



Department
for Transport

Transport Resilience Review

A review of the resilience of the
transport network to extreme weather
events

July 2014



Transport Resilience Review

A review of the resilience of the transport network to extreme weather events

Presented to Parliament
by the Secretary of State for Transport
by Command of Her Majesty

July 2014



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Foreword



Last winter saw much disruption of our transport networks because of the prolonged period of extreme weather, with many thousands of passengers and road users impacted. Transport operators, highway authorities, emergency responders and many communities worked exceptionally and commendably hard in often challenging conditions to restore services and repair damage caused by the high winds, storms and flooding.

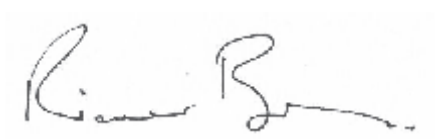
But the winter's events also pose the question of how our transport systems could be made more resilient, so as to reduce the level of disruption from extreme weather in future. This question can only be of growing importance as there is a widening consensus and understanding that climate change will increase the frequency of extreme weather events in future years. The purpose of this Independent Review, commissioned by the Secretary of State for Transport, has been to answer that question and produce practical recommendations on how we can strengthen the resilience of our transport systems and learn the lessons from last winter.

This will also be ever more important in future as travel and freight transport demands on our transport systems continue to grow. The UK already has some of the most intensively used roads, railways, ports and airports in the world, meaning that any disruption is felt by more people more quickly than elsewhere. Ensuring they are as resilient as practicable must be an important economic and social priority for our country.

There is no silver bullet or instant solution to make our transport systems more resilient, instead it is a task of attending to one hundred and one details. But by prioritising our efforts, applying already good practices much more widely and ensuring that transport operators and authorities learn continuously from other's experience as well as their own, there is much that can be achieved. It will not be possible to make our transport systems totally resilient, the forces of nature will still on occasions prove too powerful, but where there is disruption there is more that can be done to minimise its duration and impact, and to improve how passengers and road users are communicated with.

In leading this Review I have been greatly supported by John Curley and Brian Smith, and by an enthusiastic team seconded from the Department for Transport as well as individuals from the Highways Agency, Network Rail and the Met Office. My heartfelt thanks go to all of them. We have also benefitted from the input, suggestions and evidence submitted by a large number of organisations, all of whom have contributed positively. We are extremely grateful to all of them, particularly to those who gave up time to talk through their experiences and learnings with us or show us the impact of the winter's weather on the ground.

Going forward I hope all road, rail, airport and port operators and authorities will take heed of our recommendations and I encourage them to work collaboratively to minimise the impact and speed up their recovery from future extreme weather events.

A handwritten signature in dark ink, appearing to read 'Richard Brown', with a stylized, flowing script.

Richard Brown CBE

Executive summary

Extreme weather and our transport system

1. Over the winter of 2013/14 we experienced some of the most extreme weather across the UK that has been seen for many years. A succession of storms brought the highest winter rainfall across southern England since records began in 1766, resulting in widespread flooding, and extensive wind and coastal damage. On 5th December a major storm surge, combined with high tides, produced the highest water levels experienced since the great coastal floods of 1953 for parts of the east coast and in some areas the water levels were even higher than in 1953.
2. The impact of this extreme weather on our transport systems was considerable. Many road users and rail passengers experienced extensive, and in some cases, prolonged disruption. The most dramatic impact was the severing of the only rail line to the South West at Dawlish, because of coastal storm damage, and resulting in rail services west of Exeter being suspended for 2 months. As a consequence, key roads in the South West (such as the M5, A30 and A38) were on a high state of alert for a period, reflecting concern that the West Country might be cut off by both road and rail.
3. But the impact was much more widespread than this, with many local roads closed for varying periods because of flooding as well as trees or power lines temporarily blocking the carriageway. The M25 was reduced to a single lane clockwise for 10 hours adjacent to junction 16 because of flooding, and there was major traffic disruption in the Thames Valley. On the railways, trees blown over in the storms caused severe disruption and damage on a number of routes and a number of days, particularly after the St Jude's storm on 28th October, and embankment slips triggered by the intense rainfall resulted in several lines being closed or disrupted for many days. Flooding also caused much disruption, particularly on the Great Western Main Line near Maidenhead and at Hinksey near to Oxford.
4. Our ports and airports did not escape either. Gatwick Airport suffered severe disruption on 23rd and 24th December, with partial closure of its North Terminal because of basement flooding knocking out key power and IT systems. The Port of Immingham was closed for a number of days in December 2013 because the east coast tidal surge overtopped the main dock gates, resulting in extensive flooding of much of the port area. Key IT and electricity substations were put out of action here too, interrupting operations across the whole port complex for several days.
5. Last winter was of course not the first time that we have experienced extreme weather. Various parts of the country also saw widespread

flooding in 2000, 2007 and again in the winter of 2012/13. The winters of 2008/09, 2009/10 and early part of 2010/11 saw significant snow and freezing conditions, producing much transport disruption, and the summer of 2003 was particularly hot, producing disruption on the railways and some roads on a number of days.

6. Whilst it is difficult to attribute any one of these episodes of extreme weather to climate change, the consensus view among the scientific community, as provided by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change is that we will see an increasing incidence of extreme weather events in the future because of climate change.
7. It is therefore important that we plan for this and ensure that our transport networks are as well prepared as they can be to minimise the impact of extreme weather events. The principal weather events we need to plan for are more rainfall over sustained periods in winters, more intense localised rain storms particularly in the summer, albeit summers on average will be drier and hotter overall with higher peak temperatures, and more severe storms, against a background of rising sea levels.
8. In the main, we consider that our various transport networks rose to the challenges presented by last winter's weather well. There was clear evidence of lessons learned from the experience of previous weather disruptions being applied. Much determination and dedicated work ensured that where services were interrupted or routes closed, they were restored relatively quickly, and there was a clear focus on doing what was seen to be the best for passengers and users.
9. But we also believe there are a considerable number of lessons that can be learned, to better anticipate the impact of extreme weather events, reduce the vulnerability of our transport networks to them and speed up the restoration of normal services. That is the purpose of this Review. It focuses on England, because transport is a devolved responsibility to the Scottish Government and to the Welsh and Northern Ireland Assemblies. It looks at all forms of extreme weather other than snow and ice and extreme cold weather, which was the subject of David Quarmby's extreme winter weather Review in 2010.
10. Resilience in the context of this Review can be described as the ability of the transport network to withstand the impacts of extreme weather, to operate in the face of such weather and to recover promptly from its effects. As such, we take the view that resilience to extreme weather has three layers to it:
 - It is about increasing the physical resilience of transport systems to extreme weather, so when extreme weather is experienced, people and goods can continue to move.
 - It would be both very difficult and prohibitively expensive to ensure total physical resilience, so secondly it is equally about ensuring processes and procedures to restore services and routes to normal as quickly as possible after extreme weather events have abated.

- Thirdly, as part of this, it is essential to ensure clear and effective communications to passengers and transport users so that the impact of disruption on people and businesses is minimised.

Common issues

11. An important question is what level of resilience we should be seeking to achieve for a transport network which is subject to a continued growing intensity of demand and where much of the logistics sector operates to 'just in time' principles. On busy motorways even a one hour interruption to traffic because of extreme weather will cause extensive disruption to many thousands of road users, as it will on the busiest commuter and intercity rail lines. In contrast, a one day closure of a railway branch line or temporary closure of a country road, where alternative routes may be available, will be rather less disruptive, although closure for a number of days or weeks becomes a major disruption. The level of resilience sought should therefore be related to intensity of use, the availability of alternatives and the economic importance of the route or service. The more intensively used and economically or socially important a route or service, the shorter the disruption that is tolerable.
12. The accuracy of weather forecasting has improved substantially in recent years and is set to improve still further with investment in even higher capacity forecasting computers. In general, transport operators consider last winter's weather events to have been accurately forecast. There would be benefit however in developing closer liaison between weather forecasters and transport operators, so that during changing weather conditions there is a shared understanding of the trigger points at which transport operators will need to take managerial decisions about the operation of their service. This will enable forecasts to be more closely tailored to those hazards and locations relevant to individual operators. Closer liaison will also enable forecasters to understand the optimum timing of warnings to enable transport operators and users to make the appropriate response.
13. The significant developments in weather forecasting and climate modelling capability has enabled most of the operators we talked with to develop Weather Resilience and Climate Change Adaptation Plans. These identify their vulnerability to different types of extreme weather, and set out mitigating actions and processes to apply learnings from their experience of extreme weather events. There is much scope however to learn from the experience of others and share best practice both with other operators and with other modes of transport.
14. Modern transport systems are increasingly dependent upon Information Technology and other computer systems. These are critical firstly in the operation of the system, for example computer based signalling systems on the railways and the software to support air traffic control. Secondly IT and customer information systems are essential to managing the smooth flow of passengers through terminals and onto trains and planes. The effective operation of airports and international stations requires that the passenger handling capability on, for example, the

land-side of an airport is able to support the full planned schedule of flights.

15. We were particularly struck that the disruption at both Gatwick Airport and the Port of Immingham was substantially increased by the unanticipated flooding of IT servers and electricity substations; the likelihood is that a number of other operators are similarly vulnerable to such dependencies. We urge that in the Adaptation Reporting to Defra under the 2008 Climate Change Act, key transport operators should demonstrate they have shared adaptation plans with peers and applied the lessons of others as well as their own.
16. The economic rationale for investing in transport resilience is currently poorly developed and needs to be strengthened. Infrastructure operators in particular need to develop methodologies for estimating the economic and social costs of disruption, and for capturing the costs of rectifying damage caused by extreme weather, so these can be factored into spending decisions on resilience measures. The Department should work with operators to help develop these methodologies, so that the level of investment in resilience is optimised. At present, spending on resilience is largely event led and reactive, in contrast to the social cost benefit analysis approach, including travel time savings, which drives most transport investment decision making.
17. At the same time, infrastructure owners and the Department need to collaborate to define a critical network of railways, highways, ports and airports which should be prioritised in strengthening resilience. This should pay particular attention to protecting 'single points of failure' in networks, such as the rail route to the South West, and critical links to key airports and ports. Local Highway Authorities should also ensure they understand what their local critical links are, such as those to ports and airports and key businesses, and prioritise their resilience.
18. In determining the optimum level of resource¹ spending to be applied to resilience, it is also important to stress that simple maintenance is a vital activity. Routine inspection and maintenance of drainage systems, clearance of vegetation and at-risk trees, and monitoring of structures and embankment slopes are all important tasks in ensuring highway and railway resilience and which have historically not always been given the priority they should have. For public sector infrastructure owners, these activities are all treated as part of resource spending, as opposed to capital spending, and often subject to greater restriction on funding. It is vitally important that in future funding decisions, adequate provision is made for maintenance expenditure to ensure resilience. In this respect, the adoption of best practice asset management principles will provide a

¹ Resource spending is money that is spent on operating and maintaining existing assets. Capital spending is money that is spent on new infrastructure as well as renewing, improving and enhancing existing assets through investment. So in this context, capital spending would, for example, cover the construction of a new bridge, whilst resource spending would cover payment to the personnel to carry out routine maintenance of that bridge. Renewing a road surface would be a capital investment. Resource is alternatively known as 'current expenditure' or 'operational expenditure' (OpEx), as opposed to 'capital expenditure' (CapEx) in the commercial sector.

sound basis for rational decision making, at both national and local levels.

19. Extreme weather not only causes transport disruption but also has a considerable impact on the condition of transport infrastructure. Deterioration and ageing of road and rail infrastructure is principally the result of two forces - the volume and weight of usage, and the impact of weather. Extreme weather has a substantial impact in accelerating the rate of deterioration, particularly of local roads, with water erosion and ingress, frost, and summer heat all having a damaging impact. Public sector spending decisions need also to take account of this impact. This is well taken care of in the rail industry, which, being regulated, has a well-developed process for determining economically efficient levels of funding and where Network Rail have increasingly effective asset management systems. However, it is an area of significant concern for local roads, where their condition is, in some cases, quite poor, there is no regulatory framework comparable to Network Rail, and asset management principles are not universally adopted.
20. Contingency plans for how to manage disruption and clear crisis management procedures are vital preparations for effective management of disruption when it happens and ensuring rapid recovery. Most transport undertakings now have these plans and procedures, often in response to their experience during the winters of 2008 to 2010, with improvements made as a result of subsequent experience. It is important that these are further reviewed and amended in the light of last winter's experience, and best practice is shared. Contingency plans should also be periodically rehearsed, via desktop or live exercises, certainly before next winter, and in the case of airports should ideally be jointly developed with key users, such as major airlines. Processing passengers at airports is a key component of overall airport resilience. The management of departing and arriving passengers is very complex and impacted not only by the operations of the airport but also the transport networks serving the airport.
21. Passengers and road users largely judge how well transport operators have handled weather related disruption by how effectively they have been communicated with. There are examples of good practice in communications, and there is much greater use of social media and websites to get information out rapidly and widely. But there is still much that operators need to do to give out clear and consistent information that helps users make informed decisions about their travel plans. Too often communication to transport users and passengers is treated as an adjunct to the main task of managing recovery, rather than a core task in its own right.

Railways

22. In common with local roads, all forms of extreme weather can impact rail operations. Compounding this challenge is the fact that large parts of the railway's earthworks and embankments are 150 or more years old and not constructed to modern design standards. Much progress has been

made by Network Rail in recent years in addressing the various challenges, with increasing focus and expenditure on these key assets in both the previous and current Regulatory Control Periods².

23. Network Rail's 18,200km of embankments and cuttings are a particular area of risk, with some 105 earthwork failures this winter, a small number of which caused lines to be closed for significant periods. Network Rail is sharpening its risk assessment process and investing in a range of monitoring technologies but needs to do more work to determine the optimum level of spend on rectification of at-risk slopes and is in the process of agreeing this with the Regulator.
24. Network Rail also needs to substantially increase its focus on vegetation management and felling of trees which pose a risk or which are damaging embankments; some 1,500 trees or branches fell on the railway last winter causing a small number of routes to be closed for a day or more on several occasions, damaging substantial numbers of trains and posing a significant safety risk.
25. Network Rail coped relatively well with a number of flooding events during the winter, developing several innovative approaches to reducing the impact on services. However, it needs to more systematically identify route sections at risk from flooding, of whatever type, and apply these solutions proactively rather than reactively. Finally, Network Rail needs to undertake a review of route sections that are at risk from coastal storms or flooding, and determine what works would be required to make them resilient. The Weather Resilience and Climate Change Adaptation Plans being prepared by each Network Rail route should be used as the opportunity to address all of these issues.

Strategic Road Network

26. In contrast to the rail network, much of England's 4,300 miles of Strategic Road Network (SRN), managed by the Highways Agency (HA), is relatively modern, constructed to higher design standards, and has enjoyed more consistent maintenance over its life to date. It is therefore physically much more resilient. A significant risk is from flooding, but instances of this have been relatively isolated and often caused by run off from adjacent land or problems at junctions. Extreme weather, particularly high winds and intense rainfall events causing poor visibility and reduced traffic speeds, can disrupt traffic flows and lead to incidents, which then cause further disruption. The HA's focus is therefore rightly on measures to manage traffic flows during extreme weather and reduce the risk of incidents, and on processes to return operations to normal as rapidly as possible after any incident.
27. The HA should engage with the haulage industry to clarify the risks of high-sided vehicles being blown over on sections of highway that are particularly exposed to high winds, such as estuarial crossings. It should then develop proposals to keep such routes open to the majority of

²This is a five year period for which the Office of the Rail Regulation (ORR) has set out the financial framework within which Network Rail can operate. These include targets for performance and assumptions for efficiency.

traffic as long as possible by restricting the use of exposed sections by at-risk vehicles.

28. The HA should also be given greater flexibility as to how it uses its digital roadside variable message signs to inform road users of hazards and to publicise its other information channels, such as its website. In using the increased flexibility, the HA needs to give greater attention to increasing the credibility and usefulness of the information it puts out to build user confidence.

Local roads

29. There are 183,300 miles of roads in England managed by 152 local highway authorities. The sheer scale of this network, the very different types of road covered, from major 'A' roads to minor country lanes, across very different geographical areas, and the wide range of type and capacity of the responsible authorities poses a big challenge. Clearly it is essential to prioritise resilience activity on the more critical roads. Away from the coast, flooding is the principal source of disruption. In periods of stormy weather, fallen trees are a problem, whilst coastal areas can suffer significant wave damage and flooding from the sea.
30. Local Highway Authorities, with a strong focus on safety, handled the disruption of 2013/14 well, linking to the work of Local Resilience Fora in the most severely affected areas. However, additional damage was caused to a network already under strain. Over recent decades, a backlog of structural maintenance and renewal of roads has built up. This has left some roads more prone to damage, particularly degradation of surfaces, often leading to potholes, a problem compounded with a series of winters with difficult weather since 2008/09. This damage has a high profile with the public and politicians and many councils are struggling to deal with these repairs because of pressure on their resource budgets.
31. This is a vicious circle, for failure to deal with this regular maintenance, including the associated drainage, speeds up the deterioration process. The flooding this year has compounded this with erosion and water ingress into the sub bases of roads. There has been a lot of emphasis in recent years on developing more efficient and innovative ways of maintaining roads, and sharing good practice. The Department for Transport (DfT) has supported this with the Highways Maintenance Efficiency Programme (HMEP). The majority of highway authorities are now following the recognised good practice of using asset management principles, which can help optimise their spending. Such actions must continue, but it seems inevitable that, with continued public expenditure reductions, and the complex world of local government finance, some local authorities will be unable to maintain the current condition of all of their roads, which inevitably impacts on the resilience of some of the less important 'C' and unclassified roads.

Ports and airports

32. Ports are an essential and usually unseen part of our transport system. 95% of our imports and exports by volume come through them. The two main weather related hazards they face are from high winds and tidal surges. Ports generally have well-rehearsed procedures for shutting down operations in very high winds, when the docking of ships would otherwise become too hazardous, and when quayside equipment such as cranes needs to be locked down. But as sea levels rise, ports will need to give greater attention to improving their resilience levels to very high tides, including how they will cope with overtopping of quays for short periods, and protect critical infrastructure, such as IT systems and electricity sub-stations. They also need to liaise more closely with highway and railway authorities to ensure their operations are not unduly interrupted by disruption to inland transport links.
33. Airports also face a more specific set of extreme weather risks. The main hazard is high winds (snow and freezing conditions being out of scope of this Review), with aircraft not being able to land or take off when cross winds are above a certain strength. However this is a regularly encountered event, with well-rehearsed procedures.
34. As the events at Gatwick on 23rd December showed, flooding is an increasing risk, particularly from intense rainfall and flooding from nearby watercourses. Airports need to review their exposure to flood risks, and ensure that all critical infrastructure is protected. Airports and airline operations are also vulnerable to fog and thunderstorms, which disrupt aircraft movements on the approaches to airports as well as on the ground. More granularity of forecasting these events, in terms of their location and timing, would be of benefit in reducing disruption, as would some changes to air traffic control arrangements.

Summary of recommendations

35. The Review is very grateful for the contributions provided by all the parties involved in the development of the Review. The evidence gathered has allowed us to develop 63 recommendations which are summarised below and encompass roads, rail, ports and airports and different types of extreme weather - storms, flooding, high winds and heat. A good number of these can and should be implemented before next winter, or at least a firm start made in implementing them. Other recommendations, particularly relating to building physical resilience of key infrastructure in a changing climate are of a longer term nature. A full list of recommendations is included at Appendix G.

Recommendations for action prior to winter 2014/15

Just under half of the recommendations involve short-term action, prior to the onset of winter 2014/15.

Cross-modal

- 36.** The report recommends that all transport operators should:
- have contingency plans for extreme weather, developed and exercised with their principal partners in the industry (e.g. airports with airlines);
 - ensure they have clear channels for receiving weather and flood forecasts, monitored in real time during periods when extreme weather is expected;
 - develop, test and implement a dedicated passenger and user communications plan for times of transport disruption.
- 37.** Moreover, on communications, we recommend:
- giving prominence on websites to the latest service information during periods of disruption, ensuring that promotional information is relegated to the background;
 - using everyday language, not technical jargon;
 - knowing which channels passengers and other users refer to and using those channels appropriately in disruption;
 - ensure consistency of information provided through different channels and by different industry partners;
 - making greater use of photographs in social media, to improve transport users' understanding of the reasons for disruption.
- 38.** In terms of the service that should be offered, the recommendation is to plan for the best service which can reasonably be delivered, offering a high degree of certainty to passengers, other users and industry partners.
- 39.** There is also a recommendation that operators of strategic transport infrastructure should revisit their Climate Change Risk Assessments and Adaptation Plans in light of recent experience. On flooding, the Review recommends that the Highways Agency and Network Rail use the recently updated national Flooding Risk Maps to identify sections of the Strategic Road Network and railway routes that are potentially at risk of flooding.
- 40.** The workshops for ports provided by the DfT prior to last winter's tidal surge were praised and there is a recommendation that consideration is given to how these can best continue to be provided for port operators and extended to other sectors.

Local roads

- 41.** It is recommended that Local Highway Authorities identify a 'resilient network' to which they will give priority, in order to maintain economic activity and access to key services during extreme weather. Where Authorities have held formal reviews of the winter's events, they should ensure that these are enacted; Authorities which were not affected

should nevertheless continue to prepare themselves for future extreme weather.

42. The report also recommends that Government should consult Local Highway Authorities on a single set of criteria to be applied to emergency highway repair funding, to consume minimum administrative resource when applying for funds at times of crisis.

Rail

43. In response to the winter's flooding it is recommended that Network Rail should:

- develop plans to raise track heights and raise lineside equipment cabinets above track level on sections of track at risk of flooding, as part of its new Route Resilience Plans;
- consider accelerating introduction of axle counters for areas at high risk of flooding;
- deploy its new temporary automatic signalling system in the event of track flooding.

44. It is also recommended that, in the event of major disruption, coordination arrangements over adjacent geographical areas are enhanced.

Ports and Airports

45. The report recommends that all major ports and airports should review the location and flood-protection of their power, communications and IT infrastructure.
46. It recommends improved liaison between port operators, the HA and Network Rail to consider and develop resilient links to and from ports.
47. In order to provide greater certainty to travellers and operators, the report proposes that airports and their principal airlines should adjust capacity on a pre-emptive basis when extreme weather is coming, rather than waiting for the weather to hit.

Longer-term recommendations

Cross-modal

48. The Review notes the importance of maintenance activity to resilience and the more difficult funding position in terms of resource funding (as opposed to capital) and recommends that:
- the DfT and Treasury ensure that funding decisions for road and rail do not unduly restrict maintenance and resource expenditure;
 - the use of Asset Management Plans is strongly encouraged and used to inform funding decisions;
 - the DfT oversees development of benchmark ratios for highway maintenance spending to inform future financial settlements and promote maintenance efficiency.

- 49. The Review also notes that the true economic cost of disruption is not consistently captured and factored into spending decisions, so recommends that the DfT reviews current economic appraisal guidance and develops robust systems to ensure that the full costs of disruption and recovery are captured in industry appraisals.
- 50. Since protecting all parts of the network against all extreme weather events would be unaffordable, the Review considers prioritisation essential. It recommends the DfT works with the Department for Energy and Climate Change (DECC) and other Whitehall infrastructure interests to identify a 'critical network', comprising routes of national economic significance. That network should be maintained, and where appropriate enhanced to a higher level of resilience.
- 51. The Review raises questions about flood defence, noting that the Environment Agency flood defence formula is driven by protection of domestic property and does not specifically protect transport infrastructure. There are some key sites such as the Port of Immingham which the nation depends upon, but which are inadequately protected. It recommends that Government considers such cases and the argument for funding to supplement the private and public sector resources currently available.
- 52. On weather forecasting, the Review recommends that the Environment Agency and Met Office should work to further improve joint flood forecasting, particularly for complex coastal events.

Strategic Road Network

- 53. Given the importance of drainage to resilience, the HA should complete its drainage asset inventory. The Review also recommends that the HA should consult freight and other interests on the restriction of vulnerable vehicles on exposed sections of the Strategic Road Network during high winds, so that these locations can be kept open longer for all other users. It further recommends that the HA works with the Met Office to improve wind forecasts for the benefit of lorry fleet operators.
- 54. The Review recommends that the HA and the DfT should review the range and wording of messages displayed on variable message signs at times of disruption, and improve and refine the content of the HA website. Driver behaviour is an important factor in secondary disruption, and there is a recommendation that the DfT should review the content of the Driving Theory Test, to ensure adequate coverage of driving techniques for use in, and preparations for, adverse weather conditions.
- 55. The DfT should ensure that the new HA Government Company has, in its top-level performance indicators, network availability and that this is supported by appropriate indicators of asset condition.

Local Roads

- 56.** Local Highway Authorities should develop, maintain and work to Asset Management Plans and these should incorporate drainage. The DfT should proceed with its plan to use a proportion of funding to encourage the development and adoption of these plans, allowing local authorities time to prepare and implement those plans.

Railways

- 57.** On engineering structures, the Review recommends that Network Rail:
- amends its classification of embankments to take account of the economic importance of the traffic on the route;
 - continues to trial newly available condition monitoring and slope stabilisation technologies.
- 58.** Lineside trees were found to be a major factor in last winter's disruption and it is recommended that Network Rail:
- develops a ten year strategy to significantly reduce the number of trees, particularly those posing a risk to the railway and its users, and the overall level of vegetation;
 - develops an active biodiversity strategy including off-setting any reduction through tree planting, generally away from the railway;
 - makes appropriate budget provision for vegetation management;
 - addresses at-risk embankment slopes, with trees confined to the bottom one third or so of the slope where they can help stabilise it;
 - prevent re-growth on embankments, cuttings and the lineside after vegetation clearance.
- 59.** The Review also recommends that there should be a sharpening for the rail industry of the economic signals on tree falls, including the cost of rolling stock damage from trees and consequent overcrowding and poor performance. A review by the DfT is recommended relating to the 1842 legislation governing Network Rail's ability to tackle potential threats to safe operation of the railway which are on neighbouring land.
- 60.** We recommend that Network Rail should commission studies of the resilience of its sections of coastal railways in light of events at Dawlish. The rail industry should also keep its design standards under regular review in the light of evolving understanding of the impact of climate change on extreme weather. Network Rail should liaise with electricity suppliers to trace through power supplies and identify single points of failure to be made suitably resilient.
- 61.** In terms of managing in a crisis, it is recommended that the Rail Delivery Group continues to investigate more flexible techniques for producing contingency timetables. It is also recommended that the DfT, the Office

of Rail Regulation, Passenger Focus and the Rail Delivery Group should collaborate on an amended approach to performance and compensation regimes during periods of extreme weather disruption, which gives the right signals to the industry but is seen to be fair for passengers.

Ports

- 62.** Finally, the Review recommends that the Environment Agency and Met Office work together to improve the granularity and accuracy of coastal flooding forecasts, involving complex modelling of a variety of factors.

1. Introduction

Background

- 1.2** The winter of 2013/14 saw the UK affected severely by an exceptional run of winter storms, resulting in serious coastal damage and widespread, persistent flooding. Our transport network has, on the whole, proved resilient to the recent weather events. Resilience planners and operational teams have worked very hard in challenging circumstances to minimise service disruption to the travelling public. However, damage has been caused to some key assets, with disruption to service delivery.
- 1.3** Following these events, Richard Brown CBE, was asked by the Secretary of State for Transport to conduct an independent review of the transport network's ability to cope with extreme weather. This included types of weather not addressed by 'The Resilience of England's Transport Systems' review led by David Quarmby CBE, which considered snow, ice and low temperatures.
- 1.4** This report covers the following transport modes:
- Road – the Strategic Road Network (Highways Agency) and local roads (Local Highway Authorities);
 - Rail – the national rail infrastructure network (Network Rail) and train and freight operating companies;
 - Aviation – airports of economic and strategic importance;
 - Maritime and ports – ports of economic and strategic importance;
 - London – transport within the remit of Transport for London.

Panel members

- 1.5** An Expert Panel was chaired by
- Richard Brown, former Chairman of Eurostar and currently Non-Executive Director of the DfT.
- 1.6** The Panel also included:
- Brian Smith, former Executive Director, Environment and Transport at Cambridgeshire County Council, President of CSS (now ADEPT³) in 2008/09 and member of the Quarmby Review in 2010.
 - John Curley, former Regional Director of Network Rail; Infrastructure and Operations Director of First Group Rail Division, non-Executive Director of HS1 and Serco Docklands Light Railway (DLR).

³ Association of Directors of Environment, Economy, Planning and Transport

1.7 The Review support team consisted of:

- Chris Watts, DfT
- Hazel Schofield, DfT
- Iain Dickson, DfT
- Miles Gidlow, DfT
- Sharon Sottin, DfT
- Jayne Hemingway, Network Rail
- Paul Furlong, Highways Agency
- Dr Matt Huddleston, Met Office

1.8 The Review builds on the existing work of practitioners and policy makers, incorporating knowledge on climate modelling, and recommending appropriate, value for money actions to deal with future transport vulnerabilities.

Terms of reference

1.9 The full terms of reference for the Review are shown in Appendix A. The aim of the study is to identify practical measures to improve the resilience of our transport network to severe weather events in the short term, whilst also giving due consideration to longer term resilience of the nation's transport infrastructure. This will include plans looking to mitigate impacts from severe weather events; contingency planning to manage the effects; investigation of increased rates of asset degradation leading to reduced service life and performance, and adaptation of infrastructure to manage projected future risks. The Review outcomes formally recommended to the Secretary of State for Transport only apply to English authorities, but take account of the wider UK context. It is for Ministers of the Devolved Administrations to decide what action is required in those countries.

Methodology

1.10 From mid-March to mid-July 2014 the Panel and supporting team gathered and analysed evidence to understand the challenges that prolonged adverse or extreme weather present to the transport industry, and how these are being addressed.

1.11 The Review was structured in the following way:

- There was a review of related literature pertaining to lessons learned and recommendations of previous reviews to help assess the extent to which recommendations have been written into resilience procedures and processes, and how this has been implemented 'on the ground'. A list of the material is included in Appendix B
- On 20th March 2014, the Review published a 'call for evidence' to seek contributions from a range of stakeholders, including transport operators and providers; the local government community; major civil

engineering practices; maintenance contractors; the freight and logistics sectors; passenger groups; weather forecasters and climate scientists. This consisted of 18 questions which can be found in Appendix C. The 61 responses gave a broad range of information and helped inform which organisations to invite to 'Oral Evidence' sessions.

- A total of 29 detailed discussions took place between a wide range of parties and the Panel. These included a number of responders to the call for evidence and allowed discussion of evidence in greater detail. More detailed discussions were held with the Highways Agency and Network Rail reflecting the size of their networks. A list of the sessions is included in Appendix D.
- The Panel made 9 visits to see transport infrastructure in a number of areas impacted by the extreme weather of last winter. The visits included seeing transport assets, control centres and management teams responsible for operations. The full list of visits is included in Appendix E. Following this, a thorough analysis of the evidence was conducted, which informed the subsequent report and recommendations. The 63 recommendations have been tested with the key respondents to the call for evidence.

2. Extreme weather

Introduction

- 2.1** Consideration of the resilience of the transport system to extreme weather needs to be informed by a deeper understanding of weather: the typical weather patterns in the UK, the characteristics of extreme weather events and the changes anticipated in the light of climate change. This chapter seeks to do all of that, but also to put the extreme weather of 2013/14 into context.
- 2.2** The UK has a highly variable weather and climate. It is sited on the north west extremity of the European continent and eastern side of the Atlantic Ocean, where the latter moderates the climate giving a mean winter temperature (between 1981 and 2000) of 3.7°C which is significantly warmer than other locations at a similar latitude e.g. Calgary in Canada which has an average winter temperature of around -15°C.
- 2.3** Natural rhythms in atmospheric flows and ocean currents drive variations to our weather and climate day by day, year by year and even decade by decade. The jet stream is a high altitude fast moving ribbon of air that marks the separation of the polar and tropical air masses and which can move north or south. The exact position of the jet stream determines whether the UK receives a conveyor of storms, as we did in the winter of 2013/14, or has a summer heat wave.
- 2.4** On top of these variations, global man-made climate change is having its impact. A global average warming of 0.85°C since 1880 hides wide variations over time and region. The UK has been warming at a faster rate than the global average at 0.23°C per decade in winter and 0.28°C in summer since 1960. The underlying warming is however super-imposed on top of the large natural variations, such that any one season, year or indeed decade may mask the underlying trend.
- 2.5** Within these variations there are times where the risks to transport infrastructure from extreme weather are enhanced. These periods may last for just a single event – or longer. There is a general acceptance now that several types of extreme events will likely increase over coming decades, and that is already becoming clearer for heat waves and intense rainfall.
- 2.6** The direct weather impacts lead to issues such as surface water and river flooding, coastal damage from wave action and inundation from waves and storm surge, ground water flooding, land slips and sink holes. The primary risks being considered in this review are below. Risks associated with cold winter weather are not covered here having been considered by the Quarmby Review, 2010.

Primary weather risks

Intense rainfall

- 2.7** Intense rainfall leading to localised surface water flooding (pluvial) and flash river flooding (a type of fluvial flood), such as Boscastle on 16th August 2004. These are often, but not exclusively, caused by summer thunderstorms. Intense rainfall events are highly localised and last from minutes to a very few hours (details of historical events are included in Appendix F). Events such as these can overwhelm drainage capacity causing severe localised flooding. By their very nature, their exact location and intensity are often hard to forecast far in advance. The events around Gatwick of 23rd and 24th December 2013 appear to have primarily been caused by surface water flooding after intense rainfall, even though river flooding was also present.

Case Study: Cloudbursts

Intense rainfall events that last a few hours do happen in the UK, at their most extreme they have been called Cloudbursts. These are usually associated with summer thunderstorms and can lead to surface water flooding.

On 4th August 1975, 170mm (6.7 inches) of rain fell in a 24-hour period on Hampstead – with most of it falling during the evening rush hour between 17:30 and 20:00. This was the largest daily total ever recorded in the London area and severe flooding caused considerable damage to property and disrupted public services. The flooding brought substantial chaos to parts of London Underground. The Bakerloo, Metropolitan and Circle Lines were brought to a standstill by flooded tunnels and extensive electrical failures. Several mainline railway stations were also affected with services almost at a standstill during the evening. Services from St. Pancras were disrupted for over a week.

A similar catastrophic cloudburst event hit Copenhagen in July 2011 with 150mm arriving in 2 hours causing more than \$1bn of insured losses alone. There was extensive damage to critical infrastructure across the city with hospitals minutes from needing evacuation. Major roads in and out of Copenhagen were closed for several days and train tracks and stations flooded. This has led to an extensive redesign of water management in the city linking both the town planning and climate adaptation strategies. Lessons learnt have been passed to cities around the world (including through the mayoral led [C40 cities](http://www.c40.org/)⁴ project). These include an understanding that the excess water has to go somewhere when the sewer systems are full and emergency services need preparation for such events.

