LIGO-India: Origins & site search

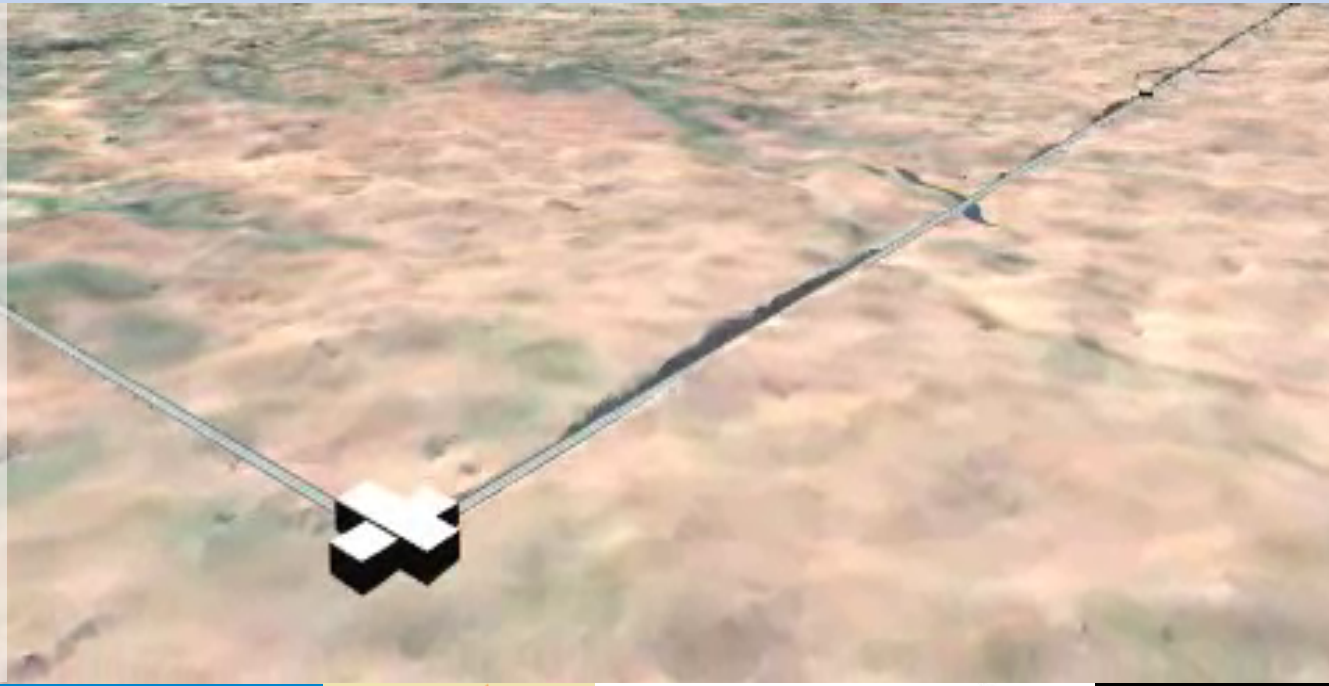
On behalf of the LIGO-India team

Tarun Souradeep
IUCAA, India

Spokesperson (science), LIGO-India

Member, Secretary LIGO-India Scientific Management Board

Project coordinator-IUCAA, LIGO-India



LIMMA-2019
Dukes Retreat, Khandala
Jan. 15-18, 2019

LIGO-India: Origins & site search

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IndIGO Consortium – a **brief** history

- **Dec. 2007 : ICGC2007 @IUCAA: Rana Adhikari's visit & discussions**

- 2009:
  - Australia-India S&T collaboration (Iyer & Blair)

  Establishing Australia-India collaboration in GW Astronomy

- **IndIGO Consortium: IUCAA Reunion meeting (Aug 9, 2009)**

- 2009-2011:
  - Meeting with Intl committee at Kochi, Pune, **Shanghai**, Perth, Delhi
  - July 2011: IndIGO admitted to GWIC in : Intl. recognition of the growing GW activity & community in India.
  - IndIGO accepted into the LIGO Science Collab. (LSC) : pan-Indian 7 institutes: 15 members

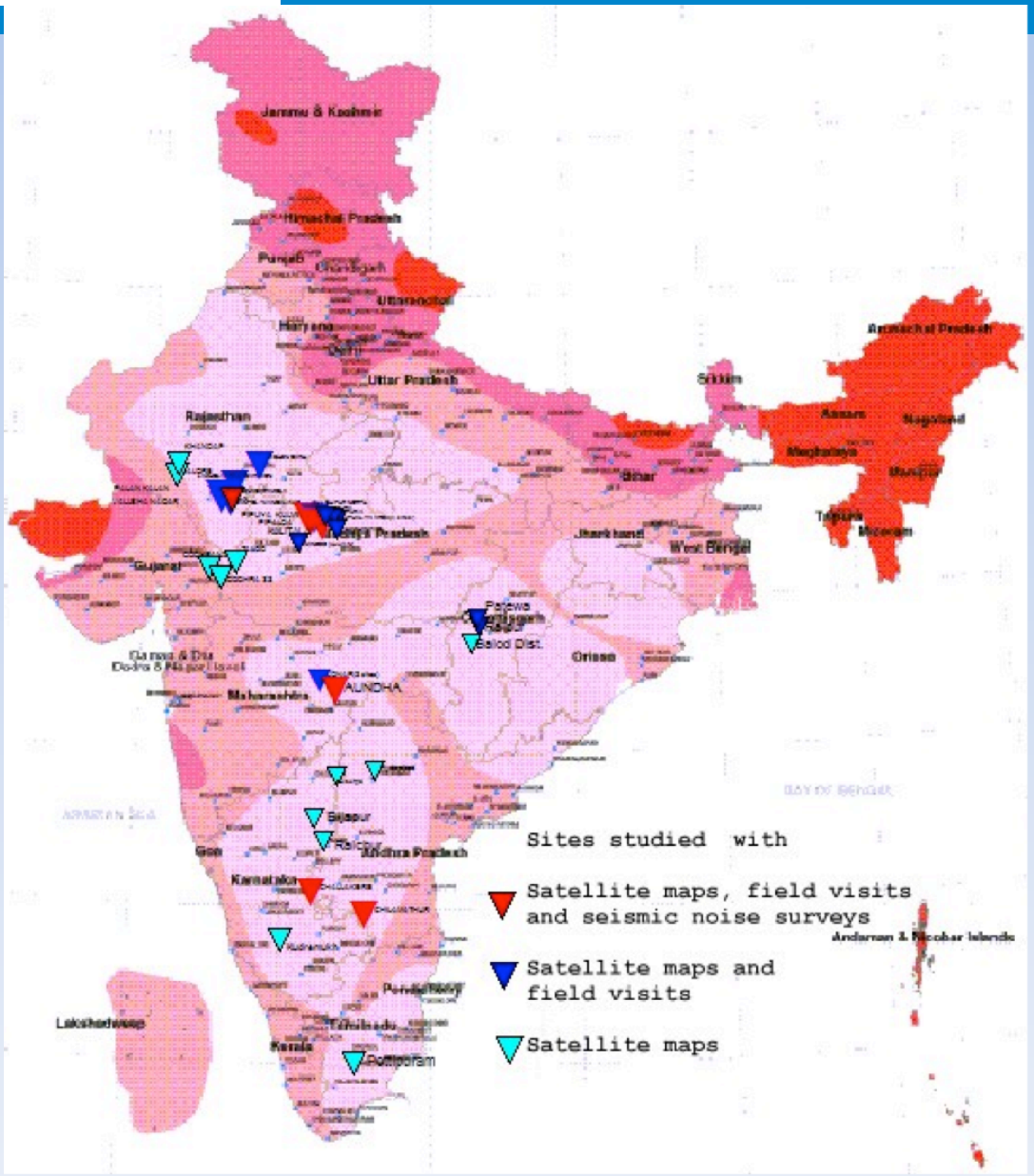
- March 2011: IndIGO-I Proposal: Participation in LIGO-Australia ~10-15%

- **May 2011+: LIGO-India..**

Rapid steps towards LIGO-India

- October 2011: LIGO-India included in the list of Mega Projects under consideration by the Planning commission
- Nov 2011: IndIGO submitted Project Proposal to DAE-DST Consortium proposing the consideration of LIGO-India as a Mega-Science Project in the XIIth five-year plan
- April 2012 – LIGO-India discussed at Atomic Energy Commission (AEC) meeting and approved
- August 2012 National Science Board go ahead for LIGO plans for relocating third detector to India

LIGO-India Site search



LIGO-India selection
(Sept 2011 – Sept 2016)
39 site leads followed up
Recommendation for primary and backup site Sep 2016

LIGO-India Site

LIGO-India site search requirements

Requirements:

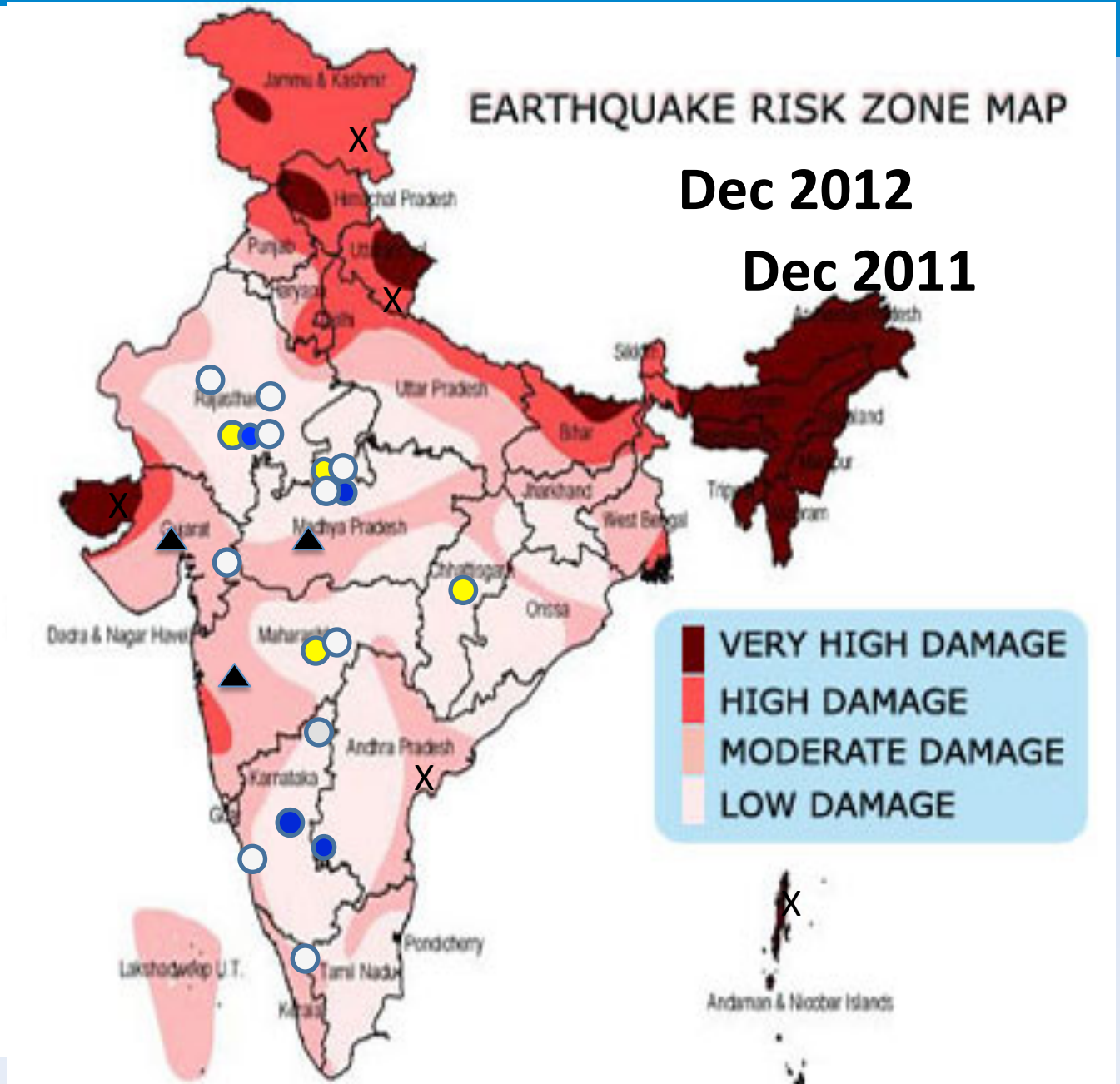
- **Low 'seismicity' (ground noise PSD)**
- **Low human generated noise**
- **Air connectivity, road connectivity, data connectivity,…**
- **Proximity to Academic institutions, labs, industry preferred, …**
-
-

Details available in the Site selection document.

Approach :

- **Identify potential sites not too far from existing facilities**
- **Establish contact with local & high level state officials**
- **Desktop survey of sites, Followed by team visit**
- **2-3wk seismic survey : ground noise PSD at 0.1-100 Hz range**
- **Site acquisition assessment**
- **Create a shortlist of best contenders**

Site search evolution



Site search *(Early)* chronology

1) Sept 2011: visit to Chitradurga site by Tarun, Albert Lazzarini, Stan Whitcomb

2) 28th March 2012: visit to Chitradurga site by Bala, Unnikrishnan and Tarun

Enter the champ, Sharad Gaonkar

3) 2nd to 16th April 2012: Seismic characterisation at site Chilmathur , Anantpur district, A.P.

4) 12th April 2012: Visit to site Udaipur-I(24o 41' N, 73o 56' E) (Vallabh Nagar tehasil, Udaipur district), 7km from Udaipur, Rajasthan.by Sharad Gaonkar, Unnikrishnan

5) 13th April 2012: Visit to site Udaipur-II, Vallabh Nagar tehasil, Udaipur district, (24°42'30.00"N: 73°57'37.00"E), by Sharad Gaonkar, Unnikrishnan.

