Inject 1

SAND2015-3278C

Physical and Infrastructure Effects Briefing

June 9, 2015
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
Paul Chodas – JPL - Trajectory
Souheil Ezzedine – LLNL – Tsunami

EXERCISE

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Sandia National Laboratories

What we have been told

Entry speed: 16 km/s (36,000 mph, ~mach 47)

Size: up to 400 meters diameter

Composition: Stone, density 2.2-3.3 g/cm^3

2250 Megaton impact cannot be ruled out

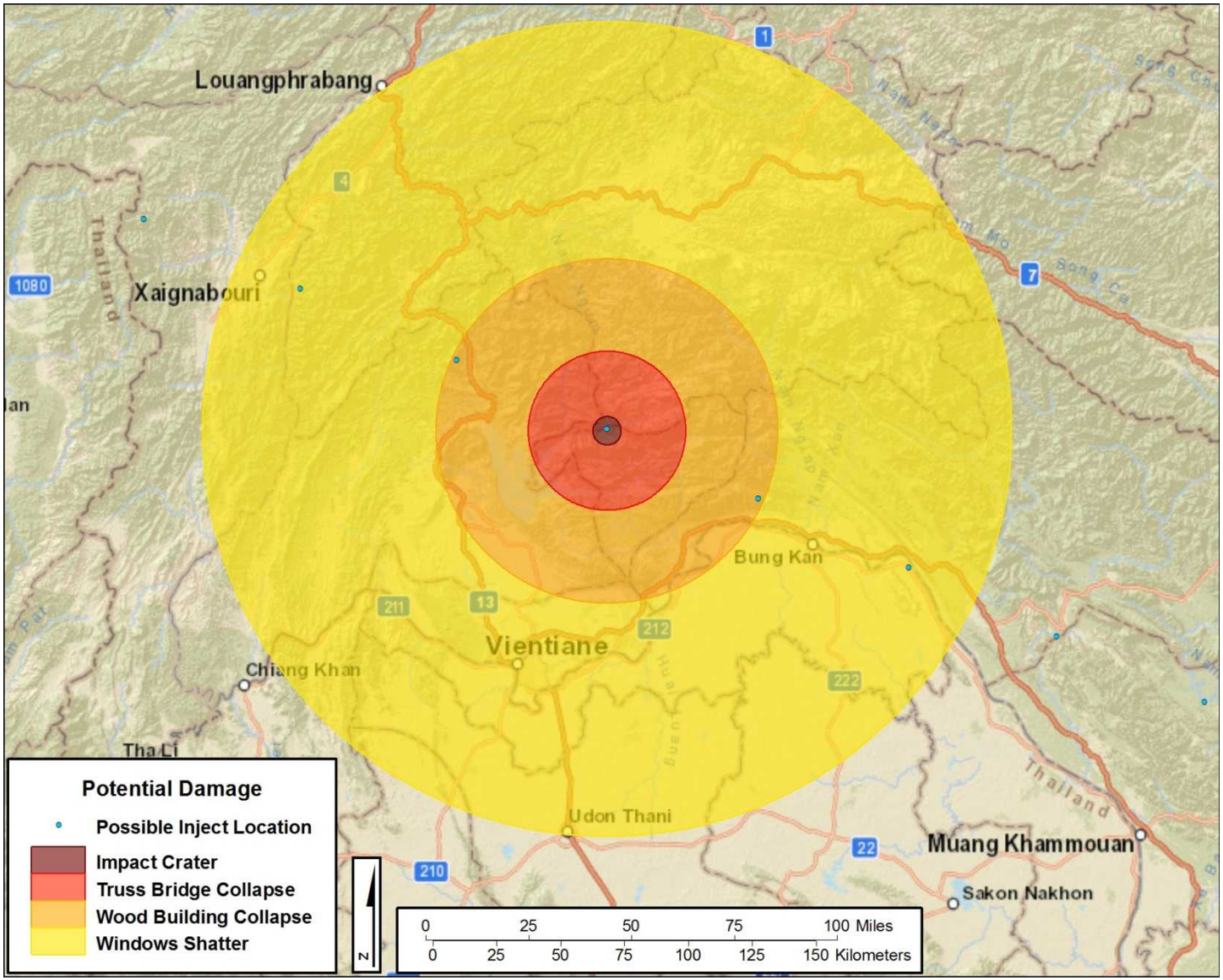
Probability of impact = 0.9%

Rapid estimate tool

Possible Impact Locations

EXERCISE

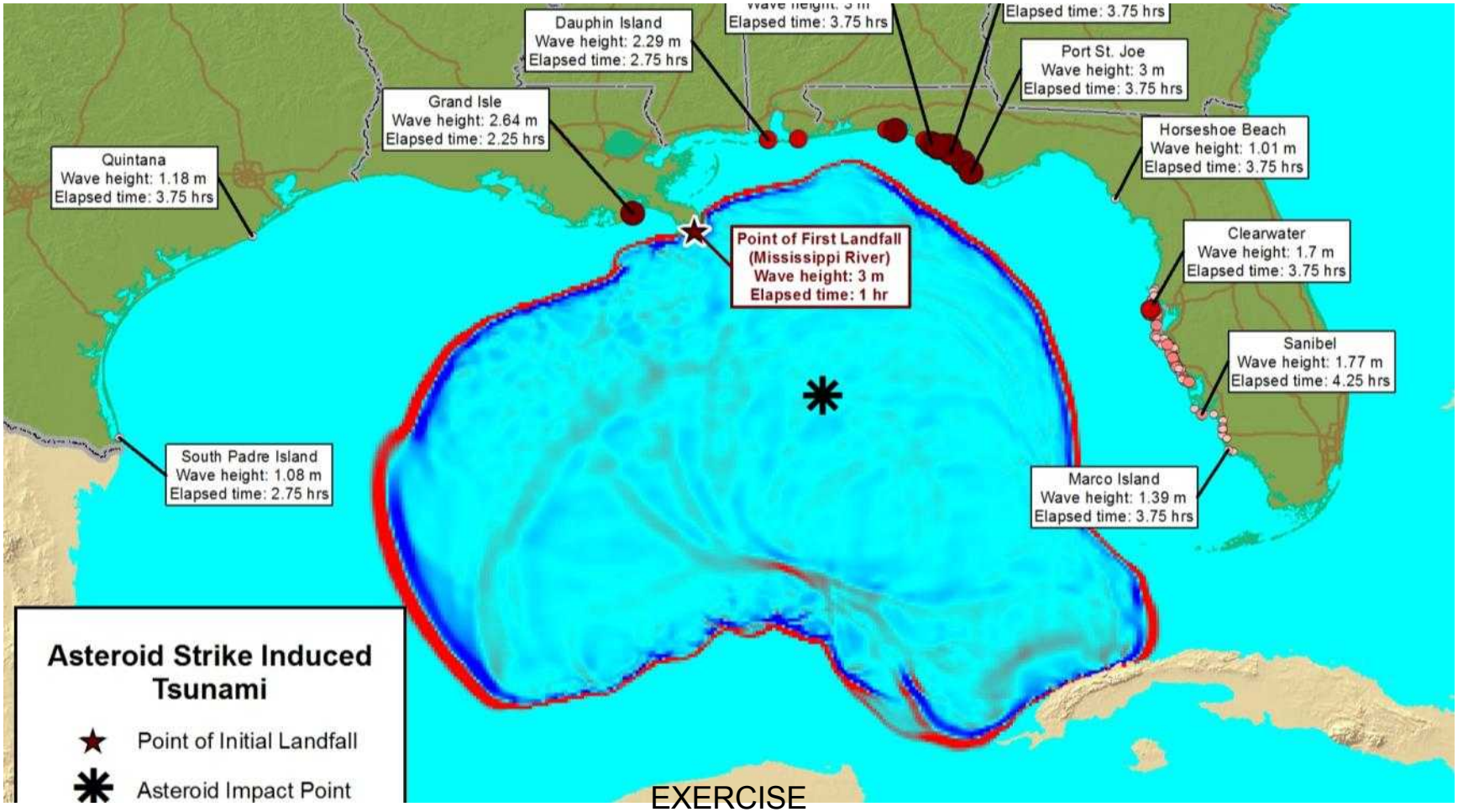
North of Vientiane, Laos



EXERCISE

Greatest threat is tsunami

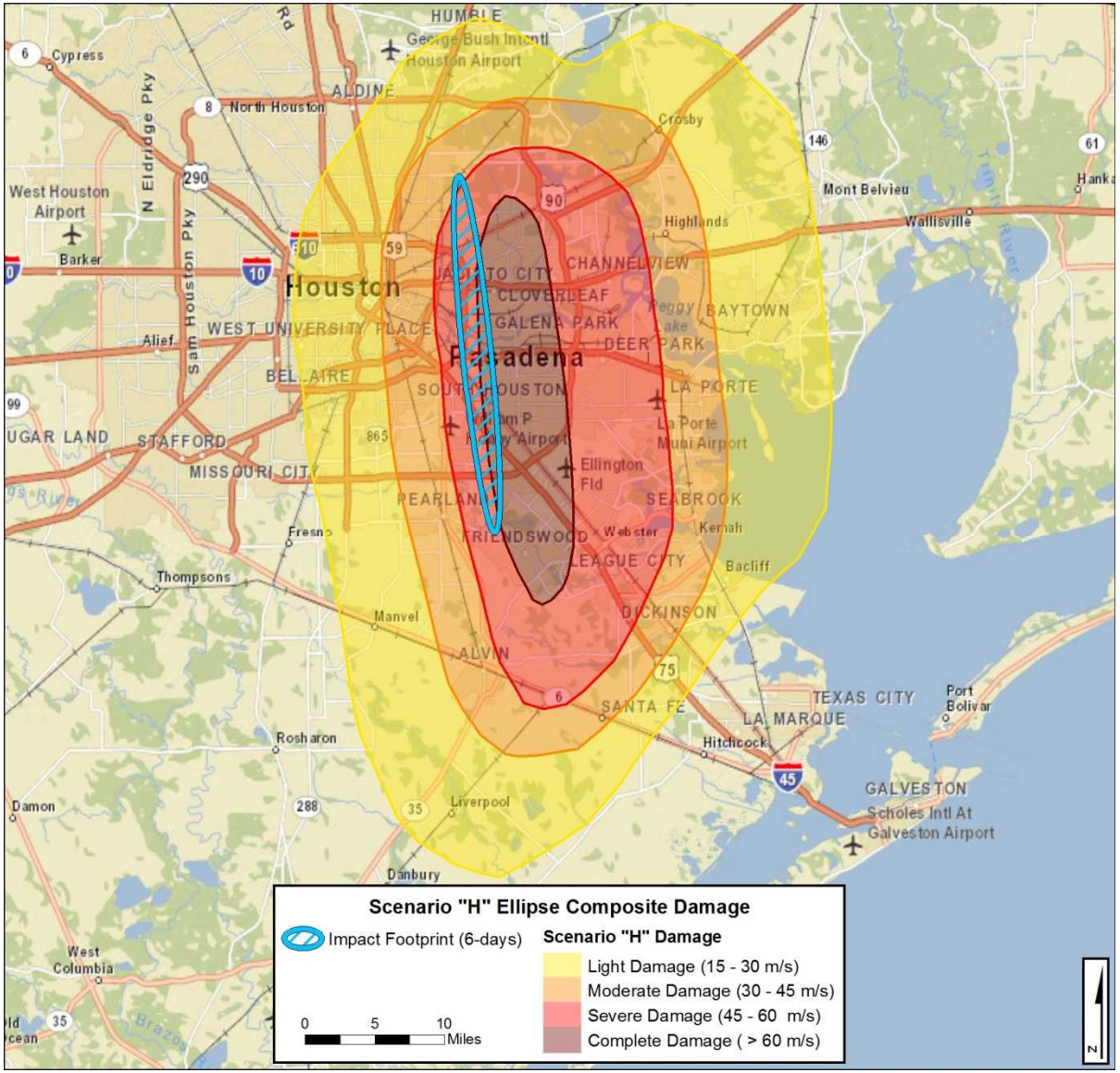
Highest priority is to run simulations as we did for 2014 FEMA exercise.
Example: Gulf of Mexico (not within current threat corridor).



EXERCISE

Example of Impact Damage Zones

From 2014 FEMA exercise



EXERCISE

Wind From Airburst Likened to a Nuclear Blast

- Pressure from a surface blast causes lateral dynamic loading; load applied rapidly for a second or more with continuously decreasing strength
- Primary infrastructure damage due to overpressure and sustained wind at

Severe; at 130 – 140 MPH (209 – 225 KMH)

Moderate; 90 – 100 MPH (145 – 160 KMH)

Light; 60 – 80 MPH (97 – 129 KM

Damage to Industry: POL, Utilities, Transportation

Structure	Severe	Moderate	Light
Petroleum, oil, lubricant tanks (POL)	100% loss of fluids due to lifting of tanks from foundation	Loss of contents due to leakage; secondary effects; e.g. fires	Loss of liquid due to sloshing
Utility lines (above ground)	100% supporting poles down	30% supporting poles damaged	All poles in tact – few lines down, undamaged
Rail	100% track and rail cars	Track in place cars blown over	Cars may be off track and sustain light damage
Parked transport planes, light aircraft, helicopters	100% to exposed	Operational damage due to being blown over or other planes and debris	Field maintenance may be required

Damage to Industrial Structures

Structure	Complete	Heavy	Moderate
Wooden structure un-reinforced	Frame shattered resulting in almost complete collapse.	Wall framing cracked. Roof severely damaged. Interior partitions blown down.	Windows and doors blown in. Interior partitions cracked.
Light corrugated steel	Complete distortion or collapse of frame.	Minor to major distortion of frame.	Windows and doors blown in. Siding ripped off.
Heavy steel-frame industrial building	Severe distortion, collapse of frame.	Some frame distortion. Not operable.	Windows and doors blown in. Siding ripped off.
Concrete and steel reinforced	Walls shattered, frame distortion, initial collapse.	Walls breached to the point of being distorted. Doors blown in.	Cracking of concrete walls and frame.

Inject 2

Physical and Infrastructure Effects Briefing

April 4, 2016
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
Paul Chodas – JPL - Trajectory
Souheil Ezzedine – LLNL – Tsunami

EXERCISE

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Size: Up to 400 meters diameter

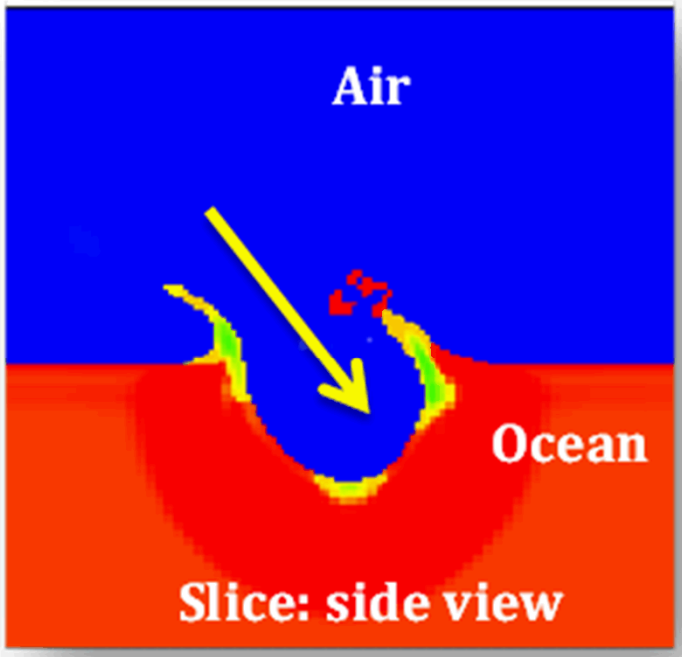
Composition: Stone, density 2.2-3.3 g/cm^3

