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Chapter 21
Flood Risk in Polder Systems in Jakarta: Present and Future Analyses

Yus Budiyono, Muhammad Aris Marfai, Jeroen Aerts, Hans de Moel, and Philip J. Ward

Abstract Polder systems in Jakarta have been implemented since 1965, but their development has been hindered by social and political issues. Currently, the government of Jakarta has started to consider polder system as seen in the Spatial Plan 2030. This chapter assesses the benefits/costs of the polder system in Jakarta under current conditions and under future scenario of climate change, land use change, and subsidence.

We calculate the benefits of each polder using Damagescanner-Jakarta, which is a flood risk model developed in previous study. Cost estimates are based on the costs of 22 dike projects in Java. We use flood design standards at 2, 5, 10, 25, and 50 years, as set out in the Minister of Public Works.

The results show that benefit/cost ratios greater than 1 exist at 21 out of 66 polders reducing 25% of risk under current conditions, and at 31 out of 66 polders reducing 52% of risk under the future scenario (for a return period of 2 years). Much of this risk reduction could be achieved in just 3 polders, namely Kapuk Muara, Penjaringan Junction, and Kapuk Polgar, in which 50% of the current risk could be reduced. The study also shows that operating 12 polders could reduce risk by 81% in the future, and polders with very high net benefits are located away from the coastline. Sensitivity testing using lower (4%) and higher (10%) discount rates show the number of net benefiting polders reduces as the discount rate increases in a predictable trend.

Keywords Benefit Cost Analyses • Damagescanner • Flood Risk • Jakarta • Polder System

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21.1 Introduction

Since 2012, Jakarta has been operating a second major structural measure to overcome flooding, the Eastern Flood Canal (*Banjir Kanal Timur*). This canal complements the Western Flood Canal (Banjir Kanal Barat), which has been in operation since 1922 and has been revitalized over time. An overview of historical flood management practices in Jakarta can be found in Caljouw et al. (2005) The two canals act as a horseshoe that prevents floodwaters from entering the city, diverting major discharges from the upland to the west and to the east. The construction of the Western Flood Canal was initiated in 1917, as part of the Van Breen plan (Caljouw et al. 2005), which was revised in 1973 as part of the Master Plan for Drainage and Flood Control of Jakarta published by the Ministry of Public Works with the help of Netherlands Engineering Consultants (Nedeco). From 1975, the Western Flood Canal was heavily extended and was completed in 1983 with the completion of the Cengkareng drain (Gunawan 2010). The Eastern Flood Canal was also based on recommendations in the Master Plan for Drainage and Flood Control of Jakarta plan, which was detailed by Nippon Koei in 1997.

Now, the government of Jakarta is examining another structural measure to reduce flooding, namely improving and upgrading the city's polder system. The system was already proposed in the van Breen plan (Caljouw et al. 2005) that was prepared by the committee for Jakarta flood prevention (*Kopro Banjir*) in 1965 (Gunawan 2010). Kopro banjir was formed by the President's authority (*Kepres*) number 29/1965 (Diskominfomas DKI 2011). Polder implementation was started in the same year with the construction of Pluit retention lake, which was later recognized as Pluit polder. In 1972, the committee was changed into Greater Jakarta Flood Control Project (PBJR), resulting in two more polders, i.e. Sunter Timur and Marunda (Gunawan 2010). Ever since, the development has been hindered by riverbank squatting, solid waste disposal (Baker 2012) and lack of planning. Referring to Provincial Government Regulation number 1/2012 about Spatial Plan 2030 (Perda DKI Jakarta 1 2012), the government of Jakarta plans to intensify the use of polder systems to prevent floods. In the regulation, 43 existing polders are recognized and 23 new polders in Jakarta are planned.

Minister of Public Works Regulation 12/2014 (*Permen* PU 12 2014) states the flood return period of the draining design criteria for polders in different types of cities and for different catchment areas (see Table 21.1). For Jakarta, polders should have a design standard of between 2 and 25 years, depending on the polder size. The size of the polders in Jakarta ranges from 32 ha to 2954 ha. To contain excess water, a storage capacity is designed relative to the volume of the design rainfall and the time needed by the pumping system to discharge excess water away from the polder. As a revived policy, some polders already have the required retention capacity, while others do not.

Using the polder system plan of Jakarta 2030 (Perda DKI Jakarta 1 2012) and flood risk study, this chapter aims to provide a first-cut estimate of the potential

Table 21.1 Flood return period of the drainage design criteria for different types of cities and catchment sizes

Type of city	Catchment area (ha)			
	<10	10–100	100–500	>500
Metropolitan city	2 year	2–5 year	5–10 year	10–25 year
Big city	2 year	2–5 year	2–5 year	5–20 year
Medium city	2 year	2–5 year	2–5 year	5–10 year
Small city	2 year	2 year	2 year	2 year

Source: Permen PU 12 (2014)

benefit and costs of each polder, both under current conditions, and under a scenario of future climate change, land subsidence, and land use change. This adds the widely available studies on polders generally focus on the individual function of polders as e.g. flood control, agriculture, recreation (e.g. Roth and Warner 2007; Klijn et al. 2010; Ritzema et al. 2011).

A large amount of scientific literature is available that examines technical aspects of polders and their functioning, including flood control, agriculture, and recreation (e.g. Roth and Warner 2007; Klijn et al. 2010; Ritzema et al. 2011). Several studies have assessed the potential reduction in flood stage or inundation extent or depth that can be achieved in polder or retention areas (e.g. Apel et al. 2004; Förster et al. 2005; Huang et al. 2007; Bouwer et al. 2009). However, few studies have specifically examined the risk reduction potential of polder systems. This is despite the fact that recent decades have seen a move towards a more risk-based approach towards flood management. In this sense, flood risk combines the probability of a flood event with its potential consequences. The concept of flood risk is usually operationalized as being a function of three elements: hazard, exposure, and vulnerability (e.g. Kron 2005; UNISDR 2011, 2013). Jonkman et al. (2004) and Bouwer et al. (2010) have assessed how flood risk may change in several polders in future scenarios of climate change, and Kind (2014) assessed the costs and benefits of a large number of polder systems in the Netherlands. However, studies on the risk reduction potential of polders and their costs elsewhere are sparse in the scientific literature. Budiyono et al. (2015) recently developed a flood risk assessment model for Jakarta, which allows for the assessment of flood risk, called Damagescanner-Jakarta, and used it to assess flood risk under current conditions and future scenarios of land use change, climate change, and subsidence Budiyono et al. (2016). However, the model has not been used to assess the potential impact of risk reducing measures on risk.