6) 13th April 2012: Bander Sindri(26^{o} 34.1' N, 75^{o} 01.5' E), near Kishengarh town, Ajmer district, of Rajasthan, by Sharad Gaonkar, Unnikrishnan

Details available in the Site selection document.

Early Site search

General view of site Kalyanpura
Kalyanpura,Dist. Udaipur, Rajasthan,
20th February 2014(24 deg 41' 30", 74deg 9' 54")

Courtesy: Sharad Gaonkar

Site Pipliya Kulmi , Rajgarh district, M.P.

- 24 December 2012 Installation of Guralp seismometer at site Pipliya kulmi, Rajgarh district, M.P.(24 12' 17.14"N, 76 20' 44")

Early Site search

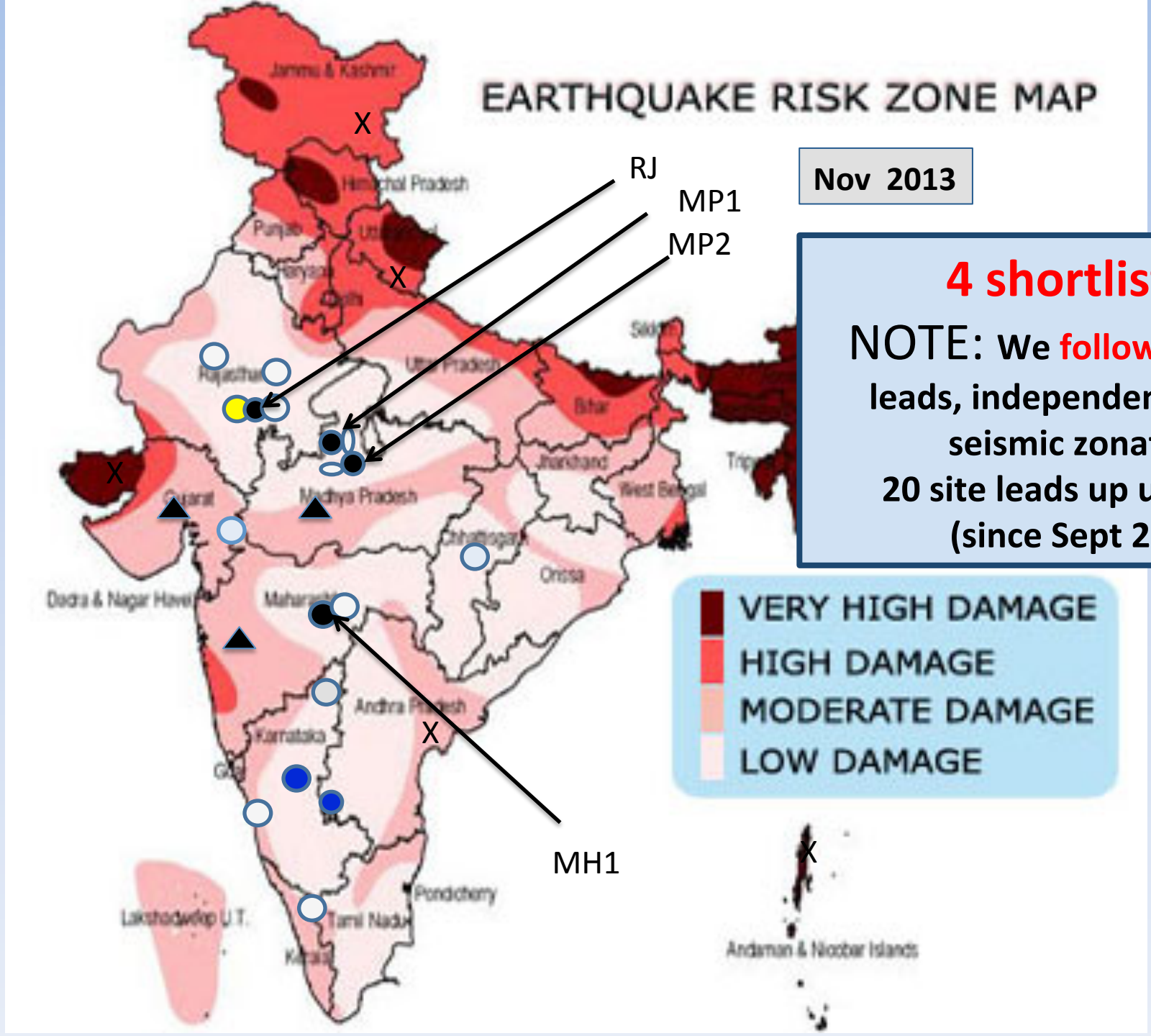
Site search in vicinity of Lonar crater, Buldhana district, Maharashtra : May 2013

4 days Sharad, Sanjeev Dhurandhar, Kurtadikar
at 45 degC+ (115F +)

Courtesy: Sharad Gaonkar

19 53’ 40” 76 36’ 21”

(19 56’ 6” ,76 28’ 32”)


EARTHQUAKE RISK ZONE MAP
Nov 2013
RJ
MP1
MP2
MH1
X
X
X
X
X
4 shortlisted
NOTE: We followed up ALL leads, independent of their seismic zonation.
20 site leads up until now (since Sept 2011)
VERY HIGH DAMAGE
HIGH DAMAGE
MODERATE DAMAGE
LOW DAMAGE
Jammu & Kashmir
Himachal Pradesh
Punjab
Uttar Pradesh
Bihar
Sikkim
Rajasthan
Gujarat
Madhya Pradesh
Jharkhand
West Bengal
Chhattisgarh
Orissa
Dadra & Nagar Haveli
Maharashtra
Andhra Pradesh
Karnataka
Goa
Pondicherry
Tamil Nadu
Kerala
Lakshadweep U.T.
Andaman & Nicobar Islands

Critical aspects of LI site selection

- **Technical requirements and restriction from scientific performance**
  (Basis for shortlisting of sites)

  i. Seismic noise power spectral density
  ii. Anthropogenic noise sources --- present & future
  iii. Operational logistics

Details available in the Site selection document.

- **Feasibility of Land Acquisition**
  Detailed site acquisition study for shortlisted site. Identifying plots to be acquired on village maps, ownership data, land acquisition procedure, time-lines & risks, with regard to LARR-2013

- **Engineering feasibility of LIGO-India base construction**
  Study by Tata Consulting Engineers Ltd. -- for site recommended
  Issues and concerns to be discussed for site (Apr 13, 2016 meeting)
  ① Annual rainfall and maximum intensity √
  ② High flood level √
  ③ Side slope of cut in proposed elevation √ [60 deg as per TCE report]
  ④ Feasibility of attaining proposed terrace level

LIGO INDIA

Usage restrictions in Adjoining region

Current + during >15 year Operations

- NO sustained heavy equipment, mining, blasting activity in the vicinity (30km)

- NO Reciprocating power-plant machinery, rock crushers and heavy machinery (> 16 km, prefer 40km from the site)

- Non-reciprocating power-plant machinery and balanced industrial machinery should be located at least 7km from the site, preferred distance of 16 km.

- Railway: >10 kms (preferably 16km) away from any busy railway track active at present, or, possible in the next 15 year.

- Roadways: More that 4-6 km from any major busy motor highway.

- Airways: More than 60km from any major airport. More that 20km from a not so busy (less than 5 flights/day) airport.

- No major water flows during most of the year near the site
(The site should be 100 km to 200 km away from the sea-coast!)

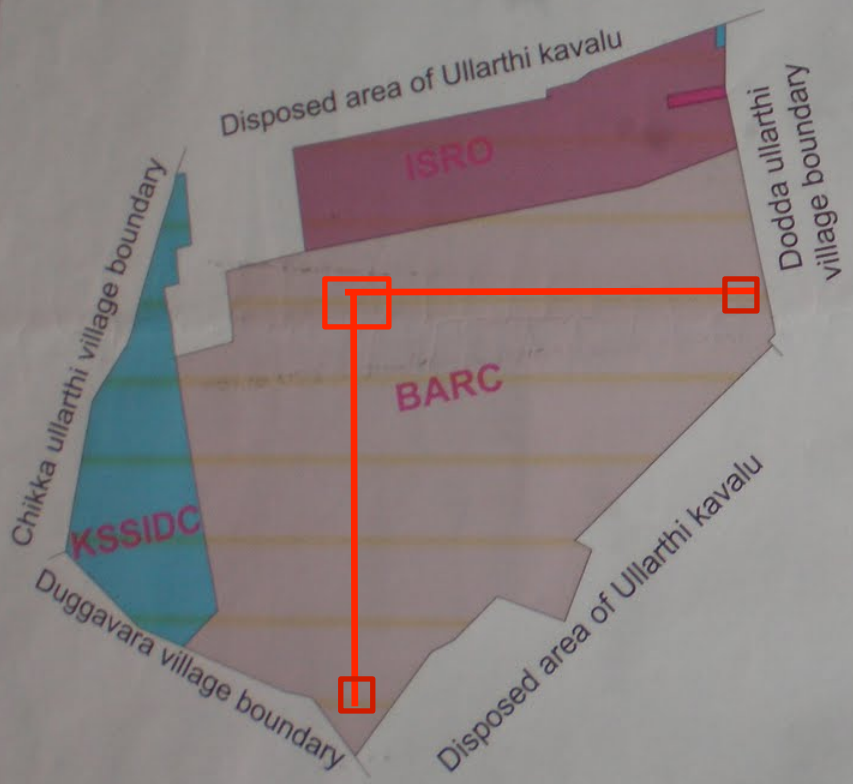
Details available in the Site selection events.

Option

- Acquire modest extra adjoining land

Iphone photo by Albert Lazzarini

Map showing the details of the land proposed for BARC, ISRO, KSSIDC in R Sy No 1 of Ullarthi kavalu Village, Talak hobli, Challakere taluk, Chitradurga dist.



Coloured area shows an extent of 473 acres - 20 guntas of land in R Sy No 1, proposed for **ISRO.**

Coloured area shows an extent of 250 acres of land in R Sy No 1, proposed for **KSSIDC.**

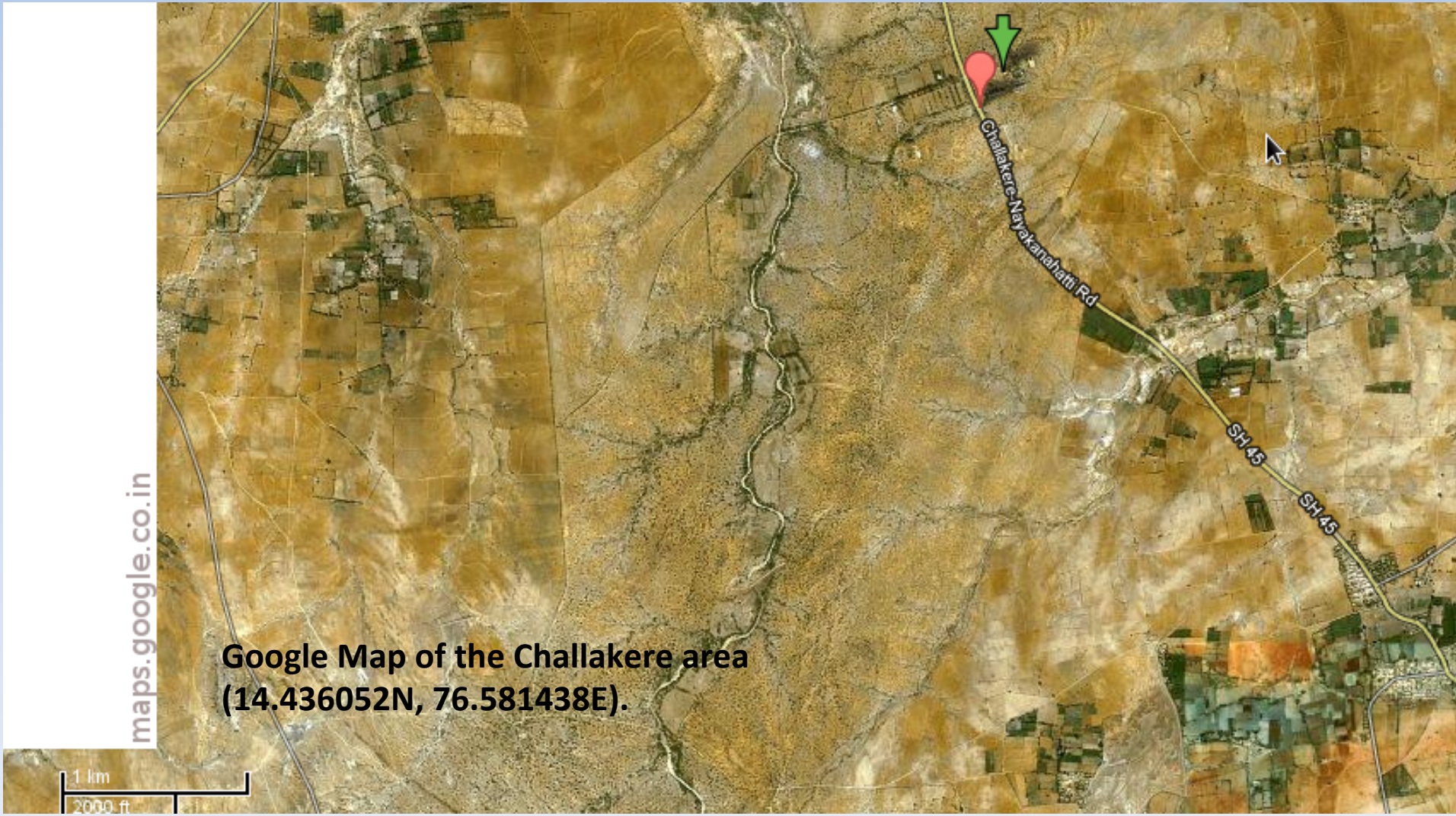
Coloured area shows an extent of 1410 acres of land in R Sy No 1, proposed for **BARC.**

Coloured area shows an extent of 8 acres 36 guntas of land in R Sy No 1, presence of burial ground.

