Rail Accident Investigation Branch

Rail Accident Report

Derailment of a freight train at Cricklewood Curve 31 January 2006

Department for Transport

Report 02/2007
January 2007

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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Contents

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, AMCO and EWS to their staff, data and records in connection with the investigation.

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

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

Summary of the report

Key facts about the accident

5 On 31 January 2006 at 02:25 hrs a freight train was traversing the Cricklewood Curve in North London on its way from St. Pancras to Acton Yard. The linespeed on this part of the curve is 10 mph (16 km/h) and the train was travelling at 7.5 mph (12 km/h) when two of the wagons derailed.

6 The derailed wagons overturned and started to slide down the embankment but were held by the couplings between them and the remainder of the train.

7 One of the wagons was loaded with aggregate which discharged from the wagon down the bank. The other derailed wagon was empty. There were residential flats at the foot of the embankment, the residents of which were evacuated by the police as a precaution in case the derailed wagons moved further down the bank.

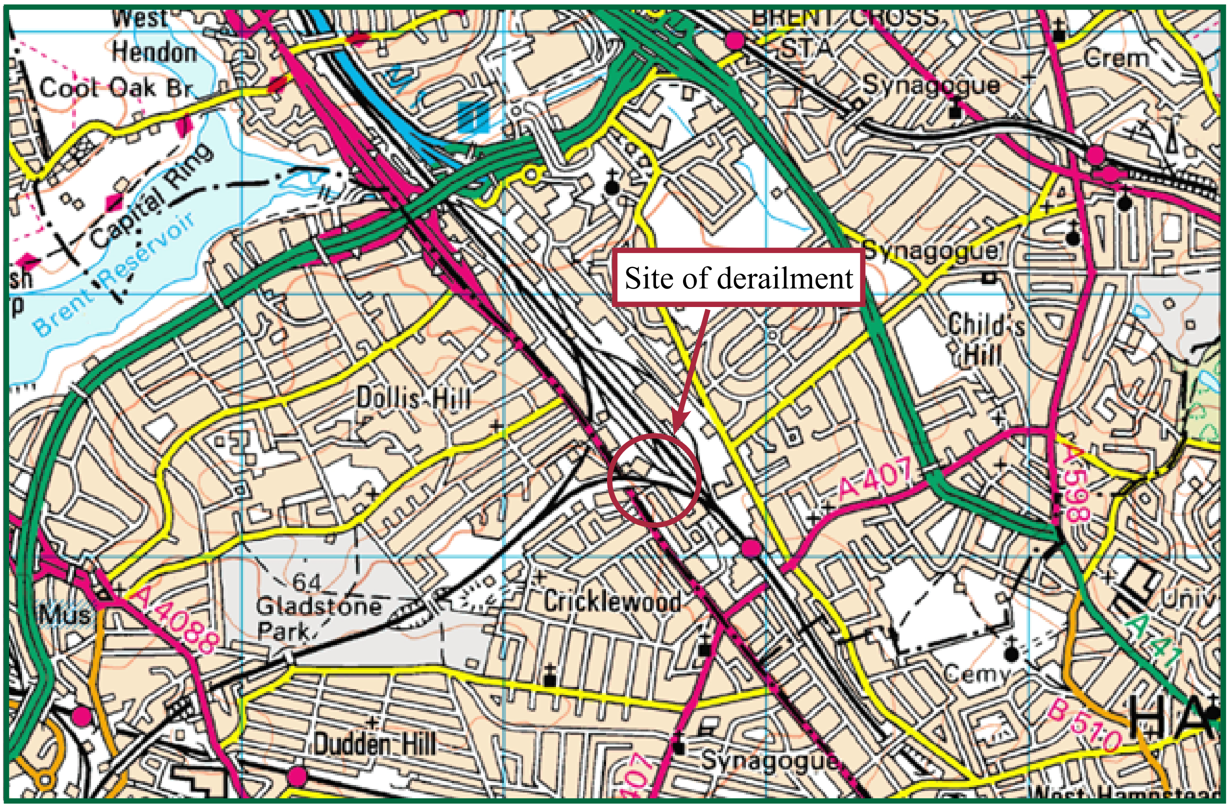

Figure 1: Extract from Ordance Survey map showing location of accident.

Conclusions

8 The derailment was caused by severe track *twist* brought about by movement of the embankment at the site of embankment repair works.

9 Prior embankment movement had been taking place for a number of years and was the reason why the repairs were being undertaken.

10 The embankment movement was mainly in the surface layers of the soil and had the effect of increasing the *cant* of the track. The track maintenance staff had not appreciated the severity of the movement before the derailment and did not carry out remedial works to correct the irregularities. The repair contractor was monitoring the cant of the track but was not monitoring track twist and so did not notice the hazard to trains.

11 The designer's risk assessment identified that the greatest risk during construction of the works was movement of the embankment leading to derailment of a train. The risk control measures were to excavate the bank in short lengths, work from the top down and monitor the embankment for movement during the repair works. This risk assessment was not fully considered by the Network Rail staff involved in planning the work.

Recommendations

12 Recommendations can be found in paragraph 105. They relate to the following areas:

- communication of information regarding a Network Rail asset to contractors repairing that asset;
- communications within Network Rail between different departments;
- time limits for fixing track defects specified in Network Rail business process document;
- consistency between Network Rail business process documents;
- training and competency of staff involved with minor works projects;
- ensuring that a project is overseen by a *competent person* through all stages from recognition of need to construction.

The Accident

Summary of the accident

13 On 31 January 2006 a freight train operated by EWS was conveying aggregates from Angerstein Wharf, in South London, to various locations in the London area. The train had called at St. Pancras to unload some of the wagons and departed there at 01:56 hrs as train 7O90. The train consisted of 18 bogie hopper wagons of types JHA and HLA. From the front, the train consisted of a class 59 locomotive, 5 empty wagons, 3 loaded wagons and 10 more empty wagons. The loaded wagons were filled with construction aggregates and were each loaded to a *gross laden weight* of 101.66 tonnes.

14 As the train traversed the Cricklewood Curve between Cricklewood Junction and Dudding Hill Junction (figure 1) at 7.5 mph (12 km/h) the last of the three loaded wagons and the first of the following unloaded wagons became derailed and overturned. The wagons were on an embankment at the time and the derailed wagons slid down the bank until arrested by the couplings to the rest of the train. The couplings remained intact throughout the train, though the brake pipes were parted. The loss of *brake continuity* caused the train to stop.

15 The derailment occurred adjacent to the site of embankment repair works that were underway at the time.

16 Nobody was injured in the incident.

Background

17 The Cricklewood Curve runs between Cricklewood Junction, close to Cricklewood Station, and Dudding Hill Junction where it joins another curve off the Midland Main Line from the north. This line runs westwards from Dudding Hill junction to Acton in west London and interconnects some of the lines radiating from London termini. It is only used by freight trains and occasional empty passenger trains. The Cricklewood Curve is owned and operated by Network Rail and, at the point of the derailment, is part of the London North Eastern Territory.

18 The line runs on embankment through most of its length, crossing over the A5 road by means of a bridge. During the Second World War air raid shelters were constructed within the embankment at several locations, mainly to the west of the A5, though some were built on the east side of the A5 bridge. Some of these shelters have deteriorated and started to collapse, leading to problems with embankment stability and loss of track alignment, though there were no shelters in the bank at the immediate site of the derailment.

19 The embankment at the site of the derailment was constructed of ash fill on a clay core placed directly on the London Clay subsoil. The embankment had started to slip 10 years ago leading to a loss of vertical track alignment on the down line (the down direction here is from Cricklewood Junction towards Dudding Hill Junction). The movements of the bank were slow and the track maintenance staff were able to keep the line safe by regularly *packing* or *tamping* the track.

20 The poor alignment of the track, both at the site of the slip and beyond the A5 bridge, led to a 10 mph (16 km/h) permanent speed restriction being imposed over this section of line. The linespeed of the curve before this change of speed restriction was 20 mph (32 km/h).

21 Repair works were proposed to be carried out on the embankment with the intention of repairing the bank slip and infilling some of the redundant air raid shelters nearby (paragraph 28). The works also included the removal of the existing topsoil from the bank, which was contaminated by Japanese Knotweed and its replacement with clean new material. The bank slope would be re-graded to a less steep angle by these repair works, requiring the installation of *gabions* at the foot of the bank to retain the fill.

22 The repair works had been contracted by Network Rail, major projects and investment (MP&I) to Amalgamated Construction Ltd (AMCO Rail).

Events preceding the accident

23 The relevant section of the Cricklewood Curve was part of the East Midlands maintenance contract area until February 2004. In February 2004 Network Rail took the maintenance of this area 'in house' and managed it as part of the Midlands zone. This arrangement was short lived as the East Midlands area transferred to London North Eastern Territory (LNET) in a reorganisation on 24 May 2004. Figure 2 shows a simplified organisation chart.

