

Draft

SINDH

TSUNAMI MANAGEMENT AND RESPONSE PLAN



**PROVINCIAL DISASTER MANAGEMENT AUTHORITY
GOVERNMENT OF SINDH**



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FORWARD

Since its inception, Provincial Disaster Management Authority, has been prioritizing critical areas for improving the effectiveness of disaster management in the Province. Over the time, various structural and non-structural reforms in provincial disaster management have been achieved but still there are grey areas which need improvements. Tsunami hazard, though rare and occurred in 1945, with meagre historical record of damage and losses, has potential to bring large scale destruction along the coastal belt of Sindh. Because since then, population density and infrastructure along the coast has increased manifold so the vulnerabilities.

Though tsunami hazard, vulnerability and risk assessment has been conducted by PDMA while conducting Multi-hazard Vulnerability and Risk Assessment study for entire province and accordingly disaster management plans have been prepared, but it is felt necessary to prepare detailed disaster management and response plan for existing hazards in Sindh. This document i.e., Tsunami Management and Response Plan has been prepared as first of the series of publications by PDMA Sindh. All efforts have been made to make this plan as practical and applicable.

I am sure, our collective efforts towards disaster management will lead us to safer and prosperous Sindh.

Syed Salman Shah

INTRODUCTION & BACKGROUND

1. Overview

In subduction zones, tectonic plates of Earth dive back into the mantle. The subduction zones are key features of earth's plate tectonic regime. At subduction zones, earth's deepest (~ 700 km) and strongest earthquakes (Magnitude ~ 9) can occur. The Makran Subduction Zone (MSZ) along the coast of Balochistan, is highly prone to tsunamigenic earthquakes. Historical evidence of seismic activity along the Makran Subduction Zone evidences the potential tsunami hazard for the entire 1100 km coast of Pakistan.

During the last 75 years, over 50 earthquakes of magnitude 8 and above have been reported along the coastline of Pakistan, out of which 1919, 1943, 1945, and 1965 were accompanied by tsunamis. The waves generated by tsunami of 1945 reached the height of 13m (40 ft) along the Makran coast. Despite incomplete historical records of losses from the tsunami, more than 4000 people died from the combined effect of the earthquake and tsunami. Though thinly populated coastal belt at that time, some entire villages and infrastructure were swapped out to the sea. The losses due to tsunami were reported beyond Makran coast stretching to Karachi and the rest of the coastal belt of Sindh. The statistical probability of tsunami similar to 1945 is 1-in-150 years.

Today, the development and population density along the coast stretching from Balochistan to Sindh is manifold in comparison to 1945 and similar tsunamigenic earthquake may result in enormous losses and damages. With the current population, the exposure and risk of communities and infrastructure to a tsunamigenic earthquake will have disastrous human, social and economic consequences for this area. The coastal belt of Sindh is prone to receive tsunami effects particularly, Karachi South, East, West, Keamari, Korangi, Malir, Sujawal, Thatta, and Badin. Mostly population and infrastructure situated in low-lying areas and along the coastal creeks may likely receive more devastating impacts.

An approaching Tsunami is a time-critical event, tsunami waves engulf coastal areas in a matter of minutes giving unprepared communities very little time to react. As per tsunami models, the coastal cities of Balochistan i.e., Gwadar, Ormara, and Pasni may inundate within 25 minutes and Karachi and the rest of the coastal belt of Sindh may receive tsunami waves within 45 minutes of occurrence of the event.

As little time is available to respond to tsunamis, therefore, awareness, preparedness, and clearly chalked out roles and responsibilities of all stakeholders, including communities at risk

is the only viable solution to reduce human loss in the wake of tsunami hazard. With regard to earthquake monitoring and tsunami warning, Pakistan Meteorological Department have designated National Tsunami Warning Centers (NTWC) along with necessary tsunami modeling software and mechanism for warning preparation and dissemination. Due to time-bound nature of actions required for post tsunami warning, it is essential to clearly work out guidelines and standard operating procedures with clear roles and responsibilities for tsunami response. This will ensure required actions in less possible time for the safety of communities at risk living in tsunami hazard-prone areas.

2. Tsunami Hazard

To date globally, seventy-five percent of all tsunamis have been caused by subduction zone earthquakes; the recent large, devastating tsunamis of Tohoku in 2011 and Sumatra in 2004 were both subduction zone tsunamis. The Makran Subduction Zone (MKZ) is highly prone not just to tsunamigenic earthquakes but also landslide tsunamis. The high seismic potential of the MSZ is indicated by the historical evidence of at least eight tsunamigenic earthquakes that occurred between 326 BC till 2013. The vicinity of the MSZ to Pakistan's coastline makes this coastal region prone to near-field tsunami threats; a near-field tsunami will affect Pakistan, Iran, India and Oman. Depending upon its moment magnitude, a tsunamigenic earthquake in the MSZ has the potential to trigger a far-field tsunami in eight countries in the north western Indian Ocean. Although the MSZ is still not well understood, it can be concluded from past events such as the 1945 tsunami that the tsunami waves generated by a Makran source could reach the shores of India, Iran, Pakistan, Oman and other adjoining countries within a very short time with height of several meters, posing enormous challenges to existing tsunami warning systems.

Tsunamis are generated when geologic events cause large, rapid movements in the sea floor that displace the water column above. These destructive waves can be caused by coastal or submarine landslides or volcanism, but they are most commonly caused by large submarine earthquakes. Pakistan's Makran coastline is at risk both from near-field and far-field tsunamis. Some key characteristics for understanding tsunami are;

- An earthquake will be 'tsunamigenic' when it occurs in a subduction zone plate boundary; has a minimum magnitude of 7 on the Richter scale; and, causes a vertical displacement of the sea bed with a commensurate collapse of the overlying water mass.

This displacement and subsequent collapse of the water mass generates a series of travelling waves of extremely long length and period which is referred to as a 'tsunami'.

- Far-field tsunamis originate from a distant source, defined as more than 1,000 km, sometimes travelling across an ocean. Usually starting as a near-field tsunami that causes extensive destruction near the source, these waves continue to travel across entire ocean basins with sufficient energy to cause additional casualties and destruction on shores more than 1000 km from its source. The Indian Ocean tsunami of 2004 was one of the most devastating far-field tsunamis in recent history.
- Near-field / local tsunamis will typically occur within 200 km of the epicentre of an earthquake. Nearfield tsunamis can be caused by earthquakes, landslides, or volcanic eruption. Pakistan is highly prone to near-field subduction zone tsunamis and will likely be less affected by non-earthquake sources.
- Tsunami is a series of waves caused by a sudden, large displacement of water most often caused by earthquakes, but also by landslides; volcanic eruptions; and comet or meteorite impacts in the ocean.
- Is like a fast-rising flood tide, storm surge or an advancing wall of water and strikes with devastating force.
- May also be first manifested as a recession of water.
- Currents may present a larger danger than the wave amplitude.
- Surges may continue for longer period of time after arrival of major tide.
- In the open ocean, tsunami waves have a long wavelength (distance from the crest of one wave to the crest of the succeeding wave) normally over 150 km/h, and a very low amplitude (height from crest to trough). As these waves approach shallow water, their speed is decreased from a deep-water speed of over 965 km/h to less than 50 km/h. The wave energy is transferred from wave speed to wave height many times that of height in the open ocean giving the tsunami a destructive power once it makes landfall.

2.1. Worst Case Scenario of Tsunami Hazard in Pakistan

The Makran Subduction Zone is an active boundary between the converging Arabian and Eurasian plates and is considered to be an area of large seismic potential. Historical evidence and scientific research suggest a worst-case scenario wherein the MSZ ruptures along the entire length of 800 km, causing an earthquake of M_w 8.7-9.2. The ensuing tsunami would likely exceed 10m in height and engulf the coasts of northern Oman, southeast Iran, Pakistan and northwest India.

2.2. Tsunami Hazard Area

Vertical movement of sea floor caused by major earthquake generates tsunami. If the sea floor movement is horizontal, tsunamis are not generated as in strike slip earthquake. However, it is equally possible that tsunamis are triggered also by marine landslides into or under the water surface. They can also be generated by volcanic activity and meteorite impacts, but such events are extremely rare. Tsunami hazard along a coastline is therefore a combination of all the potential sources of tsunamis that lie in the neighboring sea or ocean. Tsunami velocity is dependent on the depth of water through which it travels, and is equal to the square root of depth times the gravitational acceleration. Tsunami waves travel at a speed of approximately 700 km/hr. in 4000 m of water. In 10 m of water the velocity drops to about 36 km/hr. Tsunami velocity and wavelength in different water depths is shown in Figure-2.2.1.

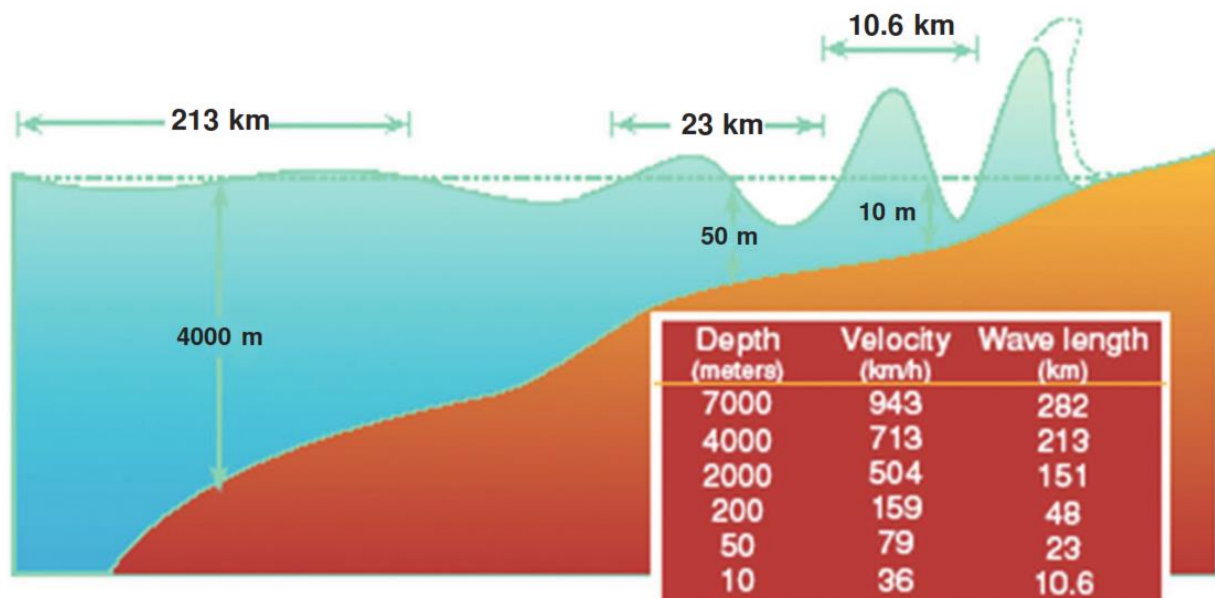


Figure- 2.2.1. Tsunami velocity and wavelength versus depth

Tsunami Hazard area can be empirically defined using deterministic approach, i.e., based on any earlier run-up and inundation during tsunami and potential maximum wave heights of scenario tsunami. As there is hardly any record of tsunami which occurred in 1945 due to

earthquake in MSZ and effected the coast of Sindh, therefore, scenario tsunami inundation can only be achieved and simulation results have been used in determination of tsunami hazard and risk assessment conducted by PDMA. With regard to Tsunami Hazard Area (THZ), the terrestrial environment, the hazards may be presented as inundation levels, in terms of run-up heights at specified land contours. Actual tsunami hazard of a coastline depends on its bathymetry and coastal topography. However, with regard to tsunami hazard, generally a coastal area can be divided into 4 zones as given in Figure-2.2.2.

These zones can be defined as;

Zone-1 maximum water depth 0-3 m

Zone-2 maximum water depth 3-6 m

Zone-3 maximum water depth 6-9 m

Zone-4 maximum water depth > 9 m

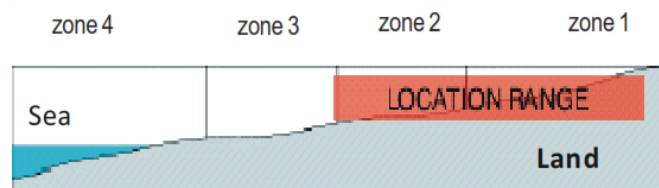


Figure 2.2.2. Coastal Zonation

In this zonation the Zone-1 is less the less dangerous zone and the zone 4 as the most dangerous zone.

2.3. Tsunami Vulnerabilities

Vulnerability is predisposition of something likely to be affected because of characteristics of a system, process and community. It is expressed as elements of the built, natural and human environments vulnerable to potential tsunami-related damage. Tsunami Hazard Zones (THZs) consisting terrestrial environments and marine environments along the coast is vulnerable to tsunami hazard. Tsunami damage is primarily caused by hydrological effects to structures by pressure and suction, scouring and liquefaction, cracking and slumping and result in structural damage to buildings, contents in the house, as well as damage to infrastructure. Additionally, tsunami waves can bring debris and other material along with which pose additional threat to structures on the way.