Coloured area shows reserved area an extent of 1 acre - 20 guntas of land in R Sy No 1 proposed for Ashraya housing and raitha kana.

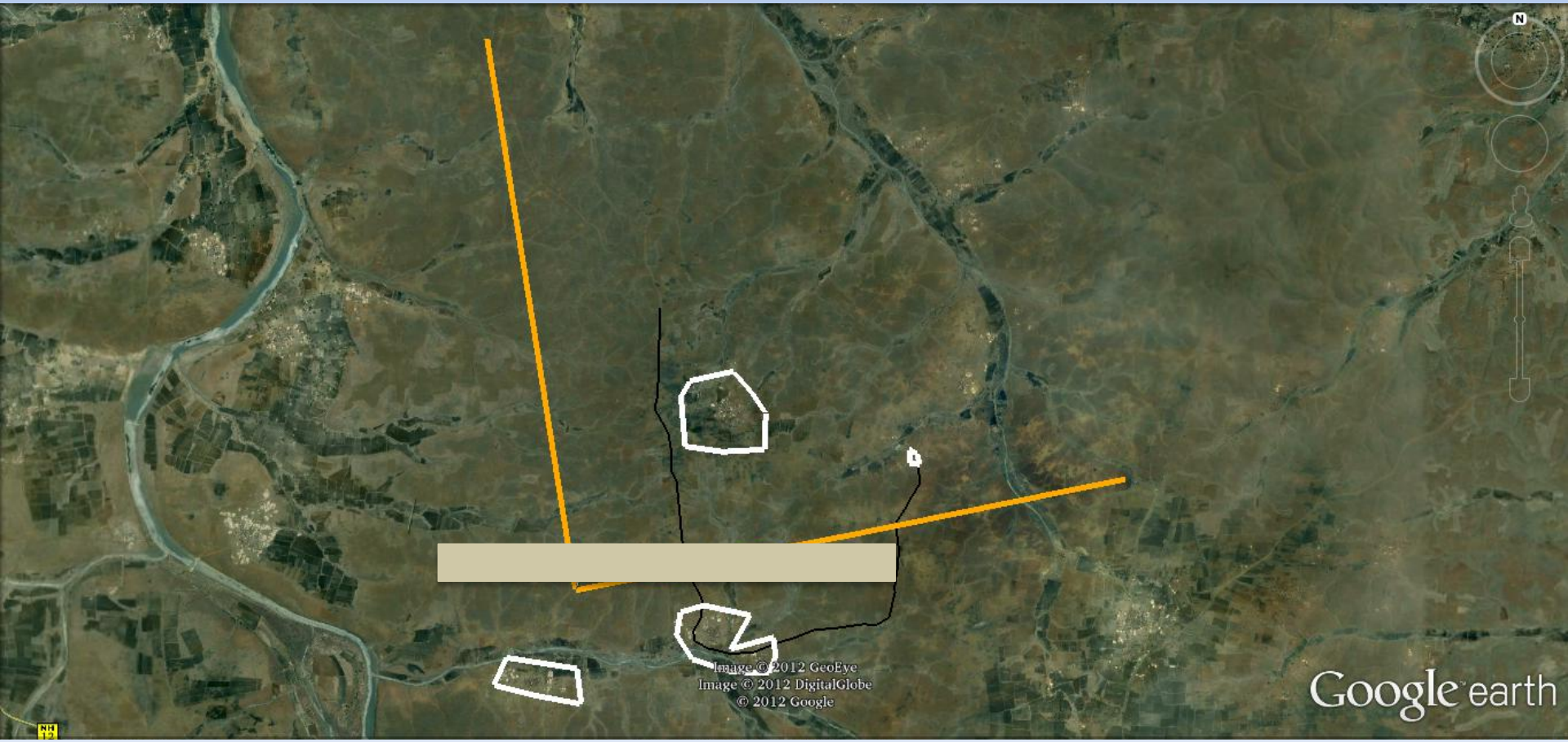
Iphone photo by Albert Lazzarini

Desktop study: Google maps, Bhuvan (ISRO)



Google Map of the Challakere area
(14.436052N, 76.581438E).

Desktop study: MP Site 2, Madhya Pradesh

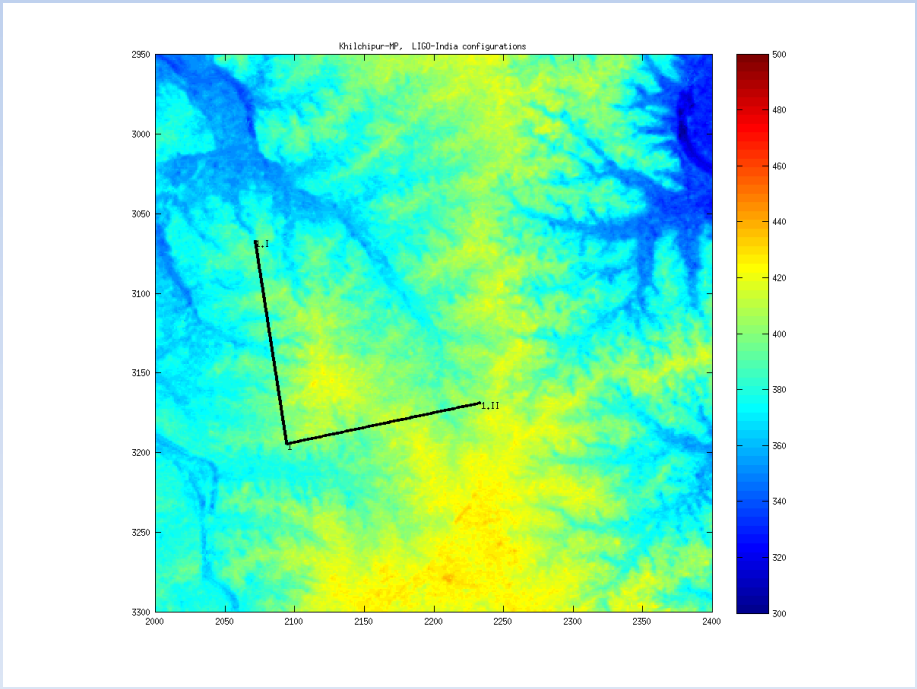


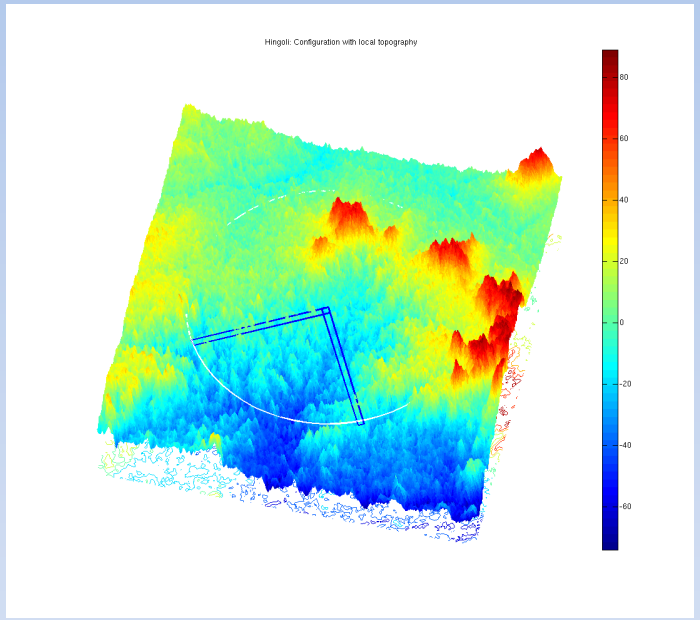
Step1: Google Earth map
With a proposed configuration

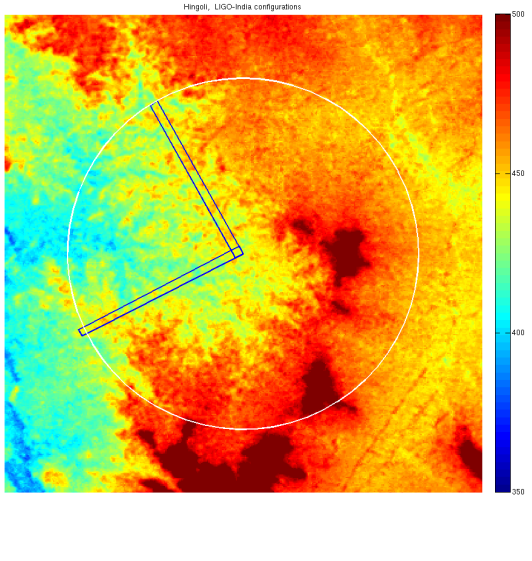
A desktop study: MP Site 2, Madhya Pradesh

Satellite Topography map with a proposed configuration

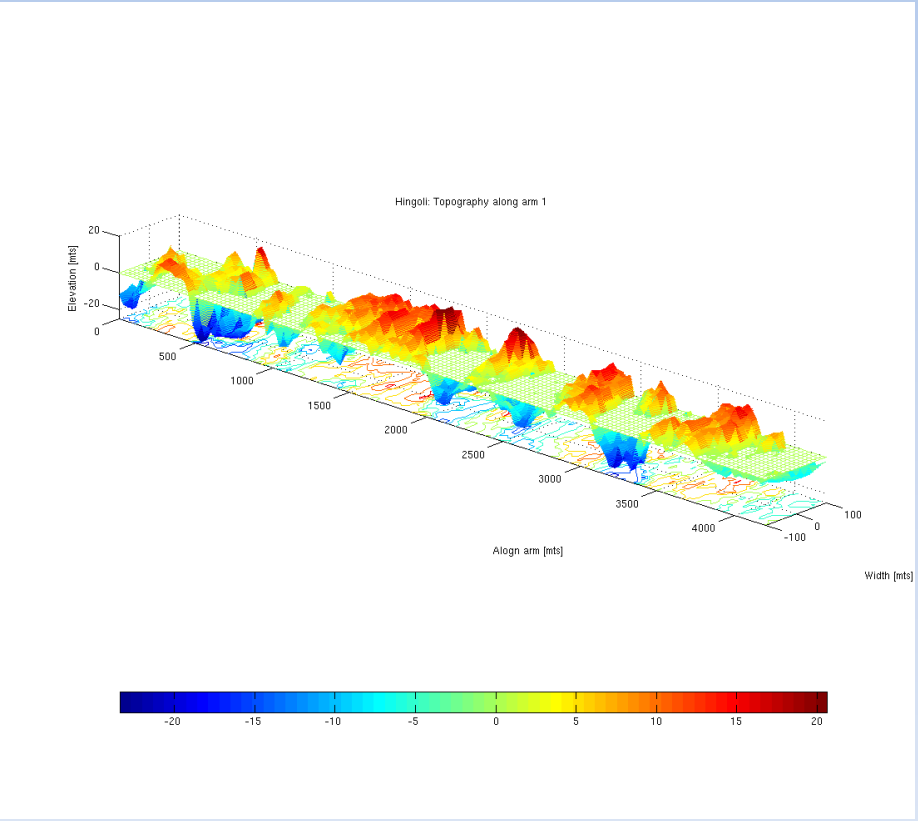
USGS ASTER GDM, resolution 1'' by 1''

