Dam Health Check & Monitoring Using Advanced Tools of Geophysics- Indian Experience

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Managing Director, PARSAN

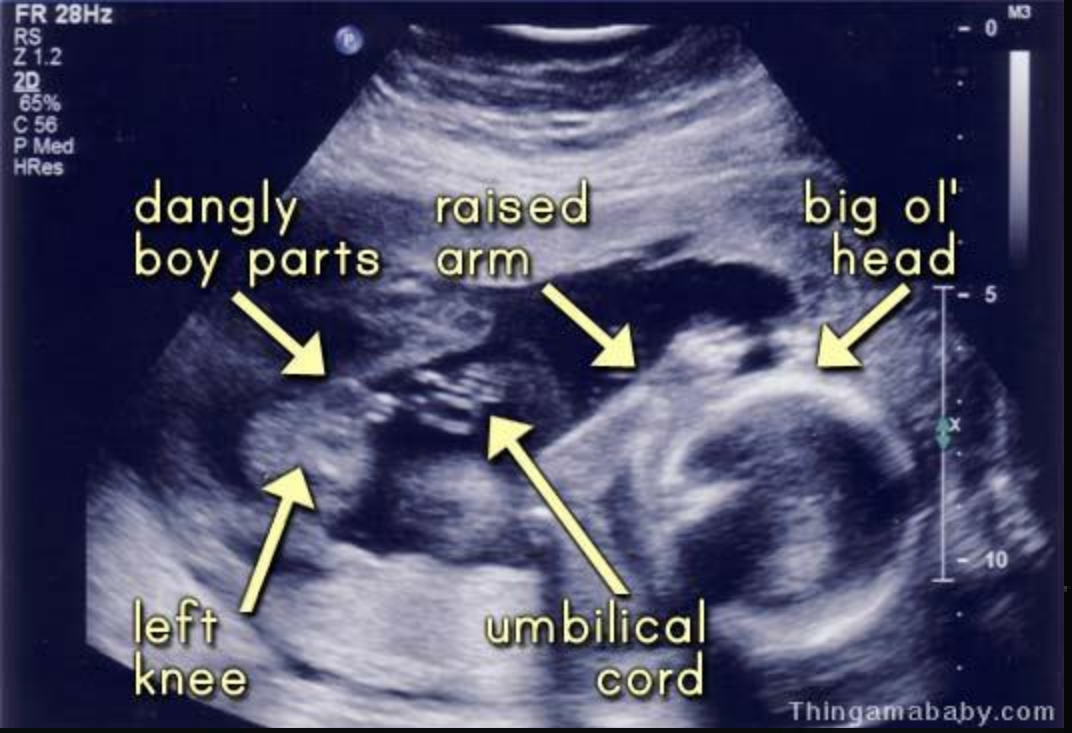
About PARSAN

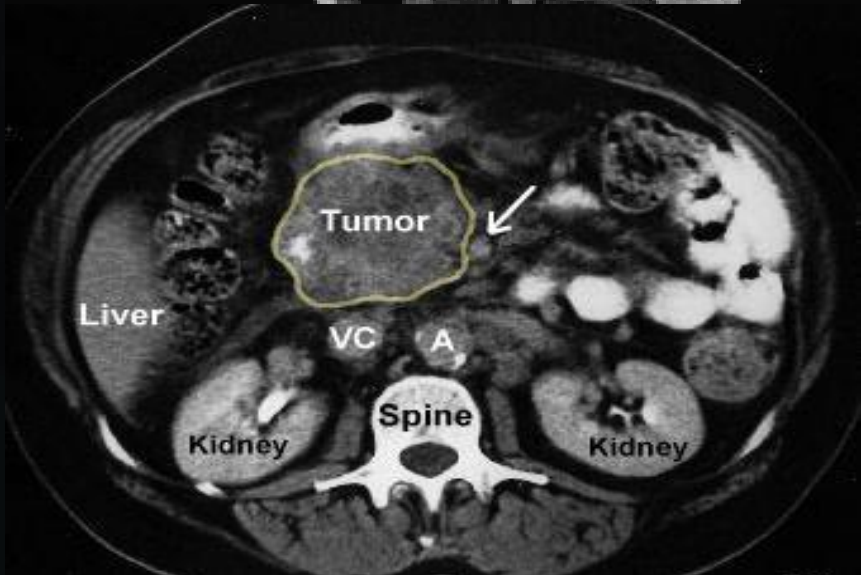
- Only company in India providing complete dam geophysical solutions (>80 dams investigated)
- Highly experienced and trained staff.
- Offices in Delhi, Bhopal, Kolkata, Bahrain, Saudi Arabia.
- Work experience in India, Nepal, Bhutan, Bangladesh, Singapore, Oman, Afghanistan, Saudi Arabia, Bahrain, Kuwait…….

