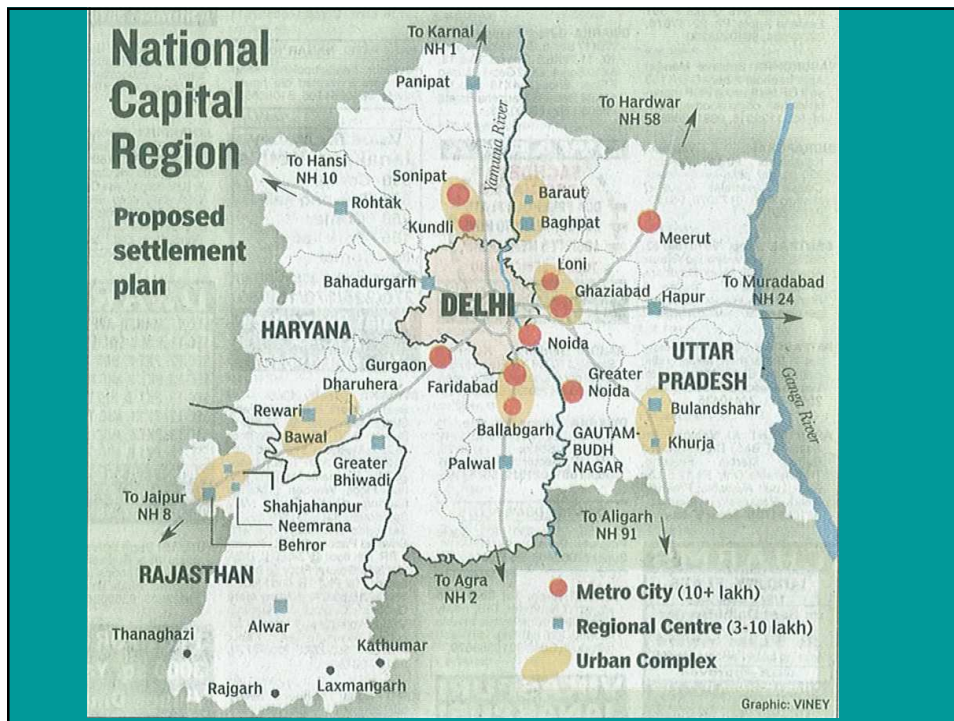


Evaluation of Liquefaction Potential of Delhi Sub-soil

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NIDM
P. Mishra & A.K. Shukla
EREC,IMD
Kishor Kumar
CRRI

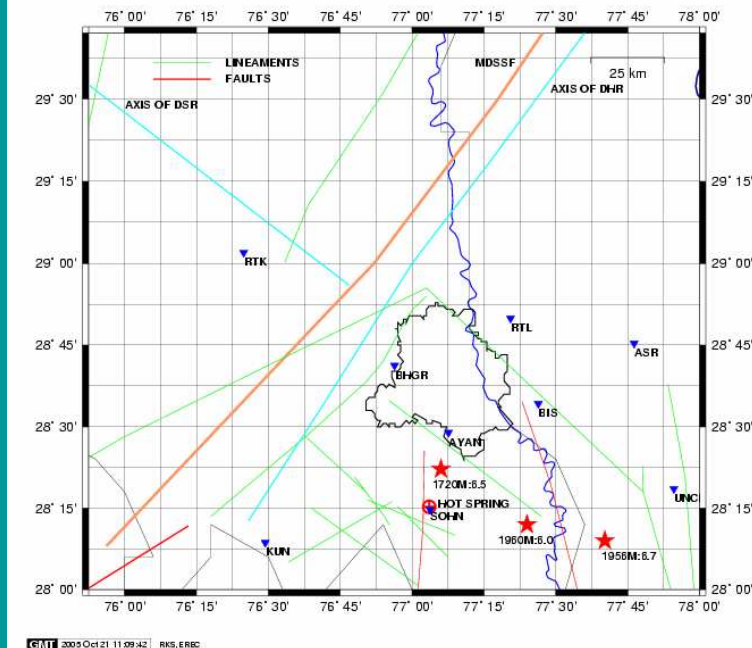
Acknowledgement
to
EREC, IMD, DST
CRRI, GSI, DST, CGWB, SOI..



