National Transportation Safety Board

Office of Highway Safety

Office of Railroad, Pipeline and Hazardous Materials

Washington, DC 20594

HWY23MH006

RAILROAD SIGNAL AND HIGHWAY FACTORS GROUP

Group Chair's Factual Report

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A. CRASH INFORMATION

Location: Delray Beach, Palm Beach County, Florida
Date: February 8, 2023
Time: 8:06 p.m. (EST)

B. RAILROAD SIGNAL AND HIGHWAY FACTORS GROUP

Group Co-Chairs	Greg Scott, Co-Chair Rail Accident Investigator NTSB - RPH
	Dan Walsh, P.E., Co-Chair Highway Factors Investigator NTSB - HWY
Group Members	Kenny Bragg Investigator-In-Charge NTSB - HWY
	Russell Hunter Signal and Train Control Inspector Federal Railroad Administration
	Bill Young Chief Engineer Signals and Communications Florida East Coast Railway
	Hossam Abdel All, P.E., PTOE Manager, Traffic Engineering Operations Palm Beach County, Florida
	Missie Barletto Public Works Director City of Delray Beach, Florida

C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Information and Summary Report*, which can be found in the NTSB docket for this investigation.

D. DETAILS OF THE INVESTIGATION

The report begins with a discussion on prefatory data that includes the crash location, crash history, rail volumes, and construction history of the double tracks. Next, the report provides a discussion on signal factors that includes a description of the signal system, highway-rail grade crossing warning system and data logs, inspection and testing of grade crossing warning system, railroad traffic control signal system damages, grade crossing regulations and industry standards, and maximum authorized speeds along the Brightline system. The report also provides a discussion on highway factors that includes geometry and lane designations for grade crossings, references from the Manual on Uniform Traffic Control Devices (MUTCD), quiet zone within the City of Delray Beach, speed limit, 2-quadrant gate system at the Lindell Boulevard grade crossing, average daily traffic, traffic accident summary at the Old Dixie Highway and Lindell Boulevard intersection, traffic controller field alarms, railroad and traffic signal time, grade crossing gate, turn prohibitions during preemption, preemption line tests, warning signs, and diagnostic reviews conducted at the Lindell Boulevard grade crossing.

1.0 Crash Location

Figure 1 is a map that illustrates the crash location was approximately 5 miles northeast from the center of Boca Raton, Florida.

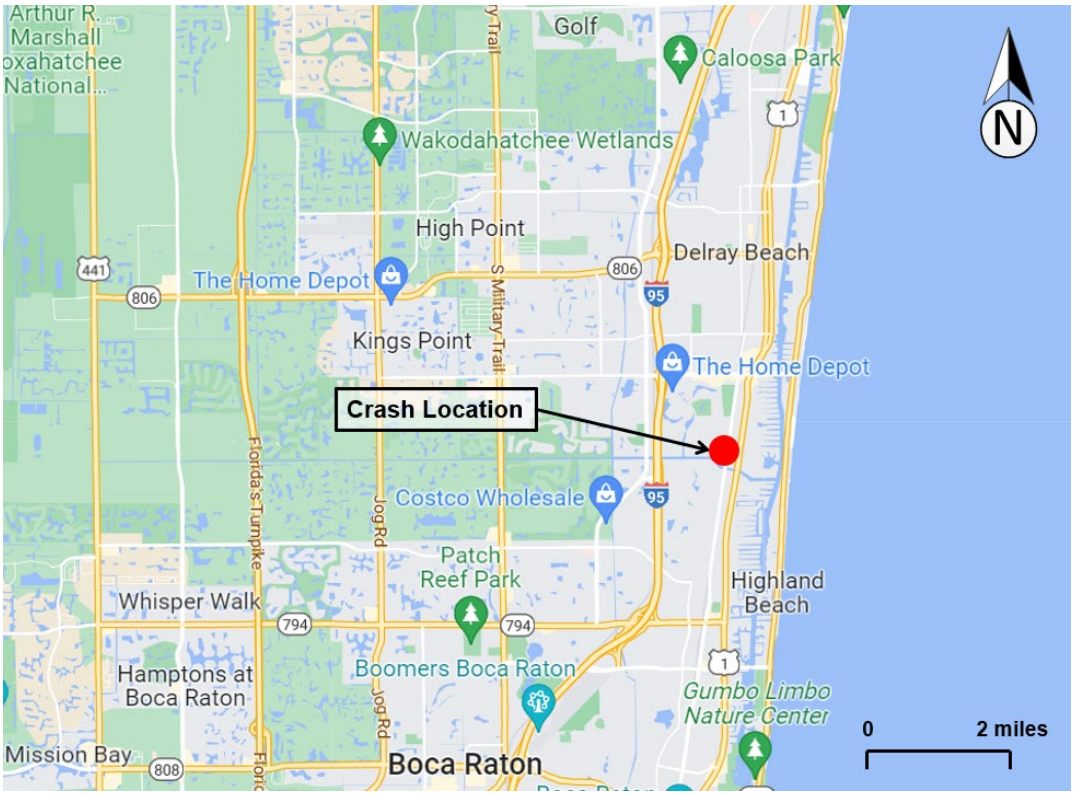

Figure 1 – Crash location map (Source: Google Maps revised).

2.0 Crash History at the Grade Crossing

Table 1 summarizes the crash history at the grade crossing from 1975 through present-day.[1]

Table 1 - Crash history at the grade crossing from 1975 through 2023.

Date	Fatalities	Injured	Track #	Narrative Description
12-12-1986	0	0	Track 2	None
7-12-1985	0	0	Main	None
4-25-1975	0	0	Main	None

3.0 Rail Volumes

The approximate rail volume before Brightline began service in 2018 at the Lindell Boulevard grade crossing was 12 freight trains per day. The approximate rail volume after Brightline service at the Lindell Boulevard grade crossing was 36 passenger trains per day and 12 freight trains per day.

4.0 Construction History of the Double Tracks

The double track through the Lindell Boulevard grade crossing was placed into service on January 15, 2016. The Florida East Coast Railway (FECR) was originally double track and was reduced to single track with passing siding sometime in the late 1970's and early 1980's. The double track was added[2] back to the railway to accommodate the Brightline service.

E. RAILROAD SIGNAL FACTORS

1.0 Florida East Coast Railway

The Florida East Coast Railway (FECR)[3] extends from mile post (MP) 0.0 Jacksonville Drawbridge to MP 369.2 Hialeah Yard in a timetable north-south direction. The subdivision consists of two main tracks. The maximum authorized timetable speed for the subdivision is 60 miles per hour (mph) for freight trains and 79 mph for passenger trains. The maximum speed at the accident location is the same as the subdivision, 60 mph for freight trains and 79 mph for passenger trains.

[1] See Railroad Signal and Highway Factors Attachment – Federal Railroad Administration (FRA) Highway-Rail Grade Crossing Accident/Incident Reports.
[2] Construction began on the double track in 2014 and service started in 2018.
[3] Florida East Coast Railway Timetable No. 8, effective September 1, 2021.

1.1 Description of Signal System

The FECR authorizes train movements with Centralized Traffic Control (CTC) from Jacksonville to Miami, which includes the area of the crash. Train movements are coordinated by the Central Desk train dispatcher located at Dispatch Center in Jacksonville, FL. Train movements on the FECR are governed by operating rules, special instruction, timetable instructions, and the signal indications of the traffic control system. The FECR centralized traffic control system was not affected, nor did it sustain any damage as a result of the collision.

The signal system uses direct current (DC) Track Circuits interfaced with an Electro Code coded circuit on the rail for train occupancy detection. Wayside signals are colored light signals with upper and lower signal heads capable of displaying green, yellow, and red to direct train movements in either direction. Locomotives are also equipped with a 40hz cab signal that communicates track status and condition to the crew of the locomotive.

2.0 Highway-Rail Grade Crossing Warning System

The FECR double main track runs through the City of Delray Beach, FL. At MP 319.36, the FECR two main tracks and three-lane Lindell Boulevard crossed at grade[4]. The grade crossing inventory number was DOT # 272498Y. The highway-rail grade crossing was equipped with an active grade crossing warning system. The grade crossing warning system consisted of flashing LED light units, two warning bells and two gate arms mounted on two signal masts and arranged to provide warning for all directions of highway traffic. The gate arms extended across incoming lanes of Lindell Boulevard to the centerline for each direction of traffic. The grade crossing warning system also included a pedestrian warning system which consisted of flashing LED light units to provide warning for all directions of pedestrian traffic. The gate arms extended across all incoming sidewalks along Lindell Boulevard warning each direction of pedestrian traffic.

The grade crossing warning system operated on commercial electric power and was equipped with a standby battery backup system.