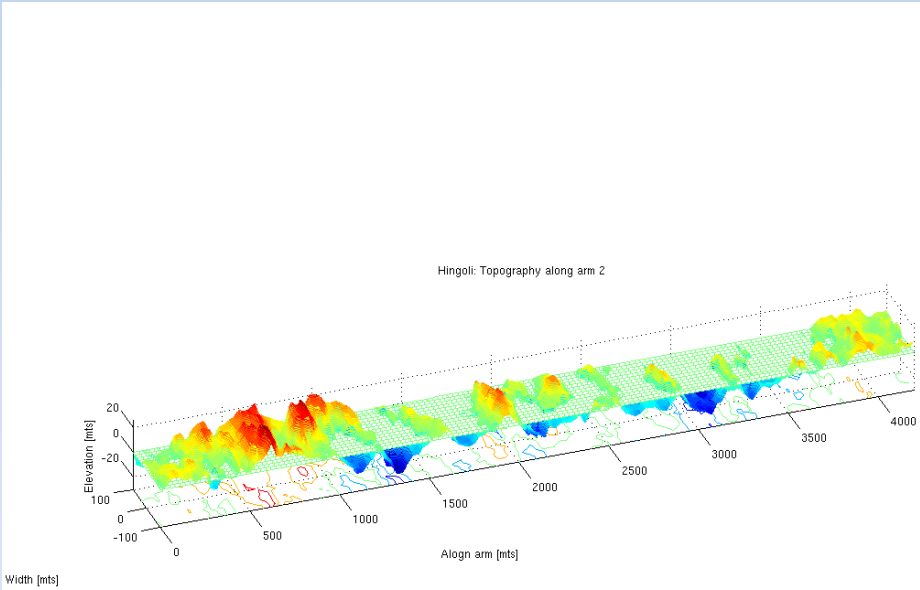






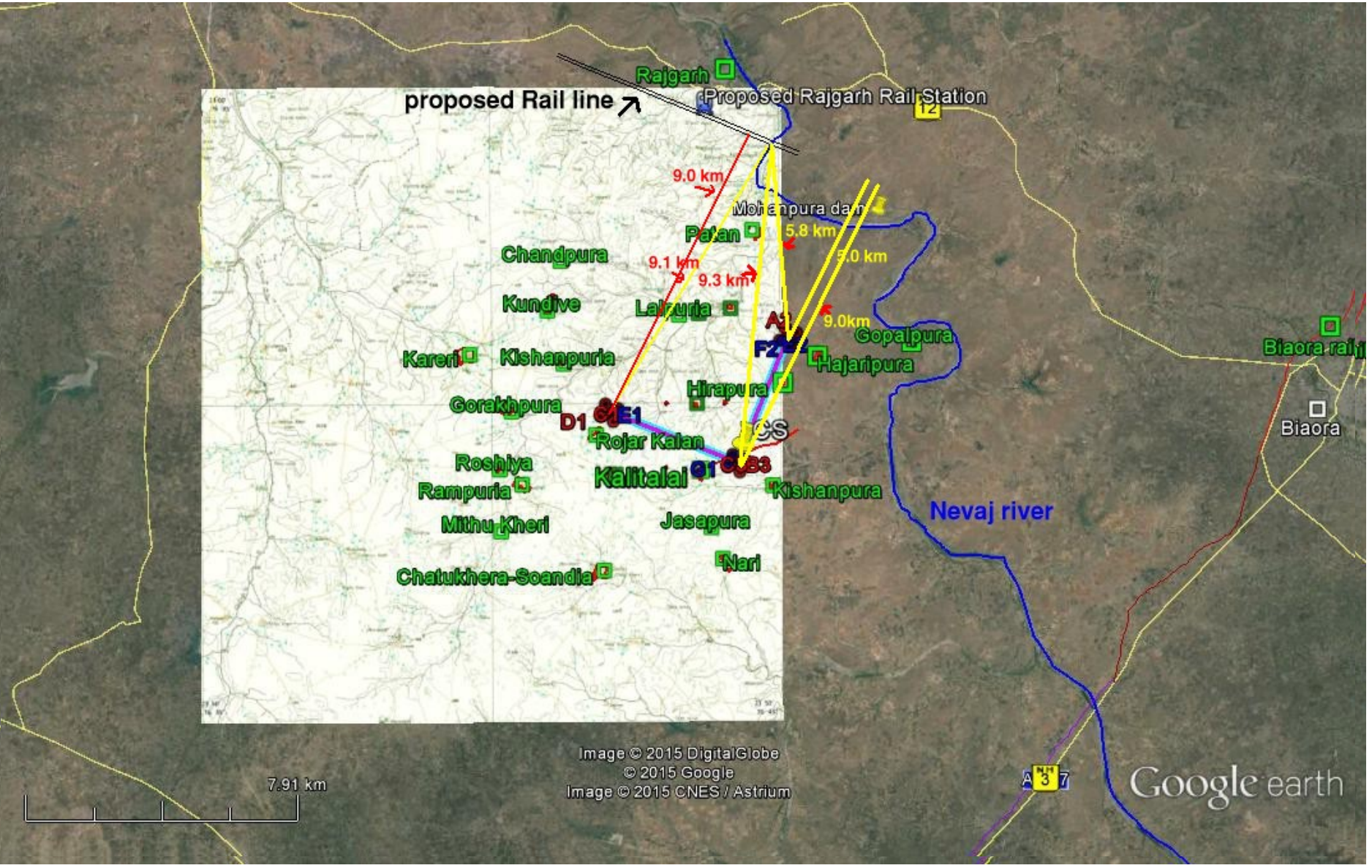
desktop study: terrain along arms





Courtesy: Rajesh Nayak

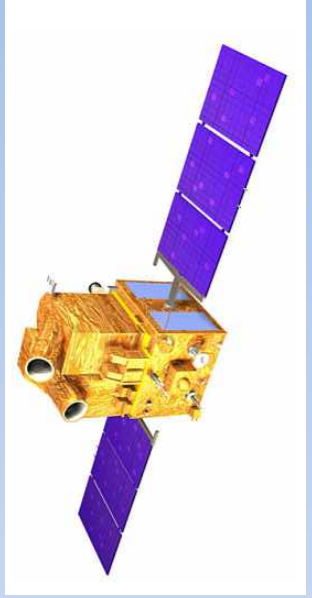
Rajgarh district setback
Planned railway (Kota-Bhopal)

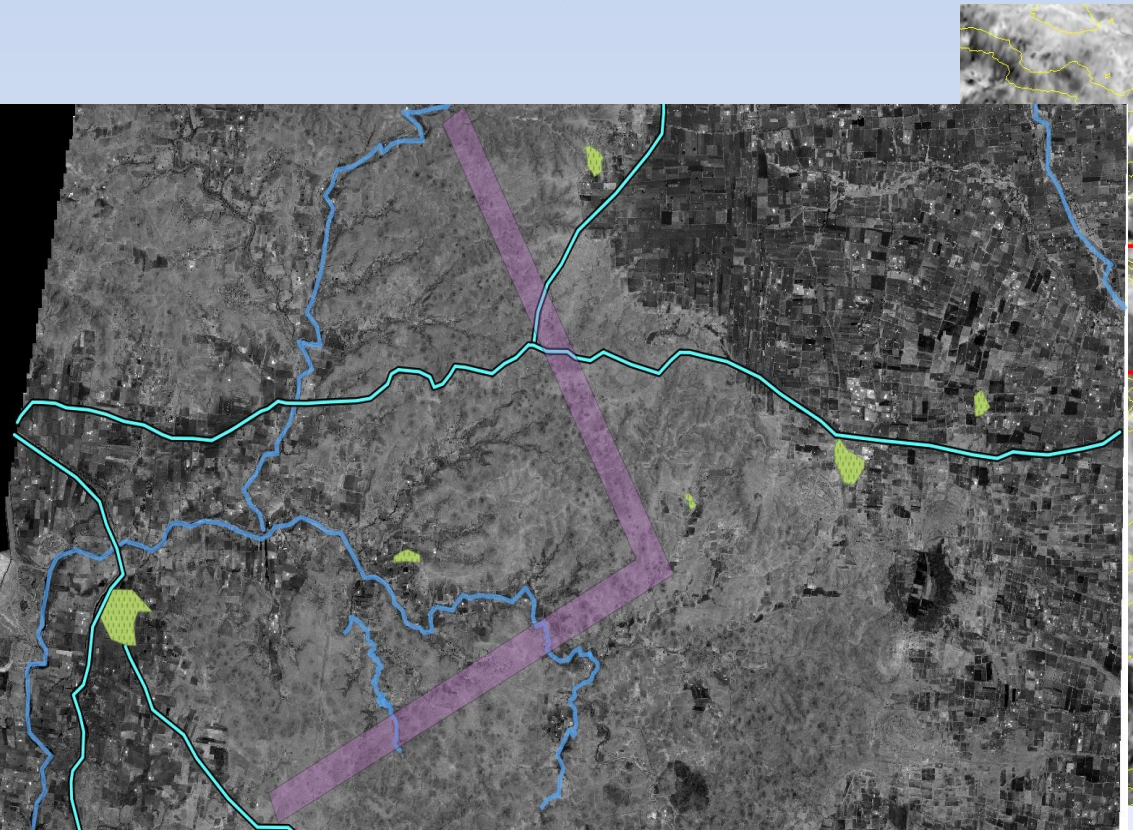


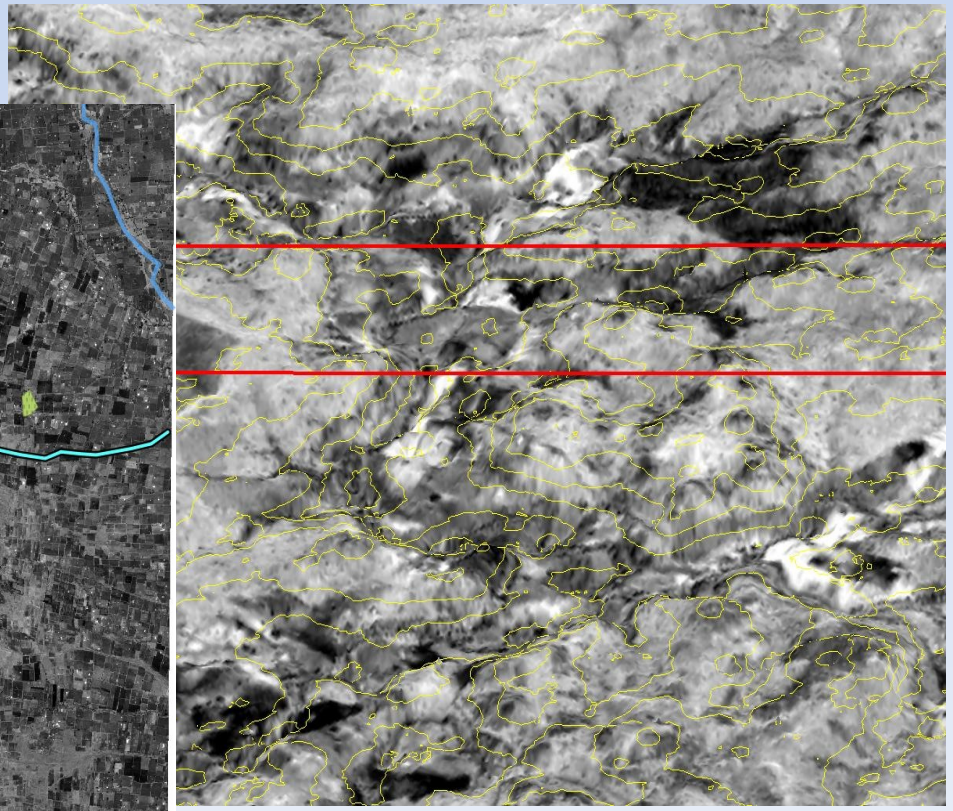
Space Application Centre ISRO

Remote Sensing data for LIGO-India site survey

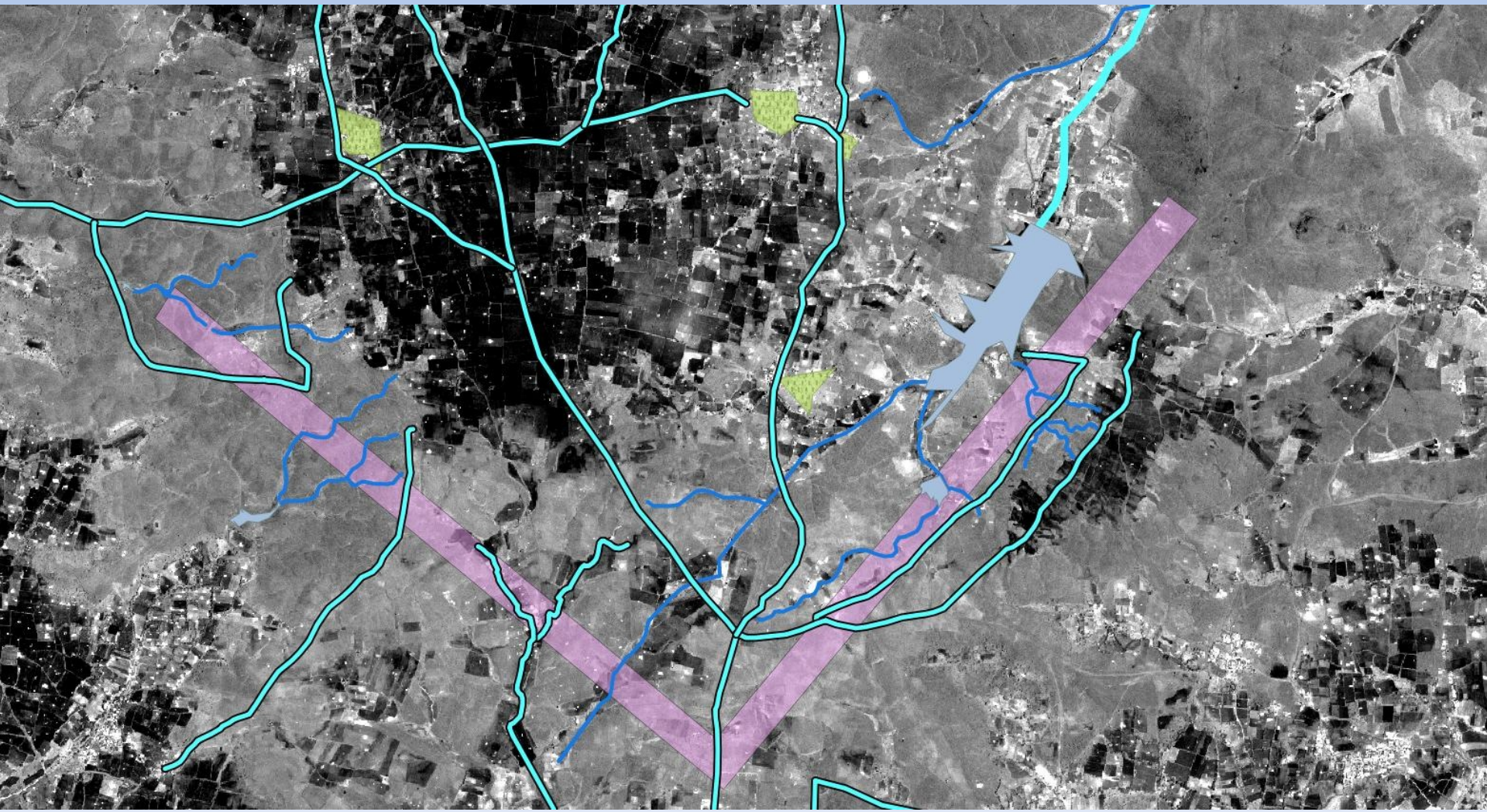
- CARTOSAT satellites sensor was built by ISRO for mainly intended for cartographic applications
- The satellite images have a spatial resolution of 2.5 meter and cover a swath of 30 km.
- With stereo imaging capability it is enable the generation of Digital Elevation Models (DEMs)





