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

Issue Date:
APRIL 15, 2007

DESIGN CRITERIA
CALTRAIN DESIGN CRITERIA

This is a Controlled Document. Any proposed changes or updates must be submitted to the Caltrain Deputy Director of Engineering for consideration. The Caltrain Deputy Director of Engineering will issue revisions to the documents and notify all Caltrain official document holders by email when and where to obtain the revisions online.

The revision will include the page number and date for each change or addition. The latest revision to the Design Criteria is marked by a side-bar in the right-hand margin of the page. It is the responsibility of the users to determine that the version being used is current.

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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 of Peninsula Corridor Joint Powers Board (PCJPB or JPB) or Caltrain facilities. This document is based on best industry standards and accepted practices for Commuter/Class 1 railroads and equals or exceeds regulatory requirements.

The Design Criteria is intended to cover the majority of Caltrain’s current and future improvements. The Criteria does not attempt to cover all the situations that might be encountered or requested throughout a project’s life. Future large projects such as Electrification, Dumbarton Rail, and Transbay Terminal (Downtown Extension) will have their own supplementary criteria. This document, to the extent possible, does not preclude such projects.

The criteria contain 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 practices. This document in no way replaces the individual designer’s adherence to the profession’s “standard of care” in design. Any deviations from these criteria are to be approved by the Caltrain Deputy Director of Engineering.

In the event of conflict between the Criteria, Specifications and Standard Drawings, and those of other criteria, including Federal Railroad Administration (FRA), California Public Utilities Commission (CPUC), and other State and Local Agencies, the most stringent requirements shall take precedence. Caltrain’s decisions regarding conflicts shall be final.

In this Document, standard (‘shall’) means required, no exception. Guidance (‘should’) means recommended, involving engineering judgment. Option (may) means permission. Support is informational statement.

1.0 REVISIONS

This is a controlled document. Any proposed changes or updates must be submitted to the Caltrain Deputy Director of Engineering for consideration. The criteria in this document will be updated on a continual basis to reflect regulatory changes and changes in Caltrain and industry practices.
The Caltrain Deputy Director of Engineering will issue revisions to the documents and notify all Caltrain list of official document holders by email where to obtain the revisions online. The Revision records will include the page number, date and appropriate section decimal notation for each change or addition. It is the responsibility of the users to determine that the version being used is current.

2.0 OTHER CALTRAIN DOCUMENTS

Caltrain has issued the following documents, which will be updated periodically, to be used in conjunction with this document.

a. GENERAL CONDITIONS (also known as Division 0)
b. SPECIAL PROVISIONS (also known as Division 1)
c. STANDARD DRAWINGS
d. STANDARD SPECIFICATIONS
e. STANDARDS FOR DESIGN AND MAINTENANCE OF STRUCTURES
f. ENGINEERING STANDARDS FOR EXCAVATION SUPPORT SYSTEMS
g. CADD MANUAL
h. TRACK CHARTS, RIGHT-OF-WAY AND RAIL CORRIDOR INFRASTRUCTURE ASSETS

This Design Criteria replaces all Caltrain’s existing standards and manuals except for those listed above. References on regulatory bodies and industry standards are included in the APPENDIX.

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 I-1 CALTRAIN SYSTEM MAP.
The current contract operator of Caltrain is National Railroad Passenger Corporation (Amtrak). Amtrak operates, maintains, and dispatches Caltrain trains and performs basic track, signal, stations and ROW maintenance and structure inspections. Additionally Amtrak supports a substantial amount of capital construction and third-party work along the corridor, primarily by providing flagging, signal maintainers, track inspectors and watchmen. Amtrak also performs minor construction tasks on track and signal work.

1.0 CALTRAIN MISSION

It is the mission of Caltrain to provide a safe, 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
c. Partnership with communities for a balanced transportation system
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 JOINT FACILITIES

The Union Pacific Railroad (UPRR) operates local freight service on the Caltrain corridor, primarily carrying lumber and rock aggregates. Freight traffic, about 3 or 4 trains daily, is typically moved at night. Additionally, the UPRR and the PCJPB have joint facility arrangements in a number of other locations. The UPRR owns and maintains Track No. 1 from CP Coast (Santa Clara) to CP Lick (San Jose), and all tracks from Lick to Gilroy. PCJPB has trackage rights from Lick to Gilroy. 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 Lick.

4.0 PROJECT DELIVERY METHODS

Caltrain generally manages all capital projects within the corridor. Construction contracts are typically awarded on the basis of a competitive bid similar to any public
works contract. Other project delivery methods may be by the procurement process for supply contracts or design-build for projects that are sufficiently large to warrant this method.

C. PLANNING AND DESIGN CONSIDERATIONS

For a successful implementation of a project, especially during the conceptual and preliminary design stages, the designer 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 design considerations that require analysis and review in the planning and design process.

A Design Basis Memorandum (DBM) shall be prepared summarizing these considerations including a summary of the project description and its limits, technical criteria, design exceptions, etc., which have been reviewed and approved by Caltrain Deputy Director of Engineering. The DBM shall include 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.

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 take into consideration 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. Operationally, they are measured as throughput, reliability, capacity and functionality. A project’s specific mission critical components shall be forwarded to the Caltrain Deputy Director of Engineering for approval. For the mission critical components, the designer shall provide in-depth technical analysis and develop alternatives for Caltrain review.

Each design level will be thoroughly reviewed prior to the beginning of next design level. Each level shall be accompanied by an updated schedule, cost estimate and Caltrain’s Safety and Security Certification.

1.0 PLANNING CONSIDERATIONS

Planning considerations include Operations, Standardization of Equipment and Materials, Environmental and Community considerations, and Right-of-way considerations.
1.1 Standardization of Equipment and Materials

Design must include the use of standardized materials and equipment 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.

1.2 Design Life

1.2.1 Permanent System Wide Facilities

Facilities shall generally be designed for a minimum life as identified below.

a. Bridges and grade separation structures (vehicular): 100 years
b. Fiber Optic Cables: 25 years
c. Parking (structure and surface): 50 years
d. Grade Separation Structures (Pedestrian underpasses and overpass): 100 years
e. Retaining walls: 50 years
f. Station platforms: 50 years
g. Technology based systems (PA System, communications, TVM’s, etc.): 10 years

1.2.2 Temporary System Wide Facilities

These facilities accommodate construction of permanent systems and shall be designed for a period up to five (5) years. Examples:

a. Shoofly (temporary tracks)
b. Temporary station and other related facilities during construction
1.3 Operations

1.3.1 Operational Planning Considerations

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.

1.3.2 Operational Impacts

It is imperative that design staging for any project which intrudes on or has the potential to intrude on rail operations during construction be planned in such a way as to mitigate any impact on Caltrain train operations. Further, the design review process shall clearly identify the required resources from Caltrain, and all impacts to operations, considering the following.

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

b. Single track closure may be allowed during weekends except for special event services.

c. Speed of temporary tracks shall be maintained at a minimum of 65 MPH.

1.4 Community Considerations

To the extent possible, and whenever appropriate, community considerations shall be incorporated into the design. The design shall:

a. Consider viewpoints of the users, residential and business communities, pedestrians, bicyclists, and motorists as long as it is within the scope and budget of the project.

b. Minimize impacts to adjacent properties.

c. Consider historic preservation, visual interest, noise mitigation, and aesthetic improvements.
1.5 Environmental Considerations

a. CEQA (California Environmental Quality Act) guidelines
b. NEPA (National Environmental Policy Act) requirements
c. Hazards and hazardous materials
d. Historic sites
e. Noise and vibration impacts
f. Permit requirements

1.6 Right-of-Way Access Considerations

All right-of-way (ROW) access locations shall be controlled to prevent trespassing and vandalism. Permanent right-of-way access shall contain sufficient controlled access space to the right-of-way for maintenance personnel and construction contractors, maintenance vehicles and emergency vehicles. Typical maintenance or emergency vehicles are one ton trucks.

Considerations shall also include possible ROW acquisitions, including temporary and permanent easements.

2.0 GENERAL DESIGN CONSIDERATIONS

Prior to each design submittal to Caltrain, the designer 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 industry standards and practices. The designer is 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 designer shall develop a specific design checklist to meet the needs and objectives, in order to facilitate the quality control process. Below are examples of design considerations that the checklists should incorporate for various design disciplines.

2.1 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

2.2 Track

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 & permanent), walkways, drainage channels, and signal foundations can be constructed without interference. Embankment and drainage design shall include footprints for signals, signal enclosures, and signal and communications 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

2.3 Station Design

Stations shall be designed to provide safety, and accessibility to all users, including bicyclists and mobility impaired persons. The resulting station shall be convenient, functional and attractive. Safety is paramount of all. The station design shall include platforms, platform crossing, station furniture and amenities and parking. It shall be functional for passengers, integrating other existing modes of local and regional transportation systems. To the extent possible, the station shall be as attractive as possible, incorporating local elements.

2.4 Station Communications

The requirements for public information/communication include the following devices, some of which are controlled from the CCF (Central Control Facility) at CEMOF (Centralized Equipment Maintenance and Operations Facility).
a. Closed Circuit Television (CCTV)

b. Fare Collection System (TVM or Ticket Vending Machine, SAV or Stand Alone Validator, Translink of regional pay system, PPM or Parking Permit Machine)

c. Public Announcements (PA)

d. Talking Signs

e. Visual Message Signs (VMS)

2.5 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)

2.6 Train Control Communication

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 tower
b. Data Radio System
c. Voice Radio System

2.7 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. Additionally, a risk analysis shall be performed on some of the vehicular crossings where there is a high pedestrian traffic. The design shall meet the requirements of FRA, Federal Highway Administration (FHWA), the CPUC and local agencies where applicable.

2.8 Civil Design

Civil design includes drainage, utilities, structures and bridges, fencing, and landscape and irrigation.

2.8.1 General Civil Work

General civil work includes grading and drainage, fencing, landscape and irrigation. Drainage is a critical component in the corridor to maintain Caltrain infrastructure. During 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 required improvements. Fencing is a critical safety component used to promote crossing at designated locations and to discourage general access to the Caltrain ROW.

2.8.2 Utilities

Close coordination is required with all utility owners. It is most important to perform utility survey consisting of a records survey to identify the utilities, potholing and other field survey. Consider impacts during construction to the utility owners and users. All utilities shall be underground.
2.8.3 Electrical, Mechanical, and Plumbing

a. Conduit and cable schedules

b. Electrical service

c. Emergency back up systems

d. Fire protection

e. Lighting

f. Mechanical systems

g. Plumbing

h. Wi-Fi

2.8.4 Structures and Bridges

Design of structures and bridges shall conform to Caltrain’s standards as contained in “PCJPB Standards for Design and Maintenance of Structures”, and “PCJPB Engineering Standards for Excavation Support Systems”.

3.0 SYSTEMS CONSIDERATIONS

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. 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 designer 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.

4.0 SYSTEM SAFETY AND SECURITY CERTIFICATION

Caltrain has a Safety and Security Certification Program Plan. 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 will be 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 designer shall refer to the Safety and Security Certification Program Plan for his responsibilities.

5.0 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 costing over $25 million. Timeline for value engineering shall be determined in the Design Basis Memorandum. 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. TRACKWORK

This Chapter includes criteria and standards for the design, materials, construction, and maintenance of Caltrain trackwork and its interface with other components of the rail system. The primary considerations are safety, economy, ease of maintenance, and constructability. The limits of trackwork are generally defined as between the subgrade and the top of rail, commonly referred to in this document as track structure.

Because of the complexity of the track system which is closely integrated 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.

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.

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


b. California Public Utilities Commission (CPUC), applicable General Orders

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

The Caltrain commuter rail system consists of revenue tracks and non-revenue tracks. 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 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 in extraordinary circumstances.

B. TRACK STRUCTURE

The track structure consists of subgrade, subballast, ballast, ties, fastening system, rail, 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 railroad signals (and for future electrification of the Caltrain commuter system).

Track structure is generally composed of rail, rail anchorage, track fasteners, ties, tie plates or pads, ballast and subballast constructed over an earth subgrade or on Hot Mix Asphalt Concrete (HMAC), or on a trough type bridge deck. See FIGURE 2-1 for typical sections of track structure.

Each of the components of the track structure is briefly described as follows. The track structure requires an effective drainage system in order to keep the subgrade well drain and stable. A well drain and stable subgrade means absence of standing water therefore preventing pumping phenomena. Additionally, any standing water may shunt the signal circuits causing signal failures.

1.0 SUBGRADE

Subgrade is referred to as the roadbed or trackbed that support the railroad loads transmitted through the rails, ties, ballast, and subballast. The subgrade or roadbed shall have adequate width for walkways and proper slope for drainage. Where possible, side ditches shall be provided to keep the subgrade free of standing water.

The top of subgrade must be graded so that there is a cross slope of three (3)% minimum towards the adjacent ditch or embankment slope. 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.
FIGURE 2-1 BALLASTED TRACK STRUCTURE

TYPICAL BALLASTED SINGLE TRACK STRUCTURE

TYPICAL BALLASTED DOUBLE TRACK STRUCTURE
2.0 SUBBALLAST

Subballast is a uniform layer of approved backfill placed and compacted over the entire width of the subgrade. Subballast shall 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 three (3)\% minimum towards the side ditch or embankment slope. 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 six (6) 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.

