2011). See TABLE 3-1 CALTRAIN STATIONS.
2.1 HSP Standards

The MTC has established technical standards by which design elements and
guidance on where to locate them, and the signs affected include directional signs,
way-finding kiosks, transit information displays, real-time transit information displays.

When implementing the HSP, designer shall consult the latest version of the MTC
Standards & Guidance Document for further guidance on the content, when, where
and how to install the signage types. (See link below):

http://mtcfilehost.net/hub_signage/final_standards/

The HSP consists of six (6) types of signs, graphic examples and design details can
be found in Appendix A of the MTC HSP Standards document:

Type 1: Wayfinding (static signs)
Type 2: Transit Center ID (static signs)
Type 3: Transit Information Displays (TIDs) – (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 outside the five (5) multi-modal stations, a tiered approach will be used
to implement additional HSP sign types for each of the Caltrain stations. During the
planning process for any major rehabilitation of stations, designer shall through
Caltrain collaborate with the MTC to ensure 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, it will result in a
greater application of the HSP at stations that may not trigger a significant level of
wayfinding signage today. See TABLE 3-1 CALTRAIN STATION (RANKING
AND HIERARCHY)

As a general guidance, the HSP sign implementation may be as follows. However,
the final determination of the signs shall consider the need to maintain the familiarity
and feel of Caltrain that the public has been accustomed to.

a. For Multi-Modal Stations: MTC HSP all 6 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. All exposed conduit on platform structures shall be painted to match the structure. The power requirements 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 PAS

d. Safety and Security Devices such as CCTVs

e. Pedestrian Crossings 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 (2) 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, mechanical equipment, etc. Designer shall coordinate with various discipline users for load requirements and overall electrical system design.

Platform power requirements typically shall have 120/208V, 3-Phase, 4-Wire, 100 amp minimum capacity for general lighting. Power requirement for parking areas is dependent on the proposed power usage. The power requirements for communications devices are included in CHAPTER 4 STATION COMMUNICATIONS, and the requirements for signaling system are included in CHAPTER 5 SIGNALS.

Each station typically has a Communications Equipment Room (CER), and other communication cabinets. The main electrical service drop will be co-located in the CER. 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 (Ticket Vending Machines, Clipper or Regional Translink Pay System), and passenger information systems (Visual Message Signs, Public Address or PA System), as well as possibly CCTV cameras. See CHAPTER 4 STATION COMMUNICATIONS for further details.
2.0 CONDUIT SYSTEMS

Station platforms and facilities shall contain power and communications conduits and pull boxes required to support all Caltrain equipment, including ticket vending machines (TVMs), Clipper, public address (PA) speakers, visual message signs (VMSs), and closed circuit televisions (CCTVs).

All conduit systems (electrical, communications, and signals) shall be located within the utility corridor located behind the platform to prevent platform closure in the event that there is a failure in the conduit system requiring excavation within the platform area. All conduit runs other than short laterals shall be a minimum of two (2) inches diameter. One (1) 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 that installed. Exposed wiring or conduit serving passenger shelters, lighting, PA speakers, electronic message boards, ticket and closed circuit televisions is not permitted.

The right-of-way is also used for fiber optic and signal lines which are buried in conduit systems within the right-of-way. 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 four (4) feet square pull boxes. These conduits will be installed in addition to any other conduit systems installed for the platform.

3.0 LIGHTING DESIGN REQUIREMENTS

3.1 General Hardware Requirements

All luminaires and lamp types shall be standardized system wide to provide design and perceptual unity and simplify maintenance requirements. 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.

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 safety and security of station facilities and will provide increase safety of 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 uniformity level of 3:1 (average to minimum). 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 illumination levels shall be as shown in TABLE 3-2 ILLUMINATION LEVELS.
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 which are 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 area and Kiss and Rides. 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 access way 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 direct to the adjacent residence. For placement of platform luminaires, see Caltrain Standard Drawings.

**TABLE 3-2 ILLUMINATION LEVELS**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>ILLUMINATION LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boarding Platform and Waiting Areas</td>
<td>5 foot candles - average</td>
</tr>
<tr>
<td>Emergency Lighting: Aerial (pedestrian overpass), Underpasses, Stairways, Escalators and Elevators</td>
<td>2 foot candles - minimum</td>
</tr>
<tr>
<td>Emergency Lighting: Parking Garage</td>
<td>1 foot candles - minimum</td>
</tr>
<tr>
<td>Escalators and Elevators</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Shelters: Passengers</td>
<td>10 foot candles - minimum</td>
</tr>
<tr>
<td>Shelters: TVM and public phone</td>
<td>15 foot candles - average</td>
</tr>
<tr>
<td>Parking Lots</td>
<td>2 foot candles - average</td>
</tr>
<tr>
<td>Parking Garages</td>
<td>4 foot candles - average</td>
</tr>
<tr>
<td>Parking Permit Machines</td>
<td>10 foot candles - minimum</td>
</tr>
<tr>
<td>Pedestrian Underpass</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Signage</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Stairs and Ramps</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Station Building: Primary Public Entrances and Exits</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Walkways, Entrances and Exits</td>
<td>10 foot candles - average</td>
</tr>
<tr>
<td>Yard Lighting</td>
<td>5 foot candles - average</td>
</tr>
</tbody>
</table>
3.4 Control of Lighting Systems

Lighting control shall be designed to use energy efficiently. Automatic and manual control arrangements shall ensure efficient utilization of energy and maintenance procedures. All exterior site areas shall be controlled by a photocell with time clock and manual override.

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 located 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.

2.0 IRRIGATION

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 to enable centralized operations and security as well as provide additional data to maintenance personnel to improve the time to repair equipment and systems at the station. Because these systems concern the travelling public and Caltrain operations and maintenance staff, as well as safety and security personnel, the general philosophy is to strive for a system that is 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 from personal cars, shared ride vehicles, bicycles, from transfers 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 machines, passenger information signs, public announcements, pay phones, and even concessions and restrooms at some stations. At terminal stations, such as Diridon, and 4th and King, station staff are available to answer questions, make local announcements and resolve issues at stations.

However, the majority of stations are not staffed and a dynamic and reliable messaging to keep passengers informed is needed. This systemwide communication system is provided from a primary headend facility located at Caltrain Central Control Facility (CCF) which also houses the train dispatchers. The CCF is located within the Centralized Equipment Maintenance and Operations Facility (CEMOF) in San Jose.

Caltrain also utilizes a secondary headend facility located at Caltrain Headquarters in San Carlos. It is mostly dedicated to Caltrain security/video surveillance and processing; and maintenance and monitoring of the Caltrain WAN/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. Timetable, listing departure times at scheduled stations
c. Commuter rail delays, status, or travel updates
d. Alternate service plan advisories
e. 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. As such, Closed Circuit Television (CCTV) cameras are present at stations to be 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.

2.0 SYSTEM-WIDE COMMUNICATIONS TO/FROM STATIONS

The existing Caltrain WAN, serving Caltrain passenger stations, is based on the Frame Relay Leased Services.

The new equipment design and installations at the stations, however, shall account for and be ready for upcoming Caltrain planned communication system upgrade to utilize future Caltrain owned fiber optic cable plant. The fiber optic cable backbone will provide for a fully redundant communication optical network, connecting all Caltrain Passenger Stations, Right-of-Way facilities and two central facilities at the speeds between 1 Gbps to 10 Gbps at optical nodes.

3.0 COMMUNICATIONS SUBSYSTEMS

There are two (2) primary communication subsystems used to convey public information and three (3) primary subsystems for fare collection and monitored security as follows.

a. Public Address Subsystem (PAS)
b. Visual Message Sign (VMS)
c. Ticket Vending Machines (TVM)
d. Clipper Card Interface Devices (CID)
e. Video Security or Closed Circuit Television (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 (2) terminal stations: San Francisco 4th/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, ADA (American with Disability Act) requirements, and applicable local codes as well as communications industry standards as listed in the APPENDIX.

B. DESIGN REQUIREMENTS

Station communications design documents shall include System Description and Interface Requirements as follows:

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

**Interface Requirements:** Interface requirements shall identify all required interfaces with other communications and non-communications systems and subsystems. This shall include the following:

a. Interfaces between new work to be performed and any other existing Communications work for example, Supervisory Control Software, Central Control Facility (CCF) provisioning, Alarm Point, and any other required interfaces.

b. Interfaces among the subsystems.

c. Identification and description of any required hardware and software modifications or additions to existing subsystems equipment.

d. 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.

e. Equipment list (bill-of-materials) depicting 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.
f. Calculations as outlined in the subject subsystem section.

g. Phasing and cutovers to identify all major system cutover events or integration activities describing techniques, methods, duration and procedures.

h. Drawings to include electrical, mechanical, and system block and functional diagrams with corresponding parts list using current Caltrain CAD Manual and complete drawing index.

i. Complete cable identification and equipment labels.

j. Complete wiring diagrams for all equipment to be installed, modified, upgraded, or interfaced.

k. Top level mechanical drawings, if applicable.

l. Grounding details.

m. Power panel schedule and distribution.

1.0 COMMUNICATIONS NETWORK CARRIER

Communication network connectivity between the CCF, Central Headquarters and the stations 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, Caltrain station WAN services shall be upgraded to a “full” T1 service with serving speeds up to 1.544 Mbps. Many of the existing Caltrain stations utilize “partial T1” services providing for typical serving speeds of 128, 256, 512 and 768 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. In the future, considerations 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 subsystem distribution side of the station Main Point of Entry (MPOE).

The station Communications shall account for Clipper network connectivity between Clipper Headquarters and the stations to serve station Clipper Card Interface Devices (CID). This network is leased by Clipper from a Competitive Local Exchange Carrier (CLEC) and is independent from Caltrain WAN/LAN.
At the current stage, the Station design will not include the interconnection by a wide area fiber network. However, the network equipment chosen for each station shall be adaptable/scalable for connection to this future wide area fiber network.

The existing network “carrier” and future Caltrain fiber network will interface with the station LAN at Communications Equipment Room (CER). Note that, in absence of CER, some Caltrain stations may still utilize 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’s/CIC’s and upgrade to CER’s. Unless specifically required, in this document, for simplicity, the terms “SCC” and “CIC” are omitted; and 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 particularly in areas beyond the physical limits of the LAN switches copper connections. Characteristics of this network distribution system should be as follows:

a. Distribution cabinets (DC) shall be optimized such that most communications devices are less than 300 ft (by cabling distance) away from either the main switch or a distribution cabinet.

b. There shall be two sets of power wiring brought into each Distribution cabinet:
   i. Essential Power (from the central UPS in CER) - battery-backed power for essential communication equipment such as LAN switches, Media Converters, TVMs, CCTV, VMS, Clipper CIDs
   ii. Non-essential Power (from the station distribution power panels) - power for non-essential devices such as fans, maintainer jacks, cabinet lights, etc.

c. Distribution cabinets (DC) shall contain the following:
   i. Dual Caltrain LAN switches (if there are more than one of each: TVM, or VMS are wired to a DC, for redundancy they shall be divided into two groups: the first group will be served by one distribution switch, the second group will be served by the second distribution switch)
   ii. CID Switch (where required) (provided by Clipper)
   iii. CAT 6 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 (UPS-backed power from CER)
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
xii. 24 V DC power supply for CIDs (one power supply per two CIDs) (where required)
xiii. Characteristics: 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. Fiber fed from main switch
iv. IEEE 802.af compliant (PoE)
v. Layer 2 switching capable
vi. Industrial Rated (i.e., operating temp range -10 deg C to at least +50 deg C; vibration tolerant, etc.)
vii. Sized to have 25% 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/from individual field devices shall be via CAT-6 cable using PoE where feasible. For cable runs over 300 ft (or if the field device’s design specifically requires) a single-mode fiber connection shall be utilized. For such devices, the fiber cabling shall be accompanied by the essential power wiring. Use of local power for such devices is allowed only as an exception, which must be approved by Caltrain.

2.1 Closed Circuit Television (CCTV) Cameras

Closed Circuit Television or CCTV is used for video surveillance of the station platforms. At some stations, the CCTV is also used for video surveillance of station indoors (station concourse), underpasses, station surrounding areas (i.e. station plaza, parking lots, stairs and ramps, bus stops, etc.) and other facilities (e.g. Operations control center, maintenance yards, etc.). In addition, the CCTV cameras can also be provided for coverage of location where money is intended to be exchanged (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 CPTED (Crime Prevention Through Environmental Design) 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 in San Carlos 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 coordinate with Caltrain personnel the design, implementation and testing details of the new equipment affecting the existing system.

All new CCTV installations shall utilize Day/Night IP Cameras only. Whenever is practical, the IP cameras shall be supplied dc power using Power-Over-Ethernet (POE) technology.

The station CCTV cameras shall provide for 100% coverage for inside stations, station train platforms, pedestrian underpass, waiting areas and stairs/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, Stairs/Steps) require detailed coverage – at least 40 pixels per foot.

b. General Detail – remaining station areas – at least 10-20 pixels per foot.

The station CCTV System shall also include PTZ cameras, which shall provide for the following:

a. Redundancy of coverage

b. Means of real-time zooming in on a crisis area by the Caltrain or local agency security personnel when a problem is reported from the field or a pre-determined alarm is triggered (i.e., TVM Intrusion Alarm)

PTZ cameras shall provide for at least 90% of area coverage provided by the fixed cameras and, where feasible, shall cover 100% of high priority targets.

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

The PTZ Camera design shall include Digital Input/Output contacts and the ability to set pre-defined Pan/Tilt/Zoom settings. When a Digital Alarm input is triggered by a station object, the associated predefined Pan/Tilt/Zoom 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 to the CCTV design for these areas of video surveillance shall be determined based on the priorities input from the stakeholders, and CPTED personnel.

Video cameras, as with all subsystem devices, shall be networked and assigned dedicated bandwidth. The network protocol shall be 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 virtual LAN (CCTV VLAN) shall be partitioned to dedicate bandwidth solely for the CCTV subsystem. Network cameras shall be equipped to interface directly with Category 6 cable installed to the assigned distribution cabinet and associated networking equipment.

At the station CER the CCTV system shall utilize a dedicated station digital video recorder (DVR), which is a computer for recording and storing of the station CCTV video data. Station DVR shall utilize 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% additional spare storage for future growth).

The CCTV System design shall allow Caltrain personnel for both local and remote recording retrieval. Additionally, the system shall support requests for remote monitoring by independent agencies (i.e., Local Police Department having jurisdiction of where the system is located).

To accommodate current low bandwidth limitations for links between the CCTV headend at San Carlos facility and remote Caltrain stations, station’s DVR shall support downscaling of the video streams to low resolution (i.e. 1-4 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 utilize Verint Media Gateway Server software.

The station DVR shall support local and remote retrieval/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 the low bandwidth leased lines from the Caltrain San Carlos facility 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 (no video tampering took place), so that it could be submitted in the court of law as evidence.

As per the stakeholder input, for non-critical areas with the least amount of human traffic, use of motion and audio detection software is allowed, which could enable slowing down of 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 address, 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 input and output 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 utilizing less cameras. As a result, even though Megapixel cameras are typically more expensive than traditional (4 CIF) cameras, however, they will more than compensate from the reduction of the number of cameras.

The designer shall produce storage design calculations showing that the capacity of video storage hard-drives is adequate. Note that typically such calculations include a variety of the various 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 a 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 additional 50% of similar station CCTV equipment.

As a part of the design submittals, the designer shall provide for Caltrain Engineering all necessary calculations for performance and storage requirements of the CCTV system and identify adequate and up-to-date equipment/software fully compatible with the existing CCTV Headend in San Carlos.

At 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% spare storage allocated for future needs).

Within the station LAN a portion of the network shall be partitioned for CCTV as CCTV Virtual Local Area Network (CCTV VLAN). The designer shall produce calculations showing that allocated CCTV VLAN bandwidth is sufficient to serve all station CCTV System needs. This Virtual Local Area Network (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 (2) units of TVM per boarding platform shall be provided for redundancy, and to handle any peak usage.

The station Fare Collection Devices communications 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). The rationale is, should one of the switches fail, there will always be another functioning TVM (and/or
group of VMS sings) 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 located near the TVMs. The quantity of Clipper Card Interface Devices is typically two per a platform; however, their exact quantity and placement shall be coordinated between the Designer and Caltrain/Clipper.

Though not a TVM, Clipper CID utilizes 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 utilize a station Clipper LAN IP-based network operating at 100 Mbps for field devices and 1Gbps for the station backbone connection (between DCs and CER).

A CID card reader is installed on a dedicated pole; and requires a 24 VDC power. The corresponding 24VDC 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 Wide Area Network connection (at MPOE).

Caltrain is responsible for provision of CID poles and poles’ temporary covers, and the MTC is responsible for their installation. The MTC is responsible for provision and installation of all remaining equipment, such as: rack space; all interconnecting conduits and comm/power wiring; and provision, installation and termination of all necessary 24VDC power supplies in DC cabinets (one power supply per two CID devices).

Each TVM or CID shall have dedicated Category 6 connectivity to the distribution network switch via physically separated conduit runs. The CIDs’ Category 6 cables shall also share the conduit with two #16 AWG power wiring conductors (for 24 VDC power).

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 Visual Message Signs (VMS)

Visual Message Sign or VMS is required by ADA to augment and complement audio public address messaging for the benefit of hearing impaired commuters. Visual messaging shall be both centrally and locally controlled.

VMS boards are typically 16.125 inches high, 62.5 inches wide and 10 inches deep, 110 lbs weight, with multiple styles of text and font displayed by LED (light emitting diode).
VMS boards shall be spaced to comply with MIL-STD-1472 for non-emergency visibility for the center 80% of the platform or any non-platform signs. For the design submittals, the designer shall submit the actual distance calculations for the selected VMS boards.

Designer shall place a minimum of two (2) dual sided units per platform for redundancy and passenger convenience. VMS design shall include a plan view depicting both message sign and support structure location within the station, including distances to platform edge, conduit size and route, and conduit pull-box locations.

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

VMS shall be equipped for Category 6 interface. Connectivity shall be made to the assigned distribution switch. Each visual messaging unit will have dedicated Category 6 data cables connectivity to the distribution network via physically separated conduit runs.

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

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

The details of the VMS specifications are in Specification Section 17750, Visual Messaging Signs.

2.4 Public Address System (PAS)

Public Address Systems are designed for Caltrain staff to communicate with passengers, locally or from remote location. Station public announcements are 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.

Public Address Subsystem or PAS consists of speakers located 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, Station concourse, etc.).

Public Address (PA) announcements shall have capability to be initiated either remotely or locally.

The remote announcements shall be initiated as follows:

a. Automated PA Announcements from the Central Control Facility (CCF) by the PAS Headend equipment
b. PA Announcements over a phone line by Caltrain end-users

Automated PA Announcements from CCF are the primary user of the PAS 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. Construction activities and interruptions

However, unplanned announcements such as emergency/security announcements and local events related information are typically initiated locally utilizing local paging microphones.

At major Caltrain passenger stations the following additional means for local PA Announcements shall be provided: one hard-wired paging microphone and one wireless paging microphone at the PIDS (Passenger Information Display System) Clerk Office. The wireless paging microphone would allow the station agent to make the PA announcements while walking along the station and guide the patrons according to the situation taking place within the station area.

Also, at multiplatform stations (with more than 2 platforms), a paging microphone for each platform shall be provided.

In order to ensure that various types of announcements do not overlap each other, station PAS shall support implementation of priority scheme. In-progress PA announcements shall be pre-empted 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 by a Caltrain end-user

For stations, where PIDS Clerk Office is implemented, the station PAS shall support the ability of turning the remote messaging off. This shall be done for special or
emergency events to prevent PAS from announcing PA messages other than related to the event.

Local announcements are expected to be of a limited duration basis. The majority of the announcements are expected to be Automated PA Announcements from CCF. These are PAS pre-recorded voice announcements, which (for ADA compliancy) 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, groups of stations, or broadcast messages to all stations as required. The station PAS shall incorporate the corresponding E&M Cards and the associated muting relays.

To prevent “prank-call” announcements, the PA Announcements over a phone line by Caltrain end-users shall utilize a phone access device, which can limit access to the PAS by requiring the phone user to enter an authorized access code.

In the future, Caltrain is planning on switching to “all Ethernet” PAS. When ready, the switchover shall take place by connecting to the Caltrain WAN the stations’ IP-to-Audio Gateways (or Station Control Units) and plugging their analog audio outputs as inputs into the existing amplifier(s).

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

- a. Station Platform: The desired STI should be minimum 0.6 measured at 95% of all station platform areas assigned to be covered by the PAS
- b. Inside Station Areas: The new PA System shall cover all publically accessed areas within the station. For new stations, the desired STI shall be minimum 0.6 measured at 95% of all station indoor areas. For an existing station with a challenging reflective materials and architectural design, the desired STI should be minimum 0.5 measured at 95% of all station indoor areas.
- c. 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 the adjacent neighborhoods and street traffic represent a large concern. For these areas, the STI should be minimum 0.5 at 25 ft within vicinity of the station doors; and minimum of 0.5 STI and uniformity of 80% coverage of the Station Plaza areas.

For the preliminary analysis of the station PAS design, the following values should be used for the ambient noise (the final design of PAS shall be based on the tested values within the station environment):

- a. Station interior has been shown to have an ambient noise level averaging between 66 dB and 73 dB
b. Platforms with stopped trains with operating car air conditioning show an average ambient noise level of 80 dB to 85 dB

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

For the design of the station PAS’ uniformity of coverage for the PA announcements the values below shall be achieved at least 95% of the station areas. The values are measured as Sound Pressure Levels (SPL) expressed in dBs. 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:

a. Complex Caltrain Station layout: Minimum Design Goal: +/- 6 dB @ 1000 Hz Octave band

b. Typical Caltrain Station (1 or 2 Platforms) layout: Maximum Design Goal: +/- 3 dB @ 1000 Hz Octave band

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

In order to mitigate changes in volume of the ambient noise, the PAS shall utilize ambient noise measuring microphones and adjust the PA output accordingly.

There shall be one ambient noise sensor per a platform; at least one ambient noise sensor per a station indoors (where applicable); and at least one ambient noise sensor for station outdoors (where applicable). Each station area with an ambient noise sensing microphone shall yield at least one associated PA Announcement Zone. All ambient noise sensing microphones shall be placed carefully, facing away from the PAS speakers; the goal is to sense the ambient audio levels; not the audio generated by the PAS.

If necessary, in order to implement this variety of PA zones, a multi-channel pre-mixer/feedback eliminator/amplifier system will be used. Each zone’s PA volume will be increased/decreased according to the ambient noise level measured by the corresponding zone’s ambient noise level microphone.

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

The new station PAS amplifier, pre-mixer and the corresponding equipment shall be rack-mounted.

### 2.4.1 Acoustic Modeling

As a rule, designers shall develop a computerized model of indoor spaces to ensure STI values noted above are met with the appropriate ambient noise. Outdoor spaces, which have little reverberation, need not require modeling. However, outdoor stations that are in areas that have a density of buildings or platform shelters etc., may need modeling to achieve the required STI performance levels.
The Pre-mixer shall accept all identified audio inputs (all remote and local phones inputs, E&M card / Mute Relay phone inputs; and all local paging and ambient noise sensing microphones); and, where necessary, digital inputs (e.g. On/Off switches, multiple-position switches, remote volume control devices). The device shall be of modern type with sophisticated software allowing programming and processing of the analog and digital inputs supporting any particular needs of the station new PAS.

The Pre-mixer software shall be programmed to support PA zones; eliminate microphone feedbacks; any undesirable “clicking/snapping” sounds and/or 50 Hz humming noise interference from power wiring; and adjust its output according to the ambient noise. Its software shall support the ability to automatically adjust the output of the system to meet day time and night time noise abatement requirements of local municipalities.

Standard Caltrain stations (center island platform or outboard platforms) shall use traditional balanced 70.7 Volt PA outputs 2-channel (stereo) PA amplifiers (one amplifier per a platform).

Major Caltrain stations with multiple PA zones and variety of the speakers shall use 70.7 Volt PA outputs multi-channel amplifier(s).

The amplifier shall provide for fine tuning of the output levels of its channels using manual volume controls; and detection/reporting of alarms, such as amplifier issues, PA output circuitry issues (i.e. shorts and/or open PA wiring circuits, etc.) for each channel.

The Pre-mixer and amplifier(s) shall support dual remote alarm monitoring: over Ethernet / SNMP; and dry contact alarm reporting via UPS Digital Input sensing (to be wired later on to future SCADA system).

PAS speakers shall be mounted on existing station structures. For a station platform speakers are typically mounted on light poles (or canopy poles) approximately 50-70 ft apart. Each PAS speaker location shall have dedicated audio speaker cable connectivity to the audio output amplifier distribution network via physically separated conduit runs.

The PA speaker wiring gauge should correspond to the amplifier allowed voltage drops and wattage requirements. The designer shall submit the wire gauge calculation for each PA cabling. Because of the transit application environment, for mechanical strength and resilience, it should be a minimum of 16 AWG size for the speaker wiring and 18 AWG for the microphone wiring.

The PA speaker (and microphone) wiring shall provide for redundancy: preferably by using two PA channels per a zone (wiring one channel to odd number speakers and wiring the second channel to even number speakers); or, as a minimum, using 2 pair wiring brought to each device (1st pair is working and the 2nd pair is “hot spare”).
2.5 Passenger Assistance and Emergency Telephones

Talking signs are provided at the terminal stations in San Francisco (4th & King) and San Jose (Diridon). Emergency Telephones are currently not provided at Caltrain stations.

3.0 CABLE AND RACEWAY

Fiber optic cable (FOC) at the station used to connect the CER to the distribution cabinets shall be loose buffered and rated for outdoor use. The minimum cable size shall be 24-strands per cable sheath. Fiber optic cable shall be enclosed in HDPE inner-duct rated to match the cable sheath.

3.1 Single-Mode Cable

Single-mode (SM) fiber optic cables shall be installed in the station backbone connecting CER with DCs and remote field devices.

The Station aggregation switch shall be single mode compatible and allow future fiber connectivity with Caltrain fiber WAN. Where possible, the Single Mode Fiber-Optic Cable (FOC) network shall be provided in a physical dual ring topology. Single mode FOC shall be installed in separate conduits and inner-ducts. FOC cable sheaths and inner-duct shall be color coded as to clearly identify single-mode cable.

All single-mode FOC, fiber connectors and patch cords shall be colored yellow. The preferred connector type is SC. At the CER and DC (distribution cabinet), fiber distribution panels shall be used for single-mode fiber demarcation.

Single-mode FOC shall be all dielectric (no metallic components).

3.2 Protection Terminal Blocks

All outdoor copper cabling (e.g. Cat 6, PA and Microphone audio cables, etc.) shall be connected through the suitable protection type terminal blocks at the entry points of the Distribution and Station Communication Cabinets.

The protection equipment shall match the application type of each terminated cable and shall be implemented according the vendor recommendations.

3.3 Conduit Raceway Systems

When designing conduit raceway systems for station communications, the following considerations shall be given:

a. Where possible, the CER or DC 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 or cabinet shall have at least two (2) pathways to each platform. This means two (2) conduit paths for single platforms and four (4) conduit paths for dual platform stations. Providing
pathway redundancy improves subsystem reliability by guarding against total subsystem failures due to conduit collapse, cable cuts, or other cable path problems.

c. The CER at outboard platform stations shall have redundant pathway to the platform pull-boxes comprised of four (4), four (4) inch conduits each with four (4), HDPE one (1) inch inner-ducts per pathway. ANSI/TIA/EIA 569B shall govern the conduit pathway design with pull-boxes.

d. The conduit system shall be placed to avoid crossing other utilities. Where crossings can not 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 six (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 five (5)-degree grade change. At no time should both utilities equipment become encased in the same trench or concrete pour.

3.4 Outside Conduits

There are three (3) types of conduit used in outside plant conduit structures. They are as follows:

a. Schedule 20 (“B”) Plastic Duct (thin-wall conduit): this conduit is used when concrete encasement is specified on design.

b. Schedule 40 (“C”) Plastic Duct (medium heavy-wall conduit): this conduit is used when conduit is to be direct buried (without any type of encasement).

c. Schedule 80 (“D”) Plastic Duct (heavy wall conduit): this conduit is used when conduit is to be exposed to direct/indirect sunlight (such as exposed bridge crossings). This type of conduit is resistant to ultraviolet light and will not become brittle due to the sun’s exposure.

The following design criteria shall be followed:

a. Outside plant rated hand-holes with covers marked “communications” shall have a highway rating of H-40 (40 tons).

b. Outside plant rated conduit shall be trenched or buried to a minimum depth of 48 inches below grade to the top of the conduits. Where this depth requirement can not be met, the conduits shall be concrete encased.

c. Fiber optic conduit pathway installed below grade shall be concrete encased when installed under rails.

d. Outside plant fiber optic cable and conduit shall be protected using detectable marking tape placed six (6) inches below grade and over the area to be protected, in addition to above grade visual markers.
e. Cable raceway shall be sized to carry Category 6 and fiber optic cables per code and industry standards. The minimum conduit size used for Category 6 and fiber optic cables shall be one (1) inch when running cables between station distribution cabinets and the subsystem device location. The minimum conduit size used for bundled fiber optic cables shall be four (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 conduits ends shall be ream and bushed. All outside plant conduit openings shall be sealed after cable installations. All unused conduits shall have pull-strings placed.

C. POWER AND UPS

All station communications equipment and subsystem devices shall operate using an uninterruptible power supply (UPS) with battery reserve capable of sustaining the full equipment current load (plus additional 50% for future growth) for a period up to 90 minutes.

All UPS equipment shall be compatible with the existing Caltrain centralized UPS monitoring software (by APC) located in CCF facility. The new UPS shall be configured to report all types of the alarms already defined by this 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 (i.e., PA pre-mixer and amplifier(s) alarms, etc.). In the future these alarms will be re-wired to report to the future SCADA. UPS 120Vac 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 subsystem as follows:

a. One 20A, 120Vac breaker per Visual Message Sign
b. One 30A, 120Vac breaker per Ticket Vending Machine
c. One 30A, 120Vac breaker per Distribution Cabinet
d. One 30A, 120Vac breaker per Communications Equipment Room

The central UPS shall provide for essential power for all station important communication devices such as Caltrain WAN interface, CER communication devices, PAS equipment, LAN switches, Media Converters, TVMs, CCTV, VMS, and Clipper Equipment.

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 120/208Vac UPS line side (input) shall be fed from the local ac electrical service on a dedicated breaker sized appropriately. The 120Vac UPS supply side (equipment side) shall have an adequate number of 120Vac receptacles for equipment distribution. If required, ac service strips with surge protection shall be installed within the main equipment room and distribution cabinets to facilitate the number of required equipment receptacles.

D. **COMMUNICATIONS EQUIPMENT ROOM (CER)**

The communications networking equipment shall be housed within the station and in the CER only accessible by authorized personnel. The CER is a prefabricated steel construction structure. All construction shall be applicable NFPA 70 (NEC) and California Building Code (CBC Title 24, Division 3).

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 per EIA 310-D.

The positioning of equipment racks shall be such to allow adequate clearance for maintenance and safety per NEC (NFPA 70). This requires at least 3 feet of space between live circuit components and walls or other obstructions.

