Tsunami Warning Center

SOPs

Concept of Operations, Overview of Routine and Event Operations, Flow Charts, Timelines and Checklists

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SOP
4 NTWC Cases

Local EQ/Tsunami
1. with Real Time seismic processing
2. with No Seismic processing

Distant EQ/Tsunami
3. with Real Time seismic processing
4. with No Seismic processing
Same quality at any time

- Scientist?
- Case by case?
Sequence and Components of Tsunami Warning System

Generation of Tsunami

Occurrence of Earthquake

Detection of Seismic Wave

Determination of Magnitude and Hypocenter

Evaluation of Tsunami

Issuance of Tsunami Warning

Re-evaluation of Tsunami

Issuance of Tsunami Information

Components of Tsunami Warning System

Network of seismometers

Real time transmission of seismic data

Real time data processing system

Criteria for Tsunami grade

Communication facility to disseminate Tsunami Warning

Network of tide gauge to monitor tsunami
JMA Standard Seismic Station Apparatus

Short period sensor (velocity type)

Accelerometer sensor
Determination of Magnitude and Hypocenter

1. Real-time Data Collection

2. Read P/S Arrival Time and Maximum Amplitude

3. Determination of the Hypocenter

Seismic Wave

- P arrival
- S arrival

Distance from the Hypocenter

Maximum Amplitude

Magnitude
The Tokachi-oki Earthquake in 2003

Determination of the Hypocenter

Seismic wave
Tsunami Monitoring Network in Japan

- Tide Gauge (Float Type)
- Tide Gauge (Acoustic Type)
- Huge Tsunami Gauge
- Pressure Sensor on Sea Floor

Map showing the locations of different types of tsunami monitoring equipment across Japan.
Tsunami Monitoring

Tsunami actually observed of the Tokachi-oki earthquake in 2003

2003/09/26 04:00 -- 2003/09/26 24:00
Example of Tsunami Simulation

Numerical simulation technique is very powerful tool for precise and detailed tsunami estimation.
Referring to the determined location and magnitude of the earthquake, the system searches tsunami database and picks up the most appropriate scenario from the database.

Issuance of tsunami warning which contains estimated arrival time and height at each coastal region (66 regions in Japan)
Time Sequence to Issue Earthquake Information and Tsunami Warning

Earthquake Information (Hypocenter and Magnitude)

Seismic Intensity Information

Tsunami Warning

Tsunami Information (Estimated Tsunami Heights and Arrival Times)

Tsunami Information (Observed Tsunami Heights and Arrival Times)
# Tsunami Information

## Tsunami Information (Observed Tsunami Data)

<table>
<thead>
<tr>
<th>Location</th>
<th>Initial Tsunami</th>
<th>Time</th>
<th>Maximum Tsunami</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>KUSHIRO</td>
<td>Initial Tsunami</td>
<td>0506 (+)</td>
<td>Maximum Tsunami</td>
<td>0903</td>
</tr>
<tr>
<td>HANASAKI</td>
<td>Initial Tsunami</td>
<td>0527 (+)</td>
<td>Maximum Tsunami</td>
<td>0540</td>
</tr>
<tr>
<td>URAKAWA</td>
<td>Initial Tsunami</td>
<td>0507 (+)</td>
<td>Maximum Tsunami</td>
<td>0624</td>
</tr>
<tr>
<td>MURORAN</td>
<td>Initial Tsunami</td>
<td>0526 (-)</td>
<td>Maximum Tsunami</td>
<td>0726</td>
</tr>
<tr>
<td>HAKODATE</td>
<td>Initial Tsunami</td>
<td>0605 (+)</td>
<td>Maximum Tsunami</td>
<td>0818</td>
</tr>
<tr>
<td>HACHINOHE</td>
<td>Initial Tsunami</td>
<td>0544 (+)</td>
<td>Maximum Tsunami</td>
<td>0817</td>
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<tr>
<td>SEKINEHAMA</td>
<td>Initial Tsunami</td>
<td>0539 (+)</td>
<td>Maximum Tsunami</td>
<td>0747</td>
</tr>
<tr>
<td>MIYAKO</td>
<td>Initial Tsunami</td>
<td>0534 (+)</td>
<td>Maximum Tsunami</td>
<td>0544</td>
</tr>
<tr>
<td>OFUNATO</td>
<td>Initial Tsunami</td>
<td>0544 (+)</td>
<td>Maximum Tsunami</td>
<td>0549</td>
</tr>
<tr>
<td>KAMAISHI</td>
<td>Initial Tsunami</td>
<td>0540 (+)</td>
<td>Maximum Tsunami</td>
<td>0747</td>
</tr>
<tr>
<td>AYUKAWA</td>
<td>Initial Tsunami</td>
<td>0559 (+)</td>
<td>Maximum Tsunami</td>
<td>0900</td>
</tr>
<tr>
<td>ONAHAMA</td>
<td>Initial Tsunami</td>
<td>0615 (+)</td>
<td>Maximum Tsunami</td>
<td>0823</td>
</tr>
</tbody>
</table>

