European Geosciences Union
General Assembly 2024
Vienna, Austria & Online | 14–19 April 2024

NH3.13
Nature-based and bio-based solutions for geohazard mitigation on slopes and streambanks
Convener: Alessandro Fraccica | Co-conveners: Vittoria Capobianco, André Evette, Paola Sangalli, Stephan Hörbinger

"Nature based Solutions and combined techniques in the immediate vicinity of infrastructure and residential areas - 5 case studies of steep bank stabilization in the Garonne water catchment area in France realized between 1999 and 2022

Klaus Peklo Dipl.-Ing., graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -

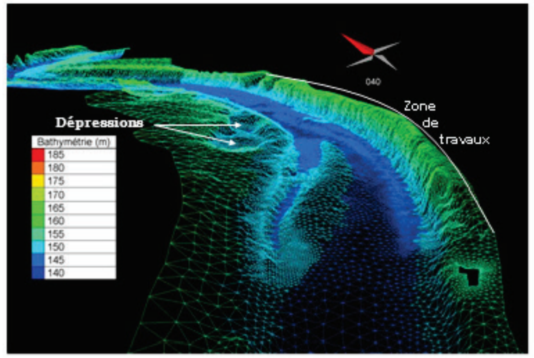

Figure 15: Illustration du maillage irrégulier

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This poster will show you 5 case study excerpts of river rehabilitation designed and directed by Klaus PEKLO from 1992 to 2022 within the Garonne catchment area in France

It will show how severe bank slides, such as those following natural disasters, can be sustainably reintegrated into the river ecosystem in a modern, contemporary way through the application of Soil and Water Bioengineering.

Likewise it will explain, how the needs of integrated engineering approach helps to find out the causes of streambank slides before onsite work starts. Pointing out the workflow of the reconstruction process by determining an efficient analysing stage, construction stage and monitoring stage.

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Sustainable Soil and Water Bioengineering needs an integrated engineering design approach

It consists of well-thought-out preliminary studies, then preliminary design, not forgetting the back-checking of your preliminary design, and only then proceeding by detailed implementation design.

During your construction stage frequent construction supervision and inspections are mandatory.

Then you will get a reliable and sustainable integration of your nature based "Soil and Water Bioengineering " solution into the existing ecosystem on your construction site.

"**Integrated design** is a comprehensive holistic approach to design which brings together specialisms usually considered separately. It attempts to take into consideration all the factors and modulations necessary to a decision making process."

(Victor Papanek (1972), "Design for the Real World: Human Ecological and Social Change", Chicago: Academy Edition, p322. Extract of Wikipedia on Friday 23/04/21)

- All pictures non credited are taken by K.Peklo -

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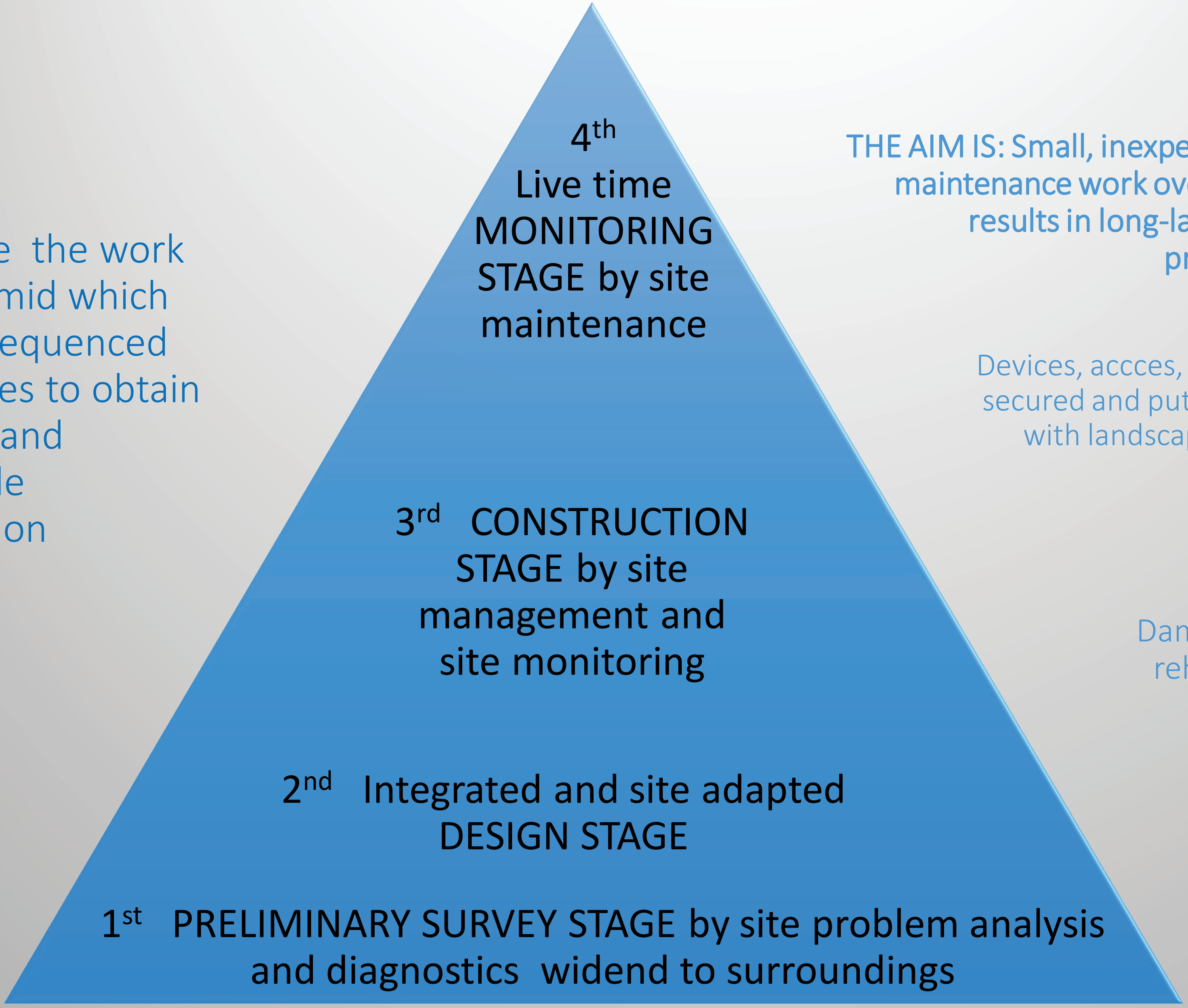
Please see the work flow pyramid which shows 4 sequenced work stages to obtain a reliable and sustainable construction

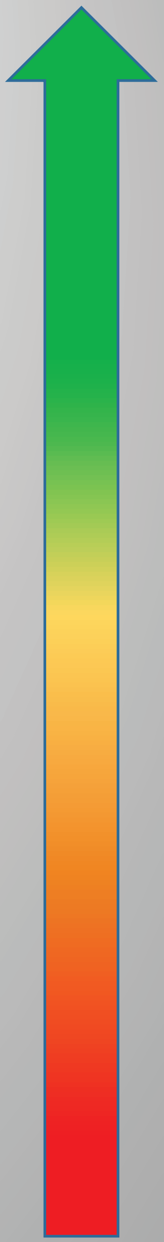


THE AIM IS: Small, inexpensive and regular riparian maintenance work over the course of a lifetime results in long-lasting ecological riverbank protection and stabilization

Devices, accces, soils or riverbanks are now secured and put into service in accordance with landscape and environnement and construction regulations

