Assessing the giant sea wall for sustainable coastal development: case study of Semarang City, Indonesia

[1]Sudharto P. Hadi, [2]Sutrisno Anggoro, [1]Hartuti Purnaweni, [3]Nany Yuliastuti, [4]Adi Ekopriyono, [1]Rizkiana S. Hamdani

[1] Graduate Program of Environmental Studies, Universitas Diponegoro, Semarang, Indonesia; [2] Faculty of Marine Science and Fisheries, Universitas Diponegoro, Semarang, Indonesia; [3] Department of Urban and Regional Planning, Universitas Diponegoro, Semarang, Indonesia; [4] Universitas Tujuh Belas Agustus, Semarang, Indonesia. Corresponding author: S. P. Hadi, sudhartophadi@yahoo.co.id

Abstract. Tidal flooding (locally called rob), which is caused by sea level rise and exacerbated by land subsidence, is a crucial problem in Semarang City. Land subsidence has occurred since the beginning of the 1990s and is stimulated by overburdened buildings and groundwater extraction. Governments have taken action by building polders consisting of a pumping station, a retention pond, and a flood gate at the western, central, and eastern sides of the Semarang North Coast. Polders only temporarily minimize tidal flooding because they deal with the phenomenon and not the sources of the problem. The Semarang North Coast is strategically located and thus has ports and recreation and housing areas and it is engaged in fisheries and agriculture; therefore, land subsidence in this area is promoted. In addition, various industries located at the industrial zone in the Genuk District rely on groundwater extraction, which leads to land subsidence. Given this situation, the government plans to build a giant sea wall with a double function: (1) as a toll road that stretches from Semarang to Demak and (2) as a barrier to prevent seawater from flowing to the inland. The Genuk area will be completed by a retention pond to accommodate water flowing from upstream and middle stream areas. The water in the retention pond will be utilized to supply industries at the industrial zone in Genuk so that they stop extracting water from deep wells. The giant sea wall is then expected to deal with tidal flooding and land subsidence. This study assesses the potential environmental and social impacts of the giant sea wall by conducting a literature review and informal interviews with relevant persons related to the project. Internalizing environmental and social aspects into development policies is required to achieve sustainable coastal management.

Key Words: tidal flood, giant sea wall, environment and social assessment, sustainable coastal management.

Introduction. Coastal areas, which are defined as ecotone areas, are transition zones where land meets the sea (Antunes do Carmo 2019; Cantasano et al 2020; Harris et al 2019). The contrast between dry and wet ecosystems results in the high habitat diversity and resource potency of coastal areas (Herrera-Silveira et al 2019). Consequently, coastal areas attract people who eventually take advantage of its abundant resources. Fisheries, tourism, and industrialization are some examples of human activity in littoral zones (Baum et al 2016; Tan et al 2018; Antunes do Carmo 2019; Bao et al 2019; Chen et al 2019). This phenomenon has intensified (littoralization) since the end of World War II (Kerguillec et al 2019).

In addition to its economic advantage that could be derived from such intensification, it also gives coastal areas some anthropogenic stressors which accelerate its natural degradation caused by climate change (Carter 1988; Baum et al 2016; Buchori et al 2018; Tan et al 2018; Herrera-Silveira et al 2019). It could also deprive the ecosystems that directly affect human activities that benefit from coastal areas (Sannigrahi et al 2019). This pattern is unsustainable and could lead to the extinction of coastal communities, thus endangering the future human population.

The coastal area of Semarang City is strategically located and thus is a site for ports, recreation/tourism, industries, housing, fisheries, and agriculture. Hadi (2018) noted that these activities overlap, thus causing environmental and social impacts. Most of these activities rely on groundwater. Massive groundwater extraction, specifically that by industries at the industrial zone in Genuk, along with load building and infrastructure, promote land subsidence. When the sea level rises, water flows to the inland, thereby causing inundation (flooded areas). Moreover, industries cause pollution, and sedimentation and various wastes from upstream exacerbate the condition of the coastal area. Tidal flooding has been occurring since the 1990s; it starts from the Tanah Mas, spreading to Tanjung Mas, Tambakharjo, Kemijen, Kaligawe, and Trimulyo, as shown in Figure 1.