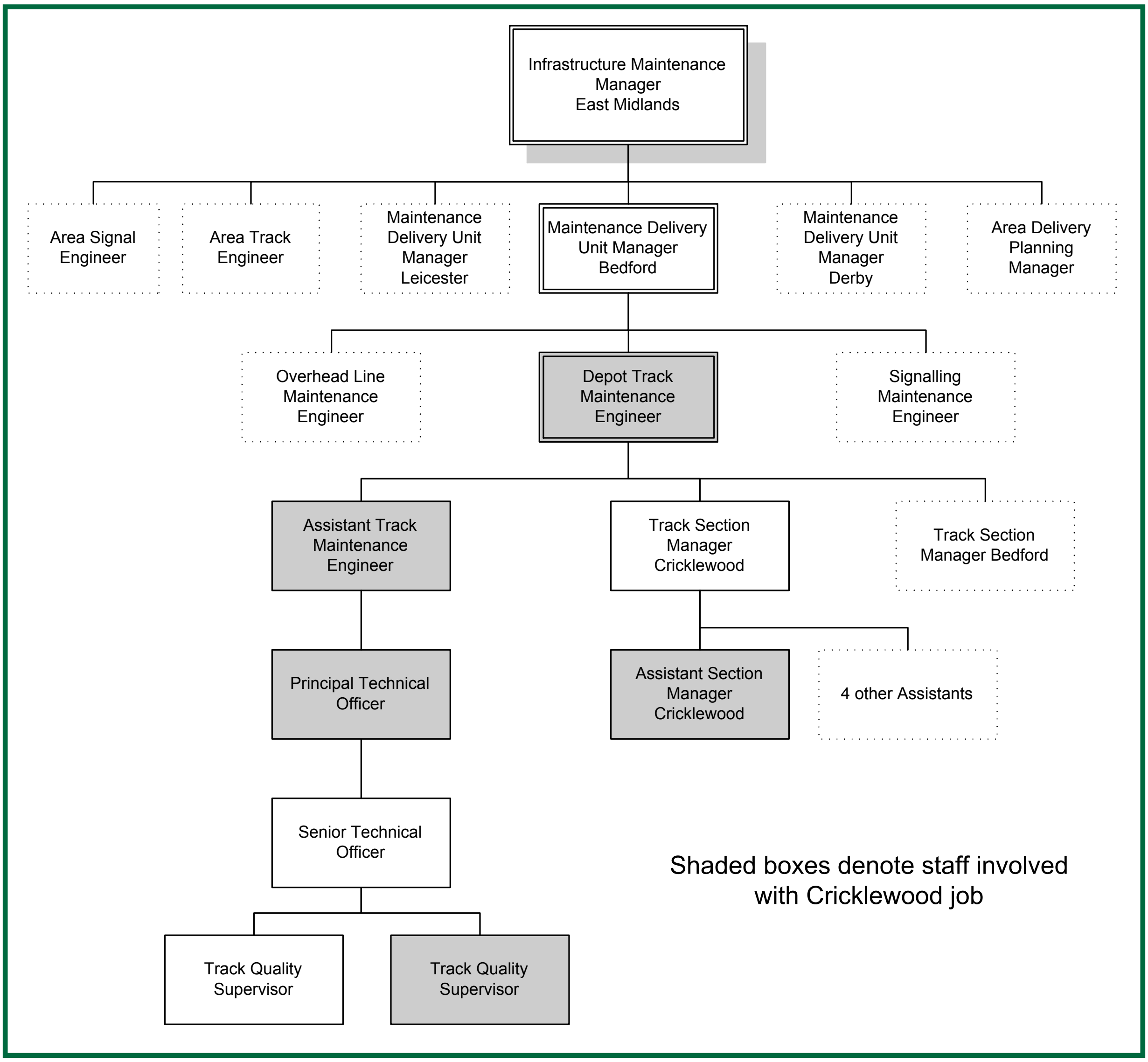

Figure 2: Simplified organisation chart for East Midlands Area.

24 LNET has its headquarters at York and is organised on functional lines. The civil engineering function is headed by a territory civil engineer. He has a number of posts reporting to him, one of which is the territory earthworks and drainage engineer. The territory earthworks and drainage engineer has three engineers reporting to him. They form a small team responsible for the management of earthworks on LNET. A simplified organisation chart is given in Figure 3.

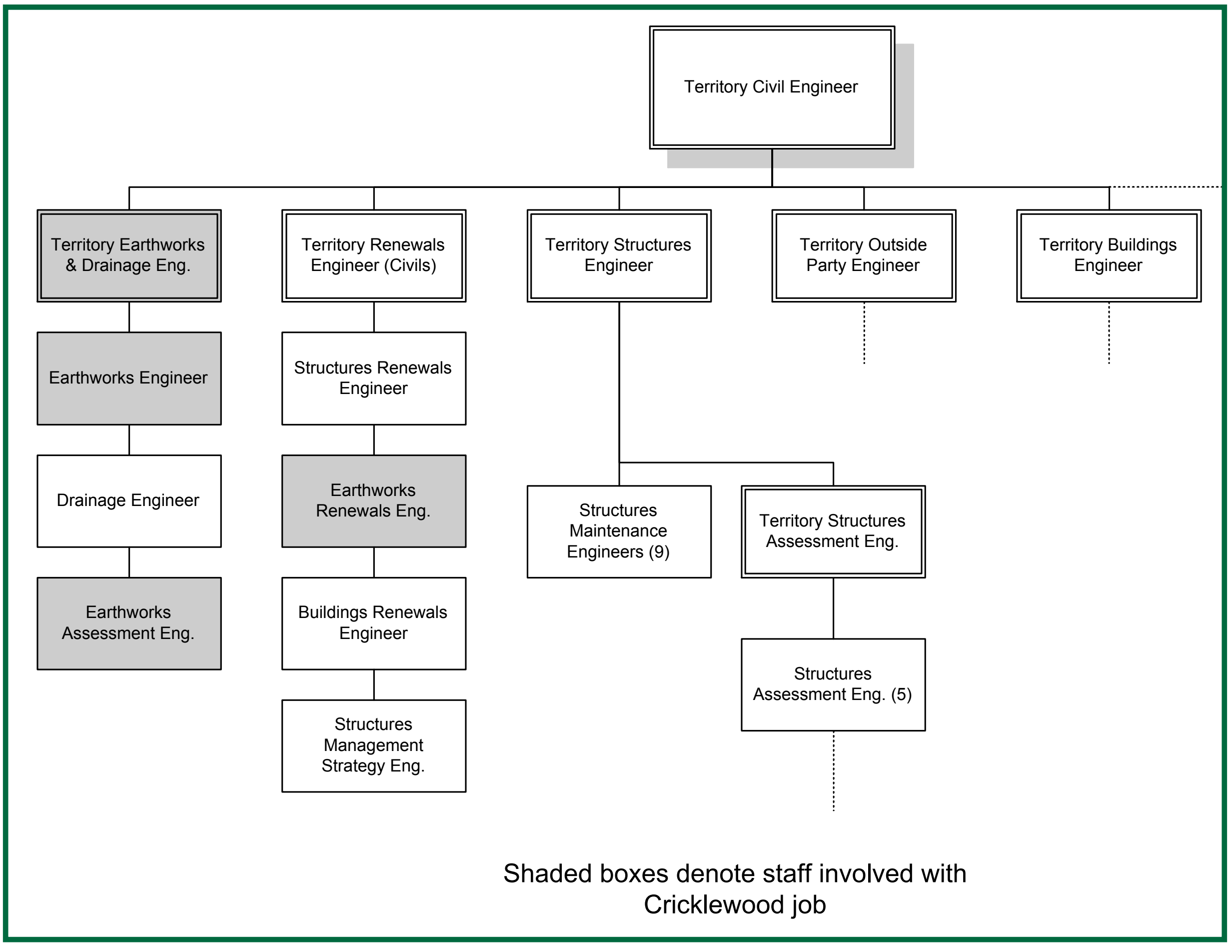

Figure 3: Network Rail LNET Civil Engineering Organisation (part).

25 When LNET took over the East Midlands area the earthworks team set about familiarising themselves with the routes they were now responsible for and meeting the local staff. As part of this process, some of the earthworks team visited the Cricklewood curve along with the local depot track maintenance engineer and one of his assistants. They viewed a number of problem areas, including the slip at the site where the derailment was to occur later. A member of the earthworks team produced a visit report following this site visit which called for a repair scheme for the bank to be prepared. This report was then used to write a sponsor's remit for the work.

26 The sponsor's remit for the design and construction of the embankment repair was developed into a project manager's remit and passed to the minor works and examinations project manager in MP&I. This was then converted by the project manager and his team into a works order. An engineer in the team, referred to in this report as project engineer 1, was called upon by the project manager to advise on the work at Cricklewood. The remit was authorized by the territory earthworks & drainage engineer (see figure 3) on 19 October 2004. The works order was sent to Murphy Ltd, one of Network Rail's minor works contractors for this area, on 26 October 2004. Murphy Ltd contracted Owen Williams Railways to design the repair works.

27 The development of the design for the repair to the embankment progressed through the following months with the *approval in principle* (AIP) form *(Form 'A')* for the design being accepted by the *Technical Approval Authority* (Network Rail, MP&I civil engineering renewals section in this case – see figure 4) on 18 July 2005. The acceptance of the Form 'A' was by a different project engineer in MP&I, identified for this report as project engineer 2. The completed design was checked by a different team within Owen Williams Railways and the *Form 'B'* recording the check completion was accepted 25 August 2005. Figure 4 shows a simplified organisation chart for the civil engineering renewals part of MP&I.

