

Role of Site Conditions on Built-Environment of Delhi

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Site Response Studies



Generally, the region closest to the EQ- directly above the ruptured fault(hypocentre) shakes most severely and sustains greater amount of damage

If damage elsewhere

Reasons

- **Building construction Quality**
- **Effects of ground deformation**
- **Liquefaction**
- **local site effects**

Understanding and characterising the site effects are important since areas that demonstrate adverse site effects will have amplified ground shaking during future EQ's

Soil Strata



- **1985 Mexico Earthquake**
- **Max. damage 400 km away from the source**
- **Amplification with respect to bed rock more than 5**
- **Lake bed zone(40 m soft clay) – most damaged**
- **Few adjacent localities experienced no damage**
- **Northridge freeway collapsed case studies**

Effect of Topography

- **Topographic amplifications well reported in literature.**
- **Tarjana, Los Angles (North Ridge, 1994)**
- **6 Km away from epicentre**
- **PGA of 1.78g recorded at Hilltop**
- **1 g for 7 to 8 seconds.**
- **Hilltop 15m high, 500 m long, 130 wide**
- **21 SMAs installed**
- **Top to base amplification ratio was 2(lateral) and 4.5 (vertical)**
- **PGA 3.5 to 7 times larger than near by sites (<2 km)**

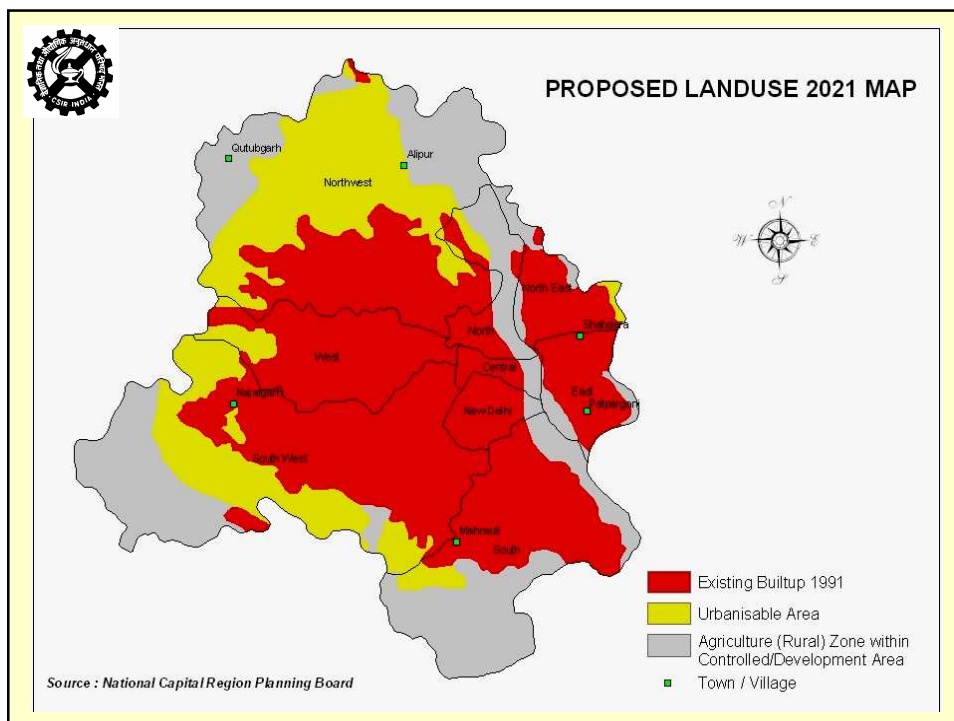
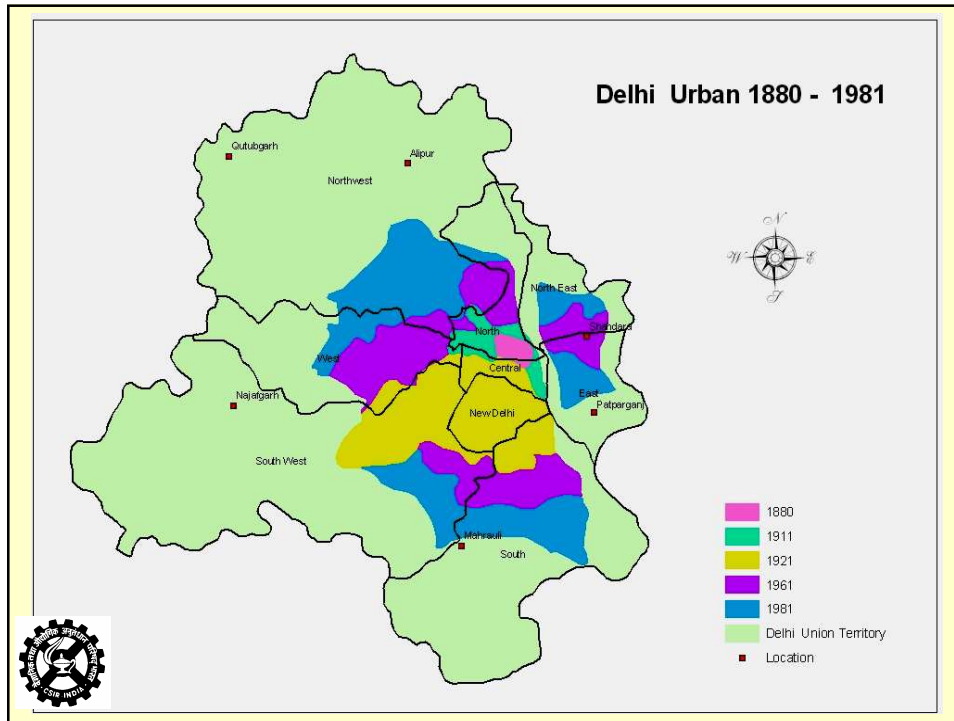