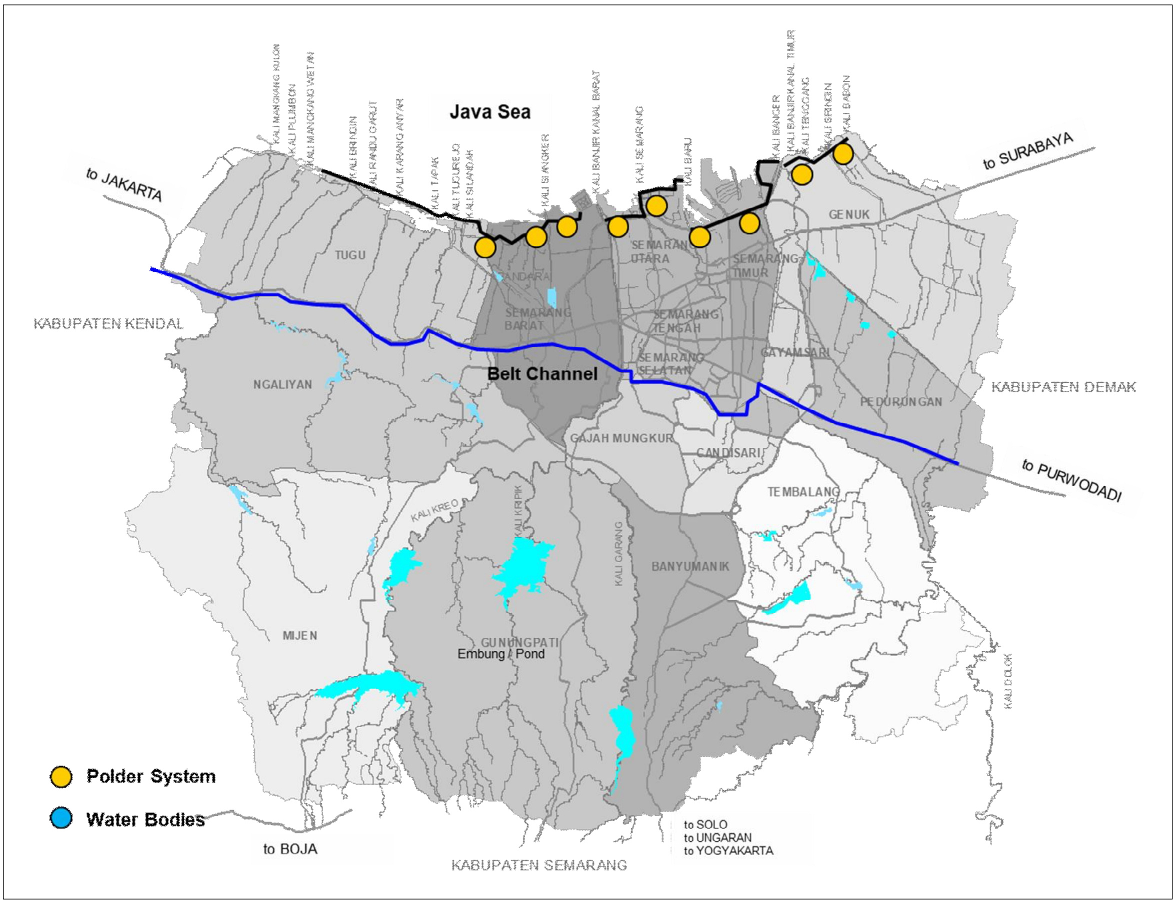

Figure 1. Drainage system of Semarang City
(data of Public Works and Housing Ministry of Indonesia).

The areas with the worst experience are Kaligawe and Trimulyo, which are parallel with the high land subsidence. The rate of land subsidence ranges from 2 cm to 12 cm per year; the worst area is Trimulyo (van Beek et al 2019). It is caused by the massive groundwater extraction by industries and its load building and infrastructure (Abidin et al 2013). How these crucial problems being dealt by the government and impacted people? What are the environmental and social impacts of giant sea wall? This paper aims to review the government and impacted people measures dealing with tidal flood. In addition, it also assesses the environmental and social impacts of giant sea wall, as a new measure dealing with tidal flood

Material and Method

Material and collection techniques. This research uses secondary data. The planning documents of the giant sea wall are gathered from various government institutions, such as the Ministry of Public Works and Housing, the Environmental Agency, and the Planning

Board Agency, The Government City of Semarang. This sea wall project is one of the national priority programs stated in the Presidential Regulation of the Republic of Indonesia Number 56/2018; thus, data vary from the national to the local government. The period of study run from June 2019 to March 2020.