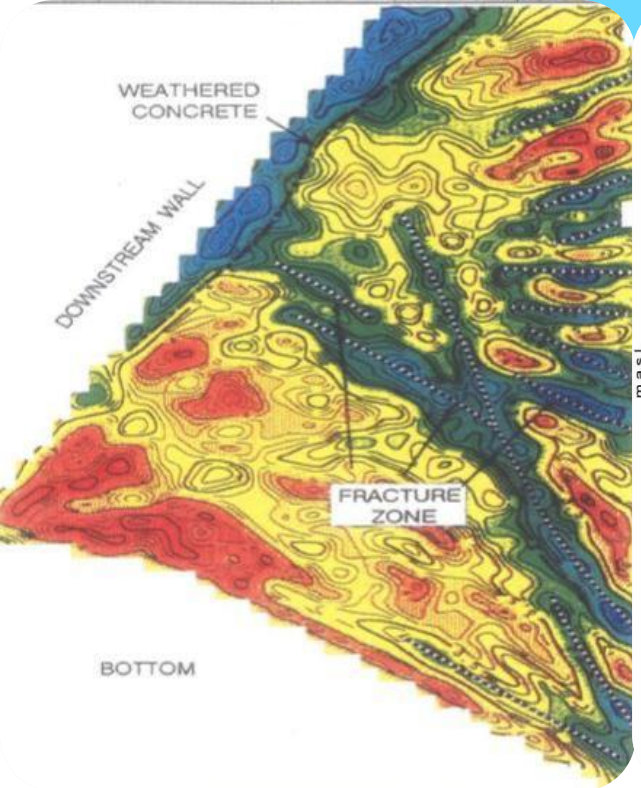
About Speaker

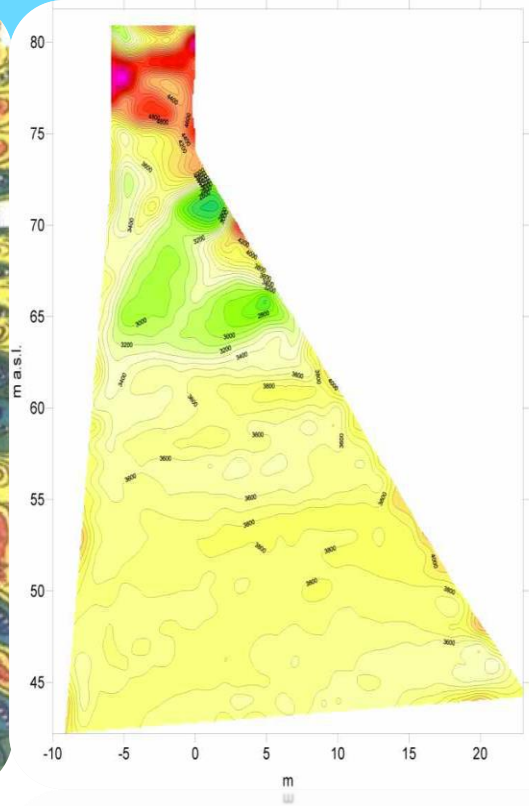
- Professional Geophysicist, with **32 years** of work experience.
- **Gold Medalist**, University of Roorkee (Now IIT-Roorkee)
- Member of various working committees for development of Code of Practices and Standards, **including IRC, BIS**.
- Have conducted 128 training programs on Geophysics for various companies in 9 countries.
- Successfully used integrated geophysical approach for investigations across flowing rivers & for dam safety
- Geophysical investigation of Dams- **>100 dams**

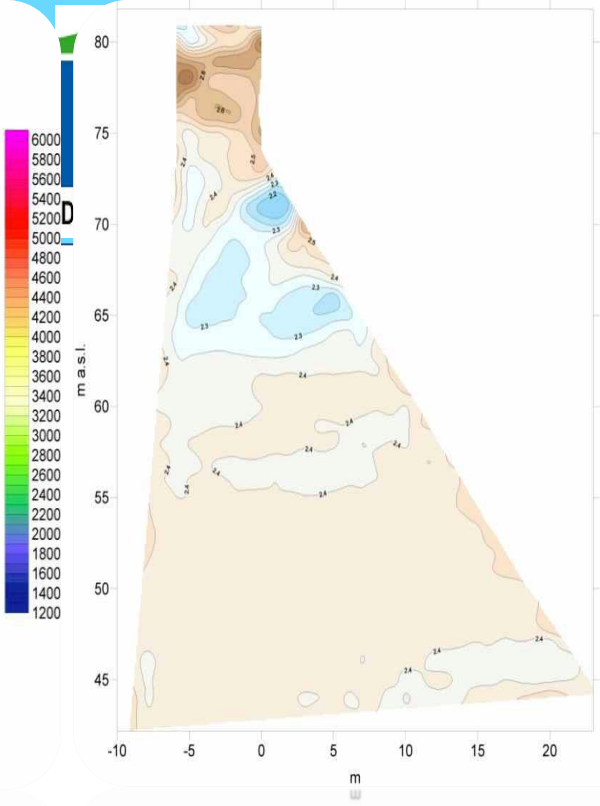
Geophysical Investigations……


FR 28Hz
RS
Z 1.2
2D
65%
C 56
P Med
HRes
M3
dangly boy parts
raised arm
big ol' head
left knee
umbilical cord
Thingamababy.com

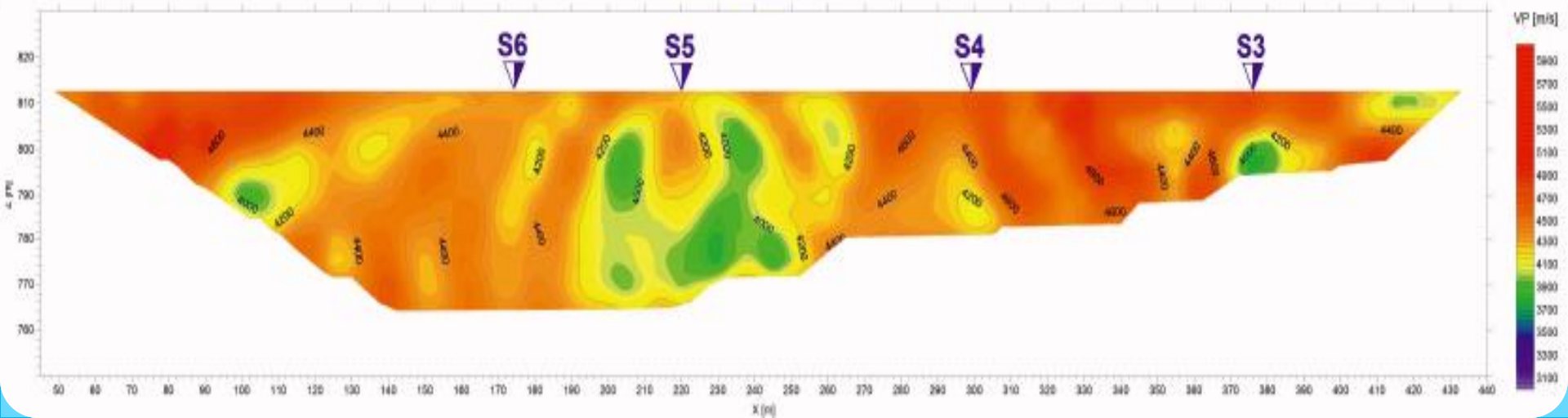

Tumor
Liver
VC
A
Spine
Kidney
Kidney







Velocity MAP



Dam Investigations

Current Inspection Practice

- Surface only
- Inspector Dependent
- Standards?

Why Geophysics for Dams Checks?

- Regular non-destructive health checks of dams
- Early detection of problems
- Helps design rehabilitation programs better and accurately
- Helps assess success of rehabilitation measures undertaken

⇨ More information + Low Cost + Quick

Geophysics presents a viable option to conduct scientific inspection & investigations of more than 5,500 specified dams within next 5 years as stipulated in Dam Safety Act 2021

