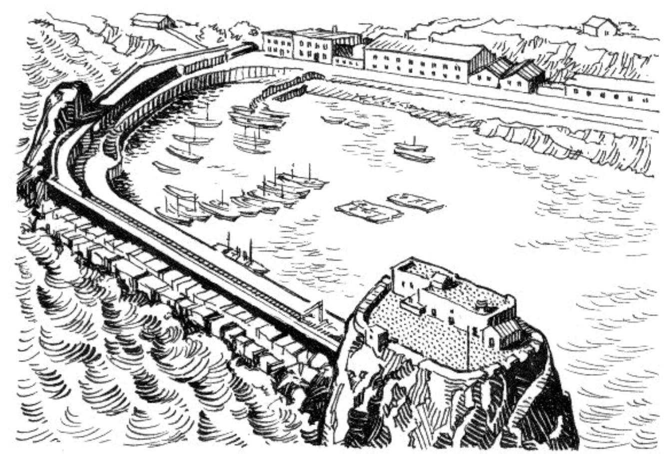
Hydraulic and Coastal Engineering Design



Jeremy D. Bricker, P.E., Ph.D.

Spring semester, 2012

Goal of this course

- Role of the practicing hydraulic/coastal engineer.
- Apply theory to design problems.
- Apply models used in the industry.

Instructor

- Jeremy Bricker, P.E., Ph.D.
- Education
  - BS Mechanical Engineering, Rutgers University (New Jersey)
  - MS, PhD Civil Engineering, Stanford University (California)
- Licensing
  - PE (Civil) in California and Washington
- Experience
  - URS Corporation (Engineering and Design) staff Hydraulic and Coastal Engineer

Project Experience

- Hydrology – San Clemente Dam Removal
- River hydraulics – Delta Habitat and Conveyance Project
- Coastal hydraulics – San Francisco Airport runway extension sediment transport study
- Wave mechanics – San Francisco Public Utility Commission wave power feasibility and erosion study

Course Outline

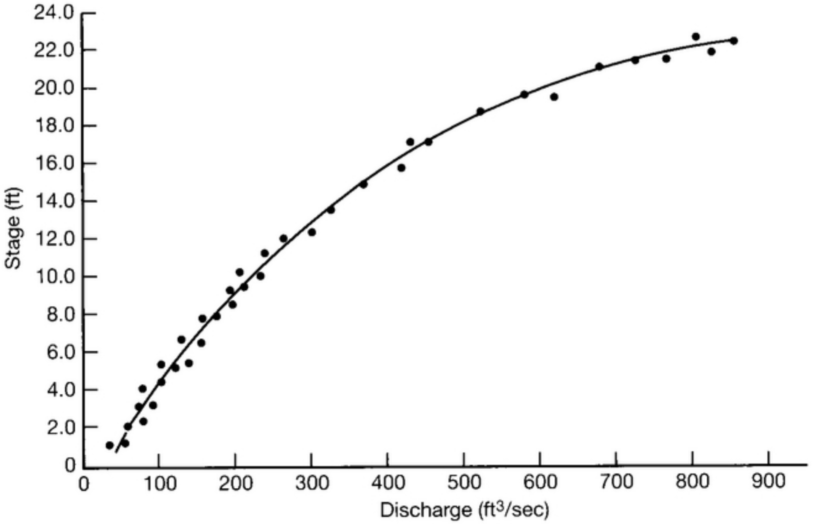
- Hydrology
- River hydraulics
- Coastal hydraulics
- Wave mechanics

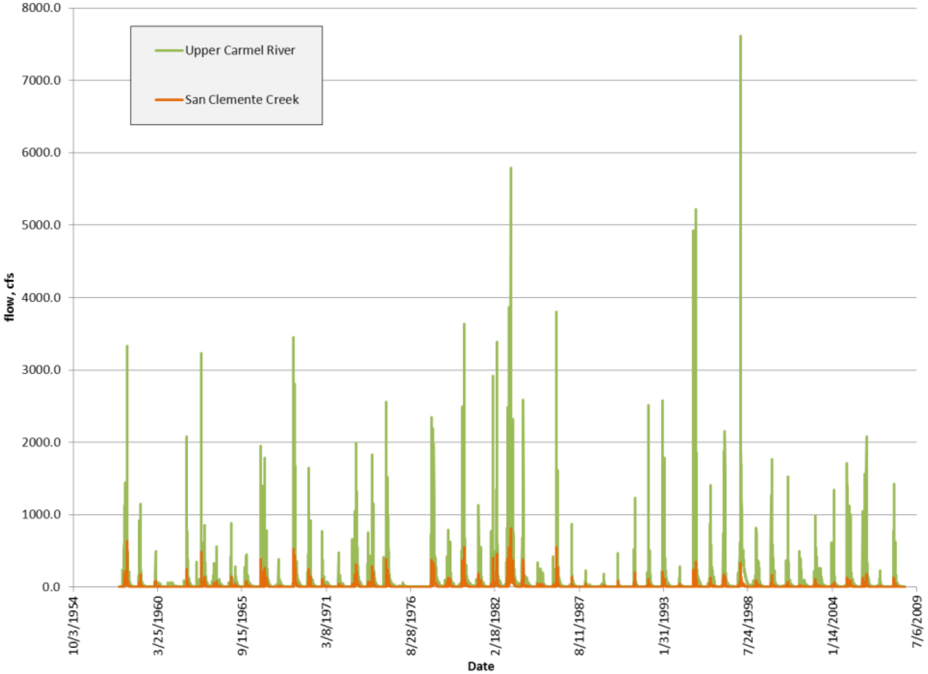
Hydrology

- Dam safety!
- Design spillways to pass the maximum possible flood!
- Gauged basins – extreme value analysis
- Ungauged basins – Rational Method
- Weir and orifice discharge equations

Hydrology – gauged basins

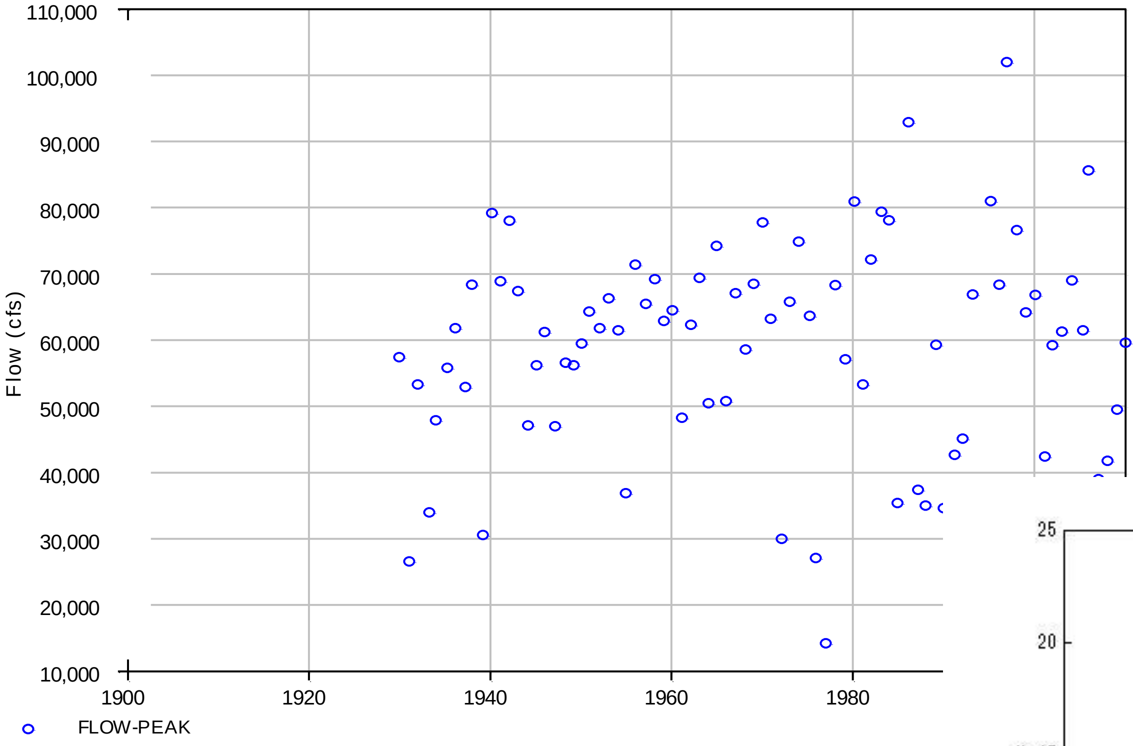
Source: USGS

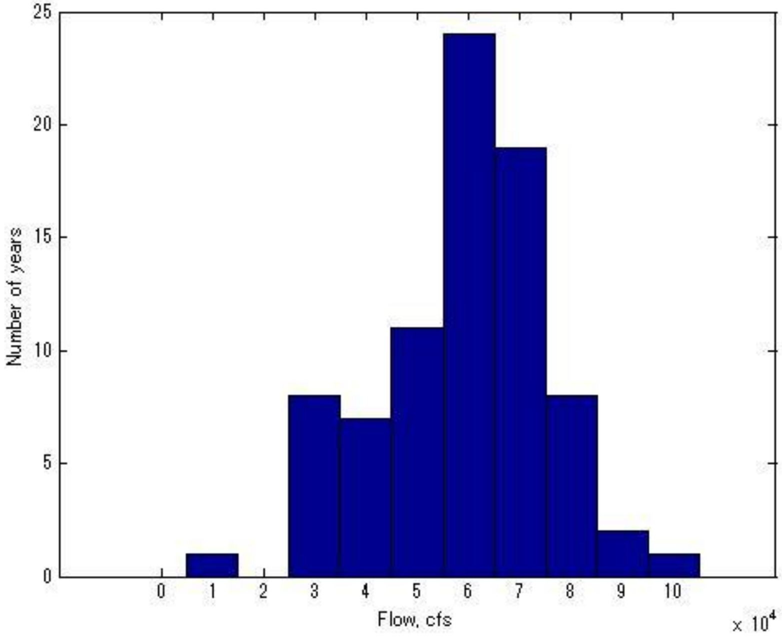




Hydrology – gauged basins

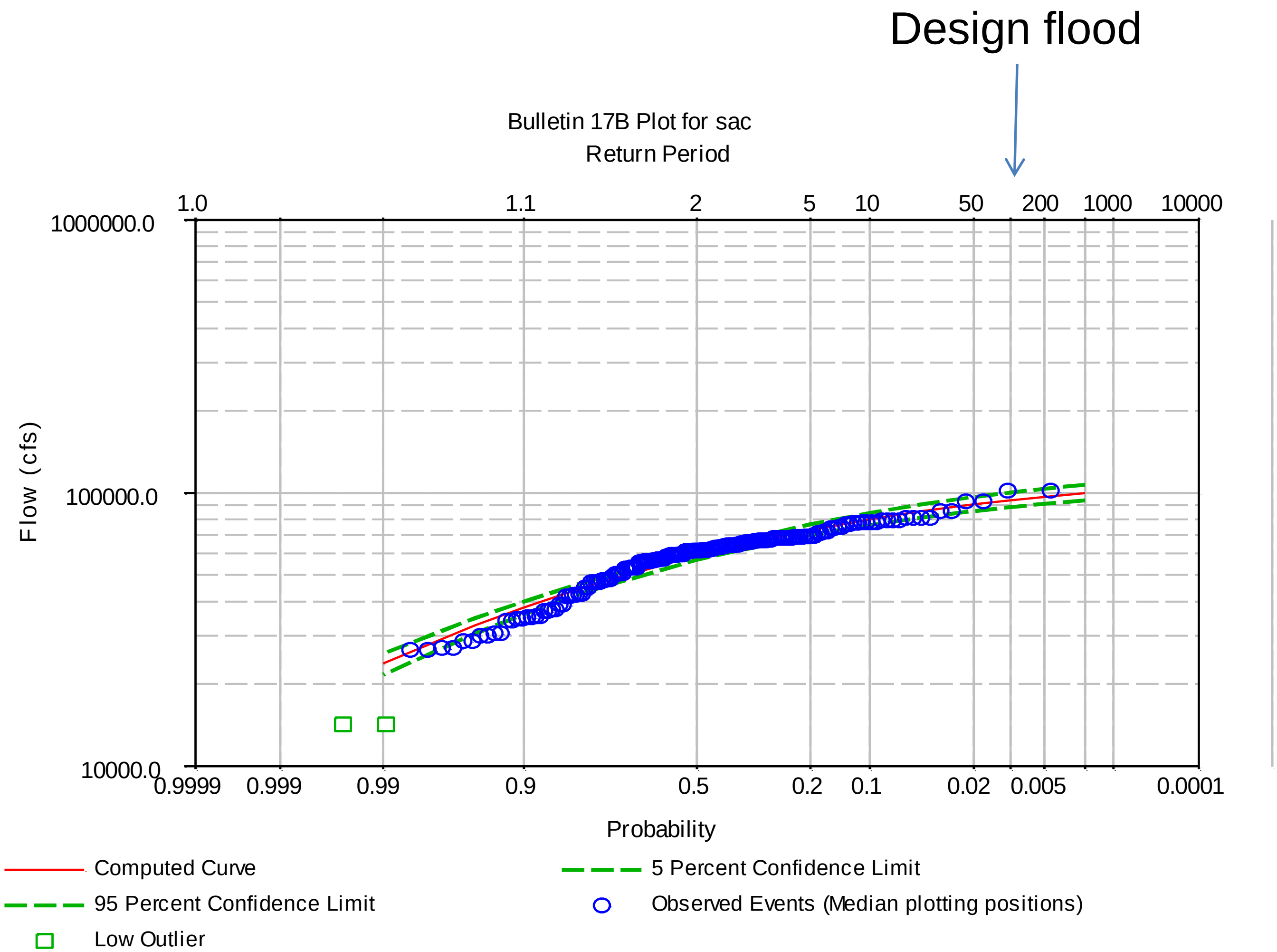
Sacramento River Annual Maxima and Exceedance Curve



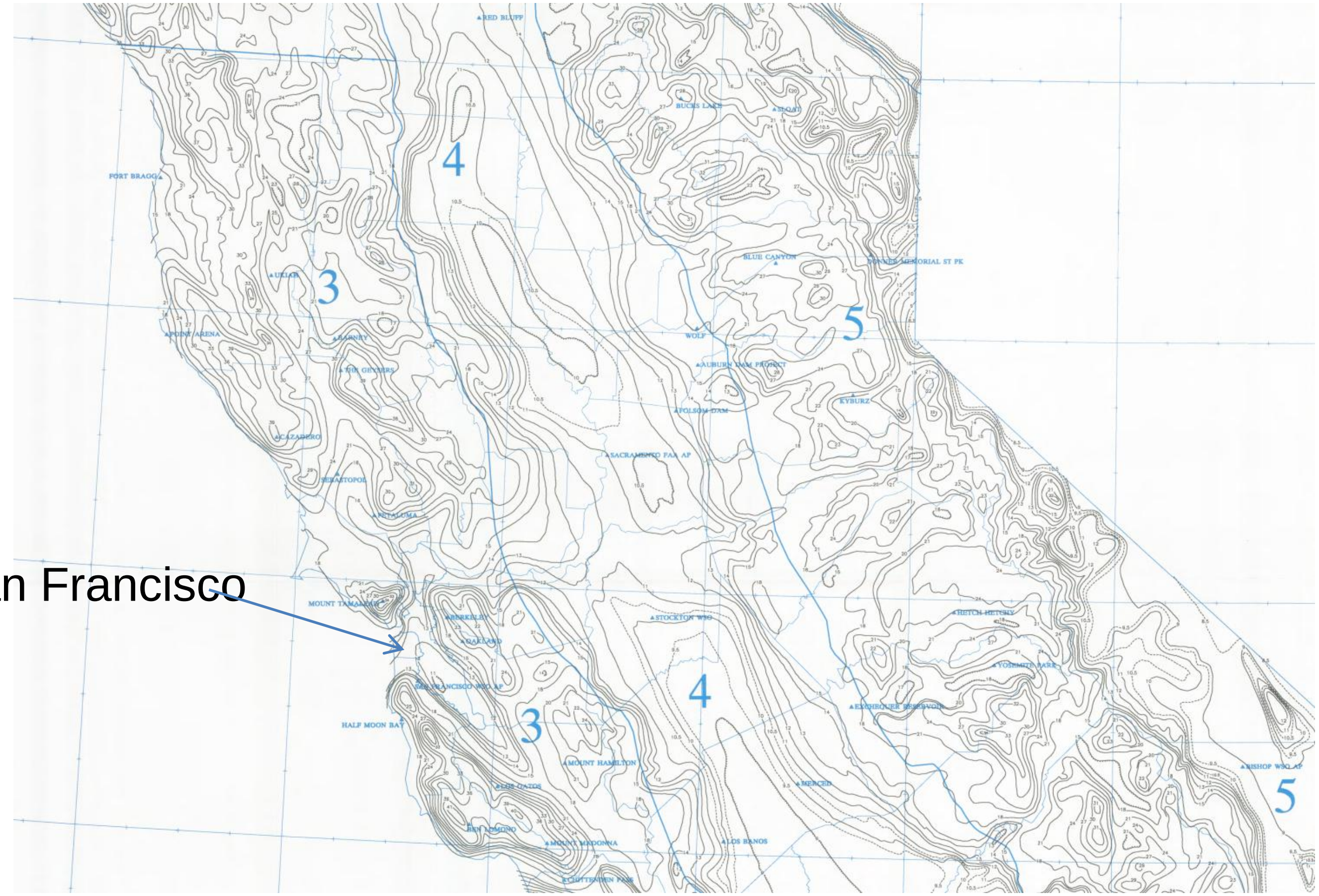


Hydrology – gauged basins

Sacramento River Annual Maxima and Exceedence Curve



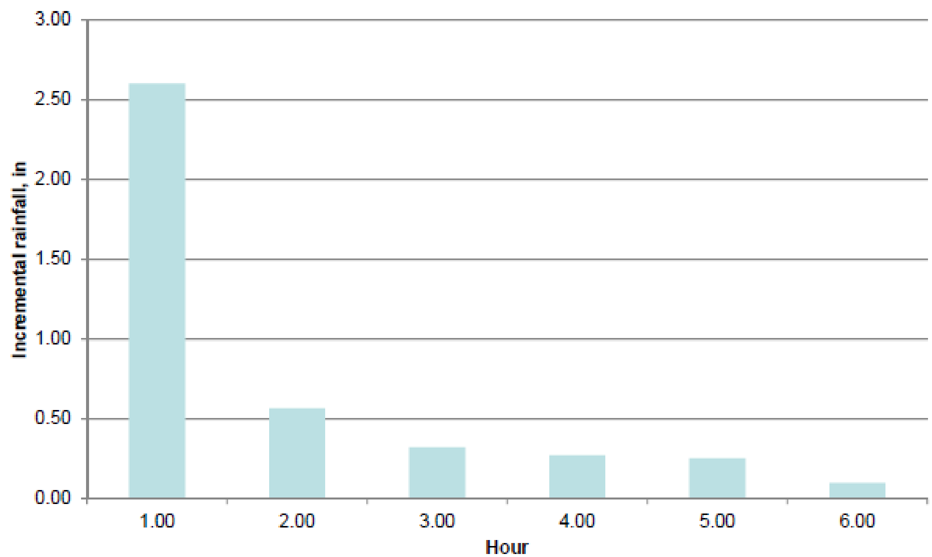
Hydrology – ungauged basins:
Probable Maximum Precipitation, NOAA HMR 59



San Francisco

Hydrology – Ungauged Basins

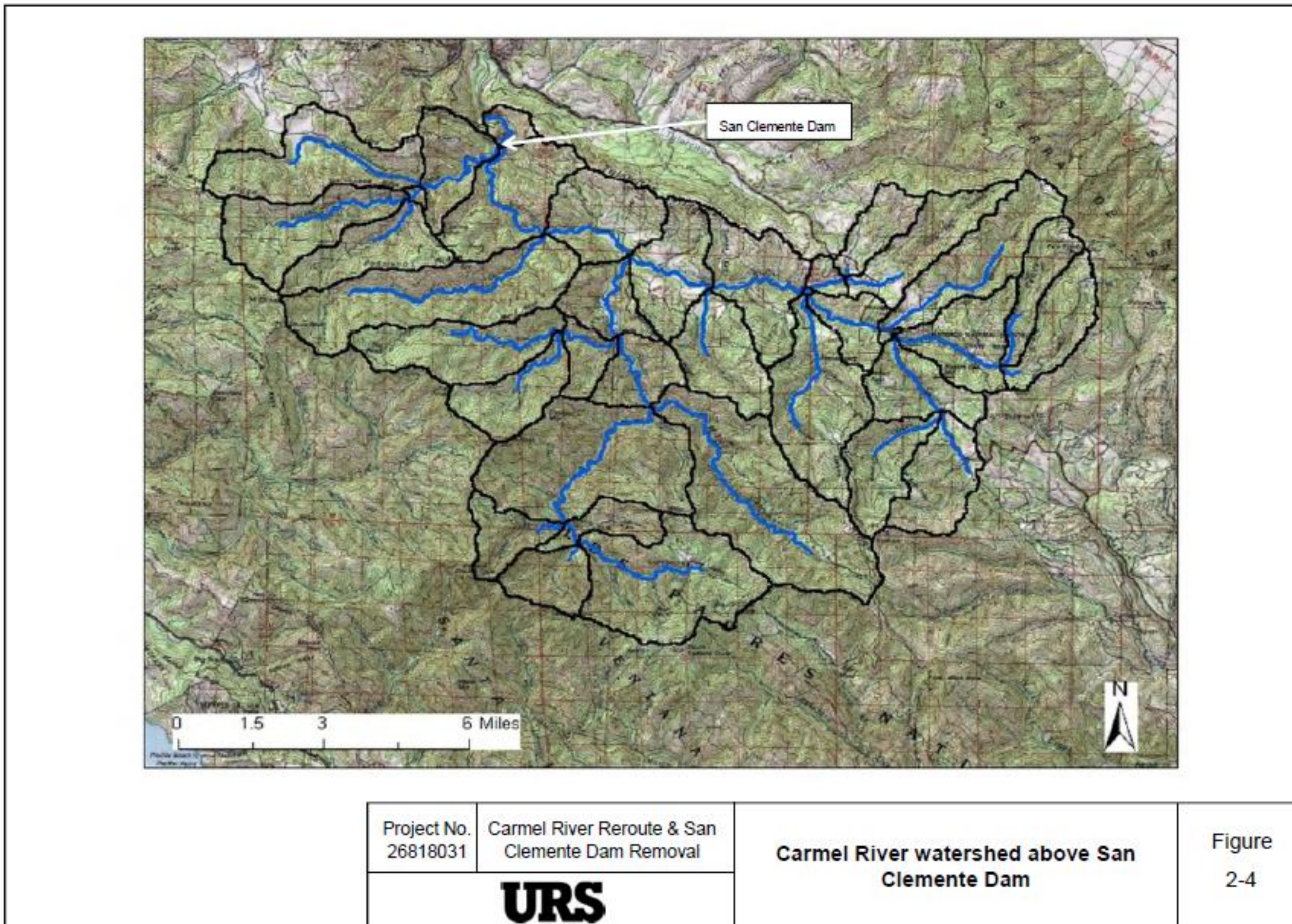
- Design storm
- Find flow rate at location of structure



Project No. 26818031	Carmel River Reroute & San Clemente Dam Removal	**Incremental depth of precipitation for the 6-hr local storm PMP for the San Clemente Dam**	Figure AB-2
URS			

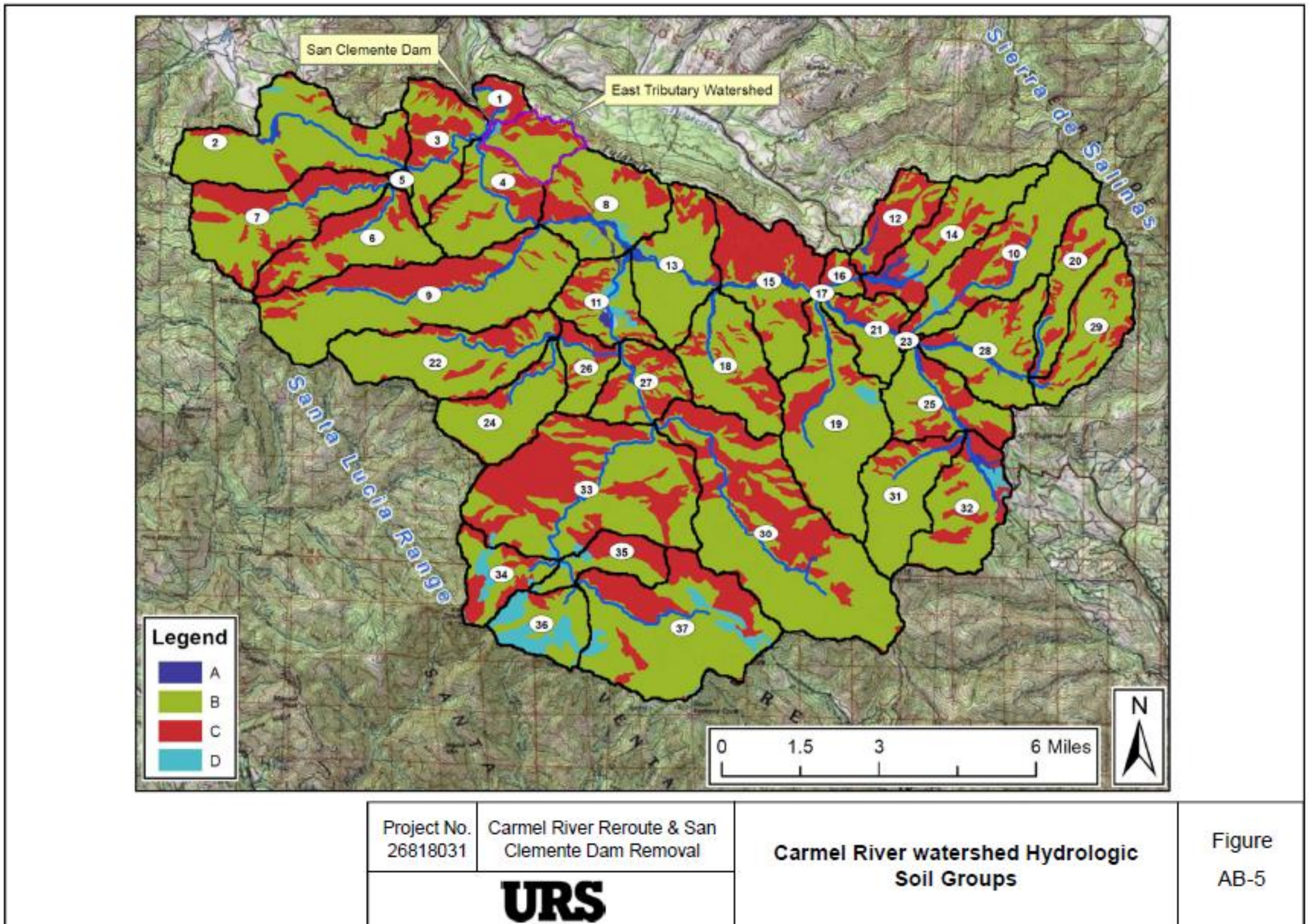
Hydrology – Ungauged Basins

- Basin length, slope, and time of concentration
- Overland flow, concentrated flow, channel flow



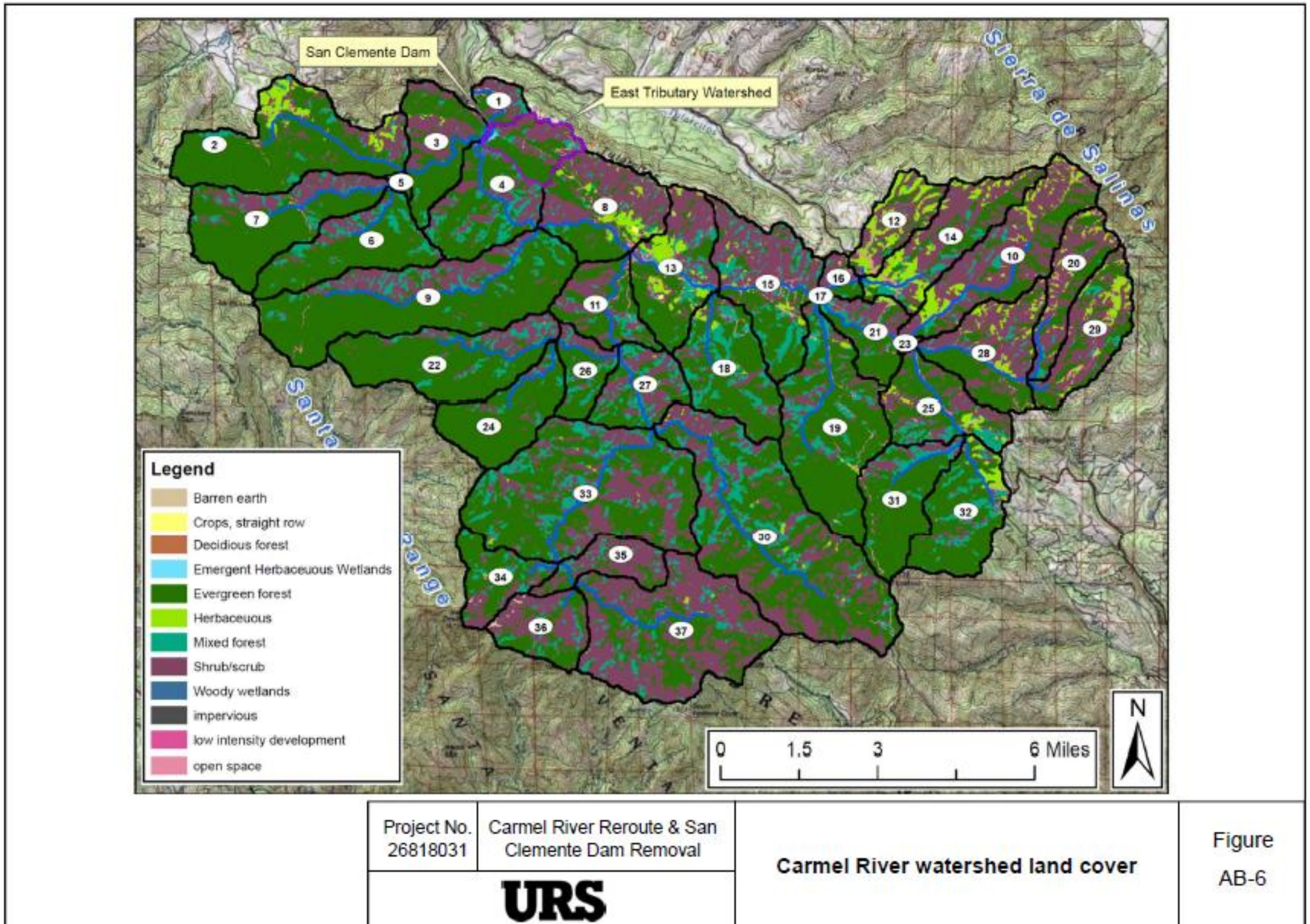
Hydrology – Ungauged Basins

- Land cover and soil type



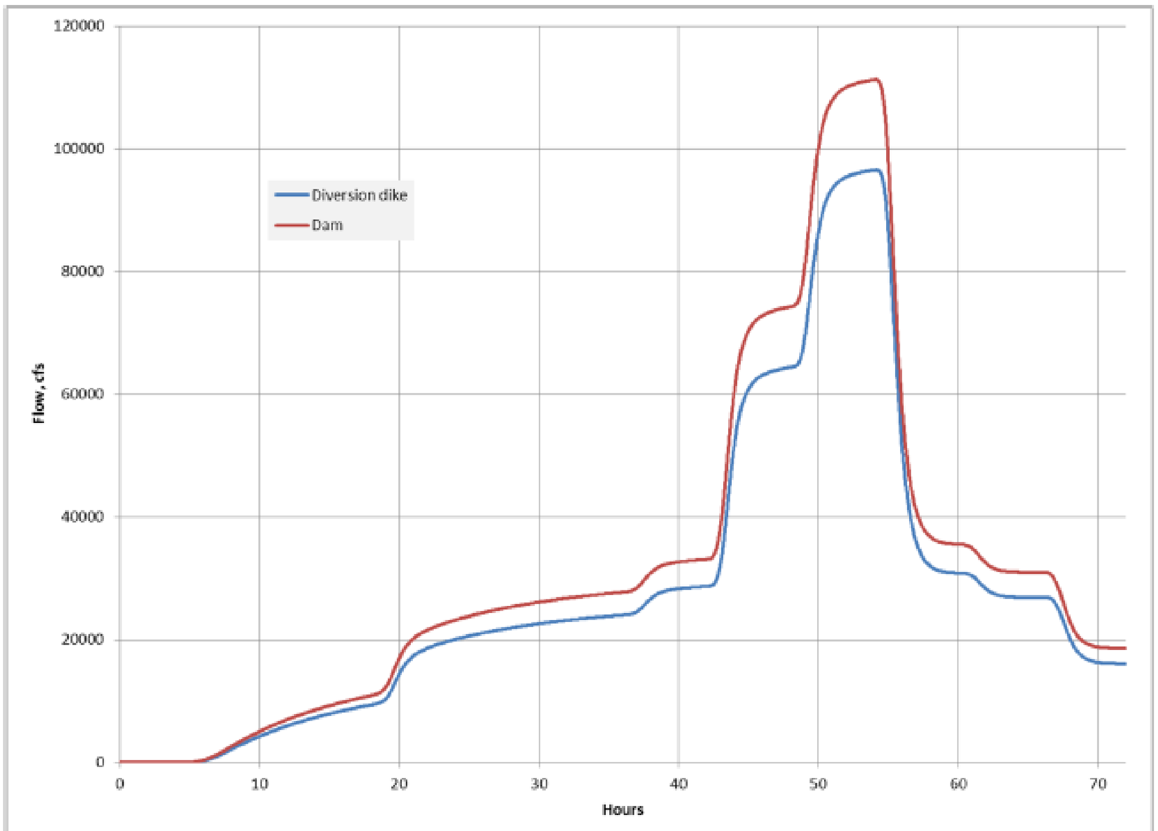
Hydrology – Ungauged Basins

- Land cover and soil type



Hydrology – Ungauged Basins

- Find flow at structure



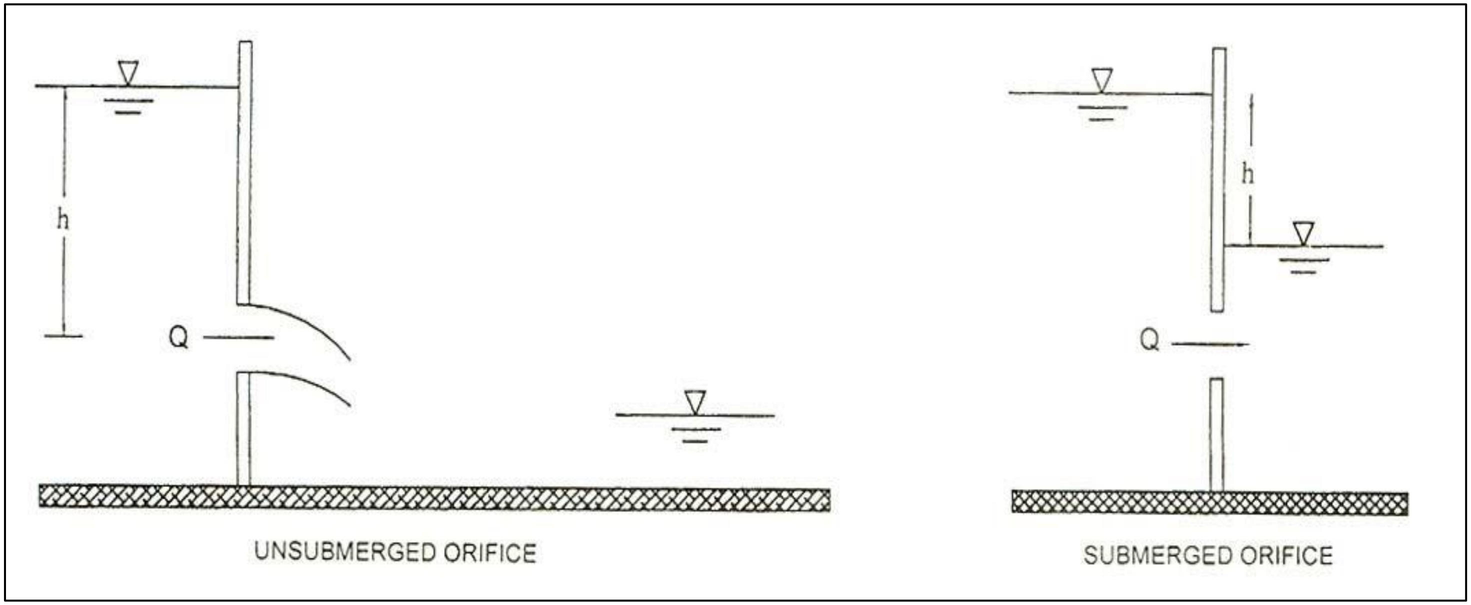
Project No. 26818031	Carmel River Reroute & San Clemente Dam Removal	**General-storm PMF hydrograph for the San Clemente Dam watershed**	Figure AB-7
URS			