Analysis method. The type of research is descriptive analysis. The data collection techniques consist of literature review, content analysis, and informal interview with relevant persons. The data gathered are analyzed quantitatively and qualitatively.

Results and Discussion

Coastal management issues. Coastal management is an essential issue in maintaining the sustainability of coastal areas. The poorer the management, the faster the degradation of coastal areas (Ali et al 2018). One of the major challenges in coastal management is how to address the high complexity of problems; thus, a breakthrough management framework or strategy is needed (Ali et al 2018; Antunes do Carmo 2019). Monitoring and mapping coastal realms are the foundation of fruitful management. However, such foundation remains to be an issue that is hardly overcome by the government of the academe (Harris et al 2019; Kerguillec et al 2019). Ecological dynamics and anthropogenic stressors have complicated the definition of coastal areas. The absence of these factors could lead to inefficient and ineffective programs.

Political–administrative issues do not seem to ease this problem. The lack of integration among decision-makers in land and sea hardly capture the dynamic and ecological bidirection between the two areas; thus, the resilience of the ecosystem is endangered (Beger et al (2010) and McLachlan & Defeo (2018) in Harris et al (2019)). The idea of integrating stakeholders, sectors, and functions in coastal management had comes into arose it salient (Cantasano et al 2020), and already sounded years ago. Earth Summit in 1992 resulted in nations committing to recognizing the need for integration in coastal management (Cicin-Sain 1993); then, it released the concept of integrated coastal area management. Later in 1998, Cicin-Sain et al (1998) offered a more comprehensive approach, with the term “area” replaced with “zone”. This concept enhanced the integration among different stakeholders, sectors, and aspects (Vespasiano et al 2019) for coastal management (Cicin-Sain 1993). Under this concept, humans are one of the essential factors to reach fruition, with human education highlighted in raising people’s awareness (Cantasano et al 2020). Even though it drives integration, it only captures sectoral problems, such as social issues, and could not portray ecological issues, such as the interaction between land and sea (Harris et al 2019).

As the environmental quality of coastal areas constantly decreases, considering sustainable approaches for integrated coastal management has increasingly attracted attention (Bao et al 2019). Sustainable strategies can not only create improved habitats in coastal areas but also help sustain the life of a city as a whole system (Sannigrahi et al 2019). Basically, sustainable principles interweave the society, the economy, and the environment (De Boni et al 2018). Using the ecosystem paradigm in which every aspect of habitats should be maintained its stability could leads to the fruitfulness coastal environment quality restoration (Herrera-Silveira et al 2019). The livelihood activities of coastal communities strengthen people’s demand for coastal resources; thus, these activities could generate bottom-up sustainable coastal management through the coastal communities (Lowe & Tejada 2019). It is further defined as inclusive wealth (Uehara & Mineo 2017), that is, the resources are highly exploited for the community’s welfare.

The ideal condition of coastal management from Japanese local indigenous emphasizes the importance of sustainable tropic aquaculture or ecological production to reach sustainable coastal management (Uehara & Mineo 2017). The ecosystem service approach is also an important indicator for assessing strategies (Uehara & Mineo 2017; Sannigrahi et al 2019) because it is the main aspect that should be addressed in any coastal management program. In addition, human intervention, such as political will, financing, and leadership capacity, are the driving forces in this management approach (Kong et al 2018).

Any management approach that is considered against the dynamics and degradation trends of coastal areas remains arduous to come to realms. In the future, coastal communities will have no choice but to adapt to the current condition. It is defined as another changing paradigm that should be considered in managing and saving the future of coastal habitats (Antunes do Carmo 2019). Vespasiano et al (2019) regarded adaptation as a constant process that results from natural environmental processes caused by any kind of pressure; such process occurs in coastal plain environments. It is also defined as a key to maintain the livability of coastal zones so that its community could continue their life in their own definition of comfort, safety, and happiness (Buchori et al 2018).

