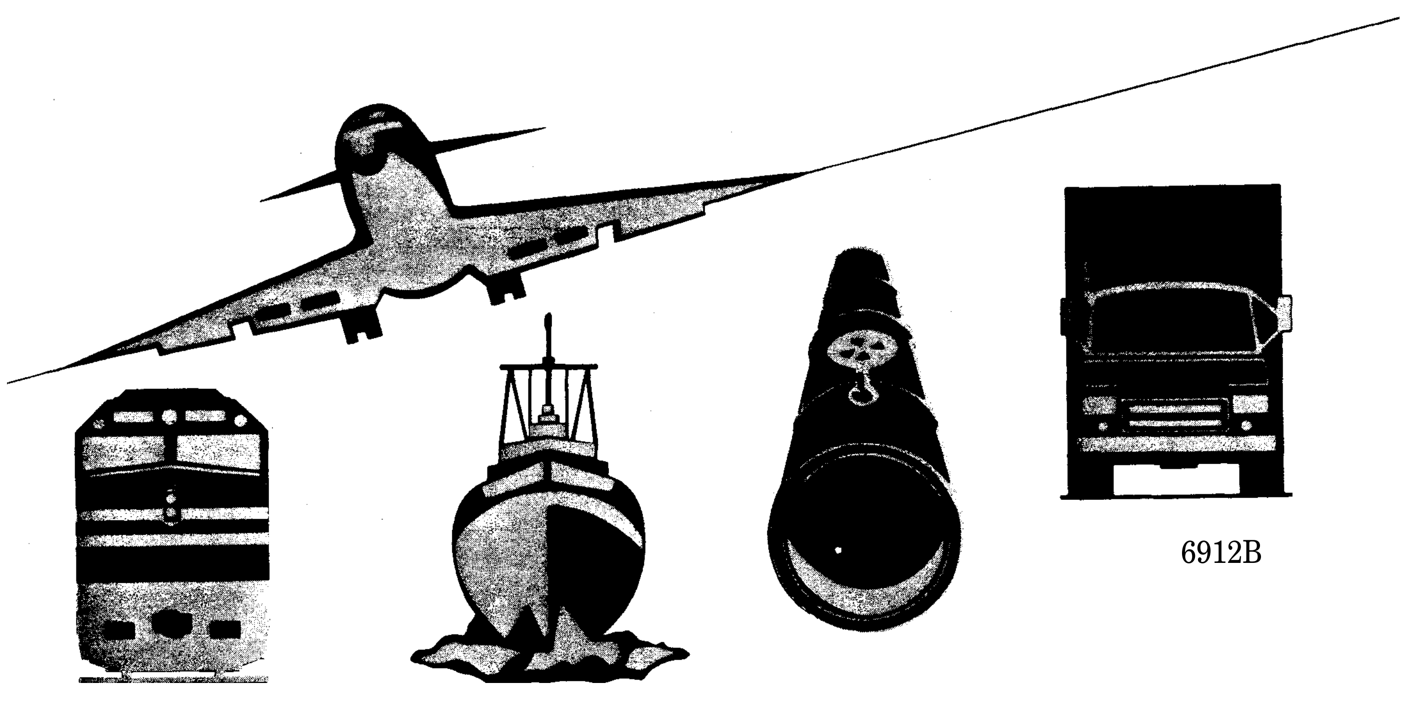
PB98-916303
NTSB/RAR-98/03

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

DERAILMENT OF AMTRAK TRAIN 4, SOUTHWEST CHIEF, ON THE BURLINGTON NORTHERN SANTA FE RAILWAY NEAR KINGMAN, ARIZONA AUGUST 9, 1997



6912B

Abstract: About 5:56 a.m., on August 9, 1997, National Railroad Passenger Corporation (Amtrak) train 4, the Southwest Chief, derailed on the Burlington Northern Santa Fe Railway tracks about 5 miles northeast of Kingman, Arizona. The engineer and assistant engineer saw a "hump" in the track as they approached bridge 504.1S. The train derailed as it crossed the bridge. Subsequent investigation revealed that the ground under the bridge's supporting structure had been washed away by a flash flood. One hundred seventy-three passengers and 10 Amtrak employees were injured. No fatalities resulted. Damages totaled about $7.2 million.

The major safety issues discussed in this report are: safety of structures subject to damage in severe storms, passenger safety and emergency response procedures, and protection of employees on or adjacent to the track in the performance of their duties.

As a result of its investigation, the National Transportation Safety Board issued recommendations to the Burlington Northern Santa Fe Corporation, the Federal Railroad Administration, the Federal Highway Administration, the Arizona Department of Transportation, Amtrak, the Mohave County Sheriff's Department, the International Association of Chiefs of Police, the National Sheriffs' Association, the Association of American Railroads, and the American Short Line and Regional Railroad Association. Also, the Safety Board reiterated one safety recommendation to the Federal Railroad Administration.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Railroad Accident Report

Derailment of Amtrak Train 4, Southwest Chief, on the Burlington Northern Santa Fe Railway near Kingman, Arizona August 9, 1997

Notation 6912B
Adopted August 31, 1998

National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington, D.C. 20594

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August 7, 2003

On August 31, 1998, the National Transportation Safety Board adopted a final report on the accident. Following the report's adoption, the Burlington Northern Santa Fe Corporation sent the Safety Board a Petition for Reconsideration, dated December 3, 1998. Based on this petition, the Safety Board reopened the investigation and contracted for additional research to be conducted by the civil engineering consulting firm Ayres Associates.

The Safety Board used the information developed by Ayres Associates to supplement the original investigation. Based on the new information, the Safety Board amended the report by adding text, revising text, and revising findings as summarized below. A concurring statement was added, and this statement is also included below.

For more information, see the full Response to Petition for Reconsideration at the Safety Board website <www.ntsb.gov>.

The following text is inserted at page 22 before the "Signals" section:

Results of Study by Ayres Associates

After the completion of its initial investigation of this accident, the Safety Board contracted with Ayres Associates of Fort Collins, Colorado, a civil engineering consulting firm, to perform additional tests and research, to include a hydraulic analysis and a hydrology study.[1] This information was used to supplement the original investigation and provide additional information on the relationship between the Burlington Northern Santa Fe Corporation railroad bridge and the ADOT highway bridge.

The tests and research assigned to Ayres Associates had two objectives:

- Reanalyze the hydrology and hydraulics and conduct a detailed scour analysis of the failure of BNSF bridge No. 504.1S near Kingman, Arizona, on August 9, 1997.
- Determine the relationship between the scour at the BNSF bridge and the ADOT reinforced concrete box (RCB) culvert located approximately 1,000 feet downstream.

[1] Ayres Associates Final Report: *Hydraulic, Erosion, and Scour Analysis of the 1997 BNSF Bridge Failure Near Kingman, Arizona.* March 2001.

As part of its work on this project, Ayers Associates developed the following timeline:

BNSF Bridge 504.1 Historical Timeline

Year	Comment
1883	Single main track constructed (now north track); consisted of 4 timber spans with total length of 37 feet.[a]
1907	Bridge 504.1N replaced on driven timber piles, bridge length 37 feet.
1922	South track and bridge 504.1S constructed on mud sills on hardpan.
1934	Hwy 66 with box culvert constructed 1,000 ± feet downstream of bridge 504.1N.
1940	Bridge 504.1N replaced; it is on driven timber pile bents; piles range from 19 to 22 feet from cutoff to pile bottom.
1940	ATSF records show a drainage area of 3.8 square miles draining to the bridge.
1954	Aerial photograph shows a headcut approximately 580 feet upstream of Hwy 66 culvert.
1958	ATSF replaces mud sills for bridge 504.1S.
1959	ATSF bridge inspector recommends putting grout and stone between spans 1 and 2. Work performed 1964.
1963	Stock tank constructed immediately upstream of bridge.
1964	Grout and stone placed between spans 1 and 2.
1966	Inspection records indicate riprap floor first placed in 1966.
1967	Aerial photograph shows a headcut approximately 690 feet upstream of Hwy 66 culvert.
1971	ADOT widens Route 66 and extends concrete box culvert 20 feet upstream.
1975	Bridge inspector first notices some erosion at the streambed under the railroad bridge.
1/2/1975	ATSF engineering department letter recommends replacing bridge 504.1 under 1977 CIP because of scouring at mud sills.
1975	ATSF bridge forces place grout and stone between spans 2 and 3.

BNSF Bridge 504.1 Historical Timeline

Year	Comment
12/9/1975	ATSF engineering calculates 19.09 square-mile drainage area.
1976	Aerial photograph shows a headcut approximately 760 feet upstream of Hwy 66 culvert.
1/13/1976	Hydraulic calculations, sketch of bridge opening, and flow line elevation with initials AAM made, flow line Elev. 3272.34 NAVD.
1/13/1976	ATSF management expresses concern about proposed concrete crosswall and removal of the bridge from the 1977 CIP.
5/18/1976	ATSF maintenance-of-way forces install concrete crosswall on downstream side of bridge.
1976	More riprap and grout placed in July; grouted riprap lined entire channel under bridge but upstream and downstream extent unknown.
5/1976	Bridge 504.1 removed from 1977 CIP.
7/24/1976	High water recorded over top rail.
7/29/1976	High water measured over 2 inches above base of bridge rail.
1978	Aerial photograph shows a headcut approximately 775 feet upstream of Hwy 66 culvert.
4/5/1987	I-90 bridge over Schoharie Cr., Albany, NY, fails killing 10 people.
4/29/1988	NTSB determines probable cause of I-90 bridge failure was severe erosion in the soil beneath the spread footing; spread footings without piles had supported the piers.
9/1988	FHWA issues TA5140.20 and “Interim Procedures for Evaluating Scour at Bridges.” TA5140.20 requires the States to evaluate all their bridges over water for scour. The interim procedures and subsequent HEC-18 states: a. Spread Footing on Soil Insure that top of the footing is below the sum of the long term degradation, contraction scour, and lateral migration. Place the bottom of the footing below the total scour line from step 4. Top of the footing can act as a local scour arrestor.

BNSF Bridge 504.1 Historical Timeline

Year	Comment
2/1991	FHWA issues HEC-18, "Evaluating Scour at Bridges," which replaces "Interim Procedures for Evaluating Scour at Bridges."
10/28/1991	FHWA issues TA5140.23, which supersedes TA5140.20.
1992	Aerial photograph shows a headcut approximately 930 feet upstream of Hwy 66 culvert, within 50 feet of crosswall.
1993	FHWA issues second edition of HEC-18.
1995	FHWA issues third edition of HEC-18.
2/18/1997	BNSF bridge inspector performs programmed bridge inspection.
7/3/1997	Aerial photograph shows a headcut approximately 930 feet upstream of the Hwy 66 culvert.
7/9/1997	BNSF bridge inspector performs bridge inspection, noting no problems.
8/9/1997	BNSF track supervisor is at bridge for special high water inspection at 4:30 a.m.; water is "lapping against bottom of bridge."
8/9/1997	Amtrak Train 4 derails while crossing bridge at 5:56 a.m.

[a]The year 1883 is listed as the year of construction for the railroad. ADOT provided the study team with an Arizona map dated 1874 that shows the Atlantic & Pacific Railroad in place, apparently on the alignment of today's BNSF railroad. It is not clear whether 1883 or 1874 or some time earlier should be stated as the railroad's construction date.

Ayres Associates conducted a hydrology study to estimate the peak discharge rates through bridge 504.1S for floods of various recurrence intervals and for the flood of August 1997 that resulted in the bridge failure. A secondary objective was to quantify the hydrologic impact of the construction of the railroad embankment in 1883. The peak discharge values developed were used to analyze potential bridge scour and as input in the hydraulic computer modeling study.

The most significant results and conclusions of the hydrology study were as follows:

- The flood-frequency relationship for bridge 504.1S was determined.
- Construction of the railroad significantly increased the peak discharge rate at the upstream side of bridge 504.1S for every recurrence interval.

- The range of plausible peak discharge values for the flood of August 1997 is from 450 cubic feet per second (cfs) to 875 cfs.
- The most probable peak discharge rate is 875 cfs, based on the box culvert high-water marks.
- The peak flow of 875 cfs is found to have a recurrence interval greater than 2 years but less than 5 years.

A bed profile and wash section survey was conducted on portions of seven channels in the vicinity of the accident site, including the channels associated with railroad bridges 501.5, 503.1, 503.7, 504.1, 505.6, 505.9, and 506.9. The purpose of the survey was to document the condition of the wash and to determine the location and extent of existing headcuts and knickpoints along the surveyed channels.

The most significant results and conclusions of the channel profiles and cross sections survey were as follows:

- Following the construction of the railroad in 1883, sheet and discontinuous channelized flows were concentrated at the railroad bridges.
- In 1934, ADOT constructed Highway 66 downstream of the railroad and placed its box culverts directly downstream of the railroad bridges. In most places, the culvert inverts (bottoms) were constructed below the invert of the channel, thus requiring excavation of the channel bed. The presence of two bridges along each drainage way resulted in the concentration of flow in the reach between the bridges causing general degradation of the channels. The placement of the Highway 66 culvert inverts below the channel bed probably produced short oversteepened reaches upstream of the culverts, causing small headcuts to form.
- The headcuts migrated upstream as flood events occurred over 63 years and helped accelerate channel incision and degradation on all the channels.
- The rate at which the headcuts progressed upstream and the rate of general degradation of the channel were dependent on the competence of the caliche. The caliche in the lower half of the reach between the bridge 504.1 and Highway 66 RCB culvert 4217 was less erosion resistant and allowed a relatively rapid progression of degradation and upstream headcut migration.
- Channel incision, the upstream progression of headcuts, and the downstream extension of the channels below the highway were caused primarily by flow concentration at both the railroad and Highway 66.
- It is likely that if the highway had not been built, flow concentration at the railroad bridge would still have resulted in the downstream

extension of the channel, which was already evident in the 1939 railroad ravine section. The general degradation that produced the downstream extension of the channel below the railroad bridge would have eventually extended beyond the erosion-resistant caliche. Once the degrading channel extended beyond the erosion-resistant caliche, a headcut would have developed that would then have migrated upstream and caused bridge 504.1S to fail.

- The stock tanks and grading activities in the watershed above bridge 504.1 had no significant effect on the incision of the channel or the failure of bridge 504.1.

A geotechnical investigation was conducted to determine the extent and variability of the caliche along channel 504.1. The most significant results and conclusions of the geotechnical investigation were as follows:

- The caliche horizon within the study area is variable in extent, thickness, degree of cementation, and resistance to erosion by flowing water.
- Based on the blow count data from the borings, there is a significant reduction in the hardness of the caliche near U.S. Highway 66. This is also verified by observations in the channel banks and in the pit and trench excavations, and by the results of the erodibility tests made at Texas A&M and Colorado State Universities.
- The caliche horizon near the upstream end of the Highway 66 box culvert is neither hard nor uniform. It is highly erodible.
- The caliche horizon is more resistant to erosion in the area upstream of and just downstream of the railroad bridge.
- Erosion of the caliche horizon is by surface shear from flowing water, plunging flow, and the undermining of the competent portion by erosion of the weaker underlying sediments. The undermined competent portion of the caliche horizon fails by gravity.

Total scour at a bridge is the combination of long-term degradation of the streambed, general scour of the stream channel under the bridge, and local scour at the piers and abutments. The measurements of the three components are added together to obtain the total scour at a pier or abutment. A scour study was conducted to determine:

- The relative importance and role of each of the three components of scour;
- The morphology of the channel, and human impacts on the morphology;
- The significance of the type of bridge foundations used;

- The interaction between bridge No. 504.1 and the U.S. Highway 66 box culvert (RCB culvert 4217) downstream;
- The importance of the crosswall downstream of bridge 504.1, and the cause of the failure of the crosswall; and
- The importance of the stock tank just upstream of the bridge.

The most significant results and conclusions of the scour study were as follows:

- The grouted riprap that was placed on the streambed under bridge 504.1N and 504.1S apparently had sufficient thickness, rock size, and binding to protect the piers from local scour.
- Assuming that the grouted riprap covered the channel bed beneath the bridge, as indicated by BNSF personnel, there was no contraction scour beneath the bridge deck in the August 1997 flood because the area was protected by grouted riprap.
- The August 1997 flood might have caused as much as 3.3 feet of local scour at the crosswall if the peak discharge rate was 450 cfs and as much as 5.6 feet if the peak discharge rate was 875 cfs. Either of these scour depths could have caused failure of the crosswall. The local scour downstream of the crosswall might not have attained its full depth because of the underlying caliche. The caliche at the location of the crosswall was highly resistant to erosion but was still erodible.
- A combination of long-term degradation and local scour downstream of the crosswall caused the crosswall to fail. Its failure allowed the long-term degradation of the streambed to undermine the grouted riprap, which was protecting the shallow mudsill foundations of the bents. The undermining of the grouted riprap allowed the foundations of bents 3, 4, and 5 to be undermined and to fail.
- Incision of the channel crossed by bridge 504.1 was initiated when the railroad was constructed in 1883. The construction of RCB culvert 4217 probably accelerated the long-term degradation, but it also formed an elevation control, which will limit the ultimate depth of degradation at bridge 504.1. Long-term degradation in this channel has occurred by headcut migration in the upstream direction and by gradual channel lowering progressing in the downstream direction.
- Without direct profile or photographic evidence from the late 1930s, it is difficult to conclusively determine the importance of the excavation of the channel at Highway 66 in the formation of the headcut that contributed to the failure of bridge 504.1.

- The construction of the crosswall and the placing of grouted riprap up to 20 inches thick across the bed under bridge 504.1 reveal that ATSF/BNSF personnel knew the bridge was vulnerable to scour.
- The stock tanks and grading activities in the watershed above bridge 504.1 had no significant effect on the incision of the channel or the failure of bridge 504.1.

The Ayres Associates study team conducted one-dimensional hydraulic analyses in order to clarify the impacts and relative importance of the railroad and Highway 66 on the morphology of the channel downstream of bridge 504.1.

The most significant results and conclusions of the hydraulic computer modeling study were as follows:

- The construction of the railroad in 1883 increased the velocity and erosion potential in the channel downstream from bridge 504.1 by increasing the drainage area (relevant for 2-year and smaller floods) and by constricting the flow to the width of the bridge opening (relevant for all floods). Because of the gradual rate of re-expansion downstream of the bridge (an assumption whose validity can be verified only by site observation of flooding or by two-dimensional modeling), the increase in velocity extended downstream beyond the present-day location of Highway 66.
- The construction of Highway 66 in 1934 caused an increase in velocity downstream of the box culvert for all discharge rates, leading to a markedly increased erosion potential downstream of the highway. Upstream of the box culvert, the highway embankment caused backwater, leading to reduced velocities and erosion potential, for discharges equal to and greater than the 5-year peak. For smaller flows, the excavation of the streambed, and the resulting oversteepened reach just upstream of the box culvert, led to locally increased velocities and a hydraulic jump. The higher velocities and hydraulic jump almost certainly led to significant scour upstream of the box culvert. If the conditions in the model are representative of the post-highway condition, they could definitely have led to the initiation of the headcut that is observable moving upstream toward the bridge in the historic aerial photographs.
- The excavation to place the culvert was and is a common practice. When the invert of a culvert is depressed below the natural channel grade, it is now advisable to consider the possible need for erosion protection in the oversteepened reach just upstream of the culvert.
- If the bottom of the box culvert had been placed at the existing channel grade, the potential for erosion upstream of the culvert would have been reduced, rather than increased, for all discharge

rates. The maximum velocity downstream of the box culvert, however, would not have been any less under these alternative conditions than under the actual conditions.

- There was little or no impact on the erosion or morphology of the channel imposed by the widening of Highway 66 in 1971.

[ORIGINAL REPORT TEXT RESUMES AT THIS POINT.]

The text beginning on page 60 is revised as follows:

~~However, the BNSF report did not include ADOT bridge inspection data or pictures of the streambed dating back to 1971, information that would have been helpful in determining the relationship between the box culverts and the railroad bridges. The Safety Board therefore concludes that the relationship of the two structures and their respective zones of influence is not fully understood.~~ The relationship between the U.S. Highway 66 box culvert and railroad bridge 504.1 is complex. Bridge 504.1, built in 1883, concentrated overland sheet flow into a single drainage course. The concentrated flow had more sediment transport capacity than the upland sheet flow and began to erode a channel at the railroad bridge. With time, the channel increased in size and progressed downstream. In the early years, the flow partially re-expanded downstream of the railroad bridge.

Highway 66, built in 1934, 1,000 feet downstream from the bridge, re-concentrated the flow that had re-expanded downstream of the railroad bridge. The concentrated flow through the box culvert accelerated channel incision downstream of the culvert. The bottom of the box culvert was set about 2 feet lower than the level of the existing swale.

The excavation to place the box culvert probably left a short, steep reach of streambed just upstream of the culvert. This could have initiated the headcut that the aerial photographs show moving upstream from 1954 to 1997 and that eventually contributed to the failure of the crosswall downstream of bridge 504.1.

Unfortunately, the available aerial photographs date back only to 1954, and no detailed channel bed profiles just upstream of the highway are available from the period just after the construction of the highway. Without direct profile and photographic evidence from the late 1930s, it is difficult to precisely determine the importance of the box culvert channel excavation in the formation of the headcut.

The box culvert also provided a positive benefit to the channel. The concrete floor of box culvert 4217 is now an elevation control point that will limit the ultimate depth of the long-term channel incision and degradation at the bridge. Had ADOT constructed a bridge on piles at this location instead of a box culvert, the ultimate degradation at the railroad bridge would have been deeper.

The Safety Board therefore concludes that both the railroad construction in 1883 and highway construction in 1934 concentrated the overland flow of water and accelerated erosion of the ephemeral streambed. The headcut that contributed to the failure of the crosswall and railroad bridge may have originated at the highway bridge after construction of U.S. Highway 66 in 1934; the upstream progression of the headcut was primarily caused by flow concentration between the railroad bridge and the highway bridge.

The American Association of State Highway and Transportation Officials provides guidelines for highway bridge construction.[2] The association's 1931 guide, "Standard Specifications for Highway Bridges and Incidental Structures," advises that

> a careful study shall be made of local conditions, including flood height and flow, size and performance of other openings in the vicinity carrying the same stream, characteristics of the channel and of the watershed area, climatic conditions, available rainfall records and any other information pertinent to the problem and likely to affect the safety or economy of the structure.

However, ADOT reported that it did not have any hydrology studies or hydraulic design documents from the initial bridge construction in 1934 or from the widening project in 1971. The construction drawings do have annotations denoting drainage areas, but no calculation sheets or other evidence was provided to demonstrate how those numbers were derived. According to ADOT, the highway bridge was performing well in 1971 and there was no reason to change the size of the waterway opening;[3] therefore, no hydrologic or hydraulic studies were needed prior to the roadway-widening project in 1971. ADOT also reported that since the accident, it has completed studies confirming that the highway bridge culverts are adequately sized and designed. However, the Safety Board believes that an opportunity was missed in 1971 when ADOT did not carry out comprehensive studies that would have identified the already existing upstream channel deterioration and that could have prompted ADOT and ATSF efforts to assess the interaction between the bridges and develop strategies to address erosion problems.

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[2] Before the 1970s, this organization was known as the American Association of State Highway Officials.

[3] According to ADOT, the highway bridges along this stretch of highway were not designed to deal with heavy flooding and, in fact, water has crossed above the highway in the area of the subject bridge several times since 1934. The 1969 "Standard Specifications for Highway Bridges" published by the American Association of State Highway Officials states that, "On wide flood plains, the lowering of approach fills to provide overflow sections designed to pass unusual floods over the highway is a means of preventing loss of structures."

In 1975, the ATSF engineering department recommended that the railroad bridge be replaced because of concerns about the bridge's ability to provide an adequate waterway opening and recurring erosion problems. Although the bridge was not replaced, records in 1976 indicate the addition of riprap along the streambed and a concrete crosswall downstream of the bridge. Therefore, the railroad also had an opportunity to communicate with ADOT and develop joint strategies to address erosion problems. Nevertheless, the railroad was aware of the vulnerability of the bridge and should have closely monitored erosion in the vicinity and taken whatever measures were necessary to ensure safe operations. Although a track supervisor conducted a track inspection during the severe weather and flooding on the morning of the accident, he was not qualified to conduct bridge inspections, and no restrictions were placed on train speeds.

The additional information developed by the Ayres Associates' study reinforces the finding that an adequate bridge inspection could have detected risk to the bridge. According to the historical photographs, at the time the crosswall was constructed, the headcut that threatened the bridges was about 240 feet away. For at least the 5 years preceding the south bridge failure (1992–1997), the headcut was about 80 feet from the bridge and less than 50 feet from the crosswall.

The railroad bridge concentrated the water flow to form a channel, which would erode and deepen over time even if the highway bridge/box culverts did not exist. Although both structures accelerated erosion of the streambed, it is the owner's responsibility to monitor and ensure a bridge's structural integrity against the effects of erosion, including headcuts or any other changes that may arise over time. Therefore, the Safety Board concludes that regardless of the cause of the headcut, Burlington Northern Santa Fe Railway and its predecessors were aware of the erosion problems affecting the railroad bridge and had ample opportunity over the years to detect the headcut and take appropriate remedial action. Moreover, the railroad decided not to replace the bridge in its 1977 Capital Improvement Program as recommended by its engineering department in 1975, reflecting that department's concern about the bridge's ability to provide an adequate waterway opening and recurring erosion problems.

[ORIGINAL REPORT TEXT RESUMES AT THIS POINT.]

Finding 8 on page 75 is deleted and a new finding 8 is inserted as follows:

8. ~~The relationship of the highway box culverts and the railroad bridges and their respective zones of influence is not fully understood.~~ Both the railroad construction in 1883 and highway construction in 1934 concentrated the overland flow of water and accelerated erosion of the ephemeral streambed. The headcut that contributed to the failure of the crosswall and railroad bridge

may have originated at the highway bridge after construction of U.S. Highway 66 in 1934; the upstream progression of the headcut was primarily caused by flow concentration between the railroad bridge and the highway bridge.

A new finding 9 is inserted on page 75 as follows:

9. Regardless of the cause of the headcut, Burlington Northern Santa Fe Railway and its predecessors were aware of the erosion problems affecting the railroad bridge and had ample opportunity over the years to detect the headcut and take appropriate remedial action. Moreover, the railroad decided not to replace the bridge in its 1977 Capital Improvement Program as recommended by its engineering department in 1975, reflecting that department's concern about the bridge's ability to provide an adequate waterway opening and recurring erosion problems.

[EXISTING FINDING 9 IS RENUMBERED TO FINDING 10 AND SUCCESSIVE FINDINGS ARE RESPECTIVELY RENUMBERED.]

