Rail Accident Investigation Branch

Rail Accident Report

Failure of Bridge RDG1 48 (River Crane) between Whitton and Feltham 14 November 2009

Department for Transport

Report 17/2010
September 2010

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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This report is published by the Rail Accident Investigation Branch, Department for Transport.

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Contents

Summary

During the evening of Saturday 14 November 2009, the foundations of a Victorian bridge carrying the railway over the River Crane near Feltham in West London failed without warning, causing part of the bridge to subside. The first indication of a problem was a track defect reported by a train driver crossing the bridge on the *up line*. Track maintenance staff, called to the site, immediately blocked the up line to all traffic when they became aware of a serious defect with the bridge. The *down line* was blocked shortly afterwards.

A total of 21 trains crossed the failing bridge between the first report and closure of the line. There was no derailment and no injuries occurred.

The RAIB have made five recommendations to Network Rail concerning the management of structures, and one recommendation to the Environment Agency concerning notification to railway infrastructure owners when obstructions are found against a structure.

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

Key Definitions

3 Appendices at the rear of this report contain the following:

- abbreviations are explained in appendix A; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in appendix B.

The Incident

Summary of the incident

4 On Saturday 14 November 2009, at approximately 22:45 hrs, the driver of train 2S74, the 22:03 hrs service from Weybridge to London Waterloo felt a dip in the track in the vicinity of signal F178 between Feltham and Feltham Junction.

5 The driver reported the track fault to the Feltham signaller who imposed a 20 mph (32 km/h) emergency speed restriction and *cautioned* following trains.

6 Maintenance staff attended site and were unable to find a track fault at the location described. After widening their search, they discovered a loss of ballast beneath sleepers on the up line at bridge 48, located before the signal, and a serious defect with the structure. The route was blocked to all traffic at 00:55 hrs on 15 November 2009.

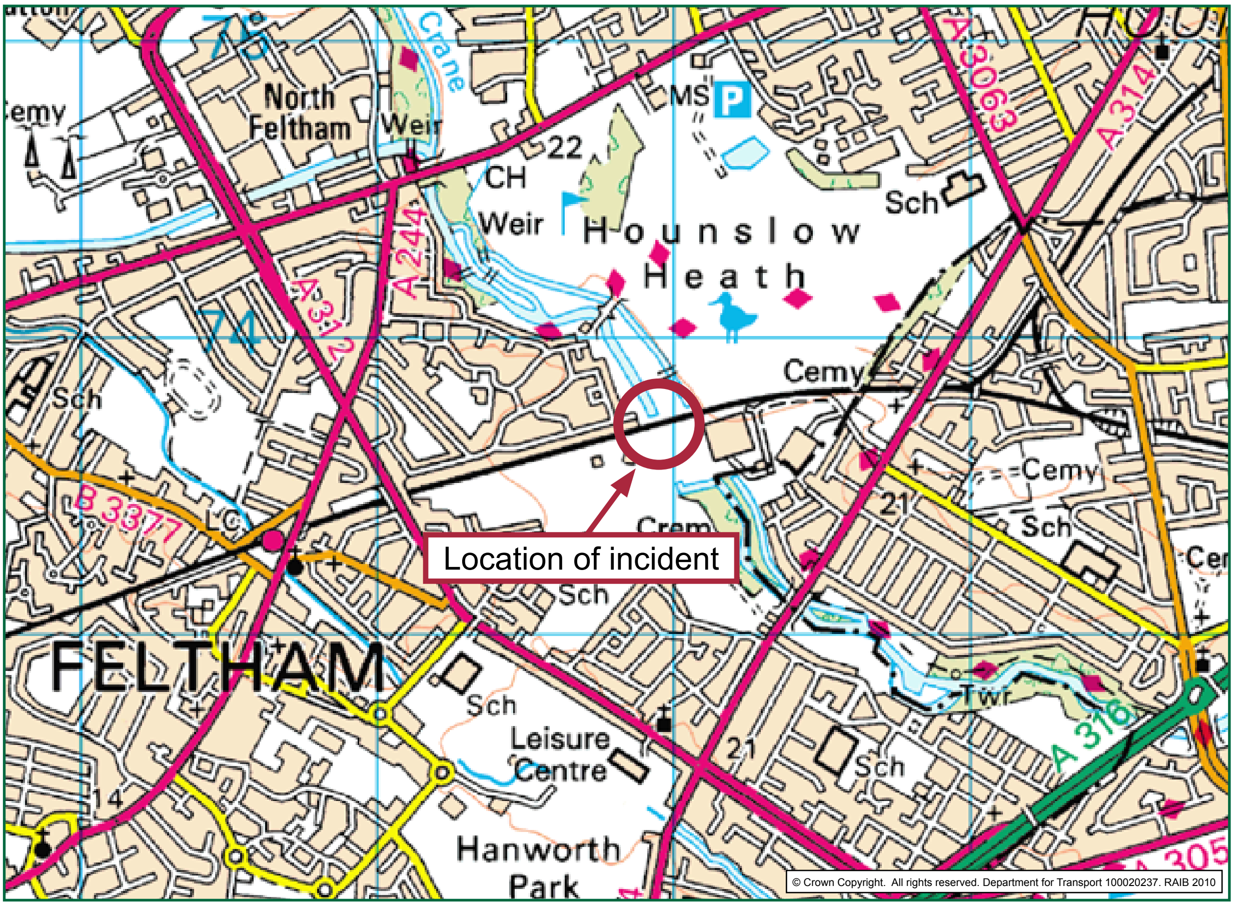


Figure 1: Extract from Ordnance Survey map showing location of incident

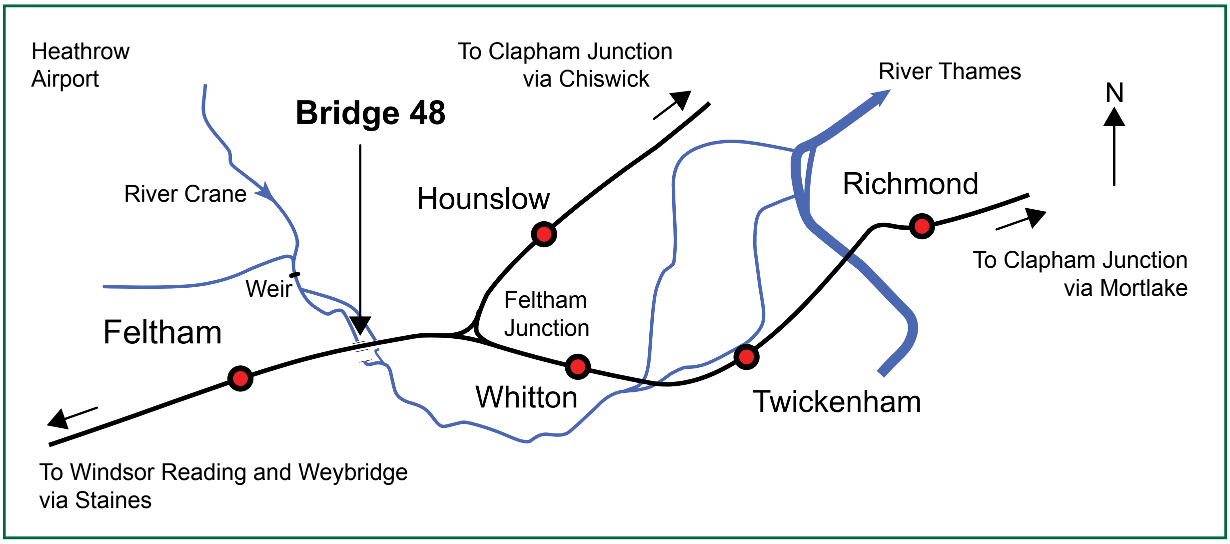


Figure 2: Schematic map showing course of River Crane

7 There was no derailment and no injuries resulted from this incident. However, bridge 48 was damaged beyond repair, and the river span was subsequently demolished and rebuilt. Due to the nature of the damage, there was the potential for a high risk accident to occur.