Generic natural and terrestrial environment which is vulnerable to tsunami include;

- The ecologically sensitive coastal physiography including mangroves; coral reefs; sand beaches; sand dunes; inland tidal water bodies, i.e., estuaries, lakes, lagoons, creeks; mudflats; marine wildlife protected areas; coastal fresh water lakes; salt marshes; turtle

nesting grounds; horse shoe crab habitats; sea grass beds; sea weed beds and nesting grounds of migratory birds.

- The other areas of particular concern are population living along the coast; livelihood resources; ports and harbors; tourism sites; mining sites and industrial estates; Special Economic Zones; cultural heritage and archaeological sites; critical defense installations; power plants; and any other strategic installations.
- In addition to physical vulnerabilities, social vulnerability is also most important factor. Social vulnerability includes lack of local institutional mechanisms, appropriate skills, local investments, rapid population changes, deforestation of coastal forests, decline in soil fertility, local income level, socio-economic conditions and cultural issues if any.

TSUNAMI HAZARD IN SINDH

3. Tsunami Signs and Clues at Coasts

When in deep ocean or sea tsunami waves are difficult to detect, even ships in waters may not differentiate tsunami wave. However, when waves reach near shores their speed and wavelength is decreased and wave trough appear as water wall travelling along the way. Near-field tsunami can reach the shores within minutes, hence little reaction time for evacuation. Today's technological developments are supporting tsunami warning and dissemination, determination of tsunami, possible wave heights, arrival timing, and dissemination of alerts and warning to communities at risk. However, processing time for all these activities may take time and so the issuance of formal tsunami warning. Therefore, awareness and preparedness of population at risk is the only feasible and viable solution for saving lives of communities living along Tsunami Hazard Zones. With respect to tsunami threat, resilience and self-reliance of communities at risk matter the most.

As mentioned, tsunami is secondary disaster triggered by earthquake or any of the other causes, therefore, communities must be aware of and respond to clues and calls of nature before arriving official alerts and warnings. Once such signs are obvious and observable, the communities must act for safe evacuation to already identified safe sites and shift to roofs of their homes. Natural calls for tsunami threat are;

- Population near the epicenter may feel long or very long shaking of ground.
- Population near the epicenter may hear loud roar from the ocean / sea similar to train or jet aircraft.
- Rapid / unusual fall or rise of water level near the shores.
- Sudden exposure of sea / ocean floor, reefs and fish.
- Unusual wave forms and sea level fluctuations.
- Appearance of bubbles in sea / ocean.
- Change in sea color.

Tsunami is unwarned natural event. Lives can be saved through raising tsunami threat perception, awareness and raising social responsibility of the communities living in tsunami hazard zones.

As per standard operating procedures, official alerts or warning are issued on occurrence of earthquake with the potential to generate tsunami, however formal warning for evacuation from tsunami hazard zone is issued after detection tsunami waves by the gauges / buoys in the sea. Before arriving the official tsunami warning, it is imperative that communities residing in tsunami hazard zone must immediately evacuate to higher / safer locations on any of above sign or clues have been appeared.

4. Tsunami Hazard and Risk in Sindh

There is hardly any recorded evidence of damages and losses caused by tsunami along the coast of Sindh. Some record suggests that during the 1945 event, the tsunami affected the coastal population of Balochistan and also reached the coast of Sindh and caused damages in Karachi harbor. The tsunami waves were 12-15 meter in height at Balochistan coast. Karachi harbor experienced 6 feet high waves which affected harbor facilities. Certainly, coastal population and infrastructure during 1945 was nominal which have been increased manifold as of today and any untoward tsunami can cause large scale destruction. The 2004 Indian Ocean Tsunami did not reach Pakistan, however, abnormal rise in sea water was detected by tide gauge station at Keti Bander.

Recently Provincial Disaster Management Authority with the technical assistance of SUPARCO have completed multi hazard vulnerability and risk assessment for entire province covering pertinent hazards in Sindh including tsunami. The tsunami hazard assessment was carried out using GeoCLAW model with synthetic earthquake accompanied with tsunami. The tsunami propagation and possible inundation have been mapped using three earthquake scenarios i.e., 9.0, 8.5, 8.0 magnitudes. The inundation maps were overlayed on attribute database to ascertain possible vulnerabilities, risks, critical infrastructure and population likely to be affected within tsunami hazard zone. Tsunami risk maps of corresponding administrative jurisdictions have been prepared for assessment of possible case-load to be caused by tsunami.

4.1 Karachi Division

In Karachi Division, particularly population and infrastructure along the coast (approx. 138 km) are highly vulnerable because of thick population density, huge infrastructure including harbor, oil refineries, power plants and other industries. The occurrence of tsunami may cause catastrophic damages and losses and domino effects including environmental and health issues.

In wake of a tsunami event, the District South followed by District Korangi, Keamari, West, Malir and East will be most at-risk districts of the Karachi Division. The map in Figure 4.1 depicts 58 vulnerable Union Councils in corresponding districts with estimated 3,700,000 (3.7 million) populations (as of Census 2017) and other critical infrastructure likely to receive impacts of tsunami.

Details of population likely to be affected is given in Table 4.1

S.No.	District	Union Councils	Total Population	Population at Risk	Percentage
1	East	Akhtar Colony	28,723	28,723	100%
2		Azam Basti	13,680	13,680	100%
3		Chanesar Goth	28,146	23,157	82%
4		Dehli Mercantile	156,038	8,037	5%
5		Faisal Cantonment	326,070	30,718	9%
6		Manzoor Colony	130,939	130,939	100%
7		Mehmoodabad	38,791	35,909	93%
8		P.E.C.H.S 1	167,203	367	0.2%
9		Pakistan Qurts	88,642	50,915	57%
10	Korangi	Awami Colony	102,905	8,042	8%
11		Bilal Colony	299,666	298,968	100%
12		Chakra Goth	88,173	50,420	57%
13		Gulzar Colony	73,333	73,333	100%
14		Ibrahim Hyderi	225,095	222,701	99%
15		Korangi 33	76,708	6,903	9%
16		Nasir colony	194,201	194,201	100%
17		Natha Khan Goth	58,877	4,747	8%
18		Pak Sadaat Colony	40,956	40,956	100%
19	Reta Plot	23,139	2,339	10%	
20	Malir	100 Qurts	103,840	20,782	20%
21		Cattle Colont	104,253	6,758	6%
22		Hasrat Mohani	98,304	17,819	18%
23		Landhi	316,171	16,626	5%
24		Rehri	121,917	80,311	66%
25	South	Agrataj Colony	48,643	48,643	100%

26		Allama iqbal Colony	179,996	179,996	100%
27		Behar Colony	48,527	48,527	100%
28		Bhagdadi	53,096	53,096	100%
29		Cantonment	79,449	53,435	67%
30		Chakiwara	98,422	98,422	100%
31		City Railway Colony	72,296	72,296	100%
32		Civil Lines	29,140	29,140	100%
33		Clifton	148,362	148,362	100%
34		Darya Abad	65,821	65,821	100%
35		Defence	302,294	302,294	100%
36		Garden	38,429	38,429	100%
37		Gazdarabad	38,617	36,671	95%
38		Kehkeshan	53,502	53,502	100%
39		Khada Memon	61,276	61,276	100%
40		Kharadar	71,643	71,643	100%
41		Millat Nagar	60,294	60,294	100%
42		Nanak Wara	39,727	39,727	100%
43		Naw Abad	25,662	25,662	100%
44		Old Haji Camp	31,107	31,107	100%
45		Rangiwara	89,383	89,383	100%
46		Saddar	10,878	5,686	52%
47		Shahbaig lane	59,861	59,861	100%
48		Singo Lane	65,065	65,065	100%
49	West & Keamari	Baba Bhatt	104,421	104,421	100%
50		Bhutta Village	146,108	146,108	100%
51		Gabo Pat	83,534	23,198	28%
52		Jahanabad	73,339	64,754	88%
53		Keamari	22,451	22,451	100%
54		Machar Colony	61,351	61,351	100%
55		Mauripur	97,020	60,078	62%
56		Old Golomar	40,913	39,833	97%
57		Shershah	83,184	83,184	100%
58		Sultanabad	42,596	42,596	100%

Table- 4.1. Karachi Division Population Likely to be Affected

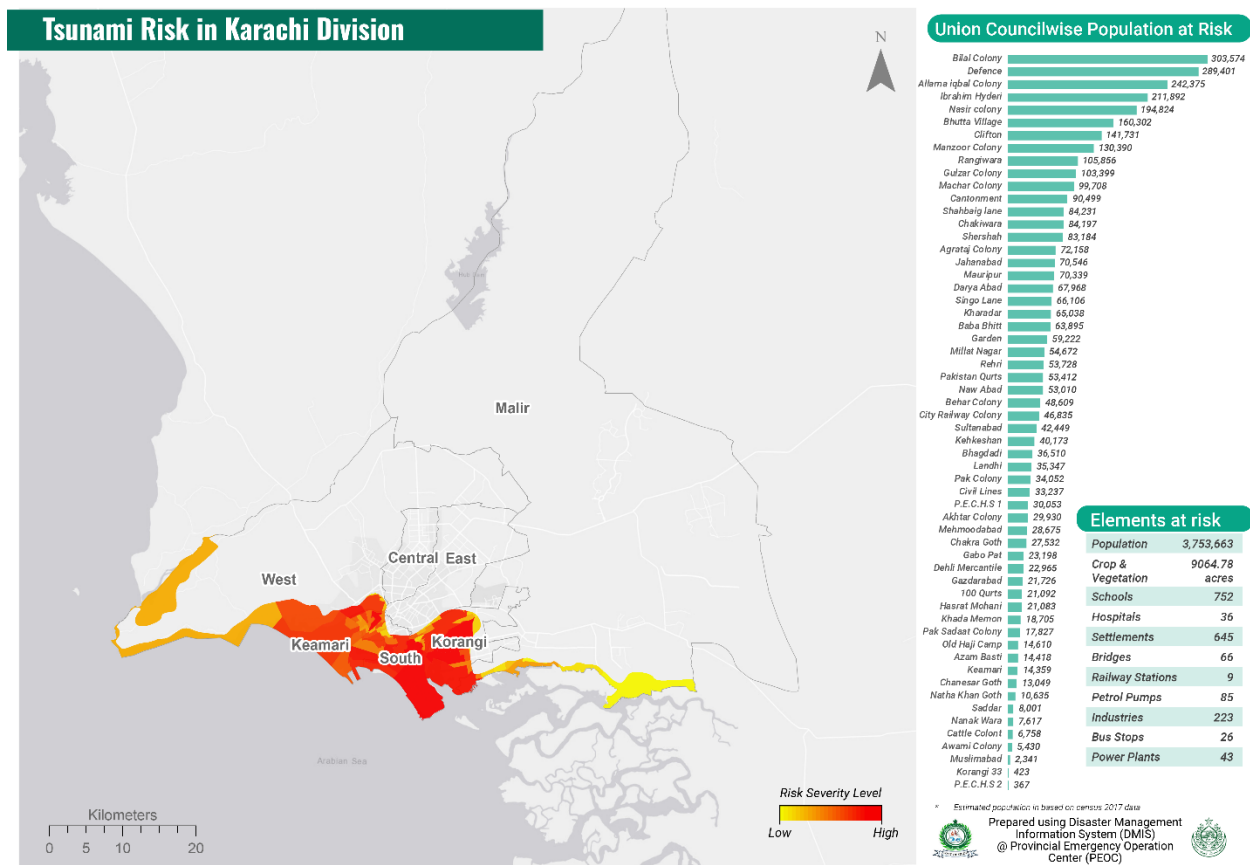


Figure 4.1 Karachi Division – Tsunami Risk Map

4.2 Thatta District

Thatta District lies immediately after Karachi division and covers approximately 149 km of coast. The coast comprises tidal creeks, mud flats, mangrove forest, River Indus and its tributaries, inland agriculture and infrastructure. A number of human settlements in 10 Union Councils as shown in Figure 4.2 comprising approximately 190,000 people (as of Census 2017). Inland cropland constitutes approximately 150,000 acres. It is also to be noted that the coastal belt of Sujawal and Thatta district support fishing as livelihood of many.

The natural ecosystem and environment along with significant population may likely receive impact of tsunami. Details of population likely to be affected is given in Table 4.2.

