APPENDIX B

PCJPB/CALTRAIN STANDARDS AND REFERENCES

1.0 PCJPB General Provisions

2.0 PCJPB Special Conditions

3.0 Caltrain Design Criteria

4.0 Caltrain Standard Drawings

5.0 Caltrain Standard Specifications

6.0 PCJPB Standards For Design And Maintenance Of Structures

5.0 PCJPB Engineering Standards For Excavation Support Systems

6.0 Caltrain CADD Manual

7.0 Caltrain Track Charts, Right-of-Way And Rail Corridor Infrastructure Assets

8.0 "Signal System Headway/ Capacity Study", Task 1 – Quantification Of Signal System Headway And Capacity Constraints, prepared by Systra Consulting for PCJPB, December 31, 2005, Revised February 10, 2006 (copy of the report at the end of the Appendix B

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:

> Theoretical Capacity = 60 minutes divided by the 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:

> Practical Capacity = 0.9 (60 minutes divided by the Practical Headway),
>
> 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 predicating 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

FROM MILEPOST	TO MILEPOST	SPEED LIMIT	REASON FOR SPEED RESTRICTION
.244	.537	15.	SAN FRAN.
.537	.700	25.	CURVE #1
.700	1.329	40.	CURVE #2
1.329	2.251	75.	ZONE SPD.
2.251	4.852	79.	MAS
4.852	5.199	65.	CURVE
5.199	7.358	79.	MAS
7.358	8.100	70.	CURVE #7
8.100	10.800	79.	MAS
10.800	11.100	60.	CURVE #11
11.100	46.400	79.	MAS
46.400	47.057	40.	ZONE SPD.
47.057	47.570	20.	SAN JOSE

FROM MILEPOST	TO MILEPOST	SPEED LIMIT	REASON FOR SPEED RESTRICTION
47.470	47.057	20.	SAN JOSE
47.057	46.300	40.	MP 47.1
46.300	14.200	79.	MAS
14.200	13.700	75.	CURVE
13.700	11.100	79.	MAS
11.100	10.800	60.	CURVE #11
10.800	8.100	79.	MAS
8.100	7.358	70.	CURVE #7
7.358	5.199	79.	MAS
5.199	4.852	65.	CURVE
4.852	2.251	79.	MAS
2.251	1.329	75.	ZONE SPD.
1.329	.700	40.	CURVE #2
.700	.537	25.	CURVE #1
.537	.214	20.	4TH ST. IL
.214	.166	10.	SAN FRAN.

FROM MILEPOST	TO MILEPOST	SPEED LIMIT		REASON FOR SPEED RESTRICTION
.257	.537	15.		SAN FRAN.
.537	.700	25.		CURVE #1
.700	1.329	40.		CURVE #2
1.329	2.251	75.		ZONE SPD.
2.251	4.852	79.		MAS
4.852	4.941	65.		CURVE
4.941	5.106	50.		TO-TUNNEL
5.106	6.945	70.		MAS TRK.#4
6.945	7.040	50.		TO BRISBNE
7.040	8.100	70.		CURVE #7
8.100	10.800	79.		MAS
10.800	11.100	60.		CURVE #11
11.100	39.362	79.		MAS
39.362	39.458	50.		TO HENDY
39.458	40.899	70.		MAS TRK.#4
40.899	41.609	50.		AL ON 4S
41.609	46.400	79.		MAS
46.400	47.057	40.		ZONE SPD.
47.057	47.890	20.		SAN JOSE
47.890	49.721	35.		M47.8-49.7
49.721	51.638	79.		MAS
51.638	51.858	50.		TO LICK
51.858	52.450	60.		UP MAS
52.450	53.464	40.	(HE)	CPTL (DIB)
53.464	60.000	60.		UP MAS

FROM MILEPOST	TO MILEPOST	SPEED LIMIT		REASON FOR SPEED RESTRICTION
60.000	55.650	60.		UP MAS
55.650	54.178	40.	(HE)	BLSM (DIB)
54.178	51.858	60.		UP MAS
51.858	51.638	50.		TO LICK
51.638	49.700	79.		MAS
49.700	47.908	35.		M47.8-49.7
47.908	47.057	20.		SAN JOSE
47.057	46.300	40.		MP 47.1
46.300	41.609	79.		MAS
41.609	41.507	50.		TO BOWERS
41.507	40.140	70.		MAS TRK.#3
40.140	39.362	50.		AL @ 411-3
39.362	14.200	79.		MAS
14.200	13.700	75.		CURVE
13.700	11.100	79.		MAS
11.100	10.800	60.		CURVE #11
10.800	8.100	79.		MAS
8.100	7.040	70.		CURVE #7
7.040	6.945	50.		XO-BRISBN
6.945	5.199	70.		MAS TRK.#3
5.199	5.106	65.		CURVE
5.106	4.941	50.		TO TUNNEL
4.941	4.852	65.		CURVE
4.852	2.251	79.		MAS
2.251	1.329	75.		ZONE SPD.
1.329	.700	40.		CURVE #2
.700	.537	25.		CURVE #1
.537	.214	20.		4TH ST. IL
.214	.166	10.		SAN FRAN.

FROM MILEPOST	TO MILEPOST	SPEED LIMIT		REASON FOR SPEED RESTRICTION
.257	.537	15.		SAN FRAN.
.537	.700	25.		CURVE #1
.700	1.329	40.		CURVE #2
1.329	46.400	50.		ZONE SPD.
46.400	47.057	40.		ZONE SPD.
47.057	47.890	20.		SAN JOSE
47.890	49.721	35.		M47.8-49.7
49.721	51.638	79.		MAS
51.638	51.858	50.		TO LICK
51.858	52.450	60.		UP MAS
52.450	53.464	40.	(HE)	CPTL (DIB)
53.464	60.000	60.		UP MAS

FROM MILEPOST	TO MILEPOST	SPEED LIMIT		REASON FOR SPEED RESTRICTION
60.000	55.650	60.		UP MAS
55.650	54.178	40.	(HE)	BLSM (DIB)
54.178	51.858	60.		UP MAS
51.858	51.638	50.		TO LICK
51.638	49.700	79.		MAS
49.700	47.908	35.		M47.8-49.7
47.908	47.057	20.		SAN JOSE
47.057	46.300	40.		MP 47.1
46.300	1.329	50.		MAS
1.329	.700	40.		CURVE #2
.700	.537	25.		CURVE #1
.537	.214	20.		4TH ST. IL
.214	.157	10.		SAN FRAN.

