THE SERIBU ISLANDS PATCH REEF COMPLEXES: A GEOSPATIAL REVISIT TOWARD A COMPENDIUM OF RISKS ON INDONESIA'S SMALL ISLANDS

Poerbandono

Faculty of Earth Sciences and Technology, Institute of Technology, Bandung,
Jalan Ganesha 10, Bandung 40312, INDONESIA.

email: poerbandono@gd.itb.ac.id

Abstract

This paper assembles important findings of selected scientific works on marine environments in Seribu Islands of the South East of Java Sea, Indonesia. Issues related to saline water intrusion and erosion will be the centre of attention and will be seen from the view of geospatial perspective. In this instance, the pattern of existing portion of a particular feature on the studied site as well as its changes in spatial dimension is used to conclude the process being occurred. The works are expected to contribute to better insight of the nature of and recent changes on the region in global, regional and local scale. In addition to environmental pressure from the mainland, current practices on local scale of are the primary basis of the high environmental risk on individual islands in the region. This result can serve as model to other small islands throughout the archipelago, in which geospatial approach plays substantial role.

Keywords: *saline water intrusion, shoreline changes, spatial approach*

1 THE SERIBU ISLANDS

A few tens of Indonesia's islands make about 97% of the total land mass of this archipelagic state (Tomascik et al., 1997). This implies that the rest of the over eleventh of thousands of islands are small and spread over the Indonesian ocean territory. One among the best known small island region is the Seribu (Thousand) Islands of the SW of Java Sea off Jakarta municipal. Seribu Islands are patch reef complexes composed by coral platforms (where some of them have coral islands) originated from presence of coral ecosystem. Seribu Islands were sub-municipal of North Jakarta and since 2001 became administrative municipal according to National Law 34/1999 and Governmental Regulation 55/2001. In 2002, this 105,489 hectares of area was declared as marine national park according to Ministry of Forestry Decree 6310/2001. Bird sanctuary, preservation of colonial buildings and conservation of marine lives are among of the primary subjects addressed. Figure 1 shows the Seribu Islands on the Java Sea and selected site, i.e. Pramuka, Karya, Panggang, Semak Daun, which will be discussed further in this presented paper. The islands in the selected site are among of 108 coral islands in SW of Java Sea. This region represents portrayal of remote small island where advances of development are considerably left behind the nearest urban areas. Socio-economic state, ecological characteristics and physical geography of the region are reasonably

well documented (Adrianto & Matsuda, 2004; Tomascik et al., 1997; Ongkosongo, 1984). Environmental quality degradation and evidence of subsistence economy are on progress (Cleary et al., 2006; Nur et al., 2001). Beyond these known information, saline water intrusion and erosion on local scale are environmental issues that have not been thoroughly addressed.