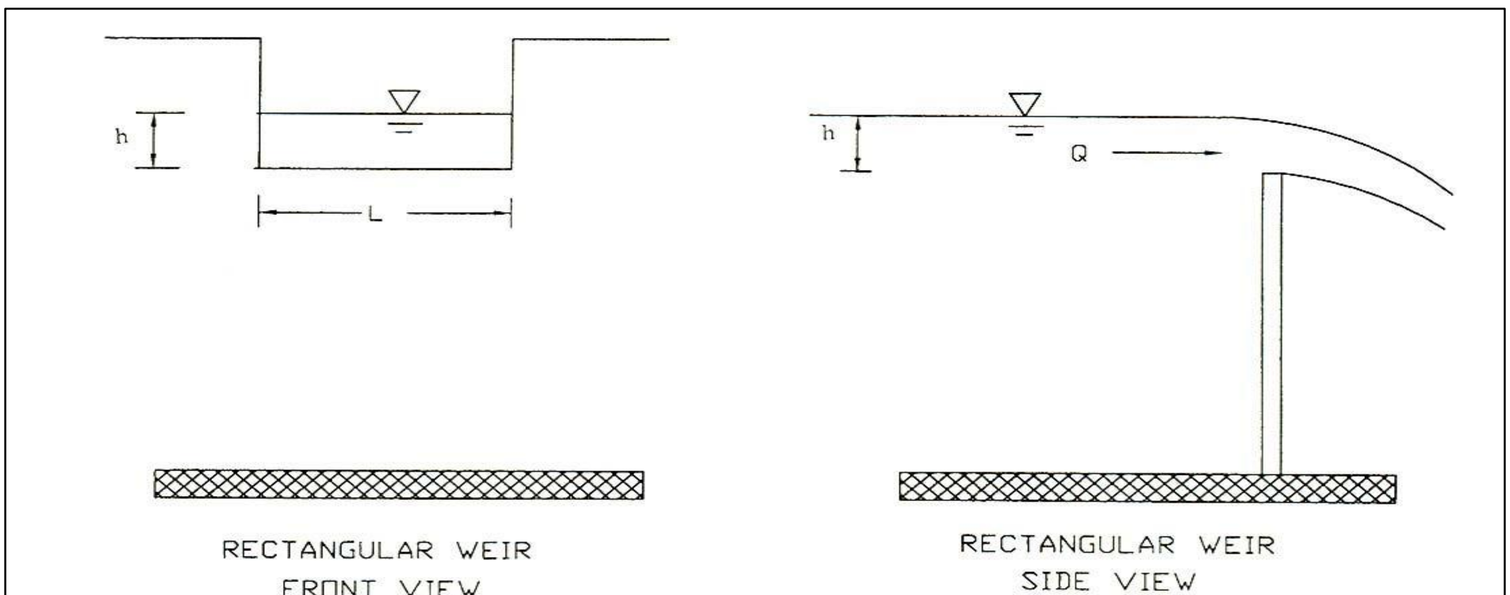
Hydrology: outlets and spillways

- Dams, gates, and spillways – San Clemente Dam, California

Source: California American Water Company

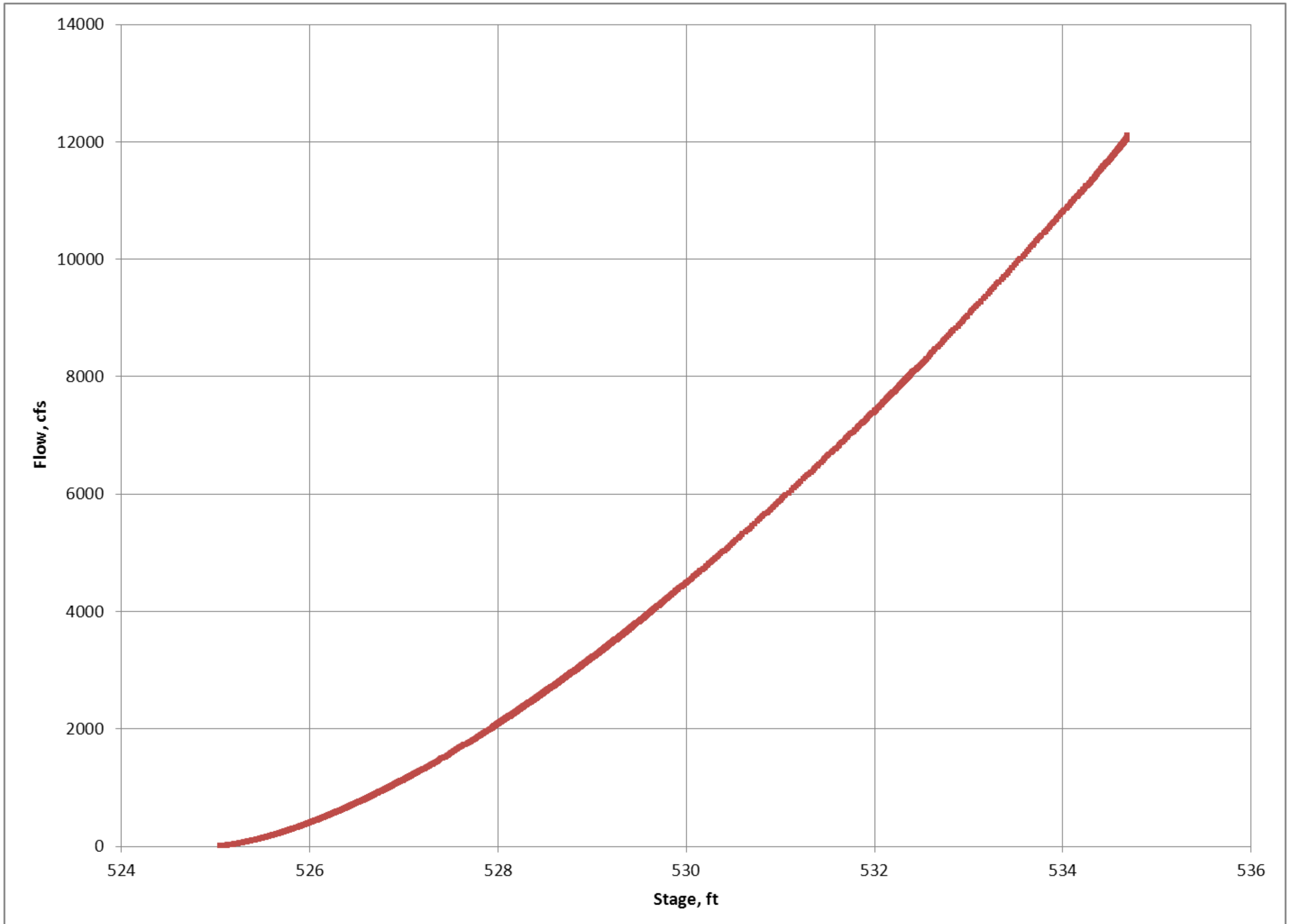
Hydrology: outlets and spillways





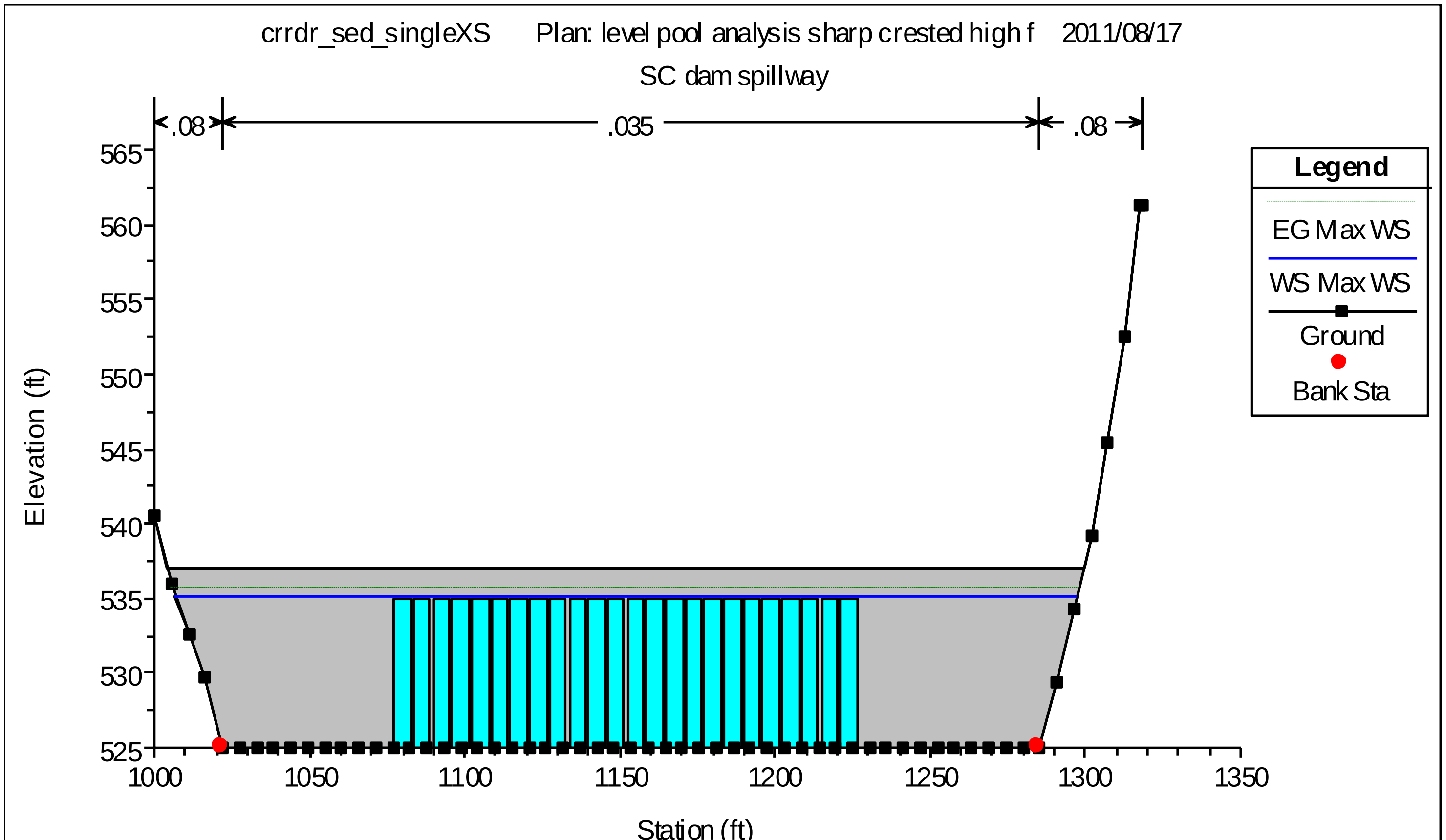
Hydrology: outlets and spillways

San Clemente dam discharge rating curve



Hydrology: outlets and spillways

- Dams, gates, and spillways – San Clemente Dam, California



Hydrology: outlets and spillways

- Spillways – Los Vaqueros Dam, California

Source: Contra Costa Water District

Hydrology: outlets and spillways

- Overtopping – Fujinuma Dam, Fukushima
- Slumped due to quake, then overtopped and scoured
- Same could happen for inadequate spillway

Source: Fukushima Prefecture

Hydrology: outlets and spillways

- Spillways – Hoover Dam, Nevada/Arizona
- Glen Canyon Dam (similar): near-failure from spillway cavitation, so vents installed

Source: Wikipedia

Hydrology: outlets and spillways

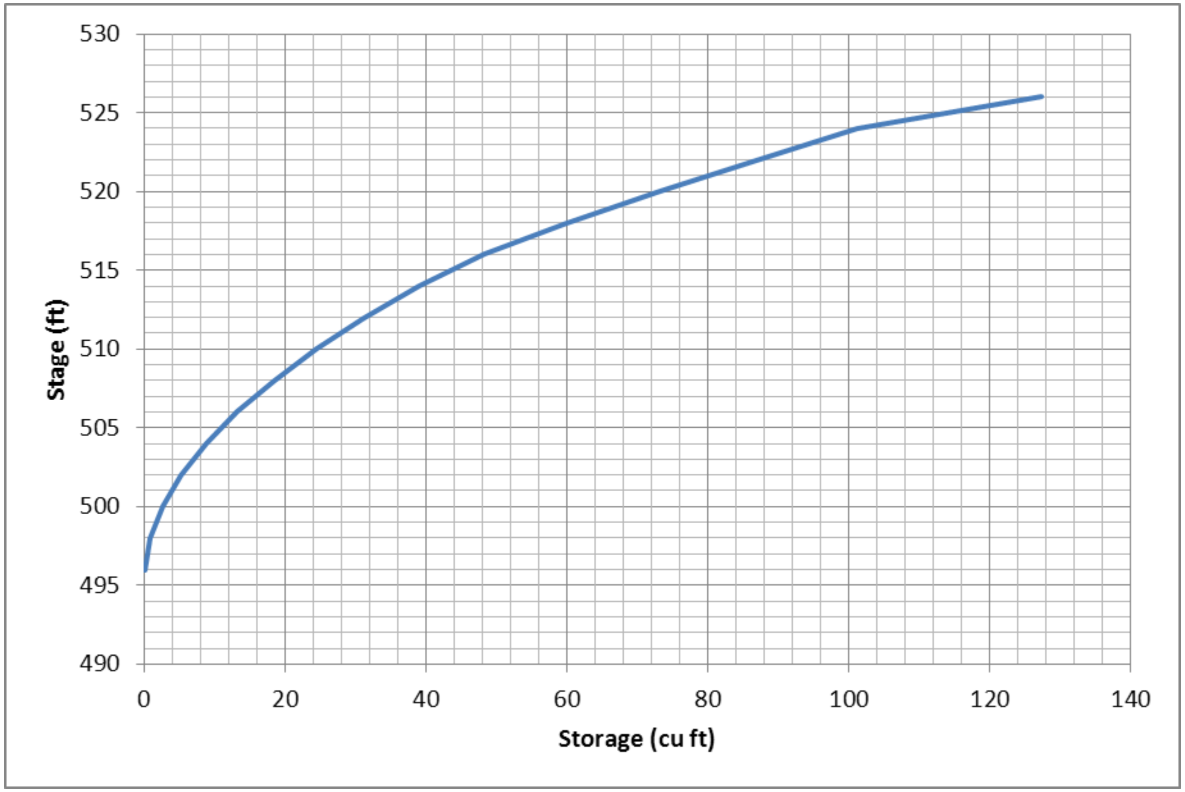
- Spillways – Kurobe Dam, Toyama

Source: Wikipedia

Hydrology: Stormwater Detention Basins

Source: USEPA

Hydrology: Stormwater Detention Basins



Stage – storage curve for San Clemente Reservoir in 2011

River Hydraulics

- Channel conveyance
- Structures
  - Weirs
  - Culverts
  - Bridges
  - Stormwater detention basins
- Flooding
- Scour
- Bank armor

River Hydraulics

- Channel conveyance – Tama River during low flow

Source: 東京都

River Hydraulics

- Channel conveyance – Tama River flood
- How high should we build the levees?
- How wide should we make the floodplain?

1974

2007

Source: MLIT

River Hydraulics

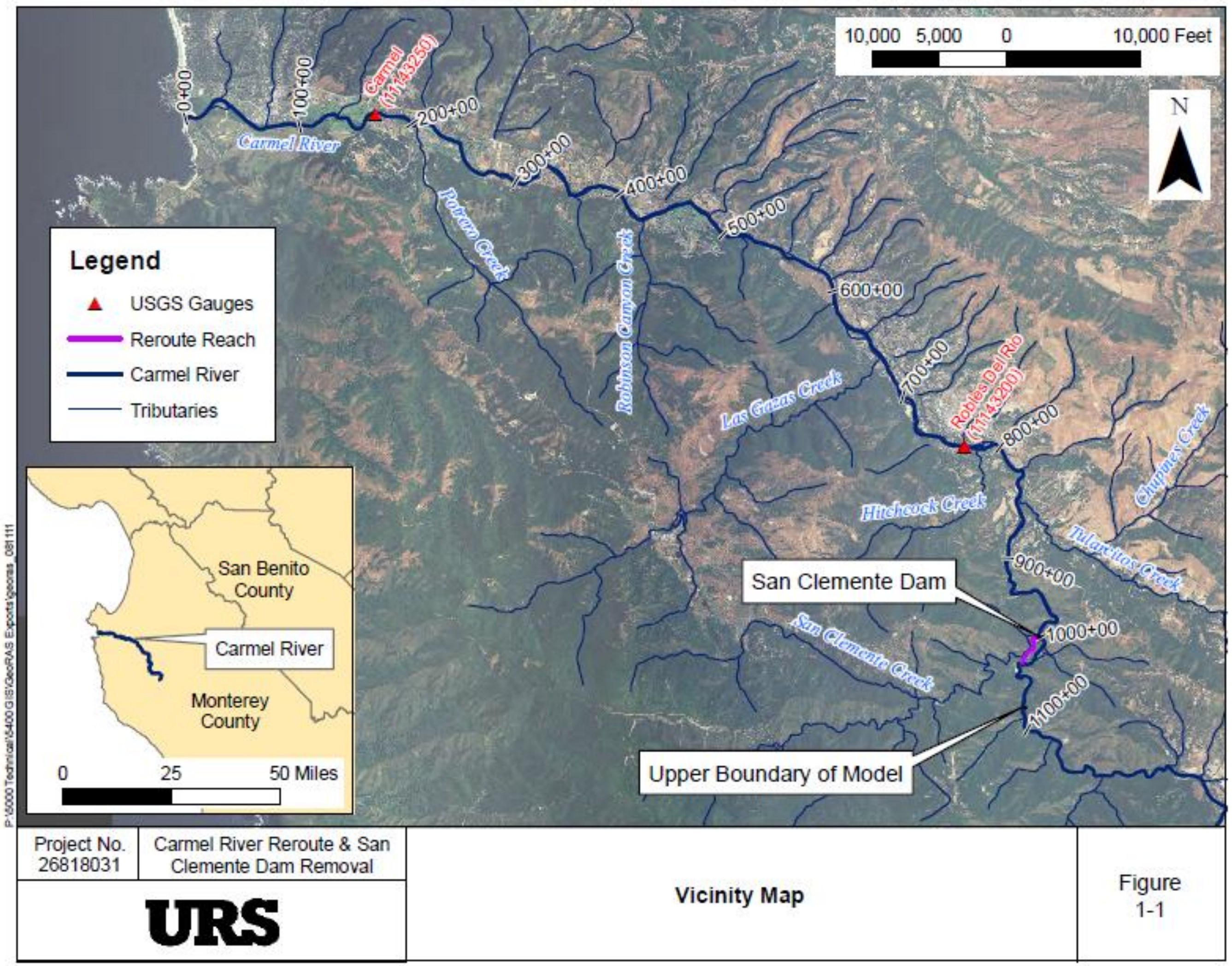
- Bridges – does the bridge have enough clearance not to be submerged in a flood? Or is it designed to be submerged?

2008 Cedar Rapids, Iowa

Source: The Boston Globe

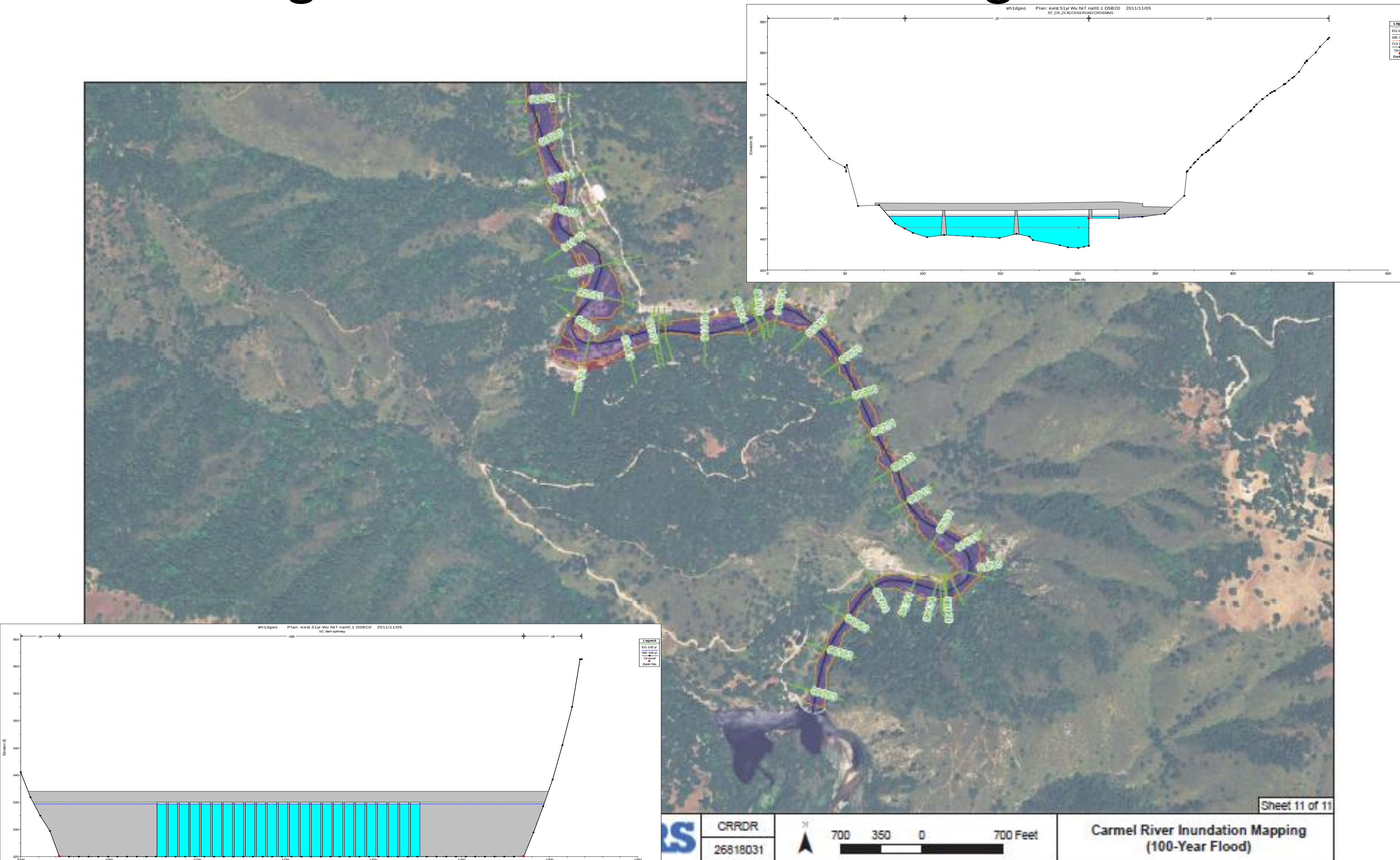
River Hydraulics

- Flooding – modeling a river with HEC-RAS



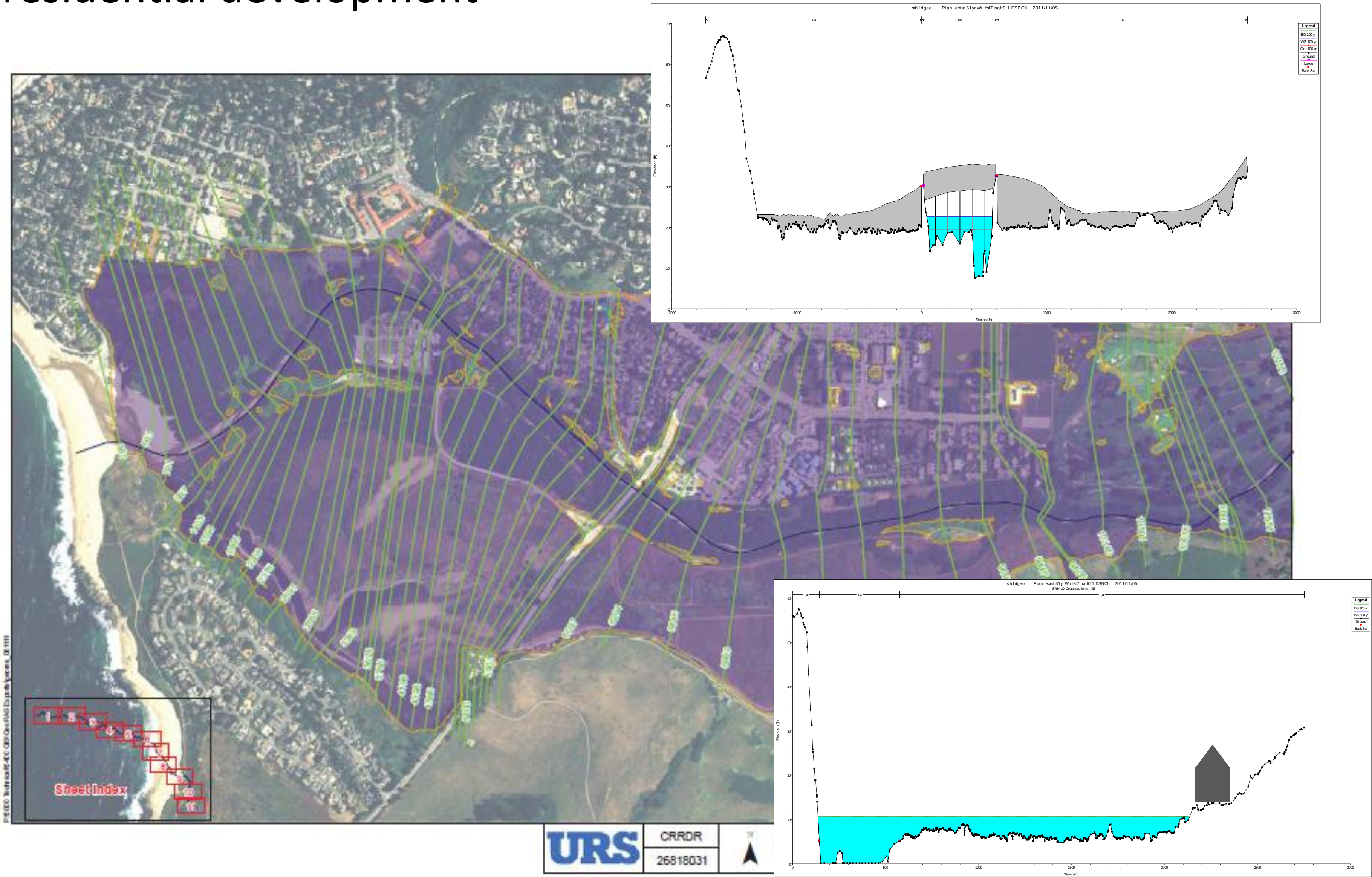
River Hydraulics

- Flooding – dam freeboard and bridge clearance



River Hydraulics

- Flooding – levee height, bridge clearance, floodplain width, residential development



River Hydraulics

- Bridges - scour

2007 神奈川県松田市酒匂川

Source: MLIT

River Hydraulics

- Bridges - scour

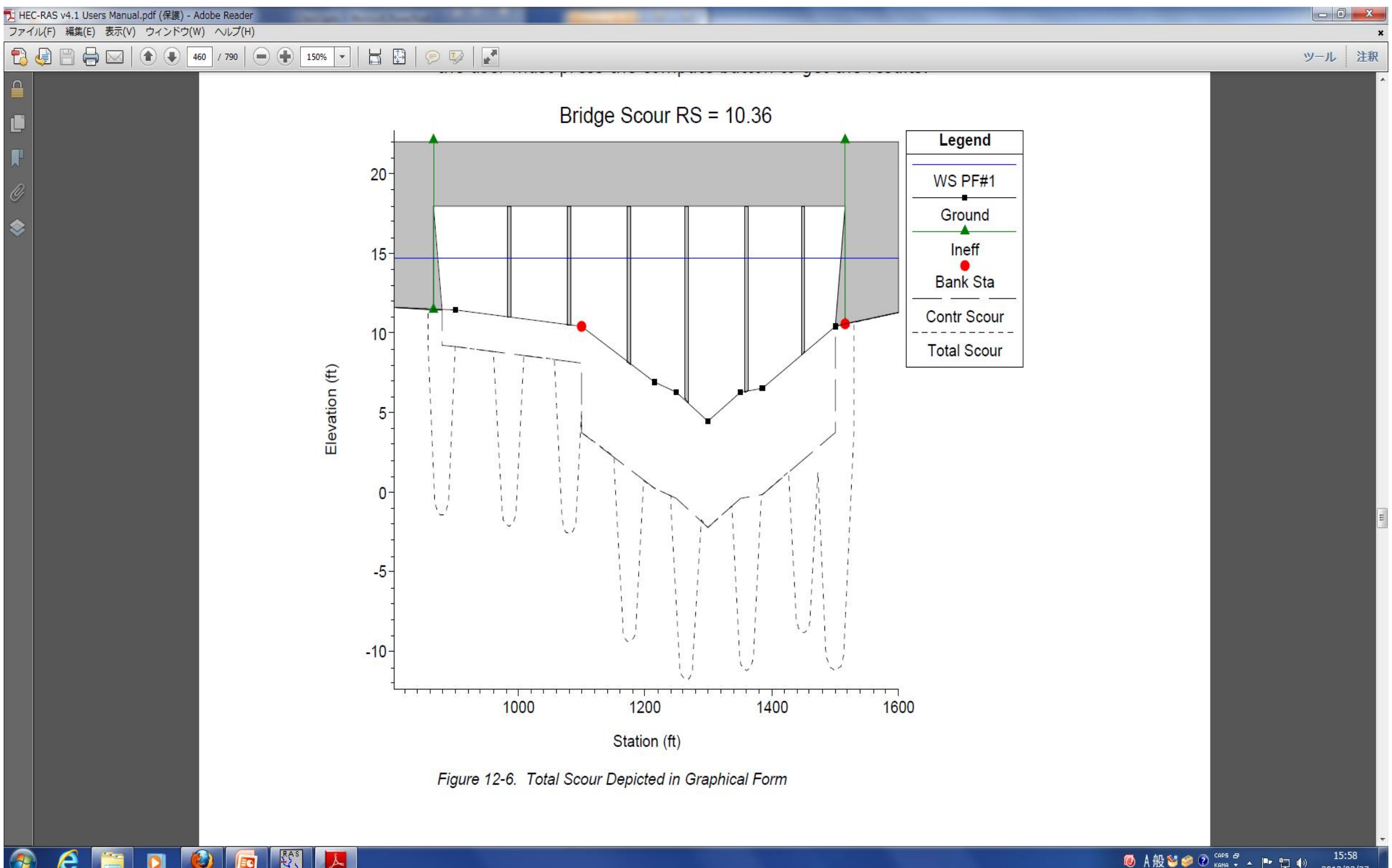


Figure 12-6. Total Scour Depicted in Graphical Form

Source: USACE HEC

River Hydraulics

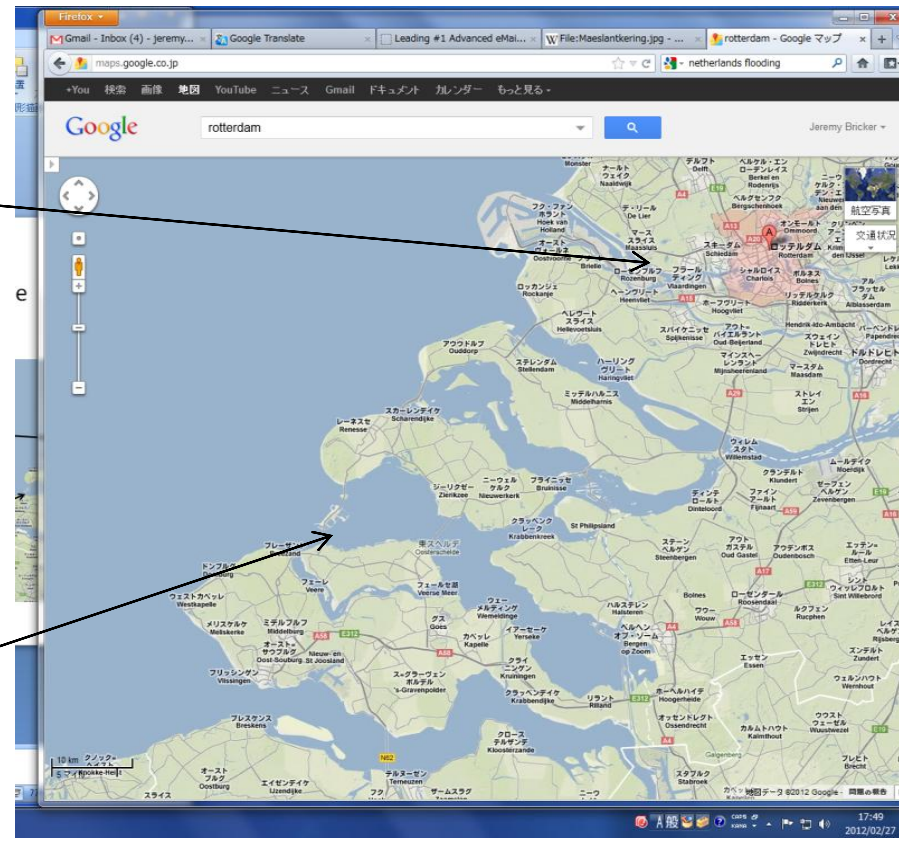
- Bank armor – riprap and gabions

Coastal Hydraulics

- Coastal disasters – models determine design water elevation for levees and gates
  - Storm surge
  - Tsunami
- Tidal in-stream power generation – models determine flow speeds and potential for power