Train detection and warning system activation was configured through an Alstom Grade Crossing Predictor (GCP), model XP-4, microprocessor unit. The crossing was equipped with a primary and standby GCP unit. Each GCP unit was configured in a semi bi-directional mode. The GCP unit was a constant warning device and could calculate the speed of an approaching train. The GCP unit provided a relatively uniform warning time, but the time could fluctuate slightly due to changing ballast and track conditions or variances in the speed of an approaching train.[5] The

[4] Lindell Boulevard had a posted speed limit of 25 mph.

[5] If the ballast gets saturated with water or mud it can cause less resistance between the rails and cause

Federal Railroad Administration (FRA) requires a minimum warning time of 20 seconds, which is also a recommended minimum by the Manual on Uniform Traffic Control Devices (MUTCD) for all train speeds up to 79 mph. The GCP unit at Lindell Blvd, was configured to provide warning time greater than the minimum requirements.

2.1 Highway-Rail Grade Crossing Warning System Data Logs

The GCP unit at the Lindell Boulevard crossing was equipped with a data logger. The data logger provided the capability to record information associated with the previous train movements through that location. The data log contained the date and time of train movements, the detected train speed[6], the average train speed[7], and island speed[8]. The log could also retain any error alarms detected by the microprocessor.

The Lindell Boulevard crossing was activated at 8:05:17 p.m. by the northbound FECR freight train. Had the northbound FECR freight train not been present the southbound Brightline train would have activated the crossing at 8:05:30 p.m.[9] Based on the warning device logs, the southbound Brightline train was traveling on the east track and activated for 34 seconds before the train occupied the island circuit.[10] The warning time is discussed under the *Railroad and Traffic Signal Time* section.

The data log for the Lindell Boulevard crossing contained multiple data log entries. A post-accident review of the data found all warning times to be in accordance with the minimum requirements. There were no error alarms detected in this incident.

2.2 Inspection & Testing of Grade Crossing Warning System

Following the accident, FECR secured the crossing signal bungalow. On February 9, 2023, representatives from the FECR and the FRA began post-accident inspection of the highway-rail grade crossing warning system at Lindell Boulevard. Their investigation found the signal bungalow and all flashing light units were locked and secured with no evidence of vandalism or tampering.

2.2.1 Track Circuits

Track components and connections were inspected, and the approach track circuits were verified.[11] Approach track circuits extended from the Lindell Boulevard crossing in both track directions. The northbound and southbound approach track

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the time to fluctuate slightly.

[6] Train speed calculated by microprocessor to determine warning device activation time.

[7] Average speed of train as it traversed approach circuit.

[8] Train speed calculated by microprocessor as it enters the island circuit, typically in close proximity to edge of paved roadway.

[9] The crossing is triggered by approaching trains.

[10] The island circuit is the grade crossing area where the pavement is located.

[11] A track circuit is also known as a shunt circuit.

circuit are set to a semi bi-directional configuration that also includes external Dax units.[12] With this configuration the approach lengths were 4,341 feet for train speeds up to 79 mph, and in accordance with the signal circuit plans for that location.

2.2.2 GCP Microprocessor Unit

The signal circuit plans for the Lindell Boulevard grade crossing indicated the GCP unit was configured to provide a minimum 20 seconds of warning time activation.[13]

The post-accident inspection found the Lindell Boulevard grade crossing warning system to be operating on the normal segment of the GCP unit that is equipped with a normal and standby unit. If an issue were to be detected with the normal portion of the GCP it would automatically switch to the standby unit as a backup attempt to recover from the problem issue.

The clock time of the GCP unit was verified with the FECR Dispatch Center clock. The GCP unit clock was ahead of the Dispatch Center time by 1 hour 14 minutes. The program configuration of the GCP microprocessor was recorded and verified against the programming parameters on file by FRA inspectors during the investigation. No discrepancies were identified in the programming parameters of the GCP unit.

2.2.3 Gate Arms

The southeast pedestrian mechanism was destroyed as a result of the accident. Post-accident testing measured the start of the descent time for the gate arms to be about 3 seconds after the flashing light units were activated. The gate arms assumed a horizontal position approximately 11 seconds after the flashing light units were activated.

2.2.4 Flashing Light Units

Post-accident insulation resistance tests were completed for the lighting cables from the signal bungalow to the signal masts. Testing determined the flashing light units were operating at 64 flashes per minute. Lamp voltage measurements were taken with the warning devices operating on primary commercial power and on the standby battery backup system. The average lighting circuit voltages measured 12.9 volts DC on standby power.

[12] Dax is a Downstream Adjacent Crossing. Crossing predictors communicate with each other, to instruct downstream adjacent crossings to activate their warning devices.
[13] Title 49, Code of Federal Regulations, Part 234.225, Activation of Warning Systems.

2.3 Railroad Traffic Control Signal System Damages

The southeast pedestrian gate mechanisms of the FECR highway-rail grade crossing warning system was destroyed as a result of the accident. Repair damages costs were estimated to be $16,000.

3.0 Grade Crossing Regulations and Industry Standards

FRA regulations specified a minimum warning time in Title 49, Code of Federal Regulations, Part 234.225, Activation of Warning Systems, which stated:

A highway-rail grade crossing warning system shall be maintained to activate in accordance with the design of the warning system, but in no event shall it provide less than 20 seconds warning time before the grade crossing is occupied by rail traffic.

The 2023 edition of the MUTCD recommended national uniformity in traffic control devices. In order to provide for uniformity, the MUTCD was the adopted national standard for traffic control devices. The MUTCD provided guidance through its recommended standards regarding flashing light units, gates, and traffic control signals.

The American Railway Engineering and Maintenance-of-Way Association (AREMA), Communication and Signal Manual of Recommended Practices recommends the addition of buffer times and equipment response times to the warning time to accommodate assurance of providing the minimum required warning time.

4.0 Maximum Authorized Speeds along the Brightline System

Figure 2 illustrates the general segments of the maximum authorized speeds along the Brightline System. The general segments included the following:

- From Miami to West Palm Beach the maximum authorized speed was 79 mph.
- From West Palm Beach to Cocoa, Brightline is currently testing at 79 mph and 110 mph, FRA will release maximum authorized speed in the future.
- From Cocoa to Orlando, Brightline plans are estimated to be 125 mph.
- Extension from Orlando to Tampa, Brightline plans are estimated to be 125 mph.

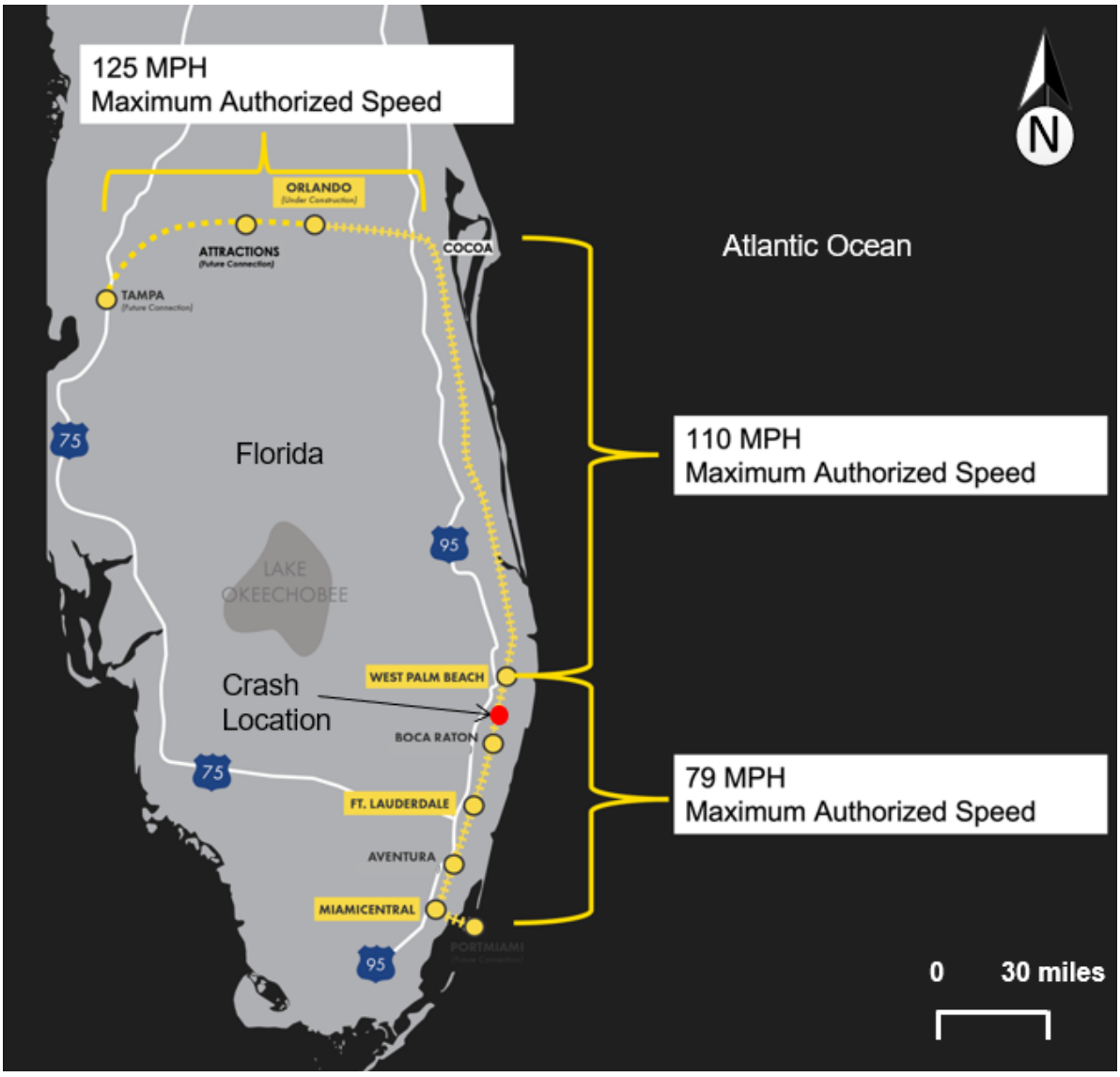

Figure 2 – General segments of the maximum authorized speeds along the Brightline System (Source: Brightline – with annotations added by the NTSB).