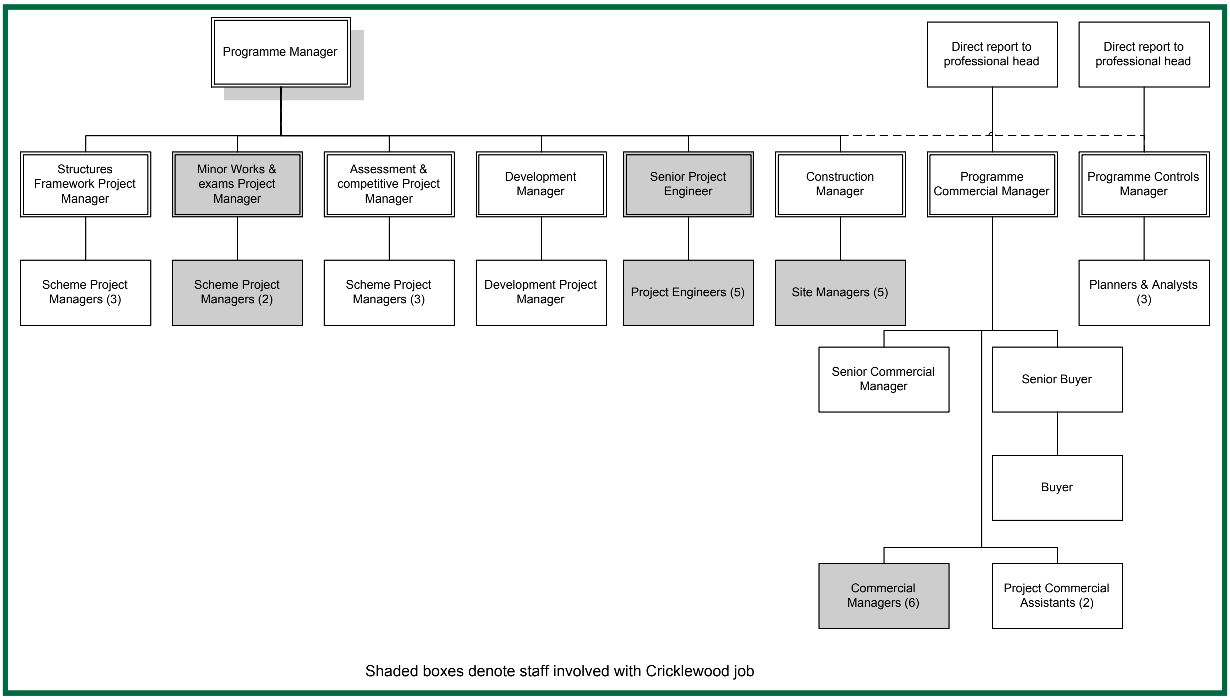

Figure 4: Network Rail MP & I Civil Renewals Organisation (part).

28 A separate remit was issued by the MP&I minor works team to AMCO Rail at this time to develop a scheme to infill some redundant air raid shelters. This work was due to start on site in the autumn of 2005 and, as Murphy Ltd had not yet progressed the embankment works to the construction phase, it was decided by MP&I to put the embankment repair works out to tender to their other minor works framework contractors. AMCO won the tender for the repair work and planned to carry out the bank repair and shelter infilling as one job. AMCO submitted a method statement for the work which was accepted by Network Rail on 17 November 2005.

29 AMCO established their site on 28 November 2005 and installed their site accommodation on the opposite side of the line to the bank slip repair site. Work commenced on the bank itself on 12 December 2005 with vegetation clearance and creation of an access route and compound with access from an adjacent road, Dorchester Court.

30 AMCO started excavation for the first three gabions on 15 December 2005 and started taking cant and gauge measurements on the track on 16 December 2005. This monitoring was done by the AMCO site manager for their own reassurance as there was no explicit requirement in the contract to monitor the track. AMCO finished work for the Christmas break on 22 December 2005 and restarted on 3 January 2006.

31 The local Network Rail assistant track section manager (see Figure 2) noticed that excavations had started adjacent to the track on 12 December 2005 and informed the Network Rail depot track maintenance engineer. He asked about arrangements for monitoring the track during the works. A member of the depot track maintenance engineer's staff at Bedford made enquiries with the MP&I office in York and was told by project engineer 1, on 13 January 2006, that AMCO were monitoring the site.

32 On either 23 January or 25 January 2006 (witness evidence is contradictory regarding the date) two track quality supervisors walked the track past the site and spoke to the AMCO site manager. They were inspecting the track in preparation for maintenance by the *stoneblower* and asked if they could borrow a cant gauge. The AMCO cant gauge was brought out and the AMCO site manager noticed that it was defective. The site manager said that it had been working correctly when he had used it earlier that day. One of the supervisors returned to the nearby Network Rail permanent way office and obtained a Network Rail cant gauge and measurements were made with it. The readings from the two different cant gauges were not compared against each other. Cant and twist of track was discussed with the AMCO site manager and he was told that he should let them know if the cant reached 150 mm. The AMCO cant gauge was sent away for repair on 27 January 2006 and a replacement gauge was received on 30 January.

33 The AMCO site manager measured the cant with the replacement gauge on 30 January 2006 at about midday, after the passage of a freight train. He discovered that the cant had reached 150 mm at two monitoring points. He reported this to his contract manager and went to the permanent way office at Cricklewood Junction to report it to Network Rail, having first printed out the latest cant and gauge values.

34 The assistant section manager at Cricklewood Junction studied the cant readings and did a rough mental calculation that the worst twist was about 1 in 130 over 3 m. He assessed this to be a fault that would require rectification within 14 days, in accordance with the Network Rail business process document 'Inspection and Maintenance of Permanent Way', NR/SP/TRK/001. The assistant section manager was aware that the track at the site of the slip had a tendency for slow movement and he had seen the track in this condition before. The assistant section manager asked how often AMCO were taking the readings and how the latest set compared with the previous ones. The AMCO site manager told him that the readings were being taken every day and that the latest set were similar to the previous ones. The assistant section manager planned to check the track later but was not able to get out that afternoon and instead asked one of his colleagues to check the track the following day.

35 No other trains passed over the down line at the site until the time of the incident, which occurred that night. The next train to pass on the down line was the train which derailed.

Events during the accident

36 Train 7O90 passed over the embankment at 02:22 hrs travelling at 7.5 mph (12 km/h). During the passage, the driver of the train felt the locomotive lean to the left rather more than he considered normal; he removed power and looked out of the window to see why. He saw that embankment works were taking place and reapplied power. The locomotive and the leading empty wagons on the train passed over the site of the embankment repairs.

37 The three loaded wagons came onto the section of embankment under repair. The leading two loaded wagons passed over the slipped section of the bank without derailing but the twist worsened as the loaded wagons passed and the third wagon encountered a severe track twist. When surveyed after the derailment, this twist was measured at 29mm (1 in 68) over the 2m bogie wheelbase. The maximum allowable twist on a line open to traffic is 33 mm (1 in 91) over a 3 m base (see paragraph 45). The twist over the outer wheelbase of the wagon was 94mm (1 in 141). The leading bogie derailed to the *sixfoot* with the *cess-side* wheel dropping into the *fourfoot*.

38 The high cant and low speed would have led to more of the wagon's weight being on the cess rail than the sixfoot rail. The heavily loaded cess side derailed wheel cut into the timber sleepers breaking them in two. The destruction of the track caused the following bogie and the following empty wagon also to derail.

39 The two derailed wagons overturned and started to slide down the embankment. Figure 5 shows the leading derailed wagon and some of the damage to the track.

Figure 5: Leading derailed vehicle and track damage.

40 The brake pipes between the derailed wagons were parted by the derailment and the train brakes applied automatically. The driver felt the train lurch and went to apply the brake, but saw that the brake pipe pressure had already dropped to zero. The train came to a halt.

41 The train driver called Dudding Hill box on his mobile phone. He informed the signaller that he had had an emergency brake application, and the signaller told him that all the *track circuits* had just gone down. The signaller confirmed that there were no other trains on the curve, that both lines would be *blocked* and that the driver could walk back along the train safely.

42 The driver walked back down the train and applied the handbrakes on the wagons each side of the derailed wagons to hold them from moving further down the embankment.

Analysis

The investigation

43 The focus of the RAIB investigation into this incident was:

- The way in which Network Rail discharged their responsibility for the safety of the line, in particular the controls on risk at contract stage.
- The way in which the part of Network Rail concerned with carrying out the repair work (the MP&I directorate) interfaced with the part of Network Rail concerned with maintaining the safety of the line (the track engineer).

Sources of evidence

44 Evidence was obtained from

- Statements by the EWS, Network Rail and AMCO staff involved;
- AMCO site records, including progress photographs;
- AMCO method statements;
- Network Rail, MP&I LNET documentation relating to this work;
- Network Rail, track maintenance engineer's records;
- Network Rail, Chief Engineer's Department, Engineering Support Centre at Derby provided copies of recent track recording information for this line;
- Evidence gathered at site by the RAIB;
- Photographs of the site taken by the British Transport Police.

Identification of immediate cause

45 The immediate cause of the derailment was severe track twist near to the end of the bank repair site. This twist came about as a result of the loss of vertical support to the cess rail over the area of the bank slip leading to a long dip in the cess rail. This loss of support ended abruptly close to the end of the site where a large tree root system had stabilised the bank. The passage of the loaded wagons over the site caused the cess rail to dip further, increasing the cant up to 160 mm, except where the bank was supported by the tree root system. Here the cant remained close to the design value of 55 mm leading to a track twist of 29 mm (1 in 68) over the 2 m wheelbase of the freight train's bogies. The limit value of twist (over a 3m base) in the Network Rail track maintenance business process document NR/SP/TRK/001 is 1 in 200 (ie 15 mm over a 3 m base, 10 mm over a 2 m base) for a curve of under 400 m radius (as here). If the twist is more severe, time limits are given for the correction of the fault; a twist between 1 in 200 and 1 in 126 must be rectified within 7 days, between 1 in 125 and 1 in 91 it must be rectified within 36 hours and a twist of 1 in 90 or worse requires immediate closure of the line. The severity of the twist following the derailment can be seen in Figure 6.

