NO MORE IN THE COMFORT ZONE – Malaysia's Response to the December 2004 Tsunami

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by

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Introduction

Nothing is more dangerous than an unknown threat. To Malaysia, a country seemingly blessed and spared from natural disasters such as earthquakes, typhoons and tornados, tsunamis were as alien as moon dust. The chance of one happening was extremely remote. Yet, the unexpected happened. At about 12:45 pm on 26th December 2004, three hours after a magnitude 9 earthquake shook Sumatra, the first waves of a tsunami swept into Malaysian waters through the north entrance of the Straits of Malacca. Although tremors from Indonesian earthquakes have often been felt, Peninsular Malaysia's west coast has not experienced any tsunami in living memory. The tsunami that arrived on the shores that day - a tidal surge preceded by a sudden falling of the sea level - was met by the innocent people on the beaches with curiosity and awe. On Sunday 26th December 2004, Malaysians learnt that ‘not knowing’ is a dangerous thing.

The tsunami event of December 2004 challenged the disaster response mechanism of the Malaysian Government and added a new word to the vocabulary of the Malaysian public. Erstwhile exposed only to the distress created by monsoonal and flash floods, the tsunami became a new threat to be confronted. The Department of Irrigation and Drainage Malaysia (henceforth, DID) being the nation’s technical center for coastal engineering and erosion control, promptly responded with investigations and reviewed its action plans in coastal management.

In this paper, the authors present their account of actions taken by DID and other government agencies in response to the December 2004 tsunami and beyond. The paper discusses the event, its general affect on Malaysians and how the government responded in its aftermath.

A Tsunami hits Malaysia

Ground Zero – West Coast of Peninsular Malaysia

The tsunami affected only the states in the northern half of the Straits of Malacca (figure 1 – Perlis, Kedah, Penang, and Perak) although tidal disturbances were detected nearly 400 km south up to the shoreline of the district of Sabak Bernam (northern Selangor and bordering Perak). Apart from the simulation created by the US National Oceanic and Aeronautical Administration (NOAA) and made public on the internet, not much is known about the true path of the 26th December 2004 tsunami. The DID established that it hit the western shores of Langkawi at 12:45 pm (local time), 4 hours after the tsunami waves had ravaged Phuket, Thailand. The tsunami penetrated the marinas of west Langkawi and surged upstream through the mouths of Sungai[1] Triang and Sungai Melaka smashing boats against hydraulic structures and bridges. Barely half an hour passed before the tsunami hit the shores of Kedah at Tanjung Dawai and Kuala[2] Muda and Pulau[3] Pinang (Penang) simultaneously.

Houses, vehicles and crops were destroyed. Holidaymakers on the beaches of Pasir Panjang (Balik Pulau) and Batu Feringghi were swept against rocks and backshore structures not knowing why and what caused the large waves that day. Tidal disturbances in the form of multiple rising and falling of the tide were observed on the coast of Perlis in the north to Selangor in the middle of the Straits of Malacca. As to the main tsunami wave, there was consistency in most observations that it was preceded by a retreat of the tide well below lowest tide levels. The nearshore height of the tsunami, based on observations were reportedly 2 to 3 meters high. However, very little is known of the speed of the tsunami in the nearshore. In Pantai Merdeka (Kedah), locals who observed the approaching tsunami described it as a single wave spreading over 1 km long which outran the fishing boats trying to escape it.

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[1] river
[2] rivermouth
[3] island

Impact Zones, Damages and Casualties

Relative to the devastation in Banda Aceh, Sumatera, the tsunami impact on Malaysia was minimal. A rapid assessment of the impact sites indicated about RM15 million in damages. A majority of the damage were village houses, light traffic bridges, fishing boats and equipment. The damage seemed particularly severe on the Kedah coastline north of Kuala Muda. Whilst damages were most serious here, it was in Penang that most lives were lost. At Pantai Pasir Panjang and the adjacent village of Kampung Kuala Pulau Betong, in the southwest of the island, 27 lives were lost. In all, sixty-eight deaths were officially recorded in Malaysia with 54 occurring in Penang (see figure 2). Most of these were the elderly and the young.

The coastal bunds and revetments that protected the mostly agricultural hinterland of Perlis, Kedah, Perak were severely tested but not seriously damaged. Overtopping of revetment and bund crests were noted in Langkawi and north Perak. Some river banks collapsed due to the sudden drawdown of water during the return-flow. On the other hand, tsunami waves created deposition at the river mouths in the north and northwest of Penang.

Most of the damaged houses in the impact areas were old wooden or part-brick buildings. In Kuala Muda, it was observed that single-brick walls could not withstand the onslaught of the tsunami waves. However, reinforced concrete walls of houses along the first row of buildings from the sea managed to stay intact.

Post-tsunami Investigations and Findings

The DID, had duly responded by inspecting the impact sites immediately on the evening of December 26, 2004. Two days later, investigators from the headquarters-based Coastal Engineering Division (CED) were dispatched simultaneously to Kedah, Penang and Perak, the three major impact areas. Photographic and anecdotal evidence was then gathered with the help of the DID offices in the respective districts and compiled by the CED.