Microzonation Issues of Delhi

- ✓ Proximity to Himalaya with multiple fault lines
- ✓ Ridge area and sandy silty soil >300m
- ✓ Yamuna river basin of Holocene times
- ✓ “Basin Margin” and “Basin effect” – Chattarpur area
- ✓ Mixed built environment

Significant Past Earthquake Near Delhi



Study of liquefaction

- Evaluation of **liquefaction hazards**
- Evaluation of potential **ground displacements**
- Mitigating liquefaction hazards by suitable **ground improvement** techniques

Parameters required for liquefaction assessment

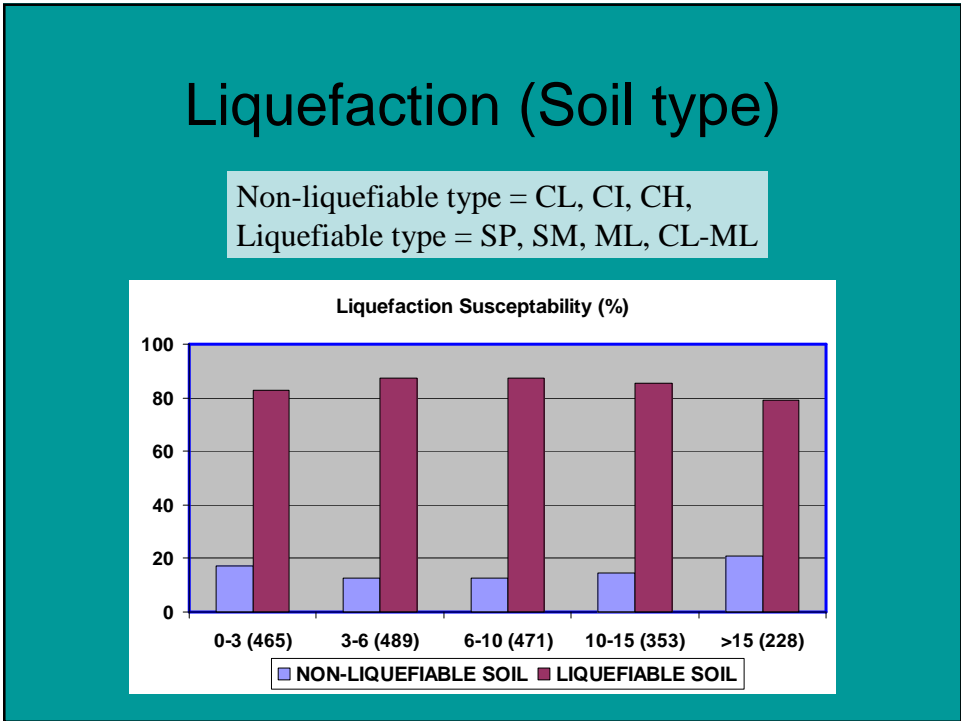
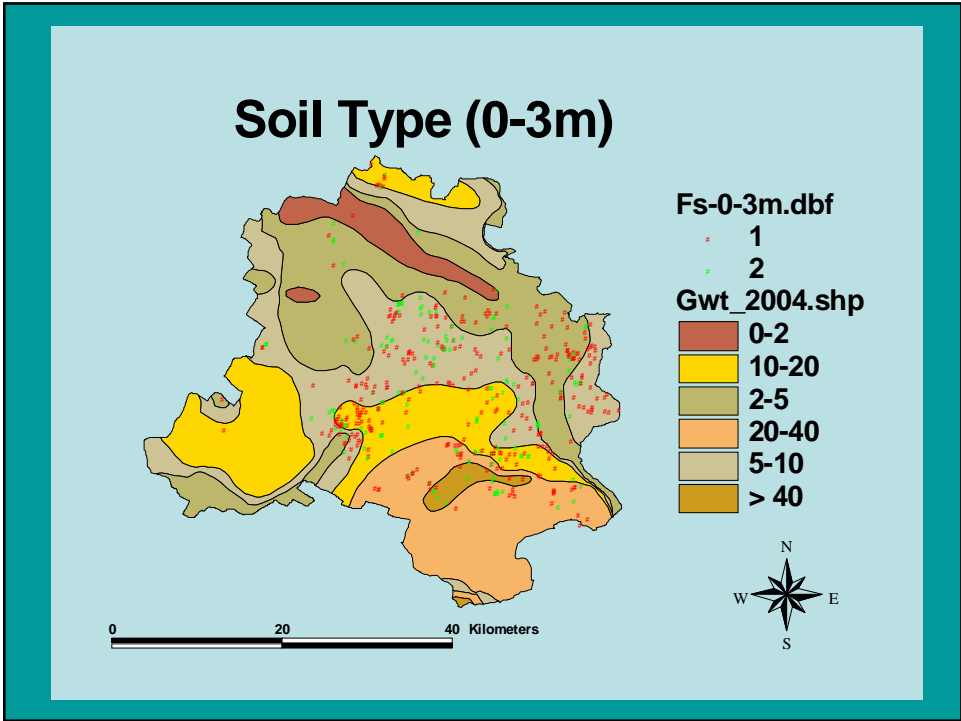
- **Seismological** – EQ. Magnitude, source distance, intensity, PGA, amplification/deamplification factor, spectral acceleration
- **Geotechnical** – penetration resistance (SPT/CPT/..), soil type, grain size, thickness of liquefiable zone, density, water table depth, bed rock depth,
- **Built environment** – Foundation type, zonation code, Building type, building dimension, soil-structure interaction factor....

