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Review of flooding incidents on the HA Network in Autumn 2000 – Stage 2

Version: Final

by A J Todd (TRL Limited)

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Environment Consultancy Framework
Review of flooding incidents on the HA Network

Client: Highways Agency
S S & R
(Mr S V Santhalingam)

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Executive summary

This Project Report describes the scope and programme of work that was carried out for the Highways Agency for the continued review of the flooding incidents on the HA network during the Autumn of 2000. This is the second stage of the project and again was undertaken by TRL Ltd and HR Wallingford Ltd. The project consisted of three phases:

Phase 1: The preparation of the Inception Report.

Phase 2: The development of guidance documentation on the runoff from the natural catchment adjacent to the carriageway and the design of culverts.

Phase 3: The provision of technical assistance to take the guidance documentation through to publication.

The Advice Notes published as outputs from this project will:

- reduce the risk of future highway drainage systems being unable to accommodate surface water from the adjacent natural catchments
- ensure that future culverts and drainage outfalls are less affected by unusually high flows.

The recommendations on maintenance and operations, if taken up, should reduce the risk to operatives of undertaking emergency works to the drainage system. The impact on road users should also be reduced.
1 Introduction

This Project Report is the final output from the Highways Agency Environment R&D Framework Contract No: 3/323/R011 which commenced on 2 September 2001 and is being carried out by TRL Ltd in association with HR Wallingford Ltd.

In Autumn 2000 many parts of England were affected by storms and periods of prolonged heavy rainfall. Particularly severe storms between 29 October and 9 November led to a large number of temporary lane or road closures on all types of roads including those operated by the Highways Agency (HA). Some of the incidents on the HA Network were caused by fallen trees and high winds but the great majority were due either to drainage systems being overloaded or to surface flooding from rivers or other watercourses.

The Traffic Safety and Environment Division of the HA therefore commissioned a project to review the performance of the Network during the storms of Autumn 2000, and identify improvements that would increase its resilience to adverse weather conditions in the future.

The review showed that about 165 separate incidents occurred on the HA Network as a result of flooding, of which approximately 65% were associated with the performance of the drainage systems and about 35% were due to high water levels in adjacent rivers or streams. Existing HA guidance on how to accommodate runoff from road surfaces was considered to be satisfactory. The main problems affecting the drainage systems were found either to be related to maintenance issues or to be located at points where these systems interfaced with the surrounding natural catchment or downstream watercourse.

Based on the findings of that review, the Highways Agency commissioned a follow-on project to produce supplementary guidance on the design and maintenance of highway drainage systems. This will serve to increase the resilience of the HA Network by improving its ability to deal with severe storms and prolonged rainfall.

2 Objectives of the project

The objectives of this project were to:

- Review the advice contained within the existing HA documentation.
- Develop and produce an HA guidance document on how to assess and deal with run-off draining to roads from natural catchments.
- Produce an HA guidance document on the design of culverts and general arrangement details for headwalls, grills and outfalls from highway drainage systems.
- Produce recommendations on improved maintenance methods and procedures for highway drainage systems for inclusion in other HA manuals and documents.

The parts of the project defined above proceeded in parallel, with the two principal outputs, the Advice Note on Run-off from Natural Catchments and the Advice Note
on Culverts and Outfalls being delivered in draft form during 2002. These Advice Notes have now been published as HA106 and HA107 respectively.

The project was undertaken on a collaborative basis. HR Wallingford Ltd investigated the “Run-off from Natural Catchments”, whereas TRL Ltd developed the “Design of Culverts and Outfalls with assistance from HR Wallingford Ltd. The recommendations on maintenance methods are contained within the report “Operation and Maintenance Issues” that forms the second project output provided by TRL Ltd.

This study never intended to reproduce CIRIA Report 168, Culvert design guide, but to direct readers to it and incorporate some of the ideas into the guidance, together with experience gained since its publication.

