



## Risk analysis of levee systems Analyse de risque des systèmes d'endiguement

Use of the results of the analysis for risk mitigation on the Authion levee system  
Exploitation des résultats de l'analyse pour la réduction du risque sur le système d'endiguement de l'Authion



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2- Réduction du risque par des mesures de gestion

### 3- Risk mitigation through functional and structural improvements of the levee

3- Réduction du risque par des améliorations fonctionnelles et structurelles de la digue

### 1- Characteristics of the levee system from the risk analysis (hazard study)

1- Caractéristiques du système d'endiguement issues de l'analyse de risque (EDD)

System composition

Composition du système

Safety / protection / overflow levels  
protection / de surverse

Niveaux de sûreté / de

Performance of the levee system during a flood    *Fonctionnement en cas de crue*

Severity of consequences associated with a system failure  
associées à la défaillance du système

Gravité des conséquences

### 2- Risk mitigation through management measures

2- Réduction du risque par des mesures de gestion

At the levee system level  
système

A l'échelle des digues du

At the territory level

A l'échelle du territoire

### 3- Risk reduction through functional and structural improvements of the levee

3- Réduction du risque par des améliorations fonctionnelles et structurelles de la digue

Drafting and implementation of a project to improve the reliability of the levee

*Elaboration et mise en œuvre d'un projet de fiabilisation*

Examples of levee reliability works

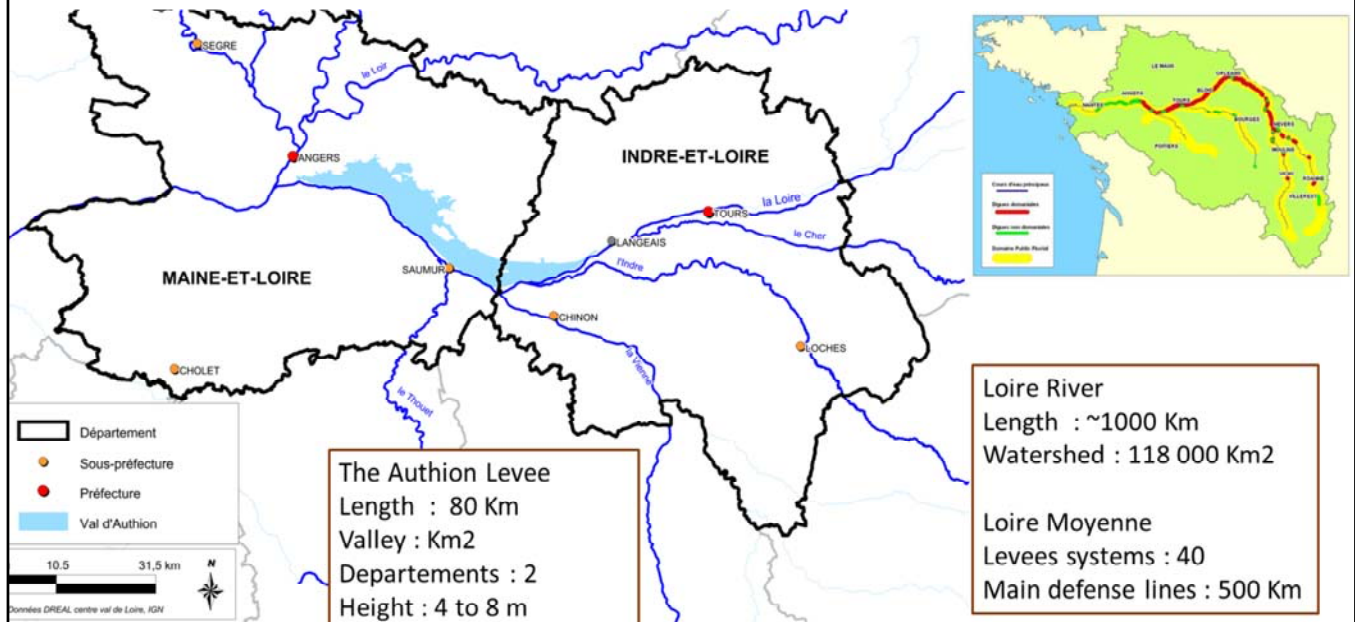
*Exemples d'opération de*

*fiabilisation*

## 1- Characteristics of the levee system from the risk analysis (hazard study)

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The Authion Levees systems is the largest of the 40 systems of the Loire Moyenne



### Loire river

The Loire is the longest river in France. It measures more than 1000 km from its source at 1400 m altitude in the mountains of the Massif Central to the Atlantic Ocean.

Its watershed covers 117 800 km<sup>2</sup>.

The Middle Loire is a part of the Loire River which extends over 450 km from the confluence of the Loire and the Allier after Nevers to the confluence of the Maine and the Loire at Angers.

The Middle Loire is characterised by an almost continuous Meta system of levees designed to protect the floodplain (from 2 to 12 km wide) from the river's floods.

### The Meta levee system of the Loire Moyenne

The Meta levee system of the middle Loire has about 500 km of levees forming the main line of defence againsts flooding. The main line of defence consists of 40 levee systems.

The Authion levee system is the largest.

# 1- Characteristics of the levee system from the risk analysis (hazard study)

## Local authorities concerned and stakeholders of the Authion Levee system

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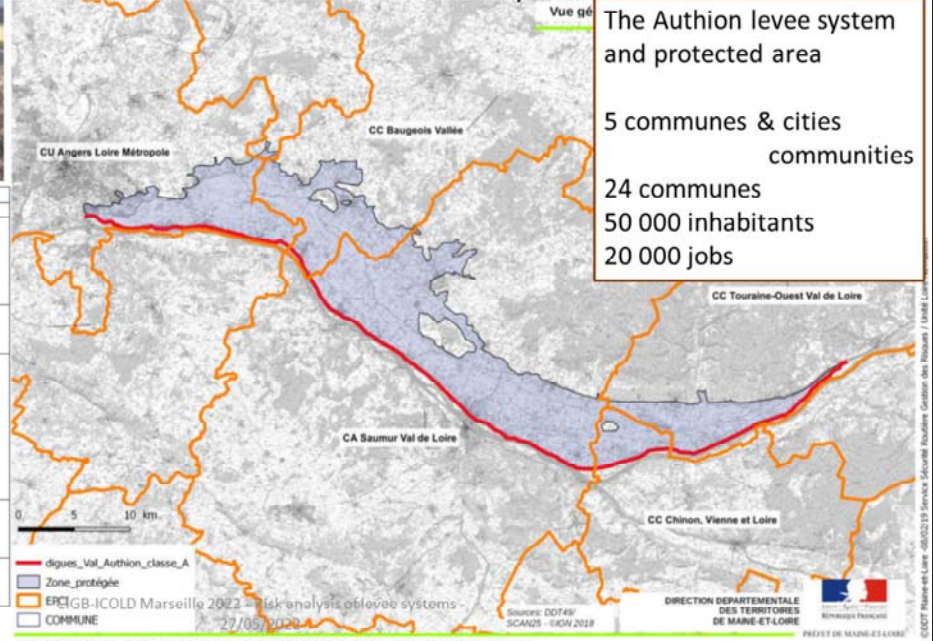


