United Nations
Educational, Scientific and
Cultural Organization

UNESCO Chair on the Prevention and
Sustainable Management of Geo-Hydrological Hazards,
University of Florence, Italy

Rilevamento frane e misure correttive a basso impatto ambientale

Nicola Casagli

PRESIDENCY OF THE COUNCIL OF MINISTERS

Delegate Commissioner for the Montaguto landslide

Consiglio Nazionale delle Ricerche
ISTITUTO DI RICERCA PER
LA PROTEZIONE IDROGEOLOGICA

F. Guzzetti
G. Lollino

UNIVERSITÀ
DEGLI STUDI
FIRENZE

N. Casagli

Università degli Studi
del Sannio

F.M. Guadagno

P. Barsotti
L. Gianmattei

C. Rivolta
D. Leva

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

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ISTITUTO DI RICERCA PER LA PROTEZIONE IDROGEOLOGICA

F. Guzzetti
G. Lollino
D. Giordan
P. Allasia
M. Baldo
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F. Barsotti
S. Nadotti
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A. Devitis
G. Bravi

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C. Rivolta
D. Leva
I. Binda Rossetti

Montaguto

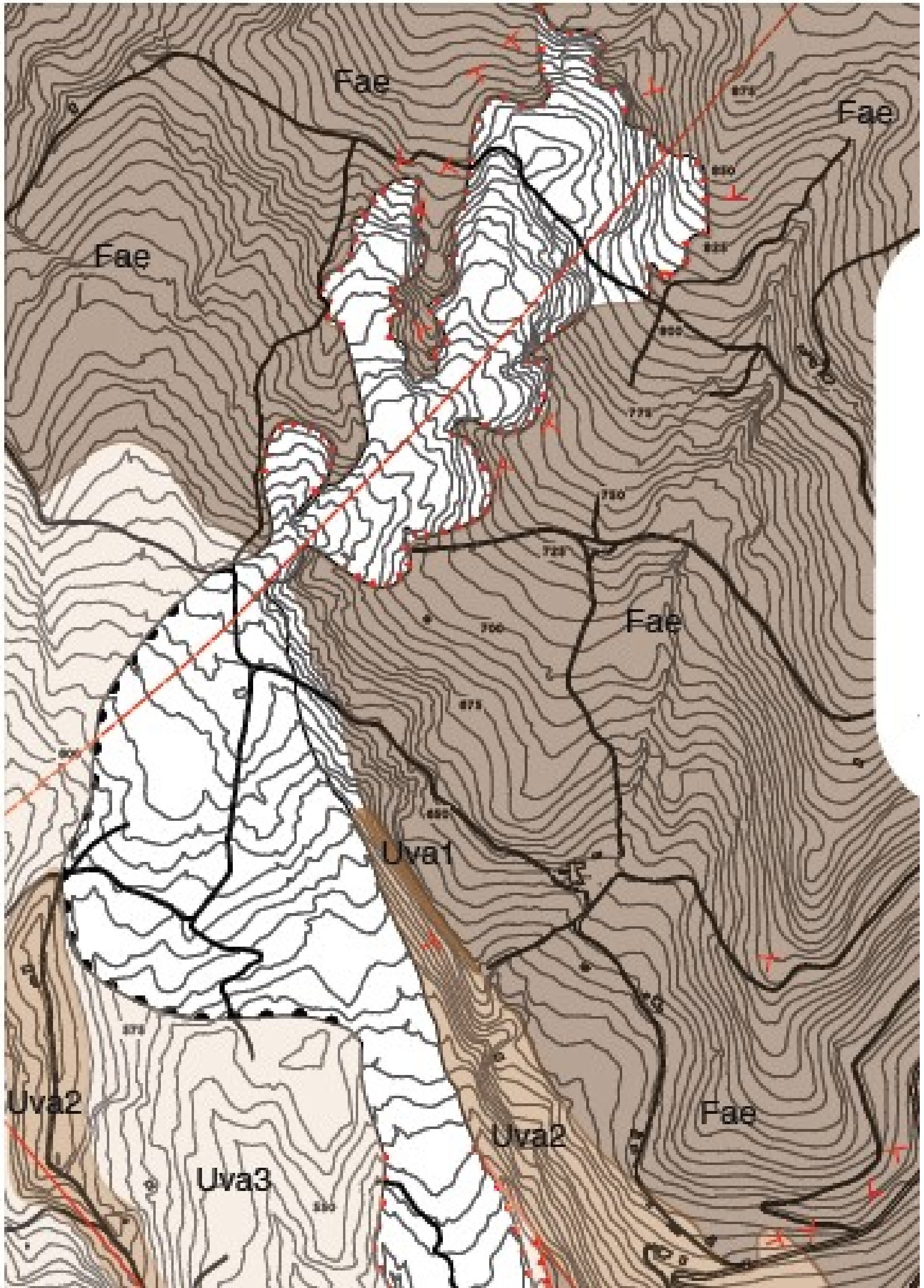
Montaguto landslide

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

- Roma-Napoli National railway
- National Road SS 90 “Delle Puglie”


Montaguto, May 2010

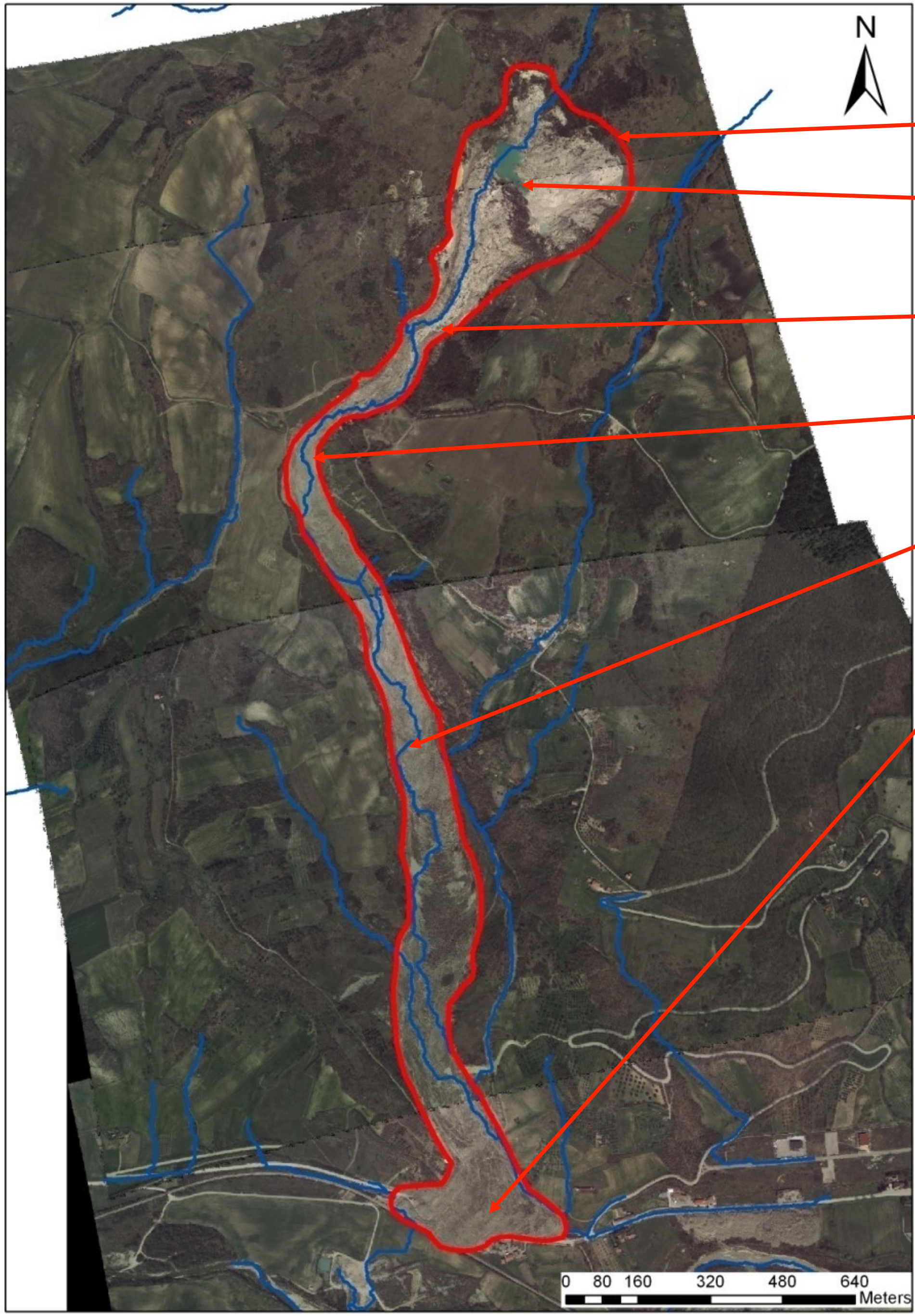
Geological setting



- Faeto Flysch (early Miocene)
- Toppo di Capuana clay loam (early Miocene)
- Altavilla Unit (late Miocene)
- Cervaro Creeck alluvial deposits (Pleistocene – Holocene)

Guadagno et al. (2010)

The landslide



- **Main headscarp**
- **Counterslope** landslide lakes
- **Upper track**
- **"Elbow"**
- **Main track**
- **Lower deposit** expanded in the valley floor, affecting National road and railway

- **Landslide volume:** 6 million m^3
- **Area:** 4.8 10^5 m^2
- **Peak velocity:** >3 m/day
- **Total length:** 3 km
- **Travel angle:** 8.4°

Before


© 2010 Cnes/Spot Image
Image © 2010 GeoEye
© 2010 Tele Atlas
©2009 Google
Imagery Date: Oct 30, 2002
41° 14.280' N 15° 13.362' E elev 425 m
Eye alt 700 m

After

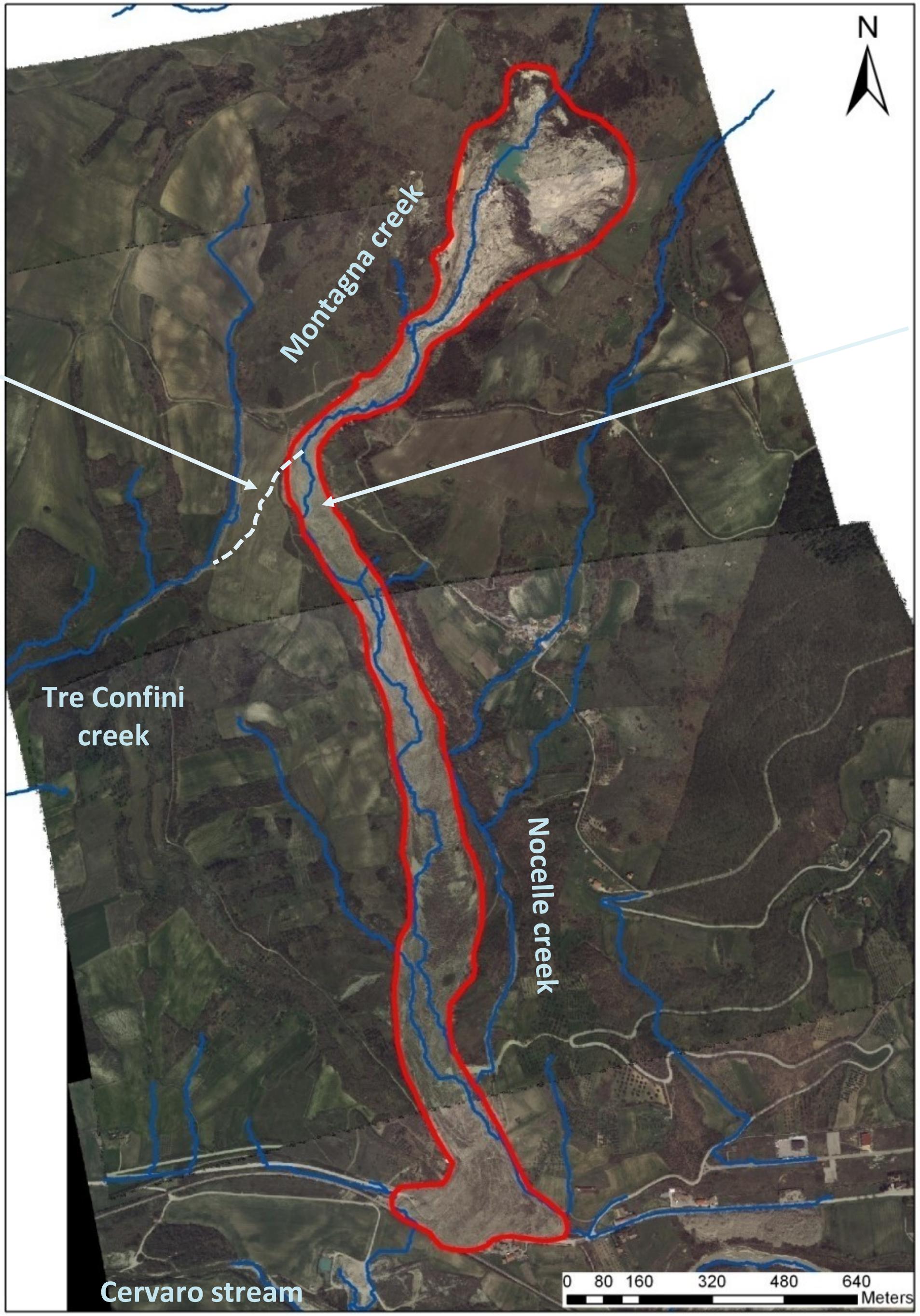

© 2010 Cnes/Spot Image
Image © 2010 GeoEye
© 2010 Tele Atlas
©2009 Google
Imagery Date: Oct 30, 2002
41° 14.280' N 15° 13.362' E elev 425 m
Eye alt 700 m

Timeline

- 1763: royal road involved, Borboni realized the first stabilization works
- 1957-58: reactivations
- Until 1980: very low activity
- 1990: deviation of Montagna creek
- 2003 – 2004: minor landslide reactivations
- May 12th 2006: major landslide reactivation and DPC ordinance
- September 2009: major landslide reactivation, the landslide reaches the road SS 90 "Delle Puglie"
- March 10th 2010: the reactivated flow destroy the road and the railway

1990 Montagna creek deviation

natural original channel



deviated channel

1955 drainage network

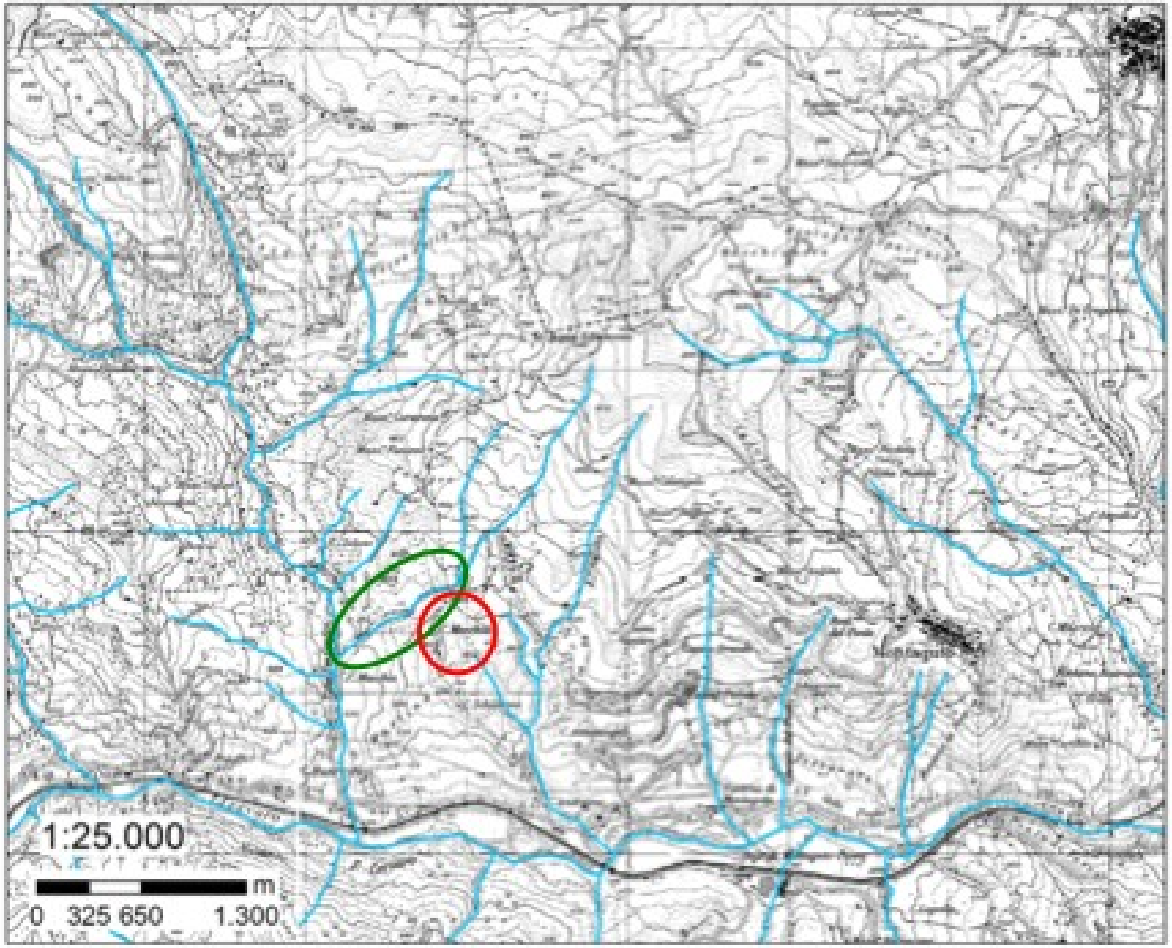
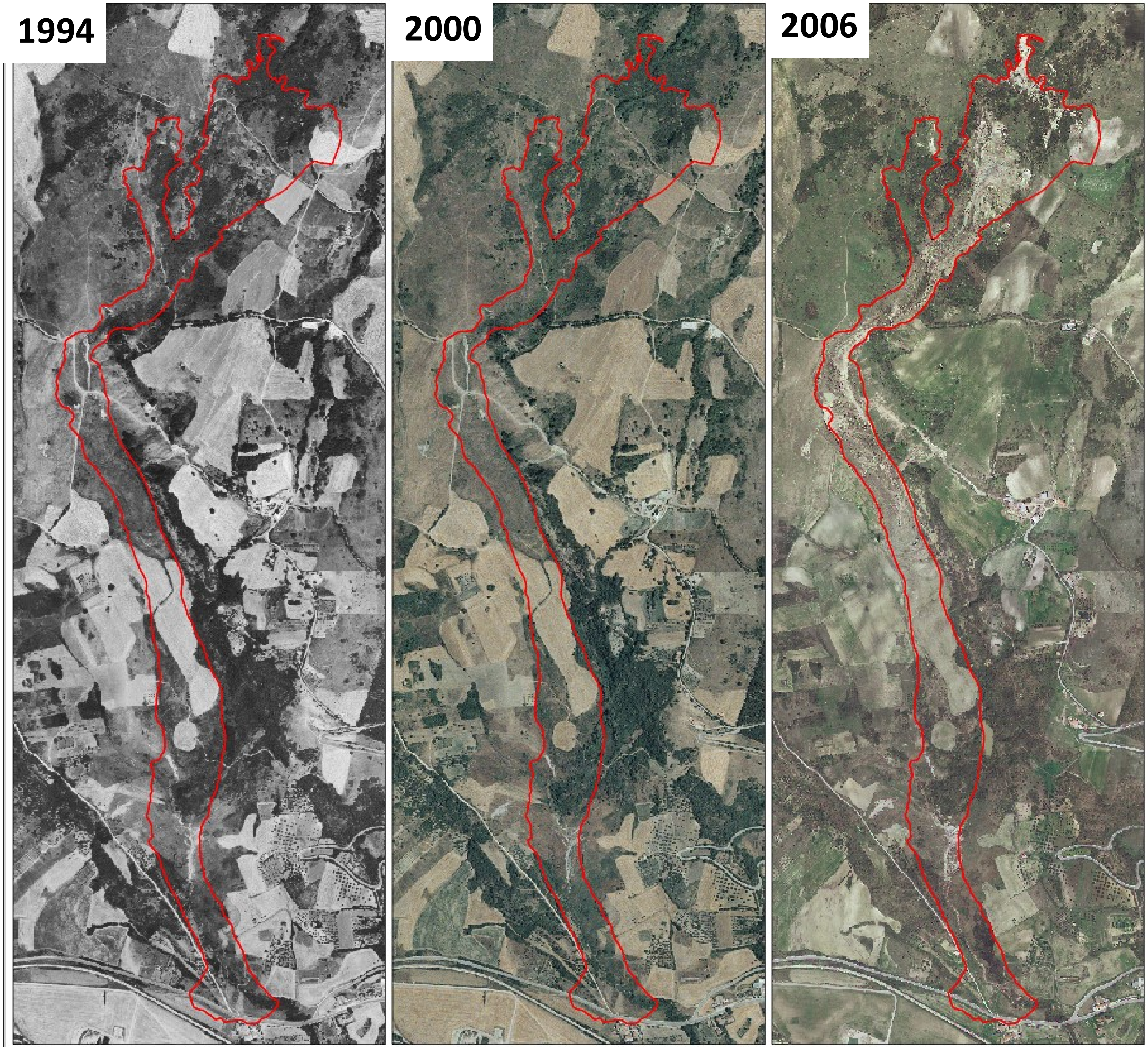
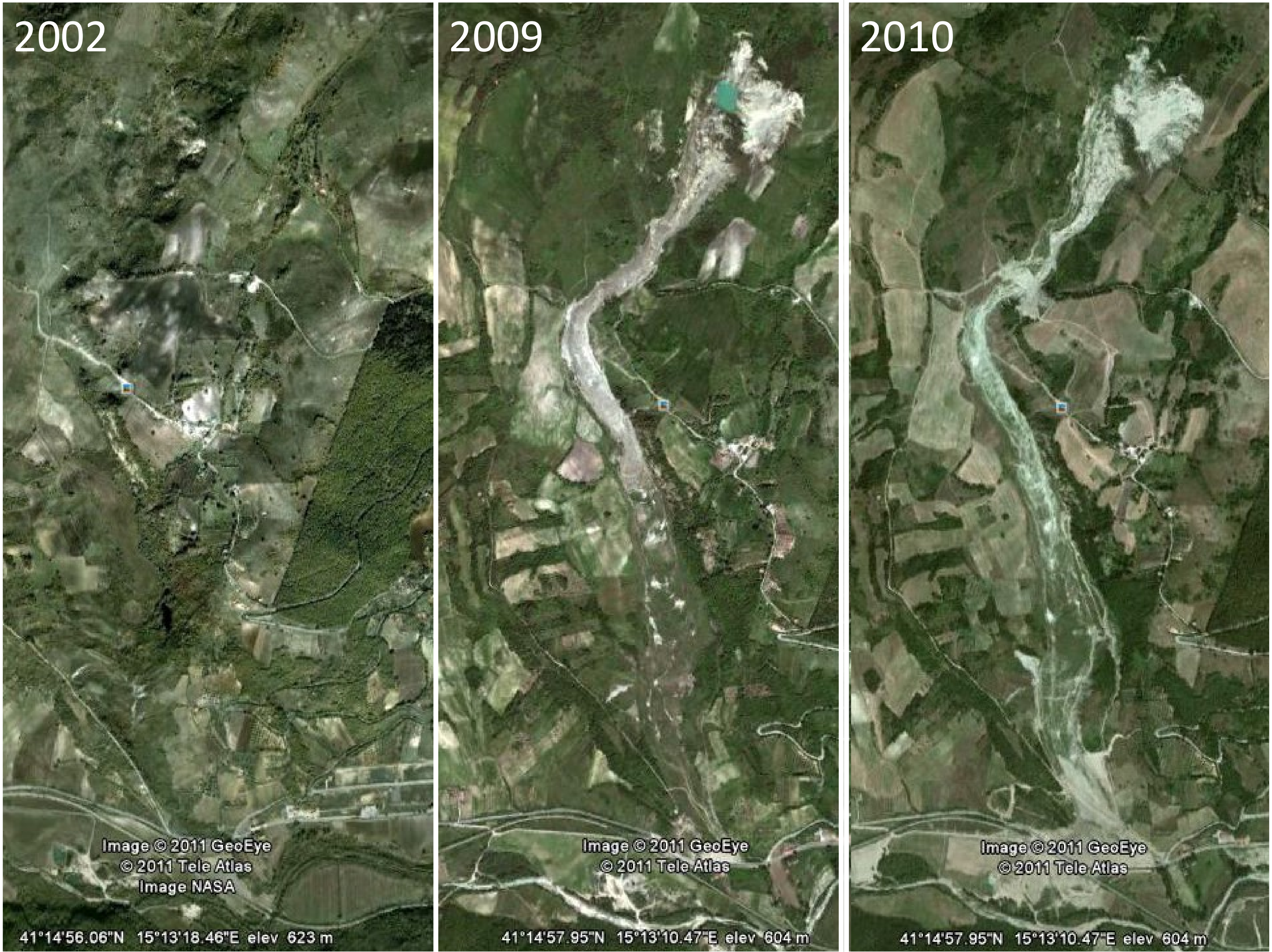


Figura 4.5 Stralcio delle Tavolette in scala 1:25.000 della Carta topografica IGM (F°174 Ariano Irpino), edizione 1955, con la segnalazione della rete idrografica evidenziata.

