Paper III-12

IMPACTS OF CHANGES ON FLOOD PROTECTION SYSTEMS CASE STUDY OF INDONESIA AND THE NETHERLANDS IN COMPARATIVE PERSPECTIVE

FEBRINASTI ALIA NASRUL[1], BART SCHULTZ[1], ROBIYANTO H. SUSANTO[2] AND F.X. SURYADI[1]

[1]*UNESCO-IHE, Core Land and Water Development, Delft, the Netherlands*
[2]*Sriwijaya University, Post Graduate Programme on Environmental Science, Palembang, South Sumatra, Indonesia*

ABSTRACT

Flood management in a changing environment needs a multidisciplinary approach to address possible impacts of future changes. The combined impacts of these changes may have significant consequences to development and may lead to an increase in flood risk. However, the nature and scale of these impacts are dependent on the form and scale of the land use change, climatic characteristics and rate of land subsidence. A study on possible impacts has been conducted in three flood prone areas, Delfland in the Netherlands and in Indonesia Pluit Polder in Jakarta and Jakabaring area in Palembang. In Delfland, man induced changes in land use, especially urbanisation take place at much more rapid speed than impacts of climate change, while land subsidence is being controlled to a large extent by relatively high polder water levels. In Pluit Polder the land subsidence rate has come to 5 cm/year and is therefore a major concern, while no significant land use change is accounted for as the area is already fully urbanised. The conditions in Jakabaring area are more or less in between, so every change could be important.

The study has been carried out to analyse possible impacts of future changes on the water management and flood protection systems in the three areas. This has been done by analyzing rainfall and evaporation data, configuration, storage and discharge capacity of the water management and flood protection systems, change in land use, sea level rise, increase in extreme rainfall and land subsidence rate. Some scenarios were designed to identify to what extent the existing water management and flood protection systems will be affected and to give recommendations for future developments.

INTRODUCTION[1]

Flood management in a changing environment needs a multidisciplinary approach to address the possible impacts of future changes with respect to man induced changes in land use, climate change, and land subsidence. The combined impacts of these changes may have significant consequences for development and may lead to an increase of flood risk. However, the nature and scale of these impacts are dependent on the form and magnitude of the changes.

A study on the possible impacts of changes has been conducted in three flood prone areas, Delfland, part of Dike Ring 14 in the Netherlands and in Indonesia Pluit Polder in North Jakarta and Jakabaring area in Palembang. In Delfland, man induced changes in land use, especially urbanisation take place at much more rapid speed than impacts of climate change, while where it still occurs land subsidence is being controlled to a large extent by relatively high polder

[1] This paper is to a large extent based on the MSc thesis of Febrinasti Alia Nasrul (2010)

water levels. In the Pluit Polder the land subsidence rate is about 5 cm/year and is therefore a major concern. There will be only limited land use change as the area is already fully urbanised. The conditions in Jakabaring are more or less in between, so every change could be important.

This research has been carried out to study possible impacts of future changes on the water management and flood protection systems. This has been done by analyzing rainfall and evaporation data, configuration, storage and discharge capacity of the water management systems, effects of man induced changes in land use, increase in extreme rainfall, sea level rise and land subsidence rate in the study areas with the help of the DUFLOW model. Some scenarios were designed to identify to what extent the existing water management and flood protection systems will be affected and to give recommendations for future development.

BACKGROUND

The study areas were selected in order to compare ‘optimal’ solutions under different conditions to cope with flooding problems in light of future changes. The extent and magnitude of land subsidence related flooding and higher discharge generated from man induced changes in land use will worsen the impacts of flooding. The combined impacts of future changes may have significant consequences to development and may lead to an increase of flood risk and pressure on water management and flood protection provisions.

Delfland in Dike Ring 14, the Netherlands

At present almost half of the Netherlands - the most downstream country in Rhine River Basin - is below mean sea level (MSL) and two-third of it is flood prone. Most of the landscapes are man-made and have led into a never ending struggle of water management and flood protection. High water levels in the main rivers occur regularly and have been the cause of many cases of flooding (Van Boetzelaer and Schultz, 2005). The frequent flooding disasters resulted in the need for flood protection and drew major investments to improve the water management and flood protection systems. Water-boards (waterschappen), institutions for local and regional water management, exist for centuries. Dike Ring 14 - 2,230 km^2 - situated in the end of the Rhine-Meuse Delta is the largest dike ring in the Netherlands (Figure 1). The area has about 3.6 million inhabitants and has important industrial, commercial and governmental functions. Important places are Amsterdam, Schiphol and the Hague, the seat of government.

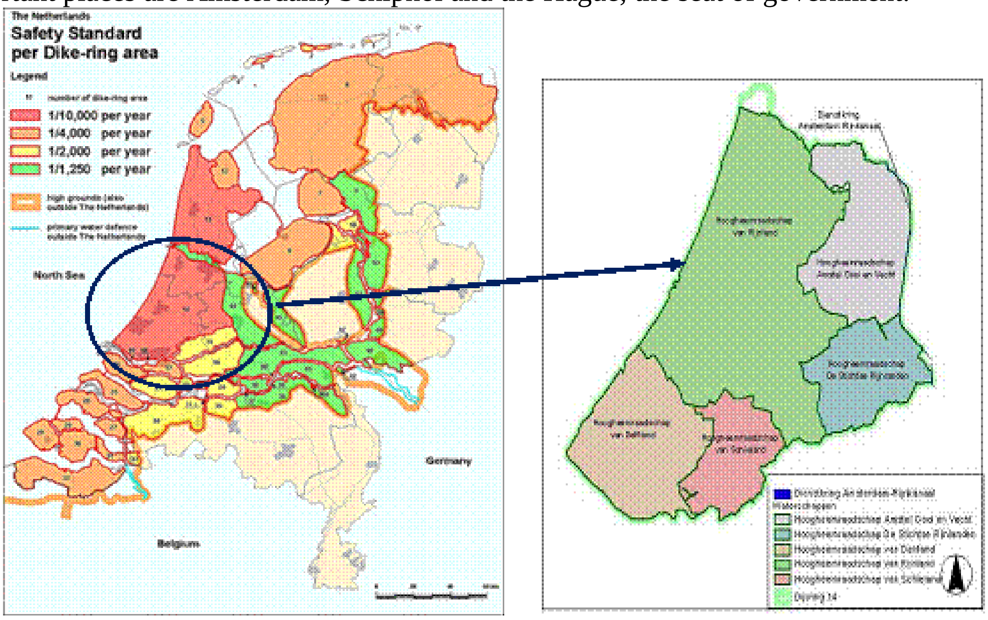

Figure 1. Dike rings in the Netherlands and their safety standards (Schultz, 2010)

Delfland is one of the twenty-seven water-boards in the country and one among five water-boards within Dike Ring 14. The area of Delfland is approximately 400 km^2 with nearly 1.4 million inhabitants and approximately 40,000 enterprises. It is therefore one of the most densely populated and industrialized areas of the Netherlands and characterized by high economic potential (greenhouses, arable land, farms) and high urbanisation rates. The economic interests in Delfland are confronted with the need of space for water to ensure a flood protection safety level within its borders. Due to rapid urbanization land use has changed dramatically during the last decades (Figure 2). Ongoing urbanization is regarded as one of the main threats for storing excess water from precipitation and to the quality of life in the area. Delfland has been used to illustrate developments in the low part of the Netherlands.