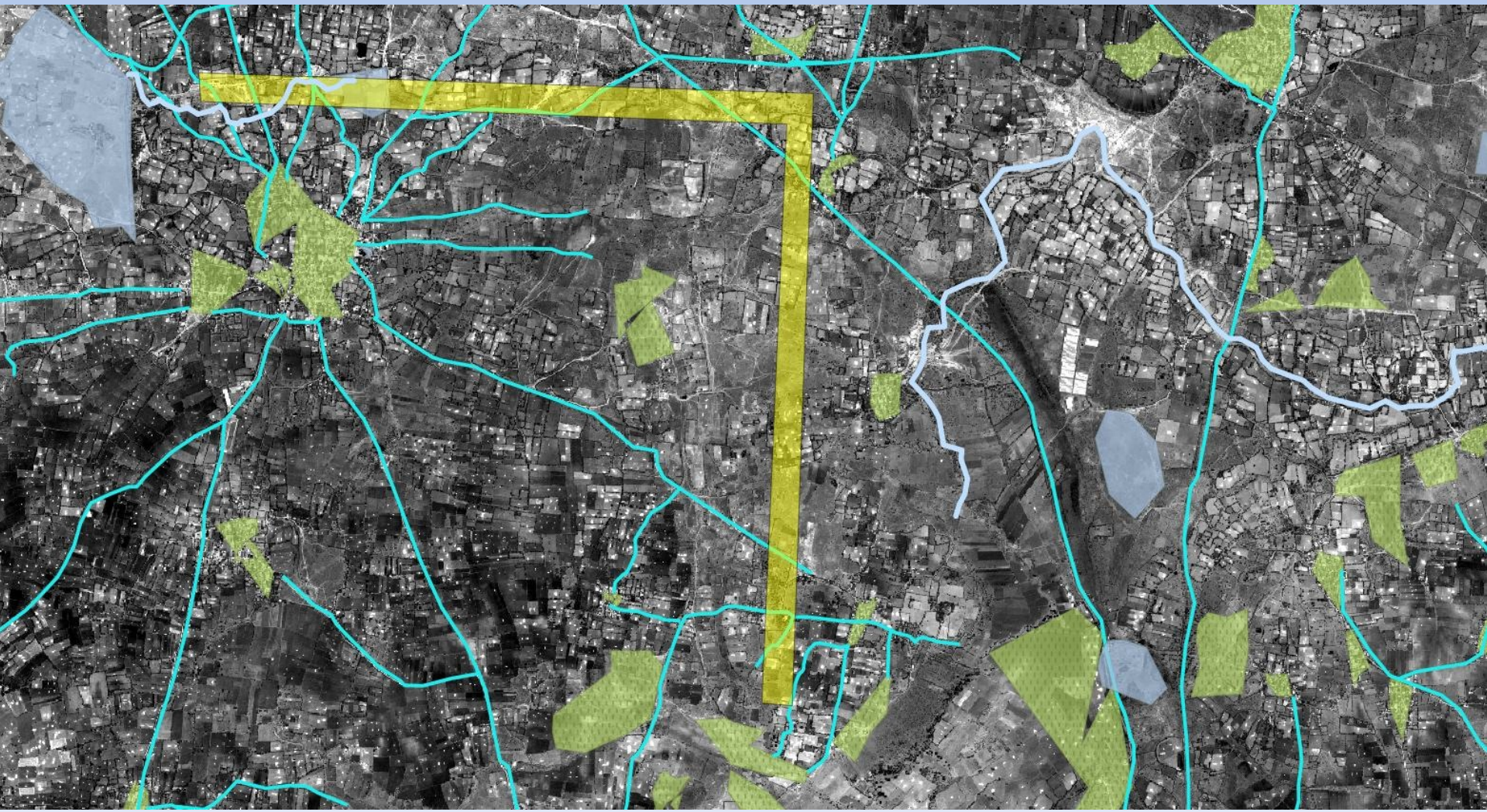


Raw Image L-I Layout Roads Villages Water Streams



Site - Piplia Kulmi

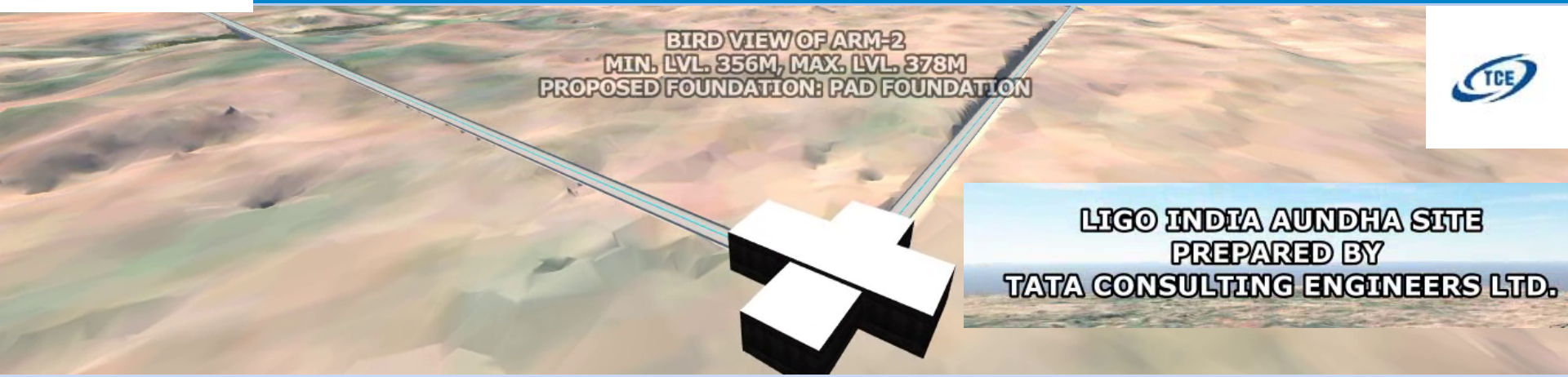
Raw Image L-I Layout Roads Villages Water Streams

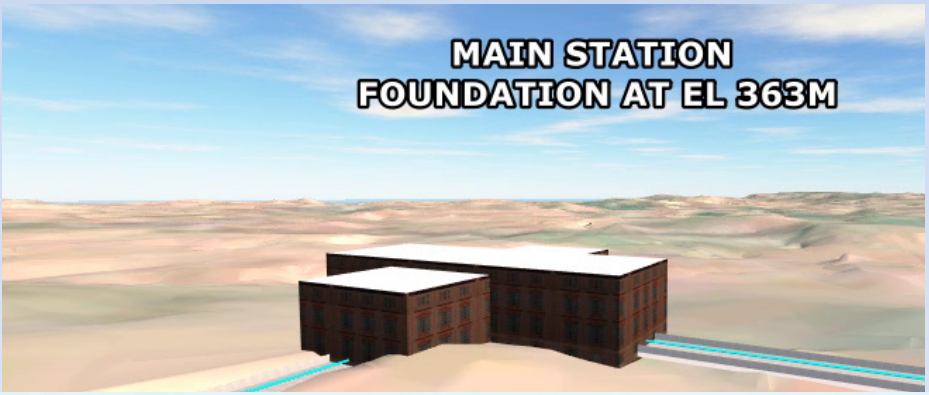


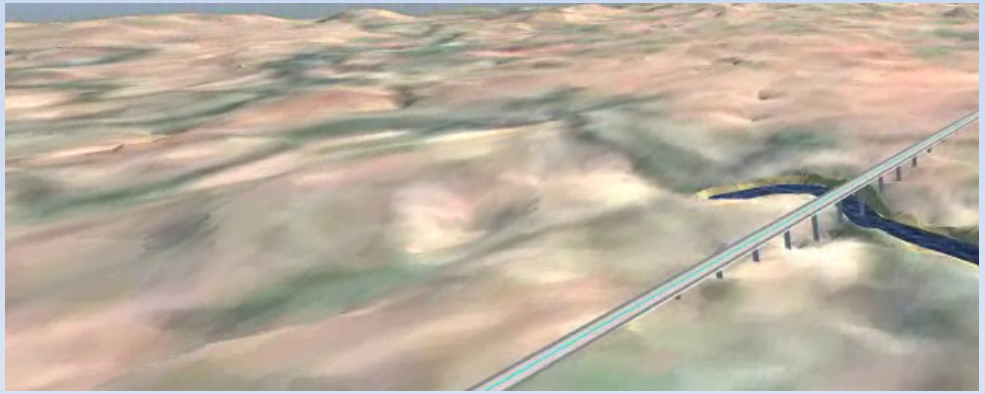
Site - Kalyanpura

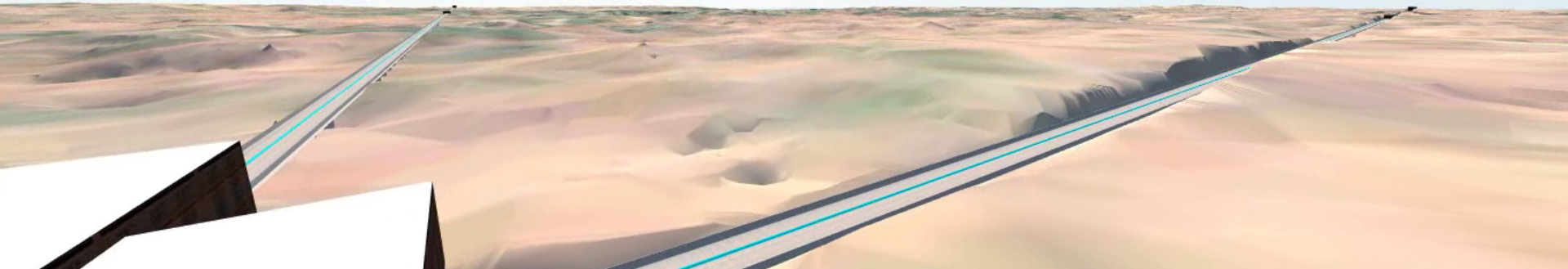
Engineering feasibility study

Completed July 2015









Engineering feasibility study

Completed July 2015

INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS (IUCAA)

FEASIBILITY STUDIES FOR EVALUATING SITES FOR CONSTRUCTION OF LIGO-INDIA PROJECT

TATA CONSULTING ENGINEERS LIMITED
4th Floor Tower A 247 Park LBS Marg Vikhroli (West) Mumbai 400 083
Tel +91 22 6114 8181 Fax +91 22 6114 8282 email mail@tce.co.in website www.tce.co.in CIN U74210MH1999PLC123010
Registered Office Matulya Centre A 249 Senapati Bapat Marg Lower Parel (West) Mumbai 400 013

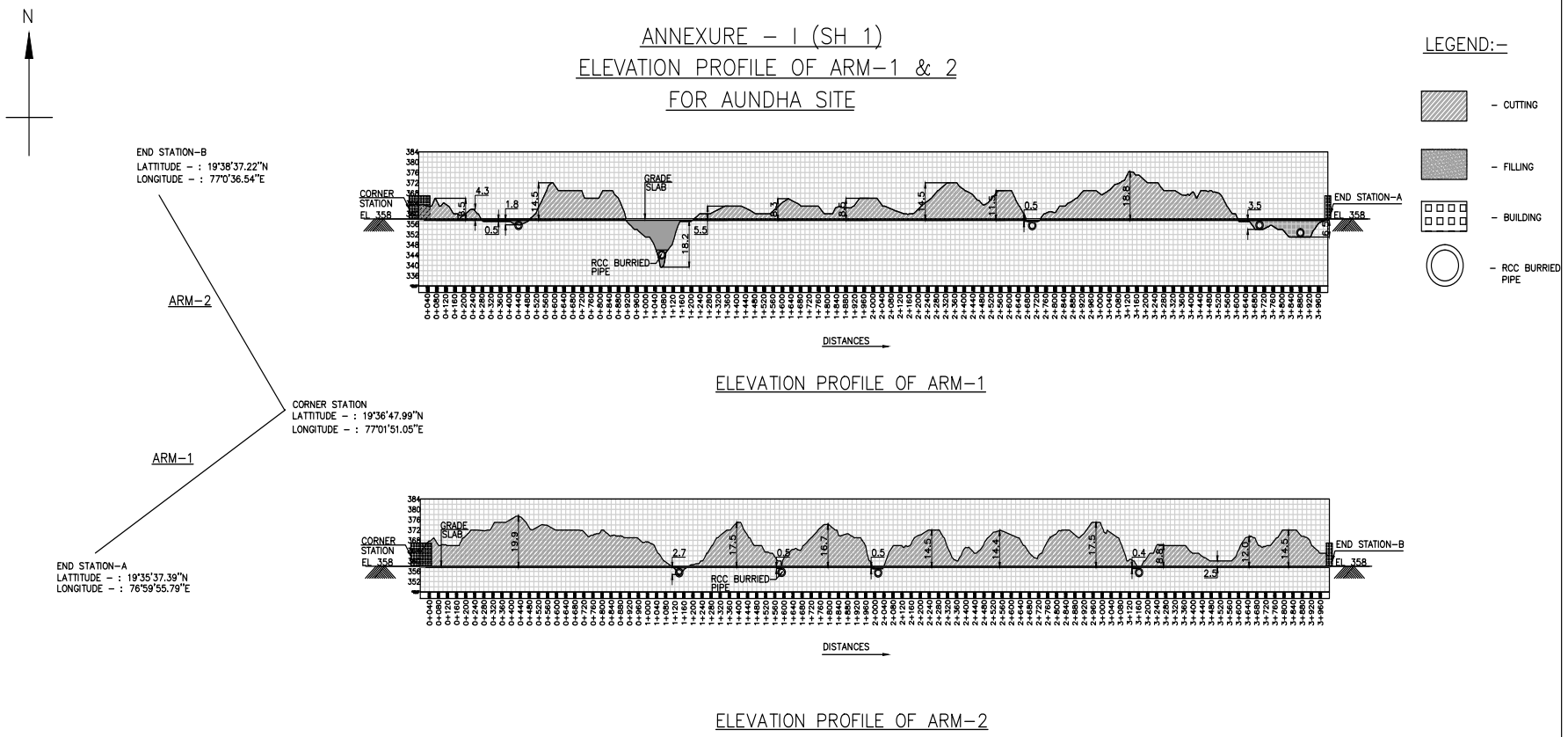
October 2015

TCE.7848-CV-400-BS-04	**TATA CONSULTING ENGINEERS LIMITED**	TOTAL PAGES 89
	FEASIBILITY STUDY REPORT	

Table of Contents

EXCELLENT:	Meets all the requirement
GOOD:	Meets the requirement with few minor exception
MODERATE:	Slightly meet the requirement
POOR:	Does not meet the requirement, major improvements needed to meet the requirements

