Safety works for the Rhone levees from Beaucaire to Arles 2007-2022

SYMADREM

A PUBLIC INSTITUTION FOR MANAGEMENT OF RIVER AND SEA LEVEES IN THE RHÔNE DELTA

Plan Rhône

A territory devastated by flooding

The Delta is submitted to the double impact of the Rhone floods and storm events.

Eight major Rhone floodings took place on the territory since 1840, leading each time to the spill of several hundreds millions of cubic metres in the protected area and creating several hundreds millions of euros damages.

1840

- 13 000 m^3/s estimated discharge
- 300 years (return period)
- 2,8 billion m^3 water spilled
- 18 breaches
- 2,4 billion present € value damages

1856 - Tarascon

1856

- 12 500 m^3/s estimated discharge
- 200 years (return period)
- 1,8 billion m^3 water spilled
- 9 breaches
- 2,1 billion present € value damages

1856 - Napoleon III visit to Tarascon

2003

The last flood was the December 2003 one.

- 11 500 m^3/s estimated discharge
- < 100 years (return period)
- 227 million m^3 water spilled
- 4 breaches
- 12 000 people flooded
- 500 to 700 million € damages

2003 - Arles

Order of magnitude

Storage volume of Serre-Ponçon dam is 1.3 billion m^3.

Surveillance and emergency interventions during flood periods allow to delay the initiation of a breach. Nevertheless, there is a point where, regarding the very old and heterogeneous state of the levees, the breach becomes unavoidable.

Old and fragile structures

A 800 year-old protection system

The actual flood defence system was created during the 19th century after the 1840 and 1856 floods.

The structures were erected on other ancient levees, including some dating from the 12th century. Given their form of construction (compaction with manual tamping devices of 15 kg) and their heterogeneous composition (alternating silt / sand) due to successive stages of building, levees are very exposed to **failures by internal erosion.**

This intrinsic fragility is worsen by **frequent badgers burrows and many crossing pipes.**

Badger burrow

Levee bordered with environmental issues

Levees close to the river

Another characteristic of these levees is that they were built very near from the river. In addition, they are bordered with environmental issues.

Their reinforcement, on the spot according to current guidelines, would have impact the riverside vegetation (called "ripisylve" in French), leading to an extra cost of the river bank protections and the destruction of endangered species.

To note:

The probability of a breach, confirmed by the historical floods, is more than 50% as soon as the Rhone flow reaches 9 500 m^3/s at Beaucaire/Tarascon, i.e. for a return period of 20 years. It switches to 100% for a 10 500 m^3/s flow.

A complete renovation of the flood defence system, environment-friendly with the delta, was necessary and urgent.

The response: le Plan Rhône

A safety program for the levees

Following the 2003 flood, a global strategy regarding the floods prevention was defined, under the aegis of State and regions located in the Rhone Bassin: le Plan Rhône.

The Symadrem has included the flood elements of this plan in a safety program for the levees from the Vallabrègues dam to the sea.

Safety program goals

- Not heighten the levees to avoid transferring inevitable water spills upstream, downstream or on the opposite riverside;
- Accept overflowing for rare floods (flow over 11 500 m^3/s between Beaucaire and Arles et more than 10 500 m^3/s downstream Arles) **with an equal amount of water spilled on each bank**;
- Consider the breaches apparition as unacceptable until a flow of 14 160 m^3/s (exceptional flood with a return period around 1 000 years).

This choice involves:

- Safety works for the whole system to avoid any breaches until an exceptional Rhone flood;
- Implementation of spillways on levees to resist to overflow. It consists in reinforcing them with concreted riprap on landward side. This allows them to resist to high speeds in case of an overflow, which can create breaches.

An environmental strategy, based on the avoidance of environmental issues and an ecological valuing of the river banks, has been put in place to accompany these works.

Considering **its scale (more than 450 million €)**, the safety program has been divided in **several operations.**

Today, 210 million € have been invested in the delta of which 195 million € for the levees, from the Vallabrègues dam to downstream of Arles.

Levee resisting to overflow


Syndicat Mixte Interrégional d'Aménagement
SYMADREM
des Digues du Delta du Rhône et de la Mer
Security program
for structures against the Rhone floods
from Vallabrègues dam to the sea
Source : SYMADREM
Basemap : IGN France Raster 1/100 000
Realisation : SYMADREM 2019 update 2022
Reference : 19002
Millenial levee
Levee resisting to overflow
Close protection levee
Sea levee
Ear
0
5 000
10 000
15 000
Meters

Consultation and acceptation

The Public authorities chose not to respond the flooding by elevating the levees, as it had always been until the Plan Rhône.

Some levees sections were thus designed to allow overflow without creating a breach. They are called levee resisting to overflow .

They are designed to contain, without overflow, rare floods with a return period about 100 years upstream Arles and 50 years downstream Arles.

Beyond these events, they are reinforced to let the water spill without leading to the levee ruin.

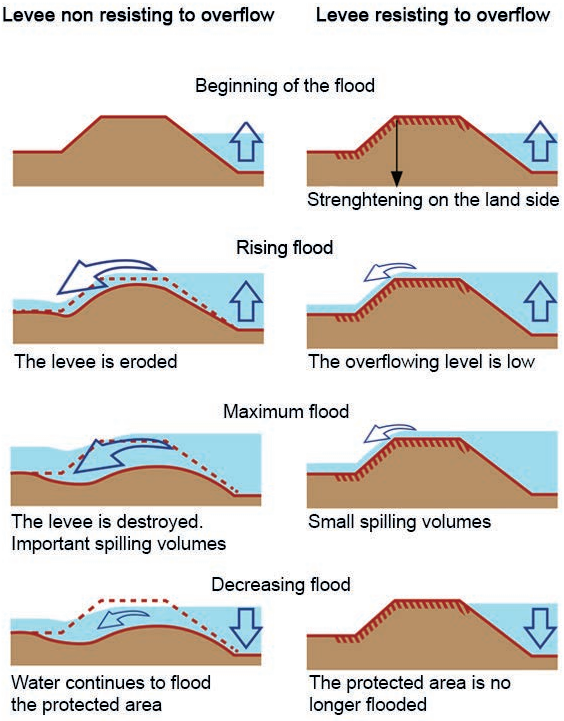
During exceptional floods with unavoidable inundations, there will be water entries, but spilling volume will be **10 to 20 times less important than in case of a breach.**

Furthermore, the inundation will be slow, known in advance and manageable by the competent authorities for rescue.

The switch between a very strong breach risk, but random and unpredictable, to a risk of overflow without breach, certain, predictable and very low, required many concertation meetings. They were organised with the State backing. They led local people to accept *in fine* the implementation of spillways on levees.

Public meeting – Arles

From a random risk, unpredictable and very strong... to a risk, certain, predictable and very low




Example of a breach – Aimargues


Example of overflow without breach

Environmental strategy

Environmental issues

Environmental aims have been included from the beginning of the design process to avoid the destruction of ecological issues. The Symadrem established, as a principle, to disassemble the levees and **to rebuild them further from the river.** This was the situation for the levee located south of Arles or the one between Beaucaire and Fourques.

Thus, the ecological issues, as the "ripisylve" (riverside vegetation), were saved. This preservation came with **the restoration and/or the creation of wetlands, the relocation of protected species, the completion of "lônes" (branch of the Rhone, set back from the mainstream bed and supplied from alluvial table or during floods)... Hence, space has been given back to the river.**

Embankment constructions requiring large amounts of earth, the recycling of former levees material and the utilisation of lands located between the river and the levee, were favoured to reduce the constructions costs and also the worksites carbon footprint.