The Authion levee system and protected area

5 communes & cities  
communities

24 communes  
50 000 inhabitants  
20 000 jobs

EPCI	Communes	Population Impactée	Emplois Impactés	
			Nbre Min	Nbre Max
Communauté de Communes Touraine-Ouest Val de Loire	Bourgueil	761	555	554
	Coteaux-sur-Loire	308	77	76
	La Chapelle-sur-Loire	1442	173	150
	Langèvres	15	0	0
	Bourgueil	210	- de 50	- de 50
Communauté de Communes de Chinon-Vienne-et-Loire	Saint-Nicolas-du-Bourgueil	101	- de 50	- de 50
	Chouzé-sur-Loire	1868	800	586
Communauté d'Agglomération de Saumur-Val-de-Loire	Albionnes	1213	424	477
	Bleu	- de 20	- de 50	- de 50
	Brissac-sur-Allonne	193	- de 50	- de 50
	Gennes-Val-de-Loire	3268	872	854
	Langou-Lumelles	1613	487	480
	Saint-Clement-des-Leves	916	136	157
	Saumur	12790	6036	9728
	Varennes-sur-Loire	1173	216	216
Communauté de Communes de Baugé-sur-Loire	Villedor	1790	175	201
	Virey	241	- de 50	- de 50
	Beauchamps-en-Angou	2361	706	1174
	La Mancelle	2088	749	951
Communauté Urbaine Angers Loire Métropole	Les Bais d'Orpèu	49	- de 50	- de 50
	Musé-Mellon	1422	291	406
	Treize	1183	806	1477
Total		50328	16346	24766



## 1- Characteristics of the levee system from the risk analysis (hazard study)

### The Authion Levee system

The Authion levee system includes a main line of flood defence of about 80 km protecting a unique floodplain of about 400 km<sup>2</sup>.

The system is made up of very old works which have been built and rebuilt, by successive elevations and enlargements, since the Middle Age.

The levees near Angers are first mentioned in 779 in a manuscript from the time of King Charlemagne.

The average height of the levee is over 4.60 m and the maximum height is over 7.40 m (height above ground level on the valley side)

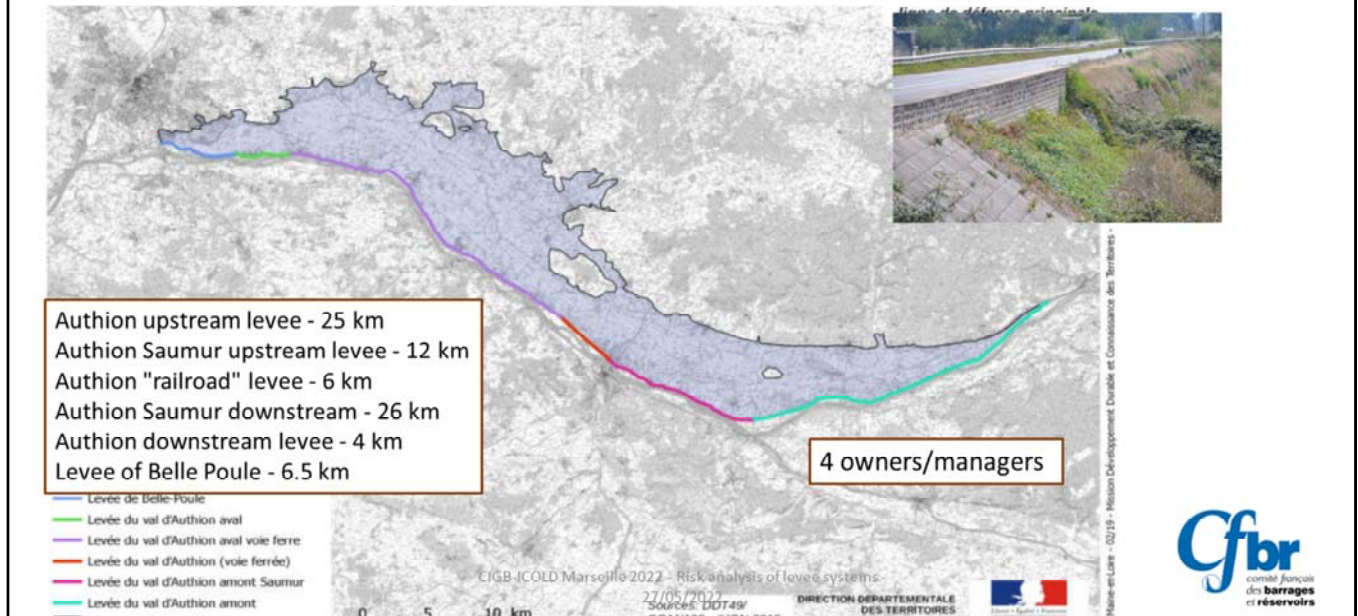
Population and local authorities : 24 communes/municipalities, over 50,000 inhabitants and about 20,000 employees



# 1- Characteristics of the levee system from the risk analysis (hazard study)

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6 sections of Levees make up the Authion flood protection system



## 1- Characteristics of the levee system from the risk analysis (hazard study)

### System composition

The flood protection system is composed of the following 6 sections of levee:

- Authion upstream levee - 25 km
- Authion Saumur upstream levee - 12 km
- Authion "railroad" levee - 6 km
- Authion Saumur downstream - 26 km
- Authion downstream levee - 4 km
- Levee of Belle Poule - 6.5 km

The first five sections are commonly associated to define what is often called the Great Levee of the Authion.

The sections " Authion upstream levee " are property of the State and managed by the technical services of the prefecture of Indre-et-Loire located in Tours (DDT37).

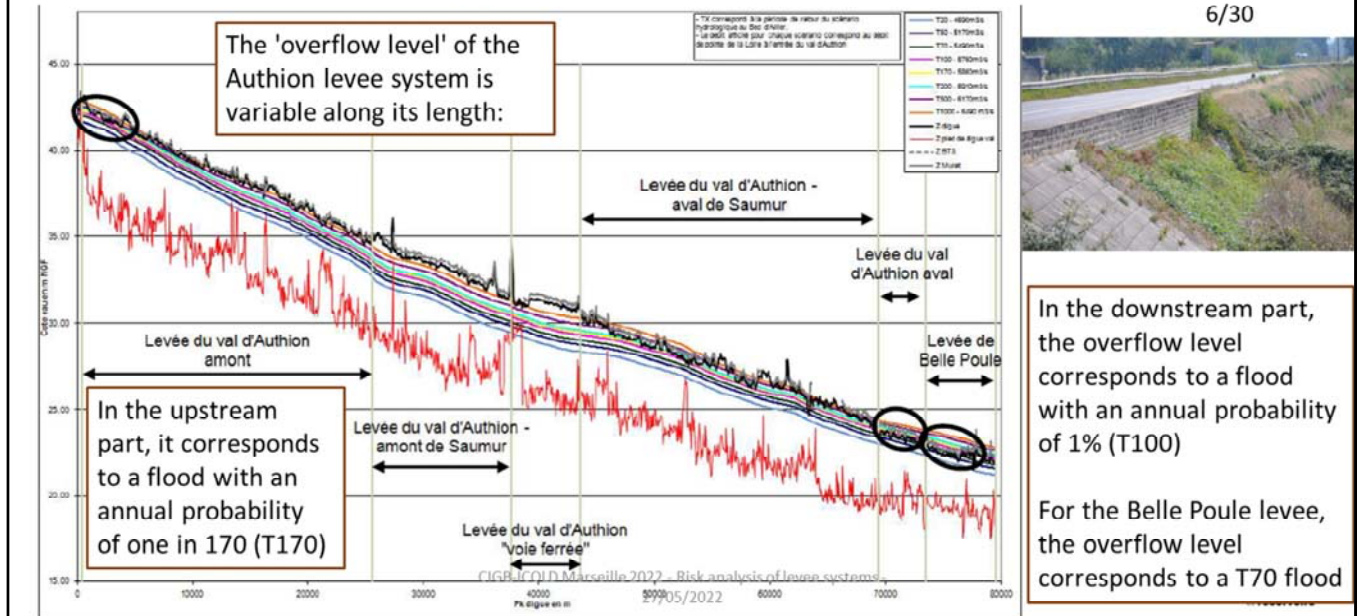
The sections " Authion Saumur upstream levee ", " Authion Saumur downstream " and "Authion downstream levee " are owned by the State and managed by the technical services of the Prefecture of Maine-et-Loire located in Angers (DDT49)