**TSUNAMI WARNING/ADVISORY WAS ALL CLEARED**

However, there may be slight sea level changes at some coasts. Caution should be paid in sea bathing or fishing.

**Earthquake Information**

Occurred at 0450 JST 26 Sep 2003

Region Name: Tokachi

Latitude: 41.7N

Longitude: 144.2E

Depth: 60KM

Magnitude: 7.8
Daily operation

• Check 1: operating system
• Check 2: Status of seismic and sea level station
• Final reading of seismogram and location
• Report of the readings and location to the international agencies such as International Seismic center (ISC)
• Publish the Reports
Preparation of Templates

- **Warning**: severity, threat area, time of arrival, action to be taken/instruction
- **Advisory**: threat area, action to be taken/instruction
- **Information**: content and timing to be issued
- **Termination**: content and timing to be issued
- In case of False Warning/Information by miss operation
Compare with past-seismicity [especially on the focal depth]
Check of Magnitude

- **O-C Residual**
- **Histogram of Station Magnitude**
- **Magnitude Time-series**

Click to see the background seismicity

Click to Finalize the Hypocenter and Magnitude
PTWC Checklist (mod) Pacific Events - Initial Bulletin (10-20 min)

Locate Epicenter (Tele-EQ, Pick, nquake) ..............................................................O
Make/Examine Location Map (nquake) .................................................................O
Determine Depth (nquake) .....................................................................................O
Determine Magnitude (Mwp) ..................................................................................O
Issue Observatory Message ...................................................................................O
Start Mm (with email to Papeete if Mw>7), SMAG, Theta .................................O
Coordinate with WC/ATWC or their parameters if EQ in their AOR ............O
Select Message Type based on Criteria ..............................................................O
Call in Other Watchstanders to Help (Warnings) ..............................................O
Compute/Print/[Map] ETAs if a Warning or Tsunami TIB .................................O
Run Message Software (for Pacific and Hawaii) ...............................................O

For Both Pacific / Hawaii Messages, Check before Sending: Pacific Hawaii

Bulletin Number (should be 1) ................................................................. O ...........O
Message Type ................................................................................................. O ...........O
Which Places in Warning/Watch and Hawaii Status .............. O ...........O
Add Statement for Anything Unusual ..................................................... O ...........O
Earthquake Parameters .............................................................................. O ...........O
Estimated Arrival Times ............................................................................ O ...........O

Read HAWAS message (hawmsg) .................................................................O

Check that all Messages Went Out and Resend if Necessary

DCS, AFTN, NMC, Fax/Telex, NWW .................................................................O
Web, Email, IDN, EMWIN, HFO Fax .................................................................O

Call Down List .................................................................................................O

Continue for all subsequent TIBs with Expected Potentially
PTWC CHECKLISTS - REMINDERS

Call Down List ........................................................................................................................................O
Continue for Warnings and TIBs with Tsunami Potential
Call Closest Countries
  Confirm they got our message ............................................................................................................O
  Ask if they have any reports ..............................................................................................................O
Make Displays and Monitor Nearest Sea Level Gauges .................................................................O
Trigger DARTS at least 30-min ahead of their ETAs .........................................................................O
Run Whitmore Model ..............................................................................................................................O
Run SIFT Model .....................................................................................................................................O
Review Historical Data ..........................................................................................................................O
Check for Tsunami or Slow Earthquake (Mw vs Ms, Theta) ...............................................................O
Monitor email for other EQ params and CMTs ....................................................................................O
Keep SCD advised on HAWAS ............................................................................................................O
SUMMARY - MOVING FORWARD