To address this, we use the polder system plan of Jakarta 2030 (Perda DKI Jakarta 1 2012) Damagescanner Jakarta to provide a first-cut estimate of the potential benefit and costs of each polder, both under current conditions, and under a scenario of future climate change, land subsidence, and land use change.

21.2 Methodology

In this study, we estimate the costs and benefits of upgrading the 43 existing polders and constructing the 23 planned polders mentioned in the Spatial Plan 2030. The benefits are estimated as expected annual damage (EAD) without the polder system, minus the EAD with the polder system. EAD is a common metric used in natural hazard risk assessment (e.g. Meyer et al. 2008), and can be interpreted as the average damage per year that one would expect over a very long period of time; its calculation is further described in section "Estimation of benefits". EAD is calculated using the existing Damagescanner Jakarta flood risk model (Budiyono et al. 2015, 2016). The costs are estimated as the total construction and maintenance costs of the polder system. The benefit/cost ratio (B/C ratio) was assessed using the standard formula:

$$B/C = \frac{\sum_{n}^{t=1} \frac{B_t}{(1+i)^t}}{\sum_{n}^{t=1} \frac{C_t}{(1+i)^t}}$$

Where n is the number of years over which the project costs and benefits are evaluated, t are the costs and benefits for individual years, B is the sum of benefits in a given year (t), C is the sum of costs in a given year (t), and i is the discount rate expressed as a decimal. In this study, we used a time horizon (n) of 100 years, and a discount rate (i) of 0.07 (i.e. 7%), 0.04, and 0.10 (see section "Estimation of benefits").

In this section, we describe the methods used to estimate these costs and benefits in more detail; an overview of the approach can be found in Fig. 21.1.

21.2.1 Estimation of Benefits

We estimated the annual benefits of the polder system as the EAD without the system, minus the EAD with the system. We assumed a project lifetime of 100 years, and a discount rate of 7% (Hallegatte 2014), and calculated the total benefits over this project lifetime. Note that in section "Uncertainty and sensitivity test" we also carry out a sensitivity analysis using discount rates of 4% and 10%. The lower rate was according to target inflation rate 2016–2017 in Ministry of Treasury Regulation (*Permenkeu* 93/PMK.011 2012), while the higher rate was according to the highest target of the Central Bank of Indonesia (Public Information Service 2013).

Damagescanner–Jakarta was developed by Budiyono et al. (2015, 2016) as a model in Python to calculate flood risk. Here, we provide a brief overview of the model; for details of the setup and model structure, we refer the reader to Budiyono et al. (2015) and Budiyono et al. (2016). In essence, Damagescanner-Jakarta is a

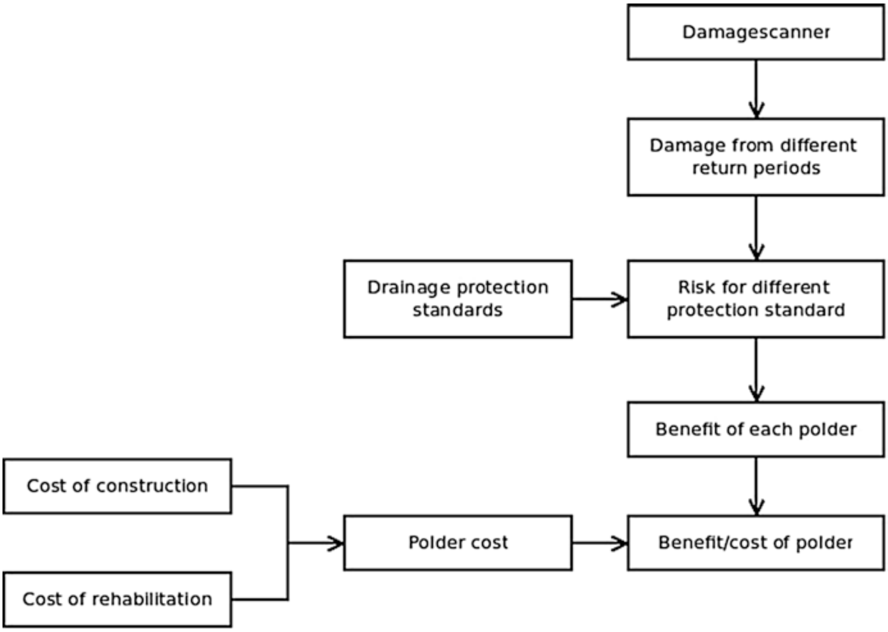

Fig. 21.1 The research framework of analysis (Source: Author's design)

grid-based flood risk model, which runs at a horizontal resolution of 50 m × 50 m. It works by combining flood hazard maps and exposure maps (showing the land use in each cell and its associated maximum economic damage) with a depth–damage function to represent vulnerability. For each cell, Damagescanner-Jakarta identifies the inundation depth from the flood hazard map produced by the SOBEK Hydrology suite (Deltares 2014). Then, for this cell it identifies the land use class available from the office of city planning (DTR DKI 2007) and its associated maximum economic damage, which was derived by Budiyono et al. (2015) through expert interviews and workshops. The model includes a set of depth-damage functions per land use class, which show the proportion of the maximum damage that would occur for floods of different depths. As with the values of maximum economic damage, these were derived from expert interviews and workshops described in.

Budiyono et al. (2015). Damagescanner-Jakarta takes the depth-damage function for the land use class of the cell in question, and uses it to identify what proportion of the maximum damage would occur for the inundation depth in that cell. This procedure is used to simulate direct economic damage for floods of several return periods between 2 and 100 years. Then, the EAD is estimated as the area under the exceedance probability-loss (risk) curve, whereby the area is estimated using a trapezoidal approximation (e.g. Meyer et al. 2008); see visualization in Fig. 21.2.