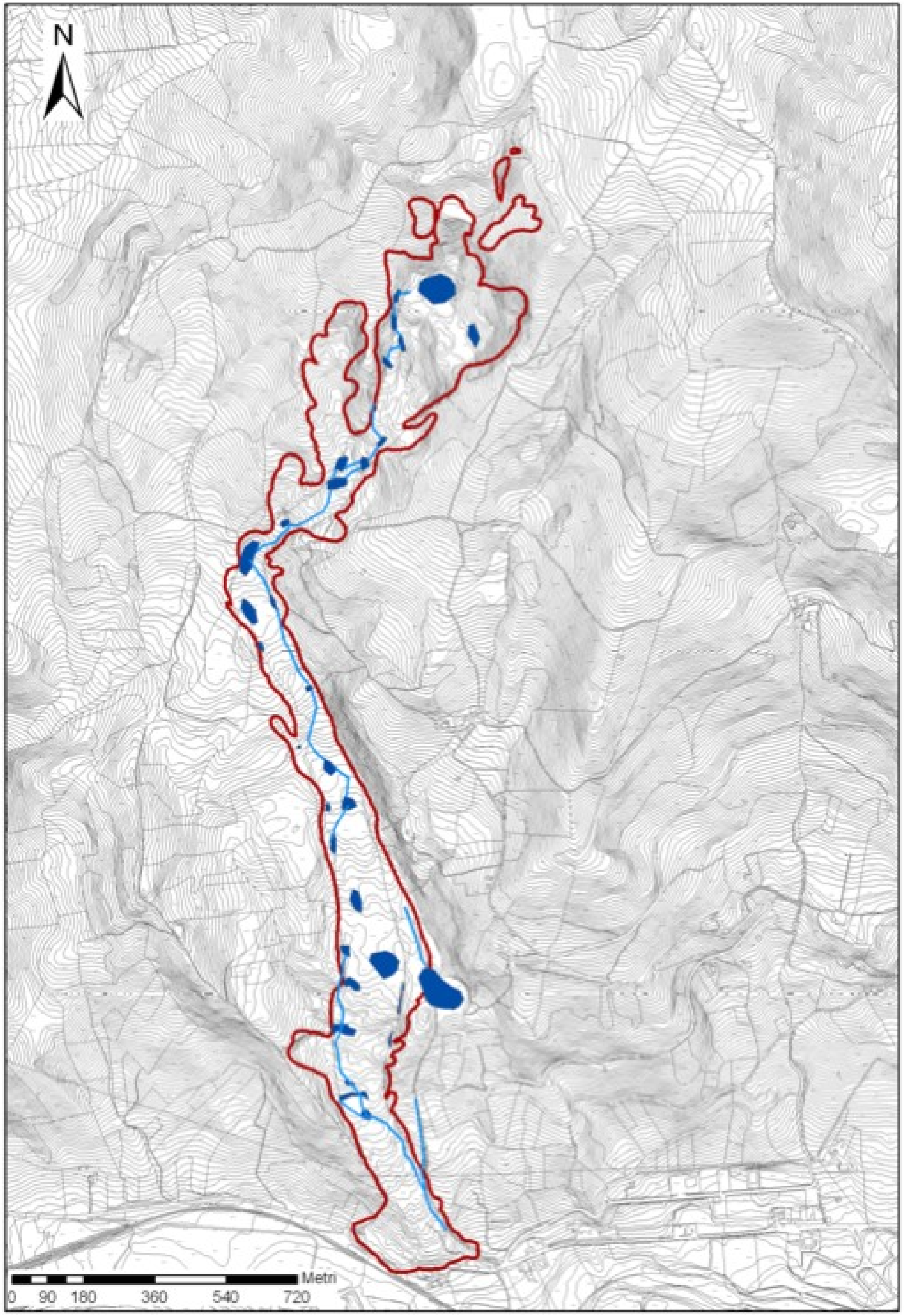

1994
2000
2006


2010


2002
Image © 2011 GeoEye
© 2011 Tele Atlas
Image NASA
41°14'56.06"N 15°13'18.46"E elev 623 m
2009
Image © 2011 GeoEye
© 2011 Tele Atlas
41°14'57.95"N 15°13'10.47"E elev 604 m
2010
Image © 2011 GeoEye
© 2011 Tele Atlas
41°14'57.95"N 15°13'10.47"E elev 604 m

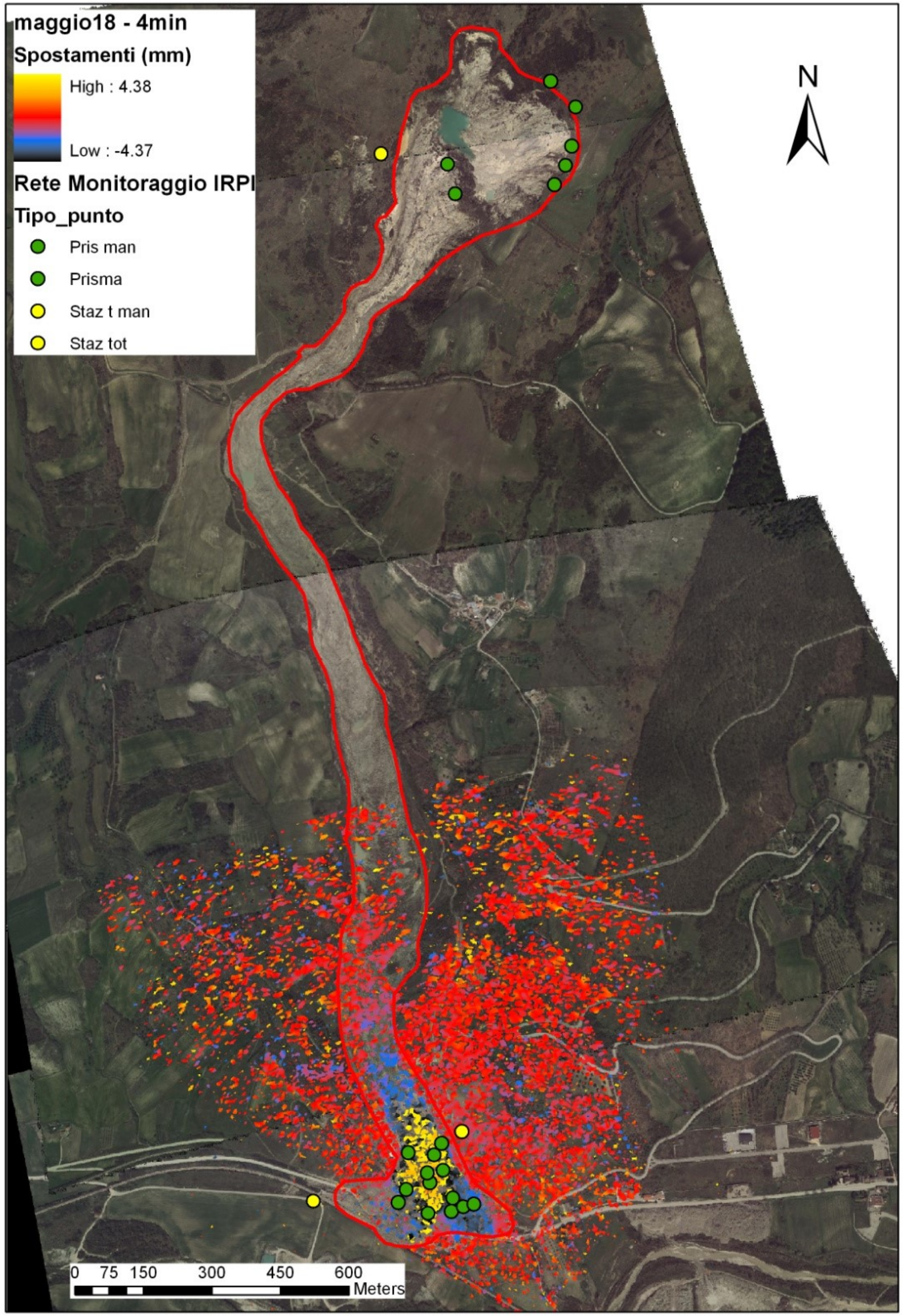
Landslide lakes

Cascini et al. (2009)



Monitoring activity
Installation 29th April 2010

GB-InSAR, LIDAR, thermal and optical imaging



Integrated monitoring system

DTM 2006

Consiglio Nazionale delle Ricerche
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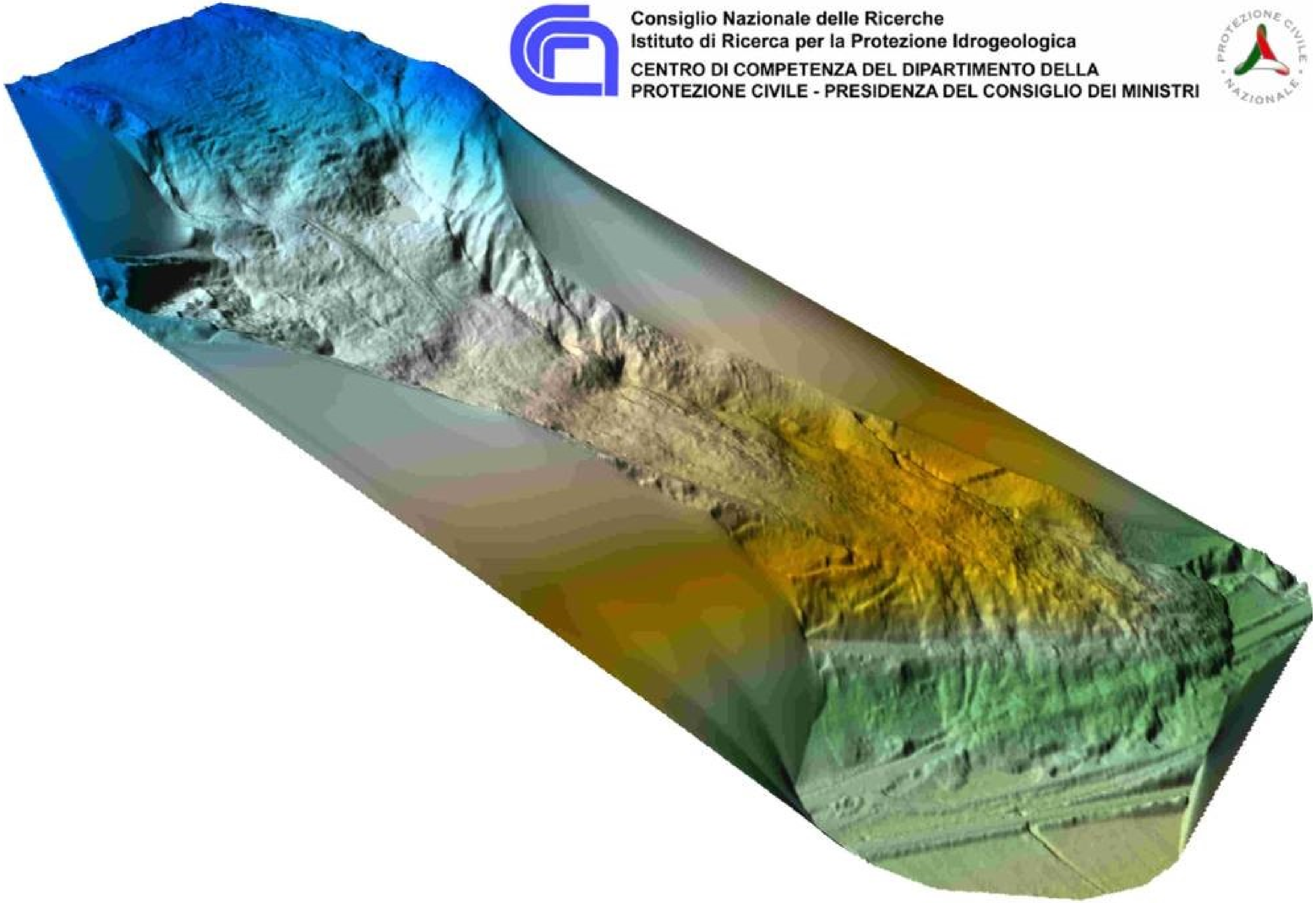
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI



DTM 2009

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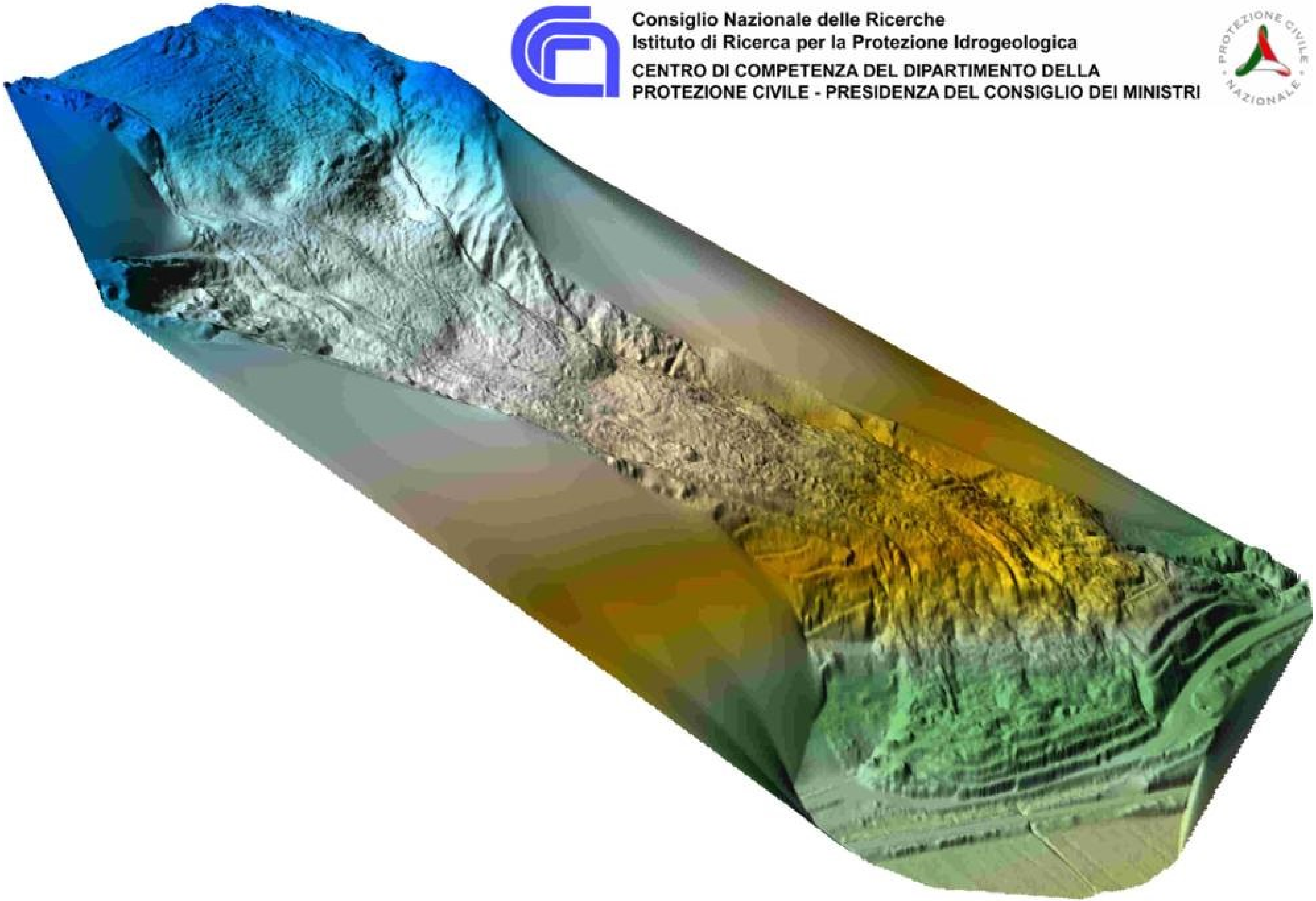
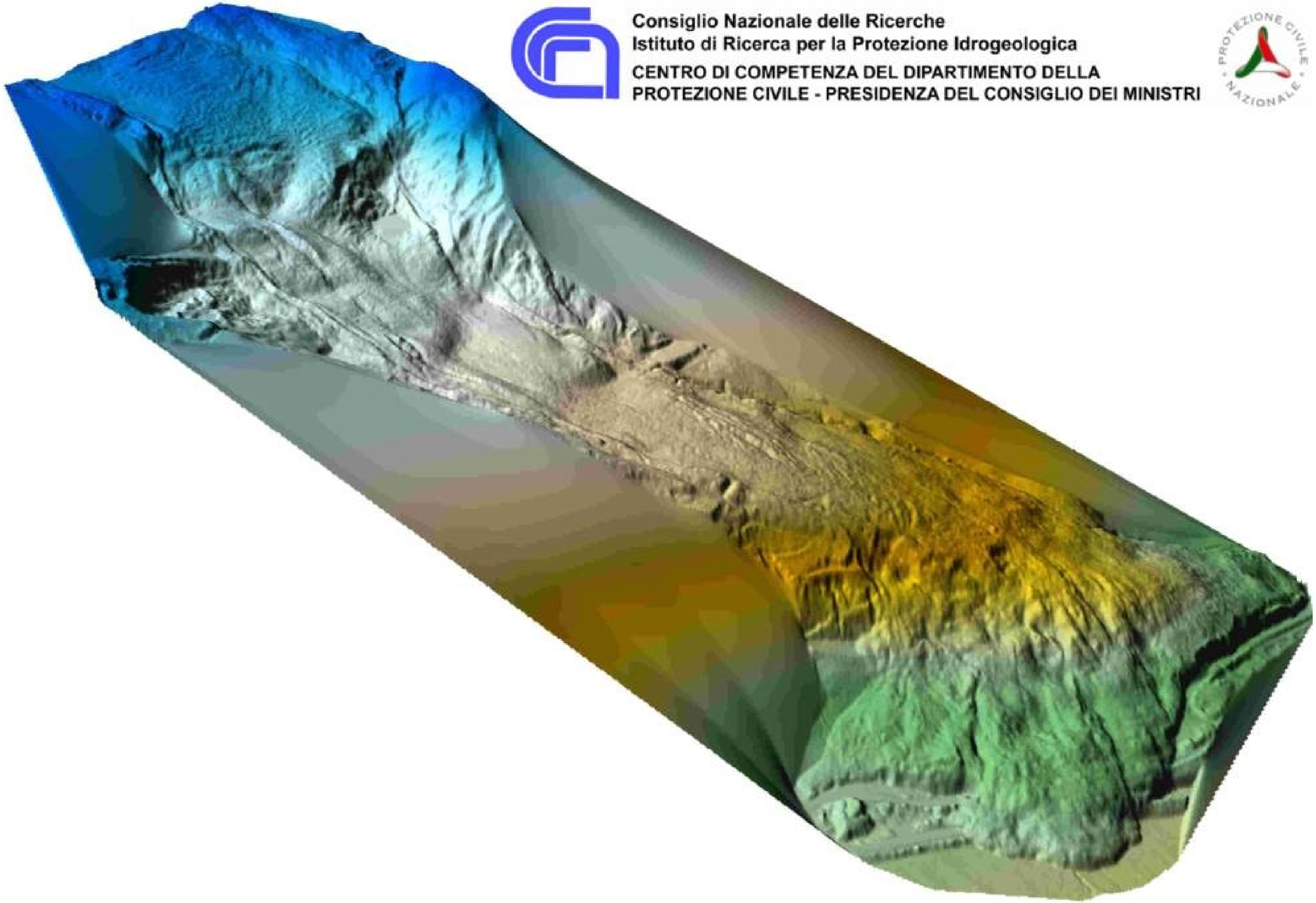
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI



DTM 2010



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DTM 2006

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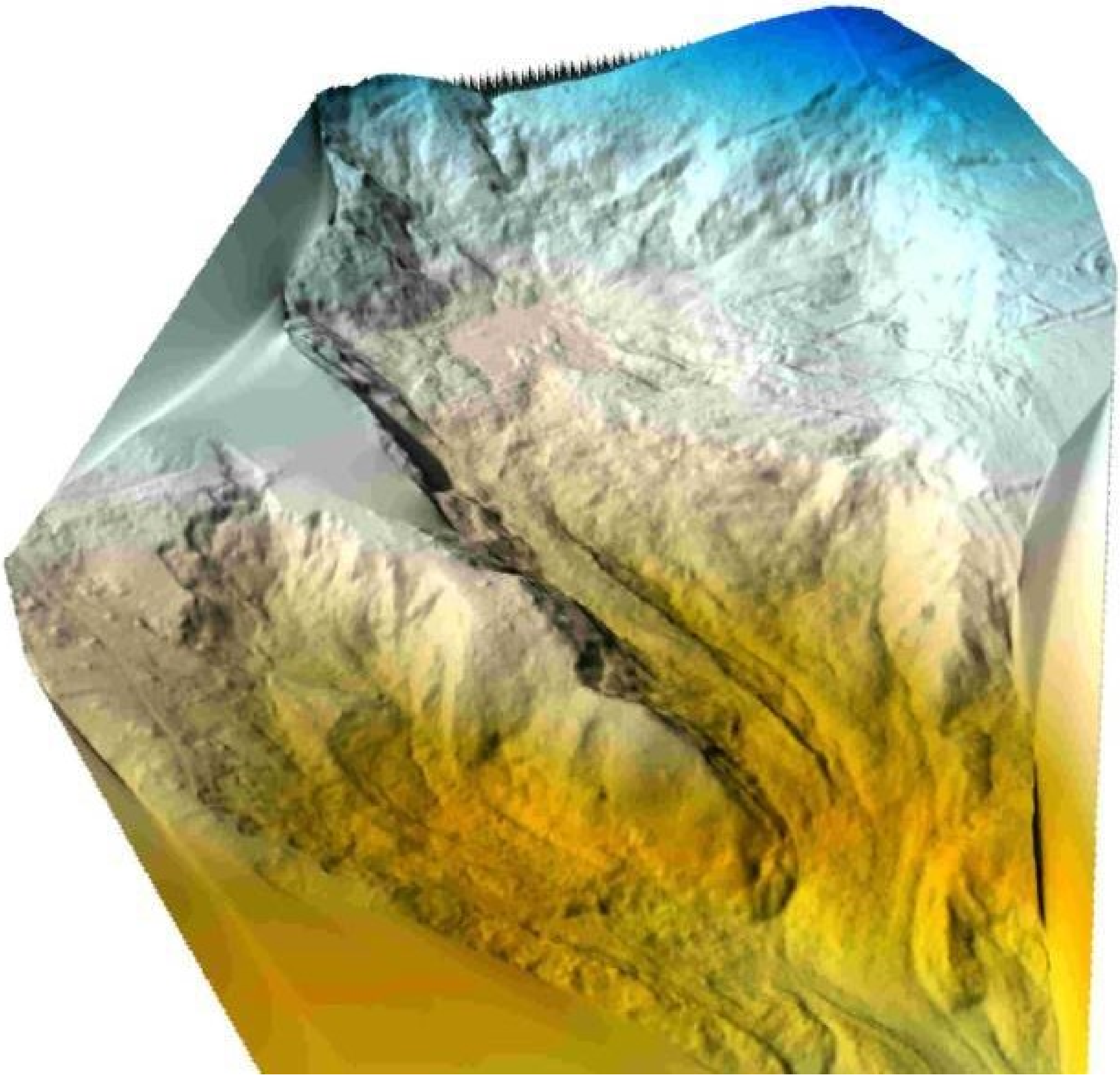
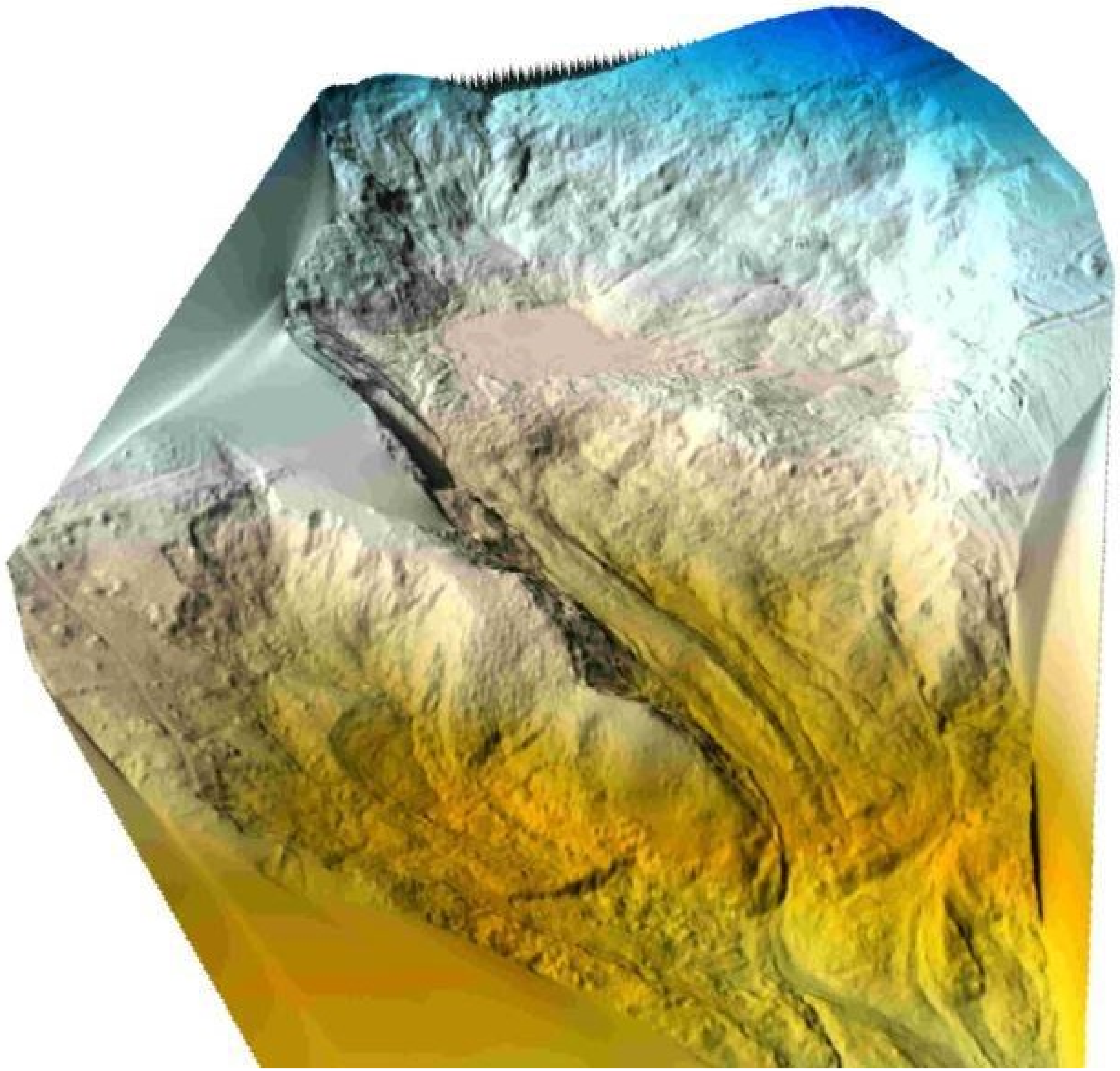
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI

PROTEZIONE CIVILE NAZIONALE



DTM 2009

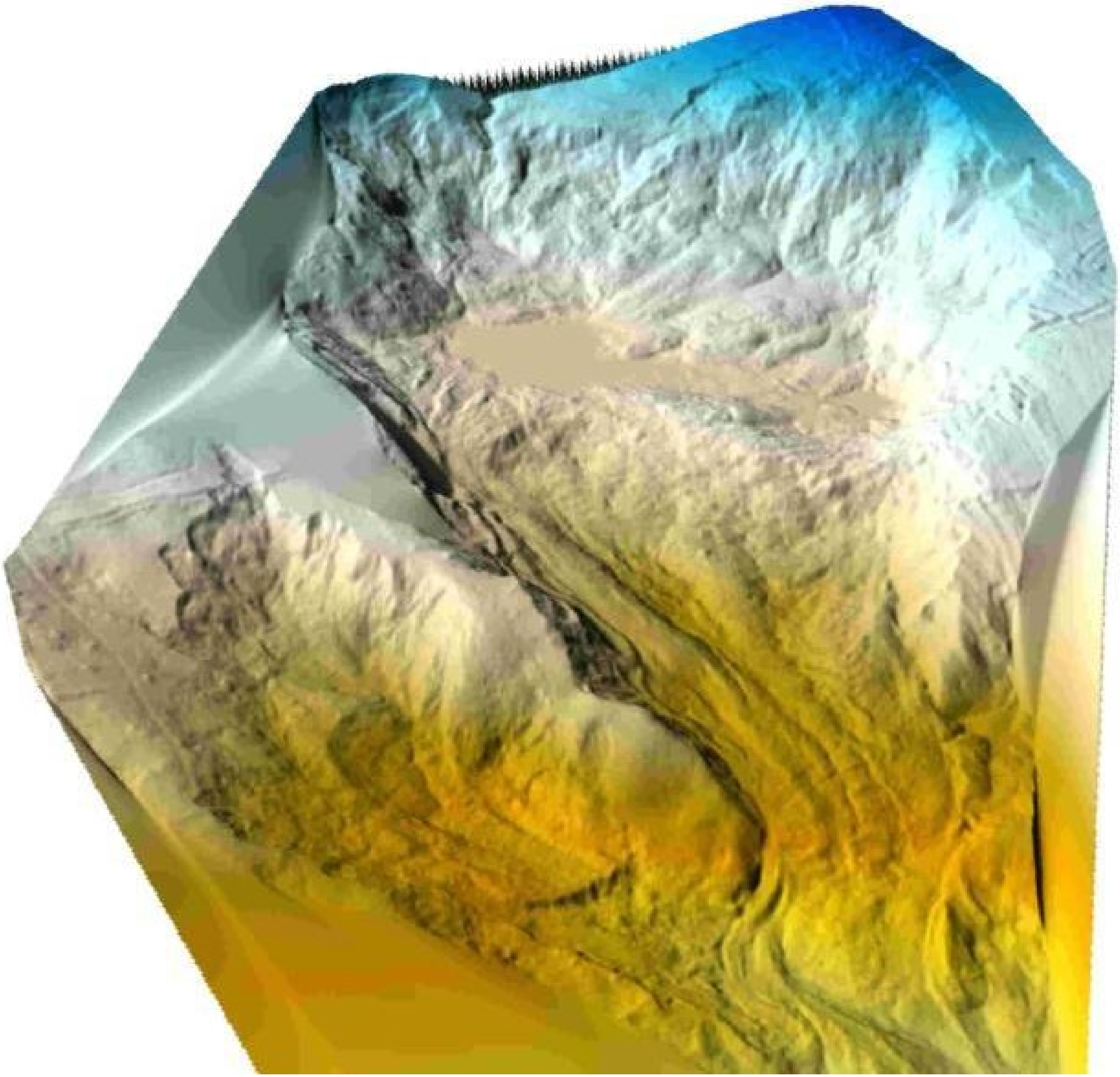
Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI



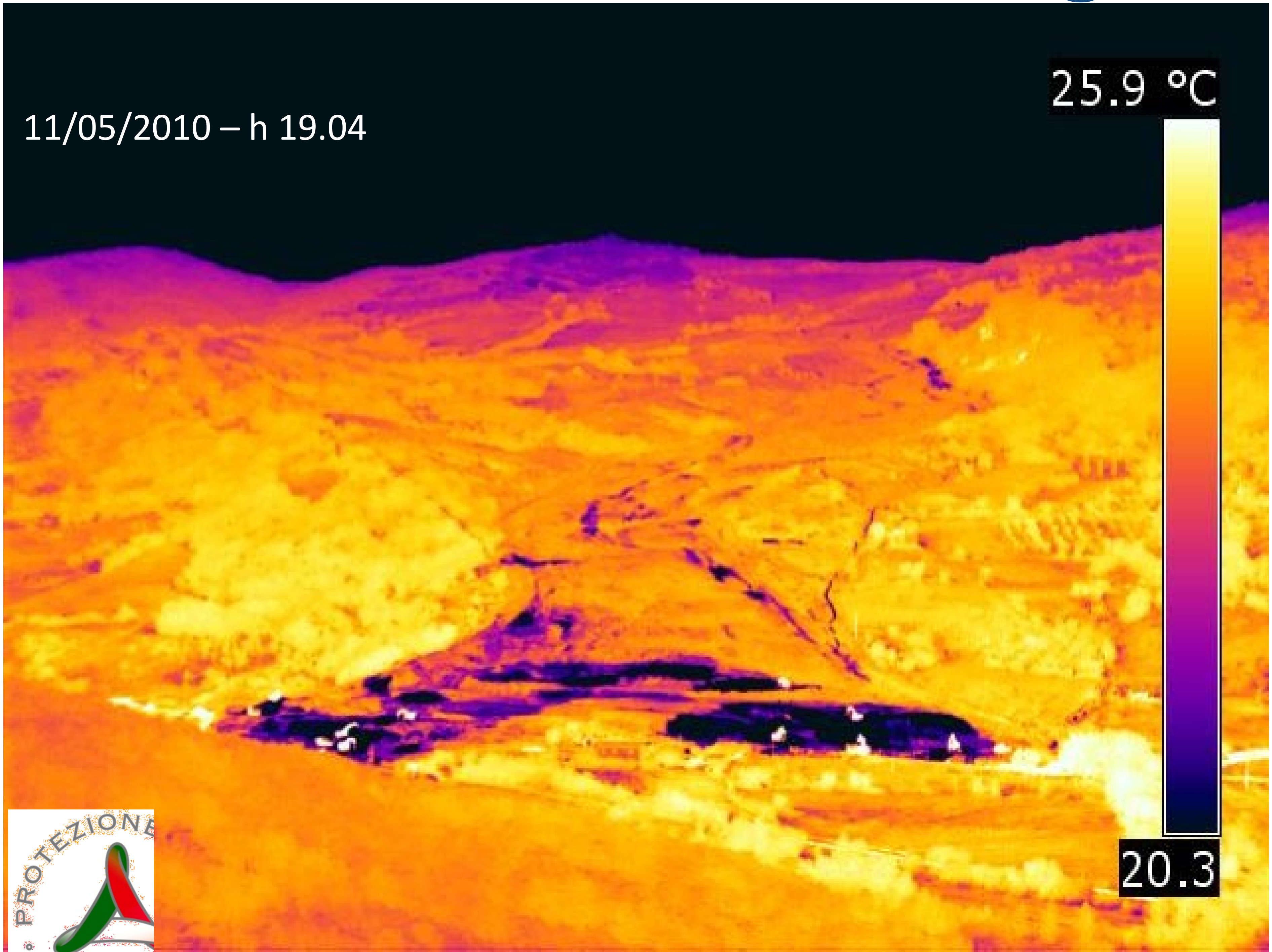
DTM 2010

Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA
PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI

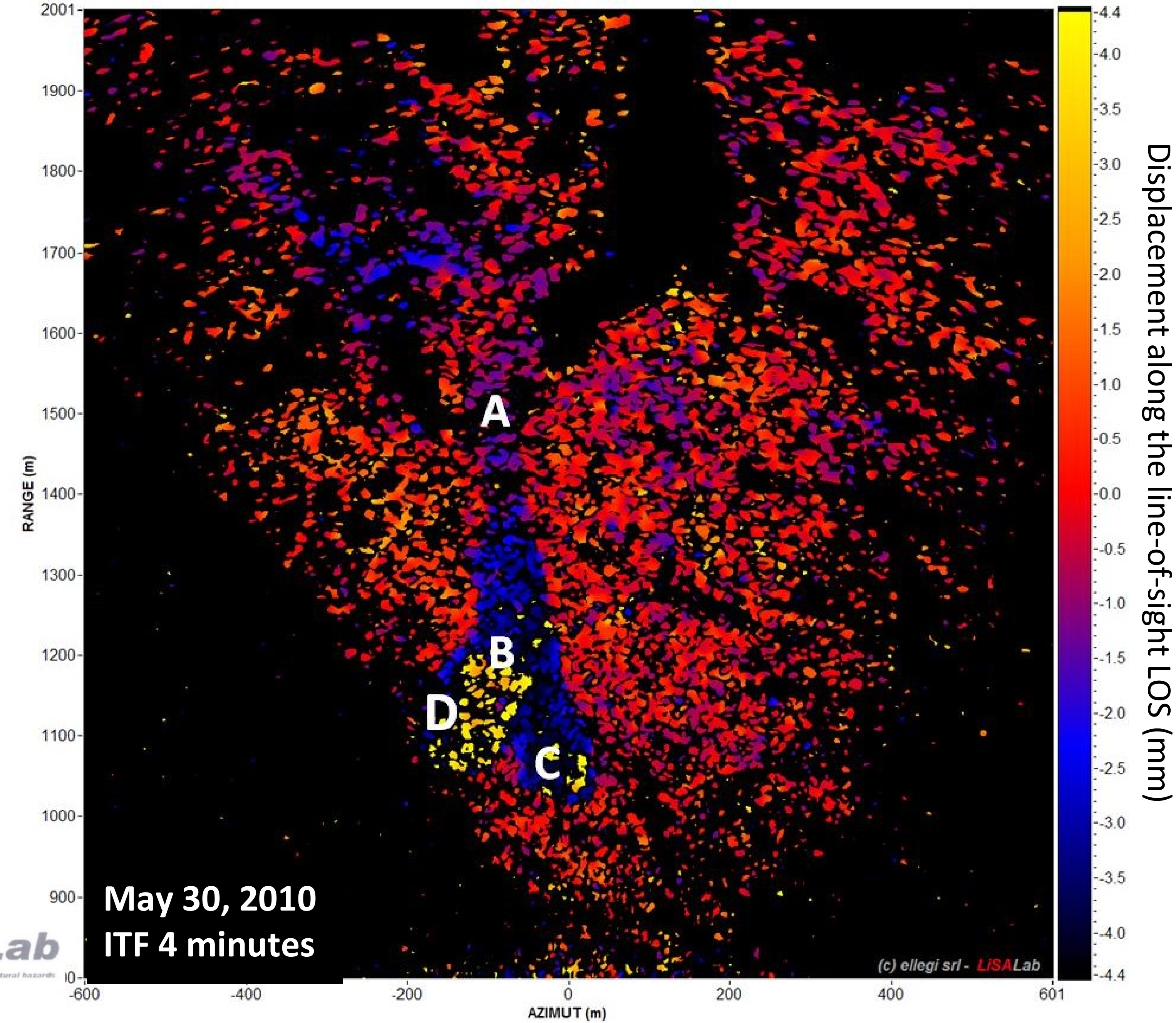
PROTEZIONE CIVILE · NAZIONALE ·



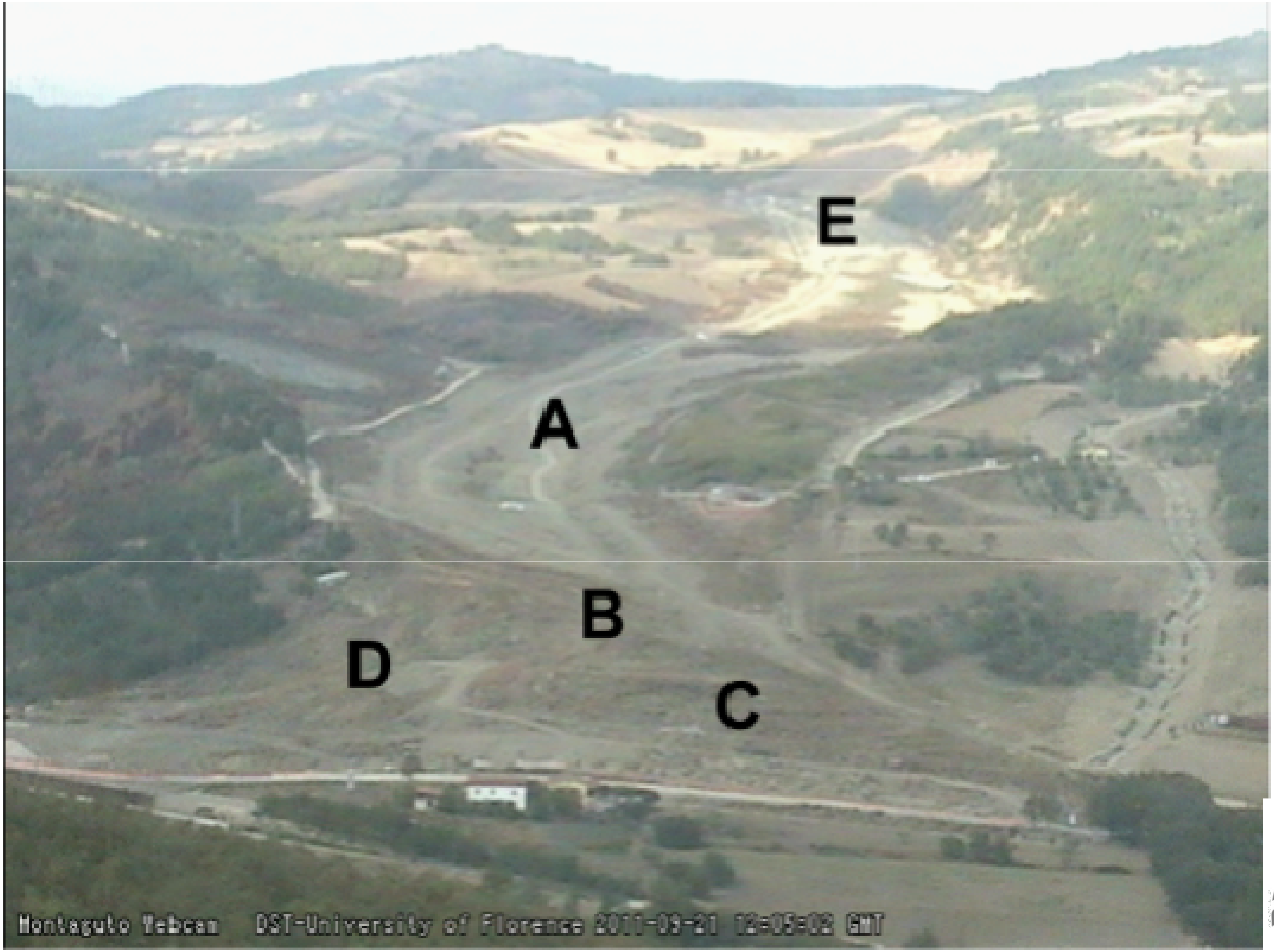
Thermal infrared image



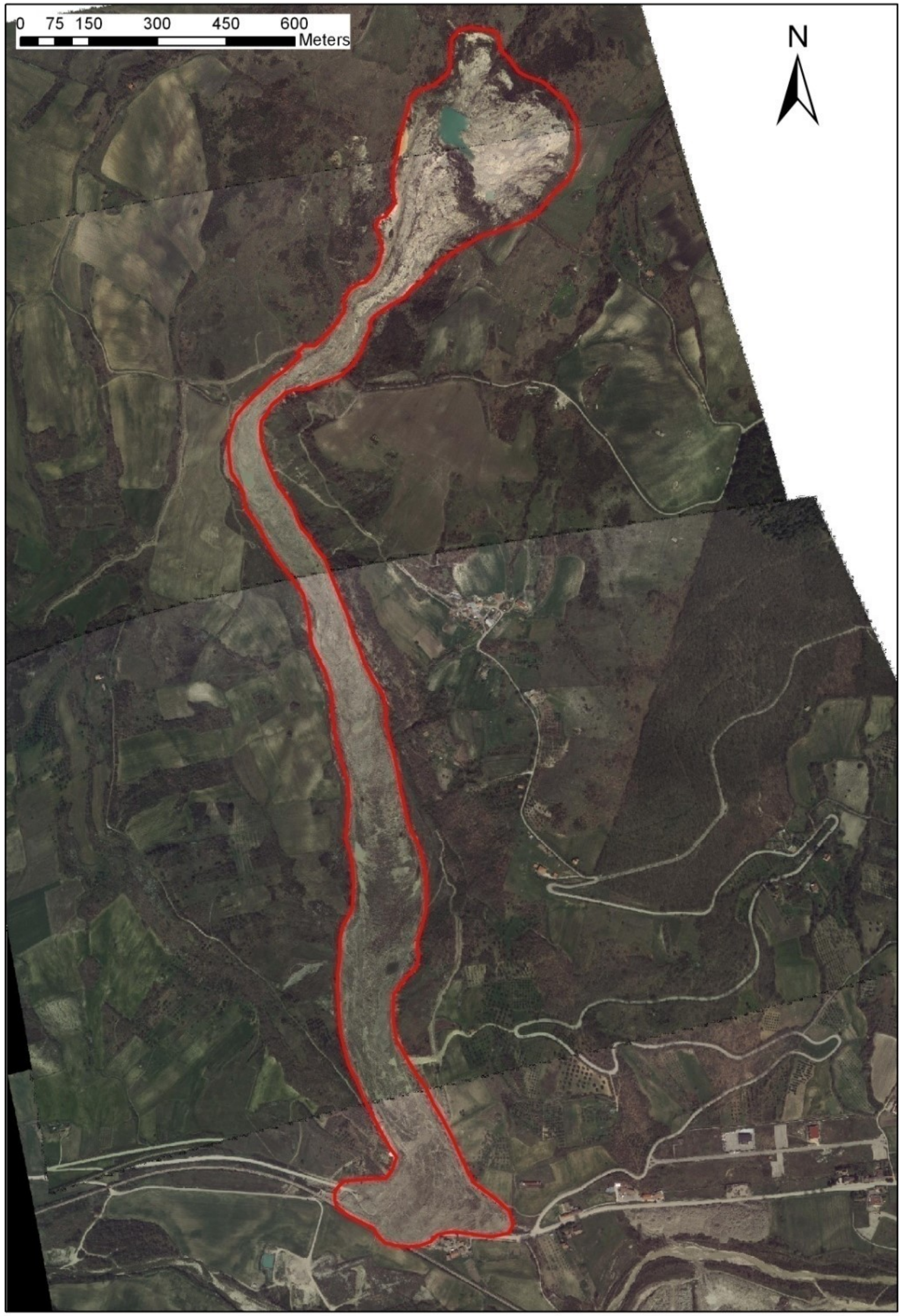
Interferogram (landslide foot)