The section " Authion 'railroad' levee " is owned by Réseau Ferré de France (SNCF) but is not managed as a dike.

The "Levee of Belle Poule" section is owned by several local authorities and managed by the Syndicat Mixte pour le Développement Agricole de la Vallée de l'Authion (SYDEVA).

## 1- Characteristics of the levee system from the risk analysis (hazard study)

The 'overflow level' is the water level in the river above which the protected area starts to be flooded



## 1- Characteristics of the levee system from the risk analysis (hazard study)

### Overflow / Safety / Protection levels

The 'overflow level' is the water level in the river above which the protected area starts to be flooded without prior breach of the levee, by overflow above the top of the levee or by a spillway.

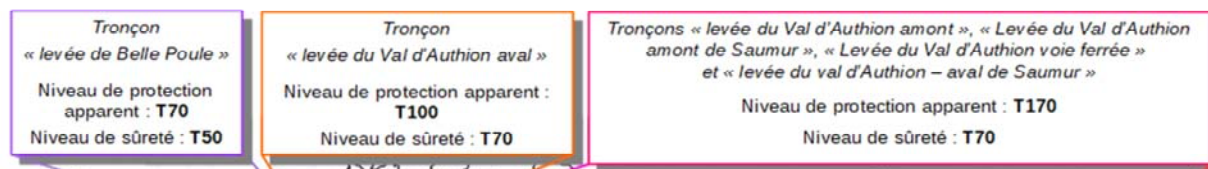
The hazard study showed that the 'overflow level' of the Authion levee system is variable along its length:

- In the upstream part, it corresponds to a flood with a return period of 170 years (this means an annual probability of one in 170)
- In the downstream part, after the town of La Bohalle, the overflow level corresponds to a flood of return period 100 years (this means an annual probability of one in 100)
- For the Belle Poule levee, the overflow level corresponds to a 70-year return period flood (this means an annual probability of one in 70)

# 1- Characteristics of the levee system from the risk analysis (hazard study)

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'Overflow' and 'Safety' level



Échelle de Saumur :

Crues modélisées	T20	T50	T70	T100	T170	T200	T500	T1000
Cote à l'échelle de Saumur (en m NGF)	29,46	29,85	30,09	30,40	30,54	30,64	31,00	31,32
Hauteur estimée à l'échelle de Saumur (en m)	5,35	5,75	5,95	6,30	6,40	6,50	6,90	7,20
Débit de pointe estimé (et fourchette d'incertitude associée) à l'échelle de Saumur (en m³/s)	4350 [3850 – 5250]	5000 [4250 – 5750]	5250 [4450 – 6050]	5500 [4750 – 6450]	5750 [4900 – 6600]	5850 [4950 – 6750]	6350 [5400 – 7300]	6700 [5700 – 7700]

Tableau 5 : cotes et débits à l'échelle de Saumur pour les crues modélisées de la Loire selon modèle LMA2

Logo de l'organisme



'safety' level = water level in the river above which the probability of the structure breaking down is no longer considered negligible.

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## 1- Characteristics of the levee system from the risk analysis (hazard study)

### Overflow / Safety / Protection levels

However, the levee system is likely to break down through internal erosion before the water from the Loire reaches the crest of the dike. This is why the level of protection must be determined according to the 'safety level' of the levee.

The 'safety level' is defined as the water level in the river above which the probability of the structure breaking down is no longer considered negligible.

In the upstream and downstream part of the Authion levee, the safety level corresponds to a flood with a 70-year return period (this means an annual probability of one in 70). For the Belle Poule levee, the safety level corresponds to a 50-year return period flood (this means an annual probability of one in 50).

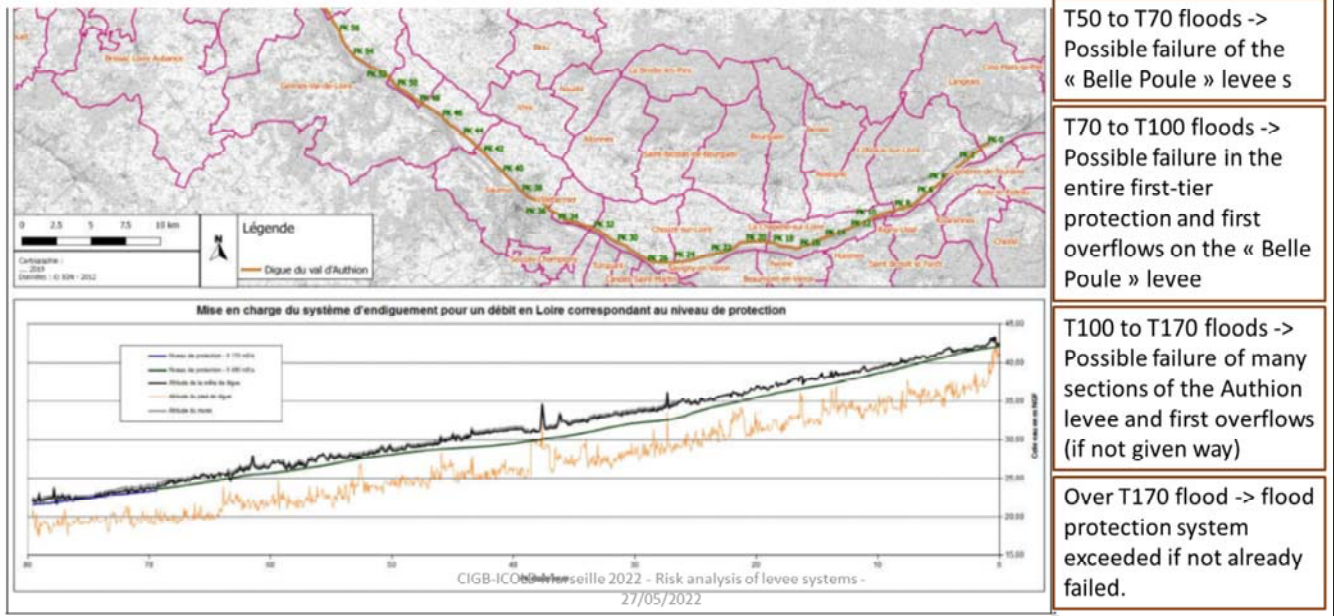
In a perfectly reliable levee system, the safety level is greater than or equal to the protection level. This means that failure before overtopping is unlikely. Under French law, the protection level is chosen by the levee system manager. For the Authion levee system the protection levels are the same as the safety levels.