The communications equipment room shall have an adequate grounding and bonding system. A single point grounding scheme shall be used and a single main ground bar (MGB) shall be installed central to the room layout. Grounding design shall comply with ANSI/TIA/EIA-j -STD-607-A.

The size of the CER will depend on the size of the station and assigned communications equipment, but in no case will the available floor space be less than 8 feet x 10 feet. Unobstructed vertical space within the room shall be eight (8) feet minimum.

Equipment room lighting, environmental controls, floor loading, space planning, service entrances, and other design criteria will be in accordance to ANSI/TIA/EIA 569-B.

For security, a means to control access to any equipment room shall be provided. A state-of-the-art card reader/access system utilizing a 56Kbps service channel via the station/CCF carrier network shall be the preferred method of choice.
E. STATION COMMUNICATION CABINETS (SCC) / COMMUNICATION INTERFACE CABINETS (CIC)

The terms “SCC” and “CIC” can be used interchangeably. “SCC” is used in this document.

As mentioned above, for temporary stations, in lieu of CERs, designer may house the station-related communication equipment (listed above as housed within CERs) within these outdoor cabinets.

They are typically housed outside the station (or within station rooms, which do not have climate control) and only accessible by authorized personnel.

Because of the variety and quantity of the equipment, which needs to be placed into SCCs, these shall be at least 6 ft tall, 6 ft wide, vandal-proof, two lockable doors, NEMA 3R cabinets and incorporate swing-out 19 inches racks for ease of access for installation and maintenance.

For outdoor SCC installations the designer shall incorporate all preventive measures mitigating affects 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 having worst case scenario for the given equipment (including provision for future 50% growth) and particulars of location (officially recorded max outdoor temperatures). Based on these calculations provide cooling means, such as: sun-shield, painting of the cabinet; cooling fans and, if necessary, a side mounted air-conditioning unit.

d. Proper conduit entrances

e. Proper protection for lightning, protection terminal blocks and overall grounding scheme

The designer shall submit UPS calculations and provide for the UPS to support of typically 90 min operation of the station essential communication equipment powered (either directly by SCC or via the DCs) by SCC UPS after loss of utility power.

The SCC shall include for 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 accommodate power outlets for ease of maintenance.

The designer shall determine the size and electric/thermal requirements of new SCC to include sufficient space, cooling and power to accommodate for 50% of future growth. The Contractor's thermo-calculations shall be based on the temperatures
for the given locale and show that the chosen equipment can still operate within the enclosure without exceeding its temperature limits.

F. OTHER DESIGN CONSIDERATIONS

1.0 ELECTROMAGNETIC INTERFERENCE (EMI)

In addition to the industry design and equipment standards listed above, the following design criteria and considerations shall be adhered to for the network protection against Electromagnetic Interference or 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 signal to noise ratio (S/N) above 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 right-of-way 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 any future Traction Power ac source sub-transmission distribution system, operating at 60 Hz and carrying harmonics typical for the configuration and the loads served.

b. Direct-current traction power system:
   i. Substation thyristor rectifier apparatus
   ii. Direct current power distribution to trains, via overhead power catenary circuit
   iii. On-board propulsion equipment, including solid-state chopper and motor circuits
   iv. Direct current arcing, catenary to pantograph
   v. Temporary faults on the ac or dc power circuits

Train Control signal system, which 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 KHz 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 FCC CFR 47 part 15 Over-voltage Protection. Over-voltage protection shall be provided for all outdoor Public Address (PA)/Visual Message Sign (VMS) and CCTV equipment.

2.0 PROHIBITED MATERIALS AND METHODS

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

a. Extra-flexible, metallic or non-metallic, non-labeled conduit.

b. Plastic conduit for interior electrical use, except that Polyvinyl Chloride (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. Steel Conduit shall not be used outside unless in concrete. Use Galvanized Rigid Steel (GRS) conduit outside and wet locations above grade.

d. Aluminum wiring.

e. 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: All dissimilar metals shall be properly insulated to prevent galvanic action.
   iv. 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.
   v. 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.
   vi. Fasteners: All exposed fasteners shall be stainless steel.
   vii. Multi-use Suspension Systems: Piggy-back suspension systems for conduits and fixtures are prohibited. All suspensions shall be hung independently from structure, or, in limited cases, from trapeze suspension systems.
   viii. Use of wire ties to support conduit: Use of splices to join communications or electrical wiring within duct banks and raceways.

3.0 ENVIRONMENTAL

Communications equipment and material shall be designed for indoor and outdoor locations along the rail right-of-way, at elevations of approximately sea level to 1000 feet above sea level, in a suburban environment. The areas adjacent to rail right-of-way are urban or suburban zones, some of which are occupied by industrial or commercial developments. Rail lines run parallel with 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 6 cabling shall be installed in protective conduits.

3.1 Climatic Conditions

The following particular climatic conditions shall be used as design guidelines and shall be considered as operational requirements. Actual localized temperatures and conditions within spaces and enclosures may be more severe than the ambient climatic conditions and the design shall include evaluating these during the design effort. The design shall address that no equipment damage occurs during manufacture, storage, and shipment as a result of climatic conditions which differ from those below:
a. Temperature and Solar Load:
   i. Minimum ambient air temperature external to equipment is 14 degrees F
   ii. Maximum ambient air temperature external to equipment is 120 degrees F
   iii. Maximum solar radiation: 275/BTU/hr*ft²
   iv. Maximum daily temperature range: 50 degrees F

b. Precipitation:
   i. Maximum rainfall rate is five (5) inches/hr and this rate may occur simultaneously with wind
   ii. Measurable quantities of ice infrequently occur
   iii. Average relative humidity >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 mg/m³
   ii. Maximum: 0.324 mg/m³

b. Ozone: 0.200 ppm, maximum

c. Noa: 0.25 ppm, maximum

d. Soa: 262 g/m³

e. CO: 20 ppm, max.

f. Chloride: 13.9 mg/m³

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 degrees F. Equipment intended to be
installed in outdoor enclosures shall be designed and tested for continuous service at 140 degrees F.

The designer shall submit thermal calculations for each outdoor enclosure for each given equipment (calculation should include 50% growth for future equipment of a similar load) and environmental particulars of the given location. If use of fans appear 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 degrees F to 120 degrees 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. 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 within enclosures between 60 degrees F to 80 degrees 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. 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 located adjacent to track on direct fixation or tie and-ballast sections, and mounted anywhere within the Caltrain right-of-way except as indicated herein below, shall be designed to operate in an environment subject to the following vibration levels: all frequencies less than 12 Hz, 0.02 inches peak-to-peak amplitude; all frequencies from 12 Hz to 1000 Hz, 0.14 g peak or 0.1 g rms.

   ii. Equipment located 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: all frequencies less than 12 Hz, 0.2 inches peak-to-peak amplitude; all frequencies from 12 Hz to 1000 Hz, 1.4 g peak or 1.0 g rms.

b. Equipment located in communications equipment spaces at Central Control Facility (CCF), Distribution Cabinets (DCs), other communications facilities, Signal Houses, or Yards:
   
   i. For all frequencies less than 12 Hz: 0.02 inches peak-to-peak amplitude

   ii. For all frequencies from 12 Hz to 1000 Hz: 0.14 g peak or 0.1 grms.

END OF CHAPTER
CHAPTER 5

SIGNALS

A. GENERAL

When the Southern Pacific Railroad (SP) owned and operated the Caltrain corridor, the signal system had been designed based on the mixed operation of freight and passenger trains. The signal system spacing was based upon single direction running, with braking distances for 80 Ton per Operative Brake (TPOB) freight trains at 60 MPH (miles per hour).

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 Interlockings 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 State Department of Transportation (Caltrans) completed the freeway I-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 by product 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 ones: All areas outside the San Francisco and San Jose Terminals 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% of the Control Points completed in 2003.

c. Replacement of dc track circuits and line circuits with Electronic Coded Track circuits: OS (On Station) tracks remain dc and there are some dc track
circuits in locations where the coded track is on line circuits completed in 2003.

d. Replacement of system of single direction running ABS (Automatic Block System) with double direction running CTC: Completed in 2003 with the completion of the construction of Caltrain CTX projects.

e. Installation of a Positive Train Control System.

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

By defining the path of migration, projects today will lay the groundwork for future projects. Since 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 bidirectional running railroad on both tracks, grade crossings were designed to accommodate the ultimate 79 MPH (miles per hour) 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 Centralized Traffic Control (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, a train only knows it is to take a diverging route and must approach a control point with different sized turnouts prepared to take the turnout at the lowest speed of any turnout, which can be reached, from that signal.

The original system was one of route signal aspects. After the system was upgraded to bidirectional 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 presently funded projects, and 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 on board 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
greater than 79 MPH. This too will require on board control of locomotives by the
signal system. The present 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 that funded. However, an intelligent design with a defined path of
migration, allows for the future projects to build upon the present 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. While
this is a system manufactured by General Electric Transportation Systems (GETS),
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 on board train control equipment.

In addition to the high number of motor vehicles which cross the railroad, there are a
large number of pedestrians who cross the Caltrain tracks. The safest crossing for
both pedestrians and motorists is one which is at a separate grade, 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 will 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 will be added to the roadway gate, and a new
gate assembly will be installed in the off quadrant on the sidewalk for pedestrians.

This document incorporates many lessons learned from recent projects, a
commitment to the judicious use of public funds by defining the migration path, and
recognizing 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
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 utilizing 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, Parts 234, 235, and 236. Signal design criteria shall incorporate the rules and instructions as contained in the most current issue of the California Public Utilities Commission General Orders, General Code of Operating Rules (GCOR), Caltrain General Orders, Timetable, and Special Instructions, and 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 Communications. Note that the Caltrain General Orders, Timetable and Special Instructions supersede the General Code of Operating Rules (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 the CHAPTER 7 – 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. American Railway Engineering and Maintenance of Way Association (AREMA)
c. California Public Utilities Commission (CPUC)
d. General Code of Operating Rules (GCOR)
e. General Orders
f. Timetable
g. Special Instructions
h. National Electrical Code (NEC)
i. Institute of Electrical and Electronics Engineers (IEEE)
j. American National Standards Institute (ANSI)
k. Electronic Industries Association (EIA)
l. Federal Communications Commission (FCC)
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 4500 feet in length where possible. Such spacing allows passenger trains to operate with optimum headways and utilization of “fourth aspect” (i.e. flashing yellow) signaling provides “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 (Tons per Operative Brake) 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 Signal Standard Drawings contain braking and deceleration tables for both types of consist. When manual calculations are used, the “average grade” 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 safe braking distance cannot be achieved by utilizing the flashing yellow aspect, the designer shall repeat the “yellow” aspect to a point where the flashing yellow aspect is applicable.

Computerized train performance programs are acceptable for calculating braking distances.