The National Transportation Safety Board, consisting of Chairman Ellen G. Engleman, Vice Chairman Mark V. Rosenker, and Members John J. Goglia, Carol J. Carmody, and Richard F. Healing, approved the Response to Petition for Reconsideration. A concurring statement was filed with the Response to Petition for Reconsideration. Consequently, the following text is inserted on page 79 immediately following the report adoption date.

On July 31, 2003, as part of the National Transportation Safety Board's response to a December 3, 1998, petition for reconsideration submitted by the Burlington Northern Santa Fe Corporation, John J. Goglia, Member, filed the following statement concurring with the Safety Board's response. Richard F. Healing, Member, joined Member Goglia in this opinion.

Notation 6912E

Member GOGLIA, concurring:

Based on the information in the docket, I believe we should have included in the contributing causes of this accident the Arizona Department of Transportation's (ADOT's) failure to react (for years) to the erosion that was progressing toward the railroad property. It is also interesting to note (and in contrast to ADOT's inaction, the BNSF's action) that on the upstream side of the railroad property the same type of erosion is occurring, yet the railroad (as a responsible landowner) has for some time taken actions to prevent this erosion from reaching the adjacent property.

Contents

Executive Summary

About 5:56 a.m., on August 9, 1997, National Railroad Passenger Corporation (Amtrak) train 4, the Southwest Chief, derailed on the Burlington Northern Santa Fe Railway tracks about 5 miles northeast of Kingman, Arizona. Amtrak train 4 was en route from Los Angeles, California, to Chicago, Illinois, and had just left the Kingman station. The train was traveling about 89 mph on the eastbound track when both the engineer and assistant engineer saw a "hump" in the track as they approached bridge 504.1S. They applied the train's emergency brakes. The train derailed as it crossed the bridge. Subsequent investigation revealed that the ground under the bridge's supporting structure had been washed away by a flash flood.

Of the 294 passengers and 18 Amtrak employees on the train, 173 passengers and 10 Amtrak employees were injured. No fatalities resulted from the accident. The damages were estimated to total approximately $7.2 million.

The National Transportation Safety Board determines that the probable cause of this accident was displacement of the track due to the erosion and scouring of the inadequately protected shallow foundations supporting bridge 504.1S during a severe flash flood because the Burlington Northern Santa Fe management had not provided adequate protection, either by inspection or altering train speeds to fit conditions. Contributing to the accident was the failure of the Burlington Northern Santa Fe management to adequately address the erosion problems at bridge 504.1S.

The major safety issues identified in this report are:

- Safety of structures subject to damage in severe storms,
- Passenger safety and emergency response procedures, and
- Protection of employees on or adjacent to the track in the performance of their duties.

As a result of this accident investigation, the Safety Board makes recommendations to the Burlington Northern Santa Fe Corporation, the Federal Railroad Administration, the Federal Highway Administration, the Arizona Department of Transportation, the National Railroad Passenger Corporation (Amtrak), the Mohave County Sheriff's Department, the International Association of Chiefs of Police, the National Sheriffs' Association, the Association of American Railroads, and the American Short Line and Regional Railroad Association. Also, the Safety Board reiterates one safety recommendation to the Federal Railroad Administration.

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Factual Information

The Accident

Synopsis

About 5:56 a.m.,[1] on August 9, 1997, National Railroad Passenger Corporation (Amtrak) train 4, the Southwest Chief, derailed on the Burlington Northern Santa Fe Railway (BNSF)[2] tracks about 5 miles northeast of Kingman, Arizona. Amtrak train 4 was en route from Los Angeles, California, to Chicago, Illinois, and had just left the Kingman station when the accident occurred. The train was traveling about 89 mph on the eastbound track when both the engineer and assistant engineer saw a “hump” in the track as they approached bridge 504.1S.[3] They stated that they applied the train’s emergency brakes. It was later discovered that the ground under the bridge supporting structure had washed away during a flash flood.

Train 4 had a four-unit locomotive, one baggage car, nine passenger cars, and six material handling cars (MHCs). As the train passed over bridge 504.1S, the first three locomotive units uncoupled and separated from the rest of the train and each other, each unit coming to a stop east of the derailed train. The fourth unit remained coupled to the train.

The third and fourth units, including all but the last car, derailed in the upright position. Although some cars were at a slight angle to each other and leaning, all cars remained coupled and generally aligned with the track. The tenth car, a sleeping car, came to rest spanning what had been the track at the location of bridge 504.1S. (See figure 1 for an aerial view, looking south, of the Kingman accident site. Figures 2 and 3 show, respectively, a map and a schematic of the derailment site.)

[1] Kingman, Arizona, is in the mountain time zone but does not change to daylight savings time. The times referenced in this report will be in accordance with the time used by the railroad for the local time, mountain daylight time (MDT), unless noted.

[2] The BNSF resulted from the October 1, 1995, merger of the former Burlington Northern Railroad and the former Atchison, Topeka and Santa Fe Railway. The mainline segment through Kingman was part of the former Atchison, Topeka and Santa Fe Railway.

[3] The BNSF designates bridges by their milepost (MP) numbers. There are two separate bridges at MP 504.1; one for the eastbound track and another for the westbound track. The bridges are designated by the BNSF as the south and north bridges, respectively. This report will designate them as bridge 504.1S (for the eastbound track) and bridge 504.1N (for the westbound track).

Figure 1. Aerial view of the derailment site, looking south

Figure 2. Map of the derailment site

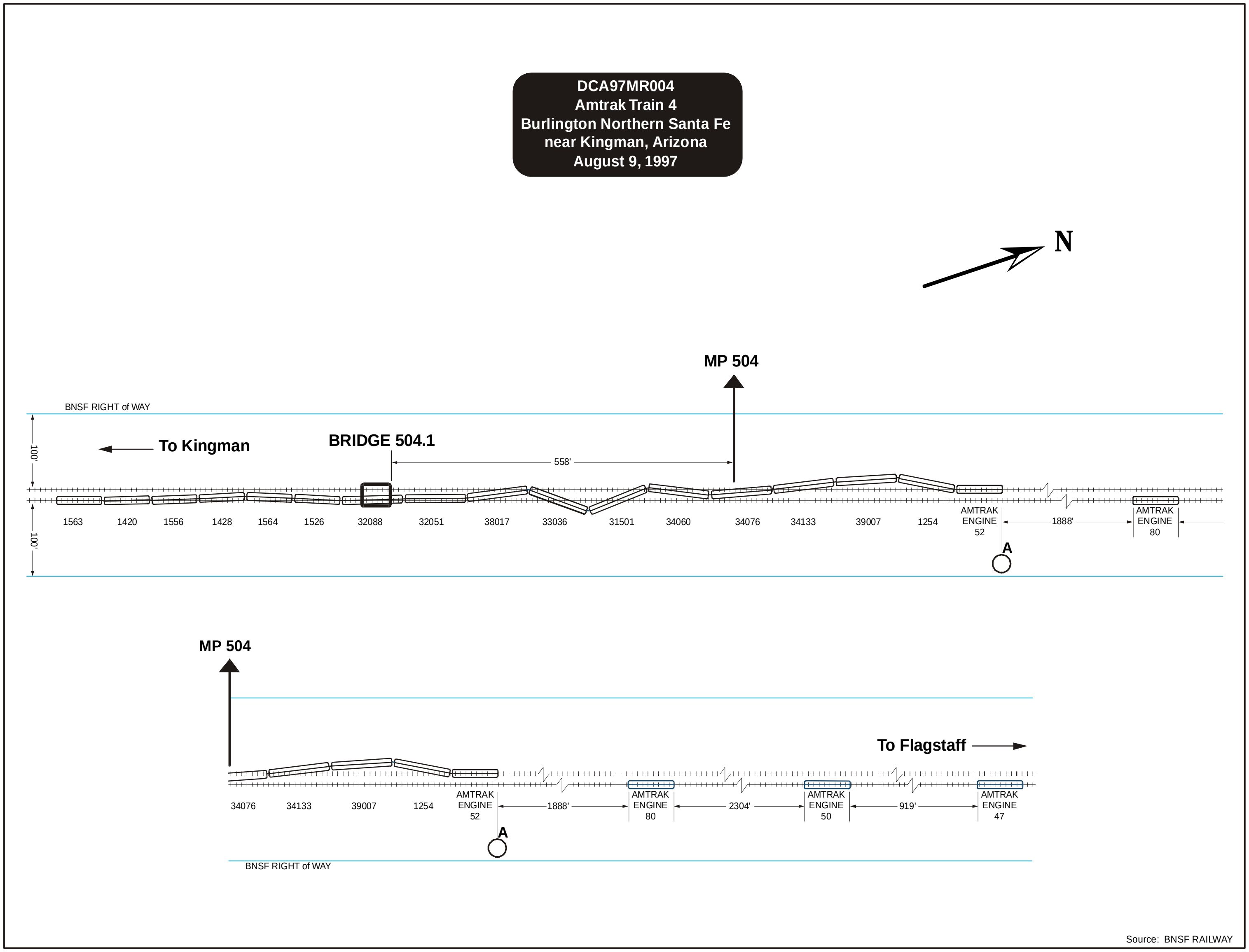

Figure 3. Schematic of the derailment site

Preaccident Events

At 12:06 a.m. August 9, the BNSF contract weather forecasting service issued a potential severe weather alert for the Kingman area, followed by an update at 12:52 a.m. At 1:43 a.m., the BNSF received a flash flood warning for the Kingman area from its contract weather forecasting service. The warning estimated that 2 inches of rain had already fallen over this stretch of track and that rain was still falling at a rate of about 1 inch per hour. In response to the warning, the BNSF Network Operations Center (NOC) arranged for a track supervisor to be called about 1:57 a.m. The track supervisor was instructed to inspect the track in his assigned area, which included the eastbound and westbound tracks east of Kingman, including the accident site.

About 4:05 a.m., the track supervisor began his inspection at MP 516.5, traveling by hy-rail vehicle eastward on the eastbound track. He stopped at and inspected three bridges west of the bridges at MP 504.1. He said that he got out of his vehicle to inspect each of these bridges. He said he did not note anything unusual.

Between 4:30 and 4:45 a.m., the track supervisor stopped at bridge 504.1S. He made his observations at this bridge without getting out of his vehicle. He later stated that he saw water flowing adjacent to and under the bridge from the south side, but that he did not note anything unusual about the track alignment or take exception to either the eastbound or westbound bridge. He stated that a light rain was falling at the time. Shortly after 5:35 a.m., the BNSF freight train B-CHCLAC1-05 passed over the westbound bridge, bridge 504.1N. The train crewmembers did not note anything unusual about either bridge from their positions in the locomotive.

The track supervisor finished the special inspection of his territory at 6:01 a.m. He was about 40 miles east of Kingman when he heard the train dispatcher communicating with someone over the radio about an Amtrak train derailing at bridge 504.1S. (See figure 4 for a photo of the water flow under the bridge immediately after the derailment took place.)

Postaccident Events

About 5:56 a.m., the BNSF NOC received a radio communication from the engineer of Amtrak train 4 informing it of the train’s derailment and its location. The NOC passed the information on to its Resource Operations Center (ROC) and a BNSF special agent, who notified the Mohave County Sheriff’s Department at 6:01 a.m.

Also about 5:56 a.m., the Mohave County Sheriff’s Department received a 911 call from a local resident reporting a train derailment. Three officers, who were already in the immediate area (searching for people who were reportedly stranded because of flash flooding), were dispatched to the scene and arrived at 6:05 a.m. Later, a Mohave County Sheriff’s Department lieutenant arrived on scene and assumed the duties of Incident Commander.

Figure 4. Flow of water under bridge 504.1S after the derailment

At 6:06 a.m., the Mohave County Sheriff's Department requested a medical response to the derailment from the Kingman Fire Department. About 6:15 a.m., a paramedic unit, a rescue unit, and a 4x4 brush engine arrived. A rescue unit from the Hualapai Fire Department was already on scene.

About 6:15 a.m., the Kingman Regional Medical Center was notified by the Mohave County Sheriff's Department dispatcher of the derailment and told that it involved about 300 people. The hospital activated its emergency plan, calling nurses and emergency room personnel to report to the hospital. Medical supplies, nurses, Red Cross personnel, and volunteers were sent to the Kingman Junior High School to assist passengers after they had gone through triage. At 6:17 a.m., the Kingman Fire Department requested mutual aid assistance from the Valley Vista, Golden Valley, and Pinion Pines fire departments.

By 6:20 a.m., the first of three Arizona Department of Public Safety helicopters arrived on scene. Two military helicopters from Nellis Air Force Base arrived on scene later with a flight surgeon and medical crew. At 6:30 a.m., a medical command post was set up next to the treatment and triage area. School buses were used to transport people with minor to moderate (or no) injuries to the local hospital and the Kingman Junior High School, which was used as a shelter for passengers and crew.

About 6:56 a.m., injured people began arriving at the hospital by helicopters, ambulances, and buses. Over 100 people were treated. The last person was admitted to the hospital at 11 a.m. Thirty-four injured people were transported to Bullhead Community Hospital, Las Vegas University Medical Center, Flagstaff Regional Medical Center, John C. Lincoln Hospital North Mountain, and Las Vegas Valley Hospital.

By 8 a.m., about 230 people had been transported from the scene. BNSF personnel, emergency medical services (EMS) personnel, and some passengers helped throughout the response. Shortly after 9 a.m., the last person was transported from the scene.

(A chronology of the entire accident event sequence appears in appendix B.)

Injuries

Table 1 is based on the injury criteria of the International Civil Aviation Organization.[4]

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[4] 49 *Code of Federal Regulations* (CFR) 830.2 defines *fatal injury* as "Any injury which results in death within 30 days of the accident" and *serious injury* as an injury that "(1) Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface."

Table 1. Injuries

	Train Crew	Passengers	Total
Fatal	0	0	0
Serious	1	24	25
Minor	9	149*	158
None	8	121	129
Total	18	294	312

*On December 5, 1997, Amtrak submitted documentation compiled by its Claims Department to the Safety Board that listed 40 reported injuries that had not been included in the medical records compiled by 6 area hospitals within 24 hours of the accident.

Damage

The BNSF and Amtrak provided the damage estimate information used in table 2.

Table 2. Damage

Equipment: Locomotives	$ 400,000
Equipment: Cars	$ 5,627,400
Track	$ 454,000
Structures	$ 681,000
Signal/Communications	$ 17,000
Engineering and Other	$ 42,000
Total	$ 7,221,400

Amtrak Train 4

The train came to rest with the last passenger car, sleeping car 32088, bridging the gap of the collapsed bridge 504.1S. The last locomotive unit, ATK 52, and the rest of the cars remained coupled. The three locomotive units that uncoupled from the train came to rest with the lead locomotive unit, ATK 47, about 5,263 feet beyond ATK 52; the second unit, ATK 50, about 4,268 feet beyond ATK 52; and the third unit, ATK 80, about 1,888 feet beyond ATK 52. All but the first two locomotive units and the last car derailed. All cars derailed upright with the passenger cars at shallow angles to each other.

Damage to the locomotive units and cars affected the end vestibule and diaphragm, coupler and coupler pocket, and undercar-mounted equipment. A rail penetrated the 4th locomotive unit, ATK 52, from its front, exited through the rear, and extended 19 feet into the first baggage car, ATK 1425. The rail penetrated below the floor level of ATK 52 through the top of the fuel tank; no significant amount of diesel fuel was lost. Several passenger cars had structural body damage to their exteriors, consisting of bent or buckled ends. All passenger cars sustained damage to the underside mid-section areas, which rendered the service lighting, emergency lighting, and public address system inoperable. Amtrak considered car ATK 31501, the 6th car in the train, a possible total loss. The supporting trucks on five of the six MHC cars had to be rebuilt. (Figures 5 and 6 show, respectively, overall damage to the north side of the train and typical damage to a single coach.)

Track, Structures, and Signals

Damage to the track required the replacement of 5,390 feet of 136-pound continuous welded rail (CWR), which comprised 3,650 feet on the south track and 1,740 feet on the north track. Bridge 504.1S was destroyed. It was subsequently replaced with three 20-foot prestressed concrete spans on steel H-pile bents. Bridge 504.1N sustained less extensive derailment damage but was replaced when bridge 504.1S was replaced with three 20-foot prestressed concrete spans on steel H-pile bents to provide the same waterway opening for the parallel bridges. Signal and telecommunications damages and costs were incidental to the track damage.

Personnel Information

Amtrak Train 4 Crew

The operating train crew consisted of an engineer, an assistant engineer, a conductor, and two assistant conductors. All five crewmembers had completed their mandatory off-duty time, as required by Federal Railroad Administration (FRA) regulations, and all were qualified on the operating rules and the area’s physical characteristics to operate passenger trains over this territory. During the interviews with Safety Board investigators, all five said that they had felt well rested on the morning of the accident and that they had had no physical problems before the accident.

Engineer. The engineer of train 4, age 52, began work in the railroad industry in 1967 with the former Chicago, Burlington and Quincy Railroad. He became a brakeman in 1969, and was promoted to engineer in 1973. In August 1987, he went to work for Amtrak as an engineer. On the day of the accident, he was working as the locomotive engineer on his regular assignment. He became certified to operate over the Kingman territory in October 1996 and had worked over that territory for about 7 months. On his latest Amtrak locomotive engineer evaluation, March 25, 1997, his supervisor had noted that he was a “thorough engineer.” He had no record of any disciplinary actions.

Figure 5. Damage to the north side of Amtrak train 4

Figure 6. Damage typical to Amtrak train 4 coaches

His last physical examination took place in July 1997, and it determined that he was in good health. He wears glasses and has stated that he has some hearing problems that he believes do not affect his ability to operate a train safely. He stated that he is not required to wear a hearing aid. He was taking a prescription nasal spray prescribed by his physician. He stated that his physician had said it was not necessary to obtain company approval to take this medication, so he did not obtain written approval.

According to statements he made to investigators, on Thursday, August 7, 1997, the engineer awoke about 8 a.m. and spent the day at home doing chores. He traveled to Kingman on Thursday night and arrived at 3:18 a.m. He went to sleep and awoke at 8:30 a.m. on Friday. He was not on duty during the day and spent it doing miscellaneous activities. On Friday night, he went to bed between 6 and 7 p.m. and slept until about 2 or 2:30 a.m. He stated that he awoke Saturday morning feeling rested and went on duty at 4:12 a.m. at Kingman.

Assistant Engineer. The assistant engineer, age 53, began railroad work in August 1972 with the former Southern Railroad as a switchman. In 1974, he was promoted to engineer. In 1987, he went to work as an engineer for Amtrak. He became qualified to work over the Kingman territory in March 1997, and he had worked over that territory for almost 7 months when the accident took place. He was not assigned to a specific train and worked as an extra board employee.[5] On the day of the accident, he was working as the assistant engineer. On his last Amtrak locomotive engineer evaluation, dated January 15, 1997, his supervisor noted that he displayed good trainhandling skills. His employee record showed three instances of disciplinary action involving suspension for operating rules violations: a STOP signal violation (30 days in 1988); a switch operating violation (5 days in 1989); and his train occupying a track without dispatcher authority (30 days in 1993).

His last physical examination took place in December 1996, and it showed that he was in good health. He wears glasses while operating the train. He reported some hearing loss that does not require the use of a hearing aid. He stated that he was not taking any medications at the time of the accident.

According to his statements, the assistant engineer reported for work on Thursday at 4:33 p.m. and departed Albuquerque, New Mexico, for Kingman at 6:30 p.m. He arrived on Friday morning about 3:18 a.m., went to a hotel, and went to bed. He said he awoke Friday morning about 11:30 a.m., felt relaxed and took a nap during the day, and went to bed Friday night about 8 p.m. He slept until 12:30 a.m. Saturday morning and went on duty at 4:12 a.m. in Kingman.

Conductor. The conductor, age 54, began railroad work in May 1964 on the former Penn Central Railroad as a road freight conductor. He began working for Amtrak in April 1986 as a conductor. He became qualified to work over the Kingman territory in November 1995 and had worked over the territory for about 1½ years. On the day of the

[5] An extra board employee is a qualified employee not working a regularly assigned position.

accident, he was working his regular assignment, which he had worked for about a week. He had no record of any disciplinary actions.

His last physical examination took place in March 1995, and it showed that he was in good health. He wears glasses for reading. He told investigators that he has suffered some hearing loss (he does not wear a hearing aid). He stated that he was not taking any medications at the time of the accident.

The conductor said he awoke about 7 a.m. on Thursday and did some work around the house. He arrived at the train station in Albuquerque about 3:26 p.m. and traveled to Kingman. He arrived at 3:18 a.m. Friday morning and slept from 4 a.m. to about 6:30 a.m. He reported that he went to breakfast, later napped for about 2 hours, and spent the rest of the day in town. On Friday night, he went to sleep about 6:30 p.m., awoke about 2 a.m., and reported for duty about 4:27 a.m. in Kingman.

Assistant Conductors. One assistant conductor, age 46, began railroad work in August 1974 as a brakeman with the former Denver and Rio Grande Western Railroad. He started working for Amtrak in April 1989 as a conductor. He was working the extra board on train 4, and he had worked over this territory for 3 weeks. He had no record of disciplinary actions. His last physical examination took place in November 1995, and it showed that he was in good health. He wears glasses and, according to him, has “bad” hearing but does not wear hearing aids. He was taking the prescription medications Norflex and Tranxene (muscle relaxers) to help him sleep; he had received company approval to use these medications.

On Thursday, the assistant conductor awoke about 10 a.m. and reported for duty about 4 p.m. He traveled from Albuquerque to Kingman and arrived about 3:18 a.m. on Friday. He slept from about 4:15 a.m. until about 10:15 a.m., then spent the remainder of the day in town. He went to bed between 7 and 8 p.m. and slept until 2:30 a.m. Saturday morning. He went on duty at 4:27 a.m.

The other assistant conductor, age 51, began working for the railroad industry in 1966 with the former Atchison, Topeka and Santa Fe Railway (ATSF); he left and returned on different occasions to attend college until 1973. In 1973, he began working as a switchman; he was promoted to conductor in 1976. He started working for Amtrak in 1987. His last physical examination, in April 1996, found that he was in good health. He worked over this territory on and off for several years and had been assigned to this job for a couple months before the accident. He became qualified to work over the Kingman territory in August 1987 and had worked this territory intermittently for several years. He had no record of disciplinary actions. He awoke Saturday morning about 2:45 a.m. and reported for duty at 4:27 a.m.

BNSF Personnel Information

The BNSF policy at the time of the accident was to use local track inspectors to perform emergency inspections within their areas.[6] Performing an emergency inspection included observing track and bridge conditions for the movement of trains. The BNSF designates track inspectors in accordance with the qualifications prescribed in the FRA's track safety standards at 49 CFR 213.7. The BNSF also has bridge inspectors who are assigned by territory to perform normal bridge inspections. According to the BNSF, because of the number of bridges and the size of the territories, bridge inspectors do not normally perform emergency inspections unless the inspector is in the area requiring the emergency inspection.

Track Supervisor. The track supervisor, age 44, began his railroad career on the former ATSF in January 1979 as a trackman in San Bernardino, California. He worked as a heavy equipment operator in 1981. That year he also became a student foreman, a position he filled until 1987. He later gained additional experience while working as a foreman in other miscellaneous assignments. In 1995, he became an assistant roadmaster with the Navajo System steel gang. On July 31, 1995, he started working in his current position as a track supervisor. One of his responsibilities as track supervisor was track inspection. His training for track inspection included a 4-week program in Albuquerque, New Mexico, that provided instruction on track charts, rules, and standards, as well as railroad maintenance and safety. He received additional on-the-job training and experience while working on other assignments.

The track supervisor's bridge inspection training was primarily on the job; he stated that his knowledge was gained through conversations with bridge inspectors about their duties and responsibilities. He had not received any formal classroom training in bridge inspection, bridge maintenance, or high-water inspection. The BNSF formal training course for Maintenance of Way Track Foremen and Inspectors does not contain a section on bridge inspections.

The track supervisor reported that he worked on Friday until 4 p.m. He went home (he lives in the Kingman area near the BNSF tracks) and did household chores and took a nap from 5 until 8 p.m. He stayed around the house and then went back to sleep at 10 p.m. About 1:57 a.m., he was awakened by a phone call from the BNSF maintenance-of-way dispatch desk in Fort Worth, informing him of heavy rain between Pica (MP 446.9) and Hackberry ["Berry"] (MP 509.4) in part of his territory and instructing him to inspect the track in his area (MP 473 to MP 516.5). Had he not been called to perform an emergency inspection, the track supervisor would have supervised a project about 4 a.m. that morning.

Bridge Inspector. The bridge inspector for the Kingman area, age 56, began working for the former ATSF in March 1968 as a bridge helper. In 1969, he became a bridge foreman; in September 1976, he became a bridge inspector. He had about 200

[6] In this instance, a track supervisor, who was a qualified track inspector, performed the inspection.

bridges on his territory, including the bridges at MP 504.1. He was responsible for performing an inspection twice a year on each bridge, culvert, and other drainage structures in the territory. He had no specific training to become a bridge inspector, only that experience gained on the job. He had attended several company training sessions on bridge inspection and welding. There are no State or Federal requirements for training or qualifications of railroad bridge inspectors.

The bridge inspector was on vacation when the accident occurred. He stated that, had he been called to inspect bridges in the Kingman area at this time, it would have taken him at least 4 1/2 hours to drive there from his home, which was located 296 miles from Kingman.

Train Information

Train 4 was assembled at Amtrak’s Redondo Junction facility at Los Angeles, California. FRA initial terminal air brake tests and mechanical inspections were performed by Amtrak mechanical forces about 2 p.m., Pacific daylight time, on August 8, 1997. Locomotive daily inspections were also performed. The tests included cab signal and automatic train stop tests, which were completed without any noted defects. (The next locomotive daily inspection was scheduled to have taken place at the next crew change point, Albuquerque, New Mexico. The train was to have received an FRA-required 1,000-mile intermediate inspection upon arrival at Kansas City, Missouri.) Beyond the initial tests and inspections, no other mechanical tests or inspections were performed on the train before the accident, nor were any due.

The locomotive consist of train 4 had four P42-8DC, General Electric (GE) diesel electric units, built in 1997 (ATKs 47, 50, 80, and 52, respectively). The passenger equipment consisted of one Heritage class baggage car, followed by a Superliner transition dormitory sleeping car for the on-board service personnel, a Superliner II coach, two Superliner I coaches, another Superliner coach, a Superliner II Sightseer Lounge, a Superliner I dining car, a Superliner I sleeping car, and a Superliner II sleeping car (32088), followed by six MHCs.