The DID's initial priorities were to inspect its coastal defences and the integrity of the coastal bunds that protected valuable agricultural lands. Evidence indicated that these structures held and that it was extremely fortunate that the tsunami maximum run-up heights did not exceed the coastal bunds protecting the major granary areas of Yan and Kota Setar. The tsunami was also found to have brought bed material inshore as no signs of erosion was found apart from a minor scarp formation at Batu Ferringhi. Based on the tidal records of the Malaysian Department of Survey and Mapping for Langkawi (see Figure 3) and Penang (see figure 4), the tsunami struck very close to the predicted high tide for the day.

Tsunami heights were approximated from the known crest heights of coastal structures and the inundation levels from the watermarks left as the waters receded. Marks as high as 1.5 meters were noted in Kuala Muda but the main tsunami wave is estimated at about +5 meters LSD. Between 300 to 400 meters of the shore width was inundated. It was also observed that the damage was less where the coastal mangroves were dense. On the tourist belt of Batu Ferringhi, the tsunami inundation distance did not reach the lobbies of the major hotels although some swimming pools were affected.

Classic tsunami damage occurred in the river mouths of Sungai Muda and Sungai Pulau Betong as the tsunami surge overtopped the river banks. Damages to the village and fishing community of Kota Kuala Muda have been described in earlier sections. Constricted by disposition, bays and inlets such as Sungai Pulau Betong suffered a worse fate where the waters rose speedily up to 2 meters above the bank level trapping villagers within their houses. At a small cove called Miami Beach in Batu Ferringhi, the deaths could partly be attributed to poor access to and from the beach - the main road lay about 3 meters above the backshore with only a footpath leading to the beach. Nevertheless, the overall findings point to the fact that it was the unknown danger that was the actual cause of deaths. Even as the killer waves were approaching, victims were seen standing and even walking towards the sea out of curiosity at a sight and sound they have never before seen or heard.

The Government's Response

Within the first week of the tsunami incident, an entire generation of Malaysians, and perhaps those of a few other equally unfortunate nations, learnt of a new threat to their coastline of which the Japanese have accepted as part and parcel of life. Malaysian rescue efforts were coordinated by the National Security Division of the Prime Minster's Department and specifically, their offices in the affected states. Ground activity involved the entire spectrum of enforcement, rescue and relief agencies.

On the international front, the Malaysian Government participated in almost all tsunami- related forums in particular the *Special ASEAN Leaders' Meeting on Aftermath of Earthquake and Tsunami* in Jakarta, Indonesia followed by the *World Conference on Disaster Reduction* in Kobe, Japan in January 2005. In February, the government sent representations to a special meeting on *Coastal Zone Rehabilitation and Management in the Tsunami-affected Region* in Cairo, Egypt and later the *International Coordination Meeting for the Development of Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework* in Paris in March 2005.

Soon after the tsunami, two factors became apparent to the government:

(i) to respond in time, forward warning was needed and;

(ii) areas with thick coastal vegetation were less damaged than those without it

Within a month after the disaster, the government announced the formation of two multi-agency task-forces:

- a National Committee for the setting up of a Tsunami Early-warning System (steered by the Ministry of Technology and Innovations and coordinated by the Department of Meteorology Malaysia); and
- a National Special Task Force for Rehabilitation of coastal forests (steered by the Ministry of Natural Resources and Environment and coordinated by the Forestry Department and Forest Research Institute of Malaysia.

The unpredictable nature of tsunami does not permit Malaysia time to wait. She must therefore establish her own early-warning system first, with a view to eventually coordinate with regional and international efforts. It envisages a system complete with sensors and communication links right down to the ground and rescue personnel.

The government's actions fell perfectly in-line and was in fact initiated even before the *Guiding Principles For Post-Tsunami Rehabilitation And Reconstruction* (UNEP, 2005) were drafted at the UNEP organized meeting on Coastal Zone Rehabilitation and Management in Regions Affected by Tsunami in Cairo, 17 February 2005. The overarching principle endorsed by the meeting was to *reduce the vulnerability to natural hazards by establishing a regional early warning system, and applying construction setbacks, greenbelts and other no-build areas in each nation, founded on a science-based mapped 'reference line'* (see Appendix).

The Malaysian Government's efforts involved the combined input of many agencies with specialised roles including the DID, the Malaysian Center for Remote Sensing (MACRES), Department of Survey and Mapping Malaysia, the Royal Malaysian Navy, universities and research institutes. The authors observe however, that while the National Security Division has been designated to oversee search and rescue operations and an tsunami awareness programme, there is none clearly designated to lead tsunami investigations. Hence, tsunami investigations were left to the initiatives of the respective agencies.

The DID's Response

The Gaps in Data and Understanding

No problem can be solved without thorough definition. Amongst the gaps in the understanding of the December 2004 tsunami is why the tsunami struck where it did. No credible explanation has been given yet to explain the tsunami propagation and concentration in the north half the Straits of Malacca. Some observers have speculated that had the epicenter been slightly north of its reported location, the speed of propagation could have been faster and damage intensity could have been much worse. Furthermore, a greater vertical displacement in plate activity might have resulted in a tsunami of greater magnitude and even wider spatial impact. Such speculations fuel further fears on the vulnerability of the coastline and local coastal engineers now realise that west coast Peninsular Malaysia is no more a comfort zone where one had previously only had to cope with the typically low wave energy seas.