⇨ More information + Low Cost + Quick

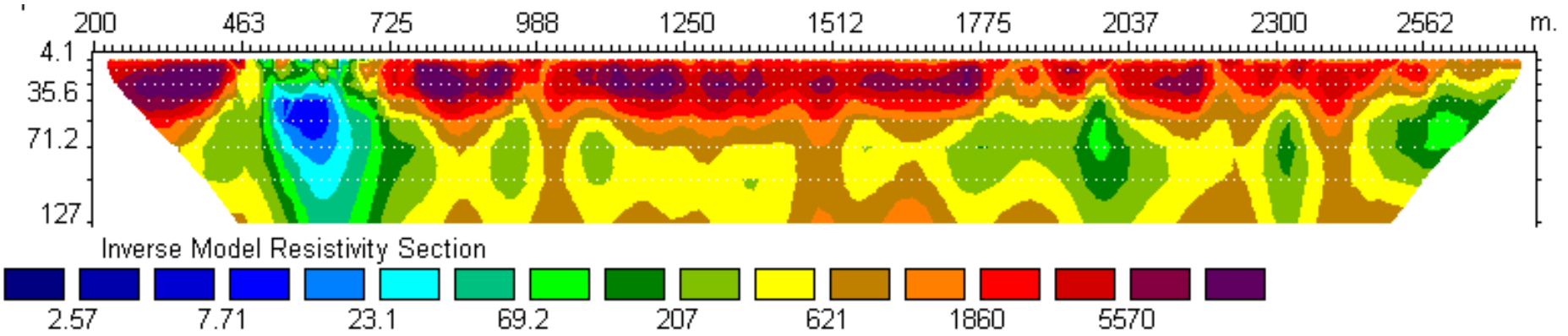
Which Technique/ Tool?

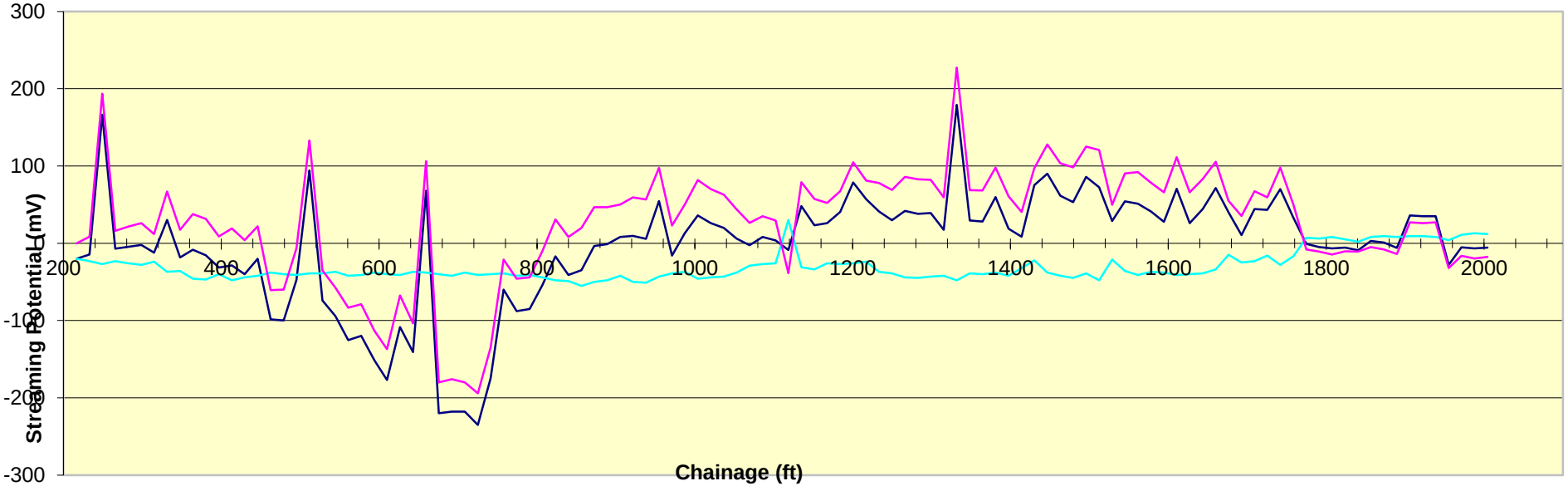
- Objective of Investigation
- Resolution required
- Depth penetration required
- Physical property to be defined
- Geometry of Dam
- Nature of target & host material

GEOPHYSICAL METHODS	ISSUES AND CONCERNS						
	CONCRETE DAM		EARTH EMBANKMENT DAMS			MASONRY DAMS	
	CRACKS	DEGRADATION	WATER LEAKS	LANDSLIDE	SINK HOLES	WATER LEAKS	STRENGTH
Electrical Resistivity			■	■		■	
Streaming Potential			■	■		■	
Georadar	■	■	■	■	■	■	
Radar Tomography	■	■	■		■	■	
Seismic Tomography	■	■	■		■		■
Seismic Refraction			■			■	■
ReMi		■		■			■

Problem- Leakage/ Seepage?

- Presence of water/ moisture primarily changes conductivity of dam material..
  - **Electrical Resistivity Imaging**
- It is also necessary to differentiate between saturated zones and zones through which active seepage/ leakage is taking place .
  - **Streaming Potential**
- Dams crest can have embedded man made objects; pipes, cables etc., and their location must be known to interpret Electrical and SP data.
  - **Ground Penetrating Radar**


200
463
725
988
1250
1512
1775
2037
2300
2562
m.
4.1
35.6
71.2
127
Inverse Model Resistivity Section
2.57
7.71
23.1
69.2
207
621
1860
5570


300
200
100
-100
-200
-300
Streaming Potential (mV)
200
400
600
800
1000
1200
1400
1600
1800
2000
Chainage (ft)

Problem- Detailed Analysis of Dam Section?