In England, locations near Gatwick had up to 76mm in 24 hours on 23rd and 24th December 2013, again with the most intense rain in a 2-hour period although the rain was not intense enough to be coined a Cloudburst on this occasion. It did however lead to extensive surface water flooding - inundating electrical switch gear serving the North Terminal.

⁴ <http://www.c40.org/>

Prolonged rainfall

- 2.8** Prolonged rainfall over a sustained period leading to inundation from river flooding (fluvial) and potentially groundwater flooding, although the latter is more likely to occur after longer periods of prolonged/ heavy rain than river flooding. These are often caused by high rainfall totals over an extended period e.g. 2007 summer or the 2013/14 winter. Ground saturation can also lead to a higher risk of surface water (pluvial) flooding. Other risks increase including dam-bursts and reservoir overtopping, land and embankment slips and sink holes.

Strong Winds

- 2.9** Wind storms (extra-tropical cyclones) can give rise to the most extensive damage over a wide area, occurring mainly in the autumn and winter, for example, the Great Storm of October 1987, and the St Jude's storm in 2013. The level of impact experienced from fallen trees can be greatly affected by contributing factors, such as whether trees are in full leaf or in saturated ground conditions, which can make them more prone to being blown over. In the winter of 2013/14, there were 12 major storms – 13 if one includes the autumnal St Jude's storm on 28th October, and although none were of exceptional magnitude, many included additional significant rainfall leading to a number of concurrent hazards. This made the winter of 2013/14 the stormiest period of weather experienced in the previous 20 years.

Heat waves

- 2.10** Heat waves occur when settled conditions in the summer lead to extended periods of high temperatures including high night-time temperatures – particularly in urban areas due to enhanced urban warming. Whilst it is typical to find a UK annual maximum temperature of around 30 to 33°C, the heat-waves of July 2006 and August 2003 stand out with daytime maximum temperatures of 36.5°C and 38.5°C respectively. For the summer of 2013, with a peak of 33.5°C, the most notable feature was its duration with 7 consecutive days exceeding 30°C - and its contrast with the previous run of wet summers.

Coastal storm surges

- 2.11** Coastal storm surges are complex events that depend on a number of conditions coming together. Firstly, strong winds push the sea water towards the coast, causing it to pile up and secondly a winter storm raises the sea level due to the low air pressure. If this occurs during a time of natural high tides, it can lead to significant coastal inundation. The surge can also impact areas away from strong winds especially along the east coast of Scotland and England. There can be additional impacts from waves and wind driven swell depending on the wind direction. In estuaries the impacts can be worse if river flows are high at the time the surge arrives. Furthermore one surge can lead to coastal flooding at a number of locations in quick succession and as such these events pose a very significant risk for coastal defences and infrastructure. The most famous event is the North Sea Flood of 31st January 1953 where 647km² of land was flooded and more than 300

lives were lost. The event of 5th December 2013 however came very close and the height of the surge exceeded the levels of 1953 at some locations. Advances in coastal defences put in place since 1953 have clearly prevented some of the worst impacts recurring.

Other weather hazards

- 2.12** Other weather hazards also affect transport. In particular fog is a hazard for most modes of transport but particularly it impacts airports and motorways. It is caused when a moist air mass is cooled and a suspension of water or ice crystals in the air directly above the land's surface leads to visibility of less than 1000m. This can happen when moist air rises (hill fog), on clear nights (radiation fog) and where moist air is blown over a colder land surface (advection fog). Typically Heathrow Airport will be in fog 5 days in winter, 1 day in spring, 1/3rd day in summer and 4.7 days in the autumn (average number of days from 1961-1990 Met Office Dataset).
- 2.13** Wind direction can be an issue where cross-winds are hazardous to landing aircraft and pose an overturning risk to high-sided and other vehicles on exposed roads. These events can receive less media and internet attention but still lead to significant disruption.
- 2.14** Hail is related to convective storms and occurs in the UK most frequently from May to August, with the South East of England having more events, although they can happen at any time of year and location. Hail stones are usually a few millimetres in size but can be up to 200mm. The UK rarely has very large hailstones that cause direct damage e.g. to car windscreens. Even small hail does pose a significant risk to drivers through skidding. An extreme hail and intense rainfall event in October 2008 in the Devon town of Ottery St Mary lead to 1.2m drifts of hail which blocked drains and caused even further flooding on melting.
- 2.15** Lightning is a huge electrical discharge that flows between clouds, from a cloud to air, or from a cloud to the ground. Apart from the obvious risks to public safety, transport infrastructure can also suffer severe damage from lightning strikes and the associated electrical discharge. Lightning is often located within violent storms and causes bursts of radio waves. These radio waves can be detected by the Met Office and are used to locate the exact position of the strikes in real time. This information is then used by transport operators to anticipate a storm's path and manage any risks.
- 2.16** All of the events lead to further impacts, and many of these are associated with flooding. See Table 2.1 for a full description of types of flooding. It is worth noting that all of the types of flooding below occurred extensively in the winter of 2013/14.

Table 2.1 - Types of flooding

| Type of flooding | Description |
|-----------------------------------|--|
| River or Fluvial Flooding | Rivers burst their banks when they cannot cope with the amount of water entering them from upstream, tributaries and surface run-off. Estuarine rivers may also be impeded depending on tidal and sea-level conditions (see Coastal Flooding). |
| Surface water or Pluvial Flooding | This happens when there is intense rainfall - often on ground that is already saturated or on hard dry ground or paved areas where drainage is poor. The intensity of the rainfall is such that the natural or man-made drainage capability cannot cope. It can lead to pooling of water that cannot drain away. Sudden snow-melt or hail-melt can also give surface water flooding. |
| Coastal Flooding | Weather and tidal conditions can increase sea levels, through surge, which can flood coastal areas. Off-shore waves and the prevailing wind direction are also important. |
| Groundwater Flooding | When rainfall causes an increase in the amount of water that is naturally stored underground, which rises to the surface and causes flooding. |

2.17 When a number of extreme weather events happen concurrently, such as a wind storm, coastal storm surge, high tide and heavy rain affecting a single critical location, this represents the highest risk for disruption.

The events of autumn and winter 2013/14

The weather

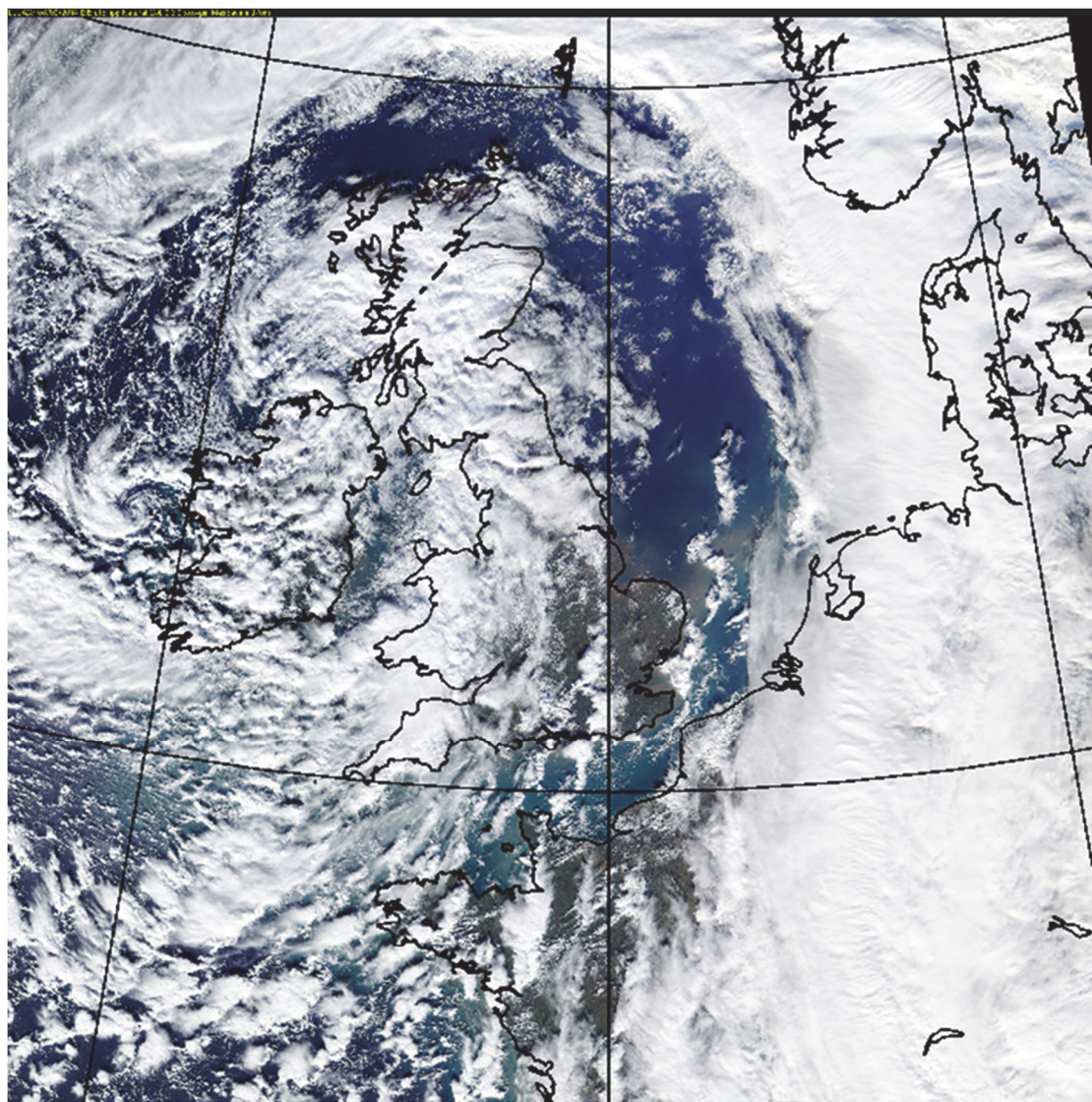
2.18 Winter 2013/14 was an exceptionally stormy season, with at least 12 major winter storms affecting the UK in two spells from mid-December to early January, and again from late January to mid-February. Whilst most of the individual storms were not exceptional and indeed could have been worse, an analysis of pressure fields by the University of East Anglia suggests this winter has had more very severe gale days than any other winter season in a series from 1871.

2.19 The persistent heavy rainfall through the season resulted in this being the wettest winter for the UK, England, Wales and Scotland, and the second wettest winter for Northern Ireland in records from 1910. It was also the wettest winter in the long running England and Wales Precipitation records from 1766. There were more days of rain during the winter than any other in records from 1961. There was major flooding, with the Somerset Levels remaining underwater for much of the season, and flooding also affected large sections of the River Thames. High winds combined with high tides and tidal surges to cause dangerous conditions and considerable damage to many coastal areas, particularly in the south west of England, and Wales. The westerly and unsettled weather meant that conditions were mild, with snowfalls largely confined to the Scottish mountains, and fewer air frosts for the UK than for any other winter in a series from 1961.

- 2.20** Mean temperatures over the UK were well above the long-term average for all three months with a mean winter temperature of 5.2°C which is 1.5°C above the average and the fifth highest in a series of observations running from 1910. There was a notable absence of frosts, and the lowest UK temperature of the winter, was -7.7°C recorded at Altnaharra, Sutherland on 17th February and this was the least cold winter value for at least 50 years.
- 2.21** Rainfall totals in December exceeded twice the monthly average across much of south east England, where it was the wettest December, in a series from 1910. The UK overall recorded 154% of December average rainfall. In January, much of southern England recorded two to three times the average rainfall and in south east England it was the wettest calendar month in the series from 1910. The UK overall recorded 151% of January average rainfall. The wet theme continued through February which was the 4th wettest in the series. For winter overall the UK received 161% of average rainfall. Some parts of the country had in excess of twice the average winter rainfall, with the south east and central south of England receiving 238% of average winter rainfall.
- 2.22** Despite the wet weather, much of central, eastern and southern England was sunnier than average throughout the winter. However, western areas of Wales and Scotland were notably dull. For the UK overall there was 104% of average sunshine hours.
- 2.23** Ahead of the 2013/14 winter a powerful autumnal storm occurred on 28th October, St Jude's day. The storm was due to a fast-moving, vigorous Atlantic depression, bringing both very strong winds and heavy rain. Winds gusted widely to 50-60 knots (58-69 mph) and reached 60-70 knots (69-81 mph) across south east England. The highest recorded gust speed was 86 knots (99 mph) at Needles Old Battery (Isle of Wight). Most of the damage was associated with falling trees - still in full leaf at this time of year - and this storm is judged to be within the top ten most severe storms to affect southern England in the last 40 years. However, it was not in the same category as the Great Storm of 16th October 1987.
- 2.24** The storm of 5th December brought very strong winds to Scotland and northern England, and a major storm surge affecting west, north and east coasts. The surge height exceeded that of 1953 in many locations including the key port of Immingham. The storm surge at Dover was calculated to be a 1 in 1000 year event. A week of quieter weather then followed, but from mid-December there was a succession of further major winter storms which continued into early January.
- 2.25** At the start of the winter most of the weather impacts related to the strong winds, first across the north of the UK and then affecting exposed areas further south. However, as rainfall totals accumulated, the focus of concern shifted from strong winds to flooding, including large river catchments such as the Severn and Thames. Finally, in early January, strong winds, combining with high spring tides and river flows, resulted in high water levels and large waves affecting exposed coastal communities in the south and west, causing coastal flooding and extensive wave damage.

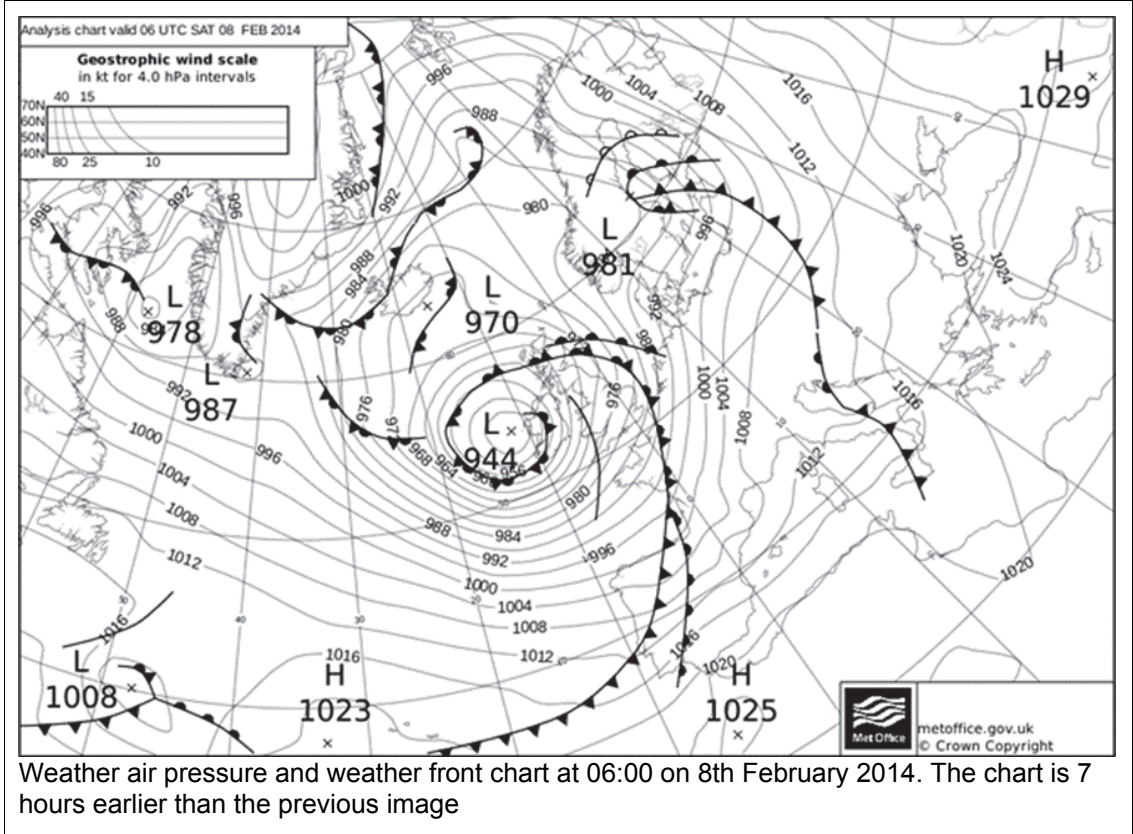
- 2.26** The UK experienced a second sustained spell of extreme weather from late January to mid-February as a succession of severe storms brought widespread impacts and damage to the UK.
- 2.27** Around 6 major storms hit through this period, separated by intervals of 2 to 3 days. See Figure 2.1 for a picture of one of these storms. Taken individually, the first two storms were notable but not exceptional for the winter period. However, the later storms from early to mid-February were much more severe. For example the Highways Agency had 37 incidents in the four day spell from 12th to 15th February.

Figure 2.1 - Satellite image from 8th Feb 2014



Visible satellite image from 13:15 on 8th February 2014 showing one of the 12 storms that hit the UK during winter 2013/14. The centre of the storm is situated to the north of Northern Ireland

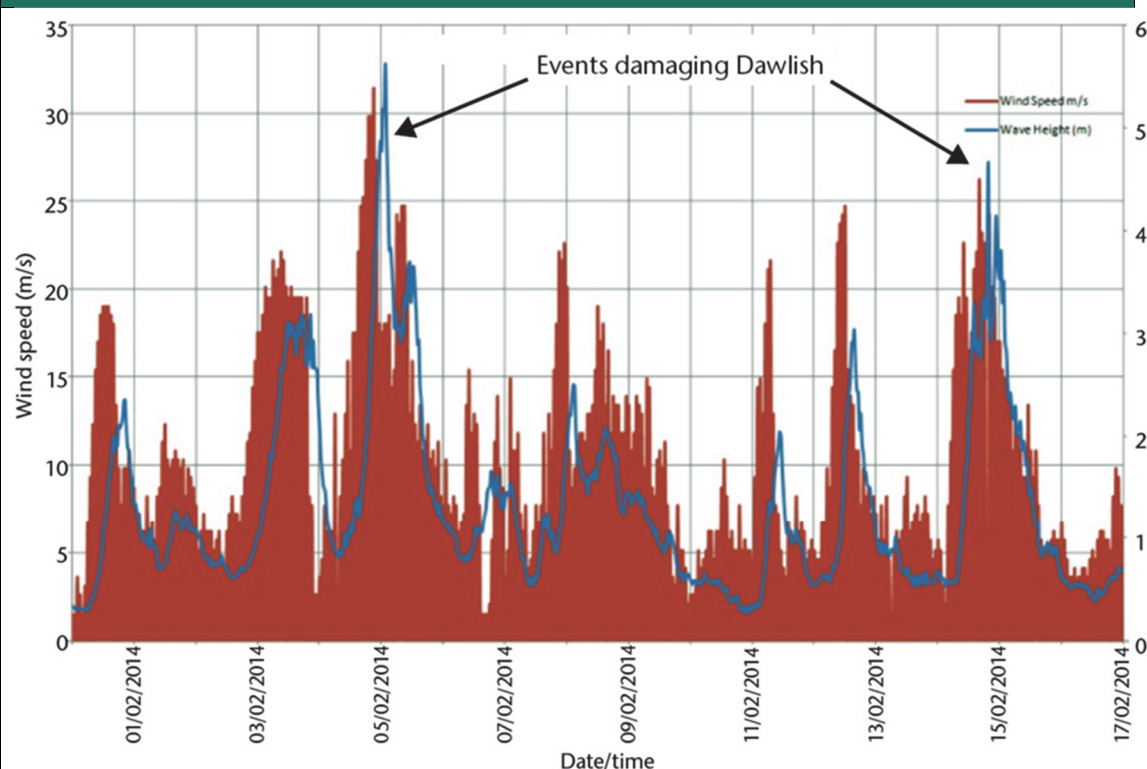
Figure 2.2 - Weather map from 8th February 2014



2.28 Only the St Jude's storm in October 2013 features significantly in the top

- 10 storms hitting the UK in the last 45 years. The St Jude's storm comes in 7th in the series, whereas the Great October Storm of 1987 comes in 2nd. The storms from winter 2013/14 do not feature in this top 10, highlighting that it was the succession of storms, rather than individual events, that led to the extensive impacts.
- 2.29** Strong winds and large, high energy waves made conditions extremely dangerous close to exposed coastlines - particularly in the south and west, and caused widespread transport disruption. An example of the wave height and wind speed near to Dawlish is shown in Figure 2.3. It was the peak event on 5th February that destroyed the main railway line to Plymouth leading to line closure for 2 months. The wind direction changed however away from the shore before the high tide and so the surge could have been worse.

Figure 2.3 - Dawlish wave buoy height vs Berry Head wind speed



This shows a comparison between the wave heights recorded at the Dawlish wave buoy against the wind speeds recorded at the Berry Head weather gauge from 31 January 2014 to 17 February 2014. Wind speed is in red, and wave height is the blue line. Berry Head is a headland approx. 10 miles south of Dawlish.

2.30 Over the winter a total of 21 Amber Warnings and one Red Warning of severe weather were issued by the Met Office. These warnings are issued in advance of the types of weather that can lead to widespread disruption – they take into account the potential impact and likelihood of severe weather. The Met Office National Severe Weather Service is communicated to the public through a range of channels, including national and regional TV broadcasts as well as to a range of public sector bodies and Local Resilience Fora.

2.31 The Environment Agency closed the Thames Barrier 50 times during the winter floods to reduce flood risk, representing 27% of the total closures in response to flooding since it became operational in 1982. Some of these were to manage potential upstream flooding rather than tidal issues or coastal storm surge.

Summary

2.32 The 2013/14 winter was exceptional in terms of the overall rainfall totals, the number of storms and the number of stormy days. These events lead to a significant number of transport impacts across all modes. However, the individual storms were not exceptional and should be expected as part of a typical winter. The concurrency of strong winds, heavy rain, flooding and the frequency of the severe weather were the significant factors in making winter 2013/14 exceptional.

Projected changes in extreme weather events

- 2.33** Underlying the natural fluctuations of weather patterns, additional trends from global climate change from greenhouse gases are of a serious concern. The global consensus view from the 2013 IPCC 5th assessment report is that: "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century".
- 2.34** The warming of the global atmosphere is accompanied by a variety of changes to components of the water cycle including rainfall, sea level, sea and land ice and other natural phenomena. The impacts of these are regionally dependent – they vary around the globe and are experienced together with the local natural variations.
- 2.35** In the UK, the impacts of climate change have been assessed by the Met Office Hadley Centre as part of the UK's [National Climate Capability](#)⁵ in a full range of detailed climate scenarios. These datasets, along with extensive historical data and other tools were released by Defra through the UK Climate Impacts Programme and UK Climate Projections 2009 (UKCP09) and have been used widely to develop Climate Change Adaptation Plans within the transport industry.
- 2.36** In 2014 the Met Office Hadley Centre additionally summarised the natural man made impacts on hazards and seasonal weather stating "the role of human influence on our climate system is already detectable on summertime heat waves and on the character of UK rainfall".
- 2.37** Extreme weather events by their nature happen rarely and as such there is relatively little data to verify past trends and patterns. The understanding of the future impact of climate change on extreme weather events is also an emerging science that faces similar data scarcity issues. Additionally, climate models have not until recently been able to run at a high enough granularity to capture events such as changes in summer intense rainfall. Given that, the impact of climate change on the weather events that impact transport have been assessed as follows:

Intense Rainfall

- 2.38** The high variability of rainfall in the UK makes trends hard to detect. However, there is an increasing body of evidence that extreme daily rainfall rates around the world are becoming more intense, and that the rate of increase is consistent with what is to be expected from fundamental physics (i.e. warm air holds more moisture). There is evidence in the UK that the character of rainfall is changing with very heavy rain becoming more frequent. A rainfall event which might have been expected on 1 in 125 days in the 1960s and 1970s might now be expected once in every 85 days. Very recent research has also developed a climate model that can reproduce summer storms and suggests increases in the most extreme summer rainfall events.

⁵ <http://www.metoffice.gov.uk/climate-guide/science/science-behind-climate-change/national-capability>

Prolonged Rainfall

- 2.39** The overall trend given in the UKCP09 climate projections is for winters to become wetter and summers drier but this does not mean that a very wet summer or very dry winter will not occur at all, only that their likelihood is expected to fall over time. Five of the last seven summers have been wetter than average and prior to that there was a run of drier than average summers. This variation is thought to be part of a natural cycle. Droughts that last several winter's seasons, when the aquifers are not recharged will also be tied to changes in these natural cycles.

Strong winds

- 2.40** There is low confidence in the trends from climate change on strong wind events. To a significant degree this is because of the large variability in the storm track caused by natural climate variations affecting the jet stream. Recent studies suggest an increase in the strength of Atlantic storms that take a more southerly track, typical of this winter's extreme weather. Also the long-term warming of the sub-tropical Atlantic will also act to enhance the amount of moisture being carried by storms that take this more southerly track.

Heat waves

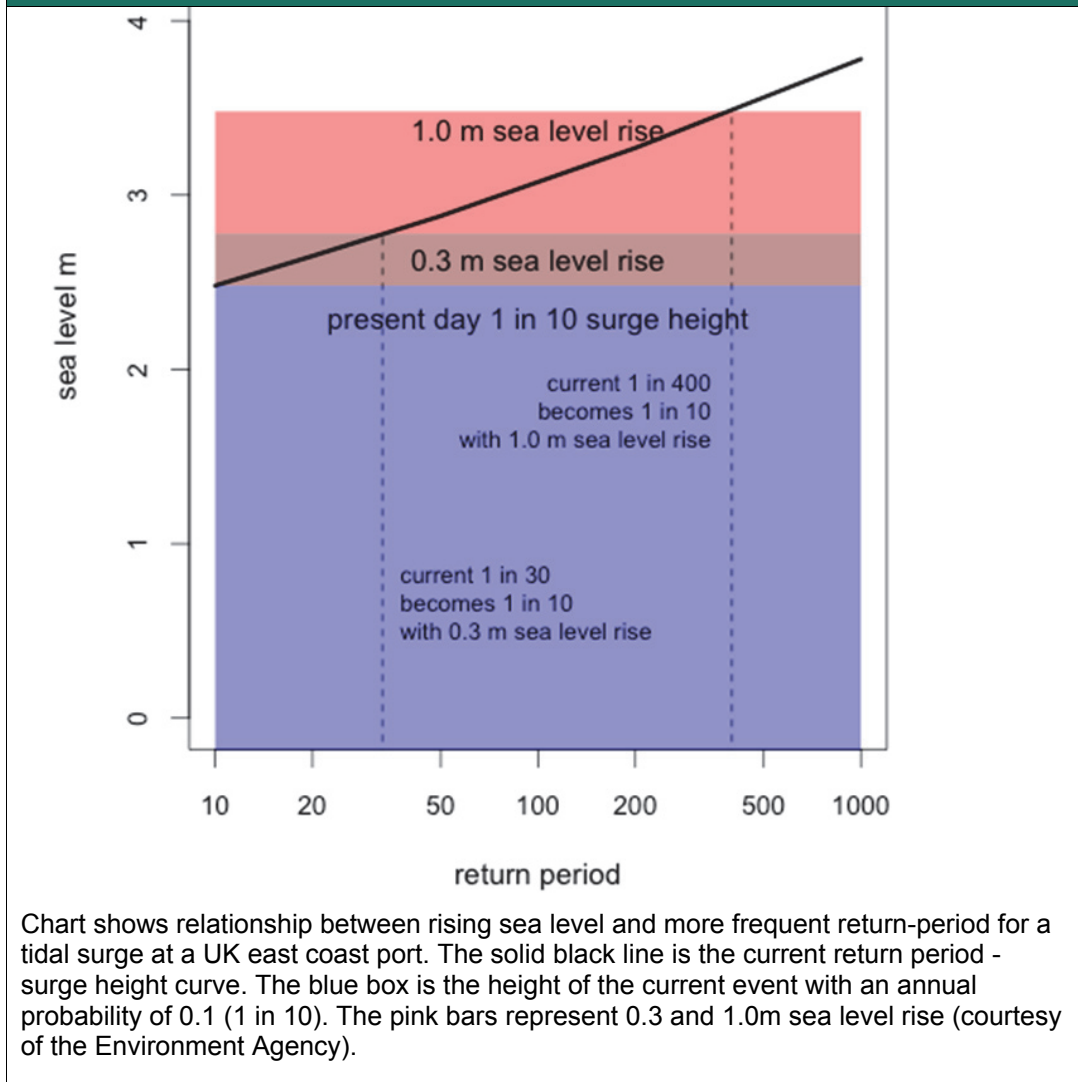
- 2.41** Heat waves in large parts of Europe are likely to have increased since 1950. Climate change has at least doubled the likelihood of a heat wave exceeding the temperatures experienced in the heat wave of 2003. Observations of temperature across Europe since 2003 suggest that we are continuing along a track where, by the 2040s, more than half of the summers are projected to be warmer than that seen in 2003 if emissions of greenhouse gases continue along their current rising path.

Storm surges

- 2.42** The main component of future climate change to affect storm surges is the inexorable rise in sea level from melting ice and expansion from warming of the oceans. This second component is because water expands in volume as it warms. Sea level along the English Channel has already risen during the 20th century due to ocean warming and melting of glaciers. With the warming we are already locked into over the next few decades, a further overall 11-16cm of sea level rise is likely by 2030, and 18 to 26cm by 2050, relative to sea levels in 1990, of which at least two-thirds will be due to the effects of climate change. These figures are for London, as the amount of sea level rise varies regionally around the coast of the UK.
- 2.43** Storm surges are an area of relative confidence in terms of changes in extremes - especially as the storm surge from Hurricane Sandy that inundated New York has already been partly attributed to climate change. Figure 2.4 - Impact of rising sea level on surge height shows the impacts of sea level rise on the return period of storm surge events for a UK port. A current 1 in 400 year event becomes a 1 in 10 year event with 1.0m of sea level rise. This means that the standard of protection of existing coastal defences will reduce over time. The longer the time

window considered, the greater the influence of sea level rise and therefore the greater the increase in chance of a significant event occurring.

Figure 2.4 - Impact of rising sea level on surge height



Other weather hazards

- 2.44** Fog has been assessed in a supplementary report of the UK Climate Projections 2009. Whilst a full assessment is not possible in comparison to, for example, heat, analysis of 11 regional climate models has been done to assess fog. In summary, reductions in the number of days with fog are projected for most places and seasons, with the main exception being southern Britain in winter, where increases of 0-30% are expected by 2080s.
- 2.45** Lightning has also been assessed in a similar manner to fog where increases in the number of lightning days are projected for all four seasons across the whole of the UK. The uncertainty in the estimated changes in lightning are substantial.
- 2.46** There has been very little research done on the impact of climate change on wind direction or hail. Hail has been assessed in one paper by the

Met Office Hadley Centre using 25km regional models, and here hail was expected to reduce under climate warming. The latest models that can resolve atmospheric convection running at 1.5km have not been assessed.

Summary

- 2.47** The UK has a highly variable weather pattern in which a wide range of events are experienced. A series of extreme weather events in the winter 2013/14 had significant impacts, both individually and cumulatively, on a major part of the UK. The impacts and experience of these are reflected in the coming chapters.
- 2.48** Whilst there is a degree of variability in the confidence attached to projected changes in weather due to climate change, we can expect more warmer wetter winters and hotter drier summers. Those summers will tend to see the most intense storms becoming even more intense. The rise in sea levels will increase the risk of coastal flooding.
- 2.49** Whilst individual events and seasonal variations will mask this long-term trend (i.e. we will still experience very cold and/or dry winters from time to time), these changes in weather need to be reflected in the plans, practices and engineering standards of the transport industry. Again, this is reflected in the chapters that follow.

3. Common issues across transport modes

Introduction

- 3.1** Before addressing the resilience of each individual mode of transport, it is important to highlight a number of issues, most of which are relevant to all forms of transport and should inform the overall approach to building transport resilience. This is partly about ensuring we develop an economically rational approach to spending on resilience, ensuring that enough is invested, with the right prioritisation, and avoiding wasteful and economically unjustified expenditure. It is also about ensuring that resilience is addressed across the transport sector as a whole, considering end to end journeys for users, passengers and freight and the alternatives available, and recognising the interdependencies between different modes.
- 3.2** Many of the UK's transport facilities are very intensively used and becoming even more so as demand continues to grow. Our railway network is the most intensively used in Europe, in terms of train-kilometres per kilometre of track and this will increase steadily in the future as both passenger and freight demand grows. Heathrow is the most intensively used two-runway airport in the world (in terms of take-offs and landings per runway), and Gatwick is the most intensively used single runway airport. The Strategic Road Network managed by the Highways Agency is also intensively used, operating at capacity on a number of sections at busy times, and with traffic volumes forecast to increase by more than 45% by 2040⁶. Many local roads are also similarly at or close to capacity at busy times.
- 3.3** But the closer to capacity that a transport route or facility is operating, the greater the impact in the event of something going wrong. The impact will be felt more quickly, with more people affected, and because there is little or no spare capacity, recovery will take longer. Often the impact of extreme weather is to restrict capacity, for instance ground water flooding on the rail network or a partly flooded road, restricts capacity and is highly disruptive to users. Access to maintain the infrastructure is also more difficult, without unduly disrupting users. It is therefore especially important that there is a good level of attention and investment devoted to physical resilience of intensively used routes and infrastructure.
- 3.4** How transport and infrastructure operators manage their services during periods of disruption is an important part of their overall resilience. Whilst the extreme weather of winter 2013/14 had a significant impact on

⁶ DfT Road Transport Forecast 2013 - results from the DfT's National Transport Model

travellers, we consider that in general most operators managed better during last winter's disruptions than in previous years, with good evidence of improvements based on learning from past experiences.

3.5 We see that ensuring resilience to extreme weather has three layers to it:

- It is about increasing the physical resilience of transport systems to extreme weather, so when extreme weather is experienced, people and goods can continue to move.
- Secondly it would be both very difficult and prohibitively expensive to ensure total physical resilience, so it is equally about ensuring processes and procedures to restore services and routes to normal as quickly as possible after extreme weather events have abated.
- Thirdly, as part of this it is essential to ensure clear and effective communications to passengers and transport users, so that the impact of disruption on people and businesses is minimised.

All three layers are important if the impact of extreme weather on travel and transport is to be minimised.

3.6 We also see that managing for resilience has close parallels to managing for safety. The first priority of transport operators and infrastructure authorities during extreme weather is to ensure the safety of passengers and road users, just as it is during day-to-day operations. The risk of accidents is greater during extreme weather, and so a number of the mitigating actions by transport operators are designed to reduce the risk of accidents and incidents - and so avoid the additional disruption they would cause.

An economically rational approach to spending on resilience

3.7 Witnesses to the review gave us a stark and consistent message that it is primarily maintenance expenditure (including capital maintenance for local roads) rather than capital investment which determines the resilience of infrastructure assets. The vast majority of the transport infrastructure that we will have in 30 years' time is infrastructure that we already have. Basic maintenance tasks such as regular clearing of drains, maintenance of pumps, clearance of vegetation, and inspection and monitoring of structures and earthworks are all essential to maintaining the resilience and performance of infrastructure assets. Equally, the resources needed for recovery, such as Highways Agency Traffic Officers and maintenance teams to clear fallen trees, are all paid for out of resource rather than capital budgets.