Restored pond

Aristolochia transplantation and Diane butterfly

Levee retreat in the South of Arles

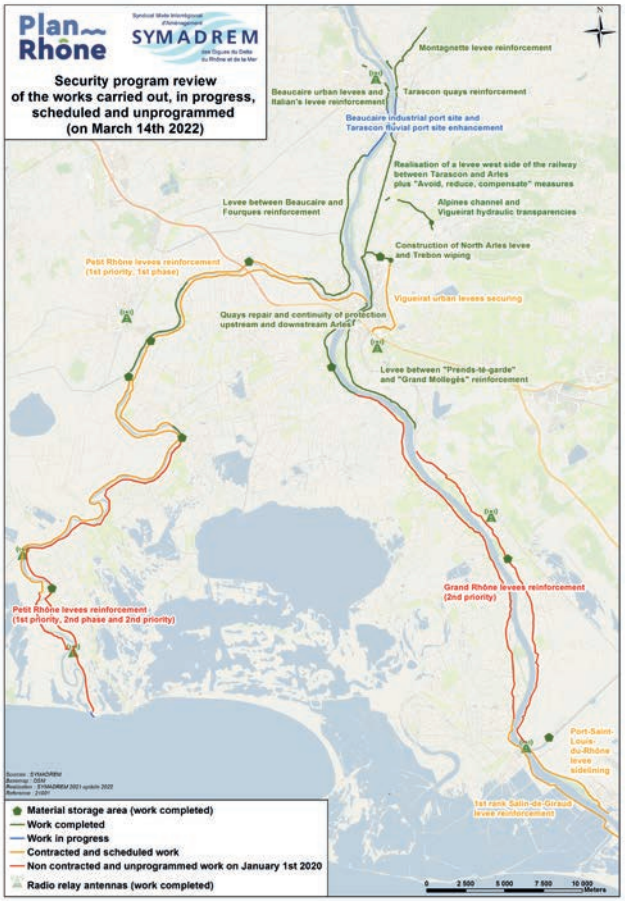
On-site material extraction and creation of a "lône"

15 years works

The constructions have been prioritized regarding the following requirements:

- Human issues nearby the levees;
- Consequences of a breach in the protected area;
- Control or not of the property;
- Regulatory constraints linked with the works;
- State of the constructions confirmed by the historical feedback or by the risks analysis;
- Financial programming.

These criteria led the Symadrem to **take action first, and foremost, in front of the urban areas and from upstream to downstream.**



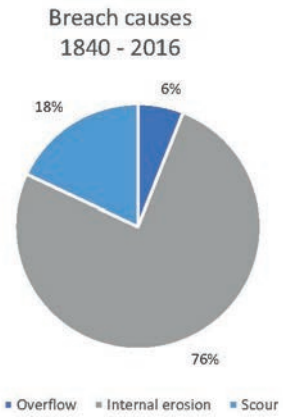
Assess, evaluate and reduce the probability of failure levees

114 breaches and breaches in progress were identified since 1840. The main cause is the internal erosion and more precisely **the concentrated leak erosion,** except the November 1840 flooding which was caused by overflow breaches which, at this time, were lower.

The concentrated leak erosion is initiated by water **that flows into a pre-existing defect in the levee**. The hole is not necessarily crossing but can become so under the effect of water head.

In the case of the Rhone delta levees, the breaches due to internal erosion were initiated in **80%** of the cases in **badgers burrows** and, in **20%** of the cases, in **spaces along crossing structures.**

The developmental kinetics of a breach by concentrated leak erosion is very fast and depends on the nature of the material. A few tens of minutes are enough between the beginning of flow in the hole and the formation of a breach, making emergency response uncertain.



The creation of a safe and sustainable levee requires prior analysis of the different possible failure causes and to evaluate their probability.

The Symadrem takes 13 scenarios into account. The 3 main events are respectively a breach due to:

- a concentrated leak erosion in a former **badger burrow partially clogged** and not visible;
- a concentrated leak erosion **along an existing hole between a crossing structure** and the levee embankment;
- an **overflow** on the levee.

It is only once this risk analysis has been carried out, that the levee design can begin. The process involves the restoration of the safety functions described below.


Badger burrow


Breach caused by a crossing pipe

Works principles

The complete renovation of the protection system and the construction of safe and sustainable levees, is based on a risk assessment (see previous page) and the restoring of following safety functions:

- Watertightness and resistance;
- Filtration and drainage;
- Stability and protection;
- Spillway (resistance to overflow);
- Surveillance;
- Environment.

Watertightness and resistance

The watertightness is the first safety barrier in a flood defence structure. Different types of intervention were carried out.

Masonry levees

For the masonry levees, the waterproofing consisted of fully taking over the siding masonry by plugging first the cracks, or by carrying out a new siding in shotcrete on the siding already concreted.

Arles quays, facing

Montagnette levee, joining

Banquette levee, clogged crack

Montagnette levee, realisation of a waterproof siding in shotcrete

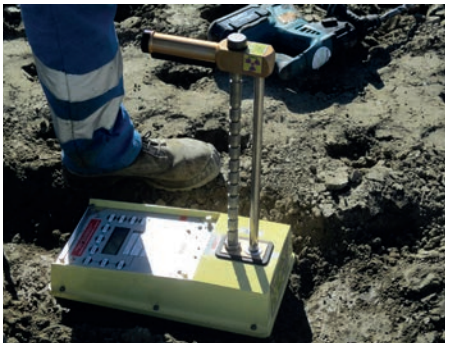
Embankment levee

The embankment constructions have been systematically dismantled, to break the multiple layers effect created by 800 years of successive risings, and rebuilt according to current guidelines.

The compactness minimum level required was 95% and the moisture content, before compaction, between 0 and 3% above the optimal moisture content (called Optimum Proctor). These two parametres are guarantor for an optimal resistance to internal erosion.

Several construction steps are required:

- Clay filled anchorage key, which allows the treatment of the foundation surface layer;
- Aeration or humidification of the material to bring it to the right moisture content;
- Reduction of clods to homogenise the material moisture content;
- 30 cm layer compaction by a vibrating roller with padfoot;
- Compaction control with a gamma densimeter and dynamic penetrometer.



Gamma densimeter

Clay filled anchorage key

Humidification in the mass

Homogenisation

Compaction

Filtration and drainage

The filtration and drainage of the embankment and its foundation allow, in case of watertightness failure, to ensure the water flow without internal erosion.

They constitute, therefore, a second safety barrier, which will increase very noticeably the levee safety level.

These functions can be ensured by a filter geotextile encompassing a gravel layer (solution adopted between Beaucaire and Arles) or by a geocomposite (solution adopted downstream Arles).

For the masonry levees, this can pass by a drilling of the facing, on the landward side, to improve the ability to drain possible seepages and to dissipate pressures within the embankment.

Drainage outlet, Boulbon spillway

Filter geotextile

Gravel

Second layer of geotextile

Draining /filtering geocomposite

Stability and protection

The filter is stabilized to avoid its uplift by an embankment shoulder on landward side, in case of an under pressure. Slopes are softened. Furthermore, a protection against the burrowing animals has been implemented to avoid new burrows creation.

Note that 80% of the breaches by internal erosion, observed since 1993, were initiated in badgers and rabbits burrows

Downstream boulder

Installation of anti-burrowing mesh

Anti-burrowing mesh

Softened slopes

Spillway - Resistance to overflow

For the levees resisting to overflow, the landward side is reinforced with concreted riprap, so as to resist to high speeds, in case of overflow. Upstream and downstream spillways, the levees are set 50 cm above the millennial flood level to avoid a risk of circumvention in case of overflowing (construction steps beside).

Laying of 200 to 400 kg riprap

Concreting of riprap

Concrete beam to determine the overflow level ...