Engineering feasibility study



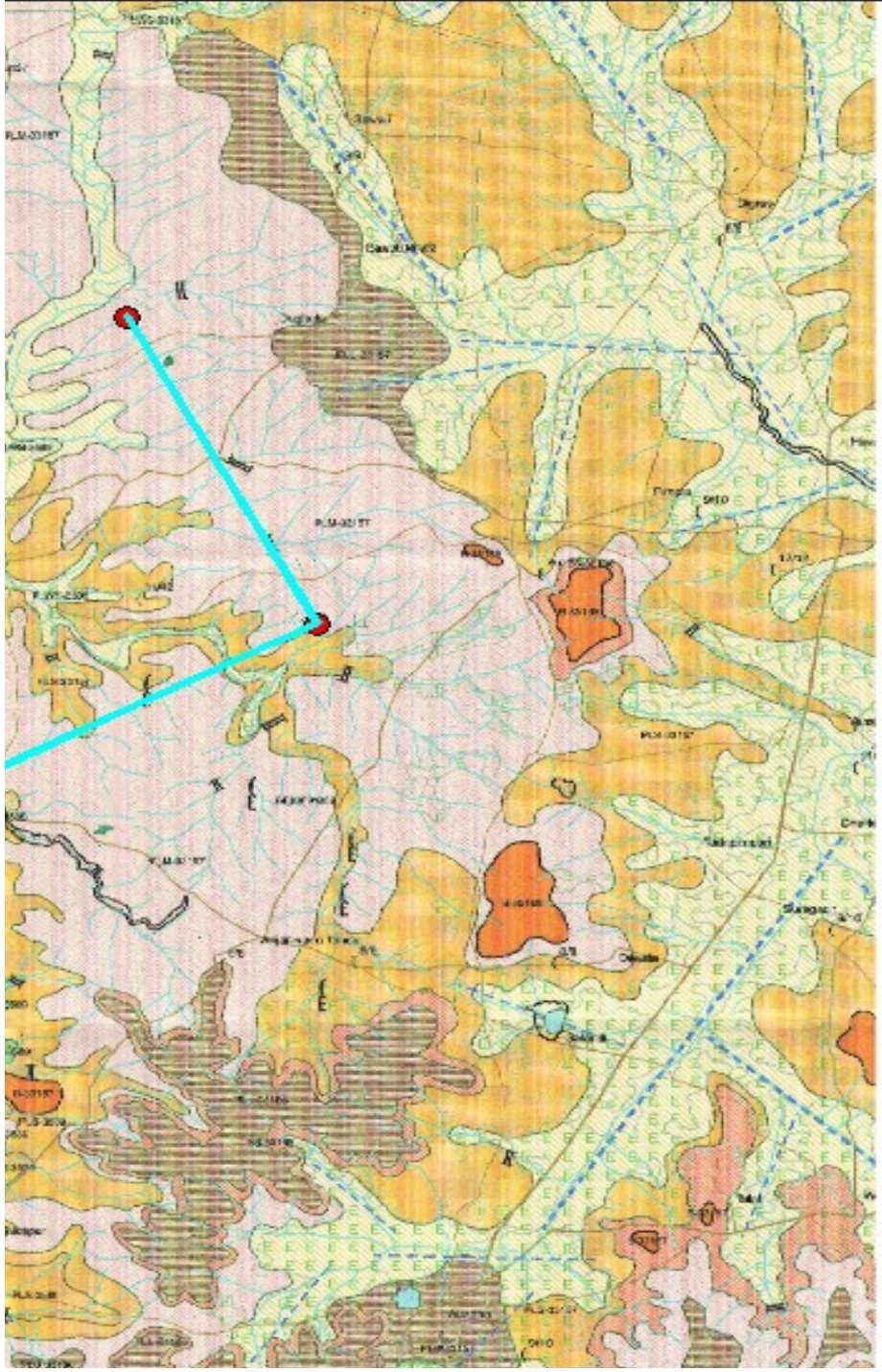
Profile along Arm1 and Arm2

Geotechnical information

MRSAC Geological map of the area Site Aundha

Vesicular traps showing

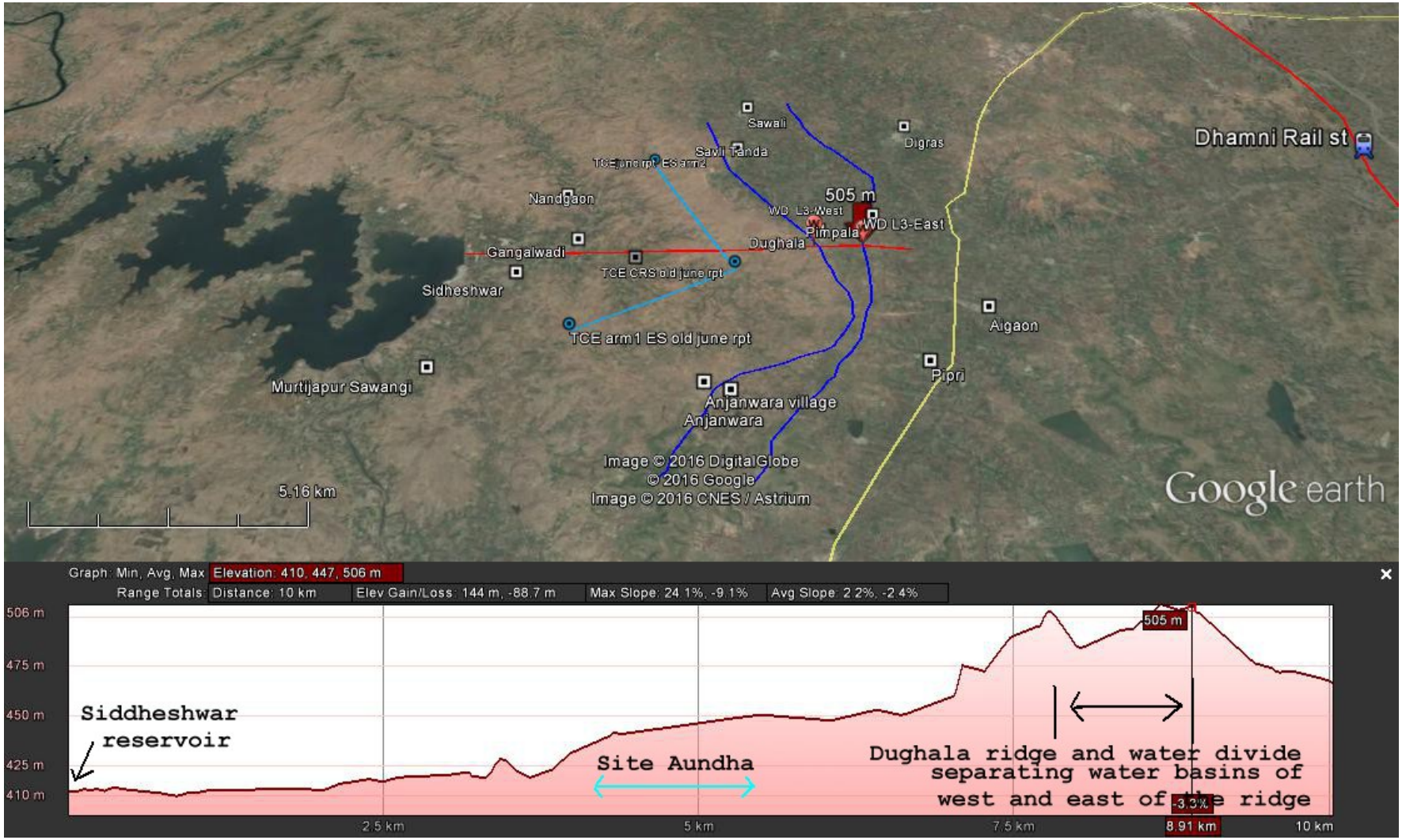
- plateau moderately dessicated(33157 pink),
- plateau weathered shallow(3589 yellow),
- plateu slightly disected(33157 brown),
- Plateau undissicated(33157 dark brown Dudhala)



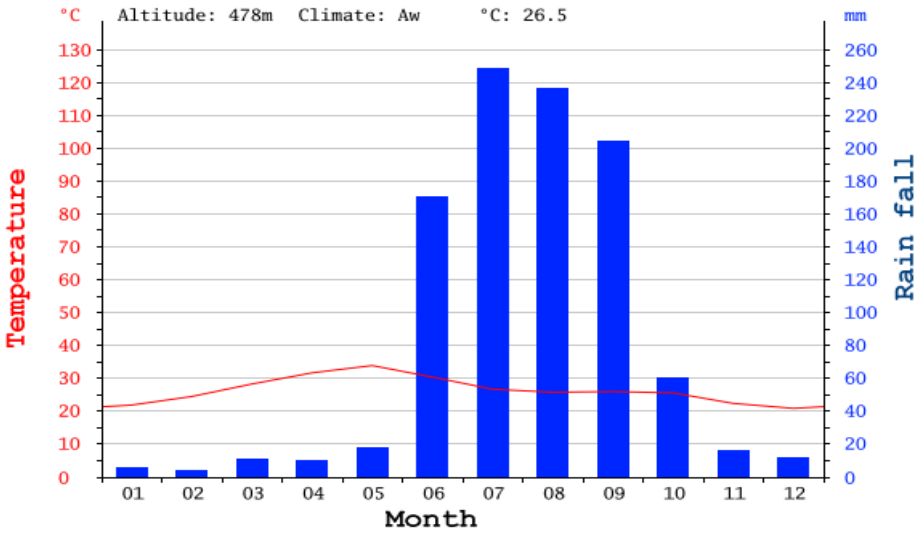

End B
Nandgaon
Gangalwadi
Dughala
Pit Digging hill 19,37,03. 4 N
Central Station
Ghara
© 2018 Google
Image © 2018 CNES / Astrium

