PRIORITIZATION CRITERIA FOR DEBRIS FLOW ENGINEERING WORKS TO PROTECT PIPELINES IN THE BRAZILIAN SERRA DO MAR REGION, SÃO PAULO

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Petrobras Transporte S.A. - TRANSPETRO

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Con el apoyo de: arpel

Organiza: C-IPG Comité Técnico IPG + ACIEM Asociación Colombiana de Ingenieros

BR TRANSPETRO

Transpetro

Pipeline operations in Brazil

Who are we?

Petrobras Transporte S.A. – Transpetro is an important company for the fuel transportation and logistics sector in Brazil. Our purpose is to provide the energy that allows people and companies to achieve their potential. We operate, through the exclusive technical capacity of our workforce, in the logistics segment for oil, by-products, biofuels and natural gas.


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AMAZONAS
PARÁ
MARANHÃO
CEARÁ
RIO GRANDE DO NORTE
PARAÍBA
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PERNAMBUCO
ALAGOAS
SERGIPE
ACRE
RONDÔNIA
TOCANTINS
BAHIA
MATO GROSSO
BRASÍLIA
GOIÁS
MINAS GERAIS
MATO GROSSO DO SUL
ESPÍRITO SANTO
SÃO PAULO
RIO DE JANEIRO
PARANÁ
SANTA CATARINA
RIO GRANDE DO SUL
Detalhe NORDESTE (BAHIA)
BAHIA
Detalhe SUDESTE (RJ)
RIO DE JANEIRO
Detalhe SUDESTE
SÃO PAULO
PARANÁ
Detalhe SUL
PARANÁ
SANTA CATARINA
TRANSPORTE MARÍTIMO
TERMINAL GNL
OLEODUTO FUTURO
OLEODUTO EXISTENTE
GASODUTO EXISTENTE
GASODUTO FUTURO
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TERMINAL
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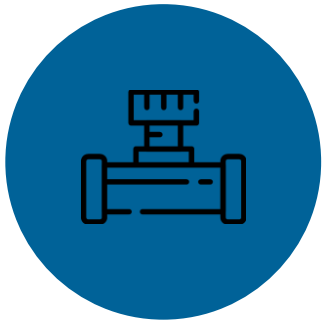
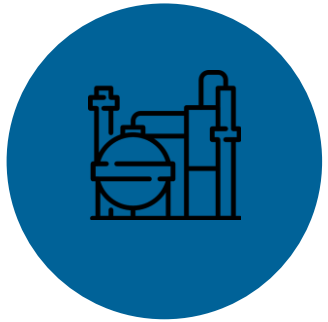
PLATAFORMA