3.0 HOT MIXED ASPHALT CONCRETE (HMAC) UNDERLAYMENT

HMAC shall be installed with positive drainage and shall have a cross slope of three (3)\% minimum toward side ditch or underdrain. An eight (8) inch thick HMAC layer shall be used to replace the subballast layer at all at-grade crossings. A six (6) inch thick HMAC layer shall be used at all other locations as listed below to improve subgrade stability and facilitate drainage:

a. Within limits of special trackwork
b. Within limits of station platforms
c. In transition zones where track modulus changes, such as at bridge approaches

4.0 BALLAST

Ballast is placed above the subballast, or HMAC, or compacted subgrade. It plays a critical role by providing support for the rail and ties, distributing railroad loads uniformly over the subgrade, maintaining proper track alignment, and facilitating track maintenance.

Ballast shall be crushed rock, and of acceptable parent material, conforming to Caltrain Standard Specifications and shall be obtained from Caltrain approved quarries. Refer to FIGURE 2-2 for standard ballast sections.

For main tracks, including bridges, the minimum depth of the ballast shall be nine (9) inches. Ballast depth is measured from the bottom of the tie to the top of subballast. Maximum ballast depth shall not exceed 18 inches. Ballast depth outside these limits must be approved by the Caltrain Deputy Director of Engineering.
FIGURE 2-2 TRACK SECTIONS

TYPICAL BALLASTED TRACK SECTION

TYPICAL SUPERELEVATED BALLASTED TRACK SECTION

Note: Maximum depth of ballast below tie to be 18 inches.
For yard tracks and industrial tracks, the minimum depth of the ballast shall be six (6) inches, and 12 inches maximum.

5.0 TIES

Concrete ties shall be used for new construction of main tracks. Timber ties with Pandrol fastening systems are 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 on timber (at 21 inch spacing), or on concrete ties that are specifically designed for yard tracks.

Standard concrete ties for main tracks, including at stations shall be 8 feet-3 inches long and shall be installed at 24 inches spacing. Timber ties for main tracks shall be 7 inches x 9 inches x 9 feet long and shall be installed at 19-1/2 inches spacing.

Standard ties for at-grade crossings shall be 10 feet long concrete to minimize maintenance. 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.

6.0 OTHER TRACK MATERIAL (OTM)

Other track materials (OTM) include cut spikes, rail clips or pads, screw spikes, fastening systems, 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.

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, if available from Caltrain's existing inventory.

C. 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 restricted areas, special trackwork units may be
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 that are integrated with signal work.

See **FIGURE 2-3** 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:

a. Lateral turnouts numbers 8 and 9 for yards

b. Lateral turnouts number 10, 14, and 20 for main line
FIGURE 2-3  TURNOUTS AND CROSSES

- LATERAL TURNOUT
- LEFT HAND TURNOUT
- EQUILATERAL TURNOUT
- RIGHT HAND TURNOUT
- LEFT HAND CROSSOVER
- RIGHT HAND CROSSOVER
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 unbalance superelevation.

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

a. 10/10 MPH for turnouts numbers 8 and 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 Drawing 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.

D. TRACK GEOMETRY

The primary goals of geometric criteria for Caltrain are to provide a safe, cost-effective, efficient, and comfortable mode of transportation, while maintaining adequate factors of safety with respect to overall operations, maintenance, and vehicle stability. The design objective is track with as few curves and to as small a degree of curvature as possible. The geometric design criteria for trackwork have been developed using best engineering practice and the experience of comparable operating Commuter and Class 1 railroads.

The following key principles are used in establishing the geometric design criteria.

a. Consideration of Caltrain’s overall system safety
b. Optimization of passenger comfort
c. Effectiveness of implementation costs
d. Maximization of speed
e. Ease of maintenance

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

1.0 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. Where possible, track alignment shall be designed to maximum operating speed.
The design criteria for tangent, curve, design speed, superelevation, and spiral transition curve are described in the next few sections.

### TABLE 2-1 LIMITING DESIGN ELEMENTS

<table>
<thead>
<tr>
<th>DESIGN ELEMENTS</th>
<th>MAJOR LIMITING FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Length between Curves</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Vehicle truck/wheel forces</td>
</tr>
<tr>
<td>Horizontal Curves (Maximum Degree of Curve - Dc)</td>
<td>• Design speed</td>
</tr>
<tr>
<td></td>
<td>• FRA curve speed</td>
</tr>
<tr>
<td></td>
<td>• Trackwork maintenance</td>
</tr>
<tr>
<td></td>
<td>• Vehicle truck/wheel forces</td>
</tr>
<tr>
<td>Compound and Reverse Curves</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Vehicle suspension travel</td>
</tr>
<tr>
<td></td>
<td>• Trackwork maintenance</td>
</tr>
<tr>
<td>Length of Spiral Transition Curve</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Trackwork maintenance</td>
</tr>
<tr>
<td></td>
<td>• Vehicle suspension travel</td>
</tr>
<tr>
<td>Superelevation</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Vehicle stability</td>
</tr>
<tr>
<td>Superelevation Runoff Rate</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Vehicle suspension travel</td>
</tr>
<tr>
<td>Vertical Tangent between Vertical Curves</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Turnout locations</td>
</tr>
<tr>
<td>Vertical Curve/Grade (Maximum Rate of Change)</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Vehicle suspension travel</td>
</tr>
<tr>
<td></td>
<td>• Slack action and train handling</td>
</tr>
<tr>
<td></td>
<td>• Horizontal and vertical tangents</td>
</tr>
<tr>
<td>Special Trackwork</td>
<td>• Passenger comfort</td>
</tr>
<tr>
<td></td>
<td>• Trackwork maintenance</td>
</tr>
<tr>
<td>Station Platforms</td>
<td>• Vehicle clearances</td>
</tr>
<tr>
<td></td>
<td>• ADA platform gap requirements</td>
</tr>
<tr>
<td>Mixed use of Commuter/Freight RR</td>
<td>• Vehicle clearance</td>
</tr>
<tr>
<td></td>
<td>• Trackwork maintenance</td>
</tr>
<tr>
<td></td>
<td>• Compatibility of operations</td>
</tr>
</tbody>
</table>

### 1.1 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. 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. 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. In determining horizontal alignment the following levels of criteria shall be considered.

c. **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.

d. **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 a secondary consideration. The standards shall meet Federal and State minimum requirements and with approval from the Caltrain Deputy Director of Engineering.

e. **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.

### 1.2 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 \( L = 3V \) for
ride comfort is based on the rail car traveling at least two (2) seconds on tangent track between two curves.

The minimum tangent length for mainline tracks shall be established as per TABLE 2-2:

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>

Note:
* 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

Using absolute minimum tangent lengths requires the approval of the Caltrain Deputy Director of Engineering.
See Caltrain Standard Drawing for calculation and layouts of reversing curves based on given reversing tangent lengths.

1.3 Curves

The Maximum Authorized Speed (MAS) is 79 MPH. Curves shall be designed to maximize the speeds throughout the corridor to accommodate for future electrification of the Caltrain commuter system, and/or to allow for future system-wide increase in MAS with signal improvements.

Design speeds for passenger train running through all curves shall be as per TABLE 2-4:

<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>79</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>79</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.

1.3.1 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, \( E_s \), (inches)
f. Amount of unbalance, $E_u$, (inches)

g. Length of Spiral, $L_s$

1.3.2 Circular Curve

The circular or simple curve for the track geometry shall be based on 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:

$$R = \frac{50}{\sin(D_C/2)};$$
$$L_C = 100 \left( \frac{D}{D_C} \right);$$
$$T = R \tan(\Delta/2);$$

where $\Delta$ = central angle

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

See FIGURE 2-4 for illustration of the simple circular curve.

2.0 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 benefits of superelevation are improved ride quality, reduced rail and equipment wear.

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.

2.1 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” and the outside rail is designated as the “line rail”.
2.2 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.
- \( V \) = 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 determined to the nearest 1/4 inch by the formulas above. For any curve calculation on the main line which yields less than 1/4 inch of the required superelevation, 1/4 inch 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.

3.0 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.

3.1 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 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.
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
- $TS\ IN$: Tangent Length of Complete Curve $= TS\ OUT$

**FIGURE 2–5  CIRCULAR CURVES WITH SPIRAL TRANSITION**
3.2 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 terms 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.

**Spiral Length Requirements**

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

1. \( L_s = 1.63E_aV; \) or \( L_s = 1.22E_uV \)

2. \( L_s = 1.2E_aV \)

3. \( L_s = 62E_a \)

*Spiral length \( L_s = 1.22E_uV \) 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

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 \( L_s=1.2E_aV \), 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.

4.0 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.

5.0 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.

5.1 Grades

The maximum continuous main line grade along the Caltrain commuter corridor is one (1)%. The preferred 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. For new extensions designed exclusively for passenger trains, grades of up to three (3)% may be implemented. Grades exceed one (1)% shall be limited to vertical tangent length less than 1200 feet.

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,

\[ L = \text{minimum tangent length, feet} \]
5.2 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:

\[ L = \frac{(D V^2 K)}{A} \]

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

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 FIGURE 2-6 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:

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

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 (FIGURES 2-7 through 2-9, respectively) were developed by Systra Consulting for Caltrain. They were 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) is included in APPENDIX.

Acceleration Tests on Level, Tangent Track
EMD F40PH-2C Locomotive with 4 to 10 Gallery Cars

FIGURE 2-7 ACCELERATION CHART FOR EMD F40PH-2C LOCOMOTIVE
Acceleration Tests on Level, Tangent Track
MPI MP36PH-3C Locomotive with 4 to 10 Bombardier Cars

FIGURE 2-8 ACCELERATION CHART FOR MPI MP36PH-3C LOCOMOTIVE
Acceleration Tests on Level, Tangent Track
MP36PH-3C Locomotive and F40PH-2C Locomotive, Each with 7 Cars

FIGURE 2-9 DECELERATION CHART FOR MP36PH-3C LOCOMOTIVE AND F40PH-2C LOCOMOTIVE

END OF CHAPTER
CHAPTER 3

STATIONS AND FACILITIES

A. GENERAL

Station Design provides the designers with the minimum requirements for the design and planning of new, rehabilitated or temporary stations. The design requirements for electronic communications for the passengers' safety and security, and for the fare collection system are covered in the CHAPTER 4 STATION COMMUNICATIONS. Pedestrian crossings are contained in CHAPTER 7 GRADE CROSSINGS.

Caltrain’s stations shall be designed to promote and sustain the ridership growth, enhance the aesthetics of the neighborhood and community, and promote security and safety by maintaining station visibility to the public and local enforcement entities. 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 transit schedule updates to passengers.

d. Be attractive to passengers and community alike.

1.0 DESIGN RATIONALE

Caltrain stations consist of site access, parking, platforms, 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 10 years: Evaluate the current and potential demand of ridership at the station for the next 10 years. 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.

2.0 CODES AND REGULATIONS

Station and facilities design shall comply with this Criteria and the accompanying Caltrain Standard Drawings and Standard Specifications. Station 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.

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.

Stations designated by the State Historic Preservation Office (SHPO) as of historical value shall address the potential applicability of requirements of the Historic Preservation Act. The designer shall identify and evaluate potential impacts to the historical areas or structures. Significant architectural features shall be identified and considered 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:

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 train crew
Note: Signal house at 25' preferred, 16' minimum from the closest track centerline.

FIGURE 3-1 MINIMUM CLEARANCES AT STATION PLATFORMS
OUTBOARD PLATFORM
FIGURE 3-2 MINIMUM CLEARANCES AT STATION PLATFORMS
CENTER ISLAND PLATFORM

*Note:* Buildings, communications equipment room at 25’ from the closest track centerline. Signal house at 25’ preferred, 16’ minimum from the closest track centerline.
2.0 CONSIDERATIONS

The clearance requirements are critical due to the following current operational characteristics of Caltrain.

a. Express trains through most stations
b. High frequency of service, i.e., increased number of trains per hour
c. Through freight trains (operated by Union Pacific Railroad) with potential wide cargo or loose cargo or cargo fastenings
d. Tendency of passengers to congregate in front of shelters and Ticket Vending Machines (TVM) while waiting for trains
e. Operations configuration: bike car, ADA accessible car, Boarding Assistance Area, and mini-high platforms are located on the north third of platforms
f. Increasing amount of passengers requiring more space (mobility impaired persons, bicyclists, persons with luggages, children and strollers)
g. Uneven platform usage: tendency of passengers to congregate on the north third of platforms

3.0 HORIZONTAL AND VERTICAL CLEARANCES

3.1 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.

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

### 3.2 Vertical Clearances

Minimum vertical clearance shall be 24 feet 6 inches (24'-6") from top of rail. This includes pedestrian crossings. Overhead utilities 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.

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 are staggered around an adjacent street. These platforms are neither efficient nor convenient for passengers, and shall not be used possibly except as a temporary platform for use during construction.

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. See FIGURES 3-3 through 3-4 for typical 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 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 for a total platform length of 2000 feet.

b. Platform width: The platform shall be a minimum of 16 feet (20 feet preferred) wide for an outboard platform and a minimum of 26 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. For center island platform, the walkway is shared between the northbound and southbound platforms. This walkway is generally 18’-8” minimum between the yellow safety stripe but the space is also being used for station amenities such as shelters (passenger, TVM), benches, light poles, information display cases, poles for VMS, etc, and possibly possible stairway, or elevators depending on the design.

c. Platform 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) % are discouraged and shall require the approval of the Caltrain Deputy Director of Engineering. Platform cross slope shall be 1% minimum (2% maximum per ADA Standards) away from the tracks to provide for proper drainage for the track structure, and to provide a rolling slope away from the tracks for safety purpose. At center island platforms an underdrain shall be provided at the center of the platform width.

d. Platform curve: Station through curved track 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. Platform located on the curve shall require prior approval from Caltrain Deputy Director of Engineering.
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 3-3 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
FIGURE 3-5  TYPICAL PLATFORM FOOTPRINT REQUIREMENTS
e. 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 track centers shall extend such to allow a minimum of 100 feet center fence beyond the end of the at-grade pedestrian crossings, or beyond the end of the platform if the station does not have at-grade pedestrian crossings.