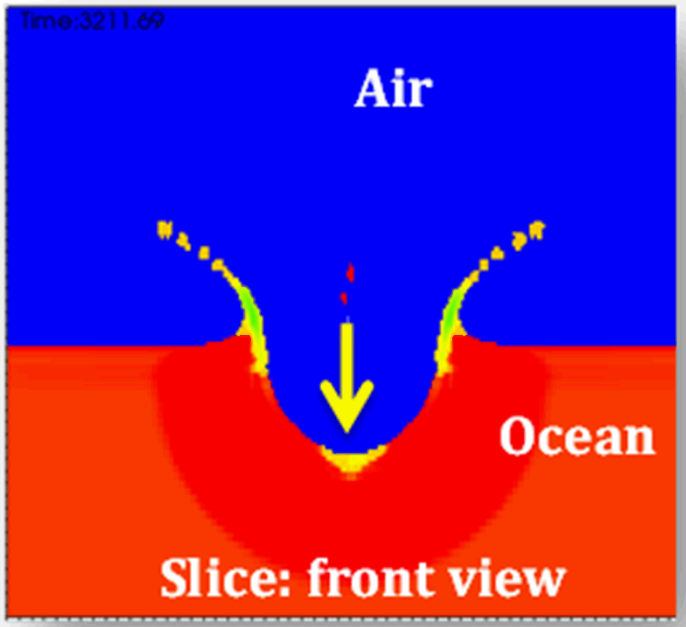
2250 Megaton impact cannot be ruled out

Impact probability: 43%

Tsunami is by far the greatest threat

We have run high-performance computer simulations



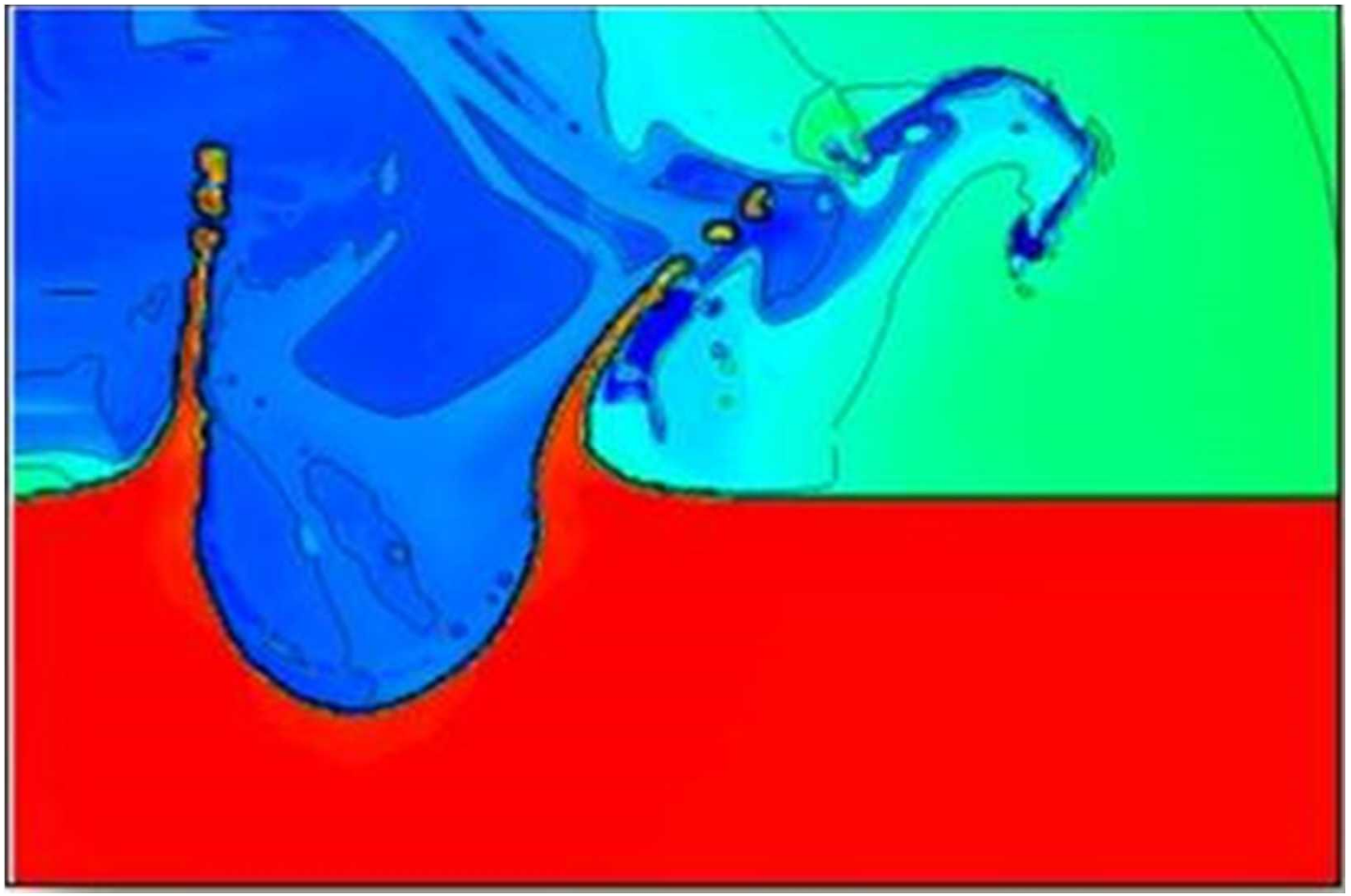


Tsunami strength depends on entry angle which depends on impact location and varies from near-grazing to 72°

EXERCISE

Tsunami is by far the greatest threat

We have run high-performance computer simulations



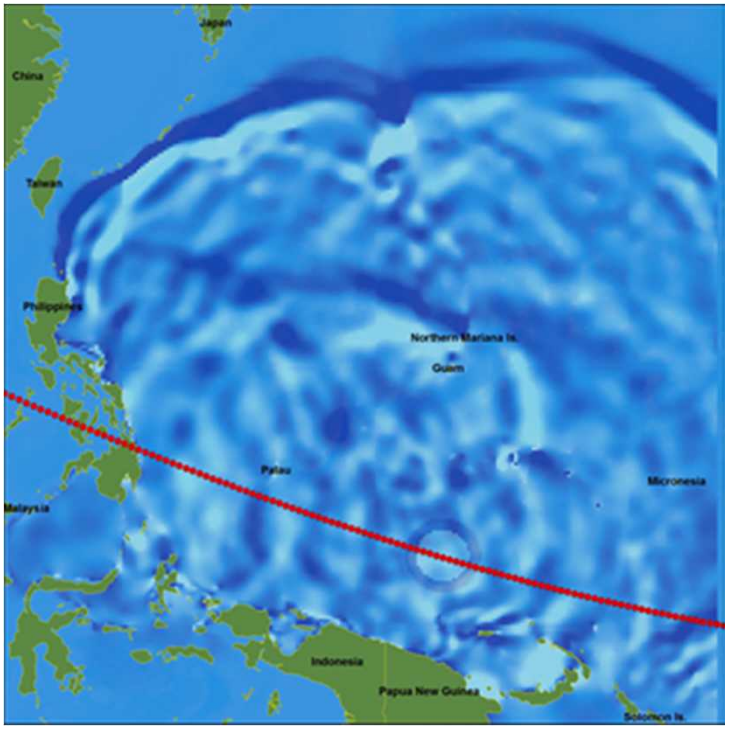
Tsunami strength depends on entry angle which depends on impact location and varies from near-grazing to 72°

EXERCISE

Tsunami is by far the greatest threat

We have run high-performance computer simulations

Western Pacific Impact



Steep entry: strong tsunami

Eastern Pacific Impact

Grazing entry: weaker tsunami

Tsunami strength depends on entry angle which depends on impact location and varies from near-grazing to 72°

EXERCISE

Inject 3

Physical and Infrastructure Effects Briefing

December 27, 2016
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
Paul Chodas – JPL - Trajectory
Souheil Ezzedine – LLNL – Tsunami

EXERCISE

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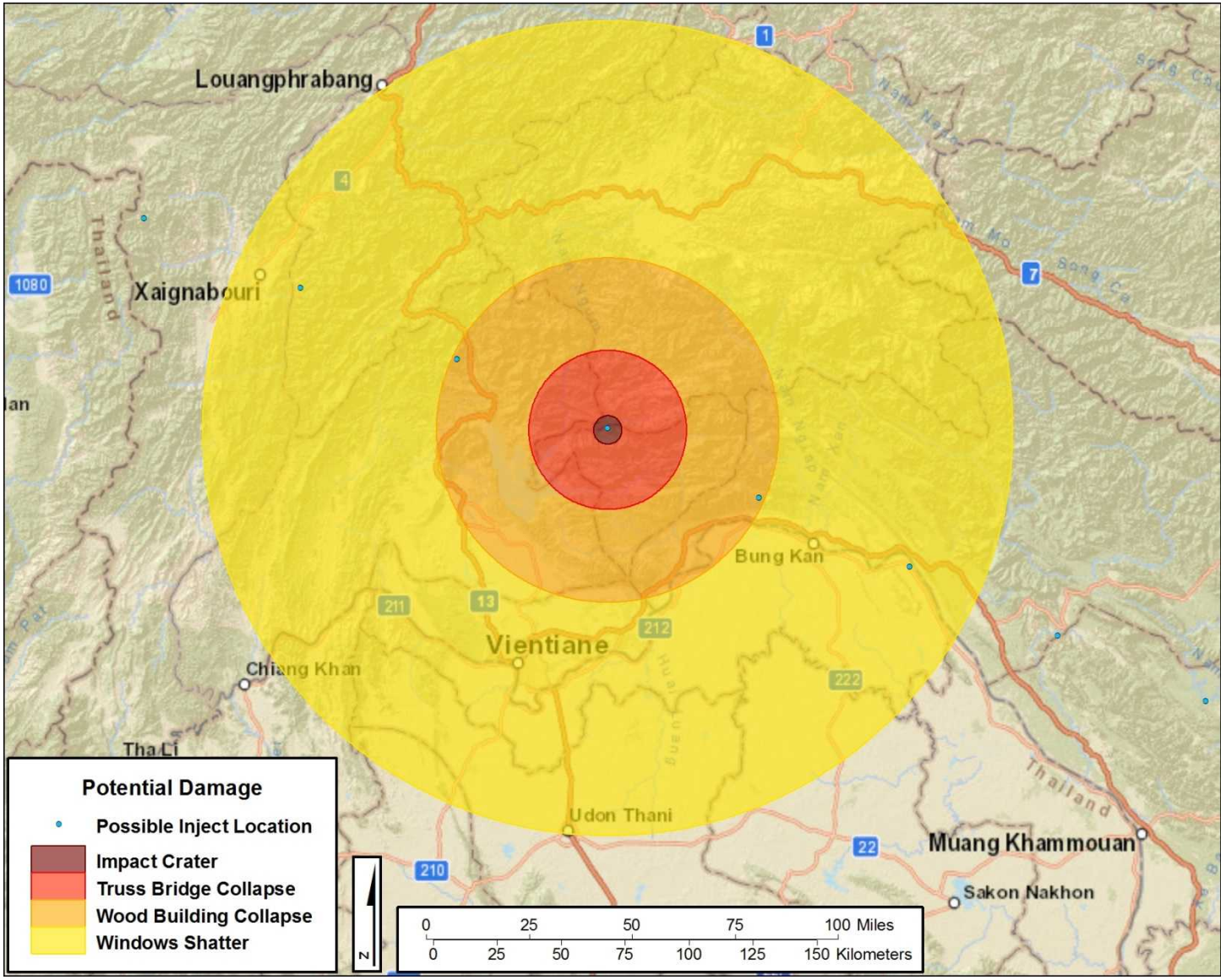
- Size: Up to 400 meters diameter
- Composition: Stone, density 2.2-3.3 g/cm^3
- 2250 Megaton impact cannot be ruled out
- Impact is certain: September 3, 2022

Possible Impact Locations

EXERCISE

Purdue Simulator

Infrastructure Risk Zones



EXERCISE

Vientiane, Laos
Impact Results

- **Impact crater 5-7 km diameter**
- **500 meters deep**
- **6.8 magnitude earthquake**
- **Damage Zones:**
  - **Impact – total destruction**
  - **29 km out – Total**
  - **63 km out – Severe**
  - **149 km – Light to Moderate**
- **Fireball would cause trees to ignite**
- **Individuals not sheltered will sustain 2nd degree burns**
- **Winds of 60 m/s blowing over 30% of trees and stripping leaves and branches**

Vientiane, Laos - At Risk

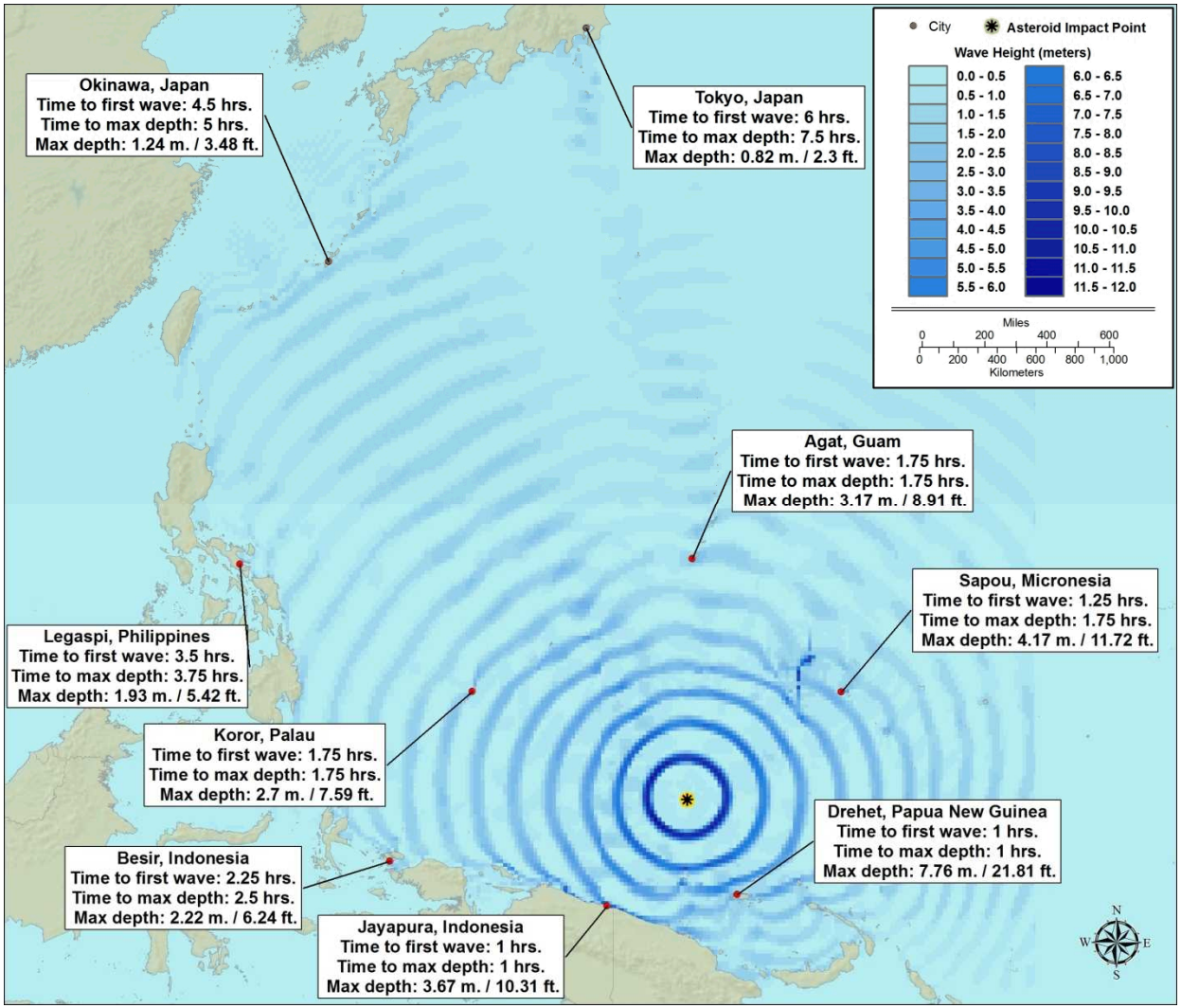
- Capital of Laos
- Population 210,000
- - 700,000 in Vientiane Prefecture
- Situated on the Mekong River
- Main roads are parallel to river
- Main government offices and Presidential Palace are here
- That Luang Stupa – most important religion monument in Laos
- International Airport
- 16 Provinces

EXERCISE

Tsunami is by far the greatest threat

We have run high-performance computer simulations

Western Pacific Impact - Steep entry: strong tsunami

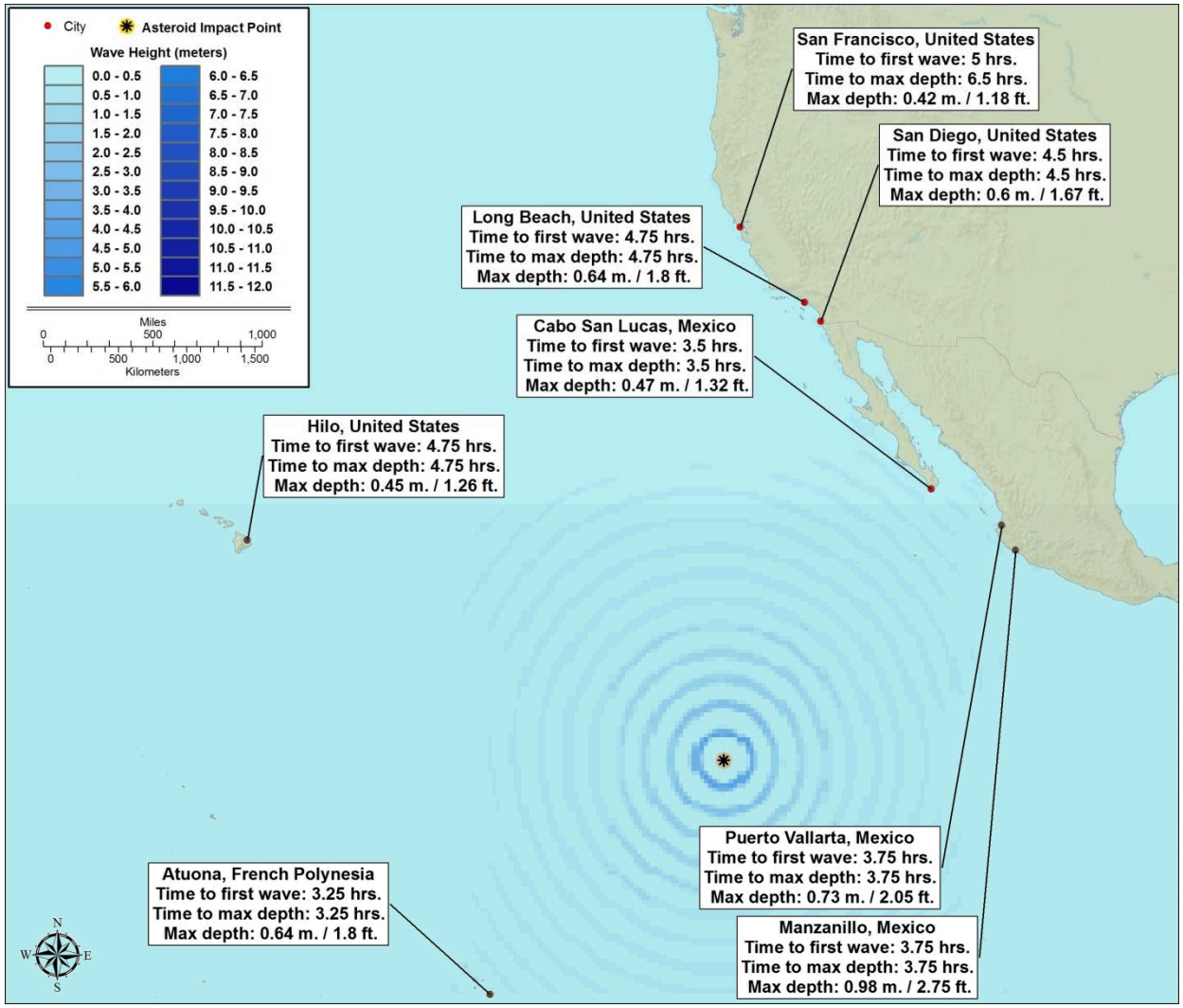


EXERCISE

Tsunami is by far the greatest threat

We have run high-performance computer simulations

Eastern Pacific Impact - Grazing entry: weaker tsunami



EXERCISE

Inject 4

Physical and Infrastructure Effects Briefing

August 1, 2019
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
Paul Chodas – JPL - Trajectory
Souheil Ezzedine – LLNL – Tsunami