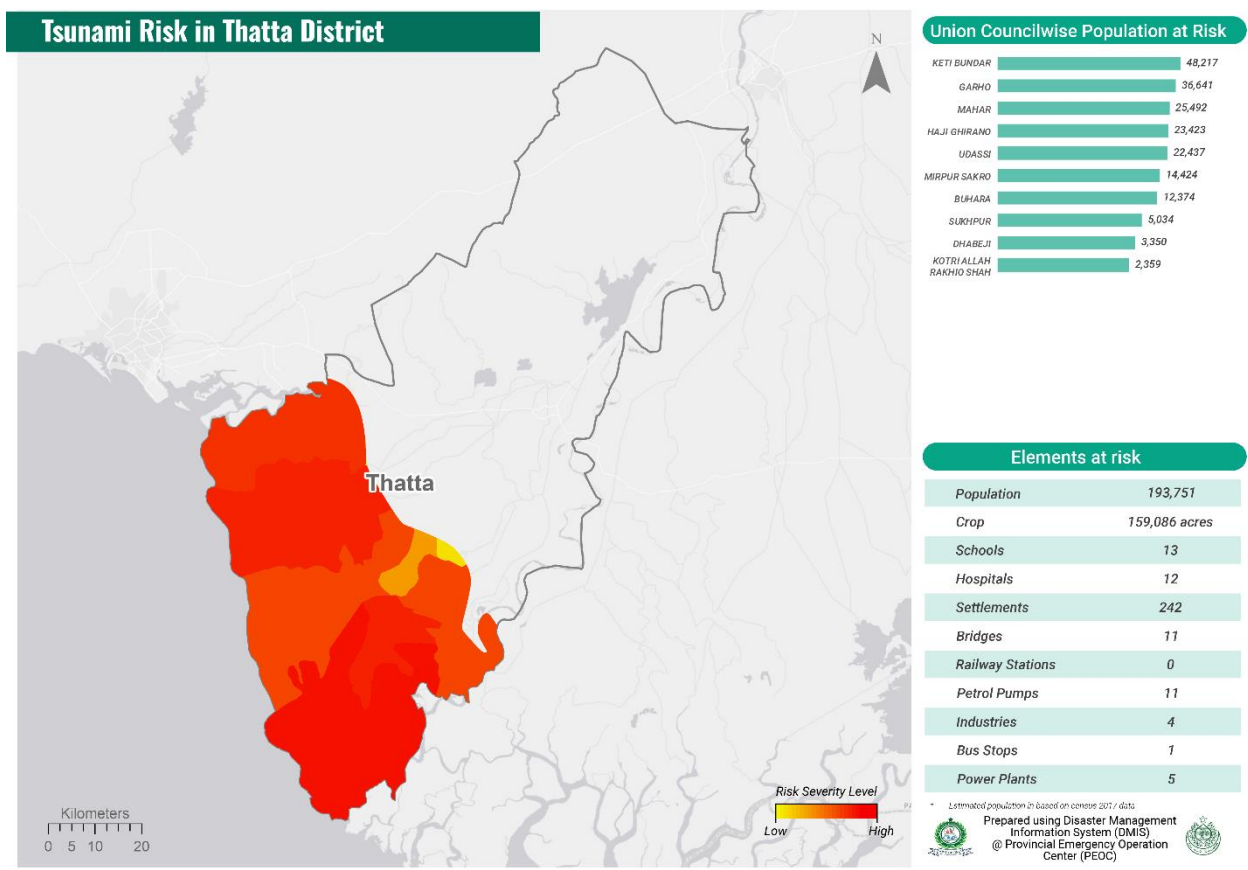


Figure 4.2 Thatta District – Tsunami Risk Map

S.No.	District	Union Councils	Total Population	Population at Risk	Percentage
1	Thatta	BUHARA	12,374	12,374	100%
2		DHABEJI	86,538	3,350	4%
3		GARHO	36,641	36,641	100%
4		HAJI GHIRANO	38,103	23,423	61%
5		KETI BUNDAR	48,217	48,217	100%
6		KOTRI ALLAH RAKHIO SHAH	36,913	2,359	6%
7		MAHAR	28,352	25,492	90%
8		MIRPUR SAKRO	15,925	14,424	91%
9		SUKHPUR	32,898	5,034	15%
10		UDASSI	26,278	22,437	85%

Table- 4.2. Thatta District Population Likely to be Affected

4.3 Sujawal District

The coast falling in Sujawal District stretches over approximately 207 km, and is composed of Indus River and tributaries, tidal creeks, mud flats, mangrove forests, and inland agriculture. Though the coastal belt is not as thickly populated as of Karachi, however still existing infrastructure and population maybe affected due to tsunami. With regard to coastal vulnerabilities natural ecosystem, environment and inland crop fields will likely receive major impact of tsunami.

The district tsunami risk map is shown in Figure 4.3. Six (6) Union Councils of the district comprising approximately 90,000 people (as per Census 2017) may receive varying impacts of tsunami. Details of population likely to be affected is given in Table 4.3.

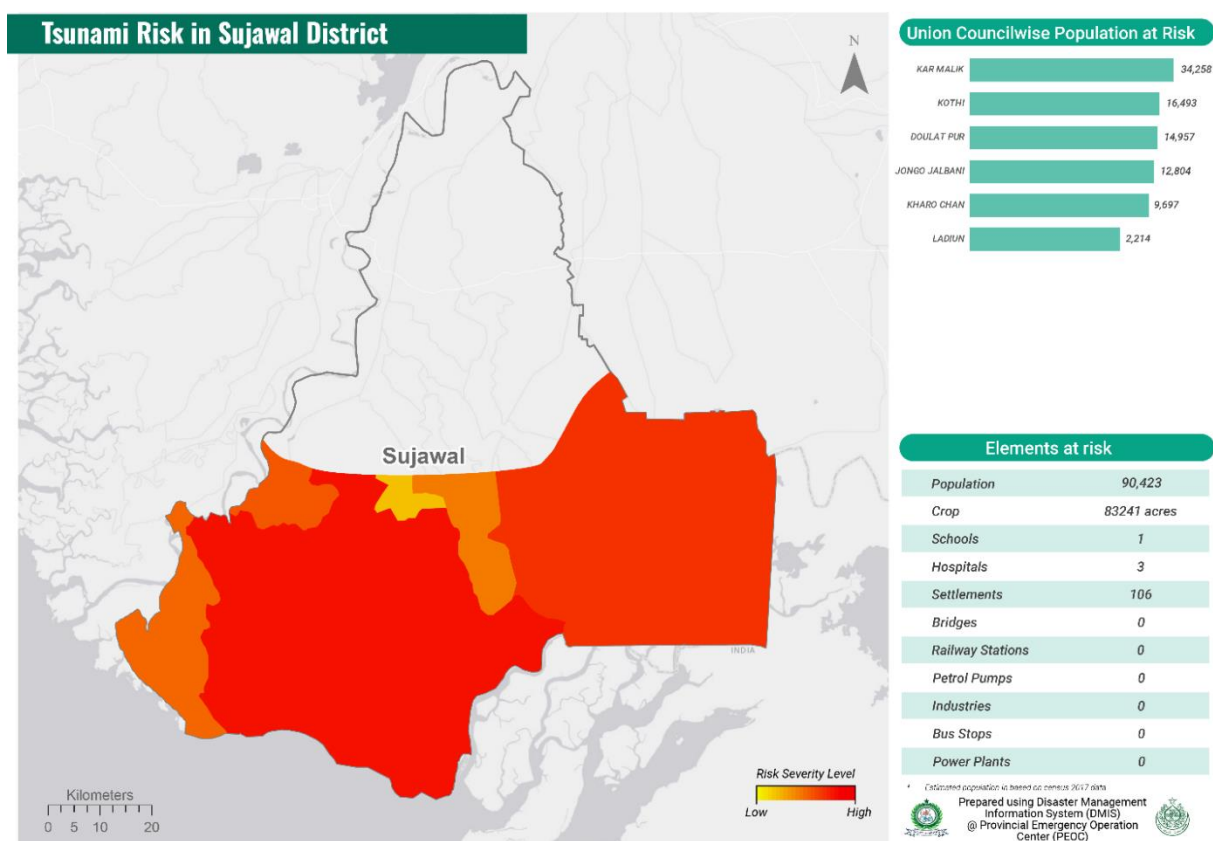


Figure 4.3 Sujawal District – Tsunami Risk Map

S.No.	District	Union Councils	Total Population	Population at Risk	Percentage
1	Sujawal	DOULAT PUR	15,707	14,957	95%
2		JONGO JALBANI	12,804	12,804	100%
3		KAR MALIK	48,091	34,258	71%
4		KHARO CHAN	9,697	9,697	100%
5		KOTHI	23,547	16,493	70%
6		LADIUN	16,158	2,214	14%

Table- 4.3. Sujawal District Population Likely to be Affected

4.4 Badin District

Coastal belt in Badin District stretches over 59 km. The coast is composed of creeks, mud flats, swamps and natural vegetation.

The district tsunami risk map is shown in Figure 4.4; five (5) Union Councils of the district comprising approximately 80,000 people (as per Census 2017) may receive varying impacts of tsunami. Details of population likely to be affected is given in Table 4.4

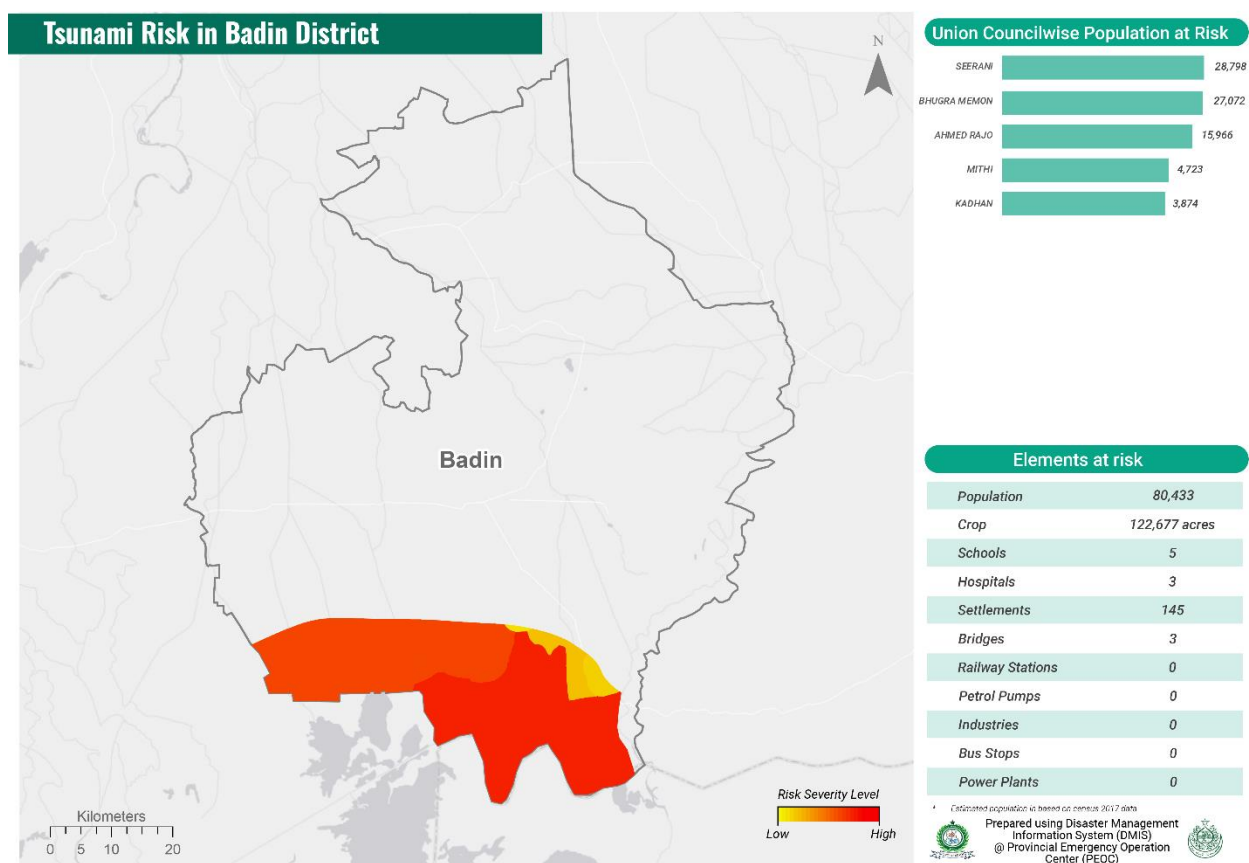


Figure 4.4 Badin District – Tsunami Risk Map

S.No.	District	Union Councils	Total Population	Population at Risk	Percentage
1	Badin	AHMED RAJO	52,001	15,966	31%
2		BHUGRA MEMON	27,072	27,072	100%
3		BOLHARI	1,010	1,010	100%
4		KADHAN	26,373	3,874	15%
5		MITHI	56,182	4,723	8%
6		SEERANI	52,468	28,798	55%

Table- 4.4. Badin District Population Likely to be Affected

TSUNAMI MANAGEMENT & STANDARD OPERATING PROCEDURE

5. Management Gaps

Tsunami in this region is rare phenomena and recorded event occurred in 1945 well before the independence of Pakistan. The public who witnessed the event may not be alive at present, therefore, tsunami threat perception is low at all levels including disaster management stakeholders and communities at risk. It imperative to understand that, possibilities of such an event in future cannot be ruled out, because MSZ is active and have potential to generate high magnitude earthquake and consequent tsunami. Tsunami alert and warning is two-step process. At first step, alert for possibility of tsunami is issued on occurrence of earthquake with magnitude 6.5 and above. Afterwards data from gauges and buoys installed in sea is processed to determine any abrupt changes in sea tides. If changes are observable, formal tsunami warning is issued. Pakistan Meteorological Department (PMD), is custodian and responsible for issuing alerts and warnings with respect to earthquakes and tsunami in Pakistan. In this regard, following initiatives / measures have already been taken by PMD and other stakeholders;

- a) PMD has installed necessary equipment to monitor earthquakes in entire country including Balochistan province and any seismic activity is monitored and reported to concerned departments.
- b) Sea gauges and buoys in region are installed by international agencies to detect changes in sea tides.
- c) PMD possess and use tsunami modelling software to determine, tsunami generation and its severity.
- d) UNDP have installed Tsunami Early Warning Systems (TEWS) along the coast of Balochistan and one in Sindh province. This system is equipped with sirens and activated through satellite communication upon reception of tsunami warning.
- e) PDMA Sindh is in process of installing TEWS along the remaining coast of Sindh through financial assistance from NDMRF. The project covers installation of TEWS and awareness programs for coastal communities.