Liquefaction studies of NCT Delhi

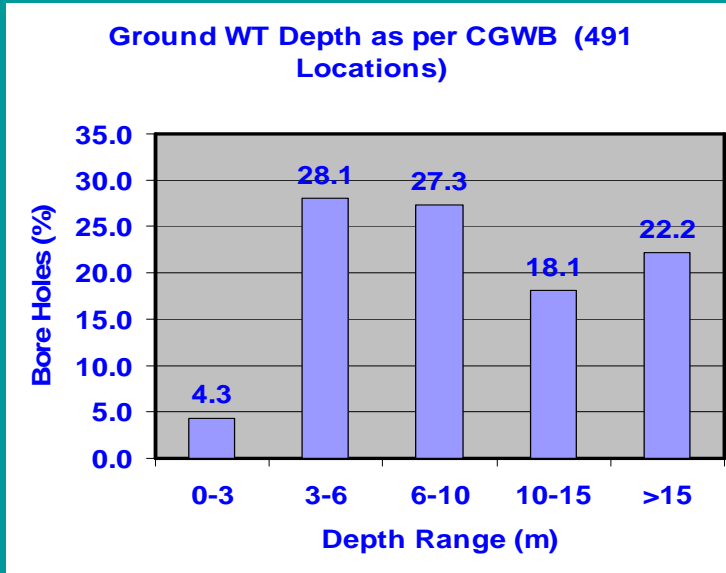
- Geotechnical data (DDA, CPWD, DMRC..) (Collected by **CRRI** (441 reports) and **EREC** (50 reports))
- Total No. of Boreholes = 1950 (CRRI) + 500 (EREC)
- **One Borehole** (from each project) having **min N** value and **possible** liquefiable soil types (based on grain size, Liquid limits, density...) selected