... and to avoid infiltration into concreted riprap

Landscape integration

Levees crossing hydraulic structures

The hydraulic structures crossing levees, represent a weak point for the flood defence system (20% of breaches by internal erosion). They can constitute preferential passages for water during floods between the crossing structure and the levee embankment. It is therefore essential to secure these crossings by well-designed works.

3 - Trenching and concreting of the excavation bottom

6 - Installation of the filter and downstream drain

1 - Opening of excavations

4 - Laying of the pipe

7 - Pipe filter link

2 - Compaction of the foundation base

5 - Full excavation and coating concreting

8 - Realisation of downstream drainage

Securing monitoring and emergency interventions

Many improvements were made to optimise and facilitate monitoring and emergency interventions during floods :

Road signs

These directional signs, compliant with regulations, have been installed along main tracks. They allow monitoring teams, made up of municipal officers or volunteers, coming from communal civil security reserves, to access faster to the levees.

Improved access to works

The most deteriorated tracks were made passable and new levees access were created.

Tracking terminal

Positioned on the entire linear, they facilitate the location of disorders and interventions. They are installed every 250 metres or so.

Tracking terminal


Levee crest after work for the vehicular traffic

Development of material storage areas

Time is determinant during floods when you have to treat a degradation or a breach in progress. These 9 storage areas facilitate the material supply (small rocks, clay materials, black furnace slags ...) in case of an emergency intervention. They avoid to travel long distances (more than 50 km) and thus let the degradation get worse.

Flood forecasting software

To palliate the possible "Vigicrues" website (specialised in flood information) access failure, the Symadrem has acquired its own forecasting tool. It is based on a model powered by hydrological data coming from all upstream hydrometric stations (by radio transmission) to forecast with 9 hours of anticipation the discharge upstream the Rhone delta.

Radio network

The Symadrem has also spread out its own radio network to secure exchanges between monitoring teams and its command post. It also allows to overcome the telephone network access difficulties, common in a crisis context. It includes 7 radio relays linked together by microwave beam forming a secured loop. They ensure, thanks to this configuration, a continuity of service even when the wireless links are broken.

Limnigraphs

In order to improve the knowledge of water heights in different places along the Rhone, more or less distant from the reference station of Beaucaire / Tarascon, the Symadrem decided to equip itself with its own measuring stations called limnigraphs.

The limnigraphs will collect the water heights data in real time and in different places along the river. Thanks to this, the Symadrem will have a real monitoring network of water heights along the Rhone delta levees. About twenty measuring stations will be installed.

Laying of the optical fibre

Optical fibre

An optical fibre has been installed, on an experimental basis, in the protected landward side drain of the Beaucaire/Fourques and Tarascon/Arles levees. It will make it possible to detect very small temperature variations, witnesses of possible infiltrations in the levee.

This device will facilitate the:

- early detection of upgradeable latent leaks;
- identification of potential failure warning signs in the whole filter-drain system;
- precise location of the leaks position on the examined linear.

Symadrem radio relay

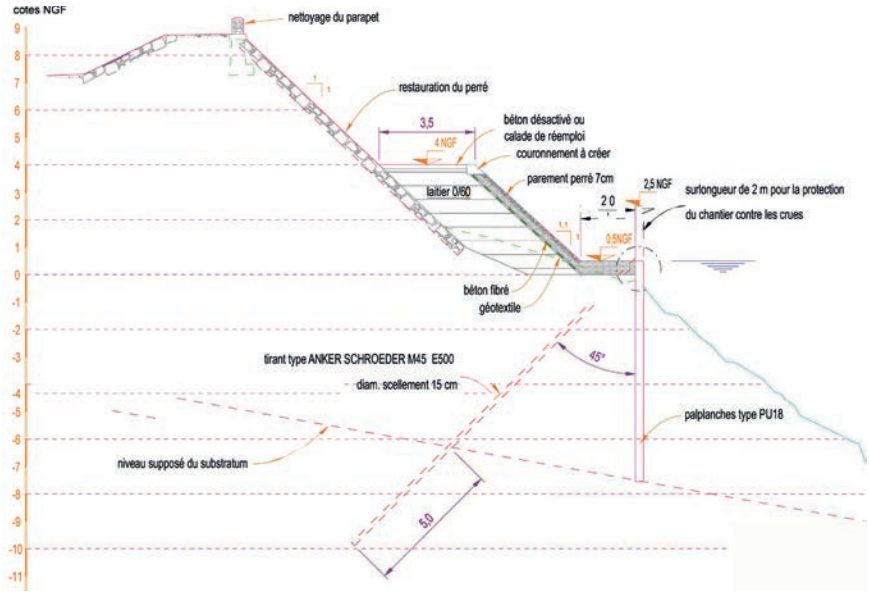
Symadrem Security command post

Arles quays before work

Stacking of the sheet pile curtain

Arles quays

Arles quays after work



Typical cross-section Max Dormoy quay* *(see glossary on last page)*

Diagnosis

The Rhone speed, very important crossing Arles, linked to the narrowing of the river, have eroded the bottom of the riverbed and led to the formation of an erosion pit destabilising quays foundations, resulting in the progressive ruin of the works by successive collapses.

Works

- Repair the collapsed parts.
- Threshing a sheet pile curtain at the foot of the levee.
- Masonry repair.
- Cofferdams modernisation.

Cost: 27 million €

Diagnosis

The Montagnette levee broke in 1840 (by an overflow) and in 1856 (by internal erosion), in different places, resulting in Tarascon destruction and the flooding of the left bank up to Port-Saint-Louis-du-Rhône (sea). In 2003, any major degradations were observed, but the post-flood diagnosis confirmed the need to secure the levee given its strategic position upstream of the flood defence system.

Works

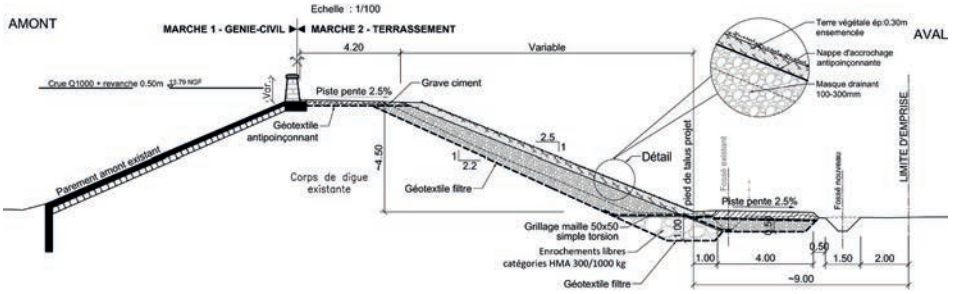
- Masonry repair.
- Realisation of a waterproof siding in shotcrete.
- Implementation of a draining filter complex on landward side.
- Modernisation of the car passages, where cofferdams can be installed.
- Securing Provence Royal Castle walls.

Cost: 11, 1 million €

Montagnette levee, Rhone side

"Montagnette" levee and Tarascon quays

Montagnette levee, landward side



Typical cross-section Montagnette levee*

Montagnette levee, after work

Beaucaire former doors

“Banquette” levee and Beaucaire doors

New metallic door being installed

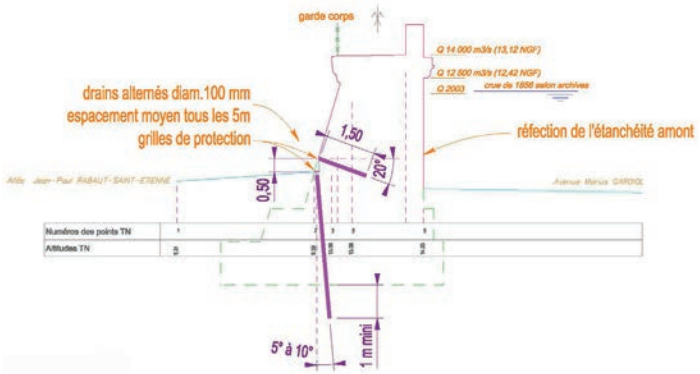
Diagnosis

The diagnosis before work showed weaknesses of the levee and a lack of height on its securing doors, despite good general condition.