- f) PDMA has conducted Multi-hazard Vulnerability and Risk Assessment study for entire province which cover tsunami hazard along the coast of Sindh. Based on synthetic earthquake scenarios, vulnerability and risk maps have been developed to identify population and other critical infrastructure at tsunami risk.
- g) UNESCO is actively engaged in the region and support various technical and awareness activities with regard to tsunami threat.
- h) PMD conduct tsunami drills involving stakeholders for sensitization of tsunami threat.

Though various activities have been conducted by different major stakeholders, however, still there are some management gaps which needs to be addressed by relevant quarters.

5.1 Gaps

For better management of tsunami threat following is necessary;

- a) Proper zonation and declaration of Tsunami Hazard Zone (THZ) is necessary along the coast of Sindh. This zonation must also consider cyclones as the coast is susceptible to storm surge as well. Pakistan Meteorological Department can play vital role in mapping of tsunami and storm surge zones along the coast.
- b) Relevant provincial and federal government departments and authorities shall devise land use / landcover rules and regulation to regulate population influx and other developments along the coast.
- c) District administration / DDMA's shall prepare and maintain database of local influentials / social mobilizers within the coastal communities which can be capitalized in emergent situations.
- d) Elevated platforms shall be identified or developed as safe zones along the coast particularly near the populated coast where population can immediately evacuate on tsunami warning call.

- e) Population residing along the coast shall be regularly sensitized on tsunami threat through awareness session specifically with reference to visual signs and clues of tsunami. Such programs shall be conducted in villages and educational institutes along the coast. Local and international NGOs can play vital role in social mobilization and awareness.
- f) Local / Community level tsunami preparedness, management and safety plans shall be prepared capitalizing local / folk wisdom. DDMA's through local and international NGOs can effectively implement such interventions.
- g) It is also important to determine details of all natural, ecosystem and manmade vulnerabilities along the coast. Concerned provincial and federal departments and authorities shall prepare such maps specially for natural ecosystem likely under threat.
- h) Specially in Karachi division, embankments / wave breakers shall be erected along vital infrastructure and populated hubs.
- i) Natural wave breaker / barrier such as mangrove forests shall be conserved / developed along the coast. Relevant provincial and federal departments and authorities can effectively implement such initiatives.

6. Standard Operating Protocols of Pakistan Meteorological Department on Tsunami

National Seismic Monitoring and Tsunami Early Warning Center (NSM & TEWC) of Pakistan Meteorological Department (PMD) prepared Tsunami Warning Standard Operating Procedures (SOPs) in March 2010. The important extract of SOPs is reproduced as under:

6.1. Bulletin Issuance Criteria

The following three parameters are used to evaluate the tsunamigenic potential of an earthquake.

- i. LOCATION: - Whether the earthquake is located under or very near the sea.
- ii. DEPTH: - Whether the earthquake is located close enough to the surface to have caused a significant displacement of that surface.
- iii. MAGNITUDE: - Various magnitude ranges and their combination with other parameters for Makran Subduction Zone are shown in the following Table 6.1.

Location	Magnitude	Tsunami Potential	Action
Under the Arabian Sea	6.5 to 7.0	A small possibility of local destructive Tsunami	Tsunami Bulletins
	7.1 to 7.5	Local destructive Tsunami	Tsunami Bulletins
	7.6 to 7.9	Regional/Wide-spread destructive Tsunami	Tsunami Bulletins
	8.0 & above	Wide-spread destructive Tsunami	Tsunami Bulletins

Table- 6.1. Bulletin Issuance Criteria

Note:

Local Tsunami: A local Tsunami is the one with destructive or life-threatening effects usually limited to within the radius of 100 km of the epicenter.

Regional Tsunami: A Regional Tsunami is one with destructive or life-threatening effects usually limited to within the radius of 1000 km of the epicenter.

6.2. Bulletin Dissemination

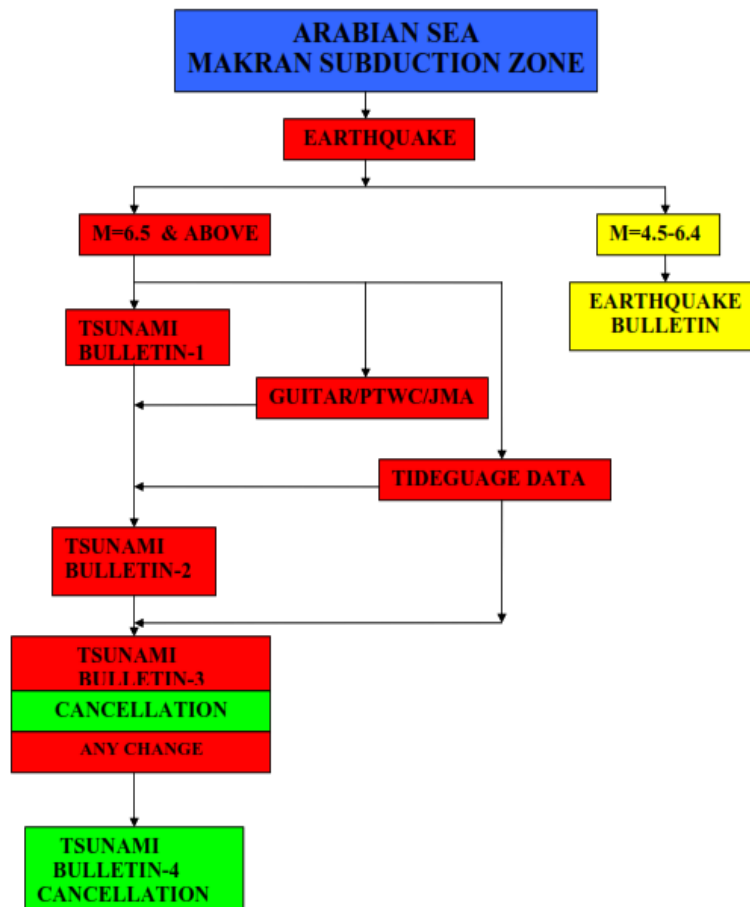
The following circuits and methods are used to disseminate Tsunami Bulletins:

- i. Automated GPRS based SMS.
- ii. Mobile phone-based SMS (Backup).
- iii. Automated fax- 2 Channel.
- iv. Manual fax- 1 Channel.
- v. Satellite telephone Communication.
- vi. Website updating www.pakmet.com.pk/seismic and e-mail

6.3. Limitations

- a) The numbers of seismic stations along Pakistan coast are limited which may cause delay in analyzing the earthquake and consequently serious delay in issuance of tsunami warnings.
- b) The Center has no real-time sea-level monitoring. OIC website is being used for this purpose, reception of data from this website is delayed up to about 30-45 minutes and only one location of Karachi is available. Serious problem is in waiting for confirmation or cancellation of tsunami warning especially in case of a future tsunami from Makran Subduction Zone.
- c) There is no GPS station to monitor co-seismic and post-seismic crustal deformation.

6.4. Schematic Diagram of Actions in event of Seismic Activity in Arabian Sea



6.5. Description and Contents of Bulletins

1. For earthquakes having magnitude between 4.5 to 6.4, only earthquake parameters will be sent to **RESPONSE AUTHORITIES** and **MEDIA** through **SMS** and **FAX**.
2. Maximum four Bulletins will be issued for earthquakes having magnitude 6.5 or above to **RESPONSE AUTHORITIES** and **MEDIA**.
3. **BULLETIN-1:** - This bulletin will contain;
 - i. Earthquake Parameters.
 - ii. Tsunami evaluation based on historical earthquake and tsunami data.
 - *This bulletin will be issued according to time line of Bulletin-1.*

4. **BULLETIN-2:** - This bulletin will contain;
 - i. Revised Earthquake Parameters (if so).
 - ii. Estimated arrival times and wave heights at various locations along Pakistan Coast based on GUITAR/PTWC/JMA.
 - iii. Tide gauge data if generation of tsunami has been confirmed.
 - *This bulletin will be issued soon after the dissemination process of Bulletin-1 is completed.*
 - *In case the Tsunami generation is confirmed, the first sentence of Evaluation will be deleted.*

5. **BULLETIN-3:** - This bulletin will contain;
 - i. Revised earthquake parameters (if so).
 - ii. Tide gauge data of Pakistan Coast to confirm the generation of tsunami.
 - iii. Any change if tsunami has been confirmed in Bulletin-2.
 - iv. This bulletin will serve as cancellation in case a sufficient time has lapsed after the estimated arrival time but no significant change is observed in sea level. In such case it will be the last bulletin.
 - *This bulletin will be issued whenever tide gauge data confirms the tsunami generation (CONFIRMATION).*

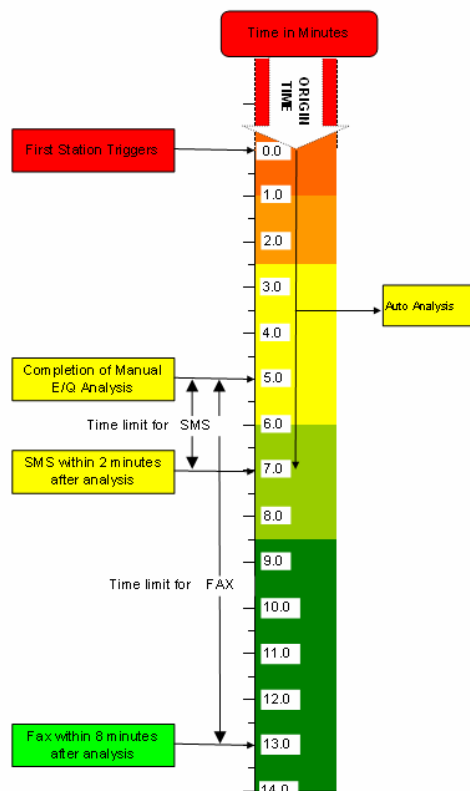
6. **BULLETIN-4: - (Cancellation)**
 - i. This bulletin will contain earthquake parameters and tsunami evaluation regarding cancellation.
 - ii. This will be the last bulletin and will serve as cancellation.

Important. Supplementary bulletins (SMS/FAX) will be issued in between regular bulletins depending upon the prevailing situation.

6.6 Description of Messages

Earthquake Magnitude Range	Description of Message
4.5 – 6.4	Earthquake Parameters
6.5 – 7.0	E/Q M 6.3 in Arabian Sea dt _____ at _____ PST. A small possibility of tsunami threat for Pak. Coast. PMD
7.1 – 7.5	E/Q M 7.5 in Arabian Sea dt _____ at _____ PST. Local Tsunami may generate. Threat to Pak. Coast. PMD
7.6 – 8.0	E/Q M 8.0 in Arabian sea dt _____ at _____ PST. Widespread Tsunami may generate. Inland destruction possible along Pak. Coast. PMD.
Greater than 8.0	E/Q M 8.5 in Arabian sea dt _____ at _____ PST. Destructive tsunami with severe inland damages possible along Pak. Coast. PMD.

6.7 Timeline for Alert and Warning Generation



Complete SOPs are given at Annex – 1.

7. Response of PDMA

Pakistan Meteorological Department (PMD) is nodal agency of issuing tsunami alerts and warnings. In case of any major earthquake, immediate coordination with PMD shall be established by PDMA. Provincial Emergency Operation Centre (PEOC) shall be activated and emergency shall be declared in all establishments of PDMA. Upon reception of earthquake of magnitude 7.0 and above following actions shall be performed by PDMA Sindh:

7.1. Pre-Tsunami Arrival Actions:

1. Activation of PEOC and emergency duties at all setups of PDMA.
2. Call to Chief Minister Sindh for information on situation.
3. Issuance of Alert / Warning depending possible scale of tsunami. The contents of message shall be;
 - i. **“Yellow Alert. Small Possibility of Tsunami along Sindh Coast. Man, and Material Resources on Standby / Ready Position.”**
 - ii. **“Yellow Alert. Possibility of Local Tsunami along Sindh Coast. Man, and Material Resources on Standby / Ready Position.”**
 - iii. **“Red Alert. Widespread Destructive Tsunami along Sindh Coast. Mobilize Man and Material Resources for Warning Dissemination and possible Evacuation.”**
 - iv. **“Red Alert. Destructive Tsunami along Sindh Coast. Mobilize Man and Material Resources for Warning Dissemination and possible Evacuation.”**
4. Heads of pertinent departments / organizations / authorities shall be contacted and immediate communication shall be established with following recipients;
 - i. Chief Minister, Sindh
 - ii. Governor, Sindh
 - iii. Chief Secretary, Sindh

- iv. Secretary Home Department, Sindh
 - v. Inspector General of Police, Sindh
 - vi. DIG Traffic Karachi and Respective Officers of Thatta, Sujawal and Badin Districts
 - vii. Commissioner Karachi
 - viii. Deputy Commissioner (s) / DDMAs, Keemari, East, West, South, Central, Korangi and Malir
 - ix. Commissioner Hyderabad
 - x. Deputy Commissioner (s) / DDMAs, Thatta, Sujawal, Badin
 - xi. Corp 5 Headquarter
 - xii. Pakistan Coast Guard
 - xiii. Pakistan Navy
 - xiv. Rescue 1122
 - xv. Defense Development Authority, Karachi
 - xvi. Cantonment Boards within Karachi
 - xvii. Edhi
 - xviii. Chippa
 - xix. Information Department, Sindh
 - xx. NDMA
 - xxi. Karachi Port Trust (KPT)
 - xxii. Port Qasim Authority
5. Central Command and Control Centre shall be activated in PDMA Head Office / or were deemed necessary (dependent on situation) with members from all above departments.
6. Public and private CCTV cameras shall be used for situation awareness. Further, SUPARCO shall be requested to deploy drones / unmanned vehicles for monitoring of situations, particularly, in Karachi Division and along thickly populated segments of coast.
7. Rescue 1122, ambulance services, traffic police, Sindh police and other departments shall be mobilized for tsunami warning announcement in Karachi Division. Deputy

Commissioner of Thatta, Sujawal and Badin will activate their departmental resources along with above mentioned offices for announcements in communities at risks.

