RAIB

Rail Accident Investigation Branch

Rail Accident Report

Train ran onto a washed-out embankment near Knockmore, Northern Ireland 28 June 2012

Report 14/2013
September 2013

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.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Fax: 01332 253301
Website: www.raib.gov.uk

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Train ran onto a washed-out embankment near Knockmore, Northern Ireland 28 June 2012

Contents

Summary

At around 07:06 hrs on 28 June 2012, a passenger train scheduled to operate between Belfast and Portrush, ran onto a section of washed-out embankment near Knockmore on the Antrim branch line. The driver applied the emergency brake when he became aware of the hazard but was unable to stop the train before the leading bogie ran over the unsupported rails at the washout. The train came to a stand with the bogies of the leading vehicle either side of the washout. The train did not derail and was subsequently reversed away. There were no injuries.

The RAIB investigation found that the following factors led to the incident:

- heavy rainfall in the area during the previous evening;
- a system of culverts at and downstream of the washout could not cope with the water flows generated by the rainfall, causing localised flooding;
- the embankment could not withstand the differential water levels that built up across it;
- the train was sent onto the Antrim branch line without any additional precautions, despite the heavy rainfall; and
- the driver was unable to see the washout in time to be able to stop the train before it.

Two underlying factors were identified:

- there was no engagement between Northern Ireland Railways (NIR) and the Rivers Agency regarding the potential for flooding due to heavy rainfall at the incident site; and
- NIR's weather preparedness procedure did not include a plan for dealing with flooding or heavy rainfall.

As a consequence of the incident, the RAIB has made five recommendations to NIR. The first relates to a review of earthworks and structures with respect to flood risk, including the development of a formalised liaison process with the Rivers Agency for the dissemination of relevant information. The second relates to the development of procedures to maintain safety of the line during and following adverse weather conditions. The other three recommendations relate to safety issues not directly connected with the cause of incident; improving safety critical communications, weed control of the Antrim branch line and improvements to accident investigation procedures.

Introduction

Preface

1 The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability.

2 Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

3 The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of all other investigations, including those carried out by the safety authority, police or railway industry.

Key definitions

4 All dimensions in this report are given in metric units, except speeds and locations which are given in imperial units, in accordance with normal railway practice. Where appropriate the equivalent metric value is also given.

5 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The incident

Summary of the incident

6 At around 07:06 hrs on 28 June 2012, train reporting number B454, the 06:45 hrs service from Belfast Great Victoria Street to Portrush, was travelling along the Antrim to Lisburn branch line (figure 1), having just departed Lisburn station a few minutes before. While running along a straight section of track, the train encountered a 10 metre long section of *washed out* embankment over which the running rails were hanging unsupported (figure 2).

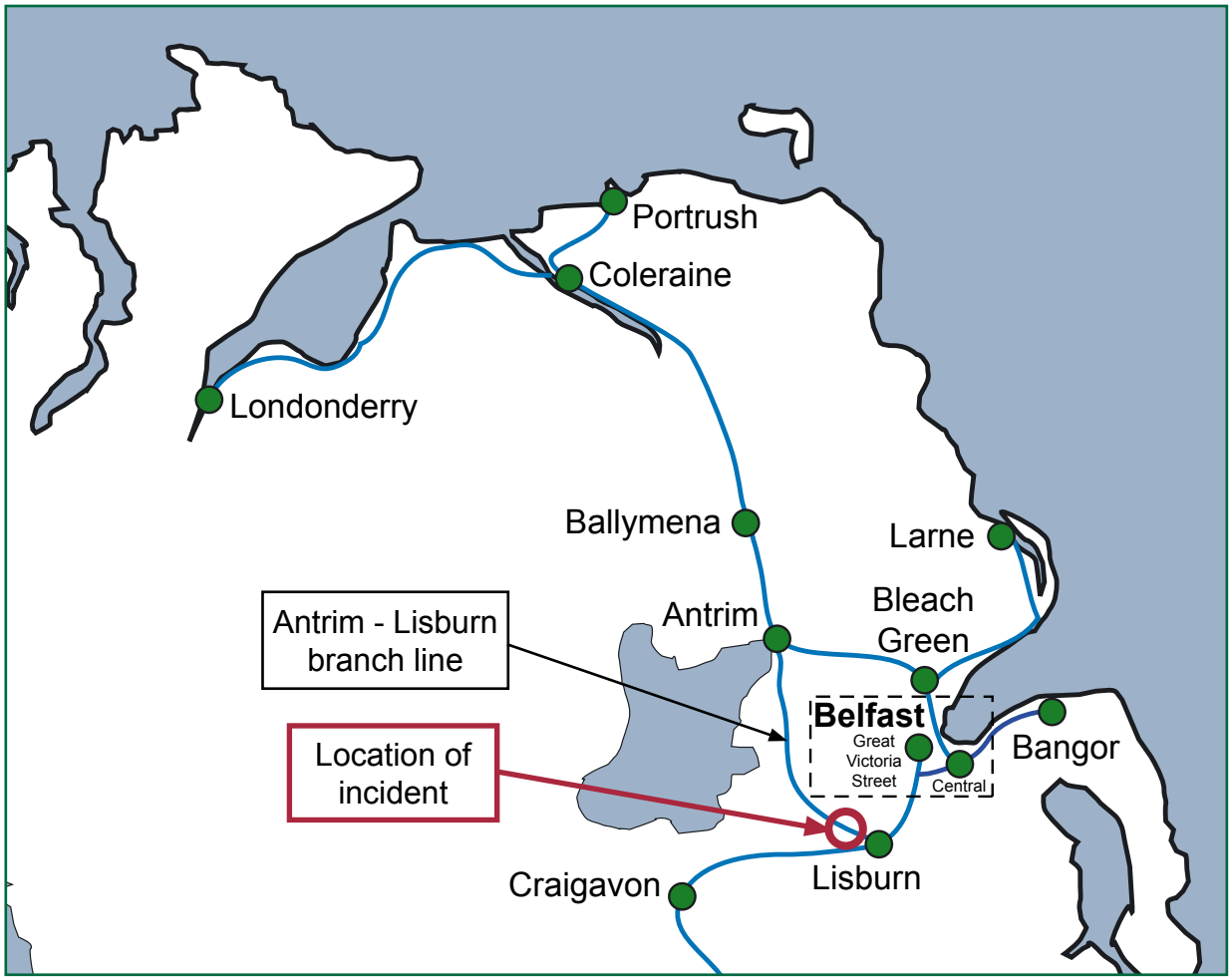

Figure 1: Location of the incident

7 A *pilotman*, who was in the cab, saw the washed out embankment ahead (figure 2a) and warned the driver who applied the train's emergency brake. The train ran onto the unsupported rails and the leading vehicle came to a stand with one bogie on each side of the unsupported track (figure 2b).

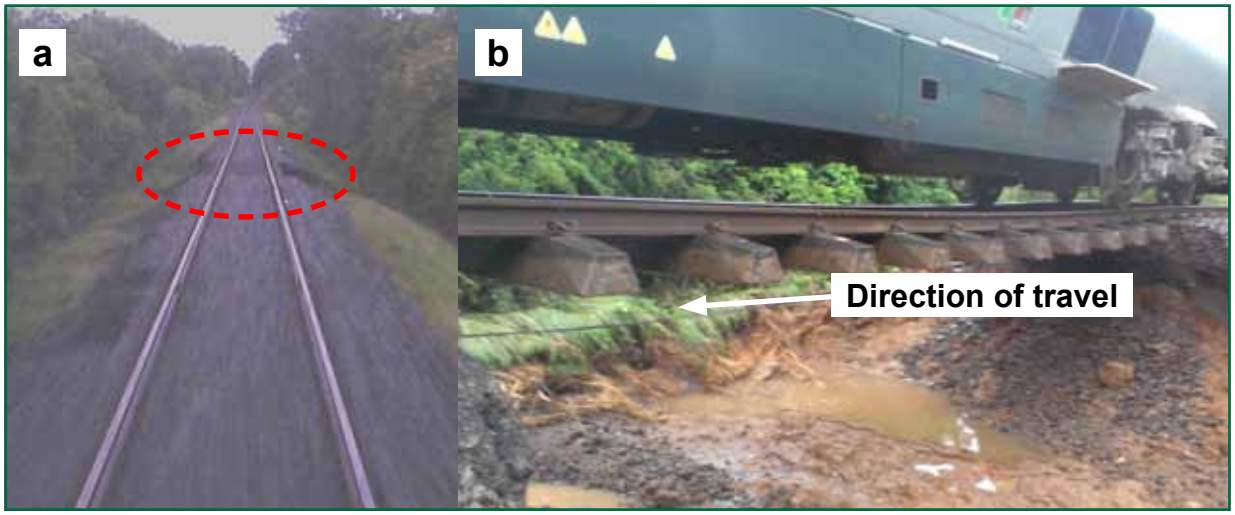

Figure 2: (a) cab view of the washed out embankment and (b) the leading vehicle stopped over the washout (images courtesy of NIR)

8 After a period of around 12 minutes of intense communication between the train crew, control office, signallers and managers, the driver reversed the train off the washed out embankment to a place of safety. The train was not damaged and was re-routed to Portrush via Lisburn and Belfast, arriving around 30 minutes late. None of the staff or passengers on board were injured.

Context

Location

9 The incident occurred on the single line running between Antrim to the north and Lisburn to the south (figure 1), commonly called the 'Antrim branch line' of Northern Ireland Railways (NIR). The line was opened in 1871 and was the main line from Londonderry and Coleraine to Belfast until 2001, when the more direct line from Antrim via Bleach Green was re-opened to passenger trains, providing faster access to and from Belfast, Londonderry and Portrush.

10 The washed out embankment was located at around 0 miles 29 chains (580 metres) from a datum located just before the start of the Knockmore curve (figure 3). Its position was around 80 metres from a culvert, the NIR bridge reference of which is '*underbridge* 11.001' (hereafter referred to as 'UB1'). Adjacent to the southern boundary of the railway at the location of the washout is a soft drinks bottling plant, which covers an area of around 45 acres and was built between 2006 and 2008 on previously rural land.

11 The Brokerstown Road stream (hereafter referred to as the Brokerstown stream) flows under the railway through UB1, and almost perpendicular to it (figure 3). It originates in an area called the 'White Mountain', north of the site, and runs over a total distance of around 4.4 km in a southerly direction under the Antrim branch line and the Belfast to Dublin main line and discharges into the River Lagan. Its *catchment area* is around 6 km^2, and around 3.2 km of the watercourse lies north of the Antrim branch line. The watercourse is *culverted* along 35% of its length by 11 *culverts* of different lengths from around 1 metre to 880 metres; five culverts lie to the south and downstream of UB1 (figure 4). It is a designated watercourse which means that the Rivers Agency is responsible for its inspection and maintenance.