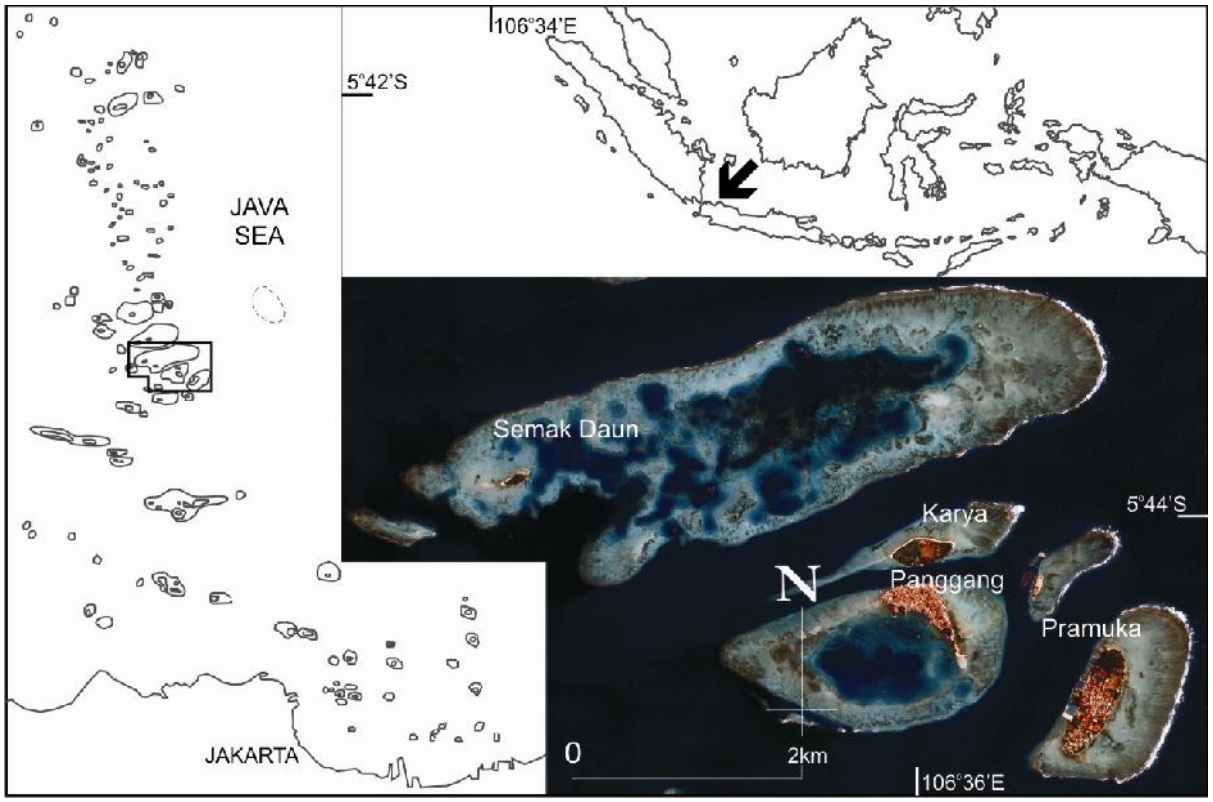


Figure 1: Pramuka, Panggang, Karya and Semak Daun of the Seribu Islands SW Java Sea, Indonesia

On small islands, groundwater storage from precipitation is the primary source of freshwater. The corresponding typical threats are excessive pumping of groundwater and reduction of recharge area due to conversion of vegetated zone into built up (White & Falkland, 2011). Such threats increase the risk of availability of freshwater. Erosion also contributes to the increasing this risk, since it may remove beach sediment resulting in destruction of the beach line belt and reduction of the total size of the island. It has been indicated that there is interrelation between global erosion and sea level rise (Zhang et al., 2004). The rising of sea level facilitates erosive waves further landward. Due to the rising of sea level, coastal inundation and saline water intrusion are expected to exacerbate (IPCC WGIII, 1990). These motivate endorsement of an integrated overview in which geospatial perspective can be the best window to look into this water-related issue. We have the believe that the basic understanding of many of physical processes, including those related to erosion and saline water intrusion on small islands, can be initiated by observing the displacement or changes of position of any related features with respect to its spatial setting.

This paper is intended to revisit novel knowledge on the domain being investigated that has been documented in various technical reports and scientific papers. We are aiming at the way spatial variables are used to examine an event of changes, its pattern and processes. The latest might probably require specific understanding of the physical processes involved. For

instance, in the case of erosion and saline water intrusion issues, it is known that dynamics of coral sands in Seribu Islands is due to the prevailing wind and wind-generated wave. This results in the shaping of coral island's geometry. Debris of coral shingle is piled up by the wind and by the breaking of wave (Umbgrove & Verwey, 1929). Further to this, it is indicated that vegetation has fixed the sands and reduce their mobility. The actual shape of an island will be hence stabilized for longer period. Kuenen (1933) speculated that presence of vegetation promotes the stabilization of a coral island by percolation of rainfall water. It would make sense if is also considered as an important mechanism of freshwater recharge on coral island.

2 ENVIRONMENTAL RISKS

Risk is the probability of unwanted loss or damage of properties or injury or death of people and could be defined as function of hazards, vulnerability and exposure. Specific identification of each of the contributing risk factor (i.e. hazards, vulnerability, exposure) is obligatory since the definition of risk itself is specific for a given hazard and the related threats, which have direct relevance to the increasing of risk. Risk of a subject with respect to known hazard shall be uniquely defined. Vulnerability is the internal property owned by the subject of risk, which may decrease or increase due to changes of the property of the subject. Exposure indicates the closeness, which may be spatial or physical, of the subject to the hazards. When we return to the study area in the Seribu Islands, it is necessary to define which threats are prominent or selected for a specific study. Unless threats are well defined, variables involved will be complex and risk assessment will be intricate. Most of risk studies are intended to support the process of decision-making. Decision maker only need managerial intervention to decide whether a technical option –in which scientific studies have been involved in its development– should be made or not. Nur et al. (2001) has compiled list of environmental issues, which become the basis of a proposal towards wise coastal management practice for the Jakarta Bay and Seribu Islands (Table 1). We propose to provide structure of the complexity of the environmental and anthropogenic issues in this region by decomposing the spatial scale of the problem into global, regional and local.