F. HIGHWAY FACTORS

1.0 Geometry and Lane Designations for Grade Crossings

NTSB investigators inventoried the geometry and lane designations for the following grade crossings:

- Lindell Boulevard grade crossing (crash location)
- Linton Boulevard grade crossing
- SE 10th Street grade crossing
- Hidden Valley Boulevard grade crossing

Figure 3 illustrates the locations of the grade crossings inventoried by NTSB investigators.

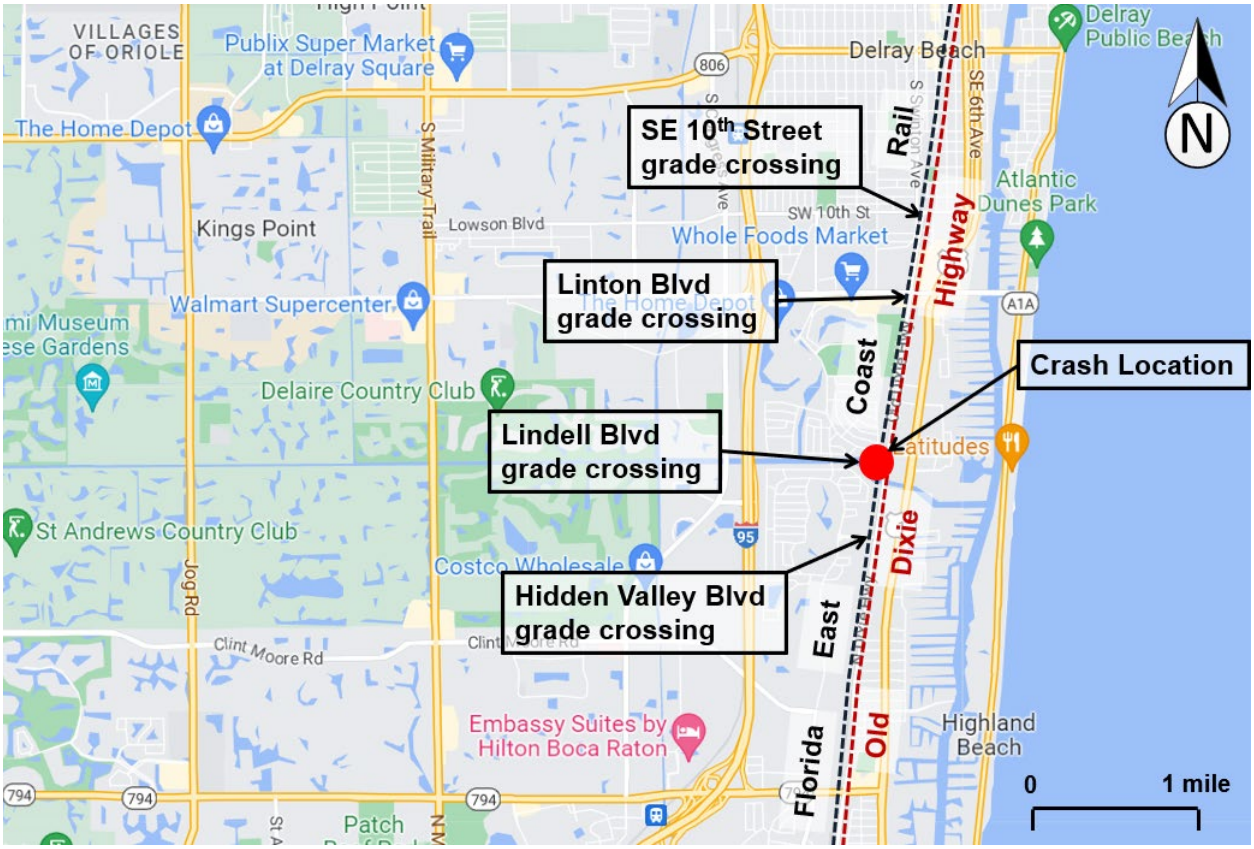

Figure 3 – Locations of the grade crossings inventoried by NTSB investigators (Source: Google Maps revised).

Figure 4 illustrates the geometry and lane designations for the SE 10th Street grade crossing, located approximately 1.5 miles north of Lindell Boulevard.

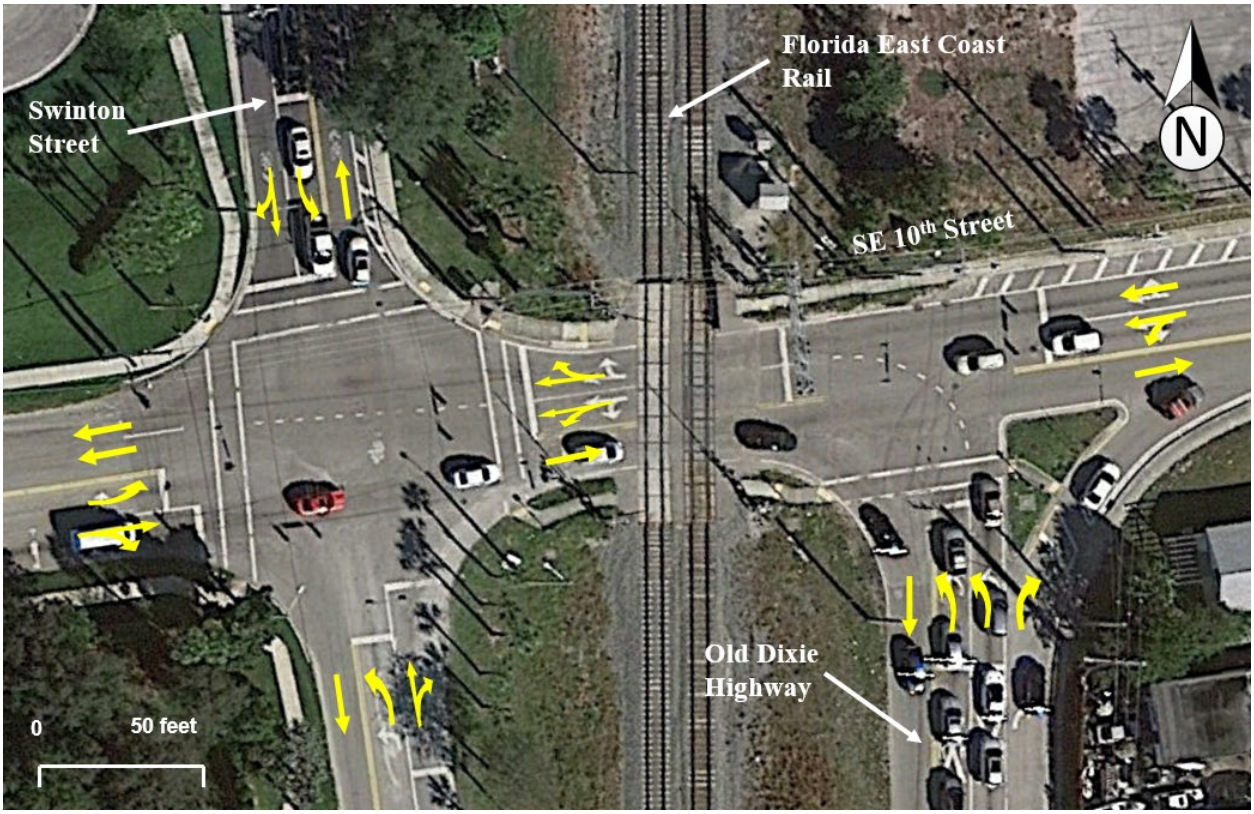

Figure 4 - Geometry and lane designations for the SE 10th Street grade crossing, located approximately 1.5 miles north of Lindell Boulevard (Source: Google Earth revised).