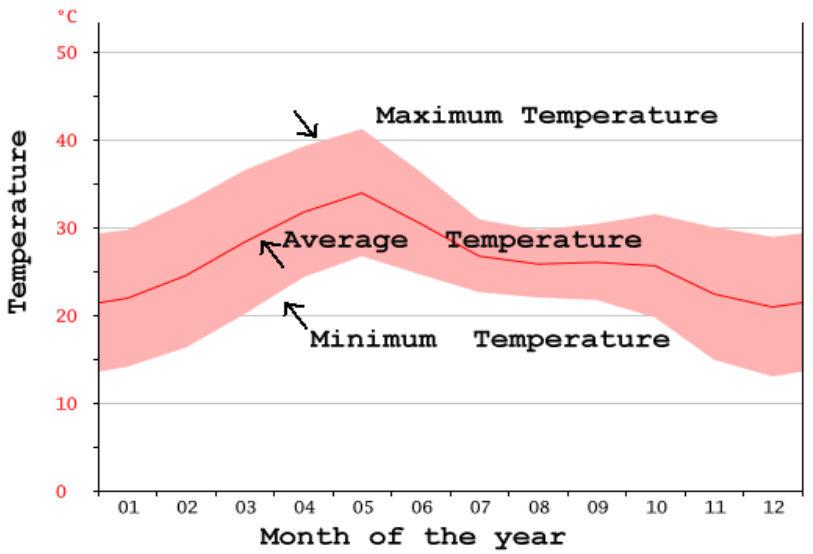

HYUNDAI

Water catchment & drainage area

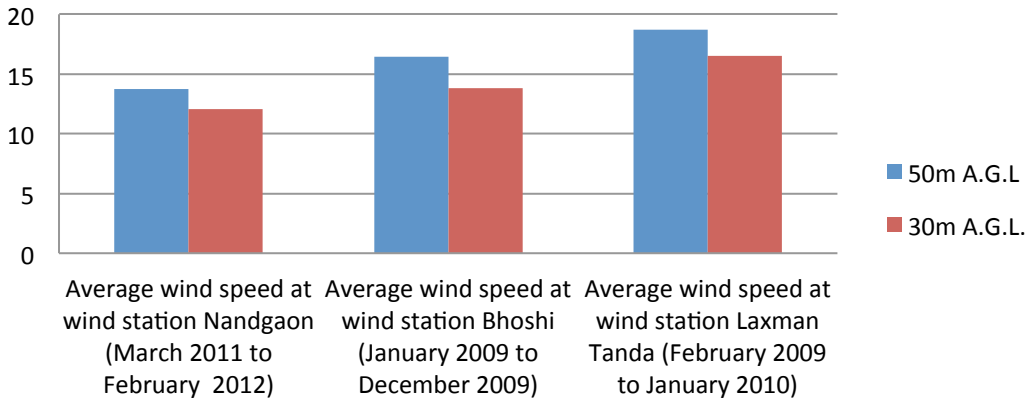


Weather & Climate

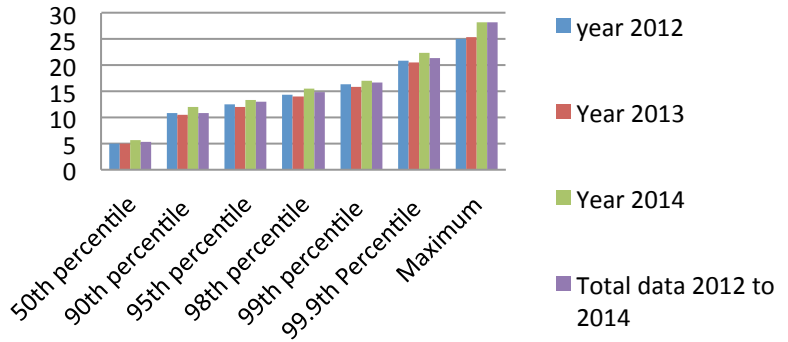




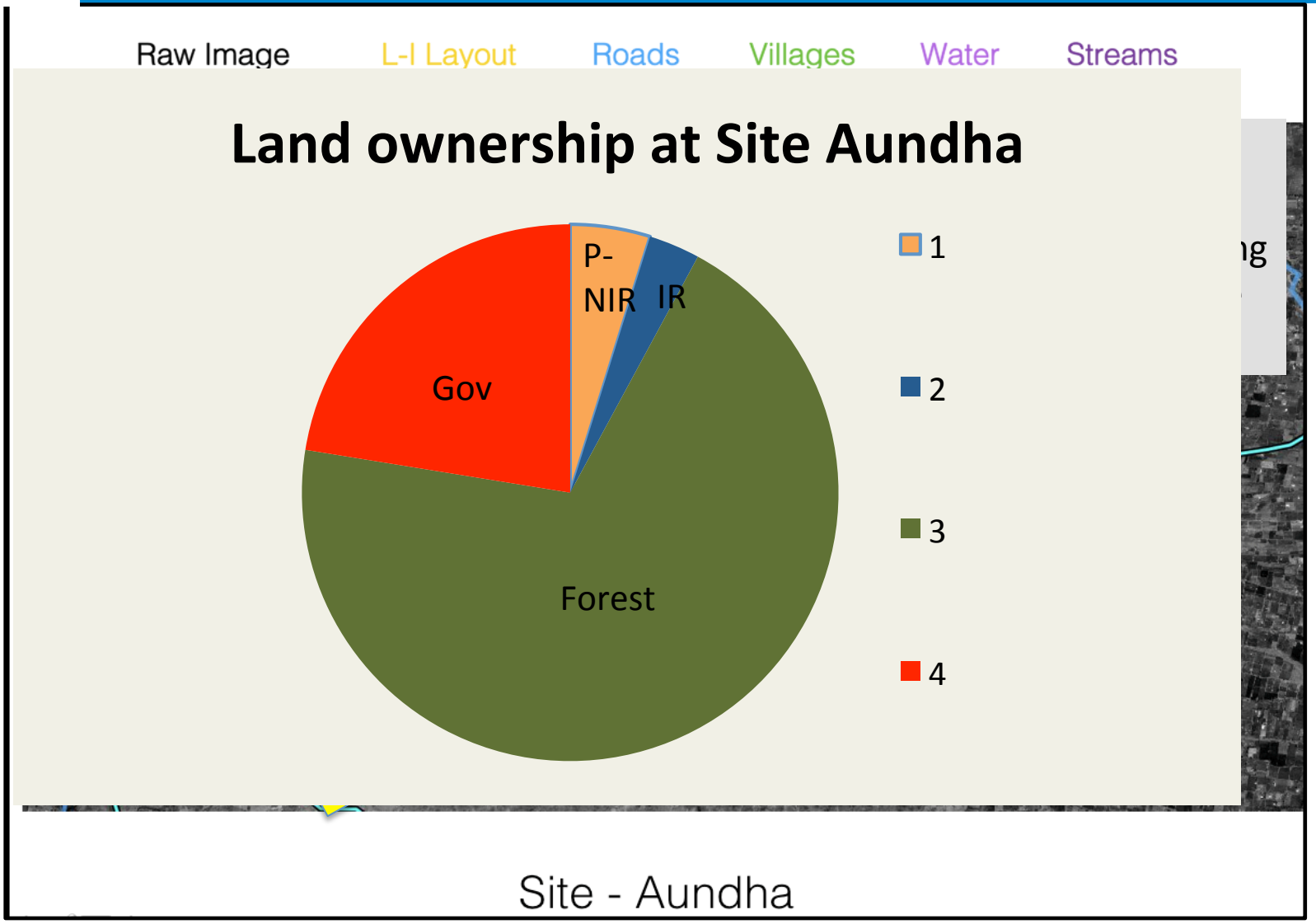
Average wind speed(Km /Hour) at three wind stations in Aundha tehasil, Hingoli district, Maharashtra



Percentile values for wind speed (Km/Hour) for wind data from AWS, Hingoli for period 2012 to 2014



Site terrain with features



CARTOSAT (ISRO) terrain data for a Aundha site. Overlays show a proposed LIGO-India configuration, the existing roads, villages, waterbodies and streams.

Issues we worry about ??

Aspect	Kalyanpura (Rajasthan)	Aundha-Nagnath (Maharshtra)	Rajgarh-I, MP (Kalitalai)	Rajgarh-II, MP (Pipliya Kulmi)
Seismic survey	Good, unknown bump at 1-2 Hz	Good	Good, unknown bump at 1-2 Hz	
Land mass movement	23 m cubic m (very flat)	66 m cubic m (small streams)		
Land ownership	Private, agriculture, small villages and roads	Government, no cultivation, grazing land. Small village, nearby reservoir	Rocky barren land. Land ownership and availability details to be followed up with the collectorate.	
Nearest City (population)	Udaipur (0.6m)	Nanded (0.55m)	Bhopal (1.8m), Indore (3.3m) Rajgarh (24k) distance: 10km, 56km	
Airport	Udaipur (100km) Ahmedabad (183km)	Nanded (60km) [operation paused] Aurangabad (191km) Indore (476km) Hyderabad (358km) Pune (412km)	Bhopal (134km) Indore (215km)	Bhopal (186km) Indore (191km)
Hotel	Many hotels in Udaipur	Few good hotels in Nanded	Many hotels in Bhopal & Indore	
Distance from nearest hotel	100km	60km	200km	
University	Udaipur has universities with MSc Physics dept. It also has an observatory. There are people involved in X-ray analysis. There is an IIM too.	Nanded SRTM University and many more. Has M.Sc. Course in Astronomy. Hosts a IRC and has build a small cluster. Has good people in seismology.	Many small universities and P.G. Colleges, e.g., Jaypee Univ. Of Engineering and Technology. Indore has IIM and IIT.	

Engineering feasibility study

Aundha, Hingoli, Maharashtra

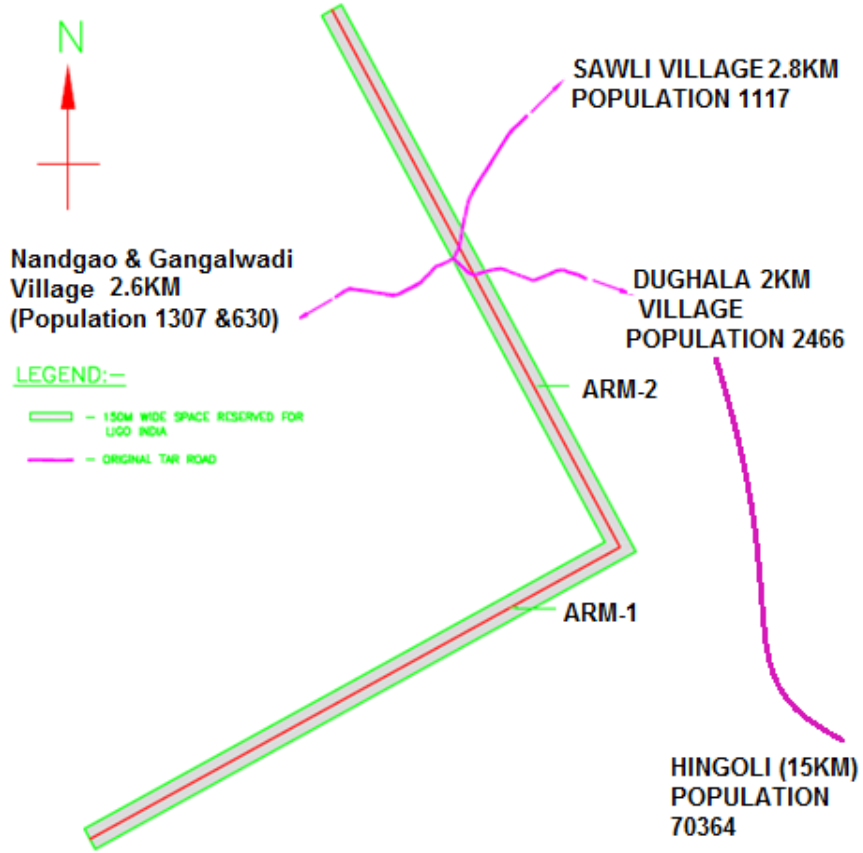


Figure 18 Existing road network

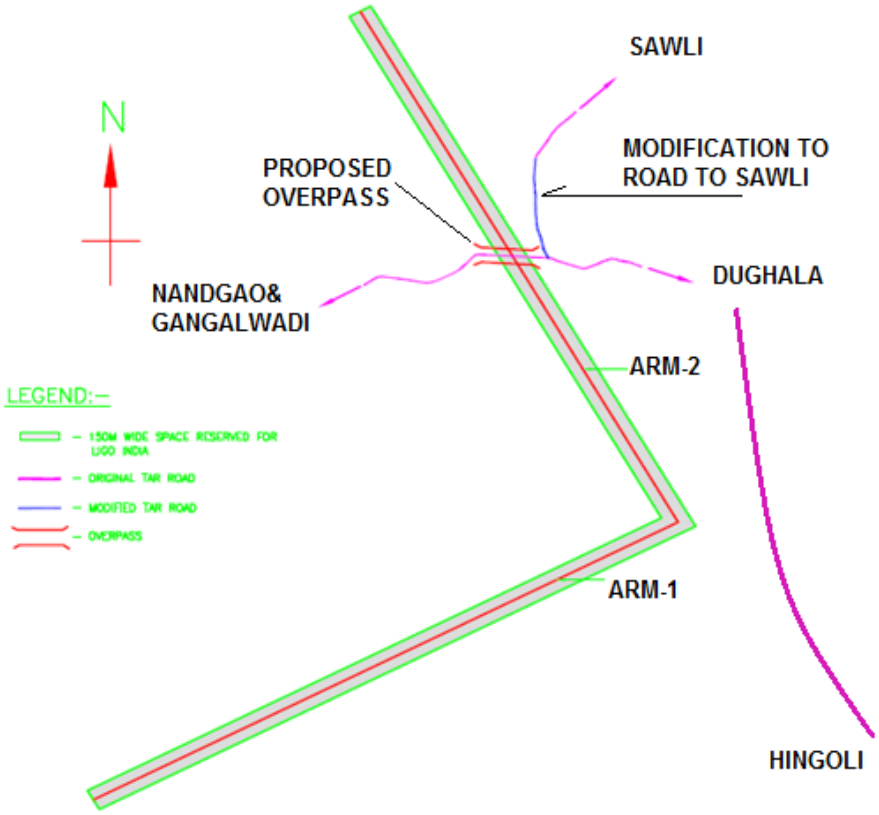
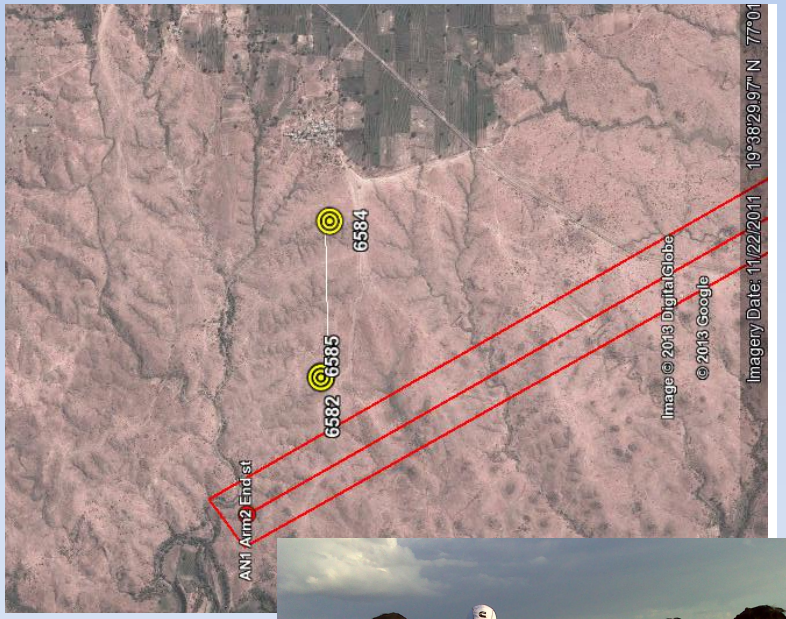
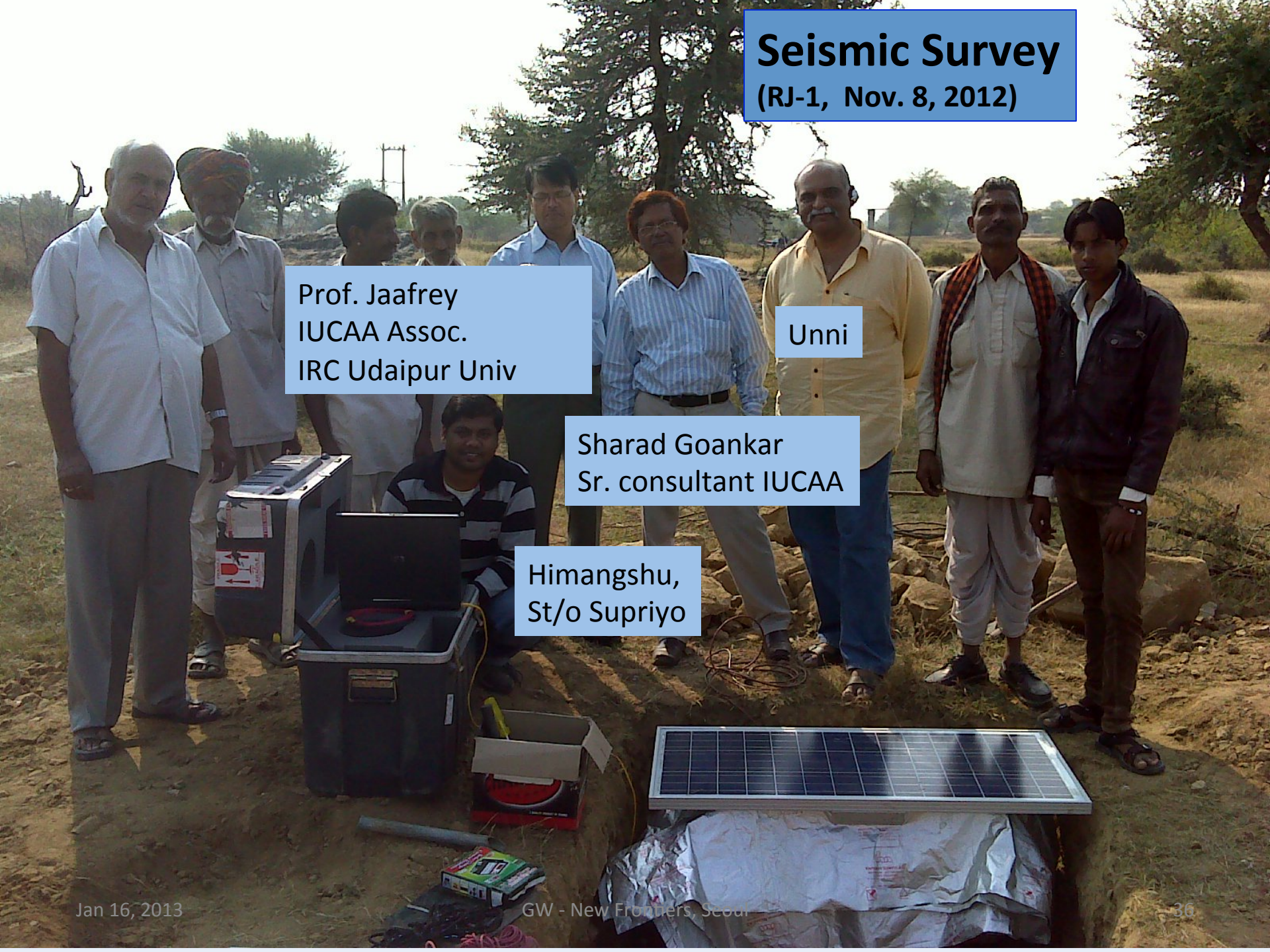


