Rail Accident Investigation Branch

Rail Accident Report

Derailment in Hooley Cutting, near Merstham, Surrey
13 January 2007

Department for Transport

Report 05/2008
February 2008

This investigation was carried out in accordance with:

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

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Introduction

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

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

3 Access was freely given by Network Rail and Southern Railway to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

- acronyms and abbreviations are explained in Appendix A;
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B;
- standards in use at the time of the derailment are listed in Appendix C;
- damage to the train is listed in Appendix D; and
- references to documents are listed in Appendix E.

Summary of the report

Key facts about the accident

5 At 12:23 hrs on Saturday 13 January 2007, the 10:59 hrs Bognor Regis to London Victoria train, reporting number 1C23, emerged from Merstham tunnel into the deep Hooley cutting on the *up* Redhill line. The train, which comprised eight cars of class 377 electric *multiple unit* stock, was travelling at 83 mph (132 km/h). The driver, observing debris from a land slip on the line approximately 100 m from the tunnel mouth, immediately made an *emergency brake* application. The train hit the debris at approximately 70 mph (112 km/h) causing the leading *wheelset* to derail to the *cess* side of the track. The train remained upright and came to a stand after travelling another 320 m.

6 The train was conveying 413 passengers, none of whom were physically injured by the incident. Passengers were eventually evacuated in small groups along the track and up steep access steps to the public highway.

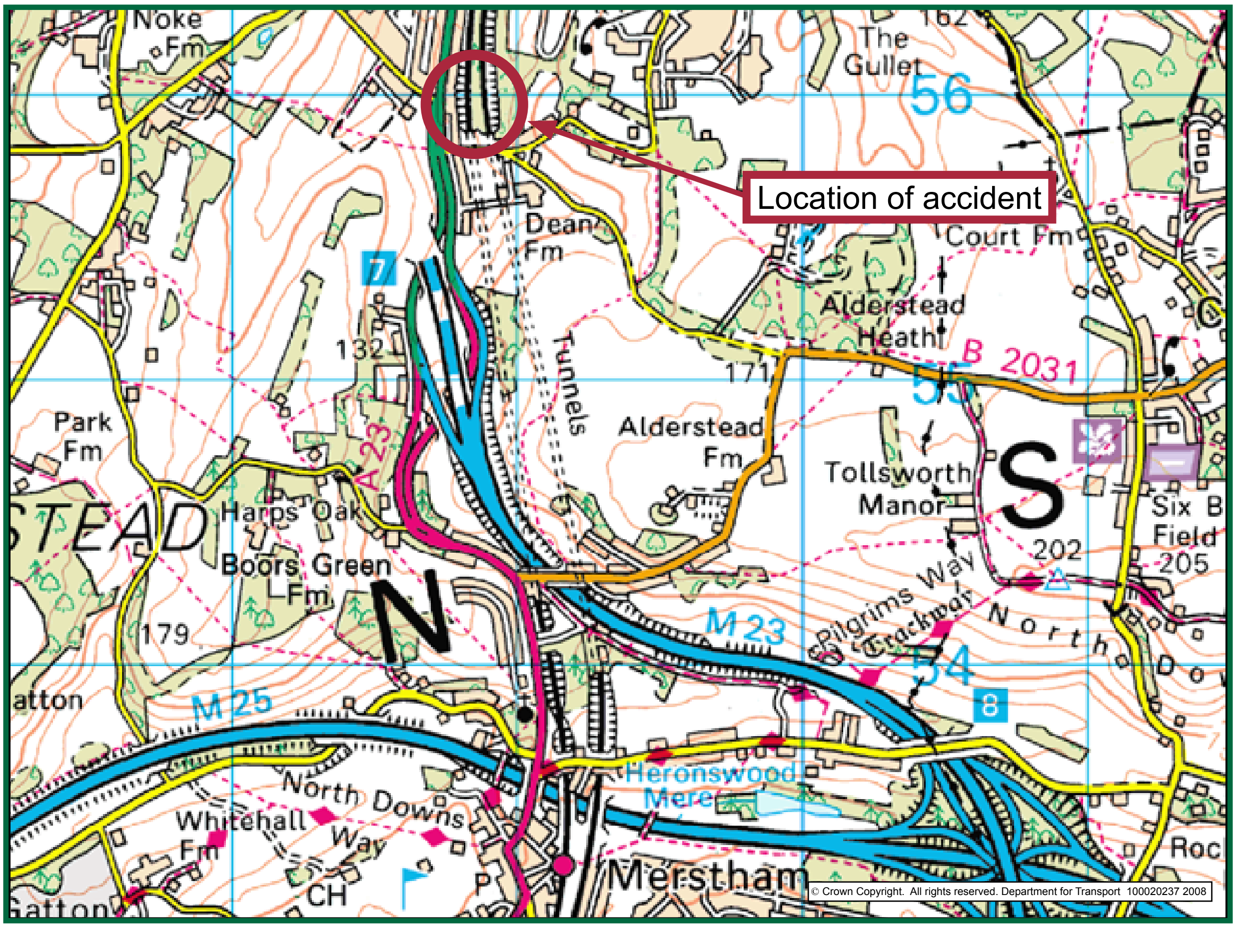


Figure 1: Extract from Ordnance Survey map showing location of accident

Immediate cause, causal and contributory factors, underlying causes

Immediate cause

7 The immediate cause of the derailment was an obstruction on the track formed by displaced timbers from a *king post wall* displaced by the fall of a 6 tonne *root ball* from the cutting side.

Causal and contributory factors

8 Causal factors were:

- the lack of understanding about the risks presented from retained root balls and complex cutting geology;
- the decision to leave root balls in situ on the cutting side after tree felling;
- the mass of the root ball that fell.

9 Contributory factors were:

- high rainfall over the south east of England prior to the derailment;
- the loss of cohesion of the materials forming the cutting side;
- the lack of a warning system;
- the speed of the train.

10 Underlying causes were:

- the lack of guidance in Network Rail standards regarding root balls;
- the backlog of earthworks examinations inherited by Network Rail.

Severity of consequences

11 Some passengers suffered discomfort and needed assistance whilst climbing the long flight of steep steps from the track to the public highway. Several passengers were monitored for a short period by ambulance personnel following the climb.

12 The first coach of the train received substantial damage (Figure 3) to the bodywork, the leading *bogie* and underfloor equipment. The following coaches received minor damage. A number of the outer panes of windows were broken. A complete list of damage is included in Appendix D.

13 Track damage was relatively minor, however several items of signalling equipment and *track bonds* required replacement.

Recommendations

14 Recommendations can be found in paragraph 132. They relate to the following areas:

- updating of guidance on root balls;
- inspection of cuttings containing root balls or stumps;
- removal of root balls or stumps posing high risks to the railway;
- consideration of whether a rock fall warning system should be installed at Hooley cutting;
- providing all track patrol and inspection staff with guidance cards relating to earthworks movements;
- providing all control locations with details of access locations; and
- considering the use of train-to-train evacuation processes.

The Accident

Summary of the accident

15 On Saturday 13 January 2007 the 1C23 service left Bognor Regis at 10:59 hrs for London Victoria. It was formed of eight cars of class 377 electric multiple unit stock. The train had an uneventful journey from Bognor to the booked stop at Redhill after which it departed for the non-stop run to East Croydon.

16 At 12:23 hrs the train emerged from Merstham tunnel into the deep Hooley cutting on the up Redhill line. The train was travelling at 83 mph (132 km/h). The driver, observing debris from a landslip on the line approximately 100 m from the tunnel mouth, immediately made an emergency brake application. The train hit the debris at approximately 70 mph (112 km/h) causing the leading wheelset to derail to the cess side of the track. The train remained upright and came to a stand after travelling another 320 m.

17 The train was conveying about 413 passengers, none of whom were injured by the incident. Passengers were evacuated in small groups along the track and up steep access steps to the public highway.