Modalities of Liquefaction studies

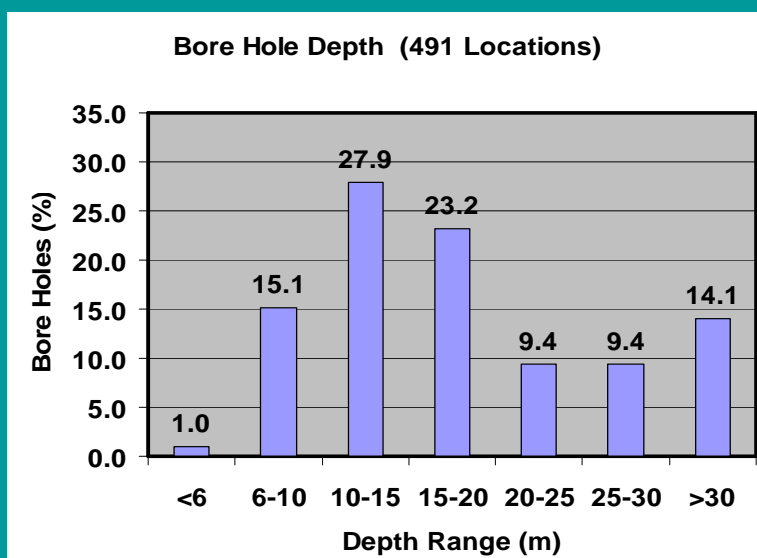
- Depth ranges taken are 0-3m, 3-6m, 6-10m, 10-15m and >15m
- Water table (as per CGWB, Nov-2004)
- PGA values of Delhi region (Sharma et al, 2003) [**0.19 to 0.33g, M=7.24**]
- Soil amplification (Rao, 2005)[**1.2 to 2.5**]
- Calculation of CRR(Cyclic Resistance Ratio) & CSR (Cyclic Stress Ratio) for SPT based on **Idriss and Boulanger (2004)**