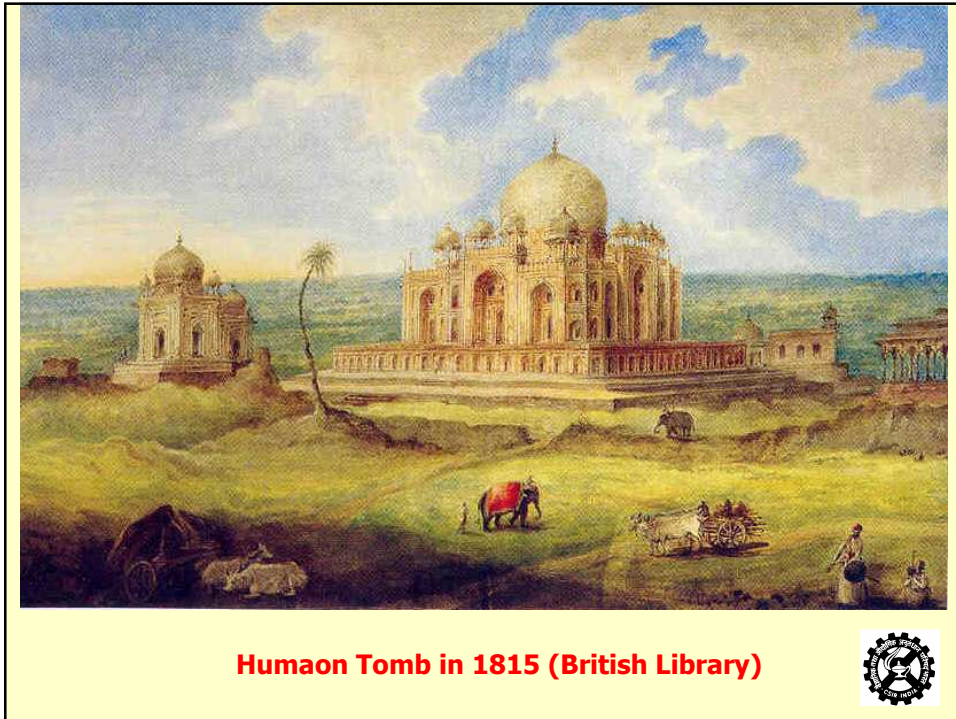
Seismic Shear Wave

- **Zones of low shear wave velocities associated with amplify ground shaking**
- **Slow velocities imply softer ground, and larger site amplification**
- **Northridge Earthquake, 12 borehole studies, 100m deep**
- **150 m/s – High site response**
250 m/s – Moderate to Low
400 m/s - Low