Although the impact areas have since been mapped, the information at hand is still insufficient to design the correct countermeasures against tsunami for these areas. The subject of tsunami amplification, a phenomena attributed to local topography and bathymetry, need to be studied in more detail in order to determine if the northern half of the Straits of Malacca is the only danger zone. Tsunami wave energy in the nearshore zone is an altogether unknown factor as the country still suffers from a lack of oceanographic data - wave measurements in particular.

The DID had for nearly two decades designed coastal protection works without having a single long-term sensor in the coastal waters. The installation of a wave sensor was a recommendation in the seminal National Coastal Erosion Study 1986 (Economic Planning Unit, 1986) which have not yet been implemented. Long-term data is crucial in determining changes in far-field phenomena. Measured wave data facilitates the design of coastal protection and the calibration of wave refraction models. Past efforts to install wave measuring instruments have often been frustrated by budget constraints and the vulnerability of the instruments when exposed to the vagaries of weather. The absence of a long-term wave measurement system in the nearshore area in light of the December 2004 tsunami has worked against efforts to better understand it.

The DID has continued to pursue its post-tsunami investigations that would lead to a local numerical model of how the tsunami propagated into the Straits of Malacca. It believes that the development of a tsunami numerical model of at least the northern part of the Straits of Malacca would be vital in predicting future tsunami. This will subsequently pave the way for the development of a tsunami-sensitivity map of the coastal area.

Coastal Strategies

Since the completion of the National Coastal Erosion Study in 1986, the DID has pursued coastal protection using a two-pronged strategy:

1. A short-term strategy focussing on curative engineering works to protect critical erosion areas; and
2. A long-term strategy of a preventive nature through the formulation of administrative guidelines to control coastal zone development. This has since progressed into the preparation of integrated shoreline management plans

These strategies have been reviewed since the tsunami and are elaborated in the following.

Coastal Protection

The tsunami has physically tested the DID's coastal protection structures along the northern shores. Nearly 30 km of revetments, built using typical design wave heights of about 1.5 to 2 meters, protect the portions of the coasts in the affected areas. Apart from minor rock armour displacements, these structures were largely found to be intact.

It was observed that the revetments on both the Kedah and Penang side of Kuala Sungai Muda and the revetment at Sungai Burung, Penang, were overtopped. With crest heights averaging at +3.0 meters, the overtopping of these revetments meant that these structures were inadequate to prevent inundation of the hinterland. The impact was also not of the breaking of a large wave on the structures but more of a sudden rise in the water level which exceeded the crests. However, from a comparison of damage intensity along the coast of Kuala Muda between an area behind the existing revetment and its unprotected neighbour, it was found that the former suffered less damage, thus indicating that the existing erosion control structures could partially reduce the impact and damage from tsunamis.

The affected shorelines of Kuala Muda and Perak are predominantly mud beaches that geo-technically are unable to support high-crested revetments. With soil strengths of 5 to 10 kN/m^2, improvement to the load bearing capacity of the soil to support higher structures may come at a very high price. To absorb tsunami wave energy, massive structures would have to be built on the shoreline with the geotechnical problems as highlighted above. Yet, the bigger question is how and should we design for an event whose magnitude and frequency of occurrence cannot be determined with certainty? Knowing that memories dull over time, would such a structure, high and obtrusive, be continually acceptable to the local population if a tsunami fails to happen over the lifespan of the current generation?

Realising that the deaths in Penang were mostly to beach-goers, it is prudent to review the coastal protection criteria with a view to incorporate better protection and safer access to beaches exposed to tsunami. The DID's role may henceforth transcend from providing erosion protection per se to providing safe beaches, at least against the tsunami threat.

Shoreline Management

Post-tsunami observations showed an uncanny accuracy in the DID guidelines on set-back. The tsunami reinforced what has been well-accepted regarding the capability of mangroves to attenuate wave energy. The DID guidelines on erosion control for coastal development state that the set-back for development on mud beaches should be no less than 400 meters from the mangrove tree-line (DID, 1997). Setbacks were designed to site development away from the dynamic zone of the beach but conditions may be waived when coastal protection and flood defences are present. It is noted that if the houses in Kuala Sungai Muda had been built to the required setback behind the existing revetment, damage could have been reduced.

The guidelines also require a setback of 60 meters for sandy beaches as a general rule but this is often not practical for land-starved islands such as Penang or Langkawi. At Pantai Pasir Panjang in Penang, a training center stood on the backshore of this pocket beach barely 30 meters from the high water line. The tsunami run-up inundated the entire complex and showed that even 60 meters is insufficient against a tsunami run-up. Setback issues continue to be debated as project proponents naturally seek to maximise the use of the valuable shorefront properties.

As a long-term strategy against coastal erosion, guidelines and development strategies incorporating coastal forms and features must be developed for the coastline and each stretch of coast. Realising its importance, the DID initiated its Shoreline Management Program in 1998 and produced its first Integrated Shoreline Management Plan (ISMP) for the northern shoreline of Pahang, starting from the Pahang-Trengganu border to Kuala Sungai Pahang in 2002. ISMPs are developed to be used as a blueprint for coastal development (The Sunday Star, 2005[2]). It identifies sensitive ecosystems, recommends the preferred economic activity for the coast and is a holistic approach towards erosion control. An ISMP will be started soon for Penang and the tsunami incident has created an urgency for this ISMP study to be completed as soon as possible. It is only logical that ISMP studies become a priority to the tsunami-affected states.