Works

- Cracks sealing on the facing river side to improve airtightness.
- Drillings on the facing city side to improve drainage of possible infiltrations.
- Change and enhancement of the metallic doors.
- Reconstruction of the parapet upstream.
- Modernisation of the car passages where cofferdams can be installed.

Cost: 0,8 million €



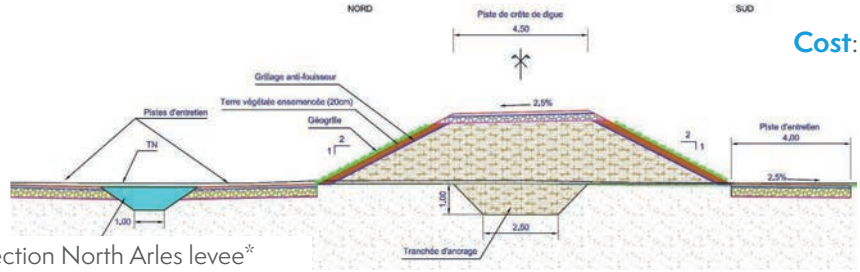
Typical cross-section Banquette levee*

Banquette levee

Vigueirat transfer siphon and control structure

Second rank levee North Arles

Protection levee



Typical cross-section North Arles levee*

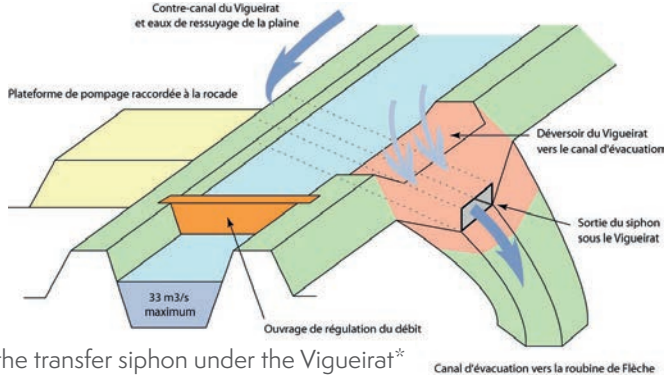


Diagram of the principle of the transfer siphon under the Vigueirat*

Diagnosis

The Vigueirat levees prevent the water coming from the Rhone to transit toward the marshes of Les Baux. In order to avoid new inundations of North Arles area, even after the construction of the levee from Tarascon to Arles, a second rank levee was built on the northside of Arles urban area.

Works

- Realisation of a levee in compacted clay silts.
- Construction of a transfer siphon under the Vigueirat to improve the water drainage of the Trébon lowland.
- Design of a Vigueirat control structure to limit its flowrate crossing the city centre.
- Creation of mobile pumping platforms.

Cost: 7.3 million€

Diagnosis

This levee built in the middle of the 19th century, has never been reinforced. Several breaches in progress have been observed in 2003. This levee was bordered by environmental issues and located very close to the river in its downstream part. Its reinforcement in place was strongly impacting the environment and very expensive in terms of bank protection.

Works

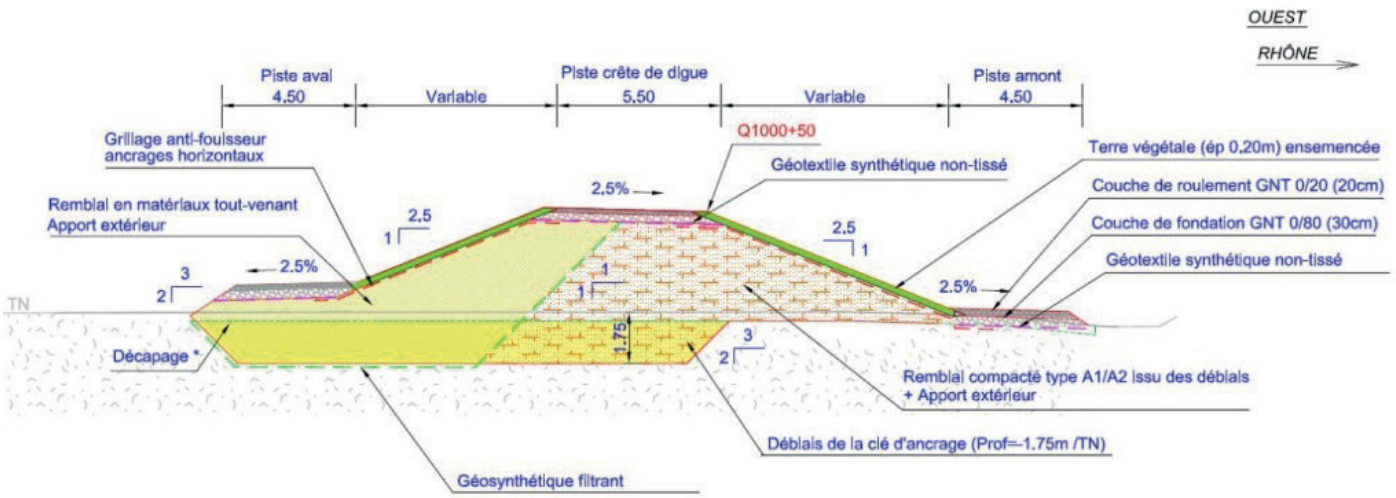
- Dismantling the existing levee.
- Construction of a clay silt embankment in retreat of the river.
- Implementation of a filter and drain geocomposite on the protected side.
- Installation of anti-burrowing mesh
- Creation of operating tracks at the foot and on the levee crest.

Cost: 16.6 million €

Original levee

South Arles levee

Retreat of the levee under construction



Typical cross-section South Arles levee*

Italians levee

Fourques levee – December 2003

Beaucaire - Fourques levee

Beaucaire – Fourques levee after work

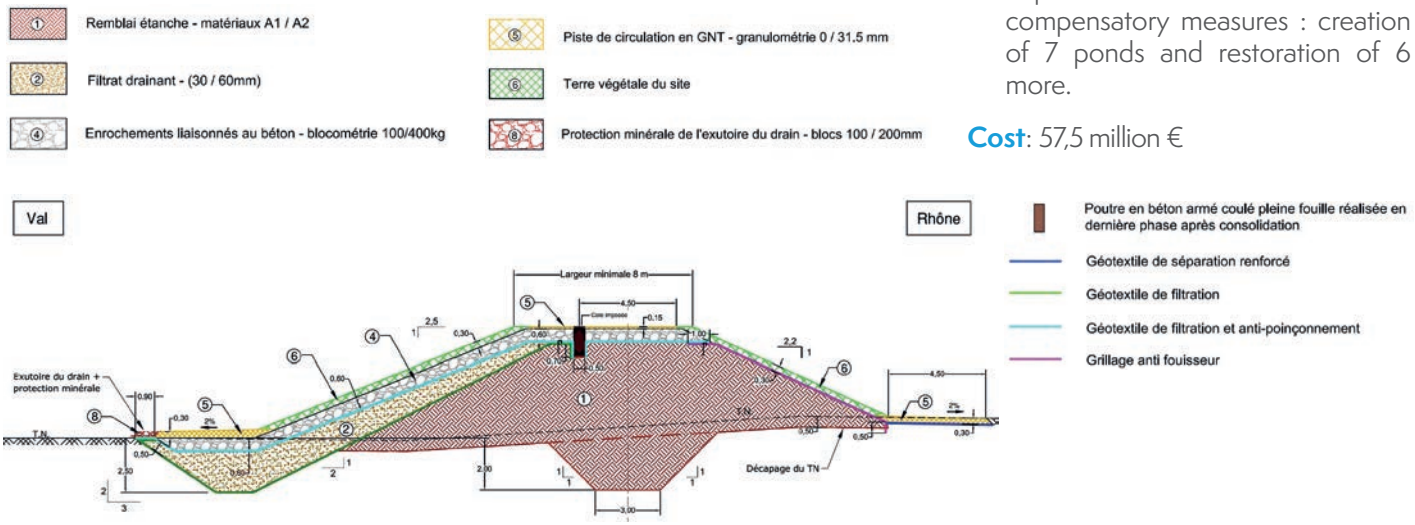
Diagnosis

This section of the levee has not suffered a breach during the 2003 flood, in spite of some overflows, especially on the right side of the "Domitia" area in Beaucaire and the BRL water intake.