Table 1. Environmental issues of the Jakarta Bay and Seribu Islands (summarized from Nur et al., 2001)

Zone	Category	Issues
Ocean: Environmental deterioration	Marine pollution and beach litter	Industrial activities Households sanitation and disposal Agricultural activities Beach litter
	Transformation of natural ecosystem	Land reclamation Mangrove destruction
	Unsustainable coastal resources exploitation	Destructive fishing practice Sand mining Coral extraction
Coastal: Endangered coastal and urban ecosystems	Water management problems	Surface water pollution Water of the rivers crossing Groundwater contamination Saltwater intrusion Flood
	Solid waste management	
Watershed: Upstream area environmental problems		

2.1 Global scale

Recent work indicates that between the 1992 and 2009 there has been annual change of sea level on the region by 2 to 4mm (Kartikasari, 2009). This work is based on analysis of altimetry satellite data. Trend of the rising of sea level around the region was already predicted by Yanagi & Akaki (1994) with annual change of one-order higher magnitude than that recently deducted from altimetry satellite data. Another possible change due to global trend is the warming. It is unfortunately least known how regional temperature representative for the region has altered due to lack of historical data. The nearest case would be probably historical record and modeling of air temperature in Jakarta in the 20th century. It is stated that there has been rising of temperature by 1.2°C between 1890 and 2003 (Poerbandono et al., 2009). This finding is complementary analysis resulted from input parameters for the application of spatial hydrological model which taken into account changes of land cover in the Jakarta area (Julian et al., 2011).

2.2 Regional scale: Watershed-coastal-small island continuum

Jakarta area, SE of Seribu Islands, becomes the focal point of discussion in regional assessment of many of marine environmental studies in this region. Anthropogenic pressures due to rapid urbanization and growth of population in Jakarta are the general threats for Seribu Islands. Rees et al. (1999) indicated that land-based contaminant plays a significant role in adding near shore stresses to benthic faunas. Stresses are pronounced in the mid and offshore zones (i.e. between 22 and 40km and >40km from Jakarta) to individual islands as disturbance related to non-sustainable fishing and local population pressure from some densely populated islands greater than land based waterborne pollutants (e.g. Cleary et al., 2006; Nur et al., 2001). These are introduced by human activities primarily through fishing and coral mining dredging, boat activities, oil spills, resort construction and the discharge of industrial and domestic effluent. A study from Cleary et al. (2006) has used richness, cover and composition of coral in the Jakarta Bay and off Jakarta to depict the intensity of human-induced disturbance. There was difference in composition and cover of coral among zones: Cover was very low and composition differed markedly in the nearshore zone (Jakarta Bay) where human-induced disturbance is most intense and cover was highest in the outlying reefs of outer zone. Local use of land in the individual coral island does not seem to contribute to the generic depiction of the intensity of human-induced disturbance. Further to this, Uneputty & Evans (1997) has previously identified the extent of floating litter from the mainland. It was stated that mainland pollution was found even in an island 45km away from Jakarta, which was not the case even only 25km away landward ten years earlier. Related to this, long-term simulation of hydrologic cycle in the Jakarta area has improved the understanding of the mainland influence to the Seribu Islands. Flow discharge and yields of sediment from major rivers in NW of Java have increased due to reduction of forest cover in the hinterland and waterproofing of soil in the coastal lowland area, i.e. Jakarta (Julian et al., 2011).

2.3 Local scale

Whilst problem related to environmental degradation on regional scale occurs due to the influence of the Jakarta area, there has been indication of local destruction, which is thought to be due to specific designation, e.g. inhabitation, resort or conservation, of a coral island and practices of Seribu Islands' inhabitants. Erosion and availability of freshwater are of among list of problem on local scale. Tomascik et al. (1997) indicated that poor