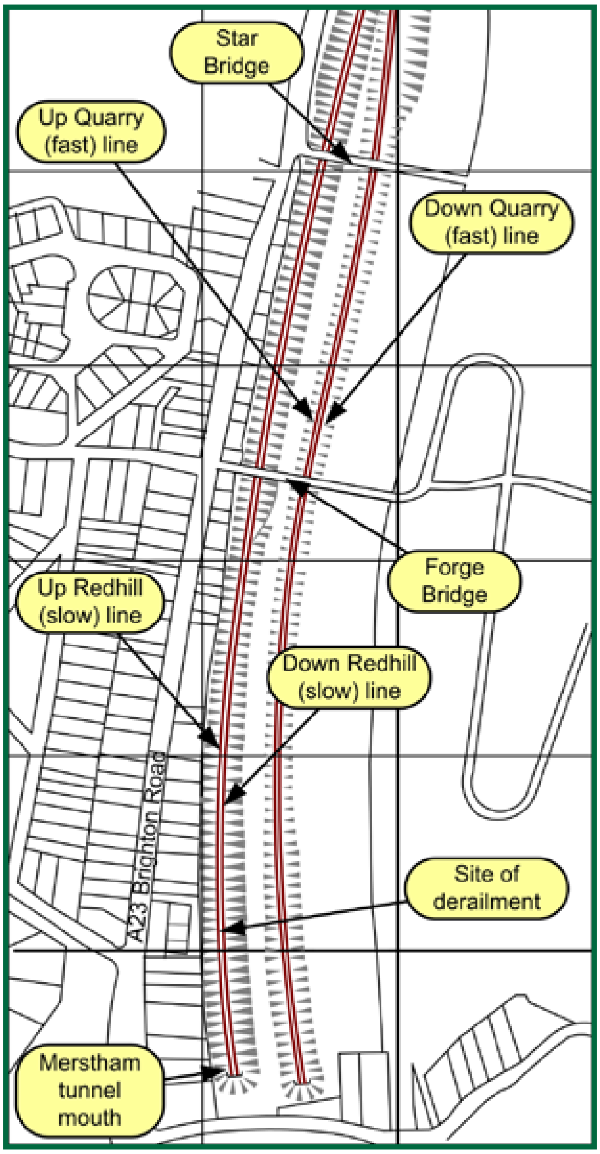


Figure 2: Drawing of railway lines in and around Hooley cutting

Figure 3: General view of the derailed train in Hooley cutting

The parties involved

18 Network Rail is the infrastructure owner, responsible for the maintenance of the track, tunnel and earthworks. Network Rail undertakes its own track maintenance and routine earthworks inspections. Major earthworks activities, detailed surveys and geological examinations are undertaken by contractors.

19 Southern was the train operating company involved. It operated the train with its own staff.

Location

20 The derailment site is approximately 100 m north of Merstham tunnel. This is located to the east of the A23 London to Brighton trunk road. The railway emerges from the tunnel though the North Downs into a deep chalk cutting. The land between the railway boundary fence situated at the top edge of the cutting and the Brighton Road is occupied by houses.

21 The railway line in the cutting is double track line. A second cutting, containing the Quarry fast lines is situated to the east of the Redhill slow lines. A central spine of land which reaches the full height of the natural topography of the area separates the two lines (Figure 4).

22 Merstham tunnel is a single bore containing both the up and *down* Redhill slow lines (Figure 2). It is 1 mile 71 yards (1.67 km) long.

23 The line speed from Merstham station, though Merstham tunnel, towards Coulsdon South is 90 mph (144 km/h), after which it reduces to 75 mph (120 km/h). The line curves gradually to the right after it has emerged from the tunnel.

Figure 4: Aerial photograph of the two lines at Merstham in 2007. The Redhill slow lines are on the right and the Quarry fast lines on the left (courtesy of Network Rail)

Geology

24 The site of the derailment is alongside or in line with the former trackbed of the Merstham and Godstone Railway which was subsequently acquired by the London and Brighton Railway for the construction of Hooley cutting in 1838. The line of the Merstham & Godstone Railway ran along the variable depth dry valley gravel beds of an ancient river. This gravel overlays weathered chalk on top of chalk rock. These gravel beds of up to 20 metres depth, meander through the existing line of the railway as may be seen from a photograph from 1947 (Figure 5). Their existence at the top of the cutting has historically posed a number of maintenance challenges for railway engineers up to the present day.

Figure 5: A rock fall on the down side of Hooley cutting during the snows of 1947. The variable depth of gravel can easily be seen on the left side of the cutting (courtesy of Network Rail)

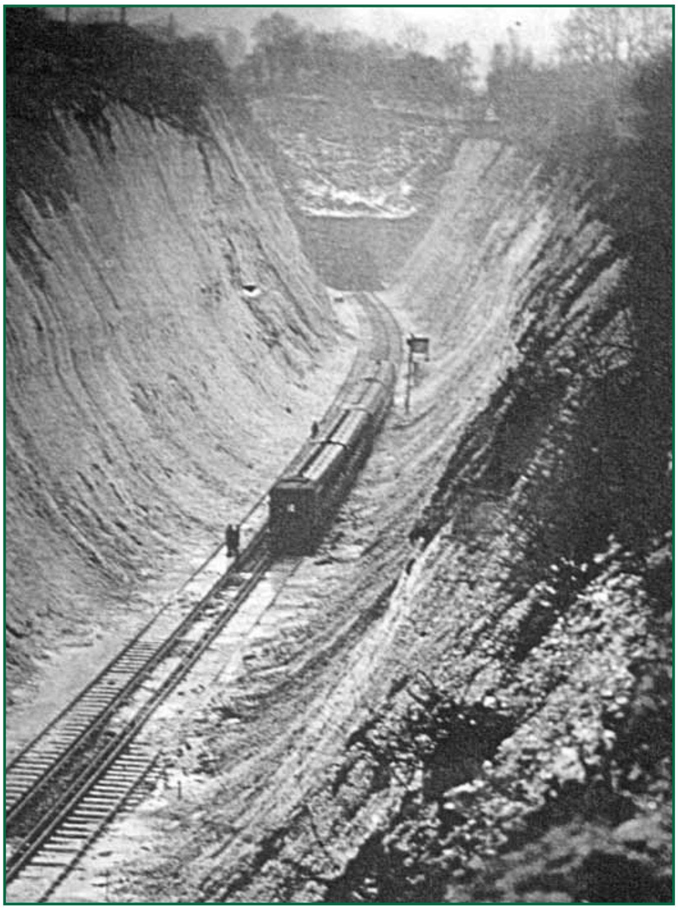


Figure 6: Photograph taken in 1947 showing a rock fall on the up side of Hooley cutting (courtesy of Network Rail)

25 In 1840 the cutting sides were constructed to an angle of approximately 53°. Since then weathering of the chalk faces, along with rock and debris falls has changed the profile substantially; in small localised places the sides can approach the vertical whilst the overall angle is now approximately 60°. Falls of chalk and gravel have been a feature of the cutting since its original construction.

26 The wet winter of 2000/1 caused an increased incidence of tree falls and chalk falls and resulted in parts of cutting being classified as a high risk site requiring urgent remedial work. Much of the work was undertaken during the winter of 2002/3 which was exceptionally wet.

Track and cess

27 The track comprises *flat bottom rail* held by *Pandrol clips* to depressed centre concrete *sleepers*. The *ballast* is granite. Drainage inspection manholes are situated between the up and down lines, in the *6 foot*.

28 The cess to the left of the up line is bounded by a king post wall which is formed of timber horizontals slotted into vertical steel I beams (Figure 7). The timber horizontals are not linked together. They are removable to permit clearance of rock and soil debris, and vegetation from behind them (see also paragraph 75).