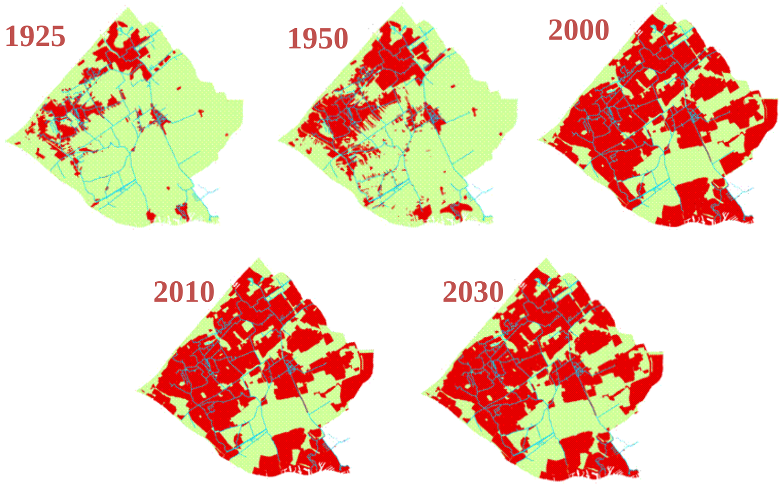

Figure 2. Urbanisation in Delfland (Joint Working Group, 2009)

Pluit Polder-Jakarta, Indonesia

The Metropolitan area, Jabodetabek, with 20 million inhabitants, is the 6th largest metropolitan area in the world. Jakarta with an area of 652 km^2 is the economical, political and cultural capital of Indonesia. In the last three decades, urban development of Jakarta and its surrounding has been very rapid. The total population of Jakarta is about 9 million (BPS Jakarta, 2007) but can increase up to 13 million during the day since many working people live in neighbouring cities, like Bogor, Bekasi and Tangerang. The increase in population and urban development mostly occupied green areas in the surrounding (Rukmana, 2008). Thirteen rivers flow through the city and create the main drainage systems. As a result, in some parts of Jakarta, flooding is a fact of live. Every year widespread flooding occurs and inundates up to 40% of the city.

Development of polders in Indonesia was adopted from the Netherlands in the beginning of the 20th century (Joint Working Group, 2009). The Pluit Polder - 20.8 km^2 - in North Jakarta was developed by a project developer around 1970, mainly for housing (Figure 3). It is the oldest urban polder in Indonesia. In 2007 there were about 215,000 people, which implies a population density of 10,300 persons/km^2 (Indonesia Statistics Board, 2007). The Pluit Polder has been used to illustrate developments in Jakarta.

Jakabaring area, Palembang, Indonesia

Palembang is the capital city of South Sumatera with a total area of 401 km^2 in the downstream part of Musi River Basin of 60,000 km^2. The average surface level is 8 m+MSL. Due to population growth, Palembang is becoming a densely populated area and one of the metropolitan cities in Indonesia. In order to fulfil the needs of population growth and urbanization, the municipality has developed the area ever since.

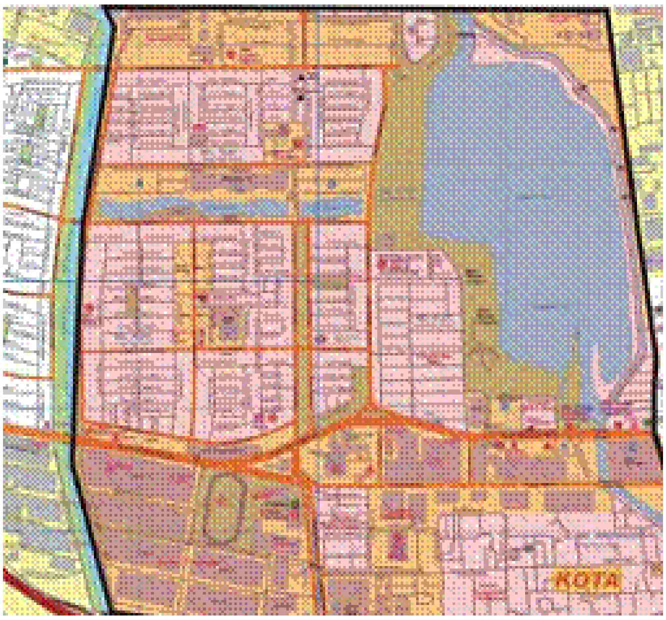

Figure 3. Pluit Polder in Jakarta

Most of the lowland areas in Jakabaring have been reclaimed since 2003. The area that can still be reclaimed is about 24 km^2 or about 6.9% of the total area of Palembang. The concept of water management at polder level has not yet been applied in Palembang. However, as the area of Jakabaring is dominated by lowlands and in the state of rapid development, one may expect that the polder concept will have to be considered in the near future. In the Detailed Land Use Planning of Jakabaring, some areas have already been designed for retention basin to temporarily store runoff during the wet season when the rainfall and tidal influence are high. Jakabaring has a total storage system of about 3,700 ha, which is divided into 10 main drainage systems (Figure 4). Jakabaring has been used to illustrate recent developments in a new urban quarter of Palembang.

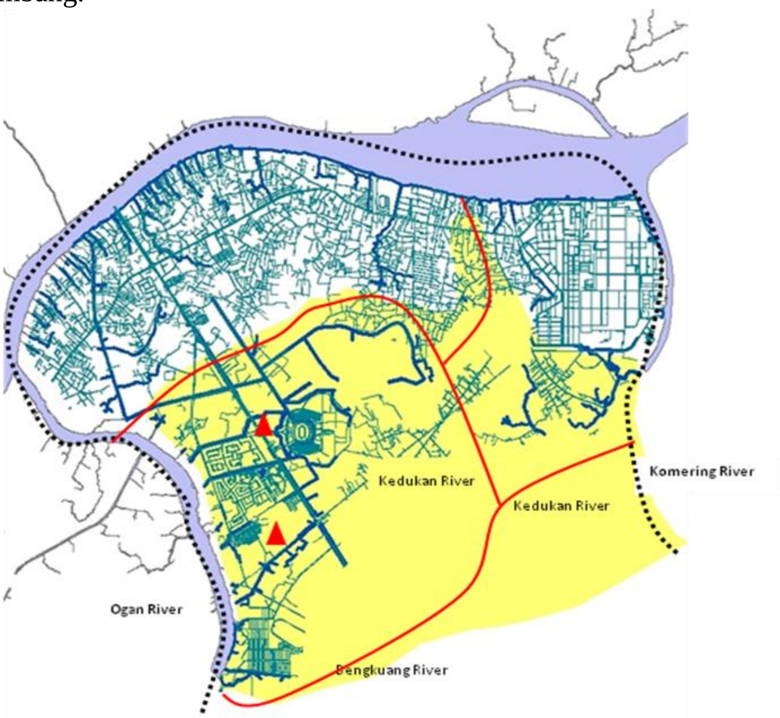

Figure 4. Structural system of Jakabaring urban flood management

RESEARCH METHODOLOGY

The methodology applied in this research consisted of several phases: literature review and formulation of research objectives, data analysis (spatial and hydrologic and hydraulic analysis, modelling (ArcGIS and DUFLOW Modelling Studio, development of flood risk maps, results, discussion in comparative perspective and recommendations. The sequence of each phase is schematised in Figure 5.