EXAMPLE:

```
RED--------YELLOW--------YELLOW---------FL. YELLOW--------GREEN

+------------
|            |
|            | UNSAFE DISTANCE
|            | SAFE DISTANCE
|            | +---------------------------

The signal system while allowing for freight train braking will also be designed for the greatest possible passenger train efficiency. In some cases, an Approach Medium or an Approach Limited may provide a more efficient operation than Advance Approach. Advance Approach should not be used where the approach block is less than 2500 feet, or where the distance from the advance approach 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 assure 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 must provide sufficient braking for the train to be at Limited Speed at the Point of Switch. It is not necessary for the Approach Limited to provide braking distance to the Limited Clear Signal.
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2.0 SIGNAL SYSTEM HEADWAYS

The present signal system will generally support headways for local trains of six (6) minutes and for express trains at five (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 “Systra Signal System Capacity Study” performed for Caltrain in the APPENDIX which explains the methodology.

D. SIGNAL PLACEMENT

Where possible, block signals shall be placed to the right of the track governed, except back-to-back ground signals 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 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 (3) lamp units. The signal units shall be color-light, stacked type, 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 C&S 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 signals placed in accordance with Caltrain standards will not be obstructed by vegetation, buildings, highway overpasses, 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 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 will 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 will have three heads, Approach Signals to Control Points will have two heads, and intermediate signals which do not serve as Approach Signals to Absolute Signals will 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. This placement will accommodate future track elevation increases and electrification.

No portion of a dwarf signal shall be placed closer than six (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 two (2) inches variation should accommodate settling of the track, thus ensuring compliance with the regulation.)

Care shall be taken to ensure 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” will 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 utilize solid-state interlocking systems configured for use with color-light signal units. Solid-state interlocking systems shall be the GETS Global Signaling Vital Logic Controller, or equivalent systems. Intermediate color-light signals shall utilize electronic coded track circuit systems such as Electrocode 4 Plus or equivalent systems which will emulate the Electrocode 4 Plus rates and communicate through the rail with existing equipment. In order to enhance system response time, transit rates will be used if possible. The utilization 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 72 hours of information.

Electronic coded track circuits shall be utilized wherever practical to transmit and receive vital block signal data. Electrocode 4 Plus code rates shall be used. New application logic software must be approved by the Caltrain Deputy Director of Engineering. The following Code Rates and Aspects in **TABLE 5-1** shall be used.
TABLE 5-1 CODE RATE AND ASPECT

<table>
<thead>
<tr>
<th>CODE RATE</th>
<th>ASPECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Clear</td>
</tr>
<tr>
<td>4</td>
<td>Advance Approach</td>
</tr>
<tr>
<td>3</td>
<td>Approach Limited</td>
</tr>
<tr>
<td>8</td>
<td>Approach Medium</td>
</tr>
<tr>
<td>2</td>
<td>Approach</td>
</tr>
<tr>
<td>9</td>
<td>Approach Slow</td>
</tr>
<tr>
<td>6</td>
<td>Accelerated Tumble Down</td>
</tr>
<tr>
<td>5</td>
<td>Non-Vital code indicating track occupancy, or a hand-throw switch in the block out of normal correspondence</td>
</tr>
<tr>
<td>M</td>
<td>Non-Vital code indicating power off in the block, or a lamp out condition in the block. Power Off will indicate from the east end CP, lamp out from the west end CP</td>
</tr>
</tbody>
</table>

“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. The principle is that the lamp out condition will be acted upon more quickly when a Restricting Aspect is displayed. When elaborate lampout downgrade schemes are used, signals may not be reported until there are multiple lamps out.

The following typical downgrade logic shall be incorporated: Lampout schemes should be shown on the circuit plans for each location. Refer to the following TABLE 5-2 through TABLE 5-7.

TABLE 5-2 ONE UNIT SIGNAL
ONE LAMP OUT

<table>
<thead>
<tr>
<th>GREEN lamp out</th>
<th>FLASHING YELLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASHING YELLOW lamp out</td>
<td>FLASHING RED</td>
</tr>
<tr>
<td>YELLOW lamp out</td>
<td>FLASHING RED</td>
</tr>
<tr>
<td>RED lamp out</td>
<td>DARK</td>
</tr>
</tbody>
</table>
### TABLE 5-3 TWO UNIT SIGNAL
#### TOP UNIT LAMP OUT

<table>
<thead>
<tr>
<th>GREEN over RED</th>
<th>FLASHING YELLOW over RED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YELLOW</strong> over <strong>FLASHING GREEN</strong> (for a Number Plated Signal)</td>
<td>DARK over <strong>YELLOW</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>FLASHING GREEN</strong> (for an Absolute Signal)</td>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>GREEN</strong> (for a Number Plated Signal)</td>
<td>DARK over <strong>YELLOW</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>GREEN</strong> (for an Absolute Signal)</td>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>YELLOW</strong> (for a Number Plated Signal)</td>
<td>DARK over <strong>YELLOW</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>YELLOW</strong> (for an Absolute Signal)</td>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>FLASHING YELLOW</strong> over <strong>RED</strong></td>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>RED</strong></td>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
<td>DARK over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>GREEN</strong></td>
<td>DARK over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>YELLOW</strong></td>
<td>DARK over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>FLASHING YELLOW</strong></td>
<td>DARK over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>FLASHING RED</strong></td>
<td>DARK over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>RED</strong></td>
<td>DARK over <strong>RED</strong></td>
</tr>
</tbody>
</table>

### TABLE 5-4 TWO UNIT SIGNAL
#### BOTTOM UNIT LAMP OUT

<table>
<thead>
<tr>
<th>GREEN over RED</th>
<th>GREEN over <strong>DARK</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YELLOW</strong> over <strong>FLASHING GREEN</strong></td>
<td><strong>YELLOW</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>GREEN</strong></td>
<td><strong>YELLOW</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>YELLOW</strong></td>
<td><strong>YELLOW</strong> over <strong>RED</strong></td>
</tr>
<tr>
<td><strong>FLASHING YELLOW</strong> over <strong>RED</strong></td>
<td><strong>FLASHING YELLOW</strong> over <strong>DARK</strong></td>
</tr>
<tr>
<td><strong>YELLOW</strong> over <strong>RED</strong></td>
<td><strong>YELLOW</strong> over <strong>DARK</strong></td>
</tr>
<tr>
<td><strong>FLASHING RED</strong> over <strong>RED</strong></td>
<td><strong>FLASHING RED</strong> over <strong>DARK</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>GREEN</strong></td>
<td><strong>RED</strong> over <strong>DARK</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>FLASHING YELLOW</strong></td>
<td><strong>RED</strong> over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>YELLOW</strong></td>
<td><strong>RED</strong> over <strong>FLASHING RED</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>FLASHING RED</strong></td>
<td><strong>FLASHING RED</strong> over <strong>DARK</strong></td>
</tr>
<tr>
<td><strong>RED</strong> over <strong>RED</strong></td>
<td><strong>RED</strong> over <strong>DARK</strong></td>
</tr>
</tbody>
</table>
### TABLE 5-5 THREE UNIT SIGNAL
#### TOP UNIT LAMP OUT

<table>
<thead>
<tr>
<th>GREEN over RED over RED</th>
<th>FLASHING YELLOW over RED over RED</th>
</tr>
</thead>
<tbody>
<tr>
<td>YELLOW over FLASHING GREEN over RED</td>
<td>FLASHING RED over RED over RED</td>
</tr>
<tr>
<td>YELLOW over GREEN over RED</td>
<td>FLASHING RED over RED over RED</td>
</tr>
<tr>
<td>YELLOW over YELLOW over RED</td>
<td>FLASHER RED over RED over RED</td>
</tr>
<tr>
<td>FLASHING YELLOW over RED over RED</td>
<td>FLASHING RED over RED over RED</td>
</tr>
<tr>
<td>YELLOW over RED over RED</td>
<td>FLASHING RED over RED over RED</td>
</tr>
<tr>
<td>FLASHING RED over RED over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over FLASHING GREEN over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over GREEN over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over FLASHING YELLOW over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over YELLOW over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over YELLOW over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over FLASHING RED over RED</td>
<td>DARK over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>DARK over RED over RED</td>
</tr>
</tbody>
</table>

### TABLE 5-6 THREE UNIT SIGNAL
#### SECOND UNIT LAMP OUT

<table>
<thead>
<tr>
<th>GREEN over RED over RED</th>
<th>GREEN over DARK over RED</th>
</tr>
</thead>
<tbody>
<tr>
<td>YELLOW over FLASHING GREEN over RED</td>
<td>YELLOW over RED over RED</td>
</tr>
<tr>
<td>YELLOW over GREEN over RED</td>
<td>YELLOW over RED over RED</td>
</tr>
<tr>
<td>YELLOW over YELLOW over RED</td>
<td>YELLOW over RED over RED</td>
</tr>
<tr>
<td>FLASHING YELLOW over RED over RED</td>
<td>FLASHING YELLOW over DARK over RED</td>
</tr>
<tr>
<td>YELLOW over RED over RED</td>
<td>YELLOW over DARK over RED</td>
</tr>
<tr>
<td>FLASHING RED over RED over RED</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over FLASHING GREEN over RED</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over GREEN over RED</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over FLASHING YELLOW over RED</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over YELLOW over RED</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over YELLOW over YELLOW</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>RED over FLASHING RED over RED</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>RED over DARK over RED</td>
</tr>
</tbody>
</table>
### TABLE 5-7 THREE UNIT SIGNAL
THIRD UNIT LAMP OUT

<table>
<thead>
<tr>
<th>GREEN over RED over RED</th>
<th>GREEN over RED over DARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>YELLOW over FLASHING GREEN over RED</td>
<td>YELLOW over FLASHING GREEN over DARK</td>
</tr>
<tr>
<td>YELLOW over GREEN over RED</td>
<td>YELLOW over GREEN over DARK</td>
</tr>
<tr>
<td>YELLOW over YELLOW over RED</td>
<td>YELLOW over YELLOW over DARK</td>
</tr>
<tr>
<td>FLASHING YELLOW over RED over RED</td>
<td>FLASHING YELLOW over RED over DARK</td>
</tr>
<tr>
<td>YELLOW over RED over RED</td>
<td>YELLOW over RED over DARK</td>
</tr>
<tr>
<td>FLASHING RED over RED over RED</td>
<td>FLASHING RED over RED over DARK</td>
</tr>
<tr>
<td>RED over FLASHING GREEN over RED</td>
<td>RED over FLASHING GREEN over DARK</td>
</tr>
<tr>
<td>RED over GREEN over RED</td>
<td>RED over GREEN over DARK</td>
</tr>
<tr>
<td>RED over FLASHING YELLOW over RED</td>
<td>RED over FLASHING YELLOW over DARK</td>
</tr>
<tr>
<td>RED over YELLOW over GREEN</td>
<td>RED over YELLOW over RED</td>
</tr>
<tr>
<td>RED over YELLOW over YELLOW</td>
<td>RED over YELLOW over RED</td>
</tr>
<tr>
<td>RED over RED over GREEN</td>
<td>RED over RED over FLASHING RED</td>
</tr>
<tr>
<td>RED over RED over FLASHING YELLOW</td>
<td>RED over RED over FLASHING RED</td>
</tr>
<tr>
<td>RED over RED over YELLOW</td>
<td>RED over RED over FLASHING RED</td>
</tr>
<tr>
<td>RED over FLASHING RED over RED</td>
<td>RED over FLASHING RED over DARK</td>
</tr>
<tr>
<td>RED over RED over RED</td>
<td>RED over DARK over RED</td>
</tr>
</tbody>
</table>

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 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) will be put to stop or Restricting, and approaches 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 utilizing “approach lighting” Caltrain Operations will make the final determination if the feature will be applied. The designer shall evaluate each location to determine if special circuits should be applied to ensure 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 utilizing the first two consecutive track
circuits. Sectional releasing shall be used wherever possible. New Installations will use Approach Locking. Separate Timers will be used on each signal in a pair where Microprocessor systems are used. Program nomenclature is to follow Caltrain naming conventions. Program Logic is to follow the Typical Caltrain Program Logic. Any relay installations are to follow the same principles of application logic as microprocessor based systems.

Companies providing Application Logic Programs must have a documented process of checking, computer simulating and rack testing all programs. All programs, upon being placed in service are to be stored on a secure web site as directed by Caltrain’s Manager Engineering Signals and Communications.

Application logic shall follow the following sequence of activities for clearing a signal.

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, good 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 are transmitted in both directions on each track, as in a four wire HD model. There will be a tumble down timer in the non-standard direction of travel, that is south on Main Track 1 (MT-1), North on MT-2.

Where Sectional Releasing is used, the switch will 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 in FIGURE 5-1, the locking will be released as soon as 1T completes Loss of Shunt Time. At this moment, the crossover can be returned to the normal position, and a new route can be created as shown in FIGURE 5-2. Signals can be cleared on track two in either direction while the first train occupies the 1AT.

![Diagram](image)

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 in FIGURE 5-1, however a new route would not be allowed since the train in the 2AT could roll back and foul the 2T.

G. SWITCH MACHINE

110 Vdc Switch machines are to be used. Backup Battery shall be provided by a separate 110 Vdc supply as manufactured by C-Can or National Railway Supply Model ERB-C Overload Timers in the Vital Program will be used. The M23A is the preferred switch machine since the points are locked in hand operation. South of CP Bowers only M23A machines should be installed. North of CP Bowers, in existing plants 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 will 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 CTC

The following is the requisites for the CTC.

a. "Approach or Time Locking" shall be applied to all approaches. Approach Locking is preferred but Time Locking may be used where directed.

b. "Indication Locking" is required in connection with all electrically locked switches, movable-point frogs, or power derails at control points and interlockings.

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 is to be five (5) Seconds in terminal areas and lower speed areas. It will be considered at Control Points in higher speed territories, however 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 there is no degradation to train tracking in the Control Office. The 10 second Detector Loss of Shunt time should be used where train tracking is a concern, or 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 is to 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 provides that the time locking will not be effective if the track is unoccupied from a point at least 1500 feet in approach to the approach signal to the controlled signal, or, in four-aspect signal territory, from a point at least 1500 feet in approach of the first normally restrictive signal approaching the control signal. In most cases, 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 satisfies the requirement for Approach Locking.

EXAMPLES:
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. It 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 either the electric locking of the interlocked switches, or the control circuits for the interlocked signals, must 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 colorlight 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. It maintains the switch locking in front of the train after the signal has been passed, and the train is still in the route. It must be accomplished by 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 to 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 will be used in new design to facilitate train operations.

When parallel routes are proposed, there must be sufficient distance between the points of switch on the common track so that neither train will foul the route of the other. In general, this is 100 ft 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](image)

**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 Vac single phase 100-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 by utilizing National Electrical Code 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. Battery chargers shall be of the programmable type equipped with temperature monitoring sensors. All storage cells shall be Ni Cad (Nickel-Cadmium). Batteries shall be of sufficient capacity to provide...
48 hours of standby time under “normal operating conditions”. “Normal operating conditions” is 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 the CHAPTER 7 – GRADE CROSSINGS.

M. SIGNAL BLOCKS

Electrocode codes will be transmitted simultaneously in both directions throughout signal blocks. “Turn of Traffic” signaling shall not be used. Tumbledown will take place after a signal has been requested into a block with vital codes being received. A timer should be installed allowing four (4) seconds per block for the signal being cleared into the Non-Standard direction of traffic.

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. At an intermediate signal, once the approach track is occupied, a Code 2 will be transmitted into the axle of the approaching train. This will prevent the potential “flash of green” behind the lead train.

Code 6 is used to accelerate the tumbledown. Code 6 will be used when a signal is cleared into a block. When a train is flagging past a signal, or a switch point pumps, vital codes will be removed, but Code 6 will not be transmitted. This is to prevent unintentional accelerated tumbledown. Code 6 will 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, then if vital codes are received in both directions, the Lock will release, and 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 average grade 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 “distance grades” and divide by the total block distance. This is the Average Grade (AG) of the block.
For Freight train braking, 6,000 feet in approach of the block must be used in averaging, unless the 6000 foot approach grade is positive, in which case it shall not be factored.

For passenger train braking calculations, 1000 feet in approach of the block must be used in averaging, unless the 1000 foot approach grade is positive, in which case it shall not be factored. Braking distance may be calculated either by using the average grade and using the charts, or converting the distance of the block to the equivalent distance of level track. Equivalent Distance may be calculated for ascending grades by the following:

\[
\frac{(Actual\ Distance) \times (6 + G)}{6}
\]

For descending grades it is:

\[
\frac{(Actual\ Distance) \times (4 - G)}{4}
\]

G is the average grade of the block being equated, plus the approach specified above. The Amtrak's Braking Curve CE-205 with a 25% safety factor, and eight (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 may be used. Any such program must be accepted for use on at least two (2) Class 1 Railroads or Passenger Railroads subject to FRA regulation.

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

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 five (5) years 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 upon 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, centralized traffic control, and interlocking must be demonstrated to the satisfaction of the Caltrain Deputy Director of Engineering. An understanding of train operations and the interaction with the signal system is required, as well as the ability to analyze braking distances, and calculate locking release times. In addition to this, knowledge of Highway Grade Crossing Warning systems must be demonstrated.

At the discretion of the Caltrain Deputy Director of Engineering, 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 five (5) years experience designing for a Class 1 or Commuter Railroad which operates under Sections 234, 235, and 236 of the FRA regulations, and an additional five (5) years of experience checking signal designs and vital signal programs.

Signal checkers may be called upon 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, centralized traffic control, and interlocking must be demonstrated to the satisfaction of the Caltrain Deputy Director of Engineering. An understanding of train operations and the interaction with the signal system is required, as well as the ability 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. The interview may require a demonstration of circuitry design and program analysis.

P. FINAL CHECK INSTRUCTIONS

In an effort 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 the Code of Federal Regulations 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 (2) 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, calculations, etc. 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 (1) 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 (2) 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. The original date shall be displayed “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 concurrence of the Caltrain Deputy Director of Engineering. 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 of the system.

**Q. FILE MANAGEMENT**

Part 236 Section 1 and Part 234 Section 201 of CFR 49 require that up to date and accurate signal drawings are 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 increases 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.
In order to maintain control of Caltrain Signal Drawings and Programs and be compliant with Federal Regulations, the following checkout procedure shall be followed by all Signal Design Firms.

A general description of the project(s) shall be submitted to the Caltrain Deputy Director of Engineering along with specific milepost limits. The designer should 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.

Upon completion of the design or program, the designer shall return the CADD files, application program files and an 11 x 17 hard copy of each drawing and 8 1/2 x 11 copy of the program to the Caltrain Deputy Director of Engineering. The designer shall include an itemized list of the files returned. The list shall categorize files by NEW FILES, MODIFIED FILES, and DELETED FILES.

If the designer is required to furnish AS-BUILT files, the designer shall provide the Caltrain Deputy Director of Engineering with CADD files of drawings that are distributed for construction and then provide corrected CADD files upon completion of the project. Program files will 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.

Empirical evidence suggests that no more than 12 control points should be on a radio codeline. Composite delivery may be used and stop bits are used in the message structure. The office sends only the bit which has changed.

The designer should make an analysis of the impact of increased radio traffic and office system capacity as a part of the 35% design submittal. This will allow Caltrain to make any necessary arrangements for capacity improvements.

S. SIGNAL AND TRAIN CONTROL SYSTEM MIGRATION

The migration path has been defined as moving the Caltrain signal and train control system from bi-directional CTC to a system of PTC. The base safety system of wayside signals is in place. The Caltrain signal system uses Electrode 4 Plus Code Rates. While this is a system manufactured by GETS, 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 GETS VHLC’s. This equipment is able to communicate from controller to controller and from controller to radio.
1.0 MIGRATION FORM CTC TO PTC

The type of PTC system being implemented is an overlay system. This system builds on the underlying safety critical signal system to first enforce compliance with signal aspects, then to provide a greater level of on track safety for roadway workers and high rail equipment. The PTC system will rely on radio communication of wayside signal information to the locomotive, and a separate path of train to office communications for civil enforcements, mandatory directives, and track occupancy permission. The new dispatch system must be able to communicate with the PTC office system at the CEMOF Dispatch Center.

It is important to understand that communications must be established with other operators on the Caltrain corridor, namely Amtrak trains, UPRR trains, ACE trains, and Capitol Corridor trains. The system must be interoperable to be truly effective, however it is possible to initially install equipment on Caltrain trains and in Caltrain wayside locations. Wayside interfaces on Caltrain shall use “vital” signal equipment.

Since PTC is still under development and interoperability is a critical component, the following strategy of implementation should be regarded as a guideline to incremental implementation of PTC.

a. Provide enforcement of wayside signals.

b. Provide train to office communications for enforcement of track restrictions, mandatory directives and track occupancy by roadway workers and on track equipment including hi-rails.

c. Apply enhancements to train handling, schedule adherence, real time train performance information and other desired features.

d. Provide enhancements to grade crossing activation such as advanced activation for higher speed trains and crossing inhibits for near side station stops.

T. SIGNAL DESIGN STAGES

The design cycle is an iterative process which 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 intending to capture the rationale for the project. It may consist of the following:

a. A conceptual overview. This is a single line drawing identifying track configuration, signals and switches.

b. A conceptual overview of any 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 5% 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 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). It 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. Preliminary Engineer’s Estimate. This estimate is developed to the same level of detail 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 are transmitted to checking firm for review.
b. The final materials list.
c. The final Engineers 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 is complete, and the construction package is ready for distribution. The package consists of the following.

a. Final design for distribution. It incorporates any changes to the 95% document which may come out of the final check.

b. The IFB package includes Plans, Specifications and 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 which 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 and the Very High Frequency (VHF) Voice Radio Communication system.

The ATCS Data Radio and the VHF Voice Radio are both independent stand-alone communication systems which are each supported by a Caltrain-owned microwave radio network and by various leased telephone subsystems, including T1, 4-Wire (Analog), 4-Wire E&M (Analog), 4-Wire (Digital), 2-Wire (Analog), Frame Relay and DSL for back-haul. The Design Criteria defines the requirements for these communication systems and sub-systems to safely and efficiently fully support the Caltrain operations, as well as the requirements to expand these systems in order to support future Caltrain communication needs. The ATCS data radio network shall interface to, and the Voice Radio system shall support, the following future system safety and passenger enhancements: Positive Train Control (PTC) and California High Speed Rail (CHSR).

In addition to these three (3) communications systems/sub-systems, there are several other communications sub-systems that are utilized by Caltrain as follows:

a. Public Address System (PAS)
b. Closed Circuit Television (CCTV)
c. Visual Message Sign (VMS)
d. Fare Collection System (Ticket Vending Machine or TVM and fastrak payment system or the “Clipper” card)

The Design Criteria for these sub-systems 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 five years.
B. ATCS DATA RADIO SYSTEM

All train movements on Caltrain tracks are managed and controlled by a Non-Vital Supervisory Control System. This supervisory control system is implemented via a data radio network, which connects the train signaling Control Points (CPs) to the computer workstations, servers and packet switches located at the Central Control Facility (CCF). The CCF is located at the Caltrain CEMOF (Centralized Equipment, Maintenance, and Operations Facility) at 585 Lenzen Avenue, in San Jose. A detailed description of each component of the data radio network and the CCF head-end interface is provided below. The data radio network is implemented via the use of ATCS channels 2 and 5. Each ATCS channel consists of a pair of Multiple-Addressing-Scheme frequencies in the 900MHz band (set aside by the Federal Communications Commission, or FCC for this application) which implements the Advanced Train Control System (ATCS) Protocol.

The ATCS protocol is central to the 900MHz band RF (Radio Frequency) communication links between the network of Control Points and Base Stations, as well as to the base-band (DS0) data links between these Base Stations and the Packet Switches located at the CCF.

1.0 CODE SERVER

At the CCF, 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) as well as deciding which Base Station site will be the most-likely-server for the Control Point being commanded (router function).

Until late 2011, Caltrain used a Code Server developed by Digital Concepts, Incorporated (DigiCon). The DigiCon’s Code Server does not implement the ATCS protocol. Instead, a variety of other protocols are supported and the following protocols are implemented in the Caltrain system:

a. The Supervisory Control Systems (SCS)-128 protocol, developed by Safetran Systems (now part of Invensys). This protocol is used for all direct telephone line links between Control Points and the CCF, as well as for the links between the Base Station sites and the CCF.

b. The Genisys Protocol, developed by Union Switch and Signal (now part of Ansaldo). This protocol is used only for the direct telephone link between the major Control Point at Fourth Street and the CCF, and the leased line to CP Army. As Caltrain expands its data radio network, the use of the Genisys protocol, for the Fourth Street site will be replaced with ATCS. The Genisys application at CP Army will be converted to ATCS. Further, in order to improve data radio throughput, the use of an ATCS protocol directly on the DigiCon’s Code Server shall be investigated. The DigiCon’s Code Server is a rack-mounted computer, using a proprietary operating system developed by DigiCon has the capability to support interfaces to multiple dispatch stations.
c. The DigiCon Console and code servers are currently being replaced with a new IP based dispatch console/head-end provided by AIRINC, called the AIM dispatch head-end console. This new dispatch system which replaces the existing Digicon Console and servers begins service towards the end of 2011.

2.0 PACKET SWITCHES

The CCF Packet Switches currently used in support of the ATCS data radio network are manufactured by Safetran Systems. They incorporate built-in hardware redundancy via the use of a dual packet-switch design in one box, one of which is redundant, and connected to the Code Server/FEP.

The packet switches are capable of performing a dual role, where required. They can perform protocol conversions, as needed as well as RSSI (Received Signal Strength Indicator) selection. Since the AIRINC’s AIM /FEP utilize an ATCS over IP protocol, this protocol conversion feature of the packet switch is not required for the interface to the AIM/FEP. However the Packet switches shall be set up to operate in dual mode. SCS-128 serial shall be connected to the DigiCon Code Servers. Additionally, ATCS over IP shall be the configuration used by the AIM system currently being implemented. Currently, the DigiCon system operates as primary with the AIM system under test. After the successful implementation of the full AIM configuration, AIM shall become primary with DigiCon remaining as backup.

The CCF Packet switches shall monitor the inbound signal quality RSSI from each of the three Base Station sites, corresponding to every transmission from a Control Point, in order to determine which Base Station site received the strongest signal from the Control Point. 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, 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 Supervisory Control System is the network of ATCS Data Radio Base Stations and Control Points. The Caltrain railroad consists of approximately 78 miles of railroad tracks serving freight and passenger operations between San Francisco and Gilroy. Currently, 31 Control Points are in operation, between CP Fourth Street in the north and CP Michael in the south, of which 27 are on the ATCS data radio network.

A total of three (3) Base Station sites are used to support all message transmissions between the CCF and these Control Points. The three Base Station sites used are located at San Bruno Mountain (SB) in Daly City, Monument Peak (MP) 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 Control Points along the Caltrain Corridor. The CEMOF and Monument Peak sites provide full radio coverage and/or coverage redundancy for the southern control points, with CP Michael at its south limit to CP Mary as its north limit.

Note, in order for a Control Point 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. CP Lick, which is the southernmost CP along the railroad is not “controlled” by Caltrain (it is ‘controlled’ by UP), but simply “monitored”, hence this coverage criterion does not apply to it.

The ATCS network was designed to grow organically, however in order to preserve system throughput and efficiency, the following parameters must be analyzed prior to adding new Control Points or Base Stations:

a. The maximum number of Control Points that can be safely served by one Base Station, given the required speeds and head-ways required for the efficient operation of the Caltrain. For current Caltrain maximum authorized speeds (MAS) of 79 mph and minimum head-ways of five (5) minutes, empirical data suggests that no more than about 15 Control Points shall be supported by a single Base Station. In order to increase maximum speeds or reduce head-ways 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 Control Points on the ATCS data network.

b. Where one or more Base Station sites have the geographical advantage, due to the terrain layout of being capable of supporting much more than the maximum number of Control Points, for the designed speeds and head-way, the usage 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 and all Control Points along the corridor. From the CCF, the Data Radio messages shall be transmitted to each of the Base Station sites via the use of 2-Wire POTS (Plain Old Telephone Service) telephone circuits or via the use of Microwave Radio links (with a reliability of 99.999% or better). From the Base Station sites, the messages shall be transmitted to the Control Points along the Corridor via a pair of Multiple-Addressing-Scheme frequencies licensed from the FCC, with a communications reliability of 99.0% or better, sufficient to assure communications at 10 $E^{-7}$ BER (Bit Error Rate) without FEC (Forward Error Correction) coding. A fade margin of 17dB shall be factored into the design to account for Rayleigh fading that will affect radio paths.

The CCF shall receive from 100% of the Control Points likewise with 99.0% or better, communication reliability, providing 10 $E^{-7}$ BER without FEC
Coding. The Data Radios shall utilize specification compliant ATCS communication protocol for communication between the Control Points and the Base Station sites.

d. The ATCS communications between the CCF (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, in order to retrieve messages sent from the various Control Points.

The ATCS communication between the Base Station sites and the Control Points shall be based on a contention scheme. Two pairs of 900 MHz band ATCS frequencies configured for a Multiple-Address-Scheme are used to implement the network. The following frequencies are currently used:

<table>
<thead>
<tr>
<th>ATCS CHANNEL</th>
<th>FREQUENCY</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>935.9375 MHz</td>
<td>Base Station Tx. Frequency</td>
</tr>
<tr>
<td>2</td>
<td>896.9375 MHz</td>
<td>Base Station Rx. Frequency</td>
</tr>
<tr>
<td>5</td>
<td>936.9375 MHz</td>
<td>Base Station Tx. Frequency</td>
</tr>
<tr>
<td>5</td>
<td>897.9375 MHz</td>
<td>Base Station Rx. Frequency</td>
</tr>
</tbody>
</table>

Under this scheme, each Control Point, which has a message to send to the CCF, will “contend” for the radio channel with all other Control Points. This will result in some RF-Network collisions, the amount of which must be kept to a minimum in order to preserve the designed maximum speeds and minimum head-ways.

e. Data Radio Base Station repeaters shall employ GMSK (Gaussian Minimum Shift Keying) direct Frequency Modulation (FM) configured for 12.5 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 radio links with each of the Control Points with the required communication reliability and signal quality. The Antennas used at Control Points 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 Control Points 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 Control Points 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. Additionally the reliability of the RF links is another factor that aggravates data throughput. As communication reliability falls below 99.0%, the number of communication re-tries increased, resulting in a longer time being required to send or receive a message.

The third factor affecting data throughput is the protocol conversion overhead. This is required in the case of the Digicon code server, but not in the case of the AIRINC’s AIM/FEP. The maximum railroad speeds and the minimum railroad head-ways 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. All control points shall be connected to the leased 4-W telephone circuit that is present at each CP site. Except for CP Sierra and the two CPs at Terminal, this connection acts as a secondary, “cold-standby” backup to the data radio network, such that, in the event of a major radio outage, the control points can be reconfigured to be controlled via the 4-W 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 are currently used to support all operations along the Caltrain 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 located at the CEMOF control center. This dispatch console is a Safetran Digital Touch Exchange (DTX). The road channel is provisioned along the entire ROW, via the use of above-ground as well as tunnel radio base stations. The yard channel is provisioned only within the confines of the two railroad yards located at Fourth Street near downtown San Francisco and CEMOF in San Jose. The MOW channel is provisioned along the entire ROW, via the use of above-ground as well as tunnel radio base stations in addition to which it is provisioned alongside streets and highways on most of the peninsula and the East Bay. The head-end for railroad
dispatch, operations and maintenance is served by a radio dispatch system which is configured as follows:

A total of two (2) 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 MP 0.0 and 44.0, and the second station supports the “Southern” portion of the railroad between approximate MP 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 the Union Pacific Railroad. Although Caltrain is capable of monitoring train movements on the UP tracks, Caltrain cannot perform any train dispatch on the UP tracks. Although each dispatch station is “stand-alone” independent of the other, they are also fully redundant to each other, since 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 North and South limits.

1.0 BASE STATION SITES

A total of eight (8) VHF voice radio base station sites currently exist to support the road channel. Of these, four (4) are “above-grade” radio base station sites, which are located along the ROW, and are each configured for carrier-squelch, simplex operation on the road channel frequency of 160.8150 MHz. The remaining four base station sites are located inside four (4) railroad tunnels located 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.

A total of six (6) VHF voice radio base station sites currently exist to support the MOW channel. Of these, four (4) are co-located with the road channel at the four tunnel sites, and two are co-located at the mountain top 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 four (4) above-ground 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, they shall use multiple low-level sites each capable of providing radio coverage within a radius of 10 to 15 miles, so as 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 above-ground MOW base station sites are located at San Bruno Mountain and Monument Peak, and each is capable of providing radio coverage along the
entire ROW and to most of the peninsula and surrounding areas. This is used to ensure 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 via the use of a Push-to-Talk (PTT) 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 6-1 below, along with their GPS (Global Positioning System) coordinates.

### TABLE 6-1 NORTHERN DISPATCH BASE STATION SITES

<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>GPS COORDINATES</th>