Figure 5 illustrates the geometry and lane designations for the Linton Boulevard grade crossing, located approximately 1 mile north of Lindell Boulevard.

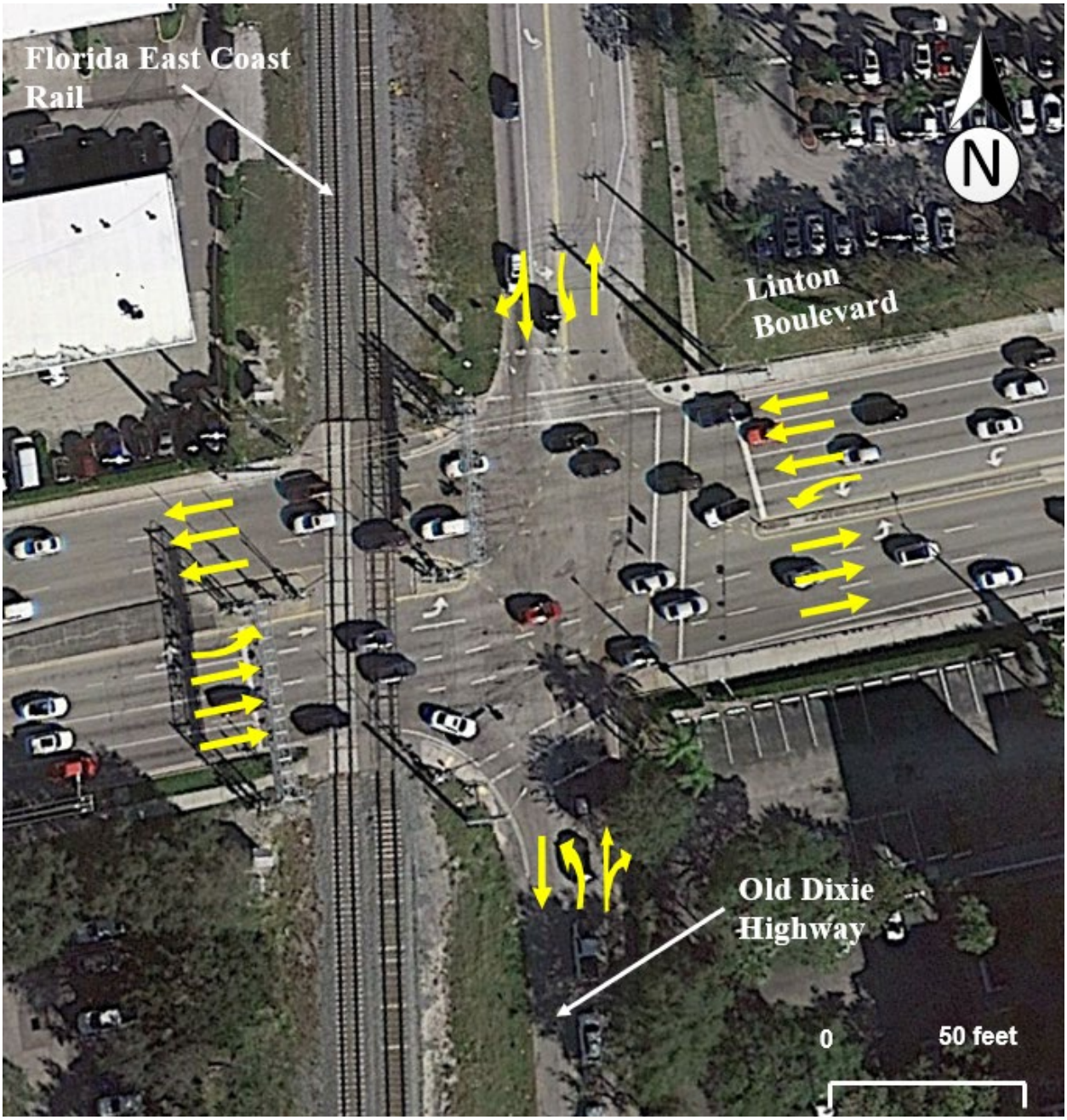

Figure 5 - Geometry and lane designations for the Linton Boulevard grade crossing, located approximately 1 mile north of Lindell Boulevard (Source: Google Earth revised).

Figure 6 illustrates the geometry and lane designations for the Lindell Boulevard grade crossing, the subject of the 2-fatal grade crossing crash.

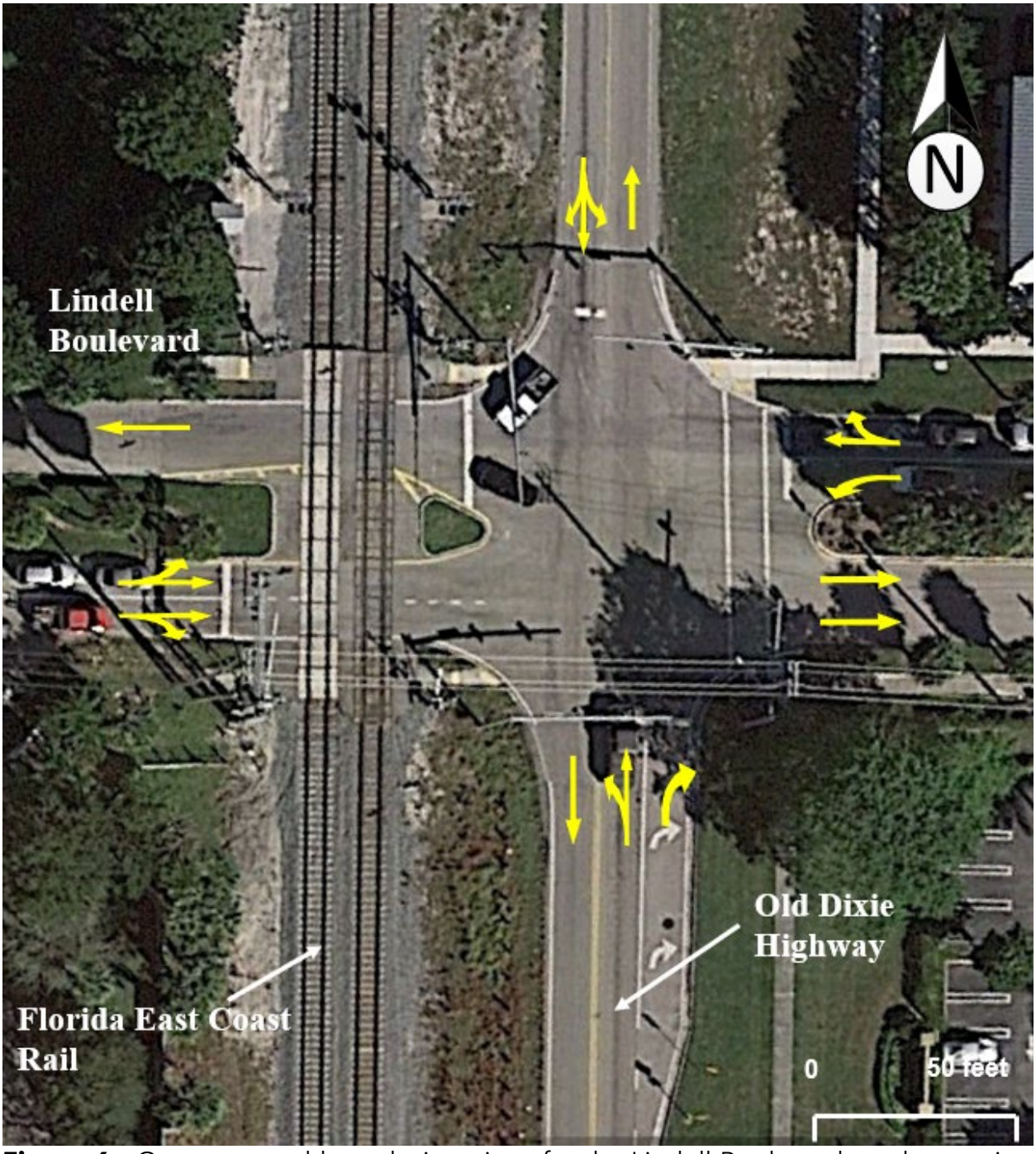

Figure 6 - Geometry and lane designations for the Lindell Boulevard grade crossing (Source: Google Earth revised).

Figure 7 illustrates the geometry and lane designations for the Hidden Valley Boulevard grade crossing, located approximately 0.5 miles south of Lindell Boulevard.