Coastal Hydraulics

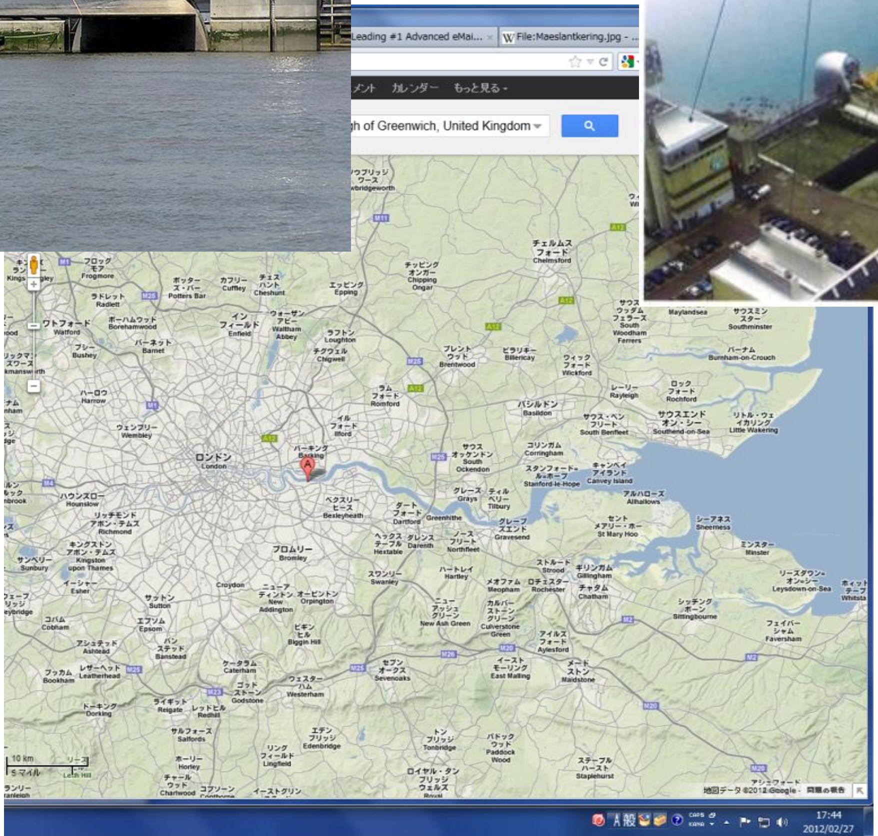
- Storm surge barrier – Rotterdam, the Netherlands

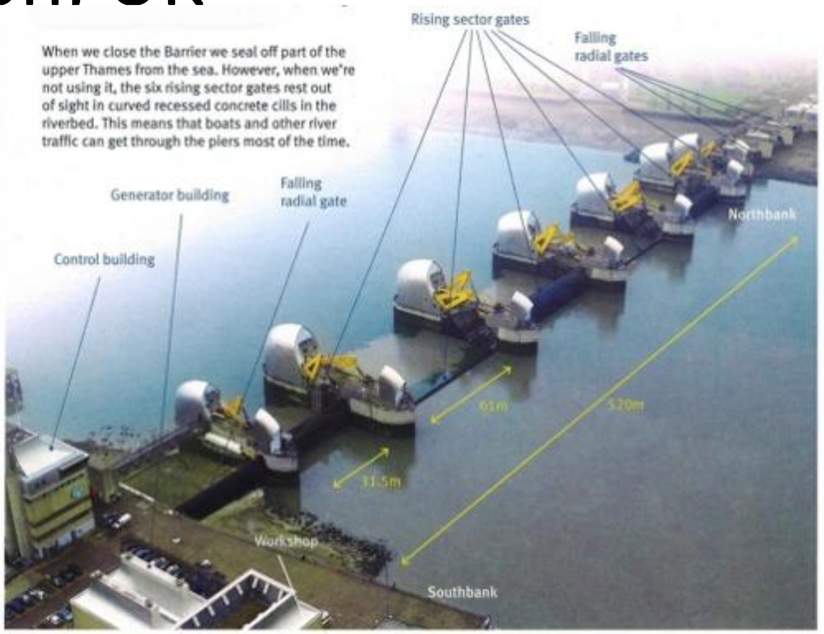


Source: Wikipedia

Coastal Hydraulics

- Storm surge barrier – London. UK

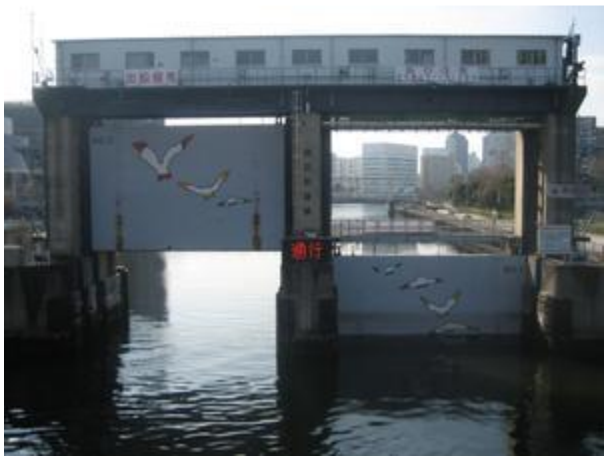


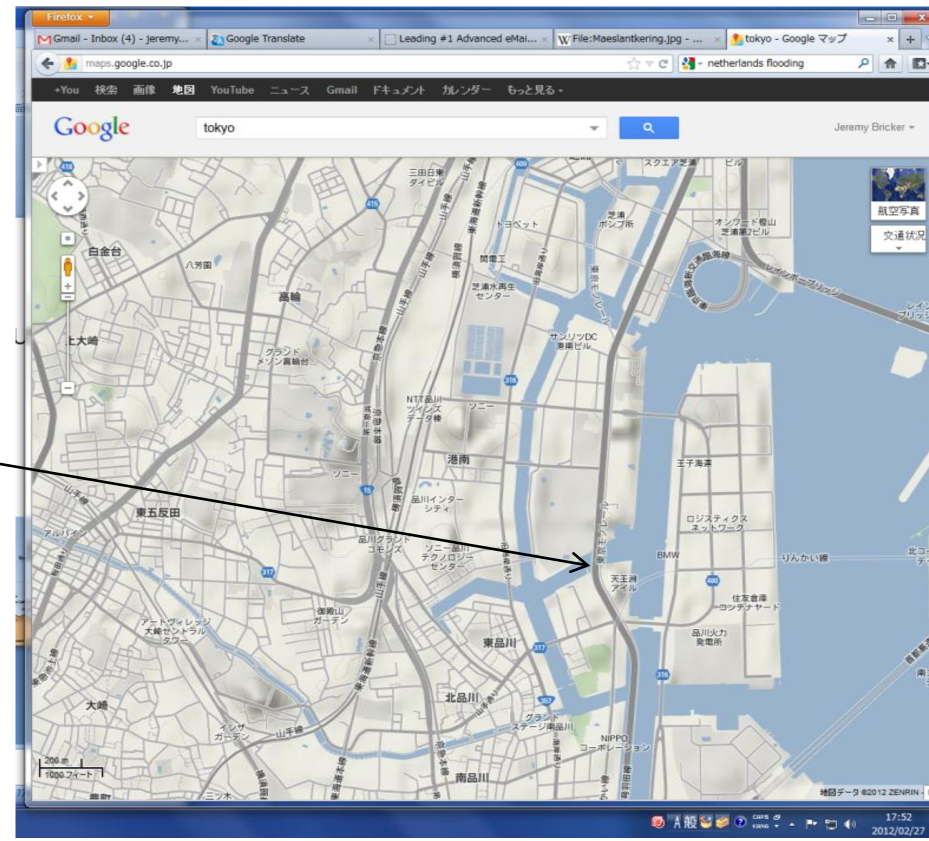


Source: Wikipedia

Coastal Hydraulics

- Storm surge barrier – Tennozu Isle Gate

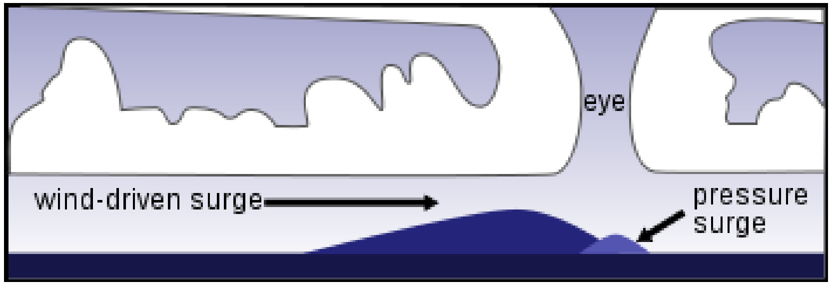


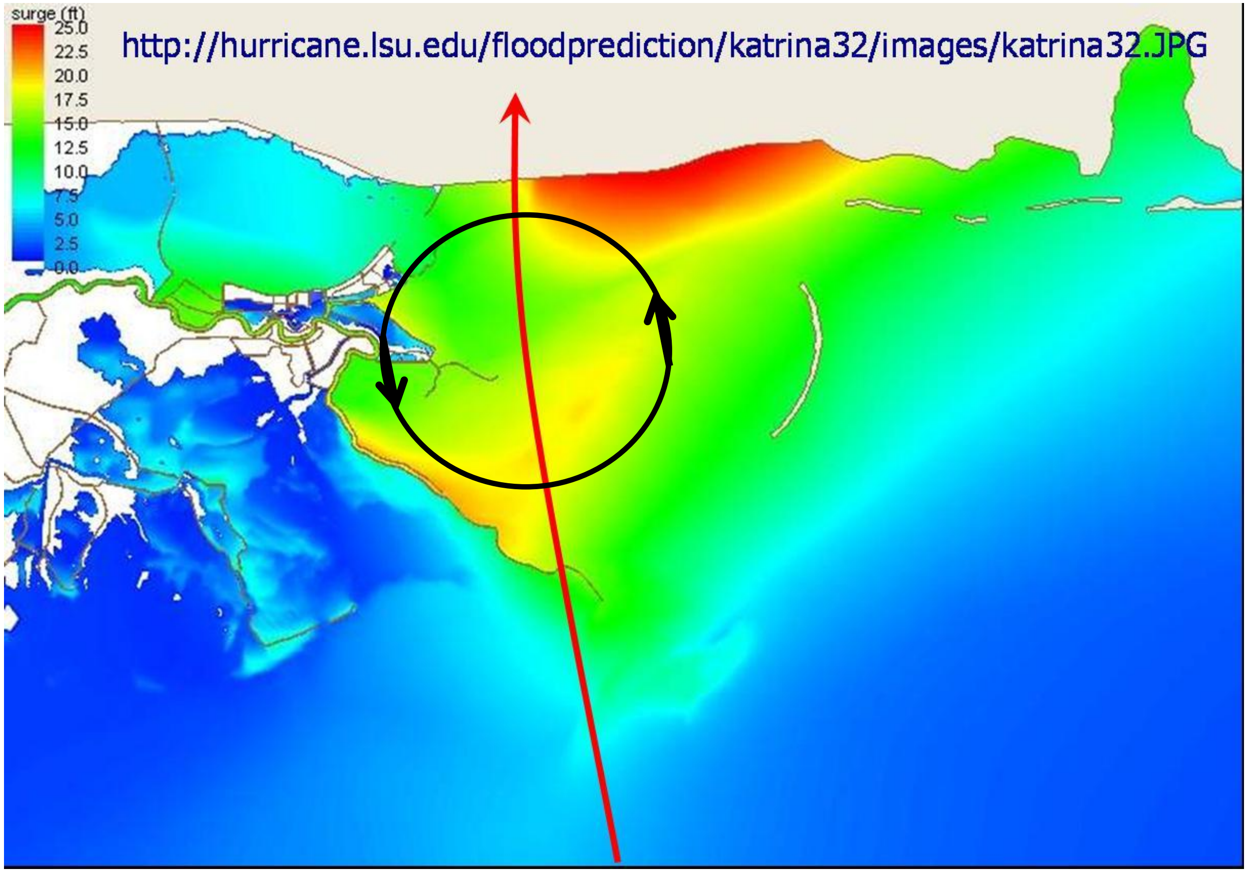


http://peepooblue.cocolog-nifty.com/blog/2010/02/post-ad2f.html

Coastal Hydrodynamics

- Storm surge





Coastal Hydraulics

- Storm surge barriers – New Orleans, USA

1 GATES AT OUTFALL CANALS
Temporary steel gates were built at the entrance to the three outfall canals that drain into Lake Pontchartrain, two of which were breached in Hurricane Katrina. Pumps push rainwater around the gates, which prevent surge from going into the city. The gates will be replaced with more robust permanent structures in 2014.

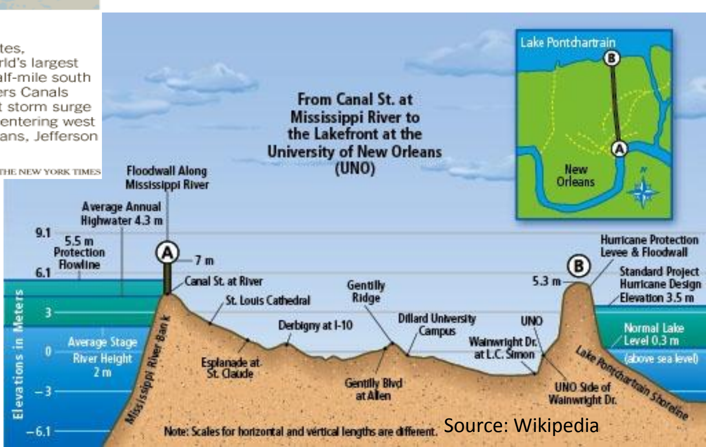
2 SEABROOK FLOODGATE COMPLEX
The complex is part of a larger system of levees, breakwaters and floodwalls to prevent storm surge from entering the Industrial Canal, a large shipping canal near the eastern side of the city that connects Lake Pontchartrain to the Mississippi River. It is intended to work in tandem with the Lake Borgne surge barrier.

3 LAKE BORGNE SURGE BARRIER
An enormous, 1.8-mile floodwall has been built to prevent storm surges from Lake Borgne and the Gulf of Mexico from being funneled into the city. It is designed to protect some of the most vulnerable areas, like New Orleans East, St. Bernard Parish and the Lower Ninth Ward, which were devastated during Hurricane Katrina.

4 WEST CLOSURE COMPLEX
A $1 billion system of floodgates, floodwalls, levees and the world's largest pump station will be built a half-mile south of where the Harvey and Algiers Canals meet. The system will prevent storm surge from the Gulf of Mexico from entering west bank communities in the Orleans, Jefferson and Plaquemines Parishes.

Source: Army Corps of Engineers

HAEYOUN PARK AND JOE BURGESS/THE NEW YORK TIMES



Source: Wikipedia

Coastal Hydraulics – Hurricane Katrina levee overtopping

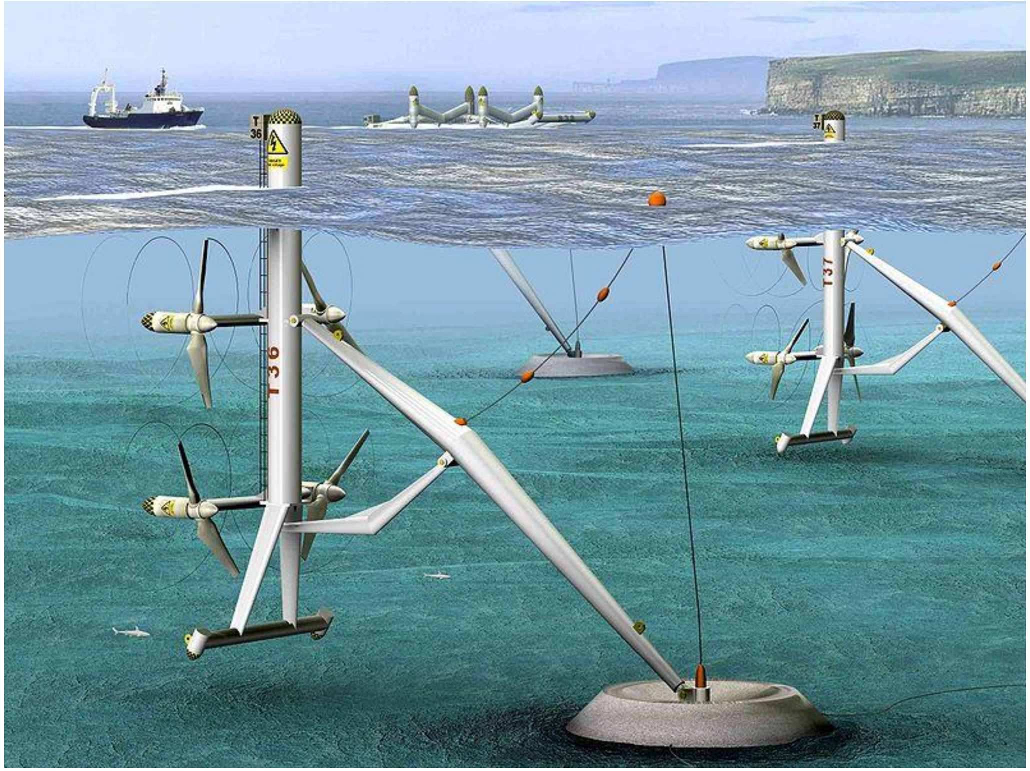
Coastal Hydraulics

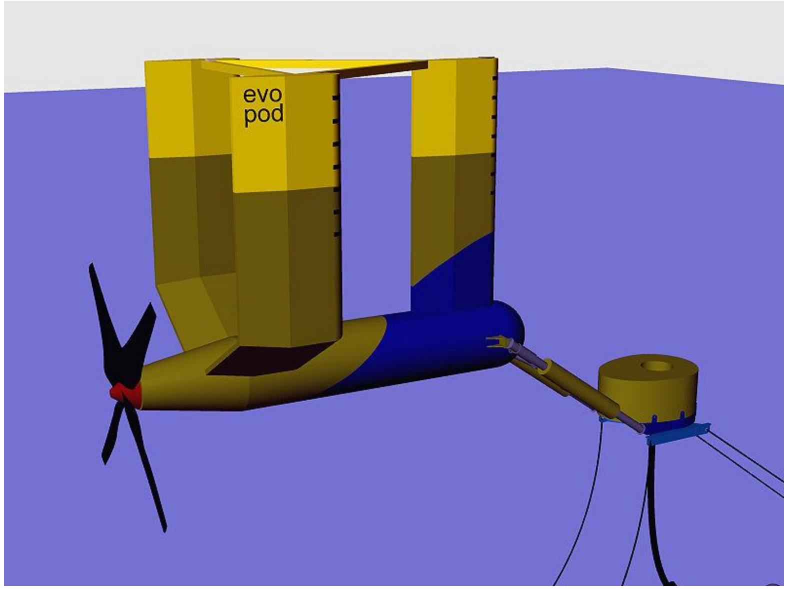
- Tidal in-stream power generation

Source: Wikipedia

Coastal Hydraulics

- Tidal in-stream power generation





Source: Wikipedia

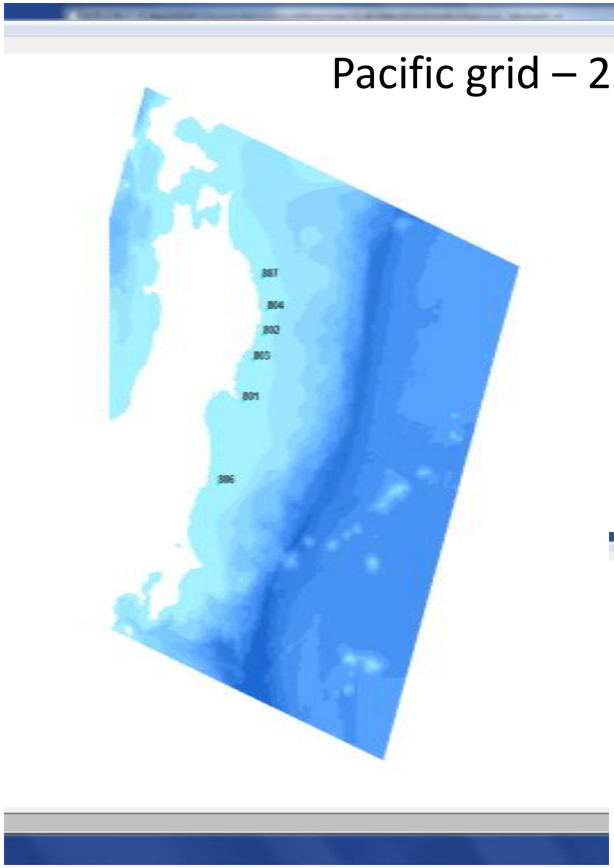
Coastal Hydraulics

- How do we design how high to make storm surge barriers?
- How do we decide where to place tidal power generators?
- Need to calculate storm water levels and tidal current speeds.
- Use a 2-D shallow water equation model.

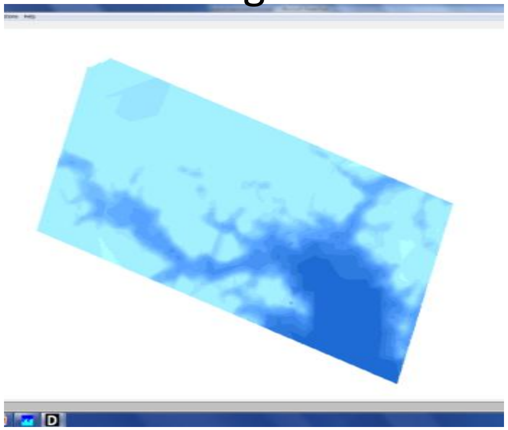
Coastal Hydraulics

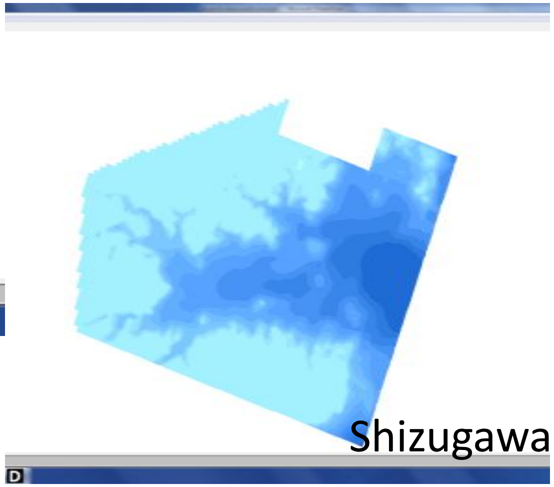
- Modeling tusnami with DELFT

Pacific grid – 2 km



Utatsu grid – 20 m



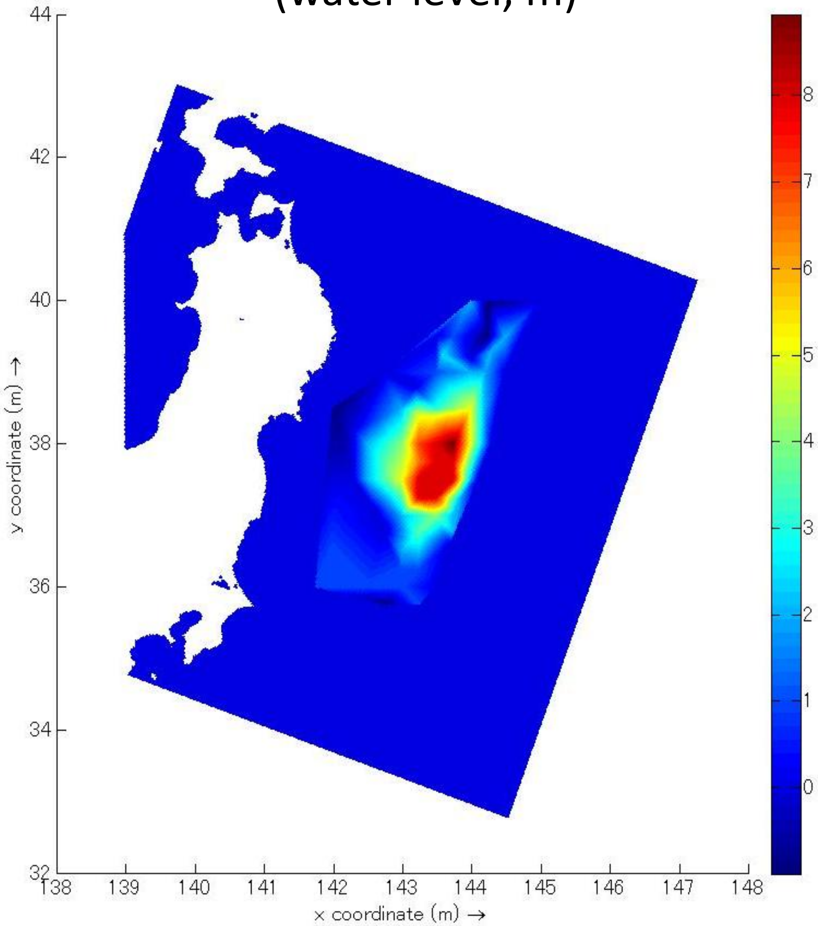


Shizugawa Bay grid – 200 m

Coastal Hydraulics

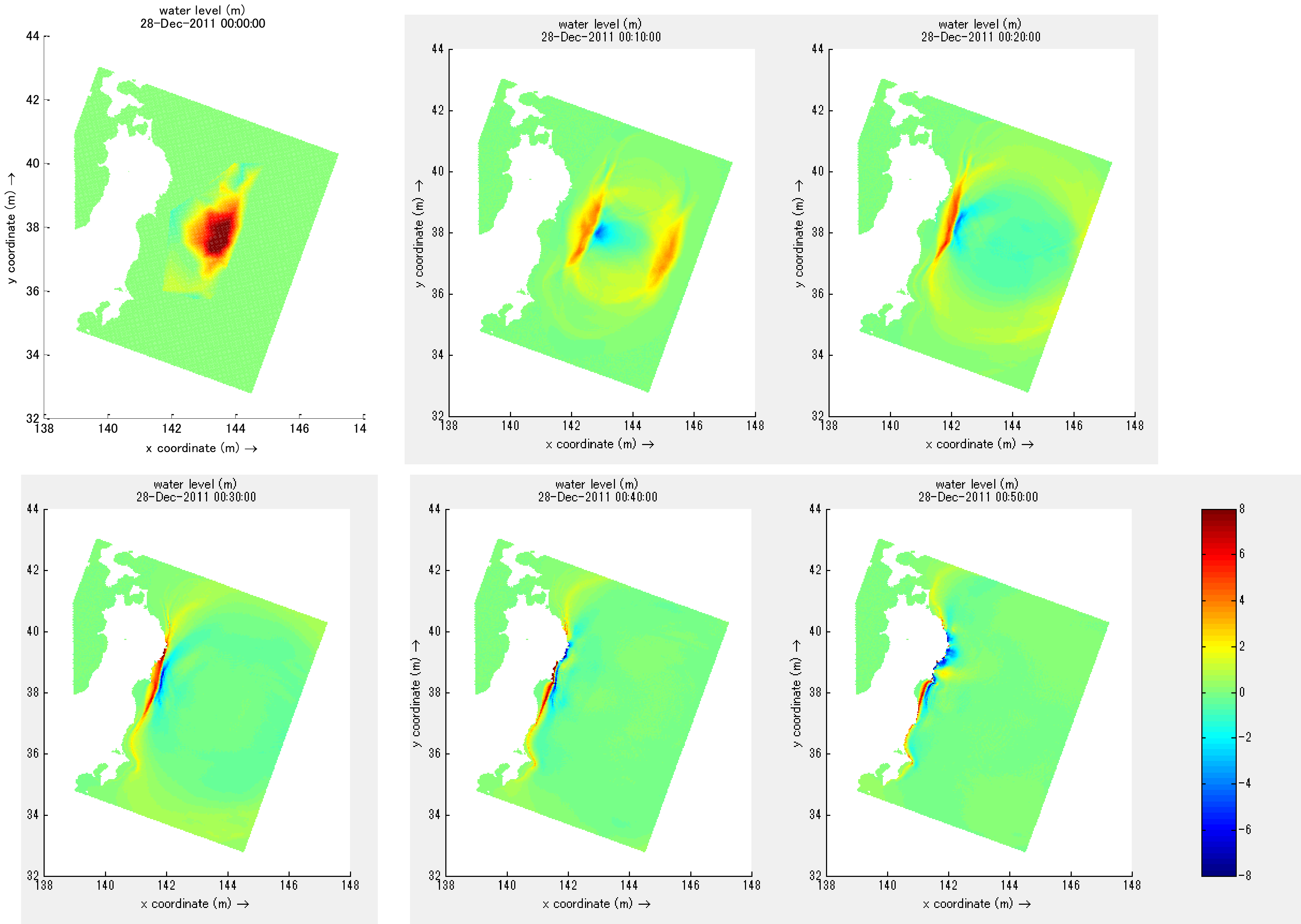
- Tsunami

(water level, m)

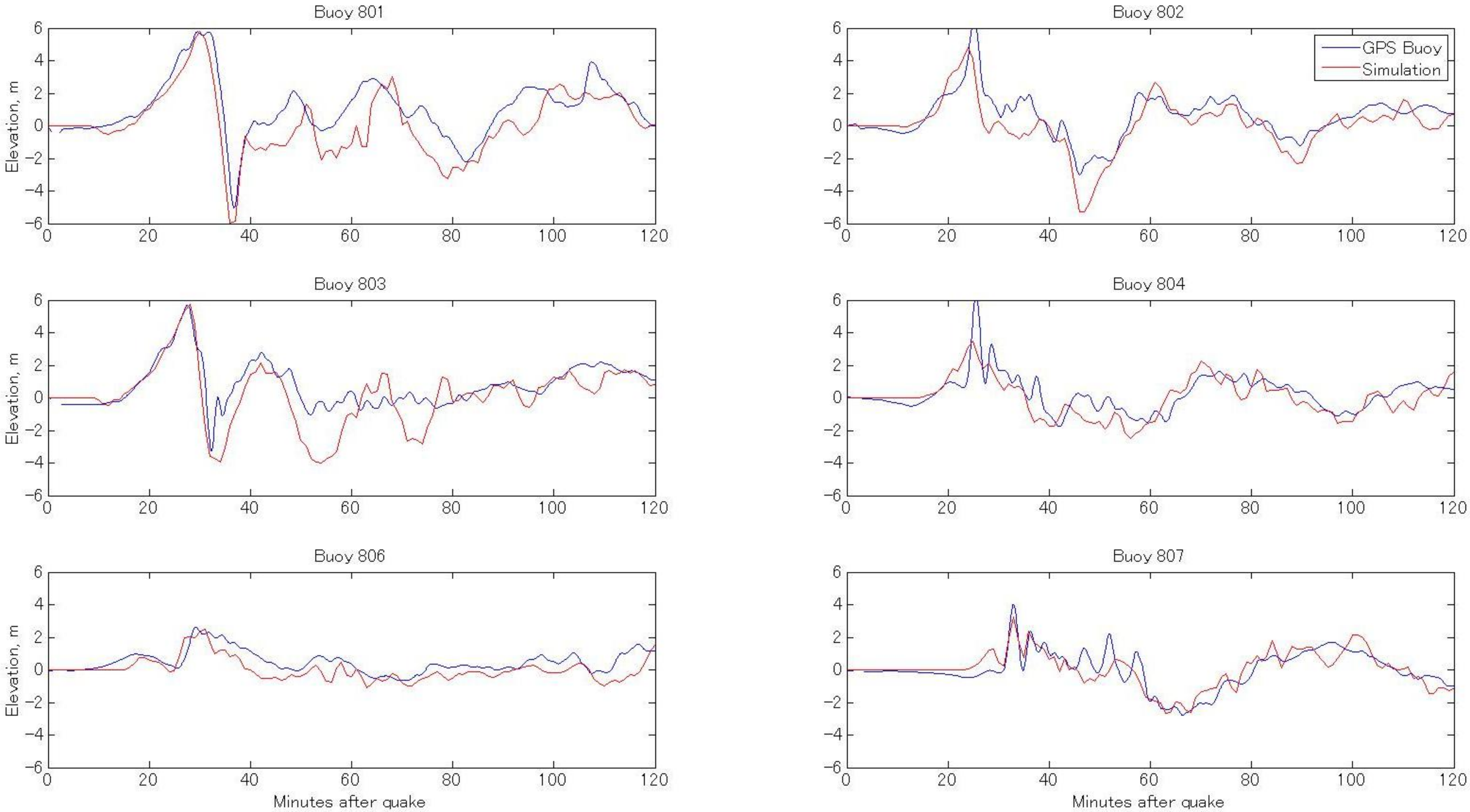


Saito et al (GRL, 2011)
Takahashi et al (PARI, 2011)

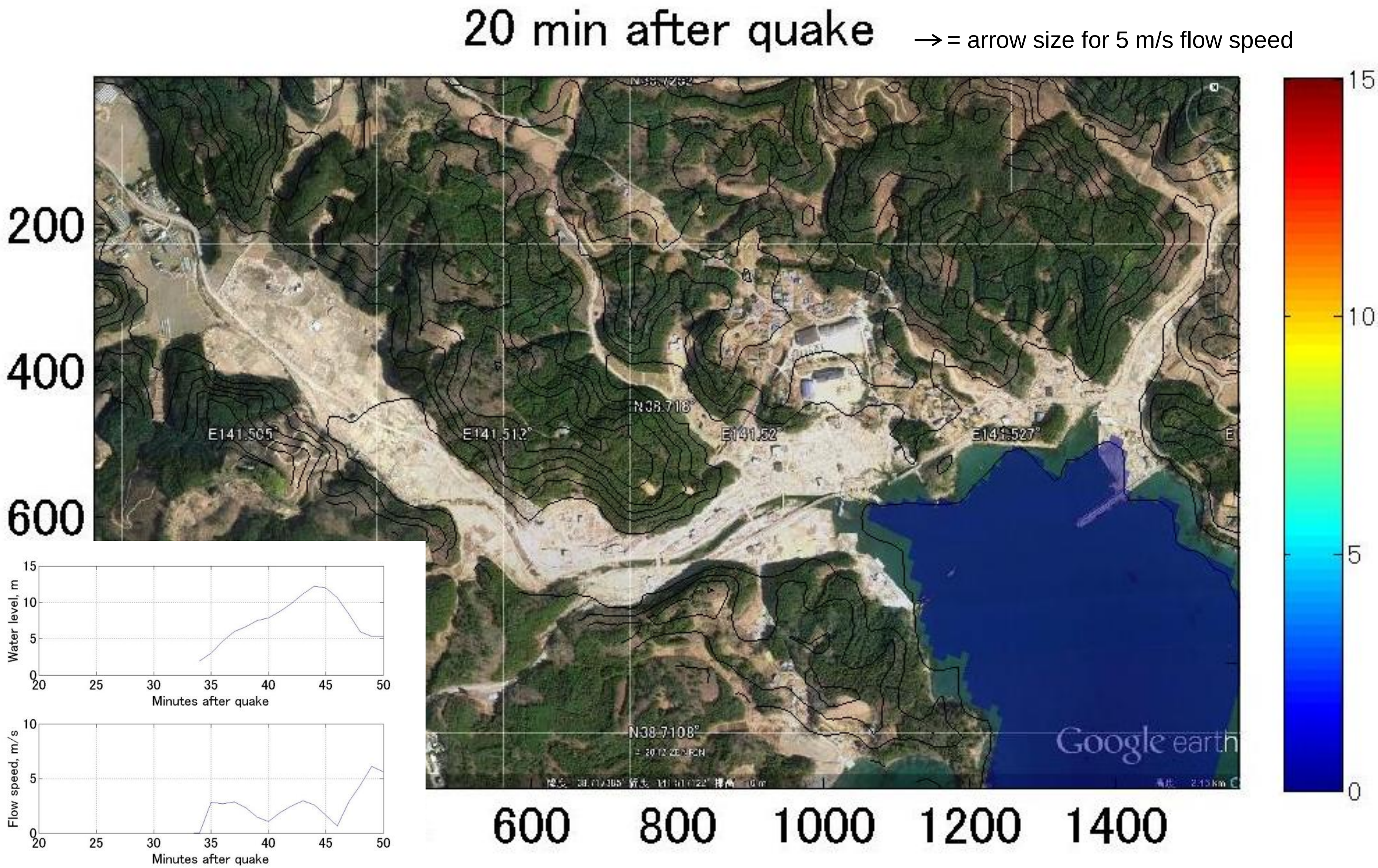
Coastal Hydraulics – Tsunami model



Tsunami behavior – model validation



Tsunami behavior – Utatsu



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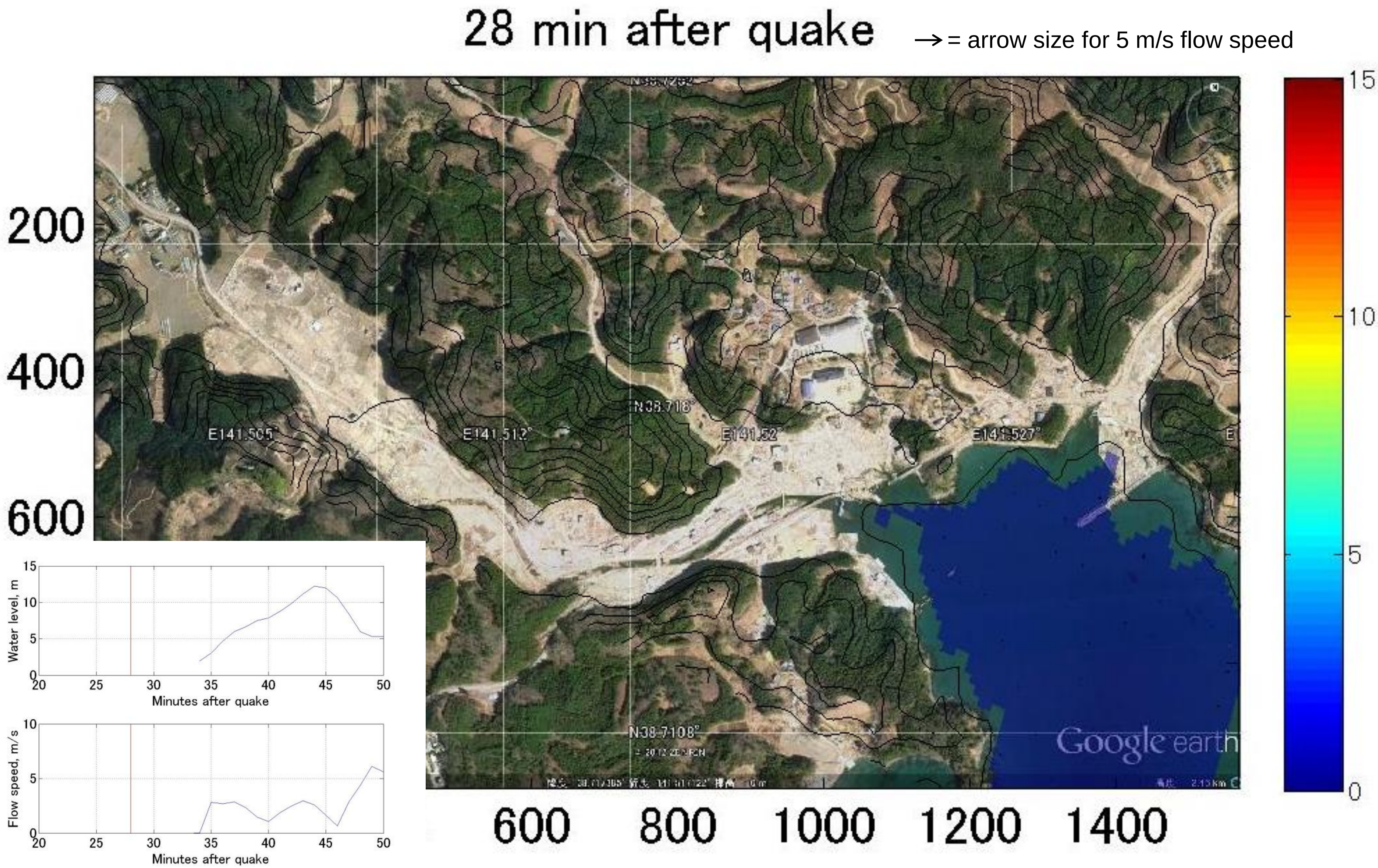