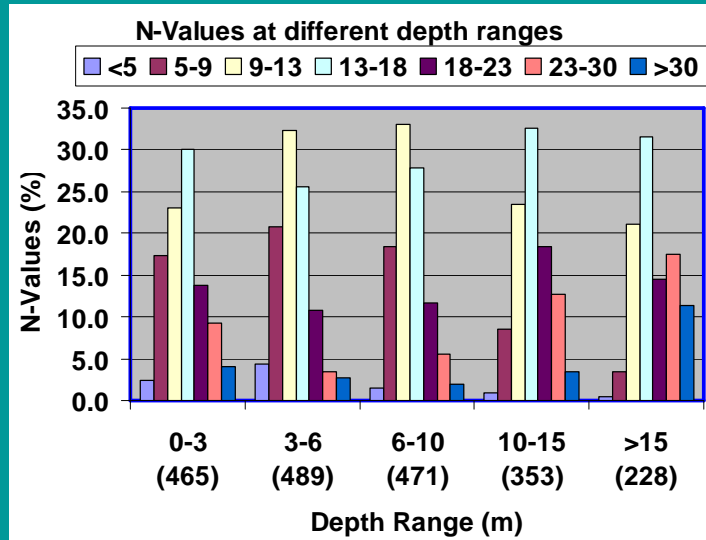
Ground water depth range



Bore hole depth

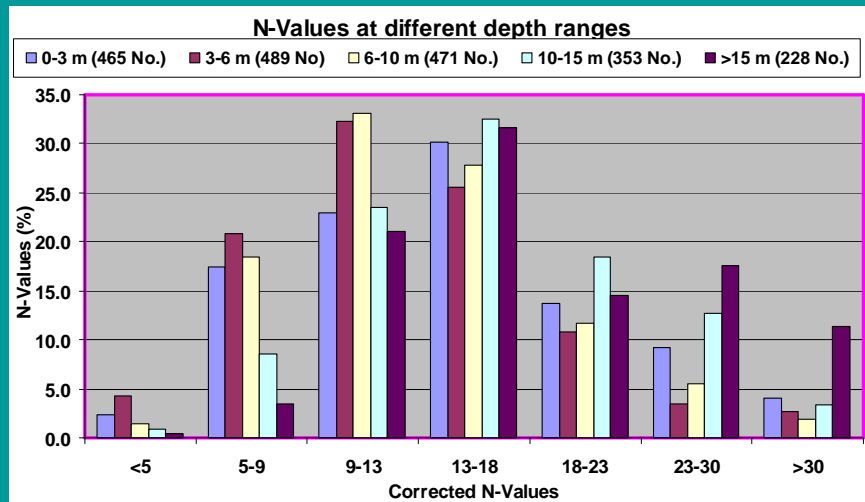


SPT values

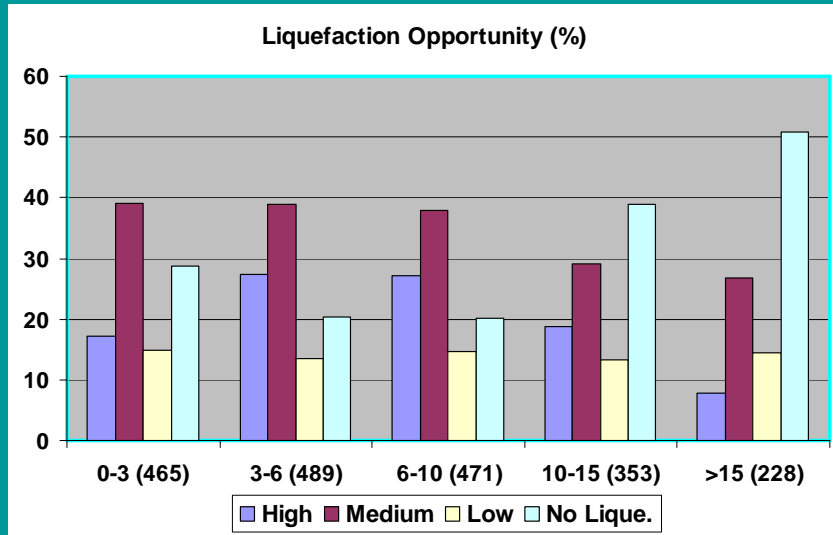


SPT values

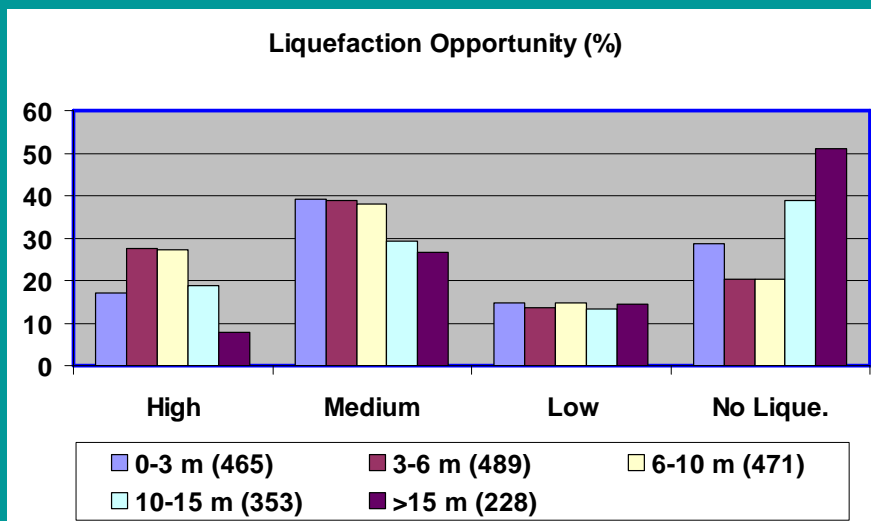
SPT values	Lique potential
<13	High
13-23	Med
23-30	Low
>30	V. low



Liquefaction opportunity



Liquefaction opportunity



Cyclic Stress Ratio (CSR)

The Cyclic Stress Ratio (**CSR**) is a measure of the shear stress that a soil “feels” during a seismic event.

$$\text{CSR} = 0.65(a_{\text{max}}/g)(\sigma_{v0}/\sigma'_{v0})r_d$$

a_{max} Peak ground accn., g Accn. due to gravity

σ_{v0} In-situ overburden pressure

σ'_{v0} Effective overburden pressure

r_d Stress reduction factor (<1)

Cyclic Resistance Ratio (CRR)

The Cyclic Resistance Ratio (**CRR**) of a soil is a measure of the soil’s ability to resist liquefaction.

Cyclic Resistance Ratio charts are available for Standard Penetration Testing (**SPT**), Cone Penetration Testing (CPT) and shear wave velocity testing (V_s).