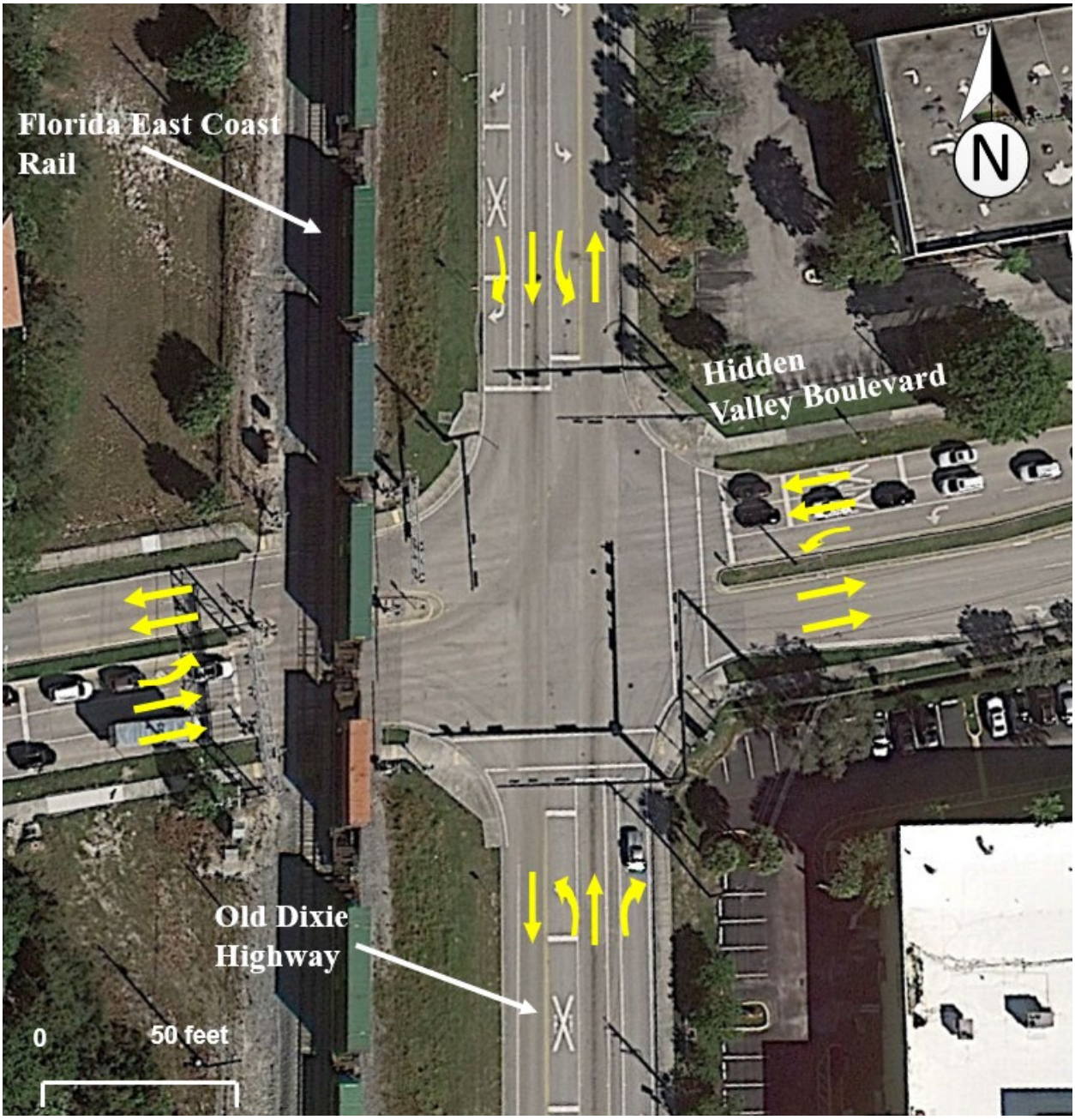

Figure 7 - Geometry and lane designations for the Hidden Valley Boulevard grade crossing, located approximately 0.5 miles south of Lindell Boulevard (Source: Google Earth revised).

Grade crossings can be protected using quad gates which controls all points of access to the grade crossing. A quad gate can have either a 2 or 4 boom barrier arm configuration. A two-quadrant gate has gate mechanisms on both sides of the track but only one arm per side. A four-quadrant gate has a gate mechanism on both sides of the tracks for both directions of automotive traffic. Lindell Boulevard had 2 quadrant gates, while Linton Boulevard, Hidden Valley Boulevard, and SE 10th Street had 4 quadrant gates (see **Table 2**).

The exit gates blocking the road leading away from the tracks in the four-quadrant gate are sometimes equipped with a delay (see North Miami, FL crash), and begin their descent to their horizontal position several seconds after the entrance gates do, to avoid trapping highway vehicles on the crossing. The 2023 MUTCD indicated "*Exit gate arm activation and downward motion shall be based on detection or timing requirements established by a Diagnostic Team*."[14]

Table 2 summarizes a comparison of key safety components of the four grade crossings with columns indicating whether the grade crossing contained a four-quadrant gate or two-quadrant gate and confirmation whether turn prohibition signs existed toward the tracks when a train was present. The 2023 MUTCD indicated "Exit Gate *systems may be installed to improve safety at grade crossings where a Diagnostic Team determines that less restrictive measures, such as automatic gates and median islands, are not effective.*"[15]

Table 2 – Comparison of key safety components of the four grade crossings.

Grade crossing	4 – Quadrant gate[16] or 2 – Quadrant gate	Turn prohibition signs toward tracks when train is present (Yes or No)
Lindell Boulevard	2 – Quadrant gate	No
Linton Boulevard	4 – Quadrant gate	Yes
Hidden Valley Boulevard	4 – Quadrant gate	Yes
SE 10th Street	4 – Quadrant gate	No

Table 3 summarizes the approximate distance measured from the edge of the track to the edge of the roadway for all four grade crossings.[17]

Table 3 – Approximate distance measured from the edge of the track to the edge of the roadway.

[14] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 1021.
[15] Ibid.
[16] A 4-quadrant gate system consists of entrance and exit gates that control and block road users on all lanes entering and exiting the grade crossing. The 4-quadrant gate system helps to prevent vehicles from going around the gates once they have been lowered.
[17] The edge of the roadway is defined as the nearest curb line of roadway which is parallel to the track.

Grade crossing	Approximate distance measured from the edge of the track to the edge of the roadway
Lindell Boulevard	42 feet
Linton Boulevard	42 feet
Hidden Valley Boulevard	42 feet
SE 10th Street	48 feet

2.0 Manual on Uniform Traffic Control Devices (MUTCD)

The MUTCD indicated the following regarding Preemption of Highway Traffic Signals at or Near Grade Crossings.[18] All four grade crossings as shown in **Table 3** had flashing-light signal systems within 200 feet of the intersection.

> "Section 8D.09 Preemption of Highway Traffic Signals at or Near Grade Crossings
>
> *Guidance:*
>
> *If a grade crossing is equipped with a flashing-light signals and is located within 200 feet or less from an intersection or midblock location controlled by a traffic control signal, a pedestrian hybrid beacon, or an emergency-vehicle hybrid beacon, the intersection should be provided with rail preemption in accordance with Section 4F.19 unless otherwise determined by the Diagnostic Team."*[19]

The MUTCD indicated the following regarding Preemption Control of Traffic Control Signals:[20]

> "Section 4F.19 Preemption Control of Traffic Control Signals
>
> *Support:*
>
> *Preemption control (see definition in Section 1C.02) is typically given to trains, boats, emergency vehicles, and light rail transit.*
>
> *Examples of preemption control include the following:*

[18] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 1024.
[19] Preemption is the transfer of normal operation of a traffic control signal to a special control mode of operation.
[20] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 4 Highway Traffic Signals, page 709.

C. A special sequence of signal phases to display a steady red indication to prohibit turning movements toward the tracks during the approach or passage of rail traffic."

The MUTCD indicated the following regarding Movements Prohibited During Preemption:[21]

"Section 8D.10 Movements Prohibited During Preemption

Guidance:

At a signalized intersection that is located within 100 feet of a grade crossing and the intersection traffic control signals are preempted by the approach of rail traffic, all existing permissive-only turning movements toward the grade crossing should be prohibited, steady red arrow signal indications should be shown to all existing protected/permissive and protected-only turning movements toward the grade crossing, and red signal indications should be shown to the straight-through movement toward the grade crossing during the signal preemption sequences. The prohibition of a permissive-only turning movement toward the grade crossing during preemption should be accomplished through the installation of a blank-out turn prohibition (R3-1a or R3-2a) sign (see Figure 8B-1)."

3.0 Quiet Zone

A Quiet Zone is a segment of a rail line, with one or a few consecutive public highway-rail grade crossings at which locomotive horns are not routinely sounded per 49 CFR Part 222. Quiet Zones are used to establish a consistent standard for communities who opt to preserve or enhance quality of life for their residents within which routine use of train horns at crossings is prohibited. The City of Delray Beach and the State of Florida established a new 24-hour Quiet Zone on the FECR effective June 2, 2018, within the City of Delray Beach, FL.

A Notice of Intent (NOI), approved by the City of Delray Beach Commission, was executed on February 16, 2016, and no comments were received from any applicable parties.[22]

[21] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 1027.