Adaptation should also be a part of management; conventional strict management should shift toward adaptive management, which emphasizes the understanding of the dynamics of the environment and adjusts the management approach and institutional strategies (Chu et al 2019). It should realize and understand the realms and the future to maintain the livability of coastal ecosystems, reduce damages, and preserve ecosystem services (Ali et al 2018).

Adaptation measures taken by the Government*.* To address tidal flooding, the government has built polders consisting of a retention pond, a flood gate, and a pumping station in Kali Semarang for the western side, Banger for the central side, and Tenggang for the eastern side (around the industrial zone of Genuk). These measures can minimize tidal flooding locally and temporarily. While impacted people as recorded by Miladan (2016), elevate their house yearly and make dykes to prevent tidal flood flowing to their houses. People prefer adaptation over finding a better and more livable space to live in (Buchori et al 2018). Local people are reluctant to move to other places due to several reasons. First, their current settlement has a good access to their workplace, that is, the industrial zone. Second, their neighborhood is cohesive. Local people work together to prevent tidal flooding on the basis of the spirit of mutual assistance. Third, most people are not economically able to buy a house in other places. The measures taken by the government and the affected people help minimize tidal flooding. However, these measures, which are considered reactive ones, do not deal with the source of the problems causing land subsidence (Antunes do Carmo 2019). These approaches are "band-aid" solutions to cure the phenomena and do not address the root of the problems (One Architecture & Urbanism et al 2019).

Initially, the government planned to build a 27.2 km toll road from Semarang to Demak. The toll road will then function as a sea wall to prevent sea water from flowing to the inland. As planned by Ministry of Public Works and Housing Republic Indonesia, there was also a proposals to build a retention pond in the following areas: (1) Trimulyo, with an area of 225 ha, a depth of 5 m, and a capacity of 11,250,000 m^3; (2) Sriwulan, district of Sayung, Demak, with an area of 150 ha, a depth of 3.3 m, and a capacity of 1,320,000 m^3. As shown in Table 1, the total water volume that would be provided by the retention pond is approximately 12,500 x 10^3 m^3. In addition to its plan of accommodating water flowing from the middle and upstream and if the water in high volume to be pumped to the sea, the retention ponds are also intended to provide water for industries. As shown in Table 2, the total water demand from industries located in the Genuk District reaches only 814.428 x 10^3 m^3 $year^{-1}$. The total amount of water supply is greater than the demand; therefore, retention pond has potential to feed the industrial area with fresh water needed for their production activities.

However, these plans have some challenges. The total water volume that would be provided in the retention ponds relies on future effective precipitation rate or the total debit from the river. The analysis in Table 3 shows that the average effective precipitation rate from 2002 to 2014 reached 705,162 mm $year^{-1}$. Suryadi et al (2018) argued that precipitation rate has a tendency to fall due to climate change. The optimistic scenario used in this research assumes that the precipitation rate would remain the same for a few years ahead. The retention pond needs approximately 4-5 years to be filled with rainwater. Moreover, the rainwater harvested should be treated before distribution to the industries. Thus, additional cost is needed to build a water treatment plant and a pipeline network before the water could be fully used by the industries.

Theoretically, a giant sea wall as a manifestation of structural adaptation could act effectively to protect coastal areas from sea-driven hazards. Things to note that engineering structure only could accommodate things under their capacity. Meanwhile, nature, climate, and sea, remain unpredictable. Thus, this structure does not rule out the possibility of dying coastal areas if a phenomenon beyond its capacity occurs (Antunes do Carmo 2019). Another thing to consider is that incomprehensive structural adaptation measures could lessen risks in its area but could increase risks in other areas (Sörensen et al 2016).

Table 1

Retention pond total capacity

Location	*Capacity (m^3)*
Trimulyo	11,250 x 10^3
Sriwulan	1,320 x 10^3
Total Volume	12,550 x 10^3

Table 2

Industrial water demand

Industry	*Total industries (unit)*	*Area (ha)*	*Water use*	
			(m^3 day^{-1})	*(m^3 $year^{-1}$)*
Tanjung Emas	10	5.41	630.50	230,132.50
Bugangan	156	14.70	1,000.30	365,109.50
Terboyo	216	5.52	600.51	219,186.15
Total	382	25.36	2,231.31	814,428.15

Derived from Industrial Water Demand Analysis in Water as Leverage report (One Architecture & Urbanism et al 2019).