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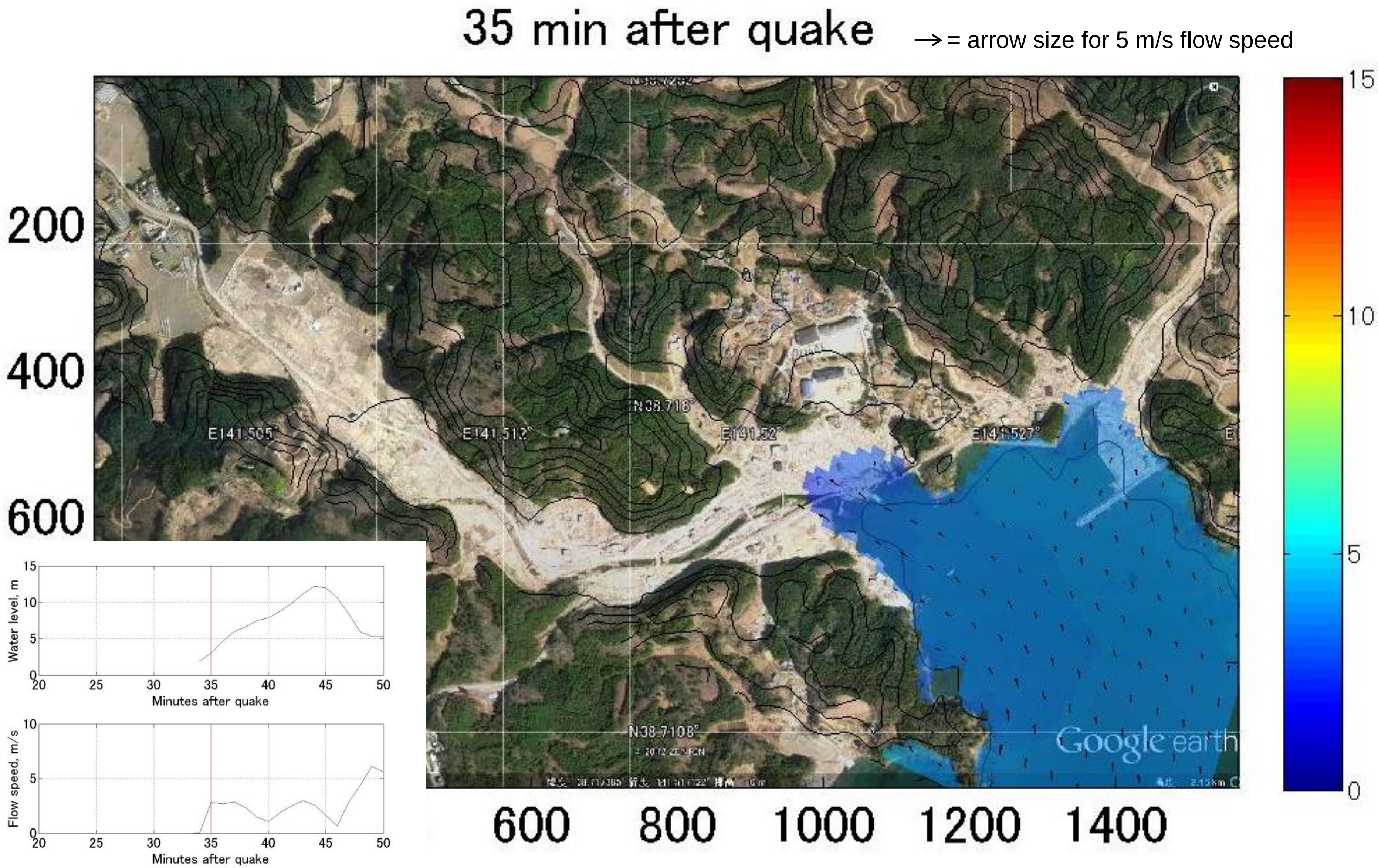

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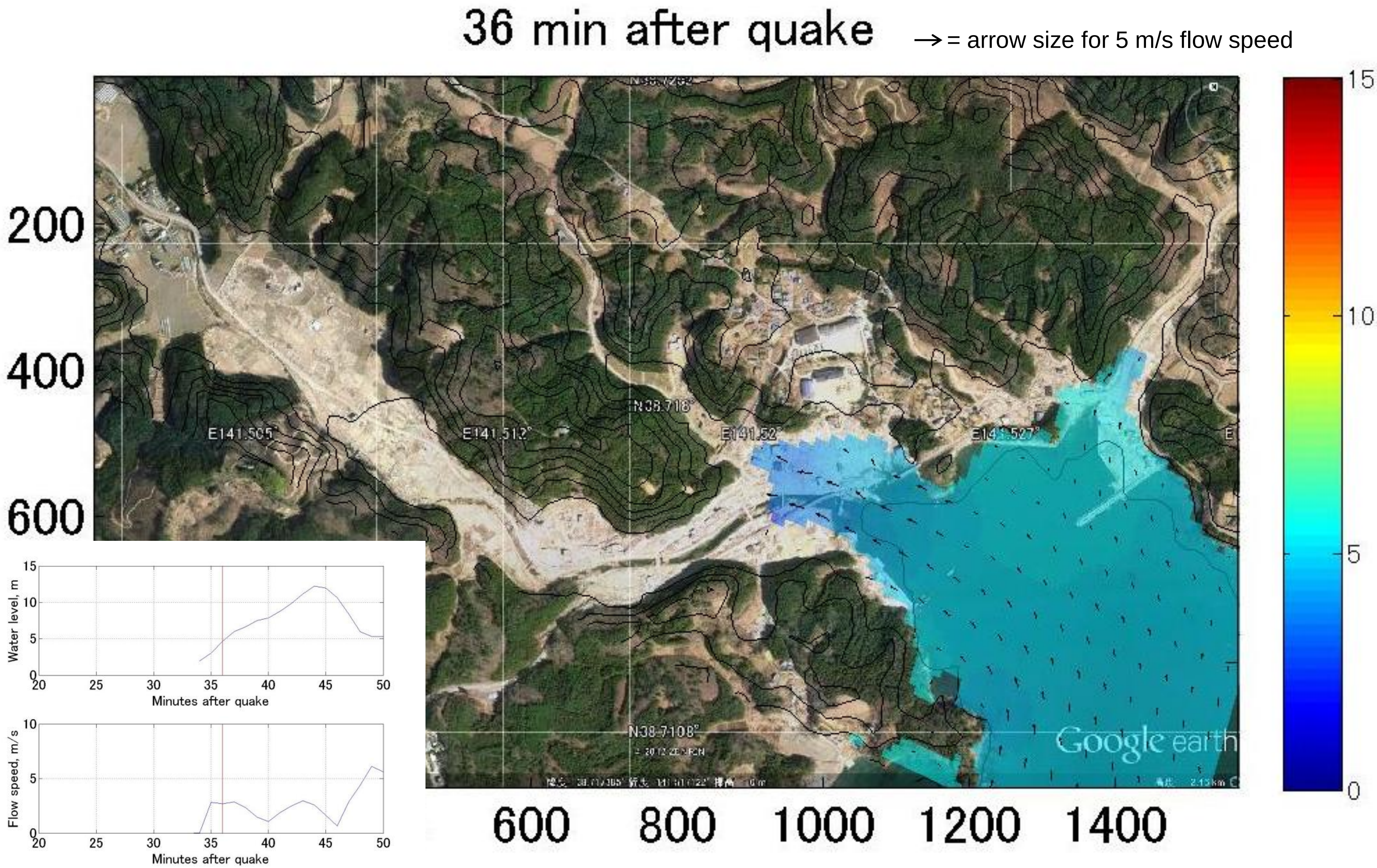

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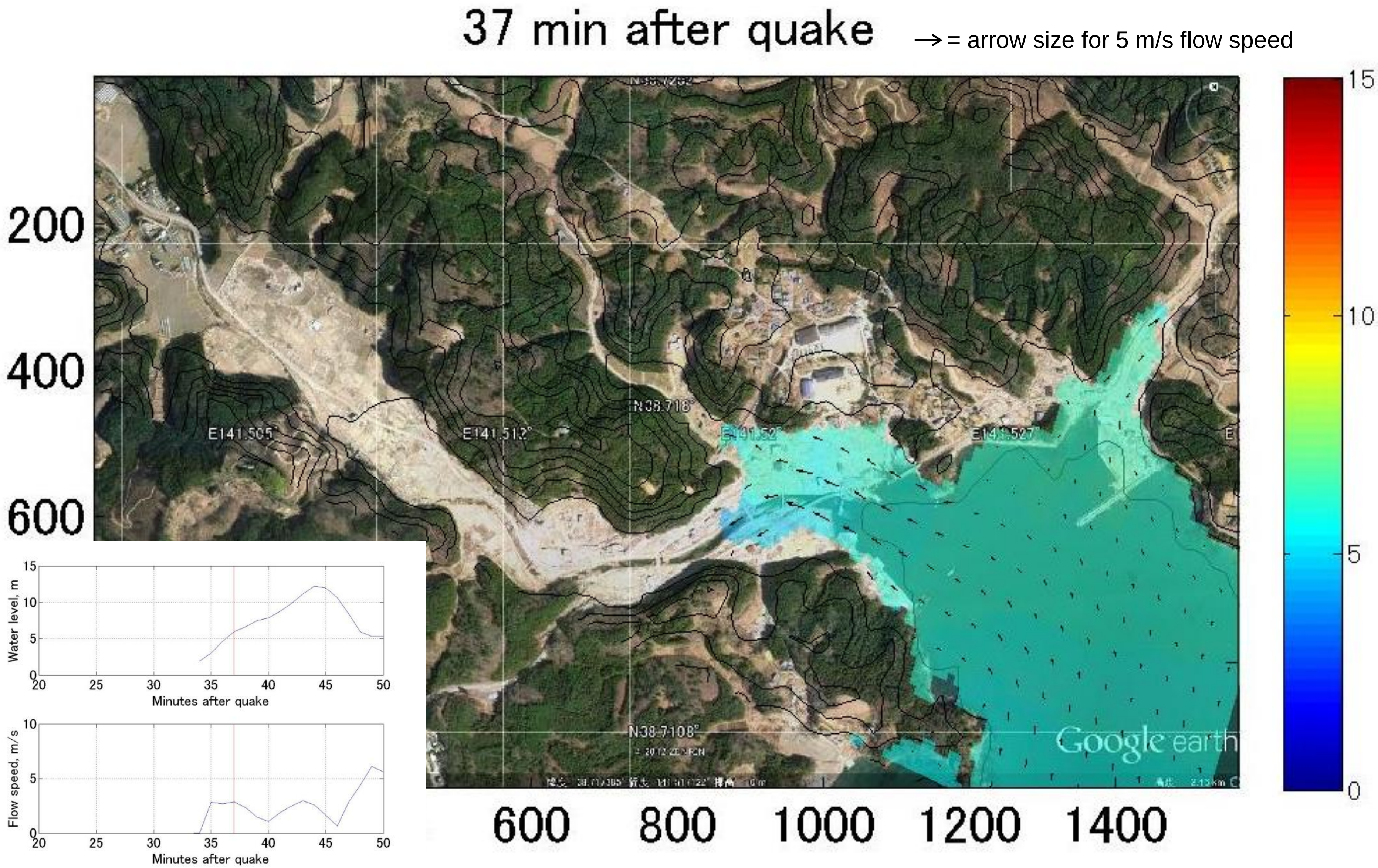

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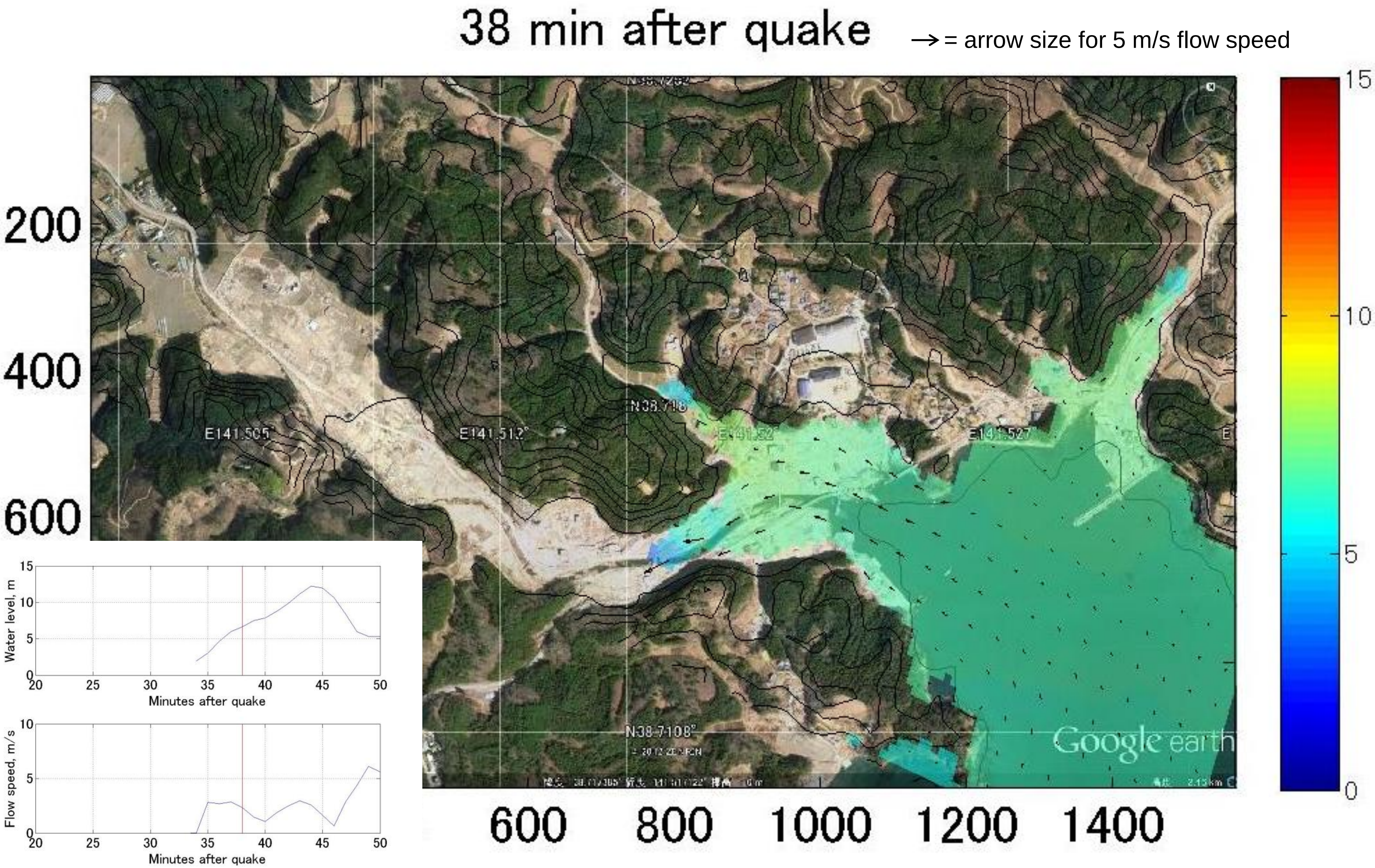
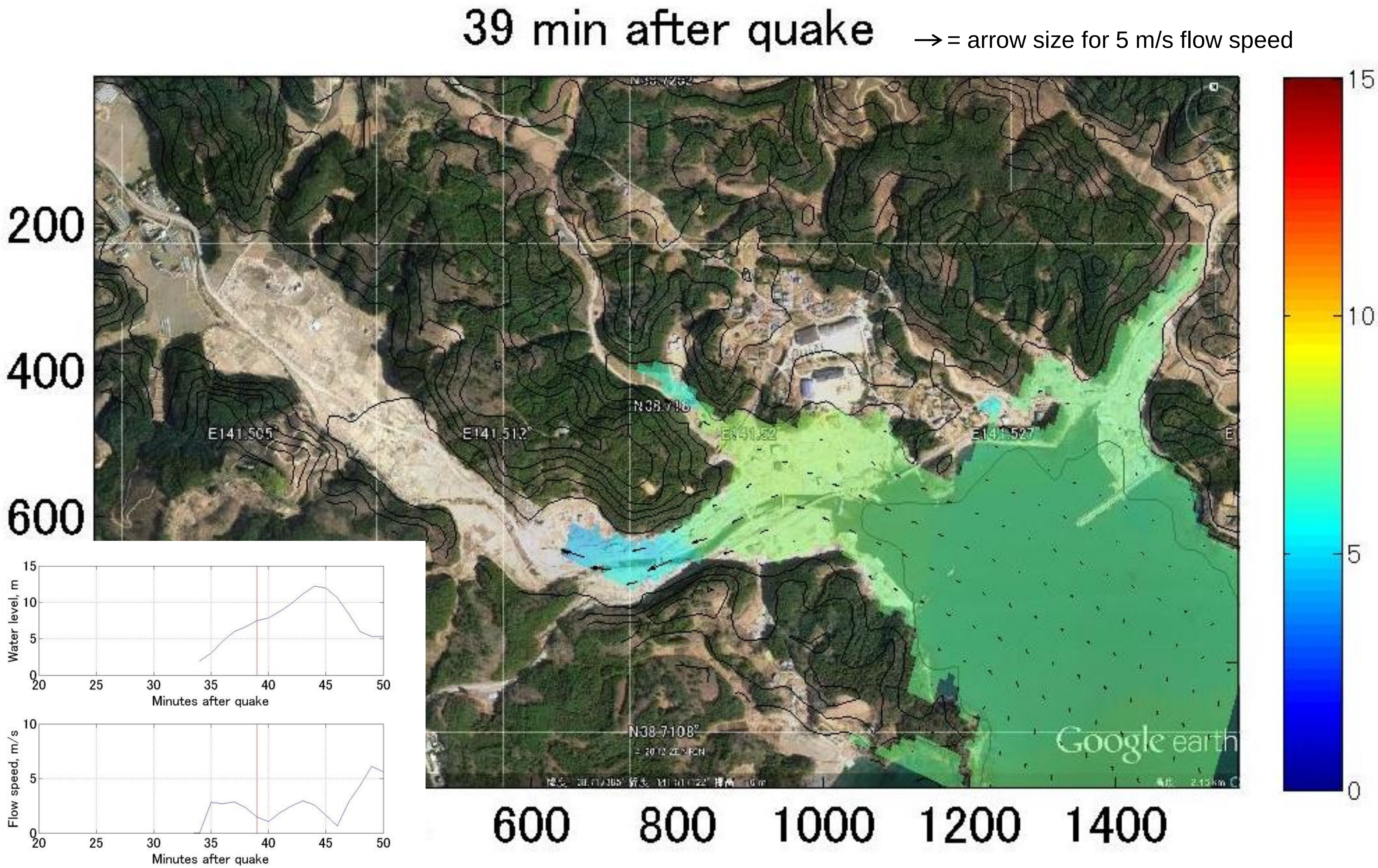
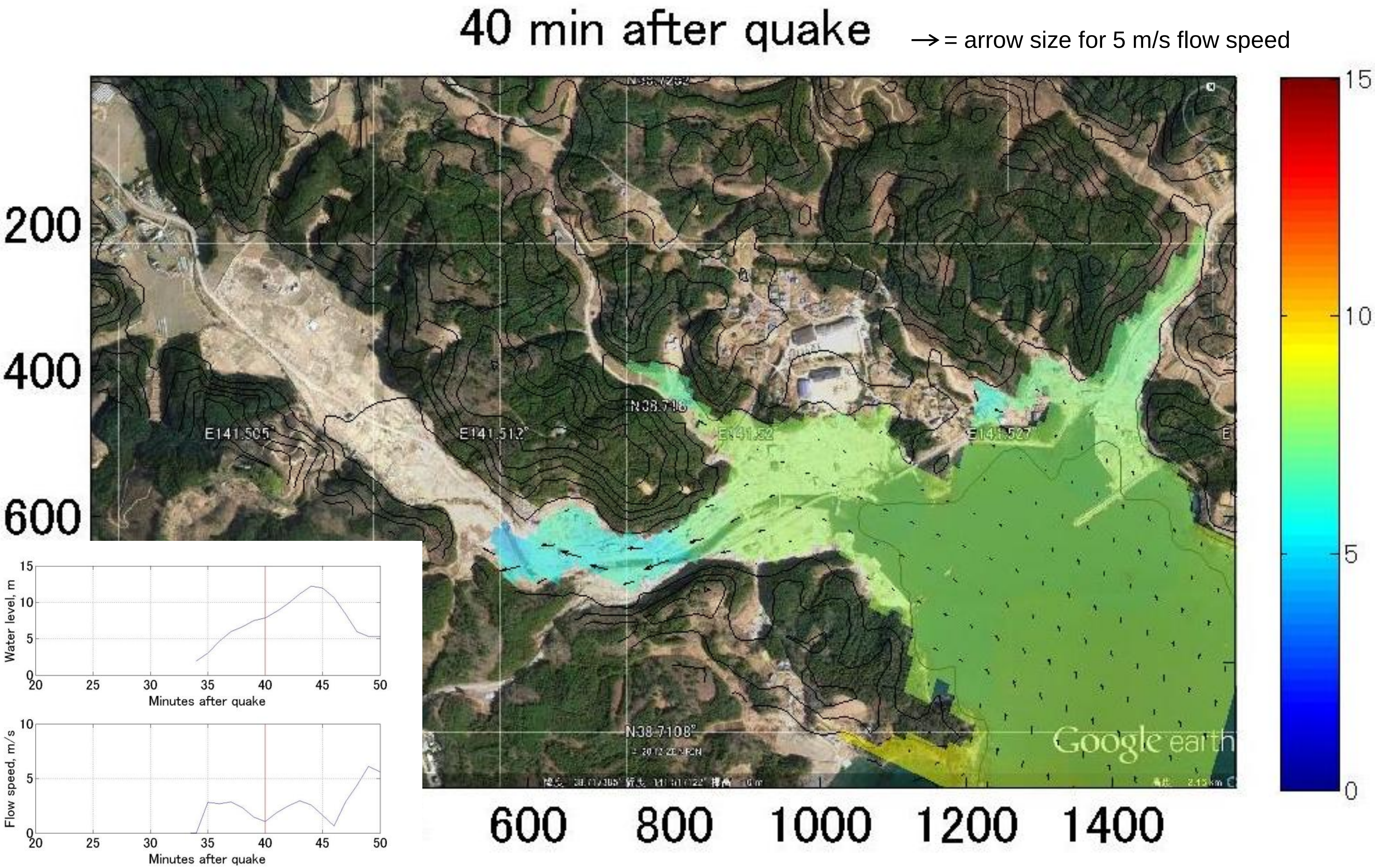


Tsunami behavior – Utatsu



Tsunami behavior – Utatsu



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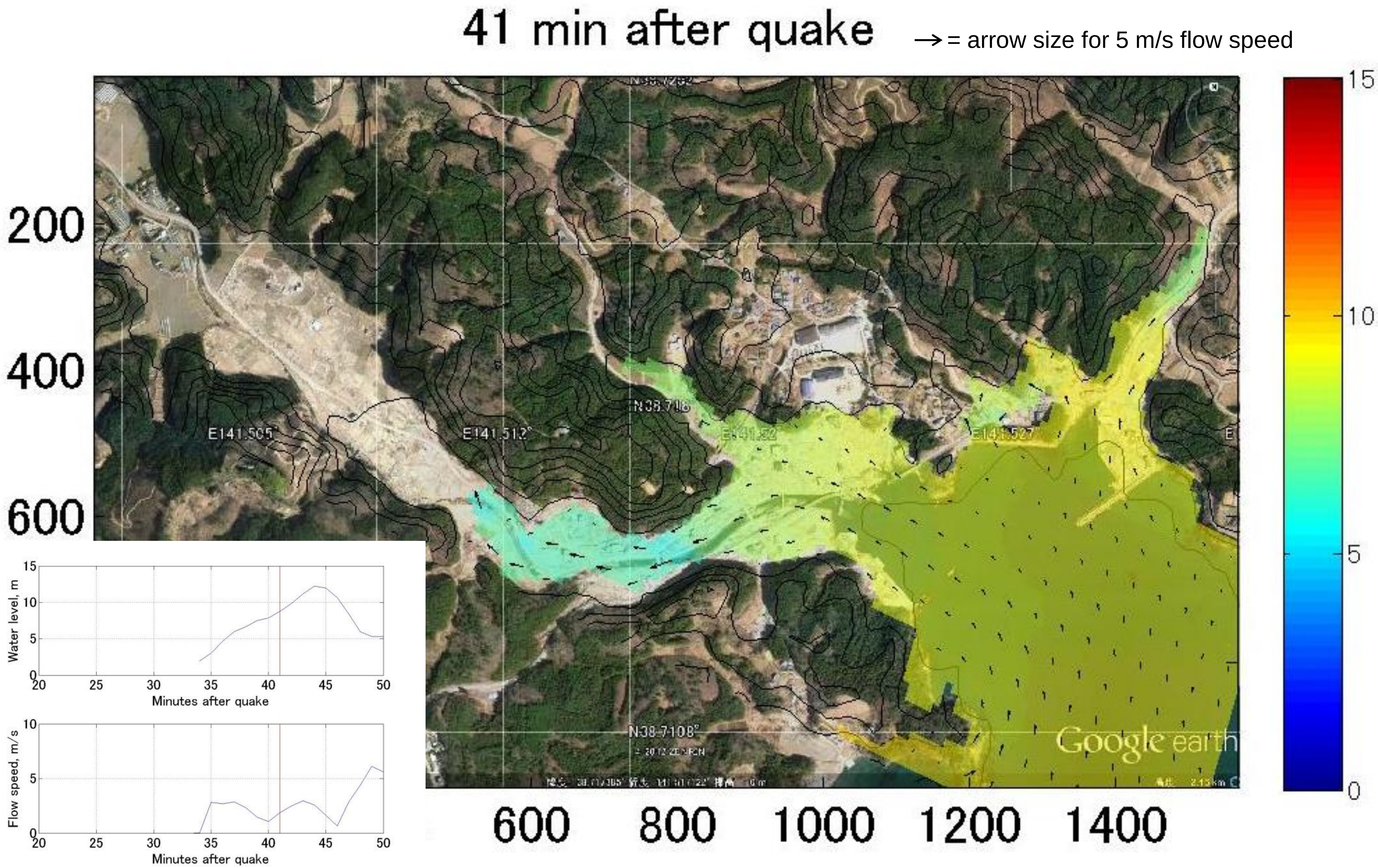

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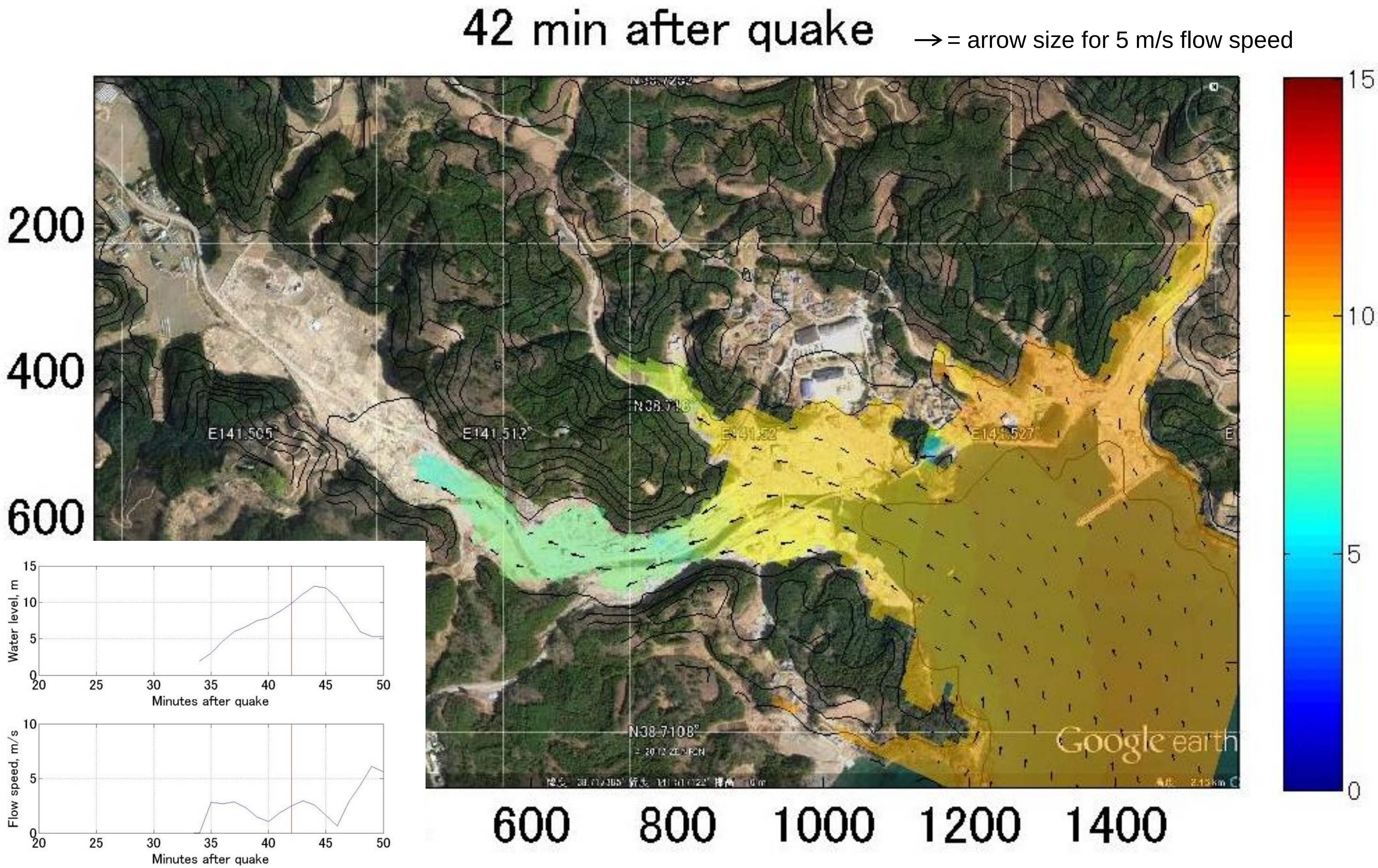

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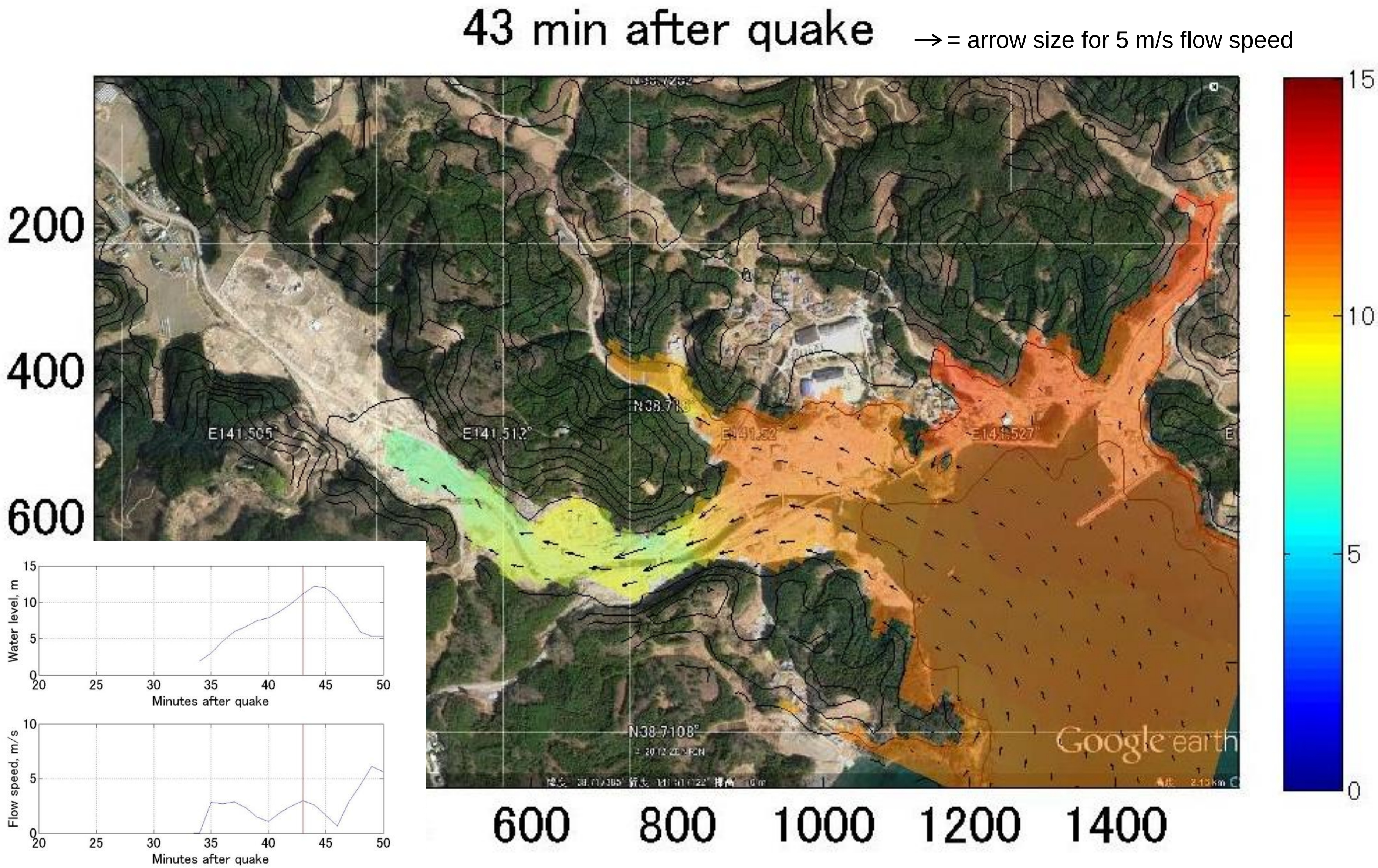