Exhibit 2

TPC Speed versus Location Plots

Non-Stop Southbound

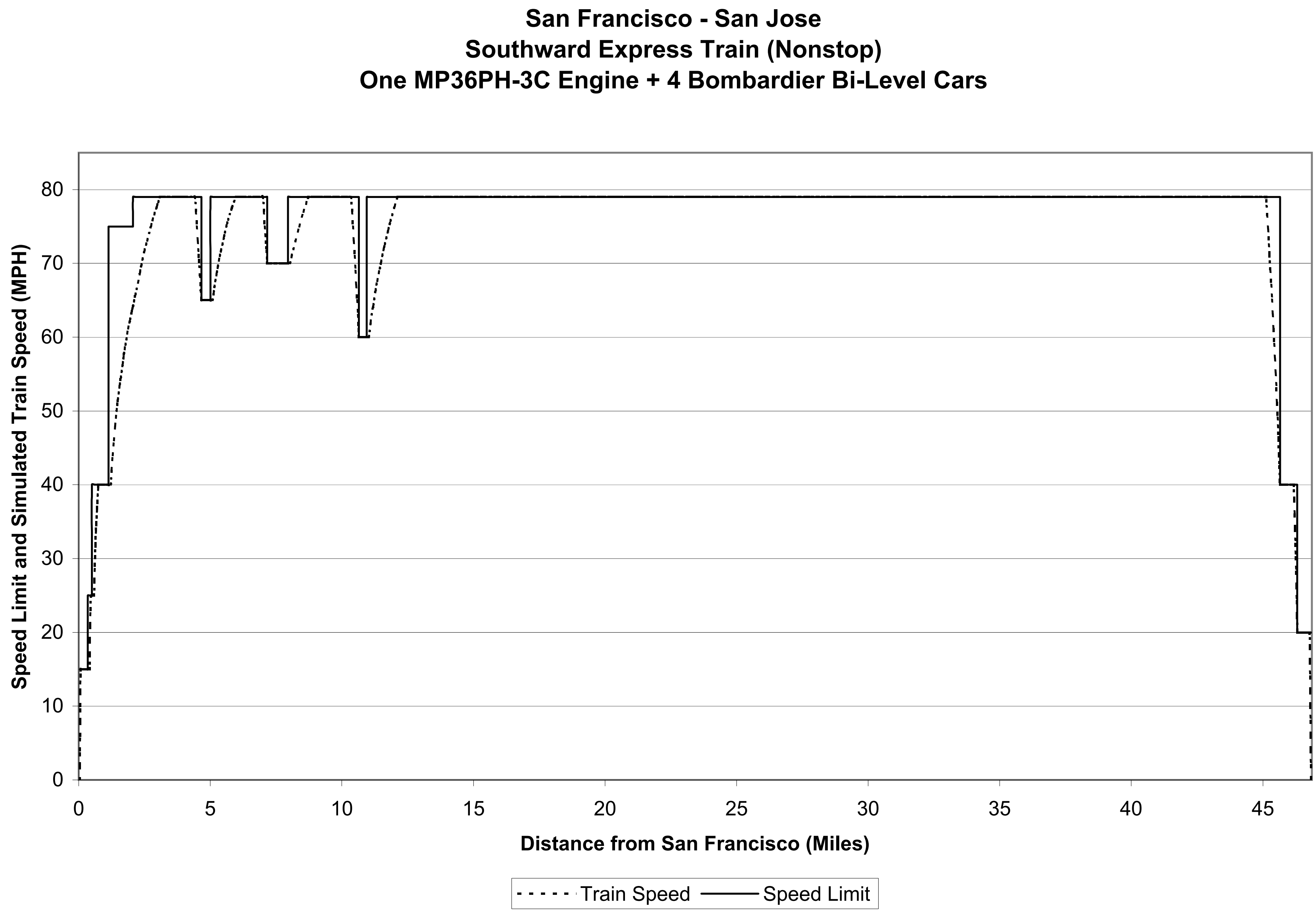
Non-Stop Northbound

Local Southbound Based on Green/Clear Aspects

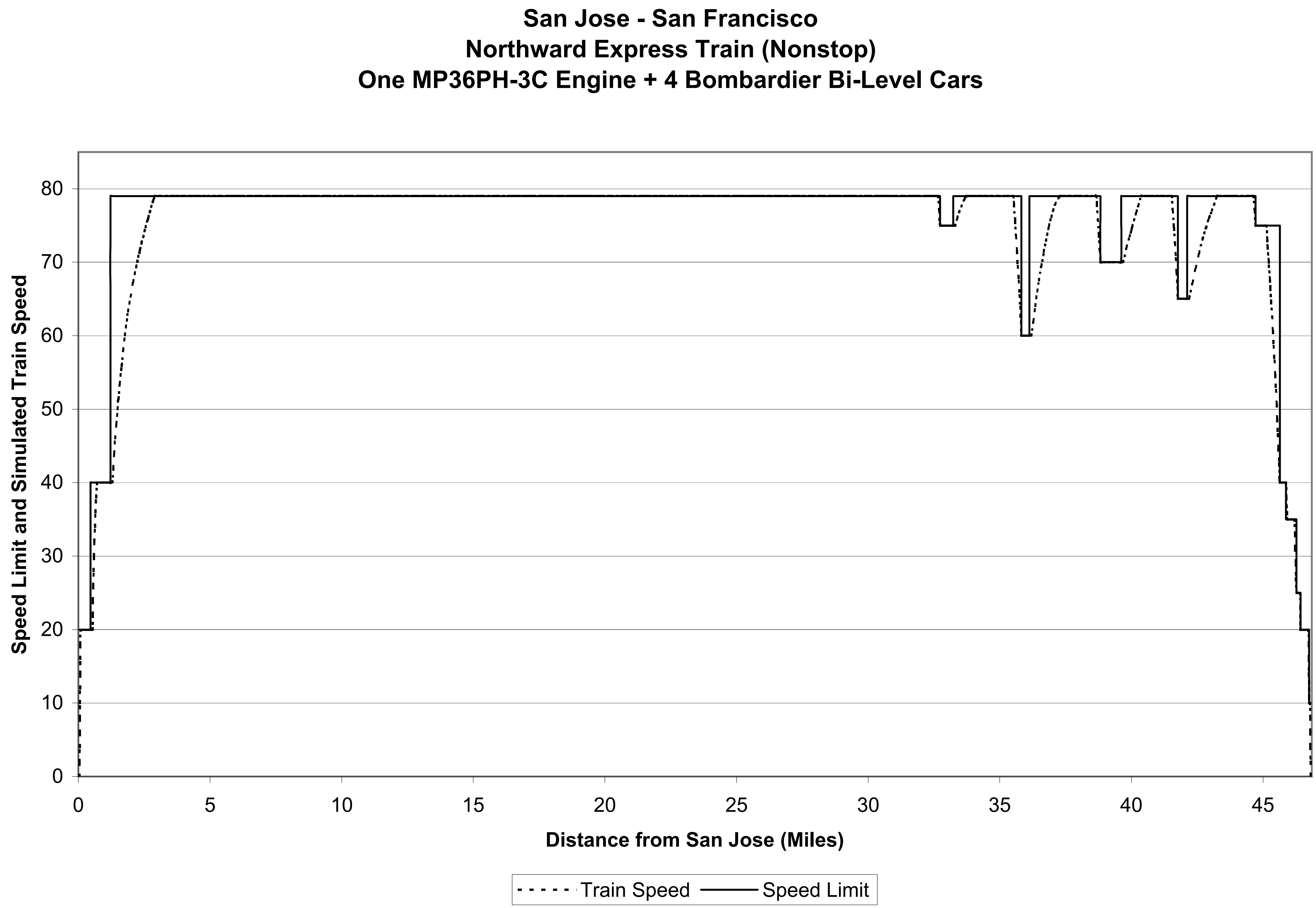
Local Northbound Based on Green/Clear Aspects