Damaged site is beginning to rehabilitate into the natural environment

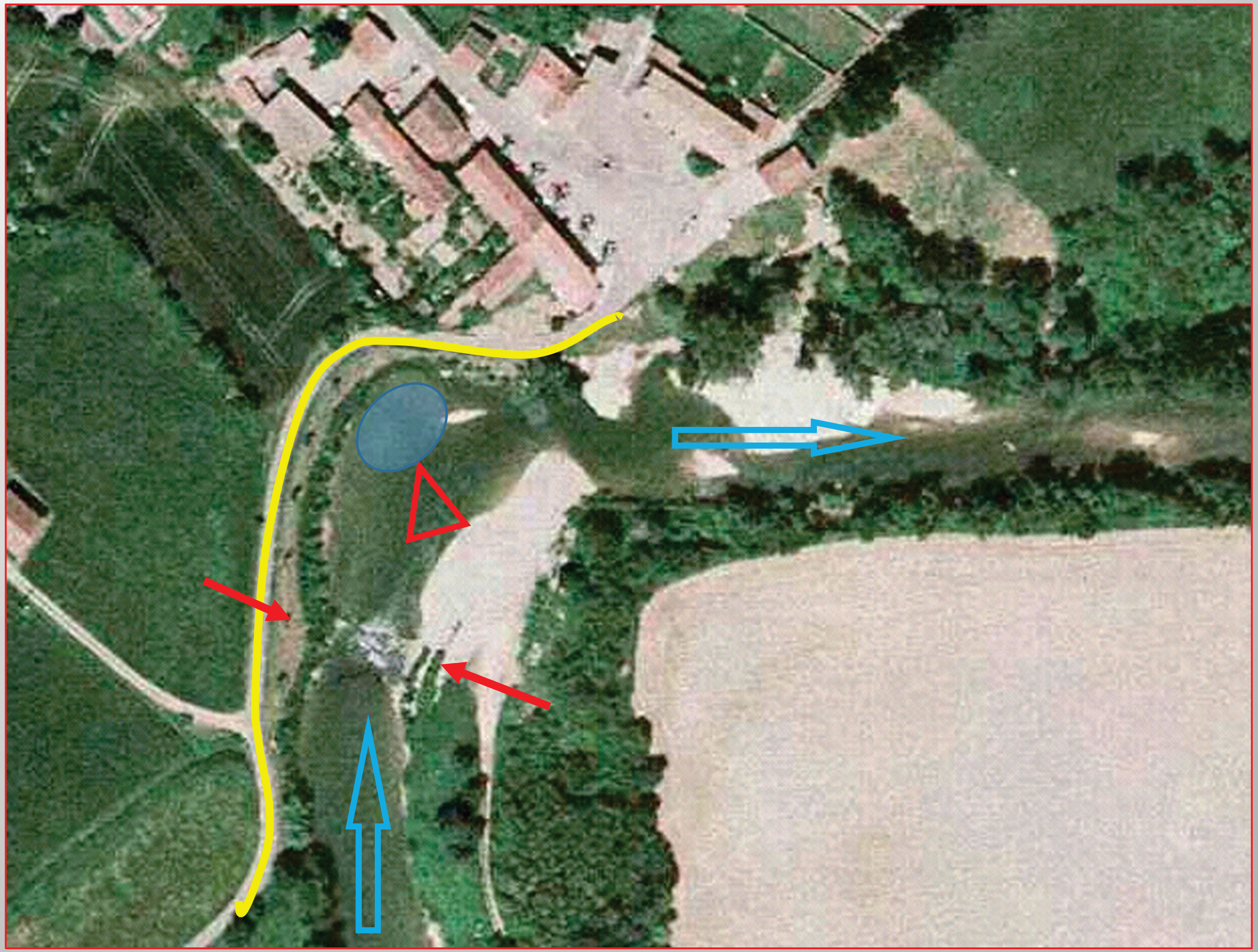
Damaged site needing rehabilitation



INFRASTRUCTURE – Protection of main roads and bridges

Case study 1) 1999: Hers Vif River – 120m Rehabilitation work of River embankment
Construction time 3 months – Pre-tax costs 75.000 € (64.500 ₤ 10/2016 rate)

Damage case: Far advanced bed and bank erosion; imminent risk of undermined embankment collapse threatening public space and communal road
Preliminary studies carried out: Topographic and bathymetric data levys, hydrodynamical analyses…
Program mission: Project establishment, contract drafting and site monitoring in order to reduce risk of bank erosion
Geometric shape: Variable bed width 30/50m; bank height 6m, subvertical and variable slope gradient; 50 year design flood Q_{50} ~ 600m^3/s
Provided longitudinal construction: Horizontal willow fascine, live Log Cribwall, live Brush Mattress, Brush Layers, Log branch cutting
Provided transversal construction: 40 m wide 3D transversal Rough Ramp anchored in live RipRap



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Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Construction aim: Permanent riverbed shifting to right riverbank and vegetated Log Cribwall fastening

Construction stage this photo: during end of octobre 1999 on left bank

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Construction stage during winter 1999: Longitudinal left bank protection ongoing as vegetated Log Cribwall

Anchoring depth =2,50m strengthend with local plant cuttings in order to obtain a riparian stratum of Salix shrub

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Construction stage during winter 1999: 3D transversal Rough Ramp construction ongoing

Larix decidua pile driving activity
into river alluvium in progress >>

Einrammen der Larix decidua Pfähle ins alluvium

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle: Detail of Log Cribwall – notice the off-centered position of wooden cross pieces

Picture taken after 600m3/s flood event in April 2000

Front of vegetated reinforced Log Cribwall constructed from Larix decidua felled in the highlands of the Pyrenees >>

Einwandige Holzstruktur aus Larix decidua gefällt in Höhenlagen der Pyrenäen

Case study 1) 1999: L’Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle April 2000: State after the 1st stress-test

5 months after completion, a floodevent occuring of ~ 6,50m height

The yellow line indicates the position of the communal road also the highest floodlevel

Bed and bank: No damage caused by the flood

April 2000 etwa 5 Monate nach Fertigstellung, Überschwemmung ~ 6,50m bis über die Strasse

Die gelbe Linie zeigt die Lage der Gemeindestrasse und den max. Hochwasserstand

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle 2005: Upstream picture towards 3D Hydraulic Rough Ramp anchoring into right bank

Background: Vegetated RipRap integrating anchoring on both Riversides >>

View towards upstream in 2005 of the 3D rough boulder ramp and the flanking vegetatively reinforced bank. The intended river bottom elevation in upstream to obtain velocity reduction through sediment deposition is clearly visible.

<< Front: Riparian Salix shrub stratum growing up of Log Cribwall after several cuttings

Case study 1) 1999: L’Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle winter 2007: Upstream picture towards Rough Ramp anchoring into left bank

Always working in perfect condition, the Rough Ramp avoids erosion damage on LRB by deviating floods to RRB and provides free river oxygenation and enjoyment for bathers >>

Die gut funktionierende 3D Rip-Rap Blocksteinrampe erlaubt es die Hauptströmrichtung weg von der Gemeindestrasse ins rechtseitige Unterwasser zu lenken, damit die Erosionskräfte erheblich zu reduzieren und die Strasse nachhaltig zu schützen

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle 2013: 4 years after completion date

View to lower left bank

Blick nach Unterwasser: Gesundheitszustand in 2013

View to upper left bank: no more undermining!

Blick nach Oberwasser: Gesundheitszustand in 2013
Keine Vortexerosion mehr im Mäanderzenith

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Lifetime cycle 2015

Satellite view indicates current state of construction: no more undermining as sedimentation now protects public road in the meander arch