A review of locomotive maintenance records revealed no anomalies. The on-site inspection found that the air brake manifolds of several cars had been knocked off in the derailment with under-bottom damage. This damage prevented the performance of any air brake tests.

Track, Structures, and Signal Information

Track

The accident site is located about 12.3 railroad miles east of Kingman, Arizona. The BNSF tracks through the accident area are within the Peacock Mountain range in the Hualapai Valley flood plain. The general terrain is flat desert land with several dry gullies that cross under the tracks and the adjacent highway, Arizona State Route 66 (Route 66).

The two main tracks in the accident area are designated as the north track (signaled for westbound trains) and the south track (signaled for eastbound trains). Railroad MPs are in descending order from west to east. The Kingman station is at MP 516.4 and the accident occurred at MP 504.1. The track was straight from MP 512 to MP 504. The south track gradient from Kingman to Getz (MP 513.9) was ascending for eastward trains on a 1.0 to 1.5 percent gradient; from Getz to the accident site, the track was descending for eastward trains from a maximum of 1.0 (MP 512 to MP 511) to 0.06 percent at the bridges at MP 504.1.

The BNSF maintains the track to meet or exceed the minimum requirements of the FRA Track Safety Standards for Class 5 track, contained in 49 CFR 213. The FRA Class 5 designation provides maximum allowable operating speeds of 80 mph for freight trains and 90 mph for passenger trains. The minimum track inspection frequency required by Class 5 standards is twice a week with 1 calendar day between inspections. The track had last been inspected on August 6, with no defects noted. The most recent track geometry test for track alignment, gauge, and surface was on July 16, with no defects noted in the accident area. A contractor performed the latest ultrasonic rail tests for determining rail integrity on August 6, with no defects noted in the accident area. Both tests were performed within the prescribed timeframes of 49 CFR 213.

The south track in the area of the derailment was constructed with 136-pound CWR. The rail was manufactured by Colorado Fuel & Iron and installed new in 1984. The rail rested in 7-inch by 14-inch double shoulder tie plates, secured to timber crossties with three to four track spikes per tie plate. Longitudinal movement of the rail was restricted by the application of base-applied drive-on rail anchors applied to every other tie. Track ballast consisted of 2-inch stone ballast with the shoulders maintained to 12 inches beyond the end of the tie.

Structures

The BNSF bridge involved in the derailment was located at MP 504.1. The railroad through the derailment site was originally constructed as a single main track, now the north track, in 1883, by the ATSF. In 1922, the south track and bridge were constructed. The bridges on both tracks at MP 504.1 are identified by the BNSF as bridge 504.1, but the two bridges are structurally independent of each other.

BNSF bridge records indicate that the system has 250 timber-framed bent bridges. Of these bridges, 143 are similar in construction to bridge 504.1S, which is a structure founded on timber mud sills[7] on erodible soils or rock. Of these 143 bridges, 80 are located on FRA Class 4 (or higher) track on which passenger trains operate. The other 63 of the 143 bridges are, with the exception of 1 bridge, located on secondary main lines or branch lines. The 107 timber-framed bent BNSF bridges dissimilar in construction to bridge 504.1S are either on pilings, on concrete footings in rock, or located over paved roadways or concrete-lined channels.

Bridge 504.1S. The bridge was a treated timber trestle with four 9-foot spans supporting a ballast deck spanning a total length of 37 feet, 2 inches. The trestle was made of: two end framed bents[8] and three intermediate framed bents, each consisting of five round timber posts of 12 inches in diameter; one timber cap,[9] 12 inches wide by 14 inches deep by 14 feet long; and one timber sill, 12 inches by 12 inches by 16 feet, resting on timber footer blocks, 6 3/4 inches by 10 3/4 inches by 32 inches, packed tightly side by side, forming a mud sill 32 inches by 16 feet. The mud sill rested on “hard pan”[10] soil and was buried about 12 inches in an upper layer of soil and concrete slurry.

Each intermediate framed bent was braced laterally with two diagonal lateral sway timber braces; each brace extended from a top corner to the opposite bottom corner of the framed bent. The bridge was braced longitudinally by four timber struts, or “hog jaws,” from the top of each end framed bent to the sill of the adjacent intermediate framed bent.

The bridge deck was made of 3-inch by 10-inch transverse deck planks. At each edge of the deck was a 6-inch by 6-inch timber stringer below the deck planks and a timber ballast curb 32 inches high with approximately 3 feet of stone ballast. The bridge had a “free board” (bottom of bridge to bottom of streambed) of 76 inches and a center height (base of rail to bottom of streambed) of 111 inches. (See figure 7 for a terminology guide for a timber-bent bridge supported on timber blocking.)

Bridge 504.1N. The existing bridge was built in 1940 to replace a bridge built in 1907, which had replaced the original 1883 bridge. The existing bridge was a ballast-deck treated-timber trestle with T-rail stringers on driven-timber pile bents.

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[7] A mud sill is a single piece of timber or a unit composed of two or more timbers placed upon a soil foundation as a support for a single column, a framed trestle bent, or another similar member of a structure.

[8] A framed bent is a framed supporting unit of a trestle made up of two or more timbers as columns connected at their topmost ends by a cap.

[9] The cap is the topmost piece of a framed timber bent, which serves to distribute loads upon the piles and to hold them in their proper relative positions.

[10] Hard pan is a layer of hard soil cemented by almost insoluble materials that restrict the downward movement of water.

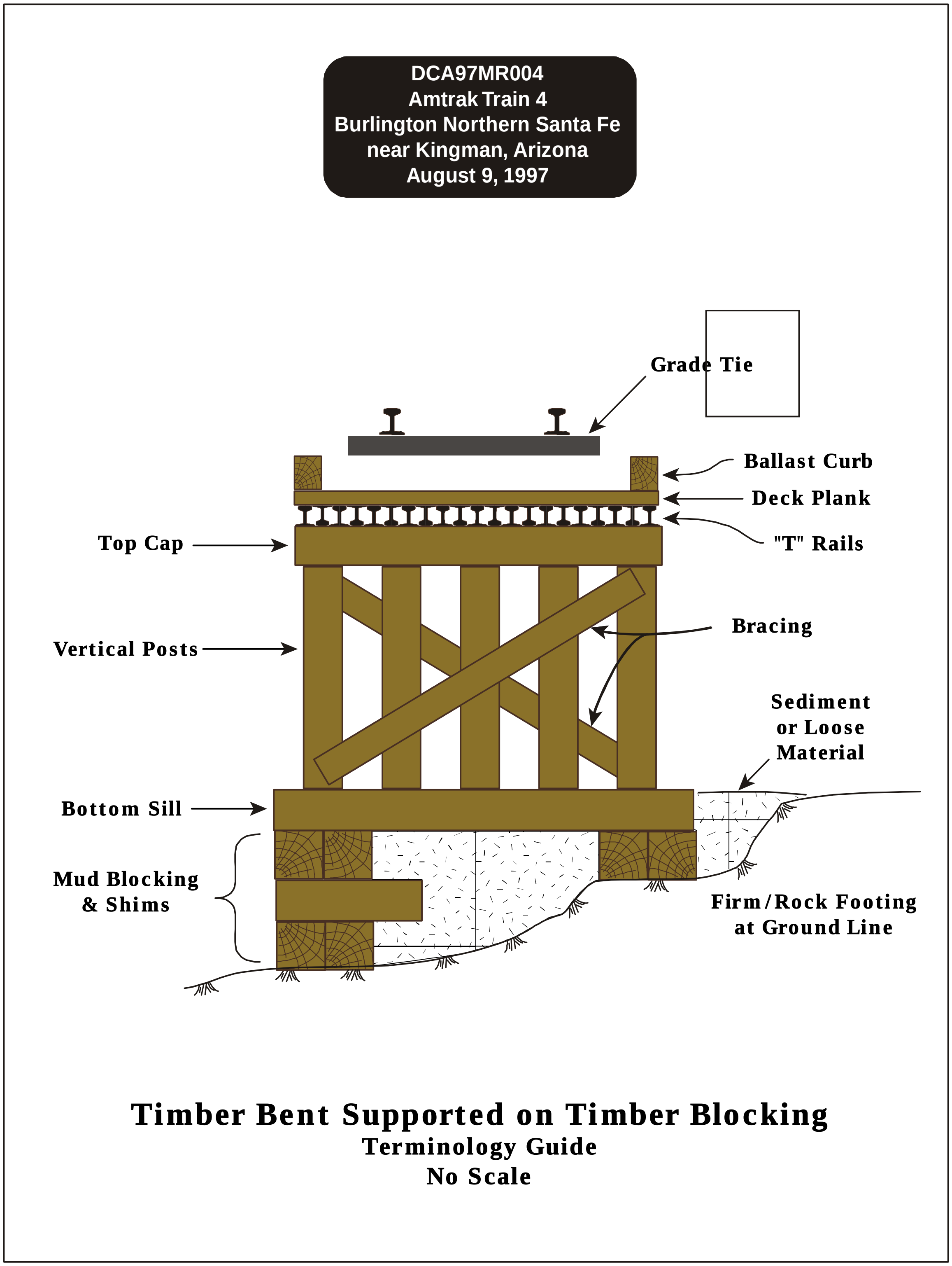

Figure 7. Guide to terms for timber-bent bridges supported on timber blocking

The overall length of the bridge was 37 feet, 2 inches; it was made of four spans with nominal span lengths of 9 feet, 3 inches each. Each of the five bents, numbered 1 through 5 from east to west, had five timber piles ranging from 19 to 22 feet from the cutoff to the pile bottom. On each framed bent was a 12-inch by 14-inch cap supporting stringers made from 90-pound steel T-rail. Six live-load T-rail stringers were centered under each running rail, and one T-rail stringer was outboard of each running rail. The T-rail stringers were secondhand rails that weighed 90 pounds per yard and were approximately 10 and 28 feet long, respectively. Each long stringer spanned three of the four panels, and each short stringer spanned one panel. The short and long stringers were interlaced over framed bents numbered 2 and 4.

The deck of bridge 504.1N was made of 3-inch by 10-inch transverse deck planks. At each edge of the deck was a 6-inch by 6-inch timber stringer below the deck planks and a ballast curb of two timbers: one 6 inches by 10 inches on the deck planks and a second 6-inch by 12-inch curb timber above the first. The track rested on approximately 24 inches of stone ballast.

Bridge 504.1S Maintenance and Inspection

Railroad documents dated 1975 showed that the bridges at 504.1 served a drainage area of 19.09 square miles. However, an ATSF document from 1940 showed that, during the 1940 renewal of the north track bridge (504.1N), the drainage area was calculated to be 3.80 square miles. Although the documents showed that a waterway opening of 267.0 square feet was required, versus the existing 174.8 square feet, they noted that no scouring[11] had occurred at either end of the bridge, and that the present opening was larger than the 120-square-foot opening under Route 66, which was located about 1,000 feet downstream to the north.

Maintenance records showed that the mud sills were replaced in 1958. In 1959, the bridge inspector recommended grouting the water path and adding stones between spans 1 and 2. This work was performed in 1964.

During 1971, the State of Arizona widened Route 66 and extended the concrete box culvert downstream from BNSF bridge 504.1. (See figure 8 for a photo of the box culvert.) The original concrete box culvert had been built in 1936. Following the accident, Safety Board investigators observed evidence of streambed erosion between the highway box culvert and bridge 504.1.

[11] Scour is the result of the erosive action of running water excavating and carrying away material from the bed and banks of streams. Different materials scour at different rates. Loose granular soils are rapidly eroded under water action while cohesive cemented soils are more scour resistant. (From *Underwater Inspection of Bridges*, FHWA-DP-80-1, November 1989.)

Figure 8. Highway box culvert downstream from bridge 504.1

A January 1975 ATSF internal memo discussed the replacement of bridge 504.1 for the 1977 Capital Improvement Program (CIP), stating that replacement was needed "due to scouring of the mud blocks for the bridge under the eastbound main track [bridge 504.1S]." Based on its calculations of the larger drainage area, the ATSF believed that a "structure several times larger than the existing bridge" would be required. The memo then stated:

> Under the circumstances, it is suggested we place a concrete crosswall downstream from the bridge in order that the streambed will silt in behind the crosswall covering the mud blocks. <u>As a matter of information we have already arranged to place the crosswall and in our opinion, this bridge will now last several more years.</u> In as much as the bridge is not capable of handling its runoff, the water now presently runs in an easterly direction adjacent to the track to the next structure.

By December 1975, additional grouted stone was placed at spans 2 and 3 because of the noted scour at the mud sills. A January 13, 1976, handwritten document from ATSF management stated, with regard to the proposed concrete crosswall and removal of bridge 504.1 from the 1977 CIP budget list, that this approach was not the appropriate way to address existing concerns. In May 1976, ATSF maintenance-of-way employees installed a 38-foot-long unreinforced concrete crosswall, 16 inches thick and 30 inches deep, about 17 feet downstream from the north side of the bridge. At this time, the bridge was removed from the 1977 budget list for replacement.

The BNSF bridge inspection program requires an annual inspection, with intermediate inspections to be conducted as needed. The last programmed bridge inspection took place on February 18, 1997. Another bridge inspection was conducted by the bridge inspector on July 9, 1997. During these inspections, no exceptions were taken to the condition of the bridge structure. In addition, no scouring was reported at the crosswall or the supporting mud sills at the timber bridge framed bents. (Table 3 summarizes the history of bridge 504.1S.)

Table 3. Summary of noted events at bridge 504.1S

Date	Events
1922	ATSF builds second track bridge (504.1S) south of existing bridge (504.1N).
1936	State of Arizona constructs Route 66 with box culverts, one 1,000 feet downstream from bridge 504.1.
1940	ATSF bridge records show 3.8 square miles drainage area.
1958	ATSF bridge forces replace mud sills.
1959	ATSF bridge inspector recommends putting grout and stone between spans 1 and 2.
1964	ATSF bridge forces place grout and stone between spans 1 and 2.
1971	State of Arizona widens Route 66 and extends the concrete box culverts.
1/2/75	ATSF engineering department letter recommends replacing bridge 504.1 under 1977 CIP because of scouring at mud sills.
1975	ATSF bridge forces place grout and stone between spans 2 and 3.
12/9/75	ATSF engineering calculates 19.09 square miles drainage area.
1/13/76	ATSF engineering department letter expresses concern about proposed concrete crosswall and removal of the bridge from the 1977 CIP.
5/18/76	ATSF maintenance-of-way forces install concrete crosswall.
May 1976	Bridge 504.1 removed from 1977 CIP.
7/24/76	High water recorded over top of rail on bridge.
7/29/76	High water measured at 2 inches above base of bridge rail.
2/18/97	BNSF bridge inspector performs last programmed bridge inspection.
7/9/97	BNSF bridge inspector performs last bridge inspection, noting no problems.
4:30 a.m. 8/9/97	BNSF track supervisor is at bridge for special high water inspection.
5:56 a.m. 8/9/97	Amtrak train 4 derails while crossing bridge.

About 3:30 a.m. on August 9, before beginning inspection of sections of his assigned track, including the eastbound and westbound tracks east of Kingman, the track supervisor contacted the dispatcher to obtain an eastbound train "informational line-up."[12] The dispatcher informed him that a hold had been placed on Amtrak train 4 at Griffith (MP 526.8). The dispatcher was not required to take this precaution, but the track supervisor understood it would provide an extra measure of protection for him. He began his on-track inspection at MP 516.5 about 4:05 a.m. His inspection took place in the dark while it was raining. He stated that he rode eastbound in a hy-rail vehicle (traveling about 15 to 20 mph) on the south track and looked for water running alongside the track, making sure it was not going over the track or scouring the ballast. He later told investigators that while traveling over bridges, he specifically looks at the tracks' gauge, line, and surface to determine whether there is trouble on the bridge. He said he pays closer attention to the bridge if water is running underneath it.

The track supervisor stated that, when beginning his inspection on the day of the accident, he observed a "greater" volume of fast-moving water running alongside the track near MP 510; it was an area where he had not seen it before. About 4:30 a.m., he stopped and got out of the hy-rail vehicle at three bridges west of bridge 504.1. At the first location where he saw water flowing underneath a bridge (507.4), he got out of his hy-rail vehicle and checked the earth around the bridge's framed bents. He repeated this procedure for the next two bridges where water had accumulated (bridges 507.3 and 505.9). Between 4:30 and 4:45 a.m., he arrived at bridge 504.1 and observed "a greater portion of water coming from the south side of the south track" from behind him, and that "a smaller portion of water was coming from in front" of him. He stated, "That's the first time that I saw that volume of water under that particular bridge." The water was "lapping against the bottom of the bridge." He did not think the volume was excessive. The water was moving rapidly, and he believed it was already subsiding. He stated that the best indicator he had of any problem was "the line gauge and surface of the track structure." As to inspecting the bridge for scour problems, he stated that "I knew from experience that what—that I was looking for anything out of the ordinary—and at the time the knowledge that I had—I took no exception to anything I observed." He did not get out of his hy-rail vehicle to inspect bridge 504.1, as he had at the other bridges.

When the track supervisor was at Truxton, MP 477.3, the dispatcher told the track supervisor that he was releasing Amtrak train 4 through Griffith and that he would let the track supervisor know when Amtrak train 4 was leaving Kingman. (Truxton is about 50 miles from Griffith.) The dispatcher informed the track supervisor when he was about 5 minutes from Peach Springs (MP 465.8) that Amtrak train 4 had left Kingman. By this time, the track supervisor had completed his inspection and had not found any abnormalities resulting from the storm. The rain had ceased by the end of his inspection.

[12] The term "informational line-up" refers to a list of trains and their approximate locations obtained from the train dispatcher and used to clear on-track equipment. Line-ups provide information to railroad personnel on the number, time, and location of trains at designated station or terminal points on the railroad for a particular track segment. They are usually valid for up to 4 hours; however, they are subject to change due to train traffic conditions.

While he was getting off the track at Peach Springs at 6:01 a.m., he overheard radio communications about the derailment.

The track supervisor stated that he had been on this job since July 31, 1995, and had only made special inspections because of heavy rain once or twice (in 1996). This was the first such occasion in 1997. He stated that “Based on what I—at that time I felt completely 100-percent confident that my railroad was able to support traffic of any nature after I had made the inspection.” He estimated that the 40 miles of territory he covered contained about 50 bridges.

For BNSF track inspectors performing special inspections for high water, the ATSF instructions, which were dated October 27, 1995, and still in effect for the BNSF, addressed special inspections in Section 82: *Track Inspection - Chief Engineer’s Instructions*, part 82.6 “Special Inspections.” These instructions state, in part:

82.6.1 High Water

Perform these inspections during heavy rain or flooding:

1. Inspect the track for the following:

- Washouts
- Scour
- Surface irregularities
- Water over the rail

2. Inspect drainage structures for the following:

- Erosion behind dump planks and headwalls and around piers and footings
- Obstructions from drift and debris

The only recorded instances of high water for the Kingman area took place on July 24, 1976, when a roadmaster recorded high water over the top of the rail on the bridges at MP 504.1, and on July 29, 1976, when a roadmaster measured high water at 2 inches above the base of the rail. No accidents involving high water or bridge failure were recorded for the Kingman area.

Signals

The signal system in the accident area is an automatic block signal (ABS) system, arranged for train movement with the current of traffic (signaled in one direction) and supplemented by an automatic train stop (ATS) system. The ABS extends about 97 miles from control point (CP) 526.9 to West Seligman, MP 429.8, on double track, and it has color light signals controlled by Electro Code Model 4 electronics track circuits. The BNSF designates the tracks as follows: (1) north track for westward train movements; and (2) south track for eastward train movements. A failed equipment detector (FED) is located at MP 512.5 and a high water detector (HWD) is at bridge 505.9. (See Tests and Research.)

Signals on the south track (for eastward train movements) are numbered according to railroad MPs and end with a numeral 2. Signals on the north track (for westward train movements) are also identified by MPs, but they end with a numeral 1. (See figure 9.)

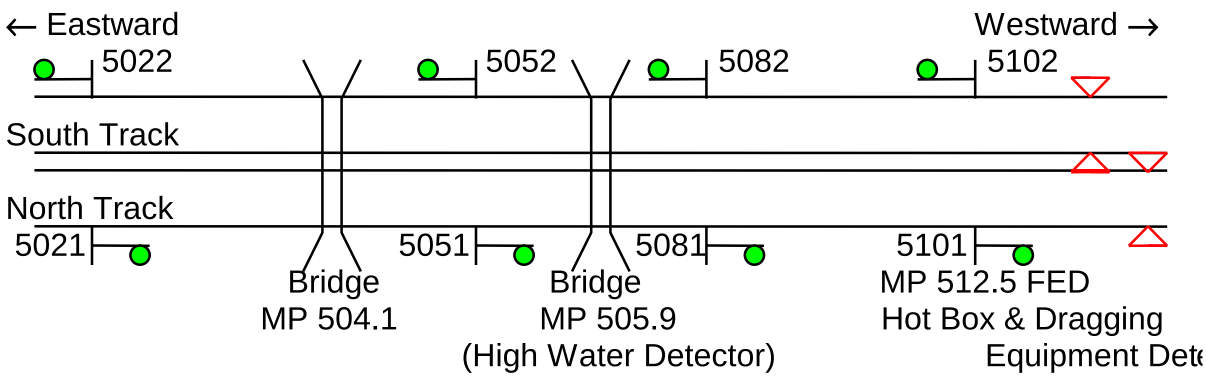

Figure 9. Signal system layout

Operations Information

Amtrak/BNSF Train Operations

The accident occurred on the south main track on the Seligman West Subdivision, Arizona Division of the BNSF. Train operations are governed by the General Code of Operating Rules, Timetable No. 1, dated August 1, 1996, and by special instructions. Train movements are controlled by the signal indications of an ABS system. Amtrak passenger trains operating over this territory are equipped with ATS systems configured to allow them to operate at the maximum permissible speed of 90 mph. The maximum permissible speed for freight trains is 70 mph.

The ATS feature is designed so that a penalty brake application will occur if the engineer does not activate a button when passing a wayside signal. The object is to enforce the observance of restricting indications of a wayside signal by requiring the engineer to “acknowledge” (depressing a button) when passing signals displaying such indications. “Restricting indications” include all signal indications other than a CLEAR or proceed signal. If the engineer fails to acknowledge such a restrictive indication, the train will automatically stop.

All four locomotive units were equipped with event recording devices. The data from the event recorders were downloaded on scene to provide a preliminary readout, which indicated that the train was proceeding at about 89 to 90 mph, with the throttle in the no. 3 position and the brakes fully released when the brake pipe pressure decreased from 110 to 0 psi. The data further indicated that a trainline-induced emergency (TLEM)[13] occurred first, followed by an engineer-induced emergency (EIE) about 3 to 5 seconds later. The automatic brake handle changed from the released position to the emergency position about the same time that the EIE took place.

Amtrak train 4 was scheduled to depart Kingman at 4:57 a.m., but for BNSF operational reasons (reported as "other trains") during its trip from Los Angeles, California, it arrived late. It left Griffith (MP 526.8) at 5:24 a.m.

BNSF Operations Center

The BNSF directs all train movements from its operations center in Fort Worth, Texas. The train dispatcher directing train movements for the Seligman West Subdivision works from the operations center and plans, directs, and monitors train movements at a DigiCon®[14] Centralized Traffic Control (CTC) system. From this location, the dispatcher can also communicate with all trains within his assigned area.

Before the accident, the BNSF did not have a formal method for instructing dispatchers about their responsibilities in the event of a flash flood warning. On August 10, 1997, the BNSF issued a "Maintenance Alert" that specified procedures relating to possible flash floods. (For the complete Maintenance Alert, see appendix C.) The BNSF provided a comparison of the "before accident" and "after accident" responsibilities of the dispatcher as follows:

August 8, 1997, instructions

> When possible flash flooding conditions were reported, Engineering Department Personnel were contacted and instructed to patrol track. While no specific restrictions were placed on train operation, if track inspection revealed a dangerous condition, the train dispatcher was to require trains to stop and examine track before movement was authorized. If a train arrived where an inspection was being made before the inspection was complete, the train would be held until maintenance personnel determined that track conditions at that particular location were safe for movement.

August 9, 1997, instructions

> In addition to the procedures outlined above, train crews are instructed that the following will also apply when notified that flash flood warning conditions exist:

[13] A TLEM means that the emergency brake was applied by some means other than the automatic brake handle or the "fireman's" emergency brake valve.

[14] Digital Concepts provided the DigiCon® system that is in use on the former ATSF.

> Passenger trains will operate at restricted speed.[15]
>
> All other trains will operate at a maximum speed of 40 mph.
>
> These restrictions will apply during the time and limits stated in the flash flood warning.

At 12:06 a.m. on August 9, the BNSF operations center service interruption desk received its first alert of potential severe weather from its contract weather service. The alert was of thunderstorms and heavy rain on the Seligman subdivision. This notification was followed by an update at 12:52 a.m. (Alert 0000).[16] According to the BNSF, the manager of the service interruption desk distributes the printed information to the train dispatcher, the train dispatcher's supervisor, the chief dispatcher or manager of corridor operations, the corridor superintendent, the maintenance-of-way desk, and other managers. Table 4 (next page) provides a chronology of weather-related events concerning the Kingman accident. All events cited took place on August 9, 1997.

Protection for Employees During Special Inspections

When the decision was made to have the track in the Kingman area inspected because of the flash flood warning, the train dispatcher on duty placed a restrictive label on the approach to Griffith because a track inspector was out ahead of Amtrak train 4 on the informational line-up. The restrictive label was noted through the CTC DigiCon® system and would have prevented the dispatcher from requesting a more favorable signal than STOP for Amtrak train 4 to move eastward. Amtrak train 4 was not held at Griffith because the track supervisor did not report any problems to the train dispatcher before the turnover to the next dispatcher occurred (at about 5:40 a.m.). This information was given to the train dispatcher who was on duty when the accident occurred, and the restrictive label was removed.

The second dispatcher told investigators that a track supervisor inspecting track would call him only if the track supervisor had something to report. Otherwise, the dispatcher might not hear again from the track supervisor after providing him an informational line-up. Because he received no reports of adverse conditions from the track supervisor, the dispatcher saw no reason not to run Amtrak train 4 into the track limits behind the track supervisor. In addition, he stated that no restrictions would have been placed on the train as long as the track supervisor was ahead of the train and had not issued a report requiring a train movement restriction. The dispatcher further stated that before the Kingman accident no restrictions were issued to trains for flash flood warnings.

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[15] Rule 6.27 of the BNSF General Code of Operating Rules defines "restricted speed" for the engineer of a train as being able to stop within half the range of vision: short of train, engine, railroad car, men or equipment fouling the track, stop signal, or derail or switch lined improperly, on the lookout for broken rail, and not exceeding 20 mph.

