NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF HIGHWAY SAFETY
WASHINGTON, D.C.

HIGHWAY FACTORS GROUP CHAIRMAN'S FACTUAL REPORT

A. CRASH INFORMATION

Location:	Rail crossing, Main Street, Biloxi, Harrison County, Mississippi
Vehicle #1:	2016 Van Hool CX45 Motorcoach
Operator #1:	Echo Transportation of Dallas, Texas
Vehicle #2:	CSX Freight Train, consisting of 3 locomotives, 27 loaded cars, and 25 empty cars
Operator #2:	CSX Transportation
Date:	Tuesday, March 7, 2017
Time:	2:12 p.m. CST
NTSB #:	**HWY17MH010**

B. HIGHWAY FACTORS GROUP

Steven L. Prouty, P.E., Senior Highway Engineer, Group Chairman
NTSB Office of Highway Safety
490 L'Enfant Plaza East, S.W., Washington, DC 20594

Ron Ries, Staff Director
Federal Railroad Administration, Highway-Rail Crossing and Trespasser Programs Division
1200 New Jersey Avenue, SE, Washington, DC 20590

Mark Swanlund, P.E., Program Coordinator
Federal Highway Administration, Office of Infrastructure Research & Development
6300 Georgetown Pike, McLean, VA 22101

Josh Stubbs, P.E., Rails Engineer
Mississippi Department of Transportation, Rails Division
401 North West Street, Jackson, MS 39201

Christy LeBatard, P.E., Director of Engineering
City of Biloxi, Department of Engineering
214 A Delauney Street, P.O. Box 429, Biloxi, MS 39533

Christopher DeBack, Lieutenant
City of Biloxi Police Department, Criminal Investigations Division
170 Porter Avenue, Biloxi, MS 39530

Brad Spencer, Director of Train Accident Prevention
CSX Transportation
500 Water Street, Jacksonville, FL 32202

C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Summary Report* in the docket for this investigation.

D. DETAILS OF THE HIGHWAY FACTORS INVESTIGATION

This Highway Group Chairman's Factual Report is based on reports, photographs, documents, and data provided by the City of Biloxi Department of Engineering, the City of Biloxi Police Department, and CSX Transportation, as well as information and photographs gathered on-scene by NTSB investigators. Data was obtained that included a limited construction history, daily traffic volumes, vehicle classification data, and grade crossing incident and crash summaries. Highway data was obtained that included functional classification, highway design, data from two total station surveys conducted by the City of Biloxi Police Department,[1] and the speed limits in place on Main Street in the vicinity of the railroad grade crossing at the time of the collision.

1. CRASH LOCATION

The crash occurred at the Main Street and CSX Transportation railroad grade crossing (DOT crossing number 340185W) at railroad milepost number 726.61 in Biloxi, Harrison County, Mississippi. The Main Street grade crossing is bordered to the north and south by Esters Boulevard, which runs parallel to the railroad tracks in this area. A map of the general crash location within the City of Biloxi is shown in **Figure 1**. A satellite view of the crash location is shown in **Figure 2**.

[1] See *Highway Attachment – City of Biloxi Police Department Total Station Survey Data*.

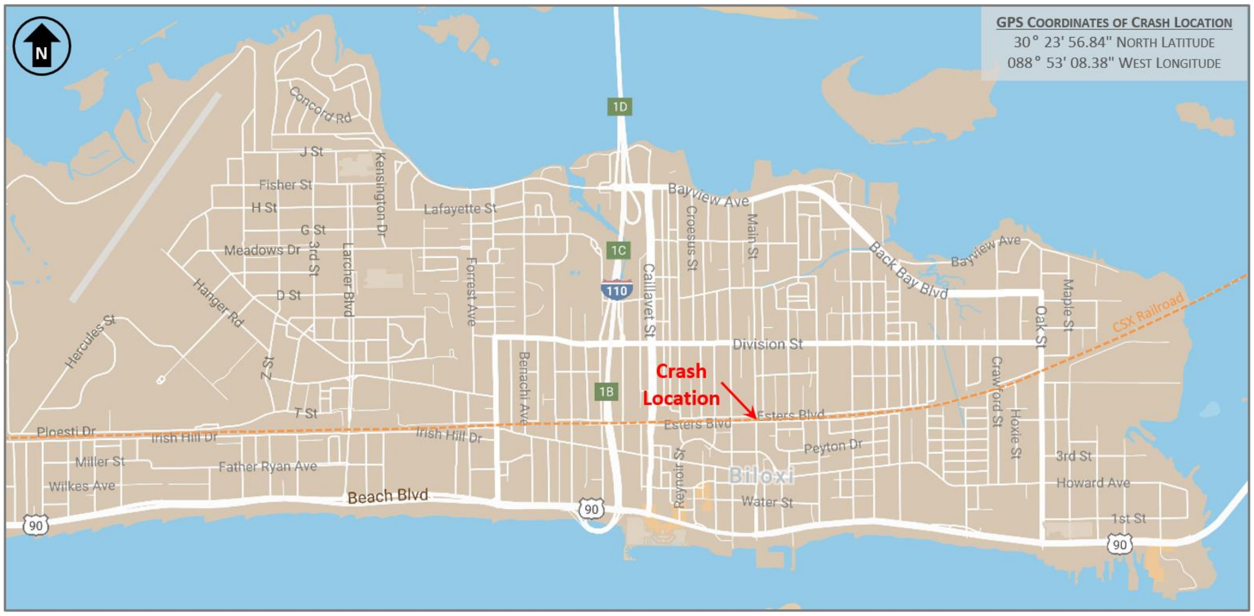

Figure 1: Map Showing General Crash Location within City of Biloxi (modified from Google Maps)

Figure 2: Satellite Image of Crash Location (modified from Google Earth)

2. HIGHWAY DESIGN

The design and configuration of Main Street and Esters Boulevard differs between the north and south sides of the Main Street railroad grade crossing, and at the crossing itself. The design and configuration of each of these road segments will be explained in greater detail in the following sub-sections. **Figure 3** illustrates the general layout of the road segments surrounding the Main Street grade crossing.

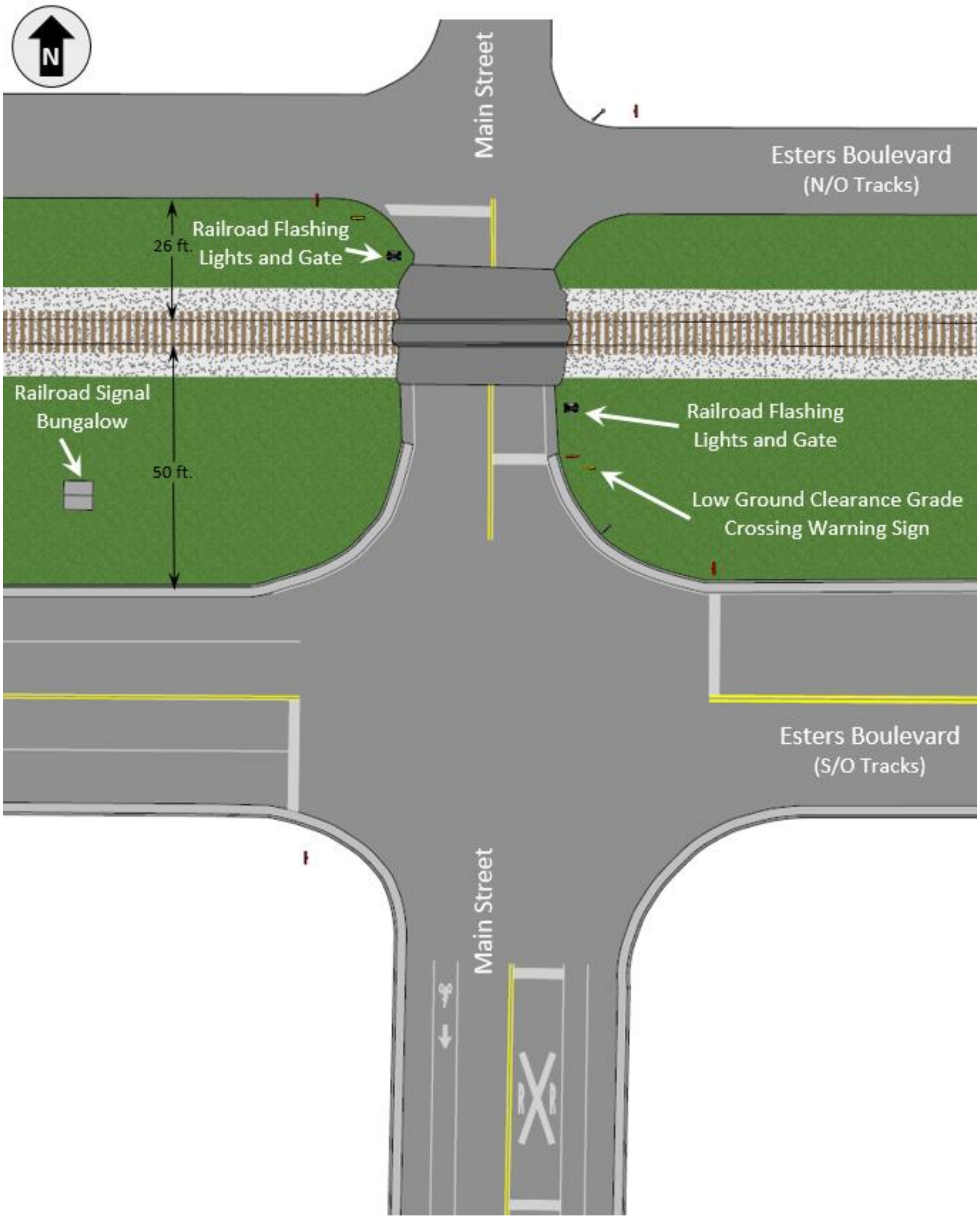

Figure 3: Layout of the Main Street and CSX Railroad Grade Crossing

2.1. Main Street South of Grade Crossing

In the area of the collision, Main Street was functionally classified as an urban collector roadway. South of the railroad grade crossing and Esters Boulevard, Main Street was a two-lane asphaltic concrete roadway that consisted of one travel lane each in the northbound and southbound directions, dedicated northbound and southbound bicycle lanes, and on street parking spaces on both sides of the roadway.[2] Concrete curb and gutter flanked both sides of the roadway. Each of the travel lanes were approximately 11-feet wide. The northbound and southbound travel lanes were separated by two 4-inch wide solid yellow pavement markings. The bicycle lanes were approximately 5-feet wide, were marked with bicycle lane pavement symbols, and were separated from the travel lanes by 4-inch wide solid white pavement markings. The asphalt portion of the on-street parking spaces were approximately 6-feet wide, with an additional 2-foot concrete gutter, making the total width of the parking spaces approximately 8-feet. The parking spaces were separated from the bicycle lanes by 4-inch solid white pavement markings. The total width of the paved portion of the two-lane cross section was approximately 48-feet. There were 6-inch concrete curbs to the outside of the on-street parking spaces. The roadway in this location was level for both directions. The posted speed limit for Main Street in the area of the collision was 25 miles per hour (mph).

2.2. Esters Boulevard South of Railroad Tracks

South of the railroad grade crossing, Main Street intersects Esters Boulevard. The distance from the nearest rail to the projected north curb-line of Esters Boulevard on the south side of the railroad tracks was approximately 50-feet. Esters Boulevard south of the railroad tracks was a four-lane asphaltic concrete roadway that consisted of two travel lanes in each of the eastbound and westbound directions.[3] The travels lanes are each approximately 11-feet wide. The eastbound and westbound travel lanes to the west of the intersection with Main Street are delineated by two 4-inch wide solid yellow pavement markings. The eastbound and westbound travel lanes to the east of the intersection with Main Street are delineated by two 6-$^{1}/_{4}$-inch wide solid yellow pavement markings. The two eastbound travel lanes and the two westbound travel lanes are generally delineated by 4-inch-wide broken white pavement markings. As the two eastbound travel lanes and the two westbound travel lanes approach the intersection with Main Street, the broken white pavement markings change to solid white pavement markings for approximately 72-feet in both the eastbound and westbound directions. The intersection of Main Street and Esters Boulevard on the south side of the railroad tracks is controlled with "STOP" signs for eastbound and westbound traffic on Esters Boulevard. Northbound and southbound traffic on Main Street is not controlled. Two-foot wide white stop bars are located at the intersection for both eastbound and westbound traffic on Esters Boulevard. Esters Boulevard was level both east and west of the Main Street intersection.