<th>SITE ELEVATION (feet)</th>
<th>ANTENNA AZIMUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fourth Street Tower</td>
<td>N 37° 46' 28.8&quot; W 122° 23' 50.2&quot;</td>
<td>65 (55+10)</td>
<td>OMNI DIRECTIONAL Gain 0 dBi</td>
</tr>
<tr>
<td>Sign Hill</td>
<td>N 37° 39' 53.8&quot; W 122° 25' 14.1&quot;</td>
<td>576 (561+15)</td>
<td>156° Gain 8 dBi</td>
</tr>
<tr>
<td>San Carlos</td>
<td>N37° 30' 23.4&quot; W122° 15' 43.1&quot;</td>
<td>106 (99+7)</td>
<td>140° Gain 8 dBi</td>
</tr>
</tbody>
</table>

The “Southern” dispatch Base Station site is listed in TABLE 6-2 below, along with its GPS coordinates.

### TABLE 6-2 SOUTHERN DISPATCH BASE STATION SITES

<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>GPS COORDINATES</th>
<th>SITE ELEVATION (feet)</th>
<th>ANTENNA AZIMUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMOF, San Jose</td>
<td>N 37° 20' 20.28&quot; W 121° 54' 29.22&quot;</td>
<td>138 (78+60)</td>
<td>314°/134° Dual Yagi Gain 10 dBi</td>
</tr>
</tbody>
</table>

1.2 The Tunnel Radio Base Station Sites

Located between the Fourth Street tower and Sign Hill Base Station sites are four (4) railroad tunnels. Each tunnel is between 1000 and 3800 feet in length and is equipped with a small, stand-alone VHF radio base station configured for simplex, carrier squelch operations located at the south entrance to the respective tunnel. Each of the four (4) tunnel radio Base Stations is identical to the four (4) above-grade radio base stations except that each tunnel radio Base Station is connected to a distributed antenna system, which is installed inside each tunnel to support radio communications inside the confines of the respective tunnel.
The recovered audio signal from each of the four road channel tunnel radio sub-systems 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 EIA (Electronic Industry Alliance) signaling tones required to control the GE Mastr III Base Stations.

The tunnel-repeater systems are located in very hilly regions, the quality of radio coverage provided by the “above-grade” Base Stations are marginal in some spots near the tunnels, and further, 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 utilized on only one side of each tunnel (the south end), with the region outside the north end of each tunnel supported by the antenna extension of the next tunnel to its north. A high gain directional antenna is used external to each tunnel in order 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 above-ground channels as a single system through a Motorola voter and TSAM (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. In order to provision radio coverage inside tunnels, trenches and other subterranean areas, the designer shall use a distributed antenna system comprising of 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 in order to determine what combination of frequencies are 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 in order to mitigate the creation of these harmful IM products.

d. The design shall guarantee radio coverage of 99% of the subterranean areas, with a reliability of 99% based on a signal quality of 20 dB SINAD (Signal In Noise and Distortion). The designer shall be allowed to test the system based on the use of a CM (Circuit Merit), DAQ (Delivered Audio Quality) or
signal level test, providing 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 (DED)

In addition to the four (4) “above-ground” Base Station sites, there are three (3) Dragging Equipment Detectors (DEDs) located 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 (3) DEDs are shown in **TABLE 6-3** below.

**TABLE 6-3 DRAGGING EQUIPMENT DETECTION SITES**

<table>
<thead>
<tr>
<th>DED NAME</th>
<th>GPS COORDINATES</th>
<th>SITE ELEVATION (feet)</th>
<th>ANTENNA AZIMUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.8</td>
<td>N 37º 37' 42.2&quot; W 122º 24' 37.0&quot;</td>
<td>15</td>
<td>Rail Tx. OMNI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gain 0 dBi</td>
</tr>
<tr>
<td>28.2</td>
<td>N 37º 27' 36.4&quot; W 122º 11' 25.9&quot;</td>
<td>36</td>
<td>Rail Tx. OMNI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gain 0 dBi</td>
</tr>
<tr>
<td>42.2</td>
<td>N 37º 22' 11.5&quot; W 121º 58' 27.6&quot;</td>
<td>44</td>
<td>Rail Tx. OMNI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gain 0 dBi</td>
</tr>
</tbody>
</table>

The DEDs are transmit-only devices, located along the ROW. They utilize a GE/Harmon Electronics (West Coast Operations) WCO-46 “talker-system” which contains a discrete Motorola HT-440 VHF voice radio connected to a small roof mounted Sinclair ‘low-profile’, omni-directional “railroad” antenna. The Motorola HT-440 has been discontinued by the Manufacturer and replaced with the HT-750 model.

The transmit power of each DED shall be reduced to provide an ERP (Effective Radiated Power, dependent on the terrain in the immediate vicinity of the DED) that will restrict radio coverage to provide a receive intensity of ≥ -109 dBm 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 by 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 within the ROW (Right-of-way) northbound through Gilroy will be equipped with a VHF-voice mobile radio. Each radio is programmable to all 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 DED’s 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 (4) above-grade Base Station sites in order to communicate with the dispatcher. In addition, these users 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 (4) Tunnel Radio Base Stations occurs, except due to logistical reasons, no more than about six (6) locomotives and a slightly greater number of mobiles and portables radios will be within range of these four (4) tunnel Base Station sites.

2.0 VOICE RADIO OPERATIONAL REQUIREMENTS

The following are non-negotiable 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 utilized 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 must report 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, in the event that there is a problem, in which case the train can be brought to a stop immediately. This configuration is currently being changed to an exceptions-based reporting configuration. DEDs configured in this way will report only when it detects a problem, but must continually report its 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, per FRA (Federal Railroad Administration) regulations, however, because all Voice Radio communication (even those localized communications utilizing the radio-to-radio mode) will be recovered by at least one Base Station site, then, in effect, all Voice Radio communication will 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 TABLE 6-4 WHO NEEDS TO HEAR FROM WHOM matrix must also be preserved with the retrofits.
All voice radio communication along the ROW takes one of the following three (3) modes: a) Point-to-Point Global, b) Point-to-Point Local and c) Point-to-Space Global. Every user on the road channel, intending to speak to the dispatcher utilizes mode ‘a’. When the dispatcher responds, mode ‘c’ is used to repeat his/her instruction to the “space” surrounding one or more Base Station sites. Finally, for localized communications, such as between a locomotive and an EIC (Employee in Charge), mode ‘b’ is utilized.

**f.** TABLE 6-4 presents a matrix showing all ten (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 6-4 WHO NEEDS TO HEAR FROM WHOM**

<table>
<thead>
<tr>
<th>Receive</th>
<th>Control Center Recording Equipment</th>
<th>Dispatcher</th>
<th>Train Engr</th>
<th>Train Cndr</th>
<th>EIC</th>
<th>Maintainer (Mobiles)</th>
<th>Maintainer (Portables)</th>
<th>Yard</th>
<th>Terminal Manager</th>
<th>CEMOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit</td>
<td>√</td>
<td>N/A</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Dispatcher</td>
<td>√</td>
<td>G</td>
<td>N/A</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
</tr>
<tr>
<td>Train Engineer</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>N/A</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
</tr>
<tr>
<td>Train Conductor</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>N/A</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
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<tr>
<td>EIC</td>
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<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>√</td>
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<td>N/A</td>
<td>√</td>
<td>L</td>
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<tr>
<td>Maintainer (Mobiles)</td>
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<td>G</td>
<td>G</td>
<td>√</td>
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<td>√</td>
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<td>N/A</td>
<td>√</td>
<td>L</td>
</tr>
<tr>
<td>Maintainer (Portables)</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>N/A</td>
</tr>
<tr>
<td>Yard</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>N/A</td>
</tr>
<tr>
<td>Terminal Manager</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
<td>√</td>
</tr>
<tr>
<td>CEMOF</td>
<td>√</td>
<td>G</td>
<td>G</td>
<td>√</td>
<td>L</td>
<td>√</td>
<td>L</td>
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<td>N/A</td>
</tr>
<tr>
<td>DED</td>
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<td>G</td>
<td>No</td>
<td>√</td>
<td>PL</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:

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 local vicinity of each other. The exact range of this local communication is a function of the terrain, the HAAT 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 local vicinity of
g. The following TABLE 6-5 defines the extent and quality of the cumulative VHF voice radio coverage that shall be provided by the four (4) above-ground and four (4) tunnel radio Base Station sites. The radio coverage required from the dragging equipment detectors shall be of the same quality, but limited to +/- 3 miles along ROW.

**TABLE 6-5 RADIO COVERAGE FOOTPRINT AND QUALITY**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>GEOGRAPHIC COVERAGE (%)</th>
<th>MINIMUM EIA SINAD/CM /DAQ LEVEL</th>
<th>% OF TIME Rx / Tx LEVELS ≥ MINIMUM LEVELS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Along the ROW</td>
<td>99</td>
<td>20/4/3.4</td>
<td>95/95</td>
<td>To Trains &amp; Trackside</td>
</tr>
<tr>
<td>Within 500 feet of Trackside</td>
<td>95</td>
<td>20/4/3.4</td>
<td>95/95</td>
<td>To Portable &amp; Mobile Radios</td>
</tr>
<tr>
<td>Inside the tunnels</td>
<td>99</td>
<td>20/4/3.4</td>
<td>95/95</td>
<td>To Trains &amp; Trackside</td>
</tr>
<tr>
<td>Around DEDs</td>
<td>99 centered +/- 3 miles along ROW</td>
<td>20/4/3.4</td>
<td>95/95</td>
<td>+/- 3 Miles along ROW</td>
</tr>
</tbody>
</table>

**D COMMUNICATIONS BACK-HAUL**

A mixture of Caltrain-owned microwave radio and POTS 2-wire telephone circuits are currently used to support all communications back-haul for the train control communication systems. Future safety and passenger enhancements such as Positive Train Control (PTC) and California High Speed Rail (CHSR) will require significant expansions of the Caltrain-owned microwave radio network and/or the deployment of new Fiber Optic based networks along the railroad ROW. Limited use of Multi Protocol Label Switching, another leased service, but significantly more costly, shall be considered where it provides the greatest cost/benefit.

At this time, the predominant back-haul resource used for the communication systems/networks is the leased 4-wire telephone service. The following TABLE 6-6 COMMUNICATION SYSTEMS AND LEASED TELEPHONE INFRASTRUCTURE, presents a summary of all leased telephone services currently in use on the railroad.

**TABLE 6-6** lists the current leased telephone infrastructure used by Caltrain to support the ATCS Data Radio and the VHF Voice Radio systems.
### TABLE 6-6  COMMUNICATION SYSTEMS AND LEASED TELEPHONE INFRASTRUCTURE

<table>
<thead>
<tr>
<th>CRITICAL SYSTEMS</th>
<th>CIRCUITS</th>
<th>TYPES</th>
<th>OFFICE PAIRS</th>
<th>FIELD PAIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VISUAL MESSAGING SYSTEM LINES</strong></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>T1 FRAME RELAY</td>
<td>1</td>
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</tr>
<tr>
<td>1</td>
<td>4W ADM 8LEGS</td>
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<tr>
<td><strong>DIGISIGN LINE</strong></td>
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<tr>
<td>1</td>
<td>DSL</td>
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<tr>
<td><strong>PUBLIC ADDRESS LINES</strong></td>
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</tr>
<tr>
<td>1</td>
<td>T1 MP IN THE CO</td>
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<td>T1 MP IN THE CO</td>
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<td><strong>ATCS BASE STATIONS LINES</strong></td>
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<td>4W PTP</td>
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<td>1</td>
<td>2W AUDIO</td>
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<td>4W PTP</td>
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<td>DSL</td>
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<td>4W PTP</td>
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<td>4W PTP</td>
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<td>1</td>
<td>4W Twisted Pair</td>
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<td>UPRR RADIO</td>
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<td>1</td>
<td>4W Twisted Pair</td>
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<tr>
<td><strong>TOTALS CIRCUITS</strong></td>
<td>26</td>
<td>43</td>
<td>51</td>
<td></td>
</tr>
</tbody>
</table>
The following four (4) circuit types are used:

a. **4-WIRE POINT to POINT (PTP)**

A 4-Wire PTP line is a leased 9600 bps baud rate telephone circuit that is provisioned between two fixed locations. It provides a single telephone circuit with 4 wires, which enable it to support full-duplex telephone communication. This type of leased circuit was required between each of the 27 ATCS Control Point sites, the two mountain top sites and the CCF.

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 4 wires, which enables it to support full-duplex data communication. The quality of the line is enhanced in order to support the more demanding channel requirements for digital communications. This type of leased circuit was used between CP Army and the CCF to support data messages between the two sites.

c. **4-WIRE E&M**

A 4-Wire E & M line is a 9600 bps baud rate leased telephone circuit that is provisioned between two fixed locations. It provides a single telephone circuit with 4 wires, which enable it to support full-duplex voice or telephone communication. In addition to the four analog audio lines, additional telephone lines (typically between 4 and 8) are provisioned to support ‘E’ and ‘M’ signaling between the two sites. This type of leased circuit is required between each station stop public address (PA) system head-end and the CCF. For ‘E’ and ‘M’ signaling, the ‘E’ lead is used to ground a DC battery voltage from the telephone company to energize a relay at the PA system head end at each station. The ‘M’ lead opens the voice input path into the PA mixer.

Note that the 2-Wire audio circuits are dial backup circuits provisioned by the service provider to act as backup communication lines between the two mountain top Base Station sites and the CCF. These are not leased circuits, and are used only in the event of a failure of the (primary) back haul or leased circuits.

E. **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 5 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 (Automatic Alternate Routing). All installations shall be in accordance with the following codes:

- National Electrical Code (NEC)
- AREMA C & S Manual
- CAL/OSHA standards
- CPUC Regulations
- State of California Electrical Safety Orders, Title 8, CAC
- FCC rules and regulations
- The Motorola R56 grounding standard

2.0 **TELCO INTERFACES**

The telephone company shall perform all electrical work up to the MPOE (Main Point of Entry). 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:

- National Electrical Code (NEC)
- AREMA C & S Manual
- CAL/OSHA standards
- CPUC Regulations
- State of California Electrical Safety Orders, Title 8, CAC
- Applicable TIA/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:

- National Electrical Code (NEC)
- CAL/OSHA standards
- CPUC Regulations
d. State of California Electrical Safety Orders, Title 8, CAC

e. FCC rules and regulations

f. The Motorola R56 grounding standard

F. 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 an RFI (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 catalog cut-sheets and other manufacturer literature describing the product being considered for installation to the Engineer for approval.

c. At least thirty (30) days prior to the start of the installation of any item, the Installer shall submit a set of installation drawings, “code plugs” and software configuration management to the Engineer for approval. 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 O&M manuals shall likewise be submitted at least 60 days prior to maintenance training and a list of recommended spare parts, test equipment and special tools, at least 60 days prior to the start of training.
### G. PRODUCTS

#### 1.0 ATCS DATA RADIO COMMUNICATION

The antenna tower shall be either eighty (80), sixty (60) or forty (40) foot, Tilt-Down Towers from Western Towers or Engineer Caltrain approved equal. The designer shall determine quantity and height of the tower. 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 from Harmon Industries (GE Transportation Systems).

The coaxial cable, CP Antennas, Ethernet Spread Spectrum radios, the 12Vdc batteries and chargers and other Data Radio products, where required, shall be procured from the sources listed in **TABLE 6-7** below.

### TABLE 6-7 DATA RADIO SYSTEM PRODUCTS AND EQUIPMENT LIST

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>EQUIPMENT DESCRIPTION</th>
<th>EQUIPMENT PART NO.</th>
<th>MANUFACTURER OR VENDOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spread Spectrum (Ethernet) radio</td>
<td>A53325</td>
<td>Safetran (Invensys)</td>
</tr>
<tr>
<td>2</td>
<td>WCP ATCS Radio MCP II</td>
<td>9011-53411-0205</td>
<td>Safetran or equal</td>
</tr>
<tr>
<td>3</td>
<td>Router</td>
<td>2811</td>
<td>Cisco Systems or equal</td>
</tr>
<tr>
<td>4</td>
<td>Ethernet Switch</td>
<td>Part of #3</td>
<td>Cisco Systems or equal</td>
</tr>
<tr>
<td>5</td>
<td>WAG</td>
<td>A53457</td>
<td>Safetran</td>
</tr>
<tr>
<td>6</td>
<td>UPS</td>
<td>APC</td>
<td>SUA1500RM2U or equal</td>
</tr>
<tr>
<td>7</td>
<td>Batteries</td>
<td>SAFT</td>
<td>ED 240</td>
</tr>
<tr>
<td>8</td>
<td>Battery Charger</td>
<td>NRS</td>
<td>ERB-C 12/201 C, ERB-C 12/401 C</td>
</tr>
<tr>
<td>9</td>
<td>DC/DC Converter</td>
<td>Part of #2</td>
<td>Safetran or equal</td>
</tr>
<tr>
<td>10</td>
<td>2.4 GHz Lightning Arrestor</td>
<td>IS-MT50LN-MA</td>
<td>Polyphaser/ Tessco</td>
</tr>
<tr>
<td>11</td>
<td>900MHz Lightning Arrestor</td>
<td>DSXL-D-ME</td>
<td>Polyphaser/ Tessco</td>
</tr>
<tr>
<td>12</td>
<td>Alarm Relays/Sensors</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>13</td>
<td>Spread Spectrum 2.4 GHz Antenna</td>
<td>As required</td>
<td>Maxrad/Tessco</td>
</tr>
<tr>
<td>14</td>
<td>ATCS 900MHz Antenna</td>
<td>As required</td>
<td>Maxrad/ Tessco</td>
</tr>
<tr>
<td>15</td>
<td>Coaxial Cables</td>
<td>LCF114-50A or equal</td>
<td>Cellwave/ Andrew</td>
</tr>
<tr>
<td>16</td>
<td>Coaxial Cables</td>
<td>LCF78-50A or equal</td>
<td>Cellwave/ Andrew</td>
</tr>
<tr>
<td>17</td>
<td>Tilt-down Antenna Mast &amp; Installation accessories</td>
<td>N/A</td>
<td>Various</td>
</tr>
<tr>
<td>18</td>
<td>Miscellaneous Accessories</td>
<td>N/A</td>
<td>Various</td>
</tr>
</tbody>
</table>
These following tables, **TABLE 6-8** through **TABLE 6-10** list specifications for the ATCS Data Radio equipment, which are based on the Safetran BCP and GE/Harmon MCP ATCS data radio transceivers.

### TABLE 6-8 BASE STATION DATA RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
</tr>
<tr>
<td>FCC Compliance</td>
<td>Parts 15, 90</td>
</tr>
<tr>
<td><strong>Transmitter</strong></td>
<td></td>
</tr>
<tr>
<td>RF Power Output</td>
<td>25-75W Adjustable</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>Continuous</td>
</tr>
<tr>
<td>Spurious Emissions</td>
<td>-90dBc</td>
</tr>
<tr>
<td>Harmonic Emissions</td>
<td>-90dBc</td>
</tr>
<tr>
<td>Audio Response</td>
<td>+1/-3 dB per TIA-603</td>
</tr>
<tr>
<td>Hum &amp; Noise</td>
<td>-45 dB per TIA-603</td>
</tr>
<tr>
<td>Frequency Spread</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Frequency Stability</td>
<td>0.1 ppm, -30°C to +60°C (-22°F to +140°F)</td>
</tr>
<tr>
<td><strong>RF Data Communication</strong></td>
<td></td>
</tr>
<tr>
<td>Frequency Range</td>
<td>Transmit @ 935-940 MHz, Receive @ 896-901 MHz</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>1 (Synthesized, programmable)</td>
</tr>
<tr>
<td>Channel Spacing</td>
<td>12.5 kHz</td>
</tr>
<tr>
<td>Channel Resolution</td>
<td>12.5 kHz</td>
</tr>
<tr>
<td>Data Modulation</td>
<td>GMSK, Direct FM</td>
</tr>
<tr>
<td>RF Bit Rate</td>
<td>4800 bits/sec</td>
</tr>
<tr>
<td>Error Correction</td>
<td>Reed-Solomon (16,12) Forward Error Correction (FEC) and 16 bit Cyclical Redundancy Check (CRC)</td>
</tr>
<tr>
<td><strong>Ground Network Port</strong></td>
<td></td>
</tr>
<tr>
<td>Port Type</td>
<td>Sync./Async., EIA-232 with Configurable port Modem Signaling</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>Up to 2.048 Mbit/sec, 9600 bit/sec typical</td>
</tr>
<tr>
<td>Data Link Protocol</td>
<td>HDLC Balanced, HDLC Polled</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
<td></td>
</tr>
<tr>
<td>Sensitivity 12 dB EIA SINAD</td>
<td>0.35 uV</td>
</tr>
<tr>
<td>20 dB Quieting</td>
<td>0.50 uV</td>
</tr>
<tr>
<td>Adjacent Channel Rejection</td>
<td>-75 dB</td>
</tr>
<tr>
<td>Intermodulation Rejection</td>
<td></td>
</tr>
<tr>
<td>(EIA SINAD)</td>
<td>-75 dB</td>
</tr>
<tr>
<td>Spurious &amp; Image Rejection</td>
<td>-90 dB</td>
</tr>
<tr>
<td>Audio Squelch Sensitivity</td>
<td>12 dB SINAD</td>
</tr>
</tbody>
</table>
### TABLE 6-8 BASE STATION DATA RADIO SPECIFICATIONS (Continue)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio Response</td>
<td>+1/-3 dB per TIA-603</td>
</tr>
<tr>
<td>Hum &amp; Noise Ratio</td>
<td>-45 dB</td>
</tr>
<tr>
<td>Frequency Spread</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Frequency Stability</td>
<td>+0.1 ppm, -30°C to + 60°C (-22°F to + 140°F)</td>
</tr>
</tbody>
</table>

**Diagnostic Service Port**
- Port Type: Async. EIA-232
- Baud Rate: 19200 bit/sec typical
- Data Link Protocol: ANSI, 8 Data bits. No Parity, 1 Stop bit

**Electrical Requirements**
- AC Input Voltage: 120-240 VAC @ 50-60 Hz
- AC Input Current:
  - 0.4A (Standby @ 117VAC) 1.8A (Tx@ 25W, @ 117VAC)
  - 3.3A (Tx @ 75W, @ 117VAC)
- AC Input Power:
  - 47W (Standby), 211W (Tx@25W), 390W (Tx@75W)
- DC Input Voltage: 26.5 VDC
- DC Input Current: 6A (Tx@25W), 11A (Tx@75W)

### TABLE 6-9 CONTROL POINT DATA RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>5”HX10”WX10”L</td>
</tr>
<tr>
<td>Weight</td>
<td>16 lbs</td>
</tr>
<tr>
<td>FCC Compliance</td>
<td>Parts 15, 90</td>
</tr>
</tbody>
</table>

**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 @ 935-941 MHz, Transmit @ 896-902 MHz, Normal, Transmit @ 935-941 MHz, T/A Mode
- Number of Channels: 6 (Synthesized, programmable)
- Channel Spacing: 12.5 kHz
- Channel Resolution: 12.5 kHz
### TABLE 6-9 CONTROL POINT DATA RADIO SPECIFICATIONS (Continue)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Modulation</strong></td>
<td>GMSK, Direct FM</td>
</tr>
<tr>
<td><strong>RF Bite Rate</strong></td>
<td>4800 bits/sec</td>
</tr>
<tr>
<td><strong>Error Correction</strong></td>
<td>Reed-Solomon (16, 12) Forward Error Correction (FEC) and 16 bit Cyclical Redundancy Check (CRC)</td>
</tr>
<tr>
<td><strong>RF Channel Access</strong></td>
<td>Data “Busy-Bit” protocol</td>
</tr>
<tr>
<td><strong>Maximum Frequency Deviation</strong></td>
<td>Adjust per the Operations Manual</td>
</tr>
<tr>
<td><strong>Client Ports</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Types of Ports</strong></td>
<td>3 software configurable interfaces, 2 Sync. / Async., EIA-422/EIA-232, 1 Sync. / Async., EIA-422</td>
</tr>
<tr>
<td><strong>Baud Rate</strong></td>
<td>9600 bit/sec typical</td>
</tr>
<tr>
<td><strong>Data Link Protocol</strong></td>
<td>HDLC Balanced (Sync. Or PPP Async.), HDLC Polled (Dial Backup), Others Available</td>
</tr>
<tr>
<td><strong>Alarm Inputs</strong></td>
<td>7 Total</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sensitivity 12 dB EIA SINAD</strong></td>
<td>0.35 uV</td>
</tr>
<tr>
<td><strong>Selectivity</strong></td>
<td>-70 dB</td>
</tr>
<tr>
<td><strong>Intermodulation Rejection (EIA SINAD)</strong></td>
<td>-65 dB</td>
</tr>
<tr>
<td><strong>Spurious and Image Rejection</strong></td>
<td>-75 dB</td>
</tr>
<tr>
<td><strong>Frequency Stability</strong></td>
<td>1.5 ppm, -30° to + 60°C(-22°F to + 140°F)</td>
</tr>
<tr>
<td><strong>Input Impedance</strong></td>
<td>50 ohms</td>
</tr>
<tr>
<td><strong>Diagnostic Service Port</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Port Type</strong></td>
<td>Async. EIA-RS-422</td>
</tr>
<tr>
<td><strong>Baud Rate</strong></td>
<td>19200 bit/sec typical</td>
</tr>
<tr>
<td><strong>Data Link Protocol</strong></td>
<td>HDLC</td>
</tr>
<tr>
<td><strong>Electrical Requirements</strong></td>
<td></td>
</tr>
<tr>
<td><strong>DC Input Voltage</strong></td>
<td>13.6 Vdc, Negative Ground</td>
</tr>
<tr>
<td><strong>DC Input Current</strong></td>
<td>3A (Rx), 14A (Tx)</td>
</tr>
</tbody>
</table>
TABLE 6-10 BASE STATION UHF ANTENNA SPECIFICATIONS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>890-940 Mhz</td>
</tr>
<tr>
<td>Bandwidth for 1.5 to 1 VSWR</td>
<td>50 Mhz</td>
</tr>
<tr>
<td>Horizontal Beam width (1/2 power points)</td>
<td>As required</td>
</tr>
<tr>
<td>Vertical Beam width (1/2 power points)</td>
<td>As required</td>
</tr>
<tr>
<td>Gain</td>
<td>As required</td>
</tr>
<tr>
<td>Antenna Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Front to Back Ratio</td>
<td>10 dB</td>
</tr>
<tr>
<td>Lightning protection (through support pipe)</td>
<td>DC Ground</td>
</tr>
</tbody>
</table>

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 sub-systems that shall be used to replace or retrofit the VHF voice radio are presented in the following tables, TABLE 6-11 through TABLE 6-15.

TABLE 6-11 BASE STATION RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>MASTR III VHF, Analog, Conventional Base Station.</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Simplex / Full Duplex</td>
<td></td>
</tr>
<tr>
<td>Squelch Gate</td>
<td>Carrier Only</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>10-110 Watts, Adjustable</td>
<td></td>
</tr>
<tr>
<td>Channel Spacing</td>
<td>12.5/25/30 KHz</td>
<td>Capable of 12.5 KHz</td>
</tr>
<tr>
<td>Sensitivity (EIA 12dB SINAD)</td>
<td>-116 dBm</td>
<td></td>
</tr>
<tr>
<td>Selectivity</td>
<td>90 dB</td>
<td></td>
</tr>
<tr>
<td>Amount of Channels</td>
<td>1 TX, 1 RX</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 6-12 LOCOMOTIVE/ CAB CAR SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>VHF, Analog, Conventional Mobile Radio</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Simplex / Half Duplex</td>
<td></td>
</tr>
<tr>
<td>Squelch Gate</td>
<td>Carrier Only</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>45 Watts, Adjustable</td>
<td></td>
</tr>
<tr>
<td>Channel Spacing</td>
<td>25/30 KHz</td>
<td>Capable of 12.5 KHz</td>
</tr>
<tr>
<td>Sensitivity (EIA 12dB SINAD)</td>
<td>-116 dBm</td>
<td></td>
</tr>
<tr>
<td>Selectivity</td>
<td>90 dB</td>
<td></td>
</tr>
<tr>
<td>Amount of Channels</td>
<td>&gt;90</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 6-13 MOBILE RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>VHF, Analog, Conventional Mobile Radio</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Simplex / Half Duplex</td>
<td></td>
</tr>
<tr>
<td>Squelch Gate</td>
<td>Carrier Only</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>45 Watts, Adjustable</td>
<td></td>
</tr>
<tr>
<td>Channel Spacing</td>
<td>12.5/25/30 KHz</td>
<td>Capable of 12.5 KHz</td>
</tr>
<tr>
<td>Sensitivity (EIA 12dB SINAD)</td>
<td>-116 dBm</td>
<td></td>
</tr>
<tr>
<td>Selectivity</td>
<td>90 dB</td>
<td></td>
</tr>
<tr>
<td>Amount of Channels</td>
<td>&gt;90</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 6-14 PORTABLE RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>VHF, Analog, Conventional Portable Radio</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Simplex / Half Duplex</td>
<td></td>
</tr>
<tr>
<td>Squelch Gate</td>
<td>Carrier Only</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>5 Watts</td>
<td></td>
</tr>
<tr>
<td>Channel Spacing</td>
<td>12.5/25/30 KHz</td>
<td>Capable of 12.5 KHz</td>
</tr>
<tr>
<td>Sensitivity (EIA 12dB SINAD)</td>
<td>-116 dBm</td>
<td></td>
</tr>
<tr>
<td>Selectivity</td>
<td>90 dB</td>
<td></td>
</tr>
<tr>
<td>Amount of Channels</td>
<td>&gt;10</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 6-15 DRAGGING EQUIPMENT DETECTOR RADIO SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Motorola VHF HT-750, Analog, Conventional Transmitter</td>
<td>Narrow-band capable</td>
</tr>
<tr>
<td>Operation</td>
<td>Transmit Only</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>5 Watts, Adjustable</td>
<td></td>
</tr>
</tbody>
</table>

#### H. INSTALLATION REQUIREMENTS

Special instructions for the installation of portions of the Voice Radio and Data Radio systems are described as follows.

#### 1.0 VHF AND ATCS BASE STATION

Base Station antennas shall meet the technical requirements of TABLE 6.10 and TABLE 6-11, in particular the horizontal and vertical beam-width shall be designed to support coverage to the range of control points 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, the size of the cable 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

A total of one (1) Tilt-down Antenna Tower, one (1) Omni-directional Antenna, one (1) MCP Radio, associated Batteries, Battery Charger, dc/dc Converter and Lightning Arrester shall be required per Data Radio CP site. The Installer shall provide the Tilt-down Antenna Tower and installation accessories, the Coaxial Cables, per 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 (1) MCP Radio configured to communicate with the two (2) 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 (1) Omni-Directional Antenna. Each Antenna shall be equipped with a Type N Female connector, and shall be 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 (1) 12 Vdc Battery plants, (each plant comprised of ten 1.2Vdc batteries), plus a 12Vdc Battery Charger, a dc/dc Converter and a Lightning Arrestor.

2.0 INSTALLATION INSTRUCTIONS

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 Manufacturers written specifications. The Manufacturers written installation instructions shall be provided with the equipment.

3.0 RADIO PROGRAMMING AND CONFIGURATION

3.1 ATCS Data Radio MCP

MCP Radios shall be configured for operation on either of two ATCS Channels based on its 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 Transmit Power, and shall have a receiver sensitivity of 0.35uV 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 per the 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 VHLC shall be performed by others. The MCP Radios provided shall be manufactured be 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 12Vdc Battery Charger shall be installed at each Control Point. All Radio Equipment shall be powered directly by the batteries which shall be configured to “Float Charge” so that momentary interruptions of 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 arrester 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 arrester and the CP ground plate.

6.0 GROUNDING AND LIGHTNING PROTECTION

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

7.0 SAFETY

The Installer shall follow the written safety instructions provided by GE/Harmon or Safetran, and Western Towers for the installation of the MCP and the Tilt-down towers respectively, in particular the installation and operation of the 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 (RWP) training and manual.

END OF CHAPTER
CHAPTER 7
GRADE CROSSINGS

A. INTRODUCTION

The term "grade crossings" or "crossings" in this document refers to all crossings at-grade. Grade crossings are commonly referred in the technical literature and government publications as at-grade highway-rail crossings or simply highway-rail crossings or, the more recent pathway grade crossings. This Chapter also covers pedestrian grade crossings.

Grade crossings are intersections where vehicles and/or pedestrians cross train tracks at the same elevation, whereas at these locations the train always has the right of way. By definition an intersection is an area of potential conflict, i.e., two (2) users cannot occupy the same space at the same time. The term, motorized users or motorists, denote all types of vehicular drivers (automobiles, buses, trucks, motorcycles, etc.). The term non-motorized users or non-motorists refers to all pedestrians, which includes mobility impaired persons, wheelchair occupants, and bicyclists.

Ideally, highway-rail grade crossings should not exist. For years one of the goals within the Federal Railroad Administration (FRA) is to eliminate all of the grade crossings. As that is not possible due to the large number of crossings, the more realistic goal is that a grade crossing that afford a safe, comfortable, and convenient passageway for all users.

The grade crossing design consists of three (3) essential elements: safety, accessibility, and functionality. In order to achieve these, the grade crossing requires a clearly defined and readily traversable pathway for both the motorist and pedestrian. 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 consideration in the design is the crossing that would 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 (2) 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 general policy in regards to vehicular grade crossings, and pedestrians 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 under utilized 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.

Grade eliminations are the safest approach to the grade crossing enhancement and should be implemented as the preferred improvements for both vehicular and pedestrian crossings.

For existing vehicular grade crossings, it is the policy of Caltrain to systematically improve all crossings by installing pedestrian gates in all four (4) quadrants of vehicular grade crossings to enhance safety and accessibility.

It is Caltrain practice to closely collaborate with the CPUC (California Public Utilities Commission) and the Local Agencies having jurisdiction over the roadways to jointly evaluate and determine the improvements over the crossings. These three stakeholders form a Diagnostic Team comprising of multi disciplines in the areas of civil and traffic engineering, and railroad signal engineering. More of this in the Section C, 5.0 - DIAGNOSTIC TEAM.

1.1 Quiet Zones

Quiet zones refer to 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.

Proposal 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 (3) 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 for revenue operations on an emergency basis, as well as for potential future operations needs. Emergency crossings are secured with gates and locks. They are not provided with active warning devices.

All vehicular grade crossings within Caltrain corridor have pedestrian crossings on either sides of the crossings. Additionally, Caltrain also has pedestrians only at-grade crossings. All except two (2) of the crossings are located within the passenger stations. Not all of the passenger stations have pedestrian at-grade crossings. The stations without the at-grade crossings have pedestrian underpasses instead, or that the stations are of center boarding configuration.

All of the grade crossings on Caltrain are equipped with an active crossing warning system to provide notice that a train is approaching 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 utilize a track-circuit based device, which usually provides a constant 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 Time Table, and Special Instructions which shall be considered in the design, installation, operations, and maintenance of the crossings.

Typical vehicular grade crossings are illustrated in the following three (3) Figures (Figure 7-1 through Figure 7-3) for right angle, obtuse, and acute intersections, respectively.
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)
B. REGULATORY AUTHORITIES AND STANDARD PRACTICES

Grade crossings are regulated by the various Federal government and state agencies. In California it is the California Public Utilities Commission (CPUC). In addition to these regulatory agencies, Railroads collaborate with the local agencies having jurisdiction over the roadway for traffic coordination. Caltrain has developed its own standard practices. AREMA (Association of Railway Engineering and Maintenance Association) and ITE (Institute of Transportation Engineers) provide the industry standard practices and recommendations.

1.0 REGULATORY AUTHORITIES

Various Federal agencies under the Department of Transportation (USDOT) have jurisdiction over the grade crossings. They are Federal Railroad Administration or FRA, Federal Highway Administration or FHWA, and Federal Transit Administration or FTA, as well as the National Transportation Safety Board (NTSB).

The other Federal Department has jurisdiction on accessibility for the people with the disabilities is the Department of Justice (DOJ) which develops and publishes the requirements for accessibility for the Americans with disabilities, as part of the Americans With Disabilities Act (ADA). The DOT has been designated to implement compliance procedures relating to transportation (highways, streets, and traffic management) with the FHWA overseeing the DOT mandate in these areas.

In the State of California, the California Public Utilities Commission (CPUC) has the overall oversight of the grade crossings.

1.1 Federal

Federal jurisdiction of the grade crossings is under the Department of Transportation (USDOT) whose three (3) agencies within the department oversee the rules and regulations at grade crossings and share the objective of reducing accidents at grade crossings. These three (3) agencies are FTA (Federal Transit Administration), FRA (Federal Railroad Administration), and FHWA (Federal Highway Administration). A fourth agency NTSB (National Transportation Safety Board) investigates accidents, including those at crossings.

1.1.1 FRA (Federal Railroad Administration)

The 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 the crossings in the country. The Agency also regulates the type of lighting to be placed on a locomotive, the audibility of the bells, the inspection, testing, and maintenance standards for active at-grade crossing signal system safety.

1.1.2 FHWA (Federal Highway Administration)

The FHWA jointly with the FRA are responsible for the safety at public vehicular grade crossings. The 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. MUTCD (Manual of Uniform Traffic Control Devices) – guidance on the design and placement of passive and active traffic control devices

c. Railroad-Highway Grade Crossing Handbook (RHGCH) – guidance on grade crossing design
d. Guidance on Traffic Control Devices at Highway-Rail Grade Crossings

1.1.3 FTA (Federal Transit Administration)

The FTA administers funding to support a variety of public transportation systems, including commuter rail. The 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 ADA (Americans with Disabilities Act)

Federal agencies follow the Americans with Disabilities Act Accessibilities Guidelines (ADAAG) guidelines which regulates accessibility to Public Rights-of-way (Prowac).

1.1.5 NTSB (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 nine (9) initiatives as follows:

a. To establish responsibility for safety at private crossings
b. To advance engineering standards and new technology
c. To expand educational outreach (help promote the Operation Lifesaver, a non-profit 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 (California Public Utilities Commission), 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 (Manual Uniform Traffic Control Devices), modified with supplement, which is commonly referred to as the California MUTCD (CA MUTCD).

The CPUC issues General Orders (GOs) pertaining to applicable requirements of the design and improvements of grade crossings. The current G.O. 75-D (Protection of Railroad Grade Crossings) covers the grade crossing warning devices. Additionally, the CPUC distributes Federal funds (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 need for improvements and determines what those improvements will be, as follows:

a. Reviews proposals for crossings
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

In addition, the CPUC publishes the “Pedestrian-rail Crossings in California” which contains design principles and recommendations. The publication is a result of collaboration by CPUC with the railroads such as Caltrain.

1.2.1 Emergency Notification Sign

The 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 problem at the grade crossings. The signs shall include the toll free phone number, and information for about the location (street name), the DOT crossing number (in California it is CPUC Crossing number). The signs shall be facing the roadway(s) visible by the incoming motorists, either on the crossing houses or on a stand alone sign posts. Other details are described in the Cal 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, the improvements could include the traffic signal and preemption requirements. The traffic control devices are described in Section D – TRAFFIC...
CONTROL DEVICES. The traffic preemption is in Section E – TRAFFIC SIGNAL PREEMPTION.

2.0 INDUSTRY GUIDELINES

2.1 AREMA (American Railway Engineering and Maintenance of Way Association)

AREMA publishes the “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)

The 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 (3) different types of user groups (trains, vehicles, 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 through FIGURE 7-3 show the typical vehicular grade crossings for right angle, obtuse, and acute intersections, respectively. FIGURE 7-4 shows the typical pedestrian grade crossings at passenger stations.