Figure 6: track twist beneath rear part of train.

Identification of causal and contributory factors

Factors relating to track maintenance

46 The track twist after the passage of the previous train on the morning of 30 January 2006 was not as severe as when surveyed after the derailment, but the embankment was in a condition where subsequent loading by a heavy train caused the cess rail to subside under load. The condition of the bank was a contributory factor to the derailment.

47 The embankment slip had been moving for at least nine years, but the movements were slow. This movement led to the cess rail dropping vertically whilst the sixfoot rail remained in place. This had the effect of increasing the cant. The track maintenance staff knew of the tendency of the bank to move in this way and arranged for packing and tamping of the track to restore the vertical alignment when required. The movements only affected the cess rail, implying that only the surface layers of the bank were slipping. There was evidence of this slippage, before the work started on site, in the distorted alignment of the cable trough route along the crest of the embankment. Three of the sleepers were broken near to the start of the slip, the breaks being due to *hogging* of the sleeper within the fourfoot. This is symptomatic of sleepers which are '*centre bound'* ie supported only at their centres and not the ends. This too is consistent with movement in the surface layers of the embankment.

48 The Network Rail *Track Recording Unit* (TRU) recorded the track geometry of this line on 3 February 2005 and again on 4 August 2005. The first of these runs revealed some vertical alignment defects at the site that required attention within 10 days. These were attended to by manual maintenance and by tamping. The run on 4 August 2005 showed no alignment defects at the site. However, if the actual numerical alignment data is examined in detail, the effect of the bank slip can be seen as an increase in cant. Figure 7 shows the cant measurements from the two track recording unit runs along with the cant measurements taken after the incident. The traces show how the cant has increased at the site from 45 mm in February, to 80 mm in August and over 160 mm at the time of the derailment. The design cant for the curve was 55 mm. These traces show that the movement of the bank was continuous throughout 2005.

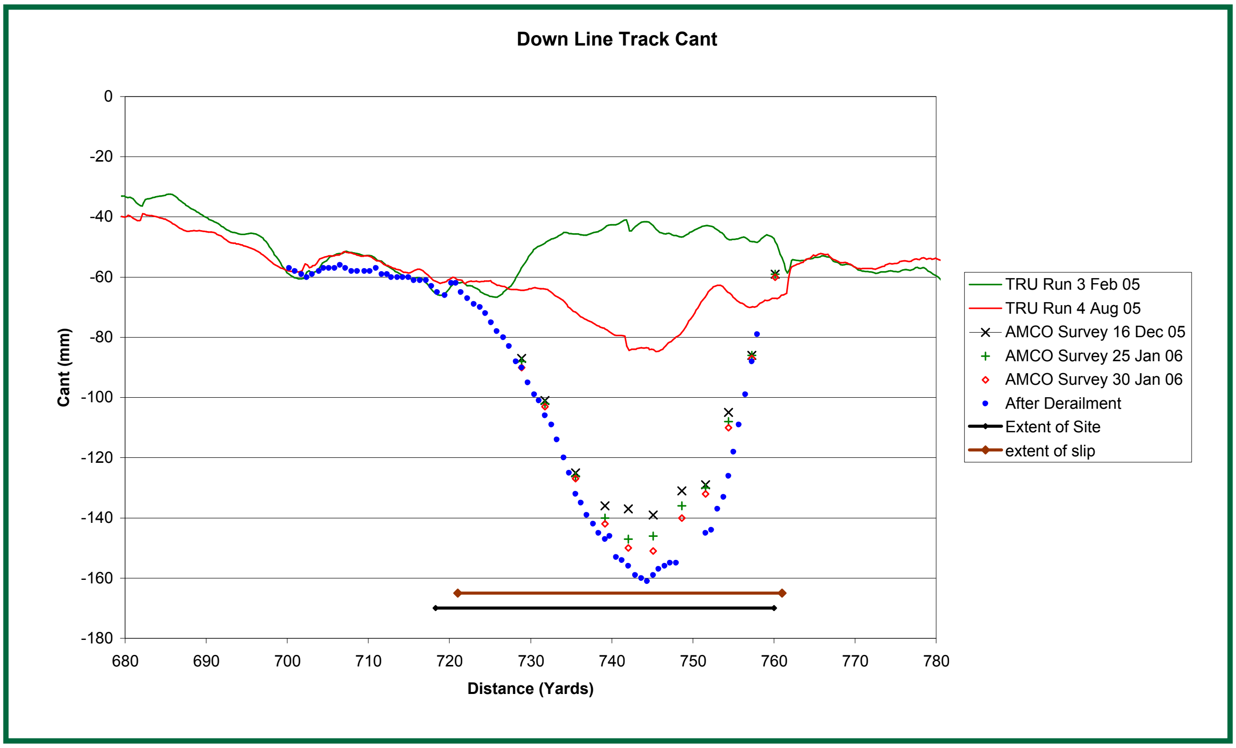

Figure 7: Track cant plotted against distance over time.

49 The track twist was output by the TRU and the twist over a 3 m base is plotted in Figure 8. Discrete values of twist over a 3 m base were also calculated from the AMCO cant readings, using the measured distance between the AMCO monitoring points rather than the 'nominal' 3 m spacing. These twist values have also been plotted in Figure 8. The limits on twist given in NR/SP/TRK/001 (and in paragraph 45) are shown in Figure 8 as broken horizontal lines. It is evident from Figure 8 that the track twist at the time that AMCO started monitoring was at a level where a twist fault existed that should have been attended to within 36 hours. As AMCO were not calculating track twist, this fault went unnoticed.

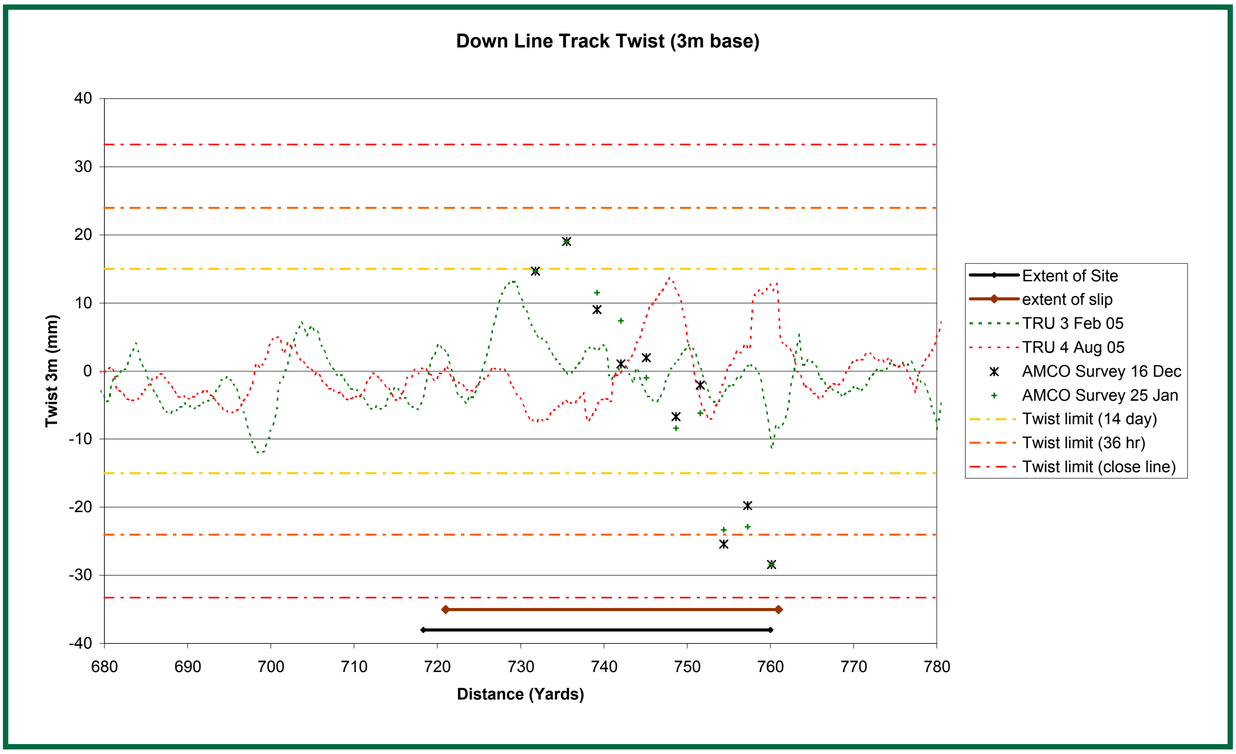

Figure 8: Track twist plotted against distance.