1.2 Temporary Station

A temporary station is constructed as part of the construction staging to allow continued passenger service during construction. 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

b. Platform material: Asphalt concrete

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. A conforming path of travel must be provided continuously from the street to the platform. All platform and parking lot facilities must comply with the referenced codes. Refer to Caltrain Standard Drawings for further details of each of the station element below.

2.1 Guide Tactile

Platforms shall contain detectable guide tactile to assist passengers in locating the ADA accessible TVM/SAV shelter, PNA (Person Needing Assistance) shelter, and Boarding Assistance areas.

2.2 Mini-High Platform

A mini-high platform, where feasible, shall be provided on each platform to assist with boarding of mobility impaired persons at all stations. The mini-high platform will be located in line with the second train car from the north.

2.3 Boarding Assistance Area

A boarding assistance area will be provided on each platform where mini-high platforms are not feasible. 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, a wheel chair lift and signage.
2.4 **Wheel Chair Lift**

A manually operated wheel chair lift shall be provided and located adjacent to the PNA shelter at the Boarding Assistance Area.

2.5 **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 **DRAINAGE**

Positive drainage away from the walkways, tracks and platforms shall be provided. Outboard platform surfaces shall slope away from the trackbed at one (1)% (2 % maximum per ADA) for drainage of runoff from rainfall. Center platforms shall drain to the center of the platform with area drains for discharge to the nearest municipal drainage collection system. Drain the entire station site and contiguous railroad right-of-way.

To enhance the effectiveness of the drainage at the station area, the track bed shall be constructed with six (6) inches thick Hot Mixed Asphalt Concrete (HMAC) 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. 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. **FURNISHINGS AND AMENITIES**

All station platform furnishings shall be standardized to provide a uniform appearance and for ease of maintenance and replacement. Canopies, shelters, bike lockers, news racks, trash receptacles and other publicly accessible receptacles shall meet Caltrain’s security requirements. They shall be securely fastened to the platform to prevent vandalism.

The principles of Crime Prevention Through Environmental Design (CPTED) shall be applied to all furnishings and amenities.

Caltrain Standard Drawings provide a general layout of each of the furnishings and amenities on the platforms.
1.0 FURNISHINGS

Station furnishings include all furniture for passengers located on the platforms. For placement of furniture and signs on the platforms, see Caltrain Standard Drawings.

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 6 feet deep and 18 feet long for outboard platforms. The shelters shall be 8 feet deep for center island platforms.

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 patron safety. Shelters should not create hiding areas. Shelter materials shall be vandal resistant.

Each shelter shall have at least one (1) electrical outlet for maintenance, and two (2) lamps. Illumination requirements are contained in Section I Electrical Systems 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 17 feet wide, vandal resistant, and furnished with schedule, two (2) lamps, and bench. Additionally, the same size shelters shall be provided for Ticket Vending Machines (TVMs), Stand Alone Validators (SAVs), and telephone. One passenger shelter shall be located in the Boarding Assistance area.

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) and Stand Alone Validator (SAV) Shelters

Shelters shall be provided for the Ticket Vending Machines (TVM) and Stand Alone Validator (SAV). These shelters are of similar design as those for passengers, with adequate space (depth and width) to accommodate wheelchair maneuver.

1.2 Benches

Benches shall be heavy duty, scratch and vandal resistant, and secured to the platform. The benches shall be configured to discourage sleeping on the benches and used as skateboard ramps. Benches shall be placed in passenger shelters and one bench shall be placed at the Boarding Assistance area. Refer to Caltrain Standard Drawings.
1.3 Trash Receptacles

Trash receptacles shall be provided on the platform as follows:

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 receptacle should be of concrete construction and standardized top loading heavy type as a deterrent to vandalism. Trash receptacles 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 pick-up crews.

1.4 Bike Lockers and Racks

Bike lockers shall be secured modular units. The number of bike lockers and bike racks shall generally be one (1) locker and one (1) bike rack 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. 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. No bike racks or lockers are to be located on the platform.

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 can be placed inside the 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.

2.0 STATION AMENITIES

Station amenities generally refer to communication to the passengers, fare collection system, security system, including other non-furnishing elements. All station amenities shall be securely fastened to the platform or pole/post. 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 Display Cases.
2.1.1 Visual Message Sign (VMS)

The Visual Message Sign (VMS) is required by ADA to augment and complement audio public address messaging for the benefit of hearing impaired commuters. Each unit has two (2) identical sides to display identical messages. A minimum of two (2) VMS boards per boarding platform shall be required for passenger 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 (8’-2”) and maximum clearance of 8 feet 6 inches (8’-6”). The tip 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 commuters waiting at a station. The PAS consists of speakers located along boarding platforms. A pair of PAS speakers will be mounted on every other light pole beginning at the second light pole on the north end of the platforms.

2.1.3 Talking Signs

Talking Signs for the visually impaired persons are currently available at the Caltrain terminal stations at San Francisco Station and the San Jose Diridon Station.

2.1.4 Public Information Display Case

Public Information Display Case for train schedule, system map, “You Are Here” map, and advisory bulletins 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.

2.1.5 Public Telephones

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/SAV shelter. Conduit provisions shall be included for public telephones.

2.2 Fare Collection System

The Fare Collection System consists of three (3) types of fare collection machines, namely Ticket Vending Machines (TVM), Parking Permit Machines (PPM), and Translink or regional smart card system. TVMs and Translink are located on the platforms and the PPMs are located on the parking lot. The machines shall be located in a well lighted area during hours of darkness.

2.2.1 Ticket Vending Machines (TVM) and Stand Alone Validators (SAV)

There shall be a minimum of two (2) TVMs and one SAV per platform area. Two (2) TVMs shall be accompanied with one (1) SAV and they shall comprise a set
(TVM/SAV). Each set shall be housed within a shelter. The location of the TVMs and validator within the shelter shall be spaced so as not to cause congestion from passengers using the equipment as shown in the Caltrain Standard Drawings. One (1) TVM/SAV set shall be located and housed approximately 220 feet from the northern edge of the platform.

If more than one (1) set of TVM/SAV are provided per platform, then the second TVM/SAV set shall be located not more than 300 feet apart from the other set.

2.2.2 Parking Permit Machines (PPMs)

Parking Permit Machines are pay by the space number. A minimum of two (2) PPMs shall be provided per parking area for passengers convenience and redundancy. The two (2) PPMs shall be located adjacent to each other near the entrance to the platform and on the pathway from the parking lot to the station. At some stations, parking permit purchase is available on the platform as an integrated purchase of parking and train ticket with automatic validation through the TVM.

2.2.3 TransLink

The Metropolitan Transportation Commission (MTC) comprising of nine (9) counties within the San Francisco Bay Area are implementing TransLink, a smart card fare payment technology. Translink 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 along with other Bay Area transit agencies are planning to or in the process of implementing this program, which is designed, installed, and managed by MTC.

As part of the Translink, a device called Card Interface Device (CID) will be installed on the platforms as the overall fare collection system. A minimum of three (3) CID will be provided on each platform. One (1) CID will be located toward the center of the platform preferably near a TVM shelter. One (1) CID will be located toward each end of the platform and near an entrance to the platform.

F. SAFETY AND SECURITY

The principles of Crime Prevention Through Environmental Design (CPTED) shall be applied to Safety and Security.

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 DETECTABLE WARNING TACTILE

A detectable warning tactile of 24 inches wide is required at the track side of the platform. The detectable warning tactile shall be installed on the full length of the platform. The detectable warning tactile shall also be installed at pedestrian
crossings to signify clear point of crossing. The tactile shall be Federal Yellow in color and must include the Federal Standard truncated domes.

3.0 SAFETY STRIPE

A six (6) inch wide yellow stripe shall be painted on the full length of the platform with the closest edge located 8 feet 6 inches (8'-6") from the center of the nearest track. One (1) foot behind the edge of the stripe, add six (6) inch black letter text “PLEASE WAIT BEHIND YELLOW LINE” to line up with every car door.

4.0 HANDRAILS AND GUARDRAILS

Handrails (3 feet 6 inches high) shall generally be provided at the back side of the platform where there is a grade drop of six (6) inches or more in accordance with ADA requirements. 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.

5.0 FENCING

5.1 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 at least 100 feet beyond the end of platform or beyond the pedestrian crossings. The fence shall be six (6) feet in height from top of rail 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 is designed to be sturdy 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.

5.2 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. Right-of-way fencing includes access gates for maintenance personnel.

6.0 CLOSED CIRCUIT TELEVISION (CCTV)

Closed Circuit Televisions will be installed on the platforms. 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.

G. 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.

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

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.

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 recommended 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 becomes the preferable alternative to an overpass where the track is at a level grade or is 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 for the convenience of 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 installed 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 shall be provided for platform access only where vertical distance makes ramps impractical, and only with approval of Caltrain Deputy Director of Engineering. Elevators should be located adjacent to the main access point of platforms.

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 10 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.

H. SIGNAGE

Signs shall be placed at sufficiently frequent intervals and at visible locations to provide clear directions and information to patrons without additional assistance. Signs should be illuminated by general lighting. The Caltrain logo shall be
configured to comply with the Caltrain graphic standards. See Caltrain Standard Drawings for all signage design and placement location.

1.0 Way Finding Signage

Way finding signs shall be installed well in advance of station destinations and in areas where there are no obstructions.

1.1 Parking Lot Signage

Caltrain signage shall be provided at the entrance to the commuter parking area, and way finding signs shall be placed to provide directions from major highway routes. General parking lot signage (No Parking, ADA Parking, etc) shall also be provided.

1.2 Platform Signage

The platform and right-of-way signs are necessary for passenger information and train operations or are required by ADA. Additional signs shall be configured to control passenger and trespasser access to the tracks and the right-of-way. For the design and location of platform signs, see Caltrain Standard Drawings.

Signs required for railroad operation shall be included in the station design and shall be located as per Caltrain Standard Drawings. These signs include:

a. Boarding Assistance
b. No Fun signs (No Smoking; No Skateboarding, etc.)
c. Pedestrian Warning and Advisory Note (at swing gate and on fence at pedestrian crossings)
d. Express Train Warning Sign (on fence)
e. Spot Cab signs
f. Station ID sign
g. Proof of Payment
h. Mile Marker, tenth mile marker or speed sign
i. Railroad Trespassing/Suicide Hotline sign

If “Mile marker, tenth mile marker or speed” signs are located at the station site, they shall be protected and kept visible to train crews throughout the construction process and accommodated in the final station design.
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 include the following:

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

b. Fare Collection Equipment

c. Station Communications Devices

d. Safety and Security Devices

e. Pedestrian Crossings Signal Equipment

f. Emergency Lighting and Power Systems (if required)

g. Mechanical Equipment

1.0 ELECTRICAL SERVICE

The electrical service shall consist of two (2) separate systems. One service is for the mission critical signal system. The other service is for all other station needs, such as general lighting, communications devices, fare collection systems, mechanical equipment, etc. Platform electrical receptacles are provided at shelters for maintenance personnel. Designer shall coordinate with various discipline users for load requirements and overall electrical system design.

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

Each station shall have a Communications Equipment Room (CER). 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, Stand Alone Validator, Parking Permit Machines, Regional Translink Pay System), and passenger information systems (Visual Message Signs, Public Address or PA System). 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), parking permit machines (PPMs), ticket validators (SAV or stand
alone validators), 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 permit machines and validators 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 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 deboard trains.

In addition to quantity of light, it is essential that illumination be designed to minimize glare and provide uniformity level of 3:1. 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 3-1.

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 Drawing.

**TABLE 3-1 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, Tunnels, 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 SAV</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 and Tunnels</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 illuminated 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, create hiding spaces or security barriers or interfere with access to any facility for maintenance. Landscaping shall not obstruct electronic or static signage. 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.

In parking lots, the principles of CPTED shall be applied.

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

“Station Communications” refers to the transmission of public information to the passenger stations using modern telecommunication systems and methods. The general philosophy is to strive for a system that is an integrated, customer driven, and near real time convenience.

Public information to the stations is generated and monitored from Caltrain Central Control Facility (CCF) which also houses the train dispatchers. CCF is located within the Centralized Equipment Maintenance and Operations Facility (CEMOF) in San Jose.

There are various types of public information made available through Caltrain stations using audible and visual communication subsystems. The objective is to provide passengers with scheduled and updated 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 public information, stations must be equipped with communications subsystems to allow fare collections and monitored security. Communication networks of adequate bandwidth shall be placed in-service between the stations and the CCF to facilitate the communication subsystems.
1.0 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. Parking Permit Machines (PPM)

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 two (2) terminal stations.

2.0 STANDARDS AND CODES

Station communication design shall comply with the latest edition/revision, unless noted otherwise, of all applicable local codes, ADA (Americans with Disabilities Act) requirements, and 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:

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 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 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) at a bandwidth not less than T1 (1.544Mbps).