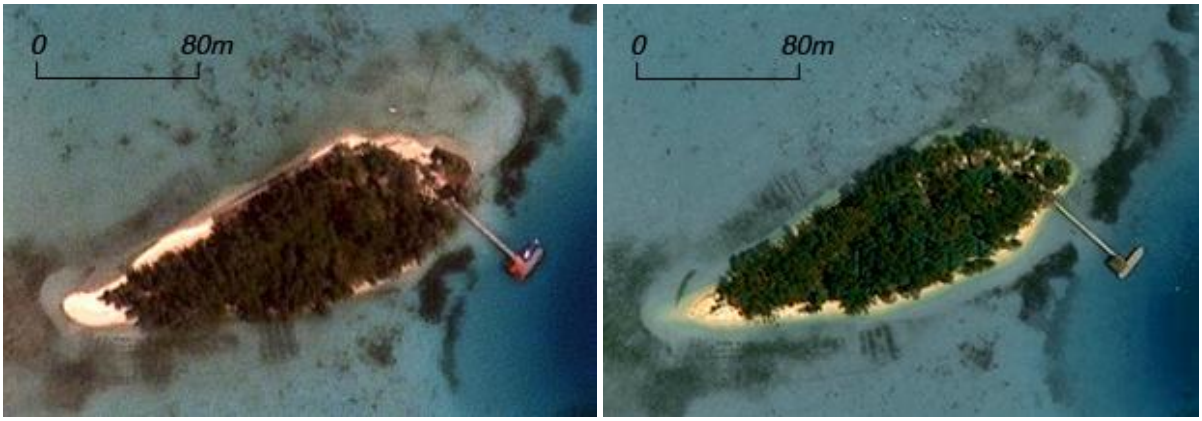
understanding on the process of erosion in the region has led to the mismanagement of coastal protection. Erosion on coral islands in Seribu Islands has been long before documented in Zaneveld & Verstappen (1952). Coral extraction in the 1930s and 1990s and sand mining in the 1980s (Nur et al., 2001) could be an irreversible threat that cause severe coastal abrasion and disappearance of coral islands. Apparently even without destructive practices, with the presently known global pressure in from of sea level change, erosion problem will become pertinent to be properly addressed. It is relevant to understand that the genesis of coral islands is due to the falling of sea level 4500 years Before Present (Ongkosongo, 1984). It promoted exposure of coral platforms to weathering that produces biogenic sediments originated from dead corals. Subsequently, the sediments are transported roughly in the focal point of the platform due to centripetal rays of wave actions and forming a shallow sand bank, which could probably be the initial stage of the forming of coral island. Many of coral islands experienced stabilization as they reached considerable size (Tomascik et al., 1997). Ecological succession (by plants and animals) and -later on- inhabitation followed this stabilization and turned several of the islands into dense human settlements. Coral islands sitting on reef platforms in Seribu Islands typically have a few tens of decimeters in height above sea level and a few hectares in area. Instabilized accumulation of sandy shoal on reef platform may subject to movement due to surfing wind-generated wave. Relation between change of wind climate and erosion on coral islands off Jakarta Bay has been recognized (Verstappen, 1954). This is due to movement of beach sands driven by the alternating monsoonal wind-induced waves, which occasionally results in negative budget of sediment. Wind direction produces subsequent shifts of shingle rampart on coral island by surf action. Awareness on the progressing erosion seems to be possessed already by inhabitants and local authority. There have been efforts attempted by construction of beach walls for coastal protection. In several cases, we found failures of such constructions. This could correspond with a consideration that erosion problem in the region seems to be mismanaged due to the poor understanding of the processes involved.

Combined natural and anthropogenic impacts in the region that has been considered to be handled through misleading management are commented in Tomascik et al. (1997). It is thought that the role of practices of local inhabitants in maintaining quality of reef platforms and coral islands seem to be prominent. Fauzy & Buchary (2002) address inhabitants' poverty alleviation and marginalization as priority action in coping with local socio-economic reason for local destruction. Latest known report confirmed that along with the growth of population and settlement area, resilience is increased (Farhan & Lim, 2010). In accordance with saline water intrusion issue, this is thought to the increased threat of water holding capacity in the island, as precipitation is known to be the only resources. As presence of vegetation is important for stabilization of coral islands and improvement of wetting of soil from precipitation, reduction of vegetation cover may degrade the capacity of storage of water in the island. Conversion of vegetated area into urban settlement is hence threatening the availability of freshwater. A study (Prabowo et al., 2012) is being carried out in order to identify types of hazards on freshwater and how recent changes in both natural and anthropogenic settings are resulting risks on saline water intrusion.