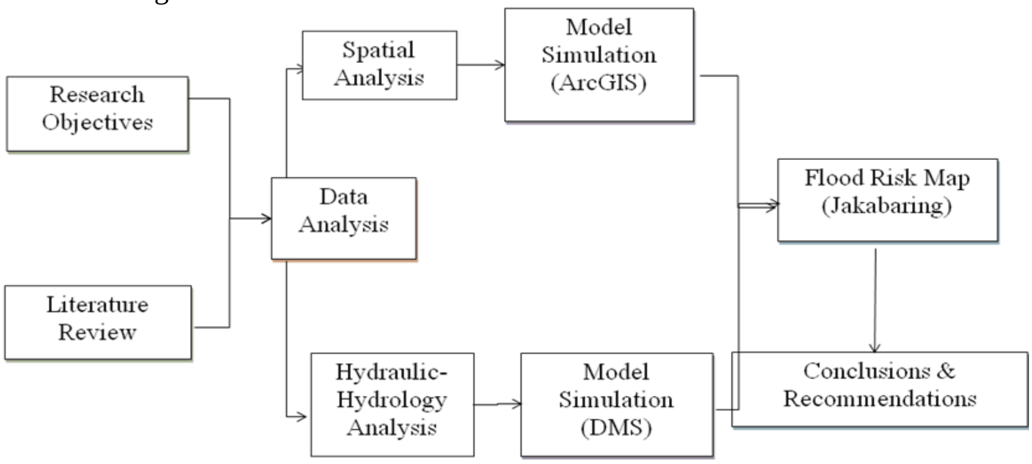

Figure 5. Research methodology

Hydrological data analysis

Rainfall frequency analysis was applied to four theoretical continuous distributions; the Normal, Log-Normal, Log-Pearson type III, and Extreme value type I (Gumbel) and the fitted chance of occurrence distribution was tested by chi-square test for goodness of fit. It was found that the hypothesis cannot be rejected at 95% confidence level. For Delfland rainfall data were taken from Hoofddorp weather station. The annual maximum data for 33 years from 1975-2007 have been used to calculate the chance of occurrence. The rainfall depth-duration curve for Delfland is shown in Figure 6. Jakarta has a wet season, which usually occurs from December to May whereas the maximum rainfall amounts are generally observed in January and February due to heavy monsoon rainfall. The rainfall in the area is characterized by high intensity-short duration storms. Rainfall is generally concentrated in the afternoons and evenings (NEDECO, 1973). For the Pluit Polder rainfall data were taken from Kemayoran weather station. The annual maximum data for 28 years from 1981 - 2008 have been used to calculate the chance of occurrence. The rainfall depth-duration curves for Pluit Polder are shown in Figure 7. In Jakabaring the rainy season occurs from August to May. The maximum monthly rainfall is in March. In the rainy season, when high rainfall is followed by spring tide, several areas in Palembang are inundated, especially in the lowlands or floodplains. For Jakabaring rainfall data of weather station Kenten were taken (Kenten Station, 2008). The annual maximum data for 32 years of 1976 - 2008 have been used to calculate the chance of occurrence. The rainfall depth-duration curves for Jakabaring are shown In Figure 8.

TOPOGRAPHIC ANALYSIS

Delfland

The surface levels in Delfland range from a few metres above MSL in and near the dune to 1 – 2 m-MSL in the old polders and 4- 5 m-MSL in the drained lakes. This implies that drainage by pumping is required in more or less the whole area.