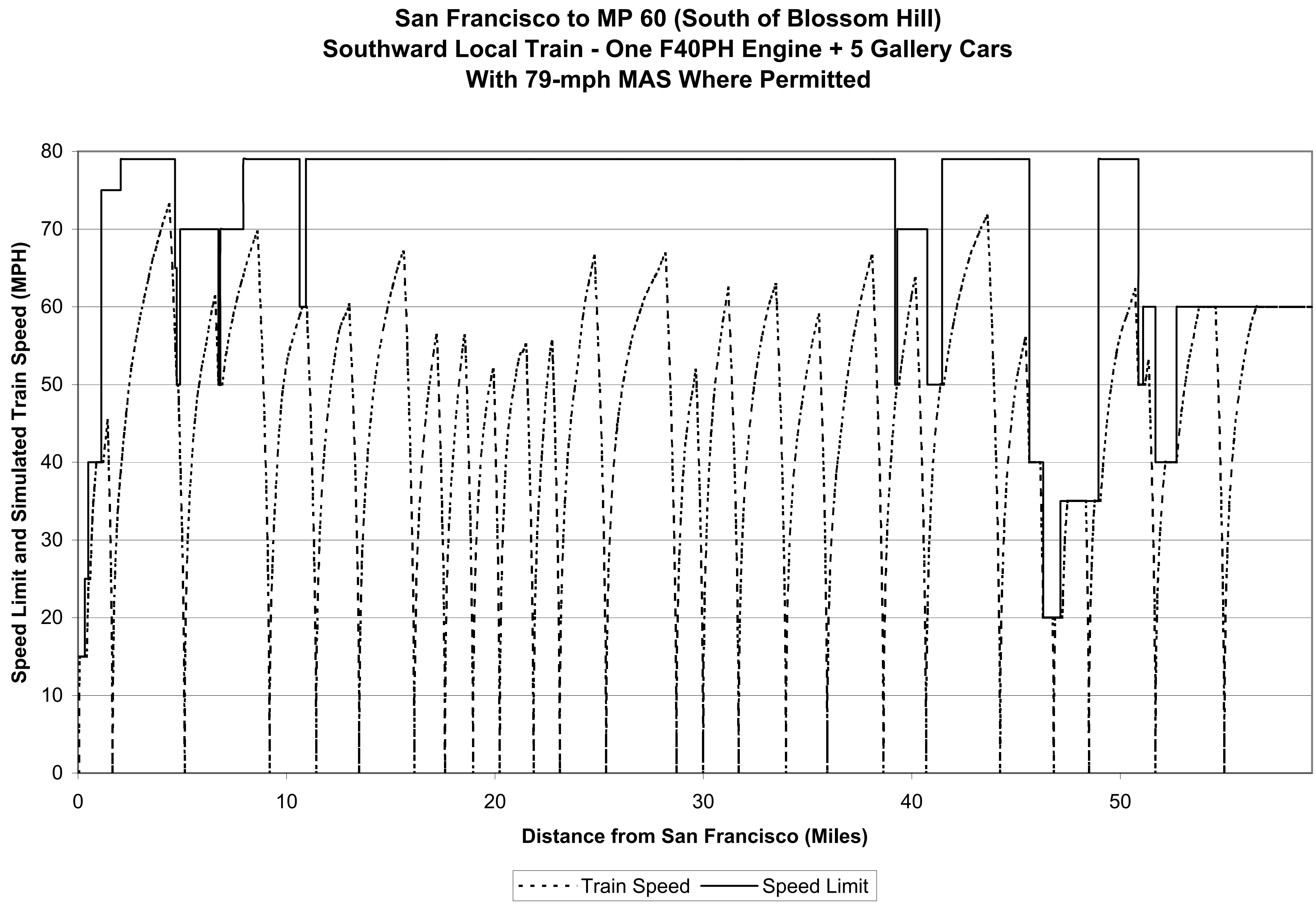
Local Southbound Based on Advance Approach/Flashing Yellow Aspects

Local Northbound Based on Advance Approach/Flashing Yellow Aspects



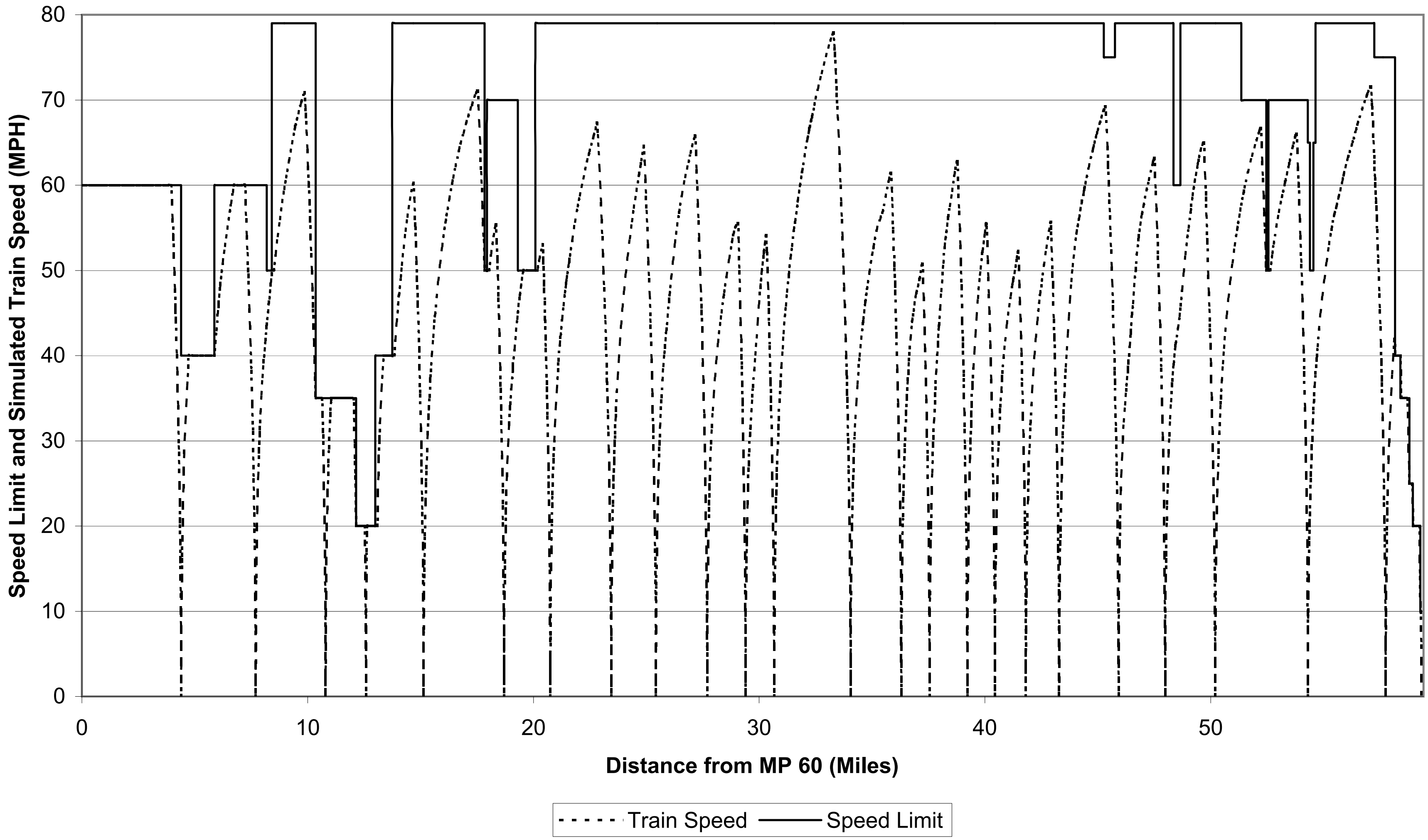
San Francisco - San Jose
Southward Express Train (Nonstop)
One MP36PH-3C Engine + 4 Bombardier Bi-Level Cars
Speed Limit and Simulated Train Speed (MPH)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
Distance from San Francisco (Miles)
Train Speed
Speed Limit

