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# Asset performance tools – asset inspection guidance

Report – SC110008/R2

Flood and Coastal Erosion Risk Management Research and Development Programme

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We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

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T: 03708 506506

Email: enquiries@environment-agency.gov.uk

**Author(s):**
Chris Bown, John Chatterton, Alexandra Purcell

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**Research Contractor:**
Black & Veatch
Treenwood House, Rowden Lane, Bradford on Avon, Wilts, BA15 12AU
Tel: 01225 868868

**Environment Agency's Project Manager:**
Christabel Mitchell, Evidence Directorate

**Theme Manager:**
Owen Tarrant, Sustainable Asset Management Theme Manager

**Collaborator(s):**
John Chatterton – John Chatterton Associates

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- **Setting the agenda**, by providing the evidence for decisions;
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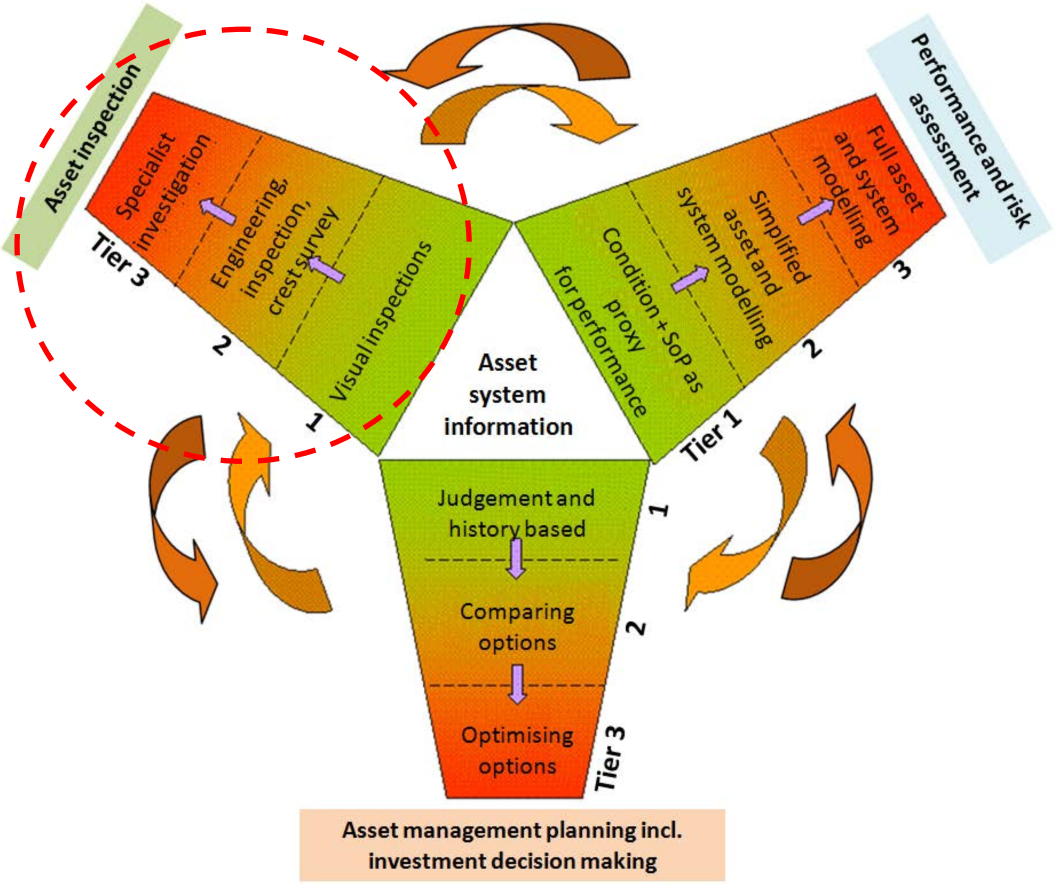
Miranda Kavanagh

**Director of Evidence**

# Executive summary

This guidance document describes an asset inspection process based on research that is part of an overall cycle of risk and performance based asset management being developed under the Asset Performance Tools (APT) programme (see ‘propeller’ figure below). The recommended asset management cycle integrates key assessment activities and directs the user to the appropriate level of activity according to risk through a process of tiering.

The figure below illustrates the key elements of the integrated tiered framework with links between the activities (as ‘arms’ of a propeller) and tiers. Each link is underpinned by data and information. Advancement up the tiers is made in response to increasing levels of assessed risk.



**‘Propeller’ illustrating the integrated, tiered framework showing the asset inspection activities**

Application of this process will ensure efficient management of assets through proactive planning and application of a risk-based approach rather than relying on a reaction to a failing asset, or one falling below its target condition. A target condition should be set for each asset taking into account risks and consequences.

The research shows that inspections can then be targeted to need and interventions can be timed to pre-empt expensive and often distressing asset failure, rather than dictated by routine alone. Inspections are driven by a considered balance of investment and flood risk, offering the greatest impact on risk reduction at least cost.

The processes used within the Environment Agency that are referred to in this guidance are established and tested best practice, and are used to illustrate the principle of the recommended approach. However, these processes should not necessarily be adopted by other organisations. It is the principle of the approach that is important.

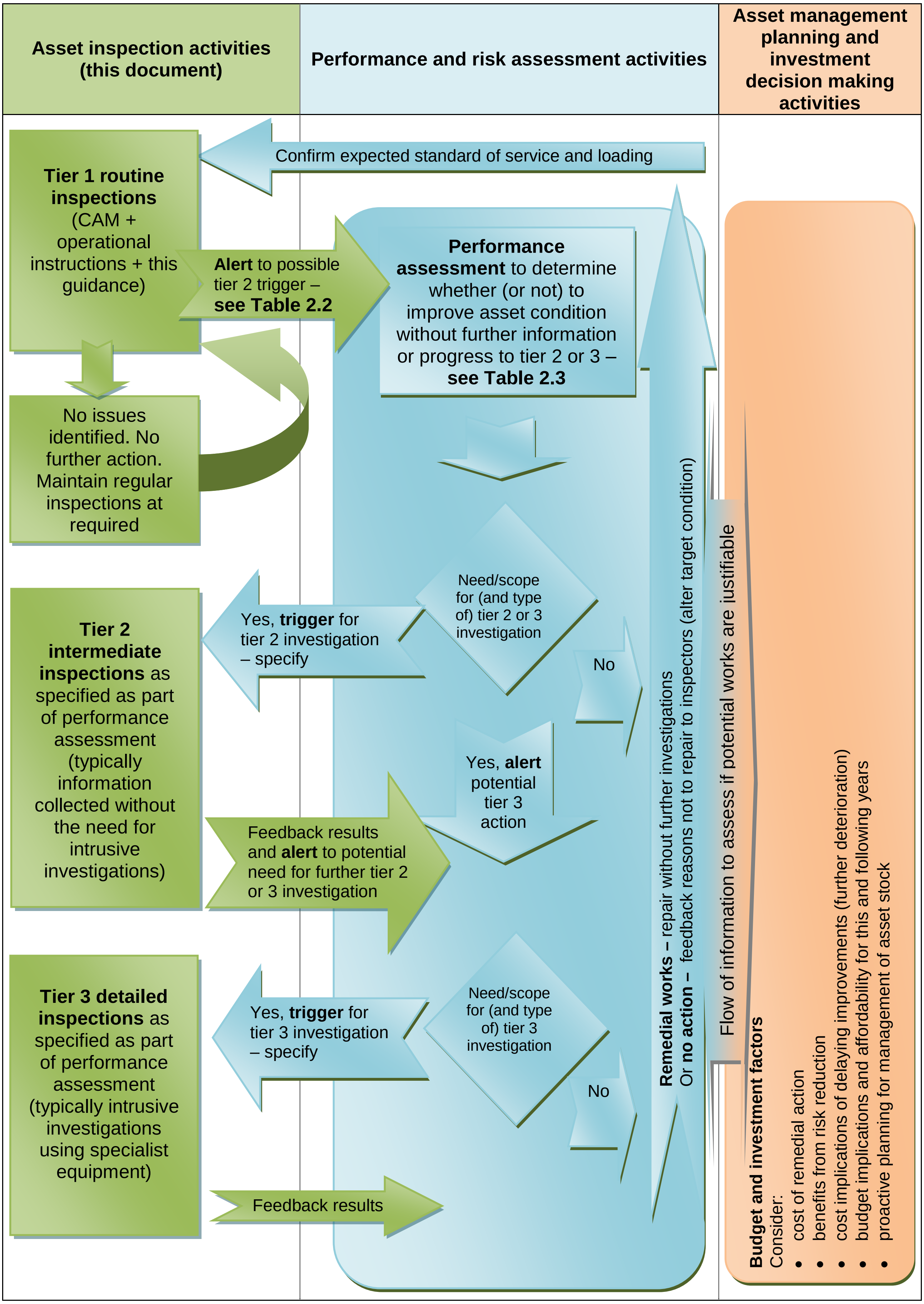
This document should be read in conjunction with further guidance on performance and risk assessments and asset management planning and investment decision making as these become available through the APT programme. Each Flood and Coastal Risk Management (FCRM) organisation may also have operational instructions for asset inspections and other investigations which should be referred to for more details.

### Targeting inspections

A tier 1 inspection is the default level, routine inspection. Procedures for routine asset inspections are well embedded in the Environment Agency using the Condition Assessment Manual (CAM) and in other organisations which use similar processes.

Tier 2 and 3 inspections and investigations are activities which seek more detailed information than is routinely collected as tier 1 inspections. Tier 2 inspections are non-intrusive investigations carried out by an appropriate expert, while tier 3 inspections are intrusive investigations into the make-up of the asset. Both require a notable investment (tier 2 less so than tier 3) and need to be justified in terms of efficiency gains, performance and risk. Thus, each can only be triggered after proper consideration in the performance and risk ‘arm’ following an alert to do so.

The flow chart below shows these basic principles and the integrated link to performance and risk ‘arm’ related activities.



**Flow chart showing general process of tiered inspections and assessments**

# Acknowledgements

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- Environment Agency – Tracy Hodsman, Dave Denness, Dave Trubshaw, Steve Haywood, Matt Goodall, Edward Morris, Lindsay Hensman, Marcus van Someren, Sam Gawad, John Rowlands, Melvin Wood, Gary Jones-Wright, Kevin Thomas, Russell Stead, Richard Cook, and Paul Wisse
- Local authorities and representatives – Andy Bradbury, Andy Ratcliffe, Mervyn Pettifor, Paul Wisse and Lee Whittle (Sefton Council)
- Somerset Drainage Boards Consortium – Iain Sturdy

# Contents

# 1 Introduction

This guidance document is intended to improve the effectiveness of inspection methods for flood and coastal risk management assets. It incorporates the findings of a review of current best practice and highlights recommendations for improvement.

Key recommendations are highlighted in a purple box as shown here. The 14 recommendations are listed together in Appendix 31.

The guidance describes an asset inspection process which is part of an overall cycle of risk and performance based asset management which is being developed under the Asset Performance Tools (APT) programme (see Figure 1.1). This programme is translating previous studies into practical guidance that can be taken up and used by all Flood and Coastal Risk Management (FCRM) authorities. A further document (Environment Agency 2014) sets out the recommendations for an integrated tiered framework for effective asset management. It integrates key activities in the assessment cycle and directs the user to the appropriate level of activity according to assessed risk through a process of tiering.

- 'Integrated' refers to the close links between 'inspections', 'performance and risk assessments' and 'planning and investment decision making' activities.
- 'Tiered' refers to the progression from simple (tier 1) to more detailed levels (tiers 2 and 3) of inspection or analysis.

Figure 1.1 illustrates the key elements of the integrated tiered framework with linked activities – as the 'arms' of a propeller – and tiers. Each link is underpinned by data and information. Advancement up the tiers is made in response to the assessed risk.

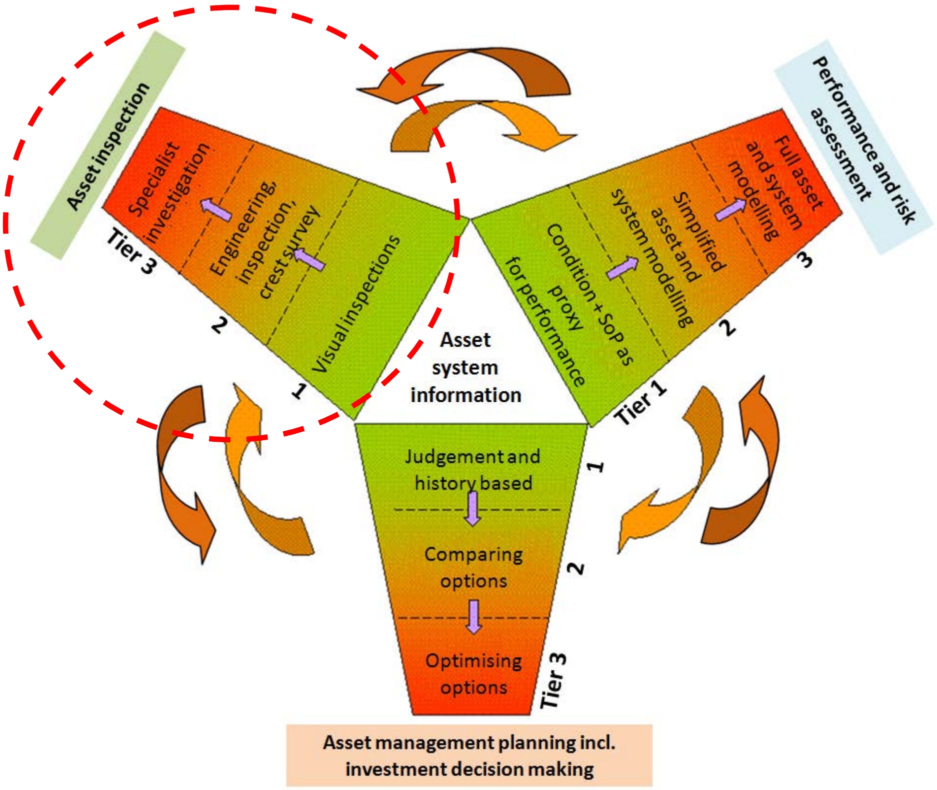

**Figure 1.1 The 'propeller' illustrating the integrated, tiered framework and asset inspection activities**

This guidance recommends the triggers for moving from routine visual inspections (tier 1) to more advanced inspections at an intermediate (tier 2) or higher (tier 3) level. It also describes the need to integrate ‘asset inspection’ with assessments carried out into ‘performance and risk’ and ‘planning and investment decision making’, with an efficient flow of information between all inspections and assessments as intended by the APT programme.

This process will ensure an efficient management of assets through proactive planning and application of processes in a risk based approach, rather than relying on a reaction to a failing asset, or one falling below its target condition.[1]. Inspections should be targeted to need and interventions timed to pre-empt expensive and often distressing asset failure. Although the planning element is introduced in this guidance, its focus is on the inspection elements that will inform planning.

Some processes used by the Environment Agency are used in this guidance to illustrate the principle of the recommended approach as they are established and tested best practice. However, these processes should not necessarily be adopted by other organisations. It is the principle of the approach that is important.

Many of the principles to incorporate performance considerations in the management of flood defence assets outlined in this guidance are already being applied by those involved in FCRM asset management.

This document provides useful guidance and forms, which will help to improve the efficiency of the visual inspection processes. However, FCRM organisations should refer to their own operational instructions for asset inspections and other investigations for more details.

Appendix 1 provides further background as to how the condition and performance of an asset are related and the importance of good quality data, with key recommendations to improve both.

This document does not include guidance for the more specific requirements of surface water or Mechanical, Electrical, Instrumentation, Control and Automation (MEICA) assets.

## 1.1 Report structure

To align with the current setup of greater part of the industry, this document is structured in line with the groupings of asset types in the Environment Agency’s Asset Information Management System (AIMS) database, which is available to all FCRM management authorities and holds the greater part of the UK’s FCRM data.

The main body of the report outlines the process. Details of the process are provided as appendices.

- **Chapter 2**: general principles that apply to all asset types to incorporate performance and risk considerations into asset inspection, including transitions between asset types
- **Chapter 3 to 7**: specific asset inspection principles for the five AIMS asset groupings shown in Table 1.1. The chapters cover the basic routine inspection carried out as a tier 1 activity and direct the reader to the detail for tiers 2 and 3.
- **Appendix 2**: further detail regarding tier 1 inspections

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[1] A target condition should be set for each asset taking into account risks and consequences.

- **Appendix 5 to Appendix 12**: engineering integrity illustrated guidance showing features that give rise to further consideration
- **Appendix 14 to Appendix 25**: guidance on tier 2 inspections, typically non-intrusive inspections by an appropriate expert
- **Appendix 26 to Appendix 29**: guidance on tier 3 inspections, typically intrusive inspections led by an appropriate expert (for example, ground investigation).

**Table 1.1 AIMS grouping of asset types and link to guidance**

| Asset group | Asset type | Asset sub-type | Asset group, type and sub-type guidance |
|---|---|---|---|
| **A Channels and culverts** | Channel | Open channel | Chapter 3 |
| | | Simple culvert | |
| | | Complex culvert | |
| **B Linear defences** | Defence | Embankment | Chapter 4 |
| | | Wall | |
| | | Demountable | |
| | | High ground | |
| | | Quay | |
| | | Flood gate | |
| | | Bridge abutment | |
| **C Coastal defences** | Defence | Beach | Chapter 5 |
| | | Dunes | |
| | | Barrier beach | |
| | | Promenade | |
| | | Cliff | |
| **D Beach structure** | Beach structure | Groyne | Chapter 6 and contents of Chapter 5 |
| | | Breakwater | |
| **E Structures and point assets** | Structure | Screen | Chapter 7 |
| | | In-channel stoplogs | |
| | | Control gate | |
| | | Outfall | |
| | | Weir | |
| | | Spillway | |
| | | Stilling basin | |
| | | Hydrobrake | |
| | | Jetty | |

## 1.2 Relationship to other ‘arms’ of the ‘propeller’

The decision to move to more detailed (higher tier) inspections takes into account the particular circumstances, expected performance and the risks. This decision is made in the performance and risk assessment ‘arm’ (Figure 1.1) and takes into account cost effectiveness tests carried out in the asset management planning including the investment decision making ‘arm’. An outline content and a flow of information into and out of the asset inspection ‘arm’ is provided in this guidance, but the detail of the steps within the other ‘arms’ to make these decisions is not.

Throughout this document, tables, figures and flow charts are colour coded as follows:

**Asset inspection activities**
**– this guidance**

Performance and risk assessment activities
– in development

Asset management planning including investment decision making activities
– in development

# 2 Inspection of all asset types

## 2.1 Understanding the role of the asset

For effective management of assets, an appropriate level of understanding of the following is required:

- The **consequences of failure** of the asset. Typically this will relate to the floodable area protected by a group of assets and the receptors (lives, property and land) which might be affected. This information will generally be obtained from flood mapping outputs and asset management planning tools such as System Asset Management Plans (SAMPs) used by the Environment Agency to determine the investment justified by the value of receptors protected by flood defence systems, or similar tools and systems employed by other FCRM authorities.
- The **expectations of performance** of the asset in fulfilling its role in a flood or coastal defence system. For example, what is the expected annual probability of an asset overtopping and whether that is different from the 'as built' design standard?
- What the **actual loading** might be on an asset. For example, how does the crest level compare with extreme water levels and wave action?

Without this understanding from a performance and risk assessment perspective, it would be difficult to target resources for inspections on those assets where risks and consequences of failure are higher. This applies to all tiers of inspection and is discussed in more detail in the following sections.

## 2.2 Targeting inspections through tiering

A tier 1 inspection is the default level, routine inspection. Procedures for routine asset inspections are well embedded in the Environment Agency using the Condition Assessment Manual (CAM) (Environment Agency 2012) and other organisations which use similar processes. These processes are discussed in the following sections, together with recommendations to ensure that risk and performance issues are always taken into account.

Tier 2 and 3 inspections and investigations are activities which seek more detailed information than is routinely collected in tier 1 inspections. Tier 2 inspections are non-intrusive investigations carried out by an appropriate expert. Tier 3 involves intrusive investigations into the fabric of the asset. Both require notable investment (tier 2 less so than tier 3) and need to be justified in terms of efficiency gains, performance and risk. Thus, each can only be triggered after proper consideration in the performance and risk 'arm' following an alert to do so.[2]

The flow chart in Figure 2.1 shows these basic principles and the integrated link to performance and risk 'arm' related activities.

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[2] In this guidance, the term 'alert' is used to indicate that an alert will be raised from an inspection or other source that there is a concern. A decision is then made by an asset manager on whether this should trigger further inspections or investigations.

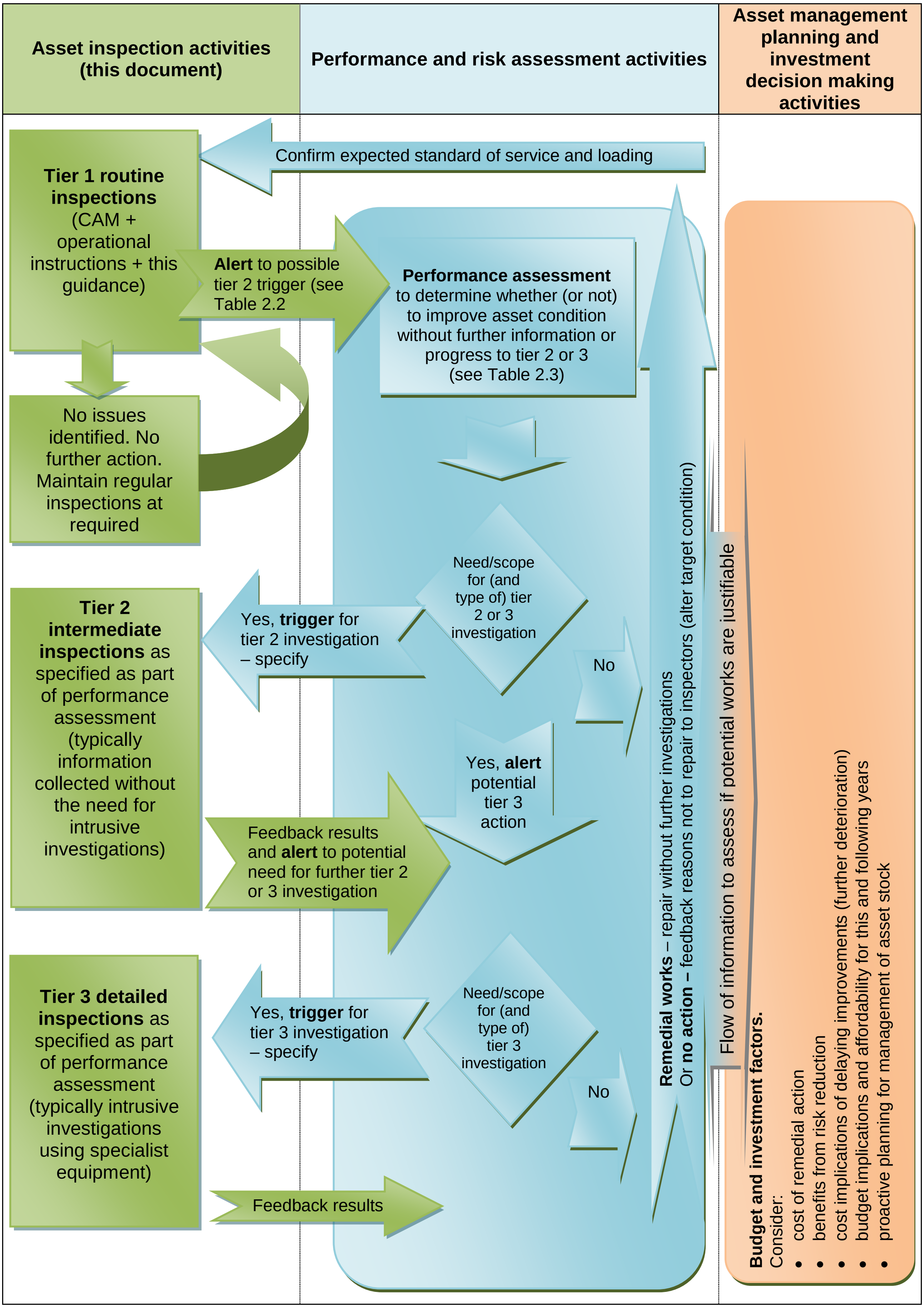

**Figure 2.1** Flow chart showing general process of tiered inspections and assessments

The following principles are embedded in the flow chart.

- There is a distinction between roles:
  - Asset inspection – those arranging and reporting the results of inspections or more detailed assessments, that is, gathering physical data
  - Performance and risk assessment – those making decisions as a result of the inspection findings and alerts, that is, desk-based analysis of inspection data and taking account of other wider considerations (often driven by policy and flood risk management plans)

  The roles are distinct, but could be carried out by the same member/s of staff depending on the needs of the organisation.

- The expected standard of protection (SoP) and loading for all assets should be well known by all. This will improve the efficiency of the inspection processes; for example, the inspection frequency can be reduced when risks are low and the need for further investigations can be given a lower priority.
- There will be a range of observations which could raise an alert. Each may lead to a trigger for more detailed investigations if assessed as required and justifiable in the performance and risk 'arm'**.**

**Recommendation 1.** Undertake further analysis of and linkages to 'performance and risk assessment' activities and those within 'asset management and investment decision making' (outside the scope of this project).

**Recommendation 2.** Recommendations and comments from inspections, particularly where highlighting an alert to the possible need for a tier 2 or 3 inspection, should be recorded in the asset database or accompanying documents for future reference and action.

Outline guidance on important health and safety considerations for inspection is given in Appendix 30. This guidance is provided to highlight typical issues to consider; it does not replace any other obligations or procedures in place.

## 2.3 Tier 1 routine inspections

### 2.3.1 Frequency of inspection

The frequency of inspection should be risk based, taking account of factors such as the nature and significance of the flood defence and particularly the consequences should the asset fail structurally, or fail to perform as expected.

The programme of asset inspections will need to be regularly reviewed and updated in response to changing circumstances such as changes in asset condition or performance expectations. These changes alter the level of risk of the asset not performing as required and therefore the required frequency of inspection (the greater the risk/consequence, the greater the inspection frequency).

Each organisation will have its own guidelines for inspection frequency, suitable for the purpose. For example, Highways Authority assets generally have a significantly different cost/risk balance than that applied to traditional flood risk management assets; this will influence the frequency of inspection. The process used by the Environment

Agency is a good, established example of a sensible risk-based approach and is set out in its Operational Instruction 50_13. The process is summarised in Appendix 3 for guidance for those organisations planning to develop a revised inspection routine. Separate guidance on inspection frequency for culverts is discussed in Chapter 3.

### 2.3.2 Assessing condition

Each organisation has its own approach to assessing asset condition. However, increasing numbers are adopting the Environment Agency's 1 to 5 scoring system (1 for very good to 5 for very poor) as an example of good practice with well-established and tested methods as presented in its Condition Assessment Manual (Environment Agency 2012).[3] Figure 2.2 shows an example of its use. This good practice is built on the documents and processes indicated in Appendix 2, which can be made available to other organisations to follow or model.

**Figure 2.2 An Environment Agency T98 accredited inspector using the Condition Assessment Manual**

Notes: T98 is a national accreditation to undertake visual flood defence asset inspections. The accreditation was developed by the Environment Agency and the Flood Hazard Research Centre (FHRC) at Middlesex University.

The 1 to 5 score for condition grade is well used within UK FCRM organisations. The overall condition grade reflects the weighted average condition grade of the various elements making up the asset (see section 2.3.3 Weighting of elements).

**Recommendation 3.** The Environment Agency's Condition Assessment Manual or equivalent should continue to form the basis of routine tier 1 inspections, but should be adapted by other recommendations in this document.

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[3] There are other examples of good practice in other organisations (for example, local authorities, Internal Drainage Boards and the Highways Agency) both in this country and overseas. However, none offered sufficient benefit over the well-established and widely adopted existing Environment Agency approach to justify an overhaul of all the associated activities linked to the 1 to 5 scoring system used to assess most flood defence assets in this country.

### 2.3.3 Weighting of elements

Weightings can be used to indicate the importance of each element to the overall integrity and performance of the asset in undertaking its primary role in flood and coastal risk management.

Any weighted system involving a number of elements is complex. The Environment Agency approach is considered a good model and is a clearly directed one (see Appendix 2). The weightings used in this model range from 1 (elements that do not have a flood or coastal risk reduction function) to 9 (critical elements whose failure would lead to the immediate or imminent failure of the whole asset or its failure to perform its intended function). But like all complex models, the Environment Agency model relies on a high degree of understanding and careful application by the inspector. Feedback obtained during production of this guidance indicates that it is not used reliably when faced with the day-to-day reality of inspections.

**Recommendation 4.** An overall condition grade should be assessed based on the grading of the individual elements. This can be done either using the weighting formula described in Appendix 2 or by judgement taking into account the importance of each element.

**Recommendation 5.** If an element, which is critical (by judgement) to the performance of the asset in its intended role, falls below target, the condition grade should be amended to show that the asset as a whole is below target grade.

Within the Environment Agency, the target condition for most assets is set at condition grade 3 and in some specific cases a target grade of 2. Care is advised in the way scores are rounded from an inspection. A score of 3.49 is actually rounded to a score of 3, which would show the asset as meeting its target, whereas it is actually below target (that is, in less than satisfactory condition) and should flag an alert.

**Recommendation 6.** Create an alert for any score above 3.0, which may prompt further investigations or to bring the date of the next inspection forward.

### 2.3.4 Assessment of data quality

Good quality data are the foundation of effective risk-based decision making as to how assets should be managed.

Poor quality data directly impact on the relevance of actions and the efficiency of decision making, and lead to wasting of resources and time. They can cast doubts and lead decision makers to turn away from established processes and make decisions based on facts and evidence that are less well-established and influenced by beliefs.

Tier 1 inspections play an especially important role as they bring an asset to the attention of others and push it out of the routine round of inspections for further assessment via an alert. Until then there is no potential for remedial action to be considered beyond routine maintenance.

Appendix 4 presents a recommended approach to the use of data quality indicators for an assigned condition grade from an inspection, defence crest levels and the standard of protection assigned to the asset in an assessment of performance and risk.

### 2.3.5 Treatment of elements not inspected

The quality of the results from any inspection is likely to be compromised by a failure to inspect one or more of asset’s elements. The risk that there may be an underlying unidentified problem increases with the time that has elapsed since the last satisfactory inspection. It is therefore important that the reason for the non-inspection is recorded as a comment, so that appropriate action can be arranged without the need for a further visit to the asset.

**Recommendation 7.** Adoption of the steps in Appendix 2 is recommended for those carrying out inspections and for the way that the inspection results should be considered by asset managers.

Alerts arise from either reported poor data quality as a result of a failure to complete the inspection, or a condition grade below the required condition, particularly one resulting from a failure to inspect on more than one occasion.

Appendix 15 includes recommendations on a follow-up visit to overcome an element not inspected (ENI) and subsequent data quality issues.

### 2.3.6 How to deal with transition elements

Transitions between different asset types, sub-types and elements have exhibited particular problems in extreme events. They should therefore be considered carefully in asset inspections, with alerts raised for observed deficiencies.

The vulnerability of transitions usually results from either or both of the following.

- The transition between different construction types may not be smooth. This will often give rise to a concentration of erosive turbulent flow, either in high fluvial flows or through wave action at the coast.
- At transitions there are breaks in a continuous line of an asset and there is frequently a reduction in the strength of the materials, leading to ‘picking out’ of the weaker material. An obvious example is the transition from a hard to a soft revetment as the joint between them is often vulnerable to damage.

Since there are a very large number of different types of transitions between asset types and materials, guidance is given in this chapter to cover all asset types and is not repeated in the chapters on specific asset groupings.

Investigations of FCRM authorities during the production of this guidance revealed that the reporting of condition grade typically used CAM procedures or similar. This often did not provide an opportunity to highlight issues at transitions, particularly where the transition was at the end of a long length of linear asset which itself might be in good condition. The approach described in Appendix 2 is recommended in tier 1 inspections.

### 2.3.7 Engineering integrity issues

A range of engineering issues could threaten the integrity of an asset, that is, its ability to perform. It is often difficult to reliably alert to integrity issues using regular CAM style inspections. This section should be read in conjunction with section 2.3.2.

Tier 1 inspectors are unlikely to be suitably qualified to assess an engineering integrity issue, though they should be able to alert others to a possible issue as a recommendation in their inspection report. Appendix 13 provides guidance on consistent reporting of these alerts.

In general, the more detailed inspections to determine whether a particular feature is considered to be of concern are included as tier 2 activities following an inspection alert and use appropriately qualified staff.

**Recommendation 8.** Inspectors should provide an alert that there may be a possible engineering integrity issue as a recommendation in their inspection report.

The alert should be made whether or not the feature influences the condition grade, that is, some features may be threatening but not yet affecting the particular asset. For example, deterioration of stonework protecting a channel side may not fail the overall target condition grade but early repair might prevent longer term failure necessitating more substantial remediation works.

Table 2.1 lists the engineering integrity issues that may pose risks to assets and directs the reader to further detail by either asset type or engineering integrity issue. Each appendix indicated on Table 2.1 includes guidance on how engineering integrity issues could be reported from tier 1 routine inspections and any more detailed inspections that may be required.

**Recommendation 9.** Incorporate engineering integrity issues into CAM or equivalent inspection guide to ensure they are considered regularly and efficiently.

### 2.3.8 Alert to consider whether there is a need to trigger more detailed investigations

The flow chart in Figure 2.1 shows the general approach to using inspection alerts in the ‘inspection arm’ to decide whether to trigger more detailed investigations and, if so, what form these could take.

Raising alerts is a crucial part of the process outlined in this guidance. Table 2.2 describes these alerts in more detail and starts to introduce consistency into their reporting. The table has been written to cover all asset types, but for some asset types, a particular alert may be inappropriate or will be rarely applicable. However, the table can still be treated as a checklist for all types of asset.

Examples of an asset defect reporting form are provided as a tab in the embedded Microsoft® Excel workbook found in Appendix 13. This form can be used as a record of the steps leading to a decision on the recommended action following an alert.

### 2.3.9 Trigger to move to more detailed investigations

Table 2.3 lists the factors, including those from activities other than tier 1 inspections, that will need to be taken into account as part of the performance and planning ‘arm’ to decide whether:

- the asset should be improved without the need for further investigations
- the alert does not need to be considered further
- further investigations are required (tier 2 or 3)

The type of asset and the particular circumstances will determine the importance that will need to be given to each of the factors. The assessment is discussed further in section 2.3.11.

A form for use in reporting is included as Appendix 13.

### 2.3.10 Reporting of tier 1 inspections

It is essential to ensure that reporting of tier 1 inspections (including recommendations from these) is applied consistently to demonstrate expenditure of public money on a consistent and justifiable basis, that is, risk-based decisions to clearly identify asset management priorities. Appropriate use of technology will support this. This is a requirement regardless of the organisation in control of the asset.

How to establish a tier 1 condition grade is outlined in section 2.3.2, while section 2.3.7 explains how the condition inspection can be extended to include observations of potential engineering integrity issues. In addition to these and on-site observation comments, Table 2.4 lists the additional data types that should be recorded. The AIMS database used by the Environment Agency is available to other FCRM authorities to use as a good model or tool available to all to maintain up-to-date records.

**Recommendation 10.** Further progress is recommended towards the use of hand-held devices for recording inspection observations. Smartphones and personal digital assistants (PDAs) are powerful tools which, with their use of global positioning systems (GPS) and storage of photographs, could be easily developed using specialist applications for inspections.