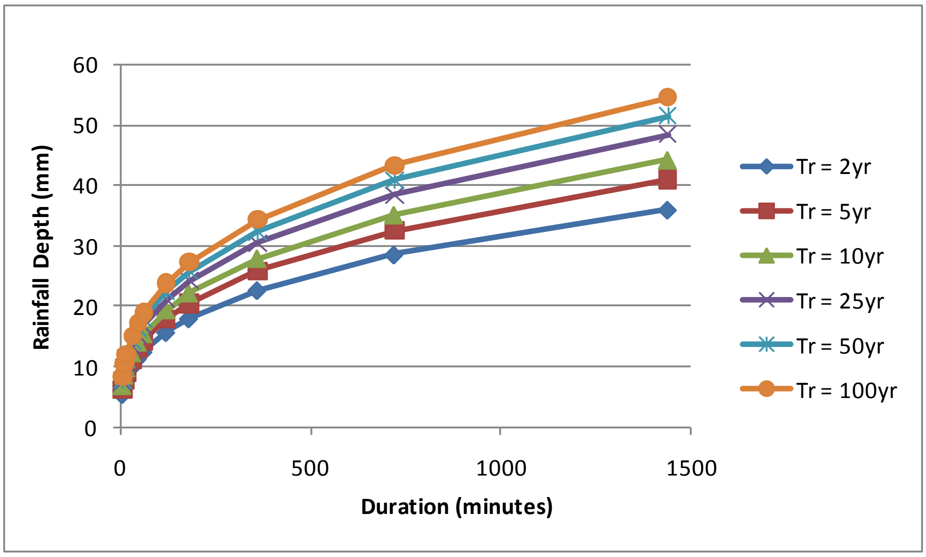

Figure 6. Rainfall depth-duration curve for Delfland

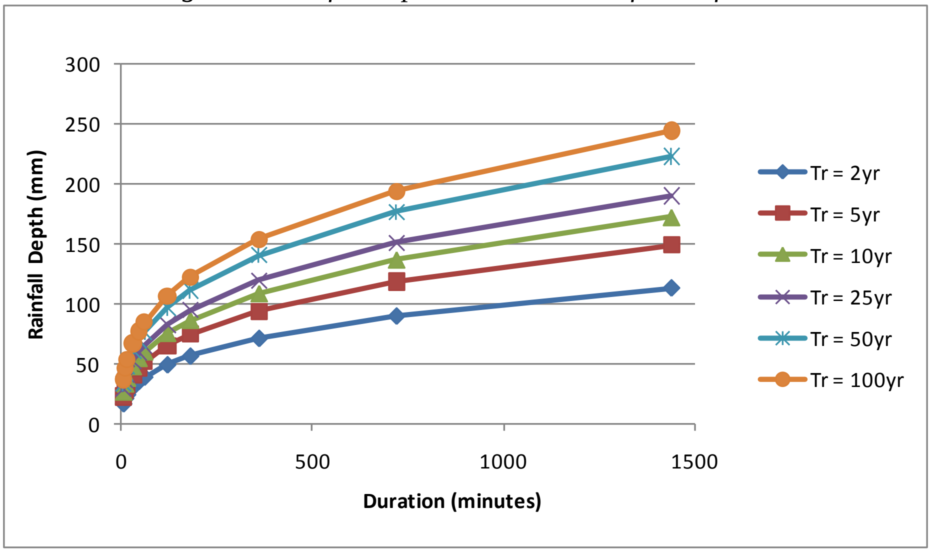

Figure 7. Rainfall depth-duration curve for Pluit Polder, Jakarta

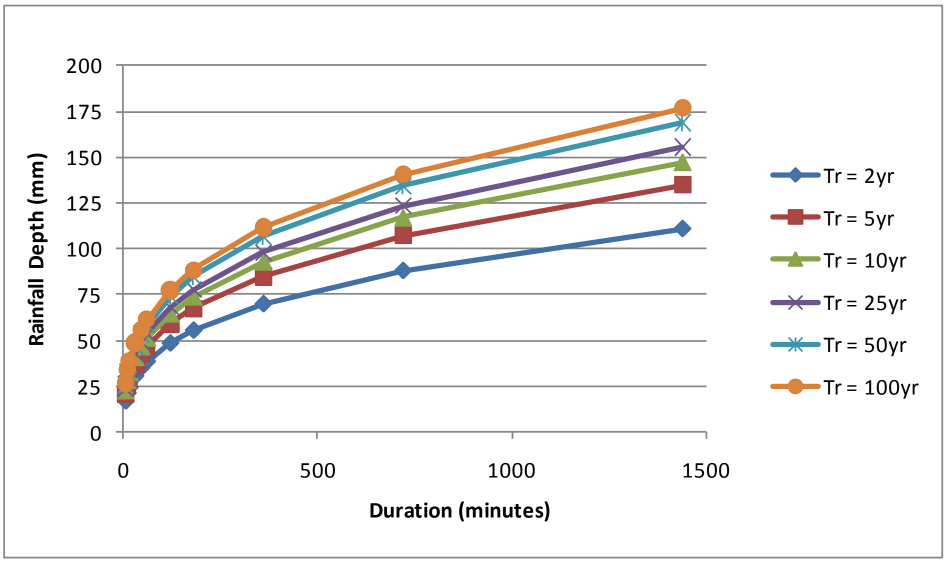

Figure 8. Rainfall depth-duration curve for Jakabaring, Palembang

Pluit Polder-Jakarta, Indonesia

The distribution of the elevation of the Pluit Polder ranges from less than 0 m up to 3.7 m+MSL (Figure 9). The area of study is dominated by land with an elevation of 0.7 - 0.3 m-MSL. All areas have been developed as high density residential area. According to tidal fluctuation data of Tanjung Priok station, the highest water level during spring tide is 0.58 m+MSL. Therefore a good maintenance of the surrounding dike will be required to protect the area. However, in 2008, 2009 and 2010 spring high tide caused sea dike failures and inundated the area (Community forum of Pluit Environment Care).

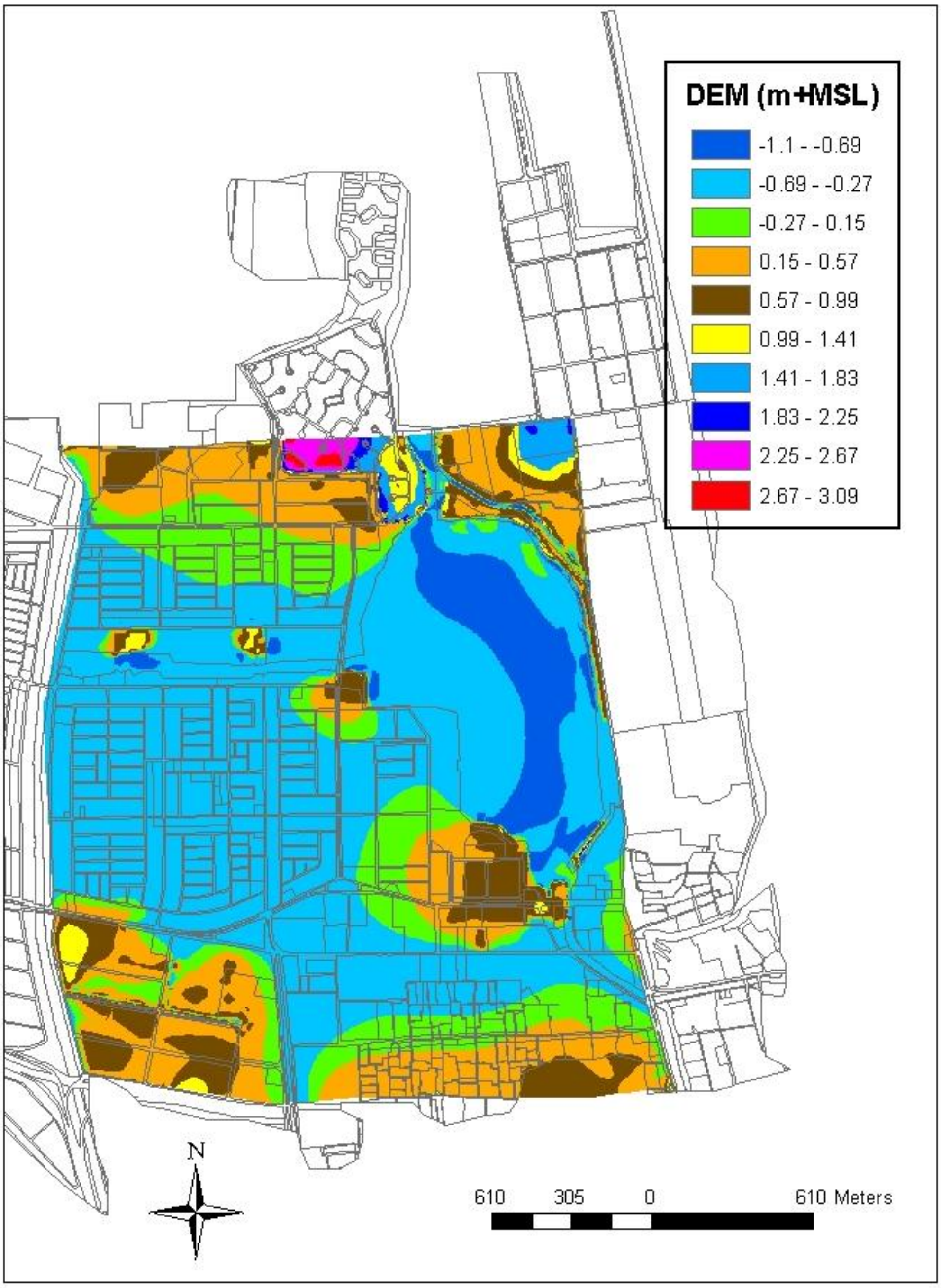

Figure 9. Surface levels of Pluit Polder, Jakarta

With respect to flood protection, the schematization of water management in Pluit Polder resembles the hydraulic transport system of polders in Netherlands. Collector drains of trapezoidal and rectangular-shape in the residential area convey the discharge through the main drains of Pluit Lake to Pluit Retention Basin and Muara Karang River. There is also a flapgate that regulates the inflow from Pluit Lake (temporary storage), which is no longer working due to lack of maintenance. Land subsidence in the area has resulted in a preferred polder water level of 1.95 m-MSL.

The water management system of the Pluit Polder is basically a drainage system that serves as a retention / temporary storage (Figure 10). It consists of the following components:

- *pumping stations.* There are 11 pumps with a total capacity of 47.3 m^3/s. The central pumping station has 4 pumps with each a capacity of 4 m^3/s and the western pumping station has 3 pumps with a capacity of 6 m^3/s each. The pumps currently operate at approximately 60 - 80% capacity only. There is another pump with a capacity of 12.6 m^3/s to drain water to Muara Karang River;
- *gates.* The gates consist of a weir in combination with siphons. Water is drained from the urban drains to the Pluit Retention Basin;
- *urban drains.* Capacities of the urban drains depend on the service area of each block.

