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Acciano Rockfill Dam Seismic case history

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Rome, 06/02/2017



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Shaping a Better Energy Future

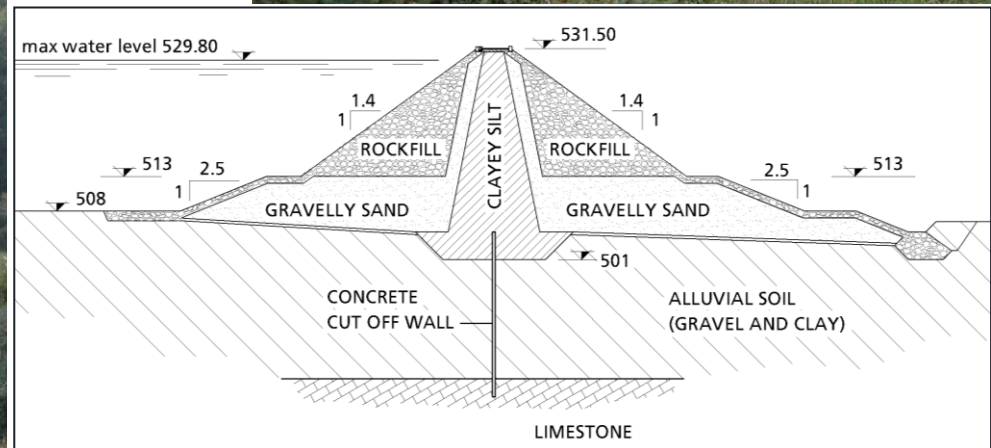
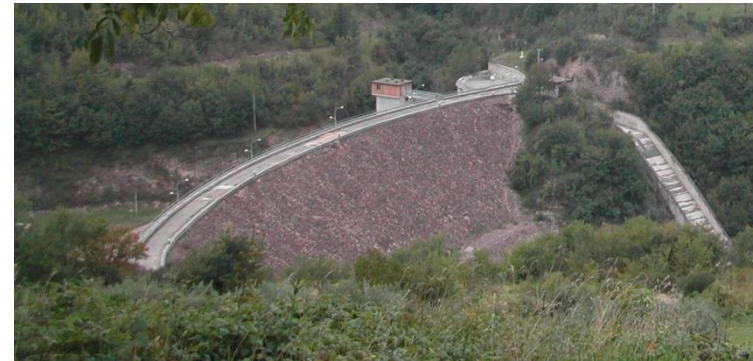
OVERVIEW

- The Acciano rockfill dam was originally designed without taking seismic action into account. The dam area (Central Italy – Umbria region) is now classified as seismic (PGA = 0.234g Tr=475y)
- On September 26th 1997, one of the largest seismic events of the last 20 years occurred in that area.
- Subsequent investigations and structural assessments were carried out to evaluate the safety condition.
- Proposal design solutions were carried out to rehabilitate the structure

MAIN FEATURES



Type = rockfill dam with clay core
Height = 29 m
Length of crest = 182 m
Reservoir capacity = 1.7 hm³
Built = 1976-1980
Owner = Consorzio Acquedotti Perugia