### Table 2.1 Engineering integrity issues which could pose risks to assets

| Engineering integrity | Brief description of problem | Typical signs | Asset types potentially affected (chapter reference) |
|---|---|---|---|
| **Slope stability (Appendix 5)** | Gravitational and seepage forces cause instability of slopes.<br>Slope failure | Longitudinal cracks prior to movement occurring<br>Slumping of material creating a step in a slope<br>Bulging of material at the base of a slope | Linear defences (4) embankments, walls, high ground, bridge abutments;<br>Coastal defences (5) beaches, dunes, cliffs<br>Structures and point assets (7) outfalls |
| **Instability of structure (Appendix 6)** | Destabilisation by foundation failure or unexpected imposed loads. May be geotechnical issues for example, failure of a slope, but may be more obvious. | Rotation of the structure<br>Sliding of the structure<br>Distortion of the structure | Linear defences (4) walls, quays, bridge abutments<br>Structures and point assets (7) Screens, control gates, outfalls, weirs, jetties |
| **Leakage and piping (Appendix 7)** | Leakage through earthworks can destabilise a defence, particularly if material is eroded by the flow through the soils | Standing water behind defences which may lead to changes in vegetation<br>Signs of leakage on the landward face of a flood defence or structure<br>Cloudy water 'springs' or deposits of material on the landward side of a defence | Linear defences (4) embankments, walls, high ground, bridge abutment<br>Coastal defences (5) beaches, dunes, promenade |
| **Backfill washout (Appendix 8)** | Many structures rely on backfill for stability. If backfill is washed out, it could precipitate damage or failure. | Visible signs of backfill loss<br>Structural deformation or damage as a result of loss of backfill<br>Holes or gaps through which backfill is likely to be lost | Linear defences (4) walls, high ground, quay, bridge abutments<br>Coastal defences (5) promenade, cliff<br>Structures and point assets(7) screens, control gates, outfalls, jetties |
| **Crest height degradation (Appendix 9)** | The crest level of flood defences may be lowered, leading to a reduction in the standard of service provided – may also affect allocated condition grade. | Rutting (machinery)<br>Animal movements<br>Subsidence<br>Erosion (water flows, waves or traffic) | Linear defences (4) embankments, walls, high ground, quay, floodgate, bridge abutment<br>Coastal defences (5) beach, dune, barrier beach, promenade<br>Beach structures (6) breakwaters<br>Structures and point assets (7) outfalls, weirs, spillways, jetties |
| **Animal burrowing (Appendix 10)** | Animal burrows can weaken flood defences, particularly when these allow leakage | Holes in soil surfaces, ranging in size from small mammals to large fox or badger burrows<br>Signs of excavated soil | Linear defences (4) embankments, or high ground<br>Coastal defences (5) dunes or cliffs<br>Structures and point assets (7) spillways |
| **Cracking or fissuring (Appendix 11)** | Cracks and fissures may lead to leakage and deterioration through loss of fine materials | Cracks and fissures in soil structures, often more obviously in dry conditions | Linear defences (4) embankments, high ground |
| **Undermining or scour (Appendix 12)** | Undermining or scour can destabilise an asset due to loss of support at its base | Evidence of erosion at the toe of a structure, typically from flows or wave action<br>In severe cases this may lead to a noticeable instability in a structure | Linear defences (4) embankments, walls, high ground, quays, floodgates, bridge abutments<br>Coastal defences (5) dunes, barrier beaches, promenade, cliffs<br>Beach structures (6) breakwaters<br>Structures and point assets (7) screen, control gate, outfall, weir, spillway, stilling basin, jetty |

### Table 2.2 Alerts which may trigger further inspections in tier 2 or 3

| Alert | Comment | Useful links |
|---|---|---|
| **Asset below target condition** | Important output from the tier 1 inspection – allows consideration of individual elements to determine the effects on the overall performance of an asset, particularly where this is a critical element (for example, the tidal flap on an outfall). | Appendix 13 |
| **Element or asset not able to be inspected** | Typical example will be a requirement for a CCTV inspection of a culvert where it has only been possible to inspect the headwall at the inlet and outlet, and to walkover the route to look for deformities. | Appendix 13<br>Section 2.3.5 |
| **Possible engineering integrity issues** | Inspectors should be trained to be able to raise alerts to possible engineering integrity issues, while accepting that more detailed assessments using qualified staff may be required in tier 2 investigations to determine whether the concerns are well founded | Appendix 13<br>Section 2.3.7<br>Table 2.1 and Appendix 5 to Appendix 12 |
| **Channel or culvert conveyance restrictions or issues** | This is not easy to judge by a simple inspection, even using staff with expertise in hydraulic engineering. Ideally there would be clear guidance to inspectors on the degree of obstruction by vegetation, siltation or other materials which have entered the watercourse. In the absence of this, inspectors can alert to a possible issue, which can be considered in more detail, using tier 2 or 3 investigations if justified. | Appendix 13<br>Covered in more detail in Chapter 3 for channel and culvert assets. |
| **Critical asset in high consequence system** | Some assets have very high consequences to receptors if they fail during a flood or storm event. In some cases this may be a trigger to move to more detailed investigations to determine the risks rather than relying visual inspections alone. This should not be applied as a requirement for all assets in high consequence systems, but it is likely to be applied where there are other concerns about the asset's state. | Appendix 13 |
| **Concerns from operational staff** | Sometimes operational staff will have concerns about the condition of some assets or threats to them. Although outside the normal inspection programme, the alert should be treated as an output from an inspection. | Appendix 13 |
| **Legal, national, regional or local drivers** | Sometimes more information may be needed on assets to answer particular concerns or to obtain a better understanding of their status (for example, the drive to undertake topographic surveys of defence crest levels). | Appendix 13 |
| **Expressed public and stakeholder concerns** | Asset managers regularly receive communications expressing concerns about the state of FCRM assets. Sometimes, depending on the nature and scale of the concerns, there may be a requirement to collect more detailed information under tier 2 or 3 to satisfy them. | Appendix 13 |
| **Recent flood or storm events** | Recent flood or storm events may prompt visual inspections outside the normal programme or more detailed investigations under tier 2 or 3 – especially if the event has had unexpected effects on receptors or it may have damaged assets. Typical examples might be:<br>• unexpected overtopping of defences in an event – are there low spots in the defences, is a channel or culvert partially blocked?<br>• a sequence of flood events which may lead to questioning of the standard of protection afforded.<br>• a storm event which has lowered a beach level or severely eroded a dune protection.<br>• velocities or wave action which might have led to undercutting of an asset's foundations | Appendix 13 |
| **Proactive planning** | The most efficient management of assets will occur when there is proactive planning of investment in assets rather than reacting to a failed or failing asset. This may, for example, involve determining the remaining life of assets. There may be a need to obtain more information on assets in a tier 2 or tier 3 investigations. This is more likely to be applied to assets for which there are high consequences should they fail. | Appendix 13 |

## Table 2.3 Factors which may influence the decision on whether to trigger tier 2 or 3 inspections in a performance and risk assessment

| Performance factor | Considerations required in a performance assessment |
|---|---|
| **Assessed condition grade of the asset and elements** | In a risk assessment, the condition grade scored will influence the next steps. A very poor (5) score will give rise to more concerns than a score of 3.6, rounded to 4. |
| **Materials and adequacy of construction** | In most cases the condition grade from the visual inspection will not be influenced by the materials making up the asset. It will be important to understand the design and construction of the asset as it will affect its integrity and the probability of failure of the asset. Records may already exist giving these details or it may be necessary to undertake further investigations (tier 2 or 3) if this is considered necessary to make a decision on how to respond to any concerns. For example, a clay embankment with a sheet pile cutoff wall will have a different risk profile to one made up of a light sandy material or one in which the construction materials are not known. |
| **Consequences of failure including health and safety (including risks to the public)** | This is an important consideration in a risk-based approach to asset management. Section 2.1 explains the importance of understanding the consequences should an asset fail. This must include health and safety considerations, including risk to life. Generally an alert to a trigger for more detailed investigations will always be acted on if there are high consequences should the asset fail. Where the consequences of failure are low or even medium, a decision may be taken that further investigations should not be prioritised or cannot be justified, but this will depend on other factors listed in this table. |
| **Consequences of delayed improvements** | There should be consideration of the likelihood of an asset deteriorating further or problem areas becoming more extensive and whether this will lead to more expensive remedial work in the future. This applies as much to the urgency of any repair work as it does to the collection of further information in tier 2 or 3 investigations. |
| **Expected and actual standard of protection and freeboard** | This applies particularly to linear defences of all types. It will be necessary to consider the loading that might be applied and its frequency (water levels and wave heights). A defence that has a freeboard of 1 m in extreme events may elicit a very different response to one that is likely to overtop during the same events, particularly if the construction materials are of suspect quality and/or defence failure would have high consequences. |
| **Reliability of data used to assess risks and standard of protection Information missing to complete an assessment or for proactive asset planning** | Further investigations, particularly at tier 2, may be required if the data used to assess risks and the standard of protection cannot be relied on. This includes cases where the data have been collected from high level studies, particularly when their collection was for a different purpose. For example, hydraulic modelling may be required to determine the standard of protection afforded by a flood defence, in which case the collection of data under tier 2 inspections may require the collection of better channel cross-section or defence crest level data. |
| **Other drivers, legal obligations, public concerns, recent events** | There may be other influences of this type which could prompt the need for tier 2 or tier 3 investigations and these are detailed in Table 2.2. These will need to be considered when deciding how to proceed. It will be important to demonstrate that decisions are being taken with an appropriate level of understanding, particularly when demands for increased investment are being rejected. |

### Table 2.4 Types of data required to document the decision to undertake more detailed inspections or investigations (tier 2 or 3)

| Data type | Comment on need |
|---|---|
| **Recommendations** | It is essential that each inspection concludes with recommendations. These may range from a recommendation to carry out the next inspection as planned, an alert to trigger further inspections or investigations, through to a recommendation to carry out urgent repairs. For efficient communication and processing, it is be preferable to ensure consistency in the wording of any recommendations. Appendix 13 includes a recommended picklist of recommendations. This has been drawn up by analysing historical recommendations and should cover most cases, but there should be the opportunity to also use the 'other' category with an explanation detailed as comments. |
| **Asset defect report form** | Essential note to record defects of elements and assets with recommendations of next steps (to be considered in a performance and risk review). A suitable format is provided in Appendix 13. |
| **Photographic record** | Photographs of assets form an essential part of effective asset management.<br>• They should be clearly labelled to show date taken (should be recorded from digital cameras unless post-processed), the location where the picture was taken, direction of view, and any relevant features such as river flows and recent storm events.<br>• They can be used to illustrate issues highlighted in the descriptions of inspections.<br>• They can be used to show changes in the condition of an asset or pressures on the asset over time. |
| **Record of choice for data quality flags** | The reason for selection of a particular data quality flag should be recorded. |
| **Report(s) of engineering integrity issues** | Any alerts to triggers for further tier 2 or tier 3 investigations – based on issues in Table 2.3 above and as detailed in Appendix 5 to Appendix 12. |
| **Record of choice of H, M or L for consequences of failure** | Record the reasons for selection of high (H), medium (M) or low (L) for the consequences of asset failure. This will be based on the consequences of failure matrix (Appendix 3), but will record any reasons for departing from that. |
| **Record of choice of H, M or L for probability of failure** | Record the reasons for selection of high (H), medium (M) or low (L)for the probability of asset failure. |
| **Reason for any alert to a trigger for tier 2 or 3 inspections or investigations.** | This will provide a record of any alerts raised from an inspection or other sources (see Table 2.2). See Appendix 13 for a recommended form. |
| **Record of the decision to progress to tier 2 or 3 inspections or investigations including a decision to repair without further investigations.** | This will provide a record of a post alert decision on whether to proceed to further inspections or investigations or whether to proceed directly to repair the asset (see Table 2.3). See Appendix 13 for a recommended form. |

### 2.3.11 Decision making and recording of information and feedback

For many organisations the best way of deciding on the course of action to take is through a meeting post-inspection or another alert to an issue. Care should be taken to record the outcomes of this meeting and the reasons for the decisions made to inform follow-on work or review decisions taken at a later date.

The decision as to how to proceed must take account of expected performance and a measure of risk by the performance and risk assessment 'arm', but also consider the budgeting and prioritisation constraints as assessed within the asset management planning and investment decision making 'arm'. This process was outlined in Figure 2.1. Guidance on these topics is planned.

**Recommendation 11.** Record for future reference the information collected and the reasons for the decision made regarding the next steps.

## 2.4 Tier 2 intermediate inspections

Tier 2 intermediate inspections include further inspection and survey activities required to provide further information to supplement the tier 1 routine visual inspections. These are typically non-intrusive inspections carried out by appropriately qualified experts. This guidance provides a more reliable and auditable approach to carrying out these inspections than is generally employed to ensure performance issues are alerted at the earliest opportunity so that they are appropriately considered within the context of risk and performance.

Each inspection is targeted and details of the most typical types of inspection and how they could be carried out are given in Appendix 14 to Appendix 25.

Table 2.5 lists the typical types of tier 2 inspections, their purpose and likely triggers for their use. It also lists the appendices which provide detail on the methodology of each inspection activity. Figure 2.3 shows the section of Figure 2.1 relating to tier 2.

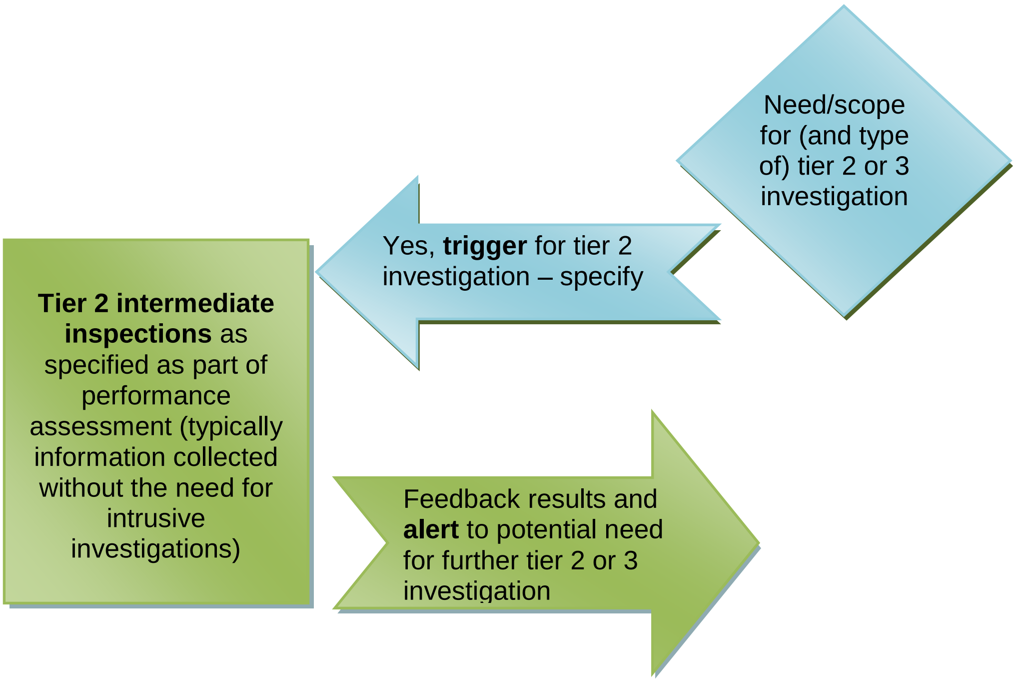

**Figure 2.3** Flow chart showing general process for tier 2

## Table 2.5 Types of tier 2 inspections

| .Alert from tier 1 inspection or other sources | Requirement to assess performance/ potential trigger for tier 2 inspection | Potential tier 2 inspection + further guidance | Purpose |
|---|---|---|---|
| **Condition grade below target** | Assist in assessing the consequences of further deterioration/ failure of the asset and potential next steps (repair timescale or further investigation) | Site inspections in cases where asset is below required condition (Appendix 14) | Part of post-inspection decision making; addresses need/urgency for further action (in this tier or tier 3) |
| **Unable to assess overall condition grade of asset** | Not usually applicable (inspection alert applies) | Follow up to 'elements not inspected' in tier 1 inspection (Appendix 15) | To make arrangements to allow elements to be inspected |
| **Possible engineering integrity issue** | Following an alert, a further inspection may be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment will be required to inform further action | Follow up inspection to decide on actions following an alert of an engineering integrity issue (Appendix 16) | To determine whether the concern justifies further action and what type of investigations would be required |
| **Usually alerts outside the normal programme of inspections** | | Follow up inspections following an event, feedback, or may need to comply with legal obligations. (Appendix 17) | To determine whether any concerns justify further action and what type of investigations would be required |
| **Stability concern (all or part of asset)**<br>**Leakage concern (piping)**<br>**Typically follow up observations post event/complaint (see above)** | A trigger for more information from flood or storm events may be part of proactive planning for improvements or to better understand an asset to determine actions following concerns. | Observation of assets under load (flood levels/wave action) (Appendix 18) | Where safe, to observe if assets show signs of movement under load or any leakage. Will also highlight low spots in defences. |
| **Low spots** | To determine the risk of defences being overtopped or breached. To improve data quality. | Crest level surveys (Appendix 19) | Determine how flood defence levels compare with design water levels. |
| **Hydraulic conveyance is being adversely affected** | To provide data for hydraulic models or conveyance estimation assessments | Cross section surveys (plus long sections if required) (Appendix 20) | Typically for hydraulic models or assess effects of blockages /vegetation |
| **Beach levels lowered/ exposed sea defences, dune erosion** | Particularly to provide data for long term monitoring of coastal systems | Beach and dune surveys (Appendix 21) | Assessment of FCERM performance of a beach or dune system |
| **Usually culverts cannot be inspected and a CCTV is needed to assess condition** | As part of a long term programme to assess performance of inaccessible assets | CCTV / confined space inspections (Appendix 22) | To inspect assets where access is difficult /not possible |
| **Usually from condition grade (part or whole). Possibly site inspection recommendations** | Could be required to confirm: if issue is likely to compromise asset; or need for further assessment | Structural inspections (Appendix 23) | Expert to assess the structural performance and detail potential improvement |
| **Requirement to minimise frequency of tier 1 inspections** | Provide data for proactive asset management planning | Remote sensing including photography (Appendix 25) | Provide data for: condition; long-term monitoring; baseline; or where access is difficult. |

| .Alert from tier 1 inspection or other sources | Requirement to assess performance/ potential trigger for tier 2 inspection | Potential tier 2 inspection + further guidance | Purpose |
|---|---|---|---|
| **Usually specialists seeking understanding of hydraulic performance** | Request for water levels for hydraulic modelling. May also indicate blockage of culverts without internal inspections. | Water level and velocity measurements (Appendix 24) | To assist in calibration of hydraulic models and to alert effects of blockage or vegetation |

## 2.5 Tier 3 detailed inspections

Tier 3 detailed inspections include investigations where specialist equipment is required, generally involving intrusive techniques. Typical aims of tier 3 inspections are to determine:

- whether an asset is stable
- whether an asset would be able to withstand imposed loads
- how deterioration might affect an asset's ability to perform in the longer term

In the post-inspection (or other alert) process shown in Figure 2.1, a tier 3 investigation may be commissioned without any need to collect further data in tier 2 surveys. However, a post-inspection site visit with qualified staff will always be required to plan and specify any tier 3 detailed investigations that may be required.

Each inspection is targeted and extensive details of the most typical types of inspection and how they could be carried out are given in Appendix 26 to Appendix 29.

Table 2.6 lists the typical types of tier 3 investigations, their purpose and likely triggers for their use. It also lists the appendices which provide more detail on the methodology of each inspection activity. Figure 2.4 shows the section of Figure 2.1 relating to tier 2.

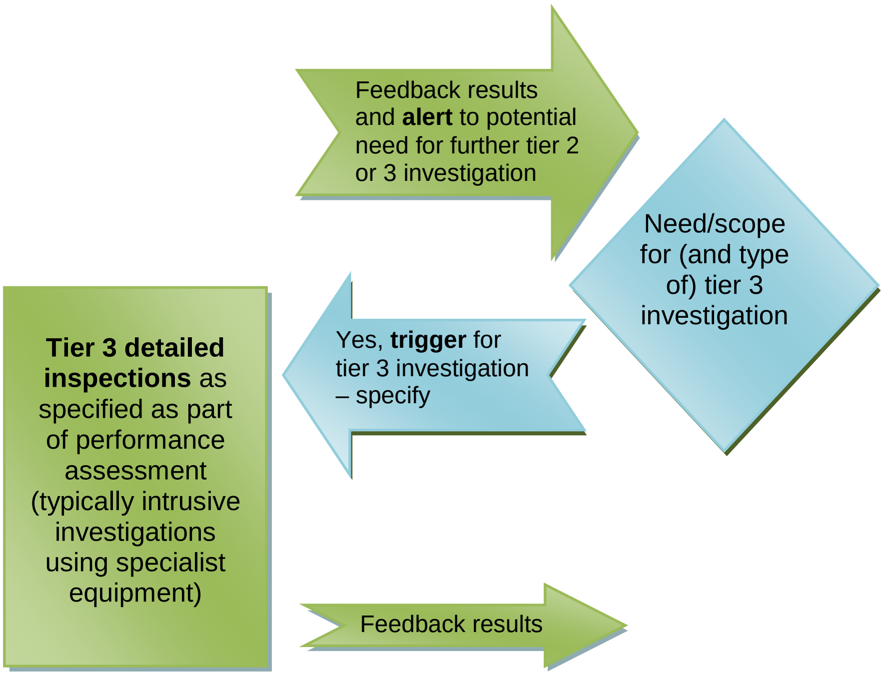

**Figure 2.4 Flow chart showing general process for tier 3**

### Table 2.6 Types of tier 3 inspections

| Trigger from performance assessment following tier 2 inspections | Type of tier 3 inspection | Purpose |
|---|---|---|
| Usually triggered by the need for further information to assess engineering integrity issues (stability and leakage) relating to geotechnical factors | Ground investigations (Appendix 26) | To confirm underlying ground conditions (layers and properties). Also used to collect information on ground water levels and variations. |
| Usually triggered by the need for information to complete structural assessments (for example, wall widths and material strengths) | Structural testing including coring (Appendix 27) | To confirm the construction materials and construction. Particularly to check deterioration or where records are not available. |
| Usually triggered by suspected presence of voids, to access cracks | Internal inspections using borescopes (endoscopy) (Appendix 28) | To collect visual inspection information where normal access is not possible |
| Usually this can be avoided by other tests. With care further information can be gathered (for example, deformations) under load which will assist in analyses. Extreme cases may require testing to destruction of part of the asset, allowing for reconstruction. | Load testing (imposed loads including water) (Appendix 29) | To confirm the ability of a structure to withstand imposed loads |

# 3 Issues to consider for asset group A: channels and culverts

## 3.1 Asset types covered

Table 3.1 lists the asset types and sub-types in group A.

**Table 3.1 Asset types and sub-types in group A – channels and culverts**

| Asset type | Asset sub-type | Description |
|---|---|---|
| Channel | Open channel | Any open channel |
| | Simple culvert | A covered channel or large pipe made of a single material to convey water below ground level (for example, concrete pipe, concrete box section, brick arched) |
| | Complex culvert | A covered channel made of more than one material to convey water below ground (for example, masonry sides covered with a concrete soffit) |

## 3.2 The importance of inspecting channels and culverts

Channels and culverts are critical assets in any fluvial flood defence system in their role of conveying floodwaters. Their efficiency in this role will directly affect the standard of protection afforded to receptors in the flood risk areas. It is therefore essential that their ability to perform as expected is monitored and any remedial action taken is a risk-based approach. Time series data built up over time are a very useful resource in making this assessment. Guidance on acceptable conditions should be advised by performance assessment activities.

Where there are no flood defences or other types of asset, channel sides are often linked to the asset type ‘defence – high ground’. Inspection of these assets is part of their role as retaining structures to maintain an open channel. For open channels and culverts where conveyance is the primary function, ‘left’ and ‘right’ bank elements are included and associated with ‘channel bed’.

## 3.3 How do we assess condition?

It is relatively straightforward to assess the condition grade of the other asset groups through the inspection process. However, the assessment of the condition grade of channels and culverts, particularly natural channels, is not so straightforward. Various factors need to be considered before determining whether obstructions such as siltation or vegetation affect the asset’s ability to perform its intended role. These factors include:

- the expected performance of the channel/culvert in terms of a standard of protection
- the relative width of the floodplain or berm which will also convey floodwater

- a number of inter-related factors relating to the size, shape, gradient and frictional resistance/roughness[4]
- other relief flow routes if there is an obstruction in the main channel
- the presence of high ground, or flood defences with significant freeboard, which would restrict the spread of floodwater if river levels were raised by obstructions
- the gradient of the watercourse will determine how far upstream of an obstruction water levels might be raised
- other hydraulic characteristics of the channel or culvert related to peak flood flows
- the difficultly of assessing siltation below water level in a tier 1 inspection
- the environmental targets for the watercourse, particularly relating to bank vegetation

For these reasons it is not appropriate to set an alert based on a general default proportion of channel/culvert blocked as defined either by width or cross-sectional area. This could lead to a significant waste of resources in keeping channels/culverts free of blockages to maintain an inappropriate target condition in situations where the flood risks may be very low. The issues are illustrated in the series of photographs shown in Figure 3.1 to Figure 3.8.

**Figure 3.1 This semi natural channel looks clear of obstructions, but siltation which has become vegetated on the bank shoulders has reduced the channel capacity over the past 15 years. Siltation below water level could not be assessed in this turbid water.**

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[4] Natural channels would normally convey a mean annual flow but, in many cases, channels have been engineered to carry a specific designed flow. Whether naturally formed, re-sectioned or even totally man-made, the capacity of any river channel to discharge its expected flow depends on all these factors.

**Figure 3.2 Minor transient shoaling, which is likely to have an insignificant effect on flood levels in peak floods.**

**Figure 3.3 Open channel – natural and defence – embankment with no berm to relieve flood flows. There is moderate accumulation of weed in channel and vegetated shoaling, which could affect channel conveyance.**

**Figure 3.4 An urban open channel. Although looking unattractive, the minor disturbance of the channel side is not compromising conveyance. But in this case, the design standard of protection recorded is below that expected for a channel in this urban area. Encroachment into the channel further downstream could increase risks to properties.**

**Figure 3.5 An urban open channel. The permanent vegetated shoaling will affect conveyance. The acceptability of this can only be assessed by considering the risks posed to nearby and upstream receptors by an increase in water levels. The channel may be over-widened at this bridge and channels will often silt up to regain a normal width.**

**Figure 3.6 An open channel choked with aquatic plants. This is likely to cause increased water levels in flood events. This should be highlighted in view of the location of the adjacent property.**

**Figure 3.7**
**An open channel with a berm fronting defence embankments. The channel side might be assigned a grade 4 (poor) but the vegetation is unmanaged to improve biodiversity. The berm is wide (>5 m) and any decay in the channel side would not compromise the embankment. The channel bed vegetation is largely flexible. A performance and risk assessment might conclude that this channel meets the target condition.**

**Figure 3.8**
**Blockage of this culvert would be likely to cause flow onto the street with high consequences. Upstream bed conditions suggest that the culvert is unlikely to be blocked and this is supported by the fact that the water is not raised. A tier 2 CCTV survey would be required to confirm both the structural condition and any obstructions to flow.**

Figure 3.1 to Figure 3.8 demonstrate that, without site-specific guidance, a tier 1 inspection cannot conclude whether a channel or culvert is meeting a target condition. This is why the Condition Assessment Manual (Environment Agency 2014) does not include guidance for assigning a condition grading to channels and culverts, apart from those relating to structural condition. However, it is important to monitor the ability of these critical assets to perform as expected in flood conditions. The following sections guide this process.

## 3.4 Setting the target condition

It is vital that the assessment to determine the target conditions for channels and culverts is made with a full understanding of any risks associated with blockage by sediment, vegetation or man-made objects. The parameters (for example, percentage blocked, extent of vegetation and type of material in channel) which could define a condition alert for each location are set in the performance and risk assessment. However, it is useful to include the steps likely to be required to enable monitoring and reporting as part of visual inspections. Figure 3.9 shows a possible sequence of steps.

**Figure 3.9 Sequence for setting a target condition for channels/culverts**

### 3.4.1 Prioritising assessments

Inspecting channels and culverts and reporting their condition in relation to their ability to perform as expected in flood conditions will depend on having a clear baseline. The baseline should indicate features that should prompt alerts to a below target asset. Most organisations do not have this information, but in many cases, background investigations and hydraulic models exist and these can be used to provide the relevant information.

**Recommendation 12.** Priority should be given to completing baseline information for high consequence systems (see Appendix 1) before moving to medium consequence systems.

A balance needs to be struck and it might be concluded that low consequence systems should not be analysed to set conveyance targets. However, alerts will continue to be received from operational staff and other stakeholders that the state of a particular channel has deteriorated (see Table 3.4 for types of trigger alerts) and these may prompt a more detailed assessment of a particular issue.

### 3.4.2 Assessment criteria

If the assessment of risk dictates that site-specific channel/culvert inspection data are important and justifiable, the parameters for the inspection should be set by the performance and assessment activity. To do this, the objective of an assessment should be to provide clear guidance – in words, photographs or sketches – to those inspecting a watercourse about:

- what the expectations are for an acceptable channel shape at selected locations
- what should prompt an alert for further investigations

Further investigations normally comprise tier 2 surveys, or CCTV inspections in the case of culverts, to provide the necessary information to complete a performance and risk assessment to determine what action, if any, needs to be taken.

Table 3.2 sets out the criteria that need to be considered in this assessment.

### Table 3.2 Assessment criteria for setting the target condition for channel conveyance

| Criteria | Comments |
|---|---|
| **The consequences of raised water levels resulting from blockages** | There should be an understanding of the consequences for sites of interest (as identified as a performance and risk assessment activity in terms of receptors at risk). This may need to use as a proxy, the consequences for the overall river system, but this may not reflect the reach-specific conditions. |
| **The hydrological and hydraulic characteristics** | These may be derived using the Conveyance Estimation System[1] or hydraulic modelling which will incorporate the various features of channel gradients, roughness of vegetation, flow routes, flood defences, berms and floodplains. |
| **The environmental objectives for the watercourse** | These will relate to other factors in recognition of the other roles of each watercourse in terms of amenity, habitats and biodiversity. Watercourses cannot usually be maintained to maximise conveyance, and management of these important assets must strike the right balance of their required roles. |
| **The expected performance of the asset** | This will be derived from the above criteria. |

Notes: [1] The Conveyance and Afflux Estimation System (CES/AES) is a software tool developed by HR Wallingford for the improved estimation of flood and drainage water levels in rivers, watercourses and drainage channels (see http://www.river-conveyance.net/index.html).

## 3.4.3 Communicating a target condition

The items listed in Table 3.3 should be included in any specification for monitoring against conveyance targets. This will enable efficient and consistent monitoring to an established baseline. Reference should also be made to sections 3.5 and 3.6 where details of tier 1 and 2 inspections are given.

### Table 3.3 Information required to directly monitor channels and culverts against conveyance targets

| Item | Comments |
|---|---|
| **Channels that should be monitored and those which will be treated as lower priority** | This information will need to be drawn up considering the consequences to receptors, the standard of protection expected, and knowledge of any historical requirements to clear blockages and maintain channels. Note that previous custom and practice does not in itself justify a continuation, but it may be an indicator of past channel siltation, growth of vegetation or blockage by debris. |
| **Location of monitoring points** | The aim should be to build up a long-term record of changes in channel shape, which will alert to the need for remedial work. Locations should be chosen that are easily identifiable, replicable and accessible. They should ideally contain reference points such as bridge abutments or pipe crossings in banks, but avoid bridges where channels are over-widened or have in channel piers. |
| **Identify the type of monitoring required** | Photographic methods are recommended (see details in section 3.5 as tier 1 inspections).<br>Topographic surveys of cross-sections for regular monitoring can only be justified for sensitive locations (described in section 3.6 as tier 2 inspections). They do allow changes in channel shape and conveyance below the water line to be monitored (see details in Appendix 20).<br>Remote sensing methods are not sufficiently developed to allow efficient monitoring, but new methods may provide better accuracy in the future. (see Appendix 25 for details).<br>In sensitive locations, the use of water level observations to determine the acceptability of a channel size should be considered. However, this will need to be linked to data from a nearby gauging station to be effective. |
| **Convey thresholds for alerts to unacceptable changes** | Those carrying out inspections will require a clear baseline against which to monitor and thresholds to alert of any changes. Whichever of the methods above is adopted, it must be easy to compare the baseline with the current conditions and against set thresholds made clear to inspectors. There will need to be an indication of an acceptable width of a blockage, based on a percentage of the cross-section covered, whether by tier 2 surveys or the tier 1 photographic record. Methods include:<br>• mark up of cross-sections or photographs to show thresholds for alerts on basis of request for information and alert parameters from performance and risk assessment activity<br>• use of archive photographs of the reach to show acceptable/not acceptable channel profiles<br>• use of photographs of channels similar to the monitored reach showing acceptable/not acceptable channel profiles<br>(The performance and risk activity may set alert thresholds where weed growth may be a feature of some watercourses and weed cutting may be undertaken to agreed programmes. In some cases the thresholds for blockage by vegetation may need to be set for summer and winter conditions.) |

## 3.5 Inspections of channels and culverts – tier 1 routine inspections

### 3.5.1 Timing of inspections

In some organisations such as the Environment Agency, channels are not included in standard inspection programmes but the channel sides are generally included as linear defences – AIMS defines these as asset sub-type ‘defence – high ground’. For such assets, the opportunity should be taken to report on any channel/culvert conveyance issues when carrying out tier 1 visual inspection of the channel sides.

Vegetation will change seasonally, and to ensure that the inspection captures as much detail as possible and to allow efficient longer term monitoring of change, inspections and photographic records should be programmed when vegetation growth does not obscure the view. There may need to be a summer visit to locations where vegetation has been reported as a particular problem. Inspections immediately following vegetation clearance will improve the inspection of siltation, but will not be representative of potential conveyance issues caused by vegetation.

Culvert headwalls and culvert centre line walkover surveys can be carried out following the recommendations in section 2.3 and Appendix 3, but CCTV inspections require a different programme (see section 3.6 for tier 2 inspections).

### 3.5.2 Reporting engineering integrity issues

The engineering integrity issues discussed in section 2.3.7 may apply to channel sides, but not to channels as conveyance assets. Ground slipping into a channel should be reported under the linear defence or defence – high ground assets.

Structural integrity issues relating to possible deformation of culverts from a walkover survey should be recorded through an asset defect report form.

### 3.5.3 Reporting channel conveyance issues

The method of reporting against thresholds defining alerts for a stretch of watercourse, suggests that inspection reports should be based on a red (not acceptable), amber (near threshold) or green (acceptable) score rather than a condition grade 1 to 5 as the latter would be difficult for an inspector to assess.

The performance and assessment activity could set alerts for green, amber and red against defined parameters or illustrated images. An example of the use of altered photographs to convey the acceptability of encroachment into a channel is shown, for illustrative purposes only, in Figure 3.10 to Figure 3.12. This series of photographs shows a channel with siltation and vegetation. As advised above, the messages are clearer if blockage can be related to a physical structure and in this case a bridge is a critical structure. Assume that modelling has shown that the level of blockage in Figure 3.10 is unacceptable. Ideally an acceptable channel and one which is only marginally acceptable could be photographed as clearance work is undertaken. However, Figure 3.11 and Figure 3.12 show how an original photograph can be manipulated using standard photo editing software to show what would be a ‘green’ and ‘amber’ reference point for monitoring the channel in the future. In this case the green and amber versions were produced in 1 hour each by a competent user. An amber alert at a critical structure would highlight a conveyance issue for further consideration. A red alert would suggest that remedial work would be required based on pre-set thresholds.

**Figure 3.10 The original photograph where modelling has shown that the level of blockage is unacceptable – the 'red' alert.**

**Figure 3.11 An edited photograph to show the level of blockage where a first alert should be raised – an 'amber' alert.**

**Figure 3.12 An edited photograph showing an acceptable channel with no alerts required – the 'green' condition.**

The main factors that could affect the conveyance/capacity will be any form of restriction to flow that occurs within the river channel or culvert. These constraints can take the following forms:

- siltation or gravel shoals forming (this could indicate that the channel has been over-widened)
- collapse of the river edges of the channel
- physical blockages of the channel that occur naturally or as a result of fly-tipping (examples range from cars, sofas to supermarket trolleys) – also fly-tipped items can easily be transported downstream and completely block a debris screen
- tree growth in and along the margins of the channel – trees or branches falling into watercourses trap other debris, increasing the significance of the blockage
- vegetation growth within the river channel – although an important environmental feature of watercourses, inflexible vegetation that is unable to be flattened in a flood can be a problem in some watercourses in high consequence areas where the conveyance capacity has to be maximised

The extent of these restrictions to flow should ideally be compared with targets for summer and winter conditions set in accordance with Table 3.3. For many watercourses, however, these will not yet be available and inspectors will need to consider whether in their opinion an alert should be raised based on what has historically been acceptable for the particular watercourse. In the first instance this may lead to a lot of alerts and will need to be managed. However, this will force a review to establish an acceptable baseline following expert assessment through performance assessment activities which should, in the long term, reduce the number of alerts and remove ‘non issues’ from the assessment process. Experienced inspectors will have a good understanding of appropriate alerts and the initial rush of alerts could be avoided in these cases.

### 3.5.4 Culvert inspections

In tier 1 inspections, the condition grade of any reasonable length culvert can only be assessed for headwalls, obvious signs of blockage or structural problems. The ground over the centre line of the culvert should be walked to look for any signs of subsidence, which could indicate a structural failure. If there are signs of problems, these can be flagged as alerts, usually prompting a tier 2 CCTV inspection and report.

Short culverts should be inspected from both headwalls where this can be done safely. This may not fully replace a CCTV inspection (if visibility is good it could do), but does give the opportunity to alert to potential problems outside the less frequent CCTV inspection programme.

## 3.6 Tier 2 inspections

The tier 2 inspections shown in Table 3.4 may be triggered following a review of tier 1 alerts by the performance and assessment activity.

An appropriate programme for culvert inspections should be drawn up and prioritised according to risk. The main purpose of inspections is normally to assess the internal condition and residual life of a culvert. However, obstructions to conveyance are particularly important where the consequences are high. Consideration should be given to supplementing less frequent CCTV inspections with observations on water levels at the upstream end which could signify the presence of a blockage.

## Table 3.4 Types of tier 2 inspections – culverts and channels

| Alert from tier 1 inspection or other sources | Requirement to assess performance/potential trigger | Type of tier 2 inspection and further guidance | Purpose |
|---|---|---|---|
| **Condition grade** below required condition or **channel conveyance issue** | Assist in assessing the consequences of further deterioration or failure and next steps (repair timescale or further investigation) | Site inspections in cases where asset is below required condition (Appendix 14) | As part of post-inspection decision making<br>To address the need for further investigations (in this table or tier 3) and urgency of any remedial action |
| **Unable to assess overall condition grade** | Not usually applicable (inspection alert applies) | Follow up to 'elements not inspected' in tier 1 inspection (Appendix 15) | To make arrangements to allow elements to be inspected |
| **Possible engineering integrity issue** – particularly applies to culvert headwalls and visible elements and channel sides | Following an alert, a further inspection may be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment will be required to inform further action. | Follow-up inspection to decide on actions after an alert of an engineering integrity issue (Appendix 16) | To determine whether the concern justifies further action and what type of investigations would be required |
| Usually alerts **from** outside the normal programme of inspections **following a flood or storm event, feedback or concern that there may be a need to comply with legal obligations** | | Follow-up inspections after a flood or storm event, feedback or concern that there may be a need to comply with legal obligations (Appendix 17) | To determine whether any concerns justify further action and what type of investigations would be required |
| Concerns that **hydraulic conveyance is being adversely affected** | To provide data for hydraulic models or conveyance estimation assessments | Cross-section surveys (channels) (including long section profiles where required) (Appendix 20) | Typically to provide data for hydraulic models or to assess hydraulic effects of blockages or vegetation |
| Usually culverts cannot be inspected internally in normal inspections and a **CCTV inspection will be required to assess condition** | As part of a long term programme to assess performance of inaccessible assets | CCTV and confined space inspections (Appendix 22) | For culverts or assets where access is difficult or not possible<br>To determine structural condition or extent of siltation and blockages |
| **Suggestion to use remote sensing to reduce frequency of inspection –** particularly applies to channels | To provide data for proactive asset management planning | Remote sensing including photography (Appendix 25) | To provide data on asset condition, particularly as part of a long term monitoring programme, where access is difficult or to provide a baseline for comparative purposes |
| **Concerns regarding water velocity or levels** – not usually an **alert** from inspections without consideration of hydraulic performance by specialists | Request for water level information for hydraulic modelling purposes. May also be used to indicate blockage of culverts without the need for internal inspections. | Water level and velocity measurements (Appendix 24) | To assist in calibration of hydraulic models and to alert effects of blockage or vegetation. (channels and culverts) |

## 3.7 Tier 3 inspections

A tier 3 structural investigation as shown in Table 3.5, may be triggered following a review of tier 2 alerts by the performance and assessment activity.

**Table 3.5 Types of tier 3 assessment – culverts and channels**

| Trigger from performance assessment following tier 2 inspections | Type of tier 3 inspection | Purpose |
|---|---|---|
| Usually triggered by the need for information to complete structural assessments (for example, wall widths, material strengths) | **Structural testing including coring (**Appendix 27) | To confirm the construction materials and construction – particularly to check deterioration or where records are not available |

# 4 Issues to consider for asset group B: linear defences

## 4.1 Asset types covered

Table 4.1 lists the asset types and sub-types in group B.

**Table 4.1 Asset types and sub-types in group B – linear defences**

| Asset type | Asset sub-type | Description |
|---|---|---|
| Defence | Embankment | All types of earthen structures found in the fluvial, tidal and coastal environment that are used for flood defence and/or erosion protection. Also to be used for dam structures that are embankments. |
| | Wall | All types of wall found in the fluvial, tidal and coastal environment that are used for flood defence and/or erosion protection. Also to be used for dam structures that are walls.[1] |
| | Demountable | Both temporary demountables that are brought to site to be erected and in situ demountables that are stored on site ready to be erected to form a flood defence. |
| | High ground | All other extents along watercourses that have not been defined elsewhere in this section. It covers extents where there are no defences other than the ground itself. Examples include the top of a river bank and a cliff adjacent to a watercourse. |
| | Quay | Quays found at the coast and along watercourses. Do not use 'quay' if the asset's primary function is as a 'breakwater'. |
| | Flood gate | Gates that form part of a flood defence, usually to provide access through the defences. Not be used for assets in a channel. |
| | Bridge abutment | Bridge abutments that tie into flood defences and therefore act as a defence.[2] |

Notes:

[1] Small wall structures found along channels that offer no flood defence/ questionable erosion protection should be defined as 'defence – high ground'.

[2] If the bridge this abutment belongs to crosses the watercourse, it will also have to be defined as a channel crossing.

## 4.2 Inspections of linear defences

Reference should be made to Chapter 2, which sets out the basic principles of inspections at each of the tiers, and the more detailed guidance in the relevant appendices as indicated in this chapter.

Inspections and reporting should be carried out bearing in mind the importance of linear defences in fluvial, tidal and coastal systems. The failure of any linear defence under load poses particularly high risks, as in most situations, the presence of the flood defence raises the water level above the level it would be without the defences in place. As these water levels are above normal ground levels, the consequences of a breach in linear defences under load is usually dangerous, putting property at risk as well as people's lives.

For this reason, it is sensible for inspectors to err on the side of caution and to raise alerts issues if they feel a grade is borderline either in the condition of the structure or associated engineering integrity. In subsequent discussions or a follow-up site inspection with a specialist, it may be decided that the risks are acceptable and no further action is required, though the reasoning needs to be recorded. This does not diminish the importance of the first alert.

## 4.3 Tier 1 routine inspections

### 4.3.1 CAM inspections and engineering integrity issues

Tier 1 routine visual inspections using CAM and T98 accredited inspectors are well established for linear defences and should be continued. Reference should be made to Chapter 3 which covers most of the issues which apply to linear defences.

In many cases the alerts to engineering integrity issues set out in section 2.3.7 will also influence the condition grade. In addition, the alert to the particular engineering integrity issue is useful in bringing it to the attention of asset managers.

The reporting through a red/amber/green response for any engineering integrity issue should be completed even if the assessed condition grade shows the asset is below target.