3 Review of current HA documentation

3.1 Culverts

3.1.1 MCHW 1 (SHW)

Clause 501 Pipes for Drainage and for Service Ducts

Refers to the type of pipe that is typically used for culvert construction and Sections from this are reproduced below.

Corrugated Steel Pipes

4 Corrugated steel pipes shall be manufactured from either:

(i) bolted segmental plate pipes complying with sub-Clause 6 of this Clause and having plate thickness’ as described in Appendix 5/1; or

(ii) galvanised steel sheet suitable for lock seam fabrication complying with BS EN 10142 grade DX51D + Z600, or aluminium coated steel sheet complying with AASHTO specification M274-87I.

Corrugated steel pipes complying with (ii) above shall be manufactured from steel of minimum thickness 1.25 mm unless otherwise described in Appendix 5/1.

5 Where described in Appendix 5/1 corrugated steel pipes shall be provided with additional protection of hot applied bitumen complying with AASHTO specification M190-80, or an equivalent coating system.

6 Bolted segmental plate pipes shall meet the following requirements:

(i) Steel for the plates shall comply with BS 1449: Part 1, Grade 3 or Grade 4, Condition HR.

(ii) After forming, the depth of the corrugations shall be within a tolerance of ± 6% and the pitch of the corrugations within a tolerance of ± 4% of the nominal dimensions. Plates shall have a minimum lip of 45 mm
beyond each end crest. Cut edges shall be free from notches, gouges, rust or burrs.

(iii) Bolts and nuts for connecting plates shall comply with ISO 4014, 4017 and 4032, for ISO 898 property class 8.8, nominal size M20; or with BS 4395, nominal size M20; or with ISO 898 Parts 1 and 2, property class 10.9.

(iv) When all the plates have been assembled, the nuts shall be tightened against a domed washer. The tightening shall be repeated if necessary to achieve the torque recommended by the manufacturer.

(v) Steel plate shall be galvanised in compliance with Clause 1909. Plates shall be galvanised after forming the corrugations and completing all necessary cutting, punching and drilling. Units in which the zinc coating has been burned by welding or otherwise damaged in fabrication, transport or handling at Site shall be made good in compliance with Clauses 1907 and 1908. Bolts and nuts shall be galvanised in compliance with Clause 1909.

Reference should also be made to Table 5/1 I the SHW.

From Clause 504.4, the following is applicable to corrugated steel pipes generally used for culverts.

Corrugated steel pipes of lock seam fabrication, not exceeding 900mm internal diameter, shall be joined in accordance with the manufacturer’s instructions. Bolted segmental plate pipe arches or circular pipes, not exceeding 900mm internal diameter, shall be joined in accordance with sub-Clause 501.6 (iv) and the manufacturer’s instructions.

Clause 2505: Drainage structures

All drains, piped and box culverts, sewers and drainage structures, other than bridges, that have a diameter or clear span exceeding 900mm shall comply with this Clause and any additional requirements described in Appendices 25/1 and 25/5.

3.1.2 MCHW 2 (Notes for Guidance)

The following is located in clause NG501.2

Piped culverts up to 900mm internal diameter shall be specified in Series 500. Drains, box culverts, piped culverts (and other drains) of clear span or internal diameter exceeding 900mm are subject to Overseeing Organisation’s technical approval and shall comply with Series 2500 (ref NG2505 and NG2506). A box culvert should not be specified where either a (concrete) box culvert or a (corrugated steel) piped culvert would be technically acceptable. Wherever possible, the Contractor should be offered a choice and the Overseeing Organisation should be consulted during the scheme preparation. Box culverts, piped culverts (and other drains) of clear span or internal diameter exceeding 900mm are structures subject to Overseeing Organisation’s technical approval. Care should be taken to ensure that there are no inconsistencies between any specific requirements included in an outline Approval in Principle form.
and the general requirements of Series 500. Where necessary, contract-specific amendments should be included in Appendix 0/1 or 0/2 to achieve consistency.