MAIN FEATURES



SEISMIC HAZARD AT DAM SITE

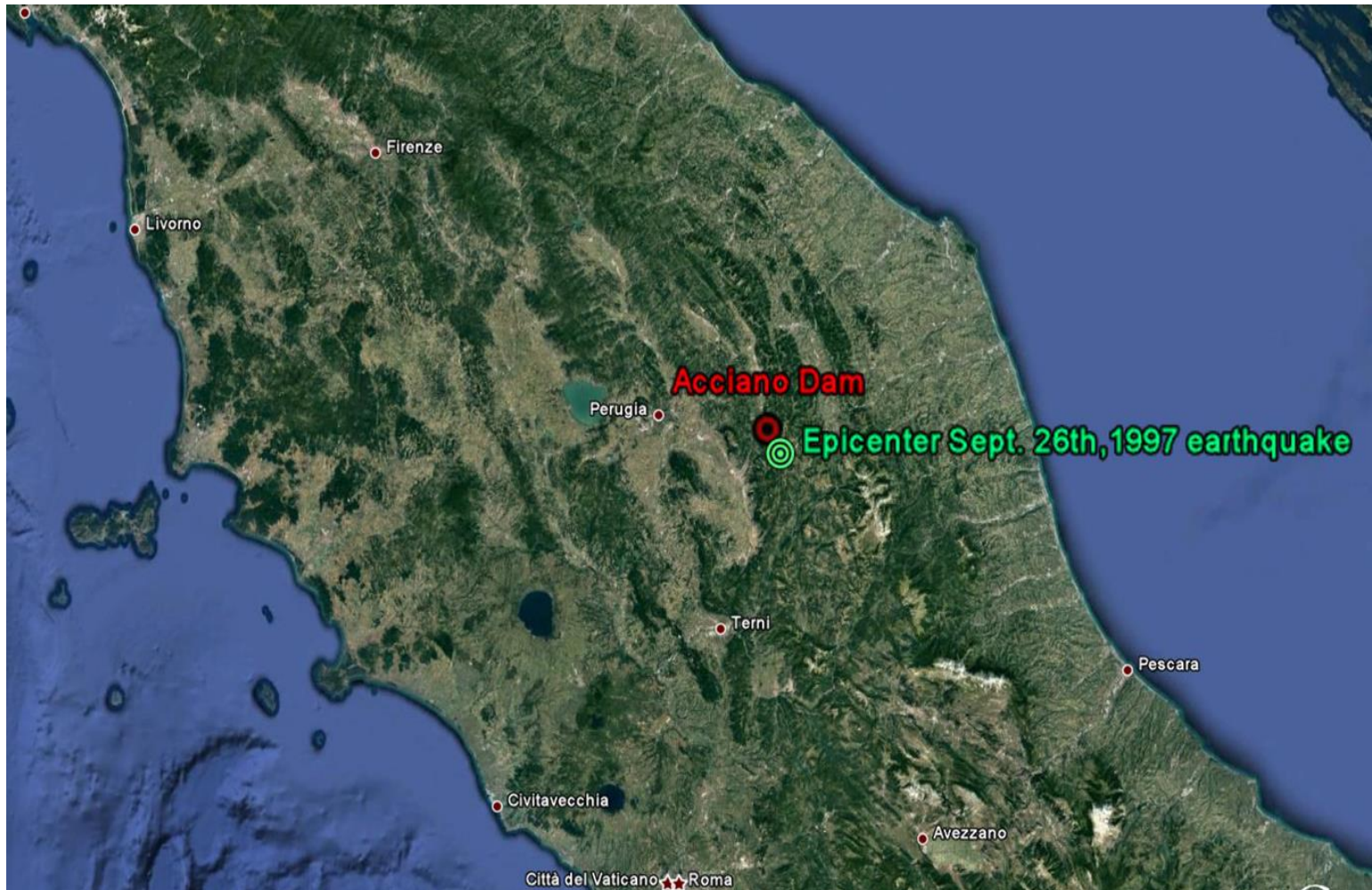
Earthquake with $M_L \geq 4$ occurred

<i>Date –Time (UTC)</i>	<i>Magnitude (Ml)</i>	<i>Epicentral distance (km)</i>	<i>PGA (g) at dam site</i>
26/03/1998 16:26	5,09	6,53	0,122
14/10/1997 15:23	5,43	21,90	0,059
06/10/1997 23:24	5,29	6,96	0,138
03/10/1997 08:55	5,05	4,99	0,138
27/09/1997 08:08	4,23	1,04	0,096
26/09/1997 09:40	5,75	8,51	0,159
26/09/1997 00:33	5,46	9,19	0,131
<i>PGA and Intensity at dam site computed with software RSD (by CESI)</i>			

September 26th 1997 →

max recorded
at Nocera Umbra
acc. station at
11 km from dam site:
N-S = 0,562g
E-W = 0,51g
Up = 0,46g