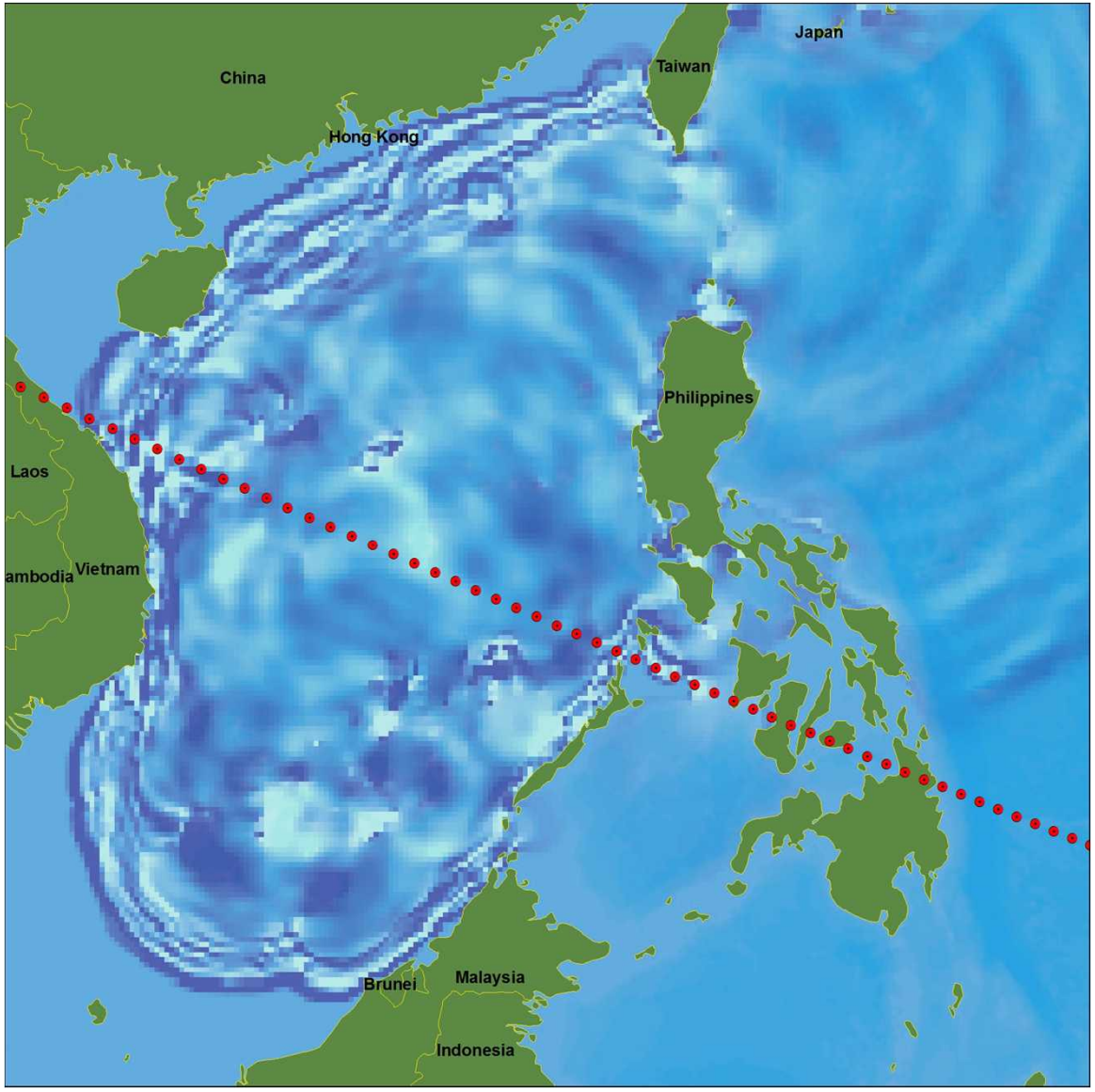
EXERCISE

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

What we have been told

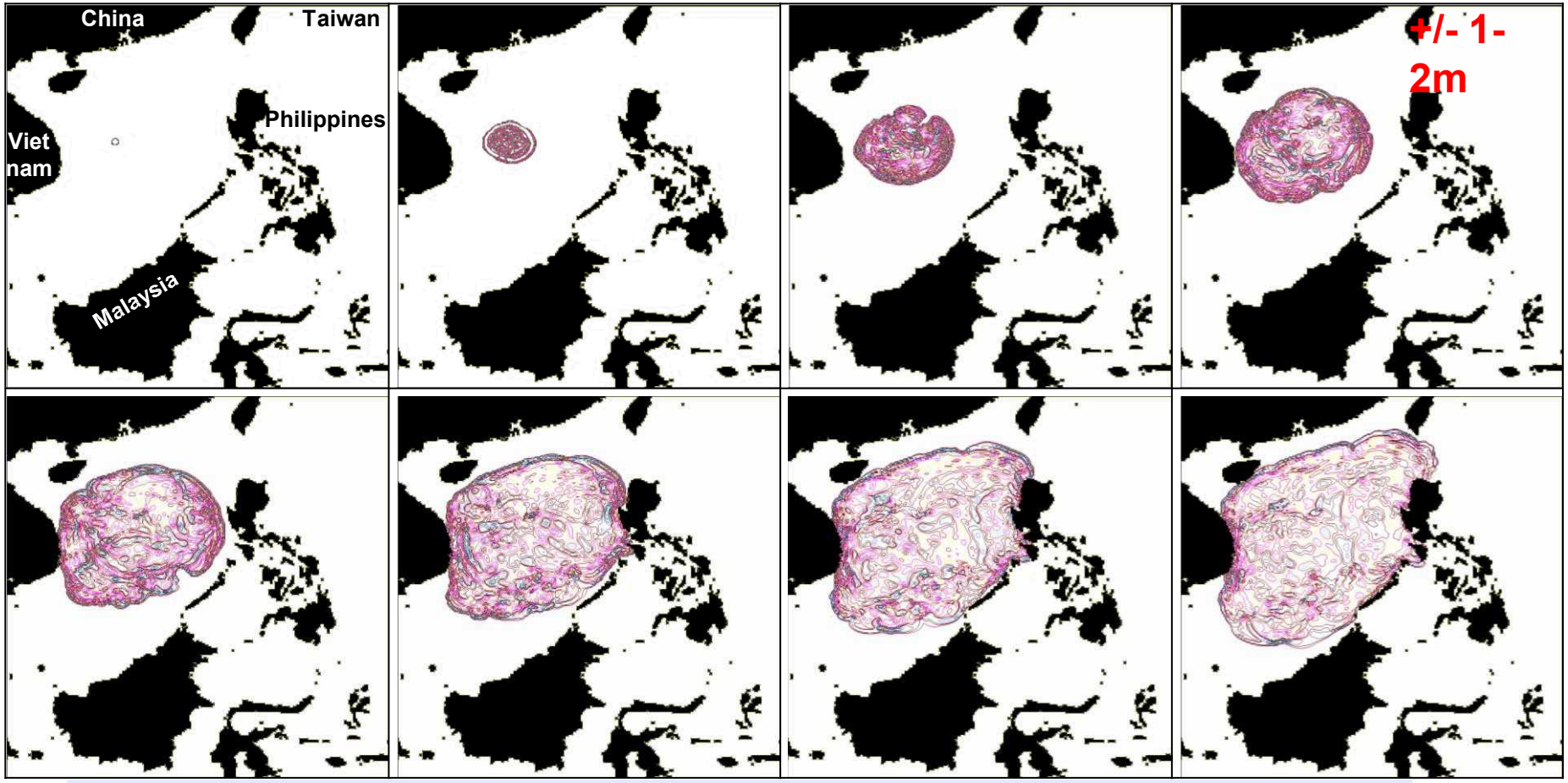
- Entry speed: 16 km/s (36,000 mph, ~mach 47)
- Size: 150 – 250 meters diameter
- Composition: Stone, density 2.2-3.3 g/cm^3
- Impact is certain: September 3, 2022

South China Sea Tsunami



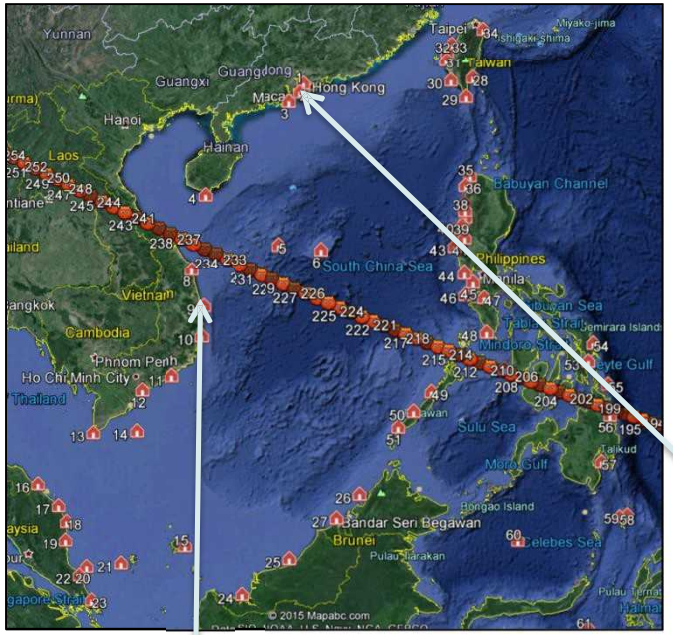
EXERCISE

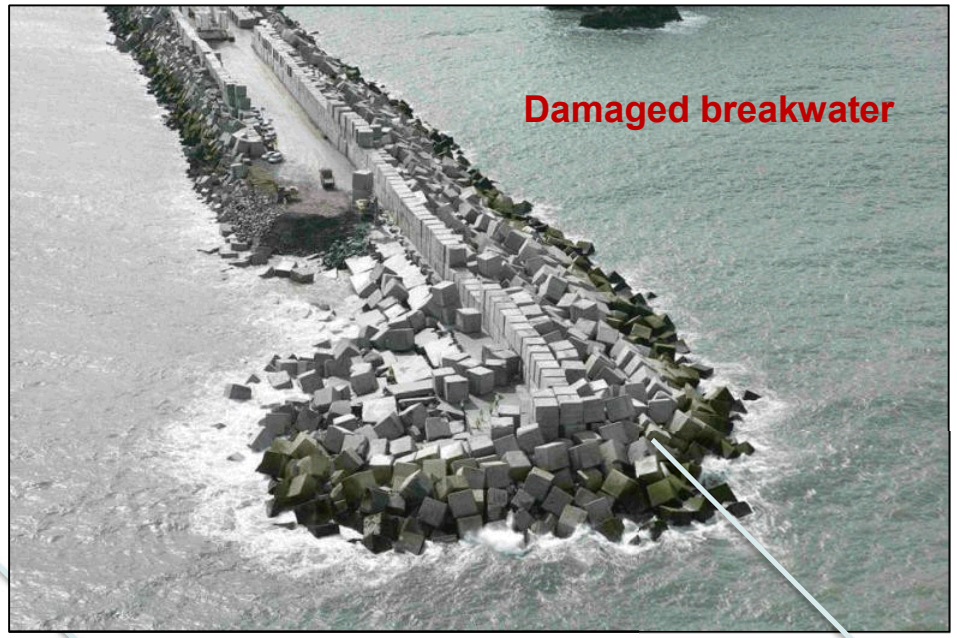
Tsunami Wave Propagation

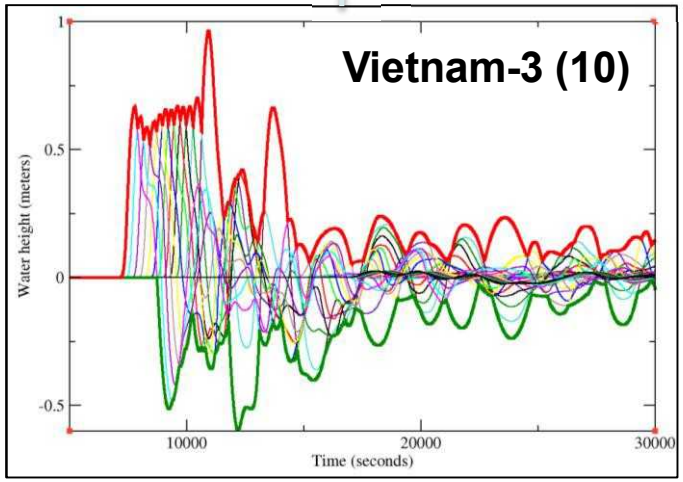


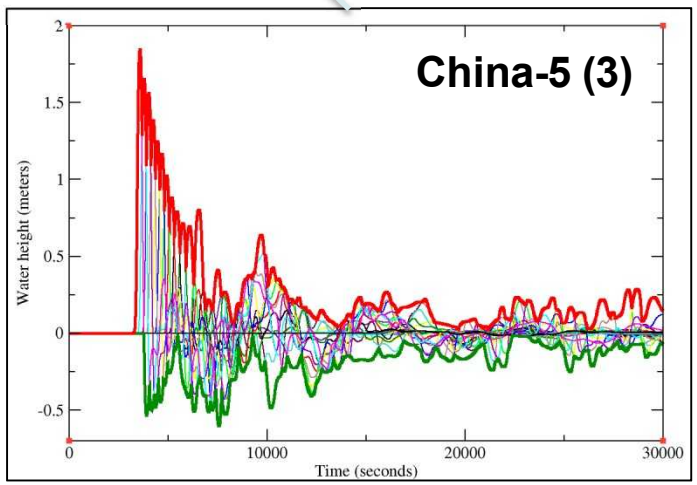
- "Shallow" waters -- presence of 2 initial "tsunamis" for the first 1/2 hour
- Only one persists and reach Vietnam, Philippines, Malaysia, China and Taiwan
- Rich wave structure due to bathymetry
- We have simulated several asteroid impacts within the South China sea for probabilistic profiles of hazards

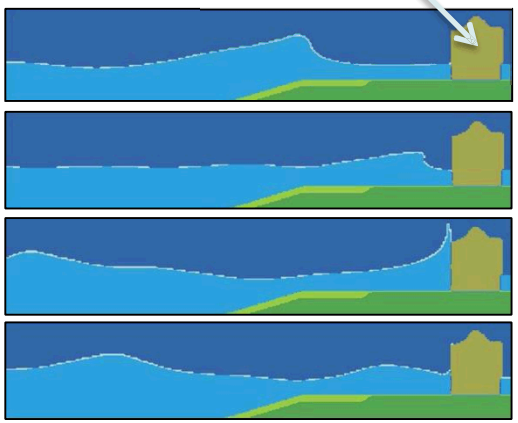
Probabilistic Tsunami Risk-Profiles







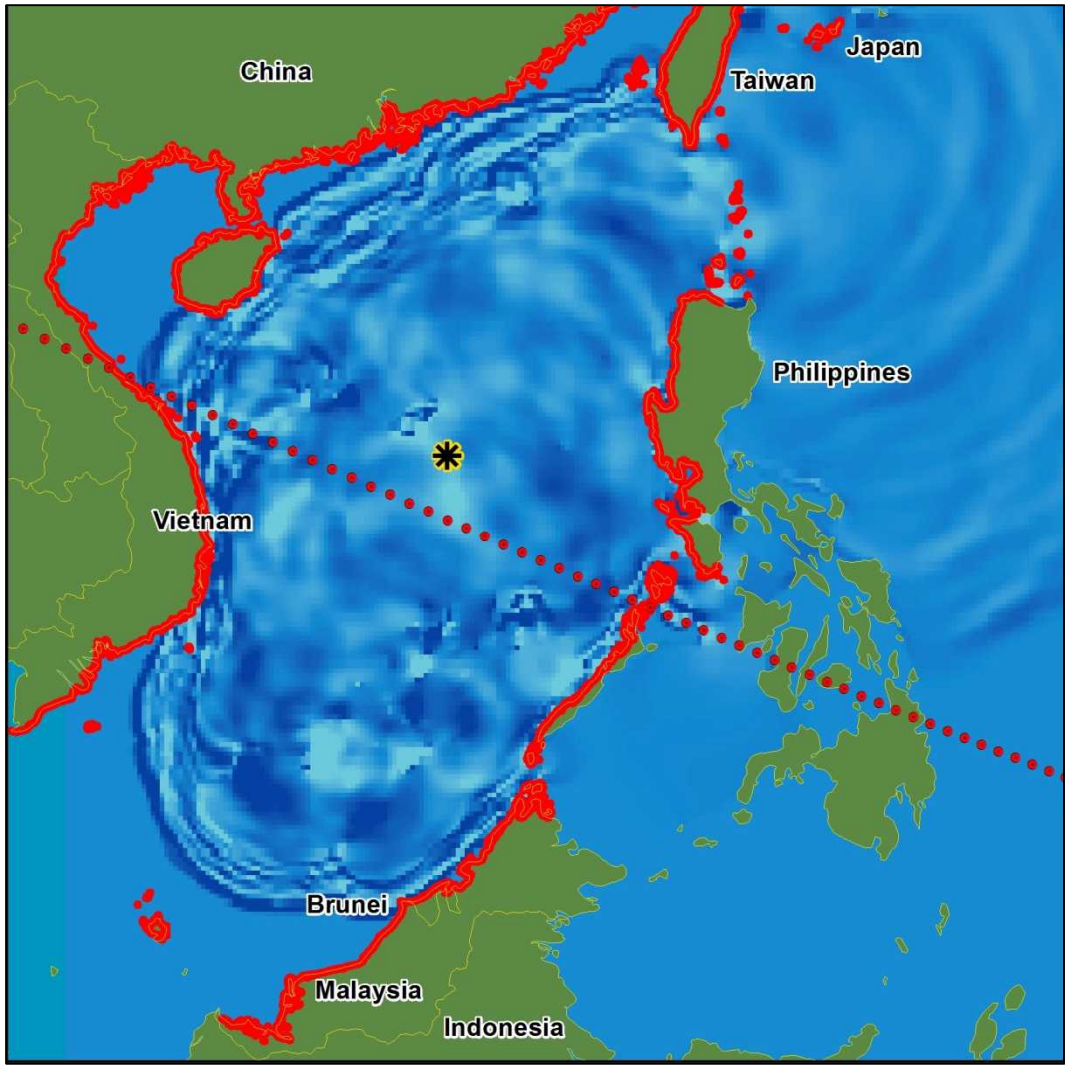




Maximum- and minimum-envelopes-of-water (MEOWs)