Coastal Rehabilitation

It was observed that in Balik Pulau (Penang) and Kuala Muda, mangrove forests helped to reduce the maximum inland limit of inundation as the wave energy is attenuated by the trunks and root systems of the mangrove trees. In both these areas, there were also existing revetments that contributed to the reduction of tsunami energy. However, in areas which are of economic importance, most of the mangrove forests have thinned and therein lies the paradox. Where mangroves are pristine, there would usually be neither any population nor development to protect, and where development has encroached there are no mangroves to provide the protection. The worst hit shoreline in Kuala Muda had no mangrove cover and the waves were strong enough to pile cars on top of each other. Yet, slightly further north at the village of Padang Salim, some of the houses with merely 50 meters of mangrove between them and the sea were not damaged. It is noted during the investigations that it is not merely the thickness of the mangrove-belt that attenuates wave energy but also the density of its growth.

The coastal forest rehabilitation initiative by the Ministry of Natural Resources and Environment and spearheaded by the Forestry Department is targeted at restoring coastal forests through management and re-planting schemes. Two objectives have been identified: to restore the coastal vegetation belt at the tsunami impacts sites where they had once dominated; and to determine methods and means to preserve or enhance existing belts to ensure their continued survival. For this initiative to be successful, the existing coastal development guidelines must not be ignored and mangrove reserves should be preserved and not be open for logging or clearing.

The DID’s input to the coastal forest rehabilitation effort is to provide coastal engineering support both in terms of site selection based on shoreline trends and structural measures. Many attempts at replanting mangroves on open coasts have failed due to the fact that the wave energy is too strong for young saplings. It is also known that natural mangrove regeneration normally follows accretion. Hence, accretion has to be induced through engineering measures before the mangroves can return naturally or through a replanting effort.

It was fortuitous that in 2003, the DID had embarked on a relatively new approach to protect coastal mangrove using low geotextile, sand-filled breakwaters (see figure 4). A pilot project had been implemented in Tanjung Piai, Johor where these breakwaters were built in front of an eroding mangrove shoreline (Ghazali N.H.M., Ong H.L., 2005). The breakwaters reduce the wave energy in its lee thereby creating a more favourable environment for accretion and subsequently for mangrove re-generation or re-planting.

Countermeasures

Several countermeasures can be employed to defend against tsunamis. The best form of defence as proposed by Shuto (2001) is a combination of structural defences, regional planning (development planning) and software (for tsunami prediction) *working in harmony with daily activities* (disaster knowledge inculcated into the local culture). The benefits and limitations of these countermeasures within the Malaysian context are explained as follows:

Coastal Defence Structures

Coastal defence structures provide security for homes on the coast as they are a physical barrier to tsunami. However, a very high revetment or sea wall of concrete or stone with a crest height of about +6.0 meters LSD would be required to counter a tsunami wave similar to that of December 2004. In the soft soils of Kedah and Penang, such structures would cost at least RM10 million per kilometer. Unfortunately, the prediction of a tsunami incident and the determination of its maximum possible height and frequency of occurrence is not yet a science.

Tsunami control structures such as offshore breakwaters can also be built to protect pocket beaches or narrow bays such as Pantai Pasir Panjang, Pantai Miami and Kuala Sungai Pulau Betong in Penang. This would only reduce the impact energy but not the level of the tsunami heights (Shuto, 2001). Structures sited in deep water are also expensive to construct and maintain.

Coastal Planning

Having identified tsunami prone areas, development must be planned so as to prevent future disasters. Set-back regulations should be enforced and important buildings such as hospitals, schools and fire stations must be sited outside the impact zones. The DID-recommended development setbacks of 400 meter and 60 meters for mud and sandy beaches respectively appear barely sufficient for this tsunami event. Coastal vegetation such as mangroves has been proven to be nature’s wave barriers and offer protection to the backshore. These must be preserved and their further enhancement and proliferation must be encouraged. DID guidelines No. 1/97 for development on mud coasts but specific setbacks and other relevant guidelines must be in place for the tsunami-hit areas.

Alternatively, safe platform levels (for building construction) must be determined for tsunami-affected zones. The DID’s shoreline management program is well-poised to establish these setbacks and platform levels through formulation of shoreline specific ISMPs.

Disaster Response Mechanism

Disaster response time is a measure of preparedness. It is thus important that the disaster response aspect of the government machinery especially rescue forces be well-trained and equipped. It must also be emphasised that the experience and thorough understanding of one tsunami event enhances the government’s readiness to face the next. A special multi-agency post-tsunami investigation team should therefore be formed when a tsunami occurs. The role of the team will be to gather post-tsunami data such as inland inundation limits and levels.

In order to improve disaster response mechanisms, the road and traffic system around tsunami impact zones must be carefully charted for better access and management. It is common that immediately after a tsunami event, the coastal road is covered with debris and often impassable. Hence, the road layout in and around the affected areas especially Kuala Muda should be reviewed and possibly re-designed for better evacuation.