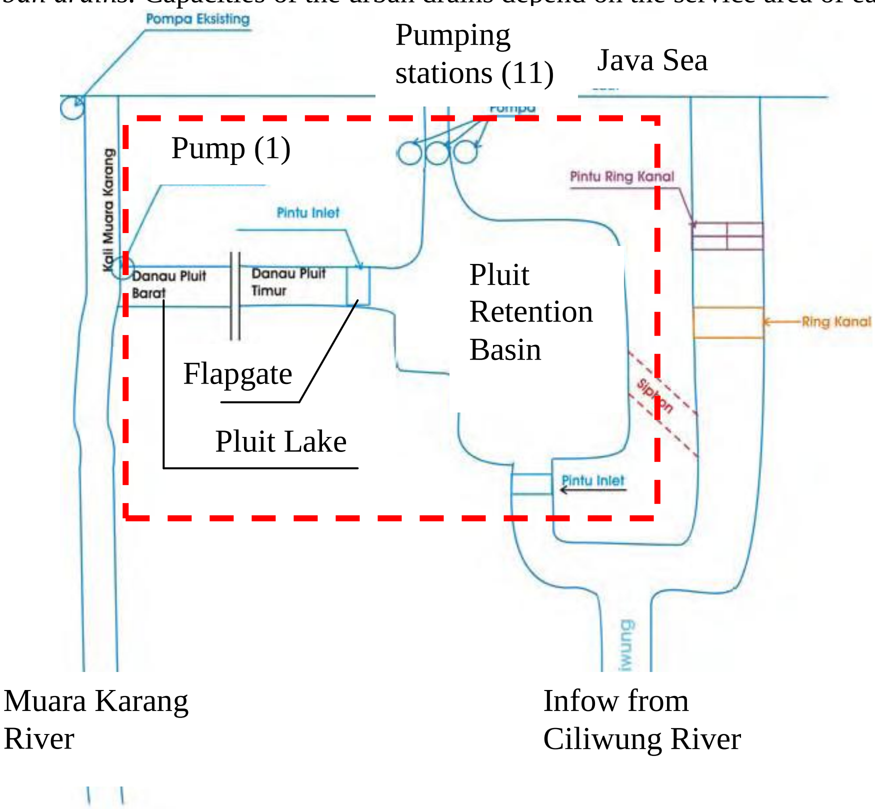

Figure 10. System of urban drainage and flood protection in Pluit Polder

The drainage water from settlements is stored temporarily in the Pluit Lake. Thereafter, most of the water flows to Pluit Retention Basin via the existing water gate and partly to Muara Karang River by pumping. The water in Pluit Retention Basin has to be pumped out to the sea.

Jakarta is also located on the Jakarta Groundwater Basin. The basin fill consists of marine Pliocene and Quaternary sand and delta sediments of up to 300 m thick. Individual sand horizons are typically 1-5 m thick and comprise only 20% of the total fill deposits. Silts and clays separate these horizons (Abidin et al., 2006 and 2008). The limited distribution of fresh water in Jakarta results in the fact that people and industries extract groundwater for their basic needs. Based on the studies by Murdohardono and Tirtomihardjo (1993) wells were extracting groundwater from depths of respectively between 40 - 140 m and between 140 - 250 m. The registered groundwater extraction in Jakarta varies from just 3 million m^3 in 1900 up to maximum of 33.8 million m^3 in 1994 and then down to 16.9 million m^3 in 1998. It should be pointed out that these numbers may not reflect the real groundwater extraction. According to Sutrisno (1997), the unregistered deep groundwater pumping in Jakarta can be up to 50%. This excessive groundwater pumping has led to the lowering of the piezometric water level inside the middle and lower aquifers. The land subsidence rate is closely related to the lowering of the groundwater in the aquifers.

Jakabaring-Palembang, Indonesia

The elevation of Jakabaring area ranges from less than 0 m up to 6 m+MSL. The distribution of the elevation can be seen in Figure 11. Most of lowland areas in Jakabaring have been reclaimed and developed as residential area and cultivation area. In Palembang Musi River is still influenced by the tide. According to data of Musi station for 2009 the highest water level during spring tide is 1.95 m+MSL. Therefore, during spring tide a high water level is likely to inundate the area with lower elevation which almost covers 50% of the total area.

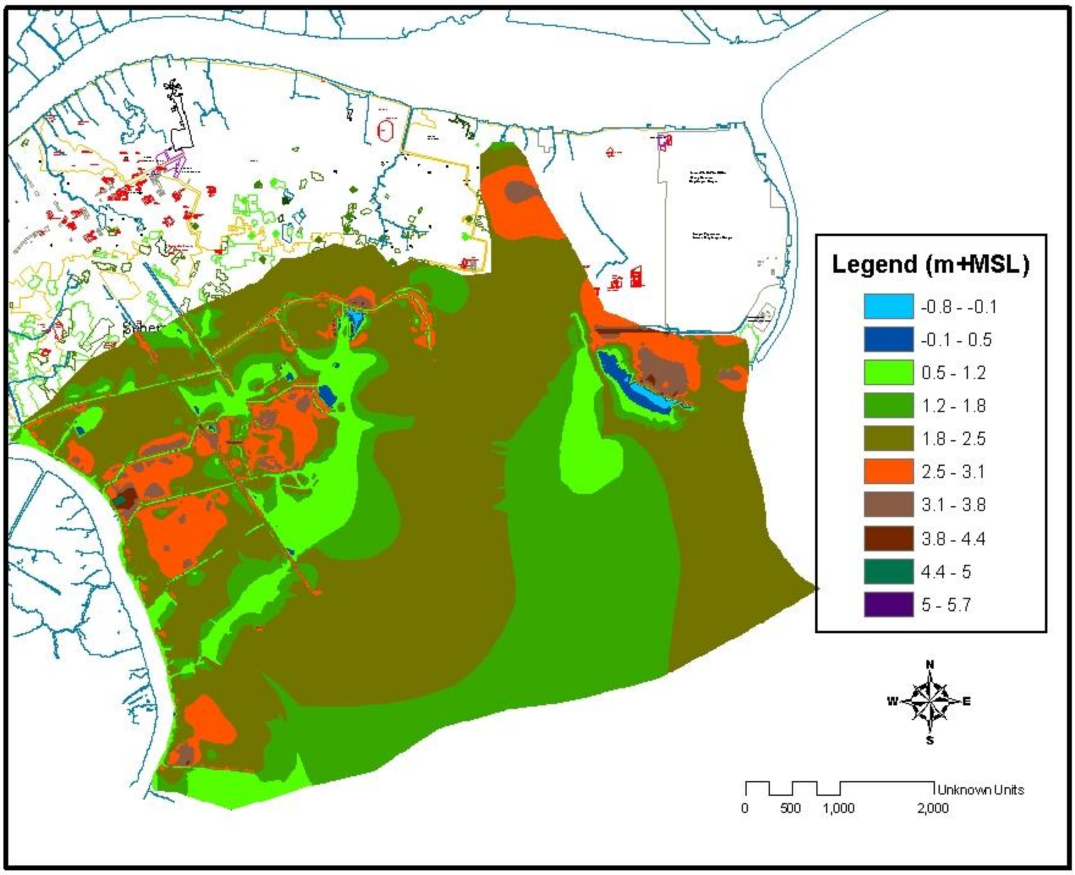

Figure 11. Surface level of Jakabaring area, Palembang

Existing canals in Jakabaring have large drainage areas and most of them are in lowland areas. They are directly connected to Ogan River. In this flat area, there is small head difference. Therefore the water in the canals flows at low velocity. When the water level in Musi River is high, the water in Ogan River and other small rivers in Jakabaring will overflow and cause flooding to the surrounding areas. The canals are generally not properly maintained. There are two retention ponds (Figure 4).