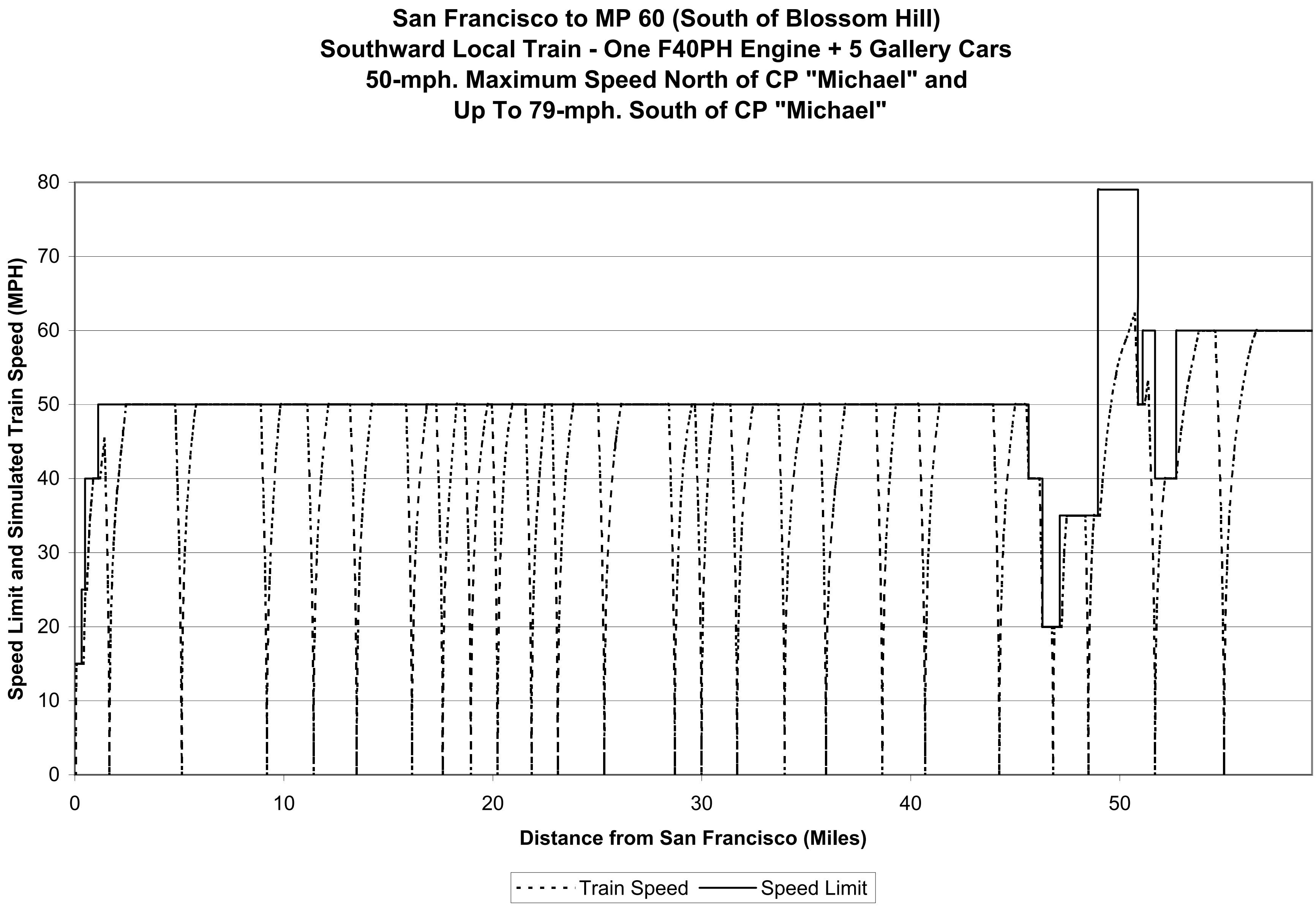

San Jose - San Francisco
Northward Express Train (Nonstop)
One MP36PH-3C Engine + 4 Bombardier Bi-Level Cars
Speed Limit and Simulated Train Speed
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
Distance from San Jose (Miles)
Train Speed
Speed Limit



San Francisco to MP 60 (South of Blossom Hill)
Southward Local Train - One F40PH Engine + 5 Gallery Cars
With 79-mph MAS Where Permitted
Speed Limit and Simulated Train Speed (MPH)
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
Distance from San Francisco (Miles)
Train Speed
Speed Limit

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"
Speed Limit and Simulated Train Speed (MPH)
0
10
20
30
40
50
60
70
80
Distance from San Francisco (Miles)
0
10
20
30
40
50
Train Speed
Speed Limit

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"