DELHI







Seismozenic Source Zone	Max. Mag. Experienced
Himalayan Seismogenic zone	: 7.0 (19th Oct. 1991)
Delhi-Haridwar Ridge zone	: 6.5 (15th July 1720)
Moradabad Fault zone	: 6.0 (10th Dec. 1956)
Rajasthan Great Boundary Fault zone	: 7.0 (31st Aug. 1803)
Mathura Fault zone	: 7.0 (31st Aug. 1803)
Sohna Fault zone	: 6.5 (15th July 1720)

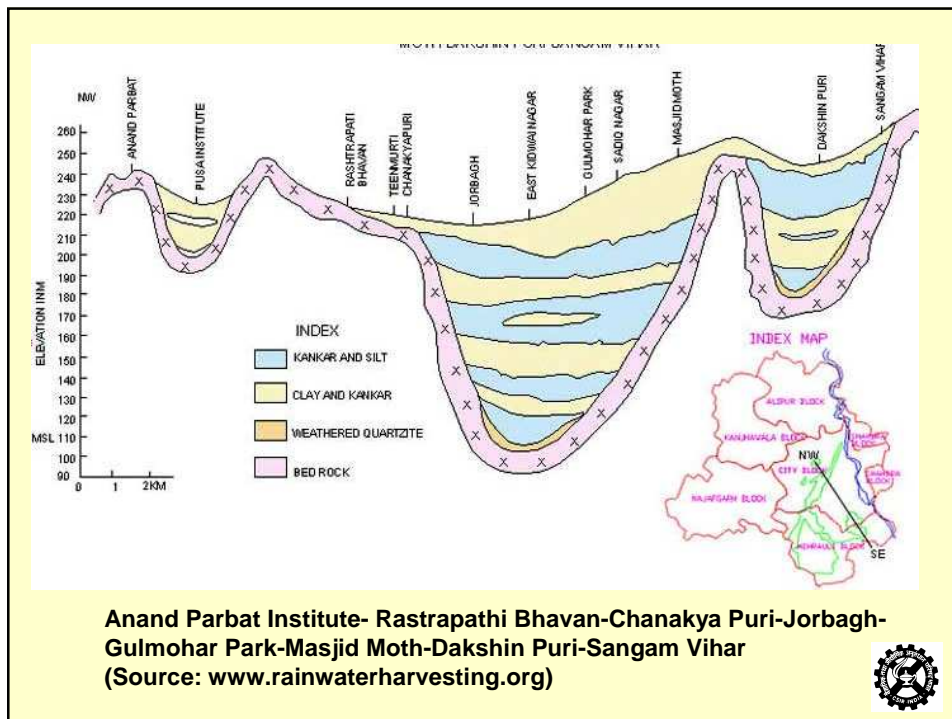
After Sharma et al., (2003)

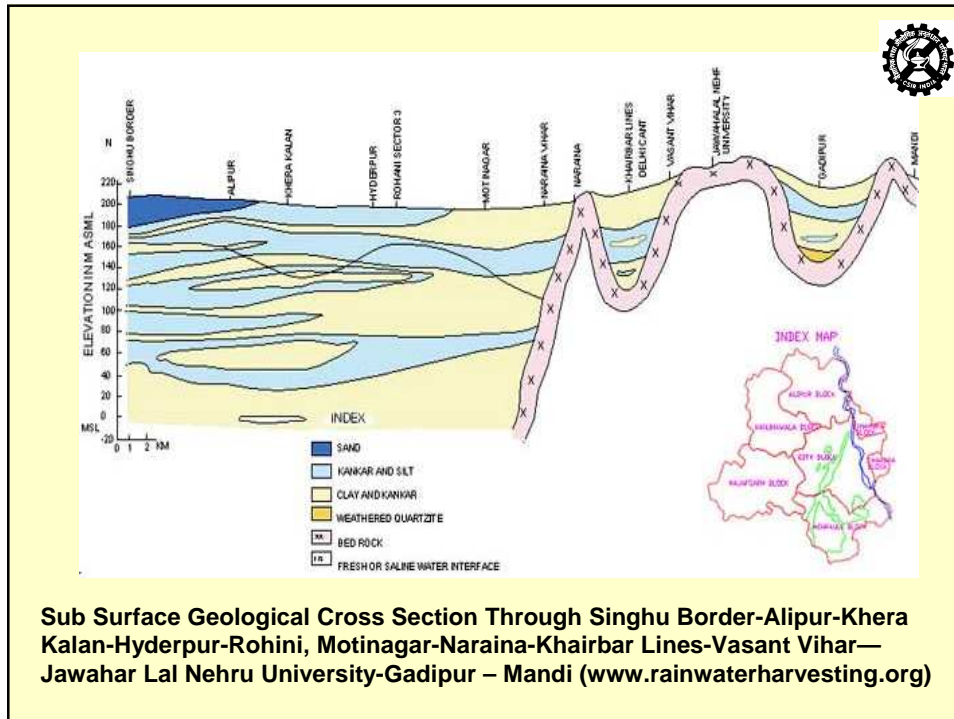
Seismic susceptibility of Delhi due to Faults (300 Km radius)