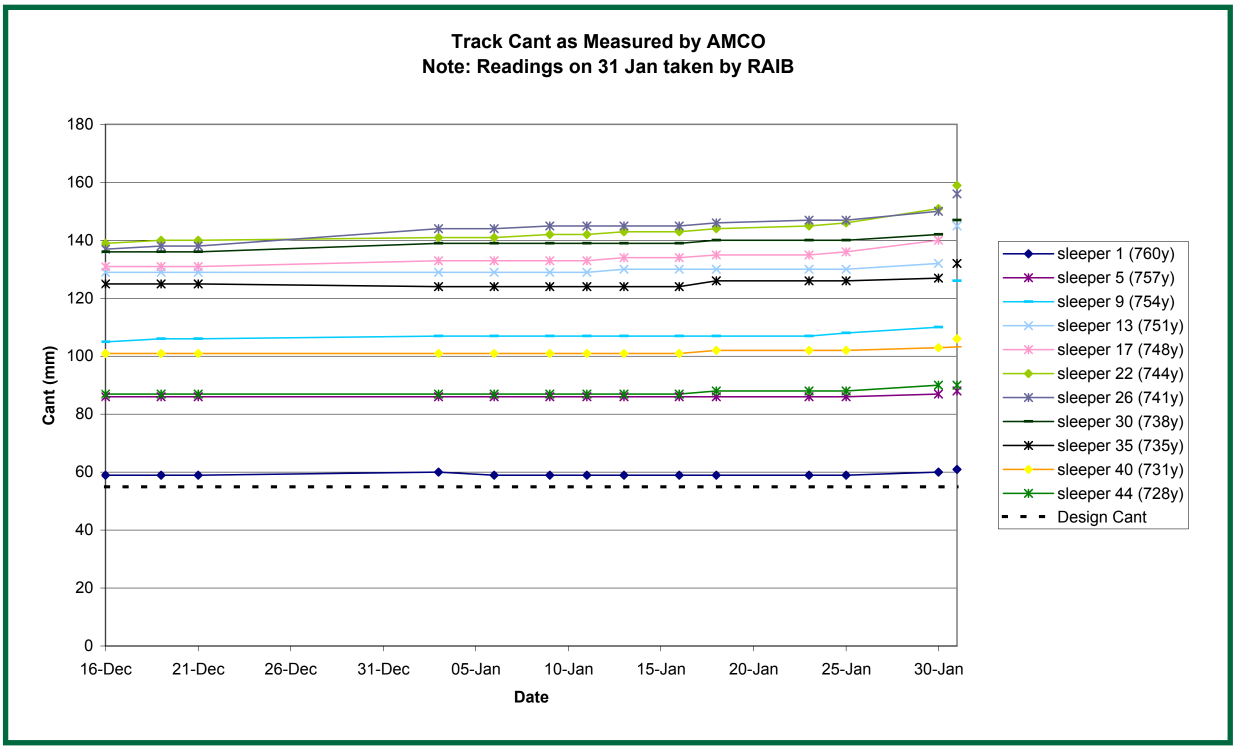

Figure 9: Cant readings taken by AMCO plotted against time.

50 The AMCO cant monitoring results have been plotted in Figure 9. These show a slow movement at most of the monitoring points up to 25 January when the apparent rate of movement increases slightly, which might indicate that the bank has become more unstable. The AMCO figures have been plotted with the figures derived from the TRU results in Figure 10 to show the relative rate of movement after the work started on site in December 2005. The apparent rate of movement is greatest at points where the cant is high, points 22, 26 and 30. However, the readings taken from 25 January onwards were taken with the new cant gauge and no correlation was done between the new cant gauge and the old, defective, cant gauge. Therefore the change in cant could be due, at least partly, to the change of instrument. However, in the area away from the derailment, the readings taken by AMCO were within 3 percent of those taken by the RAIB, so the AMCO cant gauge was in reasonable calibration. The only clear conclusion that can be drawn from this is that the bank was unstable and was moving throughout 2005.

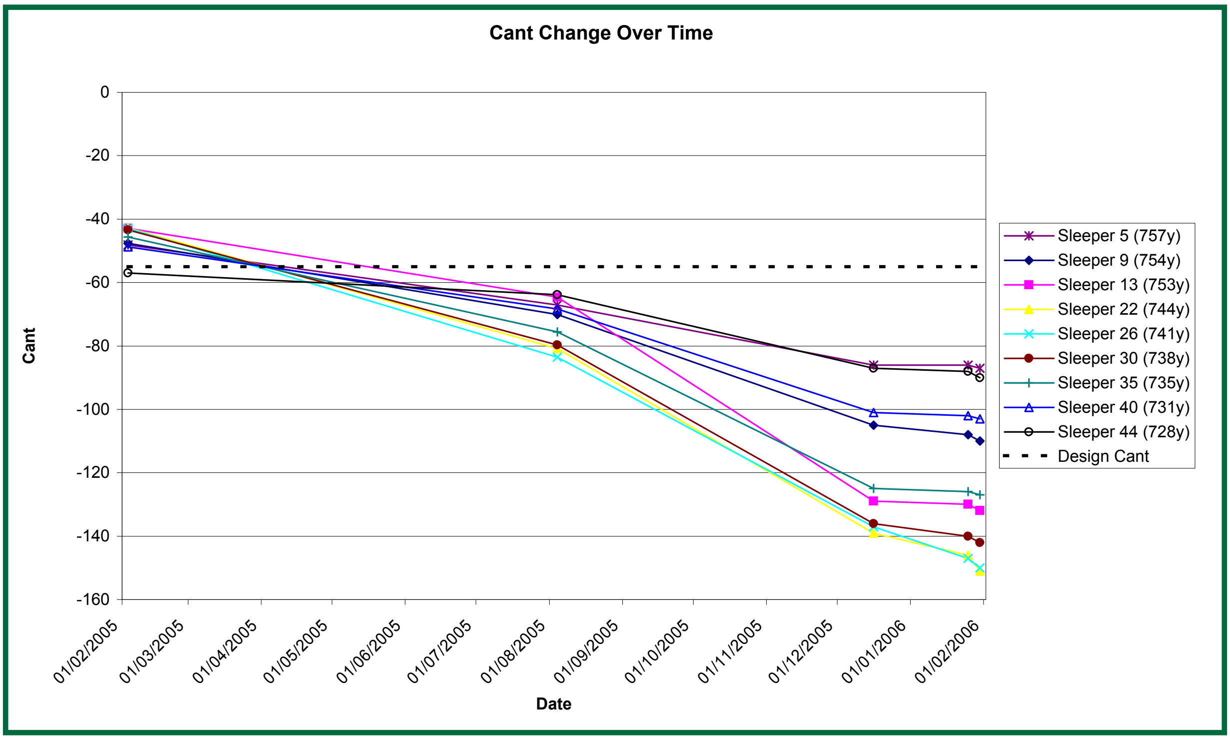

Figure 10: Cant readings from both sources plotted against time.

51 The design cant on this curve was 55 mm and maintenance work should have aimed to restore the track to this cant. However, the cant at the site at the time of the TRU run in February 2005 was 45 mm. Track maintenance had been carried out prior to this run on 4 January 2005 when shovel packing had been carried out. This procedure involves jacking the track to above the correct level and compacting stone beneath the sleepers. The track is then lowered back onto the stone to finish at the correct level. In this case, the track was over lifted, possibly in expectation of the likely settlement, though this could not be confirmed.

52 As the bank slipped, the cant increased and by the time of the next TRU run in August 2005 it had reached 80 mm. The track maintenance business process document NR/SP/TRK/001 gives limits on the permitted variation of track geometry from its design value. These limits are given in table E.1 of the document and consist of three sets of limits. The first is the design tolerance and this applies at the time of track installation. Maintenance work should aim to return the track to this condition.

The second is the maintenance limit and this is the maximum deviation from the design that should be permitted before carrying out remedial work. The third column is described as the intervention limit and the document states that if this is reached, action should be taken within a specified time to rectify the defect. If no specified time is given, action should be taken as quickly as practicable. The limits are generally related to linespeed and, for the linespeed of 10 mph (16 km/h) which applied here, the cant maintenance limit is +/- 20 mm and the intervention limit is +/-50 mm.

53 The design cant at the site was 55 mm and applying the permitted variations from NR/SP/TRK/001 gives the maintenance limit as 75 mm and the intervention limit as 105 mm. The 80 mm measured by the TRU in August should therefore have triggered maintenance work to correct the defect. The cant measurements taken by AMCO just before the derailment show the cant to have reached 150 mm, 45 mm beyond the intervention limit.

54 Evidence of work requests and work completion was obtained from the Network Rail *MIMS* work planning system. All track inspection and maintenance work was controlled through this system. The MIMS records showed that maintenance work was scheduled to correct some vertical alignment *level 2 exceedences* following the August TRU run, but no work was scheduled to correct the cant at that time.

55 The track was regularly inspected by the *track patroller*, the section manager or his assistant, and the depot track maintenance engineer. The frequency of each of these inspections was given in NR/SP/TRK/001 and the patrollers were required to inspect the line at least every two weeks. In fact, the track was patrolled every week. The patrollers were issued with a work instruction in the form of the Track Inspection Handbook, NR/WI/TRK/001, which was derived from NR/SP/TRK/001. The patrollers carried out a visual inspection of the track and the lineside as they walked the line. Patrollers carried a printed list of MIMS work items that had been scheduled but not yet completed. They were expected to look for defects and then check the MIMS list to see if they had already been reported for action. If they found new defects, they filled in a blank form to record the defect for input to MIMS. The patroller's records did not show any work being scheduled to correct the cant but the inspection sheets relating to the inspection by the track section manager on 20 October 2005 showed a work request to lift and pack the track at the site of the bank slip. This work was given a priority rating of M1. The rating of M1 means that work to correct the defect should be carried out within one month subject to any reassessment or reprioritisation arising from subsequent inspections carried out. The lack of implementation of control measures for the excessive cant is a causal factor to the derailment.