Table 3

Period needed to fill the retention pond with rainwater

Average net precipitation rate		*Area*		*Water volume*	*Retention pond capacity*	*Period needed*
(mm)	*(m $year^{-1}$)*	*(ha)*	*(m^2)*	*(m^3 $year^{-1}$)*	*(m^3)*	*(year)*
705,162*	0,705	375	3.750.000	2.644.355,769	12.550.000	4,75

*Average net precipitation rate trends from 2002-2014 (One Architecture & Urbanism et al 2019).

Environmental and social impacts*.* Land subsidence could be possibly minimized by implementing the plan of feeding industries with freshwater from the retention pond. It could lessen the groundwater extraction activity that is mainly conducted by industries. Moreover, the retention pond acts as a man-made water recharge area; thus, it could enhance and accelerate the recharging of groundwater. Consequently, confined aquifer pressure could be stabilized because retention ponds also slow down the subsidence rate. This plan could be implemented if no structural problem occurs. Building a giant sea wall also gives further load on the land; thus, it could possibly spike the potential subsidence.

Given that the retention pond relies only on rainwater harvest, the Sringin and Tenggang rivers could potentially be involved in this process. The water flow rates of the main river system in giant sea wall areas are 82.3 and 49.6 m^3 s^{-1}, respectively. Thus, constructing a river weir to supply water to the retention pond could also be an alternative way to feed the industries. However, a water treatment facility would also be needed to process pluvial water before use.

By contrast, this project has a negative impact to the riverine system. Under existing conditions, Demak (western part of giant sea wall) is already experiencing coastal abrasion caused by sediment transport that occurs on the coastal areas of alluvial soil (Sugianto et al 2017c). The current that affects its coastal morphology also has dynamics in directions and speed (Sugianto et al 2017b). In addition, recent condition of riverine system in Semarang had been experiencing severe sedimentation caused both by eroded soil from the hills and by the waste that polluting the river. As reported in Semarang City's Drainage System Masterplan 2011-2031 (2014), sedimentation at the river mouth of Tenggang and Sringin reached 8,908 m^3 per year, it potentially decreases the retention pond capacity. These issues should be halted in construction planning to minimize coastal environment degradation as an effect of sedimentation and erosion.

Al Hakim et al (2015) argued that the giant sea wall could change the natural hydrodynamic patterns. Moreover, it could block the seawater flowing to the inland and thus affect the coastal ecosystem's biodiversity. It could also block the circulation system of saline water with fresh water required by fishpond, as shown in Figure 2. The ecosystem below the yellow line (the sea wall) and the blue line (the planned national road) is at risk as well as the existing coastal ecosystem between those two planned projects and the red line (toll road), also within the toll road towards the inland. Consequently, this condition threatens the existence of fishponds, thereby causing the loss of jobs and income of local people. The toll road, giant seawall, and retention pond will eventually replace the fishponds owned by the local people. These projects also threaten the fishing grounds and trips of fishermen. These effects are relevant because 21.3% of the population in the district of Genuk and 37% in the district of Sayung rely on fishing and agriculture. In addition, it could further be engineered to create a wave arrangement. Wave energy has potential for development in Indonesia (Sugianto et al 2017a). Although regulation or investment problems exist, the giant sea wall could perform as a wave engineering measure to add energy diversification in Semarang and its surroundings. By contrast, waves should also be considered in accommodating marine transportation as one of strategic use of the Java Sea (Sugianto et al 2017d).