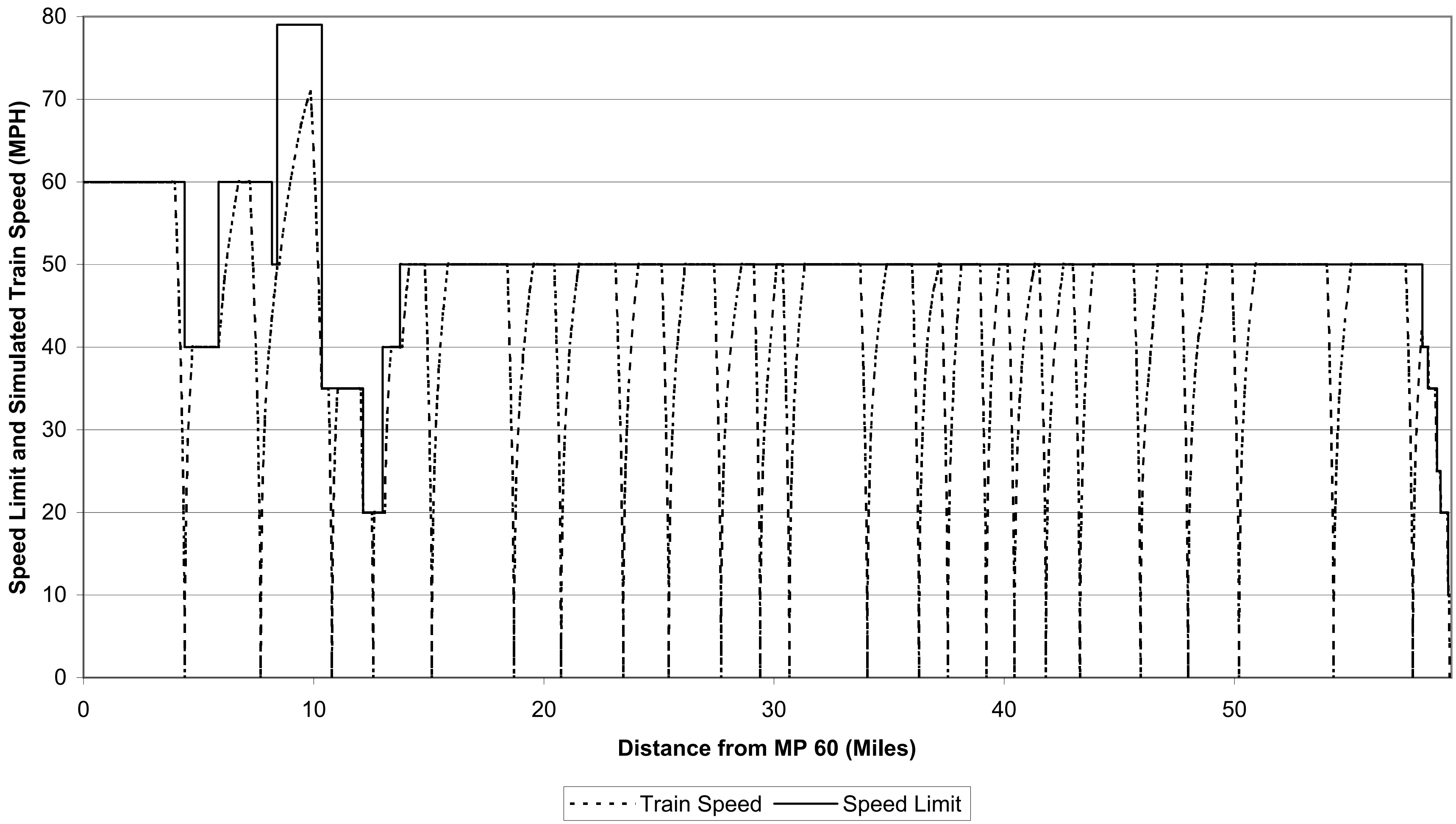


Exhibit 3

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 .**

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
76R Fourth St.	RSC	1.58	1	0.07	1.65	3.15
86R Fourth St.	C	2.38	3	0.20	2.58	4.08
4S Common	C	2.46	4	0.27	2.72	4.22
(16-2)	C	1.83	3	0.20	2.03	3.53
4S Army	C	2.33	3	0.20	2.53	4.03
32-2	C	2.02	3	0.20	2.22	3.72
42-2	C	1.92	3	0.20	2.12	3.62
4S Tunnel	C	1.69	3	0.20	1.89	3.39
4S Geneva	C	2.11	3	0.20	2.31	3.81
64-2	C	2.35	4	0.27	2.62	4.12
4Sa Brisbane	C	2.73	4	0.27	2.99	4.49
4S Sierra	C	2.59	4	0.27	2.85	4.35
92-2	C	2.70	3	0.20	2.90	4.40
102-2	C	2.20	3	0.20	2.40	3.90
110-2	C	2.16	3	0.20	2.36	3.86
122-2	C	1.46	3	0.20	1.66	3.16
4S Center	C	1.86	3	0.20	2.06	3.56

[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: Non-stop . Page 2 of 4 .

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
138-2	C	1.77	3	0.20	1.97	3.47
4S Trousdale	C	2.19	3	0.20	2.39	3.89
152-2	C	1.93	3	0.20	2.13	3.63
160-2	C	2.19	5	0.34	2.53	4.03
170-2	C	2.12	5	0.34	2.45	3.95
176-2	C	1.60	4	0.27	1.87	3.37
4S Palm	C	1.92	3	0.20	2.12	3.62
188-2	C	1.88	3	0.20	2.08	3.58
196-2	C	2.05	4	0.27	2.32	3.82
204-2	C	1.92	4	0.27	2.19	3.69
212-2	C	1.41	3	0.20	1.61	3.11
4S Ralston	C	1.66	3	0.20	1.86	3.36
222-2	C	2.01	3	0.20	2.21	3.71
230-2	C	2.40	4	0.27	2.67	4.17
236-2	C	2.69	4	0.27	2.96	4.46
248-2	C	2.26	4	0.27	2.53	4.03
4S Dumbarton	C	2.01	3	0.20	2.21	3.71

(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:** Non-stop.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
4S Junction	C	1.57	4	0.27	1.84	3.34
276-2	C	1.70	4	0.27	1.96	3.46
286-2	C	1.56	4	0.27	1.83	3.33
4S Alma	C	1.98	3	0.20	2.18	3.68
300-2	C	2.11	3	0.20	2.31	3.81
306-2	C	2.38	3	0.20	2.58	4.08
316-2	C	2.44	3	0.20	2.64	4.14
326-2	C	2.60	3	0.20	2.80	4.30
4S Mayfield	C	2.33	3	0.20	2.53	4.03
348-2	C	2.13	3	0.20	2.33	3.83
358-2	C	1.72	4	0.27	1.99	3.49
366-2	C	2.15	4	0.27	2.41	3.91
376-2	C	2.07	4	0.27	2.34	3.84
4S Mary	C	2.17	3	0.20	2.37	3.87
4S Hendy	C	2.38	4	0.27	2.65	4.15
402-2	C	1.79	3	0.20	2.00	3.50
410-2	C	1.95	4	0.27	2.22	3.72

(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:** Non-stop.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
4Sa Bowers	C	1.99	4	0.27	2.25	3.75
424-2	C	2.72	5	0.34	3.06	4.56
432-2	C	1.99	3	0.20	2.19	3.69
4S De La Cruz	C	2.75	3	0.20	2.96	4.46
4S Franklin	C	3.93	2	0.13	4.06	5.56
8Ea Stockton	AA	2.87	1	0.07	2.94	4.44
6Ea Julian	A	1.74	0	0.00	1.74	3.24
14E West Cahill	R	1.01	0	0.00	1.01	2.51

(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 4

Northbound Non-Stop Express-Train Headway Constraints

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order

Northbound Non-Stop Signal System Headways
Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

Direction: N/B. Stopping Pattern: Non-stop. Page 1 of 4.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
10Wc West Cahill	C	2.25	1	0.07	2.32	3.82
4W Julian	AA	3.21	2	0.13	3.35	4.85
6W Stockton	C	2.48	3	0.20	2.68	4.18
2N Franklin	C	1.80	4	0.27	2.07	3.57
2N Coast	C	1.47	3	0.20	1.67	3.17
2N De La Cruz	C	1.94	4	0.27	2.21	3.71
433-1	C	1.95	4	0.27	2.22	3.72
425-1	C	1.79	3	0.20	2.00	3.50
2N Bowers	C	1.69	3	0.20	1.89	3.39
411-1	C	2.01	3	0.20	2.21	3.71
401-1	C	2.07	4	0.27	2.34	3.84
2Na Hendy	C	2.22	4	0.27	2.49	3.99
2N Mary	C	1.89	4	0.27	2.15	3.65
375-1	C	2.13	3	0.20	2.33	3.83
367-1	C	2.15	3	0.20	2.35	3.85
359-1	C	2.60	3	0.20	2.80	4.30
347-1	C	2.44	3	0.20	2.64	4.14

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

[2] Sum of cascading electronic-track-circuit delay times.