For the current situation, we assume that the polder system does not provide protection against flooding. Hence, the damages simulated for floods of all return periods are used in the calculation of EAD. We then calculated the EAD that would

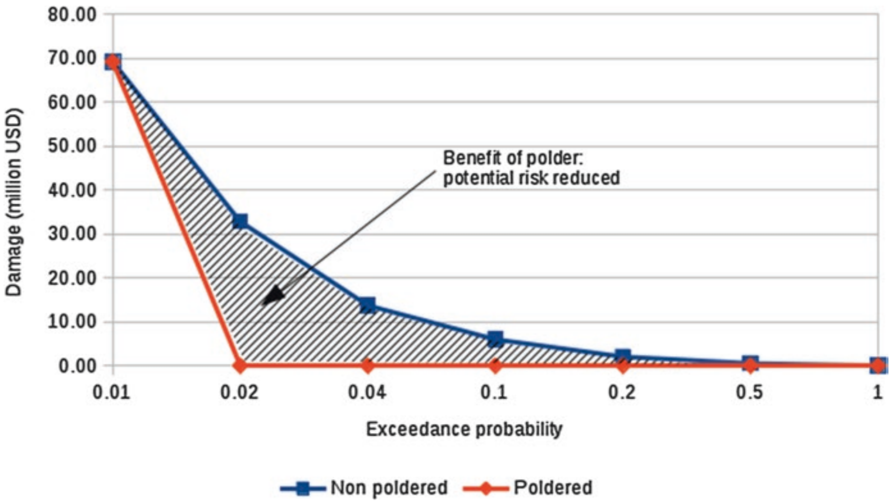

Fig. 21.2 Theoretical example of the damages for different exceedance probabilities (1/return period) with and without a polder system showing benefit of polder designed at 50 years return period (Adopted from Mechler 2005)

occur if the polder system were implemented to provide protection against floods of different return periods, namely 2, 5, 10, 25, and 50 years; these are based on the return periods stated in the Permen PU 12/ 2014. This is carried out by assuming zero flood damage to occur for floods up to this return period (Fig. 21.2). This is first carried out for current climate conditions and based on the current land use map of Jakarta.

Next, we calculated the benefits that could be achieved under a scenario of climate change, land use change, and land subsidence. For this study, to demonstrate the use of the method, we use the median scenario amongst all scenario combinations described in Budiyono et al. (2016), which is USD 521 million per year. Future climate change in 2030 and 2050 was represented by taking changes in precipitation intensity. From downscaled output data of five global climate models (GCMs), namely GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M (Hempel et al. 2013), forced by four Representative Concentration Pathways (RCPs), namely RCP2.6, RCP4.5, RCP6.0, and RCP8.5 (IPCC 2014). For sea-level rise, we used the likely range in global sea level rise projections of the IPCCs Fifth Assessment Report (AR5) (IPCC 2013, Table AII7.7) for 2010–2030 of 6 cm to 11 cm, and 14 cm to 24 cm for 2010–2050. For land use change, we used the official Jakarta Spatial Plan 2030 (Perda DKI Jakarta 1 2012), which is an idealized land use scenario for 2030.

Finally, a hypothetical scenario of land subsidence was developed, in which the current rate of subsidence (Abidin et al. 2011) continues at the same rate, and ultimately stops in the year 2025. This is based on an assumption that the government will successfully implement the "100-0-100 sanitation policy" (*Direktorat Jenderal Cipta Karya* 2014), which means that the government will provide 100% of water supply needed by Jakarta by 2019 and consequently groundwater extraction and subsidence would cease, as also seen in Tokyo (Endo et al. 2001), Tokyo lowlands (Aichi 2008), and Bangkok (Phien-wej et al. 2006).

21.2.2 Estimation of Costs

The costs are estimated as the total construction and rehabilitation costs of 22 dike projects carried out in Java during the period 2007–2012 by the Ministry of Public Works (Direktorat *Bina* Program 2012). The cost of construction per meter is estimated at USD 554.26 while the cost of rehabilitation is estimated at USD 371.48. The minimum and maximum length of the dikes for these projects is 2000 m and 65,157 m respectively, with an average length of 7308 m. This is comparable to the dike lengths of 2431 m-34,229 m required for the polder systems in Jakarta. The maintenance costs per polder are assumed to be 1% of the construction costs per year, and begin in the year after dike construction. Note that the costs of each polder omit the price that could be shared by two adjacent polders, in order to make the costs comparable. We assumed the costs to be constant for different return periods of protection, since the dikes mostly follow street lines on top of older streets without the need for reworking the basis. The cost also neglects the need for retention lakes and pumping systems as suggested by e.g. Moerwanto et al. (2009) and Mechler (2005), which means that the results are subject to underestimation. As with the benefits, we assumed a project lifetime of 100 years, and a discount rate 7%, and calculated the total costs over this project lifetime. Again, note that in section "Uncertainty and sensitivity test" we also carry out a sensitivity analysis using discount rates of 4% and 10%.

21.3 Results

In this section, we describe results of our benefit/cost analysis for the 66 polders found in Jakarta Spatial Plan 2030. Section "Current situation" describes the results for the current situation, followed by results for the future scenario in section "Future situation". To simplify the discussion, we use the term net benefiting polders to refer to polders with a B/C ratio greater than 1. Similarly, we use the term polders with very high net benefits to refer to polders with a B/C ratio greater than 20.

We also use the division of western polders and eastern polders using the Ciliwung Lama river as border. The Ciliwung Lama is the lower part of the main river of Jakarta and is contained in the Pluit polder. The Ciliwung is the biggest river system in Jakarta, extending from the mountains (*Puncak*) to the coast.