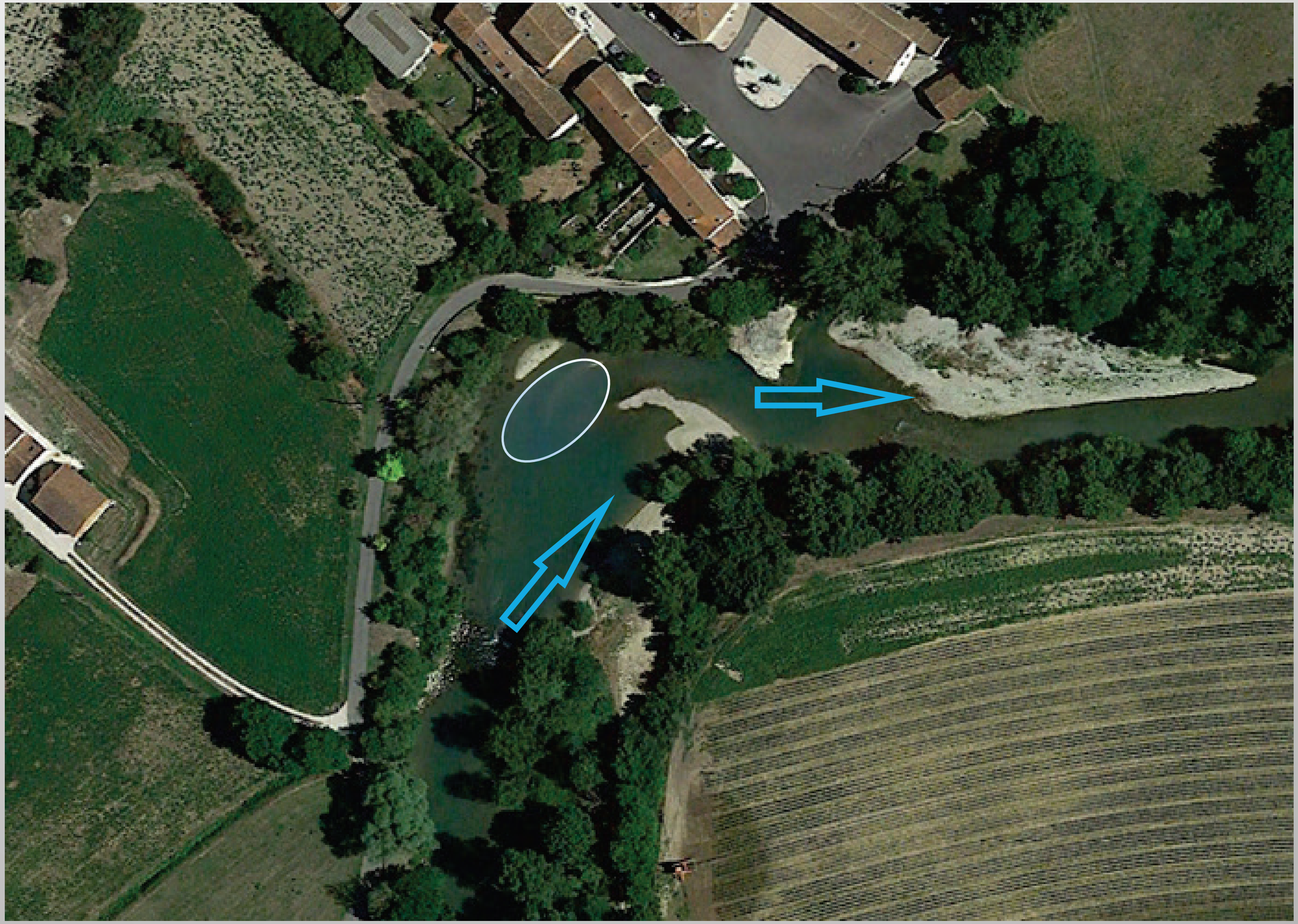


Image GoogeEarthPro

Satellitenfoto 2015: Sedimentation am Prallhang; keine Unterspülung der Strasse mehr

INFRASTRUCTURE – Protection of main roads and bridges

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall protecting residential area and his access road – Construction time 5 months – Pre-tax costs 346.000 €

Both satellite view and X are indicating the most damaged right river bank in front of the resedential area.

Yellow rectangle is the site equipment position.

Blue line is the position of longitudinal construction provided.

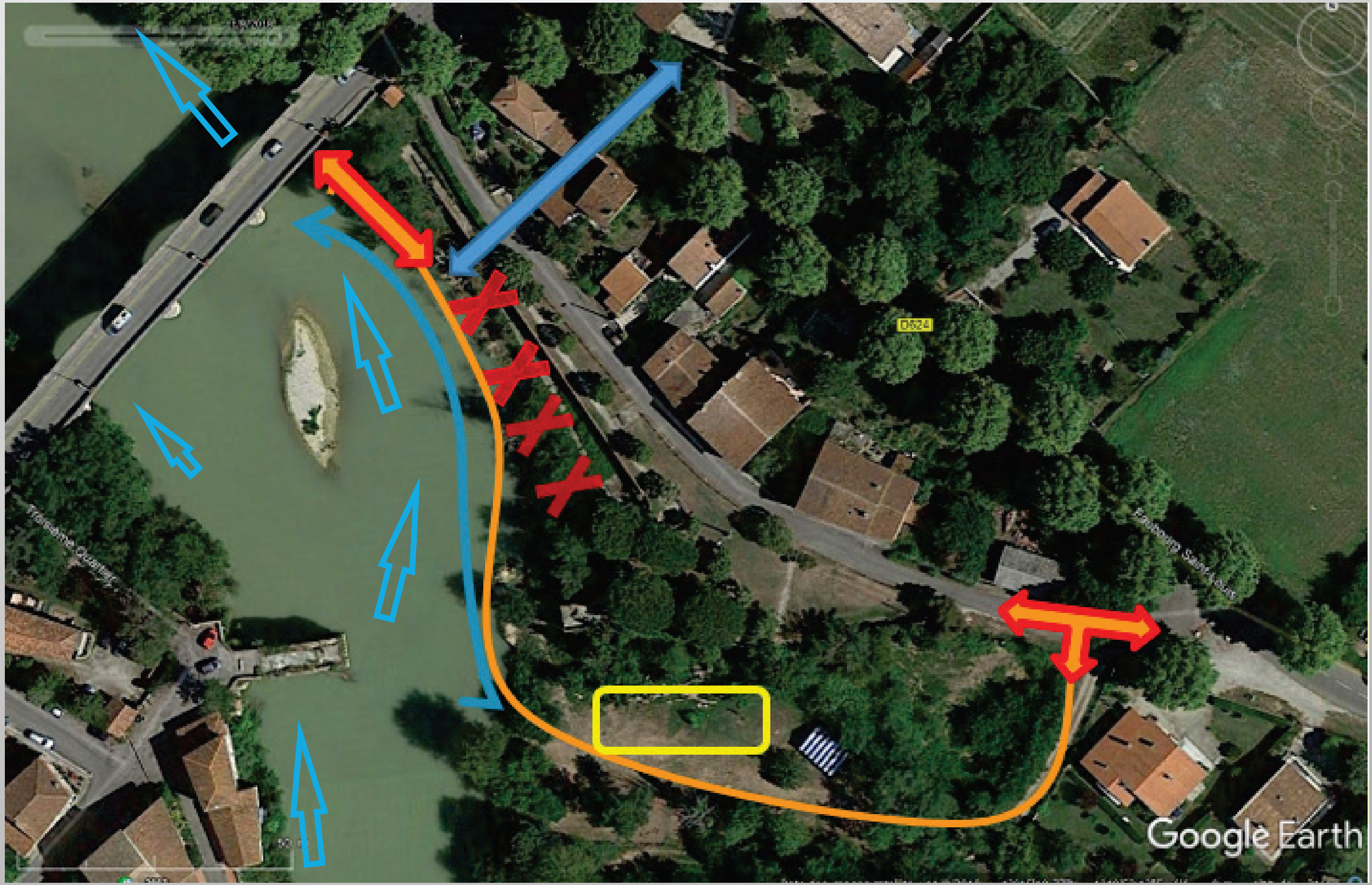
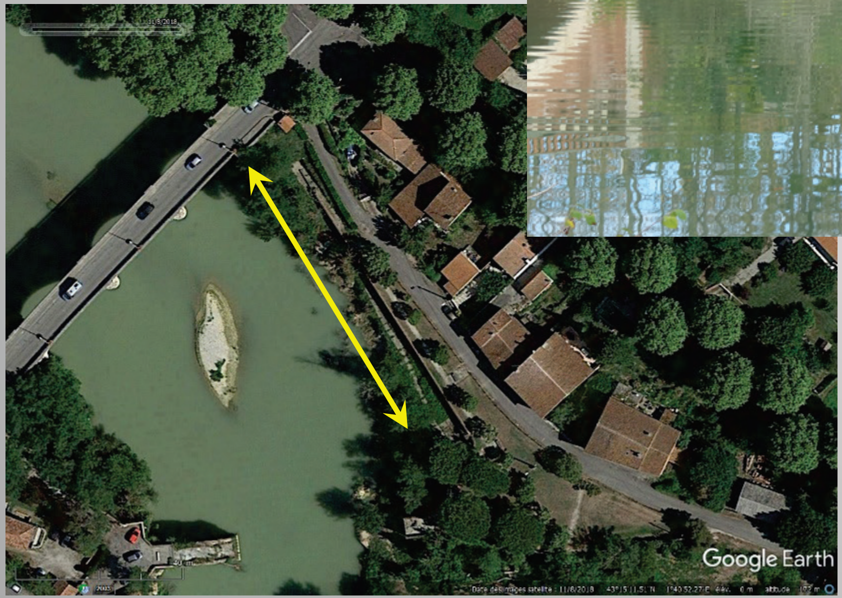