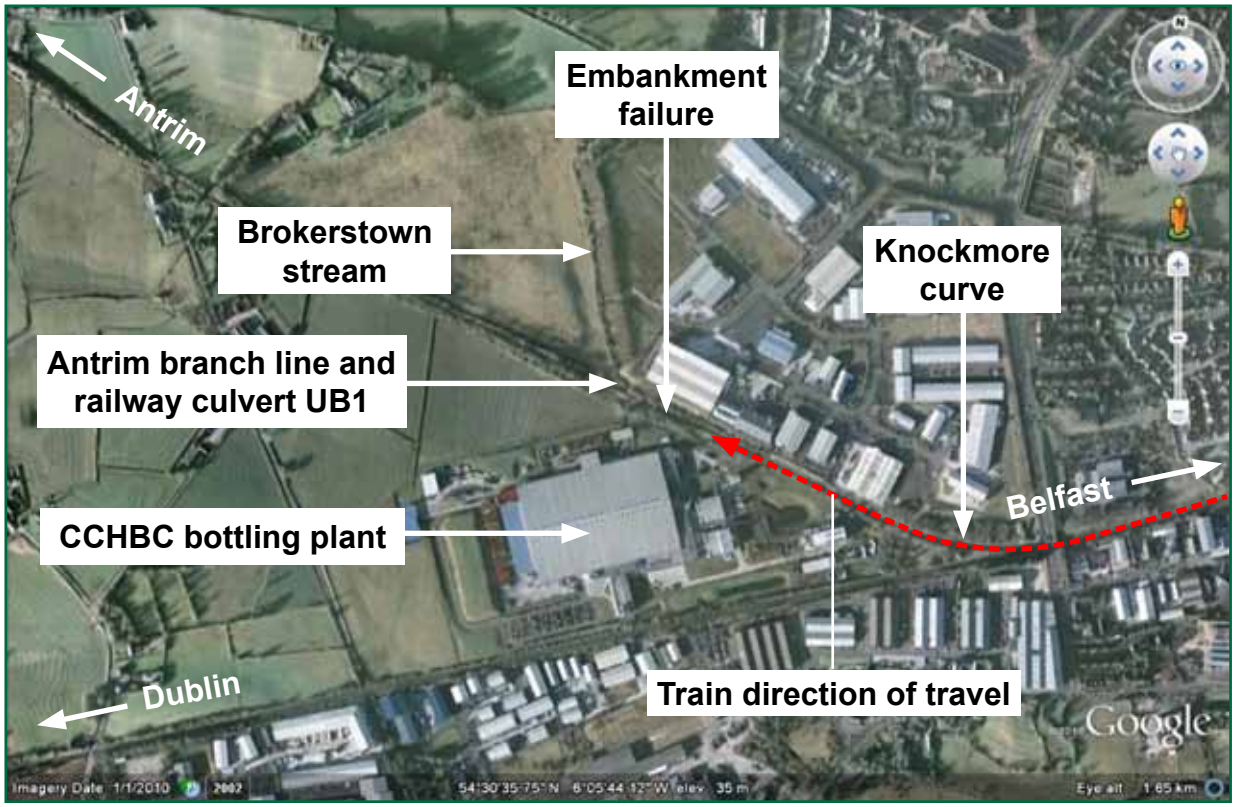

Figure 3: Google Earth image showing location of the failed embankment, UB1, and environs

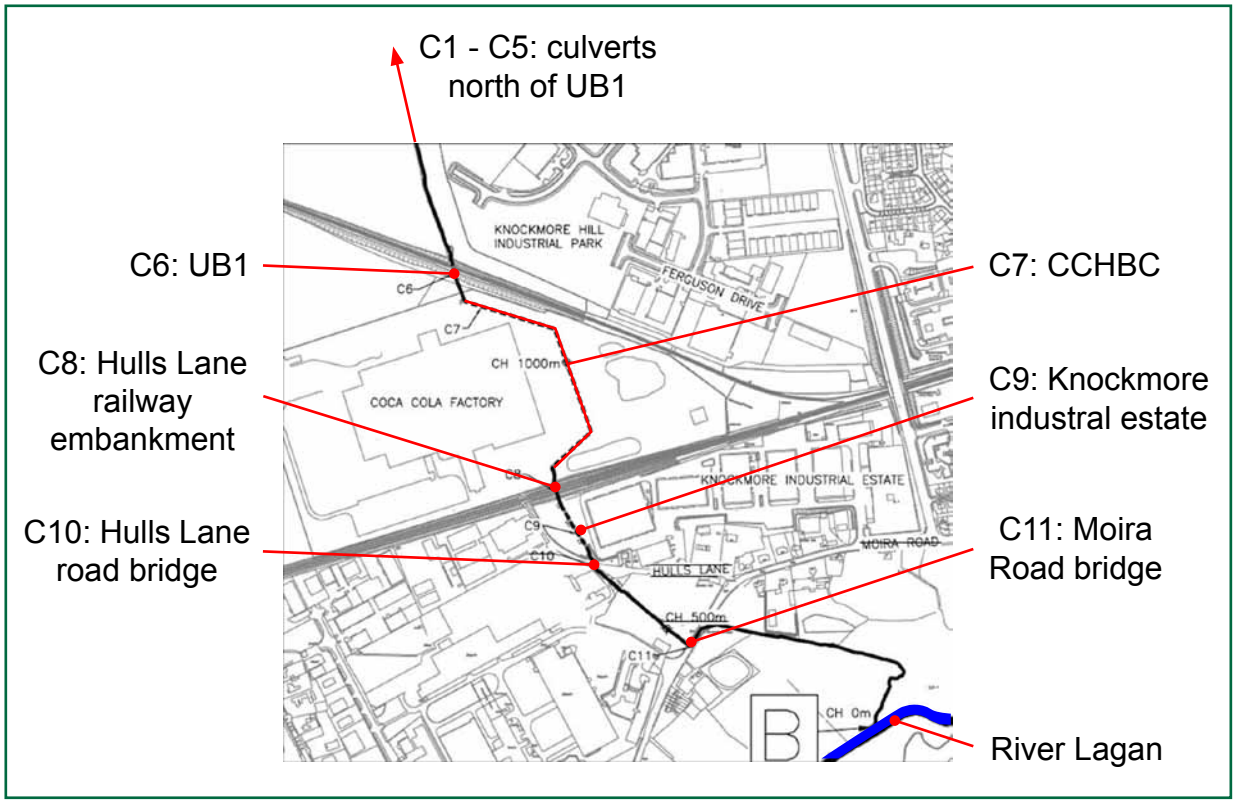

Figure 4: Culverts at and downstream of UB1 (courtesy of WDR & RT Taggart)

Organisations involved

12 Train B454 was operated by Northern Ireland Railways (NIR), which is the main line railway operator in Northern Ireland. NIR is a subsidiary of the Northern Ireland Transport Holding Company (NITHCo), which is the public corporation providing rail and bus transportation in Northern Ireland and which operates under the brand name 'Translink'. NIR employed the driver and other train crew and is responsible for maintaining the infrastructure, including railway culverts.

13 The Rivers Agency is an executive agency within the Department of Agriculture and Rural Development (DARD) in Northern Ireland, and undertakes the statutory drainage and flood protection responsibilities of the DARD.

14 Coca Cola Hellenic Bottling Company, Northern Ireland (CCHBC) manufactures soft drinks under license from the Coca Cola Company, Atlanta, USA. It owns and operates the bottling plant adjacent to the location of the embankment failure. It is also the owner and maintainer of the culvert carrying the Brokerstown stream through its site.

15 All the above organisations freely co-operated with the investigation. Some issues with the initial notification of the incident are covered at paragraph 114.

Train involved

16 Train B454 was a six-car, Class 4000 diesel multiple unit, formed from two three-car sets coupled together. There was no interconnecting gangway between the two sets. The Class 4000 units were introduced into service in 2011 - 2012 and have forward facing and internal CCTV on board.

Train crew involved in the incident

17 The driver of the train at the time of the incident (driver A) had 21 years experience of driving trains on NIR and was approved by NIR to drive trains on the Antrim branch line. He had been a *driver assessor* since 1996 and according to NIR's records, had not been involved in any previous relevant safety related incidents. His last formal driver's competence assessment carried out by NIR, which he passed successfully, was on 18 April 2012.

18 The pilotman in the cab at the time of the incident was a qualified signaller based in Portadown signal box with 27 years experience. His last formal signaller's competence assessment carried out by NIR, which he passed successfully, was on 28 September 2011.

19 The third person in the cab was another driver (driver B) with five years driving experience. He had driven the train from Belfast to Lisburn, where he had handed over to driver A because he was not signed off as competent to drive over the Antrim branch line. Driver B had remained in the cab after Lisburn with the permission of driver A, and in accordance with the NIR *Rule Book*, to become familiar with the line.

20 There were also two conductors on board the train, one located in each three-car set.

External circumstances

21 At the time of the incident, it was daylight and raining lightly. During the afternoon and early evening of the day before, there had been heavy rain and thunderstorms in and around the Belfast area. There had also been heavy rain in the area during the preceding three weeks; further details are given at paragraph 45.

The investigation

Sources of evidence

22 The following sources of evidence were used:

- on-train forward facing and internal CCTV;
- NIR control office voice recordings;
- interviews with relevant NIR staff;
- site visit and cab ride along the Antrim branch line;
- CCTV footage from the CCHBC plant;
- meetings and correspondence with the parties involved;
- NIR's records, operating procedures, structures examination reports, records of previous earthworks failures and internal investigation reports;
- feasibility study of the Brokerstown and Flushbridge streams commissioned by the Rivers Agency in 2009[1], which included *hydraulic* modelling of the Brokerstown stream and its culverts; and
- Met Office rainfall data for the catchment area of the Brokerstown stream.

[1] Brokerstown and Flush Bridge streams, report on feasibility study, WDR & RT Taggart, November 2009.

Key facts and analysis

Sequence of events

Events preceding the incident

23 Train B454 was one of three 'golf specials' which NIR had scheduled for each day of the Irish Open Golf tournament at Portrush, from 28 June to 1 July 2012. NIR had provided the extra trains to meet the expected increased demand for travel between Belfast and Portrush during the tournament. While planning for these extra trains, the timing of this particular service was found to clash with normal scheduled services on the main route via Bleach Green, and it was decided by NIR that the best solution was to route the service via the Antrim branch line for the first two (week) days of the tournament. For the other two (weekend) days of the tournament, the 'golf specials' could all be routed along the main route. The routing and timing of the 'golf specials' had been published in the *weekly operating notice* during the previous week.

24 During the week before on 21 June, a routine weekly track inspection patrol was carried out between Ballinderry (located at 5 miles 29 chains) and Lisburn. No issues were found except for the need to carry out weed spraying, which was noted on the track patroller's report sheet.

25 On 22 June a steam special from Belfast to Ballymena ran via the Antrim branch line. No problems were reported by the train crew.

26 Between 25 June and 27 June a *tamping* machine had traversed the line between Lisburn and Antrim several times within a possession as part of refresher training of the operator. Again, no problems were reported by the machine's crew.

27 On 27 June 2012, from around 17:00 hrs to 20:00 hrs there were thunderstorms and heavy rain around the Belfast area with intense downpours in localised areas (paragraph 48). The rainfall was severe enough to cause flooding of around 1600 homes. Some industrial premises were also flooded, including the CCHBC plant.

28 CCTV footage from the CCHBC plant shows that by around 19:45 hrs the inlet to its culvert had become submerged and water had started to spill over onto adjacent land. By 20:32 hrs, flood water had reached the main building of the plant and by 21:50 hrs it was completely flooded. There are no CCTV images to show what was happening to the adjacent railway during this time, but there is evidence from the images (discussed later at paragraph 53) that at around 21:50 hrs, the railway embankment was breached by the flood water.

29 On 28 June, train B454 departed Belfast Great Victoria Street station at 06:45 hrs, with between 100 and 150 passengers on board. All but two passengers had got into the trailing three-car set, which was nearest to the platform entrance gate. The two passengers in the leading three-car set were at the back of the third vehicle from the front.

30 At around 06:54 hrs, train B454 arrived at Lisburn station and driver A took over from driver B. A pilotman came into the cab, in accordance with the operating rules for the Antrim branch line. Having obtained the requisite permissions from the signaller at Portadown signal box, the train left Lisburn at around 07:00 hrs, bound for Antrim via the branch line.

Events during the incident

31 Train B454 proceeded onto the Antrim branch line and after the 15 mph (24 km/h) speed limited Knockmore curve, driver A started to accelerate up to the line speed of 30 mph (48 km/h). At around 07:06 hrs, as the train approached the incident site, driver A reported that he noticed that ballast at the edges of the embankment on the left-hand side had been eroded away. The pilotman reported that shortly afterwards, he saw that a section of the embankment ahead was missing (figure 2a) and he shouted a warning to the driver. Driver A applied the emergency brake and all three cab occupants ran out of the cab and into the saloon.

32 The leading bogie ran over the 10 metre long section of washed-out embankment just as driver A, who was the last to leave, exited the cab. Train on-board CCTV footage shows the leading end of the train dipped noticeably. The track did not collapse under the train and the leading bogie reached the supported track on the far side of the washout. The leading vehicle came to a rest with its bogies straddling the washout (figure 2b).

33 At 07:07 hrs, having recovered from the initial shock of the event, and having had a look at the washout from a door he had opened, driver A contacted the NIR control office by mobile phone. There were two controllers on duty at the time (referred to here as controllers A and B) and they both became involved in the incident. Driver A told controller A what had happened, and that the train was straddling a washout with nothing underneath the middle of the leading vehicle and that he believed all the passengers were safe for the time being in the rear three-car set. At that time he was not aware there were two passengers at the back of the third vehicle from the front, a fact he later found out when he walked through the leading set. Driver A told controller A that he did not know whether he should reverse the train off the washout. Driver A was concerned about the crumbling edges of the washout he had observed and that the leading vehicle might fall into the void. Controller A, who considered he was not in position to make a judgement on whether it was safe to reverse the train, told driver A not to do anything and that he would ring him back. Meanwhile the pilotman informed the signallers at Portadown and Belfast Central signal boxes of the incident.