EARTHQUAKE –SEPTEMBER 26TH 1997



SEPTEMBER 26th, 1997 EARTHQUAKE

Damages: cracks at the dam crest and on the right bank

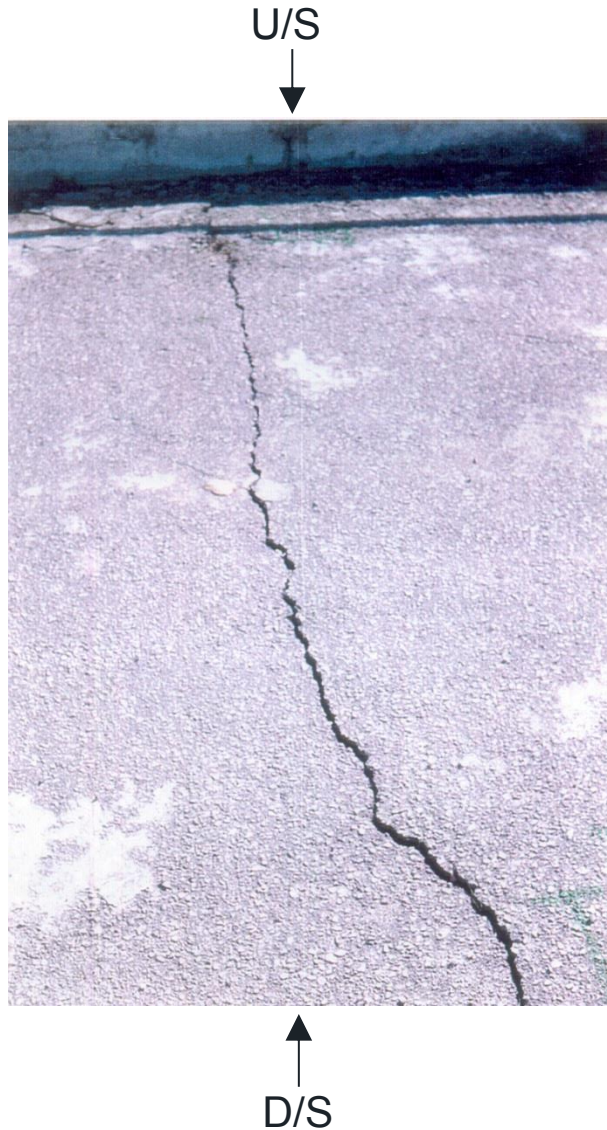
U/S
→

Detail



←
D/S

SEPTEMBER 26th, 1997 EARTHQUAKE

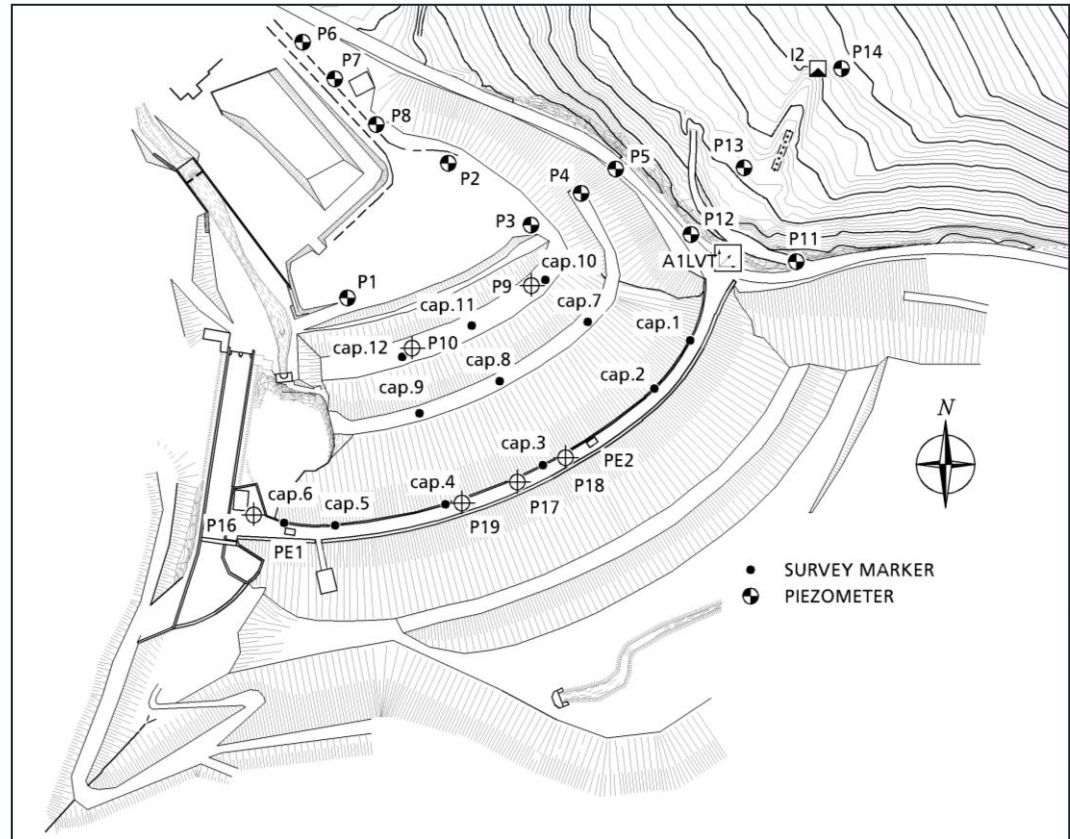


U/S
→



MONITORING SYSTEM

- Topographic collimation to observe:
 - upstream-downstream displacement
 - settlement at the crest and at the downstream berms
- Casagrande piezometers placed downstream respect to the dam body and into the right foundation rock