Delhi Region

Name	Probable EQ
Great Boundary Fault	7
Mahendragarh- Dehradun	7
Moradabad	6.5
Chahapoli	5.5
Sabi fracture	5.5
Near Mathura	5
Parellel to Mathura	5.5
Alwar left	5
Alwar	5
Jaipur	5
Mathura	6
Sohna	6
Delhi (Near karolBagh)	4.5
Himalayan Region	
Main Central Thrust	8
North Almora thrust	6.9
Main boundaryn Thrust	8
Alaknanda	5.5
Ropar	5
Ramgarh	5
South Almora thrust	6.5

After Iyengar & Ghosh (2004)





RISK AT DELHI

Khatti (1999)

Central Gap between 1905 & 1934 EQs. may produce two great earthquakes.

Bilham (2001)

Out of ten regions in Himalaya, six may produce at least one 1934 EQ. (exposing 50 million people at risk).

Singh (2002)

M 8.0 may produce 96 – 140 cm / sec*sec PGA

M 8.5 may produce 174 – 218 cm / sec*sec PGA

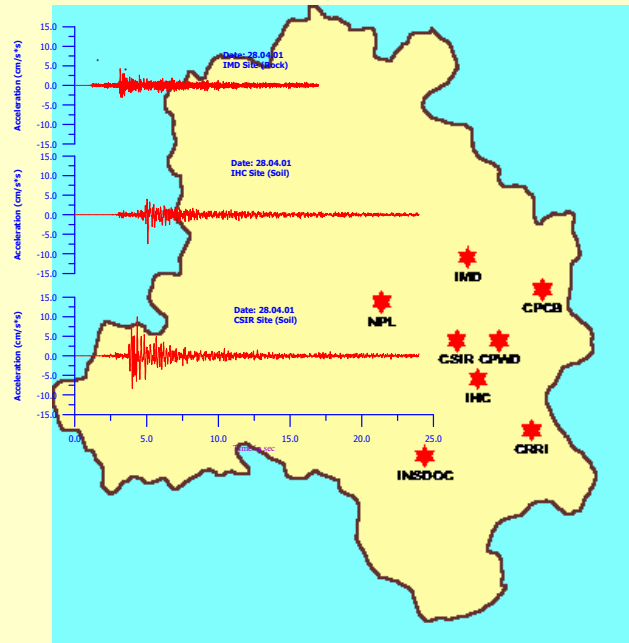
Amplifications may go upto 20 times at certain pockets.

❖ Large scale liquefaction predicted

❖ Most vulnerable area – EAST OF YAMUNA



Variation of PGA values in Delhi for Local Earthquake



AMPLIFICATION IN DELHI

Theoretically based on Kanai's relation

IMD RIDGE (ROCK) – 1.0
 CSIR HQ. (SOIL, 60M) – 2.5
 CPCB (SOIL, 100M) – 4.6

Observed Data in Delhi

Date	Mag	Peak Ground Acc.		Ratio	Type
		IMD (Rock)	CSIR (Soil)		
28/04/01	3.8	4.0325	10.2675	2.55	Local
25/02/01	5.8	0.3945	1.3999	3.55	Distant



**Delhi Earthquake 18.03.04
Epicenter (28.622, 77.257)**

Station	Acceleration
	PGA
INSDOC	3.772
IMD	5.537
CSIR	3.974
IHC	6.070
NPL	5.798
CPWD	18.577
CRRRI	7.167
DVB	10.933