Works

- Raising the Beaucaire lock (VNF works – *Company governing the French waterways*) and the "Italians" levee.
- Levee reinforcement to resist an overflow without breach, to the millennial flood between the "Fer à Cheval" and BRL water intake.
- Levee reinforcement and raising from the BRL water intake to "Les Tourettes" station downstream Fourques.
- Extraction of 390 000 m^3 of material downstream the Vallabrègues dam, which were used for backfill as part of the operation.
- Implementation of environmental compensatory measures : creation of 7 ponds and restoration of 6 more.

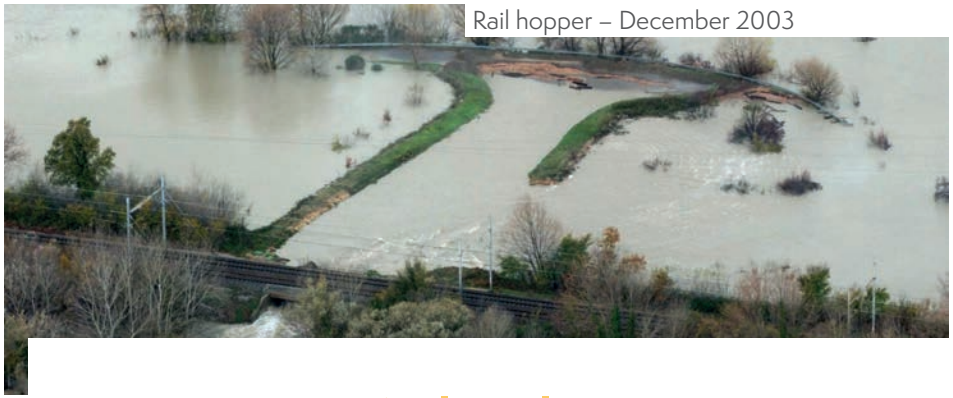
Cost: 57,5 million €



Typical cross-section levee resisting to overflow*

Diagnosis

The two rail hoppers protection levees broke in 2003, leading to the flooding of Arles North area and the Trébon lowland. A railway embankment diagnosis has been made after the flood by the SNCF *(National society of the railways)*. It revealed the railway embankment weaknesses, of whom avoided failure in 2003, could have led to spillings of several hundreds of millions of cubic metres, in comparison with the 17 million m^3 observed.



Rail hopper – December 2003

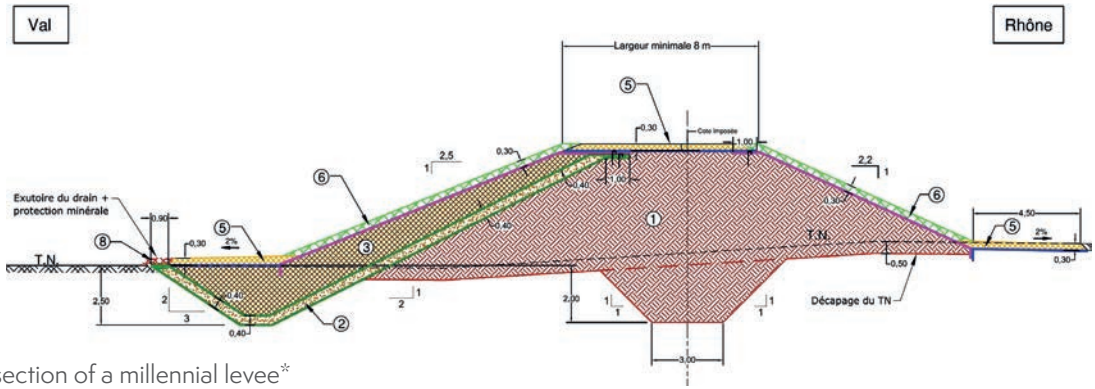
Tarascon - Arles levee

Works

- Creation of a 8,5 km long embankment levee.
- Creation of a sheet pile curtain on the right side of the Fibre Excellence factory.
- Hydraulic transparency of the railway embankment by the creation of 10 crossing works in the railway embankment, by SNCF network (70 million €).
- Measures to cancel and mitigate impacts :
  - o Enhancement of flood defences upstream (Boulbon and Comps spillways, Aramon and Marguilliers levees),
  - o Extraction of 500 000 m^3 sediments and creation of a "lône",
  - o Extraction of 600 000 m^3 of sediments in front of the Fibre Excellence factory,
  - o Increasing water drainage in case of flooding.

Tarascon-Arles levee after work

Cost: 67,6 million € (off hydraulic transparency and drying development)



Typical cross-section of a millennial levee*

SIP on the left side and SIF on the right side behind the bridge

Industrial port and fluvial sites of Beaucaire and Tarascon

Works on the Industrial fluvial site in Tarascon

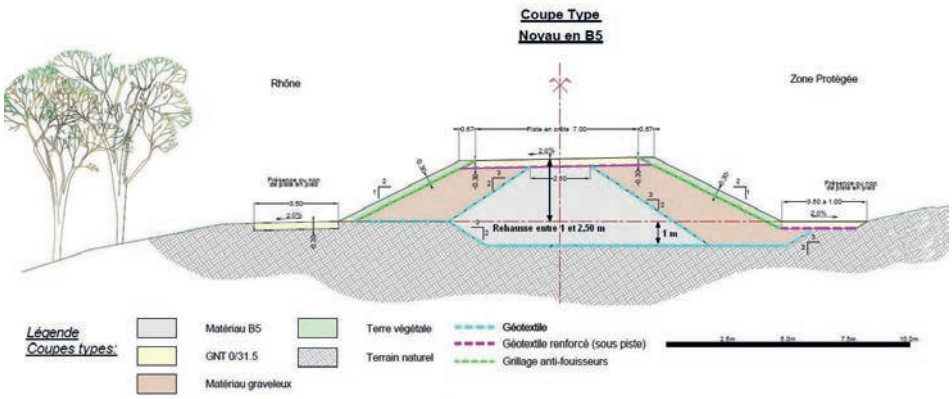
Diagnosis

The vulnerability of industrial port (SIP) and fluvial (SIF) sites of Beaucaire and Tarascon, for floods below the exceptional ones, poses problems with the circumvention of the spillways during overflowings.