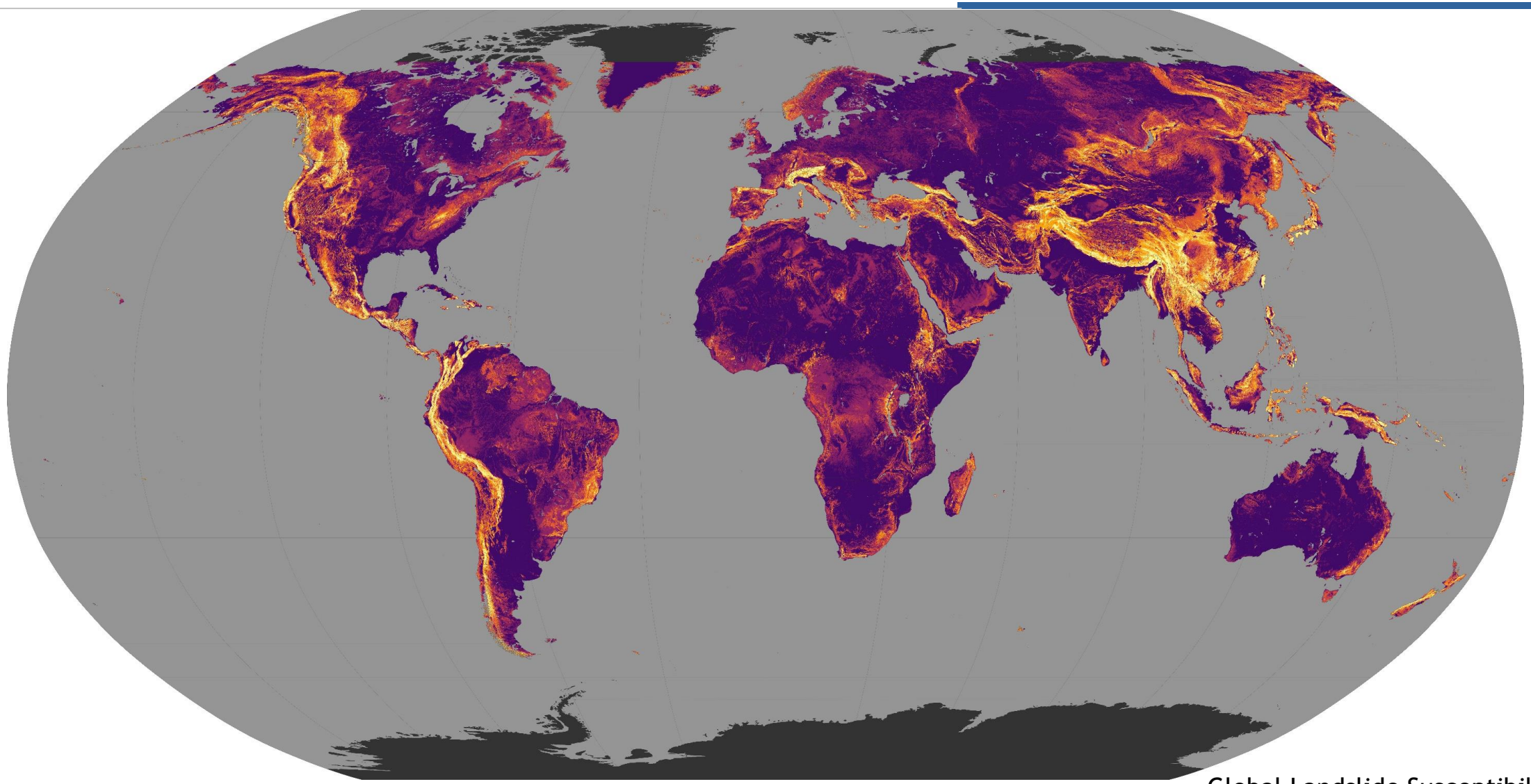
More than 12 thousand km of pipelines
10 million m³ of oil capacity

21 Land terminals
28 Marine terminals
540 tanks

5326 employees



50 ships (34 currently in operation)



Global Landslide Susceptibility Map, 2000-2013
Nasa, Earth Observatory (2017)

Serra do Mar (Sea Ridge):