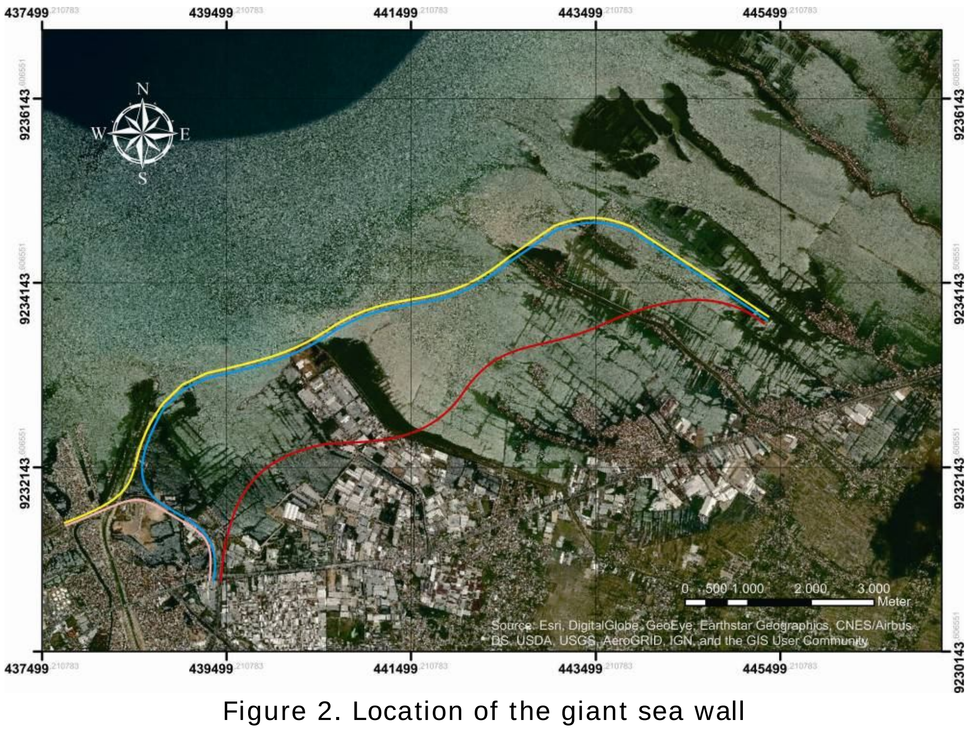

Figure 2. Location of the giant sea wall
(Source: BBWS Pemali Juana in Juyantono & Alfianto 2019).

Conclusions and Recommendations. The giant sea wall is expected to minimize tidal flooding by preventing seawater from flowing into the inland, whereas the retention pond is intended to reduce the exacerbation of land subsidence by providing water resources for industries, therefore preventing industries from extracting groundwater excessively. However, the projects have environmental and social impact. Mangrove clearance will cause coastal ecosystem disturbance and diminish the existing fishponds, adversely affecting the local people’s livelihood. If these effects are not dealt with carefully, problems will occur and thus, sustainable coastal management will not be achieved. Thus, as the plan for the giant sea wall project is focused only on civil construction, plans for natural ecosystem restoration and life adaptation toward integrated sustainable coastal management are required.

Acknowledgements. We are thankful to Municipal Government of Semarang City, Indonesia for giving us opportunity to review the Semarang Resilient City plan.

References

Abidin H. Z., Andreas H., Gumilar I., Sidiq T. P. P., Fukuda Y., 2013 Land subsidence in coastal city of Semarang (Indonesia): characteristics, impacts and causes. Geomatics, Natural Hazards and Risk 4(3):226-240.

Al Hakim B., Wibowo M., Kongko W., Irfani M., Hendriyono W., Gumbira G., 2015 Hydrodynamics modeling of giant seawall in Semarang Bay. Procedia Earth and Planetary Science 14:200-207.

Ali S., Darsan J., Singh A., Wilson M., 2018 Sustainable coastal ecosystem management – an evolving paradigm and its application to Caribbean SIDS. Ocean and Coastal Management 163(1):173-184.

Antunes do Carmo J. S., 2019 The changing paradigm of coastal management: the Portuguese case. Science of the Total Environment 695:133807.

Bao J., Gao S., Ge J., 2019 Centralization and decentralization: coastal management pattern changes since the late 19th century, Jiangsu Province, China. Marine Policy 109:103705.

Baum G., Kusumanti I., Breckwoldt A., Ferse C. A., Glaser M., Dwiyitno, Adrianto L., van der Wulp S., Kunzmann A., 2016 Under pressure: investigating marine resource-based livelihoods in Jakarta Bay and the Thousand Islands. Marine Pollution Bulletin 110(2):778-789.

