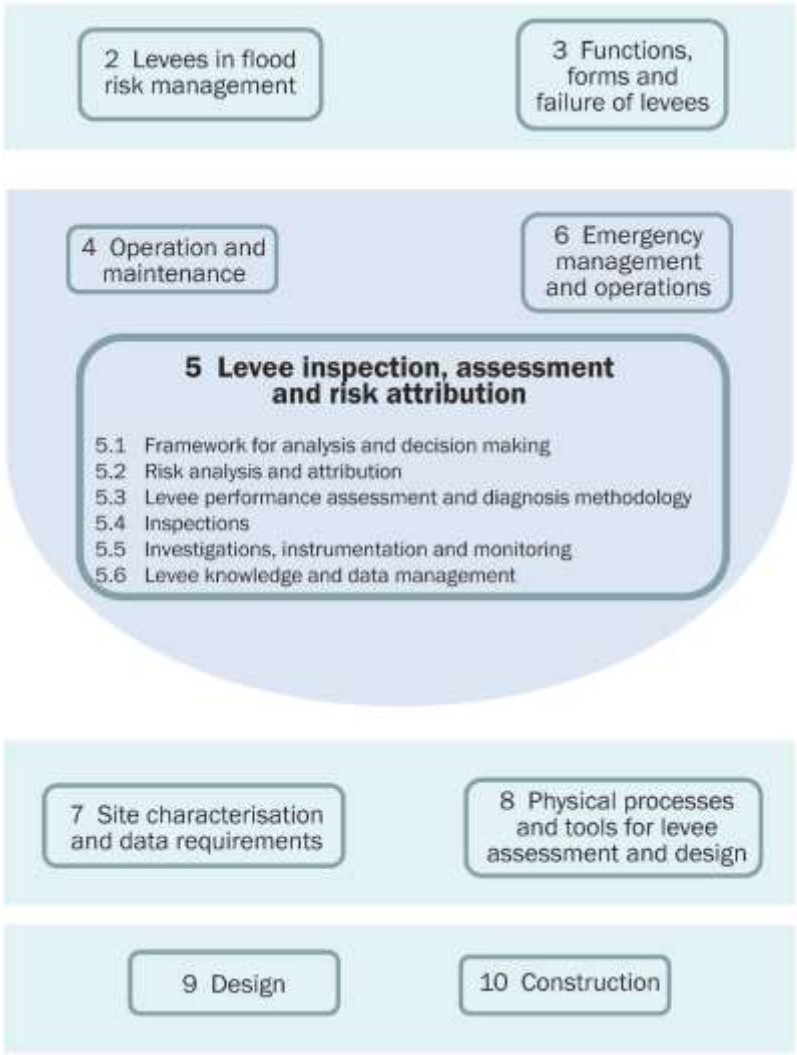
Overview of the handbook

Chapter 5:

Levee inspection, assessment and risk attribution

Content and aims



Chapter 5 introduces levee performance assessment and flood risk analysis. These support all decisions about levee management.

Key inputs from other chapters

- **Chapter 2** ⇨ basic concepts
- **Chapter 3** ⇨ forms, functions and failure mechanisms
- **Chapter 4** ⇨ operations and maintenance
- **Chapters 7 and 8** ⇨ toolbox (data and models)

Key outputs to other chapters

- inspections ⇨ **Chapters 4 and 6**
- decision making ⇨ **Chapters 4, 6 and 9**

Note: The reader should revisit **Chapters 2 and 3** throughout the levee life cycle for a reminder of important issues.

Chapter 5 purpose

- Outlines assessment related activities, which include:
  - Flood risk analysis of a levee system and risk attribution to levee segment
  - Levee (or levee system) performance assessment and diagnosis
  - Inspections
- Details the principles, sources of data and data management
- Presents the first attempt to provide a consistent and comprehensive framework for performance and risk assessment – encompassing quite different approaches in different countries and situations.

Chapter 5 target users and table of contents

- These issues are important for levee managers as well as specialized engineers, as they give important information to be used in any decision making related to management or design
- Chapter 5 is a central chapter in the handbook, for existing levee systems