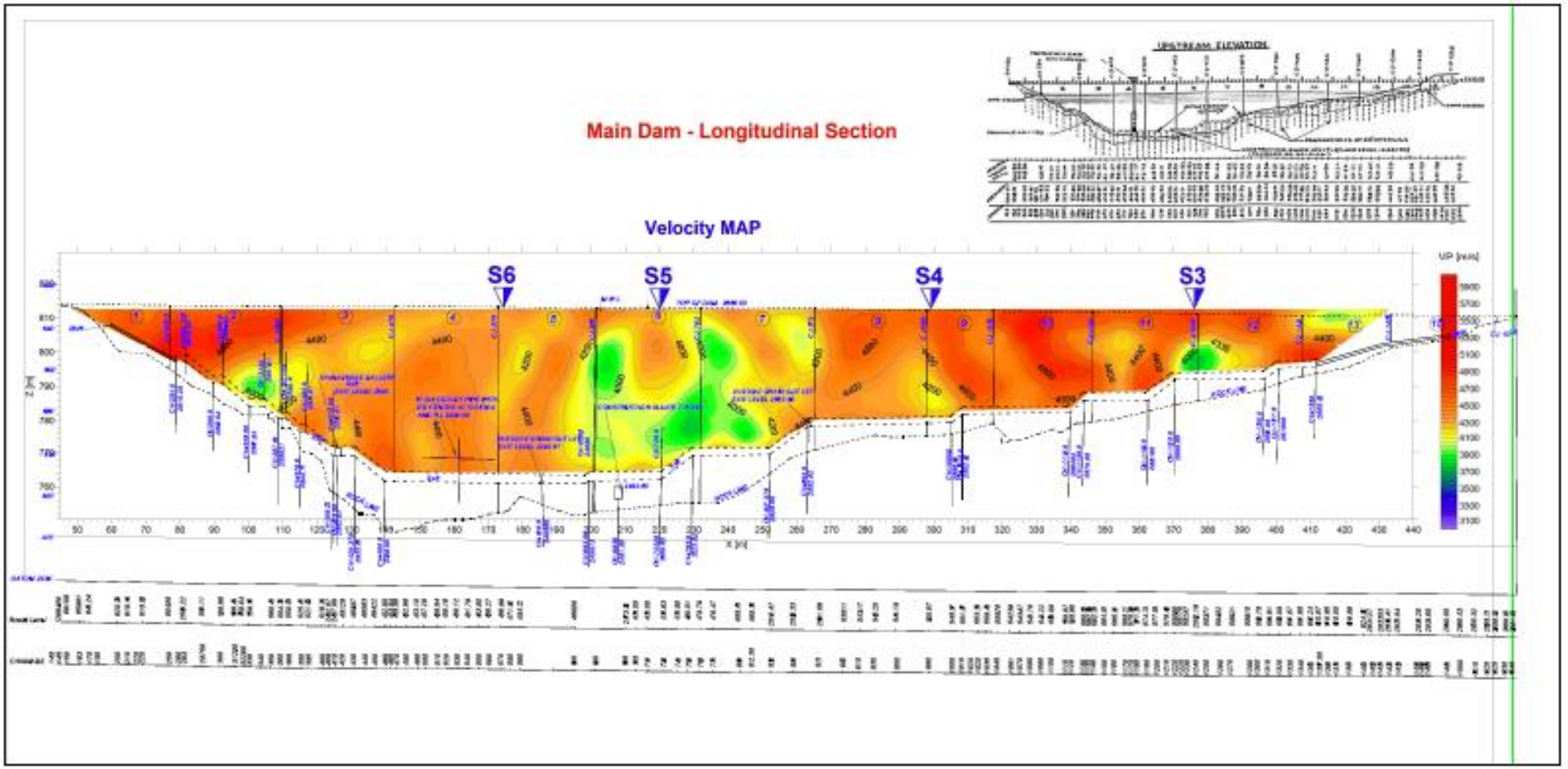
- Surface methods to detect dam condition along entire length
- Detailed information across anomalous zone as a dam section
  - **Seismic Tomography (cross-face or between boreholes)**
- Possible between d/s & u/s face
- Possible between dam top and gallery

INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

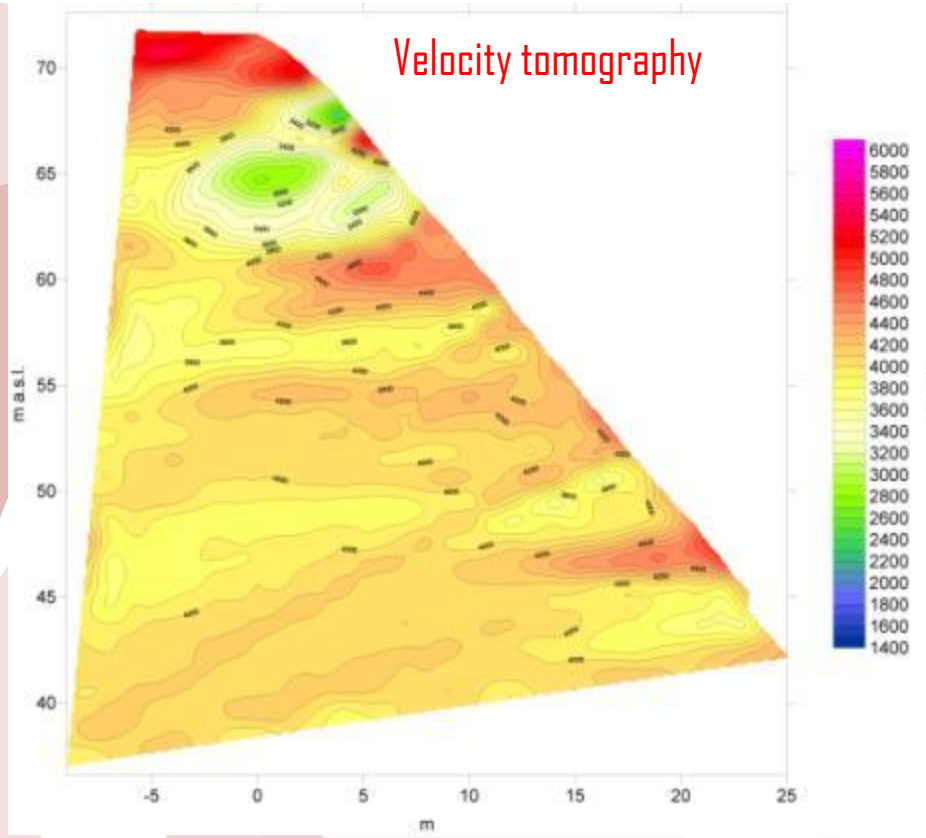
DRIP
Dam Rehabilitation & Improvement Project