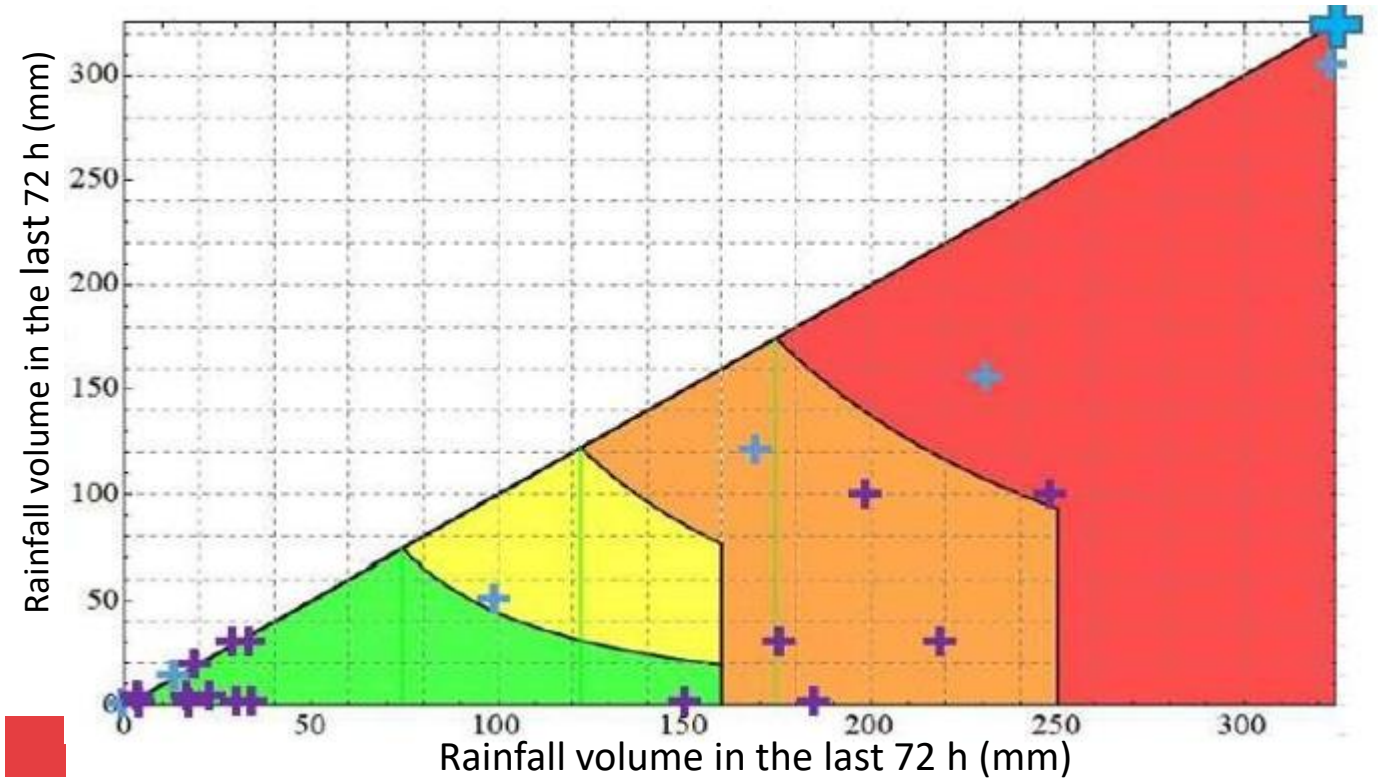
- Extension of 1,500 km;
- Rain volumes between 2000 mm to 2500 mm annually;
- Slopes with declivity between 35° to 40°;
- Other common mass movements: Debris flows, erosions, slumps, etc;
- Usually shallow landslides, with 1,5 m to 2,0 m depth.

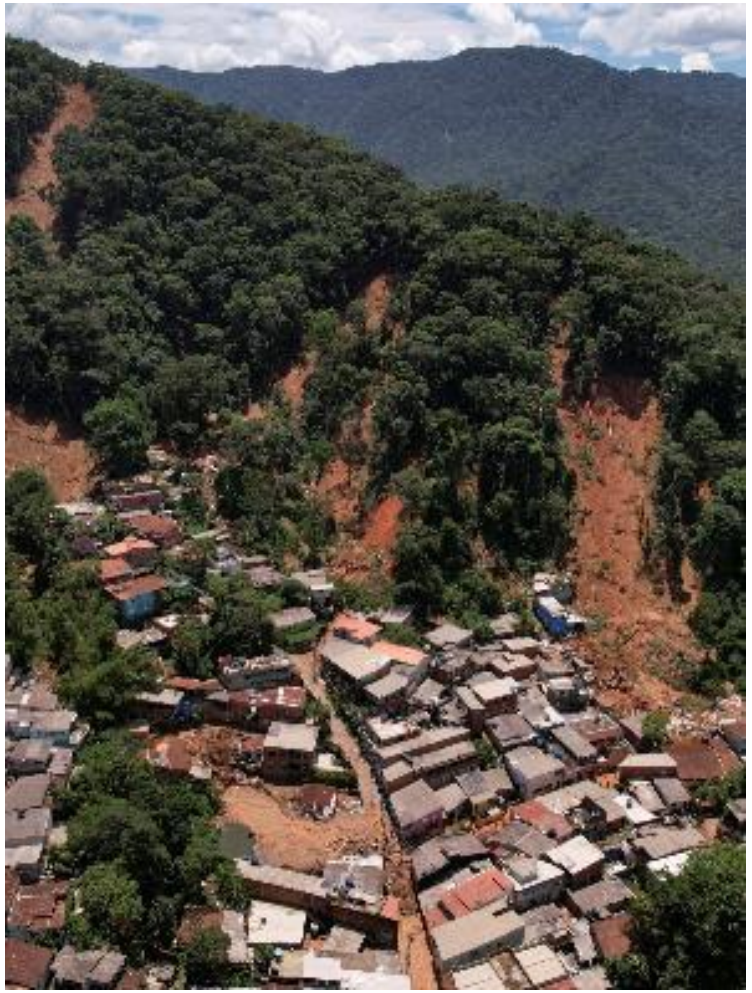
São Paulo rights of way

RISK MANAGEMENT

Rainfall event of February, 2023

- Highest rainfall volume ever registered in the shortest time in Brazil: 684 mm in 11 h