5 Levee inspection, assessment and risk attribution

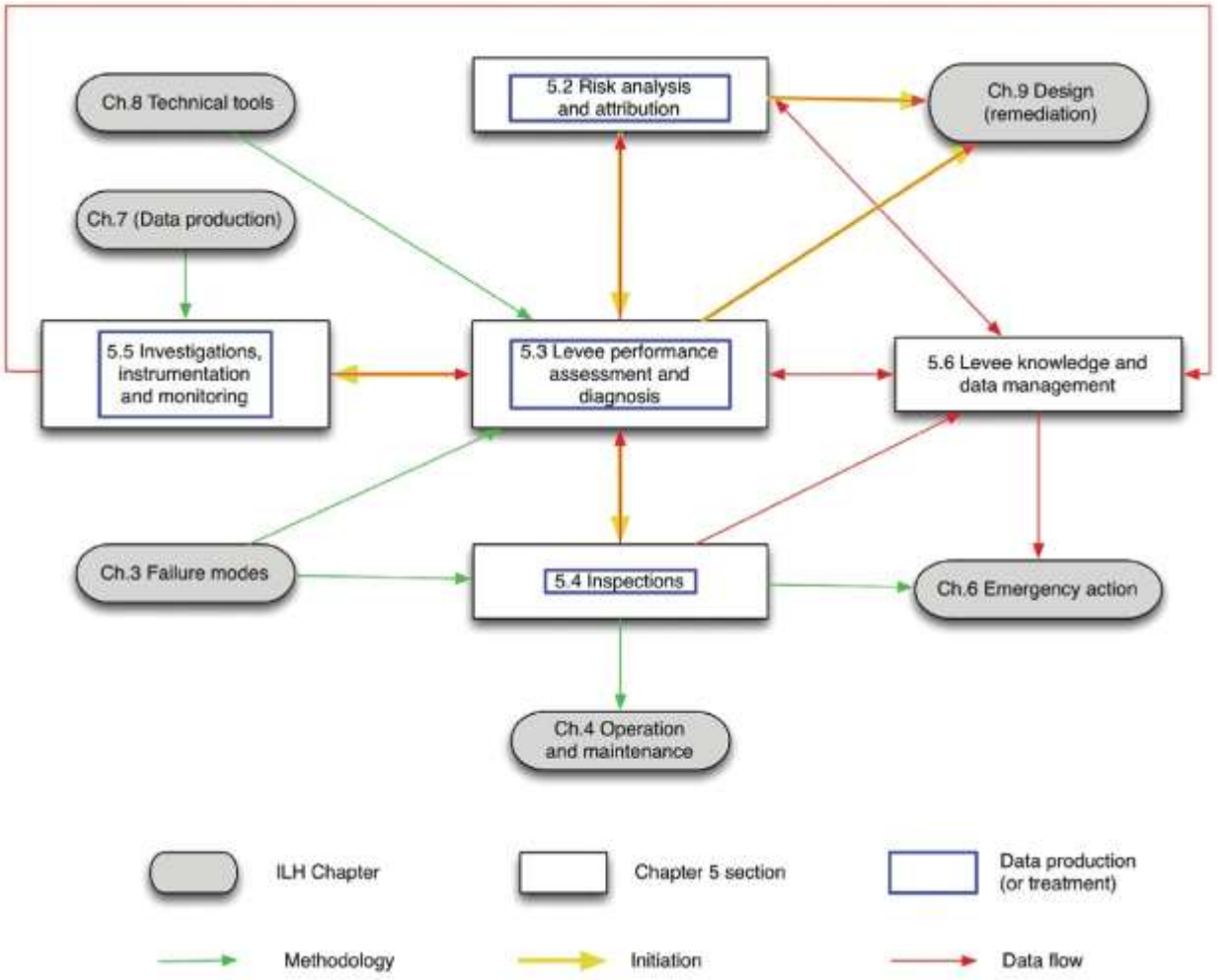
5.1 Framework for analysis and decision making
5.2 Risk analysis and attribution
5.3 Levee performance assessment and diagnosis methodology
5.4 Inspections
5.5 Investigations, instrumentation and monitoring
5.6 Levee knowledge and data management

5.1 FRAMEWORK FOR ANALYSIS AND DECISION MAKING

- This section provides a basis for the rest of the chapter and includes:
  - a framework for levee performance assessment tools
    - definitions and differences of the various types
    - use of the results in decision making
  - the importance of the role of data in levee performance assessments
  - types of data acquisition: inspections, investigations, monitoring and instrumentation
  - links to other parts of the handbook (next slide)

5.1 FRAMEWORK FOR ANALYSIS AND DECISION MAKING
Links with the rest of the Handbook

- For existing levee systems, chapter 5 is a central chapter in the handbook.