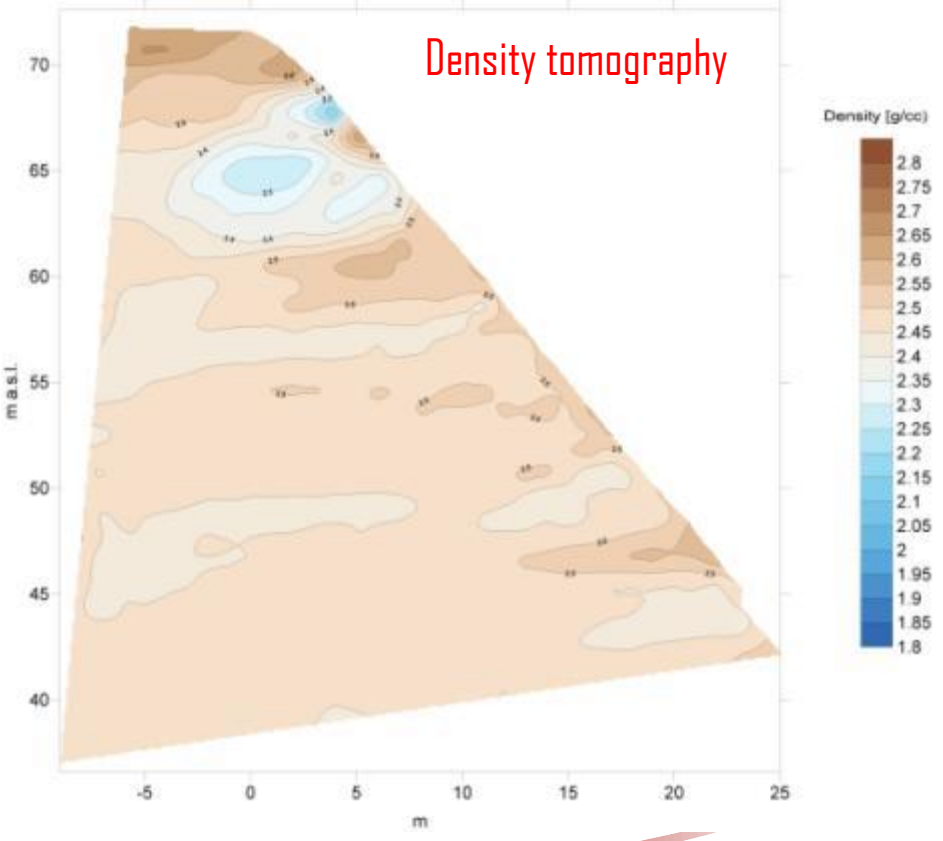
Central Water Commission



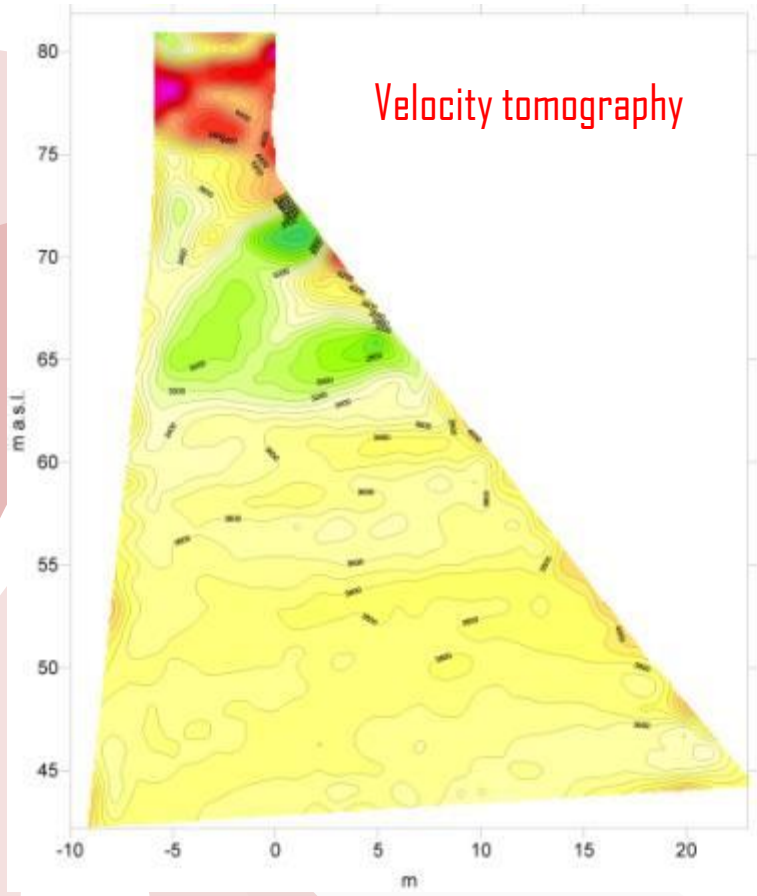
10-12 October 2022 at Jaipur, Rajasthan (India)