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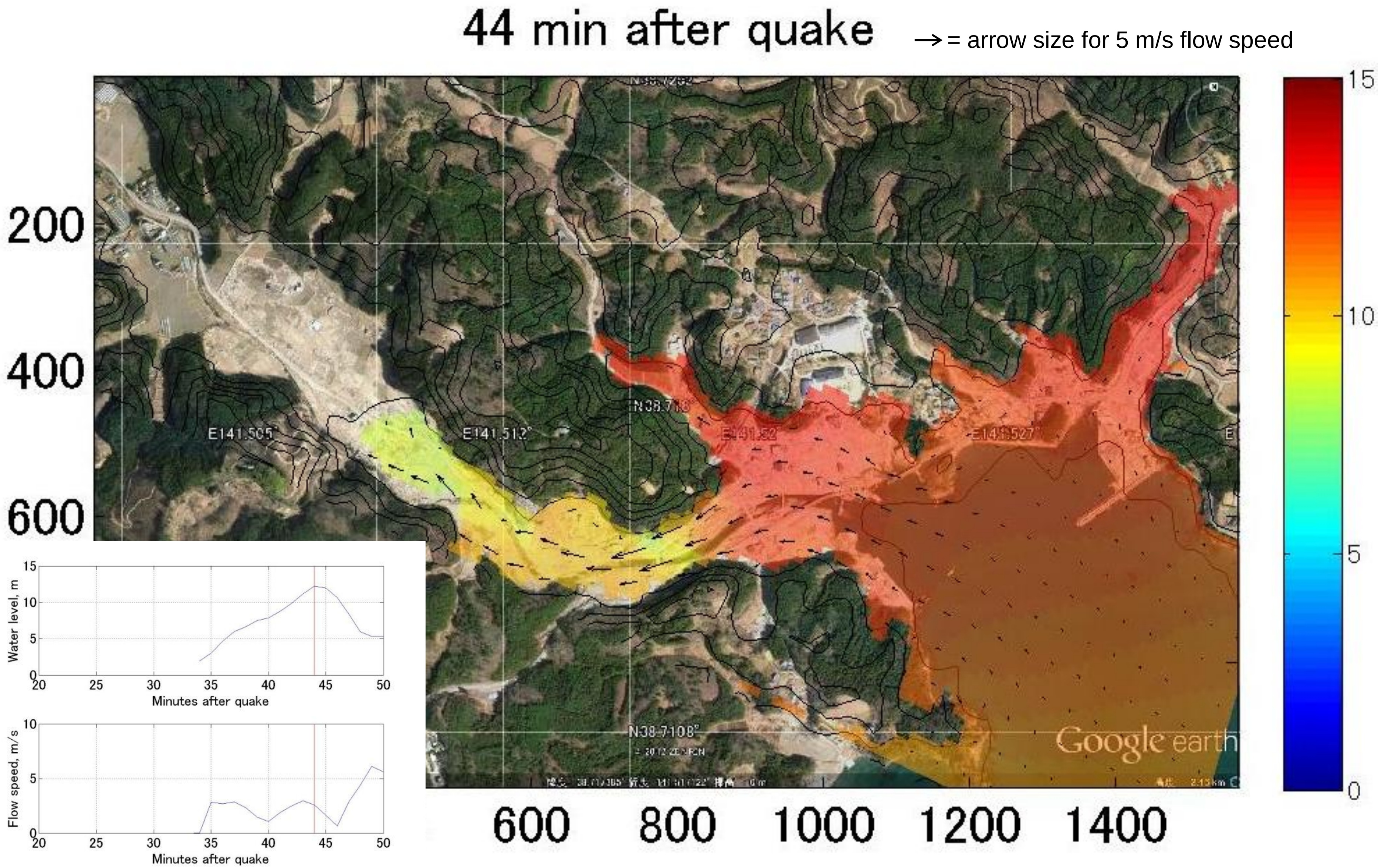

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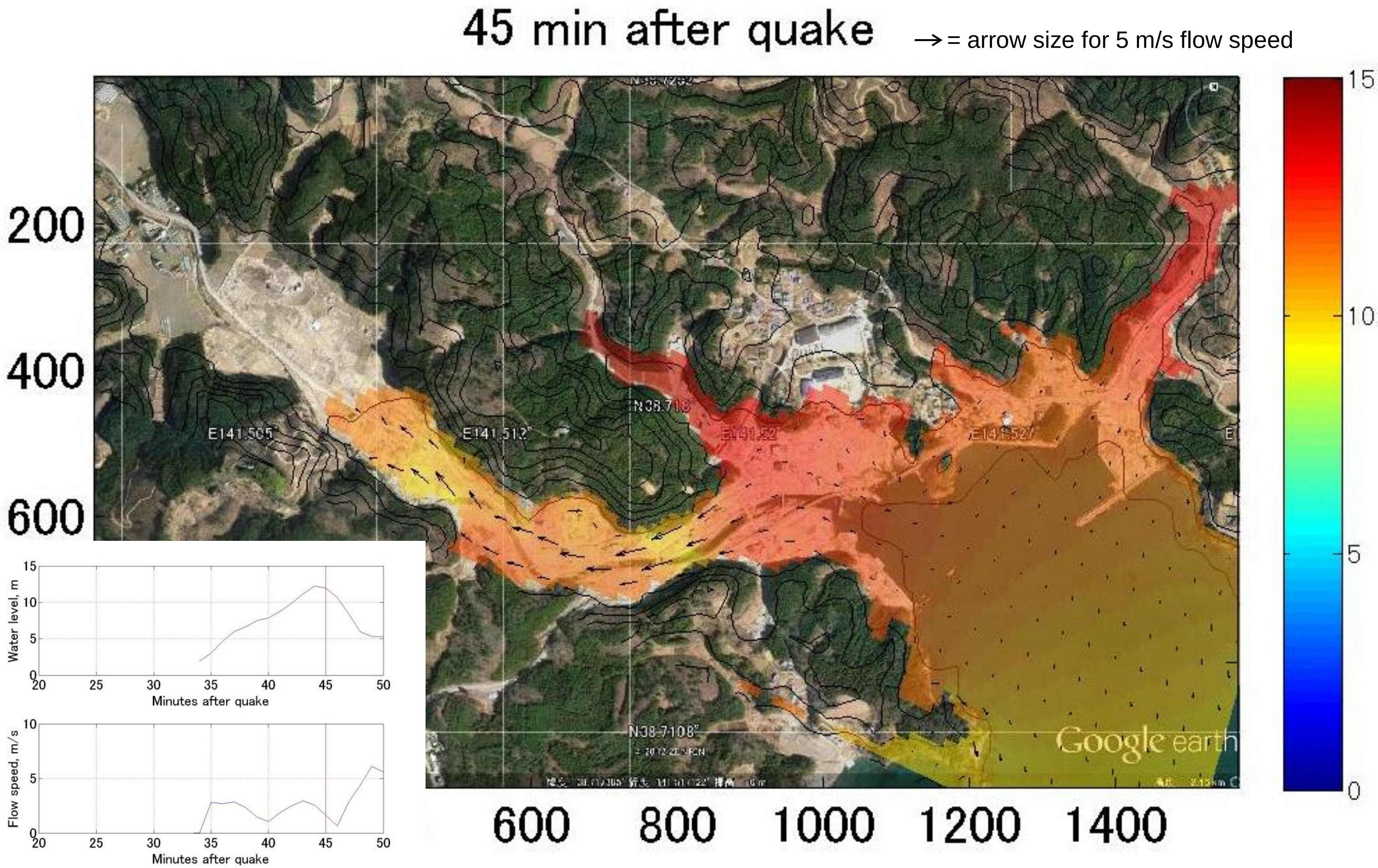

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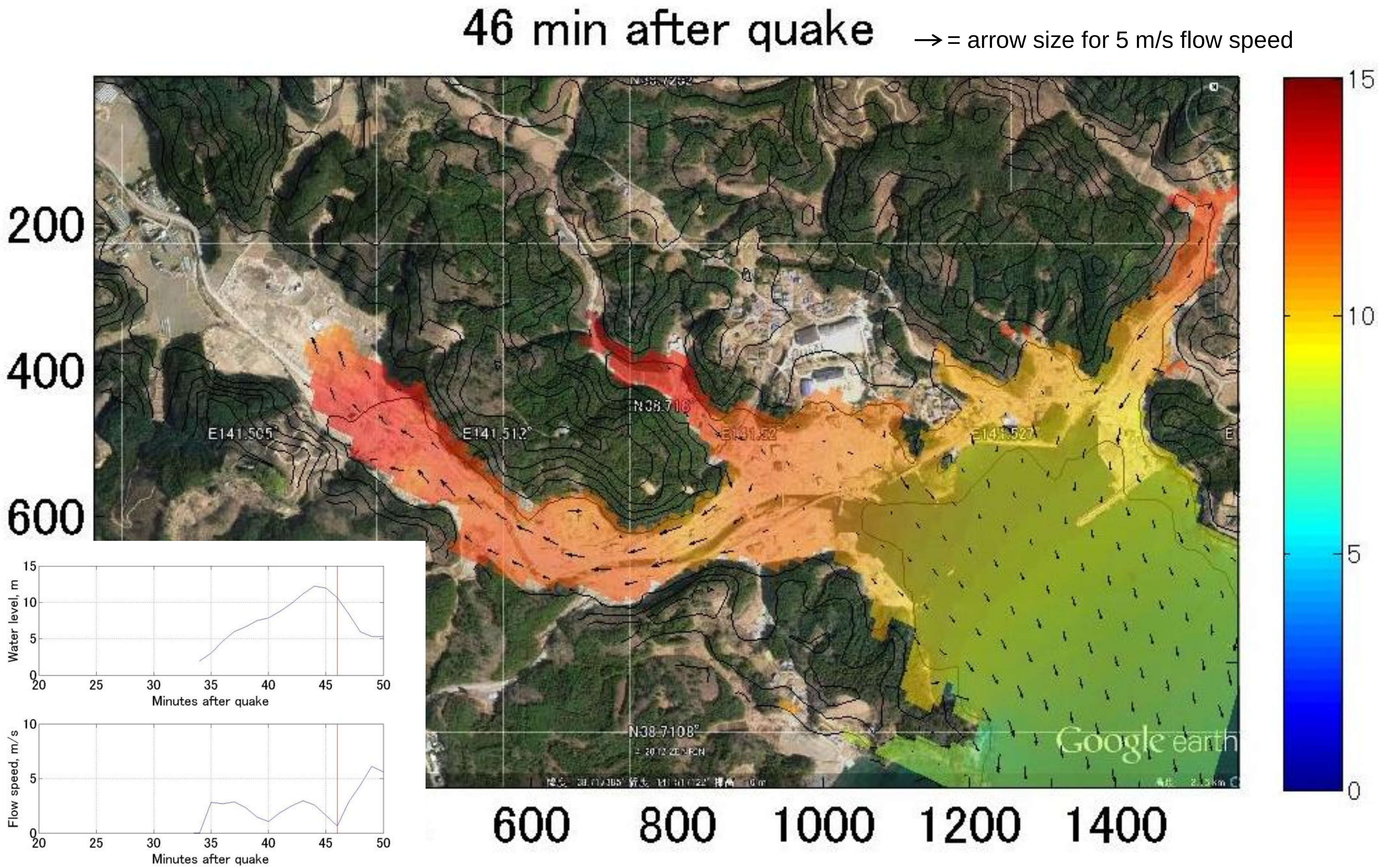
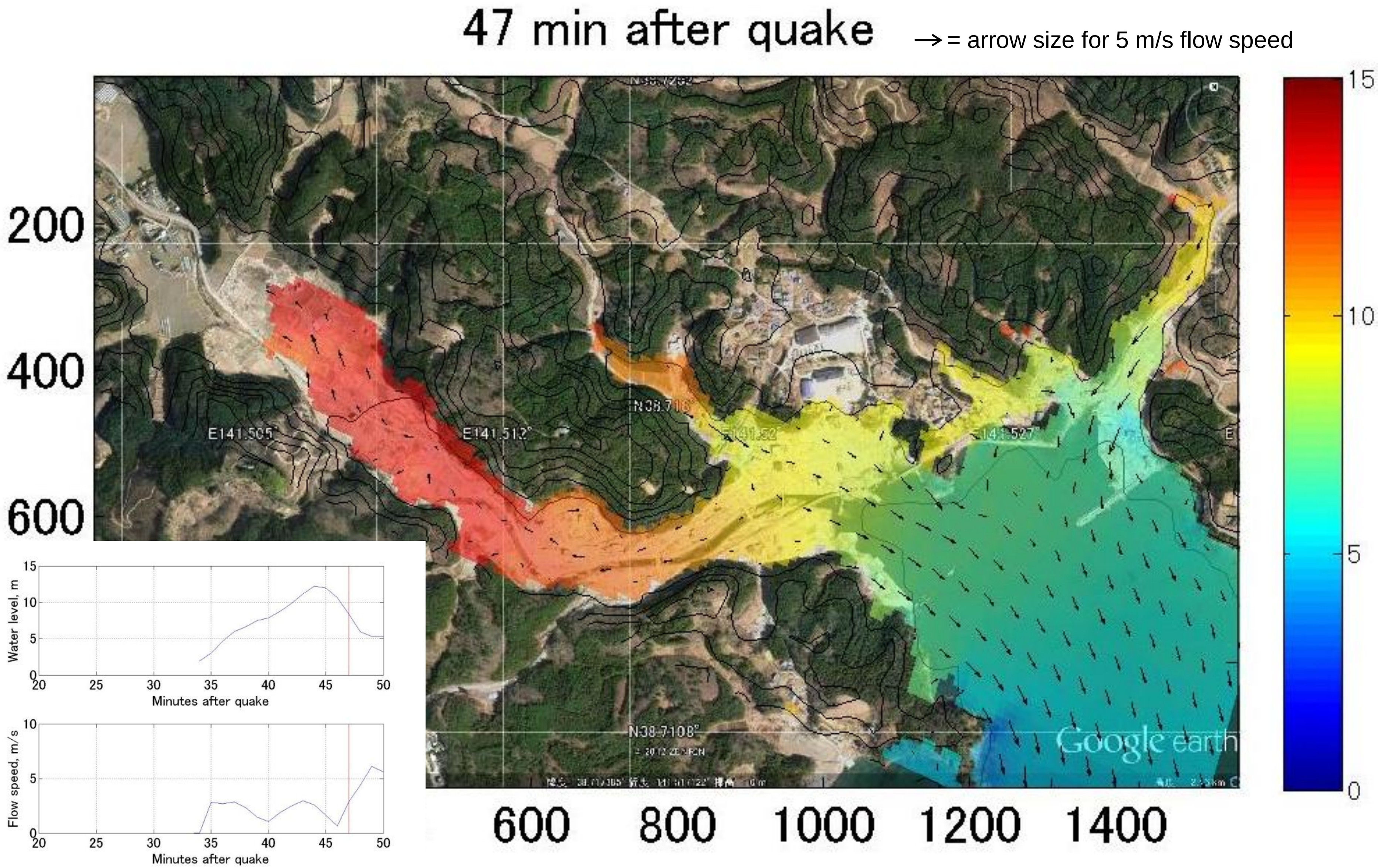


Tsunami behavior – Utatsu



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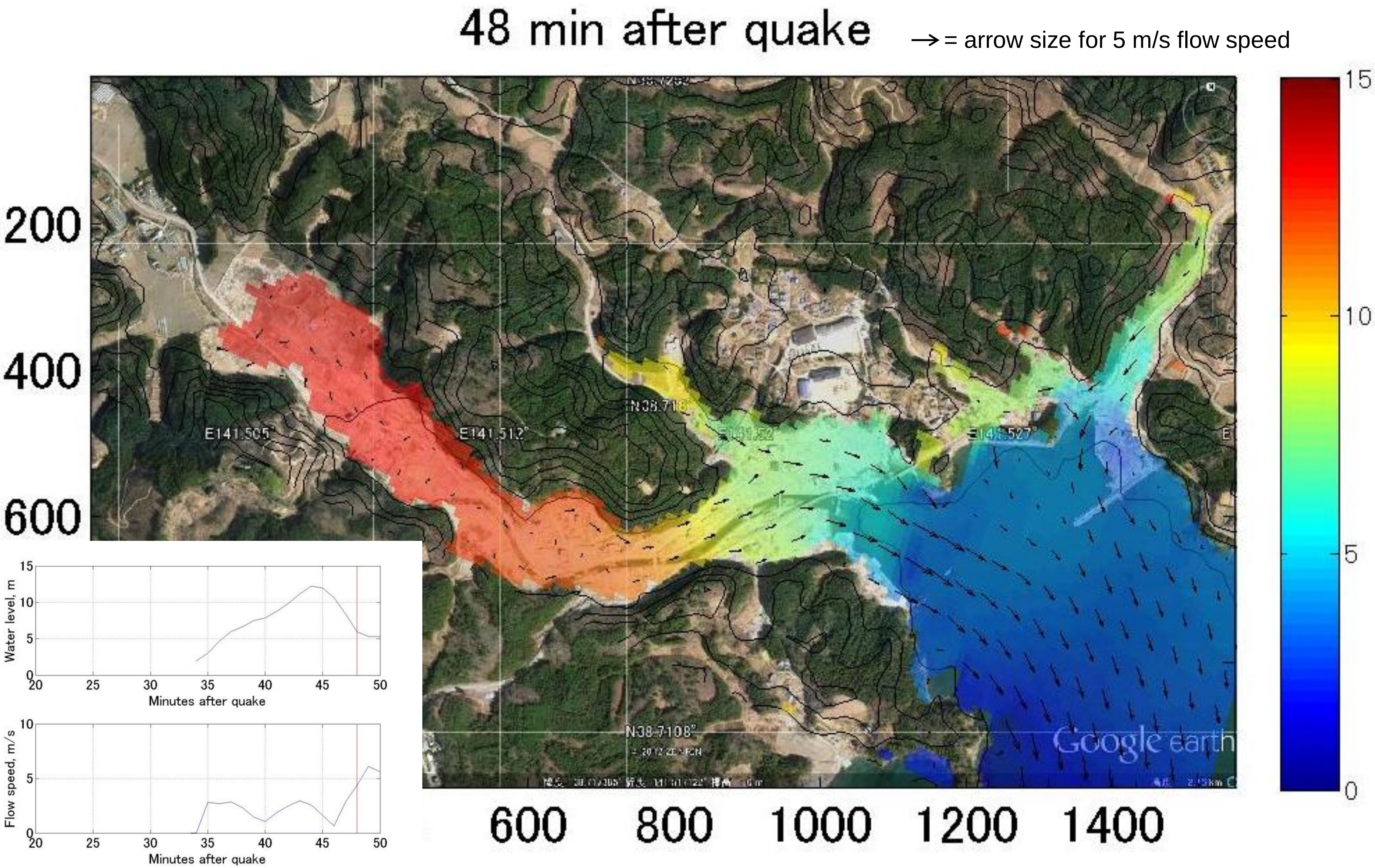

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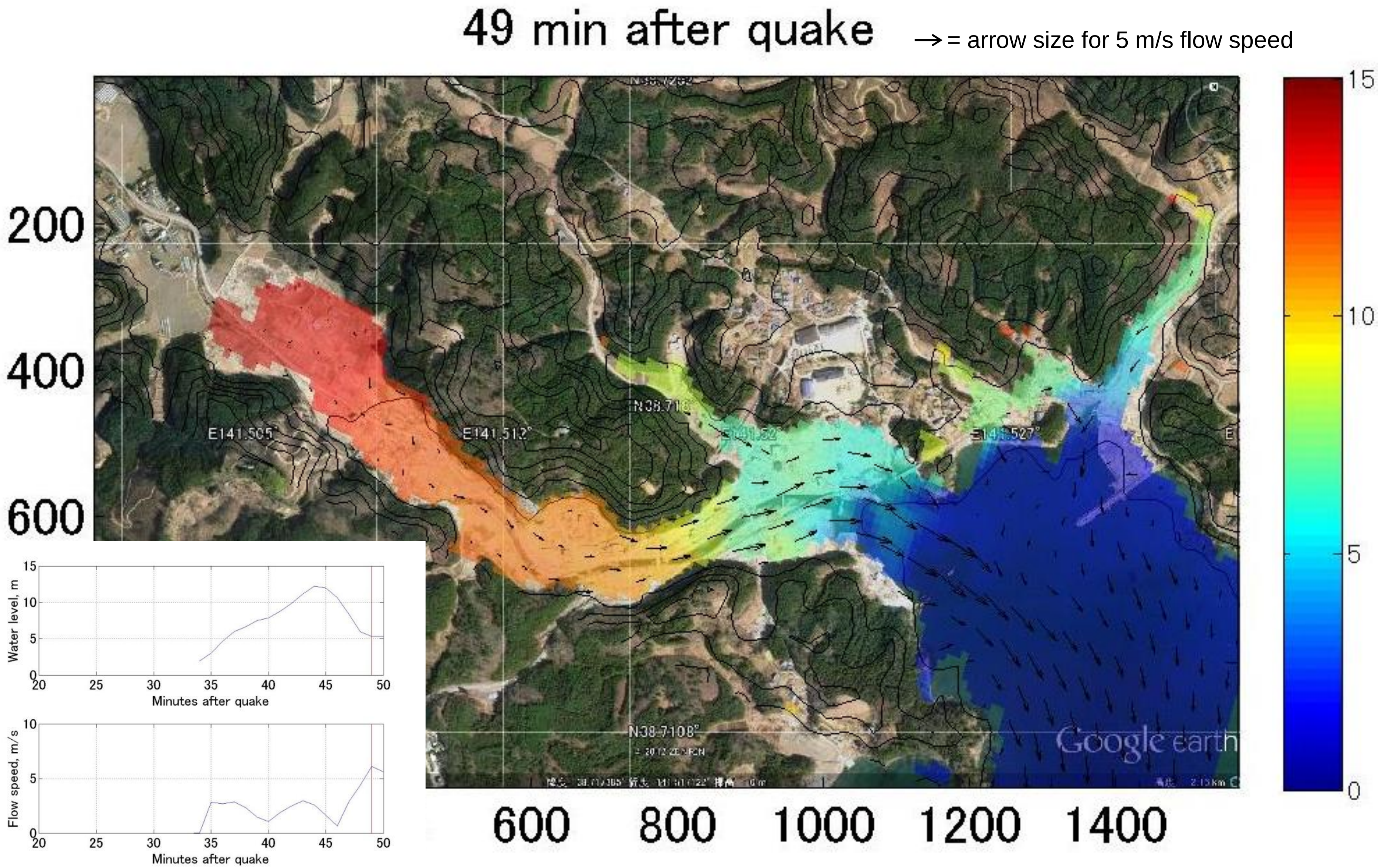
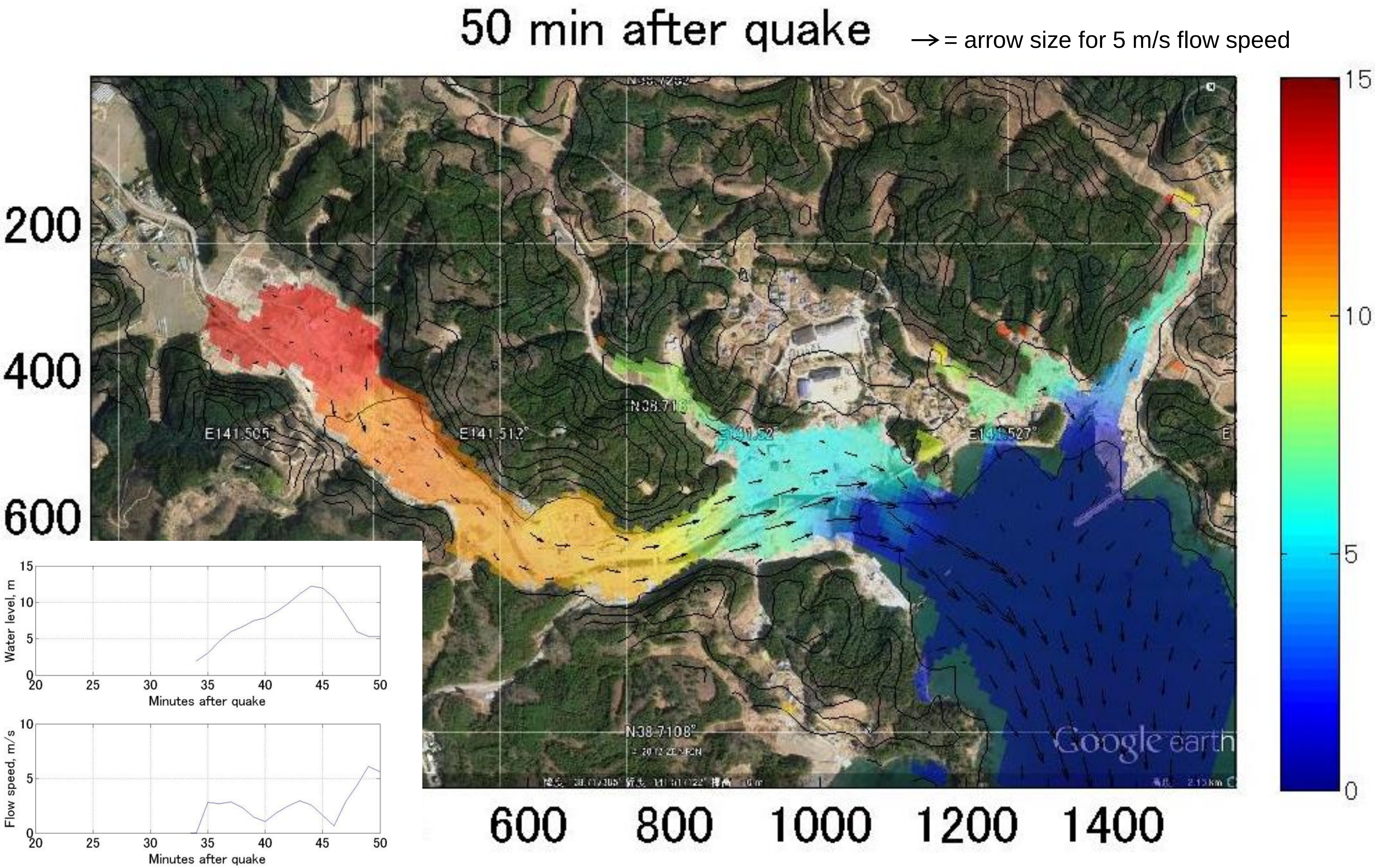
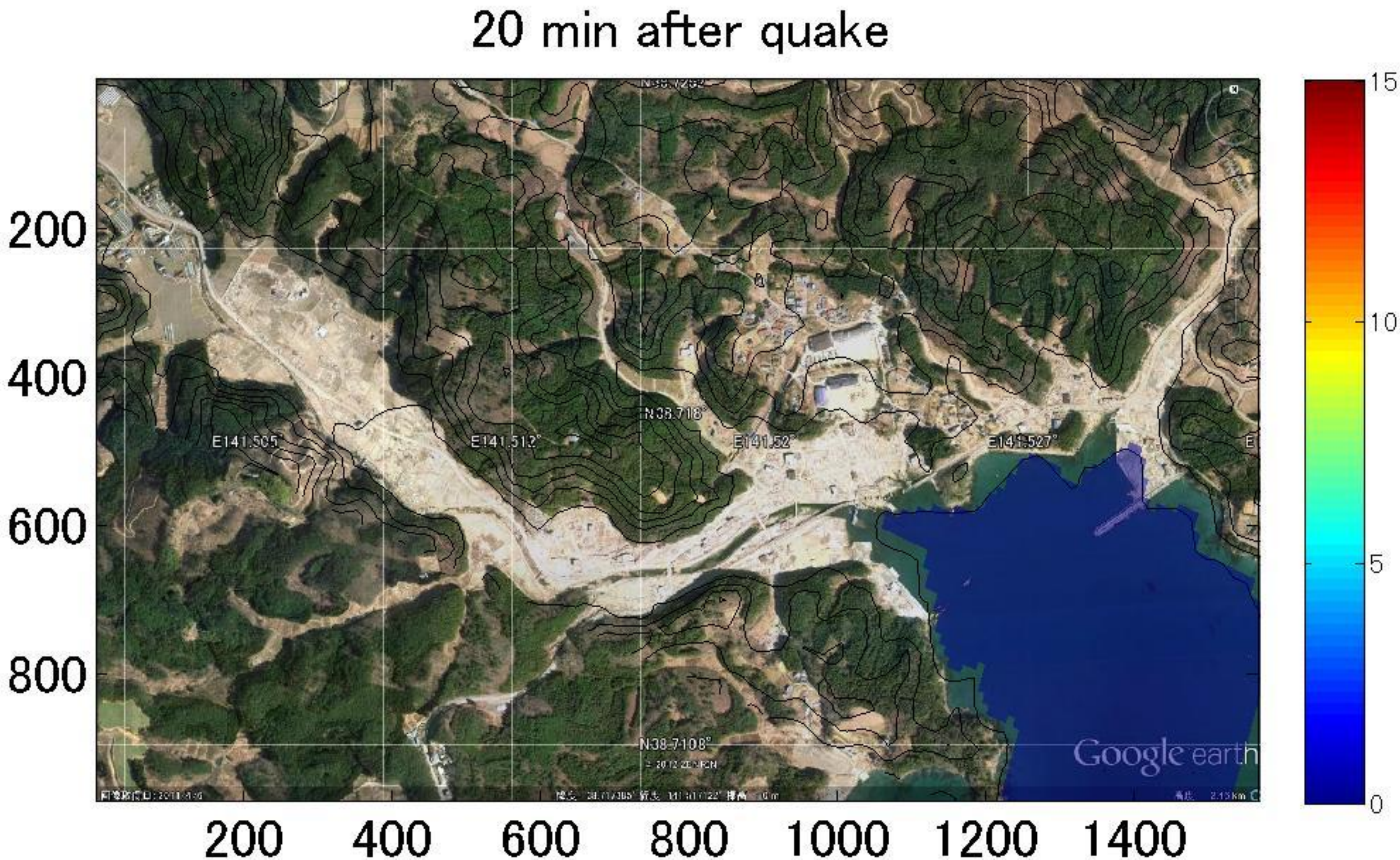