### 4.3.2 Treatment of critical elements

Section 2.3.3 sets out the principles of weighting of asset elements to calculate the overall condition grade. Good practice is represented by the automated approach in AIMS which calculates the overall grade, initially using the default weighting suggested in the FCRM Asset Templates: Guidance on Element Weightings (Environment Agency 2013a). However, it is important to ensure that any poor condition of **any** element that is **critical** to the performance of an asset influences the condition grade to reflect that condition for the overall asset. This could be done by amending the default weightings as set out in the Environment Agency's guidance or using the simplified approach suggested in section 2.3.3.

Some examples of where this adjustment might be required include:

- poor condition of revetments (rock and stone, precast concrete, gabion or Reno mattresses) – critical where wave action or high flow velocities could quickly erode (or may already have eroded) core material in an embankment or wall
- poor condition of wall material and joints – may apply to all types of retaining wall (concrete, masonry or sheet piles), including those forming part of a quay or bridge abutment, and particularly important if it appears the poor condition could lead to partial or complete loss of structural performance when under load from retained earth, flood water or wave action (if structural instability is already apparent, this should also be reported as an engineering integrity issue – Appendix 6)
- poor condition of anchors in a sheet pile wall – could lead to sudden collapse

- poor condition of the crest or landward side of a fluvial, tidal or sea defence which could precipitate failure in an overtopping event – particularly important for defences with a low standard of protection and/or those with associated high consequences of failure

## 4.4 Tier 2 inspections

The tier 2 inspections shown in Table 4.2 may be required. These are detailed in Appendix 14 to Appendix 25.

## 4.5 Tier 3 inspections

There may be a requirement to undertake any of the tier 3 inspections or investigations listed under Table 2.6 for all types of assets. Details are included in Appendix 26 to Appendix 29.

**Table 4.2 Types of tier 2 inspections – linear defences**

| Alert from tier 1 inspection or other sources | Requirement to assess performance/potential trigger | Type of tier 2 inspection and further guidance | Purpose |
|---|---|---|---|
| **Condition grade is below the required condition.** | Assist in assessing consequences of further deterioration or failure and next steps (repair timescale or further investigation) | Site inspections in cases where asset is below required condition (Appendix 14) | Part of post-inspection decision making. To address need for further investigations (in this table or tier 3) and urgency of any remedial action |
| **Unable to assess overall condition grade of asset** | Not usually applicable (inspection alert applies) | Follow up to 'elements not inspected' in tier 1 inspection (Appendix 15) | To make arrangements to allow elements to be inspected |
| **Possible engineering integrity issue** | Following an alert, a further inspection will be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment will be required to inform further action | Follow up inspection to decide actions following an engineering integrity alert (Appendix 16) | To determine whether the concern justifies further action and what type of investigations would be required |
| **Usually alerts outside the normal programme of inspections** | | Follow up inspections following an event, feedback, or concern to comply with legal obligations (Appendix 17) | To determine whether any concerns justify further action and what type of investigations would be required |
| **Concerns about:**<br>• **stability of the overall asset or elements**<br>• **leakage issues (piping)**<br>Likely to be follow-up observations following a site visit to respond to an alert (see above) | A trigger for more information from events may arise as part of proactive planning for improvements or to better understand a defence's role and performance to determine actions. | Observation of assets under load (flood levels or wave action) (Appendix 18) | Where safety concerns can be overcome, to observe whether assets show signs of any movement under load or the extent of any leakage paths. Will also highlight low spots in defences. |
| **Low spots in defences** | Determine risk of overtopping or breach<br>To improve quality of data | Crest level surveys (Appendix 19) | To determine how flood defence levels compare with design water levels |
| **Usually an alert from the condition grade of elements or the asset.**<br>May be an alert from site inspection recommendations | Structural inspection to confirm:<br>• if issue is likely to compromise ability to perform<br>• further assessments required | Structural inspections (Appendix 23) | Using qualified staff to assess the condition of an asset, its likely performance under load and the type and extent of improvements that may be required |
| **As a tool for assessing asset condition to reduce the frequency of required inspections** | To provide data for proactive asset management planning | Remote sensing including photography (Appendix 25) | Provide data on asset condition, particularly as part of a long-term monitoring programme, where access is difficult or to provide a baseline for comparative purposes |

# 5 Issues to consider for asset group C: coastal defences

## 5.1 Asset types covered

Table 5.1 lists the asset types and sub-types in group C. Note that linear defences at the coast, including estuaries, are covered in Chapter 4.

**Table 5.1 Asset types and sub-types in group C – coastal defences**

| Asset type | Asset sub-type | Description |
|---|---|---|
| Defence | Beach | Coastal beaches that perform a flood defence and/or erosion protection function |
| | Dunes | Coastal dunes found at the coast that perform a flood defence and/or erosion protection function |
| | Barrier beach | Barrier beaches that perform a flood defence and/or erosion protection function |
| | Promenade | Coastal promenades found along the coast that perform a flood defence and/or erosion protection function |
| | Cliff | Coastal cliffs found at the coast or estuaries that perform a flood defence function and/or required to manage erosion |

## 5.2 The need for inspections of beaches, dunes and coastal defences

Reference should be made to Chapter 2, which sets out the basic principles of inspections at each of the tiers, and the more detailed guidance given in the relevant appendices as indicated in this chapter.

Beaches and coastal systems exhibit dynamic changes in response to tidal cycles, swell and storm events. The nature and magnitude of these changes can have dramatic effects on the performance of any defence in fulfilling its role in preventing flooding or erosion. Sudden beach erosion in a storm may be followed by a slow rebuilding over several months. This raises the importance of the programming and nature of inspections, and the use of the data in monitoring long-term as well as short-term trends.

Routine tier 1 inspections are normally used to alert any particular problems, but also form an important part of the long-term monitoring of change at the coast. This means that the timing of inspections requires careful planning, as does the data collected, for both tier 1 and 2 and, on occasions, tier 3 inspections.

This document gives overall guidance. More detailed guidance can be found in *The Beach Management Manual* (CIRIA 2012), which offers extensive information for all those involved in the monitoring and management of beaches. Part 2 of the Manual covers the monitoring of beaches and the assessment of their performance, while its chapter 5 details the monitoring of beaches.

## 5.3 Inspections of coastal defences – tier 1 routine inspections

### 5.3.1 Timing of inspections

The need for and timing of inspections will vary depending on the vulnerability of the particular stretch of coastline and the need for active management. Those considering the performance and risk aspects of coastal systems usually require frequent repeat inspections in order to observe the natural fluctuations in beach morphology and the ability of the beach to recover from storm events. Such data are needed on a regular basis to inform understanding of both long-term and seasonal evolution.

As inspections need to both alert to damage that has occurred to assets and to assist in the monitoring of longer term changes, the timing of tier 1 inspections set out below is recommended. The timing of tier 2 inspections using remote sensing and photography is discussed in section 5.4.

It is important to carry out baseline surveys against which change can be monitored. These are more comprehensive than a visual inspection and involve:

- collection of beach profiles to mean low water in spring tides at intervals not exceeding 50 m
- assessment of sediment types and sizes
- surveys of structures

Baseline surveys, which combine tier 1, 2 and 3 activities, are normally carried out in the summer season when beaches are unlikely to be depleted by storm action. Reference should be made to *The Beach Management Manual* (CIRIA 2012) for more details.

There should be a regular programme of inspections to monitor the condition of coastal defences, generally in conjunction with the inspection of linear coastal defences (see Chapter 4).

Beaches, dunes, barrier beaches, cliffs and promenades where storm damage is likely should be inspected immediately after a severe storm event that has driven wave action into that length of coastline. In the case of weak cliffs, inspection may be required after prolonged periods of rainfall. The beach levels are likely to be lowered and this will allow inspection of areas normally buried. Recent damage can be assessed and appropriate actions can be taken.

### 5.3.2 Data from tier 1 inspections

Chapter 2 included general guidance for visual inspections of all assets. The following additional guidance particularly applies to coastal defences (see Chapter 4 for linear defences).

To monitor long-term change, there may be a requirement to collect the data shown in Table 5.2. Direction as to what data to collect and how to collect them needs to come from a performance and risk activity, but in practical terms, it could be collected by a tier 1 inspector at the time of the routine tier 1 inspection, if advised to do so.

**Table 5.2 Data to be collected for coastal defences and beach structures from routine and post-storm inspections**

| Type of data | Comments |
|---|---|

| | |
|---|---|
| **Beach changes compared with the baseline:**<br>• beach levels against seawalls, groynes or other beach structures<br>• evidence of erosion of dune faces, or steep scarps at the beach crest<br>• loss of beach material and exposure of underlying strata in the intertidal zone<br>• measurements of cliff erosion adjacent to beaches by measuring offsets to pegs | Inspectors will need good information from any baseline survey and also results from previous inspections to ensure that the changes are accurately conveyed.<br>Reference will need to be made to photographs at key structures from previous inspections.<br>Use of pre-prepared checklists to record changes is recommended. |
| **Beach texture**, for example:<br>• deposition or loss of sand covering a shingle upper beach<br>• deposition or loss of mud on the lower beach face<br>• evidence of overtopping at the beach crest | Comments on beach texture will also need a clear baseline for comparison purposes. |
| **Damage to structures**, for example:<br>• missing groyne planking<br>• spalling or abrasion of concrete walls<br>• displacement of rock armour<br>• exposure of structure foundations | These fall under beach structures in Chapter 6, but are included here for completeness as they will be reported in the same inspections. They should be reported as a condition grade, but it is also important to be able to comment on changes over time and raise alerts of engineering integrity as required (see Appendix 3 to Appendix 10). |
| **Fixed aspect photography** from pre-determined fixed points (from baseline) can provide valuable performance information | This data is needed on a regular basis, to inform an understanding of both long-term and seasonal evolution. Photographs should be taken from the same point, in the same direction and zoomed to capture the same field of view as baseline and previous photographs. |

### 5.3.3 Storage of data

Individual risk management authorities have their own arrangements for storage of data. It is important for these data to be made available to the Strategic Regional Coastal Monitoring Programme through the regional Coastal Observatories, if the observatory is not itself being used as the main storage facility of the data. The Coastal Observatories are linked nationally to monitor long-term change with the objective of improving planning for the coastal change that may occur.

### 5.3.4 Engineering integrity alerts

Section 2.3.7 discusses how alerts should be raised for potential problems associated with engineering integrity. Types of problems are listed in Table 2.1 and further details are given in Appendix 5 to Appendix 12. Reference should be made to these to ensure that the alerts are captured if they are not covered by the recommendations for data in Table 5.2.

## 5.4 Tier 2 inspections

The following tier 2 inspections may be required. These are detailed in Appendix 14 to Appendix 25.

## Table 5.3 Types of tier 2 inspections – coastal defences

| Alert from tier 1 inspection or other sources | Requirement to assess performance/potential trigger | Type of tier 2 inspection and further guidance | Purpose |
|---|---|---|---|
| **An alert will be prompted when the condition grade is below the required condition.** | To assist in assessing the consequences of further deterioration or failure of the asset and next steps (repair timescale or further investigation) | Site inspections in cases where asset is below required condition (Appendix 14) | As part of post-inspection decision making. To address the need for further investigations (in this table or tier 3) and urgency of any remedial action |
| **Unable to assess overall condition grade of asset.** Not normally an issue for coastal defences if inspections are appropriately programmed (tide and weather) | Not usually applicable (inspection alert applies) | Follow-up to 'elements not inspected' in tier 1 inspection (Appendix 15) | To make arrangements to allow elements to be inspected |
| **A tier 1 inspection may include a recommendation to investigate a possible engineering integrity issue** | Following an alert, a further inspection will be required to confirm:<br>• whether the issue is likely to compromise the asset's performance<br>• what further assessment will be required to inform further action | Follow-up inspection to decide on actions after an alert of an engineering integrity issue (Appendix 16) | To determine whether the concern justifies further action and what type of investigations would be required |
| **Usually alerts outside the normal programme of inspections** | | Follow-up inspections after a flood or storm event, feedback or concern that there may be a legal issue (Appendix 17) | To determine whether any concerns justify further action and what type of investigations would be required |
| **Where concerns have been raised. Particularly useful to observe wave run up and overtopping in extreme events** | A trigger for more information from flood or storm events may arise as part of proactive planning for future improvements or to better understand an asset's role. | Observation of assets under load (flood levels or wave action) (Appendix 18) | Where safety concerns can be overcome, to observe whether assets show signs of any movement under load or the extent of any leakage paths. Will also highlight low spots in defences. |
| **Concerns that beach levels have lowered, (including exposure of sea defence structures), erosion of dunes** | Particularly to provide data for long term monitoring of coastal systems | Beach and dune surveys (Appendix 21) | To provide data for assessment of the performance of a beach or dune system in a flood or erosion risk management role |
| **Usually from condition grade of elements or the asset. May be an alert from site inspection** | Following an alert and site visit, a structural inspection will be required to confirm performance issues and the need for any | Structural inspections (Appendix 23) | Using qualified staff to assess the condition of an asset, its likely performance under load and the type and extent of |

| Alert from tier 1 inspection or other sources | Requirement to assess performance/potential trigger | Type of tier 2 inspection and further guidance | Purpose |
|---|---|---|---|
| **recommendations** | further assessments. | | improvements that may be required |
| **As a tool for assessing asset condition to reduce the frequency of required inspections** | To provide data for proactive asset management planning | Remote sensing including photography (Appendix 25) | To provide data on asset condition, particularly as part of a long-term monitoring programme, where access is difficult or to provide a baseline for comparative purposes |

## 5.5 Tier 3 inspections

Most of the tier 3 inspections and investigations discussed in section 2.5 and listed in Table 2.6 are not normally required for coastal defences. However, there may be a requirement to undertake ground investigations, in particular concentrating on beach material particle sizes to inform assessments of the stability and performance of the beach. See Appendix 26 for more details.

# 6 Issues to consider for asset group D: beach structures

## 6.1 Asset types covered

Table 6.1 lists the asset types and sub-types in group D.

**Table 6.1 Asset types and sub-types in group D – beach structures**

| Asset type | Asset sub-type | Description |
|---|---|---|
| Beach structure | Groyne | All types of groyne – coastal and in some cases fluvial. Used to control the movement of beach material and/or control erosion. |
| | Breakwater | All types of breakwaters that provide coastal erosion protection. Some breakwaters also provide the secondary function of a quay. |

## 6.2 Inspections of beach structures – tier 1 routine inspections

Reference should be made to Chapter 2, which sets out the basic principles of inspections at each of the tiers, and the more detailed guidance given in the relevant appendices as indicated in this chapter.

In general, the guidance in Chapter 5 for the coastal defences asset group also applies to this group. Reference should be made to sections 5.2 and 5.3 in particular for tier 1 inspections; their contents are not repeated in this chapter.

Table 5.2 sets out recommendations for the data to be collected in beach surveys to supplement the requirements set out in Chapter 2 and Table 2.4.

For groynes and breakwaters, routine and post-storm inspections are important to alert to structural damage to posts and planking, or movement of rock or concrete armour units. Repairs made following an alert could avoid the need for large-scale work to rebuild a structure. Beach structures can often deteriorate rapidly in a series of storm events without remedial work to repair the first signs of damage.

## 6.3 Tier 2 inspections

The tier 2 inspections listed in Table 6.2 may be required for beach structures and detailed in Appendix 14 to Appendix 25.

**Table 6.2 Types of tier 2 inspections – beach structures**

| Alert from tier 1 inspection or other sources | Requirement to assess performance/potential trigger | Type of tier 2 inspection and further guidance | Purpose |
|---|---|---|---|
| **Condition grade is below the required condition** | To assist in assessing the consequences of further deterioration or failure of the asset and next steps | Site inspections in cases where asset is below required condition (Appendix 14) | As part of post-inspection decision making. To address the need for further investigations (in this table or tier 3) and urgency of any remedial action |
| **Recommendation to investigate a possible engineering integrity issue**<br>**Also from alerts outside the routine inspection programme** | Following an alert, a further inspection will be required to confirm:<br>• whether the issue is likely to compromise the asset's performance<br>• what further assessment will be required to inform further action | Follow-up inspection to decide on actions after an alert of an engineering integrity issue or from a post-storm inspection (Appendix 16 – engineering integrity; Appendix 17 – post event; Appendix 23 – structural) | To determine whether the concern justifies further action and what type of investigations would be required |
| **Concerns that beach levels have lowered (including exposure of sea defence structures), erosion of dunes** | Particularly to provide data for long-term monitoring of coastal systems | Beach and dune surveys (Appendix 21) | To provide data for assessment of the performance of a beach or dune system in a flood or erosion risk management role. |
| **Requirement to reduce frequency of investigation**<br>As a tool for assessing asset condition to reduce the frequency of required inspections | To provide data for proactive asset management planning | Remote sensing including photography (Appendix 25) | To provide data on asset condition, particularly as part of a long-term monitoring programme, where access is difficult or to provide a baseline for comparative purposes |

## 6.4 Tier 3 inspections

Most of the tier 3 inspections and investigations discussed in section 2.5 and listed in Table 2.6 are not normally required for beach structures. However, there may be a requirement to carry out ground investigations of foundation materials if there is a stability issue or to inform the design of remedial work. See Appendix 26 for more details.

# 7 Issues to consider for asset group E: structures and point assets

## 7.1 Asset types covered

Table 7.1 lists the asset types and sub-types in group E.

**Table 7.1 Asset types and sub-types in group E – structures and point assets**

| Asset type | Asset sub-type | Description |
|---|---|---|
| Structure | Screen | All screens (grids) used to collect debris and/or prevent access to culverts, outfalls, channels and so on |
| | In-channel stoplogs | In-channel stoplogs used to control the level of water in a channel. Do not use this for out of channel stoplogs that are used as flood defences (see defences demountables, Chapter 4 ). |
| | Control gate | Penstocks, sluice gates, mitre gates, sector gates and radial gates<br>These structures can be adjusted to alter the flow of water. |
| | Outfall | Discharge point of collected flow into watercourses or the sea. Primarily small surface water drains that discharge into watercourses or the sea. However, also applies to larger flapped outfalls where a smaller watercourse flows under a defence and discharges into a larger watercourse or the sea. |
| | Weir | Fixed weirs, manual weirs and mechanical weirs that cross channels to increase the upstream water level |
| | Spillway | Overflow spillways, side spillways, and shaft spillways found at reservoirs, flood storage areas, and along defences |
| | Stilling basin | Pool structure usually found at the outfall of a reservoir/flood storage area or spillway that reduces the water velocity before it is passed further downstream |
| | Hydrobrake | Fixed structures that control flow of water using a vortex |
| | Jetty | Basic jetty structures found in fluvial and coastal environments that do not provide a defensive function |

## 7.2 Inspections of structures and point assets

Reference should be made to Chapter 2, which sets out the basic principles of inspections at each of the tiers, and the more detailed guidance given in the relevant appendices as indicated in this chapter.

Inspections and reporting should bear in mind the importance of structures and point assets in fluvial, tidal and coastal systems. The failure of a structure within a linear defence under load poses risks to receptors protected by the defences and there is also the risk that failure of a structure could precipitate failure of longer lengths of adjacent defences. For this reason, it is sensible to err on the side of caution and to raise alerts to issues either relating to the condition of the structure or its associated engineering integrity. In subsequent discussions or a follow-up site inspection with a specialist, it may be decided that the risks are acceptable and no further action is required. However, this does not diminish the importance of the first alert.

## 7.3 Tier 1 routine inspections

### 7.3.1 CAM inspections and engineering integrity issues

Tier 1 routine visual inspections should be continued for structures and point assets. Reference should be made to Chapter 2 which covers most of the issues that apply. In many cases the alerts to engineering integrity issues set out in section 2.3.7 will also influence the condition grade. In addition, the alert to the particular engineering integrity issue is useful in bringing it to the attention of asset managers. The reporting through a red/amber/green response for any engineering integrity issue should be completed even if the assessed condition grade shows the asset is below target.

### 7.3.2 Treatment of critical elements

Section 2.3.3 sets out the principles of weighting of asset elements to calculate the overall condition grade.

Examples of where adjustments might be required to ensure the weighting of critical assets creates and alert are:

- poor condition of critical elements in assets subject to high hydraulic loading – applies particularly to spillways, stilling basins and control gates
- blockage of most of these assets by debris

The issue of blockage is addressed in detail in Chapter 3 and is not repeated here. For many of these asset types (for example, screens, outfalls and control gates), blockage by debris can have catastrophic consequences, often leading to uncontrolled flooding. It is essential that alerts are raised to allow operational staff to clear blockages as a priority. Alerts may also arise from inspections upstream where there are sources of debris which could cause problems downstream.

## 7.4 Tier 2 inspections

This asset group includes a wide range of structures and point assets. This means that any of the tier 2 detailed inspections may be called for to follow up a routine inspection or other alert as appropriate to the particular situation. The tier 2 inspections are discussed in section 2.4 and shown in Table 2.5 and are not repeated in this chapter. Details of the inspections are given in Appendix 14 to Appendix 25.

## 7.5 Tier 3 inspections

Any of the tier 3 inspections may be required to follow up a routine inspection or other alert or to provide further information following a tier 2 inspection. The tier 3 inspections are discussed in section 2.5 and shown in Table 2.6 and are not repeated in this chapter. Details are given in Appendix 26 to Appendix 29.

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# List of abbreviations

| Abbreviation | Meaning |
|---|---|
| **AIMS** | Asset Information Management System |
| **APT** | Asset Performance Tools |
| **CAM** | Condition Assessment Manual |
| **CCTV** | closed circuit television |
| **CDM** | construction, design and management |
| **ENI** | element not inspected |
| **FCRM** | Flood and Coastal Risk Management |
| **GPS** | global positioning system |
| **MLWS** | mean low water springs |
| **ODN** | Ordnance Datum Newlyn |
| **OS** | Ordnance Survey |
| **PDA** | personal digital assistant |
| **RMSE** | root mean square error |
| **RTK** | real time kinematic |
| **SAMPs** | System Asset Management Plans |
| **SoP** | standard of protection |
| **SPT** | standard penetration testing |
| **UXO** | unexploded ordnance |

# Glossary

| Word or term | Meaning |
|---|---|
| **Abutment** | End support of a bridge<br>Walls flanking the water passage through a control structure |
| **Accretion** | Process by which particles carried by the flow of water or by the wind are deposited and accumulate (opposite is erosion) |
| **Alert** | To draw attention to an issue or concern for further consideration |
| **Anchor** | An object beneath the ground which is designed to provide restraint against upward or forward movement |
| **Apron** | A layer of stone, concrete or other scour protection laid downstream of a control structure or energy dissipator, or at the toe of flood defence works such as bank protection, wave protection and seawalls |
| **Armour layer** | Outer layer of larger and/or more durable material used in bank protection or wave protection (large quarried stone or concrete) |
| **Asset** | In flood defence or coast protection, any man-made or natural object – such as a raised defence, retaining structure, channel, pumping station, culvert or beach – that performs a flood defence, land drainage or coast protection function. (includes components owned by any organisation, whether or not flood defence was its primary purpose) |
| **Asset Information Management System (AIMS)** | An Environment Agency database which has updated and replaced the National Flood and Coastal Defence Database (NFCDD) |
| **Asset management** | Systematic and coordinated activities through which an organisation optimally and sustainably manages its assets and asset systems – including their associated performance, risks and expenditures – over their life cycles for the purpose of achieving its strategic aims |
| **Assessment** | The process of understanding the state, performance or structural competence of an existing asset or asset system in order to inform the planning of future interventions |
| **Asset Performance Tools (APT)** | A phased programme of projects to improve the adoption of performance and risk management considerations in asset management planning and decision making. The guidance and tools are being developed in accordance with an integrated tiered framework. |

| Word or term | Meaning |
|---|---|
| **Bagwork** | A system of building revetments or walls consisting of dry concrete in fabric bags |
| **Bank** | Strip of land forming the edge of any channel or body of water (left bank and right bank are as viewed looking in a downstream direction) |
| **Bastion** | A massive groyne, or projecting section of seawall, normally constructed with its crest above water level |
| **Beach** | Shore of sand or shingle |
| **Benefits** | In flood defence, land drainage or coast protection appraisal, the value placed on the reduced likelihood of flooding, waterlogging or coastal erosion provided by the asset, asset system or project |
| **Berm** | Horizontal ledge formed in the side slope of an embankment or cutting |
| **Blockwork** | The use of blocks of concrete or stone to form a revetmen |
| **Blowout** | Wind-eroded area in sand surface |
| **Borehole** | A small diameter exploratory hole in the ground formed by an auger or shell and auger methods for investigating the sub-surface ground conditions |
| **Breach** | Gap in an embankment, flood defence or dam, caused by failure that may allow the escape of water |
| **Breakwater** | Long coastal or estuarine structure designed to protect a harbour or the shore from wave attack |
| **Bund** | Embankment |
| **Canal** | Channel constructed to convey or contain water, usually for navigation or irrigation |
| **Cantilever wall** | (1) Reinforced concrete retaining wall of relatively thin cross section which depends for its stability on the weight of retained material on its heel.<br>(2) Sheet-piled wall stabilised by its length of penetration into the ground. |
| **Cascade** | Spillway or channel whose floor is arranged as a series of steps, with the purpose of dissipating most of the kinetic energy resulting from the loss of potential energy |
| **Catchment/catchment area** | The land which drains, normally naturally, to a given point on a river or drainage system or other body of water |
| **Clay** | Strictly a constituent of soil the grain size of which is predominantly less than 0.002 mm, but the term is used colloquially to describe a soil which is cohesive. |

| Word or term | Meaning |
|---|---|
| **Coastal cells** | A division of the coastline into sections within which any changes do not affect adjacent sections – particularly with reference to the movement of sand and shingle |
| **Cohesive soil** | Soil whose major constituent is clay, which tends to shrink on drying, expands on wetting and gives up water when compressed. Cohesive soils possess a measurable plastic limit. |
| **Condition** | State of repair of deterioration of an asset. The condition grade is a systematic evaluation of asset condition by visual inspection, generally using the Condition Assessment Manual (CAM). |
| **Condition Assessment Manual (CAM)** | This document gives guidance for the efficient and consistent inspection and condition grading of a full range of flood risk assets. The manual includes the consideration of performance in the determination of condition grade while recognising that the initial inspection may be the catalyst for further more specialist inspections. |
| **Consequence** | Impact such as economic, social or environmental damage of any event such as extreme storm, asset failure or coastal erosion. Can be expressed quantitatively (for example, monetary value), by category (for example, high/medium/low) or descriptively. |
| **Control structure** | Device constructed across a channel or between water bodies or water passages, used to control the discharge passing the device and/or the water level on either side of the device. The structure can be fixed (for example, weir) or adjustable (for example, gate or penstock) |
| **Conveyance** | For a channel, function of the flow area, shape and roughness of a channel, which can be used as a constant in a formula relating discharge capacity to channel gradient |
| **Creep** | The slow downhill movement of soil which occurs close to the ground surface |
| **Crest** | Top surface of a weir or other control structure over which water passes, or highest part of flood bank, or highest part of a coastal defence structure such as a seawall or breakwater |
| **Crest level** | Level of highest point of an asset at a particular cross-section above which overtopping could occur |
| **Culvert** | Covered channel or large pipe to convey water below ground level, for instance under a road, railway or urban area, or beneath a building or other structure |
| **Deterioration** | Decline in the material properties of some or all components of an asset caused by external agents (for example, freeze/thaw) leading to a reduction in its |

| Word or term | Meaning |
|---|---|
| | structural strength |
| **Element** | A component part of a system or asset |
| **Engineering inspection or survey** | Detailed assessment of an asset, including its foundations and internal structure as appropriate, to determine its condition, including any structural faults |
| **Engineering integrity** | The degree to which an asset may fail as a result of structural or geotechnical mechanisms |
| **Event** | Conditions which may lead to flooding or trigger a coastal landslip. An event is, for example, the occurrence in source terms of critical variables such as a flood water level being exceeded at the same time a specific sea level, or in receptor terms a particular flood depth. |
| **Failure** | Inability to achieve a defined performance threshold. 'Catastrophic failure' describes the situation where the consequences are immediate and severe. |
| **Failure mode** | Description of one or any number of ways in which an asset or asset system may fail to meet a particular performance indicator. |
| **Flood defence asset** | An asset that by its failure would increase the likelihood of flooding from any main river, watercourse and/or the sea to people, property or infrastructure. |
| **Flood defence system** | Two or more flood defence assets acting to achieve a common goal (for example, maintaining flood protection to a floodplain area/community) |
| **Flow** | General term used to describe movement of water in a particular direction (as distinct from specific descriptors such as discharge or velocity. |
| **Fragility** | The likelihood of particular defence of system to fail under a given load condition. Typically expressed as a fragility curve relating load to probability of failure. Combined with descriptors of deterioration, fragility relationships enable performance to be described over time. |
| **Function** | The purpose that an asset fulfils for those who benefit from or use it and the environment in which it exists. An asset will have a primary function of flood defence, land drainage or coast protection plus some secondary functions such as ecological, access, health and safety, or amenity. |
| **Frontage** | Sub-division of the coastline for asset management purposes |
| **Hazard** | A situation (physical event, phenomenon or human activity) with the potential to result in harm. A hazard |

| Word or term | Meaning |
|---|---|
| | does not necessarily lead to harm – it can be managed. |
| **Infrastructure** | Collective term for a group of assets essential to normal life whose primary function is to provide a service to the community |
| **Intervention** | A planned activity designed to effect an improvement in an existing natural or engineered system (particularly with asset management) |
| **Maintenance** | Work that sustains the desired condition and intended performance of an asset. |
| **National Flood and Coastal Defence Database (NFCDD)** | The Environment Agency's former asset information database, now superseded by the Asset Information Management System (AIMS). |
| **Pathway** | Route that enables a hazard to propagate from a source to a receptor. A pathway must exist for a hazard to be realised and cab be constrained to mitigate risk. |
| **Performance** | The degree to which a process or activity succeeds when evaluated against some stated aim or objective. In asset terms this can refer to its ability to withstand loading in flood or storm conditions. This also refers to the standard of service provided by, or expected from, a flood defence system. |
| **Performance-based Asset Management System (PAMS)** | A programme of projects to determine how performance and risk should be incorporated into asset management planning. The Asset Performance Tools programme is the means of delivering the tools and guidance based on these principles. |
| **Performance indicator** | Meaningful and measureable objective(s) of a particular asset management policy or project. May be technical performance indicators, such as acceptable wave overtopping rates or conveyance capacity, or more generic indicators such as public satisfaction. |
| **Probability** | Measure of the chance that an event will occur. Typically defined as a relative frequency of occurrence of that event out of all possible vents and expressed as a percentage with reference to a time period for example, 1% annual exceedence probability. |
| **Raised defence** | Any raised structure that protects an area from flooding |
| **Reach** | A defined length of defence or frontage |
| **Receptor** | The entity (such as a person, property, habitat and so on.) that may be harmed by an event via a source and pathway. The vulnerability of a receptor can be reduced by increasing its resilience. |
| **Resilience** | In asset management, the ability of an asset or asset system to resist the damaging effect of extreme loading. Resilience measures can for example help to achieve |

| Word or term | Meaning |
|---|---|
| | design standards above the standard of protection. |
| **Risk** | Risk can be considered as having two components – the probability that an event will occur and the consequence associated with that event to receptors. Risk = Probability × Consequence. Flood risk to a receptor can be indicated graphically with probability and consequence as the *x* and *y* axes. The area under the curve is the overall risk. |
| **Risk assessment** | The process of identifying hazards and potential consequences, estimating the magnitude and probability of consequences, and assessing the significance of the risk(s). A 'tiered' approach can be used with the effort in assessing each risk proportionate to its importance in relation to other risks and likely consequences. |
| **Risk management** | The systematic process of risk assessment, options appraisal and implementation of any risk management measures to control or mitigate risk |
| **Service life** | The period of time after construction or refurbishment during which an asset meets or exceeds its functional performance requirements |
| **Source** | The origin of a hazard (for example, storm rainfall, strong winds, surge and so on) |
| **Standard of protection (SoP)** | In flood risk management economic appraisal, the probability (annual exceedence) of the flood level associated with the defence (crest level less freeboard) |
| **Standard of service** | The performance of an asset at a specific point in time expressed in terms of a physical attribute(s) of the asset or system (for example, crest level, pump capacity) |
| **System** | Assembly of elements, and the interconnections between them, constituting a whole and generally characterised by its behaviour (for example, elements in a structure, assets in an asset system). Concept also applied to social and human systems. |
| **System asset management plans (SAMPs)** | Long-term investment plans for flood defence and coast protection asset systems that identify the investment needed and the benefit they bring. |
| **Target condition** | The condition which defines the limit of acceptability of an asset condition |
| **Transition point** | The point at which a change of physical properties takes place |
| **Trigger** | An activity that leads to an action |
| **Visual asset inspection** | Systematic visual assessment of the condition of the visible elements of an asset resulting in the assignment of a condition grade |

| Word or term | Meaning |
|---|---|
| **Vulnerability** | Characteristic of a particular asset, system or receptor group that describes its potential to be harmed |
| **Whole life cost** | Total cost of managing an asset over its life, including cost of construction, use, operation, inspection, maintenance and refurbishment, replacement of disposal |
| **Withdrawal of maintenance** | Process of ceasing maintenance of flood defence or coast protection assets because it is uneconomic to continue |

# Appendix 1 How are the condition and performance of an asset related and why do we need to monitor them?

Condition and performance are monitored to support efficient management of assets. Improvements are seen through proactive planning and application of processes in a risk based approach rather than relying on a reaction to a failing asset, or one falling below its target condition.[5] The advantages of this approach include:

- inspections can be targeted in terms of tier 1 routine inspections and possible need for tier 2 or 3 detailed investigations
- appropriate timing and type of interventions can be planned as asset deterioration rates have been established for different types of assets of varying age and condition under different maintenance regimes

Asset **condition** reflects the physical state of an asset, which may or may not affect its ability to perform as required. **Asset inspections** (tiers 1 to 3) relate to observing and recording physical data on FCRM assets. **Performance and risk assessment** activities inform the frequency and type of inspections, and include the analysis of the data collected to inform further appropriate actions.

**Performance** has different components and these are often confused.

- Performance expectation relates to the standard of protection which an asset should provide, for example, 1 in 50 or 2% chance of overtopping (or different chance of breaching) in any one year.
- Performance in engineering or hydraulic terms relates to the way the asset performs under load, in particular, is it likely to fail? For clarity this is referred to as ‘engineering integrity’ in this document.
- Asset condition monitoring provides critical information for determining the remaining useful life of an asset (it collects data which feed into a process of assessment of rate of deterioration against performance requirement). This is important for determining the timing for possible intervention steps to bring the performance of an asset back to a desired standard.

Understanding the condition and performance characteristics (both performance expectation and engineering integrity) of an asset and similar asset types allows:

- identification of risk management factors associated with asset failures and mitigation of the consequences of failure
- avoidance of premature and unmanaged asset failure
- ability to plan for and manage the delivery of the appropriate level of protection/service through maintenance and improvement strategies

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[5] A target condition should be set for each asset taking into account risks and consequences.

- improved accuracy in predicting future expenditure requirements through understanding remaining asset life and capital investment needs

# Appendix 2 Detailed guidance on inspection of all asset types

This appendix presents further detail to Chapter 2.

## A2.1 Assessing condition

Each organisation has its own approach to assessing asset condition. However, increasing numbers are adopting Environment Agency practice with its well-established and tested methods as an example of good practice. This good practice is built on the following documents and processes, which can be made available to other organisations to follow or model:

- Condition Assessment Manual (CAM) (Environment Agency 2012)
- internal Operational Instructions used by the Environment Agency to standardise the approach to inspections and the frequency of these relating to the risks
- asset inspectors' training and accreditation through the T98 programme

The assessment of a 1 to 5 score for condition grade is well-established throughout FCRM organisations in the UK[6] and works well. The overall condition grade reflects the weighted average condition grade of the various elements making up the asset (see section A.2.2). The five-point CAM grading system is shown in Table A.2.1.

**Table A.2.1 Definitions of condition grade in the Condition Assessment Manual**

| Grade | Rating | Description |
|---|---|---|
| **1** | Very Good | Cosmetic defects that will have no effect on performance |
| **2** | Good | Minor defects that will not reduce the overall performance of the asset |
| **3** | Fair | Defects that could reduce the performance of the asset |
| **4** | Poor | Defects that would significantly reduce the performance of the asset |
| **5** | Very Poor | Severe defects resulting in complete performance failure |

## A2.2 Weighting of elements

The principle of weighting is described in section 2.3.3. The Environment Agency method is described below as an example of current good practice to serve as a model, although as noted in the main text this could be simplified to reduce the range.

- The overall grade of the asset is the sum of (weightings × condition grades) divided by the sum of the weightings.

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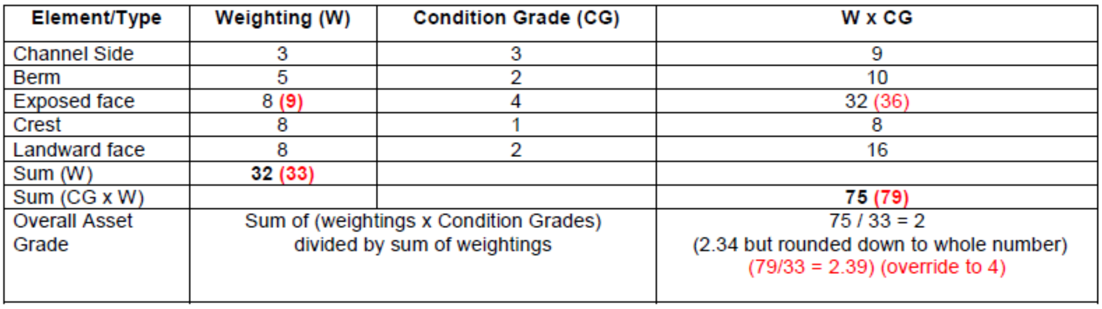
[6] The Netherlands uses a four score 'good, reasonable, moderate and bad' and the USA a three score 'acceptable, minimally acceptable and unacceptable' reporting system.

- If any individual element with a weighting of 9 (a critical element) falls below the target condition and the above calculation shows the asset is numerically meeting its target condition, this should be overridden to give an overall condition grade below the target.

The calculation is illustrated in Table A.2.2 for a fluvial flood defence embankment.