[3] Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

Direction: N/B. **Stopping Pattern: Non-stop.**

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
2N Mayfield	C	2.56	3	0.20	2.76	4.26
325-1	C	2.11	3	0.20	2.31	3.81
317-1	C	1.81	3	0.20	2.01	3.51
305-1	C	1.56	4	0.27	1.83	3.33
299-1	C	1.70	4	0.27	1.96	3.46
2N Alma	C	2.44	5	0.34	2.77	4.27
285-1	C	1.87	3	0.20	2.07	3.57
277-1	C	2.26	4	0.27	2.53	4.03
2N Junction	C	2.85	4	0.27	3.12	4.62
2N Dumbarton	C	2.54	5	0.34	2.87	4.37
249-1	C	2.42	5	0.34	2.75	4.25
237-1	C	1.94	5	0.34	2.28	3.78
229-1	C	2.57	5	0.34	2.90	4.40
2N Ralston	C	1.65	3	0.20	1.85	3.35
211-1	C	1.88	3	0.20	2.08	3.58
203-1	C	1.72	3	0.20	1.92	3.42
197-1	C	2.12	5	0.34	2.45	3.95

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

[(2)] Sum of cascading electronic-track-circuit delay times.

[(3)] Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways

Headway Constraints by Individual Signal

Direction: N/B. **Stopping Pattern:** Non-stop.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
187-1	C	1.45	4	0.27	1.72	3.22
2N Palm	C	1.84	4	0.27	2.11	3.61
175-1	C	1.93	3	0.20	2.13	3.63
169-1	C	1.94	3	0.20	2.14	3.64
159-1	C	1.80	3	0.20	2.00	3.50
151-1	C	1.59	3	0.20	1.79	3.29
2N Trousdale	C	1.74	3	0.20	1.94	3.44
2N BART	C	2.11	3	0.20	2.31	3.81
2N Center	C	2.49	3	0.20	2.69	4.19
123-1	C	2.69	3	0.20	2.89	4.39
111-1	C	2.41	3	0.20	2.61	4.11
103-1	C	2.66	3	0.20	2.86	4.36
91-1	C	2.35	3	0.20	2.55	4.05
2Na Sierra	C	2.64	4	0.27	2.91	4.41
2N Brisbane	C	2.51	4	0.27	2.78	4.28
63-1	C	1.93	3	0.20	2.13	3.63
2N Geneva	C	2.32	4	0.27	2.58	4.08

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

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

Direction: N/B. **Stopping Pattern: Non-stop.**

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
2Na Tunnel	C	2.36	4	0.27	2.62	4.12
41-1	C	2.33	5	0.34	2.67	4.17
31-1	C	3.16	5	0.34	3.50	5.00
2N Army	AL	2.54	4	0.27	2.81	4.31
13-1	AA	1.68	2	0.13	1.81	3.31
2N Common	AS	2.06	1	0.07	2.13	3.63
80L 4th Street	SC	0.97	0	0.00	0.97	2.47

(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 .

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
76R Fourth St.	RSC	1.69	1	0.07	1.76	2.76
86R Fourth St.	C	3.99	3	0.20	4.19	5.19
4S Common	AA	3.76	3	0.20	3.96	4.96
(16-2)	AA	1.91	2	0.13	2.05	3.05
4S Army	AA	2.47	2	0.13	2.61	3.61
32-2	AA	2.36	2	0.13	2.49	3.49
42-2	AL	4.38	3	0.20	4.58	5.58
4S Tunnel	LAA	3.27	2	0.13	3.41	4.41
8S Geneva	AA	2.00	2	0.13	2.13	3.13
64-4	AL	2.20	2	0.13	2.34	3.34
4Sd Brisbane	LAA	2.78	3	0.20	2.98	3.98
4S Sierra	AA	4.47	3	0.20	4.68	5.68
92-2	AA	4.14	2	0.13	4.28	5.28
102-2	AA	4.20	2	0.13	4.33	5.33
110-2	AA	3.77	2	0.13	3.91	4.91
122-2	AA	3.79	2	0.13	3.93	4.93
4S Center	C	5.11	3	0.20	5.31	6.31

[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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
138-2	AA	2.14	2	0.13	2.27	3.27
4S Trousdale	AA	2.33	2	0.13	2.46	3.46
152-2	AA	3.88	2	0.13	4.02	5.02
160-2	AA	3.86	2	0.13	3.99	4.99
170-2	AL	4.04	4	0.27	4.31	5.31
176-2	AA	3.18	3	0.20	3.38	4.38
4S Palm	AA	3.76	2	0.13	3.89	4.89
188-2	AA	5.48	2	0.13	5.61	6.61
196-2	AA	3.69	2	0.13	3.82	4.82
204-2	AL	4.00	3	0.20	4.20	5.20
212-2	AA	3.02	2	0.13	3.15	4.15
4S Ralston	AA	3.44	2	0.13	3.57	4.57
222-2	AA	3.48	2	0.13	3.61	4.61
230-2	AA	4.02	2	0.13	4.16	5.16
236-2	AA	4.99	3	0.20	5.19	6.19
248-2	AA	4.83	3	0.20	5.04	6.04
4S Dumbarton	AA	2.17	2	0.13	2.30	3.30

(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
4S Junction	AA	1.90	2	0.13	2.04	3.04
276-2	AA	3.34	3	0.20	3.54	4.54
286-2	AA	3.34	3	0.20	3.54	4.54
4S Alma	AA	3.99	2	0.13	4.12	5.12
300-2	AA	4.27	2	0.13	4.41	5.41
306-2	AA	4.28	2	0.13	4.41	5.41
316-2	AA	4.24	2	0.13	4.37	5.37
326-2	AA	4.42	2	0.13	4.55	5.55
4S Mayfield	AA	4.64	2	0.13	4.77	5.77
348-2	AA	4.39	2	0.13	4.52	5.52
358-2	AA	4.05	2	0.13	4.18	5.18
366-2	AA	1.96	3	0.20	2.16	3.16
376-2	AA	4.15	3	0.20	4.35	5.35
4S Mary	AL	6.73	3	0.20	6.93	7.93
4S Hendy	LAA	3.44	2	0.13	3.57	4.57
402-4	AA	3.38	2	0.13	3.52	4.52
410-4	AL	3.36	4	0.27	3.63	4.63

[(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
4Sd Bowers	LAA	2.37	3	0.20	2.57	3.57
424-2	AA	1.80	3	0.20	2.01	3.01
432-2	C	4.70	3	0.20	4.90	5.90
4S De La Cruz	AA	4.16	2	0.13	4.29	5.29
4S Franklin	AA	3.09	2	0.13	3.22	4.22
8Ea Stockton	AA	2.91	1	0.07	2.98	3.98
6Ea Julian	A	1.78	0	0.00	1.78	2.78
14E West Cahill	R	1.05	0	0.00	1.05	2.05
22Ea East Cahill	AA	2.79	2	0.13	2.93	3.93
4E Delmas	AA	3.37	2	0.13	3.51	4.51
8E Mack	AA	4.36	2	0.13	4.50	5.50
4S Michael	C	7.70	4	0.27	7.97	8.97
504-2	AD	5.90	3	0.20	6.10	7.10
1W Lick	DC	11.29	3	0.20	11.49	12.49

[(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 .