3.8 But in the public sector it is resource expenditure that successive governments have sought to bear down on, in contrast to capital expenditure which has been maintained or increased for railways and is now planned to increase for roads. Many witnesses cautioned about the risk of cutting the resource expenditure necessary for road and rail resilience, and expressed concern that local roads already had a backlog of maintenance. In addition, basic tasks such as drainage maintenance

had not always received the necessary priority so that assets did not perform as designed.

- 3.9** Ensuring the right balance between asset maintenance and replacement is a central feature of good asset management. Understanding what level of maintenance is necessary to maintain the performance of an asset is core to optimising its whole life cost and performance. This is exactly what effective asset management systems seek to achieve. Government should therefore use the asset management planning process as its guide to ensuring an appropriate balance between resource and capital expenditure, and strongly encourage those infrastructure operators that do not have such plans to produce them. It should also encourage the wider adoption of benchmarking to ensure that maintenance expenditure and activities are undertaken as efficiently as possible.

Recommendation 1:

The Department for Transport (DfT), Department for Communities and Local Government, Office of Rail Regulation and Treasury should ensure that funding decisions for road and rail are informed by asset management plans and do not unduly restrict maintenance and resource expenditure that is necessary to maintain transport network resilience.

Recommendation 2:

For railways, strategic roads and local roads, the DfT should develop benchmarks for expected volumes and efficient costs of maintenance activity related to given transport asset populations and associated condition assessments. These benchmarks should inform the financial settlements with the respective infrastructure bodies.

- 3.10** Transport assets may often perform satisfactorily in normal weather conditions, but not always in extreme weather. There is therefore an additional judgement to be made as to how much extra it is worth spending to achieve extreme weather resilience, where feasible. This is essentially a risk decision: what is the likelihood of an extreme weather event, what is the cost of repairing any damage caused and of the disruption to users that results, compared to the cost of the measures necessary to prevent damage and disruption? Too often, decisions to fund resilience are reactive to specific events, rather than based on any established economic rationale.
- 3.11** For investments involving the rail network or the Strategic Road Network, Network Rail and HA are responsible for preparing the business cases. To ensure consistency, the DfT has a well-developed methodology for appraising transport investment schemes, known as WebTAG. This provides a framework with which to appraise options, and although it does not provide explicit guidance on issues of resilience, it does provide the information required to compare the costs and benefits of schemes with varying levels of resilience.
- 3.12** Because the responsibility for preparing the business case rests primarily with Network Rail and the HA, the costs of non-resilience are often

estimated, using the direct costs to these network operators rather than the wider social and economic losses. For example, in the case of national rail, the industry performance regimes established by the Office of Rail Regulation (ORR), as part of the periodic review process, which apply when the network is not available for normal running, lead to an underestimate of the costs of non-resilience. It would therefore be useful for the DfT to have a dialogue with those charged with making investment decisions on their networks as to how the full economic costs of disruption can be captured in the decision-making process.

Recommendation 3:

The DfT should work with Network Rail, the Highways Agency and local highway authority representatives to understand how the full costs of disruption can be better accounted for in network investment decisions.

Potential single points of failure

3.13 One question raised with the Review Panel was whether there are potential 'single points of failure' on our strategic transport networks. This arose particularly because of the experience of the winter of 2013/14, where the South West peninsula was at times perceived to be at threat of being 'cut off' through a combination of coastal storm damage to the Great Western main line on the railway at Dawlish, flooding at Cowley Bridge between Taunton and Exeter on that same line, fluvial flooding of the Somerset Levels severely affecting rail capacity and groundwater flooding affecting strategic road sites such as the A303 and A36.

3.14 We commissioned an initial analysis in response to this question by the Transport Systems Catapult and Professor Chris Baker. This has provided us with a plausible methodology for identifying areas where strategic transport routes are vulnerable to extreme weather in such a way as to threaten essential connections. We consider that further analysis can usefully be undertaken working with the Met Office, Highways Agency, Network Rail and others, and considering the potential of 'big data' to assist in identifying such vulnerabilities. This in turn could help to inform decisions on investment in the resilience of the network.

Recommendation 4:

The DfT should work with researchers, the devolved administrations and the transport industry to further consider whether there are potential 'single points of failure' in the strategic transport networks, which leave parts of the country at risk of having vital economic and social links severed.

End to end journeys

3.15 A number of respondents emphasised the importance of considering transport resilience across modes so that people can continue to travel and freight can continue to be moved on end to end journeys. Getting to

and from the airport is as important as being able to fly after getting there, and moving goods to and from ports is as important as being able to dock and unload ships at the port. Local roads to and from bus depots and train depots are important in ensuring both essential staff can get to work and buses can get out onto the main highway network.

- 3.16** Equally all respondents acknowledged that it is not possible to ensure all roads and rail lines are resilient to all extreme weather and not all routes have equal significance. Some roads, rail routes, ports and airports have a particular national economic importance, either because of the number of passengers or weight of freight using them, or the significance of particular commercial traffic. It is important to prioritise investment in resilience in these routes. Given this, the DfT should identify the critical network, know which routes these are and seek to ensure that they are maintained, and where appropriate enhanced to a higher standard in order to mitigate the effects of extreme weather. The critical network is likely to include the SRN and inter-city rail routes, but it should also include key commuter routes into major centres of employment and a small number of local roads and minor rail lines where these link to ports and airports with economically and socially vital traffic flows, such as energy supplies.

Recommendation 5:

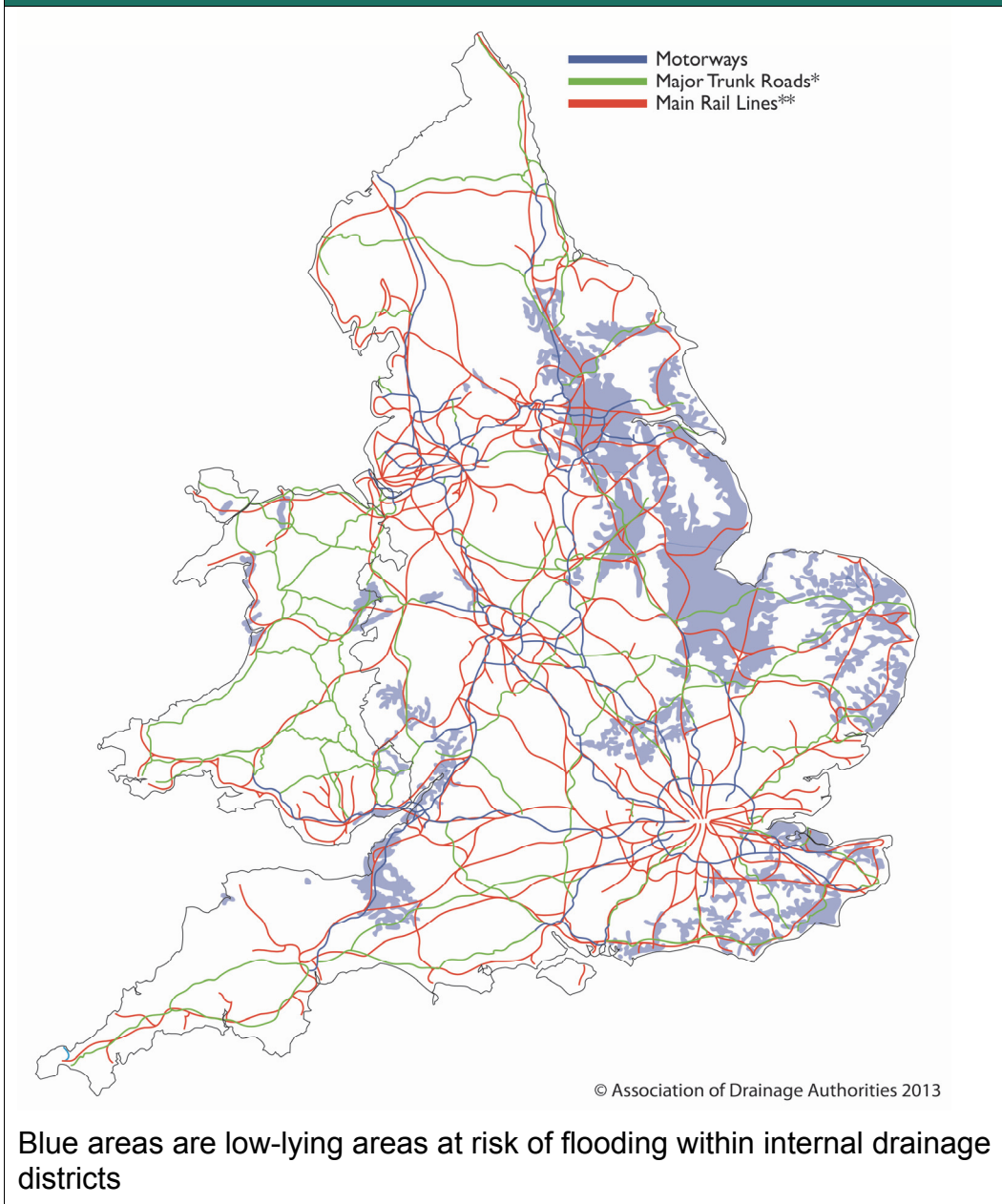
The DfT should work with other Whitehall infrastructure interests and industry to identify a 'critical network', comprising those routes which are of national economic significance. Once identified, the DfT should work with the relevant industry partners to ensure that this network is maintained and enhanced where appropriate to a standard which provides for a higher level of resilience to the effects of extreme weather.

Flood defences

- 3.17** We have found that the management of drainage, water levels and flood prevention in England involves a large and complex network of organisations. The Environment Agency has overall strategic responsibility for flood defence planning, and is the main funder of flood defence works. However its remit is primarily to protect homes and manage natural habitats. Within the overall framework, county councils and unitary authorities have responsibility to produce local Flood Risk Management Strategies for their areas, in consultation with district councils and other interested parties. There are also Regional Flood and Coastal Defence Committees, which have responsibility for producing Shoreline Management Plans for coastal flood defences, although the prime responsibility for maintaining sea defences lies with the coastal landowner. Finally, there are 114 Internal Drainage Boards (IDBs), covering nearly 10% of the land area of England, which are statutory local public bodies in areas of special drainage need, usually land areas below river or sea level. IDBs manage the water levels in their areas to ensure optimum land drainage and reduced flood risk.

3.18 All of these organisations and fora are relevant to transport operators in their resilience planning. Clearly county councils and unitary authorities are also local highway authorities, and therefore better able to engage, and we discuss how drainage and flood risk planning needs to be better integrated with local Highway Asset Management Plans in Chapter 5. But it is important that the HA and Network Rail map out their interfaces with these various bodies and cross refer to their plans and flood defence works. Some 6% of the motorway network and 5% of the rail network in England lie within IDB areas, which would be highly prone to flooding but for the activities of the IDBs, and we believe that a closer relationship between the HA, Network Rail and relevant IDBs would be beneficial to both. There may even be benefit in them supporting the creation of new IDBs, in flood risk areas not covered by an IDB currently. See Figure 3.1.

Figure 3.1 - Drainage authority areas mapped against road and rail network



- 3.19** Likewise it is important that transport operators liaise closely with the Environment Agency on the planning of flood defence works. We note that Network Rail and the HA have signed Memoranda of Understanding (MoU) with the Environment Agency which is an important step towards building closer relationships. We suggest all parties build on their MoUs by holding regional workshops of their respective engineers and planners to better understand each other's constraints and objectives, within a shared interest in more resilient flood defences.
- 3.20** Funding of flood defence works is a particular issue. Because the Environment Agency's main focus is not to protect transport infrastructure or businesses, and it has a limited budget, it often seeks partnership funding from local authorities, businesses or infrastructure operators in order to fund planned projects. We have come across cases

in the course of this review where there is a clear intellectual case for a wider, community flood protection scheme to protect households, businesses and infrastructure, but where the compartmentalisation of the approach means that part of a potential scheme is fundable, but funding of other elements cannot be justified. This is true of the Immingham, as noted in Chapter 7.

- 3.21** The Review is of the view that, while the focus on protection of homes and people is understandable, it leads to a regime in which transport infrastructure can be left relatively exposed to flood risk. This is particularly concerning where such unprotected transport links provide important economic corridors, such as strategic ports and major rail routes which are vital to economic and social wellbeing.

Recommendation 6:

HM Government needs to identify cases where transport infrastructure which supports nationally vital passenger flows and supply chains, is insufficiently protected and enhancement cannot be fully funded by the current flood protection funding formula. Where such cases are identified, it should closely consider the case for funding to supplement the resources, from both public and private sectors, which are currently available.

Neighbouring property

- 3.22** A common theme for both road and rail networks is the impact that neighbouring property owners can have on the resilience of a route when they fail to adequately discharge their responsibilities as land owners. Trees from neighbouring land blown over in high winds are a frequent cause of disruption, blocking roads and rail lines. Similarly, poorly maintained neighbouring drains or surface water run-off from adjacent fields are a common cause of road or rail flooding. We came across a useful [information leaflet](http://www.gloucestershire.gov.uk/CHttpHandler.ashx?id=26530&p=0)⁷ from Gloucestershire County Council for owners of property with watercourses running through, which provided helpful guidance on their rights and responsibilities as 'riparian owners'. Network Rail and highway authorities have some powers of access to address these hazards, but ideally they should be addressed on a proactive basis and by agreement. More generally, however, there may be a case for a straightforward 'code', along the lines of the Gloucestershire model, setting out the responsibilities of both transport infrastructure owners and adjacent landowners and the consequences of failing to maintain assets.

⁷ <http://www.gloucestershire.gov.uk/CHttpHandler.ashx?id=26530&p=0>

Recommendation 7:

The Highways Agency, Local Government Association and Network Rail should consider the value of a 'land owner code of responsibility'. Put simply, this would set out the responsibilities of the transport infrastructure owner and neighbour in terms of maintenance of their respective assets, including right of access. It would need to be tailored for application to roads and railways respectively, given the different legislative regimes that apply.

Planning for resilience

3.23 Many of the transport operators we took evidence from have conducted Climate Change Risk Assessments, and a number were already updating them to take account of experience gained last winter and in previous years. Resilience planning and adaptation planning are fast developing fields, and it is important that best practice and the experience of others is shared. Operators need to learn from each extreme weather event, but often only a subset of them will be impacted by any one event. Mechanisms to cross fertilise experience and best practice are therefore essential, if lessons learned are not to be repeated unnecessarily. The DfT was commended to us by the ports sector for the round of workshops they convened last autumn on resilience planning for port operators. We believe this approach could usefully be repeated and extended to other sectors such as airports, as well as considering the value of sharing experience and best practice across different sectors.

Recommendation 8:

The DfT should consider how further resilience planning workshops can best be provided for port operators; extended to other sectors; and cross-sector groups brought together to share experience and best practice.

3.24 Scientific understanding of how climate change is likely to affect both the frequency and degree of extreme weather that we will experience in future is steadily improving. As this occurs it will be important that transport operators keep plans under review, if necessary amending them to take account of the latest scientific advice.

3.25 Under the Climate Change Act 2008, a number of operators of strategic transport infrastructure – ports, airports, rail and strategic road networks – were required to report to Defra on their Climate Change Risk Assessments. These in turn fed Defra's National Adaptation Programme. These were submitted during 2011 and comprised a rigorous assessment of the risks posed by different aspects of a changing climate and the mitigations in place. It was clear to us talking to interests as diverse as Heathrow Airport, the Highways Agency, Associated British Ports and Gatwick Airport that the process of drawing up these documents had taken operators through a valuable thought process of:

- identifying the risks faced from disruption and damage by different types of extreme weather event;

- assessing the current mitigation of those risks and;
- proposing further mitigating and adaptation measures.

With the benefit of hindsight these Assessments did not correctly judge all the risks.

- 3.26** The above transport operators are not obliged to produce an update of their Risk Assessments and Adaptation Plans in the next round of reporting and we share the view that this should not be mandatory, since experience of the past winter was not uniform across the country. However, it is clear to us that many operators would benefit from revisiting the process and, having routinely described the 2013/14 events to us as 'a wake-up call', that they will want to do so.

Recommendation 9:

With the winter's experience fresh in the mind, operators of strategic transport infrastructure should revisit their Climate Change Risk Assessments and Adaptation Plans in advance of winter 2014.

Recovery planning

- 3.27** Resilience planning is not just about the physical resilience of transport systems but also about how disruption is managed and the speed of recovery.
- 3.28** Many operators have contingency plans in place for reasons other than just extreme weather. For infrastructure operators it is important that these plans extend to include their major customers so disruption is managed in a consistent way, and they are jointly rehearsed via periodic exercises. There were several examples last winter of disruption being managed in less than ideal ways because of a lack of joined-up contingency plans. As experience of different types of extreme weather grows, contingency plans should be amended and developed to take account of a wider range of possible scenarios. Where two or more parties are involved, it is important that these are jointly agreed or as a minimum produced in consultation between the parties.
- 3.29** In general the transport industry has got better at managing extreme weather related disruption because it has had a lot of practice in recent years, effectively through a series of real 'exercises' providing regular testing and increasing familiarisation with procedures. It would be preferable for familiarisation and testing to be achieved through rehearsals rather than in real-time with real passengers involved.

Recommendation 10:

All transport operators should have contingency plans to cope with extreme weather events. For infrastructure operators these should extend to include their major customers, and at a minimum be developed in consultation with them. Contingency plans should be regularly rehearsed and progressively extended to take account of a wider range of extreme weather scenarios as experience develops.

Forecasts of extreme weather events

- 3.30** Witnesses were generally complimentary about the accuracy of forecasting of extreme weather events, recognising that forecasting has steadily improved in accuracy and is likely to improve further in future. There was a widely shared desire to see more granularity in forecasts, in terms of both geographic specificity of where high winds and rainfall were most likely, and in terms of their precise timing. This would enable more detailed and specific information to be provided to transport users on the possible routes and areas that could be subject to disruption, as well as more accurate pre-positioning of response and recovery resources. We understand the investment the Met Office is making in higher powered computers will enable improved granularity to be achieved in the near future. Transport operators should, in the meantime, liaise closely with the Met Office to understand how best the improved granularity can be used.
- 3.31** Several operators in the ports and airports sector admitted they had not paid sufficient attention to weather and flood forecasts. In some cases these had simply been received as faxes, which had not been acted on with the appropriate urgency.

Recommendation 11:

All transport operators should ensure they have clearly agreed channels for receiving weather and flood forecasts. These should be monitored in real time during periods when extreme weather is expected.

- 3.32** The forecasting of flood events, particularly the likely timing of fluvial flooding and the potential height of coastal flooding, is however an area that needs to be further improved, albeit the setting up of the joint Environment Agency/Met Office Flood Forecast Centre has achieved great improvements in this area. Prediction of ground water flooding is also still particularly difficult.

Recommendation 12:

The Environment Agency and Met Office should work to further improve their joint flood forecasting, particularly for potential coastal flooding events, where tides, storm surges, wind strength and wind direction all combine to influence the outcome, and for potential ground water flooding.

Communication

- 3.33** Passenger Focus stressed to us, rightly, that passengers judge how well disruption is handled principally by the information they receive from transport operators. Providing timely, credible and useful information to allow passengers to make informed decisions before they travel, and give advanced indication of what they can expect if they decide to travel is central to this. This is challenging, particularly as consumer expectations continue to rise, driven by 24-hour news availability and the ubiquity of internet information and social media. Most transport

operators now use both websites and social media as core communications channels during disruption. There are areas of good practice, but in general the transport sector is often playing catch up with other consumer industries. The rail industry has made significant progress in recent years with its 'Passenger Information During Disruption' (PIDD) initiative but there is scope for much more to be done.

- 3.34** It is obviously very important that transport and network operators communicate with passengers and other stakeholders as clearly as possible on how services are being affected by the weather, or as a result of weather induced damage to infrastructure. Achieving this with maximum effect requires an understanding of the available information channels and how those are being used by travellers and freight customers. Openness and honesty in communication is important in building confidence from passengers and users. Even if little information is available, letting people know when they can expect an update is helpful. Passengers and users who have confidence in the information they are being given are more likely to act on advice, potentially helping to relieve rather than add to the situation.

Recommendation 13:

All transport operators and authorities should develop, test and implement a dedicated passenger and user communications plan for times of transport disruption.

- 3.35** This plan should build on best practice, in particular taking account of the channels their customers use and tailoring plans accordingly; and ensuring the provision of real-time information throughout the 24-hr day. Whilst significant changes to communications systems may take time, we believe it is essential that all operators and authorities review and make whatever deliverable improvements are possible before winter 2014/15.
- 3.36** When it comes to what is communicated, we heard interesting evidence from a number of quarters in the course of the review. TfL, for example, explained that they had recruited specialists in communication to turn any technical jargon into information which could be readily understood by passengers. We are also conscious that not all users of a given transport network are the same. So whilst a train line, for example, might have seasoned commuters using it, it will equally have more occasional users making a rare journey. 'Trains via Wimbledon are subject to disruption' might mean a good deal to the first group and nothing to the second, who might well know only their points of departure and arrival. Therefore it might be necessary to have differently phrased messages.
- 3.37** Clarity of communication is vital. This is not easy in a world of internet communication and social media; Gatwick airport, for example, made the point to us that their experience on Christmas Eve showed that there is now a multiplicity of channels through which passengers receive information. Operators' websites must be a consistent point of reference during times of disruption and must be up-to-date, unambiguous and consistent. Passenger Focus made the point very persuasively to us that this was not the case with a number of train operator websites during the winter, with marketing campaigns and promotional material dominating

the website front pages and information on disruption relegated to the background. By way of contrast, Transport Northern Ireland (Transport NI) has a dedicated road travel news web site – [trafficwatch NI](#). This site is free from advertising and offers traffic news including current and planned roadworks, other disruption, and some traffic camera live feeds allowing road users to see the real situation before embarking on their journey.

- 3.38** A further complicating factor can be the potential for partners in a given sector – airports and airlines, Network Rail and train operators, local authorities and bus companies - to give different messages to customers. It is important, in such situations to ensure consistency of messages to passengers and other customers.

Case Study: Darwin Customer Information Systems

The rail industry is working together to provide 'one version of the truth' in terms of real time train running; with a consistent message when a train is delayed. Prior to the start of a project called 'Darwin Customer Information Systems' (CIS) which commenced with a Proof of Concept on the 17 stations on the West Coast Mainline in July 2011, each individual train operator would know the reason for any alteration to one of their trains, however this may not have been shared with other operators due to the complexity and diversity of the source information systems – which makes it confusing for the travelling public. This undermines the confidence of people travelling by rail.

The Darwin CIS Programme aims to address this issue by joining up all the station CIS to one central system, and will, therefore, show a consistent message. Any delay that is experienced is communicated to all relevant station information screens from Darwin, which is a central real time database. Darwin currently provides feeds to all National Rail Enquiries real time systems; train operator websites, station staff information systems, social media feeds as well as a number of customer applications.

The Darwin CIS Programme is part of the wider industry Customer Information Strategy which is designed to provide more consistent information to users.

- 3.39** A number of operators stressed to us the importance of managing passenger and user expectations. Some degree of disruption is often unavoidable during periods of extreme weather, but user expectations of what is feasible and reasonable are sometimes unrealistic. When the weather event is remote from where a road or service is being used, for instance flooding elsewhere on a road or rail route, it can be hard for transport users to understand. A photograph of the incident, circulated via text message or social media, can make a huge difference to user expectations and understanding, and we suggest this should be standard practice for transport operators wherever possible.
- 3.40** User expectations are often more realistic when extreme weather and the resulting disruption are the 'news', as was often the case last winter, rather than just a feature on 'travel news'. Likewise media commentary

can either be helpful or unhelpful, and it is important that public officials and politicians in commenting on disruption do not unrealistically stoke expectations. Operators will also know about parts of their network which are susceptible to extreme weather disruption, or become problematic in the event of any type of disruption. They therefore need to educate their passengers and other customers about these vulnerabilities.

Recommendation 14:

Transport and network operators should:

- **Give prominence on websites to the latest service information during periods of disruption, ensuring that marketing and promotional information is relegated to the background at these times.**
- **Use everyday language, not technical jargon to explain what is going on and causing the disruption. There is scope to research descriptions and phrases to use to test passengers reactions during 'peacetime'.**
- **Ensure consistency of information provided through different channels and by different parties. This will involve lines being agreed and re-agreed by all the key parties involved – e.g. airports and airlines, Network Rail and the train operating companies - and communicated through the variety of channels available.**
- **Make greater use of photographs distributed by text or social media, to improve transport users' understanding of the reasons for disruption.**

3.41 Social media, particularly group text and twitter feeds, is an increasingly useful channel for providing targeted information to users of a particular station, train, vehicle, bus route or flight, provided the information is credible and meaningful. See Figure 3.2 for an example. Similarly, email can give more detailed information, where a carrier has individual passengers' email addresses.

3.42 The fact that Passenger Focus are soon to have a role in representing road user interests to the Highways Agency, in addition to their existing role in representing rail and bus passenger interests, provides an opportunity to cross-fertilise good practice between different transport operators.

Figure 3.2 - Tweet from Southeastern



One of rail operator Southeastern's tweets about the line closure at Stonegate showing a picture of the problem

Planning a realistic service

- 3.43** It is particularly important that transport operators are realistic about the services which can feasibly be operated during extreme weather disruption. It is surprising how often operators with the best of intentions will over-optimistically try to run too full an operation, but then find they cannot deliver it, so let down their customers and cause more disruption as a consequence. This was classically the case just before Christmas at Gatwick, when the Airport and airlines tried to operate too full a flight programme for the available terminal capacity and ended up cancelling a number of flights late in the day with major inconvenience and distress for the passengers affected. Being realistic about what can be delivered, communicating this in advance to passengers and users, and then delivering it successfully is always better than being over-optimistic, struggling to deliver and causing added disruption for passengers.

Recommendation 15:

In the face of an extreme weather event, or a high-confidence forecast of extreme weather, transport operators should plan for the best practicable service which they can realistically deliver, and which manages expectations, providing a high degree of certainty to passengers, other users and industry partners.

Pre-planning of recovery resources

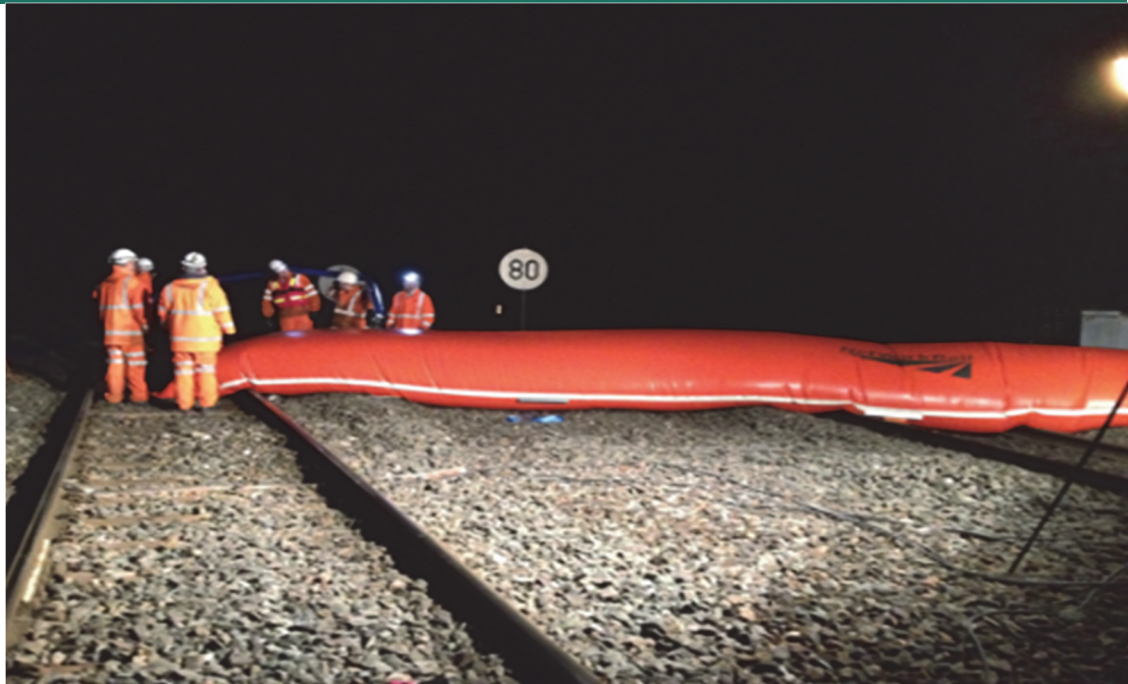
3.44 We heard that many operators and highway authorities now have robust routines in place to ensure they have adequate resources available ahead of potential seasonal disruption.

3.45 It is important that every operator and authority has a checklist of the resources they may need to manage the recovery from weather related disruption, where they can be sourced and that best practice is shared on the types of equipment that proves most useful. For instance a number of operators have spoken to us about using temporary or mobile bunds to protect sensitive installations such as electricity sub-stations from flooding, Network Rail has been trialling the use of portable flood barriers (See Figure 3.3) to protect short sections of line and we also heard that the City of Copenhagen is looking at using temporary portable storage ponds into which surface water can be pumped.

Recommendation 16:

Transport operators should have checklists of resources which they will need as part of their recovery effort from different weather-related events, with details such as the location, owner and source(s).

Figure 3.3 - A portable flood barrier on the railway



An inflatable temporary dam being put in place to protect infrastructure from flooding.

Co-operation during a crisis response

- 3.46** Co-operation between relevant responders is essential during an emergency situation, and the best way to achieve this is to have plans and procedures which are developed and rehearsed prior to a crisis occurring.
- 3.47** There has been a significant improvement in co-operation and understanding of how to operate in a crisis through use of:
- intra-industry crisis management fora, such as the Extreme Weather Action Team (EWAT) in the rail sector, bringing together the industry interests;
 - strengthened crisis management processes within the HA, together with improvements in capability;
 - cross-sector crisis response machinery such as the Local Resilience Fora and Strategic Co-ordinating Groups (SCGs) established by the Civil Contingencies Act 2004, which bring together local authorities, emergency services and other key local and regional interests.
- 3.48** However, a number of operators expressed the view that there is still scope for better liaison and coordination between different transport modes. We were surprised to hear, for example, that National Express were not initially asked to provide additional coach services to the West Country during rail disruption, but decided to offer to do so. Suspension

or severe disruption to one mode can have knock-on impact on another as passengers switch, and the same weather will often affect several modes within a geographic area requiring a more coordinated response if passengers and freight movements are not to be severely disrupted. This works well in London, where Transport for London is an integrated transport authority for all modes, but less well elsewhere.

- 3.49** Local Resilience Fora are a possible arena for this, since they meet regularly for planning purposes, and usually convene a Strategic Co-ordination Group (SCG) during periods of serious disruption. These are usually chaired by the local police force and involve all of the relevant local authorities. However their focus is on protecting homes and communities, and their number and smaller geographies do not readily match those of national transport operators. A further suggestion would be to convene a forum similar to the Olympic Transport Coordination Centre, which brought together all transport operators before and during the London 2012 Olympics to ensure coordinated oversight of all aspects of transport during the Games. Again this could be stretching the resources of many operators and risks duplicating other fora. We believe the best approach would be to treat each situation case by case, considering whether or not there would be benefit in ensuring appropriate transport operator representatives at local resilience fora. The DfT should act as an informal clearing house for multi-modal issues nationally, in exceptional circumstances such as where there is widespread disruption over a large geographic area.
- 3.50** During the widespread disruption of winter 2013/14, both Network Rail and the HA found that they were unable to attend all of the SCGs being convened, since they were often scheduled at the same time of day. It is important that HA and Network Rail engage fully with the Local Resilience Fora during 'peacetime' and ensure that the level of resource that may be available during widespread disruption is communicated. Given a situation of competing calls on Network Rail and HA resource, they will need to be selective as to which SCGs they attend or dial into, and those which they simply provide with Situation Report information.
- 3.51** In reviewing the guidance relating to the Civil Contingencies Act, there are some areas where the information relating to transport could be improved; sharing this kind of information prior to a crisis can lead to a more effective response. For example, in the guidance document⁸ which deals with emergency response and recovery, HA has a few paragraphs describing its responsibilities and organisation (para 3.3.6); there is no equivalent for Network Rail or TfL.
- 3.52** In Northern Ireland there is currently no civil contingency legislation, a situation which is being addressed. However, both Transport NI and Translink (the Northern Ireland rail operator) participated in multi-agency planning and response throughout the course of the winter and felt that it was beneficial and improving.

⁸https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/253488/Emergency_Response_and_Recovery_5th_edition_October_2013.pdf

3.53 Even for the intra-industry crisis management machinery, we heard that there could be resourcing and organisational issues. For example, the EWAT process in rail might usefully be organised on a multiple-route basis where there is a single operator running across adjacent routes, to improve the strategic control and the consistency of approach across routes, as well as reducing the call on stretched resources. Not dissimilar was the organisation of roads policing and operational management in the West Midlands Regional Control Centre, which sees staff from the HA and multiple West Midlands police forces working together to manage the motorway network. Whilst this struck us as an exemplary model for business-as-usual operations, we were also told, and can well believe, that it has proved hugely beneficial in managing weather-related emergencies, given the co-operation and improved understanding that it engenders.

Recommendation 17:

Transport operators should consider whether they have the best possible organisation of their intra-industry crisis management machinery, taking account of the benefits of working more closely with their partners. They should similarly review their participation in wider cross-sector fora, to ensure they are appropriately represented and the benefits of closer liaison between modes are secured.

3.54 In Scotland, a dedicated [Multi Agency Response Team](http://www.transportscotland.gov.uk/road/winter-service-ready-winter-and-severe-weather#Mart)⁹ (MART) was created following the disruption in winter 2010/11. MART operates during severe weather events, to help co-ordinate disruption to the transport networks and manage travel information. Scottish MART is a group of partners that work together to improve the quality and timing of transport information. MART co-ordinates the flow of information between agencies and the public. A Met Office representative works in MART to ensure that any changes to the severity or area effected by severe weather (or other similar events) can be updated and provided to the public.