34 At around 07:12 hrs driver A rang the control office again and asked for permission to reverse the train off the washout, stressing that he needed to do it quickly as the embankment looked like it was about to collapse. Controller B told driver A that he could not make that decision and declined to give permission.

35 Driver A reported that, confronted with signs that the edges of the washout were beginning to collapse further, he then took the decision himself to reverse the train to a place of safety. He had considered whether to split the two three-car sets but decided against this because, after his conversations with control, he had walked through to the back of the leading three-car set and noted that there were two elderly people in the third vehicle. They would need to be evacuated onto the track and then into the trailing set and this would take some time.

36 Driver A and driver B then changed ends to the cab at the Lisburn end of the train and driver A attempted to reverse the train slowly off the washout. However, the train would not move and he realised this was because the emergency brake was still engaged in the cab at the Antrim end. He contacted the conductor responsible for the originally leading three-car set, who was in the third vehicle from the washout, and gave instructions on what to do to release the emergency brake. Once the emergency brake was released, driver A was able to move the train off the washout. Meanwhile the pilotman stayed on the ground at the washout so that he could tell driver A when the train was clear.

37 At around 07:20 hrs driver A informed controller B that he had reversed the train off the washout to a place of safety near Knockmore curve. The controller asked driver A to contact Portadown signal box to get permission to proceed on to Lisburn. Meanwhile the two conductors kept passengers informed that the train could not proceed along the line and that they would have to turn back.

38 In between the phone calls coming into the control office from driver A and from the signallers at Portadown and Belfast Central, who were reporting the incident to the control office, the two controllers had made a series of phone calls to inform various NIR line managers of the incident. The controllers explained to them that they were not in a position to give driver A permission to reverse without someone inspecting the track first. The on-call structures engineer was contacted by the control office at around 07:16 hrs and requested to attend site, arriving around 08:00 hrs.

Events following the incident

39 As train B454 proceeded to Lisburn, arrangements were made by controllers for it to be routed to Portrush on the main line via Belfast. The train was then driven to Portrush by driver B. The rest of the crew remained on the train except for the pilotman who got off at Belfast. Train B454 arrived in Portrush at around 09:15 hrs, around 30 minutes later than originally planned.

40 NIR made arrangements to survey the failed embankment, carry out repair work and commence a technical investigation into the cause of the embankment failure. The track was restored to its normal operational status by 6 July 2012.

41 On 4 July 2012, NIR notified the RAIB that a *permanent way* inspector had reported that approximately 150 tonnes of embankment had been washed away because significant rainfall had overwhelmed the capacity of a culvert, resulting in rain water collecting behind the embankment. The line would be closed until repairs could be carried out. The notification did not mention that the leading bogie of a train had run onto the washed out embankment.

42 On 14 August 2012, the RAIB first became aware that a train carrying passengers had run over the section of washed out embankment near Knockmore. The RAIB made enquiries of NIR about the full circumstances of the incident and, on 3 September 2012, decided to commence an investigation.

Identification of the immediate cause[2]

43 A ten metre long section of embankment had been washed away prior to the arrival of train B454, which was unable to stop before its leading bogie ran onto the unsupported track, which was at risk of collapsing under the train (figure 2).

Identification of causal factors[3]

44 The incident occurred due to a combination of the following causal factors:

- there was heavy rainfall in the catchment area of the nearby Brokerstown stream on 27 June 2012 (paragraph 45);
- the culvert system on the Brokerstown stream was unable to cope with the water flows generated by the heavy rainfall (paragraph 50);
- the railway embankment could not withstand the differential water levels either side of it and the resulting water flow across the track completely eroded the ballast formation (paragraph 62);
- train B454 was sent onto the Antrim branch line without any additional precautions, despite heavy rainfall during the previous evening (paragraph 69); and
- the driver was unable to see the washout in time to be able to stop the train before it ran onto the unsupported track (paragraph 80).

Each of these factors is discussed in turn, below.

Heavy rainfall in the catchment area of the Brokerstown stream

45 **There was heavy rainfall in the catchment area of the nearby Brokerstown stream on 27 June 2012.**

46 The Met Office records[4] show that June 2012 was abnormally wet in Northern Ireland. The total rainfall amounted to 179 mm, over twice the regional average value for June in the 30 years between 1981 – 2010. The total number of rainy days in the month (defined as ≥1 mm of rainfall) was 19 days, compared to the 30 year average of 6.6 days.

47 The nearest rainfall monitoring station to the incident site is at Tullynacross, located about 5 km east north-east of the incident site and outside the catchment area of the Brokerstown stream. Daily rainfall records there, for the period 6 to 30 June 2012 (figure 5), indicate that 27 June was the third wettest day, with 31 mm rainfall. More rain fell on 11 and 22 June (around 40 mm rainfall each) than on 27 June but no flooding was reported on these two days, either at the railway embankment or the CCHBC plant. This could be because the rainfall for Tullynacross on those days did not reflect the conditions in the Brokerstown stream catchment area. Alternatively, it is also possible that the intensity of rainfall and the state of the ground water saturation on 27 June in the catchment were higher, resulting in higher water flows in the Brokerstown stream than on 11 and 22 June.

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

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

[4] www.metoffice.gov.uk/climate/uk/2012/june/averages.html.

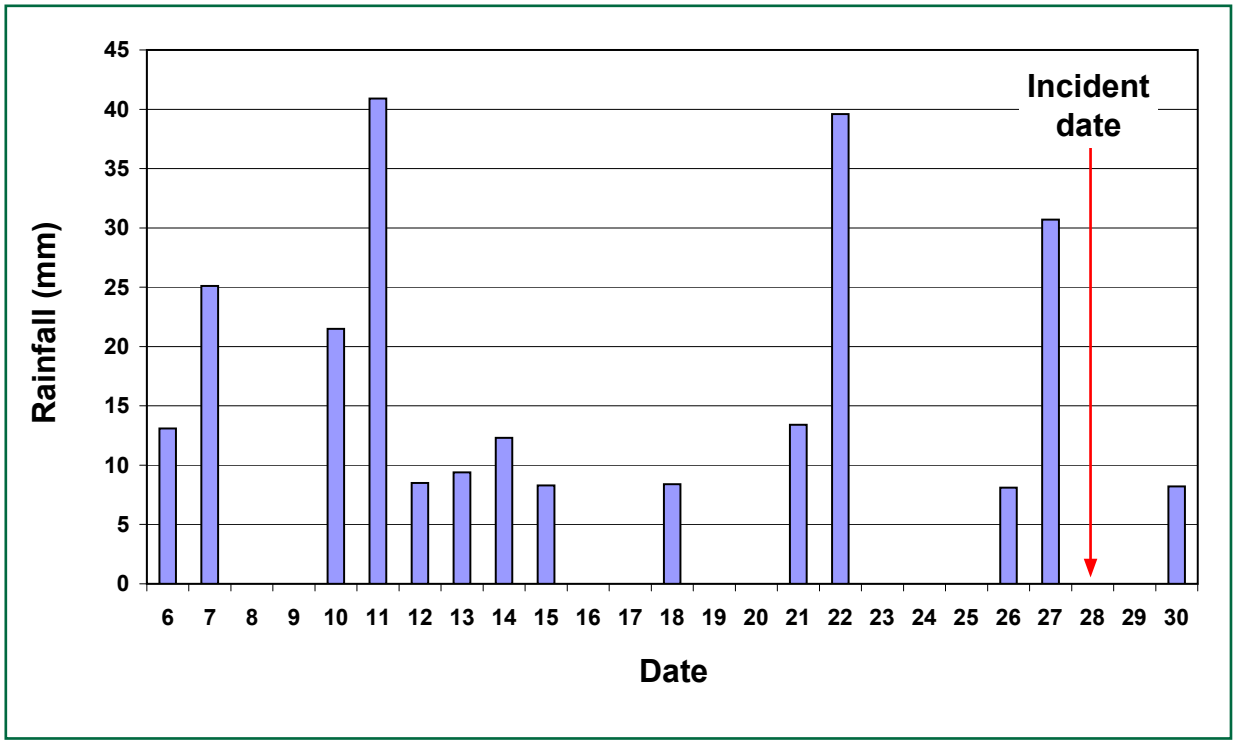

Figure 5: Daily rainfall at Tullynacross, 6 - 30 June 2012

48 To better understand the nature of the rainfall on 27 June for the catchment area of the Brokerstown stream, hourly rainfall data for that area, derived from radar images, was obtained from the Met Office. Rainfall radar is routinely used by the Met Office to estimate rainfall in areas where there are no physical gauges. The catchment area was divided into 1 km square grid boxes as shown in figure 6. The data shows that the main rainfall event occurred between 17:00 hrs and 19:00 hrs. The amount of rain that fell in each grid box during this two hour period is shown in figure 6.

49 Figure 6 shows that there was a wide variation in rainfall within the catchment area. The greatest amount of rain fell in the central part of the catchment area nearest to the watercourse (grid boxes 5 to 8), where between 43.7 and 52.4 mm fell in the two hour period, corresponding to hourly rainfall rates of around 22 - 26 mm. These rates are around five to six times greater than the four mm per hour threshold used by the Met Office to describe heavy rain. The frequency of occurrence of rainfall events is often expressed as the average interval between events of a given magnitude. For example an event with an estimated probability of occurrence of 0.1 per year is said to have a *return period* of 10 years. The rainfall rates in grid boxes 5 to 8 correspond to return periods of between 171 - 373 years. The average for the whole of the catchment has been estimated by the RAIB to have been around 1 in 100 years. The result of this intense rainfall was an abnormally large water flow in the Brokerstown stream.

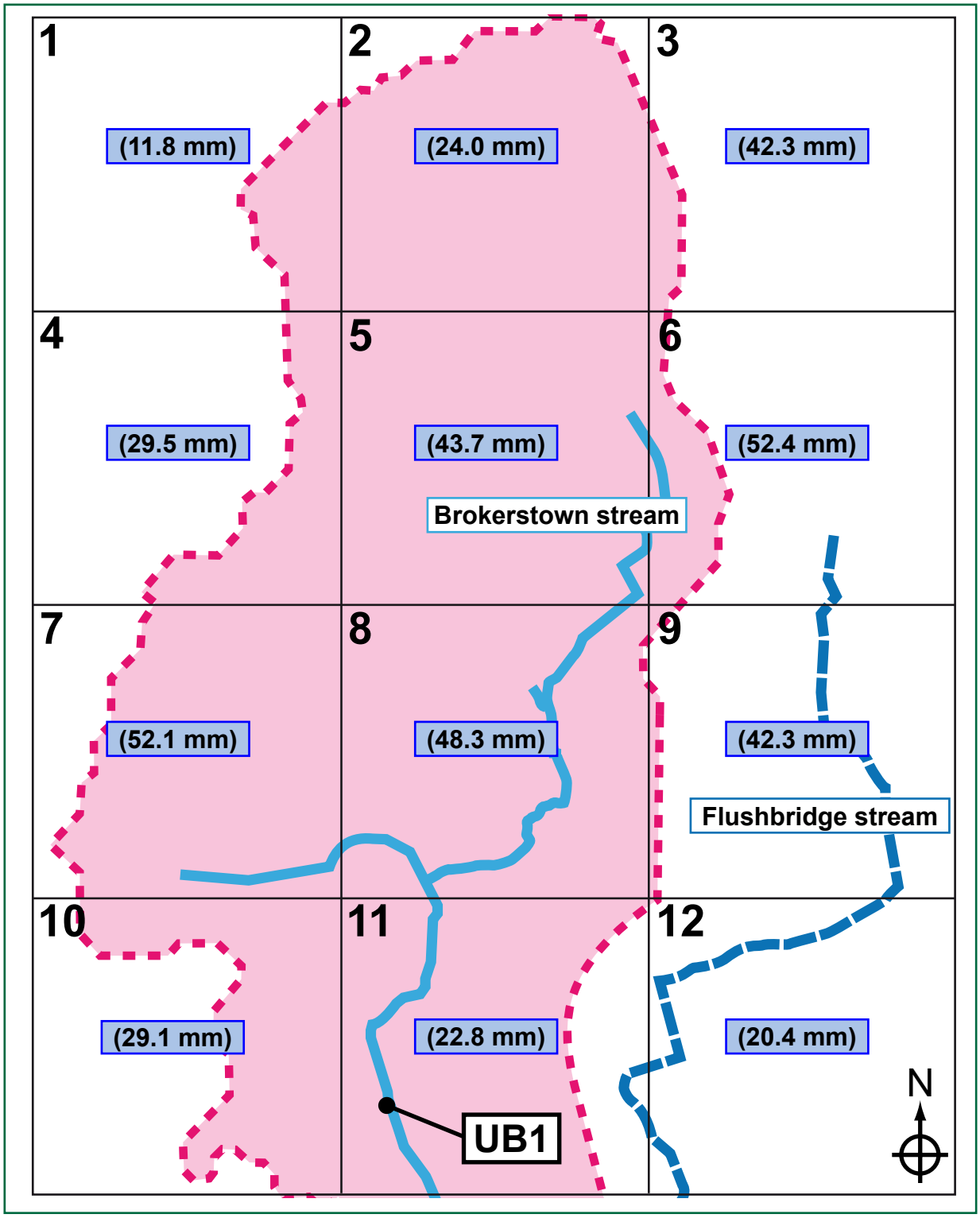

Figure 6: Rainfall in the Brokerstown stream catchment area on 27 June 17:00 - 19:00 hrs