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[2] See *Highway Photograph 1 – Main Street, South of Grade Crossing – Facing North*.
[3] See *Highway Photograph 2 – Esters Boulevard (South of Tracks) – Facing Southwest*.

2.3. Main Street Railroad Grade Crossing

At the railroad grade crossing, Main Street was a two-lane asphaltic concrete roadway that consisted of one travel lane each in the northbound and southbound directions.[4] The northbound lane south of the railroad tracks was approximately 11-feet wide. The southbound lane south of the railroad tracks was approximately 16-feet wide. There were 6-inch curbs and 2-foot gutters that flanked both the northbound and southbound lanes on the south side of the railroad tracks. The northbound travel lane north of the railroad tracks was approximately 12-feet wide. The southbound travel lane north of the railroad tracks was approximately 16-feet wide. A 6-inch curb and 2-foot gutter flanked the northbound travel lane north of the railroad tracks but had been covered with asphalt. The travel lanes were delineated by two 4-inch wide solid yellow pavement markings. The pavement markings were worn and difficult to see. Additional asphalt had been applied over the original asphalt between the south rail and line parallel to the tracks approximately 5 feet south of the south rail, between the rails, and between the north rail and a line parallel to the tracks approximately 11-$^{1}/_{2}$-feet north of the north rail. The double yellow pavement markings were covered by this asphalt application. The northbound approach to the railroad tracks had an average slope of +4.2% (uphill), with an approximate maximum slope of +7.5% measured approximately 5.7-feet south of the nearest rail.[5] The northbound departure from the railroad tracks had an average slope of -13.3% (downhill), with an approximate maximum slope of -24.4% measured approximately 10.6-feet north of the nearest rail. The crossing of Main Street and the railroad tracks formed an angle that was approximately 90 degrees, or perpendicular. The railroad track structure at the crossing included wooden ties under an asphalt crossing surface, with rubber interface material between the rails and the asphalt.

2.4. Esters Boulevard North of Railroad Tracks

North of the railroad grade crossing, Main Street intersects Esters Boulevard. The distance from the nearest rail to the projected south edge of Esters Boulevard on the north side of the railroad tracks was approximately 26-feet. Esters Boulevard north of the railroad tracks was a two-lane asphaltic concrete roadway that had previously been milled up to prepare it for future resurfacing.[6] At the time of the collision, any traffic on Esters Boulevard north of the railroad tracks would have been traveling on the gravel-like debris left over from the milling process. Esters Boulevard is approximately 19-feet wide to the east of Main Street, and approximately 22-feet wide to the west of Main Street. Following the milling operation, there were no pavement markings. The intersection of Main Street and Esters Boulevard on the north side of the railroad tracks is controlled with "STOP" signs for eastbound and westbound traffic on Esters Boulevard.

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[4] See *Highway Photograph 3 – Main Street Grade Crossing – Facing North,* and *Highway Photograph 4 – Main Street Grade Crossing – Facing South*.

[5] Because the grade crossing's approach and departure slopes are vertical curves, the grade measurements are constantly changing over the length of the crossing. The reported average grade measurements were calculated from the difference in vertical total-station survey measurements taken at distances of 2-feet and 30-feet from the nearest rail. The maximum reported slope value for each approach was obtained from the steepest total-station survey data segment along the measured profile line. Data points along the profile line were collected at approximate 1-foot intervals, and reported measurements should therefore be considered approximate values.

[6] See *Highway Photograph 5 – Esters Boulevard (North of Tracks) – Facing Southeast*.

Northbound and southbound traffic on Main Street is not controlled. Esters Boulevard was level in both directions.

2.5. Main Street North of Grade Crossing

North of the railroad grade crossing, Main Street was a two-lane asphaltic concrete roadway that had previously been milled up to prepare it for future resurfacing.[7] In the interim, the roadway had been re-paved with asphalt as a temporary measure until the final resurfacing could be completed. Main Street was approximately 22-feet wide north of the railroad tracks. There were no pavement markings on the roadway. Esters Boulevard was level for both northbound and southbound traffic.

3. SIGNAGE AND PAVEMENT MARKINGS NEAR GRADE CROSSING

Along the northbound approach at the time of the collision, a grade crossing advance warning symbol was located approximately 382-feet from the nearest rail. A Low Ground Clearance Grade Crossing warning sign accompanied by a "LOW GROUND CLEARANCE" plaque was located on the southeast corner of the Main Street railroad grade crossing approximately 25-feet from the nearest rail. A "CONSTRUCTION AHEAD" sign with a 15 mph Advisory Speed plaque was located approximately 24-feet from the nearest rail. A Grade Crossing (Crossbuck) sign was located approximately 13-feet from the nearest rail, in conjunction with the flashing-light signal assembly. A summary of the signs found along the northbound approach to the grade-crossing can be found in **Table 1**.

Along the southbound approach, approximately 1,500 feet north of the grade crossing, a Low Ground Clearance Grade Crossing Warning Sign accompanied by a "NO TURNAROUND" plaque was visible to traffic traveling southbound on Main Street from Division Street. A grade crossing advance warning sign was located approximately 255-feet from the nearest rail. A Low Ground Clearance Grade Crossing warning sign accompanied by a "LOW GROUND CLEARANCE" plaque was located on the northwest corner of the grade crossing, approximately 20-feet from the nearest rail. A Grade Crossing (Crossbuck) sign was located approximately 14-feet from the nearest rail, in conjunction with the flashing-light signal assembly.

[7] See *Highway Photograph 6 – Main Street, North of Grade Crossing – Facing South*.

Table 1: Roadway Signs Along the Northbound Main Street Approach to CSX Grade Crossing

Type	MUTCD Code	Design	Condition	Size	Distance to Crossing
Grade Crossing Advanced Warning	W10-1		Good	36-inch diameter	382 feet
Low Ground Clearance Grade Crossing Warning	W10-5		Good	30-inch x 30-inch	25 feet
"LOW GROUND CLEARANCE" Plaque	W10-5P		Good	24-inch x 18-inch	25 feet
"CONSTRUCTION AHEAD" Temporary Traffic Control Warning	Non-Standard		Good	36-inch x 36-inch	24 feet
15 mph Advisory Speed Plaque	W13-1P (15)		Good	18-inch x 18-inch	24 feet
Grade Crossing (Crossbuck)	R15-1		Good	36-inch x 36-inch	13 feet

Parallel Grade Crossing and Intersection Advanced Warning signs were in place along the sections of eastbound and westbound Esters Boulevard, located both north and south of the tracks. The placement of the advanced warning signs ranged from approximately 105-feet to 170-feet in advance of the Main Street grade crossing. An aerial view of the area surrounding the Main Street grade crossing is shown in **Figure 4**, and has been annotated to show the crossing related advanced warning signs.

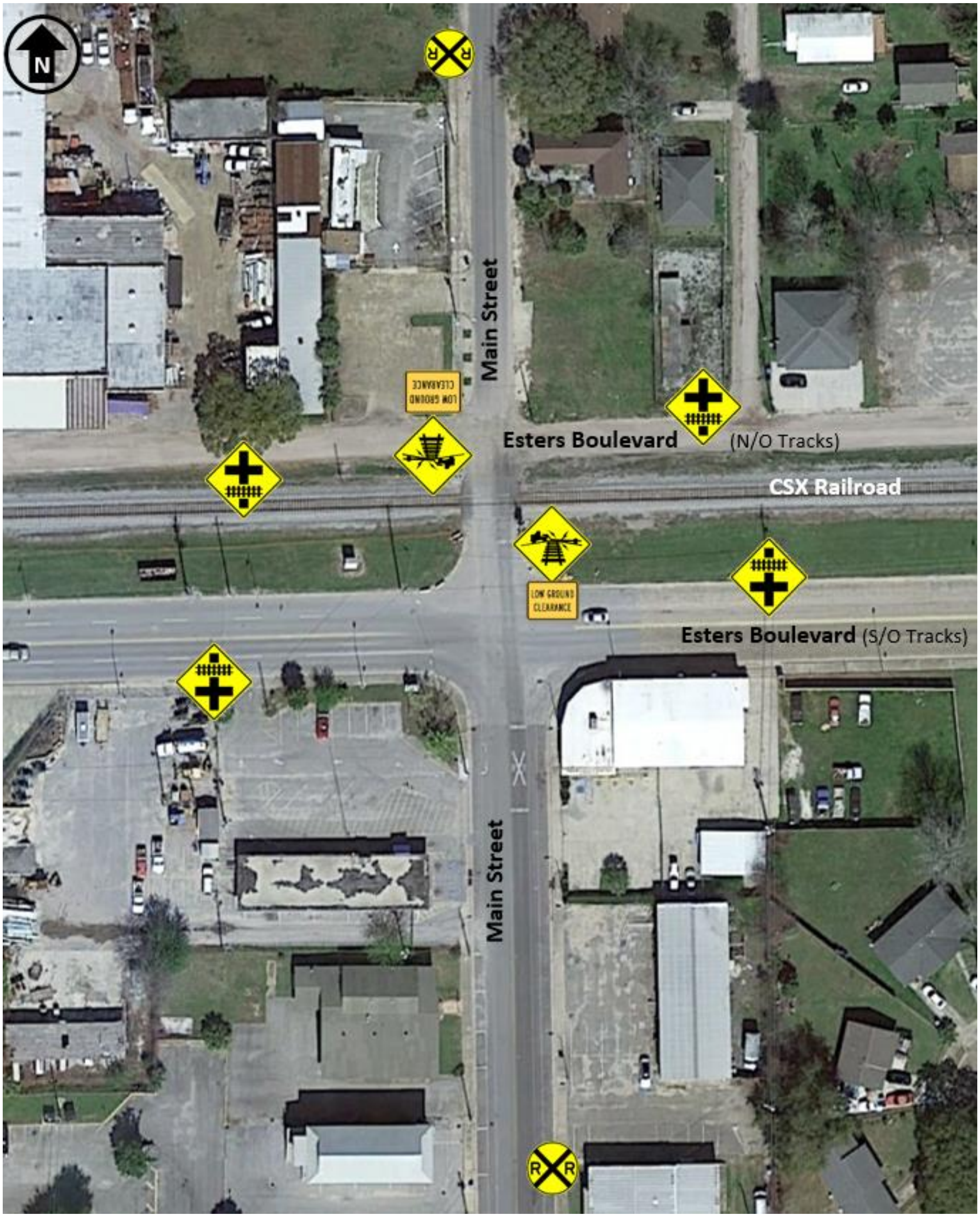

Figure 4: Crossing Related Advanced Warning Signs Near the Main Street Grade Crossing (modified from: Google Earth)

A grade crossing pavement-marking symbol was located in the northbound travel lane of Main Street south of the railroad tracks.[8] The center of the northbound grade crossing pavement marking symbol was located approximately 155-feet south of the nearest rail. There were no grade crossing related pavement markings for traffic traveling southbound on Main Street.

On the northbound approach to the grade crossing, a 2-foot wide white stop line was located approximately 9-$^{1}/_{2}$-feet prior to the automatic gate arm.[9] On the southbound approach to the grade crossing, a 2-foot wide white stop line was located approximately 8-$^{1}/_{2}$-feet prior to the automatic gate arm.[10] Both stop lines were worn and difficult to see.

The 2009 *Manual on Uniform Traffic Control Devices* (MUTCD) recommends the following regarding stop lines[11]:

> ***Section 8B.28 <u>Stop and Yield Lines</u>***
>
> *Guidance:*
>
> *If a stop line is used, it should be a transverse line at a right angle to the traveled way and should be placed approximately 8 feet in advance of the gate (if present), but no closer than 15 feet in advance of the nearest rail.*

4. POST-MOUNTED FLASHING LIGHT SIGNAL SYSTEM

The flashing light signal system used at the railroad crossing consisted of an electronic bell, two post-mounted flashing light signals (four sets of horizontally mounted 2-light units), two standard Crossbuck signs, two emergency notification system signs, and two automatic gate assemblies.[12] The flashing light signals were placed to the right of Main Street on both approaches to the grade crossing. On each signal mast, two sets of 12-inch diameter LED lights were mounted back-to-back such that they were visible to traffic on Main Street that was approaching the crossing from either direction. Two additional sets of 12-inch diameter LED lights were mounted back-to-back such that they were visible to traffic on Esters Boulevard that was approaching Main Street from either direction. The automatic gate arm consisted of a drive mechanism and fully reflectorized red and white striped gate arm with lights. In the down position, the gate arm extended across the approaching traffic lane, and consisted of alternating red and white vertical stripes. The automatic gate arm contained three red lights. When activated, the gate arm light nearest the tip illuminated continuously, and the other two lights flashed alternately in unison with the flashing light signals. When activated, each lamp flashed at a rate of approximately 49 flashes per minute. The electronic bell activated with the flashing light signals.