# 1- Characteristics of the levee system from the risk analysis (hazard study)

Performance of the levee during a flood (from T50 to T500)

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## 1- Characteristics of the levee system from the risk analysis (hazard study)

### Performance of the levee system during a flood

The functional and structural analyses in the Hazard Study allow us to imagine the expected performance of the system during a flood.

For water heights lower than those of a T50 flood (height at the Saumur Bridge scale  $H = 5.75$  m, peak flow  $Q_p = 5,000$  m<sup>3</sup>/s), the levee system protects the entire Authion valley.

For water heights between those of the T50 and T70 floods (height at the Saumur Bridge scale  $H = 5.95$  m, peak flow  $Q_p = 5,250$  m<sup>3</sup>/s), the "Belle Poule levee" section could fail and give way, without overflowing the structures. The sectors of La Daguenière and Les Ponts-de-Cé, are the sectors that stand out as being the most fragile due to the height of the load on the structures, the presence of vegetation and/or the presence of pipes in the dike body.

For water heights between those of the T70 and T100 floods (height at the Saumur Bridge scale  $H = 6.30$  m, peak flow  $Q_p = 5,600$  m<sup>3</sup>/s), the entire first third protection system of the Authion valley could fail. The first overflows would be observed on the "Belle Poule levee" section, if it wouldn't have broken before, but without any



consequences due to the slopes on the valley side being very favourable to flows.

The most fragile sectors are those subject to the highest hydraulic loads, due to the presence of depressions on the valley side (old erosion pits for example) or those which suffer from the presence of disorders such as pipes in the lower part, vegetation or embedded buildings.

For water heights between those of the T100 and T170 floods (height at the Saumur Bridge scale  $H = 6.40$  m, peak flow  $Q_p = 5,750$  m<sup>3</sup>/s), beyond the overflow areas on the "Belle Poule levee" section which will be more obvious, the first overflows could be observed on the "Authion valley levee" section if these sections have not already given way.

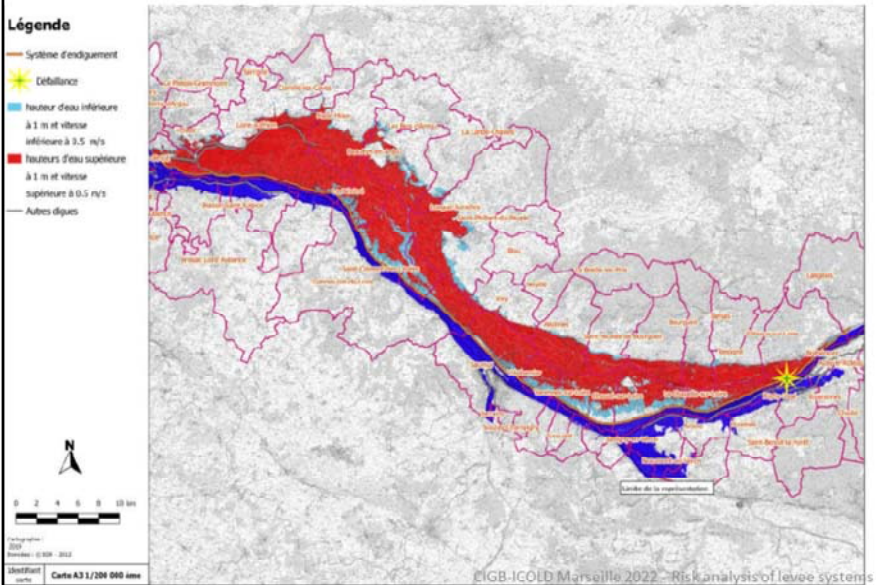
For water heights above that of the T170 flood (height at the Saumur Bridge scale  $H = 6.40$  m, peak flow  $Q_{pointe} = 5,750$  m<sup>3</sup>/s), the top of the upstream end of the flood protection system could be exceeded if it has not already failed.

In conclusion, the protection system constituted by the Loire levees in the Authion valley would probably present, today, a worrying and abnormal operating mode for floods greater than a T50 type flood of the Loire as far as the Belle Poule levee is concerned and for floods greater than a T70 type flood for the rest of the system.

# 1- Characteristics of the levee system from the risk analysis (hazard study)

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## Performance of the levee during a flood (from T50 to T500)



In the event of a breach upstream of the levee system, the population directly affected by flooding would be a maximum of 42,000 people, 5,900 of whom would be considered to be at risk.

In conclusion, the Authion protection system probably presents a worrying and abnormal operating mode for floods greater than a T50 type flood of the Loire as far as the Belle Poule levee is concerned and for floods greater than a T70 type flood for the rest of the levees.



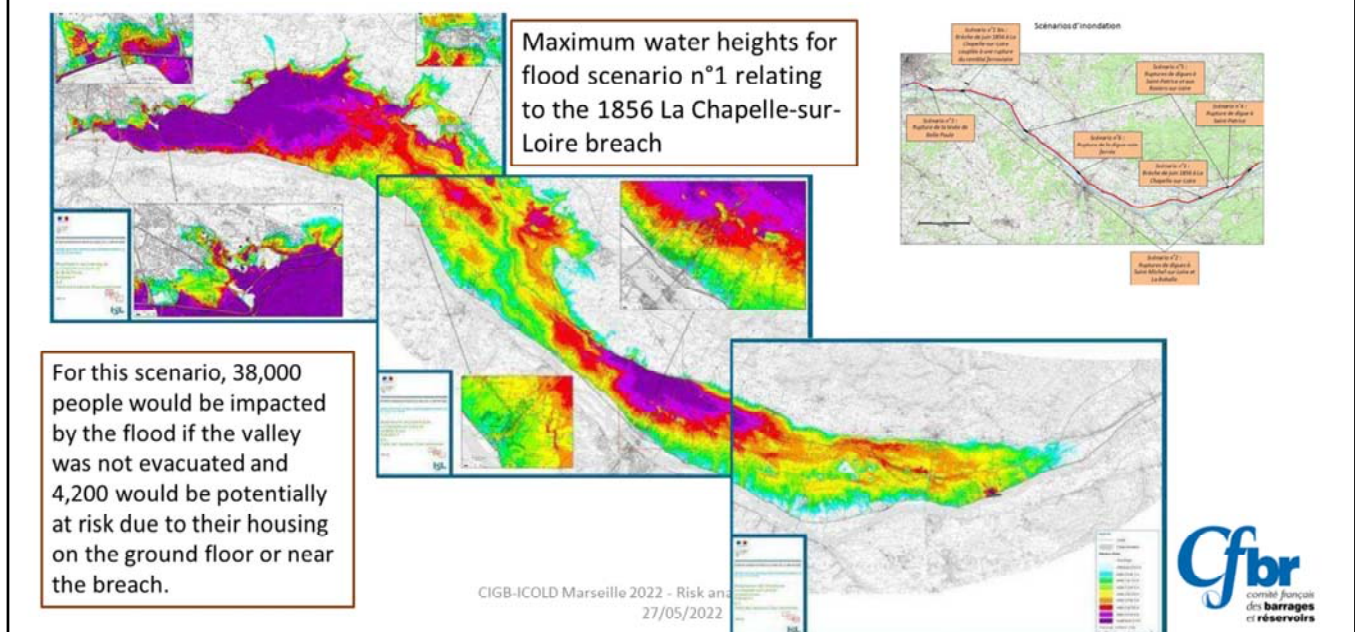
## 1- Characteristics of the levee system from the risk analysis (hazard study)

### Performance of the levee system during a flood

In the event of a breach upstream of the levee system, the population directly affected by flooding would be a maximum of 42,000 people, 5,900 of whom would be considered to be at risk.