[22] See Railroad Signal and Highway Factors Attachment – Letter to Associate Administrator for Safety, Federal Railroad Administration, from the City of Delray Beach dated May 11, 2018, regarding Quiet Zone.

The crossings in the Quiet Zone are listed in **Table 4** with any Supplemental Safety Measures denoted as (SSM).

Table 4 – Crossings in the Quiet Zone within the City of Delray Beach.

USDOT Crossing ID Number	Street or Highway Name
272486E	N.E. 36th Street (SSM)
272487L	N.E. 14th Street
272488T	N.E. 8th Street (SSM)
272489A	N.E. 4th Street
272490U	N.E. 2nd Street (SSM)
272491B	N.E. 1st Street (SSM)
272492H	Atlantic Avenue (SSM)
272869G	S.E. 1st Street
272493P	S.E. 2nd Street (SSM)
272494W	S.E. 4th Street (SSM)
272495D	S.E. 10th Street (SSM)
272497S	Linton Boulevard (SSM)
272498Y	Lindell Boulevard

Within the quiet zone, the 2-quadrant gate system at the Lindell Boulevard grade crossing functioned under simultaneous preemption with the adjacent traffic signals. Simultaneous preemption refers to notification of approaching rail traffic forwarded to the highway traffic signal controller unit and railroad active warning devices at the same time. The warning devices were installed in April of 2018. There are flashing lights on a cantilever structure in the eastbound direction of Lindell Boulevard.

4.0 Speed Limit on Old Dixie Highway and Lindell Boulevard

The speed limit on Old Dixie Highway and Lindell Boulevard in the vicinity of the crash was 45 miles per hour (mph) and 25 mph, respectively.

5.0 Average daily traffic

The Lindell Boulevard grade crossing has an average daily traffic of 6,100 vehicles per day.

6.0 Traffic accident summary

Table 5 summarizes the traffic accident summary at the intersection of Old Dixie Highway and Lindell Boulevard from 2018 through 2022.[23] The traffic accident summary is for all non-grade crossing crashes.

[23] See Railroad Signal and Highway Factors Attachment – Traffic accident summary at the Lindell

Table 5 - Traffic accident summary at the intersection of Old Dixie Highway and Lindell Boulevard from 2018 through 2022.

Crash severity	Number
No injury	44
Possible injury	5
Non-Incapacitating injury	2
Incapacitating injury	4
Total	**55**

7.0 Traffic Controller Field Alarms

The traffic signal at the Old Dixie Highway and Lindell Boulevard intersection went into preemption status on February 8, 2023, at approximately 8:05:20 p.m.[24] The crash occurred at about 8:06:02 p.m., approximately 40 seconds later.

The heavy damage from the crash to the southeast pedestrian gate mechanism caused a disruption of power and turned off power to the traffic signal at approximately 8:06:09 p.m. in which the traffic signals appeared dark on the mast arm. Communication failed at approximately 8:08:52 p.m. between the traffic signal controller and Palm Beach County's Active Traffic Management System (ATMS) communications server. Power was restored to the traffic signal at 9:22:11 p.m.

Table 6 summarizes the Palm Beach County traffic controller field alarms at the time of the crash on February 8, 2023.[25]

Table 6 - Palm Beach County traffic controller field alarms at the time of the crash on February 8, 2023.

Time	Description
8:05:20 p.m.	Preemption On
8:06:02 p.m.	Approximate time of crash
8:06:09 p.m.	Power Alarm Off
8:08:52 p.m.	Communications Failure
9:22:11p.m.	Power Alarm On

The traffic signal at the Old Dixie Highway and Lindell Boulevard intersection did not have a back-up power supply.

The MUTCD indicated the following regarding back-up power supply:[26]

Boulevard and Old Dixie Highway intersection.

[24] See Railroad Signal and Highway Factors Attachment – Signalization Plan at the Lindell Boulevard and Old Dixie Highway intersection.

[25] See Railroad Signal and Highway Factors Attachment – Traffic controller field alarms for the traffic signal at the Lindell Boulevard and Old Dixie Highway intersection.

[26] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway RAILROAD SIGNAL AND HIGHWAY FACTORS GROUP

"Section 4F.19 Preemption Control of Traffic Control Signals

Guidance:

Except for traffic control signals interconnected with light rail transit systems, traffic control signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply."

8.0 Railroad and Traffic Signal Time

Figure 8 illustrates the timeline configuration of the railroad and traffic signal timing for the Lindell Boulevard grade crossing. The railroad signal time is in the upper half of the slide and the traffic signal facing southbound on Old Dixie Highway approaching Lindell Boulevard is in the lower half of the slide. **Figure 8** shows the typical design condition for the railroad and traffic signal time and does not represent the conditions at the time of the crash in which the northbound freight train activated the warning devices initially on approach to the grade crossing and the southbound Brightline passenger train came immediately thereafter.

As the train crossed the shunt circuit; the railroad crossing lights flash for approximately 3 seconds (see **Figure 8**). The gates started to descend and become fully lowered (or gate down) in approximately 8 seconds. The time between the gates being fully lowered and the train occupying the tracks was approximately 23 seconds. The total warning time was approximately 34 seconds. As the train crossed the shunt circuit, the traffic signals facing southbound on Old Dixie Highway transitioned from the normal cycle to the preemption cycle[27] with the signal immediately turning a yellow indication for 5 seconds. The preemption cycle began with a red indication for 19 seconds followed by a green indication that varied depending on when the train crossed the shunt circuit after departing the track.[28]

Additionally, if a turn prohibition sign at the Lindell Boulevard grade crossing was present, the sign would have activated immediately when the railroad crossing lights begin to flash.

Administration, 2023 Edition, Part 4 Highway Traffic Signals, page 710.

[27] When a preemption signal is received, the controller enters a preemption routine. That is, the activation of a preemption routine is not only pertinent to a specific movement (e.g., signals facing southbound on Old Dixie Highway), rather, the sequence of movements constituting the preemption routine.

[28] See Railroad Signal and Highway Factors Attachment – Controller time sheet for the traffic signal at the Lindell Boulevard and Old Dixie Highway intersection.

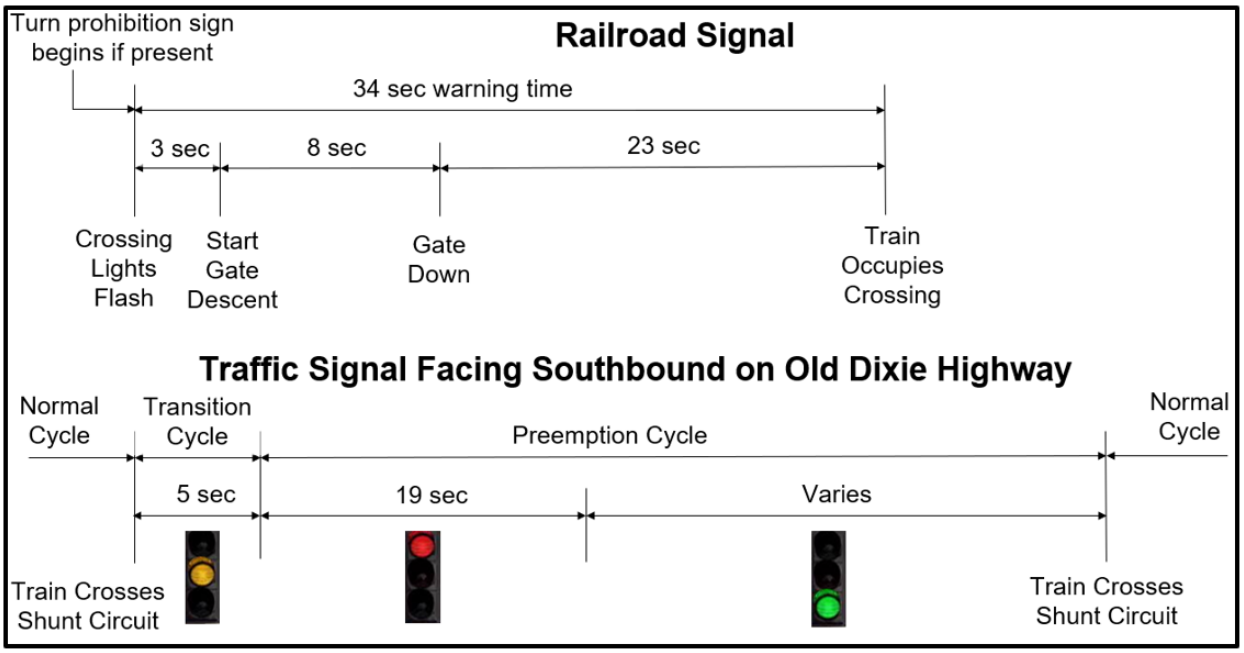

Figure 8 - Timeline of the railroad and traffic signal time with the railroad signal time in the upper half of the slide and the traffic signal facing southbound on Old Dixie Highway approaching Lindell Boulevard in the lower half of the slide.