From NG501.3 the following relates to corrugated pipes for culverts;

Protection to the lower third of the inside of corrugated steel piped culverts by means of an asphalt or in situ concrete coating will be required where stones and rocks are likely to be carried by the flow

From NG504 Jointing of Pipes,

3 Culverts are generally considered to be drains but they do not necessarily require watertight joints. Where watertight joints are required for culverts this should be stated in Appendix 5/1.

3.1.3 MCHW 3 (Highway Construction Details)

Other than the pipe bedding details and possibly the manhole details, there are no drawings relating specifically to culverts.

3.1.4 DMRB 4 (Geotechnics and Drainage)

HA71-The Effects of Highway Construction on Floodplains

Some information in this AN could be considered useful in relation to culverts: for example,

Acceptable Afflux, Clauses 2.12 and 2.13.

Afflux is the increase in flow surface level as the water flows through the constriction of the culvert. Applicable only to larger culverts on watercourses where significant flows can be anticipated. Need to refer to Environment Agency for guidance.

Clause 3.3 refers to the need to maintain clear approaches to the opening to prevent debris catching on wire fences and the like.

Clause 3.4 refers to the “Water practice manual for the hydraulic design of channels and culverts”.

Clauses 3.5 and 3.6 refer to river diversions, applicable to culverts where watercourse alignment may require amending either for construction purposes or to fit highway alignment.

Clauses 3.11 and 3.12 refer to culverts for local land drainage flows.

Chapter 6 deals with the assessment of bridge afflux.
3.2 Headwalls

There is no guidance in the documentation in relation to headwalls.

The 1700 Series is applicable to the concrete used in the structure and other Series may be appropriate for the waterproofing of the rear face of the structure or the use of alternative materials. There is no guidance in the 500 Series or in the DMRB for determining the general arrangement, size, shape, orientation to the watercourse or the provision of security and trash screens.

3.3 Flow from areas beyond the highway boundary

There is virtually no guidance given in any of the Highways Agency’s documents. The most appropriate is in MCHW1 Clause 511 Land drains.

This clause primarily relates to the location, marking and reconnection of land drains severed by new road construction. The Notes for Guidance recommend that a separate system be maintained. However, where this is impractical, land drains are to be connected to the new drainage, which would imply to the designer that cognisance of flows from the surrounding catchment is important. However, flows from land drains tend to be small and, due to the long time of concentration, insignificant in terms of sizing the highway drainage carrier pipes.

Of far greater significance is the over land flow from the adjacent catchment. With particular ground conditions, such as high water tables or cohesive soils, at certain times of the year the volume of flow from these catchments can be large.

Works that affect watercourses or ditches, including the creation of new ones, are to be described in Appendix 6/3 (Clause 606, MCHW1).

4 Guidance on drainage of runoff from natural catchments

Aspects investigated in the study and covered in the guidance document include,

(a) Method for defining natural catchments and estimating run-off
The method needs to be straightforward to use and appropriate to the degree of accuracy required. It is likely that the method will be mainly used as a screening tool for identifying sections of road at risk of receiving significant runoff from natural catchments. Account should be taken of the data and prediction methods in the recently published Flood Estimation Handbook (1999).

(b) Choice of design return period for rainfall on natural catchments
Uncontrolled runoff from natural catchments onto roads can result in surface flooding persisting for relatively long periods. Recommendations are made on the choice of return period for design storms. These take account of the fact that traffic disruption due to runoff from natural catchments can last much longer than that caused by short-period runoff from the surface of roads during heavy storms.

(c) Sizing and location of drainage ditches
A method should be provided for sizing drainage ditches to cater for predicted rates of runoff from natural catchments (obtained from (a) and (b) above). Guidance is given on land drainage issues, arrangements for reducing blockage by debris, and suitable locations for ditches (allowing for effects that ditches at the top or bottom of cuttings have on soil stability, surface erosion, etc).

(d) Modified design of carriageway drainage systems
Guidance is given where ditches are not used and carriageway drainage systems need to be able to deal with additional runoff from natural catchments.