Capacity of the culvert system

50 **The culvert system on the Brokerstown stream was unable to cope with the water flows generated by the heavy rainfall, causing water to back up behind the railway embankment.**

51 The brick arch culvert structure, UB1, is 38 metres long, with cross sectional dimensions, 1.8 metres high by 2.25 metres wide (figure 7). The Brokerstown stream flows from UB1 through a 40 metre long open section, to another culvert at the CCHBC plant, which is 390 metres long and has a series of bends in it (figure 4). This culvert has an inlet which is almost perpendicular to the watercourse and is protected by a *trash screen* (figure 8). Water then flows under the Belfast to Dublin main line though another culvert, (NIR bridge reference 02.278, shown as C8 in figure 4), before flowing through three other culverts and into the River Lagan.

Figure 7: Culvert UB1 inlet under Antrim branch line (image courtesy of URS)

52 CCTV footage from a CCHBC camera aimed at the inlet to its culvert, showed the flood event developing on the CCHBC side of the boundary fence, between the plant and the downstream side of the railway embankment. A series of four still images taken from the footage are shown in figure 9.

Figure 8: CCHBC culvert inlet with trash screen (image courtesy of URS)

53 By 19:45 hrs the inlet to the CCHBC culvert was completely submerged (ie the water level was higher than the top of the culvert inlet). By around 20:32 hrs, water had spilled over onto the adjacent land and had reached the plant itself. There is no CCTV footage which shows what was happening on the upstream side of the railway embankment at this time, but water would have been impounding on that side (figure 10) and its level would have been higher than on the downstream side in order to push water through UB1. Figure 9 shows that at around 21:53 hrs there was a sudden change in the pattern of water flow within the camera's field of view, and the simultaneous arrival of floating debris and an oily sheen. This was probably when the breach of the railway embankment occurred, releasing a large amount of water from the upstream side. The mechanism of embankment failure is discussed later at paragraph 62.

54 The CCTV footage from a camera aimed at the outlet from the CCHBC culvert shows that from around 19:40 hrs it was also completely submerged (figure 11). This indicates that culverts downstream of the CCHBC culvert were restricting flows through it. This in turn would have caused water levels to increase at the upstream end of the CCHBC culvert.

Figure 9: Flooding sequence at the adjacent CCHBC plant (images courtesy of CCHBC)

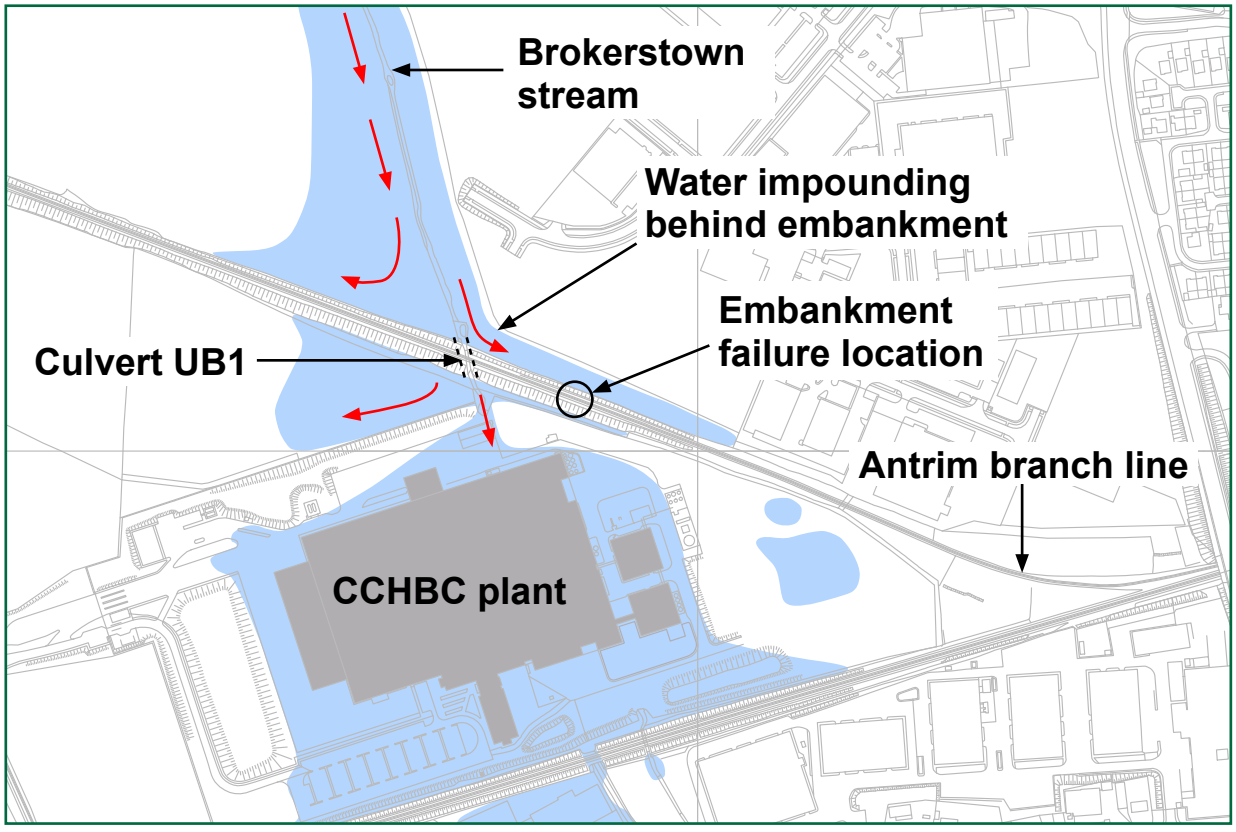

Figure 10: Schematic of water impounding behind the upstream side of the railway embankment

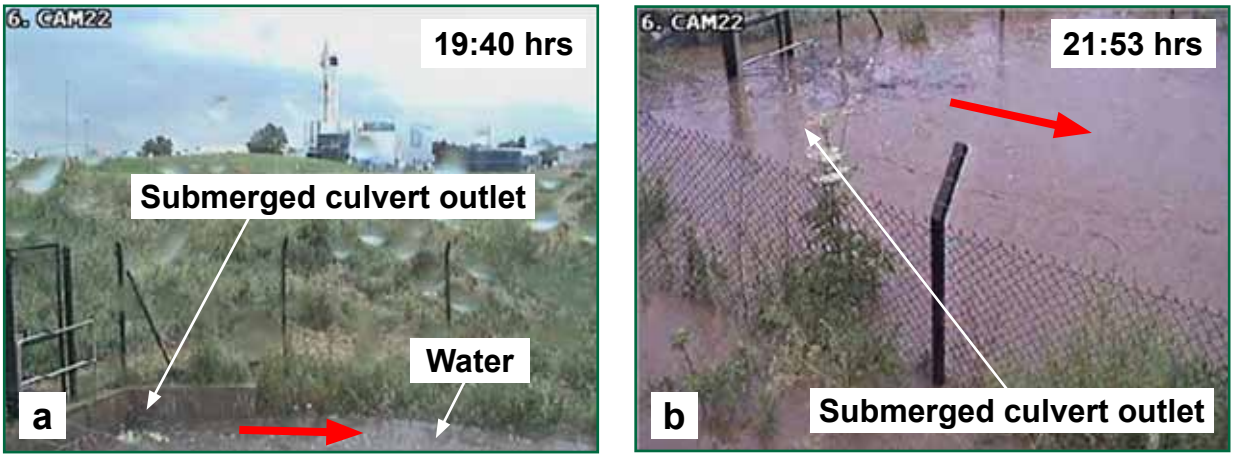

Figure 11: CCTV images of the CCHBC culvert outlet (images courtesy of CCHBC)

55 The flow capacity of the culverts on the Brokerstown stream had previously been estimated by a firm of consultants, using a hydraulic model of the Brokerstown stream, as part of the feasibility study commissioned by the Rivers Agency in 2009 (see footnote 1). Table 1 shows the calculated culvert flow capacities and the return periods at which the culverts would be expected to reach the *surcharged* condition (ie the upstream water level has reached the top of the culvert inlet). If the flow conditions exceed that which just causes a culvert to surcharge, then a head of water builds up at the upstream end of the culvert which forces more water through it. Flooding only occurs if the head of water is sufficient to spill over onto the surrounding ground.

Culvert	Flow capacity to first surcharge m^3/s	Return period where culvert is first surcharged (years)
C6: UB1 railway embankment	5.4	25
C7: CCHBC plant	3.3	5
C8: Hulls Lane railway embankment	4.6	10
C9: Knockmore industrial estate	7.7	100
C10: Hulls Lane road bridge	4.6	10
C11: Moira Road bridge	2.7	2

Table 1: Estimated flow capacities and flood return periods to surcharge culvert UB1 and those downstream of it (culverts C6 - C11 in figure 4)

56 The feasibility study also estimated the water flows that would be generated at particular points in the Brokerstown stream for various flood return periods. From this data, the RAIB has estimated[5] that for flood events with probabilities of 1 in 50 years, 1 in 100 years and 1 in 200 years, the flows at UB1 would be expected to be 7.1, 8.2 and 9.5 m^3/s, respectively. These are significantly greater than the flow capacities in table 1 and all the culverts at and downstream of UB1 would have been running significantly beyond the surcharged condition.

57 The study further predicted that a 1 in 100 year flood event would result in upstream water levels at UB1 around 2.4 metres below rail level. In the event, the water level rose to around 1 metre below rail level, indicating that the water flows generated were significantly greater than a 1 in 100 year event. Following the 27 June 2012 flood event, the Rivers Agency commissioned a further study of the Brokerstown stream during that event. Preliminary results reported by the Rivers Agency to RAIB in May 2013, indicate that the flood event had a return period of approximately 1 in 200 years. This is consistent with the rainfall return periods given in paragraph 49. Given that June 2012 was a very wet month, close correlation between rainfall return periods and flood return periods would be expected[6].

58 It was the limitation of the culvert system as a whole, rather than that of any one culvert in particular, which caused the flooding at the railway embankment. The feasibility study of the Brokerstown stream (see footnote 1) concluded that the capacity of several sections of culvert were below the Rivers Agency's design standard for a major water course, which at the time was a design flood return period of 1 in 50 years for new build structures. Since around 2010, the Rivers Agency has revised the design standard to a 1 in 100 year return period, with a test for climate change (equivalent to an additional 20% increase in flow rate).

59 Culvert UB1 and all those downstream of it, with the exception of the CCHBC culvert and culvert C9 (table 1), are historic structures built before the 1 in 50 year flood design standard was adopted by the Rivers Agency. Their flow capacities fall short of this standard. The CCHBC culvert however was built in late 2005/ early 2006 when the ground works for the factory were built. The size of the culvert was specified by the Rivers Agency to CCHBC's design consultants. It stipulated twin 1500 mm diameter concrete pipes (or equivalent box culvert), laid to an optimum gradient, avoiding 90 degree bends and with further conditions on the positioning of manholes.

[5] The water flows for UB1 for each return period were estimated by interpolating between flow rates for adjacent locations, contained in the feasibility study commissioned by the Rivers Agency in 2009 (see footnote 1).