9.0 Grade Crossing Gate

Figure 9 illustrates the northbound freight train video and the gate down and fully lowered behind the SUV at the Lindell Boulevard grade crossing. The approaching southbound Brightline passenger train is shown in the background.

Figure 9 - Freight train video and the gate down and fully lowered behind the SUV at the Lindell Boulevard grade crossing looking to the north (Source: Florida East Coast Railway).

At the Lindell Boulevard grade crossing, the distance from the lowered gate to the centerline of the eastern track (mid-point between rails) was approximately 16 feet which complied with the 2023 MUTCD in which locations of gates are to be determined by the Diagnostic Team.[29] The painted white stop line was placed about 8 feet from the lowered gate, which complied with the 2023 MUTCD guidance that a stop line be placed approximately 8 feet from a gate, when present.[30]

10.0 Turn Prohibitions During Preemption

The Lindell Boulevard grade crossing did not have turn prohibition signs as was found at the Hidden Valley Boulevard grade crossing shown in **Figure 10** and the Linton Boulevard grade crossing shown in **Figure 11**.[31] Both grade crossings were located approximately one-half mile to the south and one mile to the north, respectively. The Hidden Valley Boulevard grade crossing had the text only turn prohibition sign indicating "*No Right Turn Across Tracks*" with the train shown in the

[29] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 1022.
[30] Ibid, page 1010.
[31] See Railroad Signal and Highway Factors Attachment – Email from Palm Beach County to NTSB investigators dated April 13, 2023.

background of the photo. The Linton Boulevard grade crossing had the figure-only turn prohibition sign indicating "*No Right Turn"*.

Figure 10 - Hidden Valley Boulevard grade crossing illustrating text only turn prohibition sign indicating "*No Right Turn Across Tracks"* with the Brightline passenger train shown in the background looking to the south.

Figure 11 - Linton Boulevard grade crossing illustrating figure-only turn prohibition sign indicating "*No Right Turn"* looking to the south. A clear image of the figure-only turn prohibition sign indicating *"No Right Turn"* is shown to the upper right when active.

As was discussed earlier in this report, the MUTCD indicated the following regarding Movements Prohibited During Preemption:[32]

"Section 8D.10 Movements Prohibited During Preemption

Guidance:

At a signalized intersection that is located within 100 feet of a grade crossing and the intersection traffic control signals are preempted by the approach of rail traffic, all existing permissive-only turning movements toward the grade crossing should be prohibited, steady red arrow signal indications should be shown to all existing protected/permissive and protected-only turning movements toward the grade crossing, and red signal indications should be shown to the straight-through movement toward the grade crossing during the signal preemption sequences. The prohibition of a permissive-only turning movement toward the grade crossing during preemption should be accomplished through the installation of a blank-out turn prohibition (R3-1a or R3-2a) sign (see Figure 8B-1)."

[32] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 1027.

R3-1a
Activated Blank-Out

R3-2a
Activated Blank-Out

11.0 Preemption Line Tests

During the on-scene investigation conducted on February 13, 2023, NTSB investigators and Palm Beach County staff observed that the railroad preemption input was not received by the traffic signal controller cabinet. In this case, the railroad crossing gates, and railroad traffic control devices were triggered by an approaching train, however, the traffic signal cycled normally as if there was no approaching train. Since the traffic signal did not go through the preemption sequence, the signal would cycle to a green indication for eastbound traffic on Lindell Boulevard with the train occupying the track and the gate down and fully lowered. It is inherent within the MUTCD that signal phases are to display a steady red indication to prohibit through movements toward the tracks during the approach or passage of rail traffic.

Palm Beach County and FECR staff met on February 15, 2023, at the Lindell Boulevard grade crossing to inspect the preemption line. First, the preemption line was physically inspected at its termination points at both the railroad cabinet and the traffic signal controller cabinet. Second, the preemption line was examined at pull boxes along its path between the two cabinets. The preemption line, consisting of 2 wires, was then disconnected and its insulation resistance was tested via a megger tester, which showed one of the wires having potential current leakage somewhere along its path. With such a result and undetermined integrity of the existing preemption line, it was determined by Palm Beach County that replacing the existing 2 wire preemption line was the best course of action. An existing 4 wire cable was already in place between the two cabinets, most likely, installed as part of the Brightline project which added an additional rail. The existing 2 wire preemption line should have been disconnected with the Brightline project and the new 4 wire cable connected in its place, however, it is not known by Palm Beach County and Florida East Coast Railway why this did not happen. The cause of the potential current leakage in the existing 2 wire preemption line could not be determined.

Palm Beach County's plan to check for any potential current leakage with preemption lines at other grade crossings will be conducted in cooperation with the railroad authorities (Florida East Coast Railway, CSX, and Tri-Rail). Palm Beach County's plan to complete the preemptive line tests consisted of the following:

- 66 grade crossings to be checked,
- Approximate time frame to be completed November 1, 2023,
- Every grade crossing requires preemption line to be disconnected on both ends and its insulation resistance tested via a megger tester, and
- Palm Beach County's results of the preemption line tests at other grade crossings will be shared with the NTSB.

Palm Beach County shared the results of the preemption line tests in an email to NTSB investigators dated October 23, 2023. Of the 66 grade crossings checked the breakdown for each railroad consisted of the following:

- Florida East Coast Railway – 48 grade crossings
- CSX – 8 grade crossings
- Tri Rail – 10 grade crossings

Palm Beach County found one location in which the preemption line was close to leakage along the Florida East Coast Railway at the George Bush Boulevard and NE 5th Avenue grade crossing, located approximately 4 miles from the Lindell Boulevard grade crossing. Palm Beach County also found three locations in which the preemption line had leakage along the Tri-Rail corridor at the Foresthill Boulevard and I-95, Lake Worth Road and Tri- Rail Station, and 6th Avenue South and I-95 grade crossings. Palm Beach County issued work orders to replace the old preemption lines with new cables at the locations mentioned above along the Florida East Coast Railway and Tri-Rail corridor.

12.0 Warning Signs

Table 7 summarizes the warning signs in the vicinity of the Lindell Boulevard grade crossing.

Table 7 – Warning signs in the vicinity of the Lindell Boulevard grade crossing.

Warning Sign	MUTCD Designation	Description of Signage	Location of Warning sign
	W10-2 and W10-9P	Grade crossing advance warning sign – parallel highway and No train horn	Southbound Old Dixie Highway on approach to the Lindell Boulevard grade crossing

	W10-2 and W10-9P	Grade crossing advance warning sign – parallel highway and No train horn	Northbound Old Dixie Highway on approach to the Lindell Boulevard grade crossing
	W10-1 and W10-9P	Grade crossing advance warning sign – crossbuck and No train horn	Westbound Lindell Boulevard on approach to the grade crossing
	W10-1 and W10-9P	Grade crossing advance warning sign – crossbuck and No train horn	Eastbound Lindell Boulevard on approach to the grade crossing

13.0 Diagnostic Reviews conducted at the Lindell Boulevard grade crossing

On February 21, 2014, a diagnostic review of the Lindell Boulevard grade crossing was conducted by parties who had interest in the grade crossing design. The organizations who participated were: Brightline, Florida East Coast Railway, the Federal Railroad Administration, the Florida Department of Transportation, and the City of Boca Raton.[33]

The timeline of the diagnostic reviews at the Lindell Boulevard grade crossing was the following:

- **February 21, 2014, Diagnostic Review** – the purpose of this diagnostic review was to identify modifications and improvements to the crossing layout needed to accommodate the second main track that was to be installed as part of the Brightline project.
- **October 16, 2014, Diagnostic Review** – the purpose of this diagnostic review was to identify the improvements to the crossing layout needed to establish a Quiet Zone, at the request and direction of the City of Delray Beach and the Palm Beach Transportation Planning Organization.

[33] See Railroad Signal and Highway Factors Attachment – Email from Brightline to NTSB investigators dated April 10, 2023.

February 21, 2014, Diagnostic Review

The list of safety improvements proposed at the Lindell Boulevard grade crossing as part of the February 21, 2014, diagnostic review consisted of the following:

- Add "Stop Here on Red" sign.
- Relocate stop bar or sign.
- Add "No Turn on Red" sign.
- Possible removal of traffic signals in front of cantilever structure in the eastbound direction of Lindell Boulevard.

October 16, 2014, Diagnostic Review

The list of safety improvements proposed as part of the October 16, 2014, diagnostic review consisted of the following:[34]

- Add exit gates with front lights to NW quadrant of grade crossing.
- Add exit gates with front lights to SE quadrant of grade crossing and back sidewalk arm.
- Replace eastbound signal cantilever.
- Fix sign and change sign to appropriate "quiet zone" messaging.
- Realign sidewalk at SE quadrant of grade crossing and add curb.