5 Guidance document on design of highway drainage outfall and culvert details

Aspects covered in the guidance document include:

(a) Levels of outfalls relative to water levels in watercourses
Guidance is needed so that levels of outfalls and detention ponds are high enough to allow free discharge, taking account of likely levels in watercourses during flood conditions.

(b) Hydraulic design of culverts
Appropriate guidelines on performance requirements and sizing of culverts should be provided taking account of current best practice (i.e. CIRIA Report 168 Culvert design guidance).

(c) Scour protection
Recommendations are given on the design of headwalls, outfalls and culverts to prevent undermining and channel erosion by flow-induced scour.

(d) Bar screens
Guidance is given on suitable types and arrangements of bar screens taking account of current best practice for security of debris collection, (e.g. recent recommendations were provide by Environment Agency and Water Company).

(e) Safety and maintenance features
Guidance is given on standard details and safety features necessary to allow safe and efficient maintenance.

6 Recommendations on maintenance methods and operational procedures

This section summarises the findings and contains recommendations both, from this project and the earlier review into ways of improving the maintenance and operation of highway drainage systems. This is in a format that can readily be inserted into the existing DMRB. Listed below are the recommendations and guidance that form the basis of the Operation and Maintenance Report included as Appendix A. This is not in the form of a guidance document because it is intended that other parties will incorporate the recommendations into existing documents such as the Trunk Road Maintenance Manual (TRMM). Relevant aspects include:
(a) Appropriate cleaning frequencies for gullies, pipes, ditches, culverts, outfalls, etc.
- The weather is an important factor in determining when maintenance is undertaken. One of the prime causes of the Autumn 2000 flooding was an occurrence of high winds during the leaf fall. Consequently large quantities of leaves accumulated in the road channels, having been washed into the gully gratings and formed blockages, as heavy rain followed directly afterwards.
- Channel sweeping during the autumn should be programmed with sufficient flexibility such that account can be taken of the variations in weather conditions.

(b) Collection and storage of information about highway drainage systems, including the recording and use of data on drainage problems and flooding incidents.
- Previous reviews of maintenance procedures have highlighted inadequacies in the drainage records held by both the Maintaining Agents and the Overseeing Organisations.
- The lack of adequate records resulted in delays to emergency flood alleviation works because the location, or even existence, of drainage systems was unknown.
- It is recommended that a record keeping system is developed by the Highways Agency and that this system is kept up to date.

(c) Division of responsibilities between HA Maintenance staff and other authorities and owners for the maintenance of hydraulic structures, drainage ditches and watercourses that interface with highway drainage systems.
- Gaining access to sections of blocked watercourse was also a problem in a number of instances, as the owners of the watercourse were unknown and difficulty with access resulted.
- A record of adjacent riparian ownership and access contact details must be maintained.

(d) Definition and signing of diversion routes for traffic in flood-prone areas.
- In most instances, during the flooding, diversion routes were set up quite quickly. Due to the depth of flooding it was not always necessary to divert vehicles with a high ground clearance.
- Dedicated diversion routes should be established in areas where there is a risk of flooding and these should aim to separate light vehicles from heavy vehicles.
- It is recommended that portable signs be manufactured that state “flood route” and have an adjustable arrow. These signs should be readily accessible at the Agent’s depot.

(e) Preventative maintenance based on forecasts of adverse weather, or high river levels, is necessary to ensure that channels are clear of leaves and that the headwall inlet grills are free from debris.
(f) Removal of obstructions to the watercourse within the highway boundary or adjacent to headwall structures. These might be; wire fences that straddle the watercourse or overhanging branches or vegetation in contact with the water surface.

(g) The access to headwall structures is, in many instances, difficult and hazardous. Access is often gained by scrambling down banks, often with little or no provision made to prevent operatives falling into the watercourse.