Organisations involved

8 South West Trains operated train 2S74, and employed the driver.

9 Network Rail owns and maintains the track and infrastructure, and employs the track patrollers who inspect the track, based at Feltham maintenance depot. Network Rail also employs the structures engineers responsible for the bridges and the signallers controlling this line.

10 Amey provides structural examination services to Network Rail under a 'Civil Examinations Framework Agreement' (CEFA), and took over the examination contract from the previous incumbent in May 2009. This agreement is based on each bridge receiving an annual visual examination and a detailed examination typically every six years. Amey employed the bridge examiner who undertook a visual examination of the structure in October 2009, and the examining engineer's nominee (hereafter referred to as the examining engineer) who signed-off the visual examination report on behalf of Amey. Both the bridge examiner and examining engineer had over ten years relevant experience in their respective fields at the time of the incident.

11 All parties freely co-operated with the investigation.

Location

12 Bridge RDG1 48 is located between Feltham and Feltham Junction in west London, 13 miles 79 chains from London Waterloo station, on the line from Clapham Junction to Reading via Staines. This line forms part of Network Rail's Wessex Route, within its south-east area.

13 The bridge is 0.9 miles (1.45 km) east of Feltham station, and carries the railway across the River Crane, a tributary of the River Thames. The River Crane is normally shallow and slow moving, but it can experience rapid increases in depth and flow during periods of heavy or prolonged rain.

External circumstances

14 The weather at the time of the incident was dry and mild, although flow levels had recently increased on the River Crane due to an earlier period of wet weather.

15 The incident occurred during darkness in an area with minimal external lighting.

Trains involved

16 Train 2S74 was formed of two 4-car class 450 electric multiple units.

17 Between the first report by the driver of train 2S74 at 22:45 hrs and the blocking of the line just over two hours later, six passenger trains and four *empty coaching stock* (ECS) trains crossed the bridge on the up line. Eleven passenger trains crossed the bridge on the down line.

Rail infrastructure involved

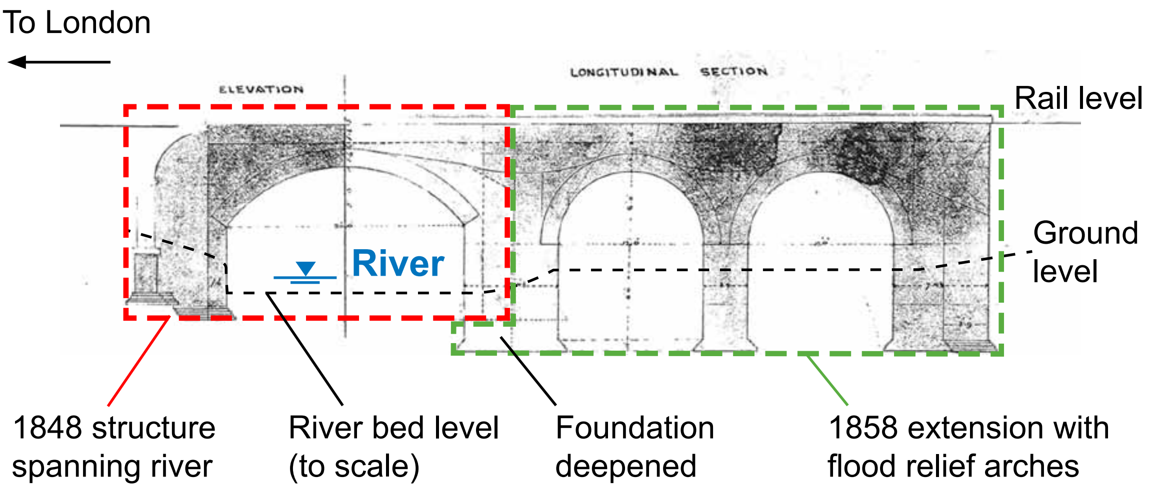
18 The railway at this location is double track plain line with *third rail electrification*. The line speed is 70 mph (113 km/h) in both directions.

19 Signal F178 controls trains on the up line and is positioned immediately east of bridge 48, such that a train travelling in the up direction would cross the bridge before passing the signal. Drivers are trained to stop approximately 20 metres before a signal at danger under normal circumstances, so a train stopped by signal F178 would normally come to a halt on the bridge, but clear of the river span.

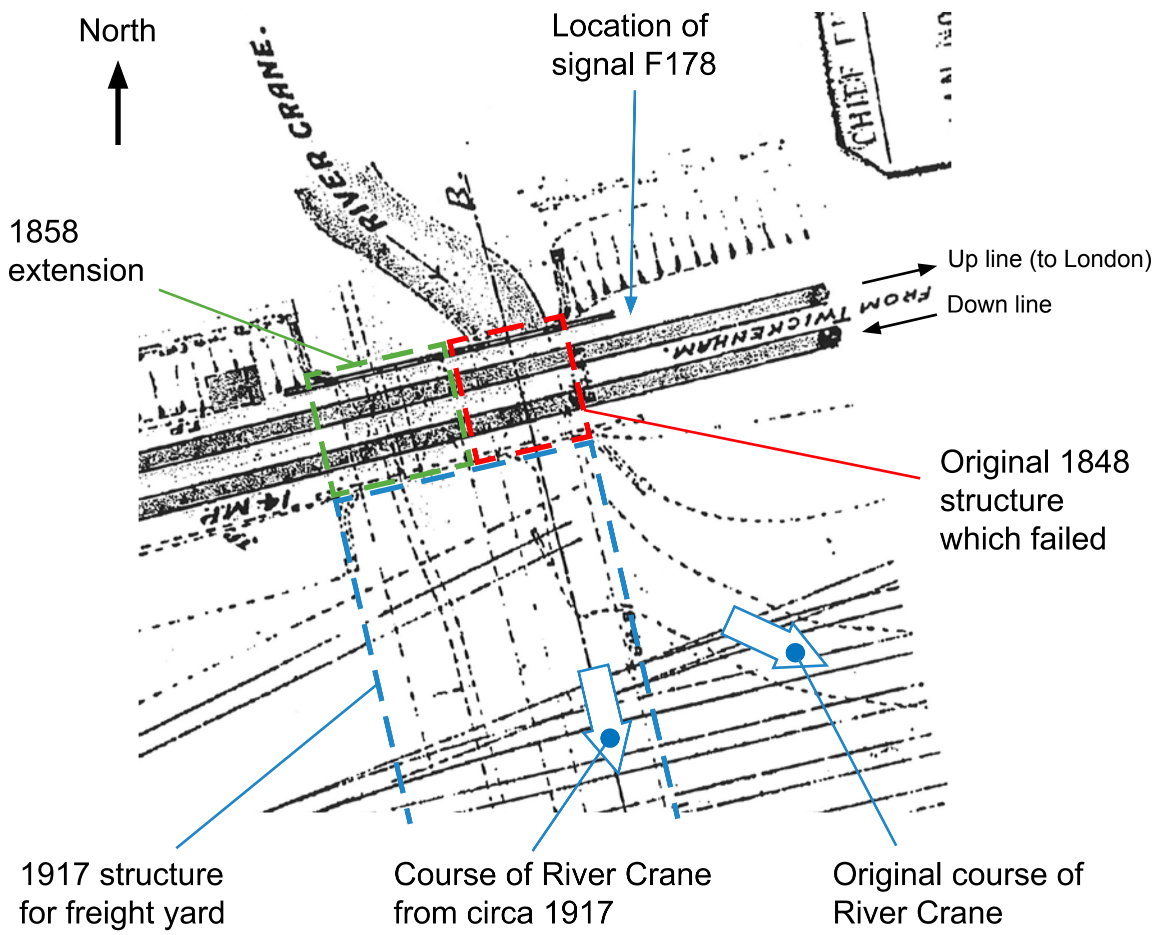
20 Bridge 48 was built prior to the opening of the railway in 1848. It was constructed as a single 20 foot (6 metre) span brick arch *underbridge* with curved *wing walls* supporting approach embankments on each side. The west *abutment* was rebuilt in 1858, and extended to incorporate two 12 foot (3.6 metre) wide flood relief arches (figure 3). In 1917, the bridge was significantly widened by the addition of an abutting two-span structure to the south to accommodate a large freight yard.