## 1- Characteristics of the levee system from the risk analysis (hazard study)

Severity of consequences associated with system failure through 7 flood scenarios <sup>10/30</sup>



### 1- Characteristics of the levee system from the risk analysis (hazard study)

#### Severity of consequences associated with system failure

The Hazard study evaluates the severity of the flood risk in the valley, through 7 flood scenarios that have been simulated with different cases of levee breaches via two-dimensional hydraulic modelling tools. These scenarios are intended to approach the severity (i.e. number of people affected by the flood) and then the criticality (i.e. severity combined with the probability of the levee breaking).

The 3 Maps of maximum water heights for flood scenario n°1 relate to the 1856 La Chapelle-sur-Loire breach.

For this scenario, 38,000 people would be impacted by the flood if the valley was not evacuated and 4,200 would be potentially at risk due to their housing on the ground floor or near the breach.

In terms of severity, the scenario's consequences are described as "catastrophic" and present an intolerable risk in the context of a modern society.

Furthermore, due to the "perched" nature of the Loire in relation to the Authion valley, another consequence of the water entering the valley would be the change in the bed of the Loire, also known as defluviation.

## 1- Characteristics of the levee system from the risk analysis (hazard study)

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Severity of consequences associated with system failure / energy dissipation zone behind levees



Energy dissipation zone behind the dikes linked to the possible failure of the levee.

The force linked to the sudden entry of water into the protected zone would destroy any construction and erode the land to a depth of several meters.

## 1- Characteristics of the levee system from the risk analysis (hazard study)

### Severity of risk associated with system failure

The analysis of the erosion pits created by the historical breaches leads to the consideration of an energy dissipation zone behind the dikes linked to the possible failure of the protection works. In this zone, the force linked to the sudden entry of water into the protected zone would destroy any construction and erode the land to a depth of several metres.

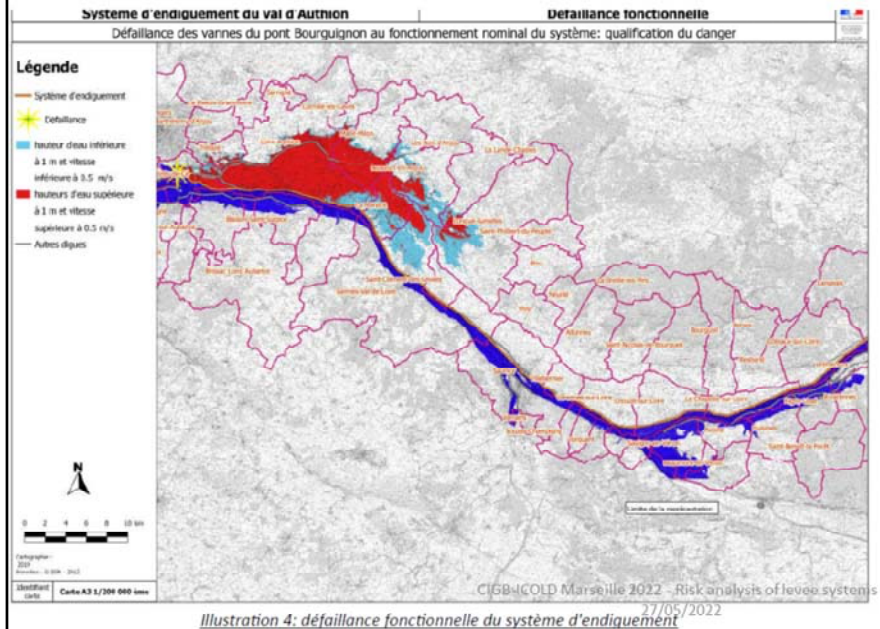
In this study based on the observations made on the Loire, the extent of this danger zone linked to the dissipation of energy behind the breach is proposed to be one hundred times the difference between the apparent protection level and the level of the ground in the valley.



## 2- Risk mitigation through management measures

### Risk management measures at the levee system level

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## 2- Risk mitigation through management measures

Following the risk analysis, a plan of risk mitigation measures was drawn up. This plan contains the emergency measures required by regulations and other measures to improve management procedures.

It includes :

- measures for managing the structure, which aim in particular to consolidate the organisation for maintaining the service and for emergency intervention in the event of flooding
- risk management measures scale that take into account the protection of the population
- structural and functional improvements
- improvement of knowledge of structures and phenomena (hydrological, related to breach formation, etc.).

### Risk management measures at the levee system level

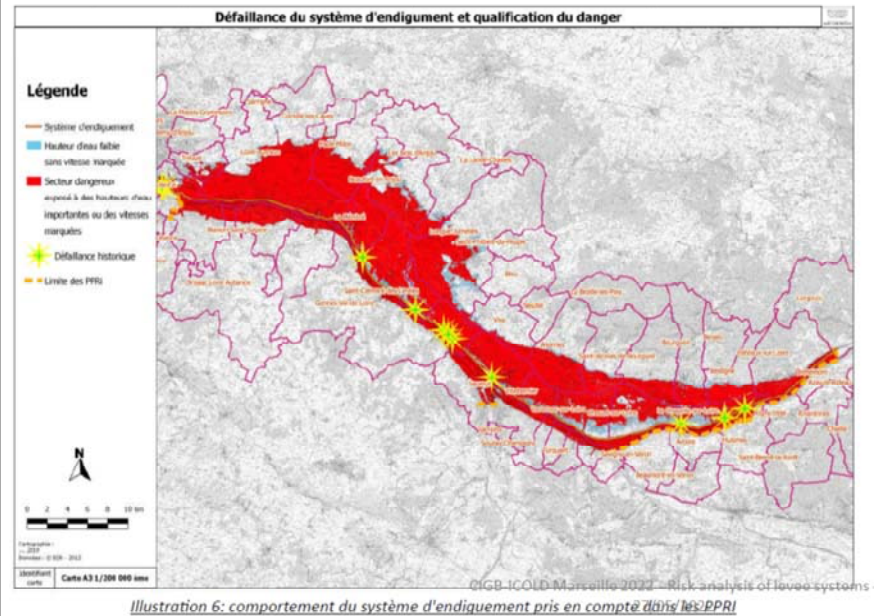
For example

- Coordination between the three managers for the entire Loire flood protection system
- Definition and prioritisation of monitoring actions for structures during flood periods in the levees manager written instructions
- Establishment of a response capacity for emergency repairs

## 2- Risk mitigation through management measures

### Risk management measures for the territory

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This map with all historical levee breaches and dangerous zones (important height of water or significant velocity) is integrated in the two Flood Risk Prevention Plans (PPRI in French) of the Authion valley which are imposed on development projects in the valley.