8. Following message shall be used in announcements in Urdu and Sindhi languages;

“Evacuate basements and lower floors of houses and use houses or taller building roofs for safety”

9. All search and rescue operations shall be initiated after arrival of final tsunami wave and recession of water. Till that time necessary machinery and equipment in ready position shall be parked at safer places.
10. Before arrival of tsunami wave, traffic police shall ensure clearance of traffic on roads for smooth mobility of rescue operations and of machinery. In Karachi, all traffic leading to city centers shall be completely halted by traffic and Sindh police and public entry in city shall be completely banned till active threat is over.

7.2. During Arrival of Tsunami Wave:

Safety of rescue workers and machinery is important because of their importance as front line force. Also, initiation of rescue operations may not be possible due to flowing water, wave pressure and accompanied debris. Therefore, rescue operation shall remain in ready to deploy position and shall be initiated after last tsunami wave which may arrive after about 10 hours of tsunamigenic earthquake. Further, the wave generation may also be compounded by earthquake aftershocks. Meanwhile, tsunami threat is over following actions shall be performed;

1. PDMA’s Central Command and Control shall be shifted to Rescue 1122 HQ at Gulshan-e-Iqbal.
2. Emergency shall be declared in affected districts and PDMA shall exercise its power to use any public or private property / machinery / resource deemed necessary for disaster management and humanitarian response.
3. Estimation of affected population shall be carried out and places / grounds / buildings / facilities shall be identified for establishment of shelters.

4. Situation shall be monitored through CCTV cameras in city and SUPARCO shall be engaged to deploy drone / unmanned vehicles to monitor situation along the coast.
5. Pakistan Navy shall be engaged to monitor the situation at sea.
6. International sources shall be explored for technical assistance and situational awareness.
7. Pakistan Airforce shall be engaged for aerial surveillance.
8. Resources of Pak Army, Rangers, and Sindh Police shall be ready position.
9. Rescue services of all agencies working in Sindh and provincial rescue services of Punjab and KPK shall be called for ready to deploy position.
10. Coordination for international relief and rescue operations shall be carried out.
11. Machinery and equipment of public and private entities working in Sindh shall be called on ready to deploy position.
12. Dewatering and debris removal machinery and equipment shall be positioned for rescue.
13. NGOs and other philanthropist organizations along with corresponding DDMA's shall be mobilized for establishment of relief camps and camp management.
14. All means of communication shall be mobilized to inform population in stress remain calm and composed till rescue operations are started.

7.3. Post Tsunami Actions:

1. All public, private, provincial and federal and resources available with authorities shall be mobilized for search and rescue of stranded population.
2. Large trucks available with any public or private entity shall be used for shifting and transportation of stranded population.

3. Local government, district administration / DDMA, concerned boards and authorities shall be mobilized for removal of stagnant water, debris and garbage. This shall be done on priority basis to bring life back to normal as early as possible.
4. PDMA will ensure provision of life commodities and facilities in relief camps through DDMA.
5. Health Department shall ensure health facilities at relief camps.
6. Social Welfare and Women Development Departments shall deploy their resources to identify people with special needs and coordinate with PDMA for fulfilling their special needs.
7. Police and law-enforcing agencies shall ensure safety and security of relief camps.
8. Local government, district administration, boards and authorities shall conduct initial house inception and house damage surveys and shall ensure rehabilitation of supply / provision of basic life facilities like water and sewerage.
9. K-Electric will conduct survey and shall ensure supply of electricity with shortest possible time.
10. Police and other law-enforcing agencies shall cordon-off affected areas for general and un-authorized public access for safety of property of affected population.
11. Affected population shall be resettled to their homes after restoration of basic facilities.
12. Post disaster need assessment survey shall be carried out as per government's decision.

8. Roles and Responsibilities of other Stakeholders

Specifically, with reference to tsunami alert and warning, the roles and responsibilities of all relevant stakeholders are tabulated below. It is emphasized that, resource of any entity working in Sindh province other than mentioned can be engaged on requirement basis.

Sr#	Stakeholders	Roles and Responsibilities
1.	Sindh Rescue 1122	<ul style="list-style-type: none"> • Mobilization of all-out man and material resources • Siren and parades to announce tsunami Alert / Warning • Search and rescue • On-site medical support during rescue operation • Provision of facilities and set-up of Central Command and Control Centre at Rescue HQ
2.	Sindh Police	<ul style="list-style-type: none"> • Siren and parades to announce tsunami Alert / Warning • Maintain law and order and cordoning off affected areas • Assist in search and rescue • Facilitation in the transportation of affectees to relief camps and safe locations • Maintenance of overall law and order • Safety and security of relief camps
3.	Traffic Police	<ul style="list-style-type: none"> • Siren and parades to announce tsunami Alert / Warning • Clearance of traffic on main / connecting roads • Closure of roads for public transport to enter city center, especially in Karachi and affected areas • Ensure public traffic clearance during the conduct of search and rescue operations
3.	Home Department	<ul style="list-style-type: none"> • Mobilization of Civil Defense resources on disposal of PDMA / Central Command and Control Centre • Ensure overall law and order during and the post-event
4.	District Administration / DDMA's	<ul style="list-style-type: none"> • Mobilization and engagement of departmental resources for Tsunami alert and warning dissemination • Arrangements for personnel, machinery, and equipment to be used in search, rescue, and post-event management • Establishment of relief camps with necessary facilities • Conduct of initial damage and need assessment
5.	Corp 5 Headquarter	<ul style="list-style-type: none"> • Mobilization of resources especially required for rescue operations • Conduct of rescue operations • Conduct of on-site medical and health services and at relief camps • Deployment of long chassis army vehicles for transportation of affectees from site to relief camps

Sr#	Stakeholders	Roles and Responsibilities
		<ul style="list-style-type: none"> • Conduct of areal operations if required for search and rescue • Support to law enforcing agencies in maintaining law and order
6.	Pakistan Air force	<ul style="list-style-type: none"> • Air surveillance for situational awareness • Conduct of areal operations if required for search and rescue • Deployment of long chassis army vehicles for transportation of affectees from site to relief camps • Conduct of on-site medical and health services and at relief camps • Conduct of rescue operations
7.	Pakistan Navy	<ul style="list-style-type: none"> • Sea and coastal surveillance for situational awareness • Deployment of long chassis army vehicles for transportation of affectees from site to relief camps • Conduct of on-site medical and health services and at relief camps • Conduct of rescue operations • Deployment of amphibious vehicles for search and rescue on requirement basis
8.	Pakistan Coast Guard	<ul style="list-style-type: none"> • Announcements for tsunami alert and warning in communities along the coast • Coastal surveillance for situational awareness • Conduct of search and rescue operation
9.	Sindh Local Government Department, Development Boards and Authorities, Metropolitan Corporation, Water and Sewerage Boards	<ul style="list-style-type: none"> • Cleaning of debris • Cleaning of water and sewerage system • Deployment of dewatering machinery • Restoration of basic facilities and services
10.	K-Electric and other concerned Supply Companies	<ul style="list-style-type: none"> • Restoration of electric supply after tsunami threat is over
11.	SUPARCO	<ul style="list-style-type: none"> • Deployment of drones and unmanned vehicles for situational awareness
12.	Information Department, GoS	<ul style="list-style-type: none"> • Round-the-clock announcements and coverage regarding pre, during, and post-tsunami
13.	Social Welfare Department, GoS	<ul style="list-style-type: none"> • Identification of differently-able population within affectees • Mobilization of social workers and social welfare organizations for humanitarian assistance and relief camp management
14.	Women Development Department, GoS	<ul style="list-style-type: none"> • Supervision of relief camps with reference to need of affected women and children

Sr#	Stakeholders	Roles and Responsibilities
		<ul style="list-style-type: none"> • Ensure gender and child protection in relief camps • Compile and report special requirements of women and children in relief camps
15.	Department of Empowerment of Persons with Disabilities (DEPD)	<ul style="list-style-type: none"> • Identification of differently-able population within affectees • Mobilization of social workers and social welfare organizations for humanitarian assistance and relief camp management
16.	Karachi Ports	<ul style="list-style-type: none"> • Ensure protection of assets
17.	Boys and Girls Scouts	<ul style="list-style-type: none"> • Volunteer services in establishment of relief camps and relief camp management
18.	Pakistan Red Crescent Society	<ul style="list-style-type: none"> • Mobilization of volunteers for search, rescue, and relief operations
19.	NGOs and other Philanthropists Organizations	<ul style="list-style-type: none"> • Relief camp management and provision of basic life facilities
20.	Ambulance Services	<ul style="list-style-type: none"> • Assistance in search and rescue • Transportation of injured and affectees

9. Evacuation Management

Evacuation of stranded population shall be carried out after arrival of final tsunami wave and announcement of threat over call. All parties as mentioned in roles in responsibilities will play their role in search and rescue operations. While evacuation following SoPs shall be followed;

1. Indiscriminate evacuation shall be carried out; however, priority shall be given to elderly, differently-able people, women and children.
2. Long chassis, large trucks shall be used for transportation of affectees to the relief camps.
3. The area evacuation in-charge shall be designated to ensure counting of people and their mobility to designated camps.
4. Record of deaths and injuries shall be managed by area evacuation in-charge and camp management officer. The record of affectees shall be maintained by camp management officer.

5. Evacuation camps and routes have already been identified in District Disaster Management Plans of concerned districts prepared by PDMA. However, routes and camp locations shall be established on requirement and emergent situations.

10. Camp Management

All camps shall be centrally managed by PDMA through DDMA, stakeholders, NGOs, volunteers and philanthropist organizations. Following SoPs shall be followed;

1. All camps shall be under administrative control of PDMA / DDMA and no NGO or philanthropist organization shall be allowed to establish relief camps on their own. If such camps other than government administration are un-avoidable then permission shall be sought from DDMA and to this effect shall be shared with PDMA along with details of affectees and camp facilities.
2. Camp management in-charge shall be an officer of BPS-17 or above for better on-site decision making and coordination with PDMA and other relevant stakeholders.
3. Details of all volunteers shall be recorded by camp management officer to avoid any mishap in relief camps.
4. Social Welfare, Women Development, and Department of Empowerment of Persons with Disabilities, Government of Sindh shall detail their officials in camps to ensure facilitation of old persons, differently-abled person, girls, women and children. Strict compliance of gender-based violation shall be ensured by said departments.
5. Provision of cooked food, safe drinking water and other routine life necessities in relief camps shall be ensured by PDMA / DDMA. Additionally, provision of seasonal requirements such as blankets, mosquito nets etc. shall also be ensured in relief camps.
6. Police and other law-enforcing agencies shall ensure safety and security of affectees.
7. Health Department, Government of Sindh and other stakeholders shall arrange 24/7 health & medical services and facilities in relief camps.

11. Resettlement of Affectees

Tsunami often brings secondary disasters such as debris, collapse of structures and building, chocking of sewerage system, contamination of home-use water supply lines, failure of electricity, damage to houses and stagnant water in low lying areas. Therefore, immediate resettlement of affectees after threat over call may not be possible. Before, resettlements following shall be ensured;

1. Sindh Building Control Authority shall inspect safety of houses in affected areas. The same shall be carried out by relevant development authorities and boards. In rural settings, this work shall be carried out by district administration / DDMA's.
2. K-electric and other concerned electric supply companies will ensure safe supply of electricity in respective affected areas.
3. Gas companies shall inspect their distribution system to ensure safety before supply of gas.
4. Concerned water and sewerage board / Public Health Engineering Department shall ensure supply of safe domestic use water in affected areas.
5. Environmental survey of affected areas shall be carried out by Environment Department, Government of Sindh through in-house or other sources to ensure health safety of affectees.

When all of the above inspections and safety measures are taken, affected population shall be resettled in their houses under management of government to avoid any mishaps.