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[8] See *Highway Photograph 7 – Grade Crossing Pavement Marking Symbol on Northbound Main Street, South of Crossing – Facing North*.
[9] See *Highway Photograph 8 – Northbound Stop Bar at Grade Crossing – Facing North*.
[10] See *Highway Photograph 9 – Southbound Stop Bar at Grade Crossing – Facing South*.
[11] *Manual on Uniform Traffic Control Devices for Streets and Highways*, U.S. Department of Transportation, Federal Highway Administration; 2009 Edition; Section 8B.28.
[12] See *Highway Photograph 10 – Post Mounted Flashing Light Signal System with Automatic Gate, Located in Southeast Quadrant of Grade Crossing – Facing North*.

The center of the post-mounted flashing light system for the northbound approach was located approximately 15-$^{1}/_{2}$-feet from the centerline of the tracks. The center of the post-mounted flashing light system for the southbound approach was located approximately 16-feet from the centerline of the tracks. The 2009 MUTCD and the 2007 *Railroad-Highway Grade Crossing Handbook*[13] recommend a minimum distance of 12-feet from the center of the post-mounted flashing light system to the centerline of the railroad tracks.

The 2009 MUTCD recommends the following regarding flashing light signals, gates, and traffic control signals (MUTCD Figure 8C-1, which is referred to frequently in the following text, is shown in **Figure 5**):

Section 8C.02 Flashing-Light Signals

Standard:

If used, the flashing-light signal assembly (shown in Figure 8C-1) on the side of the highway shall include a standard Crossbuck (R15-1) sign, and where there is more than one track, a supplemental Number of Tracks (R15-2P) plaque, all of which indicate to motorists, bicyclists, and pedestrians the location of a grade crossing.

If used, flashing-light signals shall be placed to the right of approaching highway traffic on all highway approaches to a grade crossing. They shall be located laterally with respect to the highway in compliance with Figure 8C-1 except where such location would adversely affect signal visibility.

Each red signal unit in the flashing-light signal shall flash alternately. The number of flashes per minute for each lamp shall be 35 minimum and 65 maximum. Each lamp shall be illuminated approximately the same length of time. Total time of illumination of each pair of lamps shall be the entire operating time. Flashing-light units shall use either 8-inch or 12-inch nominal diameter lenses.

Section 8C.04 Automatic Gates

Standard:

The automatic gate (see Figure 8C-1) shall consist of a drive mechanism and a fully retroreflectorized red- and white-striped gate arm with lights. When in the down position, the gate arm shall extend across the approaching lanes of highway traffic.

In the normal sequence of operation, unless constant warning time detection or other advanced system requires otherwise, the flashing-light signals and the lights on the gate arm (in its normal upright position) shall be activated immediately upon the detection of approaching rail traffic. The gate arm shall

[13] *Railroad-Highway Grade Crossing Handbook*, U.S. Department of Transportation, Federal Highway Administration; Revised Second Edition, August 2007.

start its downward motion not less than 3 seconds after the flashing-light signals start to operate, shall reach its horizontal position at least 5 seconds before the arrival of the rail traffic, and shall remain in the down position as long as the rail traffic occupies the grade crossing.

When the rail traffic clears the grade crossing, and if no other rail traffic is detected, the gate arm shall ascend to its upright position, following which the flashing-light signals and the lights on the gate arm shall cease operation.

Gate arms shall be fully retroreflectorized on both sides and shall have vertical stripes alternately red and white at 16-inch intervals measured horizontally.

Standard:

Gate arms shall have at least three red lights as provided in Figure 8C-1.

When activated, the gate arm light nearest the tip shall be illuminated continuously and the other lights shall flash alternately in unison with the flashing-light signals.

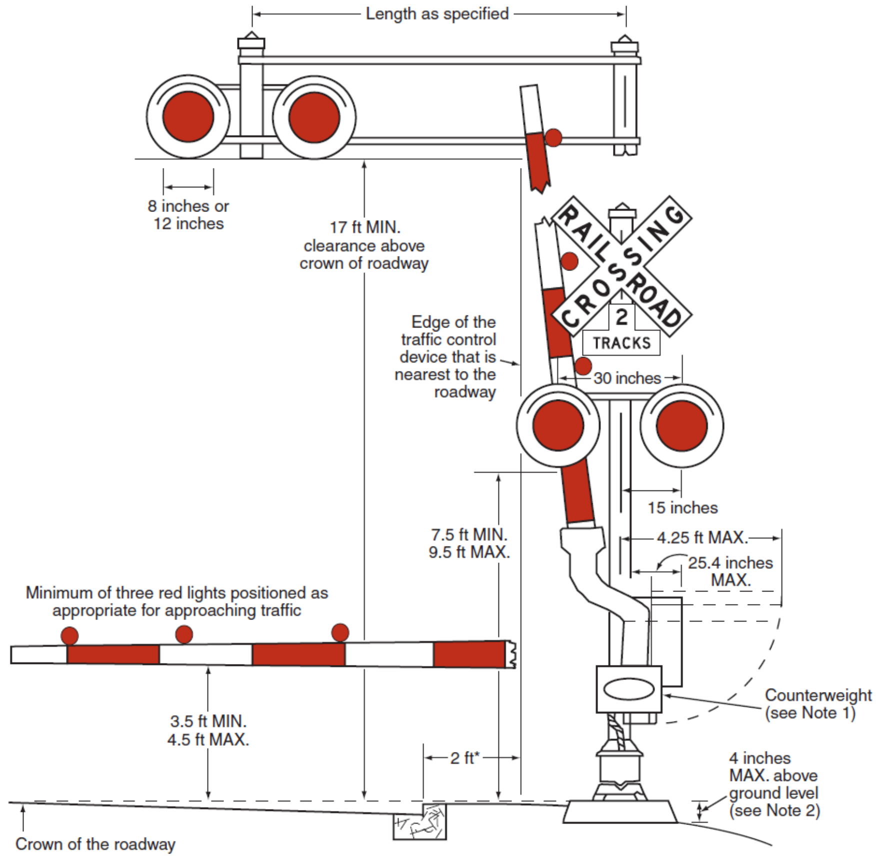
The entrance gate arm mechanism shall be designed to fail safe in the down position.

Guidance:

The gate arm should ascend to its upright position in 12 seconds or less.

In its normal upright position, when no rail traffic is approaching or occupying the grade crossing, the gate arm should be either vertical or nearly so (see Figure 8C-1).

The gates should cover the approaching highway to block all highway vehicles from being driven around the gate without crossing the center line.



*For locating this reference line on an approach that does not have a curb, see Section 8C.01.

Notes:

1. Where gates are located in the median, additional median width may be required to provide the minimum clearance for the counterweight supports.
2. The top of the signal foundation should be no more than 4 inches above the surface of the ground and should be at the same elevation as the crown of the roadway. Where site conditions would not allow this to be achieved, the shoulder side slope should be re-graded or the height of the signal post should be adjusted to meet the 17-foot vertical clearance requirement.

Figure 5: Composite Drawing of Active Traffic Control Devices for Grade Crossings Showing Clearances (source: Figure 8C-1 in FHWA's Manual on Uniform Traffic Control Devices)

5. VERTICAL PROFILE OF MAIN STREET CROSSING

The vertical grade for northbound traffic as it approached the railroad tracks on Main Street was an average +4.2% (uphill) slope (+7.5% maximum). The vertical grade for northbound traffic as it departed from the railroad tracks was an average -13.3% (downhill) slope (-24.4% maximum). **Figure 6** shows a plan and profile overview of the Main Street grade crossing. **Figure 7** shows a detailed view of the northbound approach grade for approximately 50-feet south of the tracks, with approximate slope measurements shown at 5-foot intervals. **Figure 8** shows a detailed view of the northbound departure grade for approximately 35-feet north of the tracks, with approximate slope measurements shown at 2-$^{1}/_{2}$-foot intervals. A photograph showing both the northbound approach and departure slopes is shown in **Figure 9**.[14]

[14] See *Highway Photograph 11 – Side View of Main Street Crossing – Looking West*.

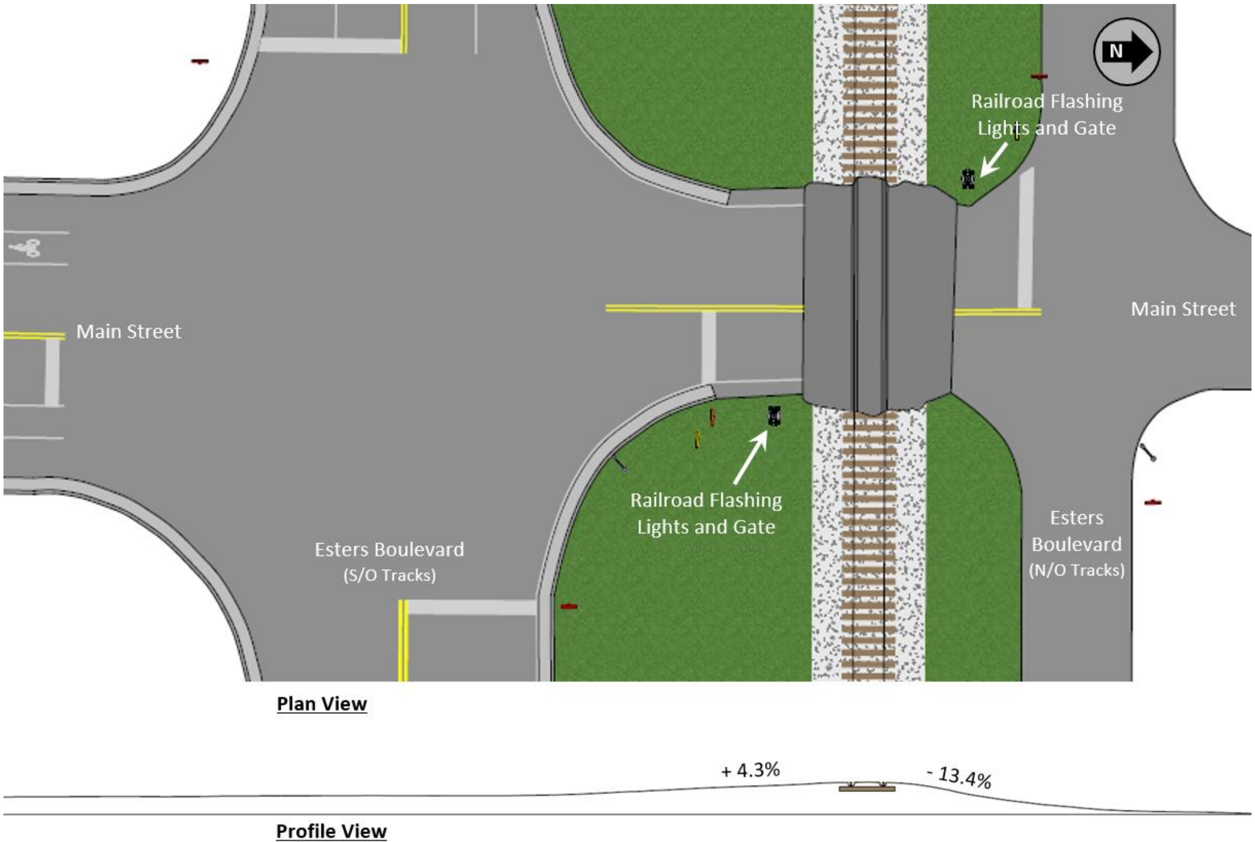


Figure 6: Plan and Profile Views of Main Street Grade Crossing

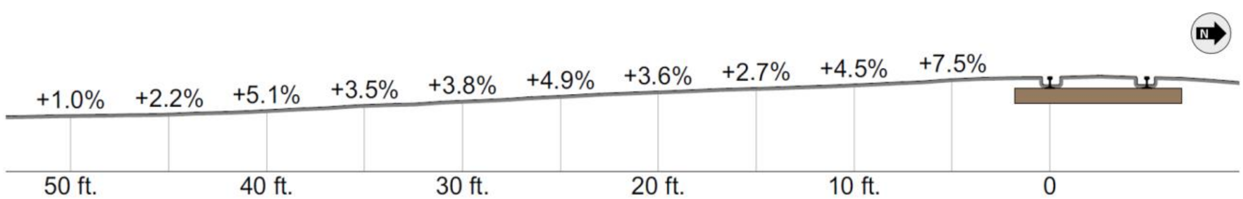


Figure 7: Detailed View of Northbound Approach Profile

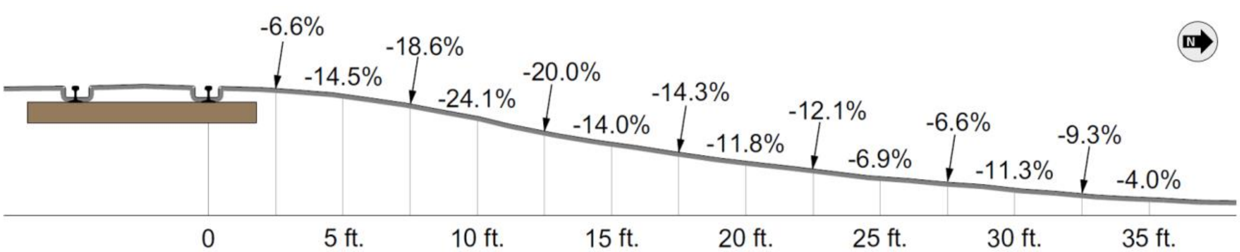


Figure 8: Detailed View of Northbound Departure Profile

Figure 9: Photograph Showing the Side Profile of the Main Street Grade Crossing – Looking West