## 2- Risk mitigation through management measures

### Risk management measures for the territory

Integration of knowledge from the hazard study :

- in the two Flood Risk Prevention Plans (PPRI in French) of the Authion valley which are imposed on development projects in the area;
- for the determination of alert thresholds triggering the safety or evacuation of people
- for the drafting of the Communal Protection Plans (PCS in French) of the 24 municipalities and towns of the Authion valley.

### 3- Risk mitigation through functional and structural improvements of the levee

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#### Définitions

**Structural measures** : reinforcement of Authion's levee in order to reach the desired safety level (i.e. mainly levee's crest)

**Functional measures** : once the structural measures are implemented, overflow management and no levee failure / breach for return period flood which leads to water level higher than the top of the levee

# Implementation of structural measures

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## A funnel-like approach

At levee system's scale

1 / Hazard studies

Global risk evaluation and levee performance to identify possible levee failures

Limited ground investigations (~ 1 survey / km)

At levee system's scale

2/ Reliability program

Analysis of hazard studies' results to identify consistent operations (reinforced geographical areas, cost estimation, prioritization)

At the operation scale

Complementary ground investigations ( 1 survey / 100 or 200 m, laboratory testing) + geotechnical analysis

Adjustment of kilometeric points of structural measures, technical choices)

Administrative procedures

A funnel-like approach.

1/ Hazard studies. Global assessment of Authion's levee. Few / simple calculations to provide a first approach of the performance of the levee. Authion's levee = "old levee", made with different materials, subject to different reinforcements, etc.

2/ Reliability program usually based on ground investigations performed for hazard studies. Valorization of hazard studies' results to identify consistent operations (clustering approach)

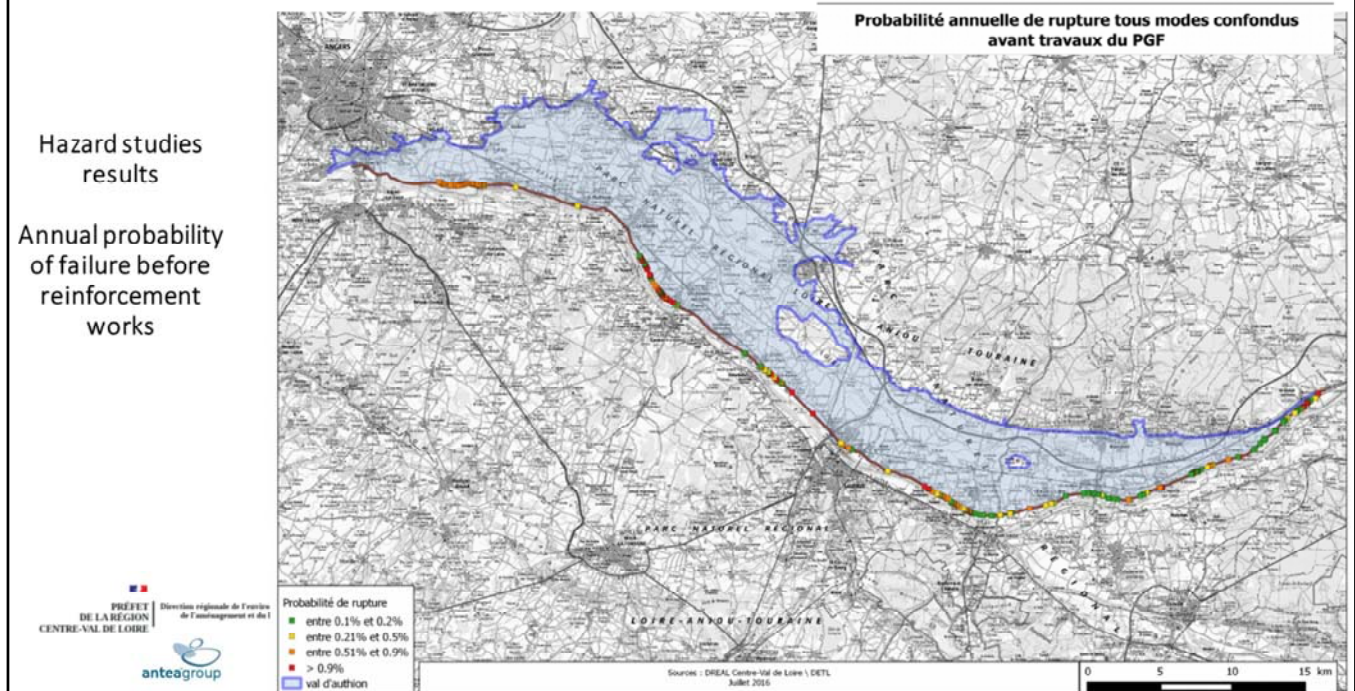
Enable to present the reliability program to the stakeholders (future levee's managers, etc.)

3 / At the operation scale : Complementary ground investigations ( 1 survey / 100 or 200 m) + laboratory testing (index and mechanical properties, erodibility, permeability) to acquire further geotechnical data on the levee itself and the foundation + geotechnical calculation to assess the behavior of the levee under different failure modes (internal erosion / seepage, etc.).



## Implementation of structural measures

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Map which precise the annual probability of failure before reinforcement works using a specific tool developed in the middle Loire catchment. Annual probability for all the possible failure modes considering: overflowing, internal erosion, external erosion, foundation breakdown, etc.

# Implementation of structural measures

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## Reliability program for Authion's area (2 French "départements")

- Valorization of all historic data (former reinforcements, historic behavior during past floods)
- Definition of reinforcement measures to face the different possible failure modes, to facilitate access and maintenance of the levee
- Cost estimation of the different works
- Operation phases taking into account geographic criteria, methodologies and technical solutions.
- Assessment of operational constraints (property issues, required administrative procedures, required ground investigations, etc.)

# Implementation of structural measures

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## The reliability program for Authion's area (2 French "départements")

- Multiple technical solutions were identified

Failure mode	Technical solutions
Overflowing	not planned at the moment
Internal Erosion	- Reduction of levee's slope on the protected side - Cut off barrier (soil mixing)
External Erosion	Protection of levee's toe with a service way made with rip rap material
Foundation breakdown	Relief well system
Serviceability	Service route with a road structure ("all weather" available)

Operations' Name Operations' location Type of reinforcement Length Costs of works  
Récapitulatif des opérations dans le département du Maine-et-Loire

N° de l'opération	Dénomination des opérations	Localisation des opérations	Descriptif des actions	Linéaire de l'opération	Estimation des travaux
1	Étanchéification de la digue à Varennes-sur-Loire Tranche 1	Varennes-sur-Loire	Écrans étanches	4 060 m	4 500 000 €
2	Épaississement de la digue à Varennes-sur-Loire Tranche 2	Varennes-sur-Loire	Reprise du talus côté val	2 360 m	2 000 000 €
3	Épaississement de la digue à Saint-Martin-de-la-Place	Saint-Martin-de-la-Place	Reprise du talus côté val	1 655 m	1 300 000 €
4	Étanchéification de la digue – Les-Rosiers-sur-Loire	Les-Rosiers-sur-Loire	Écrans étanches	3 780 m	3 900 000 €
5	Étanchéification et Épaississement de la digue La Bohalle – La Daguenière	La Bohalle La Daguenière	Écrans étanches Reprise du talus côté val	1 990 m	2 100 000 €
6	Accessibilité à l'ouvrage Saumur – Saint-Martin-de-la-Place	Saumur Saint-Martin-de-la-Place	Création de chemin de service côté val	4 600 m	1 500 000 €
Total opération travaux					15 300 000 €

Multiples reinforcement works are possible for a given failure mode (to be noted that a levee segment often suffers from different failure modes)

Non-exhaustive list :

Technical solutions for **overflowing** : raise the level of levee's crest, spillways, overflow resistant profile (armourstone revetment, reinforced mattresses, gabions, flexible concrete block revetments), etc.