Rainfall event of February, 2023

Schedule

Critical points were identified during aerial surveys and categorized into High Risk (8 points, with 5 points classified as operationally prohibitive for OSBAT) and Moderate Risk (12 points) for the start of intervention. The construction work was divided into phases:

Phase 1

Immediate action works at high-risk points (5 points with high impediments) in the affected areas to restore OSBAT's operational capability, which remained suspended from February 19, 2023, to March 11, 2023.

Low I	22
Low II	12
Moderate III	7
Moderate IV	3
High V	8
High VI	0
TOTAL	52

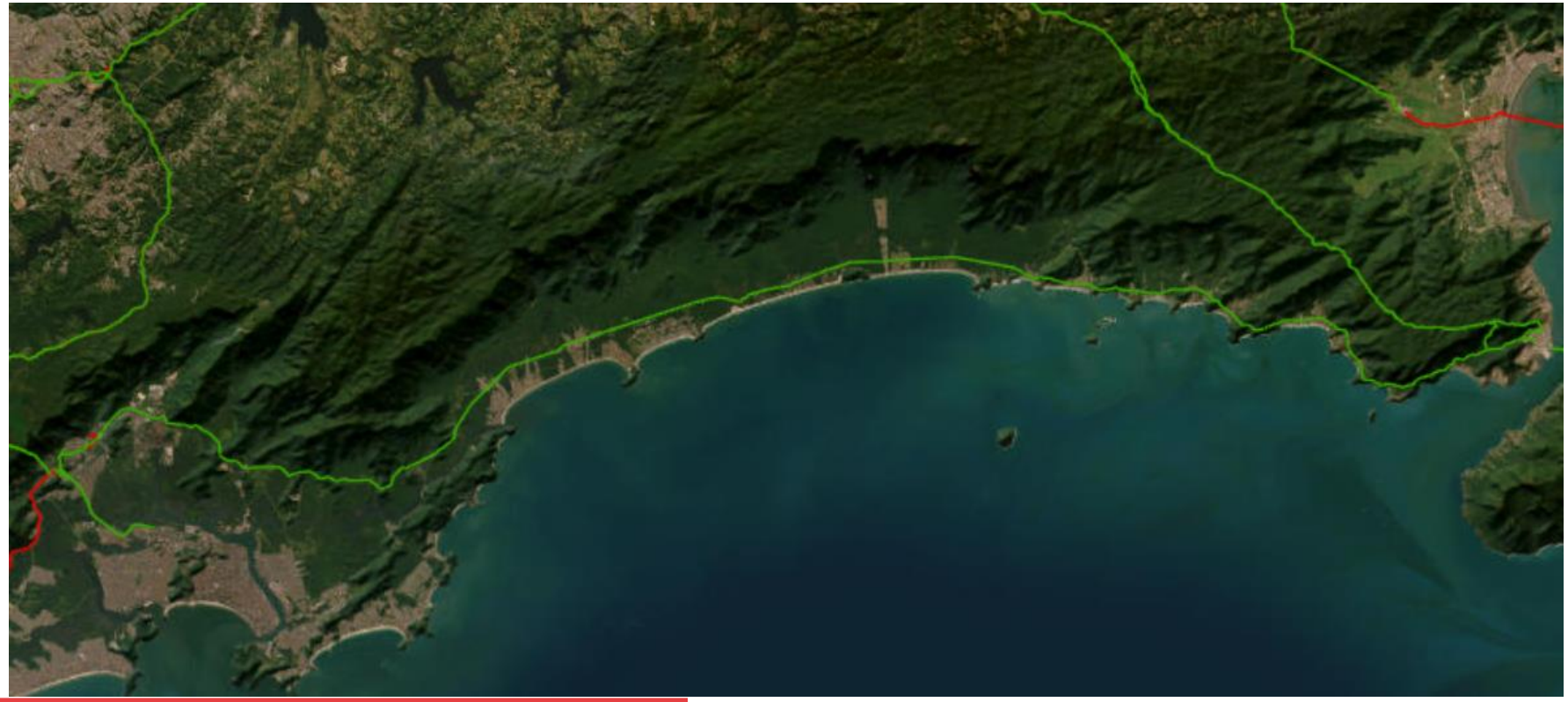
OSBAT km 11+050

OSBAT km 11+050

OSBAT km 11+050

Debris flow protection works priorization study

Hydrological catchments discretization → Susceptibility ranking through a qualitative method → 8 hydrological catchments were select for further studies