- Access should be by means of constructed steps.
- Handrails or balustrades should be provided above the headwall structure. These should be firmly fixed in order to support the weight of operatives clearing debris from the screen. Where headwalls are of brick construction, the handrail should be fixed to concrete footings.
- Anchor points for the attachment of safety harness should be fixed into the headwall or suitable concrete blocks cast adjacent to the structure.

(h) Vertical screens located on the upstream headwall make debris difficult and hazardous to remove.

- Vertical screens should be replaced by ones inclined no steeper than 60° to the horizontal.
- The screen should be constructed with a flat section at the top to facilitate raking.

7 Conclusion

The flooding that occurred in Autumn 2000 resulted from a combination of unusually severe weather conditions, routine maintenance that takes little account of predicted poor weather conditions and the inadequacies of the recorded data on highway drainage systems.

The Advice Notes published as outputs from this project will;

- reduce the risk of future highway drainage systems being unable to accommodate surface water from the adjacent natural catchment
- ensure that future culverts and drainage outfalls are less affected by unusually high flows.

The recommendations on maintenance and operations, if taken up, should reduce the risk to operatives of undertaking emergency works to the drainage system. The impact on road users should also be reduced.
8 References


(MCHW 1) Volume 1: Specification for Highway Works

(MCHW 2) Volume 2: Notes for Guidance on the Specification for Highway Works

(MCHW 3) Volume 3: Highway Construction Details


HA106 Drainage of Runoff from Natural Catchments

HA107 Design of Highway Drainage Outfall and Culvert Details

Appendix A

Operation and Maintenance Issues Report
Review of flooding incidents on the HA Network in Autumn 2000 – Stage 2

Operation and Maintenance Issues

by AJ Todd

PR/IS/052/03
3/323F/R011
PROJECT REPORT PR/IS/052/03

Review of flooding incidents on the HA Network in Autumn 2000 – Stage 2

Operation and Maintenance Issues

by AJ Todd (TRL Limited)

Prepared for: Project Record: 3/323F/R011 Environment Consultancy Framework
Client: Highways Agency, QS, TS&E Division
Mr S V Santhalingam

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Approvals

Project Manager

Quality reviewed

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Executive summary

During the Autumn 2000, the country suffered one of the worst periods of prolonged heavy rainfall recorded. This resulted in an unprecedented number of flooding incidents affecting the Highways Agency network. During the course of the works to alleviate the flooding, shortcomings in the Highways Agency’s records of drainage systems and maintenance practises became apparent.

Subsequently the Highways Agency commissioned a review of the flooding incidents, the causes and measures necessary to address these shortcomings.

This report addresses the maintenance issues that came to light, in particular the need for safe access to culvert and outfall headwalls and for easier to maintain screens at these structures. Also identified are the benefits to be obtained by separating heavy goods vehicles from the lighter traffic on the flood diversion routes.
REVIEW OF FLOODING INCIDENTS ON THE NETWORK IN AUTUMN 2000 – STAGE 2

OPERATION AND MAINTENANCE ISSUES

1 Introduction

This Report is the second output from the Highways Agency Environment R&D Framework Contract No: 3/323/R011 which commenced on 2 September 2001 and is being carried out by TRL Ltd in association with HR Wallingford Ltd.

In Autumn 2000 many parts of England were affected by storms and periods of prolonged heavy rainfall. Particularly severe storms between 29 October and 9 November led to a large number of temporary lane or road closures on all types of roads including those operated by the Highways Agency (HA). Some of the incidents on the HA Network were caused by fallen trees and high winds but the great majority were due either to drainage systems being overloaded or to surface flooding from rivers or other watercourses.

The Quality Services, Traffic Safety and Environment Division of the HA therefore commissioned a project to review the performance of the Network during the storms of Autumn 2000 and to identify improvements that would increase its resilience to adverse weather conditions in the future.

The review showed that about 165 separate incidents occurred on the HA Network as a result of flooding, of which approximately 65% were associated with the performance of the drainage systems and about 35% were due to high water levels in adjacent rivers or streams. Existing HA guidance on how to deal with runoff from road surfaces was considered to be satisfactory. The main problems affecting the drainage systems were found either to be related to maintenance issues or to be located at points where these systems interfaced with the surrounding natural catchment or downstream watercourse.