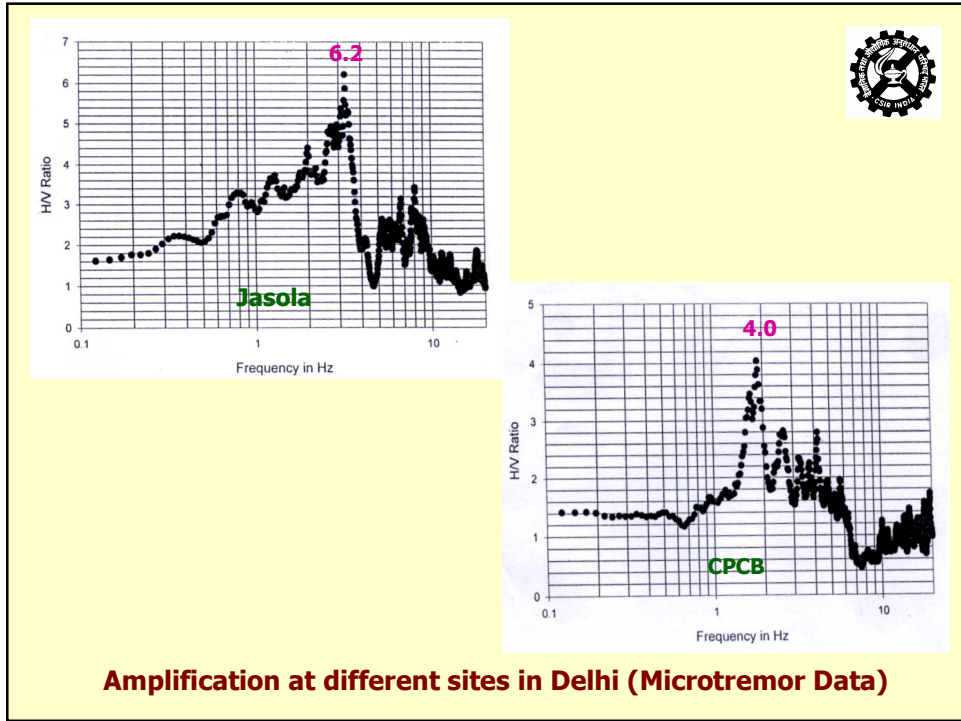


**Variation in amplification factor at different locations
(Real earthquake data)**

Sl. No.	SMA Stations	Amplification	Frequency (Hz)
1.	CSIR	7.66	2.34
2.	IHC	6.91	0.90
3.	CPCB	8.10	1.36
4.	CPWD	9.5	0.74
5.	IMD	2.53	3.04

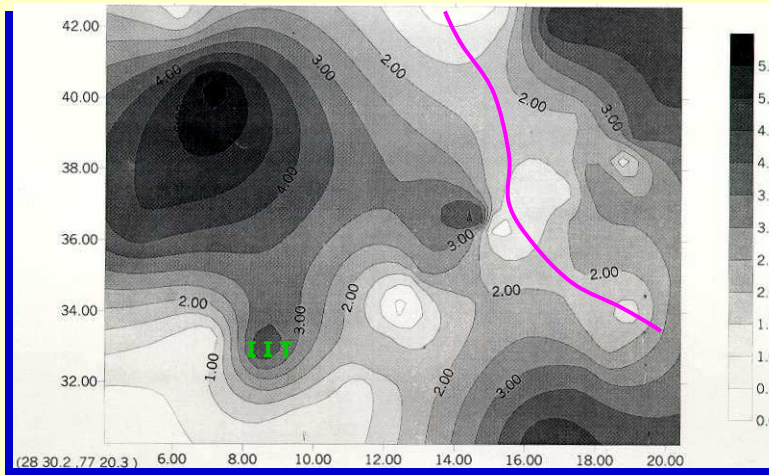
CPWD (ITO) & CPCB (Trans Yamuana) - Soil thickness – Maximum
 CSIR (Rafi Marg), IHC (Lodhi Road) - Soil thickness – Moderate
 IMD (Ridge) - Soil thickness – Almost nil