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 the wheel chairs 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, namely the Railroad, the Local Agency, which has the authority of the roadway, and the California Public Utilities Commission (CPUC), which has the overall oversight of the state grade crossings. This collaboration is in the form of a diagnostic team evaluates, assesses, and analyzes and jointly concurs on the optimum type, number and placement of the traffic control devices. Additionally, the team coordinates the requirements for the traffic signal preemption and design of...
warning time. More on the Diagnostic team is 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 not on curves requiring rail superelevations. 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 people on wheelchairs and strollers, as well as to the visually impaired persons.

1.2 Visibility

Approaching crossings (within 150 feet), fences other than the center fence at stations higher than four (4) feet, vegetation higher than three (3) feet, signs not part of the passive traffic control devices, cases, cabinets, or any equipment or structures or other physical sight obstructions which interfere the view of the warning devices are discouraged.

1.3 Illumination

A well lighted crossing will assist the motorists, pedestrian, and bicyclists to assess 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 users safety, accessibility, and comfort. Removable prefabricated concrete panels achieve these objectives.
Curb ramps shall be installed or tapered to daylight not closer than six (6) feet from the nearest rail, with a six (6) inch solid thermoplastic white line to connect the curb lines across. This line marks the edge of the roadway, hence to keep the motorists from entering into the tracks.

The crossing panels shall be extended by a minimum of eight (8) feet from the street side of the curb line. This eight (8) feet sidewalk extension provides a buffer zone between the vehicular lane from the sidewalks, and to accommodate uninterrupted passing. The buffer zone increases the comfort level and preceived safety of pedestrians.

The crossing cross slopes follow the track grade, and since the track grade is typically one 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, foot, 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) section between the crossing panels and between the panels and the sidewalk shall always be maintained smooth to eliminate or minimize cracks, uneven surface, broken pavement, potholes, etc. so as not to increase travel time. This is critical especially for mobility impaired people, for the elderly, and people with strollers.

It is essential that the crossing be designed with ease of maintenance to minimize maintenance that may cause train service interruptions, and requirement for lane or roadway closure.

Removable crossing panels will expedite maintenance work. The track structure shall be on the HMAC to accommodate the ever increasing roadway traffic, and to facilitate drainage, hence, reduce the crossing settlement. Only concrete ties shall be used at the crossing. Timber ties shall not be used as they deteriorate quickly under constant moisture conditions. There shall be no rail joints within the crossing and at least 20 feet beyond. Other track details are contained in the Caltrain Standard Drawings.

1.5 Drainage

The discontinuity or differences between the roadway surface and rail present drainage and maintenance problems. Ideally the rail crossing shall be at least equal or slightly higher than the approaches in order 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, curb inlets) shall be coordinated with the Local Agency for discharge away and into the storm water system of the Local Agency.
2.0 LAND USE CONSIDERATIONS

Other improvements to enhance the guidance and warning to the crossing users include review of the land use adjacent to the crossings at and near the crossings.

The design team should identify any such hazards and work with the CPUC, 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 a “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 located near a grade crossing, such as diagonally through the tracks, crosses one or two approaches, or crosses in the median of an intersection, special considerations should be considered in regards to roadway intersection geometry. Some of the geometric design considerations are as follows:

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 that had advanced to the intersection,

b. Space requirement for vehicles to escape on the far side of any grade crossing for vehicles that might be potentially trapped on the crossing when a train approaches the crossing.

c. Use of raised median islands to prevent motorists from driving around the crossing gates.

d. Evaluation of the appropriate length for left and right-turn lanes in order 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 paying attention to 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

Parking within 75 feet from the crossing should be discouraged. Parked vehicles restrict the motorist’s view of the crossing warning devices.

2.4 Street Furniture

The 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 possibility of obstructing the view of the motorists and obstructing the view and access to the pedestrians. They may also interfere with the access and maneuverability of the pedestrians on wheelchairs and with strollers, as well as bicyclists. The furniture shall only be placed not closer than 50 feet from the crossing.

2.5 Traffic Signage

The traffic signage placed near the grade crossings shall only be those related to the crossings. Parking info 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

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 consideration.
All designs shall adhere to the rules and regulations contained in Code of Federal Regulations, Title 49 Parts 234, 235, and 236. Grade Crossing design criteria shall incorporate the rules and instructions as contained in the most current issue of the Caltrain General Code of Operating Rules, Caltrain General Orders, Caltrain Timetable, and Caltrain Special Instructions.

Any modification 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. Reference CHAPTER 5 - SIGNALS for wayside signal considerations and design criteria.

3.1 Train Detection System

The preferred grade crossing control incorporates the use of uni-directional or bi-directional redundant constant warning devices (i.e., units fully contained with an internal transfer function) without utilization of “wrap” circuits. These train detection systems shall be combined with solid-state crossing controllers to ensure compliance with “lamp voltage” and “standby lamp voltage” regulations. Event recorders shall be utilized to record data useful in the maintenance, troubleshooting, and repair of the entire system. Where it is necessary to deviate from preferred grade crossing control standard, approval must be obtained from the Caltrain Deputy Director of Engineering.

On multiple track where uni-directional applications are utilized, a single two-track unit shall control warning for train movements on Main Track No. 1, a second unit shall control warning for movements on Main Track No. 2, a third unit for Main Track No. 3, and so on. Where it is determined that applying this standard is too costly, obtain guidance from the Caltrain Deputy Director of Engineering.

An application program sheet shall be included in the drawing set where constant warning equipment is installed.

Design for the Caltrain’s Electrification project will require a program to replace present Constant Warning Time systems since these devices will not work in a traction power system.

3.2 Frequency Selection and Application

All systems shall be applied in accordance with the manufacturer’s recommendations. The preferred application is bi-directional but uni-directional applications shall be utilized to provide adequate frequency separation, where following train movements may occur, and where insulated joints must be maintained in the vicinity of crossings to support wayside signal systems.

Remote applications shall be used where insulated joints exist within the approach limits to the crossing. Tuned joint couplers may be used only when applied in accordance with the manufacturer’s recommendations. Additional systems may be required to accommodate special applications and unique train operations. When a
grade crossing adjoins a Control Point, the designer must carefully analyze moves towards the grade crossing and determine whether special circuits are required to mitigate a potential momentary loss of detection as the train diverges from the track on which detection is active.

The preferred constant warning device frequencies to be utilized are 86, 114, 156, 211, 285, 348, 430, 525, 645, 790, and 970 Hertz for the primary system. Utilization of the 348 HZ system shall be confined to areas where 60 HZ interference is not likely and electrified transit systems do not parallel the Caltrain tracks. The frequency selected shall be dependent upon the required approach distance and ballast conditions. A four (4) Ohm/1000 feet distributed ballast resistance value shall be utilized in comparing frequency to required “look” distance. “Six wire” applications shall be avoided where possible. Field Selectable Terminating Shunts are preferred. High impedance termination shunts, such as the NBS-2 should be used. As much as possible, 86 Hz and 114HZ applications should be used where termination shunts are next to non-bypassed insulated joints.

Signal circuitry island frequencies shall be 10 KHz, 11.5 KHz, 13.2 KHz, and 15.2 KHz. Harmon Electronics Random Signature Island (RSI) modules are acceptable for use on Caltrain. Careful evaluation of existing frequencies and equipment shall be made prior to selecting island frequencies.

A careful and detailed review of train operations shall be completed prior to finalizing the application to be used. Where trains accelerate from a station, or slow to stop at a station, additional systems may need to be incorporated.

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 utilized for the crossing warning devices. Chargers shall be equipped with temperature compensation devices. A third, battery set, to be maintained by the Roadway Authority shall also be provided for the roadway traffic signal. Where the total load of the crossing warning devices exceeds 30 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. Battery capacity for the constant warning device shall be sufficient to provide a minimum of 48 hours of normal operation.

The manufacturers’ recommended surge protection apparatus shall be incorporated into all grade crossing design. Surge protection units shall be installed on the ac supply source, battery supply, and track leads.

Terminals for dc 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 upon the equipment loads and the operating parameters determined by the equipment manufacturers. Minimum conductor sizes to be used shall be in accordance to the following TABLE 7-1 CABLE SIZE.

### TABLE 7-1 CABLE SIZE

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>CABLE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal House/ Case Wire</td>
<td></td>
</tr>
<tr>
<td>Battery chargers and feeds</td>
<td># 6-259 strand welders cable</td>
</tr>
<tr>
<td>Flasher lighting circuits</td>
<td># 10 flex</td>
</tr>
<tr>
<td>Track circuits</td>
<td>#10 flex</td>
</tr>
<tr>
<td>Loads in excess of 1 ampere</td>
<td># 10 flex</td>
</tr>
<tr>
<td>Loads less than 1 ampere</td>
<td># 14 flex</td>
</tr>
<tr>
<td>Flashing Light Signals/ Gates</td>
<td></td>
</tr>
<tr>
<td>Light wires</td>
<td># 6 flex</td>
</tr>
<tr>
<td>All other circuits</td>
<td># 10 flex</td>
</tr>
<tr>
<td>Cable</td>
<td></td>
</tr>
<tr>
<td>Flasher lighting circuits &amp; gate feeds</td>
<td># 6 solid</td>
</tr>
<tr>
<td>All other circuits</td>
<td># 14 solid</td>
</tr>
</tbody>
</table>

Grade crossing flasher lamps must be provided a minimum of 8.5 Vdc. Cable shall be sized to limit voltage drop to 3 Vdc. Cable conductor sizes in TABLE 7-2 shall be increased where needed to assure these voltage levels.

LED’s (light emitting diodes) shall be installed on all new installations or significant upgrades to existing locations. Either relays or an approved solid state crossing controller such as the SSCCIIMA or later model should be installed when modifying a crossing. The SSCCIIMA is preferred. Where LED lamps are used, #10 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 MUTCD requires a minimum warning time of 20 seconds to be provided for the crossing system. The design minimum on
Caltrain is 25 seconds and is based upon 20 seconds minimum warning time plus 5 seconds 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 Part 234 of CFR Title 49, however 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 four (4) feet per second (FPS). Americans with Disability Act Accessibility Guidelines (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 MPH requires over 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, perhaps to minimize delays or inconvenience. 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 distance of a train from a grade crossing, speed of train and are generally not aware of the distance it takes for a train to stop.

Where crossing warning times are long or inconsistent, motorists and pedestrians are more likely to engage in risky behavior. Therefore it is desirable to follow the Caltrain standard pedestrian station configuration and not increase warning times. For these reasons, MUTCD prescribes standard devices for vehicular and pedestrian warning and control. At a station, the risk is that the devices lose credibility and a person ignores the devices and steps out in front of an express train traveling in the opposite direction. When warning times increase, impatience grows and the probability of risk taking increases.

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. Since the grade crossing is based on a 25 second warning time for a 79 miles per hour (MPH) train (80 MPH when the PTC or Positive Train Control system is installed), 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 for a decelerating train by over 50%
and thus increasing risk. For this reason, the standard configuration should be used at Caltrain stations and deviations occur only for special circumstances.

Electrifying the Caltrain system will require a program to replace present Constant Warning Time systems since these devices will not work in a traction power system.

4.2 Warning Time

If possible, all constant warning devices shall be configured to provide 25 seconds of warning time for trains operating at the maximum authorized district speed. Although federal regulations require a minimum of 20 seconds warning time, the 25 second application should allow for train acceleration in the approach. Additional warning time may be required for “wide track” applications, traffic signal interconnects, and increased time that may be desirable in lowering the gate to accommodate slow moving vehicles clearing the track area. The most current AREMA guidelines shall be followed in determining warning times.

A wide track is a crossing that consists of more than one (1) 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 six (6) feet beyond the furthermost rail on which trains operate. When this distance is greater than 35 feet, one second shall be added for each additional 10 feet, or fraction thereof.

The termination shunt shall be placed in accordance with the manufacturers recommendations. The minimum placement shall be the required distance to provide the 25 seconds warning time, plus the required reaction time of the device (i.e., normally four seconds). Additional time may be required to preempt an adjacent traffic signal and/or to accommodate clearing vehicles from the wide track sections.

Once the total time requirement is calculated the designer shall determine the required approach circuit distance. The actual location of the termination shunt shall be measured from the point where the signal island circuit is terminated on each side of the crossing.

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 FRA 23CFR646.204 for additional information regarding a Diagnostic Team.

The Local Agency is responsible for providing a detailed written description of the roadway traffic signal operation, including 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 to provide 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.

An example of the check list of the diagnostic is as Reference at the end of the 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 within corridor
e. Train handling
f. Maximum Authorized Speed (MAS) through the crossings
g. Warning time requirements and/or type of preemption, simultaneous or Advanced Preemption time
h. Type of vehicles which must stop at all crossings, such as busses and trucks.
5.2 Maintenance and Operational Responsibilities

Caltrain and the Roadway Authority shall jointly perform the following:

a. Testing and commissioning: 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 traffic control devices and passive traffic control 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 active railroad traffic control devices is active warning devices which provide users of the crossing information as to 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 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 device 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 details under Section E, TRAFFIC SIGNAL PREEMPTION.

The automatic gate arms are generally on a stand alone signal mast. When automatic pedestrian gate arms are required on the pedestrian sidewalks, then the pedestrian gate arms shall be a separate stand alone 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 which crosses the railroad, as well as at a sidewalk gate assembly, the warning flashing lights on the pedestrian signal mast will be the conventional side by side arrangement. At station crossings which are only used by pedestrians the flashing light signals are vertical. The design and installation must allow an exit path and be mindful of the pedestrian who has already started crossing the tracks when activation occurs. This is provided by installing 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, 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 for visually impaired persons. Signage and pavement markings shall follow the requirements defined in the California 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, number of tracks. The signage is mounted on the signal mast that 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 six (6) inch wide thermoplastic white striping indicating the curb lines shall be painted through the crossing.

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. Other markings such as curb painting (in red designating no parking), directional arrows, turning information, etc.

2.2 Raised Median Islands

The installation of raised median islands on the roadway should receive a serious consideration as they 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 California MUTCD.

Median islands become 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, and the relative skew of the roadway with respect to the crossing, and existence of adjacent frontage roads, and driveways.

Raised median islands are within the jurisdiction of the Local Agency. The designer shall clearly identify and justify the need of 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, and with the 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 the pedestrian 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 the visually impaired persons of the limit to the tracks, as well as an indication to the pedestrians of a safe stopping location and safe refuge area that is outside the rail dynamic envelope.

3.2 Pavement Marking

Within the pedestrian crossing area, a 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

Guard railing is railing installed at the approaches to the crossing to guide the users to the crossing points in front of the pedestrian gate arm and the swing gate. For the visually impaired persons, this will guide them 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 be 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 right-of-way provides a physical barrier in an attempt to prevent motorists and pedestrians from entering the tracks near the grade crossings.

3.3.3 Swing Gates

Swing gates should be installed where pedestrian gate arms are installed. The swing gates are not electrically connected into approaching train or vehicular traffic
signal systems. The purpose of the swing gates is to allow people to reach the clear point on the far side of the automatic gate arm. This happens when the person is already on the crossing when the automatic gate lowers due to approaching train.

The swing gates shall be ADA compliant to allow pedestrians or persons in wheel chairs to exit the crossing by pushing the gate. Swing gates require regular maintenance to ensure proper operation.

E. TRAFFIC SIGNAL PREEMPTION

The vehicular crossings consist of the railroad signal system and the roadway traffic signal system that 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 crossings
b. Improve vehicular traffic through the crossings
c. Improve the planning, and design of the railroad and roadway signal systems
d. Expedite the diagnostics processing of both the railroad and roadway signal systems

The safety and operations through the vehicular crossings 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 as prepared by the Institute of Traffic Engineers (ITE), AREMA, MUTCD, CA MUTCD, CPUC and other knowledgeable parties.

Older, widely used traffic signal controller units used 2-wire interconnection circuits between the railroad active warning system cabinet and the traffic control signal cabinet for preemption. This interconnection circuit consisted of two wires/cables buried in the ground between the above two points. 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.

If there is a break in either or both wires or cables of the interconnection circuit, (as example, an excavation contractors inadvertently breaking the wires or cables) the traffic signal controller unit would respond as if a train is approaching, clearing vehicles off the tracks, even though a train may not be approaching. The traffic signals remain in the preemption mode as long as the circuit remains open. If a train
approaches during such a malfunction, the railroad active warning devices will activate, yet the traffic signal preemption cannot be reinitiated to clear vehicles off the tracks.

Another potential problem with the 2-wire interconnection is a short in the circuits. If the wires/cables between the traffic signal control cabinet and the railroad active warning system cabinet became shorted together, the preemption relay in the traffic control signal cabinet could be falsely energized even if the relay contact opened. The active warning devices would operate, but the traffic signal controller unit would not receive the preemption input.

To address these potential problems, a supervised double break, double wire circuit shall be installed between the railroad and the traffic signal control system on all new work. In order to detect a shorted or open interconnection circuit, two additional wires are used to provide a supervised circuit. The energy source originates at the traffic signal controller, and two wires provide a return path verifying the railroad preemption control relay is energized and there is no call for preemption. The two additional wires verify circuit integrity when the railroad issues a call for preemption. The circuit logic is Exclusive OR. One circuit must be energized and the other de-energized. Both energized or both de-energized is indicative of a problem with the interconnect circuit and the traffic signal controller should assume a state known to be safe and to issue a notification that there is a circuit deficiency.

The following **TABLE 7-2 WIRES AND FUNCTIONS FOR PREEMPTIONS** identifies the number of wires and functions for the supervised interconnection circuit for Simultaneous and Advance Preemptions:

**TABLE 7-2 WIRES AND FUNCTIONS FOR PREEMPTIONS**

<table>
<thead>
<tr>
<th>Wires</th>
<th>Simultaneous Preemption</th>
<th>Advance Preemption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Source energy positive</td>
<td>Source energy positive</td>
</tr>
<tr>
<td>2</td>
<td>Source energy negative</td>
<td>Source energy negative</td>
</tr>
<tr>
<td>3</td>
<td>Preempt relay positive</td>
<td>Preempt relay positive</td>
</tr>
<tr>
<td>4</td>
<td>Preempt relay negative</td>
<td>Preempt relay negative</td>
</tr>
<tr>
<td>5</td>
<td>Supervision relay positive</td>
<td>Supervision relay positive</td>
</tr>
<tr>
<td>6</td>
<td>Supervision relay negative</td>
<td>Supervision relay negative</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Gate down relay positive</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Gate down relay negative</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Traffic signal health positive</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Traffic signal health negative</td>
</tr>
</tbody>
</table>

A preempt trap is that condition where the clear track green interval ends before the flashing-light signals start to flash and gates start to descend) and it can occur with advance preemption. One of the solutions to avoid preempt trap is to use a "gate-
The purpose of the “gate-down” circuit is to prevent the traffic signal from leaving clear track green interval until it is determined that the gates controlling access over the tracks are fully lowered. The “gate-down” circuit notifies the traffic signal controller unit when the gates controlling access over the tracks on the approach to the intersection have either fully lowered or the train has occupied the crossing. The traffic signal controller unit shall change to the clear track green interval as usual, but shall 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 Circuits

A health check circuit provides an indication to the railroad active warning system cabinet when the traffic signals are in flashing mode or dark such as when the controller is in failure. This health check circuit requires additional wires/cables between the traffic control signal cabinet and the railroad active warning system cabinet. Consideration should be given to a fail-safe design for the health check circuit so that there shall be no case in which the circuit shall remain energized while the traffic signals are flashing or dark. The fault condition in the supervisory circuit as described above, would result in a fault in the traffic signal controller and thus would de-energize the output to the Railroad Health Relay.

1.2 Interconnection Circuits

In FIGURE 7-4 INTERCONNECTION CIRCUITS WITH SUPERVISION, GATE DOWN CIRCUITRY, AND HEALTH CIRCUIT below, energy (BX, CX) is supplied to the railroad from the traffic signal controller. The TCPR is the relay which 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 SUP and NSUP. 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.

If both are energized, or both are de-energized, that is indicative of a fault in the interconnection. 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 can terminate 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 which 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 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 since the traffic signals will not be able to clear out traffic as designed.
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 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 have the gates 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 non-surmountable medians shall be considered. Due to the increased amount of gate down time where second train logic is employed, there is the possibility motorists may interpret the gate
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 density is such that the gates may be held down for three (3) consecutive trains.

The programmed time on a Constant Warning Time Device may be different than the “Design Time”. This may be necessary to compensate for acceleration or deceleration in the crossing approach. Excess warning time must be avoided as much as possible.

F. VEHICULAR CROSSINGS DESIGN

All Caltrain vehicular grade crossings are treated 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 the passenger stations which function as pedestrian access between the two station platforms.

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 four (4) feet of the field side of the near running rail.

Four feet from the nearest running rail is approximately 6 feet 6 inches from track center. CPUC clearance is 8 feet 6 inches from track center. The designer shall use the 8 feet 6 inches distance from 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 feet per second (FPS) to allow for the mobility impaired individuals.

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 (2) tracks at 15 feet track centers, and clear point of 8 feet 6 inches from the nearest track center. Where the crossing consists of three (3) 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 (4) tracks (passing tracks).

Where the crossing is of a significant skew, it increases the complexity of the crossing due to the increase in travel distance, hence the corresponding need for increased warning time which in turn increases the likelihood of risky behavior. To mitigate this, the channelization should be provided to direct the pedestrians to cross on a walkway which is as perpendicular as possible to the tracks.
2.0 VEHICULAR CROSSING WITH SIDEWALKS

Pedestrian sidewalks should always be an integrated part of all of the vehicular grade crossings on the Caltrain corridor. The rationale is that Caltrain is located in a densely urbanized area with residential and commercial properties adjacent to the tracks, which results in a heavy usage of crossing by pedestrians. Caltrain will collaborate with the Local Agency for installation of the appropriate fencing and channelization to direct pedestrians to cross the tracks at authorized grade crossings with active warning devices.

See FIGURE 7-5 TYPICAL PEDESTRIAN SIDEWALK AT PEDESTRIAN CROSSING

3.0 VEHICULAR CROSSING WITHOUT SIDEWALKS

The crossings without sidewalks should receive the same treatment as the vehicular crossings with pedestrian sidewalks. The same rationale for the vehicular crossings with sidewalks also applies for crossings without sidewalks. The pedestrians will cross whether or not there is a sidewalk at the crossing. Providing crossings that the pedestrians could cross safely, comfortably, and conveniently at all vehicular crossings is consistent with the general objective of Caltrain, which should ideally also be shared by the Local Agency.

It is very likely that over time the Local Agency will provide the sidewalks and the necessary transition as a result of increasing public awareness of the need for the sidewalk. Caltrain shall take the initiative to collaborate with the Local Agency for the need for the pedestrian sidewalks connecting to the grade crossings.

4.0 PEDESTRIAN CROSSING GATE ARMS

It is Caltrain’s general goal to install automatic pedestrian gate arms and associated passive traffic control devices at all four (4) quadrants of all vehicular crossings. The need for gates in all four (4) 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 gate arms are required on the pedestrian sidewalks, an auxiliary gate arm on the vehicular gate mechanism is discouraged as a pedestrian raising such a pedestrian gate would simultaneously raise the vehicular gate. On the other two (2) quadrants without the vehicular gate arms, a stand alone pedestrian signal mast shall be installed with pedestrian automatic gate arms, swing gates, channelization, and other traffic control devices.
FIGURE 7-5 TYPICAL PEDESTRIAN SIDEWALK AT VEHICULAR CROSSING
The signal mast configuration for the pedestrian 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 railing
- 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 the 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 configuration at stations, and have since implemented them since 1999. These standard practices utilize active warning devices similar to those at vehicular crossings: signal equipment modified from that of vehicular crossing, crossing gate arm, and a crossing configuration which channels pedestrians. There is an increasing awareness of the need to enhance the safety of pedestrians at crossings.

1.0 DESIGN CRITERIA FOR PEDESTRIAN CROSSINGS

Normal operation is for the bells to activate, lights to flash, and three (3) seconds later, the gates to descend. The bells will continue to sound until the train has cleared the signal island circuit and the gates begin their ascent. At that time, the bells will cease to ring. Bells are considered pedestrian warning devices, and a grade crossing shall have enough bells so that the bell can 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 feet per second (FPS) for a mobility impaired person, shall be used as the basis for calculating pedestrian warning times. Since one cannot rely on a locomotive engineer seeing a person in the crossing and being able to brake in sufficient time, the individual is relying on the warning devices to provide sufficient warning time. The 1.5 FPS walking rate allows sufficient time for a mobility impaired person to safely travel across the crossing.

As previously stated, the standard warning time at Caltrain grade crossings is 25 seconds. The Caltrain warning time is defined as the time from when the warning devices begin operating, i.e., when the bells ring and the lights flash and after a delay, automatic gate arms begin their decent. There are special circumstances where the warning times are lengthened, depending on site conditions and/or the
circumstances of train operations. The public is accustomed to this standard warning time, as well as to a slightly longer time caused by decelerating trains.

Since the flashing lights for pedestrians are aimed across the tracks and the bells are primarily a pedestrian warning device, walking times are calculated for the mobility impaired person (at 1.5 FPS) from the clear point on the start point to the clear point across the tracks. So a warning time of 25 seconds allows a mobility impaired individual to safely traverse 37 feet and 6 inches.

### 1.2 Center Fence

Track centers at stations with outboard platforms are widened to 18 feet minimum 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 railing 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 train approach warning system. A separate gate mechanism for sidewalks should be provided in lieu of a supplemental or auxiliary gate arm installed as a part of the same mechanism to prevent a pedestrian from raising the vehicular gate at a highway-rail grade crossing.

#### 1.3.2 Swing Gates

At a crossing with pedestrian gate arms, a person may have begun crossing the tracks when an approaching train activates the crossing. For this person not to perceive that he is trapped by the gate arms, a swing gate is provided adjacent to the pedestrian gate arm. This gate only swings away from the crossing and is marked “EXIT”. The back side of the swing gate is marked “STOP, $ FINE” 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 and the gate arms and swing gate. This will allow a person to recognize the gate arms with adequate space for a group to stand in safety, or a wheel chair to maneuver. The perpendicular alignment of the gate to the tracks allows a maximum safety buffer zone. This is the preferred arrangement, although where available space prohibits it a parallel alignment may be used.

A safety buffer zone also provides accommodation for the slower moving individual to turn back and take refuge if he has passed the gate arms and sees and hears the
crossing activation. The presumption is the mobility impaired person will not attempt to beat the train.

1.5 Warning Assemblies

Pedestrian warning assemblies at stations will consist of lights arranged in a vertical configuration rather than in a horizontal arrangement. The vertical configuration, borrows from a State of Oregon DOT pedestrian flasher assembly, will take up less platform space. One (1) pair of the lights will be aimed down the platform and the other pair across the tracks. The lights aimed across the tracks are similar to the pedestrian walk light across a street at a standard pedestrian roadway crossing. If auxiliary lights are needed due to station entries perpendicular to the tracks or parallel to the tracks, they will be provided as needed.

1.6 Gate Recovery

After a train stops at the station, the gate arms should recover, and passengers should 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 as required.

2.0 PEDESTRIAN CROSSINGS AT STATIONS

Pedestrian crossings at stations are for pedestrians accessing the platforms. However, the crossings are also used by the public at large to go from one side to the other of the tracks.

There are presently no at grade crossings with grade crossing warning systems for center island platforms on Caltrain. 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 (refuge) zone in order to accommodate potentially large numbers of pedestrians since access to the platforms need to be only through the crossings. Ideally, center island platforms should be grade separated. Any installation of a center island crossing would require a thorough analysis and the development of a new standard.

Caltrain pedestrian crossings at stations are located at each end of the 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 trains. Gate arms will recover when the trains stop at the stations, but will stay down for approaching trains on the other tracks.

Caltrain platforms are of various lengths. Constructed stations have been of 620 feet, with about 20 feet of ADA compliant ramps to the crossing level. The platform lengths shall now be designed for 700 feet for a six (6) car consist. They are slightly longer for conventional six (6) cars to accommodate different types of cars and locomotives which have different dimensions and operational requirements. The
ADA ramps are 40 feet long to allow for future higher level boarding platforms. See Figure 7-6 TYPICAL PEDESTRIAN CROSSING AT STATIONS (OUTBOARD PLATFORMS)

FIGURE 7-6 TYPICAL PEDESTRIAN CROSSING AT STATIONS
The ideal situation is to have the platforms as short as practicable in order to make access to the crossings more convenient. Like other commuter railroads, Caltrain stations are at-grade, and access to the platforms is typically not ‘controlled’ in a sense as it is in a system with high platforms. Pedestrians typically access the platforms from the parking area close to the crossing they need to cross.

Due to property constraints on the east side, the station parking and bike locker facility are predominately located on the west side of the stations, which are also of population centers. This means access to the stations is mostly from one side of the station.

3.0 PEDESTRIAN CROSSINGS AT STATION AND ROADWAY

Some of the stations are adjacent to a street. In this case, the station has a dedicated pedestrian crossing at one end of the platform, and the other crossing shares the street sidewalk. Automatic pedestrian gate arms will be required at the pedestrian sidewalk, and provided with full treatments including swing gates, pavement striping, markings, and texturing. If the station parking is located 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 within two (2) adjacent streets, the station two (2) pedestrian crossings are located on both streets. Automatic pedestrian gate arms will be required at the pedestrian sidewalk, and provided with full treatments 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 (2) pedestrian crossings for use by the public at large which are located on the Caltrain right-of-way, and not directly at a station. These crossings are inherited from the former owner of the corridor Southern Pacific Railroad. 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 in order to:

a. Enhance safety at crossings
b. Increased deterrence of vehicles driving around lowered entrance gates
c. Create an effectively “Sealed Corridor” for train travel
The safety and operations through the vehicular crossings are the responsibility of both Caltrain and the Local Agency having jurisdiction of the roadway. Installation of Exit Gates must be approved by the CPUC. In general, the installation of Exit Gates will be recommended by a diagnostic team. (CA MUTCD 8A.01) 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 General Order 75-D, CA MUTCD 8D.05)

b. Entrance Gates shall begin their descent before Exit Gates and shall be horizontal before the Exit Gates are Horizontal. (CPUC General Order 75-D)

c. A vehicle intrusion detection system shall be installed whenever exit gates are used. (CPUC General Order 75-D, CA MUTCD 8D.05)

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 8D.05)

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 8D.05)

Designer shall follow the latest standard practices and recommendations for the Exit Gates of the AREMA Communications and Signals Manual of Recommended Practices and the latest recommendations of the Institute of Transportation Engineers.

Entrance Gates are required to be fully horizontal five (5) seconds prior to a train arriving at a crossing. This requirement does not apply to Exit Gates. (CFR 49 part 234 section 223).

Highway crossing warning systems on Caltrain which require Exit Gates shall use a solid state control system for the timing of the Exit Gate that is integrated with the roadway vehicle detection system. The Exit Gate Management System as manufactured by Railroad Controls Limited or equal shall be used.

The Inductive Loops for 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, within 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. Vehicle detection loops shall be preformed and water repellent with an integral check loop such as that manufactured by Reno A & E.

In general, the loops will be placed between the Entrance Gate and the nearest rail, between each set of tracks, and between the furthest rail and the Exit Gate. The vehicle detection loop system shall hold up the Exit Gate based upon the vehicle’s direction of travel. Separate detection loops shall be provided for each direction of roadway travel such that detection of a roadway vehicle that is wholly within a single lane of travel for a given direction will not hold up both Exit Gates 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, bicycles.

b. Provide “occupied/not occupied” indications to railroad control circuits within two seconds of any state change.

c. Verify, not less often than one time each time that 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 that the crossing gates are called down and the occupied indication is working.

e. Not to generate false highway vehicle occupied indications, more often than 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 individually isolated outputs for each loop 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 such magnitude that will cause false occupancy or false vacancy of trains under any normal or abnormal mode of operation.
k. Detection loops shall not be vulnerable to EMI that is generated within 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 one 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 loop 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 have occurred within the system (CA MUTCD 8D.05).

Back lights directed toward the motorist shall not be installed on exit gates due to the possibility of confusing a motorist crossing the tracks (Preemption of Traffic Signals Near Railroad Crossings, A Recommended Practice of the Institute of Transportation Engineers, 2006)

Where Pedestrian gates are used, a separate gate mechanism shall be used in the quadrant containing the Exit Gate. Either the Exit Gate or the Pedestrian Gate shall have a bell. The pedestrian gate shall fall 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 three 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 should be determined by the Engineering Study.

The need for Exit Gate Clearance time shall be evaluated based upon the criteria in the AREMA Communications and Signals Manual of Recommended Practices. When warning time is calculated at crossings with Exit Gates, the warning time is calculated to the Exit Gate rather than to the point clear of the furthest rail.

END OF CHAPTER

(Crossing Evaluation Report form follows)
# Crossing Evaluation Report

## Location Data

<table>
<thead>
<tr>
<th>Railroad</th>
<th>State</th>
<th>County</th>
<th>City: (In or Near)</th>
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<table>
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<tr>
<th>R.R. Division</th>
<th>Street/Road Name</th>
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</table>

<table>
<thead>
<tr>
<th>Nearest R.R. Timetable Station</th>
<th>R.R. Milepost</th>
<th>Branch/Line Name</th>
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## Diagnostic Review

Initiated By:  
- [ ] Railroad  
- [ ] State  
- [ ] Local  
- [ ] Other  

Date Initiated:

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<th>Affiliation</th>
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<td>6</td>
<td></td>
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## Railroad Data

### Daily Train Movement

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<th>Total Trains</th>
<th>Check if less than one movement per day</th>
<th>Main</th>
<th>Type and Number of Tracks</th>
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<table>
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<th>Day Thru</th>
<th>Train Movements per Day</th>
<th>Other</th>
<th>If Other, Specify</th>
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<table>
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<tr>
<th>Night Thru</th>
<th>Speed of Train</th>
<th>Can two trains occupy crossing at the same time?</th>
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<th>Day Switch</th>
<th>Max. speed, m.p.h.</th>
<th>Can one vehicle block another motorist’s view of proposed warning devices?</th>
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<th>Typical speed to Max. speed, m.p.h.</th>
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### Crossing Surface

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<th>Track</th>
<th>Type</th>
<th>Width</th>
<th>Condition</th>
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## Crossing Angle:

### Comments

---

Diagnostic Form (Page 1 of 4)  
Criteria Ch 7
## ROADWAY DATA

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<th>PERCENT TRUCKS</th>
<th>Roadway Surface:</th>
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<td>PERCENT TRUCKS:</td>
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### Speed of Vehicle

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### Roadway Width:

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### Roadway Condition:

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<th>Is the Shoulder Surfaced? Yes/No</th>
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<th>Is Sidewalk Present? Yes/No</th>
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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)

### EXISTING WARNING DEVICE

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<th>Yes/No Qty.</th>
<th>Type of Warning Device</th>
<th>Location:</th>
<th>Lens 8&quot;</th>
<th>Lens 12&quot;</th>
<th>Yes/No Qty.</th>
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<th>Location:</th>
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<td>Mast Mounted Flashing</td>
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<td>Stop Signs</td>
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<td>Stop Ahead Signs</td>
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### FIVE-YEAR ACCIDENT DATA

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<th>TOTAL ACCIDENTS</th>
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### TYPE OF DEVELOPMENT

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If Yes, Describe:

Location of Nearby Schools:

Diagnostic Form (Page 2 of 4)
### ADJACENT CROSSINGS

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</table>

**Is there adequate access from this crossing to adjacent crossings?**
- [ ] Yes
- [ ] No

**If yes, which crossing(s):**

**Can roadway realignment be accomplished to allow consolidation of crossings? If yes, provide sketch.**
- [ ] Yes
- [ ] No

**Impact of Closure:**

---

**Diagnostic Form (Page 3 of 4)**

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<table>
<thead>
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<th>Yes</th>
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<th>Type of Improvement</th>
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If Yes, what improvements?

If No, Explain:
CHAPTER 8

CIVIL DESIGN

A. GENERAL

This Chapter includes standards and design considerations for other civil engineering design in structural, drainage and utilities. 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 overpasses, tunnels, retaining walls, culverts, and other structures such as buildings, signal structures, and their related facilities.

Signal structures include signal bridges and signal cantilevers are typically specification driven, manufactured product with manufacturer’s recommended foundation design. 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 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 “PCJPB Standards for Design and Maintenance of Structures”. The shoring requirements shall follow the criteria of the “Caltrain Engineering Standards for Excavation Support System”.

Caltrain standards and requirements take over the precedence over other codes, such as AREMA and BDS (Caltrans’ Bridge Design Specifications Manual). CBC (California Building Codes) takes precedence over ACI, AISC and AWS 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, or relocation, or modification of the existing facilities. Even though these structures do not encroach into the Caltrain ROW, the facilities however are close enough that it may have an impact on the Caltrain 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 Caltrain Deputy Director of Engineering.

C. DRAINAGE

The drainage design criteria and requirements are intended to protect Caltrain corridor and facilities from storm water damage, and to protect Caltrain liability for damage to other property from storm water flows caused by the construction of Caltrain improvements and to provide Caltrain passengers and maintenance personal walking surfaces that are safe and free from ponding.

Caltrain drainage system typically consists of the following:

a. Track drainage at stations, grade crossings, and right-of-way
b. Station drainage (station platforms and parking)
c. Bridge deck drainage
d. Other structures such as buildings, pedestrian underpasses, etc.

An effective drainage system is a critical element in the design of Caltrain facilities. Inadequately drained storm water damages the infrastructure and other facilities. An effective system is required to:

a. Protect the track structure and other facilities from storm water damage
b. Expedite drainage flow
c. Maintain access to pedestrians and maintenance personnel.
d. Retard vegetation growth.
e. Prevent storm water runoff from entering into 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 does not encroach on the Caltrain ROW, shall conform to the design criteria and standards of that agency.

1.0 DESIGN REQUIREMENTS

Drainage facilities within the railroad zone of influence shall be designed in accordance with Caltrain railroad loadings. The criteria and requirements of the
loadings within 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 minimum 3 feet from the bottom of ties. If the drainage system cross the tracks, the system shall cross at a 90 degree angle to the center of tracks.

Drainage from pedestrian underpasses need to be discharged to the municipal sewer system.

The design of drainage facilities owned and maintained by other agencies that are relocated or modified because of Caltrain construction, and do not encroach on the Caltrain right-of-way, shall conform to the design criteria and standards of the Local Agency having jurisdiction of the area. In absence of the criteria, California Department of Transportation’s (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 right-of-way
- **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 where the project is located.

1.2 Underdrain Pipe

Underdrain pipe shall be minimum six (6) inches in diameter at minimum grade of 0.2%. If the pipe is connected to the municipal system, then it shall be compatible to the system of the Local Agency. For track drainage within the limits of the stations, and within the limits of grade crossings, use perforated PVC or HDPE of Schedule 80.

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 because of risk of clogging and difficult pipe access for maintenance. Use ditches where possible instead of perforated pipe.

Pipe cover shall be a minimum of 48 inches below top of rail for all pipes, including RCP (Reinforced Concrete Pipe) and PVC and HDPE pipes.

Manhole/inlet spacing: 500 feet max (up to 30 inches in diameter), 650 feet to 1000 feet for larger than 30 inches in diameter.

1.3 Culvert

The minimum pipe size for a storm drain pipe or culvert shall be 12 inches in diameter. For pipes directly under the track or within 15 feet from the centerline of the tracks, Caltrans Class V RCP (Reinforced Concrete Pipe) shall be used, and the minimum size shall be 24 inches in diameter.

2.0 PUMP STATIONS

Caltrain pump stations are lift stations which may consist of a sump pump or a series of sump pumps. The lift station raises the hydraulic head of storm water sufficiently to discharge by gravity to other drainage systems such as ditch, municipal storm water system, or to other lift stations, etc.

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 of 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 combined system duct bank to be installed wherever possible. The combined systems duct bank provides a common and coordinated underground structure for cables and wires for electrical, signals, and communications systems along the corridor. At the stations, the duct bank will be located within the designated utility corridor.

Fiber optic carriers on Caltrain corridor also prefer the combined system duct bank. This is preferred for economy and for the space constraints within the corridor.

1.0 CALTRAIN UTILITIES

Utilities owned and maintained by Caltrain consist of wires and cables for signal, electrical, communication, and piping for irrigation and drainage.

Utilities specifically designed for the Caltrain facilities at stations and right-of-way shall conform to the standards, codes, and requirements of the 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 government. Work shall be coordinated with and done in accordance with the standards of the utilities owner. Design, relocation, restoration, and construction shall be the responsibility of the facility owner.

Third party utilities consist of natural gas, jet fuel, electrical facilities, telephone and television cable, fiber optic cable, fire protection, water, sewers, etc.

3.0 DESIGN GUIDELINES

3.1 Regulations and Standards

a. Applicable standards and criteria established by the utility owners

b. CPUC 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 right-of-way at a 90 degree angle to the track centerline.

c. Materials: Utilities shall be constructed with non-conductive materials

d. Sleeves: Third party utilities that cross tracks shall be sleeved.

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 within 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 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 require 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 right-of-way
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 the Survey Plan. The Plan shall include all utility maps and drawings and descriptions of easements.

END OF CHAPTER
Chapter 9

Right-of-Way, Surveying and Mapping

A. Right-of-Way (ROW)

The phrase “right-of-way” generally refers to an easement, but railroads adopted this phrase to describe their property.

Caltrain right-of-way 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 right of way is sometimes interrupted by the acquisition of private or public parcels of land that adjoin the original right-of-way.

1.0 Caltrain Policy

The intent of Caltrain policy on right-of-way is to acquire and maintain the minimum right-of-way required consistent with the safety, maintenance, and operating requirements. The policy eliminates or reduces unnecessary property dispositions for proposed corridor improvements.

Caltrain general policy on right-of-way is as follows:

a. Preserve the existing right-of-way

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 right-of-way for current and potential uses in the future

Caltrain may work, on a partnership basis, with local land use authorities in early corridor planning phases to identify properties adjacent to 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 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 right-of-way 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 such that should the subsequent owner violate the condition set out in the instrument that created it, the estate can be terminated and recovered.

2.3 Easement

An easement is the right of use over the property of another for a special purpose. Literally, portions of the railroad property that were acquired through an easement are right-of-way.

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 easement shall be proposed for construction accesses.

2.4 Franchise Right

A franchise right is a non-transferable privilege to use the property of another. The grantee of the franchise right does not hold any interest or ownership to 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 right-of-way 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 right-of-way 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 Right-of-Way Assessment is meant to be a tool for assessing property issues during the conceptual stage of proposed improvements. A Preliminary Right-of-Way 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 the Chapter.
3.2 Right-of-Way Boundary Resolution

Right-of-way boundary resolution shall be performed at the final design stage for projects with definite right-of-way takes and permanent easements. Detailed requirements for the ROW Boundary Resolution are provided in the Reference at the end of the Chapter.

3.2.1 Legal Descriptions

Prior to the preparation of legals and plat maps, all proposed parcels for right-of-way takes shall be clearly identified in the right-of-way exhibit maps for the approval of the Caltrain Deputy Director of Engineering. The following documents shall be included in the maps.


b. Right-of-way exhibits clearly define areas of right-of-way takes.

c. Right-of-way appraisal maps and record maps.

A complete legal description shall consist of two (2) 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. It shall be drawn to scale. Detailed requirements for the Plat Maps are provided in the Reference at the end of the Chapter.

B. SURVEYING

Most of Caltrain improvements involve rehabilitation and improvement of existing facilities.

Supplemental surveys shall be provided for planning and engineering when detail 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 method 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. The survey control network ensures that adjacent projects have compatible control, hence it provides consistent and accurate horizontal and vertical control for all subsequent project surveys including photogrammetric, mapping, etc.
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. Surveyors must understand the elements that comprise geodetic surveys in order to perform geodetic surveys along Caltrain corridor.

1.1.1 Horizontal Datums

The Caltrain corridor control network is based upon NAD 83 (North American Datum of 1983), and all geodetic surveying work performed for Caltrain shall adhere to this datum. State Code of the State of California requires surveyors to utilize NAD 83 as the reference frame for geodetic surveys.

Caltrain allows GPS software utilizing the WGS 84 system because the WGS 84 (World Geodetic System of 1984) and GRS 80 (Geodetic Reference System of 1980) ellipsoids are so close, that the resulting computed data is correct.

Relative positioning data collected by surveyors can be tied to the NAD 83 datum using a State HARN (High Accuracy Reference Network), the national CORS (Continually Operating Referencing Stations) network or calculated from either a HARN or CORS. HARN’s and CORS are from different adjustments and should not be utilized 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 (NSRS). The NGS will be combining all control points, both HARN and CORS points under this one system. At that time, Caltrain will begin to utilize this new system.

1.1.2 Epochs

The NGS has planned to publish a 2007.0 epoch. Caltrain will be specifying this epoch, the 2007.0 epoch, 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) to be used 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 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 utilize new or adjusted NGS NAVD 88 bench marks only. 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. Caltrain will not accept control point data utilizing RTK (Real Time Kinematic) or GPS (Global Positioning Systems) derived elevation data.

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 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 utilize as-built plans on 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 insure that the survey meets FGCS (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 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 is comprised of five (5) zones. Zone III covers 15 counties including San Francisco, San Mateo, Santa Clara. All survey work performed for Caltrain shall be based upon 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 digital terrain models (DTMs) and topographic maps 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 right of way 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 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 (ASPRS) Class I and II. Caltrain, and more and more municipalities, requests mapping projects to be compliant with the NMAS (National Map Accuracy Standards) for large-scale mapping.

1.0 ACCURACIES

1.1 Horizontal Accuracy

The TABLE 9-1 below 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 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. 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

<table>
<thead>
<tr>
<th>Scale</th>
<th>Engineering Scale</th>
<th>National Map Accuracy Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:480</td>
<td>1”=40’</td>
<td>+/- 1.33 feet</td>
</tr>
<tr>
<td>1:600</td>
<td>1”=50’</td>
<td>+/- 1.67 feet</td>
</tr>
<tr>
<td>1:1,200</td>
<td>1”=100’</td>
<td>+/- 3.33 feet</td>
</tr>
<tr>
<td>1:2,400</td>
<td>1”=200’</td>
<td>+/- 6.67 feet</td>
</tr>
<tr>
<td>1:4,800</td>
<td>1”=400’</td>
<td>+/- 13.33 feet</td>
</tr>
<tr>
<td>1:9,600</td>
<td>1”=800’</td>
<td>+/- 26.67 feet</td>
</tr>
<tr>
<td>1:12,000</td>
<td>1”=1000’</td>
<td>+/- 33.33 feet</td>
</tr>
<tr>
<td>1:24,000</td>
<td>1”=2000’</td>
<td>+/- 40.00 feet</td>
</tr>
</tbody>
</table>

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

The following TABLE 9 -2 depicts various mapping scales and their applications.

TABLE 9 - 2 MAPPING APPLICATIONS

<table>
<thead>
<tr>
<th>MAP SCALE</th>
<th>CONTOUR INTERVAL</th>
<th>MAPPING APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”= 20’</td>
<td>1 foot</td>
<td>Grade Crossing, Bridge, and Station Sites for Final Design</td>
</tr>
<tr>
<td>1”= 40’</td>
<td>2 foot</td>
<td>Standard Maps for Engineering Design (Preliminary Engineering and Plans, Specifications and Estimates)</td>
</tr>
<tr>
<td>1”= 100’</td>
<td>5 foot</td>
<td>Standard Maps for Environmental Studies, Feasibility Studies, Planning, and Conceptual Engineering</td>
</tr>
<tr>
<td>1”= 200’</td>
<td>10 foot</td>
<td>Corridor Studies</td>
</tr>
</tbody>
</table>

3.0 ORTHOPHOTOGRAPHY

In digital orthophotography, pixel resolution correlates with map scale. The TABLE 9 - 3 below 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

<table>
<thead>
<tr>
<th>TARGET MAP SCALE</th>
<th>ORTHOPHOTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in = x ft</td>
<td>Ratio, ft/ft</td>
</tr>
<tr>
<td>40</td>
<td>1:480</td>
</tr>
<tr>
<td>50</td>
<td>1:600</td>
</tr>
<tr>
<td>100</td>
<td>1:1,200</td>
</tr>
<tr>
<td>200</td>
<td>1:2,400</td>
</tr>
<tr>
<td>400</td>
<td>1:4,800</td>
</tr>
</tbody>
</table>

REFERENCE FOLLOWS
CHAPTER 9 REFERENCE

A. RIGHT-OF-WAY

1.0 GENERAL

The phrase “right-of-way” 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 right-of-way (ROW) is dependent on many variables, and the determination of the right-of-way 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 right-of-way 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 right-of-way 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 right-of-way has to answer.

1.1 Caltrain Right-of-way

The Caltrain corridor is a right-of-way 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 right-of-way was owned by the San Francisco and San Jose Railroad, a single track system. Several line changes and curve revisions have occurred along the right-of-way 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 right-of-way 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 right-of-way is sometimes interrupted by the acquisition of private or public parcels of land that adjoin the original right-of-way. 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.

Right-of-way engineers work in conjunction with the Caltrain Real Estate Department and the Caltrain Engineering Department to determine existing right-of-way conditions and assess right-of-way 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 recorders 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 right-of-way 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 “right-of-way” is generally referring to an easement, but the railroad's adopted this phrase to describe their property. So those portions of the railroad property that were acquired through an easement are quite literally, right-of-way.

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 non-transferable 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

Right-of-way 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 right-of-way requirements are temporary, while other right-of-way requirements are permanent as dictated by operating and maintenance needs. The intent is to acquire and maintain the minimum right-of-way required consistent with the operating requirements of the Caltrain system. Because right-of-way plans approved by the agency are used as a basis for acquisition of property, all interests and uses required shall be shown on the right-of-way plans together with the detailed property dispositions.
The proposed right-of-way 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 right-of-way shall be preserved, and additional right-of-way 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 right-of-way requirements and to calculate areas of ownerships, right-of-way requirements, excesses, and remainders as a basis for all R/W maps and descriptions. Since Caltrain’s survey control network and its railroad design criteria are based on the California Coordinate System, right-of-way calculations must also be based on the California Coordinate System. Products, deliverables and calculations having to do with right-of-way engineering will be based on the California Coordinate System, the NAD 83 horizontal datum and the 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 right-of-way requirements (California Coordinate System) for:

i. Partial acquisition parcels.
ii. Total acquisitions with a boundary line coincident with the right-of-way 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 Right-of-way Engineer.

2.2.1 Preliminary Right-of-Way Assessment

A Preliminary Right-of-way 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 Right-of-way Assessment, if requested by the Caltrain, shall be performed at the preliminary engineering stage of all projects to identify right-of-way impacts. The preliminary right-of-way 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 Right-of-Way Mapping that may have been prepared in and around subject property, which may influence the location of subject property.

g. Gather all SP Right-of-Way 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 right-of-way 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 right-of-way mapping gathered and prepare an electronic file of this record right-of-way.

k. The base map and resulting ROW will be prepared from available record deeds and record mapping and available topographic information.

A Preliminary Right-of-way Assessment is meant to be a tool for assessing property issues during the conceptual stage of an improvement project. A Preliminary Right-of-way Assessment process is not a boundary survey and is not designed to be used in replacement of, or in conflict with, state law and local law regarding boundary surveying.

2.2.2 Right-of-Way Boundary Resolution

Right-of-way boundary resolution shall be performed at the final design stage for projects with definite right-of-way takes and permanent easements. The right-of-way 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 right-of-way, 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 right-of-way 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 right-of-way lines. This procedure assists the Title Company greatly and minimizes the cost of Preliminary Title Report preparation.

h. Field verification of records

2.2.3 Legal Descriptions

The preparation of legal descriptions and plat maps for right-of-way 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 right-of-way takes shall be clearly identified in the right-of-way 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.


b. Right-of-way exhibits clearly define areas of right-of-way takes.

c. Right-of-way appraisal maps and record maps.

A legal description prepared for the Caltrain will consist of two (2) 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 utilizes 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:

i. North arrow  
ii. Legend  
iii. Point of beginning  
iv. Point of commencement if applicable  
v. Thicker line indicating the land being described  
vi. Adjoiner record deed or map information  
vii. Relevant record deed or map data on the subject parcel of land  
viii. Adjacent street names, right-of-way lines and right-of-way widths  
ix. Distances and bearings of all lines along the land being described  
x. Relevant bearings or distances to adjoiners  
xi. Area of described land  
xii. Stamp and signature of the licensed California land surveyor responsible for the map  
xiii. Title block  
xiv. Date  
xv. Scale  
xvi. Title or name of the land being described  
xvii. Assigned Caltrain Real Estate Department Parcel Number  
xviii. Plat Map prepared on an 8.5 x 11 or 8.5 x 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 under utilized existing rail corridors or properties and to explore all appropriate means for acquisition and preservation of those corridors or properties. Preserving right-of-way for commuter rail use can be accomplished through various methods including:

a. Donations  
b. Dedications  
c. Transportation Impact Mitigations  
d. Advance Right-of-way Purchase
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 right-of-way.

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 in order 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 (Caltrans) 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, or NAD 27, is based upon Clarke’s Spheroid of 1866. The origin of this datum is the triangulation station at Meade’s Ranch in Kansas. The orientation was the geodetic azimuth from the Station at Meade’s Ranch Kansas to the Station at Waldo in the town of Waldo, Kansas.

With the launching of satellites, the NAD 27 horizontal datum was rendered unusable. All near-earth satellites orbit around the center of the earth’s mass, so an ellipsoid for satellite positioning had to have its origin at the center of mass. The Clarke Spheroid of 1866 had its center roughly 300 meters away from the center of the earth’s mass.
In recent years, better mathematical models have been developed by the National Geodetic Survey (NGS) and the U.S. 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 WGS 84 that is based upon 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 (BIH) terrestrial system of 1984 (BTS-84).

The NGS or National Geodetic Survey developed the North American Datum of 1983 (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 this NAD 83 or North American Datum of 1983, and all geodetic surveying work performed for Caltrain shall adhere to this datum. State Code of the State of California requires surveyors to utilize NAD 83 as the reference frame for geodetic surveys. In addition, all Plane Surveying performed on the PCJPB’s rail corridor should be tied to this reference frame.

GPS software utilizing 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 HARN, the national CORS network, or calculated from either a HARN or CORS. HARN’s and CORS are from different adjustments and should not be utilized 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 (NSRS). The NGS will be combining all control points, both HARN and CORS points under this one system. At that time, Caltrain will begin to utilize 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 re-calculated and became known as the 1998.5 epoch. Much of the geodetic survey work completed in southern California is on this epoch. In northern California we are presently using the 2002 epoch. After the 2004 San Simeon earthquake, the NGS and the California Spatial Reference Center (CSRC) published a new epoch known as the 2004.0 epoch.

Currently there are plans by the NGS to publish a 2007.0 epoch and the CSRC would be moving all of it data from the 2004.0 epoch to this new 2007.0 epoch. Caltrain will be
specifying this epoch, the 2007.0 epoch, 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 North American Vertical Datum of 1988 (NAVD 88) is a vertical network defined by one (1) station, Father Point/Rimouski, which is an International Great Lakes Datum (IGLD) water-level station located at the mouth of the St. Lawrence River in Quebec, Canada. This one (1) station mean sea level elevation was held fixed in a minimally constrained least-squares adjustment performed by the NGS. Because only one (1) 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 utilize 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 North American Vertical Datum of 1988 or NAVD 88 as established by the National Geodetic Survey. All scope of services developed for Caltrain shall be specified as NAVD 88 vertical datum based projects.
Control surveys performed for Caltrain will utilize 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 utilizing RTK or GPS derived elevation data.

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 FGCS 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 (3) 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 California Coordinate System (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 utilizing 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. 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. Thus while 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.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Engineering Scale</th>
<th>National Map Accuracy Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:480</td>
<td>1&quot;=40'</td>
<td>+/- 1.33 feet</td>
</tr>
<tr>
<td>1:600</td>
<td>1&quot;=50'</td>
<td>+/- 1.67 feet</td>
</tr>
<tr>
<td>1:1,200</td>
<td>1&quot;=100'</td>
<td>+/- 3.33 feet</td>
</tr>
<tr>
<td>1:2,400</td>
<td>1&quot;=200'</td>
<td>+/- 6.67 feet</td>
</tr>
<tr>
<td>1:4,800</td>
<td>1&quot;=400'</td>
<td>+/- 13.33 feet</td>
</tr>
<tr>
<td>1:9,600</td>
<td>1&quot;=800'</td>
<td>+/- 26.67 feet</td>
</tr>
<tr>
<td>1:12,000</td>
<td>1&quot;=1000'</td>
<td>+/- 33.33 feet</td>
</tr>
<tr>
<td>1:24,000</td>
<td>1&quot;=2000'</td>
<td>+/- 40.00 feet</td>
</tr>
</tbody>
</table>

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 National Map Accuracy Standards, 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 National Map Accuracy Standards (NMAS) for large-scale mapping.

The American Society of Photogrammetry and Remote Sensing (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 or 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 chart depicts various mapping scales and their applications.
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.

<table>
<thead>
<tr>
<th>TARGET MAP SCALE</th>
<th>ORTHOPHOTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in = x ft</td>
<td>1:480</td>
</tr>
<tr>
<td>50</td>
<td>1:600</td>
</tr>
<tr>
<td>100</td>
<td>1:1,200</td>
</tr>
<tr>
<td>200</td>
<td>1:2,400</td>
</tr>
<tr>
<td>400</td>
<td>1:4,800</td>
</tr>
</tbody>
</table>

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 (TSSS), 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 right-of-way 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 right-of-way 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 right-of-way
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 right-of-way lines
   ii. For lines parallel to right-of-way: location ties necessary to show relationship to the right-of-way lines
   iii. Vents
   iv. Angle points
   v. Meter vaults, valve pits, etc.

b. Water and Sewer Lines
   i. Intersection point with centerlines and/or right-of-way lines
   ii. For lines parallel to right-of-way: location ties necessary to show relationship to the right-of-way 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 right-of-way lines
   iv. For lines parallel to right-of-way: location ties as necessary to show relationship to the right-of-way lines

END OF REFERENCE
END OF CHAPTER
# APPENDIX A

## ABBREVIATIONS

### A
- **A** - Vertical Acceleration
- **AAR** - Association of American Railroads
- **AASHTO** - American Association of State Highway and Transportation Officials
- **ABS** - Automatic Block System
- **ac** - Alternating Current
- **AC** - Asphalt Concrete
- **AC Transit** - Alameda-Contra Costa Transit District
- **ACE** - Altamont Commuter Express
- **ACI** - American Concrete Institute
- **ACTS** - Advanced Train Control System
- **ADA** - Americans with Disabilities Act
- **ADAAG** - Americans with Disabilities Act Accessibility Guidelines
- **ADT** - Average Daily Traffic
- **AG** - Average Grade
- **AIM** - Advance Information Management
- **AISC** - American Institute of Steel Construction
- **AISI** - American Iron and Steel Institute
- **AMP** - Ampere
- **AMTRAK** - National Passenger Railroad Corporation
- **ATCS** - Advanced Train Control System
- **ANSI** - American National Standards Institute
- **APC** - American Power Conversion
- **API** - American Petroleum Institute
- **AREA** - American Railway Engineering Association
- **AREMA** - American Railroad Equipment and Maintenance of Way Association
- **ASCE** - American Society of Civil Engineers
- **ASHRAE** - American Society of Heating, Refrigerating and Air-Conditioning Engineers, Incorporated
- **ASME** - American Society of Mechanical Engineers
- **ASPRS** - American Society of Photogrammetry and Remote Sensing
- **ATCS** - Advanced Train Control System
- **AWG** - American Wire Gage
- **AWPA** - American Wood Preservers Association
- **AWS** - American Welding Society
- **AWWA** - American Water Works Association

### B
- **BAA** - Boarding Assistance Area
- **BAAQD** - Bay Area Air Quality District
- **BART** - Bay Area Rapid Transit District
- **BER** - Bit Error Rate
- **BDS** - (Caltrans) Bridge Design Specifications Manual
- **BICSI** - Building Industries Consulting Services International
- **BIH** - Bureau International de l’Heuer
- **BMP** - Best Management Practices
- **BTU** - British Thermal Unit
- **BVC** - Beginning of Vertical Curve

### C
- **C** - Celcius
- **CADD** - Computer-Aided Design And Drafting
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<td>MOW</td>
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<td>Potential of Hydrogen</td>
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<td>Passenger Needed Assistance</td>
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<td>Received Signal Strength Indicator</td>
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APPENDIX B

PCJPB/CALTRAIN STANDARDS AND REFERENCES

1.0 PCJPB General Provisions
2.0 PCJPB Special Conditions
3.0 Caltrain Design Criteria
4.0 Caltrain Standard Drawings
5.0 Caltrain Standard Specifications
6.0 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
9.0 Caltrain Safety And Security Certification Program Plan
Capital Project Operations Planning Support

Caltrain JPB Work Directive No. 2999
SYSTRA Project No. 5592

Signal System Headway/Capacity Study

Task 1
Quantification of Signal System Headway and Capacity Constraints

Submitted By

December 31, 2005
Revised February 10, 2006
1.0 INTRODUCTION

The achievable headways and capacities of a commuter-railroad signal system affect both train scheduling and train operations.

Ideally, trains should be scheduled far enough apart (in terms of time) so that there are no signal delays under normal on-time operations. And when one moving train is following another moving train, the signal system (signal locations, block lengths and signal-aspect sequences) keeps the following train a significant distance and time interval behind the preceding train.

If trains are scheduled closer together than the signal system can accommodate at the Maximum Authorized Speed (MAS), trains will encounter signal delays even under normal/ideal conditions. While not desirable, some high-density commuter railroads do schedule “built-in” signal delays in order to achieve the optimum capacities of their rail systems (at intermediate speeds that are less than the Maximum Authorized Speed). This is quite common on the Long Island Rail Road (LIRR), and their published peak-period scheduled running times (especially between Jamaica and Manhattan) reflect the expected level of signal delays.

SYSTRA prepared and issued the Task 4.1 “Signal System Study – Updated Signal System Headways” report dated November 11, 2003 to support SYSTRA’s and Caltrain’s efforts in preparing the new “Caltrain Express/Baby Bullet” timetable schedules. That 2003 report was based on the CTC signal-system design as it “stood” in early 2003, and that report did not reflect the As-Built signal system. Because of safety checks and other analyses that were performed of the signal-system design during the same 2003 time frame, some signal locations were “moved” and some signal-aspect sequences were modified after the 2003 Task 4.1 report was issued.

SYSTRA and Caltrain recently agreed that the 2003 Signal System Headway report needed to be updated to reflect the As-Built signal system and plans, and this new report presents the Signal System Headway and Capacity Constraints of the As-Built CTC Signal System.

2.0 METHODOLOGY

Specialized Train Performance Calculator (TPC) simulations were processed to quantify the signal-system headway characteristics of the As-Built signal layout and signal-aspect sequences for same-direction express and local trains by individual wayside signal.

The Theoretical Headway constraint of a signal is defined as the time interval from when the head-end of a train passes the signal displaying a particular favorable aspect (usually
Clear) until that same signal again displays that same aspect for a following train. Theoretical (signal-system) Headways are not achievable or stable. When a signal aspect “upgrades” just as the head-end of a train passes it, the engineer (at that moment) is no longer in a position to see the signal-aspect upgrade.

For wayside signaling without cab signaling such as exists at Caltrain, SYSTRAs defines the Practical Headway constraint of a signal to be the Theoretical Headway constraint plus an additive of at least 1 minute for local trains and at least 1.5 minutes for non-stop trains. This minimum additional 1.0 to 1.5 minutes not only allows for signal “sighting”, but also provides for a minimum level of operational reliability when trains operate on close headways. Please be reminded that when a following train encounters signal delay because of a preceding train, the following train must slow down to comply with the signal aspect(s) displayed. Since the following/second train is being delayed by restrictive signals, the time and distance separation between the two trains is normally continually increasing when the second/following train is operating under signal delay from the first train. When the signals again display Clear for the second/following train allowing it to accelerate back to the MAS speed, the following train winds up being spaced behind its leader by a time interval that is greater than the Theoretical Headway constraints.

On a commuter railroad, the Theoretical and Practical Headways of individual signals are directly affected by the station-stopping pattern and by the station-dwell times. (This is not the case on most transit systems, where all trains operating on a given track typically make the same station stops, and where the station-dwell times for all trains operating on the same track at a given station are assumed to be the same.)

Non-stop express trains generally have the shortest signal-system headways and all-stop local trains generally have the longest signal-system headways. The station-dwell times used in our calculations are based on the Caltrain Dwell-Time Study that was conducted in 2000.

As will be explained in more detail later in this report, the signal-system headway constraints for following trains can be somewhat affected/increased by any delays inherent in the signal system, especially when electronic track circuits are used without line circuits (as they are at Caltrain) between successive interlockings. These signal-system delays have been included in the Theoretical Headway and Practical Headway results presented in this report.

The TPC simulation output was analyzed to determine whether two express trains not making any station stops could be scheduled 4 minutes apart without the following train being delayed. For this to be feasible, the Clear/Green Theoretical Headways should generally all be no greater than 2.5 minutes (the Clear/Green Practical Headways should generally all be no greater than 4.0 minutes). This report identifies those signals for which
the Clear/Green Theoretical and Practical Headways between express trains exceed 2.5 minutes and 4.0 minutes respectively.

The TPC simulation output was also analyzed to determine whether two local trains making all of the typical local station stops could be scheduled 5 minutes apart without the following train being delayed. For this to be feasible, the Advance Approach/Flashing Yellow (AA/FY) Theoretical Headways should generally all be no greater than 4.0 minutes (the Advance Approach/Flashing Yellow Practical Headways should generally all be no greater than 5.0 minutes). This report identifies those signals for which the AA/FY Theoretical and Practical Headways between local trains exceed 4.0 minutes and 5.0 minutes respectively.

Normally, all signal-system headways are computed based on trains operating under Clear/Green signal aspects. However, as will be seen later in this report, the Caltrain signal-system headways for Clear/Green signal aspects to be displayed behind local trains are unusually long in duration. This is because of the relatively close station “spacings” between San Francisco and San Jose in concert with the signal-block lengths, which cause more than one station to be located within the Clear/Green “control line” of many signals.

The close station “spacings” at Caltrain do minimize the attainable speeds between successive station stops. Fortunately, the 50-mph Limited Speed prescribed by the AA/FY signal aspect marginally permits local trains to maintain the scheduled running times. This, in turn, makes it reasonable to calculate all-stop local-train signal-system headways (both theoretical and practical) based on the AA/FY signal aspect and not on the Clear/Green signal aspect as is usually done. Thus, the local-train headways reported herein are based on operating under a low level of signal delay.

Each station-stopping pattern has its own unique signal-system headway characteristics, since each station-stopping pattern requires a different amount of time for a train to operate the length of a signal’s control line. However, it is not deemed practical to compute (and use for train scheduling) a large number of signal-system headway tabulations. Instead, it is common to compute the signal-system headways for both express/non-stop and local/all-stop (the two extreme) operating patterns as we have done for Caltrain, and to use these signal-system constraints as a guide when preparing train schedules and timetables, which timetables may include a mix of local, express, skip-stop and zone station-stopping schedule operating patterns.

As this report will demonstrate, there are many signals for which the Clear/Green Practical Headway constraint between express trains exceeds 4.0 minutes, and for which the AA/FY Practical Headway constraint between local trains exceeds 5.0 minutes.

These larger than desirable signal-system headways do occur in the commuter-railroad industry when signal systems are designed not just for passenger trains, but also for freight
trains that have much longer safe-braking distances. The Caltrain signal system south of MP 5.2 (near the Bayshore Station) was designed for a freight-train MAS of 50 mph because of Caltrain’s contractual responsibilities to the UPRR.

As with any signal system, trains should not be scheduled closer together than can be supported by the signal locations and signal-aspect sequences. As will be seen, the Caltrain signal-system headway constraints vary significantly by location and by direction. This report provides the information that is necessary to properly schedule trains with respect to the many signal-system headway constraints that currently exist.

This report also identifies the signals that have the longest (worst-case) headway constraints, which information can and will be used under Task 2 to develop signal-system improvements that will be designed to reduce the longest headway constraints and thereby increase overall line capacity.

The headway “benchmarks” for signal-system analysis previously stated in this report of 2.5-minute Theoretical Headways and 4.0-minute Practical Headways for express/non-stop trains, and 4.0-minute Theoretical Headways and 5.0-minute Practical Headways for local/all-stop trains, are somewhat arbitrary. During the review of this report with Caltrain, Caltrain will be able to direct SYSTRA to use shorter or longer headway “yardsticks” during Task 2, under which we will be developing site-specific modifications to the existing signal system for the purpose of enhancing and optimizing the signal-system headways and capacities.

We previously presented definitions for Theoretical Headway and Practical Headway. Theoretical Capacity for a particular stopping pattern is defined to be:

\[
\text{Theoretical Capacity} = \frac{60 \text{ minutes}}{\text{Theoretical Headway (in minutes)}},
\]

with the result being in trains per hour.

For similar reasons to those presented earlier in this report, Theoretical Capacities are not achievable or stable.

For wayside signaling without cab signaling such as exists at Caltrain, SYSTRA defines the Practical Capacity to be:

\[
\text{Practical Capacity} = 0.9 \left( \frac{60 \text{ minutes}}{\text{Practical Headway}} \right),
\]

with the result again being in trains per hour.
The 90% factor has been chosen to provide for a minimum level of operational reliability when many successive trains are operated on close headways.

Track capacity is very complex and dependent on the mix of train traffic that is operated. If all of the signals on a route supported an express-train Practical Headway of 4 minutes, our estimate of Practical Capacity would be $0.9(60/4) = 13.5$ trains per hour. The express trains in this illustration do not make any intermediate station stops – no Millbrae, no Hillsdale, etc.

If all of the signals on a route supported a local-train Practical Headway of 5 minutes, our estimate of Practical Capacity would be $0.9(60/5) = 10.8$ trains per hour.

Mixing trains of dissimilar average operating speeds (without scheduling overtakes) would (depending on the level of signal delays that is tolerated) generally result in a Practical Capacity that is much less that the lower of the two values - much less than 10.8 trains per hour.

It is for this reason that zone trains typically use significant amounts of capacity when interspersed between local trains.

Passing tracks (such as those constructed at Caltrain) allow trains with dissimilar operating speeds to be operated while reducing the amount of capacity required/used by such trains.

In summary, line capacity is a very complex issue that is affected by the line configuration and availability of passing tracks, by the types of trains and schedule patterns operated, by the traffic mix, and by how “cleverly” the trains are scheduled.

3.0 SIGNAL-SYSTEM DELAYS WHEN SIGNAL ASPECTS UPGRADE

When electronic track circuits are used instead of line circuits, as they are at Caltrain, there is a propagation delay (“tumble-up”) time in upgrading following signal aspects behind a train. In consultation with Caltrain, Southwest Signal Engineering Company (SWE) (Caltrain’s Signal Engineering Consultant) and Harmon (the equipment supplier) in late 1999, and based upon more recent information from SWE, it was agreed that we would assume the following typical signal-system delays for non-interlocking track circuits in our signal-system headway analyses when there are no extra cut-sections:

1) The Red aspect upgrades to a Yellow aspect 4 seconds (0.067 minutes) after the block is cleared.

2) The Yellow aspect upgrades to a Flashing Yellow aspect another 4 seconds later, or a total of 8 seconds (0.133 minutes) after the next "downstream" block is cleared.
3) The Flashing Yellow aspect upgrades to a Green aspect another 4 seconds later, or a total of 12 seconds (0.200 minutes) after the "second-downstream" block is cleared.

4) For each additional non-interlocking electronic track circuit involved, the upgrading time increases by 4 seconds (0.067 minutes).

The above illustration and explanation are for the typical sequence of aspects approaching an occupied block, and do not apply to interlocking track circuits, which we have been advised “pass through” signal-logic upgrades much more quickly. Our calculations that are presented in this report reflect the site-specific track-circuit configurations and signal-aspect sequences that exist at each location.

Commuter railroads such as the LIRR and MetroNorth do not use electronic track circuits on lines with high traffic volumes. They use conventional track circuits with line circuits, which cause signals to upgrade almost instantaneously as trains vacate downstream blocks. The same is true for Amtrak on the high-density portions of the Northeast Corridor (NEC). In addition, the LIRR, MetroNorth and Amtrak only provide 5 seconds of loss-of-shunt (LOS) protection within interlockings (the minimum required by 49CFR236.309) versus the 10 seconds provided at Caltrain.

In recent (2005) conversations with GE Transportation (who purchased Harmon), we were advised that the Electro Code 5 signal-aspect upgrades may be somewhat slower than reported herein.

4.0 TPC SPEED TABLES

The southbound and northbound TPC speed tables for all six of the TPC simulations that were processed are presented in Exhibit 1. The first two pages are the express-train speed tables – southbound first and northbound second. The third and fourth pages are the local-train speed tables based on the Clear/Green signal aspect being displayed. The fifth and sixth pages are the local-train speed tables based on the Advance Approach/Flashing Yellow signal aspect being displayed permitting train movements to be made at the 50-mph passenger-train Limited Speed.

The TPC speed tables are based on the current Caltrain “employee-timetable” maximum speeds and speed restrictions.
5.0  **TPC SPEED VERSUS LOCATION PLOTS**

The southbound and northbound TPC speed versus location plots for all six of the TPC simulations that were processed are presented in Exhibit 2. The first two pages are the express-train speed plots – southbound first and northbound second. The third and fourth pages are the local-train speed plots based on the Clear/Green signal aspect being displayed. The fifth and sixth pages are the local-train speed plots based on the Advance Approach/Flashing Yellow signal aspect being displayed.

The TPC speed plots reflect the TPC speed tables and are based on the current Caltrain “employee-timetable” maximum speeds and speed restrictions.

6.0  **SIGNAL-SYSTEM HEADWAYS BETWEEN NON-STOP EXPRESS TRAINS**

6.1  **Southbound Non-Stop Express-Train Headway Constraints**

Exhibit 3 presents a 4-page tabulation of the southbound signals and the Practical Headways of each individual signal for non-stop express trains, and these values include the signal-system delays previously discussed. All Practical Headways in excess of 4.0 minutes are shown in the color red. The “Signal Aspect” column lists the minimum signal aspect that we believe is necessary for the following train not to be delayed. For CP 4th Street, we assumed a 15-mph route with Reduced Slow Speed signal aspects being displayed.

Please note that the signal-system delay times because of the electronic track circuits (which increase signal-system headways) are as much as 16 to 20 seconds (0.27 to 0.33 minutes) for many signals, which is not operationally desirable.

These non-stop express-train headways only directly apply when two successive trains are operating non-stop through an area.

Following the 4-page tabulation is a “bar chart” that graphically depicts the signal-system headways in geographical sequence.

Following the first “bar chart” is a second “bar chart” that graphically depicts the signal-system headways in a “worst-signal-longest-headway to best-signal-shortest-headway sequence”.

The signal-system headways reported for CP Franklin Signal 4S, CP Stockton Signal 8Ea, CP Julian Signal 6Ea and CP West Cahill Signal 14E are all based on the following/second train being routed to a different track at Diridon Station. The assumed route-reset time used
in our calculations is 23 seconds, which includes Caltrain’s 10-second LOS protection. The other 13 seconds allow for code transmission times, human reaction times, switch “throw” times, etc.

For the arbitrary 4.0-minute Practical Headway benchmark, there are up to 20 signal-system headways that need to be reduced.

Signal-system headways can be improved by classical techniques such as by reducing or eliminating the electronic-track-circuit delays, changing signal-aspect sequences, moving signals, and/or adding signals. These options as well as the headway benchmarks to be applied will be discussed during the review of this report. The Task 2 work will be based on the decisions and technical direction emanating from these discussions.

6.2 Northbound Non-Stop Express-Train Headway Constraints

Exhibit 4 presents a 4-page tabulation of the northbound signals and the Practical Headways of each individual signal for non-stop express trains, and these values include the signal-system delays previously discussed. All Practical Headways in excess of 4.0 minutes are shown in the color red. The “Signal Aspect” column lists the minimum signal aspect that we believe is necessary for the following train not to be delayed. For CP 4th Street, we assumed a 20-mph route with Slow Speed signal aspects being displayed.

For CP Common, we also assumed (and included in our calculations) the recently approved most-favorable-signal-aspect changes to Approach Slow (Y/Y/R) for the straight moves and Medium Approach Slow (R/Y/Y) for the diverging moves, which require a reduction from 40 mph to 35 mph upon passing the CP Common northbound signals.

Please note that the signal-system delay times because of the electronic track circuits (which increase signal-system headways) are as much as 16 to 20 seconds for many signals, which is not operationally desirable.

These non-stop express-train headways only directly apply when two successive trains are operating non-stop through an area.

Following the 4-page tabulation is a “bar chart” that graphically depicts the signal-system headways in geographical sequence.

Following the first “bar chart” is a second “bar chart” that graphically depicts the signal-system headways in a “worst-signal-longest-headway to best-signal-shortest-headway sequence”.

The signal-system headways reported for CP Common Signal 2N and CP 4th Street Signal 80L are both based on the following/second train being routed to a different track at the 4th
and King Station. The assumed route-reset time used in our calculations is 23 seconds, which includes Caltrain’s 10-second LOS protection.

For the arbitrary 4.0-minute Practical Headway benchmark, there are up to 23 signal-system headways that need to be reduced.

### 7.0 SIGNAL-SYSTEM HEADWAYS BETWEEN LOCAL TRAINS

#### 7.1 Southbound Local-Train Headway Constraints

Exhibit 5 presents a 4-page tabulation of the southbound signals and the Practical Headways of each individual signal for all-stop local trains, and these values include the signal-system delays previously discussed. All Practical Headways in excess of 5.0 minutes are shown in the color red. The “Signal Aspect” column lists the minimum signal aspect that we believe is necessary for the following train not to be delayed below the passenger-train 50-mph Limited Speed. (This 50-mph criterion was applied north of CP Michael.) For CP 4th Street, we assumed a 15-mph route with Reduced Slow Speed signal aspects being displayed.

The TPC calculations presented in Exhibit 5 are based on the assumption that a train will operate at 50 mph (or the MAS when it is less than 50 mph) when traversing a block governed by a FY aspect.

These local-train headways apply when two successive trains make common station stops. These signal-system headways are based on trains making all of the common station stops. This excludes Broadway, Atherton and College Park.

Following the 4-page tabulation is a “bar chart” that graphically depicts the signal-system headways in geographical sequence.

The tabulation and the first “bar chart” include the signaling south of Diridon Station to CP Lick.

Following the first “bar chart” is a second “bar chart” that graphically depicts the signal-system headways in a “worst-signal-longest-headway to best-signal-shortest-headway sequence”. The second “bar chart” does not include the signals south of Diridon Station because short headways are not required in that area.

The signal-system headways reported for CP Stockton Signal 8Ea, CP Julian Signal 6Ea and CP West Cahill Signal 14E are all based on the following/second train being routed to a different track at Diridon Station. The assumed route-reset time used in our calculations is 23 seconds.
For the arbitrary 5.0-minute Practical Headway benchmark, there are up to 25 signal-system headways that need to be reduced.

SYSTRA recommends changing the local-train headway benchmark to a 6.0-minute Practical Headway, which would require up to 5 signal-system headways (a more manageable number) to be reduced. Otherwise, we are talking about a major redesign of the signal system and not just “spot” improvements.

The 7.93-minute Practical Headway reported for CP Mary Signal 4S is based on waiting for a Y/FG/R (AL) aspect to be displayed (requiring three blocks to be unoccupied) and not predicing the calculations on a Y/G/R (AM) aspect requiring two blocks to be unoccupied). Our analysis has indicated that the Y/G/R (AM) aspect may be sufficient in this case. In any case, we will be recommending during Task 2 that CP Mary Signal 4S display FY/R/R (AA) when the next CP Hendy Signal 4S displays R/Y/R (MA). This change would allow a train to operate through the entire block at Limited Speed and would provide a “better” and more-definitive warning that the train must stop in two blocks.

We thought that Caltrain may be interested in knowing the local-train Practical Headways for operation under Clear/Green signal aspects. These results are included as Exhibit 6. As can be seen, the Green/Clear local-train headways are very large (many are above 8 minutes), and we recommend using the 50-mph headways presented in Exhibit 5 instead, which are based on operating under some signal delay.

### 7.2 Northbound Local-Train Headway Constraints

Exhibit 7 presents a 4-page tabulation of the northbound signals and the Practical Headways of each individual signal for all-stop local trains, and these values include the signal-system delays previously discussed. All Practical Headways in excess of 5.0 minutes are shown in the color red. The “Signal Aspect” column lists the minimum signal aspect that we believe is necessary for the following train not to be delayed below the passenger-train 50-mph Limited Speed. (This 50-mph criterion was applied north of CP Michael.) For CP 4th Street, we assumed a 20-mph route with Slow Speed signal aspects being displayed.

The TPC calculations presented in Exhibit 7 are based on the assumption that a train will operate at 50 mph (or the MAS when it is less than 50 mph) when traversing a block governed by a FY aspect.

For CP Common, we also assumed (and included in our calculations) the recently approved most-favorable-signal-aspect changes to Approach Slow (Y/Y/R) for the straight moves and Medium Approach Slow (R/Y/Y) for the diverging moves, which require a reduction from 40 mph to 35 mph upon passing the CP Common northbound signals.
These local-train headways apply when two successive trains make common station stops. These signal-system headways are based on trains making all of the common station stops. This excludes Broadway, Atherton and College Park.

Following the 4-page tabulation is a “bar chart” that graphically depicts the signal-system headways in geographical sequence.

The tabulation and the first “bar chart” include the signaling south of Diridon Station to CP Lick

Following the first “bar chart” is a second “bar chart” that graphically depicts the signal-system headways in a “worst-signal-longest-headway to best-signal-shortest-headway sequence”. The second “bar chart” does not include the signals south of Diridon Station because short headways are not required in that area.

The signal-system headways reported for CP Common Signal 2N and CP 4th Street Signal 80L are both based on the following/second train being routed to a different track at the 4th and King Station. The assumed route-reset time used in our calculations is 23 seconds, which includes Caltrain’s 10-second LOS protection.

For the arbitrary 5.0-minute Practical Headway benchmark, there are up to 25 signal-system headways that need to be reduced.

SYSTRA recommends changing the local-train headway benchmark to a 6.0-minute Practical Headway, which would require up to 5 signal-system headways (a more manageable number) to be reduced. Otherwise, we are talking about a major redesign of the signal system and not just “spot” improvements.

We thought that Caltrain may be interested in knowing the local-train Practical Headways for operation under Clear/Green signal aspects. These results are included as Exhibit 8. As can be seen, the Green/Clear local-train headways are very large (many are above 8 minutes), and we recommend using the 50-mph headways presented in Exhibit 7 instead, which are based on operating under some signal delay.

### 8.0 ASSUMED TRAIN OPERATING SPEEDS FOR THE ADVANCE APPROACH/FLASHING-YELLOW ASPECT

It is somewhat unusual (but not unprecedented) for signal-system headway/capacity calculations on a commuter railroad to be based on other than Clear/Green signal aspects. However, because many of the stations are located very close together, local passenger trains should be able to operate under Flashing Yellow/Advance Approach aspects without
incurring any significant delays or increased trip times. Our analyses to determine local-train (but not express-train) signal-system headways are largely based on local trains only needing Advance Approach/Flashing Yellow aspects to proceed expeditiously along the railroad. Specifically, our TPC calculations are based on the assumption that passenger-train engineers will attempt to maintain the AA/FY Limited Speed of 50 mph (or the MAS when the MAS is less than 50 mph) when traversing a block governed by a FY aspect. If this assumption does not prove true in actual operations, the real-world signal-system headways may be slightly longer/worse than calculated and documented herein.

However, we believe that this is a very reasonable assumption. One reason for this belief is that SWE did not assign the AA/FY aspect to an aspect sequence unless the length of the second block was at least approximately 2,500 feet. Trains should be able to easily stop within this distance since the 50-mph safe-stopping distance under the historical CE205 Pennsylvania Railroad safe-braking criteria is only 2,083 feet. The CE205 was in effect for many decades and trains should normally be able to stop within 75% of this distance.

9.0 HEADWAY/CAPACITY EVALUATION CRITERIA

The signal-system-headway-evaluation criteria that has been used in this study is slightly aggressive but in line with our years of experience in using and applying Publication 405-1/R of the International Union of Railways (UIC), which is titled “Method to be Used for the Determination of the Capacity of Lines”. The standards and formulas contained in this UIC manual are the result of actual research and experiments, and are used and endorsed by many railroads around the world.

10.0 CONCLUDING COMMENTS

This report presents the results of Task 1 – Quantification of Signal System Headway and Capacity Constraints. The scope of Task 2 is to Enhance and Optimize the Existing Signaling (reduce the governing signal-system headways and increase capacity) by making “spot” improvements using classical/standard techniques. This includes such things as reducing or eliminating the electronic-track-circuit delays, changing signal-aspect sequences, moving signals, and/or adding signals.

This Task 1 report will be reviewed with Caltrain and these options as well as the headway benchmarks to be applied will be discussed. The Task 2 work will be based on the decisions and technical direction emanating from these discussions.

The results of Task 2 will be the identification of modified signal-system configurations (signal locations, aspect sequences, etc.) for which the headway constraints of each and every signal on the line will conform to a maximum headway standard for the entire line.
This will ensure that the entire line supports the specified “design headway” requirements, whatever they are defined to be during our review (of Task 1) meeting with Caltrain.
Exhibit 1

TPC Speed Tables

Non-Stop Southbound

Non-Stop Northbound

Local Southbound Based on Green/Clear Aspects

Local Northbound Based on Green/Clear Aspects

Local Southbound Based on Advance Approach/Flashing Yellow Aspects

Local Northbound Based on Advance Approach/Flashing Yellow Aspects
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Exhibit 2

TPC Speed versus Location Plots

Non-Stop Southbound

Non-Stop Northbound

Local Southbound Based on Green/Clear Aspects

Local Northbound Based on Green/Clear Aspects

Local Southbound Based on Advance Approach/Flashing Yellow Aspects

Local Northbound Based on Advance Approach/Flashing Yellow Aspects
San Francisco - San Jose
Southward Express Train (Nonstop)
One MP36PH-3C Engine + 4 Bombardier Bi-Level Cars
San Francisco - San Jose

Distance from San Francisco (Miles)

Speed Limit and Simulated Train Speed (MPH)
San Jose - San Francisco
Northward Express Train (Nonstop)
One MP36PH-3C Engine + 4 Bombardier Bi-Level Cars
San Jose - San Francisco
San Francisco to MP 60 (South of Blossom Hill)

Southward Local Train - One F40PH Engine + 5 Gallery Cars
With 79-mph MAS Where Permitted
San Francisco to MP 60 (South of Blossom Hill)
MP 60 (South of Blossom Hill) to San Francisco
Northward Local Train - One F40PH Engine + 5 Gallery Cars
With 79 mph MAS Where Permitted

MP 60 (South of Blossom Hill) to San Francisco
San Francisco to MP 60 (South of Blossom Hill)

Southward Local Train - One F40PH Engine + 5 Gallery Cars

50-mph. Maximum Speed North of CP "Michael" and Up To 79-mph. South of CP "Michael"

San Francisco to MP 60 (South of Blossom Hill)

UP To 79-mph South of CP "Michael"
50-mph Maximum Speed North of CP "Michael" and Southward Local Train - One F40PH Engine + 5 Gallery Cars
MP 60 (South of Blossom Hill) to San Francisco

Northward Local Train - One F40PH Engine + 5 Gallery Cars

Up To 79 mph Limit South of CP "Michael" and
50-mph Limited Speed North of CP "Michael".

MP 60 (South of Blossom Hill) to San Francisco
Exhibit 3

Southbound Non-Stop Express-Train
Headway Constraints

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order
# Southbound Non-Stop Signal System Headways

Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways

Headway Constraints by Individual Signal

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal


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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal  

Direction: **S/B**.  
Stopping Pattern: **Non-stop**.  

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(3) Based on wayside signals without cab-signaling.
Exhibit 4

Northbound Non-Stop Express-Train
Headway Constraints

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order
## Northbound Non-Stop Signal System Headways

Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

Direction: ____ N/B ____  Stopping Pattern: ____ Non-stop ____  Page 1 of 4

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Headway Constraints by Individual Signal

Direction: N/B. Stopping Pattern: Non-stop.

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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal

Direction: N/B. Stopping Pattern: Non-stop.

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(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Exhibit 5

Southbound Local-Train Headway Constraints for Advance Approach/Flashing Yellow Signal Aspects to be Displayed

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order
Southbound All-Stop Local Signal System Headways
Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
**Caltrain Capital Project Operations Planning Support**  
**SYSTRA Project No. 5592; Task 1 - Signal System Headways**  
Headway Constraints by Individual Signal

**Direction:** S/B  
**Stopping Pattern:** Local  
**Page 2 of 4**

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.  
(2) Sum of cascading electronic-track-circuit delay times.  
(3) Based on wayside signals without cab-signaling.
Exhibit 6

Southbound Local-Train Headway Constraints for Green/Clear Signal Aspects to be Displayed

Tabulation of Signals and Associated Headways
Geographical Bar Chart of Practical Headways by Individual Signal
Bar Chart of Practical Headways by Individual Signal in Ranked Order
Southbound All-Stop Local Signal System Headways  
Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal

**Direction:** S/B  
**Stopping Pattern:** Local @ 79 mph

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal  

Direction: **S/B**. Stopping Pattern: **Local @ 79 mph**.  

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.  
(2) Sum of cascading electronic-track-circuit delay times.  
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Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

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(1) Number of track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Exhibit 7

Northbound Local-Train Headway Constraints for Advance Approach/Flashing Yellow Signal Aspects to be Displayed

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order
### Northbound All-Stop Local Signal System Headways

*Caltrain Capital Project Operations Planning Support*

**SYSTRA Project No. 5592; Task 1 - Signal System Headways**

**Headway Constraints by Individual Signal**

**Direction: N/B**  
**Stopping Pattern: Local**

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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
### Headway Constraints by Individual Signal

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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
## Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

**Direction:** N/B  
**Stopping Pattern:** Local  
**Page:** 4 of 4

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(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Exhibit 8

Northbound Local-Train Headway Constraints for Green/Clear Signal Aspects to be Displayed

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order
# Northbound All-Stop Local Signal System Headways

**Caltrain Capital Project Operations Planning Support**

**SYSTRA Project No. 5592; Task 1 - Signal System Headways**

Headway Constraints by Individual Signal

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## Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways

### Headway Constraints by Individual Signal

**Direction:** N/B  
**Stopping Pattern:** Local @ 79 mph  
**Page 2 of 4**

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</table>

(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
Caltrain Capital Project Operations Planning Support  
SYSTRA Project No. 5592; Task 1 - Signal System Headways  
Headway Constraints by Individual Signal

**Direction:** N/B  
**Stopping Pattern:** Local @ 79 mph  

<table>
<thead>
<tr>
<th>Signal</th>
<th>Signal Aspect</th>
<th>Base Theoretical Headway</th>
<th>Number of Track Circuits (1)</th>
<th>Total Delay Time (2)</th>
<th>Actual Theoretical Headway</th>
<th>Practical Headway (3)</th>
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</table>

(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
### Signal Headway Constraints by Individual Signal

**Direction:** N/B  
**Stopping Pattern:** Local @ 79 mph  

<table>
<thead>
<tr>
<th>Signal</th>
<th>Signal Aspect</th>
<th>Base Theoretical Headway</th>
<th>Number of Track Circuits (1)</th>
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<th>Actual Theoretical Headway</th>
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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.
APPENDIX C

REGULATORY AGENCIES AND INDUSTRY STANDARDS

1.0 APPLICABLE GOVERNMENT CODES AND REGULATIONS

All improvements of the facilities within the jurisdiction of the PCJPB 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 – Standard for Accessible Transportation Facilities, ADA Accessibility Guidelines for Buildings and Facilities
b. Part 192 Transportation of Natural and Other Gas by Pipeline
c. Part 195 Transportation of Hazardous Liquids by Pipeline
d. Part 213 Track Safety Standards for Class 5 Track
e. Part 214 Railroad Workplace Safety
f. Part 234 Grade Crossing Signal System 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

1.1.2 Manual of Uniform Traffic Control Devices (MUTCD)

1.2 State

a. California Department of Transportation (Caltrans)
   2. Caltrans Standard Specifications
   3. Caltrans Standard Plans
   4. Bridge Design Specifications

1.2.1 California Public Utility Commission - CPUC General Orders:

a. CPUC GO No. 26 Clearances
b. CPUC GO No. 33 Interlocking Plants
c. CPUC GO No. 36 Abolition of Services  
d. CPUC GO No. 72 At-Grade Crossings  
e. CPUC GO No. 75 Protection of Crossings  
f. CPUC GO No. 88 Rules for Altering Public Grade Crossings  
g. CPUC GO No. 95 Rules Governing Overhead Electric Line Construction  
h. CPUC GO No. 112 Utility Construction  
i. CPUC GO No. 118 Walkways Maintenance and Construction  
j. CPUC GO No. 128 Rules for Underground Electric Construction

1.2.2 State of California Codes and Code of Regulations (CCR)  
a. Title 5, Division 1, Part 1, Chapter 5.5, The Elder California Pipeline Safety Act of 1981.  
b. Title 8, Industrial Relations  
   1. California Occupational Safety and Health Administration (Cal/OSHA)  
c. Title 24, Parts 1 to 10 and Part 12, California Building Standards Code (CBSC)  
d. California Disabled Accessibility Guidebook (CalDAG)

1.2.3 State Historic Preservation Office (SHPO)

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 (ANSI)
1. 455 Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers and Other Fiber Optic Components
2. 568-B Commercial Building Telecommunications Cabling Standard
3. 569-B Commercial Building Standard for Telecommunications Pathways and Spaces – October, 2004
4. 606-A Administration Standard for the Telecommunications Infrastructure of Commercial Buildings – May, 2002
6. Z55.1 Gray Finishes for Industrial Apparatus and Equipment

f. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   1. AREMA Communications and Signals Manual and Recommended Practices
      Part 1.5.10 Recommended Instructions for Painting and Protective Coatings
   2. AREMA Manual for Railway Engineering
   3. AREMA Portfolio of Trackwork Plans

g. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)

h. American Society for Testing and Materials International (ASTM)
   3. B3 Specification for Soft or Annealed Copper Wire

i. American Welding Society (AWS)

j. Americans with Disabilities Act Accessibility Guidelines (ADAAG) for Buildings and Facilities


l. Crime Prevention Through Environmental Design (CPTED)

m. Electronic Industry Alliance (EIA)
   1. 310-D Cabinets, Racks, Panels, and Associated Equipment

n. Illuminating Engineering Society of North America (IESNA)

o. International Building Code (IBC)

p. Institute of Electrical and Electronics Engineers, Inc. (IEEE)

q. Insulated Cable Engineers Association, Inc. (ICEA)
   1. S-84-608-2002 Filled Telecommunications Cable, Polyolefin, Insulated, Copper Conductor
r. Motorola R56 grounding standard
s. National Electric Code (NEC)
t. National Electrical Safety Code (NESC)
u. National Electrical Manufacturers Association (NEMA)
   1. WC5 Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
   2. WC7 Cross Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
v. National Fire Protection Association (NFPA)
   1. 70E Standard for Electrical Safety Requirements for Employee Workplaces
   2. 71 Central Station Signaling Systems
   3. 72 National Fire Alarm Code
   4. 75 Protection of Electronic Computer Data Processing Equipment
   5. 101 Life Safety Code
   6. 130 Standard for Fixed Guideway and Passenger Rail System
   7. 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces
   9. 780 Standard for the Installation of Lightning Protection Systems
w. Rural Utilities Services (RUS)
   1. Specification for Filled Telephone Cable with Expanded Insulation (7 CFR 1755.890)
x. Safety Code For Mechanical Refrigeration (SCFMR)
y. Southern California Public Works Handbook (Green Book)
z. Telecommunications Industry Associates/ Electronic Industry Alliance (TIA/EIA)
   1. TSB67 Transmission Performance Specifications for Field Testing of Unshielded Twisted Pair Cabling Systems
   2. TSB72 Centralized Optical Cabling Guidelines
   3. TSB75 Additional Horizontal Cabling Practices for Open Offices
aa. Underwriters Laboratories (UL)
   1. 1581 Reference Standard for Electrical Wire, Cable, and Flexible Cords* UL-969, Standard for Marking and Labeling Systems
   2. 444 Communication Cables
3. 1690 Data Processing Cable
   bb. Uniform Building Code (UBC)
Appendix D

Caltrain: Caltrain Maintenance and Construction Rules, Regulations, Specifications and Procedures

OSHA Construction Part 1926

Homeland Security

Federal Railroad Administration (CFR 49)

...
APPENDIX E

CALTRAIN HISTORY AND BACKGROUND

A. PENINSULA CORRIDOR

1.0 HISTORY OF PASSENGER SERVICE

San Francisco and San Jose Railroad Company began passenger service in the peninsula corridor from San Francisco to San Jose on October 18, 1863. In 1870, the Company was acquired by the firm that was eventually consolidated into the Southern Pacific Railway. Southern Pacific double-tracked the line in 1904, and operated passenger service in the corridor successfully until after World War II. In 1977, citing declined ridership, Southern Pacific petitioned the State of California Public Utilities Commission (CPUC) to abandon the passenger service.

From 1980 until 1992, California Department of Transportation (or Caltrans), sharing operating subsidies with the San Francisco, San Mateo and Santa Clara counties, contracted with Southern Pacific to continue the service. Caltrans assumed sole responsibility for station acquisitions and other capital improvements until the formation of the Peninsula Corridor Joint Powers Board (PCJPB) in 1987.

2.0 CALTRAIN COMMUTER RAIL SERVICE

PCJPB assumed the operating responsibilities for the commuter rail service or Caltrain effective July 1, 1992, and began to shoulder 100 percent of the operating subsidy a year later.

In December 1991, PCJPB purchased Caltrain right-of-way between San Francisco and San Jose (51.5 miles), and trackage rights further south to Gilroy (26 miles). Caltrans deeded 26 stations, 20 diesel locomotives and 73 bi-level passenger cars to the PCJPB in 1993. The Union Pacific Railroad (UP) acquired Southern Pacific in 1996, and retains rights to operate freight service along the corridor. PCJPB contracted with Amtrak to operate/maintain Caltrain until late 2011 when Transit America Service, Inc. (TASI) took over.

B. DUMBARTON RAIL CORRIDOR

In 1994, SamTrans purchased the Dumbarton Rail Corridor between Redwood Junction and Newark Junction for future commuter rail service. The Dumbarton Rail Corridor (DRC) will extend commuter rail service across the bay between the Peninsula and the East Bay.
C. CALTRAIN DESIGN DOCUMENTS AND GUIDELINES

1.0 CALTRAIN DESIGN STANDARDS

In 1994, Caltrain developed its first design standards and guidelines (*PCJPB Standards, Volumes 1 and 2*). These documents, drawn largely from former Southern Pacific’s standards, provided general guidelines to the construction and encroachment activities within the corridor. They were used for several projects (stations and grade separations) sponsored and managed by the Cities.

In 1999, Caltrain developed its first design criteria and standard technical drawings for signals (*Communication/Signal Engineering Standards*, and *Communication/Signal Design Standards*), and for track (*Track Standard Drawings*).

In 2007, the above documents (including all others as except those listed in APPENDIX B) were superseded by Caltrain Engineering Standards. These Standards, consisting of Design Criteria, Standard Drawings, and Standard Specifications were the first Caltrain comprehensive Engineering Standards. Together with “Standards for Maintenance and Construction of Structures” (2003), “Engineering Standards for Excavation Support System” (2003), and ‘CADD Manual’ (2003), they formed complete Caltrain Engineering Standards.

This 2011 documents are the first revision of the above 2007 Standards.