**TSUNAMI WARNING
STANDARD OPERATING PROCEDURES (SOPs) of PMD**

**TSUNAMI WARNING
STANDARD OPERATING PROCEDURES (SOPs)**



PREPARED BY
**National Seismic Monitoring & Tsunami Early Warning Centre,
PAKISTAN METEOROLOGICAL DEPARTMENT
KARACHI, March, 2010**

Preface

Tsunamis are infrequent high impact hazards. These events can cause a considerable number of fatalities, inflict major damage, and cause significant economic loss to large sections of coastlines. Pakistan (Sindh-Makran coast) was also hit by a tsunami in 1945 due to a major earthquake in subduction zone in Indian Ocean (Makran subduction zone). Some recent studies have also revealed that the coastal areas from Runn of Kutch to Pasni (along Sindh - Makran coast) are under threat of any future tsunami that may generate owing to some big earthquake in the Arabian Sea.

In the aftermath of catastrophic trans-Indian Ocean Tsunami of 26th December, 2004 and unprecedented Kashmir Earthquake of 8th October, 2005 and keeping in view the potential risk of any tsunami along Pakistan coast, Pakistan Meteorological Department (PMD) has established a state-of-the art Seismic Monitoring and Tsunami Early Warning Centre at PMD Complex, Karachi (with a back centre at Islamabad) with the support by the Government of Pakistan and UNESCO / IOC. However, for an effective early warning system it is imperative that the system operates according to predefined protocols, commonly known as Standard Operating Procedure (SOP). I feel satisfaction and pleasure that the document entitled “Standard Operating Procedure (SOP) for National Seismic Monitoring and Tsunami Early Warning Centre (NSM & TEWS), Karachi” is ready for implementation. The SOP has been developed by a team of experts headed by Mr. Muhammad Riaz, Chief Meteorologist (NSM & TEWS) to disseminate tsunami early warnings in a timely and well understandable manner. The document can also be shared with other agencies. It is a live document and is subject to review from time to time. The document consists of two parts, Part-I for the Arabian Sea (Makran subduction zone) and Part-II for rest of the Indian Ocean (Sumatra & surroundings). Every effort has been made to make the document accurate, however, any error(s) or suggestion(s) will be appreciated in order to make it more reliable and useful.

I appreciate the efforts of the expert team of PMD for their dedication towards development of this important document of national interest. I am also indebted to UNESCO/IOC for their valuable contribution to hold the training workshops for the training of staff of NSM & TEWC and for the development of end-to-end SOP for tsunami early warning system. I wish to express my gratitude to Mr. Uli Wolf, Mr. Tony Elliot, Mr. Masahiro Yamamoto, Dr. Fouzi, Mr. Adito M. Kodijat, Ms. Jane Cunneen and Mr. Arslan Syed for their cooperation, support and guidance during the training workshops jointly held by PMD and UNESCO/IOC.

Islamabad, the April 28, 2010

(Dr. Qamar-uz-Zaman Chaudhry)

National Seismic Monitoring and Tsunami Early Warning Centre (NSM &TEWC)

(An overview).

1. INTRODUCTION

Following the December 26, 2004 Sumatra tsunami and October 8, 2005 Kashmir earthquake Pakistan Meteorological Department (PMD) which is carrying out multifarious activities under the Ministry of Defence planned to establish National Seismic Monitoring and Tsunami Early Warning Centre (NSM & TEWC) at Karachi. The centre has been operational since 28th November, 2008 on round-the-clock basis. The mission of the National Tsunami Warning Centre (NTWC) is to provide timely and well understandable tsunami warnings when a major earthquake occurs under sea at a shallow depth. In order to achieve the objectives NTWC uses National and Global Seismographic networks data on real-time basis to monitor seismic activity in order to locate potential tsunamigenic earthquakes. NTWC also receives tsunami advisories issued by the International Tsunami Warning Centres like Pacific Tsunami Warning Centre (PTWC) and Japan Meteorological Agency (JMA) for Indian Ocean. Upon receiving all the necessary data/information, the centre evaluates the threat to the coastal areas of Pakistan and issues Tsunami Bulletins to Emergency Response Authorities(ANNEX-I) and Media. NTWC also receives sea level data through IOC website to verify the generation and severity of the potential tsunami. This information is also disseminated in subsequent bulletins according to the procedure laid down in SOPs.

Multiple communication channels have been established for dissemination of the bulletins. Two SMS terminals for mobile phone dissemination and three FAX terminals (two automated and one manual) have been reserved for this purpose. Routine tests and exercises are carried out to test the Standard Operating Procedure.

The NTWC keeps watch on Indian Ocean and Pacific Ocean in general and Arabian Sea in particular. The Arabian Sea floor is comprised of four tectonic plates named as Eurasian Plate, Arabian Plate, Indian Plate and African Plate. In North Arabian Sea, near the Makran coast, Arabian Sea Plate is subducting underneath the Eurasian plate, resulting into a subduction zone commonly known as Makran Subduction Zone. Subduction zones in the oceans mainly responsible for destructive tsunami generation.

Separate Standard Operating procedures have been prepared for each oceanic area.

2. BULLETIN ISSUANCE CRITERIA

The following three parameters are used to evaluate the tsunamigenic potential of an earthquake.

- i. **LOCATION:-** Whether the earthquake is located under or very near the sea.
- ii. **DEPTH:-** Whether the earthquake is located close enough to the surface to have caused a significant displacement of that surface.
- iii. **MAGNITUDE:-** Various magnitude ranges and their combination with other parameters for Makran Subduction Zone are shown in the following table.

LOCATION	MAGNITUDE	TSUNAMI POTENTIAL	ACTION
Under the Arabian sea	6.5 to 7.0	A small possibility of local destructive Tsunami	Tsunami Bulletins
	7.1 to 7.5	Local destructive Tsunami	Tsunami Bulletins
	7.6 to 7.9	Regional/Wide-spread destructive Tsunami	Tsunami Bulletins
	8.0 & above	Wide-spread destructive Tsunami	Tsunami Bulletins

2.1 TYPE OF MAGNITUDE

The magnitude used by NSM & TEWC is the moment magnitude, M_w , because for large earthquakes, it is more accurate and reliable than other magnitudes.

2.2 LOCAL TSUNAMI

A local Tsunami is the one with destructive or life threatening effects usually limited to within the radius of 100 km of the epicentre.

2.3 REGIONAL TSUNAMI

A Regional Tsunami is one with destructive or life threatening effects usually limited to within the radius of 1000 km of the epicentre.

2.4 OCEAN-WIDE TSUNAMI

By Ocean-Wide Tsunami is meant a Tsunami with destructive or life threatening effects that can extend across the entire ocean basin.

3. BULLETIN CONTENTS

Bulletins are divided into four sections. A "Header" gives the Bulletin number and time of issuance. The number starts from 1 and is incremented to maximum 4 for a tsunami event in Arabian Sea and 2 to 4 for Sumatra and surroundings. Below header, it is indicated that who is issuing agency, e.g. PMD, followed by the earthquake parameters including origin time, location co-ordinates, location name, depth and magnitude. The next section is the evaluation regarding potential and destructive effects of tsunami. The incremental Bulletins 2 and 3 have the sections regarding estimated arrival times/wave heights and tide gauge data at key locations. In case of no

tsunami generation, Bulletin-3 will be treated as cancellation for Makran and Sumatra Subduction Zones. In case of confirmation of tsunami generation Bulletin-4 will serve as cancellation. Sample Bulletins are provided, separately for Makran Subduction Zone and Sumatra. Arrival times and wave heights provided by GUITAR simulation software are also placed as sample. This software has been provided by UNESCO. UNESCO played very important role to help PMD in establishing such type of facilities at NTWC and in providing the training to the staff of the warning centre. For this purpose three training workshops were conducted in collaboration with PMD to develop end-to-end tsunami SOPs.

4. BULLETIN DISSEMINATION

The following circuits and methods are used to disseminate Tsunami Bulletins:

- i. Automated GPRS based SMS.
- ii. Mobile phone based SMS (Backup).
- iii. Automated fax- 2 Channel.
- iv. Manual fax- 1 Channel.
- v. Satellite telephone Communication.
- vi. Website updating www.pakmet.com.pk/seismic and e-mail

5. RECEPTION OF THE TSUNAMI BULLETINS FROM INTERNATIONAL ORGANIZATIONS

The centre has WMO based GTS terminal, through which Tsunami information bulletins are received from PTWC/JMA. The information contained in these bulletins is incorporated in the products of the centre.

6. TESTS AND EXERCISES

NSM & TEWC conducts regular tests to check the operational status of data acquisition system, communication system and dissemination system. Exercises are also carried out repeatedly to test the SOP. For this purpose dummy messages are sent with the header of "TEST", to ensure that the message is not misunderstood.

7. STANDARD OPERATING PROCEDURE (SOP)

A Standard Operating Procedure or SOP:

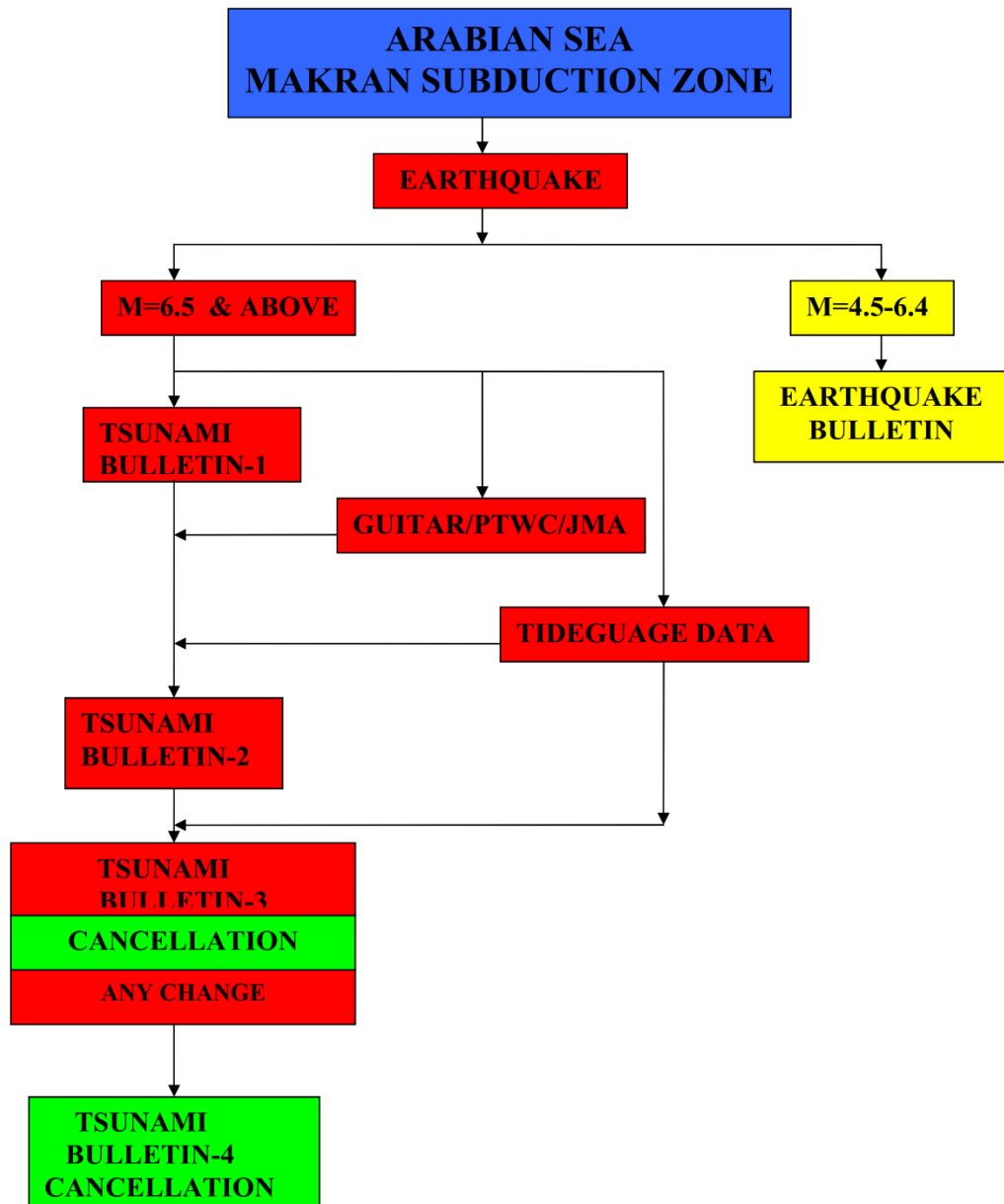
- i. Is the procedural guidance and actions to be taken to notify the Tsunami information, in case an earthquake occurs in the Arabian Sea (Makran Subduction Zone) or Indian Ocean (Sumatra & Surroundings).
- ii. Is a set of written instructions describing routine or repetitive activities to be followed by NSM & TEWC staff during a Tsunami event which may occur in any of the above oceanic area. These activities include data processing, evaluation of tsunami, issuance of bulletins using multi-channeled communication; estimation of the arrival times and wave heights using software; monitoring sea level data to confirm or cancel the Tsunami

warning; collection of information from PTWC/JMA through GTS/website/Media channels and incorporate this information in the bulletins issued by the centre.

8. LIMITATIONS

- i. The numbers of seismic stations along Pakistan coast are limited which may cause delay in analyzing the earthquake and consequently serious delay in issuance of tsunami warnings.
- ii. The centre has no real time sea level monitoring. OIC website is being used for this purpose, reception of data from this website is delayed up to about 30-45 minutes and only one location of Karachi is available. Serious problem is in waiting for confirmation or cancellation of tsunami warning especially in case of a future tsunami from Makran Subduction Zone.
- iii. There is no GPS station to monitor co-seismic and post-seismic crustal deformation.