**Table A.2.2 Example calculation of condition grade from grade and weighting of elements**



| Element/Type | Weighting (W) | Condition Grade (CG) | W x CG |
|---|---|---|---|
| Channel Side | 3 | 3 | 9 |
| Berm | 5 | 2 | 10 |
| Exposed face | 8 (9) | 4 | 32 (36) |
| Crest | 8 | 1 | 8 |
| Landward face | 8 | 2 | 16 |
| Sum (W) | **32 (33)** | | |
| Sum (CG x W) | | | **75 (79)** |
| Overall Asset Grade | Sum of (weightings x Condition Grades) divided by sum of weightings | | 75 / 33 = 2<br>(2.34 but rounded down to whole number)<br>(79/33 = 2.39) (override to 4) |

Recommendations as a default for the weighting of elements for assets which have an FCRM purpose and variance to the defaults under specific conditions are given in the Environment Agency's FCRM Asset Templates and Weighting Document (Environment Agency 2013a). For other organisations a simplified approach is recommended:

## A2.3 Assessment of data quality – see Appendix 4

## A2.4 Treatment of elements not inspected

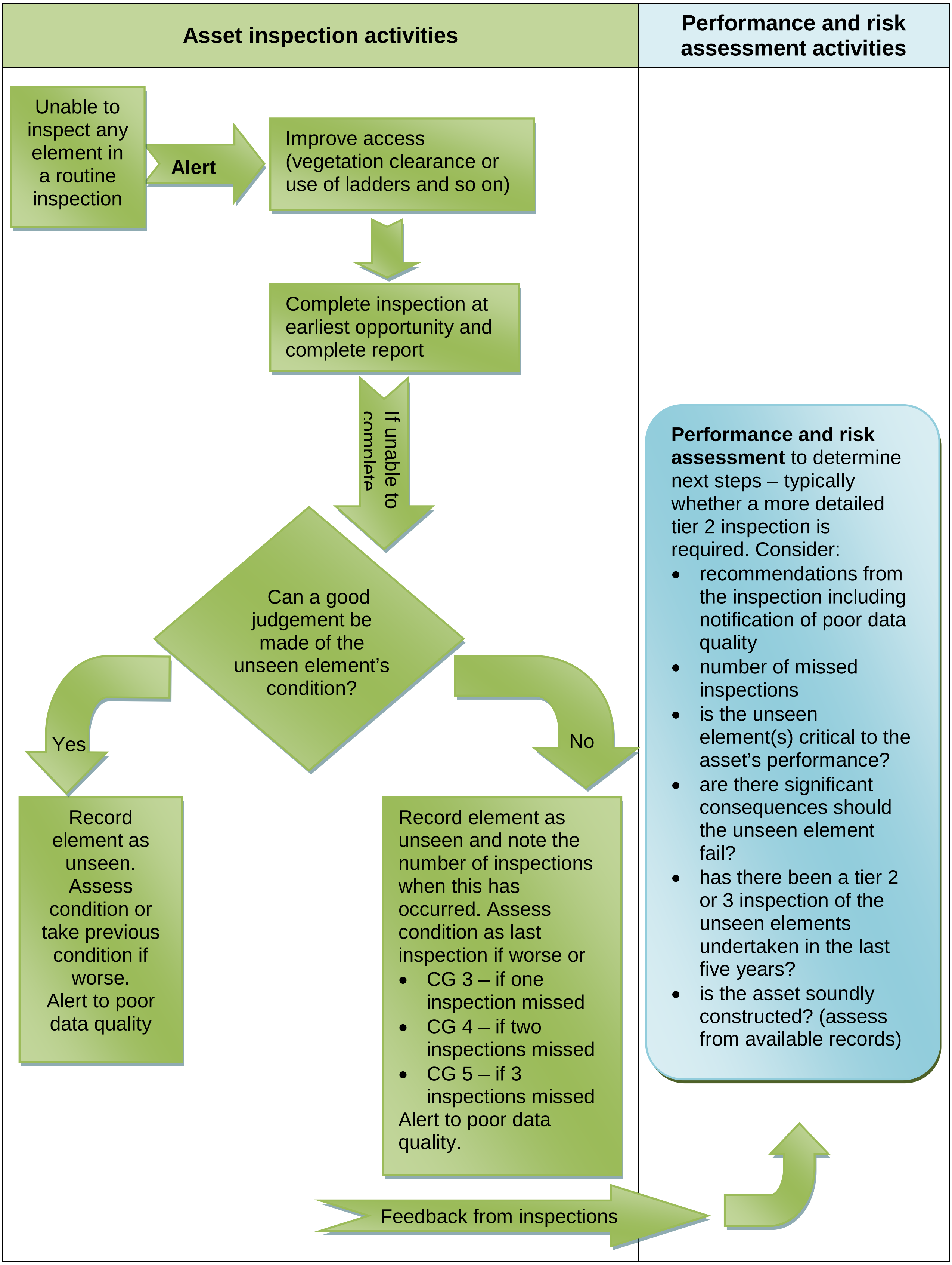
The quality of the results from any inspection is likely to be compromised by a failure to inspect one or more of the asset's elements. The risk that there may be an underlying unidentified problem increases with the time that has elapsed since the last satisfactory inspection.

Adoption of the steps in Figure A.2.1 is recommended for those making the inspections and the way that the inspection results should be considered by asset managers.

Alerts arise from either reported poor data quality as a result of a failure to complete the inspection, or a condition grade below required condition, particularly one resulting from failure to inspect on more than one occasion.

Appendix 13 contains recommendations on a follow-up visit to overcome an element not inspected (ENI) and subsequent data quality issues.

Figure A.2.1 Flowchart for elements not inspected



### A.2.4.1 How to deal with transition elements

The reporting of condition grade using CAM procedures or similar may not provide the opportunity to highlight issues at transitions, particularly where the transition is at the end of a long length of linear asset which itself may be in good condition.

The scale of this issue is not clear as records tackling this specific issue are generally not good. However, flood risk managers often report problems in this area from experience on the ground.

The following approach is recommended in tier 1 inspections.

- Where the condition of any transition between individual assets is considered to be a concern, this should be raised as an alert through recommendations that are used to record issues for further consideration. The spreadsheet embedded in Appendix 13 includes a suggested picklist of recommendations for a consistent approach. An extract relating to transitions is shown in Table A.2.3.

**Table A.2.3 Extract from recommendations picklist relating to transitions**

| Primary recommendation | Secondary recommendation | Comments |
|---|---|---|
| **Alert to issues at transition(s)** | Amber alert to downstream transition | For coastal assets, add direction of adjacent asset for clarity. |
| | Red alert to downstream transition | Use amber to alert to possible future problem and red alert where structural issues requiring urgent attention are already visible.<br>Add comments and photographs to clarify. |
| | Amber alert to upstream transition | |
| | Red alert to upstream transition | |

- The alert should be recorded with the reporting of either the downstream or upstream asset, depending on the timing of the inspections. The aim is to record only the alert to the problem at the transition once; if the inspector knows that the alert has already been raised in association with the adjacent asset, there will be no need to duplicate it.
- The recommended approach is to use an amber alert where a problem is observed, but in the inspector's opinion there is no urgent need for remedial action. A red alert is used when a problem is identified that may justify urgent action to avoid partial or complete failure or to avoid more extensive remedial work where deterioration is likely to progress quickly.
- Additional comments, photographs and sketches should be prepared to assist in post-inspection discussions to decide on future action that may be justified (remedial work with or without the need for tier 2 or 3 inspections) and the priority these should attract.
- It is recommended that an alert to a problem at a transition is raised even if the condition grade of an adjacent asset falls below target partly as a result of the conditions at the transition.
- It may not be clear who would be responsible for any remedial work, but that is a subject for post-inspection discussions and should not stop an alert being raised.

Both vertical and horizontal transitions may cause issues depending on the environment and the materials involved, and the significance varies greatly. In general, transitions at a vertical interface are more often overlooked as they form the boundary between inspection reaches which may be in good condition but with a weak transition point. Horizontal transitions often run a significant length of a reach, if not the whole length, and will be inspected as part of the reach infrastructure.

Figure A.2.2 to Figure A.2.8 illustrate typical issues, without the need for detailed knowledge of the particular circumstances.

**Figure A.2.2 A smooth transition between materials lining a channel. Although vegetation growth may cause an issue in the future, on this evidence there is no need to raise either a red or amber alert for the transition.**

**Figure A.2.3 A typical transition between stone work channel side and a natural bank where erosion can occur. On this evidence there is no need to raise either an amber or red alert, particularly bearing in mind the low consequences of failure in this rural location.**

**Figure A.2.4 These issues of engineering integrity and at vertical transitions should be picked up in tier 1 inspections and will be reflected in the assessed condition grade and picklist recommendations. Transition alerts are not required.**

**Figure A.2.5 A problem at a transition between a revetted bank and a bridge abutment. This should be highlighted as a red alert as there is a risk of progressive erosion of the downstream bank.**

**Figure A.2.6 A failure of a bank at the transition with an upstream gabion wall. The tipped stone may have already been placed to stabilise this and it also may not be clear whose responsibility this is. The collapse does not itself increase flood risk. An amber alert may be appropriate to ensure the wider asset management team is aware of the issue.**

**Figure A.2.7 This is clearly not a new issue and riparian responsibilities may be important in deciding whether action should be taken. However, the obvious problems at this transition should be recorded through a red alert. This is also likely to be reflected in the condition grade of the 'defence – high ground'.**

**Figure A.2.8 This transition between sheet piles and a masonry wall has the potential for backfill washout close to the current water line when subjected to high fluvial flows. An amber alert is appropriate to raise awareness and to ensure the transition is monitored for any further movement or loss of integrity.**

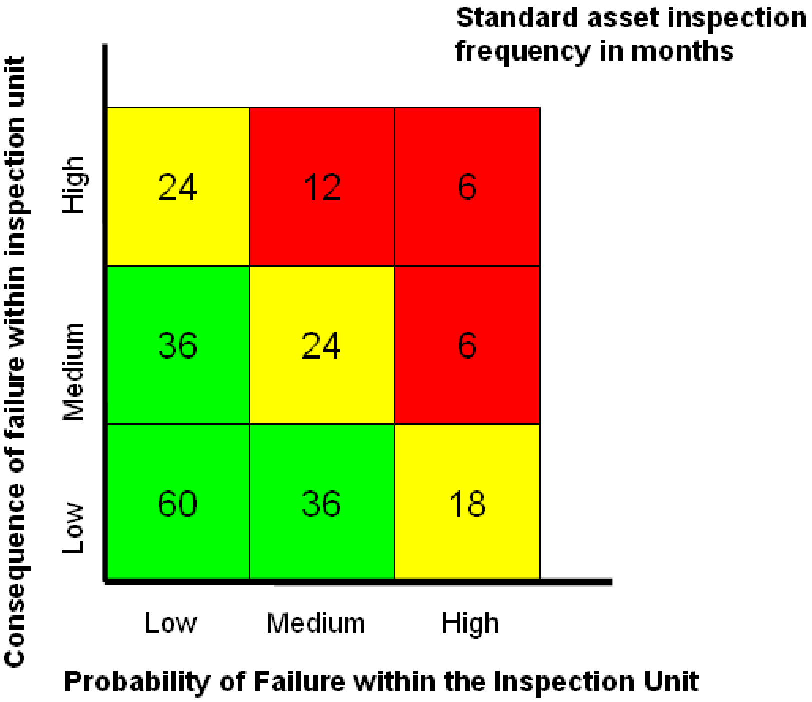
# Appendix 3 The risk-based approach to frequency of inspection

Good practice is set out in the Environment Agency's Operational Instruction 50_13, which presents the rationale for determining the risk-based inspection frequency. Other organisations will have their own guidelines for this, but the process used within the Environment Agency adopts a sensible risk-based approach. This is summarised below to illustrate the principles and provides a good model. Guidance on the inspection frequency for culverts is discussed in Chapter 3.

## A.3.1 Setting inspection frequency

The frequency of inspection is usually assessed for a river reach or coastal frontage unit containing groups of assets forming a defence system. However, there may be a need to increase the frequency or initiate an unprogrammed inspection for a particularly critical asset or one prompted by a particular concern.

For the reach or frontage under consideration, the normal inspection frequency is based on the consequences and probability of failure. This derives from a 'performance and risk assessment' activity which is an essential input into the visual inspection activities (see Figure 2.1 of the main document). The standard frequency of inspection is the maximum interval allowed between inspections. For particularly high consequence systems such as Thames tidal defences, the frequency of inspection is likely to be increased even if the probability of failure is low. Figure A.3.1 is an extract from Operational Instruction 50_13.

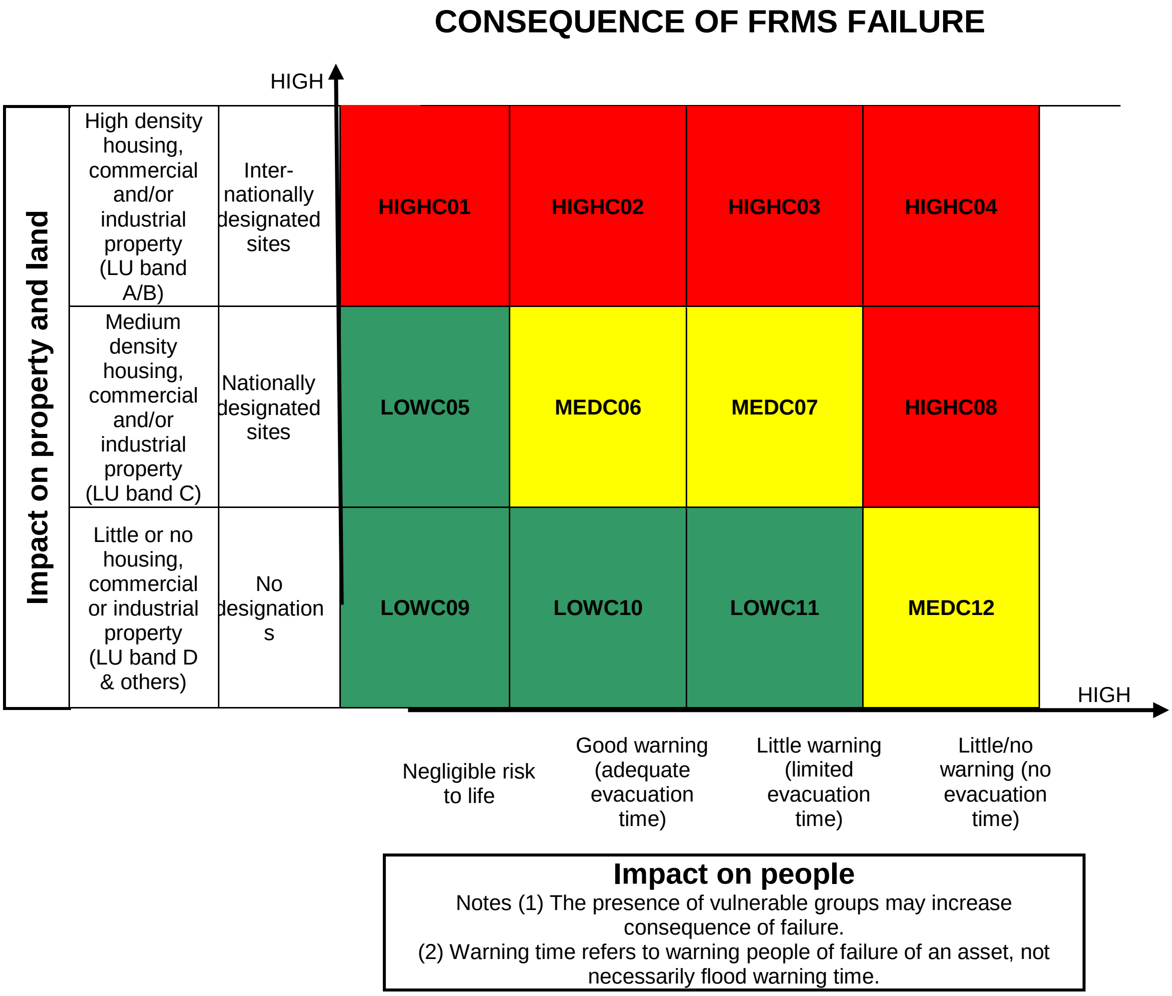


| | Low | Medium | High |
|---|---|---|---|
| High | 24 | 12 | 6 |
| Medium | 36 | 24 | 6 |
| Low | 60 | 36 | 18 |

**Figure A.3.1 Matrix of consequences and probability of failure for setting inspection frequencies**

## A.3.2 Consequences of failure

The matrix used by the Environment Agency to assign high, medium or low consequences to a system, inspection unit or group of assets is shown in Figure A.3.2.



CONSEQUENCE OF FRMS FAILURE

| Impact on property and land | | | Negligible risk to life | Good warning (adequate evacuation time) | Little warning (limited evacuation time) | Little/no warning (no evacuation time) |
|---|---|---|---|---|---|---|
| HIGH | High density housing, commercial and/or industrial property (LU band A/B) | Internationally designated sites | HIGHC01 | HIGHC02 | HIGHC03 | HIGHC04 |
| | Medium density housing, commercial and/or industrial property (LU band C) | Nationally designated sites | LOWC05 | MEDC06 | MEDC07 | HIGHC08 |
| | Little or no housing, commercial or industrial property (LU band D & others) | No designations | LOWC09 | LOWC10 | LOWC11 | MEDC12 |
| | | | | | | HIGH |

**Impact on people**

Notes (1) The presence of vulnerable groups may increase consequence of failure.

(2) Warning time refers to warning people of failure of an asset, not necessarily flood warning time.

**Figure A.3.2 Consequences of flood risk management system (FRMS) failure matrix**

Other factors in addition to the Environment Agency's current list of factors[7] that may require an increase to the consequences assigned to an asset or group of assets include:

- additional areas that might benefit from the asset's performance
- adjoining reaches
- clusters of dwellings
- topography
- population
- social/political/legal obligations

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[7] At the time of writing

- environmental designation (where flooding would damage the interests)
- development proposals
- better information
- vulnerable population

The spreadsheet in Appendix 13 includes a template that can be used to record the criteria used to assign the consequences of failure to any asset or groups of assets.

## A.3.3 Probability of failure

The probability of failure can be given a high, medium or low rating based on a number of criteria (Table A.3.1). The importance of any of the criteria will be different in each case and it is important to record the reasons.

The spreadsheet in Appendix 13 includes a template which can be used to record the criteria been used to assign the probability of failure to any asset or groups of assets.

**Table A.3.1 Suggested criteria for assessing the probability of failure**

| Feature type | Criteria which may increase previously assigned probability of failure |
|---|---|
| **Expected loading of an asset in flood or storm events** | • Freeboard (crest level exceeding extreme flood levels)<br>• Asset critical to the integrity of a group of assets |
| **Findings of previous inspection, reports from operational staff or other monitoring** | • Condition below target<br>• Gaps, breaches or low spots<br>• Flood or storm event damage<br>• Presence of vermin<br>• Concern on engineering integrity<br>• Susceptibility to blockages<br>• Channel conveyance issues |
| **Type of flood defence** | • Whether or not purpose built<br>• Hard or soft defences<br>• Construction type, materials, presence of resilient core, wide berm and so on |
| **Other factors affecting fragility of an asset** | • Age<br>• Maintenance regime<br>• Expected deterioration rate and residual life (combination of age, defence type and maintenance regime)<br>• History of problems<br>• Susceptibility to erosion<br>• History of vandalism |

# Appendix 4 Data quality

It is vital that the data used in making effective risk-based decisions on the way that assets should be managed are of good quality. This starts with the data collected in tier 1 standard inspections.

## A.4.1 Data management essentials

All FCRM organisations have their own arrangements for the management of data from inspections and more detailed assessments. A good model is provided by the Environment Agency's Asset Information Management System (AIMS), a database containing a wide range of information on flood defence assets, results of asset inspections and information relating to performance measures. The first tier of asset inspections uses the Condition Assessment Manual (Environment Agency 2012) as the standard tool for determining the condition grade of the majority of the Environment Agency's assets. This database is available to all FCRM organisations to use or model for their own purpose.

The first output from the APT programme was a report on data management (Environment Agency 2010). This highlighted the importance of good data management and made recommendations for improvements to incorporate the results of performance assessments and higher level, more detailed, tiers of asset inspections.

Asset information is needed to provide the evidence to support the choices made in managing the stock of assets to an appropriate standard and to demonstrate, when required, that robust decision-making processes are in place. Asset information is also important as a record of how assets have changed over time and the interventions that have occurred in that period. This helps in proactive planning of asset management rather than reactive responses to problems.

During discussions with those involved directly in asset management, it was acknowledged that there are deficiencies and inaccuracies in some of the data held relating to physical asset data and performance. This applies to all organisations. This may be because the data were collected for other purposes and so may not be reliable for making certain asset level decisions.

**Recommendation 13.** Evidence suggests a need to improve data management to ensure the data held are of consistently good quality to allow efficient asset management based on risk and performance measures.

The emphasis in this document is on the importance of risk-based decision making. This principle also applies to the collection of data to ensure that the required investment is well targeted. Significant investment in time and money is required to collect original data, starting with inspections. Historical data cannot easily be replicated and the need to duplicate any data is wasteful. Section 2.3.1 and Appendix 3 discuss the appropriate frequency of asset inspections, which should be based on the nature of the asset and assessment of risks, including the consequences of asset deterioration or failure.

Asset inspection is directed by the performance and assessment activity in terms of identifying assets to inspect and the required frequency.

**Recommendation 14.** To target inspections appropriately, more detailed assessments are needed to establish key inspection parameters such as element weightings, inspection frequency and target grade. This will result in alerts that are be targeted and relevant, rather than a flood of general alerts which obscure important information.

An important principle is that data should be managed as an important asset in its own right. This is consistent with the government's commitment to Building Information Modelling (Cabinet Office 2011) to improve the flow of information for efficient management of assets throughout their life cycle.

## A.4.2 Data quality – condition grade

Data quality flags are one method of identifying the quality of the data and therefore their suitability for purpose, though there is a shift away from them in general. However, at least a basic indication of whether data are complete and reliable should be maintained.

Table A.4.1 summaries a scoring for data quality that could be applied to the condition grade depending on the elements that could be inspected. A simplified version might use a 1 to 3 score system of 'good' (score of 1 in Table A.4.1), 'adequate' (score of 2 in Table A.4.1) and 'potentially unreliable' (scores of 3–5 in Table A.4.1 combined), where 'potentially unreliable' creates an alert.

**Table A.4.1 Data quality indicators for condition grade**

| Data quality flag Condition Grade | Definition |
|---|---|
| **1 – good** | All elements visually assessed and graded. |
| **2 – adequate** | One or more elements were not inspected, but a recent detailed or engineering survey has been undertaken and a manual override has been used to change the calculated asset condition. |
| **3 – suspect** | A single element that was inspected satisfactorily on the last inspection is not visible at the current inspection. |
| **4 – poor** | Two or more elements that were inspected satisfactorily on the last inspection are not visible at the current inspection. |
| **5 – missing** | One or more elements are not visible for two or more consecutive inspections since the last satisfactory inspection. |

## A.4.3 Data quality – defence crest levels

The quality of the performance and risk assessment data is important in determining the frequency of inspection and the steps that should be taken following an inspection (or another) report of an asset or any of its elements below target condition.

Table A.4.2 and Table A.4.3 contain recommendations for data quality indicators for the performance and risk assessments of defence crest levels. Again a simplified version could use a 1 to 3 score system of 'good' (score of 1 in tables below), 'adequate' (score of 2 in tables below) and 'potentially unreliable' (scores of 3–5 in tables below combined).

**Table A.4.2 Data quality indicators for defence crest levels (flag for upstream and downstream)**

| Data quality score<br>Defence crest levels | Definition |
|---|---|
| **1 – good** | ±1–5 cm vertical accuracy (typically on-site survey or differential GPS) within last five years. |
| **2 – adequate** | ±>5–15 cm vertical accuracy (typically LiDAR or photogrammetry) or site survey older than five5 years. |
| **3 – suspect** | ±>15–75 cm vertical accuracy (typically older, pre 2004, LiDAR or photogrammetry) |
| **4 – poor** | ±>75 cm vertical accuracy (typically handheld GPS walkover) |
| **5 – missing** | No reliable recorded defence crest levels. |

**Table A.4.3 Data quality indicators for actual standard of protection**

| Data quality score<br>Actual standard of protection | Definition |
|---|---|
| **1 – good** | Detailed assessment or design within last five years if still 'as designed' |
| **2 – adequate** | Compared with recent flood event for which return period is known with good confidence, or based on nearby modelled assessment using surveyed information |
| **3 – suspect** | Compared with historical flood with lower confidence in return period, or based on high level modelling for strategic purposes. |
| **4 – poor** | Based on historical flood with unknown return period. |
| **5 – missing** | Based on assumptions/guesstimate for key variables. |

# Appendix 5 How to inspect for engineering integrity: slope stability

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| **Slope stability** | Details follow |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

Mainly applicable to **linear defences:** embankments, walls, defence – high ground

Less often but also applicable to **coastal defences:** beaches, dunes, promenade, cliff

## A.5.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the stability of an asset or may lead to future problems. This appendix describes:

- how to identify problems arising from instability of slopes, typically in flood embankments
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert can be raised from a tier 1 programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.5.2 What to look for during a tier 1 inspection

During an inspection, there are a number of indicators of instability of slopes[8] that may lead to an alert for further investigation:

- **Evidence of rotation or damage to joints** of a retaining structure or flood defence – see also 'instability of structures' (Appendix 6)

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[8] Some judgement may be required for natural channels where there is a normal sequence of a build-up of sediment followed by slips. This may be common for channels with a high silt load. Alerts should only be raised where slips are more extensive than those normally observed or where it appears that the stability of a flood defence asset may be under threat.

- **Evidence of shallow surface slips –** it is sometimes difficult to tell whether a slip is a deeper rotational slip
- **A pronounced step in a slope –** may be combined with bulging nearer to the toe of the slope, though in some cases, material which might have been displaced at the toe will have been carried away by river flows or wave action
- **Cracks and fissures** without other signs of movement are included in 'cracking or fissuring' (Appendix 11).

Typical evidence is shown in Figure A.5.1.

Slips close to a tidal embankment which should prompt an amber alert at least and possible further investigation by specialists. They will concentrate on the following:

- Is this different from historic slips in this area? What might have prompted a change?
- The tidal embankment is set back by over 30 metres. Is it at risk?

A slip close to a fluvial flood defence embankment which should prompt a further inspection involving specialists. They will consider:

- Is the slip likely to progress to threaten the embankment?
- Is the slip acceptable as the flood defence has a sheet piled core?

A slip in a river with a high silt load, which is a frequent occurrence. An alert may only be raised if a flood defence is threatened.

Slips likely to prompt an alert due to the proximity of the floodbank

**Figure A.5.1 Typical evidence of slope instability**

## A.5.3 Alerts to a possible problem from tier 1 inspection

Table A.5.1 lists questions for use in a tier 1 inspection by personnel without any geotechnical experience to test whether an alert should be raised that there could be a slope stability issue. The indicators described in section A.5.2 should also be used.

**Table A.5.1 Possible questions applicable to a tier 1 inspection relating to slope stability**

| Question no. | Evidence of a slope stability issue | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of slips in a slope, including steps in the slope or bulging at the toe, which are affecting (or could affect in the future) the stability of an asset? | Move to Q2 | No alert |
| Q2 | Is this similar to slips which are a regular feature of the asset length under consideration without causing instabilities of flood defence assets? | No alert | Move to Q3 |
| Q3 | Is the slope stability issue threatening the stability of an asset in the short term? Are there any of the following:<br>• evidence of movement?<br>• significant step in slope?<br>• bulging at the toe? | Raise red alert and continue to monitor | Raise amber alert of a slope stability issue and continue to monitor |

## A.5.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert** from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations –** the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations (refer to Appendix 14 to Appendix 29 – the tier of follow-on inspection will be directed by particular need)

The questions in Table A.5.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider more geotechnical details in deciding on next steps and whether ground investigations might be required (see Appendix 26).

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 6 How to inspect for engineering integrity: instability of structures

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| **Instability of structure** | Details follow |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

Mainly applicable to:

- **culverts and headwalls**
- **linear defences:** high ground, walls, quays, bridge abutments
- **coastal defences:** promenades
- **beach structures**: groynes, breakwaters
- **structures:** screens control gates, outfalls, weirs, spillways, hydrobrakes, jetties

## A.6.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the stability of an asset or may lead to future problems. This appendix describes:

- how to identify problems which cause structures to be unstable
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert can be raised from a tier 1 programmed routine inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.6.2 What to look for during a tier 1 inspection

During an inspection, there are a number of visual indicators of the instability of structures that may lead to an alert for further investigation:

- **Evidence of tilting and/or damage to joints** of a structure or flood defence – see also ‘slope stability’ (Appendix 5)
- **Evidence of horizontal movement** of a structure – this will usually arise from unequal pressure, either from landward earth pressures or water pressures from flood or storm conditions
- **Evidence of soil deformation** caused by movement of the asset
- **A lowered crest level** which could indicate settlement, a problem relating to the foundations (bearing capacity) or be associated with a rotational failure

The evidence will be different for the wide range of structures that may be affected, but Figure A.6.1 shows examples of what to look for. See also Appendix 5.

| | |
|---|---|
|  |  |
| An obvious sign of failure of ‘defence – high ground’. The failure will be reflected in the assessed condition grade, but the engineering integrity issue should also be reported. | Signs of instability in a sea wall which can be highlighted. |
|  |  |
| The failure in this gabion wall can be highlighted as an engineering integrity issue. The question of ownership, cause and responsibility for repairs can be considered in the performance and risk assessment. | The rotation of this estuary wall is significant in the context of the narrow defence and merits further investigation. |

**Figure A.6.1 Typical evidence of structure instability**

## A.6.3 Alerts to a possible problem from tier 1 inspection

Table A.6.1 lists questions for use in a tier 1 inspection by personnel without any geotechnical or structural expertise to test whether an alert should be raised that there could be a structural integrity issue. The indicators described in section A.6.2 should also be used.

**Table A.6.1 Possible questions applicable to a tier 1 inspection relating structural instability**

| Question no. | Evidence of a structural instability issue | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of rotation (tilting), horizontal movement, or damage to joints from movement or differential settlement in an asset? | Move to Q2 | No alert |
| Q2 | If this has been previously reported, has there been a change in the movement since the last inspection? | Move to Q3 | No new alert – comment as a reminder |
| Q3 | Does the tilting, movement or settlement suggest that the stability of the asset could be threatened? | Raise red alert and continue to monitor | Raise amber alert of a structural integrity issue and continue to monitor |

## A.6.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert** from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations** – the alert may trigger the need for further investigations by more detailed inspections, ground investigations or structural assessments (see Appendix 16, Appendix 23, Appendix 26 and Appendix 27 for details of how these might proceed if triggered – the tier of the follow-on inspection will be directed by particular need as assessed by a performance and risk activity)

The questions in Table A.6.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider structural and geotechnical factors in deciding on next steps and whether more detailed investigations might be required.

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 7 How to inspect for engineering integrity: leakage and piping

| Engineering Integrity Issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| **Leakage and piping** | Details follow |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

Mainly applicable to **linear defences:** embankments, walls

Less often also applicable to:

- **linear defences**: high ground, bridge abutment
- **coastal defences**: beaches, dunes, promenades, cliffs

## A.7.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the stability of an asset or that may lead to future problems. This appendix describes:

- how to identify problems arising from leakage through soils, typically in flood embankments
- how the issue can be escalated for further consideration by qualified staff

With help from guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.7.2 What to look for during a tier 1 inspection

During an inspection, there are a number of indicators of leakage through an earth defence that may lead to an alert for further investigation. Some of these may be apparent even when water levels in the river or tidal waters are low:

- **Evidence of standing water behind the defence or nearby** – this can easily be confused with poor land drainage arrangements for water trapped behind the defence, but can be a useful first alert

- **Patches of vegetation which are more usually found in wetland areas behind the defence or nearby** – this may also be an indicator of restricted drainage, but can be a useful first alert to possible leakage
- **General evidence of water leaking above the base of the embankment** on the landward side – this will differentiate between land drainage issues and leakage
- A **localised 'spring' of water on the landward face** of an embankment – where this water is cloudy, containing fine particles of soil, this indicates a serious problem, that is, internal erosion of the embankment due to the flow of water
- **Material, washed out** by water leaking through an embankment, deposited near the base of an embankment – an indicator of a serious problem.

Typical evidence is shown in Figure A.7.1.

| | |
|---|---|
|  |  |
| Water on the landward face of a floodbank from leakage | Evidence of cloudy water leaking through a floodbank |

**Figure A.7.1 Typical evidence of leakage from piping**

## A.7.3 Alerts to a possible problem from tier 1 inspection

Table A.7.1 lists questions for use in a tier 1 inspection by personnel without any geotechnical experience to test whether an alert should be raised that there could be a leakage or piping issue. The indicators described in section A.7.2 should also be used.

**Table A.7.1 Possible questions applicable to a tier 1 inspection relating to leakage and piping**

| Question no. | Evidence of piping | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of water leaking through the asset or close to it? | Move to Q2 | No alert |
| Q2 | Is there evidence of leakage of cloudy water, including presence of deposited fine material? | Move to Q3 | Amber alert of some leakage and continue to monitor |
| Q3 | Is there any evidence of structural deformation (holes, significant washout of material)? | Raise red alert and continue to monitor | Amber alert of probable piping issue and continue to monitor |

## A.7.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert** from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations** – the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations (refer to Appendix 14 to Appendix 29 – the tier of follow on inspection will be directed by particular need)

The questions in Table A.7.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider more geotechnical details in deciding on next steps and whether ground investigations might be required (see Appendix 26).

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 8 How to inspect for engineering integrity: backfill washout

Mainly applicable to:

- culverts and headwalls
- linear defences: high ground, walls, quays, bridge abutments

Less often but also applicable to:

- coastal defences: promenades
- beach structures: breakwater
- structures: screens, control gates, outfalls, weirs, spillways, hydrobrakes, jetties

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| **Backfill washout** | Details follow |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

## A.8.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the stability of an asset or may lead to future problems. This appendix describes:

- how to identify problems associated with washout of backfill, which could destabilise a structure
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.8.2 What to look for during a tier 1 inspection

During an inspection, there are a number of visual indicators of washout of backfill, which could lead to a loss of support to a structure, leading to instability. Evidence of these may lead to an alert for further investigation:

- Evidence of **loss of backfill material** from the structure – voids, accumulated deposits in vicinity
- Evidence of **structural damage** caused by backfill washout
- **Holes or gaps** in a structure exposing backfill

## A.8.3 Alerts to a possible problem from tier 1 inspection

Table A.8.1 lists questions for use in a tier 1 inspection by personnel without any structural expertise to test whether an alert should be raised that there could be a problem associated with washout of backfill. The indicators described in section A.8.2 should also be used.

**Table A.8.1 Possible questions applicable to a tier 1 inspection relating to backfill washout**

| Question no. | Evidence of a backfill washout issue | Yes | No |
|---|---|---|---|
| Q1 | Is there any evidence of loss of backfill material from the structure or are there any gaps in the structure exposing backfill? | Move to Q2 | No alert |
| Q2 | If this has been previously reported, has there been a change since the last inspection? | Move to Q3 | No new alert |
| Q3 | Do any of the following apply?<br>• Is there evidence of structural damage as a result of loss of backfill?<br>• Are the gaps exposing the backfill significant that is, large enough for backfill to be lost through the holes? | Raise red alert and continue to monitor | Raise amber alert of a structural integrity issue and continue to monitor |

## A.8.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert**[9] from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

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[9] It is likely that signs of backfill washout will influence the condition grade as an output from the inspection. However, raising a specific engineering integrity alert is useful in highlighting particular problems which can be included in the inspection report package.

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations –** the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations (see also Appendix 16, Appendix 23 and Appendix 25 – the tier of follow-on inspection will be directed by particular need)

The questions in Table A.8.1 need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider structural and geotechnical factors in deciding on next steps and whether more detailed investigations might be required.

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 9 How to inspect for engineering integrity: crest height degradation

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| **Crest height degradation** | Details follow |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

Mainly applicable to:

- **linear defences:** embankments, walls, high ground, quay, floodgate, bridge abutment
- **coastal defences:** beach, dune, barrier beach, promenades
- **beach structures:** breakwaters; structures and point assets: outfalls, weirs, spillways, jetties

## A.9.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the ability of an asset to perform as intended or may lead to future problems. This appendix describes:

- how to report problems of crest height degradation
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.9.2 What to look for during a tier 1 inspection

During an inspection, there are a number of visual indicators that the crest level has been degraded which may lead to an alert for further investigation:

- **Low points** in a linear defence visible by 'eying in'

- A marked **drop in level from a hard structure to a soft defenc**e, indicating that there may have been degradation over time
- Evidence of **animal trampling** that has reduced a crest level locally
- Evidence of **rutting** by machinery
- Areas of local **subsidence**
- Evidence of crest height reduction though **erosion** (water flows, waves or traffic)

In some cases an alert to crest level degradation over time may come from overtopping of a defence, or a ‘near miss’ in a flood or storm event, or concerns that the standard of protection afforded is less than that recorded in the database. Typical evidence is shown in Figure A.9.1.

| | |
|---|---|
|  |  |
| Degradation in a dune crest where the dune is narrow should prompt an alert. | A crest in poor condition with an obvious low spot |
|  |  |
| Locally degraded crests due to overtopping in flood events. Should prompt an alert even though operational staff may know about it. | |

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Crest degraded by animal trampling. This should prompt an alert to determine whether this is significant, considering reduction in crest level, flood risks and consequences.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>An embankment crest degraded by foot traffic. This should prompt an alert to determine whether further investigations are required to assess the significance.</td><td>A transition between a defence wall and an embankment. This could be a sign of a long term degradation of the embankment defence level.</td></tr>
</table>

**Figure A.9.1 Typical evidence of crest height degradation**

## A.9.3 Alerts to a possible problem from tier 1 inspection

Table A.9.1 lists questions for use in a tier 1 inspection to test whether an alert should be raised of a possible degradation in crest level. The indicators described in section A.9.2 should also be used.

**Table A.9.1 Possible questions applicable to a tier 1 inspection relating to crest height degradation**

| Question no. | Evidence of a crest degradation issue | Yes | No |
|---|---|---|---|
| Q1 | Are there signs that the crest level may have been degraded? (local low spots, step from hard to soft defence, erosion or animal, pedestrian or machinery traffic) | Move to Q2 | No alert |
| Q2 | If this has been previously reported, has there been a change in the movement since the last inspection? | Move to Q3 | No new alert |
| Q3 | Is the height reduction significant taking into account nearby properties and so on at risk, the linear length affected and the width (say >20%) of the crest degraded (Defra and Environment Agency 2009)? | Raise red alert and continue to monitor | Raise amber alert of crest degradation issue and continue to monitor |

## A.9.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert**[10] from a tier 1 inspection, usually followed by a further site visit, is considered as a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works** – the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations** – the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations, or structural assessments (refer to Appendix 16, Appendix 19, Appendix 20, Appendix 21 and Appendix 26 – the tier of follow-on inspection will be directed by particular need)

The questions in Table A.9.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider structural and geotechnical

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[10] The reduction in crest level is also likely to influence the condition grade as an output from the inspection. However, raising a specific engineering integrity alert is useful in highlighting particular problems which can be included in the inspection report package.

factors in deciding on next steps and whether more detailed investigations might be required.

The red, amber or green flag should be used in reporting on engineering integrity issues in the post inspection report.

# Appendix 10 How to inspect for engineering integrity: animal burrowing

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| **Animal burrowing** | Details follow |
| Cracking or fissuring | Appendix 11 |
| Undermining or scour | Appendix 12 |

Mainly applicable to

- **linear defences:** high ground, embankments, walls
- **coastal defences:** dunes, cliffs
- **structures:** spillways

## A.10.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening stability of an asset or may lead to future problems. This appendix describes:

- how to identify problems arising from animal burrowing through soils, typically in flood embankments
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.10.2 What to look for during a tier 1 inspection

Animal burrows may be evident during a routine inspection or they may be reported by operations staff, particularly when carrying out maintenance work. Evidence may lead to an alert for further investigation.

Animals which burrow and create voids in earthworks vary in size. The effect of the burrowing will depend on:

- the size of the animal and its burrow

- the density of the holes
- the depth of the hole into the earthworks

In ascending order of size, burrows may be associated with:

- mice
- crayfish
- moles
- rats
- water voles
- rabbits
- foxes
- badgers

In reporting the presence of animal burrows, it is not essential to identify the exact type of animal that has dug the burrow, but it is useful to indicate what it might be to convey to others the scale of the problem. Similarly it is necessary to indicate whether the density of the holes suggests a serious problem. The burrows may not be in the asset itself, but the extent may be sufficient to alert to a developing problem.

Typical evidence is shown in Figure A.10.1. See also Appendix 7.

| | |
|---|---|
|  |  |
| Extensive rabbit burrowing on an embankment crest. This would prompt an alert. This would probably trigger further investigations into the extent of the damage, particularly in high or medium consequence systems. | A large vermin hole, which could extend a significant way into the embankment. |

An extensive badger sett close to a flood embankment which should prompt an alert. Note the presence of excavated soil, indicating the extent of the burrows.

**Figure A.10.1 Typical evidence of animal burrowing**

## A.10.3 Alerts to a possible problem from tier 1 inspection

Table A.10.1 lists questions for use in a tier 1 inspection without the need for specialist knowledge or the need to identify the species that has made the burrows. The answers can be used to test whether an alert should be raised that there may need to be further investigations to determine whether the burrowing was acceptable. The indicators described in section A.10.2 should also be used.