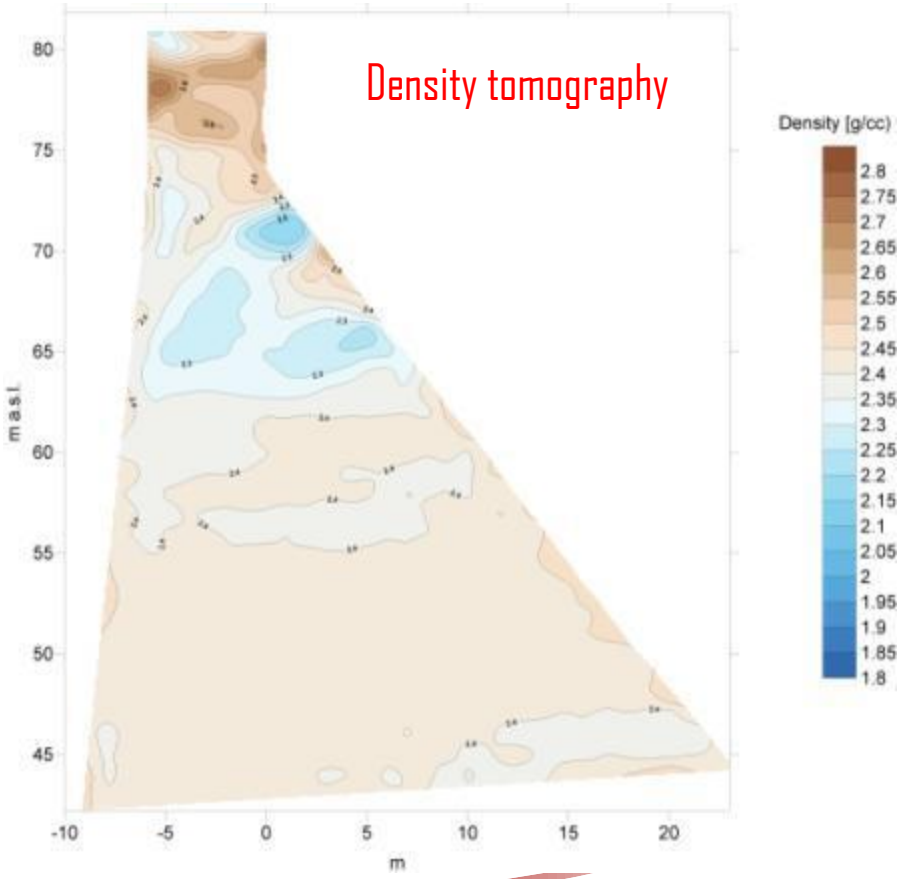
SPILLWAY SECTIONS

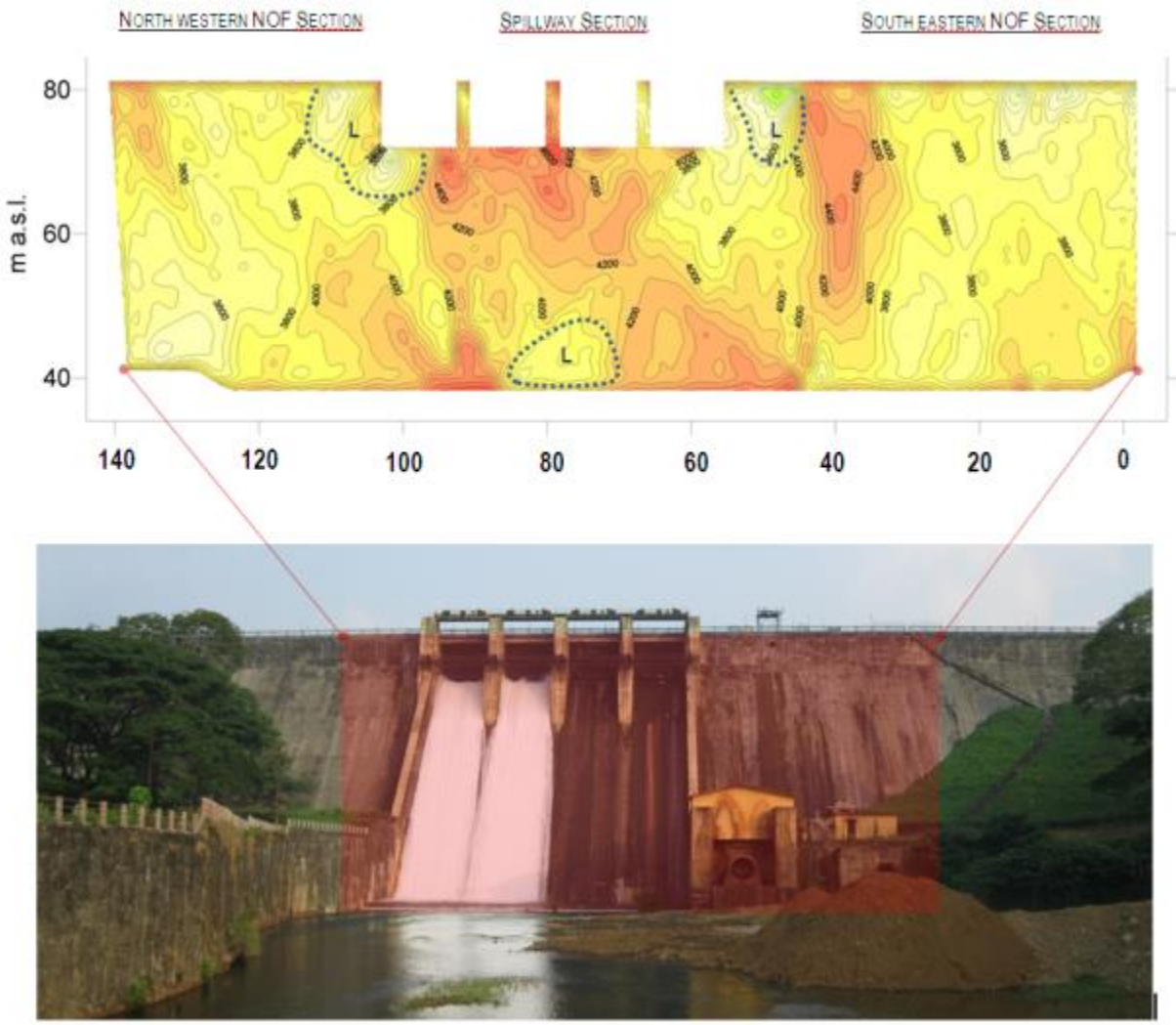




SHOULDER SECTIONS

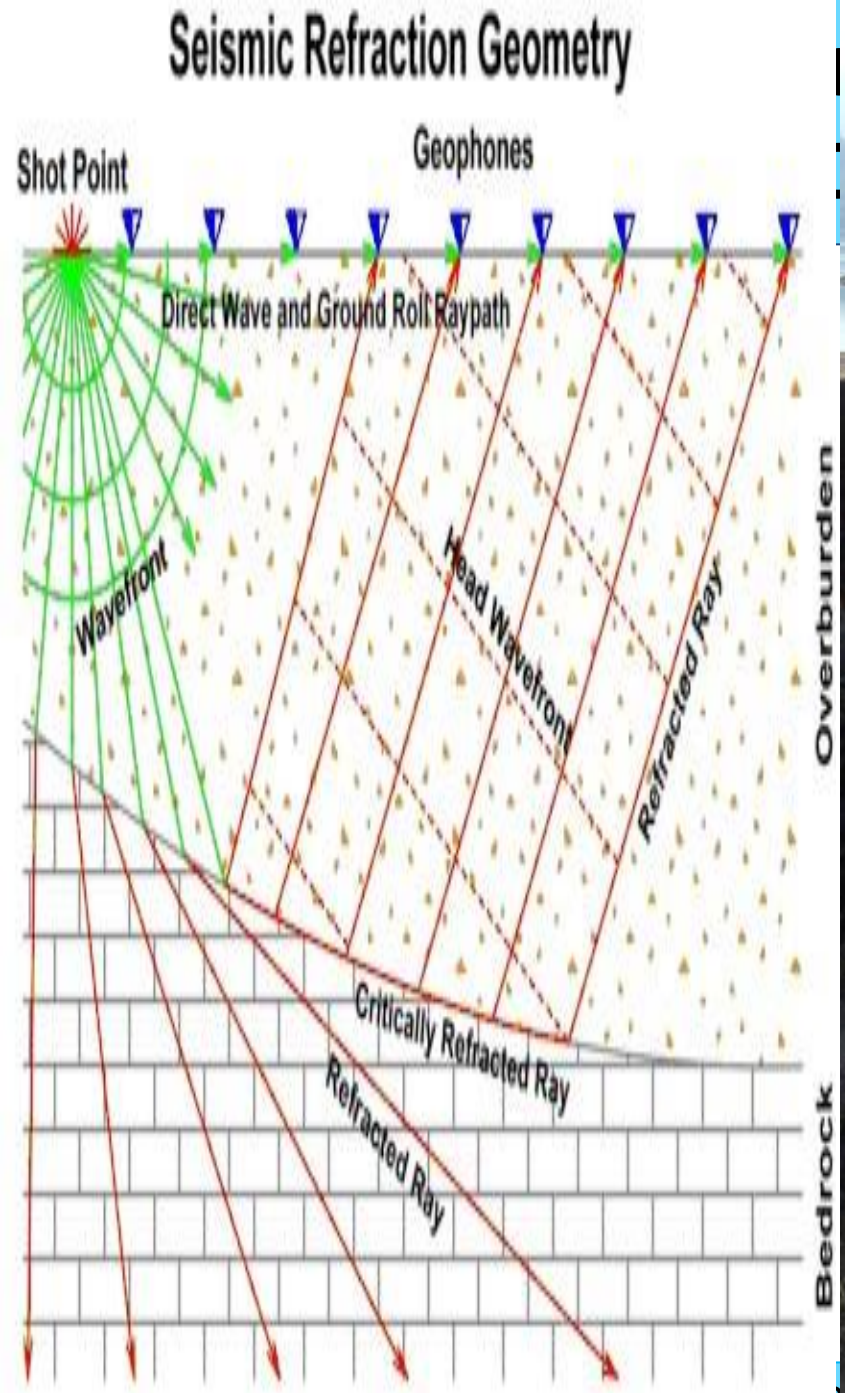


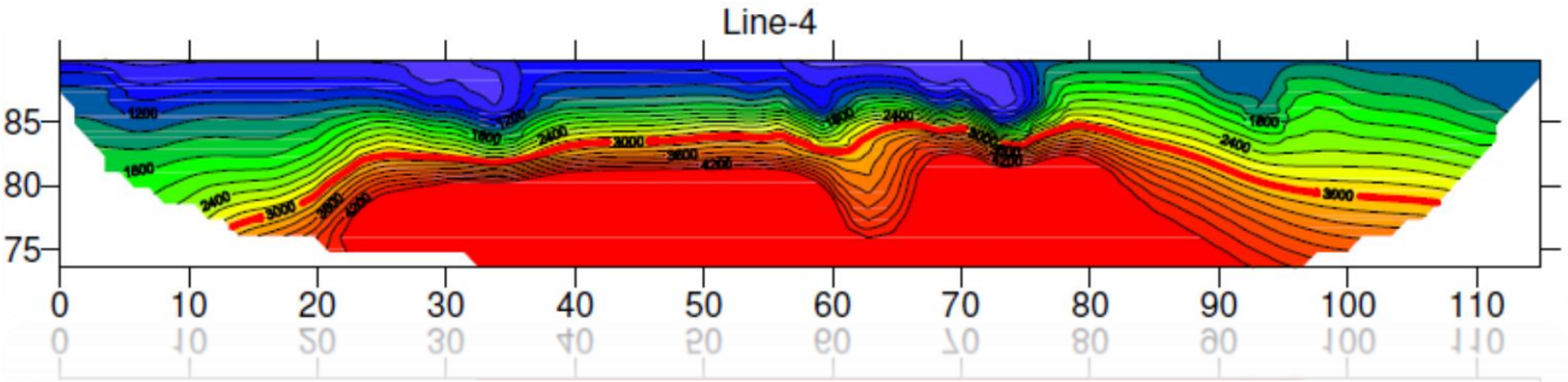