Technical solutions for **internal erosion** : cut off barriers, drainage of the levee (on the protected side / "downstream" side with internal drains, toe drain, ...), impervious layer on the river's side, crossing network treatment

Technical solutions for **the stability** : stabilizing berms, decrease of levee's slope

Technical solutions for **external erosion** : armourstone revetment, natural techniques,

Technical solutions for **the foundation breakdown** : relief well system

Technical solutions for **serviceability** : service route with a "road structure"

# Implementation of structural measures

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## At operation scale

- Geotechnical investigations and laboratory testing program



Borehole

Undisturbed sampling

Borehole

Static penetrometer

Laboratory characterization

SONDAGE CAROTTE	Tous les 100 m au niveau de la zone de confortement par écran étanche et sur les secteurs jugés en déficit de reconnaissances.
PRELEVEMENT INTACT	A définir sur site en fonction des découvertes géologiques pour essais mécaniques et essais de perméabilité en laboratoire
SONDAGE A LA TARRIERE	Tous les 100 m (en alternance avec les sondages au pénétromètre) pour identification et pour caractérisation des matériaux réalisés en quinconce avec les carottés
PENETROMETRE STATIQUE	Tous les 100 m (en alternance avec les sondages tarières) pour identification et pour caractérisation des matériaux réalisés en quinconce avec les carottés
PRELEVEMENT EN VRAC	A chaque changement de faciès
GRANULOMETRIE	A chaque prélèvement
TENEUR EN EAU	A chaque prélèvement
IP	Un par formation et par sondage
VBS	Un par formation et par sondage
C'/ $\phi$ '	Par formation et par sondage

- Asbestos analysis on the road surface layer
- HET (Hole Erosion Test)
- Organic matter rate
- Design study to precise the cement proportion



Implementation of structural measures required a series of investigations during detailed design but also often during civil works to face unexpected issues

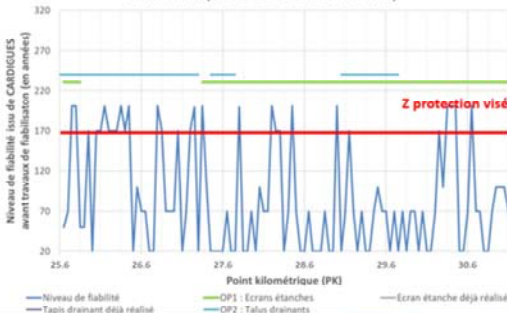


# Implementation of structural measures

## At operation scale

- Example of diagnosis on a specific area and optimization analysis

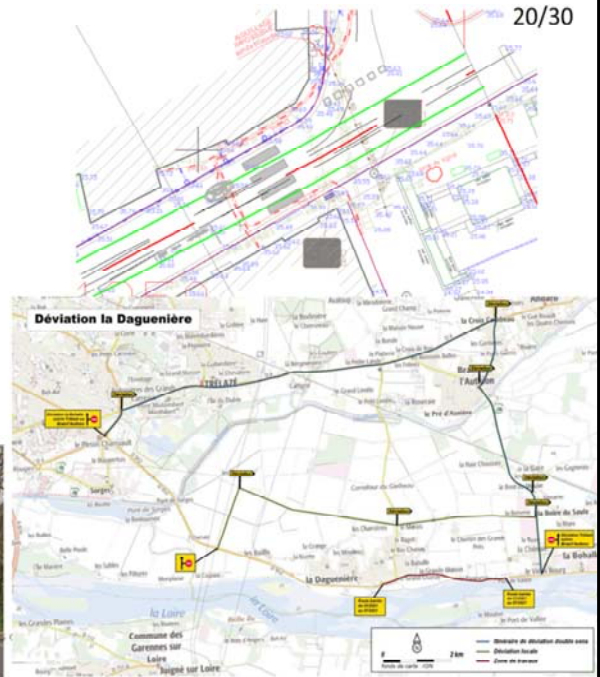
Niveau de fiabilité et programme de fiabilisation envisagés sur les digues du Val d'Aurion (OP1 et OP2 à Varennes-sur-Loire)



- Alternative route during works,
- stakeholders information

- Crossing networks management (electricity, telecommunications, etc.) and singularities

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PREFET  
DE LA RÉGION  
CENTRE-VAL DE LOIRE

anteagroup

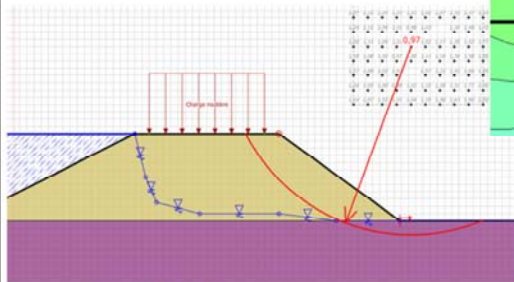


Multiples elements have to be considered and not only technical issues : networks managers (electricity, telecom, drinking water system, sewage system, etc.), removal waste, access for emergency services, local authorities, etc.

# Implementation of structural measures

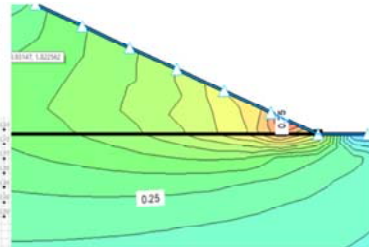
## At operation scale

- Detailed design based on geotechnical calculations



Slope stability

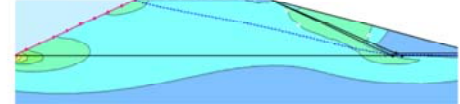
Etat actuel : gradient > gradient critique