Investigations would need to consider:

- the consequences of damage to the embankment
- the material making up the floodbank
- whether there was any cutoff, including sheet piles, within the structure

**Table A.10.1 Possible questions applicable to a tier 1 inspection relating to animal burrowing**

| Question no. | Evidence of animal burrowing | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of burrowing within the embankment or other asset or close to it? | Move to Q2 | No alert |
| Q2 | If this has been previously reported, has there been a change since the last inspection? | Move to Q3 | No new alert |
| Q3 | Do the burrows fall into any of the following categories:<br>• fox or badger size hole in or close to the asset?<br>• evidence that the hole extends from landside to waterside (evidence of washout of material)?<br>• density of holes suggesting a large population that may be degrading the asset? | Raise red alert and continue to monitor | Raise amber alert of animal burrows and continue to monitor |

## A.10.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert** from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations** – the alert may trigger tier 2 or 3 further investigations, usually involving an environmental scientist (who will need to consider protected species and licensing issues) which may lead to further ground investigations to discover the extent of the problem

The questions in Table A.10.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider more geotechnical details together with protected species and licensing issues in deciding on next steps and what further investigations might be required.

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 11 How to inspect for engineering integrity: cracking or fissuring

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| **Cracking or fissuring** | Details follow |
| Undermining or scour | Appendix 12 |

Mainly applicable to **linear defences:** embankments, walls, defence – high ground

Less often but also applicable to **coastal defences:** beaches, dunes, promenades, cliffs

## A.11.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the stability of an asset or may lead to future problems. This appendix describes:

- how to identify problems that may arise from cracks or fissures which are visible in the vicinity of assets
- whether the issue should be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.11.2 What to look for during a tier 1 inspection

During an inspection, there may be evidence of cracks or fissuring. Where these features are accompanied by slips or steps in a slope, reference should be made to Appendix 3 which covers slope instability issues.

The following features may be observed and may prompt an alert to trigger further inspections or investigations:

- Cracks may be evidence of movement of a structure or in the case of an embankment of cohesive soil, of rapid shrinkage, during dry periods.

- Cracks will usually be along the length of a linear flood defence.
- The severity of any effects from cracking or fissuring will be dependent on the size. A crack that is more than 10 cm deep can be regarded as significant.
- Fissures are less obvious, but may be seen as a matrix of smaller cracks when vegetation has been cropped.

Typical evidence is shown in Figure A.11.1.

| | |
|---|---|
|  |  |
| A longitudinal crack in a bank which could be the first signs of a major slip. This would merit an amber alert which could become an urgent (red) issue if the embankment is narrow and in an area where properties are at risk (high or medium consequence). | Full length vertical crack in masonry wall. No deformation but structurally unsound. Should merit an amber alert. |
|  |  |
| A horizontal crack 1 m from the landward face. The main flood defence is CG 1. This could be evidence of movement landward or towards the river or it could be evidence of problems in laying the tarmac and its formation. This should prompt an amber alert. | A similar situation on a narrow berm protecting a gravity wall. |
| | |

Cracks in walls which should give rise to an alert, (they could threaten structural integrity) which should prompt a further inspection involving specialists.

**Figure A.11.1 Typical evidence of cracking or fissuring**

## A.11.3 Alerts to a possible problem from tier 1 inspection

Table A.11.1 lists questions for use in in a tier 1 inspection by personnel without any geotechnical experience to test whether an alert should be raised. The indicators described in section A.11.2 should also be used.

**Table A.11.1 Possible questions applicable to a tier 1 inspection relating to cracking or fissuring**

| Question no. | Evidence of cracking or fissuring | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of cracks or fissures that might be affecting (or could affect in the future) the ability of an asset to perform its intended role? | Move to Q2 | No alert |
| Q2 | • Are the cracks more than 10 cm deep **or**<br>• present over 10% of the length of the asset **or**<br>• allowing a loss of fine material through the cracks **or**<br>• appear likely to threaten the stability of an asset? | Move to Q3 | No alert |
| Q3 | • Are the cracks more than 10 cm deep **and** present over 10% of the length of the asset? **or**<br>• is there a loss of fine material through the cracks? **or**<br>• does the crack suggest movement will take place which could threaten the stability of the asset? | Raise red alert and continue to monitor | Raise amber alert of a cracking and fissuring issue and continue to monitor |

## A.11.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert** from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses.

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations
- **Further investigations –** the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations

Specialists should decide what further action (if any) may be required:

- Is the crack evidence of the start of movement or is it longstanding?
- Is the integrity of a flood defence asset at risk in the short or longer term?
- Are ground investigations to examine this in more detail needed?

The questions in Table A.11.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider more geotechnical details in deciding on next steps and whether ground investigations might be required (see Appendix 26).

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

# Appendix 12 How to inspect for engineering integrity: undermining or scour

| Engineering integrity issue | Where to find information |
|---|---|
| General guidance | Section 2.3.7 |
| Slope stability | Appendix 5 |
| Instability of structure | Appendix 6 |
| Leakage and piping | Appendix 7 |
| Backfill washout | Appendix 8 |
| Crest height degradation | Appendix 9 |
| Animal burrowing | Appendix 10 |
| Cracking or fissuring | Appendix 11 |
| **Undermining or scour** | Details follow |

Mainly applicable to:

- **linear defences:** embankments, walls, high ground, quays, floodgates, bridge abutments
- **coastal defences:** beach, dune, barrier beach, promenades, cliffs
- **beach structures:** breakwaters; structures and point assets: outfalls, weirs, spillways, stilling basins, jetties

## A.12.1 Introduction

As part of visual inspections, there is a need to identify engineering integrity issues that may be threatening the ability of an asset to perform as intended or may lead to future problems. This appendix describes:

- how to identify and report problems of undermining or scour
- how the issue can be escalated for further consideration by qualified staff

With help from this guidance, it is intended that a first alert may be raised from a tier 1 routine programmed inspection. It is not expected that the inspector will necessarily be in a position to decide on the extent of the problem and the risks it poses, but the first alert is an important step in managing assets safely and effectively.

## A.12.2 What to look for during a tier 1 inspection

Undermining or scour is usually as a result of high flows or wave action in flood or storm events. In severe cases, the asset itself will be destabilised by undermining of its foundations (see also Appendix 4).

During an inspection, there are a number of visual indicators that there has been undermining or scour. Evidence of these may lead to an alert for further investigation:

- signs of a lowered bed level adjacent or close to a structure – this will be easier to see at low water levels and in clear water; a stick or pole can be used to probe safely to confirm a suspicion
- a change in the flow pattern of water in the vicinity of a scour hole
- evidence of material from scour deposited in the vicinity of a hole
- evidence of scour above the water line, either as a result of loss of support from below or erosion at the higher level
- undermining or scour could occur in a storm or flood event and this is particularly relevant to coastal defences (see Appendix 15 for inspections following an event) – look for signs of reduced beach levels

Typical evidence is shown in Figure A.12.1.

| | |
|---|---|
|  |  |
| An obvious failure which will also be reflected in the condition grade from the inspection. In this case heavy wave action has undermined the revetment on the face of this sea defence. | Undercutting at a transition adjacent to a bridge abutment |

**Figure A.12.1 Typical evidence of undermining or scour**

## A.12.3 Alerts to a possible problem from tier 1 inspection

Table A.12.1 lists questions that can be used in a tier 1 inspection to test whether an alert should be raised of a possible undermining or scour issue. The indicators described in section A.12.2 should also be used.

**Table A.12.1 Possible questions applicable to a tier 1 inspection relating to undermining or scour**

| Question no. | Evidence of a crest degradation issue | Yes | No |
|---|---|---|---|
| Q1 | Is there evidence of undermining or scour which could affect an asset in the short or longer term or do you have suspicions that this might have occurred but is not visible? | Move to Q2 | No alert |
| Q2 | If this has been previously reported, has there been a change since the last inspection? | Move to Q3 | No new alert |
| Q3 | Do any of the following apply?<br>• Is the extent of the undermining or scour over a significant length of the asset?<br>• Is the hole created of a depth that may reduce the support to the asset, threatening its stability?<br>• Has the asset moved as a result of the hole?<br>• You have sufficient concerns even though the hole is not visible to determine its size and likely effect? | Raise red alert and continue to monitor | Raise amber alert of a possible issue as a result of undermining or scour and continue to monitor |

## A.12.4 Following a tier 1 red or amber alert

(Refer also to Figure 2.1 for general principles and Appendix 13 for a potential tool for recording the alerts, following decisions and triggers.)

The **alert**[11] from a tier 1 inspection, usually followed by a further site visit, is considered a performance and risk activity, which will **trigger** one of the following responses:

- **Remedial works –** the problem may be sufficiently obvious to justify remedial works within an agreed timescale
- **No further action** – the problem may not be considered serious enough in a risk-based assessment to justify further work or investigations

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[11] Evidence of undermining or scour is also likely to influence the condition grade as an output from the inspection, but it also may not yet be affecting the asset and the condition grade may not be affected. However, raising a specific engineering integrity alert is useful in highlighting particular problems which can be included in the inspection report package.

- **Further investigations –** the alert may trigger tier 2 or 3 further investigations by more detailed inspections or ground investigations (refer to Appendix 16, Appendix 20, Appendix 21 and Appendix 26 – the tier of follow-on inspection will be directed by the particular need)

The questions in Table A.12.1 also need to be asked in any follow-up tier 2 or 3 inspections using qualified staff. They will also consider structural stability, geotechnical and geomorphological factors in deciding on next steps and whether more detailed investigations might be required.

The red, amber or green flag should be used in reporting on engineering integrity issues in the post-inspection report.

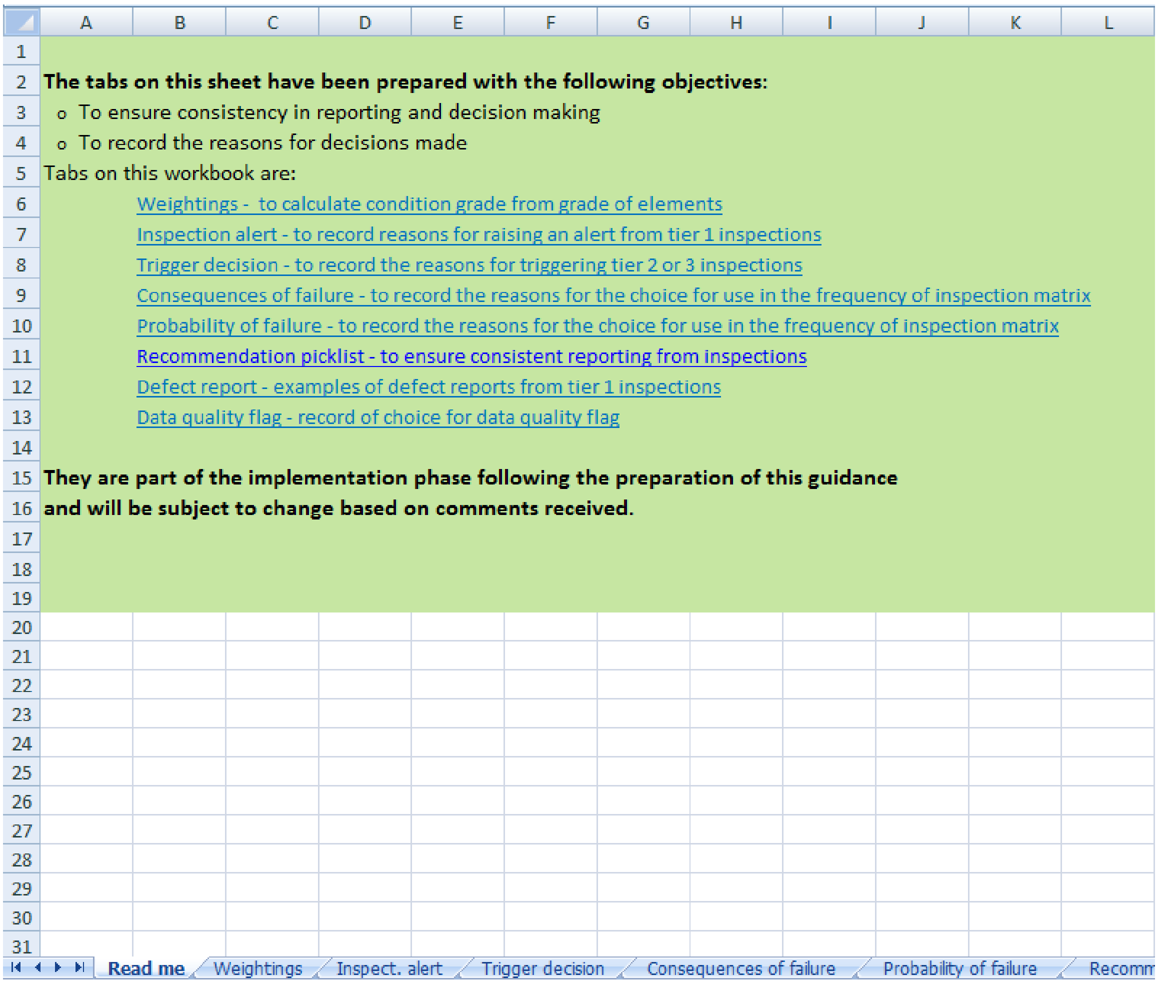
# Appendix 13 Consistent reporting and recommendations from inspections

To establish relative priorities and confidence in the asset management process, consistent reporting and decision making is essential. It is also important to be able to demonstrate how these decisions have been made for auditing reasons.

Embedded in this document is a prototype tool which could serve as a baseline model for developing a consistent interface between ‘inspection activities’ and ‘performance and risk activities’. The basis of this spreadsheet tool is a standardised series of picklists designed to bring consistency and direction to the actions following tier 1 inspections. Inspection activities are indicated by green headings and performance and risk activities by blue headings.

Decision audit
toolv1.xlsx

A series of screenshots of key elements of this tool follow in Figures A.13.1 to A.13.8.



**The tabs on this sheet have been prepared with the following objectives:**

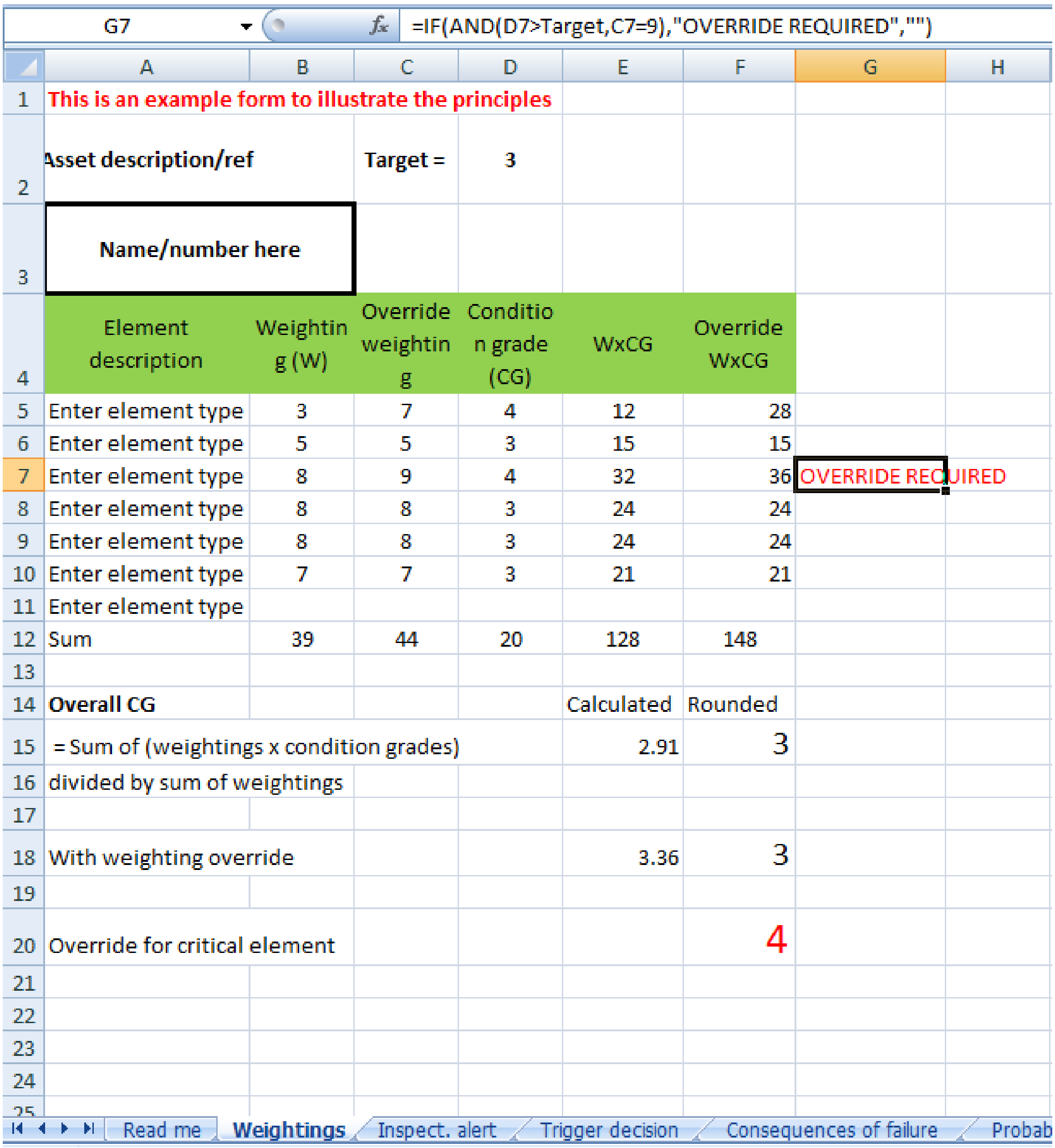
- To ensure consistency in reporting and decision making
- To record the reasons for decisions made

Tabs on this workbook are:

Weightings - to calculate condition grade from grade of elements
Inspection alert - to record reasons for raising an alert from tier 1 inspections
Trigger decision - to record the reasons for triggering tier 2 or 3 inspections
Consequences of failure - to record the reasons for the choice for use in the frequency of inspection matrix
Probability of failure - to record the reasons for the choice for use in the frequency of inspection matrix
Recommendation picklist - to ensure consistent reporting from inspections
Defect report - examples of defect reports from tier 1 inspections
Data quality flag - record of choice for data quality flag

**They are part of the implementation phase following the preparation of this guidance and will be subject to change based on comments received.**

**Figure A.13.1 Screenshot of ‘Read me’ tab**

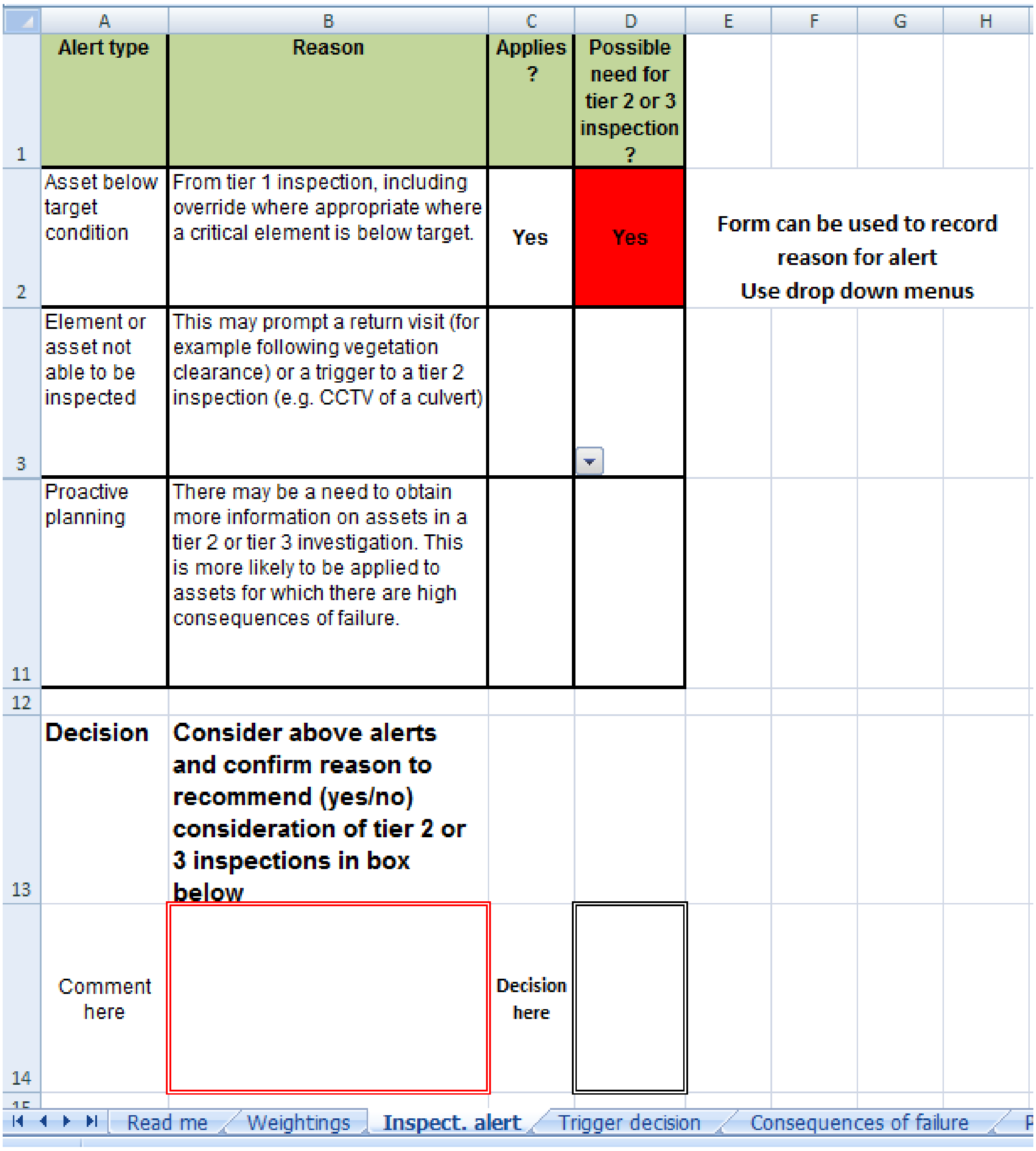


G7 =IF(AND(D7>Target,C7=9),"OVERRIDE REQUIRED","")

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | This is an example form to illustrate the principles | | | | | | | |
| 2 | Asset description/ref | | Target = | 3 | | | | |
| 3 | Name/number here | | | | | | | |
| 4 | Element description | Weighting (W) | Override weighting | Condition grade (CG) | WxCG | Override WxCG | | |
| 5 | Enter element type | 3 | 7 | 4 | 12 | 28 | | |
| 6 | Enter element type | 5 | 5 | 3 | 15 | 15 | | |
| 7 | Enter element type | 8 | 9 | 4 | 32 | 36 | OVERRIDE REQUIRED | |
| 8 | Enter element type | 8 | 8 | 3 | 24 | 24 | | |
| 9 | Enter element type | 8 | 8 | 3 | 24 | 24 | | |
| 10 | Enter element type | 7 | 7 | 3 | 21 | 21 | | |
| 11 | Enter element type | | | | | | | |
| 12 | Sum | 39 | 44 | 20 | 128 | 148 | | |
| 13 | | | | | | | | |
| 14 | Overall CG | | | | Calculated | Rounded | | |
| 15 | = Sum of (weightings x condition grades) | | | | 2.91 | 3 | | |
| 16 | divided by sum of weightings | | | | | | | |
| 17 | | | | | | | | |
| 18 | With weighting override | | | | 3.36 | 3 | | |
| 19 | | | | | | | | |
| 20 | Override for critical element | | | | | 4 | | |
| 21 | | | | | | | | |
| 22 | | | | | | | | |
| 23 | | | | | | | | |
| 24 | | | | | | | | |

**Figure A.13.2 Screenshot of 'Weightings' tab**

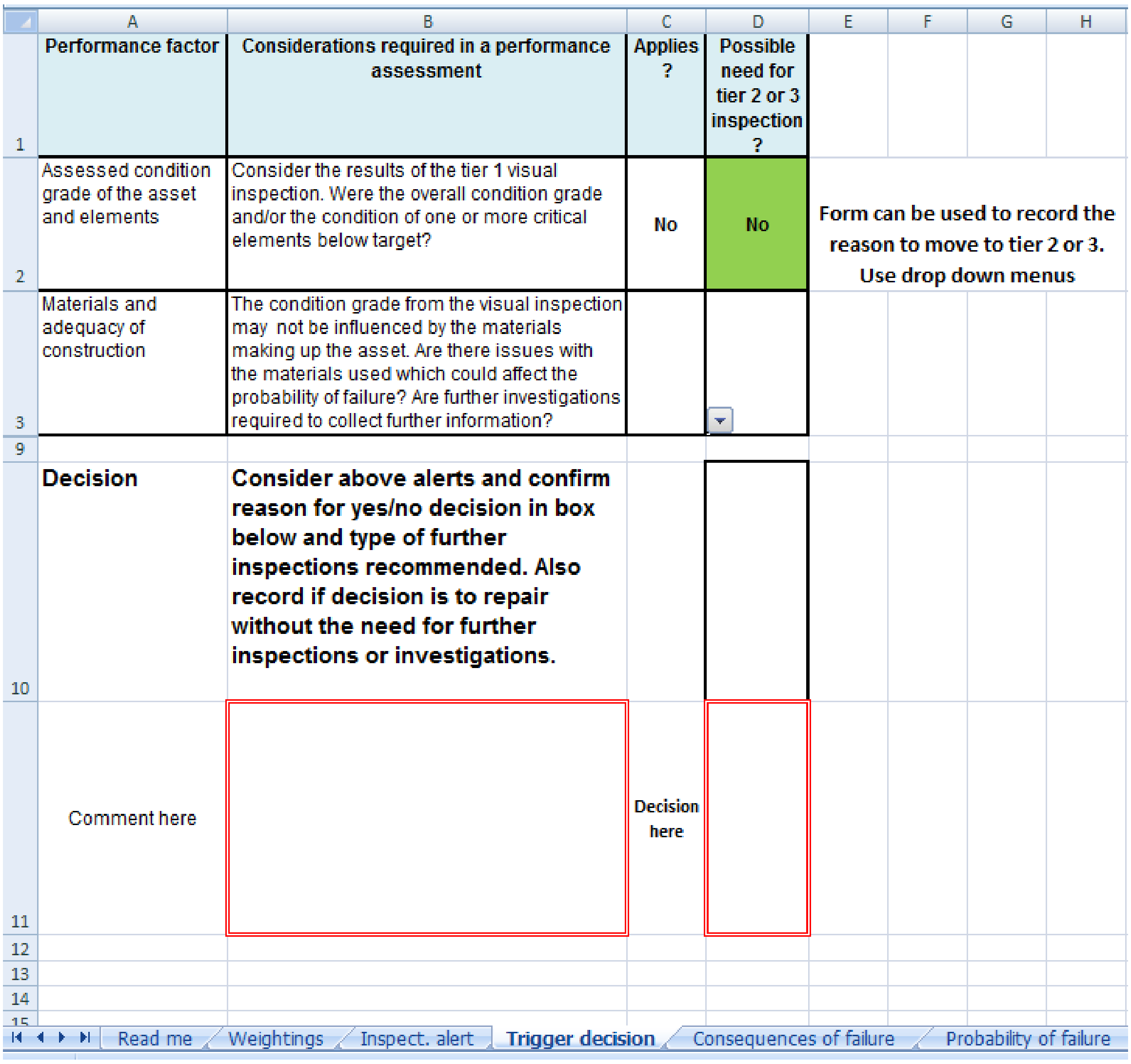
Note that the automatic override set up to ensure that key elements in poor condition can raise an alert even if the average condition score does not.



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Alert type** | **Reason** | **Applies ?** | **Possible need for tier 2 or 3 inspection ?** | | | | |
| 2 | Asset below target condition | From tier 1 inspection, including override where appropriate where a critical element is below target. | **Yes** | 🟥 **Yes** | **Form can be used to record reason for alert**<br>**Use drop down menus** | | | |
| 3 | Element or asset not able to be inspected | This may prompt a return visit (for example following vegetation clearance) or a trigger to a tier 2 inspection (e.g. CCTV of a culvert) | | ▾ | | | | |
| 11 | Proactive planning | There may be a need to obtain more information on assets in a tier 2 or tier 3 investigation. This is more likely to be applied to assets for which there are high consequences of failure. | | | | | | |
| 12 | | | | | | | | |
| 13 | **Decision** | **Consider above alerts and confirm reason to recommend (yes/no) consideration of tier 2 or 3 inspections in box below** | | | | | | |
| 14 | Comment here | | **Decision here** | | | | | |

**Figure A.13.3 Screenshot of 'Inspect. alert' tab**

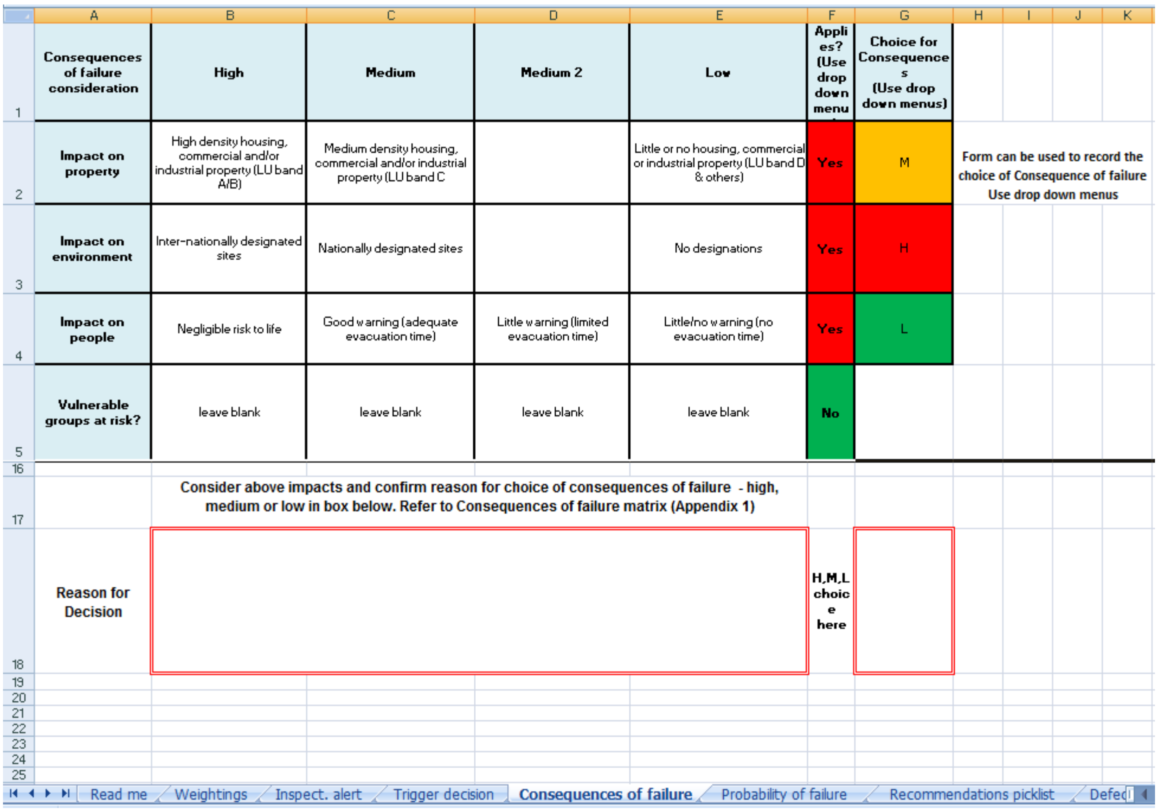
In the screenshot in Figure A.13.3, many of the alert types listed in column A have been hidden to allow the decision boxes below to be clear. Columns C and D are standard 'yes, no' answers. Any 'yes' should raise an alert.



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Performance factor** | **Considerations required in a performance assessment** | **Applies ?** | **Possible need for tier 2 or 3 inspection ?** | | | | |
| 2 | Assessed condition grade of the asset and elements | Consider the results of the tier 1 visual inspection. Were the overall condition grade and/or the condition of one or more critical elements below target? | **No** | **No** | **Form can be used to record the reason to move to tier 2 or 3. Use drop down menus** | | | |
| 3 | Materials and adequacy of construction | The condition grade from the visual inspection may not be influenced by the materials making up the asset. Are there issues with the materials used which could affect the probability of failure? Are further investigations required to collect further information? | | | | | | |
| 9 | | | | | | | | |
| 10 | **Decision** | **Consider above alerts and confirm reason for yes/no decision in box below and type of further inspections recommended. Also record if decision is to repair without the need for further inspections or investigations.** | | | | | | |
| 11 | Comment here | | **Decision here** | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |

**Figure A.13.4 Screenshot of 'Weightings' tab**

In the screenshot in Figure A.13.4, the list of performance factors has been truncated to be able to show the decision elements.



| Consequences of failure consideration | High | Medium | Medium 2 | Low | Applies? (Use drop down menu | Choice for Consequences (Use drop down menus) |
|---|---|---|---|---|---|---|
| Impact on property | High density housing, commercial and/or industrial property (LU band A/B) | Medium density housing, commercial and/or industrial property (LU band C | | Little or no housing, commercial or industrial property (LU band D & others) | Yes | M |
| Impact on environment | Inter-nationally designated sites | Nationally designated sites | | No designations | Yes | H |
| Impact on people | Negligible risk to life | Good warning (adequate evacuation time) | Little warning (limited evacuation time) | Little/no warning (no evacuation time) | Yes | L |
| Vulnerable groups at risk? | leave blank | leave blank | leave blank | leave blank | No | |

Form can be used to record the choice of Consequence of failure
Use drop down menus

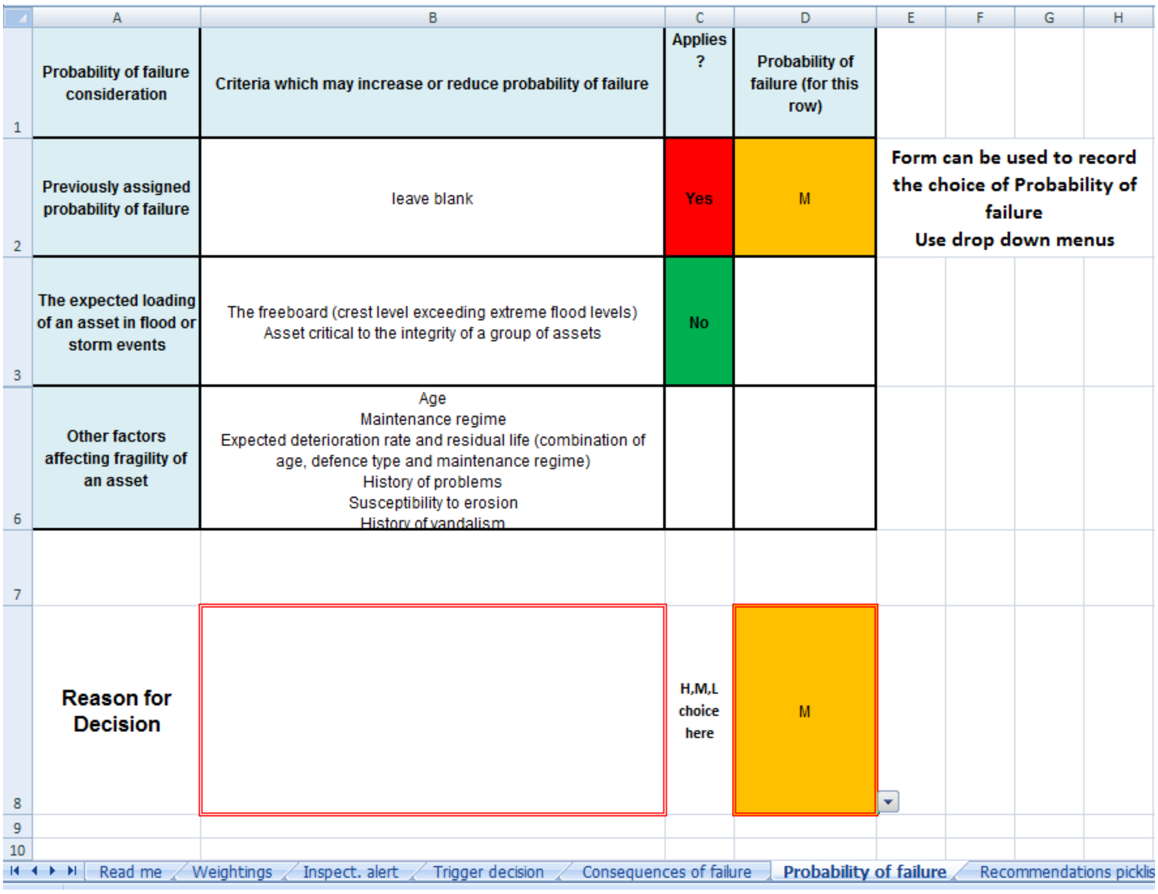
Consider above impacts and confirm reason for choice of consequences of failure - high, medium or low in box below. Refer to Consequences of failure matrix (Appendix 1)

Reason for Decision

H,M,L choice here

**Figure A.13.5 Screenshot of ‘Consequences of failure’ tab**

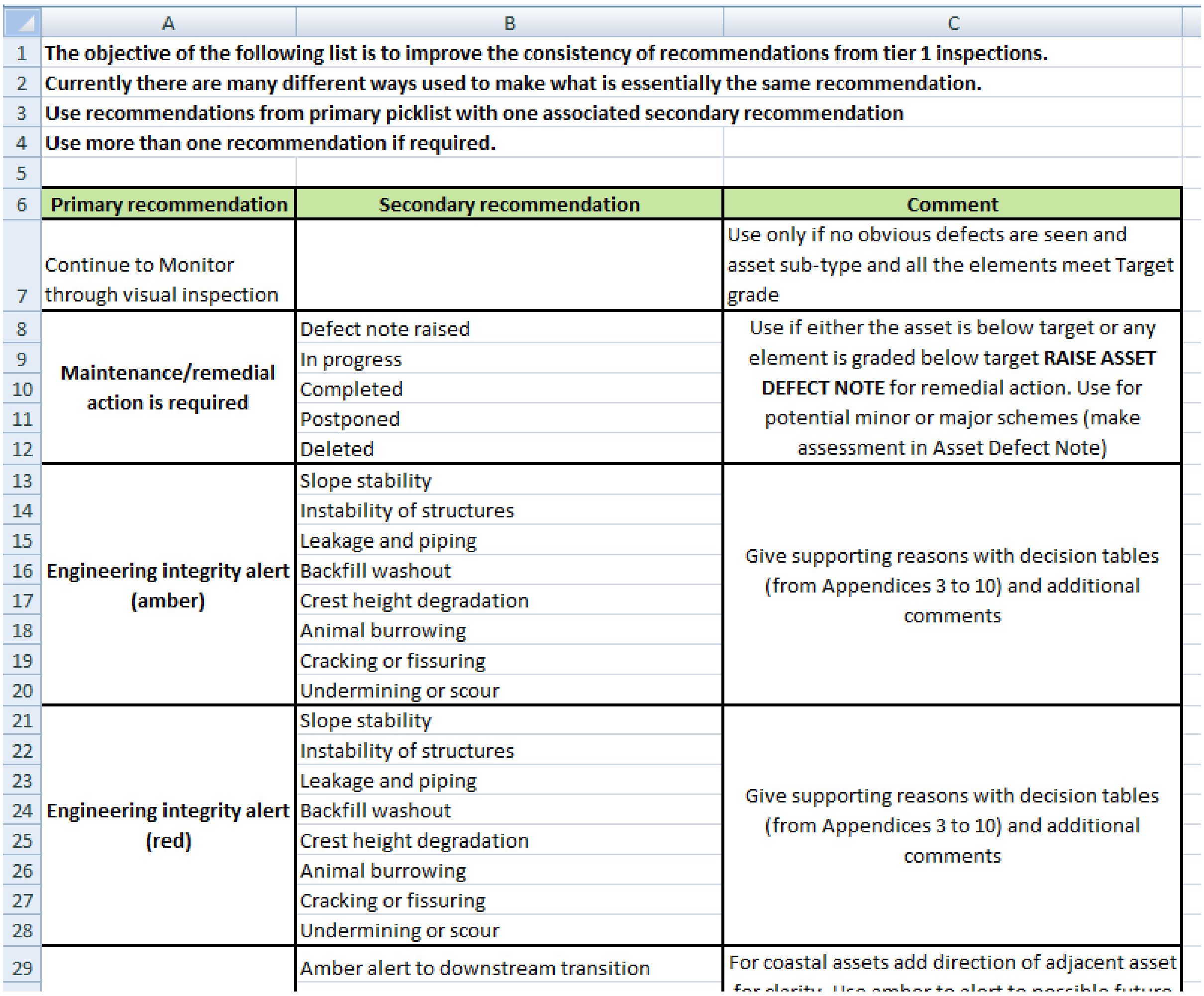
In the screenshots in Figures A.13.5, the list of consequences has been truncated to be able to show the decision elements.