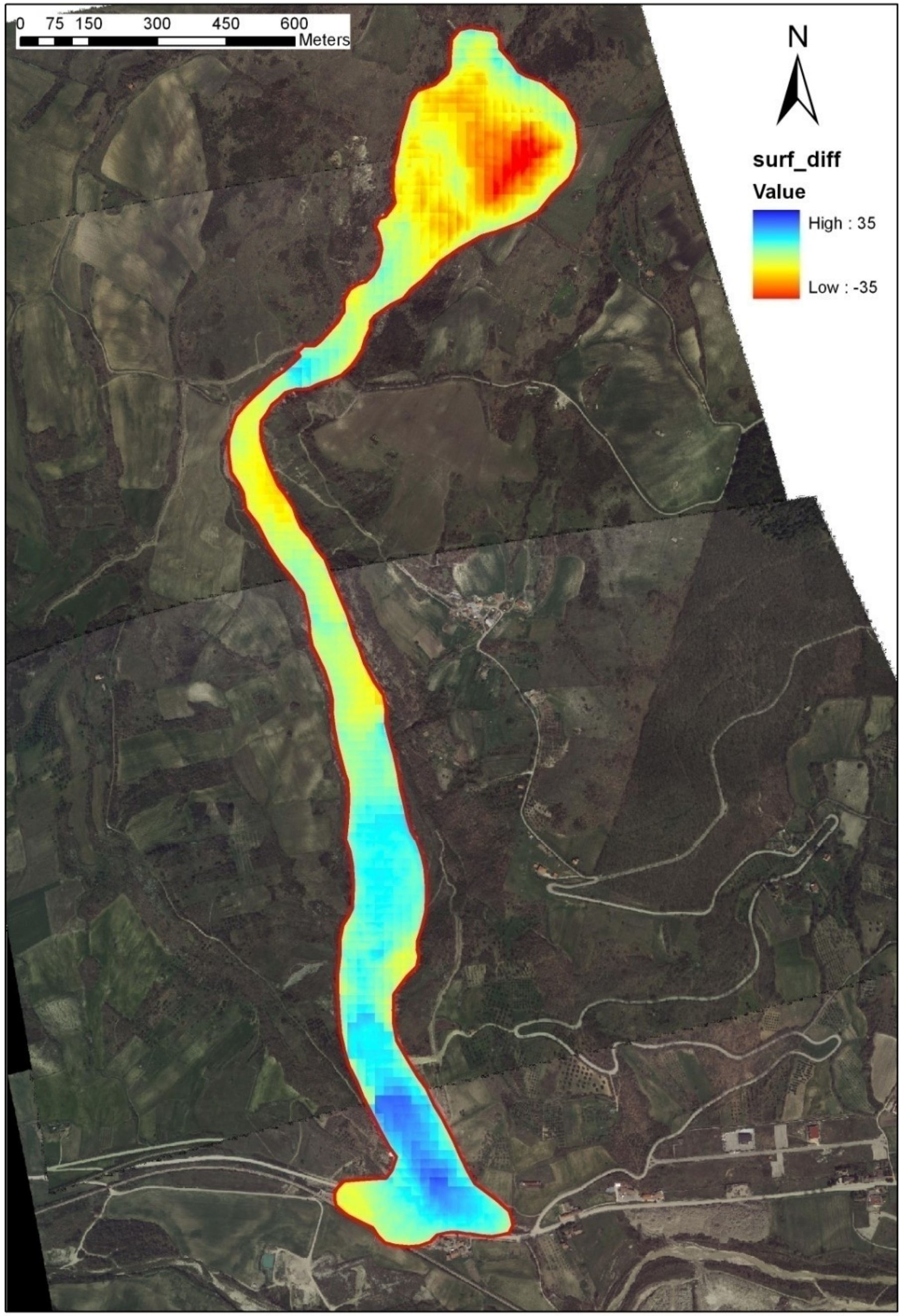


GBInSAR monitoring sectors

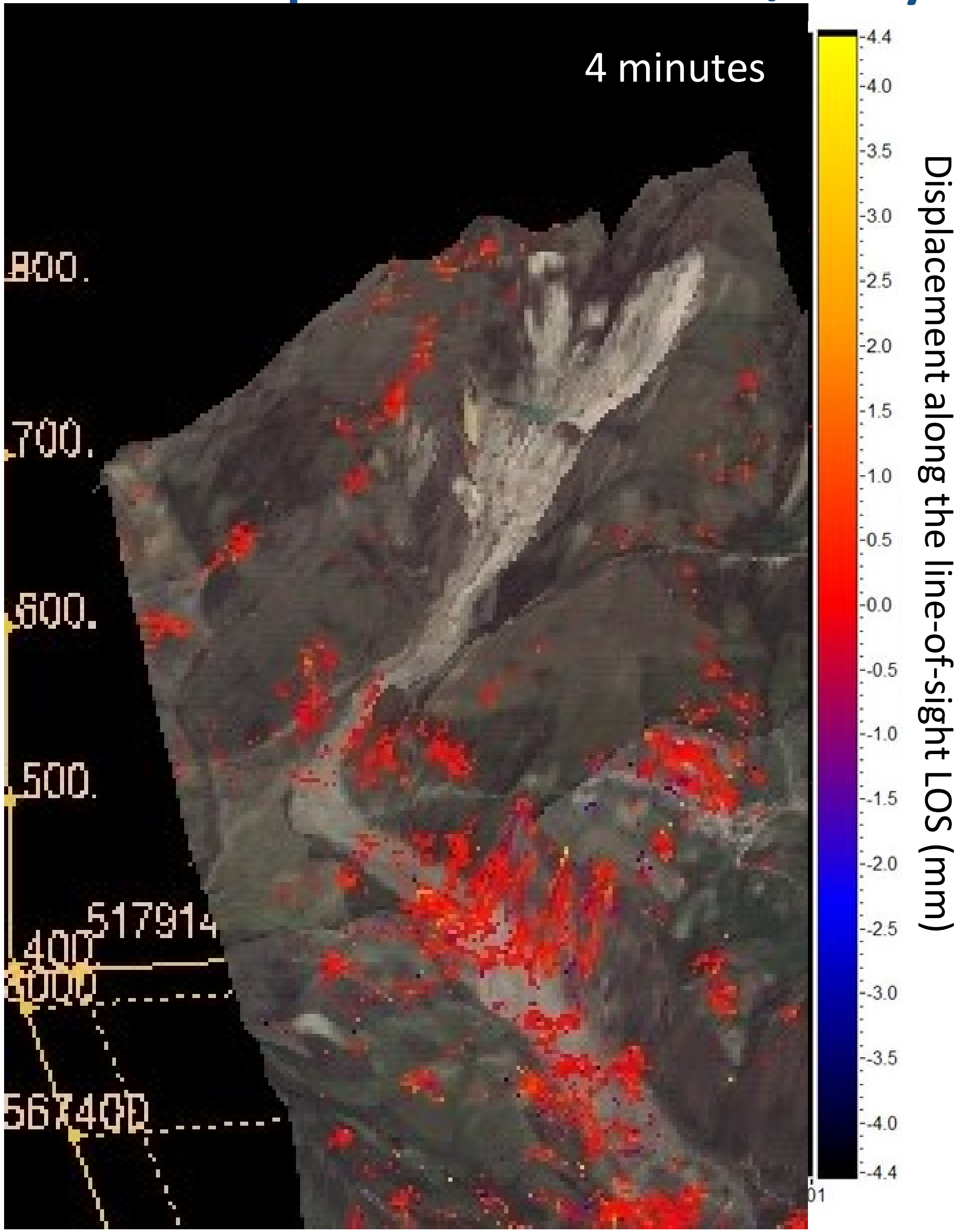


DTM difference 2006-2010





Interferogram May 26th , 2010
maximum speed = 2.7 m/day

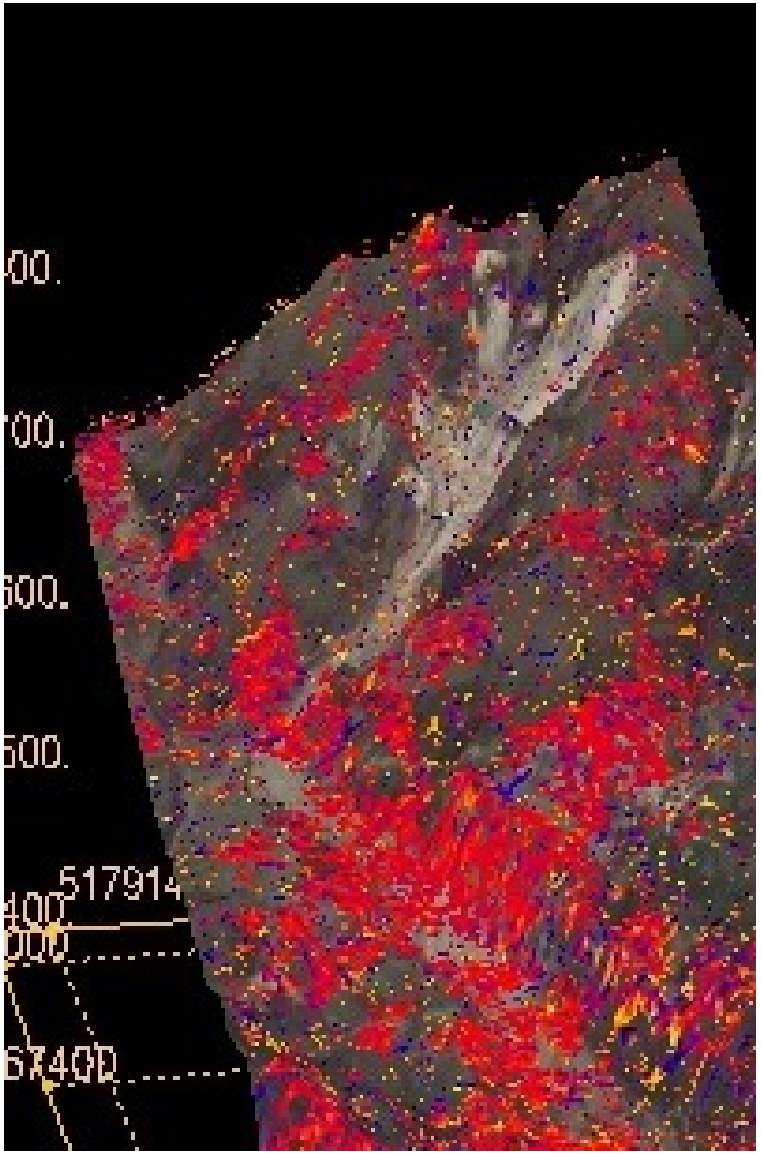


LiSALab
... a step ahead in monitoring structures and natural hazards

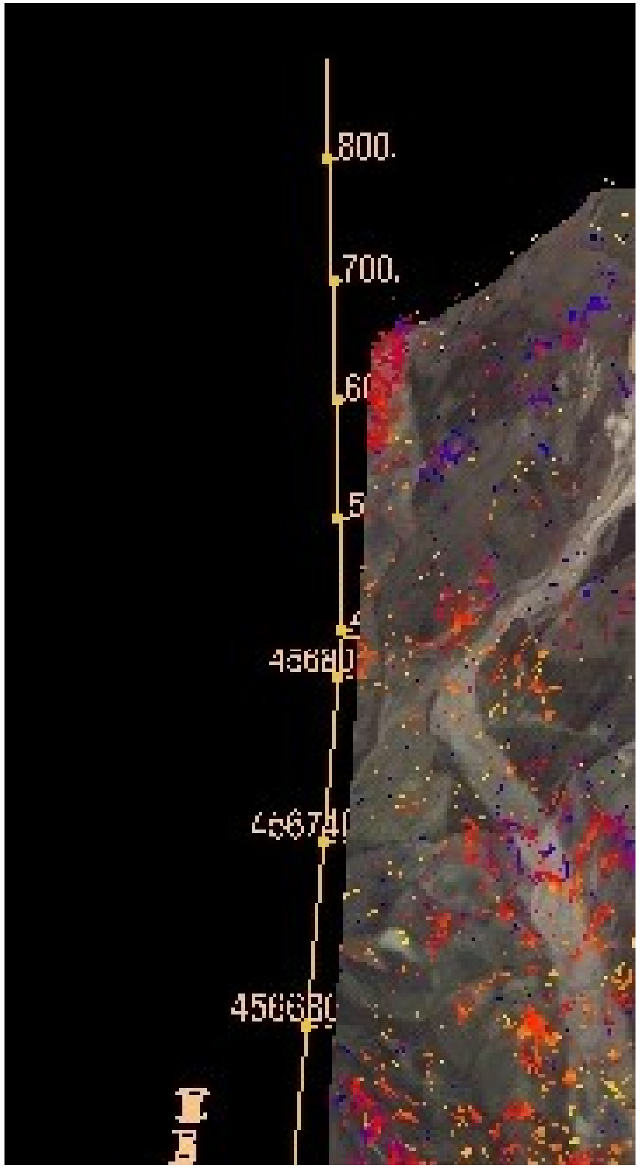
PROTEZIONE

Interferograms - July 26th, 2010
maximum speed = 3 x 10^{-2} m/day

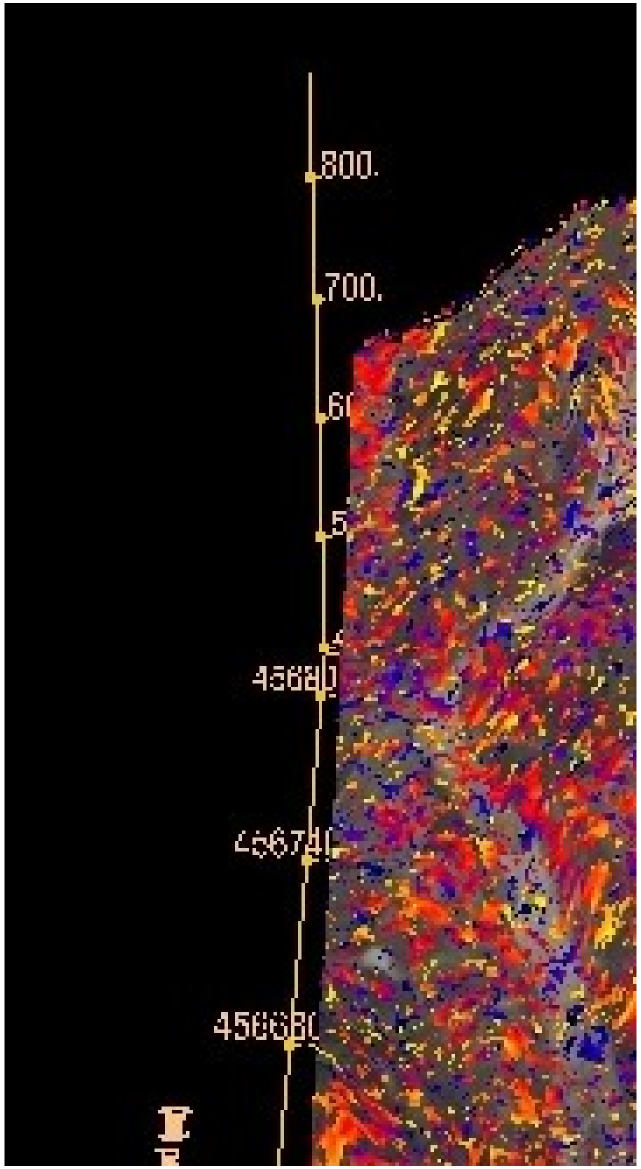
4 minutes



4 hours

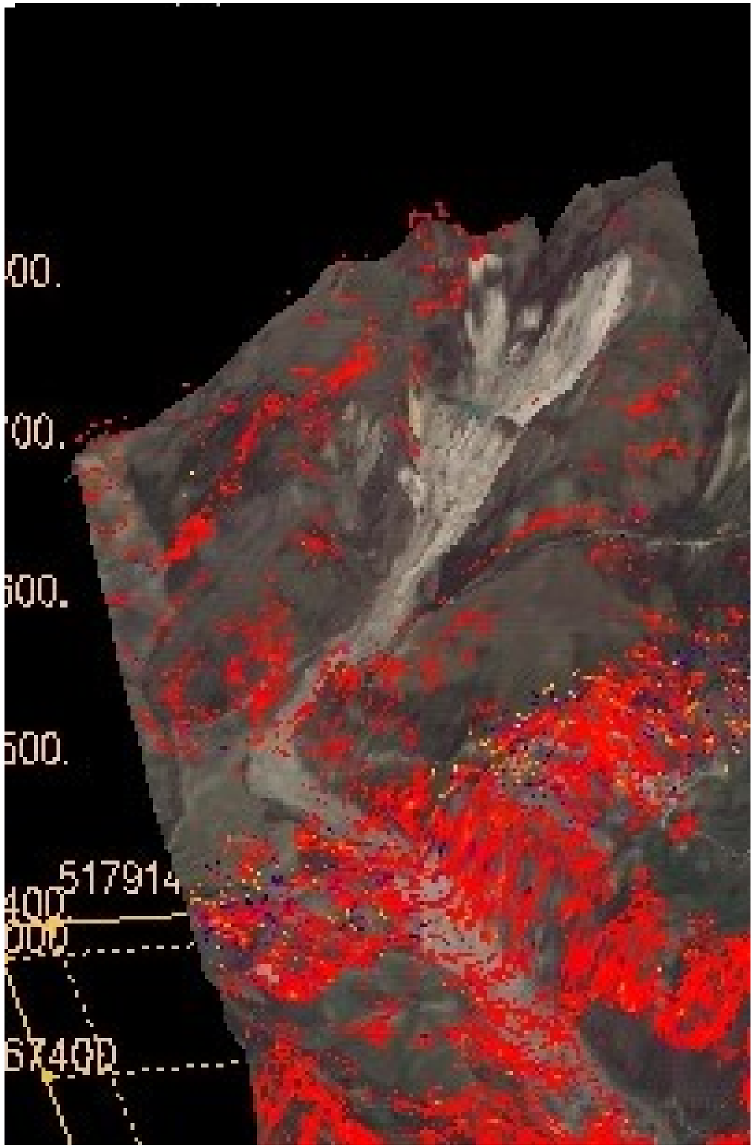


24 hours

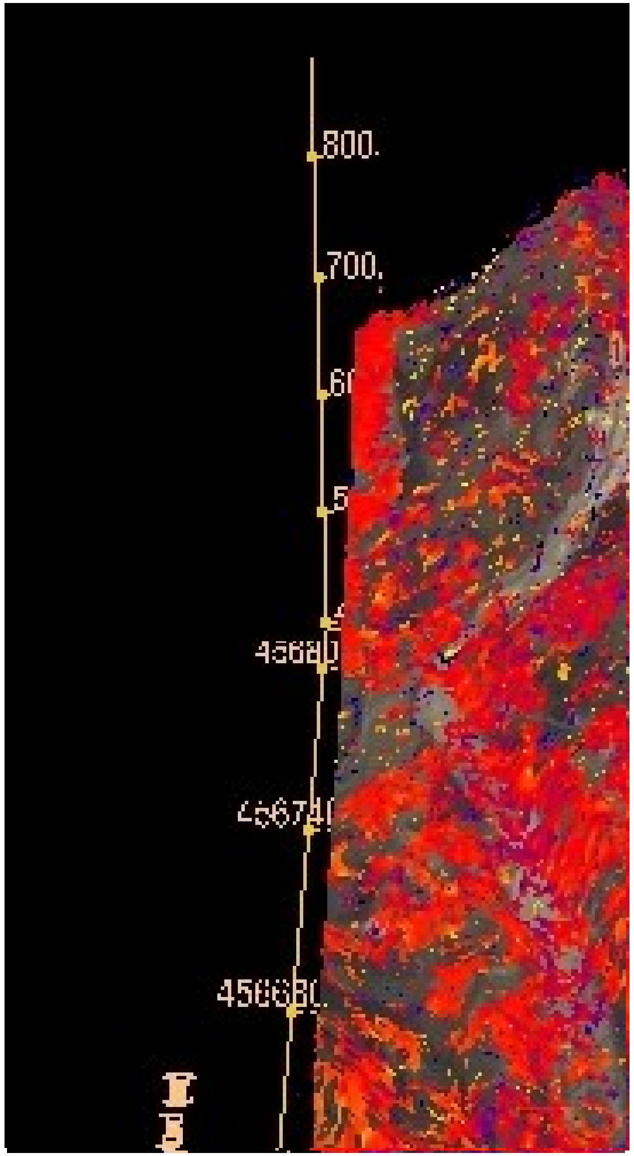


Interferograms – December 26th , 2010
maximum speed = 4 x 10^{-3} m/day

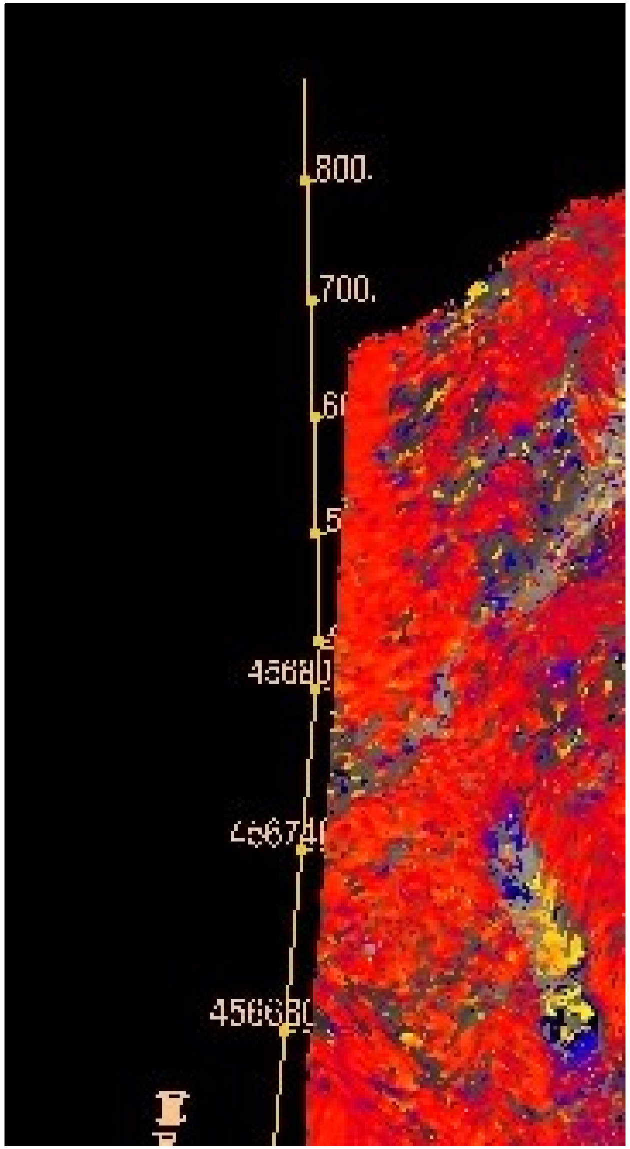
4 minutes



4 hours



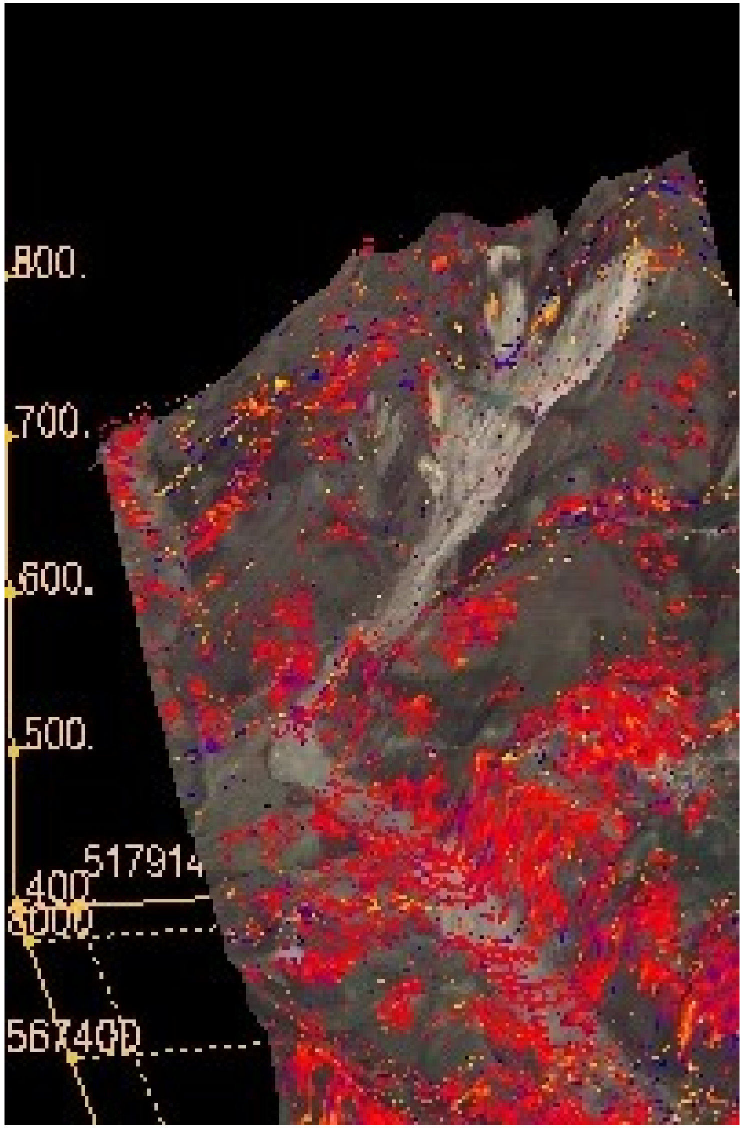
24 hours



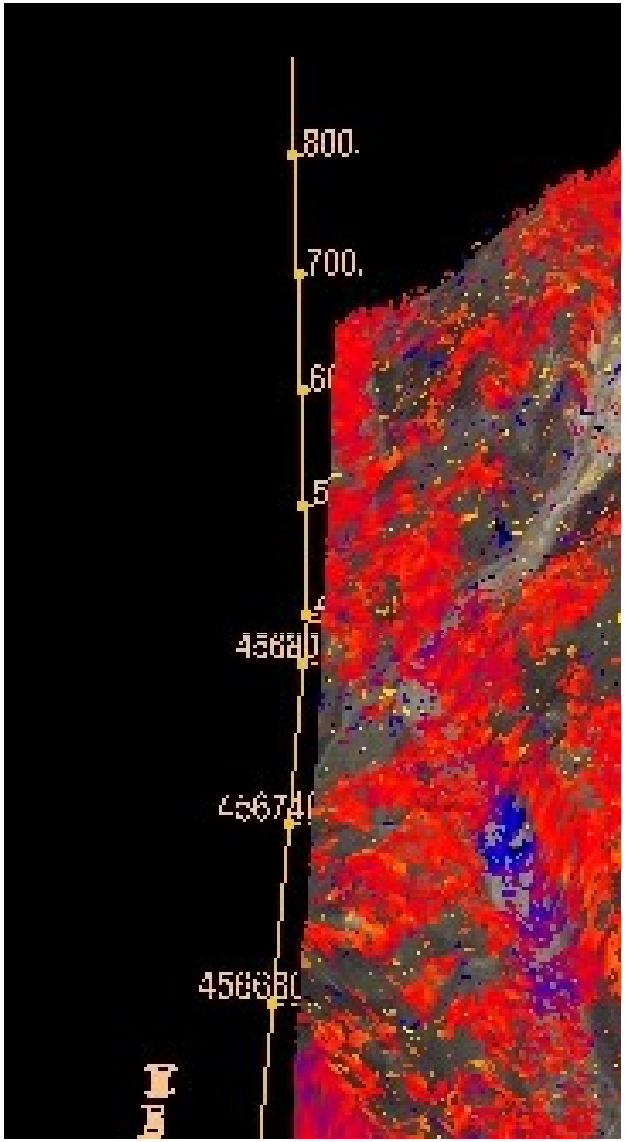
Interferograms – March 26th , 2011
maximum speed = 5 x 10^{-4} m/day

LiSALab

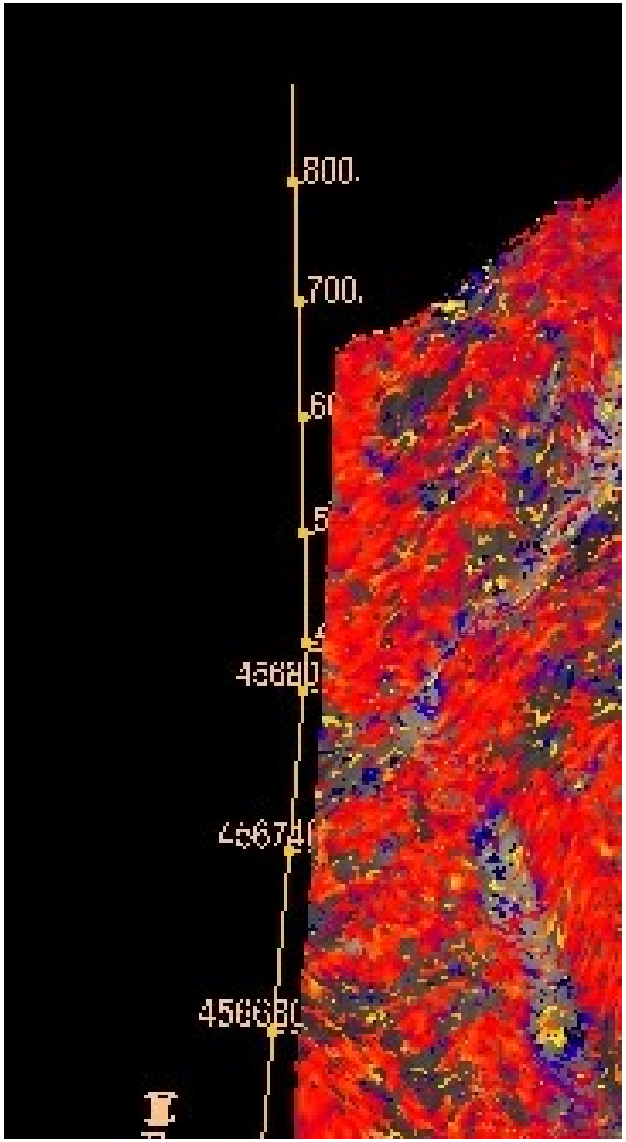
4 minutes



4 hours

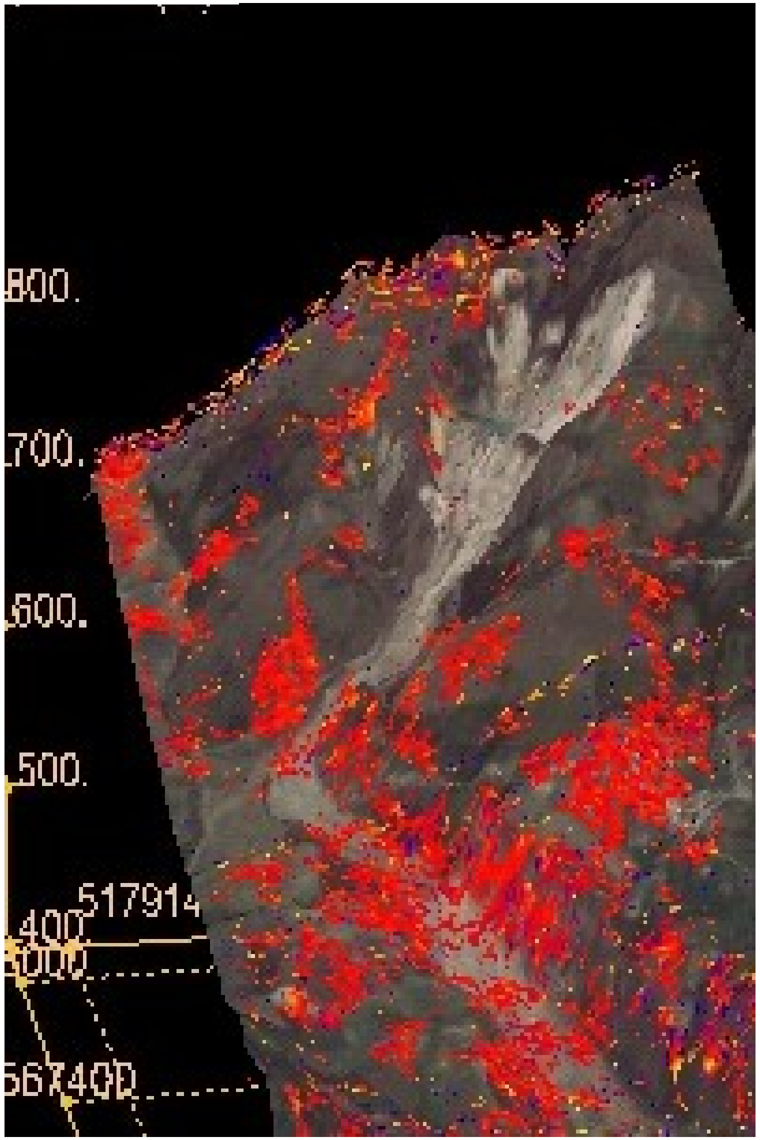


24 hours

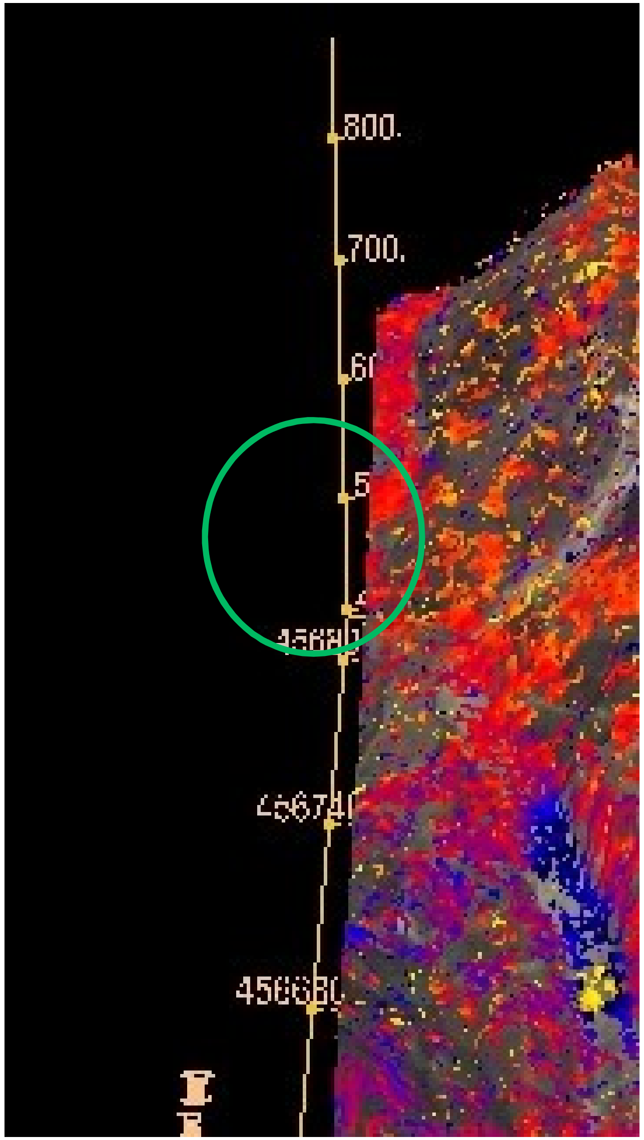


Interferograms – July 26th , 2011
maximum speed = 3 x 10 $^{-4}$ m/day (E sector)