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).

2.0 SUBSYSTEM NETWORKING

The objective of station subsystem design is to provide a flexible and robust infrastructure for the next 20 years. Towards this objective, an understanding of constants and variables are necessary to achieve efficient long-term planning.
2.1 Key Elements

a. The use of fiber optic cable, as a physical layer medium for subsystem backbone distribution, provides advantages over a copper based plant and will remain the solution of choice for several years. The main advantages are high bandwidth and elimination of electro-magnetic interference (EMI).

b. Subsystem products are regularly brought to market and their evolution trends towards having integrated network capability and interfacing directly with fiber optic cable, eliminating the need for third party conversion equipment.

c. The communications industry has seen constant changes in product development creating some product life cycles at less than five (5) years. Manufacturers have routinely discontinued product lines or in many cases discontinued operations entirely. To safeguard against these variables is a state-of-art fiber distribution infrastructure which confines changes or modifications to the equipment side, and not the cable distribution side of station design. The design objective for distribution cable plant and associated raceway is to avoid future replacement costs as subsystem products become available and upgrades occur.

d. In an ideal subsystem design, all subsystem components (PAS, VMS, CCTV, TVM) would be provided by the same manufacturer; all subsystem components would interface directly with fiber optic cable of the same type (single or multi-mode); and all subsystem components would have integrated media conversion or protocol signal equipment to avoid external enclosures or third party parts. Product manufacturers are migrating towards this ideal scenario but until that time, the subsystem infrastructure design must remain flexible.

2.2 Distribution System

Station communications distribution design shall be based on a hybrid ring and star topology. Ring topology for the high capacity fiber optic backbone; and star topology for connectivity between network distribution points (cabinets) and subsystem devices.

The distribution backbone shall consist of a high capacity (bandwidth) TCP/IP Ethernet protocol. The minimum bandwidth shall be 1000Mbps.

The distribution backbone shall originate at the station Communications Equipment Room (CER). Physically diversified single-mode fiber optic cable paths will provide backbone connectivity from the CER to distribution (aggregate) 1000Mbps switches located throughout the station. This design forms a physical fiber optic ring to protect against cable cuts or equipment outages.

At all network distribution locations, dual 1000Mbps network switches shall be deployed. The first switch at each location shall be assigned to fiber optic ring number one. The second switch at each location shall be assigned to fiber optic ring number two.
At the distribution (aggregate) switch location, subsystem devices are connected using TIA/EIA Category 6 data cable. ANSI/TIA/EIA-568B standard governs the maximum cable distance between the distribution switch and the subsystem device to be 328 feet, inclusive of all patch or cross-connect cables. This standard shall apply to all subsystem distribution, to include the Public Address System or PAS, to ensure that as products evolve, integrate, and adapt to digital signal format, then the cable infrastructure will remain conformed to industry standards.

At the distribution (aggregate) switch location, connectivity of subsystem devices shall be distributed between both network switches. For example, a platform area occupied by two (2) Ticket Vending Machines will assign TVM number one to aggregate switch number one; and TVM number two to aggregate switch number two. This configuration ensures one working TVM in the event of a switch hardware failure.

To ensure network reliability using Category 6 copper data cabling when absent redundant cable/network path to the subsystem device, the following shall be observed:

a. Category 6 data cabling between the distribution switch and the subsystem device demarcation points shall be continuous and without splices. At the distribution switch, the demarcation point shall be a Category 6 RJ45 female patch panel. At the subsystem device end, the demarcation point shall be an RJ45 female connector protected in a steel 4 inches x 4 inches junction box.

b. Solid-state surge protection shall be placed on the distribution switch cable side for equipment protection. Protection shall meet Category 6 standards, and shall be fast clamping zener diode type protection.

c. Category 6 distribution cables shall be placed in steel conduit, dedicated per cable run and system device. Distribution cable shall never be exposed outside the conduit raceway.

2.2.1 Closed Circuit Television

Closed Circuit Television or CCTV is used for station video surveillance. The quantity and location of cameras will depend on the type and size of station. CCTV shall be installed at the pedestrian underpasses, or overpasses within or adjacent to the station, and at parking area.

Video cameras, as with all subsystem devices, shall be networked and assigned dedicated bandwidth. The network protocol shall be TCP/IP for all subsystems. Communication network architecture shall be based on optical transport as described later in this Chapter to deliver greater bandwidth and improved system reliability.

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 (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.
The IP camera shall be supplied dc power using Power-Over-Ethernet (POE) technology.

At the station CER, computer based hard-drives shall be used to record and store video information up to 14 days. Motion and audio detection software shall 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 MPEG-4 while recording at Motion JPEG.

At the CER, a means to connect the CCF and Caltrain Central Office in San Carlos with the station video server using TCP/IP shall be designed to allow the CCF and the Caltrain Central Office to retrieve stored records. Additionally, some Local Agencies may request monitoring capability.

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.

The capacity of video storage hard-drives is a product of network camera parameters. As an example:

- Number of network cameras = 53
- Frame rate (15 fps)
- Resolution (320 x 240)
- Compression Type (Motion JPEG)

At minimum, the station design shall provide for redundant hard-drives capable of recording and storing video information for 14 days.

At least 200Mbps of each available 1000Mbps fiber optic ring capacity shall be partitioned for CCTV. 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.

2.2.2 Ticket Vending Machines (TVM)

A minimum of two (2) units of TVM per boarding platform shall be provided for redundancy, and to handle any peak usage. Though not a TVM, Translink utilizes the same network topology, connectivity, or other considerations when comparing these locations. This subsystem design shall utilize a VLAN IP-based network operating at 100 Mbps.

At minimum, each TVM shall have dedicated Category 6 or fiber optic connectivity to the distribution network switch via physically separated conduit runs.
Distribution cabinets shall house dual network (aggregate) switches. Each TVM device shall be assigned to a separate distribution switch for additional network reliability.

Stand Alone Validator (SAV) validates the ticket, and is located adjacent to a set of TVM units. SAV requires only ac power, but no wiring is needed.

Translink is a regional system that is designed and administered by the MTC or Metropolitan Transportation Agency.

2.2.3 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 15.8 inches high x 65.6 inches wide, with a six (6) inches high LED (light emitting diode) text. A minimum of two (2) 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.

Depending on product availability, the VMS will either be equipped for Category 6 or direct fiber optic cable interface. Connectivity shall be made to the assigned distribution switch.

Each visual messaging unit will have dedicated Category 6 or fiber optic 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.

2.2.4 Public Address System (PAS)

Public Address Subsystem or PAS consists of speakers located along boarding platforms to provide clear, audible communication to commuters. These announcements are controlled from the Central Control Facility (CCF), and may also be at the station office on a limited duration basis. PAS pre-recorded voice announcements shall be coordinated with stored, preset text messages for display on the VMS.

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

At the station, local announcements via phone system (local or remote dial access), or local microphone shall be provided.

An IP-to-Audio gateway shall be provided at each network switch requiring conversion between data and analog signals. Analog (voice) signals are required at distribution amplifiers to drive the PA speakers throughout the station.

A pair of PAS speaker shall be mounted on every other light pole. Each PAS speaker location shall have dedicated Category 6 or fiber optic connectivity to the distribution network via physically separated conduit runs.

The PA system shall provide intelligible output coverage at a level 6 dB to 12 dB over normal train, equipment, and station ambient noise. Nominal sound pressure level shall be 77dBA +/- 3dBA at five (5) feet above platform level. On station platforms the coverage shall be a uniform level (+/- 3 dB) over 90% of the open platform area.

2.2.5 Parking Permit Machines (PPM)

Similar to Translink, Parking Permit Machines and Translink are considered TVM's. PPM is a separate pay per space machine at the parking area, which requires power, but no wiring. However, designer shall provide alternatives for the unit to enable communication to the Caltrain Central Office in San Carlos.

There's no difference in network topology, connectivity, or other considerations when comparing these locations. At some Caltrain stations, parking permit may be purchased directly at the TVMs.

2.2.6 Passenger Assistance and Emergency Telephones

Where required to comply with Americans with Disabilities Act (ADA) regulations. Talking signs are provided at the terminal stations in San Francisco and San Jose Diridon.

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 and Multi-Mode Cable

With consideration to available subsystem devices given changes in technology and implementation costs, both single-mode (SM) and multi-mode (MM) fiber optic cable shall be installed in the station backbone. Both types of FOC shall be provided in a physical ring topology. Single-mode and multi-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 or multi-mode cable.

To distinguish between single and multi-mode cable distribution, all single-mode FOC, fiber connectors and patch cords shall be colored yellow. All multi-mode FOC, fiber connectors and patch cords shall be colored orange. At the CER and DC (distribution cabinet), separate fiber distribution panels shall be used for single-mode and multi-mode fiber demarcation.

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

3.2 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 cannot be avoided, adequate clearances must be adhered to when crossing either under or over another utility. Outside plant conduits will be spaced at least 12 inches from other paralleled utilities, and at least 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.

3.3 Outside Conduits

There are three (3) types of conduit used in outside plant conduit structures:

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 cannot 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 will operate using an uninterruptible power supply (UPS) with battery reserve capable of sustaining the full equipment current load for a period up to eight (8) hours.

UPS 120Vac receptacles shall be orange type NEMA L5-XX for identification.

The UPS load center shall be sized for the full compliment 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

All network switches and PAS amplifiers shall be equipped with dual ac power supply for redundancy.

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. 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.
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:

   Average – 0.175 mg/m3
   Maximum – 0.324 mg/m3

b. Ozone – 0.200 ppm, max.

c. Noa – 0.25 ppm, max.

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.

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 4 and shall have a stainless steel finish.

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.

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 (TOPB) 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 backup 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 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.

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
A 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.

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. 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.

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...
system. Application logic software shall be “safe” and conform to all applicable regulatory rules and regulations but “simple in form” so as to be easily understood by personnel responsible for the maintenance and care of the system. As much as is practical, within the scope of a project, equipment to be installed shall be scalable for future expansion, and the signal houses shall be sized accordingly.

Where these criteria make reference to system logic and design criteria 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. 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 in CHAPTER 7 – GRADE CROSSINGS.

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. 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
+------------
+---------------------------
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.

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 masted 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 advance of the signal. Where conditions require placement in advance of, or on 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 10-volt/25-watt bulb, or LED assembly as described in AREMA C&S Manual Part 7.5.1.

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.

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>
<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>
</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 thusly: 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 TABLES 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>YELLOW over FLASHING GREEN (for a Number Plated Signal)</td>
<td>DARK over YELLOW</td>
</tr>
<tr>
<td>YELLOW over FLASHING GREEN (for an Absolute Signal)</td>
<td>FLASHING RED over RED</td>
</tr>
<tr>
<td>YELLOW over GREEN (for a Number Plated Signal)</td>
<td>DARK over YELLOW</td>
</tr>
<tr>
<td>YELLOW over GREEN (for an Absolute Signal)</td>
<td>FLASHING RED over RED</td>
</tr>
<tr>
<td>YELLOW over YELLOW (for a Number Plated Signal)</td>
<td>DARK over YELLOW</td>
</tr>
<tr>
<td>YELLOW over YELLOW (for an Absolute Signal)</td>
<td>FLASHING RED over RED</td>
</tr>
<tr>
<td>FLASHING YELLOW over RED</td>
<td>FLASHING RED over RED</td>
</tr>
<tr>
<td>YELLOW over RED</td>
<td>FLASHING RED over RED</td>
</tr>
<tr>
<td>FLASHING RED over RED</td>
<td>DARK over FLASHING RED</td>
</tr>
<tr>
<td>RED over GREEN</td>
<td>DARK over FLASHING RED</td>
</tr>
<tr>
<td>RED over FLASHING YELLOW</td>
<td>DARK over FLASHING RED</td>
</tr>
<tr>
<td>RED over YELLOW</td>
<td>DARK over FLASHING RED</td>
</tr>
<tr>
<td>RED over FLASHING RED</td>
<td>DARK over FLASHING RED</td>
</tr>
<tr>
<td>RED over RED</td>
<td>DARK over RED</td>
</tr>
</tbody>
</table>
### TABLE 5-4  TWO UNIT SIGNAL
#### BOTTOM UNIT LAMP OUT

| GREEN over RED | GREEN over DARK |
|                |                |
| YELLOW over FLASHING GREEN | YELLOW over RED |
| YELLOW over GREEN | YELLOW over RED |
| YELLOW over YELLOW | YELLOW over RED |
| FLASHING YELLOW over RED | FLASHING YELLOW over DARK |
| YELLOW over RED | YELLOW over DARK |
| FLASHING RED over RED | FLASHING RED over DARK |
| RED over GREEN | RED over FLASHING RED |
| RED over FLASHING YELLOW | RED over FLASHING RED |
| RED over YELLOW | RED over FLASHING RED |
| RED over FLASHING RED | FLASHING RED over DARK |
| RED over RED | RED over DARK |

### TABLE 5-5  THREE UNIT SIGNAL
#### TOP UNIT LAMP OUT

| GREEN over RED over RED | FLASHING YELLOW over RED over RED |
|                        |                                |
| YELLOW over FLASHING GREEN over RED | FLASHING RED over RED over RED |
| YELLOW over GREEN over RED | FLASHING RED over RED over RED |
| YELLOW over YELLOW over RED | FLASHING RED over RED over RED |
| FLASHING YELLOW over RED over RED | FLASHING RED over RED over RED |
| YELLOW over RED over RED | FLASHING RED over RED over RED |
| FLASHING RED over RED over RED | DARK over FLASHING RED over RED |
| RED over FLASHING GREEN over RED | DARK over FLASHING RED over RED |
| RED over GREEN over RED | DARK over FLASHING RED over RED |
| RED over FLASHING YELLOW over RED | DARK over FLASHING RED over RED |
| RED over YELLOW over GREEN | DARK over FLASHING RED over RED |
| RED over YELLOW over YELLOW | DARK over FLASHING RED over RED |
| RED over YELLOW over RED | DARK over FLASHING RED over RED |
| RED over FLASHING RED over RED | DARK over FLASHING RED over RED |
| RED over RED over RED | DARK over RED over RED |
### TABLE 5-6 THREE UNIT SIGNAL
SECOND UNIT LAMP OUT

<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 GREEN</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 GREEN</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over RED over FLASHING YELLOW</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over RED over YELLOW</td>
<td>FLASHING RED over DARK over RED</td>
</tr>
<tr>
<td>RED over FLASHING RED over RED</td>
<td>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 YELLOW over YELLOW over RED</td>
<td>RED over YELLOL over RED</td>
</tr>
<tr>
<td>RED over YELLOW over RED</td>
<td>RED over YELLOW over RED</td>
</tr>
<tr>
<td>RED over RED over GREEN</td>
<td>RED over RED over DARK</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. Control 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 the secure web site as directed by Caltrain.