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Probability of failure consideration** | **Criteria which may increase or reduce probability of failure** | **Applies ?** | **Probability of failure (for this row)** | | | | |
| 2 | **Previously assigned probability of failure** | leave blank | Yes | M | **Form can be used to record the choice of Probability of failure**<br>**Use drop down menus** | | | |
| 3 | **The expected loading of an asset in flood or storm events** | The freeboard (crest level exceeding extreme flood levels)<br>Asset critical to the integrity of a group of assets | No | | | | | |
| 6 | **Other factors affecting fragility of an asset** | Age<br>Maintenance regime<br>Expected deterioration rate and residual life (combination of age, defence type and maintenance regime)<br>History of problems<br>Susceptibility to erosion<br>History of vandalism | | | | | | |
| 7 | | | | | | | | |
| 8 | **Reason for Decision** | | **H,M,L choice here** | M | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

**Figure A.13.6 Screenshot of ‘Probability of failure’ tab**

In the screenshot in Figure A.13.6, the list of considerations has been truncated to be able to show the decision elements.

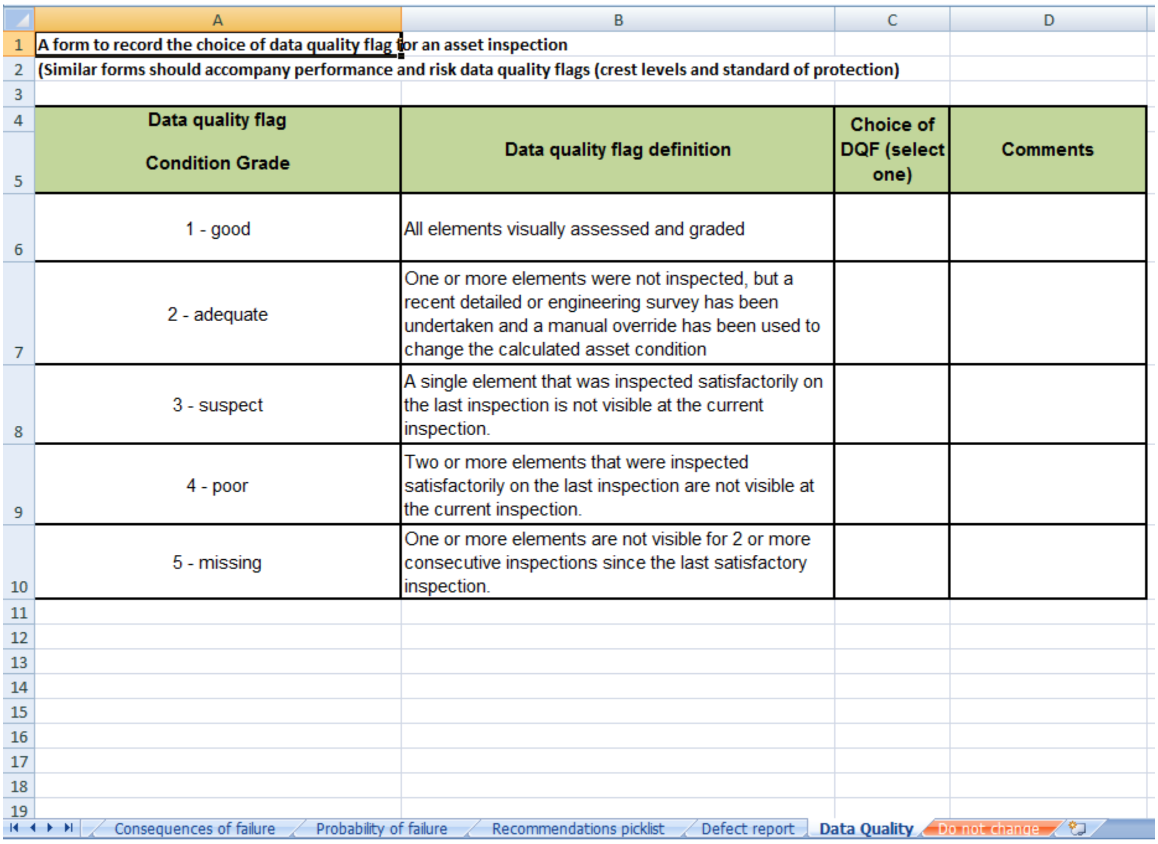


|  | A | B | C |
|---|---|---|---|
| 1 | **The objective of the following list is to improve the consistency of recommendations from tier 1 inspections.** |  |  |
| 2 | **Currently there are many different ways used to make what is essentially the same recommendation.** |  |  |
| 3 | **Use recommendations from primary picklist with one associated secondary recommendation** |  |  |
| 4 | **Use more than one recommendation if required.** |  |  |
| 5 |  |  |  |
| 6 | **Primary recommendation** | **Secondary recommendation** | **Comment** |
| 7 | Continue to Monitor through visual inspection |  | Use only if no obvious defects are seen and asset sub-type and all the elements meet Target grade |
| 8 | **Maintenance/remedial action is required** | Defect note raised | Use if either the asset is below target or any element is graded below target **RAISE ASSET DEFECT NOTE** for remedial action. Use for potential minor or major schemes (make assessment in Asset Defect Note) |
| 9 |  | In progress |  |
| 10 |  | Completed |  |
| 11 |  | Postponed |  |
| 12 |  | Deleted |  |
| 13 | **Engineering integrity alert (amber)** | Slope stability | Give supporting reasons with decision tables (from Appendices 3 to 10) and additional comments |
| 14 |  | Instability of structures |  |
| 15 |  | Leakage and piping |  |
| 16 |  | Backfill washout |  |
| 17 |  | Crest height degradation |  |
| 18 |  | Animal burrowing |  |
| 19 |  | Cracking or fissuring |  |
| 20 |  | Undermining or scour |  |
| 21 | **Engineering integrity alert (red)** | Slope stability | Give supporting reasons with decision tables (from Appendices 3 to 10) and additional comments |
| 22 |  | Instability of structures |  |
| 23 |  | Leakage and piping |  |
| 24 |  | Backfill washout |  |
| 25 |  | Crest height degradation |  |
| 26 |  | Animal burrowing |  |
| 27 |  | Cracking or fissuring |  |
| 28 |  | Undermining or scour |  |
| 29 |  | Amber alert to downstream transition | For coastal assets add direction of adjacent asset |

**Figure A.13.7 Screenshot of ‘Recommendations picklist’ tab**

Figure A.13.7 only shows an example. There are many more standard recommendations on this list.

Working through the various sheets of the workbook will allow the user to complete an asset defect report form. Possible suitable examples (not shown here) are provided in the embedded spreadsheet.



**A form to record the choice of data quality flag for an asset inspection**

**(Similar forms should accompany performance and risk data quality flags (crest levels and standard of protection)**

| **Data quality flag**<br>**Condition Grade** | **Data quality flag definition** | **Choice of DQF (select one)** | **Comments** |
|---|---|---|---|
| 1 - good | All elements visually assessed and graded | | |
| 2 - adequate | One or more elements were not inspected, but a recent detailed or engineering survey has been undertaken and a manual override has been used to change the calculated asset condition | | |
| 3 - suspect | A single element that was inspected satisfactorily on the last inspection is not visible at the current inspection. | | |
| 4 - poor | Two or more elements that were inspected satisfactorily on the last inspection are not visible at the current inspection. | | |
| 5 - missing | One or more elements are not visible for 2 or more consecutive inspections since the last satisfactory inspection. | | |

**Figure A.13.8 Screenshot of ‘Data Quality’ tab**

Finally the importance of understanding the quality of the data and ensuring this is reflected in the decision making is recorded in the ‘Data Quality’ Tab (Figure A.13.8). This should be updated as the industry moves away from data quality flags. See section 2.3.4 and Appendix 4 for further details.

# Appendix 14 Tier 2 inspections: expert site inspections where asset is below target

## A.14.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| **Condition grade below target** | | Details follow |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.14.2 Why?

| Alert detail from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| An alert will be prompted when the condition grade is below the required condition. Note: this does not automatically trigger tier 2 or 3 inspections – the need will be decided considering performance issues. | To assist in assessing the consequences of further deterioration or failure of the asset and next steps (repair timescale or further investigation) | To address the need for further investigations (in this table or tier 3) and urgency of any remedial action |

## A14.3 Typical requirements

It will be necessary to revisit the site to help identify what further steps are needed – this may be the first step in tier 2 process to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

In the case of a condition grade falling below the target condition, the inspector who completed the inspection should revisit the site with a technical specialist.

In some cases the site visit may not be needed, but this should only apply in cases where photographic or other evidence from the inspection is clear enough to determine:

- that the asset should be repaired
- the type of tier 2 or 3 inspection required
- that no further action is necessary (for example, in view of the expected performance of the asset)

## A.14.4 Preparing for the inspection

It is important to prepare for an expert’s visit by ensuring the following.

- The reason for the assessment of a below target condition grade is clear from the grading of elements, photographic evidence and so on.
- An appropriate technical specialist will attend; who that is will depend on the issues that have resulted in the failure. Someone involved in the operation of the asset may also be required.
- There is a good understanding of the expected performance of the asset, both in relation to other assets in the system and in terms of crest level compared with extreme flood levels for example.
- There is a good understanding of the consequences of asset failure.
- The results of previous inspections are on hand to show how condition has changed over time.

## A.14.5 Typical methods

There are no particular methods involved, but the following approach is recommended.

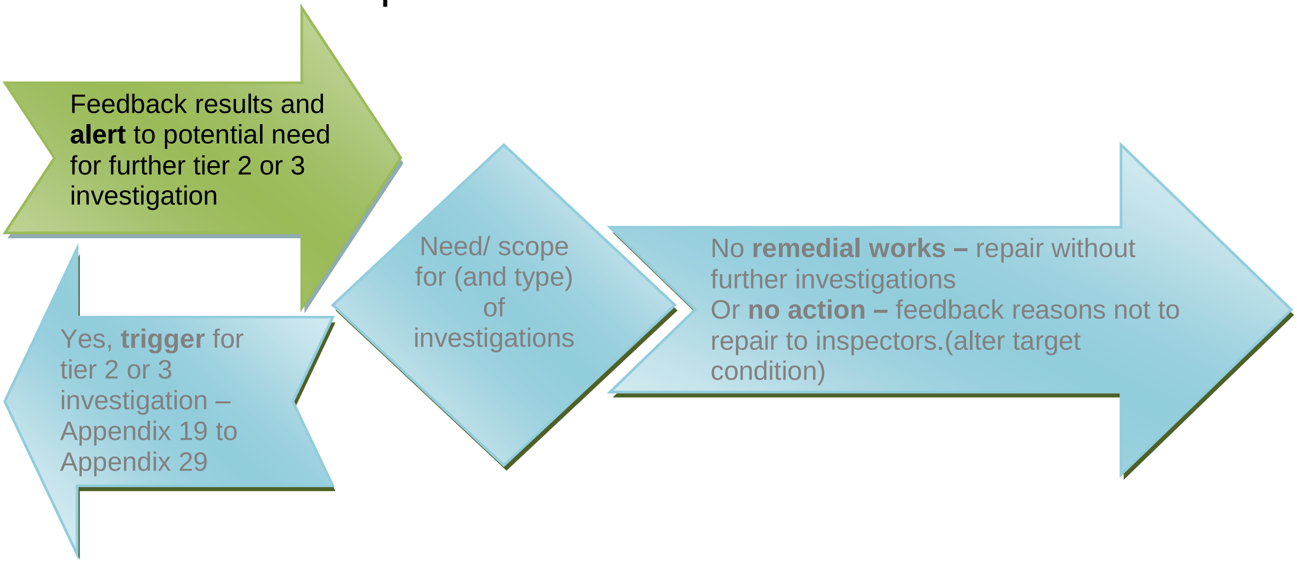
- The inspector should explain how the condition grade of elements has been scored and how the overall grade of the asset has been assessed.
- Experts in attendance should point out any reasons whether or not the asset should be scored differently, including the weightings given to each element.
- The options of repair, further investigations or no further action should be discussed and explained.

## A.14.6 Reporting

There should be a record of the visit and agreed actions.

The decision to trigger further tier 2 or tier 3 inspections should be recorded. A recommended form entitled ‘Trigger decision’ is included for that purpose in the spreadsheet tool embedded in Appendix 13.

## A.14.7 Next step



# Appendix 15 Tier 2 inspections: follow up to elements not inspected

## A.15.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| **Unable to assess overall condition grade of asset** | | Details follow |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.15.2 Why?

| Alert detail from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Unable to assess overall condition grade of asset | Not usually applicable (inspection alert applies) | To make arrangements to allow elements to be inspected |

## A.15.3 Typical requirements

A follow-up visit is required to complete the inspection when it is not possible on the previous visit to do this due to element(s) not inspected (ENI).

It will be necessary to revisit the site to help identify what further steps are needed – this may be the first step in tier 2 process to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

## A.15.4 Preparing for the inspection

The reason for the failure to inspect elements should be made clear. Preparation in advance will depend on the nature of the problem on site. The objective of the planning is to allow the unseen elements to be inspected. As a minimum, a risk assessment should be completed before going to the site.

Reference should be made to section 2.3.5.

## A.15.5 Typical methods

The methods will depend on the reasons for not being able to complete the inspection on the first visit and should be tailored to maximise the likelihood of completing the survey on a second visit. This may be the first step after a tier 1 alert to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

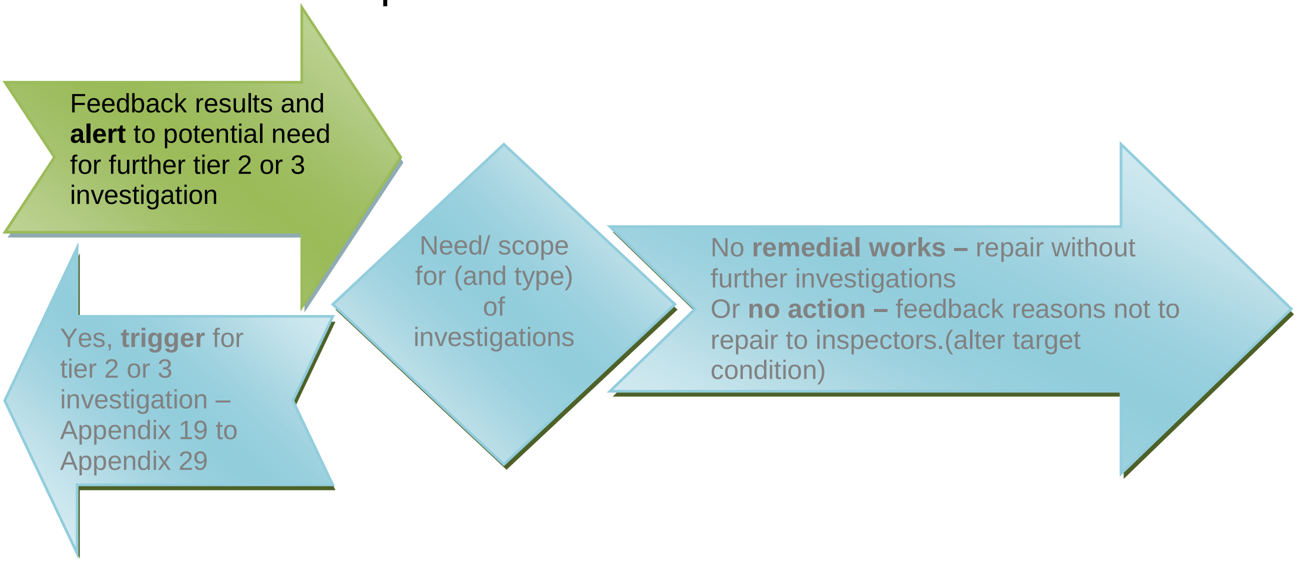
Possible questions to consider include:

- Would an additional person on site allow the elements to be inspected?
- Was vegetation or debris obscuring the element? Could this be cleared in advance of the follow-up visit?
- Is a ladder required to access the element(s) and can this be used safely?
- Is confined space access required?
- Were weather conditions a problem or were river or tide levels high? Would reprogramming of the inspection overcome this issue?
- Is boat access required and can arrangements be made to undertake this safely?
- Were there problems in accessing the site, including the hostile register, dog or other animal risks? Can these be overcome?

## A.15.6 Reporting

Recording should be completed as normal following a successful inspection. A second or third failure to inspect should raise a data quality alert (see section 2.3.4 and Appendix 4).

## A.15.7 Next step



Feedback results and **alert** to potential need for further tier 2 or 3 investigation

Need/ scope for (and type) of investigations

Yes, **trigger** for tier 2 or 3 investigation – Appendix 19 to Appendix 29

No **remedial works –** repair without further investigations
Or **no action –** feedback reasons not to repair to inspectors.(alter target condition)

# Appendix 16 Tier 2 inspections: follow-up inspection after engineering integrity alert

## A.16.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| **Engineering integrity issue** | | Details follow |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.16.2 Why?

| Alert detail from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| A tier 1 inspection may include a recommendation to investigate a possible engineering integrity issue | Following an alert, a further inspection will be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment will be required to inform further action | To determine whether the concern justifies further action and what type of investigations would be required |

## A.16.3 Typical requirements

It is necessary to revisit the site following an alert to an engineering integrity issue affecting one or more assets. The inspector who made the first inspection should revisit the site with a technical specialist – this may be the first step in the tier 2 process to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

In some cases the site visit may not be required, but this should only apply in cases where the photographic or other evidence from the inspection is clear enough to determine which of the above steps apply.

If further tier 2 or 3 inspections are required, a site visit will be required to plan for that inspection.

## A.16.4 Preparing for the inspection

It is important to prepare for the visit by ensuring the following.

- The reason for the engineering integrity alert is clear. Completing the tables in each of Appendices 3 to 10 giving a red/amber/green flag will be useful in recording the process. Photographs should also be available.
- An appropriate technical specialist will attend; who that is will depend on the issues that have resulted in the alert (for example, structural or geotechnical expertise may be required). Someone involved in the operation and maintenance of the asset may also be required.
- There is a good understanding of the expected performance of the asset, both in relation to other assets in the system and in terms of crest level compared with extreme flood levels for example.
- There is a good understanding of the consequences of asset failure.
- The results of previous inspections are on hand to show how conditions have changed over time.
- A full risk assessment is completed and recorded. The engineering integrity issue identified should be considered in this.

## A.16.5 Typical methods

Appendix 5 to Appendix 12 set out the issues which will affect how the engineering alert should be dealt with.

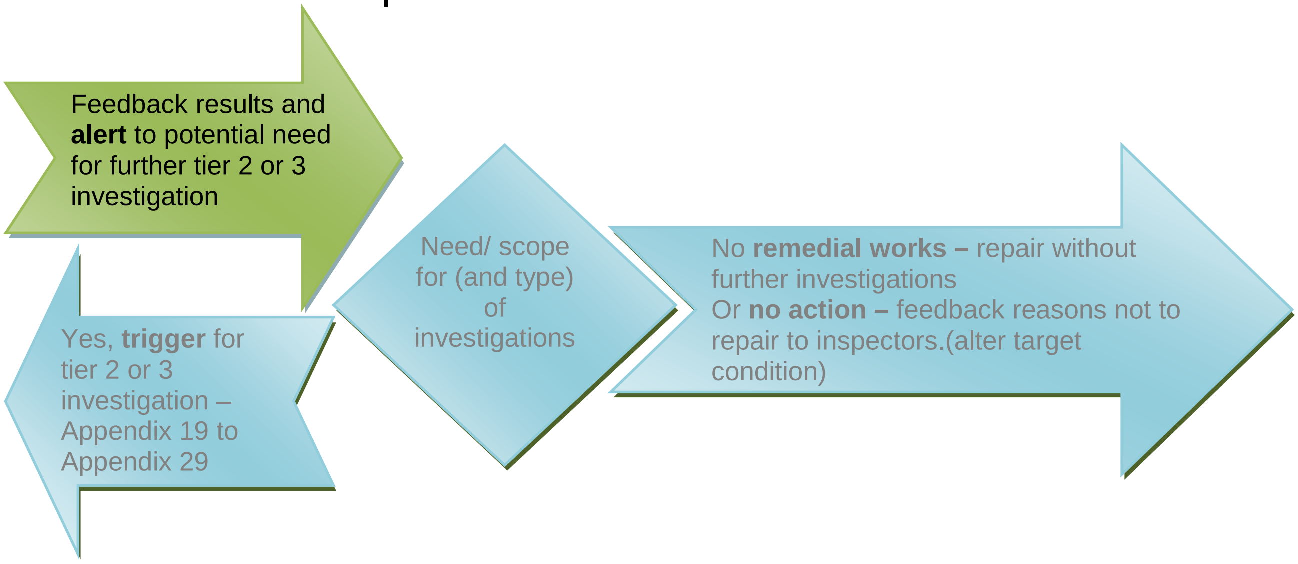
- The inspector should gain experience from this visit and this will improve the accuracy and confidence in raising engineering integrity alerts.
- Specialists in attendance should explain the likely reasons for the problems with the asset and how they have assessed how the issue should be dealt with.
- The options of repair, further investigations or no further action should be discussed and explained.

## A.16.6 Reporting

There should be a record of the visit and agreed actions.

The decision to trigger further tier 2 or tier 3 inspections should be recorded. A recommended form entitled ‘Trigger decision’ is included for that purpose in the spreadsheet tool embedded in Appendix 13.

## A.16.7 Next step



# Appendix 17 Tier 2 inspections: following flood events or other concerns

## A.17.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| **Alerts outside the normal programme of inspections** | | Details follow |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.17.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Usually alerts from outside the normal programme of inspections | Following an alert, a further inspection may be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment may be required to inform further action<br>Further investigations may also be required to gather information from flood or storm events to help in | To determine whether any concerns justify further action and what type of investigations would be required |

|  |  |
|---|---|
|  | proactive planning of future interventions. |

## A.17.3 Typical requirements

Following a flood or storm event (that is, loading), it is necessary to assess how a flood and/or coastal defence system has performed. This also applies following feedback from the public or organisations that a system has not performed as expected. This may be the first step in tier 2 process to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

The objective should be to collect as much information as possible to serve a number of purposes:

- to identify any weaknesses or problems which might have exacerbated the effects of the event or led to feedback (for example, low spots, blockages)
- to make any necessary improvements to flood maps
- to improve the data quality of the standard of protection quoted for a group of assets
- to determine whether any problems were consistent with the severity of the event and the design standard of protection
- to collect information on flooding mechanisms and flow routes
- to collect data to assist in future analyses of performance or for future projects

And as a preliminary view, to identify any improvements that could be effective to reduce risks in the future.

## A.17.4 Preparing for the inspection

It is important to prepare for the visit by ensuring the following.

- Any available information on the nature of the event or the complaint is absorbed prior to any site visit. This should include the event severity (rainfall, tides or waves) and any information on properties and so on affected. Photographs, videos (YouTube or other) or media sources may be available.
- Information has been collected on the involvement of emergency services, local authority and specialist groups.
- The team proposed to carry out any reconnaissance is appropriate and well briefed, with a clear idea of the information to be collected.
- In the case of a complaint, an appropriate technical specialist should attend; who that is depend on the issues that have resulted in the alert. These might be operational or involve hydraulic capacity for example. Someone involved in the operation and maintenance of the asset may also be required to attend.

- There is a good understanding of the expected performance of the asset, both in relation to other assets in the system and in terms of crest level compared with extreme flood levels for example.
- There is a good understanding of the consequences of asset failure.
- Maps are available on which to record flow routes, areas and properties affected and so on.

## A.17.5 Typical methods

Table A.17.1 lists the type of the data to be collected during the first and subsequent visits.

**Table A.17.1 Type of data to collect during a tier 2 inspection following a flood event or other concern**

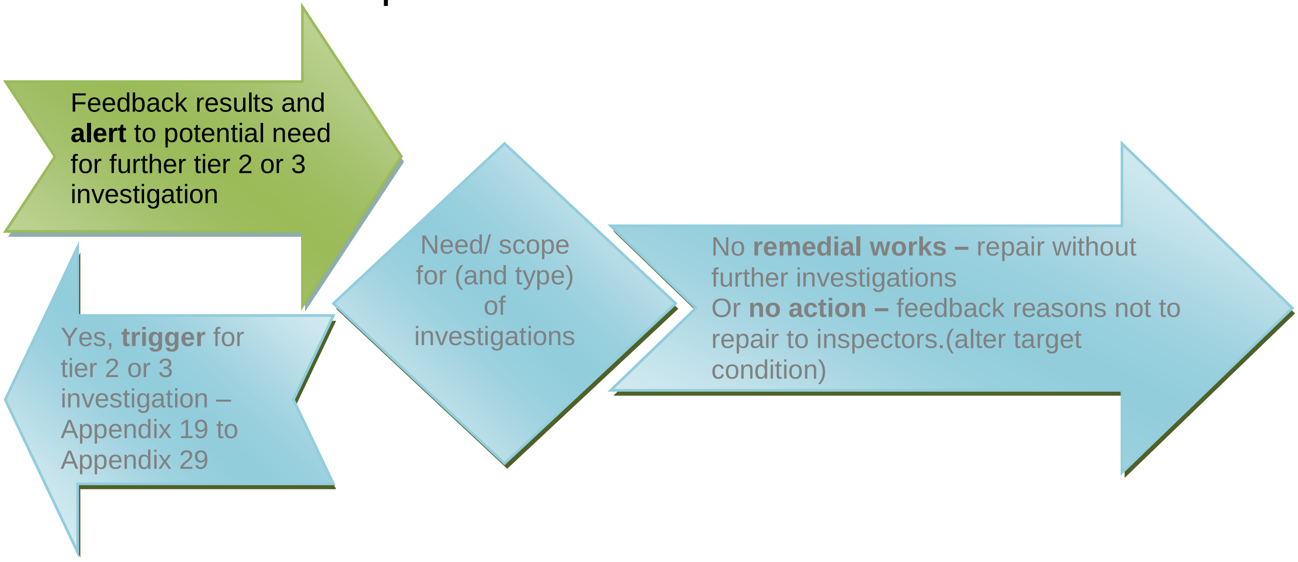
| Type of data to collect | Comments |
|---|---|
| Extent and timing of flooding, erosion and so on | Mark on maps. Record timing of event. |
| Properties and other infrastructure affected, depths, damages | First assessment of effect on receptors. Use mapping to record. Take contact details of residents for future reference.<br>Note ‘tide marks’ to assess flood levels in a follow-up survey. Residents may be somewhat confused immediately following an event. |
| Flood wrack marks | Record where these are for a future topographic survey to pick up. Aim to obtain a long profile for help in future modelling by also picking up peak levels upstream and downstream of affected area.<br>Use reliable wrack marks only and beware of the influence of bow waves from traffic driving through flood water, which might indicate higher levels. |
| Identify where there might be low spots in defences, blockage issues. | Also speak to local people to understand their perception. |
| Identify flow routes, sources and flood mechanisms. | Speak to residents who experienced the event. If there have been previous events, determine any differences. |
| Involvement of operational staff, deployment of sand bags | Record involvement of operational, risk management authorities and emergency services. |
| Data to understand the nature of a complaint | If reconnaissance is in response to a complaint rather than a particular event, data should be collected to fully understand the nature of the complaint. |
| Identify any recent changes which might have exacerbated flooding | Check for physical changes such as culverting, land raising and tipping on the floodplain. |

## A.17.6 Reporting

Reporting should be through the use of marked up maps and an inspection report detailing the data collected. A standard post-event proforma may be useful to prompt questions in completing the report.

It is essential that the findings from an inspection of this type are well documented. The information should be understandable and clear to anyone else picking up the maps and report in the future.

## A.17.7 Next step



# Appendix 18 Tier 2 inspections: observations of assets under load

## A.18.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| **Stability concern(all or part of asset)**<br>**Leakage concern (piping)**<br>**Observations post event/complaint (see above)** | Details follow | |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.18.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Where concerns have been raised:<br>• questions on the stability of the overall asset or elements<br>• alert to leakage issues (piping)<br>These are likely to be follow-up observations after a site visit to respond to an alert. | A trigger for more information from flood or storm events may arise as part of proactive planning for future improvements or to better understand an asset's role and performance to determine actions following concerns. | Where safety concerns can be overcome, to observe whether assets show signs of any movement under load or the extent of any leakage paths. Will also highlight low spots in defences. |

## A.18.3 Typical requirements

Inspection of assets under load can highlight issues, clarify deficiencies and add to the understanding of the way an asset performs as part of a system. This may be the first step in the tier 2 process to confirm the nature of the problem before further assessing the need and possibly progressing to a more targeted tier 2 or detailed tier 3 investigation.

The inspection could involve:

- measuring deflections or movement under load
- observing leakage or piping (see also Appendix 7)
- observing hydraulic losses or other features at structures such as adequacy of any protection and so on

## A.18.4 Preparing for inspections

### A.18.4.1 Timing

In most cases, the timing of an inspection will need to coincide with a time when the asset is under load. This will need to take into account:

- tide levels and wave heights
- river flows and levels
- presence of other imposed loads (traffic, maintenance plant and so on)
- safe access

### A.18.4.2 Location

The location for observing assets under load will need to take into account:

- assets to be inspected
- safe access to a location (with forecast conditions) which will not put observers at risk
- location where any required measurements can be taken and recorded (this may be easier if baseline survey points have been installed in advance)

## A.18.5 Typical methods

- Observations are usually recorded with photographs and video.
- Where there is a need to measure deflections and movement, the selected method must to allow relative movements to be measured.
- Observation of leakage must be related to the water levels driving the flow of water (tide or river).
- Low spots in flood defences are often easier to identify when water levels approach the crest of the defence.
- Overtopping or run up by high water levels and/or wave action can be observed from a safe vantage point. This should include recording of flow routes for any overtopping water.

- Erosion by river or tidal flows or wave action can be observed to confirm mechanisms.
- Structures in rivers can be observed to confirm whether head losses or turbulence are issues.
- Control gates can be observed to identify operational problems, vibration or leakage.
- Consider remote methods such as aerial photographs and LiDAR if an extensive area.

## A.18.6 Reporting

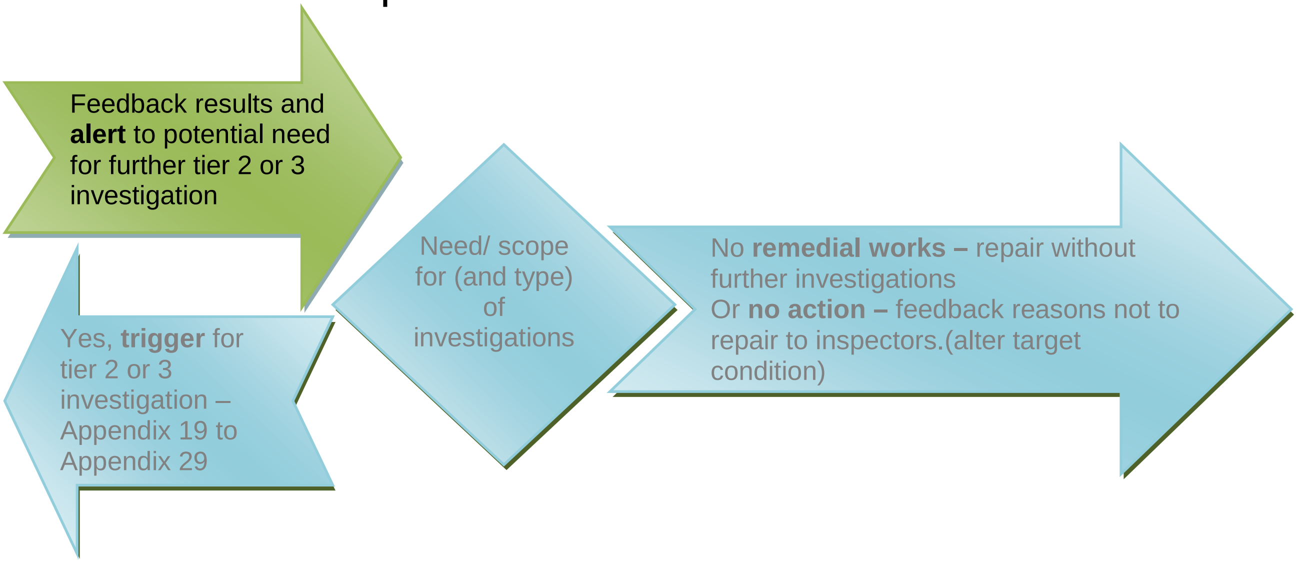
Preparation of a good quality report containing all observations from the inspection under load is important. Care should be taken to include:

- location and times of observations
- supporting information of river flows tide levels or wave action at the time of the observations

Such a document is particularly useful in terms of:

- consideration of short-term action including remedial measures
- information with which to calibrate hydraulic or coastal models
- informing the appraisal of improvement options through a capital project

## A.18.7 Next step



# Appendix 19 Tier 2 inspections: crest level surveys

## A.19.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| **Low spots** | | Details follow |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.19.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose of inspection |
|---|---|---|
| Concerns raised that there are low spots in defences | To determine the risk of defences being overtopped or breached.<br>To improve quality of data | To determine how flood defence levels compare with design water levels |

## A.19.3 Typical requirements

A tier 2 crest level survey is typically required to determine how flood defence levels compare with design water levels to determine the standard of protection or service provided by the defence. This might be alerted for one or more of the following reasons:

- concerns regarding low spots in defences, highlighted in a tier 1 inspection, operational report or actual or near miss overtopping in a recent event
- to monitor settlement, typically in embankments

- as part of proactive performance assessments for flood defence assets, including as inputs into hydraulic models (see also Appendix 20 on cross-section surveys)

The frequency of this type of tier 2 inspection will be determined through a risk-based approach and may be part of a structured programme. Frequency is not discussed in this appendix but is covered in section 2.3.1.

A short summary of the typical main features of crest level surveys is given below. **This is not intended to replace fuller guidance and procedures applicable to individual organisations.**

## A.19.4 Preparing for surveys

A risk assessment and a method statement should be prepared before carrying out the survey. Key issues to be addressed during the preparation of these documents are summarised in Table A.19.1.

**Table A.19.1 Issues to address during preparations for crest level survey**

| Issue | Comments/Actions |
|---|---|
| **Public liaison** | • Inform landowners, note any constraints, and obtain agreement. |
| **Details of asset** | • Type and condition of flood defence<br>• Existing survey control stations in the vicinity |
| **Access** | • Location of access points<br>• Water levels and flows – tidal and fluvial, response to rainfall<br>• Weather forecast |
| **Risks** | Site-specific, may include:<br>• working near water<br>• uneven ground conditions or vertical drops<br>• working in isolated areas<br>• adverse weather conditions<br>• hostile landowners and livestock |
| **Environmental safeguards** | • Any restrictions on when the survey can be undertaken<br>• Presence of invasive species<br>• Confirm whether any biosecurity arrangements are required. |
| **Emergency plan** | • Make arrangements for raising the alarm and safe evacuation of personnel in event of high water levels, personnel injury or illness. |
| **Datum requirements** | • A consistent level datum must be used for all related surveys and models. This must be stated clearly to avoid discrepancies between the crest levels and historic cross-sections used in hydraulic modelling. |
| **Information requirements** | • Level of detail required<br>• All topographic survey instruments must be calibrated or verified (as appropriate) in line with Royal Institute of Chartered Surveyors (RICS) guidelines (for example, *EDM Calibration*; ISBN 9781842193525) or industry standard practice if no published guidance is available. |

## A.19.5 Typical methods

Crest level surveys should be carried out by a topographic survey team (typically two operatives) with the appropriate skills, qualifications and experience. Some organisations may have internal capability for this; otherwise a number of specialist contractors operate in this field.

The ‘crest’ is defined as the level at which water will flow over a flood defence asset such as an embankment or wall to lower ground on the other side. The crest level is not always on the centre line of an embankment for example.

The crest level should be surveyed at:

- intervals to be specified, typically between 10 and 25 m, or less
- observed low spots, including localised low points for example, due to vehicle rutting or trampling by livestock
- changes in direction
- changes in gradient
- changes in construction type

A cross-section through the defence at 50 m centres is also useful.

It is also necessary to determine the location and details of any of the following:

- defects such as erosion or seepage
- features that could provide a pathway for water to flow past the defence such as outfalls, temporary flood barriers and stoplogs where these form part of the defence

Surveyed points should be accurate to 1 m or less in plan and 0.02 m root mean square error (RMSE) in height above Ordnance Datum Newlyn (ODN).

If required, new control stations should be established with the permission from the relevant landowner. Control stations – either temporary or permanent – should be established at a density of not less than one per km of watercourse.

Photographs should be taken as required to provide a representative view of the defence including all key features such as the specified points above. All structures should be photographed close up and from distance, looking both upstream and downstream. Vegetation should be cleared if necessary to provide an unobstructed view.

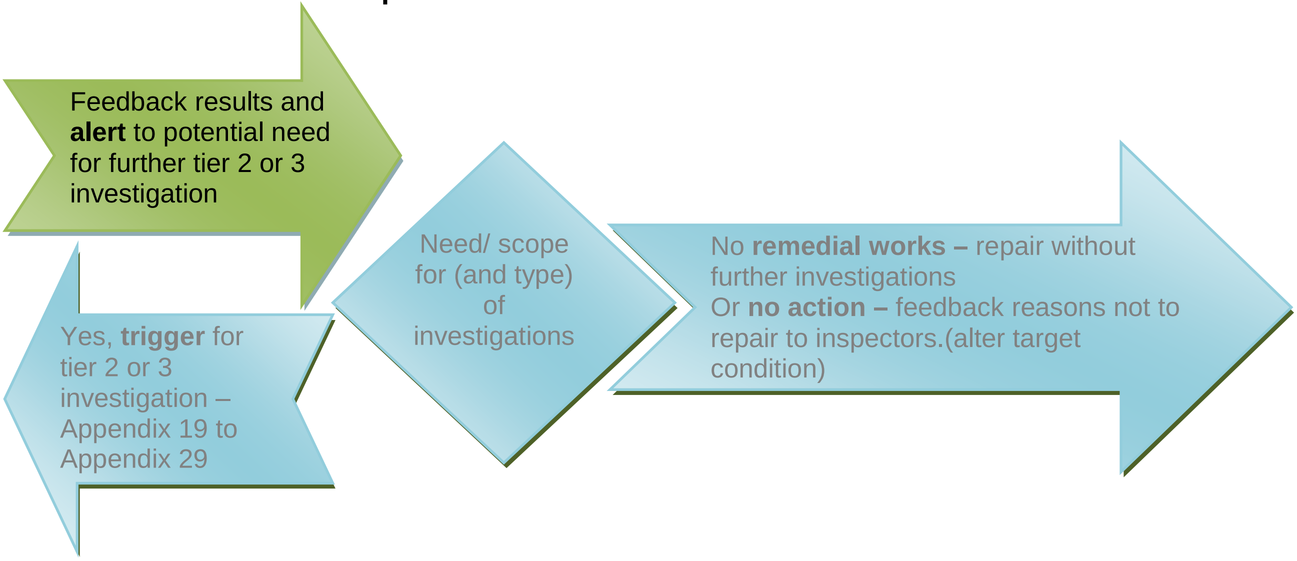
## A.19.6 Reporting

The written report should include the items listed in Table A.19.2.