Works

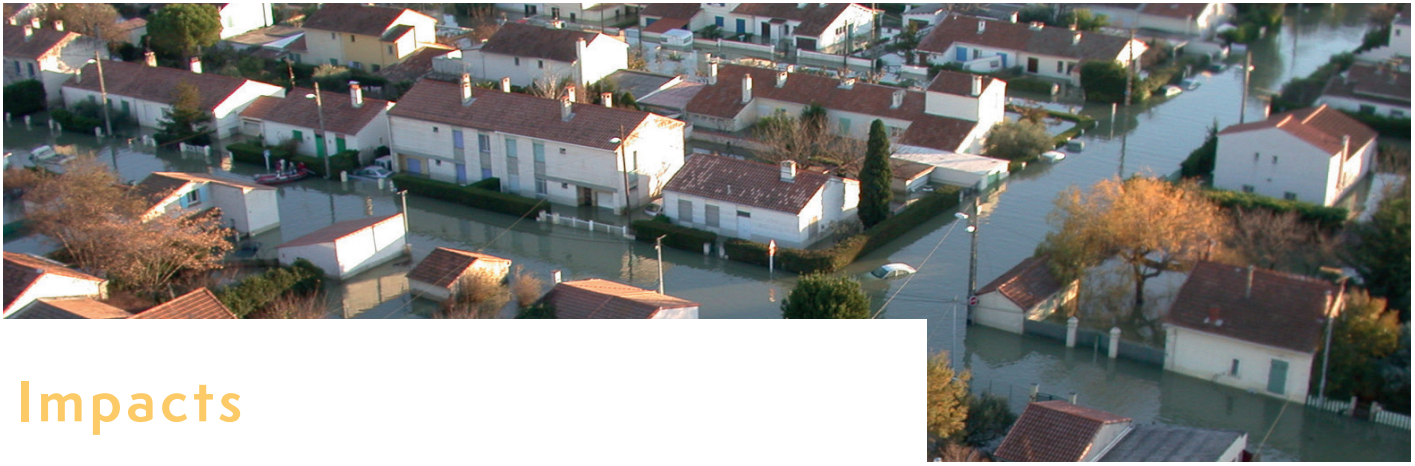
- Creation of an earthen levee on each platform elevated on the millennial mark with 50 cm more :
  - o Enhancement of 1m on 3.8km, for the industrial port site (SIP) of Beaucaire,
  - o Enhancement of 1.5m on 1.9 km, for the industrial fluvial site (SIF) of Tarascon.
- Extraction of material constituting the works of an extraction site on "l'île du Comte" (65 000 m^3).

Cost: 5,4 million €



Typical cross-section of SIP and SIF enhancement*

Works on the Industrial port site in Beaucaire



Impacts

Hydraulic impacts

Two types of hydraulic impacts are estimated, the impacts on the river levels in its bed and the hazard in the protected area, once the protection level is exceeded.

The design (elevation rating and the length) of the levees resisting to overflow have been determined so as not to aggravate the river water lines. It guarantees the absence of impact on structuring structures such as the Vallabrègues dam or on the other river Rhone arms.

The gain for the safety of the population living in the protected areas, was appreciated on the base of historical feedback and overflow hydraulic modelling, without breach, after the work.

Discharged water volumes into protected area

Thanks to these works, the discharged water volume into protected area will be from **7 to 14 times lower** to the one discharged during historical floods.

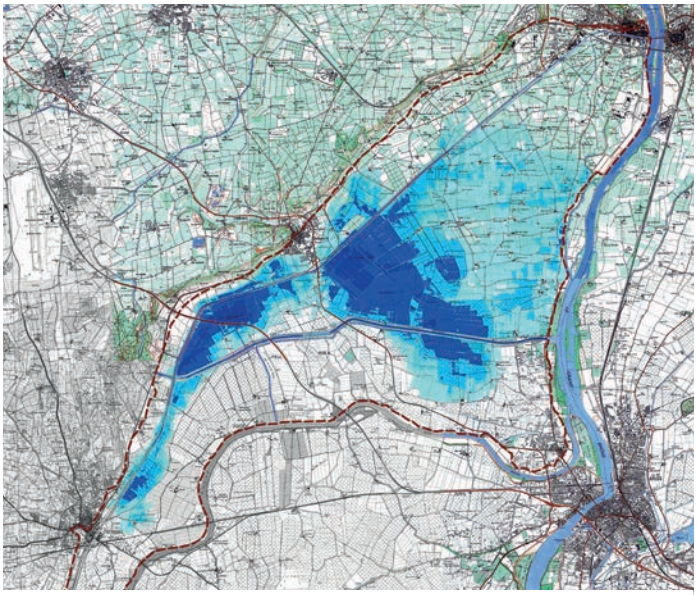
Illustration of the gain brought by the work

During the 1856 flood, whose flow rate was 12 500 m^3/s upstream the delta, 1.8 billion m^3 of water spilled into the territory. After the work, for the same flood level, the discharged volume is estimated to 130 million m^3 of water, fairly distributed between the 3 Rhône river arms, in other words 14 times lower.

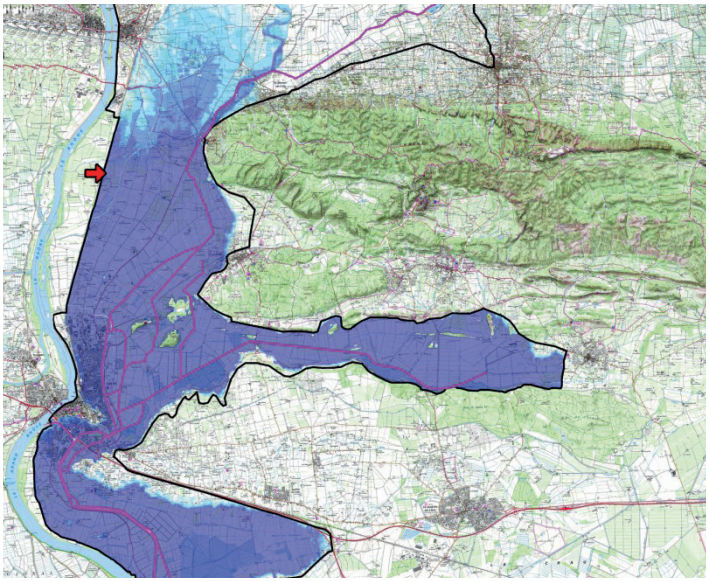
	Volumes discharged (in million m^3) according to the hydrological scenario				
Levee resisting to overflow	**Q9500**	**Q10500**	**Q11500**	**Q12500**	**Q14160**
Right bank of the Rhone Beaucaire-Fourques Levee	0	0	0	20 to 25	100 to 115
Left bank of the Rhone Tarascon-Arles Levee	0	0	0	20 to 25	95 to 115
Petit Rhone levee right bank - Versadou	0	0	0 to 1	3 to 5	5 to 8
Petit Rhone levee right bank - La fosse	0	0	4 to 7	12 to 20	20 to 32
Petit Rhone levee left bank - Figarès	0	0	3 to 7	12 to 25	20 to 35
Grand Rhone levee Right bank dowstream Salin	0	0	10	50	90 to 110
Grand Rhone levee Left bank Port Saint Louis	0	0	0	0	0,7
Total final state	0	0	20	130	375
Total initial state historical feedback	2 for Q9500 (Nov. 2002) 130 for Q9300 (Oct. 1993)	60 for Q10300 (Jan. 1994)	227 for Q11500 (Dec. 2003)	1800 for Q12500 (May 1856)	2800 for Q13000 (Nov. 1840)
Discharged volumes reduction (EP 20/ EI)	$-\infty$	$-\infty$	11	14	7

Hydraulic modelling of a flood like the 1856 one (12 500 m^3/s)

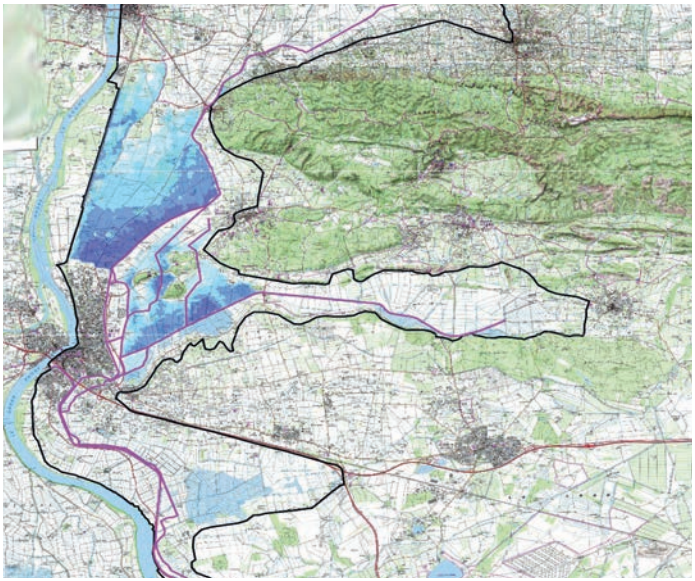
Breach, almost certain, before the works between Beaucaire and Fourques