Inculcate Disaster Culture

Educating the public is the best way of saving lives. This extends towards all walks of life and is particularly important for the next generation who did not experience the tsunami or were too young to understand it during the incident. At public places such as hotels, “What to do during a tsunami” guides must be installed either in the rooms or on signboards. While these signs may appear to be a grim reminder of the incident, it is the only way to advise or warn people who are visitors to the tsunami impact zone and who may have no prior knowledge of tsunami. A similar impact may be achieved by the construction of monuments to commemorate the incident.

The Lessons Learnt

The probability of another tsunami occurring along the Indian Ocean fault and generating a tsunami must never be discounted. NOAA claims that an Indian Ocean Tsunami Warning System has been mooted as early as 1985 without much progress. It suggests that, without a significant precedent in recent memory to rely on, even scientific rationale is insufficient to push the initiative. Dr. Smith Dharmasaroja, the former Director-general of Thailand's Meteorological Department believed ten years earlier that such a tsunami would destroy Phuket, and became the subject of ridicule (The Sunday Star, 2005[1]). At the risk of similar treatment, local researchers must be intrepid enough to report future tsunami threat no matter how controversial. However, first and foremost, the tsunami of December 2004 - its propagation and impact - must be properly studied and understood.

In the creation of a tsunami-ready society, all levels of rescue personnel must be trained specifically to tsunami dangers. Amongst the most important lesson is to understand the tsunami itself. The rescue and relief teams working on the beaches and conducting their search and rescue missions on the 26th and 27th December 2004, were not sufficiently aware of the danger that another tsunami could have struck again. Continuous monitoring and rapid dissemination through an early-warning system needs no further justification.

Education overcomes ignorance and awareness saves lives. Publicity, however, is needed for both efforts to be successful. It requires intense and continuous coverage by the media for any concept to be publicly accepted. In the case of the mangroves acting as tsunami buffers, the widely-reported statements of the Prime Minister on the importance of mangrove preservation gave much support to its cause. It is felt that current efforts into shoreline management and development planning as a countermeasure could be strongly boosted through political will and similar coverage by the media.

Conclusion

The tsunami incident of December 2004 has added a new dimension to Malaysian coastal management. In order to face this new threat, the DID and its counterparts in the Malaysian Government need to review their criteria in delivering their services. This is a considerable task since the occurrence of tsunami in the Straits of Malacca is rare and that very little is known of the tsunami characteristics. The government therefore needs to focus on understanding the tsunami of December 2004 in order to design appropriate countermeasures. To achieve this, future post-tsunami research and investigation must be as well-coordinated as search and rescue efforts.

The Malaysian Government’s main post-tsunami response thus far - initiating an early-warning system and coastal forest rehabilitation programme - is very much aligned with the requirements of the UNEP. From the DID’s perspective, the tsunami has forced the department to re-examine its criteria and practices in the design of coastal protection works and shoreline management. The main findings are that the tsunami-affected states must awaken to the fact that their shorelines in the Straits of Malacca are no more in the comfort zone and that better shoreline management is needed. A combined approach involving engineering, development control, planning and education is seen to be the best strategy against the tsunami threat.

The DID plans to formulate Integrated Shoreline Management Plans throughout the country and the tsunami has created an urgency for certain states to expedite efforts. As these initiatives continue, it must be supplemented by a concerted effort in raising tsunami and conservation awareness at all levels of society which is the key to saving lives and our coastal environment in the future. Undeniably, the 26th December 2004 tsunami has caused us to give our coastlines the respect they rightfully deserve. Let us pray that a reminder would not be necessary.