14.0 Diagnostic Reviews associated with Quiet Zone

FRA provided NTSB investigators the diagnostic reviews conducted at grade crossings from February 24, 2022, through February 11, 2023, in the City of Delray Beach, FL. The diagnostic reviews were conducted because of the quiet zone that became effective on June 2, 2018.

FRA conducts diagnostic reviews at grade crossings within a quiet zone for the following purposes: ensure compliance with supplementary and alternative safety measures that include four-quadrant gate systems, gates with medians or channelization, and one-way street with gates. Additional checks are made to ensure compliance with signage for advance warning signs, flashers, gates, no train horn signs, crossbuck signs, stop signs, and issues/obstructions.

The following summarizes the diagnostic reviews conducted by FRA from February 24, 2022, through February 11, 2023, associated with a quiet zone in the City of Delray Beach, FL:

[34] No follow up action was taken since the purpose of this diagnostic review was to identify the possible improvements to the crossing layout needed to establish a Quiet Zone.

- 16 diagnostic reviews were conducted at the Linton Boulevard grade crossing. No exceptions were noted with 15 of the diagnostic reviews. One exception was noted for failing to properly submit the crossing inventory.
- 14 diagnostic reviews were conducted at the SE 10th Street grade crossing. No exceptions were noted with 13 of the diagnostic reviews. One exception was noted for failing to properly submit the crossing inventory.
- 1 diagnostic review was conducted at the Hidden Valley Boulevard grade crossing. An exception was noted for trespassing activities observed and fence damage on west side of the tracks.
- 2 diagnostic reviews were conducted at the SW 10th Street grade crossing.[35] One of the diagnostic reviews indicated no exception and the second diagnostic review indicated signage was obstructed by heavy vegetation.
- 5 diagnostic reviews were conducted at the Lindell Boulevard grade crossing after the crash on February 8, 2023. No exceptions were noted with 4 of the diagnostic reviews. One exception was noted for failing to properly submit the crossing inventory. The dates of the 5 FRA diagnostic reviews associated with quiet zones after the crash on February 8, 2023, were the following: 3 diagnostic review reports were conducted on February 9, 2023; 1 diagnostic review report was conducted on February 10, 2023; and 1 diagnostic review report was conducted on February 11, 2023.

15.0 Diagnostic Reviews recommended in the 2023 MUTCD

The 2023 MUTCD indicated the following regarding Diagnostic Reviews:[36]

"Section 8A.01 Introduction

Support:

Grade crossings and the traffic control devices that are associated with them are unique in that in many cases, the highway agency or authority with jurisdiction, the regulatory agency with statutory authority (if

[35] The SW 10th Street grade crossing is on a different set of tracks which are located between Congress Avenue and I-95 in the City of Delray Beach.

[36] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, Federal Highway Administration, 2023 Edition, Part 8 Traffic Control for Railroad and Light Rail Transit Grade Crossings, page 987, 989, and 1024..

applicable), and the railroad company or transit agency are jointly involved in the development of engineering judgment or the performance of an engineering study. This joint process is accomplished through the efforts of a Diagnostic Team made up of the highway agency with jurisdiction, the regulatory agency with statutory authority (if applicable), and the railroad company and/or transit agency (if applicable).

Section 8A.03 Traffic Control Systems and Practices at Grade Crossings

Standard:

Among the types of changes at a grade crossing for which a Diagnostic Team shall conduct an engineering study are: additions, removals, or modifications of the lanes approaching or traversing the grade crossing; addition or removal of tracks; significant changes in the number or speed of trains; significant changes in the number or speed of vehicles; addition of vehicle access near the grade crossing; additions or modifications to sidewalks; additions or modifications to bicycle lanes, especially if a counter- flow bicycle lane is added on a one-way street; changes to roadway use, including conversion to or from one-way operation or reversible lanes; and the installation of or significant operational changes to traffic control signals that might affect the grade crossing.

Section 8A.05 Engineering Studies at Grade Crossings

Guidance:

Among the factors that should be considered in the determination by a Diagnostic Team of which traffic control devices would be appropriate to install at a grade crossing are road geometrics, stopping sight distance, clearing sight distance, the proximity of nearby roadway intersections (including the traffic control devices at the intersections), adjacent driveways, traffic volume across the grade crossing, extent of queuing upstream or downstream from the grade crossing, train volume, pedestrian and bicycle volumes, operation of passenger trains, presence of nearby passenger station stops, maximum allowable train speeds, variable train speeds, accelerating and decelerating trains, multiple tracks, high-speed train operation, number of school buses or hazardous material haul vehicles, and the crash history at or near the location.

Section 8D.09 Preemption of Highway Traffic Signals at or Near Grade Crossings

Guidance:

The highway agency or authority with jurisdiction, and the regulatory agency with statutory authority, if applicable, should jointly determine the preemption operation and the timing of highway traffic signals interconnected with grade crossings adjacent to signalized locations."

G. NORTH MIAMI, FL CRASH

The reader is encouraged to consult the Factual Report for the North Miami, FL crash that involved a Brightline passenger train on March 3, 2023. The Railroad Signal and Highway Factors Group Chairman Factual Report for the North Miami, FL crash is in the NTSB public docket.

H. HOLLYWOOD, FL CRASH

The reader is encouraged to consult the Factual Report for the Hollywood, FL crash that involved a Brightline passenger train on April 12, 2023. The Railroad Signal and Highway Factors Group Chairman Factual Report for the Hollywood, FL crash is in the NTSB public docket.

I. APPENDIX A

The following attachments and photographs are included in the docket for this investigation:

LIST OF ATTACHMENTS

Railroad Signal and Highway Factors Attachment – Federal Railroad Administration (FRA) Highway-Rail Grade Crossing Accident/Incident Reports

Railroad Signal and Highway Factors Attachment – Letter to Associate Administrator for Safety, Federal Railroad Administration, from the City of Delray Beach dated May 11, 2018, regarding Quiet Zone

Railroad Signal and Highway Factors Attachment – Traffic accident summary at the Lindell Boulevard and Old Dixie Highway intersection

Railroad Signal and Highway Factors Attachment – Traffic controller field alarms for the traffic signal at the Lindell Boulevard and Old Dixie Highway intersection

Railroad Signal and Highway Factors Attachment – Signalization Plan at the Lindell Boulevard and Old Dixie Highway intersection

Railroad Signal and Highway Factors Attachment – Controller time sheet for the traffic signal at the Lindell Boulevard and Old Dixie Highway intersection

Railroad Signal and Highway Factors Attachment – Email from Palm Beach County to NTSB investigators dated April 13, 2023

Railroad Signal and Highway Factors Attachment – Email from Brightline to NTSB investigators dated April 10, 2023.

LIST OF PHOTOGRAPHS

Railroad Signal and Highway Factors Photo 1 – View of freight train video and the gate down and fully lowered behind the SUV at the Lindell Boulevard grade crossing looking to the north (Source: Florida East Coast Railway)

Railroad Signal and Highway Factors Photo 2 – View of Hidden Valley Boulevard grade crossing illustrating text only prohibition sign indicating "*No Right Turn Across Tracks"* with the Brightline passenger train shown in the background looking to the south

Railroad Signal and Highway Factors Photo 3 – Linton Boulevard grade crossing illustrating figure only prohibition sign indicating "*No Right Turn"* looking to the south. A clear image of the figure only turn prohibition sign indicating *"No Right Turn"* is shown to the upper right when active.

Railroad Signal and Highway Factors Photo 4 – View of Lindell Boulevard grade crossing looking to the south

Railroad Signal and Highway Factors Photo 5 – View of eastbound Lindell Boulevard on approach to the grade crossing

Railroad Signal and Highway Factors Photo 6 – View of Lindell Boulevard grade crossing looking to the north

Railroad Signal and Highway Factors Photo 7 – View of westbound Lindell Boulevard on approach to the grade crossing

Railroad Signal and Highway Factors Photo 8 – View of southbound Old Dixie Highway on approach to the Lindell Boulevard intersection

Railroad Signal and Highway Factors Photo 9 – View of approximate location in which SUV turned right to westbound Lindell Boulevard on approach to the grade crossing

Railroad Signal and Highway Factors Photo 10 – View of westbound Hidden Valley Boulevard on approach to the grade crossing

Railroad Signal and Highway Factors Photo 11 – View of southbound Old Dixie Highway on approach to the Hidden Valley Boulevard intersection

Railroad Signal and Highway Factors Photo 12 – View of westbound Linton Boulevard on approach to the grade crossing

Railroad Signal and Highway Factors Photo 13 – View of southbound Old Dixie Highway on approach to the Linton Boulevard intersection with the Brightline passenger train shown in the background

Railroad Signal and Highway Factors Photo 14 – View of northbound Old Dixie Highway on approach to the S. 10th Street intersection

Railroad Signal and Highway Factors Photo 15 – View of westbound S. 10th Street on approach to the grade crossing

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