Estimated Population at Potential Risk

Country Name	Estimated Population within 5km of Shoreline (2020)
Brunei	215,886
China	40,044,535
Hong Kong	7,640,921
Indonesia	102,906
Japan	53,472
Macao	601,679
Malaysia	7,396,489
Philippines	12,067,546
Taiwan	5,565,213
Vietnam	10,037,728
Total Estimated Population	83,726,375



EXERCISE

Inject 5

Physical and Infrastructure Effects Briefing

February 4, 2021
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
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EXERCISE

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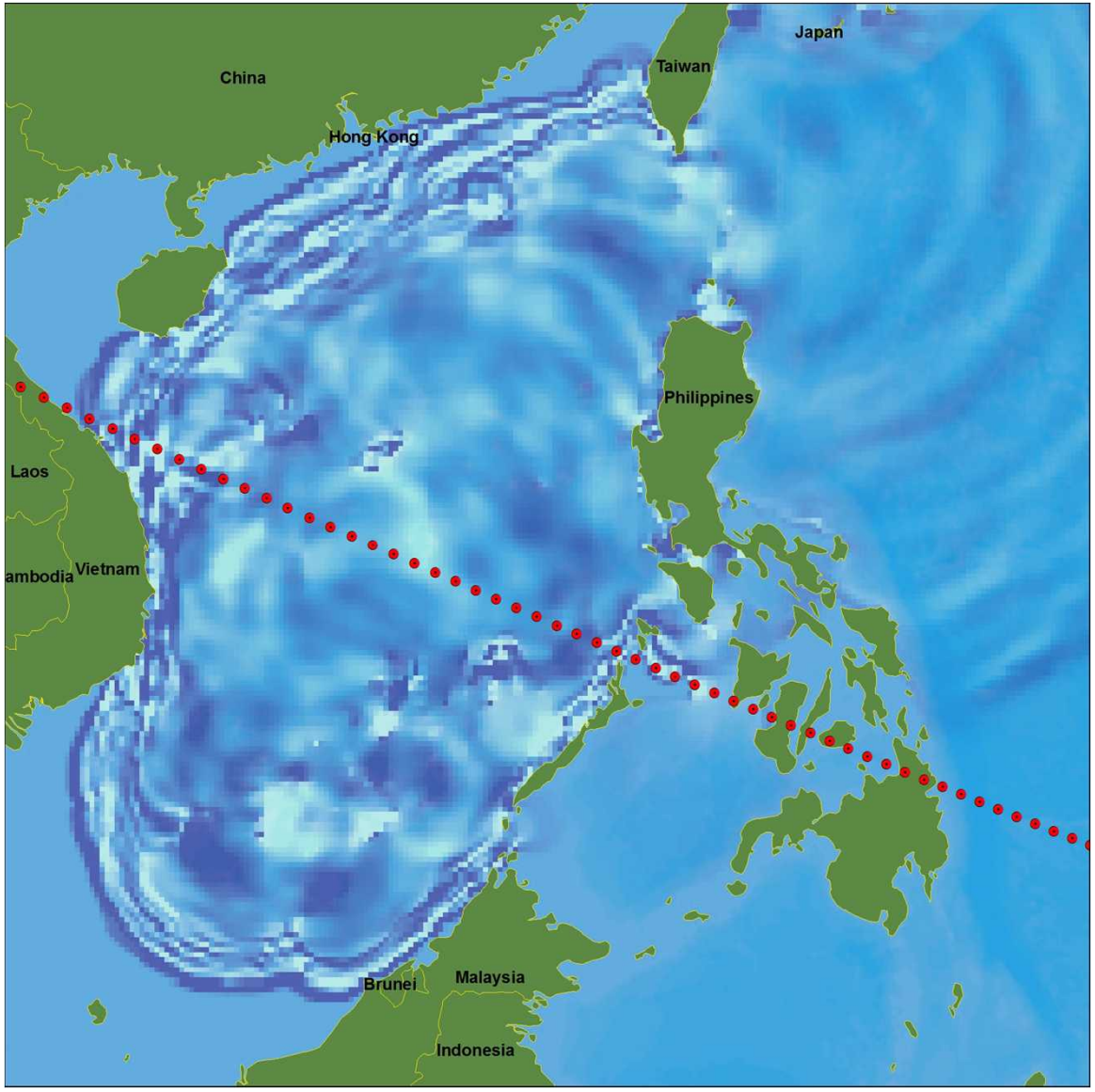
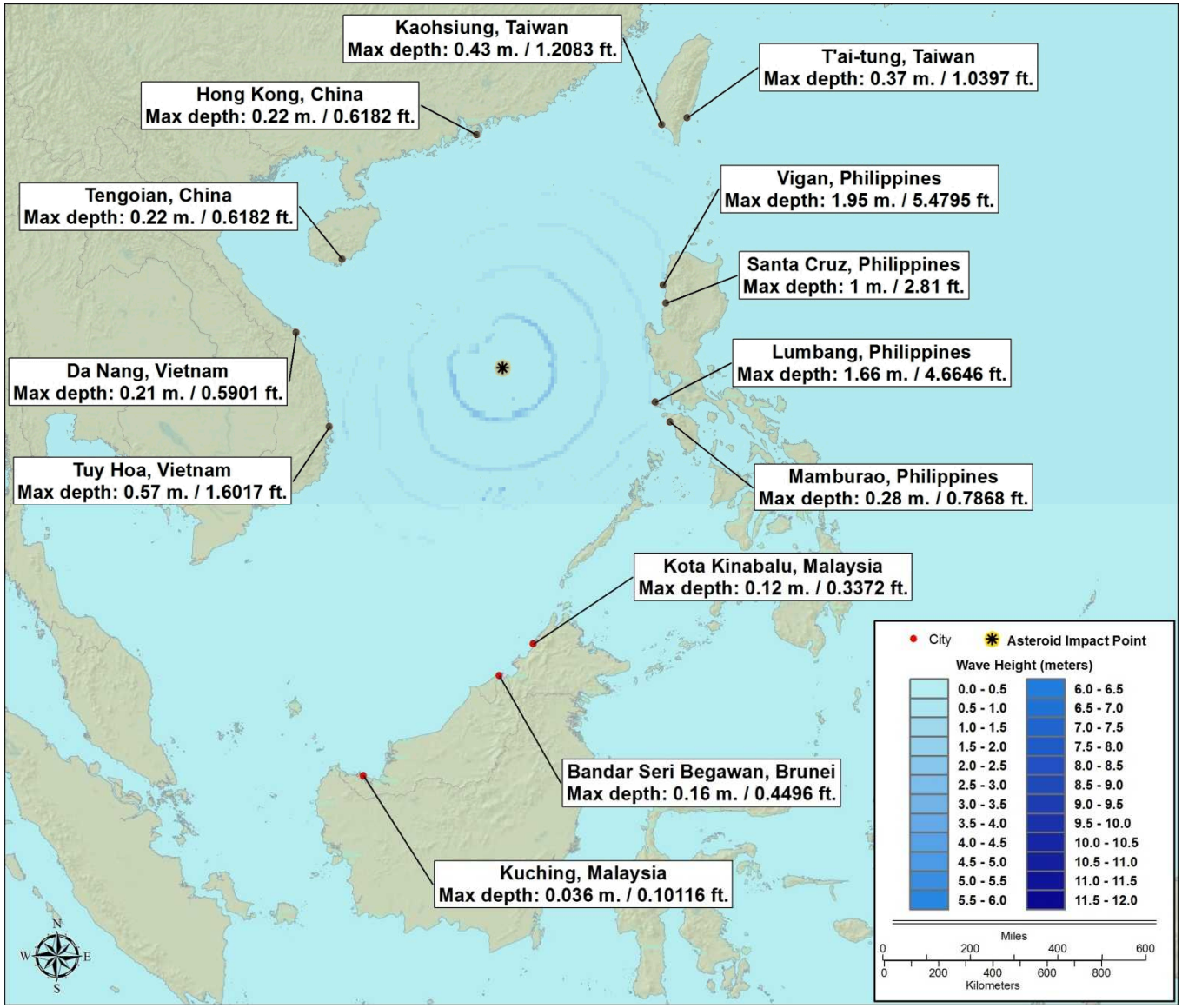
- Size: up to 100 meters diameter
- Composition: Stone, density 2.2-3.3 g/cm^3
- 50 Megaton impact cannot be ruled out
- Impact is certain: September 3, 2022

Tsunami From 100-m Fragment



EXERCISE

Tsunami From 100-m Fragment

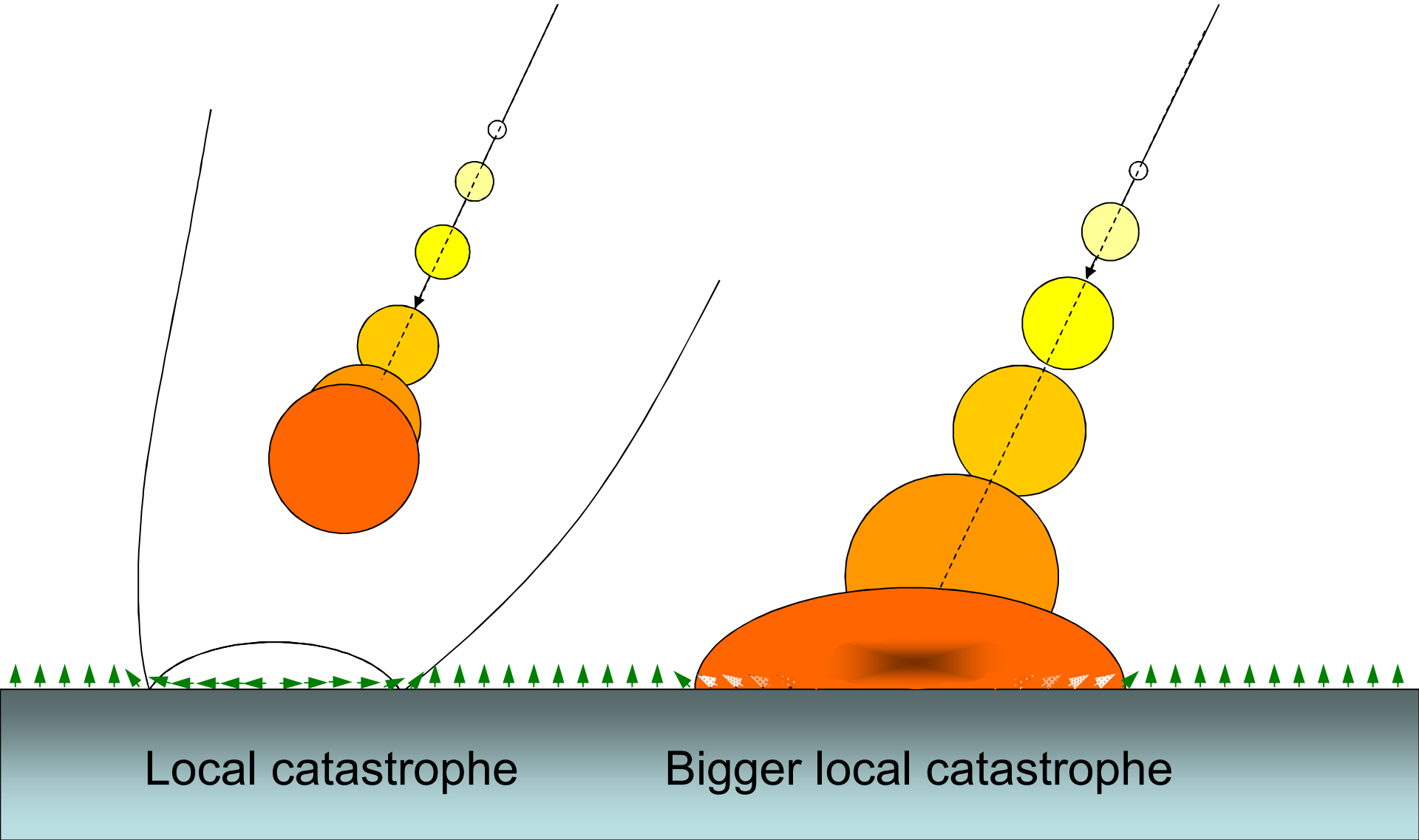


EXERCISE

There are two types of Low-Altitude Airburst

Type 1: Tunguska

Type 2: Libyan Desert



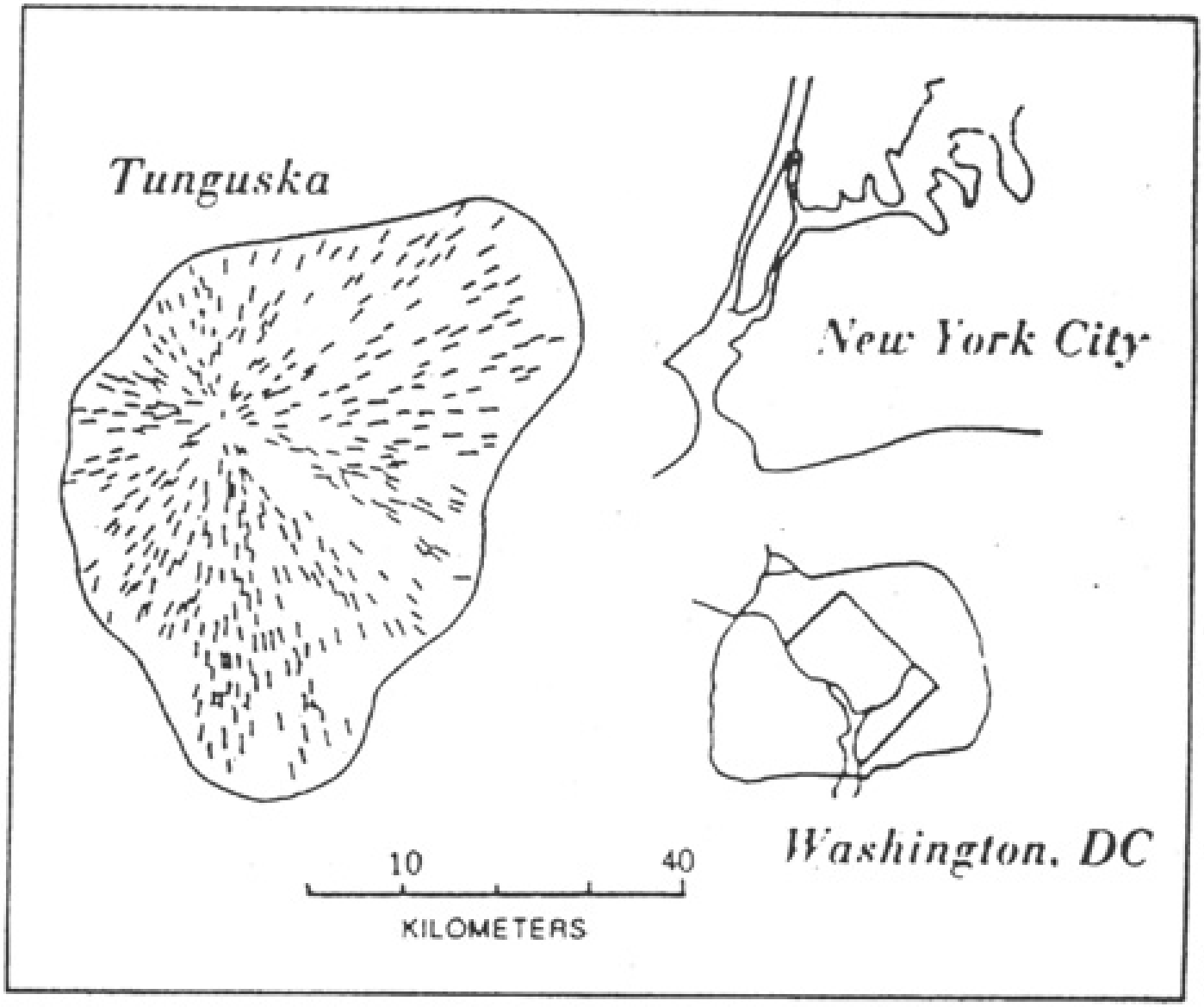
Local catastrophe

Bigger local catastrophe

Tunguska:
June 30, 1908

Fig. 485 — The siberian forest devastated by the blast from the meteorite of 30 june 1908.