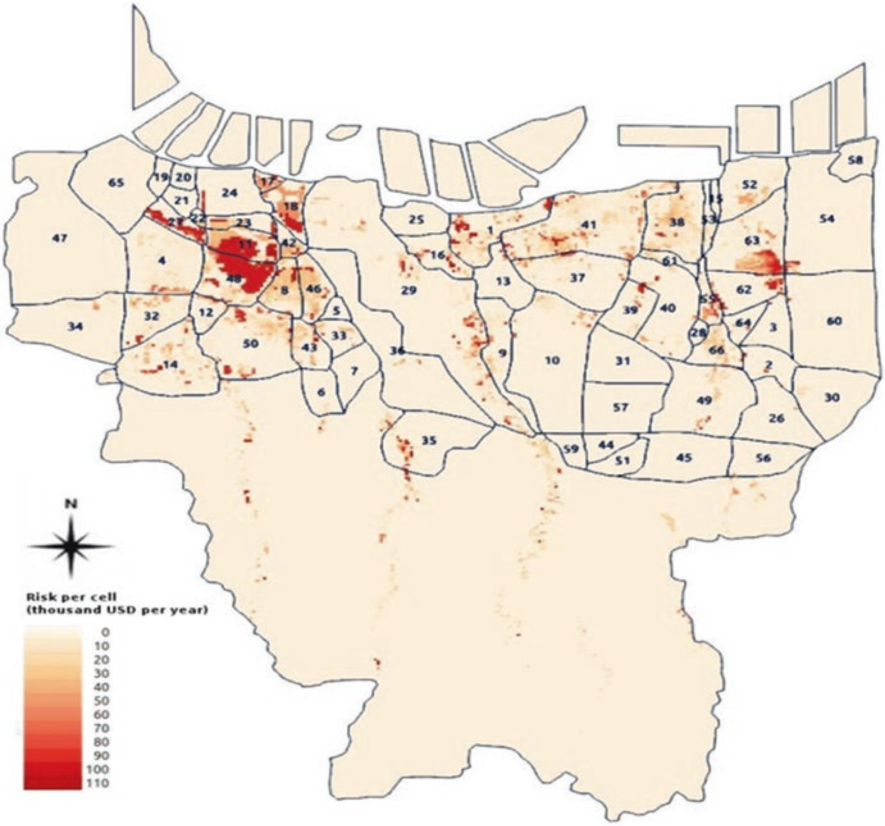

Fig. 21.3 The 66 polders (43 existing and 23 new) overlaid on a map of simulated flood risk 2013 (Source: Author's analysis) (For polder numbering refers to numbers in Tables 21.1 and 21.2)

At Manggarai, most of the water is diverted to the Western Flood Canal to avoid excess water from entering the city center. We take the border following PAM Jaya area service division (PAM Jaya 2012; PAM Jaya 2015) from 1997. The western area has long benefited from the Western Flood Canal while the eastern area has only benefited from the Eastern Flood Canal since 2010 (Adhi Ksp. 2010).

In Fig. 21.3, we show the current distribution of flood risk, before the construction/upgrading of the polder system. Here, flood risk is expressed in terms of expected annual damage, as calculated using Damagescanner-Jakarta. In Fig. 21.3, we also show the location of the polders that make up the polder system in the plan discussed in this chapter.

21.3.1 Current Situation: Kapuk Muara and Penjaringan Junction Give the Highest Net Benefits

Table 21.2 shows the B/C ratios that could be achieved by increasing the design standards for the existing polders, under current climate and land use conditions. Zero benefits in a cell means that our model simulates no risk. From the table, we see that 13 of the 43 polders could give immediate net benefits even if they were designed for a relatively frequent 2 year return period flood. Nine of them are situated in the west, while the other four are in the east. Fifteen polders could provide net benefits at the higher design return periods of 5, 10, 25 and 50 years. The table also shows that two polders, Kapuk Muara (Kapuk I, II, III) and Penjaringan Junction, give very high net benefits with B/C ratios of 23 and 49 respectively.

For planned polders, Table 21.3 shows that 8 out of 23 polders give immediate net benefits even for a design return period of 2 years. All of the polders are situated on the east. Four polders give net benefits for higher return period design standards (5, 10, 25, and 50 years). Among the nine net benefiting polders at a design standard of 2 years, Kapuk Polgar has a very high B/C ratio of 29, while the maximum B/C ratio among the other 8 polders is 3.9. The most inland planned polder is Kayu Putih, situated in the east (17 km from coast).

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In Fig. 21.4, we show the distribution of the B/C ratios, assuming a design return period of 25 years, which relates to the highest standards for a Metropolitan City, as stated in the Permen PU 12/ 2014. See also Fig. 21.6 for the increase between present situation and future scenario for twelve polders with high net benefits.

21.3.2 Future Situation: Kapuk Poglar and Nine Others Give High Net Benefits

When designing structural flood defense measures, investments are made for a long time horizon. Therefore, we also assessed the B/C ratios for the different polders using a future scenario including climate and land use change. As described in the methods section, the results shown here refer to the median scenario of all scenario combinations used to assess changes in precipitation intensity, sea level, land use, and subsidence. This scenario results in expected annual damage of USD 493 million, when the polder system is not taken into account.

Table 21.2 Benefit/cost ratio of existing polders in Jakarta on current risk

No	Polder name	Size (ha)	Perimeter (km)	Design return period (year)				
				2	5	10	25	50
1	Ancol Pademangan	557	12	1	2	2	3	3
2	Cakung Timur Selatan	278	8	1	2	2	3	3
3	Cakung Timur Utara	290	9	0	0	0	1	1
4	Cengkareng	791	11	4	9	11	13	14
5	Grogol	82	4	0	0	0	0	0
6	Hankam Slipi	247	7	0	0	0	0	0
7	Jati Pulo	304	8	0	0	0	0	0
8	Jelambar Barat (Wijaya Kusuma II)	286	8	1	2	3	6	7
9	Johar Baru	468	15	0	0	0	0	0
10	K. Item Serdang	1530	18	1	3	3	4	4
11	Kapuk Muara (Kapuk I, II, III)	329	8	49	114	144	160	167
12	Kedoya Green Garden	165	5	3	7	10	12	13
13	Kemayoran	377	10	0	1	1	1	1
14	Kembangan	896	12	1	3	5	6	7
15	Komplek Dewa Ruci	53	5	0	0	0	0	0
16	Marina	302	8	1	3	4	6	6
17	Muara Angke	70	4	0	0	0	0	1
18	Muara Karang	290	9	0	2	3	6	7
19	Pantai Indah Kapuk	36	2	7	16	20	23	24
20	Pantai Indah Kapuk	95	4	0	0	0	0	0
21	Pantai Indah Kapuk	107	5	0	0	0	0	0
22	Pantai Indah Kapuk	128	5	0	1	2	2	2
23	Pantai Indah Kapuk	172	7	3	10	14	16	18
24	Pantai Indah Kapuk	491	9	1	2	2	3	3
25	Pasar Ikan	313	7	0	0	0	0	0
26	Penggilingan	601	11	0	0	0	0	0
27	Penjaringan Junction	202	7	23	55	71	81	86
28	Perum Walikota (Don Bosco)	58	3	2	3	4	4	4
29	Pluit	2954	34	0	1	2	2	3
30	Pulo Gebang	701	11	0	0	1	1	1
31	Pulo Mas	589	10	0	0	0	0	0
32	Rawa Buaya	443	9	8	18	23	27	29
33	Rawa Kepa	203	6	0	2	2	3	4
34	Semanan	946	13	4	10	13	15	16
35	Setiabudi Barat	754	11	0	2	3	3	4
36	Siantar Melati	1365	25	0	0	0	0	0
37	Sunter Selatan	773	11	0	1	2	2	2
38	Sunter Timur I (Kodamar) atas	800	14	0	1	1	1	2
39	Sunter Timur I (Kodamar) bawah	335	7	1	3	4	6	6
40	Sunter Timur III (Rawa Badak)	650	11	0	1	1	1	2
41	Sunter Utara	1324	18	1	2	3	4	4
42	Teluk Gong	108	5	0	1	1	1	2
43	Tomang Barat	253	7	1	2	2	3	4