Using an exemplar motorcoach with an experienced driver and a spotter, NTSB investigators conducted a series of tests under controlled circumstances.[15] These tests including capturing video of the motorcoach's approach to the crossing, acceleration testing, and ground clearance measurements as the motorcoach drove up and onto the crossing. During this testing, the motorcoach was slowly moved forward onto the crossing, and was stopped when it was in a position just short of bottoming out, as shown in **Figure 10**.[16] In this position, the exemplar motorcoach would have been close to the position that the collision involved motorcoach was in when it became immobilized on the crossing.

[15] During the testing, the Main Street grade crossing was closed to vehicular traffic, and the railroad tracks were closed to train traffic.
[16] See *Highway Photograph 12 – Exemplar Motorcoach Positioned on the Main Street Grade Crossing – Looking East*.

Figure 10: Exemplar Motorcoach Positioned on the Main Street Grade Crossing – Looking East

Available guidance for the design of new railroad grade crossings in the State of Mississippi includes: *A Policy on Geometric Design of Highways and Streets*[17] (commonly referred to as the "Green Book"); the *Railroad-Highway Grade Crossing Handbook*[18]; and the Mississippi Department of Transportation (MDOT) *Roadway Design Manual*[19]. All three of these sources recommend that the highway and railroad crossing should intersect as near to perpendicular as possible, it should not be located on a horizontal curve for either the highway or the railroad to maximize sightlines, and the crossing be as level as possible.

The forward of the 2001AASHTO Green Book, offers the following regarding the comparison of design values to existing roadways:

> *The fact that design values are presented herein does not imply that existing streets and highways are unsafe, nor does it mandate the initiation of improvement projects. This publication is not intended as a policy for resurfacing, restoration, or rehabilitation (3R) projects. For projects of this type,*

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[17] A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO); 6th Edition, 2011.

[18] Railroad-Highway Grade Crossing Handbook, U.S. Department of Transportation, Federal Highway Administration; Revised Second Edition, August 2007.

[19] See *Highway Attachment – At-Grade Railroad/Highway Crossings (Section 8-3.0) of the Mississippi Department of Transportation Roadway Design Manual*.

where major revisions to horizontal or vertical curvature are not necessary or practical, existing design values may be retained. Specific site investigations and crash history analyses often indicate that the existing design features are performing in a satisfactory manner. The cost of full reconstruction for these facilities, particularly where major realignment is not needed, will often not be justified. Resurfacing, restoration, and rehabilitation projects enable highway agencies to improve highway safety by selectively upgrading existing highway and roadside features without the cost of full reconstruction. When designing 3R projects, the designer should refer to TRB Special Report 214, Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation, and related publications for guidance.

To prevent drivers of low-clearance vehicles from becoming caught on the tracks, both AASHTO and FHWA recommend that the crossing surface should be level with the top of the rails for at least 2-feet outside the rails. They both also recommend that the road surface should not be more than 3-inches higher or lower than the top of the nearest rail at a distance of 30-feet from the nearest rail in most cases. These dimensions are shown graphically in **Figure 11**.

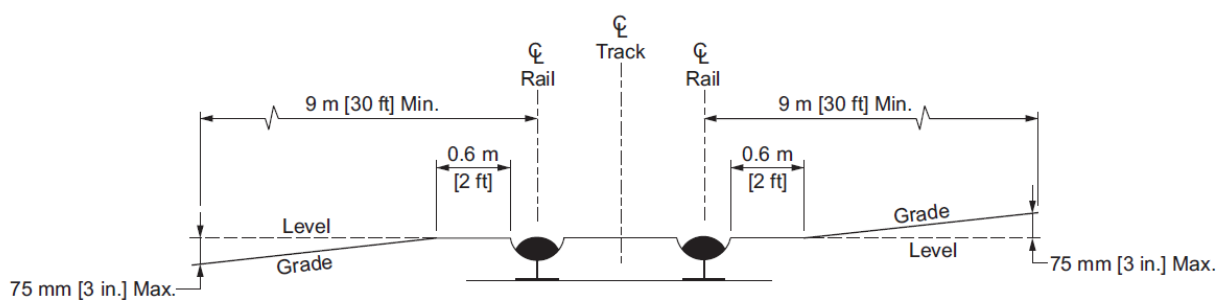

Figure 11: AASHTO and FHWA Recommended Grade Crossing Design Profile (source: Figure 9-75 in AASHTO Policy on Geometric Design of Highways and Streets)

When designing a new crossing, the 2001 MDOT Roadway Design Manual, which was in effect at the time of the collision, recommended that the crossing surface should be level with the top of the rails for at least 2-feet outside the rails. MDOT also recommended that the road surface should not be more than 3-inches above, or 6-inches below the top of the nearest rail at a distance of 10-feet from the nearest rail unless the railroad track superelevation dictated otherwise. The MDOT design guidance is shown graphically in **Figure 12**. It should be noted that, at the time of this report, the MDOT Roadway Design Manual was in the process of being revised. Some of the revisions to the MDOT Roadway Design Manual are expected to include changes in the highway-railroad grade crossing vertical design profile.[20] Once revised, the grade crossing vertical design profile is expected to match the criteria recommended by AASHTO and FHWA described earlier in this section. Revisions to the MDOT Roadway Design Manual are tentatively expected to be completed by the end of 2017. Additionally, the MDOT Rails Division, who is responsible for the approval of all grade crossing design and improvement plans for new or reconstructed crossings

[20] See *Highway Attachment – Draft Revisions to Mississippi Department of Transportation Roadway Design Manual – At-Grade Railroad/Highway Grade Crossings (Figure 6-11-C).*

within the State, has required that all plans met the AASHTO and FHWA design guidance since the end of 2010, or beginning of 2011.[21]

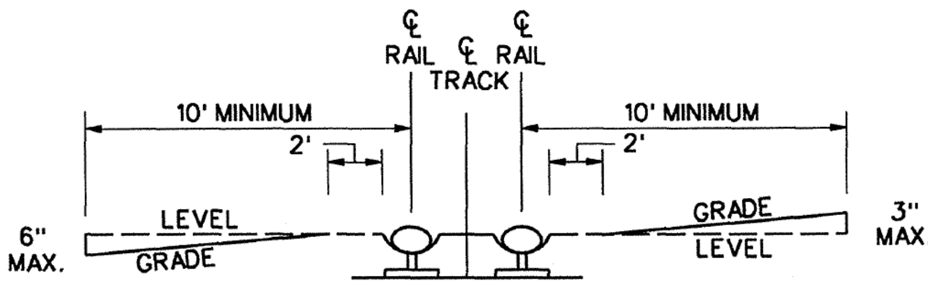

Figure 12: MDOT Recommended Grade Crossing Design Profile (source: Figure 8-3C in MDOT Roadway Design Manual)

Main Street crossing to the south of the tracks, 2-feet from the south rail, the crossing surface was approximately $^1/_8$-inch below the top of the south rail. To the north of the tracks, 2-feet from the north rail, the crossing surface was approximately $^1/_2$-inch below the top of the north rail. The northbound approach grade was found to be approximately 14.4-inches below track level at a distance of 30-feet from the nearest rail, with the southbound approach grade being approximately 45.4-inches below track level at a distance of 30-feet from the nearest rail.[22] The northbound approach grade was found to be approximately 4.5-inches below track level at a distance of 10-feet from the nearest rail, and the southbound approach grade was found to be approximately 13.4-inches below track level at a distance of 10-feet from the nearest rail.

The FHWA *Railroad-Highway Grade Crossing Handbook*[23] offers the following information with respect to the vertical alignment of grade crossings and the development of high-profile crossings[24]:

> *It is desirable that the intersection of highway and railroad be made as level as possible from the standpoint of sight distance, rideability, and braking and acceleration distances. Drainage would be improved if the crossing were located at the peak of a long vertical curve on the highway. Vertical curves should be of*

[21] The Mississippi Department of Transportation, Rails Division, holds jurisdiction over all highway-railroad grade crossings in the State, regardless of whether they are on State, county, or local roadways.

[22] Design guidance typically only applies at the time a crossing is either originally being constructed or when a crossing is being re-constructed, and is not a standard which must be maintained beyond the original construction stage. The design guidance and actual approach slope profiles are only examined here for comparative purposes.

[23] Railroad-Highway Grade Crossing Handbook, U.S. Department of Transportation, Federal Highway Administration; Revised Second Edition, August 2007. Crossing Geometry, Vertical Alignment Section on pages 138-139.

[24] High-profile or "humped" crossings are railroad-highway grade crossings at which the railroad bed is higher than the roadway it is crossing, causing a hump for the motorist to cross.

sufficient length to ensure an adequate view of the crossing and consistent with the highway design or operating speed.

Track maintenance can result in raising the track as new ballast is added to the track structure. Unless the highway profile is properly adjusted, this practice will result in a "humped" profile that may adversely affect the safety and operation of highway traffic over the railroad.

Two constraints often apply to the maintenance of grade crossing profiles: drainage requirements and resource limitations. Coordination of maintenance activities between rail and highway authorities, especially at the city and county level, is frequently informal and unstructured. Even when the need to coordinate has been identified, there may be a lack of knowledge regarding whom to contact.

In some cases, highway authorities become aware of increases in track elevation (a by-product of track maintenance) only after the fact. As a result, even if state standards exist, there is little opportunity to enforce them. Often, an individual increase in track elevation may not violate a guideline, but successive track raises may create a high-profile crossing.

Low clearance vehicles, such as those low to the ground relative to the distance between axles, pose the greatest risk of becoming immobilized at highway-rail grade crossings due to contact with the track or highway surface. With the exception of specialized vehicles such as tank trucks, there is little standardization within the vehicle manufacturing industry regarding minimum ground clearance.

At the time the Main Street grade crossing was last fully reconstructed in 1977, some of the only available vertical profile design guidance would have been found in the American Railway Engineering Association's Railway Design Manual.[25] Guidance pertaining to vertical alignment at railroad grade crossings first appeared in AASHTO's *A Policy on Geometric Design of Highways and Streets* in 1990.[26] This guidance recommended that the crossing remain level with the top of the rails for a distance of two feet outside of the rails, and not more than 3-inches higher nor 6-inches lower than the top of the nearest rail at a distance of 30-feet from the rail.

6. GRADE CROSSING CONSTRUCTION & MAINTENANCE HISTORY

While an exact date of when Main Street was first constructed is not available, information and land deeds provided by the City of Biloxi indicate that Main Street existed prior to 1854, when

[25] Despite an exhaustive search, NTSB investigators were unable to locate a copy of the American Railway Engineering Association's Railway Design Manual that would have been in effect at that time and was therefore unable to determine what that guidance would have been.

[26] A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO); 1990. The previous edition (1984) of the manual did not provide any vertical alignment guidance for railroad grade crossings.

a petition to construct a railroad through Harrison County was filed by residents.[27] It is believed that the railroad was constructed through the City of Biloxi sometime between 1860, and 1867. Another land deed granted the specific property at the Main Street Crossing to the New Orleans-Mobile-Chattanooga Railroad in 1869.