[6] Flood return periods do not directly correlate with rainfall return periods. How closely they correlate depends on several factors, such as existing river levels, ground water saturation, rainfall intensity, and the influence of any river the watercourse flows into; in this case the River Lagan.

60 The Rivers Agency had calculated at that time that the capacity of a pair of 1500 mm diameter pipes would be 7.2 m^3/s. It believed this would be sufficient to cope with a 1 in 50 year stream flow, based on its own predicted stream flows, (subsequently verified by the feasibility study (see footnote 1), paragraph 55). However, the hydraulic study of the Brokerstown stream revealed that the capacity of the culvert was only around 3.3 m^3/s. The River Agency's consultant has explained to the RAIB that this difference occurred because the original sizing calculation for the culvert did not account for the losses caused by the four almost right angle bends in the pipe (figure 4), manholes and the presence of a trash screen at the inlet. Water levels upstream of the CCHBC culvert would have been lower, and downstream levels would have been higher, if this culvert had been installed with the larger capacity intended by the Rivers Agency. It is not possible to establish the likelihood of the embankment failing in these circumstances without calculating the likely water levels on the upstream side of the railway embankment. This would need detailed hydraulic modelling to allow for the interaction of flows between culverts on the watercourse. Such modelling was not undertaken by the RAIB because it was not needed to identify the railway safety lessons.

61 It is possible that a temporary partial blockage of the culvert system contributed to the extent of the flooding. Floods often wash down debris which can block culverts. CCHBC reported to the RAIB that it did not find any evidence of debris around the trash screen at the inlet to its culvert after the flood event, and that it had cleaned the trash screen the day before. The Rivers Agency found some evidence of a partial blockage at the inlet trash screen to the Knockmore Industrial estate culvert (C9 in figure 4); however it is impossible to say when this happened and so there is no firm evidence of a pre-existing blockage.

Failure of the railway embankment

62 **The railway embankment could not withstand the differential water levels either side of it, and the resulting water flow across the track completely eroded the embankment.**

63 The embankment at the failure location is approximately 3 metres high, reducing progressively to grade (ie level) around 150 metres from the site of the washout in the direction of Lisburn and increasing to around 5 metres in height at UB1.

64 Photographs taken on site after the washout on 28 June 2012 show a clay-like brown embankment core of low permeability, with a dark grey material on top; mostly made up of ash[7] and ballast (figure 12). The top of the core was about 1.1 metres below rail level.

65 The photographs also recorded *scour holes* on the downstream side of the railway embankment, on the approach to the washout. These were formed as water seeped through the permeable upper layers of the track formation. The position of these scour holes provides an indication of the maximum water level on the upstream side of the embankment, which was around 1 metre below rail level.

[7] Ash from the fire boxes of steam locomotives and factories was used to build track formations of railway lines in the past.

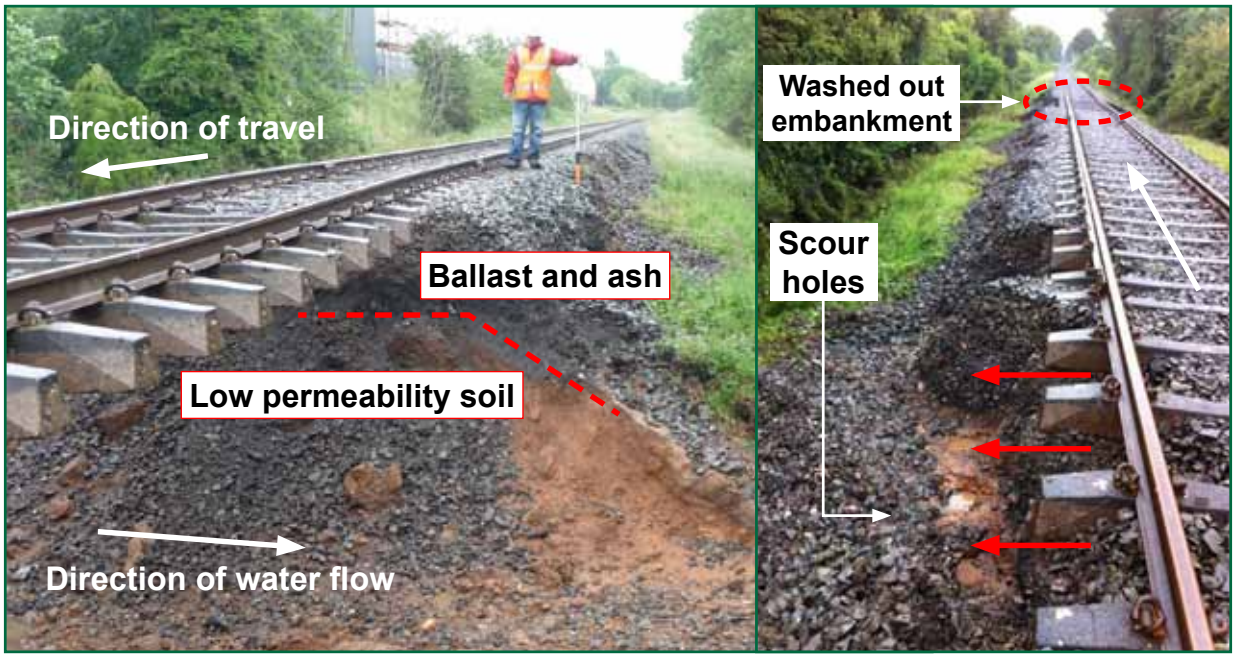

Figure 12: Washed out embankment and scour holes on approach to the site (images courtesy of URS)

66 Survey measurements, undertaken by NIR's contractors after the washout, recorded the height of a tide mark left on the walls of the CCHBC factory. From this, it is estimated that on the downstream side of the embankment, the maximum water level reached 1.54 metres below rail level. The images from CCHBC's CCTV camera nearest their culvert inlet indicate that this level was reached at around 22:15 hrs. Between the embankment breaching at around 21:53 hrs, and 22:15 hrs, the CCTV footage indicates that the downstream water level rose by around 150 mm. This indicates that just before the embankment was breached, the downstream water level was around 1.7 metres below rail level. The difference in water level between the upstream and downstream sides of the embankment just before the embankment breached was therefore around 0.7 metres.

67 The difference in water levels across the embankment was caused by a greater flow of water arriving at the upstream side of UB1 than could be passed through the combination of UB1 and the downstream culverts, causing water to build up on the upstream side (figure 13). This water level difference would have provided a driving head to force water through the permeable upper layers of the embankment. When water levels were relatively low, it is likely that the embankment was effective as a dam because the embankment was relatively wide near its base, the grassy vegetation on the upstream face strengthened this surface, and the brown embankment core material offered a greater resistance to water seepage than the upper layers of ash and ballast.

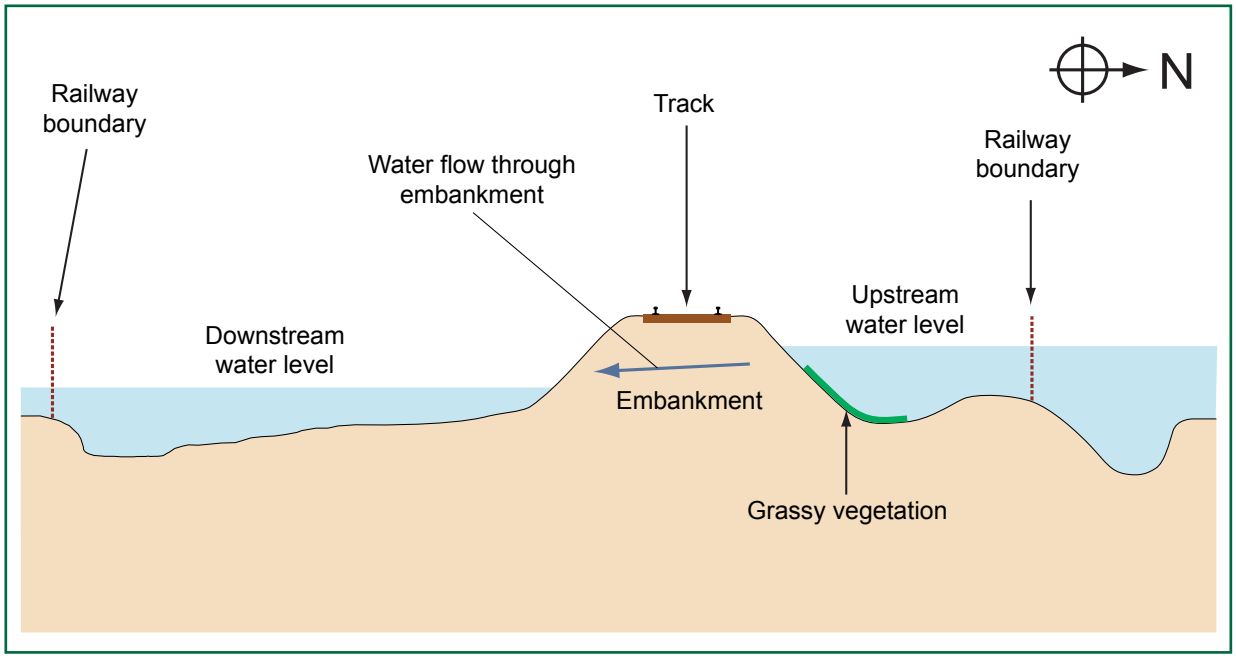

Figure 13: Schematic cross section through embankment at the failure location, showing difference in water levels across it

68 The breach occurred where the top of the grassy vegetation was lowest. At this location the upstream water level over-topped both the grassy vegetation and the clay-like core material. Once this happened, it is likely that the seepage through the upper part of the embankment led to the smaller soil particles being eroded to form small channels through the embankment. As these channels became larger, the speed of the water flowing through them would have increased, leading to more rapid erosion and the formation of scour holes similar to those observed nearby (figure 12). This process would have continued until the water speed and volume was sufficient to cause rapid, large scale erosion of the ballast and brown clay-like core of the embankment during the final breach. Railway embankments are not usually designed to act as dams and the failure of this embankment is not surprising given the conditions that existed at the time.

Routing of the train onto the Antrim branch line

69 **Train B454 was sent onto the Antrim branch line without additional precautions, despite the heavy rainfall during the previous evening.**

The Antrim branch line

70 The current status of the Antrim branch line is as an emergency diversionary route which is to be available for use at any time. It is used primarily for the purpose of operating and positioning engineering trains, engineering testing and for driver training. It can also be used for passenger trains in the event of a blockage of the main line between Lisburn and Antrim and is used for special steam passenger train services during the summer months. The number of weekly train movements on the line is very few and sometimes none.

71 Because the line no longer has a functioning signalling system, the operation of trains on the line is controlled by either taking a *possession* of the line or by *pilotman working*. There is no standard requirement to carry out an examination of the line before routing a passenger train through. The maximum speed limit is 30 mph (48 km/h).

72 Following the suspension of normal passenger train services on the line, its maintenance was reduced to a level which NIR considered appropriate for its frequency of use and speed of operation. NIR reports that at the time of the incident, this comprised the following activities:

- weekly track patrols;
- annual *ultrasonic inspection* of the running rails;
- bi-annual inspection of user worked crossings;
- vegetation management, including weed spraying; and
- inspection of bridges, culverts and embankments to the same standard as the rest of the network.

The weather forecast and NIR's response

73 NIR has a system in place to receive daily weather forecasts from the Met Office. The forecast for 27 June 2012, was sent to the control office and nominated NIR staff in the Infrastructure and Operations departments. It forecast light rain, clearing quickly during the afternoon with further persistent rain from the late evening to all parts through into the early hours of 28 June. The forecast highlighted heavy rain as a hazard with the potential for 25 mm of rain in the 24 hour period, but this was for Sligo and Ballina, located in the Republic of Ireland, south west of Lisburn. Subsequently, the Met Office issued an updated forecast around 19:30 hrs (after the main rainfall event at the incident site), also highlightling heavy rain and warning that scattered thunderstorms had been detected around Belfast and northern coasts and that these had been giving rainfall rates of 8 mm per hour and with rates of 15 mm per 3 hours very likely. The forecast did not mention heavy rain in the Lisburn area.

74 When specific hazards are identified, NIR's control office is required to make direct contact with on-call Infrastructure and Operations staff to discuss any appropriate mitigation that may be necessary. However during the evening of 27 June when the updated forecast was received by NIR, it was not relayed to the on-call infrastructure engineer. Later that night there was a landslip near Seahill on the Belfast to Bangor line which fouled the track and to which the on-call engineer was sent.