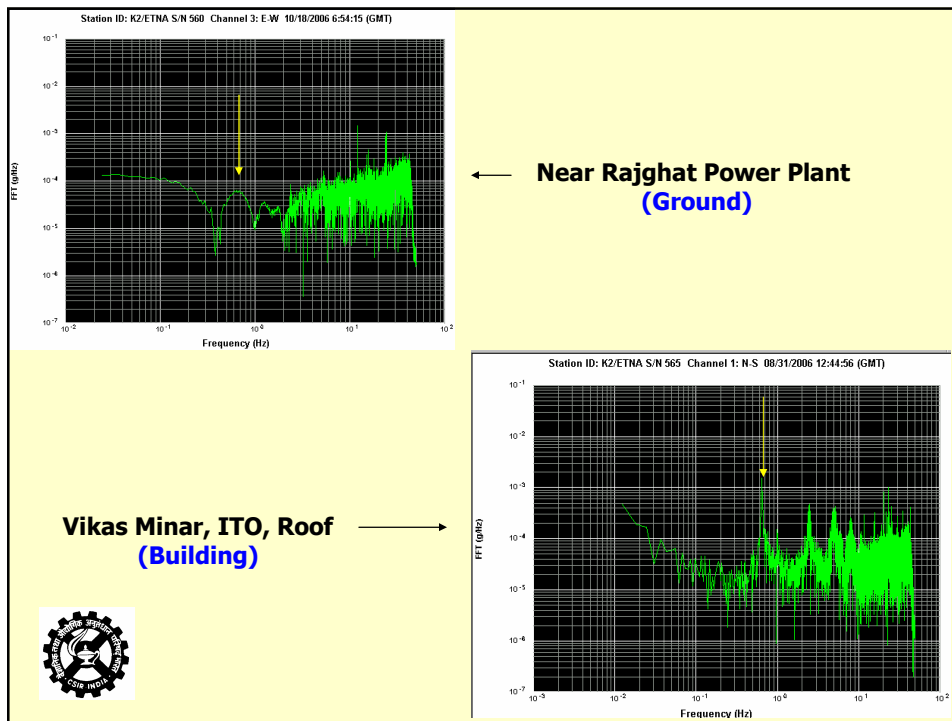
Ground frequency at sites near Yamuna.

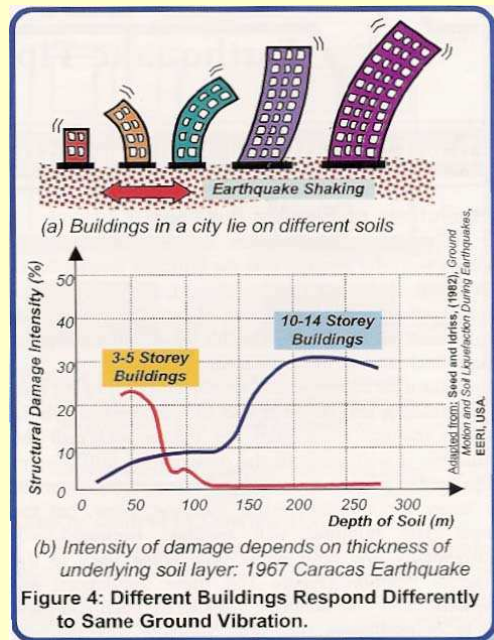
Site no	Ground frequency in Hz	Location
1	0.9	Zoological park
2	1.5	Near Crossing of NH24bypass road from Sarai Kale Khan to ITO
3	1.25	Near Paltun Bridge
4	0.4	Behind Old Fort
5	1.2	Maharani Bagh Guest House
6	1.0	CRRI, Mathura Road
7	0.6	DDA, Sports Complex, Jasola
8	0.7	ITO Building
9	0.8	Rajghat Power Plant



(Ambient noise data of about 80 locations in Delhi were collected using SMA instruments with minimum threshold level; natural frequencies using Nakamura's techniques have been obtained analyzing the data)

Variation of natural frequency in and around Delhi



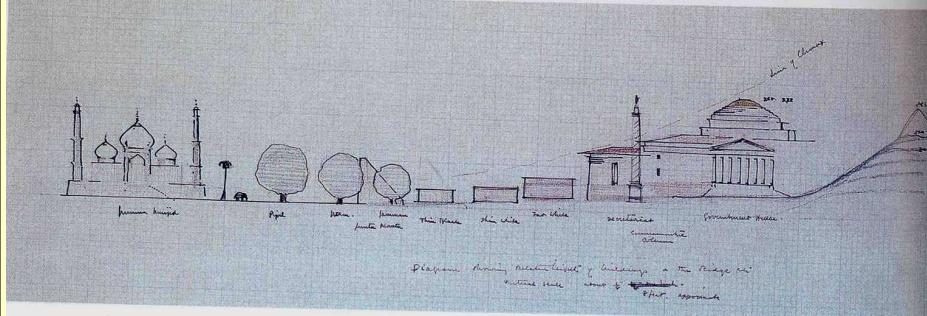


EFFECT OF RESONANCE

It was found at many places that the ground frequency is quiet close to the frequency of the Buildings in the area.