Image GoogeEarthPro

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road

Preliminary stage: Onsite bathy, geotech and hydrodynamic investigations



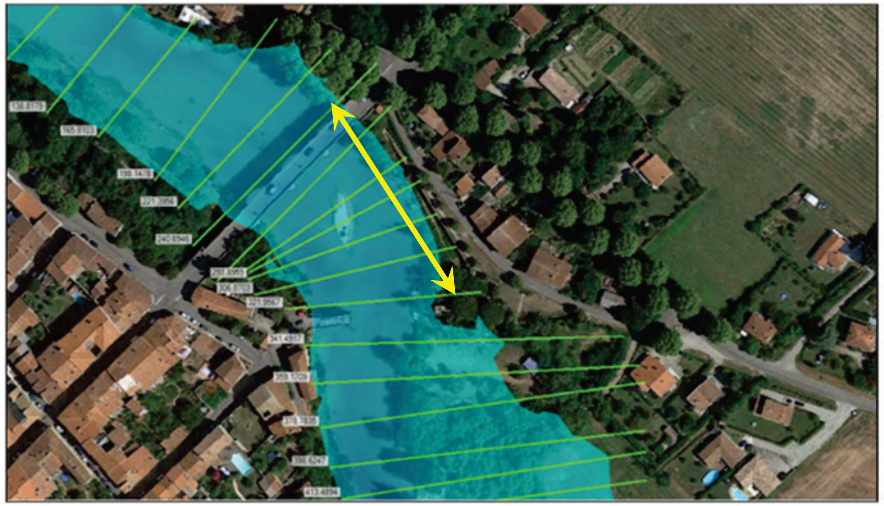
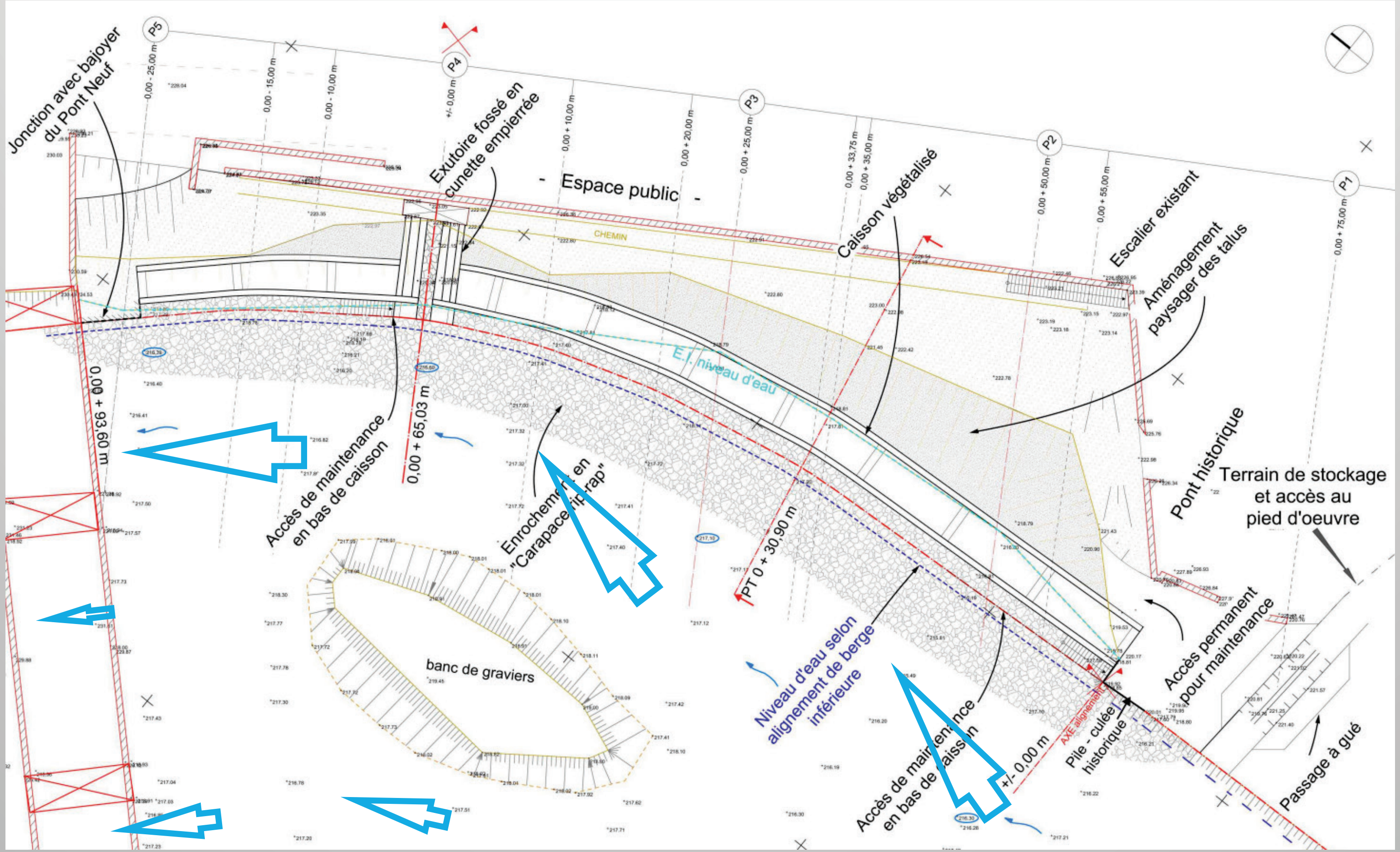


Figure 15 : Zone inondable pour T50ans

Yellow arrow indicates the most damaged right river bank in front of the resedential area. Blue arrow indicates the flood direction.

Case study 2a) 2020: L’Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road

Final design stage: The final exécution plan for public tender.



Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road

Final design stage: The final outflow section for public tender.