Figure 7: Hooley cutting viewed from the site of the derailment looking towards the tunnel mouth.

Figure 8: Hooley cutting following the derailment showing the king post wall viewed looking towards London.

Figure 9: Hooley cutting showing the landslip

Signalling

29 The area is controlled from an *"NX" panel* at Three Bridges Area Signalling Centre (ASC). *Track circuit block* regulations apply throughout. The section leading up to the blockage is unusual in that a signal, T470, is located within Merstham tunnel (normally signals are not located in tunnels).

30 Alongside the track signalling cables are contained in concrete *troughing* which is in very good condition. This troughing provided a level walking surface for the passengers during the evacuation although it is not a recognised walking route.

Train

31 The train comprised two 4-coach units of class 377 stock built by Bombardier and introduced into service between 2001 and 2004; 377 426 was leading with 377 405 trailing. The first coach, number 73826, derailed and suffered the most damage.

32 The train was fitted with a Secheron *On-Train Data Recorder* (OTDR). This was downloaded at Selhurst depot and provided details of the train speed and the status of power and braking functions immediately before the collision (Figure 10).

33 The train was fitted with a *cab secure radio* (CSR) that permits the driver to talk to the signalling centre. The driver used this system to report the derailment.

34 The train was crewed by a driver and conductor. Two off duty members of staff were also on the train and assisted with managing the incident. No allegations were made that the design or condition of the train contributed to the occurrence of this incident.

Driver

35 The driver had been assessed in accordance with Southern's competence procedures on 9 August 2006. This had been followed by an off-line assessment of his driving technique by means of an OTDR download on 2 November 2006. The driver was reported as competent with no areas of concern. There was no history of safety concerns.

Events preceding the accident

36 At 11:50 hrs the driver joined train 1C23 at Horsham, relieving another driver who had driven the train from Bognor Regis.

37 Train 1C23 had an uneventful journey from Bognor to Horsham. Following a stop at Redhill the train commenced its diagrammed fast run to East Croydon via the Redhill lines with 413 passengers on board. The train speed increased to a maximum of 83 mph (132 km/h) inside Merstham tunnel, below the permitted line speed of 90 mph (144 km/h).

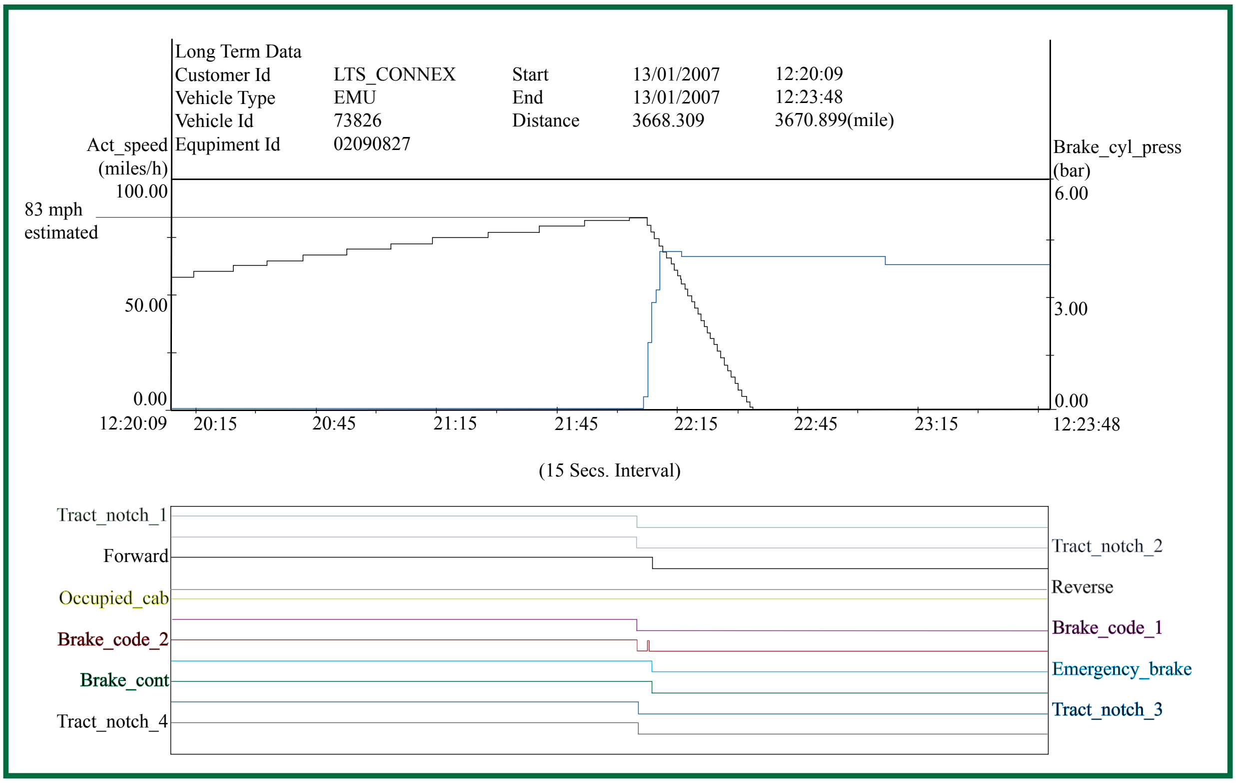


Figure 10: Output from the OTDR

38 Prior to train 1C23 emerging from the tunnel, a root ball from a previously felled tree (paragraphs 70 and 104) slipped down the cutting side approximately 100 m from the tunnel mouth. The root ball and ground material hit the king post wall, breaking the horizontal timber beams that formed the wall. Two of the beams were projected forward on to the up line (Figure 2), together with debris formed of gravel, clay, soil and small pieces of rock. The root ball was stopped from reaching the track by a vertical steel wall I beams. Most of the debris came to rest between the cess and the left hand rail (Figure 8).

External circumstances

39 The weather prior to the incident had been very wet causing saturation of the ground at the cutting *crest*.

40 Visibility at the time of the incident was good, allowing the driver of the train to see the obstruction as the train emerged from the tunnel.

41 There were no external distractions for the driver, such as approaching trains, or people working on the track. There were no internal distractions such as radio or cab-to-cab messages, or the presence of other personnel.

Events during the accident

42 As the train emerged from the tunnel the driver saw a substantial amount of debris lying in the train's path about 100 m from the tunnel portal. The driver immediately made an emergency brake application, and this reduced the speed to approximately 70 mph (117 km/h) before the train hit the debris.

Figure 11: Debris on the track following the derailment

Figure 12: Debris and rootball against the king post wall

43 The leading wheelset derailed to the left (cess) side of the line and continued to run on the sleeper tops outside the Pandrol clips. Various items of train equipment were either detached or damaged by the debris or rails. In the derailed state the leading end of the front bogie ran approximately 200 mm lower than normal.

44 As they travelled over the sleepers the derailed wheels generated a large dense white cloud of concrete dust that obscured visibility through the side widows of the coaches. The train passed T466 signal before coming to a stand alongside Forge Bridge.

Figure 13: Damage to the front bogie of the train

45 At 12:22 hrs, as the train came to a stand the driver made an emergency call on the CSR to *panel 3* on Three Bridges Area Signalling Centre to advise the signaller that the collision / derailment had occurred. He requested that the line be blocked after his train had hit a landslip.

46 The Panel 3 signaller immediately requested the panel 2 signaller to stop train 1C16, the 12:02 hrs Victoria to Fratton service, which was travelling in the opposite direction on the down Redhill line. The train was stopped at Coulsdon South.

47 The driver of train 1C23 then activated the *Drivers Reminder Appliance*, leaving the *Combined Power Brake Controller* in the emergency position. He then inspected his train and confirmed to the signaller that the train had derailed. He was aided by an off duty driver who had offered his assistance. The off-duty driver also assisted the conductor by walking through the train checking for passenger injuries.