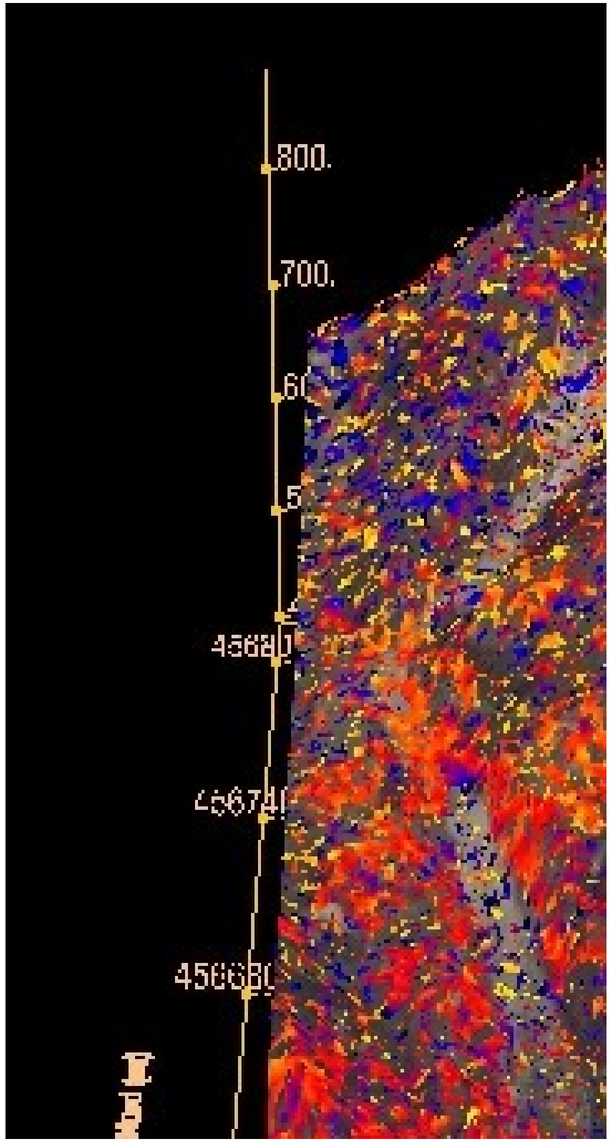
4 minutes



4 hours

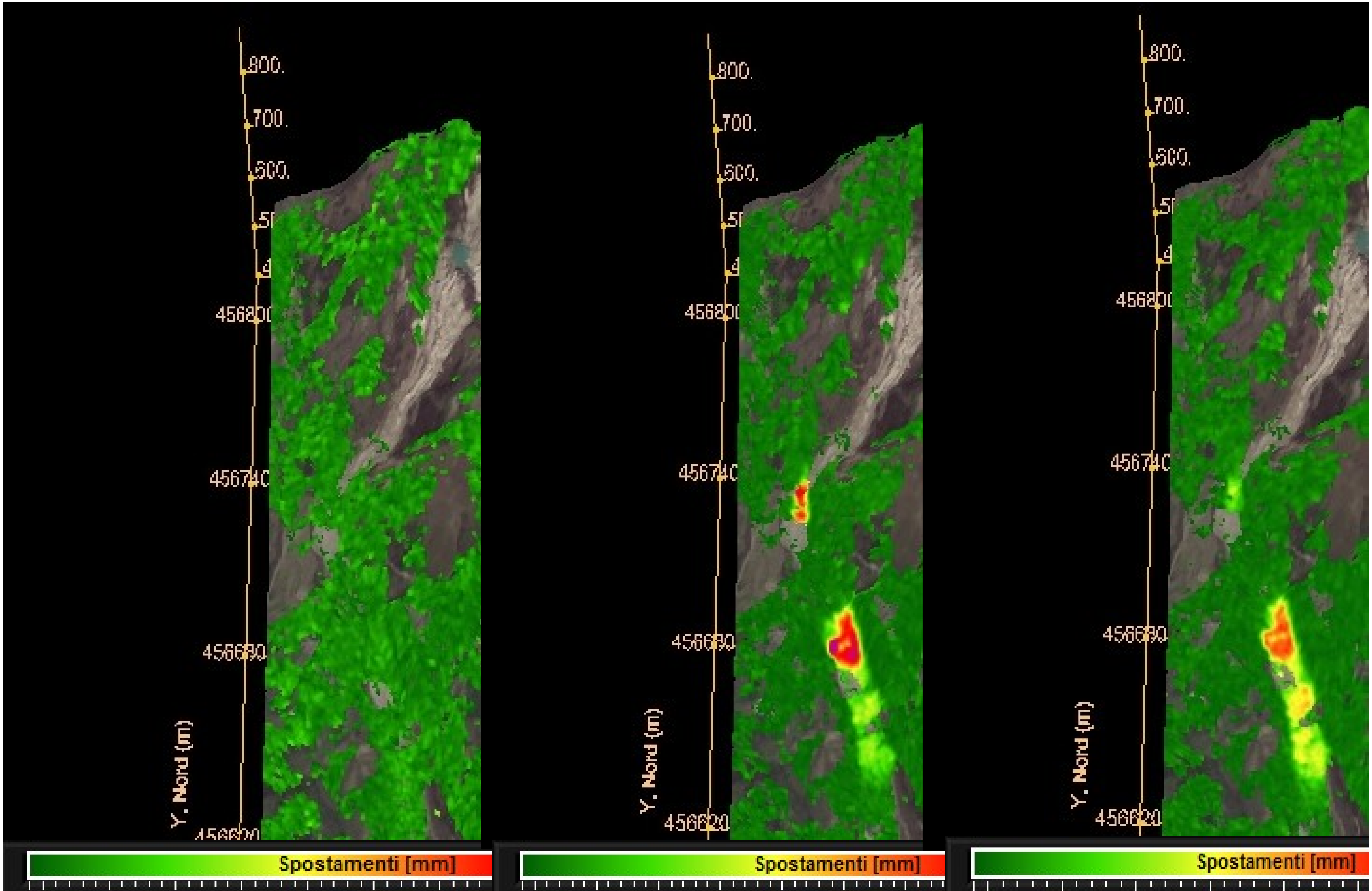


24 hours

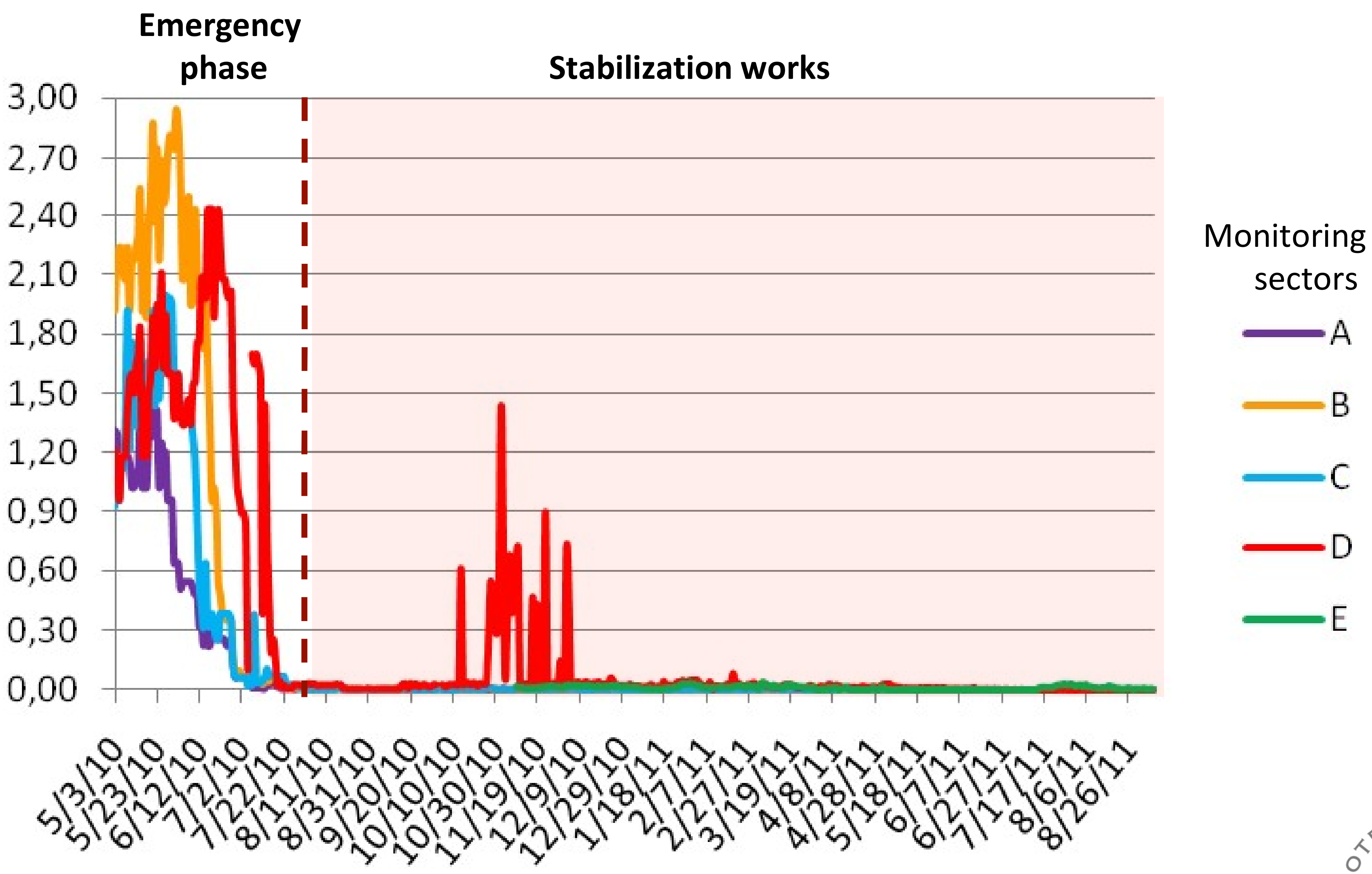


Cumulated displacement maps

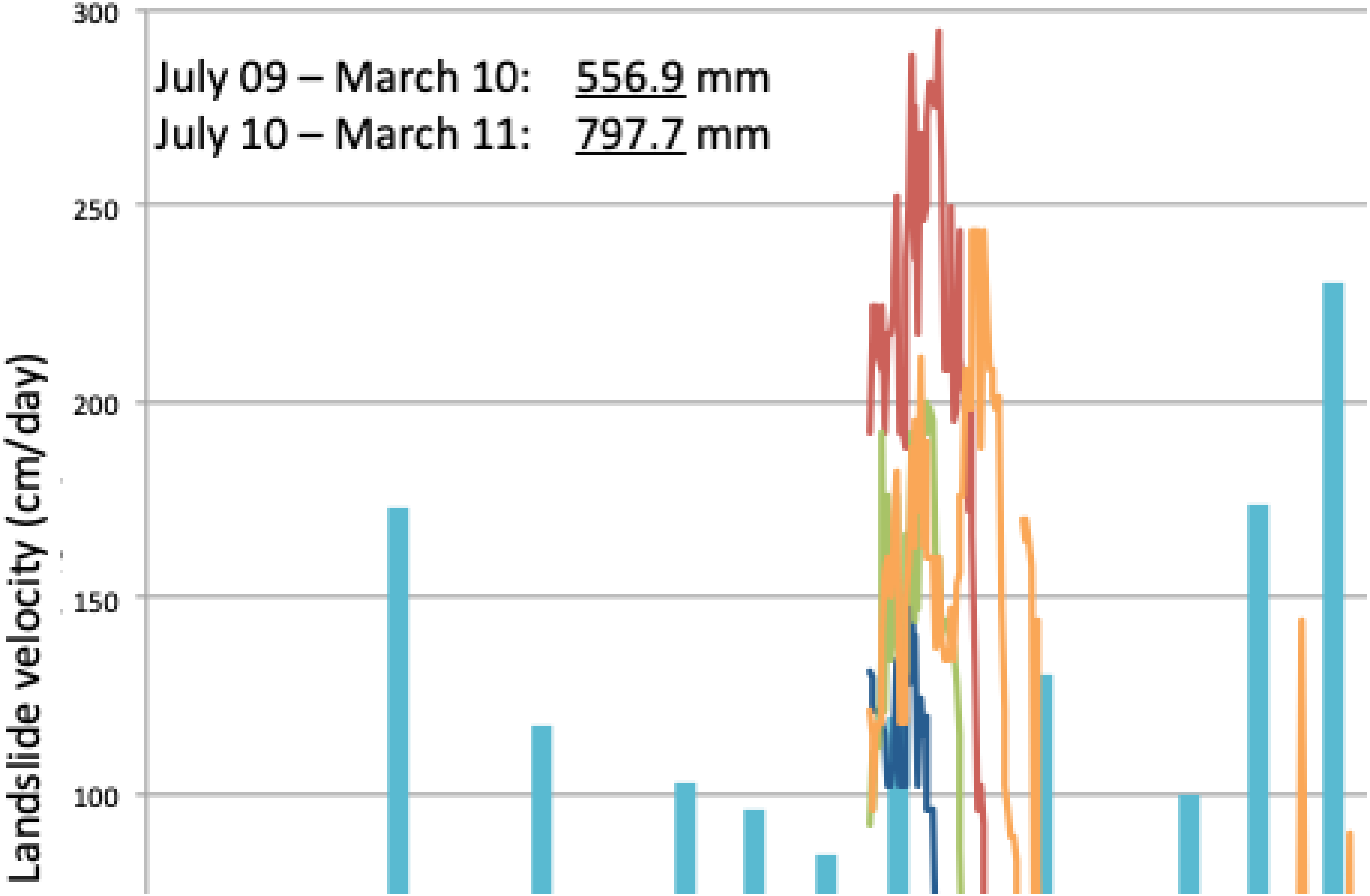
September 2010 | December 2010 | January 2011



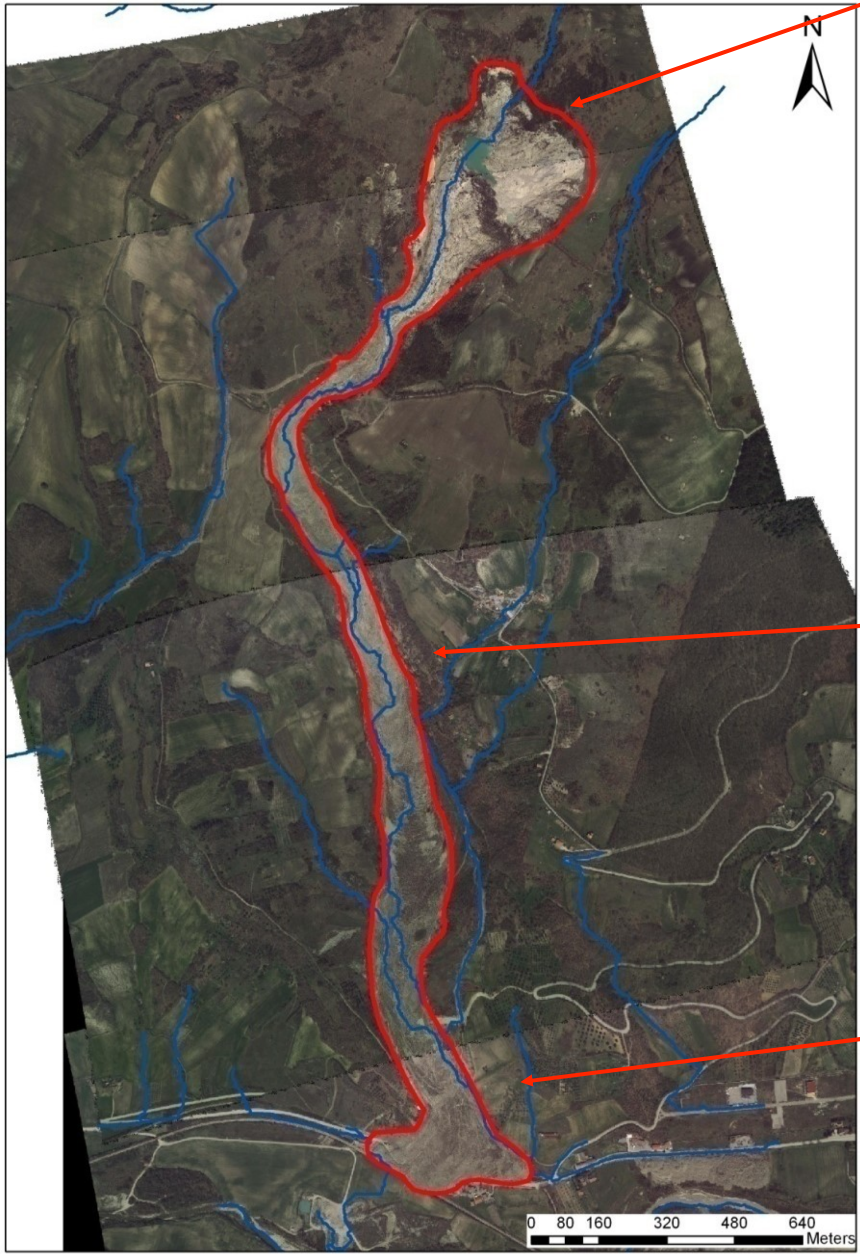
Recorded velocity (m/day)



Comparison with rainfall



Stabilization works



Upper sector (depletion zone)

- upstream surface drainage (diversion ditches)
- drainage wells
- re-profiling of the main scarp
- lake drainage
- modification of the slope profile
- surface drains (ditches)
- shallow drains (trenches with gabions)
- deep drains (drainage diaphragm)
- stream channels restoration to natural conditions

Middle sector (main track)

- modification of the slope profile
- surface drains coupled with deep trench drains
- left-bank stream channelization
- right-bank stream channelization

Lower sector (deposition zone)

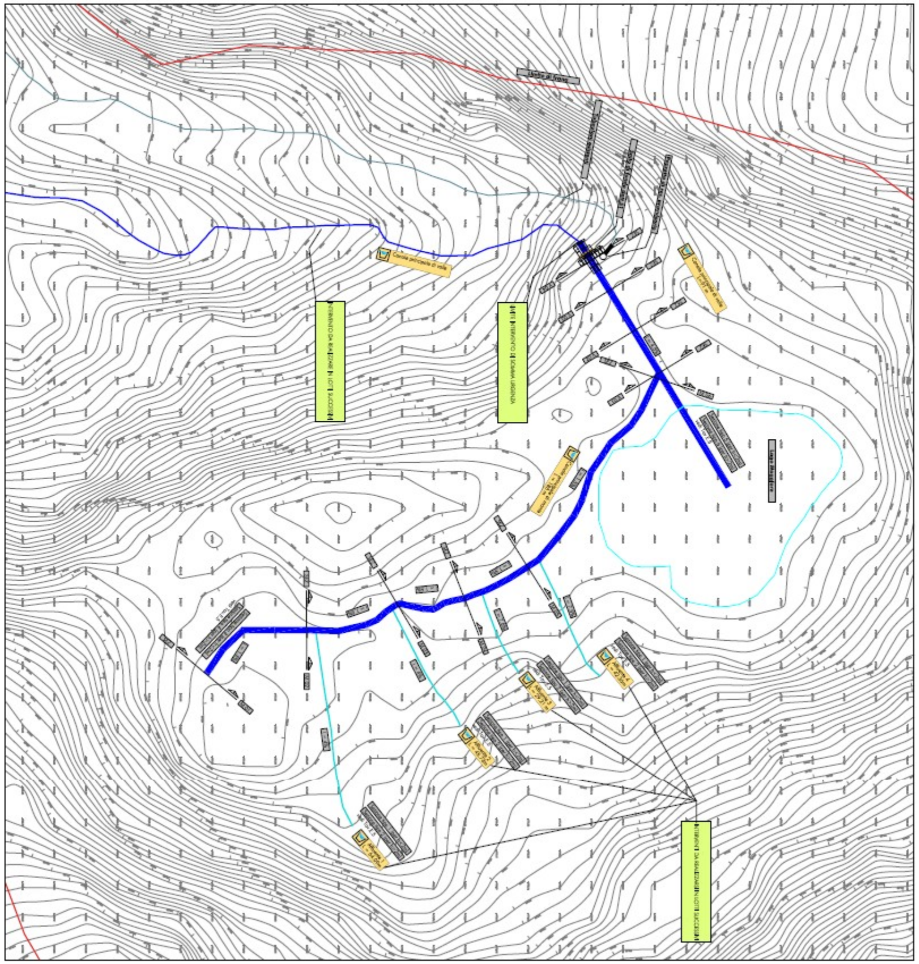
- re-profiling of landslide deposits on the right side
- gabion toe drain and buttressing
- landslide deviation on the left side
- surface drains coupled with deep trench drains
- left-bank stream channelization

Observational method

Advantages and Limitations of the Observational Method in Applied Soil Mechanics. Géotechnique, Volume 19 Issue 2, June 1969, pp. 171-187

Ralph Peck and Karl Terzaghi
at Lake Maracaibo in 1956
(From The Terzaghi & Peck Libraries NGI, Oslo)