**TARANG APARTMENTS
VIKAS MINAR**

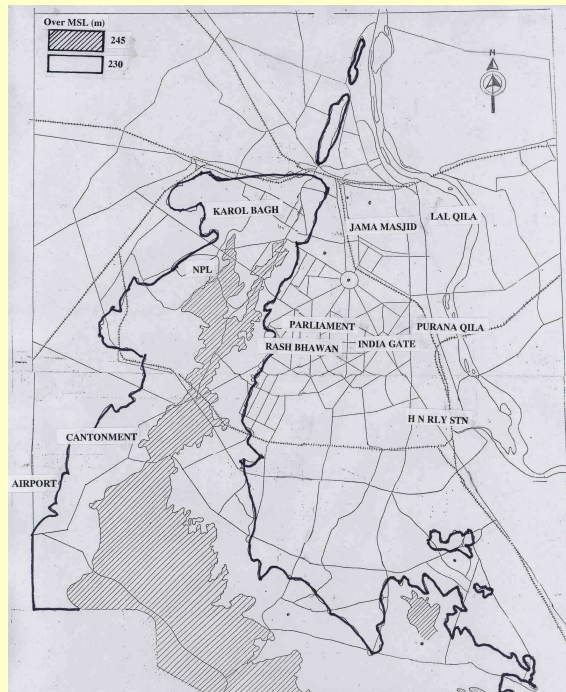




Topographic Difference in Delhi (Lutyens Hand Sketch)



Topographic Variation in Delhi (ASI, 1989)



DELHI : WATER BODIES

30 Big Ancient Lakes
508 Waterbodies (INTACH)

Najafgarh Lake (220 km*km)
Bhalswa Lake
Old Fort Lake
Hari Nagar Lake
Naini Lake
Prasd Nagar Lake
Sanjay Lake (2.5 km long)
Shahadara Lake
Reclamtion of Hauz Khas (16 acre)

(Delhi Planning 2005-06)