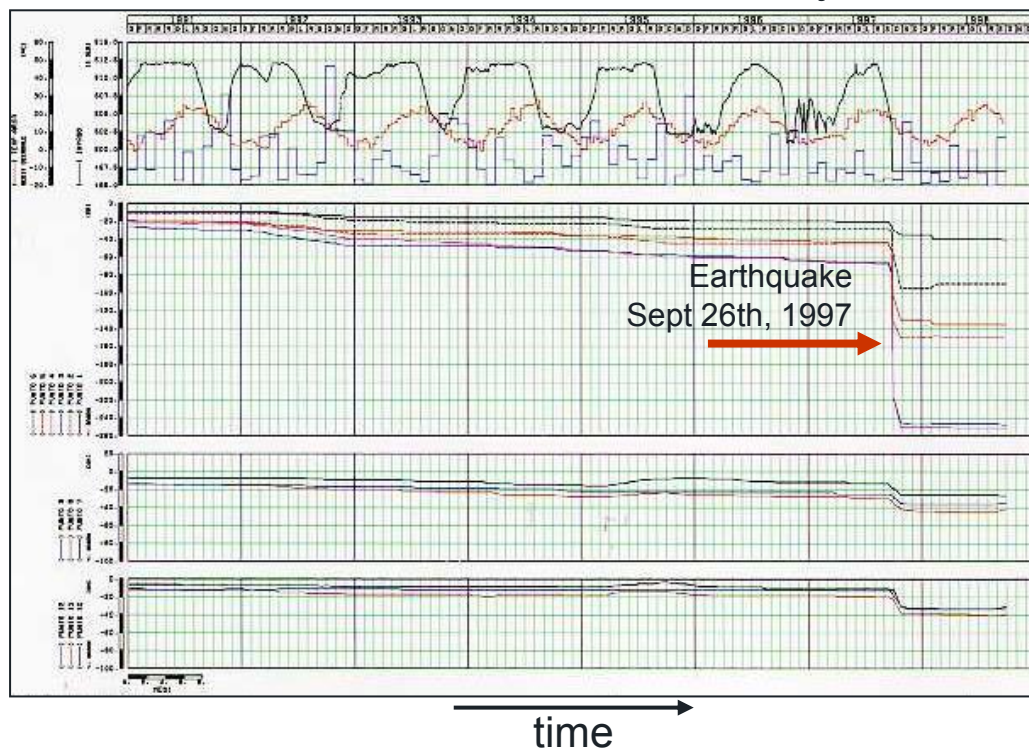


SEPTEMBER 26th, 1997 EARTHQUAKE

Vertical displacement [mm]

1, 2,

7 years



Marker		from jan 1986 to sept,26 1997	After Earthquake	%
Crest	P1	-25	-16	64
	P2	-51	-84	165
	P3	-77	-171	222
	P4	-74	-177	239
	P5	-52	-97	187
	P6	-32	-58	181
Berm 1	P7	-18	-9	50
	P8	-32	-10	31
	P9	-26	-9	35
Berm 2	P10	-13	-18	138
	P11	-22	-17	77
	P12	-15	-18	120