Upper sector: Before drainage



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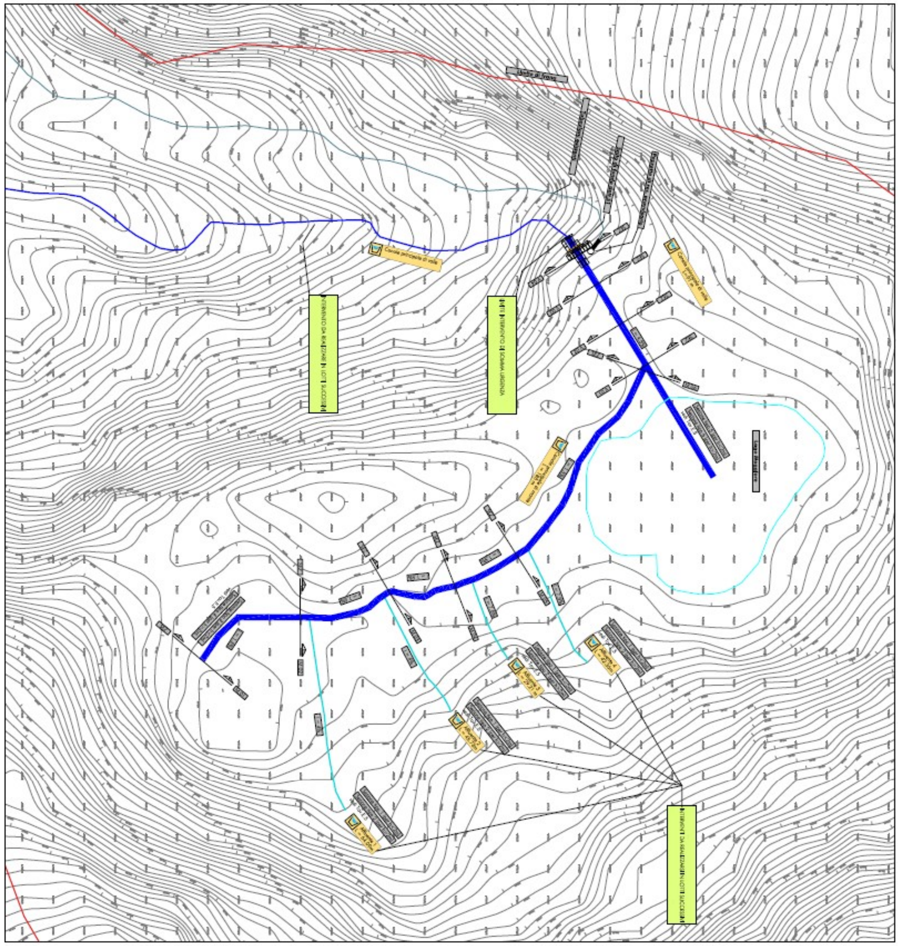
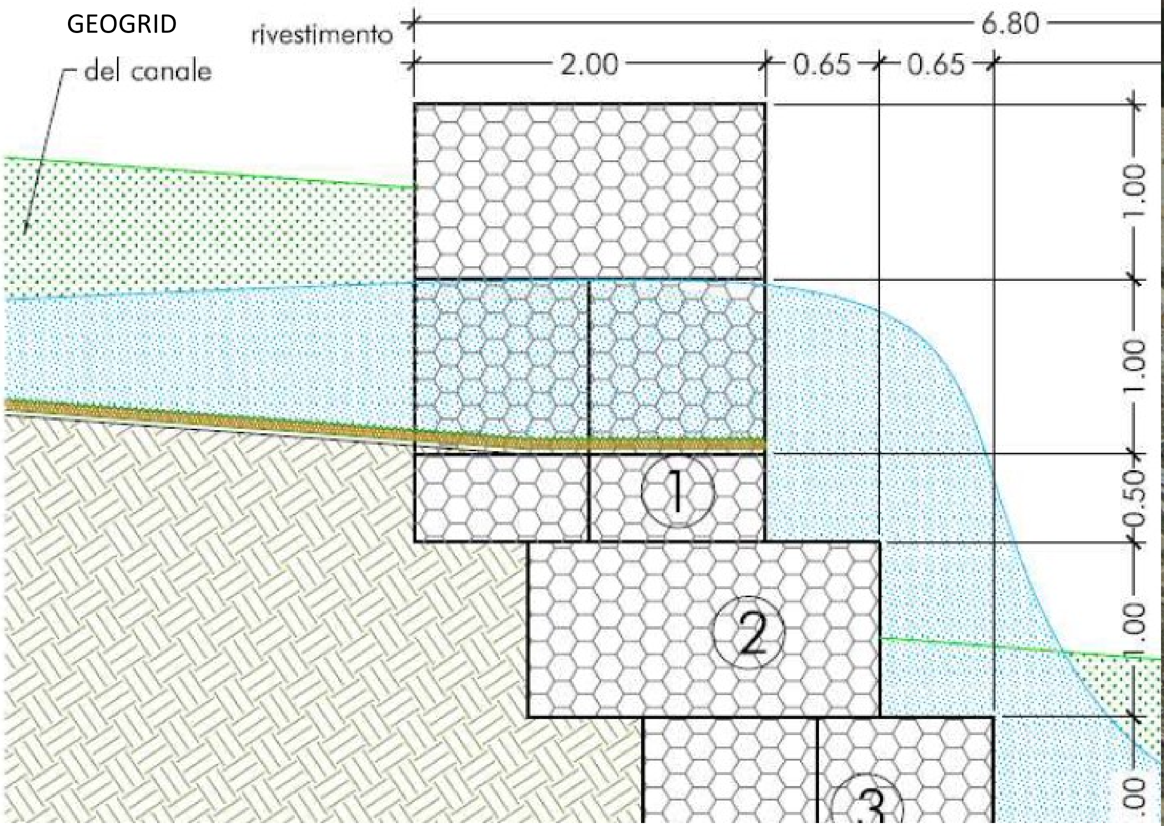
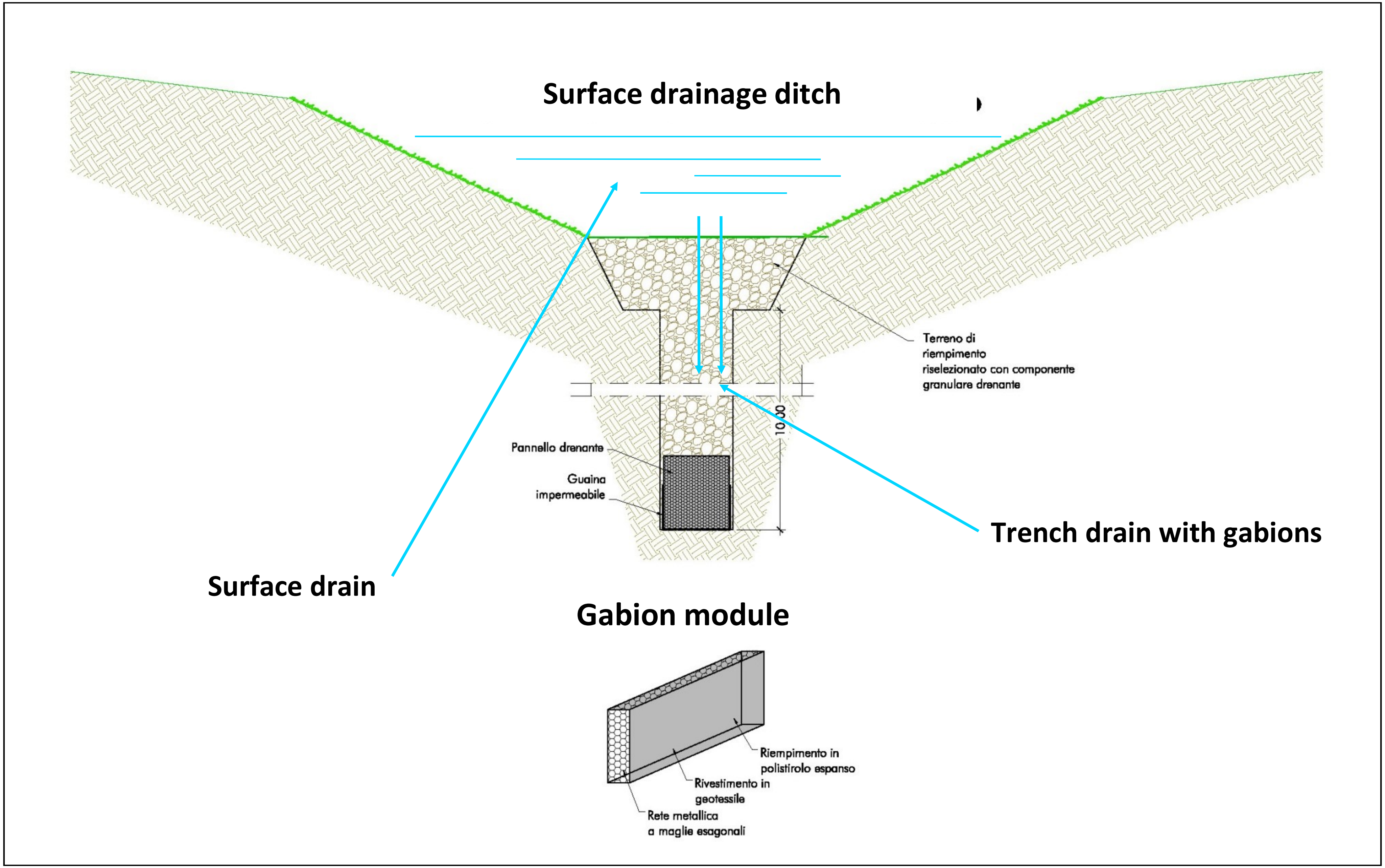
Upper sector: After drainage



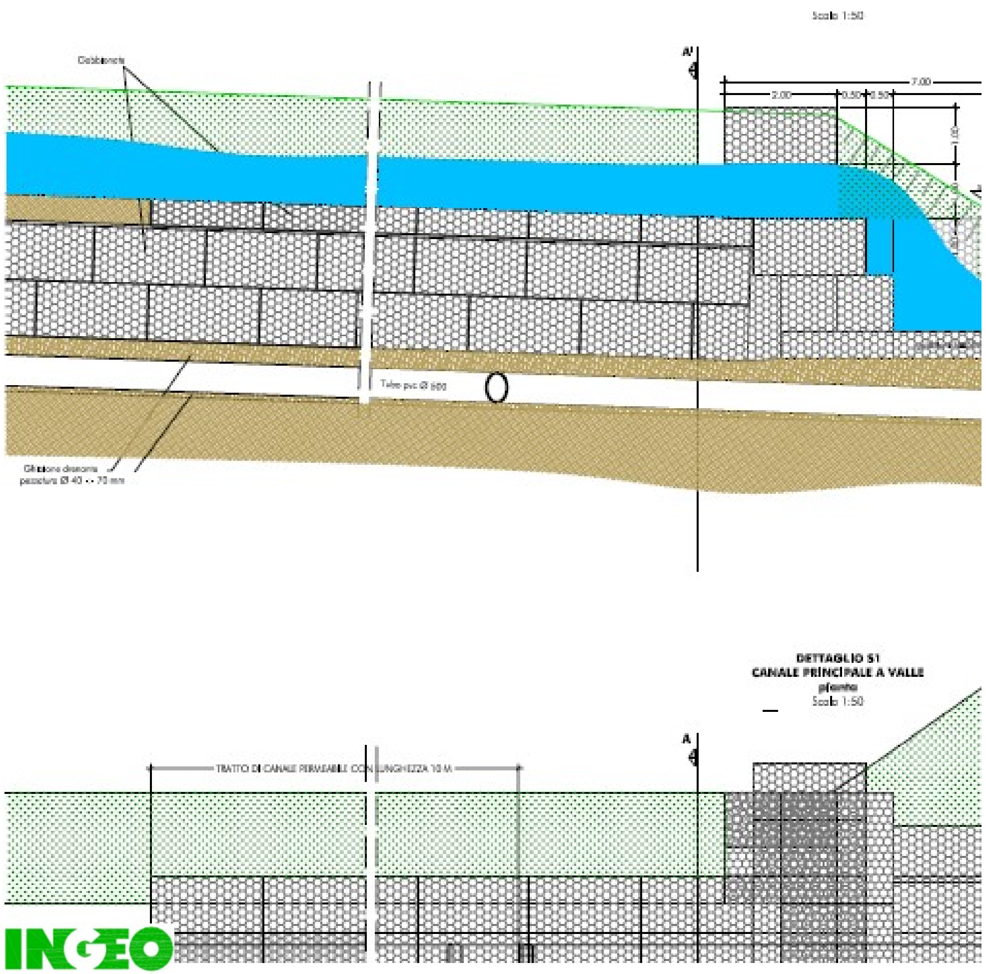
Gabion weir


GEOGRID
rivestimento
del canale
6.80
2.00
0.65
0.65
1.00
1.00
0.50
1.00
1
2
3

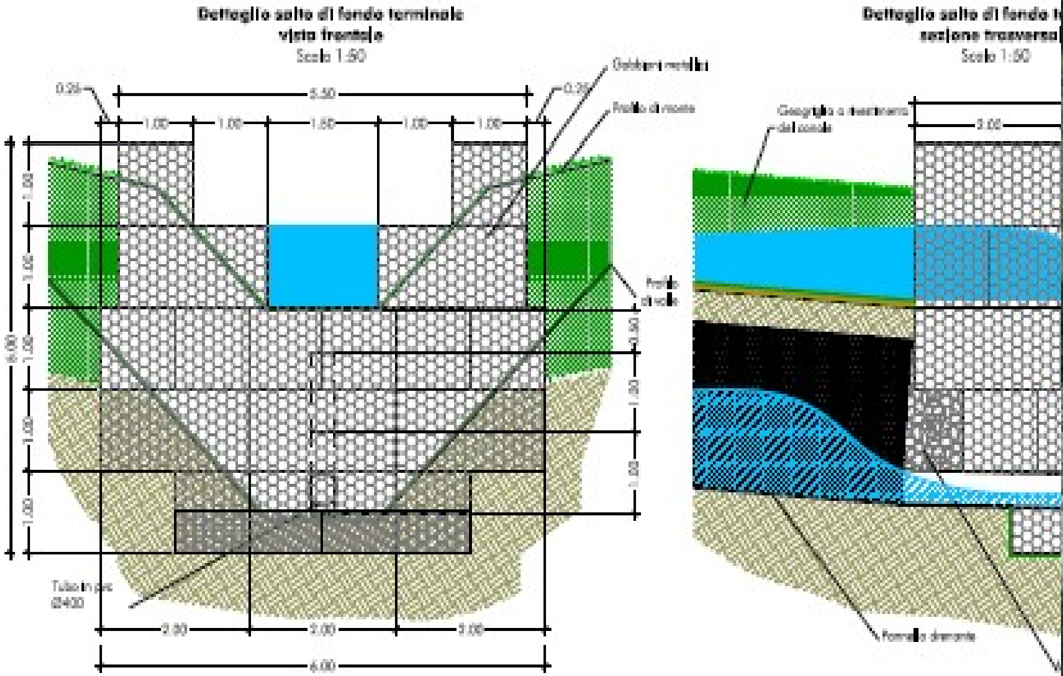
Deep drainage trench built with gabions and coupled with a surface concrete ditch



Drainage trench and well



Middle sector: drainage trench and gabion



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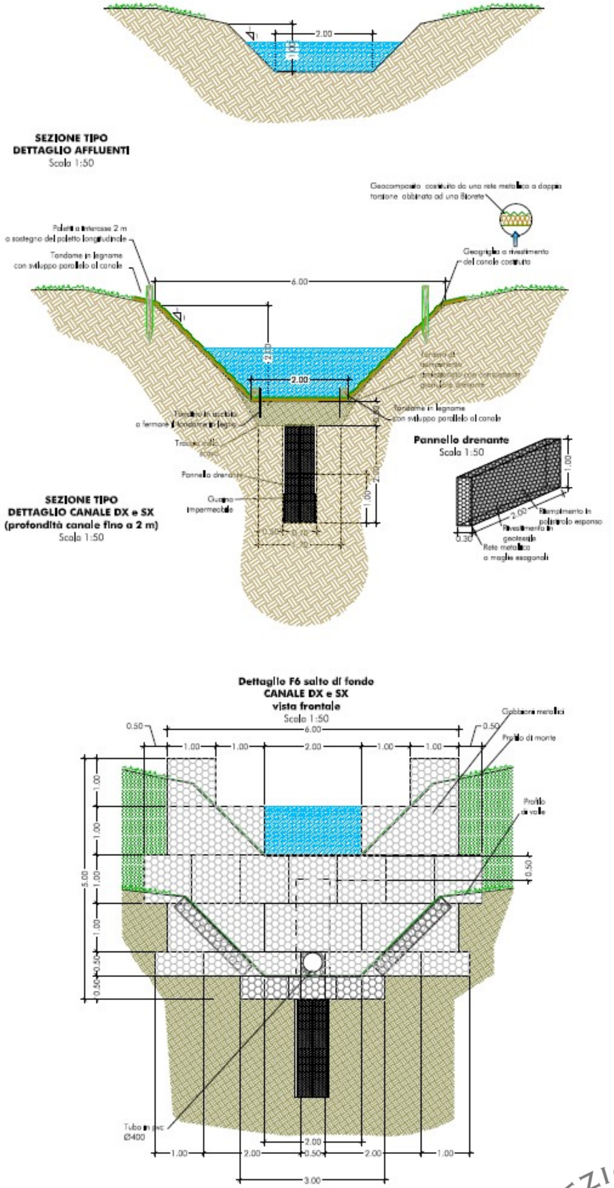
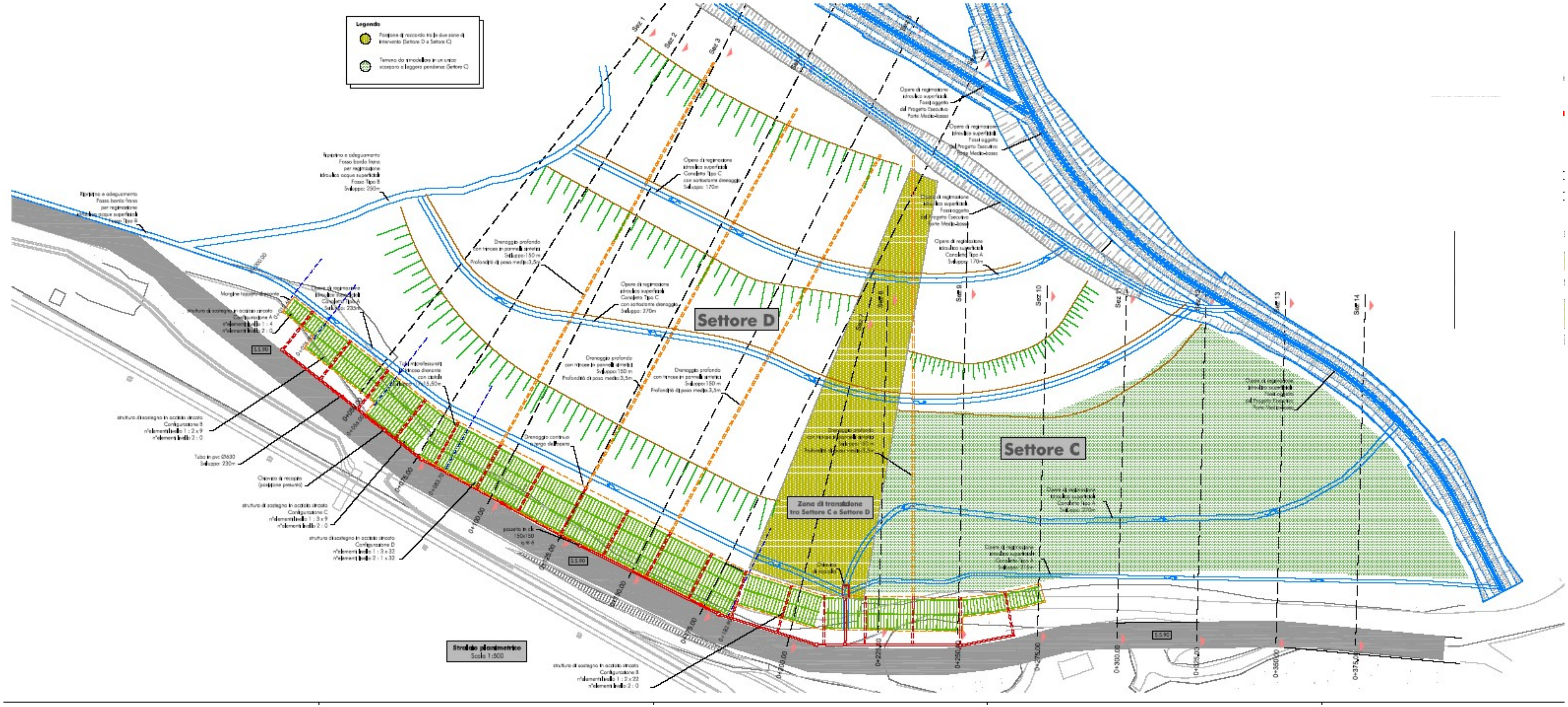
Gabion weir


SEZIONE TIPO
DETTAGLIO AFFLUENTI
Scala 1:50
SEZIONE TIPO
DETTAGLIO CANALE DX e SX
(profondità canale fino a 2 m)
Scala 1:50
Pannello drenante
Scala 1:50
Dettaglio F6 salto di fondo
CANALE DX e SX
vista frontale
Scala 1:50

Lower sector stabilization



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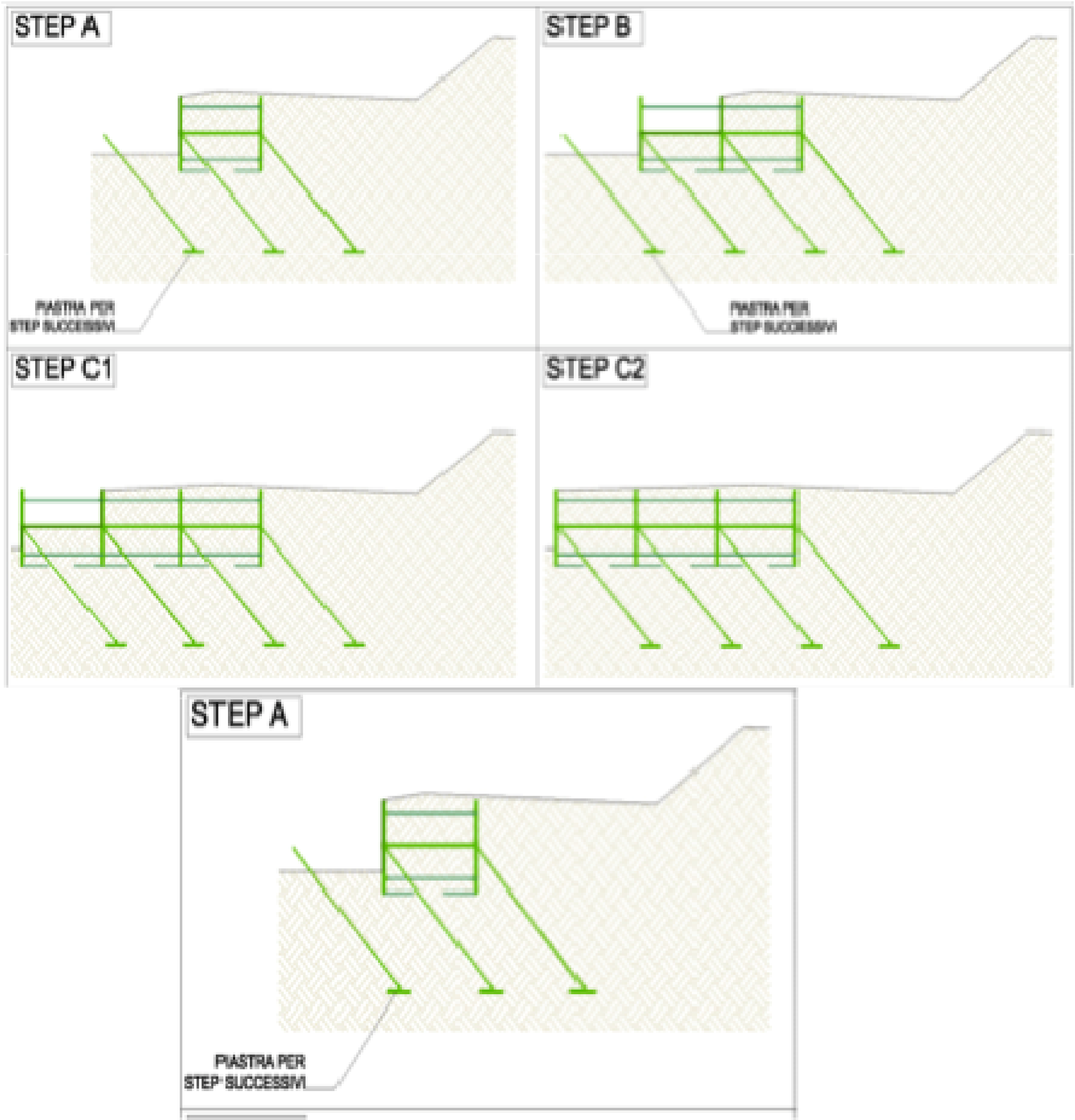
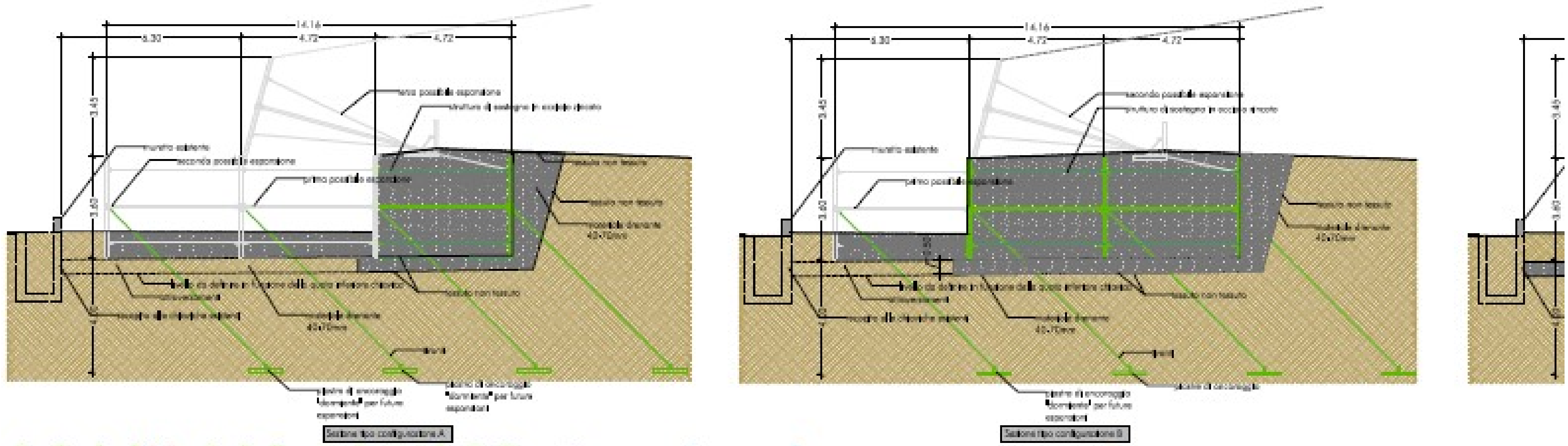
Gabion toe drain and buttressing