Acknowledgement

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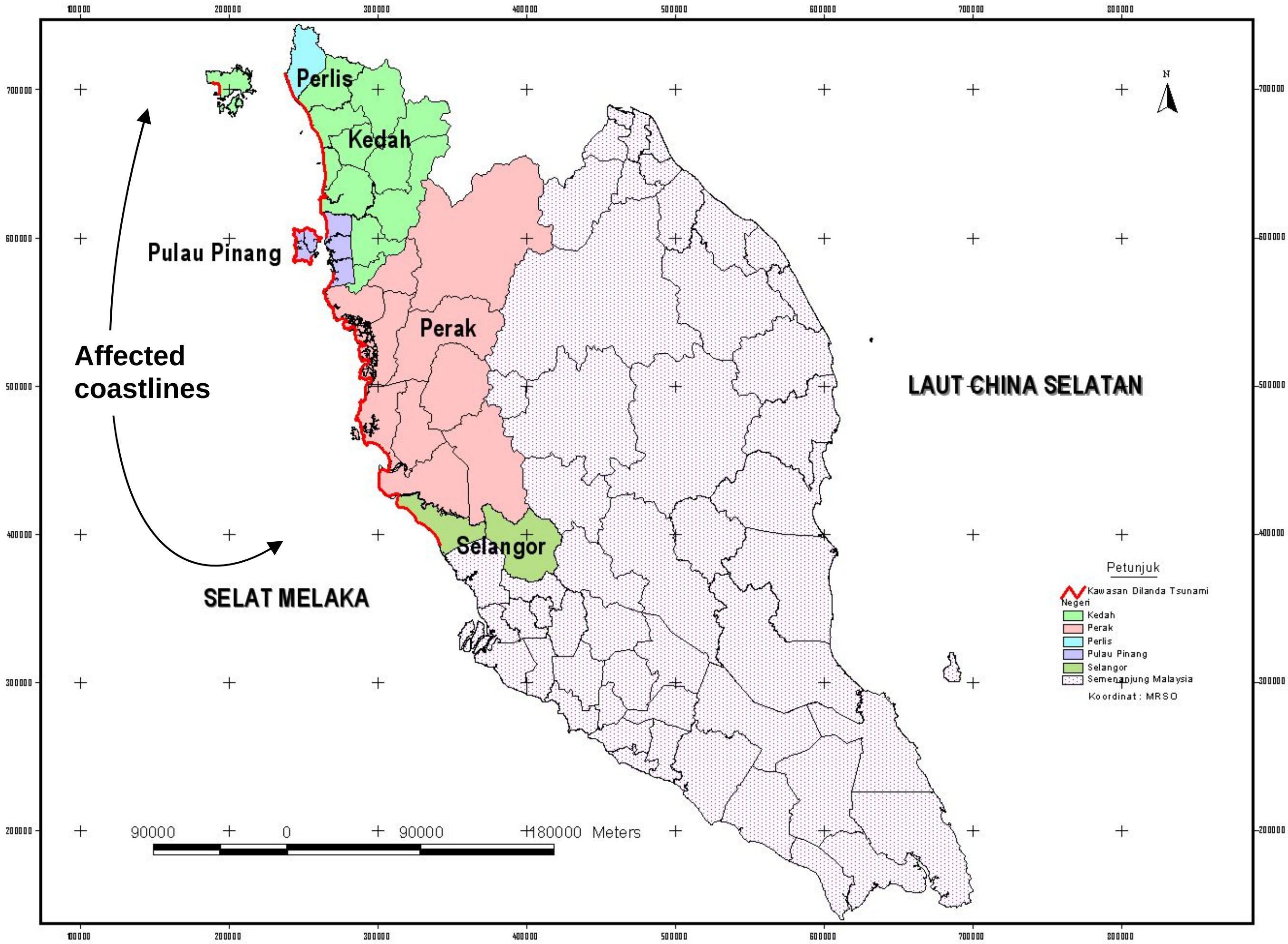

Figure 1: Coastlines affected by tsunami (Selat Melaka = Straits of Malacca)