Figure 14: The derailed bogie and side of the train

48 At 12:30 hrs, following a request from the panel 3 signaller, the Electrical Control Room Operator at Brighton confirmed that traction current had been discharged from both lines in the vicinity of the derailment. The driver then carried out emergency protection for his train by placing *track circuit clips* on the down line and applying the *short circuiting bar* on the up line.

49 At 12:53 hrs the driver of train 1C23 confirmed to the panel 3 signaller that there were no injuries on board the derailed train.

Consequences of the accident

50 There were no injuries to those on the train, although several passengers were concerned by the event.

51 Both slow lines (Figure 2) remained closed until start of traffic on Monday morning at 04:50 hrs. A 40 mph *emergency speed restriction* (ESR) was imposed on both the up and down Redhill lines. This was reviewed on 14 January 2007 during a site meeting; the 40 mph ESR subsequently remained in force for several weeks.

Events following the accident

52 The signaller called the emergency services at 12:28 hrs. The three emergency services (police, fire and ambulance) initially had difficulty in locating the site. At one time police viewed the railway from six overbridges trying to identify the location of the train.

53 After the arrival of the emergency services at 13:02 hrs, and their assessment of the situation, passengers were evacuated in small groups, commencing at 13:45 hrs. The passenger evacuation route comprised a long walk along the cess. The troughing route was in good condition with only one displaced lid; the position was pointed out to each group by fire brigade staff. The troughing provided a good walking surface especially for the elderly and children. The route from the railway line at Starr Bridge to the Brighton Road was difficult. It involved climbing several long and steep flights of unevenly spaced steps. A handrail was present along the whole flight. At road level passengers had to climb over a crash barrier to access the pavement.

54 The evacuation was completed without incident although several passengers did receive attention for temporary breathlessness. Buses were waiting to convey passengers for their onward journeys. All passenger luggage was left on the train.

55 Both units involved in the derailment were damaged. The flanges on the derailed wheelset were originally considered be unsuitable for travel by Southern's Selhurst Traction Maintenance Depot Production Engineer, Southern's Lovers Walk Breakdown Supervisor and the EWS Breakdown Supervisor and arrangements were made for a *skate* to be used. When attempts were made to fit the skate to the leading bogie it was found that it would not fit. The original decision to require the train to be moved using a skate was reviewed by the above mentioned individuals. They decided to permit the train to be hauled to Selhurst depot at a very slow speed (10 mph) with inspections of the wheelset at approximately every mile. A 5 mph speed limit was imposed over switches and crossings. The movement was achieved without incident.

56 Immediately after the derailment Network Rail surveyed the tree stumps on the cutting side. Stumps were categorised as high, medium and low risk (paragraph 92). Remedial work was undertaken on stumps that were considered to be an immediate risk. An ESR remained in place until all large and medium size stumps were removed.

The Investigation

Sources of evidence

57 Information used in the investigation was obtained from:

- site examination;
- examination of the train;
- witness statements;
- records of the history, geology and vegetation management of the cutting;
- survey, inspection and patrolling records;
- staff briefing and training processes;
- records of works previously undertaken on the cutting;
- design documentation for the king post wall and netting; and
- work undertaken following the derailment on the cutting.

Factual Information

History of the cutting

58 Ever since the cutting was dug in the 1830's there have been problems with slips of chalk or gravel. These have resulted in a number of trains striking debris, although no passenger train derailments were experienced until an incident in 2003 (paragraph 66).

59 Vegetation growth within the cutting was originally minimal, probably because it was effectively controlled by steam locomotives. On the chalk face tree seedlings would become unstable due to their poor footings and fall to the bottom of the slope where they either decayed naturally or were destroyed by sparks or steam from the locomotives.

60 Photographic evidence shows that when the line was electrified in 1932 the types of vegetation growth changed as there were fewer sparks to initiate burning of any groundcover. Shrubs and creepers in particular grew to a more mature stage and slowly began to cover the cutting sides; small trees began to grow at the bottom. To combat this growth, the Southern Railway introduced a programme of pruning and cutting of large bushes; an activity that was inherited by British Rail in 1947. Subsequently, financial stringency resulted in a year by year reduction of vegetation control activity. By the mid 1990's very little expenditure was authorised and no precautionary tree removal or pruning was being undertaken. The cumulative effect was to allow small saplings to grow into mature trees.

61 Under British Rail, to combat the effect of rock falls reaching the track, a wall was built on each side at the bottom of the cutting. It is believed that this was done in the early 1960's however no definitive records have been found to confirm this. The wall was constructed of old sleepers and retained by vertical lengths of *bullhead rail*. It remained in place until 2003 when it was replaced by the present king post wall.

Previous occurrences of a similar character

62 In the late 1990's concern was raised about the likelihood of land falls from the boundaries of railway property at the top of the cutting. These could potentially destabilise some domestic dwellings and outbuildings; a number were considered to be at risk of falling onto the railway. Garden boundaries had already been eroded and a number of garden sheds were cantilevered out from the private property or were supported by props from the cutting sides.

63 A preliminary report was produced in March 2001 for Railtrack Southern Region which included the results of a risk assessment and identified options for further investigation and possible remedial work. Railtrack opted for a solution that enabled a rapid mitigation of risk to the properties concerned. It was implemented during the period 2001 to 2003 to address the areas of highest risk (paragraphs 71 to 73).

64 At the end of December 2002, following a period of prolonged heavy rainfall, a series of landslips occurred on both the Redhill slow and Quarry lines. These resulted in a number of ESRs being imposed with watchmen placed to ensure that any further slips were reported promptly. Emergency works were undertaken that involved the removal of debris and the installation of the double link wire mesh fence along the area of the landslip.

65 On 31 December 2002 a further slip occurred on the down line which resulted in debris spilling over the cess side rail. Almost immediately a Bedford to Brighton Thameslink train ran into it and damaged a conductor shoe. The train was not derailed and was able to continue its journey after minor repairs had been made.

66 On 1 January 2003 a further landslip demolished the existing rail and sleeper wall and caused debris to spill over into the cess and on to the track. Before the watchmen could contact the signalman, train 2A35, the 10:56 hrs Brighton to Victoria service, ran into the blockage causing the leading wheelset to derail to the cess side of the up slow line. Two minor injuries were sustained by passengers during the subsequent evacuation. The site of that derailment was very close to the site that is the subject of this investigation.

67 There has been no recorded history of tree roots or stumps falling or sliding down cutting sides that have caused the derailment of a train, either at Hooley or elsewhere within Network Rail South East Territory. However, derailments and damage have been caused from time to time elsewhere on the network by fallen mature trees.

Stabilisation works of 2001 - 2003

68 The increasing incidence of landslips and tree falls during the winter of 2000/1 initiated a series of emergency stabilisation works to protect the railway, to stop land erosion from the crest of the cutting and to prevent damage to buildings on the Brighton Road that backed on to the railway. The highest risk site was identified as the up side cutting face (see Figure 2 for the areas at high risk to properties and land boundaries).

69 House owners with trees close to the crest boundary were visited. They were offered the opportunity for Network Rail to cut down the tree at no expense to the owner. A process existed that should the tree owner refuse the offer then legal letters would be sent clearly identifying the legal and financial risk that the owner was taking. No owners refused the offer. The up and down side cutting faces were cleared of trees but tree roots were mostly left in situ due to difficulties in their removal.

70 The up side cutting face was then subject to a detailed geological survey, with an emphasis of identifying the risk to adjacent properties. The consultant's report (Appendix E - Reference 1) identified that the typical 53° slope of the cutting at was significantly steeper than demanded by present day practices for this type of geology, namely 34°. Other documents held by Network Rail have assessed parts of the cutting to be inclined at 60°.