⁹ <http://www.transportscotland.gov.uk/road/winter-service-ready-winter-and-severe-weather#Mart>

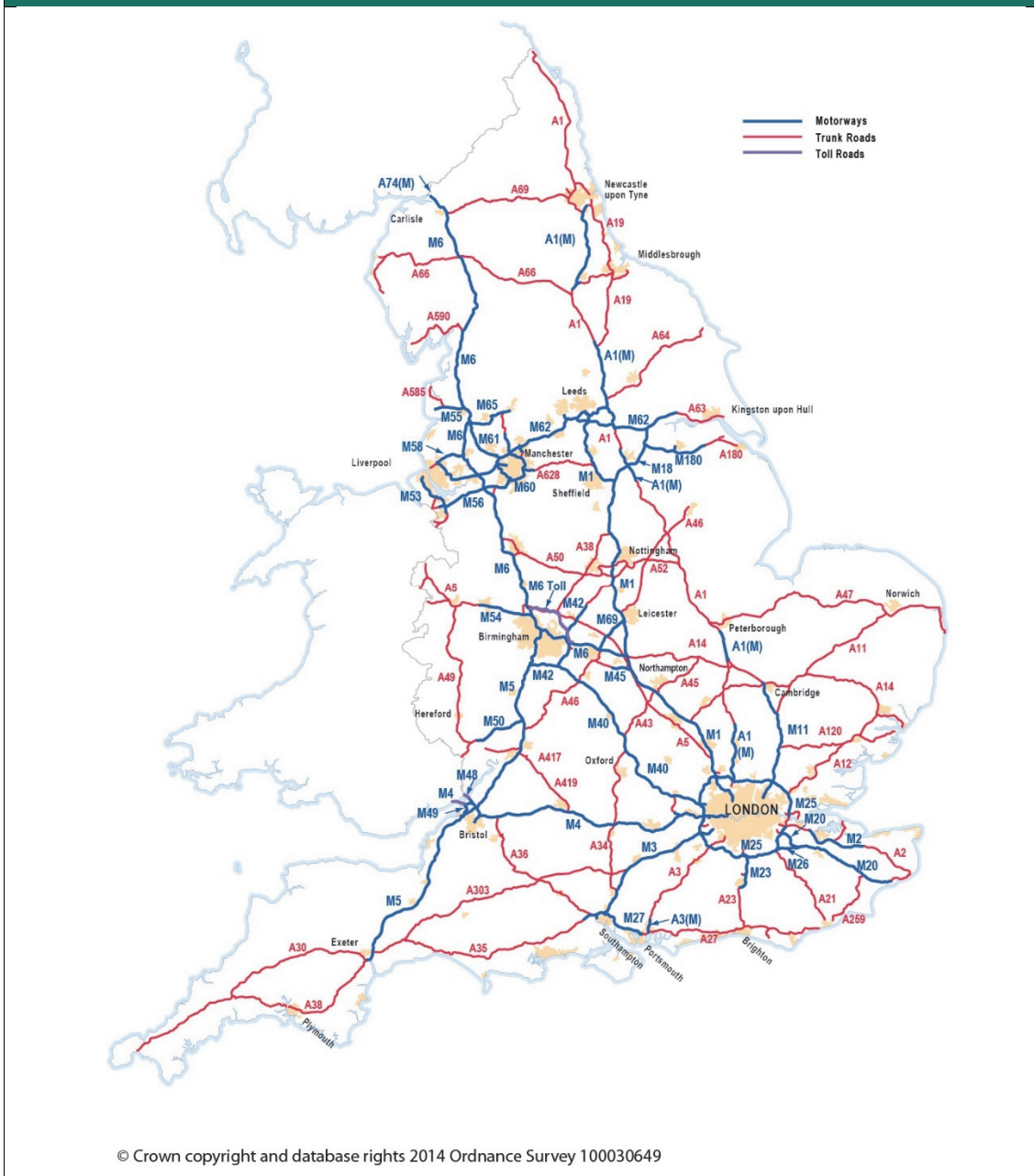
4. Strategic Road Network

Introduction

- 4.1** The Strategic Road Network (SRN) is operated and maintained by the Highways Agency (HA) in England¹⁰. See Figure 4.1. It covers some 4,300 miles of motorways and major 'A' roads and although only representing 2% of the total road network in England it carries roughly one third of all traffic in terms of vehicle miles and two thirds of freight traffic. Around 4 million vehicles use the SRN each day. It is therefore of critical importance to the nation's transport system, and with a valuation of £109 billion is a significant national asset.
- 4.2** The HA was formed in 1994 and has evolved significantly since then. In effect it is the operator and manager of the SRN, procuring maintenance, renewals and new works from private sector contractors. These contractual structures vary, from individual contracts for the construction of major schemes, through five year regional maintenance and improvement contracts, to some longer term contracts (typically 25 years) via the Private Finance Initiative. As well as being responsible for setting standards and managing contracts, using asset management principles, the HA controls the network through seven regional control centres and a central National Traffic Operations Centre. These centres manage the deployment of HA Traffic Officers who respond to and manage incidents on the ground on the busiest sections of the network, as well as controlling the growing network of variable message signs and advisory and mandatory speed limits. The HA is currently an Executive Agency of the Department for Transport, but legislation is planned for this autumn for it to become a Government Owned Company with greater autonomy and delegated responsibility, with five year funding certainty for capital programmes and maintenance.
- 4.3** The motorway network is of course relatively new compared to the majority of local roads and much of the railway network, having been built since the late 1950s. Motorways were designed and constructed to modern engineering standards and therefore have a good level of physical resilience to extreme weather. 'A' roads form the majority (57%) of the SRN, with some being relatively modern, but some being older roads which have been upgraded over the years. Nevertheless, the SRN is considerably more resilient physically than the local road network, and has benefited from being maintained by a single-purpose highway authority.

¹⁰ In London, TfL is responsible for all major through routes, including trunk roads – the Transport for London Road network or TLRN – except for motorways, which the Highways Agency manages

Figure 4.1 - Highways Agency operated Strategic Road Network



- 4.4** It is important to understand that the SRN, and indeed the local road network, are open networks with usage governed only by wider driver and vehicle licensing regimes. Driver behaviour is therefore an important factor, and can affect capacity and performance of the network. Significant parts of the network are running at capacity at busy times, so there is often little or no spare capacity to absorb any disruption to traffic flow. The HA estimates that 65% of congestion on the network is caused by traffic volumes at or above capacity, 25% by incidents and 10% by roadworks.
- 4.5** Many of England's motorways now use a range of new technologies to vary speed limits in response to driving conditions. These Smart Motorways also increase capacity by making the hard shoulder available

for traffic, either permanently or at particularly busy times of the day. Smart Motorways are operated by the HA's regional control centres.

- 4.6 Road capacity varies with conditions and with user behaviour. Capacity tends to be lower in conditions of heavy rain, fog or snow as traffic speeds slow and vehicle spacing increases.
- 4.7 The number of incidents tends to increase in adverse weather conditions, and it is important to manage user behaviour to reduce the risk of incidents occurring, and manage recovery to resume normal operation as speedily as possible after an event. This is as important in determining the resilience of the SRN as its physical design and condition.
- 4.8 The Road Haulage Association and Freight Transport Association reminded this Review that disruption of some sort occurred almost daily on the SRN network, and that weather was but one of a number potential causes of this. From a user point of view, weather related disruption was little different to any other type of disruption, and many of the same procedures and mitigations could be used to the benefit of both.

Specific vulnerabilities of the SRN

- 4.9 **Snow and ice** represent the biggest risks of disruption to the SRN, albeit they are outside the scope of this Review. The winters of 2008/09 and 2009/10, together with the very cold start to winter in December 2010, provided the impetus for the HA to develop its current Crisis Management processes, although this is designed to be used in all major disruption events.
- 4.10 **High winds** are a significant source of disruption because of the risk of high-sided vehicles being blown over, and the heightened risk for other vulnerable vehicles such as motorbikes, caravans and other towed trailers. The HA closes some exposed sections of the network, such as estuarine crossings, on a precautionary basis when high winds or strong gusts are forecast to reduce the risk of incidents.
- 4.11 **Flooding** is another cause of disruption on the SRN. The majority of flooding events are localised and of short duration, typically resulting only in lane closures rather than complete closures of roads. However they can, on occasion, cause more significant disruption, such as during the flooding in July 2007 which has demonstrated the HA's ability to learn from experience of extreme weather.

Case Study: Highways Agency 2007 floods

Unprecedented downpours across the country caused widespread flooding in July 2007, resulting in travel disruption for many drivers. Closures affected the motorway network (M1, M4, M5, M18, M25, M40, M50, and M54) and many local and trunk roads were also disrupted. The repair costs for all roads (including non-HA roads) were estimated at £40–60 million. Flooding on one day alone – 20 July – caused 2% of the delays for the whole year. The flooding of what was a small part of the road network led to almost 10,000 people being stranded. Particularly hard hit were the M5 and M50, which were closed in both directions.

Following this flooding and the recommendations of the Pitt Review, the Agency introduced a number of improvements in many areas of their work:

- Emergency Planning Teams were established in each of the Agency's seven regions, and these teams now ensure that the Agency's emergency response planning is closely linked to other emergency response organisations through the local resilience fora.
- The Agency constructed additional emergency access/egress points and central reservation crossing points intermediate to motorway junctions to allow trapped traffic to be directed off the motorway or onto the opposite carriageway to reduce the risk of people becoming stranded on motorways.
- New procedures were introduced by the HA Traffic Officer Service to safely turn trapped traffic around and drive it off the motorway on the same side of the carriageway.
- The Agency works with the local resilience fora as part of a multi-agency approach to provide welfare support to people who do become stranded in exceptional circumstances.
- The HA has identified flooding 'hot spots' and priority drainage assets (such as culverts) on its network so that prioritised measures to improve resilience to flooding can be developed.

All flooding events on the SRN are logged on a central national register and prioritised for further investigation and action.

4.12 Extreme summer heat does not often cause disruption to the SRN.

Extended hot periods can increase the risk of damage to certain types of road construction, due to thermal expansion, resulting in an uneven road surface that needs repair. During such conditions the HA increases its monitoring of at-risk sections of the SRN. Extreme heat can also accelerate the rate of deterioration of older types of road surfaces, such as those formed of hot rolled asphalt, through softening and rutting of the surface. Hot conditions also pose a heightened welfare risk to road workers, road users and livestock in transit, particularly when vehicles are delayed.

- 4.13** **Fog** is a hazard to traffic due to reduced visibility increasing the risk of vehicle collisions. The most effective mitigation is for traffic speeds to reduce, and the extension of smart motorways on the SRN will give a greater ability to manage traffic speeds and therefore the risk of incidents.

The experience of last winter

- 4.14** The SRN performed well during the winter of 2013/14, with most disruption from the weather being of relatively short duration with only minor delays. Even so, parts of the network were affected during the most extreme conditions. Over the winter as a whole (between the end of October and the end of February) the HA recorded a total of 124 weather-related critical incidents, where lanes were closed resulting in measurable delay (of 10 minutes or more) to road users on the SRN. Such critical incidents include lane closures due to an obstruction (such as flooding or an overturned vehicle) as well as precautionary closures to avoid incidents (such as during high winds). This compares to an average of 75 such incidents experienced over the three winters between 2010 and 2013 (including those caused by snow).
- 4.15** Most of the 124 weather related critical incidents occurred in the south and west of England. Of these, approximately 60% were related to high wind speeds, and approximately 40% were related to flooding. Precautionary closures of exposed bridges, such as the M48 Severn Bridge, formed the majority of incidents caused by high wind speeds (56%) with a smaller proportion (30%) caused by over-turned vehicles or by fallen trees (14%). These precautionary closures are implemented when wind speeds are very high, not only to avoid the risk of serious accidents that may occur if vehicles are blown over, but also to avoid the delays that result from the lengthy recovery of overturned vehicles, and also helping to ensure the bridge is re-opened at the earliest opportunity. When such closures are implemented, traffic is signed onto diversion routes.
- 4.16** Some of the most significant spells of severe weather, and associated impacts on the SRN are outlined below:

The St Jude's storm (28th October 2013)

- 4.17** A total of 11 weather related critical incidents were recorded during this time, mostly due to high wind speeds. Many estuarial crossings in the south of England were closed on a precautionary basis, such as the A282 (M25) QEII Bridge at Dartford (See Figure 4.2) and the A249 Sheppey Crossing. Both the M48 Severn Bridge and the M4 Second Severn Crossing were closed overnight, the only time that both Severn crossings were closed simultaneously all winter. There were two incidents involving fallen trees in Kent, one on the A2 and one on the A21.

Figure 4.2 - QEII Bridge, Dartford



Storm on 5th December 2013

4.18 A total of 12 weather related critical incidents were recorded during this time, 11 of these due to high wind speeds. The majority of these were in the northern half of the country, with delays caused by vehicles being blown over in the high winds. As an example, significant delays resulted from three vehicles overturning in high winds on the M62 in Humberside, where a nearby HA weather station recorded a gust of over 60mph. Other routes affected by overturned vehicles included the M6 in Cheshire, the M60 in Greater Manchester and the A1 in West Yorkshire. Flooding was much less of an issue, reflecting that little of the SRN is to be found in coastal areas, although the A63 in Hull was closed overnight due to tidal flooding caused by the storm surge.

Storms from mid-December 2013 to early January 2014

4.19 There were a total of 40 weather-related critical incidents during this time, with a mix of high wind speeds and flooding causing delays at different times. Precautionary closures of long bridges due to high wind speeds occurred on 17 occasions, including the M48 Severn Bridge on 8 occasions. There were also a number of incidents resulting from flooding, the most significant being the A303 near Ilchester in Somerset, which was closed with traffic diverted from 24th to 25th December, when a river burst its banks, flowing over the dual carriageway.

4.20 Flooding also occurred on the A303 at Deptford in Wiltshire on 9 January, caused by groundwater rising from fields next to the dual carriageway.

Storms from late January to mid-February 2014

4.21 This period of weather, characterised by a succession of intense storms and heavy rainfall, represented the most sustained period of disruption on the SRN. There were a total of 55 weather related critical incidents between 31 January and 15th February, 37 of which occurred in the four day spell from 12th to 15th February. A sink hole closed the M2 in Kent on 12th February. This is not the first time the SRN has experienced this type of event on its network and although these geological phenomena are rare, they have the potential to cause significant damage and delay. Whilst broad areas prone to sink holes have been identified, it is impossible to predict exactly when or where one will occur. Precautionary closures of major bridges due to high wind speeds occurred on 17 occasions, and a further 7 incidents in the south of the network caused by falling trees on 14th to 15th February. Flooding was the cause of around 40% of the incidents during this time, the most notable being the closure of several lanes of the clockwise M25 between J16 and J17 in Buckinghamshire on 7 February, when water overflowed from a ditch on adjacent land onto the motorway. The clockwise carriageway was reduced from four lanes to one for around 10 hours, including the morning peak hours, causing significant delays to traffic.

Wind

- 4.22** The impact of high wind speeds on the SRN is largely operational, because of the vulnerability of certain types of vehicle and the risk of accidents or vehicle blow-overs. The infrastructure itself, particularly its structures, is resilient to very high winds. The HA's main preoccupation is therefore to manage user behaviour and access to minimise the risk of accidents and avoid the resulting disruption to traffic.
- 4.23** The HA sees high-sided lorries as a particular risk, representing a substantial hazard to other vehicles if blown over, physically blocking more of the carriageway and taking longer to clear away, especially if their load is shed. However, other vehicle types, such as motorcycles and caravans, are also a risk both to themselves and other road users.
- 4.24** The HA has procedures in place to close or restrict usage of exposed sections of the network, such as estuarine crossings, high viaducts and the A66 trans-Pennine route, to reduce the risk of vehicle blow-overs and other accidents at times of high winds. Working in conjunction with the police, it can close roads and can also use the powers of its Traffic Officers under the Traffic Management Act to restrict certain types of vehicles. At the M48 Severn Bridge for instance, Traffic Officers can be deployed to restrict vulnerable vehicles (defined there as vehicles over 2.1 metres in height and motorcycles) from using the crossing during periods of high winds. At some other locations similar restrictions can be signed on an advisory basis. Clearly complete closure of a road because of high winds is a major cause of disruption, particularly where diversion routes are lengthy, and affects all users. The HA has said that it would like to be able to restrict access at more locations, in particular at the QEII Bridge at Dartford, to avoid complete closure, and so restrict

disruption to fewer users. However, this depends on the ability to reroute or park up restricted vehicles whilst the high winds continue, and on the ability to ensure compliance with any necessary restrictions on use.

- 4.25** The Road Haulage Association and the Freight Transport Association however expressed some caution about this idea, and also pointed to the need for a better understanding of the underlying causes of the risk: for instance what heights of vehicle are truly at risk, to what extent is the risk modified by the load and weight of the vehicle and what other types of vehicle might also be a risk? They considered that analysis of the blow-overs that had occurred could give useful indicators of risk.

Recommendation 18:

The Highways Agency should consult with the Freight Transport Association, Road Haulage Association and other affected groups in developing proposals to restrict vulnerable vehicles from using exposed sections of the Strategic Road Network, in particular the QEII Bridge at Dartford, during times of high winds so that the crossing can be kept open for all other users for as long as possible. The Highways Agency should then work with the Department for Transport to establish how best to implement any additional restrictions considered appropriate, including how to ensure road user compliance.

- 4.26** The Road Haulage Association and the Freight Transport Association also expressed a desire for greater granularity of wind forecast information, in terms of the likely timing and location of high winds, to allow hauliers to take more informed decisions on routeing and when or whether to despatch a vehicle

Recommendation 19:

The Highways Agency should work with the Met Office to agree how best to utilise the improving granularity of wind forecasts to give the best possible wind forecast information to lorry fleet operators, ensuring it includes more specific and more useful information on its website and wider Highways Agency information services. This should include more specific information as to what drivers should do in the event of high winds after starting their journey.

- 4.27** It was also suggested to us by transport bodies that erecting wind socks at exposed sections of the SRN would be a low cost means of alerting drivers of all vehicles to the direction and strength of the wind and a reminder of the potential hazard.
- 4.28** A further hazard from high winds is the risk of debris and particularly of trees being blown over (See Figure 4.3) and obstructing roads. This is less of a risk on the SRN, especially on motorways, because of the greater width of verges and embankments, than it is on local roads and the railways.

Figure 4.3 - A tree blocking the A36 in Hampshire



- 4.29** Over the years the HA and its predecessor authorities have planted large numbers of trees alongside the highway, partly for ecological reasons and partly for visual screening and appearance. These will increasingly need active management, pruning and selective felling, as they mature to prevent them becoming a hazard and being blown onto the carriageway during wind storms. As we note in Chapter 6 trees have become a significant hazard on the rail network, because of decades of relative neglect, and it will be important that the HA does not allow this to happen on the SRN and continues to receive adequate funding for vegetation management.

Flooding

- 4.30** As noted above there were 49 instances of flooding causing measurable delay on the SRN last winter, with a range of impacts on users but usually lasting no more than 6 hours. See Figure 4.4. Flooding varies in type and impact and is often the result of surface water run-off from neighbouring fields and land. Intense rainfall over a short period can also lead to the presence of standing surface water on the carriageway, creating a risk of vehicles aquaplaning, but this is usually short-lived until the carriageway drains have had time to clear it. A notable risk last winter was ground water flooding, impacting the eastbound carriageway of the A303 in Wiltshire (see case study on page 65) for almost two weeks. Fluvial flooding has been a limited risk to the SRN to date because carriageways are generally constructed above the potential water level on flood plains.

Figure 4.4 - Flooding on the A303 near Ilchester, Somerset



The Bearley Brook flowing over the A303 dual carriageway. The fence in the middle is the central reservation safety barrier,

- 4.31** The HA maintains a log of locations that have experienced flooding, and tasks its maintenance contractors with ensuring that flooding does not recur. The contractors then implement the drainage maintenance regime most appropriate in order to meet the requirements of the contract. Whilst the log of flood risk locations is likely to reflect the bulk of flooding risk, based as it is on actual flood events, it will miss potential flood locations which have not to date experienced intense local rainfall. We therefore consider that the HA should use the newly-updated Environment Agency flood risk maps, and localised topographical information, to check what further locations might be at risk of flooding.

Recommendation 20:

The Highways Agency should conduct a flooding risk assessment exercise using the newly updated Environment Agency flood risk maps and other data to identify potential flood risk locations on the Strategic Road Network, to supplement its log of actual flooding events.

- 4.32** Detailed knowledge of drainage assets and local watercourses is also an essential starting point for effective drainage maintenance, both those belonging to the HA itself and also those adjacent to the SRN, which could discharge onto the network or into which the HA's drains discharge. This is not a simple task because, at junctions on the SRN for instance, some drains will belong to the adjacent Local Highway Authority, and often the drainage network was constructed as an

integrated system, before the SRN was split off from the local network. The HA told us that it has knowledge of some 85% of its drainage asset inventory, but it has significantly less knowledge of its condition.

Recommendation 21:

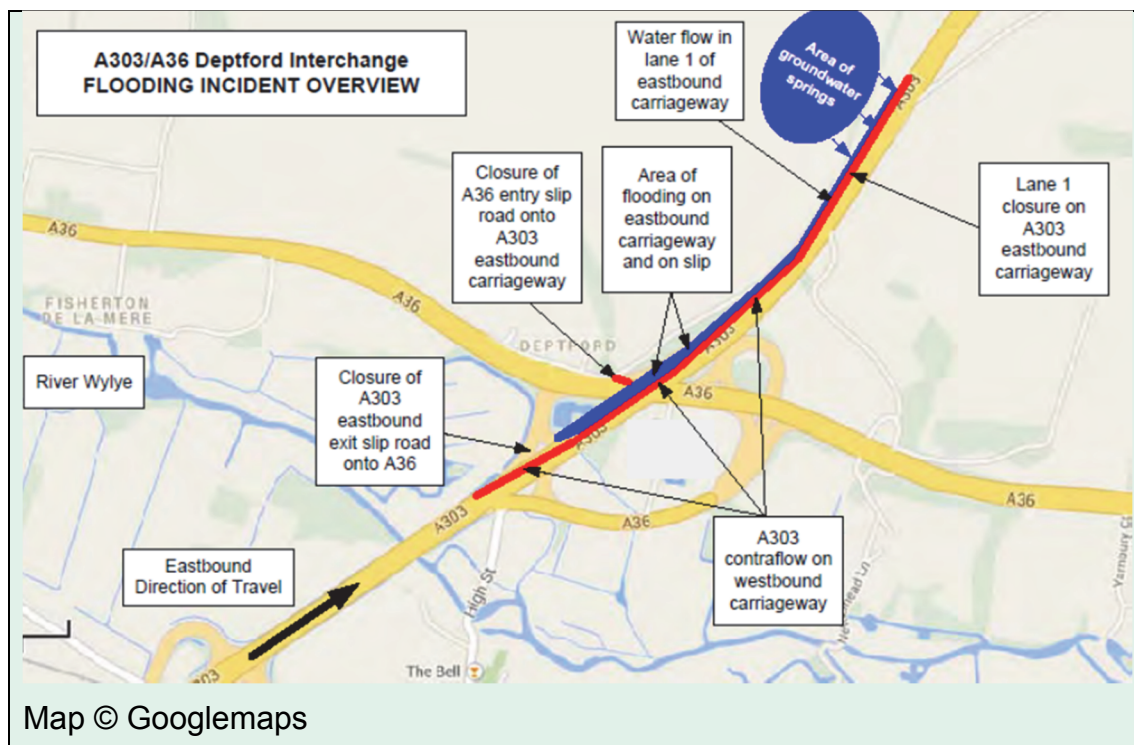
The Highways Agency should carry out the necessary work to complete its drainage asset inventory and if appropriate should make the case, in the process of establishing the new government owned company, for funding of the survey work necessary to significantly improve its understanding of the condition of its drainage assets and the interfaces with adjoining drainage networks.

Case Study: A303 at Deptford, Wiltshire

The A303 trunk road provides a key strategic route between the M3 near Basingstoke and the A30 near Honiton in Devon, which in turn links to the M5 at Exeter. As it passes through Wiltshire, the A303 is a mix of single and dual carriageway, with one of the dual carriageway sections located at the junction with the A36 at Deptford.

Following an extended period of heavy rainfall over December and into January 2014, large volumes of groundwater began to run off from adjacent agricultural land on the edge of Salisbury Plain onto lane 1 of the eastbound A303 just west of its junction with the A36. Due to the exceptionally high groundwater levels in the area, and the rate of flow onto the eastbound carriageway, the floodwater overwhelmed the road's drainage system. The eastbound carriageway was closed to traffic just after 7 a.m. on 9th January, including the eastbound entry slip road from the A36. Eastbound traffic was diverted into Salisbury and then back to the A303, which added some 12 miles to road user's journeys, although there was no significant queuing of traffic on the A303.

By early evening on 10th January the Highways Agency had removed the central reservation barrier and established a contraflow on the westbound carriageway, allowing traffic to remain on the A303 and travel through the scene in both directions. Traffic remained unable to join the A303 eastbound from the A36 until 16th January. The contraflow remained in place until late on 21 January, when the groundwater flows had reduced sufficiently to allow the eastbound A303 to safely reopen, some 12 days after it had closed. During this time the contraflow enabled traffic to continue using the A303 without any appreciable delay in either direction.



Managing road user behaviour

- 4.33** A key part of the SRN's resilience is the need for the HA to manage and influence road user behaviour, to ensure that during extreme weather, the disruption directly caused by the weather, such as reduced traffic speeds, is not exacerbated by incidents caused by inappropriate driving. When accidents do occur, the HA's ability to return the road to normal traffic within a reasonable time period is important, and as traffic volumes continue to grow, this will become ever more important.
- 4.34** The HA Traffic Officer Service is a key resource in this context. Likewise, the steadily expanding network of smart motorways (see Figure 4.5), providing the ability to influence and actively manage traffic speeds, and convey hazard and other essential information to road users, will also greatly help. An important tool which we consider could and should be better utilised is the variable message signs. The HA is currently constrained in the range and content of the messages it can display on these, being required to follow the DfT's road signs rules and guidelines. We are aware that such messages as there are do not always resonate with road users, and information displayed can sometimes appear out of date or in conflict with the actual local conditions at the time. This undermines the credibility of the information displayed, and potentially encourages the signs to be ignored or overlooked by a proportion of drivers.

Recommendation 22:

The Highways Agency and the Department for Transport should review the range and wording of messages displayed on variable message signs at times of disruption, including severe weather, and establish a dialogue with road users to determine what is seen as useful and credible.

Figure 4.5 - Smart motorway with variable message sign



- 4.35** The HA also has an extensive website, a telephone information and reporting service and is increasingly making use of social media to communicate information to SRN users. However it is prohibited from publicising these channels on variable message signs despite these being an obvious and low-cost means of directly communicating with SRN users. Encouraging drivers to check the HA website before starting their journey during extreme weather would undoubtedly assist drivers to plan their route to avoid known disruption, or even re-time their journey, and prepare them for the driving conditions they are likely to experience on their journey.

Recommendation 23:

The Highways Agency should continue to improve and refine the content of its website to make it still more useful and influential, regularly canvassing feedback from users. The Highways Agency should also be allowed appropriate flexibility to use variable message signs to direct road users to more comprehensive sources of information, such as its website, twitter channels and its contact centre number. This will help to build awareness and

encourage drivers to check for information before starting their journeys during extreme weather and any resulting disruption.

- 4.36** As an open network, the safety and resilience of the SRN is at least partly dependent on the behaviour of its users. Knowledge of the correct driving techniques during extreme weather conditions and also of appropriate preparations for travel is undoubtedly an area that could be improved - for instance the advisability of carrying a bottle of water during very hot weather, or a coat or a blanket during very cold weather. This is a further area where greater use of the HA's website and other information channels could assist. However we also consider that more could be done to educate new drivers on the subject.

Recommendation 24:

The DfT should review the content of the Driving Theory Test, and the associated materials available, to ensure it gives adequate coverage to driving techniques that can be used in adverse weather conditions, and travel preparations.

Ensuring priority for resilience

- 4.37** We have already highlighted in Chapter 3 the importance of ensuring adequate levels of resource expenditure for resilience purposes. This is certainly important for the HA since much resource expenditure - drainage surveys and maintenance, vegetation management, the work of the Traffic Officers and the operation of control centres - are key components of maintaining the resilience of the SRN. Capital investment in extending the Smart Motorway network will also help build resilience, but it is essential that future funding settlements for the HA, as it assumes its new status, give adequate weight to its role as operator and maintainer of the existing SRN. Our Recommendation 1 in Chapter 3 on ensuring a proper balance between capital and resource expenditure should be of benefit to the SRN in this respect.
- 4.38** The DfT intends to give the Highways Agency Government Company (GoCo) status, in order to allow it greater certainty over its longer-term funding and greater freedoms and flexibilities. As part of that change, the Office of Rail Regulation will become regulator for strategic roads and Passenger Focus will be given a formal role as representative of the HA's customers.
- 4.39** There is an opportunity, in the new regulatory regime to ensure that maintenance, asset management and resource funding are given due weight, in order to ensure the continued resilience of the SRN. We understand that the new GoCo will be required to have an asset management plan and will be subject to a performance indicator regime.

Recommendation 25:

In establishing the new Highways Agency Government Company, the DfT should ensure that its top-level performance indicators encompass network availability and that this is supported by appropriate indicators of asset condition.

5. Local roads

Introduction

- 5.1** The nature and strategic importance of local roads varies hugely. Key 'A' Roads provide some of the crucial links to international gateways, such as ports and airports, between cities and towns and to key locations such as major business parks and shopping centres. The network of other roads not only links us to important locations such as hospitals, doctors, schools and leisure facilities, but enables us to go about our everyday lives as it links where we live with many of the places where we want to go.
- 5.2** It is also a very large network of some 183,300 miles, comprising all roads outside the Highways Agency's jurisdiction, apart from some private roads. The network includes dual carriageways, a few motorways, and busy urban distributor roads, many constructed or upgraded to modern standards. These are generally 'A' roads and make up 9.5% of roads, with a length of 17,499 miles. It also takes in smaller and often important 'B' roads which comprise 12,363 miles and form 6.7% of the total network, as well as most minor roads, many of which are classified as 'C' and 'unclassified' roads. Many of these, including quiet, single-track country lanes, follow old cart tracks and largely consist of tarmac laid over the surface – often described as evolved roads. However, these designations go back many years and there are many instances where they do not reflect today's social or economic importance, or indeed resilience.

Table 5.1 – Lengths of 'B', 'C', and unclassified roads in England

| | 'B' roads | 'C' and unclassified roads |
|-------|-----------|----------------------------|
| Urban | 2,870 | 67,424 |
| Rural | 9,493 | 85,964 |
| Total | 12,363 | 153,388 |

- 5.3** The network also covers areas of great geographical diversity. Some parts are very flat, sometimes across land that has previously been drained, other parts are in exposed areas close to the sea or in more isolated areas, and there are many parts where the terrain is undulating or hilly. It is also worth noting that in the southern half of England, which received the highest volumes of rainfall this winter,

the underlying subsoils for the network are predominately clay or chalk/limestone, a factor contributing to some of the difficulties which were experienced.

- 5.4** There are also a significant number of bridges and other structures across the network. Many of the bridges are obvious, but the smaller bridges and other structures may not be apparent to road users unless there is closure or restrictions for maintenance. The number and type of other structures will tend to vary with the topography of an area, but typically will include embankments, cuttings, retaining walls and culverts.
- 5.5** So there is enormous variety in the type and length of roads for which each local highway authority is responsible, and the related structures. This variety is reinforced by the governance structure for local highways, the function being the responsibility of Transport for London, the London boroughs, metropolitan districts, the county council in areas where there are two tiers of local government, or the local (unitary) council in those areas where there is a single tier of local government. There are 152 highway authorities in total, and they are of very different sizes.

Disruption to local road network during winter 2013/14

- 5.6** The main extreme weather problems for road users in winter 2013/14 came from various types of flooding and water damage, and problems with falling trees during the high winds.
- 5.7** Many coastal authorities were affected by the tidal surge on 5th December. For example, the Newhaven swing bridge was damaged, with some operational impacts ongoing till May; there was flooding in parts of north Lincolnshire that led to the closure of the A1077 Scunthorpe to Immingham road for a week; and close to Stockton-On-Tees, a breach of sea flood defences had to be repaired by the Environment Agency, requiring a consequent closure of the nearby A178 Seaton Carew road for a significant length of time from 5th December to 31st January, with temporary access provided for two weeks over the festive period. This road links the industrial areas of the north of the Borough of Stockton with Hartlepool and is the main access route for the chemical industries in this area. Businesses had to use a 16 mile diversion route during the period of the road closure.
- 5.8** The battering from coastal storms mainly impacted on authorities in the south, the west and Wales, and there were many problems from the power of wave action and flooding. Many will recall the images of the damage at Aberystwyth and the reports of flooding in places like Looe, and there was considerable damage to some roads in Devon (both the South Hams area and the Exe estuary). We did not seek evidence from every authority for this review, but it was notable that Cornwall, Devon, Dorset and Hampshire all reported not only

flooding in many coastal areas but direct damage to the road network and associated infrastructure.

- 5.9** The most widespread problems came from various combinations of pluvial, fluvial and groundwater flooding. In the first part of the winter, much of the flooding was mainly short term, as drainage systems were unable to cope with the large volumes of rain; some rivers burst their banks and water gathered in places known to be prone to flooding, before draining off. However, as the wet weather continued into January and February, groundwater levels continued to rise, something which is particularly significant across parts of southern England, for the areas of chalk and limestone act like a giant sponge.
- 5.10** The problem for many local authority highway networks was that the saturated ground meant that the further heavy rain ran off the land, rather than being absorbed by it, additional springs developed as groundwater levels reached very high levels and this water continued to emerge even when it was not raining. These factors meant much of the flooding took longer to drain away, with parts of the road network saturated for longer periods of time. Many reported that groundwater stayed high right through the spring and continued to impact on the network.
- 5.11** It is not surprising that with so much water around, river systems were unable to cope with the volumes of water and many rivers across southern England burst their banks, and water spread across their flood plains. A high profile case was the Somerset Levels, a low-lying area drained by the rivers Parrett and Tone, and there was also a lot of focus on the river Thames, which flooded in many parts, inundating both homes and roads. There was also flooding along parts of the river Severn, which was accentuated by the high water levels and winds in the Bristol Channel.
- 5.12** It is worth noting that whilst the focus of this report is the transport network and associated infrastructure, a related and key issue for local authorities is trying to prevent the flooding of residential and business premises, and also dealing with the aftermath. Sometimes, the source of these problems can be the inability of the road network and its drains to cope with the volume of rainwater, but there were also examples where floodwaters were managed onto the highway to keep water away from homes.

Figure 5.1 - The problems of wash from passing cars



- 5.13** In many instances, homes are adjacent to roads and both are affected, or threatened at the same time. One of the problems this can create if there is standing water on the highway, is the wash created by passing vehicles.
- 5.14** When there is any incident on the highway, whether a tree has been blown down or there has been a road traffic collision which has damaged part of the highway, this is very much 'business as usual' and the priority for the highway authority is to deal with the incident, having regard to the safety of all road users, and to manage any disruption. Many authorities use external contractors for this work, although some use directly employed staff. It becomes more difficult for the highway authority and its contractors when there are a series of incidents or their scale is much larger.
- 5.15** Several authorities stressed the importance of working with their local communities, and noted this can be a source of additional help. The Case Study on St Blazey on page 94 highlights the important role of volunteer flood wardens. We heard of several authorities who have established flood wardens, with various roles from monitoring to managing local situations. Local communities can also provide valuable local information: we heard of examples where local people were able to provide knowledge about parts of local drainage where formal knowledge was limited. The message is very clear: there is much to gain by engaging local communities to support both the disruption that can follow from extreme weather and measures to improve resilience.