[16] See Meteorological Information section.

Table 4. Weather-related events and information

Time (a.m.)	Events before the accident
1:43	BNSF receives flash flood warning (0001) for the Kingman area.
1:57	Track supervisor for Kingman area is notified.
2:24	National Weather Service issues severe thunderstorm and flash flood warning for central Mohave County, effective until 3:30 a.m. Also, before 3 a.m., weather updates (0002 and 0003) are issued to BNSF, including to “watch for flash flooding,” effective until 4:30 a.m.
3:39	Crewmembers of westbound train Q-LACMEM1-08 report to the BNSF train dispatcher that the rain is letting up at Walapai (MP 501.3), and that they saw water in the culverts.
3:56	Train Q-LACMEM1-08 crewmembers at MP 489.7 report to the train dispatcher that there is no water on the ground and only “trickles” in the ditch.
4:05	The track supervisor begins his special inspection at MP 516.5, moving in an eastward direction.
4:12	Dispatcher tells track supervisor of Q-LACMEM1-08 information.
4:28	Contract weather service issues update 0004 to BNSF, advising to “watch for flash flooding,” until 6 a.m.
4:30-4:45	Track supervisor reports from Hackberry (MP 509.4) to the BNSF train dispatcher. He does not report high water. He inspects bridge 504.1. He notes water flowing adjacent to and under the bridge. He does not note any unusual track alignment or take exception to either the east- or westbound bridge.
5:07	Dispatcher reports to track supervisor that eastbound Amtrak train 4 is leaving Franconia (west of Kingman).
5:35	Westbound train B-CHCLAC1-05 passes Walapai (MP 501.3). Shortly thereafter, this train crosses the bridge on the north track at MP 504.1. Train crew notices nothing unusual about the bridge on the south track.
5:46	Track supervisor reports from Peach Springs (MP 465.8) to dispatcher. He says he will clear shortly for Amtrak train 4. He does not report any high water.
5:56	Amtrak train 4 derails at bridge 504.1S.

The track supervisor confirmed that no mechanism is in place to protect him or other track inspectors if they are unable to contact the dispatcher for any reason; it is up to the employee to get out of the way of trains. He stated that his protection is “with the informational line-up.” He stated that the informational line-up is only good for about 4 hours and then “you have no authority to be on the track.” He also stated that the dispatcher is not expected to locate the inspector. Further, he stated that he does not notify the dispatcher when he stops to inspect a bridge.

Both train dispatchers told investigators that they had not traveled the track through the area where they were responsible for dispatching trains.

Meteorological Information

WeatherData, Inc., (WDI) provides track-specific storm weather alerts and warnings to the BNSF. WDI is a private meteorological company located in Wichita, Kansas; it has been in business since 1981. WDI employs 38 associates and serves about 200 clients throughout North America. The company has two meteorological divisions; Weather Research and Weather Operations. Within Weather Operations, meteorologists are designated to work as either media meteorologists or storm warning meteorologists. All WDI meteorologists have bachelor’s of science degrees in meteorology or the equivalent training. All WDI storm warning meteorologists must pass internal training and certification before issuing storm warnings to WDI clients.

WDI notifies the BNSF service interruption desk at its NOC with either a weather “alert” or “warning.” Whenever the meteorological state of the art allows, weather warnings are to be delivered to the NOC no less than 15 minutes before the weather affecting a certain portion of track is due. Warnings differ from alerts in that warnings require that some specific, immediate action be taken to safeguard the movement of trains. Alerts are informational and require no immediate action.

At the time of the accident, BNSF instructions to WDI were that warnings were to be issued for tornadoes, winds in excess of 60 mph, hurricanes, blizzards, and flash floods. The actions to be taken by dispatchers and train crews for tornadoes and winds in excess of 60 mph are defined in System Special instruction number 35 (see appendix C). The BNSF reported that at the time of the accident no timetable or special instructions related to flash floods; however, the BNSF had an unwritten policy that a track inspector would be called to inspect tracks in areas that had flash flood warnings.

The following are excerpts from the alerts and warnings issued by WDI to the BNSF concerning the weather around Kingman for the period on Saturday, August 9, that preceded the derailment:

Initial alert

Start Time: 12:06 a.m.

Locations: Seligman subdivision

Conditions: Thunderstorms and Heavy Rain

Comments: Strong thunderstorms are rapidly developing just southeast of, is that Pica, Pica, Arizona, moving east at 15 miles per hour. Radar estimates, moderate rainfall over track with up to 0.7 inches per hour rainfall rates. Expect from 0.4 to 0.6 inch of rain in the next 40 minutes, will monitor for flash flooding.

Alert 0000

Start Time: 12:52 a.m.

Expire Time: 2:30 a.m.

Locations: Pica, AZ, to Kingman, AZ

Conditions: Thunderstorms, Heavy Rain, Moderate Winds

Comments: Update to previous warning. Strong to severe thunderstorms producing heavy rain with up to 1 inch an hour and gust wind continues to redevelop over this stretch of track. Kingman, AZ, has reported a gust to 50 miles per hour in the last 45 minutes. Therefore we are extending the previous warning.

Warning 0001

Start Time: 1:43 a.m.

Expire Time: 2:30 a.m.

Locations: Truxton, AZ, to Hackberry, AZ

Conditions: Flash Flood, Thunderstorms, Heavy Rain

Comments: Thunderstorms continue to move to the east at 20 miles per hour. Radar estimates that nearly 2 inches of rain has fallen over this stretch of track with hourly rates of 1 inch an hour still falling. Watch for flash flooding!

Warning 0002

Start Time: 2:21 a.m.

Expire Time: 4:30 a.m.

Locations: Pica, AZ, to Harris, AZ

Conditions: Flash Flood, Thunderstorms, Heavy Rain, Moderate Winds

Comments: Strong thunderstorms continue to redevelop and move over this stretch of track this morning. Movement of these storms is to the east-southeast at 10 miles per hour. Rainfall amounts of 1 to 2 inches is likely, as well as, peak wind gusts less than 60 miles per hour. Watch for flash flooding.

Alert 0003

Start Time: 2:32 a.m.

Expire Time: 4:30 a.m.

Locations: Harris, AZ, to Athos, AZ

Conditions: Thunderstorms, Heavy Rain, Moderate Winds

Comments: Strong thunderstorms continue to redevelop and move over this stretch of track this morning. Movement of these storms is to the east-southeast at 10 miles per hour. Rainfall amounts of 1/2 to 1 inch is likely over this stretch of track, as well as, peak wind gusts less than 60 miles per hour.

Warning 0004

Start Time: 4:28 a.m.

Expire Time: 6 a.m.

Locations: Truxton, AZ, to Harris, AZ

Conditions: Flash Flood, Thunderstorms, Heavy Rain

Comments: Thunderstorms producing heavy rain continue to remain nearly stationary around the Kingman, AZ, area this morning. Radar estimates that nearly 3 to 3.5 inches of rain has fallen near this stretch of track with hourly rates of 1 inch an hour still falling. Watch for flash flooding! The threat for high wind has diminished, however, a gust to 45 miles per hour is still possible.

The BNSF NOC managers told Safety Board investigators that “Warning 0001” had initiated the request to the BNSF maintenance-of-way operations desk to have the track inspected in the Kingman area. This warning covered the track between Truxton, MP 477.3, and Hackberry, MP 509.4.

A WDI employee told Safety Board investigators that he had been working that Friday night and early Saturday morning. He said he had issued the warnings on the basis of base reflectivity, "storm total precipitation," "1-hour precipitation," and vertically integrated products from the National Weather Service's (NWS's) Las Vegas and Flagstaff WSR-88D radar. These sources indicated heavy rates of rainfall, and data from the National Lightning Detection Network indicated intensifying thunderstorms over northwest Arizona. His SmartWARN[17] Storm Warning System highlighted the area around Kingman as prone to flash flooding. He was aware that rains had fallen in the Kingman area during the 24 hours before his shift began.

NWS postaccident interviews with local authorities and citizens showed that a light rain had begun around 1 a.m., with heavy rain starting around 1:30 a.m. and lasting for about 2 hours before tapering off to a light rain that continued until about 5 a.m. At 3 a.m., flooding was reported at East Bank and Kingman Avenue, causing people in the area to require rescue from three stalled cars. A plastic rain gauge at the airport recorded 1.76 inches of rainfall. A "bucket survey" north of the airport, closer to the train derailment and about where the strongest rain cells were located at 3 a.m., showed an estimated 3 to 4 inches of rainfall. Public works reported a measured 3.7 inches of rainfall but was not sure of the report's source. A rancher to the northwest of the accident site (about 12 miles north of Kingman) recorded 2 inches in his rain gauge.

NWS reports stated that approximately 2 inches of rain fell within the Hualapai Valley area, with a possible core precipitation of at least 3 inches, and possibly up to 4 inches, and that a considerable amount of water ran through Kingman, beginning around 1:30 a.m. Police and public works representatives could not get barricades up fast enough to keep people out of the washes. Four people had to be rescued by helicopter from two stranded vehicles.

Medical and Pathological Information

The accident caused no fatalities. Of the 294 passengers and 18 train crew members, 173 passengers and 10 train crewmembers were injured. Passengers and train crew personnel were injured by striking interior surfaces, such as seats, armrests, footrests, tables, luggage racks, walls, and beds, and from being thrown into the aisles during the impact. Passengers and train crewmembers who were injured were treated at six hospitals. Injuries consisted of strains, sprains, fractures, contusions, and multiple trauma.

About 2 p.m., or 8 hours after the accident took place, the engineer, assistant engineer, conductor, and assistant conductors from Amtrak train 4 provided urine specimens and gave breath tests for postaccident alcohol and drug testing. Amtrak and

[17] SmartWARN is a computer workstation developed by WDI to allow its storm warning meteorologists to quickly and effectively display meteorological data in a format that can easily be analyzed so accurate decisions about warnings can be made.

BNSF officials were present during the sample collection. All crewmembers tested negative for alcohol.

Although samples from the train crewmembers had been collected, an FRA official on scene determined that postaccident toxicological testing for drugs and alcohol was not required. As a result, neither the track supervisor nor the dispatcher was tested. According to 49 CFR 219.201(b),

> No test shall be required in the case of an accident/incident the cause and severity of which are wholly attributable to a natural cause (e.g., flood, tornado or other natural disaster), as determined on the basis of objective and documented facts by the railroad representative responding to the scene.

Emergency Response

Notification

About 5:56 a.m., the BNSF NOC received a radio communication from the engineer of Amtrak train 4 informing it of the train's derailment and location. The NOC passed the information on to its ROC and a BNSF special agent, who notified the Mohave County Sheriff's Department at 6:01 a.m. The NOC said it did not know the number of passengers on the train, the extent of the injuries, or the prospect of fatalities. The BNSF notified the U.S. Coast Guard National Response Center of the accident at 6:15 a.m.

About 6:20 a.m., the BNSF special agent called the ROC manager and advised that the Mohave County Sheriff's Department dispatcher had reported that at least two cars had derailed and that two unconfirmed fatalities were reported on the first car [dormitory car]. According to the BNSF transcript of the recorded communications between the BNSF special agent and the Mohave County Sheriff's Department dispatcher, the sheriff's dispatcher said, "Well, I got word that so far one car, two really serious, probably gonna be DOA [dead on arrival]."

The BNSF special agent's communication with the NOC Service Interruption Desk manager about the accident was also recorded. The agent said, "When I talked to Mohave County, they said … two fatalities and they're still trying to get to the scene." The NOC manager replied, "Two fatalities?," and the BNSF special agent said,

> Yeah, two DOAs is what they called them, dead on arrival.… That's just when they first got on the scene, that's what they reported. Two cars for sure derailed and two, it looked like two DOAs.

During further conversation with an employee at BNSF operations, the BNSF special agent said, "… it's not a confirm, but that's pretty much what they said when they first got on [scene]."

At 6:45 a.m., the BNSF special agent called the Mohave County Sheriff's Department to get an update and talked to a sergeant who relayed information being transmitted over his radio from the scene. According to the BNSF transcript of the recorded communication, the sergeant said, "We've got two dead downstairs now… we're still in the initial response stage and a lot of our information is gonna be really confusing." The BNSF special agent replied, "Right, I understand. I thought I heard her say six possible on the downstairs side." The sergeant said "Yes… they were in the first car." The updated information was relayed to the BNSF Service Interruption Desk manager, who communicated it to the FRA and the Safety Board.

The dispatchers at the Mohave County Sheriff's Department did not remember whether a sergeant had been present during these conversations or had reported possible fatalities. The dispatchers did recall reporting critical injuries. A copy of the dispatch tape recording was provided by the Mohave County Sheriff's Department to the Safety Board. The tape included radio and telephone conversations; the conversation between the Mohave County Sheriff's Department dispatchers and the BNSF special agent was not recorded.

The initial reports made by the BNSF to the Safety Board's communications center via the U.S. Coast Guard National Response Center cited 8 to 13 fatalities. The general manager of Operations, Standards, and Compliance for Amtrak stated that the report of 8 to 13 fatalities resulted in Amtrak's high-level response to the accident. The report of 13 fatalities was not recorded in transcripts. The source of the number could not be verified.

The general manager told Safety Board investigators that he believed, after consulting Amtrak police officers, that inaccurate information regarding fatalities may have arisen because of confusion over terminology. He thought that someone on scene may have referred to the 13 on-board service crewmembers who were asleep in the dormitory car as "deadheads."[18] He also believed that this expression may have been misinterpreted by someone unfamiliar with railroad terms as indicating 13 fatalities in the dormitory car or 2 fatalities downstairs and 6 fatalities upstairs in the dormitory car.

Mohave County Sheriff's Department Response

At 5:56 a.m., the Mohave County Sheriff's Department received a 911 call from a local resident reporting a train derailment. Three officers who were already in the immediate area (searching for people who were reportedly stranded because of the flash flooding) were dispatched to the scene and arrived at 6:05 a.m. They helped the Kingman

[18] "Deadhead" is a term used by railroad employees to identify off-duty railroad employees who are either going to or from work and traveling on the train.

Fire Department and emergency services personnel transport passengers and crew to triage areas, searched for train occupants, and secured the scene. They reported that no "life threatening" injuries were noted. Later, a Mohave County Sheriff's Department lieutenant arrived on scene and assumed the duties of Incident Commander. The Incident Commander's responsibilities were to coordinate the activities of the various responding fire departments (eight fire departments) and medical personnel (six organizations, including the Kingman Regional Hospital). The Incident Commander stated that he requested a passenger manifest from an unidentified Amtrak employee but did not receive one. He stated that Amtrak did not provide a complete passenger manifest. It took several days for Amtrak to provide an accurate passenger count of the entire train.

Fire Departments' and Other Groups' Responses

At 6:06 a.m., the Kingman Fire Department responded to a request from the Mohave County Sheriff's Department for a medical response to the derailment. About 6:15 a.m., a paramedic unit, a rescue unit, and a 4x4 brush engine arrived. A rescue unit from the Hualapai Fire Department was already on scene. At 6:17 a.m., the Kingman Fire Department requested mutual aid assistance from the Valley Vista, Golden Valley, and Pinion Pines fire departments. An unidentified Amtrak employee told the captain of the Hualapai Fire Department that over 300 passengers and crew were on board train 4.

By 6:20 a.m., the first of three Arizona Department of Public Safety helicopters arrived on scene. Two military helicopters from Nellis Air Force Base arrived on scene later with a flight surgeon and medical crew. At 6:30 a.m., a medical command post was set up next to the treatment and triage area. About 6:50 a.m., the city of Kingman activated its emergency operations plan to provide a shelter and staffing. School buses were used to transport people with minor to moderate (or no) injuries to a local hospital and the Kingman Junior High School, which was used as a shelter.

Emergency responders placed injured passengers from the top level of the cars onto backboards and extricated them through the cars' emergency windows. Ladders from fire trucks were used to provide stable platforms for lowering people onto the ground. By 8 a.m., about 230 people had been transported from the scene. BNSF personnel, EMS personnel, and some passengers helped throughout the response. No fatalities were reported by the EMS personnel. Shortly after 9 a.m., the last person was transported from the scene.

At 11 a.m., the scene was cleared after the Kingman fire chief determined that no further fire or medical treatment issues were evident. During the emergency response, a total of 19 paramedics, 44 emergency medical technicians, 11 ambulances, 6 air units, and 6 school buses responded.

Hospitals

About 6:15 a.m., the Kingman Regional Medical Center was notified by the Mohave County Sheriff's Department dispatcher of the derailment and told that it involved about 300 people. The hospital activated its emergency plan, calling nurses and emergency room personnel to report to the hospital. Nurses, assisted by the Red Cross and volunteers, and supplies were sent to the Kingman Junior High School to help those who had completed triage.

By 6:56 a.m., the injured people began arriving at the hospital by helicopters, ambulances, and buses. Over 100 people were treated. The last person was admitted to the hospital at 11 a.m. Thirty-four injured people were transported to Bullhead Community Hospital, Las Vegas University Medical Center, Flagstaff Regional Medical Center, John C. Lincoln Hospital North Mountain, and Las Vegas Valley Hospital.

Emergency Preparedness

Upon notification of the accident, the Kingman Regional Medical Center implemented its emergency plan, which had been created in December 1987 and last revised in June 1996. The plan is designed to provide rapid and effective emergency services in the event of a disaster internal or external to the facility. Medical staff members are to work with local police, fire, and ambulance services during an emergency. No problems were reported with the operation of the plan. Additional staff was called, and preparations were made for transfer of patients as necessary.

The Mohave County Emergency Management Agency implemented its Emergency Operations Plan, which had last been updated on May 28, 1997. The plan detailed the responsibilities of responding agencies and listed the telephone numbers of agencies such as the Association of American Railroads and the ATSF. It did not include telephone numbers for Amtrak or the BNSF.

Before the accident, on November 15, 1996, a joint full-scale exercise was held by Clark County, Nevada, and Mohave County, Arizona. Since the accident, three drills have been held (a tabletop exercise on September 30, 1997, for the Hoover, Davis, and Parker Dams to evaluate the operational readiness of the program; a full-scale exercise on November 11, 1997, involving hazardous materials transportation; and another tabletop exercise on December 3, 1997, assuming a Statewide flood affecting Mohave County, Kingman, Lake Havasu, and Bullhead City).

On August 12, 1997, the Mohave County Emergency Management Agency held a postaccident critique. The critique was attended by the Arizona Department of Transportation, the Red Cross, the Arizona Department of Public Services, and the participating fire and law enforcement departments. During the critique, several agencies noted the need to improve communications. Poor weather conditions reportedly affected the operation of portable radios used by Mohave County Sheriff’s Department deputies. Also, because the primary radio frequency was used, it was difficult to hear other emergency traffic in the city. The Mohave County Emergency Management Coordinator planned to meet with county officials to improve the county’s communications system and to add the telephone numbers of the emergency service coordinators from Amtrak and the BNSF to its plan. Amtrak and the BNSF were not invited to participate in the critique.

Amtrak Passenger Train Emergency Response Training

On April 29, and 30, and May 1, 1997, a Festival of the Emergency Arts was held at the Lake Havasu City Convention Center in Glendale, Arizona. At this festival, Amtrak's manager of Emergency Preparedness addressed emergency responders about considerations that might affect emergency response procedures involving Amtrak train emergencies, such as:

> Railroad operations, equipment familiarization, passenger car construction, railroad right-of-way safety precautions, passenger evacuation, forcible entry, locomotive propulsion systems, train crew orientations, electrical and pneumatic hazards, on-board emergency equipment, use of emergency exit doors and windows, hazardous materials, tunnels and bridges, grade crossing accidents, search and rescue, fire suppression, derailments, and other types of incidents.

Although Kingman fire and rescue personnel were invited by a State representative, the festival attendance sheet did not indicate that anyone from Kingman had attended this training. No evidence was found of the Mohave County Sheriff's Department being invited to or attending the festival.

Fire

There was no postaccident fire.

Survival Aspects

When the accident took place, the engineer and assistant engineer were in the lead locomotive. They stated that, upon traversing the bridge, they saw a "hump" in the track. When the derailment occurred, they were thrown upward and back down and around inside the cab before the engineer could hit the emergency button. The assistant engineer broadcast "emergency" over the train radio and called the dispatcher, telling him to stop any trains in the area and to call emergency responders. The engineer and assistant engineer said they remained inside the locomotive cab and did not help during the evacuation because the locomotives came to a stop about 1 mile away from the evacuation site.

The conductor and an assistant conductor were in the diner car (8th car). According to passenger statements, when the train went into emergency, the lights went out and the emergency lights came on in some cars. The train began to "jerk," causing the conductor to grab the table in front of him as the train came to a stop. The assistant conductor fell underneath a table. The conductor attempted to go out the forward door, but it was jammed. The conductor, chef, and assistant conductor went into the galley to open a window, then they tried to open the door using a crowbar. After opening the door, the conductor used his radio to call the engineer to ascertain the condition of the train. The conductor stated that he then assessed the condition of the train. At this time, he saw other train crewmembers inside the train; they had light sticks and were trying to open jammed doors.

Another assistant conductor, who was in the dormitory car (2nd car), stated that he tumbled and bounced around inside the car. He joined the conductor and other train crewmembers who were walking along the train, opening jammed doors and distributing light sticks to passengers because the emergency lighting was not working in several cars.

A sledgehammer was used to open jammed doors. The conductor instructed passengers to stay inside the train to avoid further injuries. The conductor asked some boy scouts on board the train to pass out light sticks and help open doors and windows. The conductor instructed train attendants to search the cars for injured passengers. The assistant conductor told the conductor that the sleeping car (10th car) was on the collapsed bridge; they began evacuating that car first. The conductor stated that he did not try to use the public address system because he did not think it was working.

A sheriff's deputy who was in the area heard noise of the derailment and was the first responder to arrive on scene. The conductor told him that about 300 people were on board the train and asked him to call for EMS and to provide portable lighting. The conductor stated he had no idea how many persons were injured or if there were any fatalities. The conductor did not have the passenger manifest with him. Subsequently, after walking through the train, the conductor determined that there were no fatalities.

The on-board service personnel were either asleep in the dormitory car or had just awoken to begin their normal work assignments. Several sleeping crewmembers stated that they were awakened by the action of the derailing train and were injured in the derailment. Those who were not injured or who were in cars other than the dormitory car assisted in the evacuation of passengers.

One train attendant, who was in a sleeping car (10th car), reported that she went downstairs to the vestibule area and noticed that the car had come to rest on the bridge. She saw and heard water on both sides of the car and immediately decided to evacuate it because she did not know whether the car would remain stable. She went upstairs and began to evacuate the sleeping car but realized it would be difficult because of its angle. She told passengers to stay calm. She informed them that a derailment had occurred. She checked each room to make sure no one was dead or needed help. She told passengers to put on their shoes, leave their luggage behind, and follow her downstairs. The lower vestibule door was opened and passengers began leaving. She led the passengers away from the train.

The train attendant had attended Amtrak's P.R.E.P.A.R.E.[19] training course in 1996 and told investigators that this training had taught her when to evacuate, how to triage, how to set up a command post, and how to assist emergency personnel and injured people. She said the training had made her "more knowledgeable, prepared, and focused on what needed to be done." She said that she thought that all crewmembers should take the course at least every 2 years for refresher purposes.

The chief of on-board services said that he made sure that the train attendants in the dormitory car were all right; he then proceeded to assist passengers. He said that he gave a copy of the passenger manifest, which contained the number of passengers in the sleeping cars, to a firefighter.

On September 17, 1997, the Safety Board mailed 210 surveys to the passengers of Amtrak train 4; the Board received 41 responses by November 7, 1997. The survey generally asked individuals to provide information such as the car they had been in, their seat location, and their observations about the events that occurred before, during, and after the accident. In addition, investigators interviewed nine patients in the Kingman Regional Medical Center following the accident.

Crashworthiness

Locomotives and Fuel Tanks

The locomotive of train 4 was made of four P-42-8DC diesel electric units, manufactured by GE.[20] The units were less than 8 months old. The first three units were positioned with the operator's cab facing east (forward), and the fourth unit was positioned with the operator's cab facing west (to the back). Only the first unit, ATK 47, was occupied. A description of the condition of each unit is provided below.

ATK 47, ATK 50, and ATK 80. These were the first three units of the four-unit locomotive consist. These units uncoupled and separated from each other after crossing the bridge. The lead unit, ATK 47, was occupied by an engineer and an assistant engineer. An inspection of the operator's cab compartment indicated no visible interior damage.

A visual inspection of the car bodies of these units made after the accident indicated a slight localized exterior side sheet panel (wrinkle) distortion, both on the left and right sides, in areas above the truck assemblies, as well as at the mid-section of the car body (of the third unit only). The distortion became slightly more progressive from the first to third units. No fuel leakage was apparent from these units.

[19] P.R.E.P.A.R.E. stands for "Passenger Railroad Emergency Preparedness And Response Education."

[20] General Electric/Transportation Systems Division, Erie, PA.

ATK 52. ATK 52 was the fourth unit of the four-unit locomotive consist. In its passage over the bridge, this unit uncoupled from the 3rd unit but remained coupled to the baggage car. A postaccident visual inspection indicated localized left and right exterior side sheet panel (wrinkle) distortion in areas above the truck assemblies, as well as at the mid-section of the car body. The forward end sill, beneath the sloping fascia panel under the windshield, was deformed inward and wedged against the baggage car (ATK 1425). Inspection of the operator's cab indicated only minor damage. The locomotive frame showed some structural damage.

A prerecovery visual examination of the underframe panels proximate to the 2,100-gallon fuel tank compartment indicated that only a small amount of diesel fuel had leaked. The sight gauge (sight-port) of the fuel tank indicated that the tank was above one-half, but less than three-quarters, full during the prerecovery inspection. Amtrak estimated that the remaining fuel in the fuel tank totaled about 1,400 gallons. About 12 and 24 inches of clearance space were observed, respectively, between the ballast surface and underframe of the locomotive, on the left and right underside surfaces of the unit.

Additional damage was sustained to this unit when an 82-foot-long piece of rail that dislodged from the track structure during the derailment became embedded in the unit. The rail had penetrated at the rear of the unit (which was its leading end) and extended its entire length. The opposite end of the rail was found to be cantilevered into the interior of the trailing baggage car. The rail segment passed through the fuel tank, puncturing at least one interior baffle. A portion of rail was visible at the right-side fuel filler pipe opening. (See figure 10.)

Passenger Cars and Emergency Lighting

The inspection of the passenger cars indicated that none had experienced any significant breach of the car body, with most of the damage focused on the car body end-structure areas. An on-scene inspection of the passenger car equipment was conducted by the members of the Safety Board's Crashworthiness Group, with the results documented on the carrier's equipment inventory forms.