Overflow without breach, almost certain, after the works between Beaucaire and Fourques



Breach, almost certain, before the works between Tarascon and Arles



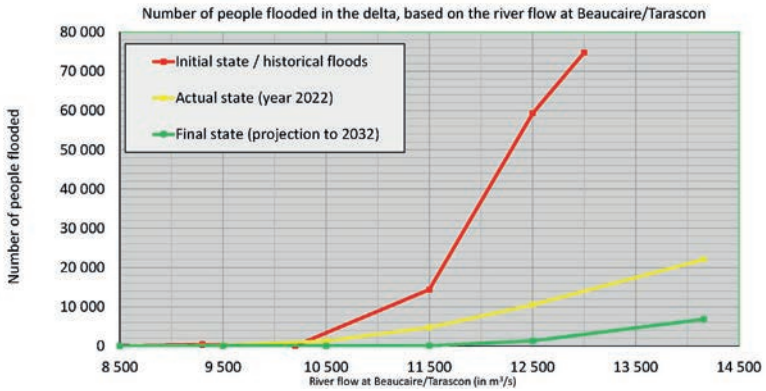
Overflow without breach, almost certain, after the works between Tarascon and Arles

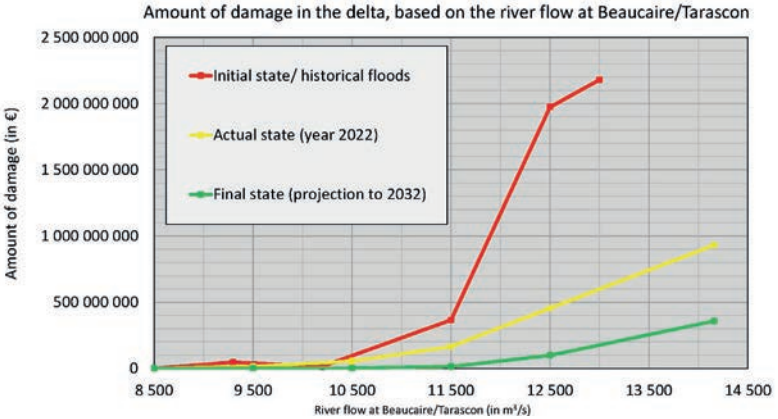
Economical and societal impacts

For each flood level, the impact on the property and people safety, is expressed in terms of reduction of damage and number of people flooded. For the latter, the dangerousness of water inflows is also taken into account.

Illustration of the gain

For a flood with a 11 500 m³/s, the equivalent of the 2003 flood, the amount of damage expected is divided by 2, thanks to the work carried out up to today. It will be eventually divided by 25. The number of people flooded would go from 14 375 to 4 765 in the current state (2022) and will be, at the end of the safety program, of 581, of which only 107 with more than 1 metre of water.

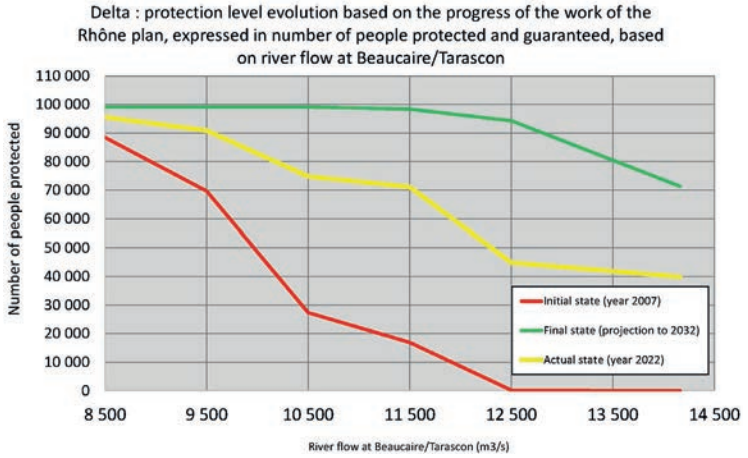




Impact on the regulatory protection levels

Before the works, a part of the population was no longer guaranteed protection as soon as the Rhone flow was exceeding 7 500 m³/s, and no one left was protected from a 12 500 m³/s flow.

Thanks to the works carried out, 75% of individuals are protected until a 10 500 m³/s and 45% are in case of a 12 500 m³/s. At the end of the safety program, these rates will respectively be of 99% and 95%.



Environmental impacts

The works led by the Symadrem have various impacts on the natural environment. To minimise them, the Symadrem applies the regulatory method "Avoid, Reduce, Compensate".

It is initially aimed to:

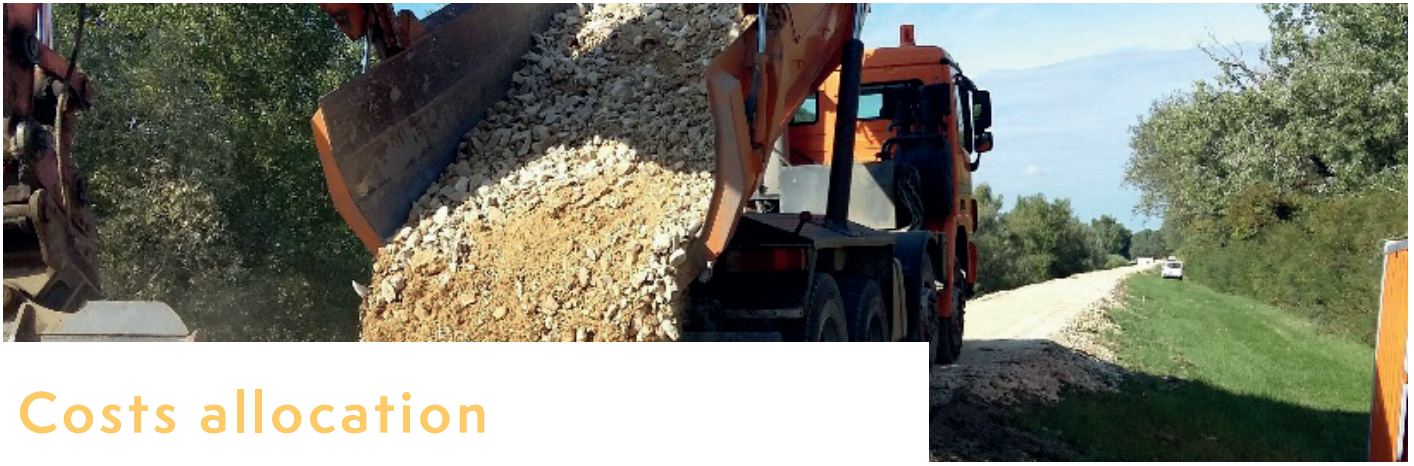
- avoid the environmental impacts;
- reduce the one which were not possible to avoid;
- compensate for effects that cannot be avoided or reduced.

The Symadrem doesn't confine itself to these only regulatory obligations and falls within a genuine value process of the environments, integrating an ecological consideration, from the first phases of conception of its constructions.