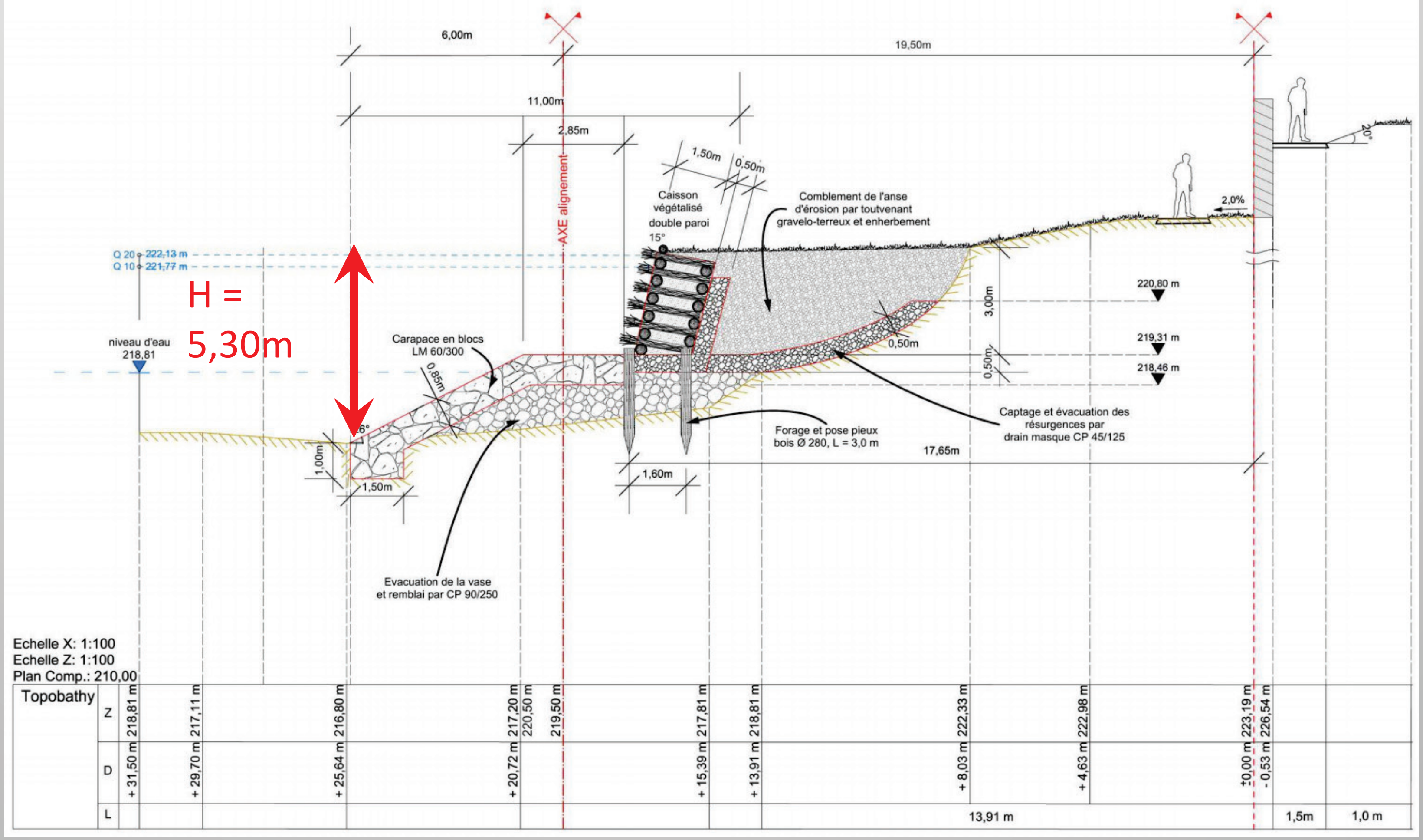
Right river bank re-construction

Soil refilled between flood wall and crib wall to obtain open space

Greened log crib wall

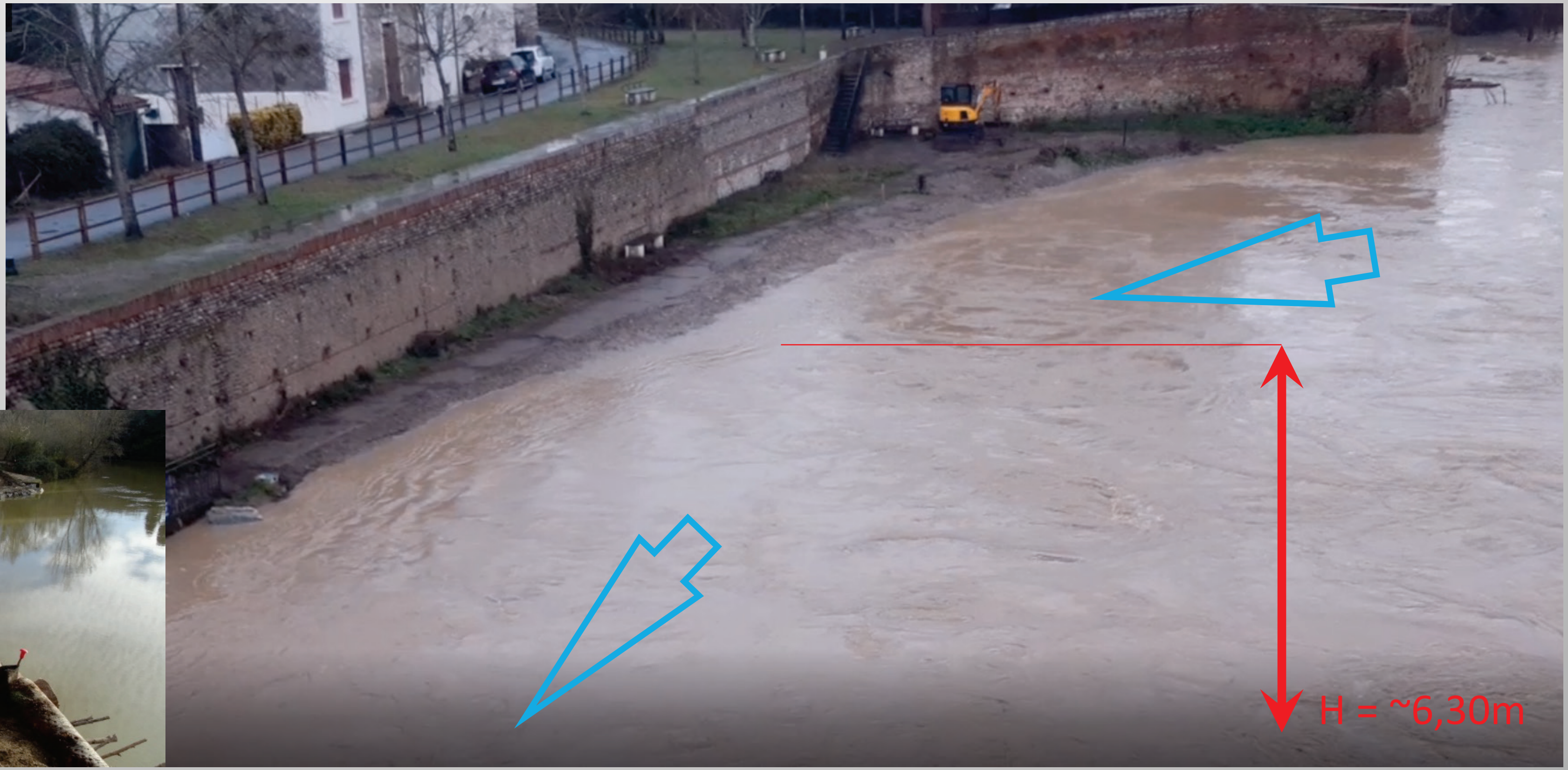
Hydraulic filter between crib wall and public open space

EN 13383 bloc-stone carapace



Case study 2a) 2020: L’Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road - construction stage -

Construction stage April 2020: Construction progress stopped due to 50 year flood estimated about 650m^3/s



Work in progress on 11/12/2019

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road – Completion date -

Beginning of lifetime cycle May 2020: Development of willow wood 4 months after the beginning of planting

Picture taken in 14/05/2020

Case study 2b) 2022: L'Hers Vif River –50m lower bank protection providing both erosion protection to the road bridge and safety access to public space

Preliminary stage: January 2022

Frontview :
Current health state in march 2022: 50m erosion process is ongoing in direction both to public space and restaurant

Detailed view to downstream: Regressive erosion progressing in close proximity to bridge pier

Case study 2b) 2022: L'Hers Vif River – 50m lower bank protection providing both erosion protection to the road bridge and safety access to public space - completion date -

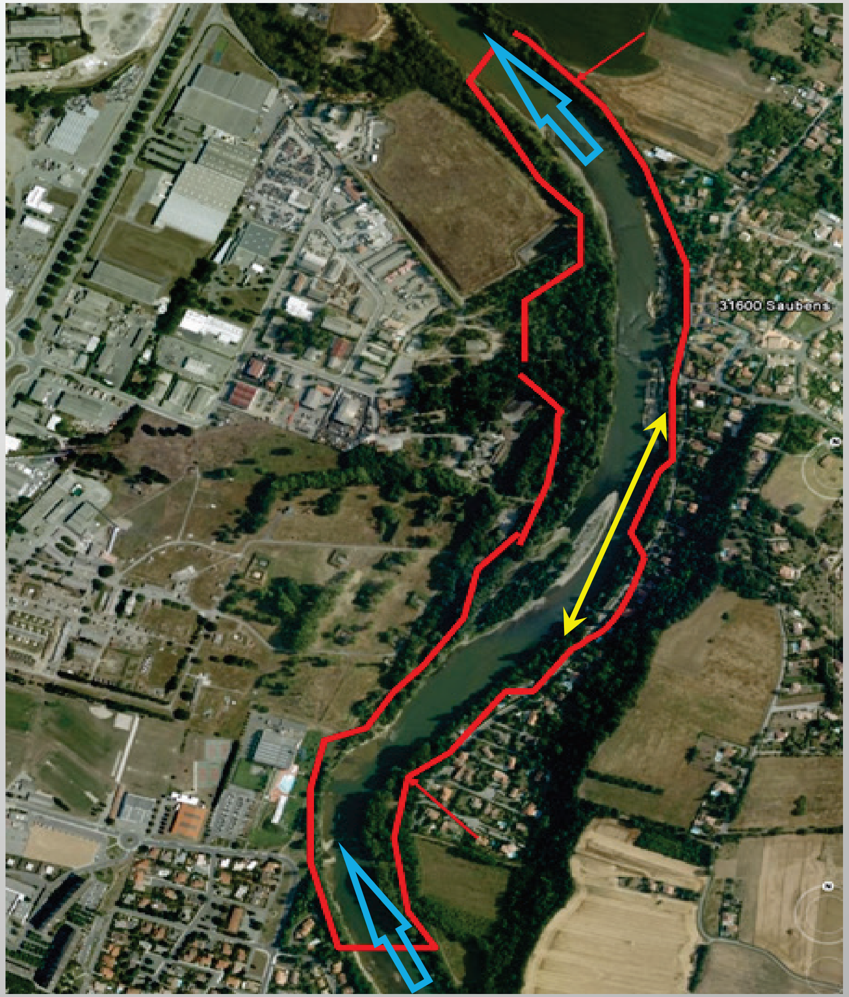
Completion date April 2022: Construction stage finished

View to upstream:
50m erosion process stopped by applying a vegetated Log Cribwall

RESIDENTIAL AREAS – Protection of acess roads and residential buildings

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment
Expected construction time 5 months – Pre-tax costs 950.000 €

Damage case: Far advanced bed shifting and bank erosion; imminent risk of embankment collapse threatening public space and communal road
Preliminary studies: Topographic and bathymetric data levys, drillings in view of geotechnical assessment, diachronical and hydrodynamical analyses…
Program mission: : Project establishment, contract drafting and site monitoring In order to reduce risk of bank erosion
Geometric flow sector shape: Variable bed width 80/150/200/80m; bank height 10/12m, variable slope gradient 30/45/55;
design flood Q_{100} ~ 2.780m^3/s
Provided longitudinal works: live RipRap, Log Cribwall, live Brush Mattress, Brush Layers, combined drilled concrete injection anchors
Provided transversal works: absolutely necessary but not yet been authorised



Fond Image GoogeEarthPro

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Preliminary stage: Diacronic analysis results in both bed shifting and bank erosion have progressed up to 6,5m over the last 50 years

GoogleEarthPro 2012: Yellow line indicates the most urgent job sections in NbS and combined techniques (total L ~ 500m)

Fond Image GoogeEarthPro

GoogleEarthPro im Juni 2012: Gelbe Linie zeigt geplanten Wiederaufbau mittels ingenieurbiolischem und kombiniertem Uferschutz