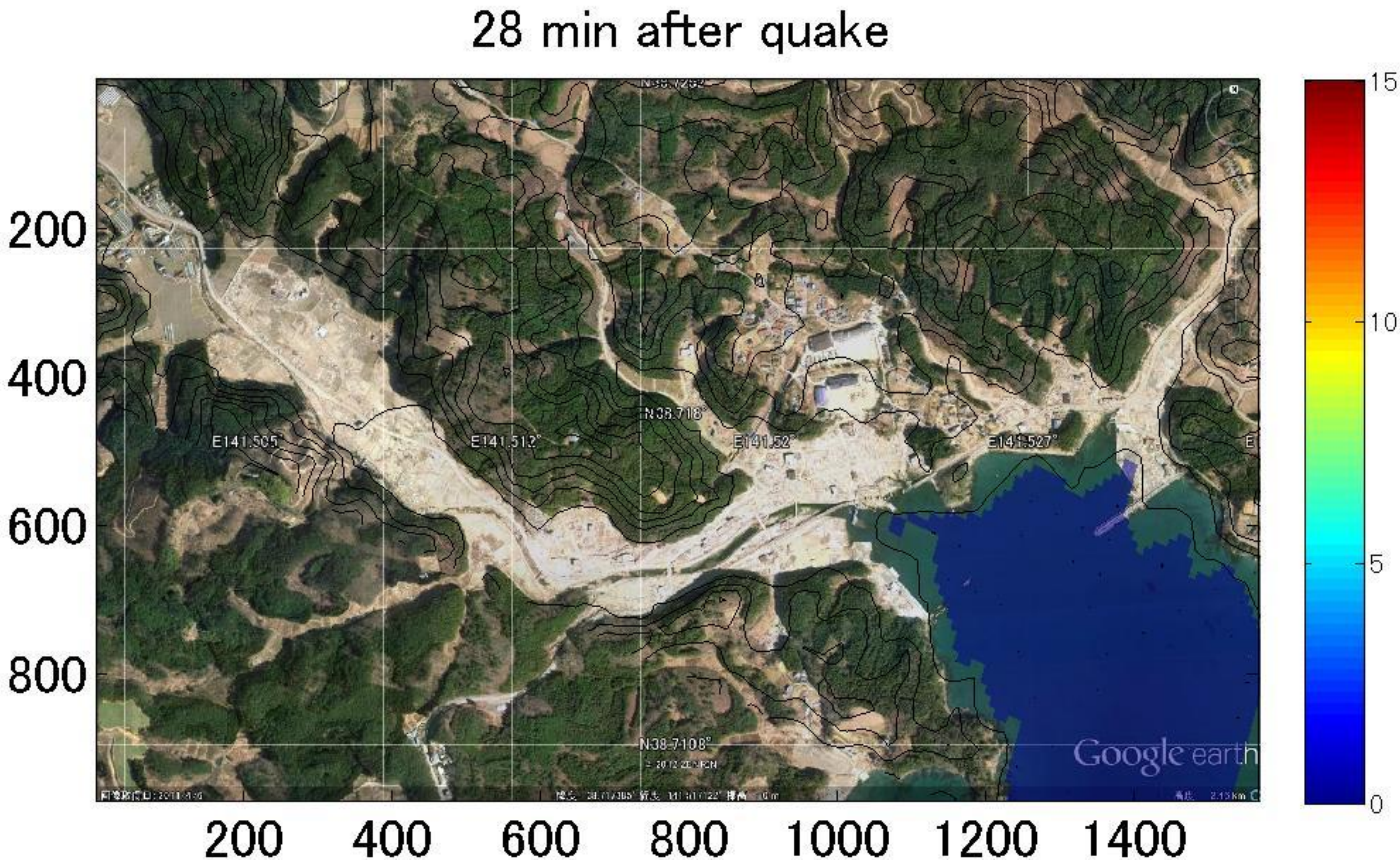
Tsunami behavior – Utatsu



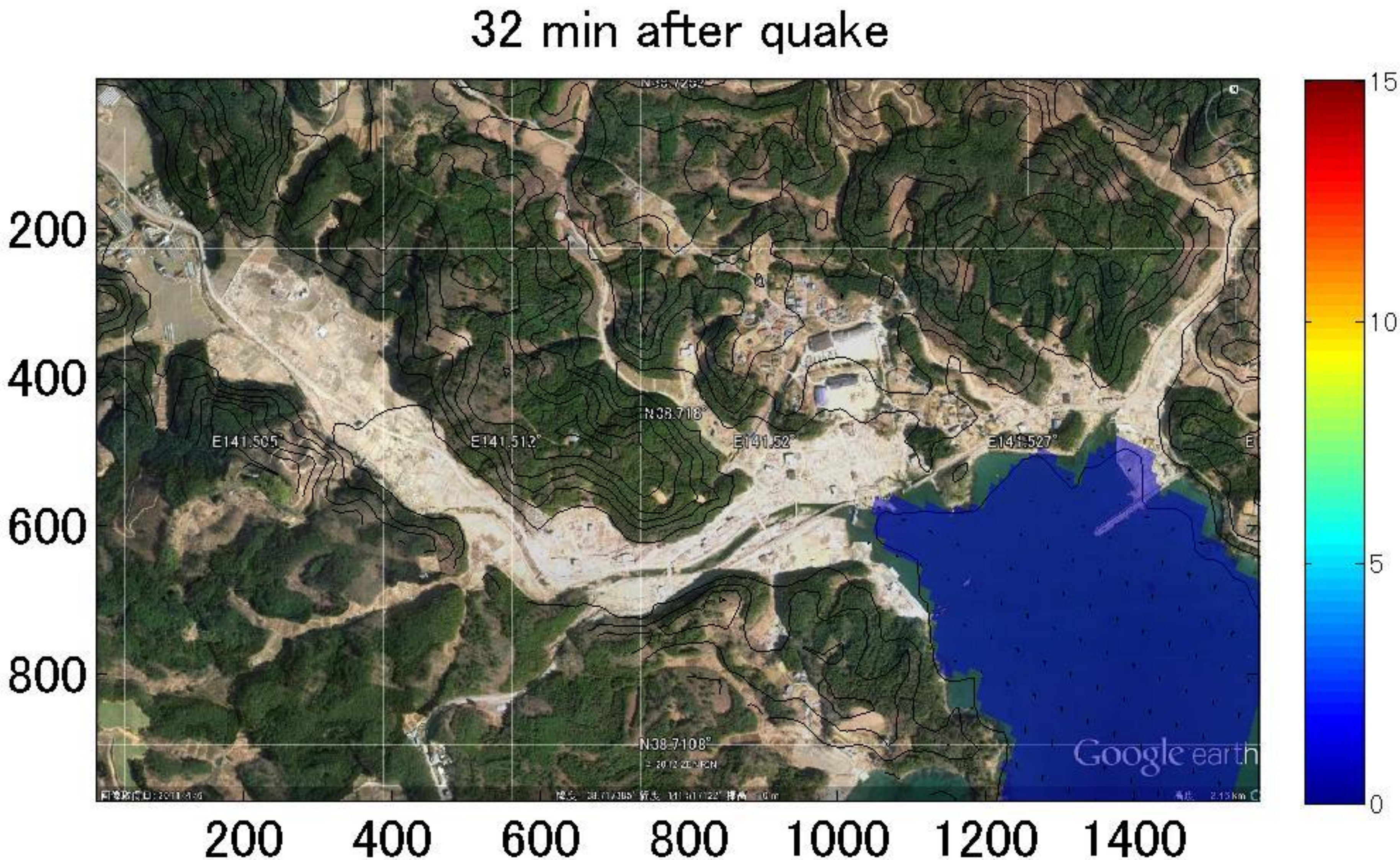
Tsunami behavior – Utatsu with Seawall



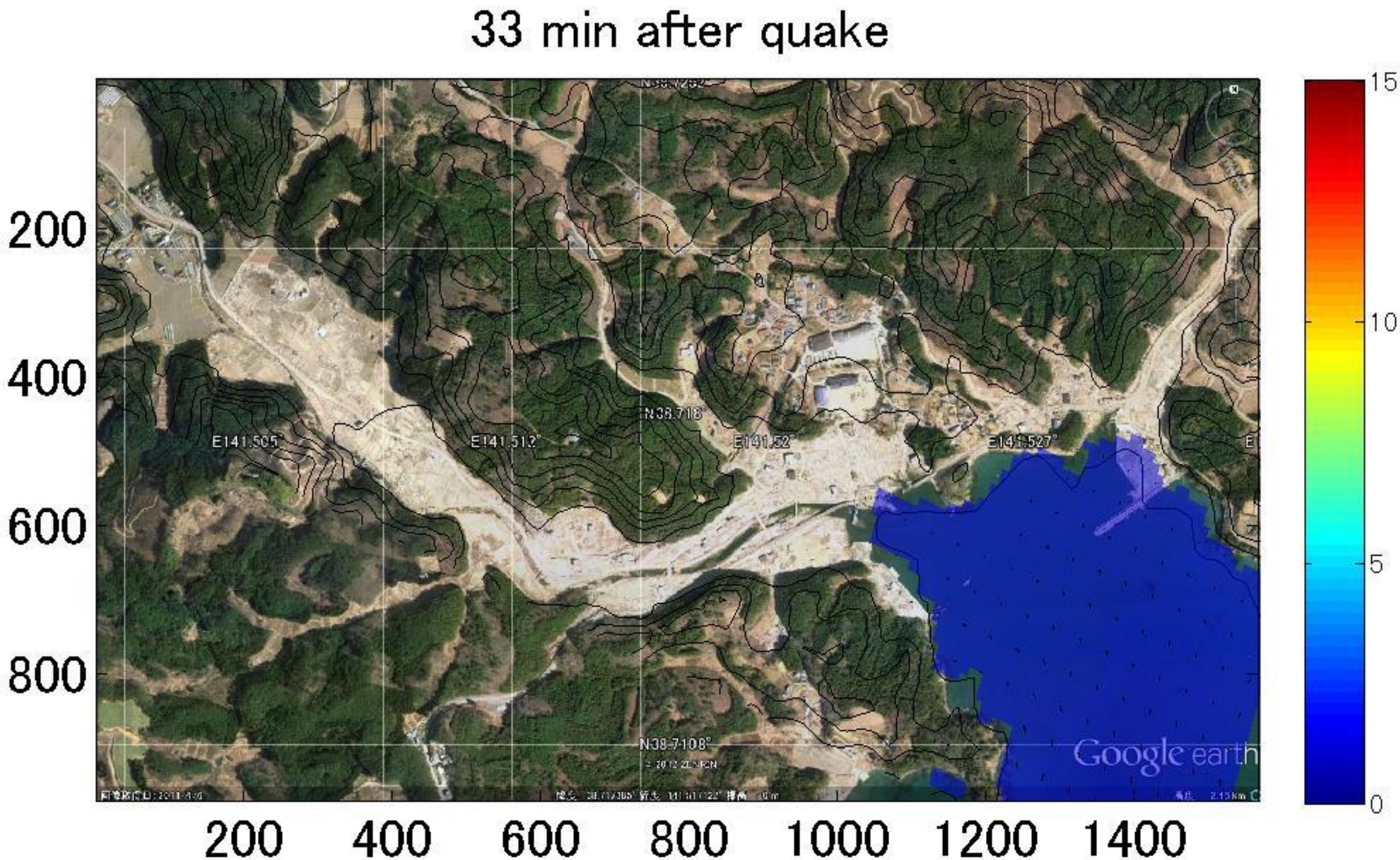
Tsunami behavior – Utatsu with Seawall



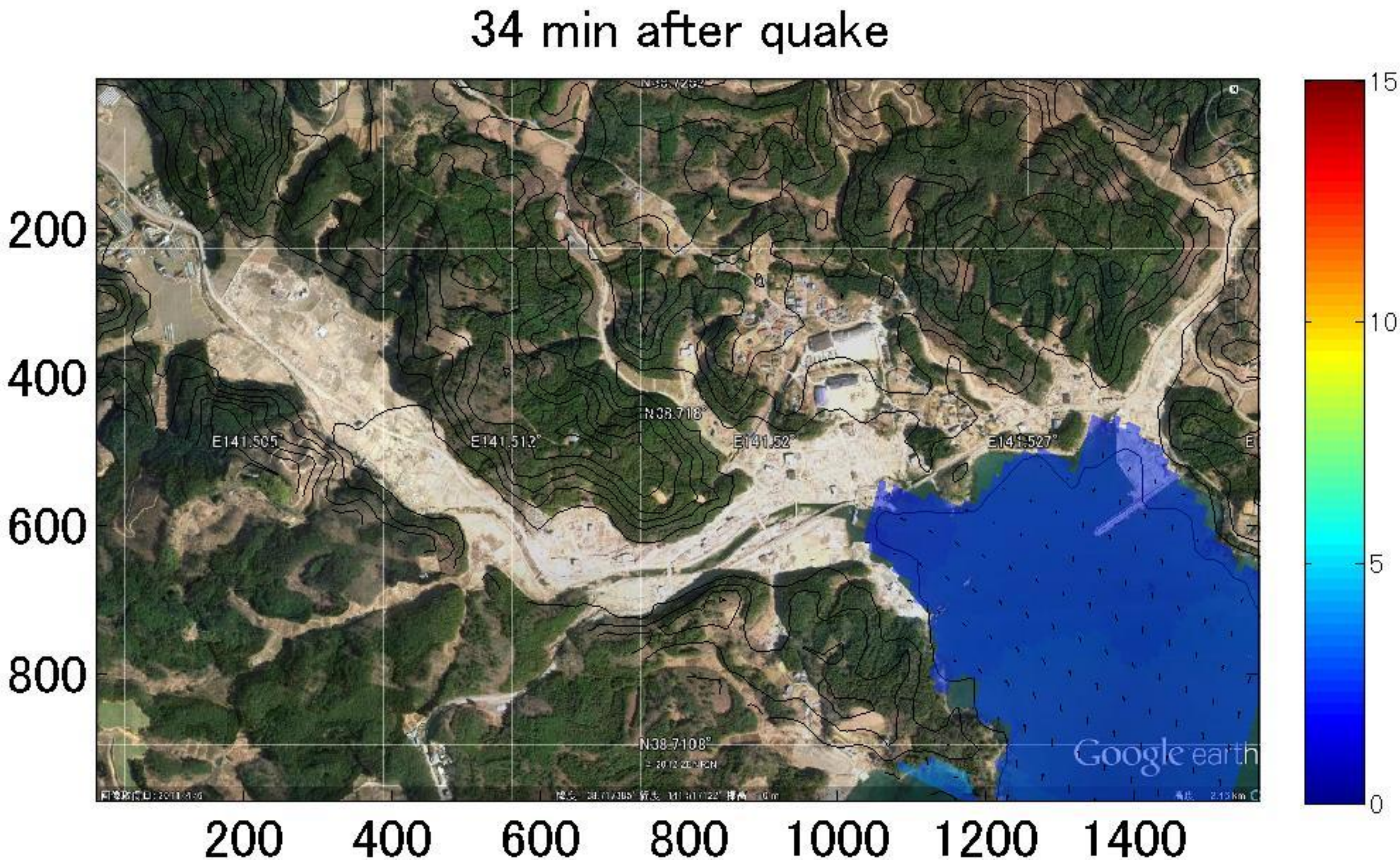
Tsunami behavior – Utatsu with Seawall



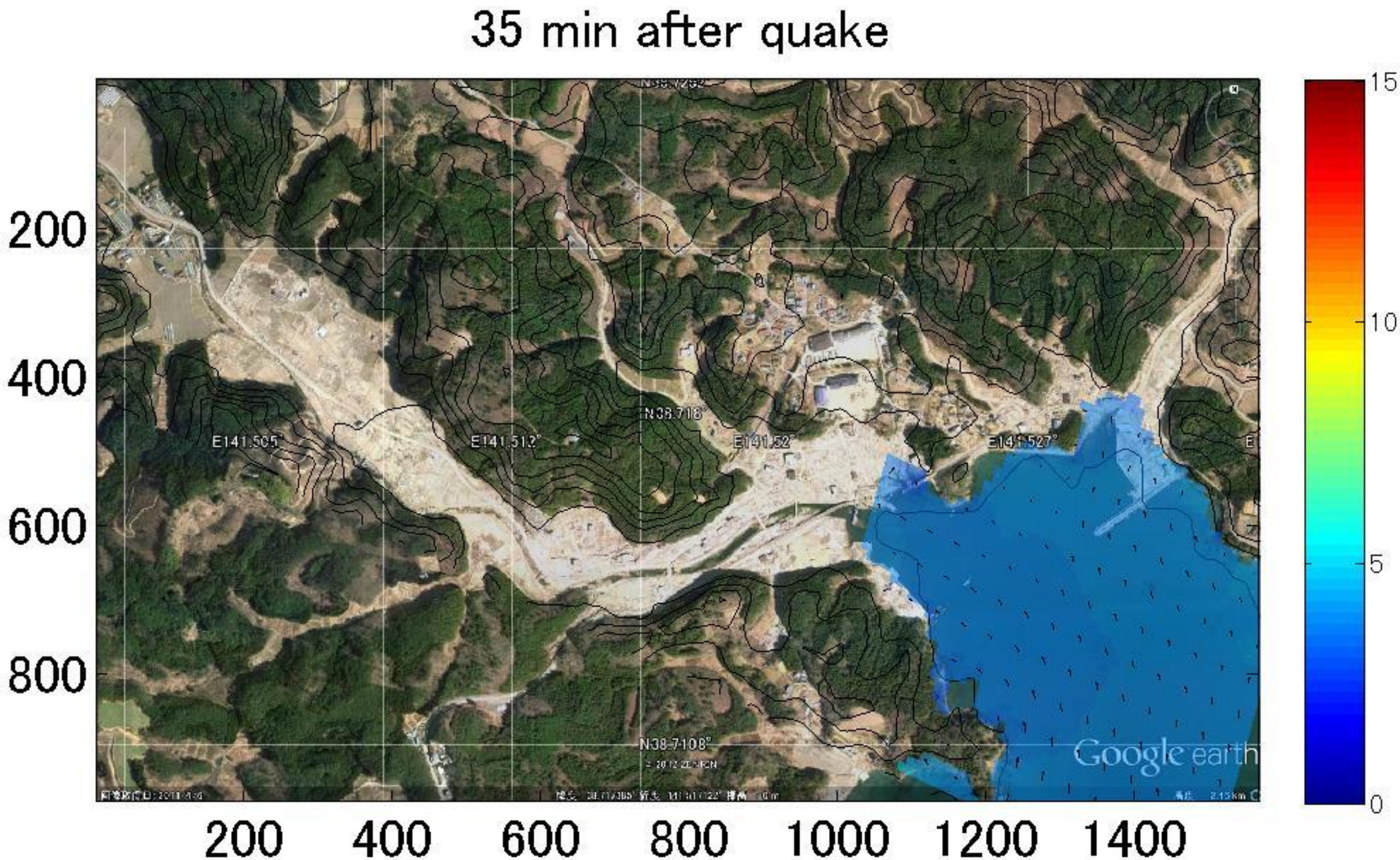
Tsunami behavior – Utatsu with Seawall



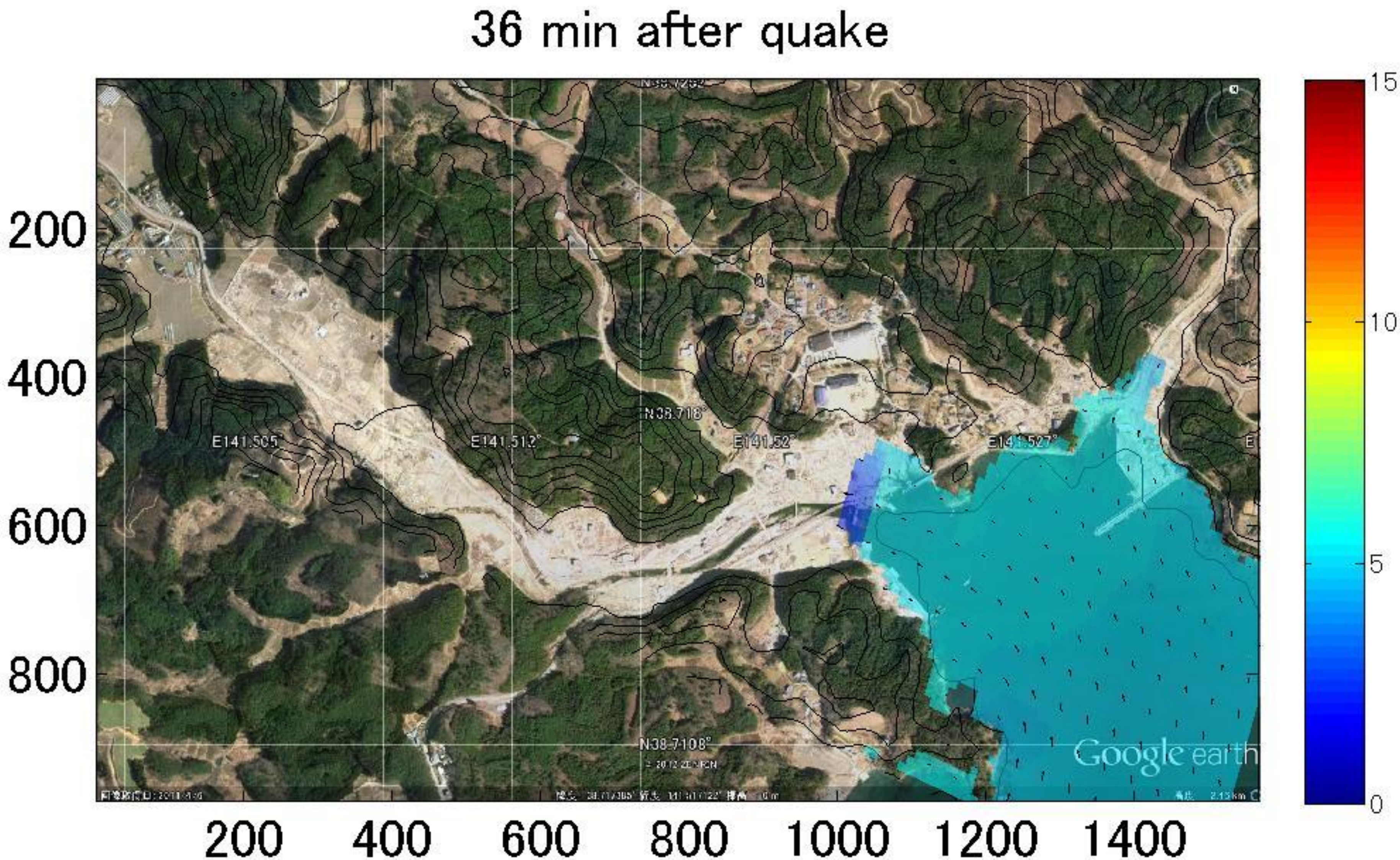
Tsunami behavior – Utatsu with Seawall



Tsunami behavior – Utatsu with Seawall

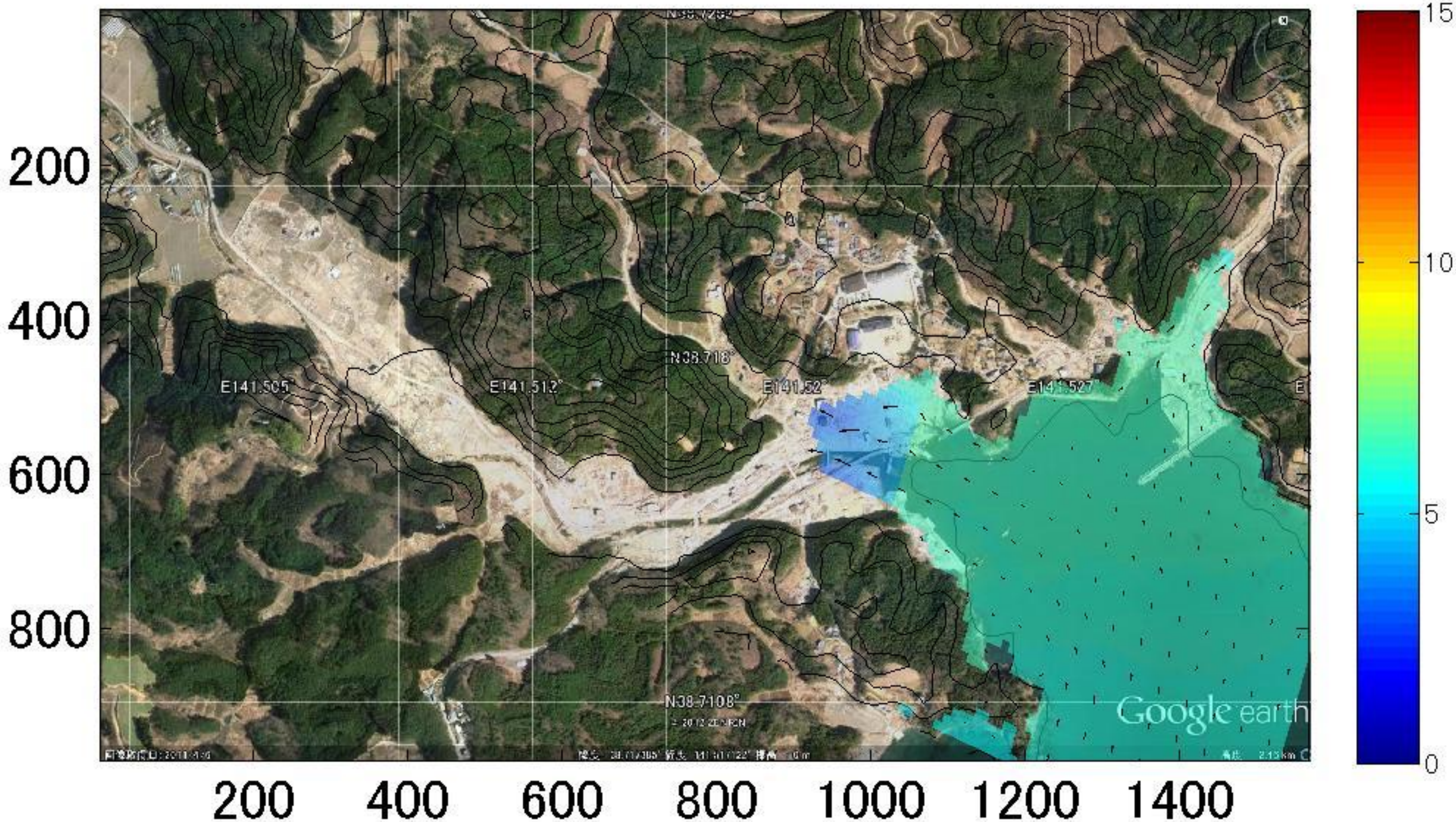


Tsunami behavior – Utatsu with Seawall

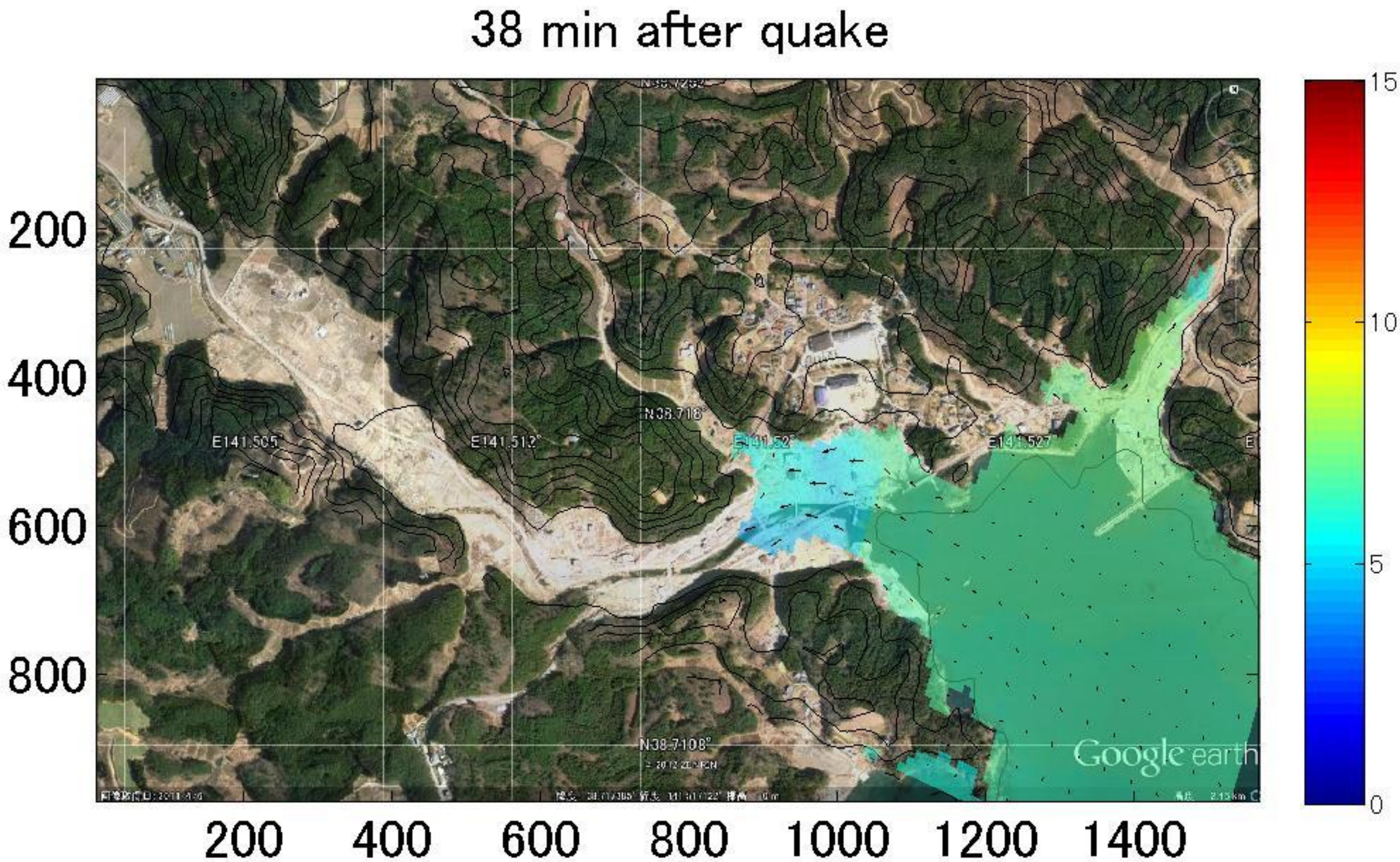


Tsunami behavior – Utatsu with Seawall

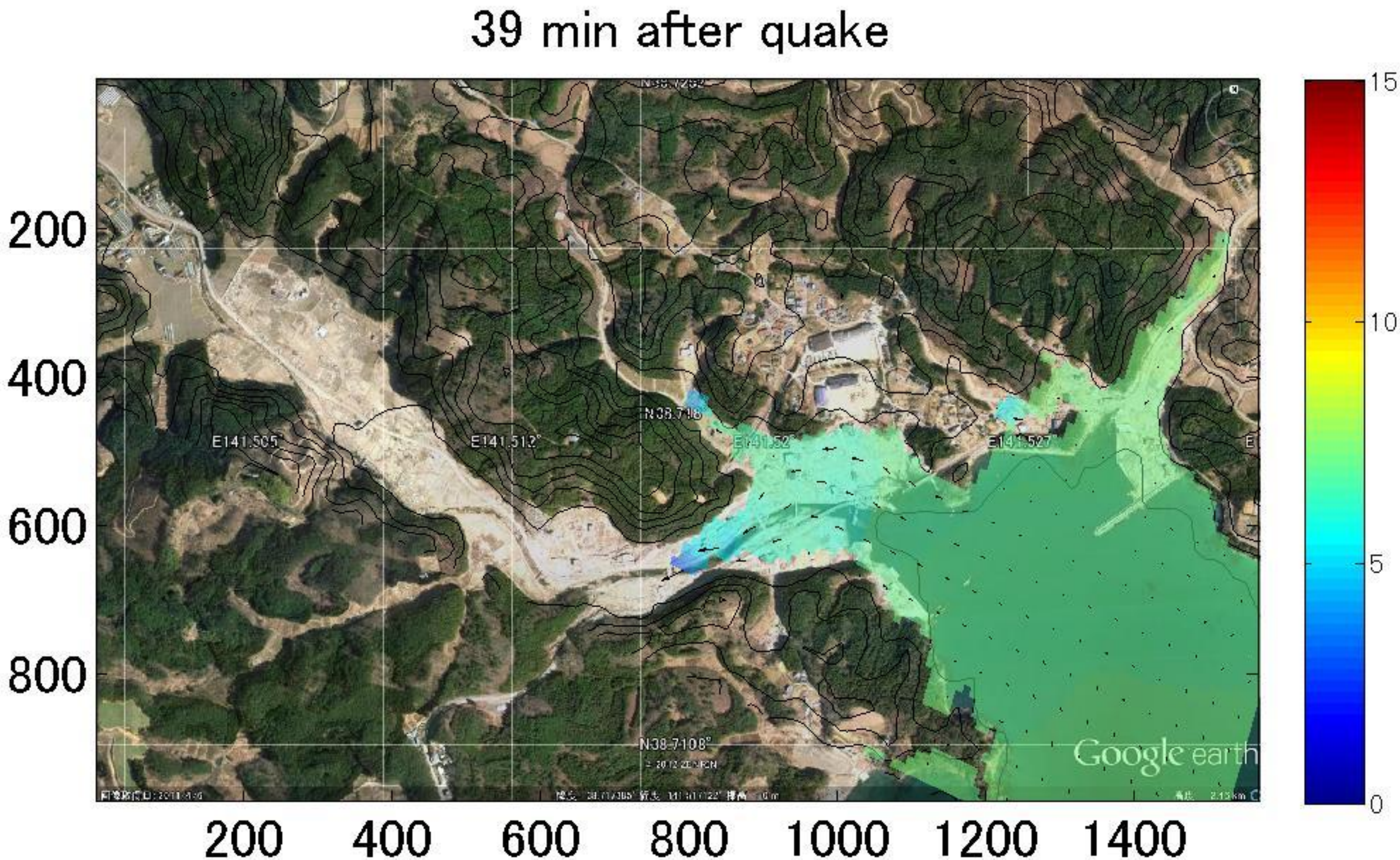
37 min after quake



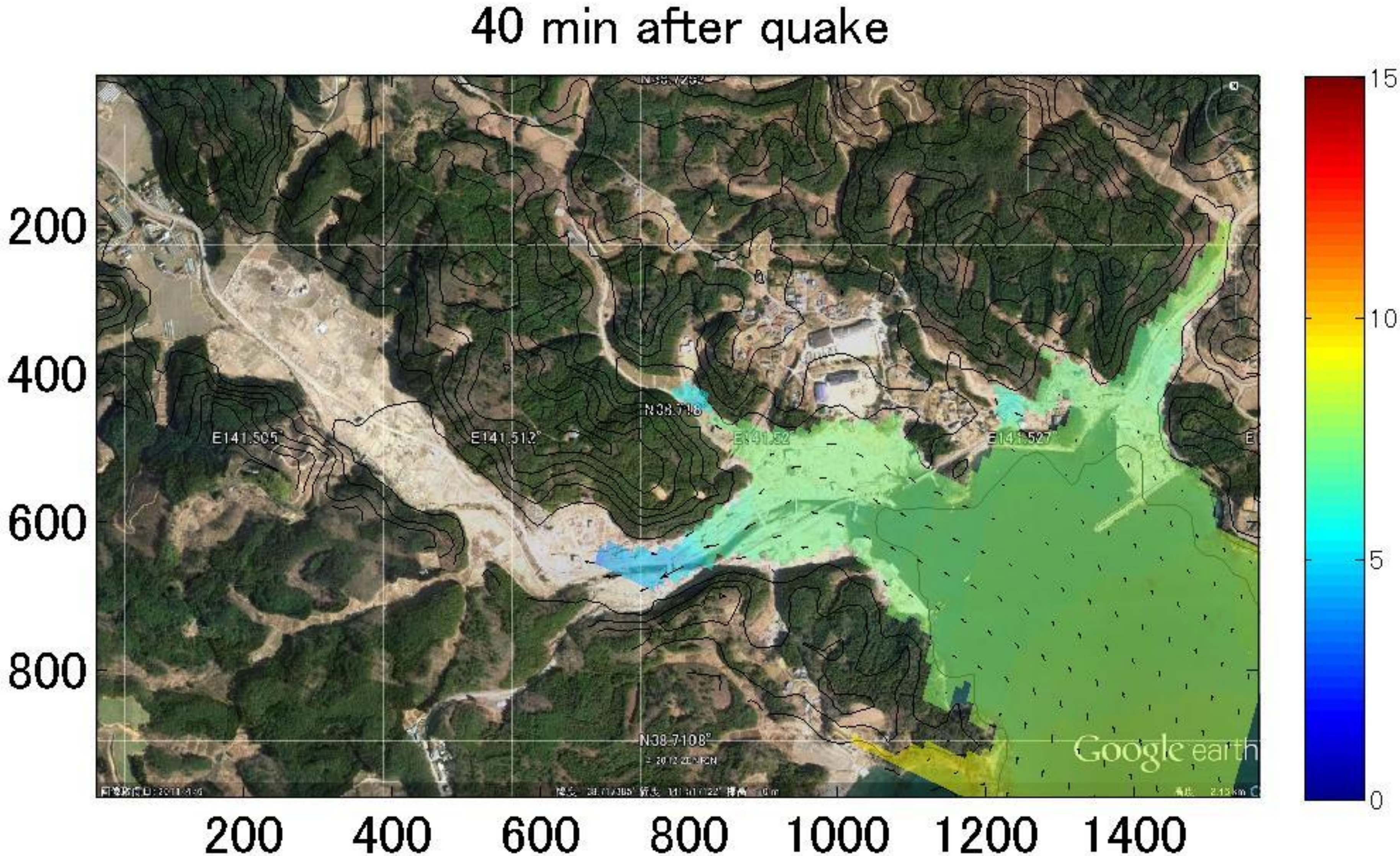
Tsunami behavior – Utatsu with Seawall



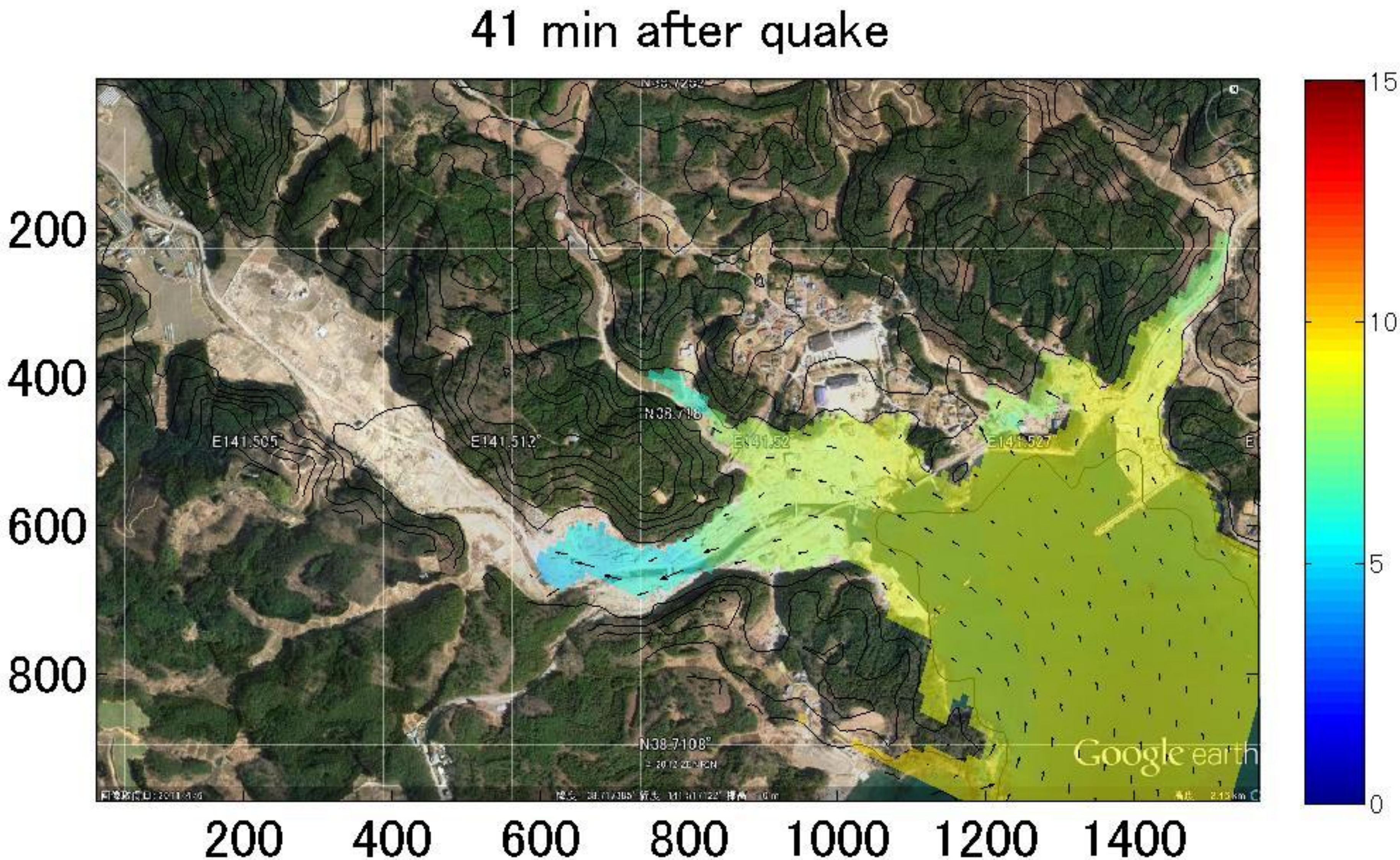
Tsunami behavior – Utatsu with Seawall



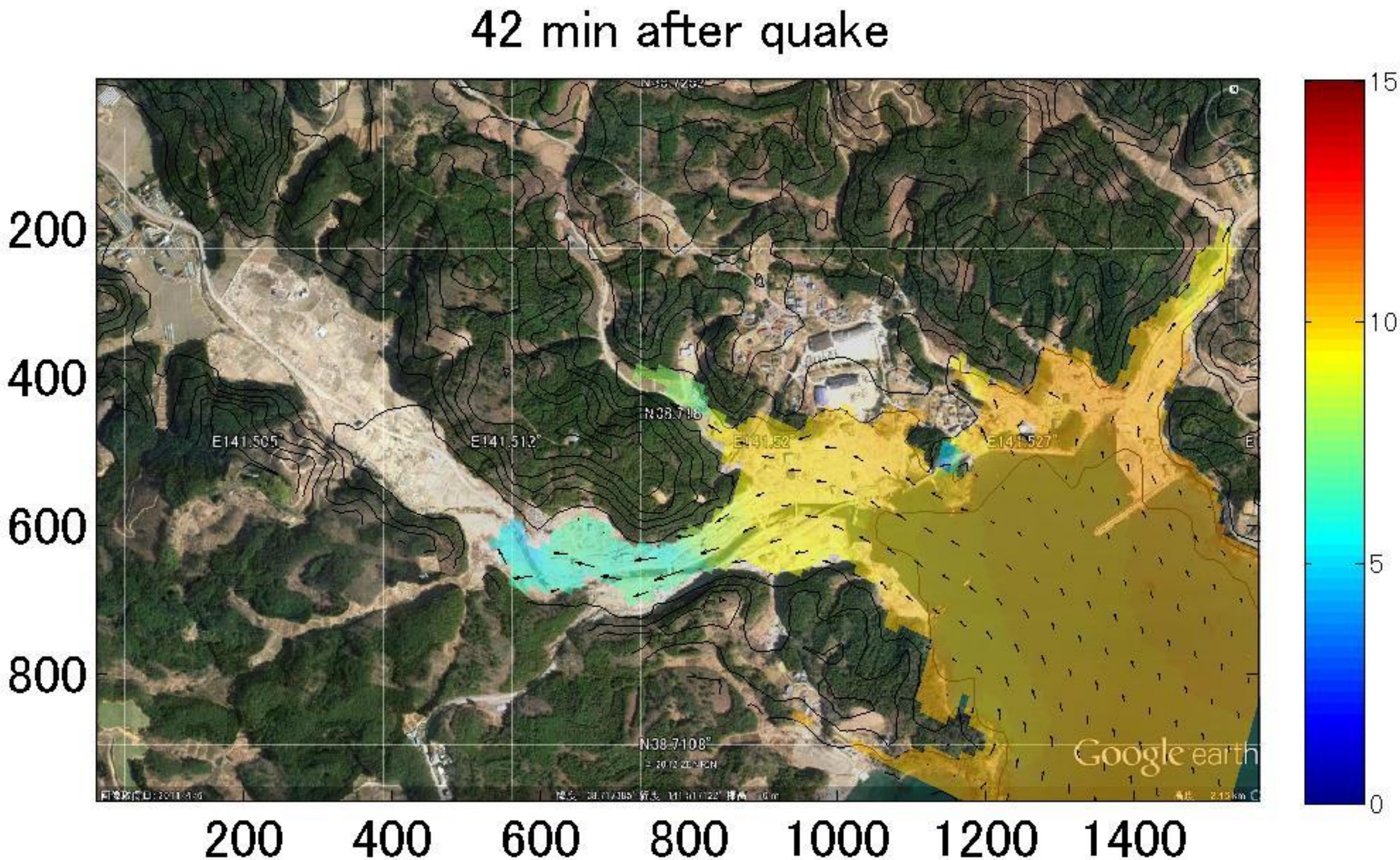