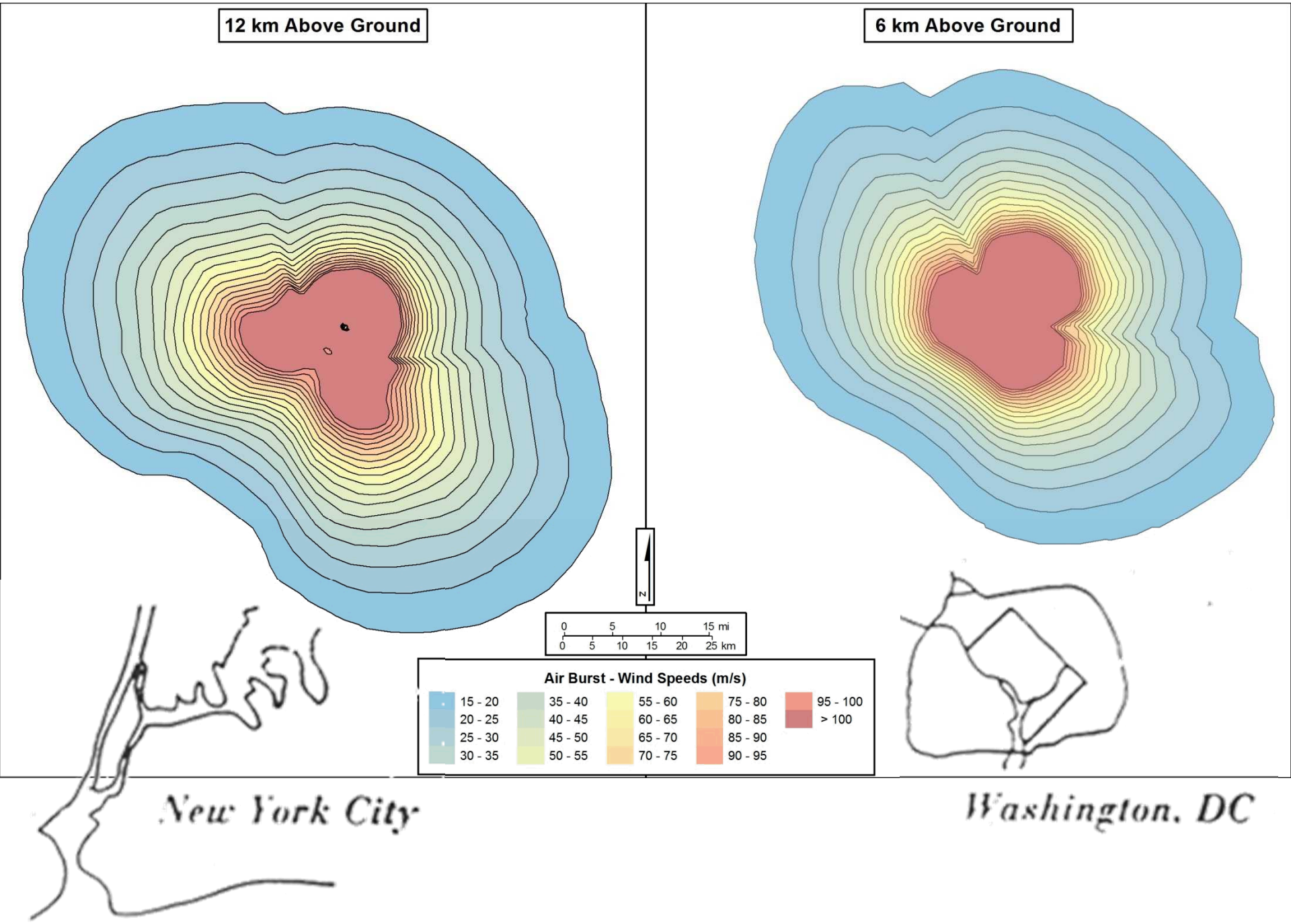
EXERCISE



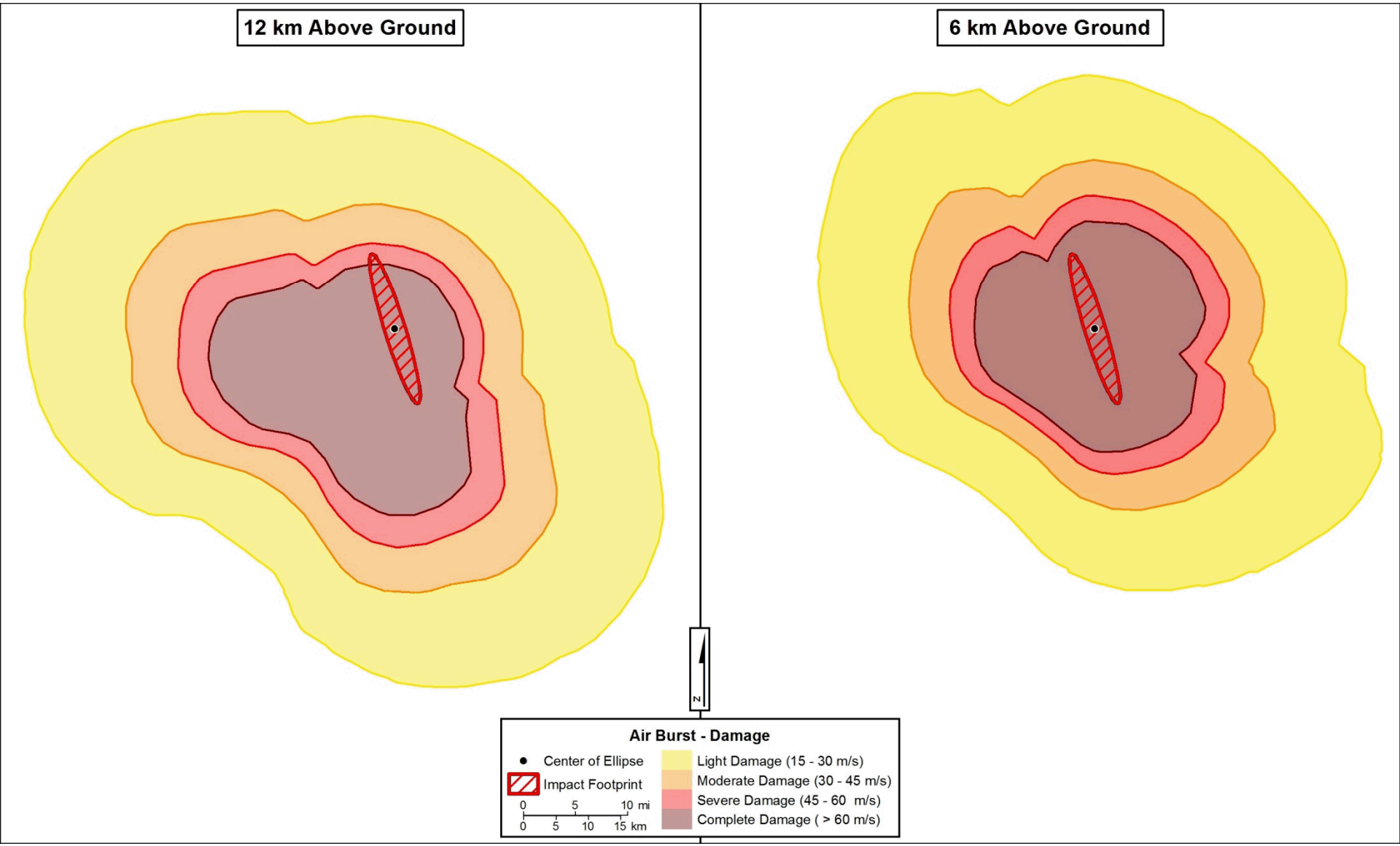
Art courtesy of John Pike

Tunguska in perspective

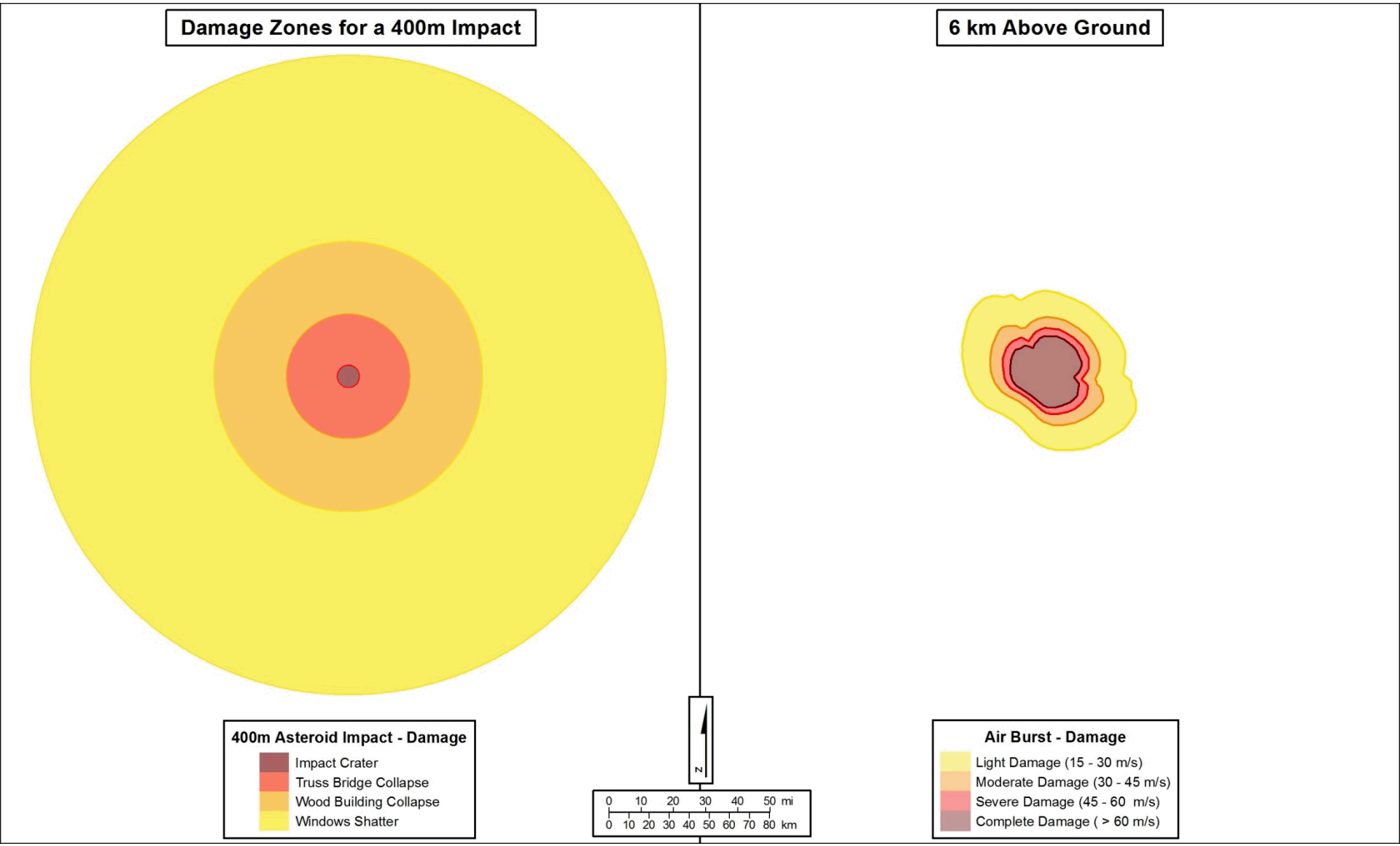
EXERCISE


12 km Above Ground
6 km Above Ground
N
0 5 10 15 mi
0 5 10 15 20 25 km
Air Burst - Wind Speeds (m/s)
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100
> 100
New York City
Washington, DC

Extent of expected airburst damage (preliminary)



Comparison of Damage Zones



Inject 6

Physical and Infrastructure Effects Briefing

February 4, 2022
2015 PDC

Mark Boslough & Barbara Jennings
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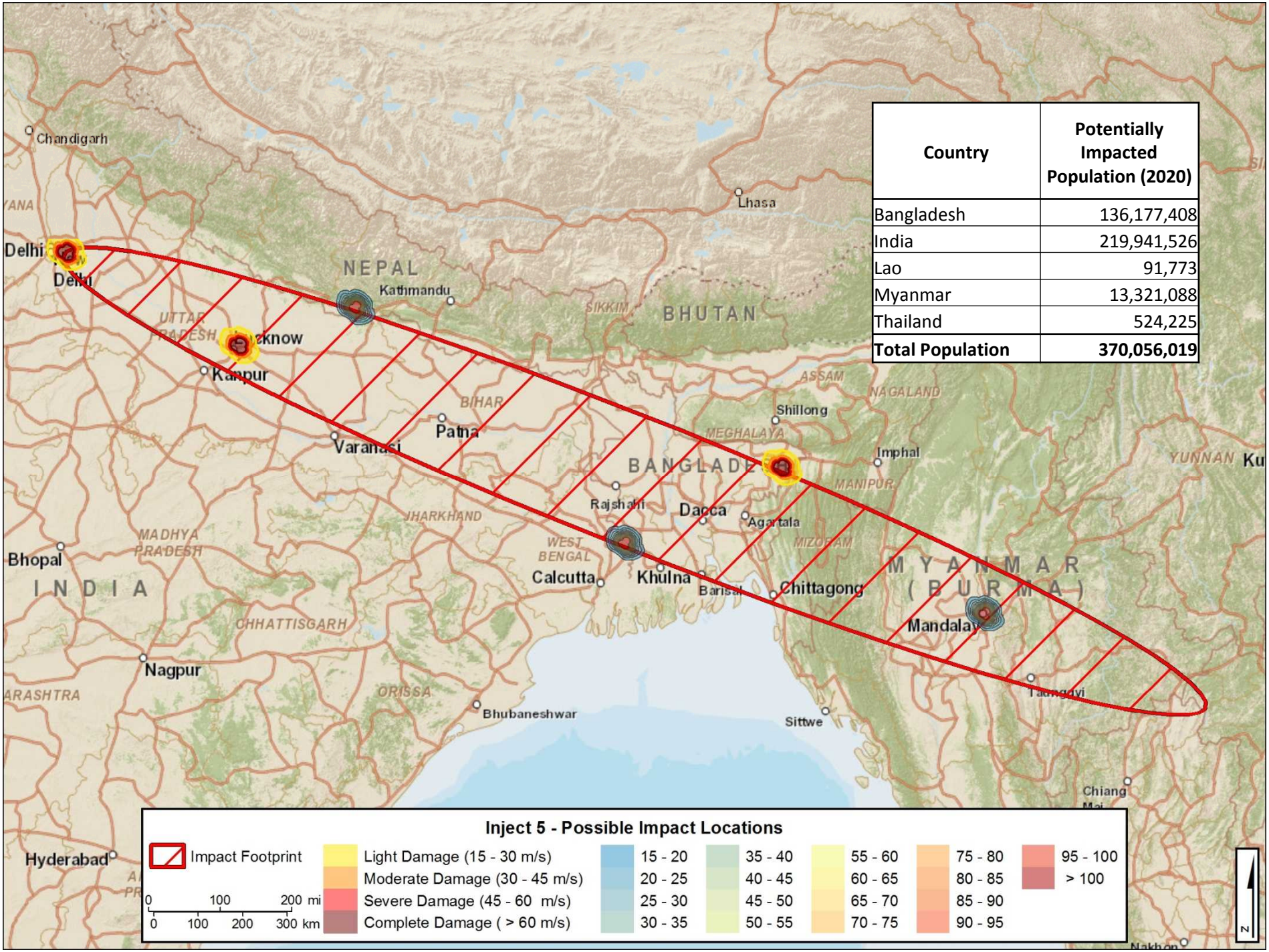
Impact is certain: September 3, 2022

EXERCISE


New Delhi
Kathmandu
Thimphu
Dhaka
Naypyidaw
Rangoon
EXERCISE

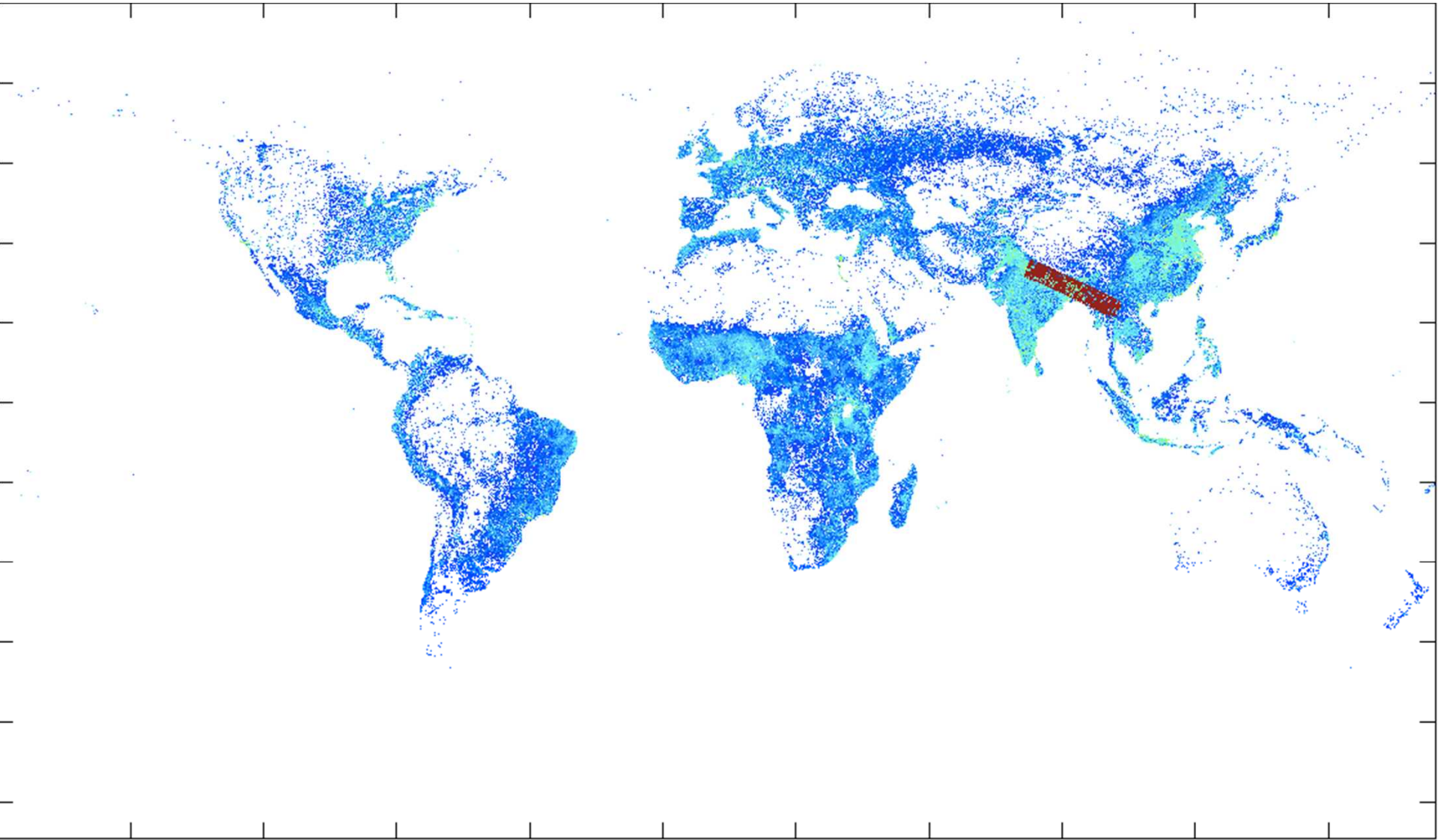


Country	Potentially Impacted Population (2020)
Bangladesh	136,177,408
India	219,941,526
Lao	91,773
Myanmar	13,321,088
Thailand	524,225
Total Population	**370,056,019**