Main Street and its grade crossing were most recently reconstructed in 1977.[28] While evidence indicates that maintenance and rehabilitation work has been conducted on Main Street since that time, records of any work prior to 2008 are not available.[29] Based on historical aerial and/or satellite images, the most recent asphalt overlay on Esters Boulevard south of the railroad tracks, including the intersection with Main Street, occurred sometime between September 2007, and September 2008.[30] The only major work performed on Main Street since 2008 included the milling of both Main Street and Esters Boulevard north of the railroad tracks, as well as the application of a temporary asphalt surface on that same section of Main Street north of the railroad tracks in March 2016.[31]

Railroad track and crossing maintenance records were obtained from CSX.[32] According to these records, new steel track rails were installed along a section of track that would have included the Main Street grade crossing in January 2012. The process used to replace the rails would not be expected to raise the track elevation, as the remainder of the track structure is typically left undisturbed. A historical Google Street View image taken in April 2013, shows at least two applications of asphalt at the crossing surface immediately adjacent to the tracks.[33]

In February 2014, some of the wooden railroad ties were replaced along a section of track that would have included the Main Street grade crossing. To accommodate the replacement of these ties, saw cuts would typically be made approximately six-feet from the nearest rail on the side being used to install the new ties, and approximately three-feet from the nearest rail on the opposite side of the tracks.[34] The asphalt crossing surface would then be removed over the track structure including the area between the saw cuts. After replacing the necessary wooden ties, the ballast would typically be tamped and regulated. The ballast must then be compacted prior to replacing the crossing surface and pavement. During this process, track elevation could typically be raised by up to two-inches, after which an approximate $^{1}/_{2}$-inch settlement of the tracks would be expected due to the compaction process. CSX maintenance of way instructions (MWI) indicate that "The minimum practical track raise should be used to limit its effect on the highway profile.",

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[27] See *Highway Attachment – Land Deeds Related to Construction of Railroad and Property at Main Street Grade Crossing*.

[28] See *Highway Attachment – Selected Pages from: 1917 Railroad Right of Way and Track Map; 1977 Main Street Improvement Plans; 1999 Main Street Improvement Survey; 2012 Infrastructure Repair Program Plans; and 2014 Infrastructure Repair Program Plans*.

[29] See *Highway Attachment – City of Biloxi Work Orders for Main Street Through March 15, 2017*.

[30] See Highway *Photograph 13 – Google Earth Aerial Image of Main Street and Esters Boulevard dated 9/17/2007*, and Highway *Photograph 14 – Google Earth Aerial Image of Main Street and Esters Boulevard dated 9/6/2008*.

[31] Main Street and Esters Boulevard, as well as many other streets in east Biloxi were milled up as part of a major ongoing road reconstruction project. Following this work, a temporary asphalt travel surface was installed on Main Street and several other key roadways until the reconstruction project is completed.

[32] See *Highway Attachment – CSX Track and Crossing Maintenance Records*.

[33] See *Highway Photograph 15 – Google Maps Street View Image of Main Street Railroad-Highway Grade Crossing dated April 2013*.

[34] See *Highway Attachment – CSX Maintenance of Way Instructions (MWI) 901-08 – Road Crossing Installation*.

and indicates that coordination with the governmental agency or outside party responsible for the crossing may be necessary.

During the installation of the new asphalt crossing surface, the CSX MWI indicate:[35]

> *Paved road surface should be level with the top of rail for 30 inches from the field side of each rail unless there is a conflict with State regulations. In case of a conflict, the State regulations will govern. For new construction, highway surface should not be more than 3 inches higher or lower than the top of the near rail 30 feet from the rail along the road centerline, unless track superelevation dictates otherwise. If practicable, slope the pavement 1 inch in 10 feet to meet existing highway surface. On high speed roads (50MPH and greater), the surface may have to be even smoother to reduce impacts on the crossing surface. High speed roadways with considerable truck traffic (20% and greater) should have the level distance increased to 20 feet.*

Based on the 1977, Main Street Improvement plans, the Main Street grade crossing surface would have had an elevation of approximately 19.14 feet above mean sea level.[36] A survey conducted in 1999, in preparation for additional improvements to Main Street show that the grade crossing had an elevation of 19.39 feet above mean sea level.

To assist in determining the roadway maintenance activities performed since the 1977, reconstruction of the Main Street grade crossing, NTSB investigators obtained several full thickness asphalt pavement core samples.[37] On May 31, 2017, investigators were present as 12 full thickness and 1 partial thickness 4-inch diameter pavement core samples were drilled from the Main Street grade crossing[38] and retained for further examination and testing at the FHWA's Turner-Fairbank Highway Research Center (TFHRC).[39] The approximate locations of the pavement core samples are shown in **Figure 13**. A more detailed description of the core sample locations and thicknesses for each collected sample are summarized in **Table 2**.

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[35] Ibid.

[36] See *Highway Attachment – Selected Pages from: 1917 Railroad Right of Way and Track Map; 1977 Main Street Improvement Plans; 1999 Main Street Improvement Survey; 2012 Infrastructure Repair Program Plans; and 2014 Infrastructure Repair Program Plans*.

[37] See *Highway Photograph 16 – Core Sample "C" After Being Removed from Roadway*.

[38] See *Highway Attachment – Terracon Core Sample Collection Report*.

[39] See *Highway Photograph 17 – Overview of All 13 Asphalt Core Samples Collected from the Main Street Crossing*.

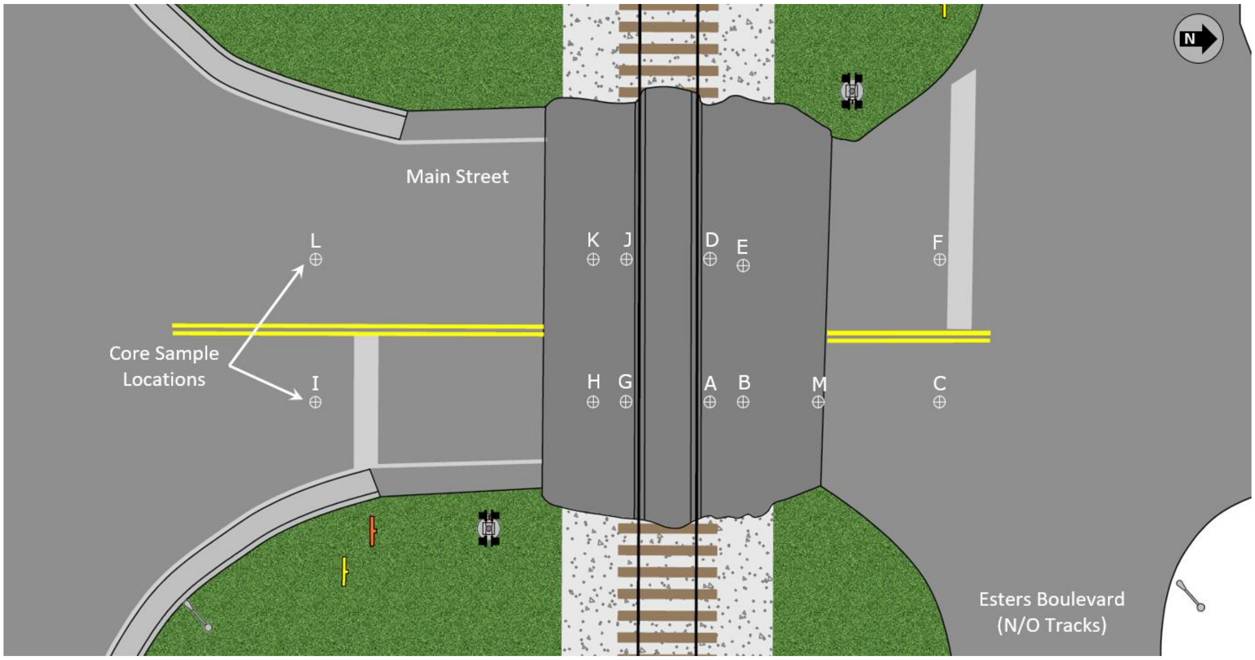

Figure 13: Approximate Asphalt Core Sample Locations

Table 2: Approximate Asphalt Core Sample Locations and Lengths

Sample	Distance from Nearest Rail	Distance from Centerline	Approximate Core Sample Length
A	13.5 in. North	6 ft. East	8 in.
B	4 ft. North	6 ft. East	5.5 in.
C	21 ft. North	6 ft. East	11.5 in.
D	13.5 in. North	6 ft. West	9 in.
E	4 ft. North	5.5 ft. West	4 in.
F	21 ft. North	6 ft. West	12.5 in.
G	13.5 in. South	6 ft. East	8 in.
H	4 ft. South	6 ft. East	11 in.
I	28 ft. South	6 ft. East	23 in.
J	13.5 in. South	6 ft. West	7.5 in.
K	4 ft. South	6 ft. West	11.5 in.
L	28 ft. South	6 ft. West	19 in.
M	10.5 ft. North	6 ft. East	10 in.[a]

[a] - Sample drill was at a depth of 15 inches, and had not reached the bottom of the asphalt layer. Unable to effectively advance the drill any farther, only the top 10-inches of the sample could be recovered.

On Tuesday, July 18, 2017, NTSB investigators and a representative from CSX met with TFHRC Aggregate and Petrography Laboratory (APL) staff, and provided them with the asphalt pavement core samples. Following an initial visual examination on that date, the thirteen samples were left in the possession of the APL staff for them to conduct a more thorough examination.[40] The detailed examination of the core samples that were collected relatively close to the tracks (samples A, B, D, E, G, H, J, and K) revealed that each of these samples consisted of a single layer with multiple lifts,[41] and had similar aggregate types. The APL examination found that:

> *This is consistent with the possibility that all eight of these close-in cores are from an asphalt pavement layer paced at about the same time with the same asphalt mixture, with the lift lines present just showing the lifts of mixture compacted in place during manual replacement of the pavement close to the rails. It appears that this mixture was placed on top of the ballast aggregate and ends of the wooden cross ties, as evidenced by pieces of large ballast aggregate at the bottom of several cores and a piece of wood at the bottom of Core D.*

According to the APL, the detailed examination of the core samples that were collected relatively far from the tracks (samples C, F, I, L, and M) contained clearly different pavement layers, and showed variability in aggregate type, size, abundance, and distribution. These core samples were thicker than the samples collected closer to the tracks, and contained between four and ten layers. The APL examination found that samples “I” and “L” appeared to have a similar placement/construction history based on the similarities found in the observed layers and their aggregate types. For the same reasons, the APL found that samples “C” and “F” also appeared to have a similar placement/construction history.

7. FUNCTIONAL CLASSIFICATION

In the area of the collision, the City of Biloxi functionally classified Main Street as an urban collector street system. The American Association of State Highway and Transportation Officials (AASHTO) describe an urban collector as follows:[42]

> *The urban collector street system provides both land access service and traffic circulation within residential neighborhoods and commercial and industrial areas. It differs from the urban arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to their ultimate destinations. Conversely, the urban collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of similar development and traffic density, the urban collector system may include the entire street grid. The urban collector street system may also carry local bus routes.*

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[40] See *Highway Attachment - FHWA-TFHRC Aggregate and Petrography Laboratory (APL) Report of Petrographic Analyses*.

[41] According to the APL, “The terminology generally used for asphalt pavements is that pavement ‘layers’ or ‘asphalt mixture layers’ generally are different mixtures/materials, often placed at different times. Whereas a ‘lift’ within a pavement layer is generally of the same or similar mixture/material placed and compacted the same day or within several days.”

[42] See section 1.3.4 – Functional Highway Systems in Urbanized Areas in “A Policy on Geometric Design of Highways and Streets”. American Association of State Highway and Transportation Officials (AASHTO), 6th edition.

8. DAILY TRAFFIC VOLUMES AND USE CLASSIFICATIONS

The average daily traffic volume at the Main Street grade crossing, in 1995, was reported to be 2,300 vehicles per day. According to the FRA National Highway-Rail Crossing Inventory for the Main Street crossing, commercial vehicles accounted for approximately 9% of the total vehicles in 1995. Annual average daily traffic (AADT) volumes for the Main Street grade crossing are collected by the Gulf Regional Planning Commission at least once every three years.[43] The available AADT volumes between 2004, and 2016, are summarized in **Table 3**. At the request of NTSB investigators, the City of Biloxi had an updated traffic count and vehicle classification study performed on July 25, 2017, for vehicles using the Main Street grade crossing.[44] The results of the July 2017 traffic count for vehicles using the Main Street grade crossing is summarized in **Table 4**.