- 5.16** When extreme weather is forecast, the authority and/or contractor will have staff at the ready and either bring in additional staff or have them on standby. All the reports we received, both from authorities and external commentators highlighted authorities were well-prepared, but even so, it can take time to clear up from a major storm where large numbers of trees have been blown over or lost branches. Many authorities reported the large numbers of tree incidents they dealt with over the winter. Devon and Hampshire reported that, over the winter, they had to deal with 1,340 and 1,000 fallen trees respectively, whilst East Sussex reported that in one 12 hour period, it had to deal with 200 fallen trees.
- 5.17** A noteworthy example of good practice was Norfolk County Council's response to tree incidents during the storm events of winter 2013/14. The Council dealt with over 200 incidents relating to fallen trees or branches affecting the highway. The incidents were dealt with through collaborative partnership with the Urban Search and Rescue team (USAR) and wholtime crews of the Norfolk Fire and Rescue Service. Emergency response to tree related incidents had typically been provided by in-house chainsaw operatives along with subcontract tree surgeons and plant hire companies. However, given current budget pressures and the need to work collaboratively across teams, Norfolk County Council proactively enlisted the services of the Norfolk USAR team.
- 5.18** Disruption from fallen trees is usually fairly short term. There is the complication for contractors when power lines are involved, for these have to be switched off, but otherwise, priority is given to main routes, or establishing a way through, even if this means leaving the full clearing up to a later time. We have seen evidence from Local Highway Authorities, such as Devon County Council, that effective management of such events is enhanced significantly where control centres exist to apply oversight and coordination of the functions associated with response and recovery. Such centres also play a vital role in disseminating information about road closures, diversions and conditions to road users and liaising with local media - a task which all highway authorities are used to performing.
- 5.19** Another task for local authorities is to set up and manage diversion routes; sometimes there will be assistance from the police. Where a road is impassable e.g. a fallen tree, most local authorities will try to have a presence at closure points to reinforce the message.
- 5.20** In busy urban areas, there can sometimes be considerable congestion from a road closure, and inconvenience and frustration to the travelling public. One example of this was the flooding from the Thames and its tributary, the Loddon in February, when a major roundabout in Wokingham became impassable for a period, blocking key routes, and impacting on the access into a major business park. See case study below. This caused significant disruption to businesses of national significance.

Case Study - The economic impact of localised flooding - Wokingham Borough Council

Wokingham Borough Council, is a geographically small unitary local authority located in the Thames Valley. Large east-west traffic movements within and through the Borough, are primarily focussed on the A329 corridor linking Reading to the west and Bracknell to the east, as well as the wider strategic network via the M4. The A329 corridor is home to two thirds of the Borough's 150,000 population and provides access to 20 primary and five secondary schools plus several core employment areas. The Borough is bordered by the River Thames to the north and northwest, while the River Loddon, a Thames tributary, flows south to north, across the predominately east-west highway network.

During the winter of 2013/14, the Borough was significantly and repeatedly affected by flooding of both rivers between the end of December and the end of February. Flooding also caused the effective closure of Sonning Bridge to through traffic (one of only two river Thames crossings between Reading and Henley-on-Thames) putting other river crossings in central Reading, already heavily peak time congested, under extreme pressure.

Flooding at Loddon Bridge caused significant disruption on the key A329 corridor at the Loddon Bridge Gyratory (see picture), affecting access to Winnersh Triangle (including the business park), links to the A329(M), with traffic backing up onto the M4 at times, and the park and ride site. Flooding of the Loddon affects the more southern A327 before the A329, so the flooding of both effectively closes the east-west highway network and makes access to central Reading and the business parks located in and around the town very difficult.

Nearby business parks and the town centre provide employment for 15,000 people; with plans for further expansion, the A329 corridor will support 40% of the housing and job growth over the next 15 years. Problems on the roads were exacerbated when the very high levels of ground water affected signalling equipment on the Great Western rail line near Maidenhead. This severely restricted the number of trains between Reading and Paddington for a number of days, forcing many rail passengers onto the roads to get to work.



- 5.21** Local Enterprise Partnerships are formed of businesses and local authorities and set local economic priorities and the context for growth. As such, they are well-placed to consider the impacts of extreme weather on the business community and to propose action to prevent repeat episodes of disruption.
- 5.22** A robust and efficient transport network is essential to support sustainable housing and employment growth. We heard from Wokingham that future flooding events could result in constraints on future business viability and employment expansion with additional costs and delays for local industry and commerce.
- 5.23** The impact of the severe flooding of the winter of 2013/14 has caused the Thames Valley Berkshire Local Enterprise Partnership (LEP) - which covers the Wokingham area - to rethink the priorities for investment, summarised in its recently published Strategic Economic Plan. This includes details of bids for a series of interventions to support future growth:
- A review of approaches to the management of flood risk in the Thames Valley, including part-funding an urgent piece of exploratory work, working with neighbouring LEPs, to ensure that those water courses that feed into main channels, and which run through other sub-regions, are tackled in a cohesive way.
 - Preparatory work to demonstrate the strategic significance of a Third Thames Crossing to address the north-south bottleneck across the Thames, working with the Oxfordshire LEP and other partners to action this.

- 5.24** We also heard that the issue of resilience and maintaining existing assets in good order has become an issue for other LEPs after this winter. In the South-West, five LEPs are working together because of concerns about the resilience of the area's strategic transport connections.

Recommendation 26:

When bidding for funds, Local Enterprise Partnerships should consider the need for funding to ensure the resilience of the existing transport network which supports businesses in their areas.

- 5.25** Where disruption lasts for several days or more, for example when there is a period of fluvial flooding, local authorities tend to set up more substantial traffic management arrangements, involving perhaps more information on road closure signs, and in some cases, if appropriate, temporary traffic signals. The nature of the network means there will always be an alternative route, but this can involve quite an extensive detour.
- 5.26** What can be difficult for local authorities to manage is intermittent flooding or disruption. Road closures may have been put in place, but local drivers in particular will start to re-use roads if they judge them passable, without regard to the damage that can occur to homes from any wash and to the network structure. See Figure 5.2. And if they break down, trying to get through, it is a further problem for the authorities. Similar problems can occur where drivers, and it is often local drivers, use minor roads to find ways around road closures. Many of these roads are not suitable for large numbers of vehicles, and if two vehicles have to pass on these roads, damage can be caused to road edges. If an HGV is involved, the damage can be considerable.

Figure 5.2 - Flooding of the A327 at Wokingham



Drivers navigating flood waters on the A327.

5.27 During this winter, the scale of flooding and threat to property meant that many local authorities were involved in Local Resilience Fora, and this meant heavy engagement for highways personnel. We heard of some initial difficulties with out-of-date call-out lists, and the need to 'get to know other partners'. However, local authorities have become well-practised at the operational demands of managing in, and recovering from, a crisis, working with a broader range of partners, and this was reflected in the evidence to us. Many highlighted that the subsequent review sessions were valuable in consolidating lessons that could be applied in future events.

Damage to road and associated infrastructure

5.28 The main issue from this year's extreme weather has been damage to the network: some of this has been fairly immediate e.g. damage from wave action and the sides of roads collapsing as a result of erosion from running water and ground movement. Some areas also experienced road collapses/sinkholes when the ground caved in. The legacy of sub-optimal maintenance spend over the years and the bad weather has manifested itself in large numbers of potholes developing. This is the publicly visible symptom, alongside general highway degradation, but of bigger concern to those who provided evidence to us was the further deterioration in the underlying network condition. We were advised that in many cases, the full extent of the impact is yet to be seen given the considerable time it can take for the ground to settle after flooding.

- 5.29** There is an important context to this damage: it has been widely accepted in recent years that the local authority network, with its vital role in delivering local economic and social prosperity, has a significant maintenance backlog, (as evidenced by the Transport Select Committee, the All Party Parliamentary Group on Highways Maintenance, the National Audit Office, the Asphalt Industry Alliance (the ALARM survey) and the Institution of Civil Engineers' 2014 State of the Nation Report).
- 5.30** Councils and the Local Government Association have been making this point for many years, although a lack of definitive data for C and unclassified roads has meant the precise scale of the backlog is difficult to quantify. Given pressure on resources, local authorities have generally targeted their spending on the 'A' and 'B' roads, leading to the situation where C and unclassified roads (where the data is weakest) are those where the backlog is greatest. The latest available Road Condition Statistics show that in 2010/11, the proportion of 'A' roads classified as 'red' or 'poor' was 6% compared with a higher figure of 9% for the proportion of B and C roads in this condition¹¹. This information is out of date due to a data processing problem; this has now been overcome and data to 2012/13 is now being analysed. That more recent data will be welcome. Given our understanding that LHAs have been prioritising 'A' and 'B' roads, it is also unhelpful to have the statistics for B and C class roads brigaded together. Considered analysis of the more recent data, the trend it shows and the variation by road class is essential, and we urge that this work is completed as soon as possible.

Recommendation 27:

The DfT, working as necessary with the Local Government Association and Local Highway Authorities should complete the analysis of road condition statistics as soon as possible, and ensure the time-series is kept up-to-date.

- 5.31** The position on other structures, particularly embankments, retaining walls and many of the smaller bridges/similar structures, is much less clear, because of a lack of data. Similarly, this also applies to drainage assets, where even the basic records do not always exist.
- 5.32** It should also be noted that Councils highlighted to us that many suffered considerable disruption and damage from flooding in the previous winter (2012/13). Whilst grateful to receive some emergency DfT funding to repair damage, this did not cover all the costs, so adding to the maintenance backlog.
- 5.33** As well as the maintenance backlog, which focuses on the structural or preventative maintenance required, authorities have been cutting back on regular or cyclic maintenance programmes in recent years. Not only does this routine maintenance cover the usual pothole filling and vegetation management, as well as signs and white lining, but also the clearing out of drains, ditches and culverts. This activity is

¹¹ Part of the Department for Transport dataset called Road Conditions in England (RCE) as referred to later on in the text.

vital to prevent subsequent, more expensive repair work, and in the case of drainage, to allow the asset to work as designed.

- 5.34** It is relatively easy to see how the action and power of moving water at coastlines causes damage, both weakening and in cases, damaging structures. Similarly, to see a river in full flow, where the water might be up to the arches, one can understand the pressure on the bridge piers, and the consequent damage which can be caused by scour, as illustrated by the events of Cumbria in 2009. And moving water, running across or alongside roads, can quickly wash away the edges of roads, especially if vehicles are driving on the edges.
- 5.35** There is general understanding of the freeze/thaw effect in winter causing potholes, especially if the surface has initial defects. However, it was interesting to hear from some of the highway engineers how this year's wet conditions have also led to many more potholes. This has applied to all classes of roads, in many cases even the better-maintained principal 'A' and 'B' road network. They suggested that this is a result of the high groundwater levels, which has sometimes meant that the pavement of the road (the main layer, below the wearing course on the top) is saturated, so weakening the road structure. When this is compounded with water lying on the surface, the hydraulic pressure caused by passing vehicles, and especially heavy vehicles, forces water into cracks or weaknesses and speeds the process of the road's deterioration.
- 5.36** Beyond these immediate visible effects, though, the concern most strongly expressed to us was about the longer-term degradation of roads and associated structures. In particular, groundwater can have significant repercussions for maintenance long after the event, with an extended 'tail' of damage to road surfaces and structures, weakened by its effects. Indeed, it is likely that we are yet to see the end of this, especially in areas where roads overlie clay soils, which are more susceptible to movement from changes in moisture content. Given the high groundwater levels, several Councils highlighted it would be some time yet before they are able to fully assess the damage from this winter's weather.
- 5.37** Bridges are a particular concern, not least because they can be very important to maintaining resilience. The ADEPT Bridges Group provided us with evidence supporting their concerns over the condition of bridges on local roads, highlighting issues with standards, inspection regimes and knowledge of these assets.
- 5.38** A particular concern in respect of bridges is 'scour' – where turbulent floodwaters erode river bed material and so undermine the bridge structures which sit in them - which is considered the most common cause of collapse. Scour is compounded by the abrasive effect directly on bridge structures themselves by debris (e.g. tree trunks) thrown at structures by rivers in flood, and by such debris becoming lodged against the bridge. These factors were found to be present in the collapse of 3 road bridges and 3 footbridges in the Cumbrian floods of autumn 2009.

- 5.39** To guard against such scour events, the DfT developed a standard (BD 97/12) for assessment of bridges. The ADEPT Bridges Group is concerned that whilst this regime, involving inspection of 100% of bridges, as envisaged by the standard, may be achievable by the HA, most of its bridges being of modern construction, it is unlikely to be so for LHAs which have many more bridges of a wide variety of construction and age. Indeed, LHA returns (for English authorities outside London) to the DfT indicate that there are around 53,000 bridges with a span of 1.5 metres or more in LHA control. Given the complexity of the task, it is hard not to agree with the ADEPT Bridges Group's conclusion that an approach based on prioritising bridges in terms of condition and level of use might be more useful for local authorities.
- 5.40** The ADEPT Group also highlights a broader problem: there is a lack of guidance about inspection regimes for bridges and the assessment of risk, and it appears that knowledge about condition is quite variable, even though there is a general bridge condition indicator. Given the importance of bridges to resilience, we believe that the DfT needs to pick up these issues and address them through the UK Roads Liaison Group, in conjunction with groups like ADEPT.

Recommendation 28:

The DfT should use the UK Roads Liaison Group to undertake a review of all matters relating to the monitoring and maintenance of bridges.

- 5.41** There was acknowledgement from all Councils that emergency monies made available by the DfT this year at least recognise some of the problems and will help to meet part of the repair bill, although there were concerns about the process and ground rules (see later). The DfT made payments of £183 million to LHAs in England in March 2014 as part of a Weather Repair Fund. This comprised £10 million to Somerset specifically, £70 million for the Severe Weather Recovery Scheme, which was subject to bidding on the basis of estimates of damage, and £103 million which was shared across authorities according to road lengths. A £200 million Pothole Fund was then announced in the Budget in March, of which £168 million was available to English LHAs, including those in London. Awards under this fund were announced on 20th June.
- 5.42** Beyond the direct costs to Councils, damaged road surfaces, and particularly potholes, can also cause damage to vehicles. The freight industry representatives drew our attention to the damage to their members' vehicles and the economic consequences for their businesses. But private motorists will face such costs, too. Sometimes, they will claim against a Council if damage is immediately apparent (and most authorities report increasing numbers of claims, a clear sign of deterioration) but generally the damage will be reflected in higher repair bills.
- 5.43** The damage this winter was not universal. Some authorities were hard hit, but others were spared disruption and the additional

damage to their networks. The former will need no reminding, but for other authorities, this winter's events should serve as a useful reminder of the vulnerability of our local transport networks, the need to be prepared for a wide range of extreme weather and the impacts it can have on the lives of communities.

Recommendation 29:

All local highway authorities need to learn from the events of winter 2013/14 and ensure they are prepared for, and able to respond to, similar extreme weather events in the future.

Funding context

- 5.44** This Review has benefited from the publication of the National Audit Office (NAO) report on highways, [Maintaining Strategic Infrastructure: Roads](http://www.nao.org.uk/report/maintaining-strategic-infrastructure-roads/)¹², on 6th June 2014. We were struck by how many of the conclusions that we had reached quite independently were also reached by the NAO.
- 5.45** Local authorities are, of course, independent legal entities, and are owners of substantial assets, including roads, bridges and other structures. They are responsible for managing and maintaining these assets, all of which are important to local economic and social prosperity, but in reality, many of these assets are potential liabilities. This needs to be seen in the context of the way local government is funded.
- 5.46** The position on structural maintenance for highways, sometimes referred to as renewals, and including funding for bridges and other structures, is relatively straightforward. The DfT provides capital grants to each highway authority, based on a formula. (The DfT funding to TfL is revenue but from 2015/16 this will be split into capital and revenue.) Following the Spending Review in 2010, and amid broader austerity measures, the DfT proposed a cut in the capital budget for roads maintenance of 15%. However, the DfT subsequently announced a number of tranches of additional capital funding amounting to £1.1 billion in the 2010 Spending Review period. The effect of this over the period was a net increase in capital funding for highways maintenance of 3%.
- 5.47** This capital funding is certainly not expected to cover the exceptional costs of extreme weather damage, and for that reason the DfT has made some additional payments. However, we heard the adequacy of the total funding remains a concern to the local government community, given the maintenance backlog.
- 5.48** The position on revenue funding is more complex, where spending on highway maintenance is competing for revenue resources with a range of other local authority services and the financing charges of borrowing for capital schemes. The competing services include adult social care, children's services, including special needs, the disposal

¹² <http://www.nao.org.uk/report/maintaining-strategic-infrastructure-roads/>

of waste, libraries and various regulatory services including trading standards and planning.

- 5.49** In outline, the funding for these services comes from the Department for Communities and Local Government (DCLG), and is paid to local authorities based on a formula, from Council tax payers (through the Council Tax levied on properties) and from local fees and charges. So government has significant control over total spending because of the grant it pays and because, over the years, it has sought to restrict increases in Council tax.
- 5.50** For many years, this has placed local government under pressure, particularly with the resource hungry and needs-led services like adult social care, children with special needs and waste disposal consuming growing percentages of the available resources. The response has been reviews of spending, a continuing search for efficiencies and different ways to deliver services and cuts to budgets. Against this background, there was the Spending Review in 2010 and significant cuts to the general local authority grant, amid broader austerity measures. However, it needs to be stressed that decisions about spending on individual services are the local decisions of the elected councillors for each authority, taking into account local circumstances, local pressures and local priorities.
- 5.51** In the 2010 Spending Review, DCLG planned to cut its revenue grant to local authorities by 28% through the spending period (this is a total figure, so individual authorities vary). Subsequently, further reductions have been made, so that local authorities faced, by the Local Government Association's reckoning, a 33% cut, as opposed to the original 28%. Current Government plans suggest a further significant reduction to local authority revenue support in the next five year period; based on this, a number of Councils indicated that their forecast highways budgets were planned to reduce from this year's level by more than 20% over the next 3 years. It is therefore very clear that the decisions in the forthcoming 2015 Spending Review will be very important to determine how much local authorities are able to allocate to highways maintenance activities. There has also been the tendency to use some of the capital monies, provided by the DfT, and intended for preventative work, to support some of the maintenance activities, such as the repair of potholes. Whilst understandable, it means less money is available to fund the essential structural maintenance work, and so this leads to a downward spiral in condition.
- 5.52** At local authority level, the budget for highways covers much more than just maintenance. It will also include the costs of the winter service including salt and vehicles to carry out precautionary salting of the highway, as well as snow clearance, the costs of traffic management, including the maintenance of traffic lights and pedestrian crossings, road safety work, including school crossing patrols, street lighting and the maintenance of associated drainage systems, signs and lines on the highway and staff, whether directly employed or through contractors responsible for these activities.

These are all high profile activities and it is against this background that local authorities have been reducing how much they spend on highways maintenance activities, alongside a continuing search for improved and less expensive methods of repair.

Emergency funding

- 5.53** A recurring area of concern in local authority evidence was that, whilst emergency funding was welcomed, the multiplicity and administrative requirements of applying for these funds for highways repair was unhelpful. They applied different eligibility and application criteria and tied up resource in developing and submitting applications at a time when local authorities could ill afford it. They can also encourage short term measures. We have a high degree of sympathy with this view.
- 5.54** For example, there is a concern that extra funding, but with a short timescale for delivery, can be counter-productive. It can encourage the short-term practices of filling potholes and moving on, rather than a longer-term, preventative approach of proper resurfacing commended elsewhere in this chapter. We share the NAO's concern that short deadlines for spending the emergency funding could also skew the market for a short period, increasing the price of repairs.
- 5.55** Nevertheless, extreme weather will continue to hit local authorities, it will continue to impact local road networks (see Figure 5.3 for a particularly dramatic example), and additional funding will, quite properly, be made available by Government to deal with the impacts. Given this, the DfT should prepare and communicate a consistent set of criteria for such funds ahead of extreme weather events striking and apply those criteria consistently from one event to the next. This should be similar to the Bellwin scheme operated by DCLG, which provides support to local authorities to clear up and effect repairs following exceptional events, but unlike Bellwin, which only focuses on the initial recovery phase, it needs to address the structural repairs which need a longer time period to complete.

Recommendation 30:

Government should consult Local Highway Authorities on a set of criteria to be applied consistently to emergency highway repair funding through the DfT whenever such funding is made available. These standard bidding criteria should include a period of time in which to invest additional funding which is long enough to encourage a longer-term approach to roads maintenance, so that additional funds are spent in accordance with an asset management approach, and do not skew the market.

Figure 5.3 - Old Beer Road, Seaton, Devon



Landslip on local road.

Asset Management Plans

- 5.56** There has rightly been a focus in recent years on local authorities adopting asset management principles and developing Asset Management Plans in respect of their roads infrastructure and actively using them to drive the organisational objectives and performance of the local road network. In 2004, CSS (previously known as the County Surveyors' Society), the predecessor of ADEPT, defined highways asset management as, "a strategic approach that identifies the optimal allocation of resources for the management, operation, preservation and enhancement of the highway infrastructure to meet the needs of current and future customers".
- 5.57** Part of the argument for developing plans was to better understand the condition of the network, and so have information to support estimates of the maintenance backlog. This work on Asset Management Plans was complemented by the requirement for local

authorities to collect a wide range of key performance indicators (KPIs) for the condition of both the 'A' and 'B' carriageway network. The collection of data on road conditions has changed somewhat in recent years with the former national KPIs being replaced by a similar dataset called Road Conditions in England (RCE). We refer earlier in the Chapter to problems in processing this dataset. Once these problems are resolved, this dataset will help reveal the trend in road condition, informing Asset Management Plans as intended.

5.58 Since the original CSS definition, practice has developed, helped by some the DfT general pump-priming of £32 million and support for a number of projects with specific local authorities by the DfT which commenced in 2008. This work is now being driven forward by the Highways Maintenance Efficiency Programme, (see later) which provides comprehensive information to support local authorities.

5.59 Asset Management Plans now, in essence, take LHAs through a series of steps to:

- Identify and correctly locate their highways assets
- Assess the condition of those assets
- Consider whether they are still required, or whether costs of upkeep can be avoided
- Make a judgement on the whole life cost of the asset – from construction/installation, through maintenance to replacement.
- Determine the level of service required from that asset.

5.60 The asset management approach is designed to move highways maintenance as far as possible from a reactive, 'patch and mend' activity, towards a preventative approach, where maintenance is rigorously prioritised. As such, the Review found that this approach is the right one: it is particularly useful at a time of very constrained funding to prioritise investment and take steps to maximise value for money. It is also a prerequisite of good highways management to have this kind of understanding of the local road network, and to link decisions to such matters as the importance of the road, rather than be driven by the road hierarchy. The Panel was encouraged to hear that there are many authorities with strong asset management approaches. We heard specifically about Hertfordshire and Cornwall (an excellent example of integrating drainage assets) and Herefordshire, but know there are others.

5.61 However, the Panel was surprised to find that around a third of LHAs do not have Asset Management Plans. Of course, it is the asset management approach, rather than the plan which is of such benefit, and the fact of having a plan is not necessarily an indication that the approach is being pursued. Nevertheless, a plan is a demonstration that the groundwork has been done to support the approach and we take the view that a plan is an integral part of the approach. Different levels of priority, capability and capacity in local authorities have led to the inconsistent uptake of Asset Management Plans across LHAs

to date, despite road condition being an issue of widespread public concern.

- 5.62** Early in 2014, the DfT issued a discussion document, "[Gearing up for efficient highway delivery and funding](#)". This addressed the allocation of £5.8 billion capital funding from the DfT to be made available over the five years of the next Parliament for local highway maintenance in England (structural maintenance and renewal) and proposed from the 2015/16 financial year, a possible route to incentivising adoption of Asset Management Plans through providing part of the funding only to authorities which have adopted such plans. As these plans are fundamental to moving from a reactive to a targeted and preventative approach to local highways maintenance, we support some incentivising, but consider the most important point is, however, to maximise the number of authorities adopting the Asset Management approach to highways maintenance. We therefore encourage the DfT to move towards the introduction, in a phased way, of a formula that rewards those following asset principles, whilst continuing to provide support to those who need it. This would suggest the implementation of the incentive should operate from 2016/17, or possibly the following year, so that those LHAs yet to complete them are given an opportunity to do so.

Recommendation 31:

Local Highway Authorities should follow asset management principles in managing their assets, and informing spending decisions.

Recommendation 32:

The DfT should proceed with its proposal to consult on using part of the capital maintenance monies to encourage the development and adoption of Asset Management Plans. However, in order to allow adoption of plans by more authorities, this should be delayed at least until financial year 2016/17.

Drainage

- 5.63** The drainage of all roads on the network is also a key issue for highway authorities. All main roads and many other roads, including residential roads, will have drainage incorporated within the carriageway, with a related drain system leading to a watercourse, river, sewer or a soakaway, discharging to ground. Sometimes, the drains will take the water into ditches, running alongside the road. For many rural roads, there are no drains as such, but water runs naturally off the road surface, helped in many cases by the cutting of 'Grips' – small drainage channels at right angles to the road, cut into the ground at the edge of the highway.
- 5.64** Most local highway drainage systems follow guidance set out in the [Design Manual for Roads and Bridges](#)¹³ which tests for exceedance

¹³ <http://www.dft.gov.uk/ha/standards/dmrb/>

in a 1:5 year event. With finite capacity, when there is intense rainfall, especially heavy summer storms, there will often be excess water on the road surface as drains are designed to give managed dispersal of the water.

5.65 However, if drains are not cleaned out, their capacity is much reduced and excess water will stay on the road surface for longer. Similarly, if drainage ditches alongside highways, or culverts are not kept clear, or pumps are not kept in good working order, water will not drain away as intended and the result is flooding on the highway. Maintenance is therefore a vital activity to prevent, or at least minimise the impact of flooding resulting from heavy rainfall.

5.66 Flooding from high groundwater levels or overflowing rivers is a different matter, and will usually overwhelm the drainage system very quickly – they are not designed to cope with such flooding. There will also be times when such problems will combine with heavy rain, and cause flooding of parts of the network.

5.67 When there is such flooding, it can also impact on the utilities, since much of their infrastructure is underground. Combined sewers are a particular problem, where flooding can lead to the escape of sewer content. Local authorities highlighted the importance of working closely with the water companies, not only when dealing with the disruption and clean up from events, but also undertaking work to improve future resilience.

5.68 The Review also heard evidence from local authorities and others of the additional problems caused by drain and ditch issues and run-off from surrounding land. Many landowners have not maintained the drains and ditches on their land and this can lead to faster run-off and flooding, both of which can impact on the highway. A similar problem applies with run-off from developments, especially with the increasing tendency to hard standings. Councils recognise little can be done to manage run-off from existing developments but consider it is vital that run-off problems and the potential for flooding are not compounded as more houses are built.

5.69 The Review is therefore disappointed to learn that the implementation of regulation for Sustainable Drainage Systems has been delayed. When implemented, this will allow for greater focus on drainage processes of attenuation and infiltration that mitigate the impacts of surface water run-off.

5.70 Flooding severely impacted the local road network over the past winter (see Figure 5.4) and, with the prospect of a trend to wetter winters in future, LHAs face the prospect of that experience become more frequent, especially if drainage systems are not operating at their maximum effectiveness, because of inadequate maintenance regimes.

5.71 Clearly, drainage systems are a key part of the road network. We were advised that many local authorities do not have comprehensive information records about these assets, and that only in some cases is information about these assets collected as part of their Asset

Management Plans. We understand that, where the starting information is poor, local authorities will, and indeed should, start this process in those parts of its network where there have been problems, or resilience is known to be an issue, but it is important for the condition of the drainage asset to be established to accurately inform maintenance requirements. We believe these should be considered as an integral part of any local authority's Asset Management Plan. All these points about drainage are well-covered in the [HMEP Guidance on the Management of Drainage Assets](http://www.highwaysefficiency.org.uk/efficiency-resources/asset-management/guidance-on-the-management-of-highways-drainage-assets.html)¹⁴ and we believe all LHAs should adopt the recommendations.

Figure 5.4 - Road closed due to flooding



5.72 It should also be noted that outside of London, the group of local authorities which have responsibility for highways (upper tier and unitary authorities) are also, under the Flood and Water Management Act 2010, designated as lead flood authority for their area, and as such, are responsible for investigating flooding and producing flood risk management strategies. In London, the 33 boroughs are the lead flood authorities (LFAs) for their areas, but their work is linked to a London-wide initiative, led by the Mayor's Office, entitled 'Drain London', which is focussed on surface water flooding. Much of the focus of LFA work is flooding or the threat of flooding to residential and commercial property, but there are also clear links to flooding which occurs on the highway. As indicated above, some of the problems for highways occur when water runs off surrounding areas too quickly, or land drainage systems are not operating as originally planned.

¹⁴ <http://www.highwaysefficiency.org.uk/efficiency-resources/asset-management/guidance-on-the-management-of-highways-drainage-assets.html>

Recommendation 33:

Local Highway Authorities must ensure that drainage assets are maintained in good working order, to reduce the threat and scale of any flooding, paying particular attention to those parts of the network known to be prone to problems, so that the drainage systems operate close to their designed efficiency.

Recommendation 34:

Drainage assets should be an integral component of a Local Highway Authority's Asset Management Plan; in addition, all Local Highway Authorities should adopt the recommendations in the Highways Maintenance Efficiency Programme Guidance on the Management of Drainage Assets

Resilient networks

- 5.73** One of the most significant spin-offs of an asset management approach is that it can help authorities not only to better understand the condition of its network, but to link this to records of those parts of the network prone to flooding or other problems, at times of extreme weather; the Asset Management Plan might then reflect that vulnerability. We believe this information should then form the basis of a related 'Resilience Plan', which will link back to the Asset Management Plan, and focus on the need for engineering solutions or alternative traffic management arrangements.
- 5.74** Just as we recommend, in Chapter 3, that the DfT should know which routes are of such vital economic importance that they comprise a 'critical network', so we think that LHAs should take a view on their network, and having regard to those parts prone to regular problems, identify the roads which are a priority in terms of ensuring resilience to extreme weather events – 'the resilient network'. This is likely to be a very similar network to the 'snow network' which the Quarmby Review of 2010 recommended local authorities identify, in that it is likely to include those routes crucial to the economic and social life of the area, although some of the 'snow network' roads may not have the resilience desired, for example, if prone to river flooding. The process for identifying this network should engage key business and interest groups and involve the community to help identify the network of critical routes.
- 5.75** The resilient network will then help prioritisation within the framework of the Asset Management Plan, given that it is unlikely an authority will be able to fund all necessary actions. The analysis underpinning the prioritisation will need to take account of the likelihood of extreme weather events and their associated economic and social impacts. The resilient network will take account of repeat events such as flooding and allow for clear recording of events for future reference and to inform action. It will take a view on which routes are absolutely essential and which can be done without for a time (see Figure 5.5). It is implicit that these decisions will not simply follow road

classification. And if, because of resource pressures, Local Highway Authorities begin to make decisions not to maintain certain roads, with clear implications for resilience, that too should be recorded in a Resilience Plan.

Recommendation 35:

Each Local Highway Authority should make an early start in identifying a 'resilient network' to which it will give priority through maintenance and other measures in order to maintain economic activity and access to key services during extreme weather.

Figure 5.5 - Flooding at Hambledon, Hampshire



Flood water being confined to the road to protect homes in Hambledon.

Collaboration

5.76 As we note above, many LHAs have a good record, in recent years, of collaborating on transport activity; a number of local authorities highlighted the value of regional workshops to support this. The technical collaboration has been driven both by resource pressures and the recognition that better outcomes can be achieved. This is also being reinforced by the strategic collaboration required by the wider geographies of Local Enterprise Partnerships and the opportunities of The Local Growth Fund.

5.77 There are a number of examples of groups of authorities working together, including the London Highway Alliance and the Midlands Highways Alliance. The technical collaboration has covered purchasing, joint contracts and the sharing of expertise i.e. both client and provider activities. We note the HMEP Shared Services Toolkit and the setting up of collaborative centres of excellence to share

technical expertise across geographic locations for subjects like asset management, drainage engineering and bridge maintenance. This collaboration is in addition to the necessary cross-border co-operation, in respect of traffic management issues, gritting routes and snow clearance, and the challenge of extreme weather described in this report, particularly flooding.

- 5.78** Given the importance of the asset management approach contributing to a more resilient network, we think there is scope for authorities to work together to move forward this work, as we understand, is already happening in Scotland and Wales. We acknowledge that there will still be the direct cost of the road condition assessment (Scanner surveys) and, for drainage, local investigation and assessment, but there is scope for collaboration in the client/specifying role and also in bringing together the data, using one of the asset management databases that are available.
- 5.79** Another potential area for collaboration, and of relevance to this Review, is flood risk management and the development of sustainable drainage. This is particularly the case as there continues to be pronounced skill and resource problems in these areas.

Recommendation 36:

Where Local Highway Authorities are faced with stretched capacity and thus find it difficult to develop and deliver the Asset Management approach and incorporation of drainage, they should investigate the potential for delivering through collaboration with other authorities.

Climate change

- 5.80** The Panel were pointed to some work undertaken by representatives of a number of authorities across the South West, looking to develop practitioner guidance on adapting existing highway infrastructure to the impact not only of extreme weather but also climate change with the aim of improving its resilience. The South West Local Transport Adaptation Task and Finish Group has developed a methodology, which concludes with the stages of prioritising adaptive actions to build resilience and embedding within the Highway Asset Management Plan. The Panel was impressed by this methodology and believes it should be further developed, and then disseminated so it can be used more widely.
- 5.81** For understandable reasons, the focus of the authorities with whom we engaged was the events of the winter, and the disruption and damage that was caused. However, most had an understanding of climate change and the increasing prospects for severe weather over the next decade or so. On the specific issue of higher temperatures in summer, the main concern expressed to us was the occasional problem with melting tar, associated particularly with roads that have been surface dressed. This is usually addressed by spreading sand on the surface.

Good practice

Highways Maintenance Efficiency Programme

- 5.82** Against a difficult resource background, local authorities have been searching for more efficient ways to deliver services, and this has certainly applied to highways maintenance. Improved methods of working and techniques have been developed with contractors; arrangements secured with local community groups, joint purchasing of services and equipment has been developed and there is growing collaboration, building on earlier benchmarking of costs and sharing of good practice. We heard of many good examples and note that when the DfT recently distributed the £168 million emergency pothole fund, it highlighted Northamptonshire, Hampshire and Lancashire as authorities amongst those which have demonstrated good practice.
- 5.83** Most, if not all, authorities are drawing on the work of the DfT-sponsored [Highways Maintenance Efficiency Programme](#) (HMEP) which has operated since 2011, a key source of guidance and good practice.
- 5.84** The HMEP is crucial to driving forward improvements to the delivery of the highways maintenance service. It connects groups across the highways sector, including representatives of contractors, and provides valuable tools and resources for highways engineers. Working closely with a wide range of interested groups, the website provides important documents, which can be downloaded, to support both decision-makers and practitioners, and the DfT is to be commended for this initiative.
- 5.85** We have referred previously to the Guidance documents produced by UKRLG, a body which brings together government and practitioners across the UK. The Panel heard that a review of one of the key guidance documents, 'Well Maintained Highways' is underway. We believe this provides an excellent opportunity to reflect many of the points covered in this Review, and particularly to address the issue of risk and resilience.
- 5.86** The Review Panel found other key routes of disseminating good practice on highways matters through, for example:
- [the UK Roads Liaison Group](#) (UKRLG) who are responsible for producing codes of practice for highways maintenance, lighting, structures and electronic traffic equipment
 - Professional bodies like ADEPT which, for example, produced a leaflet for all authorities entitled 'Best practice flood alleviation schemes' in March 2014
 - The Chartered Institution of Highways and Transportation, which can reach out to a membership of 12,000 members

Recommendation 37:

All Local Highway Authorities should make themselves familiar with the guidance and good practice promoted by the Highways Maintenance Efficiency Programme and ensure it informs their decision-making.