• Develop SOPs
• Use SOPs (Real Event or Exercise)
• Did they work?
  If not, revise them IMMEDIATELY
• KEEP IT CLEAR, CONCISE, SIMPLE
• FOLLOW YOUR PROCEDURES
• It becomes your basis for action, and is defendable post-event
Tsunami and Earthquake Monitoring System

Operation and maintenance
24 hours a day 7 days a week

Battle against time
Earthquake in Hawaii Region

Timeline to Issue Initial Warning Bulletin

- First Location
- Watchstanders Paged
- Refining Location, Magnitude
- Heads Up Voice Message
- Voice Warning Issued
- Text Bulletin Issued

Time in Seconds:

0 30 120 180 240
Earthquake Outside Hawaii Region

Timeline to Issue Initial Bulletin

- Watchstanders Paged
- First Location
- Refining Location, Magnitude
- Earthquake Msg. Issued (CISN)
- Text Bulletin Issued

Time in Minutes

ITP Training Course, Honolulu HI, Aug. 20-31, 2012
Earthquake Components - Tsunami Warning system

- Network of seismographs
- Real time data transmission
- Real time data processing
- Criteria for Tsunami grade
- Communication facility to Disseminate Tsunami Warning
- Sea Level Network to monitor tsunami

Tsunami Detection
- Detect Seismic Wave
- Determine Magnitude, Hypocenter
- Evaluate Tsunami
- Issue Tsunami Warning
- Issue Tsunami Information

Detection Tsunami

Re-evaluate Tsunami

Tsunami
Standard Operational Procedure (SOP)

“A description and procedure on agreed steps by TWC used in coordinating Who, What, When, Where, How for tsunami early warning”
Requirement for Operator in case of an Event

• Skill of quick and reliable operation
• Quick recognition of location from a pattern of P arrival times
• Confirm NOT multiple events in a same time window
• Quick recognition of magnitude
• Selection of necessary stations to be amended
"Review Tool" – (1)

- Epicenter distribution
- Background Seismicity
- Hypocenter Information
- Cross section
- Hypocenter and station distribution
- Residual (Upper diagram for P phase and lower for S phase)
"Review Tool"– (2)

Green : Residual of P phase is from over -0.5 to under +0.5 sec
Pink : Residual of P phase is above +0.5 sec
Light Blue : Residual of P phase is below -0.5 sec
Small orange dot : Not used for phase reading

O-C of P phase
Green : Residual of P phase is from over -0.5 to under +0.5 sec
Pink : Residual of S phase is above +0.5 sec
Light Blue : Residual of P phase is below -0.5 sec

O-C of S phase
If the hypocenter is determined inside the mantle wedge, it should be reviewed.
0. **EQ!!! - Digital Alarm - Duty Staff paged**

1. Detect and Analyze Large Earthquake
2. Determine Tsunami Hazard based on Pre-Determined Criteria
3. Issue Initial Message
4. Further Seismic Analyses
5. Detect and Analyze Tsunami Signals
6. Re-evaluate Tsunami Hazard
7. Issue Additional Message
8. Repeat Steps 4-7 until Threat Passed
9. Cancellation or Final Message
Different Types of SOP Documents

1. Official SOP documents for management purposes

2. Comprehensive TW operations SOP documents with many details for study and reference during non-crisis

3. Quick-Reference SOP documents for reference during crisis

4. Systems SOP documents so recipients understand TWC/TER SOP and what to expect (Users Guide)
For TWC Customers – Users Guide

• System overview / history
• Arrangements / Organizations
• TWC Procedures / Criteria (SOPs)
• Products and their Meaning, includes Example Products
• Technical Background and Interpretation Guidance
  – Tsunami science and hazard
  – EQ source characterization
  – Message interpretation for emergency response
  – Sea level measurement
  – Travel time calculation
  – Wave forecasting
• Glossary
Official SOPs for Management

• Directives
  – TWC Performance Expectations
  – Roles & Responsibilities / Concept of Operations
  – Maintained by Parent Organization
  – Formal Review / Change Process with Organizational Stakeholders

• Station Duty Manual
  – Duty Staff Performance Expectations
  – Maintained by TWC Management
  – Includes Tasks outside Crisis Operations
  – Formal Review / Change Process with Staff
Tsunami Warning Systems as an end-to-end system

upstream
detection, verification, tsunami forecast, warning dissemination

• downstream
delivery of warnings, initiate national counter-measures, prepare and implement standardized reaction

--- Goal: same quality at every time ---
TWC - Concept of Operations
Roles and Responsibilities
Transmission / Dissemination of Warning

**TWC...**
- Issues tsunami warning
- Takes measures for warning dissemination
- Makes efforts to disseminate warning to public, asking for media cooperation

**Local governments / DMO ...**
- Disseminate warning to residents
- Warn residents and relevant organizations to take actions against expected disasters
TWC - Concept of Operations
Operation 24 hrs/day, 7 days/week ...