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Preliminary stage: Diacronic analysis results in both bed shifting and bank erosion have progressed up to 6,5m over the last 50 years

2012: Far advanced bed deepening due to lack of bedload caused substratum outcrop

2014: Lateral movement continues and causes bank collapse close to the residential area access (position in yellow line)

2014 Die Flussverlagerung bewirkt, in zeitlichen Schüben, dauerhafte Uferabbrüche auf der gesamten Höhe von ca. 10/12m, die schützende Ripisylve/Auwaldreste sind nicht mehr vorhanden, gelbe Linie > Zufahrtstrasse

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Preliminary stage: Important upper bank erosion in close proximity to residences

Same propertie, garden border shown by brown line

2015 Uferabbruch im Hausgarten; braune Linie ist das Mäuerchen im rechten Foto

2014 Uferabbruch im Hausgarten; braune Linie ist das Mäuerchen im linken Foto

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Preliminary stage: Based on a terrestrial 3000m long DTM covering area of centennial flood Q_{100} ~2,780m³/s, we had to compute the channel morphology (TELEMAC 2D)

River bank reconstruction parameters

Flow rates:

Q_{min}=150 m3/s, Q_{max} 4.350 m3/s (1952)

Design base:

Slope $_{average}$ I = 0,0023

H_{max} = riverbed bottom + 10/12m

$V_{max\ channel}$ = 4,0m/s

HQ100 = 2.780 m3/s

Shearstress $T_{max\ bankborder}$ = 160N/m² > 220 N/m²

Hier das vorab erstellte DGM im HW Fall Q100 mit Hilfe von TELEMAC 2D auf Basis von 3000m terrestrischen und bathymetrischen Geländeaufnahmen

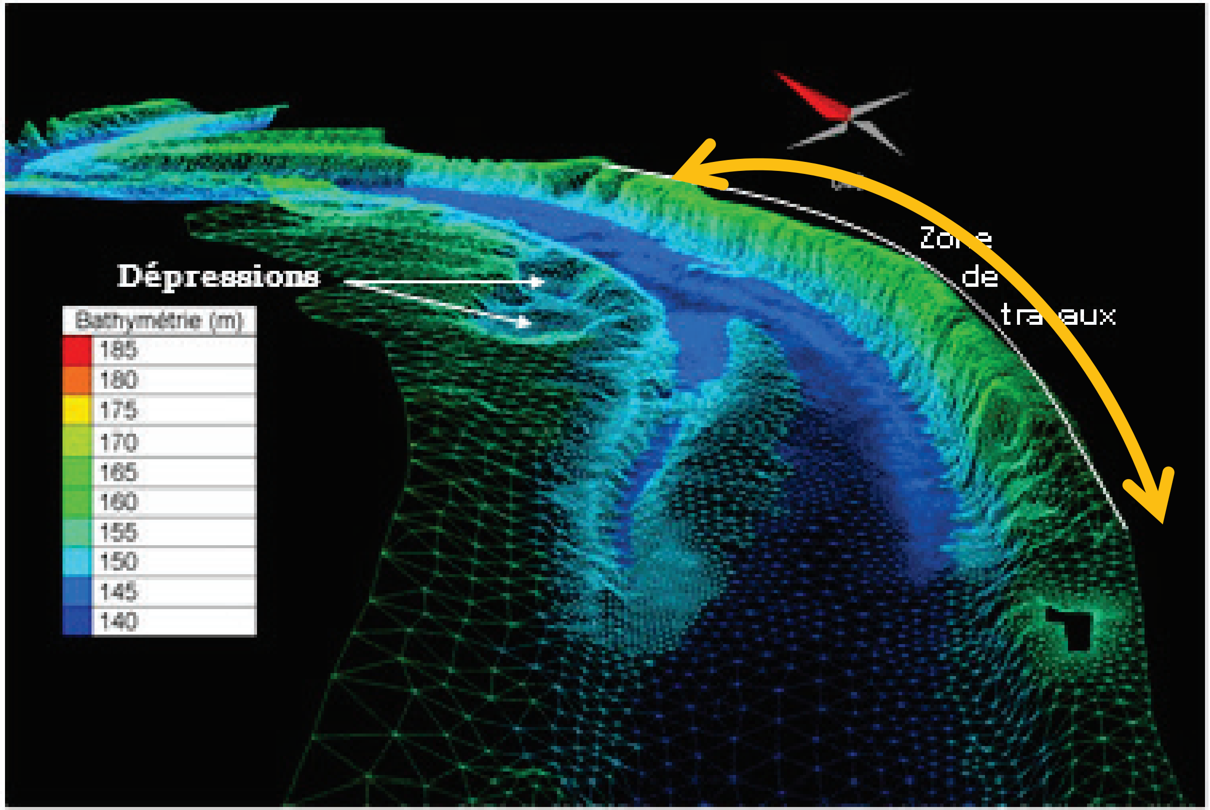
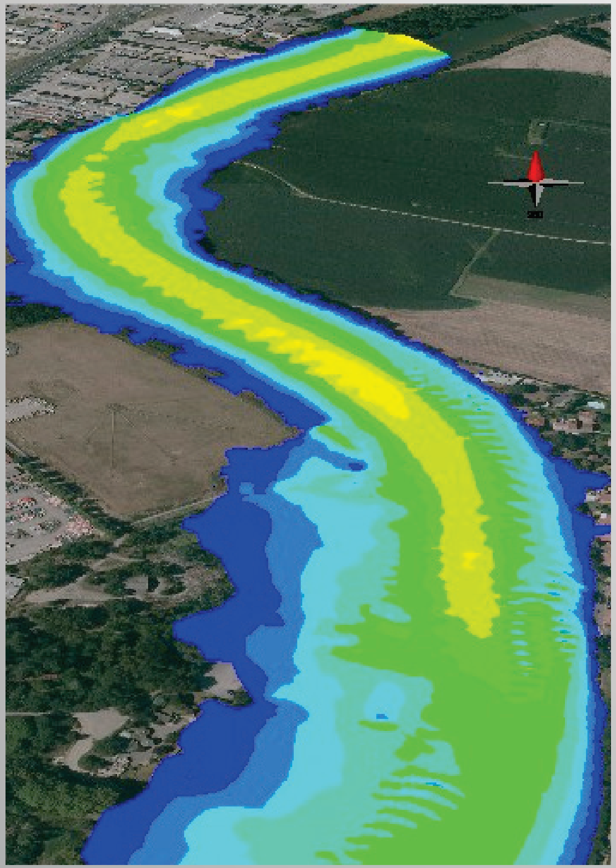


Figure 15: Illustration du maillage irrégulier

Auszug aus der Vorstudie « 2015 Hydrodynamisches Abflussgeschehen 2D des Flusses Garonne »

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: Extract of this hydrodynamic 2D assessment (distance of 3000 m) with the aim of obtaining multiple runoff characteristics to provide a basis for structural design of biological and mixed techniques

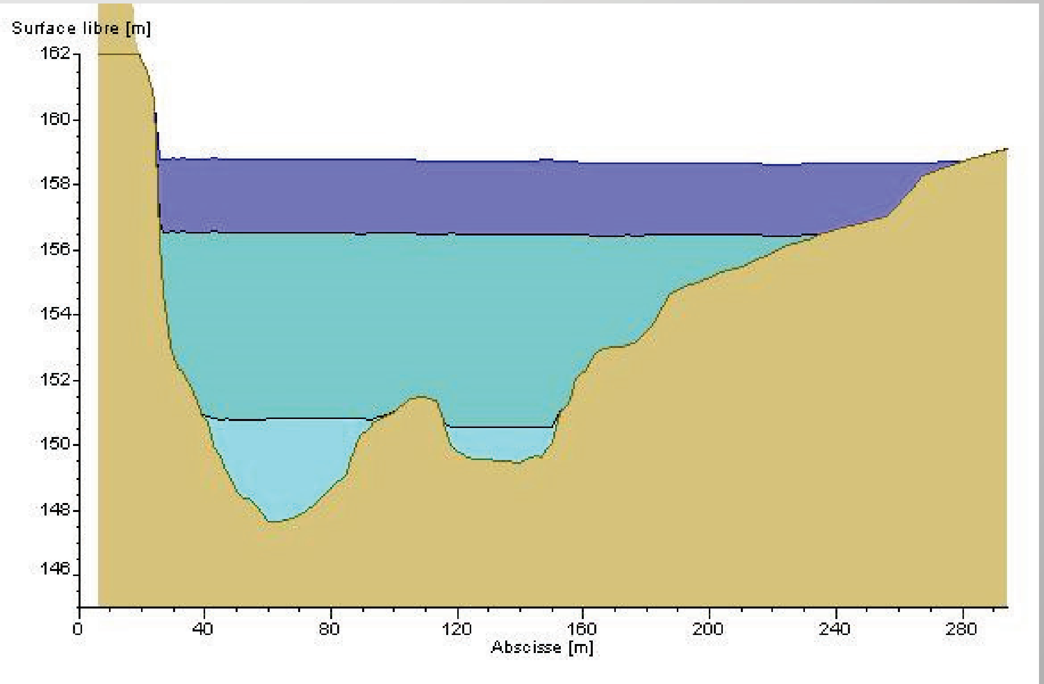


<< Velocity values are computed by TELEMAC 2D for required levels

Auszug der Vorstudie « 2015 I.C.E Hydrodynamisches Abflussgeschehen 2D des Flusses Garonne »