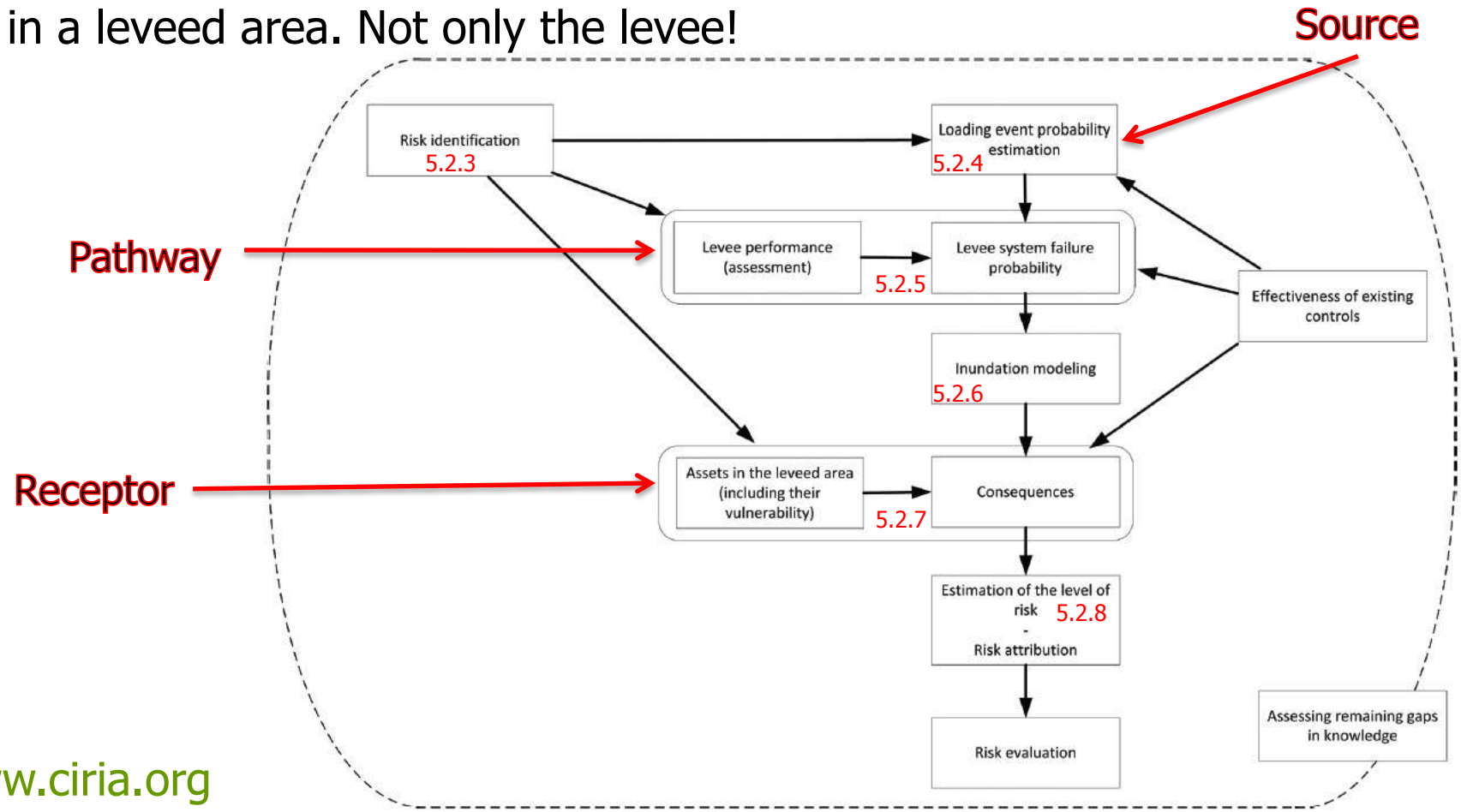


5.2 RISK ANALYSIS AND ATTRIBUTION

- A risk-based approach has become a general objective of flood risk managers as well as levee managers, although the tools and methods required to implement it are still being developed.
- This section details the principles of flood risk analysis (FRA) of levee systems including:
  - an overview building on the general principles of flood risk management presented in Chapter 2,
  - tiered and phased approaches to FRA,
  - knowledge gaps and uncertainty (see next slide),
  - different components of FRA (see next slide),
  - risk attribution and evaluation (see next slide).

5.2 RISK ANALYSIS AND ATTRIBUTION

- FRA of levee systems include all components of the SPR model in order to understand the nature and value of the residual flood risk in a leveed area. Not only the levee!



5.2 RISK ANALYSIS AND ATTRIBUTION

- Example results:

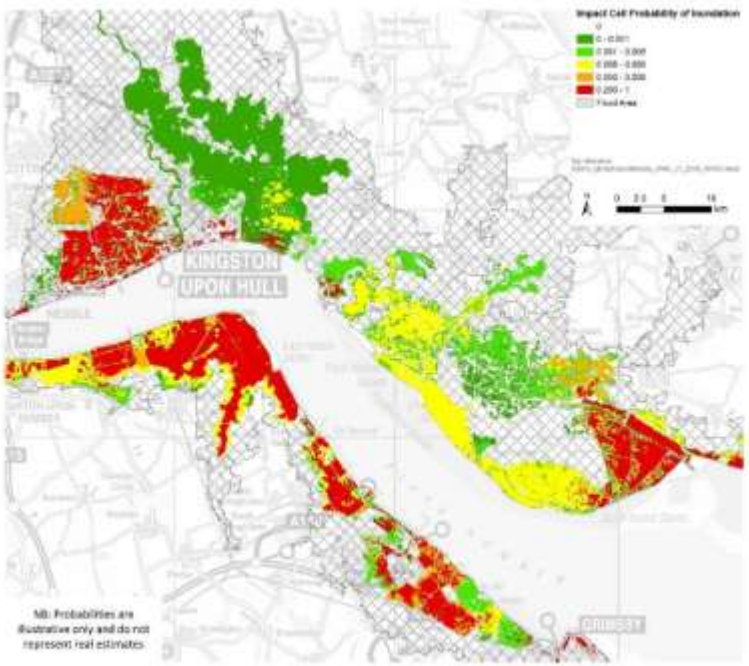


Figure 5.15 *Example of a probability of inundation map from the UK (courtesy of the Environment Agency).*