71 The consultant's report assessed areas of the cutting for risks to the garden and structures at the top of the cutting. It considered the effect of saturated ground conditions. The individual risk areas in the cutting were assessed as high, moderate or low (paragraph 92), however no definition of these rankings was included in the report. Subsequent risk assessment by Railtrack considered the risks of rock falls on to the railway.

72 A package of stabilisation works was developed that addressed the risks of landslips to the properties at the top of the cutting and for rock falls towards the railway. The means of controlling the risk to the railway was by using steel netting secured by ground anchors at the top and bottom of the cutting. The netting had a capability of withholding rock falls of 0.5 tonnes per linear metre.

Figure 15: Photograph showing the stabilisation works of 2001 - 3 (courtesy of Network Rail)

73 The area identified at highest risk lay between two road overbridges: Forge Bridge and Starr Bridge (Figure 2). Here a 500 mm reinforced concrete beam was installed at the top of the cutting. It was supported by a grid of concrete columns and beams supported by piles from the bottom and face of the cutting. A chain link catchment fence was installed at cess level along part of the route.

74 The majority of the cutting face between Merstham Tunnel and Forge Lane Bridge was assessed as low risk for the properties at the top of the cutting. Although it did not merit the concrete grid solution over the whole length, the concrete grid was installed for 180 m south of Forge Bridge. Steel netting was fixed over the whole cutting face between Forge Bridge and Merstham tunnel mouth. The containment wall at the bottom of the cutting was retained; it comprised old sleepers held in place by vertical lengths of bullhead rail. The derailment covered by this report occurred in this location.

75 By the end of 2002 the stabilisation works were substantially complete. Following the derailment in January 2003, emergency works were undertaken to remove all remaining trees that were in danger of falling on to the railway between Merstham tunnel mouth and Star bridge. A steel post and netting fence was installed at the foot of the concrete grid. From the end of the grid to the tunnel mouth a new king post wall was authorised; it was designed to have a load capability of 1 tonne with a *safety factor* of 2. None of the remaining records held by Network Rail detail why these load capabilities or safety factors were used, other than by reference to prior testimonial service at other undefined sites. It comprises vertical steel I beams, spaced at maximum centres of 2 metres and inserted into the ground to a minimum depth of 2 metres. Each of the six horizontal beams of the wall is treated timber, 300 mm by 150 mm. They are slotted into the steel I beams but are not otherwise retained; this allows them to be easily lifted out for the removal of accumulated debris.

76 A specialist contractor undertook the felling of trees; however the contract did not include for the removal of stumps which were left in situ. The contractor treated the tree stumps with *Timbrel* herbicide to prevent the growth of shoots, to speed the death of the stump and thus to initiate natural rotting. The contractor recommended that Railtrack continue to apply further treatments during the forthcoming growing season. No evidence was found that the follow up treatment was undertaken.

77 No risk assessments were undertaken by Railtrack concerning the breakthrough either of the netting or of the king post wall, or for falling tree stumps.

78 By the summer of 2003 a number of minor tasks remained to be completed adjacent to the up Redhill line between the Merstham Tunnel and Forge Bridge. These works included the reinforcement of netting seams and the installation of the new king post wall. All works were completed by the spring of 2004.

Track Patrols

79 Network Rail standard NR/SP/TRK/001 Inspection and Maintenance of Permanent Way requires cuttings & embankment slopes to be observed for material falls, cracking and signs of movement when large trees are present. These requirements apply to all Network Rail infrastructure.

80 The line in Hooley cutting is subject to a weekly patrolling regime. The patrol team walks along the *4 foot* of one line, closely inspecting the track and attending to any minor remedial work such as replacing Pandrol clips. They also observe the condition of the other line. The following week the other line is inspected and the first line observed. Thus each length of track is closely inspected every two weeks.

81 For a long time Hooley cutting has been recognised as a high risk area for landslips from the cutting side. Following the 2003 derailment, new patrolling instructions were issued to track patrol staff to look for signs of events or deterioration to the cutting faces, such as new rock falls or new debris at the foot of the cutting. Patrolling staff were additionally issued with specific guidance; 'Special Inspections in Adverse Weather', these being of credit card size that list features to be observed in adverse weather. (Although these cards were specifically issued for use in adverse weather, their guidance was used universally in all conditions). The patrol staff observe the cutting during their walk in the 4 foot. They have to look over the king post wall, which is approximately 1.8 m (6 ft) high, to identify any build up of material; however this is only done when signs of land slips are seen.

82 RAIB inspection of earthworks records showed that concerns were being regularly raised by patrol staff. For example, most recently there is a patrol record for a site within the cutting: *'Bank slip - netting is holding it but may cause problem to houses up bank. Reported to office 12/12/06'*. This was not in the vicinity of the fallen tree root that caused the derailment.

83 Faults and information such as the above are recorded on the Permanent Way Examination Report form which is forwarded to the section supervisor for entry into MIMS database. The slip mentioned above was entered on to the database on 21 December 2006, along with 5 other sites noticed by the patrol.

84 The section manager rang details of the cutting movement to the track maintenance engineer, who in turn reported the matter to the earthworks engineer. This initiated a site inspection by the earthworks engineer who inspected the site from the top of the spine between the Redhill and Quarry lines within the following seven days. The earthworks engineer did not find significant movement that merited further action.

Inspection and examination of the cutting

85 Network Rail standard NR/SP/CIV/065 Examination of Earthworks (formerly known as RT/CE/S/065) defines how earthworks and slopes are to be managed. The company standard was first issued in 2005. It details how examinations should be undertaken and how the results should be assessed. It does not specifically detail matters relating to the assessment of root balls.

86 Following privatisation, the lack of financial provision meant that no earthworks examinations were made within the Southern Region (now South East Territory) until a programme started in 2004. A large amount of work is involved; the first cycle of earthwork examinations are expected to be completed on the South East Territory by 2009. Examinations are then intended to proceed at the frequency specified in the standard. At the time of the derailment attention was focused upon sites with underlying clay and on sites that had not received any recent remedial works. No examination had been made of Hooley cutting since the stabilisation works of 2001-3.

87 Network Rail engineers were unaware of the number or details of root balls and stumps remaining in Hooley Cutting following the completion of remedial works in 2003.

Response to inclement weather

88 Following the 2003 derailment Network Rail reviewed its processes for the imposition of ESRs. Network Rail now operates an Earthworks Watch system that identifies periods of high risk over parts of the network. Rainfall and soil saturation forecasts are supplied by the Metrological Office. There are separate predictions for Wessex, Sussex and Kent for South East Territory. These are reviewed by the Territory Earthworks and Drainage Engineer who then has the authority to activate control and inspection measures. ESRs may be imposed as a result of this review.

Weather

89 Rainfall over south east England in the three months to January 2007 was recorded by the Metrological Office as being between 100 % to 175 % of the monthly long-term average. There was no rainfall on the day of the derailment, or the previous day.

The root ball

90 The root ball was estimated to weigh about 6 tonnes, this figure being obtained from Network Rail by using lifting indications on the crane that unloaded the root ball after recovery.

91 The central mass of the root ball had not begun to rot to any significant extent. There were several small suckers growing from one side of it, however most of the root ball mass appeared to be dead. There were very few small roots or tendrils present.

92 Subsequent to the derailment 14 high risk, 11 medium risk and 76 low risk stumps and root balls were found on both sides of the cutting. The risk ranking was as follows:

High risk:	Very large and large sized tree stump; stump movement (loose); dead stump; ground movement around stump.
Medium risk:	Large sized tree stump; ground movement around stump
Low risk:	Small to medium sized tree stump; ground movement around stump; located towards base of cutting.

The king post wall

93 The fall of the root ball was contained by the steel verticals forming the king post wall. The impact displaced some of the timber beams, several of which were buried under small amounts of debris. Two beams were thrown forward towards the track. These were found in a broken condition. It was not possible to determine whether they had been broken by the initial impact from the tree stump or subsequently by the impact from a train wheel.