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
76R Fourth St.	RSC	1.69	1	0.07	1.76	2.76
86R Fourth St.	C	3.99	3	0.20	4.19	5.19
4S Common	C	4.56	4	0.27	4.82	5.82
(16-2)	C	2.76	3	0.20	2.96	3.96
4S Army	C	3.02	3	0.20	3.23	4.23
32-2	C	3.96	3	0.20	4.16	5.16
42-2	AL	4.07	3	0.20	4.27	5.27
4S Tunnel	LC	3.94	3	0.20	4.14	5.14
8S Geneva	C	3.02	3	0.20	3.22	4.22
64-4	AL	1.93	2	0.13	2.07	3.07
4Sd Brisbane	LC	5.33	4	0.27	5.60	6.60
4S Sierra	C	5.03	4	0.27	5.30	6.30
92-2	C	7.05	3	0.20	7.25	8.25
102-2	C	4.57	3	0.20	4.77	5.77
110-2	C	6.71	3	0.20	6.91	7.91
122-2	C	4.33	3	0.20	4.53	5.53
4S Center	C	4.90	3	0.20	5.10	6.10

(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** 2 **of** 4.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits (1)	Total Delay Time (2)	Actual Theoretical Headway	Practical Headway (3)
138-2	C	2.80	3	0.20	3.00	4.00
4S Trousdale	C	4.82	3	0.20	5.02	6.02
152-2	C	4.58	3	0.20	4.78	5.78
160-2	C	6.78	5	0.34	7.12	8.12
170-2	C	6.67	5	0.34	7.01	8.01
176-2	C	5.85	4	0.27	6.11	7.11
4S Palm	C	6.39	3	0.20	6.59	7.59
188-2	C	6.36	3	0.20	6.56	7.56
196-2	C	6.55	4	0.27	6.81	7.81
204-2	C	4.79	4	0.27	5.06	6.06
212-2	C	3.82	3	0.20	4.02	5.02
4S Ralston	C	5.86	3	0.20	6.06	7.06
222-2	C	4.73	3	0.20	4.93	5.93
230-2	C	7.22	4	0.27	7.49	8.49
236-2	C	5.98	4	0.27	6.25	7.25
248-2	C	5.25	4	0.27	5.51	6.51
4S Dumbarton	C	2.78	3	0.20	2.98	3.98

(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
4S Junction	C	3.73	4	0.27	4.00	5.00
276-2	C	4.15	4	0.27	4.42	5.42
286-2	C	6.14	4	0.27	6.41	7.41
4S Alma	C	5.20	3	0.20	5.40	6.40
300-2	C	6.99	3	0.20	7.19	8.19
306-2	C	5.24	3	0.20	5.44	6.44
316-2	C	7.10	3	0.20	7.31	8.31
326-2	C	5.62	3	0.20	5.82	6.82
4S Mayfield	C	7.32	3	0.20	7.53	8.53
348-2	C	5.33	3	0.20	5.53	6.53
358-2	C	4.58	4	0.27	4.85	5.85
366-2	C	4.98	4	0.27	5.25	6.25
376-2	C	4.76	4	0.27	5.03	6.03
4S Mary	AL	6.50	3	0.20	6.70	7.70
4S Hendy	LC	4.17	3	0.20	4.37	5.37
402-4	AL	4.29	3	0.20	4.49	5.49
410-4	AL	2.96	4	0.27	3.23	4.23

[(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
4Sd Bowers	LC	2.35	4	0.27	2.62	3.62
424-2	C	5.32	5	0.34	5.66	6.66
432-2	C	4.44	3	0.20	4.64	5.64
4S De La Cruz	C	5.34	3	0.20	5.54	6.54
4S Franklin	C	4.54	2	0.13	4.68	5.68
8Ea Stockton	AA	2.91	1	0.07	2.98	3.98
6Ea Julian	A	1.78	0	0.00	1.78	2.78
14E West Cahill	R	1.05	0	0.00	1.05	2.05
22Ea East Cahill	AA	2.79	2	0.13	2.93	3.93
4E Delmas	AA	3.37	2	0.13	3.51	4.51
8E Mack	AA	4.36	2	0.13	4.50	5.50
4S Michael	C	7.70	4	0.27	7.97	8.97
504-2	AD	5.90	3	0.20	6.10	7.10
1W Lick	DC	11.29	3	0.20	11.49	12.49

[(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
2E Lick	DC	5.47	4	0.27	5.73	6.73
505-2	C	6.39	5	0.34	6.72	7.72
4N Michael	AA	3.94	2	0.13	4.07	5.07
8W Mack	AA	2.43	2	0.13	2.57	3.57
4W Delmas	A	1.58	1	0.07	1.64	2.64
22W East Cahill	R	1.28	0	0.00	1.28	2.28
10Wc West Cahill	C	2.34	1	0.07	2.41	3.41
4W Julian	AA	3.51	2	0.13	3.65	4.65
6W Stockton	AA	4.01	2	0.13	4.15	5.15
2N Franklin	AA	3.31	2	0.13	3.44	4.44
2N Coast	C	2.66	3	0.20	2.86	3.86
2N De La Cruz	AA	2.20	3	0.20	2.40	3.40
433-1	AA	2.24	3	0.20	2.45	3.45
425-1	AL	4.54	3	0.20	4.74	5.74
2N Bowers	LAA	3.56	2	0.13	3.69	4.69
411-3	AA	3.50	2	0.13	3.64	4.64
401-3	AL	4.00	2	0.13	4.14	5.14

[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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits (1)	Total Delay Time (2)	Actual Theoretical Headway	Practical Headway (3)
2Nd Hendy	LAA	4.21	3	0.20	4.41	5.41
2N Mary	AA	2.22	3	0.20	2.42	3.42
375-1	AA	4.01	2	0.13	4.15	5.15
367-1	AA	4.48	2	0.13	4.61	5.61
359-1	AA	4.36	2	0.13	4.49	5.49
347-1	AA	4.38	2	0.13	4.51	5.51
2N Mayfield	AA	4.56	2	0.13	4.69	5.69
325-1	AA	4.30	2	0.13	4.44	5.44
317-1	AA	4.50	2	0.13	4.64	5.64
305-1	AA	3.77	2	0.13	3.90	4.90
299-1	AA	3.49	3	0.20	3.69	4.69
2N Alma	AA	3.74	3	0.20	3.95	4.95
285-1	C	3.09	3	0.20	3.29	4.29
277-1	AA	1.94	2	0.13	2.08	3.08
2N Junction	AA	5.17	3	0.20	5.38	6.38
2N Dumbarton	AA	5.27	3	0.20	5.47	6.47
249-1	AA	4.05	3	0.20	4.26	5.26