Figure 19 Proposed modification to road network

Seismic study

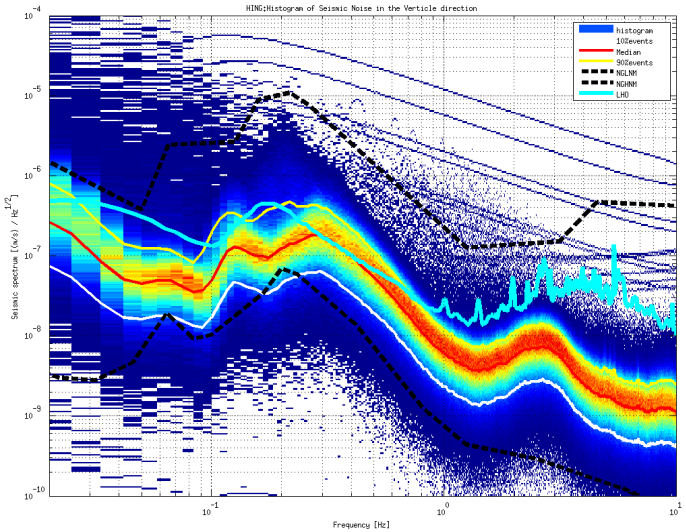
Aundha site, Hingoli District, Maharashtra (near Nanded)
[Sep 29-Oct 15, 2013]

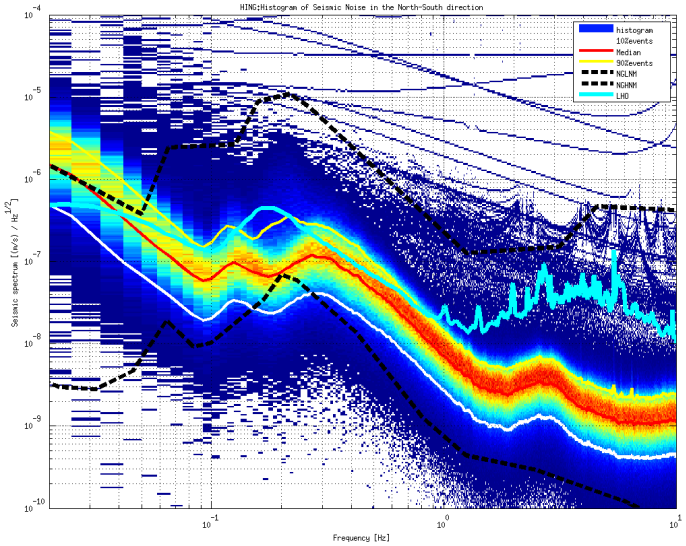


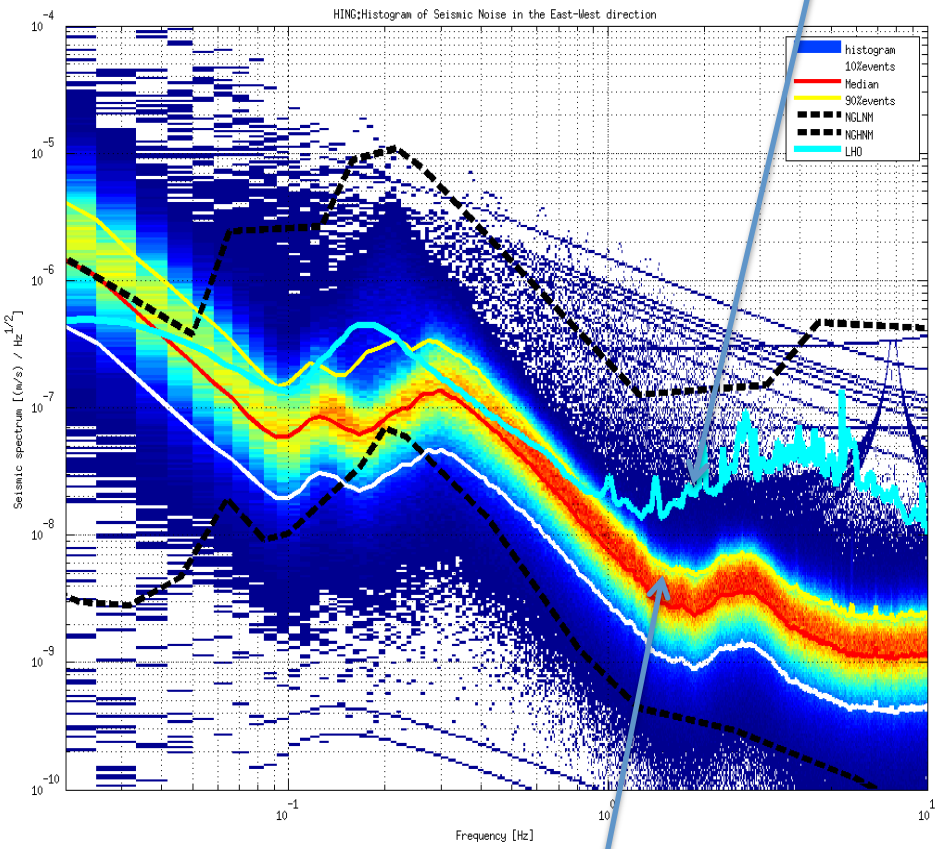

Seismic Survey
(RJ-1, Nov. 8, 2012)
Prof. Jaafrey
IUCAA Assoc.
IRC Udaipur Univ
Unni
Sharad Goankar
Sr. consultant IUCAA
Himangshu,
St/o Supriyo

Seismic study

Aundha site, Hingoli District, Maharashtra (near Nanded)
[Sep 29-Oct 15, 2013]





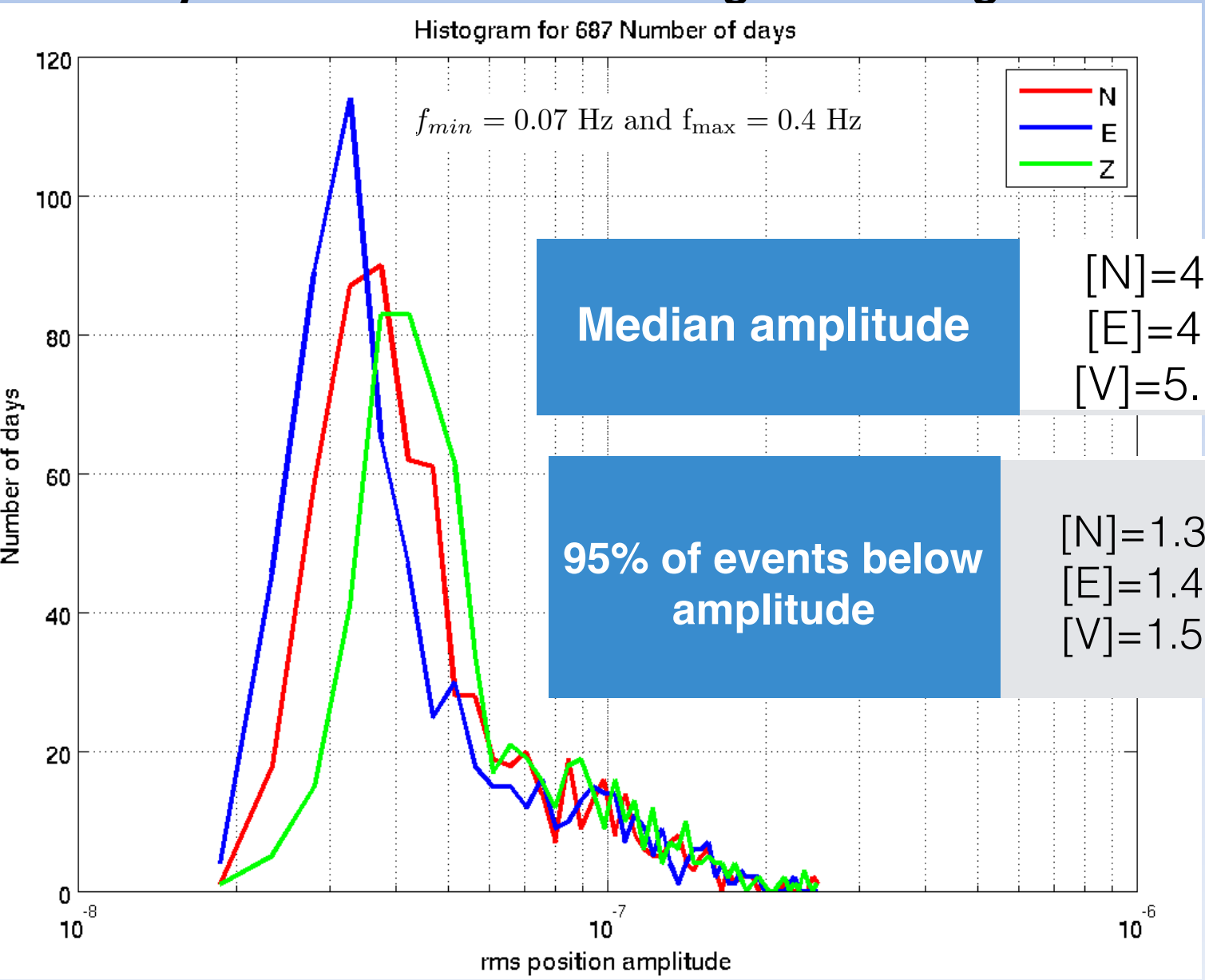


Noise level at US detector site (cyan)

Noise level at our site (red)

Micro-Seismic study

2 year data at Nanded College seismological observatory



(2010-2011)

Median amplitude

[N]=4.587x10^{-8} M
[E]=4.083x10^{-8} M
[V]=5.1301x10^{-8} M

95% of events below amplitude

[N]=1.362x10^{-7} M
[E]=1.456x10^{-7} M
[V]=1.503x10^{-7} M

LIGO-India ‘preferred’ site

LIGO-India ‘preferred’ site

LIGO-India 'preferred' site

LI-PMB visit

Site acquisition Team visit

Campus land near LIO site

Summary

- Continued top level support and goodwill for LIGO-India

PMO India @PMOIndia · 4h

Our Government has already given the go-ahead to establish 3rd LIGO detector in the country. It will expand our knowledge in basic sciences in the areas of lasers, light waves & computing. I am told that our scientists are tirelessly working towards making this a reality: PM

57 247 821

Mar. 16, 2018: PM at Indian Science Congress
Jan. 03 2019: PM at Indian Science Congress

- LIGO-India site acquisition "**COMPLETE**". Critical steps passed.
- Work towards launch of Civil construction. Prototyping Vacuum infstruc
- Developing scientific HRD through pan-Indian R&D program

Thank you !!!

- Enormous challenges ahead, but good progress so far !!!