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.

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.

In FIGURE 5-2, 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 ERBC (Error Rate Block Control). 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

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 assure 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:

!----------(adequate braking distance)--------!-------------1500’---------------!
RED-------------------------------YELLOW-----------------------------GREEN
!---------------------------(Approach Locking limits)-------------------

!----------(adequate braking distance)--------!-------------1500’---------------!
RED---------YELLOW----------FLASING YELLOW---------GREEN
!---------------------------(Approach Locking limits)-------------------

Time or approach locking should be released by a train occupying two consecutive track circuits beyond the control signal. On low-speed routes, where a second track circuit is not available, one track circuit may be used to release time and/or approach locking; however, two-track circuit releasing is preferred. 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, 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 after the signal has been passed, and the train is 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 will 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 may 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 insure 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.

![Diagram of 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.
minimum, a 120/240 Vac 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 CHAPTER 7 – GRADE CROSSINGS.

M. SIGNAL BLOCKS

Electrocode Code Rates 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

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.

\[
AG = \frac{DG + DG + DG + DG + \ldots}{\text{TOTAL BLOCK LENGTH}}
\]

For Freight train braking, 6,000 feet in approach of the block must be used in averaging.

For passenger train braking calculations, 1000 feet in approach of the block must be used in averaging. 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:

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

For descending grades it is:

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

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 SIGNAL DESIGNER

Signal designers who work on Caltrain signal circuits or programs must be approved by the Caltrain Deputy Director of Engineering. In general, a circuit 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 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.

The designer may be interviewed, at the discretion of the Caltrain Deputy Director of Engineering. The interview may require a demonstration of circuit and program analysis.

P. QUALIFICATIONS OF SIGNAL CHECKER

Signal Checkers who work on Caltrain signal circuits or programs must be approved by the Caltrain Deputy Director of Engineering. In general, a circuit Checker should have a minimum of five 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.

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 circuit and program analysis.

Q. 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 Communication/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 the Caltrain to provide such services. Upon completion of the design, two (2) complete plan sets shall be distributed to an outside firm authorized by the Caltrain to perform “final checks”.
Included with the plan 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 plans 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 Caltrain standards, field survey requirements, service contracts agreements, CPUC application drawings, and circuit integrity. On one (1) plan set the final checker shall indicate any corrections that are needed. Once completed the “marked-up” plan set shall be returned to the originating design firm for correction. Upon completing the revisions, a corrected 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 plans 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 plans shall be clearly marked PRELIMINARY and the checker’s field in the JB NOTE cell shall be left blank. At the time of this preliminary distribution, two (2) plan 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 plan set is completed and corrections have been made, a final plan 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 plan date and a statement will be incorporated instructing construction forces to destroy the preliminary plan set in lieu of the final plan 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 Engineer. In such instances, the modifications shall be clearly marked on a plan set and the modified plan set delivered to a final checker as soon as possible. All field modifications shall be thoroughly tested to ensure the integrity of the system.

R. FILE MANAGEMENT

Part 236 Section 1 and Part 234 Section 201 of CFR 49 require that up to date and accurate signal plans 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 Drawings and Programs and be compliant with Federal Regulations, the following checkout procedure will be followed by all 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 or his representative. 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 or his representative 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.

S. 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 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 the Caltrain to make any necessary arrangements for capacity improvements.

END OF CHAPTER
CHAPTER 6

TRAIN CONTROL COMMUNICATION

A. GENERAL

The 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 various leased telephone subsystems, including T1, 4Wire (Analog), 4Wire E&M (Analog), 4Wire (Digital), 2Wire (Analog), Frame Relay and DSL. 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.

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 Parking Permit Machine or PPM)

The Design Criteria for these sub-systems are addressed separately in CHAPTER 4 STATION COMMUNICATIONS.

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) 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 system uses 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 of deciding which Base Station site will be the most-likely-server for the Control Point being commanded (router function).

Caltrain currently uses a Code Server manufactured 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. This protocol is used for all direct telephone 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. 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 SCS 128. 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 Digital Concepts, Incorporated. It has the capability to support interfaces to multiple dispatch stations.

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 via an A/B switch. The Packet Switches shall convert all messages from the Code Server, which shall be encoded with the SCS-128 protocol to the ATCS protocol. Likewise, DS0 messages from the
field Base Station sites, which are encoded with the ATCS protocol, shall be converted to SCS-128 before being routed to the Code Server.

This two-way protocol conversion adds significant delay overhead to the throughput of the Supervisory Control System, but is required in order to interface the ATCS network with the DigiCon’s Code Server. Note also that the TCP/IP (Transmission Control Protocol/Internet Protocol) (or UDP/IP or User Datagram Protocol/Internet Protocol) is an intermediate protocol that must be used by the Packet Switches in the protocol conversion from ATCS to SCS-128 and vice versa.

The CCF Packet switches shall also monitor the inbound signal quality (RSSI or Received Signal Strength Indicator) 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 approximately 30 Control Points are in operation, between CP Common and CP Fourth Street in the north and CP Lick in the south, of which 20 are on the ATCS data radio network.

A total of three 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 in Daly City, Monument Peak in Milpitas, and a third site which is located at CP Lick in South San Jose. The site in South San Jose was installed to support the Control Point at CP Lick.

The two primary Base Stations are configured as redundant to each other, and hence each shall be capable of providing ATCS data radio support to all of the remaining Control Points along the Caltrain corridor. 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 99.0%, from a minimum of two Base Station sites; otherwise it shall be supported using leased telephone circuits.

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 such as 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 leased 4Wire telephone circuits or via the use of Microwave Radio links (with a reliability of 99.9999% 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 shall 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.

e. The ATCS communication between the Base Station sites and the Control Points shall be based on a contention scheme. A pair of 900 MHz band ATCS frequencies configured for a Multiple-Address-Scheme is used to implement the channel. The following frequencies are used currently, and additional ATCS pairs shall be added as required:
Under this scheme, each Control Point, which has a message to send to the OCC, 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.

f. Data Radio Base Station repeaters shall employ GMSK (Gausian 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. 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. Currently there are four (4) protocol conversions required per message round-trip (two per direction). 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.

g. All control points shall be connected to the leased 4W telephone circuit that is present at each CP site. This connection shall however act 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 quickly reconfigured to be controlled via the 4W telephone connections.

### 4.0 TELCO INTERFACES

**TABLE 6-1** lists the current leased telephone infrastructure used by the Caltrain to support the ATCS Data Radio and the VHF Voice Radio systems described in Sections 1.0 and 3.0 respectively. The following four circuit types are used:

<table>
<thead>
<tr>
<th>ATCS CHANNEL</th>
<th>FREQUENCY</th>
<th>DESCRIPTION</th>
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<td>935.9375 MHz</td>
<td>Base Station Transmit Frequency</td>
</tr>
<tr>
<td>2</td>
<td>896.9375 MHz</td>
<td>Base Station Receive Frequency</td>
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### TABLE 6-1 COMMUNICATION SYSTEMS AND LEASED TELEPHONE INFRASTRUCTURE

<table>
<thead>
<tr>
<th></th>
<th>CRITICAL SYSTEMS</th>
<th>CIRCUITS</th>
<th>TYPES</th>
<th>OFFICE PAIRS</th>
<th>FIELD PAIRS</th>
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</tbody>
</table>

**TOTALS CIRCUITS**

|   | 26 | 43 | 55 |
a. 4 WIRE POINT to POINT (PTP)

A 4 Wire PTP line is a 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 telephone communication. This type of leased circuit is required between each of the three ATCS Data Radio Base Station 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 single telephone circuit with 4 wires, which enables it to support full-duplex telephone 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 is 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 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 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 of the eight Voice Radio Base Station sites and the CCF. For ‘E’ and ‘M’ signaling, the ‘M’ lead is used to haul the PTT command from the CCF to the Base Station sites. The ‘E’ lead is capable of hauling status information from the Base Station sites to the CCF, but is currently not used.

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

C. VOICE RADIO

A VHF (Very High Frequency) Voice radio system consisting of two channels; a road (dispatch) channel and a yard (blue flag) channel are currently used to support all operations along the Caltrain ROW. 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 the Fourth Street near downtown San Francisco and CEMOF in San Jose. 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. 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, they 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.

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.

1.1 The Above-Ground Base Station Sites

Of the four (4) above-ground base station sites, three are controlled by the “Northern Zone” dispatch, and one by the “Southern Zone” 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.

As Caltrain expands, a Maintenance channel will be added. The design configuration for such a Maintenance channel shall be different than that used for the road channel. This design shall be based on the use of high-level radio Base Station sites, located at very high elevation, and therefore capable of providing radio coverage along the entire ROW from a single site. 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. In this regard, high elevation radio sites such as the existing Caltrain sites at Monument Peak and San Bruno mountain shall be investigated.

To support this configuration, the Maintenance Base Station 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 6-2 below, along with their GPS (Global Positioning System) coordinates.

**TABLE 6-2 NORTHERN DISPATCH BASE STATION SITES**

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<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” W 122° 23’ 50.2”</td>
<td>65 (55+10)</td>
<td>OMNI DIRECTIONAL Gain 0dBi</td>
</tr>
<tr>
<td>Sign Hill</td>
<td>N 37° 39’ 53.8” W 122° 25’ 14.1”</td>
<td>576 (561+15)</td>
<td>156 º Gain 8dBi</td>
</tr>
<tr>
<td>San Carlos</td>
<td>N37° 30’ 23.4” W122° 15’ 43.1”</td>
<td>106 (99+7)</td>
<td>140º Gain 8 dBi</td>
</tr>
</tbody>
</table>

The “Southern” dispatch Base Station site is listed in TABLE 6-3 below, along with its GPS coordinates.

**TABLE 6-3 SOUTHERN DISPATCH BASE STATION SITES**

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<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” W 121° 54’ 29.22”</td>
<td>138 (78+60)</td>
<td>314º /134º Dual Yagi Gain 10dBi</td>
</tr>
</tbody>
</table>

1.2 The Tunnel Radio Base Station sites

Located between the Fourth Street 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 one 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 tunnel radio sub-systems is voted amongst themselves to select the best audio signal to present to the dispatcher. The voters, which are manufactured by M/ACom (formerly GE/Ericson), 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 tunnel’s 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 shall be 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 antenna is used external to each tunnel in order to extend the radio coverage into the hilly regions adjacent to these tunnels.

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 11.3 (between Millbrae and San Bruno), MP 28.2 (between Menlo Park and Atherton) and MP 42.2 (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 6-4.
### TABLE 6-4 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>11.3</td>
<td>N 37° 37’ 42.2” W 122° 24’ 37.0”</td>
<td>15</td>
<td>Rail Tx. OMNI Gain 0dBi</td>
</tr>
<tr>
<td>28.2</td>
<td>N 37° 27’ 36.4” W 122° 11’ 25.9”</td>
<td>36</td>
<td>Rail Tx. OMNI Gain 0dBi</td>
</tr>
<tr>
<td>42.2</td>
<td>N 37° 22’ 11.5” W 121° 58’ 27.6”</td>
<td>44</td>
<td>Rail Tx. OMNI Gain 0dBi</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 built-in Motorola HT-440 VHF voice radio connected to a small roof mounted omni-directional antenna. The Motorola HT-440 has been discontinued by the Manufacturer and replaced with the HT-1250 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 $\geq -109$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 between within the ROW through Gilroy is equipped with a VHF-voice mobile radio. 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. All such radios will require reprogramming in order to support the future Caltrain Maintenance channel, which shall be added to all field radios.

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 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 system. 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 dispatch operations. It is therefore repeated along the entire ROW. A second simplex channel, the Yard (aka ‘blue flag’) channel is used to support maintenance and yard related activities and is only broadcast within the confines of the two “yard” locations along the ROW.

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.