94 One of the vertical steel I beams was displaced towards the track by the impact from the tree stump. It did not foul the *structure gauge* of the line.

Analysis

Identification of the immediate cause

95 The debris blocking the line comprised gravel, clay, small pieces of rock, and broken parts of several timber beams from the king post wall. Most of the debris lay between the cess and the left hand rail. Only a small amount of debris lay between the rails. The 6 tonne (estimated) root ball had been contained by the wall; no part of it infringed the line, nor were any of the vertical columns displaced sufficiently to hit the train (Figures 8 and 9). Apart from the timber beams no material was present that was sufficiently large to derail a train.

96 The immediate cause of the derailment was an obstruction on the left hand rail formed by displaced timbers from the king post wall.

Identification of causal and contributory factors

<u>Condition of the train</u>

97 No evidence has been found that indicate that the condition of the train affected the derailment (paragraph 34).

<u>Operation of the train</u>

98 The train was being driven correctly and in accordance with speed limits. The driver correctly made an emergency brake application when he observed the obstruction and this reduced the train speed by approximately 13 mph (21 km/h) before the train derailed (paragraph 16). The speed of the train was a contributory factor.

<u>Condition of the track and signalling</u>

99 No defects were found with any part of the track or signalling that could have any bearing on the accident.

<u>Climate and geology</u>

100 There are many historical reports relating to the Bourne Valley and the area between Merstham and Coulsden, detailing occurrences of saturation of the ground and its flooding potential. The winters of 2002/3 and 2006/7 were very wet winters; however no evidence has been found to indicate that the ground saturation during those periods was out of the ordinary. Thus it has not been possible to identify any clear and directly attributable effect of climate change with regard to this accident.

101 There was exceptionally wet weather over south east England during the previous three months (paragraph 89). The normal geophysical behaviour of the ground water from the surrounding area would be for it to flow into the gravels of the prehistoric dry valley which would then become saturated. The water would then permeate along the valley bed until it emerged from the cutting side at the fault line between the gravels and the underlying chalk causing a reduction of cohesion of the gravel and reducing the grip on the root ball (paragraphs 24 - 26). Whilst no specific tests have been undertaken to validate that this process did occur just prior to the derailment, no evidence has been found that any other mechanism caused the bank slip. The process is consistent with that contained in the consultants report prior to the 2003 remedial works (Appendix E - Reference 1) and with published data held by the British Geological Survey. High rainfall was a contributory factor.

102 The saturation of the gravels caused the materials forming the cutting side to reduce its stability, cohesion and load bearing ability. It is probable that had the root ball not been present then only minimal erosion of the surface would have occurred. Examination of the debris showed that apart from the root ball and broken timbers from the king post wall relatively little other material had fallen (Figure 8). The loss of cohesion of the materials forming the cutting side was a contributory factor.

103 The Earthworks Watch system is an intrinsic part of the management of the operational railway within South East Territory. Advice about adverse weather conditions has been integrated into pre-planned mitigation measures that include additional observations of critical earthworks and the imposition of ESRs on high risk parts of the railway. The means by which this information is received and reviewed by senior managers is adequately defined. No evidence has been found that this process is not functioning adequately.

<u>The root ball</u>

104 The root ball came from a tree which had been felled sometime between 2001 and 2003. No records exist to determine the exact date although it is probable that it was felled in 2003 when most of the larger trees received attention. By 2007 the root ball had only rotted to a small extent. There were some small suckers growing from it indicating that it had not completely died. Most of the small roots that would have provided stability within the cutting side were missing (Figure 8).

105 The existence of the root ball on the cutting side stems from a decision made during the project works of 2001 – 3 (paragraph 68). A number of other tree roots were left in the side of the cutting. No records were kept of the number, species, size, condition or location of the remaining roots, either on the crest or sides of the cutting. After the derailment a survey identified those that existed (paragraph 92).

106 The removal of root balls is difficult due to the depth and steepness of the cutting sides and the limited access at the top. There was a general belief within Network Rail that a root ball would rot safely to material of small size and of low strength within a period of about six to eight years. The source of this information has been difficult to trace however it is used by commercial forestry as a guideline for the period until ground is substantially free from root balls. A decision was thus adopted by the stabilisation project to leave the root balls in position. The decision to leave root balls in situ on the cutting side was a causal factor.

107 The steepness of Hooley cutting imposes substantially different conditions to those of flat land or a gentle slope. On flat land the early loss of the small extremity roots will do little to reduce the stability and retention of the root in the ground; gravity will hold it in place. On a slope the retention capability of the roots begins to play a more important role as the mass of the root ball generates a force attempting to pull it from the ground. Much of the necessary retention force is provided by the large number of smaller roots. As the slope becomes steeper the retention force needed also becomes greater. No analysis was undertaken to consider the hazards that might occur if root balls were left in situ. The hazard was not recognised by the project team in 2001 – 3, or subsequently, by Network Rail asset engineers. The RAIB investigation found no other records of falling root balls causing damage to a train or a derailment. The lack of understanding about the risks presented from retained root balls on slopes was a causal factor.

108 The mass of the root ball (paragraph 90) played a significant role in the damage that it caused to the king post wall. Had it been of lower mass then it may not have broken though the wall. The mass of the root ball was a causal factor.

Stump treatment by herbicide

109 The works of 2000 included the felling of mature trees and the treatment of the stumps with a herbicide called Timbrel. The contractor advised that to be totally effective a cyclical programme of several applications should be applied over the growing season (paragraph 76). This was beyond the project to undertake and the Network Rail earthworks engineer was advised regarding this. No evidence has been found that further Timbrel was applied.

110 It has not been possible to determine whether further applications of the chemical would have changed the outcome; however, the appearance of the root ball was that it was substantially dead with just a few suckers growing from one place (paragraph 104). The original application of Timbrel thus appears to have killed the majority of the root as intended and rotting was taking place. It has thus been concluded that the lack of further applications of Timbrel played no part in the accident.

Design of the king post wall and netting

111 Documentation held by Network Rail relates to both the design of the wall and the netting. The netting was part of the original stabilisation works of 2001 – 3. It adopted a material specification that had been used successfully elsewhere by the contractor, although the locations are not detailed in surviving documentation. The containment value of 0.5 tonnes/m was accepted by the Network Rail approval process (paragraph 72). No evidence has been found that would suggest that the design was inadequate for its intended purpose, nor have other sites using similar design criteria been reported to South East Territory as performing inadequately, or of having failed prematurely. The figure used is more than adequate to cope with the amount of landslip historically experienced and expected. The slip of the root ball imposed loadings on the netting far higher than the design was intended to contain. The performance of the netting was not a contributory factor.

112 The king post wall was not originally going to be replaced. It was only decided to do so following the derailment in January 2003. The wall was designed by contractors. Full details of the design are not currently held by Network Rail. Several subsidiary documents detail the design capability that was adopted i.e. 1 tonne loading using a factor of safety of 2 (paragraph 75). This was more than adequate for its purpose of containing gravel and small rock falls from the cutting side as evidenced from the lack of problems with similar walls. Given the performance of the wall under impact from the 6 tonne root ball, and its performance for arresting other rock falls, the design has shown itself to be adequate. The performance of the king post wall in relation to its design criteria was not a contributory factor.

113 No documentation was found that relates to any operational risk assessment for the break-through of the netting or king post wall (paragraph 107).

114 With any earthworks design it is recognised that it is only practical to address the expected duty and to include an appropriate factor of safety. The decision on what the expected duty may be is a matter addressed by the designer through experience and by reference to applicable codes of practice and testimonial performance from elsewhere. The generation of the type of earthworks specification for Hooley cutting remedial works is not a perfect process that could eliminate all possible risks. Consequently the documentation for both the netting and the wall recognised that a bank slip might occur that could exceed the design loading. The adopted specification was expected to address the all the risks from falls that existed in the cutting; however, neither the design for the netting nor that of the wall appears to have considered the possibility of root ball falls.