56 The inspection by the patroller was meant to be a visual inspection and no measurements of track geometry were to be made, according to NR/SP/TRK/001. However, a local arrangement existed in the East Midlands area whereby patrollers were expected to carry cant gauges with them on alternate patrols and to take cant and gauge measurements where they deemed appropriate. Witnesses on the AMCO site did not see any track staff passing the site carrying cant gauges and the patrollers records for the period the bank repair work was underway from 3 January 2006 to 30 January 2006 did not show any measurements of cant or gauge. The patroller is expected to be familiar with work instruction NR/WI/TRK/001 'Track Inspection Handbook'. This work instruction contains a copy of the track geometry limits from NR/SP/TRK/001 but this does not include mention of the allowable cant deviations. This omission is regarded as a contributory factor to the derailment.

57 The MIMS work request arising from the track section manager's inspection on 20 October 2005 was not carried out and the patroller's inspection on 16 January 2006 contained the note 'RM1' against this work item. This meant that the work was still necessary and should be rescheduled to be carried out within one month. There was no record of a cant measurement being taken to back up this decision. The cant measurements taken by AMCO at this time showed the cant to have reached a peak value of 145 mm. This amount of cant was beyond the intervention limit by a margin of 40 mm. The lack of measurement of the cant at the time the work was rescheduled is a causal factor as, if the cant had been measured, it should have triggered action to remedy the defect.

58 Document NR/SP/TRK/001 does not give a definite timescale for rectifying faults and instead states that the work should be done 'as quickly as practicable'. The document goes on to state that 'until rectified, the line may require the protection of immediate closure or ESR' (emergency speed restriction). As the linespeed here was already permanently restricted to only 10 mph (16 km/h), the only options available would have been a 5 mph (8 km/h) ESR or closure. No guidance is given in NR/SP/TRK/001 on the values of ESRs to be set for cant variations or the timescales for carrying out remedial work. This omission is regarded as a contributory factor.

59 The assistant track section manager at Cricklewood was approached by the AMCO site manager on 30 January to report that the track cant had reached 150mm. The assistant track section manager looked at the AMCO cant figures, asked how far apart the measuring points were and was told that they were at 3m spacings. Based on this spacing, the assistant track section manager calculated that the worst twist was 1 in 130. A twist of this magnitude should have been attended to within 7 days, according to NR/SP/TRK/001. The calculation of this twist value was done using an assumed spacing of 3m between the points. In fact the points were closer than this and the calculation was not accurate; the twist at this time was actually 1 in 105 (Figure 8). This should have been attended to within 36 hours. It is likely that the track twist had been at the '36 hour' level since before AMCO started on site and should have been noticed when the MIMS work request to lift and pack the track was rescheduled on 16 January. The lack of cant measurement when rescheduling the work is a causal factor in the derailment.

<u>Factors Relating to rail traffic</u>

60 Details of the traffic passing over the line were obtained from the Network Rail *Actraff* computer system. The trains using the line consisted of three main types; trains of containers conveying domestic refuse, trains of vans conveying car parts and trains of empty and loaded aggregate wagons. The heaviest wagons to use the line were the loaded wagons in the aggregate trains, which each had a gross laden weight of 102 tonnes. These trains passed the site during the night. The Actraff data was reported by financial period and the duration of the site works was covered by two periods; period 10, starting on 11 December 2005 and period 11, starting on 8 January 2006. In period 10 there were no loaded 102 tonne wagons passing the site and in period 11 there were 4 such wagons. Three of the four loaded wagons were on the train that derailed and were marshalled together. The train involved in the incident was therefore the heaviest load to pass the site during the course of the works. The fact that this was the heaviest loading applied to the bank during the repair works is considered a contributory factor.

Factors relating to site construction works

61 The AMCO site team operated from AMCO's office in Bristol. It had previously worked on railway jobs at sites on Network Rail Great Western Territory. Where these jobs involved monitoring the track for movement, the monitoring consisted of measuring the cant of the track at the site of the works before and after the work was carried out, to ensure that the track had not moved. The work involved was to dig trial pits beneath the track; this work would only have affected two or three sleepers and no movements were detected. The AMCO team's lack of experience in monitoring track for twist faults is regarded as a contributory factor to the incident.

62 When excavation started at Cricklewood, the AMCO contract manager decided to monitor the track as a precaution. This monitoring was done on the same basis as in their previous jobs, which was to measure the cant and gauge and see if it changed as work progressed. The cant measurements were taken using a cant gauge placed on the down line at intervals of approximately 3 m. The monitoring positions were marked by spray painted numbers on the sleepers and the 3 m intervals were determined by pacing out the distance and marking the nearest sleeper to the estimated 3 m.

63 Excavation work was slow during December but additional resources were brought to site from 9 January 2006 to increase the work rate which settled down to a steady progress of 3 m of embankment repair per day.

64 The Network Rail assistant track section manager walked the track on 3 January 2006 and noticed that excavation was taking place close to the sleeper ends. He asked the Network Rail depot track maintenance engineer about the arrangements for monitoring the track for movement in an email the following day (4 January 2006).

65 The Network Rail depot track maintenance engineer asked an assistant to follow this up and the assistant had difficulty finding out whom at York to contact regarding this work. On 13 January, he eventually contacted the section of MP&I responsible for the more substantial repair works underway nearby at Silkstream Junction. He was then passed across to the project engineer supporting the minor works project team responsible for the Cricklewood job (project engineer 1). When asked about whether the site was being monitored, project engineer 1 did not have a list of sites which were being monitored quickly to hand so he telephoned the AMCO contracts manager. The meaning of the term 'monitoring' was not defined in the conversation and, since AMCO were monitoring the track in the same way that they monitored when digging trial pits, the depot track maintenance engineer's assistant was told that AMCO were monitoring. This gave rise to a misunderstanding by the depot track maintenance engineer's assistant. The fact that no list of jobs where monitoring was supposed to be being done was available to project engineer 1 is a contributory factor to the incident.

66 The misunderstanding arose because, up to this point, the Network Rail depot track maintenance engineer's staff had always received handover documents for sites where MP&I contractors were working. This led them to expect to always receive some form of handover document for MP&I sites. The Network Rail company procedure NR/SP/MTC/088 requires that an asset management plan for the work is produced and agreed with the maintainer before works commence; there is no evidence that this was done for Cricklewood. The company procedure also requires the project manager to ensure that no work takes place until a notification of asset change (form 'MR1') or transfer of maintenance responsibilities (form 'MR2') has been issued. Neither MR1 nor MR2 forms were issued for the job at Cricklewood. The Network Rail depot track maintenance engineer's staff at Bedford were familiar with the 'MR2' (ie transfer maintenance

responsibility formal handover process) and the monitoring arrangements usually associated with it, having encountered it several times, but had not encountered the 'MR1' (ie no maintenance responsibility or measurements by the contractor) arrangement. The Cricklewood job was the first one commissioned by York MP&I in the Bedford area for which an 'MR1' form would have been issued.

67 The misunderstanding in the telephone conversation of 13 January was compounded when MP&I project engineer 1 confirmed that monitoring was being done by AMCO in an email to the Network Rail depot track maintenance engineer. This email told the track maintenance staff that the track was being checked for levels and gauge by AMCO purely as a precaution, as the repair works were not expected to cause any track movements.

68 Network Rail MP&I project engineer 1 visited the site on 24 January 2006 and met the AMCO site manager. The matter of track monitoring was raised and the AMCO site manager reported that the track was being monitored and that the local permanent way staff were being kept informed. Movements were said to be small, but were not quantified. The AMCO site manager did not explain how this communication was taking place. In fact, the means of informing the Network Rail permanent way staff was by a short verbal exchange as the patroller passed the site. This was informal to the extent that the Network Rail permanent way staff did not recognise it as a meaningful communication of the track movement. The lack of clarity of the monitoring arrangements and the communication misunderstandings are causal factors in the accident.

69 The excavation works for the embankment repair included the excavation of an access road along the length of the repaired section. This roadway was to provide access for an excavator and a dumper. The width of this roadway was about 2.5 m and a level surface was created, partly by placing fill material on the lower part of the bank and partly by cutting into the bank. This cutting-in left a near-vertical face in the embankment fill. At the site of the derailment, adjacent to the tree stump, this face was 1 m high. On completion of each stage of the repair work, this cut face, and the access road, was buried under the stone fill that forms the repaired embankment. At the time of the derailment, this cut face was exposed over a distance of 5 m. The cut face was approximately 3 m from the cess rail (Figure 11).

Figure 11: Cut face beside access road at site of derailment.

Figure 12: Access road through site, looking towards Cricklewood Junction, in early stage of works.

70 The construction of the access road was mentioned in the method statement but its position was not defined. An AMCO progress photograph (Figure 12) shows the roadway to have been situated part way up the bank. The steep face cut into the bank on the track side of this access road would have reduced the stability of this part of the bank. It is not possible to determine whether the bank movement under the train was due to its inherent weakness or whether presence of the access road cut made it unstable.

Factors relating to management and supervision of the contract

71 The Network Rail civil engineers' and MP&I departments at York are in adjacent parts of a large open plan office. However, misunderstandings arose between them with regard to the requirement for monitoring of the track during earthworks repair. The MP&I project engineer expected the territory earthworks engineer to specify any long term monitoring requirements but the territory earthworks engineer considered the need for monitoring to be dependent on the manner in which the repair works were to be carried out, and therefore a delivery function which was the responsibility of MP&I. It was unclear who was responsible for specifying monitoring of the track in the short term, ie while works were underway. As a result of this, neither party specified that monitoring should take place at Cricklewood.