European Cistudes

Wetland south levee

Inside the "lône"

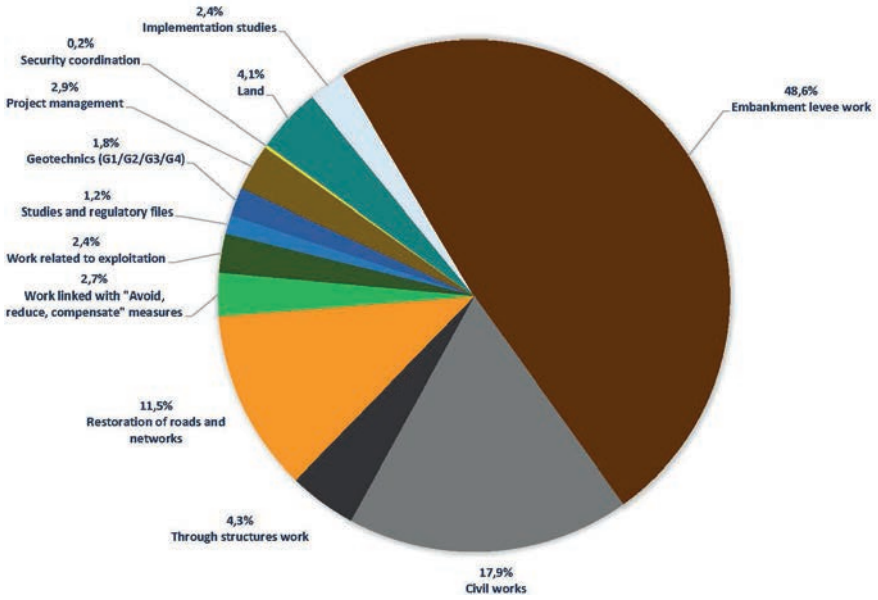


Costs allocation

Today, all the levees from Vallabrègues dam to Arles downstream have been reinforced for an amount of 195 million €.

The costs allocation beside, aims to show the weight of each item of expenditure during a major operation.

Management works in flood period security costs (vehicular traffic on the levees...) were prorated to the tranche of operations described in this document, namely between Beaucaire/ Tarascon and Arles. They have been evaluated to 20% of the security operation total cost.



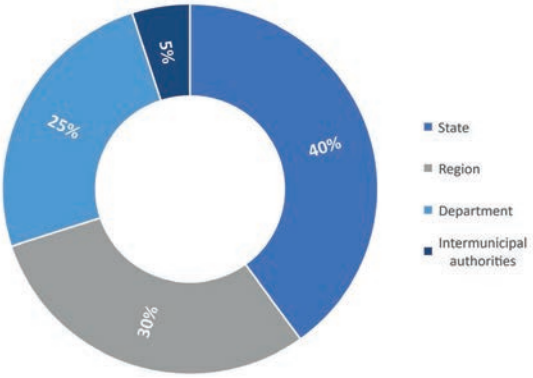
Network diversion

Work on through structures

Financing

The security program operations financing comes from **public subsidies** for 100%.

It is contractually included in the Inter-regional plan contract with State and regions.



Distribution of funding

Main funders

One-time funding

*Typical cross-sections glossary

French – English

- Altitude – Altitude
- Amont – Upstream
- Ancrages horizontaux – Horizontal anchors
- Apport extérieur – External contribution
- Aval – Downstream
- Béton désactivé ou calade de réemploi – Desactivated concrete or re-use calade
- Béton fibré – Fiber concrete
- Canal d'évacuation vers la roubine de Flèche – Escape channel to the irrigation canal of the "Flèche"
- Contre canal du Vigueirat et eaux de ressuyage de la plaine – Counter-channel and lowland wiping water
- Corps de digue existante – Existing levee core
- Cote imposée – Imposed rating
- Couche de fondation / Couche de roulement – Foundation layer / Bearing layer
- Couronnement à créer – Crowning to be created
- Crue / Crue de 1856 selon archives – Flood / 1856 flood according to the archives
- Déblais de la clé d'ancrage / Tranchée d'ancrage – Anchorage key removals / Anchorage trench
- Décapage – Stripping
- Détail – Detail
- Déversoir du Vigueirat vers le canal d'évacuation – Vigueirat spillway to the drainage channel
- Diam scellement 15cm – Sealing diametre 15 cm
- Drains alternés diamètre 100 mm – Alternating drains diametre 100 mm
- Enrochements liaisonnés au béton / blocométrie – Concreted riprap / Blocometry
- Enrochements libres catégories – Free riprap categories
- Espacement moyen tous les 5 m – Medium spacing every 5m
- Exutoire du drain et protection minérale – Drain outlet and mineral protection
- Filtrat drainant – Draining filtrate
- Fossé nouveau – New ditch
- Garde corps – Guardrail
- Géogrille – Geogrid
- Géosynthétique filtrant – Filtering geosynthetic
- Géotextile antipoinçonnant / Géotextile filtre – Anti-punch geotextile / Filtering geotextile
- Géotextile renforcé (sous la piste) – Reinforced geotextile (under the runway)
- Géotextile synthétique non-tissé – Synthetic geotextile non-woven
- Grave ciment – Gravel cement
- Grillage anti fouisseur / Grillage simple torsion – Anti-burrowing mesh / Single twist mesh
- Grilles de protection – Protective grids
- Laitier – Black furnace slags
- Largueur minimale – Minimum width
- Limite d'emprise – Right-of-way limit
- Marché 1 - Génie civil / Marché 2 : Terrassement – Contract 1 - Civil engineering / Contract 2 : Earthworks
- Masque drainant – Draining siding
- Matériau B5 / Matériau graveleux – B5 material / Gravel material
- Nappe d'accrochage antipoinçonnante – Anti-punch gripping table
- Nettoyage du parapet – Parapet cleaning
- Niveau supposé du substratum – Substratum assumed level
- Noyau en B5 – Core made in B5
- Numéros des points – Points numbers
- Ouvrage de régulation du débit – Flow control structures
- Palplanches type PU18 – Sheet piles type PU18
- Parement amont existant / Parement perré – Existing upstream facing / Perrated facing
- Piste amont / Piste aval / Piste pente – Upstream track / Downstream track /Slope track
- Piste de circulation / Granulométrie – Traffic track / Particle size
- Piste de crète de digue – Levee crest track
- Pistes d'entretien – Maintenance track
- Plateforme de pompage raccordée à la rocade – Pumping platform connected to the ring road
- Poutre en béton armé coulée pleine fouille – Reinforced concrete beam
- Présence ou non de piste en pied – Presence or absence of track at the foot
- Réfection de l'étanchéité amont – Repair of the upstream sealing
- Rehausse entre 1 et 2.5m – Enhances between 1 and 2.5m
- Remblai compacté type A1/A2 issu des déblais – Compacted embankement A1/A2 from excavated material
- Remblai en matériaux tout-venant – Embankment made in all-types material
- Remblai étanche - matériaux A1/A2 – Waterproof backfill - A1/A2 material
- Restauration du perré – Perrated restoration
- Revanche – Freeboard
- Sortie du siphon du Vigueirat – Vigueirat siphon output
- Surlongueur 2m pour la protection du chantier contre les crues – 2m added to protect the construction site against floods
- Terrain naturel – Natural ground
- Terre végétale du site/Terre végétale ensemencée – Topsoil of the site /Seeded topsoil
- Tirant type Anker Shroeder M45 – Anker Shroeder M45 draft type
- Zone protégée – Protected area

Design and realisation: SYMADREM – April 2022

Photo credits : SYMADREM – Balbus – BLOT - Arles town hall, Daniel Bounias - Drone Sud Est – FRTP 13 – GUINTOLI - Jean-Luc MASSON - Tarascon town hall, environment department – Naturalia environnement – Paul Royet – Photo-aérienne-france.fr – Saphyre gyrocoptère – SDIS 13 - SIDR

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