Evaluation of Liquefaction

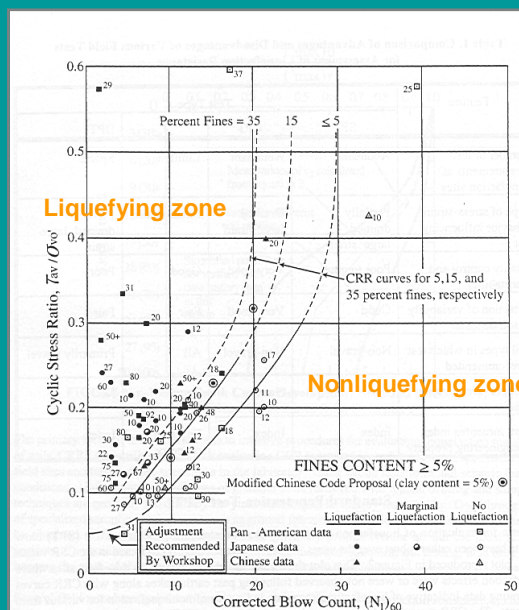
The Factor of Safety (FS) for liquefaction of a cohesionless soil deposit is typically defined as;

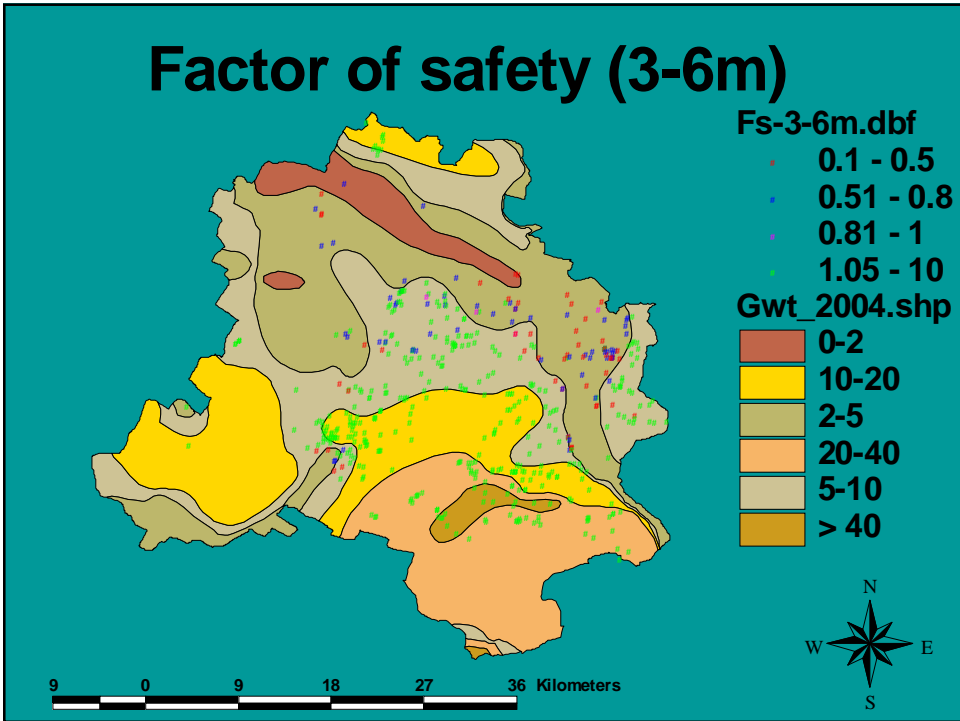
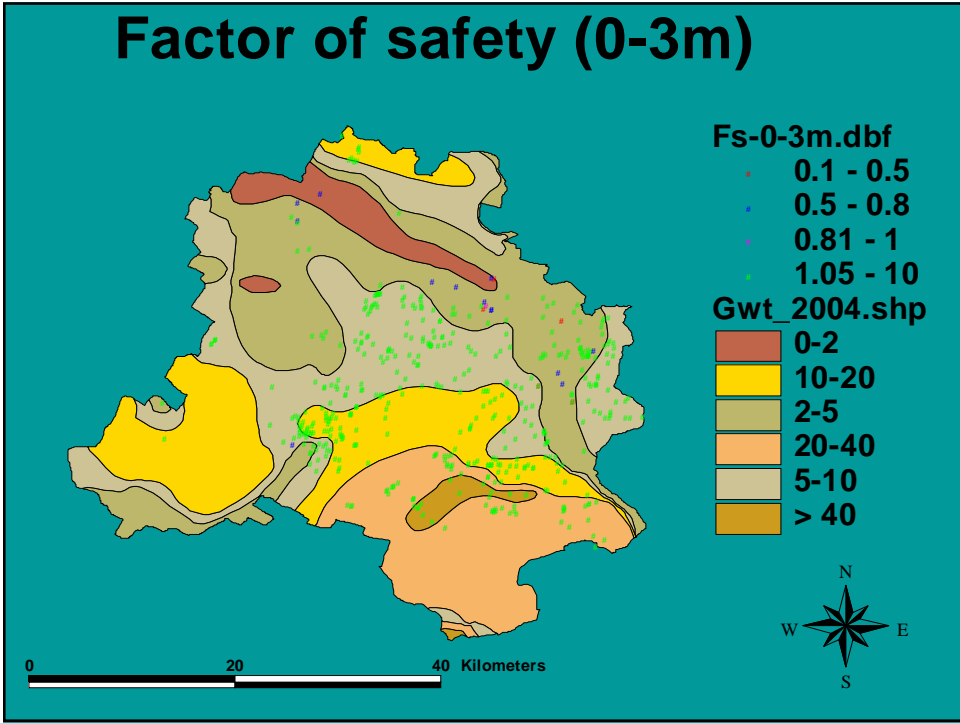
$$FS = CRR / CSR$$