Buchori I., Pramitasari A., Sugiri A., Maryono M., Basuki Y., Sejati A. W., 2018 Adaptation to coastal flooding and inundation: mitigations and migration pattern in Semarang City, Indonesia. Ocean and Coastal Management 163:445-455.

Cantasano N., Pellicone G., Ietto F., 2020 The coastal sustainability standard method: a case study in Calabria (Southern Italy). Ocean and Coastal Management 183:104962.

Carter R. W., 1988 Coastal environment: an introduction to the physical, ecological, and cultural systems of coastlines. Academic Press Limited, London, 617 pp.

Chen C., Lee T., Liu C., 2019 Beyond sectoral management: enhancing Taiwan’s coastal management framework through a new dedicated law. Ocean and Coastal Management 169:157-164.

Chu E., Brown A., Michael K., Du J., Lwasa S., Mahendra A., 2019 Unlocking the potential for transformative climate adaptation in cities. Background Paper prepared for The Global Commission on Adaptation, Washington DC and Rotterdam. Available at: https://wrirosscities.org/research/publication/unlocking-potential-transformative-climate-adaptation-cities. Accessed: November, 2019.

Cicin-Sain B., 1993 Sustainable development and integrated coastal management. Ocean and Coastal Management 21(1-3):11-43.

Cicin-Sain B., Knecht R. W., Knecht R., Jang D., Fisk G., 1998 Integrated coastal and ocean management: concept and practices. Washington DC: Island Press, 517 pp.

De Boni A., Roma R., Ottomano Palmisano G., 2018 Fishery policy in the European Union: a multiple criteria approach for assessing sustainable management of Coastal Development Plans in Southern Italy. Ocean and Coastal Management 163:11-21.

Hadi S. P., 2018 Integrated community based coastal management: lesson from the field. IOP Conference Series: Earth and Environmental Science 116:012064.

Harris L. R., Bessinger M., Dayaram A., et al, 2019 Advancing land-sea integration for ecologically meaningful coastal conservation and management. Biological Conservations 237:81-89.
Herrera-Silveira J. A., Lara-Domínguez A. L., Day J. W., et al, 2019 Ecosystem functioning and sustainable management in coastal systems with high freshwater input in the southern Gulf of Mexico and Yucatan Peninsula. In: Coasts and estuaries – the future. Wolanski E., Day J. W., Elliot M., Ramachandran R. (eds), Elsevier, pp. 377-397.
Juyantono, Alfianto K., 2019 Kajian proyek tanggul laut kota semarang. BEng Thesis, Universitas Islam Sultan Agung, 106 pp. Available at: http://repository.unissula.ac.id/id/eprint/14748. Accessed: November, 2020. [in Indonesian]
Kerguillec R., Audère M., Baltzer A., et al, 2019 Monitoring and management of coastal hazards: creation of a regional observatory of coastal erosion and storm surges in the pays de la Loire region (Atlantic coast, France). Ocean and Coastal Management 181:104904.
Kong H., Yang W., Sun Q., 2018 Overcoming the challenges of integrated coastal management in Xiamen: capacity, sustainable financing and political will. Ocean and Coastal Management Article In Press:104519 Available at: https://doi.org/10.1016/j.ocecoaman.2018.05.015.
Lowe J., Tejada J. F. C., 2019 The role of livelihoods in collective engagement in sustainable integrated coastal management: Oslob Whale Sharks. Ocean and Coastal Management 170:80-92.
Miladan N., 2016 Communities' contribution to urban resilience process: a case study of Semarang city (Indonesia) toward coastal hydrological risk. PhD Thesis, Architecture and Space Management, Universite Paris Est-Universitas Diponegoro, 547 pp.
One Architecture & Urbanism, Kota Kita, Deltares, … University of Pennsylvania, 2019 Water as Leverage for Resilient Cities Asia: Volume II Concept Design Proposals. One Architecture & Urbanism, 364 pp. Available at: https://issuu.com/one_architecture/docs/wal_final_report_raster_pages-m. Accessed December, 2020.
Sannigrahi S., Joshi P. K., Keesstra S., et al, 2019 Evaluating landscape capacity to provide spatially explicit valued ecosystem services for sustainable coastal resource management. Ocean and Coastal Management 182:104918.
Semarang City's Drainage System Masterplan 2011-2031, 2014 [Regional Law Number 07/2014 about Semarang City's Drainage System Masterplan 2011-2031]. 353 pp. Available at: https://jdih.semarangkota.go.id/jdih-anggota/www/storage/document/perda72014.pdf. Accessed: December, 2020. [in Indonesian]
Sugianto D. N., Kunarso, Helmi M., et al, 2017a Wave energy reviews in Indonesia. International Journal of Mechanical Engineering and Technology 8(10):448-459.
Sugianto D. N., Rochaddi B., Wulandari S. Y., et al, 2017b Current characteristics in Demak waters based on acoustic measurement. International Journal of Civil Engineering and Technology 8(9):749-760.
Sugianto, D. N., Widada, S., Wirasatriya, A., Ismanto, A., Darari, A., & Suripin. (2017c). Modelling of suspended sediment transport in coastal demak Indonesia by using currents analyzing. ARPN Journal of Engineering and Applied Sciences, 12(16), 4666–4678.
Sugianto D. N., Zainuri M., Darari A., Suripin S. D., Yuwono N., 2017d Wave height forecasting using measurement wind speed distribution equation in Java Sea, Indonesia. International Journal of Civil Engineering and Technology 8(5):604-619.
Suryadi Y., Sugianto N. D., Hadiyanto, 2018 Climate change in Indonesia (case study: Medan, Palembang, Semarang). E3S Web of Conferences 31:09017.
Sörensen J., Persson A., Sternudd C., et al, 2016 Re-thinking urban flood management-time for a regime shift. Water 8(8):332.