The emergency lighting system in each car is powered by a series of wet cell storage batteries, which are secured in a utility rack located in an interior compartment that is accessed from the exterior of each car. Inspectors found the electrical systems of most cars at minimum or no power. The electrical systems were disabled because of extensive undercarriage damage, resulting from severed wiring and related electrical conduits located on the car undercarriage.

Postaccident inspection of the train seats found that the rotating locking devices or mechanisms were not engaged on 18 seat assemblies. No seat assemblies were found separated from their floor mountings.

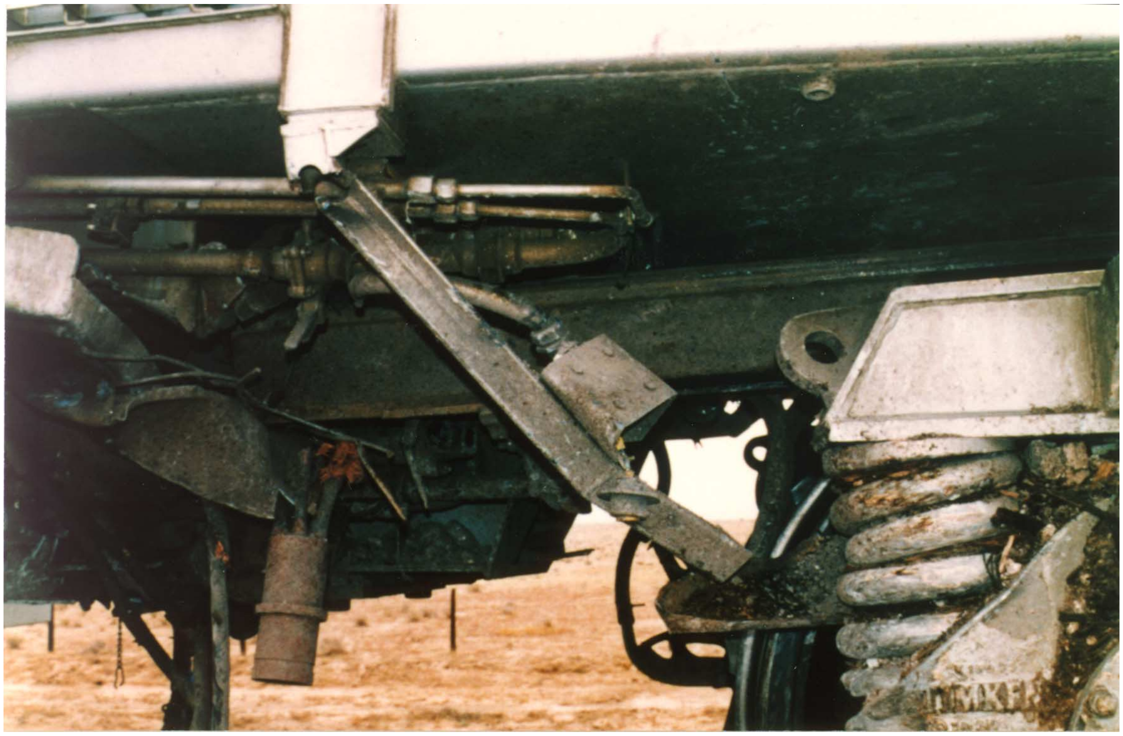

Figure 10. Visible rail segment

Tests and Research

Locomotive Event Recorders

All four locomotive units were equipped with GE Integrated Function Computer (IFC) event recorders, which were successfully downloaded on scene to PCMCIA[21] memory cards.

The data from the lead locomotive (ATK 47) indicate that the train was traveling approximately 89 to 90 mph, with the throttle in position 3 (with a change to 4 and then 1), when the brake pipe pressure decreased from approximately 110 to 0 psi, and the emergency parameter changed from NONE to TLEM. Within the next 2 seconds, the pneumatic control switch (PCS)[22] parameter changed from CLOSED to OPEN. Between 2 and 4 seconds after the PCS OPEN indication, the position of the air brake handle changed from RELEASED to EMERGENCY, and the EIE parameter changed from OFF to ON.

[21] PCMCIA refers to the Personal Computer Memory Card Industry Association. Although the memory cards are often referred to as "PCMCIA cards," the correct terminology is "PC cards." The PCMCIA defines and publishes the PC card standard.

[22] The PCS automatically retards the throttle to the IDLE position when a rapid reduction in automatic brake pipe pressure occurs.

Although the recorder is equipped to record end-of-train (EOT) device data, no EOT device was installed on the accident train.

Recorded and Played Back Parameters. The GE recorder stores the recorded data in a Permanent Core Memory (PCM) module, manufactured by Pulse Electronics, Inc. The number and type of parameters that are recorded are determined by GE as well as the individual railroad. GE provides a standard minimum list of parameters (which are always recorded, for all railroads), and the particular railroad may choose to add other parameters to that list. All the parameters in both the GE list and the customer optional list (if one exists) are "recorded"; however, they are not necessarily "played back" when the data are read out.

To view the recorded data, two basic but separate steps must be taken. First, all the recorded data in the memory module are downloaded to a laptop computer file, or a file on a PCMCIA memory card. Second, the downloaded file must be read out or played back. The downloaded file is read out using an analysis program designed and written by Pulse Electronics, according to the railroad's specifications. The program is designed to play back only those parameters specifically chosen by the individual railroad. The Amtrak GE IFC analysis program did not extract all the available parameters because the program was written to meet an older GE data format specification, which was not the specification for the recorders installed on the accident locomotives.

Readout. The on-scene readout was performed using the Pulse Electronics GE IFC Data Analysis Software program PPN 17502 v3.2.[23] This program version did not reveal any data related to emergency brake application(s), other than the PCS and brake pipe pressure parameters.

These two parameters are sufficient to indicate whether an emergency brake application was made; they cannot be used to determine whether the crew initiated the emergency brake application. Subsequent to the on-scene portion of the investigation, Amtrak informed the Safety Board that the type of emergency ("Emergency" parameter) actually was recorded; a different type of readout software was needed to extract it.

After the Safety Board consulted the recorder manufacturer, it was determined that six other parameters were actually recorded but not extracted by the Amtrak IFC analysis program. These were: emergency type, EOT emergency (on or off), bell, brake handle position, EIE (on or off), and dynamic brake derate (on or off).

Because these parameters could not be extracted from the recorded data using the Amtrak analysis program, another analysis program had to be used to attempt to retrieve this data. A program that is intended for use with BNSF data was used in this case (Pulse Electronics Data Analysis Software program PPN 17463 v2.1). This program was used to print tabular data for ATK 47 for the last 2 miles of recorded data. Because this program

[23] This is the latest Amtrak IFC analysis and readout program.

was designed for use with BNSF and not Amtrak recorders, none of the Amtrak optional parameters could be recovered.

Signal Event Recorders

Signal event recorders are located at Griffith, CP 526.8, and at automatic signals 5052 and 5051 for eastward and westward trains, respectively. The signal event recorder monitoring the position of signals, switches, and track occupancy at CP 526.8 indicated that Amtrak train 4 had passed CP 526.8 at 5:24 a.m. The event recorder at eastbound automatic signal 5052, the last signal Amtrak train 4 passed before derailing, recorded a time of 5:56 a.m. The last train that passed signal 5052 before the derailment was recorded at 3:36 a.m. The event recorder at westbound automatic signal 5051 indicated trains passing at 4:15 and 5:34 a.m. on the north track.

Equipment Detectors

Track-side FEDs are located at MP 512.5 for both tracks; each FED consists of a "hot box"[24] and a dragging equipment detector that use radio communications. Amtrak train 4 was recorded as it passed the hot box detector on the south track at MP 512.5 at 5:49 a.m., operating at 89 mph. The printout indicated 80 axles (4 locomotives and 16 cars) with a recorded length of 1,474 feet. No defects were detected.

High Water Detector

Bridge 504.1, where Amtrak train 4 derailed, had no HWD; however, an HWD was located at bridge 505.9, which was linked to signals 5051 and 5082. (See figure 11, which shows the HWD location.) When the HWD is activated, it causes the signals at 5051 and 5082 to display a RED aspect, which, according to BNSF operating rules, requires the engineer to stop the train and proceed at restricted speed to the next signal. The HWD must then be manually reset before the signals will display any other aspect. The HWD at bridge 505.9 did not activate during the storm preceding the derailment because the flow of water was not high enough to contact the HWD. The HWD is mounted under the south bridge, approximately 18 inches below the bottom of the bridge deck, or about 5 feet above the streambed. (See figure 12 for a closeup view of the HWD.)

On August 9, 1997, the HWD at bridge 505.9 was tested by submerging it in water. This de-energized the ZR relay that shunted or shorted the track circuit in approach to the danger of high water. Signal 5082 displayed a RED aspect for eastbound movements on the south track, and signal 5051 displayed a RED aspect for westbound trains on the north track.

[24] Railroad jargon for an overheated bearing.

Figure 11. HWD on bridge 505.9

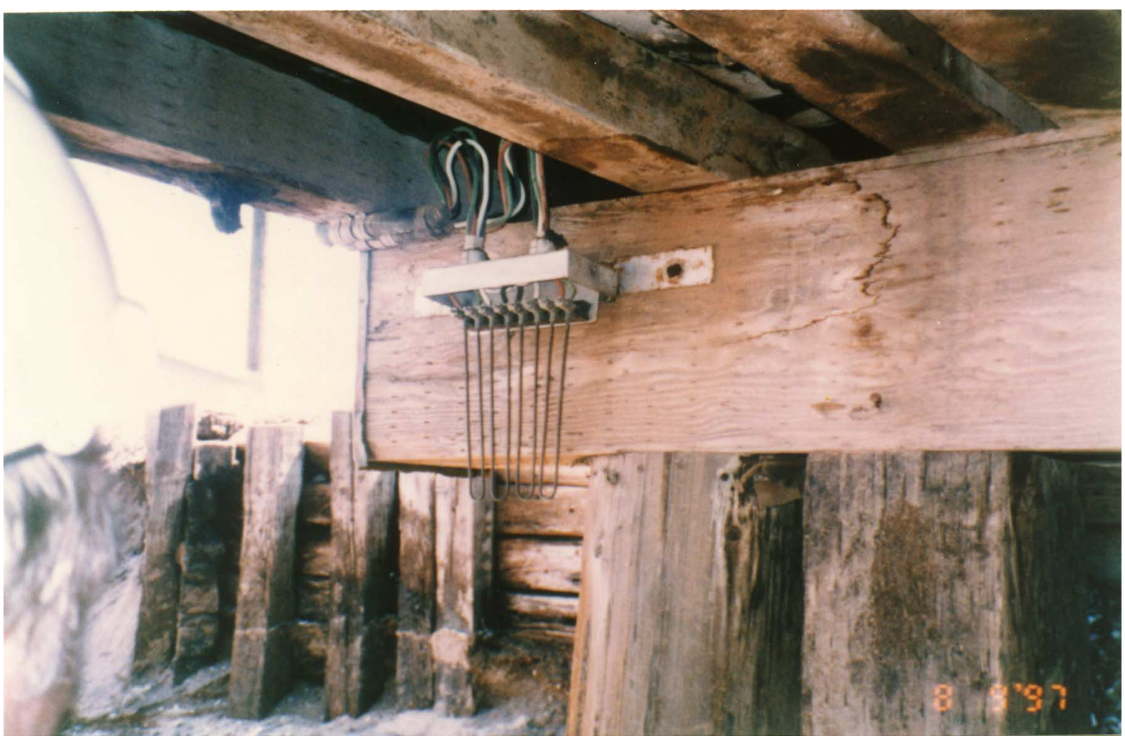

Figure 12. Closeup view of HWD

Bridges are not required to have HWDs. The BNSF does not have specific requirements for installing an HWD. According to the BNSF, an HWD was usually installed, with the concurrence of division level officers, at specific bridges when local maintenance personnel were aware of previous history of high water at that location. The BNSF informed the Safety Board that some superintendents preferred installing HWDs, while others did not. According to the BNSF, HWDs were installed before weather forecasting services were used.

Amtrak Locomotive Couplers

After the accident, the first three of the four locomotive units were found uncoupled and separated from the train and dispersed up to a mile away from the point of derailment. The front couplers on the second and third units had opened, allowing the preceding locomotive units to separate. The abutted rear-end couplers between the third and fourth units also had uncoupled. Each of the four GE P42-8DC locomotive units involved in the accident was equipped with an F8306E coupler and an F514E knuckle. The couplers had been manufactured by National Castings, Inc. They were F-type couplers made of E-grade steel. F-type couplers interlock to prevent vertical separation by means of a tang or metal horn on the opposite side of the knuckle, which fits into a pocket of a mate F coupler next to the knuckle. These F couplers also had a bottom shelf to prevent a coupler from falling between the rails and derailing a train in the event of a drawbar separation; the shelf would hold the detached coupler in place.

Stopping Distance

At the request of the Safety Board, Amtrak calculated train 4’s stopping distance with an emergency brake application on level, straight track with clean, dry rail from an initial speed of 88 mph and with the variance of one to four locomotive units in the train. For each locomotive unit consist, the calculation of the stopping distance reflects three different modes of braking: friction (no blended/dynamic), friction with dynamic, and no brake effort from the locomotives. The results of these tests are shown in table 5.

Table 5. Calculated braking distances for an emergency brake application with 1 to 4 locomotive units and 16 cars

Locomotive Type	Units	Total Weight (pounds)	Train Braking Distances (feet)		
		Add 2,469,200 for 10 pass and 6 MHC	Friction Only	Blended	No Locomotive Brake
P42-8DC	4	1,072,000	3,862	3,431	4,686
P42-8DC	3	804,000	3,705	3,365	4,306
P42-8DC	2	536,000	3,603	3,363	3,991
P42-8DC	1	268,000	3,488	3,362	3,675

Geotechnical Investigation

The Safety Board requested geotechnical and drainage area information for bridge 504.1. The BNSF contracted with HDR Engineering, Inc.,[25] to develop such information. The BNSF consultant's work included a site reconnaissance, surface exploration, and laboratory testing of soils from the site. Following its analysis, HDR Engineering stated in its report[26] that "Scour and undermining of shallow foundations with a loss of bearing support and settlement was the most probable cause of the bridge failure."

The consultant's report also stated that "Transient subsurface groundwater and moisture conditions … and the vibration caused by the train passage could have possibly liquefied or greatly reduced the shear strength of the foundation soils and caused additional settlement under load." The HDR Engineering report concluded that the probability of this second failure mode was small.

HDR Engineering also performed a hydrology study to determine the drainage basin of bridge 504.1. The study included the hydrologic and hydraulic conditions associated with the accident bridge and other adjacent BNSF bridges. These included the bridges numbered 503.1, 503.7, 504.1 (the accident bridge), 505.6, and 505.9. All these bridges are located within interconnected drainage basins along the north side of the railroad grade fill.

The bridges on the north and south tracks are of similar construction to bridges 504.1N and 504.1S, respectively. (That is, the north track bridges are timber-pile-supported and the south track bridges are on shallow foundations or mud sills.) In addition, bridges 503.1 and 503.7 each have a concrete crosswall immediately downstream, as did bridge 504.1.

The HDR Engineering study showed that bridge 504.1 had a 19.5-square-mile drainage area basin within the Peacock Mountain range to a broad smooth valley (Hualapai Valley), drained by a major wash referred to as the Hualapai Wash. Flood flows would carry long distances overland before collecting into the washes. The watercourse for bridge 504.1 sloped at 207 feet per mile.

With respect to scour, the study found the soils within the area highly erosive and unstable, with flow velocities approaching 3 fps. Scour at the accident site varied depending on its location within the basin. Graded roadways above the bridge area provided for collection and concentration of flow. The flow at the bridge is fully concentrated, which greatly increases the stream power potential and results in scour hole formation. The depth was unknown because of sedimentation filling the holes on the

[25] HDR, Inc., offers a broad range of architectural and engineering services. The company employs more than 1,800 engineers, architects, scientists, and support personnel worldwide and is based in Omaha, Nebraska. Its subsidiary company, HDR Engineering, Inc., provides water/wastewater, transportation, and waste/energy services.

[26] HDR Engineering, Inc., under contract with the BNSF, produced an engineering report entitled "System Analysis Seligman Subdivision Bridge No's. 503.1-505.9."

recession side of the flood. At all structures studied, the study found that the potential for scour depths sufficient to undermine shallow footings is great. HDR Engineering considered that structures supported on deep piles (such as 60-foot depths at bridge 504.1N) should be adequate.

The HDR Engineering study stated that the highway box culvert downstream from railroad bridge 504.1 was undercapacity to carry the 50- and 100-year floods but more than adequate to handle the 10-year flood. It further noted that the washes draining bridges 503.1, 504.1, and 505.9 were eroded below the Route 66 structures. The channel bed immediately downstream from these highway structures had degraded from 3 feet to over 10 feet. The study also stated that these highway structures have the potential of being washed out with the next major flood event. The study stated that:

> At this time, based on the bed degradation which has developed below all five of the downstream highway 66 bridge structures, the highway structures have the potential of being washed out with the next major flood event, with the potential for the resultant headcut (of a potential magnitude of 5 feet) proceeding through the railway bridges (Br. 503.1, 504.1, and 505.9).

The HDR Engineering report recommended installing a replacement structure for bridge 504.1 that would have longer spans of concrete slabs to provide a reduced risk of debris collection at the bridge, an increased waterway opening area for reduced stream velocities, and 60-foot piling to protect against scouring relative to the former shallow footings.

Postaccident Actions

The BNSF

The BNSF replaced the two existing bridges at MP 504.1 with two separate ballasted deck structures, consisting of three 20-foot concrete slabs on steel H-pile bents with concrete caps and a concrete spreader at the ground line. The BNSF informed the Safety Board that the new structure provides a waterway opening of about 503 square feet with a capacity of 5,540 cubic fps. The BNSF further stated that the bridge is theoretically capable of handling runoff from a 40-year storm event. According to the BNSF, with the adjacent structures' runoff capacity, a storm event of the 100-year-storm category could be handled. In addition, the downstream side of the stream channel has been widened.

The BNSF engineering department is conducting systemwide training classes for its track and bridge inspection personnel, signal employees, and maintenance-of-way supervisors on how to recognize and report scouring around bridges and culverts. During this training, the employees are provided information to allow them to make reasonable judgments on the condition of the bridge or culvert and encouraged to call the bridge inspector for final evaluation. Numerous pictures are shown during the training, including those representing this accident. Since the accident, the BNSF has identified all its bridges with similar supporting foundation structures for special inspection attention.

The track supervisor involved in the inspection of the bridge in this accident stated, regarding his attendance at a class, that it:

> …made us aware of what that entails, what—they made us aware of the profile of downstream activity under any bridge, culvert, streambed or all that business, which I had prior—before the incident no—no knowledge of. The bridges with mud sill foundation or shallow foundation have been clearly marked on my territory so that I would be able to identify their location in any inclement weather or darkness. If I would observe water bank to bank at any depth in these locations trains are going to stop, and would not be allowed to proceed until [a] competent bridge inspector has made a determination that the mud sill bridge, which is a sound structure in itself if protected properly, is okay, and that sums that up pretty good.

On March 2, 1998, the BNSF informed the Safety Board of a revision to the Maintenance Alert it issued following the accident at Kingman. This revised Maintenance Alert was the result of severe storm-related conditions and traffic delays on BNSF's Northern California Division through the San Joaquin Valley. The revision states that when a flash flood warning has been issued for an area by the BNSF NOC, passenger trains are limited to 50 mph and freight trains are limited to 40 mph with the following exception—if the limits of the designated area include bridges having been identified as vulnerable to scour, all passenger trains and "key"[27] freight trains are limited to restricted speed—the same as the initial Maintenance Alert.[28] (See appendix C.)

The FRA

On September 4, 1997, the FRA issued Safety Advisory 97-1[29] recommending that railroads take certain actions to reduce the risk of train derailments that could result from severe weather conditions, particularly undetected flash floods. (The advisory is not regulatory but a recommended action.) The FRA determined that each railroad controlling train operations on Class 4 or higher track, or passenger trains in commuter or intercity service, should have programs and procedures in place to protect train operations during severe weather, and particularly flash flooding, by the means cited below:

1. The railroad should have in place a procedure that will assure that all notifications issued by the NWS of flash flood warnings will be received within 15 minutes of issuance from the NWS, directly or through a contract

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[27] The BNSF has defined "key" freight trains as those carrying hazardous materials.

[28] The BNSF has identified 14 bridges on the Northern California Division as being vulnerable to scour because their foundations do not have piling.

[29] SA 97-1; 62 FR 46793.

weather forecasting service, by the train dispatchers or other employees controlling the movement of trains on all track of Class 4 or higher or upon which passenger trains operate in commuter or intercity service, within the warning area. In the case of such track located outside of the warning area but subject to damage from water resulting from the storm, the information should be obtained in time to permit timely response by the railroad.

2. After the receipt of a warning of a flash flood which might damage track or bridges, the railroad should notify train crews and limit the speed of all freight and passenger trains to that which will permit the train to operate safely, consistent with the potential water levels and visibility conditions, on all track subject to damage from the flood. The limitations should continue until a special inspection in accordance with 49 CFR 213.239 has been performed of that track and it is determined that a hazard no longer exists. In making that inspection and determination, the time taken for the heaviest flow of water to reach the track should be considered.

3. Each railroad affected by this advisory should identify its bridges carrying track of Class 4 or higher or over which passenger trains operate in commuter or intercity service, which are vulnerable to damage from flash floods or similar weather-related phenomena. Particular attention should be given to bridges which incorporate piers, bents, or abutments, which are founded on soil or degradable rock which could lose its integrity as a result of scour by moving water, and which are commonly referred to as “mud sills'” or “spread footings.”

4. The information developed in paragraph 3 should be compiled and made available to each person who can be called upon to perform special inspections on the subject track following a flash flood warning. Consideration should be given to placing identifying marks on bridges that need particular attention in special inspections, along with the bridge number, to assist inspectors in locating them with certainty during inclement weather. Consideration should also be given to the use of automated high water detectors or similar sensing and warning systems on specific bridges which could incur water damage that would be hidden from or not otherwise detectible by a human inspector.

5. In addition to the bridge-specific information called for in paragraph 3, each affected railroad should implement a training program for the persons performing special inspections. The training should include methods to recognize and protect the safety of railroad operations from the damaging characteristics of flowing water in general, with particular regard to the effects of a watercourse that takes a significant change in horizontal direction or vertical profile near the track; the effects of drift material accumulation on scour and the capacity of the waterway opening; and the potential for damage by impact of heavy floating objects.

6. Refresher training of track inspectors on the subjects addressed in paragraph 5 should be conducted at least once each calendar year. Where practicable, that refresher training should include a joint inspection by a track inspector and a cognizant bridge maintenance or engineering employee over the inspector's assigned territory. During that joint inspection they should locate the vulnerable components in the bridges identified in paragraph 3, discuss the precautions to be taken in the event of indications of distress in those components, observe drainage conditions on and adjacent to the right-of-way, and note changes for inclusion in the revisions of information called for in paragraph 9.

7. If a track inspector is assigned to perform a special inspection in accordance with paragraph 2, and bridges identified as vulnerable are in the track segment subject to damage from the flash flood, a cognizant bridge maintenance or engineering employee should be readily available by telephone or radio to assist in the interpretation of findings by the track inspector.

8. Each affected railroad should brief all of its track and bridge inspectors on the contents of this advisory. These briefings should occur within 14 calendar days of the date of publication of this safety advisory in the *Federal Register*.

9. FRA believes that the actions described in paragraphs 3, 4, and 5 should be completed within 60 calendar days of the date of publication of this safety advisory in the *Federal Register*. During this period, each affected railroad should complete an initial review of its bridges for vulnerability to high or rapidly flowing water and provide that information to its inspectors. More detailed reviews should be substantially completed and provided to inspectors during calendar year 1998 and then maintained in a current status.

10. FRA requests a letter within 45 calendar days of the date of publication of this safety advisory in the *Federal Register* from each affected railroad specifying the actions it has taken and will initiate to enhance the safety of train operations in the event of a flood or a high or rapid water condition.

On November 14, 1997, the FRA issued an amendment to Safety Advisory 97-1 that permits the use of other competent commercial weather services that receive and review warnings and weather data from the NWS as part of its procedures.

The FRA Track Safety Standards (49 CFR part 213) state, “In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection must be made of the track involved as soon as possible after the occurrence.” The advisory states that the FRA purposely made the provision general in nature, because “It is not practicable to specify in a minimum safety standard all the conditions which could trigger a special inspection, nor the manner in which any particular special inspection must be conducted." The FRA considers that, "It is more effective to provide information and guidance to the railroad industry, which each railroad can then adapt to its own circumstances."

Arizona Department of Transportation

On August 12, 1997, the Arizona Department of Transportation (ADOT) inspected the box culvert immediately downstream from BNSF bridge 504.1. ADOT informed the Safety Board that it routinely inspects structures after major flash flood events. The remarks and recommendations section of the ADOT inspection form for that inspection included the following: "There were no significant culvert problems caused by the recent flow; recommend replace minor eroded fill behind the outlet wings."

According to 23 CFR 650.301, a structure is considered a bridge if the opening measures 20 feet or more along the roadway centerline. ADOT inspection reports indicated that the box culvert immediately downstream from BNSF bridge 504.1 is 32 feet long along the centerline of the roadway. As a result, the bridge (box culvert) is on the Federal Highway Administration's inventory and is subject to inspection every 4 years,[30] in accordance with Arizona's box culvert inspection plan. The box culvert's last scheduled inspection before the accident had taken place on February 26, 1997. With respect to the waterway opening, the ADOT inspection report for this inspection stated (in part): "3) channel openings 100 percent both ends, has 1.8 feet scour at outlet; ok, High water mark: 1 foot below ceiling near inlet." The report did not indicate how recently the high water mark had been made.

According to ADOT, an inspection of a scour-critical bridge includes a measurement of evidence of scour and scour calculations. ADOT considers a box culvert, because of the nature of the structure's design, to be a low-risk or scour-stable structure.

Other Information

Amtrak's Proposed Procedures for Passenger Manifests

Amtrak's general manager for Operations, Standards, and Compliance told the Safety Board that Amtrak has a contract with a service to provide a satellite-based communications system. The system is about 75-percent installed. It consists of a satellite communications unit in the body of the train that can permit portable two-way communications between the train and Amtrak's national operations center.[31] The locomotive would have a laptop-type computer, and the conductors would be able to

[30] From 1971 to 1995, all box culverts over 20 feet in length on the State Highway System were inspected every 2 years. In 1995, the frequency interval was changed to every 4 years.