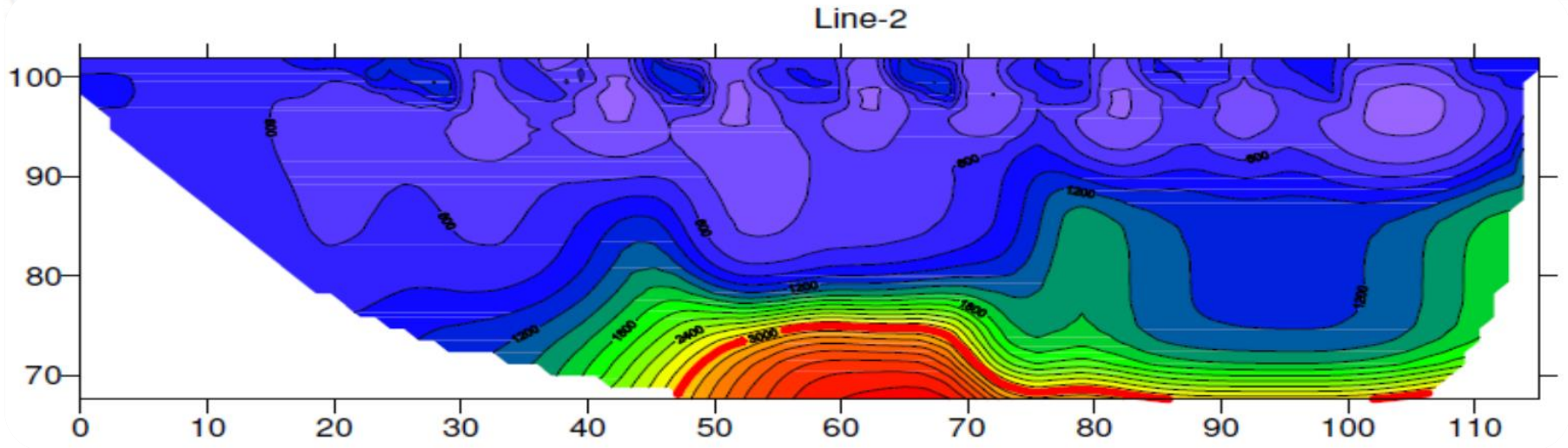

NORTH WESTERN NOF SECTION
SPILLWAY SECTION
SOUTH EASTERN NOF SECTION
m a.s.l.
80
60
40
140
120
100
80
60
40
20
0
L
L
L

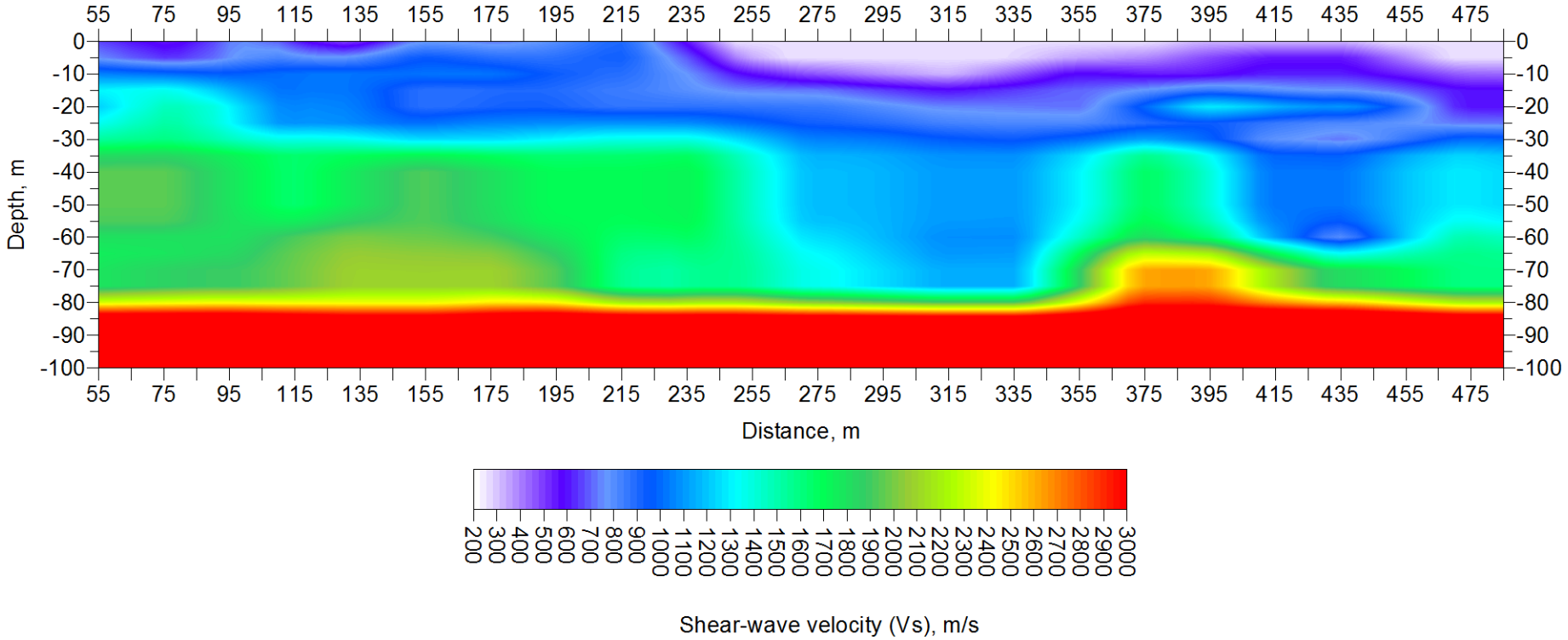
Problem- Determining Dam Strength?