Source: Author's analysis

Table 21.3 Benefit/cost ratio of planned polders on current risk

No	Polder name	Size (ha)	Perimeter (km)	Designed return period (year)				
				2	5	10	25	50
44	Cipinang	181	6	0	0	0	0	0
45	Duren Sawit	671	13	0	0	0	0	0
46	Jelambar Timur	284	8	0	0	2	4	5
47	Kalideres	2230	23	0	1	1	1	1
48	Kapuk Polgar	527	10	29	66	84	94	98
49	Kayu Putih	980	14	1	3	4	4	4
50	Kedoya Taman Ratu	942	12	1	3	5	6	6
51	Klender	211	6	0	0	0	0	0
52	Komplek Dewa Kembar	529	10	1	3	4	4	5
53	Kramat Jaya	109	8	0	1	1	1	1
54	Marunda besar	1555	18	0	0	1	1	1
55	Marunda kecil	241	7	0	0	0	0	0
56	Pegangsaan Dua	159	7	4	8	10	12	13
57	Pondok Kopi	381	8	0	0	0	0	0
58	Pulo Gadung	628	10	0	0	0	0	0
59	Rawa Bunga	151	6	0	0	0	0	0
60	Rorotan	1405	16	0	0	0	1	1
61	Sunter Timur I B	101	6	0	0	0	0	0
62	Sunter Timur II KBN	398	9	2	6	8	10	11
63	Sunter Timur II Kebantenan	784	12	1	2	3	4	4
64	Sunter Timur II Petukangan	156	6	1	3	4	4	4
65	Tanjungan	928	12	0	0	0	0	0
66	Warung Jengkol Vespa	262	8	2	5	6	7	8

Source: Author's analysis

The resulting B/C ratios for existing polders are shown in Table 21.4. The results show that 19 out of 43 polders could provide net benefits at a 2-year return period design standard; 11 of these polders are situated in the west, while the other eight are in the east. Seven more polders could provide net benefits for higher return period design standards.

Table 21.5 shows the B/C ratios using the future scenario, for planned polders. From the table, 13 out of 23 polders could provide net benefits for all return period design standards; only two of the polders are on the west. The increase of net benefiting planned polders using the future scenario compared to the current situation shows the importance of considering future changes when considering the polder system. Figure 21.5 shows the distribution of B/C ratios for future scenario.

Combining data on the net benefiting polders available in Table 21.2 to Table 21.5, we produce Fig. 21.6, which shows the number of polders with a B/C ratio greater than one for the different return period design standards. Looking at the steepness, existing polders are more sensitive to the selection of return periods than planned polders for both current situation and the future.

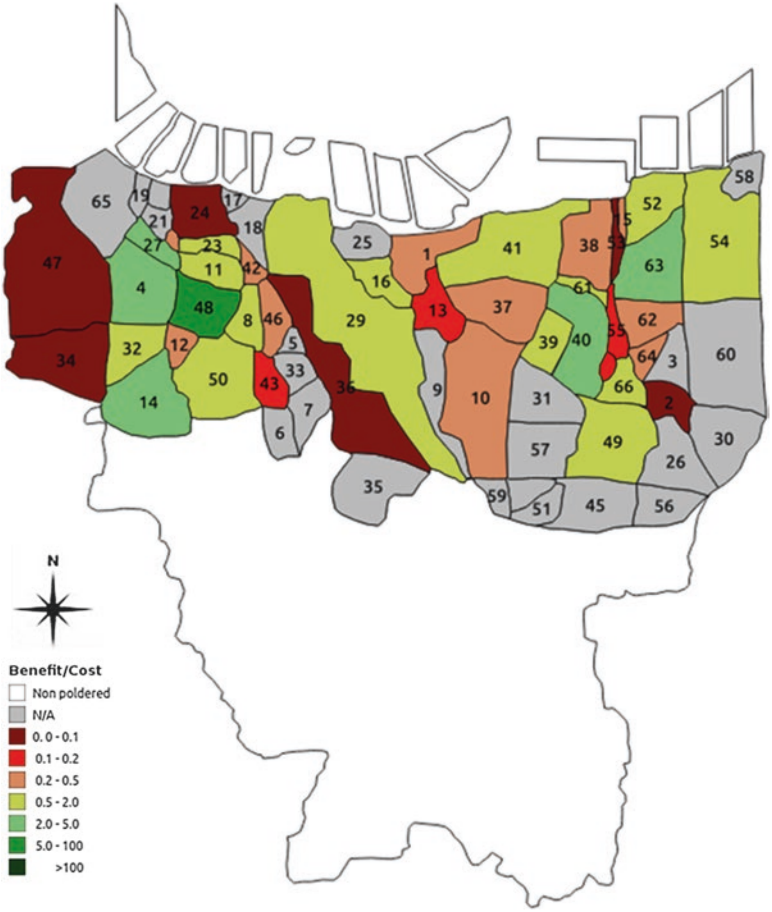

Fig. 21.4 Distribution of benefit/cost for present situation (The grey area ("N/A") relates to polders where no risk is simulate using Damagescanner-Jakarta) (Source: Author's analysis)

We assessed the B/C ratios under the current and future scenarios for the 12 polders with the highest net benefits; these results are shown in Fig. 21.6. The total risk reduction that could be achieved through the implementation of these polders is very large, both under current conditions (USD 104 million per year) and future conditions (USD 400 million per year). Again, the figure also shows the importance of considering the future conditions when planning for such structural measures with a long lifetime, since the overall benefits of the projects are much higher when the potential future changes are included (Fig. 21.7).