115 Some other sites on Network Rail are subject to repeated rock falls. Some of these sites are fitted with detection systems that can provide either a warning to the signaller or the driver. One type operates by a mechanical trip wire that operates an alarm in the signalling centre; another type causes a warning signal to be displayed directly to an approaching train when a tensioned wire is displaced or broken.

116 The fitment of such a system to the king post wall in Hooley cutting may have prevented the derailment if the fall of the root ball had occurred before the train reached signal T470. No information exists to identify precisely when the root ball fell. The lack of a warning system is thus a contributory factor.

Reporting lines

117 For Hooley cutting, sufficient documentary evidence exists to show that the reporting lines between patrol staff, the section supervisors and the earthworks engineer functions adequately. The process is mandated by a local instruction.

Earthworks inspections and examinations

118 South East Territory activities do take account of risk arising from both inside and outside the railway boundary. There is specific evidence about the latter in the files of the 2000/1 Stabilisation Works where house owners with trees close to the crest boundary had them removed at no expense to the owner.

Identification of underlying causes

119 Network Rail company standard NR/SP/CIV/065 'Examination of Earthworks' details how inspections should be carried out. At the time of the derailment it did not completely address the particular conditions of Hooley Cutting; there is reference to movement of rock and unstable trees, but nothing about hazards from root balls. NR/SP/TRK0521 'Management of Lineside Vegetation' addresses the issues of trees and bushes that grow alongside the railway line, but not the management of retained root balls.

120 NR/SP/CIV/065 also excludes issues relating to complex geology such as exists at Hooley cutting, where the valley gravels meander across the existing railway alignment at variable depths. The lack of guidance in Network Rail company standards regarding retained root balls on cutting sides, particularly in an area of complex geology is an underlying cause.

121 The backlog of examination work inherited from Railtrack has meant that knowledge about the current state of earthworks throughout Network Rail South East Territory is not complete with regard to the requirements of NR/SP/CIV/065. Following the 2001 consultants report (Appendix E - Reference 1) and the subsequent 2003 remedial works the knowledge about Hooley cutting was considered by the South East Territory Safety Review Panel and earthworks engineer to be adequate. Consequently the concentration on examining other high risk sites or those with little documentation was an appropriate approach for Southern Territory given the professional knowledge available. The inherited backlog of examinations is an underlying cause.

Severity of consequences

122 The capability of the king post wall prevented the root ball from reaching the up line and thus prevented the train from suffering more serious damage. Had the root ball or debris travelled further then the consequences could well have been more severe.

Other factors for consideration

123 Elderly passengers and children found it difficult to climb the flights of steps after their long walk along the cess. It took a considerable time to evacuate all the passengers. Evacuation to a parallel train may have been an easier option if appropriate procedures and equipment had been available. A train was available nearby at Coulsdon South down platform. Although the recharging of traction current would have needed careful management to ensure that everyone was in a safe place, a train-to-train transfer may have been easier and quicker than the evacuation strategy that was implemented. Train-to-train transfer using a suitable ramp to bridge the gap between the trains might have been easier to manage.

124 By design the CSR switched off a short time after the loss of traction current. This is a design feature to ensure that radio frequencies do not become congested with long conversations. Under emergency conditions the driver is able to make further calls. This feature did not cause any communications difficulties because the driver was able to use a mobile phone. Had the derailment occurred elsewhere with poor or no reception, and with no adjacent signal post telephone, then the incident would have been more difficult to manage.

125 Immediately after the derailment there was a lot of confusion by emergency services over where the incident had occurred. This was due to the lack of information from Network Rail in a form relevant to the emergency services. The information was in the form of mileage along the railway and the description of the up Redhill line, rather than by the grid reference of the access point. The confusion was exacerbated by the closely parallel route of the Quarry Line.

Conclusions

Immediate cause

126 The immediate cause of the derailment was an obstruction on the track formed by timbers from the king post wall displaced by the fall of a 6 tonne root ball from the cutting side (paragraph 95).

Causal factors

127 Causal factors were:

a. the lack of understanding about the risks presented from retained root balls and complex geology (paragraph 107 and Recommendation 2);

b. the decision to leave root balls in situ on the cutting side after tree felling (paragraph 77 and Recommendation 3);

c. the mass of the root ball that fell (paragraph 108 and Recommendation 3).

Contributory factors

128 The following factors were considered to be contributory:

a. above average rainfall over the south east of England prior to the derailment (paragraph 89 and Recommendation 4);

b. the loss of cohesion of the materials forming the cutting side (paragraph 81 and Recommendation 4);

c. the lack of a warning system (paragraph 115 and Recommendation 6);

d. the speed of the train (paragraph 98, no recommendation).

Underlying causes

129 The underlying causes were:

a. the lack of guidance in NR/SP/CIV/065 'Examination of Earthworks', NR/SP/TRK05201 'Management of Lineside Vegetation' or other Network Rail company standards regarding root balls (paragraph 119 and Recommendations 1 and 5);

b. the backlog of earthworks examinations inherited by Network Rail (paragraph 59 and 86, No recommendation).

Additional observations

130 The following observations are made as a result of the investigation:

a. During the investigation it became evident that a common process for reporting earth movements did not exist throughout all Network Rail Territories. This had no bearing on the derailment at Hooley Cutting (paragraph 117 and Recommendation 7).

b. The (credit card size) guidance 'Special Inspections in Adverse Weather' provides a useful aide memoire for track inspection and patrolling staff. Its application could usefully be extended to any observation of earthworks (paragraph 81 and Recommendation 8).

c. The emergency services did have difficulty in establishing the location of the derailment. This did not have any effects on the evacuation from Hooley Cutting other than a short delay. However in other circumstances, the delay might have had more serious consequences. Control and management locations, such as signalling centres could usefully hold details of the access locations, including the Ordinance Survey grid reference for each section of track along with information for the emergency services to use during train evacuation (paragraphs 52, 125 and Recommendation 9).

d. The means of passenger evacuation was by the commonly used method of walking them in small groups to the nearest access gate. Whilst this method might be appropriate for many locations, the difficulties of climbing the long, steep and uneven steps to the access gate at Hooley Cutting were stressful to some of the passengers and required several of them to receive medical checks for breathlessness and pulse prior to their onward journey. The use of train-to-train evacuation using a pre-planned process might have provided less hazardous conditions (paragraph 123 and Recommendation 10).

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

131 Network Rail are carrying out the following actions:

- review of cuttings and embankments that may be affected by extreme weather conditions, with details and mitigation measures circulated to the route directors and infrastructure maintenance managers;
- review and amendment of Control Manual C22 to ensure that all Control Offices have a complete list of high risk areas which could be affected by adverse weather conditions;
- survey of all cuttings which have undergone tree clearance in the last ten years;
- review of above locations to confirm that risks associated with tree stumps has been suitably addressed;
- undertaking a full assessment on Hooley Cutting;
- undertaking to a full assessment of the Redhill and Quarry lines and to produce a mitigation plan to address any further earthworks movement;
- review and amendment of NR/SP/CIV/065 to include cuttings that are made of more than one material and to mandate that such cuttings are fully assessed from *toe* to crest;
- review and amendment of NR/SP/TRK/001 to formalise the process for reporting earthworks movement which do not immediately affect the safe running of trains;
- review of all locations within the network to provide grid references for access gates in the Signalbox and Control emergency plans;
- installation of equipment in Hooley cutting to monitor rain fall and soil movement, and to provide real time camera monitoring, has been completed;
- production of a guidance note for the felling of trees on cuttings and embankments with actions to be taken for root balls.