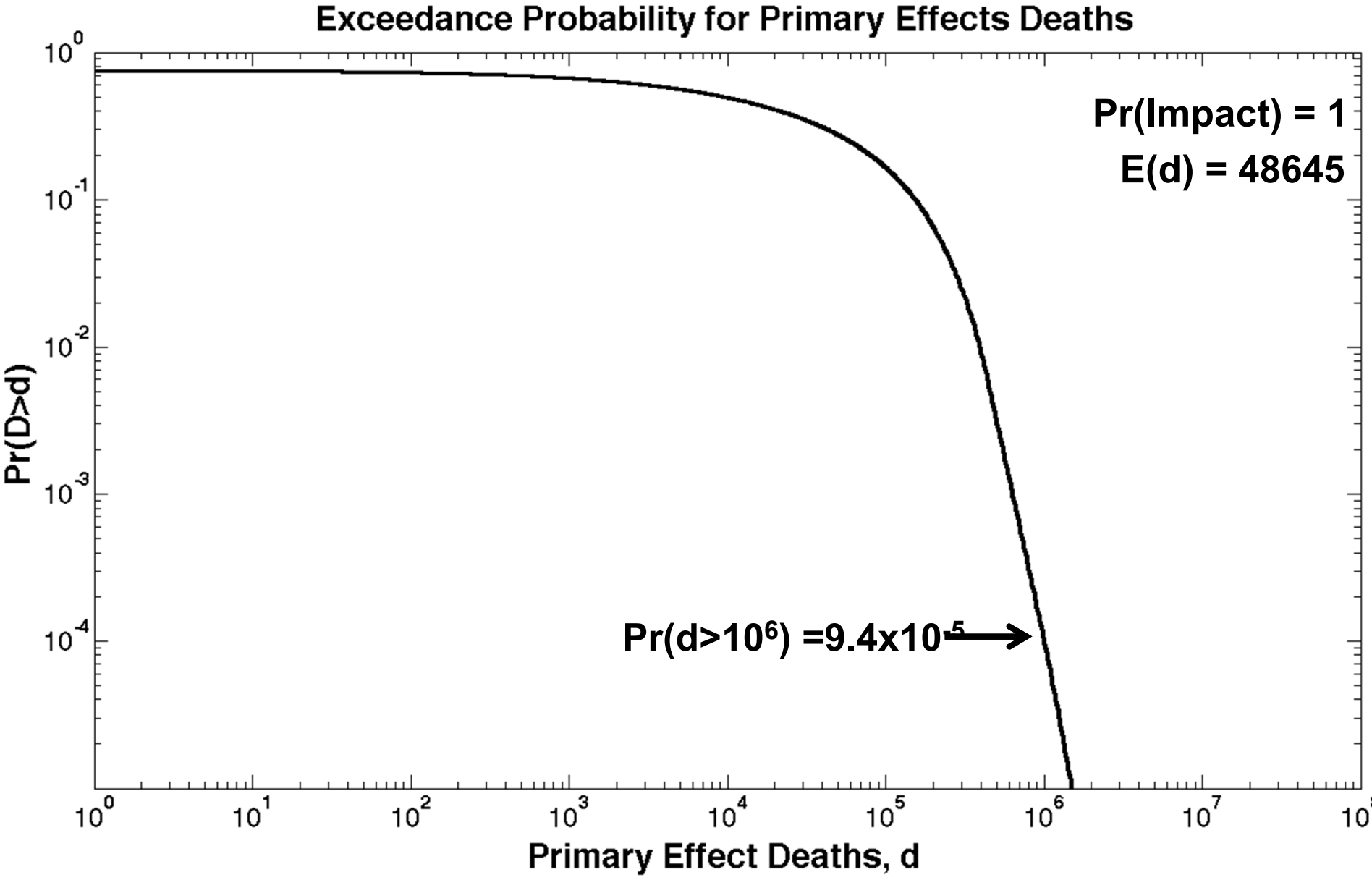
PDC2015 Scenario: A Probabilistic Risk Analysis

Jason C. Reinhardt
Stanford University
reinhardt@stanford.edu

The Feb. 2022 Risk Corridor and Human Population



Distribution over fatalities (Feb. 4, 2022)



Probability of Total Fatalities

Total Fatalities (d)	~Pr(d in Range)
$d < 10^2$	0.271
$10^2 < d < 10^3$	0.061
$10^3 < d < 10^4$	0.175
$10^4 < d < 10^5$	0.328
$10^5 < d < 10^6$	0.164
$10^6 < d$	<0.001

Inject 7

Physical and Infrastructure Effects Briefing

August 27, 2022
2015 PDC

Mark Boslough & Barbara Jennings
Sandia National Labs
Albuquerque, NM

Bill Fogleman, GRIT – Mapping
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What we have been told

Deflection partially successful

Entry speed: 16 km/s (36,000 mph, ~mach 47)

Elevation angle is ~36° from horizontal

Coming from southeast (~ 36° south of east)

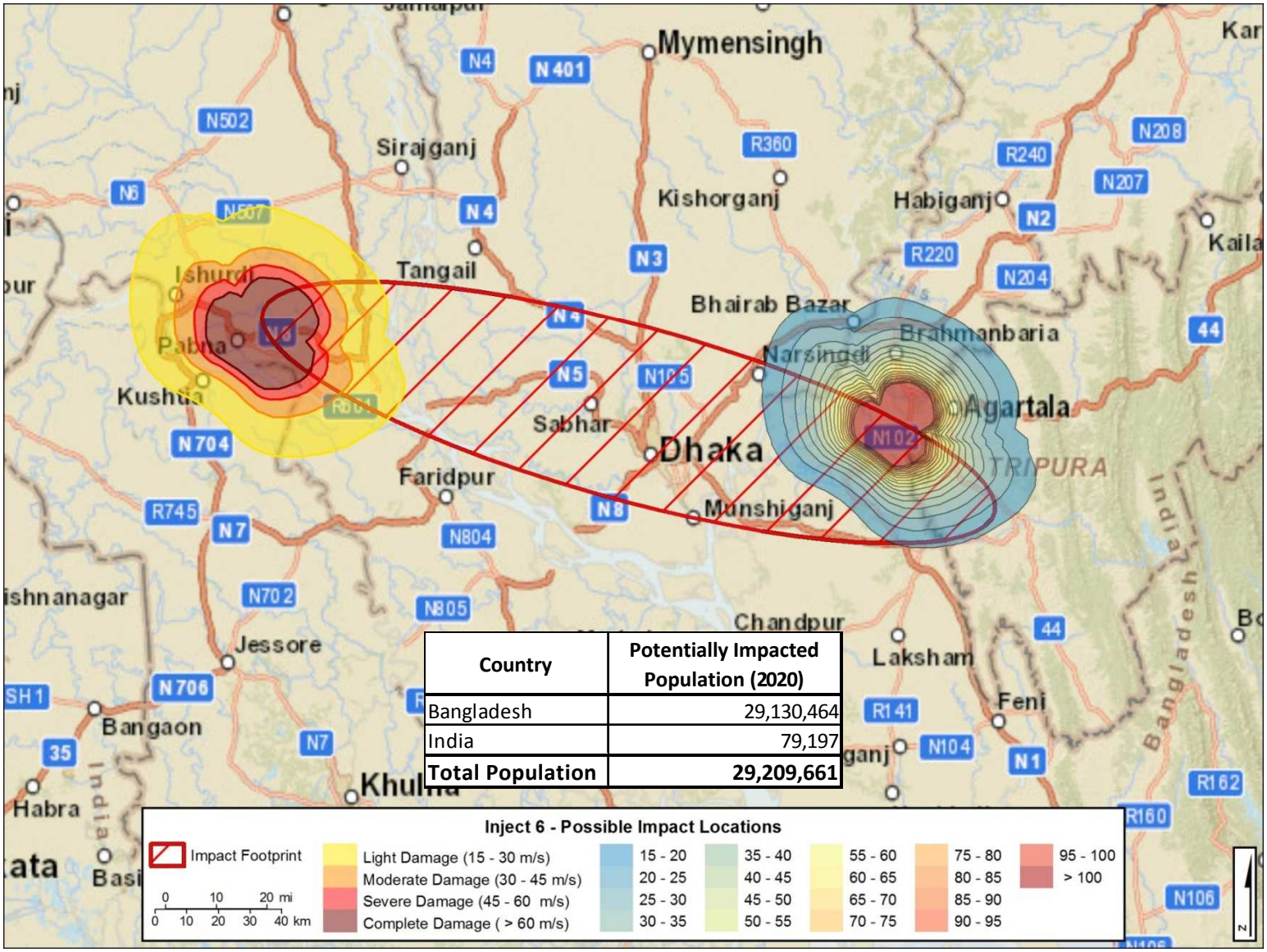
Size: 80 meters in diameter

Composition: Stone, density 3.3 g/cm^3

18 - 25 Megaton impact expected

Impact is certain: September 3, 2022

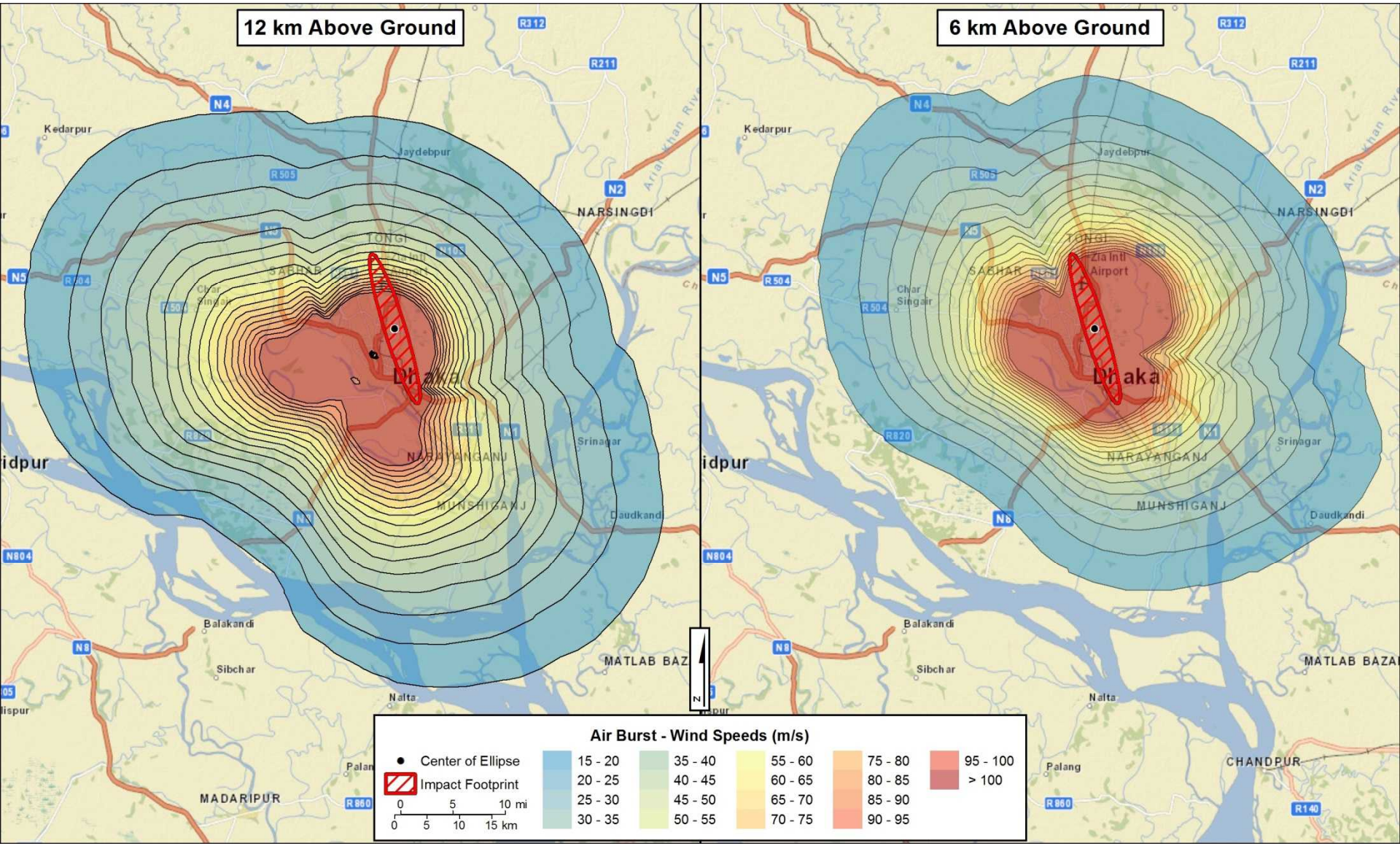
Last footprint before radar data



Country	Potentially Impacted Population (2020)
Bangladesh	29,130,464
India	79,197
Total Population	**29,209,661**

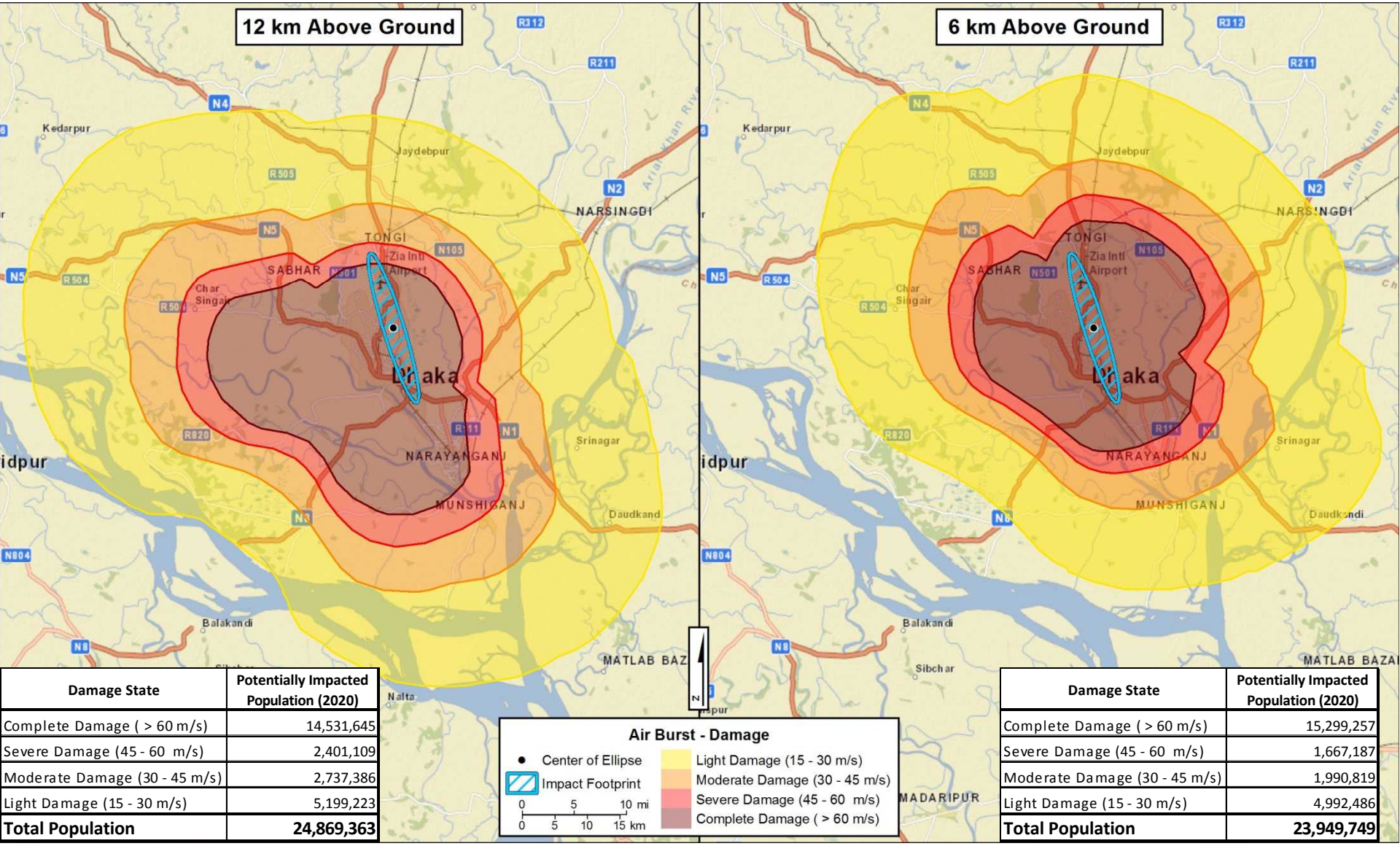
EXERCISE

Wind maps for final footprint



EXERCISE

Damage maps for final footprint

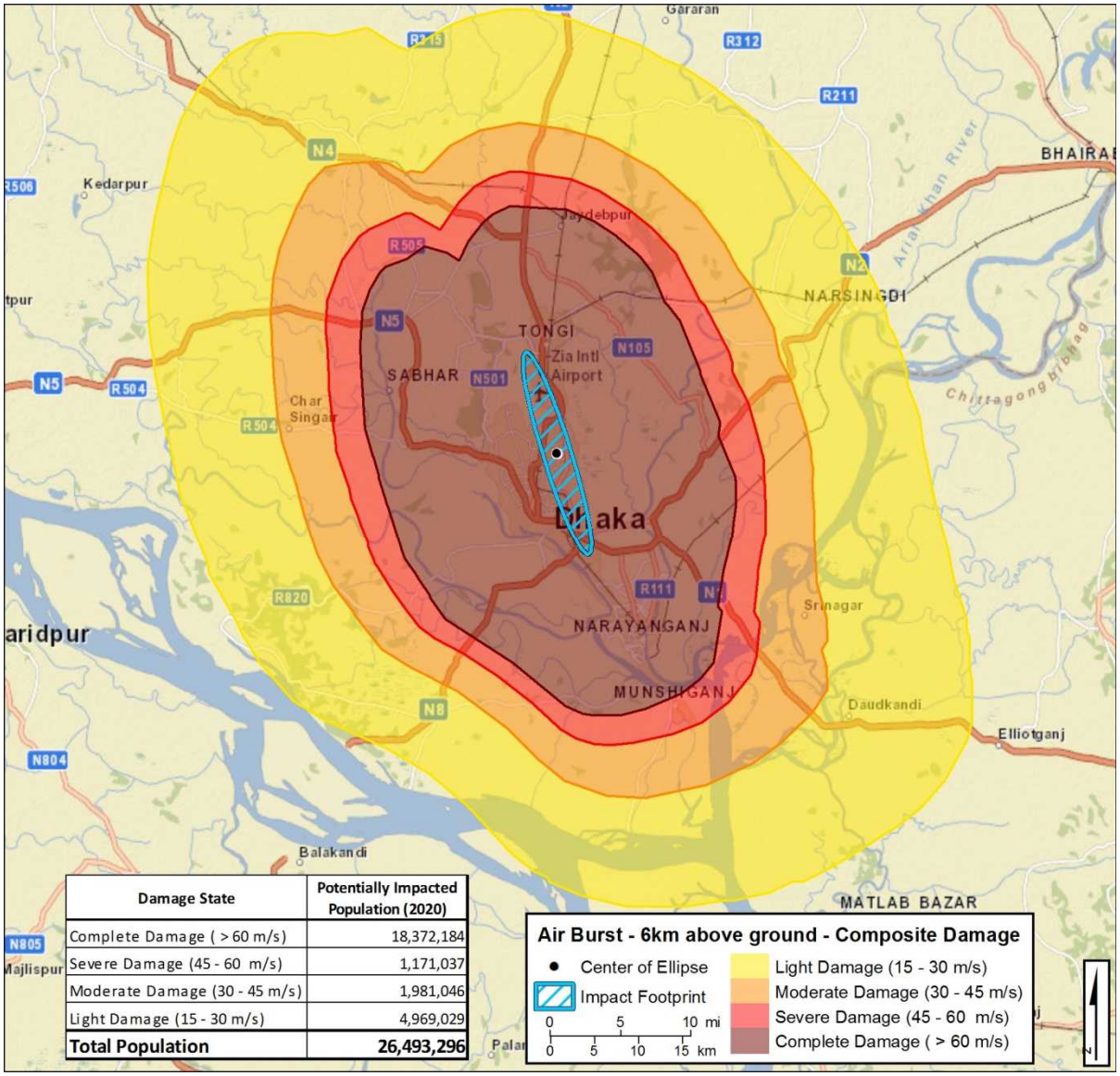


Damage State	Potentially Impacted Population (2020)
Complete Damage (> 60 m/s)	14,531,645
Severe Damage (45 - 60 m/s)	2,401,109
Moderate Damage (30 - 45 m/s)	2,737,386
Light Damage (15 - 30 m/s)	5,199,223
Total Population	**24,869,363**