Based on the findings of that review, the Highways Agency commissioned a follow-on project to produce supplementary guidance on the design and maintenance of highway drainage systems. This will serve to increase the resilience of the HA Network by improving its ability to deal with severe storms and prolonged rainfall.

2 Objectives of the project

The objectives of this project were to:

(i) Review the advice contained within the existing HA documentation.

(ii) To develop and produce an HA guidance document on how to assess and deal with run-off draining to roads from natural catchments.
(iii) To produce an HA guidance document on the design of culverts and general arrangement details for headwalls, screens and outfalls from highway drainage systems.

(iv) To produce recommendations on improved maintenance methods and procedures for highway drainage systems for inclusion in other HA manuals and documents.

This report addresses the fourth objective above and contains recommendations for improvements to maintenance practice.

3 Recommendations on maintenance methods and operational procedures

This short report summarises the findings and contains recommendations both, from this project and the earlier review into ways of improving the maintenance and operation of highway drainage systems. This report lists the recommendations and guidance although this is not in the form of a guidance document because it is intended that other parties will incorporate the recommendations into existing documents such as the Trunk Road Maintenance Manual (TRMM).

4 Highway maintenance

Gully cleaning and channel sweeping

A significant cause of the flooding problems arose from the very high winds that preceded the heavy rainfall. The high winds removed a large amount of leaves from the trees, many of which fell adjacent to the highway. The high winds and subsequent heavy rainfall resulted in large accumulations of leaves in the highway channels. This led to numerous blockages of gullies where drainage was by conventional kerb and gully systems and the obstruction of outlets from channels and ditches.

The weather is an important factor in determining when maintenance is undertaken. Appropriate cleaning frequencies for gullies, pipes, ditches, culverts, outfalls, etc should be scheduled such that they coincide with the predicted weather. A certain degree of flexibility will be essential.

Channel sweeping during the autumn should be programmed with sufficient flexibility such that account can be taken of the variations in weather conditions.

Watercourse and hydraulic structures

A similar problem occurred with watercourses adjacent to, or culverted beneath, the highway. Dying vegetation coupled with the heavy leaf fall caused obstructions within the stream channel and on the grills / screens at culvert headwalls.
Preventative maintenance based on forecasts of adverse weather, or high river levels, is necessary to ensure that channels are clear of leaves and that headwall inlet screens are free from debris.

Preventative maintenance should also include the removal of obstructions to the watercourse within the highway boundary or adjacent to headwall structures. These obstructions that retain floating debris might be; wire fences that straddle the watercourse or overhanging branches and vegetation that are in contact with the water surface.

5 Data storage and asset management

The lack of adequate records resulted in delays to emergency flood alleviation works because the location, or even existence, of drainage systems was unknown.

Instances were reported where ditches had become overgrown and blocked, the maintaining organisation being unaware of the existence of the ditch. The presence of trees in the ditch line indicated that maintenance had been infrequent. Another organisation reported that gullies had been paved over.

Previous reviews of maintenance procedures have highlighted inadequacies in the drainage records held by both the Maintaining Agents and the Overseeing Organisations.

As a matter of urgency there needs to be a programme of collection and storage of information about highway drainage systems, including the recording and use of data on drainage problems and flooding incidents.

It is recommended that a record keeping system is developed by the Highways Agency and that this system is kept up to date.

6 Access and land ownership

Maintaining organisations reported instances where gaining access to sections of blocked watercourse was also a problem. The flooding of the carriageway was not necessarily the result of inadequate maintenance to the highway culvert, but resulted from obstructions to the downstream watercourse. The prime cause of the access problem was that the owners of the adjacent watercourse were unknown and the subsequent difficulty in gaining access.

To prevent reoccurrence, the division of responsibilities for the maintenance of hydraulic structures, drainage ditches and watercourses that interface with highway drainage systems, between HA Maintenance staff, other authorities and riparian owners must be agreed.