- Gabion modules 3.6 x 3.1 x 4.7 m
- Anchored concrete plates

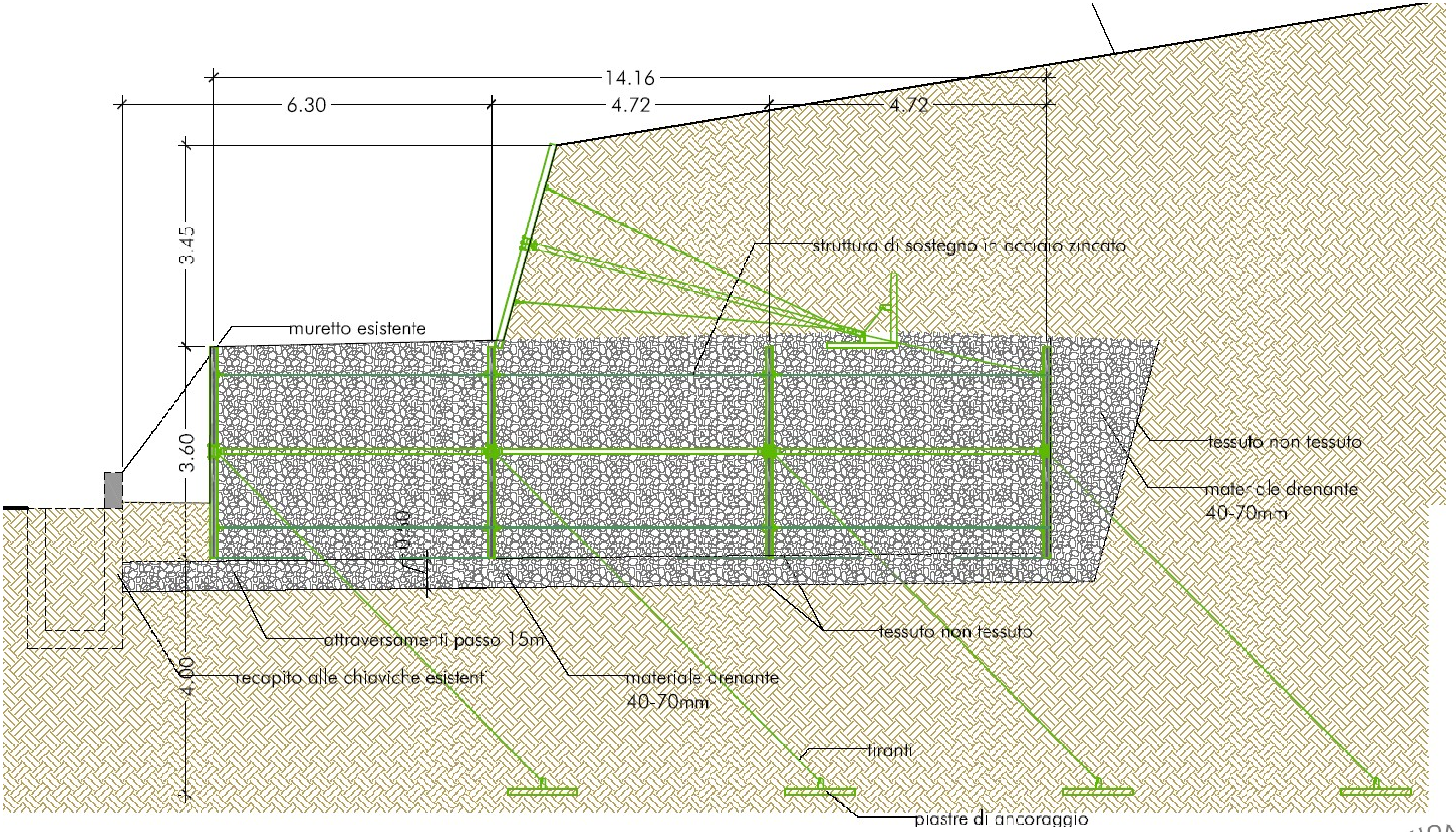
- **Toe buttressing**
- **Drainage**
- **Support and reinforcement**



Gabion toe drain and buttressing



Gabion toe drain and buttressing



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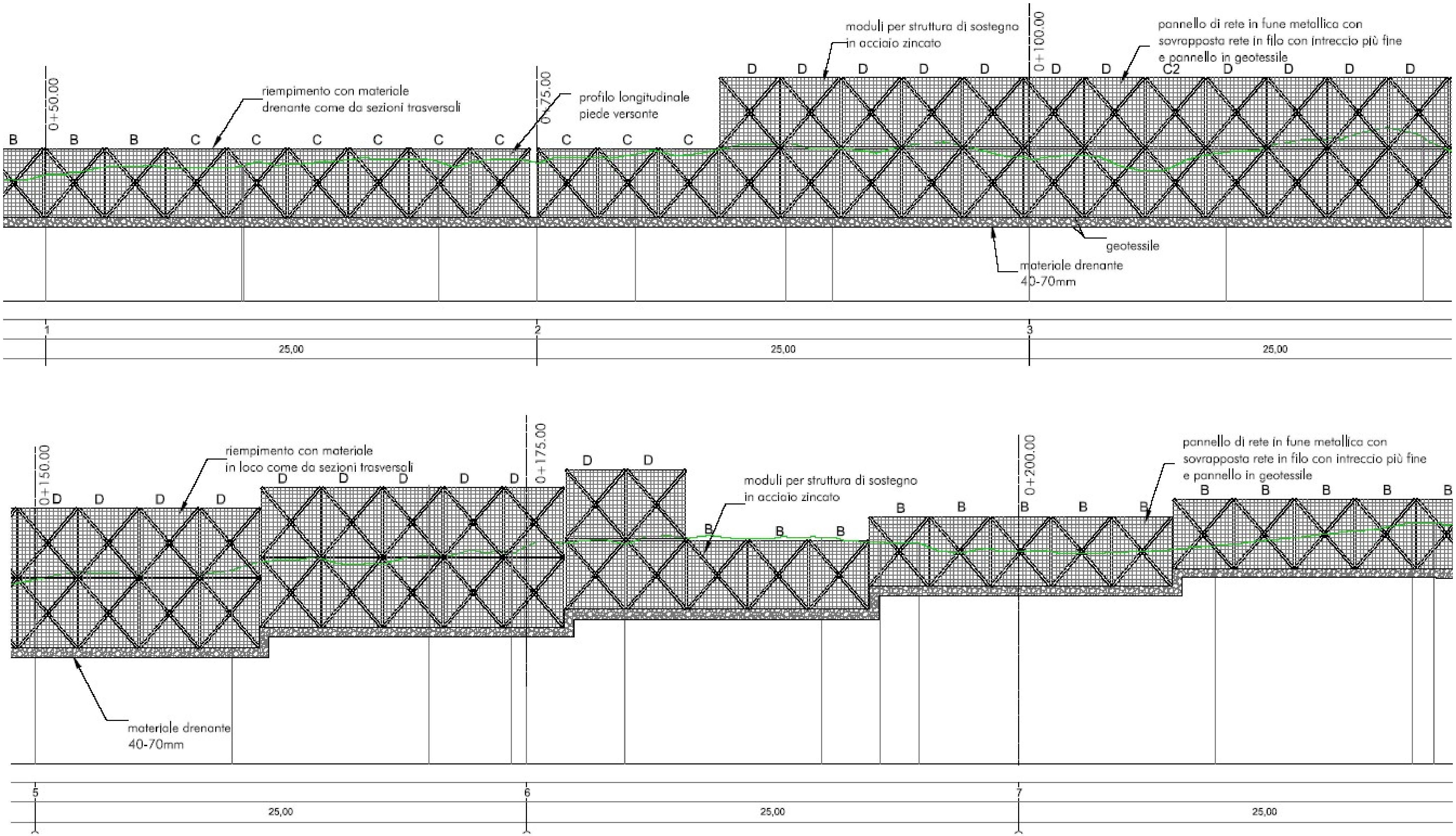
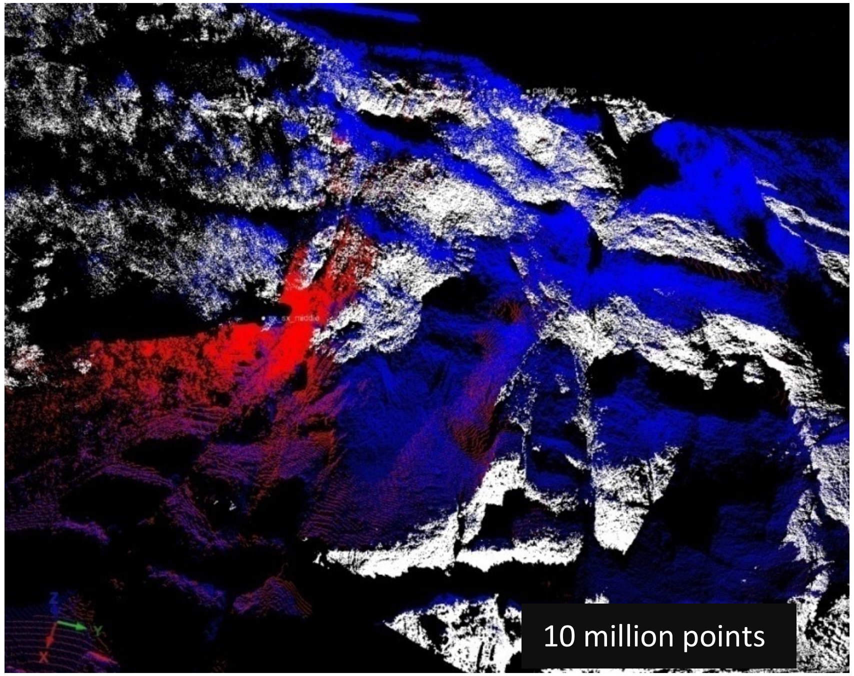
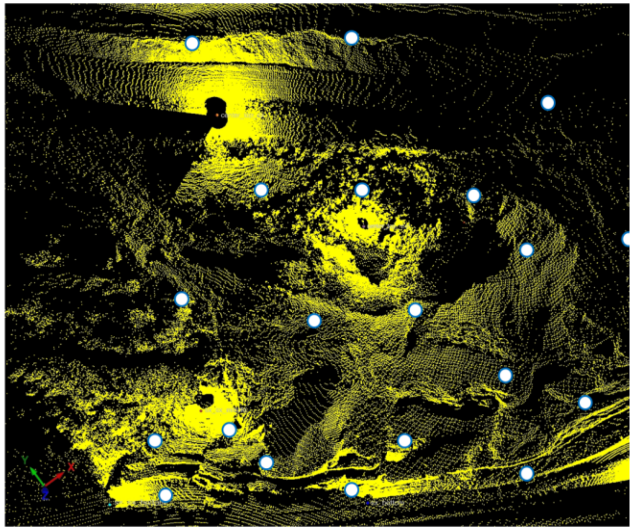
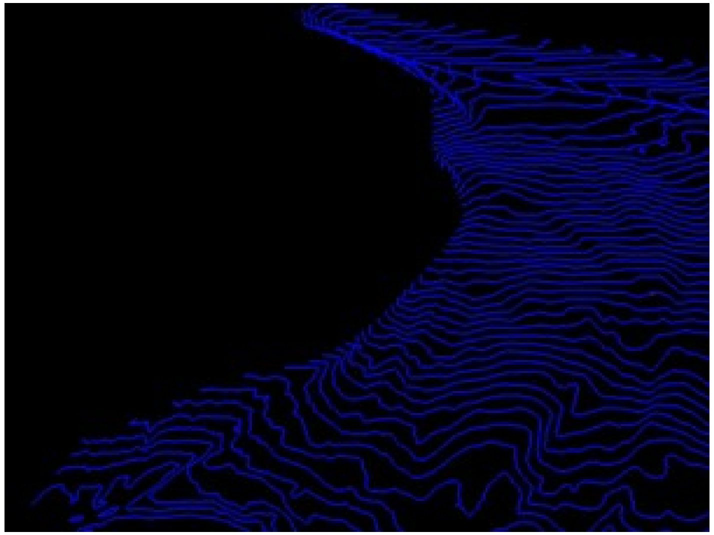
Gabion toe drain and buttressing

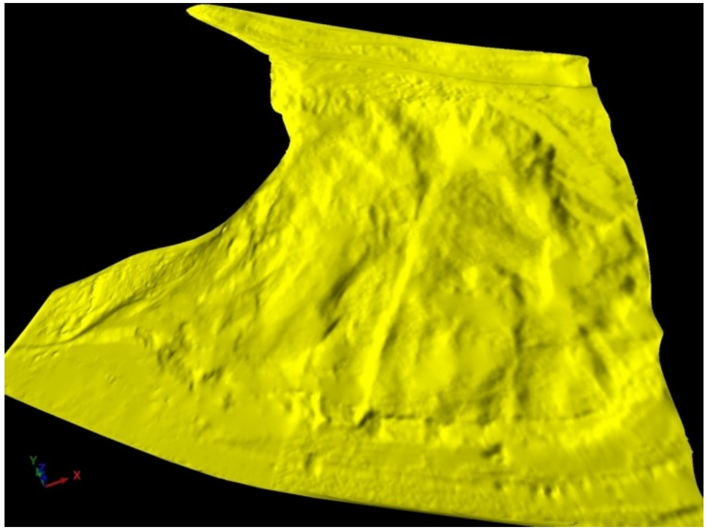


Laser Scanner of landslide foot

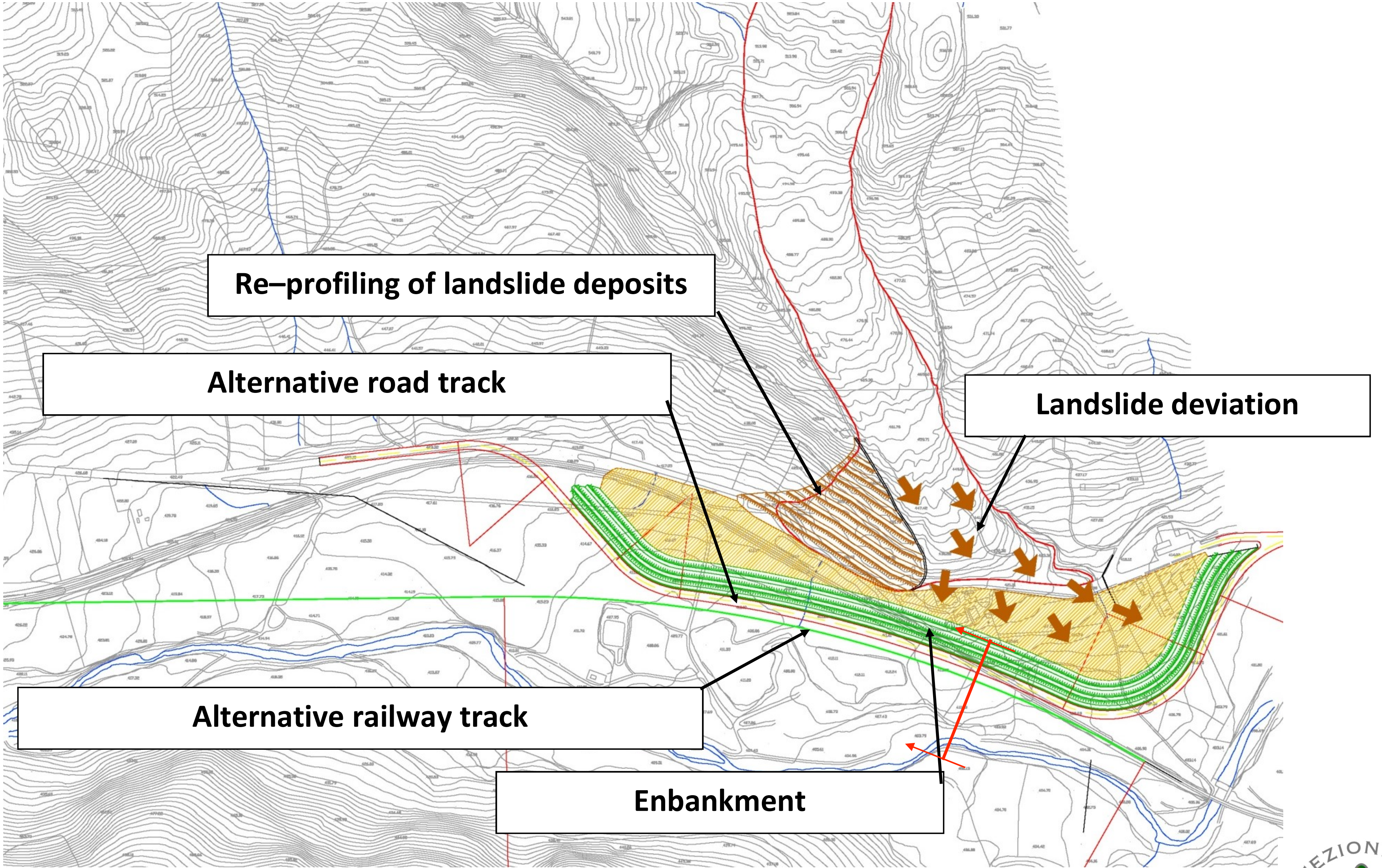




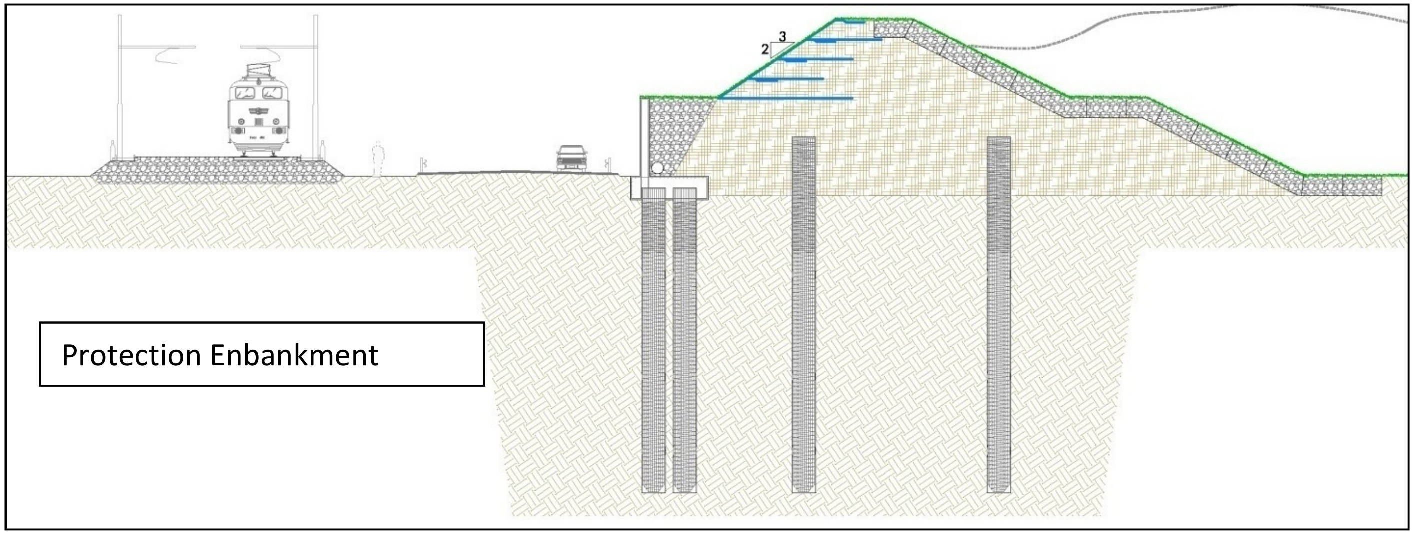


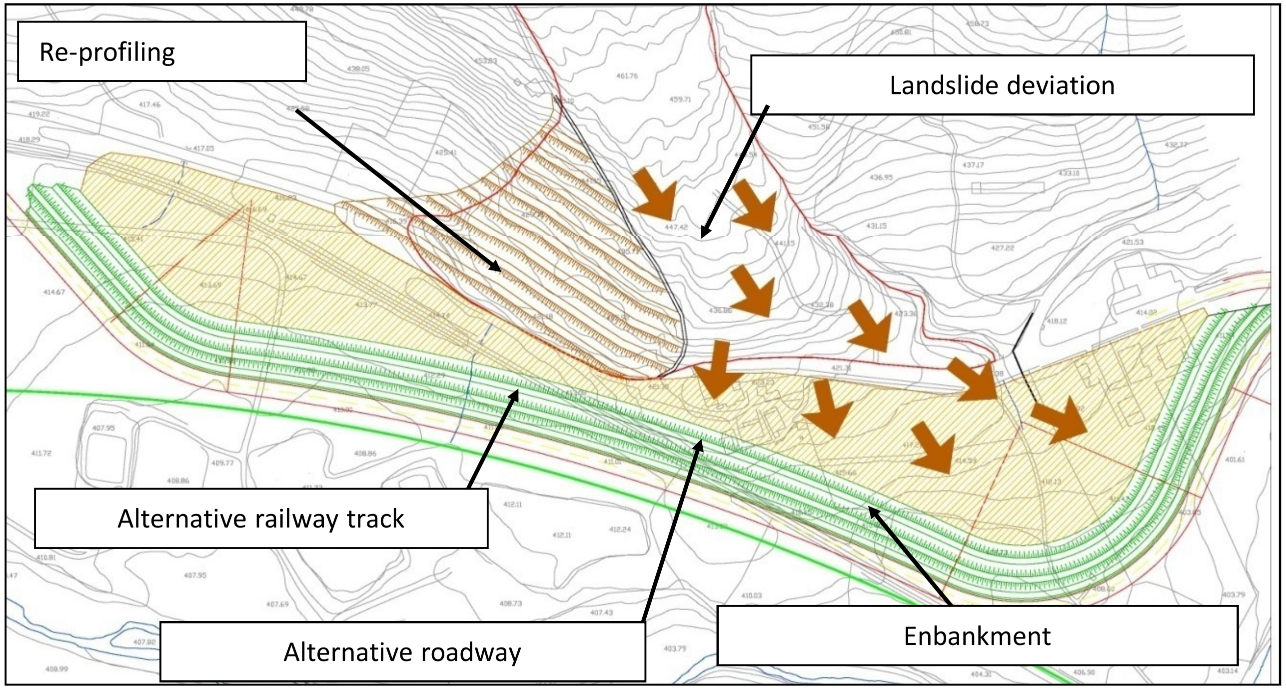


1st solution for infrastructure protection



Proposal for infrastructure protection (1st solution)