21 Network Rail record drawings indicate that the east abutment of the original 1848 structure retained its original foundations. A core hole drilled in 1991 recorded the depth of this foundation as 0.65 metres below river bed level. Record drawings indicate that the foundations of the west abutment were deepened to 1.5 metres below bed level when it was rebuilt in 1858. The 1917 widening was also constructed with deeper foundations.

22 The River Crane approaches the bridge from the north at a 10° angle, placing the east abutment on the outside of the bend (figure 3). The shape of the river channel directs the river flow towards this abutment, regardless of whether any obstruction is present.



a) 1858 drawing of the north (upstream) face of bridge 48 and extension incorporating twin flood relief arches



b) 1917 drawing showing widening of existing bridge for freight yard

Figure 3: Extracts from historical drawings showing bridge 48 and later extensions

Events preceding the incident

23 On 20 August 2009, a member of the public took a photograph of a recently cut willow branch positioned across the upstream face of bridge 48. The branch was sufficiently long to span the full width of the watercourse, constricting the flow (figure 4).

Figure 4: Branch across upstream face of bridge 48 on 20 August 2009 (photograph: N Banks)

24 Local fishermen were aware of an obstruction which raised the level of the river upstream of the bridge by an estimated 600 mm from the late summer.

25 On 2 October 2009, a bridge examiner employed by Amey examined the bridge on behalf of Network Rail and took four photographs showing both sides of the bridge, an internal view and a track level view. None of these showed the full width of the upstream river arch or the water level through it. The examination report did not record any defects and the examiner did not observe an obstruction in the river.

26 On 28 October 2009, an Asset Inspector employed by the Environment Agency (EA) observed a large obstruction at the upstream face of bridge 48 (figure 5) formed of logs, branches and other detritus. This constricted the flow and directed it towards the east abutment. The inspector did not report the obstruction to Network Rail.

27 By the evening of 14 November 2009, the flowing water had *scoured* a void beneath the east abutment, leaving a 5.5 metre long section unsupported (65% of the abutment's width). The void extended beneath both the up and down lines.

Figure 5: Obstruction across upstream face of bridge 48 on 28 October 2009 (photograph: Environment Agency)

28 At 22:35 hrs, train 2C74 left Feltham station on its journey between Reading and London Waterloo. It crossed bridge 48 at about 22:37 hrs and the driver did not report any defect.

Events during the incident

29 During the six minute period between train 2C74 and the following train 2S74 crossing the bridge, the unsupported section of the east abutment subsided. This movement caused dislocation of the arch at the upstream face and resulted in a loss of track support to the up line (figure 6).

30 At 22:41 hrs, train 2S74 left Feltham station bound for London Waterloo, and accelerated to about 50 mph (80 km/h). Its driver felt an unusual movement and contacted the Feltham signaller to report a 'dip' in the track. He described the location of the fault as "10 yards beyond signal F178" (i.e. not on the bridge).

31 The signaller recorded the event in the signal box log at 22:49 hrs. He contacted the driver of the following train, 2U74, using the train's *cab secure radio* as it approached signal F178 at approximately 60 mph (96 km/h), and alerted him to the reported track defect. The signaller remained in contact with the driver of 2U74 until it had passed through the area, and received confirmation that there was a "bad dip" in the track close to the signal.

Figure 6: upstream face of bridge 48 following the incident showing failed arch

32 The signaller put signal F178 under manual control so that it would revert to red and stop each train. This required each driver to contact the signaller, who was able to alert them to the track defect and inform them that a 20 mph (32 km/h) emergency speed restriction had been applied. The signaller asked the driver of the next up train, 2C76, to examine the line as he progressed and be prepared to stop if required. After crossing the bridge at about 23:07 hrs, the driver informed the signaller that he could not see any problem or feel a dip while travelling at low speed.

33 The signaller contacted Network Rail's incident control to report the track defect.

Events following the incident

34 Incident control notified the on-call track maintenance supervisor for Feltham depot and asked him to inspect the track. While waiting for the on-call supervisor to arrive at site, the signaller maintained the 20 mph (32 km/h) emergency speed restriction on the up line. He did not impose any restriction on trains using the down line as there was no indication that this line was affected.

35 The on-call supervisor, who was at Feltham depot and preparing to start overnight engineering work at a different location when he received the call, consulted the track section manager (Feltham TSM) who suggested that the problem might relate to an area of ballast known to be contaminated with slurry beyond signal F178.

36 The on-call supervisor attended site, accompanied by six men with equipment to lift the track and consolidate the ballast. He arranged for the signaller to block the line while he examined the track, but was unable to find a dip at the reported location. He subsequently widened his search in both directions.

37 At 00:14 hrs on Sunday 15 November, the on-call supervisor contacted the signaller and instructed him to limit the speed of the next train, 5S80, an ECS movement standing at signal F178, to 5 mph (8 km/h) so that he could watch it pass. As it crossed bridge 48, he observed the rails dipping by an estimated 150 mm. On inspection, he found ballast missing around and beneath six sleepers and a hole between the up and down lines through which he could see the river (figures 7 and 8).

Figure 7: Overview of track showing loss of support to up line

38 At 00:19 hrs, the on-call supervisor contacted the signaller and reported that he could hear objects dropping into the water. He instructed the signaller to block the up line to all trains. The next train, 5C72, another ECS movement stopped by signal F178, was sent back towards Feltham.