A record of adjacent riparian ownership and access contact details must be maintained preferably on the same database as the highway drainage data.
7 Flood route management

Where flooding has previously occurred, the maintaining organisations generally had flood diversion routes identified.

In most instances, during the flooding, diversion routes were set up quite quickly. However, where the depth of carriageway flooding was not severe, it was not always necessary to divert vehicles with a high ground clearance.

Dedicated diversion routes should be established in areas where there is a risk of flooding and these should aim to separate light vehicles from heavy vehicles.

It is recommended that portable signs be manufactured that state “flood route” and have an adjustable arrow. These signs should be readily accessible at the maintaining organisation’s depot.

8 Safety issues

By their nature, culverts are located beneath the highway and, in order to inspect or maintain the culverts and the headwall structures, access is often gained by scrambling down the embankment. Access to headwall structures is, in many instances, difficult and hazardous, often with little or no provision made to prevent operatives falling into the watercourse. Sometimes the structure may be beyond the boundary fence.

It is recommended that access should be by means of constructed steps similar to those provided for access to electrical installations located at the highway boundary.

The removal of debris from the screens fixed to the culvert headwalls can be particularly dangerous when the watercourse is in spate or the screen has become obstructed, causing water levels to rise.

Galvanised steel handrails or balustrades should be provided above the headwall structure. These should be firmly fixed in order to support the weight of operatives clearing debris from the screen. Where headwalls are of brick construction, the handrail should be fixed to concrete footings.

In order to minimise the risk of operatives falling into the swollen waters, anchor points for the attachment of safety harness should be fixed into the headwall or suitable concrete blocks cast adjacent to the structure.

Vertical screens located on the upstream headwall make debris difficult and hazardous to remove as the water pressure forces the debris into the screen. This pressure can be sufficient to cause the screen to buckle into the culvert. Similarly vertical screens on the downstream headwall trap debris within the culvert. Clearing this material can require operatives to enter the watercourse below the screen thereby placing themselves at considerable risk. The design of screens should be such that entry into the watercourse is not necessary for cleaning work.
Vertical screens should never be fitted to culvert headwalls. Where vertical screens are fitted to Highways Agency structures it is recommended that these are replaced by ones inclined no steeper than 60º to the horizontal as a matter of urgency.

Ideally, the screen should be constructed with a flat section at the top on to which debris can be raked to facilitate removal. At the downstream headwall, and at outfall headwalls, if there is a difference in level between the culvert invert and the apron; consideration should be given to providing a 150mm gap between the underside of the screen and the apron. This will minimise the risk of debris that has penetrated the upstream screen becoming trapped on the downstream screen.

Where a culvert is provided with a screen at the downstream headwall, there must always be a screen installed at the upstream headwall.

9 Conclusion and recommendations

The flooding that occurred in the Autumn 2000 resulted from unusually severe weather conditions. The impact of these conditions on the highway drainage systems was compounded by:

- routine maintenance of drainage systems that appears to take little account of predicted poor weather conditions,
- the inadequacies of the recorded data on highway drainage systems.

The following recommendations on maintenance and operations contained in this report, if taken up, should reduce the frequency of flooding incidents and the risk to operatives of undertaking emergency works to the drainage system. The impact on road users should also be reduced.

- Preventative maintenance based on forecasts of adverse weather.
- Establishment of a highway drainage record database together with a programme of data collection that should also include data on drainage problems and flooding incidents.
- The database should record adjacent riparian ownership and access contact details.
- Dedicated diversion routes should be established in areas where there is a risk of flooding.
- Manufacture of portable signs that state “flood route” and have an adjustable arrow.
- Access to headwall structures is improved by the provision of access steps.
- Handrails and balustrades to be installed at headwalls for the safety of operatives.
- Harness anchor points are provided for the safety of operatives.
- All vertical screens at headwalls should be removed and replaced by ones inclined by no more than 60º the horizontal.