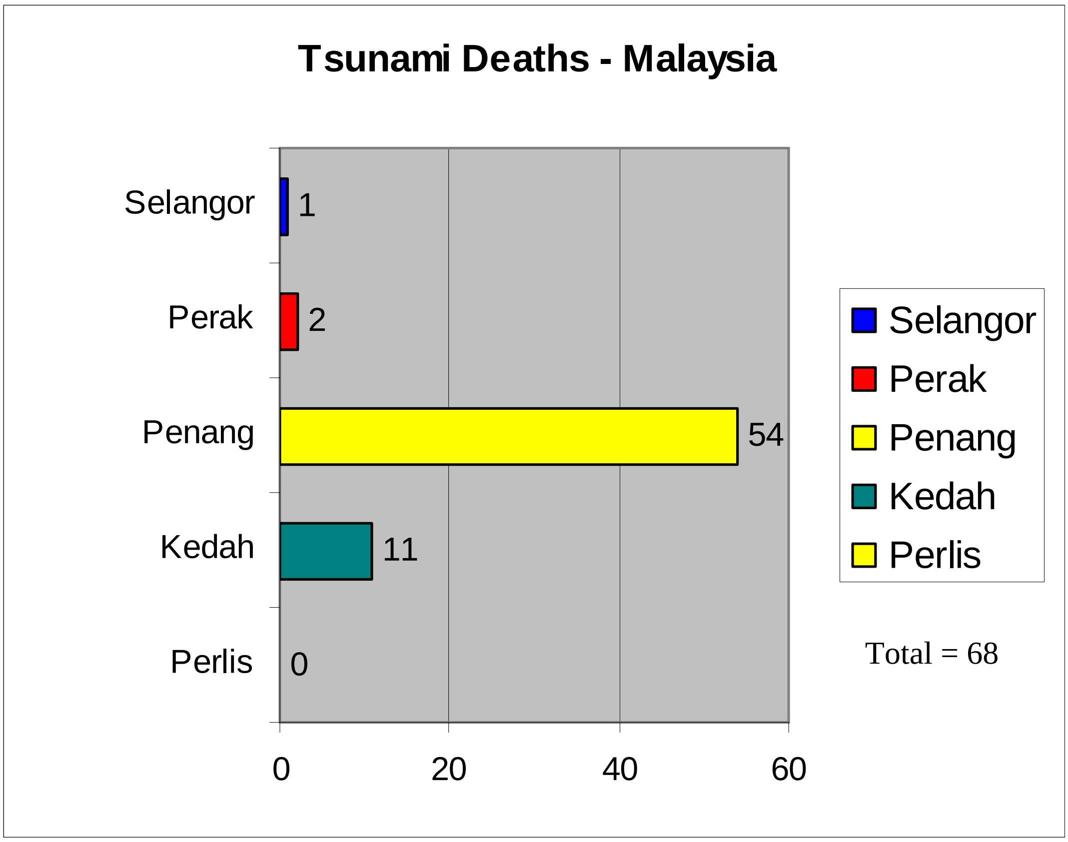

Figure 2: Deaths from 26th December 2004 Tsunami, Malaysia

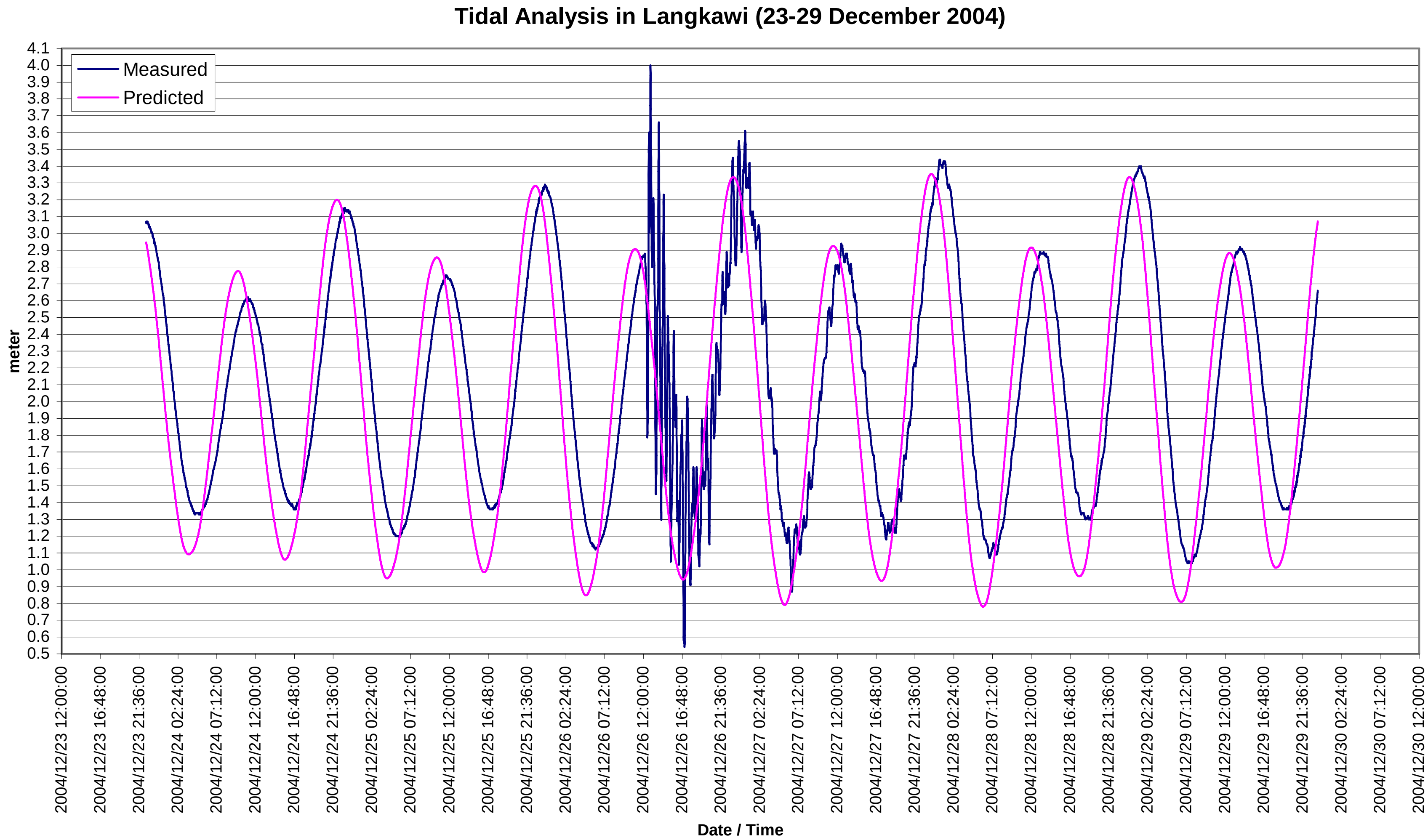

Figure 3: Tidal records from Langkawi indicating sea levels during the tsunami (Dept. of Survey & Mapping Malaysia)