Debris flow protection works priorization study

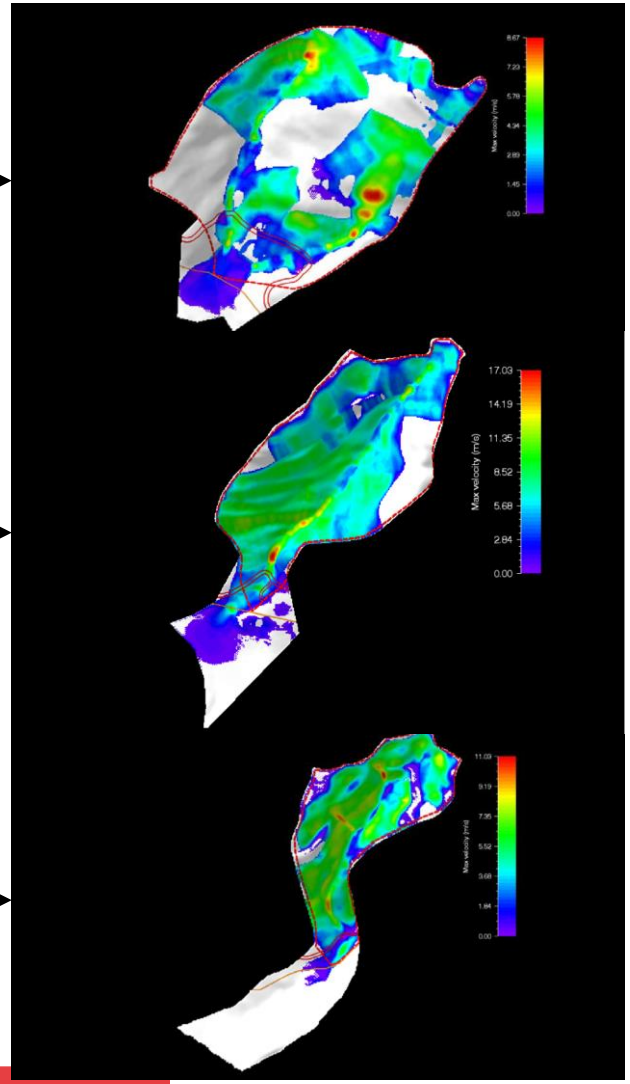
$$FS = \sum PS_i . w_i$$

Catchment	score	Rank
1	1.90	5
2	1;60	6
3	1.00	8
4	1.41	7
5	2.24	4
6	3.86	3
7	4.31	1
8	4.19	2

PARAMETER	CLASS	WEIGHT	PARAMATER VALUE	PARTIAL SCORE
RAINFALL (mm/h)	R1	3,0	>80	10
	R2		60 - 80	6,6
	R3		30 - 60	3,3
	R4		<30	0
SLOPE ANGLE (DEGREES)	S1	2,5	>45	10
	S2		45 - 30	6,6
	S3		15 - 30	3,3
	S4		<15	0
STREAM DECLIVITY (DEGREES)	D1	0,5	>25	10
	D2		15 - 25	6,6
	D3		10 - 15	3,3
	D4		<10	0
WATERSHED AREA (km²)	A1	1,0	<5	10
	A2		5 - 10	6,6
	A3		10 - 20	3,3
	A4		>20	0
WATERSHED HEIGHT (m)	H1	1,0	>750	10
	H2		500 - 750	6,6
	H3		200 - 500	3,3
	H4		<200	0
LAND USAGE AND OCCUPATION (%)	V1	0,5	90 - 100	10
	V2		50 - 90	6,6
	V3		30 - 50	3,3
	V4		<30	0
GEOMORPHOLOGY	G1	1,5	G1	10
	G2		G2	6,6
	G3		G3	3,3
	G4		G4	0