- Density of dam material affects the P wave velocities.
  - **Seismic Refraction Tomography**
- Material strength is also defined by S wave velocities
  - **MASW/ ReMi**
- P & S wave velocity information can be used to compute Poisson's Ration, Bulk Modulus, Shear Modulus, Young's Modulus
- Seismic Refraction results can also be used to determine Phreatic line.


Seismic Refraction Geometry
Shot Point
Geophones
Direct Wave and Ground Roll Raypath
Wavefront
Head Wavefront
Refracted Ray
Critically Refracted Ray
Refracted Ray
Overburden
Bedrock


Line-4
85
80
75
0
10
20
30
40
50
60
70
80
90
100
110


Line-2
100
90
80
70
0
10
20
30
40
50
60
70
80
90
100
110


55 75 95 115 135 155 175 195 215 235 255 275 295 315 335 355 375 395 415 435 455 475
0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100
Depth, m
Distance, m
200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000
Shear-wave velocity (Vs), m/s

When?

When do you need to investigate your dam?

- It is desirable to have a 'base line' data of dam soon after completion of dam.
- For older dams, this time is 'now'.
- Before designing rehabilitation plan
- After carrying out rehabilitation works (to check efficacy)
- ‘Changes' in physical properties are much easier to interpret than one time measurement values.
- Under 'normal' conditions, such measurements should be repeated every couple of years as a routine dam inspection program.

Indian Experience

Duration	Assignment Name & brief description of main deliverables/ outputs	Name of client
May 2022	ERT, SP, MASW and tomography for Mannalar, Sarvalar, Kodayar-II, Pykara Forebay dam, Tamil Nadu	WRD, Gujarat
Mar 2022	ERT, SP, MASW and tomography for Amli dam, Gujarat	WRD, Gujarat
Nov 2021	ERT, SP, MASW and tomography for Damanganga dam, Gujarat	WRD, Gujarat
Sep 2021	ERT, SP, MASW and tomography for KRS dam, Karnataka	WRD, Karnataka
Feb 2021	ERT, SP, MASW and tomography for Talakalale dam, Karnataka	KPCL, Karnataka
Aug 2020	ERT, SP, MASW and tomography for Dharoi dam, Gujarat	WRD, Gujarat
July 2020	ERT, SP, MASW and tomography for Ukai dam, Gujarat	WRD, Gujarat
Nov 2019	ERT, MASW and tomography for Kadana dam, Gujarat	WRD, Gujarat
Dec 2018	ERI, MASW and GPR for earthen embankment settlement study	MB Power, MP
Apr 2018	Resistivity imaging, SP, ReMi and seismic tomography for KSPABR Dam, AP	WRD, AP
May 2017	Resistivity imaging and seismic tomography for Sholayar Dam, Kerala	KSEB, Kerala
Apr 2017	Bathymetry and GPR survey in stilling basin at Kurichhu Hydroelectric Plant, Mongar Bhutan	Druk Green Power Corporation, Bhutan
Oct 2015	Resistivity Imaging, Streaming Potential, Seismic Refraction,Shear Wave Velocity Test-ReMi for Chitraon Tank	WRD, MP

Jun 2015	**ERI and SP for barrage structure**	**Lalitpur Powe Company, Lalitpur UP**
Apr 2015	Geophysical investigation in earthen dam portion of Kanupur Irrigation Project	WRD, Odisha
Jan 2015	Geophysical investigations for analysis of heavy seepage In Kanhirapuzha, Kuttiyadi and Malankara Dams.	IDRB, WRD, Kerala
Jan 2015	Electrical Resistivity Imaging, Streaming Potential, Seismic Refraction Test at Shikarwadi	WRD, MP
Jan 2015	Electrical Resistivity Imaging, Streaming Potential, Seismic Refraction Test at Sihora (MP)	WRD, MP
Nov 2014	Geophysical investigations for Temghar dam	WRD, Maharashtra
Jun 2014	Resistivity Imaging,Streaming Potential, & Seismic Refraction at Betul	WRD, MP
Apr 2014	Resistivity Imaging,Streaming Potential, & Seismic Refraction at Raisen	WRD, MP
Mar 2012	Geophysical Investigations at Mullaperiyar Main Dam & Baby Dam	WRD, Tamil Nadu
Feb 2012	Geophysical Investigations at Madikhera Dam, MP	WRD MP
May 2012	Geophysical Investigations for Beerpur Dam, Madhya Pradesh	WRD MP
May 2012	Geophysical Investigations & Rehabilitation recommendations for Tigra Dam, Madhya Pradesh	WRD MP
Mar 2011	Geophysical Investigations to detect & locate seepage path in Daroli Dam, District Damoh, Madhya Pradesh	WRD MP

Recommendations…

Recommendations

- Geophysical investigations must be made an integral component of dam safety inspection programs/ procedures.
- Periodic inspection must be carried out on all large dams to detect problems at early stages
- Geophysical investigations MUST be carried out before designing the rehabilitation program, and after rehabilitation.
- These methods has great potential for other applications like canal seepage studies, stilling basin checks etc.

Recommendations

- Geophysics presents a viable option to conduct scientific inspection & investigations of more than 5,500 specified dams within next 5 years as stipulated in Dam Safety Act 2021.

- **Guideline document is already available for geophysical investigations for dam safety, which should be deliberated upon and adopted by ICOLD.**

Thanks for your attention

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