DUFLOW MODEL SIMULATION

For the three areas DUFLOW simulations have been made to analyse the situation for various characteristic years. The results are summarised underneath.

Delfland

The DUFLOW model simulation has been made to analyse the effects of urbanisation and climate change on the water management in the polder areas. The hydraulic transport system of the polders generally consists of collector drains, sub-main drains, main drains and structures. While the hydraulic gradient in a polder is generally very small, in the simulations only water storage and pumping capacity have been taken into account. The fluctuations in the open water level in a theoretical polder have been analysed under different percentages of urban and rural areas in three characteristic years: 1925, 2010 and 2030. Impacts of climate change on increase in extreme rainfall have been simulated simultaneously with the land use changes. Design rainfall for a chance of occurrence of 1% per year has been used to calculate the peak flow and rise in the water level. An increase of 10% in the extreme rainfall in 2030 has been assumed to represent the effect of climate change both for urban and rural areas.

The given parameters for the peak flow calculation were different for the urban and rural areas. For the urban area a storage area of 3% of the total area, a preferred water level of 1.0 m-surface and a runoff coefficient of 0.8 have been assumed. For the rural area, a storage area of 5% of the total area, a preferred water level of 0.8 m-surface and a runoff coefficient of 0.4 have been taken. The DUFLOW schematisation is shown in Figure 12. The computation results for the resulting discharge in three characteristic years is shown in Table 1.

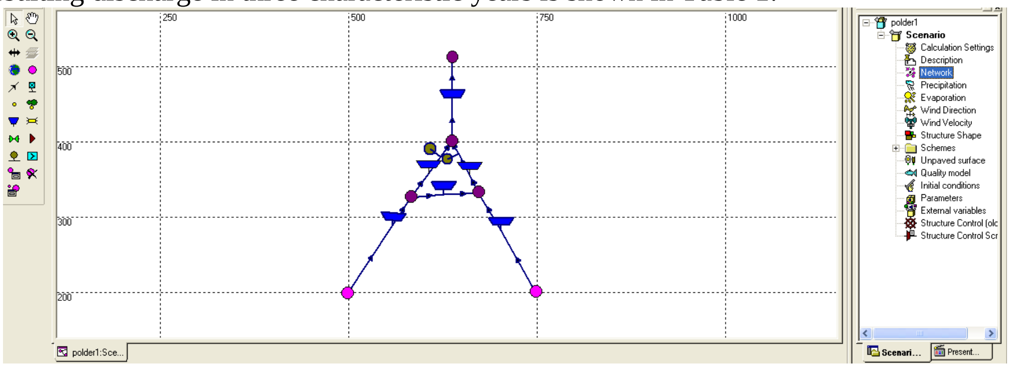

Figure 12. DUFLOW schematization of urban and rural area in a theoretical polder

Table 1. Maximum discharge from the urban and rural areas in the characteristic years

	Urban area			Rural area		
	1925	2010	2030	1925	2010	2030
Q for 1 day (m^3/s)	30.3	172.0	189.0	85.8	15.1	16.7
Q for 3 days (m^3/s)	14.5	82.4	90.7	41.2	7.3	8.0
Q for 6 days (m^3/s)	9.2	52.2	57.4	26.1	4.6	5.1

To control the water level in the polder, pumps are used to discharge excess water to the collection and transport system, which has in case of Delfland a preferred level of 0.40 m-MSL. From this system the excess water is discharged to the North Sea. The assumed pumping capacity was 15 mm/day, which is normal for a polder in the Netherlands.

The preferred water level in both the urban and rural area is considered to be the same at 4.2 m-MSL or 1.0 m-surface (Figure 13). The simulations were intended to see how much the water level would rise with discharge as shown in Table 1 the given storage areas and the pumping capacity. In order to keep the preferred water level, the pumps start at the level of 4.1 m-MSL and stop at the level of 4.3 m-MSL.

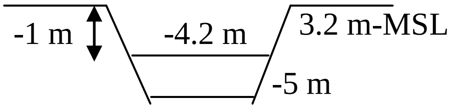

Figure 14. Preferred water level in the rural and urban areas

The computed highest water levels for the three characteristic years are shown in Table 2. From Table 2 it can be observed that only in 2030 the 1 day rainfall with a chance of occurrence of 1% per year may result in some inundation of the urban area. To bring the water level down a higher pumping capacity will be needed. It was found that with a pumping capacity of 20 mm/day the water level in the urban area after 1-day rainfall drops to 3.33 m-MSL.

Table 2. Water levels in m-MSL during extreme rainfall in the three characteristic years at a pumping capacity of 15 mm/day

	Urban area			Rural area		
	1925	2010	2030	1925	2010	2030
1 day-rainfall	3.72	3.28	3.15	3.78	3.39	3.23
3 day-rainfall	4.1	3.68	3.48	4.1	3.69	3.50
6 day-rainfall	4.1	4.1	4.1	4.1	4.1	4.1

Water levels in 2010 and 2030 increase significantly compared to 1925. This is primarily caused by the massive conversion of rural to urban areas since 1925, resulting in up to respectively 7.6% and 10% higher discharges. The DUFLOW simulation results for three consecutive years have underlined that in Delfland, man induced changes in land use, especially due to urbanisation take place at a much more rapid speed than climate change.

Pluit Polder, Jakarta, Indonesia

The present condition and a future scenario after the impacts of future changes have been analysed. Climate change and land subsidence have been taken into consideration. Change in land use has not been taken into account while the area is already fully urbanised. A chance of occurrence of 4% per year for the design drainage capacity has been used. Maximum rainfall for the period of 3 hours has been used for rainfall-runoff analysis. According to the Intergovernmental Panel on Climate Change (IPCC) (2007) the increase of extreme rainfall in Indonesia will be 3 - 3.2% up to 2030. However, in order to get an impression of the worst scenario 10% increase in extreme rainfall and 2 mm/year (0.04 m for a 20 years period) sea level rise have been assumed. For land subsidence in Pluit Polder the Ministry of Public Works projected a rate of 0.05 m/year (1.00 m for a 20 years period). In the analysis only the macro urban drainage management system consisting of Pluit Lake and Pluit Retention Basin has been taken into account. The schematisation is presented in Figure 16.

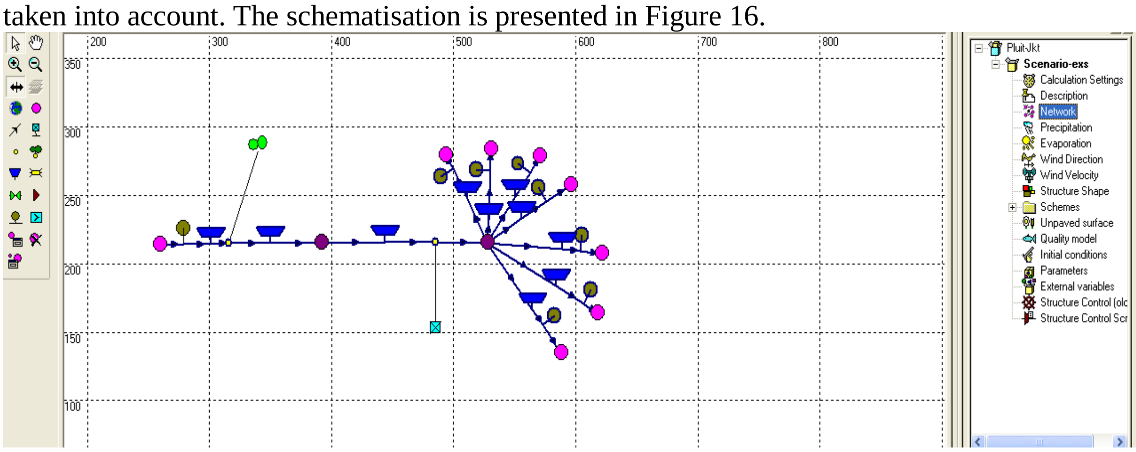

Figure 16. Model schematization of the urban drainage system of the Pluit Polder

Based on the existing macro drainage system of Pluit, eight pumps have been simulated with respect to the real-time operation procedure. Each pump had its own working capacity and efficiency that eventually determined the discharge for every start level.