Recommendation 38:

The update to Well-Maintained Highways should be used to reflect the drive towards asset management in highways maintenance, with the inclusion of drainage. It should also reflect the points covered in this Review, and particularly address the issue of risk and resilience.

Designing for exceedance

- 5.87** All drainage systems have a designed maximum capacity, and if rainfall is heavy enough then that capacity will be exceeded, resulting in water flowing across the surface of the ground with the associated risk of flooding. Although capacities can be increased, for example through larger pipes, this is often very expensive and disruptive, and may not offer a sustainable solution for rainfall events that happen only occasionally.
- 5.88** Designing for exceedance is based on the principle of managing excess surface water when it occurs, ensuring that it flows along appropriate routes to locations where it can be temporarily stored, or diverted, in a controlled way. By adopting this approach in suitable locations, the more serious effects of flooding on property and transport links can be mitigated or even avoided. By design for exceedance we can make our transport and communities more resilient to a changing climate. The principle has been promoted by the Construction Industry Research and Information Association (CIRIA) in their 2006 guidance document C635 "[Designing for Exceedance in Urban Drainage](http://www.highwaysefficiency.org.uk/efficiency-resources/asset-management/guidance-on-the-management-of-highways-drainage-assets.html)"¹⁵. More recently CIRIA have sought to encourage greater use of this technique through their research project C738 "Managing Urban Flooding from Heavy Rainfall – Encouraging the Uptake of Designing for Exceedance". Twelve case studies have shown practical examples of where designing for exceedance has reduced the impact of flooding, often in a cost effective way. These case studies include techniques to retrofit solutions to local landscape and more strategic interventions for regeneration and new development.

¹⁵ <http://www.highwaysefficiency.org.uk/efficiency-resources/asset-management/guidance-on-the-management-of-highways-drainage-assets.html>

Case Study - St Blazey, Cornwall



In November 2010, St Blazey suffered major flooding following extremely heavy rainfall. 55 properties were flooded and the A390, one of three main east-west routes through Cornwall, was closed, causing economic disruption to businesses. The main source of the flooding was the normally small Prideaux Stream, which overflowed onto a minor road which then channelled the flood water towards St Blazey and the A390.

Following investigation, a package of measures were identified and developed collectively by the Environment Agency, Cornwall County Council, St Blazey Town Council and the Par and St Blazey Community Flood Group. The solution identified was to reprofile a short section of the minor road so that flood water on the road could be diverted back into the stream, combined with the use of a field as a temporary storage area and property level protection in the town. These measures, achieved at modest cost, have reduced the risk of flooding to the community, businesses and the road network, and have proven to be effective to date.

Of particular note has been the partnership working between the various affected parties, and particularly the active involvement of the Par and St Blazey Community Flood Group, who have worked with Cornwall County Council to mobilise 80 volunteer flood wardens to help the community in the event of further flooding.

Severe Weather Impacts Monitoring System (SWIMS)

5.89 Originally developed by Kent County Council, SWIMS enables local authorities throughout the UK, and their partners, to collect data about how the services they provide are affected during severe weather events. It provides a valuable decision-support tool for service providers that allows them to build up a picture of their vulnerability to severe weather, develop business cases for taking appropriate action and plan better for the future. Partners can use the system to:

- record details about how their service and service users have been affected;

- record information on how they have responded to an event, both in the immediate aftermath of the event and any longer-term responses;
- generate a report to show how their organisation has been affected by severe weather;
- share data with other organisations to identify common barriers and areas of vulnerability;
- share best practice, expertise and lessons learnt and
- support business cases for resilience actions.

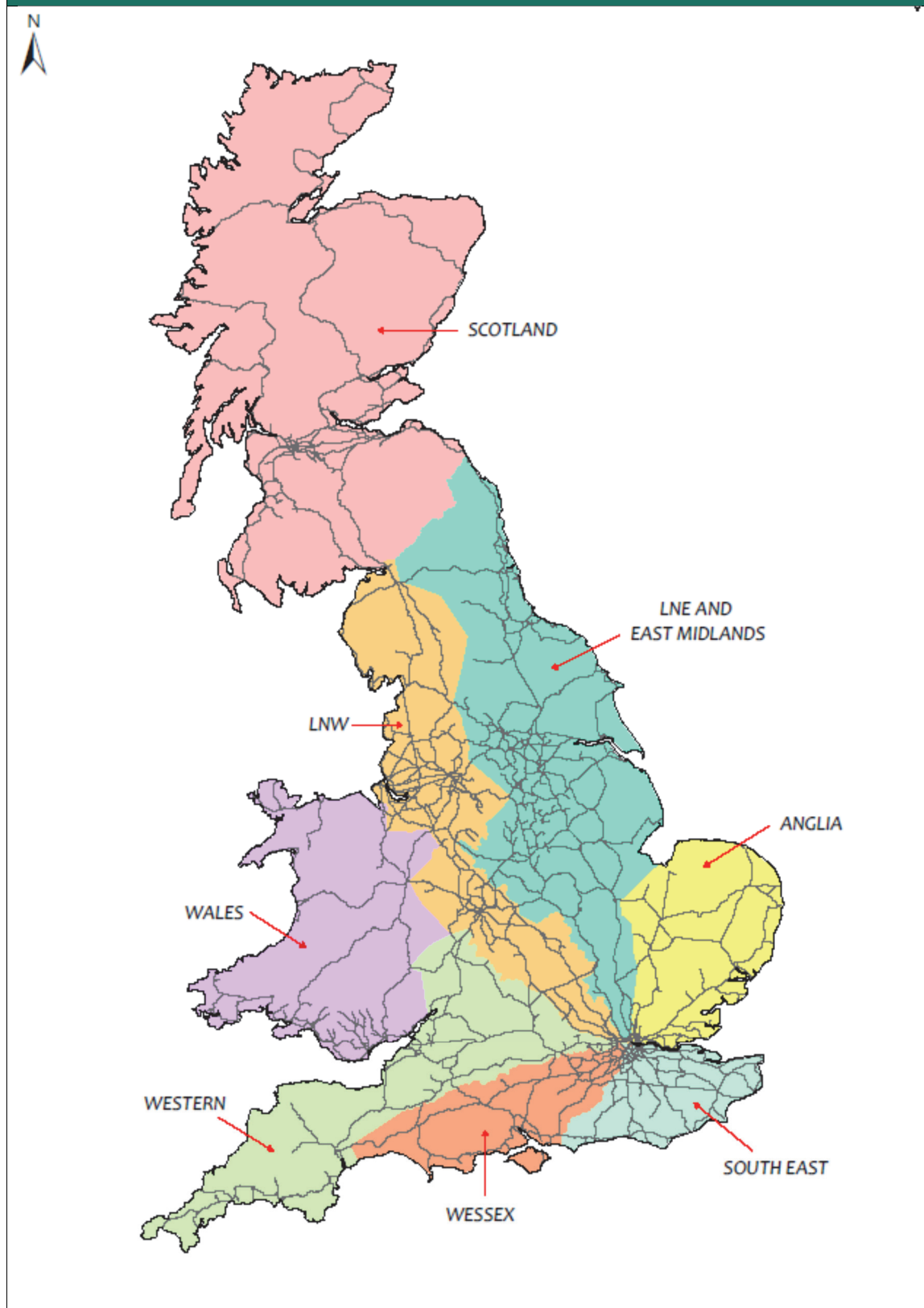
5.90 SWIMS will be made available nationally to local authorities through the 'Climate Ready' programme (in partnership with the Environment Agency, Defra, LGA and Climate UK). Climate UK will host the system and support a staged roll out to all willing local authorities in 2014.

6. Railways

Introduction

- 6.1** Network Rail is the owner, operator and maintainer of the large bulk of Britain's railway network, providing the tracks on which a number of passenger train operating companies (TOCs) and freight operating companies (FOCs) run the trains. Network Rail responsibilities cover the track, signalling systems and all the associated structures such as bridges, tunnels and embankments, which are most exposed to the effects of weather. As network operator Network Rail works closely with the TOCs and FOCs to manage disruption, including that caused by extreme weather, and there are a number of cross-industry processes and fora to facilitate this, led by the Rail Delivery Group which brings together the principal operators to set overall policy. Network Rail is regulated by the Office of Rail Regulation, and most of the Passenger TOCs are franchise operations let and overseen by the DfT. In total Network Rail manages 20,000 miles of railway in Britain, on which some 22,000 passenger trains run each day (7.3 million per year), carrying 4.4m passengers daily on average (some 1.6bn per year), and 700 freight trains each day which carry some 11 % of Britain' s freight traffic.
- 6.2** Railways in Northern Ireland are managed by Translink, an integrated organisation with responsibility for rail infrastructure, train operations and bus operations across Northern Ireland.
- 6.3** As part of Transport for London, London Underground operates the 'Tube' network in and around the Capital. It has 11 lines covering 1150km of which 52% runs above ground. There are 616 trains in service handing 4.2 million passenger journeys each weekday totalling 1.25 billion passenger journeys per year.

Figure 6.1 National Railway Map



The experience of winter 2013/14

- 6.4** The national railway network suffered significant damage and disruption from the extreme weather of last winter, with large numbers of passengers experiencing disruption to their normal service, in some cases for prolonged periods, and communities in some parts of the country, particularly the West Country, losing their rail link for a number of weeks. Passenger Focus and others told us they thought that the industry performed generally well in handling the widespread impacts of last winter's extreme weather and resulting disruption, and returning services to normal as soon as was practicable. There was clear evidence of improved processes and practices, learned from the experience of previous weather disruption particularly the winters of 2008/09 and 2009/10. The information flow to passengers has improved since the Quarmby Review, with closer collaboration between TOCs and Network Rail. But everyone we talked to acknowledged that there is much more that needs to be done to strengthen the railway's resilience, in all three layers of resilience, and many valuable lessons that can be learned from last winter's experiences. It is essential to ensure that similar weather events next winter would be managed to cause much less disruption to passengers, and that the physical resilience of the network is progressively strengthened in future years.
- 6.5** The national railway industry proactively suspended services because of safety concerns on a number of London commuter lines prior to the St Jude's storm, to be able to clear the large number of fallen trees and restore services to normal in as short a time as possible. It also implemented contingency timetables on a number of routes and occasions where the damaged infrastructure was impeding operations, in order to match the services offered to what the conditions allowed and more reliably deliver the albeit reduced service to passengers. In these cases the objective was to provide a safe railway minimising the duration of disruption and not overpromising to passengers by offering a service which was not realistically deliverable and communicate this with more clarity to passengers. Considerable ingenuity was shown by Network Rail in running progressively more services through the section of line near Maidenhead where ground water flooding affected services. The most severe disruption from flooding lasted 10 days and caused significant signalling problems.
- 6.6** By contrast, the services of London Underground (LU) operated normally throughout the period of St Jude's storm. This was a reflection on the extent to which LU have made significant progress in managing lineside trees and vegetation and addressing drainage maintenance. This higher level of resilience was demonstrated throughout the extended period of extreme weather during the winter of 2013/14.
- 6.7** A number of other national rail lines were affected by earthwork slips brought on by intense rainfall, resulting in either temporary speed restrictions or complete closure whilst the earthworks were rebuilt. In all cases Network Rail and its contractors worked commendably quickly to restore normal service.

- 6.8** The headline event was of course the severed main line to the South West at Dawlish, where again Network Rail and its contractors should be commended for rebuilding the sea wall and rail line ahead of schedule. But this was not the only instance of coastal storm damage. Several sections of line further west in Cornwall were damaged, and the West Wales line between Barmouth and Harlech was extensively damaged and closed for 17 weeks .
- 6.9** Network Rail has undertaken a wide ranging review of lessons learned and had already tasked each of its Routes with producing a Weather Resilience and Climate Change Adaptation Plan by September. Similar reviews have been undertaken by individual TOCs and by the National Task Force, commissioned by the Rail Delivery Group. In addition the industry as a whole has been collaborating for several years on a programme of research led by the Railway Safety and Standards Board (RSSB) entitled Tomorrow's Railway and Climate Change Adaptation (TRaCCA). We expect our recommendations to be adopted as appropriate by these various work streams.

Specific vulnerabilities of railways to extreme weather

- 6.10** Railways can be impacted by a wide range of extreme weather: flooding, high winds, coastal storms, lightning, heavy snow, ice and heat can all disrupt operations. Perhaps the only form of weather that has no material impact is fog, through which trains are able to operate normally.
- 6.11** Much of the network was constructed 150 or more years ago. Trains in those days were not capable of operating over other than very slight gradients, so much of the network is built on embankments or cuttings, which were not constructed to modern standards, with usually much steeper embankment slopes than would be normal now and therefore at greater risk of slips. It is striking that the only rail line in Britain that has not suffered any material weather related disruption over the last few years, and certainly last winter, was HS1 which has been built and maintained to modern standards throughout. See Figure 6.2.

Figure 6.2 - Cutting profiles



A steep historical cutting shown side by side with the modern design standards used on HS1

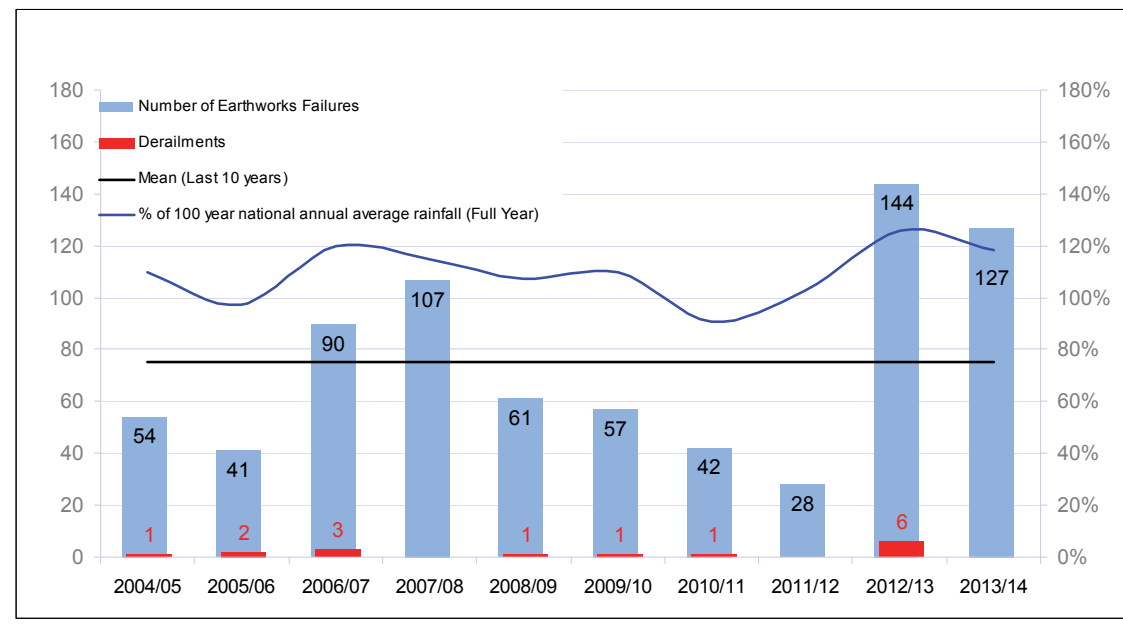
- 6.12** It is also the case that the railway network suffered from severe investment restrictions and tight financial constraints for a number of decades under British Rail, and subsequently under Railtrack. A number of areas of asset management suffered as a result, particularly earthworks, drainage and vegetation management, with priority given to trains and track. Much of this relative neglect is in the process of being rectified by Network Rail through its work programmes for the last regulatory Control Period, 2009-2014 (CP4) and the current regulatory Control Period just started (CP5), but the experiences of last winter indicate that there are several areas that need sharper focus. This is underpinned by an increasingly robust asset management approach.

Earthworks

- 6.13** Network Rail has 9,800 kilometres of embankments and 6,900 kilometres of soil cuttings and 1,500 kilometres of rock cuttings on its network. As already noted these were mostly constructed 150 or more years ago, were not designed to modern standards or with today's knowledge of the performance of earthworks, and the fill material used to build the embankments was rarely recorded. Embankment and cutting slopes are generally much steeper than would be the case for modern structures such as on HS1 or a motorway.
- 6.14** As Thomas Telford reputedly said, water is the enemy of the Civil Engineer, and water ingress is the principal threat to slope stability. Sustained and intense rainfall is therefore a particular vulnerability, and likely to cause slips and slope failures. This is of course not a new phenomenon, but as the graph below shows the last two winters have seen unusually large numbers of embankment slips with 144 and 127 slips across the network in both years. Only a minority of these led to speed restrictions or temporary route closures but they all represent potential hazards.

Figure 6.3

Network Rail Earthworks slips and resulting derailments since 2004/05



- 6.15** The problem is well recognised by Network Rail, with a considerable amount of work in both CP4 and planned in CP5 to assess, strengthen and rebuild at risk slopes. Network Rail's priority has rightly been on ensuring safety of operation, with cuttings particularly those made of rock being a clear safety risk, since a rock or earth fall into the cutting could cause a serious derailment and potential subsequent train collision. The fact that there were no derailments caused by any of last winter's slope failures, compared to 6 derailments over the winter of 2012/13, with some 144 earthwork failures that year, is indicative of progress being made in addressing this risk.
- 6.16** Network Rail has a well-developed process for assessing the condition of its embankments, currently a three-tier system, and is in the process of refining this classification further to improve its targeting of the poorest slopes for attention. The classification takes account not just of the condition of the slope but also the potential risk to safety, measured principally by the number and speed of trains on the route. However we believe this classification needs to be further refined to take account of the relative economic importance of the traffic on the route, such as its role in linking key ports or airports as referred to our Recommendation in Chapter 3, and which is not necessarily reflected by the volume of traffic on the route. This will ensure that Network Rail is prioritising its activity according to the wider needs of transport resilience not just on safety grounds.

Recommendation 39:

Network Rail should amend its classification system for embankment and slope stability risk to take account of the economic importance of the traffic on a route in addition to the risk to train safety from a slope failure.

- 6.17** Rebuilding an embankment or cutting is often an expensive and substantial heavy engineering task. Access usually has to be negotiated from neighbouring landowners, and temporary access roads built to bring in plant and construction materials and remove spoil. We were struck by Network Rail's engineers' estimates that rebuilding a soil embankment in an emergency after it has failed is only some 35% more expensive than rebuilding it on a pre-planned basis, although this takes no account of the cost of disruption to train operators and their customers if the line has to be closed because of the failure. See Figure 6.4.
- 6.18** Emergency repairs to soil cuttings are generally twice as expensive as pre-planned work and reactive response to rock cuttings is significantly more expensive than planned intervention. For soil embankments in particular and to some extent cuttings, this puts a premium on accurate risk assessment and forecasting of slopes that are going to or are very likely to fail, in order to avoid wasted expenditure on rebuilding slopes which would not otherwise have failed. Network Rail's Geotechnical Engineers have a much better understanding of the behaviour of their earthworks than a few years ago and have much work in hand to trial different methods of monitoring at risk slopes. We understand some 230 embankments currently have some form of monitoring installed. However this is an area of rapid technical innovation, with a variety of monitoring technologies under development or now available.
- 6.19** At present there are a limited number of techniques available to stabilise an at-risk embankment in situ, as opposed to partially or completely rebuilding it. We understand that one such possible technique is at an early stage of trials, involving the insertion of electrodes into a slope to remove water by a process of electro-osmosis. We believe that research could usefully be undertaken into this and other potential innovative stabilisation techniques.

Recommendation 40:

Network Rail should maintain a strong focus on trialling newly available condition monitoring and slope stabilisation technologies, working with academic and other researchers and with other railway administrations, to improve its ability to identify and anticipate slopes that will fail and target remedial work as efficiently as possible. In addition Network Rail should continue to commission academic research into possible slope stabilisation techniques short of physically rebuilding.

Figure 6.4 - Work underway to repair the landslip at Botley, Hampshire



- 6.20** Good drainage is obviously an important component in preventing the deterioration of embankments and slopes, and reducing their vulnerability to intense rainfall, as well as maintaining track quality. We note that Network Rail is planning to spend £328 million in CP5 on drainage improvements and maintenance, and we endorse this priority. This must include repair and subsequent maintenance of crest drains above cutting slopes, which have often been neglected or fallen into disrepair, as well as toe drains at the foot of embankments to help take excess water out of them.
- 6.21** The railway can also be impacted by surface water run-off from adjacent land, which can be caused by lack of maintenance of neighbour's drainage or changed farming practices. We recommend elsewhere in this Chapter that Network Rail's powers to access neighbours' land to maintain drains be modernised. We also recommend in Chapter 3 that a suitable 'code' be developed to give neighbours of transport infrastructure better information on their rights and responsibilities. Both these recommendations stand to improve the situation in respect of run-off onto the railway.

- 6.22** Good vegetation management can also affect the condition, rate of deterioration and vulnerability of embankment slopes to failure. This is recognised by Network Rail in the case of cuttings and embankments, where tree roots can undermine stability of the slope, trees suck water out of embankments in the summer growing season, at a time when moisture content should be ideally conserved to prevent shrinkage, but do nothing to take water out in winter when conditions are normally much wetter. Trees and excessive vegetation can also impede effective examination of the condition of slopes. At best trees are a nuisance on embankment and cutting slopes and at worst they are a hazard, exacerbating the shrink-swell cycle between summer and winter, particularly on clay embankments, and contributing to the long term deterioration of slope stability.

Vegetation management

- 6.23** We recognise that tree felling is an emotive issue, potentially affecting visual amenity and of concern to conservationists. But trees can be a serious safety hazard in high winds when blown onto railway lines (see Figure 6.5), blocking the line and a potential cause of derailments or worse. They can be damaging to the long term stability and safety of earthworks, as noted above, and their leaf fall in autumn is a regular cause of adhesion problems often causing significant delay for passengers. Network Rail must address this threefold hazard by an active programme of pruning and felling. But in parallel it should develop an active biodiversity strategy, looking at alternative vegetation approaches, such as hydro seeding or pollarding to maintain visual amenity and undertaking off-setting tree planting away from the railway itself.
- 6.24** It is worth noting that it is only 50 years since the last steam trains operated on British Railways. Tree growth was much less of a problem in the steam era, because the sparks from the engines' fire boxes readily caused line side fires. Length gangs therefore frequently cleared vegetation, in order to reduce the scale and risk from line side fires, but these were progressively withdrawn in the 1960s and 1970s as continuous welded rail replaced jointed rail with a consequent reduced need for maintenance. Lineside vegetation used therefore to be actively managed, and the now large number of line side trees are a problem that has grown up slowly over the last few decades, with most of these trees dating from the end of the steam era or later.
- 6.25** There were 1,500 incidents where trees or substantial branches were blown over onto rail lines over last winter, causing widespread disruption particularly after the St Jude's storm on 28th October. Overall this was one of the largest sources of disruption over the period. Roundly a third of these resulted in contact with trains, with 430 cases reported of trains striking trees or branches over the winter, often causing significant damage to trains, as well as disrupting the service. On South West Trains, for instance, one half of all trains suffered at least some damage, with substantial total cost of repairs arising, as well as subsequent short formations as trains are repaired with resultant short term overcrowding.

It was only fortunate there were no significant accidents as a result, largely achieved by Network Rail prioritising safety by not reopening lines before inspections were complete.

Figure 6.5 - Clearing a fallen tree from the railway



A maintenance team clearing a fallen tree at Keymer, near Brighton.

- 6.26** Network Rail estimate they have a total of 2.5 million line side trees with a trunk diameter of 150mm or more. Of these approximately 25,000 are in a risk category based on the likelihood of failure, the size of the piece of timber involved and the potential consequence of any resulting incident. This risk assessment relies on a ground level, visual inspection following industry recognised procedures and if no defect is visible or the size of tree involved is below the 150mm threshold, then the tree is not recorded. The Beaufort scale for wind measurement details progressive failure of tree parts through to complete failure in Storm force 10 - this complete failure will occur at lower wind speeds if the tree is compromised by a defect of some sort, i.e. one of those identified during visual inspection. So in very high wind speeds it is possible that trees without defects could be blown over. The National Lineside Tree Survey has also provided data on species distribution and this has shown that across the network, 16% of the tree population is ash which is at risk of infection from ash dieback disease as it spreads from the South East. The risk from such infected trees needs to be closely monitored. Climate change is likely to increase the rate of growth of vegetation and trees and the incidence of pests and diseases. Unless there is a significant increase in the maintenance activity, the overall population of trees will continue to increase as young trees and coppiced trees mature.

6.27 Network Rail's current vegetation standard is to clear trees and bushes to a distance of between 3 and 5 metres from the rail depending on line speed, and 3.5 metres from overhead power lines and also to clear trees from sections of line at particular risk during autumn leaf fall. The former is more about maintaining sightlines for train drivers than increasing the resilience of the railway to extreme weather. However this policy in no way adequately addresses the risk of trees being blown onto the line in high winds, or the damage they can do to the long term stability of slopes. It is not clear to us that there is a defined budget for vegetation management, with what spend there is apparently being drawn from several different budgets, or that there is an appropriate line of management responsibility. We consider that Network Rail needs to substantially strengthen its vegetation management policy, and have two recommendations to achieve this:

Recommendation 41:

Network Rail should substantially strengthen their focus on the management of vegetation by:

- **Developing a ten year strategy to bring about a significant reduction in the number of line side trees and the overall level of vegetation. It should support this strategy with appropriate business plan and budget provision.**
- **Developing an active biodiversity strategy to adopt alternative vegetation approaches on cleared sections and engage in off-setting tree planting, generally away from the railway.**
- **Revising their vegetation management strategy to include at-risk embankment slopes, particularly on more vulnerable clay embankments, with ideally trees confined to the bottom one third or so of the slope where they can help stabilise the toe of the slope.**
- **Developing a strategy to prevent vegetation re-growth on embankments, cuttings and the lineside after vegetation clearance. We note that significant sections of route which have had trees cleared over past years are already seeing significant re-growth of saplings and small trees. This will also require a separately identified fund for maintenance.**

Recommendation 42:

Network Rail should also work with train operating companies and the Office of Rail Regulation to sharpen the economic signals it receives to drive the case for a sustained vegetation management strategy. This should include the cost of rolling stock damage, and the subsequent losses associated with overcrowding and poor performance as a result of reduced rolling stock availability, as well as the risk to safety from collision or derailment.

6.28 To put this issue in perspective, we note that the electricity distribution industry is planning to spend £70 million in the period 2015-19 on clearing trees at risk of bringing its power lines down, as part of its own climate change resilience programme. This is on top of the £422 million

that it will spend in the same period on vegetation management for safety purposes, but which inherently provides a level of resilience.

- 6.29** Finally the problem of trees being blown over onto the railway is not confined to those on Network Rail land. Network Rail estimate that over 60% of the trees blown over last winter were from outside Network Rail's boundary. This is a much bigger problem for railways than it is for the strategic highway network, because most railway lines have a narrow footprint as a result of the original constructors wishing to minimise land take and keep the costs of land acquisition at a minimum. It is also a problem for many local roads. This is clearly not an easy issue to address with the need to liaise with third party neighbours to procure the felling of those trees at risk. The legislation governing Network Rail's ability to intervene in respect of physical features which might be a threat to the safe operation of the railway is contained in the Railway Regulation Act of 1842, an archaic piece of legislation which is not easy to interpret. For the most part we understand Network Rail do not use the statutory route, but seek to reach mutual agreement with neighbours for the necessary access or action. However we believe that the legislation should be modernised for those cases where agreement is not possible, with consideration not just of the needs of Network Rail and rail users, but also the reasonable rights of the third parties. The new legislation should seek to address issues arising from neighbouring landowners' trees, drains and earthworks.

Recommendation 43:

The DfT should review, and at the earliest opportunity modify or replace, the 1842 legislation governing Network Rail's ability to access neighbours' property, with more explicit powers to deal with both potential threats to the safe operation or resilience of the railway and for planned maintenance.

- 6.30** The new provisions will need to be clear in allowing Network Rail the ability to access neighbours property in order to rectify or prevent a failure. They will also need to ensure reasonable rights for neighbours to contest Network Rail's use or proposed use of their powers. In the meantime Network Rail should adopt a proactive approach to tackling the problem of neighbour's trees hazarding the railway, setting up teams including Land Agent, Arboriculturalist and Community Relations specialists, to progress clearance of at risk trees.
- 6.31** Translink noted that they would also benefit from a strengthening of their rights of inspection of third-party land around railway tracks in Northern Ireland.

Inland flooding

- 6.32** The railways were disrupted by flooding at a number of locations over the winter, the most significant being at Maidenhead, Hinksey near Oxford, and Bridgewater (see Figure 6.6). Rail can be impacted by all forms of inland flooding, fluvial where the line runs alongside a river or watercourse, pluvial where intense rainfall or run off from adjacent land

causes flash flooding, and groundwater flooding as at Maidenhead last winter. Like the HA, Network Rail has a reasonable appreciation of those sections of route which are vulnerable to flooding based on historic experience, but like the HA it needs to use the recently reissued Flooding Risk Maps issued by the Environment Agency to identify potentially at risk sections.

Recommendation 44:

Network Rail should use the recently updated Environment Agency Flooding Risk Maps to identify sections of line that are potentially at risk of fluvial flooding, to supplement its register of at-risk sections based on historic experience.

Figure 6.6 - Flooding at Bridgewater, Somerset



- 6.33** There is also much that Network Rail can and is doing to increase the physical resilience of its infrastructure to flooding. An investment of £ 328 million in drainage maintenance and improvements is planned in CP5 which will help reduce the risk of pluvial or surface water flooding, as well as reduce the number of potential embankment slips. It is a substantial increase in activity compared to CP4, with £201 million on track drainage in CP5 compared to £81 million in CP4 for instance. As part of the package of resilience measures for the Great Western route Network

Rail is raising track heights over several sections as well as raising line side electrical equipment cabinets (location cabinets) above track level so the equipment inside is not at risk of water ingress and consequent short circuiting. Network Rail should include similar measures in the Resilience Plans that it is preparing for other routes.

Recommendation 45:

Development of the route Resilience Plans by Network Rail will identify locations where the railway is at risk of flooding. For these locations Network Rail should examine the feasibility of raising location cabinets and track height and make an economic appraisal of the cost and benefits of achieving higher resilience to future flood events.

- 6.34** One of the major impacts of flooding on the railway is that standing water short circuits the electrical circuits installed in the track (track circuits) that are used to identify the presence of trains. This disables the automatic signalling, with the normal remedy being to deploy hand signallers on the track side to pass trains until the signalling system is restored. This is a very slow procedure and very substantially reduces the capacity of the line concerned. Increasingly Network Rail has been installing axle counters, which are much less sensitive to the presence of water, as an alternative to track circuits on sections of route such as along the coast at Dawlish where the presence of water is a regular problem. We understand that Network Rail intend to replace track circuits with axle counters much more widely and we welcome this.

Recommendation 46:

Network Rail should consider accelerating the conversion of track circuits to axle counters at those sites identified through the route resilience plans as being at high risk of flooding.

- 6.35** At Maidenhead last winter Network Rail also deployed a newly developed temporary automatic signalling system which enabled trains to be run much closer to normal speed and line capacity. We understand that adapting the system to a particular section of line requires five days of design work currently, but that Network Rail is working to reduce this to closer to one day. We commend Network Rail for this initiative and recommend Network Rail should plan to use this new technology widely.

Recommendation 47:

Network Rail should work up and deploy its new temporary automatic signalling system widely whenever appropriate

Coastal damage

- 6.36** The vulnerability of sections of the rail network to coastal storms has been well demonstrated last winter with prolonged closure of the railway at Dawlish and on the West Wales line. Other sections at risk include the North Wales line, the Cumbrian coast line, the Folkestone to Dover line and sections of line in Cornwall. The risk will clearly grow in future as sea levels rise, some of the strongest storms become more intense the risk of

more storm tide surges and more frequent damage from large, more powerful waves.

- 6.37** Network Rail has of course reinstated the railway at Dawlish, in effect rebuilding the section of sea wall that was destroyed in February. However whilst the new wall is of modern reinforced concrete construction it replicates the design that was destroyed and is therefore not materially more resilient to future sea level rises and severe storm damage. Network Rail is currently raising the low-level walkway in front of the sea wall at Dawlish prior to next winter to help protect the railway further.
- 6.38** The Dawlish sea wall is also not the only section of line in the area that is at risk, with regular land slips occurring in the cliffs between Dawlish Warren and Teignmouth, and increasing vulnerability where the line runs adjacent to the rivers Exe and Teign estuaries, because of rising sea levels. Network Rail is currently undertaking a series of studies into the options for strengthening resilience in all these locations, as well as possible options for a new inland line which avoids the coast between Exeter and Newton Abbott – the first of these studies (West of Exeter Route Resilience Study) was published on 15th July 2014. The issues involved are complex, and it is important that they are thoroughly explored, but we would stress that the one option that is not tenable from a resilience perspective is to do nothing more.

Dawlish Case Study

On the 4th February 2014 around 80 metres of both railway lines at Dawlish was severely damaged by wind and the sea's high tide, washing away ballast and the foundations on which the track is built. There was also severe damage to the sea wall and the track and platforms at Dawlish station. A second lesser breach of the wall was discovered near Dawlish Warren following the storms of 15th February. This also made the original hole 30% larger. Initially the complete railway between Exeter and Penzance was closed after damage at several locations along the route. Some parts reopened quickly as work continued between Exeter and Plymouth.

The complete reopening of this line was further challenged when a new landslide occurred in early March when about 20,000 tonnes of a cliff face near Teignmouth sheared away and slumped about 20m onto the toe of the railway, which sits at the bottom of the cliff at this point. With the help of Devon and Cornwall Fire and Rescue Service, engineers sprayed thousands of litres of water per minute onto the slip to wash away the earth and encourage the slip to complete its fall to the railway below.