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 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 6-5 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 6-5 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 6-5 WHO NEEDS TO HEAR FROM WHOM

<table>
<thead>
<tr>
<th>Transmit</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></td>
<td></td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Dispatcher</td>
<td></td>
<td>N/A</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Train Engineer</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Train Conductor</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>N/A</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>EIC</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Maintainer (Mobiles)</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Maintainer (Portables)</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
</tr>
<tr>
<td>Yard</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>N/A</td>
<td>√ PL</td>
</tr>
<tr>
<td>Terminal Manager</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>N/A</td>
</tr>
<tr>
<td>CEMOF</td>
<td></td>
<td>√ G</td>
<td>√ G</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>√ L</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>DED</td>
<td></td>
<td>√ G</td>
<td>No</td>
<td>√ PL</td>
<td>No</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 each other, this Local Communication capability is protected and guaranteed by the Radio System design. In the case of the DED, this Local Communication capability is guaranteed for a distance of +/- 3 miles with respect to the DED along the track. In the case of the Yard and Terminal Manager, this Local Communication capability is guaranteed within a circle of radius about 5 miles centered about the Fourth Street tower and about the CCF.

No = NO COMMUNICATION REQUIRED

N/A = NOT APPLICABLE
g. The following **TABLE 6-6** 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 6-6 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. **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.

1.0 **ATCS DATA RADIO**

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

a. National Electrical Code (NEC)
b. CAL/OSHA standards
c. CPUC Regulations
d. State of California Electrical Safety Orders, Title 8, CAC
e. FCC rules and regulations
f. The Motorola R56 grounding standard
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:

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

3.0 VOICE RADIO

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

All Installations shall be in accordance with the following codes:

a. National Electrical Code (NEC)
b. CAL/OSHA standards
c. CPUC Regulations
d. State of California Electrical Safety Orders, Title 8, CAC
e. FCC rules and regulations
f. The Motorola R56 grounding standard

E. 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
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 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.

F. 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 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, or from GE.

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</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>LCFS114-50A or equal</td>
<td>Cellwave/ Andrew</td>
</tr>
<tr>
<td>16</td>
<td>Coaxial Cables</td>
<td>LCF78-50A LCF12-50A or equal</td>
<td>Cellwave/ Andrew Cellwave/ Andrew</td>
</tr>
<tr>
<td>17</td>
<td>Antenna Mast and Installation accessories</td>
<td>NA</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 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>±0.1ppm, -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 Cyclic 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 (EIA SINAD)</td>
<td>-75 dB</td>
</tr>
<tr>
<td>Spurious and Image Rejection</td>
<td>-90 dB</td>
</tr>
<tr>
<td>Audio Squelch Sensitivity</td>
<td>12 dB SINAD</td>
</tr>
<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>
</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>Frequency Stability</td>
<td>+0.1 ppm, -30°C to + 60°C (-22°F to +140°F)</td>
</tr>
<tr>
<td>Diagnostic Service Port</td>
<td></td>
</tr>
<tr>
<td>Port Type</td>
<td>Async. EIA-232</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>19200 bit/sec typical</td>
</tr>
<tr>
<td>Data Link Protocol</td>
<td>ANSI, 8 Data bits. No Parity, 1 Stop bit</td>
</tr>
<tr>
<td>Electrical Requirements</td>
<td></td>
</tr>
<tr>
<td>AC Input Voltage</td>
<td>120-240 VAC @ 50-60 Hz</td>
</tr>
<tr>
<td>AC Input Current</td>
<td>0.4A (Standby @ 117VAC) 1.8A (Tx@ 25W, @ 117VAC) 3.3A (Tx @ 75W, @ 117VAC)</td>
</tr>
<tr>
<td>AC Input Power</td>
<td>47W (Standby), 211W (Tx@25W), 390W (Tx@75W)</td>
</tr>
<tr>
<td>DC Input Voltage</td>
<td>26.5 VDC</td>
</tr>
<tr>
<td>DC Input Current</td>
<td>6A (Tx@25W), 11A (Tx@75W)</td>
</tr>
</tbody>
</table>

### 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&quot;HX10&quot;WX10&quot;L</td>
</tr>
<tr>
<td>Weight</td>
<td>16 lbs</td>
</tr>
<tr>
<td>FCC Compliance</td>
<td>Parts 15, 90</td>
</tr>
<tr>
<td>Transmitter</td>
<td></td>
</tr>
<tr>
<td>RF Power Output</td>
<td>30W Normal</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>Per TIA-603</td>
</tr>
<tr>
<td>Spurious Emissions</td>
<td>-65 dBC</td>
</tr>
<tr>
<td>Harmonic Emissions</td>
<td>-65 dBC</td>
</tr>
<tr>
<td>Frequency Stability</td>
<td>1.5 ppm, -30°C to 60°C (-22° to + 140°F)</td>
</tr>
<tr>
<td>RF Data Communications</td>
<td></td>
</tr>
<tr>
<td>Frequency Range</td>
<td>Receive @ 935-941 MHz, Transit @ 896-902 MHz, Normal, Transmit @ 935-941 MHz, T/A Mode</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>6 (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 Bite Rate</td>
<td>4800 bits/sec</td>
</tr>
</tbody>
</table>
## TABLE 6-9  CONTROL POINT DATA RADIO SPECIFICATIONS (Continue)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Correction</td>
<td>Reed-Solomon (16, 12) Forward Error Correction (FEC) and 16 bit Cyclic Redundancy Check (CRC)</td>
</tr>
<tr>
<td>RF Channel Access</td>
<td>Data “Busy-Bit” protocol</td>
</tr>
<tr>
<td>Maximum Frequency Deviation</td>
<td>Adjust per the Operations Manual</td>
</tr>
<tr>
<td><strong>Client Ports</strong></td>
<td></td>
</tr>
<tr>
<td>Types of Ports</td>
<td>3 software configurable interfaces, 2 Sync./Async., EIA-422/EIA-232, 1 Sync./Async., EIA-422</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>9600 bit/sec typical</td>
</tr>
<tr>
<td>Data Link Protocol</td>
<td>HDLC Balanced (Sync. Or PPP Async.), HDLC Polled (Dial Backup), Others Available</td>
</tr>
<tr>
<td>Alarm Inputs</td>
<td>7 Total</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>Selectivity</td>
<td>-70 dB</td>
</tr>
<tr>
<td>Intermodulation Rejection (EIA SINAD)</td>
<td>-65 dB</td>
</tr>
<tr>
<td>Spurious and Image Rejection</td>
<td>-75 dB</td>
</tr>
<tr>
<td>Frequency Stability</td>
<td>1.5 ppm, -30° to +60°C (-22°F to +140°F)</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td><strong>Diagnostic Service Port</strong></td>
<td></td>
</tr>
<tr>
<td>Port Type</td>
<td>Async. EIA-RS-422</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>19200 bit/sec typical</td>
</tr>
<tr>
<td>Data Link Protocol</td>
<td>HDLC</td>
</tr>
<tr>
<td><strong>Electrical Requirements</strong></td>
<td></td>
</tr>
<tr>
<td>DC Input Voltage</td>
<td>13.6 Vdc, Negative Ground</td>
</tr>
<tr>
<td>DC Input Current</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 per 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 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</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>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># of Channels</td>
<td>&gt;90</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</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># 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</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># 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</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>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># of Channels</td>
<td>&gt;4</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-1250, Analog, Conventional Transmitter</td>
<td></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>

G. 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, in particular the horizontal and vertical beamwidth 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 beamwidth.

Transmission line used shall be 50 ohm, flexible coaxial cable, the size of the cable as per 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 bungalows.

Base Station towers, antennas and equipment shall be grounded per Caltrain Standard Specifications.

1.1 ATCS Data Radio Control Point

A total of one (1) Antenna Tower, one (1) Omni-directional Antenna, one (1) MCP Radio, associated Batteries, Battery Charger, dc/dc Converter and Lightning Arrestor shall be required per Data Radio CP site. The Installer shall provide the 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. Quantity 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. Quantity one (1) Omni-Directional Antennas. Each Antenna shall be equipped with a Type N Female connector, and shall be mounted to the top of each tower using a 10 to 12 foot section of Aluminum pipe, weighing no more than 16 pounds.

c. A quantity of 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 Arrester.

2.0 INSTALLATION INSTRUCTIONS

2.1 ATCS Data Radio Control Point

Installation of the Antennas, 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 ATCS Channel number two (2), which corresponds to a MCP Transmit frequency of 896.9375 MHz and a MCP
Receive frequency of 935.9375 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.

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 connection between the MCP Radio and the VHLC shall be performed by others. The MCP Radios provided shall be manufactured by either GE Harmon or by Safetran Systems. The Installer shall follow the directions provided in of the Grounding requirements provided with the Contract Documents to ensure the proper grounding of the MCP, Antenna, Antenna Tower and other Radio equipment.

4.0 ANTENNA AND ANTENNA MAST

Antennas shall be grounded through their antenna masts. This shall be provisioned by ensuring a reliable electrical connection between each antenna and the supporting 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 arrestor directly to the coaxial antenna cable, at the closest convenient location to the point of entry to the CP signal house. A 2/0 ground cable shall be installed between the lightning arrestor and the CP ground plate.

6.0 GROUNDING AND LIGHTNING PROTECTION

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

7.0 SAFETY

The Installer shall follow the written safety instructions provided by 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 the Caltrain to determine the minimum distance, on a case by case basis, of the foundation of each 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 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.

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 to in the technical literature and government publications as highway-rail grade crossings.

Grade crossings are intersections where three (3) distinct modes of travel meet: trains, vehicles, and pedestrians, and where the train always has the right of way. In other words, grade crossings are where trains meet motorized users and non-motorized users. 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 and bicyclists.

Ideally, a grade crossing should afford a safe, comfortable and convenient passageway for all users. The design should encourage lawful behavior. The grade crossing design consists of three (3) main goals: safety, accessibility and functionality. In order to achieve this, 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.

The third element is the crossing warning system which must provide notice that a train is approaching and sufficient warning time for the motorist and pedestrian to stop short of the crossing, or if they have already entered the crossing, to continue past the area of potential conflict.

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 on roadways 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.
1.0 GRADE CROSSING SYSTEM

Each grade crossing is unique and complex. It is site specific, and each of the three (3) different user groups (trains, vehicles, pedestrians) has distinct characteristics in crossing behavior and limitations. Even among users of the same group these differences vary widely. These system requirements represent the three distinct and different users requiring an integration among all in order to function properly.

The design of a grade crossing becomes more challenging due to the following factors:

a. Increase in traffic (trains, motorists and pedestrians)
b. Increase in commitment to accessibility and ADA compliance
c. Increase in the number of trains operating in an urbanized area, both passenger and freight.
d. Possibility of high-speed rail or electrified services.
e. Increase in population density near tracks

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.

Improvements to the existing crossings in terms of pedestrian usage are hampered by a lack of standards and varying standard practices. There are no standards at present that are uniform and consistent and that are applicable to the grade crossings where pedestrians are involved, especially at or adjacent to stations. Development of grade crossing standards and practices are evolving. The crossing is subject to legal and jurisdictional matters.

FIGURES 7-1 through FIGURE 7-3 show the typical vehicular grade crossings for right angle, obtuse, and acute intersections, respectively.

2.0 GRADE CROSSING SYSTEM DESIGN

The review and update of design guidance and standards relating to the design of station pedestrian crossing shall take into account a modern understanding of human factors and recent technological developments. This will require the collaboration of all stake holders, namely the Railroad, the Local Agency, and the CPUC, which has the overall oversight of the state grade crossings.

Any modifications to the existing grade crossings, whether rehabilitation or improvement will require an integrated effort among the track, civil and signal disciplines, as well as roadway traffic signaling. The crossing shall be designed to
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)
provide the required integration between the pedestrian grade crossing and the sidewalk belonging to the Local Agency. Ideally, there shall be adequate access in width and transition smoothness 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.

The pedestrian sidewalk through the crossing shall be ADA compliant, complete with appropriate signage and pavement markings. The sidewalk connecting to the grade crossing shall be wide to accommodate the wheelchairs, in accordance with ADA requirements and the requirements of the Local Agency.

The following principles shall guide the designers in the design of grade crossing.

a. General Engineering Principles: roadway, track system, signal system, etc.
b. Understanding of Operational Requirements: commuter service, train signaling, roadway traffic controls, users needs.
c. Understanding of Users Behavior: human behavior and limitations
d. Technology Developments: new technology, research and development
e. Stake Holders Collaboration: Federal, state, local, communities

The underlying principle of grade crossing safety is to provide a defined path for safe and efficient passage across the tracks. The design of the crossing surface including channelization provides for efficient passage. Safety is enhanced by credible warning devices which are appropriate to the different target users. The crossings may be evaluated using risk assessment formulas by accounting the physical conditions of the crossing, the characteristics of the users, the nature of the adjacent land use, etc. The resulting rating of the crossing is compared to that of other crossings.

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).

Standards and Recommended Practices are articulated by the MUTCD (Manual Uniform Traffic Control Devices), AREMA (American Railway Engineering and Maintenance of Way Association), ITE (Institute of Transportation Engineers) and other organizations. At present, there is no guidance for pedestrian crossings of railroads under FRA jurisdiction.
1.0 REGULATORY AUTHORITIES

In addition to the federal and state governments, the Americans with Disabilities Acts of 1990 (ADA) provides guidelines for accessibility which should be considered in all public locations.

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 ADA (Americans with Disabilities Act)

Federal agencies follow the Americans with Disabilities Act Accessibilities Guidelines (ADAAG) guidelines which regulates accessibility to public places.