Table 21.4 Benefit/cost ratio of existing polders for the future scenario of climate change, sea level rise, land use change, and land subsidence

No	Polder name	Design return period (year)				
		2	5	10	25	50
1	Ancol Pademangan	35	53	60	63	64
2	Cakung Timur Selatan	0	0	1	1	1
3	Cakung Timur Utara	0	0	0	0	0
4	Cengkareng	11	18	21	22	23
5	Grogol	0	0	0	0	0
6	Hankam Slipi	0	0	0	0	0
7	Jati Pulo	0	0	0	0	0
8	Jelambar Barat (Wijaya Kusuma II)	7	12	14	15	15
9	Johar Baru	0	0	0	0	0
10	K. Item Serdang	0	1	1	1	2
11	Kapuk Muara (Kapuk I, II, III)	44	67	77	81	83
12	Kedoya Green Garden	1	1	1	2	2
13	Kemayoran	1	1	1	1	2
14	Kembangan	6	12	15	17	18
15	Komplek Dewa Ruci	6	9	10	11	11
16	Marina	9	14	17	18	19
17	Muara Angke	31	47	54	57	58
18	Muara Karang	24	36	41	43	44
19	Pantai Indah Kapuk	12	18	20	21	22
20	Pantai Indah Kapuk	0	0	0	0	0
21	Pantai Indah Kapuk	0	0	0	0	0
22	Pantai Indah Kapuk	0	0	0	0	0
23	Pantai Indah Kapuk	10	16	18	20	20
24	Pantai Indah Kapuk	0	0	0	0	0
25	Pasar Ikan	0	0	0	0	0
26	Penggilingan	0	0	0	0	0
27	Penjaringan Junction	78	120	137	146	149
28	Perum Walikota (Don Bosco)	0	0	1	1	1
29	Pluit	1	2	2	3	3
30	Pulo Gebang	0	0	0	0	0
31	Pulo Mas	0	0	0	0	0
32	Rawa Buaya	2	4	5	6	7
33	Rawa Kepa	0	0	0	0	0
34	Semanan	0	0	0	0	1
35	Setiabudi Barat	0	0	0	1	1
36	Siantar Melati	0	0	0	0	0
37	Sunter Selatan	7	11	13	14	14
38	Sunter Timur I (Kodamar) atas	5	10	12	13	14
39	Sunter Timur I (Kodamar) bawah	3	5	6	6	6
40	Sunter Timur III (Rawa Badak)	85	127	145	153	157
41	Sunter Utara	54	81	92	98	100
42	Teluk Gong	4	6	7	7	8
43	Tomang Barat	1	1	2	2	3

Source: Author's analysis

Table 21.5 Benefit/cost ratio of planned polders for future scenario resulting from median of three scenarios i.e. climate change, sea level rise and land subsidence

No	Polder name	Design return period (year)				
		2	5	10	25	50
44	Cipinang	0	0	0	0	0
45	Duren Sawit	0	0	0	0	0
46	Jelambar Timur	2	3	4	4	4
47	Kalideres	0	0	0	0	0
48	Kapuk Poglar	91	139	158	168	172
49	Kayu Putih	1	3	4	4	5
50	Kedoya Taman Ratu	2	4	5	5	6
51	Klender	0	0	0	0	0
52	Komplek Dewa Kembar	31	47	54	57	58
53	Kramat Jaya	5	8	9	9	9
54	Marunda besar	1	2	2	3	3
55	Marunda kecil	0	0	0	0	0
56	Pegangsaan Dua	1	2	3	3	3
57	Pondok Kopi	0	0	0	0	0
58	Pulo Gadung	0	0	0	0	0
59	Rawa Bunga	0	0	0	0	0
60	Rorotan	0	0	0	0	0
61	Sunter Timur I B	11	17	20	21	21
62	Sunter Timur II KBN	1	2	2	3	3
63	Sunter Timur II Kebantenan	17	28	33	36	38
64	Sunter Timur II Petukangan Timur	1	2	2	2	3
65	Tanjungan	0	0	0	0	0
66	Warung Jengkol Vespa	2	4	5	6	6

Source: Author's analysis

21.4 Discussion

Overall, we show that the implementation of the polder system could greatly reduce flood risk compared to the current situation. In the current situation, even if polders were designed for a 2 year return period flood, they could reduce risk by 25% (from a current risk of USD 186 per year without polders, to 139 per year with polders). The potential reduction of future risk is even greater. Again, if polders were designed for a 2 year return period flood, they could reduce risk in 2030 by 52% (from a current risk of USD 521 per year without polders, to 261 per year with polders). Of course, we show that bet benefits are not achieved for all polders, and so our benefit-cost results are also useful for highlighting those polders where the benefits are expected to outweigh the costs. In the following sections, we first discuss the polders in which these potential net benefits are particularly high. We then discuss policy implications of the polder system, before discussing the uncertainty and sensitivity tests carried out for this study, and potential future research directions.