Damage State	Potentially Impacted Population (2020)
Complete Damage (> 60 m/s)	15,299,257
Severe Damage (45 - 60 m/s)	1,667,187
Moderate Damage (30 - 45 m/s)	1,990,819
Light Damage (15 - 30 m/s)	4,992,486
Total Population	**23,949,749**

EXERCISE

Composite damage map



Damage State	Potentially Impacted Population (2020)
Complete Damage (> 60 m/s)	18,372,184
Severe Damage (45 - 60 m/s)	1,171,037
Moderate Damage (30 - 45 m/s)	1,981,046
Light Damage (15 - 30 m/s)	4,969,029
Total Population	**26,493,296**

EXERCISE

Nouka Dingi – Rowboat Taxis on the Buriganga River

EXERCISE

http://www.independent.co.uk/travel/asia/bangladesh-travelling-from-buzzing-dhaka-to-the-bay-of-bengal-9820901.html

Dhaka, Bangladesh

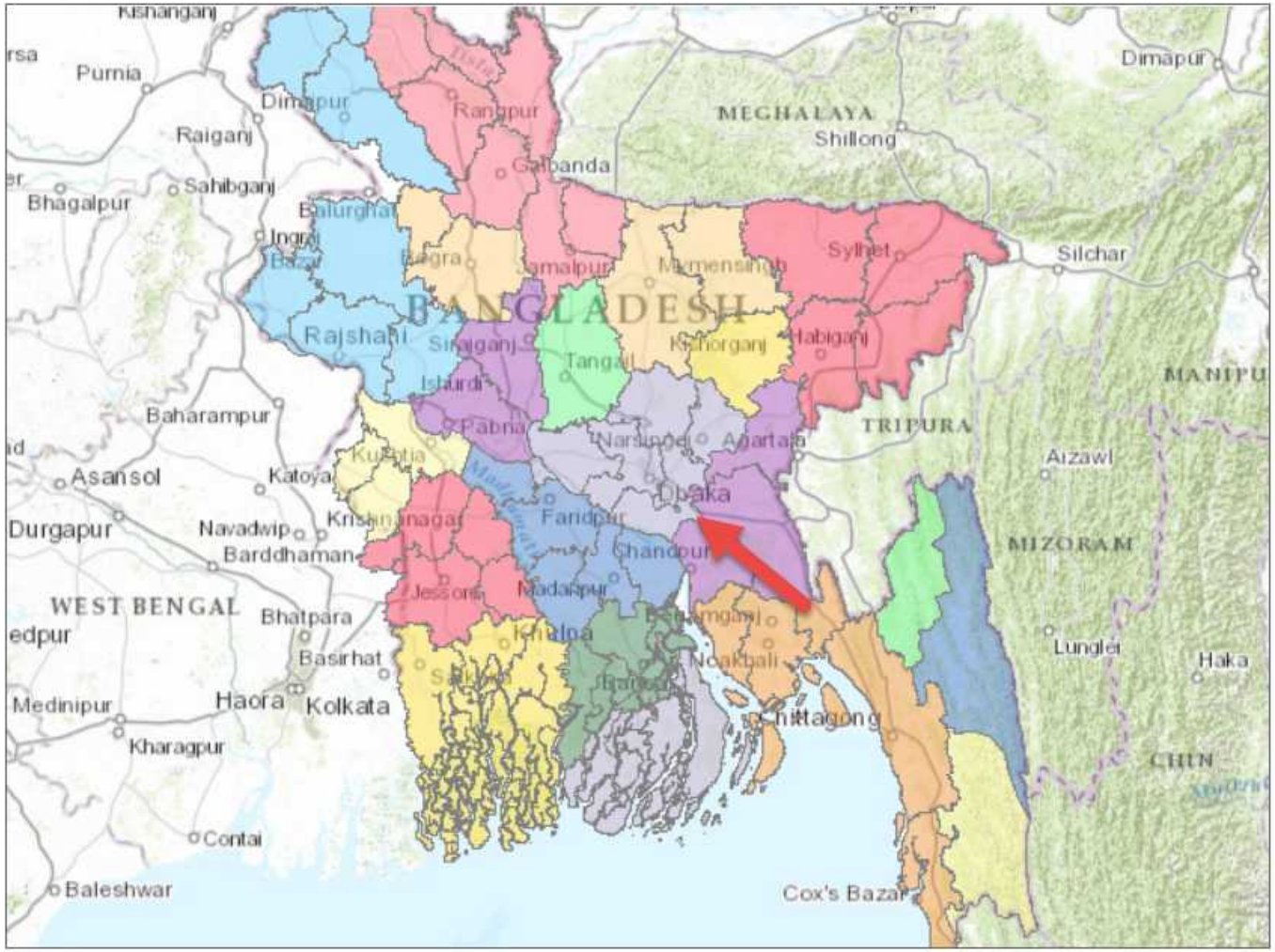
Esri, DeLorme, FAO, USGS, NOAA

EXERCISE

Bangladesh Districts

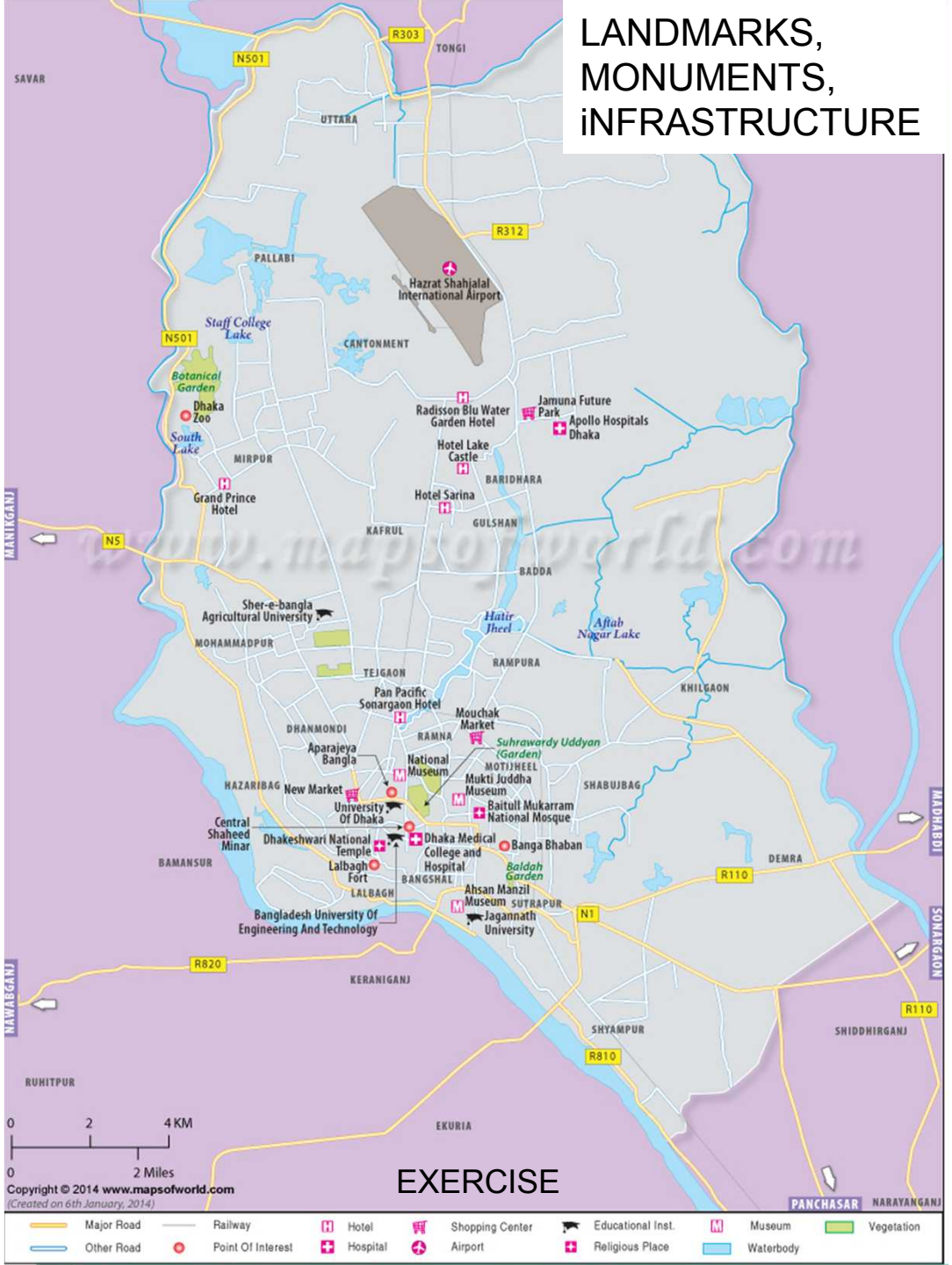
Local Governments

*No Central Authority
*20 independent & uncoordinated governing zones
*Ministries govern Dhaka and supply independent services



EXERCISE

LANDMARKS, MONUMENTS, iNFRASTRUCTURE



EXERCISE

Dhaka Demographics

- Capital of Bangladesh
- Headquarters of the Dhaka Division and Dhaka District
- Fastest growing megacity in the world
- Most populous city in Bangladesh and 10th largest city in the world
- Population15M (Unofficial)
- One of the largest Muslim (Sunni – small Shia community) Countries 80%/ 16% Hindu
- 28 Major Hospitals & Medical Centers
- U.S. Ambassador – Marcia Stephens Bloom Bemicat
- Delta region between two rivers Ganges and Brahmaputra
- Known as the city of mosques
- The only mega city in Bangladesh
- Political economic and cultural heart of Bangladesh
- Over ½ population live in extreme poverty
- Major Transportation Dhaka Metro and Dhaka Elevated Expre
- Largest number of rickshaws in the world
- Most homes are hand built
- Problems- congestion, poverty and overpopulation, over dependence on groundwater
- University of Dhaka

EXERCISE

More Information - Holidays

- Government – Dhaka City Corporation is self-governing corporation
  - 2 administrative parts: north and south each headed by an administrator
  - Each incorporated area has several wards with elected commissioners.
- Public schools
- Home to numerous state and diplomatic establishments: the President of Bangladesh, National Parliament House, the Prime Minister, the Bangladesh Supreme Courts and the Dhaka High Court and the Foreign ministry and Defense Ministry
- 48 Embassies and high commissions and many international organizations
- September 05 Krishna Janmashtami Holiday
- Nearly 80% of annual rainfall between May and September(83.6 inches)
- Average temperature 25°C
- One of the worlds leading rice and jute growing regions
- Industries include textiles, food processing and manufacturing
- More that 700 mosques and historic buildings
- 3M work in garment factories
- Possessions are minimal

EXERCISE

Dhaka Delta

Fragile landscape very susceptible to floods and destruction from monsoons.

EXERCISE

Modern High-rise Buildings in Dhaka

- Greater Dhaka (**conurbation)** 15.5M
- Unplanned Mega-city
- Fastest growing megacity in the world
- Some of the largest shopping malls in the world
- Dhaka is considered as a less economically developed country (LEDC)
- 2025 Projected population 25M

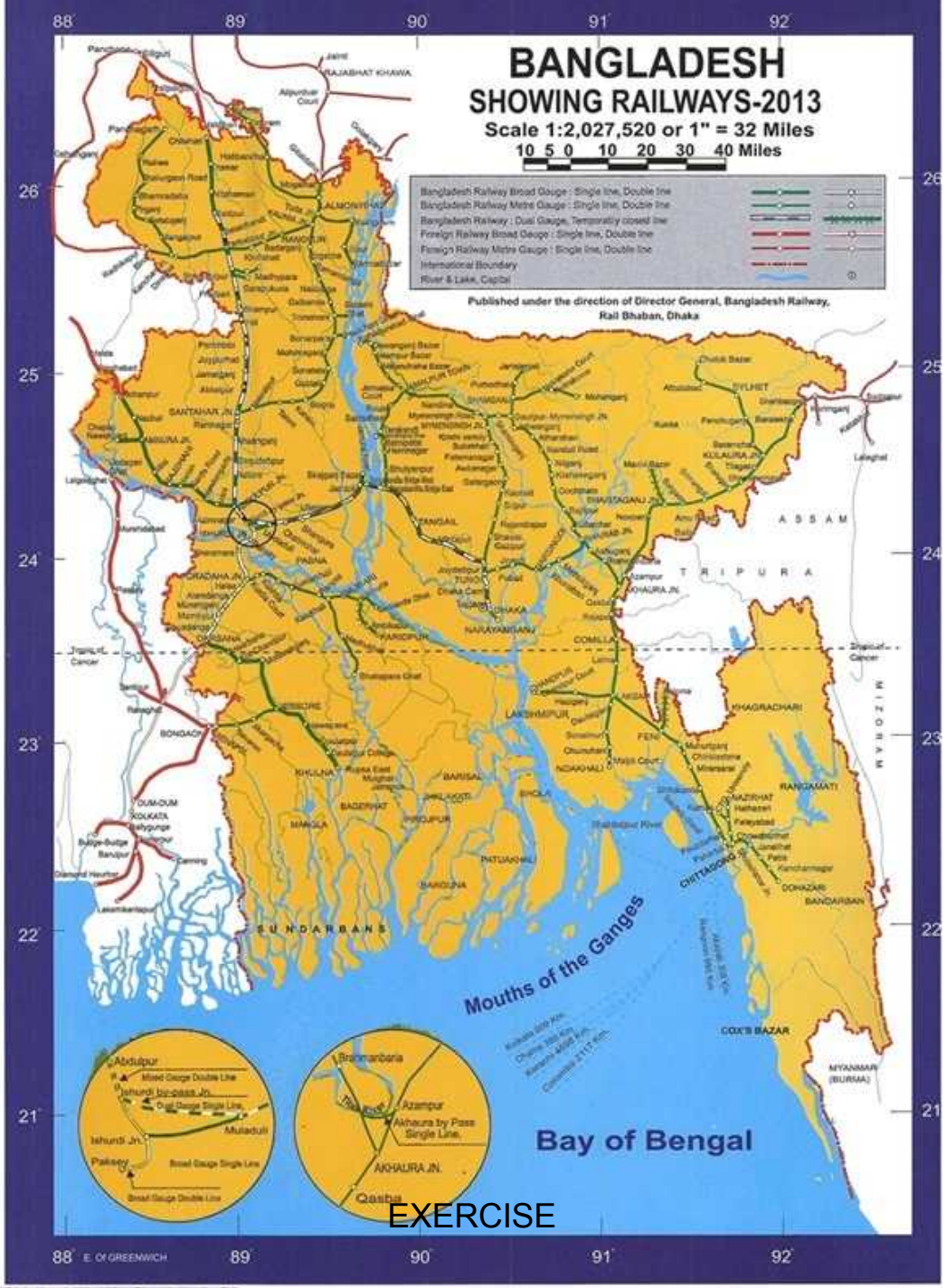
EXERCISE

http://wikitravel.org/en/Dhaka

Transportation

- Shahjalal International Airport – located 11 miles (17 kilometers) from Dhaka largest airport in Bangladesh operated and maintained by the Civil Aviation Authority, used by the Bangladesh Air Force.
- Bangladesh Railway – state owned; metre-gauge network
  - Both intra-city and inter-city travel between Dhaka and Chittagong, Calcutta
- Waterways
- Rickshaw


TRANSPORT NETWORK
50 0 50 100 km
Airport
Divisional Headquarters
International Boundary
District Boundary
River
Highways
Broad Gauge
Meter Gauge
Internal Air Route
Waterway (BIWTA)
88°
89°
90°
91°
92° E
26° N
25°
24°
23°
22°
21°
Tentulia
Patgram
West Bengal (INDIA)
PANCHAGARH
THAKURGAON
KURIGRAM
Assam (INDIA)
DINAJPUR
RANGPUR
West Bengal (INDIA)
Meghalaya (INDIA)
Tamabil
SYLHET
Surma R
SUNAMGANJ
NAOGAON
SHERPUR
BOGRA
NETROKONA
Assam (INDIA)
NAWABGANJ
MYMENSINGH
RAJSHAHI
SIRAJGANJ
HABIGANJ
MAULVI BAZAR
Ganges R
TANGAIL
KISHOREGANJ
KUSHTIA
PABNA
Ganges R
Arichа
DHAKA
Tripura (INDIA)
JHENAIDAHA
FARIDPUR
COMILLA
CHANDPUR
KHAGRACHHARI
Mizoram (INDIA)
West Bengal (INDIA)
Benapole
JESSORE
GOPALGANJ
Meghna R
FENI
Kaptai Lake
NOAKHALI
KHULNA
BARISAL
Sandwip
CHITTAGONG
RANGAMATI
Mongla
BHOLA
PATUAKHALI
Hatiya
SUNDARBAN
Kuakata
BANDARBAN
Chin (MYANMAR)
South Talpatti
COX'S BAZAR
B A Y O F B E N G A L
Arakan (MYANMAR)
Teknaf
St Martin's Island
EXERCISE