< Geschwindigkeits-verteilung

Flood cross-section values are computed by TELEMAC 2D for required levels



< Flussgrund und verschiedene HW Stände

RESIDENTIAL AREAS – Protection of residential buildings

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats
Construction time 2 months – Pre-tax costs 70.000 €

Damage case: Far advanced bed shifting and bank erosion; imminent risk of embankment collapse threatening residential area
Preliminary studies: Topographic data levys, drillings in view of geotechnical assessment and hydrodynamical analysis
Program mission: Project establishment, contract drafting and site monitoring In order to reduce risk of bank erosion

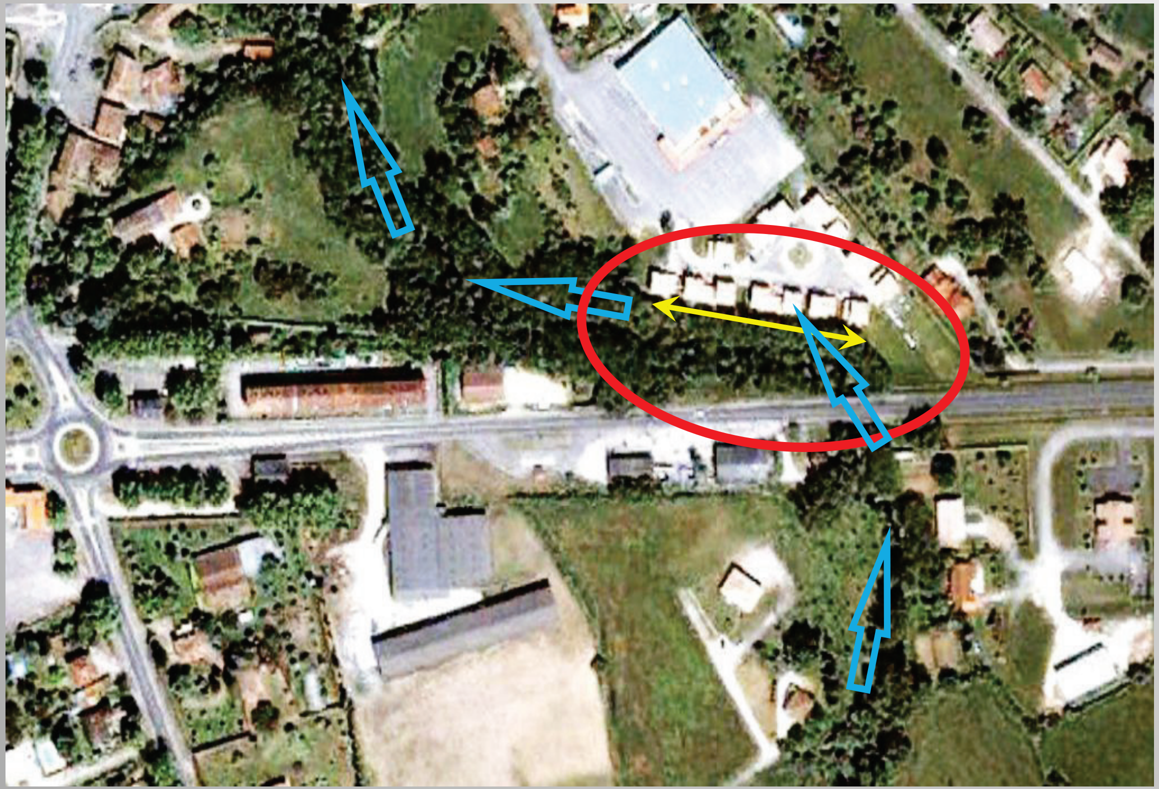


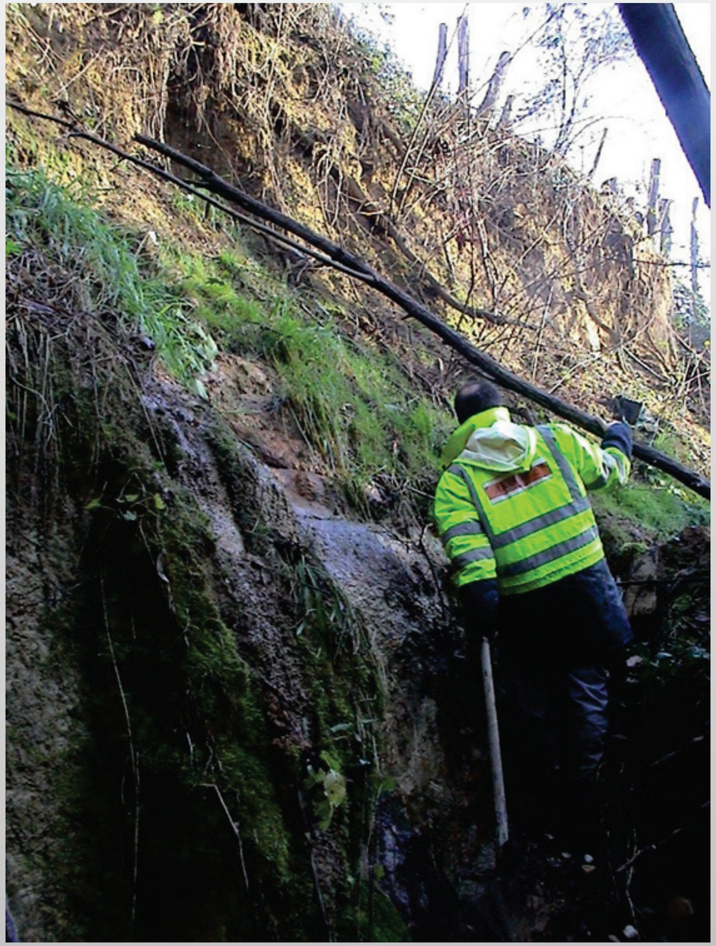
Image GoogeEarthPro

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Preliminary study stage

After clearing work we discovered broken sewers, huge building rubbish and a pretty nice groundwater horizon

As usual a subsoil geotechnical investigation ongoing to obtain soil properties in proximity of buildings



Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Construction stage

Catch and drainage of natural groundwater discharges by means of drainage packings

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Completion date: Pictures taken March 2012

Picture to upstream right riverbank

Same position but picture to downstream right riverbank

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Lifetime monitoring stage: Shrub stratum condition during a small 1.50m high flood one year after completion date in 2013

Image of shrub stratum captured on mai 2013

Vegetationsentwicklung im Mai 2013 während des ersten Hochwassers im 1ten Vegetationszyklus

Public spaces – Erosion protection of a city museum area

Case study 6) 2007: Hers Vif River – 1.000m² Steep cliff stabilisation and 50m Log Cribwall onto Gabions ensuring safety access to classified medieval buildings
Construction time 4 months – Pre-tax costs 290.000 € (249.400 ₤)