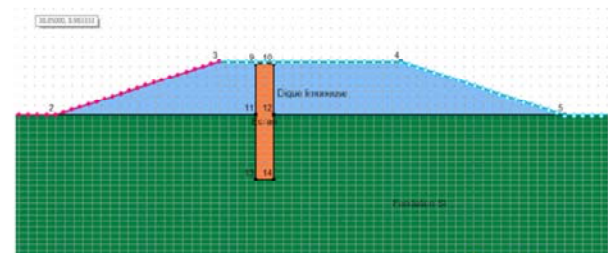
Hydraulic gradient and internal erosion

21/30

Etat futur : gradient < gradient critique



Impact of a cut off barrier



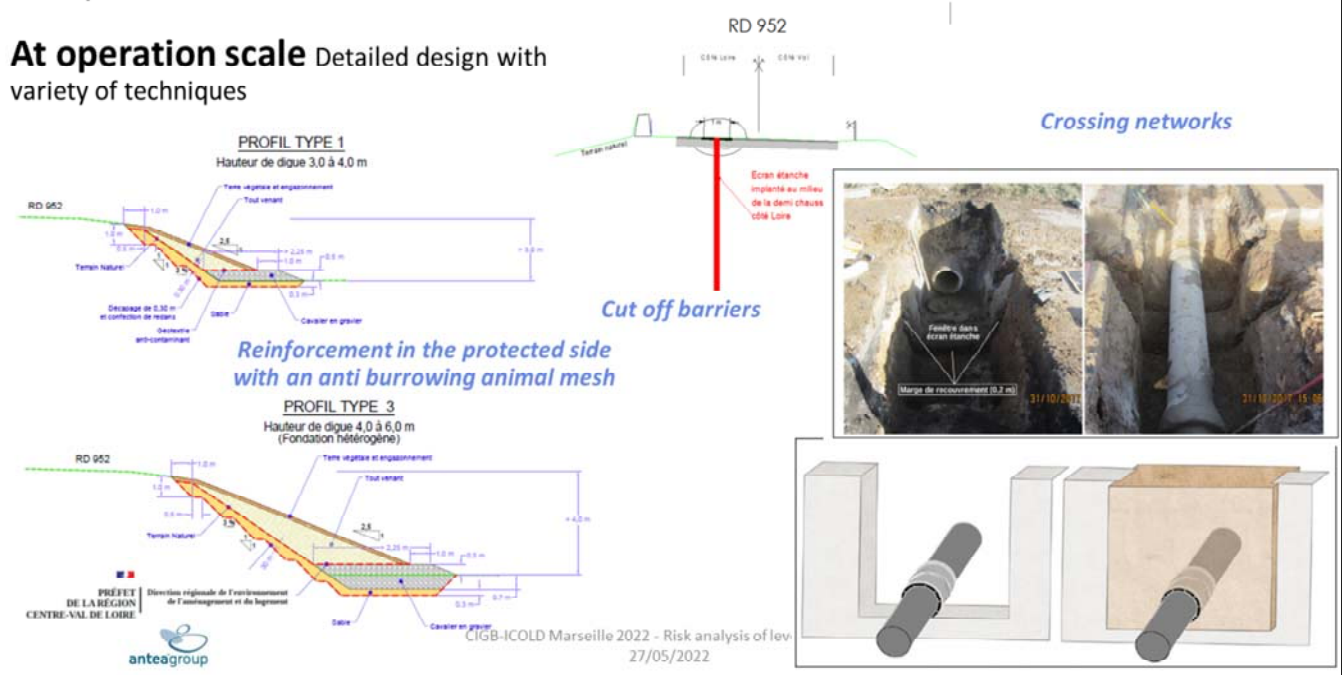
Multiple calculations are required on different levee's segments to design and optimize reinforcements (slope stability, hydraulic gradient, foundation breakdown, etc.). Thanks to the geotechnical linear profile / model, it is possible to extrapolate results everywhere

Uncertainties must be considered (geotechnical parameters, flood water level)

# Implementation of structural measures

22/30

**At operation scale** Detailed design with variety of techniques



Multiple techniques exist. They have to fit to the diagnostic. They can answer to different given failure modes (for example internal erosion and stability on the protected side). For crossing network, reinforcement works have to take into account different items : network depth, pipe material, network type, etc.

# Implementation of structural measures

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*Road marking*



*Pavement planing*



*Excavation*



*Pre trench*



*Addition of cement in the pre trench*



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Different steps of the realization of a cut off barrier (trechmix) :

- Road marking,
- Pavement planing,
- Pre trench using sometimes specific tool (hydraulic hammer for example)
- Addition of cement in the pre trench (sometimes other hydraulic blinders are required, following the results of the mix design testing – for example limestone in case of a high rate of organic matter)



# Implementation of structural measures

*Soil mixing*

*Road structure*

24/30



*Road surface layer*



Different steps of the realization of a cut off barrier (trechmix) :

- Trench mix : mix cement and other hydraulic blinders with water and levee materials
- Road structure rehabilitation
- Road surface layer rehabilitation including markings

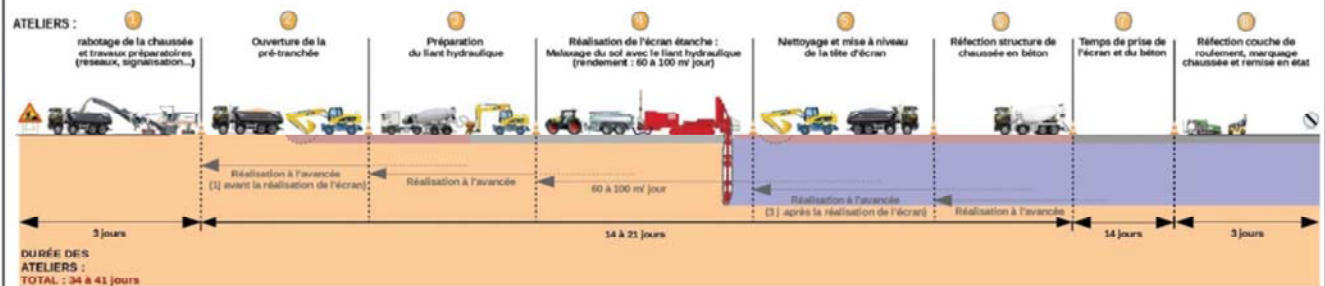
# Implementation of structural measures

25/30

*Various phases of a cut off barrier with working rates*

## SCHÉMA DES PHASES DE RÉALISATION D'UN ÉCRAN ÉTANCHE EN CORPS DE DIGUE

*Durées indicatives des ateliers pour la production de 1000 mètres linéaires d'écran étanche*



PREFET  
DE LA RÉGION  
CENTRE-VAL DE LOIRE

Direction régionale de l'environnement  
de l'aménagement et du logement

anteagroup

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des barrages  
et réservoirs

The drawing precises the different steps of a cut off barrier and the duration of each phase. Specific constraints can reduce the scale of the production (cross section networks, cement setting difficulties, etc.)

## Implementation of structural measures



In 2021, two operations on the Authion levee are realized on the Maine-et-Loire Department. They enable to reach the desired safety level on these segments (a 170 years flood return period) but other segments have to be done !

## A virtuous circle

27/30



It is necessary to update frequently the risk analysis and to valorize feedback. In France, at least each 10 years for levees which protects more than 30 000 inhabitants.

In addition to reinforcement, other tools are available and complementary :

- maintenance,
- safety guidelines,
- networks management,
- public and stakeholders' communication



**For Authion's levee, functional measures consist in, once the structural measures are implemented,**

- Data acquisition and complementary studies (hydrology, climate change, etc.)
- Overflow management in conjunction with local authorities and stakeholders

## Conclusion

**Risk analysis**

**Hazard studies (EDD)**



**Complete and detailed diagnosis**



**Basis of risk mitigation  
for levees managers  
and engineering offices**



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In conclusion, risk analysis as used in hazard studies (EDD in French) provides a complete diagnosis of the levee system.

This detailed diagnosis allows the manager to improve the management procedures of his levees in order to mitigate the risk.

This diagnosis is also the basis of the design work for the engineering office for structural improvement works on levees.

*Thanks for your attention*

The 1866's flood caused 88 breaches in the Loire levees and destroyed many buildings and transport infrastructures. Levee's breach in Saumur (middle of the Authion levee system) and flooding of Saumur station.