[31] The Amtrak national operations center has been relocated from Philadelphia, Pennsylvania, to Wilmington, Delaware.

communicate through the locomotive's computer and antennae. This communications system would be independent of the locomotive radio for communicating with the host railroad's train dispatcher for train operations.

According to Amtrak's general manager for Operations, Standards, and Compliance, Amtrak will next develop a method to use the system to account for passengers on the train. This general manager stated that it is difficult to account for passengers on unreserved trains because tickets can be bought one day and not used for weeks, be given to someone else, or be used to board the train at other locations by paying the difference in fare. Amtrak compares the unreserved trains to transit and commuter systems, which passengers get on and off frequently.

He stated that Amtrak must be able to provide a manifest to account for passengers on its reserved trains, despite the current practice of not requiring tickets for infants and small children. Amtrak has tried issuing nonrevenue tickets to account for such passengers but has found the process cumbersome and ineffective.

The general manager for Operations, Standards, and Compliance also stated that, in past accidents and incidents, Amtrak personnel have had to search for the conductor's pouch to count the tickets to determine the number of people on the train. This general manager has prepared a draft policy to change those procedures, and Amtrak has established a working group to ensure that an official passenger count is provided to the national operations center. The official count would include ticketed revenue passengers and nonrevenue nonticketed passengers such as infants, Amtrak employees traveling on a pass (regardless of travel status), employee dependents, and authorized employees of a railroad over which tracks Amtrak is operating.

According to this general manager, Amtrak will use the satellite communications system to put a form in the computer. Each train conductor will add to the form some information about the number of people on board each train, and the information will be sent to the national operations center and made immediately available to other Amtrak personnel. He also stated that when the process has been tested satisfactorily, it will be implemented on all reserved seat trains.

Amtrak train 4 was not equipped with the new communications equipment. According to the conductor and one assistant conductor, at the time of this accident, they were in the dining car working on tickets. The conductor said that he did not have time to look at the manifest because it was in the dormitory car. He also stated that the manifest contained the number of passengers in coach sections and a complete list of passengers in the sleeping cars. The conductor said that the manifest should have been up to date except for tickets taken at Kingman.

On March 24, 1998, Amtrak demonstrated its new satellite communications system for Safety Board investigators. The system included an on-board mobile communications terminal in the locomotive, a conductor's portable unit, and a global positioning system locator for the locomotive. The system demonstrated that Amtrak now has the ability to communicate, independently of a host carrier, with its own trains anywhere in the United States (with certain exceptions, such as tunnels). The system is programmed to accommodate 19 preformatted messages for train status and direct communications between the train and its national operations center. These communications are also interactive between maintenance and customer service personnel. The system depends on accurate input by the on-board service personnel and on such personnel updating passenger information accurately. It has no remote printing capability. Also, if the locomotive unit loses power, the on-board computer will not work.

Amtrak's On-Board Service Personnel Emergency Situation Training

Amtrak provides emergency situation training to its personnel through P.R.E.P.A.R.E. training, courses on assisting disabled passengers, and videotapes illustrating emergency procedures. In this training, emergency procedures are discussed while crewmembers are taught how to perform their duties, depending on their positions. Employees are taught about the classes of fires, what to do in an emergency, options to consider when deciding whether to evacuate a train, and how emergency personnel classify injuries during a triage. A Critical Assistance and Response for Employees program is also available to Amtrak employees.

The Amtrak *Manual for On-board Services Employees*, dated February 1, 1992, Section A-4-6, details the procedures to be followed when responding to train emergencies involving fires, assisting in evacuations from different types of train cars, communicating using the public address system and intercom, and providing first aid for different types of injuries. In addition, the manual instructs train attendants to:

> … Ensure that all beds are properly made before boarding passengers. All beds will be made with the head toward the reading light. [According to an Amtrak representative, the beds are made with their 'feet' toward the engine]. Rooms with beds parallel to aisle, with a reading light at both ends of the bed will be made up to permit passengers to sleep with their feet toward the engine.

Amtrak's general manager for Operations, Standards, and Compliance stated that, in an emergency, it is the conductor's responsibility to ensure that the appropriate entities are notified and to evaluate the scene to determine the type of evacuation procedures to be followed. The conductor is also responsible for providing information and assistance to emergency responders.

This general manager also stated that Amtrak engineers usually review emergency procedures every 3 years, and the conductors review them every 2 years. On-board service crewmembers are scheduled for emergency situation training every 3 years. He further stated that employees who have been relocated recently may have missed scheduled training and that Amtrak determines which employees need training in emergency procedures by using the computer database for training records information. Table 6 shows Amtrak's recorded dates of the last emergency situation training taken by its train crew and on-board service personnel involved in this accident.

Table 6. Emergency situation training record of train 4 personnel, as provided by Amtrak

Train crewmember position	Date of last emergency situation training
Engineer	
Assistant Engineer	
Conductor	1993
Assistant Conductor 1	
Assistant Conductor 2	
Chief On-Board Service	6/3/97
Lead Service Attendant 1	6/10/93
Lead Service Attendant 2	2/7/90
Service Attendant 1	6/24/93
Service Attendant 2	
Service Attendant 3	
Train Attendant 1	3/14/96
Train Attendant 2	5/2/97
Train Attendant 3	
Train Attendant 4	4/24/96
Chef	4/18/90
Food Service 1	
Food Service 2	4/24/96

The train 4 engineer did not indicate that he had received any emergency situation training. The assistant engineer said that he had never been trained in handling a derailment. He further stated that the crew just developed teamwork to help each other. The conductor stated that he had received emergency training by watching a videotape that demonstrated how to remove windows and open doors. One assistant conductor had received training on how to flag oncoming trains and on notification procedures. The other assistant conductor stated that he had seen videotapes on emergency procedures and had participated in a course on how to evacuate passengers from tunnels. He said that Amtrak crewmembers needed more hands-on training and that, “Films every 3 years or so just doesn’t do it.”

An Amtrak train attendant who received P.R.E.P.A.R.E. training in 1996 stated that the training afforded her the opportunity to be “more knowledgeable, prepared, and focused on what needed to be done” when the Kingman derailment occurred. The attendant recommended that all crewmembers take the training and have refresher courses every 2 years.

Analysis

General

The BNSF's FRA-qualified track supervisor had last inspected the track through the accident area on August 6, 1997, and did not note any defects. Neither the track geometry car tests nor the ultrasonic rail inspection tests noted any deficiencies. In addition, a postaccident inspection by investigators did not reveal any deficiencies from the BNSF-designated FRA Class 5 track safety standards. The Safety Board therefore concludes that the track did not cause or contribute to the accident. The signal system was thoroughly tested after the accident and no anomalies were found. All inspection and test reports were within the prescribed requirements of the FRA's signal regulations. The Safety Board concludes that the signal system was not a factor in the accident.

At the time of the accident, "Warning 0004," issued by the BNSF contract weather service, WDI, was in effect for the accident location. The warning called for flash flooding, thunderstorms, and heavy rain. The Safety Board concludes that the weather warnings and alerts issued by WDI were both timely and substantially correct.

A Safety Board review of Amtrak and FRA forms documenting the required predeparture mechanical and air brake tests and inspections revealed that all tests and inspections were performed as required and no defects were noted. Examination and testing of the train equipment at the accident site did not reveal any preexisting condition that may have caused or contributed to the accident. In addition, the operating crew did not report any anomalies with the mechanical condition of the train before the accident. Therefore, the Safety Board concludes that the mechanical condition of the train was not a factor in the accident.

The engineer, assistant engineer, and conductors all were in good health, well rested, and qualified on the operating rules and physical characteristics to operate passenger trains over this territory. Because of the darkness and the speed at which the train was traveling, the operating crew had only a few seconds to identify and respond to (that is, apply the brakes) the anomaly noted in the track at the bridge. The crew applied the brakes about the time the train crossed the bridge. The Safety Board concludes that the health, rest, and qualifications of the train crew were not factors in the accident.

On the day of the accident, the track supervisor was in good health. Although he had been awakened earlier than he had planned, no evidence indicates that fatigue impaired his performance. He was adequately trained to perform track inspections over his territory, and he responded in a timely manner to the instructions to inspect the track. However, he had not received training specific to bridge inspections; consequently, he was not qualified to conduct the necessary inspection of the bridge structures under these circumstances. The Safety Board therefore concludes that, although the track supervisor conducted a track inspection over his territory during the flooding, he was not qualified to conduct bridge inspections.

Under the FRA's regulation at 49 CFR 219.201(b), toxicological testing was not required to be performed in the case of this accident. The Safety Board found no evidence to indicate that the circumstances of the accident were related to fatigue or impairment.

The Accident

About 5:56 a.m. on the day of the accident, both the engineer and assistant engineer of Amtrak train 4 saw a "hump" in the track as they approached bridge 504.1S. They applied the train's emergency braking but did not have sufficient time or distance to stop the train short of the "hump." The train derailed, and the locomotive units separated as the train was crossing the bridge. The train came to a stop with the last occupied passenger car spanning the failed bridge. The ground under the bridge support structure had been washed away, and the bridge was probably collapsing while the train was passing over it.

After receiving severe weather alerts and flash flood warnings from WDI earlier on the morning of the accident, the BNSF NOC had notified its maintenance-of-way operations desk of the information that applied to the Kingman area. The BNSF NOC had the responsibility to ensure the safety of its train operations through the Kingman area through its train dispatchers. Train operation personnel rely on the maintenance-of-way personnel to perform the appropriate inspections to provide the necessary level of safety for continued train operations. (This is an expected function of maintenance-of-way personnel and not unusual in the railroad industry during severe weather conditions.) When an unsafe condition is found, the track inspector has the responsibility to notify the train dispatcher so that the dispatcher can alert engineers of trains operating in the affected area to stop their trains or coordinate their trains' movements with the track inspector, or both.

About 1:57 a.m. on the morning of the accident, the track supervisor was ordered by the maintenance-of-way desk to perform a track inspection for his territory. He began his track inspection about 4:05 a.m., stopping at several bridges before bridge 504.1 without noting anything unusual. However, at bridge 504.1, the accident bridge, he did not stop but made his observations from his hy-rail vehicle. He later stated, "That's the first time that I saw that volume of water under that particular bridge… [the water was] lapping against the bottom of the bridge." He also stated, "I knew from experience that what—that I was looking for anything out of the ordinary—and at the time the knowledge that I had—I took no exception to anything I observed." He did not report any problems to the dispatcher and continued with his inspection.

The Safety Board identified several concerns as a result of its investigation. The most important were the circumstances that precipitated the bridge failure, the adequacy and method of the bridge inspection process, and the injuries to passengers of the Amtrak train. Because of these concerns, the investigation focused on safety issues identified in the following areas: safety of structures subject to damage in severe storms, passenger safety and emergency response procedures, and protection of employees on or adjacent to the track in the performance of their duties.

Safety of Structures Subject to Damage in Severe Storms

Failure of Bridge 504.1S

The investigation examined the adequacy of the design, maintenance, inspection, and drainage area characteristics of bridge 504.1S in light of the severe weather and flash flood conditions affecting the bridge and the subsequent failure of the crosswall and the bridge supporting structure.

The south bridge, 504.1S, was supported by a shallow foundation consisting of timber mud sills and timber blocking. BNSF records showed that the bridge supports were susceptible to scouring and erosion as early as 1959, when it was necessary to add stones and grout to a portion of the streambed. In the succeeding years, additional stones and grouting were added. Records also showed that, in 1975, maintenance personnel were still concerned about the bridge supporting structure and its water-carrying capacity. In fact, they remained so concerned that they recommended that the bridge be placed on the CIP list for replacement.

BNSF bridge records identifying the size of the drainage area for bridge 504.1 were inconsistent. One record showed the drainage area as encompassing 3.8 square miles, while another showed the drainage area as totaling 19.09 square miles. The size of the drainage area is an important element in determining the required waterway opening for drainage structures. After the accident, the BNSF's consultant (HDR Engineering, Inc.) determined that the drainage area for bridge 504.1 was 19.5 square miles. The consultant's report cited the accepted engineering practice of using the 100-year storm criteria to provide for drainage structures but noted that local conditions and circumstances, such as the desert nature of the Kingman area, allowed for making an engineering judgment resulting in higher or lower values. According to the consultant's report, the bridges located at MP 504.1 at the time of the accident were capable of withstanding a 24-year storm. The storm related to this accident was determined to have been approaching a 50-year storm event of 2 hours' duration. (The August 9, 1997, storm's effect differed among the five railroad bridges in the area. Bridge 504.1 experienced an approximate 50-year storm event, while bridge 503.7, for example, experienced an approximate 10-year storm event.) The bridge with which the BNSF replaced bridge 504.1 following the accident is capable of withstanding a 40-year storm.

In 1975, ATSF (BNSF)[32] management placed bridge 504.1 on the 1977 CIP replacement program because the results of engineering studies raised concerns about the bridge's ability to provide an adequate waterway opening and about recurring erosion problems. In early 1976, however, ATSF (BNSF) bridge maintenance personnel made a field decision to build an unreinforced concrete crosswall on the downstream side of bridge 504.1. Bridge 504.1 was subsequently removed from the 1977 replacement program.

Only two instances of high water were recorded for bridge 504.1 and both took place in 1976. This was after 1971 work affecting the box culverts downstream from the BNSF bridges had been performed by the ADOT and after bridge 504.1 had been removed from the CIP budget list. Before the 1997 derailment at bridge 504.1S, no accidents involving high water or bridge failure were recorded for the Kingman area.

The purpose of the unreinforced concrete crosswall was to allow silt to back up and accumulate around the mud sills, thus acting to mitigate further scouring and erosion. However, no engineering evaluation was performed on the design and construction of the unreinforced concrete crosswall to determine the necessary anchorage, the appropriate size, the need for reinforcement, or the hydrologic characteristics of the waterway.

The severe flash flooding and resultant stream flow between bridge 504.1 and Route 66 caused severe erosion that rapidly progressed upstream. The Safety Board cannot determine whether channel improvements made in 1971 contributed to this development, but evidence of streambed erosion was found during the on-site investigation. This erosion progression caused the failure of the unreinforced concrete crosswall because it was not anchored and was only 33 inches in depth. Because it was unreinforced, the crosswall broke into several pieces when its shallow footing was undermined.

When the concrete crosswall failed, the rate of erosion accelerated through the accumulated silt to the point that it quickly progressed to the shallow foundation of the bridge. This process undermined the bridge's mud sills and timber blocking and compromised the bridge's ability to support Amtrak train 4. The Safety Board therefore concludes that the failure of the bridge 504.1S was caused by scour and erosion affecting the inadequately protected shallow foundations that supported the bridge; the scour resulted because a poorly designed concrete crosswall was built instead of a new and better-engineered bridge. (See figures 13 through 16.)

[32] At this time, the October 1, 1995, merger between the ATSF and the Burlington Northern Railroad had not yet taken place.

Figure 13. Crosswall after the accident

Figure 14. Closer view of failed crosswall

Figure 15. Scour and erosion at bridge 504.1

Figure 16. Another view of scour and erosion at bridge 504.1

Consequently, the Safety Board believes that the BNSF should identify and perform a risk assessment of all system bridges that have shallow foundations of similar construction to the bridge that failed in the Kingman, Arizona, accident and replace those bridges determined to be susceptible to undermining and loss of the supporting foundation structure. In conjunction with the risk assessment, the BNSF should perform a hydrology study on shallow foundation structures with questionable drainage areas to determine their current drainage areas. The Safety Board also believes that the FRA should require that all railroads identify and perform a one-time risk assessment of the bridges on their systems that have shallow foundations of similar construction to the bridge 504.1 that failed in the Kingman, Arizona, accident and require replacement of those bridges determined to be susceptible to undermining and loss of the supporting foundation structure. In addition, the Safety Board is concerned that similar situations may exist on other railroad systems in the country that are subject to flash flooding. Therefore, the Safety Board believes that the Association of American Railroads and the American Short Line and Regional Railroad Association should provide information to make their memberships aware of the facts and circumstances of this accident.

Risk Concern for Route 66 Concrete Box Culverts

In its report to the BNSF, HDR Engineering noted concerns regarding the concrete box culverts under Route 66 adjacent to and downstream of the BNSF bridges in the accident area. Results of the BNSF hydrology study revealed that the highway box culvert downstream from railroad bridge 504.1 was apparently engineered to withstand a 25-year flood. According to the study,

> At this time, based on the bed degradation which has developed below all five of the downstream highway 66 bridge structures, the highway structures have the potential of being washed out with the next major flood event, with the potential for the resultant headcut (of a potential magnitude of 5 feet) proceeding through the railway bridges (Br. 503.1, 504.1, and 505.9).

ADOT inspectors did not find any significant problems with the bridge (box culvert) either during the last scheduled inspection in February 1997 or the postaccident inspection of August 12, 1997. Although scour observations and measurements were made by the ADOT inspector, no scour calculations were made during either inspection. ADOT did not require scour calculations.

Although the Safety Board did not request that the BNSF conduct a hydrology study or a scour vulnerability assessment of either the highway box culvert or the railroad bridges for the Kingman investigation, the BNSF provided this information to the Safety Board in its report. The Safety Board is concerned about the statements made in the BNSF report regarding the vulnerability of the box culverts and the potential effect such culverts might have on the railroad bridges in another severe storm situation.

However, the BNSF report did not include ADOT bridge inspection data or pictures of the streambed dating back to 1971, information that would have been helpful in determining the relationship between the box culverts and the railroad bridges. The Safety Board therefore concludes that the relationship of the two structures and their respective zones of influence is not fully understood. The Safety Board believes that the ADOT should examine the "System Analysis Seligman Subdivision Bridge No.'s 503.1-505.9" report in light of its own historical bridge inspection information and take any action it deems appropriate. In addition, the Safety Board believes that the Federal Highway Administration should examine the "System Analysis Seligman Subdivision Bridge No.'s 503.1-505.9" report and the ADOT historical bridge inspection data to determine the hydrologic relationship between the box culvert and bridge 504.1. If the examination determines that the structures have a detrimental hydrologic effect on each other, the Federal Highway Administration should alert the States and the FRA that similarly related structures may be vulnerable to similar problems.

Adequacy of Inspection Procedures During Severe Weather Events

The track supervisor inspecting the track and bridges stated that on the day of the accident he took no exception to anything that he observed. He stated that, based on his knowledge of bridge inspections at that time, he was, "Completely 100-percent confident that my railroad was able to support traffic of any nature after I had made the inspection." He stated that if he had observed debris under the bridge, he would have become concerned, notified the dispatcher to stop trains in that area, and requested help from a roadmaster. He also stated that he had no knowledge that one bridge would be less able to support train traffic than another.

On the day of the accident, the presence of water above the bridge foundation would have prevented thorough inspection of the bridge supporting structure by anyone, even a qualified bridge inspector. However, the high water levels could have indicated a potential for structural failure of the bridge foundations. A track inspector with relevant bridge inspection training could have recognized that the flooding had the potential to cause problems with several bridges in the Kingman area—including bridge 504.1—and taken measures to stop train traffic until a thorough inspection of the bridge supporting structure could be conducted.

Following the accident, the BNSF developed a 1-hour training program concerning bridge inspections for maintenance-of-way employees. The training describes various types of bridges and their supporting structures (such as shallow-foundation and deep-foundation bridges) and "tell-tale" signs that the structure may have been damaged. The track supervisor who inspected bridge 504.1 on the day of the accident has since taken the BNSF training, and, in hindsight, found that his knowledge of bridges at the time of the derailment would not have been adequate for him to assess possible damage.

For instance, before his training, the track supervisor was not alarmed by the presence of high water under bridge 504.1. Since his training, however, he recognizes the possibility of the bridge supporting structure being damaged as a result of any amount of water around it. The BNSF expects that this training will provide basic insight for track inspectors to recognize the types of bridges susceptible to damage in severe flash flooding conditions when a qualified bridge inspector is not immediately available to perform an inspection. Also, it will teach track inspectors to stop trains before they reach the bridge if they have any doubt as to the bridge's safety. The program has not been in place long enough to evaluate its effectiveness.

Before the training program was instituted, the BNSF should not necessarily have relied on its track inspectors to adequately assess possible bridge damage caused by flooding conditions; rather, the BNSF should only have relied on qualified bridge inspectors to perform these inspections. In this case, had the qualified bridge inspector for the area been notified immediately of the flash flooding near Kingman, he would not have arrived in time to have inspected the bridge before Amtrak train 4 derailed. When the derailment occurred, the bridge inspector assigned to this area was at home, on vacation, and he told investigators that it would have taken him at least 4 1/2 hours to drive to Kingman. Therefore, additional responsibility (such as for bridge inspections) was placed on the track supervisor, who at that time had not been trained to recognize the potential damage flood waters could cause to bridge foundations.

Because the track supervisor was not a qualified bridge inspector and had not received formal training in this area, he was ill prepared to complete rudimentary bridge inspections. The BNSF understood that, during flooding conditions, a bridge inspector could take several hours to arrive on scene. As a result, the responsibility for ensuring the integrity of both the track and bridges was often placed on the track inspector (or, in this case, the track supervisor). The Safety Board concludes that Amtrak train 4 derailed when bridge 504.1S failed because the BNSF maintenance-of-way managers lacked proper foresight and planning regarding the assignment or training or both of personnel designated to conduct bridge inspections during severe weather. The Safety Board believes that the BNSF should evaluate, and improve as necessary, its basic bridge inspection training program for track inspectors to ensure that appropriate procedures are used in emergency situations. Further, the Safety Board believes that the BNSF management should periodically review bridge inspection training for track inspectors to ensure that it meets program objectives.

Protection of Trains During Severe Weather Conditions

On August 10, 1997, (the day after the accident) the BNSF issued a Maintenance Alert that stated a policy for trains operating during severe flooding. The Maintenance Alert was subsequently updated on February 20, 1998, because of severe storm-related conditions and traffic delays that affected the BNSF's Northern California Division through the San Joaquin Valley. The updated version of the alert is applicable only to that BNSF division. Trains on all other BNSF divisions must comply with the August 10, 1997, Maintenance Alert requirements of 40 mph for freight trains and "restricted speed" for passenger trains until the weather warning expires.

In the February 20, 1998, version, the train speed restrictions for both freight and passenger trains were relaxed from the earlier Maintenance Alert. When weather warnings are issued for a "flash flood warning," freight and passenger trains are restricted to 40 mph and 50 mph, respectively, except in the areas where the 14 bridges have been identified as being vulnerable to scour because their foundations do not have piling. In those instances, the BNSF's passenger trains and "key trains" (those transporting hazardous materials) are required to operate at restricted speed, but all other freight trains can operate at 40 mph. The Maintenance Alert stays in effect until the weather warning expires.

The Safety Board recognizes the added safety for the train crews and passengers provided by reducing the speed of the passenger trains to a level from which they can be stopped in a relatively short distance in the event of an emergency. The Safety Board does not understand, however, the safety rationale for BNSF freight train crews being permitted to travel at speeds that may still require stopping distances of up to a mile. The Safety Board concludes that when, because of flash flooding conditions, the integrity of bridges has yet to be validated, it is critical that trains be operated at a reduced speed such as "restricted speed." Train operations at restricted speed provide a margin of safety for the engineer to operate the train at a speed slow enough, while not exceeding 20 mph, to be able to safely stop the train within one-half his range of vision, which could be affected by weather conditions such as heavy rain or darkness or both. Therefore, the Safety Board believes that the BNSF should conduct a thorough analysis to determine the appropriate personnel, inspection, and operating policies to be used during flash flooding conditions and establish procedures designed to ensure the safe passage of all trains. The analysis should address the minimum training requirements for personnel responding to emergency inspections and should evaluate current inspection procedures and response actions to determine their adequacy during abnormal or emergency situations. In addition, the Safety Board believes that the BNSF should change its policy regarding freight train operating speeds so that it is consistent with the required operating speeds of other trains during flash flooding weather warnings, as noted in the August 1997 BNSF Maintenance Alert.

The Safety Board acknowledges the prompt action taken by the FRA in issuing its Safety Advisory 97-1 for special inspection procedures for bridges, which resulted from the Kingman accident. The Safety Board, however, is concerned because the items listed in the FRA's advisory are only recommended; they are not regulatory requirements. When issuing the advisory, the FRA cited the Track Safety Standards (49 CFR 213), which state in part, "In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection must be made of the track involved as soon as possible after the occurrence…" as justification for the advisory. The FRA stated that it purposely made this provision general in nature, because, "It is not practicable to specify in a minimum safety standard all the conditions which could trigger a special inspection, nor the manner in which any particular special inspection must be conducted." The FRA believed, "It is more effective to provide information and guidance to the railroad industry, which each railroad can then adapt to its own circumstances."

Although bridge inspections during severe weather circumstances are not mentioned in the FRA's Track Safety Standards, it appears that the FRA assumes that the language in 49 CFR Part 213.239 is a "catch-all" for everything that should be done but is not specifically addressed. Had the FRA's Safety Advisory 97-1 been in effect before the accident, the BNSF may have: had a program in place to identify those bridges that had specific features susceptible to damage in severe weather; analyzed the potential for damage to those bridges; and made that information available to those responsible for inspecting the bridges in such situations. As noted in this accident, however, the track supervisor did not have this type of information before the accident. If he had had this information, he should have been able to recognize the susceptibility of bridge 504.1S to damage during the severe flash flooding and could have taken action to stop trains until an appropriate inspection could be made by a bridge inspector; alternatively, he could have halted train traffic until the water subsided and it could be determined that the bridge was not in danger. The Safety Board concludes that, had the FRA issued minimum standards for special inspection procedures for bridges that would be at risk during severe weather, such as those standards recommended in its Safety Advisory 97-1, the BNSF track supervisor would have had better guidance for making the special inspection. Because the FRA issued the safety advisory as an informational guideline, it has already taken the first step in specifying some minimum safety standards for bridge inspection. Therefore, the Safety Board believes that the FRA should incorporate the intent of Safety Advisory 97-1 into minimum safety standards for special inspection procedures for bridges that would be at risk during severe weather.

Passenger Safety and Emergency Response Procedures

Passenger and Crew Accounting

During the emergency response to the Kingman accident, the Incident Commander requested a copy of the train 4 manifest from an Amtrak employee. The conductor told Safety Board investigators that a passenger manifest was located in the dormitory car, but he did not have time to obtain it because he was helping passengers. The chief of on-board services said that he gave a copy of a sleeping car manifest to a firefighter. It took several days for Amtrak to provide an accurate passenger count of the entire train.