1.1.2 FTA (Federal Transit Administration)

The FTA administers funding to support a variety of public transportation system, 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.

1.1.3 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 at 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 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
1.1.4 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.

1.1.5 NTSB (National Transportation Safety Board)

NTSB investigates collisions at crossings and at-grade railroad right-of-way; 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, modified with supplement, which is commonly referred to as the California MUTCD.

The CPUC issues General Orders (GO’s) pertaining to applicable requirements of the design and improvements of grade crossings. Additionally, it 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 nineteen fifties.
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.

1.3 Local Agency

Counties and cities and towns generally collaborate with railroads on the traffic signal and pre-emption requirements. More on traffic pre-emption is on Section D – Traffic Pre-Emption below. The Local Agency administers installation and maintenance of other passive traffic control such as pavement markings and signage at crossings.

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 vehicular grade crossings, including warning time calculations.

2.2 Institute of Transportation Engineers (ITE)

ITE publishes guidelines for pre-emption of traffic signals near railroad crossings.

3.0 CALTRAIN STANDARD PRACTICES

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.

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 pre-emption. 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, partnership with the Local Agency on the pre-emption diagnostics, and
evaluation of current practices and improvements at grade crossings regarding traffic control devices. Caltrain publishes the General Code of Operating Rules (GCOR), General Orders (GOs), Time Table, and Special Instructions which shall be considered in the design, installation, operations and maintenance of the crossings.

3.1 Caltrain General Policy

As a general policy, Caltrain actively promotes the following policies on grade crossings:

a. Closure of under utilized existing crossings  
b. Consolidation of existing grade crossings  
c. Enhancement of safety and accessibility of existing crossings  
d. Grade separation of existing crossings  
e. Adaptation of new technologies

New grade crossings, if approved by the Caltrain Deputy Director of Engineering, shall only be considered in conjunction with closure of adjacent crossing(s).

Where practical, 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. Where this is not practical, the appropriate active warning devices shall be implemented for all grade 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.

3.2 Quiet Zones

Quiet zones refer to elimination or reduced intensity 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.
4.0 OTHER RAILROADS AND TRANSIT AGENCIES

Railroads have only recently begun to develop their own standard practices at vehicular grade crossings with regard to pedestrian crossing safety. As a result, the criteria and standards for the pedestrian crossings lag behind. Light Rail systems are more developed in their treatments of pedestrian crossings at streets and at stations.

C. 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

Active traffic control devices are activated by approaching trains. The key component of active traffic control devices is an active warning device which detects the approaching trains at grade crossings.

1.1 Active Warning Device

The active warning device serves warning to both the vehicular crossings and pedestrian crossings of the approaching trains. It activates the lights, bells and flashing lights or flashers, and the automatic gate arms (gates) which together form active control devices. Therefore, warning to the motorists and pedestrians of approaching trains is provided as follows:

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 may be interconnected to the roadway traffic controller to provide either simultaneous or advanced pre-emption to the roadway traffic signal system. This interconnection will be described in more details under Section D, Traffic Pre-emption.

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 may be attached at the back of the vehicular crossing gate arm. 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. 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. This element of the design and installation must be coordinated between the civil and signal designers in determining whether swing gates are recommended, and the placement of the gate arm and the swing gate for maximum effectiveness considering space constraints.

2.0 SELECTION OF WARNING TIME

The warning time at a grade crossing must be sufficient for both vehicles and pedestrians to clear the tracks. The minimum warning time, required by law for motor vehicles is 20 seconds. The design minimum on Caltrain is 25 seconds. 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.

2.1 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 crossings.
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 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, 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.

### 2.2 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 pre-empt 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.
3.0 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 signage including railroad signage, striping, pavement markings and texturing, and channelization. Signage, striping and pavement markings provide visual warnings, and pavement texturing for visually impaired people. Signage and pavement markings for crossings 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.

3.1 Passive Traffic Control Devices For Vehicular Crossings

Passive traffic control devices for vehicular crossings include railroad signage, striping, and pavement markings. Other devices may include raised median islands, delineators, and additional pavement markings, which require collaboration with the Local Agency.

3.1.1 Railroad Signage

Railroad signage includes a Crossbuck Rail Crossing sign mounted above the bells and flashers on the signal mast. Crossbuck is a type of YIELD sign indicating the motorists should be prepared to stop at least 15 feet before the nearest rail, if necessary. The signage includes information to warn the motorists of the number of tracks through the crossing.

3.1.2 Striping and Pavement Markings

A six (6) inch wide thermoplastic yellow striping indicating the curb lines shall be painted through the crossing. The striping is complemented with white traffic reflectors placed at every two (2) feet.

The following markings on the pavement approaching the crossing are typically provided and maintained by the Local Agency.

a. RR Crossing
b. Stop Bars
c. Other markings such as curb painting, directional arrows, turning information, etc.

3.2 Passive Traffic Control Devices For Pedestrian Crossings

Passive traffic control devices for the pedestrian crossings include signage, pavement markings and texturing, and channelization. Channelization includes handrailing and railing, and possibly other barriers.
3.2.1 Pavement Texturing

Pavement texturing is provided by the warning tactile. The warning tactile shall be a 36 inch panel with the Federal truncated cones installed across the entire width of the sidewalk immediately in front of the pedestrian automatic gate arm. The purpose of the warning tactile 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. A 12 inch high black marking stating “STOP HERE” shall be painted directly in front of the warning tactile.

3.2.2 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.

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 warning tactile 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.

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.
Pedestrian Barriers

In some cases, physical barriers may need to be provided to physically block certain access of the crossings by motorists and pedestrians, and to channel the passageway to other areas.

D. TRAFFIC PRE-EMPTION

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 two (2) traffic signal systems 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. Expedite the planning, and design of the railroad and roadway signal systems
d. Expedite the diagnostics process of 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.

1.0 DESIGN CRITERIA

New Traffic Pre-emption Circuits shall be a minimum of a four (4) wire circuit and shall conform to the latest AREMA guidelines. A supervisory circuit should be considered and where Clear Track Storage is a concern, a Gate Down Repeater circuit to the Traffic Signal Controller should be considered to hold the Track Clearance Green Aspect until the gate arms are down.

In the case of Advanced Preemption, a Health Status relay should be provided by the traffic control system so that a failure of the traffic signal controller will cause the gates to hold for the longer gate down time. A fixed interval timer may be necessary where there are speed changes on either approach. The railroad signal system will have a signal event recorder which facilitates rapid response to and diagnosis of signal malfunction.

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.

2.0 DIAGNOSTIC TEAM

Both Caltrain and the Local Agency should jointly determine the pre-emption operation at the crossings with the Local Agency providing the calculations of pre-emption timing. Both agencies shall form a Diagnostic Team to jointly coordinate and share the responsibilities of the management of design, construction, and
maintenance and improvement of the operations of the grade crossing system. It is a multi-disciplinary team that requires a system approach.

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 pre-emption call. Where a “traffic pre-emption” is requested by a Local Agency, a written agreement should be executed indicating that any changes in the traffic signal operation or changes to the operation of the railroad warning devices will be communicated and jointly evaluated prior to implementation.

A example of the check list of the diagnostic is as Reference at the end of the Chapter.

2.1 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. 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 pre-emption, simultaneous or Advanced Pre-emption time
h. Type of vehicles which must stop at all crossings, such as buses and trucks.

2.2 Maintenance and Operational Responsibilities

Caltrain and the Local Agency 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

E. VEHICULAR CROSSINGS

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 (stations). Design parameters, standards and guidelines for vehicular grade crossings are generally well established.

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 under 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 crossing where there are four (4) tracks (passing 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 shall collaborate with the Local Agency for installation of the appropriate fencing and channelization to direct pedestrians to crossing the tracks at authorized grade crossings with active warning devices.

See FIGURE 7-4 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 SKEWED CROSSING

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.
FIGURE 7-4  TYPICAL PEDESTRIAN SIDEWALK
AT VEHICULAR CROSSING
5.0 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 may be considered. 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.

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

F. PEDESTRIAN CROSSINGS

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.

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, $271 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. The CPUC standard number 10 pedestrian flasher is obsolete and a single burnt out lamp will make the crossing out of compliance with FRA regulations (Part 234 of CFR49).

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 is 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 platform with an at-grade 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 7-5 TYPICAL PEDESTRIAN CROSSING AT STATIONS (OUTBOARD PLATFORMS)

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.
FIGURE 7-5  TYPICAL PEDESTRIAN CROSSING AT STATIONS
G. GENERAL DESIGN 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 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. Introduction of new materials which will require an inventory of spare parts and additional training must be approved by the Caltrain Deputy Director of Engineering.

1.0 GENERAL SIGNAL REQUIREMENTS

The design shall incorporate features that shall aid signal personnel in the inspection, testing, repair, and overall maintenance of the system.

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.

1.1 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.

Design for the Caltrain electrification project will require a program to replace present Constant Warning Time systems since these devices will not work in a traction power system.
1.2 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.

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. 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.

1.3 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. Similarly, battery set 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.

Dc power input terminals 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 Ohm.

1.4 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**.

**TABLE 7-1 CABLE SIZE**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>CABLE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal House/ Case Wire</strong></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># 6 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><strong>Flashing Light Signals/ Gates</strong></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><strong>Cable</strong></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.
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 SSCCIIIA or later model should be installed when modifying a crossing. The SSCCIIIA is preferred.

2.0 GENERAL CIVIL REQUIREMENTS

Whenever practicable, Caltrain shall collaborate with CPUC to solicit their inputs, and assistance, as well as to provide direction and guidelines to convince the Local Agencies on the street and traffic circulation issues and the crossings such as by providing direction and guidance regarding the following safety critical improvements:

a. Prohibit left turn
b. Prohibit U-turn near crossing
c. Build median islands
d. More attention, installation and maintenance of active passive devices, such as striping, pavement parking, signage, parking, driveways, signage
e. Close streets

2.1 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. The roadway approach geometry shall generally follow the requirements of the Local Agency having jurisdiction of the roadway.

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.
2.2 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.

2.3 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.

The 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 skewness of the roadway with respect to the crossing, and existence of adjacent frontage roads, and driveways.

The 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 feasible yellow pavement markings should be provided. Median islands, and delineators are typically not popular with the Local Agency, and with the property owners adjacent to the crossings. In many cases, the CPUC assistance will be required to facilitate gaining approval from the private property owners, and the Local Agency.

2.4 Crossing Surface
The crossing surface requirements through grade crossings are dictated by the following requirements: drainage, access for maintenance, and pedestrian safety and accessibility. Removable prefabricated concrete panels achieve these objectives. Hot mixed asphalt concrete (HMAC) will be placed between the panels and between the panels and the roadway.

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 white line to connect the curb lines across, complemented with white traffic reflectors at every two (2) feet. This thermoplastic line serves as a warning to 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 perceived 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 HMAC shall always be maintained smooth (no cracks, uneven, broken, potholes) so as not to increase travel time. This is critical especially for mobility impaired people, for the elderly, and people with strollers.

2.5 Track Structure

Because track structure is embedded under the grade crossing surface, maintenance of the crossing and track not only become difficult and costly, but approval from the Local Agency for lane or street closure, and for rail service interruptions are becoming ever more difficult to secure. Therefore, it is essential that the crossing be designed with ease of maintenance as its main objective.

The 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.

2.6 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.

3.0 OTHER CROSSING IMPROVEMENTS

Other improvements to enhance the guidance and warning to the crossing users include review of the land use adjacent to the crossings, and illumination at and near the crossings. The stakeholders involve the private property owners and the Local Agency.
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.

3.1 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 a 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 pre-emption time for both grade crossing. The pre-emption time may have to be substantially lengthened.

The design team must pay particular attention to parallel streets, especially to those allowing a left turn across the tracks.
3.2 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 crossing shall be discouraged. If this is not practical, the separation from tracks shall be a minimum of 75 feet.

3.3 Street Parking

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

3.4 Street Furniture

Furniture placed on the sidewalk by the Local Agency includes benches, roadway traffic control cabinets, parking meters, light poles, trash receptacles, or other sight obstructing structures 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.

3.5 Traffic Signage

The traffic signage placed near the grade crossings shall only 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.

3.6 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.

END OF CHAPTER
# Diagnostic Team Crossing Evaluation Report

## Location Data
- **Railroad:**
- **State:**
- **County:**
- **City:** (In or Near)
- **R.R. Division:**
- **Street/Road Name:**
- **Nearest R.R. Timetable Station:**
- **R.R. Milepost:**
- **Branch/Line Name:**

## Diagnostic Review
- **Initiated By:**
  - Railroad
  - State
  - Local
  - Other
- **Date Initiated:**

## Diagnostic Team
<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
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<td>5</td>
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</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

## Railroad Data

### Daily Train Movement
- **Total Trains:**
- **Day Thru:**
  - Check if less than one movement per day
  - Main
  - If other, specify
- **Night Thru:**
  - Train movements per day
  - Other

### Speed of Train
- **Day Switch:**
  - Max. m.p.h.
- **Night Switch:**
  - Typical to m.p.h.

### Can two trains occupy crossing at the same time? [ ]
- Yes
- No

### Can one vehicle block the another motorist’s view of proposed warning devices? [ ]
- Yes
- No

<table>
<thead>
<tr>
<th>Track</th>
<th>Type</th>
<th>Width</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Crossing Surface
- **Crossing Surface:**
- **Crossing Angle:**

### Comments

---

Diagnostic Form (Page 1)
## ROADWAY DATA

<table>
<thead>
<tr>
<th>Agency Having Jurisdiction:</th>
<th>ADT:</th>
<th>PERCENT TRUCKS</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Roadway Surface:</td>
<td></td>
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</tbody>
</table>

### Speed of Vehicle

<table>
<thead>
<tr>
<th>Max. m.p.h.</th>
<th>Typical to m.p.h.</th>
<th>School Bus Operation</th>
<th>Hazardous Materials</th>
<th>Pedestrians</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>□ YES □</td>
<td>□ YES □</td>
<td>□ YES □</td>
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<table>
<thead>
<tr>
<th>No./Day</th>
<th>No./Day</th>
<th>Curb &amp; Gutter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>□ YES ☐</td>
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</tbody>
</table>

### Shoulder:

<table>
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<tr>
<th>YES ☐</th>
<th>NO ☐</th>
</tr>
</thead>
</table>

If Yes, Width:

<table>
<thead>
<tr>
<th>YES ☐</th>
<th>NO ☐</th>
</tr>
</thead>
</table>

Is the Shoulder Surfaced?