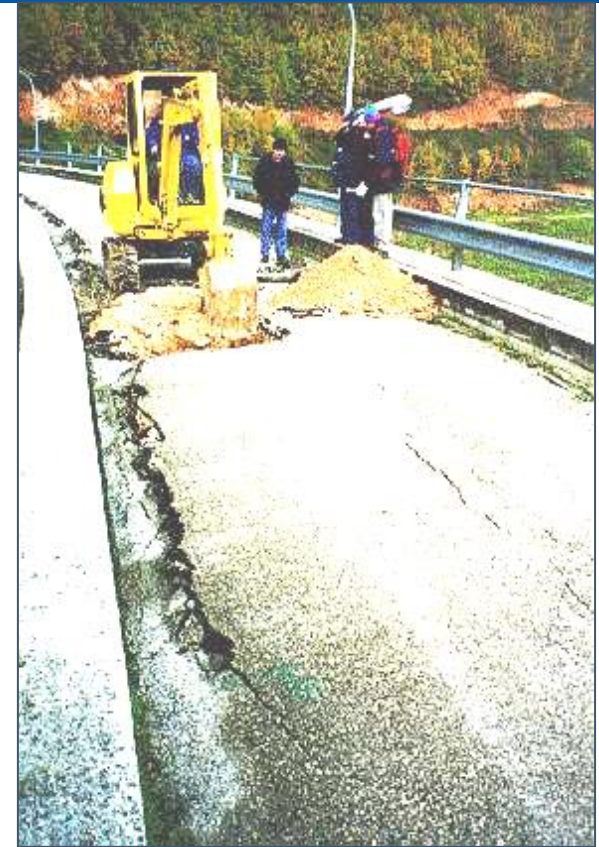
MAIN ISSUES INVESTIGATED AFTER EVENT

- Identification of damage in dam core
- Seismic stability of dam
- Risk assessment of right bank failure
- Post earthquake water tightness
- Level of upgrading works required



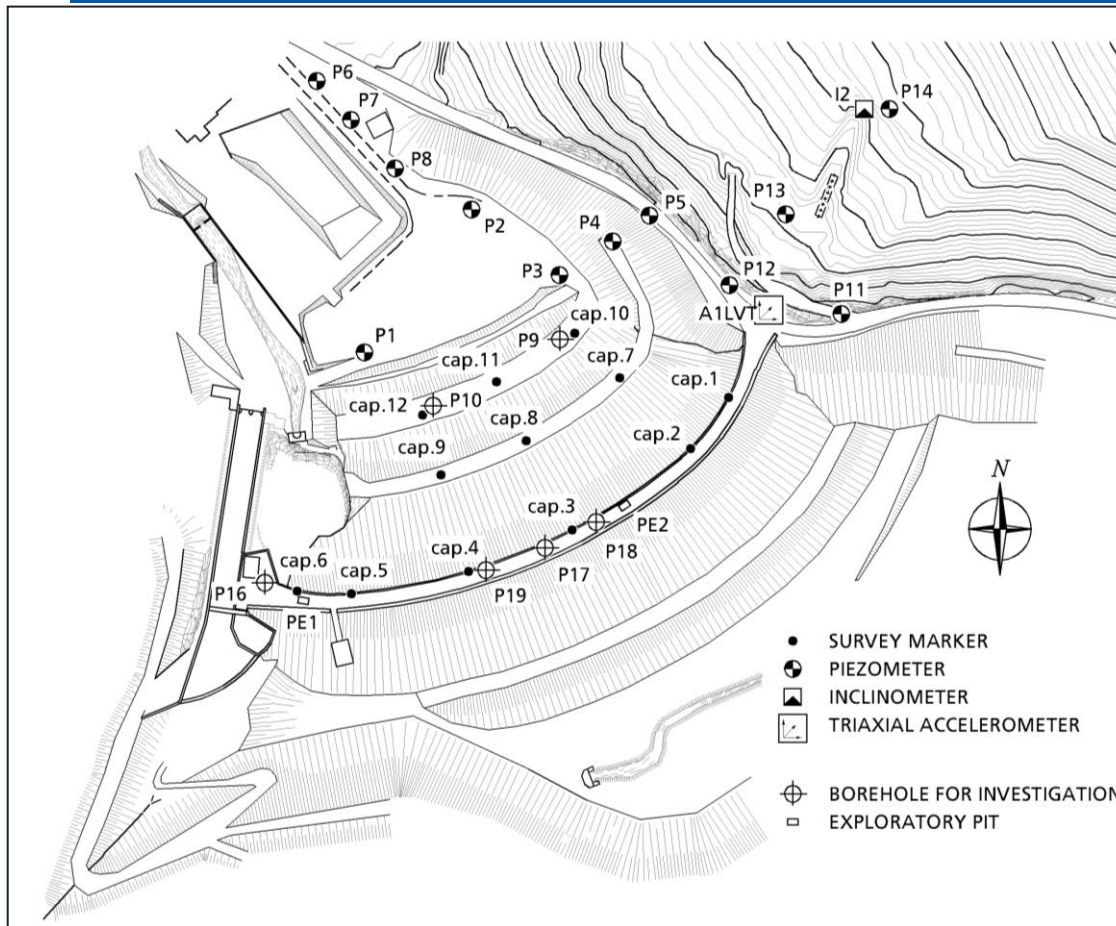
Preliminary activities

- Dam inspection and activity planning
- Geological survey
- Geotechnical investigation of dam – core and foundation materials



The damage is confined to the crest of the dam

GEOLOGICAL AND GEOTECHNICAL SURVEY



Borings:

N.4 on the crest,
N.2 on the d/s berm.

Exploration pits:

N.2

Field tests:

SPT,
Lugeon,
Lefranc.