39 At the same time, the on-call supervisor imposed a 20 mph (32 km/h) emergency speed restriction on the adjacent down line as a precaution, even though it was not visibly affected. This allowed the last two scheduled passenger trains from London Waterloo to cross the bridge at about 00:26 hrs and 00:33 hrs respectively.

Figure 8: Void to river in six-foot between up and down lines

40 At 00:55 hrs, following further investigation, the on-call supervisor contacted the signaller and stated that it appeared that the brick arch was collapsing. He instructed the signaller to also block the down line and requested assistance from a structural engineer.

41 At 04:50 hrs, the structural engineer completed an inspection and confirmed that the bridge was in danger of collapsing. The north-east corner of the bridge stabilised after subsiding by about 400 mm.

The Investigation

Sources of evidence

42 The following sources of evidence were used:

- witness statements;
- site photographs and measurements;
- signaller's logs;
- train running records;
- historical structural records;
- structures examination reports;
- *scour assessment* (using ex-BR 'EX 2502' method);
- Environment Agency records; and
- weather reports.

Key Facts and Analysis

Identification of the immediate cause[1]

43 **The east abutment of bridge 48 was undermined by scour.**

Identification of causal factors[2], contributory factors[3] and underlying factors[4]

Presence of an obstruction in the watercourse

44 **An obstruction in the watercourse channelled the flow towards the east abutment, increasing its velocity and making it more likely that scour would occur, particularly during periods when the river flow was raised. The presence of an obstruction across the upstream face of the bridge prior to its failure was a causal factor.**

45 A photograph taken in August 2009 shows a tree branch in the watercourse at the upstream face of the bridge. The branch had foliage indicating that it had been cut from a willow tree shortly beforehand (figure 4). There are willow trees overhanging the river from which branches have been lopped immediately upstream of the bridge, and it is probable that the material originated from this area. The size of the branches and the positions from which they were cut suggests that this work was done professionally. However, the RAIB has not been able to determine how the branches creating the obstruction entered the river or became lodged across the upstream face of the bridge, or whether their presence in the water was accidental or deliberate. Witnesses have suggested that children played in the river at this location during the summer of 2009.

46 The obstruction spanned the full width of the bridge and, during times of increased flow, acted as a weir, impounding water behind it. As it attracted more floating debris, the effect increased. The obstruction channelled water through a reduced gap adjacent to the east abutment, which increased its velocity and made it more likely that scour would occur at this location. Turbulence can be seen close to the east abutment in photographs (figures 4 and 5).

47 Local fishermen, with knowledge of the river, believe that the obstruction in the river was present from late August 2009, and that the branch was lifted by a rise in the river level to settle above the bank support boards adjacent to the bridge's east abutment (figure 5). They also said that a hole in the river bed close to the east bank had been developing, and was visible in clear water.

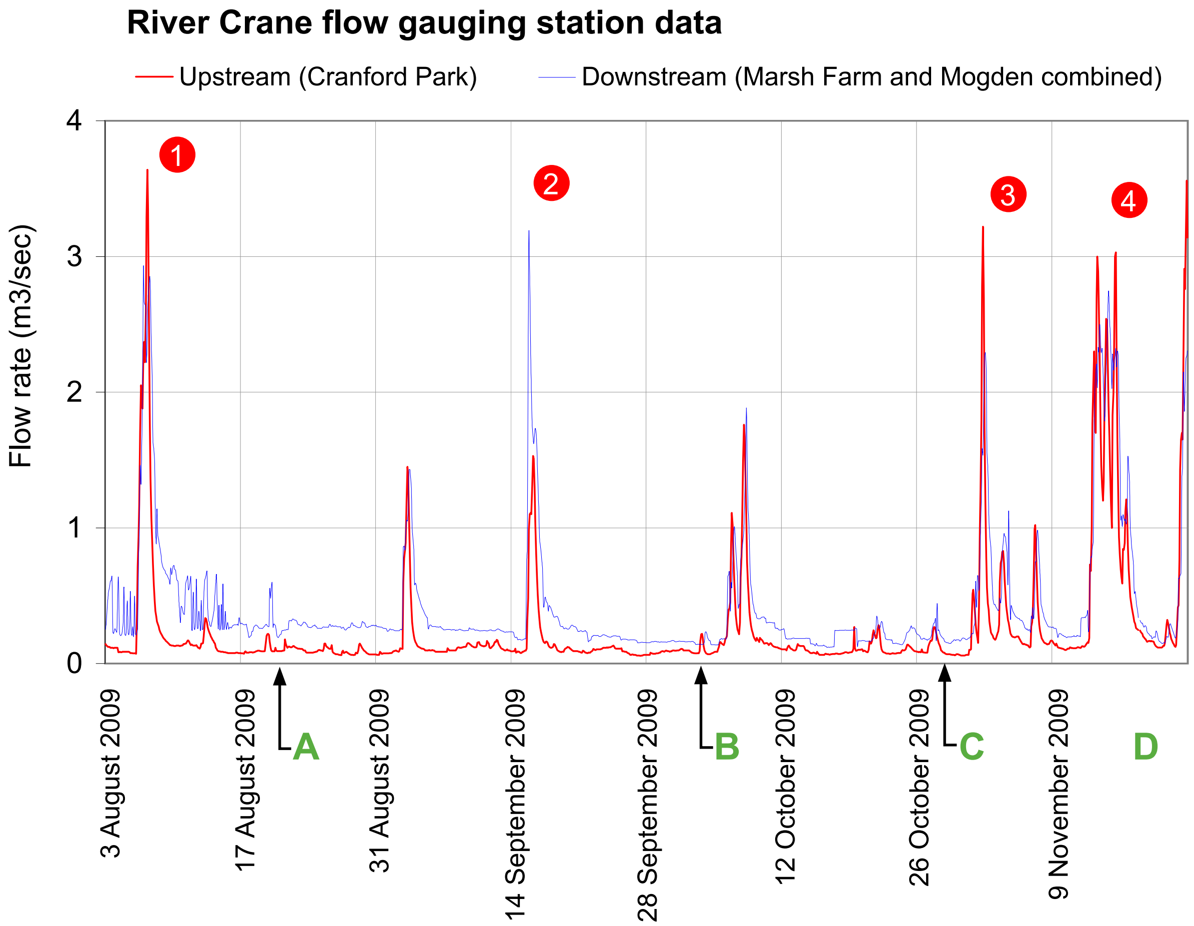
[1] The condition, event or behaviour that directly resulted in the occurrence.

[2] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

[3] Any condition, event or behaviour that affected or sustained the occurrence, or exacerbated the outcome. Eliminating one or more of these factors would not have prevented the occurrence but their presence made it more likely, or changed the outcome.

[4] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

48 Data for the River Crane upstream and downstream of bridge 48, recorded at *gauging stations* operated by the EA, indicates that the flow significantly increased on four occasions between August and November 2009. Flow levels were raised during the 48 hours prior to the incident (figure 9).