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Utilities/Power

- Bangladesh consumes approximately .1% of the total world consumption. Commercial consumption is about 50% of the total.
- Most intensive use sectors transport(50%) and industries (43%)
- Natural Gas Use 66%
- Oil
- Hydropower
- Coal
- 2014 produces 49B kWh electric
- Nuclear Reactors – 2 1000 MWc

EXERCISE

Power plant in Bangladesh

EXERCISE

http://en.wikipedia.org/wiki/Electricity_sector_in_Bangladesh#/media/File:ORION_Group_constructed_two_100_MW_HFO_based_powerplant._in_due_time_and_is_supplying_the_national_grid..jpg

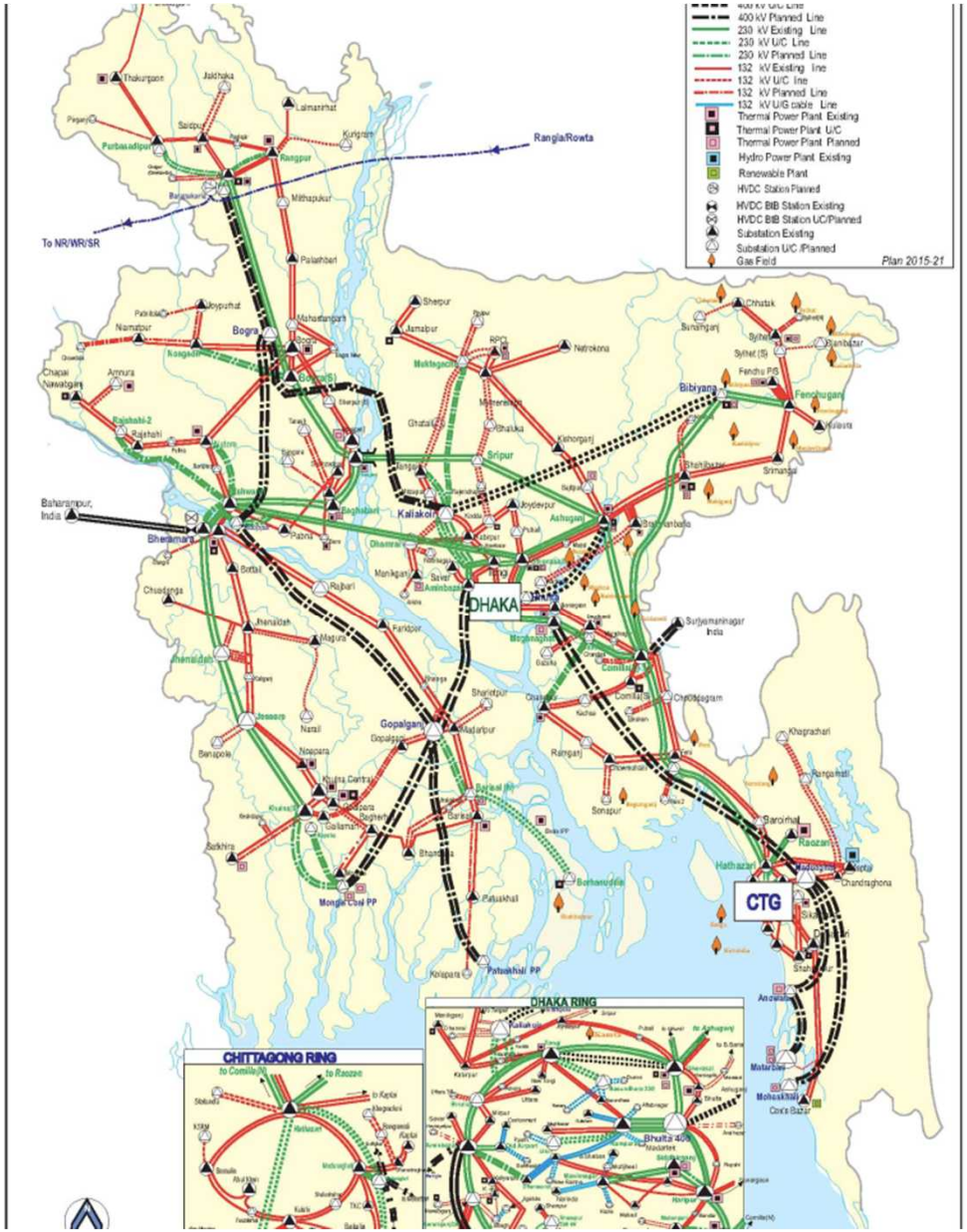
Bangladesh Electricity Regulatory Commission (BERC)

	Number Circuit km	kVolt Lines
Transmission Lines	1444	230 kV
	5255	132 kV
	6 nos	230/132 kV
	63 nos	132/33 kV
Distribution Lines	164.70	400 kV
	3044.45	230 kV
	6210	132 kV
	1 nos	400 kV
	18 nos	230/132 kV
	88 nos	132/33 kV
Power Production	49 B kWh/day	

EXERCISE

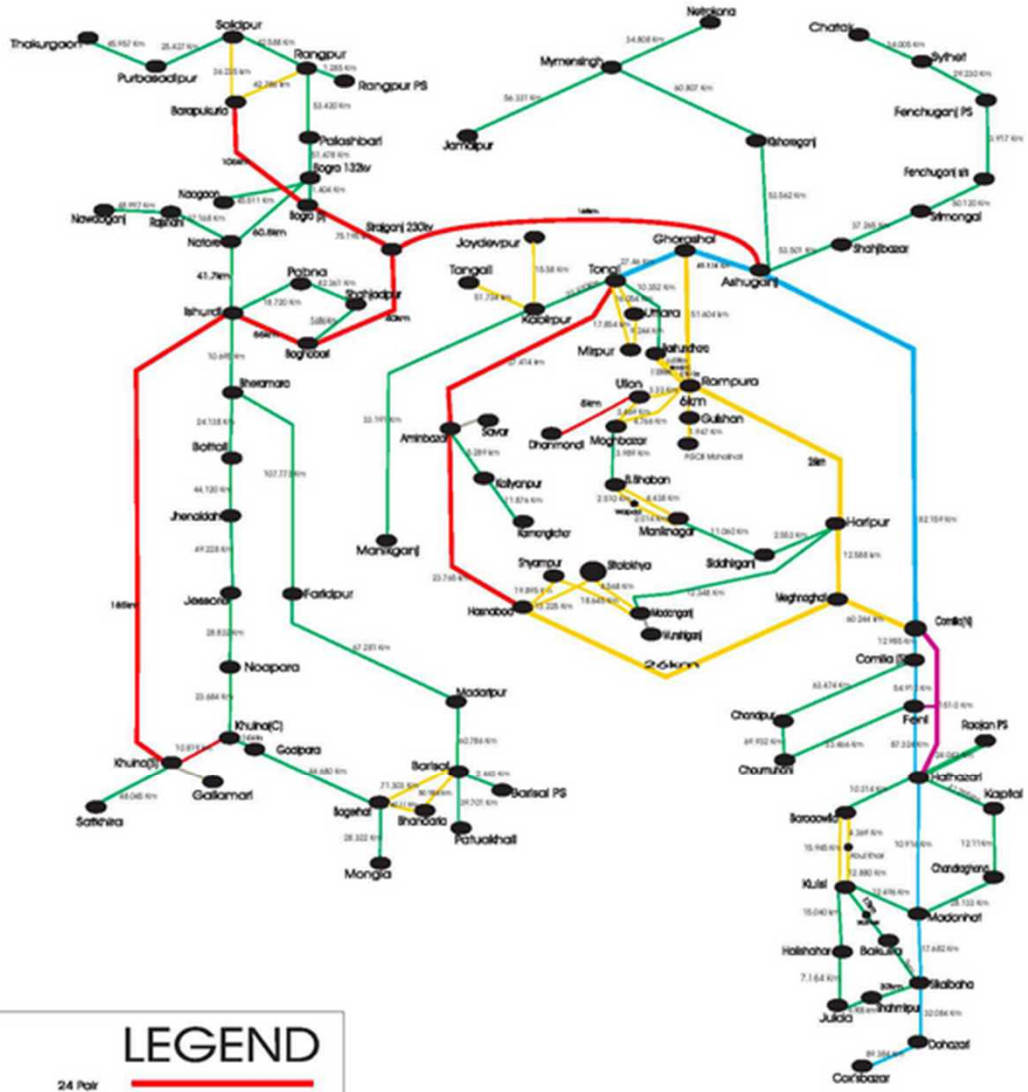
Electric Transmission

- Power Grid Company of Bangladesh (PGCB)
- Maximum Generation 7418 MW
- 400 KV Substations 1 – 27.35 km line
- 230/123 KV Substations 18 – 1523.23 km line
- 132/33 /KV Substations 88 – 3505.55 km line



EXERCISE

OPTICAL FIBRE BACKBONE OF PGCB



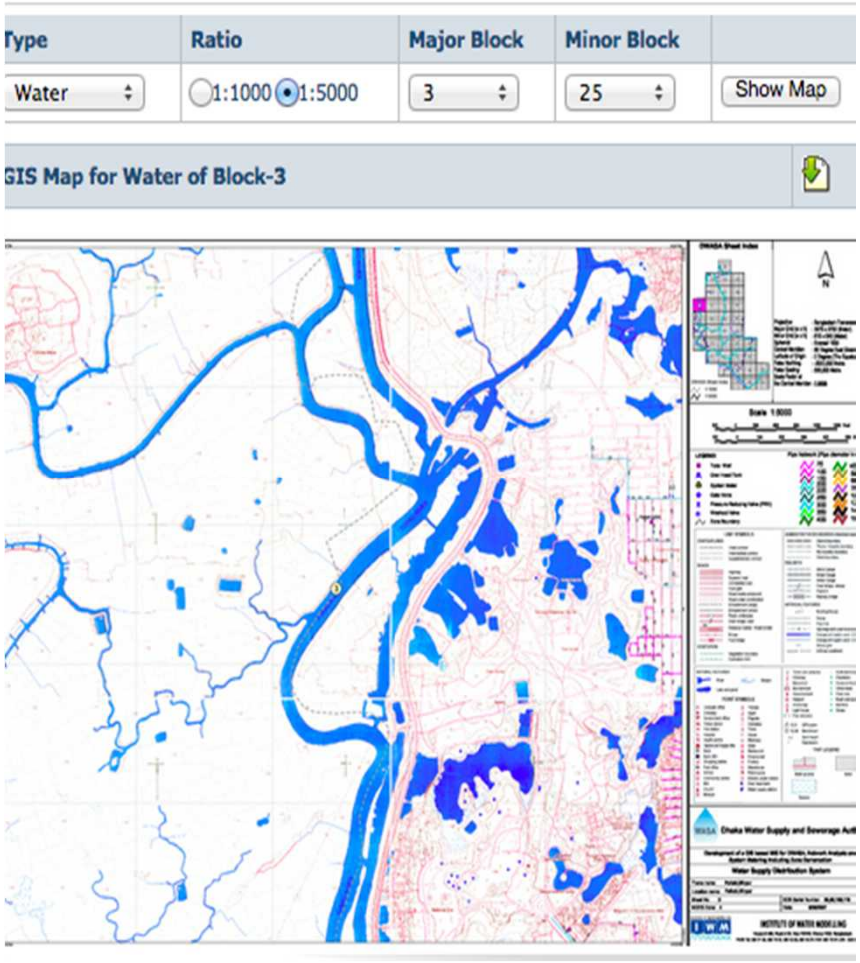
LEGEND

- 24 Pair
- 16 Pair
- 12 Pair
- 6 Pair
- 4 Pair
- OPGW to be installed

EXERCISE

JULY 2011

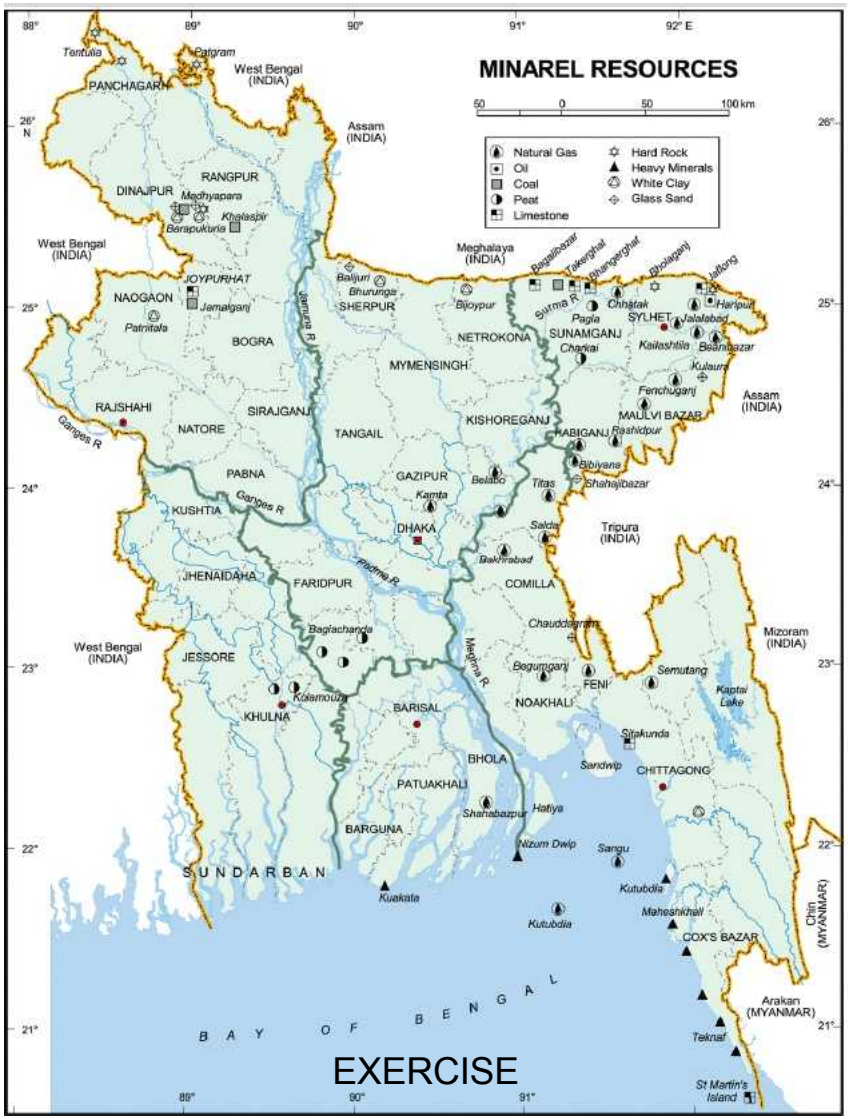
DWASA Water Supply and Sewerage Authority



- In 2012 City required 2.2B liters of water per day
- Official population 12.8M unofficial 15M 3-400,000 increase each year
- Over-dependence on surface water
- 11 geographic zones, 10 in Dhaka
- I office per zone

EXERCISE

Natural Gas & Mineral Resources




BANGLADESH
NEPAL
INDIA
I N D I A
I N D I A
MYANMAR
BANGLADESH
R A J S H A H I
D H A K A
K H U L N A
C H I T T A G O N G
B A R I S A L
Dhaka (Dacca)
Rajshahi
Khulna
Barisal
Chittagong
Jalpaiguri
Koch Bihar
Dingram
Kishanganj
Panchagarh
Thakurgaon
Nilphamari
Pirganj
Saidpur
Lalmanir Hat
Raiganj
Dinajpur
Rangpur
Kurigram
Dhuburi
Goalpara
Guwahati
Tura
Gaibandha
Jaipur Hat
Bogra
Naogaon
Farraka
Nawabganj
Nator
Sirajganj
Jamalpur
Sherpur
Jaria
Sunamganj
Chhatak
Sylhet
Silchar
Rautpara
Gouripur
Mymensingh
Maulvi Bazar
Habiganj
Kishorganj
Tangail
Bhairab Bazar
Gazipur
Narsinghdi
Brahmanbaria
Agartala
Manikganj
Bahamrapur
Pabna
Kushtia
Meherpur
Chuadanga
Rajbari
Dabgram
Jhenida
Magura
Faridpur
Narayanganj
Munshiganj
Comilla
Aijal
Chandpur
Laksham
Palong
Madaripur
Gopalganj
Narail
Santipur
Burdwan
Bangaon
Jessore
Lakshmipur
Feni
Khagrachari
Barrackpore
Habra
Satkhira
Bagherhat
Bhola
Noakhali
Rangamati
Chalna
Pirojpur
Jhalakati
Kolkata (Calcutta)
Patuakhali
Barguna
Diamond Harbour
Haldia
Bungtlang
Bandarban
Satkania
Bichari
Cox's Bazar
Maungdaw
Kutubdia I.
Matarbari I.
Maiskhal I.
Sandwip I.
Daulatkhan I.
Karnaphuli Res.
Kaladan
Brahmaputra
Tista
Jamuna
Ganges
Ganges (Padma)
Gorai
Hooghly
Damodar
Meghna
Surma
S u n d a r b a n s
M o u t h s o f t h e G a n g e s
B A Y O F B E N G A L
National capital
Provincial capital
Town, village
Major airport
International boundary
Provincial boundary
Main road
Railroad
0 25 50 75 100 km
0 25 50 75 mi
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
88° 89° 90° 91° 92° 93°
26° 25° 24° 23° 22° 21°

EXERCISE

Cyclone Preparedness Programme

- Grassroots; 42,675 trained volunteers
- Public awareness through drills & demonstrations, films, publicity campaigns, radio/TV, scenarios, posters
- Received award in 1998 for outstanding response that saves many thousand lives
- Ministries of Disaster Management & Relief
- Supportive neighbors: India & Saudi Arabia
- Recently evacuated Bangladeshi's from Yemen.

Resources

- http://www.usea.org/sites/default/files/event-file/493/overviewofbpdb.pdf
- https://energypedia.info/wiki/Bangladesh_Energy_Situation#Introduction
- http://www.petrobangla.org.bd/photo_gallery.php