Lab tests:

N. specimens= 40

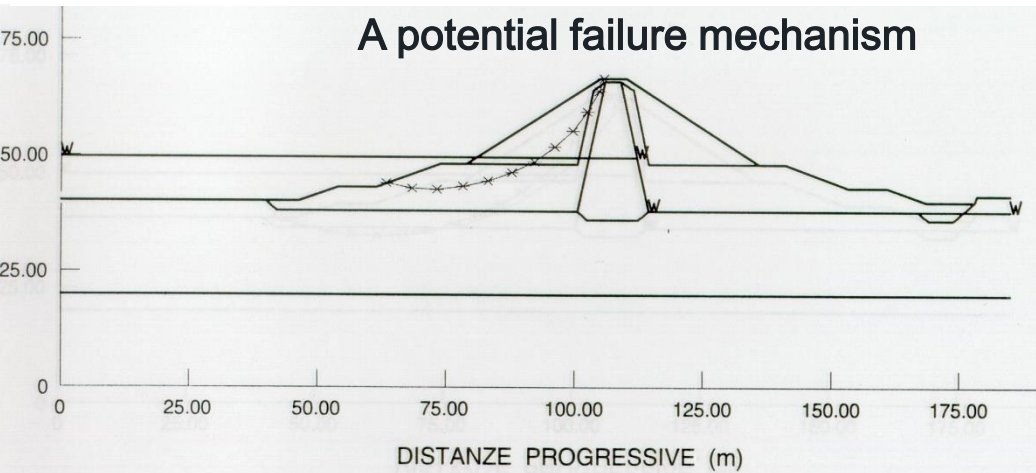
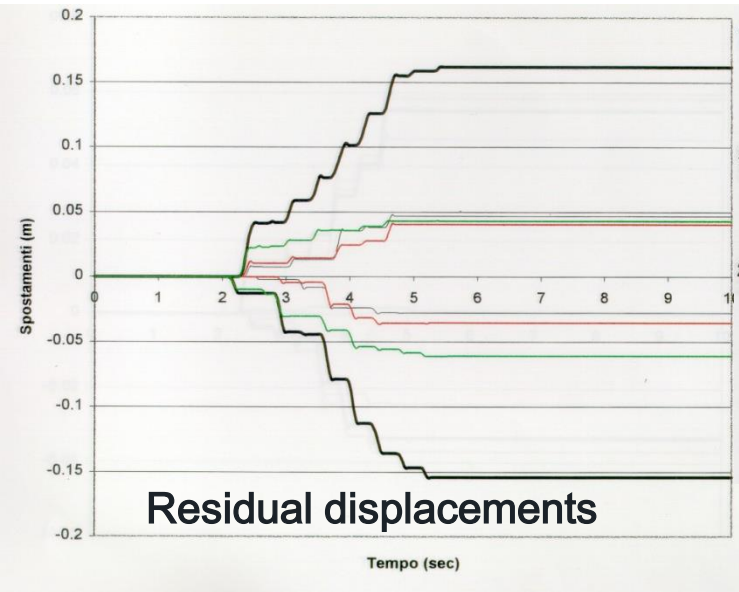
N.tests= 131

Triaxial (cons.drained and
undrained),
Direct permeability,
Oedometer,
Resonant column

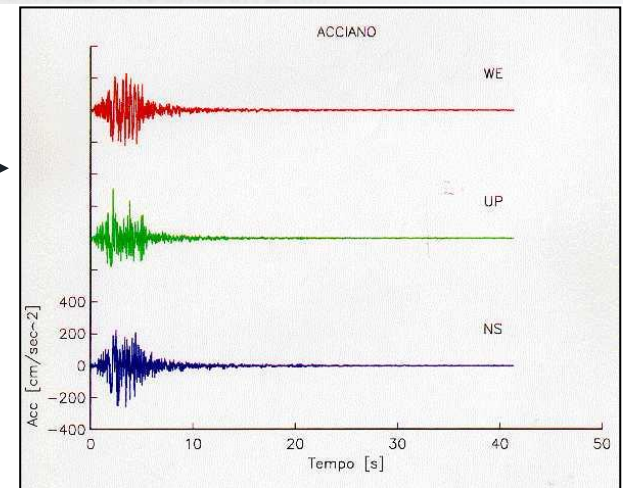
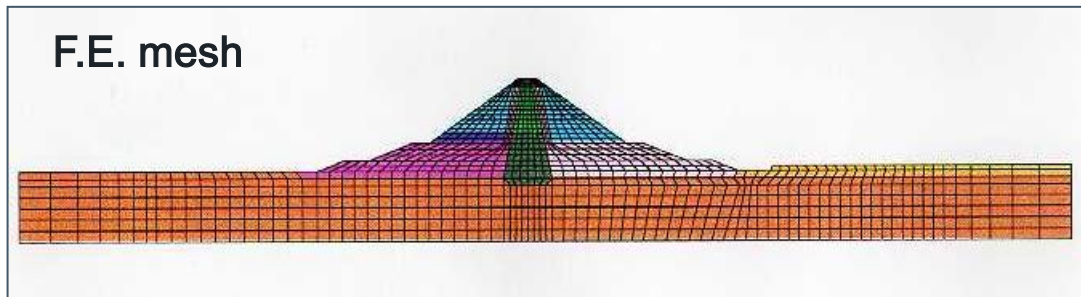
The stiffness and strength are suitable and consistent in order to represent characteristics for new design. The cumulative damage is moderate, and concentrated on the crest area.