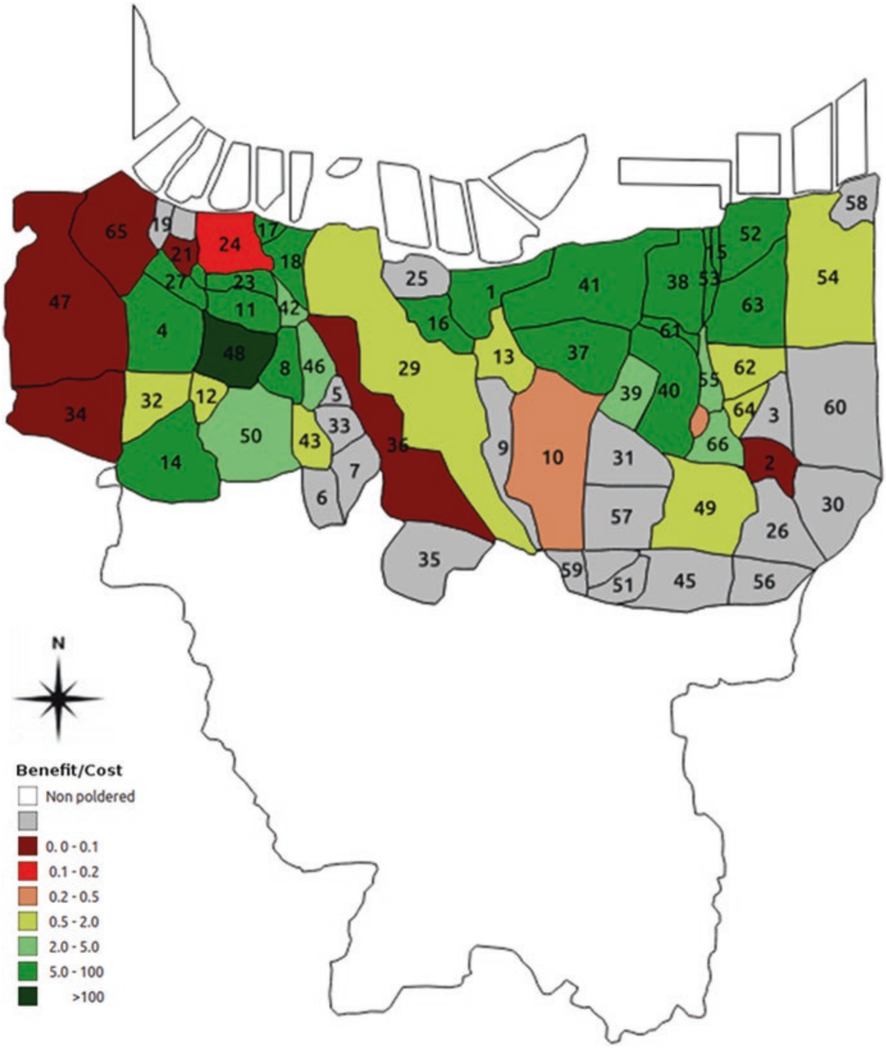

Fig. 21.5 Distribution of benefit/cost for future scenario (The grey area ("N/A") relates to polders where no risk is simulate using Damagescanner-Jakarta) (Source: Author's analysis)

21.4.1 Polders with Very High Net Benefits Are Located Away from the Coastline

From Fig. 21.4, we can see that the polders with very high net benefits for the current situation are located away from the coastline. This is similar to the situation in the Netherlands (Klijn et al. 2010), but with a different rationale. In the Netherlands, the lower benefit of further compartmentalization in coastal polders was due to the prior existence of many ancient and secondary embankments including road and railroad verges.

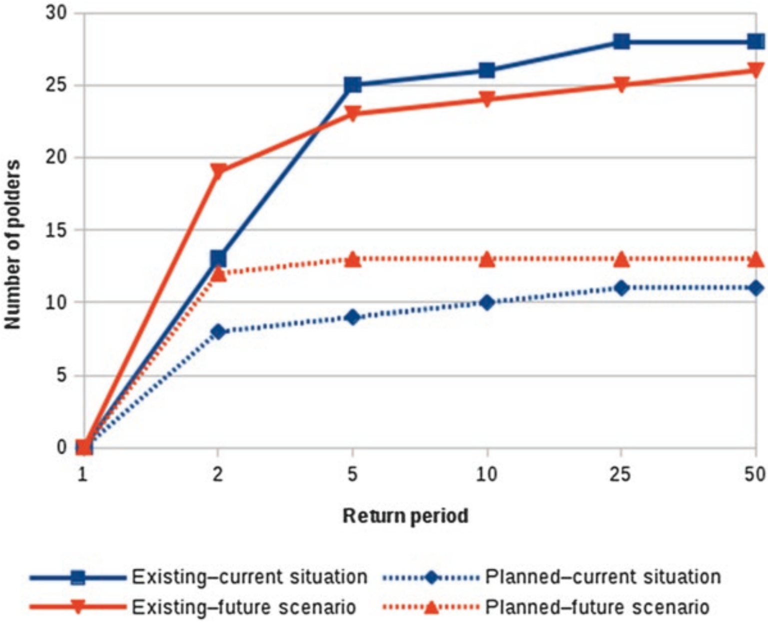

Fig. 21.6 Plot of the number of net benefiting polders for each return period design standard (Source: Author's analysis)

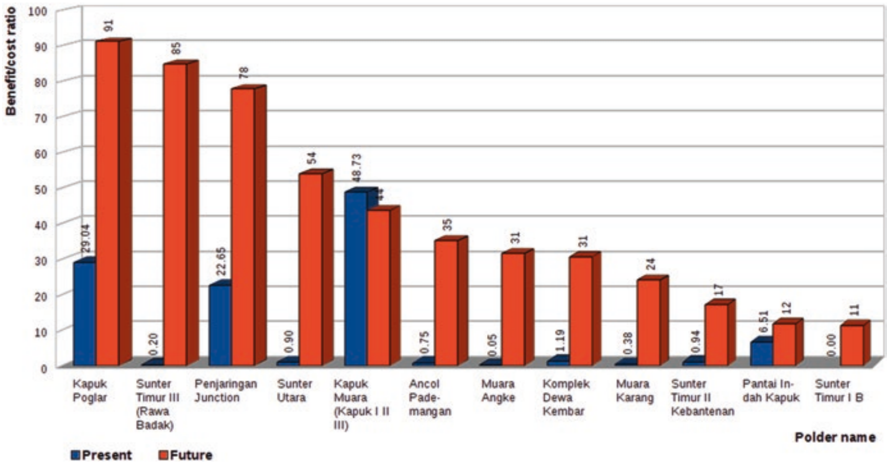

Fig. 21.7 Bar chart showing the B/C ratios for the 12 polders with the highest net benefits for current situation and future scenario (Source: Author's analysis)

It is also important to note that the high number of polders with very high net benefits in this study may be related to an underestimation of costs. As stated previously, we do not include operational costs and costs of pumping stations, which can add significantly to the overall costs (Spackova and Straub 2015). Here, we provide first cut estimates that reveal that the plan may be beneficial for a large number of polders, but for those polders more detailed studies would be required to assess the costs more accurately, and also to assess the potential co-benefits (e.g. using the storage lakes for recreation and so forth). For this first study, it was difficult to include the costs of pumping in a way that would allow comparison of the results between polders, because the techniques used can vary widely. For example, Tanjungan pumping station uses screw pumps with lower maintenance while Pluit pumping station uses axial pumps that require more energy and capital investment. Also the Tanjungan polder depends on a long shore type of retention pond that diverts flood water slower (and tends to give more risk) compared to the state of the art Pluit Lake together with the solid waste filtration system and the recreational park. Similar variations also exist in Ancol station, which is moderately active compare to Tanjungan and Pluit. In addition to that, morphology of inland and near shore polders will make large differences in costs between polders, which should be examined in detailed studies of each polder.