Event	Dates between	Peak flow (m^3/sec) Upstream	Downstream	Volume (m^3) x1000
❶	6-8 August 2009	3.64	2.91	299
❷	15-17 September	1.56	3.17	105
❸	31 October – 4 Nov	3.24	2.33	186
❹	12-16 November	3.09	2.88	587

Event	Date	Description
A	20 August 2009	Obstruction photographed in river (fig 4)
B	2 October 2009	Visual examination
C	28 October 2009	Obstruction photographed in river (fig 5)
D	14 November 2009	Bridge failure

Figure 9: Flow data

49 The data indicates that the flow rate, measured upstream of the bridge, averaged 0.21 m^3/sec during the three months prior to the incident. Flow peaked at 3.02 m^3/sec in the 48 hours prior to the incident (ie 14 times greater than the average flow). Although the increase in flow was significant, it was not exceptional and the depth of water, measured at the gauging stations, was not sufficient to trigger a flood alert.

The presence of the obstruction was not identified and/or reported

50 **Network Rail was not aware of the obstruction and therefore did not take action to mitigate the risk of scour. This lack of awareness was a causal factor.**

51 The opportunities for detecting the obstruction are described in paragraphs 52 to 71 below.

Basic Visual Track Inspections

52 **Staff undertaking basic visual track inspections (patrols) check the track and infrastructure for defects which could affect the safety of the railway or its reliable operation. Their remit includes checking bridges for signs of obstructions against their upstream faces when it is reasonable to do so, and detection of the blockage might have resulted in action that would have avoided the scour. The track patrollers at this location were unaware of the requirement to check for obstructions, and had no information on which bridges required checking or how frequently. The lack of such checks was probably a causal factor.**

53 Network Rail standard NR/L2/TRK/001 (issue 3), which was in place at the time of the incident, defines the frequency and purpose of inspections. The line between Feltham and Feltham Junction is patrolled on a weekly basis, with the patroller walking on the up and down lines on alternate weeks. Patrols are supplemented by a supervisor's visual track inspection every two months. In December 2009, NR/L2/TRK/001 was substantially revised and reissued for reasons unrelated to this incident.

54 Section 9.3 of NR/L2/TRK/001 (issue 3) contains two lists of features to be observed during basic visual track inspections. The first list contains mandatory items, while the second contains features to be observed 'to the extent that it is reasonable to do so' (ie non-mandatory). The second list includes checking for 'flooding and signs of obstructions against upstream faces' of bridges. This requirement was first introduced in Railtrack company specification RT/CE/S/103 (issue 4), published in April 2001, and was retained in Network Rail standard NR/L2/TRK/001 which replaced it. It was included in Network Rail's training syllabus for new track patrol staff from 2005, but not briefed to existing staff as they should already have been aware of this requirement. Since 2006, staff are subject to annual competency assessments using a computer-based system, known as 'Assessment in the Line'. This type of assessment, which replaced assessment and training by dedicated staff, did not include any questions relating to observing obstructions of this type.

55 The Feltham TSM was responsible for signing-off patrol reports submitted by his staff, the most recent taking place on 10 November, four days before the failure. The TSM had no specific information on which structures required checking for flooding and signs of obstructions, and had never received a report of an obstruction against the upstream face of any bridge in his area. However, he occasionally received reports of damage to bridges over the line, which are more easily visible to patrollers, and had forwarded this information to Network Rail's incident control for action.

56 The lack of reports of obstructions against bridges discovered by track patrollers was common across the Wessex route, indicating that this was not an issue peculiar to Feltham depot.

57 The primary purpose of a basic visual track inspection is to inspect the track itself; other items should be observed as opportunity permits, but without compromising the primary purpose of the inspection or the safety of the patroller. A patroller is required to cover a set distance within a booked shift and will not normally leave the track unless there is a specific reason for doing so. This is not necessarily compatible with the need to look over a bridge *parapet* in order to assess whether there are problems at the upstream face of a structure.

58 River bridges are frequently difficult to inspect from track level due to poor access and the presence of vegetation. Some structures, including bridge 48, have restricted clearances at track level, meaning that patrollers need to cross the bridge as quickly as possible if trains are running. It is not certain that a patroller has sufficient opportunity to make checks on structures beneath the track, safely and effectively, during a patrol. The fact that such checks were not mandatory also increased the likelihood that some structures were never being checked by patrollers.

Visual examination of bridge and review of the examination report

59 **The bridge examiner's report for bridge 48 made no recommendation for action required to maintain the structure in a safe condition. Visual reports which do not identify new defects largely comprise factual information about the structure (e.g. location) and may contain no other information except for photographs. The examining engineer, who reviewed a large number of similar reports each day, was required to make a judgement on whether the bridge would remain safe for the next 12 months with only superficial information. The process is dependent on a bridge examiner's ability to identify new defects, and is vulnerable to the risk of error by omission. This is an underlying factor.**

60 The overall process of examination of structures used by Network Rail has the following steps:

a. An examiner (from May 2009 employed by the contractor Amey) completes a visual or detailed examination of the structure according to the requirements of Network Rail standard NR/L2/CIV/017 'Examination of bridges and culverts'. The purpose of a visual examination is to detect and record any significant visible changes, or evidence of impending changes, in the condition of a structure since the previous examination. An examiner is also required to review previous reports to identify any previous defects and establish the basis for identifying any changes in the rate of deterioration. The effectiveness of this process is dependent on previous reports identifying all significant defects and providing a benchmark against which to measure change.

b. The examiner's report is passed to an examining engineer (also employed by Amey) who checks that it is compliant with the standard and makes recommendations for any action necessary.

c. The report is then passed to the local Network Rail structures team who will decide what to do, if anything, about any defects or deterioration identified, and check against previous reports if necessary.

61 Bridge 48 received a planned visual examination on 2 October 2009. The resulting report, prepared by the bridge examiner using a standard report template, confirmed that the whole structure had been examined and that there were no outstanding recommendations from the previous year's report. The report made no comment on the condition of the river bank, and neither was this visible in the photograph of the upstream face.

62 The RAIB has been unable positively to conclude whether the obstruction was present on 2 October. The bridge examiner has stated that he did not observe an obstruction in the watercourse while on site, and there are three possible explanations for this:

a. The bridge examiner saw the obstruction but did not record or report it:

It is possible that the bridge examiner saw the obstruction, but considered it insignificant or forgot to report the problem. He said he was aware that, on discovering an obstruction in a watercourse, he was to inform his line manager and had taken similar action previously at other locations.

b. The obstruction was present but the bridge examiner did not see it:

The bridge examiner photographed the bridge from several locations which required him to walk past the site of the obstruction. He said that he looked into the arch of the river span during his inspection. If present, the obstruction should have been visible to him unless it was entirely under the water.

c. The obstruction was not present:

There are similarities between the obstruction photographed on 22 August (figure 4) and that photographed on 28 October (figure 5). In both instances, the branches are long enough to span the full width of the river, and they are orientated across the river with their sawn ends against the east abutment. However, there were other branches and logs floating in the river during this period, and it is possible that the river became obstructed in a similar way on two separate occasions.

63 If a bridge examiner determines that no action is necessary following a visual examination, he will normally take a small number of general photographs. Standard NR/L2/CIV/017 requires photographs in visual examination reports in cases where there are significant changes, or defects are recorded as developing or requiring attention. While this keeps the number of photographs in circulation to a minimum, it may deny the examining engineer who reviews the report the opportunity to verify a bridge examiner's conclusions and hence add value to the process.