A complete manifest is necessary, in addition to the counts provided by the conductor, so that emergency responders will be able to locate people on the train as quickly as possible and be alerted about those people who may need immediate assistance because of injuries or disabilities. Although a complete manifest of train 4 was eventually available, infants and small children were not included on it because Amtrak does not require tickets for infants and small children. Because the survival of passengers or crewmembers could depend on their timely rescue by emergency responders, the complete manifest should be provided to the Incident Commander as soon as he arrives on scene. Although no complete manifest was available during the emergency response in this instance, the lack of one did not appear to negatively affect the efficiency of the emergency response.

As a result of the Safety Board's investigation of the Amtrak train accident in Mobile, Alabama,[33] the following safety recommendation was issued to Amtrak on September 30, 1994:

> <u>R-94-7</u>
>
> Develop and implement procedures to provide adequate passenger and crew lists to local authorities with minimum delay in emergencies.

Amtrak responded to the safety recommendation on July 18, 1995, stating that a three-phase project to provide a satellite and messaging system between long-distance trains and the corporate entities associated with their operation would be implemented. According to Amtrak, phase I would install the system, phase II would expand the system to more trains, and phase III would provide nationwide voice communications. In a letter dated October 4, 1995, the Safety Board stated that it was pleased to learn that Amtrak was about to implement this project to provide satellite communications capability on trains and that the new system would provide more accurate passenger manifests. Pending implementation of the new system, the Board classified the safety recommendation "Open—Acceptable Response."

On October 19, 1997, an Amtrak official provided the Safety Board with an update of Amtrak's progress in developing the satellite system. The official stated that it would be difficult to account for passengers on Amtrak's unreserved trains because of the frequent stops such trains make. He compared the unreserved trains to transit systems. However, he said that a procedure to account for passengers on reserved Amtrak trains is possible, and that Amtrak has a computer system in place that could do it.

The Safety Board recognizes the practical limitations concerning Amtrak's providing a manifest on unreserved trains because those trains are frequently commuter trains on which passengers may board and detrain quickly, purchase tickets ranging from a per ride to a monthly basis, and not be confined to certain cars or seating. However, reserved trains do not have these characteristics, and the procedure currently used to account for reserved train passengers, by counting tickets, can be improved. The Safety Board is aware that Amtrak has taken steps to improve its means of communication and ability to account for all occupants on board its reserved trains, and the Safety Board is encouraged by Amtrak's progress in this area.

The Safety Board concludes that because an accurate passenger manifest was not provided by the Amtrak train 4 crew to the Incident Commander, the emergency response

[33] Railroad Accident Report—*Derailment of Amtrak Train No. 2 on the CSXT Big Bayou Canot Bridge Near Mobile, Alabama, September 22, 1993* (NTSB/RAR-94/01).

to evacuate and account for all passengers from the train could have been delayed, thus endangering passengers whose locations or circumstances were unknown to emergency responders. Therefore, the Safety Board hereby reclassifies Safety Recommendation R-94-7 to Amtrak “Closed—Reconsidered” and believes that Amtrak should expedite the development and implementation of a passenger and crew accountability system on reserved trains.

Adequacy of Emergency Training

Although passengers were safely evacuated, statements from the on-board service personnel and a review of their training records indicated that the reactions of several of them were based on instinct rather than organized emergency training. For example, one Amtrak attendant stated, “We had no real instruction or direction. We all went on instinct to help one another to see if there were injuries.” He stated that they needed more emergency training. Another attendant had attended Amtrak’s P.R.E.P.A.R.E. training course, which she said made her feel “more knowledgeable, prepared, and focused on what needed to be done.” This attendant recommended that all Amtrak crewmembers take the P.R.E.P.A.R.E. course on at least a 2-year cycle.

The Safety Board reviewed Amtrak’s emergency situation training records for the 18 on-board service persons and operating crewmembers involved in this accident. The training time intervals recorded varied between employees. The most recent training that could be identified from the employee records ranged from training taken 2 months before the accident to training taken as much as 7 years before the accident. Eight employees did not have any emergency situation training dates listed in their training records. These findings are inconsistent with Amtrak’s stated policy of scheduling emergency situation training at least every 3 years for on-board service attendants. Also, although the operating crew participated in refresher or recertification training, their training records indicate that the operating crew did not participate in emergency situation training with on-board service attendants.

Train 4’s on-board service personnel did not use the public address system to communicate evacuation information to the passengers. Although some crewmembers believed that the public address system did not work, they did not attempt to use it even though Amtrak’s emergency training procedures, as provided in the Amtrak training manual, call for its use in emergency situations. Wreckage documentation showed that the public address system was inoperable in some of the cars because of the damage sustained by the equipment.

During emergency situations, particularly those involving passenger evacuations, the train crew and on-board service personnel are responsible for managing and directing the safe evacuation of passengers. Passengers rely on the training, experience, and leadership of the on-board service personnel. Required periodic emergency situation training should prepare the train crewmembers to confidently perform their duties when emergency situations occur.

Since 1984, the Safety Board has addressed the need for Amtrak to improve its emergency situation training program. Over the years, the Safety Board has recognized improvements in Amtrak's training program.

Following its investigation of the Amtrak train accident in Lugoff, South Carolina, on July 31, 1991,[34] the Safety Board recommended that Amtrak:

R-93-23

> Require that all on-board service personnel periodically take training in emergency operating rules and first aid, cardiopulmonary resuscitation, and the use of the public address system during train emergencies.

In a letter dated December 27, 1993, Amtrak concurred with the merit of this recommendation. Amtrak formed a committee to develop an appropriate program to address these issues. The Safety Board responded on February 10, 1994, that a meeting with Amtrak would be postponed until the committee began its review of the issues. As a result, the Safety Board classified Safety Recommendation R-93-23 "Open—Acceptable Response."

Based on the personnel training record data reviewed in this accident, however, not all Amtrak employees appear to have received the necessary training or retraining in accordance with Amtrak's program. All employees should be provided the same level of emergency situation training within a reasonable time period. Although the evacuation went well in this accident, the responsibilities of train crewmembers should not be carried out in an ad hoc manner. Amtrak employees should be trained in their emergency responsibilities and not have to rely on instinct alone.

The lack of communication between the conductor and on-board service chief in providing a complete passenger manifest to the Incident Commander demonstrates a need for additional training of Amtrak personnel to emphasize their responsibilities when receiving requests from emergency responders and coordinating the emergency response on scene. In the Safety Board's investigation of an accident that occurred on February 16, 1996, near Silver Spring, Maryland,[35] the importance of the timely exchange of information between train crew personnel and the Incident Commander was examined. Coincident with the accident investigation, the FRA published, on February 24, 1997, the Notice of Proposed Rulemaking for *Passenger Train Emergency Preparedness*, which proposed requiring minimum Federal safety standards for the preparation, adoption, and implementation of emergency preparedness plans by railroads connected with the operation of passenger trains, including freight railroads hosting the operations of rail passenger service. The rule also required each affected railroad to instruct its employees

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[34] Railroad Accident Report—*Derailment and Subsequent Collision of Amtrak Train 82 With Rail Cars on Dupont Siding of CSX Transportation, Inc., at Lugoff, South Carolina, on July 31, 1991* (NTSB/RAR-93/02).

[35] Railroad Accident Report—*Collision and Derailment of Maryland Rail Commuter* MARC *Train 286 and National Railroad Passenger Corporation* Amtrak *Train 29 Near Silver Spring, Maryland, on February 16, 1996* (NTSB/RAR-97/02).

about the provisions of the plan. The FRA issued the final rule on *Passenger Train Emergency Preparedness* on May 4, 1998, with an effective date of July 6, 1998.

The Safety Board concludes that Amtrak's current system for providing emergency training for train crews and on-board service personnel has not been effective, which has resulted in personnel being provided differing levels of emergency situation training. The Safety Board believes that Amtrak should implement effective controls to monitor and ensure that all train crews and on-board service personnel receive the necessary initial and recurrent emergency training to provide for passenger safety.

Emergency Lighting and Public Address Systems

The failure of emergency electrical systems to provide emergency power can be a serious problem in critical situations such as derailments. The emergency electrical system for each passenger car on train 4 was either at minimal output or at no power as a result of the derailment. Extensive undercarriage damage resulted in severed wiring and electrical conduits. Consequently, neither the interior emergency lights nor the public address system was reliable for operation, and no back-up system was provided. Passengers either had to rely on the instructions they were given by the Amtrak personnel in their car or to evacuate the train on their own.

Following a June 15, 1982, derailment of an Amtrak train in Emerson, Iowa,[36] the Safety Board issued the following safety recommendation to Amtrak:

> R-83-25
>
> Evaluate and modify, as necessary, emergency lighting systems in passenger-carrying cars to better protect the functioning of emergency lights in emergency situations.

Amtrak responded in 1984 that the emergency lighting system was designed to provide a minimum of 2 hours of acceptable illumination when the primary power source was interrupted. Amtrak believed that this 2-hour period was a reasonable length of time in an emergency situation. Amtrak also stated that using the existing commercial, battery-operated, self-contained fixtures on railway cars is not feasible. The safety recommendation was classified "Closed—Unacceptable Action" in April 1988.

On September 22, 1993, Amtrak train 2 struck a displaced railroad bridge and derailed into the Big Bayou Canot near Mobile, Alabama,[37] at about 2:53 a.m. Forty-two passengers and 5 crewmembers were killed; 103 passengers were injured. The Safety Board issued the following safety recommendation to Amtrak:

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[36] Railroad Accident Report—*Derailment of Amtrak Train No. 5 (the San Francisco Zephyr) on the Burlington Northern Railroad, Emerson, Iowa, June 15, 1982* (NTSB/RAR-83/02).

[37] NTSB/RAR-94/01.

R-94-8

Equip cars with portable lighting for use by passengers in an emergency.

In July 1995, Amtrak stated that it was evaluating the use of portable chemical light sticks for permanent installation on all Amtrak trains. Such light sticks are weatherproof, maintenance-free, nontoxic, nonflammable, and not sources of ignition. They provide immediate and dependable light for up to 8 hours. Amtrak placed light sticks on all its passenger trains, and Safety Recommendation R-94-8 was classified "Open—Acceptable Action."

In the Kingman accident, the Amtrak light sticks provided sufficient emergency lighting until the arrival of emergency responders. Light stick use was limited, but the usefulness of the light sticks was well acknowledged by the passengers, and they provided a measure of safety when the emergency lighting failed. Based on these actions by Amtrak, the Safety Board classified Safety Recommendation R-94-8 "Closed—Acceptable Action" on March 26, 1998.

The Safety Board is, however, concerned that not enough is being done to provide for passenger safety when emergency power is lost. In the 1996 Silver Spring accident,[38] a contributing factor to the severity of the accident and the loss of life was the lack of appropriate regulations to ensure adequate emergency egress features on railroad passenger cars. One of the safety recommendations issued following this investigation called for the FRA to:

R-97-17

Require all passenger cars to contain reliable emergency lighting fixtures that are each fitted with a self-contained independent power source and incorporate the requirements into minimum passenger safety standards.

On February 25, 1998, the FRA responded to this safety recommendation, stating that:

> FRA findings in recent accidents support the Safety Board's implied concern that placement of electrical conduits and battery packs below the floor of passenger coaches can result in damage that leads to the unavailability of emergency lights precisely at the time they are most needed. However, from initial investigation it is not certain whether current 'ballast' technology provides illumination of sufficient light level quality with reliable maintainability.

At a meeting in December 1997, the FRA delegated this issue to its Railroad Safety Advisory Committee for Passenger Equipment Safety Standards Working Group and stated that this group will aggressively pursue this option for more reliable

[38] NTSB/RAR-97/02.

emergency illumination. The status of Safety Recommendation R-97-17 is "Open—Response Received."

The Safety Board concludes that passenger car interiors must have interior emergency lighting because a sufficient quantity of light sticks may not always be available, and light sticks may not be suitable for a large-scale evacuation such as the one that occurred in this accident. In addition, while the light stick may serve adequately as a personal emergency light source during an evacuation, it is not a self-contained emergency lighting source. Therefore, the Safety Board believes that Amtrak should install, in all new passenger equipment purchased after January 1, 2000**,** and in existing passenger cars during their major overhaul/rebuild operations, fixtures that use a "self-contained back-up energy reserve feature" to make the fixtures less vulnerable to the disruption of electrical power during derailments. In addition, the Safety Board reiterates Safety Recommendation R-97-17 to the FRA.

Seat Securement

Inspection of train 4's seats indicated that none had become separated from their floor mountings. However, 18 seat assemblies were found with their rotating locking mechanisms not engaged. A disengaged seat lock can result in an uncontrolled rotation of the seat assembly, even in cases of a minor derailment, which may result in serious injuries to passengers. In the August 23, 1990, Batavia, Iowa,[39] accident report, the Safety Board stated its concern regarding Amtrak's seat locks and noted that seats can become unlocked either because the locking mechanisms are disengaged en route by passengers or because they are defective. The Safety Board issued the following safety recommendation to Amtrak:

> <u>R-91-71</u>
>
> Implement procedures for on-board-service personnel to periodically check passenger seats en route for unlocked anti-rotational devices and take action to ensure seats are functional.

On May 22, 1992, this safety recommendation was classified "Closed—Acceptable Action," based on Amtrak's response that it was immediately issuing instructions systemwide to check and ensure that seat locks are functional and engaged.

Absolute assurance is not always possible, however, because passengers can readily disengage the mechanism to rotate the seat to suit their personal requirements and may fail to ensure that the locking mechanism is again positively engaged. Further, on-board service personnel may not be able to provide the constant vigilance necessary to ensure that the seat locking mechanisms have been properly restored, because the seat locking mechanism is not readily visible. A simple solution may be to employ a positive locking mechanism that requires use of a special keying feature accessible only to

[39] Railroad Accident Report—*Derailment of Amtrak Train No. 6 on the Burlington Northern Railroad, Batavia, Iowa, April 23, 1990* (NTSB/RAR-91/05).

crewmembers (such as a conductor's coach key). This procedure could provide for seat locking security and effectively eliminate manipulation by passengers.

The Safety Board concludes that the current procedures used to check and ensure that passenger car seat locks are functional and engaged are inadequate. The Safety Board believes that Amtrak should install a positive seat securement system to prevent disengagement and undesired rotation in all new passenger cars purchased after January 1, 2000, and incorporate such a system into existing passenger cars when they are scheduled for overhaul. Furthermore, the Safety Board believes that the FRA should include in the passenger car safety standards a requirement for positive seat securement systems to provide against the disengagement and undesired rotation of seats in all new passenger cars purchased after January 1, 2000, and require the incorporation of such a system into existing passenger cars when they are scheduled for overhaul.

Emergency Response

General

The Mohave County sheriff's deputies who were in the vicinity of the derailment responded within minutes. The Kingman Fire Department and other mutual aid agencies responded to help with the search and rescue efforts and to transport the train crew and passengers. Emergency responders carried out triage on survivors and transported them to hospitals by helicopter, bus, and ambulance in a timely manner. Adequate resources and personnel were available to effectively manage the response. The Safety Board concludes that the emergency response was timely, and the resources provided for the emergency response were adequate.

Unverified Notification Information

During the initial communication of on-site information by local agencies, some confusion resulted in the erroneous reporting of 8 to 13 fatalities, when no fatalities had actually occurred. A BNSF special agent called the Mohave County Sheriff's Department to inquire about the accident and was told that two persons in the upper level of the dormitory car were seriously injured and that those injured would probably be DOA. The BNSF relayed this information to other BNSF employees and, in some cases, stated that two DOAs were reported. In subsequent conversations with the Mohave dispatcher and a sergeant, the BNSF special agent overheard the dispatcher talking to someone on scene over the radio referring to "six downstairs." The special agent asked if she had heard that there were two DOAs upstairs and six DOAs downstairs in the dormitory car; the sergeant replied, "Yes." The initial speculation by the Mohave dispatcher that those persons with serious injuries would become DOAs apparently caused others to use that same terminology. This incorrect information was subsequently relayed to various, including Federal, organizations. The Safety Board recognizes that conflicting reports of the circumstances of an accident often are communicated initially, and that in the early stages of the response, emergency responders must speculate and evaluate the situation to ensure that adequate resources are available for the worst-case scenario; but speculation is not fact.

The information that is relayed to responding agencies must be as accurate as possible, and information that is relayed to other parties must either be confirmed as factual or clearly characterized as unverified. The Safety Board concludes that the inaccurate reporting of fatalities that took place during the accident notification process was a result of unconfirmed information being relayed to Federal agencies by local organizations. Therefore, the Safety Board believes that the Mohave County Sheriff's Department, the International Association of Chiefs of Police, and the National Sheriffs' Association should review the circumstances of this accident with their dispatchers and emphasize the importance of relaying verified factual information when communicating with other agencies.

Protection for Employees on or Adjacent to Track in Performance of Their Duties

The FRA was required by the Rail Safety Enforcement and Review Act of September 3, 1992, to review the Track Safety Standards and revise them based on information derived from that review. One of the issues identified to be addressed was the safety of maintenance-of-way employees working on or along the railroad right-of-way. This issue was separated from the ongoing review of the Track Safety Standards and assigned to a separate Railroad Safety Advisory Committee, which was to study the issue and develop recommendations.

As part of this study, FRA records identified 22 fatalities that occurred in the period between 1989 and 1993. An independent labor-management task force focused on 43 accidents that resulted in 46 fatalities and 150 injuries from 1986 through 1994. Most of the fatalities occurred while some form of protection system was available or in use. Through this process, the FRA initiated rulemaking activity, which resulted in the Roadway Worker Protection (RWP) regulations (found in 49 CFR 214) that became effective January 15, 1997.

The track supervisor involved in the Kingman accident was, while inspecting the main track, operating with a track car operator informational line-up. This practice was permissible under the requirements of the FRA RWP regulations.

Class I railroads, including the BNSF, were required to be in compliance with the new regulations as of March 15, 1997. The regulations also provided that carriers each prepare a plan for compliance and notify the FRA, at least 1 month before March 15, 1997, that its plan was prepared and available for FRA review.

The RWP regulations permitted railroads that used informational line-ups as of March 14, 1996, to continue using them. However, the RWP regulations also required that the carrier's plan for compliance with the regulations contain a schedule for the discontinuance of the informational line-up procedure by a definite date.

The BNSF developed a plan as required by the regulations and notified the FRA before March 15, 1997. The plan called for the use of both train location line-ups and track car operator line-ups to be discontinued by August 1, 2016. The FRA reviewed this plan with the BNSF on April 9, 1997, at BNSF headquarters in Fort Worth, Texas. As of July 14, 1998, the FRA had not approved the BNSF plan.

An internal BNSF memorandum, dated February 13, 1998, stated that, as of January 29, 1998, train location/track car operator line-ups were still in use on 14 branch lines and 4 main line subdivisions. The memo further stated that, although the BNSF had committed to discontinue the use of these line-ups by August 1, 2016, ongoing efforts were underway to employ alternate methods wherever possible, given communications constraints. The BNSF timeline for eliminating the use of line-ups was tied to expansion of cellular telephone coverage on remote territories and implementation of emerging control and voice communications technologies.

Although the operational practices that the track supervisor used during his special inspection were not factors in the derailment of Amtrak train 4, the Safety Board is concerned about the potential risk to employees engaged in special inspections while located on or adjacent to the railroad tracks. In this accident, the track supervisor confirmed that no mechanism was in place to protect him or other track inspectors if they could not contact the dispatcher for any reason. He considered it the employee's responsibility to get out of the way of trains. Track inspectors believe that their protection lies in the informational line-up, even though they know that the line-up is only valid for about 4 hours and that the dispatcher would not try to locate them. This practice places the responsibility on the employee to protect himself, and generally he can. If, however, the track inspector becomes incapacitated, or the communications equipment fails, or the dispatcher does not stop trains from entering the area occupied by the inspector, the inspector could be put in jeopardy.

The RWP regulations were intended to provide protection and safety for on-track workers. They specifically address the need to discontinue the use of informational line-ups as the sole protection for track inspectors. The Safety Board concludes that the BNSF's 18-year timeframe for discontinuing the practice of using informational line-ups to ensure worker safety is too long and, until eliminated, the practice has the potential to place railroad workers in danger. The Safety Board therefore believes that the BNSF should immediately discontinue the use of informational line-ups. The Safety Board is disappointed by the FRA's lack of aggressive action to ensure that railroads become more responsive to the issue of roadway worker protection in a timely manner.

Locomotive Event Recorders

The problem of mismatched software readout programs being used to read event recorder information is not new to the Safety Board. Hundreds of software readout programs and versions of those programs are used to read out today's solid-state event recorders. The Safety Board laboratory is constantly updating its readout programs to keep current with the many programs and software revisions as they evolve. Unlike magnetic tape recorders, solid-state event recorders can only be read out using a computer and appropriate software. Therefore, it is imperative that event recorder data be read out using the correct software, to ensure that all the recorded data are extracted and that the data are accurate.

In this particular accident, however, Amtrak did not have the capability to read out all the data on its own recorders. Amtrak was unaware that valuable additional data had been recorded on its event recorders; six more parameters were actually recorded but not extracted by the Amtrak IFC analysis program. These parameters—emergency type, EOT emergency (on or off), bell, brake handle position, EIE (on or off), and dynamic brake derate (on or off)—provide data about the operational characteristics of the train important for performing an accurate accident investigation. The Safety Board therefore concludes that, had Amtrak been more familiar with the specifications of the event recorders on train 4, it could have obtained additional information from them that would have been useful.

The FRA, in conjunction with the railroads and recorder/software manufacturers, is responsible for ensuring that all recorded data can be accurately and reliably retrieved after any train accident. No industry-wide procedures or Federal regulations address documentation of locomotive event recorders or readout system specifications. These specifications are necessary to conduct accurate readouts of event recorders. Physical inspections of the locomotive to determine the recording system specifications can be impractical or, in the case of severe accidents, impossible, because of component damage.

Therefore, the Safety Board believes that the FRA should require that event recorder system specifications be kept as part of the locomotive's records. These records should be readily accessible for FRA or Safety Board inspection and must be kept up to date. These records should include, at a minimum: (1) the name, version, and date of the readout program intended for use with the recorder currently installed on the locomotive; (2) the manufacturer, model number, and serial number of the event recording device and its associated components (to include the air brake manifold, axle generator or equivalent, and signal conditioning devices) currently installed on the locomotive; (3) a complete list of parameters that the recording system is currently configured to record; and, (4) the recording system's manufacturer-prescribed modification, revision, and software-hardware version numbers.

Locomotive Fuel Tank Crashworthiness

All four units in the train 4 locomotive power consist were GE model P-42 locomotives, which is a relatively new locomotive design having a monocoque body incorporating a relatively high undercarriage clearance (to the top of the rails) and an integrated fuel tank. The fourth unit in the consist sustained noteworthy damage, being impaled by a length of rail that had dislodged from the track structure during the derailment. The rail punctured the end panels of the fuel tank and inflicted other serious structural damage, yet it caused no catastrophic rupture of the fuel tank or fire and only a minor amount of fuel spillage. Contributory to this lack of fuel tank damage was the ample undercarriage clearance available in this unit, as compared to other locomotives with conventional frame-suspended fuel tanks.

Only performance in future accidents will prove whether the high ground clearance and integrated fuel tank design found in this type of unit will permit such tanks to continue to resist catastrophic rupture or breach, but the Safety Board acknowledges the crashworthiness performance of the advanced fuel tank design of the locomotives in this accident. The P-42 locomotive fuel tank of the fourth locomotive in the consist, with its relatively high ground clearance, integral location, and internal baffle system, demonstrated its ruggedness and ability to withstand the rigors of a serious derailment, as compared to a conventional, frame-suspended locomotive fuel tank, which in past derailments has been shown to be vulnerable to catastrophic puncture and potential fire. The Safety Board concludes that, in this accident, the new Amtrak P-42 locomotive fuel tanks demonstrated a level of crashworthiness that has not been shown by conventional, frame-suspended locomotive fuel tanks that have been vulnerable to catastrophic puncture and fire.

The Safety Board has previously expressed its concern to the FRA about other locomotives built before the effective date of September 1, 1995, noting that many of these locomotives will remain in service for several years, and this accident demonstrates that new designs can improve the crashworthiness performance of locomotive fuel tanks. The Safety Board will continue to address the crashworthiness issue in future accident investigations and to monitor FRA progress in improving locomotive fuel tank crashworthiness.

Conclusions

Findings

1. The track did not cause or contribute to the accident.

2. The signal system was not a factor in the accident.

3. The weather warnings and alerts issued by WeatherData, Inc., were both timely and substantially correct.

4. The mechanical condition of the train was not a factor in the accident.

5. The health, rest, and qualifications of the train crew were not factors in the accident.

6. Although the track supervisor conducted a track inspection over his territory during the flooding, he was not qualified to conduct bridge inspections.

7. The failure of bridge 504.1S was caused by scour and erosion affecting the inadequately protected shallow foundations that supported the bridge; the scour resulted because a poorly designed concrete crosswall was built instead of a new and better-engineered bridge.

8. The relationship of the highway box culverts and the railroad bridges and their respective zones of influence is not fully understood.

9. Amtrak train 4 derailed when bridge 504.1S failed because the Burlington Northern Santa Fe maintenance-of-way managers lacked proper foresight and planning regarding the assignment or training or both of personnel designated to conduct bridge inspections during severe weather.

10. When, because of flash flooding conditions, the integrity of bridges has yet to be validated, it is critical that trains be operated at a reduced speed such as “restricted speed.”

11. Had the Federal Railroad Administration issued minimum standards for special inspection procedures for bridges that would be at risk during severe weather, such as those standards recommended in its Safety Advisory 97-1, the Burlington Northern Santa Fe track supervisor would have had better guidance for making the special inspection.

12. Because an accurate passenger manifest was not provided by the Amtrak train 4 crew to the Incident Commander, the emergency response to evacuate and account for all

passengers from the train could have been delayed, thus endangering passengers whose locations or circumstances were unknown to emergency responders.

13. Amtrak's current system for providing emergency training for train crews and on-board service personnel has not been effective, which has resulted in personnel being provided differing levels of emergency situation training.

14. Passenger car interiors must have interior emergency lighting because a sufficient quantity of light sticks may not always be available, and light sticks may not be suitable for a large-scale evacuation such as the one that occurred in this accident.

15. The current procedures used to check and ensure that passenger car seat locks are functional and engaged are inadequate.

16. The emergency response was timely, and the resources provided for the emergency response were adequate.

17. The inaccurate reporting of fatalities that took place during the accident notification process was a result of unconfirmed information being relayed to Federal agencies by local organizations.

18. The Burlington Northern Santa Fe's 18-year timeframe for discontinuing the practice of using informational line-ups to ensure worker safety is too long and, until eliminated, the practice has the potential to place railroad workers in danger.

19. Had Amtrak been more familiar with the specifications of the event recorders on train 4, it could have obtained additional information from them that would have been useful.