SOP
for
ARABIAN SEA
(MAKRAN SUBDUCTION ZONE)



SOP FOR ISSUANCE OF “TSUNAMI BULLETINS” IN ARABIAN SEA (MAKRAN SUBDUCTION ZONE)

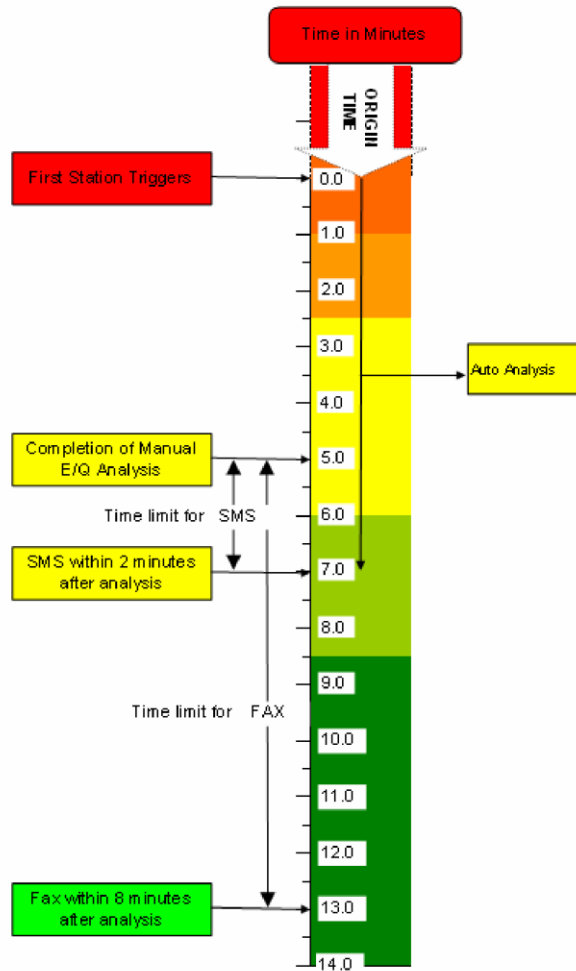
1. For earthquakes having magnitude between **4.5** to **6.4**, only earthquake parameters will be sent to **RESPONSE AUTHORITIES** and **MEDIA** through **SMS** and **FAX**.
2. Maximum four Bulletins will be issued for earthquakes having magnitude **6.5** or above to **RESPONSE AUTHORITIES** and **MEDIA**.
3. **BULLETIN-1:-** This bulletin will contain;
 - i. Earthquake Parameters.
 - ii. Tsunami evaluation based on historical earthquake and tsunami data.
•This bulletin will be issued according to time line of Bulletin-1.(page-9)
4. **BULLETIN-2:-** This bulletin will contain;
 - i. Revised **Earthquake Parameters** (if so).
 - ii. **Estimated arrival times and wave heights** at various locations along Pakistan Coast based on **GUITAR/PTWC/JMA**.
 - iii. **Tide gauge data** if generation of tsunami has been confirmed.
•This bulletin will be issued soon after the dissemination process of Bulletin-1 is completed.
•In case the Tsunami generation is confirmed, the first sentence of Evaluation will be deleted.
5. **BULLETIN-3:-** This bulletin will contain;
 - i. Revised **earthquake parameters** (if so).
 - ii. **Tide gauge data** of Pakistan Coast to confirm the generation of tsunami
 - iii. Any change if tsunami has been confirmed in **Bulletin-2**.
 - iv. This bulletin will serve as cancellation in case a sufficient time has lapsed after the estimated arrival time but no significant change is observed in sea level. In such case it will be the last bulletin.
•This bulletin will be issued when ever tide gauge data confirms the tsunami generation (CONFIRMATION).
6. **BULLETIN-4:- (Cancellation)**
 - i. This bulletin will contain earthquake parameters and tsunami evaluation regarding cancellation.
 - ii. This will be the last bulletin and will serve as cancellation.

Important. Supplementary bulletins (SMS/FAX) will be issued in between regular bulletins depending upon the prevailing situation.

SMS FORMAT FOR ARABIAN SEA

EARTHQUAKE MAGNITUDE RANGE	DESCRIPTION OF MESSAGE
4.5-6.4	Earthquake Parameters
6.5-7.0	E/Q M 6.3 in Arabian Sea dt 06-12-2009 at 15:55 PST. A small possibility of tsunami threat for Pak. Coast. PMD
7.1-7.5	E/Q M 7.5 in Arabian Sea dt 06-12-2009 at 11:24 PST. Local Tsunami may generate. Threat to Pak. Coast. PMD.
7.6-8.0	E/Q M 8.0 in Arabian sea dt 06-12-2009 at 09:53 PST. Widespread Tsunami may generate. Inland destruction possible along Pak. Coast. PMD.
Greater than 8.0	E/Q M 8.5 in Arabian sea dt 06-12-2009 at 18:35PST. Destructive tsunami with severe inland damages possible along Pak. Coast. PMD.

**TIME LINE FOR EARTHQUAKE PROCESSING AND DISSEMINATION OF TSUNAMI BULLETIN
(FOR MAKHRAN SUBDUCTION ZONE)**



Bulletine
for
Magnitude
4.5 to 6.4

EARTHQUAKE BULLETIN

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

Bulletine
for
Magnitude
6.5 to 7.0

6.5-7.0

TSUNAMI BULLETIN-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

There is a very small possibility of a local Tsunami that could affect coasts located up to one hundred kilometers from the earthquake epicenter and also may cause minor to moderate damages in land areas. However, based on historical earthquake and tsunami data, a destructive widespread Tsunami threat does not exist.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

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TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

EVALUATION: It has not been confirmed whether Tsunami *has been generated or not*. However, Based on historical earthquake and tsunami data a destructive widespread Tsunami threat does not exist.

SIMULATION RESULTS:

Estimated initial tsunami wave arrival times and wave heights, at the various locations are given below. However, actual arrival times and wave heights may differ.

CITY NAME ARRIVAL TIME (UTC) WAVES HEIGHT (meters)

OBSERVATION OF TSUNAMI ACTIVITY

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below.

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)
LON - LONGITUDE (E-EAST, W-WEST)
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.
VALUES ARE GIVEN IN BOTH METERS (M) AND FEET (FT).
PER - PERIOD OF TIME IN MINUTES (MIN) FROM ONE WAVE TO THE NEXT

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. Therefore, the Tsunami Bulletin, issued by this centre, is cancelled.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Any change)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below;

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN
ORMARA PK	25.42	64.62	0125Z	4.0M/13.1FT	17MIN

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-04

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

Evaluation:

The sea level readings indicate that threat is over for most of the area. Therefore, the Tsunami warning, issued by this centre, is now cancelled. For any affected area, where no major waves have occurred for at least 2 hours, after the estimated arrival time or damaging waves have not occurred for 2 hours, the local authority may assume that the threat is passed.

Action regarding the "all clear", decision must be made by local authorities.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

Bulletine
for
Magnitude
7.1 to 7.5

TSUNAMI BULLETIN-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

There is a possibility of a local Tsunami that could affect coasts located usually not more than a hundred kilometer from the earthquake epicentre and may cause moderate to large scale infrastructure damages. However, based on historical earthquake and Tsunami data, a destructive widespread tsunami threat does not exist.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

EVALUATION: It has not been confirmed whether Tsunami *has been generated or not*. However, Based on historical earthquake and tsunami data a destructive widespread Tsunami threat does not exist.

SIMULATION RESULTS:

Estimated initial tsunami wave arrival times and wave heights, at the various locations are given below. However, actual arrival times and wave heights may differ.

CITY NAME ARRIVAL TIME (UTC) WAVES HEIGHT (meters)

OBSERVATION OF TSUNAMI ACTIVITY

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below.

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)
LON - LONGITUDE (E-EAST, W-WEST)
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.
VALUES ARE GIVEN IN BOTH METERS (M) AND FEET (FT).
PER - PERIOD OF TIME IN MINUTES (MIN) FROM ONE WAVE TO THE NEXT

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. Therefore, the Tsunami Bulletin, issued by this centre, is cancelled.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Any change)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below;

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN
ORMARA PK	25.42	64.62	0125Z	4.0M/13.1FT	17MIN

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-04

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

Evaluation:

The sea level readings indicate that threat is over for most of the area. Therefore, the Tsunami warning, issued by this centre, is now cancelled. For any affected area, where no major waves have occurred for at least 2 hours, after the estimated arrival time or damaging waves have not occurred for 2 hours, the local authority may assume that the threat is passed.

Action regarding the "all clear", decision must be made by local authorities.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

Bulletine
for
Magnitude
7.6 to 8.0

TSUNAMI BULLETIN-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

Based on the historical data, earthquakes of this size may cause large scale infrastructure damages besides generation of widespread tsunami in the Arabian Sea. However, it is not known that a tsunami has been generated. This watch is based only on the earthquake evaluation. However, aftershocks of lesser magnitude may follow the main event.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
 Depth: _____
 Lat: _____
 Long: _____
 Location: _____
 Pak.Met.Dept

EVALUATION: It has not been confirmed whether Tsunami *has been generated or not*. Based on historical earthquake and tsunami data, earthquakes of this size may cause large scale infrastructure damages besides generation of widespread tsunami in Arabian Sea..

SIMULATION RESULTS:

Estimated initial tsunami wave arrival times and wave heights, at the various locations are given below. However, actual arrival times and wave heights may differ.

CITY NAME ARRIVAL TIME (UTC) WAVES HEIGHT (meters)

OBSERVATION OF TSUNAMI ACTIVITY

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below.

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)

LON - LONGITUDE (E-EAST, W-WEST)

TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)

AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.

IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.

VALUES ARE GIVEN IN BOTH METERS (M) AND FEET (FT).

PER - PERIOD OF TIME IN MINUTES (MIN) FROM ONE WAVE TO THE NEXT

Sd/=

Duty Seismologist
 Phone: 021-99261429
 Fax : 021-99261423

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. Therefore, the Tsunami Bulletin, issued by this centre, is cancelled.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Any change)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below;

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN
ORMARA PK	25.42	64.62	0125Z	4.0M/13.1FT	17MIN

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-04

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

Evaluation:

The sea level readings indicate that threat is over for most of the area. Therefore, the Tsunami warning, issued by this centre, is now cancelled. For any affected area, where no major waves have occurred for at least 2 hours, after the estimated arrival time or damaging waves have not occurred for 2 hours, the local authority may assume that the threat is passed.

Action regarding the "all clear", decision must be made by local authorities.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

Bulletine
for
Magnitude
8.0 and above

8.0 and above

TSUNAMI BULLETIN-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

Based on the historical data, earthquakes of this size may cause wide-spread infrastructure damages and Tsunami generation in the Arabian Sea and along coastline of Pakistan. However, it is not known that a tsunami has been generated. This watch is based only on the earthquake evaluation. However, aftershocks of lesser magnitude may follow the main event.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

8.0 and above

TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

EVALUATION: It has not been confirmed whether Tsunami has been generated or not. However, based on the historical data, earthquakes of this size may cause widespread infrastructure damages and Tsunami generation in the Arabian Sea and along coastline of Pakistan.

SIMULATION RESULTS:

Estimated initial tsunami wave arrival times and wave heights, at the various locations are given below. However, actual arrival times and wave heights may differ.

CITY NAME ARRIVAL TIME (UTC) WAVES HEIGHT (meters)

OBSERVATION OF TSUNAMI ACTIVITY

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below.

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)
LON - LONGITUDE (E-EAST, W-WEST)
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.
VALUES ARE GIVEN IN BOTH METERS (M) AND FEET (FT).
PER - PERIOD OF TIME IN MINUTES (MIN) FROM ONE WAVE TO THE NEXT

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

8.0 and above

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. Therefore, the Tsunami Bulletin, issued by this centre, is cancelled.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Any change)

TSUNAMI BULLETIN-03

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below;

<u>GAUGE LOCATION</u>	<u>LAT</u> N	<u>LON</u> E	<u>TIME</u> UTC	<u>AMPL</u> m/ft	<u>PER</u> min
PASNI PK	25.40	63.48	0125Z	4.0M/13.1FT	17MIN
ORMARA PK	25.42	64.62	0125Z	4.0M/13.1FT	17MIN

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

(Cancellation)

TSUNAMI BULLETIN-04

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

Evaluation:

The sea level readings indicate that threat is over for most of the area. Therefore, the Tsunami warning, issued by this centre, is now cancelled. For any affected area, where no major waves have occurred for at least 2 hours, after the estimated arrival time or damaging waves have not occurred for 2 hours, the local authority may assume that the threat is passed.

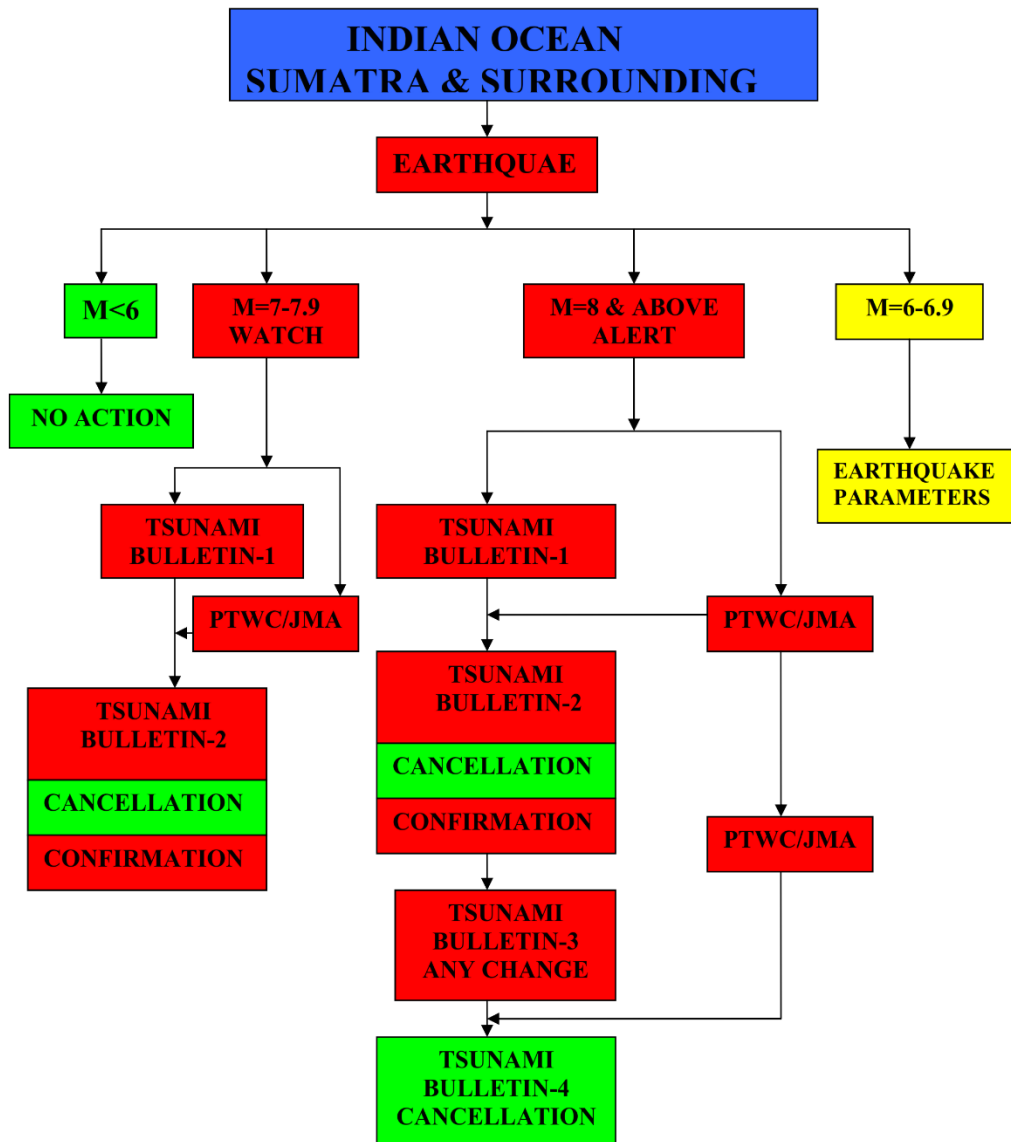
Action regarding the "all clear", decision must be made by local authorities.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

CONTANTS OF BULLETIN-1 FOR ARABIAN SEA

MAGNITUDE RANGE	MATTER TO BE SENT ON FAX
4.5-6.4	Earthquake Parameters
6.5-7.0	Earthquake Parameters & Tsunami Evaluation.
7.1-7.5	Earthquake Parameters & Tsunami Evaluation.
7.6-8.0	Earthquake Parameters & Tsunami Evaluation.
Greater than 8.0	Earthquake Parameters & Tsunami Evaluation.

SOP
for
INDIAN OCEAN
(SUMATRA & SURROUNDINGS)



**SOP FOR ISSUANCE OF “TSUNAMI WATCH”
IN INDIAN OCCEAN (SUMATRA & SURROUNDINGS)**

M 7-7.9 (WATCH)

1. No **SMS** or **Fax Bulletin** will be issued for **Earthquake** having magnitude less than **6.0**.
2. For Earthquakes having magnitude **6-6.9**, only Earthquake parameters will be sent to designated authorities through **SMS**.
3. There will be only two Bulletins for earthquakes having magnitude 7-7.9
4. Both the Bulletins i.e. 1 & 2 will be issued to **RESPONSE AUTHORITIES** only for information. However, if generation of tsunami has been confirmed, Bulletin-2 will also be sent to **MEDIA** only through **FAX**.
5. **BULLTIN-1 (TSUNAMI WATCH)** will be issued for earthquakes having magnitude 7-7.9. This bulletin will contain:
 - i. **Earthquake parameters.**
 - ii. **Evaluation:-** Based on historical data an earthquake of this magnitude may generate local/Regional Tsunami. However, there is no threat for Pakistan.
1. **BULLETIN-2**
 - i. Will be based entirely on PTWC/JMA information.
 - ii. Will contain the revised earthquake parameters (if so) and information whether Tsunami has been generated or not. It will be the last Bulletin for the Indian Ocean.

SMS FORMAT FOR INDIAN OCEAN

MAGNITUDE RANGE	DESCRIPTION OF MESSAGE
Less than 6	No Action
6.0-6.9	Earthquake Parameters
7.0-7.9	E/Q M 7.8 in Indian Ocean dt 20-12-2009 at 14:50 PST. Regional Tsunami may generate .No Tsunami threat for Pakistan. PMD.
8.0 & Above	E/Q M 8.9 in Indian Ocean dt 20-12-2009 at 13:55 PST. Ocean wide tsunami may generate and can affect Pakistan. PMD.

Bulletine
for
Magnitude
7.0 to 7.9

7.0-7.9

TSUNAMI BULLETIN-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

Based on the historical data, earthquakes of this magnitude have potential to generate local/regional tsunami. However, it is not known that a tsunami has been generated, as yet. This watch is based only on the earthquake evaluation.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

7.0-7.9
Confirmation

TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. This bulletin is forwarded only for information.

* No Tsunami Threat for Pakistan coast

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

7.0-7.9
Cancellation

TSUNAMI BULLETIN-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. This bulletin is forwarded only for information.

* No Tsunami Threat for Pakistan coast

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

Bulletine
for
Magnitude
8.0 and above

**SOP FOR ISSUANCE OF “TSUNAMI ALERT”
IN THE INDIAN OCEAN (SUMATRA & SURROUNDINGS)**

M 8.0 & ABOVE (ALERT)

1. **BULLETIN-1 (TSUNAMI ALERT)** will be issued for earthquakes of magnitude 8 and above with earthquake parameters and tsunami evaluation.
2. **BULLETIN-2**
 - i. Will be based entirely on GUITAR simulation and PTWC/JMA information.
 - ii. This bulletin will be issued 10 minutes after PTWC/JMA message. In case PTWC/JMA message is not received, the GUITAR simulation output will be incorporated in this bulletin.
 - iii. This Bulletin will contain revised earthquake parameters (is so) and tide gauge data, in case generation of Tsunami has been confirmed **OR** this bulletin will be treated as cancellation, if Tsunami has not been generated.
3. **BULLETIN-3 (Cancellation)**
Will be issued after two hours of the estimated arrival time, in case tsunami generation has been confirmed in Bulletin-02

8.0 and above

OCEAN WIDE TSUNAMI ALERT BULLETIN NO-01

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____

Depth: _____

Lat: _____

Long: _____

Location: _____

Pak.Met.Dept

EVALUATION:

Based on the historical data, earthquakes of this magnitude have potential to generate ocean wide destructive tsunami. However, it is not known that a tsunami has been generated, as yet. This alert is based only on the earthquake evaluation.

* The Tsunami may affect Pakistan coast.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

8.0 and above
Cancellation

OCEAN WIDE TSUNAMI ALERT BULLETIN NO-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has not been generated. Therefore the tsunami alert issued by this centre may be treated as cancelled.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

8.0 and above
Confirmation

OCEAN WIDE TSUNAMI ALERT BULLETIN NO-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

ESTIMATED ARRIVAL TIMES

Estimated initial Tsunami wave arrival times, at various locations are given below. However, actual arrival times may differ.

<u>COUNTRY</u>	<u>CITY NAME</u>	<u>LAT</u>	<u>LON</u>	<u>ARRIVAL TIME</u>	<u>DATE</u>
INDIA	BOMBAY	18.8N	72.6E	0856Z	14 OCT
	GULF OF KUTCH	22.7N	68.9E	0926Z	14 OCT
OMAN	SALALAH	16.9N	54.1E	0827Z	14 OCT
	MUSCAT	23.9N	58.6E	0837Z	14 OCT
IRAN	GAVATER	25.0N	61.3E	0840Z	14 OCT
SRI LANKA	COLOMBO	6.9N	79.8E	0409Z	14 OCT
MALDIVES	MALE	4.2N	73.6E	0446Z	14 OCT

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations indicate that a tsunami has been generated. Arrival times and wave heights, as observed at tide gauge locations, are given below:

<u>GAUGE LOCATION</u>	<u>LAT</u>	<u>LON</u>	<u>TIME</u>	<u>AMPL</u>	<u>PER</u>
SABANG ID	5.8N	095.3E	0125Z	4.0M/13.1FT	17MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)
LON - LONGITUDE (E-EAST, W-WEST)
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.
VALUES ARE GIVEN IN BOTH METERS (M) AND FEET (FT).
PER - PERIOD OF TIME IN MINUTES (MIN) FROM ONE WAVE TO THE NEXT.

Sd/=
Duty Seismologist
Phone: 021-99261429
Fax: 021-99261423

8.0 and above
Cancellation

OCEAN WIDE TSUNAMI ALERT BULLETIN NO-02

Issued at 00:00:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Earthquake Originated on 05-03-2010 at 21:07 PST

Mag: _____
Depth: _____
Lat: _____
Long: _____
Location: _____
Pak.Met.Dept

Evaluation:

The sea level readings indicate, as reported by PTWC, that threat is over for most of the area. Therefore, the Tsunami alert issued by this center is now cancelled. For any affected area when no major wave have occurred for at least 2 hours, after the estimated arrival time or damaging waves have not occurred for 2 hours, the local authority may assume that the threat is passed.

Action regarding the all clear, decision must be made by local authorities.

Sd/= _____
Duty Seismologist
Phone: 021-99261429
Fax : 021-99261423

CONTANTS OF BULLETIN-1 FOR INDIAN OCEAN

MAGNITUDE RANGE	MATTER TO BE SENT ON FAX
Less than 6.0	No Action
6.0-6.9	Earthquake Parameters
7.0-7.9	Earthquake Parameters & Tsunami Evaluation.
8.0 & Above	Earthquake Parameters & Tsunami Evaluation.

SOP FOR OPERATIONAL STAFF OF NSM & TEWC KARACHI **(WHEN JOIN THE DUTY)**

1. Proper **briefing** from the outgoing shift.
2. Check the **operational status** of all components;
 - i. Seiscomp-3
 - ii. SMS system
 - iii. DSL & Telephone lines.
 - iv. FAX
 - v. GTS System for PTWC/JMA tsunami Advisories.
 - vi. Uploading of data on website.
 - vii. Guitar.
 - viii. Status of Electric Generator.
 - ix. Air Conditioners installed in the Hall.
 - x. All Computers.
 - xi. Operational Status of all Broad Band Stations.
 - xii. Satellite.
Report O. K.; otherwise mention **unserviceability** and inform the concerned officer for action and advice;
 - a) Mr. Sohail, Computer Expert 03332100936.
 - b) Mr. Attaullah, EE 03442221103.
 - c) Mr. Nasir, EE (for Generator) 03332189724.
 - d) Director (seismic) 03337899442.
 - e) Chief Met. Karachi 03008026286.
3. Chalk out **strategy** for performing the jobs;
 - i. Earthquake Analysis.
 - ii. Guitar simulation.
 - iii. SMS Message.
 - iv. Satellite phone Message.
 - v. Earthquake report/Bulletin through FAX.
4. Check **SOP(s)** for;
 - i. Arabian Sea.
 - ii. Indian Ocean.
 - iii. Pacific Ocean.
5. Contact Islamabad, UARS Peshawar and G. C Quatta for **stand by** in case of system failure at NSMC.
 - i. Seismic Islamabad 051-9250291.
 - ii. UARS Peshawar 091-921084.
 - iii. G. C. Quatta. 081-9213378

► **Stay in position that earthquake of high target is going to be occurred very soon.**

RESPONSE AUTHORITIES

- a. National Disaster Management Authority (NDMA).
- b. Provincial Disaster Management Authority (PDMA) Balochistan.
- c. Provincial Disaster Management Authority (PDMA) Sindh.
- d. District Coordination Officer(s) (DCO) Gwadar, Lasbella, Karachi, Thatta and Badin.
- e. Pakistan Army and Pakistan Navy.
- f. Karachi Port Trust (KPT).
- g. Maritime Security Agency (MSA).



Author

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Disaster Management Specialist, PDMA Sindh

Contributors

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