75 During the early evening of 27 June, the thunderstorms arrived as forecast, but the intensity of the rainfall was much greater than expected, with average two-hourly rates of 26 mm per hour between 17:00 and 19:00 hrs around the incident site (paragraph 49), and similar rainfall intensities in various parts of Belfast. Some NIR staff who could have initiated a response were aware that the rainfall was exceptionally heavy and that parts of Belfast had been subject to flooding, but no precautionary measures were put in place on the evening of 27 June nor for the following morning, in case there was a rainfall related earthwork failure such as a landslip or washout of the track. There were two reasons for the lack of consideration of special precautions.

76 Firstly and generally, there was no procedure in place to guide on-call staff about what they should do in the event of heavy rainfall or flooding. This underlying factor is discussed further at paragraph 93.

77 Secondly and specifically, NIR did not have any weather related concerns about the Antrim branch line, since there had never been a landslip or track washout on that line before. NIR was not aware of a previous flooding incident around the CCHBC plant in August 2008, which was also caused by heavy rain in the area and water backing up from the River Lagan. In that incident water had reached the CCHBC main factory building. A study undertaken by consultants for CCHBC after that event assessed that the incident had been a 1 in 100 year flood event. The state of the railway embankment during the 2008 flood event is not known but the amount of traffic on the line was similar to that in 2012. On the basis of the information available now, it is probable that there would have been a build up of water along the upstream side of the Antrim branch line, although at a lower level than was the case with the event on 27 June 2012.

78 Furthermore NIR had not been made aware of the existence of the feasibility study of the Brokerstown stream (paragraphs 91 and 92). Consequently it was unaware that the area around UB1, the CCHBC plant and the culvert under the main Belfast to Dublin line were all vulnerable to flooding during heavy rainfall. Impounding of water on the upstream side of the railway embankment around UB1 had been predicted by that study (paragraph 57).

79 As a consequence of these factors, no special precautions were taken for the 'golf special' train B454 on 28 June, and the driver was not instructed to proceed at caution (ie sufficiently slow to be able to stop within the distance he could see) in the vicinity of UB1. NIR has explained that in their judgement the permanent speed restriction of 30 mph (48 km/h), mitigates the risks arising from the infrequent use of the line.

Operation of the train

80 **The driver was unable to see the washout in time to be able to stop the train before it ran onto the unsupported section of track.**

81 The driver's attention on the approach to the washout was on the eroded ballast shoulder on the downstream (driver's) side of the line, where water flowing through the scour holes (paragraph 65) had removed the edges of the ballast formation. While he was looking at the ballast shoulder, the pilotman saw the hazard ahead and shouted a warning to the driver.

82 The maximum train speed reached on approach to the washout had to be estimated from the forward facing CCTV images because data from the on-train data recorder was not available (paragraph 113). The speed was around 25 mph (40 km/h) and therefore below the line's speed limit. At that speed, and allowing for the rainy conditions at the time, the train would be expected to stop in a distance of around 62 metres, following an emergency brake application. Assuming the driver applied the emergency brake within 1.5 seconds[8] of the pilotman's warning (during which the train would have travelled up to around 17 m), the pilotman must have first seen the washout when the train was around 80 metres away. Unlike a landslip on the side of a cutting or a fallen tree, a track washout is not an obstruction on the line and therefore from a distance of around 80 metres, it is not easy to recognise it as a hazard.

[8] See RAIB report No. 10/2012, 'Fatal accident at Mexico footpath crossing (near Penzance), 3 October 2011, June 2012, paragraph 56, in which reaction times in various situations are considered.

83 The reaction of the driver to the warning from the pilotman was swift and he correctly applied the emergency brake. All three cab occupants then ran out of the cab just before the leading vehicle went over the washout. The crew could not have done anything else to prevent the train from running over the washout or mitigate any risk to passengers.

Identification of underlying factors[9]

Communication between NIR and the Rivers Agency

84 **There was no engagement between NIR and the Rivers Agency regarding the potential for flooding due to heavy rainfall around the incident site. This was an underlying factor.**

85 In Northern Ireland, the Department of Agriculture and Rural Development (DARD) is the statutory drainage and flood protection authority. It discharges these duties through the Rivers Agency, an Executive agency within DARD, which is responsible for:

- maintaining designated watercourses and sea defences;
- constructing and maintaining drainage and flood defence structures; and
- protecting the drainage function of all watercourses.

86 DARD is also the Competent Authority under the European Union (EU) Floods Directive (2007/60/EC) which was transposed into Northern Ireland law in the form of local regulations in December 2009. Under this legislation, the Rivers Agency (on behalf of DARD) is required to assess flood risk from all significant sources, to make the information publicly available by December 2013, and to produce flood risk management plans by December 2015.

87 As part of its duties, the Rivers Agency assesses site specific flood risks following flooding incidents and in response to proposals for land development, to determine if flood alleviation works are viable. It also provides information and advice in relation to flood risk on request. However, unlike the Environment Agency in England and Wales, and the Scottish Environment Protection Agency, there is no formal flood warning system in Northern Ireland and the Rivers Agency does not have a statutory duty to provide one.

88 The Rivers Agency has advised the RAIB that in November 2008, it published the Strategic Flood Map for Northern Ireland on the internet and this was publicised in the media. The purpose of the map is to provide an overview of flood risk in the region, showing areas that have been subject to flooding in the past and those which could be at risk in the future. However, it is ultimately the responsibility of land and infrastructure owners and managers to assess the level of risk to their properties on the basis of the information provided. The map was updated in November 2011 to include the risk of flooding from surface water. The flood map shows that the area where the Brokerstown stream flows under the Antrim branch line around UB1 is liable to flooding, although it does not indicate water levels.

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

89 On 10 November 2010, the Rivers Agency hosted a workshop for representatives of key infrastructure owners and operators to provide those organisations with information to help them understand flood risk to their assets. Another objective of the workshop was for the infrastructure owners/operators to assist the Rivers Agency in identifying important assets adjacent to areas of significant flood risk. NIR was invited to the workshop but did not attend because the invitation (by email) was mistaken for unsolicited marketing material. The Rivers Agency reported to the RAIB that it subsequently sent computer disks to NIR on 5 January 2011 with the flood mapping information and requested information back on any high value assets adjacent to flood risk areas. However, NIR reports that it has no record of receiving such information and it did not respond to the Rivers Agency.

90 As a consequence, NIR remained unaware of the Rivers Agency's strategic flood maps and the potential flood risk to the embankment at the incident site. While knowledge of the flood maps would not necessarily have led to preventative action at the site, such knowledge may have caused NIR to look at flood mitigation in a wider context.

91 During the feasibility study of the Brokerstown stream (see footnote 1) there was a telephone discussion, in September 2009, between NIR and the consultant who undertook the work for Rivers Agency. The consultant had contacted NIR about the civil engineering options for improving the capacity of NIR's culverts on the Brokerstown stream. However, neither the context of the study nor its purpose were made known to NIR at the time. Following completion of the feasibility study in November 2009, the Rivers Agency was aware that the newly introduced CCHBC culvert was not capable of performing as intended and more generally, that the capacity of the culverts at and downstream of UB1 would not be able to cope with a 1 in 100 year flood event. This had already been demonstrated in the August 2008 flood event at the CCHBC plant, but the Rivers Agency had been unaware of this.

92 The Rivers Agency has advised the RAIB that it does not, for reasons of practicality, inform all relevant parties of every report it commissions. The agency expects each duty holder to use the information it makes available on its web site to assess the risk to their infrastructure, and if necessary, ask for further information or advice from the Rivers Agency, which it is willing to provide. The agency publicises the strategic flood maps and the access details by means of various forums it holds with stakeholders, such as the meeting on 10 November 2010 (paragraph 89). However, where approval has already been given by the Rivers Agency for a culvert design (in this case the CCHBC culvert) which it later finds is not performing as expected, the agency considers it would be prudent to inform affected parties. In this case the Rivers Agency did not tell NIR, because the Rivers Agency did not perceive that the findings indicated a significant risk to the railway.

Planning for adverse weather

93 **NIR's weather preparedness procedure did not include a plan for flooding or heavy rainfall events, and therefore NIR was not in a position to react appropriately to the rainfall event of 27 June 2012. This was an underlying factor.**

94 At the time of the incident, NIR had an operations management procedure in place; R/OP/OPR/016, 'Weather Preparedness', Issue 1, June 2009. It specifies how to prepare for seasonal weather generally, such as snow and icy conditions in the winter months, hot weather and autumn leaf fall. It states that if hazardous or extreme weather is forecast, the duty controller should contact the on-call infrastructure engineer and other departments, including operational on-call staff, to confirm receipt of the forecast (or if during out-of-hours periods, to relay the information). It is the responsibility of the relevant on-call infrastructure engineers (covering each of the signalling, permanent way and structures disciplines) to decide whether to apply any mitigation measures to alleviate the risk from the adverse weather. Typical mitigation measures comprise enhanced situation monitoring by means of further weather reports, staff reports or site inspections and temporary speed restrictions. If any special measures are introduced, they remain in place until the on-call engineer tells the control office that it is safe for them to be removed.

95 The procedure does not however, specify any criteria at which action should be taken for different hazards or what the recommended actions are. It leaves the decision on when to take action and what to do, to the discretion of the on-call infrastructure engineer. No specific training is provided on handling extreme weather conditions. More specific to this incident, the procedure did not specify at what predicted level of rainfall action should be taken. NIR's data on landslips indicates that there are on average about four landslips a year. NIR reports that usually, if a weather forecast mentions 'heavy rain' (paragraph 49), temporary speed restrictions are considered or applied on the main line from Belfast to Bangor, which has a history of landslip problems.

96 For an adverse weather plan to be effective, it should set out which specific parts of the infrastructure are at risk for each type of hazard and how best to mitigate these. This requires a detailed knowledge of problem areas of the infrastructure. In relation to heavy rainfall, NIR has a list of locations which have flooded in the past due to blockage of culvert structures and crest drains. These locations are visited routinely and cleared by NIR's structures maintenance contractor. When heavy rain is forecast the contractor is requested to make additional visits before and after the rainfall event to check that there is no blockage. NIR reports that the problem areas were visited five times during June 2012, the last visit being on 22 June. Culvert UB1 was not on the list, because as far as NIR was aware, there had not been any problems at that location in the past.

Factors affecting the severity of consequences

97 The passage of the train's leading bogie over the unsupported track could have resulted in derailment, with the attendant possibility of injuries to the staff that were in the cab. Two factors helped to prevent the incident from having worse consequences:

- although the line is laid with jointed track, there were no rail joints in the unsupported section of track; and
- the train happened to come to a stand with its bogies straddling the unsupported section.

98 Once the train had come to rest, it remained in a precarious position. Driver A had to make a difficult decision; whether to immediately reverse the whole train off the washout or to uncouple the trailing three-car set from the leading set and drive the trailing set away. The latter would have required the evacuation of two elderly passengers located in the back of the third vehicle onto the track and then into the trailing set, since there was no interconnecting gangway between the sets. This would have taken time which the driver believed, from the visible crumbling edges of the washout, he did not have. Therefore, despite not having permission from the control office, the driver made the decision to reverse the whole train and acted swiftly to do so with the help of the other members of the train crew and pilotman. His timely action quite likely saved further collapse of the track and derailment of the leading vehicle.

Observations[10]

The immediate response to the incident

99 The crew in the driving cab reported to the RAIB during the investigation, that they had been shaken by the incident. However, after moving the train off the washout and on to Lisburn, they were allowed to operate the train to Portrush before anyone checked on their welfare. According to NIR's procedure for trauma management, checks should have been made to assess if the crew were fit enough to carry on with their duties.

100 No physical examination of the train was undertaken after the incident to check that it was fit to continue in service. NIR's rule book requires drivers to check their train in the event of collisions, derailment or heavy impacts. NIR also has a procedure for the post incident examination of trains based on a Railway Group Standard (RGS) GM/RT2273. However the circumstances of Knockmore were outside any of the scenarios envisaged in the RGS or the NIR rule book.

Safety critical communications

101 Notwithstanding the stressful nature of the incident, voice tapes of the communications between those directly involved in dealing with the incident, revealed deficiencies in the standard of safety critical communication. The main deficiencies noted by the RAIB were; a lack of proper identification by those initiating and receiving calls, incomplete repeat back of messages to check the message had been fully understood, and the informal style of the conversation, including the use of slang terms.