Tsunami behavior – Utatsu with Seawall



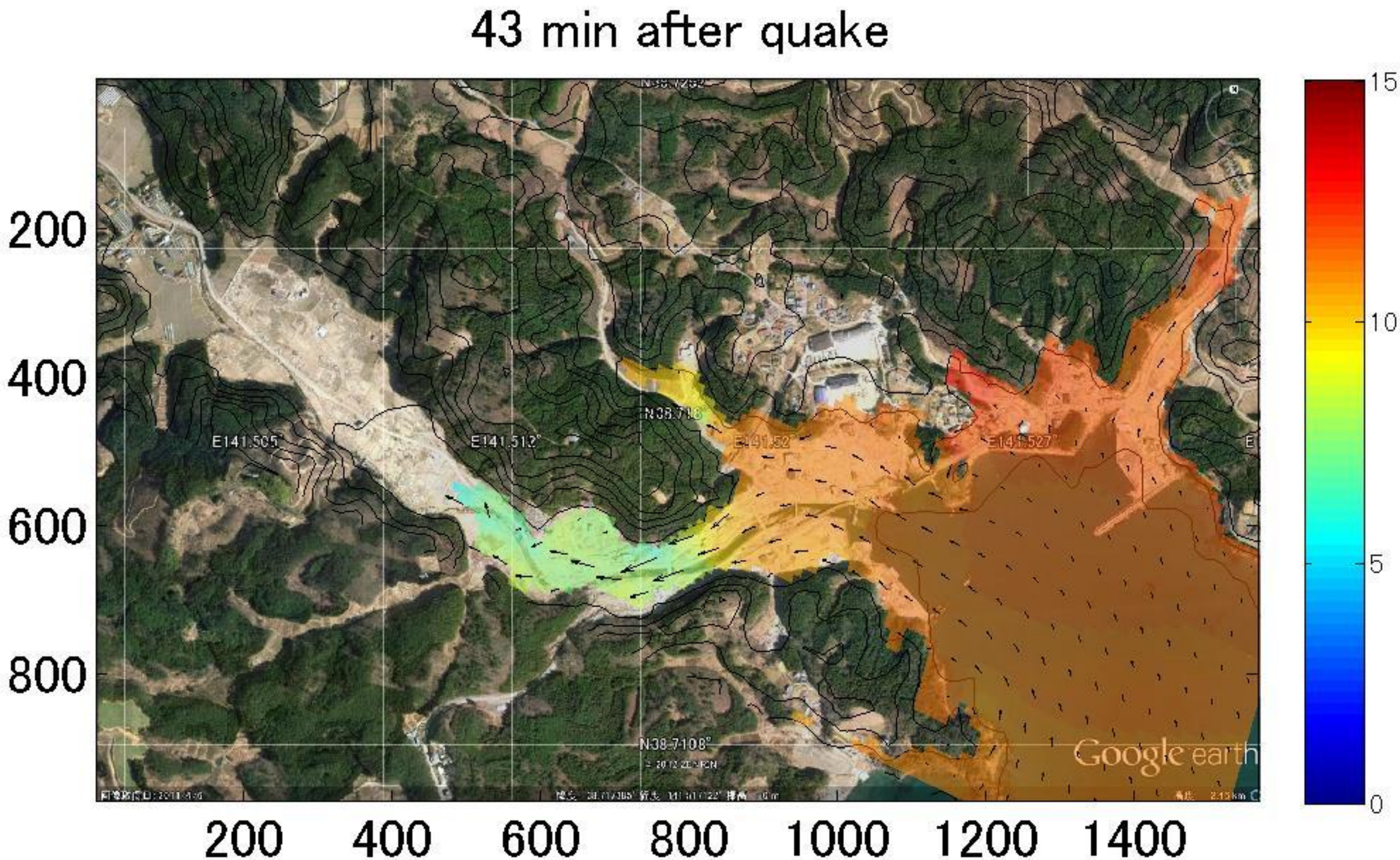
Tsunami behavior – Utatsu with Seawall



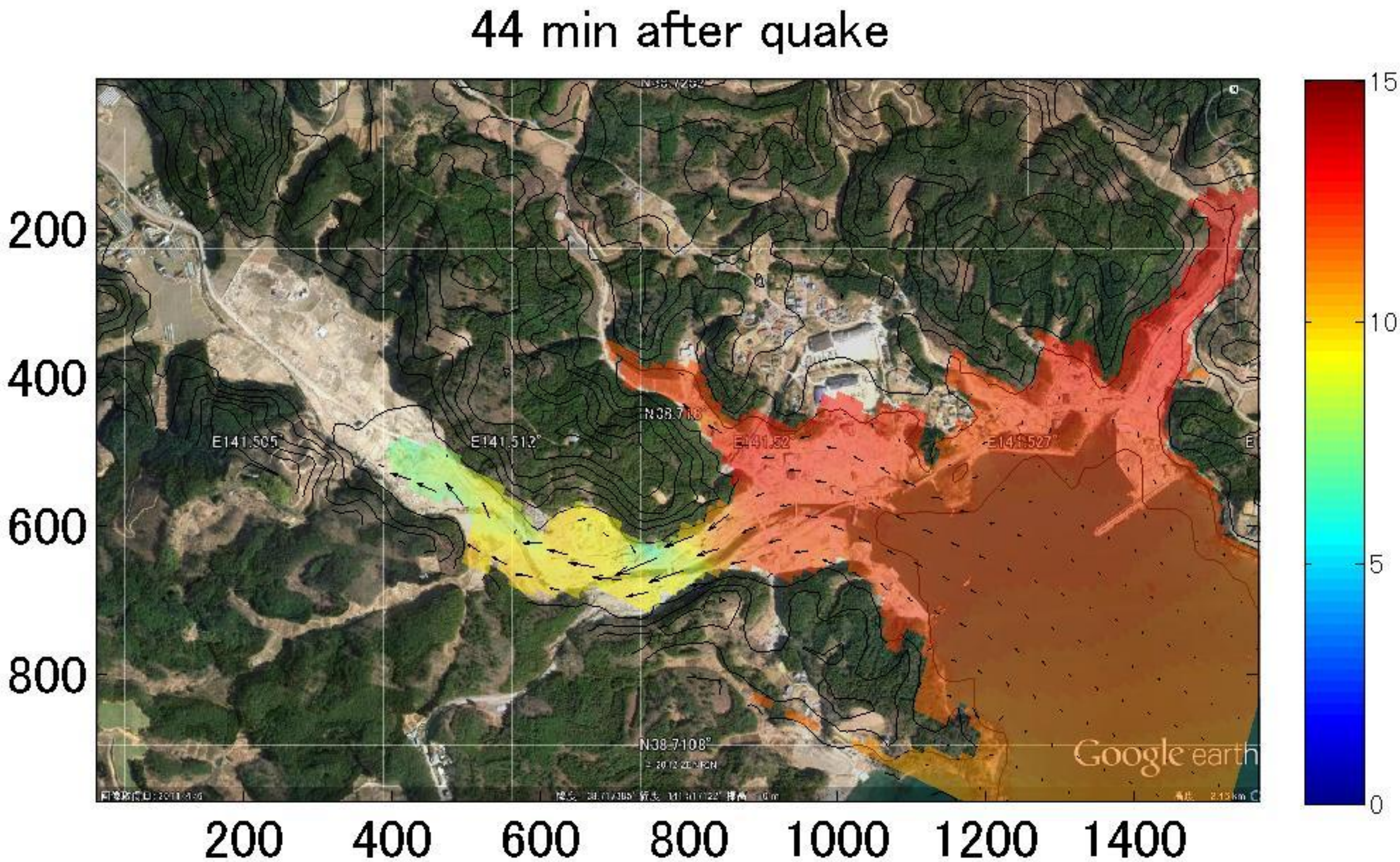
Tsunami behavior – Utatsu with Seawall



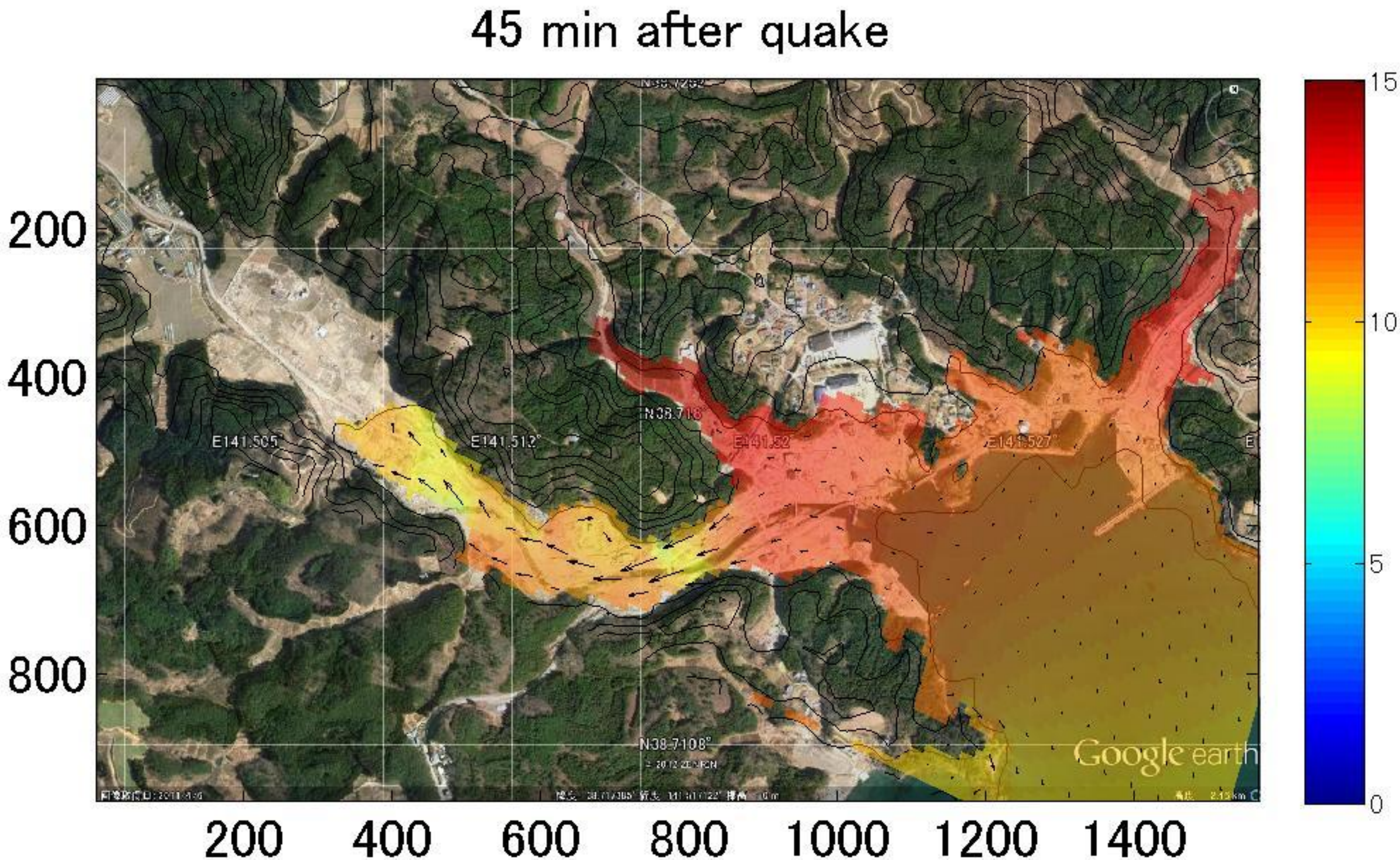
Tsunami behavior – Utatsu with Seawall



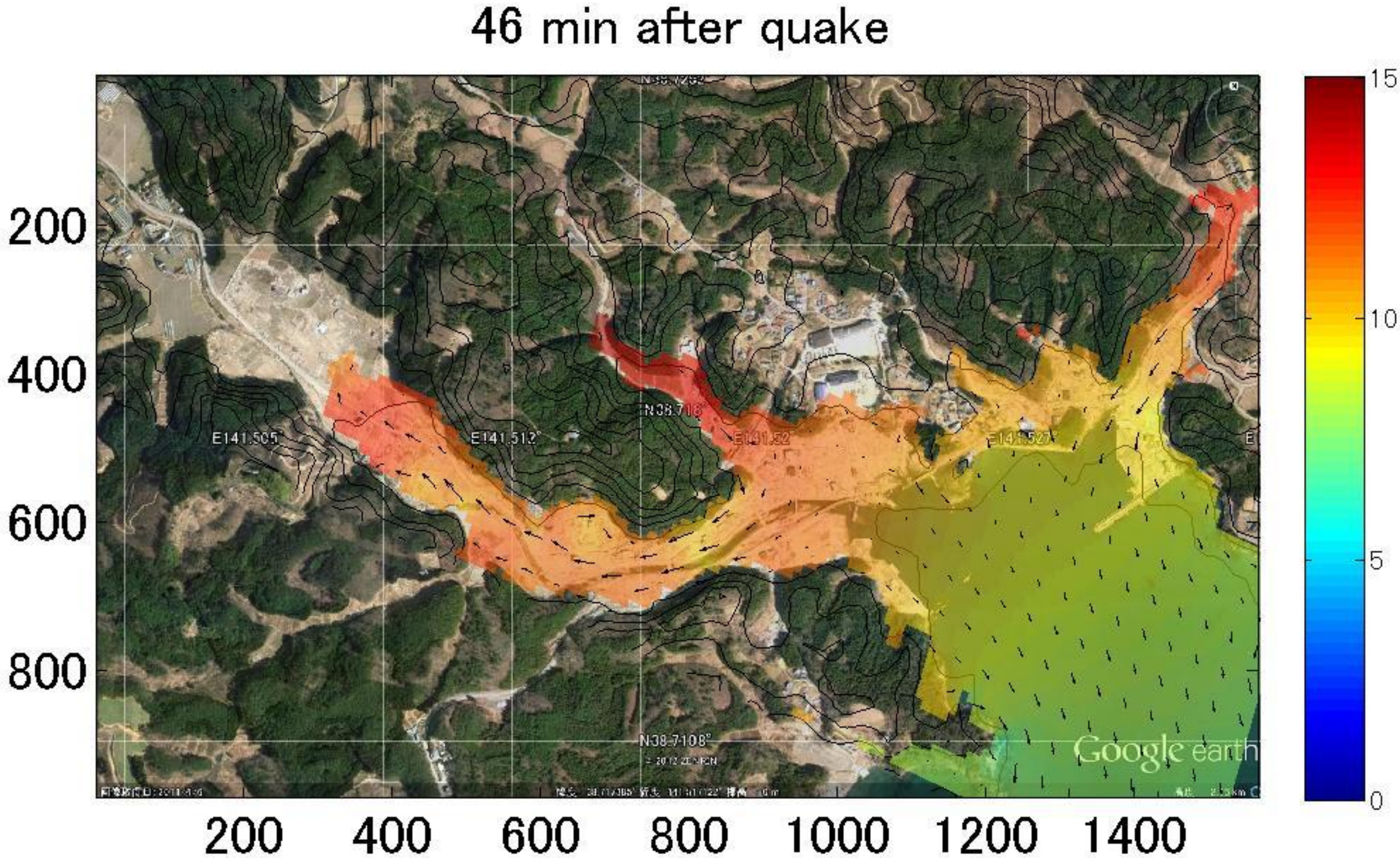
Tsunami behavior – Utatsu with Seawall



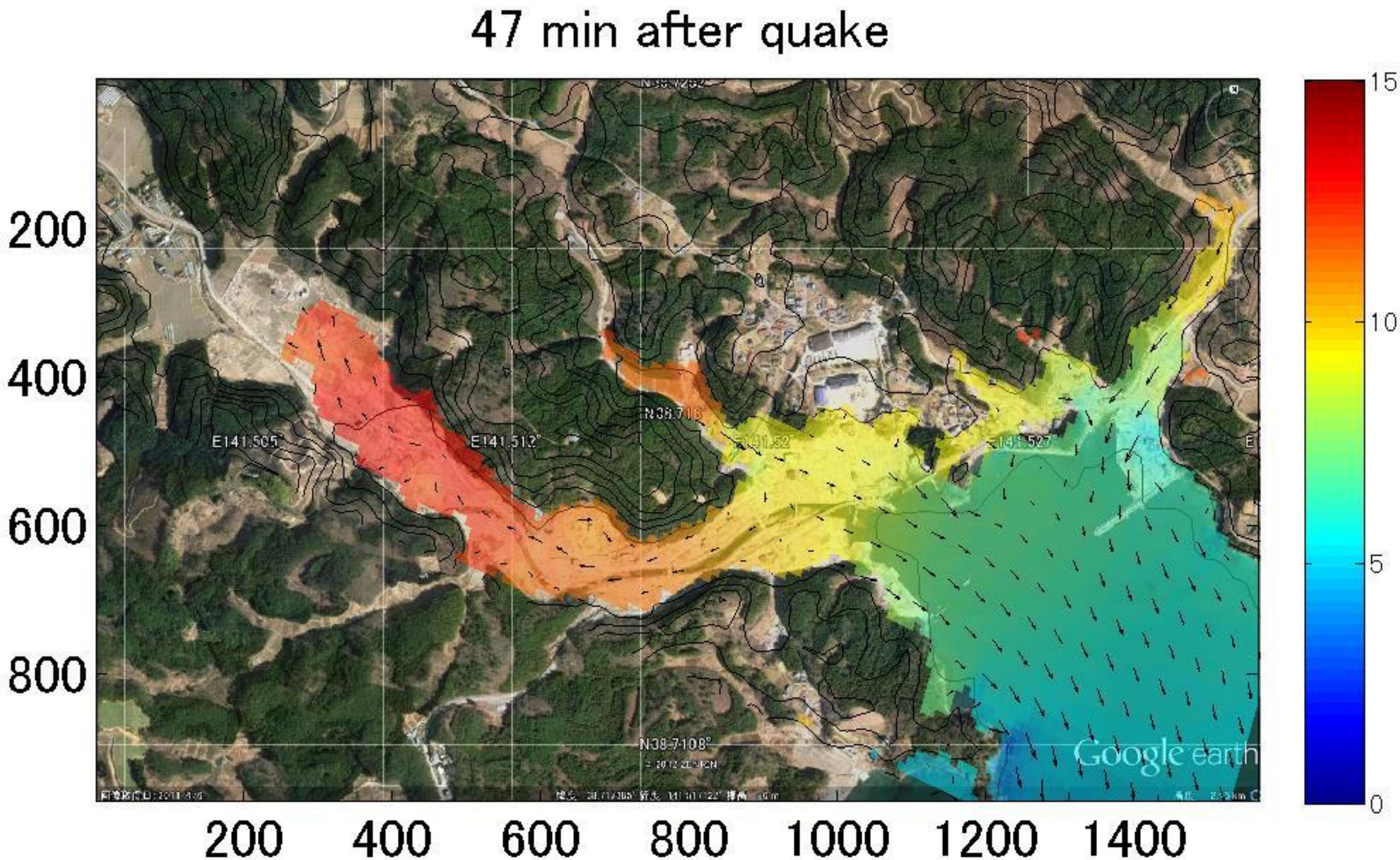
Tsunami behavior – Utatsu with Seawall



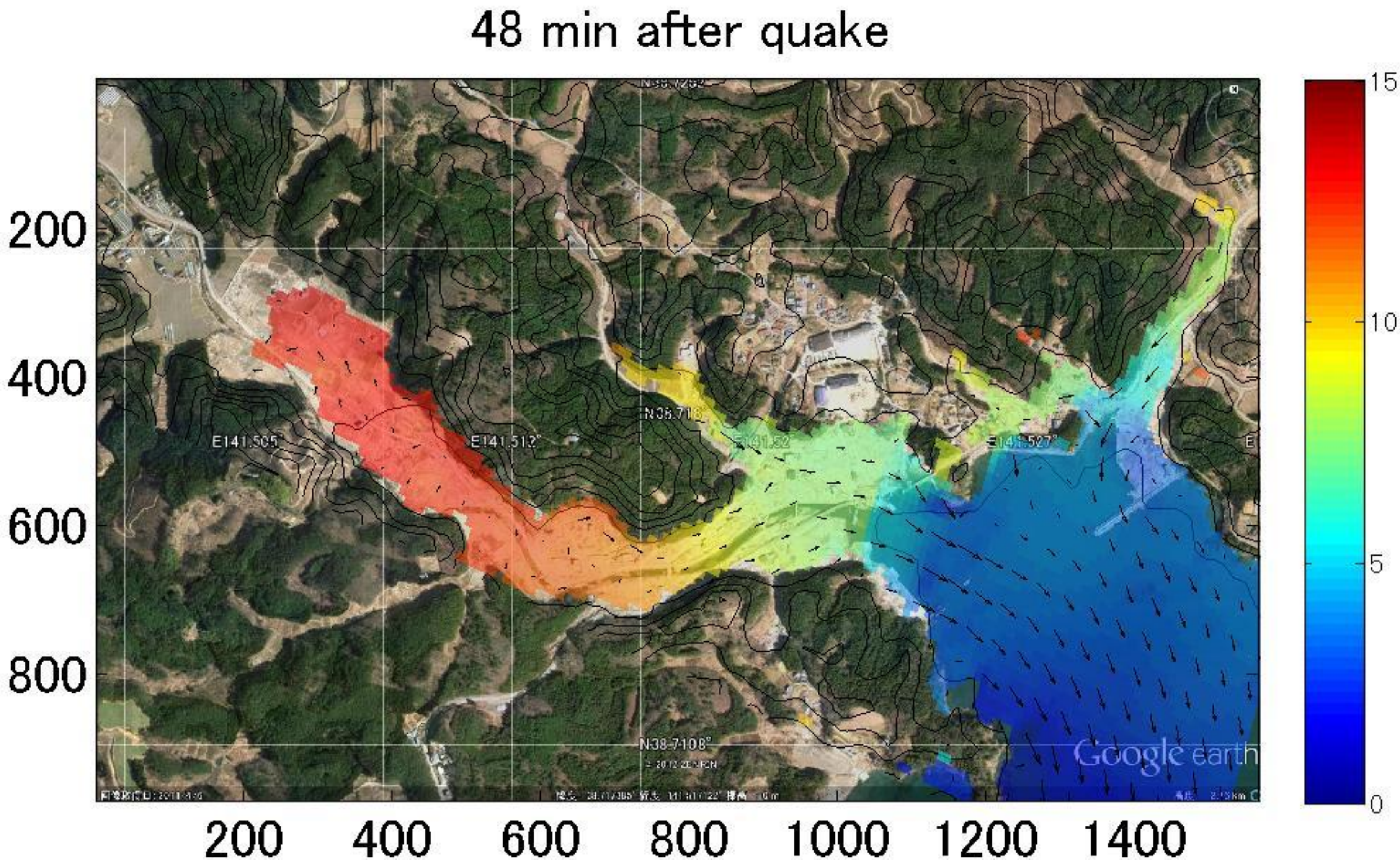
Tsunami behavior – Utatsu with Seawall



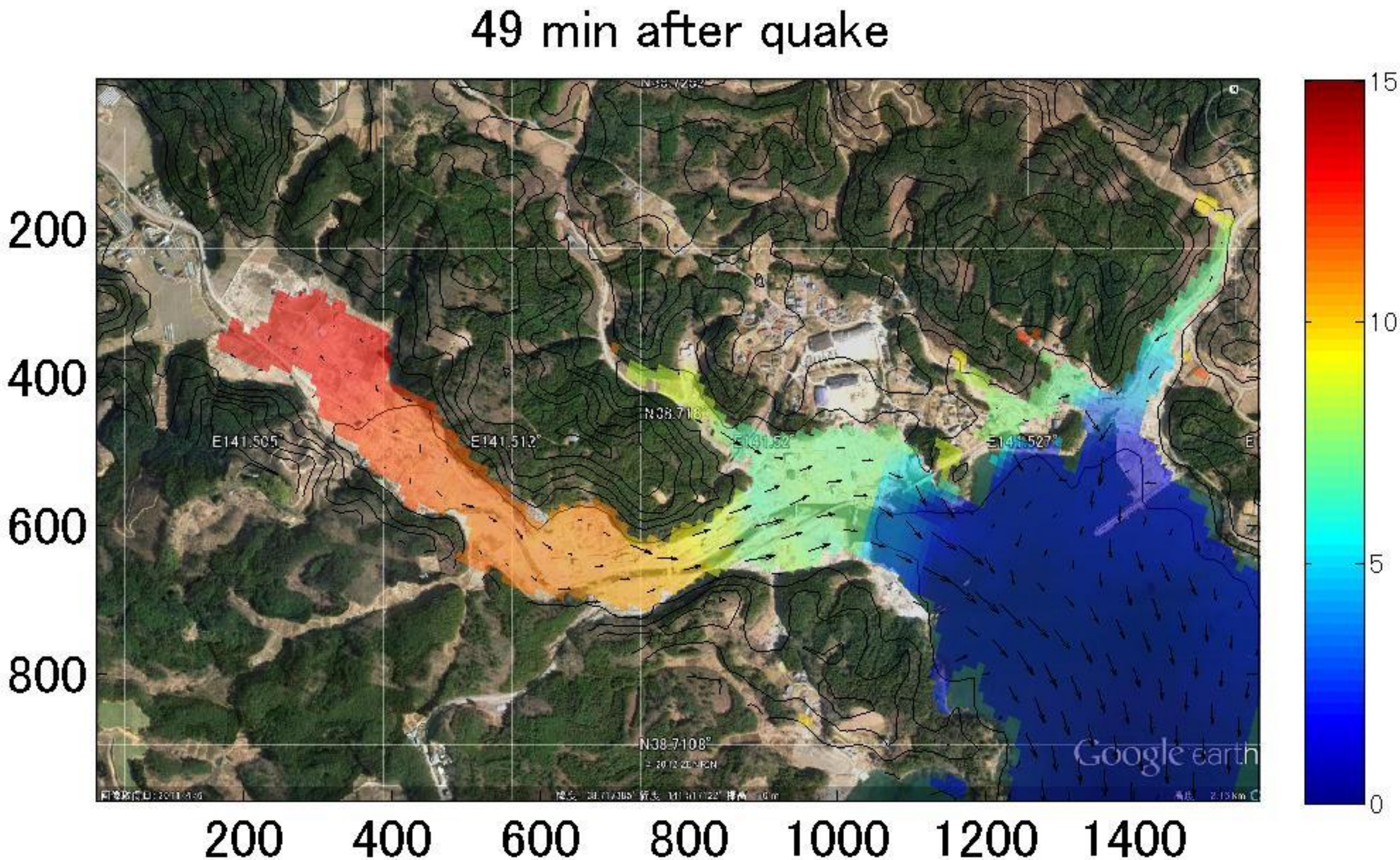
Tsunami behavior – Utatsu with Seawall



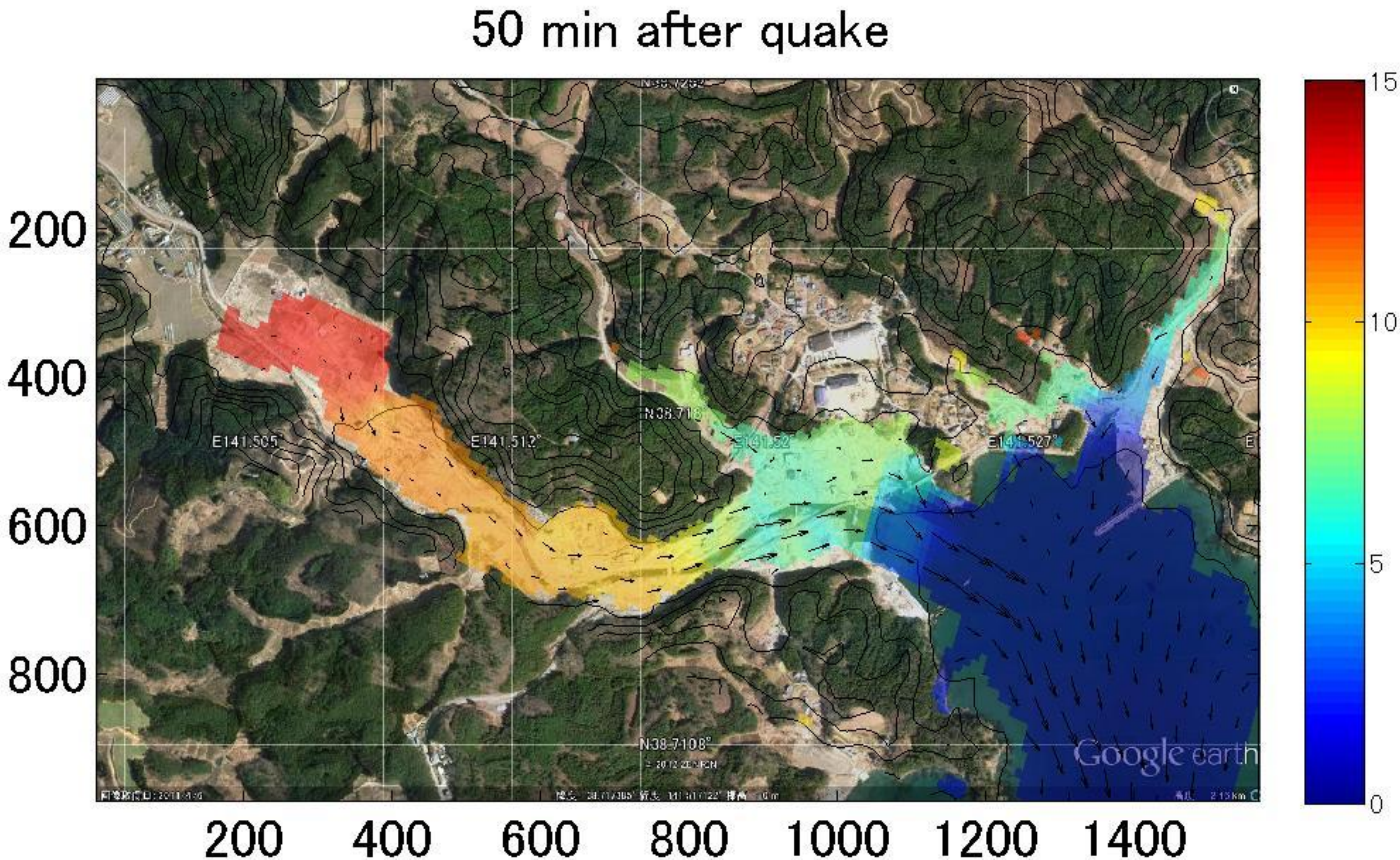
Tsunami behavior – Utatsu with Seawall



Tsunami behavior – Utatsu with Seawall



Tsunami behavior – Utatsu with Seawall

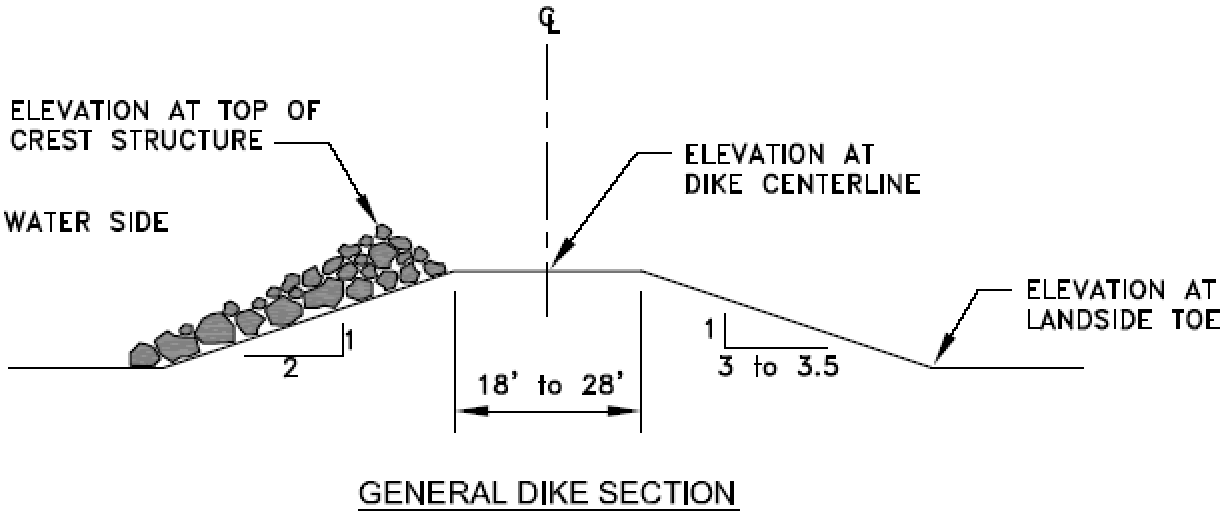


Wave Mechanics

- Coastal levees and shore protection
- Breakwaters
- Generating power from waves