The Network Rail construction team of 300-strong engineers and contractors, known locally as the 'orange army', battled for over two months to overcome the challenges of the winter's weather. This work included:

- Building a temporary sea wall from 18 welded shipping containers to protect homes and engineers as they worked to rebuild and fortify a breach with more than 6,000 tonnes of concrete and 150 tonnes of steel

- Removing 25,000 tonnes of collapsed cliff at Woodlands Avenue, Teignmouth, using high pressure water cannon, fire hoses, helicopter-borne water bombs, specialist roped access team and 'spider' excavators
- Repairing dozens of other sites along the coastal railway, clearing hundreds of tonnes of debris and repairing over 600m of parapet walls
- Rebuilding half of Dawlish station with a new platform, new canopy and repainting throughout
- Installing over 13 miles of new cables, designed and installed a new temporary signalling system and replaced over 700m of track and ballast

During this time the rail industry worked closely to ensure that passengers were given as much information about the impact this disruption made to their journeys. Train operators put in place rail replacement bus services covering the area between Exeter and Plymouth to minimise disruption to rail services and the local community and brought volunteers from across their business to help keep people moving. The recovery operation also involved working with local authorities and other supporting agencies to re-instate the railway as quickly as possible. The impact that the loss of this line had to passengers, local communities and businesses was recognised and work continues to develop a more resilient railway in the South West. The reopening of the railway on the 4th April 2014 was marked by a visit from the Prime Minister.



- 6.39** The experience at Dawlish and on the West Wales line underline the importance of Network Rail commissioning similar studies into what will be needed to strengthen the resilience of each of its sections of coastal railway. It should agree with the ORR and with the Environment Agency what level of resilience it should be planning for, in terms of sea level

rise, storm vulnerability and tidal surge - which will vary around the coast - and ascertain from the Environment Agency what funding could be available where Network Rail's coastal defences provide wider benefits. It is already engaged with the relevant Regional and Coastal Defence Committees, and it should ensure that where it is dependent on other parties coastal defences to protect the railway that these defences are compatible with its own and vice versa.

Recommendation 48:

Network Rail should commission studies of the resilience of its sections of coastal railway.

Extreme heat

- 6.40** Railways are affected by extreme summer heat, the main risk being rails buckling as they expand beyond reasonable design limits in high temperatures. This is a well understood risk, which is best mitigated by ensuring that tracks are appropriately stressed, adequately supported and maintained within tolerances. Extreme heat can also affect signalling circuits, because of overheating of printed circuit boards inside lineside equipment cabinets. Overhead line cables (see Figure 6.7) are designed to extend and contract with temperature variation and extension can be accommodated within design limits otherwise speed restrictions are imposed. High temperatures demand greater attention to both staff and passenger welfare; whilst air conditioning can help, should power supplies be lost personal comfort deteriorates particularly rapidly.

Figure 6.7 - Freight train under overhead line equipment



6.41 After new rail has been laid on a section of track it is then stressed. Likewise when a rail is cut to remove a defect and a new section is welded in, the process needs to protect against the loss of stress or subsequently the site will need to be re-stressed. To minimise the risk of buckling a Stress Free Temperature is selected, this is the temperature when the rail is neither in tension or compression. Installation processes then calculate the stress required to balance temperature at installation with the operating range. The Stress Free Temperature is chosen to balance between the coldest expected winter temperatures, and the highest expected summer temperatures. In cold temperatures the rail contracts, increasing the tension in the rail with, in the extreme, a risk of rail breakage, whereas in high temperatures the rail expands with a risk of buckling in extreme temperatures when the rail is in a state of compression because of its expansion. Railways in hotter climates will hence adopt a higher Stress Free Temperature than those in temperate climates, and it is likely that in future Network Rail will need to use higher Stress Free Temperatures as our climate warms. Network Rail last reviewed the level of the Stress Free Temperature in 2007, and regularly reviews it to accommodate long term climatic changes. It intends to keep this issue under review in the light of emerging expectations of extreme summer temperatures.

Recommendation 49:

Network Rail should keep the Stress Free Temperature under regular review in the light of evolving climate change guidance on extreme summer heat.

- 6.42** The condition of the track, particularly the adequacy of the ballast, plays a major role in stabilising the track allowing a significant amount of rail compression to be safely accommodated on properly maintained infrastructure. For any section of track there is a Critical Rail Temperature (CRT) above which there is a risk of buckling, which is driven partly by the Stress Free Temperature and partly by the stability of the ballasting. Network Rail closely monitors summer temperatures on each route and when CRTs are exceeded implements a speed restriction to reduce the consequences of a derailment in the event of a rail buckling.
- 6.43** Provided compliant rail stressing is implemented and maintained with good ballast conditions there is considered to be minimal risk of a track buckle at temperatures up to the critical temperature. Maintaining rail stress can however be a challenge on the very busiest and economically critical routes, such as between Waterloo and Clapham Junction, where the time slots available for maintenance work are highly restricted. Emerging operating conditions to meet customer demands increasingly means that re-stressing of rail after a new section is welded in cannot be undertaken straight away. It is considered best practice to prepare for summer conditions by the end of March (before the onset of hot weather) and not undertake any non-essential track related maintenance during very hot weather. Summer preparedness work therefore largely consists of ensuring rail stressing is known and managed, correction of track geometry defects, rail adjusting for jointed track and laying additional ballast where necessary to ensure stability. Where concerns exist and there is a performance imperative to minimise disruption, painting the rails white can decrease rail temperature (by reflection of solar energy) by up to 3°C. This is particularly helpful where the expansion of rails affects point detection contacts such as are found in switches and crossings. 50 metres either side of the switches needs to be painted for the force reduction to be effective. This is only a mitigation measure and does not remove the need for effective stress control.
- 6.44** Where maintenance interventions have to be made during hot summer weather, lateral resistance in the track is affected and the changing risk is accommodated by a temporary lower CRT. When temperatures rise there is the need for precautionary speed restrictions until the ballast is re-compacted by trains. The imposition of temporary speed restrictions can cause substantial disruption to train services. Effective maintenance planning seeks to avoid these interventions during these periods of hot weather unless dictated by other safety concerns.
- 6.45** The extent of maintenance work required is largely a function of the age of the track, with relatively little being required on newly laid track and for the first 15 or so years of its life. As track ages the frequency with which defects arise increases and more frequent maintenance intervention may be necessary. On very busy sections of route such as between Waterloo and Clapham, gaining the access to deliver the required volume of maintenance to ensure reliability and weather resilience can be highly challenging. In such circumstances there may well be a case for renewal at an earlier stage in the asset life than would normally be the case under asset management principles. There are clearly significant and delicate

trade-offs to be made which Network Rail should explore and discuss with the ORR.

- 6.46** The problem of very high temperatures interfering with lineside signalling circuits is less complex. Network Rail routes have a variety of measures they are trialling to reduce the temperature gain inside equipment cabinets, including painting them white, fitting them with 'hats' to shade them and redesigning the cabinets to allow some natural air cooling or active air conditioning. In the longer term as Network Rail replaces signalling it should ensure that circuit boards and other electrical components are specified to operate over a wider temperature range.
- 6.47** In a similar way a progressive increase in temperatures needs to be considered in the specification and procurement of new rolling stock, associated depot facilities and stations. The impact of higher temperatures will affect both electrical and electronic equipment and the need for passive and active cooling of vehicles and buildings.

Ensuring resilience of new infrastructure and equipment

- 6.48** Clearly when building new infrastructure or procuring new equipment it is much easier to ensure resilience by designing from the outset for extreme weather such as flooding, wind or heat. As already noted it is striking that the only major piece of new railway in Britain, HS1, was also the only line to be unaffected by the extreme weather events of recent years. It was also striking that the Copenhagen Metro was the only major piece of transport infrastructure that was not flooded in that city during the intense rainstorm and city wide flooding in July 2012. The Metro had been designed to withstand a 1 in a 1,000 year flood.
- 6.49** We have asked HS2 Ltd and Crossrail Ltd to confirm that they are designing and building their new railways to withstand extreme weather events and they have confirmed this. HS2 for instance is also being designed to be resilient to a 1 in a 1,000 year flooding event.
- 6.50** Network Rail is also investing extensively in electrification and new signalling systems, which are further opportunities to ensure higher resilience levels from the outset. Overhead line electrification systems increase the railways' vulnerability in high winds, but we note that Network Rail will be designing these systems to the European standard¹⁶, which will ensure considerably higher resilience than the earlier designs currently in place across part of the national network. Network Rail will be progressively concentrating signalling control on 12 new centres nationally during CP5, which are all being designed to be resilient to extreme weather events and will have back up power supplies and stand-by generator capability.
- 6.51** It is likely that as the Met Office and others develop a more detailed understanding of how climate change will affect extreme weather there

¹⁶ BS EN 50125-2:2002(incorporating corrigendum June 2010), Railway applications - Environmental conditions for equipment - Part 2: Fixed electrical installations

will be a need to further modify design standards for new rail infrastructure and equipment. Network Rail and the rail industry should therefore keep its standards under regular review.

Recommendation 50:

Network Rail and the rail industry should keep their design standards for new infrastructure and rolling stock under regular review in the light of evolving understanding of the impact of climate change on extreme weather.

Resilience of electricity supply

- 6.52** An area of potential vulnerability is in the electricity supply network to the railway. Electricity to power the trains themselves is usually considered to be relatively robust, and would be given priority at times of national rolling rationing (under the Electricity Supply Emergency Code). But the experience of recent years is that electricity sub-stations can be vulnerable to flooding and much work has been undertaken in the electricity distribution sector to identify and protect these. The experiences of both Gatwick Airport and the Port of Immingham last winter highlighted that sub-station failures can be an unforeseen source of vulnerability. We therefore recommend that Network Rail should liaise with its electricity suppliers to trace through the routes and sub-stations through which it is supplied with traction power to ensure adequate system redundancy and protection for any critical sub-stations. This should also extend to power supplies to line side signalling systems, which are generally fed off local networks and are therefore more vulnerable to local interruption.

Recommendation 51:

Network Rail should liaise with its electricity suppliers to trace through the routes and sub-stations through which it is supplied to ensure adequate system redundancy and any single points of failure are identified and made suitably resilient. To assist in preparation and planning for times of power disruption the Electricity Networks Association chairs an Emergency Planning Managers' Forum which we would recommend that Network Rail should consider joining.

Managing disruption and recovery

- 6.53** As already noted we believe that the rail industry performed reasonably well in managing the disruption caused by last winter's weather and in achieving quick recovery of normal operations. The industry has a well-developed extreme weather management process, which has been progressively refined since 2010 in the light of experience and is being further updated to take account of the latest experiences. The core of this is the Extreme Weather Action Team (EWAT) process, which is led by the affected Network Rail Route(s) and brings together all the affected TOCs and FOCs via a daily phone conference to share information and take key decisions on operations. A forecaster also attends to provide

and interpret the latest weather forecast information. EWATs take the decisions on whether to operate a contingency or amended timetable on the following day.

- 6.54** All parties we spoke to consider the EWAT process works well, although some TOCs and FOCs find it difficult to resource attendance at a number of EWAT conferences, where their operations spread across multiple Network Rail Routes. In some cases the timing of EWATs makes for difficulties, because the decision to trigger operation of a contingency timetable for the following day needs to be taken by 11.00am to give sufficient time to implement and communicate it, meaning that all EWAT conferences need to be completed by this time.

Recommendation 52:

Network Rail should investigate the feasibility of convening multi-route Extreme Weather Action Team conferences where appropriate to assist those Train Companies who operate over multiple routes. Extreme Weather Action Team conferences should always be timed to ensure decisions on contingency timetables can be implemented.

- 6.55** All parties also considered that weather forecasts were becoming increasingly reliable, and that last winter's storms were generally accurately forecast however more advance warning to allow the decision to operate an amended timetable is required. But there was also a consensus that as forecasting capabilities improve further greater granularity of forecasts, in terms of both more specific timing and detailed location of extreme weather would be useful.

Recommendation 53:

Network Rail, on behalf of the rail industry, should liaise with the Met Office to inform how most usefully to exploit greater granularity of forecasts as forecasting capability improves further.

- 6.56** The operation of pre-planned contingency timetables during periods of extreme weather disruption is generally considered to be the most effective means to ensure a reliable, albeit amended service is provided for passengers which can be systematically communicated via passenger information systems. However these are very resource-intensive to produce, and for this reason have generally only been produced for snow. Ideally the industry should have a wider range of contingency timetables, covering a wider range of disrupted events so that services can be better tailored to the specific conditions prevailing. One route to do this could be to have contingency timetables that cover individual lines or groups of lines rather than whole train operators' areas, so as to be able to implement them over those lines most affected. However this is currently a difficult area technically, and Network Rail has not yet found another railway operator internationally that has better technology that Britain could adopt.

Recommendation 54:

The Rail Delivery Group should continue to investigate improved techniques and technologies for producing contingency timetables so as to be able to have a wider range of timetables on hand to better match different weather events.

- 6.57** An area of concern to both the rail industry and its customers is that current train performance regimes do not necessarily encourage the right behaviours from TOCs and Network Rail during periods of disruption. When there is extreme weather disruption it is generally agreed that the industry should use best endeavours to provide a service, and that moving passengers and freight, and getting them safely to their destinations is more important than providing a punctual service. The ORR has agreed with Network Rail that when there is extreme weather, its performance on the same day in the previous year will be substituted for the purposes of monitoring performance against its objectives. However TOCs do not have a similar substitution process agreed and feel that they can be penalised for doing what is best for passengers. Performance regimes are a complex area, but it is clearly important that they give the right incentives to TOCs and Network Rail during disruption, and are seen to be fair by passengers.

Recommendation 55:

The DfT, the Office of Rail Regulation and Passenger Focus should work with the Rail Delivery Group to develop an amended approach to performance and compensation regimes during periods of extreme weather-related disruption, which gives the right signals to the industry but is seen to be fair for passengers.

- 6.58** One area of recovery which received some criticism was Network Rail's process for locating and clearing trees and other obstructions after high winds. TOCs felt this could have been completed more quickly. The process relied on the use of multi-purpose vehicles and ordinary trains, with a chainsaw crew on board, to inspect each line looking for fallen trees and other debris and then clearing the trees sequentially. In a number of cases Network Rail did not have enough chainsaw-trained teams available, relying largely on contractors for this task, so reducing the number of trains that could have been used to clear lines. The same contractors are likely to have been in wider demand because the railway will not have been the only party impacted by fallen trees. Being a visual inspection the process also has to be undertaken in daylight.

Recommendation 56:

Network Rail should increase the resource available for clearing fallen trees, including considering training more of its own staff in the use of chainsaws. Additionally it should fit multi-purpose vehicles and other trains with powerful lighting to facilitate night time line inspections. It should also investigate other means of identifying fallen trees to direct teams to their location more speedily.

- 6.59** We note that Network Rail is planning to install more weather stations on their network, and these could also be used to determine where winds have been strongest and so direct clearance teams to those sections where trees are more likely to have been blown over.
- 6.60** Both rail and other sector representatives said they thought that there would be benefit in closer liaison between different transport modes during periods of weather related disruption. We have already raised the suggestion that this might be facilitated at national level by a similar forum to that which operated during the London 2012 Olympics (Chapter 3). At local level this would probably be through Local Resilience Fora. Network Rail did attend a number of these during last winter's disruption, but it is often difficult to resource this given the number of Fora that may be in operation, alongside the resourcing of EWAT meetings within the industry. We therefore suggest that each EWAT agrees representatives to attend relevant Local Resilience Fora on behalf of the rail industry, where helpful, but that these be drawn from TOCs, FOCs or Network Rail rather than just Network Rail.
- 6.61** Finally it is obviously very important that TOCs and Network Rail communicate with passengers and other stakeholders as clearly as possible, on how services are being affected by the weather or as a result of weather induced damage to infrastructure. We cover this in Chapter 3, because many of the issues are common to more than one mode of transport.

7. Ports and airports

Common Lessons

- 7.1** Whilst sea ports and airports have different vulnerabilities to extreme weather, we found that there were issues in common arising from their experience of last winter. We also consider that there are some lessons which can be carried across from one sector to the other.
- 7.2** In general, both sectors stood up well in the face of a series of extreme weather events, but the impacts of individual and combined weather events put them under considerable strain. A number of ports suffered the effects of the east coast tidal surge, but most recovered promptly and told us that they were 'used to operating with their feet wet'. Airports had to cope with a number of episodes of high winds, but consider that as part of their business as usual operation.
- 7.3** However, there were two conspicuous examples of flooding which the Panel spent a good deal of time considering:
- At Immingham on 5th December, the port was extensively flooded as a result of the east coast tidal surge. The port's own operations were severely disrupted for a number of days following this due to the impacts on IT and power systems, but 75% of the port's area was underwater at some point and businesses within the port boundary were also severely affected, in some cases for several weeks or more;
 - London Gatwick was flooded on Christmas Eve by an extreme rainfall event. Its power and IT infrastructure was severely affected, leading to significant confusion and disruption for passengers.
- 7.4** Whilst very different in many ways, these events were clear evidence to us of a particularly striking similarity. There seemed to have been an oversight in contingency planning in respect of protecting the underpinning power and IT systems which their operations rely upon (see Figure 7.1). Moreover, in taking evidence from other operators in these sectors, it appeared that their IT and power systems might be similarly vulnerable. The events at Immingham and Gatwick and their significance are considered at greater length below.

Recommendation 57:

All major ports and airports should review the location and flood-protection of their power, communications and IT infrastructure in light of the winter's experience at Immingham and Gatwick.

Figure 7.1 - Flooded 11000V transformer at the Port of Dover



Ports

The economic importance of ports

7.5 The ports sector comprises a number of different types of business and can be broadly characterised as comprising four sub-sectors:

- Roll-on, roll-off and ferry ports, such as Dover which are a key part of broader just-in-time practices. Dover, for example, might be described as a link between the UK and French motorway networks and any significant port disruption quickly causes tailbacks on those networks and adjacent local roads.
- Container ports, such as Southampton, Felixstowe, and London Gateway. In the event of disruption at one of these ports, other ports are likely to have some capacity.
- Bulk commodity ports, such as those on the Humber and the Tyne, are becoming increasingly specialised with handling equipment optimised for particular commodities and often forming part of an

integrated just-in-time delivery chain, so that there is often no alternative port facility readily available.

- Local and leisure ports.

7.6 As an island nation, the UK relies on shipping for about 95% of its imports and exports by weight, including many commodities (e.g. fuel, food, industrial materials) vital to national wellbeing. A tidal surge on the east coast could potentially impact around half of the UKs' port capacity.

Vulnerability to extreme weather

7.7 Ports are in themselves vulnerable to high winds, tidal surge, coastal storms and fluvial flooding. High winds disrupt loading and unloading of ships, due both to the difficulty of berthing in such conditions and the potential for damage to cranes. We saw a weight of evidence, however, that ports have sound contingency plans for working with high winds, regarding it as part of their regular business operation.

7.8 Tidal surge, where astronomical tide and low atmospheric pressure combine, sometimes with high wind, can inundate ports, disrupting their own operating systems and their associated businesses (see Figure 7.2). Fluvial flooding can also affect ports, given that many are positioned on estuaries rather than in more exposed, seaward-facing positions.

Figure 7.2 - Tidal surge at Grimsby, Humberside



7.9 These vulnerabilities to inundation arising from different types of events are increased by the context of rising sea levels. As we say in Chapter 2, the sea level has risen during the 20th century due to ocean warming and melting of glaciers and, with the warming we face, a further overall

11 to 16cm rise in sea level rise is likely by 2030, relative to sea levels in 1990.

- 7.10 Whilst ports themselves have these vulnerabilities to extreme weather, they are essentially modal transfer points and are consequently (as the British Ports Association pointed out) also vulnerable to weather-related disruption to inland transport connections. So disruption to road and rail links can have substantial impacts.
- 7.11 It is important not to consider ports as stand-alone entities. They will often have large numbers of businesses within the broader port footprint and on adjacent sites. These businesses themselves can be of considerable significance to UK business and the economy. It is also true that because of their position in the supply chain and their remote location, these areas can be good sites for potentially hazardous industries in terms of health and safety or environmental impacts, such as those for chemicals and fuels, which are strategically important to the wider economy.

Weather forecasting

- 7.12 In general, the ports industry advised the Review that forecasts were good. The British Ports Association, for example, said that forecasts of the east coast tidal surge were “remarkably accurate all along the coast” – a view also supported by the UK Major Ports Group.
- 7.13 ABP, the owners of Immingham acknowledged that their response to the weather warnings for the Humber was not all that it might have been and have improved their response systems as a result. However, they also felt that improved, more up-to-date modelling of the Humber Estuary might have made the forecast of impacts more specific. This seems to us to flag a point of more general application, in that the complexities of tidal flows within estuaries and the changing nature of the estuary, mean that regular model updates are potentially of considerable benefit.
- 7.14 Forecasting of high wind through winter 2013/14 seems to us to have been broadly accurate, but lacks the specificity from which ports operators would really benefit. In addition, the kinds of coastal extreme weather events which impacted ports to such a degree last winter are comprised of a combination of weather events. Forecasting the effects of such combinations of low pressure, tide, high wind and storm events is undoubtedly very complex, but benefits could be significant, not just in the ports sector, but among other coastal interests

Recommendation 58:

The Environment Agency and Met Office should work together to improve the granularity and accuracy of coastal flooding forecasts, taking in the complex interaction of tides, wind, wave height and estuarine modelling. Ports should look to be involved in this work to ensure that forecasts take account of known vulnerabilities and are suitably tailored to assess key impacts.

- 7.15 Ports are different in their business models and in their topography. For example, Dover was inundated in December's tidal surge, but in spite of a short power outage managed to move and protect most vulnerable

assets in advance and watch the flood recede down the slope to the quay with the tide, whereas Immingham, experiencing a higher surge even than 1953, without the benefit of the Dover slope and not having protected its power substations was flooded for a number of days, with some businesses on site severely affected for many weeks afterwards. On our visit to Immingham, we met representatives of renewable fuels and chemical storage businesses, for example, whose businesses had suffered considerable disruption from the flooding of the wider port area.

- 7.16** It is not generally for this Review or for Government, to take a view on the appropriate level of flood protection which a private sector organisation should put in place for its business, but ports need to be clear about their vulnerability and level of flood protection.

Recommendation 59:

Given the context of rising sea levels and a higher likelihood of extreme weather events, strategic ports should commission a range of tide-height data and return periods from the Met Office, Environment Agency and other relevant partners. The port operators should decide what defences to put in place against this range of potential surge events.

- 7.17** Nevertheless, we have come across some transport links in our Review which are of such strategic importance to the UK economy that their protection from inundation is vital, but whose owners may not realistically be able to justify the funding required to install the necessary defences. As we say in Chapter 3, we are concerned that such exceptional cases represent a real threat to national economic and social wellbeing.
- 7.18** Immingham is the UK's busiest port by tonnage and a key conduit for petro-chemicals and fuel (see Figure 7.3). Indeed, the vulnerability of the fuel supply chain through Immingham is increasing with the switch from coal to biomass for electricity generation. This has particularly stringent storage and handling requirements to prevent water contamination or spontaneous combustion and is therefore operated on a tight 'just-in-time' supply chain basis. As a consequence there will be very limited buffer stocks compared to coal and consequently any disruption to the supply chain will have a more immediate impact on power stations.

Figure 7.3 - Port of Immingham



- 7.19** In the tidal surge of 5th December 2013, the height of water at Immingham exceeded the 1953 flood event, rising to some 50cm above the port's flood defences. The port has an enclosed dock, which is separated from the Humber by lock gates. When the lock gates were exceeded, surge waters were able to get into the enclosed dock and then washed onto the quaysides and further into the port site. Immingham's owners, ABP, are in the process of buying higher and better-engineered lock gates.
- 7.20** ABP has further made clear to us that it will fund flood protection of its site scheme for Immingham, the lock gates and sea wall, at a cost of £20 million or more, as part of a scheme of wider community and national benefit (as it has in nearby Grimsby). However, the Grimsby scheme was affordable because it protected sufficient numbers of homes to justify funding under the Environment Agency Partnership Funding formula, which gives weight to protection of domestic property. In Immingham, there are not the homes to protect to justify funding under the Environment Agency formula. The problem this leaves is that flooding to either side of the port site could still leave the port flooded from beyond the port boundary – that is, flood water could come round the sides of the heightened ABP defences.
- 7.21** Whilst there is also a possible role for the Humber LEP in marshalling the broader business interest, and potentially brokering a contribution to such a scheme, this remains unlikely pending resolution of the issues in terms of public funding. Given the national interest in the commodities of strategic importance passing through Immingham, we see this as an issue of national rather than local importance. We made observations and recommendations in this regard in Chapter 3.

- 7.22** A feature of the inundation at Immingham was that power and IT infrastructure was flooded and out of commission for some days. ABP said that at the time of the 1953 coastal surge, the port operation was very different with less technology and much less reliance on electricity and IT. Like much of the ports industry, ABP saw the events of the past winter as 'a wake-up call'.
- 7.23** Indeed, we heard evidence that ports including Immingham have already taken action, in light of the winter's experience, to better protect electricity substations, communications and IT infrastructure, for example, by elevated siting of such assets or providing for temporary bunds to be deployed in the event of a flood forecast.
- 7.24** In their evidence to us, port operators and their representative bodies were consistently appreciative of the workshops run by the DfT in 2013 and 2014 on east coast flooding. These provided an expert view on the meteorological aspects, explained the flood warning system, the potential impacts for the east coast and ports more specifically, and national and local emergency response roles. Experience and views on mitigation measures were then shared between port operators.

Recommendation 60:

The DfT should facilitate the running of further workshops for ports, region-by-region, in order to ensure that the experience of winter 2013/14 and initiatives to improve resilience are shared within the sector.

- 7.25** In our evidence sessions, there was some concern on the part of the ports industry that dialogue with Network Rail, the Highways Agency and Local Highway Authorities in respect of inland links to and from ports was not all that it might be. In keeping with our broader thinking (see Chapter 3) that there needs to be greater focus within the transport sector on routes of national economic importance and the identification of a 'critical network' subject to a higher level of resilience, we are concerned that relationships between the major ports and the operators of crucial inland connections need to be of high quality, in order to assist in mitigating the effects of extreme weather on transport.
- 7.26** Relationships should be developed both directly and through Local Resilience Fora in 'peacetime', to facilitate close working when extreme weather strikes. This is particularly important, since the HA and Network Rail are likely to be having to service a number of emergency fora across a region in weather crisis and might not be able to be present at all 'Strategic Co-ordination Group', crisis meetings.

Recommendation 61:

Port operators and operators of rail and road links to ports should liaise regularly to consider and develop the resilience of inland links to and from ports, including their physical resilience and alternative routes.

Airports

Vulnerability to extreme weather

- 7.27** Simply characterised, the challenge to the passenger aviation industry has two parts: (1) to get passengers onto aircraft and (2) to get aircraft in the sky. Both of these can be impacted by extreme weather, as the events of the past winter demonstrate. Losing the capacity to do either can seriously disrupt operations.
- 7.28** Airports are susceptible to high wind, particularly cross winds and gusts, since this can restrict or prevent aircraft taking off and landing. However, airports' evidence to us was that they regard this as a relatively routine event, dealt with within their business-as-usual contingency planning. They are also at risk from pluvial and fluvial flooding, fog and lightning. Their susceptibility to extreme heat is not huge, with equipment designed to run at temperatures of up to 40°C, though given the amount of glass that tends to be in terminals, it can put air conditioning systems under strain.
- 7.29** In addition to their own vulnerabilities, there are concerns about the vulnerability of surface transport links. Disruption of road and rail links to airports leave them vulnerable to loss of custom, unmanageable numbers of passengers in terminals and low staff levels for operations associated with the airport. In the case of Heathrow, the Thames Valley flooding in February kept large numbers of staff away from work and on Christmas Eve at Gatwick, there was a time when both the M23 and the rail route to Gatwick Station were closed, causing significant difficulty for passengers arriving and departing.
- 7.30** We found that airports were well aware of their vulnerability to surface transport disruption and generally communicated well with the operators of that infrastructure: the HA, Local Highway Authorities and train operators. However, the recommendations we make in Chapter 3 on identification of critical networks, which should be subject to a higher standard of resilience, should be of benefit to the busier airports in preserving surface transport links.
- 7.31** The vulnerability of the UK's two largest airports, Heathrow and Gatwick, is exacerbated by the fact that they operate at full capacity; in Heathrow's case the whole time; and in Gatwick's case it operates at capacity in peak times. This means that when extreme weather leads to delay in flights, it is difficult for either to manage and recovery can take time.

Weather forecasting

- 7.32** Airports and airlines told us that the degree of accuracy of forecasts was high, with the exception of fog. Rainfall, temperature and wind conditions were all generally well forecast. Weather warnings from the Met Office were seen to be useful in that they provided a definitive view upon which to take action, when reliance by different parties on different forecasters' data would otherwise lead to different views of what action was appropriate.

- 7.33** BA and Heathrow have taken the decision to have an embedded weather forecaster, whilst Gatwick relies on an external service. However Gatwick and indeed all those we spoke to in the aviation sector had a positive relationship with their forecasters and were trying to move to more tailored forecasts for their operations and vulnerabilities.
- 7.34** It is clear that airports make the fullest use of the forecasts available to them at present. Nevertheless, they saw some scope for improvement in forecasting. British Airways made the case that the micro-climate around Heathrow Airport suggested that a more specific forecasting model, in terms of time and granularity, was justified.

Disruption to operations

- 7.35** In the case of Gatwick on Christmas Eve, its greatest problems concerned boarding passengers: while aircraft could come and go, the systems for processing passengers to get them onto the aircraft were disrupted due to the problems that flooding caused the airport. Gatwick's Board, to its credit, commissioned an early and comprehensive report into the problems by David McMillan, Non-Executive Director and former Director General of Eurocontrol. This found failings in operations and infrastructure and made 27 recommendations for flood protection, resilience and contingency planning, passenger welfare and air traffic control. We benefited from a meeting with David McMillan in the course of the Review. Moreover, it was clear to us in taking evidence that other airport operators had read his report and had considered the applicability of the lessons for their own operations.
- 7.36** Gatwick had, well before Christmas 2013, worked with consultants, the Environment Agency and the local authority to consider its flood risk and concluded that its South Terminal was more vulnerable, with mitigating action being undertaken. Indeed, Gatwick's initial concern on receiving the forecast of the storm which would hit on 23rd December, was not about the potential for flooding at all, but for high wind disrupting aircraft arrival and departure. However, the high levels of rainfall over the previous three weeks had left local watercourses at elevated levels and heavy rain was forecast.
- 7.37** The wind was indeed disruptive, with delays and cancellations leaving aircraft out of scheduled position on the morning of Christmas Eve. A total of 35 flights were diverted away from Gatwick on 23rd December. Heavy rain continued to fall as the area around Gatwick was subject to around 75mm of rainfall in 24 hours, with the most intense rain in a 2 hour period. The Environment Agency copied general flood warnings to Gatwick for three watercourses running in or near the airfield: the Gatwick Stream, the River Mole (both late on the afternoon of 23rd) and the Ifield Brook (early on the morning of 24th). Because these were general in nature, it appears that their significance was not picked up.
- 7.38** A telephone call came through from The Environment Agency at 4.15am on the morning of Christmas Eve, warning that the River Mole was close to bursting its banks, which it did at 4.40am. The Gatwick Stream then also flooded, exacerbated by blocked culverts. These caused airfield electricity substations to become flooded, but not to the extent that

operations were greatly impacted, because of the availability of stand-by generation capacity (see Figure 7.4).

Figure 7.4 - Flooding at Gatwick Airport



- 7.39** The most significant impact of the extreme weather was from pluvial, rather than fluvial flooding and in the North Terminal rather than on the airfield. It came at 5 a.m., as rainwater found its way, through ducting, into two electrical switch rooms in the basement of the North Terminal. The disruption of power systems led to loss of baggage reclaim facilities, check-in systems, flight information systems, telephone systems, luggage screening equipment and toilets in that Terminal. The South Terminal remained unaffected.
- 7.40** It being Christmas Eve, both the airport and the airlines were very keen to get passengers to their destinations – the motivation for the decisions taken was entirely understandable. However, not for the first time in the transport industry, hindsight tells us that a deliverable strategy would have been better than an aspirational one.
- 7.41** The complex nature of airport operations had a major bearing on the chaotic events precipitated at Gatwick by the extreme weather. Many distinct businesses operate at an airport and there is a strict limit to which the airport itself can dictate action to airlines, who are themselves clients of services from ground handling agents and other service providers. At Gatwick, instructions issued by the airport operator to ground handlers to ensure that mobile equipment was tied down on the evening on 23rd December was not fully heeded. This led to damage to airfield equipment as containers were blown around.
- 7.42** But the most significant impacts came from the different decisions made by airlines on Christmas Eve. British Airways (BA) decided to limit its operation at Gatwick to one which it was confident it could sustain; this still enabled it to successfully fulfil the majority of its scheduled flights, and to advise passengers whose flights were cancelled, not to come to the airport, but await advice on rebooking. EasyJet, by contrast, advised

passengers to come to the airport early because of the disruption. This swelled the numbers of passengers at the airport.

- 7.43 There was a plan agreed between the airport and the airlines to have flights scheduled to fly from the North Terminal depart from the South Terminal on a case-by-case basis. However, passengers became aware of this and started to move to the South Terminal, where check-in desks became overwhelmed.
- 7.44 There were major problems in communicating consistently with passengers, partly due to failure in communication systems, but also because of inconsistent and unclear messages. Triage systems in queues failed because of lack of handling agent staff to service them.
- 7.45 We were struck, in taking evidence, that there is no longer a 'single source of the truth' in such events, with a mixture of fact and rumour circulating not just through a variety of more official channels – airport and airline websites, for example – but through social media being shared by passengers in the airport and contacts outside picking up new feeds and offering advice. Nevertheless, airports and airlines need, in such circumstances, to work together to offer consistent messaging, in the spirit of our recommendation in Chapter 3
- 7.46 In the event, EasyJet had to cancel a number of flights late in the day, disappointing passengers who had been waiting for extended periods in difficult conditions. Overall, around half of passengers scheduled to fly from the North Terminal and around one-third of passengers scheduled to arrive there had their flights cancelled.
- 7.47 It was very striking to us in terms of flight operations that Gatwick managed the threat both of high winds and fluvial flooding well. These were risks which had been registered and mitigated and were well dealt with operationally. The risks to essential terminal systems had not been subject to the same level of planning and were what caused such significant disruption on Christmas Eve. This is in part the basis for our Recommendation, at the start of this chapter.
- 7.48 Airports and airlines have a culture of contingency planning, as might be expected from a sector which runs a lean commercial regime but is also subject to the impact of uncertain events. However, evidence to us suggested to us that plans are worked up by the individual operators to too great an extent. One of the key McMillan recommendations was that such planning should be done transparently with the key airlines at Gatwick. We believe this has wider application.

Recommendation 62:

Airports should draw up contingency plans jointly with their major airlines. These should also be jointly exercised.

- 7.49 The DfT is not particularly interventionist in aviation, largely leaving the sector to operate commercially, within the accepted framework of safety, security and economic regulation conducted by the Civil Aviation Authority (CAA). This is largely true, too, of ports, however, the Department had the foresight to run workshops for ports on the potential east coast tidal surge which were felt to be of great value to the ports

sector. This is, in part, the basis for our recommendation in Chapter 3 that the DfT should consider how best such workshops might be provided for other sectors - they might well be of assistance in sharing best practice, problems and solutions.