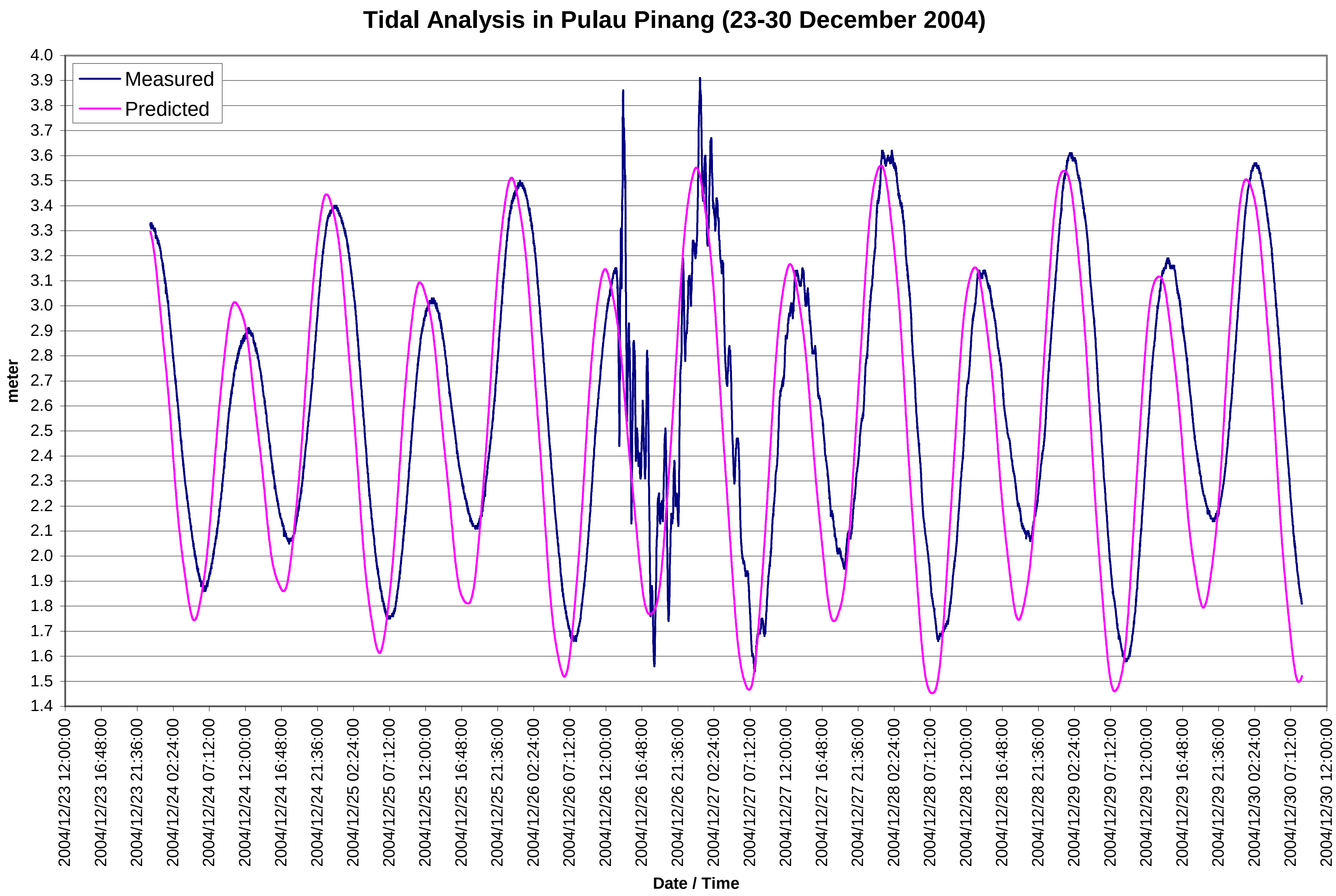

Figure 4: Tidal records from Penang indicating sea levels during the tsunami (Dept. of Survey & Mapping Malaysia)

Figure 5: Sand-filled Geotextile tubes placed in front of eroding mangrove shoreline

Appendix

The Cairo Principles

1. (Overarching principle) Reduce the vulnerability of coastal communities to natural hazards by establishing a regional early warning system; and applying construction setbacks, greenbelts and other no-build areas in each nation, founded on a science-based mapped "reference line".

Using concepts of integrated coastal management, including public engagement in local decision-making, employ a rapid assessment zoning and planning process to:

2. Promote early resettlement with provision for safe housing; debris clearance; potable water, sanitation and drainage services; and access to sustainable livelihood options.

3. Enhance the ability of the natural system to act as a bioshield to protect people and their livelihoods by conserving, managing and restoring wetlands, mangroves, spawning areas, seagrass beds and coral reefs; and by seeking alternative sustainable sources of building materials, with the aim of keeping coastal sand, coral, mangroves and rock in place.

4. Promote design that is cost-effective, appropriate and consistent with best practice and placement of infrastructure away from hazard and resource areas, favouring innovative and soft engineering solutions to coastal erosion control.

5. Respect traditional public access and uses of the shoreline, and protect religious and cultural sites.

6. Adopt ecosystem based management measures; promote sustainable fisheries management in over-fished areas, and encourage low impact aquaculture.

7. Promote sustainable tourism that respects setback lines and carrying capacity, benefits local communities and applies adequate management practices.

How things are done is as important, sometimes more important, than what is done. Local knowledge and insights are critically important to successful planning and decision-making, and local citizens must be engaged in the rehabilitation and reconstruction process at every stage. It is essential that the application of the construction setback line and the boundaries of bioshields are defined in consultation with the local communities coastal reach by coastal reach.

8. Secure commitments from governments and international organizations to abide by these Principles and build on and strengthen existing institutional arrangements where possible.

9. Ensure public participation through capacity building and the effective utilization of all means of communication to achieve outcomes that meet the needs and realities of each situation.

10. Make full use of tools such as strategic environmental assessment, spatial planning and environmental impact assessment, to identify trade-offs and options for a sustainable future.

11. Develop mechanisms and tools to monitor and periodically communicate the outcomes of the reconstruction through indicators that reflect socio-economic change and ecosystem health.

12. Widely disseminate good practices and lessons learned as they emerge.