72 The Network Rail technical approval process involves the designer submitting details of his proposed design to the Technical Approval Authority (ie Network Rail) at the start of the design process. The purpose of this is to allow the design assumptions to be checked. The first stage is to get AIP and details are submitted on a standard form called Form 'A'. In the case of the Cricklewood job, the Form 'A' was submitted by the designer of the repair, Owen Williams Railways, through the main contractor at the time, Murphy, to Network Rail MP&I on 13 April 2005. The MP&I designated project engineer, project engineer 1, was not satisfied with some details of the scheme and rejected the submission pending further site investigation. This was carried out and a revised Form 'A' submitted on 18 July 2005. The Form 'A' was accepted by project engineer 2 and endorsed by the territory earthworks engineer, to confirm that the scheme would meet his requirements.

73 Having obtained AIP the designer carried out the detailed design of the repair and submitted details and drawings with the Form 'B' submission on 15 August 2005. The Form 'B' gives full details of the design and certifies that it has been checked by a competent person. The AIP and checking process is defined in Network Rail business process document NR/SP/CIV/003 'Technical Approval of Design, Construction and Maintenance of Civil Engineering Infrastructure'. There are four categories of checking; category 0 is for designs where calculations would not normally be carried out. Category 1 is for 'standard or simple designs using simple methods of analysis … all aspects of the design are in accordance with the relevant standards'. Category 3 is for 'complex or unusual designs or where significant departures from relevant standards, novel methods of analysis or considerable exercise of engineering judgement are involved'. Category 2 is for designs that do not fall into one of the other categories. The Cricklewood design was category 2. Category 2 jobs are checked by an engineer in the same organisation as the designer, but in a completely independent team. The design of the Cricklewood scheme was therefore checked by Owen Williams Railways.

74 The designer is required, with the Form 'B' submission, to include information on risks that cannot be avoided in the construction of the works. This risk information is required by the Construction (Design and Management) Regulations 1994 (CDM). Owen Williams Railways included a risk assessment with the Form 'B' and this risk assessment showed the risk with the highest rating was 'excavation adjacent to track: instability leading

to derailment'. The risk control measures were stated in the Form 'B' as being the excavation of the bank in short lengths and the excavation to start from the top of the bank. The 'comments' column stated 'it is expected that the ground profiles will be carefully monitored during construction'. The risk of the bank moving during the works and causing a derailment was therefore clearly recognised by the designer.

75 The CDM regulations require that this type of risk is identified and communicated to the contractor in a document called the *Health and Safety Plan*. The pre-construction stage health and safety plan should contain details of risks identified by the client and the designer and should be supplied to the contractors tendering for the work. The person who prepares the health and safety plan is termed the *Planning Supervisor*. The planning supervisor is also responsible for maintaining the health and safety plan by keeping it up to date as the works progress.

76 The planning supervisor would normally be employed by the client. Network Rail MP&I have delegated their planning supervisor responsibilities to the minor works contractors and the pre-construction health and safety plan took the form of a generic document that could be applied to any work on or about the railway. Network Rail supplied this document to the minor works contractors at the time that they tendered for the framework contract. Each successful tenderer was then expected to take on the role of planning supervisor for all the works entrusted to them. This would include the production and maintenance of the health and safety plan.

77 The change of contractor between Murphy and AMCO therefore led to a change in planning supervisor. When this change occurred, the health and safety plan should also have been transferred. A copy of the health and safety plan obtained by the RAIB from Network Rail MP&I consisted of the generic document issued at pre-tender stage, the project remit, the Form 'B' (which included the designer's risk assessment) and a series of photocopied pages from the Network Rail *hazard directory*, *sectional appendix, rules of route* and *Marlin* system. (The latter is a computer system for recording information regarding land ownership, sites of special scientific interest, conservation areas and other similar information.) There was no commentary on the information provided to draw the contractor's attention to significant risks identified by the client or designer and no mention of the instability of the embankment.

78 When the work was transferred from Murphy to AMCO, AMCO assumed the role of planning supervisor. The pre-construction health and safety plan consisted of documents drawn from other sources, and it is unclear whether these documents were handed over directly from Murphy to AMCO or whether a new set were generated. As client for the work, Network Rail should have ensured that the pre-construction health and safety plan was supplied to AMCO.

79 AMCO did not notice the need for monitoring in the designer's risk assessment, which was one of the documents they were given. Their construction phase health and safety plan and method statement did not, therefore, contain any reference to monitoring as a control measure. This omission is regarded as causal.

80 The nature of the work normally done by the minor works team was such that a large number of very small jobs were carried out. The CDM regulations only apply to works where there are more than 5 people on site and the work lasts more than 30 days. The Cricklewood job was, however, larger than the CDM threshold and if a proper health and safety plan had been provided it would have drawn everyone's attention to the risk of bank slip causing a derailment and the need for monitoring. The way in which the CDM regulations were applied to this work is the underlying cause of this derailment.

81 AMCO submitted a method statement to Network Rail on 11 November 2005. This was checked by project engineer 2 and some deficiencies were found. The project engineer considered that the deficiencies were not so serious as to prevent the acceptance of the method statement so he wrote back to AMCO on 17 November 2005 to accept the statement and list the outstanding deficiencies. AMCO then revised the method statement to reflect these matters and the final version was dated 19 November 2005. Network Rail's acceptance of the method statement did not include a cross check between the designer's risk assessment in the Form 'B' and the method statement risk assessment. Consequently, the lack of monitoring was not noticed. This omission was a causal factor of the incident. The method statement did not detail where the access roadway would be made in the embankment face and this omission was not noticed in the method statement check. This omission is regarded as a contributory factor.

82 The supervision of construction sites by Network Rail was done by means of roving site managers who reported to the construction manager in MP&I. These managers covered all the MP&I sites in an area and apportioned their time between them. There was no formal process for the apportionment of their time between sites and this was left to the judgement of the construction manager and his team. The apportionment of time between sites was related to the size and complexity of the work and minor works sites would only be inspected once or twice during construction. The Cricklewood site was inspected on 24 January 2006. At the time of the inspection, the access road had been in place for over a month and had been covered by stone fill throughout most of its length. There was no visit made to the site during the time when the excavation came its closest to the track. If a site construction manager had seen the site when the excavation was close to the track he may have noticed the potential instability and acted accordingly. The level of Network Rail supervision of the site is considered a contributory factor.

83 The site works were considered by MP&I to be of low risk and not likely to affect the track. This judgement was not based on the designer's risk assessment but on an internal unwritten rule that was applied by project engineers 1 and 2 attached to the minor works team. This 'rule' was based on experience and stated that the works would only be likely to affect the track if they infringed on an area within the bank projected down from the sleeper ends at an angle of 45 degrees to the vertical. The decision by the MP&I project engineer to apply the 'rule' rather than the designer's risk assessment is a contributory factor but it arises from one of the root causes, not checking the designer's risk assessment thoroughly. Project engineer 2 had seen the risk assessment but did not study it sufficiently closely to appreciate the significance of the risks. Project engineer 2's main experience was in carrying out small items of minor works on or about the track. He perceived the main risks to arise from collision of trains with personnel or equipment.

84 The MP&I civil engineering renewals section at York was focussed on the safe delivery of projects to time and budget. The department was headed by a Chartered Civil Engineer but there were no other professionally qualified civil engineers in the department who were directly involved with the Cricklewood job at the time of the accident. Chartered Civil Engineers were available to be called upon in other parts of the MP&I civils renewals department, but they were not called on to provide assistance in the case of the Cricklewood job. The emphasis in professional qualifications in the department was towards project and programme management. The minor works team was headed by a project manager and his personal objectives were concentrated on project and programme delivery, safety inspections of works in progress and contractor's safety strategy. The training and development emphasis for project managers within MP&I at York was not directed towards general civil engineering knowledge and competence, but towards contract and programme management.

The department viewed themselves as being responsible for the safe delivery of projects with the technical aspects, such as knowledge and expertise of earthworks, being the responsibility of the client department. This situation had originated at the time MP&I was set up within Railtrack and had not changed when Network Rail took over from them.

85 The lines of communication between the civil engineer's organisation and MP&I within the Network Rail York office and between that office and the Network Rail track maintenance engineer's offices at Bedford and Cricklewood were not fully effective. The discrepancy between the earthworks engineer's and MP&I project engineer's views of who specifies monitoring has already been noted. The communication with the Bedford office was also deficient in that Bedford only received advice of earthworks jobs that involved a handover meeting (ie transfer of maintenance responsibility,'MR2', in accordance with NR/SP/MTC/088). No 'MR1' form was issued for the Cricklewood job. Information was sent to all track engineers as a weekly email listing all the sites where MP&I contractors were planned to work. This email was not sent to Bedford at the time owing to an address error in the email. Acknowledgement of the email was not required, so MP&I at York were not aware of the communications breakdown. As 'MR2' jobs involved a handover meeting with the track maintainer, the communications breakdown only affected 'MR1' jobs. The Bedford staff therefore assumed that all MP&I earthworks jobs involved monitoring the track. The poor communication within the York office is regarded as contributory and the inadequate communication between MP&I and the depot track maintenance engineer is regarded as causal.