1. Profiling and landslide deviation

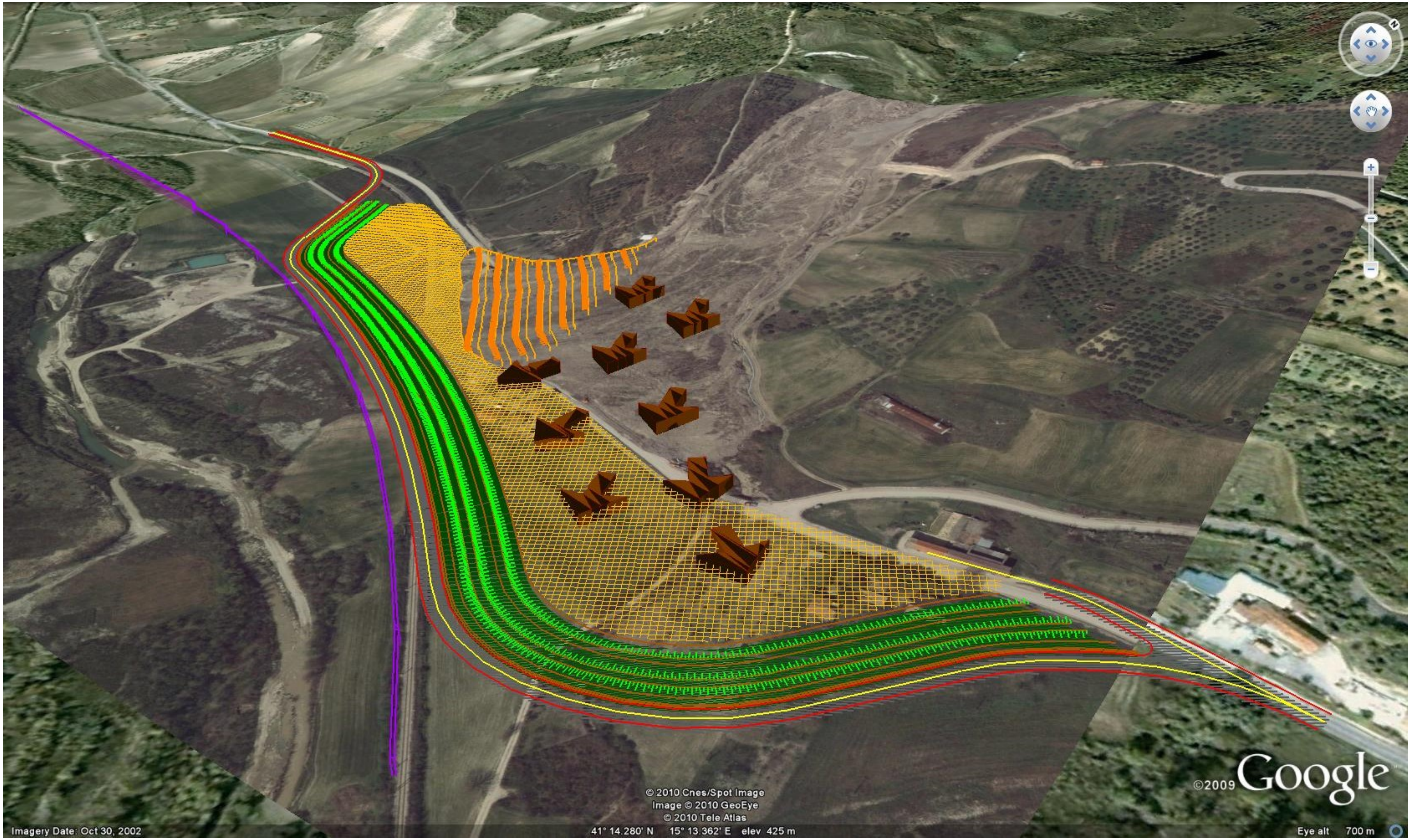
2. New railway track

INGEO

PROTEZIONE

3. Embankment

4. New road track



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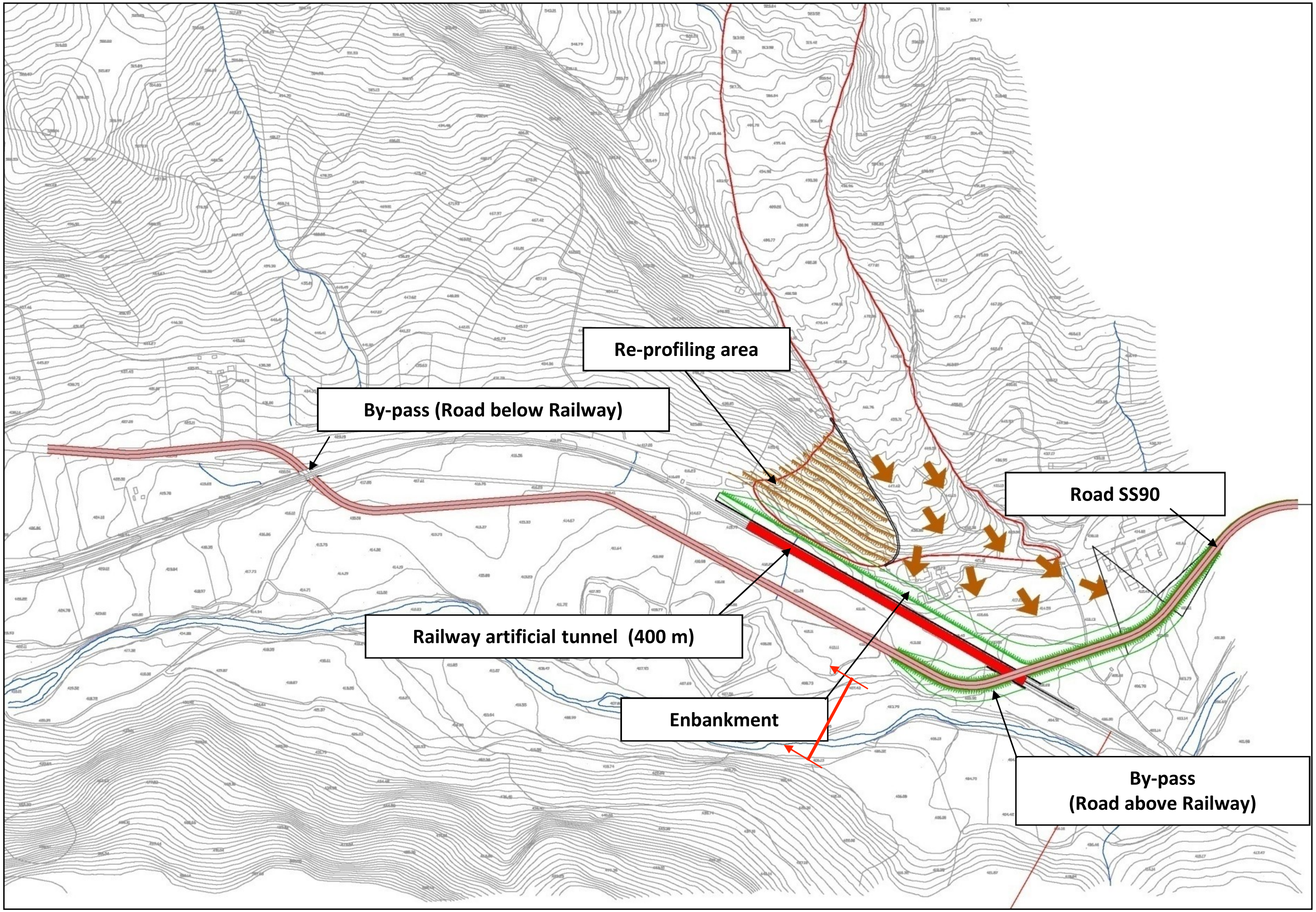
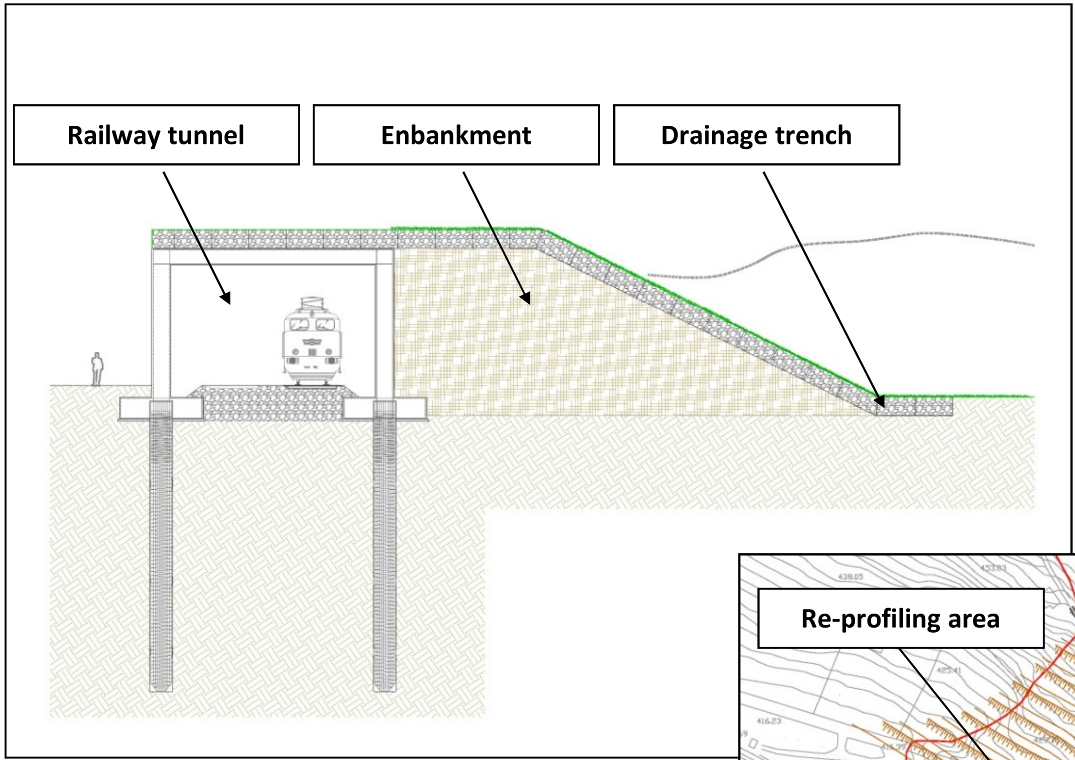
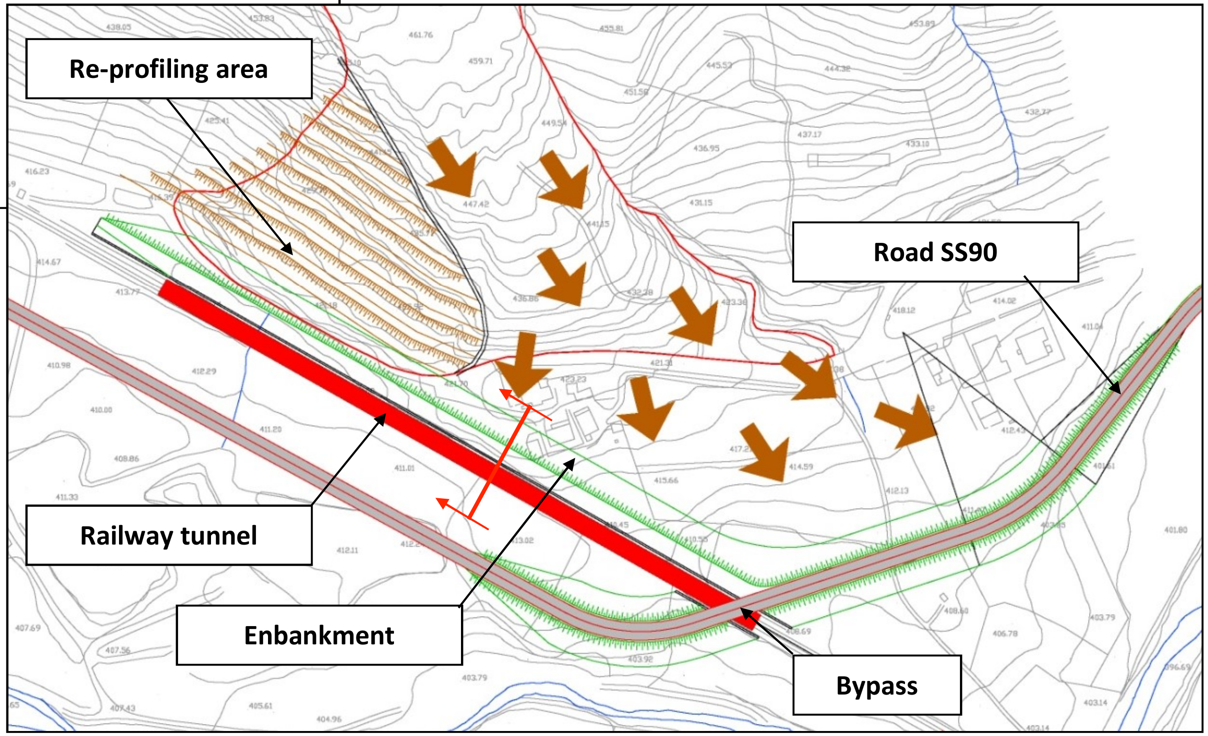
PROTEZIONE

2nd solution for infrastructure protection

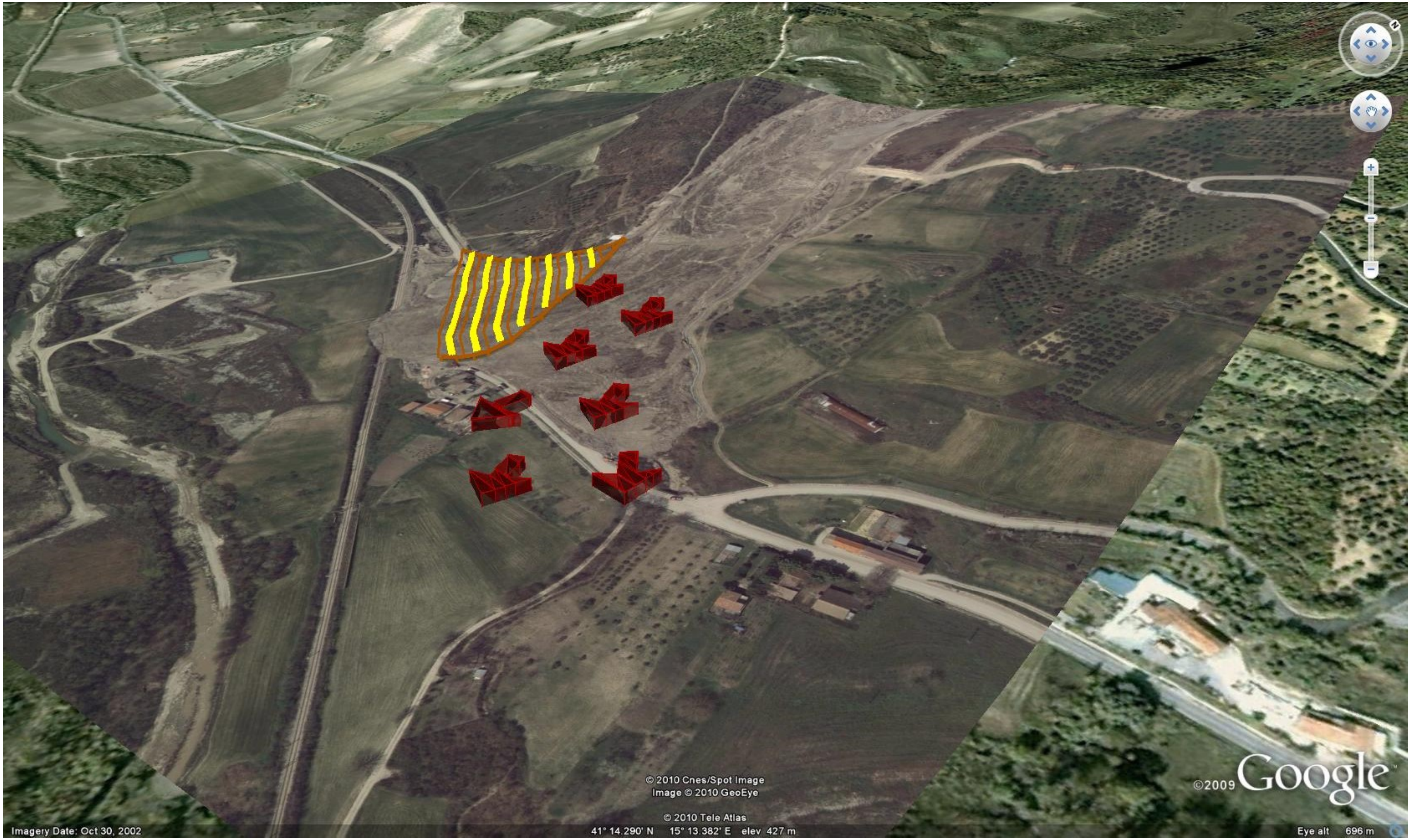


Proposal for infrastructure protection (2nd solution)





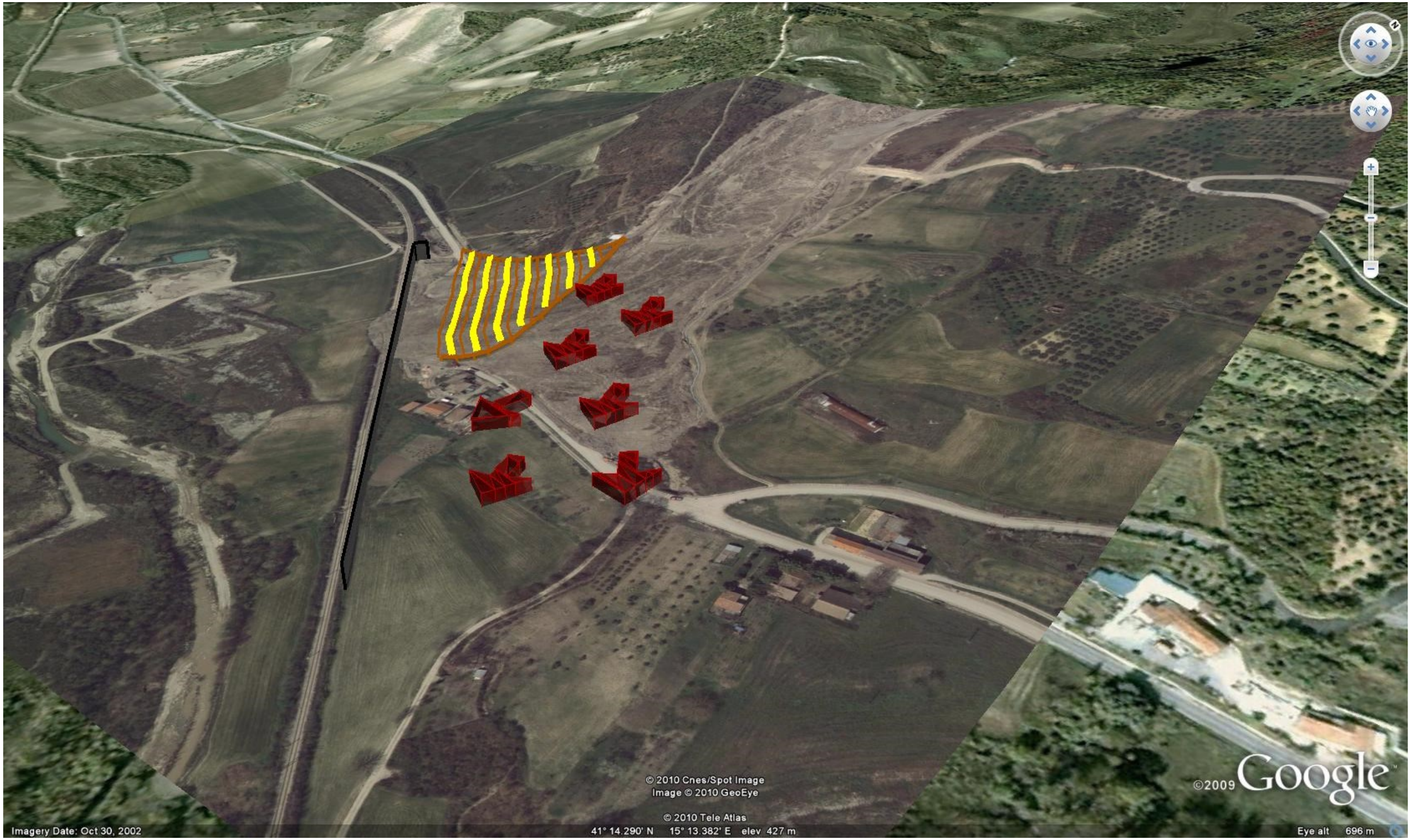
1. Profiling and landslide deviation



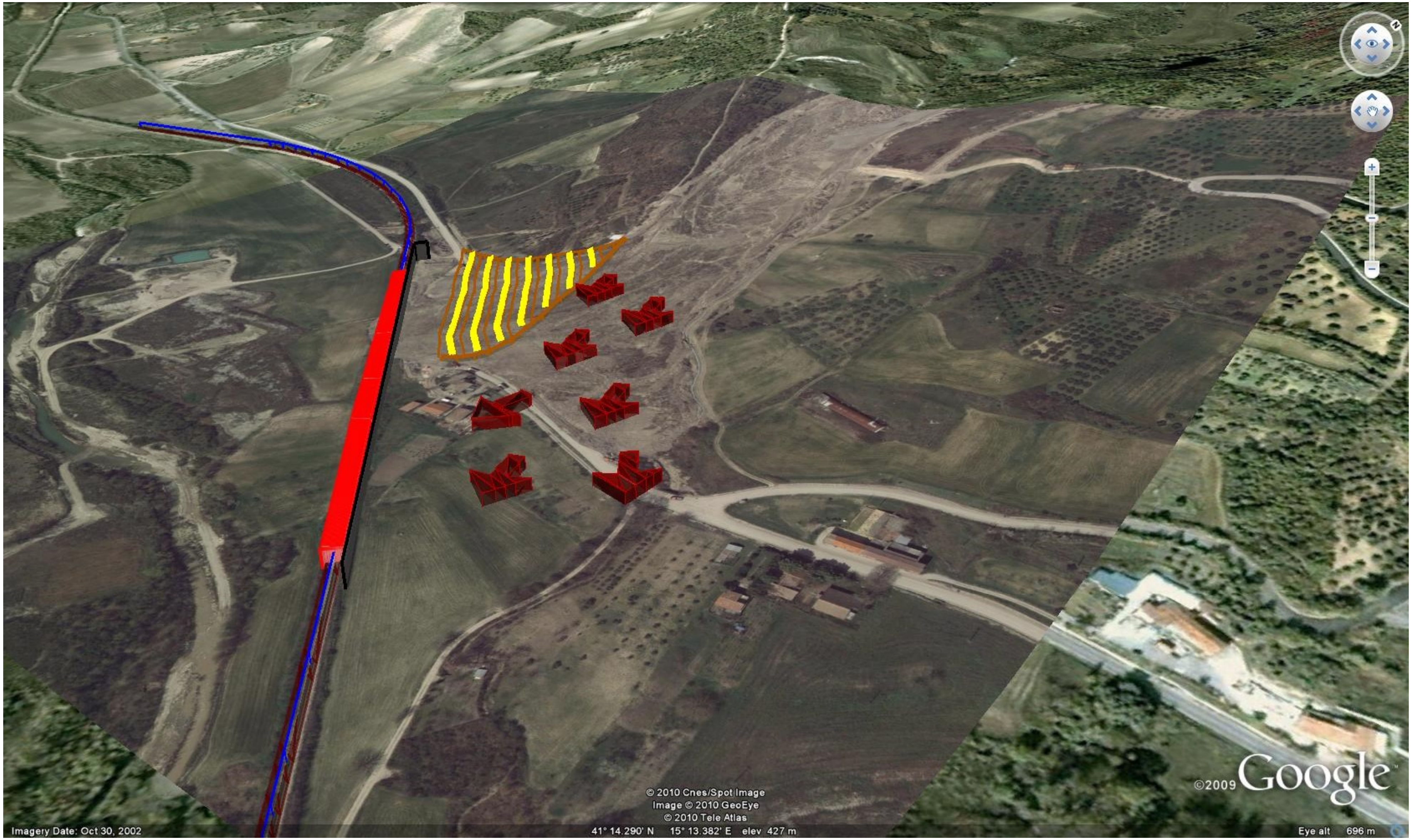
INGEO

PROTEZIONE

2. Railway protection wall



3. Artificial tunnel for the railway



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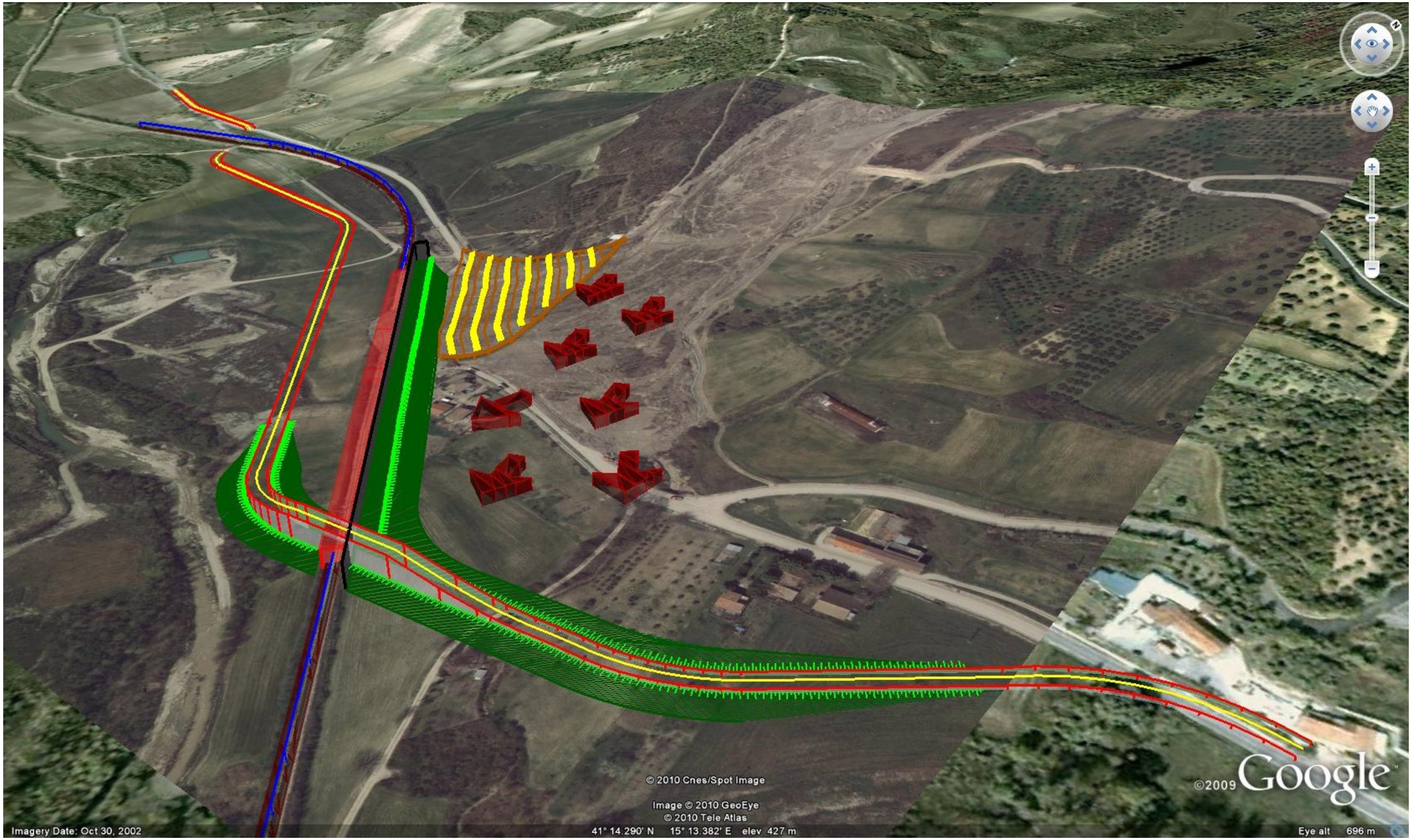
4. New road track



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16 months after

May 2010

September 2011

Recent works

2011-09-07

2011-09-10

Conclusion

- Support to emergency management
- Problem solution in less than 16 months
- Monitoring with new tecnologies for fast track diagnosis and design
- Continuous monitoring of the effectiveness of stabilization works
- Observational design method based on radar monitoring
- Landslide stabilization based on drainage and engineering solutions at low environmental impact
- Two solutions for the protection of the infrastructures in the valley bottom

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GB-InSAR monitoring and observational method for landslide emergency management: the Montaguto earthflow (AV, Italy)

Federica Ferrigno, Giovanni Gigli, Riccardo Fanti, Emanuele Intrieri, and Nicola Casagli

Department of Earth Sciences, University of Florence, Via La Pira 4, Florence, Italy

Correspondence to: Federica Ferrigno (federica.ferrigno@unifi.it)

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