**Continuous Operation**

- Morning/Evening Briefings - overlap in shifts to brief next shift
- Daily Report - issued EQ info, seismic activity, system status during shift
- Daily Schedule Sheet - checklist of daily tasks

*Same Quality at any time*
Why are SOPs important?

• Foundation of effective, reliable warning systems
• All warning systems require SOPs, but for tsunami, rapid evaluation, warning and response is essential to save lives
• In an end-to-end system, communications links between stakeholders must be robust or warning chain will be broken
• SOPs should be developed, practiced and modified as necessary – a “living document”
SOPs are Living Documents

Main TWC Characteristics
– Fast
– Accurate
– Reliable
– Effective

Main TWC Activities
– Seismic Data Collection and Analysis
– Sea Level Data Collection and Analysis
– Decision-Making Tools and Procedures
– Message Creation and Dissemination
TWC Operations Manual:
(Refer to during non-crisis)

- Most Detailed
- Steps to Carry Out
  - How? Why?
- Logical Flow
  - Flow Charts, Timelines
- Background Information
  - Scientific Basis
  - Organizational Basis
  - Definitions
- Format
  - Paper, Electronic (Web Based)
For Warning Centers, SOPs are not just on what to do in an Earthquake.

They should also be geared to maintaining:

100% Operational Reliability
1. Data availability monitoring
2. Data quality monitoring
3. Maintenance and repair priorities
4. System Alteration Procedures
5. System Failure Procedures

Long Term Readiness:
1. Communication Tests
2. Table-top Exercises
The first warning should be announced by detecting the earthquake before tsunami is observed.
What are SOPs?

Based on US Environmental Protection Agency Manual

- Set of **written instructions** for routine/repetitive organization activities. Procedure followed in an emergency.

- Detail **work processes** conducted/followed within organization.

- Document way activities performed for **consistent conformance** to system requirements and organisation’s mission.
Flow Charts

Effective Way of Presenting SOPs

Flow Charts Indicate:

• Steps to be followed
• Decision Tree
• Systems or subsystems involved

• Flow Charts can be nested
• BUT, often not useful in real event (cannot give answer when there is uncertainty or data lacking) (experience is most important)
e.g., For Warning Centers, SOPs are not just on what to do in an Earthquake.

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Flow Charts

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<table>
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<tr>
<th>Elapse</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 min</td>
<td><strong>JMA: Major Tsunami Warning M: 7.9</strong>&lt;br&gt;6 m for Miyagi, 3 m for Iwate &amp; Fukushima</td>
</tr>
<tr>
<td>10</td>
<td>PTWC: Warning for Japan, Russia M: 7.9 (JMA)</td>
</tr>
<tr>
<td>13</td>
<td>JMA: “observed tsunami height; 20 cm”</td>
</tr>
<tr>
<td>28</td>
<td><em>(Updated Warning)</em> JMA: more than 10 m for Miyagi 6 m for Iwate &amp; Fukushima 3 m for Aomori</td>
</tr>
<tr>
<td>33</td>
<td>DART (E off Tohoku): 1.1 m tsunami</td>
</tr>
<tr>
<td>57</td>
<td>PTWC: M: 8.8</td>
</tr>
<tr>
<td>57</td>
<td>DART (S of Kuril): 0.7 m</td>
</tr>
<tr>
<td>1:22</td>
<td>JMA M: 8.4</td>
</tr>
<tr>
<td>2:44</td>
<td>JMA: Mw: 8.8</td>
</tr>
</tbody>
</table>
Comments to JMA from the 3rd party

- 1st Warning was extremely lower
- Improvement of the Warning message; clear and simple message
  
  (3 m tsunami warning & 0.2 m observed tsunami height were understood as safety information)

- Multiple procedures for M estimation
- Need off-shore tsunami measurement
- Challenge for a gigantic tsunami (M: 9)
Thank You

Laura Kong
Director
International Tsunami Information Center