(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits (1)	Total Delay Time (2)	Actual Theoretical Headway	Practical Headway (3)
237-1	AA	5.68	4	0.27	5.95	6.95
229-1	AA	3.97	3	0.20	4.17	5.17
2N Ralston	AA	1.74	2	0.13	1.87	2.87
211-1	AA	3.59	2	0.13	3.73	4.73
203-1	AA	5.42	2	0.13	5.56	6.56
197-1	AL	5.74	4	0.27	6.01	7.01
187-1	AA	3.14	3	0.20	3.34	4.34
2N Palm	AA	3.51	3	0.20	3.71	4.71
175-1	AA	4.05	2	0.13	4.18	5.18
169-1	AA	3.85	2	0.13	3.98	4.98
159-1	AA	2.00	2	0.13	2.14	3.14
151-1	AA	1.93	2	0.13	2.06	3.06
2N Trousdale	AA	3.78	2	0.13	3.91	4.91
2N BART	AA	3.99	2	0.13	4.12	5.12
2N Center	AA	4.34	2	0.13	4.47	5.47
123-1	AA	4.24	2	0.13	4.37	5.37
111-1	AA	4.12	2	0.13	4.25	5.25

(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.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
103-1	AA	4.17	2	0.13	4.31	5.31
91-1	AA	2.80	2	0.13	2.94	3.94
2Na Sierra	AL	3.05	3	0.20	3.25	4.25
2N Brisbane	LAA	1.56	2	0.13	1.69	2.69
63-3	AA	2.95	2	0.13	3.08	4.08
10N Geneva	AL	3.86	2	0.13	3.99	4.99
2Nd Tunnel	LAA	2.82	3	0.20	3.02	4.02
41-1	AA	2.23	3	0.20	2.44	3.44
31-1	AA	3.74	3	0.20	3.94	4.94
2N Army	AL	4.34	4	0.27	4.61	5.61
13-1	AA	1.72	2	0.13	1.85	2.85
2N Common	AS	2.10	1	0.07	2.17	3.17
80L 4th Street	SC	1.01	0	0.00	1.01	2.01

[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 8

Northbound Local-Train Headway Constraints
for
Green/Clear Signal Aspects to be Displayed

Tabulation of Signals and Associated Headways

Geographical Bar Chart of Practical Headways by Individual Signal

Bar Chart of Practical Headways by Individual Signal in Ranked Order

Northbound All-Stop Local Signal System Headways
Caltrain Capital Project Operations Planning Support
SYSTRA Project No. 5592; Task 1 - Signal System Headways
Headway Constraints by Individual Signal

Direction: N/B . **Stopping Pattern:** Local @ 79 mph .

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
2E Lick	DC	5.47	4	0.27	5.73	6.73
505-2	C	6.39	5	0.34	6.72	7.72
4N Michael	AA	3.94	2	0.13	4.07	5.07
8W Mack	AA	2.43	2	0.13	2.57	3.57
4W Delmas	A	1.58	1	0.07	1.64	2.64
22W East Cahill	R	1.28	0	0.00	1.28	2.28
10Wc West Cahill	C	2.34	1	0.07	2.41	3.41
4W Julian	AA	3.43	2	0.13	3.56	4.56
6W Stockton	C	4.79	3	0.20	5.00	6.00
2N Franklin	C	4.20	4	0.27	4.47	5.47
2N Coast	C	2.40	3	0.20	2.60	3.60
2N De La Cruz	C	2.71	4	0.27	2.98	3.98
433-1	C	2.72	4	0.27	2.99	3.99
425-1	AL	4.28	3	0.20	4.48	5.48
2N Bowers	LC	4.36	3	0.20	4.56	5.56
411-3	AL	6.55	3	0.20	6.76	7.76
401-3	AL	3.99	2	0.13	4.13	5.13

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

[2] Sum of cascading electronic-track-circuit delay times.

[3] Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways

Headway Constraints by Individual Signal

Direction: N/B. **Stopping Pattern:** Local @ 79 mph.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [(1)]	Total Delay Time [(2)]	Actual Theoretical Headway	Practical Headway [(3)]
2Nd Hendy	LC	4.97	4	0.27	5.24	6.24
2N Mary	C	4.77	4	0.27	5.04	6.04
375-1	C	5.17	3	0.20	5.37	6.37
367-1	C	6.91	3	0.20	7.11	8.11
359-1	C	5.70	3	0.20	5.90	6.90
347-1	C	6.83	3	0.20	7.03	8.03
2N Mayfield	C	5.74	3	0.20	5.94	6.94
325-1	C	7.02	3	0.20	7.23	8.23
317-1	C	5.24	3	0.20	5.44	6.44
305-1	C	6.26	4	0.27	6.53	7.53
299-1	C	4.52	4	0.27	4.79	5.79
2N Alma	C	4.98	5	0.34	5.31	6.31
285-1	C	2.51	3	0.20	2.71	3.71
277-1	C	5.02	4	0.27	5.29	6.29
2N Junction	C	5.93	4	0.27	6.19	7.19
2N Dumbarton	C	7.49	5	0.34	7.82	8.82
249-1	C	6.99	5	0.34	7.32	8.32

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

[(2)] Sum of cascading electronic-track-circuit delay times.

[(3)] Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways

Headway Constraints by Individual Signal

Direction: N/B . **Stopping Pattern:** Local @ 79 mph .

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits (1)	Total Delay Time (2)	Actual Theoretical Headway	Practical Headway (3)
237-1	C	6.38	5	0.34	6.72	7.72
229-1	C	7.33	5	0.34	7.66	8.66
2N Ralston	C	4.27	3	0.20	4.47	5.47
211-1	C	6.10	3	0.20	6.30	7.30
203-1	C	6.03	3	0.20	6.23	7.23
197-1	C	6.74	5	0.34	7.08	8.08
187-1	C	4.16	4	0.27	4.43	5.43
2N Palm	C	6.20	4	0.27	6.46	7.46
175-1	C	4.97	3	0.20	5.17	6.17
169-1	C	4.42	3	0.20	4.62	5.62
159-1	C	2.61	3	0.20	2.81	3.81
151-1	C	4.28	3	0.20	4.48	5.48
2N Trousdale	C	4.66	3	0.20	4.86	5.86
2N BART	C	6.89	3	0.20	7.09	8.09
2N Center	C	5.18	3	0.20	5.38	6.38
123-1	C	6.87	3	0.20	7.07	8.07
111-1	C	5.03	3	0.20	5.23	6.23

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

(2) Sum of cascading electronic-track-circuit delay times.

(3) Based on wayside signals without cab-signaling.

Caltrain Capital Project Operations Planning Support

SYSTRA Project No. 5592; Task 1 - Signal System Headways

Headway Constraints by Individual Signal

Direction: N/B. Stopping Pattern: Local @ 79 mph.

Signal	Signal Aspect	Base Theoretical Headway	Number of Track Circuits [1]	Total Delay Time [2]	Actual Theoretical Headway	Practical Headway [3]
103-1	C	5.22	3	0.20	5.43	6.43
91-1	C	3.33	3	0.20	3.53	4.53
2Na Sierra	AL	2.58	3	0.20	2.78	3.78
2N Brisbane	LC	3.60	3	0.20	3.80	4.80
63-3	C	4.18	3	0.20	4.38	5.38
10N Geneva	AL	3.74	2	0.13	3.87	4.87
2Nd Tunnel	LC	3.26	4	0.27	3.53	4.53
41-1	C	4.37	5	0.34	4.71	5.71
31-1	C	5.02	5	0.34	5.36	6.36
2N Army	AL	4.31	4	0.27	4.58	5.58
13-1	AA	1.72	2	0.13	1.85	2.85
2N Common	AS	2.10	1	0.07	2.17	3.17
80L 4th Street	SC	1.01	0	0.00	1.01	2.01

(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.