3 EROSION OF CORAL ISLANDS

An example of examination of erosion in Seribu Islands is documented in Poerbandono & Harto (2010) and Poerbandono (2012). The examination is focused on Pramuka, Panggang, Karya and Semak Daun islands. This site possesses unique appearance as each of the islands

is occupied by distinct type of inhabitation. Panggang represents an island with a very dense inhabitation. Pramuka and Karya are respectively representing medium and low inhabitation, whereas Semak Daun is uninhabited. Visual interpretation of QuickBird image from July 2008 and WorldView image from December 2009, which are representing respectively NW and SE monsoons, indicates that there is considerable visible change of shoreline position (Figure 2). Such a change is seen quite distinctly at Semak Daun. During SE monsoon, shoreline position of the southern side of the island is shifted north-westward and tied in with the water-vegetation boundary on the island. During the opposite season, i.e. NW monsoon, the shoreline position is shifted south-eastward. It is also reported from direct visits to the site for direct inspection on Semak Daun islands have been made that there is evidence of different situations which reflect movement of sand covers due to the changing monsoons. Exposed pebbles were observed in July 2008 in the SW corner of Semak Daun. This site was actually covered entirely by sand just three months earlier on March 2008. As documented in Poerbandono (2012), July is known as typical peak of SW monsoon when ESE wind-induced waves shift beach sands north-eastward resulting in removal of sand accumulation which has been developed during the preceding season, i.e. NE monsoon. Comparable information as it is visually seen on Semak Daun cannot be obtained from the three other islands considered in the study, i.e. Panggang, Pramuka, Karya. This is thought to be due to the full fortification of those islands along their shorelines. Such a protection does not leave any natural stripes of sandy beach lines surrounding those islands.



(a) QuickBird image July 2008, SE monsoon (b) BirdView image December 2009, NW monsoon

Figure 2: Shift of shoreline due to opposing monsoon in Semak Daun (Alodia et al., 2012)

Direct observation has also collected of indication of erosion. It is confirmed that abrasion is severe. In many places in the investigated sites, evidence of failure of coastal protection and eroded sites are found. Karya could probably be the best fortified island. Less failure -with respect to other island- is indicated. Karya is a dedicated island for authority offices, which may become well understood that governmental budget can be directed to afford such a civil construction. Evidence of erosion is in Pramuka is seen in the eastern part of the island. This is the windward side of the reef platform and subjects to attack of SE monsoon's wind-induced waves. Efforts for coastal protection were already definitely made previously, as there have been evidences of eroded concrete beach walls on the NE edge of Pramuka. Panggang might also be among the most stable island considered here given the fact that extensive reclamation were in place. Exception would be the SE tail of Panggang, a place that attracts lesser amount requirements for protection due to its considerable narrow size. In Semak Daun on an event of SE monsoon, ESE waves are directing beach sands to move

along the shore through drift mechanism. This develops sand spit in the west end of the island which can be said as the nodal point. Failure of concrete beach walls in the NE edge of the island is thought due to compensation of bending of wave energy which initially strikes the SE edge of the island. Stable natural beach line in the southern part of the island might probably be maintained by the availability of sand budget. Absence of hard protection of in this particular section of beach might facilitate equal distribution of wave energy, which also helps to maintain the stability of the shoreline position.