86 The problems of communication arose in large part due to the project being passed from one part of the organisation to another as the project progressed. There was no single person with a view of all stages of the project. If a competent person with a reasonable level of civil engineering knowledge and experience had overseen each stage of the bank repair project from identification of need through to construction, they may have been more likely to obtain information from the track engineer about the nature of the instability, liaise with the designer and contractor and ensure that nothing was overlooked at any stage. This is very similar to the function of the planning supervisor under CDM and the competent person would have to work closely with the planning supervisor. If responsibility for the competent person role had to change, for example due to staff changes, it would be necessary for a managed handover between them to take place. The lack of a competent person with knowledge of all stages of the project is a contributory factor in the derailment.

Severity of consequences

87 There were no injuries caused in the derailment and no damage to third parties' property. However, there was the potential for injury had the locomotive derailed and potential for third party damage and injury if the derailed wagons or their load had impacted the residential properties at the foot of the bank. The aggregate discharged from the derailed wagons was projected towards the residential properties and the risk of the wagons slipping further down the bank led to the evacuation of these properties.

Conclusions

Immediate cause

88 The derailment was caused by excessive track twist. The track twist was caused by movement of the embankment at the site of the repair works leading to a general 'sag' in the cess rail. This sag came to an abrupt end at the site of a tree stump which stabilised the embankment at that point. The overall effect was to produce the twist.

Causal factors

89 The responsibility for monitoring the track during the work was not made clear, due to poor communication between the teams in the Network Rail York office and between the Network Rail offices at York and Bedford/Cricklewood (Recommendation 2).

90 The local track maintenance staff did not recognise the potential hazard of excessive cant and did not apply control measures to reduce the risk. Controls would have been to lift and pack the track immediately or to close the line (Recommendation 4).

91 The local track maintenance staff did not measure the cant at the site when rescheduling maintenance work to correct the cant (Recommendation 3).

92 The AMCO method statement did not fully take into account the designer's risk assessment (Recommendation 5).

93 The MP&I minor works team classified the job as low risk on the basis of an internal unwritten 'rule' instead of implementing all parts of the designer's risk assessment.

Contributory factors

94 The bank was in a condition where it was prone to failure under heavy loading.

95 The train which derailed was the heaviest load that the bank had been called upon to carry since the repair works started.

96 The technical control of the job by the MP&I minor works team was not robust and allowed the following events to occur, all of which contributed to the incident (Recommendation 5):

- Network Rail's method statement acceptance process did not consider the designer's risk assessment;
- Network Rail's method statement acceptance process did not identify the risk posed by cutting an access road into the slope;
- A list of jobs showing the monitoring requirements at each one was not readily available to the project engineer.
- The level of site supervision was low and allowed excavation to encroach closer to the track than the method statement stated.

97 The Network Rail work instruction NR/WI/TRK/001 did not mention the limits on cant deviation specified in the business process document NR/SP/TRK/001 (Recommendation 4).

98 The Network Rail business process document NR/SP/TRK/001 did not give guidance on time limits for fixing cant deviations or on appropriate actions for cant excess (Recommendation 3).

99 The AMCO site team were not experienced in monitoring track for settlement during this type of earthworks (Recommendation 5).

100 Network Rail's organisation did not include a competent person with overall knowledge of all stages of the repair scheme throughout its life cycle (Recommendation 6).

Underlying cause

101 Information on the bank condition, risks inherent in carrying out construction works on it and the means of mitigating the risk to rail traffic were not clearly communicated to AMCO. Correct application of the CDM regulations should have ensured that this was done (Recommendation 1).

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

102 Network Rail LNET MP&I have implemented a new procedure aimed to ensure that monitoring of the track at earthworks sites is properly considered. This procedure has been circulated to MP&I on the other territories and is being considered for adoption as a formal Network Rail standard.

103 AMCO have briefed their site staff on the importance of track twist and the method of measurement.

104 Network Rail LNET MP&I have briefed all their project engineers and site managers on the importance of track twist and the methods of measuring it.

Recommendations

105 The following safety recommendations are made[1]:

Recommendations to address causal and contributory factors

1 Network Rail LNET MP&I should revise their systems for implementing the CDM regulations to minor works so as to ensure that information on the condition of the asset that might affect the safety of those who might be affected by the construction work is passed to the contractor in a manner which is clear, precise and in a form suitable for the users (paragraph 101).

2 Network Rail LNET MP&I and the Network Rail LNE territory civil engineer should revise their internal procedures (paragraph 89) to ensure the following:

- for division of responsibility: MP&I, in conjunction with the earthworks engineer, should establish for each project the responsibility for determining the need for, and the implementation of, monitoring of the track;
- for internal Communication**:** All MP&I project engineers and project managers on all territories should be made aware of the procedures used to monitor the track during site works and when these procedures should be employed;
- for external Communication**:** MP&I should ensure that they communicate clearly the responsibilities for track monitoring, and any other matters that might affect safety of the line, to the track engineers and that this information is received and understood by them.

3 Network Rail should revise NR/SP/TRK/001 to give guidance on appropriate measures to be taken on discovery of excessive cant with timescales for action (paragraphs 90 and 98).

4 Network Rail should revise the track inspection handbook associated with work instruction NR/WI/TRK/001 to refer to the cant deviation limits in NR/SP/TRK/001 (paragraphs 91 and 97).

5 Network Rail MP&I should improve the technical control of works undertaken by the minor works team to ensure that risk information provided by the designer of a scheme and any knowledge within Network Rail of risks inherent in the condition of the asset are properly taken into account (paragraphs 92, 96 and 99).

6 Network Rail should ensure that at all stages of a project there is an appropriate competent person to oversee it, and that if the competent person changes at any stage in the life of the project, an appropriate handover takes place (paragraph 100).

[1] Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on the RAIB's web site at www.raib.co.uk

Appendices

Glossary of abbreviations and acronyms — Appendix A

AIP	Approval in Principle (see Appendix B)
AMCO	Amalgamated Construction
BTP	British Transport Police
CDM	Construction (Design and Management) Regulations 1994
ESR	Emergency Speed Restriction
LNET	(Network Rail) London North East Territory
HMRI	Her Majesty’s Railway Inspectorate
MIMS	Minicom Information System (see Appendix B)
MP&I	(Network Rail) Major Projects and Investment
NRN	National Radio Network (see Appendix B)
TRU	Track Recording Unit

Actraff	A computer system that records the actual traffic over each section of railway.
Approval in Principle	The process of ensuring that a civil engineering design is carried out correctly.
Blocked	The closure of a running line or lines, usually in an emergency.
Brake continuity	The state where the braking system is intact and functional. Loss of brake continuity causes the emergency brakes to apply.
Cant	The amount by which the outer rail on a curve is raised above the inner rail.
Cant gauge	A device for measuring cant of track.
Centre bound	The state where a sleeper is supported only at its centre.
Cess	The area to either side of the railway, immediately away from the ballast.
Competent Person	An individual with an appropriate level of technical expertise who maintains an overall knowledge of an item of work that is to be carried out on a civil engineering asset.
Emergency speed restriction	A speed restriction applied to the track at no notice to cater for an unforeseen condition that has arisen.
Form 'A'	A document that describes how the design of a piece of infrastructure is to be carried out along with the design constraints. Part of the Approval in Principle (AIP) process (see Appendix A).
Form 'B'	A document that certifies that the design of a piece of infrastructure meets the requirements of the Form 'A' and all relevant standards. Part of the AIP process.
Fourfoot	The area between the running rails.
Gabion	A wire mesh basket filled with rocks that is used in earthworks stabilisation.
Gauge	Distance between the inner running faces of two rails on the same track.
Gross Laden Weight	The total weight of a wagon including the load it is carrying.
Hazard directory	The Network Rail database of hazards on or around the track
Health and safety plan	A collection of information about the significant health and safety risks of a construction project.
Hogging	The mode of bending that involves upwards deflection at the centre of a beam.

Level 2 exceedence	A measured track geometry defect which exceeds a threshold prescribed in Network Rail Standard. Level 2 exceedences generally result in maintenance action or safety action.
Linespeed	The maximum permitted speed at which trains may normally run when not subject to any other instruction or restriction.
Marlin	Network Rail computer system which records details of the land alongside the railway. It records such information as conservation areas and areas of special scientific interest.
Minicom Information System	A Network Rail computer system for work planning.
National radio network	A railway system for communication from train to Control office.
Packing	The process of compacting the ballast beneath sleepers to improve their support.
Planning supervisor	The person appointed by the client of a construction project to coordinate and manage health and safety during design and construction.
Rules of the route	A set of guidelines defining when the line can be closed so that engineering work can be carried out.
Sectional appendix	The Network Rail operational document that describes the operating features of the railway.
Signal post telephone	The telephone attached to a signal that the driver can use to communicate with the signaller.
Sixfoot	The space between one line and another. This distance may be less than six feet wide.
Stoneblower	A track maintenance machine which operates by injecting stone beneath the sleepers using compressed air.
Tamping	The track maintenance process which involves a machine (tamper) positioning the track and compacting the ballast beneath a sleeper by vibration and mechanical pressure to ensure it is maintained to a defined quality.
Technical Approval	The process of ensuring that the design of a piece of infrastructure meets the necessary technical requirements and standards.
Technical Approval Authority	The body responsible for technical approval, usually Network Rail for railway structures.
Track circuit	An item of electrical signalling equipment connected to the rails to detect the presence of a train.
Track patroller	The person responsible for carrying out the regular visual inspection of the track.
Track recording unit	A train made up of special wagons for recording the geometry of the track.

Twist	The distortion of a section of track caused when the cant at one point differs significantly from the cant at a point a short distance away. This can cause a wagon to derail.

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