### Table A.19.2 Recommended contents of written report following a crest level survey

| Item | Content |
|---|---|
| **Introduction** | • Purpose and extent of the survey<br>• Date carried out, prevailing weather condition and water level including state of tide if applicable |
| **Description** | • Location of defence<br>• Construction material, shape and dimensions of defence<br>Location and details of any:<br>• Changes in section/construction/direction<br>• Low spots<br>• Defects<br>• Evidence of animal activity affecting the crest level<br>Use of the asset (for example, cattle or machinery on an embankment):<br>• Vegetation |
| **Survey control and quality assurance** | • Description of the survey control utilised<br>• Full details of any permanent control stations established<br>• Relevant instrument calibration/verification certificates |
| **Photographic evidence** | • A minimum of three digital photographs of each end of the asset showing typical construction and any defects<br>• Supplementary photographs of key features and defects. |
| **Drawings** | Survey drawings in AutoCAD and PDF format |
| **Digital files** | Digital files should be consistent with import into the organisation's intended software for drawings, GIS or hydraulic models |

## A.19.7 Next step



Feedback results and **alert** to potential need for further tier 2 or 3 investigation

Need/ scope for (and type) of investigations

No **remedial works –** repair without further investigations
Or **no action –** feedback reasons not to repair to inspectors.(alter target condition)

Yes, **trigger** for tier 2 or 3 investigation – Appendix 19 to Appendix 29

# Appendix 20 Tier 2 inspections: cross-section surveys

## A.20.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target. | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| **Hydraulic conveyance is being adversely affected** | | Details follow |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.20.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Concerns that hydraulic conveyance is being adversely affected | To provide data for hydraulic models or conveyance estimation assessments | Typically to provide data for hydraulic models or to assess hydraulic effects of blockages or vegetation |

## A.20.3 Typical requirements

A cross-section survey may be required to:

- provide data for hydraulic modelling
- assess the stability of embankments, retaining walls and structures
- investigate erosion, undercutting or scour

If a large area is required to be surveyed and there is a reasonable depth of water and a hard bed, a bathymetric survey may be preferable.

The frequency of this type of tier 2 inspection will be determined through a risk-based approach and may be part of a structured programme. Frequency is not discussed in this appendix but is covered in section 2.3.1.

A short summary of the typical main features of cross-section surveys is given below. **This is not intended to replace fuller guidance and procedures applicable to individual organisations.**

## A.20.4 Preparing for surveys

A risk assessment and a method statement should be prepared before carrying out the survey. Key issues to be addressed during the preparation of these documents are summarised in Table A.20.1.

**Table A.20.1 Issues to address during preparations for cross-section survey**

| Issue | Comments/Actions |
|---|---|
| **Public liaison** | • Inform landowners, note any constraints, obtain agreement |
| **Details of asset** | • Type of flood defence, condition of defences<br>• Existing survey control stations in the vicinity |
| **Access** | • Location of access and egress points to banks and watercourse<br>• Depths of water and silt<br>• Water levels and flows – tidal and fluvial, response to rainfall<br>• Can the survey be undertaken by wading or is a boat required?<br>• Weather forecast |
| **Risks** | Site-specific, may include:<br>• working in and/or near water<br>• uneven ground conditions or vertical drops<br>• working in isolated areas<br>• adverse weather conditions<br>• hostile landowners or grazing animals<br>• waterborne diseases |
| **Environmental safeguards** | • Any restrictions on when the survey can be undertaken<br>• Presence of invasive species<br>• Confirm if any biosecurity arrangements are required. |
| **Emergency plan** | • Make arrangements for raising the alarm and safe evacuation of personnel in event of high water levels, personnel injury or illness. |
| **Datum requirements** | • It is essential that a consistent level datum is used for all related surveys and models. This will need to be stated clearly to avoid discrepancies with other local surveys. |
| **Information requirements** | • Level of detail required and spacing – this will depend on gradient of the river and the type of modelling required<br>• Requirements for survey of hard bed and silted layer<br>• Information required upstream and downstream of structures<br>• Define channel cross-section and width of flood plain required<br>• All survey instruments must be calibrated or verified (as appropriate) in line with Royal Institute of Chartered Surveyors (RICS) guidelines or industry standard practice. |

## A.20.5 Typical methods

Cross-section surveys should be carried out by a topographic survey team (typically two operatives) with appropriate skills, qualifications and experience. Some organisations may have internal capability for this; otherwise a number of specialist contractors operate in this field.

If a boat is required a third operative may be necessary to enable safe navigation of the boat in addition to carrying out the survey work.

All bed and water levels should be directly measured if possible. If this is not feasible they can be determined by calculation using a depth of water read by staff or echo sounder and a measured water level. If silt is present both soft and hard bed levels should be measured.

A temporary wooden peg should be established on the bank at the location of each cross-section.

Cross-sections should be surveyed:

- viewed downstream
- perpendicular to the centre line of the watercourse (where this is not possible, mark this clearly on the drawings with an angle from the perpendicular)
- with points located to accurately depict the shape of the channel
- from the channel to the true land level on each side and at least 10 m beyond the bank top or vegetation lining the channel, unless specified otherwise
- at no more than the specified maximum interval spacing, and at specific points as marked up on a survey plan
- providing a full elevation of the upstream face of any permanent bridge including full details of openings and flood arches, and key dimensions of the downstream face – where the downstream section is significantly different to the upstream section, the full section should be surveyed
- upstream and downstream of all permanent structures or natural features which will significantly affect the river flow at bankfull condition
- including a long section through any weir structure
- at locations where the width of the watercourse changes significantly

Any flood defences should be surveyed as a separate string to facilitate hydraulic modelling of the watercourse with and without flood defences.

Open channel sections should be accurate to ±0.1 m in height above ODN or better, allowing for 0.2 m of movement along the section line. Structure details should be accurate to ±0.04 m in height above ODN or better allowing for 0.04 m of movement along the section line.

Sections should include any details of vegetation and permanent features (for example, buildings, walls) with these clearly marked on any drawings.

If the intention is to use the cross-section data in combination with LiDAR data then a string of levels should be included along a hard surface (for example, road or playing field) to allow calibration of the LiDAR data.

Photographs should be taken at each cross-section, looking across the watercourse, upstream and downstream. All structures should be photographed close up and from distance, looking both upstream and downstream. Vegetation should be cleared if necessary to provide an unobstructed view.

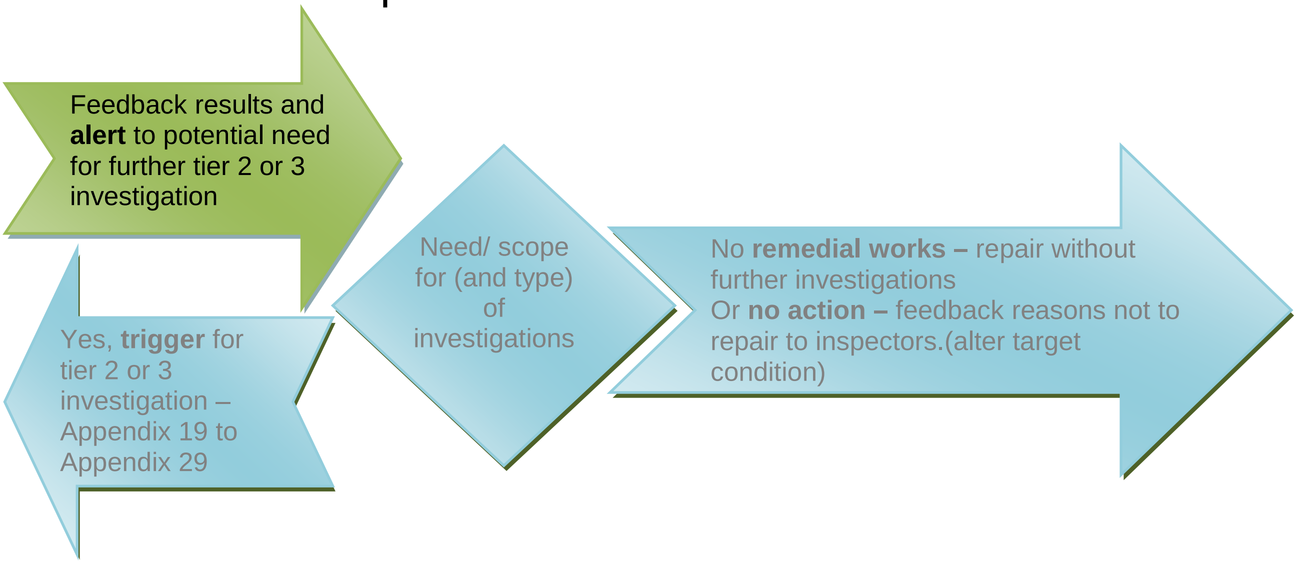
## A.20.6 Reporting

The written report should include the items listed in Table A.20.2.

**Table A.20.2 Recommended contents of written report following a cross-section survey**

| Item | Content |
|---|---|
| **Introduction** | • Purpose and extent of the survey<br>• Date carried out, prevailing weather condition and water level including state of tide if applicable |
| **Survey control and quality assurance** | • Description of the survey control utilised<br>• Full details of any permanent control stations established<br>• Relevant instrument calibration/verification certificates |
| **Photographic evidence** | • A minimum of three labelled digital photographs from each cross-section<br>• A minimum of three digital photographs of each end of structures showing typical construction and any defects<br>• Supplementary photographs of key features and defects. |
| **Drawings** | • Survey drawings in CAD and pdf format |
| **Digital files** | • Digital files should be consistent with import into the organisation's intended software for drawings, GIS or hydraulic models |

## A.20.7 Next step



# Appendix 21 Tier 2 inspections: beach and dune surveys

## A.21.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| **Beach levels lowered/exposed sea defences, dune erosion** | | Details follow |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.21.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Concerns that beach levels have lowered (including exposure of sea defence structures), erosion of dunes | Particularly to provide data for long term monitoring of coastal systems | To provide data for assessment of the performance of a beach or dune system in a flood or erosion risk management role |

## A.21.3 Typical requirements

A tier 2 beach or dune survey is typically required to provide data for the assessment of the performance of a beach or dune system in a flood or erosion risk management role. This might be triggered for one or more of the following reasons:

- concerns regarding erosion of beach or dunes (potentially exposing sea defence structures), highlighted in a tier 1 inspection, operational report or actual or near miss overtopping in a recent event
- to provide data for long-term monitoring of coastal systems
- as part of proactive performance assessments of the performance of beach or dune systems in a flood or erosion risk management role

The frequency of this tier 2 inspection will be determined through a risk-based approach and may be part of a structured programme. This is not discussed in this appendix but is covered in section 2.3.1.

*The Beach Management Manual* (CIRIA 2012) contains extensive information for all those involved in the monitoring and management of beaches. Part 2 of that document covers the monitoring of beaches and the assessment of their performance, while its chapter 5 details the monitoring of beaches. Reference should also be made to Chapter 5 of this guidance document.

A short summary of the typical main features of beach and dune surveys is given below. **This is not intended to replace fuller guidance and procedures applicable to individual organisations.**

## A.21.4 Preparing for surveys

A risk assessment and a method statement should be prepared before carrying out the survey. Key issues to be addressed during the preparation of these documents are summarised in Table A.21.1.

**Table A.21.1 Issues to address during preparations for beach and dune survey**

| Issue | Comments/Actions |
|---|---|
| **Public liaison** | • Inform landowners of requirements, note any constraints<br>• Obtain landowner agreement |
| **Details of asset** | • Has a baseline survey of the beach or dune already been established?<br>• Topography and sediment types<br>• Structures<br>• Tidal range, exposure to waves, currents and winds<br>• Expected landward extent of storm wave influence<br>• Conservation designations<br>• Recent and forecast weather conditions<br>• Long-term trends<br>• Anticipated rates of change<br>• Management strategy<br>• Existing survey control stations in the vicinity |
| **Access** | • Location of access points<br>• Water levels and flows – tidal and fluvial (where applicable in estuaries)<br>• Weather forecast |
| **Risks** | Site-specific, may include:<br>• working near water<br>• uneven ground conditions or vertical drops<br>• working in isolated areas<br>• adverse weather conditions<br>• hostile landowners or animals (dunes) |
| **Environmental** | • Any restrictions on when the survey can be undertaken |

| Issue | Comments/Actions |
|---|---|
| **safeguards** | • presence of invasive species |
| **Emergency plan** | • Make arrangements for raising the alarm and safe evacuation of personnel in event of high water levels, personnel injury or illness. |
| **Datum requirements** | • A consistent level datum must be used for all related surveys and models. This must be stated clearly to avoid discrepancies between recently recorded and historic levels. |
| **Quality records** | • Any survey instruments must be calibrated or verified (as appropriate) in line with the relevant guidelines, for example, Royal Institute of Chartered Surveyors (RICS) guidelines or industry standard practice. |
| **Purpose of survey** | Baseline:<br>• establishing a detailed and repeatable baseline is good practice where this does not exist<br>• may not be justified in low risk areas where no intervention is proposed<br>• surveys are likely to require a combination of profiles and detailed topographic survey<br>• regular surveys over, for example, a year may be required due to seasonal variation and the effects of storms<br>• used as inputs into cross and long shore models for wave overtopping and sediment transport forecasting<br>Monitoring long-term trends:<br>• repeat surveys of beaches should be at the same point of a tidal cycle and season<br>• re-survey profiles established in baseline if using topographic survey<br>Establishing extremes of variability:<br>• survey immediately after storms to assess beach loss, erosion and associated increase in flood risk and at regular intervals to monitor recovery<br>• monitor during long periods of settled weather<br>• re-survey profiles established in baseline if using topographic survey<br>• consider speed of mobilisation- flown LiDAR may not be feasible quickly enough after a storm event |

## A.21.5 Typical methods

A topographic survey using total station or real time kinematic (RTK) GPS is the most commonly used technique for baseline surveys.

Topographic survey outputs should be adequate to describe the plan and section shape of the beach or dune in context with any structures present. This will involve a combination of:

- profile sections surveyed perpendicular to the shore or a defined line
- profiles or spot levels parallel to the shore and at any additional point required to capture the plan shape of the or dune
- feature strings, for example, of hard defences

Section profile lines on beaches should extend from the expected landward extent of storm wave influence to mean low water springs (MLWS) if possible. They should be sited to provide representative coverage, away from structures unless these are specifically being investigated For example, establishing the effect of groynes on beach sediment transport is likely to require profiles surveyed each side of groynes and in the centre of bays between them. Determining the extent of profile lines for dunes should consider past trends and possible future movement of sand. In both cases it should be possible to re-establish the profiles in successive monitoring surveys.

If required, new control stations should be established with permission from the relevant landowner.

Depending on the extent of the survey, difficulty of access and the level of detail required, a range of alternative techniques may also be used. The advantages and disadvantages of the various methods are described in more detail in industry guidance documents, and are summarised in Table A.21.2.

Ground truthing should be carried out to check the results of all vehicle mounted or flown surveys. Supplementary topographic survey may be necessary at key locations.

**Table A.21.2 Advantages and disadvantages of different methods used for beach and dune surveys**

| Type of survey | Advantages | Disadvantages |
|---|---|---|
| **Topographic** | • Most user control of survey<br>• Sediment types can be clearly identified<br>• Profiles can be re-surveyed<br>• Possible in poor weather<br>• Possible to survey down to MLWS<br>• Very short lead time | • Most labour intensive and time-consuming |
| **Ground-based continuous observation methods (RTK mounted on vehicle, backpack or wheel, or laser mounted on vehicle)** | • Quicker than topographic survey<br>• Possible in poor weather<br>• Possible to survey down to MLWS | • Labour intensive<br>• Structures may restrict access |
| **Aerial (photography, photogrammetry or LiDAR)** | • Rapid and cost-effective coverage of large areas<br>• Least labour intensive<br>• Least disturbance to beach or dune environment | • Poor definition of features such as crest levels and structures<br>• Long lead time<br>• Flights limited by weather and tides |

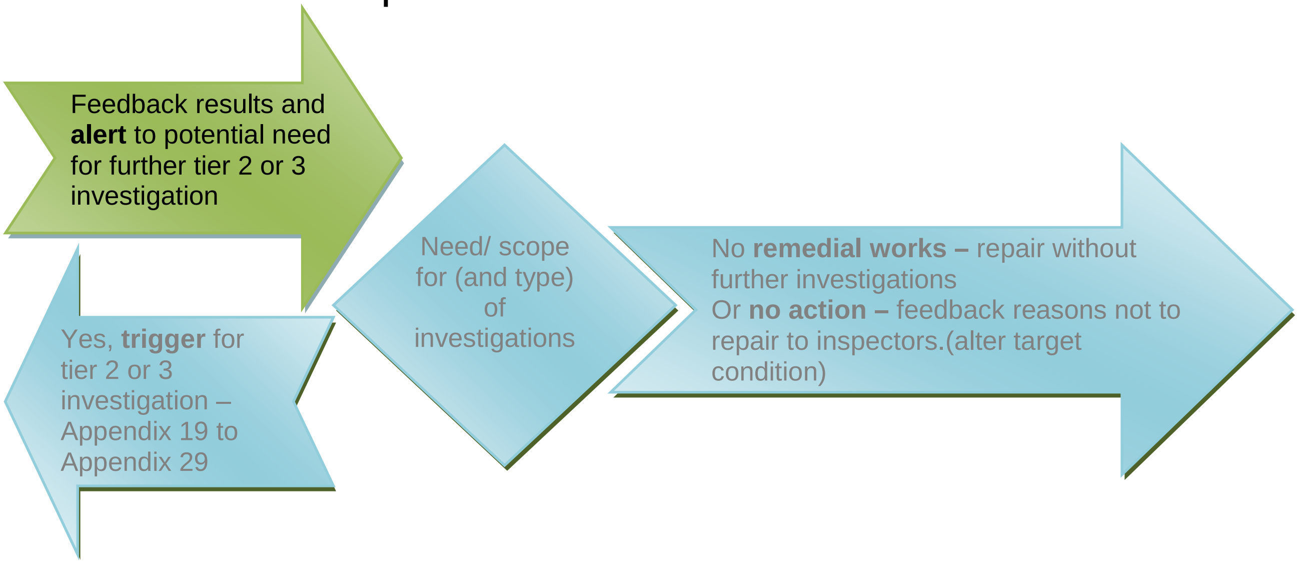
## A.21.6 Reporting

The written report should include the items listed in Table A.21.3.

**Table A.21.3 Recommended contents of written report following a beach and dune survey**

| Item | Content |
|---|---|
| **Introduction** | • Purpose and extent of the survey<br>• Date carried out, prevailing weather condition and water levels including state of tide if applicable |
| **Description** | • Location<br>• Sediment material and any exposed bedrock<br>Location and details of any:<br>• changes in section/direction<br>• low spots or scour holes<br>• structures |
| **Survey Control and Quality Assurance** | • Description of the survey control utilised<br>• Full details of any permanent control stations established<br>• Relevant instrument calibration / verification certificates<br>• Details of ground truthing if applicable |
| **Photographic Evidence** | • A minimum of three digital photographs at each profile<br>• Supplementary photographs of key features and any scour holes or defects in structures. |
| **Drawings** | • Survey drawings in CAD and pdf format |
| **Digital files** | • Digital files should be consistent with import into the organisation's intended software for drawings, GIS or hydraulic models |

## A.21.7 Next step



# Appendix 22 Tier 2 inspections: CCTV and confined space inspections

## A.22.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| **Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition** | | Details follow |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.22.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Usually culverts cannot be inspected internally in normal inspections and a CCTV inspection is required to assess condition | As part of a long-term programme to assess performance of inaccessible assets | For culverts or assets where access is difficult or not possible. To determine structural condition or extent of siltation and blockages. |

## A.22.3 Typical requirements

A tier 2 inspection may be required to determine the condition of culverts or assets where access to make a tier 1 inspection is not feasible. This is likely to be a culvert, tunnel or other enclosed or deep chamber, which may be subject to varying flows and/or tidal water levels. Typical aims include determining the structural condition or the extent of siltation and blockages of an asset.

A CCTV survey should be the preferred option for tier 2 inspections of this type. However, if this is not technically viable then entry by trained personnel may be necessary. A confined space is defined under the Confined Spaces Regulations 1997, which should be referred to when determining the precautions that should apply in this instance.

The frequency of this tier 2 inspection will be determined through a risk-based approach and may be part of a structured programme. Frequency is not discussed in this appendix but is covered in section 2.3.1.

A short summary of the typical main features of crest level surveys is given below. **This is not intended to replace fuller guidance and procedures applicable to individual organisations.**

## A.22.4 Preparing for inspections

An initial site visit before carrying out the works will be required to prepare the risk assessment and method statement. Key issues to be addressed during the preparation of these documents are summarised in Table A.22.1.

**Table A.22.1 Issues to address during preparations for CCTV and confined space inspection**

| Issue | Comments/Actions |
|---|---|
| **Public liaison** | • Inform landowners of requirements, note any constraints<br>• Obtain landowner agreement |
| **Details of asset** | • Trace full route, entrances, air vents and shafts.<br>• Note any signs of deformation or collapse of the asset<br>• Note any obvious signs of siltation and blockage |
| **Access** | • Use of safety lines and equipment<br>• Lighting and ventilation<br>• Water levels and flows – tidal and fluvial, response to rainfall<br>• Weather forecast<br>• Structures – culvert dimensions, trash screens and flap valves.<br>• Surrounding area – space for preparation, entry and exit; traffic management |
| **Risks** | • Arrangements for monitoring water levels, gas<br>• Need for personal or respiratory protective equipment<br>• Other site specific risks including vertical drops, use of hoists, safety lines |
| **Temporary works** | • Placement of stoplogs or temporary sheet piling<br>• Pre clearance of silt or debris and appropriate disposal to avoid polluting the watercourse or surrounding areas<br>• Need for over-pumping |
| **Environmental safeguards** | • Discuss arrangements required to avoid pollution of downstream and riparian land by siltation or contaminants |
| **Emergency plan** | • Make arrangements for raising the alarm and safe evacuation of personnel in event of high water levels, personnel injury or illness or presence of gas.<br>• Consider requirement for permit to work.<br>• Inform fire and rescue services. |
| **Information requirements and Image quality** | • The choice of survey method should take account of the quality and detail of the data to be collected. |

If entry by personnel to a confined space is necessary, additional preparation is required to mitigate the risks involved. Further key issues are summarised in Table A.22.2.

**Table A.22.2 Issues to address during preparations for survey involving personnel entry to a confined space**

| Issue | Comments/Actions |
|---|---|
| **Suitability of personnel** | • Training, qualifications and experience<br>• Medical suitability |
| **Breathing** | • Air quality and monitoring<br>• Ventilation<br>• Feasibility of entering using breathing apparatus |
| **Emergency arrangements** | • Emergency evacuation plan<br>• Rescue and resuscitation equipment and training |

## A.22.5 Typical methods

Such surveys are typically carried out by a skilled contractor with a camera for a CCTV inspection. The camera can be mounted on:

- a rod pushed along the culvert
- a wheeled vehicle
- a floating vehicle
- a vehicle that operates underwater

The feed should be continuously monitored to ensure quality. The operator should direct the camera and take still photographs of all key physical features or defects identified, along with video footage and a log of all notable observations and measurements.

Confined space entry must be undertaken by a team of trained personnel, taking appropriate precautions as identified by the risk assessment.

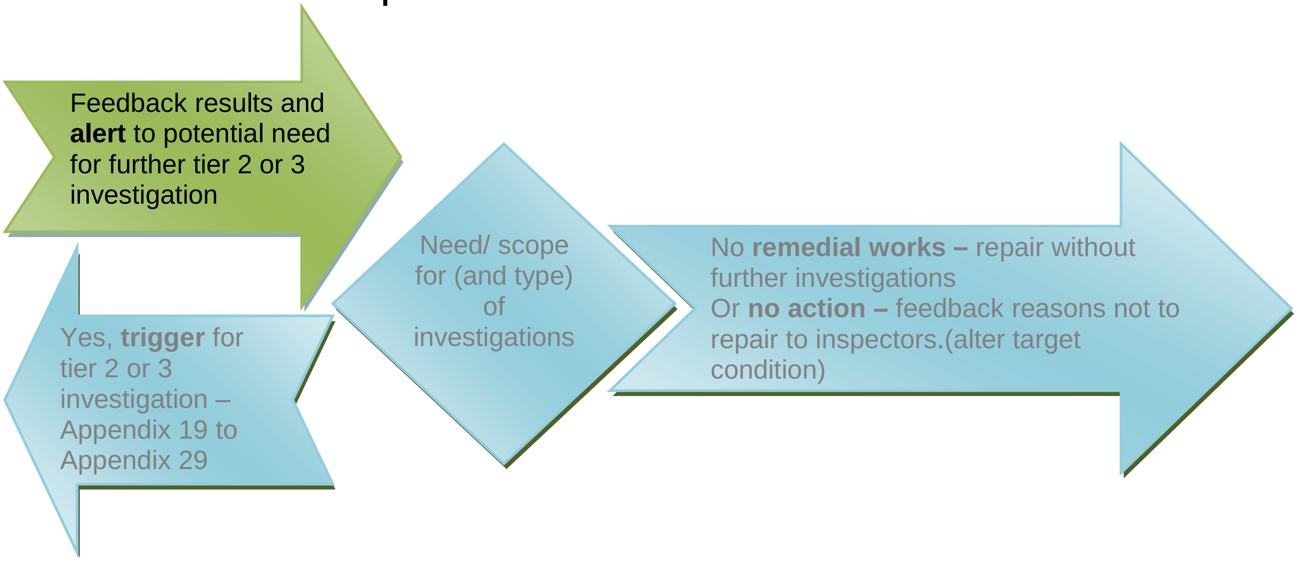
## A.22.6 Reporting

The written report should include the items listed in Table A.22.3.

**Table A.22.3 Recommended contents of written report following a CCTV and confined space inspection**

| Item | Content |
|---|---|
| **Introduction** | • Purpose and extent of the survey<br>• Date carried out and prevailing weather/flow conditions |
| **Description** | • Location of culvert, pipe or tunnel and all key features, for example, entrances/exits, headwalls and aprons<br>• Construction material, shape and dimensions of culvert, pipe or tunnel (including any cross-sectional or construction type changes) and all key features<br>• Manhole record card for any chambers |
| **Condition report** | • In the form of a pipe survey report as per the *Manual of Sewer Condition Classification* (WRc 2014) or approved equivalent<br>Location and details of any:<br>• chambers or connections<br>• changes in section/construction/direction<br>• defects<br>• siltation, seepage or blockages |
| **Photographic evidence** | • A minimum of three digital photographs of each end of the structure showing typical construction and any defects<br>• Supplementary photographs of key features and defects<br>• A DVD of the CCTV recording |
| **Recommendations** | The report should provide clear recommendations, which should include the following:<br>• any health and safety issues identified<br>• whether the structure inspected was found to be structurally sound and, if not, the deficiencies identified<br>• appropriate remediation and/or improvement works if required (briefly described in writing and sketch form, including an estimate of costs)<br>• any key site constraints for future works are recorded<br>• the remaining life of the structure should be estimated<br>• any reasons why the proposed interval to the next internal inspection should be amended |

## A.22.7 Next step



# Appendix 23 Tier 2 inspections: structural inspections

## A.23.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| **Usually from condition grade (part or whole). Possibly site inspection recommendations** | | Details follow |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.23.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Usually from condition grade of elements or the asset. May be an alert from site inspection recommendations. | Following an alert and site visit, a structural inspection will be required to confirm:<br>• whether the issue is likely to compromise the asset's ability to perform its required role<br>• what further assessment will be required | Using qualified staff to assess the condition of an asset, its likely performance under load and the type and extent of improvements that may be required. |

## A.23.3 Typical requirements

This type of tier 2 survey is usually carried out in response to an alert from a tier 1 inspection, including those referring to an engineering integrity issue. It may also be required in response to concerns raised by operations and maintenance staff, riparian owners, members of the public or local organisations.

The objective should be to collect as much information as possible to serve any of a number of purposes:

- identify any weaknesses, instability or problems with an asset and if so whether the issue is likely to compromise the asset's ability to perform its required role
- make an estimate of the remaining life of the asset, with and without remedial treatment and for different maintenance regimes
- give an initial assessment of options for improvements
- identify whether further structural testing is required as a tier 3 activity (Appendix 27)

## A.23.4 Preparing for inspection

If there has been an alert from a site inspection, the inspector who completed the inspection should revisit the site with a technical specialist.

It is important to prepare for the visit by ensuring the following.

- Any available information on the nature of the suspected problem is identified.
- Original drawings of the asset should be retrieved from the archive – these can be used for marking up.
- The requirement for any specialist equipment is identified – to give safe access to parts of the asset or survey equipment. Sheet pile thicknesses and reinforcement cover can be measured in this survey, but these are described in more detail in Appendix 27 describing structural testing as a tier 3 activity.
- An appropriate technical specialist should attend; who that is will depend on the issues that have resulted in the alert. These could refer to problems with the structure and its materials, or the overall structural stability, or there might be indications that the problem has a geotechnical cause. Someone involved in the operation and maintenance of the asset may also be required.
- There is a good understanding of the expected performance of the asset, both in relation to other assets in the system and in terms of crest level compared with extreme flood levels for example.
- There is a good understanding of the consequences of asset failure.
- An appropriate risk assessment and mitigation is in place and conveyed to those in attendance.

## A.23.5 Typical methods

A range of methods are available and the choice will depend on the nature of the specific problem identified. Table A.23.1 summaries typical problems observed during structural inspections.

### Table A.23.1 Typical problems found during structural inspections

| Type of problem | Details |
|---|---|
| **Dimensional checks** | A full dimensional check of the asset under consideration, or as a minimum those parts which are causing concern, should be made. The findings can be used in any subsequent analyses. |
| **Cracks and movement** | Cracks, distortion or movement should be noted, measured with a crack width gauge and photographed. If movement is expected to continue, tell-tale strips could be positioned to allow future monitoring. |
| **Structural instability** | Any tilting, settlement, horizontal movement or disconnected components should be noted and recorded. |
| **Material damage including abrasion or erosion, perforations, corrosion, decay or cavities** | Typically this applies to concrete (spalling), masonry or steel structures. Damaged areas should be recorded and photographed. Both the area and depth of the damage will be important factors. In the case of sheet piles or other steel structures, metal thickness can be tested with a calibrated gauge, for comparison with installed thickness. Testing for accelerated low water corrosion may be required. |
| **Damage to components** | Components such as ground anchor heads should be inspected carefully. It is important to distinguish between cosmetic damage in an aggressive environment and damage that may affect the performance of the component to withstand load. |
| **Services affected** | Determine whether any utility services are affected. |
| **Leakage and backfill** | Report any signs of water leakage or backfill washout. |

## A.23.6 Reporting

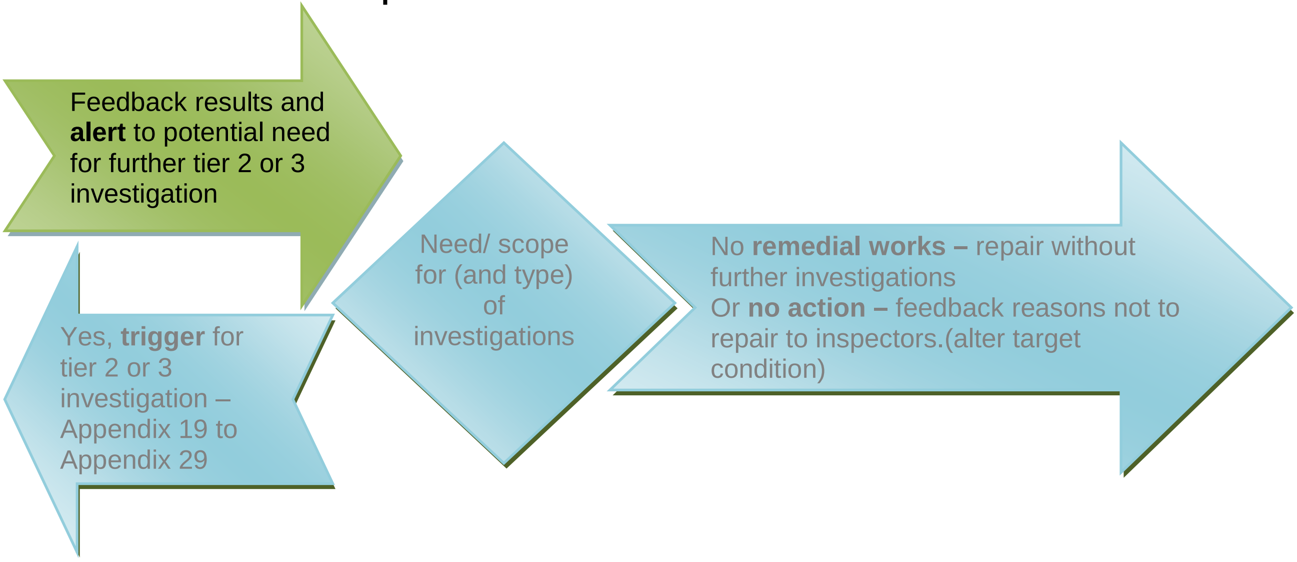
The written report should include the items listed in Table A.23.2.

### Table A.23.2 Recommended contents of written report following a structural inspection

| Item | Content |
|---|---|
| **Description of asset** | • Location<br>• OS Grid reference<br>• Description of overall asset and elements inspected |
| **History of asset** | • Year of construction<br>• Major modifications<br>• Maintenance and operational procedures<br>• Previous alerts or inspections |
| **Inspection details** | • Date and time of inspection<br>• Weather conditions<br>• Names of those inspecting<br>• Purpose of survey<br>• Nature of the alert and source<br>• List of elements inspected and those which could not be accessed |
| **Observations undertaken** | • Detail the observations made, including a record of the problem areas and also those areas which were found to be sound. Include photographs and additional sketches if required. |
| **Additional supporting analyses** | • Details of any analyses of the observations. In particular this may apply to stability calculations. |
| **Conclusions and** | The report should include clear recommendations, which should |

| | |
|---|---|
| **recommendations** | include the following:<br>• any health and safety issues are identified (including to the public or operators)<br>• whether the structure inspected was found to be structurally sound and, if not, the deficiencies identified<br>• whether accelerated low water corrosion was identified<br>• the likely cause of any deficiencies<br>• appropriate remediation and/or improvement works if required (briefly described in writing and sketch form, including an estimate of costs)<br>• identification of any further tier 2 or tier 3 inspections that may be required (for example, ground investigations to support a stability analysis)<br>• the need to record any important site constraints for future works<br>• the remaining life of the structure should be estimated, with and without remedial repairs and for different maintenance regimes.<br>• any reasons why the proposed interval to the next internal inspection should be amended |

## A.23.7 Next step



# Appendix 24 Tier 2 inspections: water level and velocity measurements

## A.24.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| Requirement to minimise frequency of tier 1 inspections | | Appendix 25 |
| **Usually specialists seeking understanding of hydraulic performance** | | Details follow |

## A.24.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| Not usually an alert from inspections without consideration of hydraulic performance by specialists | Request for water level information for hydraulic modelling purposes. May also be used to indicate blockage of culverts without the need for internal inspections. | To assist in calibration of hydraulic models and to alert effects of blockage or vegetation |

## A.24.3 Typical requirements

The ability of channels, culverts and control structures to convey flood flows is one of the most important features of flood risk management in the fluvial environment.

There are many different methods of forecasting water levels that will be reached in extreme events; such levels are usually of most interest to flood risk managers. The available methods range from high level models on a catchment or sub-catchment scale, one or two dimensional models of reaches of a river system and its floodplain through to detailed models of a particular structure or sub-reach.

All computational models that are used to calculate the water levels which will be reached for any given flow will be more accurate if calibration data are available giving water levels and velocities for given flow conditions. This appendix gives a brief description of the requirements, but each case will be different and those charged with running a model of the reach under consideration should advise on particular requirements.

Monitoring of water levels can also be useful to warn of blockages in a river or culvert or at a debris screen.

## A.24.4 Preparing for surveys

The timing, equipment and arrangement for any surveys will depend on the particular requirements specified. Table A.24.1 summarises important considerations.

**Table A.24.1 Issues to address during preparations for measurements of water level and velocity**

| Item | Comments/Actions |
|---|---|
| **Public liaison** | • Inform landowners, note any constraints. |
| **Details of reach to be monitored** | • Length and typical cross-section<br>• Locations where water level and velocity measurements are required |
| **Timing** | • Does the monitoring need to coincide with particular flood conditions? |
| **Access and equipment** | • Location of access and egress points to banks and watercourse<br>• Depths of water<br>• Water levels and flows – tidal and fluvial, response to rainfall<br>• Can the survey be undertaken from the bank, by wading? Is a boat required? Is specialist equipment required?<br>• Weather forecast |
| **Need to determine river flows** | • Is there a nearby gauging station which can be used to determine the river flow ($m^3$/sec)?<br>• Is the equipment required to measure flows in the river? |
| **Risks** | Site-specific, may include:<br>• working in and/or near water<br>• uneven ground conditions or vertical drops<br>• working in isolated areas<br>• adverse weather conditions<br>• hostile landowners or grazing animals<br>• waterborne diseases |
| **Environmental safeguards** | • Any restrictions on when the survey can be carried out<br>• Presence of invasive species<br>• Confirm if any biosecurity arrangements are required. |
| **Emergency plan** | • Make arrangements for raising the alarm and safe evacuation of personnel in event of high water levels, personnel injury or illness. |
| **Datum requirements** | • A consistent level datum must be used for all related surveys and models. This needs to be stated clearly to avoid discrepancies with other local surveys. |

## A.24.5 Typical methods

There is a range of methods to suit particular requirements.

### A.25.5.1 Peak level recorders and gauge boards

These are the simplest type of gauge for measuring water levels. They require installations of gauge boards and peak water level recording tubes (a float sticks at the highest level). They need to be levelled in to a datum. They cannot be used to measure velocities. They can only give a single level at the time of observation.

### A.25.5.2 Use of standard survey equipment

A standard level and staff or total station instrument can be used to record water levels at various stages of a flood. The choice of locations to take levels should ensure the water profile is well represented. The time for each reading should be recorded to relate to measured flows in the river, determined for a nearby gauging station. This equipment could also be used to survey wrack marks after a flood event.

### A.25.5.3 Portable or fixed water level recorders

Water levels can be recorded electronically by monitoring the output from a transducer introduced into the river. The electrical output from the transducer changes with the water pressure and this can be translated into water level by appropriate calibration. The recording device needs to be set above flood levels; if there is no nearby high ground, this can be achieved by mounting on a pole. These devices cannot measure velocities.

### A.25.5.4 Hand-held or cable hung flow gauges

These can be used to measure flow velocities (related to the speed of turning a propeller). They are more useful for measuring low flows when hand held. They are unlikely to be used to measure flood flows due to safety concerns. Figure A.25.1 shows a hand-held flow meter in use.

**Figure A.245.1 A hand held flow meter**

Similar devices hung from a cable across the river are usually for permanent installations. The total flow in the river can be calculated by taking measurements of velocity in fixed ‘slices’ of the river.

### A.25.5.5 Acoustic Doppler current profiler (ADCP)

Acoustic Doppler current profilers work by monitoring the reflection of sound waves generated in a small floating platform. The advantages are that these can be deployed at short notice to locations that only require access to secure a rope to steer the device across a river channel.

ADCPs are able to measure velocities and depths, and by tracking across the channel, they can be used to measure total river flows. They can use GPS to track vertical and horizontal position.

Although the most expensive to buy of the options available, their flexibility and ability to be used safely usually means they are an invaluable tool for those needing to monitor water levels and velocities in flood events. They can also be used to measure flow across floodplains.

Figure A.25.2 shows an ADCP in use.