20. In this accident, the new Amtrak P-42 locomotive fuel tanks demonstrated a level of crashworthiness that has not been shown by conventional, frame-suspended locomotive fuel tanks that have been vulnerable to catastrophic puncture and fire.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was displacement of the track due to the erosion and scouring of the inadequately protected shallow foundations supporting bridge 504.1S during a severe flash flood because the Burlington Northern Santa Fe management had not provided adequate protection, either by inspection or altering train speeds to fit conditions. Contributing to the accident was the failure of the Burlington Northern Santa Fe management to adequately address the erosion problems at bridge 504.1S.

Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following safety recommendations:

—to the Burlington Northern Santa Fe Corporation:

> Identify and perform a risk assessment of all system bridges that have shallow foundations of similar construction to the bridge that failed in the Kingman, Arizona, accident, and replace those bridges determined to be susceptible to undermining and loss of the supporting foundation structure. In conjunction with the risk assessment, perform a hydrology study on shallow foundation structures with questionable drainage areas to determine their current drainage areas. (R-98-48)
>
> Evaluate, and improve as necessary, your basic bridge inspection training program for track inspectors to ensure that appropriate procedures are used in emergency situations. (R-98-49)
>
> Require your management to periodically review bridge inspection training for track inspectors to ensure that it meets program objectives. (R-98-50)
>
> Conduct a thorough analysis to determine the appropriate personnel, inspection, and operating policies to be used during flash flooding conditions, and establish procedures designed to ensure the safe passage of all trains. The analysis should address the minimum training requirements for personnel responding to emergency inspections and evaluate current inspection procedures and response actions to determine their adequacy during abnormal or emergency situations. (R-98-51)
>
> Change your policy regarding freight train operating speeds so that it is consistent with the required operating speeds of other trains during flash flooding weather warnings, as noted in the August 1997 Burlington Northern Santa Fe Maintenance Alert. (R-98-52)
>
> Immediately discontinue the use of informational line-ups. (R-98-53)

—to the Federal Railroad Administration:

> Require that all railroads identify and perform a one-time risk assessment of the bridges on their systems that have shallow foundations of similar construction to the bridge 504.1 that failed in the Kingman, Arizona, accident, and require replacement of those bridges determined to be

susceptible to undermining and loss of the supporting foundation structure. (R-98-54)

Incorporate the intent of Safety Advisory 97-1 into minimum safety standards for special inspection procedures for bridges that would be at risk during severe weather. (R-98-55)

Include in the passenger car safety standards a requirement for positive seat securement systems to provide against the disengagement and undesired rotation of seats in all new passenger cars purchased after January 1, 2000, and require the incorporation of such a system into existing passenger cars when they are scheduled for overhaul. (R-98-56)

Require that event recorder system specifications be kept as part of the locomotive's records. (R-98-57)

—to the Federal Highway Administration:

Examine the "System Analysis Seligman Subdivision Bridge No.'s 503.1-505.9" report and the Arizona Department of Transportation's historical bridge inspection data to determine the hydrologic relationship between the box culvert and bridge 504.1. If the examination determines that the structures have a detrimental hydrologic effect on each other, alert the States and the Federal Railroad Administration that similarly related structures may be vulnerable to similar problems. (H-98-41)

—to the Arizona Department of Transportation:

Examine the "System Analysis Seligman Subdivision Bridge No.'s 503.1-505.9" report in light of your own historical bridge inspection information and take any action you deem appropriate. (H-98-42)

—to the National Railroad Passenger Corporation (Amtrak):

Expedite the development and implementation of a passenger and crew accountability system on reserved trains. (R-98-58)

Implement effective controls to monitor and ensure that all train crews and on-board service personnel receive the necessary initial and recurrent emergency training to provide for passenger safety. (R-98-59)

Install, in all new passenger equipment purchased after January 1, 2000, and in existing passenger cars during their major overhaul/rebuild operations, fixtures that use a "self-contained back-up energy reserve feature" to make the fixtures less vulnerable to the disruption of electrical power during derailments. (R-98-60)

Install a positive seat securement system to prevent disengagement and undesired rotation in all new passenger cars purchased after January 1, 2000, and incorporate such a system into existing passenger cars when they are scheduled for overhaul. (R-98-61)

—to the Mohave County Sheriff's Department (R-98-62):
—to the International Association of Chiefs of Police (R-98-63):
—to the National Sheriffs' Association (R-98-64):

Review the circumstances of the derailment accident that occurred at Kingman, Arizona, on August 9, 1997, with your dispatchers and emphasize the importance of relaying verified factual information when communicating with other agencies.

—to the Association of American Railroads (R-98-65):
—to the American Short Line and Regional Railroad Association (R-98-66):

Make your membership aware of the facts and circumstances of the derailment accident that occurred at Kingman, Arizona, on August 9, 1997.

Also as a result of its investigation of this accident, the National Transportation Safety Board reiterates the following safety recommendation:

—to the Federal Railroad Administration:

R-97-17

Require all passenger cars to contain reliable emergency lighting fixtures that are each fitted with a self-contained independent power source and incorporate the requirements into minimum passenger safety standards.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

August 31, 1998

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Appendix A—Investigation

The Safety Board was notified of this accident about 8:30 a.m., eastern standard time, on August 9, 1997, and dispatched a major railroad accident investigation team. Investigative groups examined the operation, track, structures, signals, mechanical, survival factors, and human performance aspects of the accident.

The Burlington Northern Santa Fe Corporation, the National Railroad Passenger Corporation, the Federal Railroad Administration, the United Transportation Union, the Brotherhood of Locomotive Engineers, the Brotherhood of Maintenance of Way Employes, the Mohave County Sheriff's Department, and the Arizona Corporation Commission assisted in the Safety Board investigation.

As part of its investigation, the Safety Board conducted a 1-day deposition proceeding in Fort Worth, Texas, on October 15, 1997, at which 11 witnesses testified.

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Appendix B—Event Chronology and Layout of Seligman Subdivision

EVENT CHRONOLOGY

(Times are in mountain daylight time unless noted.)

8/8/97 FRIDAY

9 p.m. to 5 a.m. (10 p.m. to 6 a.m. CDT) Third-shift dispatcher is on duty.

8/9/97 SATURDAY

12:06 a.m. The first alert of potential severe weather is issued by the Burlington Northern Santa Fe (BNSF) contract weather service, WeatherData, Inc. (WDI). The alert is for thunderstorms and heavy rain on the Seligman subdivision, and its text read, "Strong thunderstorms are rapidly developing just southeast of, is that Pica, Pica, Arizona, moving east at 15 miles per hour. Radar estimates moderate rainfall over track with up [to] 0.7 inches per hour rainfall rates. Expect from 0.4 to 0.6 inch of rain in the next 40 minutes, will monitor for flash flooding."

12:30 a.m. The National Weather Service (NWS) office in Las Vegas issues a severe thunderstorm warning until 1:30 a.m. Saturday for Mohave County.

12:52 a.m. The BNSF receives an update from WDI (alert 0000). "Strong to severe thunderstorms producing heavy rain with up to 1 inch an hour and gust wind continues to redevelop over this stretch of track. Kingman, Arizona, has reported a gust to 50 miles per hour in the last 45 minutes. Therefore, we are extending the previous warning. To expire at 2:30 a.m."

1:29 a.m. The NWS issues a Severe Thunderstorm and Flash Flood Warning effective until 2:30 a.m. for central Mohave County.

1:43 a.m. The BNSF is warned of flash floods by WDI (warning 0001). "Thunderstorms continue to move to the east at 20 miles per hour. Radar estimates that nearly 2 inches of rain has fallen over this stretch of track with hourly rates of 1 inch an hour still falling. Watch for flash flooding! To expire at 2:30 a.m." (This warning initiated the track inspection.)

1:57 a.m.	The track supervisor is called by the dispatcher.
2:21 a.m.	The BNSF receives an update from WDI (warning 0002). “Strong thunderstorms continue to redevelop and move over this stretch of track this morning. Movement of these storms is to the east-southeast at 10 miles per hour. Rainfall amounts of 1 to 2 inches is likely, as well as peak wind gusts less than 60 miles per hour. Watch for Flash Flooding. To expire at 4:30 a.m.”
2:24 a.m.	The NWS issues a Severe Thunderstorm and Flash Flood Warning effective until 3:30 a.m. for central Mohave County.
2:32 a.m.	The BNSF receives an update from WDI (alert 0003). “Strong thunderstorms continue to redevelop and move over this stretch of track this morning. Movement of these storms is to the east-southeast at 10 miles per hour. Rainfall amounts of 1/2 to 1 inch is likely over this stretch of track, as well as peak wind gusts less than 60 miles per hour. To expire at 4:30 a.m.”
3:00-4:30 a.m.	The track supervisor calls his personnel. By this time, the rain had begun to diminish.
3:30 a.m.	The track supervisor talks to the dispatcher; he obtains the eastbound train line-up and learns that no trains are east of Cadiz. Also, the NWS Severe Thunderstorm and Flash Flood Warning expires.
3:39 a.m.	Train EB Q-LACMEM1-08 is at Walapai (MP 501.3)—on adjacent track—and notes water in culverts and rain letting up.
3:56 a.m.	Train EB Q-LACMEM1-08 is at MP 489.7—on adjacent track—and reports no water on the ground.
4:01 a.m.	The dispatcher informs the track supervisor of the report of train EB Q-LACMEM1-08.
4:05 a.m.	The track supervisor begins the track inspection at MP 516.5.
4:12 a.m.	The dispatcher informs the track supervisor of EB Q-LACMEM1-08’s report of no water on the ground between Truxton (MP 477.3) and Hackberry (MP 509.4).

4:15 a.m.	The track supervisor stops at MP 515.2 and MP 515.4, noting slight water movement. He talks to a westbound train at Getz (MP 513.9), reporting no high water near rails.
4:25 a.m.	The track supervisor stops at bridge 507.4.
4:28 a.m.	The BNSF receives an update from WDI (warning 0004) for the area between Truxton (MP 477.3) and Harris (MP 521.4). “Thunderstorms producing heavy rain continue to remain nearly stationary around the Kingman, Arizona, area this morning. Radar estimates that nearly 3 to 3.5 inches of rain has fallen near this stretch of track with hourly rates of 1 inch an hour still falling. Watch for flash flooding! The threat for high wind has diminished; however, a gust to 45 miles per hour is still possible. To expire at 6 a.m.”
4:30-4:45 a.m.	The track supervisor reports from Hackberry (MP 509.4) and makes no report of high water. He stops at bridges 507.3 and 505.9. He inspects bridge 504.1.
5:00 a.m.	The first-shift dispatcher comes on duty. (Serves till 1 p.m.)
5:07 a.m.	The dispatcher informs the track supervisor near Truxton (MP 477.3) that Amtrak train 4 is leaving Franconia (west of Kingman).
5:24 a.m.	Amtrak train 4 departs Griffith (MP 526.8).
5:35 a.m.	Train WB B-CHCLAC1-05 passes Walapai (MP 501.3) and, shortly after, passes bridge 504.1.
5:40 a.m.	The first-shift dispatcher and the third-shift dispatcher begin their changeover.
5:46 a.m.	The track supervisor reports from Peach Springs (MP 465.8) that he will shortly clear for Amtrak train 4. He does not report any high water.
5:56 a.m.	The derailment occurs. The BNSF Operations Center is notified by the crew of Amtrak train 4. The BNSF first-shift dispatcher notifies the BNSF Resource Operations Center (ROC) of the accident.
6:00 a.m.	(7 a.m. CDT) The BNSF police department is notified of the accident by the BNSF operations desk. (8 a.m. EDT) The Safety Board Communications Center notifies the Rail Division duty officer.

6:01 a.m.	The track supervisor gets off the track at Peach Springs (MP 465.8). The BNSF Operations Center notifies the Mohave County Sheriff's Department of the accident.
6:06 a.m.	The Kingman Fire Department responds to a request for aid from the Mohave County Sheriff's Department.
6:15 a.m.	The Kingman Regional Medical Center is notified of the accident. The first emergency response personnel arrive on scene. The BNSF notifies the U.S. Coast Guard National Response Center of the accident.
6:16 a.m.	The command post is established.
6:17 a.m.	The Kingman Fire Department requests mutual aid.
6:18 a.m.	The fire department notes multiple injuries and no trapped victims.
6:19 a.m.	The BNSF reports the accident as noted to the U.S. Coast Guard National Response Center.
6:20 a.m.	The first reports cite up to 300 injured. The Mohave County Sheriff's Department reports two unconfirmed fatalities to the BNSF ROC.
6:45 a.m.	The Mohave County Sheriff's Department reports two fatalities on the top deck of the first car and six fatalities on the lower deck to the BNSF ROC. The fatality situation is reported by the BNSF to the Federal Railroad Administration and the Safety Board.
6:56 a.m.	Passengers begin to arrive at the hospital.
7:00 a.m.	(9 a.m. EDT) The Safety Board Investigator-In-Charge is notified by the chief of the Railroad Division of the accident and of the 8 to 13 fatalities. Launch procedures are enacted.
9:10 a.m.	The last passenger is transported from the scene.
10:00 a.m.	(12 p.m. EDT) The Safety Board is informed that the news media is reporting no fatalities.
11:00 a.m.	The last passenger is admitted to the Kingman hospital.
4:20 p.m.	The Safety Board team from the D.C. office arrives on site (time approximate).

LAYOUT OF THE SELIGMAN SUBDIVISION

WESTWARD ↓ — EASTWARD ↑

Seligman Subdiv MAIN LINE

Length of Siding in Feet	Station Nos	Mile Post Location	STATIONS	Method of Oper	Track Diagram
		294 5	EAST WINSLOW	2MT CTC ATS	
			0 8		
		295 3	EAST PASS	3MT CTC ATS	
			0 9		
	20500	296 2	WINSLOW BCPT		
			0 4		
		296 6	WEST PASS		
			1 7		
		298.3	WEST WINSLOW		
			22.2		
N8436	20440	310.5	EAST CANYON DIABLO	2MT CTC ATS	
			1.6		
		312.1	WEST CANYON DIABLO		
			14.6		
	20420	326.7	EAST DARLING	2MT CTC	
			2.8		
		329.5	WEST DARLING		
			9.3		
		338.8	RAILHEAD		
			3.3		
		342.1	EAST FLAGSTAFF		
			2.7		
	20400	344.8	WEST FLAGSTAFF		
			9 7		
		354 5	EAST BELLEMONT		
			1 8		
S4884	20380	356.3	BELLEMONT		
			6.0		
	20382	362 5	MAINE		
			11.8		
	20125	374 3	EAST WILLIAMS JCT	2MT CTC ATS	
			0.7		
		375.0	WEST WILLIAMS JCT		
			8 1		
		383 1	EAST PERRIN		
			2 5		
	20120	385 6	WEST PERRIN		
			6 4		
		392 0	EAST DOUBLEA		
			3 1		
	20115	395 1	WEST DOUBLEA		
			10 4		
		405 5	EAST EAGLE NEST		
			2 0		
	20109	407 5	WEST EAGLE NEST		
			10 8		
	20105	418 3	EAST CROOKTON		
			2 2		
		420 5	WEST CROOKTON	2MT CTC	
			7 4		
	2010C	427 9	EAST SELIGMAN T		
			1 9		
		429 8	WEST SELIGMAN		
			17.1		
N5355	19955	446 9	PICA X	DT TWC ATS ABS	
			5.2		
N8784 S5329	19950	452 2	YAMPAI X		
			7.9		
N4647 S5783	19945	460 2	NELSON X		
			5 6		
N5714 S7743	19935	465.8	PEACH SPRINGS X		
			11.4		
N5423 S5557	19930	477 3	TRUXTON X	DT TWC ABS ATS	
			7 0		
S8376	19925	484 0	VALENTINE X		
			17 2		
N5550 S5939	19915	501 3	WALAPAI X		
			8 2		
N7130 S7132	19910	509 4	BERRY TX		
			4 5		
	19905	513.9	GETZ X		
			2 5 (NT) — 2 8 (ST)		
	1990C	516 4	KINGMAN BCP		
			4 8		
N3350	19850	521 2	McCONNICO (NT)		
			5 1		
S7117	19840	521.5	HARRIS (ST)		
			5.8 — 5.6		
N5198	19835	526 8	GRIFFITH X		
			0 1		

Seligman Subdiv (Cont) MAIN LINE

Length of Siding in Feet	Station Nos	Mile Post Location	STATIONS	Method of Oper	Track Diagram
S9169		526 9	CP 5269	TWC ABS	
			1.9		
		528 8	CP 5288	(NT) TWC-ABS ATS (ST) CTC ATS	
			6 8		
S7100	19830	535 6	ATHOS X	DT TWC ABS ATS	
			4.6		
N7115 S5160		540.2	YUCCA X		
			11.5		
		551 7	CP 5517		
			1.0		
S8473	19815	552.7	FRANCONIA	2MT CTC ATS	
			0.8		
		553.5	CP 5535		
			11.6		
N5357 S5491	19805	565.1	TOPOCK, AZ X	DT TWC ABS ATS	
			9 6		
		574 7	EAST NEEDLES, CA		
			3.3		
	19800	578.0	NEEDLES NT (294.0) ST (294.6) BCPT	2MT CTC ATS	

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Appendix C—Applicable BNSF Instructions

Excerpt from BNSF System Special Instructions for All Subdivisions No. 2 in Effect at 0001 Central, Mountain, and Pacific Continental Time, Saturday, March 1, 1997

35. Excessive Wind, Tornado, and Earthquake Instructions

Excessive Wind Instructions:

When weather bulletins forecasting high winds are received in the Network Operations Center, the train dispatcher will notify all trains in the area, giving the time and limits of the expected high winds.

When notified that winds are forecast to be in excess of 60 MPH in the area, all trains except loaded unit coal and grain trains must stop during the time and within the limits stated.

Tornado Watch and Warning Instruction

Tornadoes are the most violent of all storms. Paths of destruction range from a few hundred feat in width to more than a mile and extend the length of a city block to 300 miles. The greatest potential for such storms exist usually from April through September.

A "tornado watch" means atmospheric conditions are such that tornadoes may develop. A tornado watch is generally issued 4-6 hours before the conditions may occur.

During a tornado watch, all train movements and yard activities will continue, keeping alert for any signs of weather change. The danger signs to look for are severe thunderstorms, hail, roaring noise, a funnel cloud or combination of the above. The radio on a locomotive or a pakset should be used to monitor instructions and information to and from the train dispatcher. In the want a crew spots a funnel cloud, the train dispatcher should be immediately notified, consistent with the crew's safety.

If a train or yard assignment has an occupied caboose, upon being notified of a tornado watch, the occupants of the caboose should immediately move to the locomotive consist. While in the process of moving to the locomotive, if the tornado watch turns into a "tornado warning", or a funnel cloud is spotted, those affected should seek shelter in a nearby ditch, ravine, culvert, under abridge or in a depression. If none of these are available, lie face down on the ground with hands over the head away from the caboose or cars in the train.

A "tornado warning" means a tornado has been sighted or verified by the National Weather Service or by persons associated with official weather spotters. The train dispatcher will keep trains and crews appraised of limits of tornado warnings. Train crews are to follow instructions as follows:

During a tornado warning, all train movements and yard activities must stop. Any train enroute will stop and employees should seek appropriate shelter consistent with the safety of all involved, avoiding the stopping of strain on a high bridge, across railroad and highway crossing at grade, or anywhere the presence of a train could be a hindrance.

After the tornado warning has been cleared and such information has reached the train crews, if the path of the tornado crossed the tracks at their location or in the immediate vicinity, crew members must inspect their train before moving to determine if any damage or derailment has occurred to the train or if the track structure has been damaged. After inspecting the train and track, and the train dispatcher has relayed the limits of the tornado's path, the train may proceed, prepared to stop when approaching bridges, culverts, or other points likely to be affected. The train dispatcher must be advised immediately of such conditions.

(Continued next page.)

Excerpt from BNSF System Special Instructions for All Subdivisions No. 2 in Effect at 0001 Central, Mountain, and Pacific Continental Time, Saturday, March 1, 1997

(Continued from page 89.)

Earthquake Instructions:

When an earthquake is reported, the train dispatcher will do the following:

1. **Instruct all trains within 150 miles of the reporting location to "proceed at restricted speed due to earthquake conditions." An acknowledgement must be obtained from each train or engine receiving these instructions.**
2. **Once magnitude and epicenter are known, the following inspection criteria apply:**
   If magitude is less than 5.0: - no inspection is required.

   If magnitude is 5.0 or greater:

   -Response will depend on the group of states and provinces within which the epicenter is located and the following criteria will apply within the designated radius from the epicenter:

   Group 1: California and Baja California, Mexico

   Group 2: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming; Alberta, Canada and Chihuahua, Mexico

   Group 3: All other states (includes area east of Group 2, Oregon, Washington and British Columbia)

Magnitude Range	Criteria for Response	Group 1 Radius	Group 2 Radius	Group 3 Radius
5.0 to 5.49	Trains proceed at restricted speed until signals have been inspected	30 miles	40 miles	70 miles
5.5 to 5.99	Trains proceed at restricted speed until signals, track and bridges have been inspected	30 miles	40 miles	70 miles
6.0 to 6.49	Trains stop until signals, track and bridges have ben inspected	50 miles	80 miles	150 miles
6.5 to 6.99	Trains stop until signals, track and bridges have been inspected	70 miles	140 miles	220 miles
7.0 to 7.49	Trains stop until signals, track and bridges have been inspected	100 miles	300 miles	400 miles
7.5 and Above	Trains stop until instructed to proceed after inspection of track, signals and bridges completed	As directed *	As directed *	As directed *

*** Radius at discretion of the command center but not less than for magnitude 7.0 to 7.49**

BNSF Maintenance Alert procedures relating to possible flash floods, issued August 10, 1997

MAINTENANCE ALERT

PROCEDURES RELATING TO POSSIBLE FLASH FLOODS

AUGUST 10, 1997

WeatherData, Incorporated Weather Warnings

Weather information received by BNSF from WeatherData, Incorporated is categorized as a "Warning" when it describes conditions which require immediate action by the train dispatcher to notify train crews of imminent danger. These warnings are immediately distributed to the relevant train dispatchers by the Service Interruption Desk.

When WeatherData, Incorporated warns of a storm which has the potential of producing flash flooding, the Network Operations Center will immediately place a 40 mph speed restriction for all freight trains and restrict all passenger trains to restricted speed on the affected route. They will also immediately request local track personnel to make an inspection. These restrictions must remain in place, unless a further reduction in operating speed is deemed necessary by local BNSF personnel at the site, until the warning is canceled by WeatherData, Incorporated. Once the warning is canceled, local personnel will assess the need for any continuing speed restrictions.

Local Observations

When local maintenance personnel become aware of conditions which might produce flash flooding that could result in damage to BNSF track or structures, they will:

- Immediately place the speed restrictions described above on the affected route.
- Inspect the track for washouts, scour, surface irregularities, and/or water over the rail.
- Carefully inspect bridge foundations and drainage structures, with careful attention to bridges with mud sills, for erosion behind dump planks and head walls, erosion around piers and footings, and obstructions from drift and debris.
- If water level, turbulence, or other conditions make a thorough inspection impossible at the site of such a bridge, operations of all trains will be reduced to no more than restricted speed until it is possible to make a proper inspection.
- If, during the initial track inspection, there is any doubt about the safety of train operations over bridges, a qualified Structures employee must be called at once, and any speed restrictions that have been placed on bridges will not be lifted until authorized by the Structures employee.
- Track and bridge foremen must continue to patrol past their respective territories if an adjoining territory is likely to have been damaged, and such damage might not have been discovered.

BNSF Maintenance Alert procedures relating to possible flash floods, issued February 20, 1998

Northern California Division
Mojave, Bakersfield and Stockton Subdivisions Only
Feb. 20, 1998

General Order

WeatherData, Incorporated Weather Warnings
Weather information received by BNSF from WeatherData, Incorporated is categorized as a "Warning" when it describes conditions which require immediate action by the train dispatcher to notify train crews of imminent danger. These warnings are immediately distributed to the relevant train dispatchers by the Service Interruption Desk.

When WeatherData, Incorporated issues a **"Flash Flood Warning"**, the Network Operations Center will immediately advise all involved trains of the specific conditions. When crews of these trains are so-advised, passenger-carrying trains will be operated at a maximum of 50 mph through the limits identified in the warning and freight trains will be operated at a maximum of 40 mph through those limits. If the **"Flash Flood Warning"** limits include railroad bridges which have been identified as being vulnerable to scour because their foundations do not have piling, all passenger trains, and freight trains designated as "key trains", will be further limited to restricted speed over those bridges. The Network Operations Center will also immediately request local track personnel to make an inspection. These restrictions must remain in place, unless a further reduction in operating speed is deemed necessary by local BNSF personnel at the site, until the warning is canceled by WeatherData, Incorporated. Once the warning expires or is canceled, local personnel will assess the need for any continuing speed restrictions.

Railroad Bridges which have been identified as being vulnerable to scour because their foundations do not have piling are:

Mojave Subdivision	Bakersfield Subdivision:	Stockton Subdivision:
755.6	974.0	1001.9
770.7	974.0 A	1020.16
773.2	976.27	1086.9
775.7		1094.4
775.9		1128.66
887.5		

Amtrak -- National Railroad Passenger Corporation, v
ATS -- automatic train stop, 22
ATSF -- Atchison, Topeka and Santa Fe Railway, 12
BNSF -- Burlington Northern Santa Fe Railway, 1
CFR -- Code of Federal Regulations, 13
CIP Capital Improvement Program, 19
CP -- control point, 22
CTC -- Centralized Traffic Control, 24
CWR -- continuous welded rail, 9
EIE -- engineer-induced emergency, 24
EMS -- Emergency Medical Services, 36
EOT -- end-of-train, 40
FED -- failed equipment detector, 22
FRA -- Federal Railroad Administration, 9
GE -- General Electric, 14
HWD -- high water detector, 22
IFC -- Integrated Function Computer, 39
MDT -- mountain daylight time, 1
MHC -- material handling car, 1
MP -- milepost, 5
NOC -- BNSF Network Operations Center, 5
NWS -- National Weather Service, 30
P.R.E.P.A.R.E. -- Passenger Railroad Emergency Preparedness And Response Education., 37
PCM -- Permanent Core Memory, 40
PCMCIA -- Personal Computer Memory Card Industry Association, 39
PCS -- pneumatic control switch, 39
ROC -- BNSF Resource Operations Center, 5
Route 66 -- Arizona State Route 66, 15
RWP -- Roadway Worker Protection, 71
TLEM -- trainline-induced emergency, 24
WDI -- WeatherData, Inc., 27

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