Recommendations

132 The following safety recommendations are made[1]:

Recommendations to address causal and contributory factors

1 Network Rail should review the content of the appropriate Company Standards including NR/SP/CIV/065 and NR/SP/TRK/05201 so that they are sufficiently comprehensive to manage the risks from root balls on, or adjacent to, their infrastructure (paragraph 129a).

2 Network Rail should review the guidance it provides on felling of trees on embankments and cuttings. This guidance should include the criteria and actions to be taken on the retention of root balls and stumps (paragraph 127a).

3 Network Rail should inspect or assess all cuttings of a depth where falling root balls or stumps could pose a risk to the operational infrastructure. Root balls or stumps posing high risk should be removed or otherwise stabilised within a defined time scale (paragraphs 127b and 127c).

4 Network Rail should develop a list of civil engineering assets that may be susceptible to severe weather conditions or rapid natural deterioration and should develop plans for mitigating the effects on the operational railway (paragraphs 128a and 128b).

5 Network Rail should periodically implement a process to assess Hooley Cutting for the risk posed to the operational infrastructure by any remaining tree roots and stumps. Such assessments should also include the stability of the cutting at the crest (paragraph 129a).

6 Network Rail should assess the practicability of installing a system to warn of the displacement of material or collapse of the king post wall in Hooley Cutting. If reasonably practicable it should do so (paragraph 128c and 131).

continued

[1] Duty holders, 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 ORR (HMRI) to enable them to carry out their duties under regulation 12(2) to:

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

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

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

Recommendations to address other matters observed during the investigation

7 Network Rail should issue the (credit card size) 'Special Inspections in Adverse Weather' to all track inspection personnel and widen its scope to cover any observation of earthworks (paragraph 130b).

8 Network Rail, in connection with Southern, should ensure that access locations for relevant parts of the network are held at control rooms, and if appropriate, at signal boxes and manned stations. It should include street references, postcodes, grid references etc, as appropriate, along with information on any difficulties of use by emergency services and for passenger evacuation (paragraph 130c).

9 In the light of the evacuation from Hooley cutting Network Rail, in conjunction with Southern should review the evacuation strategies from deep cuttings, high embankments, and other difficult areas across the network. In doing so they should consider the practicality of passenger evacuation by a train on the adjacent track (paragraph 130d).

Appendices

Glossary of abbreviations and acronyms — Appendix A

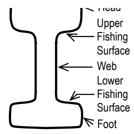
CSR	Cab Secure Radio
ESR	Emergency Speed Restriction
EWS	English, Welsh and Scottish Railway
MIMS	Mincom Information Management System.
OTDR	On Train Data Recorder

Glossary of terms

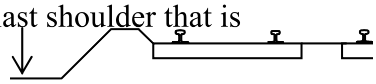
Appendix B

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

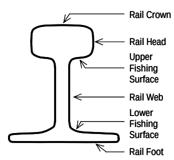
4 foot	The area between the two running rails.*
6 foot	The space between two adjacent tracks, irrespective of the distance involved.*
ballast	Crushed stone, nominally 48 mm in size and of a prescribed angularity, used to support sleepers both vertically and laterally. The stone used is generally Granite, but Limestone has been employed.*
bogie	A metal frame equipped with two wheelsets and able to rotate freely in plan, used in pairs under rail vehicles to improve ride quality and better distribute forces to the track.*
bullhead rail	The former standard rail section in Britain, not normally laid in as new. The rail has a rail head and rail foot that are similarly shaped.*



cab secure radio	A radio system provided to allow signaller and train driver to communicate safety critical information as securely as if they were speaking on a land line.*
cess	The part of the track bed outside the ballast shoulder that is deliberately maintained lower than the sleeper bottom to aid drainage.*



combined power-brake controller	A train controller that combines power and braking functions on one control handle.
crest (of cutting)	The top of a cutting or embankment slope.*
down (line)	A track on which the normal direction of trains is away from London.
driver's reminder appliance	A device in the driving cab of a train that allows the driver to set a reminder when brought to a stand at a signal showing a stop aspect. When set, the driver's reminder appliance prevents the driver applying power and moving off.*
emergency brake	The application of all train braking effort.
emergency speed restriction	A speed restriction imposed for a short time, at short notice, generally for safety reasons.
flat bottom rail	A rail section having a flat based rail foot or flange.*



king post wall	A wall comprising vertical posts that retain horizontal beams in place.
multiple unit	A train consisting of one or more vehicles (semi-permanently coupled together) with a driving cab at both ends. Some or all the vehicles may be equipped with powered axles.*

NX panel	A signal box control panel that allows a signaller to set a route by pressing buttons corresponding to the beginning and end points.
on-train data recorder	A data recorder fitted to a train that records information on the status of train equipment, including speed and brake applications.
Pandrol clips	A rail clip for flat bottom rail manufactured by the Pandrol company.
panel 3	One of the signaller's panels in Three Bridges Area Signalling Centre that controls the signalling between Merstham and Coulsdon South.
root ball	The large and small roots, the attached earth and the remaining part of the trunk of a felled tree.
safety factor	An additional design allowance above that needed for normal usage.
short circuiting bar	An electrically conductive metal bar that is placed by hand between the running rail and conductor rail using an insulated handle. It will either cause the electrical supply to be automatically disconnected or it will reduce the electrical potential locally to a safe level.
(wheel) skate	A device that raises a wheelset slightly above the rails which allows the train to be moved without the wheelset rotating. A wheeled device reminiscent of a skateboard, used to lift a damaged rail wheel clear of the rail, in turn allowing the vehicle to be moved (slowly) to a place of repair.*
sleeper	A beam made of wood, concrete or steel placed at regular intervals at right angles under the rails. Their purpose is to support the rails and to ensure that the correct gauge is maintained between them.*
structure gauge	The minimum dimensions relative to the track to which any structure must conform.*
Timbrel	A commercially available herbicide authorised for use on railway land by Network Rail. It is intended to prevent further growth of felled saplings and trees.
toe (of cutting)	The bottom of a cutting or embankment slope.
track bond	An electrical cable connecting tow pieces of rail.
track circuit block	A signalling system which operates by automatically detecting the absence of a train by electrical circuits through the track.
track circuit (operating) clip	A pair of spring clips connected by a wire, used to short out a track circuits by connection across the rails in times of emergency.*
troughing	Pre-cast concrete units comprising a U shaped base with a separate lid which laid in the cess and contain lineside cables.
up (line)	A track on which the normal direction of trains is towards London.
wheelset	Two rail wheels mounted on their joining axle.

Key standards current at the time — Appendix C

Documents directly referenced in this report are marked with an asterisk, thus (*).

NR/SP/TRK/001*	Inspection and Maintenance of Permanent Way
NR/SP/CIV/032	Managing Existing Structures
NR/SP/CIV/065*	Examination of Earthworks
NR/SP/CIV/086	Management of Existing Earthworks
RT/LS/S/021	Weather – Managing Operational Risk
TIH	Track Inspection Handbook

Damage sustained to train — Appendix D

The following only lists the main items that were damaged:

73826 (Leading coach)	Lower valances at front Shoe gear and fuse boxes Paint finish on bodywork Underfloor equipment cases Whistle and horns Electrical cables Guard irons Wheelsets, axles, axle boxes and gear cases Traction motor Bogie guard irons Air piping and cocks Brake equipment and brake discs
78626	Paint finish on bodywork End bodywork panel Axles and axle box with impact marks Damper brackets Electrical burning on bogie frame Air piping and cocks Air reservoirs Brake equipment
78826	Paint finish on bodywork Axle Traction motor and speed sensors Air reservoirs
73426	Paint finish on bodywork Axles and axle box Shoe fuse box Gangway wearing plate

References Appendix E

1. Preliminary Assessment of Cutting Stability at Hooley, Surrey for Railtrack Southern. Report No Ra-0106. Produced by John H. Chapman, Consulting Engineering Geologist, March 2001.

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