64 The visual examination report for bridge 48 incorporates the four photographs taken by the bridge examiner on 2 October, one of which is blurred. The photograph of the upstream face was taken from a distance in order to capture as much of the structure as possible in a single image. However, trees and vegetation obscure much of the east side of the structure (ie the river span) and the river is not visible in this photograph.

65 Standard NR/L2/CIV/017 requires any change in the bank regime to be recorded, and dated photographs taken looking up stream and down stream, as part of both a visual and a detailed examination for bridges over water. The bridge examiner's report does not confirm whether these checks were made, and there was no prompt to include this information in the report template used by Amey.

66 The role of the examining engineer is defined in standard NR/L2/CIV/017 as being the person responsible for ensuring that 'examination reports are reviewed to identify defects or aspects that could affect the fitness for purpose or operational safety of the structure or railway.' A suitably qualified (ie chartered) and experienced engineer appointed by the CEFA contractor (ie external to Network Rail) undertakes this role.

67 Between May and October 2009, the examining engineer reviewed over 8500 reports, an average of 350 per week. Of these, he rejected 223, mainly due to the poor quality of the photographs. Prior to the incident, the examining engineer was involved in briefing bridge examiners as part of an ongoing process to improve the quality of reports.

68 When reviewing the report for bridge 48, the examining engineer expected to see comments on the water, the condition of the bridge and the condition of the banks. He had no way of knowing whether this information was omitted because there was no change to report, or because this part of the inspection was missed. He accepted that the photographs were not good, but he had confidence in the examiner and assumed that a thorough examination had been undertaken. On this basis, he accepted the report and signed it off.

69 The report was submitted electronically to Network Rail's Route Structures Engineer's team for review. Due to the high volume of reports entering the system, only reports containing recommendations for action are reviewed in detail. Reports are loaded into Network Rail's 'Civil Asset Register and electronic Reporting System' database (CARRS), but the time taken to open reports using CARRS means that no-action visual reports receive little scrutiny, and often only the front page of the report is reviewed. For this reason, CARRS has been modified to allow reports to be signed-off in bulk, with a sample audit of reports. The visual examination report for bridge 48 was processed in this manner, and the absence of information on the condition of the river banks was not identified.

Observations by members of the public

70 **The lack of a mechanism to encourage members of the public to report the obstruction meant that an opportunity to remove the obstruction and protect the bridge was missed. This sustained the hazard and was a contributory factor.**

71 Several members of the public were aware of the obstruction, and observed the deepening scour hole prior to the failure of the bridge (paragraph 47). Network Rail states that had they been aware of the obstruction, they would have taken immediate steps to remove it. This did not occur because members of the public were not prompted to report the hazard and they had no means of communicating this information to the Route Structures Engineer's team.

Vulnerability of the east abutment to scour

72 **The east abutment of the bridge was located on the outside of a bend in the river where the flow of water was directed at it. It was constructed with shallow foundations which were not renewed when the structure was extended in 1858, and it was founded on erodible material. These features, taken together, increased its vulnerability to scour and this was a causal factor.**

73 Network Rail uses a scour assessment method which was originally developed by HR Wallingford Ltd, and published in their February 1993 report EX 2502 'Hydraulic Aspects of Bridges: Assessment of the Risk of Scour'. The EX 2502 methodology takes account of such factors as the effect of water flow on a structure located on a bend in the river, the constriction of the river through the structure, and the river bed material. It also takes foundation depth and a structure's vulnerability to blockage by trapped debris (which is greatest for single spans of less than 10 metres) into account.

74 The EX 2502 assessment method gives each structure a priority score of between 10 and 20. A score of between 14 and 15.99 represents a 'medium' priority for any remedial action required, whereas a score of 16 and above represents a 'high' priority. This enables Network Rail to rank structures according to scour risk.

75 Network Rail employs specialist consultants to undertake scour assessments throughout the UK. A scour assessor visited bridge 48 in October 2006 and undertook a site survey for the EX 2502 assessment. The assessor used the 1991 core hole records to establish the east abutment's foundation depth (paragraph 21).

76 The scour assessment consultant issued a scour assessment report for bridge 48 to Network Rail in November 2006. This report concluded that the east abutment was at highest risk of undermining by scour due to its shallow foundations and location on the outside of the bend in the river. The report gave Bridge 48 an EX 2502 assessment score of 15.72, placing it at the upper end of the 'medium' category. This assessment was based on normal conditions and did not account for the increased risk due to a temporary obstruction.

77 The scour assessment report included the statement 'no underwater exams have been found for this structure'. It recommended that underwater examinations should be carried out at three yearly intervals or following a flood event. The report also recommended that the priority score be reviewed at three yearly intervals, following a flood or following any change to the channel or structure.

78 The ground conditions beneath the abutments were subsequently confirmed by analysing borehole samples taken during the reconstruction of bridge 48 in early 2010. The bridge is founded on sandy gravel with some clay, the gravel being sub-angular flint. These soil descriptions are characteristic of *river terrace deposits* with 5% to 20% sand content, but significantly, this is consistent with a localised zone at the site containing a sufficiently high proportion of sand for this material to wash away. The risk is increased if local water velocities are relatively high as might be expected in the vicinity of the obstruction.

Network Rail's knowledge of the condition of the foundations

79 **Network Rail's knowledge of the condition of the foundations was very limited as there had been no underwater examinations at this site despite such an examination being mandated by Network Rail company standards. Bridge 48 was one of a number of structures missing from the underwater examinations task list because the process for identifying the structures that required such examinations was weak. This was an underlying factor.**

80 The requirement to examine underwater structures is a longstanding requirement, and was incorporated in Railtrack specification RT/CE/S/017 (issue 1), published in February 2002. The successor to this document, Network Rail standard NR/L2/CIV/017, specifies that 'parts of bridges which are under water in a watercourse, and where the depth of water prevents a visual examination' should receive a detailed examination at a normal interval of three years. Clause 10.2 of the standard specified that this 'shall be a close examination of all accessible parts of the structure, including underwater parts, in order to: establish the condition; identify the nature; severity and extent of defects', etc.

81 In 1997, Railtrack issued its examinations contractor with a list of structures requiring underwater examinations. Bridge 48, possibly because it spanned a relatively shallow river, was not included on this list. The 'task list' was maintained electronically by the examinations contractor, but with a change control process in place such that amendments could only be made when instructed by Railtrack, later Network Rail. This arrangement meant that Railtrack/Network Rail did not have access to data in a form that could be analysed.

82 Within Network Rail's south-east area, the examination of underwater parts of bridges spanning shallow rivers was included within the six yearly detailed examination where a full diving inspection was considered unnecessary. This arrangement was not formalised and there was no list kept of structures within this category.

83 Bridge 48 was subject to a detailed examination in April 2007 by Network Rail's then structures examinations contractor. The report that followed states that the river span was subject to a visual examination only 'due to fast flowing water'. The examination was therefore incomplete, but neither the examinations contractor nor Network Rail recognised that the underwater parts had not been examined or identified the need for remedial action. The lack of evidence that the foundations were in good condition at that time means that the RAIB cannot determine whether the scouring of the east abutment foundations pre-dated the obstruction of the river during 2009.