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

102 No voice records were available for the controlling signal box at Portadown, which controls entry to the Antrim branch line, because the voice recorder was reported by NIR to be faulty at the time. The recorder is reported to have broken down on 16 June 2012. Such recorder failures are not detectable until a download is attempted.

103 After the train had stopped over the washout, the first phone call from the driver was to the control office. NIR's rule book, section M, requires that in the event of a train stopping due to accident, failure, obstruction or other exceptional incident, the signaller should be notified in the first instance. This is because the signaller is best placed to protect a stopped train from other train movements. However, in this case, there was no chance of another train being in the vicinity because the appointed pilotman was on board the incident train. Since the pilotman was a signaller, he agreed with the driver that he would make and maintain contact with the signaller.

104 This deviation from the rules reduced the time it took, in this particular situation, to make phone calls and relay messages. However, there is an apparent conflict of instructions about who should be contacted in the event of an incident. The NIR rule book and signaller's handbook are consistent and clear in that the driver should contact the signaller in the first instance. The signaller must then inform the control office if the train is unable to continue normally. However, there is an inconsistency with the controller's handbook which states that all incidents should be reported in the first instance to the control office and that they will immediately implement management procedures to ensure the line is protected.

105 The practice of drivers contacting the controller first in the event of an incident, rather than the signaller (as happened in this incident), appears to be common on NIR. This hierarchy of communication is not in accordance with the NIR rule book.

Weed control of the Antrim branch line

106 On 12 September 2012, the RAIB carried out a cab ride in a Class 4000 train along the Antrim branch line. It was noted that some short sections of the track were severely overgrown with weeds and in some locations one or both rails were not visible to the driver (figure 14).

107 The lack of weed control could compromise the efficacy of the track patrolling regime undertaken on that line. Additionally, there have been reports of attempted theft of rail from the line and, given that the line is rarely used, it would be desirable for train drivers to be able to see the running rails.

108 NIR has explained that the Antrim branch line had not been sprayed with weed killer in 2012 prior to the RAIB's visit, due to the prolonged wet weather. The weed spray used by NIR is not effective in wet weather because it gets washed away before it can take effect. During the reduced number of opportunities to carry out weed spraying, priority had been given to the main lines.

Evidence preservation and accident investigation

109 Following the incident, NIR's infrastructure department commenced an investigation into the technical cause of the washout and called in its specialist contractors to survey and photograph the site and its surroundings.

Figure 14: A section of the Antrim branch line with excessive weeds and lack of visibility of the track, September 2012

110 NIR has three separate accident investigation procedures, for its Infrastructure, Operations and Fleet Engineering departments, which sit under a Translink Group (high level) standard. For minor incidents, the relevant department carries out the investigation, requesting help from other departments as necessary. In the event of a major incident or accident the Safety department of the Translink Group is required to take the lead and commence a formal, cross-departmental, investigation.

111 On 14 August 2012, nearly seven weeks after the incident, the RAIB first learned from an anonymous source, that the front of a train had run onto the washout. The RAIB made enquiries to NIR the following day about the full circumstances of the incident. On 17 August 2012, NIR launched a formal investigation into the incident. Two investigating officers were formally appointed and provided with an investigation remit. NIR has stated that a few days prior to this, the Infrastructure department viewed the forward facing CCTV footage and this led the department to start thinking in terms of a more formal investigation with a wider scope than the existing technical investigation into the cause of the washout. Later, in early September 2012, NIR appointed its own internal auditor (a function which is provided by an external firm) to carry out a separate investigation into the notification of the incident to statutory bodies (paragraph 114).

112 The delay in starting the formal investigation was due to a combination of several factors:

- since no one had been injured and the rolling stock had not been damaged, there was a high degree of focus on service recovery, in the midst of a busy period for NIR, with the ongoing Irish Open golf tournament;
- the Operations department had decided that the incident should be classified as a schedule 3(3) incident, as defined in the Railways (Accident Investigation and Reporting) (RAIR) Regulations 2005[11]; instead of the more serious, 'near miss', schedule 1(9) type incident (discussed further at paragraph 119);
- the Operations department considered the incident to be an infrastructure incident and not an operational one, and therefore did not instigate any investigation, assuming that the Infrastructure department would do so and call in their help if required;
- the Infrastructure department assumed that if a formal investigation was required it would be called by the Translink Group Safety department and so it carried on with its technical investigation into the cause of the embankment failure;
- the responsible manager in the Safety department at Translink Group level has stated that he was not aware that the front of the train had run onto the washout and therefore did not see the incident as requiring a formal investigation; and
- the incident occurred just before key staff went on holiday, leading to insufficient senior management oversight of the evidence preservation and investigation activities.

113 As a consequence of not commencing a formal investigation, which included both operational and infrastructure aspects, normal evidence preservation procedures were not followed and some evidence was not collected in a timely manner. Relevant staff were not interviewed until September 2012 and the on-train data recorder was not downloaded in sufficient time to prevent the data being overwritten.

Notification of the incident

114 NIR is legally required to notify three statutory bodies in the event of a reportable accident:

- the RAIB, under the RAIR Regulations[11];
- the Health & Safety Executive, Northern Ireland (HSENI) under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations, 1995 (RIDDOR); and
- the Department for Regional Development, Northern Ireland (DRDNI), under historically agreed protocols with NIR for the notification of accidents to the safety authority.

[11] A copy of the Railways (Accident Investigation and Reporting) (RAIR) regulations 2005 and guidance on its use, is available at http://www.raib.gov.uk/guidance_and _procedures/regulations.cfm.

115 The DRDNI received a text message about the landslip near Seahill (referred to as being at Cultra) but does not recall receiving a text or phone call about the incident at Knockmore. NIR has reported that the content of the text message sent out shortly after the incident on 28 June to DRDNI and others in NIR, including senior managers read:

> "Due to adverse weather resulting in a landslip at Cultra, a bus substitution was operated between Belfast and Bangor from 21:00 until close last night, Wednesday 27 June 2012. This morning the Lisburn to Antrim line has been closed for same reasons - Irish Open special has been re-routed through Bleach Green."

116 The HSENI was notified on 29 June 2012 with the following text on a standard form:

> "PW Inspector reported that the railway embankment at MP105.5 Knockmore Junction had been washed away after severe flooding. Lisburn Antrim line closed until further notice."

117 The RAIB was notified on 4 July 2012 in a monthly return of schedule 3 events for June 2012. NIR's notification contained two events, the incident at Knockmore on 28 June and the landslip near Seahill on the Belfast to Bangor line on 27 June (paragraph 74). The notification regarding the incident at Knockmore read:

> 'PW Inspector reported that part of an embankment (approx 150 Tons) had been washed away. Significant rainfall had overwhelmed the capacity of a culvert resulting in rain water to dam behind the embankment. The line was closed until repairs can be carried out.'

118 The notifications to all three statutory bodies were different in the wording but were consistent in omitting to say anything about the involvement of a train in the incident and the significant risk that resulted. As a result of this omission the full circumstances of the incident were not conveyed to the statutory bodies.

119 NIR's classification of the incident as a schedule 3(3) event (paragraph 112), which must be notified to the RAIB no later than 10 days after the end of the month in which the incident occurred, was incorrect. The RAIR regulations define a schedule 3(3) event as:

> *'The failure of a structure on railway property, including a tunnel, bridge, viaduct, culverts, railway cutting, embankment, station, signal or fixed electrical equipment which under slightly different circumstances may have led to a serious accident or otherwise reduces the level of railway safety.'*

120 NIR should have notified the incident as a schedule 1(9) event, to be notified to the RAIB immediately and by the quickest means available (ie a phone call followed up by a written notification on a standard form). The RAIR regulations define a schedule 1(9) incident *as:*

> *'An accident or incident which under slightly different conditions might have led to a death, serious injury or extensive damage to rolling stock, the infrastructure or the environment.'*

121 When deciding whether to notify the RAIB immediately, NIR has indicated that it referred to the 'quick guide to notification' document issued by the RAIB. The contemporary version of this document paraphrased the wording of schedules 3(3) and 1(9) as follows:

- Schedule 3(3): 'Failures of structures on the railway such as cuttings, bridges, embankments and stations where under slightly different conditions there may have been a death, two or more serious injuries or 2m euros worth of damage to rolling stock, infrastructure or environment.'
- Schedule 1(9): 'Accidents or incidents which could have led to deaths or serious injuries or 2m euros worth of damage to trains, infrastructure or environment, but did not do so. If in doubt notify.'

122 Although this incident may appear to fall within schedule 3(3), that classification does not reflect the serious 'near miss' nature of the incident, which is covered by schedule 1(9). NIR did not use the reporting schedules as they are meant to be used on two counts. Firstly if an incident fits the description of a schedule 1 event and a schedule 3 event, the (more serious) schedule 1 event applies. Secondly, where there is doubt about the appropriate classification, duty holders were advised (in the RAIB's quick guide to notification) to notify the RAIB anyway. During the morning following the incident, there was discussion within NIR about the severity and classification the incident. It was agreed that the Translink Group Safety department would ring the RAIB to discuss the incident. There is no record of such a phone call ever having being made to the RAIB.

123 On 17 June 2013, the RAIB issued version 2 of the RAIB quick guide to notification[12] on its website. This version now emphasises that the schedules should be read in order of severity (ie check if an incident fits schedule 1 first before any other schedules) and has revised wording to describe schedule 3(3). Its contents were included in NIR's briefing sessions on notification to statutory bodies (paragraph 136).

The role of the safety authority

124 The national safety authority (NSA) for the railways in Northern Ireland is the DRDNI. The DRDNI reports that its current safety regulation activities with respect to railways are to:

- manage the introduction and implementation of EU safety related legislation relevant to railways;
- consider and approve NIR's *safety management system* to enable NIR to operate its trains and infrastructure;
- monitor safety performance;
- oversee the management of safety critical work;
- promote the improvement of NIR's engineering standards for rolling stock and infrastructure;
- monitor and enforce the implementation of RAIB recommendations; and
- conduct studies into particular risk areas, such as level crossings.

[12] http://www.raib.gov.uk/report_an_accident/guidance_2.cfm.

125 The DRDNI is assisted in its regulation activities by the HSENI, who are the enforcing authority. The HSENI has been delegated the enforcement and investigation duties of the DRDNI by means of legal regulations. The HSENI also assists DRDNI with advice on rail related matters to help identify key risk areas, monitor safety performance and on the implementation of RAIB recommendations. Both the DRDNI and HSENI have agreements in place with the Office of Rail Regulation (the rail safety authority for Great Britain) to request assistance and/or advice if required.

126 The supervision of railways by safety authorities generally in the European Union (EU) is in the process of being standardised to comply with the requirements of EU Commission regulation No. 107/2012. This regulation specifies a common method for the supervision of the safety performance of the railway undertaking (in this case, the part of NIR that operates the trains) and infrastructure manager (the part of NIR that maintains the track, structures and signalling). The DRDNI has reported to the RAIB that it does not expect its current processes for the supervision of NIR to change significantly in the future, except for the introduction of a more formal supervision strategy and plan. These are to be developed shortly.

Previous occurrences of a similar character

127 NIR reports that it has not had a washout on its network before. It has had 23 relatively minor landslip incidents between December 2006 and October 2012 (excluding the Knockmore washout). While some of these had fouled the running line, none had resulted in derailment.

Summary of conclusions

Immediate cause

128 A ten metre long section of embankment had been washed away prior to the arrival of train B454, which was unable to stop before its leading bogie ran onto the unsupported track, which was at risk of collapsing under the train (**paragraph 43**).

Causal factors

129 The causal factors were:

a. there was heavy rainfall in the catchment area of the nearby Brokerstown stream on 27 June 2012, (**paragraph 45, no recommendation**);

b. the culvert system on the Brokerstown stream was unable to cope with the water flows generated by the heavy rainfall, causing water to back up behind the railway embankment (**paragraph 50, Recommendation 1**);

c. the railway embankment could not withstand the differential water levels either side of it and the resulting water flow across the track completely eroded the embankment (**paragraph 62, Recommendation 1**);

d. train B454 was sent onto the Antrim branch line without additional precautions, despite the heavy rainfall during the previous evening (**paragraph 69, Recommendation 2**); and

e. the driver was unable to see the washout in time to be able to stop the train before it ran onto the unsupported section of track (**paragraph 80, no recommendation**).