2.0 CALTRAIN CONSTRUCTION DOCUMENTS

In 1999, Caltrain completed its first comprehensive construction documents for use on the 1998/99 Facility Upgrade Project (Ponderosa). The construction documents included General Conditions (Division 0) and Special Provisions (Division 1) and Standard Specifications (Divisions 2 through 16 and 18). These documents, including the construction drawings, have since been used as a basis for design and construction of subsequent capital and maintenance projects. They were also the basis for the development of the Caltrain Engineering Standards 2007.

3.0 CALTRAIN SIGNAL SYSTEM MIGRATION

3.1 Migration of Caltrain Signal System Defined as Bidirectional

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

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

2. Replacement of telephone leased lines with Advanced Train Control System (ATCS) Radio: ATCS Radio is the primary medium of train control communication with Telco back up at 80% of the Control Points completed in 2003.
3. Replacement of dc track circuits and line circuits with Electronic Coded Track circuits: OS (On Station) tracks remain dc and there are some dc track circuits in locations where the coded track is on line circuits completed in 2003.

4. Replacement of system of single direction running ABS (Automatic Block System) with double direction running CTC: Completed in 2003 with the completion of the construction of Caltrain CTX projects.

5. Installation of a Positive Train Control System

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

By defining the path of migration, projects today will lay the groundwork for future projects. Since 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 bidirectional running railroad on both tracks, grade crossings were designed to accommodate the ultimate 79 MPH (miles per hour) 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.

### 3.2 Migration to Centralized Traffic Control (CTC)

Caltrain has successfully migrated to Centralized Traffic Control (CTC). With the construction of express tracks and a track structure of numbers 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, a train only knows it is to take a diverging route and must approach a control point with different sized turnouts prepared to take the turnout at the lowest speed of any turnout, which can be reached, from that signal.

Control Points have been designed to accommodate the presently funded projects, and 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 on board 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 greater than 79 MPH. This too will require on board control of locomotives by the
signal system. Whether it is a form of intermittent automatic train stop, or a form of automatic train control, the present system has been designed to allow for the addition of the new equipment.

### 3.3 Signal System and Future Electrification

Caltrain Board of Directors have 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 that funded. However, an intelligent design with a defined path of migration, allows for the future projects to build upon the present 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 bidirectional 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. Caltrain’s new criteria on signal system uses Electrode 4+ Code Rates. While this is a system manufactured by GETS, 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 on board train control equipment.

### 3.4 Signal System at Pedestrian Crossings

In addition to the high number of motor vehicles, which cross the railroad, there are a large number of pedestrians who cross the Caltrain tracks. The safest crossing for both pedestrians and motorists is one which is at a separate grade, 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 will have microprocessor based Constant Warning Time systems, and pedestrian gates. At stations, and on sidewalks where major work is taking place, auxiliary sidewalk gate arms will be added to the roadway gate, and a new gate assembly will be installed in the off quadrant on the sidewalk for pedestrians.

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

### 4.0 CALTRAIN GRADE CROSSINGS

The Caltrain line is the oldest passenger line west of the Mississippi. As such, it has been a double track operation through the city centers of a major west coast metropolitan area for over 100 years. Grade crossing control systems have evolved to enhance public safety and to provide more efficient train operations.
4.1 Vehicular Crossings

The former Southern Pacific Railroad (SP) developed several innovative treatments for the grade crossing control systems. Among these treatments was a series of calibrated track circuits where speed measurements were used to determine whether a train approaching a grade crossing was going to stop short of the crossing, or go through the crossing. These applications were costly in terms of relays, insulated joints and cabling.

In the 1960’s, in order to enhance the operation through grade crossing, the SP, in partnership with Stanford University sponsored the development of Constant Warning Time devices, known as predictors.

In 1990, as part of the rehabilitation of the property as a condition of sale to the State of California, the SP upgraded 10 vehicular crossings with “next generation” microprocessor based Constant Warning Time devices. These crossings were Broadway Avenue (Burlingame), Holly Street, Watkins Avenue, Rengstorff Avenue, Castro Avenue, Sunnyvale Avenue, Stockton Avenue, Lenzen Avenue, Auzerais Avenue, and Virginia Street. The benefits of the upgrade are enhancement to both vehicular and train operations through the crossings.

As part of the 1998/1999 Facility Upgrade project (Ponderosa), Caltrain began an extensive vehicular grade crossing rehabilitation. The three most important components of the rehabilitation are installation of new signal control equipment, removable concrete panels, and drainage system. There have since been several projects of rehabilitating the grade crossings.

4.2 Pedestrian Crossings at Stations

In 1998, during the construction of BART extension to the San Francisco Airport (BART SFO Extension), it became necessary to relocate the San Bruno station to just north of I-380 Overpass. Since this area was just north of a 3 degree track curve, it was observed that a person crossing the tracks would have only about 5 seconds to visually detect an approaching northbound train. To complicate the matter further, the area was also a high noise environment with both the freeway and the flight paths to San Francisco Airport (SFO) being directly overhead.

The permanent San Bruno station is now just south of the I-380 overpass.

4.3 Caltrain Grade Crossing Standards

The need was clear to reevaluate the pedestrian at-grade crossings. There are, however, no nationally or state recognized standards for the design of pedestrian crossing warning systems on railroads. This was the catalyst for the development of the Caltrain Pedestrian crossing at stations. At its own initiative, Caltrain, in collaboration with Signal and other Consultants developed its own recommended practices of pedestrian grade crossing configuration at stations.
These resulting standards utilize active warning devices similar to those of vehicular crossings, signal equipment modified from that of vehicular crossing, crossing gate arm, and a crossing configuration. These standards are an example of the integrated effort required from the various disciplines to provide a safe and effective means for pedestrians to cross the tracks. This prototype was first used at the relocated San Bruno station, and during the Ponderosa project at the San Mateo, Hayward Park, Redwood City, Menlo Park and Mountain View stations. In 2004, the then new San Bruno Station was built to this standard, and the Sunnyvale station was brought into conformance with this standard.

D. CALTRAIN TODAY

1.0 CALTRAIN SERVICES

Currently Caltrain’s service includes Express (“Baby Bullet”) service on top of a blend of local, skip stop, and limited express services. Caltrain is a diesel push-pull system operating over a mostly double track line, with a small amount of three and four track sections of bypass tracks. All trains operate at the maximum authorized speed (MAS) of 79 miles per hour. Average ridership is over 32,000 passengers (2006).

The Baby Bullet service (or Express service) began in June 2004. The current service includes 11 morning and 11 afternoon/evening weekday trains, shortening the commute time between San Francisco and San Jose to just under one hour. Baby Bullet trains make up time by stopping at fewer stations and by bypassing other trains.

Caltrain’s current commuter service includes (2011), which is reduced from a high of 96 trains on weekday.

a. 86 scheduled weekday trains (including 22 express service, and 28 limited express service)
b. 36 (Saturday) and 32 (Sunday) scheduled trains including 4 express service each weekend day
c. 34 Stations, most with parking
d. About 40 bicycle spaces per train consist
e. Transfer to San Francisco MUNI system at 4th and King Station
f. Transfer to BART system at Millbrae Station
g. Transfer to VTA system at Mountain View Station
h. Transfer to VTA, Capitol Corridor, and Amtrak at San Jose Diridon Station
i. Transfer to Altamont Corridor Express (ACE) at Santa Clara Station and San Jose Diridon Station

2.0 CALTRAIN CORRIDOR ASSETS

Caltrain corridor assets include the following.

a. 77 route miles
b. 105 miles of main tracks and controlled sidings
c. 34 passenger stations (67 boarding platforms)
d. 31 locomotives, 112 cars, including 34 cab cars
e. 106 support buildings and station buildings
f. 65 railroad bridges, 13 pedestrian underpasses, and 4 tunnels
g. 31 control points
h. 48 grade crossings between San Francisco and San Jose
i. 38 grade crossings between San Jose and Gilroy
j. 612 acres fee owned operating rail corridor
k. 79 acres of easement operating rail corridor

For more details, see Caltrain Track Charts, Right-of-Way and Rail Corridor Infrastructure Assets.
A. CARS

Nippon-Sharryo :
Quantity: 52
Weight: 118,000 lbs
Length: 85 ft
Bike 32: No

Nippon-Sharryo :
Quantity: 14
Weight: 122,000 lbs
Length: 85 ft
Bike 32: No

Nippon-Sharryo :
Quantity: 21
Weight: 125,000 lbs
Length: 85 ft
Bike 32: Yes

Nippon-Sharryo :
Quantity: 6
Weight: 127,000 lbs
Length: 85’
Bike 32: Yes

Bombardier :
Quantity: 10
Weight: 119,000 lbs
Length: 85 ft
Bike 32: No

Bombardier :
Quantity: 5
Weight: 122,000 lbs
Length: 85 ft
Bike 16: Yes

Bombardier :
Quantity: 2
Weight: 122,000 lbs
Length: 85 ft
Bike 16: No
B. LOCOMOTIVES

General Motors-EMD:
- Quantity: 20
- Horse Power: 3200
- Weight: 260,000 lbs
- Length: 56 ft - 2 in

Boise Locomotive Inc.:
- Quantity: 3
- Horse Power: 3200
- Weight: 282,000 lbs
- Length: 64 ft - 3 in

Motive Power Inc.:
- Quantity: 6
- Horse Power: 3600
- Weight: 293,500 lbs
- Length: 70 ft

C. CAPITAL EQUIPMENT

Flat Car:
- Quantity: 4
- Notes: 70 Ton Truck

Low Railer:
- Quantity: 1
- Notes: 30K lb Capacity

Caboose:
- Quantity: 2
- Notes: N/A

General Motors-EMD GP-9:
- Quantity: 4
- Notes: EMD Overhauled SP

D. MAINTENANCE OF WAY EQUIPMENT

Geometry Car (Plasser American):
- Quantity: 1
- Mark: JPBX-505
- Built: 1980
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<th>Year Built</th>
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<td>1500</td>
<td>1974</td>
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<tr>
<td>Caboose</td>
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<td></td>
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<td>1974</td>
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<td>Flat Car</td>
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</tr>
<tr>
<td>Gondola</td>
<td>1</td>
<td>E530</td>
<td></td>
<td>1976</td>
</tr>
<tr>
<td>Hopper, Ballast</td>
<td>6</td>
<td>JPBX</td>
<td>100 tons</td>
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<td>AMTK</td>
<td>100 tons</td>
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</tr>
<tr>
<td>Difco M110 Side Dump</td>
<td>3</td>
<td></td>
<td>100 tons</td>
<td>1978</td>
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CALTRAIN
STATIONS AND FACILITIES
SUSTAINABILITY DESIGN CRITERIA

Prepared for Caltrain
by Mary Nowee and ..........
Under Work Directive No. 5250

Submitted: June 28, 2011
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8. ABBREVIATIONS AND DEFINITIONS
1.0 GENERAL

These design criteria establish requirements for sustainability for Caltrain infrastructure development and improvements, in particular for stations and facilities. Sustainability refers to meeting the needs of today without sacrificing the capacity of future generations to meet their own needs.

1.1 CALTRAIN POLICY

It is Caltrain’s intent to follow the general policy commitment of SamTrans (San Mateo County Transit District) in regards to sustainability as follows:

1. Deploy sustainability-themed programs that encourage the use of public transit and that support our local communities.
2. Evaluate and improve the long-term resource efficiency of our facilities and equipment, including the life cycle return on investment.
3. Streamline business practices to reduce waste and improve operational effectiveness.
4. Educate and incentivize Caltrain employees to integrate sustainability practices into their work and their personal lives.
5. Encourage business partners to incorporate sustainability practices into their own operations.
6. Measure the environmental impacts of our activities on an ongoing basis, and set and meet targets to reduce our impacts.

1.2 SCOPE AND APPLICABILITY

These design criteria concern new facilities, refurbishment or renovation of existing facilities. Their purpose is to integrate sustainable design into Caltrain facility development, renovation and maintenance, including the following areas:

1. Planning and Design
2. Energy Efficiency
3. Water Efficiency and Conservation
4. Materials Conservation and Resource Efficiency
5. Environmental Quality

Caltrain capital improvement projects shall establish project specific sustainability goals, following the framework of the California Building Code, Part 11, Green Building Standards Code (CalGreen). New construction shall comply with CalGreen Nonresidential Mandatory Measures and these design criteria. Renovation and rehabilitation projects shall develop project specific goals following these design criteria and the general principles and design considerations per CalGreen.
Compliance with CalGreen Nonresidential Voluntary Measures, including Tier 1 and Tier 2, shall be considered and added based on cost/benefit considerations. CalGreen Tier 1 and Tier 2 measures are intended to further encourage incorporation of additional green building practices that improve public health, safety, and welfare as well as encourage environmental sustainability.

Designers for each project shall complete a sustainability design compliance checklist, detailing sustainability targets for each area.

2.0 REFERENCE STANDARDS AND PRACTICES

2.1 GOVERNMENT

1. California Code of Regulations, Title 24
   a. Part 6, California Energy Code (CEC)
   b. Part 11, Green Building Standards Code (CalGreen)

2. California Division of the State Architect Environmentally Preferable Products Database

3. Comprehensive Procurement Guidelines (CPG) website ‘buy-recycled’ product list
   http://www.epa.gov/epawaste/conserve/tools/cpg/index.htm

4. Environmental Protection Agency (EPA) Environmentally Preferred Purchasing. This site is useful for consumers, particularly those engaged in sustainable design projects, to find and evaluate green products, services and tools.
   http://www.epa.gov/epp/index.htm

2.2 INDUSTRY


   
   http://www.ashrae.org/publications/page/927


   http://www.aptastandards.com/LinkClick.aspx?fileticket=FWiDPdAQdU8%3d&tabid=330&mid=1686&language=en-US

5. Collaborative for High Performance Schools (CHPS) criteria, 2009


   http://www.nist.gov/el/economics/BEESSoftware.cfm

7. Resilient Floor Covering Institute (RFCI) FloorScore Program


   http://www.usgbc.org/

3.0 PLANNING AND DESIGN

3.1 SITE SELECTION AND OPTIMIZATION

Site selection shall optimize transit use and access, including intermodal opportunities such as pedestrian and bike routes, and the potential for transit-oriented development.
(TOD). Site selection shall comply with the Nonresidential Voluntary Measures described in Section A5.103 of CalGreen concerning community connectivity and brownfield and greyfield sites and shall avoid site disturbance or development on previously undeveloped land having an elevation lower than 5 feet above the elevation of the 100 year flood as defined by USFEMA.

Consideration should be given to locating facilities in an existing building envelope, on a brownfield site, or on a greyfield site. A brownfield site is a site that is contaminated or potentially contaminated, and a greyfield site is one which is previously developed with impervious surfaces over 50 percent or more of site.

3.2 TRANSIT-ORIENTED DEVELOPMENT

Caltrain supports and encourages community planners to explore opportunities to develop transit-oriented development (TOD) adjacent to Caltrain facilities. TODs are mixed-use, walkable communities developed around transit stops.

1. In developing opportunities for TOD at existing or proposed Caltrain stations, consider exercising the principles of high-performance, sustainable neighborhoods, as addressed in the LEED for Neighborhood Development (ND) guidance, and in compliance with potential local Sustainable Communities planning requirements under SB 375.
2. Consider modifications at existing facilities that would support the construction and operation of TOD on or adjacent to Caltrain property.
3. Parking is an important factor in TOD. Housing developed in close proximity to a station should include fewer parking spaces per unit than is typically required. Consider replacing station surface parking with a parking structure freeing up land for TOD. Since parking may be plentiful at stations after hours and on weekends, TOD may incorporate attractions that draw primarily after-hours patrons that could share station parking facilities.

3.3 REDUCE IMPACT OF PROJECT SITE

Designers and planners shall consider the range of impacts, including erosion, stormwater, heat island effect, light pollution, noise, and vibration, a site can have on the surrounding community, and investigate means to reduce those impacts.

1. Stormwater: Limit disruption and pollution of natural water flows by managing stormwater runoff.¹

¹ LEED NC SS 6.1 or LEED ND GIB credit 8 are relevant areas of the USGBC system that pertain to this topic.
a. **Stormwater design:** Design stormwater system in accordance with the Nonresidential Voluntary Measures of the CalGreen Code or local requirements, whichever are stricter.

b. Use site planning, design, construction, and maintenance strategies to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of sites with regard to the temperature, rate, volume, and duration of flow.

c. Evaluate multiple techniques to limit disruption and pollution of natural stormwater flows including:
   i. Minimize impervious surfaces through use of pervious paving and other elements
   ii. Raingardens, or bioretention areas, are planted depressions that allow the collection, filtration, and infiltration of rainwater runoff from impervious surfaces
   iii. Vegetative roof treatments
   iv. Collect stormwater and use it for site irrigation, toilet and urinal flushing, and custodial uses

2. **Mitigation of heat island effect on both hardscapes and roofs (CalGreen A5.106.11):** The term "heat island" describes built up areas that are hotter than nearby rural areas. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

Site Hardscape (For the purposes of this requirement, a site’s hardscape includes roads, sidewalks, courtyards, and parking lots, but not constructed building services, or any portion covered by photovoltaic panels generating electricity or other solar energy systems): Designers shall evaluate providing at least 50 percent of the site hardscape with one or any combination of the following or put 50 percent of parking underground.

a. Existing trees and vegetation or new bio-diverse planting or native plants and adapted plants located to provide shade within five years.

b. Paving materials with a minimum initial Solar Reflectance Index (SRI) of 0.29. This applies to porous pavers, and open-graded aggregate materials as well as conventional pavement. These materials should be light colored and high-albedo.

c. Shading through the use of structures, provided that the top surface of the shading structure complies solar reflectance and thermal requirements in CalGreen A5.106.11.

d. Building or structures that provide shade to the site hardscape.
e. Use open-grid pavement system for non-walking surfaces. Open-grid pavement is a system that is less than 50 percent impervious and contains vegetation in open cells. Special design considerations shall be given to ensure even walking surfaces and ease of maintenance.

3. Light Pollution: In addition to following Caltrain’s design criteria for lighting, follow CalGreen requirements in Section 5.106.8 regarding light pollution and design interior and exterior lighting such that zero direct-beam illumination leaves the building site. This shall eliminate, to the extent possible, light trespass from the buildings and site to improve night sky access and reduce the impact of facilities on nocturnal environments.

4. Noise and Vibration: Per Caltrain’s Design Criteria, the designer shall consider noise and vibration mitigation as part of facility development. The object of this design requirement is to minimize the impacts to the adjacent residents from train loads and traffic.

4.0 ENERGY EFFICIENCY

Designers shall evaluate opportunities for buildings to achieve exemplary performance in the area of energy efficiency, and in compliance with the goal stated in CalGreen Section A5.201 designers shall evaluate methods to achieve at least a 15 percent reduction in energy usage when compared to the State’s mandatory efficiency standards.

4.1 PASSIVE DESIGN

Passive design strategies are the lowest cost way to minimize energy consumption for buildings and facilities. Optimally orient the station or facility to minimize heat gain in summer, while maximizing natural light. Consider solar orientation, wind direction, and natural features.

4.2 BUILDING ENVELOPE

1. Design building envelope to optimize energy efficiency including the following:
   a. Provide adequate insulation
   b. Utilize cool roofing to decrease heat gain through roof and to reduce heat island effect
   c. Place windows and skylights to provide natural lighting while using glazing types, shading, and orientation to reduce heating and air conditioning energy use.
d. Optimize natural ventilation through use of operable windows, vents, and other devices.
e. Optimize building tightness to increase heating and cooling efficiencies during periods when natural ventilation is not sufficient for comfort.

2. Building Envelope Requirements:

The building envelope shall comply with the relevant code criteria, including the CalGreenCode and California Energy Code (CEC). Designers shall comply to the extent practicable with CalGreen Section A5.205.

4.3 BUILDING MECHANICAL SYSTEM

Optimize building mechanical systems energy use through maximizing systems performance and using energy efficient appliances and equipment.

Designers shall select energy efficient appliances and equipment (EnergyStar and Environmentally Preferred Purchasing).

4.4 LIGHTING

Maximize lighting system performance through selection of energy efficient equipment and controls and incorporating natural lighting to the extent practical. Lighting shall comply with the Nonresidential Voluntary Measures in CalGreen A5.209.

4.5 TOTAL BUILDING PERFORMANCE

1. New facilities should be commissioned in a manner that is equal to the provisions of CalGreen Nonresidential Mandatory Measures Section 5.410.2, or preferably, Voluntary Measures Section A504.4. Commissioning is a systematic process that starts during design and helps assure that building performance meets project requirements, including energy efficiency, air quality, and water conservation.

2. Consider the following in the design and operations and maintenance of facilities for optimum energy efficiency and other performance criteria:

a. Utilize building controls / automation and reporting systems to help ensure optimum energy use. Allow for optimization of building performance and energy and water consumption over time.

b. Recommend a program of periodic re-commissioning of buildings to check and then adjust building mechanical and other systems.

c. Incorporate and optimize energy and environmental control devices and procedures as follows:
i. Incorporate, commission, and maintain control and monitoring devices including CO₂ monitoring sensors; energy monitoring/optimization devices; and temperature, ventilation, and humidity control devices.

ii. Add control devices to existing facilities for optimum energy and environmental performance.

iii. Establish and perform procedures including calibration and validation of control devices and sampling for air quality.

3. Energy Budget:: Achieve a level of energy performance above that required by the California Energy Code by reducing energy costs compared to the energy cost budget for energy systems as demonstrated by a whole building simulation using the performance approach described in CalGreen Section A5.203

4.6 ON-SITE RENEWABLE ENERGY SYSTEM

Evaluate and consider implementing on-site renewable energy systems that provide at least 1 percent of the electric power for each facility. Calculation and documentation should comply with CalGreen A 5.211.

5.0 WATER EFFICIENCY AND CONSERVATION

5.1 LANDSCAPE

Comply with CalGreen Division 5.3 and, to the extent practicable, with the Nonresidential Voluntary Measures, Division A 5.3, in the CalGreen Code and the following requirements.

1. Landscaping and any landscape irrigation system shall be designed to be water-efficient and to reduce or eliminate the need for irrigation, herbicides, pesticides, and fertilizers. Plant selection shall be done in accordance with water conservation strategy. At minimum, 60% of the landscaping shall be in bio-diverse planting of native plants and adapted plants. In general, landscaping shall not include turfgrass.

2. Irrigation system design: Design irrigation system so that it will deliver the amount of water the specific plants need. Where practical, group plants by how much irrigation water they need. The goal for landscaping should be to eliminate the need for potable water in the irrigation system and maximize the use of rain water catchment, drip irrigation systems, and recycled water from water treatment facilities. Alternatively, eliminate the need for a permanent irrigation completely through plant selection. The irrigation system shall be controlled by a smart
controller. A smart controller is a device with moisture sensors so that irrigation systems only operate when soil is dry and there is no pending rainfall.

3. Use recycled water for landscape irrigation where available. Where landscape irrigation is provided and no recycled water source is available, design system for conversion to recycled water whenever such becomes available at the site.

5.2 PLUMBING FIXTURES

Comply with the mandatory measures of CalGreen Division 5.3 and to the extent practicable with the Nonresidential Voluntary Measure in the CalGreen Code.

Plumbing fixtures (water closets and urinals) and fittings (faucets and showerheads) shall be water efficient and comply with CalGreen Section 5.303.

5.3 VEHICLE WASHER

Minimize the amount of vehicle wash water usage. Filter, recycle, and reuse vehicle wash water.

6.0 MATERIAL CONSERVATION AND RESOURCE EFFICIENCY

6.1 LIFE CYCLE EVALUATION OF FACILITIES

To optimize the facility’s performance over its entire life-span, an analysis of life cycle value of the facility should be performed as part of evaluating construction materials and systems. A life cycle value of a facility shall consist of the initial investment, operability, maintainability, longevity, and life cycle operational and maintenance costs, as well as its reusability and adaptability. Life cycle value considers the total performance of materials and assemblies in an objective, balanced approach.

6.2 EVALUATION OF MAJOR BUILDING MATERIALS AND ASSEMBLIES

To optimize the embodied impacts (e.g. land use, resource use, climate change, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, and eutrophication) of the facility due to materials, consider making a life cycle analysis evaluation of major building materials and assemblies to reduce consumption of natural resources and reduce the impact on the natural environment using Building for Environmental and Economic Sustainability (BEES), Athena Impact Estimator, or equivalent method acceptable to Caltrain, in accordance with ISO Standard 14044. ²

² BEES software incorporates a technique for balancing environmental and economic performance of building projects. It includes actual environmental and economic performance data for a number of building products.

The designers should use the results of the evaluation to select the alternative that has a 5% improvement over other alternatives assessed in the life cycle analysis, in a minimum of two impact categories.

6.3 EVALUATION AND SPECIFICATION OF MATERIALS AND CONSTRUCTION PRACTICES

Evaluate materials and assemblies and configure construction contract requirements to reduce consumption of natural resources and reduce the impact on the natural world.

1. Incorporate recycled materials into transit projects when transit-specific requirements are met, (including longevity, durability, low-maintenance), and favor post-consumer recycled content.
2. Favor materials that can be further reused within the transportation system or recycled at the end of their useful life within the transportation system.

Designers shall use tools such as EPA’s Environmentally Preferred Purchasing and Comprehensive Procurement Guidelines in selecting materials and assemblies. Designers shall incorporate selected materials and assemblies in construction contact documents.

Note: Materials traditionally considered environmentally preferable are not always best for transit systems. Designers shall select materials that meet both environmental and performance objectives.

6.4 CONSTRUCTION WASTE REDUCTION, DISPOSAL AND RECYCLING

Require that construction contractors and demolition contractors shall develop a construction waste management plan for diverted materials according to CalGreen Section 5.408, or meet local construction and demolition waste ordinances, whichever is more stringent. In addition to the construction waste reduction required under the CalGreen Code, consider requiring the enhanced construction waste reduction, Tier 1 or Tier 2, in accordance with the Nonresidential Voluntary Measures of the CalGreen Code.

1. All subcontractors shall comply with the contractor’s waste management plan.
2. Require in the construction contract that Caltrain projects generate the least amount of waste possible by planning and ordering carefully, following proper storage and handling procedures to reduce broken and damaged materials, and reusing materials whenever possible.

Athena Institute’s Impactor Estimator for Building helps designers assess the environmental implications of new buildings and renovations to existing buildings.
6.5 SUSTAINABLE MATERIALS AND POLLUTANT CONTROL

1. Heating, Ventilating, and Air Conditioning (HVAC) Equipment: Select equipment which utilizes no CFC and no HCFC-based refrigerants, or ozone-depleting materials. When appropriate, phase-out CFCs in existing building HVAC equipment.
2. Install HVAC, refrigeration, and fire suppression equipment that do not contain halons.
3. Designers shall evaluate the use of sustainable materials as described in CalGreen Section A5.405.
4. Designers shall specify materials, equivalent in performance to virgin materials, with postconsumer or preconsumer recycled content value for a minimum of 10 percent of the total value, based on estimated cost of materials on the project.
5. Finish material pollutant control: Finish materials shall comply with CalGreen Sections 5.504.4.1 through 5.504.4.4. These sections detail standards for VOC limits, based on the local and regional air pollution control or air quality management district rules for California.
6. For floor area receiving resilient flooring, install resilient flooring complying with the VOC-emission limits defined in the 2009 Collaborative for High Performance Schools (CHPS) criteria and listed on its Low-emitting Materials List (or products registry) or certified under the Resilient Floor Covering Institute (RFCI) FloorScore program.

Also, consider the use of linoleum, a rapidly renewable product, where resilient flooring is required.

6.6 OPERATION AND MAINTENANCE

Establish and follow routine maintenance procedures to maintain and optimize HVAC equipment itself as well as of control devices.

Minimize pollution resulting from operation and maintenance.

1. Use environmentally preferred purchasing for lubricants, cleaning agents and paint.
2. Utilize methods that reduce pollution including methods that extend life of lubricants and reduce pesticide, herbicide, and fertilizer use.
3. Recycle magnetic ballast and older fluorescent lamps containing poly-chlorinated biphenyls (PCBs) and other toxic chemicals in such a manner that potentially dangerous chemicals are safely reprocessed.
7.0 ENVIRONMENTAL QUALITY

7.1 CONSTRUCTION INDOOR AIR QUALITY PLAN

In addition to the CalGreen Code requirements for Indoor Air Quality during construction, consider implementing the Nonresidential Voluntary Measures, Section A 5.504 for the construction and pre-occupancy phases of buildings to prevent indoor air quality problems resulting from construction.

7.2 INDOOR AIR QUALITY

Indoor air quality shall be addressed throughout facilities’ life cycle including during construction and through operations and maintenance.

Design and operate facility to ensure indoor air quality as follows:

1. Incorporate indoor air quality procedures into construction contracts. Procedures shall include for protection of air quality in selection and application of materials and protection of permanent HVAC system from dust and other contaminants.
2. Ventilation requirements: The building shall comply with California Energy Code, 2008 Building Efficiency Standards, Section 121. Designers shall evaluate methods to increase ventilation rates above the minimum.
3. Outdoor air delivery monitoring: For spaces ventilated by mechanical systems, a permanently mounted, direct total outdoor airflow measurement device shall be provided that is capable of measuring the system minimum outdoor airflow rate.
4. Filtration Requirements: The particulate matter filters or air cleaners shall have a minimum efficiency reporting value (MERV) of not less than 8 and shall comply with and be provided for all regularly occupied areas of the building. Designers shall evaluate the use of MERV 13 filters for all regularly occupied areas of the building.
5. Building Entrance: All building entrances shall employ an entry mat system that shall have a scraper surface, an absorption surface, and a finishing surface. Each surface shall be a minimum of the width of the entry opening, and the minimum length, 6 feet, is measured in the primary direction of travel.
6. Thermal Comfort: The building shall be designed, at a minimum, to comply with A5.507 of CalGreen.
7.3 LIGHTING AND VIEWS

Design spaces and provide openings to visually connect the indoor environment and outdoor spaces, particularly the natural environment.

1. Daylight regularly occupied spaces
2. Provide quality lighting to maximize productivity and safety
3. Views: To the extent practicable, design spaces and provide openings to visually connect the indoor environment and outdoor spaces, particularly the natural environment

7.4 ACOUSTIC AND VIBRATION CONTROL

Comply with CalGreen Section 5.507 concerning the selection of materials with appropriate Sound Transmission Class coefficient values and design indoor environments for comfort and audibility in regard to the acoustics and vibration. Control impact noise and vibration to the extent possible as part of ensuring occupants' comfort and productivity.

8.0 ABBREVIATIONS AND DEFINITIONS

Abbreviations:

- APTA: American Public Transportation Association
- ANSI: American National Standards Institute
- ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers
- BEES: Building for Economic and Environmental Sustainability
- CEC: California Energy Code
- CFC: Chlorofluorocarbon
- CHPS: Collaborative for High Performance Schools
- CPG: Comprehensive Procurement Guidelines
- EPA: Environmental Protection Agency
- EPP: EPA's Environmentally Preferred Purchasing
- FTA: Federal Transit Administration
- HCFC: Hydrochlorofluorocarbon
- HVAC: Heating, Ventilation and Air Conditioning
- IAQ: Indoor Air Quality
- ISO: International Standards Organization
### CALTRAIN STATIONS AND FACILITIES - SUSTAINABILITY DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>LCA</td>
<td>Life Cycle Assessment</td>
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<td>LEED™</td>
<td>Leadership in Energy and Environmental Design</td>
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<td>MERV</td>
<td>Minimum Efficiency Reporting Value</td>
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<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>PCB</td>
<td>Poly-Chlorinated Biphenyl</td>
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<td>RFCI</td>
<td>Resilient Floor Covering Institute</td>
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<tr>
<td>SB 375</td>
<td>State Bill 375 (California’s Sustainable Communities and Climate Protection Act)</td>
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<td>SRI</td>
<td>Solar Reflectance Index</td>
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<td>TOD</td>
<td>Transit Oriented Development</td>
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<td>USFEMA</td>
<td>United States Federal Emergency Management Agency</td>
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<td>USGBC</td>
<td>United States Green Building Council</td>
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<td>VOC</td>
<td>Volatile Organic Compound</td>
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**Definitions:**

- **Albedo:** Synonymous with solar reflectance, which is a ratio of the energy reflected back into the atmosphere to the energy absorbed by the surface, with 100 percent being total reflectance.

- **Bioretention (raingarden):** A shallow depression that utilizes conditioned soil and vegetation for the storage, treatment, or infiltration of storm water runoff.

- **Brownfield Site:** Real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant, with certain legal exclusions and additions.

- **Building Commissioning:** A systematic quality assurance process that spans the entire design and construction process, including verifying and documenting that building systems and components are planned, designed, installed, tested, operated and maintained to meet the owner’s project requirements.

- **Chlorofluorocarbons (CFC):** An organic compound, a hydrocarbon, commonly used as a refrigerant, with a direct environmental impact of ozone depletion.

- **Embodied Energy:** The energy used for raw material extraction, transportation, manufacturing, assembly, installation and disposal during the life of a product, including the potential energy stored within the product.
Energy Star: A joint program of the US Environmental Protection Agency and the US Department of Energy. Energy Star is a voluntary program designed to identify and promote energy-efficient products and practices.

Eutrophication: A syndrome of ecosystem responses to human activities that fertilize water bodies with nitrogen (N) and phosphorus (P), often leading to degradation of water and habitat quality.

Greyfield site: Any site previously developed with at least 50 percent of the surface area covered with impervious material.

Graywater: Untreated household waste which has not come into contact with toilet waste. This includes water from bathtubs, showers, bathroom wash basins and water from clothes washing machines and laundry tubs.

Halon: A compound consisting of bromine, fluorine, and carbon, commonly used as a fire extinguishing agent. It contributes to ozone depletion.

Heat Island. Describes built up areas that are hotter than nearby rural areas.

Hydrochlorofluorocarbons (HCFC): A refrigerant, a subclass of CFCs but containing hydrogen, developed as a substitute for CFCs. HCFCs do not deplete stratospheric ozone layer, but some have a high global warming potential, so are not environmentally benign.

Life Cycle Assessment (LCA): A technique to evaluate the relevant energy and material consumed and environmental emissions associated with the entire life of a product, process, activity or service.

Low Impact Development (LID): Control of stormwater at its source to mimic drainage services provided by an undisturbed site.

Permeable Paving: Permeable paving materials and techniques which allow the movement of water around the paving material and allow precipitation to percolate through the paving surface to the soil below.

Potable Water: Water that is drinkable and meets the US Environmental Protection Agency (EPA) Drinking Water Standards.

Recycled Water: Water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur.

MERV: Filter minimum efficiency reporting value, based on ASHRAE 52.2-1999.
Solar Reflectance Index: The fraction of the incident solar energy reflected by a given surface is its solar reflectance. Solar reflectance and thermal emittance are importance factors affecting surface and near-surface ambient temperatures. Determination of solar reflectance and thermal emittance, and subsequent calculation of the relative temperature of the surfaces with respect to black and white reference temperatures is the Solar Reflectance Index (SRI).

Sound Transmission Class (STC): STC is a single number rating of the barrier effect of a material or assembly. Higher STC values are more efficient for reducing sound transmission.

Volatile Organic Compound (VOC): Carbon compounds with vapor pressures greater than 0.1 millimeters of mercury at room temperature, i.e., they become a gas at normal room temperatures. These compounds typically contain hydrogen and may contain oxygen, nitrogen, and other elements.