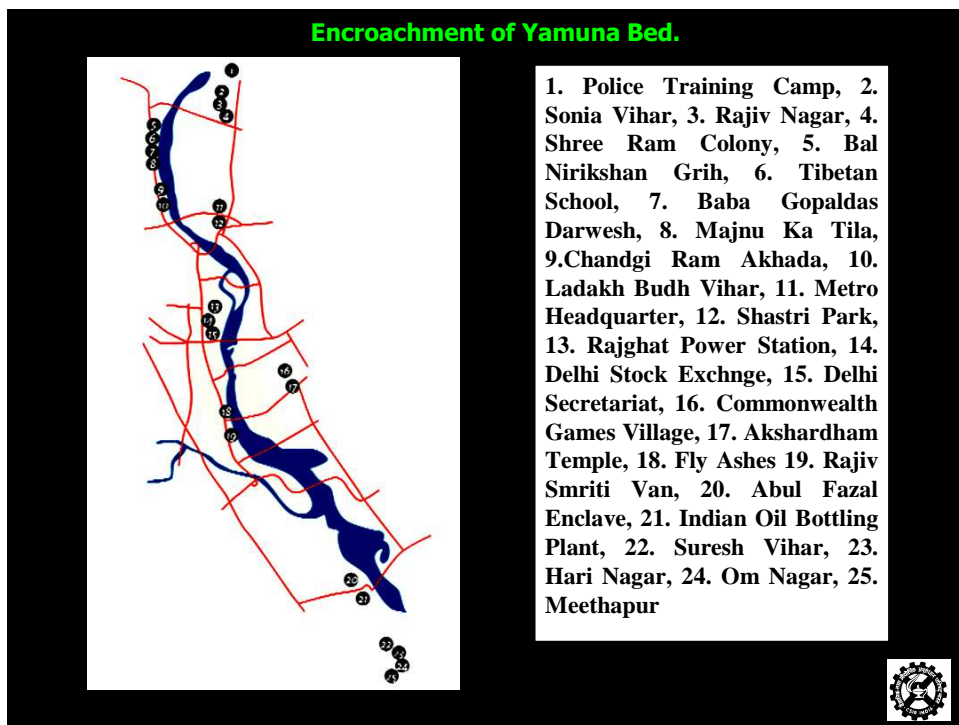
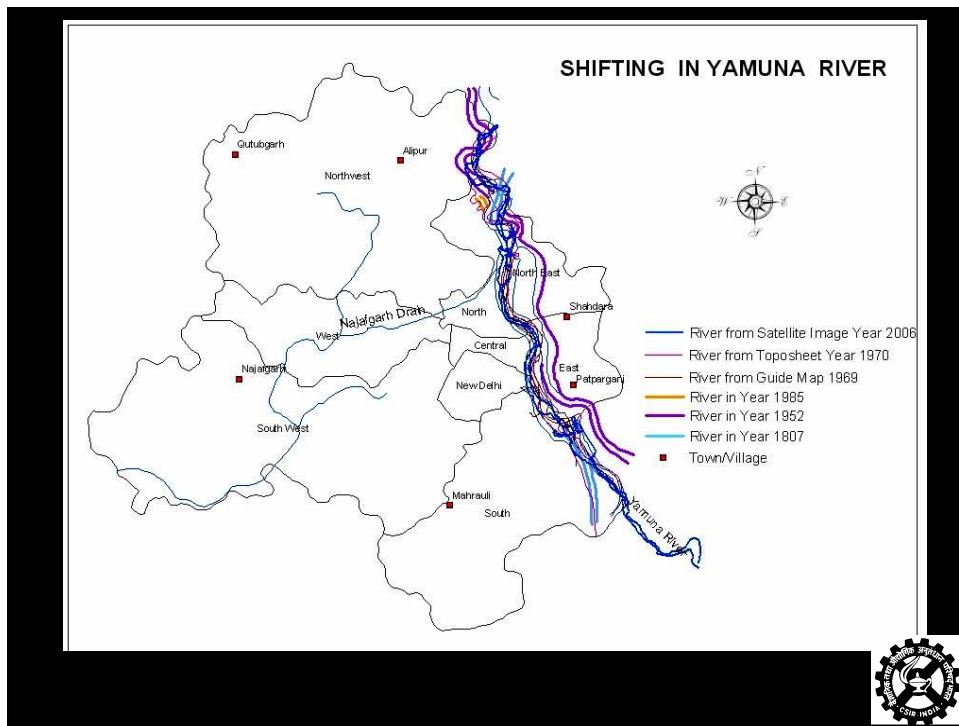
DELHI :LANDFILLED SITES

10,000 ton/day solid waste generted
About 1% of total Delhi area is Landfilled

14 Landfill Sites are filled up
4 sites are in progress.
7 are proposed (total area 228 acre).
These include one in Northwest Delhi (58 acre)
and one is Ghazipur Dairy Farm (52 acre).
These sites are 18 – 22 m deep.

(White Paper {ME&F})





Delhi : Areas of Concern

An NGO Indian National Trust of Art, Culture and Heritage (INTACH) has identified 508 water bodies in Delhi – most of them have been encroached by settlers now.

Once functional Nazafgarh lake spread over more than hundred square km have been taken over by unprecedented urban growth of the city.

All these vulnerable pockets may play havoc when a major earthquake strikes Delhi, and every effort should be made to pinpoint the critical players.

Strong motion studies undertaken by CBRI in Delhi has clearly illustrated the site amplifications taking place with moderate earthquake (< 4 M) at the locations with thicker soil cover.

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Topography plays very important role in site amplification.

Delhi district has a surfacial level difference of 685' in its area -highest point is 1045' near Bhatti and the lowest point is 360' at Jamuna Rail bridge.

Even river Yamuna has an average fall of 10 inches/mile in its stretch in the district- it enters at 710' feet level and leaves at 630'.

'Delhi Fault' passes through highly densified Karolbagh area and have the potential to generate one earthquake of 4.5M



Thanks