Table 3: Annual Average Daily Traffic Volumes for the Main Street Grade Crossing

Year	Annual Average Daily Traffic Volume
2004	3,200[a]
2007	2,700
2010	2,500
2013	2,400
2016	2,000[b]

[a] The 2004 count was prior to damage caused by Hurricane Katrina in 2005.

[b] The 2016 count was likely impacted by infrastructure improvements underway on nearby streets.

Table 4: Vehicle Count and Classification at the Main Street Grade Crossing on July 25, 2017

Vehicle Type	Northbound		Southbound		Total Vehicles Crossing	
	Number	Percent	Number	Percent	Number	Percent
Passenger Vehicles	1,179	99.24%	938	98.84%	2,117	99.06%
Busses/Single Unit Trucks	5	0.42%	7	0.74%	12	0.56%
Tractor Trailer Units	4	0.34%	4	0.42%	8	0.37%
Total	1,188	100%	949	100%	2,137	100%

9. FRA NATIONAL HIGHWAY-RAIL CROSSING INVENTORY INFORMATION

The FRA National Highway-Rail Crossing Inventory information for the Main Street and CSX Transportation grade crossing is summarized in **Table 5**.[45]

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[43] See *Highway Attachment – Vehicle Count and Classification Data for Main Street Crossing*.
[44] Ibid.
[45] See *Highway Attachment – National Highway-Rail Crossing Inventory History for the Main Street Grade Crossing*.

Table 5: National Highway-Rail Crossing Inventory Information

Inventory Item	Crossing Inventory Information
Crossing Number	340185W
Railroad	CSX Transportation
Type and Position	Public at Grade
Division	Atlanta
Subdivision	N O and M
Railroad Milepost	0726.61
State	Mississippi
County	Harrison
City	Biloxi
Street or Road Name	Main Street
Highway Type	LS
Latitude	30.3991225
Longitude	-88.8856615

10. TRACK DESIGN SPEED AND MAXIMUM TRACK SPEED

The rail line in the area of the Main Street grade crossing is comprised of Class 4 track, which allows for a maximum train speed of 60 mph.[46] The CSX timetable speed in place for this track, however, limits train speeds to 45 mph.

11. DAILY TRAIN VOLUMES

The average daily train volume at the Main Street grade crossing between February 1 and March 6, 2017 was reported by CSX to be 12 trains per day.[47] The annual average daily train volumes at the Main Street grade crossing from 2006 through April of 2017 are shown in **Figure 14**.

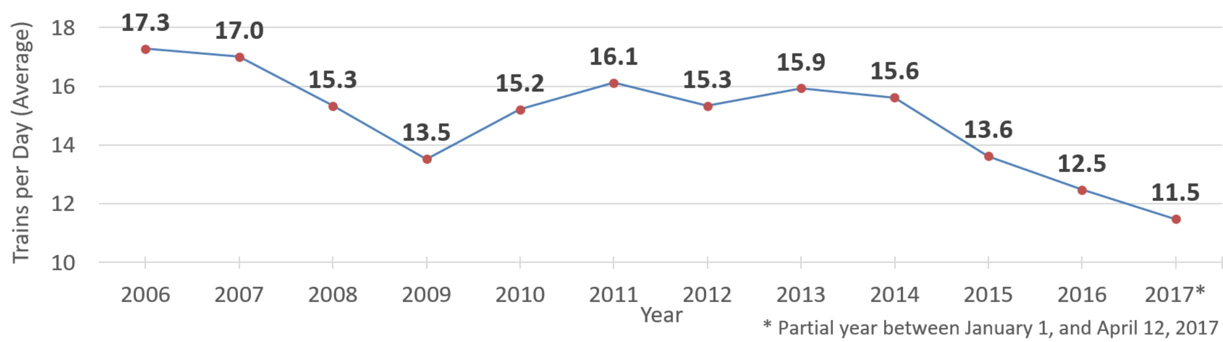

Figure 14: Annual Average Daily Train Volumes at Main Street Crossing

[46] See *Highway Attachment – Track Design Speed and Daily Train Volumes for Main Street Crossing*.
[47] Ibid.

12. MAIN STREET GRADE CROSSING CRASH HISTORY

The Federal Railroad Administration (FRA) grade crossing accident report history indicated that there have been 18 collisions at the Main Street grade crossing, including this collision, between November 1976, and March 2017.[48] Eleven crashes involved passenger cars, six involved commercial vehicles, and one involved a pedestrian. Prior to the collision being investigated in this report, there were two fatal collisions, both of which involved passenger cars moving across the grade crossing at the time of the crashes. Two prior collisions involved commercial vehicles that were stalled or stuck on the crossing. A summary of the Main Street grade crossing crash history data can be found in **Table 6**.

Table 6: Main Street Grade Crossing Crash Summary

Date	Highway User Type	Highway User Position/Action	Highway User Fatalities	Highway User Injuries
11/20/1976	Auto	Moving over crossing	0	0
1/15/1978	Auto	Stalled or Stuck on Tracks	0	0
1/16/1978	Auto	Moving over crossing	0	1
1/19/1978	Truck	Moving over crossing	0	0
12/21/1978	Auto	Moving over crossing	0	0
2/11/1979	Auto	Moving over crossing	0	0
11/25/1980	Auto	Stalled or Stuck on Tracks	0	0
10/31/1981	Auto	Moving over crossing	0	0
10/20/1982	Truck-trailer	Moving over crossing	0	0
3/23/1983	Auto	Moving over crossing	1	0
6/19/1986	Truck-trailer	Stopped on Crossing	0	0
2/7/1989	Auto	Stopped on Crossing	0	0
4/26/1997	Auto	Moving over crossing	0	1
11/25/1997	Pedestrian	Moving over crossing	0	1
9/12/2003	Auto	Moving over crossing	1	0
8/28/2014	Truck-trailer	Stalled or Stuck on Tracks	0	0[a]
1/5/2017	Truck	Stalled or Stuck on Tracks	0	0[b]
3/7/2017	Bus	Stalled or Stuck on Tracks	4	46
		Totals:	**6**	**49**

[a] One railroad employee was injured in this collision.

[b] Two railroad employees were injured in this collision.

13. MAIN STREET GRADE CROSSING INCIDENT HISTORY

A review of all "Calls for Service" recorded by the City of Biloxi Police Department (CBPD) and all "Trouble Tickets" recorded by CSX at the Main Street railroad grade crossing was

[48] See *Highway Attachment – FRA Grade Crossing Accident History for Main Street Crossing*. The crash report dates ranged from November 20, 1976 to March 7, 2017.

conducted for the five-year period between March 2012, and March 2017.[49] These records indicated that there was a total of 27 incidents of vehicles becoming stuck on the railroad tracks at the Main Street grade crossing. Three of the incidents resulted in collisions between a train and the vehicle stuck at the crossing. The recorded incidents are summarized in **Table 7**.

Table 7: Reported Incidents of Vehicles Stuck on Tracks at Main Street Grade Crossing

Date	Vehicle Type Stuck on Tracks	Source	Resulted in Collision
9/19/2012	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
12/1/2012	Truck with Horse Trailer	CSX & Biloxi P.D.	No
12/11/2012	Truck-Tractor Semi-Trailer	Biloxi P.D.	No
3/14/2014	Truck - Unspecified Type	CSX & Biloxi P.D.	No
6/3/2014	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
8/7/2014	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
8/28/2014	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	Yes
10/22/2014	Truck-Tractor Semi-Trailer	CSX	No
10/31/2014	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
3/30/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
3/31/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
5/26/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
6/15/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
11/30/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
12/29/2015	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
3/12/2016	Motorcoach	CSX	No
4/18/2016	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
4/23/2016	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No[a]
5/2/2016	Tanker Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
5/10/2016	Vehicle - Unspecified Type	CSX	No
6/21/2016	Truck-Tractor Semi-Trailer	CSX	No
10/17/2016	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
10/21/2016	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	No
1/2/2017	Truck-Tractor Semi-Trailer	CSX	No
1/5/2017	Truck-Tractor Semi-Trailer	CSX & Biloxi P.D.	Yes
2/23/2017	Truck-Tractor Semi-Trailer	Biloxi P.D.	No
3/7/2017	Motorcoach	CSX & Biloxi P.D.	Yes
Total Incidents: 27		**Total Crashes: 3**	

[a] Oncoming train reportedly stopped 3 car lengths short of striking the truck.

[49] See *Highway Attachment – CSX "Trouble Tickets" for the Main Street Grade Crossing, March 2012 – March 2017*.

14. POST-CRASH BILOXI AREA GRADE CROSSING IMPROVEMENTS

On March 10, 2017, approximately three days after the collision, three No Trucks selective exclusion signs in combination with "NO BUSSES TRUCKS RVS" plaques were placed near the grade crossing by the City of Biloxi.[50] One was placed along northbound Main Street approximately 234-feet south of the nearest rail. A second was placed in the southeast corner of the grade crossing approximately 25-feet from the nearest rail. And the third was placed along southbound Main Street approximately 104-feet from the nearest rail.

On March 13, 2017, approximately six days after the collision, two additional Low Ground Clearance Grade Crossing warning signs accompanied by "LOW GROUND CLEARANCE" plaques were placed near the grade crossing by the City of Biloxi.[51] One was placed in the southwest corner of the grade crossing facing south approximately 25-feet from the nearest rail. The second was placed in the northeast corner of the grade crossing facing north approximately 12-feet from the nearest rail.

During a conversation with the City of Biloxi's Chief Administrative Officer on May 2, 2017, investigators learned that the Biloxi City Council passed a resolution to close six of the highway-railroad grade crossings within the city in connection with the Popps Ferry Road extension project.[52] The six grade-crossings to be closed include:

- Nixon Street;
- Holley Street;
- Iroquois Street;
- Dorries Street;
- Querens Avenue; and
- Delauney Street.

Investigators also learned that the City of Biloxi was starting the process to make emergency repairs to the Main Street grade crossing, to reduce the severity of the approach grades at the crossing. The emergency re-design and repairs to the Main Street crossing were described as being similar to the redesign that was previously done at the Porter Street crossing. To complete the repairs, they were expecting to need to go back several hundred yards from the crossing in either direction in order to provide less abrupt approach slopes. **Figure 15** shows the longer approach slopes at the Porter Street crossing.[53] Investigators learned that the City was also planning to implement dedicated truck and bus routes through the City, which they hoped would further restrict which highway-railroad grade crossings are used by commercial vehicles.

[50] See *Highway Photograph 18 – No Trucks Selective Exclusion Signs, Placed at Main Street Grade Crossing on March 10, 2017*, and *Highway Attachment 16 – City of Biloxi Work Order for Installation of No Trucks Selective Exclusion Signs*.

[51] See *Highway Photograph 19 – Additional Low Ground Clearance Grade Crossing Warning Sign Placed in Southwest Quadrant of Grade Crossing on March 13, 2017*, and *Highway Attachment 17 – City of Biloxi Work Order for Installation of Additional Low Ground Clearance Warning Signs at Main Street Crossing*.

[52] See *Highway Attachment – Summary Information for Potential At-Grade Crossing Closure Locations*, and *Highway Attachment 19 – Biloxi City Council Resolution No. 127-17*.

[53] See *Highway Photograph 20 – Porter Street Grade Crossing – Facing South-Southeast*.

Figure 15: Photo of the Approach Slopes at the Porter Avenue Crossing

During an additional conversation with the City of Biloxi's Chief Administrative Officer on May 31, 2017, investigators learned that a contract had been signed that morning to complete the design work for the emergency repairs/reconfiguration of the Main Street crossing. Investigators were told that the City was working on funding options, including using available Federal grade-crossing improvement funds to expedite the emergency repairs to the Main Street crossing. Investigators were also informed that the City is moving forward with the bid process for reconfiguring the streets necessary to provide permanent re-routing of traffic in preparation for the closing of the six highway-railroad grade crossings in connection with the Popps Ferry Road extension project.

On January 31, 2017, the City of Biloxi, CSX, and MDOT met to discuss how to move forward with opening two new grade crossings; the Popps Ferry Road extension, and a potential Pine Road extension. Because CSX required that three crossings be closed for each new crossing, a total of six existing crossings would have to be closed in order to open the two proposed crossings. During this meeting, MDOT pointed out that there were 11 crossings within the City that did not have lights and gates. MDOT also recommended that, following the selection of the six grade crossings to be closed, that a safety project be initiated to address closing or installing lights and gates at any remaining un-gated crossings. Following the March 7, 2017, grade crossing collision that is the subject of this investigation, MDOT and CSX jointly decided to perform a diagnostic review of all grade crossings within the City of Biloxi. These reviews confirmed that there were 11 crossings that did not have gates. The MDOT would like to put forward a collaborative safety project that includes a combination of crossing closures with installing lights and gates at any of them that remain after the six grade crossings are closed by the City of Biloxi as part of the Popps Ferry Road and potential Pine Road extension projects.