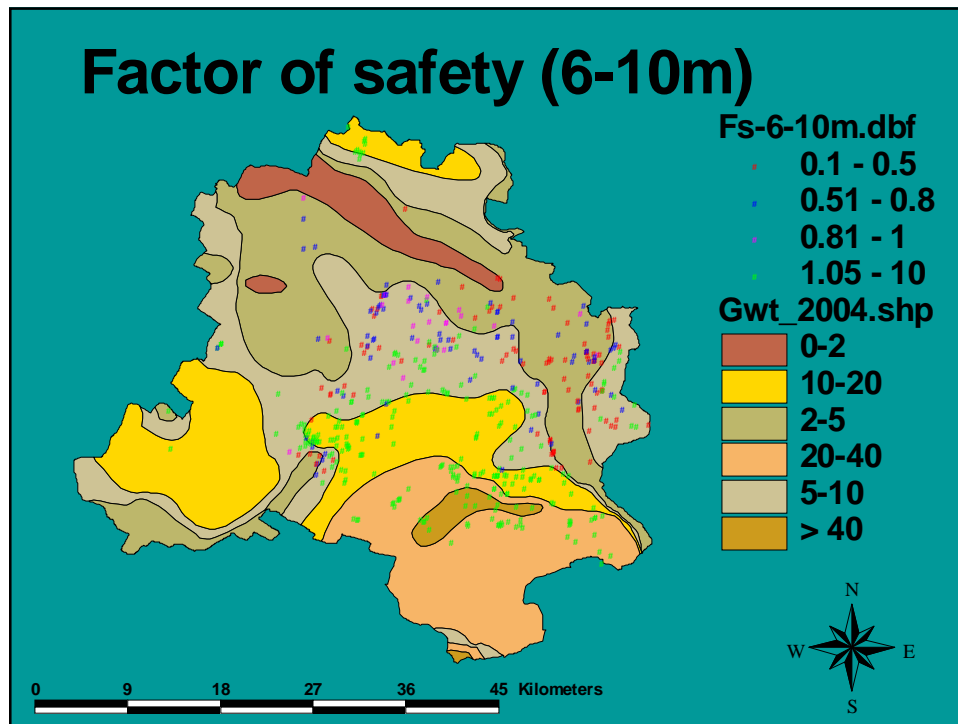
where,

- CRR = cyclic resistance ratio, and
- CSR = cyclic stress ratio.

CSR vs SPT-N







Conclusions

- Trans-Yamuna area of Delhi is prone to liquefaction damage (based on **M7.2 EQ.**)
- >80% of the soil have potential to liquefy
- Geotechnical/Geophysical investigation up to 30 m depth have to undertaken