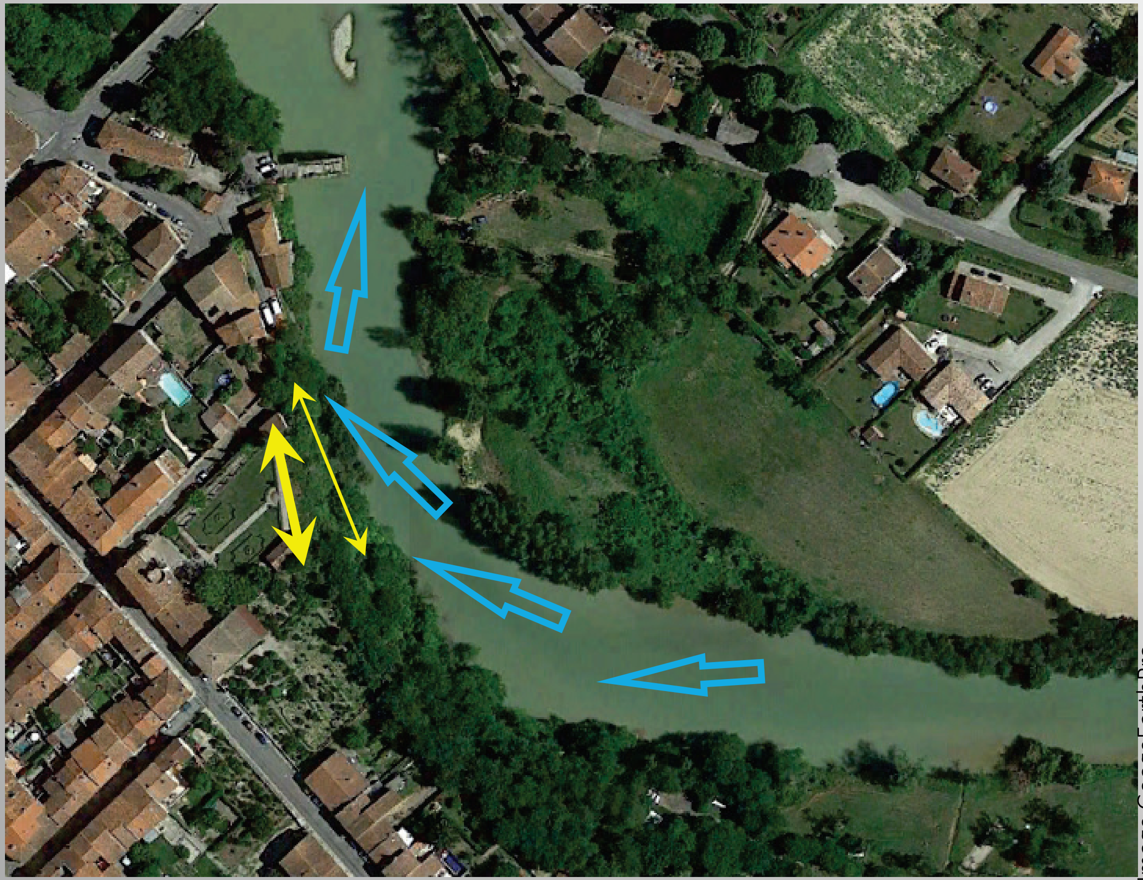


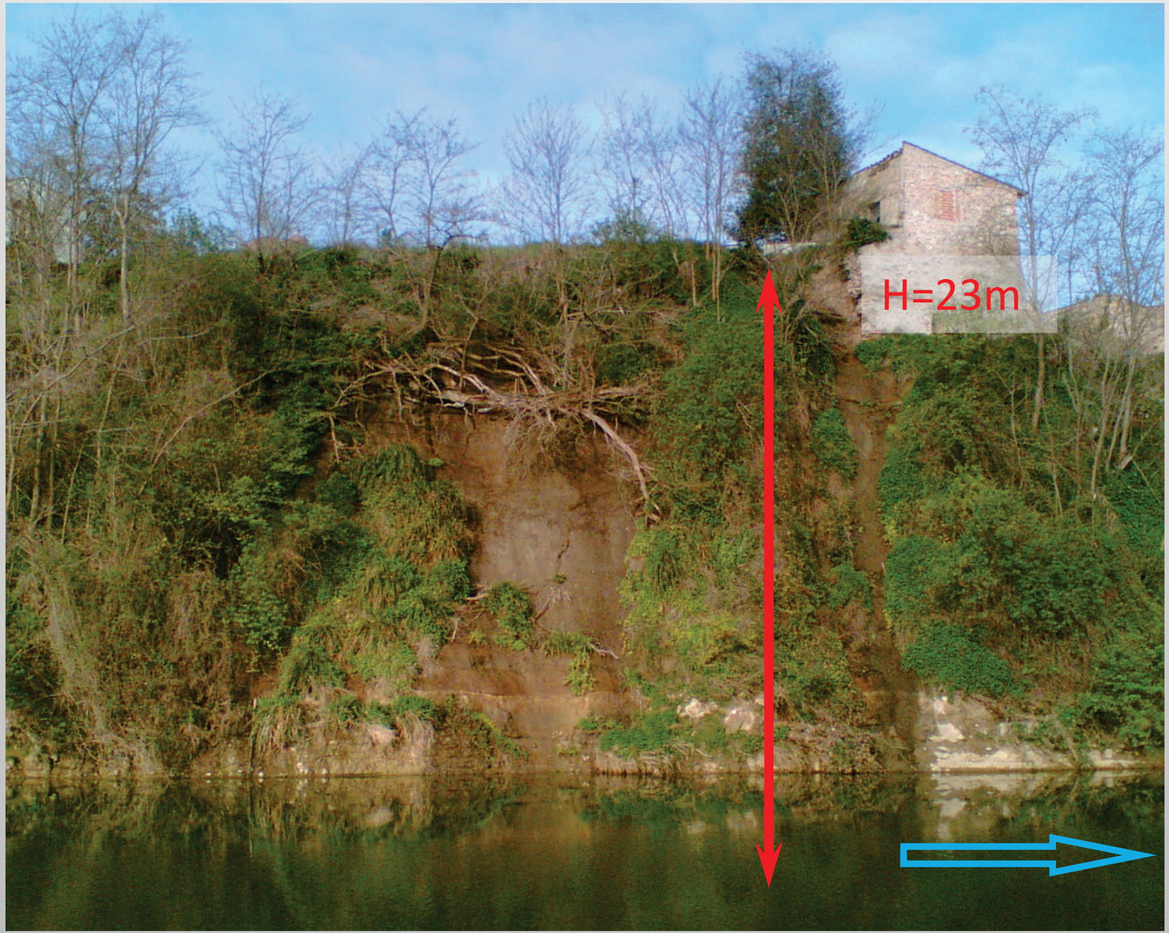
Image GoogeEarthPro

Damage case: Far advanced cliff erosion but less bank erosion problem; imminent risk of upper cliff edge collapse threatening public space
Preliminary studies: Historical, topographical and bathymetrical data levys, subaquatic river bed survey, hydrodynamical analyses…
Program mission: Project establishment, contract drafting and site monitoring in ordert to reduce erosion risk **Geometric shape:** Variable bed width 55/35/45m; protected bank height 23m by slope gradient roughly 60° and design flood Q_{50} ~ 600m³/s
Realised longitudinal works: Live Log Cribwall built onto submerged Gabion wall
Realised cliff works: Combined drilled concrete injection anchors on top bank and greenable 3D steel structure on cliff surface
Transversal works: Not required at this time

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Preliminary studies: State of health of the steep limestone cliffs in 2006:
several rockfalls areas are visible up to just before the public viewing platform

Public viewing platform position >>



Direction of flood discharge

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Pre-construction stage: Logging work in March/April 2007 to check the stability of the whole steep cliff

7m thick sand and gravel layer >>

<< At least 16m high limestone marl layer

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Construction stage

Anchors for tightly placing the 3D steel structure onto the purged steep slope, sizing in accordance to geotechnical survey results

Implementing 3D KRISMER steel structure panels

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Construction stage

Installing steel structure in progress from upstream to downstream

Filling the 3D steel structure with ballast and topsoil (protected with cellulose layer against rain erosion) by using a hydraulic crane

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Lifetime monitoring stage: Cliff condition one year later after completion date (picture taken in April 2008)

<<Growing vegetated log crib wall onto gabion wall

Case study 6) 2007: L’Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Lifetime monitoring stage: Cliff condition **5 years later after completion date**
(picture taken in June 2013)

Conclusion of carrying out ‘Soil and Water Bioengineering’ by applying both ‘Nature based Solutions’ and ‘mixed techniques’ since 1981

This presentation serves as a demonstration of the potential of sustainable geological steep bank revegetation to protect infrastructure and residential areas - All constructions are based on an integrated workflow process and accompanied by geotechnical analysis.

Remediation measures applying nature based solutions to severe bank slides in the immediate vicinity of residential areas and infrastructure facilities are feasible.

The release prerequisites are: Application of the integrated engineering approach (with back-checking of preliminary design stage ☺!) as a working method, well-thought-out damage cause analysis and the good training and experience of the construction companies commissioned during the construction.stage.

This will obtain a reliable and sustainable integration of your nature based “Soil and Water Bioengineering Constructions” into the existing river ecosystem on your construction site.

Thank you for your interest and attention
Dankeschön für Ihr Interesse und Aufmerksamkeit
Merci de votre intérêt et de votre attention
Děkujeme vám za váš zájem a pozornost
Gracias por su interés y atención
Obrigado pelo seu interesse e atenção
Takk for din interesse og oppmerksomhet
Kiitos kiinnostuksestanne ja huomiostanne

☺ I WISH YOU MUCH JOY IN CREATING SOIL AND WATER BIOENGINEERING CONSTRUCTIONS ! ☺

Poster from Klaus Peklo Dipl.-Ing., graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -

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