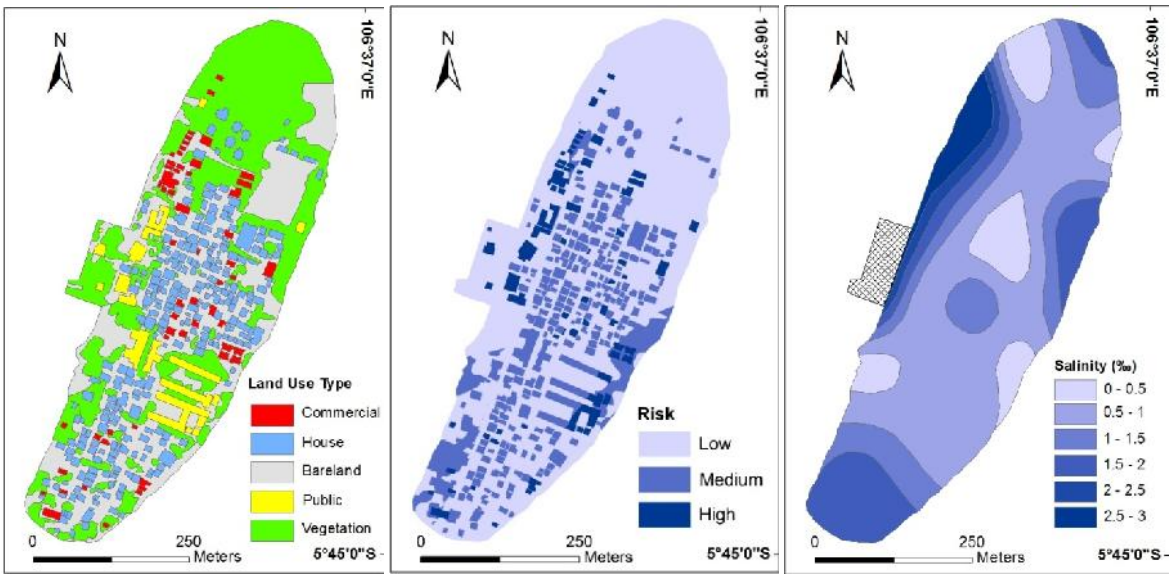
4 SALINE WATER INTRUSION

Groundwater is the primary source of freshwater for drinking and sanitation purposes. On inhabited small islands, negative budget of freshwater may occur due to imbalance between extraction and recharge of groundwater storage. This will become severe environmental problem when excessive pumping of freshwater from an aquifer reduces the water pressure and intensifies the drawing of saline water into new areas (Adeoti et al., 2010). Such water problems also occur worldwide. Increase in population and the corresponding changes of land cover have driven the occupation of space to support human activities (Vörösmarty et al., 2000). On small islands, freshwater budget is even more sensitive to changes of land cover, since little reduction of vegetation zone may have significant proportion of recharge area with respect to the entire size of the island. This will in turn increase the vulnerability of groundwater from contamination due to intrusion of saline water. It is the intention of this paper to address risk of saline water intrusion on small islands. We will use Pramuka –a coral island of 22.8Ha area lying on 109.1 Ha reef platform– as example. Here, we have measured a few tens of groundwater salinity throughout the island. During the latest few years there has been rapid growth of marine tourism business in the region, which was since late 1990s promoted as marine national park. This growth and also the increasing population are suspiciously thought to drive conversion of land cover, typically from vegetation into built up (Figure 3).

(a) 2004 (b) 2008 (c) 2012

Figure 3: Land cover of Pramuka

It is known that decrease of vegetation cover in such a small island might lead to reduction of zone of freshwater recharge and hence increasing the risk of saline water intrusion. It is however least known how recent changes and known threats have impacted the quality of freshwater, specifically in terms of increasing water salinity. It is hence proposed to generate risk model of saline water intrusion by considering hazard, exposure and vulnerability of groundwater. Hazard map to groundwater is developed according to land use. It is assumed that the primary threat to saline water intrusion is the pumping from households. Exposure map is generated from the land cover and the vicinity of the location being evaluated with the shoreline. Types of land use (Figure 4a), in this instance built up (commercial, public, residential house), bare land and vegetation, distinguish the degree of contact groundwater storage and the most possible factors that can degrade its quality. It is possible then to generate risk map (Figure 4b) according to the identified hazard, exposure and vulnerability which are relevant to the decreasing of freshwater quality from saline water intrusion. Vulnerability map is generated according to depth of water table, precipitation rate, aquifer media, soil, topography and impact of vadose zone (Falkland, 1993). Samples of water throughout the investigated island are collected and their salinity is measured (Figure 4c). The produced risk map indicates that spatial distribution of groundwater risk shows a relationship with salinity distribution throughout the island. Zones with greater salinity are located in the areas identified as higher risk. Lower risk areas spatially correspond to zones with lower salinity.



(a) Land use (b) Risk level (c) Observed groundwater salinity

Figure 4: Groundwater risk assessment maps of Pramuka Island

5 CLOSING REMARK

In this presented paper findings of selected scientific works on marine environments in Seribu Islands of the South East of Java Sea, Indonesia have been shown. Issues related to erosions and saline water intrusions at local (a single island) scale are discussed and could put on novel insight to the thorough understanding of the nature and dynamics involved. On the basis of this insight, sustainable measure of adaptation could be developed. It is critical to optimize such a measure since it is often irreversible once capitalized. We expect to contribute to better insight of the nature of and recent changes on the region in global and

regional scales emphasizing in local scale context. Such emphasize is underlined due to the fact that current practices at island scale are critical in increasing environmental risks. We also expect that this result can be used to serve as model to other small islands throughout the archipelago, in which geospatial approach plays substantial role.

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