SEISMIC STABILITY ANALYSIS

Limit equilibrium and FEM dynamic analyses in support of design proposal



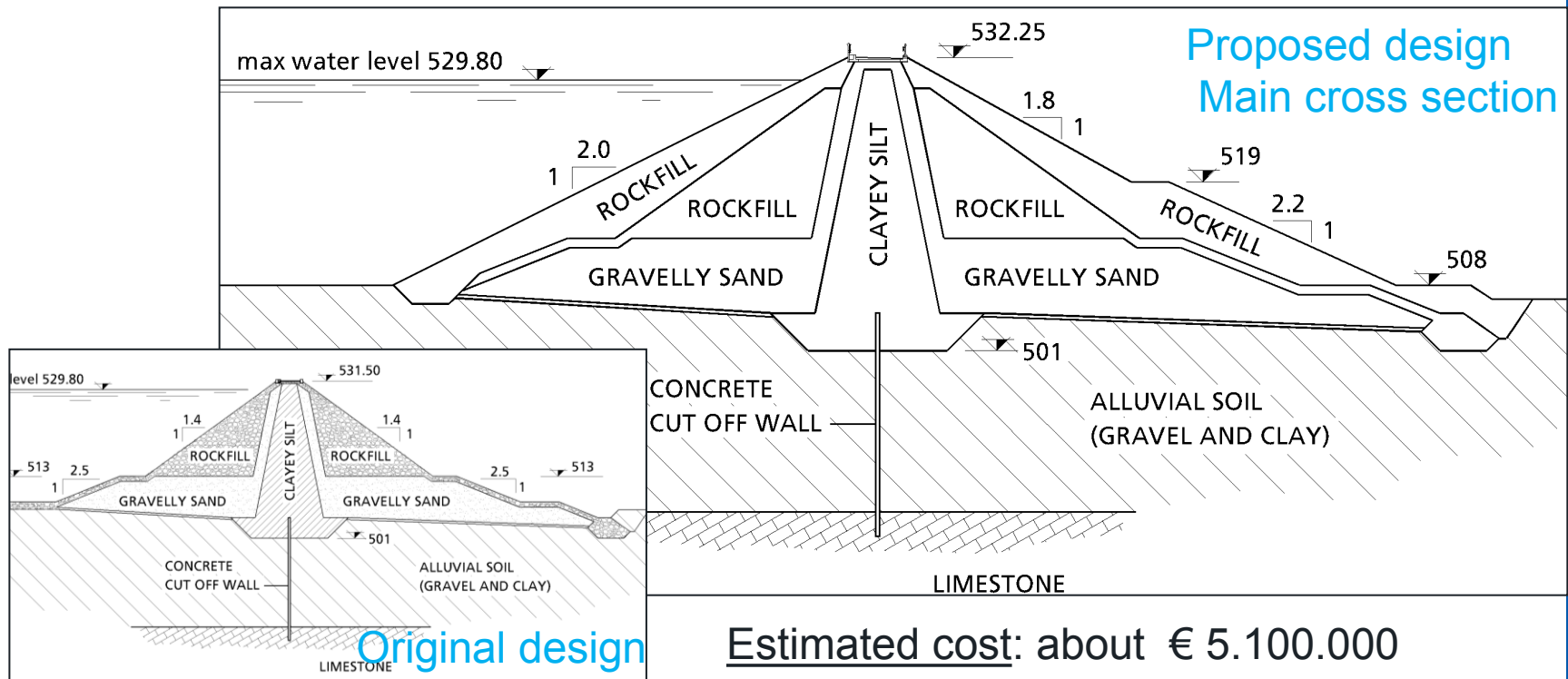
September 26th 1997 Input at dam site



DESIGN PROPOSAL (2006)