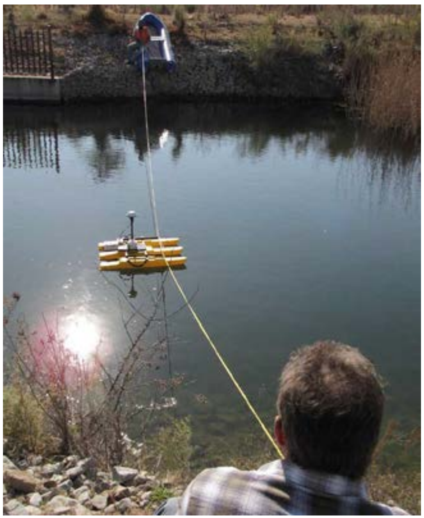


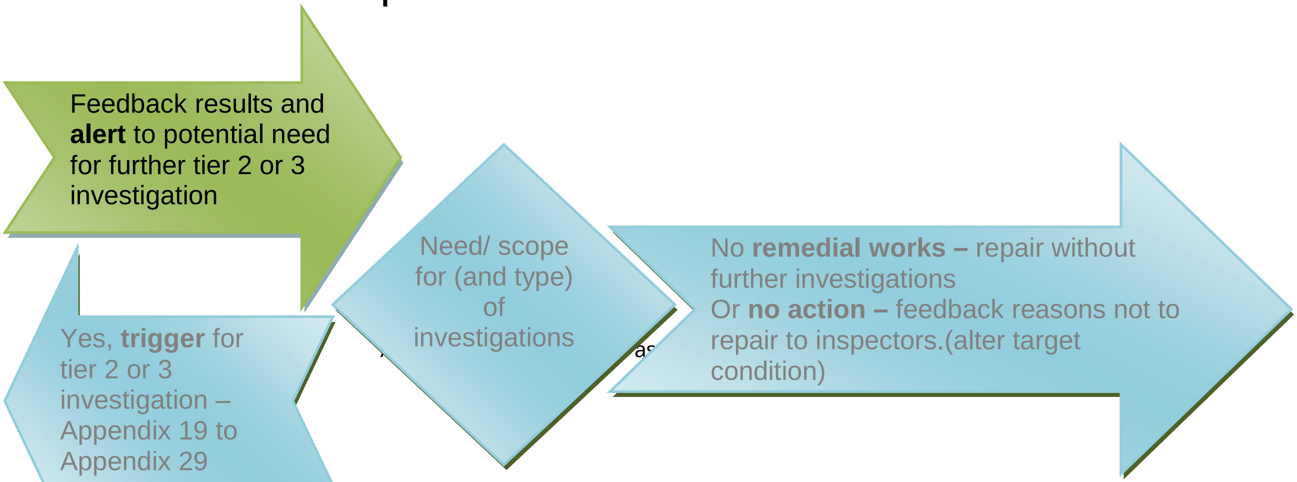
**Figure A.25.2 Acoustic Doppler current profiler in use**

## A.24.6 Reporting

Reports should include a full record of:

- location – needs to be precise
- water level and velocity measurements, total river flows, with date and timing of each reading
- photographs of river conditions
- note of any obstructions or structures affecting the flow

## A.24.7 Next step



# Appendix 25 Tier 2 inspections: remote sensing including photography

## A.25.1 Relationship to tier 1

| Alert from tier 1 inspection or other sources<br>Refer to section 2.3.8 | Review. If action triggered | Tier 2 inspection + further guidance |
|---|---|---|
| Condition grade below target | | Appendix 14 |
| Unable to assess overall condition grade of asset | | Appendix 15 |
| Engineering integrity issue | | Appendix 16 |
| Alerts outside the normal programme of inspections | | Appendix 17 |
| Stability concern(all or part of asset)<br>Leakage concern (piping)<br>Observations post event/complaint (see above) | | Appendix 18 |
| Low spots | | Appendix 19 |
| Hydraulic conveyance is being adversely affected | | Appendix 20 |
| Beach levels lowered/exposed sea defences, dune erosion | | Appendix 21 |
| Usually culverts cannot be inspected and a CCTV inspection is needed to assess condition | | Appendix 22 |
| Usually from condition grade (part or whole). Possibly site inspection recommendations | | Appendix 23 |
| **Requirement to minimise frequency of tier 1 inspections** | | Details follow |
| Usually specialists seeking understanding of hydraulic performance | | Appendix 24 |

## A.25.2 Why?

| Alert from inspection or other sources | Requirement to assess performance | Purpose |
|---|---|---|
| As a tool for assessing asset condition to reduce the frequency of required inspections | To provide data for proactive asset management planning | To provide data on asset condition and performance, particularly as part of a long-term monitoring programme, where access is difficult or to provide a baseline for comparative purposes |

## A.25.3 Typical requirements

A tier 2 inspection using remote sensing may be carried out to:

- assess asset conditions using less resources – this could be combined in a rotating programme with traditional routine inspections to confirm data quality and to potentially reduce the required frequency of inspections
- assess asset condition and performance measures (for example, crest height), particularly as part of a long-term monitoring programme – the need may be driven by a drive to reduce costs compared with traditional surveys or as a replacement for conventional site based inspections where access is difficult
- provide a baseline for comparative purposes
- provide data for proactive asset management planning

The frequency of this type of tier 2 inspection will be determined through a risk-based approach and may be part of a structured programme. Frequency is not discussed in this appendix but is covered in section 2.3.1.

A short summary of the typical main features of crest level surveys is given below. **This is not intended to replace fuller guidance and procedures applicable to individual organisations.**

## A.25.4 Preparing for surveys

Careful planning of this type of survey is necessary to ensure the objectives are met. As a minimum, a risk assessment and a method statement are required before carrying out the works. Key issues to be addressed during the preparation of these documents are summarised in Table A.25.1.

**Table A.25.1 Issues to address during preparations for remote sensing including photography**

| Issue | Comments/Actions |
|---|---|
| **Public liaison** | • The requirements will depend on the nature of the investigations.<br>• It is important to appreciate public concerns about the principles of remote sensing, as there may be a perception of unwarranted surveillance techniques. |
| **Details of asset** | • Type, extent and location<br>• Current condition<br>• Estimated rates of change<br>• Seasonal variation<br>• Access |
| **Information requirements and image quality** | • Purpose of survey<br>• Quality of data to be collected<br>• Level of detail of data to be collected<br>• Anticipated frequency of inspection |

The content of risk assessments and method statements are not discussed in detail as the requirements and issues will vary significantly depending to the techniques to be employed.

## A.25.5 Typical methods

Table A.25.2 summarises details of available techniques and their potential applications.

**Table A.25.2 Available remote sensing techniques and their potential applications**

| Technique | Details | Potential applications |
|---|---|---|
| **Bathymetric survey** | - Uses echo sounder linked to RTK GPS. | - Extend beach profile beyond MLWS to provide a full picture of net erosion and accretion between surveys or other purposes |
| **Flown or mobile LiDAR (light detection and ranging) survey** | - See section A.25.5.1 for further details. | - LiDAR is now used across the UK to provide three-dimensional topographic data. Use to monitor changes in beach levels, cliff erosion. Can also be used to monitor defence levels when used at high resolution. |
| **Aerial photography, satellite imagery** | - These can be ordered for specific purposes, but there is also a large archive of historic images. | - Qualitative comparisons, for example, beach extents over time<br>- Monitoring of flood events<br>- Retrospective analysis may be possible with historical images. |
| **Photogrammetry / stereographic pairs of aerial photographs** | - Elevation shown by layering photographs. | - Creation of topographic maps<br>- Retrospective analysis may be possible with historical images. |
| **Small unmanned aircraft surveys** | - Camera mounted in a small unmanned aircraft (see section A.25.5.2) | - Developing technology with high potential. May also be appropriate to replace or supplement tier 1 inspections. |
| **Infra-red thermography** | - Mapping of temperature variation – can be carried out locally or from aircraft | - Enables detection of discontinuities, especially water seepage. |
| **Video recording** | - Permanent or mobile applications | - Qualitative comparison for example, beach extents over time<br>- Monitoring of flood events |
| **Multi-spectral or hyper-spectral imaging for example, Landsat, Compact Airborne Spectographic Mapper (CASI)** | - Thematic mapping using images taken with multiple wavelengths, geo-referenced using LiDAR data | - Mapping of land usage to provide understanding of catchment management<br>- Habitat mapping<br>- Flood event monitoring |
| **Smartphones / PDAs** | - Enables location of data entry and photographs to be recorded on-site and imported to GIS. | - Streamlines recording of data from on-site inspections, provides system for keeping spatially referenced electronic record in GIS. |

## A.25.5.1 LiDAR

### *Flown LiDAR*

Depending on the scope of the survey and the level of detail required, it may be appropriate to use a LiDAR survey. This uses aircraft-mounted equipment calibrated to give the height of square cells in a grid of a defined resolution. Data can be filtered to remove vegetation and buildings to give a bare ground level.

Individual cell heights should be accurate to better than ±0.15 m RMSE, with system error of less than 0.07 m unless otherwise specified.

The grid size should be a third or less of the dimension of the key features to be levelled. Therefore for an embankment crest level survey the grid should typically be no more than 1 m.

LiDAR is generally not suitable where defences consist of walls or other narrow structures, and may not record localised low spots.

Ground truthing should be carried out to check the results and a supplementary topographic survey may be necessary at key locations.

### *Mobile LiDAR*

LiDAR devices can be mounted on vehicles and used to scan horizontally, allowing for cost-effective monitoring of cliff faces, for example.

## A.25.5.2 Small unmanned aircraft surveys

These are small ‘model aircraft’ size fixed or rotary (helicopter type) aircraft. When used in conjunction with photogrammetry, they provide an innovative platform for low-level aerial imagery. They are easy to mobilise and flexible in operation.

When equipped with appropriate cameras and a global navigation satellite system, they can be used to provide data to create digital surface models and orthophotographs for areas up to 1 km$^2$ depending on battery life.

Control is from the ground or can be pre-programmed. Data are downloaded to a notebook computer on site. The schematic in Figure A.25.2 shows how such surveys work.

There is now the opportunity to use this type of survey to supplement tier 1 inspections, particularly of river channels and long flood defences with restricted access.

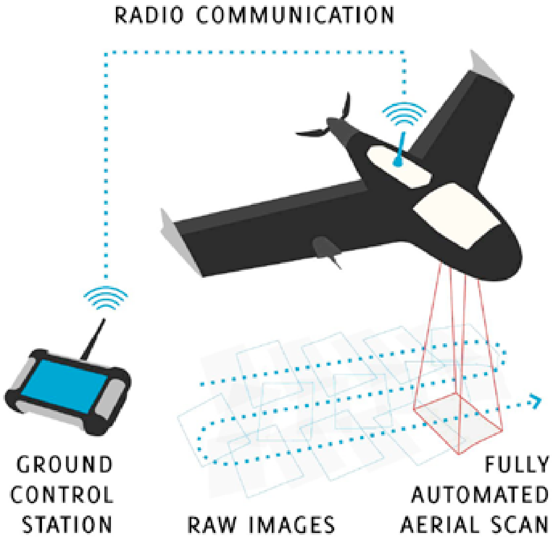


**Figure A.25.2 Schematic showing operation of small unmanned aircraft surveys**

## A.25.6 Reporting

The written report should include the items listed in Table A.25.3.

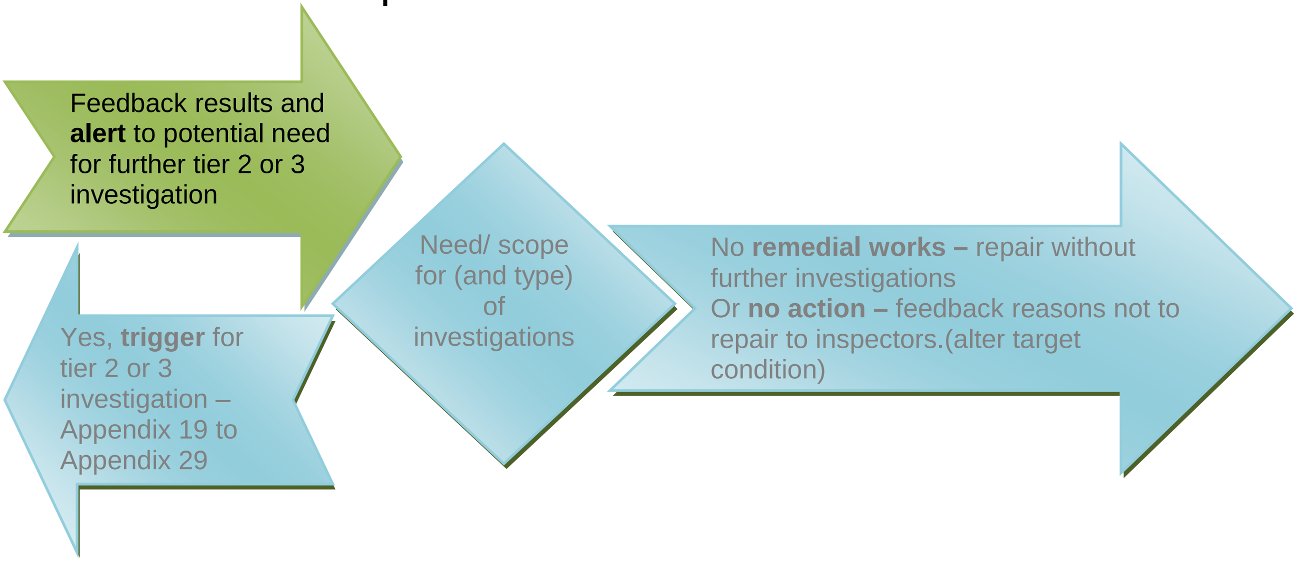
**Table A.25.3 Recommended contents of written report following remote sensing inspection**

| Item | Content |
|---|---|
| **Introduction** | • Purpose and extent of the survey<br>• Date carried out and prevailing weather conditions, tide height, river levels and so on |
| **Description** | • Description of the techniques used, methods adopted and verification controls employed |
| **Digital evidence** | • This will vary depending on the techniques employed. Raw data should be made available if required, as well as the processed data, which will be the useable form. |

## A.25.7 Further information

- *Quantitative Assessment Methods for the Monitoring and Inspection of Flood Defences: New Techniques and Recent Developments*, CIRIA report C717, available from: http://www.ciria.org/Resources/Free_publications/Quantitative_assessment_methods_flood_defences.aspx
- *Client Guide to Small Unmanned Aircraft Surveys*, The Survey Association, available from: http://www.tsa-uk.org.uk/for-clients/guidance-notes/

## A.25.8 Next step



# Appendix 26 Tier 3 inspections: ground investigations

This guidance given in this appendix on this tier 3 inspection activity is an outline guide to inform the inspection process. It should not replace reference to BS 5930:1999 Code of Practice for Site Investigations and, where appropriate, BS EN 1997 Geotechnical design – Ground investigation and testing.

## A.26.1 Relationship to tiers 1 and 2

A performance and risk assessment of an issue may trigger the need for an intrusive tier 3 investigation. This typically follows a tier 2 inspection alert, but may in exceptional circumstances where a large amount of data are already on record, follow a tier 1 inspection alert.

## A.26.2 Why?

| **Purpose** | **Trigger from performance assessment following tier 2 inspections** |
|---|---|
| To confirm underlying ground conditions (layers and properties). Also used to collect information on ground water levels and variations. | Usually triggered by the need for further information to assess engineering integrity issues (stability and leakage) relating to geotechnical factors |

## A.26.3 Typical requirements

Ground investigations may be required for all stages of the asset cycle. The most obvious requirement is to:

- give information for the design of assets
- determine foundation strengths and depths (including sheet piles), earth pressures, the stability of slopes
- provide information on groundwater and profiles

In the context of determining the condition of existing assets, ground information may be required as a tier 3 investigation for any of the following reasons:

- to determine the reasons for slope instability raised as an engineering integrity alert (see Appendix 5)
- to determine the reasons for observed instability of a structure raised as an engineering integrity alert (see Appendix 6)
- to investigate the causes of leakage or piping through soils raised as an engineering integrity alert (see Appendix 7)
- to undertake more extensive investigations into the extent of animal burrowing (see Appendix 10)

All triggers to a ground investigation will usually require information on the depth and properties of the underlying strata, including identifying any weak spots and the reasons for their formation. Usually there will be a requirement to determine the level of groundwater and how its profile changes across the area to be investigated.

While the main objective of this type of tier 3 inspection is the determine the reasons for a particular problem, the specification for the investigations needs to also recognise what further information may be required to complete the design of any remedial work. There is clearly a balance to be struck. There will be savings in mobilisation costs if any further design information can be collected at the same time as the investigatory work. However it may be difficult at the investigation stage, prior to determining the cause, to identify the exact requirements for the design of remedial works. Any savings in mobilisation costs will not be realised if a second visit is needed anyway.

For small areas it is usually cost-effective to try to anticipate the design requirements, where applicable, by increasing the cover of trial pits or boreholes and by ensuring that strata to use as a firm foundation are reached.

The extent of ground investigation is always a compromise. Trial pits, probes and boreholes must be assumed to be representative of an area surrounding the actual hole. Where strata are shown to lie horizontally or on a constant slope when drawn on a cross-section, there can usually be more confidence that the holes are representative. However, in alluvial soils and other situations where there is a lot of variation, confidence should be lower. The extent to which any compromises can be accepted must be determined in a risk-based approach. However, this is usually less of an issue for tier 3 ground investigations into a particular problem at a defined location.

## A.26.4 Preparing for surveys

Table A.26.1 sets out the aspects to consider when preparing for ground investigations.

**Table A.26.1 Preparing for ground investigations**

| Planning element | Details |
|---|---|
| **Desk study** | • Locate site accurately on Ordnance Survey (OS) mapping.<br>• Obtain indication of strata to be encountered from 1:50,000 and 1:10,560 geological maps and view the British Geological Survey studies of regional geology for England, Wales and Scotland (see http://www.bgs.ac.uk/downloads/start.cfm?id=832).<br>• Search aerial photography archives for useful information – change in river course, previous slope failures and so on<br>• Check whether former mine workings may be present – National Archives for National Coal Board, other local archives<br>• Obtain information for all services in the vicinity of the site. Consider purchasing this as a 'one stop' package rather than contacting all companies.<br>• Determine the unexploded ordnance (UXO) risk for the site.<br><br>Information may already be available that may reduce the need for some or all of the ground investigations.<br>• Make sure previous ground investigation information is retrieved from archives.<br>• Determine whether there is existing information in British Geological Survey records. |
| **Site reconnaissance** | A site visit is required as part of the planning for any ground investigation. The following should be observed:<br>• access arrangements and constraints |

| Planning element | Details |
|---|---|
| | • signs of services<br>• signs of springs or seepage<br>• slope instability<br>• suitable locations for pits or boreholes |
| **Public liaison** | • Ensure any landowner permissions have been obtained.<br>• Note any constraints for access or undertaking the works.<br>• Consider grazing livestock. |
| **Timing** | • Does the investigation need to be made at a particular time of year, river or tide levels, or to meet environmental and ecological constraints? |
| **Consents or licences** | • Determine what consents (for example, flood defence consent) or licences may be required and what constraints may be imposed. |
| **Type of information to be collected** | • Taking note of the requirements for the information to be gathered, consider any combination of the techniques listed below under 'typical methods'.<br>• Plan information collection to give an appropriate coverage and to collect the data required. Planning should make use of knowledge gained from the desk study on likely strata, likely depth of bedrock and so on. |
| **Access and equipment** | • Determine how site will be accessed, bearing in mind the plant required.<br>• Ensure weight of equipment is appropriate for ground conditions, slopes and so on.<br>• Will access constraints limit the use of the results? If so, can arrangements be made for better access and platforms?<br>• Consider weather forecast. |
| **Health, safety and environmental considerations** | • Consider whether the ground investigation should be notified under construction, design and management (CDM) legislation and whether a CDM co-ordinator needs to be appointed to ensure notifications are in place and to review method statements.<br>• Ensure all environmental safeguards are in place. These may be site-specific (protected or invasive species) or more general (hydraulic oils, spill kits, contamination). |
| **Procurement strategy** | • This will be determined by the organisation involved using tendering arrangements or use of site investigation framework contractors.<br>• Make checks to ensure the company to be appointed has the appropriate resources, skills and equipment available at the planned dates for the work. |
| **Sample testing schedules** | • Based on available knowledge of likely soils and strata to be encountered, make a preliminary list of material samples and tests.<br>• Reassess this list once the nature of the materials is clearer, both on site to ensure that good samples of the strata encountered are sampled and for the subsequent laboratory tests. |
| **Underground services tracing** | • Plan to trace any services on site that may be affected by the ground investigation work.<br>• Use approved specialists. |
| **Risks** | Site-specific, may include:<br>• working in and/or near water<br>• uneven ground conditions or vertical drops<br>• risks associated with the problem or ground failure being investigated<br>• adverse weather conditions<br>• hostile landowners or grazing animals<br>• waterborne diseases. |
| **Environmental safeguards** | • Are there restrictions on when the investigation can be carried out (for example, birds nesting)?<br>• Are protected or invasive species present?<br>• Confirm if any biosecurity arrangements are required.<br>• Put in place normal safeguards for mechanical plant. |

| Planning element | Details |
|---|---|
| **Datum requirements** | - It is essential that boreholes and other probings are related to a known level datum, either to OS datum or to a site datum that can be resurveyed when surveying the site for any future works. |

## A.26.5 Typical methods

A choice of techniques is available to determine the nature and strengths of the underlying strata. What combination of techniques will be determined by:

- the nature of the problem being investigated
- site conditions
- whether the data are being collected to inform the design of remedial works

Investigating the cause of a problem usually only involves a limited series of tests. The available techniques are briefly described in Table A.26.2.

**Table A.26.2 Available techniques for ground investigations**

| Technique | Details |
|---|---|
| **Trial pits** | The cheapest method of exploring the ground. Usually employed for holes up to 2 m deep, which may require ground support, but can be to 4 m deep with appropriate support. Good for taking block samples directly from hand or machine excavations. Also for sampling soils by:<br>• disturbed samples<br>• block samples<br>• push in tube samples or vane tests<br>Groundwater observations can be made. |
| **Dynamic probing** | Provides a rapid and cost-effective means of assessing ground conditions. Particularly useful where access is difficult. A simple test consisting of driving a rod with an oversize point at its base with uniform hammer blows. Blows are counted per 100 mm of penetration and plotted to give a measure of soil properties. Depths up to 5 m and possibly to 15 m in soft strata. Piezometer tubes can be installed to monitor groundwater levels. |
| **Static cone penetration testing** | Provides a cost-effective technique for obtaining soil profiles and soil strengths. Rods with an oversized tip are driven from a lorry or self-propelled machine at a constant rate into the ground. The tip includes electronic sensors that record the resistance to penetration plus (optionally) water pressure and other parameters. Data from the sensors are processed to provide rapid assessment of soil types and strength properties. A mag-cone tip can be used to detect potential UXOs. Depths to around 30 m are possible in soft ground. Can be used to improve coverage of a site quickly and relatively cheaply and in locations where access is difficult for drilling rigs. |
| **Window and windowless sampling** | Window sampling uses portable equipment to drill small diameter boreholes to take soil samples in hollow steel tubes with windows cut into them. This is a cost-effective tool, useful in restricted sites. Soils can easily be logged on site and small samples can be taken for testing. Dynamic probing and standard penetration testing (SPT) can also be carried out during the drilling process.<br>Windowless sampling uses similar techniques, but a plastic liner is used to retrieve the sample – this can be split on site or in the laboratory.<br>Samples obtained by these techniques are not suitable for accurate |

| Technique | Details |
|---|---|
| | determination of strength or compression parameters. |
| **Shell and auger drilling** | This is the most common method of drilling boreholes, using a cable percussive rig. It is used to collect disturbed and undisturbed soil samples for testing. SPTs can be taken as the drilling proceeds. Groundwater depth can be determined and piezometer tubes can be installed for long-term monitoring of groundwater. Depths of up to 80 m have been achieved. |
| **Rotary drilling** | Rotary drilling is used to drill into rock or dense gravels. It is usually employed to gather data for foundation and pile design purposes rather than as a tier 3 investigation of a structural problem. |
| **Geophysical investigations** | Despite advances in recent years, geophysical investigation techniques are useful as indicators rather than giving accurate data on strata depths and materials. To improve accuracy, results should be calibrated with evidence from trial pits or boreholes. Therefore this type of investigation is not usually suitable for a tier 3 investigation into a specific problem. |
| **Sampling materials** | Soil samples will need to be analysed to provide information to geotechnical engineers to analyse a particular problem and to assess available options for remedial work. The usual methods are:<br>• bulk or block samples – usually taken from trial pits or soils which have little or no cohesion<br>• U100 undisturbed samples – 100 mm diameter and 450 mm long, usually employed in boreholes. Smaller diameter samples may be used, but testing results will be lower confidence. |
| **Groundwater tests** | Groundwater is an important consideration when analysing the stability of structures and slopes. Groundwater levels can be measured from piezometer tubes installed in borehole tubes, but care needs to be taken to ensure that seals are inserted at the appropriate levels to monitor ground water levels in different strata (for example, groundwater pressures and levels in underlying gravels may be different from those in surface strata). |
| **Testing materials** | See BS 1377:1990 Methods of test for soils with civil engineering purposes.<br>Site techniques include:<br>• dynamic cone penetrometer testing<br>• static cone penetration testing<br>• California Bearing ratio<br>• in situ density tests<br>• infiltration testing<br>• plate loading (bearing) testing<br>Laboratory techniques include:<br>• plasticity<br>• particle size<br>• compaction testing<br>• triaxial (strength) testing<br>• long-term consolidated drained and undrained triaxial and permeability testing |

## A.26.6 Reporting

Reports from site investigations should include the following as a minimum requirement.

### A.26.6.1 Ground investigation report

- Description of site, date undertaken and details of the investigations
- Plan showing location of all boreholes, trial pits or other excavations

- Logs of all explorations undertaken. These logs should give as much information as possible on the soil or rock structure from the investigations undertaken. Descriptions should be in accordance with the requirements set out in BS EN 1997.

### A.26.6.2 Geotechnical design report

Geotechnical design reports including interpretation of the site data can be ordered from the company carrying out the ground investigation or through a geotechnical specialist.

# Appendix 27 Tier 3 inspections: structural testing

## A.27.1 Relationship to tiers 1 and 2

A performance and risk assessment of an issue may trigger the need for an intrusive tier 3 investigation. This typically follows a tier 2 inspection alert, but may in exceptional circumstances where there is a large amount of data already on record, follow a tier 1 inspection alert.

## A.27.2 Why?

| Purpose | Trigger from performance assessment following tier 2 inspections |
|---|---|
| To confirm the construction materials and construction. Particularly to check deterioration or where records are not available. | Usually triggered by the need for information to complete structural assessments (for example, wall widths, material strengths) |

## A.27.3 Typical requirements

It may be necessary to collect further information to complete structural analysis of an asset. Typically this is because there is uncertainty regarding the strength of the construction materials, the type of construction or other details. Typical requirements are summarised in Table A.27.1.

**Table A.27.1 Typical requirements for structural testing**

| Structural test | Details |
|---|---|
| **Estimate the strength of reinforced concrete** | • Extract a core by diamond drilling for subsequent testing.<br>• Carry out a rebound test on the concrete.<br>• Determine reinforcement cover. |
| **Measure material thicknesses (see also Appendix 21)** | Do this for structural steel members or sheet piles, particularly to compare with as installed thickness to determine past erosion and to estimate remaining life. |
| **Confirm wall thicknesses and construction types when only one wall is exposed** | Core into wall, vertically or horizontally. Vertical drilling allows wall construction materials to be assessed in quay walls for example. |

## A.27.4 Preparing for surveys

Efficient planning of this type of inspection requires knowledge of:

- the requirements of the inspection

- the purpose and type of information sought
- access restrictions – particularly if coring is to be carried out
- working area, power and water supply arrangements
- specific site risks, including the potential instability of the structure

The choice of team and their experience will depend on the testing requirements. Specialist equipment and personnel will be needed for diamond drilling to extract cores.

## A.27.5 Typical methods

Typical methods are detailed in Table A.27.2.

**Table A.27.2 Methods used for structural testing**

| Structural test | Details |
|---|---|
| **Strength of reinforced concrete** | • Assess the in situ strength of the concrete. The most common method is to extract a concrete core sample from the structure under investigation by diamond drilling. A compressive strength test on the extracted core can be performed in the laboratory to give an estimated in situ cube strength.<br>• Use a Schmidt hammer. This carries out a rebound test on concrete or rock and from the results an estimate can be made of the strength of the material.<br>• Use a calibrated reinforcement cover meter to indicate the location of reinforcement in concrete up to 150 mm below the surface. An estimate of bar diameter can also be given. |
| **Steel thickness measurements** | • Use a calibrated ultrasonic gauge to measure the thickness of steel or other metal sections. |
| **Confirming wall thickness or construction** | • Use coring techniques, usually using diamond drills, to drill and extract cores. Drilling can be horizontally through walls or vertically. Vertical drilling can be used to reveal the construction widths and materials in old stepped gravity walls for example. |

## A.27.6 Reporting

A short report should be produced detailing the location of the asset, date and time of testing, methods employed and results of all tests. The report should include photographs to clarify points and details of any problems encountered. The report should indicate the expected accuracy of the quoted results.

# Appendix 28 Tier 3 inspections: internal inspections using borescopes (endoscopy)

## A.28.1 Relationship to tiers 1 and 2

A performance and risk assessment of an issue may trigger the need for an intrusive tier 3 investigation. This typically follows a tier 2 inspection alert, but may in exceptional circumstances where there is a large amount of data already on record, follow a tier 1 inspection alert.

## A.28.2 Why?

| Purpose | Trigger from performance assessment following tier 2 inspections |
|---|---|
| To collect visual inspection information where normal access is not possible. | Usually triggered by suspected presence of voids, to access cracks. |

## A.28.3 Typical requirements

It may be necessary to look inside or behind an asset, particularly if there is concern that there may be voids which could threaten the integrity of the structure. The alert about a possible void could come from an inspection report and recommendation, or be associated with an engineering integrity alert such as backfill washout, undermining or scour. Where access cannot be gained to view the void, use of a specialist device will be required.

A borescope is an optical device consisting of a rigid or flexible tube with an eyepiece on one end and an objective lens on the other linked together by a relay optical system in between. The optical system is usually surrounded by optical fibres used for illumination of the remote object. An internal image of the illuminated object is formed by the objective lens and magnified by the eyepiece which presents it to the viewer's eye. Rigid or flexible borescopes may be fitted with an imaging or video device.

## A.28.4 Preparing for surveys

A number of steps are required to prepare for this type of survey:

- There should be a clear understanding of the reason why the alert has been raised, preferably with a sketch or marked up photographs to highlight the issue.
- If the requirements are not clear and no further information is available, a preliminary site visit may be needed to confirm the method to be used.
- An indication of the size and depth of the void to be probed would assist planning of the further inspection, although this may not have been obvious

from the initial inspection. Use of a rigid borescope is more straightforward and an indication of whether this could perform the inspection is useful.

- If the void is likely to be full of water or access to the void is through water, specialist equipment will need to be obtained. The use of divers may be necessary.

## A.28.5 Typical methods

The void should be probed, feeding the borescope into the void. Dimensions should be checked and a photographic record taken.

## A.28.6 Reporting

The report should give details of:

- the method used
- the dimensions and nature of the void
- whether the void has removed support to parts of the structure, noting whether there is a risk of collapse or further loss of material
- a suggested cause(s) for the formation of the void
- options for methods of filling the void

A photographic or video record should also be produced.

# Appendix 29 Tier 3 inspections: load testing

## A.29.1 Relationship to tiers 1 and 2

A performance and risk assessment of an issue may trigger the need for an intrusive tier 3 investigation. This typically follows a tier 2 inspection alert, but may in exceptional circumstances where there is a large amount of data already on record, follow a tier 1 inspection alert.

## A.29.2 Why?

| Purpose | Trigger from performance assessment following tier 2 inspections |
|---|---|
| To confirm the ability of a structure to withstand imposed loads | Usually this can be avoided by other tests. With care further information can be gathered (for example, deformations) under load which will assist in analyses. Extreme cases may require testing to destruction of part of the asset, allowing for reconstruction. |

## A.29.3 Typical requirements

In rare cases it may be necessary to test a structure under load. This should generally be avoided if at all possible and should be treated as a last resort type of test when there really is no other way of assessing the ability of an asset to withstand a load.

An example might be to assess the strength of an asset where a floor slab may be of varying thickness and normal structural calculations cannot be applied. Load testing is sometimes applied to bridge decks where the construction has been built up over many years and section dimensions and strengths cannot be estimated.

Load testing of ground anchors in situ is a specialist task work; advice will be needs from an appropriate individual or company on feasible methods for the particular type of anchors.

In extreme cases it may be necessary to test to destruction a small part of the structure and allow for its reconstruction. This would allow greater confidence in the assessment of the strength of the remaining structure.

## A.29.4 Preparing for surveys

Care is needed in preparation for such testing and a specialist company should be engaged in the planning phase to ensure safe execution.

One of the most important aspects is to make arrangements to ensure the structure could fail safely if that occurs. In the case of a suspended floor slab, for example, supports should be placed underneath to take the weight of a collapsed slab and the loads that have been imposed.

Access is a particularly important part of planning when load testing ground anchors.

## A.29.5 Typical methods

### A.29.5.1 Loading by weights

Loads should be added gradually and deflections monitored so that structural properties can be assessed without the need to fail the structure.

### A.29.5.2 Loading with water

Usually the need to load test a structure with water can be avoided. However if such testing is required the following will need to be considered:

- Can a length of a flood defence, for example, be isolated to allow a short length to be tested?
- How can the head of water be built up to create the load? The space to accommodate the reservoir of water does not need to be wide, as the water load is only related to the depth of the water column. The confined area could use sheet piles or similar components which can be easily placed and removed on completion.
- Does the testing require a source of water or can river water be used, pumped to a higher level if necessary?

### A.29.5.3 Testing of ground anchors

Testing of ground anchors under load is usually a rare part of an inspection regime and is prompted by a concern.

#### *Maintenance testing*

This involves inspection of the condition of materials and components of the anchorage and, where appropriate, testing to determine the nature and severity of the condition, for example, metallurgical and tension tests to assess the type and significance of a corroded tendon unit. The prime purpose of maintenance testing is to establish whether:

- the anchorage has suffered corrosion or mechanical damage
- the conditions recorded are within acceptable limits

#### *Service behaviour monitoring*

This focuses on the performance of:

- the anchored structure with respect to overall movement and local deformation
- individual anchorages with particular reference to residual load and anchor head displacement

The testing of ground anchors under tension load is a specialist activity. It is not appropriate to include a summary here as the testing method will depend on the particular circumstances and types of anchor.

## A.29.6 Reporting

Reports need to include an explanation of the purpose of tests the undertaken, details of the methods employed and all results. Results should clearly show how the structure has responded to load, deflections or movement.

Conclusions should be drawn by analysis of the results of the testing, with recommendations regarding:

- allowable working loads in the future
- constraints that need to be placed on the asset
- the need for any remedial work to extend the life of the asset

# Appendix 30 Health, safety and environmental considerations

## A.30.1 Risk assessments

Inspections of assets and any follow-up inspections or investigations are often made in locations and at times which have associated risks. It is essential that these risks are fully considered in the planning of site inspections and that they are reconsidered on site as conditions change or are not as previously expected.

The safety of those making the inspections and anyone else who might be affected is paramount. If risks cannot be reduced, inspections should be postponed rather than unnecessary risks be taken.

Table A.30.1 details the risks that should be covered in generic and site-specific risk assessments. (See also the guidance in the appendices for tier 2 and 3 inspections and investigations). This list is not exhaustive and the risks for each site need to be considered in accordance with the procedures in place in the organisations concerned. Inspectors should be made aware of the legal obligations detailed in the registers maintained by the health and safety specialists in each organisation.

**Table A.30.1 Health and safety risk assessment for inspections**

| Risk | Mitigation and comments |
|---|---|
| **Driving to site** | Are public road conditions good enough to access the site safely? |
| **Off road access** | Can the site be accessed safely using the proposed vehicle? Should an alternative vehicle be used? |
| **Vehicle parking** | Can your vehicle be parked legally and safely without disrupting residents, the public, landowners and users? |
| **Pedestrian access from vehicle** | Can access from the vehicle to the asset be achieved safely? What precautions need to be taken? |
| **Weather conditions** | Do current and forecast weather conditions pose particular hazards? |
| **Personal protective equipment (PPE)** | Has the requirement for PPE been considered and is the equipment available? |
| **Lone working** | Is lone working really necessary? Can a ‘buddy’ arrangement be put in place to use a two person team to inspect assets in the same vicinity? Is the site inspection in compliance with the lone working procedures in your organisation? Is there phone coverage? |
| **Notification of visit and hostile register** | Do office staff know your planned route? Are there any special precautions that need to be made as a result of entries in the hostile register? |
| **Access for inspection of the asset** | Can all elements be inspected with acceptable risks? Is special equipment required? (If this cannot be planned in advance, consider a follow up visit.) Have all precautions been taken for working near water? |
| **Livestock** | Do livestock pose a risk at the site to be inspected? |
| **Waterborne diseases** | These may be a risk if access into the water is required. |
| **Confined space access** | No confined space access should be attempted without appropriate training, equipment and approvals. (See also guidance in Appendix 20.) Note that any space where access and |

| Risk | Mitigation and comments |
|---|---|
|  | escape is difficult should be designated a confined space. |
| **Vegetation or silt clearance** | Vegetation and silt can be cleared if the inspector is equipped with appropriate and approved tools and has received appropriate training in their use. A follow-up inspection may be required after vegetation clearance by fully equipped operations staff if the asset cannot be graded as a result of element(s) not inspected (see section 2.3.5). |

## A.30.2 Environmental considerations

Environmental interests may need to be taken into account when planning, timing and performing visual inspections and any follow-up inspections or investigations in tier 2 or tier 3. Table A.30.2 indicates the type of issues that may need to be considered.

**Table A.30.2 Environmental considerations for inspections**

| Risk | Mitigation and comments |
|---|---|
| **Protected species** | Are there protected species of flora and fauna that need to be considered before and during inspections? |
| **Nesting or over-wintering birds** | Can the site be accessed without disturbing nesting or over-wintering birds? Can the visit be rescheduled to avoid disturbance? |
| **Biosecurity** | Are there any particular precautions required for biosecurity, including consideration of any disease notifications for the area? |
| **Pollution or contamination** | Is there known contamination or the potential to cause contamination by the planned activity? |

# Appendix 31 List of recommendations

1. Undertake further analysis of and linkages to ‘performance and risk assessment’ activities and those within ‘asset management and investment decision making’ (outside the scope of this project).
2. Recommendations and comments from inspections, particularly where highlighting an alert to the possible need for a tier 2 or 3 inspection, should be recorded in the asset database or accompanying documents for future reference and action.
3. The Environment Agency’s Condition Assessment Manual or equivalent should continue to form the basis of routine tier 1 inspections, but should be adapted by other recommendations in this document.
4. An overall condition grade should be assessed based on the grading of the individual elements. This can be done either using the weighting formula described in Appendix 2 or by judgement taking into account the importance of each element.
5. If an element, which is critical (by judgement) to the performance of the asset in its intended role, falls below target, the condition grade should be amended to show that the asset as a whole is below target grade.
6. Create an alert for any score above 3.0, which may prompt further investigations or to bring the date of the next inspection forward.
7. Adoption of the steps in Appendix 2 is recommended for those carrying out inspections and for the way that the inspection results should be considered by asset managers.
8. Inspectors should provide an alert that there may be a possible engineering integrity issue as a recommendation in their inspection report.
9. Incorporate engineering integrity issues into CAM or equivalent inspection guide to ensure they are considered regularly and efficiently.
10. Further progress is recommended towards the use of hand-held devices for recording inspection observations. Smartphones and personal digital assistants (PDAs) are powerful tools which, with their use of global positioning systems (GPS) and storage of photographs, could be easily developed using specialist applications for inspections.
11. Record for future reference the information collected and the reasons for the decision made regarding the next steps.
12. Priority should be given to completing baseline information for high consequence systems (see Appendix 1) before moving to medium consequence systems.
13. Evidence suggests a need to improve data management to ensure the data held are of consistently good quality to allow efficient asset management based on risk and performance measures.
14. To target inspections appropriately, more detailed assessments are needed to establish key inspection parameters such as element weightings, inspection frequency and target grade. This will result in alerts that are be targeted and relevant, rather than a flood of general alerts which obscure important information.

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