In the present situation the water level in the outlet of the Pluit Retention Basin reaches its peak at 1.62 m-MSL due to one day rainfall and the discharge from Ciliwung River. The lowest surface level in the polder is 0.2 m-MSL, so there will be no inundation. After almost 12 hours the water level will reach the preferred level of 1.95 m-MSL. With respect to this it has to be realised that although theoretically the capacity of the existing pumps is adequate to serve the whole polder area, several things in the field have created major limitations, for instance:

- the lined banks of some drains are in a state of deterioration;
- accumulation of sediment and solid waste in some drains and in the inlet of Pluit Retention Basin clogs the flow, which may result in higher water levels;
- illegal encroachment in rivers, drains and reservoirs constitute another significant factor for reduced capacities;
- the syphon (inlet structure) that regulates the inflow from Ciliwung River was not modelled due to lack of data. However, the siphon is also clogged resulting in a reduced inflow from outside;
- the flapgate that regulates the inflow from Pluit Lake (temporary storage) is no longer working due to lack of maintenance. This flapgate causes a problem to the inflow of water from Pluit Lake to the inlet of Pluit Retention Basin.

For the future scenario, the outlet of the Pluit Retention Basin will reach its peak at the level of 2.26 m-MSL due to one day rainfall and discharge hydrograph input from Ciliwung River. By that time the lowest surface level in the polder is 1.32 m-MSL, so there will be no inundation. After almost 24 hours the water level will reach the assumed preferred level of 3.0 m-MSL.

Jakabaring, Palembang

For the simulation of Jakabaring the existing condition and the situation after the impacts of future changes have been analysed. For future changes, land use change, climate change and land subsidence have been taken into consideration. A chance of occurrence of 4% per year for the design capacity has been applied by using Nakayasu Unit Hydrograph Method. The peak discharge of the rainfall-runoff has been distributed to each primary drainage system of Jakabaring. With respect to the impacts of future changes 30% increase in urban area is assumed for 2030. For climate change similar figures have been taken as for the Pluit Polder. For land subsidence 50 mm/year has been assumed, 1.00 m for a 20 years period. The schematisation is presented in Figure 17.

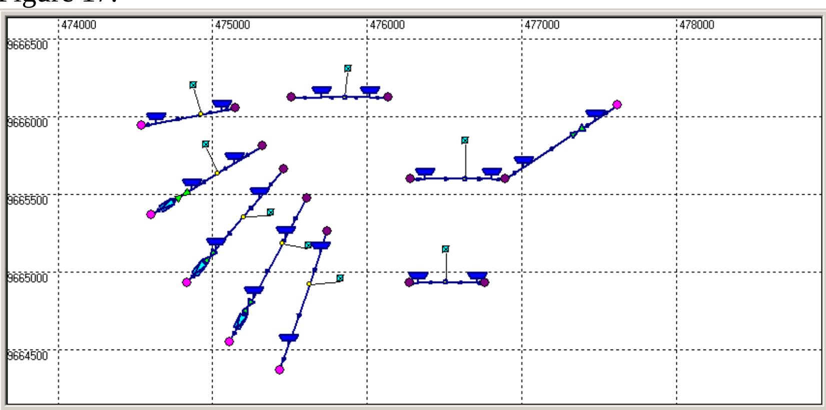

Figure 17. Model schematization of Jakabaring urban drainage system

The two important boundary conditions were the water level fluctuation at Ogan River and computed discharge from upstream. The discharge hydrograph has been proportionally distributed to all sub systems (rivers and retentions) based on their storage capacity.

In the present situation Perupitan River will cause inundation in the area of as much as 0.67 m, Solok Udang River 0.28 m and Kedukan River 0.6 m. While the highest water levels will occur in the storage basins of Gor and Opi with respectively 1.80 m and 1.32 m. A flooding map has been prepared as shown in Figure 18.

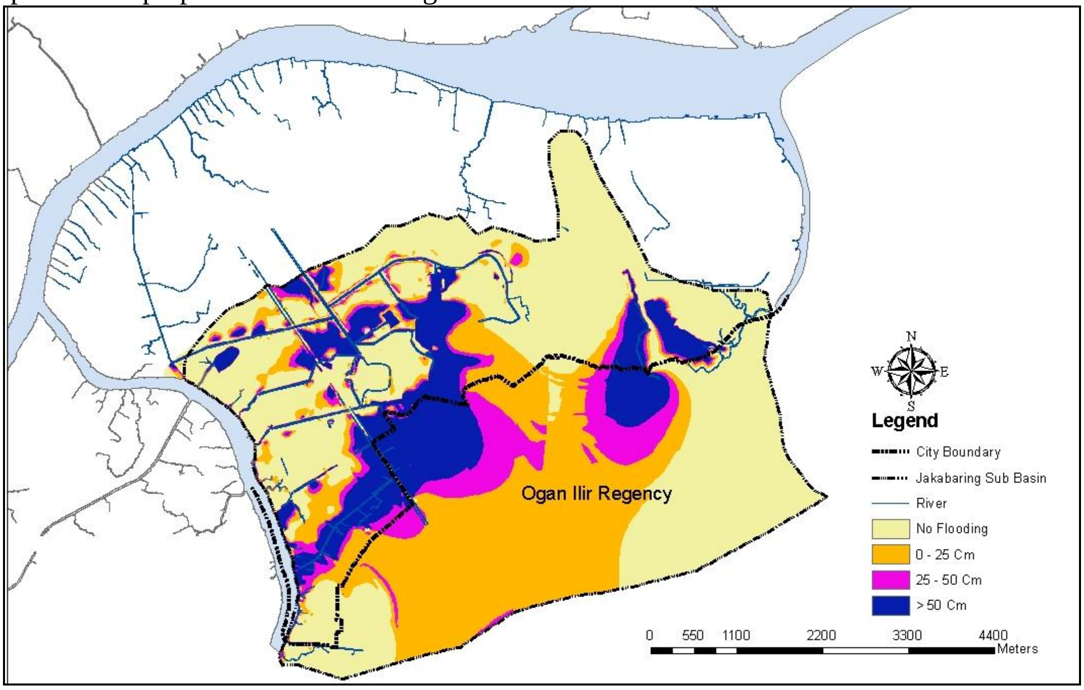

Figure 18. Flooding area due to maximum rainfall and tidal fluctuation in Jakabaring

For the situation in 2030 the expected flooding depth is shown in Figure 19. The percentage of the increase inundation varied from 3.5 - 29%. However, those future changes are taken based on the worst scenario therefore the chance of occurrence is likely to be small.