Also, as a result of the Main Street grade crossing collision, the MDOT Rails Division launched a safety program in April 2017, to provide Low Ground Clearance Grade Crossing warning signs, free of charge, to road maintenance jurisdictions along the CSX rail corridor within the State of Mississippi. Beginning in April, MDOT staff began meeting with the road maintenance jurisdictions (counties, cities, townships, etc.), along the isolated 74 miles of CSX railroad tracks that run along the Gulf of Mexico from the Alabama State line to the Louisiana State line. During their meetings, they conducted an inventory of all the grade crossings to determine which crossings needed signs. With a lack of any clear national guidance for when Low Ground Clearance Grade Crossing warning signs should be installed, MDOT used the AASHTO and FHWA design guidance (±3-inches at 30-feet from the rail) as their criteria for determining if signs should be installed. For the local jurisdictions to get the signs from MDOT, they only need to submit a letter formally requesting the signs and agree to install and maintain the signs. As of February 2018, 6 of the 12 local transportation agencies eligible to receive signs under this program had submitted requests for the signs.

15. BILOXI AREA GRADE CROSSING INVENTORY

An inventory of the 29 railroad grade crossings in the City of Biloxi, plus 2 grade crossings in nearby Gulfport, Mississippi, was conducted by NTSB investigators.[54] Maps showing the location of the grade crossings can be found in **Figure 16**. Each crossing street name, crossing ID number, and railroad milepost number was recorded. Several photographs of each crossing were taken. The northbound and southbound approach grades were measured at each crossing.[55] A summary of the grade crossing inventory data is available in **Table 8**.

The crossing information collected was later compared to the current National Highway-Rail Crossing Inventory records for each of the crossings.[56] Of the 31 grade crossings examined by NTSB investigators, the space documenting the presence of Low Ground Clearance Grade Crossing warning signs (Part III, Box 2.E.) was blank on 18 of the forms.[57] Of the 18 forms that had Box 2.E. left blank, three of the crossings had Low Ground Clearance Grade Crossing warning signs posted at the crossings. Only one of the four crossings, that had Low Ground Clearance Grade Crossing warning signs, was properly documented in the National Highway-Rail Crossing Inventory.

NTSB investigators also counted the number of crossbuck assemblies at each crossing. Of the 31 grade crossings examined, the space documenting the presence of crossbuck assemblies (Part III, Box 2.A.) contained a zero on 24 of the forms. Investigators found a minimum of 2, and as many as 5, crossbuck assemblies at those 24 crossings.

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[54] The grade crossings in Gulfport, Mississippi were chosen due to their steep approach grades.

[55] Grade measurements were made using a digital inclinometer at a location where the slope appeared to be representative of the overall grade, and are therefore approximate values.

[56] See *Highway Attachment – National Highway-Rail Crossing Inventory Records for All City of Biloxi Crossings plus the Walston Avenue and Gulf Avenue Crossings in Gulfport, MS*.

[57] See *Highway Attachment – Revised National Highway-Rail Crossing Inventory Form*.

Figure 16: Map of Highway-Railroad Grade Crossings in City of Biloxi (modified from: Google Maps)

Table 8: Railroad Grade Crossing Inventory for Biloxi, MS Area

Cross Street Name	Crossing ID	RR Milepost	% Grade South of Tracks	% Grade North of Tracks	Passive vs. Active	Crossing Gates	Low Clearance Signs?
Oak Street	340177E	725.52	4.0%	7.5%	Active	Yes	No
Crawford Street	340178L	725.69	6.5%	9.5%	Active	Yes	No
Dorries Street	340179T	725.97	7.0%	4.5%	Active	Yes	No
Holley Street	340180M	726.08	7.7%	13.7%	Passive	-	No
Keller Avenue	340181U	726.17	5.8%	3.5%	Active	No	No
Lee Street	340182B	726.25	8.9%	11.4%	Active	Yes	Yes
Nixon Street	340183H	726.5	15.5%	17.6%	Passive	-	No
Main Street	340185W	726.61	6.9%	21.5%	Active	Yes	Yes
Lameuse Street	340186D	726.7	8.4%	15.8%	Active	Yes	Yes
Delauney Street	340187K	726.77	5.9%	0.9%	Passive	-	No
Magnolia Street	340189Y	726.81	8.2%	5.1%	Passive	-	No
Reynoir Street	340190T	726.89	4.2%	0.0%	Active	Yes	No
Caillavet Street	340191A	727.01	1.7%	3.5%	Active	Yes	No
Bohn Street	340193N	727.11	9.5%	5.2%	Active	Yes	No
Hopkins Boulevard	340194V	727.19	11.0%	3.7%	Active	Yes	No
Seal Avenue	340195C	727.3	10.0%	10.0%	Passive	-	No
Iroquois Street	340196J	727.36	10.7%	9.3%	Passive	-	No
Benachi Avenue	340197R	727.48	12.1%	16.4%	Active	Yes	No
Querens Avenue	340198X	727.53	14.1%	11.7%	Active	Yes	Yes
Porter Avenue	340199E	727.58	11.7%	4.5%	Active	Yes	No
Gill Avenue	340200W	727.69	8.4%	2.6%	Active	No	No
White Avenue	340202K	728.14	5.4%	8.4%	Active	Yes	No
Iberville Drive	340204Y	729.53	5.6%	6.6%	Active	Yes	No
Rodenberg Avenue	340205F	729.78	6.1%	7.5%	Active	No	No
McDonnell Avenue	340206M	730.19	10.0%	7.9%	Active	Yes	No
Veterans Avenue	340207U	730.29	4.4%	2.8%	Active	Yes	No
Iris Street	340208B	730.83	9.3%	5.1%	Active	Yes	No
Beauvoir Road	340209H	731.85	1.7%	5.6%	Active	Yes	No
Eisenhower Drive	340210C	733.02	5.1%	3.7%	Active	Yes	No
Walston Avenue - Gulfport	340216T	736.03	23.5%	12.6%	Active	Yes	No
Gulf Avenue - Gulfport	340223D	737.51	16.0%	13.0%	Active	Yes	No

16. CRASH HISTORY FOR ALL CITY OF BILOXI GRADE CROSSINGS

The FRA grade crossing accident report histories for all crossings within the City of Biloxi were examined.[58] The available reports indicated that there have been 190 collisions at the grade crossings in the City of Biloxi between June 1975, and March 2017.[59] Crashes involving passenger cars accounted for 146 of the collisions, 26 involved commercial vehicles, and 14 involved pedestrians.[60] Including the collision being investigated in this report, there were 39 reported fatal grade crossing collisions in the City of Biloxi. Five collisions involved commercial vehicles that were stalled or stuck on a crossing. A graph showing the total number of crashes and fatal crashes at the 29 grade crossings in the City of Biloxi is shown in **Figure 17**.

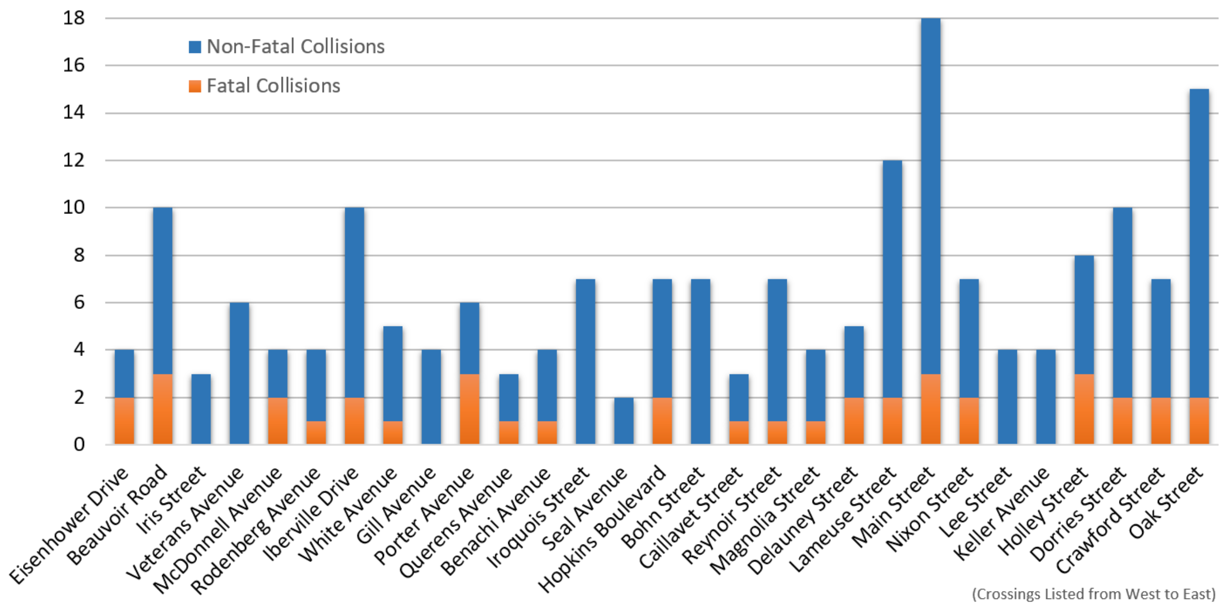

Figure 17: Collisions at City of Biloxi Grade Crossings from June 1975, to March 2017

17. INCIDENT HISTORY FOR ALL CITY OF BILOXI GRADE CROSSINGS

A review of all "Calls for Service" recorded by the CBPD and all "Trouble Tickets" recorded by CSX at each of the highway-railroad grade crossings within the City of Biloxi was conducted for the five-year period between March 2012, and March 2017.[61] These records indicated that there was a total of 44 incidents of vehicles becoming stuck on the railroad tracks at grade crossings within the City. Of these incidents, 27 occurred at the Main Street crossing; 6 occurred at the Iberville Drive crossing; 2 each occurred at the Oak Street, Lameuse Street, and Hopkins Boulevard crossings; and 1 each occurred at the Crawford Street, Magnolia Street,

[58] See *Highway Attachment – FRA Grade Crossing Accident Histories for All City of Biloxi Railroad Crossings*. The original National Highway-Rail Crossing Inventory and crash database began January 1, 1975. Reports available for the City of Biloxi crossings date back as far as June 1975.
[59] Including the March 7, 2017 collision that is the subject of this report.
[60] Four collisions involved vehicles of an unknown or unspecified type.
[61] See *Highway Attachment – CSX "Trouble Tickets" for All City of Biloxi Railroad Crossings, March 2012 – March 2017*.

Caillavet Street, Porter Avenue and Eisenhower Drive crossings. Five of the incidents resulted in collisions between a train and the vehicle stuck at the crossing. Three of these collisions occurred at the Main Street Crossing, with one each occurring at the Lee Street and McDonnell Avenue crossings.

18. FIRE TRUCK AND SCHOOL BUS CROSSING USE RESTRICTIONS

During the investigation, NTSB staff learned that both the City of Biloxi Fire Department and the Biloxi Public School District have placed restrictions on which highway-railroad grade crossings could be utilized by certain vehicles. In a Fire Department directive dated July 26, 1999, the aerial apparatus designated "Aerial-1" was restricted to only crossing the CSX railroad tracks at Oak Street, Caillavet Street, and Reynoir Street.[62]

In the summer of 2003, the transportation director for the Biloxi Public School District conducted a visual assessment of all highway-railroad grade crossings within the City to determine which crossings should be utilized by District school busses.[63] Following the 2003 assessment, certain district school busses were restricted from using the two railroad grade crossings at Querens Avenue and Benachi Avenue. Following the March 2017, collision that is the subject of this report, the transportation director conducted a more thorough assessment of all railroad grade crossings in the City.[64] Following the March 2017, assessment, district school busses are now required to avoid using the following seven grade crossings:

- Querens Avenue;
- Benachi Avenue;
- Iroquois Street;
- Lameuse Street;
- Main Street;
- Nixon Street; and
- Lee Street.