84 The RAIB has been unable to establish why bridge 48 was not added to the underwater examinations task list as a result of either the scour assessment recommendation (paragraph 77) or the incomplete detailed examination report. However until September 2007, the Route Structures Engineer's staff used paper records as the primary means of managing the structures portfolio, and incoming underwater examination reports were handled separately from detailed examination reports. This, combined with the remote storage of records, contributed to some lower priority issues being overlooked.

85 In September 2007, Network Rail introduced a new database, CARRS (paragraph 69). This database was populated with data provided by the examinations contractors and this gave Network Rail's structures engineers better access to the underlying data.

86 In April 2008, CARRS was used to compile the task list for the first time. The Route Structures Engineer subsequently became aware of a discrepancy between the aggregated number of structures receiving scour assessments and those receiving underwater examinations. However, action to reconcile this variance was delayed by conflicting priorities within the Route Structures Engineer's team, including responding to issues identified following the failure of a bridge at Stewarton, Ayrshire in January 2009 (RAIB report 02/2010), and preparation for re-letting the structures examination contract. As a consequence, the issue remained unresolved at the time of the incident.

87 Following the failure of bridge 48, the Route Structures Engineer's team found 59 structures within the south-east area omitted from the underwater examinations task list. These structures were added to the list in November and December 2009.

Environment Agency inspections

88 **Environment Agency (EA) staff undertake routine inspections of watercourses within their jurisdiction. The EA has a process for notifying infrastructure owners whose assets present a flood risk, or are in a poor condition. The obstruction identified at bridge 48 by an EA Inspector on 28 October (figure 5) presented a low flood risk so this did not trigger an immediate response within the EA, or a notification from the EA to Network Rail. The lack of a process for reporting non-flood risks meant that the obstruction remained, sustaining the risk to railway users. This was an underlying factor in the subsequent failure of the bridge.**

89 The process of EA staff inspecting Third Party Assets (Non Environment Agency Owned or Operated) originated from the 'Bye Report', commissioned to examine issues arising from flooding which had occurred at Easter 1998. As a consequence, since 1999, the EA has informed third-party asset owners of health or safety issues discovered during routine inspections. This includes the presence of debris where this presents a flood risk, and visible structural damage.

90 The EA issues notifications by writing to infrastructure owners, giving details of the location and condition of the structure using grid references, maps and photographs. However, EA records show that some notifications issued to Network Rail have not been responded to.

91 The EA's records show that obstructions were observed in the channel beneath bridge 48 in September 2008 and again during an internal inspection in December 2008. An EA Inspector also observed and photographed the large obstruction against the upstream face of the bridge by 28 October 2009, but he considered that the risk of flooding was low due to the size of the arch. The EA was considering removing the obstruction using its own resources and at its own expense, but no action had been taken prior to the failure occurring.

92 The EA did not notify Network Rail of any of the identified obstructions as the risk of upstream flooding was judged to be low and there was no visible damage to the structure. The scour risk was not recognised.

Previous occurrences of a similar character

93 Research into similar bridge failures commissioned by the Rail Safety and Standards Board (RSSB) indicates that most scour failures are caused by flooding. This research, published in 2004 as report T112, states that structure damage is dependent on many local factors in addition to flood. The most important factor is the build up of debris around bridge piers and at culverts, and modification to the river within the immediate vicinity of the bridge.

94 A bridge pier supporting the Lower Ashenbottom Viaduct on the East Lancashire Railway failed in June 2002. This event has been attributed to scour caused by debris accumulation on the pier coinciding with flooding.

95 The loss of a bridge which was swept away by a swollen river at Glanrhyd, Carmarthenshire, in 1987 led to four fatalities when a train ran onto the collapsing structure. Since Glanrhyd, there have been 16 scour incidents causing severe damage to railway structures within the UK. In the Irish Republic, the collapse of a pier supporting the Malahide viaduct on 21 August 2009 has also been attributed to undermining by scour following changes to the water flow.

Severity of consequences

96 Railway users were put at risk by the subsidence of the east abutment of bridge 48, which rotated to the left as a single section about a point approximately 5.5 metres from the upstream face, beneath the down line, and subsided by about 400 mm. The movement of the abutment in a single section confirms that it was structurally sound prior to becoming undermined, but the resulting *differential settlement* caused the brick arch to twist. This is a known failure mode for arch structures, and led to a complete dislocation of the arch ring at the upstream face (figure 6), compromising its structural integrity, and greatly reducing its capacity to support train movements. It is probable that the arch would have collapsed into the river within a short time if trains had continued to run.

97 Train services between Feltham and Whitton were suspended for eight days following the incident while a temporary track diversion was installed. This remained in use until the tracks were restored to their original alignment in May 2010. During the intervening period, the river span of bridge 48, dating from 1848, was rebuilt as a reinforced concrete structure spanning 16.5 metres between piled foundations, with scour protection for the east abutment.

Observation[5]

Immediate response to the incident

98 Network Rail staff responded promptly to the report of a track defect made by the driver of train 2S74, even though they were unaware it was related to the bridge. The signaller cautioned following trains and arranged for an inspection by track maintenance staff who attended with tools and equipment to correct the reported defect and subsequently located the unsupported sleepers above bridge 48. Their prompt action meant that six trains which were scheduled to use the up line between 00:19 hrs and 01:49 hrs were prevented from crossing the bridge. This prevented a more serious incident from occurring.

99 The on-call supervisor’s decision to impose an emergency speed restriction on the down line, rather than blocking it, allowed two further trains to cross the bridge (paragraph 39). He did not seek further advice before deciding that it was safe to allow trains to continue, and could not know whether the structure remained stable. Although his decision had no adverse consequence, he made it without sufficient consideration of the risk involved.

Improvement Notice issued by the Office of Rail Regulation

100 In March 2010, the Office of Rail Regulation (ORR) served an Improvement Notice on Network Rail concerning the management of structures inspection. This followed the identification of serious issues with the inspection process by the ORR’s inspection programme, including ‘visual inspections did not meet the requirement of the standard for such matters’. Network Rail is required to comply with the Improvement Notice by 31 March 2011.

[5] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the incident but does deserve scrutiny.

Summary of Conclusions

Immediate cause

101 The east abutment of bridge 48 was undermined by scour (paragraph 43).

Causal factors

102 The causal factors were:

a. The obstruction of the watercourse, which channelled the flow towards the east abutment, increasing its velocity and making it more likely that scour would occur (paragraph 44);

b. Network Rail being unaware of the obstruction and therefore not taking action to mitigate the risk of scour (paragraph 50); and

c. The vulnerability of the east abutment of the bridge to undermining by scour by virtue of being located on the outside of a bend in the river, constructed with shallow foundations and founded on erodible material (paragraph 72).

103 It is probable that the following factor was causal:

a. The absence of checks for obstructions against the upstream faces of bridges by track patrollers, who did not know that they should make such checks if it was reasonable to do so, and had no information on which bridges to check or how frequently (paragraph 52, **Recommendation 1**).

Contributory factor

104 A contributory factor was:

a. The lack of a mechanism to encourage members of the public who were aware of the obstruction to report it to Network Rail (paragraph 70, **Recommendation 2**).