<table>
<thead>
<tr>
<th>YES ☐</th>
<th>NO ☐</th>
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</thead>
</table>

If Yes, Width:

<table>
<thead>
<tr>
<th>YES ☐</th>
<th>NO ☐</th>
</tr>
</thead>
</table>

Is Sidewalk Present?

<table>
<thead>
<tr>
<th>YES ☐</th>
<th>NO ☐</th>
</tr>
</thead>
</table>

### 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

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Qty.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of Warning Device</th>
<th>Location:</th>
<th>mast Mounted Flashing Lights</th>
<th>Location:</th>
<th>Curb &amp; Gutter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance Warning Signs</td>
<td>Location:</td>
<td>Cantilever Flashing Lights</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Stop Signs</td>
<td>Location:</td>
<td>Side Lights</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Stop Ahead Signs</td>
<td>Location:</td>
<td>Automatic Gates</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Pavement Markings</td>
<td>Location:</td>
<td>Bells</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Crossbucks</td>
<td>Location:</td>
<td>Inventory Tags</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Number of Tracks Signs</td>
<td>Location:</td>
<td>&quot;No Turn&quot; Signs</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Inventory Tags</td>
<td>Location:</td>
<td>Personal</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
</tr>
<tr>
<td>Interconnected Highway Traffic Signals</td>
<td>Location:</td>
<td>“No Turn” Signs</td>
<td>Location:</td>
<td>Curb &amp; Gutter</td>
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</tbody>
</table>

### FIVE-YEAR ACCIDENT DATA

<table>
<thead>
<tr>
<th>TOTAL ACCIDENTS</th>
<th>Property</th>
<th>Personal</th>
<th>“No Turn” Signs</th>
<th>Illumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fatalities</td>
<td>Other</td>
<td>Specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TYPE OF DEVELOPMENT

- Open Space ☐ | Residential ☐ | New developments that could affect ADT? ☐ Yes ☐ No |
- Industrial ☐ | Institutional ☐ | If Yes, Describe: |
- Commercial ☐ | | |

Location of Nearby Schools:
## ADJACENT CROSSINGS

<table>
<thead>
<tr>
<th>DOT No.</th>
<th>Street/Road Name</th>
<th>Warning Device</th>
<th>ADT</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</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:

Sketch:
## RECOMMENDATIONS

**ARE IMPROVEMENTS TO THE CROSSING RECOMMENDED?**

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

If No, Explain:

If Yes, what improvements?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Type of Improvement</th>
<th>Describe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sight Improvement</td>
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<tr>
<td></td>
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<td>Crossing Surface</td>
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<td>Roadway Approaches</td>
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<td>Highway Traffic Signs</td>
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<td></td>
<td></td>
<td>Crossing Closure</td>
<td></td>
</tr>
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Prepared By:  
Title:  
Date:  

Comments:

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Diagnostic Form (Page 4)
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 (Caltrain 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 walking surfaces for Caltrain passengers and maintenance personal 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. In general, relocation of exiting drainage facilities shall be “replacement in kind”, or “equal construction”, unless conditions of flow, loading, or operations are altered If the conditions are altered, designs shall conform the design criteria and the standards of the agencies involved.
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 and generally made of concrete. 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, 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

HORIZONTAL ACCURACY EXAMPLES

<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”.

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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
B. SURVEYING AND MAPPING

1.0 SURVEY CONTROL

Survey control establishes a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of rail transportation improvement projects and facilities. The survey control network ensures that adjacent projects have compatible control. Furthermore, a precise control network provides consistent and accurate horizontal and vertical control for all subsequent project surveys including photogrammetric, mapping, planning, design, construction, and 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 know 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, Contra Costa, 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”=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>

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>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>

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

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Vertical Acceleration</td>
</tr>
<tr>
<td><strong>AAR</strong></td>
<td>Association of American Railroads</td>
</tr>
<tr>
<td><strong>AASHTO</strong></td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td><strong>ABS</strong></td>
<td>Automatic Block System</td>
</tr>
<tr>
<td><strong>ac</strong></td>
<td>Alternating Current</td>
</tr>
<tr>
<td><strong>AC</strong></td>
<td>Asphalt Concrete</td>
</tr>
<tr>
<td><strong>ACE</strong></td>
<td>Altamont Corridor Express</td>
</tr>
<tr>
<td><strong>ACI</strong></td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td><strong>ADA</strong></td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td><strong>ADAAG</strong></td>
<td>Americans with Disabilities Act Accessibility Guidelines</td>
</tr>
<tr>
<td><strong>ADT</strong></td>
<td>Average Daily Traffic</td>
</tr>
<tr>
<td><strong>AG</strong></td>
<td>Average Grade</td>
</tr>
<tr>
<td><strong>AISC</strong></td>
<td>American Institute of Steel Construction</td>
</tr>
<tr>
<td><strong>AISI</strong></td>
<td>American Iron and Steel Institute</td>
</tr>
<tr>
<td><strong>AMP</strong></td>
<td>Ampere</td>
</tr>
<tr>
<td><strong>AMTRAK</strong></td>
<td>National Passenger Railroad Corporation</td>
</tr>
<tr>
<td><strong>ATCS</strong></td>
<td>Advanced Train Control System</td>
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<td>UBC</td>
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<td>Uninterruptible Power Supply</td>
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<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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</tbody>
</table>
APPENDIX B

PCJPB/CALTRAIN STANDARDS AND REFERENCES

1.0 PCJPB General Provisions
2.0 PCJPB Special Provisions
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, SYSTRA 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:

\[
\text{Practical Capacity} = 0.9 \times \left( \frac{60 \text{ minutes}}{\text{Practical Headway}} \right),
\]

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.

***** End of Report Text *****
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

Distance from San Francisco (Miles)

0 5 10 15 20 25 30 35 40 45

Speed Limit

Train Speed
San Jose - San Francisco
Northward Express Train (Nonstop)
One MP36PH-3C Engine + 4 Bombardier Bi-Level Cars
San Francisco to MP 60 (South of Blossom Hill)
Southward Local Train - One F40PH Engine + 5 Gallery Cars
With 79-mph MAS Where Permitted
MP 60 (South of Blossom Hill) to San Francisco
Northward Local Train - One F40PH Engine + 5 Gallery Cars
With 79 mph MAS Where Permitted
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"
MP 60 (South of Blossom Hill) to San Francisco
Northward Local Train - One F40PH Engine + 5 Gallery Cars
Up To 79 mph South of CP "Michael" and
50-mph Limited Speed North of CP "Michael"
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**

**Direction:** __S/B__,  **Stopping Pattern:** __Non-stop__,  **Page 1 of 4**

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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.
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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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(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:** ___________________________  
**Stopping Pattern:** __Non-stop__  
Page 4 of 4

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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

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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:** Non-stop  
**Page:** 3 of 4

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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

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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.
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

**Direction:** S/B  
**Stopping Pattern:** Local  

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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.

(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 3 of 4

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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** 4 of 4

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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.

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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: 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**.  Page 3 of 4.

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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.
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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  
**Page 1 of 4**

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(1) Number of electronic 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: __N/B__  Stopping Pattern: __Local__.  
Page 2 of 4.

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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 3 of 4**

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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

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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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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
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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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(1) Number of electronic track circuits involved in signal-aspect upgrade, excluding interlocking track circuits.

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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

<table>
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<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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(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.

b. American Association of State Highway and Transportation Officials (AASHTO)

c. American Concrete Institute (ACI)

d. American Institute of Steel Construction (AISC)

e. American Iron and Steel Institute (AISI)

f. 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
g. 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
h. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
i. American Society for Testing and Materials International (ASTM)
   3. B3 Specification for Soft or Annealed Copper Wire
j. American Welding Society (AWS)
k. Americans with Disabilities Act Accessibility Guidelines (ADAAG) for Buildings and Facilities
l. Building Industries Consulting Services International (BICSI)
m. Crime Prevention Through Environmental Design (CPTED)
n. Electronic Industry Alliance (EIA)
   1. 310-D Cabinets, Racks, Panels, and Associated Equipment
o. Illuminating Engineering Society of North America (IESNA)
q. Institute of Electrical and Electronics Engineers, Inc. (IEEE)
r. Insulated Cable Engineers Association, Inc. (ICEA)
   1. S-84-608-2002 Filled Telecommunications Cable, Polyolefin, Insulated, Copper Conductor
s. Motorola R56 grounding standard

t. National Electric Code (NEC)

u. National Electrical Safety Code (NESC)

v. 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

w. National Fire Protection Association (NFPA)
   1. 70E  Standard for Electrical Safety Requirements for Employee Work places
   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

x. Rural Utilities Services (RUS)
   1. Specification for Filled Telephone Cable with Expanded Insulation (7 CFR 1755.890)

y. Safety Code For Mechanical Refrigeration (SCFMR)

z. Southern California Public Works Handbook (Green Book)

aa. 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

bb. 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

c. Uniform Building Code (UBC)
APPENDIX D
Caltrain Maintenance and Construction Rules, Regulations, Specifications and Procedures

Federal Railroad Administration (CFR 49)
- Part 213: Track Safety Standards
- Part 214: Railroad Workplace Safety
- Part 217: Railroad Operating Rules
- Part 219: Control of Alcohol and Drug Use
- Part 220: Railroad Communications
- Part 222: Railroad Accidents and Incidents
- Part 228: Hours of Service
- Part 231: Railroad Safety Appliances Standards
- Part 233: Signal Systems Reporting Requirements
- Part 234: Grade Crossing Signal System Safety
- Part 235: Application to Discontinue Signal Systems
- Part 236: Rules and Standards for Train Control Systems

ADA (Americans With Disabilities Act)
Accessibility Guidelines for Buildings and Facilities

Homeland Security
Transportation Security Administration (TSA)

OSHA Construction Part 1926
- Subpart E: Personal Protective Equipment
- Subpart K: Working and Cutting
- Subpart M: Fall Protection
- Subpart N: Cranes, Derricks and Hoists
- Subpart O: Motor Vehicles and Mechanical Equipment
- Subpart P: Excavations
- Subpart Q: Ladders
- Subpart R: Toxic and Hazardous Substances

Issued and Controlled By the Contract Operator
- GCOR (General Code of Operating Rules)
- General Code of Operating Rules for Maintenance of Way Employees
- Caltrain Timetable and Special Instructions
- General Orders
- Maintenance of Way General Orders
- Additions and Revisions to the General Code of Operating Rules
- Air Brake and Train Handling Rules

Engineering Department
CALTRAIN ENGINEERING STANDARDS
- Design Criteria
- Standard Drawings
- Standard Specifications (Divisions 2-20)

STANDARD CONTRACT DOCUMENTS
- General Provisions
- Special Provisions

Standard Procedures for Track Maintenance and Construction (SPTM&C)
Engineering Standards for Excavation Support Systems
Standards for Design and Maintenance of Structures
CADD Manual
Standard Operating Procedures (SOP) for Configuration Management
Electrification Program Design Criteria Manual

April 15, 2007
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 contracts with Amtrak to operate/maintain Caltrain.

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 CRITERIA

In 1994, Caltrain developed its first design criteria 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 design criteria and standard technical drawings for signals (*Communication/Signal Engineering Standards*, and *Communication/Signal Design 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.

Beginning in 2000, Caltrain has produced several manuals and standards. This Design Criteria, along with Caltrain Standard Drawings and Caltrain Standard Technical Specifications, replaces all Caltrain’s existing standards and manuals, except those listed in APPENDIX B.

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.

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.

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 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 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 (2006):

a. 96 scheduled weekday trains (22 baby bullet trains)
b. 32 scheduled weekend/holiday trains
c. 34 Stations, most with parking
d. 24 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. 28 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.*
APPENDIX F

ROLLING STOCK

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

GP-9:
- Quantity: 2
- Horse Power: 1750
- Built: 1959
MP 15DC:
- Quantity: 2
- Horse Power: 1500
- Built: 1974

Caboose:
- Quantity: 2
- Built: 1974

Flat Car:
- Quantity: 8

Gondola:
- Quantity: 1
- Model: E530
- Built: 1976

Hopper, Ballast:
- Quantity: 6
- Mark: JPBX
- Capacity: 100 tons

Hopper, Ballast:
- Quantity: 15
- Mark: AMTK
- Capacity: 100 tons

Difco M110 Side Dump:
- Quantity: 3
- Capacity: 100 tons
- Built: 1978