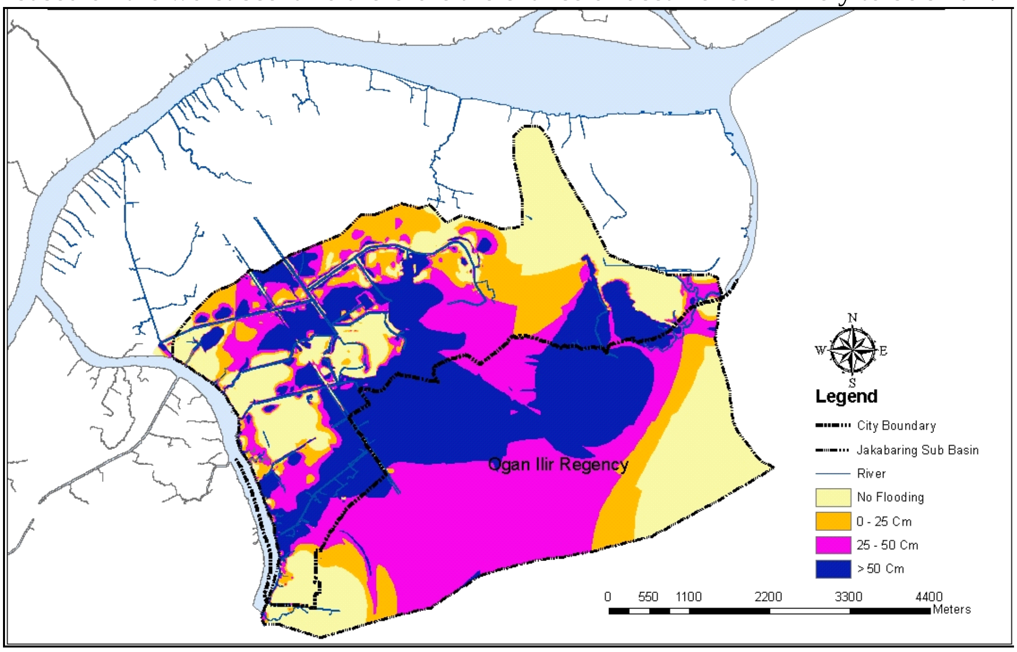

Figure 19. Flooding area due to future changes (2030) in Jakabaring

During the field survey some problems were identified that may contribute to a higher flood risk, these were:

- improper operation and maintenance of drains;
- blockage in the existing drains;
- absence of integrated network comprising secondary drains and reservoirs;
- uncontrolled of disposal solid waste into the drainage system.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The vulnerability of flood management in a changing environment needs a multidisciplinary approach, since it simultaneously has to address the possible impacts of future changes. The general understanding of the changes for the study areas is shown in Table 3.

Table 3. Impacts of future changes on the study areas

Area of study	Future changes		
	Land use change	Climate change	Land subsidence
Delfland, Dike Ring 14	Most important	Important	-
Pluit Polder, Jakarta	-	Important	Most important
Jakabaring, Palembang	Important	Important	Important

In Delfland despite the massive conversion of urban areas so far a pumping capacity of 15 mm/day together with the used figures for storage is adequate to serve the whole polder area from flooding. For the scenario of 2030 a pumping capacity of 20 mm/day would be needed. For the Pluit Polder land subsidence is the most important. This will require regular adaptations of the water management system to cope with the lower surface levels. When the system is well operated and maintained the present storage and pumping capacity are sufficient. The Jakabaring area is in a state of development. Therefore change in land use is still pronounced. Regular adaptations in the water management systems will be required to cope with future changes,

Recommendations

For the Netherlands, the impacts of future changes on water management and flood protection can be easily accommodated during improvement works of water management systems, pumping stations and dikes that from time to time will be required. For Indonesia the major causes are related to poor water and waste management, lack of community awareness on operation and maintenance of structures, lack of control on zoning regulation and on pumping of groundwater. Future developments need to be carried out based on a well-balanced approach between resources utilization and valuation of ecological functions as called for in the principles of conservation. For Pluit Polder, an integrated water resource management and sustainable urban polder development is needed in order to improve the existing water management on flood protection system. A collaborative approach by the stakeholders (Government, Private and Community) is very important in order to implement a sustainable approach for urban polder management. Jakabaring will need to consider developing an urban polder concept. Even though no investigation on land subsidence has been conducted, the possibility of having land subsidence in the future is quite well possible due to oxidation and compaction of peat soil due to development processes. In order to control the drawdown of water, a preferred water level needs to be kept in the area by using a polder concept.

For long-term provisions, again and again measures will have to be updated and improved in an answer to new developments. Anticipating future developments, rather than only reacting to them will be the challenge.

ACKKNOWLEDGEMENT

This paper is based on the results of an MSc study that was funded by Rijkswaterstaat, the Netherlands.

REFERENCES

Abidin, H., H. Andreas, et al. (2006). 'Studying Land subsidence of Bandung Basin (Indonesia) Using GPS Survey Technique.' Survey review **38**(299): 397-405.

Abidin, H., H. Andreas, et al. (2008). 'Land subsidence characteristics of Jakarta between 1997 and 2005, as estimated using GPS surveys.' GPS Solutions **12**(1): 23-32.

Boetzelaer M. Van, Schultz B, (2005). 'Historical development of approaches and standards for flood protection along the Netherlands part of River Rhine. In: Proc. History Workshop Frankfurt am Order, Germany, 19 May 2005

BPS Jakarta (2007). 'Jakarta Dalam Angka 2007', Katalog BPS: 1403.31, Badan Pusat Statistik Propinsi DKI Jakarta, 520 pp.

Indonesia Statistics Board (2007). 'Penduduk Indonesia Menurut Provinsi', can be accessed at: http://www.bps.go.id/tab_sub/view.php?tabel=1&daftar=1&id_subyek=12&notab=1

IPCC (2007). 'Climate Change 2007: The Physical Science Basis, Summary for Policymakers', Report of Intergovernmental Panel On Climate Change, Can be accessed at: http://www.ipcc.ch/.

Joint Working Group, 2009. Urban Polder Guidelines. Volume I: general aspects. Semarang, Indonesia

Murdohardono,D. and H. Tirtomihardjo (1993). 'Penurunan tananh di Jakarta dan rencana pemantauannya.' *Proceedings of the 22nd Annual Convention of the Indonesian Association of Geologists*, Bandung, 6-9 December, pp. 346 - 354.

Nasrul, Febrinasti Alia (2010), Impacts of future changes on flood protection systems. Case study of Indonesia and the Netherlands in comparative perspective. MSc thesis UNESCO-IHE and Sriwijaya University

NEDECO, 1973: 'Masterplan for Drainage and Flood Control of Jakarta'

Rukmana, D. (2008). 'Decreasing Green Areas in Jakarta', The Jakarta Post, March 17, 2008, http://www.thejakartapost.com/news/2008/03/16/decreasing-green-areas-jakarta.html

Soetrisno,S., Satrio H., and Haryadi T. (1997). 'To Anticipate Impacts of Reclamation of Jakarta Bay, A Groundwater Conservation's Perspective.' Paper presented at *Workshop on Coastal and Nearshore Geological/Oceanographical Assessment of Jakarta Bay : A Basis for Coastal Zone Management and Development*, Jakarta, 25 - 28 June.

WJEMP report (2005). 'Indonesia: Western Java Environment Management'.