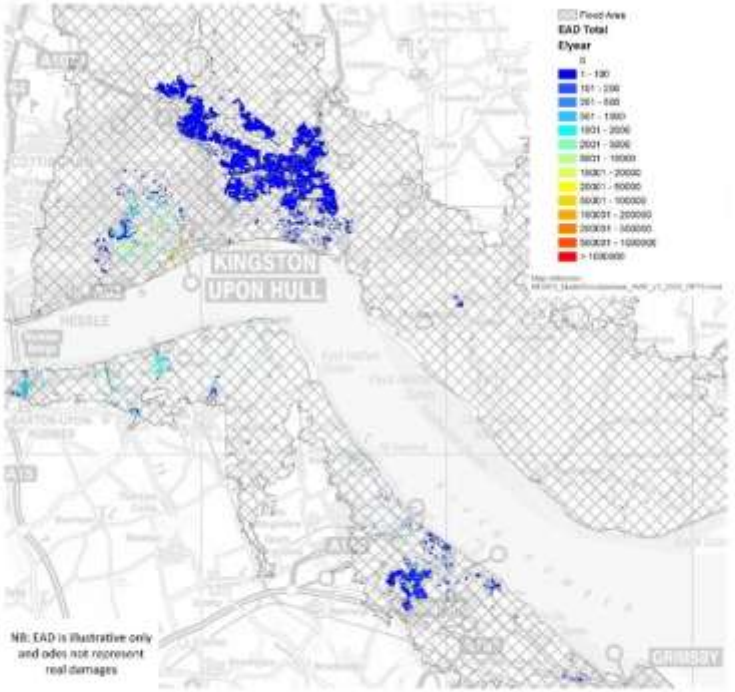


Figure 5.16 *Example of an expected annual damage map from the UK. (courtesy of the Environment Agency).*

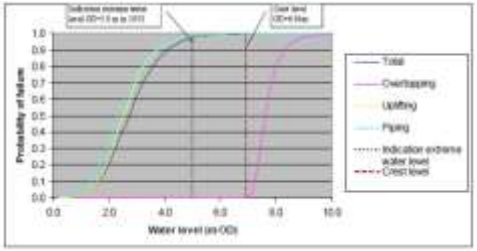
For illustration purposes only

5.3 LEVEE PERFORMANCE ASSESSMENT AND DIAGNOSIS METHODOLOGY

- This section presents the:
  - principles of performance assessment of levee or levee systems,
  - place and level of detail of the different types of assessment in the levee management cycle
  - importance of the analysis of failure modes,
  - different types of assessment methods, including a typology of data, data processing and nature of results, illustrated by some different examples,
  - reporting of assessments,
  - link with regulations.

5.3 LEVEE PERFORMANCE ASSESSMENT AND DIAGNOSIS METHODOLOGY

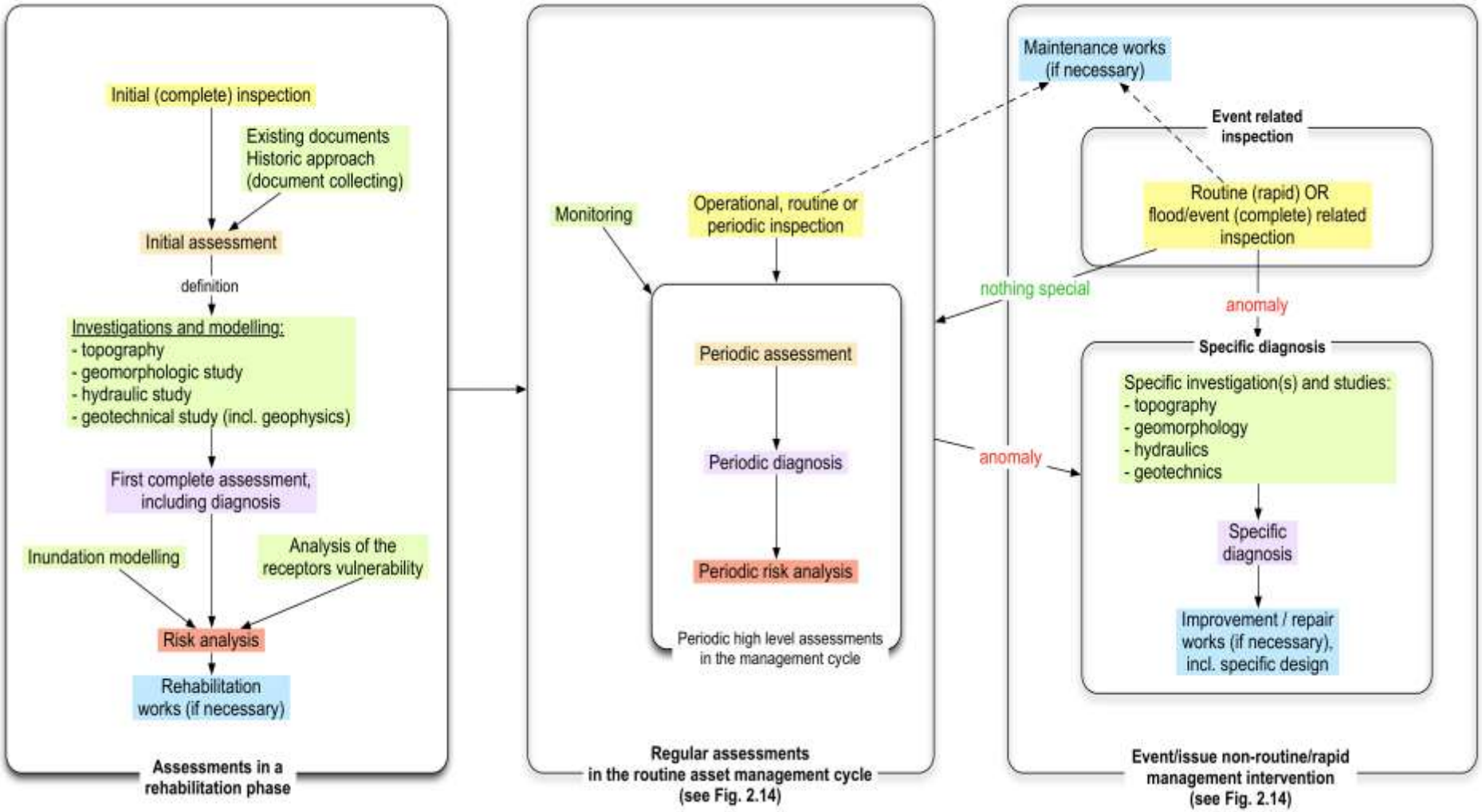
- Levee performance assessments results are related to:
  - its main (hydraulic) function (to protect against flooding) and,
  - its resistance to structural failure modes.
- There are different possible forms of result of a levee performance assessment:
  - threshold (a limit load),
  - conditional chance of failure (for a given load),
  - fragility curve (conditional chance of failure given for a range of loads),
  - safety factor,
  - index (examples: on a 0-5 or 0-10 scale)
  - qualitative (example: Very Good. Good, Fair, Poor, Very poor).



- The form of the result depends on:
  - the data processing method used, but also
  - on the way it will be used thereafter.

  It is possible to build equivalences between the different types of results.
- Assessments should take into account all available data related to the different possible failure modes
- Different type of models can be used to combine data:
  - models (see Ch8 for all applicable models), using both physical or empirical based equations,
  - index based methods, using predefined combination of index rating different observations or parameters,
  - expert judgement, direct or using one or more of the above method types as pre-processed data.

5.3 LEVEE PERFORMANCE ASSESSMENT AND DIAGNOSIS METHODOLOGY



5.4 INSPECTIONS

- Inspections are the most frequent data gathering method used in levee assessments. They are either:
  - part of a wider assessment process or
  - a specific "operation" that is, in itself, the simplest type of assessment.

- This section presents:
  - the purpose and principle of inspections,
  - their place in the assessment process,
  - the different types of inspections and different occasions
  - inspection methodology,
  - inspection management,
  - the conduct, reporting and follow-ups of inspections.

5.4 INSPECTIONS

- Inspections can (have to) be conducted in normal conditions as well as during (if security allows) and immediately after loading events (river floods, storms).

- Inspections need to be prepared in advance, both in terms of staff, equipment, safety, list of features to inspect and describe, condition grading, reporting methods.

- A table in the handbook presents the common visual indicators, example of condition grading, the associated mechanisms and failure modes for various items

Visual Indicators (Field Observations)	Description (examples of condition grading)	Associated Mechanism(s) and/ or Failure Mode(s)	Description of Mechanisms
	is likely to impact levee integrity.		
Erosion: The removal of sod, soil or rip rap that has invaded near or into the levee prism.	• no areas of erosion near or within the levee footprint • minor erosion near or within the levee footprint • erosion areas near or within levee footprint that diminish the function or integrity of the levee.	**External erosion** **Slope instability**	Continued erosion removes enough soil that promote slope instability.
Any sign of levee **slope instability** such as a scarp	• no slides, sloughs, slope depressions, or bulges present within levee prism. • minor slope stability issues will likely not diminish proper levee performance. • major slope stability issues (i.e. deep seated sliding, cracks that exhibit vertical movement) that will affect levee performance.	**Slope instability**	Unstable levee slopes increase the probability of slope failure during hydraulic loading
Cracking of the levee crown or side slopes.	• minor longitudinal, transverse, or desiccation cracks with no vertical movement along crack. • longitudinal and/or transverse cracks with no vertical movement along the crack but is not expected to affect the integrity of the levee. No cracks extend continuously through the levee crest. • numerous longitudinal and transverse cracks that could impact levee integrity. Transverse cracks extend through the entire levee width of the crest.	**Slope instability** **Internal erosion**	Cracks in the levee create a plane of weakness which infiltrating water can exploit to initiate a slope failure event.
	• minimal number of burrowing		

5.5 INVESTIGATIONS, INSTRUMENTATION AND MONITORING

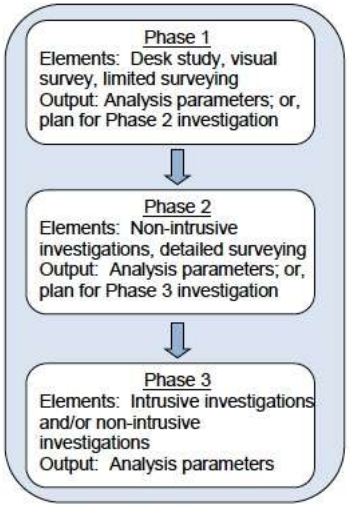
- This section presents these different types of data acquisition activities, which are of utmost importance in detailed assessments:
  - investigations, which are conducted on a one time basis in a specific process,
  - monitoring (including the use of instrumentation) consists in repeated measurements or observations; monitoring measurements have to be analysed.

- It also presents principles for planning investigations

- The detailed presentation of the different types of investigations and instrumentation methods is made in Chapters 7 (mainly) and 8 (partly)

5.5 INVESTIGATIONS, INSTRUMENTATION AND MONITORING

- The section presents the principles of investigation planning, taking into account previously available data, and using a phased approach, progressively refining the program.



Example of phased approach to levee investigation

- The section makes the link between data gathered by investigation and monitoring with the possible failure modes - the starting point for performance assessment.

Table 5.8. *Summary of Mechanism/Failure Modes and Potential Testing and Sampling Programs*

Mechanism(s) and/or Failure Mode(s)	Test /Parameter	Investigation or Sampling Method
Mechanism: Scouring, overtopping, or overflowing Failure Mode: Erosion	Embankment geometry (Section 7.9.1) Channel geometry (Section 7.9.2) Index properties (Section 7.8.3.1) Erodibility (Section 7.8.3.6)	Terrestrial surveys for embankment geometry (Section 7.9.1) Bathymetric surveys for channel geometry (Section 7.9.2) Intrusive investigations for soil characterization and laboratory testing (Sections 7.9.6)
Mechanism: Backward erosion, concentrated erosion (piping), contact erosion, dissolution Failure Mode: Internal Erosion	Embankment geometry (Section 7.9.1) Channel geometry (Section 7.9.2) Index properties (Section 7.8.3.1)	Terrestrial surveys for embankment geometry (Section 7.9.1) Bathymetric surveys for channel geometry (Section 7.9.2)

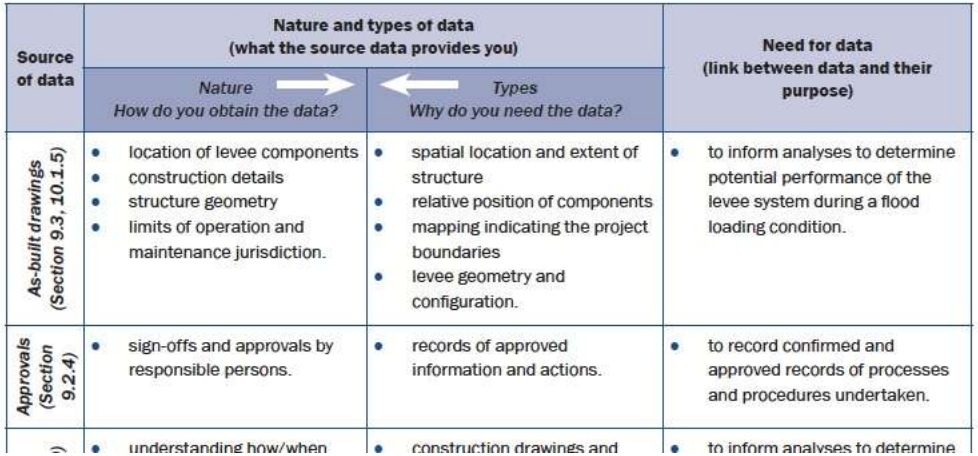
Table 5.9 *Instrumentation observations and associated failure mechanisms*

Instrumentation Type	Observation/Data	Associated Mechanisms and Failure Modes	Description of Issue(s)
1. Piezometer Pore pressure cell	Elevated total head Pore water pressure	Seepage issues, potentially leading to stability failure (uplift) and/or internal erosion	Increased pore water pressure decreases effective stresses and shearing resistance along potential failure planes. Decreasing shearing resistance may ultimately lead to slope failure.
2. Survey Ground anchors Extensometers Settlement cells/plates Fibre optic (strain)	Loss of freeboard due to settlement	Overtopping / overflowing	Long-term settlement should be monitored for new levees to confirm predicted settlement used to define required overbuild for adequate freeboard

(incomplete tables)

5.6 LEVEE KNOWLEDGE AND DATA MANAGEMENT

- Levee related data has an important value: its initial cost, and chiefly its possible use in all future assessments, as well for management (including during floodings) and design issues.
- So, data has to be preserved, and managed in a way that it is accessible
- The section presents, in a table, the various sources, natures and types of data, as well as their purpose.

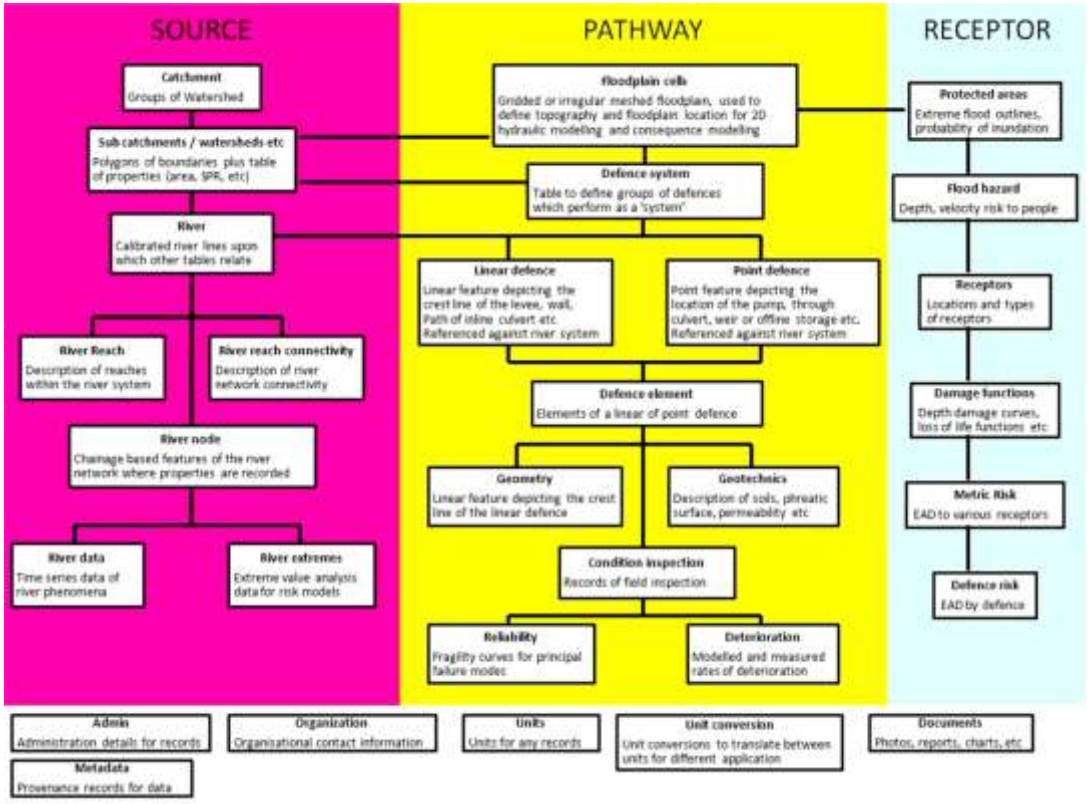


Source of data	Nature and types of data (what the source data provides you)		Need for data (link between data and their purpose)
	Nature → *How do you obtain the data?*	← *Types* *Why do you need the data?*	
As-built drawings (Section 9.3, 10.1.5)	• location of levee components • construction details • structure geometry • limits of operation and maintenance jurisdiction.	• spatial location and extent of structure • relative position of components • mapping indicating the project boundaries • levee geometry and configuration.	• to inform analyses to determine potential performance of the levee system during a flood loading condition.
Approvals (Section 9.2.4)	• sign-offs and approvals by responsible persons.	• records of approved information and actions.	• to record confirmed and approved records of processes and procedures undertaken.
	• understanding how/when	• construction drawings and	• to inform analyses to determine

- It justifies the need for data management and presents the principle of information systems, including paper and digital medium. Specific information is given on the design of computer based systems (databases and GIS).

5.6 LEVEE KNOWLEDGE AND DATA MANAGEMENT

- The design of levee related data management and information systems is a complex task, but it is absolutely necessary in order for the system to fulfil the needs of the levee manager
- The data model is the most critical step in this design, which should include the analysis of the different data processes
- The automated processes can include tools to help the assessment and risk analysis, and enhance the presentation of the results.



CONCLUSION FOR Chapter 5

Assessments and risk analysis are conducted in:

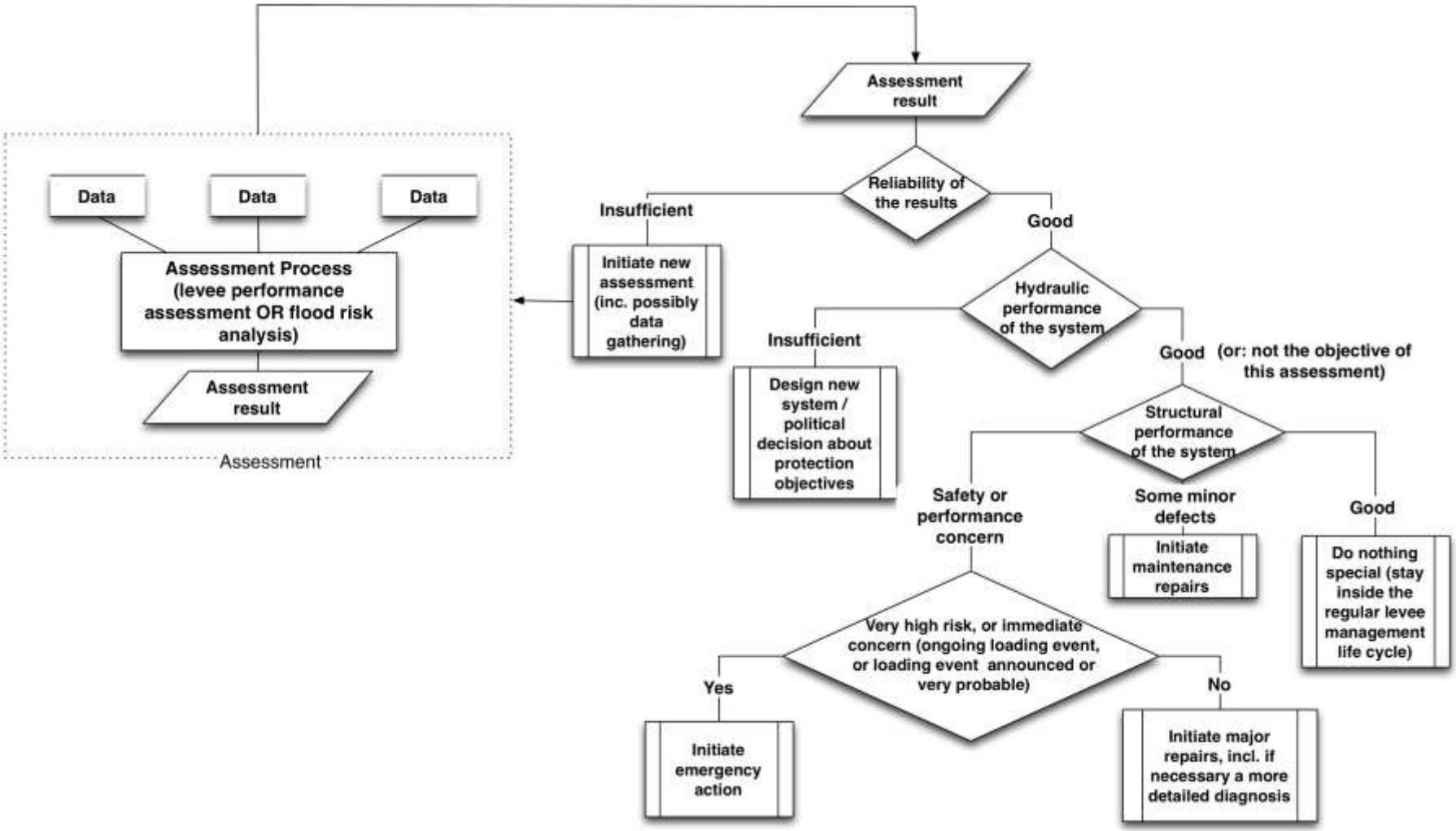
- progressive,
- tiered and
- phased approaches

all along existing levees life cycle.

Their results are essential tools for helping decision making, for both the management and the design of improvements.

The flowchart on the next slide proposes a logical process linking assessments and risk analysis to decision making.

CONCLUSION FOR Chapter 5 : assessments & decision making



Thank you

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