- 7.50** As of 1st April 2014, the CAA licence conditions for Gatwick and Heathrow airports now require the two airports to have operational resilience plans aimed at securing continued operation. This seems to us a useful development and it was interesting to hear that Heathrow had communicated with its stakeholders on the site about the implications of the new conditions and giving them practical effect. This seems to the Review a useful innovation from the CAA.
- 7.51** Because of the way in which they operate at, or close to, capacity, Heathrow and Gatwick have particular issues in managing the effects of disruption on airspace. After the 2010/11 disruption due to snow and ice at Heathrow, Professor David Begg conducted a review. He proposed a mechanism to bring together the airport and airlines in the event of severe weather striking, or being anticipated, in order to manage the available airspace and allocate slots. The Heathrow Air Traffic Management Demand and Capacity Balancing Group (HADACAB) meets when air space is, or is expected to be, unusually constrained to come to a collective view on the appropriate action.
- 7.52** We were struck by the good sense of this approach and consider that it is more broadly applicable. It helps provide certainty both to the passengers and the operators and is likely to bring about a better outcome, though it is a relatively young initiative which will doubtless be refined as it matures.
- 7.53** The broader issues of hastening Heathrow's recovery from disruption have been considered by the Airports Commission. The Commission commented favourably on the use of 'enhanced TEAM' ('Tactically Enhanced Arrivals Mode') to aid recovery. TEAM enables the designated departures runway to also take some arrival flights for a limited period, in order to minimise the duration of the disruption to timetables.
- 7.54** There are certain conditions or 'triggers' for the use of TEAM, including in weather-related disruption. The interim report by the Airport Commission recommended, following recent trials supervised by the CAA, that the trigger point for use of TEAM be reduced from 20 to 10-minute delay on arrivals. This appears to this Review a helpful recommendation.
- 7.55** As for capacity in the air, we heard from representatives that modern aerospace technology allowed for more efficient use of London airspace, which could allow quicker recovery following disruption, with the prospect of reducing passenger frustrations. The CAA is currently undertaking a review of the London Terminal Manoeuvring Area - the control area for air traffic using London's airports. The CAA review, known as the London Airspace Management Programme, or LAMPS, seems to us the right vehicle for considering how best to manage London's airspace to manage recovery from disruption, in the fuller context of business as usual operations.

Recommendation 63:

In order to provide greater certainty to travellers and operators, airports should work with their principal airlines to adjust capacity on a pre-emptive basis when there is a high degree of confidence in the forecast of extreme weather, rather than waiting for the weather to hit.

Appendix A - Terms of reference

Background

The winter of 2013/14 saw the UK affected severely by an exceptional run of winter storms, culminating in serious coastal damage and widespread, persistent flooding. Although no individual storm can be regarded as exceptional, the clustering and persistence of the storms was highly unusual and December through February were exceptionally wet. For southern England this was one of the most exceptional period of winter rainfall in at least 248 years. January and February saw severe gales along the south and west coasts. Peak wave periods were exceptionally long; each wave carried a lot of energy and inflicted significant damage on coastal infrastructure. Flow rates on rivers such as the Thames remained exceptionally high for longer than in any previous flood episode. Correspondingly, floodplain inundations were extensive.¹⁷

Our transport network has, on the whole, proved very resilient to the recent weather events. Resilience planners and operational teams have worked very hard in challenging circumstances to minimise service disruption to the travelling public. However, damage has been caused to some key assets, with disruption to service delivery. Ports have experienced storm surges; coastal rail infrastructure has been subject to prolonged exposure to damaging storms; overhead rail lines, exposed road structures and airports have been impacted by gales, and large numbers of local rural and urban roads have seen flooding. Despite the best efforts of our transport operators and maintenance contractors, it is clear that there is no room for complacency in managing resilience. The impact of the exceptional run of weather has brought into sharp focus the need to take stock of the vulnerabilities facing transport and the way in which we respond. Government must maintain a resilient transport network that enables public access to critical services such as health, education and employment whilst providing value for money for the taxpayer.

Purpose of the study

The aim of this study is to identify practical measures to improve the resilience of our transport network to severe weather events in the short term, whilst also giving due consideration to longer term resilience of the nation's transport infrastructure. This will include plans looking to mitigate impacts from severe weather events; contingency planning to manage the effects; investigation of increased rates of asset degradation leading to reduced service life and performance, and adaptation of infrastructure to manage projected future risks. The review will build on the existing work of transport resilience practitioners and policy makers, and incorporate expert knowledge on climate modelling to

¹⁷ Content of paragraph informed by Met Office publication 'The Recent Storms and Floods in the UK (Feb 2014)'

recommend proportionate and value for money responses to future transport vulnerabilities.

Governance

The review will be led by DfT Non-Executive Director Richard Brown who will be supported by independent experts:

- John Curley, representing rail
- Brian Smith, representing roads and local

A review team will be supplemented with resilience experts from the Highways Agency and Network Rail, and climate science expertise from the Met Office. DfT officials will provide administrative, project management and analytical support. Aviation and ports/maritime will be closely consulted at each stage of the review.

The review outcomes formally recommended to the Secretary of State for Transport will only apply to English authorities, but will take account of the wider UK context. The Scottish, Welsh and Northern Irish administrations will be fully involved in the work of the review. It will be for Ministers of those administrations to decide what action is required in those countries.

Methodology

Operational performance -The operational performance of all transport modes will be assessed against the 2013/14 winter storms and flooding to understand the key vulnerabilities.

Lessons learned -The recommendations of previous reviews will be assessed, to determine the extent to which recommendations have been written into resilience procedures and processes and how this has been implemented 'on the ground'.

The review will seek evidence from a range of stakeholders, including transport operators and providers; the local government community; major civil engineering practices; maintenance contractors; the freight and logistics sectors; passenger groups; weather forecasters and climate scientists. Evidence will be gathered through stakeholder workshops and calls for written evidence covering the full scope of the review. The evidence will be used to identify practical measures to improve the resilience of the UK's transport infrastructure and operations, presenting case studies and culminating in a package of recommendations.

Scope of the review

Transport modes -all key modes within scope:

- Road – Strategic road network (Highways Agency) and local roads (Local Highway Authorities).
- Rail – The national rail network (Network Rail) and train operating companies
- Aviation – Airports of economic and strategic importance

- Maritime and Ports – Ports of economic and strategic importance
- London – transport within the remit of Transport for London

Extreme weather events and impacts - Determining the key vulnerabilities of transport modes and assessing the impacts of extreme weather on the asset, operations and customers

- Increase in maximum temperature -extreme summer temperatures
- Increase in winter precipitation (light touch on snow due to Quarmby)
- More extreme rainfall events – impacts on fluvial, pluvial and groundwater flooding, sink holes
- Increased wind speed for worst gales -wind speed more frequently exceeding
- infrastructure operational limits
- Sea level rise -higher frequency of extreme storm surges
- Combinations of hazards, exposure and vulnerabilities leading to increased risks and severe impacts

Economic analysis -The costs and benefits of different approaches to resilience. Analysis to consider:

- The political, commercial and consumer risk appetite for asset failure and service disruption
- Prioritisation of vulnerable assets for action
- The need for specifying resilience-specific performance criteria
- Long term asset vulnerability and the trigger points for retro-fits and changes to
- design standards
- Funding revised maintenance and renewals regimes; the cost of future-proofing assets against projected stresses, and the affordability of optimising Whole Life Cost

Weather forecasting and climate modelling -The quality, availability and application of short, medium, long-term and seasonal weather forecasting and climate projections

- The value of forecasts to current service delivery
- The contribution of weather forecasting to management of the 2013/14 storms and floods
- Investigation of the source of meteorological data used by different transport
- Operators
- Additional resilience offered by bespoke forecasting services
- Availability and application of longer term climate projections
- Potential of climate modelling in advising transport resilience plans

Communications and public expectations – Integration of resilience and the customer experience

- How lessons and best practice are shared
- The value of resilience fora, panels and groups
- Regional equity of resilience provided to taxpayers
- Management of the public's expectations
- Case studies from international transport and infrastructure administrations Communication of risk across a range of hazards in a way the end-user understands

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Appendix C - Call for evidence

This study was commissioned by the Secretary of State for Transport to identify practical measures to improve the resilience of the transport network to severe weather events in the short term, whilst also giving due consideration to longer term resilience of the nation's transport infrastructure. This will include plans looking to mitigate impacts from severe weather events; contingency planning to manage the effects, and adaptation of infrastructure to manage projected future risks. The review will build on the review led by David Quarmby in 2010, which considered the resilience of transport systems to extreme winter weather – snow and ice.

This review will not, therefore, consider snow and ice, but will include:

- more extreme rainfall events, leading to fluvial, pluvial and groundwater
- flooding
- increased incidence and severity of storms and high winds
- higher frequency of extreme coastal storm surges and sea level rise
- extreme high temperatures

It will also consider the following parts of the transport industry:

- the strategic road network and local roads
- the national rail network, including private and public transport
- aviation – airports of economic and strategic importance
- maritime – ports of economic and strategic importance
- light rail and underground systems

Providing evidence to the Review

Respondents with very different backgrounds will wish to contribute to the Review's thinking. Written evidence is particularly welcome from transport and infrastructure operators, highway and transport authorities, maintenance contractors, passenger organisations and representative groups with an interest in the resilience of the transport sector. The Expert Panel may wish to invite some interested parties to give additional evidence face-to-face.

Respondents should structure their responses according to the questions below, though different questions will be relevant to different respondents.

Please answer only those questions which are relevant to you. Please provide examples to support your answers wherever possible and **limit your response to a maximum of 6 pages of A4.**

Responses should:

- be in Word (doc, docx, rtf, txt, ooxml or odt) format, not PDF
- contain as few logos or embedded pictures as possible
- contain no macros
- comprise a single document. If there are any annexes or appendices, these should be included in the same document.

We expect to publish the written evidence received on the Review website. If you do not wish your submission to be published, you must clearly say so and explain your reasons. The Expert Panel will take this into account in deciding whether to publish.

Please send your response by **2nd May 2014** to:

(email) resilience.review@dft.gsi.gov.uk

(post) Transport Resilience Review, c/o 2/26 Great Minster House, 33 Horseferry Road, London SW1P 4DR.

If you have any further questions, please contact the Review Team via the above email address or telephone 0207 944 3904.

Please use the structure which follows for your response.

About You

What is the name of your organisation?

Do you represent a particular interest group? If so who?

Which transport sectors are you particularly interested in?

What are your contact details for any follow-up?

Questions

The Transport Network in Extreme Weather

- What weather or climate related impacts to transport concern you most, and for what reasons?
- How accurate have you found forecasting of extreme weather? How have you acted on forecasts?
- What was your experience of the extreme weather of autumn-winter 2013/14? What lessons have you learned?
- What other, historical weather events have impacted you most, and how?
- How well did the UK's transport network respond to the extreme weather? In particular, what worked well and what do you consider needs to be improved?
- How was the service to customers and transport users modified to manage the impact of the extreme weather?
- How well did transport operators communicate with their customers and transport users?

- How well did transport operators communicate among themselves and coordinate their response?
- What action do you have underway or planned as a result of the challenges faced?
- What action would you like to see taken by others to reduce the impact of extreme weather on transport?

Managing the Impacts on Transport from Extreme Weather

- In the context of your business or interests, what are your planning assumptions about extreme weather?
- In the context of your business or interests, what is the economic basis for investment and resource allocation decisions related to the effects of extreme weather on transport networks?
- Are investment and resource allocation decisions prioritised to reduce the vulnerability of transport systems and their users to weather events? Is there a case to revise the approach?
- The transport network serves many needs for our society and economy. Are there parts of our transport infrastructure which cannot be allowed to fail in any eventuality? If so, why?
- What level of service can customers and transport users reasonably expect in extreme weather?
- How do you work with other bodies to improve resilience to extreme weather events?
- What can we learn by the experience of and approach taken by other nations in terms of planning and managing resilience?
- Are there any other issues which you think relevant to the Review's Terms of Reference and would like to raise?

Appendix D - Organisations interviewed by the Review Panel

Automobile Association
Association of Drainage Authorities
Association of Directors of Environment, Economy, Planning & Transport
Arriva Trains Wales
Association of Train Operating Companies
British Airways
British Geological Survey
Birmingham Airport
British Ports Association
Buckinghamshire County Council
Civil Aviation Authority
Committee on Climate Change
Civil Engineering Contractors Association
Centre for Ecology & Hydrology
Chartered Institution of Highways and Transportation
Confederation of Passenger Transport UK
Cross Country Trains
DB Schenker
Environment Agency
First Great Western
Freight Transport Association
GB Railfreight
Highway Agency
Highways Term Maintenance Association
Institution of Civil Engineers
Institute of Highway Engineers
Institution of Mechanical Engineer
City of Copenhagen Technical and Environmental Administration
Local Government Association
Met Office
MeteoGroup
National Express Coaches
Network Rail
Office of Rail Regulation
Passenger Focus
RAC Foundation
Road Haulage Association
Rail Safety and Standards Board
The Department for Transport Science Advisory Council
Southeastern (Rail)
Southern (Rail)

Local Government Technical Advisers' Group
Transport for London
Transport Scotland
United Kingdom Major Ports Group Limited

Appendix E - Panel visits

| | |
|------------------------|---|
| Airports | Gatwick Airport Heathrow Airport |
| Local Authorities | Devon County Council Gloucestershire County Council Surrey County Council Wiltshire Council Wokingham Borough Council |
| Network Rail | Dawlish, Devon Folkestone Warren, Kent Hooley, Sussex Llanaber, Wales Network Rail, National Centre, Milton Keynes Oxted, Sussex Sandilands (Tywyn), Wales Stonegate, Kent Tonfanau, Wales Wessex Route, Network Rail / South West Trains Alliance Western Route, Swindon |
| Operation centres | British Airways Operation Centre Highways Agency, Birmingham Met Office, Exeter HA National Traffic Operations Centre, Quinton HA West Midlands Regional Control Centre, Quinton |
| Port Operators | Port of Immingham (Associated British Ports) |
| Strategic Road Network | Highways Agency offices, Birmingham |

Appendix F - Historical flood events in the UK

Data from the Environment Agency

Table 7.1 - Historical flood events in the UK

| Flood Event | Rainfall statistics | Properties Flooded | Environment Agency Area | Notes |
|-----------------------|---|--------------------|---|--|
| Cornwall Nov 2010 | 60mm in 2 hours | 250 | Cornwall Area, South West Region | Roads closed and rail services affected. |
| Cumbria Nov 2009 | 316mm in 24 hours | 1500 | North Area, North West Region | 1 fatality. Collapse of bridges (Calver Bridge Workington, Northside Bridge Workington, etc.) and road closures. Workington dock closed. |
| Morpeth Sept 2008 | 237mm in 48 hours | 1250 | Northumbria Area, North East Region | Almost every road in Morpeth impassable. Power cut off to 300 properties in Morpeth. |
| Summer 2007 | 294mm in June (North East) 157mm in 48hrs (Midlands) | 55000 | North East Region Midlands Region Thames Region | 13 fatalities. Mythe Water Treatment Works flooded – 140000 homes without normal water supply for up to 2 weeks. 300 schools damaged. Many motorways closed. |
| Cumbria Jan 2005 | 200mm in 48 hours | 2500 | North Area, North West Region | Closure of police stations, council offices, schools. Loss of electricity, land line and mobile phone network failure and water supply notably at Carlisle. Quarter million houses affected by power cuts. Road closures, M6 and West Coast mainline closed. |
| Boscastle Aug 2004 | 200mm in 24 hours | 60 | Devon & Cornwall Area, South West Region | 3 buildings demolished. 8 buildings partially destroyed. Footbridge swept away. |

| | | | | |
|-------------------------------------|-----------------------|--------|--|--|
| Thames Dec 2002 – Jan 2003 | 105.5mm in 12 days | 717 | Thames SE and West areas | Some erosion and damage to Jubilee River. Closure of 2 trunk roads in Oxford, 4 A roads and main railway. |
| Autumn 2000 | 156mm in 48 hours | 10,000 | Widespread including, Southern region (specifically Kent & East Sussex), North East region | Many properties were flooded several times during Oct/Nov. Widespread disruption to road and rail services. Weather-related Insurance claims totalled some £1 billion. |
| Easter 1998 | 80mm in 24 hours | 1,900 | Midlands region | 5 fatalities. 1, 500 evacuated. Electricity supplies were lost and there was damage to cars, boats and caravan parks. Cost to the insurance industry of around £500 million. |
| 1953 North Sea Flood | | 24000 | | 307 (estimated Inland) 224 (estimated at sea) people died. 1600km coastline damaged. 1000km sea walls damaged. 30000 people evacuated. 647km ² (160,000 acres) of land flooded. 1200 flood defence breaches. Over 30,000 emergency workers operating. |

Appendix G - List of recommendations

Recommendation 1

The Department for Transport (DfT), Department for Communities and Local Government, the Office of Rail Regulation and Treasury should ensure that funding decisions for road and rail are informed by asset management plans and do not unduly restrict maintenance and resource expenditure that is necessary to maintain transport network resilience.

Recommendation 2

For railways, strategic roads and local roads, the DfT should develop benchmarks for expected volumes and efficient costs of maintenance activity related to given transport asset populations and associated condition assessments. These benchmarks should inform the financial settlements with the respective infrastructure bodies.

Recommendation 3

The DfT should work with Network Rail, the Highways Agency and Local Highway Authority representatives to understand how the full costs of disruption can be better accounted for in network investment decisions.

Recommendation 4

The DfT should work with researchers, the devolved administrations and the transport industry to further consider whether there are potential 'single points of failure' in the strategic transport networks, which leave parts of the country at risk of having vital economic and social links severed.

Recommendation 5

The DfT should work with other Whitehall infrastructure interests and industry to identify a 'critical network', comprising those routes which are of national economic significance. Once identified, the DfT should work with the relevant industry partners to ensure that this network is maintained and enhanced where appropriate to a standard which provides for a higher level of resilience to the effects of extreme weather.

Recommendation 6

HM Government needs to identify cases where transport infrastructure which supports nationally vital passenger flows and supply chains, is insufficiently protected and enhancement cannot be fully funded by the current flood protection funding formula. Where such cases are identified, it should closely consider the case for funding to supplement the resources, from both public and private sectors, which are currently available.

Recommendation 7

The Highways Agency, Local Government Association and Network Rail should consider the value of a 'land owner code of responsibility'. Put simply, this would set out the responsibilities of the transport infrastructure owner and neighbour in terms of maintenance of their respective assets, including right of access. It would need to be tailored for application to roads and railways respectively, given the different legislative regimes that apply.

Recommendation 8

The DfT should consider how further resilience planning workshops can best be provided for port operators; extended to other sectors; and cross-sector groups brought together to share experience and best practice.

Recommendation 9

With the winter's experience fresh in the mind, operators of strategic transport infrastructure should revisit their Climate Change Risk Assessments and Adaptation Plans in advance of winter 2014.

Recommendation 10

All transport operators should have contingency plans to cope with extreme weather events. For infrastructure operators these should extend to include their major customers, and at a minimum be developed in consultation with them. Contingency plans should be regularly rehearsed and progressively extended to take account of a wider range of extreme weather scenarios as experience develops.

Recommendation 11

All transport operators should ensure they have clearly agreed channels for receiving weather and flood forecasts. These should be monitored in real time during periods when extreme weather is expected.

Recommendation 12

The Environment Agency and Met Office should work to further improve their joint flood forecasting, particularly for potential coastal flooding events, where tides, storm surges, wind strength and wind direction all combine to influence the outcome, and for potential ground water flooding.

Recommendation 13

All transport operators and authorities should develop, test and implement a dedicated passenger and user communications plan for times of transport disruption.

Recommendation 14

Transport and network operators should:

- **Give prominence on websites to the latest service information during periods of disruption, ensuring that marketing and promotional information is relegated to the background at these times.**
- **Use everyday language, not technical jargon to explain what is going on and causing the disruption. There is scope to research descriptions and phrases to use to test passengers reactions during 'peacetime'.**
- **Ensure consistency of information provided through different channels and by different parties. This will involve lines being agreed and re-agreed by all the key parties involved – e.g. airports and airlines, Network Rail and the train operating companies - and communicated through the variety of channels available.**
- **Make greater use of photographs distributed by text or social media, to improve transport users' understanding of the reasons for disruption.**

Recommendation 15

In the face of an extreme weather event, or a high-confidence forecast of extreme weather, transport operators should plan for the best practicable service which they can realistically deliver, and which manages expectations, providing a high degree of certainty to passengers, other users and industry partners.

Recommendation 16

Transport operators should have checklists of resources which they will need as part of their recovery effort from different weather-related events, with details such as the location, owner and source(s).

Recommendation 17

Transport operators should consider whether they have the best possible organisation of their intra-industry crisis management machinery, taking account of the benefits of working more closely with their partners. They should similarly review their participation in wider cross-sector fora, to ensure they are appropriately represented and the benefits of closer liaison between modes are secured.

Recommendation 18

The Highways Agency should consult with the Freight Transport Association, Road Haulage Association and other affected groups in developing proposals to restrict vulnerable vehicles from using exposed sections of the Strategic Road Network, in particular the QEII Bridge at Dartford, during times of high winds so that the crossing can be kept open for all other users for as long as possible. The Highways Agency should then work with the DfT to establish how best to implement any additional restrictions considered appropriate, including how to ensure road user compliance.

Recommendation 19

The Highways Agency should work with the Met Office to agree how best to utilise the improving granularity of wind forecasts to give the best possible wind forecast information to lorry fleet operators, ensuring it includes more specific and more useful information on its website and wider Highways Agency information services. This should include more specific information as to what drivers should do in the event of high winds after starting their journey.

Recommendation 20

The Highways Agency should conduct a flooding risk assessment exercise using the newly updated Environment Agency flood risk maps and other data to identify potential flood risk locations on the Strategic Road Network, to supplement its log of actual flooding events.

Recommendation 21

The Highways Agency should carry out the necessary work to complete its drainage asset inventory and if appropriate should make the case, in the process of establishing the new government owned company, for funding of the survey work necessary to significantly improve its understanding of the condition of its drainage assets and the interfaces with adjoining drainage networks.

Recommendation 22

The Highways Agency and the DfT should review the range and wording of messages displayed on variable message signs at times of disruption, including severe weather, and establish a dialogue with road users to determine what is seen as useful and credible.

Recommendation 23

The Highways Agency should continue to improve and refine the content of its website to make it still more useful and influential, regularly canvassing feedback from users. The Highways Agency should also be allowed appropriate flexibility to use variable message signs to direct road users to more comprehensive sources of information, such as its website, twitter channels and its contact centre number. This will help to build awareness and

encourage drivers to check for information before starting their journeys during extreme weather and any resulting disruption.

Recommendation 24

The DfT should review the content of the Driving Theory Test, and the associated materials available, to ensure it gives adequate coverage to driving techniques that can be used in adverse weather conditions, and travel preparations.

Recommendation 25

In establishing the new Highways Agency Government Company, the DfT should ensure that its top-level performance indicators encompass network availability and that this is supported by appropriate indicators of asset condition.

Recommendation 26

When bidding for funds, Local Enterprise Partnerships should consider the need for funding to ensure the resilience of the existing transport network which supports businesses in their areas.

Recommendation 27

The DfT, working as necessary with the Local Government Association and Local Highway Authorities should complete the analysis of road condition statistics as soon as possible, and ensure the time-series is kept up-to-date.

Recommendation 28

The DfT should use the UK Roads Liaison Group to undertake a review of all matters relating to the monitoring and maintenance of bridges.

Recommendation 29

All local highway authorities need to learn from the events of winter 2013/14 and ensure they are prepared for, and able to respond to, similar extreme weather events in the future.

Recommendation 30

Government should consult Local Highway Authorities on a set of criteria to be applied consistently to emergency highway repair funding through the DfT whenever such funding is made available. These standard bidding criteria should include a period of time in which to invest additional funding which is long enough to encourage a longer-term approach to roads maintenance, are spent in accordance with an asset management approach, and do not skew the market.

Recommendation 31

Local Highway Authorities should follow asset management principles in managing their assets, and informing spending decisions.

Recommendation 32

The DfT should proceed with its proposal to consult on using part of the capital maintenance monies to encourage the development and adoption of Asset Management Plans. However, in order to allow adoption of plans by more authorities, this should be delayed at least until financial year 2016/17.

Recommendation 33

Local Highway Authorities must ensure that drainage assets are maintained in good working order, to reduce the threat and scale of any flooding, paying particular attention to those parts of the network known to be prone to problems, so that the drainage systems operate close to their designed efficiency.

Recommendation 34

Drainage assets should be an integral component of a Local Highway Authority's Asset Management Plan; in addition, all Local Highway Authorities should adopt the recommendations in the Highways Maintenance Efficiency Programme Guidance on the Management of Drainage Assets

Recommendation 35

Each Local Highway Authority should make an early start in identifying a 'resilient network' to which it will give priority through maintenance and other measures in order to maintain economic activity and access to key services during extreme weather.

Recommendation 36

Where Local Highway Authorities are faced with stretched capacity and thus find it difficult to develop and deliver the Asset Management approach and incorporation of drainage, they should investigate the potential for delivering through collaboration with other authorities.

Recommendation 37

All Local Highway Authorities should make themselves familiar with the guidance and good practice promoted by the Highways Maintenance Efficiency Programme and ensure it informs their decision-making.

Recommendation 38

The update to Well-Maintained Highways should be used to reflect the drive towards asset management in highways maintenance, with the inclusion of drainage. It should also reflect the points covered in this Review, and particularly address the issue of risk and resilience.

Recommendation 39

Network Rail should amend its classification system for embankment and slope stability risk to take account of the

economic importance of the traffic on a route in addition to the risk to train safety from a slope failure.

Recommendation 40

Network Rail should maintain a strong focus on trialling newly available condition monitoring and slope stabilisation technologies, working with academic and other researchers and with other railway administrations, to improve its ability to identify and anticipate slopes that will fail and target remedial work as efficiently as possible. In addition Network Rail should continue to commission academic research into possible slope stabilisation techniques short of physically rebuilding.

Recommendation 41

Network Rail should substantially strengthen their focus on the management of vegetation by:

- Developing a ten year strategy to bring about a significant reduction in the number of line side trees and the overall level of vegetation. It should support this strategy with appropriate business plan and budget provision.
- Developing an active biodiversity strategy to adopt alternative vegetation approaches on cleared sections and engage in off-setting tree planting, generally away from the railway.
- Revising their vegetation management strategy to include at-risk embankment slopes, particularly on more vulnerable clay embankments, with ideally trees confined to the bottom one third or so of the slope where they can help stabilise the toe of the slope.
- Developing a strategy to prevent vegetation re-growth on embankments, cuttings and the lineside after vegetation clearance. We note that significant sections of route which have had trees cleared over past years are already seeing significant re-growth of saplings and small trees. This will also require a separately identified fund for maintenance.

Recommendation 42

Network Rail should also work with train operating companies and the Office of Rail Regulation to sharpen the economic signals it receives to drive the case for a sustained vegetation management strategy. This should include the cost of rolling stock damage, and the subsequent losses associated with overcrowding and poor performance as a result of reduced rolling stock availability, as well as the risk to safety from collision or derailment.

Recommendation 43

The DfT should review, and at the earliest opportunity modify or replace, the 1842 legislation governing Network Rail's ability to access neighbours' property, with more explicit powers to deal with

both potential threats to the safe operation or resilience of the railway and for planned maintenance.

Recommendation 44

Network Rail should use the recently updated Environment Agency Flooding Risk Maps to identify sections of line that are potentially at risk of fluvial flooding, to supplement its register of at-risk sections based on historic experience.

Recommendation 45

Development of the route Resilience Plans by Network Rail will identify locations where the railway is at risk of flooding. For these locations Network Rail should examine the feasibility of raising location cabinets and track height and make an economic appraisal of the cost and benefits of achieving higher resilience to future flood events.

Recommendation 46

Network Rail should consider accelerating the conversion of track circuits to axle counters at those sites identified through the route resilience plans as being at high risk of flooding.

Recommendation 47

Network Rail should work up and deploy its new temporary automatic signalling system widely whenever appropriate

Recommendation 48

Network Rail should commission studies of the resilience of its sections of coastal railway.

Recommendation 49

Network Rail should keep the Stress Free Temperature under regular review in the light of evolving climate change guidance on extreme summer heat.

Recommendation 50

Network Rail and the rail industry should keep their design standards for new infrastructure and rolling stock under regular review in the light of evolving understanding of the impact of climate change on extreme weather.

Recommendation 51

Network Rail should liaise with its electricity suppliers to trace through the routes and sub-stations through which it is supplied to ensure adequate system redundancy and any single points of failure are identified and made suitably resilient. To assist in preparation and planning for times of power disruption the Electricity Networks Association chairs an Emergency Planning Managers' Forum which we would recommend that Network Rail should consider joining.

Recommendation 52

Network Rail should investigate the feasibility of convening multi-route Extreme Weather Action Team conferences where appropriate to assist those Train Companies who operate over multiple routes. Extreme Weather Action Team conferences should always be timed to ensure decisions on contingency timetables can be implemented.

Recommendation 53

Network Rail, on behalf of the rail industry, should liaise with the Met Office to inform how most usefully to exploit greater granularity of forecasts as forecasting capability improves further.

Recommendation 54

The Rail Delivery Group should continue to investigate improved techniques and technologies for producing contingency timetables so as to be able to have a wider range of timetables on hand to better match different weather events.

Recommendation 55

The DfT, the Office of Rail Regulation and Passenger Focus should work with the Rail Delivery Group to develop an amended approach to performance and compensation regimes during periods of extreme weather-related disruption, which gives the right signals to the industry but is seen to be fair for passengers.

Recommendation 56

Network Rail should increase the resource available for clearing fallen trees, including considering training more of its own staff in the use of chainsaws. Additionally it should fit multi-purpose vehicles and other trains with powerful lighting to facilitate night time line inspections. It should also investigate other means of identifying fallen trees to direct teams to their location more speedily.

Recommendation 57

All major ports and airports should review the location and flood-protection of their power, communications and IT infrastructure in light of the winter's experience at Immingham and Gatwick.

Recommendation 58

The Environment Agency and Met Office should work together to improve the granularity and accuracy of coastal flooding forecasts, taking in the complex interaction of tides, wind, wave height and estuarine modelling. Ports should look to be involved in this work to ensure that forecasts take account of known vulnerabilities and are suitably tailored to assess key impacts.

Recommendation 59

Given the context of rising sea levels and a higher likelihood of extreme weather events, strategic ports should commission a range

of tide-height data and return periods from the Met Office, Environment Agency and other relevant partners. The port operators should decide what defences to put in place against this range of potential surge events.

Recommendation 60

The DfT should facilitate the running of further workshops for ports, region-by-region, in order to ensure that the experience of winter 2013/14 and initiatives to improve resilience are shared within the sector.

Recommendation 61

Port operators and operators of rail and road links to ports should liaise regularly to consider and develop the resilience of inland links to and from ports, including their physical resilience and alternative routes.

Recommendation 62

Airports should draw up contingency plans jointly with their major airlines. These should also be jointly exercised.

Recommendation 63

In order to provide greater certainty to travellers and operators, airports should work with their principal airlines to adjust capacity on a pre-emptive basis when there is a high degree of confidence in the forecast of extreme weather, rather than waiting for the weather to hit.

Appendix H - Glossary

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|--------------------------------|---|
| ABP | Associated British Ports |
| ADEPT | Association of Directors of Environment, Economy, Planning and Transport |
| BA | British Airways |
| CapEx | 'Capital' expenditure on improving and enhancing (infrastructure) assets through investment |
| CIRIA | Construction industry research and information association |
| Climate Change Adaptation Plan | Plans put in place by organisations to make infrastructure more resilient to rising sea levels or other effects likely to result from climate change and changing weather patterns. |
| CP | 'Financial' Control Period (CP) e.g. used by Network Rail for work programmes during 2009-2014 (CP4) or planned for 2014-2019 (CP5) |
| COBR | A crisis response committee set up to coordinate the actions of bodies within the UK government |
| CSS | County Surveyors' Society now known as ADEPT |
| DA | Devolved Administrations |
| DCLG | Department for Communities & Local Government |
| Defra | Department for Environment Food & Rural Affairs |
| DfT | Department for Transport |
| EWAT | Extreme Weather Action Team is an intra-industry crisis management fora used in the rail sector |
| Flooding | Unwanted water above the land surface |
| Fluvial | River flooding |
| FOCs | Freight Operating Companies |
| GHG | Greenhouse gas emissions are gases which contribute to climate change and global warming |
| Groundwater flooding | Subsurface flooding which can affect foundations of structures, basements and underground utilities |
| HA | Highways Agency (an executive agency of the Department for Transport) responsible for the SRN |
| HADACAB | Heathrow Air Traffic Management Demand and Capacity Balancing Group |
| IDB | Internal Drainage Boards are statutory local public bodies in areas of special drainage need, usually land areas below river or sea level responsible for controlling |
| LA | Local Authority |
| Land drainage | Water beneath the land surface which can affect land usage |
| LEP | Local Enterprise Partnerships are voluntary partnerships between local authorities and businesses |

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|-------------------------|---|
| | set up in 2011 by the Department for Business, Innovation and Skills to help determine local economic priorities and lead economic growth and job creation within the local area. |
| LGA | Local Government Association |
| LHA | Local Highway Authority |
| LRF | Local Resilience Forum - established by the Civil Contingencies Act 2004 |
| Met Office | The United Kingdom's national weather service. It is an executive agency and trading fund of the Department for Business, Innovation and Skills and is also a member of the Public Data Group. |
| MeteoGroup | A private weather business providing customers with bespoke weather services. |
| MPV | Multi-Purpose Vehicles |
| NAO | National Audit Office |
| NTOC | National Traffic Operations Centre |
| ORR | Office of Rail Regulation |
| PIDD | Passenger Information During Disruption |
| pluvial | localised surface water flooding due to intense rainfall |
| Quarmby Review | David Quarmby's review into extreme winter weather carried out in 2010 |
| RSSB | Railway Safety and Standards Board |
| SCG | Strategic Co-ordinating Groups established by the Civil Contingencies Act 2004 |
| Smart motorways | Motorways managed by HA regional control centres which use a range of new technologies to vary speed limits in response to driving conditions |
| SRN | Strategic Road Network managed by the Highways Agency |
| Stress free temperature | Temperature at which a metal object e.g. a rail is neither in tension or compression |
| SWIMS | Severe Weather Impacts Monitoring System a web based tool used to assess vulnerability to severe weather and develop business cases for taking appropriate action. e.g. services provided by Kent Partners (including Kent County Council, Kent Police, district and borough councils and the Environment Agency) |
| TfL | Transport for London |
| TOCs | Passenger Train Operating Companies |
| TRaCCA | Tomorrow's Railway and Climate Change Adaptation is a research programme led by the RSSB |
| TRO | Traffic Regulation Order which is the legal instrument by which traffic authorities implement most traffic management controls on their roads. |
| UKMPG | United Kingdom Major Ports Group Limited |
| VMS | variable message signs |

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