Underlying factors

105 The underlying factors were:

a. The verification role performed by the examining engineer was wholly dependent on the completeness of the bridge examiner's report. For visual examination reports where bridge examiners propose no action, the low level of information required in the report may mean that the examining engineer's review can add no value (paragraph 59, **Recommendation 3**).

b. Network Rail having inadequate knowledge about the condition of the foundations of bridge 48 as it had not commissioned mandatory underwater examinations (paragraph 79, **Recommendation 4**).

c. Environment Agency staff not being aware of the safety risk presented by the obstruction found in the watercourse at bridge 48 in the absence of visible structural damage, and not being under an obligation to report non-flood risks to the infrastructure owner (paragraph 88, **Recommendation 5**).

Additional observation

106 Track maintenance staff could not know whether the structure was stable before allowing down line trains to cross the bridge after blocking the up line to all traffic (paragraph 99, **Recommendation 6**).

Action reported as already taken or in progress relevant to this report

107 Network Rail track maintenance staff have completed a one-off inspection of all structures spanning watercourses within the south-east area comprising the Wessex, Sussex, Kent and Anglia routes. Where patrollers have identified problems, these have been reported to the relevant route structures engineer.

108 Network Rail has issued the structures examination contractor, Amey, with the scour assessment list for structures within the south-east area indicating scour risk priority.

109 Network Rail has updated the underwater examinations task list for the south-east area to include structures that were previously missing.

110 Amey has audited a sample of visual examination reports for structures over water, to establish the level of compliance to the examination contract and standard NR/L2/CIV/017. This audit concluded that all reports contained sufficient information for the examining engineer to make a judgement, but that 3 out of 75 did not fully match the specification. The audit also found issues with the interpretation of the specification by some examining engineers. Action to correct the identified issues has been taken.

111 As a consequence of the Improvement Notice served by the ORR (paragraph 100), Network Rail and Amey have:

a. Added a historical actions list to reports so that bridge examiners, and staff who review their reports have visibility of previous recommendations; and

b. Introduced measures to positively report that inspections are complete.

Recommendations

112 The following recommendations are made:[6]

Recommendations to address causal, contributory and underlying factors

1 *The purpose of recommendation 1 is to establish a sustainable process for the routine inspection of bridges spanning watercourses and avoid the risk associated with structures not receiving frequent checks for obvious signs of hazards.*

Network Rail should positively identify which structures require checking for obstructions against upstream faces, and how frequently. Such checks should be mandatory and the process for delivering them should be enhanced such that those who perform the task have the time, competence and information available to do the job effectively (paragraph 103a).

2 *The purpose of recommendation 2 is to increase the probability of debris being reported and removed prior to structural damage occurring.*

Network Rail should provide means by which members of the public can report obstructions or other defects, particularly at locations where public access exists. This could include the provision of bridge identification plates giving a telephone number similar to those provided at low headroom highway bridges, together with a location description, map reference and structure number (paragraph 104a).

continued

[6] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation, and Recommendation 5 is also addressed to the Environment Agency, to enable each to carry out their duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's web site www.raib.gov.uk.

3 *The purpose of recommendation 3 is to reinforce the role of the examining engineer so that the review of examination reports can add value to the examination process, particularly in cases where no action is proposed.*

Network Rail should re-consider the purpose of the role currently performed by the examining engineer and then identify the information and resources (including time) that are required to undertake the task effectively (paragraph 105a). This may include:

a. requiring bridge examiners positively to confirm that particular requirements for different types of bridge have been considered during an examination, for example by means of a checklist within the examination report (paragraph 65);

b. requiring bridge examiners to submit elevation photographs of bridges spanning watercourses, which show the surface of the water at each pier and abutment, and direction of flow for the purpose of identifying obstructions (paragraph 64); and

c. requiring bridge examiners to submit supplementary photographs in support of a visual examination report to enhance the level of information available to the examining engineer (paragraph 68).

4 *The purpose of recommendation 4 is to improve the assessment of scour risk.*

Network Rail should review its underwater examination task lists nationwide to check for further omissions, and require that underwater examinations are normally undertaken in advance of scour assessments to enable a fuller picture of a structure's condition to be realised (paragraph 105b).

5 *The purpose of recommendation 5 is to give infrastructure managers the opportunity to respond to scour risk where identified by an EA inspection.*

The Environment Agency should, in conjunction with railway infrastructure owners, introduce processes to allow the immediate reporting of obstructions in watercourses where these occur adjacent to railway structures such as bridge piers or abutments, and regardless of whether there is an associated flooding risk (paragraph 105c).

Recommendation to address other matters observed during the investigation

6 *The purpose of recommendation 6 is to reduce the risk of a secondary incident occurring following the failure of a structure.*

Network Rail should review the guidance provided for non-specialist staff who may be required to assess the failure of track support in the vicinity of a structure, and determine whether it is safe for trains to run over that structure (paragraph 106).

Appendices

Appendix A - Glossary of abbreviations and acronyms

CARRS	Civil Asset Register and electronic Reporting System
CEFA	Civil Examinations Framework Agreement
EA	Environment Agency
ECS	Empty coaching stock
EX 2502	Report EX 2502 'Hydraulic Aspects of Bridges: Assessment of the Risk of Scour', the scour assessment method used by Network Rail
ORR	Office of Rail Regulation
RSSB	Rail Safety and Standards Board
TSM	Track section manager

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis's British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com.

Abutment	Structure which supports the deck at the extreme ends of a bridge.*
Cab secure radio	A radio system provided to allow signaller and train driver to communicate safety critical information as securely as if they were speaking on a land line such as a signal post telephone.*
Cautioned	An indication or instruction requiring the driver to be ready to stop. Such an indication or instruction can be given by fixed signals, handsignals, signs or verbal communication (e.g. from a pilotman or signaller).*
Differential settlement	Relative movement of different parts of a structure caused by uneven sinking of the structure.
Empty coaching stock	An empty passenger train, normally travelling to or from a depot or siding.
Down line	A track on which the normal passage of trains is in the down direction (i.e. away from London).*
Gauging station	A facility used to monitor river flow and water level.
Parapet	The wall or railing built along the edges of a bridge deck or arch to prevent ballast, pedestrians or vehicles straying over the edge.*
River terrace deposits	Flood plain deposits created as a river progressively erodes its valley.
Scour	The removal of material by the action of flowing water.
Scour assessment	An assessment of the relative risk posed to a structure by scour.
Third rail electrification	A type of electrification that involves the supply of DC traction current to trains by means of a conductor rail laid along one side of the track, known as the third rail.*
Underbridge	Bridge passing beneath the railway
Up line	A track on which the normal passage of trains is in the up direction (i.e. towards London).*
Wing wall	Retaining wall on either side of the bridge abutment, supporting an embankment.

Appendix C - Key standards current at the time

NR/L2/TRK/001 Issue 3	Inspection and Maintenance of Permanent Way
NR/L2/CIV/017 Issue 2	Examination of bridges and culverts
NR/CS/CIV/032 Issue 1	Managing existing structures
NR/SP/CIV/080	Management of existing bridges and culverts

This report is published by the Rail Accident Investigation Branch,
Department for Transport.

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