Tan W. J., Yang C. F., Château P. A., Lee M. T., Chang Y. C., 2018 Integrated coastal-zone management for sustainable tourism using a decision support system based on system dynamics: a case study of Cijin, Kaohsiung, Taiwan. Ocean and Coastal Management 153:131-139.

Uehara T., Mineo K., 2017 Regional sustainability assessment framework for integrated coastal zone management: Satoumi, ecosystem services approach, and inclusive wealth. Ecological Indicators 73:716-725.

van Beek W., Letitre B., Hadiyanto H., Sudarno S., 2019 Alternatives to groundwater abstraction as a measure to stop land subsidence: a case study of Semarang, Indonesia. E3S Web of Conferences 125:01003.

Vespasiano G., Cianflone G., Romanazzi A., Apollaro C., Dominici R., Polemio M., De Rosa R., 2019 A multidisciplinary approach for sustainable management of a complex coastal plain: the case of Sibari Plain (Southern Italy). Marine and Petroleum Geology 109:740-759.

Received: 27 May 2020. Accepted: 22 September 2020. Published online: 17 December 2020.

Authors:
Sudharto P. Hadi, Graduate Program of Environmental Studies, Universitas Diponegoro, Jalan Imam Bardjo SH, 50241, Semarang, Indonesia, e-mail: sudhartophadi@yahoo.co.id
Sutrisno Anggoro, Faculty of Marine Science and Fisheries, Universitas Diponegoro, Jalan Prof H. Soedarto, 50275, Semarang, Indonesia, e-mail: sutrisno.anggoro@yahoo.co.id
Hartuti Purnaweni, Graduate Program of Environmental Studies, Universitas Diponegoro, Jalan Imam Bardjo SH, 50241, Semarang, Indonesia, e-mail: hartutipurnaweni@gmail.com
Nany Yuliastuti, Department of Urban and Regional Planning, Universitas Diponegoro, Jalan Prof H. Soedarto, 50275, Semarang, Indonesia, e-mail: nanyuliastuti@gmail.com
Adi Ekopriyono, Universitas Tujuh Belas Agustus, Jalan Pemuda, 50133, Semarang, Indonesia, e-mail: adiekopriyono@hotmail.com
Rizkiana S. Hamdani, Graduate Program of Environmental Studies, Universitas Diponegoro, Jalan Imam Bardjo SH, 50241, Semarang, Indonesia, e-mail: rizkiana.sidqi@gmail.com

How to cite this article:
Hadi S. P., Anggoro S., Purnaweni H., Yuliastuti N., Ekopriyono A., Hamdani R. S. 2020 Assessing the giant sea wall for sustainable coastal development: case study of Semarang City, Indonesia. AACL Bioflux 13(6):3674-3682.