Refinement of the studies in catchments 6, 7 and 8

Catchments
6 (km 12+280)
7 (km 11+050)
8 (km 9+600)



RAMMS

Discharge Hydrograph Method Rainfall return periods: 25, 50, 100 and 200 Years

Erosion process speed: 0.025 m/s

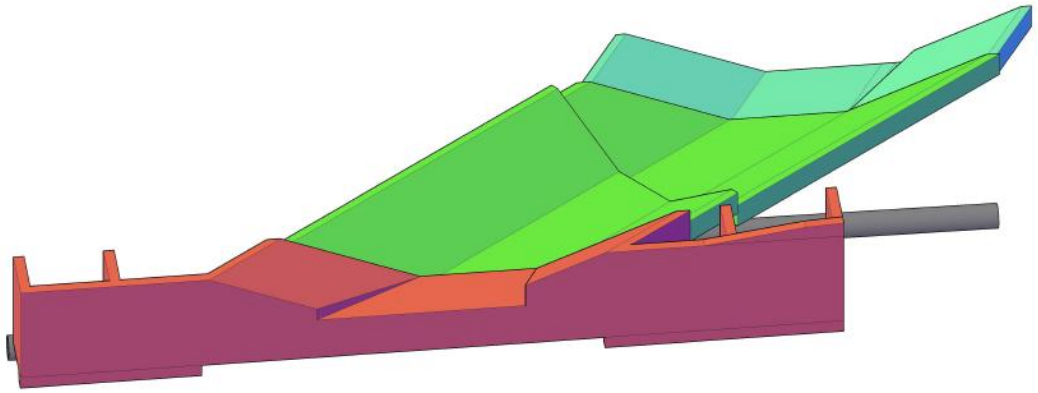
Friction parameters: $\mu = 0.2$, $\xi = 120$ m/s².

For the simulation of debris flow, the Area Release Method was also used. landslides with 4 thicknesses (0.10, 0.50, 1.00, and 1.50 m)

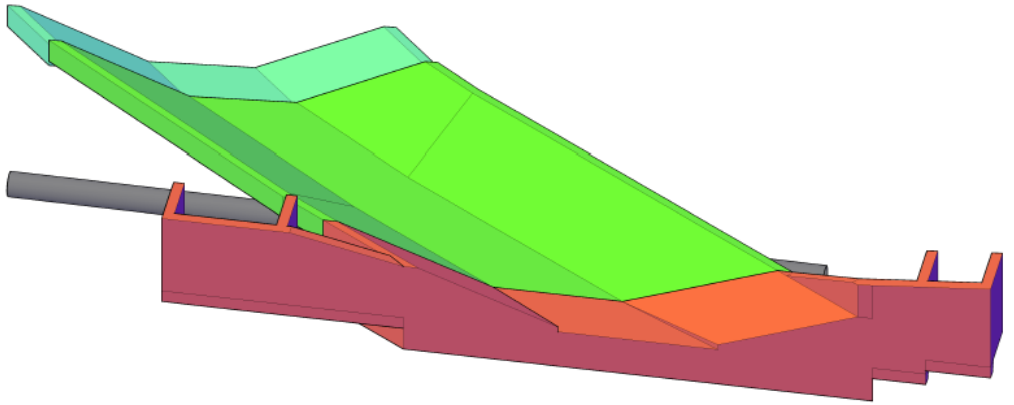
Refinement of the studies in catchments 6, 7 and 8

Debris volume exceeds the available reservoir área in catchments 6 and 7 → **Engineering solution: concrete channel with na underlying buried beam wall**

Catchment 6



Catchment 7



Refinement of the studies in catchments 6, 7 and 8

Debris volume exceeds the available reservoir área in catchments 6 and 7

→

Engineering solution: concrete channel with na underlying buried beam wall

Catchment 6

Catchment 7

Conclusions

- The preventive works avoided a certain pipeline failure;
- the choice of the selected return period (TR), as opting for higher TR values could potentially lead to deeper excavation profiles;
- Another limitation lies in the assumptions made during the calculations and the accuracy of input parameters within the software;
- New studies are being performed over the possibility of new debris flow occurrences, using refined input data and widening the study scope over new regions.