Wave Mechanics

- Coastal levees and shore protection



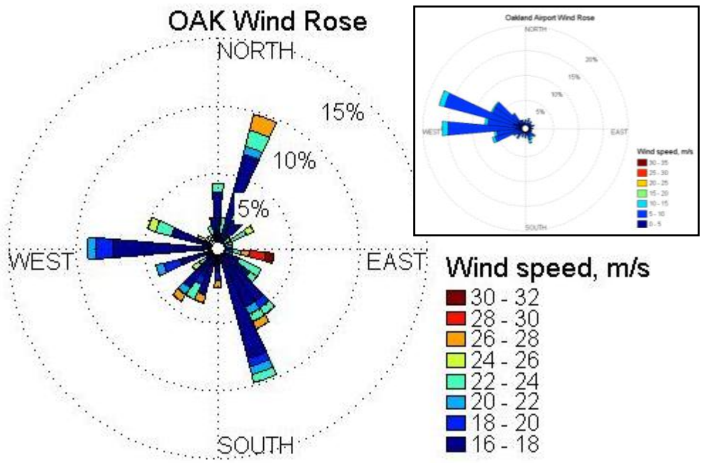
Wave Mechanics

- Coastal erosion – San Francisco Ocean Beach
- Riprap to protect highway and wastewater outfall

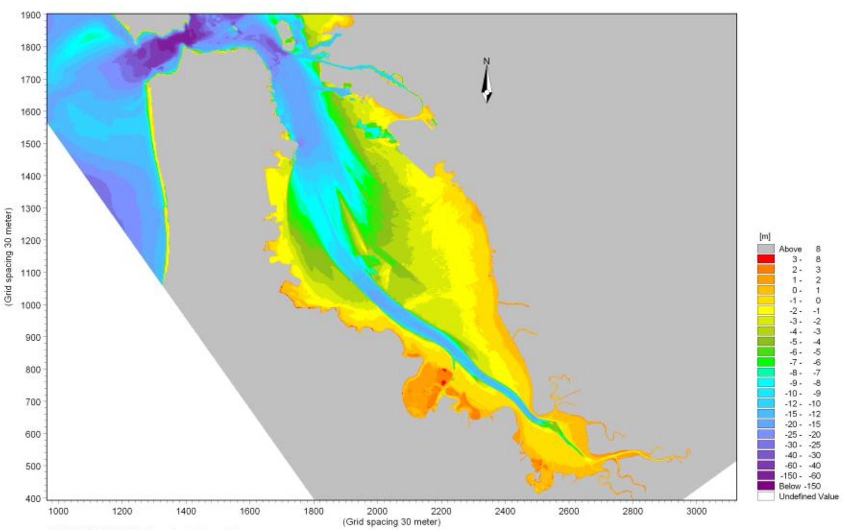
Wave Mechanics

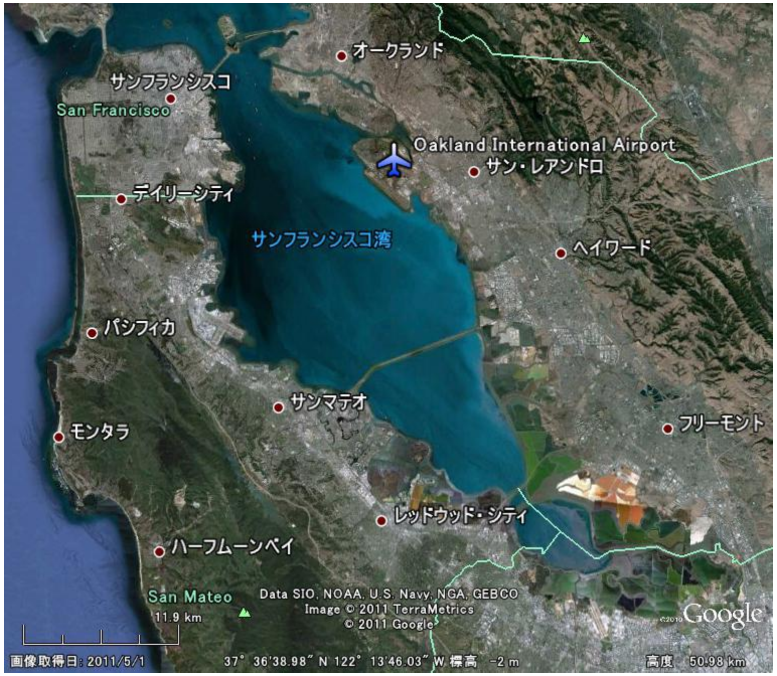
- Coastal levees and shore protection
- Oakland International Airport and San Francisco International Airport
- How do we design levee height and armor size?
- Wave modeling

Wave Mechanics



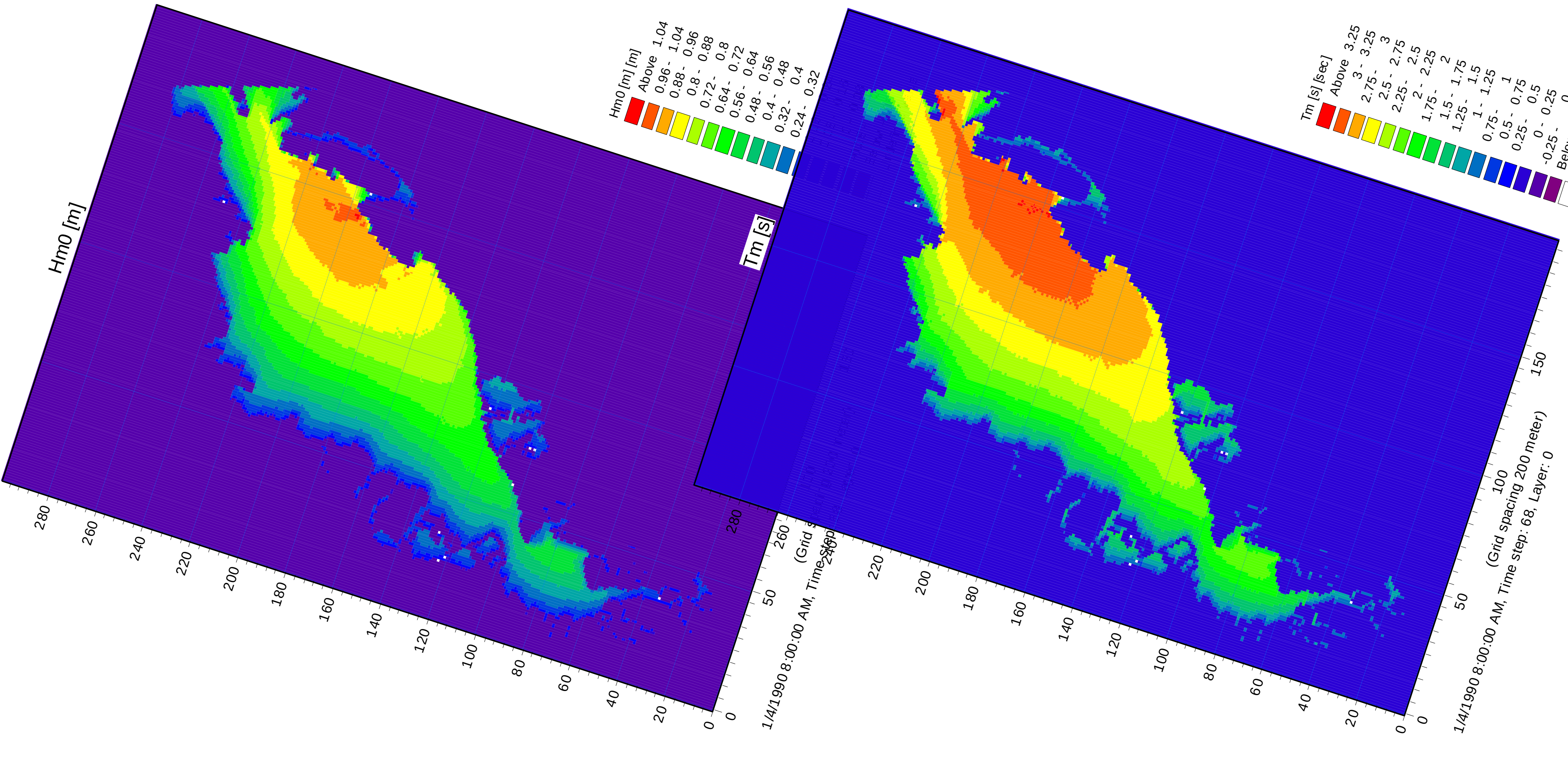
- Hindcast wave field at airports





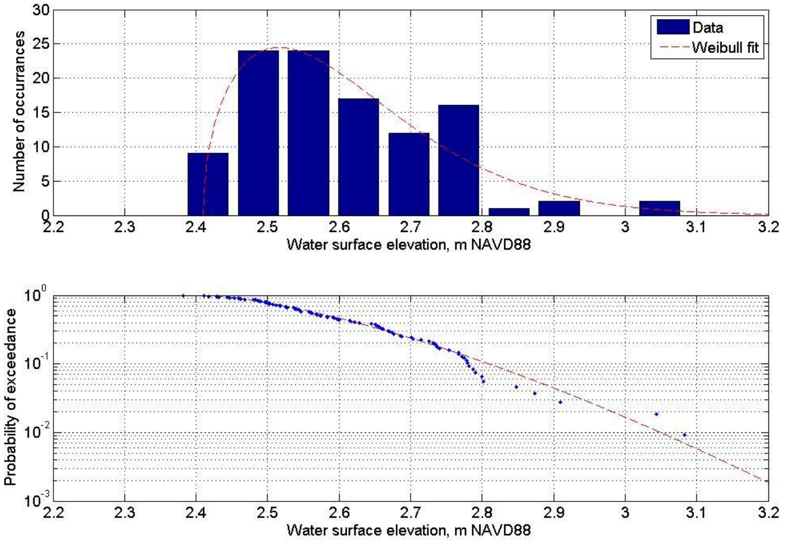
Wave Mechanics

- Hindcast wave field at airports

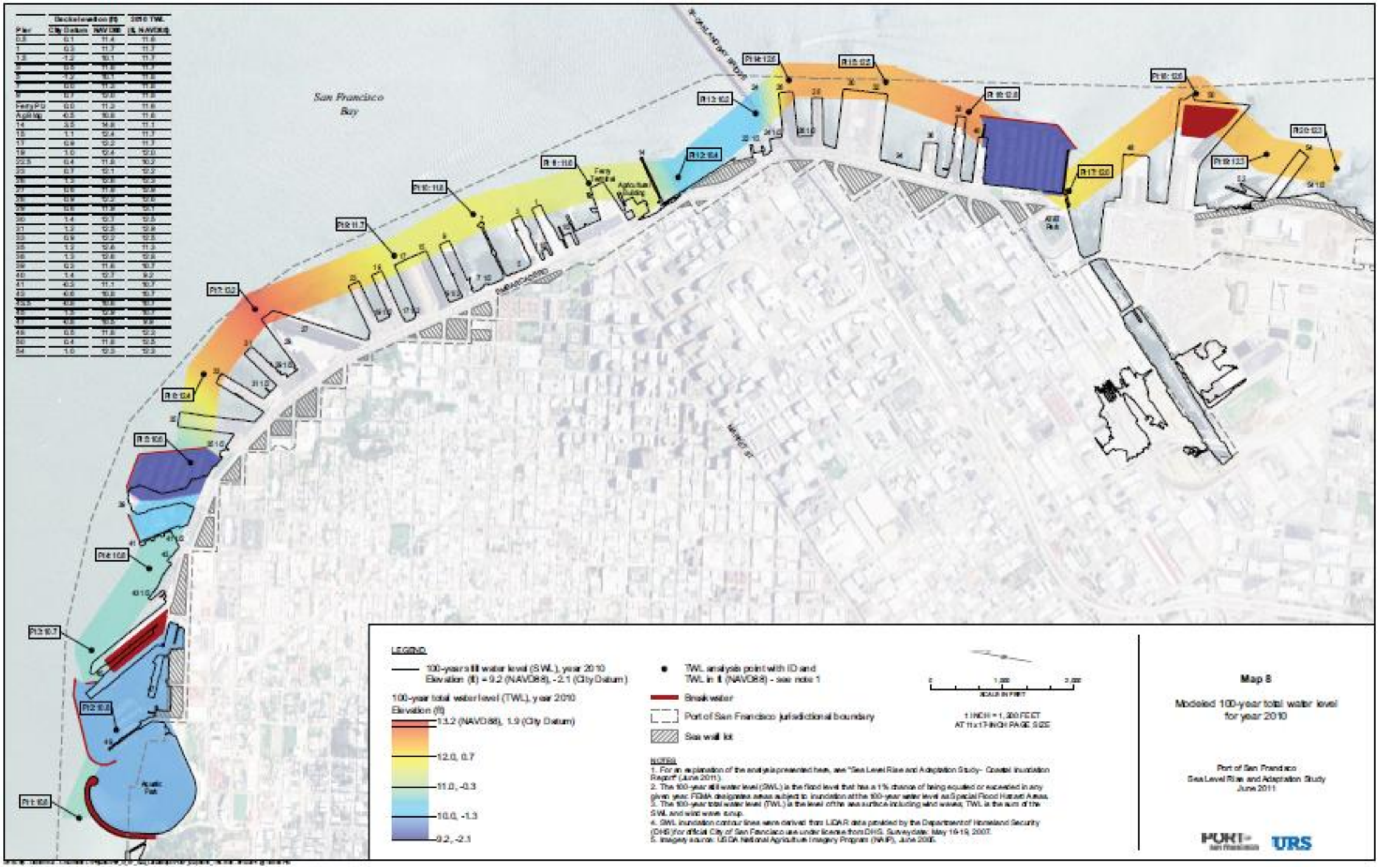


Wave Mechanics

- Hindcast wave field at airports
- Model results -> Annual maximum wave heights
- Design wave height

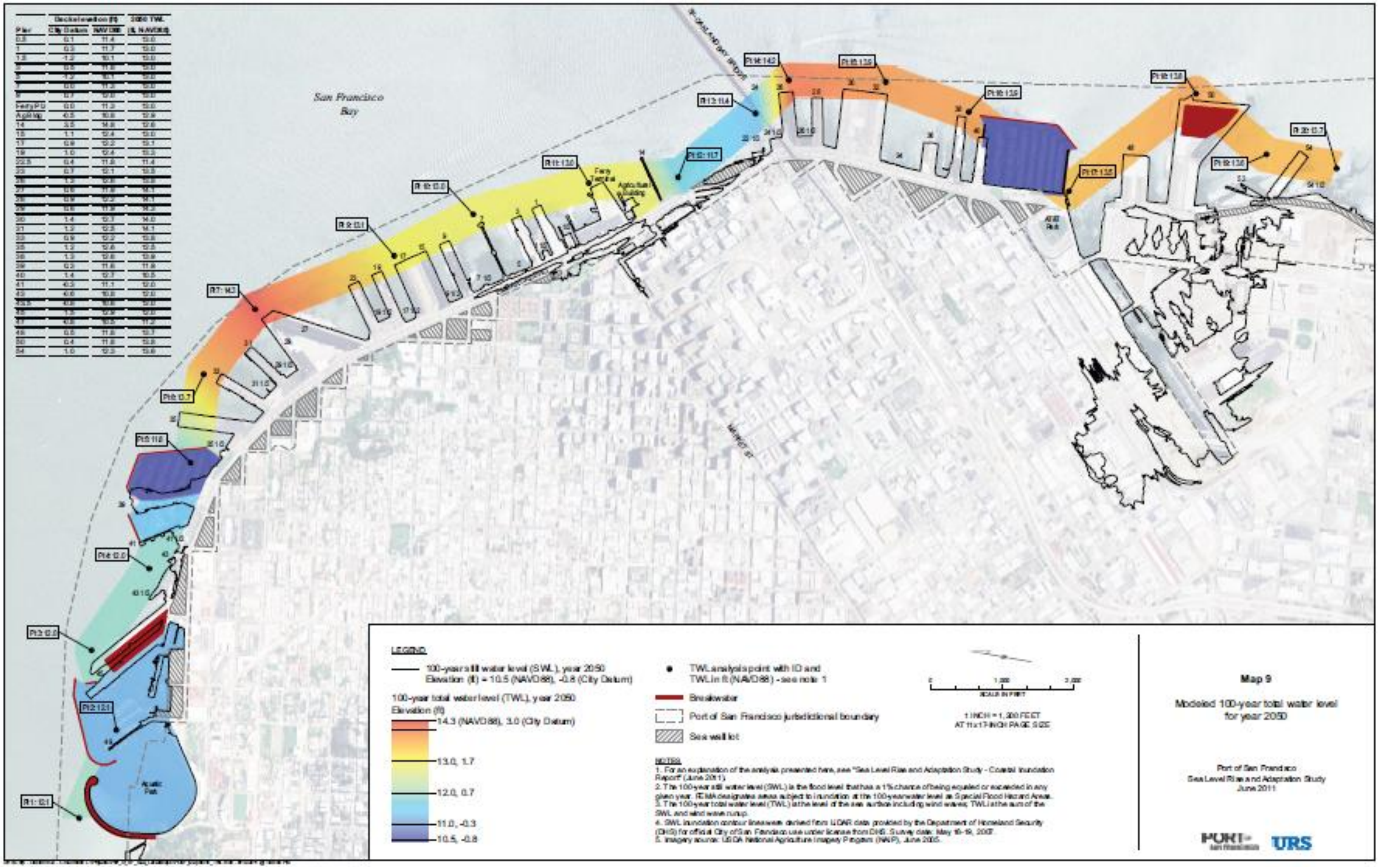


Wave Mechanics



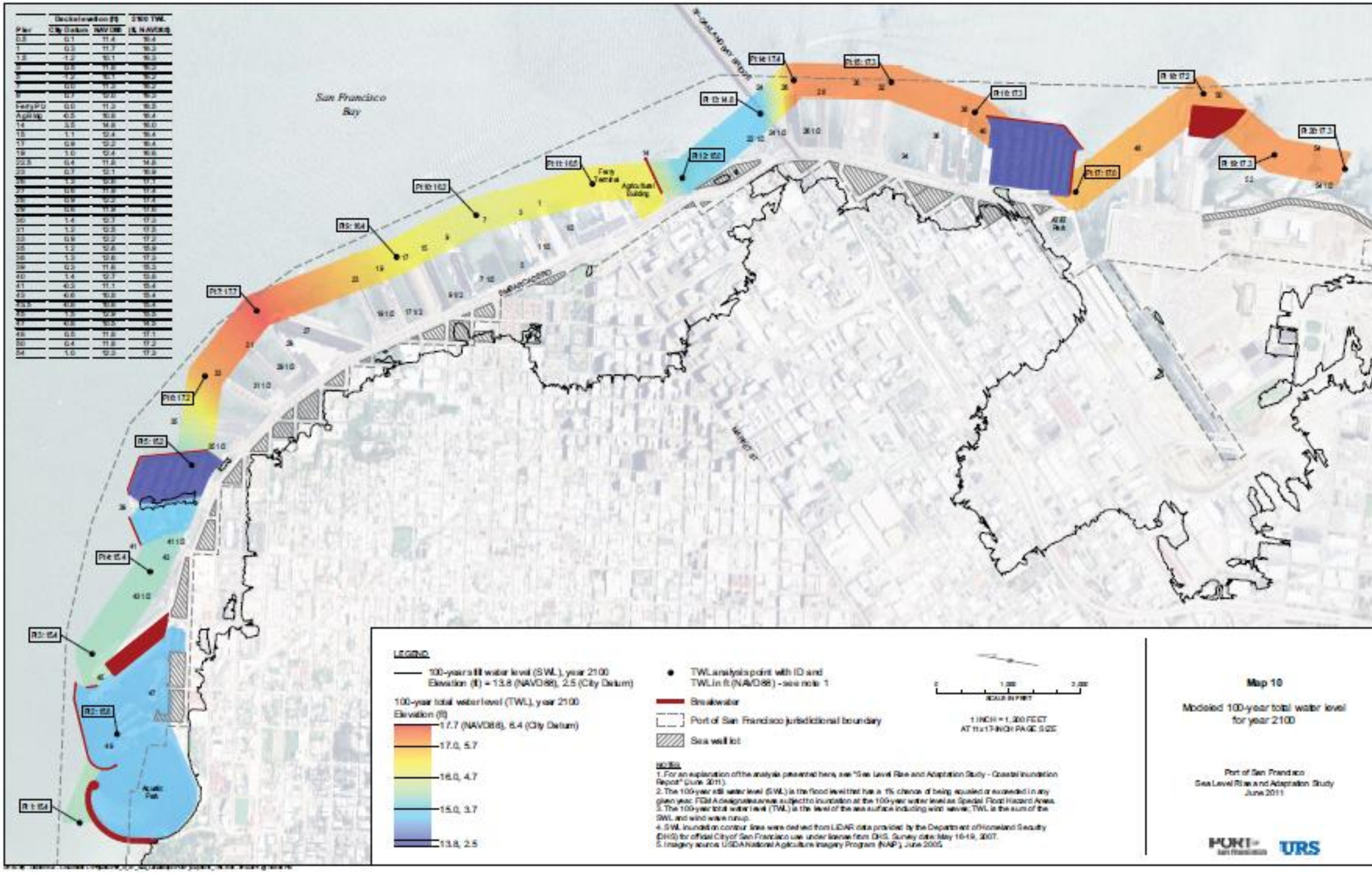
Port of San Francisco Sea Level in 2010

Wave Mechanics



Port of San Francisco Sea Level in 2050 (40 cm higher than today)

Wave Mechanics



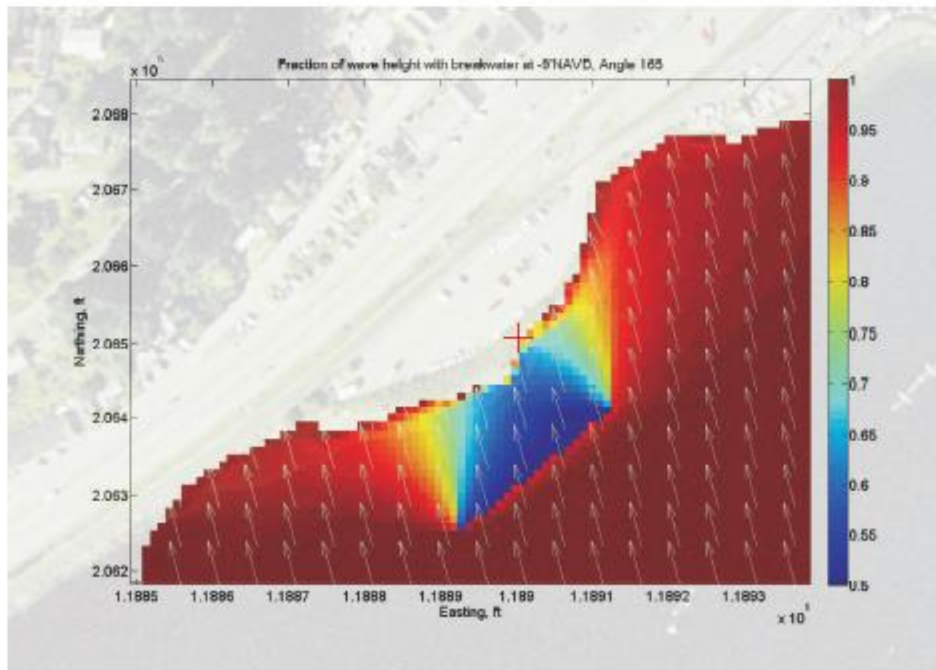
Port of San Francisco Sea Level in 2050 (140 cm higher than today)

Wave Mechanics

- Breakwaters

Wave Mechanics

- Modeling breakwaters with SWAN



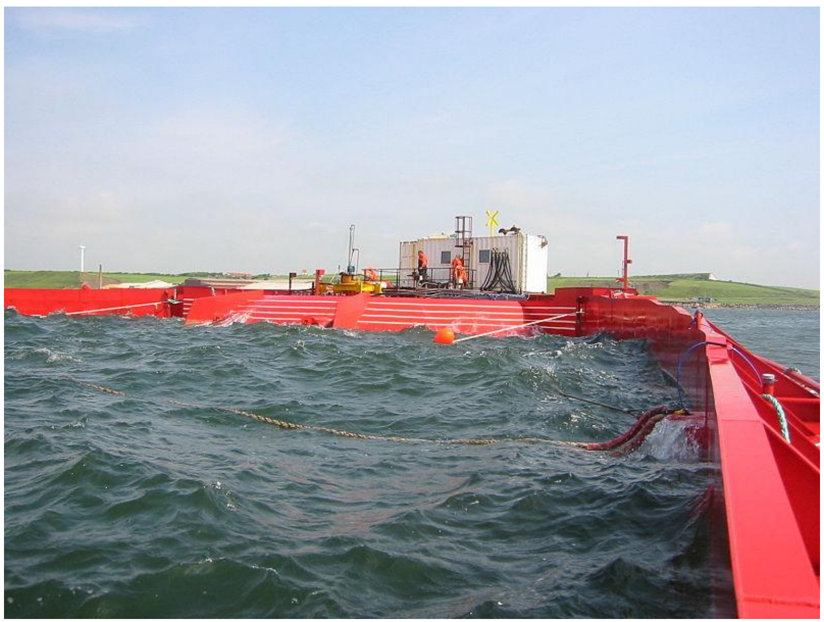
U.S.NAVY

Delivery Order 0057
Bremerton Naval Complex
CHARLESTON BEACH
ALTERNATIVES EVALUATION

Figure 4-14
Predicted Wave Dissipation for Alternative 4 with a 165° Wind

Wave Mechanics

- Wave power absorbers

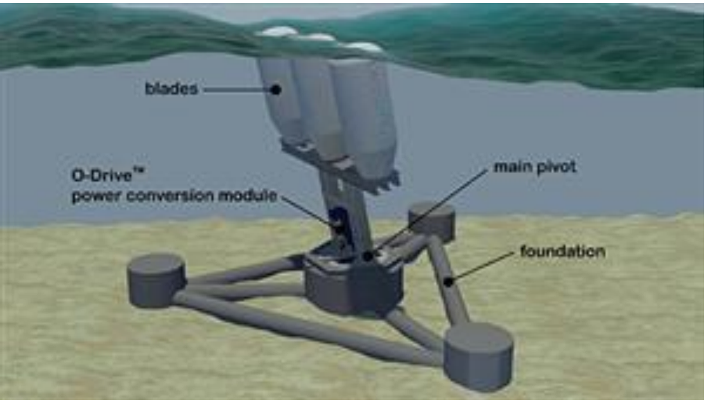


Wave Dragon

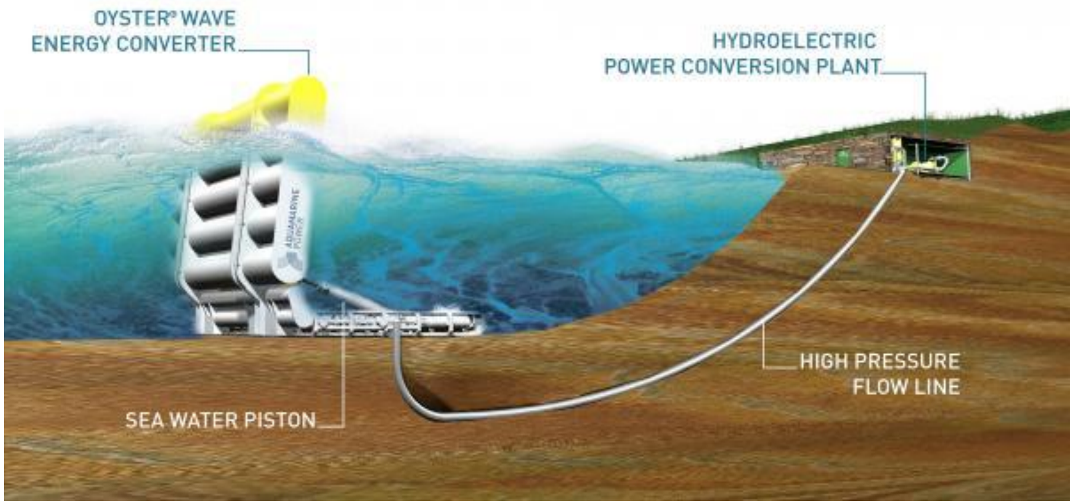
Pelamis

Wave Mechanics

- Wave power absorbers



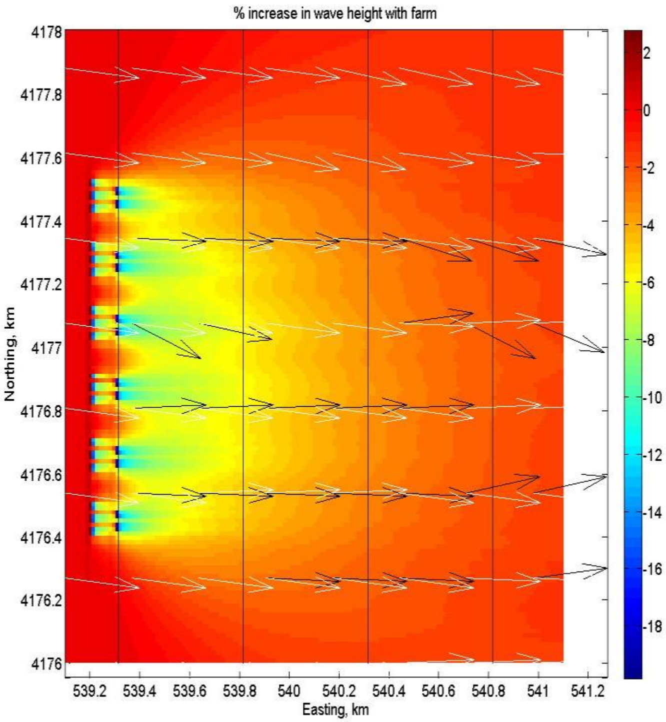
BioWave

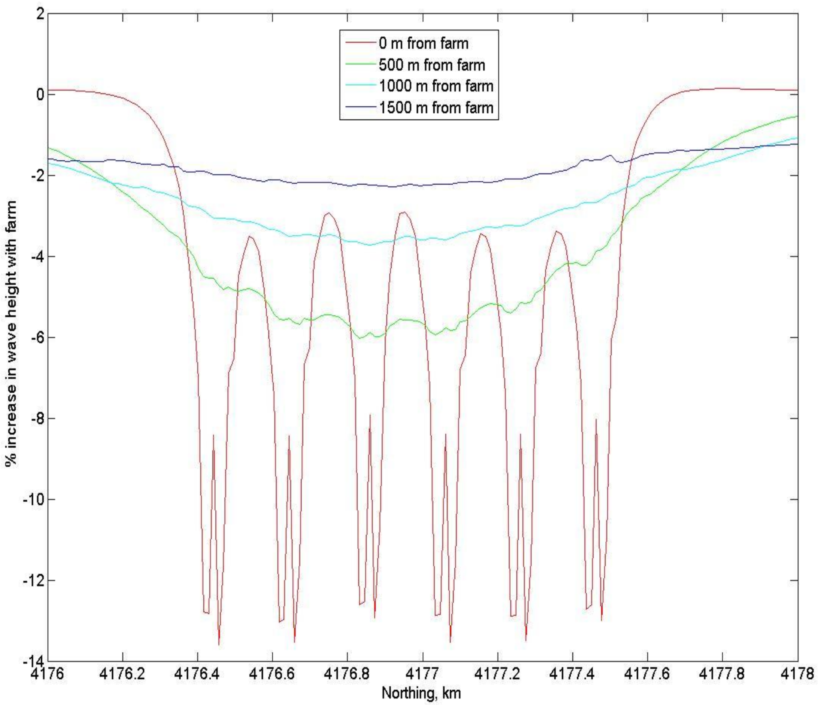


Aquamarine Power

Wave Mechanics

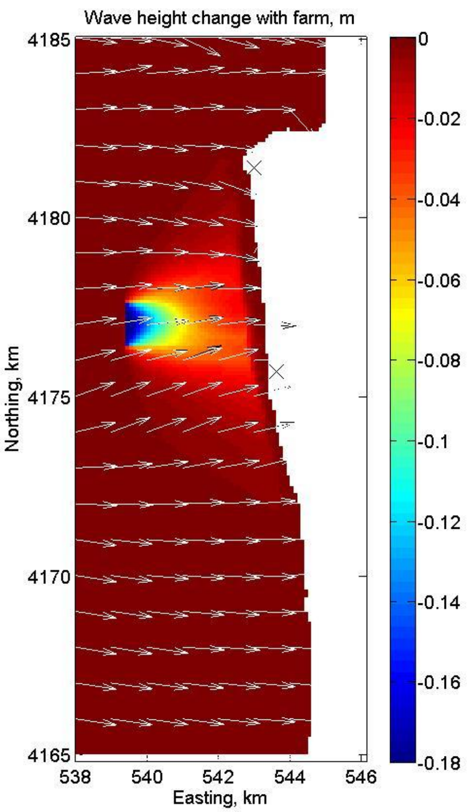
- Wave power absorbers – wave field





Wave Mechanics

- Wave power absorbers – coastal erosion



Course Outline

- Hydrology
- River hydraulics
- Coastal hydraulics
- Wave mechanics

Next Week!

- Form groups
- Each group: bring a laptop
- Hydrology – gauged basins
    - Statistics theory: normal and log-normal distributed data
    - Practice: use HEC-SSP to calculate the design (100-yr) flood
- Ungauged basins
    - Theory: rational method
    - Practice: apply rational method to calculate design flood