19. NATIONAL HIGHWAY-RAIL CROSSING INVENTORY

The National Highway-Rail Crossing Inventory was established in the early 1970's when the States, FHWA, National Highway Traffic Safety Administration (NHTSA), FRA, Association of American Railroads (AAR), and the American Short Line and Regional Railroad Association (ASLRRA) defined the DOT crossing inventory numbering system as well as the operating procedures and database. In 1973, the Federal-Aid Highway Act required each State to maintain an inventory of all crossings, as well as a list prioritizing crossing improvements.[65] The original inventory started on January 1, 1975, and contains both current and historical records. The FRA is the custodian of the National Highway-Rail Crossing Inventory data file; however, the inventory

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[62] See *Highway Attachment – City of Biloxi Fire Department Directive, Dated July 26, 1999*.

[63] For the purposes of the assessments conducted by the Biloxi Public School District, 30 highway-railroad grade crossings were examined. The additional crossing, Debuys Street, borders on the western edge of the City of Biloxi, and is likely utilized by district school busses. According to the National Highway-Rail Crossing Inventory, however, the Debuys Street crossing is located in Gulfport, MS, and therefore is not discussed in other parts of this report.

[64] See *Highway Attachment – Biloxi Public School District Grade Crossing Report, Dated March 15, 2017*.

[65] Federal-Aid Highway Act of 1973 - Public Law 93-87 Section 203.

is only updated with the data that is provided to the FRA from the 50 states and approximately 750 railroads. The FRA processes between 90 and 120-thousand updates each year. In 1975, the inventory contained approximately 365,000 at-grade crossings. By November 2012, that number had dropped to approximately 212,033 at-grade crossings.

The Rail Safety Improvement Act (RSIA) of 2008, required a number of actions by the FRA, including requiring mandatory reporting and updating the National Highway-Rail Crossing Inventory.[66] A Notice of Proposed Rulemaking (NPRM), that included a proposed rule, a proposed revised inventory form, a proposed revised inventory form completion guide, and draft instructions for electronic updating of the inventory was published in October 2012.[67] The final rule was published in January 2015, with a published effective date of March 9, 2015. Due to petitions for reconsideration received by the FRA, however, the actual date the rule became effective for enforcement was August 9, 2016. This rule requires railroads to submit an updated inventory form at least every three years from the date of its most recent update, or by August 9, 2016, whichever came later. Railroads are also required to update the inventory within 3 months if the crossing is: 1) sold; 2) closed; or 3) changed by the installation of a different type of crossing surface or the installation of different warning device(s). It should be noted that in most situations, the railroad is only responsible for completing certain sections of the inventory form, with State DOTs being responsible for other sections.[68]

The RSIA of 2008 also required States to submit and update crossing information as follows:[69]

> *(l) National Crossing Inventory.-*
>
> > *(1) Initial reporting of crossing information.-*
> > *Not later than 1 year after the date of enactment of the Rail Safety Improvement Act of 2008 or within 6 months or a new crossing becoming operational, whichever occurs later, each State shall report to the Secretary of Transportation current information, including information about warning devices and signage, as specified by the Secretary, concerning each previously unreported public crossing located within its borders.*
> >
> > *(2) Periodic updating of crossing information.-*
> > *On a periodic basis beginning not later than 2 years after the date of enactment of the Rail Safety Improvement Act of 2008 and on or before September 30 of every year thereafter, or as otherwise specified by the Secretary, each State shall report to the Secretary current information, including information about warning devices and signage, as specified by the Secretary, concerning each public crossing located within its borders.*

[66] RSIA of 2008 – Public Law 110-432 Section 204
[67] NPRM Docket # FRA-2011-0007
[68] See *Highway Attachment – Federal Railroad Administration Guide for Preparing U.S. DOT Crossing Inventory Forms*, for an explanation of which portions of the inventory form is to be completed by the railroads and/or the State.
[69] Title 23 U.S. Code § 130(l)

The RSIA of 2008 also required the Secretary to issue a rulemaking to require the States to update the National Highway-Rail Crossing Inventory; however, this requirement was removed in the Moving Ahead for Progress in the 21st Century Act (MAP-21).[70]

20. NATIONAL HIGHWAY-RAIL CROSSING INVENTORY OF LOW GROUND CLEARANCE CROSSINGS

Historical National Highway-Rail Crossing Inventory information was obtained for five full years preceding the crash (2012 – 2016), and for the first three months of 2017.[71] The information contained the number of public crossings, public high-profile crossings, crashes at public crossings, and crashes at high-profile public crossings for each state.[72] For a high-profile grade crossing to be included in these data sets, it first needs to meet the following requirements: 1) It must have been posted with a "Low Clearance Grade Crossing" warning sign, and 2) the existence of that warning sign must have been recorded in the National Highway-Rail Crossing Inventory. A summary of the crossing and crash data for all states, plus the District of Columbia, is shown in **Table 9**. A summary of the crossing and crash data for the State of Mississippi is shown in **Table 10**. According to MDOT, they have been working on updating their portions of the crossing inventory for all crossings within the State. They plan to keep Mississippi's crossing inventory information updated annually by using the MDOT rail inspectors performing their annual track inspections. MDOT is working on developing a mobile/tablet application to assist the rail inspectors in gather and logging the crossing inventory related information.

Table 9: Summary of High-Profile Grade Crossing and Crash Information for All States

	Total Public Crossings	High-Profile Public Crossings	Percent High-Profile Crossings	Crashes at All Public Crossings	Crashes at High-Profile Crossings	Percent of Crashes at High-Profile Crossings
2012	129,661	1,582	1.2%	1,694	35	2.1%
2013	130,308	1,618	1.2%	1,756	33	1.9%
2014	130,345	1,587	1.2%	1,942	51	2.6%
2015	130,971	1,595	1.2%	1,767	44	2.5%
2016	131,462	3,400	2.6%	1,724	57	3.3%
2017[a]	131,775	10,740	8.2%	449	45	10.0%

[a] - Crossing Data as of 3/31/2017; Crash Data is for Partial Year 1/1/2017 through 3/31/2017

[70] MAP-21 - Public Law 112-141 Section 1519(c)(6)(C).
[71] See *Highway Attachment – Historical National Highway-Rail Crossing Inventory Data, 2012 – 2017*.
[72] The grade crossing inventory data related to high-profile grade crossings is limited to public crossings. The posting of Low Ground Clearance Grade Crossing warning signs is not required to be reported to the National Highway-Rail Crossing Inventory for private crossings.

Table 10: Summary of High-Profile Grade Crossing and Crash Information for Mississippi

	Total Public Crossings	High-Profile Public Crossings	Percent High-Profile Crossings	Crashes at All Public Crossings	Crashes at High-Profile Crossings	Percent of Crashes at High-Profile Crossings
2012	2,210	6	0.3%	32	0	0.0%
2013	2,214	6	0.3%	36	0	0.0%
2014	2,212	6	0.3%	31	0	0.0%
2015	2,223	7	0.3%	28	0	0.0%
2016	2,269	20	0.9%	33	0	0.0%
2017[a]	2,283	65	2.8%	7	0	0.0%

[a] - Crossing Data as of 3/31/2017; Crash Data is for Partial Year 1/1/2017 through 3/31/2017

E. RESEARCH & TECHNOLOGY FOR IDENTIFYING AND IMPROVING SAFETY AT HIGH-PROFILE GRADE CROSSINGS

In an effort to identify dangerous and/or problematic crossings, as well as to help improve the accuracy of the National Highway-Rail Crossing Inventory, the FRA is exploring the use of rail-based grade crossing surveying and mapping.[73, 74] To accomplish this, the FRA has developed LiDAR-based grade-crossing scanning and surveying equipment, that when mounted on the FRA's DOTX 218 research vehicle (rail car), they are able to produce highly accurate three-dimensional maps of grade crossings while traveling at speeds up to 55 mph. The survey data can be used in simulation analysis to identify crossings that have a high risk for "hang-up" incidents with low-ground clearance vehicles. The mapping information can provide other safety-related information about the crossings, such as the skew angle between the highway and the railroad tracks. As the project continues, the FRA will be working to develop procedures that will integrate the mapping data into the National Highway-Rail Crossing Inventory.

In another project, the FRA has issued a research contract to investigate the feasibility of developing a Low Ground Clearance Vehicle Detection System (LGCVDS).[75] The development of this technology utilizes LiDAR and/or other sensors to model the underside of vehicles approaching a known high-profile grade crossing. As the underside of the vehicle is being modeled, it is being compared in real time to the known contours of the high-profile grade crossing. If at any point a portion of the vehicle model crosses the interference boundary that is modeling the grade crossing's profile, a "hang-up" will be detected. The detection system would be linked to a roadside alert system, which would be triggered to activate upon the detection of a potential "hang-up". This warning would provide the driver of the low ground clearance vehicle enough time to safely stop and choose an alternate route before entering the high-profile grade crossing.

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[73] P. Van Arman and L. Al-Nazer, "Automated Technology for Rail-Based Highway-Rail Grade Crossing Surveying," in *Proceedings of the 2008 IEEE/ASME Joint Rail Conference*, Wilmington, DE, 2008.
[74] "The Federal Railroad Administration's LiDAR-Based Automated Grade Crossing Survey System," U.S. Department of Transportation, Federal Railroad Administration, Research Results 16-36, August 2016.
[75] "Low Ground Clearance Vehicle Detection and Warning," U.S. Department of Transportation, Federal Railroad Administration, Research Results 15-18, June 2015.

F. DOCKET MATERIAL

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

LIST OF ATTACHMENTS

Highway Attachment – City of Biloxi Police Department Total Station Survey Data

Highway Attachment – At-Grade Railroad/Highway Crossings (Section 8-3.0) of the Mississippi Department of Transportation Roadway Design Manual

Highway Attachment – Draft Revisions to Mississippi Department of Transportation Roadway Design Manual – At-Grade Railroad/Highway Grade Crossings (Figure 6-11-C)

Highway Attachment – Land Deeds Related to Construction of Railroad and Property at Main Street Grade Crossing

Highway Attachment – Selected Pages from: 1917 Railroad Right of Way and Track Map; 1977 Main Street Improvement Plans; 1999 Main Street Improvement Survey; 2012 Infrastructure Repair Program Plans; and 2014 Infrastructure Repair Program Plans

Highway Attachment – City of Biloxi Work Orders for Main Street Through March 15, 2017

Highway Attachment – CSX Track and Crossing Maintenance Records

Highway Attachment – CSX Maintenance of Way Instructions (MWI) 901-08 – Road Crossing Installation

Highway Attachment – Terracon Core Sample Collection Report

Highway Attachment – FHWA-TFHRC Aggregate and Petrography Laboratory (APL) Report of Petrographic Analyses

Highway Attachment – Vehicle Count and Classification Data for Main Street Crossing

Highway Attachment – National Highway-Rail Crossing Inventory History for the Main Street Grade Crossing

Highway Attachment – Track Design Speed and Daily Train Volumes for Main Street Crossing

Highway Attachment –	FRA Grade Crossing Accident History for Main Street Crossing
Highway Attachment –	CSX "Trouble Tickets" for the Main Street Grade Crossing, March 2012 – March 2017
Highway Attachment –	City of Biloxi Work Order for Installation of No Trucks Selective Exclusion Signs
Highway Attachment –	City of Biloxi Work Order for Installation of Additional Low Ground Clearance Warning Signs at Main Street Crossing
Highway Attachment –	Summary Information for Potential At-Grade Crossing Closure Locations
Highway Attachment –	Biloxi City Council Resolution No. 127-17
Highway Attachment –	National Highway-Rail Crossing Inventory Records for All City of Biloxi Crossings plus the Walston Avenue and Gulf Avenue Crossings in Gulfport, MS
Highway Attachment –	Revised National Highway-Rail Crossing Inventory Form
Highway Attachment –	FRA Grade Crossing Accident Histories for All City of Biloxi Railroad Crossings
Highway Attachment –	CSX "Trouble Tickets" for All City of Biloxi Railroad Crossings, March 2012 – March 2017
Highway Attachment –	City of Biloxi Fire Department Directive, Dated July 26, 1999
Highway Attachment –	Biloxi Public School District Grade Crossing Report, Dated March 15, 2017
Highway Attachment –	Federal Railroad Administration Guide for Preparing U.S. DOT Crossing Inventory Forms
Highway Attachment –	Historical National Highway-Rail Crossing Inventory Data, 2012 – 2017

LIST OF PHOTOGRAPHS

Highway Photograph 19 – Additional Low Ground Clearance Grade Crossing Warning Sign Placed in Southwest Quadrant of Grade Crossing on March 13, 2017

Highway Photograph 20 – Porter Street Grade Crossing – Facing South-Southeast

END OF REPORT

Steven L. Prouty, P.E.
Senior Highway Engineer