Underlying factors

130 The underlying factors were:

a. there was no engagement between NIR and the Rivers Agency regarding the potential for flooding due to heavy rainfall around the incident site, (**paragraph 84, Recommendation 1**); and

b. NIR's weather preparedness procedure did not include a plan for flooding or heavy rainfall events, and therefore NIR was not in a position to react appropriately to the rainfall event of 27 June 2012 (**paragraph 93, Recommendation 2**).

Additional observations

131 Although not linked to the cause of the incident on 28 June 2012, the RAIB observes that:

a. NIR's procedures for post incident checks on the welfare of the train crew were not followed (**paragraph 99, Recommendation 5a**).

b. There were deficiencies in the standard of safety critical communications between those directly involved in dealing with the incident (**paragraph 101, Recommendation 3**).

c. Some short sections of the Antrim branch line had been allowed to become severely overgrown with weeds, to the extent that one or both rails would not have been visible to track patrollers and drivers; (**paragraph 106, Recommendation 4**).

d. NIR did not launch a formal investigation into the incident until 17 August 2012; the long delay was caused by several factors which revealed deficiencies in NIR's procedures for accident investigation and evidence collection (**paragraph 109, Recommendation 5**).

e. NIR's notifications to all three statutory bodies (RAIB, HSENI and DRDNI) omitted to say anything about the involvement of a train in the incident and the significant risks that resulted. As a result of this omission, the full circumstances of the incident were not conveyed to the statutory bodies (**paragraphs 114 and 135 - 136, no recommendation**).

Previous RAIB recommendations relevant to this investigation

132 The following recommendations, which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

133 Derailment in Summit Tunnel, Todmorden, West Yorkshire, 28 December 2010, RAIB report No 16/2011, published September 2011.

Recommendation 2

The intent of this recommendation is to prevent the first train, after a cessation of traffic due to extreme weather, from passing at the line's maximum permitted speed through or over an unsafe structure. By identifying which structures on a route are at risk of becoming unsafe due to extreme weather, Network Rail can then check their state prior to reopening the route, eg by using the first service train to examine the route, a route proving train or staff on foot.

Network Rail should identify the structures (as defined in NR/L3/CIV/006/1C) where passengers or staff might be put at risk when train services are resumed following an extended cessation of traffic during, or following, periods of extreme weather (as defined in NR/L2/OPS/021). Network Rail should then put in place procedures that result in checks that it is safe for trains to operate at the permitted line speed over or through these structures before resuming the train service.

It should be noted that this recommendation was not addressed to NIR. If NIR had taken action as a result of this recommendation, it may have prevented the incident at Knockmore, but only if NIR had also recognised the risk from flooding due to heavy rainfall at that location.

134 Derailment at Trooperslane near Carrickfergus, Northern Ireland, 23 April 2006, RAIB report 25/2007, published July 2007.

Recommendation 7

NIR should ensure all appropriate staff are briefed on the requirements of the RAIR with particular reference to reporting incidents promptly to RAIB and the management and access to site and evidence preservation.

The DRDNI reported to the RAIB in June 2007, that NIR had implemented the recommendation. As a result of this incident near Knockmore, NIR has taken further action as described at paragraph 135 and therefore the same recommendation is not remade here, to avoid duplication.

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

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

135 NIR has changed its notification procedure to statutory bodies (RAIB, HSENI and DRDNI) by including requirements to:

- notify immediately if there is any doubt;
- carry out an independent review of any formal notification report by a senior manager, to check the accuracy of the report; and
- notify any changes in the circumstances of an incident if any emerge after the original report.

136 On 3 May 2013, NIR organised training on notification to statutory bodies for relevant staff. Briefings were provided by DRDNI, HSENI and the RAIB. Subsequently, NIR reports that it briefed out the formal issue of the RAIB's revised quick guide to notification (paragraph 123).

Other reported completed and ongoing actions

Completed actions

137 NIR has reported to the RAIB that it has completed the following actions in response to the incident:

a. The washout was repaired and the track reinstated approximately one week after the incident. NIR installed two additional overflow culverts at the site of the washout to protect the embankment in the event of a similar flood event.

b. Voice communication recording equipment at Portadown signal box, which was defective at the time of the incident, has been replaced with an upgraded unit.

c. A contact has been established with CCHBC so that in the event that CCHBC becomes aware of another flood event at its plant, it will be able to alert NIR.

d. Train drivers and signallers were re-briefed in January 2013 on rule book emergency and communications procedures.

e. NIR's incident management procedure has been changed to ensure that key staff are debriefed in a timely manner and on-train recorded data is preserved.

f. Weed spraying of the Antrim branch line was carried out on 4 October 2012, and twice more in 2013 up to the publication of this report.

g. NIR has completed a review into how earthwork failures should be recorded and analysed in the future, to enable trends and lessons to be identified.

h. A procedure has been introduced to describe how to manage the risk posed by rain and flooding, using current practice of other infrastructure owners for guidance.

i. The control office has been re-briefed on the requirement to contact on-call managers when adverse weather is forecast.

Ongoing actions

138 NIR has also reported to the RAIB that it is progressing the following actions. Where NIR has indicated target completion dates, these are given in square brackets.

a. NIR met with the Rivers Agency on 11 January 2013 to discuss the agency's information on flood risk management. Following this, NIR reports it is currently developing a register of sites at risk from flooding, using the strategic flood maps provided by the agency (paragraph 88) and other information. Over 150 bridges over watercourses have been identified for assessment to determine their vulnerability to flooding, including UB1 at the incident site and the culvert under the main Belfast to Dublin line. NIR plans to undertake site investigations to assess the risk at these locations.

b. NIR is exploring with the Met Office means of providing site specific weather forecasts, to be used in conjunction with other information from (a) to manage the risk from heavy rainfall and flooding [June 2014].

c. A review of incident management systems has been completed, including information capture, as a precursor to considering the introduction of a single accident/incident investigation procedure.

d. Management procedures for the regular monitoring of safety critical voice communications are being reviewed and NIR is developing training material for re-training of signallers, controllers and managers.

Recommendations

139 The following recommendations are made[13]:

1 *The intent of this recommendation is that in future, NIR will be fully aware of locations on its network which are vulnerable to heavy rainfall or flooding events and that NIR will know what actions it should take and when, to maintain the safety of the line.*

NIR, with the assistance of the Rivers Agency, should:

a. complete the ongoing review of earthworks and structures on its infrastructure with respect to flood risk, including, where necessary, the assessment of the hydraulic capacity of relevant culverts, and identify and prioritise those sites which require mitigating action (eg enhanced monitoring, speed restrictions) in the event of heavy rain or flooding, and the trigger levels for those actions.

b. develop and implement a formalised procedure for liaison with the Rivers Agency so that NIR is informed of any future developments or changes to watercourses which might adversely affect its infrastructure by an increased risk of flooding.

(paragraphs 129b, 129c and 130a)

continued

[13] 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 Department for Regional Development Northern Ireland, and the Rivers Agency of the Department for Agriculture and Rural Development Northern Ireland (for Recommendation 1 only), to enable them 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 200 to 203) can be found on RAIB's website www.raib.gov.uk.

2 *The intent of this recommendation is that NIR has plans in place for adverse weather events, including but not limited to, heavy rainfall and flooding, to maintain safety of the line during and following such events.*

NIR should develop its adverse weather procedures in order to address the risks to train operational safety and include the following:

a. improved weather data collection and dissemination within NIR;

b. action trigger levels for each type of weather event, the corresponding mitigating actions to be taken (eg enhanced weather monitoring, site patrolling, speed restrictions, line blockage) and the nominated person to make those decisions;

c. identification of at-risk locations where special measures must be taken, and the methods and frequency of monitoring at these locations until cessation of the hazard;

d. definition of what safety of line checks should be made before the line is opened at full line speed (eg by using the first service train to examine the route at caution, a route proving train or staff on foot); and

e. any special measures for infrequently used lines, such as the Antrim branch line.

(paragraphs 129d and 130b)

3 *The intent of this recommendation is that the protocols for safety critical communications following incidents and accidents are clear and in accordance with the NIR rule book, and that the general standard of communications and the operational status of voice recording equipment is improved.*

NIR should:

a. carry out checks to confirm whether drivers are correctly applying the rule book when first reporting incidents, and implement sufficient re-training of its staff as deemed necessary to address any identified areas of deficiency;

b. review the actual quality of safety critical communications between train crew, signallers and controllers in practice, and implement sufficient re-training of its staff to address any identified areas of deficiency;

c. review how it monitors and enforces good practice in communications, and implement any necessary changes to relevant practices and procedures; and

d. implement a system for routinely checking the correct operation of its voice recording equipment.

(paragraph 131b)

continued

4 *The intent of this recommendation is that there is adequate ongoing weed control of the Antrim branch line in the future, to enable the safety of the line to be maintained at all times.*

NIR should put in place a process for the ongoing monitoring and control of weeds on the Antrim branch line, including measures to mitigate the risk to train operations arising from any future missed or ineffective treatments, which result in excessive weed cover that could compromise track inspections, and brief this process out to relevant staff (paragraph 131c).

5 *The intent of this recommendation is that there is improved clarity and consistency in the procedures for incident response, evidence preservation, and accident investigation throughout the company, and that there is appropriate senior management oversight of investigations so that opportunities to learn safety lessons are not compromised or missed.*

NIR should:

a. review the effectiveness of its procedures for checking on the welfare of staff involved directly in an incident or accident and for arranging for their debriefing;

b. develop an integrated accident investigation procedure with common types of investigation and clarity about roles and responsibilities for each type;

c. arrange to have sufficient competent senior management oversight of its investigations so that the full scope of the event which occurred is recognised early, and to supervise the timely collection of relevant evidence (if the RAIB is not attending), set a thorough remit, and review progress; and

d. implement its revised procedures and provide training to relevant staff.

(paragraphs 131a and 131d)

Appendices

Appendix A - Glossary of abbreviations and acronyms

CCHBC	Coca Cola Hellenic Bottling Company
CCTV	Closed circuit television
DARD	Department of Agriculture and Rural Development
DRDNI	Department of Regional Development, Northern Ireland
HSENI	Health and Safety Executive, Northern Ireland
NIR	Northern Ireland Railways
NITHCo	Northern Ireland Trasport Holding Company
RAIR	Railways (Accident Investigation and Reporting) regulations
RGS	Railway Group Standard

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.

Catchment area	The area of land drained by a river or other watercourse.
Culvert	A structure, usually comprising a pipe, that allows water to flow under a railway or road or some other obstruction.
Culverted (section)	A section of watercourse that passes through a culvert.
Driver assessor	A senior train driver appointed to instruct and assess other train drivers.
Hydraulic	In the context of this report, relating to the mechanical properties and behaviour of flowing water.
Permanent way	The track structure which includes rails, sleepers, ballast, blanketing material and drainage.
Pilotman	Person appointed in connection with the passage of trains over a double line, single line or bi-directional line during a failure of equipment. In the case of the Antrim branch line, a pilotman is used because the line does not have a functioning signalling system.
Pilotman working	A system of railway operation which uses a person (the pilotman) as a human 'token' to provide the driver authorisation to proceed. It is usually used in emergency situations or where the signalling system is not working.
Possession	A section of the line which is under exclusive occupation of an engineer for maintenance or repairs. The engineer may run his own trains within the limits of the possession but no other trains are allowed to run within it and comprehensive safety arrangements ensure that these conditions are kept.
Return period	The expected probability of occurrence of a rainfall event, expressed as the average interval between events of a given magnitude.
Rule Book	A document describing the duties and responsibilities of staff and the regulations in force to ensure the safe operation of the railway.
Safety management system	A management system which provides the guide to specific arrangements designed to control health and safety risks on a railway system.
Scour holes	Holes formed (in this case through the track formation) by the removal of material by the action of flowing water.
Surcharge (of a culvert)	A condition in which the level of water flowing through a culvert has reached the top of the culvert interior.

Tamping	The operation of lifting the track and compacting the ballast beneath the sleepers.
Ultrasonic inspection	The use of high frequency sound waves to detect internal defects in a material.
Underbridge	A bridge passing beneath the railway.
Washout (re embankment)	A rapid erosion of the embankment material by flowing water, usually following heavy rain or localised flooding.
Weekly operating notice	On NIR, a publication issued weekly which lists temporary speed restrictions, details of special trains and timetables, engineering works, party travel bookings, additional operating instructions, and modifications to the Rule Book Appendix.

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Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk