Surveillance, maintenance and diagnosis of flood protection dikes

A practical handbook for owners and operators

Patrice Mériaux, Paul Royet

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Foreword

Objectives and content of this handbook

This technical handbook is intended for the personnel of companies or organisations involved in the management of dikes designed to provide protection against flooding caused by a rise in river levels. Written for engineers and technicians, its aim is to increase understanding of:
– How dike systems work.
– The risks faced.
– Surveillance operations.
– Maintenance operations.

It also aims to describe and explain the work to be done to ensure the long-term future and safety of such structures, in view of water resource and flood prevention legislation in France.

Produced upon the initiative of the French Ministry of the Environment (water resources department), this book was written by Cemagref, under the guidance of, and with contributions from, a working group.

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– Jean-Michel Tanguy	Mediterranean technical studies & engineering centre (CETE)
– Jean-Luc Roy & Marie-Pierre Nerard	Ministry of the Environment – water resources department

This book forms part of a nationwide French initiative to improve the safety of flood protection installations the failure of which would have serious repercussions for both people and property (dikes that pose a potential risk to public safety).

To this end, the French government has introduced a scheme (see Appendix 5) to control:
– Practical measures implemented by operators.
– The safety of such structures.

It is for this reason that the last chapter of this book describes one method of dike diagnosis.

Layout

Following a description of dikes and their functions in Chapter One, Chapter Two considers the various malfunctions and failure mechanisms that may affect these structures.

Visual inspection, upon which diagnosis and surveillance are based, is dealt with in Chapter Three. Appendix 3 contains a methodology for recording information obtained from visual inspections, together with standard anomalies record forms.

Specific aspects of dike surveillance during flooding form the subject of Chapter Four.

Chapter Five deals with the maintenance of dikes and appurtenant works; it provides practical advice on the most common repairs.

Finally, Chapter Six briefly describes the stages in dike diagnosis.

A separate French publication provides further information on this subject: "*Méthodologie de diagnostic des digues appliquée aux levées de Loire moyenne*" (methodology of dike diagnosis applied to levees along the middle reaches of the River Loire, March 2000, Cemagref Éditions).

This handbook also contains a short list of terms specific to dikes (see Fig. 1 also), including explanations of abbreviations used in the book, as well as the basic principles of soil mechanics (Appendix 1) and soil hydraulics (Appendix 2). Finally, references to prices are given in euro (excluding taxes).

Appendix 5, which briefly outlines French legislation on flood protection dikes in the last decade, has been added to the 2004 edition.

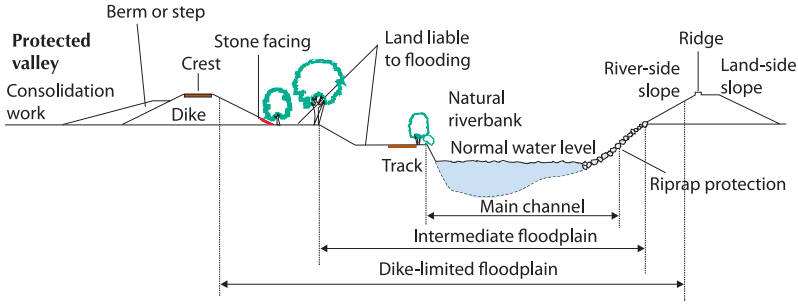

Figure 1. Typical cross-section of diked land

Roles and responsibilities of those involved in dike management

Several categories of interested parties or players are more or less concerned by dike management. The initial difficulty lies in identifying them. To this end, we propose the following list (see Fig. 2):

– ***Dike owner:*** This is usually the dike builder and may be the State, a local community or group of local communities, a property owners' syndicate, private individuals, etc.

– ***Site owner:*** The owner of the foundations upon which the dike stands. More often than not, the site owner is also the dike owner (the ideal situation), but they may be different entities whose relationship is not always clearly defined.

– ***Owner or operator of structures or networks*** built on or into the body of the dike, including buildings, functional premises, electricity or telephone lines, gates and

stop log structures, culverts, conduits and pipes, communications channels, etc. It is a very good idea for a written agreement to be signed with the dike owner and/or operator, in which each party's responsibilities are specified.

– ***Owner or manager of land and/or constructions (liable to flooding)*** situated between the dike and the main channel of the river or stream.

– ***Owner or manager of land and/or constructions*** (valley side, land side) protected by the dike, but exposed to the risks of failure or of flooding in the wake of failure.

– ***Dike operator:*** When the owner and operator are different entities, the owner makes the operator responsible for the maintenance and correct working of the dike, in principle by way of a formal agreement.

– ***Director of works:*** In charge of dike building, heightening and upgrading. Logically this is the dike owner, but it is possible for an institution to assume the role of director of works for structures not belonging to it (e.g. a group of local communities in charge of works on private land or structures).

– ***Design office*** or ***engineering office*** (private or public), under contract from the owner, director of works or operator to carry out preliminary research (diagnosis, design, consultancy, etc.) or to supervise work done on the dike.

– ***Company:*** Responsible for the construction, heightening or upgrading of a dike.

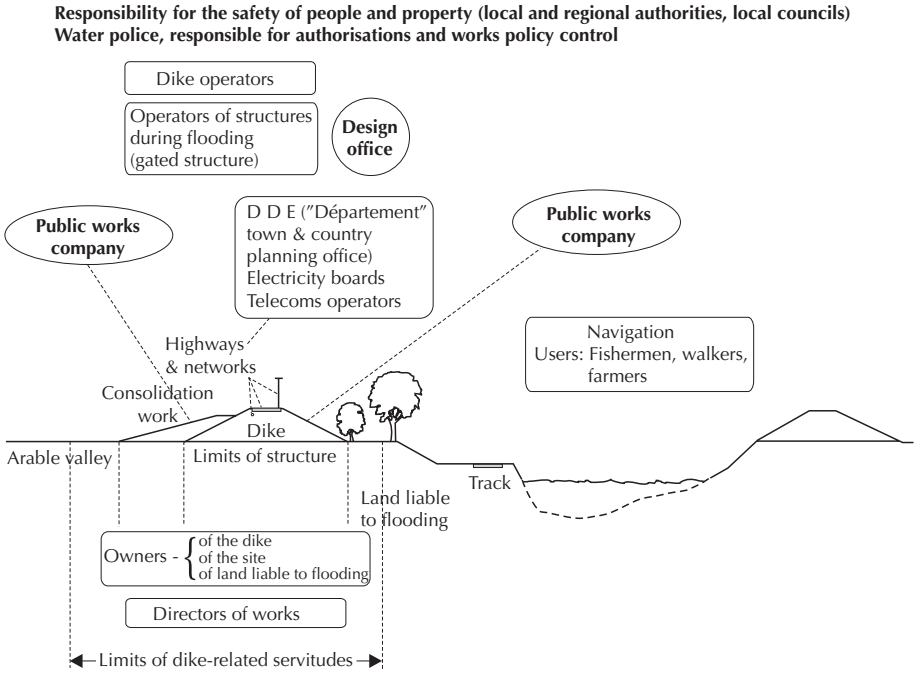

Figure 2. Responsibility for the safety of people and property

– ***French Water Police:*** In charge of controlling authorisation procedures relating to structures and of verifications of dikes identified as structures that pose a threat to public safety.

– ***Official bodies responsible for the safety of people and property:*** local and regional authorities, local councils.

Responsibility of the owner

The dike *owner* (local community, group of local communities, a property owners' syndicate, private individual, etc.) is wholly responsible, under both civil and criminal law, for any damage that may be caused by the structure, and, in particular, by its failure.

This responsibility may, in principle, be reduced in certain situations (major floods classed as natural disasters or considered to be unforeseeable). On the other hand, an obvious failure to correctly monitor and maintain structures is likely to worsen circumstances.

The need to monitor and maintain dikes

Responsibility apart, the objective of keeping structures in good condition provides sufficient justification for regular surveillance and maintenance for two main reasons:

– Regular surveillance means that a great many anomalies and malfunctions can be detected at an early stage, that subsequent developments can be tracked and that any necessary maintenance and repair work can be carried out in good time.

– If a structure is properly maintained, it will age more slowly and have a longer service life. For instance, routine work to clear invasive ground cover or dissuade burrowing animals can do away with the need for more substantial rehabilitation work. Good maintenance of structures (especially control of vegetation and maintenance of service tracks) also makes surveillance and inspection easier.

Technical skills required for structure management

To fully assume the role described above, the *owner* of a dike system needs field technicians who have been trained to carry out the various tasks associated with surveillance and maintenance. If these technicians work directly for the owner, the latter is also considered to be the *operator*. The supervisors of operating and maintenance workers should also be conversant with geotechnics, civil engineering, hydraulics and environmental engineering. Therefore, and if need be, it is recommended that owners sign formal agreements for the management of dikes with organisations that have suitably qualified staff or technical departments that are capable of operating a stand-by system in the event of an emergency.

In this case, the owner is distinct from the operator, but their contractual ties should be clearly defined.

It is therefore recommended for small entities that own dikes to entrust their management (or even transfer ownership) to appropriately-sized organisations that have the resources needed for good management and operation.

Classification of dikes: recent changes to French regulations

Since 2002, flood-protection dikes in France have been governed by a system of authorisation or declaration, depending on their size (*cf.* decree dated 13/02/2002 mentioned in Appendix 5). They may be classed as being "a potential threat to public safety" if their failure would result in a serious risk to human life (*cf.* circular dated 06/08/2003 referred to in Appendix 5).

1 Nature, functions and composition of dikes

DIKE: An artificial structure, flood protection embankment or barrier that protects against river flooding, at least a part of which is built above natural ground level. It is designed to periodically contain a high discharge of water and thus protect areas that are naturally prone to flooding. (The term "levee" is often used along the French River Loire in common with certain areas of the USA).

Simple constructions that protect the slopes of riverbanks (masonry walls, riprap or concrete facings) but that are no higher than the top of the natural bank are not considered to be dikes. Neither are quay walls, unless incorporated into a dike in the above-mentioned sense of the word, nor structures intended to protect against coastal erosion (groynes, seawalls, etc.) or harbour jetties.

This handbook does not cover:
– *Canal embankments (navigable waterways, hydroelectric plant feeder canals, etc.).*
– *Highway and railway embankments situated in floodplains.*
– *Bank protections not topped by a dike.*

We should also mention "sea dikes", the function of which is to protect estuaries and coastal areas against high tides or unusually high seawater levels created by storms, as in the Camargue, for example, at Salins-de-Giraud. A French guide to such structures is to be published at a later date.

1.1 Overview of existing structures in France

Though not very well known, France has a considerable number of flood protection dikes. It is generally only during major floods that they make the news headlines, when failure leads to the flooding of supposedly protected areas.

A national enquiry, initiated in 1999 by the French Ministry of the Environment with a view to compiling a complete evaluation and survey of these facilities (creation of a DIKES database of structures, operators and potential consequences of failures), led to the initial observation that the country has some 8,000 kilometres of dikes and a thousand or so operators. To mention just some:

– Along the 450 km of the middle reaches of the River Loire (between the confluences of the Allier and Maine rivers), 600 km of mainly state-owned dikes (known locally as "levees") protect 1,000 sq.km or so of valleys liable to flooding. To this should be added the levees built along tributaries such as the Rivers Cher, Indre and Vienne. Several large towns are protected by levees, including Tours, where 90,000 people are concerned, Orléans and its urban area with 40,000 inhabitants, Blois with 10,000 and the Authion flooding valley, close to Saumur, with 45,000. The Loire levee system has not been subject to major flood peaks since the three great floods of the middle of the 19th century, the consequences of which were considerable.

– The course of the River Garonne (in southwest France) was extensively diked following flooding in 1875, when 500 people lost their lives, including 200 in Toulouse. The dikes did not, however, prevent the loss of another 200 lives in the 1930 flood. Although over 90% of the land liable to flooding and protected by dikes alongside the Garonne is agricultural, the populations of a number of large towns are still directly at risk, including 40,000 people in Toulouse and 25,000 people in Agen. The status of dikes along the Garonne varies widely.

– Along the two branches of the Rhône delta, the Camargue is protected against flooding by approximately 200 km of dikes, which were breached in 16 places during flooding in October 1993 and January 1994 (floods considered to be hundred-year events). These breaches were largely due to deficient dike surveillance and maintenance; the management system (small property owners' syndicate) was acknowledged to be inappropriate and has since been substantially modified.

1.2 How dike systems work (dikes and spillways)

The hydraulic behaviour of a dike-limited floodplain can be described as follows:

– During a flood, rising water levels cause the river to break out of its main channel and spread over into the diked floodplain (Fig. 3a).

– A dike system limits the spread of flood waters during minor and medium-intensity floods, but it also leads to a rise in water levels at the point where it reduces the width of the natural river bed (a common feature in urban areas).
– Flood peak reduction (which attenuates maximum discharge by propagation into parts of the floodplain) is thus limited during regular floods.
– Areas protected by dikes may, in certain cases, be flooded by main river water backing up into a tributary, by runoff from lateral catchment basins whose outlets into the river are saturated or by a rise in the water table (Fig. 3b).
– To prevent overtopping (and the virtually certain failure) of dikes during a major flood, spillways are sometimes built into them which, when the water exceeds a certain level, make it possible to flood areas that are less built-up, giving flood waters more room to propagate and thus facilitate discharge (Fig. 3c).These deliberate flood propagation areas are sometimes themselves divided by embankments into a number of flood spreading plains that are inundated in turn.
– In an extreme flood, the whole valley is inundated, either following spillway operation or because of breaching as the result of dike overtopping. The watercourse then covers its entire floodplain as though in the absence of flood defences.

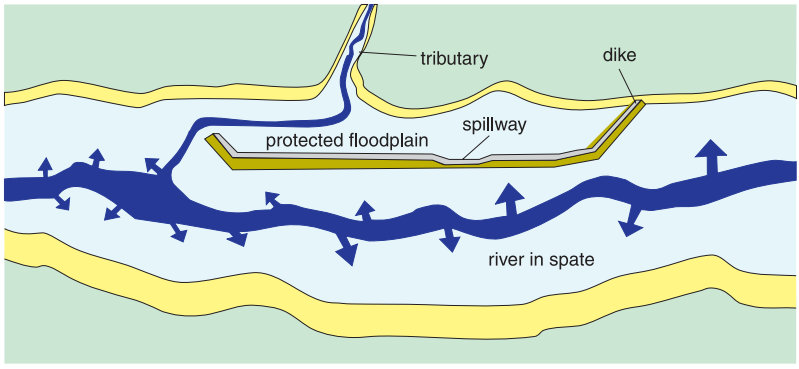

Figure 3a. Propagation of flood waters in a diked floodplain

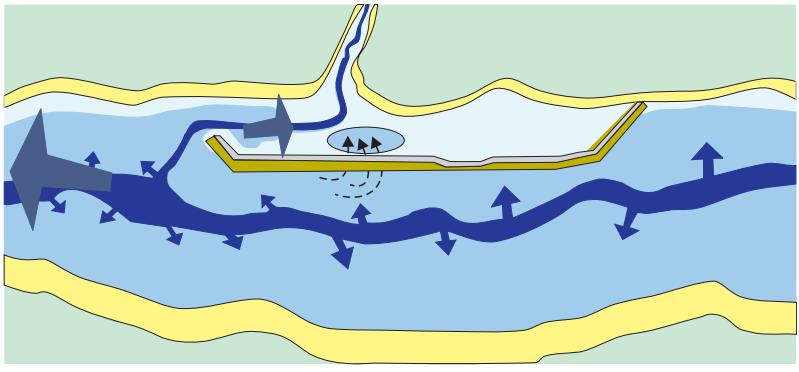

Figure 3b. Flooding of a valley by backing up, runoff from a catchment basin or a rise in the water table

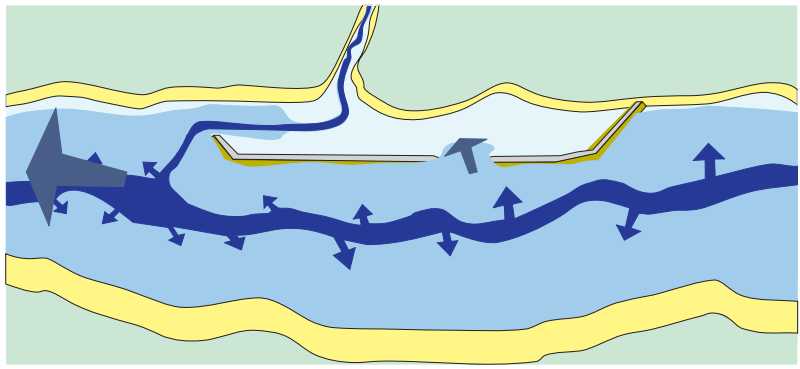

Figure 3c. Spillway operation

1.3 Composition of dikes

1.3.1 Fill dikes

The majority of dikes in France are earthfill embankment constructions made with materials ranging from silt to sand and occasionally gravel. Their composition can largely be explained by the history of their construction.

– Very often they were built in stages during different periods as the use of rivers and the need for defences changed (Fig. 4).

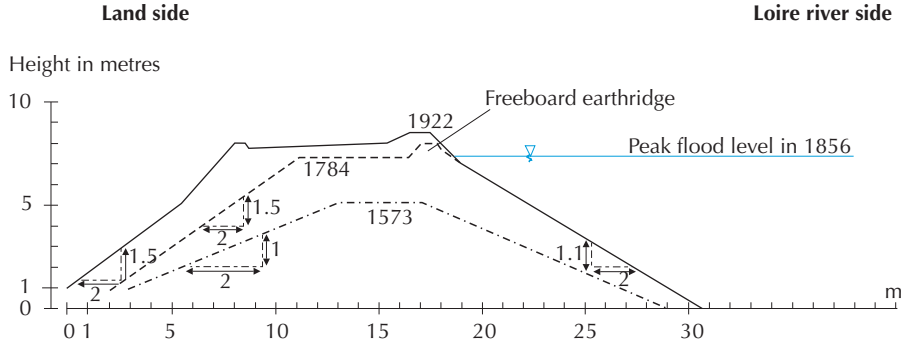

Figure 4. Typical cross-sections of River Loire levees before recent upgrading work

– Since powerful earth-moving equipment was not available at the time, dike embankments were generally built with materials taken from the immediately surrounding area; the remains of old borrow pits can still be seen at the toe of some dikes.

The nature of earthfill materials may therefore vary widely, even along the same river (sandy in the middle reaches and silty nearer the mouth). Generally, however, single sections are of a homogeneous nature with no zoning and no special internal drainage system (Fig. 5).