21.4.2 Policy Implications of Polder Systems in Jakarta

Our results show that the implementation and management of just 3 polders, namely Kapuk Muara (Kapuk I, II, III), Kapuk Poglar, and Penjaringan Junction (see Tables 21.2 and 21.3), could have a huge impact on reducing overall risk. These could reduce risk by USD 92 million per year under the current situation, or USD 153 million per year under the future scenario (50% of current risk). The three decrease 31% of risk under the future scenario. Total investment of the three is USD 10.25 million, or 3.2% of total cost for all 66 polders.

Our results suggest that building and maintaining the 12 polders shown in Fig. 21.6, to a return period design standard of 50 years (see last column of Tables 21.2, 21.3, 21.4 and 21.5), could reduce the current risk by USD 104 million per year (i.e. 56% of current risk), or by USD 400 million per year under the future scenario (i.e. 81% of future risk). These examples show how risk based benefit-cost analysis can help to identify and prioritize polder construction.

21.4.3 Uncertainty and Sensitivity Test

As mentioned previously, this study is intended to provide first cut estimates of the costs and benefits of the proposed polder system. This allows us to identify polders where the potential net benefits are the highest, which could be prioritized. However, the study is subject to large uncertainties. Especially, the costs considered here do

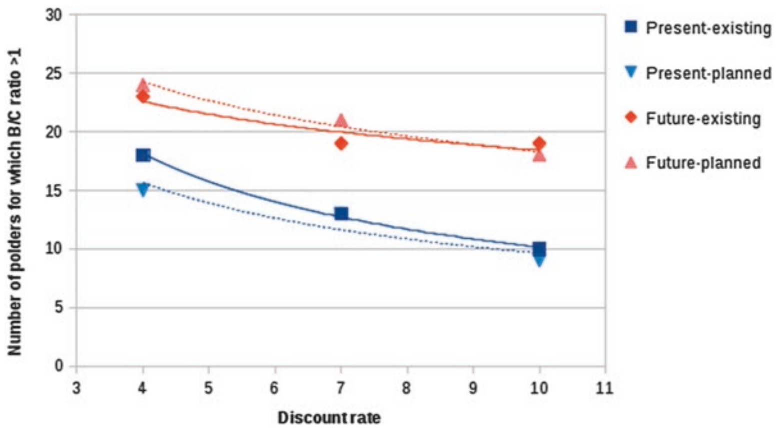

Fig. 21.8 Sensitivity test using inflation rate 4%, 7%, and 10% showing number of polders that give immediate benefit at return period 2 years (Source: Author's analysis)

not include the costs for the pumping stations and retention lakes, which could add up to a significant part of project costs. Therefore, for polders with a B/C ratio that only exceeds 1 by a relatively small amount, caution must be exercised. For all polders, if one were to want to move towards implementation, much more detailed studies of both the costs, benefits, and hydraulics systems would be required at the local scale. Nevertheless, the results are useful for opening a dialogue between planners and decision-makers on the potential of the proposed polder system to reduce risk.

We tested the sensitivity of the BCA to the choice of discount rate, by also carrying out the analyses using lower (4%) and higher (10%) discount rates, and examining the number of polders for which the resulting B/C ratio > 1. The results are shown in Fig. 21.8, including a power fit between the discount rates of 4%, 7%, and 10%. As expected, the number of net benefiting polders reduces as the discount rate increases, since most of the costs are incurred early on whilst the benefits accrue over the lifetime of the polder. Nevertheless, even at the higher discount rate, a large number of polders show a B/C ratio >1, indicating that these polders are relatively insensitive to the discount rate used.

21.4.4 Future Research Needs

This study provides a first cut analysis of the costs and benefits of the described polder system. In future work, it will be important to use more detailed local information to assess the costs and benefits of the polder systems more accurately, especially for those polders that have shown potentially high net benefits in this chapter. In this regard, learning from existing polders that show cases of good practice would be useful; a case in point is Pluit polder. Such future studies would need to include detailed data on aspects such as the dike line, the underlying soil type, retention lake capacity and placement, and costs of the pumping system. Moreover, the co-benefits of the polders should be examined, such as potential uses of the retention lakes for recreation and ecosystem services.

This chapter estimates the potential benefits based on hydraulic modeling of fluvial flooding. However, floods in the polders can also be caused by local precipitation, as seen in the flood of 19 February 2015 (Kadarsah et al. 2015). These extreme rainfall events may become more frequent or extreme in the future. It would be beneficial to also develop a flood hazard model based on scenarios of current and future pluvial flooding within a polder, which could increase the potential benefits of the polder system.

The results presented here for the future scenario are based on the median scenario of a large number of future scenarios of climate change, land use change, and subsidence, carried out by Budiyono et al. (2016). In future studies, it would be useful to examine the B/C ratios under all of the scenarios, in order to give a more complete picture of how the B/C ratios develop under each of the different scenarios.

Finally, this study does not examine the institutional and/or governance issues related to the potential implementation of polders in Jakarta; future research on this aspect is also essential.

21.5 Conclusions

We have demonstrated the use of a risk-based benefit-cost analysis for assessing potential effectiveness of the polder system described in Permen PU 12/ 2014 in Jakarta. The study provides first cut estimates of the benefits and costs involved, although costs of the pumping stations and retention lakes are not included in the analysis. Nevertheless, the results are useful for identifying polders where the potential benefits are the highest, and for prioritizing those polders. The results showed that implementing three polders could reduce current flood risk by 50%, namely Kapuk Muara (Kapuk I, II, III), Penjaringan Junction, and Kapuk Poglar. If we account for a future scenario of climate change, land use change, and land subsidence, the future risk could be reduced from USD 493 million per year to USD 340 million per year. Under this future scenario, nine additional polders could also provide net benefits, namely Sunter Timur III (Rawa Badak), Sunter Utara, Ancol Pademangan, Muara Angke, Komplek Dewa Kembar, Muara Karang, Sunter II Kebantenan, Pantai Indah Kapuk (19) and Sunter Timur IB. The 12 polders could decrease 81% of future flood risk, with the benefits far outweighing the costs.

Based on the findings, it appears that the highest immediate benefits could be obtained from developing the first group of polders. In the longer run, developing the other polders showing high net benefits could further reduce the risks from fluvial flooding in Jakarta.

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