Solution 1

- New slope geometry for seismic aspect
- Rebuilding a small portion of the top of core (increasing freeboard)
- Foundation reinforcement work for seepage (grouting)

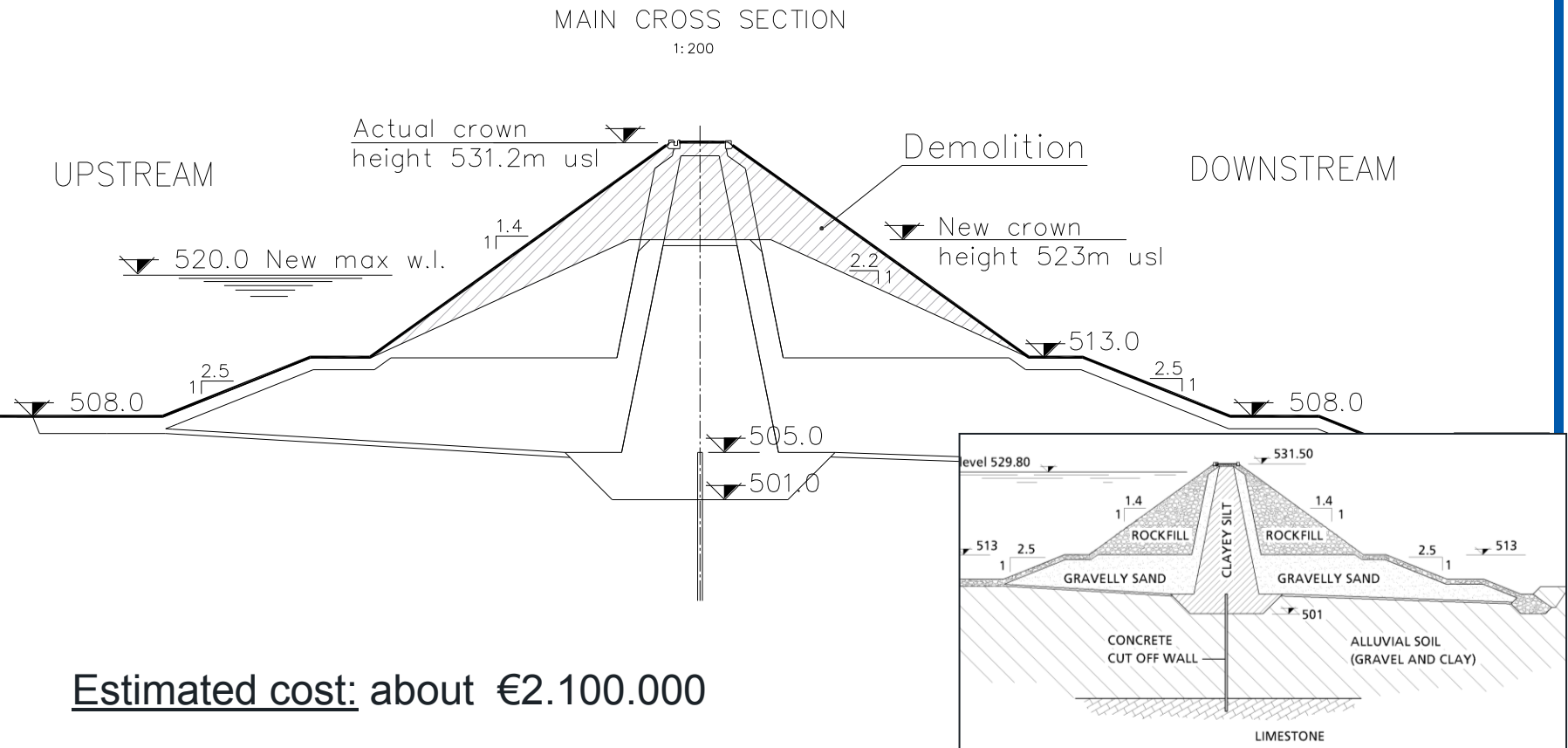


DESIGN PROPOSAL (2006)

Solution 2 (adopted by the Owner)

Downgrading to “small” dam with volume of reservoir: 650.000 m³

(For Italian Dam Code: High dam: $H \geq 15\text{m}$ or Volume of reservoir $\geq 1.000.000 \text{ m}^3$)



Estimated cost: about €2.100.000

THANK YOU
FOR YOUR ATTENTION!!

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